XIIth Quark Confinement and the Hadron Spectrum

Sunday 28 August 2016 - Sunday 04 September 2016

Book of Abstracts

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QCD propagators and vertices from lattice QCD (in memory of Michael Müller-Preussker)

Andre Sternbeck[1]

[1] *University of Jena*

We review lattice calculations of the elementary Greens functions of QCD with a special emphasis on the Landau gauge. These lattice results have been of interest to continuum approaches to QCD over the past 20 years. They are used as reference for Dyson-Schwinger- and functional renormalization group equation calculations as well as for hadronic bound state equations. The lattice provides low-energy data for propagators and three-point vertices in Landau gauge at zero and finite temperature even including dynamical fermions. Michael Mueller-Preussker's important contributions to this field will be remembered in this talk and put into the perspective of his other research interests. We will also report on new results for the triple-gluon and the quark-gluon vertex on which Michael collaborated with us.

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QCD kinetic theory and its applications

Eero Aleksi Kurkela[1]

[1] *CERN*

A

Summary:

The caluclation of many real time quantities in weakly coupled
thermal QCD can be reduced to computations in an effective kinetic theory
including a resummation of all the relevant diagrams needed to reproduce
consistent leading order results. I will discuss the kinetic theory,
its recent applications to far-from-equilibrium dynamics and its generalisation to next-to-leading order.

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Precision physics with QCD

Antonio Pich[1]

[1] *IFIC, University of Valencia - CSIC*

Inclusive observables, insensitive to hadronization effects, are adequately described with the short-distance Operator Product Expansion. Higher-order perturbative calculations and improved experimental data sets make possible performing precise tests of QCD and accurate deteminations of the strong coupling at the NNNLO. The present status will be reviewed.

Summary:

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Jets at the LHC

Wouter Waalewijn[1]

[1] *University of Amsterdam*

Recent theoretical developments in the description of collisions involving jets will be discussed, as well as the insights they shed on the nature of jets and the experimental ramifications for pp and heavy ion collisions.

Summary:

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ROUND TABLE: Can we understand confinement and the role of anomalies by studying analog materials?

Author(s): Thomas Schaefer[1] ; Vladimir Shevchenko[2]

Co-author(s): Antti Niemi [3] ; Dmitri Kharzeev [4] ; Maria Cristina Diamantini Trugenberger [5] ; Tin Sulejmanpasic [1]

[1] *North Carolina State University*

[2] *National Research Centre Kurchatov Institute (RU)*

[3] *Uppsala University/cnrs*

[4] *Stony Brook University and BNL*

[5] *Universita e INFN, Perugia (IT)*

Summary:

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Neutron Matter from Low to High Density

Joseph Carlson[1]

[1] *Los Alamos National Lab*

I will discuss the properties of neutron matter from very low to very high density.
At low densities dilute neutron matter is very similar to cold atoms with an energy nearly a constant times the Fermi gas and a very large pairing gap. At higher densities the superfluid pairing is dramatically reduced. Above saturation densities the equation of states controls the mass radius relation of neutron stars, eventually transitioning to one or more quark phases. We review the results for low and intermediate densities and discuss the prospects for determining the high-density equation of state.

Summary:

Superfluidity and the equation of state of neutron matter from very low density to very high densities will be discussed, reviewing results to date and discussing future prospects.

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Welcome

Pericles A. Mitkas[1]

[1] *Aristotle University of Thessaloniki*

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Makedonian Thombs and Palaces of King Philippos

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ROUND TABLE: Flavour anomalies - New Physics or QCD effects?

Author(s): Marco Gersabeck[1]

Co-author(s): Lars Hofer [2] ; Roman Zwicky [3] ; Sebastian Jaeger [4] ; Thomas Blake [5] ; Zhaofeng Liu [6]

[1] *University of Manchester (GB)*

[2] *Universitat de Barcelona*

[3] *edinburgh university*

[4] *Sussex University*

[5] *University of Warwick*

[6] *Institute of High Energy Physics*

Summary:

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ROUND TABLE: Nucleon tomography. What can we do better today than Rutherford 100 years ago?

Author(s): Nikolaos Stefanis[1]

Co-author(s): Constantia Alexandrou [2] ; Elke-Caroline Aschenauer [3] ; Hervé Moutarde [4] ; Ignazio Scimemi [5] ; Tanja Horn [6]

[1] *Ruhr University Bochum, Germany*

[2] *University of Cyrus and The Cyprus Institute*

[3] *BNL*

[4] *Irfu, CEA-Saclay*

[5] *Universidad Complutense Madrid*

[6] *Catholic University of America*

Summary:

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Dark matter at the LHC

Michael Kramer[1]

[1] *RWTH Aachen University*

I will discuss (QCD)-techniques and calculations for dark matter production at the LHC, but also briefly review the physics case and the theoretical status of dark matter models.

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The November Revolution

Alvaro De Rujula[1]

[1] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

In a few years — right before and after the November Revolution of 1974 — particle physics, with full wind in its sails, changed very significantly. Quarks, somewhat reluctantly invented during the 1963/64 Christmas holidays, turned out to be for real. QCD and the rest of the Standard Model evolved from being considered a tropical disease affecting an overwhelmed minority of field theorists to being spoused by practically "everybody". I shall revisit, from the very personal point of view of a witness, the main theoretical and observational aspects of QCD in its infancy. I shall try to very briefly comment on the QCD progress made during the past half century, as well as the two main challenges still remaining.

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Overview of FAIR physics

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Future plans for heavy-ion physics at LHC

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Summary

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Approaching precision information on the QCD phase diagram

Peter Braun-Munzinger[1]

[1] *GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE)*

Summary:

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Irregularities at chemical freeze-out of hadrons as evidence of quark-gluon plasma formation

Violetta Sagun[1]

[1] *Bogolyubov Institute for Theoretical Physics*

Based on the new fit of hadron yield ratios within the multicomponent hadron resonance gas model we have found several remarkable irregularities at chemical freeze-out. In particular, 121 hadron multiplicity ratios measured in the nucleus-nucleus collisions at AGS, SPS and RHIC energies were successfully described within the new formulation of HRGM with $\chi^2/dof \simeq 63.978/65 \simeq 0.98$.
A dramatic jump in the center of mass collision energy dependence of pressure, energy density and baryonic charge density in the narrow range between 4.3 and 4.9 GeV is found. These irregularities are also accompanied by a sudden increase of the particle decays at chemical freeze-out which is seen at this collision energy range.

We argue that a strong correlation which we observe between the previously found irregularities and an enhancement of strangeness production can serve as the quark-gluon plasma formation signature. Thus, we conclude that a dramatic change in the system properties seen in the narrow collision energy range $\sqrt{s_{NN}} = 4.3 - 4.9$ GeV opens entirely new possibilities for experimental studies of quark-gluon plasma properties at NICA JINR and FAIR GSI accelerators.

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Studies of Λc production in pp and p-Pb collisions with ALICE at the LHC

Elisa Meninno[1]

[1] *Unversity of Salerno and INFN*

A Large Ion Collider Experiment (ALICE) was designed for the study of the strongly interacting medium created in heavy-ion collisions at LHC energies, the Quark-Gluon Plasma. Heavy quarks (charm and beauty) are very powerful probes to study this state of matter, since they are produced in the early stages of heavy-ion collisions and they traverse the QCD medium interacting with its constituents. Together with charmed mesons, the measurement of Λc in Pb-Pb collisions would address the baryon over meson enhancement in the heavy-quark sector, giving an insight into the hadronization mechanisms. The measurements of the Λc production in pp and p-Pb collisions provide the necessary baseline to understand the heavy-ion collision results and to measure the total charm cross section. In this poster we will present the status of the charmed baryon Λc analyses in pp collisions at √s = 7 TeV and p-Pb collisions at √sNN = 5.02 TeV, via the reconstruction of the decay channels Λc → pKπ and Λc → pK0S. Furthermore, we will discuss the perspectives for future measurements of Λc. In particular, with the ITS upgrade (after the second long LHC shutdown) which will improve the track impact parameter resolution, the tracking efficiency and the pT resolution, the Λc could be measured for the first time in Pb-Pb collisions.

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Event shape sorting

Boris Tomasik[1]

[1] *Univerzita Mateja Bela (SK)*

We present novel method for the organisation of events. The method is based on comparing event-by-event histograms of a chosen quantity Q that is measured for each particle in every event. The events are organised in such a way that those with similar shape of the Q-histograms end-up placed close to each other.
We apply the method on histograms of azimuthal angle of the produced hadrons in ultrarelativsitic nuclear collisions. By selecting events with similar azimuthal shape of their hadron distribution one chooses events which are likely that they underwent similar evolution from the initial state to the freeze-out. Such events can more easily be compared to theoretical simulations where all conditions can be controlled. We illustrate the method on data simulated by the AMPT model.

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Chiral magnetic effect and anomalous transport from real-time lattice simulations

Sayantan Sharma[1] ; Soeren Schlichting[1]

[1] *Brookhaven National Lab*

We present a first-principles study of anomaly induced transport phenomena by performing real-time lattice simulations with dynamical fermions coupled simultaneously to non-Abelian SU(Nc) and Abelian U(1) gauge fields. We investigate the behavior of vector and axial currents
during a sphaleron transition in the presence of an external magnetic field, and demonstrate how the interplay of the Chiral magnetic (CME) and Chiral separation effect (CSE) lead to the formation of a propagating wave. We also analyze the quark mass dependence of these phenomena
and extract spectral information about the carriers of axial and vector charge.

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Quasi-exotic open flavor mesons

Author(s): Thomas Hilger[1]

Co-author(s): Andreas Krassnigg [1]

[1] *University of Graz*

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Novel and innovative applications of the lattice: Calculation of Parton Distributions, proton charge radius and neutron electric dipole moment

Constantia Alexandrou[1]

[1] *University of Cyprus and The Cyprus Institute*

We will present new methods to compute the parton distributions, the proton charge radius and the neutron electric dipole moment. We will demonstrate the applicability of our methods using twisted mass fermion configurations and compare to the results of other lattice QCD collaborations. Finally we will discuss future directions and perspectives for baryon structure studies within lattice QCD.

Summary:

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QCD with chiral imbalance: models vs. lattice

Author(s): Alexander Andrianov[1]

Co-author(s): Domenec Espriu Climent [2]

[1] *Saint Petersburg State University*

[2] *University of Barcelona (ES)*

QCD with chiral(axial) chemical potential will be reconstructed with the help of effective low energy Lagrangians and different models of NJL type. Their thermodynamic properties will be confronted to lattice predictions. Possible signatures of chiral imbalance will be guessed.

Summary:

QCD with chiral(axial) chemical potential will be reconstructed with the help of effective low energy Lagrangians and different models of NJL type. Their thermodynamic properties will be confronted to lattice predictions. Possible signatures of chiral imbalance will be guessed.

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Frequentist statistics in High Energy Physics

Eilam Gross[1]

[1] *Weizmann Institute of Science (IL)*

We will review the frequentist methods used in High Energy Physics for deriving limits, establishing a discovery and making a measurement in the presence of Nuisance Parameters. In particular asymptotic methods and the Look Elsewhere Effect will be reviewed.

Summary:

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Challenges in Heavy Flavor and Quarkonium Production in p+p and p+Pb Collisions at the LHC

Ramona Vogt[1]

[1] *LLNL*

I will discuss new results and open challenges in open heavy flavor and quarkonium production in $p + p$ and p+Pb collisions at the LHC.

Summary:

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Recent progress in understanding deconfinement and chiral symmetry breaking transitions

Edward Shuryak[1]

[1] *Stony Brook University*

While the crucial role of gauge topology was recognized from 1970's,
confinement was associated with monopoles and chiral symmetry breaking with instantons.
Recognizing presence of non-zero holonomy, van Baal and others discovered
splitting of the instantons into their constituents — the instanton-dyons.
Several groups now work out properties of their ensembles, which generate
both the deconfinement and chiral phase transitions. The results of mean field and
numerical simulations are in good agreement with lattice data for QCD-like theories.
Furthermore, introducing variable phases for quark periodicity conditions —
known as flavor holonomies — one can switch quark coupling to different dyons, which dramatically change both transitions. First lattice studies of
modified — so called Z_N-symmetric QCD — have also found these effects,
thus confirming the instanton-dyon mechanism.

Summary:

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Confinement and center vortices: a review of old and new results

Jeff Greensite[1]

[1] *San Francisco State University*

I review the motivation and evidence for the center vortex confinement mechanism, including the relevance of multiple-winding Wilson loops to the confinement problem, and the recent work of Trewartha, Kamleh, and Leinweber connecting center vortices with instantons and chiral symmetry breaking.

Summary:

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Frontiers of finite temperature lattice QCD

Szabolcs Borsanyi[1]

[1] *University of Wuppertal*

I review the recent finite temperature lattice results that push the simulations to the limits. The covered topics include the hadronic degrees of freedom near Tc, very high temperatures, finite density, and attempts to extract real time physics from Euclidean correlators.

Summary:

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Emergent phenomena and partonic structure in hadrons

Craig Roberts[1]

[1] *Argonne National Laboratory*

The overarching science challenges for the coming decade are to discover the meaning of confinement, its relationship to dynamical chiral symmetry breaking (DCSB) - the origin of visible mass - and the connection between these two, key emergent phenomena. There is strong evidence to suggest that they are intimately connected with the appearance of momentum-dependent masses for gluons and quarks in QCD, which are large in the infrared: $m_g \sim 500\,\mathrm{MeV}$ and $M_q \sim 350\,\mathrm{MeV}$. DCSB, expressed in the dynamical generation of a dressed-quark mass, has an enormous variety of verifiable consequences, including an enigmatic result that the properties of the (almost) massless pion are the cleanest expression of the mechanism which is responsible for almost all the visible mass in the Universe. These emergent phenomena are expressed with particular force in the partonic structure of hadrons, e.g. in valence-quark parton distribution amplitudes and functions, and, consequently, in numerous hadronic observables, including elastic and transition form factors. This presentation will highlight that with the identification of these connections we are now in a position to exhibit the consequences of confinement and DCSB in a wide range of hadron observables, opening the way to empirical verification of their expression in the Standard Model.

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The Chiral Magnetic Effect: from quark-gluon plasma to Dirac/Weyl semimetals

Dmitri Kharzeev[None]

Chiral anomaly induces a variety of novel macroscopic quantum phenomena in systems possessing charged chiral fermions, including the Chiral Magnetic Effect (CME). I will review the manifestations of CME in nuclear and condensed matter physics, and present recent results on the link between CME and evolution of magnetic helicity.

Summary:

An overview of the recent developments in anomaly-induced transport will be presented.

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EFT for heavy probes in a hot QCD plasma and in the early universe

Miguel Ángel Escobedo Espinosa[1]

[1] *Institut de Physique Théorique*

There are many interesting problems in heavy-ion collisions and in cosmology that involve the interaction of a heavy particle with a medium. An example is the dissociation of heavy quarkonium seen in heavy-ion collisions. This was believed to be due to the screening of chromoelectric fields that prevents the heavy quarks from binding, however in the last years several perturbative and lattice computations have pointed out to the possibility that dissociation is due to the finite lifetime of a quarkonium state inside the medium. Regarding cosmology, the study of the behavior of heavy Majorana neutrinos in a hot medium is important to understand if this model can explain the origin of dark matter and the baryon asymmetry. A very convenient way of studying these problems is with the use of non-relativistic effective field theories (EFTs), this allows to make the computations in a more systematic way by defining a more suitable power counting and making it more difficult to miss necessary resummations. In this talk I will review the most important results obtained by applying the EFT formalism to the study of quarkonium suppression and Majorana neutrinos, I will also discuss how combining an EFT called potential non-relativistic QCD (pNRQCD) with concepts coming from the field of open quantum systems it is possible to understand how the population of the different quarkonium states evolve with time inside a thermal medium.

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Meson spectroscopy, resonances and scattering on the lattice

Christopher Thomas[1]

[1] *University of Cambridge*

I will review some recent progress in studying the spectra of mesons using first-principles lattice QCD calculations. In particular, I will highlight some new results on resonances, near-threshold states and related scattering phenomena this is an area which is very interesting experimentally and theoretically and where we have made significant advances in the last few years. An outlook on future prospects will also be given.

Summary:

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Roy-Steiner analysis of pion nucleon-scattering and a precision determination of the sigma-term

Ulf-G. Meißner[1]

[1] *Univ. Bonn & FZ Jülich*

I review recent work on the Roy-Steiner equations for pion-nucleon scattering. This allows to extract the S- and P-wave phase shifts in the low-energy and subtreshold regions and a precise extraction of the much debated pion-nucleon sigma term. I also discuss these results in view of recent sigma term determination from various lattice QCD collaborations.

Summary:

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Hadron physics meets gravity

Felipe J. Llanes-Estrada[1]

[1] *Dept. Física Teórica I, Universidad Complutense de Madrid*

Presented at Confinement XII

Summary:

Gravitational-wave observatories are reporting findings at last. The two events detected by LIGO so far are assigned to black-hole mergers, largely because of the large mass of the compact objects triggering the event, so I will start by reviewing what the equation of state of neutron/hadron matter tells us about that maximum mass, and viceversa.
I will quickly mention the Equations of State that astrophysicists and computational physicists working on numerical relativity are using and what improvements seem possible from the particle physics point of view. At last, I will turn the glove around and discuss how one can use the available information from the hadron physics side to constrain modifications of General Relativity.

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X, Y, Z states

Marina Nielsen[1]

[1] *Universidade de São paulo*

The X, Y and Z resonances observed by BaBar, Belle, BESIII, CDF, CLEO-c, CMS, D0 and LHCb Collaborations in the last years provide a challenge to our understanding of QCD. Among them the X(3872), first observed in 2003 by Belle, is the most famous one and the X(5568), observed this year by D0, would be (if confirmed) the most recently acquisition to the list of undoubtedly exotic mesons, since its wave function would consist of four different flavors: u, b, d and s quarks. In this talk I present and discuss some experimental information and theoretical calculations about some of these exotic states. I also discuss the possibility that some of them can be just threshold effects instead of real resonances.

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Heavy ion experiments at NICA JINR

Oleg Rogachevskiy[1]

[1] *JINR*

The main goal of physics program at the Nuclotron-based Ion Collider fAcility (NICA) accelerator complex is a search for the possible mixed phase of quark matter and baryon rich hadronic matter as a consequence of the first order phase transition.

Fixed target experiment Baryonic Matter at Nuclotron (BM@N) and collider experiment Multi Pupose Detector (MPD) at the NICA facility will work at the energy range from a few AGeV up to $\sqrt{s_{NN}} = 11$ GeV and will study the most interesting area on the nuclear matter phase diagram.

The status of the NICA project and a feasibility study of the considered investigations which could be performed with this experiments are reported.

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One and two nucleon matrix elements from lattice QCD for precision tests of the SM in NP environments

Andre Walker-Loud[1]

[1] *LBNL*

There are a number of high profile, high impact experiments planned to probe the limits of the Standard Model through precision measurements at low energies in nuclear physics environments. These experiments include searches for: direct dark matter detection through the elastic recoil of large nuclei; CP-violation manifested in permanent electric dipole moments in nucleons and nuclei; neutrinoless double beta-decay of large nuclei indicating lepton number violation. The interpretation of the experimental results will require input from theoretical nuclear physics quantitatively connected to the fundamental theory of strong interactions, QCD. I will describe how lattice QCD and effective field theory can be used to make this connection and conclude with a brief survey of recent results in this vein.

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Welcome

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ROUND TABLE: Collectivity in Small Systems

Author(s): Jean-Yves Ollitrault[1]

Co-author(s): Denes Molnar [2] ; Piotr Bozek [3] ; Roberta Arnaldi [4] ; Soeren Schlichting [5] ; Wei Li [6] ; Wilke van der Schee [7]

[1] *CNRS*

[2] *Purdue University*

[3] *AGH University of Science and Technology*

[4] *Universita e INFN Torino (IT)*

[5] *Brookhaven National Lab*

[6] *Rice University (US)*

[7] *MIT*

One of the main surprises brought by the heavy ion program at the LHC is the observation of long-range correlations in collisions involving relatively small systems, like proton-proton or proton-lead. Similar phenomena were previously observed in collisions between two heavy nuclei, like Au+Au (at RHIC) and Pb+Pb (at the LHC) and in that context they were associated with collective phenomena, like hydrodynamic flow. Such phenomena look indeed natural for systems which are sufficiently large, long-lived, and which have relatively strong interactions.
Yet, the fact that they are also seen in smaller systems rises interesting questions.
Are these phenomena a signal of genuine collective motion, like flow ?
Or are they related to other sources, like jets or glasma correlations in the initial state?
What are the limits of hydrodynamics, in terms of size and lifetime ?
What is the smallest droplet of liquid that can meaningfully exist ?
Such questions give often the opportunity of intense debates among experts, at various conference and also via dedicated papers.

Summary:

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Review of present experimental and theoretical status of the proton radius puzzle

Richard Hill[1]

[1] *TRIUMF, Perimeter Institute and U. Chicago*

The discrepancy between the measured Lamb shift in muonic hydrogen and expectations from electron-proton scattering and hydrogen spectroscopy has become known as the proton radius puzzle, whose most "mundane" resolution requires a $\sim 5\sigma$ shift in the value of the Rydberg constant. I review the status of spectroscopic and scattering measurements, recent theoretical developments, and implications for fundamental physics.

Summary:

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Flavour anomalies

Thomas Blake[1]

[1] *University of Warwick*

Precision measurements of flavour observables can provide powerful tests of many extensions of the Standard Model. I will present a review of recent heavy flavour results, focussing on places where tensions have started to appear between experimental measurements and Standard Model predictions. The talk will discuss possible explanations for these tensions and highlight areas where theoretical progress (in QCD) is needed to keep pace with increasing experimental precision.

Summary:

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Review on exotic hadrons

Sebastian Neubert[1]

[1] *Ruprecht-Karls-Universitaet Heidelberg (DE)*

The hadron spectrum above the open charm threshold continues to surprise and challenges our understanding of confined systems of strongly interacting particles. While for the established mesons of the X,Y and Z families we have entered the era of precision measurements, new exotic resonances are still being discovered in the meson sector and lately in the baryon sector as well. This talk will review the status of the spectroscopy of these enigmatic hadrons with hidden charm and discuss recent experimental results from the pentaquark candidates to the evidence for multiflavor states.

Summary:

The hadron spectrum above the open charm threshold continues to surprise and challenges our understanding of confined systems of strongly interacting particles. While for the established mesons of the X,Y and Z families we have entered the era of precision measurements, new exotic resonances are still being discovered in the meson sector and lately in the baryon sector as well. This talk will review the status of the spectroscopy of these enigmatic hadrons with hidden charm and discuss recent experimental results from the pentaquark candidates to the evidence for multiflavor states.

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Aristotle's Apprehension of Reality

Ioannis Antoniou[1]

[1] *Aristotle University of Thessaloniki, Mathematics Department*

Following Plato's definition of Knowledge as Justified True Belief, Aristotle understood Reality, and our description of Reality, as the emergence of actual-observable events (ενεργεία) from potentialities (δυναμει). This model is still the basis of relating models with observations, as illustrated by the following examples: 1) selecting admissible solutions from differential and difference equations (boundary conditions, asymptotic conditions), in electromagnetism, diffusion, scattering, 2) Theory of Phase Transitions, 3) non-equilibrium transitions of self-organizing complex systems, resulting

from bifurcations, 4) The measurement problem in Quantum Theory, 5) Statistical Mechanics, Irreversibility and Chaos, 6) Network Dynamics.

The Aristotelian transition to actuality is conditioned by entelechy, filtering or shaping the actual from the possibilities inherent in our models.

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PDFs from Jefferson Lab to the LHC

Wally Melnitchouk[1]

[1] *Jefferson Lab*

We present a status report of our current knowledge of parton distribution functions in the nucleon, including the flavor and spin decomposition, using the latest information from experiments ranging from lower-energy fixed target facilities to the highest-energy hadron colliders.

Summary:

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Experimental perspectives for the study of QCD matter at high net-baryon densities

Volker Friese[1]

[1] *GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE)*

While the current heavy-ion programmes at RHIC and LHC address QCD matter at the hoghest achievable energies, but vanishing net-baryon densities, nuclear collisions at lower energies give access to matter at large baryo-chemical potential. This region of the QCD phase diagram is hardly accessible by first-principle QCD calculations, but QCD-inspired models suggest it to have a rich structure. Among the key questions here are: is there a first-order phase transition from confined to deconfined matter, and if yes, at which collisions energy is it first reached? Do the confinement and chiral phase transitions coincide, and if not, do new phases like Quarkyonic matter exist? Is there a critical point, and if yes, where?

Several experimental programmes will address these questions in the near future, both at existing accelerators (RHIC, SPS) and at upcoming, new facilities such as FAIR and NICA. In this talk, we will discuss the relevant observables and the prospects for their measurement in the years to come.

Summary:

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Model-Independent Simplified Limits on Resonances at the LHC

Elizabeth Simmons[1]

[1] *Michigan State University*

When an excess appears in LHC data, we should be comparing the data with entire classes of models, to get an immediate sense of which ones could conceivably be relevant. Often, the new physics is likely to be a relatively narrow s-channel resonance. In this case, a simplified model of the resonance can translate an estimated signal cross section into model-independent bounds on the product of the production and decay branching ratios. This quickly reveals whether a given class of models could possibly produce a signal of the required size at the LHC. This talk will outline a general framework, show how it operates for resonances with different numbers of production and decay modes, and analyzes cases of experimental interest, including resonances decaying to dibosons, diphotons, dileptons, or dijets. If the LHC experiments were to report searches for BSM resonances in the simplified limits variable ζ defined here, the community could home in more quickly on the models most likely to explain any observed excess.

Summary:

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Beam Energy Scan and Future Plans of RHIC

Rachid Nouicer[1]

[1] *Brookhaven National Laboratory*

The flexibility of the Relativistic Heavy Ion Collider (RHIC) facility to collide atomic nuclei of different sizes over a wide range of
energies provides the experimental leverage necessary to clarify the nature of QCD matter. RHIC launched a multi-step experimental program to investigate the phase diagram of strongly interacting nuclear matter. The exploratory phase I of the Beam Energy Scan (BES) program with larger data sets ranging from 7.7 GeV up to 200 GeV, allowed for an initial look into the uncharted territory of QCD phase diagram. New discoveries made over the past decade have sharpened some questions and posed several new ones that address the core of our understanding of the nature, structure and origin of the QGP liquid. These questions frame our research program for the coming decade. To address them requires, in the short term, a suite of facility and detector upgrades at RHIC and a series of new experiments that exploit these upgrades.

This talk summarizes the latest RHIC experiments' results concerning Beam Energy Scan and their interpretation with respect to the current theoretical models. The plans and the preparation for phase II of the BES program, with one order of magnitude larger statistics, are discussed. The future decadal plan for facility and detector upgrades at RHIC are highlighted.

Summary:

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Probing the Quark-Gluon Plasma at the LHC with heavy flavor observables

Johanna Stachel[1]

[1] *Ruprecht-Karls-Universitaet Heidelberg (DE)*

The energy loss and degree of thermalization of charm and beauty quarks in a quark-gluon plasma is one of the key observables to probe this medium. Spectra and azimuthal anisotropies of open charm hadrons are reported on and first results on open beauty are becoming available. Of crucial relevance are also the total charm and beauty production cross sections. Quarkonia habe long been considered a probe of deconfinement. The large charm production cross section at the LHC leads to a new production mechanism of charmonia from deconfined charm quarks, as has been predicted well

before the start of the LHC. The increasingly precise data follow this prediction. Data on charmonia and bottomonia production at the LHC will be discussed for pp, pPb and PbPb collisions.

Summary:

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HEP in the Greek classrooms

Author(s): Christine Kourkoumelis[1]

Co-author(s): Dimitris Fassouliotis [1]

[1] *National and Kapodistrian University of Athens (GR)*

The HEP Inquiry learning resources created over the last three-four years by the Inspiring Science Education and Go-lab European outreach projects will be reviewed. The resources are mostly addressed to high school students and the purpose is to ignite their interest on science. To that end, science exhibitions as well as science fairs (like the ones organized by this conference) try to reach a very wide audience.
In addition, at the University of Athens for the last four years we have been using the HYPATIA on-line event analysis tool as a lab course for fourth year undergraduate physics students, majoring in HEP. Each year 25-30 students highly appreciated the course, since they get a direct involvement in the actual top-level research. Up to now, the course was limited to visual inspection of a few tenths of ATLAS events. Recently we have enriched the course with additional analysis exercises, which involve large samples of events. The students, through a user friendly interface can analyze the samples (both signal and background ones) and optimize the cut selection in order to search for the Higgs decay H->4 leptons. Recently ATLAS released 1/fb of data, so starting next fall the students will analyse real data

Summary:

Plenary / **439**

Flavor Physics and Flavor Anomalies: Beyond the Standard Model

Matthias Neubert[1]

[1] *Johannes Gutenberg University*

I review current anomalies seen in the quark flavor sector at LHCb and the B factories. I then discuss a simple and minimal model, which can resolve these anomalies in an elegant way.

Summary:

Poster Session and Wine Tasting / **137**

Confinement in F4 exceptional gauge group using domain structures

Author(s): Shahnoosh Rafibakhsh[1]

Co-author(s): Shahlaei Amir [1]

[1] *Plasma Physics Research Center, Science and Research Branch, Azad University*

We calculate the potential between static quarks in the fundamental representation of the F4 exceptional gauge group using domain structures of the thick center vortex model. As non-trivial center elements are absent, the asymptotic string tension is lost while an intermediate linear potential is observed. SU(3) is a subgroup of F4. Investigating the decomposition of the 26 dimensional representation of F4 to the SU(3) representations, might explain what accounts for the intermediate linear potential, in the exceptional groups with no center element.

Summary:

Poster Session and Wine Tasting / 343

Magnetic susceptibility of the QCD vacuum in a nonlocal SU(3) PNJL model

Author(s): Valeria Pagura[1]

Co-author(s): Daniel Gomez Dumm ; Norberto Scoccola [2] ; Santiago Noguera [3]

[1] *Universidad de Valencia - CSIC*

[2] *CONICET - CNEA - U. Favaloro*

[3] *Universidad de Valencia*

The magnetic susceptibility of the QCD vacuum is analyzed in the framework of a nonlocal SU(3) Polyakov-Nambu-Jona-Lasinio model. We estimate the values of the u and s-quark tensor coefficients and magnetic susceptibilities and then we extend the analysis to finite temperature systems, comparing numerical results to those obtained in other theoretical approaches and in lattice QCD calculations.

Summary:

Poster Session and Wine Tasting / 238

Study of BBbar* and B*Bbar* interactions in I=1 and relationship to the Zb(10610), Zb(10650) states

Author(s): Francesca Aceti[1]

Co-author(s): Eulogio Oset ; Jorgivan Dias

[1] *IFIC - Universidad de Valencia*

We use the local hidden gauge approach in order to study the BBbar*and B*Bbar*interactions for isospin I=1. We show that both interactions via one light meson exchange are not allowed by the Okubo-Zweig-Iizuka rule and, for that reason, we calculate the contributions due to the exchange of two pions, interacting and noninteracting among themselves, and also due to the heavy vector mesons. Then, to compare all these contributions, we use the potential related to the heavy vector exchange as an effective potential corrected by a factor which takes into account the contribution of the other light meson exchanges. In order to look for poles, this effective potential is used as the kernel of the Bethe-Salpeter equation. As a result, for the BBbar* interaction we find a loosely bound state with mass in the range 10587–10601 MeV, very close to the experimental value of the Zb(10610) reported by the Belle Collaboration. For the B*Bbar* case, we find a cusp at 10650 MeV for all spin J=0,1,2 cases.

Summary:

Poster Session and Wine Tasting / 302

Chiral magnetic effect and anomalous transport from real-time lattice simulations

Author(s): Sayantan Sharma[1] ; Soeren Schlichting[2]

Co-author(s): Mark Mace [3] ; Niklas Mueller [4]

[1] *BNL*

[2] *Brookhaven National Lab*

[3] *Stony Brook University and BNL*

[4] *Heidelberg University*

We present a first-principles study of anomaly induced transport phenomena by performing real-time lattice simulations with dynamical fermions coupled simultaneously to non-Abelian SU(Nc) and Abelian U(1) gauge fields. We investigate the behavior of vector and axial currents during a sphaleron transition in the presence of an external magnetic field, and demonstrate how the interplay of the Chiral magnetic (CME) and Chiral separation effect (CSE) lead to the formation of a propagating wave. We also analyze the quark mass dependence of these phenomena and extract spectral information about the carriers of axial and vector charge.

Summary:

Poster Session and Wine Tasting / 320

Relations among spin-1 meson decay widths from an SU(4) emergent symmetry in QCD

Hiroki Nishihara[1]

[1] *Nagoya University*

Introduction
Chiral model with SU(4) $\times$ U(1) HLS
Relations obtained from the emergent symmetry
Numerical analysis
Summary

Summary:

Recently, existence of an SU(4) symmetry in QCD is suggested via the lattice QCD, which is called as "emergent symmetry". The spin-1 mesons $(\rho, \rho, \omega', a_1, f_1, b_1, h_1)$ belong to a multiplet of the emergent symmetry. To investigate the interactions of the spin-1 mesons, we construct a chiral model with an SU(4) $\times$ U(1) hidden local symmetry(HLS), where the spin-1 mesons are introduced as an HLS gauge field.
We find extended Goldberger-Treiman relations, relations among one-pion decays of spin-1 mesons, and extended KSRF relations. They give us some predictions which are testable in future experiments, such as ratios of the spin-1 meson decay widths.

Poster Session and Wine Tasting / 174

Chiral symmetry breaking in continuum QCD

Author(s): Mario Mitter[1]

Co-author(s): Anton Cyrol ; Jan M. Pawlowski [2] ; Nils Strodthoff [3]

[1] *Univ. Heidelberg*

[2] *University of Heidelberg*

[3] *LBNL*

Model parameter free investigations of Yang-Mills theory and quenched QCD in the vacuum are presented as a necessary prerequisitve for corresponding investigations of the QCD phase structure with the functional renormalisation group equation. Preliminary results for Yang-Mills theory at finite temperature are discussed. Finally, a phenomenological application of the vacuum results to the etaprime-meson mass at the chiral crossover is presented.

Summary:

Poster Session and Wine Tasting / **120**

CANCELLED: Thermal Behaviors of the Strong Form Factors of Charmonium and Charmed Beauty Mesons from Three Point Sum Rules

Author(s): Enis Yazici[1]

Co-author(s): Elsen Veli Veliev [1] ; Hayriye Sundu [1]

[1] *Kocaeli University*

1. Introduction
2. Thermal Sum Rule for Charmonium and Charmed Beauty Vertex
3. Numerical Analysis and Discussion

Summary:

In order to understand the nature of strong interactions and QCD vacuum, investigation of the meson coupling constants have an important role. The knowledge on the temperature dependence of the form factors is very important for the interpretation of heavy-ion collision experiments. Also, more accurate determination of these coupling constants plays a crucial role in understanding of the hadronic decays. With the increasing of CM energies of the experiments, researches on meson interactions have become one of more interesting problems of hadronic physics.
In this study, we analyze the temperature dependence of the strong form factor of the BcBcJ/ψ vertex using the three point QCD sum rules method. Here, we assume that with replacing the vacuum condensates and also the continuum threshold by their thermal version, the sum rules for the observables remain valid. In calculations, we take into account the additional operators, which appear in the Wilson expansion at finite temperature. We also investigated the momentum dependence of the form factor at T = 0, fit it into an analytic function, and extrapolate into the deep time-like region in order to obtain a strong coupling constant of the vertex. Our results are consistent with the results existing in the literature.

Poster Session and Wine Tasting / **108**

Predictions on the second-class current decays $\tau^- \to \pi^- \eta^{(\prime)} \nu_\tau$

Author(s): Rafel Escribano[1]

Co-author(s): Pablo Roig [2] ; Sergi Gonzàlez-Solís [3]

[1] *Universitat Autònoma de Barcelona*

[2] *CINVESTAV*

[3] *IFAE-UAB*

We analyse the second-class current decays $\tau^- \to \pi^- \eta^{(\prime)} \nu_\tau$
in the framework of Chiral Perturbation Theory with Resonances.
Taking into account π^0-η-η' mixing,
the $\pi^- \eta^{(\prime)}$ vector form factor is extracted, in a model-independent way,
using existing data on the $\pi^- \pi^0$ one.
For the participant scalar form factor,
we have considered different parameterizations ordered according to their increasing fulfillment of analyticity and unitarity constraints.
We start with a Breit-Wigner parameterization dominated by the $a_0(980)$ scalar resonance
and after we include its excited state, the $a_0(1450)$.
We follow by an elastic dispersion relation representation through the Omn\'{e}s integral.
Then, we illustrate a method to derive a closed-form expression for the
$\pi^- \eta$, $\pi^- \eta'$ (and $K^- K^0$) scalar form factors in a coupled-channels treatment.
Finally, predictions for the branching ratios and spectra are discussed emphasizing the error analysis.
An interesting result of this study is that both $\tau^- \to \pi^- \eta^{(\prime)} \nu_\tau$ decay channels
are promising for the soon discovery of second-class currents at Belle-II.
We also predict the relevant observables for the partner $\eta^{(\prime)}_{\ell 3}$ decays,
which are extremely suppressed in the Standard Model.

Summary:

Predictions on the second-class current decays $\tau^- \to \pi^- \eta^{(\prime)} \nu_\tau$

Poster Session and Wine Tasting / 21

One-loop calculations in Supersymmetric Lattice QCD

Author(s): Marios Costa[1]

Co-author(s): Haralambos Panagopoulos [1]

[1] *University of Cyprus*

Super QCD Lagrangian and Feynman rules; self energies of quark, gluon, squark and gluino fields; 2-pt Green's functions of quark bilinears; lattice perturbation theory.

Summary:

We study the self energies of all particles which appear in a lattice regularization of supersymmetric QCD ($calN = 1$). We compute, perturbatively to one-loop, the relevant two-point Green's functions using both the dimensional and the lattice regularizations. Our lattice formulation involves a variety of discretizations for the gluino and quark fields, including Wilson, clover and overlap fermions. For gluons we employ the Wilson action, as well as Symanzik improved variants. For scalar fields (squarks) we use naive discretization. The gauge group that we consider is $SU(N_c)$ while the number of colors, N_c and the number of flavors, N_f, are kept as generic parameters. We have also searched for relations among the propagators which are computed from our one-loop results. We have obtained analytic expressions for the renormalization functions of the quark field (Z_ψ), gluon field (Z_A), gluino field (Z_λ) and squark field (Z_ϕ). In this study we also describe the perturbative calculation of the renormalization of quark bilinear operators which, unlike the non-supersymmetric case, exhibit a rich pattern of operator mixing at the quantum level.

Poster Session and Wine Tasting / 49

Coupling of $t\bar{t}$ with a strongly interacting EWSBS

Andrés Fernando Castillo Ramirez[1] ; Antonio Dobado[2] ; Felipe J. Llanes-Estrada[2] ; Rafael Delgado[2]

[1] *Universidad Nacional de Colombia*

[2] *Universidad Complutense de Madrid (UCM)*

We report on the coupling of an external $t\bar{t}$ state to a strongly interacting EWSBS. We exploit perturbation theory in the small $M_t/\sqrt{s}$ quantity, whereas the EWSBS is taken as strongly interacting. We use a modified version of the IAM unitarization procedure to model such a strongly interacting regime. The scattering matrix elements $V_LV_L \to V_LV_L$, $V_LV_L \to hh$, $hh \to hh$, $V_LV_L \to t\bar{t}$ and $hh \to t\bar{t}$ are computed at NLO level within the framework of a non-linear Effective Field Theory and the Equivalence Theorem.

We are interested in $t\bar{t}$ both as initial and final state. Considering it as final state would allow us to study the possible appearance of resonances in the tt production channel at the LHC. And the initial $t\bar{t}$ state is a first step to look for resonances starting from two gluon states, via the triangle diagram with quark tops inside. Both cases have direct applications to the LHC phenomenology.

Summary:

Poster Session and Wine Tasting / 53

Goldstone-type pseudoscalar mesons: instantaneous Bethe–Salpeter models

Wolfgang LUCHA[None]

Within QCD, the light pseudoscalar mesons assume a twofold role: they may be described as quark–antiquark bound states but also have to be interpreted as the (almost) massless (pseudo) Goldstone bosons of the spontaneously broken chiral symmetries of QCD. The application of suitably adapted inversion techniques enables us to construct exact bound-state solutions to the Bethe–Salpeter equation for massless pseudoscalar mesons, in the form of rigorous (and, under particularly favourable circumstances, even analytic) relationships between the underlying interactions and the resulting Bethe–Salpeter solutions. Needless to say, this procedure is not confined to the Salpeter equation but, with little more effort, may be carried over to more general three-dimensional reductions of the Bethe–Salpeter formalism.

Summary:

Poster Session and Wine Tasting / 67

Transverse flow induced by inhomogeneous magnetic fields in the Bjorken expansion

Di-Lun Yang[1] ; Shi Pu[2]

[1] *RIKEN*

[2] *Institute for Theoretical Physics, Goethe University, Frankfurt am Main*

We investigate the magnetohydrodynamics in the presence of an external magnetic field following the power-law decay in proper time and having spatial inhomogeneity characterized by a Gaussian distribution in one of transverse coordinates under the Bjorken expansion. The leading-order solution is obtained in the weak-field approximation, where both energy density and fluid velocity are modified. It is found that the spatial gradient of the magnetic field results in transverse flow, where the flow direction depends on the decay exponents of the magnetic field. We suggest that such a magnetic-field-induced effect might influence anisotropic flow in heavy ion collisions.

Summary:

Poster Session and Wine Tasting / 84

QCD fixed points: Banks-Zaks scenario or dynamical gluon mass generation?

Author(s): John Gómez[None]

Co-author(s): Adriano Natale [1]

[1] *UFABC*

Fixed points in QCD can appear when the number of quark flavors (N_f) is increased above a certain critical value as proposed by Banks and Zaks (BZ). There is also the possibility that QCD possess an effective charge indicating an infrared frozen coupling constant. In particular, an infrared frozen coupling associated to dynamical gluon mass generation (DGM) does lead to a fixed point even for a small number of quarks. We compare the BZ and DGM mechanisms, their β functions and fixed points, and within the approximations of this work, which rely basically on extrapolations of the dynamical gluon masses at large N_f, we verify that near the so called QCD conformal window both cases
exhibit fixed points at similar coupling constant values (g^*). We argue that the states of minimum vacuum energy, as a function of the coupling constant up to g^* and for several N_f values, are related to the dynamical gluon mass generation mechanism.

Summary:

Poster Session and Wine Tasting / 89

Numerical study of the electron and muon lateral distribution in atmospheric showers of high energy cosmic rays.

Giorgos Atreidis[1]

[1] *PhD student Aristotle University of Thessaloniki*

The lateral distribution of an atmospheric shower depends on the characteristics of the high energy interactions and the type of the primary particle. The influence of the primary particle in the secondary development of the shower into the atmosphere, is studied by analyzing the lateral distribution of electron and muon showers having as primary particle, proton, photon or iron nucleus.
This study of the lateral distribution can provide useful conclusions for the mass and energy of the primary particle. This paper compares the data that we get from simulations with CORSIKA program with experimental data and the theoretical NKG function expressing lateral electron and muon distribution. Then we modify the original NKG function to fit better to the simulation data and propose a method for determining the mass of the original particle started the atmospheric shower.

Summary:

Poster Session and Wine Tasting / 206

The Quark propagator in QCD and QCD-like theories

Author(s): Romain Contant[1]

Co-author(s): Markus Huber [1]

[1] *University of Graz*

QCD-like theories provide testing grounds for truncations of functional equations at non-zero density, since comparisons with lattice results are possible due to the absence of the sign problem. As a first step towards such a comparison, we determine for various theories the chiral and confinement/deconfinement transitions from the quark propagator Dyson-Schwinger equation at zero chemical potential by calculating the chiral and dual chiral condensates, respectively.

Summary:

The confinement/deconfinement and chiral transitions are calculated from the quark propagator in QCD and QCD-like theories at vanishing chemical potential.

Poster Session and Wine Tasting / **212**

The dyamics of gluon plasma with center vortices

Takuya Saito[1]

[1] *Kochi University*

We study the physics of the strongly-correlated gluon plasma with color-center vortices in the lattice SU(2) simulations.
We observe in the deconfinement phase how the equation of state, gluon propagators and transport correlators depend on degrees of freedom of lattice center vortices in the temporal and spatial directions.
It is found that the magnetic sector of gluons is more non-perturbative object than the electric one still at finite temperature.

Summary:

Poster Session and Wine Tasting / **230**

Charmed mesons at finite temperature and chemical potential

Author(s): Fernando Serna[1]

Co-author(s): Gastão Krein [2]

[1] *Institute for Theoretical physics of São Paulo Statate University*

[2] *Institute for Theoretical Physics of São Paulo State University*

Hadron physics

Summary:

We will present results for the temperature dependence of the masses of D^+, D_s^+, D^{*+}, D_s^{*+} and also the hidden charm mesons η_c, J/ψ as well as the light mesons π, K and η. In order to do that, we use the NJL-model with a symmetry preserving-regularization method of the ultraviolet divergences. The regularization method is based on a subtraction scheme that avoids standard steps in the evaluation

of divergent integrals that invariably lead to symmetry violation. At zero temperature this approach has already been applied successfully in the computation of masses and decay constants of heavy-light mesons, where we have found a correct trend in the decay constants contrary to the results using the standard approach to handle divergent integrals in NJL-model and also with Bethe-Salpeter computations. The aim of this computation is study charm mesons diffusion in mesonic matter, where for instance, we can be able to compute the drag and diffusion coefficients of D^+ in hadronic medium.

Poster Session and Wine Tasting / **241**

Heavy Quark Dynamics from Entropy shifts

Author(s): Enrique Ruiz Arriola[1]

Co-author(s): Eugenio Megias [2]

[1] *Universidad de Granada*

[2] *Max Planck Institut fur Physik*

The presentation is based on these works

1) Heavy Quark Entropy shift: From the Hadron Resonance Gas to Power Corrections
By E. Megias, E. Ruiz Arriola, L.L. Salcedo.
arXiv:1605.04453 [hep-ph].

2) Heavy quark-antiquark free energy and thermodynamics of string-hadron avoided crossings
By E. Megias, E. Ruiz Arriola, L.L. Salcedo.
arXiv:1603.04642 [hep-ph].

3) Heavy $\bar{Q}Q$ free energy from hadronic states
By E. Megías, E. Ruiz Arriola, L.L. Salcedo.
arXiv:1507.08606 [hep-ph].
10.1016/j.nuclphysbps.2016.02.034.
Nucl.Part.Phys.Proc. 93-97 270-272, Nucl.Part.Phys.Proc. 270-272 (2016) 170-174.

4) Quark properties from the Hadron Resonance Gas
By E. Ruiz Arriola, L.L. Salcedo, E. Megias.
arXiv:1505.02922 [hep-ph].
10.5506/APhysPolBSupp.8.439.
Acta Phys.Polon.Supp. 8 (2015) no.2, 439.

5) Quark Hadron Duality at Finite Temperature
By E. Ruiz Arriola, L.L. Salcedo, E. Megias.
arXiv:1410.3869 [hep-ph].
10.5506/APhysPolB.45.2407.
Acta Phys.Polon. B45 (2014) no.12, 2407-2454.

Summary:

The correlation function between two Polyakov loops encodes the free-energy shift due to a pair of separated colour conjugated sources in the hot QCD vacuum. This is analyzed in terms of a novel K\"all\'en-Lehmann spectral representation for the separating distance, implying an increasing and concave free-energy at all temperatures. We express the heavy $Q^{-}Q$ entropy shift below the phase transition in QCD in terms of colour neutral purely hadronic states with no explicit reference to quarks and gluons. Good agreement with lattice data is achieved when considering the avoided crossing mechanism underlying string breaking and with standard quenched values of the string tension known from charmonium and bottomonium phenomenology.

Poster Session and Wine Tasting / **307**

Exact sum rules for vector channel at finite temperature and their application to lattice QCD analysis

Daisuke Satow[None]

We derive three exact sum rules for the spectral function of the electromagnetic current channel at finite temperature, by using operator product expansion and hydrodynamics, focusing on zero spatial momentum case. We also discuss the possibility to use these sum rules to constrain and improve the functional form of the spectral function assumed in the lattice QCD analysis, and to evaluate the transport efficient at the second order, which does not directly appear in the spectral function, from the lattice QCD data.

Summary:

We derive three exact sum rules for the spectral function of the electromagnetic current channel at finite temperature, by using operator product expansion and hydrodynamics, focusing on zero spatial momentum case. We also discuss the possibility to use these sum rules to constrain and improve the functional form of the spectral function assumed in the lattice QCD analysis, and to evaluate the transport efficient at the second order, which does not directly appear in the spectral function, from the lattice QCD data.

Poster Session and Wine Tasting / **310**

Universal behaviour of gluon and ghost propagators in the infrared

Fabio Siringo[1]

[1] *Università degli Studi di Catania*

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Summary:

A universal behaviour is predicted for ghost and gluon propagators in the infrared.
All lattice data, for different color numbers (and even quark content for the ghosts)
collapse on the same universal curve by a scaling of units and by
adding an integration constant. The universal behaviour is shown to be a signature of a
one-loop approximation and emerges naturally by any modified one-loop approximation that
is capabale of predicting a massive gluon, provided that the Lagrangian is not modified and that the gluon mass arises from the loops in the expansion.
For instance, a massive expansion, with massive gluon propagators in the loops, is shown to
predict universal analytical functions for the derivatives of the inverse dressing functions that do not depend on any parameter or color number. All lattice data are shown to collapse on the anlytical curves.

Poster Session and Wine Tasting / **312**

Generalized dispersion relations for unphysical particles with complex masses

Fabio Siringo[1]

[1] *Università degli Studi di Catania*

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Summary:

A generalized dispersion relation is discussed for confined degrees of freedom
that are not present in the physical spectra but can give rise to observable bound states.
The propagator of the unphysical particles can have complex poles and cannot be reconstructed from the knowledge of the imaginary part. Under reasonable assumptions the missing piece of information is shown to be in the rational function that contains the poles and must be added to the integral representation.
For pure Yang-Mills theory, the rational part and the spectral term can be sorted out
by the explicit analytical expressions of the one-loop massive expansion, where a massive gluon propagator is inserted in the loops.
The spectral function turns out to be very small and from first principles, the simple rational part provides an approximate propagator that is equivalent to the tree-level result of simple phenomenological models like the refined Gribov-Zwanziger model.

Poster Session and Wine Tasting / **315**

Zero-momentum $SU(2)$ gluon correlator at various boundary conditions

Igor Bogolubsky[1]

[1] *Joint Institute for Nuclear Research*

We make simulations of the zero-momentum $SU(2)$ Landau gauge gluon correlator both for periodic and zero-field boundary conditions at varying β and $L_t * L_s^3$ lattice sizes.

Summary:

Poster Session and Wine Tasting / **324**

Holographic study of the QCD matter under external conditions

Alisa Katanaeva[1] ; Sergey Afonin[1]

[1] *Saint Petersburg State University*

Holographic QCD is based on the AdS/CFT duality and offers new nonperturbative approaches to understand the strongly interacting regime of gauge theories. One of the primary questions in Quantum Chromodynamics is the clarification of the whole phase diagram of matter out of quarks and gluons as a function of temperature, baryon or quark chemical potential, and other external parameters.

We use methods of the bottom-up AdS/QCD approach to bring out the phase structure of several holographic models in which transition to a deconfined phase is related to a (first order) Hawking-Page phase transition. The impact of phenomenological model parameters on the critical temperature and chemical potential is studied in detail. Comparison of the model predictions with results of experimental investigations, lattice QCD simulations and other methods is also done.

Summary:

Poster Session and Wine Tasting / **373**

Muon reconstruction performance in ATLAS at Run II

Despoina Sampsonidou[1]

[1] *Aristotle University of Thessaloníki (GR)*

The ATLAS reconstruction algorithm, in Run-II, has been improved and extended compared to the one used in Run-I. In this presentation, we will discuss the precise measurement of the muon reconstruction efficiency measured in pp collisions at sqrt(s)= 13 TeV in 2015 and 2016 using samples of J/ψ⟶μμ and Z⟶μμ decays. The reconstruction efficiency, transverse momentum resolution and momentum scales measurements in the various regions of the detector and for muon momenta between 6 and hundreds of GeV are presented.

Summary:

Poster Session and Wine Tasting / **376**

Event shape sorting

Boris Tomasik[1]

[1] *Univerzita Mateja Bela (SK)*

We present novel method for the organisation of events. The method is based on comparing event-by-event histograms of a chosen quantity Q that is measured for each particle in every event. The events are organised in such a way that those with similar shape of the Q-histograms end-up placed close to each other.
We apply the method on histograms of azimuthal angle of the produced hadrons in ultrarelativsitic nuclear collisions. By selecting events with similar azimuthal shape of their hadron distribution one chooses events which are likely that they underwent similar evolution from the initial state to the freeze-out. Such events can more easily be compared to theoretical simulations where all conditions can be controlled. We illustrate the method on data simulated by the AMPT model.

Summary:

Poster Session and Wine Tasting / **337**

The mass spectrum of double heavy baryons in new potential quark models

Andrei Puchkov[1] ; Vladimir Kovalenko[1]

[1] *St Petersburg State University (RU)*

A new approach to study the mass spectrum of double heavy baryons containing strange and charmed quarks is proposed. It is based on the separation of variables in the Schrödinger equation in the prolate spheroidal coordinates. Two non-relativistic potential models are considered.

In the first model, the interaction potential of the quarks is the sum of the Coulomb and non-spherically symmetrical linear confinement potential. In the second model [1] it is assumed that the quark confinement provided by a spherically symmetric harmonic oscillator potential.
In both models the mass spectrum is calculated, and a comparison with previous results [2, 3] from other models is performed.

This work is supported by the Russian Science Foundation (grant No. 16-12-10176).

References

[1] D.U. Matrasulov, F.C. Khanna, Kh.Yu. Rakhimov and Kh.T. Butanov Spectra of baryons containing two heavy quarks, Eur. Phys. J. A 14, 81-86 (2002)

[2] Y. Namekawa et all (PACS-CS Collaboration), Charmed baryons at the physical point in 2 +1 flavor lattice QCD, Phys. Rev. D 87, 094512 (2013)

[3] Tetsuya Yoshida, Emiko Hiyama, Atsushi Hosaka, Makoto Oka, Katsunori Sadato, Spectrum of heavy baryons in the quark model, Phys. Rev. D 92, 114029 (2015)

Summary:

The mass spectrum of double heavy baryons is studied in two new potential quark models based on the separation of variables in the Schrödinger equation.

Poster Session and Wine Tasting / **303**

Poster: Studies of Λc production in pp and p-Pb collisions with ALICE at the LHC

Elisa Meninno[1]

[1] *Universita e INFN, Salerno (IT)*

A Large Ion Collider Experiment (ALICE) was designed for the study of the strongly interacting medium created in heavy-ion collisions at LHC energies, the Quark-Gluon Plasma. Heavy quarks (charm and beauty) are very powerful probes to study this state of matter, since they are produced in the early stages of heavy-ion collisions and they traverse the QCD medium interacting with its constituents. Together with charmed mesons, the measurement of Λc in Pb-Pb collisions would address the baryon over meson enhancement in the heavy-quark sector, giving an insight into the hadronization mechanisms. The measurements of the Λc production in pp and p-Pb collisions provide the necessary baseline to understand the heavy-ion collision results and to measure the total charm cross section. In this poster we will present the status of the charmed baryon Λc analyses in pp collisions at √s = 7 TeV and p-Pb collisions at √sNN = 5.02 TeV, via the reconstruction of the decay channels Λc ⟶ pKπ and Λc ⟶ pK0S. Furthermore, we will discuss the perspectives for future measurements of Λc. In particular, with the ITS upgrade (after the second long LHC shutdown) which will improve the track impact parameter resolution, the tracking efficiency and the pT resolution, the Λc could be measured for the first time in Pb-Pb collisions.

Summary:

Poster Session and Wine Tasting / **237**

Prediction of an I=1 DDbar* state and relationship to the claimed Zc(3900), Zc(3885)

Author(s): Francesca Aceti[1]

Co-author(s): Eulogio Oset ; Jorgivan Dias ; Marina Nielsen [2] ; Melahat Bayar [3]

[1] *IFIC - Universidad de Valencia*

[2] *Universidade de São paulo*

[3] *Kocaeli University*

We study here the interaction of DDbar*in the isospin I=1 channel in light of recent theoretical advances that allow us to combine elements of the local hidden gauge approach with heavy quark spin symmetry.*

We find that the exchange of light qqbar is Okubo-Zweig-Iizuka (OZI) suppressed and thus we concentrate on the exchange of heavy vectors and of two pion exchange. The latter is found to be small compared to the exchange of heavy vectors, which then determines the strength of the interaction. A barely DDbar bound state decaying into ηcρ and πJ/ψ is found. At the same time we reanalyze the data of the BESIII experiment on e+e-⟶π±(DDbar*)∓, from where a Zc(3885) state was claimed, associated to a peak in the (DDbar)∓* invariant mass distribution close to threshold, and we find the data compatible with a resonance with mass around 3875 MeV and width around 30 MeV. We discuss the possibility that this and the Zc(3900) state found at BESIII, reconfirmed at 3894 MeV at Belle, or 3885 MeV at CLEO, could all be the same state and correspond to the one that we find theoretically.

Summary:

Poster Session and Wine Tasting / 156

Coupled channel model of the scalar isovector meson photoproduction

Author(s): Lukasz Bibrzycki[1]

Co-author(s): Kaminski Robert [2]

[1] *Pedagogical University of Cracow*

[2] *Institute of Nuclear Physics PAN*

Electromagnetic processes are known to be a good source of information on the meson inner structure. Analysis of these processes turned out to be particularly fruitful in case of scalar mesons which emerge eg. in the phi(1020) radiative decays in both \pi\pi and \pi\eta channels.
Photoproduction of isoscalar and isovector scalar resonances can be treated as a complementary source of information on the scalar meson
structure. Here we are concerned with the photoproduction of isovector scalars, ie. a_0(980) and a_0(1450). Moreover, we are interested in photoproduction at photon energies of about 10 GeV, ie. energies achievable in new JLab experiments CLAS12 and GlueX. In this kinematic region the process is dominated by the t channel meson exchange which leads to production of pseudoscalar pairs \pi\eta, K\overline{K} and \pi\eta'. These in turn can resonantly interact in the final state. So, construction of the photoproduction amplitudes is inevitably the coupled channel problem.
In ref.[1] we constructed the \pi\eta-K\overline{K} coupled channel photoproduction amplitudes where a_0(980) and a_0(1450) resonances emerged due to final
state interactions. Here we present the extended version of the model which takes into account also the \pi\eta' channel. The model is also applicable to higher partial waves (see [2]) and is relevant in the context of CLAS12 and GlueX experiments to be started shortly at Jefferson Laboratory, USA. In these experiments the \pi\eta, K\overline{K} and \pi\eta' pairs will be photoproduced copiously (also by polarized photons) enabling the partial wave analysis. Reliable models of the resonance photoproduction a thus timely and opportune.

Literature:

1. L. Bibrzycki, R. Kaminski, https://arxiv.org/abs/1509.06135
2. L. Bibrzycki, R. Kaminski, Phys.Rev. D87, no.11, 114010 (2013)

Summary:

We present the coupled channel model of the scalar isovector resonance photoproduction where \pi\pi, K\overline{K} and \pi\eta' channels are taken into account..

Poster Session and Wine Tasting / 223

Phase diagram of the Nambu–Jona-Lasinio model in the presence of explicit symmetry-breaking interactions

Author(s): Joao Moreira[1]

Co-author(s): A. A. Osipov [1] ; Alex Blin [1] ; Brigitte Hiller [1] ; Jorge Morais [1]

[1] *Center for Physics of the University of Coimbra*

A recently developed extension of the Nambu–Jona-Lasinio model includes all the explicit chiral symmetry breaking interactions which contribute
at the same order in the large 1/Nc counting as the UA(1) 't Hooft flavor determinant [1]. In addition to the usual 4, 6, 8 fermion vertices this
generalization includes the relevant interaction terms proportional to the current quark masses. It has shown an unprecedented success in the correct
description of the low lying mesonic spectra;
in particular an accurate ordering and magnitude of the splitting of states in the low lying pseudoscalar nonet [2]
can be achieved.

As has been shown [3] a correct thermodynamical behavior can be achieved with careful and thouroughly consistent implementation of the regularization procedure
thus avoiding the pitfalls resulting from the inclusion of arbitrarily high momentum states in unregularized contributions to the thermodynamical potential.

The phase diagram of strongly interacting matter as a function of temperature, chemical potential and magnetic field has been a very active topic of research in
recent times, both from the theoretical and experimental sides, with implications ranging from heavy ion collisions to astrophysics.

Here we will present the latest results obtained with this powerful model extension.

References

[1]
A. A. Osipov, B. Hiller, A. H. Blin, Eur. Phys. J. A 49, 14 (2013);
A. A. Osipov, B. Hiller, A. H. Blin, Phys. Rev. D 88, 054032 (2013).

[2]
A. A. Osipov, B. Hiller, A. H. Blin, J. Moreira, arXiv:1606.01945v1

[3]
J. Moreira, B. Hiller, A.A. Osipov, A.H. Blin, Int.J.Mod.Phys. A27 (2012) 1250060

Summary:

Poster Session and Wine Tasting / 349

Strong Couplings of Three Mesons with Charm(ing) Involvement

Dmitri Melikhov[1] ; Hagop Sazdjian[2] ; Silvano Simula[3] ; Wolfgang Lucha[4]

[1] *HEPHY*

[2] *University Paris-Sud*

[3] *INFN*

[4] *Austrian Academy of Sciences*

Within a relativistic dispersion approach based on the constituent-quark model, we extract the strong couplings of three mesons among which there is, at least, one charmonium from the residues of

resonance poles in adequate transition form factors for timelike momentum transfer. Confrontation of our results with corresponding earlier ones by QCD sum rules reveals significant disagreement between the outcomes of these two approaches.

Summary:

Within a relativistic dispersion approach based on the constituent-quark model, we extract the strong couplings of three mesons among which there is, at least, one charmonium from the residues of resonance poles in adequate transition form factors for timelike momentum transfer. Confrontation of our results with corresponding earlier ones by QCD sum rules reveals significant disagreement between the outcomes of these two approaches.

Poster Session and Wine Tasting / **351**

Irregularities at chemical freeze-out of hadrons as an evidence of quark-gluon plasma formation

Author(s): Violetta Sagun[1]

Co-author(s): Dmytro Oliinychenko [2] ; Kyrylo Bugaiev [3] ; Oleksii Ivanytskyi [3]

[1] *Bogolyubov Institute for Theoretical Physics*

[2] *CERN*

[3] *National Academy of Sciences of Ukraine (UA)*

Based on the new fit of hadron yield ratios within the multicomponent hadron resonance gas model we have found several remarkable irregularities at chemical freeze-out. In particular, 121 hadron multiplicity ratios measured in the nucleus-nucleus collisions at AGS, SPS and RHIC energies were successfully described within the new formulation of HRGM with $\chi^2/dof \simeq 63.978/65 \simeq 0.98$.
A dramatic jump in the center of mass collision energy dependence of pressure, energy density and baryonic charge density in the narrow range between 4.3 and 4.9 GeV is found. These irregularities are also accompanied by a sudden increase of the particle decays at chemical freeze-out which is seen at this collision energy range.

We argue that a strong correlation which we observe between the previously found irregularities and an enhancement of strangeness production can serve as the quark-gluon plasma formation signature. Thus, we conclude that a dramatic change in the system properties seen in the narrow collision energy range $\sqrt{s_{NN}} = 4.3 - 4.9$ GeV opens entirely new possibilities for experimental studies of quark-gluon plasma properties at NICA JINR and FAIR GSI accelerators.

Summary:

Poster Session and Wine Tasting / **375**

Flow anisotropy due to momentum deposition in ultra-relativistic nuclear collisions

Author(s): Boris Tomasik[1]

Co-author(s): Martin Schulc [2]

[1] *Univerzita Mateja Bela (SK)*

[2] *Czech Technical University in Prague*

Minijets and jets are produced in large numbers in nuclear collisions at TeV energies, so that there are many of them in a single fireball. They deposit non-negligible amount of momentum and energy

into the hydrodynamically expanding bulk and cause anisotropies of the expansion. Moreover, due to their multiple production in a single event the resulting anisotropies are correlated with the collision geometry and thus contributes positively also to event-averaged anisotropies in non-central collisions. Using simulations with three-dimensional ideal hydrodynamic model we demonstrate the importance of this effect. It must be taken into account if conclusions about the properties of the hot matter are to be drawn.

Summary:

Poster Session and Wine Tasting / **387**

H-dibaryon in Holographic QCD

Author(s): Hideo Suganuma[1]

Co-author(s): Kohei Matsumoto [1] ; Yuya Nakagawa [1]

[1] *Kyoto University*

We investigate the H-dibaryon (uuddss) in holographic QCD [1, 2].
Holographic QCD is derived from a QCD-equivalent D-brane system
in the superstring theory via the gauge/gravity correspondence.
In holographic QCD, all baryons appear as topological chiral solitons
of Nambu-Goldstone bosons and (axial) vector mesons [1, 2].
In this framework, the H-dibaryon can be described as an SO(3)-type
hedgehog state [3]. In this paper, we present the formalism of
the H-dibaryon in holographic QCD, and investigate its properties.

[1] T. Sakai and S. Sugimoto, Prog. Theor. Phys. 113 (2005) 843; 114 (2005) 1083.

[2] K. Nawa, H. Suganuma and T. Kojo, Phys. Rev. D75 (2007) 086003.

[3] A.P. Balachandran et al., Phys. Rev. Lett. 52 (1984) 887.

Summary:

We investigate the H-dibaryon (uuddss) in holographic QCD, which is derived from a QCD-equivalent D-brane system via the gauge/gravity correspondence.

Satellite Workshop: Accelerators Revealing the QCD Secrets / **454**

LHeC and FCChe: overview of the performances, designs and challenges

Summary:

Satellite Workshop: Accelerators Revealing the QCD Secrets / **456**

eRHIC Design Status and Plans

Satellite Workshop: Accelerators Revealing the QCD Secrets / **455**

RHIC upgrades for the next decade

Satellite Workshop: Accelerators Revealing the QCD Secrets / 443

Colliding relativistic nuclei: selected remarks on future opportunities and challenges

Satellite Workshop: Accelerators Revealing the QCD Secrets / 448

HL-LHC Challenges

Satellite Workshop: Accelerators Revealing the QCD Secrets / 449

Introduction: Setting the Stage

Satellite Workshop: Accelerators Revealing the QCD Secrets / 447

The Spin Structure of the Proton: What RHIC and EIC can teach us

Satellite Workshop: Accelerators Revealing the QCD Secrets / 450

The LHC

Satellite Workshop: Accelerators Revealing the QCD Secrets / 451

HL-LHC accelerator physics challenges

Satellite Workshop: Accelerators Revealing the QCD Secrets / 452

Future Circular Collider Study

Satellite Workshop: Accelerators Revealing the QCD Secrets / 453

High Field Magnets for the Future Circular Collider

Satellite Workshop: Accelerators Revealing the QCD Secrets / **445**

Near and Far Future of Colliding Nuclear Beams at LHC and FCC

Satellite Workshop: Accelerators Revealing the QCD Secrets / **458**

CANCELLED: Strategy for making susteinable the field of Accelerator Science in Europe

Eugenio Nappi[1]

[1] *INFN*

Summary:

Satellite Workshop: Accelerators Revealing the QCD Secrets / **444**

Delineating the QCD phase diagram with data from different accelerators

Satellite Workshop: Accelerators Revealing the QCD Secrets / **457**

Talk from JLAB

Satellite Workshop: Accelerators Revealing the QCD Secrets / **446**

FAIR

Jens Stadlmann[1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung*

Summary:

Section A / **59**

Confinement and Chiral Symmetry Breaking from an ensemble of interacting Instanton-dyons(monopoles) in SU(2) QCD

Author(s): Rasmus Larsen[1]

Co-author(s): Edward Shuryak [2]

[1] *Stony Brook University*

[2] *stony brook university*

We show how the increase in the Instanton-dyon density can explain both Confinement and Chiral symmetry breaking. We simulate an ensemble of 64 interacting Instanton-dyons for 2 colors and 0 or 2 quark flavors. We find that at low temperatures, the high density of dyons prefer a symmetric density, which leads to the confining value of the Polyakov Loop. At the same time the Chiral condensate is highly sensitive to the Polyakov Loop. As the Polyakov Loop gets close to the confining value, the Chiral condensate develops a non-zero expectation value, thus breaking Chiral symmetry.

Summary:

This talk is based on the results of the following papers:

Instanton-dyon Ensemble with two Dynamical Quarks: the Chiral Symmetry Breaking
http://arxiv.org/abs/1511.02237

Interacting Ensemble of the Instanton-dyons and Deconfinement Phase Transition in the SU(2) Gauge Theory
http://arxiv.org/abs/1504.03341

Section A / **85**

Properties of QCD with nonzero chiral chemical potential

Author(s): Victor Braguta[1]

Co-author(s): Andrey Kotov [1] ; Bengt Petersson [2] ; Ernst-Michael Ilgenfritz [3]

[1] *ITEP*

[2] *Bielefeld U.*

[3] *JINR*

This report is devoted to the study of the QCD phase diagram with nonzero chiral chemical potential within lattice simulation. In particular, it is studied the question how nonzero chiral chemical potential influences the transitions: confinement/deconfinement and breaking/restoration of chiral symmetry. The results of the calculation can be explained by the phenomenon which we called chiral catalysis. This phenomenon is based on the fact that the chiral chemical potential plays a role of the catalyst of dynamical chiral symmetry breaking.

Summary:

Section A / **115**

Confinining properties of QCD in strong magnetic backgrounds

Massimo D'Elia[1]

[1] *University of Pisa*

Strong magnetic backgrounds are known to modify QCD properties at a non-perturbative level. We will discuss recent lattice results, obtained for N_f = 2+1 QCD with physical quark masses, concerning in particular the modifications and the anisotropies induced at the level of the static quark-antiquark potential and of other confining properties of strong interactions.

Summary:

Strong magnetic backgrounds are known to modify QCD properties at a non-perturbative level. We will discuss recent lattice results, obtained for N_f = 2+1 QCD with physical quark masses, concerning in particular the modifications and the anisotropies induced at the level of the static quark-antiquark potential and of other confining properties of strong interactions.

Section A / **131**

On Schwinger-Dyson equations for QCD in Coulomb gauge from local action

Daniel Zwanziger[1]

[1] *New York University*

X

Summary:

An intuitive picture of confinement was first proposed by Gribov in which the color-Coulomb potential provides the long-range confining force. This picture has been successfully studied by Hamiltonian methods. We propose here to develop a non-perturbative calculational scheme adapted to local Lagrangian quantum field theory in Coulomb gauge. We are encouraged to do so because of the theorem, "No confinement without Coulomb confinement," which asserts that if the gauge-invariant Wilson potential $V_W(r)$ is confining, then the color-Coulomb potential $V(r)$ is more strongly attractive than $V_W(r)$ at large r, $V(r) > V_W(r)$. The color-Coulomb potential is the instantaneous part of the time-time component of the gluon propagator $D_{00}(x) = V(r)\delta(t) + P(x)$, where $V(r)$ is the instantaneous color-Coulomb potential and $P(x)$ is non-instantaneous.

Starting from the local Lagrangian of quantum gauge field theory in Coulomb gauge, we develop a truncation scheme for a closed set of Schwinger-Dyson (SD) equations that involves only one time. The propagators that appear are either instantaneous, such as $V(r)$, or at equal time, such as the space-space components of the gluon propgator $D^{ET}_{ij}(\vec{x}-\vec{y}) \equiv D_{ij}(x-y)|_{x_0=y_0}$. The local Lagrangian in Coulomb gauge may be either of Yang-Mills type or of the type developed by Gribov and Zwanziger.

Section A / **181**

A gauge-independent Higgs mechanism and the implications for quark confinement

Kei-Ichi Kondo[1]

[1] *Chiba University*

1. Introduction
2. Conventional Higgs mechanism

3. Higgs-Confinement: SU(2) case
4. Higgs-Confinement: SU(3) case
5. Conclusion and discussion

Summary:

We propose a gauge-independent description for the Higgs mechanism by which a gauge boson acquires the mass in a manifestly gauge-invariant way
without assuming spontaneous breakdown of gauge symmetry signaled by a non-vanishing vacuum expectation value of the scalar field.
This enables us to discuss the confinement-Higgs complementarity from a new perspective.
Moreover, we discuss the implications of this Higgs mechanism for quark confinement for the SU(N) Yang-Mills theory.

Section A / **301**

Dyons and Roberge - Weiss transition in lattice QCD

Vitaly Bornyakov[1]

[1] *IHEP*

We study $N_f = 2$ lattice QCD with improved Wilson fermions at imaginary chemical potential μ_I. Simulations are made in the deconfinement phase at few values of μ_I/T to study Roberge-Weiss phase transitions at $\mu_I/T = \pm\pi/3$ and π. We measure spectrum of overlap Dirac operator in background of equilibrium configurations with variable μ_I/T. Numerical evidence is presented to show that Roberge-Weiss transitions are related to changes in the spectrum gap. We suggest explanation of our numerical results in terms of dyons.

Summary:

Section A / **28**

QCD inspired determination of NJL-model parameters

Author(s): Paul Springer[1]

Co-author(s): Fabian Rennecke [2] ; Jens Braun [3] ; Stefan Rechenberger [3]

[1] *Technical University of Munich*

[2] *Justus Liebig University Giessen*

[3] *Technische Universität Darmstadt*

Studies of the QCD phase diagram at finite temperature and quark chemical potential are currently one of the most discussed topics in theoretical physics and are of great importance to better our understanding of heavy-ion collision experiments. However, there is considerable uncertainty about the detailed structure of the QCD phase diagram at high baryon densities. Models provide some insight into the phase structure but usually rely on various parameters and therefore require validation from the point of view of the fundamental theory. We propose to apply nonperturbative functional Renormalization Group methods (FRG) to QCD in order to determine constraints on the parameters used in low-energy QCD models. In particular, this includes a determination of the dependence of these parameters on temperature and quark chemical potential. We present first results and argue that our findings can be used to improve the predictive power of model calculations.

Summary:

Section A / 83

The Dark Side of the Propagators: exploring their analytic properties by a massive expansion

Fabio Siringo[1]

[1] *Università degli Studi di Catania*

A massive expansion, based on *massive* free-particle propagators,
can be set up from first principles[1-3] and shown to be
a powerful variational tool disguised to look like a perturbative approximation[3].
By its optimization, the method provides an analytical tool for exploring the
propagators of QCD deep in the infrared of Minkowski space[3] and from first principles,
without having to alter the Landau gauge Faddeev-Popov Lagrangian in any way.

The expansion is safe in the infrared and is equivalent to the standard perturbation theory in the UV[2,3].
At one-loop, all diverging mass terms cancel exactly without spurious mass counterterms that
would spoil gauge and chiral symmetry of the Lagrangian.
Gluon mass generation and dynamical breaking of chiral symmetry are described in the
same framework.

The propagators emerge as analytic functions and can be easily studied in Minkowski space, shading some
light on analytic properties that could be hardly explored by numerical methods.
Among the main findings, universal scaling properties are predicted for the inverse dressing functions and
shown to be satisfied by the lattice data that collapse on a universal function, irrespective of couplings,
number of colors and of quarks. Direct evidence is given for positivity violation and confinement of gluons and
quarks. Complex conjugated poles are found for the gluon propagator, in agreement with the *i-particle* scenario[4]. The relatively small contribution of the
continuos gluon spectral function explains the phenomenological success of simple tree-level
rational propagators that arise in the refined Gribov-Zwanziger[5] and replica models[6].

[1] F. Siringo, *Perturbative study of Yang-Mills theory in the infrared*, arXiv:1509.05891.

[2] F. Siringo, *Analytical study of Yang-Mills theory in the infrared from first principles*, Nucl.Phys.B907, 572 (2016); arXiv:1511.01015.

[3] F. Siringo, *Analytic structure of QCD propagators in Minkowski space*,
arXiv:1605.07357

[4] L. Baulieu, D. Dudal, M. S. Guimaraes, M. Q. Huber, S. P. Sorella, N. Vandersickel, D. Zwanziger, Phys.Rev.D82, 025021 (2010).

[5] D.Dudal, S.P.Sorella, N.Vandersickel, H.Verschelde, Phys.Rev.D77, 071501 (2008).

[6] S. P. Sorella, J.Phys.A44, 135403 (2011).

Summary:

Analytical functions for the propagators of QCD, including a set of chiral quarks, are derived by a one-loop massive expansion in the Landau gauge, and are studied in Minkowski space, yielding a direct proof of positivity violation and confinement from first principles. Complex conjugated poles are found for the gluon propagator.

Section A / 304

QCD Gluon Green functions free of Quantum fluctuations

Author(s): José Rodríguez-Quintero[1]

Co-author(s): Andreas Athenodorou ; Feliciano De Soto [2] ; Philippe Boucaud [3] ; Savvas Zafeiropoulos

[1] *University of Huelva*

[2] *Universidad Pablo de Olavide*

[3] *Université Paris-Saclay*

Paper recently submitted to arXiv on the subject

Summary:

I shall report on how the Wilson flow technique can efficaciously kill the short-distance quantum fluctuations of 2- and 3-gluon Green functions, remove the ΛQCD scale and destroy the transition from the confining non-perturbative to the asymptotically-free perturbative sector. After the Wilson flow, the behavior of the Green functions with momenta can be described in terms of the quasi-classical instanton background. The same behavior also occurs, before the Wilson flow, at low-momenta. This last result permits applications as, for instance, the detection of instanton phenomenological properties or a cheap lattice calibration.

Section A / **112**

Dyson-Schwinger approach to Hamiltonian QCD

Author(s): Davide Campagnari[1]

Co-author(s): Hugo Reinhardt [1] ; Markus Huber [2]

[1] *Universität Tübingen*

[2] *University of Graz*

Dyson-Schwinger equations are an established, powerful non-perturbative tool for QCD. In the Hamiltonian formulation of a quantum field theory they can be used to perform variational calculations with wave functionals going beyond the Gaussian approximation. The various n-point functions, needed in expectation values of observables like the Hamilton operator, can be thus expressed in terms of the variational kernels of our trial ansatz. Finally, the equations of motion for these variational kernels are derived by minimizing the energy density.

Summary:

Section A / **87**

Hamiltonian Approach to QCD in Coulomb gauge at finite temperatures

Hugo Reinhardt[1]

[1] *Universität Tübingen*

I will review recent results obtained within the Hamiltonian approach to QCD in Coulomb gauge at finite temperatures. The temperature is introduced by compactifying a spatial dimension. Results are presented for the chiral and dual quark condensate as well as for the Polyakov loop and the pressure

Summary:

Section A / 122

Superconformal Algebraic Approach to Hadron Structure: The Perturbative-Nonperturbative Interface in QCD

Guy de Teramond[1]

[1] *University of Costa Rica*

Essential nonperturbative dynamical features of QCD are well captured in a semiclassical effective theory based on the extension of superconformal quantum mechanics to the light-front and its holographic embedding in a higher dimensional gravity theory. This new approach to hadron physics incorporates confinement, the appearance of a massless pion, and Regge spectroscopy consistent with experiment. It also gives remarkable connections between the meson and baryon spectrum. In this talk I will discuss the extension of this approach to describe the structure of heavy-light bound states and the perturbative-nonperturbative interface in QCD.

Summary:

Section A / 124

Polyakov line actions from SU(3) lattice gauge theory with dynamical fermions via relative weights

Author(s): Roman Höllwieser[1]

Co-author(s): Jeff Greensite [2]

[1] *NMSU/VUT*

[2] *SFSU*

We extract an effective Polyakov line action from an underlying SU(3) lattice gauge theory with dynamical fermions via the relative weights method. The center-symmetry breaking terms in the effective theory are fit to a form suggested by the hopping-parameter expansion, and the effective action is solved at finite chemical potential by a mean field approach. We show results for a small sample of lattice couplings, lattice actions, and lattice extensions in the time direction. We find in some instances that the long-range couplings in the effective action are very important to the phase structure, and that these couplings are responsible for long-lived metastable states in the effective theory. Only one of these states corresponds to the underlying lattice gauge theory.

Summary:

We extract an effective Polyakov line action from an underlying SU(3) lattice gauge theory with dynamical fermions via the relative weights method. The center-symmetry breaking terms in the effective theory are fit to a form suggested by the hopping-parameter expansion, and the effective action is solved at finite chemical potential by a mean field approach. We show results for a small sample of lattice couplings, lattice actions, and lattice extensions in the time direction. We find in some instances that the long-range couplings in the effective action are very important to the phase structure, and that these couplings are responsible for long-lived metastable states in the effective theory. Only one of these states corresponds to the underlying lattice gauge theory.

Section A / 151

Three-point functions in Yang-Mills Theory and QCD in Landau gauge

Author(s): Adrian Lorenz Blum[1]

Co-author(s): Andreas Windisch [2] ; Markus Huber [3] ; Reinhard Alkofer [3]

[1] *Karl-Franzens Universität Graz*
[2] *Washington University in St Louis*
[3] *University of Graz*

All the information about a quantum field theory is contained in the n-point functions. Once the n-point functions are computed they can be used in a next step to calculate hadron properties e.g. via the Bethe-Salpeter approach. On the level of three-point functions especially the three-gluon and quark-gluon vertices are of interest. The three-gluon vertex captures the property of self-interactions between gauge bosons in non-Abelian theories which is linked to confinement. On the other hand the quark-gluon vertex is crucial for the coupling of the Yang-Mills sector to the matter sector. In this work we will discuss solutions for the three-gluon and quark-gluon vertices from Dyson-Schwinger Equations (DSEs) and the three-particle irreducible (3PI) formalism.

Summary:

Based on arguments from Dyson-Schwinger Equations (DSEs) and the three-particle irreducible (3PI) formalism a truncated and closed set of equations for propagators and three-point functions is derived and solutions for the three-gluon vertex and the quark-gluon vertex are discussed.

Section A / **173**

On Landau gauge Yang-Mills correlation functions

Author(s): Anton Cyrol[None]

Co-author(s): Jan M. Pawlowski [1] ; Leonard Fister [2] ; Mario Mitter [3] ; Nils Strodthoff [4]

[1] *University of Heidelberg*
[2] *IPhT, Saclay*
[3] *Univ. Heidelberg*
[4] *LBNL*

We investigate Landau gauge $SU(3)$ Yang-Mills theory in a systematic vertex expansion scheme for the effective action with the functional renormalisation group.
Particular focus is put on the dynamical creation of the gluon mass gap at non-perturbative momenta and the consistent treatment of quadratic divergences. The non-perturbative ghost and transverse gluon propagators as well as the momentum-dependent ghost-gluon, three-gluon and four-gluon vertices are calculated self-consistently with the classical action as only input. The apparent convergence of the expansion scheme is discussed and within the errors, our numerical results are in quantitative agreement with available lattice results.

Summary:

http://inspirehep.net/record/1456147

Section A / **175**

Towards a theoretical description of dense QCD

Author(s): Owe Philipsen[1]

Co-author(s): Jonas Glesaaen [2]

[1] *Goethe-University Frankfurt*

[2] *University Frankfurt*

The properties of matter at finite baryon densities plays an important role for the astrophysics of compact stars as well as for heavy ion collisions or the description of nuclear matter. Because of the sign problem of the quark determinant, lattice QCD cannot be simulated by standard Monte Carlo at finite baryon densities. I describe an alternative attempt to treat dense QCD with an effective 3d lattice theory, which is valid for very heavy quarks only, but shows all qualtitative features of nuclear physics emerging from QCD. In particular, the nuclear liquid gas transition and an equation of state for baryons can be directly calculated from QCD.

Summary:

Section A / **177**

Confinement, NonAbelian monopoles, and 2D CP(N-1) model on finite length strings

Kenichi Konishi[1]

[1] *University of Pisa*

We discuss the confinement mechanism based on nonAbelian variety of dual superconductivity. Important hints come from physics of strongly-coupled infrared-fixed-point theories in N=2 supersymmetric QCD, which turn into confining vacua under a small relevant perturbation. The quest for the semiclassical origin of these nonAbelian monopoles, ubiquitous as the infrared degrees of freedom of supersymmetric gauge theories, motivates us to study the quantum dynamics of 2D CP(N-1) model defined on a finite-width world-strip. Latest results on these problems are presented.

Summary:

Section A / **14**

Deconfinement and chiral transition in AdS/QCD wall models supplemented with a magnetic field

Author(s): David Dudal[None]

Co-author(s): Diego Rocha Granado [1] ; Thomas Mertens [2]

[1] *Departamento de Física Teórica, Instituto de Física, UERJ - Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, 20550-013, Maracanã, Rio de Janeiro, Brasil*

[2] *Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544, USA*

We discuss the phenomenon of (inverse) magnetic catalysis for both the deconfinement and chiral transition. We discriminate between the hard and soft wall model, which we suitably generalize to include a magnetic field. Our findings show a critical deconfinement temperature going down, in contrast with the chiral restoration temperature growing with increasing magnetic field. This is at odds with contemporary lattice data, so the quest for a holographic QCD model capable of capturing inverse magnetic catalysis in the chiral sector remains open.
We outline further directions in this research.

This talk is based on joint work with Diego Rocha Granado and Thomas Mertens (see http://inspirehep.net/record/14041

Summary:

Section A / 39

CANCELLED: suitability of quadratic gauge for non-perturbative QCD

Haresh Raval[1]

[1] *Indian Institute of Technology Bombay*

The confinement and the gribov ambiguity are two non-perturbative phenomena of great importance in QCD. Abelian dominance, a signature to the confinement, is mostly studied in Maximal abelian gauge which is Abelian projection. The Gribov ambiguity exists in various gauges. Algebraic gauges are more likely to be ambiguity free but are not compatible with the boundary conditions i.e.,the ambiguity continues to exist on a compact manifold. In general, algebraic gauges are not Lorentz invariant, which is their fundamental flaw. We consider a quadratic gauge, which is an algebraic gauge. It is Lorentz invariant and does not fall into the class of Abelian projection. We show that the gauge has two strong signatures of the confinement. We then provide an example of spherically symmetric gauge field and prove that with a proper boundary condition on the configuration, this gauge removes the ambiguity on a compact manifold $\mathbb{S}^3$. Thus, It is more suitable for the non-perturbative phenomena in QCD.

Summary:

Section A / 47

CANCELLED: Thermal ground state of SU(2) Yang-Mills theory

Ralf Hofmann[1]

[1] *KIT/U Heidelberg*

We discuss how the thermal ground state of an SU(2) Yang-Mills theory in its deconfining phase is composed of Harrington-Shepard (HS) (anti)calorons that are subject to deformation due to overlapping and static peripheries. The construction first performs a spatial coarse-graining over the central regions for HS (anti)calorons in isolation – a unique process which determines the temperature and Yang-Mills scale dependence of an inert adjoint scalar field – and then uses an adiabatic argument to quantify the effect of overlap by slowly
letting (protected) centers approach one another spatially (dense packing). The resulting effective thermal quantum field theory's equation of motion possess a ground-state
solution which summarizes this physics collectively and breaks the gauge symmetry SU(2) down to U(1). We show that this ground state carries densities of electric/magnetic dipoles that are associated with a temperature independent permittivity/permeability.

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Section A / **64**

Gauge engineering and propagators

Axel Maas[1]

[1] *University of Graz*

Beyond perturbation theory gauge-fixing becomes more involved due to the Gribov-Singer ambiguity: The appearance of additional gauge copies requires to define a procedure how to handle them. For the case of Landau gauge the structure and properties of these additional gauge copies will be investigated. Based on these properties new gauge conditions are constructed to account for these gauge copies.

The dependence of the propagators on the choice of these complete gauge-fixings will then be investigated using lattice gauge theory for Yang-Mills theory. It is found that the implications for the infrared, and to some extent mid-momentum behavior, can be substantial. In going beyond the Yang-Mills case it turns out that the influence of matter can generally not be neglected. This will be briefly discussed for various types of matter.

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Section A / **70**

Domain wall network as QCD vacuum: confinement, chiral symmetry, hadronization

Author(s): Sergei Nedelko[1]

Co-author(s): Vladimir Voronin [2]

[1] *Joint Institute for Nuclear Research, BLTP*

[2] *Joint Institute for Nuclear Research*

An approach to QCD vacuum as a medium describable in terms of statistical ensemble of almost everywhere homogeneous Abelian (anti-)self-dual gluon fields is briefly reviewed. These fields play the role of the confining medium for color charged fields as well as underline the mechanism of realization of chiral $SU_{\rm L}(N_f) \times SU_{\rm R}(N_f)$ and $U_A(1)$ symmetries. Hadronization formalism based on this ensemble leads to manifestly defined quantum effective meson action. Strong, electromagnetic and

weak interactions of mesons are represented in the action in terms of nonlocal n-point interaction vertices given by the quark-gluon loops averaged over the background ensemble. New systematic results for the mass spectrum and decay constants of radially excited light, heavy-light mesons and heavy quarkonia as well as electromagnetic form factors are presented. Interrelations between the present approach, models based on ideas of soft wall AdS/QCD, results of functional renormalization group and DSE results, and the picture of harmonic confinement are outlined.

S.N. Nedelko and V.E. Voronin,
"Regge spectra of excited mesons, harmonic confinement and QCD vacuum structure,"
Phys. Rev. D 93, no. 9, 094010 (2016)
[arXiv:1603.01447 [hep-ph]].

S.N. Nedelko and V.E. Voronin,
"Domain wall network as QCD vacuum and the chromomagnetic trap formation under extreme conditions,"
Eur. Phys. J. A 51, no. 4, 45 (2015)
[arXiv:1403.0415 [hep-ph]]

B.V. Galilo and S.N. Nedelko,
"Impact of the strong electromagnetic field on the QCD effective potential for homogeneous Abelian gluon field configurations,"
Phys.Rev. D84 (2011) 094017
[arXiv:1107.4737 [hep-ph]].

Summary:

Section A / **86**

From QCD's n-point functions to nucleon resonances

Gernot Eichmann[1]

[1] *University of Giessen*

I will present recent progress in the calculation of nucleon resonances using the framework of Dyson-Schwinger and Bethe-Salpeter equations. The resulting mass spectra are obtained both from the three-body bound-state equation as well as its quark-diquark approximation starting from the level of QCD's propagators and vertices. I will outline how a better understanding of these n-point functions can improve the description of the hadron spectrum. The advancements and challenges with functional methods in the extraction of resonance properties will be discussed in comparison with analogous efforts in lattice QCD. I will show results for the Roper resonance as the nucleon's first radial excitation, together with other resonances and their structure properties including electromagnetic transition form factors.

Summary:

Section A / **188**

QCD-like theories at finite density

Lorenz von Smekal[1]

[1] *Justus-Liebig University Giessen*

Studies of QCD-like theories without a fermion sign problem at finite density by now have a rather long history already. I will report recent results from two-color QCD, with two instead of the usual three colors, and G_2-QCD, with gauge group G_2 instead of $SU(3)$. Both have bosonic diquark

baryons. The physics of those is believed to be fairly well understood and qualitatively resembles QCD at finite isospin density with pion condensation. There is good guidance from effective field theory predictions and model studies of the BEC-BCS crossover inside the condensed phase. This allows to test effective lattice theories such as those for heavy quarks derived for QCD from combined strong-coupling and hopping expansions. We observe good evidence that they are indeed able to resolve the characteristic differences between the various theories. In order to understand the generic features of the density at very low temperatures for light quarks in more detail as well, at reasonable costs, we have also simulated these theories in two dimensions and compared our results with the corresponding free lattice fermions to better disentangle lattice artifacts from baryonic bound states and identify manifestations of confinement at finite density.

Summary:

Section A / **202**

CANCELLED:The pseudoscalar meson octet in term of SU(N) Gauge Invariant Lagrangian

Andrew Koshelkin[1]

[1] *National Research Nuclear University (MEPhI)*

By breaking the initial SU(N) symmetry, we derive the Lagrangian1 governing the dynamics of the massive scalar particles, which can be treated as the octet of the pseudoscalar mesons. The contribution of both the quark-gluon interaction and self-interaction gluon field into the masses of the octet particles is considered. Provided that the hadronization of the confinement matter into the pion triplet only occurs, the QCD coupling constant is evaluated in this case in the developed model.

References

1.A.V.Koshelkin,Phys.Rev., v. D92, p. 045017 (2015).

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References

1.A.V.Koshelkin,Phys.Rev., v. D92, p. 045017 (2015).

Section A / **203**

Next-to-leading order corrections to the heavy quark potentials in the effective string theory

Author(s): Sungmin Hwang[1]

Co-author(s): Antonio Vairo ; Nora brambilla

[1] *Technical University of Munich*

We present the calculation of the next-to-leading order in the heavy quark-antiquark potentials within the framework of the effective string theory. Elaborate arguments for simplifying and reducing the number of dimensionful parameters of the effective string theory are also discussed.

Summary:

Section A / 219

Detecting magnetic defects in continuum Yang-Mills theory, ensembles, and gluon topological confinement

Luis E. Oxman[1]

[1] *Universidade Federal Fluminense*

Initially, we discuss a family of gauge fixing conditions that detect sectors of magnetic defects in continuum YM theories. The BRST symmetry cannot be globally defined, due to sector-dependent regularity conditions on the ghosts fields. This opens a window for the space of quantum states to be different from that implied when defects are removed. Next, we review how to integrate the partial contributions originated from non-Abelian monopoles, characterized by phenomenological dimensionful parameters. Using polymer techniques, we suggest how the ensemble can be related with a gauge model containing adjoint Higgs fields. In the SSB phase, due to topological reasons, there are no isolated adjoint magnetic charges, which can be interpreted as the absence of gluons in asymptotic states.
Furthermore, a colour singlet quark-antiquark pair would be confined by a smooth center string, while a nonsinglet pair would combine with a valence gluon to form a hybrid meson.

Summary:

Section A / 221

The density of states approach to Lattice Gauge Theory

Roberto Pellegrini[1]

[1] *The University of Edinburgh*

The LLR method was recently proposed for numerical computations of continuous density of states. The density of states approach is particularly useful when dealing with meta-stabilities and for computing free-energies. In this talk I will review the method and discuss compact U(1) Lattice Gauge Theory, for which our algorithm has proved to be highly efficient and provided results that significantly improve upon the previous literature.
The method can also be applied to theories at finite density affected by the sign problem, reducing a high dimensional oscillatory integral to a one-dimensional one. I will discuss our results for the relativistic Bose gas.

Summary:

Section A / 225

Thermodynamics and the Polyakov loop in the covariant variational approach to Yang-Mills theory

Author(s): Markus Quandt[1]

Co-author(s): Hugo Reinhardt [1]

[1] *Universität Tübingen*

We extend the covariant variational approach for Yang-Mills theory in Landau gauge to non-zero temperatures. The renormalization of the system is revisited and it is shown how the zero-temperature counter terms can be used to render the system finite at *any* temperature. Numerical solutions for the thermal propagators are presented and compared to high-precision lattice data. To study the deconfinement phase transition, we adapt the formalism to background gauge and compute the effective action of the Polyakov loop for the colour groups SU(2) and SU(3). Using the zero-temperature propagators as input, all parameters are fixed at *T=0* and we find a clear signal for a deconfinement phase transition at finite temperatures, which is second order for SU(2) and first order for SU(3). The critical temperatures obtained are in reasonable agreement with lattice data. Continuing this investigation, we study thermodynamics and, in particular, the pressure of the Yang-Mills system, and compare to both lattice data and the results of the non-convariant Hamiltonian approach. Finally, we briefly discuss the inclusion of fermions and possible ways to extended our method beyond the Gaussian ansatz.

Summary:

Section A / **239**

Asymptotic freedom in the Hamiltonian approach to binding of colour

Maria Gomez Rocha[None]

The renormalization group procedure for effective particles (RGPEP) has been developed during the last years as a non-perturbative tool for constructing bound-states in quantum field theories 1. It stems from the similarity renormalization group procedure (SRG) 2 and introduces the concept of effective particles, which differ from the point-like canonical, bare ones by having a finite size s. The effective particles in the Fock space build the hadronic eigenstates of a family of effective Hamiltonians H_s depending on the size s as the RGPEP scale parameter. We apply the RGPEP to QCD using an expansion in powers of the coupling constant up to third order. The Hamiltonian running coupling, g_s, is extracted from the interaction terms in H_s^{QCD} 3. We thus demonstrate that the RGPEP passes the test of describing asymptotic freedom, which is a precondition for any approach aiming at using QCD for explaining hadrons in the Minkowski space-time, especially for tackling nonperturbative issues, such as the ones that emerge when one allows effective gluons to have masses 2. Applications of this method beyond the leading order are under way and it is hoped that the interaction terms relevant to understanding of confinement will be gradually determined.

1 S. D. Glazek, Acta Phys. Polon. B42 (2011) 1933; Acta Phys. Polon. B43 (2012) 1843.

2 K. G. Wilson, T. S. Walhout, A. Harindranath, W.-M. Zhang, R. J. Perry, and S. D. Glazek, Phys. Rev. D49 (1994) 6720-6766

3 M. Gomez-Rocha and S. D. Glazek, Phys. Rev. D92 (2015) 065005.

Summary:

Section A / **345**

Chiral symmetry breaking in continuum QCD

Author(s): Mario Mitter[1]

Co-author(s): Anton Cyrol ; Jan M. Pawlowski [2] ; Nils Strodthoff [3]

[1] *Univ. Heidelberg*

[2] *University of Heidelberg*

[3] *LBNL*

Yang-Mills theory and 2-flavour QCD are investigated with the functional renormalisation group equation in the vacuum. Starting from the perturbative parameters of QCD as only input, the effective action is calculated in a vertex expansion. The focus is put on the properties of the corresponding 1PI correlations functions as well as the relation between confinement and chiral symmetry breaking.

Summary:

Section A / **145**

Heavy-heavy and heavy-light quarks interactions generated by QCD vacuum

Mirzayusuf Musakhanov[1]

[1] *National University of Uzbekistan*

The QCD vacuum is populated by instantons that correspond to the tunneling processes in the vacuum. This mechanism creates the strong vacuum gluon fields. As result, The QCD vacuum instantons induce very strong interactions between light quarks, which was initiall almost massles. Such strong interactions bring about a large dynamical mass M of the light quarks and can bound them to produce almost massless pions in accordance with the spontaneous breaking of chiral symmetry ($S\chi$SB). On the other hand, the QCD vacuum instantons also interact with heavy quarks and responsible for the generation of the heavy-heavy and heavy-light quarks interactions, which has a traces of the $S\chi$SB (see 1 and references therein). If we take the average instanton size ρ =0.35 fm, and the average inter-instanton distance $R = 0.856$ fm from our previous estimates, we obtain at leading order in the $1/N_c$ expansion the dynamical light quark mass to be $M = 570$ MeV and the instanton media contribution to the heavy quark mass ΔM=148 MeV. These factors define the coupling between heavy-heavy and heavy-light quarks induced by the QCD vacuum instantons.

We consider first the instanton effects on the heavy-quark potential, including its spin-dependent part. We also discuss those effects on the masses of the charmonia and their hyperfine mass splittings 1.

At the second part of the present talk, we discuss the interactions between a heavy quark and light mesons in the case of the light quark flavor number $N_f = 2$ case 2.

1 U. Yakhshiev, Hyun-Chul Kim, B. Turimov, M.M. Musakhanov, Emiko Hiyama, Instanton effects on the heavy-quark static potential, [arXiv:1602.06074 [hep-ph]].

2 M. Musakhanov, Heavy-light quarks interactions in QCD vacuum, PoS BaldinISHEPPXXII {\bf } (2015) 012 [arXiv:1412.4472 [hep-ph]].

Summary:

Section A / **293**

On lowest Landau level dominance in QCD

Author(s): Falk Bruckmann[1]

Co-author(s): Ferenc Pittler [2] ; Gergely Endrodi [3] ; Matteo Giordano [4] ; Sandor Katz [5] ; Tamas G. Kovacs [6]

[1] *U Regensburg*

[2] *PTE*

[3] *University of Regensburg*

[4] *CEA-Saclay*

[5] *Eotvos University*

[6] *Institute for Nuclear Physics, Debrecen*

QCD thermodynamics in strong magnetic fields shows some unexpected features like inverse catalysis, which have been revealed mainly through lattice studies. Many effective descriptions, on the other hand, use Landau levels or approximate the system by just the lowest Landau level (LLL). Analyzing lattice configurations we ask whether such a picture is justified. We find the LLL to be separated from the rest by a spectral gap in the two-dimensional Dirac operator and look for the corresponding signals in four dimensions. We determine to what extent the quark condensate is LLL dominated at various magnetic fields and temperatures.

Summary:

Section A / **440**

CANCELLED: Conclusions from the simplifications provided by Effective Locality in QCD

Peter Tsang[1]

[1] *Brown University*

A new analytic non-perturbative, gauge invariant exact solution to QCD is derived. This solution is then compared with experimental data. Specifically high-energy proton-proton elastic scattering at ISR energies. A first proposal for LHC energies is examined also.

Summary:

Section A: Focus Subsection / **128**

Chiral Magnetic Effect in Condensed Matters

Author(s): Dmitri Kharzeev[1]

Co-author(s): Qiang Li [2]

[1] *Stony Brook University*

[2] *Brookhaven National Laboratory*

The chiral magnetic effect (CME) is the generation of electrical current induced by chirality imbalance in the presence of magnetic field. It is a macroscopic manifestation of the quantum chiral anomaly in systems possessing charged chiral fermions. In quark-gluon plasma containing nearly massless quarks, the chirality imbalance is sourced by the topological transitions. In condensed matter systems, the chiral quasiparticles emerge in the so-called Dirac and Weyl semimetals having a linear dispersion relation. Recently, CME was discovered first in a 3D Dirac semimetal $ZrTe_5$ [Li,

Kharzeev, et al arXiv:1412.6543, Nature Physics (2016) doi:10.1038/nphys3648)]. It is now observed in more than half a dozen Dirac and Weyl semimetals. 3D Dirac/Wyl semimetals have opened a fascinating possibility to study the quantum dynamics of relativistic field theory in condensed matter experiments, with potential for important practical applications.

Summary:

Section A: Focus Subsection / **191**

Liberation on walls in gauge theories and quantum anti-ferromagnets

Tin Sulejmanpasic[None]

I will discuss the phenomenon of quark liberation on domain walls in gauge theories which are confining in the bulk. Specifically I will discuss confinement-preserving compactifications of such theories. These are confining due to the magnetic bion mechanism. I will show that liberation on domain walls becomes natural in such theories. I will also discuss the spin-1/2 or "spinon" confinement in the valence bond solid phase of quantum anti-ferromagnets in two spatial dimensions. This phase generically has a degenerate ground state and allows for stable domain walls. I will discuss the circumstances under which spinon excitations are liberated on the domain wall, and present numerical evidence of this phenomenon.

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Section A: Focus Subsection / **150**

Some Relations for Quark Confinement and Chiral Symmetry Breaking in QCD

Author(s): Hideo Suganuma[1]

Co-author(s): Chihiro Sasaki ; Kohei Matsumoto [2] ; Krzysztof Redlich [3] ; Takahiro Doi [1] ; Yuya Nakagawa [2]

[1] *Kyoto U*

[2] *YITP, Kyoto U*

[3] *University of Wroclaw*

We study the relation between quark confinement and chiral symmetry breaking in QCD.

First, we analytically derive some relations of the Polyakov loop or its fluctuations with Dirac eigenmodes for Wilson, clover and Domain-Wall fermions in QCD [1-3]. For these quantities related to confinement, the contribution from the low-lying Dirac eigenmodes is found to be negligibly small, while the modes are essential for chiral symmetry breaking.

Second, we study quark confinement and chiral symmetry breaking in holographic QCD in various space-time dimensions.

1 T.M. Doi, H. Suganuma and T. Iritani, Phys. Rev. D90, 094505 (2014).

2 T.M. Doi, K. Redlich, C. Sasaki and H. Suganuma, Phys. Rev. D92, 094004 (2015).

3 H. Suganuma, T.M. Doi and T. Iritani, Prog. Theor. Exp. Phys. 2016, 013B06 (2016).

Summary:

We study the relation between quark confinement and chiral symmetry breaking in QCD. First, we derive some analytical relations between the Polyakov loop and Dirac eigenmodes
for Wilson, clover and Domain-Wall fermions in QCD. Second, we study quark confinement and chiral symmetry breaking in holographic QCD in various space-time dimension.

Section A: Focus Subsection / 192

CANCELLED: Folding proteins at the speed of life

Antti Niemi[1]

[1] *Uppsala University/cnrs*

The protein folding problem, it has been claimed, is one of the most important problems in science; Dirac stated that the problem of life is one in theoretical physics. We argue that gauge invariance can be employed, to develop an energy function that describes the dynamics of a folding protein, with sub-atomic precision.

Summary:

The protein folding problem, it has been claimed, is one of the most important problems in science; Dirac stated that the problem of life is one in theoretical physics. We argue that gauge invariance can be employed, to develop an energy function that describes the dynamics of a folding protein, with sub-atomic precision.

Section A: Focus Subsection / 90

Higgsless superconductivity from topological defects in compact BF terms

Author(s): Maria Cristina Diamantini[1]

Co-author(s): Carlo Trugenberger [2]

[1] *Universita e INFN, Perugia (IT)*

[2] *SwissScientific*

We present a new Higgsless model of superconductivity, inspired from anyon superconductivity but P- and T-invariant and generalizable to any dimension. While the original anyon superconductivity mechanism was based on incompressible quantum Hall fluids as average field states, our mechanism involves topological insulators as average field states. In D space dimensions it involves a (D-1)-form fictitious pseudovector gauge field which originates from the condensation of topological defects in compact low-energy effective BF theories. In the average field approximation, the corresponding uniform emergent charge creates a gap for the (D-2)-dimensional branes via the Magnus force, the dual of the Lorentz force. One particular combination of intrinsic and emergent charge fluctuations that leaves the total charge distribution invariant constitutes an isolated gapless mode leading to superfluidity. The remaining massive modes organise themselves into a D-dimensional charged, massiv!
e vector. There is no massive Higgs scalar as there is no local order parameter. When electromagnetism is switched on, the photon acquires mass by the topological BF mechanism. Although the

charge of the gapless mode (2) and the topological order (4) are the same as those of the standard Higgs model, the two models of superconductivity are clearly different since the origins of the gap, reflected in the high-energy sectors are totally different. In 2D this type of superconductivity is explicitly realized as global superconductivity in Josephson junction arrays. In 3D this model predicts a possible phase transition from topological insulators to Higgsless superconductors.

Summary:

Section A: Focus Subsection / 160

Towards overcoming the Monte Carlo sign problem with tensor networks - the case of the two-flavour Schwinger model with chemical potential

Author(s): Krzysztof Cichy[1]

Co-author(s): Hana Saito [2] ; J. Ignacio Cirac [3] ; Karl Jansen [4] ; Mari Carmen Banuls [5] ; Stefan Kühn [3]

[1] *Goethe University Frankfurt*

[2] *University of Tsukuba*

[3] *Max Planck Institute for Quantum Optics*

[4] *DESY*

[5] *Max-Planck-Institute fo Quantum Optics*

The study of lattice gauge theories with Monte Carlo simulations is hindered by the infamous sign problem that appears under certain circumstances, in particular at non-zero chemical potential. So far, there is no universal method to overcome this problem. However, recent years brought a new class of non-perturbative Hamiltonian techniques named tensor networks, where the sign problem is absent. In previous work, we have demonstrated that this approach, in particular matrix product states in 1+1 dimensions, can be used to perform precise calculations in a lattice gauge theory, the massless and massive Schwinger model. We have computed the mass spectrum of this theory, its thermal properties and real-time dynamics. In this work, we extend our calculations to the case of two flavours and non-zero chemical potential. We are able to reliably reproduce known analytical results for this model, thus demonstrating for the first time that tensor networks can tackle the sign problem of a lattice gauge theory at finite density.

Summary:

Section A: Focus Subsection / 231

CANCELLED:Gauge fixing in first order phase transition using quantum annealing

Vesna Berec[1]

[1] *Institute of Nuclear Sciences Vinca*

We consider a quantum annealing simulation optimized for lattice QCD, reflecting the nonlinear network topology of the Kuramoto model where all the oscillators are considered to have distinct intrinsic natural frequency and a coupling scheme in which the optimum weight of a link to neighboring sites depends on the number of shortest paths crossing it. The onset of synchronization relies on incoherent quantum tunneling in the mean field regime, manifesting that the spacing between lattice sites approaches to zero range. We theoretically analyze the performance of quantum annealing considering a Discrete Nonlinear Schrödinger (DNLS) equation that allows for a mean-field solution and, we demonstrate the first-order phase transition in synchronization manifold.

Summary:

Section A: Focus Subsection / **291**

Protein phase structure study within gauge field theory model

Author(s): Alexander Molochkov[1]

Co-author(s): Antti Niemi [2]

[1] *School of Biomedicine, Far Eastern Federal University*

[2] *Uppsala University/cnrs*

The gauge field theory approach, which allows a natural way to introduce collective degrees of freedom and nonlinear topological structures based on fundamental principles of gauge symmetry is considered. This approach use description of the local geometry of proteins based on the formalism of discrete coordinates of Freney. Under this formalism, proteins are considered as one-dimensional discrete uniformity, which determined the free energy functional, defined solely by the angles of curvature and torsion. Upon rotation of the local coordinate system doublet of dynamic variables is transformed just as two-dimensional Abelian Higgs multiplet. Within this approach structure of protein backbone is defined by superposition of one-dimensional topological solitons (kinks), what allows accurate parameterise the three-dimensional structure of the protein backbone with precision up to 1A. We apply the developed approach to study of the protein phase diagram.

Summary:

Section B / **341**

Recent Results on Light Meson Decays at BES III

Achim Denig[1]

[1] *Johannes Gutenberg University Mainz*

We report on BESIII measurements of the timelike pion form factor obtained via the initial state radiation technique, the decays of η' into the final states $\pi^+\pi^-\gamma$, $e^+e^-\gamma$ as well as the observation of the η' decay into ωe^+e^-.

Summary:

We report on recent results from the BESIII collaboration in the field of
light meson physics with primary focus on measurements of transition form factors as
well as studies of the decay dynamics of η' mesons. The new results include measurements of the Dalitz decay of η', the observation of its decay into ωe^+e^- as well as a new high statistics measurement of the anomalous decay into $\pi^+\pi^-\gamma$.
Those investigations have been shown to be of relevance for an improved theoretical determination of the hadronic light-by-light contribution to the anomalous magnetic moment of the muon, $g-2$. In that context, we also report on a new precision measurement of the pion form factor, which is of utmost importance for the hadronic vacuum polarization contribution of the muon $g-2$.

Section B / **329**

CANCELLED Unitary coupled channel approach to diffractive scattering and its application to axial vector states

Ed Berger[1]

[1] *Argonne National Laboratory (US)*

Bernhard Ketzer [Bernhard.Ketzer@cern.ch]

Summary:

We show that a single $I = 1$ spin-parity $J^{PC} = 1^{++}$ a_1
resonance can manifest itself as two separated mass peaks, one decaying into an S-wave $\rho\pi$ system and the second
decaying into a P-wave $f_0(980)\pi$ system, with a rapid increase of the phase difference between their amplitudes arising mainly
from the structure of the diffractive production process. This study clarifies questions related to the mass, width, and decay rates of the
a_1 resonance raised by the recent high statistics data of the COMPASS collaboration on a_1 production in
$\pi N \to \pi\pi\pi N$ at high energies. This presentation will be based on Phys Rev Letters 114, 192001 (2015) with Jean-Louis Basdevant and more recent research.

Section B / **249**

CANCELLED: Polarizability of pseudoscalar mesons from the lattice calculations

Author(s): Elena Luschevskaya[1]

Co-author(s): Olga Solovjeva [2]

[1] *State Scientific Center of Russian Federation - Institute of Theoretical and Experimental Physics*

[2] *Alikhanov Institute of Theoretical and Experimental Physics*

We explore the ground state energy of pseudoscalar charged and neutral mesons as a function of external magnetic field in SU(3) lattice gauge theory. We calculate the dipole magnetic polarizabilities and hyperpolarizabilities of charged and neutral pseudoscalar pi and K mesons. It was found that the magnetic polarizability of charged pion agrees with the experimental prediction of COMPASS collaboration.

Summary:

Section B / **319**

Nucleon matrix elements and charges in lattice QCD

Constantia Alexandrou[None]

We will discuss the extraction of the axial, scalar and tensor charges using twisted mass fermions with simulations at a physical value of the u and quark mass. In addition, we will discuss the nucleon sigma-terms and compare the results obtained recently within lattice QCD.

Summary:

Section B / **10**

Exotic Hadrons and Large Nc QCD

Thomas Cohen[1]

[1] *University of Maryland*

While QCD is the theory underlying hadronic physics, much of our intuition about hadronic states has been developed in the context of the constituent quark model. Exotic states—ones that cannot be described in the simplest version of the quark models with mesons as a quark-antiquark state and baryons as a three quark state—are important since they clarify the limitation of the quark model as a description of QCD. Recently, there has been considerable excitement in the spectroscopy of hadrons containing heavy quarks: pentaquarks containing a charm and anti-charm quarks have been discovered and there is strong evidence that at least some of the observed X, Y, Z states are exotic tetraquarks. However, the question of whether exotics composed of light quarks exist remains murky. This talk uses the theoretical perspective of large Nc QCD to focus on the possibility of light quark exotics. A world where the number of colors is large simplifies many of the issues that make the phenomenology of light quark states so complicated. The status of light quark exotics at large Nc will be briefly reviewed. A key result stressed in this talk is that there exists a variant of the large Nc limit in which quarks are in the two-index symmetric representation of color. In this limit, tetraquarks composed of light quarks are shown to exist as narrow resonant states. Minimally, this proves that there is nothing generic in the structure of gauge theories that prevents light-quark tetraquarks from existing.

Section B / 17

Dispersive approach to QCD and hadronic contributions to electroweak observables

Alexander Nesterenko[1]

[1] *Joint Institute for Nuclear Research*

The dispersive approach to QCD, which extends the applicability range of perturbation theory towards the infrared domain, is applied to the study of the hadronic vacuum polarization function and related quantities. This approach merges the intrinsically nonperturbative constraints, which originate in the kinematic restrictions on the relevant physical processes, with corresponding perturbative input. The obtained hadronic vacuum polarization function agrees with pertinent lattice simulation data. The evaluated hadronic contributions to the muon anomalous magnetic moment and to the shift of the electromagnetic fine structure constant conform with recent estimations of these quantities.

1 A.V.Nesterenko, J. Phys. G42, 085004 (2015).

2 A.V.Nesterenko, Phys. Rev. D88, 056009 (2013).

3 M.Baldicchi, A.V.Nesterenko, G.M.Prosperi, and C.Simolo, Phys. Rev. D77, 034013 (2008).

[4] A.V.Nesterenko and J.Papavassiliou, J. Phys. G32, 1025 (2006).

Section B / 29

Recent results from CMD-3 at VEPP-2000

Simon Eydelman[1]

[1] *Budker Institute of Nuclear Physics (RU)*

Regular operation of the VEPP-2000 electron-positron collider started at the end of 2010 and about 60 pb^{-1} were collected so far by the CMD-3 detector in the whole available c.m. energy range from 0.32 GeV to 2.0 GeV. These measurements allow improvements in the precision of the predicted value of the muon anomalous magnetic moment. We report here current results of analysis of the collected data for various modes of $e^+e^+ \to$ hadrons.

Summary:

Section B / **31**

On the description of the exotic states within QCD sum rules

Author(s): Dmitri Melikhov[1]

Co-author(s): Wolfgang LUCHA [2]

[1] *HEPHY*

[2] *Austrian Academy of Sciences*

The method of QCD sum rules is based on the extraction of hadron observables (decay constants, form factors, etc) from the correlation functions of the appropriate quark currents. Because of the properties of the correlation functions containing the exotic multiquark (i.e. four-quark, five-quark) currents, the contribution of the exotic multiquark hadrons to these correlation functions emerge only at order alpha_s and higher; the leading-order diagrams do not contain the contributions of the exotic multiquark states. Respectively, for the analysis of the exotic-states properties within QCD sum rules, the knowledge of the radiative corrections to the correlations functions is mandatory.

Summary:

Section B / **98**

Pion-photon transition form factor at low-mid momenta within collinear QCD

Sergey Mikhailov[1]

[1] *Joint Institute for Nuclear Research*

We consider the predictions and estimate systematically all theoretical uncertainties of pion-photon transition form factor using the light-cone sum rules at low-mid momenta-transfer.

Summary:

Section B / **33**

Flavour decomposition of electromagnetic transition form factors of nucleon resonances

Author(s): Jorge Segovia[None]

Co-author(s): Craig Roberts [1]

[1] *Argonne National Laboratory*

Strong diquark correlations inside baryons is a consequence of two emergent phenomena in Quantum Chromodynamics (QCD): dynamical chiral symmetry breaking and confinement. That is to say, any interaction capable of creating pseudo-Goldstone modes as bound-states of a light dressed-quark and -antiquark, will necessarily also generate strong colour-antitriplet correlations between any two dressed quarks contained within a baryon.

The presence of these correlations must be evident in numerous empirical differences between the response of the bound-state's doubly- and singly-represented quarks to any probe whose wavelength is small enough to expose the diquarks' nonpointlike character. We have recently exploit information provided by QCD's DSEs in order to study baryon properties in the continuum using a Poincare' covariant bound-state formulation. In particular, we have argued that the presence of strong diquark correlations inside the nucleon is responsible of the suppression of the d-quark contribution with respect the u-quark one in both Dirac and Pauli proton's form factors.

The u- and d-quark contributions to the transition form factors of most prominent nucleon resonances will be measured in the near future following completion of the Thomas Jefferson Laboratory $12\,\mathrm{GeV}$ upgrade (JLab12). Theoretical predictions for the flavour separated transition form factors are thus demanded by the JLab12 programme. We provide them for the nucleon's first radial, $\gamma^* N \to N(1440)$, and first spin, $\gamma^* N \to \Delta(1232)$, excitations. This is the first theoretical computation. The non-flavoured form factors of these reactions have been already presented, together with the elastic form factors of the nucleon, showing an overall agreement with the existing experimental data.

Summary:

Section B / **43**

Inclusive Cross Sections, Parton Density Functions and the strong coupling at HERA

Stefan Schmitt[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

A combination is presented of all inclusive deep inelastic cross sections previously published by the H1 and ZEUS collaborations at HERA for neutral and charged current ep scattering for zero beam polarisation. The data were taken at proton beam energies of
920, 820, 575 and 460 GeV and an electron beam energy of 27.5 GeV. The data correspond to an integrated luminosity of about 1 fb –1 and span six orders of magnitude in negative four-momentum-transfer squared, Q2, and Bjorken x. The combined cross sections were input to QCD analyses at leading order, next-to-leading order and at next-to-next-to-leading order, providing a set of parton distribution functions, HERAPDF2.0. By including jet cross sections, a precise determination of the strong coupling alpha_S is performed.

References: Eur.Phys.J.C75 (2015) 12, 580 [arxiv:1506.06042] and DESY-14-089 Eur.Phys.J.C75 (2015) 2, 65 [arxiv:1406.4709]

Summary:

Section B / **52**

The role of the strange quark in the $\rho(770)$ meson

Author(s): Raquel Molina[1]

Co-author(s): Andrei Alexandru [1] ; Dehua Guo [1] ; Michael Doring [1]

[1] *The George Washington University*

Recently, the GWU lattice group has evaluated high-precision phase-shift data for $\pi\pi$ scattering in the $I = 1$, $J = 1$ channel. Unitary Chiral Perturbation Theory describes these data well around the resonance region and for different pion masses. Moreover, it allows to extrapolate to the physical point and estimate the effect of the missing $K\bar{K}$ channel in the two-flavor lattice calculation. The absence of the strange quark in the lattice data leads to a lower ρ mass, and the analysis with UχPT shows that the $K\bar{K}$ channel indeed pushes the $\pi\pi$-scattering phase shift upward, having a surprisingly large effect on the ρ-mass. The inelasticity is shown to be compatible with the experimental data. The analysis is then extended to all available two-flavor lattice simulations and similar mass shifts are observed. Chiral extrapolations of $N_f = 2 + 1$ lattice simulations for the $\rho(770)$ are also reported.

Summary:

Section B / 56

Pion and Kaon Properties from Dyson-Schwinger Equations

Peter Tandy[1]

[1] *Kent State University, USA*

We summarize results on the internal structure and properties of the pion and kaon as an illustration of how insights into hadron physics can be obtained from calculations based on the Dyson-Schwinger equations of QCD. The light pseudoscalar mesons are the best possible case for such considerations as the approach is very well-constrained by symmetries and there is direct connection to continuum QCD. Emphasis is upon the parton structure as a reflection of QCD-mechanisms such as dynamical chiral symmetry breaking and flavor symmetry breaking. The full dependence upon the momentum fraction variable x is available this way, and the results here complement and extend the results for low moments obtained from lattice-QCD. Specific topics include distribution amplitudes $\phi(x)$, parton distribution functions $q(x)$, and relationships to the ultraviolet behavior of exclusive elastic and transition form factors of pions and kaons. If time permits, we will discuss a simple model exploration of the spacelike correlator approach for obtaining quasi-pdfs $\tilde{q}(x, P_z)$ that should approach $q(x)$ as $P_z \to \infty$.

Summary:

Section B / 61

Constrains on the NLO coefficients in S=-1 sector.

Author(s): Albert Feijoo[1]

Co-author(s): Angels Ramos [2] ; Volodymyr Magas [2]

[1] *Universitat de Barcelona*

[2] *University of Barcelona*

The precise SIDDHARTA value of the energy shift and width of kaonic hydrogen has awaken a renewed interest for the meson-baryon interaction in the $S = -1$ sector. Our study has been carried out based on a chiral SU(3) Lagrangian up to next-to-leading order (NLO) and implementing unitarization in coupled channels, since the presence of $\Lambda(1405)$ resonance makes not applicable a

perturbative treatment of the Chiral Lagrangian in the energy region we are dealing with. The parameters of the model have been fitted to a large set of experimental K^-p scattering data in different two-body channels, to threshold branching ratios, and to the above cited data from SIDDHARTA . In contrast to other groups we take into consideration the $K\Xi$ channels which are very important to obtain more reliable values of the fitting parameters, in particular the NLO coefficients. We have shown in [1,2] that the $K^-p \to K\Xi$ reactions are very sensitive to the NLO terms of the Lagrangian and also to the Born direct and cross diagrams. This fact is due to the null direct contribution of the Weimberg-Tomozawa (WT) term to the scattering amplitude of these particular reactions.

On the other hand, the $K^-p \to \eta\Lambda$ reaction has associated a pure isospin 0 ($I = 0$) amplitude, and therefore, it constrains the relevance of the role played for each isospin component. In general, a good description in terms of the isospin decomposition is crucial to reproduce properly processes in which a single isospin component is filtered, such as for instance the $K_L^-p \to K^+\Xi^0$ reaction which could be measured at the proposed secondary K_L^0 beam at Jlab and which is a pure $I = 1$ process. Another interesting measurement is the $\Lambda_b \to J/\psi K\Xi$ decay which filters I=0, as was studied in 3.

1 A. Feijoo, V. K. Magas and A. Ramos, Phys. Rev. C 92 015206 (2015).

2 A. Ramos, A. Feijoo and V. K. Magas, arXiv:1605.03767 [nucl-th].

3 A. Feijoo, V. K. Magas, A. Ramos and E. Oset, Phys. Rev. D 92, 076015 (2015).

Summary:

Section B / **142**

Exotic and excited states from functional approaches

Christian Fischer[1]

[1] *Institute for Theoretical Physics, JLU Giessen*

We summarise recent advances on the description of exotic and excited states using an approach to QCD via Dyson-Schwinger and Bethe-Salpeter equations. We discuss first steps in the calculation of (quenched) glueball states, explain in more detail methods and results to extract the spectrum of four-(anti-)quark states from the four-body Faddeev-Yakubovski equation and present first results for the excited baryon spectrum obtained from the three-body Faddeev equation. Particular emphasis is given to the comparison with corresponding results from lattice QCD.

Summary:

Section B / **75**

Nucleon structure functions and longitudinal spin asymmetries

Author(s): Harleen Dahiya[1]

Co-author(s): Monika Randhawa [2] ; Nisha Dhiman [3]

[1] *Dr. B.R. Ambedkar National Institute of Technology*

[2] *University Institute of Engineering and Technology, Panjab University, Chandigarh,*

[3] *Department of Physics, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar*

We have analysed the phenomenological dependence of the spin independent ($F_1^{p,n}$ and $F_2^{p,n}$) and the spin dependent ($g_1^{p,n}$) structure functions of the nucleon on the the Bjorken scaling variable x using the unpolarized distribution functions of the quarks $q(x)$ and the polarized distribution functions of the quarks $\Delta q(x)$ respectively. The chiral constituent quark model (χCQM), which is known to provide a satisfactory explanation of the proton spin crisis and related issues in the nonperturbative regime, has been used to compute explicitly the valence and sea quark flavor distribution functions of p and n. In light of the improved precision of the world data, the p and n longitudinal spin asymmetries ($A_1^p(x)$ and $A_1^n(x)$) have been calculated. The implication of the presence of the sea quarks has been discussed for ratio of polarized to unpolarized quark distribution functions for up and down quarks in the p and n $\frac{\Delta u^p(x)}{u^p(x)}$, $\frac{\Delta d^p(x)}{d^p(x)}$, $\frac{\Delta u^n(x)}{u^n(x)}$, and $\frac{\Delta d^n(x)}{d^n(x)}$.

Summary:

Section B / **111**

Hadron properties from nPI: towards first principles results

Richard Williams[1]

[1] *University of Giessen*

The Green's functions of QCD encode the properties of hadrons, with the appearance of (colour singlet) poles in n-point functions corresponding to bound-states and resonances. There are several techniques by which such information may be extracted, including lattice QCD and functional methods. We discuss recent progress in applying nPI effective action techniques to the systematic truncation of Dyson-Schwinger and Bethe-Salpeter equations, with particular emphasis on the spectrum of mesons and baryons.

Summary:

Section B / **113**

Neutral pion form factor measurement by the NA62 experiment

Monica Pepe[1]

[1] *INFN Perugia (IT)*

The NA62 experiment at CERN collected a large sample of charged kaon decays with a highly efficient trigger for decays into electrons in 2007. The kaon beam represents a source of tagged neutral pion decays in vacuum. A measurement of the electromagnetic transition form factor slope of the neutral pion in the time-like region from ~1 million fully reconstructed pi0 Dalitz decay is presented. The limits on dark photon production in pi0 decays from the earlier kaon experiment at CERN, NA48/2, are also reported.

Summary:

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Section B / **114**

Hadron Reaction and Spectroscopy Studies at JPAC

I will review activities of the Joint Physics Analysis Center

Summary:

I will review activities of the Joint Physics Analysis Center

Section B / **129**

3π resonance poles from COMPASS data

Author(s): Mikhail Mikhasenko[1]

Co-author(s): Adam Szczepaniak [2] ; Andrew Jackura [3] ; Bernhard Ketzer [1]

[1] *Universitaet Bonn (DE)*

[2] *iu*

[3] *Indiana University, JPAC*

High-energy peripheral reactions provide an excellent opportunity to study the excitation spectrum of hadrons. The COMPASS experiment at CERN has measured the diffractive scattering of pions to the 3-pion final state with unprecedented statistical precision. Partial wave analysis techniques have been employed to obtain an expansion of the reaction cross section in terms of partial waves with quantum numbers $J^{PC}\,M^{\varepsilon}$, which is differential in the 3π invariant mass and the squared transverse momentum (invariant mass squared of the virtual pomeron).

The aim of our analysis is the interpretation of the mass-dependence of the spin-density matrix in terms of short- and long-range interactions using analyticity and unitarity constraints. Using the K-matrix approach, we build the amplitude for scattering of a quasi-two-body final state ($\pi\pi$-subchannnel resonance + pion), and include a unitarization procedure to incorporate non-resonant long-range production processes via pion exchange, i.e. "Deck"-like processes.

The approach is demonstrated on COMPASS data for the 2^{-+} sector. We discuss the long standing puzzle about $\pi_2(1670) - \pi_2(1880)$ interplay. Higher excited resonance poles are tested.

Summary:

A new method fulfilling unitarity and analyticity constraints to extract resonance poles from 3π final states

Section B / **134**

The transverse momentum dependent distribution functions of partons. Status and prospects

Ignazio Scimemi[1]

[1] *Universidad Complutense (ES)*

In the last few years we have had a major advance on our understanding
of the motion of partons inside nuclei. This has been achieved recognizing the role
of rapidity divergences in the factorization theorems for transverse momentum dependent cross sections (for Drell-Yan, Semi-inclusive DIS, ee-> 2 hadrons), using effective field theories, performing

higher order calculations in perturbative QCD. This progress can provide us with a universal picture of QCD effects and a higher precision in current and future experiments. In this talk I try to resume the status of all this and discuss prospects.

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Section B / **135**

Chiral-Scale Perturbation Theory and the Renormalization Group

Author(s): Lewis Tunstall[1]

Co-author(s): Rod Crewther [2]

[1] *University of Bern*

[2] *The University of Adelaide*

Three-flavor chiral perturbation theory with t, b, c quarks decoupled tests the infrared limit of three-flavor QCD. The standard theory $\chi\mathrm{PT}_3$ (before being unitarized) assumes that there is no infrared fixed point α_{IR}. If α_{IR} exists, we get chiral-scale perturbation theory $\chi\mathrm{PT}_\sigma$ about a scale-invariant theory where the quark condensate is also a scale condensate with nine Nambu-Goldstone (NG) bosons: a massless 0^{++} dilaton σ ($f_0(500)$ in the real world) as well as π, K, η. The effective Lagrangian for $\chi\mathrm{PT}_\sigma$ is the standard one modified by σ-dependent terms and factors required to give the correct scaling dimensions, and can be systematically extended to include higher-order and electroweak corrections. The most important result is a neat explanation of the $\Delta I = 1/2$ puzzle for kaon decays; we propose to test it on the lattice via $K \to \pi$ with both on shell.

Summary:

Section B / **143**

Pion-eta scalar-isovector 3-coupled channel amplitude fitted to branching ratio as and threshold plus subthreshold parameters

Robert Kaminski[1]

[1] *Institute of Nuclear Physics PAS, Krakow, Poland*

The low energy (below ~2 GeV) pi-eta channel interaction amplitude becomes an object of interest mainly because of the search for exotic mesons in just beginning to collect data detector GlueX in Jefferson Lab. Finding and interpretation of expected weak signals from these states require a comparison with a very accurate amplitude containing standard (q-bar q) states i.e. a0(980) and a0(1450). The main problem in the determination of such amplitude is a total absence of data about the phases and inelasticities in the elastic and inelastic region.
In addition, it is necessary to take into account the next two coupled higher channels - KK and pi-eta^prime. Presented here amplitude is based on separable potential model (working very well for the scalar-isoscalar pi-pi interactions) with only 9 free parameters. To determine such 3-coupled

channel amplitude, the following information has been taken into account: experimental branching ratios and positions of both a0 resonances, theoretical couplings, scattering length from ChPT and value of squared radius of the pi-eta form factor.
Phase shifts, inelasticities and cross sections in all single and crossed channels are presented.

Summary:

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Phase shifts, inelasticities and cross sections in all single and crossed channels are presented.

Section B / **158**

Roy-Steiner-equation analysis of pion-nucleon scattering

Author(s): Jacobo Ruiz de Elvira[1]

Co-author(s): Bastian Kubis [2] ; Martin Hoferichter [3] ; Ulf Meißner [4]

[1] *HISKP, Bonn University*

[2] *HISKP, Bonn*

[3] *INT, Seattle*

[4] *meissner@hiskp.uni-bonn.de*

A precise understanding of low-energy pion-nucleon interactions is central for many areas in nuclear and hadronic physics, ranging from the scalar couplings of the nucleon to the long-range part of two-pion-exchange potentials and three-nucleon forces in Chiral Effective Field Theory. We present a calculation that combines the general principles of analyticity, unitarity, and crossing symmetry with modern high-precision data of hadronic atoms, leading to a phenomenological description of the pion-nucleon amplitude with unprecedented rigor and accuracy. Consequences for the pion-nucleon sigma-term and the matching to Chiral Perturbation Theory will be discussed.

Summary:

Section B / **162**

The Neutron Electric Dipole Moment from lattice QCD

Author(s): Andreas Athenodorou[1]

Co-author(s): Constantia Alexandrou ; Giannis Koutsou [2] ; Karl Jansen [3] ; Konstantin Ottnad [4] ; Kyriakos Hadjiyiannakou [5] ; Marcus Petschlies [4] ; Martha Constantinou [2]

[1] *University of Cyprus*

[2] *The Cyprus Institute*

[3] *DESY*

[4] *Bethe Center for Theoretical Physics, Universitat Bonn*

[5] *The George Washington University*

We calculate the neutron electric dipole moment within the framework of lattice QCD. In particular we
analyze configurations produced with $N_f = 2 + 1 + 1$ twisted mass fermions with light quark mass which
corresponds to pion mass of 370 MeV. We do so by extracting the CP-odd form factor F_3 at the limit of
zero momentum transfer and at small values of the θ vacuum angle. The zero momentum limit is realized via fitting the momentum dependence by a dipole fit as well as using position space methods. The computation of F_3 requires the calculation of the topological charge. We measure the field theoretical topological charge via cooling and the gradient flow using the Wilson, Symanzik tree-level
improved and Iwasaki actions. Our analysis yields a value for the neutron electric dipole moment of $-0.045(6)(1)$ e·fm in units of θ.

Summary:

Section B / 163

OPE of Green functions in the odd sector of QCD

Author(s): Tomas Kadavy[1]

Co-author(s): Jiri Novotny [2] ; Karol Kampf [2]

[1] *Charles University in Prague*

[2] *Charles University (CZ)*

A review of familiar results of the three-point Green functions of currents in the odd-intrinsic parity sector of QCD is presented. Such Green functions include very well-known examples of VVP, VAS or AAP correlators. We also present new results for VVA and AAA Green functions that have not yet been studied extensively in the literature before, more importantly with a phenomenological study and a discussion of the high-energy behaviour and its relation to the four-quark condensate.

Summary:

Section B / 170

CANCELLED: Dual parametrization of the GPDs v.s. the Mellin - Barnes transform approach and the J = 0 fixed pole

Author(s): Kirill Semenov-Tian-Shansky[None]

Co-author(s): Dieter Mueller ; Maxim Polyakov [1]

[1] *RUB*

The dual parametrization of of generalized parton distributions (GPDs) and the
Mellin-Barnes integral approach represent two frameworks for handling the double
partial wave expansion of GPDs in the conformal partial waves and in the cross-channel
$\mathrm{SO}(3)$ partial waves. We explicitly show the complete equivalence of these two independently developed GPD representations. This provides additional insight into the GPD properties and their physical interpretation. We discuss the relation between the $J = 0$ fixed pole contribution into the Compton scattering amplitude and the D-term form factor. We argue that in the Bjorken limit
the $J = 0$ fixed pole universality hypothesis of S.Brodsky is equivalent to the conjecture

that the D-term form factor is given by the inverse moment sum rule. This implies that the D-term is an inherent part of the corresponding GPD. We also briefly discuss applications for GPD modeling and map the phenomenologically successful Kumericki-Mueller GPD model to the dual parametrization framework.

Summary:

Section B / **186**

Polarized Drell-Yan at COMPASS

Riccardo Longo[1]

[1] *Universita e INFN Torino (IT)*

The COMPASS experiment at CERN took the first ever polarized Drell-Yan data in 2015. The muon pairs originating from pion induced collisions provide a way of accessing the transverse momentum dependent parton distribution functions of the nucleon. The study of the azimuthal spin asymmetries in Drell-Yan complements a wealth of results already obtained from transversely polarized semi-inclusive deep inelastic scattering at COMPASS.

The first results from the polarized Drell-Yan measurements will be shown in the context of the previously obtained SIDIS results. The expected impact of these data will be discussed, as well as prospects for future Drell-Yan related studies.

Summary:

Section B / **226**

Recent results on the meson and baryons spectrum from lattice QCD

Daniel Mohler[1]

[1] *Fermilab*

I will review recent lattice results on the meson and baryon spectrum with a focus on the determination of hadronic resonance masses and widths using a combined basis of single-hadron and hadron-hadron interpolating fields. I will emphasize how these mostly exploratory calculations differ from traditional lattice QCD spectrum calculations for states stable under QCD.

Summary:

Section B / **235**

Finite-volume techniques in lattice hadron spectroscopy

Max Hansen[None]

Numerical Lattice QCD calculations are necessarily performed in a finite volume and with Euclidean time. For scattering and transition amplitudes these constraints have important consequences. In particular, it is not possible to directly access such amplitudes from numerically determined Euclidean correlators. In the past decades, great progress has been made to overcome this limitation

by using finite volume as a tool rather than an artifact, and deriving non-perturbative relations between the finite- and infinite-volume theories. I will review recent developments in this work with particular focus on three-hadron final states.

Summary:

Section B / **245**

Hadronic matrix elements and distribution amplitudes from lattice QCD

Sara Collins[1]

[1] *University of Regensburg*

A wealth of information on the properties of hadrons of both theoretical and experimental interest can be provided by lattice methods. This includes wavefunctions, their response to electromagnetic, weak or beyond the Standard Model probes and their internal dynamics in terms of the contributions from quarks and gluons. Tremendous progress has been achieved recently in the evaluation of benchmark quantities which are well determined from experiment as well as more challenging and less well known observables. I present selected highlights of recent calculations, including the nucleon charges and form factors, nucleon sigma terms and the distribution amplitudes of baryons and mesons.

Summary:

Section B / **250**

Electromagnetic transition form factor and radiative corrections in decays of neutral pions

Jiri Novotny[1] ; Karol Kampf[1] ; Stefan Leupold[2] ; Tomas Husek[1]

[1] *Charles University (CZ)*

[2] *Uppsala University (SE)*

In this talk we present the Two-hadron saturation (THS) scenario for the PVV correlator and apply it to two important processes of the low energy hadron physics: the Dalitz decay of π^0 and $\pi^0 \to e^+e^-$. We briefly summarize experimental and theoretical results on the rare decay $\pi^0 \to e^+e^-$. The notorious $3.3\,\sigma$ discrepancy between the SM prediction and the experimental value provided by KTeV collaboration is discussed in the view of a complete set of NLO QED radiative corrections. The important contribution of analytical two-loop QED corrections together with the bremsstrahlung contribution beyond the soft-photon approximation are reviewed. Using the leading logarithm approximation, the possible contribution of QCD corrections is estimated. The discrepancy under discussion then reduces down to $1.8\,\sigma$. The obtained results can be also used in a theoretical calculation of the hadronic light-by-light scattering contribution to the $g-2$ type experiments.

Summary:

Section B / **255**

Hadron Scattering, Resonances and QCD

Raul Briceno[1]

[1] *Thomas Jefferson National Accelerator Facillity*

The non-perturbative nature of quantum chromodynamics (QCD) has historically left a gap in our understanding of the connection between the fundamental theory of the strong interactions and the rich structure of experimentally observed phenomena. For the simplest properties of stable hadrons, this is now circumvented by utilizing lattice QCD (LQCD). In this talk I outline a path towards a rigorous determination of few-hadron observables from LQCD. I illustrate the power of the methodology by presenting recently determined scattering amplitudes in the light-meson sector and discuss their resonance content.

Summary:

Section B / 273

Scheme variations of the QCD coupling and phenomenological applications

Matthias Jamin[1]

[1] *ICREA & IFAE*

The Quantum Chromodynamics (QCD) coupling, αs, is not a physical observable of the theory since it depends on conventions related to the renormalization procedure. We introduce a definition of the QCD coupling, denoted by αˆs, whose running is explicitly renormalization scheme invariant. The scheme dependence of the new coupling αˆs is parameterized by a single parameter C, related to transformations of the QCD scale Λ. It is demonstrated that appropriate choices of C can lead to substantial improvements in the perturbative prediction of physical observables. As phenomenological applications, we study e+e− scattering and decays of the τ lepton into hadrons, both being governed by the QCD Adler function, as well as the scalar correlation function.

Summary:

Section B / 140

Properties of exotic and non-exotic quark-bilinears within the Dyson-Schwinger–Bethe-Salpeter equation approach

Thomas Hilger[None]

Results of a sophisticated approach to a comprehensive meson phenomenology within the rainbow-ladder truncated Dyson-Schwinger–Bethe-Salpeter equation framework are presented and discussed.
The exotic and non-exotic light and heavy quarkonium mass spectrum in the spin-0 and spin-1 channel, as well as for tensor mesons is evaluated.
Quasi-exotic counterparts of exotic quarkonia in the open-flavor sector are identified and discussed.
Leptonic decay constants and orbital angular momentum decompositions are analysed and open up new perspectives on the identification of experimentally observed states.

Summary:

Section B / 344

CANCELLED: The anomalous triangle singulrity and its implications of threshold enhancements

Qiang Zhao[1]

[1] *Insitute of High Energy Physics, Chinese Academy of Sciences*

I will review the conditions and properties of the anomalous triangle singularity (ATS) in the transition matrix elements. For certain processes, the ATS condition can be fulfilled and will produce measureable effects in physical observables. In particular, when the ATS threshold is located within the physical regime, it may produce threshold enhancements which can mix with pole structures generated by dynamic interactions. Criteria for distinguishing the kinematically produced ATS peaks and dynamically generated poles will be discussed. Examples will be given regarding the understanding of some of those recently observed threshold states.

Summary:

Section B / 20

CANCELLED: Excited states from the Bethe-Salpeter equation in Minkowski space

Cristian Gutierrez[1]

[1] *IFT-Unesp*

We compute for first time the spectrum of the Bethe-Salpeter equation, for a system composed of two bosons exchanging a massive scalar. The ladder approximation for the kernel is used. This study is performed directly in the Minkowski space by using the Nakanishi representation of the Bethe-Salpeter amplitude and the projection onto the null plane or light-front projection. The eigenvalues, momentum space light-front wave function, transverse momentum amplitudes and 3D structure of impact parameter space wave function are computed for the first excited state. The latter is an important dynamical ingredient for evaluating parton transverse-momentum distributions, which depend upon both the Bjorken momentum fraction and the transverse components of parton momentum, or parton density distributions in impact parameter space. Also, a comparison of the eigenvalues and transverse-momentum distributions with the Euclidean space show a great agreement within our numerical the accuracy. The results show the reliability of our method, allowing to extend it to real systems, composed by fermions and kernels beyond of the the ladder one, which are topics in current research in hadron physics.

Summary:

We provide a new approach to obtain solutions of the Bethe-Salpeter equation in Minkowski space. This relativistic equation allows to study bound states in nuclear and hadron physics where relativistic effects are large and the full relativistic description is required. As a natural extension of the previous calculation where the ground state was studied, here we show results for the excited states. Finally, perspectives of this approach are also presented.

Section B / 339

CANCELLED: Baryon Spectroscopy: Recent Results and Impact

Reinhard Beck[1]

[1] *University Bonn*

The nucleon excitation scheme has been under intensive investigation with meson photoproduction experiments during the last few years world wide. Currently, a lot of new experimental results are coming out from the CLAS experiment at Jlab, the Crystal Barrel experiment at the ELSA accelerator in Bonn and the Crystal Ball experiment at the MAMI accelerator in Mainz. These experiments focus on the investigation of single and double polarization observables for different meson production reactions using longitudinally and transversely polarized targets, linearly and circularly polarized photon beams as well as the polarization of the recoil protons. The new data sets provide stringent constraints for partial wave analyses of meson photoproduction on the nucleon and will lead to an unique determination of the contributing resonances. The new experimental results will be presented and the impact of the new results to the nucleon excitation spectrum will be discussed.

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The nucleon excitation scheme has been under intensive investigation with meson photoproduction experiments during the last few years world wide. Currently, a lot of new experimental results are coming out from the CLAS experiment at Jlab, the Crystal Barrel experiment at the ELSA accelerator in Bonn and the Crystal Ball experiment at the MAMI accelerator in Mainz. These experiments focus on the investigation of single and double polarization observables for different meson production reactions using longitudinally and transversely polarized targets, linearly and circularly polarized photon beams as well as the polarization of the recoil protons. The new data sets provide stringent constraints for partial wave analyses of meson photoproduction on the nucleon and will lead to an unique determination of the contributing resonances. The new experimental results will be presented and the impact of the new results to the nucleon excitation spectrum will be discussed.

Section B / 331

Light-front field theory in the description of hadrons

Chueng Ji[1]

[1] *North Carolina State University*

We discuss the use of light-front field theory in the descriptions of hadrons. In particular, we clarify the confusion in the prevailing notion of the equivalence between the infinite momentum frame and the light-front dynamics and the advantage of the light-front dynamics in hadron physics. As an application, we present our recent work on the flavor asymmetry in the proton sea and identify the presence of the delta-function contributions associated with end-point singularities arising from the chiral effective theory calculation. The results pave the way for phenomenological applications of pion cloud models that are manifestly consistent with the chiral symmetry properties of QCD.

Summary:

Session invited talk

Section B / 326

Light-Meson Spectroscopy at COMPASS

Fabian Michael Krinner[1]

[1] *Technische Universitaet Muenchen (DE)*

The goal of the COMPASS experiment at CERN is to study the structure and dynamics of hadrons. The two-stage spectrometer used by the experiment has good acceptance and covers a wide kinematic range for charged as well as neutral particles allowing to access a wide range of reactions. Light mesons are studied with negative (mostly π^-) and positive (p, π^+) hadron beams with a momentum of 190 GeV/c.

The light-meson spectrum is measured in different final states produced in diffractive dissociation reactions with squared four-momentum transfer t to the target between 0.1 and 1.0 (GeV/c)^2. The flagship channel is the $\pi^-\pi^+\pi^-$ final state, for which COMPASS has recorded the currently world's largest data sample. These data not only allow to measure the properties of known resonances with high precision, but also to search for new states. Among these is a new axial-vector signal, the $a_1(1420)$, with unusual properties. The findings are confirmed by the analysis of the $\pi^-\pi^0\pi^0$ final state.

Summary:

Section B / **322**

H-dibaryon spectroscopy using modern lattice methods

Author(s): Parikshit Junnarkar[1]

Co-author(s): Anthony Francis [2] ; Hartmut Wittig ; Jeremy Green [3] ; Thomas Rae [4]

[1] *Helmholtz-Institute Mainz*

[2] *York University*

[3] *Johannes Gutenberg-Universität Mainz*

[4] *Wuppertal university*

Studies of multi-baryon systems present a formidable challenge to lattice QCD.
The H-dibaryon represents the simplest multi-baryon system and yet in the current lattice calculations at unphysical quark masses no conclusive results can be seen regarding its binding energy.
One of the contributing factors could be the inability to reliably extract the spectrum of states on the lattice.
Using the state-of-art spectroscopy method of distillation, we attempt a detailed lattice calculation of the spectrum of two-baryon states in the H-dibaryon channel.
The calculations are performed at several pion masses of 450 and 1000 MeV.
The method of distillation allows for the construction of a large basis of operators, which is crucial for reliably extracting the spectrum.
A comparison with earlier calculations will also be presented.

Summary:

Section B / **299**

Concurrent approaches to Generalized Parton Distribution modeling: the pion's case

Hervé MOUTARDE[1]

[1] *Irfu, CEA, Université Paris-Saclay*

The concept of Generalized Parton Distributions promises an understanding of the generation of the charge, spin, and energy-momentum structure of hadrons by their fundamental constituents,

quarks and gluons. Forthcoming measurements with unprecedented accuracy at Jefferson Lab and at CERN will presumably challenge our quantitative description of the three-dimensional structure of hadrons. To fully exploit these future experimental data, new tools and models are currently being developed.

We will explain the difficulties of Generalized Parton Distribution modeling, and present some recent progresses. In particular we will describe the symmetry-preserving Dyson-Schwinger and Bethe-Salpeter framework. We will also discuss various equivalent parameterizations and sketch how to combine them to obtain models satisfying a priori all required theoretical constraints. We will explain why these developments naturally fit in a versatile software platform, named PARTONS, dedicated to the phenomenology of GPDs.

Summary:

Section B / **298**

Recent experimental results on hadron structure, GPDs and TMDs

Gerhard Mallot[1]

[1] *CERN*

A gobal effort is ongoing in the study of transverse-momentum dependent structure functions and in generalised parton distribution functions. Both are linked to orbital angular momentum of quarks and gluons in the nucleon. Recent results from various experiments will be discussed.

Summary:

The talk will summarise recent experimental results on hadron structure functions from inclusive and semi-inclusive deep inelastic scattering as well as from deeply virtual Compton scattering, hard exclusive meson production and Drell-Yan processes and proton-proton collisions. The focus will be on results related to transverse momentum dependent PDFs, generalized parton distributions and nucleon spin structure.

Section B / **288**

Meson Form Factors and Deep Exclusive Meson Production Experiments

Tanja Horn[1]

[1] *Catholic University of America*

Meson electroproduction data play an important role in our understanding of hadron structure and the dynamics that bind the basic elements of nuclear physics. Pion and kaon form factors are of particular interest as they are connected to the Goldstone modes of chiral dynamical symmetry breaking. The last decade saw a dramatic improvement in precision of charged pion form factor data and new results have become available on the pion transition form factor. Increasing the virtual photon mass in electron scattering experiments allows one to reach smaller distance scales. In this regime one becomes more and more sensitive to the partonic picture where hard and soft physics have been shown to factorize and Generalized Parton Distributions (GPDs) provide the most complete description of the non-perturbative physics. Recent data and prospects for deep exclusive pion electroproduction are presented. Experimental tests of our theoretical understanding of the reaction mechanism are shown including longitudinal-transverse separated charged-pion cross section data and ratios. The prospects to use projected charged- and neutral pion data to further determine the spin, charge-parity and flavor of GPDs, including the helicity-flip GPDs, are discussed.

Summary:

Section B / **278**

The RHIC Spin Program

Elke-Caroline Aschenauer[1]

[1] *BNL*

A myriad of new techniques and technologies made it possible to inaugurate the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory as the world's first high-energy polarized proton collider in December 2001. RHIC delivers polarized proton-proton collisions at center-of-mass energies of up to 500 GeV. This unique environment provides opportunities to study the polarized quark and gluon spin-structure of the proton and QCD dynamics at a high energy scale and is therefore complementary to existing semi-inclusive deep inelastic scattering experiments. This talk summarizes recent achievements of the RHIC spin program and their impact on our understanding of the nucleon's spin structure, i.e. the individual parton (quarks and gluons) contributions to the helicity structure of the nucleon and to understand the origin of the transverse spin phenomena.

Summary:

Section B / **126**

Resonance production and decay in pion induced collisions with HADES

Federico Scozzi[None]

The main goal of the High Acceptance Di-Electron experiment (HADES) 1 at GSI is the study of hadronic matter in the $1 - 3.5$ GeV/nucleon incident energy range. The obtained dilepton spectra measured in nucleon-nucleon, nucleon-nucleus and heavy-ion reactions at various beam energies demonstrate important contributions from baryon resonances decays ($R \rightarrow Ne^+e^-$). The resonance-nucleon electromagnetic transitions are described by respective transition form-factors in time-like region which are predicted by various models to be strongly influenced by the intermediate vector mesons (mainly ρ/ω).

In order to directly access such transitions, HADES has started dedicated pion-nucleon programme. For the first time a combined measurement of hadronic and dielectron final states have been performed in $\pi - N$ reactions at four different pion beam momenta (0.656, 0.69, 0.748 and 0.8 GeV/c) 2. In this measurement two targets (polyethylene $(C_2H_4)_n$ and carbon C) were used with the aim to subtract events from scattering on carbon and identify pure contribution from scattering on protons. Exclusive channels with one pion ($\pi^- p$), two pions ($n\pi^+\pi^-$ and $p\pi^-\pi^0$) and dileptons (ne^+e^-) in the final state were identified. Exclusive channels with two pions in the final state were put to extend studies in the framework of a partial wave analysis (PWA) of the Bonn-Gatchina group 3 together with the world data on pion and photon production. The obtained solution provides the excitation function of two-pion and photon production around the pole of the $N(1520)D_{13}$ resonance with the decomposition into contributing resonances and in particular the intermediate ρ meson. Next, the obtained ρ contribution has been converted into e^+e^- cross section via strict Vector Dominance Model and compared to the measured exclusive ne^+e^- channel to verify the meson contribution in the resonance-nucleon transition. The results of this analysis will be presented.

1 G. Agakishiev et al. (HADES), Eur. Phys. J. A 41 (2009) 243.

2 P. Salabura, J. Stroth, L. Fabbietti (HADES), Nucl. Phys. News 25 (2015) 22

3 A.V. Anisovich, E. Klempt, A.V. Sarantsev, U. Thoma, Eur. Phys. J. A 24 (2005) 111

Summary:

Section B / 107

A data-driven model-independent approach to π^0, η and η' single and double Dalitz decays

Author(s): Rafel Escribano[1]

Co-author(s): Sergi Gonzàlez-Solís [2]

[1] *Universitat Autònoma de Barcelona*

[2] *IFAE-UAB*

The
dilepton invariant mass spectra and branching ratios of the single and double Dalitz decays
$\mathcal{P} \to \ell^+\ell^-\gamma$ and $\mathcal{P} \to \ell^+\ell^-\ell^+\ell^-$
($\mathcal{P} = \pi^0, \eta, \eta'$; $\ell = e$ or μ) are predicted by means of a
data-driven model-independent approach based on the use of rational approximants applied to
π^0, η and η' transition form factor experimental data in the space-like region.

Summary:

A data-driven model-independent approach to π^0, η and η' single and double Dalitz decays

Section B / 79

Quark Propagator with electroweak interactions in the Dyson-Schwinger approach

Author(s): Walid Mian[1]

Co-author(s): Axel Maas [1]

[1] *University of Graz*

By β-decay a Neutron transforms into a Proton and emits a Positron and a Neutrino. The latter only interacts weakly. During Neutron Star formations and mergers, we have a high Neutrino flux, which can be measured. Therefore by Neutrino measurement, we can learn about the inner structure of Neutron Star formations and mergers. Because during these processes the matter is dense, we have a back coupling of Neutrinos with the matter. Thus for a better understanding, it is necessary to analyze strong and weak interactions in a coupled non-perturbative way. We choose Dyson-Schwinger-Equations as our method and evaluate QPs in a first step. Due to the presence of the weak interaction, quarks can propagate from one flavor in to the other and thus we have in addition to QPs for pure flavors also QPs for mixed flavors. Thus the Dyson-Schwinger-Equations for the QPs in particular for the mixed flavor have additional contributions to the self energy, which can be diagrammatically represented by a loop graph for emitting and absorbing weak gauge bosons. In the first step, the loops in these graphs are approximated by point interactions. For the strong interaction we used the Rainbow truncation with the Maris-Tandy coupling. The QPs for pure and mixed flavor are calculated in the chiral limit and for physical quark masses of all three generations. Because of parity violation the QPs have in addition to the usual vector- and scalar channels also axial- and pseudo-scalar channels. We find different contributions to the QPs coming from dynamical and explicit chiral symmetry breaking. Furthermore we have, due to the Iso-Spin breaking, also contributions arising from mass splitting of the quarks. We analyze the effect of the different contributions on the parity breaking.

Summary:

We analyze strong and electroweak interactions using Dyson-Schwinger-Equations. Due to the weak interaction, the quark propagators (QPs) have additional contribution to the self energy, due to emission and absorbing of weak gauge bosons. In the first step the exchange of weak gauge bosons are approximated by point interactions and for the strong interaction the Rainbow truncation is used. In this case we also have mixed flavors, because quarks can change flavor due to the weak interaction. Because of parity violation the QPs have in addition to the usual vector- and scalar channels also axial- and pseudo-scalar channels. The QPs are calculated in the chiral limit and for physical quark masses of all three generations. Dynamical and explicit breaking of the chiral symmetry and in particular mass splitting of quarks have different effects on the parity breaking, which is explicitly analyzed.

Section B / **136**

Mesons and baryons in ultra-intense magnetic field: an evaded collapse

Author(s): Boris Kerbikov[1]

Co-author(s): Maxim Andreichikov [2] ; Yurii Simonov [2]

[1] *ITEP and Lebedev*

[2] *ITEP*

Huge magnetic fields (MF) up to eB value of the order of the QCD Lambda square are created for a short time in peripheral heavy ion collisions at RHIC and LHC.The field about four orders of magnitude less is anticipated to operate in magnetars.This brought about an extraordinarly large interest to the behavior of quark systems (mesons and baryons) in strong MF.In a series of papers we developed a relativistic formalism for any composed system in MF and evaluated the mass spectrum and the wave functions of mesons and baryons
(rho-, pion, neutron, proton) as a function of the MF strength.To separate the internal degrees of freedom we make use of pseudomomentum which commutes with the Hamiltonian in MF and takes the role of the center-of-mass momentum.The quarks Green's functions are taken in the Fock-Feynman-Schwinger representation.The confinement and color Coulomb interactions are derived using the minimal Wilson loop.The dynamical quark masses are introduced via the Dirac einbein formalism.The end-result is the relativistic Hamiltonian to which the additional hyperfine spin-spin interaction is added.As anticipated,the hadron wave function takes the form of an elongated ellipsoid in the MF direction with its size along the MF restricted by the confining string tension.Important to note that for the RHIC and LHC MF values the Landau magnetic radius becomes of the order,or smaller,than the hadron size and therefore the hadron mass problem should be solved at the quark level.For the quark system the question is whether MF induces the "fall to the center" phenomenon (zero mass value).We present negative answer to this question.The hadron mass trajectories vs MF values agree with lattice results in cases the latter are available

Summary:

The relativistic formalism for any composed system (from atoms to hadrons) embedded in arbitrary strong magnetic field (MF) is developed.The mass spectrum and wave functions of mesons and baryons made of light quarks as functions of MF strength are evaluated.
For the maximum field values reached at RHIC and LHC the masses of the ground states significantly decrease but zero mass value remains unattainable.

Section C / **149**

Rare B meson decays on the lattice

Author(s): Andria Agadjanov[None]

Co-author(s): Akaki Rusetsky [1] ; Ulf-G. Meißner [2] ; Veronique Bernard [3]

[1] *University of Bonn*

[2] *University of Bonn, Forschungszentrum Jülich*

[3] *Paris-Sud University*

The extraction of the $B \to K^*$ transition form factors from lattice data at (close to) physical pion masses is discussed. The possible mixing of πK and ηK states is taken into account. Applying non-relativistic effective field theory in a finite volume, the two-channel analogue of the Lellouch-Luscher formula is reproduced. Due to the resonance nature of the K^* , it is shown how the form factors can be determined at the pole position in a process-independent manner. The infinitely-narrow width approximation of the results is also discussed.

Summary:

Section C / **185**

Heavy Hybrids: decay to and mixing with heavy quarkonium

Author(s): Joan Soto[1]

Co-author(s): Rubén Oncala [1]

[1] *Universitat de Barcelona*

In the framework of pNRQCD, we calculate the partial decay width of heavy hybrid states to heavy quarkonia, and the mixing potential between them. We discuss their phenomenological relevance concerning the identification of some XYZ states with heavy hybrids.

Summary:

Section C / **252**

QCD threshold logarithms analystic resumming

Giulia Ricciardi[1]

[1] *Dipartimento di Fisica E Pancini Università di Napoli Federico II*

We present a new technique to resum analytically large threshold logarithms in heavy quark decay which simplifies multi-scale problems and apply it to the B -> X_s gamma decay

Summary:

We present a new technique to resum analytically large threshold logarithms in heavy quark decay which simplifies multi-scale problems and apply it to the B -> X_s gamma decay

Section C / **166**

Exotic quarkonium states in CMS

Leonardo Cristella[1]

[1] *Università & INFN, Bari (IT)*

Using large data samples of di-muon events, CMS has performed detailed measurements and searches for new states in the field of exotic quarkonia. We report on measurements of the charmonium X(3872), and search for its counterpart in the bottomonium sector. The investigation of the B+ to J/ψ φ K+ decay reveals two structures in the J/ψ φ mass spectrum. For the one closest to the kinematical threshold, and compatible with the Y(4140) state by CDF, a few explanations have been suggested such as a tetraquark partner of the X(3872), a molecular partner of the Y(3940) or a charmonium hybrid. Charged Z charmonium-like states are particularly interesting as candidates for tetra-quark states. Results from CMS are foreseen to be provided by applying a full amplitude analysis method to the neutral B meson 3-body decays into J/Psi(or Psi(2S)) Kaon Pion. Finally, the state called X(5568) and observed by D0 experiment in Bs+pion system needs to be confirmed or not: a result from CMS is foreseen to be provided.

Summary:

We report on measurements of the charmonium X(3872), and search for its counterpart in the bottomonium sector. The investigation of the B+ to J/ψ φ K+ decay reveals two structures in the J/ψ φ mass spectrum. Charged Z charmonium-like states are particularly interesting as candidates for tetra-quark states. Results from CMS are foreseen to be provided by applying a full amplitude analysis method to the neutral B meson 3-body decays into J/Psi(or Psi(2S)) Kaon Pion. Finally, the state called X(5568) and observed by D0 experiment in Bs+pion system needs to be confirmed or not: a result from CMS is foreseen to be provided.

Section C / **394**

Production and decay of η_c states at LHCb

Sebastian Neubert[1]

[1] *Ruprecht-Karls-Universitaet Heidelberg (DE)*

The LHCb experiment is designed to study the decays and properties of heavy flavoured hadrons produced in the forward region from pp collisions at the CERN Large Hadron Collider. It has recorded the world's largest data sample of beauty and charm hadrons, enabling precise studies into the production and decay of such particles. η_c production has been studied in B decays and in prompt production. For the first time its production cross-section has been measured in pp collisions. For the $\eta_c(2S)$ the decay into $p\bar{p}$ is observed for the first time. We report latest results of those measurements.

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Section C / **139**

D and B mesons masses in chiral perturbation theory with heavy quark symmetry

Mohammad Alhakami[1]

[1] *KACST*

The aspects of mesons containing a single heavy quark are governed by the spin symmetry $SU(2)_s$ of the heavy quark and the chiral symmetry $SU(3)_L \times SU(3)_R$ of the light quarks. Incorporating

both approximate symmetries in a single framework was achieved by defining the heavy meson chiral perturbation theory (HMChPT).
The masses of D and B mesons are analysed within this effective theory including one-loop chiral and $O(m_Q^{-1})$ corrections.
The free parameters are determined in certain linear combinations using the physical values of D meson masses, light meson masses and coupling constants.
The fitted parameters are then used to predict the masses of the full set
of the low-lying B meson states. There is a good agreement between our theoretical predictions and the available experimental data on the masses of the ground state, $J^P = 0^-$ and $J^P = 1^-$, B mesons. For the first excited, $J^P = 0^+$ and $J^P = 1^+$, B mesons, our results may be helpful to experimentalists looking for such states.

Summary:

Section C / 172

Quarkonium hybrids in Effective Field Theories

Jaume Tarrus Castella[1]

[1] *TU Munich*

In the last decade new, unexpected, quarkonium states close and above open flavor thresholds have been discovered. Some of these states are candidates for quarkonium hybrids, i.e states containg a gluonic excitation. Quarkonium hybrids are characterized by a set of well separated scales, in particular, the heavy quark and gluon dynamics have very different dynamical time scales, that be exploited in an effective field theory description. Using input from lattice computations, this effective field theory description can be used to obtain the quarkonium hybrid masses. We compare the results thus obtained with experimental observations and other determinations.

Summary:

In the last decade new, unexpected, quarkonium states close and above open flavor thresholds have been discovered. Some of these states are candidates for quarkonium hybrids, i.e states containg a gluonic excitation. Quarkonium hybrids are characterized by a set of well separated scales, in particular, the heavy quark and gluon dynamics have very different dynamical time scales, that be exploited in an effective field theory description. Using input from lattice computations, this effective field theory description can be used to obtain the quarkonium hybrid masses. We compare the results thus obtained with experimental observations and other determinations.

Section C / 275

CANCELLED: η_c production at the LHC and indications on the understanding of J/ψ

Author(s): Ce Meng[1]

Co-author(s): Hua-Sheng Shao [2] ; Kuang-Ta Chao [1] ; Yan-Qing Ma [3] ; hao han [1]

[1] *Peking University*

[2] *Peking University,Beijing,China*

[3] *BNL*

η_c production at the LHC and indications on the understanding of J/ψ

Summary:

We present a complete evaluation for the prompt η_c production at the LHC at NLO in α_s within the framework of NRQCD factorization formula. By assuming heavy quark spin symmetry, the recently observed η_c production data by LHCb results in a very strong constraint on the upper bound of the color-octet long distance matrix element $\langle \mathcal{O}^{J/\psi}(^1S_0^{[8]}) \rangle$ of J/ψ. We find this upper bound is consistent with our previous study of the J/ψ yield and polarization and can give good descriptions for the measurements. This may provide important information for understanding the nonrelativistic QCD factorization formulism.

Section C / **58**

Recent Results on Bottomonium Studies at Belle

Simon Eidelman[1]

[1] *Budker Institute and Novosibirsk State University*

Belle, a general-purpose detector operated at the KEKB electron-positron B-factory at KEK, Japan, collected the world largest integrated luminosity at the peak of the $\Upsilon(4S)$ meson as well as in a scan of the center-of-mass energy range from 10.63 to 11.05 GeV.
We describe recent results on various bottomonium states studied - mass and width measurements of the $\Upsilon(5S)$ and $\Upsilon(6S)$ mesons, update of the $\eta_b(1S)$ and $h_b(1P)$ parameters, new investigation of the exotic $Z_b(10610)$ and $Z_b(10650)$ states.

Summary:

Section C / **13**

CANCELLED: Impact of eta_c hadroproduction data on charmonium production and polarization within NRQCD framework

Author(s): Hong-Fei Zhang[None]

Co-author(s): Rong Li [1] ; Wen-Long Sang [2] ; Zhan Sun [3]

[1] *Xian Jiaotong University*

[2] *Southwest University, China*

[3] *Chongqing University*

Recent η_c hadroproduction data provided an excellent opportunity for the determination of the color-octet matrix elements for the charmonia production. This talk will present the theoretical results for the η_c hadroproduction versus the LHCb data and its impact on the J/ψ production and polarization.

Summary:

Section C / **18**

Recent charmonium results at BESIII

Beijiang Liu[None]

Hadron spectroscopy is one of the most important physics goals of BESIII. BESIII brings great opportunities to study the XYZ states of charmonium by directly producing the Y states up to 4.6 GeV. We focus on the investigation of XYZ states and the discovery of new charged charmonium-like structures. Two isospin triplets Z(3900) and Z(4020) have been discovered, decaying into J/psi pi and hc pi, respectively. Structures with compatible parameters have been found decaying to DD*and* *D*D*, respectively.
Furthermore, we have investigated the new transitions between charmonium states, e.g. Y(4260)->gamma X(3872).

Section C / 23

eta_c production at the LHC challenges nonrelativistic-QCD factorization

Zhiguo He[1]

[1] *Hamburg University*

We analyze the first measurement of η_c
production, performed by the LHCb Collaboration, in
the nonrelativistic-QCD (NRQCD) factorization framework
at next-to-leading order (NLO) in the
strong-coupling constant α_s and the relative velocity v
of the bound quarks including the feeddown
from h_c mesons. Converting the long-distance matrix elements (LDM
Es) extracted by various groups from J/ψ
yield and polarization data to the η_c
case using heavy-quark spin symmetry, we find that
the resulting NLO NRQCD predictions greatly overshoot the L
HCb data, while the color-singlet model provides an excellent description

Section C / 36

pNRQCD determination of E1 radiative transitions

Author(s): Sebastian Steinbeißer[1]

Co-author(s): Antonio Vairo ; Jorge Segovia [1] ; Nora brambilla

[1] *Technische Universität München*

Electromagnetic E1 (and M1) multipole transitions have been studied since the early days of hadron spectroscopy because they allow to access heavy quarkonium states which are below open-flavour threshold. Moreover, they are interesting by themselves because they are an important tool to check particular regions of the hadrons' wave function and thus to determine their internal structure and dynamics.

From a theoretical point of view, electromagnetic transitions between heavy quarkonium states have been treated for a long time by means of potential models using nonrelativistic reductions of phenomenological interactions. However, the progress made in effective field theories (EFTs) for studying heavy quarkonia and the new large set of accurate experimental data taken in the heavy quark sector by B-factories (BaBar, Belle and CLEO), τ-charm facilities (CLEO-c, BESIII) and even proton-proton colliders (CDF, D0, LHCb, ATLAS, CMS) ask for a systematic and model-independent analysis.

This contribution aims to present the first numerical determination of the $2\,^3P_J \to 1^3S_1\gamma$ ($\chi_{bJ}(1P) \to \Upsilon(1S)\gamma$) decay rates within the low-energy EFT called potential NRQCD (pNRQCD). We assume that

the heavy mesons involved in the studied reactions lie in the weak-coupling regime of pNRQCD and thus a full perturbative calculation can be performed. Relativistic corrections of relative order v^2 to the leading electric dipole operator are included. The analysis separates those contributions that account for the electromagnetic interaction terms in the pNRQCD Lagrangian, which are v^2 suppressed, and those that account for quarkonium state corrections of relative order v^2. Within the last ones, corrections come from higher-order potentials ($1/m$ and $1/m^2$ terms), and from higher Fock states which account for the coupling of the quark-antiquark state to other low-energy degrees of freedom and thus demand nonperturbative input.

Summary:

Section C / **66**

Phenomenology of near-threshold states: a practical parametrisation for the line shapes

Alexey Nefediev[1]

[1] *ITEP*

In the last decade many states in the spectrum of charmonium and bottomonium lying above the open-flavour threshold have been observed experimentally. Most of these states reside in the vicinity of strong thresholds and cannot be described by simple quark models. Description and understanding of such exotic states is a challenge for phenomenology of strong interactions which requires building adequate theoretical tools and approaches. In this work, a practical parametrisation for the line shapes of near threshold resonance(s) is derived in the framework of a coupled-channel model which includes an arbitrary number of elastic and inelastic channels as well as a bare pole term. Parameters of the distribution have a direct relation to phenomenology and the resulting analytical parametrisation is therefore ideally suited to investigate the full
information content provided by the measurements and to establish a link between the experimental data and their theoretical interpretation.

Summary:

A practical parametrisation for the line shapes on near-threshold states is derived in the frame work of a coupled-channel model. The power of the suggested approach is demonstrated at the example of the combined data analysis for the Zb(10610) and Zb(10650) states in the spectrum of bottomonium.

Section C / **72**

Relativistic corrections to electromagnetic heavy quarkonium production

Author(s): Vladyslav Shtabovenko[1]

Co-author(s): Antonio Vairo ; Nora Brambilla [2] ; Wen Chen [3] ; Yu Jia [3]

[1] *TUM*

[2] *Technical University of Munich*

[3] *IHEP Beijing, China*

We study higher order relativistic corrections to the electromagnetic production cross-section of a heavy quarkonium and a hard photon in the factorization framework of non-relativistic QCD (NRQCD). We obtain new matching coefficients and discuss the importance of contributions from color octet operators, that were not considered in the previous studies of this process.

Summary:

Section C / 99

Open charm meson and baryon spectroscopy from lattice QCD

Author(s): Gunnar Bali[1]

Co-author(s): Andreas Rabenstein [2] ; Andreas Schäfer [2] ; Antonio Cox [2] ; Sara Collins [2] ; Stefan Hofmann [2] ; Wolfgang Söldner [2]

[1] *Universität Regensburg*

[2] *University of Regensburg*

We present results of simulations of the RQCD Collaboration on open charm states, including a scattering analysis of scalar and axialvector D_s mesons near the physical pion mass, utilizing different spatial volumes. The spectra are obtained, using $N_f = 2$ QCDSF and RQCD as well as $N_f = 2 + 1$ CLS ensembles, employing non-perturbatively improved Wilson fermions. In the latter case, extrapolations to the physical point are performed along two lines in the quark mass plane: keeping the strange quark mass constant and keeping the sum of the three sea quark masses (approximately) constant.

Summary:

We present results of simulations of the RQCD Collaboration on open charm states. This includes a scattering analysis of scalar and axialvector D_s mesons near the physical pion mass, utilizing different spatial volumes with $N_f = 2$ sea quark flavours. Moreover, open charm spectra are obtained, using $N_f = 2+1$ CLS (Coordinated Lattice Simulations) ensembles, employing non-perturbatively improved Wilson fermions with open boundary conditions in time. In this case, extrapolations to the physical point are performed along two lines in the quark mass plane: keeping the strange quark mass constant and keeping the sum of the three sea quark masses (approximately) constant.

Section C / 100

The Pc(4450) pentaquark-like structure and triangle singularity

Feng-Kun Guo[1]

[1] *Institute of Theoretical Physics*

We want to discuss the Pc(4450) pentaquark-like structure observed by the LHCb Collaboration in the J/psi proton final states. We point out that it is located exactly at the chi_{c1}-proton threshold, and coincides with the leading Landau singularity of the triangle loop Lambda(1890)-chi_{c1}-proton. We also discuss the possibility of distinguishing a genuine resonance from the kinematical singularity.

Summary:

Section C / 125

Open-charm production measurements in pp, p-Pb and Pb-Pb collisions with ALICE at the LHC

Elisa Meninno[1]

[1] *Universita e INFN, Salerno (IT)*

Heavy quarks (charm and beauty) are interesting probes to study the Quark-Gluon Plasma (QGP) in high-energy heavy-ion collisions, since they are produced in initial hard partonic scattering processes on a short time scale and experience the whole evolution of the medium. They are expected to traverse the QCD medium, interacting with its constituents and losing energy through radiative and collisional processes. As a consequence of these interactions, the momentum distributions of open heavy-flavour hadrons are modified. A strong modification of the transverse-momentum distributions of heavy-flavour hadrons in Pb-Pb collisions with respect to binary-scaled pp collisions is observed, via the measurement of the nuclear modification factor RAA. The azimuthal distribution of heavy-flavour hadrons, in particular the elliptic flow v2, reflects the initial spatial anisotropy of the overlap of the colliding nuclei. The elliptic flow brings information on the medium transport properties: on the question whether heavy quarks take part in the collective expansion of the medium at low pT, and on the path-length dependence of parton energy loss at high pT. Heavy-flavour measurements in pp collisions not only provide the necessary baseline to understand the results in Pb-Pb collisions. They are also an important test of perturbative QCD calculations. Moreover, heavy-flavour production in p-Pb collisions is affected by cold nuclear matter effects in the initial and final state, such as modification of parton densities in nuclei, kT broadening and gluon radiation. Heavy-flavour measurements in p-Pb collisions can help to disentangle the influence on particle production of those effects from that of the QGP formation.
In ALICE, open-charm production is studied through the reconstruction of the hadronic decays of D0, D+, D*+ and Ds+ mesons at mid-rapidity. The high precision tracking, good vertexing capabilities and excellent particle identification offered by ALICE allow for the measurement of particles containing heavy quarks (particularly D mesons) in a wide transverse-momentum range in pp, p-Pb and Pb-Pb collisions.
In this talk, a review of the main results on D-meson production in pp collisions at √⊠ = 7 TeV, p-Pb collisions at √⊠NN = 5.02 TeV and Pb-Pb collisions at √sNN = 2.76 TeV will be presented.

Summary:

Section C / **138**

New observables in quarkonium production

Jean-Philippe Lansberg[1]

[1] *IPN Orsay, Paris Sud U. / IN2P3-CNRS*

References:

1 J/Psi -pair production at large momenta: Indications for double parton scatterings and large alpha_s^5 contributions. By J.P. Lansberg, H.S. Shao. arXiv:1410.8822 [hep-ph]. Phys.Lett. B751 (2015) 479.

2 Production of J/psi+eta(c) vs. J/psi+J/psi at the LHC: Impact of Real alpha_s^5 corrections. By J.P. Lansberg, H.-S. Shao. [arXiv:1308.0474 [hep-ph]]. Phys.Rev.Lett. 111 (2013) 122001.

3 Double-quarkonium production at a fixed-target experiment at the LHC (AFTER@LHC). By J.P. Lansberg, H.S. Shao. arXiv:1504.06531 [hep-ph]. Nucl.Phys. B900 (2015) 273-294.

[4] Observation of J/psi pair production in pp collisions at sqrt{s}=7 TeV. By LHCb Collaboration. arXiv:1109.0963 [hep-ex]. Phys.Lett. B707 (2012) 52-59.

[5] Measurement of prompt J/psi pair production in pp collisions at sqrt{s} = 7 TeV. By CMS Collaboration. arXiv:1406.0484 [hep-ex]. JHEP 1409 (2014) 094.

[6] Observation and studies of double J/psi production at the Tevatron. By D0 Collaboration. arXiv:1406.2380 [hep-ex]. Phys.Rev. D 90 11 (2014) 111101.

[7] Evidence for simultaneous production of J/psi and Upsilon mesons. By D0 Collaboration. [arXiv:1511.02428 [hep-ex]]. Phys.Rev.Lett. 116 (2016) 082002.

[8] Next-to-leading-order QCD corrections to the yields and polarisations of J/Psi and Upsilon directly produced in association with a Z boson at the LHC. By B. Gong, J.P. Lansberg, C. Lorce, J.X. Wang. [arXiv:1210.2430 [hep-ph]]. JHEP 1303 (2013) 115.

[9] Reassessing the importance of the colour-singlet contributions to direct J/psi + W production at the LHC and the Tevatron. By J.P. Lansberg, C. Lorce. [arXiv:1303.5327 [hep-ph]]. Phys.Lett. B726 (2013) 218.

[10] Next-to leading order QCD corrections to quarkonium + vector bosons hadroproduction. J.P. Lansberg, H.S. Shao, L.P. Sun (work in progress).

[11] Observation and measurements of the production of prompt and non-prompt J/psi mesons in association with a Z boson in pp collisions at sqrt{s} = 8 TeV with the ATLAS detector. By ATLAS Collaboration. arXiv:1412.6428 [hep-ex]. Eur.Phys.J. C75 (2015) 5, 229.

[12] Measurement of the production cross section of prompt J/psi mesons in association with a W^+/- boson in pp collisions at sqrt{s} = 7 TeV with the ATLAS detector. By ATLAS Collaboration. arXiv:1401.2831 [hep-ex]. JHEP 1404 (2014) 172.

Summary:

In this talk, I will focus on the study of associated-quarkonium production in a number of channels at the LHC. First, I will address the case of quarkonium-pair production [1,2,3] which has recently been studied by LHCb [4], CMS [5] and D0 [6,7]. I will argue that the inclusion of Double-Parton Scattering (DPS) and Next-to-Leading Order (NLO) contributions are necessary to account for the existing data. I will then address the case of quarkonium + vector boson [8,9,10] which has recently been studied by ATLAS [11,12].

Section C / **161**

CANCELLED: AFTER@LHC: A fixed-target programme at the LHC for heavy-ion, hadron, spin and astroparticle physics

Barbara Antonina Trzeciak[1]

[1] *Utrecht University*

In this talk, we will review a number of recent ideas□ put forward in favour of a fixed-target programme at the LHC - AFTER@LHC. By extracting the beam with a bent crystal or by using an internal gas target, the multi-TeV LHC beams allow one to perform the most energetic fixed-target experiments ever and to study with high precision pp, pd and pA collisions at $\sqrt{s_{NN}}$=115 GeV and Pbp and PbA collisions at $\sqrt{s_{NN}}$=72 GeV. A broad programme, covering large-x frontier for particle and astroparticle physics, spin and heavy-ion physics will greatly complement collider experiments, in particular those of RHIC and the EIC project.
We will present feasibility studies with first simulations of quarkonium, Drell-Yan production in pp, pA and AA collisions and Drell-Yan and charmed meson single transverse-spin asymmetries in pp collisions using a transversally polarised target. Drell-Yan and quarkonium production can be studied in different systems in a wide rapidity range providing important information concerning quark and gluon (n)pdf at large x, cold nuclear matter effects, quarkonium formation time in the medium, expected sequential suppression in QGP and final state interaction effects.

□: for a complete list of references see
http://after.in2p3.fr/after/index.php/Recent_published_ideas_in_favour_of_AFTER@LHC

for the current list of authors see: http://after.in2p3.fr/after/index.php/Current_author_list

Summary:

Section C / **183**

Molecular partners of the X(3872) from heavy-quark spin symmetry: a fresh look.

Author(s): Vadim Baru[1]

Co-author(s): Alexey Nefediev [2] ; Arseniy Filin [3] ; Christoph Hanhart ; Evgeny Epelbaum [3] ; Ulf-G. Meißner [4]

[1] *Ruhr University Bochum*

[2] *ITEP*

[3] *Institut fuer Theoretische Physik II, Ruhr-Universitaet Bochum, D-44780 Bochum, Germany*

[4] *Forschungszentrum Jülich, Institute for Advanced Simulation, Institut für Kernphysik and Jülich Center for Hadron Physics, D-52425 Jülich, Germany*

The heavy-quark spin symmetry (HQSS) partners of the X(3872) molecule are investigated based on a chiral effective field theory (EFT) approach involving contact and one-pion exchange interactions. The integral equations of the Lippmann-Schwinger type are solved for a coupled-channel problem involving the $D\bar{D}$, $D\bar{D}^*$, and $D^*\bar{D}^*$ interactions to yield the scattering amplitudes with the quantum numbers J^{PC}=1^{++}, 1^{+-}, 0^{++} and 2^{++}. As a starting point, we confirm that, if the X(3872) were a 1^{++} $D\bar{D}^*$ molecular state, in the strict heavy-quark limit, it should have three partner states degenerate in the mass, with the quantum numbers 1^{+-}, 0^{++} and 2^{++}. At first glance, in presence of pions, this result might look mysterious since pions relate heavy meson-antimeson pairs in various partial waves depending on the quantum numbers. It can be shown, however, that the integral equations can be brought to the block-diagonal form by appropriate unitary transformations, where one of the blocks appears to be the same for all quantum numbers, thus accounting for the degeneracy of the states. We stress that neglecting some of the coupled-channel transitions in an inconsistent manner leads to a severe violation of HQSS and yields regulator-dependent results for the partner states.

Deviations from the heavy-quark limit predictions are investigated for the 2^{++} partner state of the X(3872) in the EFT with nonperturbative pions. While going away from the strict heavy-quark limit suggests the presence of an additional (unknown) counter term for the $D^{(*)}\bar{D}^{(*)}$ scattering system in order to absorb the dependence of the results on the regulator, it is still possible to conclude that the spin-2 partner of the X(3872) acquires a significant shift of the mass as well as a width of the order of 50 MeV due to coupled channels governed by the nonperturbative pionic dynamics.

Summary:

Section C / **193**

pNRQCD at N^3LO: the potential for unequal masses and the Bc spectrum

Clara Peset[1]

[1] *UAB/IFAE*

We determine the $1/m$ and $1/m^2$ spin-independent heavy quarkonium potentials in the unequal mass case with $\mathcal{O}(\alpha^3)$ and $\mathcal{O}(\alpha^2)$ accuracy, respectively. Furthermore, we discuss in detail different methods to obtain the potential and we provide the explicit field redefinition that relates them, thus clarifying the relation between different previous partial results.
Of special relevance is the computation of the manifestly gauge invariant $1/m$ and $1/m^2$ potentials in terms of Wilson loops with next-to-leading order (NLO) precision. As an application of our results we derive the theoretical expression for the Bc spectrum in the weak-coupling limit up to next-to-next-to-next-to-leading order (N^{3}LO).

Summary:

Section C / **196**

Heavy quark physics from Fermilab/MILC collaboration

Alexei Bazavov[1]

[1] *Brookhaven National Laboratory*

We present the results of our recent calculations of the hadronic form factors for semileptonic decays of B mesons and the matrix elements of local operators contributing to neutral B and Bs meson mixing. From joint fits of the lattice results and the experimental data we are able to determine the magnitude of the CKM matrix elements Vub and Vcb, and also (with Vtb as an additional input) the matrix elements Vtd and Vts. These calculations were performed on 2+1 flavor MILC asqtad configurations with the Fermilab Wilson clover action for the charm and bottom quarks. The variety of lattice spacings and sea and valence quark masses allows for controlled continuum and chiral extrapolations.

Summary:

Section C / 213

Scattering of charmed mesons from lattice QCD

Graham Moir[1]

[1] *University of Cambridge*

We present a lattice QCD study of coupled-channel $D\pi$, $D\eta$ and $D_s\bar{K}$
scattering, as well single-channel DK scattering. Our methodology allows us to determine precise finite volume spectra which we use to constrain scattering amplitudes as a function of energy. We interpret our results in terms of poles in the S-matrix and provide a measure of the coupling of each channel to a given pole. By exploring S, P and D wave interactions we comment on the nature of states with $J^P = 0^+$, relevant for the $D_0^*(2400)$ and $D_{s0}^*(2317)$, as well as states with $J^P = 1^-, 2^+$.

Summary:

Section C / 232

Effective field theory for long-range properties of bottomonium states

Author(s): Gastao Krein[1]

Co-author(s): Antonio Vairo ; Jaume Tarrús-Castellà [2] ; Nora brambilla

[1] *UNESP*

[2] *Physik-Department, Technische Universität München*

We derive an analytical expression for the chromopolarizability of bottomonium states using the framework of potential nonrelativistic QCD. Next, using the QCD trace anomaly we obtain the two-pion production amplitude for the chromopolarizability operator and match the result to a chiral effective field theory for bottomonium states and pions as degrees of freedom. In this chiral effective field theory we compute long-range properties of bottomonium states such as the leading chiral logarithm correction to the mass of the 1S bottomonium and derive the van der Waals potential between two bottomonium states. Finally, we discuss the perspectives of using the developed chiral effective theory to evaluate two-pion decay amplitudes of bottomonium states.

Summary:

We derive an analytical expression for the chromopolarizability of bottomonium states using the framework of potential nonrelativistic QCD. Next, using the QCD trace anomaly we obtain the two-pion production amplitude for the chromopolarizability operator and match the result to a chiral effective field theory for bottomonium states and pions as degrees of freedom. In this chiral effective field theory we compute long-range properties of bottomonium states such as the leading chiral logarithm correction to the mass of the 1S bottomonium and derive the van der Waals potential between two bottomonium states. Finally, we discuss the perspectives of using the developed chiral effective theory to evaluate two-pion decay amplitudes of bottomonium states.

Section C / **267**

Fragmentation contributions to J/psi photoproduction at HERA

Geoffrey Bodwin[1] ; Hee Sok Chung[2] ; Jungil Lee[3] ; U-Rae Kim[3]

[1] *Argonne National Laboratory*

[2] *CERN*

[3] *Korea University*

We compute leading-power fragmentation corrections to J/ψ photoproduction at DESY HERA, making use of the nonrelativistic QCD factorization approach. Our calculations include parton production cross sections through order α_s^3, fragmentation functions though order α_s^2, and leading logarithms of the transverse momentum divided by the charm-quark mass to all orders in α_s. We find that the leading-power fragmentation corrections, beyond those that are included through next-to-leading order in α_s, are small relative to the fixed-order contributions through next-to-leading order in α_s. Consequently, an important discrepancy remains between the experimental measurements of the J/ψ photoproduction cross section and predictions that make use of nonrelativistic-QCD long-distance matrix elements that are extracted from the J/ψ hadroproduction cross-section and polarization data.

Summary:

Section C / **268**

The bottom-quark mass from non-relativistic sum rules at NNNLO

Jan Piclum[1]

[1] *University of Siegen*

The mass of the bottom quark can be determined with high precision from moments of the pair-production cross section $\sigma(e^+e^- \to b\bar{b})$ near threshold. We present the first complete NNNLO determination from non-relativistic sum rules, obtaining a bottom-quark mass of $m_b^{\mathrm{PS}}(2\,\mathrm{GeV}) = 4.532^{+0.013}_{-0.039}$ GeV in the potential-subtracted scheme. For the mass in the $\overline{\mathrm{MS}}$ scheme we find $m_b^{\overline{\mathrm{MS}}}(m_b^{\overline{\mathrm{MS}}}) = 4.203^{+0.016}_{-0.034}$ GeV using the recently computed four-loop correction to the scheme conversion.

Summary:

Section C / 32

Isospin-breaking in the decay constants of heavy mesons from QCD sum rules

Author(s): Dmitri Melikhov[1]

Co-author(s): Silvano Simula [2] ; Wolfgang LUCHA [3]

[1] *HEPHY*

[2] *INFN*

[3] *Austrian Academy of Sciences*

We show that having at hand the analytic expression for the correlation functions allows one to study subtle effects related to isospin-breaking effects in the decay constants of heavy pseudoscalar and vector mesons. We obtain predictions for these effects in fD, fD, *fB and fB* mesons.

Summary:

Section C / 41

Form factors and differential distributions in rare radiative leptonic B-decays

Author(s): Anastasiia Kozachuk[1]

Co-author(s): Dmitri Melikhov [2] ; Nikolai Nikitin [1]

[1] *M.V. Lomonosov Moscow State University (RU)*

[2] *HEPHY*

We analyze long-distance QCD effects in $B_{d,s} \to \ell^+\ell^-\gamma$ decays.
Taking into account photon emission from the b-quark loop, weak annihilation,
and Bremsstrahlung from leptons in the final state, we give predictions
for dilepton spectrum and various asymmetries in $B_{d,s} \to \ell^+\ell^-\gamma$ decays within the Standard Model.

Summary:

Section C / 44

Description of the $X(4260)$ and $X(4360)$ mesons as a $\rho D\bar{D}$ system

Author(s): Melahat Bayar[1]

Co-author(s): Beyza Durkaya [1]

[1] *Kocaeli University*

X(4260) and X(4360) mesons

Summary:

We investigate $\rho D \bar{D}$ three body system using the fixed center approximation to the Faddeev equations. The study is made assuming scattering of a ρ or a $\bar{D}$ on a $D\bar{D}$ cluster, which is known to generate the $X(3700)$ or a ρD cluster, which
has been shown to generate the $D_1(2420)$. In the case of the $\rho - X(3700)$ scattering we find a state with mass around 4320 MeV and width is about 25 MeV for the total three body isospin-1. Considering the $\bar{D} - D_1(2420)$ scattering we obtain a state with mass around 4256 MeV and width is similar to that of the $\rho - X(3700)$ state for the $I = 1$ case. For the case of the $I = 0$ we find a state with mass around 4241 MeV and width is about 20 MeV. In all cases we find bound states and for $I = 1$ case the states could be associated with $X(4260)$ and $X(4360)$ mesons.

Section C / **55**

Traces of the hidden-charm S=-1 pentaquark in the Lambda_b –> J/psi eta Lambda decay

Author(s): Volodymyr Magas[1]

Co-author(s): Albert Feijoo [2] ; Angels Ramos [1] ; Eulogio Oset

[1] *University of Barcelona*

[2] *Universitat de Barcelona*

The hidden charm pentaquark state $P_c(4450)$, observed recently by the LHCb collaboration in the $\Lambda_b \to J/\psi K^- p$ decay, may be of molecular nature, as advocated by some unitary approaches that also predict pentaquark partners in the strangeness S=-1 sector. In this work we argue that a hidden-charm strange pentaquark could also be seen in the decay of the Λ_b, but through the $J/\psi\eta\Lambda$ decay mode, by studying the invariant mass spectrum of $J/\psi\Lambda$ pairs.

In our model we assume a standard weak decay topology, then incorporate the hadronization process and final state interaction effects, and finally we find that the $J/\psi\eta\Lambda$ final state is populated with the strength similar to that of the $J/\psi K^- p$. We have studied the dependence of our results on reasonable changes in the parameters of the models involved in our description of the process, as well as on the unknown properties of the speculated hidden charm strange pentaquark. We have observed that, while there appear changes in the position of the peak and in the shapes of the distributions, a resonance signal in the $J/\psi\Lambda$ invariant mass spectrum is clearly seen in all the cases. This gives us confidence that such an experimental study could result into a successful proof of the existence of this new state.

Summary:

Section C / **68**

Approximate degeneracy of heavy-light mesons with the same L

Author(s): Takayuki Matsuki[1]

Co-author(s): Qi-Fang L\"u [2] ; Toshiyuki Morii [3] ; Yubing Dong [2]

[1] *Tokyo Kasei University*

[2] *Institute of High Energy Physics, CAS, Beijing 100049, People's Republic of China*

[3] *Faculty of Human Development, Kobe University, 3-11 Tsurukabuto, Nada, Kobe 657-8501, Japan*

In this work, we pint out that there exists an approximate degeneracy among heavy-light systems with the same L.
This is supported by an experimental fact which can be seen from the observed data. This approximate symmetry explains why the GI model obtains results similar to those of the heavy-light systems

which are fitted well with experimental data. This is because the GI model has this symmetry from the beginning which is broken by the spin-orbit interactions. Numerical results of the GI model together with those of other models respecting heavy quark symmetry are compared with the experimental data of the D mesons and they well give similar results to each other.

We analytically show that expectation values of $[H_0, \vec{L}^{\,2}]$ give us at most of the order of $1/m_Q$ for 0^- and 1^- states and the similar arguments will give us the same conclustion for other higher states in our model which respects heavy quark symmetry. Note that this order of magnitude, $1/m_Q$, is the same as those which break degeneracy of a spin doublet of heavy-light systems. It is shown that there is a rotational symmetry in the limit of $m_Q \to \infty$ and nonrelativistic limit of heavy-quark symmetry.

Simple application of our idea to other states can be given by baryons QQq like Ξ_{cc}^+, multiquark states in which one light quark is included like $QQ\bar{Q}q$, and probably other states in which a couple of light quarks can be regarded as a brown mock. A good expample is given by a spectrum of Λ_c which gives us $\Lambda_c(2286)$ with $L = 0$, $\Lambda_c^+(2595)$ and $\Lambda_c^+(2625)$ with $L = 1$, and $\Lambda_c^+(2880)$ and $\Lambda_c^+(2940)$ with $L = 2$, where a spin multiplet is given by member/members with the same L. L is defined by an angular momentum between a heavy quark c and two light quarks (ud). One can easily see that gaps between different spin multiplets are nearly equal to $\Lambda_{QCD} \sim 300$ MeV, which coincides with the observation of heavy-light mesons.

This property may be explainged by adopting a string picture of a heavy-light system, i.e., having a fixed end and a free end and connecting both ends with a string.

Summary:

Careful observation of the experimental spectra of heavy-light mesons tells us that heavy-light mesons with the same angular momentum L are almost degenerate. The estimate is given how much this degeneracy is broken in our relativistic potential model, and it is analytically shown that expectation values of a commutator between the lowest order Hamiltonian and $\vec{L}^{\,2}$ are of the order of $1/m_Q$ with a heavy quark mass m_Q. It turns out that nonrelativistic approximation of heavy quark system has a rotational symmetry and hence degeneracy among states with the same L. This property may be explainged by adopting a string picture of a heavy-light system, i.e., having a fixed end and a free end and connecting both ends with a string. This feature can be tested by measuring higher orbitally and radially excited heavy-light meson spectra for $D/D_s/B/B_s$ in LHCb and forthcoming BelleII.

Section C / **77**

X(3872) production in heavy ion collisions

Fernando Navarra[1]

[1] *IFUSP / São Paulo - Brazil*

This talk will be based on the e-print "X(3872) production and absorption in a hot hadron gas", arXiv:1604.07716.

Summary:

We calculate the time evolution of the X(3872) abundance in the hot hadron gas produced in the late stage of heavy ion collisions. We use effective field Lagrangians to obtain the production and dissociation cross sections. We include anomalous couplings which were neglected in previous calculations. With these new terms the X(3872) interaction cross sections are much larger than those found in previous works. Using these cross sections as input in rate equations, we conclude that during the expansion and cooling of the hadronic gas, the number of X(3872), originally produced at the end of the mixed QGP/hadron gas phase, is reduced by a factor of 4.

Section C / **97**

Relativistic phenomenology of meson spectra with a covariant quark model in Minkowski space

Author(s): Sofia Leitão[1]

Co-author(s): Alfred Stadler [2] ; M. T. Peña [3]

[1] *CFTP, IST, Lisbon*

[2] *CFTP, IST, Lisbon and University of Évora*

[3] *CFTP, IST, University of Lisbon*

Our formalism is based on the Covariant Spectator Theory (CST), a framework based on field theory originally developed to study systems of few nucleons. The distinctive feature of this approach is that it approximates the full Bethe-Salpeter-equation by taking into account, effectively, the contributions of both ladder and crossed ladder diagrams in the kernel.

Another notable feature of the CST equations is that they are established in physical Minkowski space. Therefore, the results obtained are not restricted to bound state masses and momentum regions which are free of propagator singularities. This is advantageous over Euclidean formulations (although it entails the difficulty of handling those singularities numerically) because form factors can be computed directly in the timelike region with no need for analytical continuations.

To model phenomenologically the interquark interaction, we adopt a kernel compatible with the requirements of chiral symmetry that contains a linear confining term, a color Coulomb term and a constant. This choice allow us to have a straightforward correspondence with the Cornell potential (plus a constant) and recover, in the nonrelativistic limit, the results from the Schrödinger equation. The parameters that characterize this model, namely the constituent quark masses and coupling constants, are fitted to data and compared with their counterparts provided by other approaches such as lattice QCD and formulations based on the Dyson-Schwinger equations.

Summary:

In this work we compute a variety of $q\bar{q}$ mass spectra, ranging from heavy to heavy-light sectors, using a unified and manifestly covariant relativistic description. Calculations for mesons with different tensor structures are performed and compared with experiment, as well as with the result of other approaches.

Section C / **154**

The non-perturbative unquenched quark model

Author(s): David Rodriguez Entem[1]

Co-author(s): Francisco Fernandez [2] ; Pablo G. Ortega [1]

[1] *University of Salamanca*

[2] *Universidad de Salamanca*

Since the discovery of the $X(3872)$ in 2003 1 it became evident that the naive quark model would not be enough to describe all the baryon spectrum. This state has properties that can not be explained in such a quark model, as its decay into $J/\Psi\pi\pi$ through a ρ meson, which is an isospin violating decay. However this property can be easily explained in a picture in which the state in understood as a DD^* bound state, due to the isospin violation in the D and D^* masses and the close position of the state to the $D_0 D_0^*$ threshold. In previous studies 2 we described the X(3872) as a DD^* molecule coupled to the $2P$ $c\bar{c}$ state, which in our framework is essential to bind the system. The coupling of two and four quark states was performed microscopically using the $^3P_0$ model 3. Although it was shown that the contribution to the mass of the coupling to the $1P$ and $3P$ states is small, some decay

properties could have a sizable contribution, like the radiative decays. Including many different states makes the problem too involved and so the contribution of all the tower of bound quark-antiquark states remains as an open question.

For this reason we have developed a new framework in which the contribution of all the states can be obtained. To do so, the main idea is not to expand the quark-antiquark wave function in a linear combination of bare quark-antiquark states, but leave the radial wave function as an unknown of the problem solving for it. We have applied it to the study of the $X(3872)$ and check that when the $^3P_0$ coupling is small the results are the same as the perturbative calculation and for the physical value of the coupling some deviations are obtained. We have studied the probability of bare states in the physical one and the most important is the $2P$ as expected. Different decay properties will be presented.

1 S.K. Choi *et al.* (Belle Collaboration), Phys. Rev. Lett. **91**, 262001 (2003).

2 P.G. Ortega, J. Segovia, D.R. Entem and F. Fernandez, Phys. Rev. D **81**, 054023 (2010).

3 J. Segovia, D.R. Entem and F. Fernandez, Phys. Lett. B **715**, 322 (2012).

Summary:

In recent years states in the quarkonium spectrum not expected in the naive quark model have appeared and created a lot of interest. In the theoretical side the study of the effect of meson-meson thresholds in the spectrum have been performed in different approximations. In a quark model framework, and in the spirit of the Cornell model, when a meson-meson threshold is included, the coupling to all the quark-antiquark states have to be considered. In practice only the closest states are included perturbatively. In this contribution we will present a framework in which we couple quark-antiquark states with meson-meson states non-perturbatively, taking into account effectively the coupling to all quark-antiquark states. The method will be applied to the study of the $X(3872)$ and a comparison with the perturbative calculation will be performed.

Section C / **165**

Pion exchange for Pc(4450)+ and related states

Timothy Burns[None]

Pion-exchange offers a natural explanation for Pc(4450)+ as a meson-baryon molecule, and implies a number of partner states. I discuss the properties of these partners and suggest experimental channels for their discovery. The molecular interpretation also implies that Pc(4450)+ is a mixture of isospins 1/2 and 3/2, which has characteristic signatures in production and decay. Several intriguing similarities suggest that Pc(4450)+ is an analogue of the X(3872) meson.

Summary:

Section C / **205**

Poincare invariance in low-energy effective field theories for QCD

Author(s): Sungmin Hwang[1]

Co-author(s): Antonio Vairo ; Matthias Berwein [2] ; Nora brambilla

[1] *Technical University of Munich*

[2] *TU Munich*

We use non-linear field transformations for non-relativistic fields to implement Poincare invariance in low energy effective theories for QCD. In these transformations we include all terms allowed by the explicit symmetries of the effective theory, but exploit the freedom to remove some of them through field redefinitions. By requiring the invariance of the Lagrangian under these transformations, relations between Wilson coefficients for both theories are derived. The calculations are presented up to the leading order in the expansion parameter. The possibility of applying this method to other types of effective theories as well as its implication will also be discussed.

Summary:

Section C / **229**

Relativistic two-body calculation of bottomonium radiative decays

Author(s): Emanuele Sorace[1]

Co-author(s): Andrea Barducci [2] ; Riccardo Giachetti [3]

[1] *INFN- Firenze*

[2] *University of Firenze and I.N.F.N.*

[3] *University of Firenze*

Numerical recovering of the spectrum and wave function of a two-body fermionic relativistic potential system.
Estimation in this framework of the widths and branching ratios of some heavy mesons radiative decays.

Summary:

In previous work we presented a unified two-fermion covariant model which predicted a very good spectrum for the masses of light and heavy mesons.
By utilising the same model we here analyse the available measured radiative decays of $\Upsilon(3s), \chi b2(2p), \chi b1(2p), \chi b0(2p)$, and we calculate their branching ratios and their widths.
The values obtained with this method are in a good agreement with the experimental data.
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Section C / **236**

CANCELLED: Prediction of a Zc(4000) D*Dbar* state and relationship to the claimed Zc(4025)

Author(s): Francesca Aceti[1]

Co-author(s): Eulogio Oset ; Jorgivan Dias ; Melahat Bayar [2]

[1] *IFIC - Universidad de Valencia*

[2] *Kocaeli University*

After discussing the OZI suppression of one light meson exchange in the interaction of with isospin I = 1 , we study the contribution of the two-pion exchange to the interaction and the exchange of heavy vectors, J/ψ for diagonal transitions and D* for transitions of to J/ψ ρ. We find these latter mechanisms to be weak, but enough to barely bind the system in J = 2 with a mass around 4000 MeV, while the effect of the two-pion exchange is a net attraction, though weaker than that from heavy-vector exchange. We discuss this state and try to relate it to the Zc(4025) state, above the threshold,

claimed in an experiment at BES from an enhancement of the distribution close to threshold. Together with the results from a recent reanalysis of the BES experiment showing that it is compatible with a J = 2 state below threshold around 3990 MeV, we conclude that the BES experiment could show the existence of the state that we find in our approach.

Summary:

Section C / **243**

$Z_c(3900)$: theory, experiment, lattice

Author(s): Feng Kun Guo[1]

Co-author(s): Juan Nieves [2] ; Miguel Albaladejo Serrano [2] ; Pedro Fernandez-Soler [2]

[1] *Beijing, Inst. Theor. Phys.*

[2] *IFIC-CSIC, U. Valencia*

In this talk we report on two recent works about the $Z_c(3900)$ resonance. A coupled channel T-matrix is used in the description of the $D^*\bar{D}$ and $J/\psi\pi$ spectra in which the $Z_c(3900)$ peak has been seen. The data can be well reproduced in two different scenarios, in which the $Z_c(3900)$ is a resonance or a virtual state. We also put this coupled channel T-matrix in a finite box, with the aim of comparing with recent lattice QCD simulations.

Summary:

In this talk we report on two recent works about the $Z_c(3900)$ resonance. A coupled channel T-matrix is used in the description of the $D^*\bar{D}$ and $J/\psi\pi$ spectra in which the $Z_c(3900)$ peak has been seen. The data can be well reproduced in two different scenarios, in which the $Z_c(3900)$ is a resonance or a virtual state. We also put this coupled channel T-matrix in a finite box, with the aim of comparing with recent lattice QCD simulations.

Section C / **287**

Nuclear Effects on Tetraquark Production by Double Parton Scattering

Author(s): Fabiana Carvalho[1]

Co-author(s): Fernando Navarra [2]

[1] *UNIFESP*

[2] *IFUSP*

Exotic Mesons Production, All charm tetra quark, Double Parton Scattering, Color Evaporation Model.

Summary:

In this work we study the nuclear effects in exotic meson production. We estimate the total cross section as a function of the center of mass energy for the pPb and pAu scattering using a version of the color evaporation model (CEM) adapted to Double Parton Scattering (DPS). We find that the cross section grows signficantly with the atomic number, indicating that the hypothesis of tetraquark states can be tested in pA collisions at RHIC and LHC.

Section C / **325**

Investigating the Structure of X(4140) in QCD

Author(s): Huseyin Dag[1]

Co-author(s): Arzu Turkan [1]

[1] *Ozyegin University, Istanbul*

This is a preliminary version of the work to be presented at Confinement XII, Thessalloniki, Greece.

Summary:

X(4140), exotic meson, was experimentally observed by several collaborations in the invariant mass spectrum of $J/\psi\phi$, and very recently its quantum numbers are announced to be $J^{PC} = 1^{++}$ by LHCb. However the decay width of the state observed by LHCb is unexpectedly wider then the previous observations. Despite these observations, its structure has not been totally understood yet, as well as other exotic mesons. In literature, its claimed that X(4140) might be a scalar, axial-vector or a tensor meson, with positive charge conjugation, which might be a $D_s^* \bar{D}_s^*$ molecule or a tetraquark state.

In this work, we chose three molecule, and three tetraquark currents, which can couple to X(4140), with $J^{PC} = 0^{++}, 1^{++}, 2^{++}$, and analysed the masses and the decay constants of the ground states coupling to these currents in the framework of QCD sum rules. In OPE, we considered terms including dimension eight, and we did pole contribution tests carefully. According to our results, five of these currents couple to ground states with degenerate masses which are in 10MeV vicinity of X(4140) , while the axial vector tetraquark current estimates a ground state with a mass which is at least 30 MeV higher then $D_s^* \bar{D}_s^*$ threshold. Therefore, we conclude that, if X(4140) has a dominant molecular content, then there are three states degenerate in mass, with $C = +1$, and different isospins. On the other hand, pole contribution studies estimates noticeable changes in the correlation function between 4-6 GeVs. Therefore we conclude that, X(4140) should be investigated more, by studying its decays, and by other approaches as well.

Section C / **333**

Short-distance current correlators on the lattice

Shoji Hashimoto[1]

[1] *KEK*

Although the main use of lattice QCD computation is to provide non-perturbative calculation of low-energy physical quantities, it can also be used to calculate short-distance quantities. By matching thus calculated short-distance current correlators to corresponding perturbative calculations one can obtain the parameters appearing in the perturbation theory, such as the strong coupling constant and quark masses. We discuss about the several uses of the short-distance current correlators.

Summary:

Section C / **374**

Multiquark resonances

Alessandro Pilloni[1]

[1] *Jefferson Lab*

The number of multiquark states and the amount of details on their properties has been growing over the years. It is very recent the discovery of two pentaquarks and the confirmation of four tetraquarks, two of which had not been observed before. We present some considerations attempting a coherent description of the so called X and Z resonances. The prominent problems plaguing theoretical models, like the absence of selection rules limiting the number of states predicted, motivate new directions in model building. Data are reviewed going through all of the observed resonances with particular attention to their common features and the purpose of providing a starting point to further research.

Summary:

Section C / 432

Experimental highlights: Heavy Quark Physics in Heavy-Ion collisions at RHIC

Rachid Nouicer[1]

[1] *Brookhaven National Laboratory*

Hadrons carrying heavy quarks, i.e. charm or bottom, are important probes of the hot and dense medium created in relativistic heavy-ion collisions. Heavy quark-antiquark pairs are mainly produced in initial hard scattering processes of partons. While some of the produced pairs form bound quarkonia, the vast majority hadronize into open heavy flavor particles. RHIC experiments carry out a comprehensive physics program which studies open heavy flavor and quarkonium production in relativistic heavy-ion collisions. The discovery at RHIC of large high-pT suppression and flow of electrons from heavy quarks flavors have altered our view of the hot and dense matter formed in central Au+Au collisions at 200 GeV. These results suggest a large energy loss and flow of heavy quarks in the hot, dense matter. In recent years, the RHIC experiments installed silicon vertex trackers both in central rapidity and in forward rapidity regions, and has collected large data samples. These silicon trackers enhance the capability of heavy flavor measurements via precision tracking.

This talk summarizes the latest RHIC experiments results concerning open and closed charm and beauty heavy quark production as a function of rapidity, energy and system size, and their interpretation with respect to the current theoretical understanding on this topic.

Summary:

Section D / 461

Discussion

Summary:

Section D / 8

NNLO calculation of the Polyakov loop

Author(s): Matthias Berwein[1]

Co-author(s): Antonio Vairo ; Nora brambilla ; Peter Petreczky [2]

[1] *TU Munich*

[2] *BNL*

We calculate the next-to-next-to-leading correction to the expectation value of the Polyakov loop or equivalently to the free energy of a static charge. This correction is of order g^5. We show that up to this order the free energy of the static charge is proportional to the quadratic Casimir operator of the corresponding representation. We also compare our perturbative result with the most recent lattice results in SU(3) gauge theory.

Based on: Phys. Rev. D **93**, 034010 (2016), [arXiv:1512.08443]

Summary:

Section D / **22**

Hydrodynamization and isotropization in HIC

Yan Zhu[1]

[1] *University of Jyvaskyla*

We numerically solve 2+1D effective kinetic theory of weak coupling QCD under longitudinal expansion relevant for early stages of heavy-ion collisions. We find agreement with viscous hydrodynamics and classical Yang-Mills simulations in the regimes where they are applicable. With a reasonable initial condition for the anisotropic system in the heavy ion collisions, we found that the system is approximately described by viscous hydrodynamics well before τ ~ 1.0 fm/c.

Summary:

Section D / **25**

Temperature dependence of QGP share viscosity within lattice SU(3)-gluodynamics

Andrey Kotov[None] ; Nikita Astrakhantsev[1] ; Victor Braguta[2]

[1] *ITEP*

[2] *IHEP*

One of the most important result obtained at RHIC experiment is the measurement of the elliptic flow of final
particles. The value of this flow can be explained within hydrodynamic
approach, if it is assumed that QGP is nearly perfect fluid. Our paper is devoted to calculation of shear viscosity of QGP at different temperatures within lattice simulation of QCD. The results of the calculation are in a good agreement with the experiment.

Summary:

Measurements of the $< T_{12}T_{12} >$ correlator of lattice SU(3)-gluodynamics were performed in a range of temperatures in order to extract data about η/s viscosity-to-entropy ratio.

Section D / **121**

Effect of magnetic field on photon production in AA collisions

Bronislav Zakharov[1]

[1] *Landau Institute*

We study the effect of magnetic field on the photon emission
from the quark-gluon plasma (QGP) in AA collisions at RHIC and LHC energies.
We develop a formalism for photon radiation from the QGP
which accounts for interplay of the synchrotron mechanism and
the photon emission due to multiple scattering.
We show that multiple scattering suppresses strongly the
synchrotron contribution. Our numerical calculations
show that, contrary to the previous qualitative calculations
(K. Tuchin, Phys.Rev. C91 (2015), 014902) the effect of magnetic field on the photon emission in AA collisions for the RHIC and LHC conditions is very small.

Summary:

Section D / **132**

Complex Langevin simulations of a finite density Matrix Model of QCD

Author(s): Savvas Zafeiropoulos[1]

Co-author(s): Jacobus Verbaarschot [2] ; Jonas Rylund Glesaaen ; Owe Philipsen [3]

[1] *Goethe Universitaet Frankfurt*

[2] *Stony Brook University*

[3] *Goethe-University Frankfurt*

We study a Random Matrix Model for QCD at finite density via Complex Langevin dynamics. This model has a phase transition to a phase with non-zero baryon density. We study the convergence of the algorithm as a function of the quark mass and the chemical potential and focus on two main observables: the baryon density and the chiral condensate. As expected, for simulations close to the chiral limit, the algorithm has wrong convergence properties when the quark mass is in the spectral domain of the quenched Dirac operator. Possible solutions of this problem are discussed.

Summary:

Section D / **141**

Thermal D mesons from anisotropic lattice QCD

Aoife Kelly[1] ; Jon-Ivar Skullerud[2]

[1] *Maynooth University*

[2] *National University of Ireland Maynooth*

We present results for correlators and spectral functions of open and hidden charm mesons using 2+1 flavours of clover fermions on anisotropic lattices. The D mesons are found to melt close to the deconfinement crossover temperature T_c. Our preliminary results suggest a shift in the thermal D meson mass below T_c.

Summary:

Section D / 144

Initial state effects in small systems (pp,pA)

Soeren Schlichting[1]

[1] *Brookhaven National Lab*

We discuss the importance of initial state effects with regard to the theoretical understanding of long range azimuthal correlations observed in high-multiplicity p + p and p + A collisions at RHIC and the LHC. Starting with a brief overview of different effects, we perform a systematic comparison of initial state calculations with experimental data and briefly discuss progress towards developing a unified picture of initial state and final state effects.

Summary:

Section D / 147

The QCD equation of state at finite density from analytical continuation

Jana Günther[1]

[1] *University of Wuppertal*

An efficient way to study the QCD phase diagram at small finite density is to extrapolate thermodynamical observables from imaginary chemical potential. In this talk we present results on several observables for the equation of state to order (muB/T)^6. The observables are calculated along the isentropic trajectories in the (T, muB) plane corresponding to the RHIC Beam Energy Scan collision energies. The simulations are performed at the physical mass for the light and strange quarks. muS was tuned in a way to enforce strangeness neutrality to match the experimental conditions; the results are continuum extrapolated using lattices of up to Nt = 16 temporal resolution.

Summary:

Section D / 216

Initial conditions in AA and pA collisions

Tuomas Lappi[1]

[1] *University of Jyvaskyla*

A full understanding of the spacetime evolution of the QCD matter created in a heavy ion collision requires understanding the properties of the initial stages. In the weak coupling picture these are dominated by classical gluon fields, whose properties can also be studied via the scattering of dilute probes off a high energy hadron or nucleus. A particular challenge is understanding small systems, where LHC data is also showing signs of collective behavior. We discuss some recent results of on the initial matter production and thermalization in heavy ion collisions, in particular in the gluon saturation framework.

Summary:

Section D / **277**

Late time thermalization in the Quark Gluon Plasma

Author(s): Umut Gursoy[None]

Co-author(s): Giuseppe Policastro [1] ; Matti Jarvinen [2]

[1] *ENS*

[2] *Ecole Normale Superieure, Paris*

We explain the approach to thermal equilibrium of strongly coupled non-conformal plasmas using the AdS/CFT correspondence. The theories we study are the holographic duals to Einstein gravity coupled to a scalar with an exponential potential. The coefficient in the exponent, X, is the parameter that controls the deviation from the conformally invariant case. For these models we obtain analytic solutions for the plasma expansion in the late-time limit, under the assumption of boost-invariance, and we determine the scaling behaviour of the energy density, pressure, and temperature as a function of time, which is found to agree with the hydrodynamical expectation. We find that the temperature decays as a function of proper time as $T \sim {}^{-s/4}$ with the exponent s determined in terms of the nonconformality parameter X as $s = 4(1-4X2)/3$.

Summary:

Section D / **46**

Chiral symmetry restoration from the hadronic regime

Author(s): Angel Gomez Nicola[1]

Co-author(s): Jacobo Ruiz de Elvira [2] ; John Morales [3] ; Santiago Cortes [4]

[1] *Universidad Complutense Madrid*

[2] *HISKP University Bonn*

[3] *Universidad Nacional de Colombia*

[4] *Universidad de los Andes*

We will present recent results regarding chiral symmetry restoration and other hadronic properties at finite temperature. In particular, we will discuss the interpretation of the temperature dependence of lattice screening masses through Ward identities relating pseudoscalar susceptibilities and quark condensates. Such identities are derived for two and three flavours and studied within the $SU(2)$, $SU(3)$ and $U(3)$ frameworks of Chiral Perturbation Theory, including axial anomaly and η' corrections. We will also examine chiral degeneration patterns and the role of the $f_0(500)$ or σ state in the saturation of the scalar susceptibility, where our results are consistent with lattice data. The $f_0(500)$ thermal state is generated dynamically from pion scattering and thermal unitarity, both within unitarized ChPT and in other schemes such as that with large number of Goldstone Bosons. Aspects regarding external magnetic fields could also be discussed. Recent references: JHEP 1603 (2016) 186, Phys.Rev. D93 (2016) no.3, 036001.

Summary:

Section D / **54**

Hydrodynamics in small systems

Piotr Bozek[1]

[1] *AGH University of Science and Technology*

The presence of collective expansion in small collision is discussed. Approaches based on relativistic hydrodynamics are compared to existing data. Possibilities to study fluctuations in the interaction region in small collision systems are described.

Summary:

The presence of collective expansion in small collision is discussed. Approaches based on relativistic hydrodynamics are compared to existing data. Possibilities to study fluctuations in the interaction region in small collision systems are described.

Section D / 60

Holographic photon production in heavy ion collisions

Chun Shen[1] ; Di-Lun Yang[2] ; Elias Kiritsis[3] ; Ioannis Iatrakis[4]

[1] *McGill University*

[2] *RIKEN*

[3] *University of Crete*

[4] *Utrecht University*

We investigate the thermal-photon emission from strongly coupled gauge theories at finite temperature via the bottom-up models in holographic QCD in the deconfined phase. Particularly, we apply a model encoding flavor degrees of freedom in the Veneziano limit of a large number of colors N_c and flavors N_f but fixed $x = N_f = N_c$ (VQCD). In this model, the normalization and gauge-field couplings pertinent to photon production have been chosen to approximately reproduce the electric conductivity obtained from lattice simulations for the quark gluon plasma (QGP). The emission rates are then embedded in hydrodynamic simulations combined with prompt photons from hard scattering and the thermal photons from hadron gas to analyze the spectra and anisotropic flow of direct photons in RHIC and LHC. We compare the results for different sources responsible for the thermal photons in QGP including the weakly coupled QGP (wQGP) in the hard-thermal-loop approximation, strongly coupled $\mathcal{N} = 4$ super Yang-Mills (SYM) plasma (as a benchmark for reference), and Gubser's phenomenological model in holography. In general, the direct-photon spectra are enhanced in the strongly coupled scenario compared with the ones in the wQGP especially in high momenta. Moreover, by using IP-glassma initial states, both the elliptic flow and triangular flow of direct photons are amplified in high momenta for VQCD and the SYM plasma. We further compare our results with experimental observations.

Summary:

Section D / 62

Parity doubling of nucleons and Delta baryons across the deconfinement phase transition

Author(s): Davide De Boni[1]

Co-author(s): Benjamin Jäger [1] ; Chris Allton [1] ; Chrisanthi Praki [1] ; Gert Aarts [1] ; Jon-Ivar Skullerud [2] ; Simon Hands [1]

[1] *Swansea University*

[2] *National University of Ireland Maynooth*

At zero temperature nucleons and their parity partners have non-degenerate
masses due to spontaneous breaking of chiral symmetry.
However, chiral symmetry is expected to be restored at sufficiently high temperature,
in particular when going from the hadronic to the quark-gluon plasma (QGP) phase,
implying that the parity partners should become degenerate.
We study the nucleon (spin 1/2) and Delta (spin 3/2) baryons in both
parity sectors for a range of temperatures in the confined and QGP phases.
Using anisotropic $N_f = 2 + 1$ flavour simulations, we analyse the correlation functions and the spectral functions
using respectively exponential fits and the Maximum Entropy Method.
We find a clear sign of parity doubling for both baryons in the QGP phase:
the parity state masses become degenerate and
their corresponding correlators become essentially identical.

Summary:

Section D / **63**

Thermalization in a holographic Confining Theory

Christopher Andrew Rosen[1] ; Ilias Kyritsis[2] ; Takaaki Ishii[3]

[1] *Unknown*

[2] *University of Crete (GR) and APC (FR)*

[3] *University of Crete*

N/A

Summary:

Time dependent perturbations of states in the holographic dual of a 3+1 dimensional confining theory are considered. The perturbations are induced by varying the coupling to the theory's most relevant operator. The dual gravitational theory belongs to a class of Einstein-dilaton theories which exhibit a mass gap at zero temperature and a first order deconfining phase transition at finite temperature. The perturbation is realized in various thermal bulk solutions by specifying time dependent boundary conditions on the scalar, and we solve the fully backreacted Einstein-dilaton equations of motion subject to these boundary conditions. We compute the characteristic time scale of many thermalization processes, noting that in every case we examine, this time scale is determined by the imaginary part of the lowest lying quasi-normal mode of the final state black brane. We quantify the dependence of this final state on parameters of the quench, and construct a dynamical phase diagram. Further support for a universal scaling regime in the abrupt quench limit is provided.

Section D / **76**

Recent progress on the understanding of the medium-induced jet evolution and energy loss in pQCD

Liliana Apolinario[1]

[1] *Instituto Superior Tecnico (PT)*

Motivated by the striking modifications of jets observed both at RHIC and the LHC, significant progress towards the understanding of jet dynamics within QGP has occurred over the last few years. In this talk, I review the recent theoretical developments in the study of medium-induced jet evolution and energy loss within a perturbative framework. The main mechanisms of energy loss and broadening will be firstly addressed with focus on leading particle calculations beyond the eikonal approximation. Then, I will provide an overview of the modifications of the interference pattern

between the different parton emitters that build up the parton shower when propagating through an extended coloured medium. I will show that the interplay between color coherence/decoherence that arises from such effects is the main mechanism for the modification of the jet core angular structure. Finally, I discuss the possibility of a probabilistic picture of the parton shower evolution in the limit of a very dense or infinite medium.

Summary:

Section D / **78**

Neutral meson production measurements with the ALICE/LHC detector

Paraskevi Ganoti[1]

[1] *National and Kapodistrian University of Athens (GR)*

Identified hadron spectra are considered to be sensitive to transport properties of strongly interacting matter produced in high-energy nucleus-nucleus collisions.
$\pi 0$ and η mesons in ALICE are identified via their two-photon decays by using calorimeters and the central tracking system. In the latter, photons are measured via their conversion to electron-positron pairs on the material of the inner ALICE barrel tracking detectors.
The measured production spectra in pp p-Pb and Pb-Pb collisions at mid rapidity and over a wide pT range will be presented in the available LHC energies of Run I.
The resulting nuclear modification factor RAA at different centrality classes shows a clear pattern of strong suppression in the hot QCD medium with respect to pp collisions.
Comparison of the ALICE results on neutral mesons with lower-energy experiments will also be discussed.

Summary:

Section D / **92**

Recent results from the NA61/SHINE strong interaction physics programme

Evgeny Andronov[1]

[1] *St. Petersburg State University (RU)*

Main physics goals of the NA61/SHINE programme on strong interactions
are the study of the properties of the onset of deconfinement and the search
for signatures of the critical point of strongly interacting matter. For these goals the scan through two dimensional phase diagram (T-μ_B) is being performed
at the SPS by measurements of hadron production in nucleus-nucleus collisions
as a function of collision energy and system size.

In this contribution intriguing results on the energy dependence of hadron spectra
and yields in inelastic p+p and centrality selected Be+Be and Ar+Sc collisions will
be presented. In particular, the energy dependence of the signals of deconfinement,
the “horn”, “step” and “kink”, and new results on fluctuations and correlations
will be shown and compared with the corresponding data of other experiments
and model predictions.

Summary:

Section D / 93

Phase diagram of dense two-color QCD within lattice simulations

Alexander Molochkov[1] ; Alexander Nikolaev[1] ; Andrey Kotov[None] ; Ernst-Michael Ilgenfritz[2] ; Victor Braguta[3]

[1] *Far Eastern Federal University*

[2] *Joint Institute for Nuclear Research Dubna, Russia*

[3] *IHEP*

We present the results of a low-temperature scan of the phase diagram of dense two-color QCD with N_f = 2 quarks. The study is conducted using lattice simulation with rooted staggered quarks. At small chemical potential we observe the hadronic phase, where the theory is in a confining state, chiral symmetry is broken, the baryon density is zero and there is no diquark condensate. At the critical point \mu = m_{\pi}/2 we observe the expected second order transition to Bose-Einstein condensation of scalar diquarks. In this phase the system is still in confinement in conjunction with nonzero baryon density, but the chiral symmetry is restored in the chiral limit. We have also found that in the first two phases the system is well described by chiral perturbation theory. For larger values of the chemical potential the system turns into another phase, where the relevant degrees of freedom are fermions residing inside the Fermi sphere, and the diquark condensation takes place on the Fermi surface. In this phase the system is still in confinement, chiral symmetry is restored and the system is very similar to the quarkyonic state predicted by SU(N_c) theory at large N_c.

Summary:

Section D / 94

Exact sum rules for vector channel at finite temperature and their application to lattice QCD analysis

Author(s): Daisuke Satow[1]

Co-author(s): Philipp Gubler [2]

[1] *Goethe university*

[2] *Yonsei university*

We derive three exact sum rules for the spectral function of the electromagnetic current channel at finite temperature, by using operator product expansion and hydrodynamics, focusing on zero spatial momentum case. We also discuss the possibility to use these sum rules to constrain and improve the functional form of the spectral function assumed in the lattice QCD analysis, and to evaluate the transport efficient at the second order, which does not directly appear in the spectral function, from the lattice QCD data.

Summary:

Section D / 96

Event-by-event picture for the medium-induced jet evolution

Edmond Iancu[1] ; Miguel Ángel Escobedo Espinosa[2]

[1] *Institut de Physique Théoriqe*

[2] *Institut de Physique Théorique*

We discuss the evolution of an energetic jet which propagates through a dense quark-gluon plasma and radiates gluons due to its interactions with the medium. Within perturbative QCD, this evolution can be described as a stochastic branching process, that we have managed to solve exactly. We present exact, analytic, results for the gluon spectrum (the average gluon distribution) and for the higher n-point functions, which describe correlations and fluctuations.
Using these results, we construct the event-by-event picture of the gluon distribution produced via medium-induced gluon branching. In contrast to what happens in a usual QCD cascade in vacuum, the medium-induced branchings are quasi-democratic, with offspring gluons carrying sizable fractions of the energy of their parent parton. We find large fluctuations in the energy loss and in the multiplicity of soft gluons.
The multiplicity distribution is predicted to exhibit KNO (Koba-Nielsen-Olesen) scaling.
These predictions can be tested in Pb+Pb collisions at the LHC, via event-by-event measurements of the di-jet asymmetry.

Based on e-Print: arXiv:1601.03629 [hep-ph] published in JHEP 1605 (2016) 008 and work in progress.

Summary:

Section D / **104**

Perturbative study of the QCD phase diagram for heavy quarks at nonzero chemical potential

Julien Serreau[1]

[1] *Université Paris Diderot*

We investigate the phase diagram of QCD with heavy quarks at finite temperature and chemical potential in the context of background field methods. In particular, we use a massive extension of the Landau-DeWitt gauge which is motivated by previous studies of the deconfinement phase transition in pure Yang-Mills theories. We show that a simple one-loop calculation is able to capture the richness of the phase diagram in the heavy quark region, both at real and imaginary chemical potential. Moreover, dimensionless ratios of quantities directly measurable in numerical simulations are in good agreement with lattice results.

Summary:

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Section D / **117**

Evolution of the jet opening angle distribution in holographic plasma

Andrey Sadofyev[1] ; Krishna Rajagopal[2] ; Wilke van der Schee[1]

[1] *MIT*

[2] *Massachusetts Inst. of Technology (US)*

We use holography to analyze the evolution of an ensemble of jets, with an initial probability distribution for their energy and opening angle as in proton-proton (pp) collisions, as they propagate through an expanding cooling droplet of strongly coupled plasma as in heavy ion collisions. We identify two competing effects: (i) each individual jet widens as it propagates; (ii) the opening angle distribution for jets within any specified range of energies is pushed toward smaller angles, comparing final jets to initial jets with the same energies. The second effect arises because small- angle jets suffer less energy loss and because jets with a higher initial energy are less probable in the ensemble. We illustrate both effects in a simple two-parameter model, and find that their consequence in sum is that the opening angle distribution for jets in any range of energies narrows. We find that either effect can dominate in the mean opening angle for not unreasonable values of the parameters. So, the mean opening angle for jets with a given energy can easily shift toward smaller angles, as experimental data may indicate, even while every jet in the ensemble broadens.
contains fewer narrow and wide jets. Either effect can dominate in the mean opening angle, for not unreasonable values of the parameters. So, the mean opening angle for jets with a given energy can easily shift toward smaller angles, as experimental data may indicate, even while every jet in the ensemble broadens.

Summary:

Section D / **118**

Heavy-flavour productions in the relativistic heavy ion collisions in LHC

Shingo Sakai[1]

[1] *Istituto Nazionale Fisica Nucleare Frascati (IT)*

Heavy quarks, i.e. charm and beauty, are produced primarily in the initial, hard partonic scatterings in hadronic collisions.
In pp collisions, their production is well described by perturbative QCD due to their large mass.
In heavy-ion collisions, heavy quarks propagate through and interact with the hot and dense QCD matter.
Therefore, measurements of heavy-flavour production provide relevant information on the early stage of the collisions and parton-medium interaction.
A strong suppression of heavy-flavour production has been observed at high p_{T} with respect to the cross
section measured in pp collisions and scaled by the number of nucleon-nucleon collisions.
Such suppression has not observed in p–A collisions which is expected absence of QGP.
Thus the suppression in Pb–Pb collisions is a result of final state effects related to the energy loss of heavy quarks.
In addition, a collectivity of heavy-flavour productions was found in azimuth in non-central heavy-ion collisions.
Those results indicate that heavy quarks strongly interact with the matter created by heavy-ion collisions.
In the Large Hadron Collider (LHC), open heavy-flavour productions in the heavy-ion collisions (Pb–Pb) has carried by measuring D mesons, leptons from semi-leptonic decay of heavy-flavours and jets which are original from heavy quarks. In this presentation, those results are shown and discussed with theoretical calculations to understand the properties of the QCD matter and heavy-flavour productions.

Summary:

In this presentation, measurements of heavy-flavour productions in the relativistic heavy ion collisions in LHC are shown and discuss with theoretical calculations.

Section D / **152**

Quarkonium Production at RHIC

Anthony Frawley[1]

[1] *Florida State University*

The modification of charmonium and bottomonium production in heavy ion collisions can provide information about the properties of the QGP, including the color screening length. But heavy quarkonia production can be modified by effects that precede QGP formation, as well as by effects that occur after hadronization. This requires that we study quarkonia formation in p+A collisions as well as A+A collisions. If we do so at both RHIC and LHC energies, where the mix of contributing effects is different due to the different initial temperatures, heavy quark production cross sections and kinematic effects, then we greatly improve our prospects for isolating the effects due to the QGP. This strategy has already shown itself to be successful. In this talk I will review quarkonia production results from the RHIC experiments, compare with those from the LHC experiments, and discuss what comes next.

Summary:

Section D / **153**

Recent progress in hard-thermal-loop QCD thermodynamics and collective excitations

Nan Su[1]

[1] *Frankfurt Institute for Advanced Studies*

I review recent developments in QCD thermodynamics and collective excitations from the hard-thermal-loop effective theory. I begin by motivating the discussion with open questions from heavy-ion collisions. I then discuss a finite-temperature and density calculation of QCD thermodynamics at NNLO from the hard-thermal-loop perturbation theory. Finally, I discuss a recent exploration of generalizing the hard-thermal-loop framework to the (chromo)magnetic scale g^2T, from which a novel massless mode is uncovered.

Summary:

Section D / **157**

Study of lattice QCD at finite baryon density using the canonical approach

Aleksandr Nikolaev[1] ; Alexander Molochkov[1] ; Atsushi Nakamura[2] ; Denis Boyda[1] ; Valentin Zakharov[3] ; Vitaly Bornyakov[4] ; Vladimir Goy[1]

[1] *School of Biomedicine, Far Eastern Federal University*

[2] *Hiroshima University*

[3] *ITEP*

[4] *IHEP*

At finite baryon density lattice QCD first-principle calculations can not be performed due to the sign problem. In order to circumvent this problem, we

use the canonical approach, which provides reliable analytical continuation from the $\mu_q^{Im.}$ region to the real chemical potential region. We briefly present the canonical partition function method, describe our formulation, and show the results, obtained for two temperatures: $T/T_c = 1.35$ and $T/T_c = 0.93$ in lattice QCD with two flavors of improved Wilson fermions.

Summary:

Section D / **159**

Effective field theory techniques applied to the hard scales of the plasmas

Author(s): Cristina Manuel[1]

Co-author(s): Joan Soto [2] ; Stetina Stephan [3]

[1] *CSIC-IEEC*

[2] *UB*

[3] *INT, U. Washington*

We show that effective field theory techniques can be applied
in the high temperature T plasmas to
improve the accuracy of the physics of the hard scales (or scales of order T).
At leading order in the
coupling constant the hard scales of the plasma can be viewed as
on-shell classical particles. Based on this observation, and without any
reference
to the state of the system, we derive an effective field
theory describing the quantum fluctuations around an on-shell fermion with
energy p, described as a set of high dimension operators over the on-shell energy
p. When applied to systems close to equilibrium, when for most on-shell particles p ~ T,
we show that the
on-shell effective field theory (OSEFT) properly describes the HTL photon
polarization tensor of QED, and its 1/T corrections. We also show how with
the OSEFT one can derive quantum corrections
to classical transport equations.

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the OSEFT one can derive quantum corrections
to classical transport equations.

Section D / **164**

Quarkonia at T>0 and lattice QCD

Alexander Rothkopf[1]

[1] *Heidelberg University*

Heavy quarkonium presents a unique observable for the study of the quark-gluon plasma in relativistic heavy-ion collisions. While Bottomonium is expected to act as a test particle traversing the medium in the collision center, recent measurements of finite J/ψ flow by the ALICE collaboration hint at the participation of the charm quarks in the collectivity of the bulk.

Here we present recent results on the in-medium properties of kinetically thermalized heavy quarkonium obtained using lattice QCD methods. Particular emphasis is placed on the computation of spectral functions either from lattice effective field theory approaches such as NRQCD 1, or via a complex real-time potential extracted from Wilson line correlators on the lattice 2. Consequences for phenomenology e.g. for the J/ψ / ψ' ratio 3, as well as χ_c(nP) feed-down [4] are discussed.

1 see e.g. S.Kim, P.Petreczky, A.R. in preparation, 1512.05289 and Phys.Rev. D91 (2015) 054511
2 Y. Burnier, O.Kaczmarek, A.R. PRL 114 (2015) 082001
3 Y. Burnier, O.Kaczmarek, A.R. JHEP 1512 (2015) 101
[4] Y. Burnier, O.Kaczmarek, A.R. in preparation

Summary:

Section D / **171**

Yang-Mills correlation functions at non-zero temperature

Markus Huber[1]

[1] *University of Graz*

In QCD many quantities, like bound states properties or positions of (pseudo-)phase transitions, can be calculated from the correlation functions of quarks and gluons. The correlation functions themselves can be determined non-perturbatively from various sets of functional equations. Here, truncated Dyson-Schwinger equations are employed for the study of the gluonic sector of QCD at non-zero temperature, the understanding of which is essential for calculations in full QCD at non-zero temperatures and densities. Various results like the behavior of three-point functions will be presented, and the effects of truncations will be discussed.

Summary:

Correlations functions of Yang-Mills theory at non-zero temperature are calculated from Dyson-Schwinger equations in the Landau gauge. Effects of various truncations are studied.

Section D / **176**

Electromagnetic probes of the quark-gluon plasma: perturbation theory meets the lattice

Jacopo Ghiglieri[1]

[1] *Universitaet Bern (CH)*

In this talk I will review recent efforts in constraining the photon and dilepton rates on the theory side. This is achieved by extending perturbative calculations to next-to-leading order in the coupling g both for photons and for dileptons in most kinematical regions. A polynomial interpolation for the

corresponding spectral function, which vanishes at zero frequency and matches to these perturbative results at large invariant masses is the employed to analyze continuum-extrapolated lattice results for the vector current correlator at spatial momenta $k \sim (2—6)T$. At vanishing invariant mass we extract the photon rate which for k>~ 3T
is found to be close to the NLO weak-coupling prediction. For k <~ 2T uncertainties are large, but the photon rate is likely to fall below the NLO prediction, in accordance with the onset of a strongly interacting behaviour characteristic of the hydrodynamic regime.

Summary:

Section D / **286**

Jets in Pb-Pb collisions at ALICE

Oliver Busch[1]

[1] *University of Tsukuba (JP)*

The research programme of the ALICE experiment at the LHC focuses on studies of the Quark-Gluon Plasma, a state of matter where quarks and gluons are deconfined. The measurement of jets originating from the fragmentation of hard-scattered partons in the early phases of a nuclear collision allows one to study parton energy loss in the hot and dense medium. The dependence of the energy loss on the in-medium path length provides deeper insight into the energy loss mechanisms and can be studied by measuring jet production relative to the event plane orientation. Measurements of the jet structure explore possible modifications of the parton fragmentation due to the interaction with the medium.

In this talk, we show results of measurements of charged jet production in central and peripheral \sqrt{s_{NN}} = 2.76 TeV Pb–Pb collisions with respect to the event plane. Furthermore, measurements of a set of jet shapes characterising the longitudinal and transverse jet structure will be discussed. The results are compared with a variety of jet quenching Monte Carlo models.

Summary:

Section D / **179**

Flavor correlations and the QCD phase structure

Chihiro Sasaki[1]

[1] *University of Wroclaw*

Modifications in magnitude of fluctuations for different observables
are an excellent probe of a phase transition or its remnant.
In heavy-ion collision, fluctuations related to conserved charges
carried by light and strange quarks play an important role to identify
the QCD chiral crossover and deconfinement properties.

Recent Lattice QCD simulations have revealed that the charmed mesons
are deconfined together with light-flavor mesons in the temperature
range where the chiral symmetry is partially restored. This result
strongly suggests that the light-flavor dynamics interferes non-trivially
with the heavy flavors.

We show that the heavy quark dynamics is tied to the light flavor
physics, and the thermodynamics is strongly dragged by the chiral
crossover dominated by the non-strange flavors. Consequently,

the fluctuations carried by the states with strangeness can be used to characterize the onset of the chiral symmetry restoration.

We also discuss a possible phase structure of dense QCD matter within a toy model that handles the onset of different Fermionic degrees of freedom, either nucleons or quarks, depepnding on densiy. Selected key quantities, the baryon number and its susceptibility as well as the Polyakov-loop fluctuations, are used to characterize phases at finite density.

Summary:

Section D / **180**

Multiplicity dependence of light flavor hadron production in proton-proton collisions measured with ALICE

Marek Chojnacki[1]

[1] *University of Copenhagen (DK)*

The combination of multiple particle identification systems along with the excellent tracking capabilities makes ALICE a unique tool for the measurement of light flavor hadron production over a broad transverse momentum (p_{T}) range.
The production of $\pi^{\pm}$, $\mathrm{K}^{\pm}$, K^{0}_{S}, p,
$\overline{\mathrm{p}}$, Λ, $\bar{\Lambda}$, Ξ^{-}, $\overline{\Xi}^{+}$, Ω^{-} and $\overline{\Omega}^{+}$ hadrons measured at midrapidity in proton-proton collisions at $\sqrt{s} =$ 7 TeV as a function of charged-particle multiplicity will be presented.
The observed multiplicity dependence of p_{T}-spectra and their ratios is reminiscent of the behavior in Pb–Pb collisions, where the spectral shapes are interpreted in the context of a hydrodynamical evolution of the colliding system.
Moreover, the ratios of strange hadron production to the pion production are seen to increase with multiplicity, which is not the case for non-strange hadrons. The strength of the increase scales with the number of the strange valence quarks.
Commonly used Monte-Carlo models (e.g. PYTHIA8, EPOS LHC) are not able to reproduce our observations for pp collisions.
The talk will also include new ALICE results on light flavor hadron production in pp collisions at $\sqrt{s} = 13$ TeV.

Summary:

Section D / **194**

Resummation of large higher order corrections in non-linear QCD evolution

DIONYSIS TRIANTAFYLLOPOULOS[1]

[1] *ECT**

Due to the non-Abelian nature of QCD and the existence of the 3-gluon coupling, the wavefunction of a high energy hadron at small-x is dominated by gluons (with x the longitudinal momentum fraction of a parton). The occupation numbers for these soft gluons increase rapidly with decreasing x and eventually saturate to their maximal allowed value, in a region where the coupling is still weak. The most suitable way to study this phenomenon of parton saturation, is to probe the hadron with a small color dipole, and the ensuing evolution equation for the scattering amplitude is the Balitsky-Kovchegov (BK) equation, with its NLO version derived a few years ago. We show that the NLO BK

eqaution leads to unphysical solutions, we identify the reason for the large and negative NLO corrections and we resum the respective terms to all orders. The emergent resummed evolution equation can be used to address many phenomenological aspects in hadronic, and in particular heavy-ion, collisions.

Summary:

Section D / **195**

Semiholography for heavy ion collisions

Author(s): Ayan Mukhopadhyay[1]

Co-author(s): Christian Ecker [1] ; Di-Lun Yang [2] ; Edmond Iancu [3] ; Florian Preis [4] ; Stefan Stricker [5] ; Yoshimasa Hidaka [2]

[1] *Vienna University of Technology*

[2] *RIKEN*

[3] *CEA/IRFU,Centre d'etude de Saclay Gif-sur-Yvette (FR)*

[4] *Technische Universität Wien*

[5] *TU Wien*

Based on arXiv:1410.6448, arXiv:1512.06445 and ongoing works

Summary:

Semiholography is a non-perturbative approach to describe weakly coupled perturbative degrees of freedom in the UV and strongly coupled IR degrees of freedom together in an integrated way. In case of heavy ion collisions, semiholography integrates the glasma description at the initial stage and kinetic description at later stages for the UV degrees of freedom with a holographic description of the IR. We will discuss how this approach can be applied to describe the spacetime evolution of matter formed by heavy-ion collisions. As full numerical simulations of semiholographic dynamics is not yet completed, we will present some simple examples which will be quite eloquent about various aspects of the full dynamics. In particular, pressure isotropization, hydrolyzation, thermalization and jet quenching have distinctive features in semiholography which cannot be obtained simply by extrapolating to somewhere intermediate between weak and strong coupling while ignoring the running of the coupling with the scale. We will discuss the mentioned dynamical aspects in the semiholographic framework.

Section D / **197**

Collectivity / hydrodynamics

Wojciech Florkowski[1]

[1] *Institute of nuclear Physics, Krakow*

General aspects of the application of hydrodynamics in theoretical description of heavy-ion collisions are shortly reviewed with the emphasis on the following issues: fluid variables, the form of hydrodynamic expansion, early thermalization vs. early hydrodynamization scenario, the use of the realistic equation of state, incorporation of the phase transition and pre-equilibrium flow, free streaming vs. hydrodynamic expansion, determination of the kinetic coefficients, quark-gluon plasma as a new state of matter with the properties determined by the hydrodynamic approach.

Summary:

General aspects of the application of hydrodynamics in theoretical description of heavy-ion collisions are shortly reviewed.

Section D / **198**

On spectral functions and transport coefficients in QCD

Jan M. Pawlowski[1]

[1] *University of Heidelberg*

The computation of single particle spectral functions and transport coefficients with functional continuum methods is discussed. Results are presented for quark and meson, and glueball spectral functions, as well as the temperature-dependent shear viscosity over entropy ratio.

Summary:

Section D / **204**

Lattice calculation of the Polyakov loop and Polyakov loop correlators

Author(s): Johannes Heinrich Weber[1]

Co-author(s): Alexei Bazavov [2] ; Antonio Vairo ; Nora brambilla ; Peter Petreczky [3]

[1] *Munich University of Technology (TUM)*

[2] *Michigan State University*

[3] *BNL*

I discuss calculations of the Polyakov loop and of Polyakov loop correlators using lattice gauge theory.
I briefly review recent calculations (since Conf. 2014) of the Polyakov loop and static quark correlators.
I cover in detail results in QCD with 2+1 flavors and almost physical quark masses using the highly improved staggered quark action (HISQ).
I examine the short- and long-distance regimes of the correlators and discuss the color-screening in the thermal medium.
I elucidate how the Polyakov loop and related observables behave in the crossover region and how these observables probe the deconfinement aspects of the crossover.
I study the onset of weak-coupling behavior at high temperatures and short distances.

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I study the onset of weak-coupling behavior at high temperatures and short distances.

Section D / **208**

The QCD equation of state and fluctuations of conserved charges at non-zero temperature and density

Christian Schmidt[1]

[1] *University of Bielefeld*

We present results from a calculation of the QCD equation of state up to the sixth order in the baryon, strangeness and electric charge chemical potentials. As the results depend on three independent chemical potential, we consider various cases to parametrize the strangeness and electric charge chemical potentials as a function of the baryon chemical potential and temperature. Among these, the conditions met in heavy ion collision are best reproduced by enforcing strangeness neutrality and a constant baryon number to electric charge ratio. We will further discuss how cumulant rations of conserved charge fluctuations that are available in both, lattice QCD simulations and heavy ion experiments, can be used to determine freeze-out parameter of the experiment including the freeze-out curvature.

The presented results are based on lattice calculations performed with the Highly Improved Staggered Quark action (HISQ) in the temperature range 140 MeV < T < 330 MeV, with lattice sizes $24^3 \times 6$, $32^3 \times 8$, $48^3 \times 12$ and $16^3 \times 16$. The strange quark mass is tuned to its physical value and we use ratios of strange to light quark masses including $m_s/m_l = 20$ and 27, which in the continuum corresponds to a pion masses of 160 and 140 MeV.

Summary:

Section D / **218**

Anisotropic hydrodynamics

Michael Strickland[1]

[1] *Kent State University*

Anisotropic hydrodynamics is a reformulation of relativistic viscous hydrodynamics which allows one to more reliably describe non-equilibrium fluid dynamics. This is accomplished by taking into account inherent local-rest-frame momentum-space anisotropies at leading order. Through comparisons with recently obtained exact solutions to the Boltzmann equation, it has been shown that anisotropic hydrodynamics is the most accurate approach to modeling relativistic dissipative fluid dynamics. The main application area for anisotropic hydrodynamics has historically been in modeling the quark-gluon plasma generated in relativistic heavy-ion collisions, however, there have also been applications to cold atomic gases. In this talk, I will review recent progress in anisotropic hydrodynamics which have included: development of realistic (3+1)d codes with fluctuating initial conditions, implementation of lattice-based equation of state, inclusion of multiple anisotropy parameters and NLO corrections, anisotropic Cooper-Frye freeze-out, and bulk viscous effects. Finally, I will present preliminary phenomenological results together with comparisons to LHC data for particle spectra and collective flow.

Summary:

In this talk I review recent progress in anisotropic hydrodynamics.

Section D / **224**

The flow paradigm

Jean-Yves Ollitrault[1]

[1] *CNRS*

Soft particle production in ultrarelativistic heavy-ion collisions is surprisingly well described by the "flow paradigm" which states that particles are emitted independently, according to a one-particle probability distribution that fluctuates event to event. I review some consequences of this flow paradigm and show how it can be used to relate correlations of different orders.

Summary:

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I review some consequences of this flow paradigm and show how it can be used to relate correlations of different orders.

Section D / **240**

Holographic energy loss in nonconformal confining theories

Author(s): Francesco Nitti[None]

Co-author(s): Ilias Kyritsis [1] ; Liuba Mazzanti [2] ; Umut Gursoy [3]

[1] *University of Crete (GR) and APC (FR)*

[2] *IBPC*

[3] *Nikhef National institute for subatomic physics (NL)*

Using the AdS/CFT correspondence, phenomenological models based on five-dimensional Einstein-Dilaton gravity can be constructed which give a realistic description of several non-perturbative properties of Yang-Mills theory at thermal equilibrium. These models can also be used to describe time-dependent and out-of-equilibrium processes, and to compute observables related to heavy quark diffusion and energy-loss in the Quark-Gluon Plasma. In this talk I will discuss quark diffusion and energy-loss in the context of holography, pointing out the main features that emerge in non-conformal models and that can be searched in heavy-ion hydrodynamic simulations.

Summary:

Section D / **253**

Early thermalisation, hydrodynamics, and energy loss in holographic heavy ion collisions

Wilke van der Schee[1]

[1] *MIT*

This talk will review recent progress in using holography to learn lessons about heavy ion collisions. I will illustrate the use of holography for the earliest stage of HIC, before hydrodynamics applies, and also during the hydrodynamic evolution in order to describe the energy loss and shape evolution of jets traversing the hydrodynamic medium. Interesting results include the fast applicability of hydrodynamics (within 0.1 fm/c), a Gaussian rapidity profile of the energy density, and a characteristic dependence of energy loss on the width of a jet.

Summary:

Section D / **262**

Overview of collectivity in small systems

Wei Li[1]

[1] *Rice University (US)*

Observation of novel long-range collective phenomena in high-multiplicity pp and pA collisions at the LHC has opened up new opportunities of exploring QCD dynamics in a high-density environment. Major progress in experimental and theoretical community has been made in recent years to unravel the physical origin of the observed phenomena. In this talk, I will review the experimental results including the latest pp data from the LHC run 2 in 2015. In the context of various proposed theoretical interpretations I will discuss what we have learned so far, and what are the opportunities and challenges in the future.

Summary:

Section D / **279**

The axial anomaly and topology in finite temperature QCD

Sayantan Sharma[1]

[1] *BNL*

The magnitude of axial U(1) symmetry breaking is believed to affect the nature of phase transition in QCD with two light quark flavors. I review the recent studies on the fate of axial U(1) in finite temperature QCD using lattice techniques. Most of them investigate the eigenvalue spectrum of the fermion Dirac operator in QCD. The current understanding from majority of these studies is that the axial U(1) is not effectively restored near Tc, the chiral crossover transition temperature. Studying the eigenvalue spectrum also gives us rich insights on the nature and interactions between the topological objects in QCD. Specifically the near-zero eigenmodes are observed to persist even at 1.5 Tc, and are primarily responsible for U(1) breaking. The near-zero eigenmodes are localized unlike those in the bulk, with a mobility edge similar to a Mott-Anderson like system. The possible microscopic origins of the near-zero mode spectra in QCD would be discussed in detail. At 1.5 Tc, its origin can be traced back to the dilute instanton gas ensemble. Consequences of these findings for finite temperature QCD and axion cosmology would be further discussed in this talk.

Summary:

Section D / **281**

Electromagnetic probes in high-energy pp and AA collisions

Thomas Peitzmann[1]

[1] *Nikhef National institute for subatomic physics (NL)*

Electromagnetic probes are penetrating and are thus particularly useful to study the initial state and the earliest phases of hadron and heavy-ion collisions. However, because of the low cross section

the measurements suffer from a small signal to background ratio and are therefore extremely challenging.
Prompt photon and Drell-Yan production are sensitive probes of the initial parton distributions and form an important complement to DIS measurements. I will argue that in the near future, such measurements at the LHC provide unique opportunities to obtain clean information on the initial state of hadrons. In particular forward direct photons should provide access to the low-x gluon structure in protons and nuclei.
Both thermal direct photons and low-mass dileptons contain information on the temperature evolution of the strongly interacting system. Measurements have been performed at RHIC and LHC, and the results are still not fully understood theoretically. It is in particular difficult to simultaneously describe the yield of photons and their azimuthal anisotropy. I will discuss the current status of measurements and their interpretation.

Summary:

Section D / **308**

Overview of experimental results on collective flow with identified particles at RHIC and the LHC

Panos Christakoglou[1]

[1] *Nikhef National institute for subatomic physics (NL)*

Anisotropic flow studies play a crucial role in improving our understanding of the behaviour and the nature of matter created in collisions of heavy ions. The different flow harmonics (v_n) harmonics for identified particles can be used to constrain the initial conditions and the value of shear viscosity over entropy density ratio. These studies allow also to reveal the role of the hadronic rescattering phase in the development of flow.
In this talk I review the results from measurements of elliptic (v_2), triangular (v_3), quantrangular (v_4) and pentagonal (v_5) of identified particles from the RHIC and LHC heavy-ion physics programs.

Summary:

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Section D / **316**

Geometrical clusterization and deconfinement phase transition in SU(2) gluodynamics

Author(s): Kyrylo Bugaiev[1] ; Oleksii Ivanytskyi[1]

Co-author(s): Dmytro Oliinychenko [2] ; Eduard Nikonov [3] ; Ernst-Michael Ilgenfritz [4] ; Gennady Zinovjev [1] ; Igor Mishustin [5] ; Violetta Sagun [6] ; Vladimir Petrov [6]

[1] *National Academy of Sciences of Ukraine (UA)*

[2] *CERN*

[3] *Joint Institute for Nuclear Research (JINR)*

[4] *Joint Institute for Nuclear Research Dubna, Russia*

[5] *Goethe University*

[6] *Bogolyubov Institute for Theoretical Physics*

A novel approach to identify the geometrical (anti)clusters formed by the Polyakov loops of the same sign and to study their properties in the lattice SU(2) gluodynamics is developed. The (anti)cluster size distributions are analyzed for the lattice coupling constant β=[2.3115; 3]. The found distributions are similar to the ones existing in 2- and 3-dimensional Ising systems 1. Using the suggested approach, we explain
the phase transition in SU(2) gluodynamics at $\beta = 2.52$ as a transition between two liquids during which one of the liquid droplets (the largest cluster of a certain Polyakov loop sign) experiences a condensation, while another droplet (the next to the largest cluster of opposite Polyakov loop sign) evaporates. The clusters of smaller sizes form two accompanying gases, which behave oppositely to their liquids. The liquid drop formula is used to analyze the distributions of the gas (anti)clusters and to determine their bulk, surface and topological parts of free energy. Surprisingly, even the monomer multiplicities are reproduced with high quality within such an approach. The behavior of surface tension of gaseous (anti)clusters is studied. It is shown that this quantity can serve as an order parameter of the deconfinement phase transition in SU(2) gluodynamics. Moreover, the critical exponent β of surface tension coefficient of gaseous clusters is found in the upper vicinity of critical temperature. Its value coincides with the one found for 3-dimensional Ising model within error bars. The Fisher topological exponent
τ of (anti)clusters is found to have the same value 1.806 ± 0.008, which agrees with an exactly solvable model of the nuclear liquid-gas phase transition 2 and disagrees with the Fisher droplet model 3, which may evidence for the fact that the SU(2) gluodynamics and the model 2 are in the same universality class.

1 L. Moretto et al., Phys. Rev. Lett. 94, 202701 (2005).

2 V. Sagun, A. Ivanytskyi, K. Bugaev and I. Mishustin, Nucl. Phys. A 924, 24 (2014).

3 M. E. Fisher, Physics 3, 255 (1967).

Summary:

Section D / 327

Azimuthal anisotropy of long-range correlations at LHC energy in Monte Carlo model with string fusion

Vladimir Kovalenko[1]

[1] *St. Petersburg State University (RU)*

Long-range multiplicity correlations in intervals separated in pseudorapidity and azimuth are studied in the framework of string fusion approach.
We applied a Monte Carlo model [1,2], in which the string configurations in the transverse plane and rapidity are simulating event-by-event.
We assumed that the azimuthal anisotropy of particle production is caused by parton energy loss travelling trough the media formed by clusters of fused strings [3-5]:

$\Delta p_t/\Delta x = -\alpha(p_t\sqrt{\eta})^{2/3}$,
where η is a string density.

An additional source of the anisotropy is related to the strong resonances decays.

This approach provides non-zero values of elliptic and higher flows in Pb-Pb and p-Pb collisions at LHC energies. The obtained results are compared with experimental data.

The author acknowledges Saint-Petersburg State University for the research grant 11.38.197.2014.

1 V. N. Kovalenko, Phys. Atom. Nucl. 76, 1189 (2013), arXiv:1211.6209 [hep-ph].

2 V. Kovalenko, V. Vechernin, PoS (Baldin ISHEPP XXI) 077, arXiv:1212.2590 [nucl-th], 2012.

3 M. A. Braun, C. Pajares, Eur. Phys. J. C 71, 1558 (2011).

[4] M. A. Braun, C. Pajares, V. V. Vechernin, Nucl. Phys. A 906, 14 (2013).

[5] M. A. Braun, C. Pajares, V. V. Vechernin, Eur. Phys. J A 51, 44 (2015).

Summary:

The results on the theoretical modeling of azimuthal anisotropy of long-range correlations at LHC energies in string fusion approach will be presented.

Section D / **332**

From p-A to A-A: an experimental overview on quarkonium at LHC

Roberta Arnaldi[1]

[1] *Universita e INFN Torino (IT)*

Since the first heavy-ion collisions which date back to thirty years ago, quarkonium is considered one among the most important probes of the formation of a plasma of quarks and gluons.
Quarkonium production is, in fact, expected to be strongly modified by the creation of a hot medium. On one side, quarkonium yields are suppressed, due to the Debye screening, with respect to those measured in pp interactions scaled by the number of binary collisions. The size of the suppression depends on the energy of the collision and on the strength of the binding energy between the c and $\bar{c}$ or b and $\bar{b}$ quarks. On the other side, for high-energy collisions, an additional quarkonium production mechanism sets in, i.e. the recombination of the quarks during the collision evolution or at the phase boundary. This process might counterbalance the suppression mechanism.
On top of these hot-matter effects, quarkonium production is also affected by mechanims related to the presence of cold nuclear matter. While the first type of effects can be investigated comparing results for several quarkonium states, obtained, in A-A interactions, at different collision energies, the cold-matter effects can be addressed by studying the quarkonium behaviour in collisions systems as p-A or d-A.
In this talk, an overview of the quarkonium results will be presented, discussing the measurements on J/ψ, ψ(2S) and Υ states at RHIC and at LHC energies, both in p-A (d-A) and in A-A collisions. Particular emphasis will be given to the most recent results from LHC Run-2.

Summary:

Experimental overview of quarkonium results from RHIC to LHC energies, from p-A to A-A collisions.

Section D / **7**

Bottomonia suppression in 2.76 TeV Pb-Pb collisions

Michael Strickland[1] ; Radoslaw Ryblewski[2]

[1] *Kent State University*

[2] *Institute of Nuclear Physics PAN*

We compute the QGP suppression of $\Upsilon(1s)$, $\Upsilon(2s)$, $\Upsilon(3s)$, χ_{b1}, and χ_{b2} states in \mbox{$\sqrt{s_{NN}} = 2.76$ TeV} Pb-Pb collisions. Using the suppression of each of these states, we estimate the inclusive R_{AA} for the $\Upsilon(1s)$ and $\Upsilon(2s)$ states as a function of $N_{\rm part}$, y, and p_T including the effect of excited state feed down. We find that our model provides a reasonable description of preliminary CMS

results for the $N_{\rm part}$-, y-, and p_T-dependence of R_{AA} for both the $\Upsilon(1s)$ and $\Upsilon(2s)$. Comparing to our previous model predictions, we find a flatter rapidity dependence, thereby reducing some of the tension between our model and ALICE forward-rapidity results for $\Upsilon(1s)$ suppression.

Literature:

1) B. Krouppa, R. Ryblewski, M. Strickland, Phys.Rev. C92 (2015) no.6, 061901

2) M. Strickland, Phys.Rev.Lett.107,132301 (2011)

3) M. Strickland, D. Bazow, Nucl.Phys.A879, 25 (2012)

Summary:

Section D / **233**

Number and density of quark-gluon strings and collective effects in hadron collisions.

Grigori Feofilov[1]

[1] *St. Petersburg State University (RU)*

Formation of color flux tubes (or quark-gluon strings), at very early stages of hadron- hadron collision, and the following hadronization, is the common general concept used by various event-generators of multiparticle production. The mechanisms of strings formation might be different (in soft and hard processes), however, the common feature in all model approaches is the number of strings and the relevant string density that might be formed in a collision. The last one may be the important factor responsible for any collectivity effects in the wide region of hadron collisions energy from SPS to RHIC and LHC .
In case of sufficiently high densities these strings may overlap and interact, for example by repelling or attracting each other, thus producing noticeable azimuthal long-range correlations (flows). This approach leads also to other manifestations of collectivity in strong correlation of the event mean transvers momenta with charged particles multiplicity (Nch) and relevant color reconnection effects, the increase of strange particles and heavy mesons yields in case of string fusion , including the long-range rapidity correlations involving heavy flavors.

We compare three independent estimates of number of such kind of particle emitting sources that may be produced in pp collisions. This includes string percolation model based on RHIC data analysis, the multipomeron exchange model with string fusion phenomenon , and MPI from PYTHIA with color reconnection. We show that high density effects from Pb-Pb down to pp collisions may play an important role in the formation of particle flows of different harmonics thus providing the initial conditions of the system evolution.

This work is supported by the Russian Science Foundation, GRANT 16-12-10176

Summary:

Section D / **358**

QGP tomography through high momentum probes

Magdalena Djordjevic[1]

[1] *Institute of Physics Belgrade*

Summary:

Section D / **412**

Transport at low and high opacity and the elliptic flow

Denes Molnar[1]

[1] *Purdue University*

Kinetic theory is one of the main dynamical frameworks to model ultrarelativistic heavy-ion collisions at RHIC and the LHC. For example, it has been used to study i) thermalization during the early partonic stage of the collision, ii) hadronic mixture evolution in late stages of the reaction, and more recently also iii) proper inclusion of nonthermal phase space density corrections for particles coming from a dissipative quark-gluon fluid. It is well-known that at large enough opacities on-shell kinetic theory gives back hydrodynamics (this has been used, for example, to systematically formulate causal versions of relativistic dissipative hydrodynamics). The practical question is how high opacities need to be for hydrodynamic behavior in the rapidly expanding small systems present in heavy ion reactions. I will address this in light of recent results from the AMPT transport model that can explain, with unexpectedly modest opacities, features in the data that have traditionally been thought to be the hallmarks of hydrodynamics.

Summary:

Section E / **211**

Lattice QCD and quark flavour anomalies of the SM

Zhaofeng Liu[1]

[1] *Institute of High Energy Physics*

Lattice QCD calculations with dynamical fermions are getting more and more precise in recent years. The uncertainties of lattice QCD results can be shrinked systematically. I will discuss lattice QCD calculations of weak matrix elements related to quark flavor anomalies in bottom quark decays.

Summary:

Section E / **265**

Neutrinoless double beta decay and particle physics

Werner Rodejohann[None]

a

Summary:

The various implications of limits or an observation of neutrinoless doble beta decay are given. In the standard interpretation of the decay light massive Majorana neutrinos are mediating the decay. This directly relates double beta decay to neutrino oscillations, direct neutrino mass experiments and cosmological determinations of neutrino mass. However, there are many non-standard interpretations, in which new physics not directly related to neutrino physics mediates the decay. Tests of such alternative mechanisms are possible e.g. with the LHC.

Section E / **227**

A precise determination of the $N_{\rm f} = 3$ QCD Λ-parameter from lattice QCD

Author(s): Mattia Dalla Brida[1]

Co-author(s): Alberto Ramos Martinez [2] ; Hubert Simma [3] ; Mattia Bruno [4] ; Patrick Fritzsch [5] ; Rainer Paul Sommer [3] ; Stefan Schaefer [6] ; Stefan Sint [7] ; Tomasz Korzec [8]

[1] *DESY - Zeuthen*

[2] *CERN*

[3] *DESY*

[4] *BNL*

[5] *H*

[6] *Deutsches Elektronen-Synchrotron (DE)*

[7] *Trinity College Dublin (IE)*

[8] *University of Wuppertal*

In this talk we present the ALPHA-collaboration computation of the three-flavour QCD Λ-parameter. Starting from the value of Λ in units of an intermediate energy scale $\mu = 1/L_0 \sim 4\,\mathrm{GeV}$ (cf. talk by S. Sint), we first discuss the connection of this scale and a given hadronic scale, $1/L_{\rm had}$, of a few hundred MeV. The latter is obtained very precisely by determining the non-perturbative scale-evolution of the recently proposed gradient flow coupling between these scales. In a second step, $1/L_{\rm had}$ is expressed in terms of some measurable hadronic quantity using results from the CLS-collaboration effort. This allows the Λ-parameter to be determined in physical units.

Summary:

Section E / 35

Recent Progress in Neutron-Antineutron Oscillation Theory

Michael Wagman[None]

The observed matter-antimatter asymmetry of the universe is an outstanding mystery of physics that cannot be explained within the Standard Model. Many beyond the Standard Model (BSM) explanations have been proposed, and experimental data is needed to constrain the wide theory space of BSM models. Neutron-antineutron oscillations are predicted to be a signature of some BSM baryogenesis models and can be cleanly probed by low-energy experiments. Connecting experimental data on neutron-antineutron transition rates to fundamental BSM theory parameters requires QCD matrix elements of six-quark operators effectively parameterizing BSM physics at low energies. I will discuss recent work by myself and others to reliably determine these matrix elements through lattice QCD simulations and renormalization group analysis necessary to connect BSM scales to computationally accessible lattice QCD scales.

Section E / 259

Precision measurements of top quark production with the ATLAS detector

Philipp Stolte[1]

[1] *Goettingen*

The top quark is the heaviest known fundamental particle. As it is the only quark that decays before it hadronizes, this gives us the unique opportunity to probe the properties of bare quarks and to test perturbative QCD. This talk will focus on a few recent precision top quark measurements by the ATLAS Collaboration: fiducial top pair and single top production cross sections including differential distributions will be presented and compared with QCD predictions. The results include the first top quark measurements at 13 TeV using data from LHC run 2.

Summary:

Section E / **263**

Status and Future of Neutrinoless Double-Beta Decay Nuclear Matrix Elements

Javier Menendez[1]

[1] *University of Tokyo*

Neutrinoless double-beta decay is a lepton-number violating process that will establish that neutrinos are its own antiparticle. In the next few years, ton-scale experiments will aim for the detection of this rare decay. Naturally, the nuclear decay rate depends on the nuclear matrix element of the transition (NME). The NMEs are necessary to constrain the neutrino mass from limits on the decay lifetime, and also, once neutrinoless double-beta decay has been observed, to obtain a value for the absolute neutrino mass.

For these purposes, reliable NME calculations are crucial. I will review he status of nuclear structure calculations for neutrinoless double-beta decay NMEs highlighting recent progress in the field. I will discuss some key issues that need to be addressed in order to meet the demand for accurate NMEs, including improvements in the nuclear structure calculations and in the treatment of the double-beta decay operator.

Summary:

Section E / **260**

Search for heavy resonances in vector boson scattering

Guangyi Zhang[1]

[1] *University of Science and Technology of China (CN)*

If the Higgs boson discovered at the LHC is not exactly the one predicted by the Standard Model the theory becomes strongly coupled at high energy and vector boson scattering violates unitarity in the TeV range. This can be regularised by the introduction of new heavy resonances. These resonances may also couple to quark pairs and can be searched for in their decay to vector or Higgs bosons.

The ATLAS detector at the LHC is collecting data at 13 TeV since 2015. A search for new heavy resonances arising from WW scattering in vector boson fusion events using these data is presented. Interference effects between the new resonances and the Standard Model amplitude are fully taken into account. In addition searches for heavy resonances in the decay to a pair of bosons without tagging the initial state are shown.

Summary:

Section E / 460

Observation of Anomalous Internal Pair Creation in ^{8}Be: A Possible Signature of a Light, Neutral Boson

Attila Krasznahorkay[1]

[1] *Inst. for Nucl. Res., Hung. Acad of Sci. (MTA-Atomki)*

Summary:

Section E / 40

CANCELLED: Perturbative and non-perturbative QCD parameters in Dispersive model.

Author(s): Mohammad Ebrahim Zomorrodian[1]

Co-author(s): Reihaneh Salehmoghaddam [2]

[1] *Ferdowsi University of Mashhad*

[2] *ferdowsi university of mashhad*

coupling constant, nonperturbative QCD parameter, dispersive model.

Summary:

Abstract: we study average of moments for event shapes in e^+ e^-⟶hadrons within the context of next to leading order (NLO) perturbative QCD prediction in dispersive model. Moments used in this article are <1-T>,⟨ρ⟩,⟨B_T ⟩ ,⟨B_W ⟩. We extract the coupling constant (α_s) in perturbative theory and α_0 in the non- perturbative theory using the dispersive model. By fitting the experimental data, we find the values of α_s (M_(Z^0))= 0.1171±0.00229 and α_0 (μ_I=2GeV)=0.5068±0.0440. Our results are consistent with the above model. Our results are also consistent with those obtained from other experiments at different energies. We explain all these features in this paper..

Section E / 116

Recent progress on QCD inputs for axion phenomenology

Massimo D'Elia[1]

[1] *University of Pisa*

The properties of the QCD axion are strictly related to the dependence of the theory on the topological parameter theta. We will present a determination of the topological properties of QCD for temperatures up to around 600MeV, obtained by lattice QCD simulations with 2+1 flavors and physical quark masses. Numerical results for the topological susceptibility, when compared to instanton gas computations, differ both in size and in the temperature dependence. We will discuss the implications of such findings for axion phenomenology.

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Section E / **346**

An effective interpretation of electric dipole moments

Jordy de Vries[1]

[1] *f*

Permanent electric dipole moments (EDMs) are sensitive probes of CP violation beyond the Standard Model. EDM experiments typically involve complicated systems such as hadrons, nuclei, and atoms. I will discuss an effective field theory framework in which EDM measurements can be interpreted in terms of more fundamental concepts. As an example, I illustrate how EDM measurements set strong constraints on CP violation in the Higgs sector. I argue that hadronic and nuclear uncertainties limit the power of EDM searches and discuss strategies that can improve this situation in order get the most out of the rich experimental program.

Summary:

Section E / **348**

The Muon g-2 Experiment at Fermilab

Antoine Chapelain[1]

[1] *Cornell University*

The Muon g-2 Experiment at Fermilab aims to measure the anomalous magnetic moment of the muon to a precision of 140 parts per billion. This four-fold improvement over the previous Brookhaven E821 measurement provides significant insight into the tantalizing 3.5 standard deviation discrepancy between measurement and the Standard Model prediction
The measurement of the anomalous magnetic moment at the design precision requires measurement of both the spin precession rate and the magnetic field strength, each with a 70 ppb systematic uncertainty, with projected equal statistical and systematic uncertainties of 100 ppb.
This talk will provide an overview and status of the experiment along with the measurement methodology.

Summary:

Section E / **127**

Measurement of the WZ boson pair production cross section at 13 TeV and limits on anomalous triple gauge couplings with the ATLAS detector

Dimitrios Iliadis[1]

[1] *Aristotle Univ. of Thessaloniki (GR)*

The WZ boson pair production at 13 TeV is measured using the ATLAS detector. Leptonic decays of the W and Z bosons to electrons and muons are considered using 2015 and 2016 data. The differential cross-section as a function of jet multiplicity, the Z-boson pT and the transverse mass of the WZ system are also measured along with the charge-dependent W+Z and W-Z cross-sections and their ratio. Finally, the integrated fiducial cross-sections ratio, measured at center-of-mass energies of 13 TeV and 8 TeV, is calculated and limits on anomalous triple gauge couplings are set.

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Section E / **148**

Measurement of the ZZ(*) production cross section in the four lepton channel at 8 TeV and 13 TeV and limits on anomalous triple gauge couplings with the ATLAS detector

Kostas Kordas[1]

[1] *Aristotle Univ. of Thessaloniki (GR)*

Measurements of the cross sections of the production of pairs of electroweak gauge bosons at the LHC constitute stringent tests of the electroweak sector of the Standard Model and provide a model-independent means to search for new physics at the TeV scale.
The ATLAS collaboration has measured inclusive and differential cross sections of the production of ZZ pairs in final states with four charged leptons using data corresponding to 20.3 /fb at a centre-of-mass energy of 8 TeV and data corresponding to 3.2 /fb at a center-of-mass energy of 13 TeV. The studies at 8 TeV are extended to the final state of two charged leptons and two neutrinos, which enhances the acceptance at high transverse momentum. These measurements are compared to calculations at NNLO in pQCD and provide constraints on new physics, by setting limits on anomalous triple gauge couplings.

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Section E / **178**

The b–>s l l anomalies: New physics or hadronic effects?

Lars Hofer[None]

The LHC has found several anomalies in exclusive semileptonic b –> s mu mu decays with a global significance of more than 4 sigma. I will discuss the hadronic uncertainties entering the theoretical prediction for the relevant decays and present model-independent global fits of new physics to the data. The discrimination between high-scale new physics and low-energy QCD effects, as well as the possibility of lepton-flavour universality violation are discussed.

Summary:

Section E / **207**

Studies of the ttH production at 13 TeV by CMS

Predrag Cirkovic[1]

[1] *inca Institute of Nuclear Sciences in Belgrade, Serbia*

In this talk, the latest results of searches for the standard model Higgs boson produced in association with a top quark-antiquark pair (ttH), where Higgs decays into photons, bottom quark-antiquark pair or leptons via WW, ZZ and tautau will be presented. The analyses have been performed using the 13 TeV pp collisions data recorded by the CMS experiment in 2015. The results are presented in the form of the best fit to the signal strength (mu=sigma/sigmaSM) measured with respect to the Standard Model prediction and its expected and observed 95% CL upper limits.

Summary:

Section E / **280**

Higher Order Corrections to Diboson Production and anomalous Triple Gauge Couplings

Author(s): Robin Roth[1]

Co-author(s): Dieter Zeppenfeld [2] ; Francisco Campanario [2] ; Sebastian Piotr Sapeta [3]

[1] *Karlsruher Institute of Technology*

[2] *Karlsruhe Institute of Technology*

[3] *CERN*

We will give an overview about the current state of the calculation of di-boson production. For precision measurements at the LHC both NNLO QCD and NLO EW corrections are important. The Di-boson production processes give access to triple gauge couplings and possible modifications in the form of anomalous couplings (AC). We will present a study on WZ production with AC at approximate NNLO QCD using the LoopSim method in combination with the Monte Carlo program VBFNLO. Higher order corrections to WZ production are dominated by additional hard jet radiation. We will discuss the use of a dynamical veto based on ratios of transverse energies to suppress those without introducing problematic logs like a fixed p_T jet veto.

Summary:

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VBFNLO. Higher order corrections to WZ production are dominated by additional hard jet radiation. We will discuss the use of a dynamical veto based on ratios of transverse energies to suppress those without introducing problematic logs like a fixed p_T jet veto.

Section E / **282**

Hadronic structure corrections to precision tests of Standard Model at low energies

Vladimir Pascalutsa[1]

[1] *University of Mainz*

Current experiments aim at measuring parameters of Standard Model to an unprecedented accuracy, and as a consequence require theoretical calculations of radiative corrections that match that precision. The so-called dispersion corrections, or hadronic box corrections represent one of the main limitations of the reach of modern experiments in determining SM parameters and constraining the New Physics contributions in low-energy experiments. I review the state of the art of the hadronic structure-dependent corrections to the measurement of the charge radii of light nuclei (most importantly, the proton radius puzzle) and the running of the weak mixing angle accessed with parity-violating electron scattering and parity non-conservation in atoms.

Summary:

Section E / **103**

Advances in neutrinoless double beta decay

Ralph Massarczyk[1]

[1] *Los Alamos National Laboratory, MAJORANA collaboration*

Neutrinoless double beta decay searches play a major role in determining properties of neutrinos as well as nuclei. The double-beta decay with neutrinos is one of the rarest process in the world. It has been observed in only a few nuclei so far. The even rarer process of neutrinoless double-beta decay will have a major impact on the current Standard
model. It would show that neutrinos are their own anti-particles and processes with neutrinos can violate the lepton number conservation. Beside this, the half life of these decays is directly connected to the nuclear matrix elements of the participating nuclei. Therefore, neutrinoless double-beta decay searches are an independent probe of nuclear theory beside accelerator based experiments.

This talk will give an introduction about the physics of neutrinoless double beta-decays. The impact of nuclear theory on our understanding of this process and the results will be discussed. An overview on the efforts made by various collaborations all over the world to measure this process will be presented.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics Program of the National Science Foundation, and the Sanford Underground Research Facility. We acknowledge the support of the U.S. Department of Energy through the LANL/LDRD Program.

Summary:

Section E / **199**

Hadronic light-by-light contribution to muon (g-2)

Peter Stoffer[1]

[1] *HISKP, Uni Bonn*

The anomalous magnetic moment of the muon $(g-2)_\mu$ has been measured and computed to very high precision of about 0.5 ppm. For more than a decade, a discrepancy has persisted between experiment and Standard Model prediction, now of about 3σ. The main uncertainty of the theory prediction is due to strong interaction effects. With the expected improvement of the input for hadronic vacuum polarisation, in a few years the subleading hadronic light-by-light (HLbL) contribution will dominate the theory error.

While some constraints from QCD exist, the calculation of the HLbL contribution to the $(g-2)_\mu$ is plagued by a substantial model dependence. In this talk, I will present a dispersive approach to HLbL scattering, based on the fundamental principles of unitarity and analyticity. We have derived a Lorentz decomposition of the HLbL tensor that is fully gauge-invariant and crossing symmetric. The scalar coefficient functions of this tensor decomposition are free of kinematic singularities and zeros and fulfil Mandelstam's double-dispersive representation. The dispersive formalism defines unambiguously and in a model-independent way both the pion-pole and the pion-box contribution. Two-pion rescattering effects are included in a partial-wave picture.

Our dispersive formalism shows a path towards a data-driven determination of the HLbL contribution to the $(g-2)_\mu$.

Summary:

Section E / 270

Quark flavour anomalies of the SM

Marcin Chrzaszcz[1]

[1] *Universitaet Zuerich (CH), Institute of Nuclear Physics (PL)*

Rare electroweak penguin processes provide a rich platform to search for new physics. Some deviations have recently been found between the rate and angular distribution of these processes measured by the LHCb experiment and theoretical predictions. In addition, LHCb has seen hints of lepton universality breaking in these rare processes. This talk will review these measurements and put them in the context of search for new physics.

Summary:

Section E / 271

Matrix elements of quark EDM and quark chromo EDM operators using lattice QCD

Rajan Gupta[1]

[1] *Los Alamos National Lab*

I will provide an overview of various leading contributions to neutron electric dipole moment (EDm) from both the standard model and beyond the standard model and then summarize the status of lattice QCD calculations of the matrix elements of two of the leading novel CP violating interactions – the quark EDM and the quark chromo EDM.

Summary:

Section E / **305**

Qweak: First Direct Measurement of the Proton's Weak Charge

Wade Duvall[1]

[1] *Virginia Tech*

The Qweak experiment, which ran for two and a half years at Jefferson Lab, will precisely determine the weak charge of the proton by measuring the parity-violating asymmetry in elastic e-p scattering at 1.1 GeV using a longitudinally polarized electron beam and a liquid hydrogen target at a low momentum transfer of $Q^2 = 0.025\,(\mathrm{GeV/c})^2$. The weak charge of the proton is predicted by the Standard Model and any significant deviation would indicate physics beyond the Standard Model. The technical challenges and experimental apparatus for measuring the weak charge of the proton will be discussed, as well as the method of extracting the weak charge of the proton. The results from a small subset of the data, that has been published, will also be presented. Furthermore an update will be given of the current status of the data analysis and of several of ancillary experiments performed.

Summary:

Section E / **311**

Recent Progress on Intrinsic Charm

Timothy Hobbs[1]

[1] *University of Washington*

In the previous decade, the topic of the nucleon's nonperturbative or *intrinsic* charm content has enjoyed something of a renaissance, largely motivated by theoretical developments involving quark modelers and PDF-fitters. In this talk I will briefly describe the importance of intrinsic charm to various issues in high-energy phenomenology, and survey recent progress in constraining its overall normalization and contribution to the momentum sum rule of the nucleon. I end with the conclusion that progress on the side of calculation has now placed the onus on experiment to unambiguously resolve the proton's intrinsic charm component.

Summary:

Section E / **328**

Effective field theories for muonic hydrogen

Clara Peset[1]

[1] *UAB/IFAE*

Experimental measurements of muonic hydrogen bound states have recently started to take place and provide a powerful setting in which to study the properties of QCD. We profit of the power of effective field theories (EFTs) to provide a theoretical setting in which to study muonic hydrogen in a model independent fashion. In particular, we compute expressions for the Lamb shift and the hyperfine splitting.

These expressions include the leading logarithmic $\mathcal{O}(m_\mu \alpha^6)$ terms, as well as the leading $\mathcal{O}(m_\mu \alpha^5 \frac{m_\mu^2}{\Lambda_{QCD}^2})$ hadronic effects. Most remarkably, our analyses include the determination of the spin-dependent and spin-independent structure functions of the forward virtual-photon Compton tensor of the proton to $\mathcal{O}(p^3)$, using HBET and including the Delta particle. Using these results we obtain the leading hadronic contributions to the Wilson coefficients of the lepton-proton four fermion operators in NRQED. The spin-independent coefficient yields a pure prediction for the two-photon exchange contribution to the muonic hydrogen Lamb shift, which is the main source of uncertainty in our computation. The spin-dependent coefficient yields the prediction of the hyperfine splitting. The use of EFTs crucially helps us organizing the computation, in such a way that we can clearly address the parametric accuracy of our result. Furthermore, we review in the context of NRQED all the contributions to the energy shift of $\mathcal{O}(m_r \alpha^5)$, as well as those that scale like $m_r \alpha^6 \times$ logarithms.

Summary:

Section E / **222**

Probing QCD perturbation theory at high energies with continuum extrapolated lattice data

Author(s): Stefan Sint[1]

Co-author(s): Alberto Ramos [2] ; Mattia Dalla Brida [3] ; Patrick Fritzsch [4] ; Rainer Sommer [5] ; Tomasz Korzec [6]

[1] *Trinity College Dublin (IE)*

[2] *CERN*

[3] *DESY - Zeuthen*

[4] *IFT, UAM/CSIC, Universidad Autonoma de Madrid*

[5] *NIC@DESY and Humboldt University Berlin*

[6] *University of Wuppertal*

A collaborative effort to determine the Λ-parameter in 3-flavour
QCD by the ALPHA collaboration has just been finalized. This requires the precise
connection of vastly different energy scales, which is achieved using suitable
running couplings in finite volume renormalization schemes and recursive step-scaling methods.
In this talk I focus on the scale evolution from an intermediate scale, $1/L_0$, of
about 4 GeV to scales of O(100) GeV. We use a 1-parameter family
of Schroedinger Functional (SF) couplings which are also very
well-suited for perturbation theory. In particular, their Λ-parameters
can be related exactly and
their respective β-functions are known to 3-loop order.
Our precise continuum extrapolated lattice data allows
for stringent tests of renormalized perturbation theory in the high energy regime.
and leads to a determination of the Λ-parameter (in units of L_0) with
a total error below 3 percent. To quote such a small error with confidence,
non-perturbative data is required around $\alpha_s = 0.1$.
In particular, our study suggests that the apparent precision
reached with data around $\alpha_s = 0.2$ can be misleading.

(cf. talk by M. Dalla Brida for the determination of L_0 in physical units)

Summary:

Section E / **228**

Controlling quark mass determinations non-perturbatively in three-flavour QCD

Author(s): Patrick Fritzsch[1]

Co-author(s): Alberto Ramos Martinez [2] ; Carlos Pena Ruano [3] ; David Preti [1] ; Isabel Campos Plasencia [4] ; Tassos Vladikas [5]

[1] *IFT, UAM-CSIC*

[2] *CERN*

[3] *IFT, UAM-CSIC & Autonoma U., Madrid*

[4] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

[5] *INFN, Rome2 & Rome U., Tor Vergata*

The determination of quark masses from lattice QCD simulations requires a non-perturbative renormalization procedure and subsequent scale evolution to high energies, where a conversion to the commonly used $\overline{\mathrm{MS}}$ scheme can be safely established. We present our results for the non-perturbative running of renormalized quark masses in $N_{\mathrm{f}} = 3$ QCD between the electroweak and a hadronic energy scale, where lattice simulations are at our disposal. Recent theoretical advances in combination with well-established techniques allows to follow the scale evolution to very high statistical accuracy, and full control of systematic effects. We close the presentation with prospects for quark mass determinations in physical units from three-flavour QCD.

Summary:

Section E / **313**

Status update of the lattice determinations of nuclear matrix elements

Martha Constantinou[1]

[1] *Temple University*

In this talk we will review recent progress in hadron structure using lattice QCD simulations, with main focus in the evaluation of nucleon matrix elements. We will highlight developments that may guide New Physics searches, such as the scalar/tensor charges, and neutron electric dipole moment. We will also give updates on a new direct approach to compute quark parton distributions functions on the lattice.

Summary:

Section E / **359**

Chiral effective field theory for dark matter direct detection

Javier Menendez[1]

[1] *University of Tokyo*

We have derived all WIMP-nucleon interactions in chiral EFT to third order in the chiral expansion, including all one- and two-body currents. Because the relevant momentum transfers involved in WIMP scattering off nuclei are of the order of the pion mass, this is a prime regime for chiral EFT.

Combined with large-scale nuclear structure calculations, we have studied spin-dependent WIMP-nucleus scattering for all experimentally relevant isotopes. In addition, we have investigated the signatures of dark matter scattering inelastically off nuclei. If detected, this would point to a spin-dependent nature of dark matter interactions and will enable constraining the WIMP mass in one experiment.

Most recently, we have used chiral EFT to propose analysis strategies for general spin-independent WIMP-nucleus scattering, covering all coherent responses. One of the free parameters in the WIMP-nucleus cross section corresponds to standard spin-independent searches, but in general different combinations of new-physics couplings are probed. We identify the dominant corrections and discuss the general consequences for the interpretation of direct-detection experiments, including minimal extensions of the standard spin-independent analysis.

Summary:

Section E / 361

Searching for Electric Dipole Moments

Peter Fierlinger[1]

[1] *TU München*

Permanent Electric Dipole Moments (EDM) of hadrons and leptons provide a unique probe for physics beyond the Standard Model (SM). As EDMs violate P and T symmetries, they also provide information about the matter-antimatter asymmetry in the universe. Although the SM prediction for EDMs is beyond the reach of current experiments, the experiments set stringent limits on many beyond SM models. In this talk I will present an overview of selected experimental efforts and discuss their roles towards an improved understanding of the underlying physics. A focus will be the neutron EDM search at TU Munich, which is the first already built apparatus in this field, which plans to reach a more than 10-fold improvement. The apparatus is being moved to a new source of ultra-cold neutrons at ILL within the next year and deals with various novelties to improve the understanding of systematic effects, including the smallest magnetic fields on earth and the investigation of non-gaussian statistics in spin precession.

Summary:

Section E / 365

Quark flavour anomalies

Sebastian Jaeger[1]

[1] *University of Sussex*

I review the theory of the search for new physics with rare flavour-changing processes, some of which may indicate departures from the Standard Model, with an emphasis on the Standard-Model predictions and their uncertainties. I will focus on semileptonic B decays, but will also discuss recent developments and prospects in K physics.

Summary:

Section E / 434

Constraining anomalous Higgs couplings at high and low energy

Emanuele Mereghetti[1]

[1] *LANL*

The study of the couplings of the Higgs boson and of the top quark plays a preeminent role at the LHC, and could unveil the first signs of new physics. I will discuss the interplay of direct and indirect probes of certain classes of top and Higgs couplings. Including constraints from collider observables, precision electroweak tests, flavor physics, and electric dipole moments (EDMs), I will show that indirect probes are competitive, if not dominant, for both the CP-even and CP-odd top and Higgs couplings we considered. I will discuss the role of theoretical uncertainties, associated with hadronic and nuclear matrix elements, and indicate targets to further improve the constraining power of EDM experiments.

Summary:

Section F / 19

Dark Matter as the quark nuggets in a colour superconducting phase

Ariel Zhitnitsky[1]

[1] *University of British Columbia*

I advocate a proposal that two of the largest open questions in cosmology, the origin of the matter/antimatter asymmetry and the nature of the dark matter (DM), may have their origin within a single theoretical framework. Furthermore, both effects may originate at the same cosmological epoch from one and the same QCD physics when the θ parameter was not zero. This source of the strong CP violation is not available at present time. I advocate a model in which "baryogenesis" is actually a charge separation process at non-vanishing θ in which the global baryon number of the universe remains zero. In this model the unobserved antibaryons come to comprise the dark matter. I review the observational support for the model (reviewed in 1305.6318 with large number of refs on the original results) and present some new computations supporting the mechanism for the charge separation effect at non-vanishing θ (ongoing work).

Summary:

Section F / 50

The EOS of neutron matter, and the effect of Lambda hyperons to neutron star structure

Stefano Gandolfi[1]

[1] *Los Alamos National Laboratory*

Recent advances in experiments of the symmetry energy of nuclear matter and in neutron star observations yield important new insights on the equation of state of neutron matter at nuclear densities. In this regime the equation of state of neutron matter plays a critical role in determining the mass-radius relationship for neutron stars. We show how microscopic calculations of neutron matter,

based on realistic two- and three-nucleon forces that reproduce very accurately properties of light nuclei, make clear predictions for the relation between the isospin-asymmetry energy of nuclear matter and its density dependence, and the mass and radius for a neutron star.

On the other side, several microscopic calculations suggested that the inclusion of hyperons softens the equation of state such that the corresponding maximum mass of neutron stars is much lower that astrophysical observations. This fact is particularly evident in non-relativistic calculations. We show that small changes in the nucleon-nucleon-Lambda interactions have a dramatic role to the equation of state, while Lambda binding energies in hypernuclei are qualitatively insensitive to the same adjustments. These results suggest that current experimental constraints are perhaps not sufficient to find a solution to the so called 'hyperon puzzle'.

Summary:

Section F / 69

Experimental results from single and multinucleonic K- absorptions with the KLOE Drift Chamber

Oton Vazquez Doce[1]

[1] *Technische Universitaet Muenchen (DE)*

The in-medium modification of hadron properties is the main field of study for the strangeness sector in the non-perturbative low-energy region of QCD.
The behaviour of strange hadrons at extreme densities are of capital importance for the description of the nuclear equation of state and the evaluation of the strangeness component in the core of the neutron stars.

The study of hyperon-nucleon(s) and hyperon-pion correlations following K^- nuclear absorption in ^{4}He and ^{12}C were investigated with the KLOE drift chamber and the results will be presented. To this end, KLOE 1 data (from 2004-2005-2012) was analyzed using the detector itself as an active target.

The Σ^0p final state has been analyzed exclusively for the first time 2.
The results include yield per stopped kaon for the simplest two nucleon "quasi-free" absorption, ratios for the two-nucleon vs three-nucleon process, and a systematic search for a ppK^- bound state.
The existence of such objects, whose experimental detection has been claimed several times recently, also in absorption experiments, would open the possibility for the formation of very dense baryonic matter implying a deep attractive value for the antikaon-nucleon potential.

The analysis of the $\Lambda(\Sigma^0)\pi$ channel from absorptions in ^{4}He will be presented as well.
The data have been interpreted within a theoretical phenomenological model which allows to quantify the role played by the resonant $\Sigma(1385)$ formation, allowing to extract the module of the non-resonant $K^-n \to \Lambda\pi$ amplitude (~ 33 MeV/c^2 below threshold).

1 F. Bossi et al. Riv. Nuovo Cimento 31 (2008) 10.

2 O. Vazquez Doce et al., Physics Letters B 758 (2016) 134.

Summary:

Section F / 73

Chiral transport of neutrinos in supernovae

Naoki Yamamoto[1]

[1] *Keio University*

Chirality of neutrinos modifies the conventional hydrodynamic behavior at the macroscopic scale and leads to anomalous transport phenomena in neutrino matter. We argue that such chiral transport of neutrinos should play important roles in the evolution of core-collapse supernovae, and, in particular, leads to the possible inverse energy cascade from small to large scales, which may be relevant to the origin of the supernova explosion.

Summary:

Section F / 95

Investigation of the low-energy kaons hadronic interactions in light nuclei by AMADEUS

Kristian Piscicchia[1]

[1] *INFN - National Institute for Nuclear Physics*

The AMADEUS experiment deals with the investigation of the low-energy kaon-nuclei hadronic interaction at the DAΦNE collider at LNF-INFN, which is fundamental to solve longstanding questions in the non-perturbative strangeness QCD sector. AMADEUS step 0 consisted in the reanalysis of 2004/2005 KLOE data, exploiting K^- absorptions in H, ^{4}He, ^{9}Be and ^{12}C, leading to the first invariant mass spectroscopy study with very low momentum (100MeV) in-flight K^- captures. With AMADEUS step 1 a dedicated pure Carbon target was implemented in the central region of the KLOE detector, providing a high statistic sample of pure at-rest K^- nuclear interaction.

The results obtained in the analyses of the hyperon-pion correlated events, searching for the resonant shapes of Y* states, and the analyses of hyperon-proton, deuteron, and triton correlations, searching for possible K^--multi nucleon bound states, will be presented.

Summary:

Section F / 109

The scenario of two families of compact stars

Author(s): Giuseppe Pagliara[None]

Co-author(s): Alessandro Drago ; Andrea Lavagno [1]

[1] *Politecnico di Torino, Italy*

We propose an astrophysical scenario in which hadronic stars and quark stars coexist. While hadronic stars would populate a branch of very compact objects (radii measurements indicate the existence of such configurations in some cases), quark stars would instead populate a branch of very massive stars (e.g. the two solar mass star PSR J1614-2230). The conversion process between a hadronic star and a quark star will be discussed in its turbulent and diffusive regimes and its phenomenological consequences for long and short gamma-ray-bursts will be also presented in connection with the protomagnetar model.

Based on:
Phys.Rev. D89 (2014) no.4, 043014
Phys.Rev. C92 (2015) no.4, 045801
Eur.Phys.J. A52 (2016) no.2, 40
Eur.Phys.J. A52 (2016) no.2, 41
Phys.Rev. D93 (2016) no.10, 103001

Summary:

Section F / 110

Fluxtubes in a proton superconductor coupled to a neutron superfluid

Alexander Haber[1]

[1] *Vienna University of Technology*

In compact stars, nucleons form an interacting multi-fluid system of a neutron superfluid and a proton superconductor. The rotation of the star and the strong background magnetic fields generate superfluid vortices and superconducting flux tubes in the core. Using a field-theoretical model of two coupled bosonic fields with entrainment and density coupling, the phase structure of the system is examined. Especially the superconducting type-I/type-II transition and possible multi fluxquantum phases under the influence of the neutron condensate is investigated, including an effective interaction between the flux tubes.

Summary:

Section F / 130

HADES experiment probing baryonic matter at SIS18 : overview of results

Piotr Salabura[1]

[1] *IFUJ*

HADES at SIS18 is currently the only experiment studying properties of strongly interacting matter by means of rare and penetrating probes using proton and heavy ion beams in a few AGeV energy range. The study of system size dependence has been recently completed with Au+Au collisions at 1.23 AGeV. The measurements provide a results on kaons, strange resonances, including the first at such low energies data on double strange Ksi(1321), and on low mass dielectrons. The particle production have been measured over large range of rapidities and transverse momenta allowing for extrapolation to full solid angle and for comparisons to thermal , statistical hadronization models and transport models. The results, in particular an unexpected large ratio of K-/phi and the cascade, will be presented and discussed. The results on dielectron production points clearly to a significant contribution of thermal emission from hot a dense phase of the collision. Characteristic features of the radiation will be presented and compared to those obtained and higher energies (RHIC/SPS).

Summary:

Section F / 155

Superfluid vortices in dense quark matter

Author(s): Andreas Windisch[1]

Co-author(s): Mark Alford [2] ; S. Kumar Mallavarapu [1] ; Tanmay Vachaspati [3]

[1] *Washington University in St Louis*

[2] *Washington University, St Louis*

[3] *Arizona State University*

None

Summary:

Superfluid vortices in the color-flavor-locked (CFL) phase of dense quark matter are known to be energetically disfavored relative to well-separated triplets of so-called semi-superfluid color flux tubes. In this talk we will present results from our numerical stability analysis of superfluid vortices in dense quark matter. We identify (physical) regions of metastability/instability in the parameter space of the couplings of our effective theory. Furthermore, we discuss the structure of the unstable mode responsible for the decay in the case of vanishing gauge coupling. If a neutron star features a superfluid quark matter core, our analysis indicates that it is very likely that it would contain semi-superfluid vortices rather than superfluid vortices. We will point out possible implications of our results to neutron stars.

Section F / 189

The symmetry energy at suprasaturation density and the ASY-EOS experiment at GSI:

Enrico De Filippo[1] ; Paolo Russotto[2]

[1] *INFN-Sezione di Catania*

[2] *INFN - National Institute for Nuclear Physics*

The Symmetry Energy is a fundamental ingredient of the nuclear matter Equation Of State.
The elliptic-flow ratio of neutrons with respect to protons or light complex particles in reactions of heavy-ions at pre-relativistic energies has been proposed as an observable sensitive to the strength of the Symmetry Energy at supra-saturation densities.
The results obtained from the existing FOPI/LAND data for Au+Au collisions at 400 MeV/nucleon in comparison with the UrQMD model indicate a moderately soft symmetry energy but suffer from a considerable statistical uncertainty 1; these results were confirmed by an independent analysis based on Tubingen QMD 2.
A new experiment, carried out at the GSI laboratory by the ASY-EOS collaboration 3, has given a more stringent constraint for the nuclear symmetry energy at supra-saturation densities. Moreover, future plans for extending these studies at higher densities, also by using Radioactive Ion Beams, will be discussed.
Talk presented on behalf of the AYS-EOS and NewCHIM collaborations
1 P. Russotto et al., Phys. Lett. B 697 (2011) 471.‘
2 M.D. Cozma, Phys. Lett. B 700, 139 (2011); M.D. Cozma et al., Phys. Rev. C 88, 044912 (2013).
3 P. Russotto et al., Eur. Phy. J A 50, 38 (2014); P. Russotto et al., submitted to Phys. Rev. C (2016).

Summary:

Section F / 210

Internal Constitution and Equation of State of Neutron-Star Crusts Within the Nuclear Energy Density Functional Theory

Author(s): Nicolas Chamel[1]

Co-author(s): Anthea Fantina [2] ; John Michael Pearson [3] ; Stéphane Goriely [1]

[1] *Université Libre de Bruxelles*

[2] *GANIL*

[3] *Université de Montréal*

The crust of a neutron star has a profound influence on various observed astrophysical phenomena such as pulsar sudden spin-ups, quasi-periodic oscillations in the giant flares from soft gamma-ray repeaters, X-ray bursts and superbursts, or the cooling of transiently accreting neutron stars. We have determined the internal constitution and the equation of state of neutron-star crusts in the framework of the nuclear energy density functional theory. Results using recent versions of the accurately calibrated Brussels-Montreal functionals based on generalized Skyrme effective interactions will be presented. The role of the stiffness of the neutron-matter equation of state, of the symmetry energy, of pairing, and of the spin-orbit coupling on the structure of neutron-star crusts will be discussed.

Summary:

Section F / **242**

The Falsification of Chiral Nuclear Forces

Enrique Ruiz Arriola[1]

[1] *Universidad de Granada*

This work is based on

1) Low energy chiral two pion exchange potential with statistical uncertainties
By R. Navarro Pérez, J.E. Amaro, E. Ruiz Arriola.
arXiv:1411.1212 [nucl-th].
10.1103/PhysRevC.91.054002.
Phys.Rev. C91 (2015) no.5, 054002.

2) Partial Wave Analysis of Chiral NN Interactions
By R. Navarro Perez, J.E. Amaro, E. Ruiz Arriola.
arXiv:1310.8167 [nucl-th].
10.1007/s00601-014-0817-3.
Few Body Syst. 55 (2014) 983-987.

3) Coarse grained NN potential with Chiral Two Pion Exchange
By R. Navarro Pérez, J.E. Amaro, E. Ruiz Arriola.
arXiv:1310.6972 [nucl-th].
10.1103/PhysRevC.89.024004.
Phys.Rev. C89 (2014) no.2, 024004.

4) Nucleon-Nucleon Chiral Two Pion Exchange potential vs Coarse grained interactions
By Rodrigo Navarro Perez, J.E. Amaro, E. Ruiz Arriola.
arXiv:1301.6949 [nucl-th].
PoS CD12 (2013) 104.

Summary:

Chiral forces are QCD based interactions which are expected to describe consistently
and systematically nuclear dynamics. We discuss some loose ends regarding their behavior
at very low energies and large distances and the possibility to validate them with the many available data.

Section F / **257**

From Nuclei to Neutron-Stars: Short-Range Fermion Correlations

Or Hen[1]

[1] *Massachusetts Institute of Technology*

The recent observation by the LIGO collaboration of black hole merges using gravitation waves opens a new portal to study our universe. The sensitivity of gravitation waves measurements is likely to be extended in the coming future to allow the detection and study of neutron stars merges. Such merges are thought to be the main source for r-process nuclear synthesis and can potentially act as a laboratory for testing high-field gravity models. As the structure of neutron stars is a delicate balance between the gravitational and nuclear forces, taking full advantage of the advanced astrophysical capability requires parallel development of our understanding of the properties of dense, cold, nuclear matter.

In this talk I will present the study of nucleon-nucleon short-range correlations in nuclei: high-density fluctuations of nuclear matter. I will show how electron- and proton-induced two-nucleon hard-knockout reactions allow us to study these objects, probing properties of nuclear matter at supranuclear densities, and discuss their implications for various fields of physics.

Summary:

Section F / 285

Quark matter Equation of State from perturbation theory

Aleksi Vuorinen[None]

I will discuss recent advances in the perturbative description of the thermodynamic properties of cold unpaired quark matter. After presenting new results for the temperature dependence of the Equation of State (EoS), I will describe recent advances in determining the next four-loop term in the weak coupling expansion of the zero-temperature EoS. The potential implications of these results to neutron star phenomenology will be discussed in detail.

Summary:

I will discuss recent advances in the perturbative description of the thermodynamic properties of cold unpaired quark matter. After presenting new results for the temperature dependence of the Equation of State (EoS), I will describe recent advances in determining the next four-loop term in the weak coupling expansion of the zero-temperature EoS. The potential implications of these results to neutron star phenomenology will be discussed in detail.

Section F / 350

Effects of Induced Surface Tension in Nuclear and Hadron Matter

Author(s): Violetta Sagun[1]

Co-author(s): Dmytro Oliinychenko [2] ; Igor Mishustin [3] ; Kyrylo Bugaiev [4] ; Oleksii Ivanytskyi [4]

[1] *Bogolyubov Institute for Theoretical Physics*

[2] *CERN*

[3] *Goethe University*

[4] *National Academy of Sciences of Ukraine (UA)*

Short range particle repulsion is rather important property of the hadronic and nuclear matter equations of state. I present a novel equation of state which is based on the virial expansion for the multicomponent mixtures with hard core repulsion.
The suggested equation of state explicitly contains the surface tension which is induced by particle interaction. At high densities such a surface tension vanishes and in this way it switches the excluded volume treatment of hard core repulsion to its proper volume treatment. I discuss possible applications of this equation of state to a description of hadronic multiplicities measured in A+A collisions, to an investigation of the nuclear matter phase diagram properties and to the neutron star interior modeling.

Summary:

Section F / **442**

Dense nuclear and quark matter in holographic QCD

Andreas Schmitt[1]

[1] *University of Southampton*

Dense matter in the core of neutron stars is strongly coupled and presents an enormous theoretical challenge. First-principle methods from QCD are currently known only for vanishing or asymptotically large densities, while phenomenological models are usually restricted to either nuclear or quark matter and/or contain many unknown parameters. I will discuss whether and how holographic methods can help. In particular, I will present latest work on nuclear matter and the chiral phase transition to quark matter in the Sakai-Sugimoto model, potentially leading to a strongly coupled equation of state with only 3 parameters that is applicable over a wide density regime.

Summary:

Section G / **321**

Strong dynamics on the lattice

Author(s): Daniel Nogradi[None]

Co-author(s): Chik Him Wong [1] ; Julius Kuti [2] ; Kieran Holland [3] ; Zoltan Fodor [4]

[1] *Wuppertal*

[2] *UCSD*

[3] *UofP*

[4] *BUW*

I will present recent progress on the lattice investigation of a nearly conformal gauge theory, SU(3) with 2 flavors of sextet fermions, that may realize a composite Higgs impostor scenario.

Summary:

Section G / **26**

CANCELLED: The anomalous transport of axial charge in QGP, induced by topological fluctuations.

Ioannis Iatrakis[1]

[1] *Utrecht University*

Axial charge imbalance is an essential ingredient in novel effects related to the chiral anomaly like the chiral magnetic effect. In non-Abelian plasma with chiral fermions, local axial charge can be generated either by topological fluctuations of the medium or by usual thermal fluctuations. We show how local topological domains in the Quark Gluon Plasma lead to the dynamical generation of an axial flavor current. The current is explicitly calculated in the context of holography and it's phenomenological importance in Heavy-Ion collisions is discussed. The transport of dynamically generated axial charge density is then presented, and the corresponding chiral magnetic current is computed.

Summary:

Section G / 48

Strongly interacting EWSBS resonances in the diphoton channel

Antonio Dobado[1] ; Felipe J. Llanes-Estrada[1] ; Rafael Delgado[1]

[1] *Universidad Complutense de Madrid (UCM)*

We present the inelastic scattering between $\gamma\gamma$ into/out of a strongly interacting EWSBS satisfying unitarity. The matrix elements $V_LV_L \to V_LV_L$, $V_LV_L \to hh$, $hh \to hh$, $V_LV_L \to \gamma\gamma$ and $hh \to \gamma\gamma$ are al computed to NLO in perturbation theory with the Nonlinear Effective Theory of the EWSBS (within the Equivalence Theorem).
Describing the EWSBS itself requires seven parameters: two LO parameters (a, b) and the NLO counterterms (a_4, a_5, g, d, e). The coupling with the $\gamma\gamma$ state requires four additional ones:
$c_{\gamma\gamma}$ and $a1$, $a2$, $a3$, though in the combination $a_1 - a_2 + a_3$ only, so the number of total coefficients is 9.

By means of a modified version of the IAM and N/D unitarization procedures, we study the prospects for detecting any new strong-EWSBS resonances in the energy range 0.75-3TeV, within reach of the LHC. Our basic assumption is that the couplings with $\gamma\gamma$ are feeble as they are governed by the electromagnetic $\alpha_{\rm ew}$, while the EWSBS is strongly interacting.

There are two cases of interest. First, the detection of resonances in the diphoton channel coming from the strong rescattering of V_LV_L states (photons in the final state). And second, the possible study of $\gamma\gamma$ scattering at the LHC by means of the new forward detectors (CMS-TOTEM and ATLAS-AFP) that tag the elastically scattered proton (photons in the initial state). Of course, this would be also a goal for the ILC and its future detectors.

Summary:

Section G / 80

Strongly-interacting mirror fermions at the LHC

George Triantaphyllou[1]

[1] *National Technical University of Athens*

Talk based on paper by
G. Triantaphyllou, EJTP 13, No. 35 (2016) 115–144

http://www.ejtp.com/articles/ejtpv13i35p115.pdf

Summary:

The existence of mirror partners (katoptrons) of Standard-Model fermions offers a viable alternative to a fundamental BEH mechanism, with the coupling corresponding to the mirror generation gauge symmetry becoming strong at around 1 TeV. The resulting non-perturbative processes produce dynamical katoptron masses on the order of 0.14 - 1.2 TeV. Moreover, they create mirror mesons with masses ranging approximately from 0.1 to 3 TeV. Since the corresponding phenomenology expected at the LHC is particularly rich, we explore some detection methods of mirror mesons that could lead to a deeper understanding of the underlying mirror fermion structure.

Section G / **105**

Inverse magnetic catalysis in holographic models of QCD

Kiminad Mamo[1]

[1] *University of Illinois at Chicago*

We study the effect of magnetic field B on the critical temperature T_c of the confinement-deconfinement phase transition in hard-wall AdS/QCD, and holographic duals of flavored and unflavored $\mathcal{N} = 4$ super-Yang Mills theories on $\mathbb{R}^3 \times \mathrm{S}^1$. For all of the holographic models, we find that $T_c(B)$ decreases with increasing magnetic field $B \ll T^2$, consistent with the \textit{inverse magnetic catalysis} recently observed in lattice QCD for B
$lesssim 1\ GeV^2$. We also predict that, for large magnetic field $B \gg T^2$, the critical temperature $T_c(B)$, eventually, starts to increase with increasing magnetic field $B \gg T^2$ and asymptotes to a constant value.

Summary:

Section G / **201**

Infrared behaviors of two color gauge theory

Kimmo Tuominen[1]

[1] *University of Helsinki*

I will review some of the recent progress in determining the infrared behavior of two color gauge theory with fermions in fundamental or adjoint representation of the gauge group. Particular focus will be given to the theory with six Dirac fermions in the fundamental reptesentation.

Summary:

Section G / **209**

Composite Higgs Dynamics on the Lattice

Author(s): Claudio Pica[1]

Co-author(s): Martin Hansen [2] ; Vincent Drach [3] ; francesco Sannino [2]

[1] *University of Southern Denmark*

[2] *CP3-Origins*

[3] *CERN*

We investigate the spectrum of the SU(2) gauge theory with Nf = 2 flavors of fermions in the fundamental representation, in the continuum, using Lattice simulations.

This model provides a minimal template which has been used for different strongly coupled extensions of the Standard Model ranging from composite (Goldstone) Higgs models to intriguing types of dark matter candidates, such as the SIMPs.
Here we will focus on the composite Goldstone Higgs paradigm, for which this model provides a minimal UV complete realization in terms of a new strong sector with fermionic matter.

After introducing the relevant Lattice methods used in our simulations, we will discuss our numerical results.
We show that this model features a SU(4)/Sp(4) ~ SO(6)/SO(5) flavor symmetry breaking pattern, as expected, and estimate the value of its chiral condensate.
Finally, we present our results for the mass spectrum of the lightest spin one and zero resonances, analogue to the QCD ρ, a_1, σ, η', a_0 resonances, which are relevant for searches of new, exotic resonances at the LHC.

Summary:

Section G / 220

Integrating out resonances in strongly-coupled electroweak scenarios

Author(s): Ignasi Rosell[1]

Co-author(s): Antonio Pich [2] ; Joaquin Santos [2] ; Juan Jose Sanz-Cillero [3]

[1] *Universidad CEU Cardenal Herrera & IFIC, Valencia*

[2] *University of Valencia*

[3] *Universidad Autonoma de Madrid*

Accepting that there is a mass gap above the electroweak scale, electroweak effective theory (EWET) is an appropriate tool to describe this sector, where only the Standard Model fields are taken into account. Since the EWET couplings contain information on the unknown high-energy dynamics, we consider a generic strongly-coupled scenario of electroweak symmetry breaking, where the known particle fields are coupled to heavier states. Then, and by integrating out these heavy fields, we study the tracks of the lightest resonances into the couplings. The determination of the low-energy couplings in terms of resonance parameters can be improved by assuming a short-distance behavior of the underlying theory. Notice that we adopt a generic non-linear realization of the electroweak symmetry breaking with a singlet Higgs.

Summary:

Section G / 264

Sum-rule constraints on possible (750 GeV?) diphoton resonances at the LHC

Author(s): Juan José Sanz-Cillero[1]

Co-author(s): Pablo Roig Garcés

[1] *Instituto de Física Teórica UAM-CSIC*

By means of forward sum-rules for γγ and gg scattering we show that a spin-0 resonance with mass of the order of the TeV and a sizable γγ or gg partial width -of the order of a few GeV- must be accompanied by higher spin resonances with JR≥2 with similar properties, as expected in strongly coupled extensions of the Standard Model or, alternatively, in higher dimensional deconstructed duals. Furthermore, independently of whether the 750 GeV diphoton candidate is a scalar or a tensor, the large contribution to the forward sum-rules in the referred scenario implies the presence of states in the spectrum with JR≥2, being these high spin particles a manifestation of new extra-dimensions or composite states of a new strong sector.

Summary:

Section G / **269**

Euler anomaly from central charge flow in N=1 gauge theories and beyond

Roman Zwicky[1]

[1] *edinburgh university*

It is based on https://arxiv.org/abs/1511.03868 as well as work which should appear soon.

Summary:

I will discuss how the RG-running of the gauge coupling can be absorbed into the metric
for N=1 gauge theories by using the Konishi anomaly. The central charge between the
UV and IR fixed point is then computed, using the construction of Komargodski and Schwimmer, within a free field theory. The non-trivial dynamics emerges from expanding the geometric quantities such as the Euler term confirming an earlier result in the literature. I will discuss how to make use of these techniques in non-supersymmetric gauge theories aka QCD-like gauge theories.

Section G / **276**

Theta angle in holographic QCD

Matti Jarvinen[1]

[1] *Ecole Normale Superieure, Paris*

I will start by an introduction to holographic QCD, concentrating on bottom-up models where the backreaction of quarks to gluon dynamics is fully included (V-QCD models). The physics of theta angle and axial anomaly can be consistently included in such models. At small quark mass the models agree with effective field theory. I show how the Gell-Mann-Oakes-Renner relation for the mass of the pion and the Witten-Veneziano relation for the mass of the eta prime meson arise.

Summary:

Section G / **314**

Consistent Perturbative Fixed Point Calculations in QCD and supersymmetric QCD

Thomas Ryttov[1]

[1] *CP3 - Origins*

In order to obtain a better understanding of QCD as well as possible strongly coupled extensions of the Standard Model it is important that we reliably can calculate anomalous dimensions of certain composite operators at fixed points. We show how to consistently calculate the mass anomalous dimension order by order in perturbation theory in a scheme independent manner. We compare our calculation to exact known results in supersymmetric QCD and find that they can astonishingly well be approximated by a few loops computation. We then calculate the mass anomalous dimension in QCD and discuss its implications for building realistic models of beyond the Standard Model.

Summary:

We study the physics of QCD and supersymmetric QCD at an infrared fixed point.

Section G / 377

Axion cosmology from lattice QCD

Author(s): Sandor Katz[1]

Co-author(s): Andreas Ringwald [2] ; Ferenc Pittler [3] ; Szabolcs Borsanyi [4] ; Tamas G. Kovacs [5] ; Zoltan Fodor [6]

[1] *Eotvos University*

[2] *Deutsches Elektronen-Synchrotron DESY*

[3] *PTE*

[4] *University of Wuppertal*

[5] *Institute for Nuclear Physics, Debrecen*

[6] *BUW*

The strong CP problem of QCD can be solved via the Peccei-Quinn mechanism. The resulting pseudo-Goldstone bosons, the axions are natural candidates for dark matter. In order to quantitatively understand axion dark matter production two important QCD inputs are required: the equation of state and the topological susceptibility at high temperatures. We determine these quantities and use them to determine the axion mass in different axion production scenarios.

Summary:

We determine the equation of state and the topological susceptibility
at high temperatures using lattice QCD and apply them to determine the axion mass in different axion dark matter scenarios.

Section G / 366

”Crossover between local and non-local scaling regimes in turbulent compressible fluid: Renormalization group analysis

Nikolay Gulitskiy[1]

[1] *Saint Petersburg State University*

We study scaling properties of the model of fully developed turbulence of a compressible fluid, based on the stochastic Navier-Stokes equation, by means of the field theoretic renormalization group (RG). This model was already considered earlier in [N.V. Antonov, M.Yu. Nalimov, and A.A. Udalov, Theor. Math. Phys., Vol. 110, No. 3, 1997]. The scaling properties in that approach are related to fixed points of the RG equation. Here we study the possibility of existence of other scaling modes and the opportunity of crossover between them. This may take place in some other space dimensions, particularly in $d = 4$. The new mode can arise there and then by continuity move into $d = 3$. Our calculations have shown that there really exists an additional fixed point, that may govern scaling behaviour.
Advection of passive scalar fields is also considered.

Summary:

Section G / **389**

Constraining effective actions via scattering amplitudes

Andrea Guerrieri[1]

[1] *INFN and University of Roma Tor Vergata*

The requirement of having a consistent S-matrix can impose highly non-trivial constraints on effective field theories. In particular, we show how supersymmetry constrains the effective action of N=4 SYM in the Coulomb branch and we introduce new constraints coming from breaking conformal symmetry in the form of soft theorems. Finally, we also discuss the interplay between scale and conformal invariance in the context of scattering amplitudes.

Summary:

Section G / **462**

On a strong coupling property of QCD

Thierry Grandou[1]

[1] *UMR-CNRS-7335, INLN, France*

The fermonic Green's functions of QCD exhibit an unexpected property of 'effective locality', which is exact. In the strong coupling limit, at quenching and eikonal approximations, effective locality implies a dependence of non-perturbative fermonic Green's functions on both C_{2f} and C_{3f} Casimir operators, that is, on the full algebraic content of the $SU(3)$ rank-2 color algebra. This result seems to extend beyond the approximations being used.

Summary:

Special Section Future Perspectives, Upgrades, Instrumentation / **215**

Future perspectives of baryon electromagnetic structure with BES III

Author(s): Stina Karin Schoenning[1]

Co-author(s): Cui Li [2]

[1] *Uppsala University (SE)*

[2] *Dept. of Physics and Astronomy, Uppsala University*

One of the most challenging questions in contemporary physics is why and how quarks are confined into hadrons. The electromagnetic structure of hadrons, parameterised in terms of electromagnetic form factors, EMFF's, can provide a key.
The focus of this talk is baryon EMFF's. EMFF's have been a powerful tool in understanding the structure of nucleons for more than 60 years but the new techniques and larger samples available at modern facilities have given rise to a renewed interest for the field. Recently, the access to hyperon structure by hyperon time-like EMFF provides an additional dimension.
The BEijing Spectrometer (BES III) at the Beijing Electron Positron Collider (BEPC-II) in China is the only running experiment where time-like baryon EMFF's can be studied in $e^+e^- \to B\overline{B}$. The BES III detector is an excellent tool for baryon form factor measurements thanks to its near 4π coverage, precise tracking, PID and calorimetry. All hyperons in the SU(3) spin ½ octet and spin 3/2 decuplet are energetically accessible within the BEPC-II energy range.
Recent data on proton and Λ hyperon form factors will be presented. Furthermore, a world-leading data sample was collected in 2014-2015 for precision measurements of baryon form factors. In particular, the large data sample will enable a measurement of the relative phase between the electric and the magnetic form factors for Λ hyperons. The modulus of the phase can be extracted from the Λ polarisation, which in turn is experimentally accessible via the weak, parity violating $\Lambda \to p\pi^-$ decay. Furthermore, from the spin correlation between the outgoing Λ and $\overline{\Lambda}$, the sign of the phase can be extracted. The methods will be outlined and the prospects of the BES III form factor measurements will be given. In particular, I will discuss how future hyperon EMFF measurements will benefit from a planned upgrade of the BES III detector.

Summary:

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Upgrade of the ALICE Inner Tracking System

Pasquale Di Nezza[1]

[1] *Istituto Nazionale Fisica Nucleare Frascati (IT)*

ALICE (A Large Ion Collider Experiment) is studying the physics of strongly interacting matter, and in particular the properties of the Quark-Gluon Plasma (QGP), using proton-proton, proton-nucleus and nucleus-nucleus collisions at the CERN LHC (Large Hadron Collider). The ALICE Collaboration is preparing a major upgrade of the experimental apparatus, planned for installation in the second long LHC shutdown in the years 2019-2020. A key element of the ALICE upgrade is the construction of a new, ultra-light, high-resolution Inner Tracking System (ITS). With respect to the current detector, the new ITS will significantly enhance the determination of the distance of closest approach to the primary vertex, the tracking efficiency at low transverse momenta, and the read-out rate capabilities. This will be obtained by seven concentric detector layers based on a Si (50 μm thick) CMOS pixel sensor with a pixel size of about 30x30 mu^2. A key feature of the new ITS, which is optimized for high tracking accuracy at low transverse momenta, is the very low mass of the three innermost layers, which feature a material thickness of 0.3% X0 per layer. This contribution presents the design goals and layout of the new ALICE ITS, with focus on the technical implementation of the main detector components, and the projected detector and physics performance.

Summary:

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Vertex detector for open charm measurements with NA61/SHINE at SPS at CERN

Grigori Feofilov[1]

[1] *St. Petersburg State University (RU)*

Report at the Session: Future Perspectives, Upgrades, Instrumentation

Vertex detector for open charm measurements with NA61/SHINE at SPS at CERN

G.A.Feofilov [1†] (for NA61/SHINE Collaboration)

(1) Saint-Petersburg State University
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Search for the critical point of strongly interacting matter and studies of the onset of deconfinement are in the focus of the current NA61/SHINE experimental programme. The last one is being conducted by means of investigation of fluctuations and system size dependences of various observables in hadron collisions energy scan at the SPS at CERN. Quite new and enhanced physics capabilities are opening after completion of the ongoing modernization of the NA61 / SHINE installation, when the total rate of statistics will be increased more than 10 times, thus allowing the study of open charm in Pb-Pb collisions at the SPS energies. It is expected that studies of rare processes of heavy flavors production (first of all, of particles containing charm quarks) and their interaction with the medium produced in such collisions - will allow us to get new information about the physical processes in the area of the hypothethical critical point of nuclear matter. These studies could help also to discriminate existing theoretical models relevant to the initial stages of hadron collisions, evolution of quark-gluon plasma, matter induced changes in the yields of quarkonia, energy loss mechanisms, ...etc.

In this report we present a physics motivation followed by the brief status of the ongoing development of the dedicated Vertex Detector (VD) designed for open charm measurements in Pb-Pb collisions with the NA61/SHINE at CERN SPS. The task is quite challenging in view of very low yields at the threshold region of open charm production. It is being solved for the NA61/SHINE by the application of the coordinate sensitive Si-sensor chips in CMOS technology for the high precision tracking to the to the vertices of hadronic decays. This precise tracking is done by a set of four Si-sensor planes in combination with the particle identification by the NA61/SHINE TPSs. The extremely low material budget of the VD (below 0.3 % X/Xo for each tracking plane) is achieved by the implementation of proven ALICE technologies of the extra-lightweight thermo- and mechanically stable structures for Si-detectors cooling and support. After completion of the VD, due to its high spatial tracking resolution and low multiple scattering contributin, it will be possible to apply geometrical selections and to separate the D-mesons decay vertex from the interaction one.

The author of this report acknowledges the support by the Russian Science Foundation research grant 16-12-10176.

Summary:

Report at the Session: Future Perspectives, Upgrades, Instrumentation

Vertex detector for open charm measurements with NA61/SHINE at SPS at CERN

G.A.Feofilov [1†] (for NA61/SHINE Collaboration)

(1) Saint-Petersburg State University
† E-mail: feofilov@hiex.phys.spbu.ru

In this report we present a physics motivation followed by the brief status of the ongoing development of the dedicated Vertex Detector (VD) designed for open charm measurements in Pb-Pb collisions with the NA61/SHINE at CERN SPS. The task is quite challenging in view of very low yields at the threshold region of open charm production. It is being solved for the NA61/SHINE by the application of the coordinate sensitive Si-sensor chips in CMOS technology for the high precision tracking to the to the vertices of hadronic decays. This precise tracking is done by a set of four Si-sensor planes in combination with the particle identification by the NA61/SHINE TPSs. The extremely low material budget of the VD (below 0.3 % X/Xo for each tracking plane) is achieved by the implementation of proven ALICE technologies of the extra-lightweight thermo- and mechanically stable structures for Si-detectors cooling and support. After completion of the VD, due to its high spatial tracking resolution and low

multiple scattering contribution, it will be possible to apply geometrical selections and to separate the D-mesons decay vertex from the interaction one.

The author of this report acknowledges the support by the Russian Science Foundation research grant 16-12-10176.

Special Section Future Perspectives, Upgrades, Instrumentation / **338**

MFT : a novel Muon Forward Detector for the ALICE upgrade

Stefano Panebianco[1]

[1] *CEA/IRFU,Centre d'etude de Saclay Gif-sur-Yvette (FR)*

ALICE is the only LHC experiment specifically devoted to the study of ultra-relativistic heavy ion collisions. Its main goal is to identify and study a new state of matter, le Quark Gluon Plasma (QGP), where quarks and gluons are deconfined, which might have existed during the first instants of the Universe. One of the most powerful signatures for QGP study is the suppression, within this hot and deconfined medium, of heavy resonances as J/psi et Upsilon. These resonances are measured in ALICE by their di-muon decay thanks to a forward spectrometer.
The muon spectrometer performances are constrained by the presence of a thick absorber, meant to stop most of the hadrons (essentially pions and kaons) before their muonic decay, thus reducing the large noise generated by their decay products. However, the presence of this absorber limits the precision of the measurement of interesting muon properties because of energy loss and multiscattering effects. This implies some limitations on the broadness of the physics results that are actually accessible. For example, only the inclusive production of J/psi can be studied and there is no room to distinguish the J/psi coming from the decay of B mesons. In order to improve the present performances of the di-muon spectrometer and thus enlarge the set of observables that ALICE can measure, a major upgrade project, called Muon Forward Tracker (MFT), is under development. The MFT will consist in a telescope of silicon-pixel detectors placed in front of the absorber, which will allow precise backtracking and vertexing from the present spectrometer. This will largely improve the energy resolution in reconstructing the heavy resonances.

The MFT is based on CMOS technology silicon pixels, assembled in Hybrid Integrated Circuits (HIC) that will equip 5 concentric disks around the beam pipe. The main detection element of these circuits is the ALPIDE chip, developed in collaboration with the ALICE-ITS detector. The chip qualification and performance studies are in their final phase before proceeding to the full production of the finalized chip. In parallel, a study and characterization campaign of the HIC, consisting of several chips connected to the final readout system developed for the MFT, is presently ongoing. This fundamental step of the project will lead to the full qualification of the base element of the MFT detector, allowing the start of the production of some 500 circuits that will equip the MFT.

In this talk, we will present the physics goal of the MFT detector and a detailed status of the R&D activities that will lead to the construction of this new detector, fundamental for the upgrade of the muon program within the ALICE collaboration.

Summary:

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The Micro Vertex Detector of the CBM Experiment

Philipp Klaus[1]

[1] *Johann-Wolfgang-Goethe Univ. (DE)*

The Micro Vertex Detector (MVD) will consist of four planar detector stations located at 5cm to 20cm downstream the target.
Its design is driven by the challenge to identify the decay vertices of particles carrying open-charm, which calls for a high spatial resolution ($\sim 5\mu m$) and a very light material budget of 0.3% (0.5%) X_0 for the first (following) stations.
To match these requirements, we will employ 50 μm thin CMOS Monolithic Active Pixel Sensors, which will be provided by the IPHC Strasbourg.
The heat dissipated by the sensors is evacuated via support structures relying on highly heat-conductive carbon materials (CVD diamond, TPG), which is essential for vacuum operation.
Dedicated flex print cables are used to power the sensors and to transport the data corresponding to up to $\sim 7 \times 10^5 hits/mm^2/s$ (peak) towards the DAQ system.
We introduce our concept for the MVD and discuss technological challenges related to its mechanical integration.
Moreover, we show the results of a feasability study, which was carried out with a prototype (PRESTO) realizing a full quadrant of a detector station.

Summary:

The Compressed Baryonic Matter experiment (CBM) forms a core experiment at the Facility for Antiproton and Ion Research in Europe (FAIR) using its future SIS-100 accelerator under construction in Darmstadt, Germany.
It is a fixed target experiment to explore the properties of hadronic matter in the regime of highest net baryon densities with beam energies of 4 to 12 AGeV (Au+Au) or up to 30 GeV (p-A).
The Micro Vertex Detector (MVD) of CBM is a silicon pixel detector, which is to reconstruct open charm and to support the tracking of low-momentum particles.
To match these goals, the highly granular, ultra-light, and vacuum compatible detector will be installed 5cm downstream the target, which introduces harsh requirements in terms of rate capability and radiation tolerance.
We introduce the concept and the technology of the MVD and discuss its design based on the results of a concluded feasibility prototype.

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Future QCD Measurements at High Energy with the LHeC

Alessandro Polini[1]

[1] *Universita e INFN, Bologna (IT)*

The Large Hadron electron Collider (LHeC) is a proposed facility which will exploit the new world of energy and intensity oered by the LHC through collisions with a new 60 GeV electron beam. Designed for synchronous operation with the other LHC experiments, the LHeC will be a high luminosity ep and eA collider with a wide ranging physics program on high precision deep inelastic scattering and new physics. Electron proton scattering is also considered as an option for of the Future Circular Collider (FCC-he). Highlights from the ep and eA physics program will be illustrated along with details on the status of the activities from accelerator, and detector design and a possible roadmap.

Summary:

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Identification of charged hadrons with CsI-RICH detectors in the high energy physics

Nico Di Bari[1]

[1] *Universita e INFN (IT)*

In high energy physics experiments a CsI photocathode coupled to a gaseous detector is used in most of the RICH detectors to identify charged hadrons. These RICH detectors have shown to be efficient and stable over long periods of time. A review of the important RICH detectors used around the world, and the technology behind them, will be shown.

Summary:

Identification of charged hadrons with CsI-RICH detectors in the high energy physics

Special Section Future Perspectives, Upgrades, Instrumentation / **436**

Event reconstruction on many-core computer architectures

Ivan Kisel[1]

[1] *Johann-Wolfgang-Goethe Univ. (DE)*

Modern and future heavy-ion experiments are focused on measurements of very rare particles at interaction rates up to 10 MHz with data flow of up to 1 TB/s, that cannot be fully stored on currently available storage devices. The data flow should be reduced by selecting collisions with potentially interesting physics. Therefore, full reconstruction of the collision topology including reconstruction of short-lived particles is required already in real time with the experiment. The algorithms for online reconstruction should be fast, vectorized, parallelized, and portable in order to utilize the full potential of different many-core CPU/GPU computer architectures.

One of the most promising approaches to the search of particle trajectories (tracks) in the detector system is the Cellular Automaton (CA) track finder. The algorithm is based on consistent accumulation of the tracking information by building of short track segments, linking them according to the track model and selecting the best track candidates.

After tracks are found, they parameters are properly estimated within the Kalman Filter (KF) approach.

Next, short-lived particles are reconstructed covering signals from all physics cases: strange particles, strange resonances, hypernuclei, low mass vector mesons, charmonium, and open-charm particles.

All discussed algorithms are fully vectorized and parallelized and show a strong linear scalability on many-core architectures.

Summary:

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Simulation and Track Reconstruction Techniques for the J-PARC muon g-2 experiment

Paschalis Tsilias[1]

[1] *Aristotle University of Thessaloniki*

The muon g-2/EDM proposed experiment at J-PARC is a promising and innovative attempt at the field of Precision Physics. The sensitivity goal of 0.1ppm will test the limits of our current understanding, and may probe for BSM observations.

Our project seeks out to investigate the computational techniques required by the experimental process.

The GEANT4 framework was used to simulate the late detection phase. This allowed us to observe the event hierarchy in different energies, and construct an event-selection algorithm.
Using techniques pertaining to Machine Learning and Image Feature Extraction, we were able to describe a Pattern Recognition algorithm, along a generic representation of these event categories

Finally, the modular GenFit2 framework was used to reconstruct tracks from sparse digitized event data.

Summary:

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The Compressed Baryonic Matter experiment at FAIR

Iouri Vassiliev[1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung*

The main goal of the CBM experiment at FAIR is to study the behaviour of nuclear matter at very high baryonic density in which the transition to a deconfined and chirally restored phase is expected to happen. The promissing signatures of this new state are the enhanced production of multi-strange particles, production of hypernuclei and dibaryons. Theoretical models predict that single and double hypernuclei, and heavy multi-strange short-lived objects are produced via coalescence in heavy-ion collisions with the maximum yield in the region of SIS100 energies. The discovery and investigation of new hypernuclei and of hyper-matter will shed light on the hyperon-nucleon and hyperon-hyperon interactions. The key CBM observables include particles containing hidden charm, open charm and low-mass vector mesons decaying into leptons. Particularly demanding is the measurement of open charm particles with very low multiplicities, which is based on the real time selection of displaced vertices with an accuracy of about 50 μm. Results of feasibility studies of the key CBM oservables in the CBM experiment are discussed.

Summary:

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FTK: the hardware Fast TracKer of the ATLAS experiment at CERN

Ioannis Maznas[1]

[1] *Aristotle University of Thessaloníki (GR)*

In the ever increasing pile-up of the Large Hadron Collider environment the trigger systems of the experiments have to be exceedingly sophisticated and fast at the same time in order to increase the rate of relevant physics processes with respect to background processes.

The Fast TracKer (FTK) is a track finding implementation at hardware level that is designed to deliver full-scan tracks with p_T above 1 GeV to the ATLAS trigger system for every L1 accept (at a maximum rate of 100kHz). To accomplish this, FTK is a highly parallel system which is currently under installation in ATLAS. It will first provide the trigger system with tracks in the central region of the ATLAS detector, and next year it is expected that it will cover the whole detector.

The system is based on pattern matching between hits coming from the silicon trackers of the ATLAS detector and 1 billion simulated patterns stored in specially designed ASIC chips (Associative memory – AM06). In a first stage, coarse resolution hits are matched against the patterns and the accepted hits undergo track fitting implemented at FPGA level. Tracks above the 1GeV threshold are delivered to the High Level Trigger within about 100 μs. The resolution of the tracks coming

from FTK is close to the offline tracking resolution and it will allow for reliable detection of primary and secondary vertices at trigger level and improved trigger performance for b-jets and tau leptons.

This presentation will provide an overview of the FTK system architecture and its commissioning status. Moreover, its expected performance will be briefly presented.

Summary:

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Unfolding techniques in Particle Physics

Stefan Schmitt[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

The problem of correcting data for detector effects (unfolding) is disussed, with emphasis on practical difficulties showing up in particle physics. A selection of unfolding methods commonly used in particle physics is presented, such as iterative algorithms (D'Agostini), methods based on matrix decomposition (SVD unfolding) and fits with Tikhonov regularisation (TUnfold). The differences between the methods are discussed and their weak and strong points are compared.

Summary:

Special Section Statistical Methods for Physics Analysis in the XXI Century / **9**

The inverse bagging algorithm

Author(s): Pietro Vischia[1]

Co-author(s): Tommaso Dorigo [2]

[1] *LIP Laboratorio de Instrumentacao e Fisica Experimental de Part*

[2] *Universita e INFN, Padova (IT)*

For data sets populated by a very well modeled process and by another process of unknown p.d.f., a desired feature when manipulating the fraction of the unknown process (either for enhancing it or suppressing it) consists in avoiding modifying the kinematic distributions of the well modeled one. A bootstrap technique is used to identify sub-samples rich in the well modeled process, and classify each event according to the frequency of it being part of such sub-samples. Comparisons with general MVA algorithms will be shown, as well as a study of the asymptotic properties of the method.

Summary:

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Deep Learning and Bayesian Methods

Harrison Prosper[1]

[1] *Florida State University*

I begin with an introduction to deep learning methods and the kinds of problems in particle physics to which the methods could be usefully applied, such as searching data for evidence of new physics. Then I discuss the Bayesian connection. I conclude with a perspective on what data analysis might look like in the not too distant future.

Summary:

The availability of low cost, massively parallel, computing systems has finally made feasible the routine use of large scale inference engines, based, in part, on deep learning methods. Deep learning systems are successfully being deployed on tasks, which, while routine, nevertheless require high-level human expertise. In this talk, I try to make two points. First, particle physicists should embrace the new paradigm, for example, by moving aggressively to automate the (artificially) intelligent searching and classification of data. Second, in the context of particle physics, deep learning systems are nothing more than high-dimensional Bayesian inference engines. From this perspective, deep learning is not so much a revolution as a coming of age of ideas that have been around for a long time, but whose routine implementation required the advent of the massively parallel computing systems available today.

Special Section Statistical Methods for Physics Analysis in the XXI Century / **168**

Statistical combination of experimental results in ATLAS

Stefan Gadatsch[1]

[1] *CERN*

The combination of experimental results requires a careful statistical treatment. We review the methods and tools used in ATLAS for the statistical combination of measurements and of limits on new physics. We highlight the methods used in the recent combination of ATLAS and CMS measurements of the Higgs boson production/decay rates and the constraints on the Higgs coupling parameters.

Summary:

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Machine Learning Software Development in High Energy Physics

Sergei Gleyzer[1]

[1] *University of Florida (US)*

In my talk, I will present an overview of on-going machine-learning software development in particle physics, in particular focusing on the recent developments related to the Toolkit of Multivariate Analysis (TMVA). I will additionally summarize the current activities of the Inter-experimental Machine Learning Working Group (IML).

Summary:

Special Section Statistical Methods for Physics Analysis in the XXI Century / **254**

QCD multijet background modelling by hemisphere mixing

Author(s): Pablo De Castro Manzano[1]

Co-author(s): Alexandra Carvalho Antunes De Oliveira [1] ; Martino Dall'Osso [1] ; Mia Tosi [2] ; Tommaso Dorigo [1]

[1] *Universita e INFN, Padova (IT)*

[2] *CERN*

A new data-driven technique for modelling the QCD multijet background component for analyses which include several jets in their final state is presented and studied in detail. By combining pairs of hemispheres from other events based on a nearest neighbour distance, a new mixed dataset can be constructed which kinematically resembles the majority component of the original mixture. Therefore, when applied to analysis where a small signal fraction is mixed with a much larger background component as the non-resonant hh $\rightarrow$ $b\bar{b}b\bar{b}$, this method can be used to provide an accurate modelling of the background shape. Several studies based on fast-simulation which try to investigate the powerfulness and limits of this technique will be provided.

Summary:

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Combination of measurements and the BLUE method

Luca Lista[1]

[1] *INFN Sezione di Napoli*

The most accurate method to combine measurement is to build a combined likelihood function and use it to perform the desired inference. This is not always possible for various possible reasons, hence approximate methods are often convenient. Among those, the best linear unbiased estimator (BLUE) is the most popular, allowing to take into account individual uncertainties and their correlations. The method is unbiased by construction if the true uncertainties and their correlations are known, but it may exhibit a bias if uncertainty estimates are used in place of the true ones, in particular if those estimated uncertainties depend on measured values. In those cases, an iterative application of the BLUE method may reduce the bias of the combined measurement.

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Statistical significance estimation of a signal within the GooFit framework on GPUs

Author(s): Leonardo Cristella[1]

Co-author(s): Adriano Di Florio [2] ; Alexis Pompili [2]

[1] *Università & INFN, Bari (IT)*

[2] *Universita e INFN, Bari (IT)*

Graphical Processing Units (GPUs) represent one of the most sophisticated and versatile parallel computing architectures available that are nowadays entering the High Energy Physics field. GooFit is an open source tool interfacing ROOT/RooFit to the CUDA platform on nVidia GPUs. Specifically it acts as an interface between the MINUIT minimisation algorithm and a parallel processor which allows a Probability Density Function (PDF) to be evaluated in parallel.

In order to test the computing capabilities of GPUs with respect to traditional CPU cores, a high-statistics pseudo-experiment technique has been implemented both in ROOT/RooFit and GooFit

frameworks with the purpose of estimating the local statistical significance of the structure observed by CMS close to the kinematical boundary of the J/psi phi invariant mass in the B+ to J/psi phi K+ decay. The optimized GooFit application running on GPUs provides striking speed-up performances with respect to the RooFit application parallelised on multiple CPU workers through the PROOF-Lite tool.
By means of GooFit it has also been possible to explore the behaviour of a likelihood ratio test statistic in different situations in which the Wilks Theorem may apply or does not apply because its regularity conditions are not satisfied.

The described technique has been extended to situations when, dealing with an unexpected signal, a global significance must be estimated.
The LEE is taken into account by means of a scanning technique in order to consider - within the same background-only fluctuation and everywhere in the relevant mass spectrum - any fluctuating peaking behavior with respect to the background model. The execution time of the fitting procedure for each MC toy considerably increases and GooFit is a reliable tool to carry out this p-value estimation method.

Summary:

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The Matrix Element Method in the LHC era

Sebastien Wertz[1]

[1] *Universite Catholique de Louvain (UCL) (BE)*

The Matrix Element Method (MEM) is a powerful multivariate method allowing to maximally exploit the experimental and theoretical information available to an analysis. The method is reviewed in depth, and several recent applications of the MEM at LHC experiments are discussed, such as searches for rare processes and measurements of Standard Model observables in Higgs and Top physics. Finally, a new implementation of the MEM is presented. This project builds on established phase-space parametrisations known to greatly improve the speed of the calculations, and aims at a much improved modularity and maintainability compared to previous software, easing the use of the MEM for high-statistics data analyses.

Summary:

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Look Elsewhere Effect in 2D

Eilam Gross[1] ; Ofer Vitells[1]

[1] *Weizmann Institute of Science (IL)*

Based on
Estimating the significance of a signal in a multi-dimensional search
Ofer Vitells, Eilam Gross (Weizmann Inst.). May 2011. 5 pp.
Published in Astropart.Phys. 35 (2011) 230-234

Summary:

What happens when one has to consider that a background fluctuation might arise at an arbitrary mass AND with an arbitrary width?

How can a multidimensional Look Elsewhere Effect be taken into account without the need for expensive Monte Carlo simulations. We will present the analytic solution and its implication to the recent di photon excess observed in the LHC.

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Experience with using unfolding procedures in ATLAS

Silvia Biondi[1]

[1] *Universita e INFN, Bologna (IT)*

In ATLAS, several unfolding methods are used to correct experimental measurements for detector effects, like acceptance and resolution. These methods use as input the raw experimental distributions, as well as Monte Carlo simulation for the description of the detector effects. The systematic uncertainties associated to the various unfolding methods are evaluated. The statistical and systematic uncertainties affecting the raw measurements and/or the simulation are propagated through the unfolding procedure. The resulting corrected measurements with their uncertainties can be directly compared with the corresponding theoretical predictions.

Summary:

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Bayesian non parametric modelling of the double Higgs production

Bruno Scarpa[1]

[1] *Università di Padova*

Statistical classification models are commonly used to separate a signal from a background. In this talk we face the problem of isolating the signal of the double Higgs production using the decay channel in which each boson decays into a pair of b-quarks. Typically in this context non parametric methods are used, such as Random Forest or different types of Boosting. We remain in the same non parametric framework, but we propose to face the problem following a Bayesian approach. A Dirichlet process is used as prior for the random effects in a logit model which is fitted by leveraging the Polya-Gamma data augmentation algorithm. Refinements of the model include the insertion in the simple model of P-splines to relate explanatory variables with the response and the use of Bayesian trees (BART) to describe the atoms in the Dirichlet process.

Summary:

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Statistical and other experience with new structures in hadron spectra

Kai Yi[1]

[1] *University of Iowa (US)*

Many challenges, such as determining significance, exist in identifying new structures in hadron spectra. This talk will summarize first-hand experience on significance determination including look-elsewhere-effect, background determination, as well
as signal extraction in hadron spectra.

Summary:

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Confidence intervals for the ratio of two quantities

Francisco Matorras[1]

[1] *Instituto de Fisica de Cantabria, Santander, IFCA (ES)*

Often physicists need to calculate the confidence interval for the ratio of two measurements and many times just use the so-called "error propagation" of the corresponding uncertainties, without being aware of the approximations involved and the limitations of this approach. We will explore these limitations, as well as some alternative and more accurate methods. "Exact" methods for the case of ratio of two quantities following a Poisson law will be described, together with approximations to more general cases showing good coverage properties.

Summary:

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Wrapping up

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A method for the construction of strongly reduced representations of ATLAS experimental uncertainties and the application thereof to the jet energy scale

Daniela Boerner[1]

[1] *Bergische Universitaet Wuppertal (DE)*

A method is presented for the reduction of large sets of related uncertainty sources into strongly reduced representations which retain a suitable level of correlation information for use in many cases. The method provides a self-consistent means of determining whether a given analysis is sensitive to the loss of correlation information arising from the reduction procedure. The method is applied to the ATLAS Jet Energy Scale (JES) uncertainty, demonstrating that the set of 60+ independent sources can be reduced to form a representation constructed of 3 nuisance parameters. By forming a set of four such representations, it is shown that JES correlation information is retained or probed over the full parameter space to within an average of 1%. This procedure is expected to significantly reduce the computational requirements placed upon early ATLAS searches in the upcoming 2015 dataset while still providing sufficient performance and correlation structure to avoid changing the analysis results.

Summary:

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The Thermal Model of Heavy Ion Collisions

Jean Cleymans[1]

[1] *University of Cape Town*

Nuclear collisions at high energies produce large numbers of secondaries.
Results from the ALICE collaboration show that more than 20 000 of them are produced in a Pb-Pb collision. In view of this it is natural to consider a statistical-thermal model to analyse these and concepts like temperature, energy density, pressure, net baryon density etc... are useful.
A presentation will be given of the present status of the thermal model as well as expectations for future experiments at CERN/RHIC/FAIR/JINR are shown.

Summary:

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Classifiers for centrality determination in nucleus-nucleus and proton-nucleus collisions

Author(s): Igor Altsybeev[1]

Co-author(s): Vladimir Kovalenko [1]

[1] *St. Petersburg State University (RU)*

Centrality, as a geometrical property of the collision, is crucial for the physical interpretation of nucleus-nucleus and proton-nucleus experimental data. However, it cannot be directly accessed in event-by-event data analysis. Contemporary methods of the centrality estimation in A-A and p-A collisions usually rely on a single detector (either on the signal in zero-degree calorimeters or on the multiplicity in some semi-central rapidity range). In the present work, we made an attempt to develop an approach for centrality determination that is based on machine-learning techniques and utilizes information from several detector subsystems simultaneously. Different event classifiers are suggested and evaluated for their selectivity power in terms of the number of nucleons-participants and the impact parameter of the collision. Finer centrality resolution may allow to reduce impact from so-called volume fluctuations on physical observables being studied in heavy-ion experiments like ALICE at the LHC and fixed target experiment NA61/SHINE on SPS.

This work is supported by the Russian Science Foundation, GRANT 16-12-10176.

Summary:

Student Lectures / 368

Introduction to Nonrelativistic effective Field Theories for QCD

Antonio Vairo[1]

[1] *TUM*

Student Lectures / **369**

Introduction to chiral QCD

Hagop Sazdjian[1]

[1] *University Paris-Sud*

Student Lectures / **370**

Introduction to Large N QCD

Jose Luis Goity[1]

[1] *Hampton University/Jefferson Lab*

Student Lectures / **371**

General Relativity and Gravitational Waves

Alvaro De Rujula[1]

[1] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

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Satellite Workshop agenda

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A study on Quark-Gluon plasma equation of state using with finite quark mass

Yogesh Kumar[1]

[1] *University of Delhi*

We study the QGP equation of state using finite quark mass with the finite size effect by taking into account of Multiple Reflection Expansion (MRE). The quark mass improves the calculation of free energy in the formation of QGP droplet. Finally, the model results provide QGP equation of state that matches well with the lattice results.

Summary:

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CANCELLED: Hadronic vacuum polarisation contribution to muon g-2 from lattice QCD

Bipasha Chakraborty[None]

The anomalous magnetic moment of the muon, defined as the fractional difference of its gyromagnetic ratio from the naive value of 2, has been measured with an impressive accuracy of 0.54 parts per million in experiment (BNL E821), thus providing one of the most stringent tests of the Standard Model. Intriguingly, the experimentally measured anomaly disagrees by around 3 standard deviations with the calculated value from the Standard Model. The current theoretical uncertainty is dominated by that from the calculation of the lowest order "hadronic vacuum polarisation (HVP)". Improvements in the experimental uncertainty by a factor of 4 in the upcoming experiment at Fermilab (E989) are expected and improvements in the theoretical determination would make the discrepancy (if it remains) really compelling in trying to ascertain the possibility of new physics beyond the Standard Model. I will report on the progress and plans for improving the theoretical calculation of the HVP contribution to the anomaly using our (HPQCD) lattice QCD method. We have achieved the most precise lattice results so far for this quantity on multiple lattices with physical up/down, strange and charm quarks in the sea. Our accuracy on the HVP is 2% and this is low enough for the first time to see (arXiv:1601.03071) a 3σ discrepancy between the Standard Model and experiment.

Summary:

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