Theory challenges for LHC physics

Monday, July 20, 2015 - Thursday, July 30, 2015

Joint Institute for Nuclear Research, Bogoliubov Laboratory of Theoretical Physics

Book of Abstracts

Contents

CALC2015 Workshop / 0

On the running strong coupling and b-quark mass in the SM: two-loop electroweak decoupling corrections

Author: Alexander Bednyakov[1]

[1] *JINR*

Corresponding Author: bednya@theor.jinr.ru

Two-loop electroweak corrections to the decoupling relations between the running $\overline{MS}$ parameters of the SM and their counterparts in the effective five-flavour QCDxQED theory are considered for the strong coupling constant $\alpha_s(\mu)$ and the bottom-quark mass $m_b(\mu)$. The decoupling procedure is outlined and the numerical impact of the obtained terms are discussed.

CALC2015 Workshop / 1

FIRE5: a C++ implementation of Feynman Integral REduction

Author: Alexander Smirnov[1]

[1] *Moscow State University*

Corresponding Author: asmirnov80@gmail.com

In modern elementary particle physics one often needs to evaluate millions of Feynman integrals. An already classical approach is to apply the so-called integration by parts relations and reduce all integrals to a smaller set, the master integrals. We present FIRE5 - a powerful program performing Feynman integral reduction.

CALC2015 Workshop / 2

Hadronic contributions to electroweak observables in the framework of dispersive approach to QCD

Author: Alexander Nesterenko[1]

[1] *Joint Institute for Nuclear Research*

Corresponding Author: nesterav@gmail.com

The dispersive approach to QCD is applied to the study of the hadronic vacuum polarization function and associated quantities. This approach merges the intrinsically nonperturbative constraints, which originate in the kinematic restrictions on the respective 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 assessments of these quantities.

[1] A.V.Nesterenko, Phys. Rev. D88, 056009 (2013).

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

[3] A.V.Nesterenko and J.Papavassiliou, Phys. Rev. D71, 016009 (2005).

[4] A.V.Nesterenko, Nucl. Phys. B (Proc. Suppl.) 258, 177 (2015).

[5] A.V.Nesterenko, arXiv:1411.2554 [hep-ph].

CALC2015 Workshop / 4

Three-loop cusp anomalous dimension in QCD

Author: Andrey Grozin[1]

Co-authors: Gregory Korchemsky [2]; Johannes Henn [3]; Peter Marquard [4]

[1] *urn:Google*

[2] *Institut de Physique Théorique, CEA Saclay, 91191 Gif-sur-Yvette Cedex, France*

[3] *IAS*

[4] *Deutsches Elektronen-Synchrotron, DESY, Platanenallee 6, D15738 Zeuthen, Germany*

Corresponding Author: a.g.grozin.gg@gmail.com

The three-loop cusp anomalous dimension Γ has been calculated analytically, as a function of the Minkowski angle ϕ,
via harmonic polylogarithms up to weight 5. The color structures
$C_F(T_F n_f)^{L-1}\alpha_s^L$ in Γ and the HQET quark field anomalous dimension have been obtained to all orders. At
large ϕ the coefficient of $1/(1-z)_+$ in the DGLAP evolution kernel is reproduced. If we introduce an effective coupling a
in such a way that the large-ϕ result is exactly first order and re-express $\Gamma(\phi)$ via a, the resulting expression
does not contain n_f (and has only one color structure at each order). The known relation between $\Gamma(\phi \to i\pi)$ and the
quark-antiquark potential (which follows from conformal invariance) is violated at three loops by a term proportional to
β_0.

CALC2015 Workshop / 5

A Simple Subtraction Scheme for Calculation of the Anomalous Magnetic Moment of the Electron in QED

Author: Sergey Volkov[1]

[1] *SINP MSU, Dubna*

Corresponding Author: volkoff_sergey@mail.ru

A “forest-like” subtraction scheme is proposed for removal both ultraviolet and infrared divergences in Feynman amplitudes. This scheme is developed especially for QED calculation of the anomalous magnetic moment. The procedure gives a finite Feynman-parametric integral for any Feynman diagram (at any order of perturbation), so we don’t need any regularization. The subtraction scheme is described in terms of linear operators that transform Feynman amplitudes of UV-divergent subdiagrams into polynomials of degree that is less or equal than the UV degree of divergence of the subdiagram. So we can say that this is a modification of Scherbina-Zavyalov-Stepanov-Zimmermann

forest formula. This subtraction is equivalent to the on-shell renormalization, so we don't need any "residual renormalizations" or other manipulations with finite values that are obtained by this procedure. The method can be used for numerical calculation at high orders of perturbation.

CALC2015 Workshop / 6

Resolving Color and Kinematics for QCD Amplitudes

Authors: Alexander Ochirov[1]; Henrik Johansson[2]

[1] *University of Edinburgh*

[2] *CERN*

We explore implications of the color-kinematics duality for quantum chromodynamics with massive quarks. We work out a decomposition n-point tree amplitudes in a small basis of color-ordered "primitive" amplitudes, using general properties of color and kinematics. First, we decompose the full scattering amplitude with 2k quarks and (n-2k) gluons in terms of the Melia basis, which consists of (n-2)!/k! primitives independent under color-algebra (Kleiss-Kuijf) relations. We find their color factors in that decomposition for an arbitrary gauge group. Then we analyze the kinematic-algebra amplitude relations that follow from the color-kinematics duality. The duality is shown to hold in amplitudes with massive Dirac fermions in the fundamental representation for up to eight particles. This gives strong evidence that QCD obeys the color-kinematics duality, at least at tree level. We identify the new (massive) amplitude relations in QCD and show that they map to a well-defined subset of the familiar BCJ relations for gluons. They restrict the amplitude basis further down to (n-3)!(2k-2)/k! primitives, in case of two or more quark lines. We give a decomposition of the full amplitude in that basis. All results in this paper generalize to supersymmetric extensions of QCD.

CALC2015 Workshop / 8

XQCAT: a model independent analysis of new heavy quarks at the LHC

Author: Luca Panizzi[1]

[1] *University of Southampton*

Corresponding Author: l.panizzi@soton.ac.uk

New heavy quarks are predicted in various scenarios of new physics; depending on their nature they can mix with SM quarks or they can even mediate the production of dark matter states. Theoretically-motivated scenarios of new physics in general predict the existence of multiple new quarks with different couplings with the SM states or dark matter. Experimental searches of new quarks at the LHC, on the other hand, have so far mostly tested minimal extensions of the SM with new quarks which decay into the third family of SM quarks. No signals have been detected, pushing mass limits above 600-800 GeV, depending on different assumptions about their couplings to SM states. The reinterpretation of mass bounds from experimental searches to test theoretical models is therefore not always straightforward. I will describe model independent methods to recast data from experimental searches. These methods have been implemented in a tool called XQCAT (eXtra Quark Combined Analysis Tool). Considering data from a set of experimental searches at the LHC, XQCAT allows to determine the exclusion confidence level for general scenarios with any number of new heavy quarks

which can mix with all SM families. Prospects for the extension of the tool to analyse scenarios where the new heavy quarks couple to dark matter will be discussed as well.

Student talks / **9**

Mass bounds in 2HDMs in the SM-like limit.

Author: Ambalika Biswas[1]

Co-author: Amitabha Lahiri [1]

[1] *S N Bose National Centre for Basic Sciences, Kolkata, India*

We consider 2HDMs with a softly broken global U(1) symmetry and the fermion transformations under this symmetry. We study the implication of a criterion of naturalness for a broad class of two Higgs doublet
models (2HDMs). In particular, we assume the cancellation of quadratic divergences in what are called the type I, type II, lepton-specific and flipped 2HDMs. This results in a set of relations among masses of the physical scalars and coupling constants, a generalization of the Veltman conditions of the Standard Model. Assuming that the lighter uncharged scalar is the observed Higgs particle of mass ~125 GeV, and imposing further the constraints from the electroweak T-parameter, perturbative unitarity constraints and stability constraints produce
a range for the masses of each of the remaining physical scalars.

Summary:

The two- Higgs doublet models are one of the most widely investigated scenarios that go beyond the Standard Model (SM). There are many motivations for 2HDMs. The primary motivation being supersymmetry. Another motivation for 2HDMs comes from axion models. Still another motivation for the 2HDMs is the fact that the SM is unable to generate a baryon asymmetry of the universe of sufficient size.

This work basically deals with the set of Veltman conditions pertaining to the 2HDMs. The mass ranges of the physical Higgs bosons have been concluded considering the Veltman conditions, the perturbative unitarity conditions, the stability conditions and electroweak T parameter of the most general 2HDM potential in the alignment limit. The conjecture that some unknown symmetry is responsible for keeping the Higgs boson light at 125 GeV does not hold for the Standard Model, where the coefficient of the quadratic divergence of Higgs boson self-energy is far from zero. The Veltman conditions are arrived at by setting the quadratic divergences to zero. In 2HDMs such quadratic divergences can be cancelled if the Veltman conditions are strictly obeyed and we use this concept to derive the mass ranges of the physical Higgs so that all the scalar masses remain at the electroweak scale and the naturalness problem can be avoided.

CALC2015 Workshop / **10**

Lepton Flavor Violation in SUSY SO(10) Theories using Non Universal Gaugino Mass Models in Light Of LHC Results on Higgs

Author: Gayatri Ghosh[1]

Co-author: Kalpana Bora [1]

[1] *Physics Department, Gauhati University*

Corresponding Author: gayatrighsh@gmail.com

Using the results from LHC on Higgs mass, we present limits on Lepton Flavor Violation(LFV), in SUSY SO(10) theories. We have used Dirac Neutrino Yukawa Couplings as calculated in such theories. We have presented our results using different models like NUHM, mSUGRA, NUGM. We have compared our results with latest data from MEG experiment on charged lepton flavor violation. Latest results from RENO, DAYA BAY are used in our calculations

CALC2015 Workshop / 11

HERAFitter project and its related studies

Authors: Ringaile Placakyte[1]; Voica Ana Maria Radescu[2]

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

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

Corresponding Author: ringaileplacakyte@gmail.com

The uncertainties of protons parton distribution functions (PDFs) play a dominant role for the precision tests of the Standard Model (SM) and they also impact substantially the theory predictions of Beyond SM high mass production. We present the HERAFitter project which provides a unique open-source software framework for the determination of the proton's PDFs and for the interpretation of the physics analyses in the context of Quantum Chromodynamics (QCD).

We report here the highlighted results based on the HERAFitter functionalities, as well as novel studies performed by HERAFitter. The latter includes the impact of correlations between uncertainties for PDFs extracted at different perturbative QCD orders as well as the QCD analysis of the recent Drell-Yan production measurements at Tevatron.

Reference of studies that the abstract covers are:

1. "HERAFitter Open Source QCD Fit Project", arXiv:1410.4412 [accepted by EPJC]
2. "Parton distribution functions at LO, NLO and NNLO with correlated uncertainties between orders", EPJC (2014) 74:3039, arXiv:1404.4234
3. "QCD analysis of W- and Z-boson production at Tevatron", arXiv:1503.05221 [submitted to EPJC]

CALC2015 Workshop / 12

Pair production of pseudoscalar and vector Bc mesons at the LHC

Author: Anton Trunin[1]

[1] *Joint Institute for Nuclear Research*

Corresponding Author: amtrnn@gmail.com

On the basis of perturbative QCD and relativistic quark model we calculate cross sections of pair pseudoscalar and vector B_c mesons production in proton–proton interaction. Relativistic factors in the production amplitude connected with the relative motion of heavy quarks and the transformation law of the bound state wave function are taken into account. The gluon and quark propagators entering the production amplitude are expanded in the ratio of the relative quark momenta to the meson mass up to the second order. Relativistic corrections to the quark–antiquark bound state wave

functions in the rest frame are considered by means of the Breit-like potential. It turns out that the examined effects significantly decrease nonrelativistic predictions for the cross section.

CALC2015 Workshop / 13

Beyond NNLL' qT resummation with CuTe

Author: Thomas Luebbert[1]

[1] *University of Hamburg*

Corresponding Author: thomas.luebbert@desy.de

qT spectra of massive bosons at hadron colliders provide important tests of the Standard Model. In the crucial region, where the boson's invariant mass M is much smaller than its transverse momentum qT, the spectra are very sensitive to initial state radiation.
Applying soft-collinear effective theory, a universal framework for its description has been established and the relevant perturbative operators have been extracted up to next-to-next-to leading order (NNLO).

For any heavy color neutral final state, these results enable us to resum logarithms of qT/M beyond next-to-next-to leading logarithmic (NNLL) accuracy and to consistently match to the corresponding NNLO fixed order result. For Drell-Yan, Z, W and H production we implemented this in the program CuTe. As two important examples, we present the qT spectra of Z and H production to NNLO+NNNLLp accuracy and confront these results with LHC data.

Student talks / 14

Constraints on Seesaw Models and Signatures at the LHC

Authors: GULAB BAMBHANIYA[1]; Subrata Khan[2]; Tanmoy Mondal[3]

Co-authors: Partha Konar [4]; Sourov Roy [5]; Srubabati Goswami [3]

[1] *PHYSICAL RESEARCH LABORATORY*

[2] *IISER Kolkata*

[3] *Physical Research Laboratory*

[4] *ITP, Uni Karlsruhe*

[5] *IACS, Kolkata*

Corresponding Author: khansubrata@gmail.com

We consider variants of TeV-scale seesaw models in which two and three additional heavy right-handed neutrinos are added to the standard model to generate the hierarchical and quasidegenerate light neutrinos respectively. These models are theoretically interesting since they can be fully reconstructed from the neutrino oscillation data except for an unknown constant in the Dirac-Yukawa coupling. We study the constraints on this coupling
coming from metastability of the electroweak vacuum. An even stronger bound comes from the lepton flavor violating decays on these models, especially in a heavy neutrino mass scenario which is within the collider's reach. With these constrained parameters, we study the production of heavy neutrinos at the Large Hadron Collider through the dominant
s-channel production mode as well as the vector boson fusion process. The conventional same-sign-dilepton signal at the Large Hadron Collider is highly suppressed in such models. We analyze the collider signatures with the trilepton final state and missing transverse energy as well as vector boson fusion type signals which are characterized by
two additional forward tagged jets. Our investigation reveals that due to stringent constraints on

light-heavy mixing coming from lepton flavor violation and metastability bounds, the model can be explored only for a light to moderate mass range of heavy neutrinos.

Summary:

Collider signatures at 14 TeV LHC have been performed in the context of realistic seesaw models (i.e. seesaw models those successfully account all the neutrino oscillation data). Effect of CP-violating phases on such signals has been discussed.

CALC2015 Workshop / **15**

Event generator LePaProGen for the Drell-Yan process

Authors: Vitaly Yermolchyk[1]; Yahor Dydyshka[1]

[1] *Byelorussian State University (BY)*

Corresponding Author: vitaly.yermolchyk@cern.ch

We present the Monte Carlo event generator *LePaProGen* for neutral and charged current Drell-Yan processes, which is intended for accurate and fast generation of events taking in account higher-order radiative corrections. We introduce some new physical algorithms and code features like independent algorithm for the optimal selection of variables for phase-space parametrization.

CALC2015 Workshop / **16**

Efficient calculation with Clifford algebra.

Author: Yahor Dydyshka[1]

Co-author: Vitaly Yermolchyk [1]

[1] *Byelorussian State University (BY)*

Corresponding Author: yahor.dydyshka@cern.ch

We present strategy for optimization of the scattering amplitude calculation using Clifford algebra. Application to the one-loop tensor integral reduction is demonstrated.

CALC2015 Workshop / **17**

Massless Propagators and Multiloop QCD: new results

Author: Konstantin Chetyrkin[1]

[1] *Karlsruhe Institute of Technology*

Corresponding Author: konstantin.chetyrkin@kit.edu

We discuss the current status of the ongoing analytical calculation of the QCD beta-function in 5 loops as well as some new results in investigating CBK (Crewther-Brodhurst-Kataev) relation in QCD. The

latter include the evaluation of the new singlet type contribution to the Bjorken sum rule (first considered by Larin) which appears first at 4-loop level only. We will also report on the calculation of the gluino dependent terms to the same sum rule (this will allow to check some non-trivial predictions of the β-expansion method (Kataev and Mikhailov, 2014) and, thus, improve our understanding of the corresponding optimization procedure.

CALC2015 Workshop / **18**

Identifying large extra dimensions in diphoton and dilepton production at the Large Hadron Collider

Author: Inna Serenkova[1]

Co-authors: Alexander Pankov [1]; Andrey Tsytriniov [1]

[1] *Gomel State Technical University*

Corresponding Author: inna.serenkova@cern.ch

The prospects of discovery and identification of large extra spatial dimensions effects in the process of lepton and photon pair production at the Large Hadron Collider (LHC) were studied. These effects can be found by the specific behavior of the invariant mass distributions of the lepton and photon pairs. Identification of the effects under study can be performed with angular distributions of lepton and photon pairs. Discovery and identification reach on the mass scale parameter M_S can be obtained for graviton Kaluza – Klein towers in lepton and photon pair production processes at the LHC.

Morning Session / **19**

Introduction to hadron collider physics (Part 1)

Corresponding Author: michelangelo.mangano@cern.ch

Morning Session / **20**

QCD for colliders (Part 1)

Corresponding Author: stefan.gieseke@cern.ch

Afternoon Session / **21**

Higgs physics (Part 1)

Corresponding Author: michael.spannowsky@googlemail.com

Afternoon Session / **22**

Heavy Elements and Island of Stablity

Morning Session / **23**

Introduction to hadron collider physics (Part 2)

Corresponding Author: michelangelo.mangano@cern.ch

Morning Session / **24**

Future colliders

Corresponding Author: joachim.mnich@cern.ch

Morning Session / **25**

QCD for colliders (Part 2)

Corresponding Author: stefan.gieseke@cern.ch

Morning Session / **26**

Higgs physics (Part 2)

Corresponding Author: michael.spannowsky@googlemail.com

Morning Session / **27**

Introduction to hadron collider physics (Part 3)

Corresponding Author: michelangelo.mangano@cern.ch

Morning Session / **28**

QCD for colliders (Part 3)

Corresponding Author: stefan.gieseke@cern.ch

Morning Session / **29**

Higgs physics (Part 3)

Corresponding Author: michael.spannowsky@googlemail.com

Afternoon Session / **30**

NICA project at JINR

Corresponding Author: trubnikov@jinr.ru

Morning Session / **31**

Modern computational methods for scattering ampllitudes (Part 1)

Morning Session / **32**

Modern computational methods for scattering ampllitudes (Part 2)

Morning Session / **33**

Computational techniques for the LHC (Part 1)

Corresponding Author: ohl@physik.uni-wuerzburg.de

34

School opening

Corresponding Author: kazakovdi@mail.ru

35

Workshop opening

Corresponding Author: kazakovdi@mail.ru

Morning Session / **36**

Modern computational methods for scattering ampllitudes (Part 3)

Morning Session / **37**

QCD amplitudes at NLO and beyond (Part 1)

Corresponding Author: simon.badger@cern.ch

Morning Session / **38**

Computational techniques for the LHC (Part 2)

Corresponding Author: ohl@physik.uni-wuerzburg.de

Morning Session / **39**

QCD amplitudes at NLO and beyond (Part 2)

Corresponding Author: simon.badger@cern.ch

Morning Session / **40**

QCD amplitudes at NLO and beyond (Part 3)

Corresponding Author: simon.badger@cern.ch

Morning Session / **41**

Computational techniques for the LHC (Part 3)

Corresponding Author: ohl@physik.uni-wuerzburg.de

Morning Session / **42**

Beyond the Standard Model (Part 1)

Corresponding Author: alexander.belyaev@cern.ch

Morning Session / **43**

Flavour Physics (Part 1)

Corresponding Author: mannel@hep.physik.uni-siegen.de

Morning Session / **44**

Symbolic Programming in HEP (Part 1)

Corresponding Author: hahn@feynarts.de

Morning Session / **45**

Beyond the Standard Model (Part 2)

Corresponding Author: alexander.belyaev@cern.ch

Morning Session / **46**

Flavour Physics (Part 2)

Corresponding Author: mannel@hep.physik.uni-siegen.de

Morning Session / **47**

Symbolic Programming in HEP (Part 2)

Corresponding Author: hahn@feynarts.de

Morning Session / **48**

Beyond the Standard Model (Part 3)

Corresponding Author: alexander.belyaev@cern.ch

Morning Session / **49**

Flavour Physics (Part 3)

Corresponding Author: mannel@hep.physik.uni-siegen.de

CALC2015 Workshop / 50

Diphoton production at Tevatron and the LHC in the NLO* approximation of the Parton Reggeization Approach

Authors: Maxim Nefedov[1]; Vladimir Saleev[1]

[1] *Samara State University*

Corresponding Author: nefedovma@gmail.com

The hadroproduction of prompt isolated photon pairs at high energies is studied in the NLO* framework of the Parton Reggeization Approach. The real part of the NLO corrections is computed, and the procedure for the subtraction of double counting between real parton emissions in the hard-scattering matrix element and unintegrated PDF is constructed for the amplitudes with Reggeized quarks in the initial state. The matrix element of the important NNLO subprocess RR->2gamma with full dependence on the transverse momenta of the initial-state Reggeized gluons is obtained. We compare obtained numerical results with diphoton spectra measured at Tevatron and the LHC, and find a good agreement of our predictions with experimental data at the high values of diphoton transverse momentum, pT, and especially at the pT larger than the diphoton invariant mass, M. In this multi-Regge kinematics region, the NLO correction is strongly suppressed, demonstrating the self-consistency of the Parton Reggeization Approach.

e-print: arXiv:hep-ph/1505.01718

CALC2015 Workshop / 51

Pair correlations in particle and jet production at the LHC in the parton Reggeization approach

Author: Alexandera Shipilova[1]

Co-authors: Anton Karpishkov [2]; Maksim Nefedov [2]; Vladimir Saleev [1]

[1] *Samara State University, Samara State Aerospace University*

[2] *Samara State University*

Corresponding Author: entscheidend@mail.ru

We study inclusive azimuthal decorrelations in jet, b-jet and D-meson pair production in proton-proton collisions at the CERN LHC invoking the hypothesis of parton Reggeization in t-channel exchanges at high energies. Using a high-energy factorization scheme with the Kimber-Martin-Ryskin unintegrated parton distribution functions and the Fadin-Lipatov effective vertices we obtain good agreement of our calculations with recent measurements by the ATLAS and CMS Collaborations at the CERN LHC.

CALC2015 Workshop / 52

The property of maximal transcendentality: calculation of master integrals

Author: Anatoly Kotikov[1]

[1] *BLTP JINR*

I will review the results for master integrals having the property of maximal transcendentality.

CALC2015 Workshop / **53**

Symmetrical approach to three-body phase space

Author: Andrei Davydychev[1]

[1] *SINP MSU and Schlumberger*

Different representations for the three-body phase space are considered, exploring their symmetry properties and geometrical meaning. We derive expressions that are explicitly symmetrical in the masses of the three particles. We study geometrical properties of the variables involved in elliptic integrals and demonstrate that it is convenient to use the Jacobian zeta function to express the results in four and six dimensions.

Student talks / **54**

Some aspects of the NMSSM Higgs sector at the LHC

Author: Jacky Kumar[1]

[1] *TIFR, Mumbai*

Corresponding Author: singlajacky@gmail.com

In the framework of non-minimal extension of SUSY model, the NMSSM is one of the interesting frameworks which can accommodate the recently discovered Higgs mass. In this model the Higgs sector is very diverse. We study the Higgs phenomenology in this model framework and its implications for future LHC experiments. In this talk I shall discuss some aspects of our observations.

CALC2015 Workshop / **55**

Taking into account of hard photons in MOLLER experiment

Author: Vladimir Zykunov[1]

Co-authors: Aleksandrs Aleksejevs [2]; Svetlana Barkanova [3]; Yury Bystritskiy [4]

[1] *BelSUT*

[2] *Memorial University of Newfoundland*

[3] *Acadia University*

[4] *Joint Institute for Nuclear Research*

A method for taking into account radiative events with hard photon emission in experiments aimed at studying Moller scattering with polarized particles was developed.
A computer code used to perform a numerical analysis with allowance for the kinematical conditions
of the MOLLER experiment at the Jefferson Lab was constructed.

The respective results were compared with their counterparts obtained in the soft-photon approximation.

CALC2015 Workshop / **56**

Reducing differential equations for multiloop integrals to epsilon form

Author: Roman Lee[1]

[1] *Budker Institute of Nuclear Physics*

Corresponding Author: r.n.lee@inp.nsk.su

Recently a remarkable observation was made concerning differential equation system for multiloop integrals. It appeared that in many cases by the proper choice of functions the differential system can be represented in the form where the dependence on regularization parameter is reduced to an overall factor ϵ in the right-hand side. Such a representation makes finding general solution of the system almost trivial. We present a systematic algorithm to find the ϵ-form.

CALC2015 Workshop / **57**

QCD at high energy and the Parton Reggeization Approach

Author: Vladimir Saleev[1]

[1] *Samara State University*

Corresponding Author: saleev@samsu.ru

An overview of recent results (2010-2015) obtained in the Parton Reggeization Approach (PRA) are presented. The dominance of multi-Regge final states in particle production at high energies needs the kt-factorization (high-energy factorization) approach for description of hard hadron-hadron collisions instead of the collinear approximation of the conventional Parton Model. The Lipatov's effective theory of Reggeized gluons and quarks is used to obtain gauge invariant amplitudes with off-shell initial Reggeized gluons and quarks. It is shown that LO in alpha_s calculations in the PRA describe well different data from HERA, Tevatron and the LHC (heavy quark jet, heavy meson and heavy quarkonium, single jet and prompt photon, pairs of jets and photons, Drell-Yuan pairs production, associated jet plus photon production). NLO* approximation of Parton Reggeization Approach for a photon plus jet production at HERA and photon pair production at Tevatron and LHC are discussed.

CALC2015 Workshop / **58**

Alternative renormalization group for the standard model

Author: Grigory Pivovarov[1]

[1] *Russian Academy of Sciences (RU)*

Corresponding Author: grigory.pivovarov@cern.ch

Two existing approaches to the evolution of the scalar mass are discussed. In particular, their opposite implications for the naturalness problem are pointed out. Next, a possibility of an alternative approach to computing the renormalization group evolution of the standard model parameters is discussed. Within this approach, the naturalness problem may be moved to a high energy scale which may be inaccessible at LHC energies.

CALC2015 Workshop / 59

S-matrix approach to the Z line shape

Author: Tord Riemann[1]

[1] *DESY*

Corresponding Author: tord.riemann@desy.de

The Z boson line shape can be studied with unprecedented precision at certain future e+e- collider projects. For example, the Fcc-ee might produce 10^13 Z bosons. This will demand for true two-loop calculations in the Standard Model, and even higher precision in the QED part. As alternative, sophisticated model-independent approaches are welcome. I discuss questions related to both theoretical scenarios, with an emphasis of the role of the S-matrix approach to data, as it is realized in the SMATASY/ZFITTER project. Existing experimental studies are reviewed.

CALC2015 Workshop / 60

Dark vector boson and (g-2) muon anomaly

Author: Nikolay Krasnikov[1]

[1] *INR, Moscow*

Corresponding Author: nikolai.krasnikov@cern.ch

We review the phenomenology and the experiments on the search for light vector boson.
The existence of the additional light vector boson was proposed for the
explanation of the (g-2) muon anomaly.

Summary:

We review the phenomenology and the experiments on the search for light vector boson.
The existence of the additional light vector boson was proposed for the
explanation of the (g-2) muon anomaly.

CALC2015 Workshop / 61

Functional equations for multiloop Feynman integrals

Author: Oleg Tarasov[1]

[1] *JINR*

New methods for deriving functional equations for Feynman integrals are proposed. Several examples of functional equations for two-loop integrals are considered in detail. Application of functional equations for analytic continuation of Feynman integrals considered in arbitrary space-time dimension is demonstrated.

Morning Session / **62**

Precision measurements with polarized beams

Author: Sabine Riemann[1]

[1] *Deutsches Elektronen-Synchrotron Hamburg and Zeuthen (DE)*

Corresponding Author: sabine.riemann@desy.de

Future e+e- collider projects focus on high precision measurements at energies up to the TeV scale. Having both the positron and electron beams polarized, a decisive improvement for many physics studies is expected. I will discuss the advantage of polarized beams for physics analyses as well as the challenge to accomplish successfully the desired precision measurements. A close collaboration between theoretical and experimental groups is essential to achieve this goal.

Student talks / **63**

New Physics signals in Vector quark models

Author: DINESH KUMAR[1]

Co-authors: Ashutosh Kumar Alok [2]; David London [3]; Subhashish Banerjee [2]; Uma Sankar S. [1]

[1] *IIT BOMBAY*

[2] *IIT JODHPUR*

[3] *Universite de Montreal*

Corresponding Author: dinesh@phy.iitb.ac.in

We investigate the vector quark models which include the addition of a vector isosinglet quark to the Standard Model. In these models, the full CKM matrix is larger than 3 × 3. A signal of the new physics will be the non-unitarity of the 3 × 3 CKM matrix. Using present flavor physics data, we perform a combined fit to this full CKM matrix, looking for signals of new physics (NP). We find that these models are very strongly constrained. There are no hints of NP in the CKM matrix.

CALC2015 Workshop / **65**

Static potential in perturbative QCD: the results and applications

Author: Andrei Kataev[1]

Co-author: Victor Molokoedov [2]

[1] *Institute for Nuclear Reserch of the Russian Academy of Sciences*

[2] *Moscow Institute of Physics and Technology State University*

Corresponding Author: kataev@ms2.inr.ac.ru

The current knowledge on the three-loop approximation of the static potential in QCD is reviewed . The results are used for the determination of the 4-th order approximation of the QCD β-function and for the e^+e^--annihilation R-ratio in the V-scheme. The results are compared with the ones obtained in the $\overline{MS}$-scheme and minimal MOM scheme in the Landau gauge. The common features of the QED expression for the β-function in the V-scheme and MOM scheme are summarized.

CALC2015 Workshop / **66**

β-expansion in QCD and generalization of BLM optimization procedure

Author: Andrey Kataev[1]

Co-author: Sergey Mikhailov [2]

[1] *INR RAS*

[2] *Joint Institute for Nuclear Research*

Corresponding Author: mikhs@theor.jinr.ru

We discuss generalizations of the Brodsky–Lepage–Mackenzie optimization procedure for renormalization group invariant quantities. In this respect, we discuss in detail the features and construction of the {β}-expansion presentation instead of the standard perturbative series with regard to the Adler D- function and Bjorken polarized sum rules S obtained in the order of $O(\frac{4}{s})$. Based on the {β}-expansion, we analyze different schemes of optimization, numerically illustrating their results

CALC2015 Workshop / **67**

Massive gluons

Author: Sergey Larin[1]

[1] *INR RAS, Moscow*

The QCD Lagrangian is modified by adding gluon masses to ensure the agreement of the theory with experiments. On mass-shell renormalizability of the resulting model is demonstrated.

CALC2015 Workshop / **68**

Exploring the 3-dimensional structure of the nucleon with QCD

Author: Igor Cherednikov[1]

[1] *University of Antwerp*

We address several unresolved issues in the QCD-based description of the three-dimensional inner structure of the nucleon accessible in the current and planned high-energy experiments. The emphasis is placed on the comparison of existing perturbative resummation methods and corresponding evolution equations (DGLAP, BFKL, CCFM, SCET etc.) for transverse-momentum dependent parton distribution functions (TMD). Practical implications of recent achievements in the theory of TMD are also presented.

Student talks / **69**

The Nielsen Identities - a useful tool for showing gauge invariance

Author: Anne Ernst[1]

[1] *University of Hamburg, II. Theoretical Institute*

Nielsen Identities are a generalisation of the Slavnov-Taylor identities which show the gauge parameter dependence of 1-PI diagrams. They are derived from a generalised BRST-invariance of the Lagrangian, in which the gauge parameter gets promoted to a scalar field. I will derive fermionic Nielsen Identities for generating functionals and proper vertex functions, and show how to use them both in general and in perturbation theory.

CALC2015 Workshop / **70**

Six loop beta function in φ^4 model

Author: Mikhail Kompaniets[1]

Co-author: Erik Panzer [2]

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

[2] *Institute des Hautes Etudes Scientifiques*

Using R* operation, IBP and integration of hyperlogarithms (HyperInt)
we perform 6 loop calculation of beta function in ϕ^4 model.
One of the remarkable features of this result is that 6 loop term contains multiple zeta values. We discuss different aspects of this calculations as well as series resummation and predictions for 6 loop term based on Kazakov/Shirkov/Tarasov (1979) paper

Student talks / **71**

Neutralino Dark Matter and Other LHC Predictions from Quasi Yukawa Unification

Authors: Cem Salih Un[1]; Sukru Hanif Tanyildizi[2]; qaisar shafi[3]

[1] *University of Delaware*

[2] *JINR*

[3] *university of delaware*

We explore the dark matter and LHC implications of t-b-tau quasi Yukawa unification in the framework of supersymmetric models based on the gauge symmetry G=$SU(4)_c \times SU(2)_L \times SU(2)_R$. The deviation from exact Yukawa unification is quantified by a dimensionless parameter C (|C| <~ 0.2), such that the Yukawa couplings at M_GUT are related by y_t:y_b:y_tau=|1+C| : |1-C| : |1+3C|. In contrast to earlier studies which focused on universal gaugino masses, we consider non-universal gaugino masses at M_GUT that are compatible with the gauge symmetry G. We perform two independent scans of the fundamental parameter space, one of which employs ISAJET, while the other uses SoftSusy interfaced with SuperIso. These scans reveal qualitatively similar allowed regions in the parameter space, and yield a variety of neutralino dark matter scenarios consistent with the observations. These include stau and chargino coannihilation scenarios, the A-resonance scenario, as well as Higgsino dark matter solution which is more readily probed by direct detection searches. The gluino mass is found to be <~ 4.2 TeV, the stop mass is >~ 2 TeV, while the first two family squarks and sleptons are of order 4-5 TeV and 3 TeV respectively.

CALC2015 Workshop / 72

Evaluating Feynman integrals by uniformly transcendental differential equations

Author: Vladimir Smirnov[1]

[1] *SINP MSU*

Evaluating Feynman integrals by uniformly transcendental differential equations

CALC2015 Workshop / 74

Pair production of quarkonia at NLO

Author: Andrei Onishchenko[None]

We will describe the methods and techniques used both to perform and automate calculations of quarkonia production at NLO accuracy. We will also present some preliminary results for the case of pair production.

CALC2015 Workshop / 75

Higgs bosons in SM extensions: temperature effective loop corrections

Author: Mikhail Dolgopolov[1]

[1] *Samara State University*

The development of the catastrophe theory methods is proposed
for the effective Higgs type potentials stability conditions. The role of temperature effective loop corrections
and the temperature evolution of phase transitions in some advanced two-doublet models are considered.

CALC2015 Workshop / **76**

New developments in the MCSANC tool.

Author: Andrey Sapronov[1]

[1] *Joint Inst. for Nuclear Research (RU)*

Corresponding Author: andrey.sapronov@cern.ch

The report presents new features of the MCSANC program, a Monte Carlo tool for calculation of the next-to-leading order electroweak and QCD corrections to various Standard Model processes.
The extensions concern implementation of the Drell-Yan-like processes and include systematic treatment of the photon-induced contribution in proton-proton collisions and electroweak corrections beyond NLO approximation. There are also technical improvements such as calculation of the forward-backward asymmetry for neutral-current Drell-Yan process. The updated code is suitable for studies of the effects due to QED, electroweak and QCD radiative corrections to Drell-Yan (and several other) processes at the LHC.

CALC2015 Workshop / **77**

Supersymmetric Yang-Mills theory in higher dimensions

Author: Dmitry Vlasenko[1]

[1] *Southern Federal University*

The SYM theory in higher dimensions, namely D=6,8,10 cases were considered. The main interest is UV divergence of the theory, basically leading pole behavior. Based on calculation of some first loops an iterative procedure which allows to predict leading poles in each order without its direct calculation were constructed. Using this procedure a set of equations which provides a possibility to investigate divergent properties of a theory in leading order was obtained. Also some features and interesting properties of these equations were revealed.

CALC2015 Workshop / **78**

Search for BFKL-evolution effects at high energy collisions

Author: Victor Kim[1]

[1] *St. Petersburg Nuclear Physics Institute - PNPI, Gatchina*

Brief overview of searches for BFKL-evolution manifestations at high energies is presented. Data comparison with the predictions of BFKL-evolution in the leading logarithm (LL) and next-to-leading logarithm (NLL) approximations are discussed.

CALC2015 Workshop / **79**

Dynamical gluon mass and linear confinement

Author: César Ayala[1]

[1] *Department of Theoretical Physics and IFIC, University of Valencia and CSIC, E-46100, Valencia, Spain*

We investigate a novel non-perturbative QCD running coupling motivated by confinement and asymptotic freedom.
This coupling is formulated in terms of a gluon mass function analogous to that of Dyson-Schwinger approaches. We calculate the corresponding potential à la Richardson and are able to reproduce the Cornell potential. The resulting gluon mass is close to the Dyson-Schwinger parameter.

Afternoon Session / 80

QCD evaluations with IR finite couplings

Author: Gorazd Cvetic[None]

We present several schemes of QCD with running coupling with finite value in the infrared (IR). Such couplings, in comparison with usual perturbative couplings with Landau singularities, usually (but not always) contain nonperturbative contributions and, when combined with OPE, better describe IR sector. We then show that evaluation of spacelike renormalization group invariant QCD quantities, such as current correlators or structure functions, in the form of truncated power series of such IR finite couplings often leads to unphysical and highly divergent results. We show that, instead, truncated expansions in the logarithmic derivatives of the coupling are more stable and keep the nonperturbative contributions under control. Extension to evaluation of timelike quantities is explained. Programs in Mathematica and in Fortran for evaluations are presented.

CALC2015 Workshop / 81

The energy evolution of dark matter halos: how to fit observational data?

Author: Anton Baushev[1]

[1] *Observatotio Cerro Calan, Departamento de Astronomia, Universidad de Chile, Santiago, Chile*

The question of the density profile of dark matter halos is extremely important for various topics of the dark matter physics. In principle, it can shed light on the physical nature of the dark matter. Now the contradiction between the standard dark matter paradigm and observations seems obvious. The main aim of the talk is to discuss the ways to agree theory with observations. We show that it is the energy evolution of a forming halo that determines the shape of its density profile. If the energy relaxation is moderate, the profile has a central core, and its shape exactly the profile that observations suggest for the central region of galaxies.

If the dark matter halos have cores, it leads to many important consequences. A very general cosmological consideration suggests that, along with galactic dark matter halos, much smaller dark matter structures may exist. These structures are usually called 'clumps', and their mass extends to $10^{-6} M_{\odot}$ or even lower. The clumps should give the main contribution into the signal of dark matter annihilation, provided that they have survived until the present time. We consider cored clumps and show that they are significantly less firm than the standard cuspy ones.

82

Registration

83

Registration

CALC2015 Workshop / **84**

Recent developments in the fast reproduction of QCD calculations with the APPLgrid project

Author: Mark Sutton[1]

[1] *University of Sussex (GB)*

Corresponding Author: sutt@cern.ch

Recent developments in the fast reproduction of the results of QCD calculations using the APPLgrid project are presented. The calculation of cross-sections at Next-to-Leading order in QCD involves the integration over the final state phase space in order to cancel the infra-red divergences. For the calculation of cross sections for observables at hadron-hadron colliders this integration requires the Monte Carlo generation of a large number of event weights. These calculations typically need to be repeated if a different choice of parton densities within the proton are required or a different choice of factorisation or renormalisation scales. This makes the full calculation with many of the available parton density function error sets, and indeed the inclusion of these calculations in iterative fits to the proton parton densities, computationally prohibitive.
The APPLgrid project allows the {\em a posteriori} inclusion of the parton densities in the calculation of the cross section by storing the weights from the Monte Carlo integration over the hard-subprocess phase space from the underlying QCD Calculation code in a look-up table so that the full calculation need be performed only once, after which the cross section can be recreated with any parton density set using a fast convolution over the stored weights This reduces the time required to obtain the cross section from many days, down to a few milliseconds. Detailed examples from the increasingly large menagery of QCD calculations of physics processes interfaced to APPLgrid will be presented.

CALC2015 Workshop / **85**

Two-loop matching relations in the SM

Author: Oleg Veretin[1]

[1] *University of Hamburg, II. Theoretical Institute*

We study the relationships between the basic parameters of the on-shell renormalization scheme and their counterparts in the $\overline{\rm MS}$ scheme at full order $\mathcal{O}(\alpha^2)$ in the Standard Model. These enter as threshold corrections the renormalization group analyses underlying, e.g., the investigation of the vacuum stability. To ensure the gauge invariance of the parameters, in particular of the $\overline{\rm MS}$ masses, we work in R_ξ gauge and systematically include tadpole contributions. We also consider the gaugeless-limit approximation and compare it with the full two-loop electroweak calculation.

CALC2015 Workshop / **86**

Towards four-loop gauge coupling beta-functions in the SM

Author: Andrey Pikelner[1]

[1] *BLTP JINR*

We present our progress in calculation of four-loop beta-functions in the SM. The results for the strong coupling is obtained in the gaugeless limit. Pure QCD part coincides with known expressions. The method of calculation and validation of the result are discussed.

Student talks / 87

Two-particle disintegration processes in covariant approach

Author: Philip Kuznietsov[1]

[1] *Institute of Electrophysics and Radiation Technologies NAS of Ukraine*

We provide a method to construct covariant two-particle nonlocal matter field disintegration amplitude. One is a sum of traditional pole series and the regular part. We explore the deposits of regular part of amplitude, and its physical sense. In the amplitudes regular part achieved absence of the singularity when fragments are scattered at right angle.We use covariant approach with conserved EM current, which gives the ability to include strong interaction into QED. Therefore, we receive the ability to describe disintegration processes of nonlocal matter fields applying standard Feynman rules of QED. Inclusion of phase exponent into wave function receives a physical sense while we deal with the dominance of strong interaction in the process. We apply Green's function formalism to describe disintegration processes. General analysis of electro-break up process of compound scalar system is given. Precisely conserved nuclear electromagnetic currents at arbitrary q^2 are received. The only undefined quantity in theory is vertex function parameterization. Therefore, we have the opportunity to describe electron scattering processes taking into account minimal necessary set of parameters. A transition from virtual to real photon considered in photon point limit $q^2 \to 0$. Total expression for matrix element of disintegration process received. Observables are calculated and compared with experimental data for disintegration of $^3\mathrm{He}$ and $^3\mathrm{H}$ in the proposed approach. For this processes $\Sigma-$asymmetry energy dependence at the right angle was predicted.