

# 2nd International Workshop on QCD Challenges from pp to AA

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Other Institutes



## Book of Abstracts



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**Initial state physics in small collisions systems / 38****Bulk and Shear viscosity for small collision systems at LHC energies**

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We study the interplay of the contribution of bulk and shear viscosities in p-p and p-Pb collisions at LHC energies in the framework of the String Percolation Model which for high multiplicities exhibit a similar behavior as the geometric phase transition given in heavy ion collision. The results show that the bulk viscosity gives a relevant contribution to the overall viscosity of the formed system.

**Initial Conditions / 30****Inverse magnetic catalysis from the properties of the QCD coupling in a magnetic field**

**Author:** Alejandro Ayala<sup>None</sup>

We compute the vacuum one-loop quark-gluon vertex correction at zero temperature in the presence of a magnetic field. From the vertex function we extract the effective quark-gluon coupling and show that it grows with increasing magnetic field strength. The effect is due to a subtle competition between the color charge associated to gluons and the color charge associated to quarks, the former being larger than the latter. In contrast, at high temperature the effective thermo-magnetic coupling results exclusively from the contribution of the color charge associated to quarks. This produces a decrease of the coupling with increasing field strength. We interpret the results in terms of a geometrical effect whereby the magnetic field induces, on average, a closer distance between the (electrically charged) quarks and antiquarks. At high temperature, since the effective coupling is proportional only to the color charge associated to quarks, such proximity with increasing field strength makes the effective coupling decrease due to asymptotic freedom. In turn, this leads to a decreasing quark condensate. In contrast, at zero temperature both the effective strong coupling and the quark condensate increase with increasing magnetic field. This is due to the color charge associated to gluons dominating over that associated to quarks, with both having the opposite sign. Thus, the gluons induce a kind of screening of the quark color charge, in spite of the quark-antiquark proximity. The implications of these results for the inverse magnetic catalysis phenomenon are discussed.

**New ideas to explore effects on small systems / 34****What can learn from non-extensive parameters in pp & pA collisions?**

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Identified hadron spectra from recent years are analyzed in the non-extensive thermodynamical framework. The Tsallis cut power-law is known to describe the  $p_T$  distributions for a wide energy range, but its origin is still unknown. We pursue the physical origin of this observation by investigating the center-of-mass energy, multiplicity, mass and strangeness dependency of the Tsallis  $q$  and  $T$  parameters comprehensively from  $ee$ ,  $pp$  to  $pA$  collisions. We describe the main characteristics of a statistical hadronization model that could explain our observations.

**Initial state physics in small collisions systems / 44**

## Small systems effects on SPM

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**New ideas to explore effects on small systems / 18**

## Revealing the source of the radial flow patterns in proton–proton collisions using hard probes

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In this work, we propose a tool to reveal the origin of the collective-like phenomena observed in proton–proton collisions. We exploit the fundamental difference between the underlying mechanisms, color reconnection and hydrodynamics, which produce radial flow patterns in Pythia 8 and Epos 3, respectively. Specifically, we proceed by examining the strength of the coupling between the soft and hard components which, by construction, is larger in Pythia 8 than in Epos 3. We study the transverse momentum ( $p_T$ ) distributions of charged pions, kaons and (anti) protons in inelastic  $pp$  collisions at  $\sqrt{s} = 7$  TeV produced at mid-rapidity. Specific selections are made on an event-by-event basis as a function of the charged particle multiplicity and the transverse momentum of the leading jet ( $p_T^{\text{jet}}$ ) reconstructed using the FastJet algorithm at mid-pseudorapidity ( $|\eta| < 1$ ). From our studies, quantitative and qualitative differences between Pythia 8 and Epos 3 are found in the  $p_T$  spectra when (for a given multiplicity class) the leading jet  $p_T$  is increased. In addition, we show that for low-multiplicity events the presence of jets can produce radial flow-like behavior. Motivated by our findings, we propose to perform a similar analysis using experimental data from RHIC and LHC.

**Jet physics / 33**

## Boson-jet correlations and boson-tagged jet fragmentation functions in heavy ion collisions with CMS

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A typical approach to study the quark gluon plasma produced in heavy ion collisions is to understand the passage of elementary particles through it. As electroweak bosons such as photons and Z bosons do not participate in the strong interaction, their correlation with jets within the same event is a clean probe of the medium-induced energy loss of jets. With high statistics PbPb and pp collision data taken at a center-of-mass energy of 5.02 TeV with the CMS detector, boson-jet correlations and, for the first time in PbPb collisions, photon-tagged jet fragmentation functions have been measured. These measurements provide strong evidence for medium-induced jet energy loss and offer a first look at jet substructure in photon-jet events.

**What Quark-Gluon Plasma in small systems might tell us about nucleons / 14**

## What Quark-Gluon Plasma in small systems might tell us about nucleons

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The origin of flow-like effects in small systems, such as those produced in ultra-relativistic proton-proton and proton-lead collisions, is still widely debated. In this talk, the goal is to look at possible consequences if indeed a mini-Quark-Gluon Plasma is formed in these collisions. It is argued that this could indicate a duality between the QGP phase and the color fields in hadrons. A qualitative dense field picture is presented for this duality and discussed.

(Based on arXiv:1709.03415)

**Experimental results on Heavy Ions / 11**

## Collectivity studies in pp, p-Pb and Pb-Pb collisions with ALICE at the LHC

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Evidence of the presence of collective phenomena has been observed in the final state hadronic observables of the strongly-interacting system created in Pb-Pb collisions. In addition, measurements in pp and p-Pb collisions as a function of event multiplicity at LHC energies have shown some features reminiscent of collectivity. Thanks to its excellent PID capabilities and  $p_T$  coverage at mid-rapidity, ALICE is an ideal instrument for the measurements of transverse momentum distributions, integrated yield and mean  $p_T$  of identified light hadrons. These measurements are important tools

to investigate the dynamics of the system under study. In the present contribution those measurements are reported for Pb-Pb collisions at the unprecedented centre of mass energy of  $\sqrt{s_{NN}} = 5.02$  TeV and are compared with results in pp and p-Pb collisions at the same energy. The measured spectral shapes at low and intermediate  $p_T$  in Pb-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV are also tested against results from hydrodynamic and recombination models. Boltzmann-Gibbs Blast Wave fits are used to quantify the radial expansion velocity and the kinetic temperature. The dependence of the blast-wave model parameters on the event multiplicity is also discussed.

**Jet physics / 23**

## **Toward Mueller-Tang jets at Next-to-leading order**

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As was pointed out long ago by Mueller and Tang, the BFKL hard Pomeron, at finite momentum transfer, can be investigated at hadron colliders by looking for the exclusive processes where the only observed radiation are two jets detected far apart in rapidity. The absence of any additional emission over a large rapidity region suggests that the color-singlet exchange contributes substantially to the jet-gap-jet cross section. The BFKL predictions for these processes have been studied at LL accuracy and partially also at NLL order. We present here the progress on the last ingredients that have to be taken into account: the NLO impact factors, improved Monte Carlo predictions, and evaluation at the current energy frontier.

**Heavy flavor and Quarkonia / 42**

**TBA**

**Author:** Federico Deganutti<sup>None</sup>

**Initial state physics in small collisions systems / 39**

## **Study of the event by event mean transverse momentum fluctuations in pp collision at LHC energies with percolation color sources**

**Authors:** Pablo Fierro<sup>None</sup>; irais bautista<sup>None</sup>

We present a study of the event by event mean transverse momentum fluctuations in high multiplicity pp and p-Pb collision systems at LHC energies in the framework of the String Percolation Model as a function of multiplicity. We found that data can be naturally described by the clustering of color sources that take place in the small collision systems in a similar manner as it does in heavy ion collisions.



**Quarkonia in heavy-ion collisions / 25****Quarkonia in heavy-ion collisions****Author:** Elena G. Ferreiro<sup>1</sup><sup>1</sup> *Universidad de Santiago de Compostela*

Quarkonium has been regarded as one of the golden probes to identify the phase transition from confined hadronic matter to the deconfined quark-gluon plasma (QGP) in heavy-ion collisions. Recent theoretical developments in the study of the  $J/\psi$  and  $\Upsilon$  families at the energies of Large Hadron Collider (LHC) are reviewed. In particular, the possible implications related to the production and propagation of quarkonia in proton-proton and proton-nucleus collisions are discussed. A special emphasis is put on the excited states such as the  $\psi'$ ,  $Y(2S)$  and  $Y(3S)$ .

**Heavy flavor and Quarkonia / 17****Neutral pion and  $\eta$  meson production in pp and p-Pb collisions with ALICE at the LHC****Author:** Pedro González Zamora<sup>1</sup><sup>1</sup> *FCMF-BUAP*

The ALICE experiment is dedicated to study the properties of the Quark-Gluon Plasma (QGP) which is expected to be formed in ultra-relativistic heavy ion collisions. Measurements of hadron production in pp and p-Pb collisions are of importance to understand the properties of this hot and dense medium. In pp collisions, meson spectra serve as a reference for heavy-ion collisions and add constrains to theoretical calculations such as NLO pQCD. In p-Pb, measurements of hadron spectra serve as reference to help disentangle initial and final-state effects for the hadron suppression observed at intermediate  $p_T$  in Pb-Pb collisions. Moreover, the measurement of neutral mesons ( $\pi^0$  and  $\eta$ ) is important to estimate the background in the direct photon analysis. ALICE has measured  $\pi^0$  and  $\eta$  mesons via their two photon decay channel  $\pi^0 \rightarrow \gamma\gamma$  and  $\eta \rightarrow \gamma\gamma$  and in the case of  $\pi^0$  in p-Pb collisions also via its Dalitz decay channel  $\pi^0 \rightarrow \gamma^*\gamma \rightarrow e^+e^-\gamma$ . Photons were measured by electromagnetic calorimeters, PHOS and EMCal, and by their conversions into  $e^+e^-$  in the central barrel using the TPC and ITS detectors.

In this talk, the measurement of the  $\pi^0$  and  $\eta$  mesons in pp and p-Pb collisions will be presented and compared to theoretical model calculations. The nuclear modification factor  $R_{p-Pb}$  will also be presented.

**Experimental results on Heavy Ions / 32****Charged particle spectra in Pb-Pb collisions and nuclear modification factors at  $\sqrt{s_{NN}} = 5.02$  TeV measured with ALICE****Author:** Julius Gronefeld<sup>1</sup><sup>1</sup> *GSI - Helmholtzzentrum für Schwerionenforschung GmbH (DE)***Corresponding Author:** j.gronefeld@cern.ch

ALICE is an experiment dedicated to the study of heavy-ion collisions at the LHC, with the aim of understanding the physics of the hot and dense deconfined medium produced in such collisions.

Since the start of its second phase of running the LHC is delivering collisions of protons and lead ions at the top energy of  $\sqrt{s} = 13$  TeV for pp and  $\sqrt{s_{NN}} = 5.02$  TeV for Pb–Pb collisions.

The study of inclusive charged particle spectra sheds light on parton energy loss in the medium by quantifying the suppression of hadron production at high transverse momentum ( $p_T$ ). A common way to investigate this effect is the determination of the nuclear modification factor ( $R_{AA}$ ) given by the ratio between a Pb–Pb centrality dependent  $p_T$  spectrum and a reference spectrum in pp collisions scaled by the number of binary collisions.

In this talk results on the transverse momentum distributions with ALICE are presented. A significant reduction of systematic uncertainties with respect to results at  $\sqrt{s_{NN}} = 2.76$  TeV was obtained. Spectra and  $R_{AA}$  will be shown in dependence on centrality. In addition the results will be compared to current models.

## Heavy flavor and Quarkonia / 4

### Investigating the multiplicity dependence in pp, pA and AA with EPOS 3

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EPOS3 is a minimum bias Monte-Carlo event generator used for Heavy Ion Collisions. It is successful in the description of particle spectra as well as flow-like observables and includes viscous hydrodynamics expansion, hadronic cascade, and heavy quark production.

In the beginning, we will present the general features of the model and show that multiple interactions play a central role for both flow-like and particle spectra.

Then, we will focus on the more specific case of heavy quark production and the study of the dynamics of high multiplicity pp events.

## Initial state physics in small collisions systems / 16

### Searching for high density effects in photon induced reactions

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We discuss possible processes which can be used to pin down the presence of high gluon densities in both photon-proton and photon-nucleus collisions. The presence of such high gluon density itself can then be argued to be characteristic for a regime of QCD where the possible on-set of gluon saturation can be observed. To this end we use the spinor helicity formalism to calculate the cross section for production of three partons of a given polarization in Deep Inelastic Scattering (DIS) off proton and nucleus targets at small Bjorken  $x$ . The resulting expressions are used to study azimuthal

angular correlations between produced partons in order to probe the gluon structure of the proton or nucleus.

**New ideas to explore effects on small systems / 15**

## **The Linear Sigma Model coupled to quarks to explore the QCD phase diagram.**

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We use the linear sigma model coupled to quarks to compute the effective potential beyond the mean field approximation, including the contribution of the plasma screening effects, at finite temperature and density. We determine uniquely the model coupling constants (the only free parameters in the model) and use them to study the phase diagram in the temperature-baryon chemical potential plane and to estimate the position of the critical end point.

**Initial Conditions / 3**

## **The parton-to-kaon fragmentation functions from global QCD fits at NLO**

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In this talk we revisit the global QCD análisis of the parton-to-kaon fragmentation functions at next-to-leading order accuracy using the latest experimental information on single-inclusive kaon production un electron-positron annihilation, lepton-nucleon deep-inelastic scattering, and proton-proton collisions. An excellent description of all data sets is achieved, and the remaining uncertainties in parton-to-kaon fragmentation functions are estimated and discussed based on the Hessian method.

**New ideas to explore effects on small systems / 43**

## **Energy and multiplicity dependence of charged particle production in pp collisions with ALICE at the LHC**

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The study of the charged particle production as a function of the multiplicity in small colliding systems, as pp, is an attractive tool to understand the similarities and differences between small and

large colliding systems. Evidence of similarities, like coherent and collective effects, well known in AA collisions, has been found experimentally even in small systems.

Recent results of the transverse momentum ( $p_T$ ) distributions of charged hadrons at central pseudo-rapidity as a function of multiplicity for pp ( $\sqrt{s} = 5.02$  and  $\sqrt{s} = 13$  TeV) are going to be presented.

In order to study the hard component of particle spectra, for pp collisions, a power law fit of the distributions for  $p_T > 4$  GeV/c is performed and the evolution with multiplicity of the resulting fit parameters is discussed. To the same purpose, the ratio of multiplicity-dependent yields over the minimum bias yield integrated over  $4 < p_T < 8$  GeV/c is studied and compared to results for heavy-flavour particles. Results are presented using two multiplicity estimators, at mid pseudo-rapidity ( $|\eta| < 0.8$ ) and forward-backward pseudo-rapidity ( $-3.7 < \eta < -1.7$  and  $2.8 < \eta < 5.1$ ) to study the differences caused by multiplicity selection in different pseudo-rapidity windows.

A comparison with Monte Carlo event generators and models, like EPOS-LHC and PYTHIA 8 and 6, is also included.

## Jet physics / 31

### Parton energy loss: From AA to pp

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Small collision systems exhibit collective effects like those seen in AA collisions, which sets the foundation to postulate the formation of a QGP even in small systems.

While indeed most if not all observations between pPb and PbPb at the LHC look alike, clear final state effects as charged particle or jet suppression induced by parton energy loss as known from hot nuclear matter have not been seen.

However, calculations employing parton energy loss formalism, which are successfully used in AA, predict a clear suppression effect that should be present in high multiplicity pPb collisions.

In the talk I will discuss generator-level studies based on PYTHIA to show that parton energy loss -if indeed present- may be shadowed by other effects such as those arising from MPI and hence are not directly observable in particle spectra for small collision systems.

## New ideas to explore effects on small systems / 36

### Universality of particle production and energy balance in hadronic and nuclear collisions

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A study of the universality of multihadron production in nucleus-nucleus and pp/ $\bar{p}$ p collisions is performed using the dependencies of the midrapidity pseudorapidity and transverse energy densities and of the mean multiplicity on the collision energy and on the number of nucleon participants,

or centrality, in the energy range from a few GeV to a few TeV. The approach in which the multi-particle production is driven by the dissipating centrality-dependent effective energy of participants is introduced exploiting the earlier proposed consideration that combines the constituent quark picture with Landau hydrodynamics. Within this approach, proposed by E. Sarkisyan and A. Sakharov (2004), the data on the energy dependence of the global variables studied and the pseudorapidity spectra from the most central nuclear collisions are well reproduced. The centrality dependence of the midrapidity pseudorapidity and transverse energy densities of charged particles are well described pointing to a similarity in the most central collisions and centrality data. The study of the mean multiplicity centrality dependence reveals a new scaling between the measured and calculated pseudorapidity spectra. Using this scaling, called the energy balanced limiting fragmentation scaling, one reproduces the pseudorapidity spectra at all centralities. The obtained scaling clarifies on the differences in the multiplicity centrality dependence from RHIC and LHC as well as on this dependence of the midrapidity pseudorapidity density vs. multiplicity at RHIC. A complementarity in the multiplicity energy dependence in the most central collisions and centrality data is obtained. A new regime in heavy-ion collisions is pointed out to occur at  $\sim 1$  TeV. Predictions are made for the forthcoming higher-energy measurements in pp and heavy-ion collisions at the LHC.

## ALICE Overview / 40

### ALICE Overview

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## New ideas to explore effects on small systems / 24

### Study the new phenomena using the underlying event

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TBA

## Nuclear like effects in pp collisions and the clustering of color sources / 2

### Nuclear like effects in pp collisions and the clustering of color sources

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Nuclear like effects are produced in pp collisions as a consequence of the clustering of color sources. In this framework are discussed the long range rapidity correlations, ridge structure, elliptic flow, multiplicity dependence of quarkonium production,  $p_T$  dependence of B/M ratios and quarkonium incoherent production.

**The evolution of jets as QGP probe / 21**

**TBA**

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**The evolution of jets as QGP probe / 29**

**The evolution of jets as QGP probe**

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**Initial state physics in small collisions systems / 22**

**Initial state and final state effects on azimuthal correlations in p+p and p+A collisions.**

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Observations of long range azimuthal correlations in small collision systems (p+p/A) have triggered an enormous excitement in the heavy-ion community. However, it is presently unclear to what extent the experimentally observed correlations should be attributed to initial state momentum correlations and/or the final state response to the initial state geometry. Starting from a brief overview of the competing explanations, I will discuss recent theoretical progress to quantify the relative importance of initial state and final state effects and distinguish their signatures.

**Review of current status (Open questions) / 28**

**Review of current status (Open questions)**

**Author:** Jurgen Schukraft<sup>1</sup>

<sup>1</sup> CERN**Corresponding Author:** jurgen.schukraft@cern.ch**New Facilities for Heavy Ions / 27**

## The sPHENIX Calorimeter System

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sPHENIX experiment is proposed to succeed the current PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC). sPHENIX experiment is capable of measuring jets, jet correlations and upsilons to determine the temperature dependence of transport coefficients and the color screening length in the quark-gluon plasma. From January to February 2017, sPHENIX Collaboration conducted test beam experiment at Fermilab Test Beam Facilities to study the performance of the 2017 prototype electromagnetic calorimeter and hadronic calorimeter. In this talk, we will present our studies on the light collection efficiency and uniformity of light guides for the sPHENIX electromagnetic calorimeter. Test beam data acquisition, electromagnetic shower calibrations, hodoscope position corrections, and position scan analysis for electromagnetic calorimeter will be discussed.

**Initial state physics in small collisions systems / 26**

## De-Confinement and Percolation in nucleus-nucleus and hadron-hadron collisions

**Author:** Brijesh Kumar Srivastava<sup>1</sup>**Co-authors:** Carlos Pajares <sup>2</sup>; Rolf Paul Scharenberg <sup>3</sup>; A. S. Hirsch<sup>1</sup> *Purdue University (US)*<sup>2</sup> *University Santiago de Compostela*<sup>3</sup> *Purdue University***Corresponding Authors:** brijesh.kumar.srivastava@cern.ch, pajares@fpaxp1.usc.es, rolf.paul.scharenberg@cern.ch

A possible phase transition of strongly interacting matter from hadron to quark-gluon plasma state has received considerable interest in the past. What conditions are necessary in the pre-equilibrium stage to achieve deconfinement and perhaps subsequent quark-gluon plasma formation? In this talk the Color String Percolation Model (CSPM) has been explored to describe the initial stages in high energy A-A and *pp* collisions in the soft region. The thermodynamics of clustering can be addressed by extracting the temperature from the transverse momentum spectra of charged hadrons. The clustering of color sources has a clear physical basis and belongs to the non-perturbative domain of the QCD and manifests its most fundamental features.

**New Facilities for Heavy Ions / 13****MExNICA: theory and experiment collaborative efforts to study nuclear matter under extreme conditions at NICA-JINR****Author:** Maria Elena Tejeda-Yeomans<sup>1</sup><sup>1</sup> *Universidad de Sonora***Corresponding Author:** unidusu@gmail.com

In this talk I will present some of the challenges and opportunities to study nuclear matter under extreme conditions using the Multi-Purpose Detector (MPD) at the Nuclotron--based Ion Collider Facility (NICA) which is located at the Joint Institute for Nuclear Research (JINR), in Dubna, Russia. I will summarize the advances made by the collaboration MExNICA within the planned program for theoretical and experimental studies in NICA in: calculation of observables, simulations (physics and detector) and preliminary prototype design. MExNICA is a multidisciplinary group of scientists which will develop observables suitable for the study of extreme nuclear matter and which will design and build a detector, to be installed in the MPD-NICA. The MExNICA proposed detector will be a beam monitor and it will contribute to the study of collision centrality in a range of pseudorapidity which will complement the MPD. The detector capabilities will allow the exploration of theoretical observables in the QCD phase diagram landscape.

**New ideas to explore effects on small systems / 12****Identified hadron production as a function of multiplicity and sphericity in pp collisions at  $\sqrt{s} = 13$  TeV****Author:** Vytautas Vislavicius<sup>1</sup><sup>1</sup> *Lund University (SE)***Corresponding Author:** vytautas.vislavicius@cern.ch

To understand the origins of collective-like phenomena observed in pp collisions at LHC energies, underlying mechanisms have to be identified. In this context, event shape observables provide a possible tool to disentangle soft and hard contributions to particle production. We report on a study of the production of pions, kaons and protons as a function of transverse sphericity in high multiplicity pp collisions at  $\sqrt{s} = 13$  TeV measured with the ALICE detector. The  $p_T$ -differential  $K/\pi$  and  $p/\pi$  ratios in different sphericity classes are presented. The results are compared to the predictions from PYTHIA 8 event generator. Finally, the evolution of charged particle mean transverse momentum with multiplicity and transverse sphericity is discussed in the context of radial flow or flow-like effects.

**Jet physics / 19****Energy density and path-length dependence of the fractional momentum loss in heavy-ion collisions at  $\sqrt{s_{NN}}$  from 62.4 to 5020 GeV****Author:** Omar Vázquez Rueda<sup>1</sup><sup>1</sup> *Universidad Nacional Autónoma (MX)*



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In this work a study of the fractional momentum loss ( $S_{\text{loss}}$ ) as a function of the characteristic path-length ( $L$ ) and the Bjorken energy density times the equilibration time ( $\epsilon_{\text{Bj}}\tau_0$ ) for heavy-ion collisions at different  $\sqrt{s_{\text{NN}}}$  is presented. The study has been conducted using inclusive charged particles from intermediate to large transverse momentum ( $5 < p_{\text{T}} < 20$ , GeV/ $c$ ). Within uncertainties and for all the transverse momentum values which were explored, the fractional momentum loss linearly increases with  $(\epsilon_{\text{Bj}}\tau_0)^{3/8}L$ . The functional form of  $S_{\text{loss}}$  vs.  $(\epsilon_{\text{Bj}}\tau_0)^{3/8}L$  seems to be universal. Moreover, for identified charged hadrons a linear relationship between  $S_{\text{loss}}$  and  $L$  is also observed. The behaviour of data could provide important information aimed to understand the parton energy loss mechanism in heavy-ion collisions and some insight into the expected effect for small systems.

**Heavy flavor and Quarkonia / 35**

## D meson nuclear modification factor and $v_n$ harmonics in PbPb collisions at 5.02 TeV with CMS

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The measurement of heavy flavour production is a powerful tool to study the properties of the high-density QCD medium created in heavy-ion collisions as heavy quarks are sensitive to the transport properties of the medium and may interact with the QCD matter differently from light quarks. In particular, the comparison between the nuclear modification factors (RAA) of light- and heavy-flavour particles provides insights into the expected flavour dependence of in-medium parton energy loss. Furthermore, azimuthal anisotropy coefficient ( $v_n$ ) of heavy-flavor particles provide insights into the degree of the thermalization of the bulk medium at low  $p_{\text{T}}$ , and unique information about the path length dependence of heavy quark energy loss at high  $p_{\text{T}}$ . Using the large statistics proton-proton and PbPb samples collected at 5.02 TeV during the 2015 LHC run, high precision open charm measurements are performed with the CMS detector in a wide transverse momentum range. This allows us to set an important milestone in our understanding of the interactions between heavy quarks and the medium. In this talk, the most recent results of RAA,  $v_2$  and  $v_3$  of D0 mesons in PbPb collisions at 5.02 TeV are presented and compared to the same results for charged hadrons at the same energy.

**Heavy flavor and Quarkonia / 41**

## Open beauty production and modifications in PbPb collisions at 5.02 TeV with CMS

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Beauty production and phenomena in heavy-ion collisions are considered to be one of the key measurements to address the flavour-dependence of in-medium energy loss in PbPb collisions at the LHC. The CMS experiment has excellent capabilities for measuring b-quark production thanks to the excellent performances of its muon and tracker system, allowing the measurement of  $J/\Psi$  mesons from B meson decays, separately from prompt production, as well as fully reconstructed B mesons. In this talk, CMS will present the measurement of the  $R_{AA}$  for  $J/\Psi$  produced in B meson decays, in PbPb collisions at  $\sqrt{s_{\text{NN}}} = 5.02$  TeV, as a function of transverse momentum, rapidity and event

centrality. As well as the measurement of  $R_{AA}$  for fully reconstructed B mesons in PbPb collisions at 5.02 TeV.

### The evolution of jets as QGP probe / 20

TBA

### Heavy flavor and Quarkonia / 5

## Quarkonium production in dilute and dense systems

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The unprecedented collision energies at LHC allow for a detailed investigation of quarkonium production in pp, p-Pb and Pb-Pb collisions. Since the time scales between the production of heavy quarks and their hadronisation are well separated, quarkonia are a valuable messenger from the hot and dense matter which can be created in heavy-ion collisions. Recent results indicate that also high-multiplicity pp or p-Pb collisions exhibit nuclear and collective effects, reminiscent of those in heavy-ion collisions. Quarkonia provide information on these effects from the perspective of hard processes.

We will present the most recent results on quarkonium production in pp, p-Pb and Pb-Pb collisions measured by the ALICE detector at mid- and forward rapidity. Emphasis will be placed on the multiplicity dependence of  $J/\psi$  production in high-multiplicity triggered pp collisions. The results are compared to available theoretical models.

### Heavy flavor and Quarkonia / 7

## Open heavy-flavour production in pp and p-Pb collisions with ALICE at the LHC

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Heavy-flavour quarks at the Large Hadron Collider (LHC) are produced during the initial stages in hard scatterings processes in pp and p-Pb collisions. Due to their large masses, their production can be calculated with perturbative quantum chromodynamics (pQCD) and provide an essential baseline for the studies of heavy-flavour production in heavy-ion collisions. Measurements of heavy-flavour in p-Pb collisions allow us to investigate possible modifications of the charmed-hadron yields due to cold nuclear matter effects and provide a reference for the interpretation of the corresponding studies in Pb-Pb collisions.

The measurement of open heavy-flavour hadrons as a function of charged-particle multiplicity in small collision systems provides an excellent tool to understand the production mechanisms, fragmentation properties, and the interplay between the hard and soft processes. The influence of multiple parton interactions (MPI) on the production of open heavy-flavours and its dependence on total

event multiplicity can not be neglected. More differential measurements as a function of event shape (sphericity) are also expected to improve the theoretical understanding of such mechanisms.

ALICE with high precision tracking, good vertex resolution, and excellent particle identification, allows for the reconstruction of D mesons ( $D^0$ ,  $D^+$ ,  $D^{*+}$  and  $D_s^+$ ) and charmed baryons ( $\Lambda_c^+$  and  $\Xi_c^0$ ), measurements of leptons from charm and beauty decays at central and forward rapidity, as well as reconstruction of jets with D mesons at central rapidity. We will present the recent results on charmed mesons and baryons production at mid-rapidity in pp collisions at  $\sqrt{s} = 5.02, 7, 8$  and 13 TeV and in p-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV, collected with the ALICE detector. In particular, we will show the production cross section, nuclear modification factor, yields as a function of charged-particle multiplicity, and  $D^0$  meson production as a function of event transverse sphericity. Recent results on the heavy-flavour production through leptonic decay channels will also be discussed, in particular for electrons from beauty hadron decays at mid-rapidity ( $|y| < 0.6$ ) and muons at forward rapidity ( $2.5 < y < 4$ ) in p-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV. The results will be compared with theoretical model predictions.