

Hard Probes 2012

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Book of Abstracts

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Parallel VA: Quarkonia / 4**Quarkonia production in relativistic heavy ion collisions****Author:** Che-Ming Ko¹**Co-authors:** Kyonchol Han²; Taesoo Song²¹ *Texas A&M University*² *Texas A&M University***Corresponding Author:** ko@comp.tamu.edu

Using the hydrodynamic model to describe the dynamics of heavy ion collisions, we have studied quarkonia production in these collisions by including both their dissociation in initial cold nuclear matter and subsequently produced quark-gluon plasma [1-4]. For the latter, we used the screened Cornell potential and the next-to-leading order perturbative QCD to determine, respectively, their in-medium properties and dissociation cross sections. Our results for the dependence of the quarkonia nuclear modification factors on the collision centrality as well as the quarkonia transverse momentum indicate that including medium modifications of the quarkonia properties in the quark-gluon plasma gives a better description of the experimentally data measured at SPS, RHIC and LHC.

References

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- 2) T. Song, K. Han, and C. M. Ko, "Charmonium production in relativistic heavy-ion collisions", *Phys. Rev. C* 84, 034907 (2011).
- 3) T. Song, K. C. Han, and C. M. Ko, "Bottomonia suppression in heavy ion collisions at RHIC and LHC", *Phys. Rev. C* 85, 014902 (2012).
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Board: 4.1 / 5

Interplay between hard and soft physics in PbPb collisions at the LHC**Author:** Sergey Petrushanko¹**Co-authors:** Alexander Snigirev¹; Alexey Belyaev¹; Elena Rogochaya²; Igor Lokhtin¹; Lyudmila Malinina³¹ *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University*² *Joint Institute of Nuclear Research, Dubna*³ *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University & Joint Institute of Nuclear Research, Dubna***Corresponding Author:** sergeant@mail.cern.ch

The started LHC heavy ion program makes it possible to probe new frontiers of the high temperature Quantum Chromodynamics. The first LHC data on multiplicity, hadron spectra, elliptic flow and femtoscopic correlations from PbPb collisions at center-of-mass energy 2.76 TeV per nucleon pair are analyzed in the framework of the HYDJET++ model which describes relativistic heavy ion collisions as a superposition of the soft, hydro-type state and the hard state resulting from multi-parton fragmentation. The key influence of the jet production mechanism on the physics observables is discussed.

Board: 4.2 / 6

Effects of quarks on the formation and evolution of $Z(3)$ walls and strings in relativistic heavy-ion collisions

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We investigate the effects of explicit breaking of $Z(3)$ symmetry due to the presence of dynamical quarks on the formation and evolution of $Z(3)$ walls and associated QGP strings within Polyakov loop model. We carry out numerical simulations of the first order quark-hadron phase transition via bubble nucleation (which may be appropriate, for example, at finite baryon chemical potential) in the context of relativistic heavy-ion collision experiments. Using appropriate shifting of the order parameter in the Polyakov loop effective potential, we calculate the bubble profiles using bounce technique, for the true vacuum as well as for the metastable $Z(3)$ vacua, and estimate the associated nucleation probabilities. These different bubbles are then nucleated and evolved and resulting formation and dynamics of $Z(3)$ walls and QGP strings is studied. We discuss various implications of the existence of these $Z(3)$ interfaces and the QGP strings, especially in view of the effects of the explicit breaking of the $Z(3)$ symmetry on the formation and dynamical evolution of these objects.

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Parallel IVA: heavy flavour / 8

Toward a Complete Description of Heavy Flavor Transport in Medium

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We evaluate heavy-flavor (HF) transport in relativistic heavy ion collisions within a nonperturbative (strong-coupling) framework. In the Quark-Gluon Plasma, heavy-quark diffusion coefficients are obtained from a potential-based T-matrix approach, which builds up resonance correlations toward the phase transition region. Those resonance correlations are also utilized for hadronizing heavy quarks via resonance recombination with light quarks from the medium. In the hadron-resonance gas, the diffusion coefficients of HF mesons are calculated in terms of empirical scattering amplitudes obtained from effective hadronic theory. A carefully constrained hydrodynamic model is used for the evolution of the background medium to implement the diffusion and hadronization components via relativistic Langevin simulations. Our calculations thus represent a conceptually self-consistent strongly-coupled framework for HF probes at both micro- and macroscopic levels. Pertinent HF observables (electron and D-meson spectra and v_2) are computed and show good agreement with available RHIC and LHC data.

Parallel VA: Quarkonia / 10

Upsilon Suppression in PbPb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV

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We suggest that gluon-induced dissociation and screening of the $Y(nS)$ states together with feed-down explain the suppression of the $Y(2S+3S)$ states relative to the $Y(1S)$ ground state that has been observed by CMS in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV at the CERN LHC.

The minimum-bias gluodissociation cross sections of the $1S$ - $3S$ states are calculated using a screened Cornell potential and a thermal gluon distribution. The $3S$ state dissolves due to screening before sizeable gluodissociation occurs, but for the $2S$ and $1S$ states there is an interplay between screening, gluodissociation, and feed-down from the $\chi_b(2P)$ and $\chi_b(1P)$ states.

The calculated suppression of the $Y(2S)$ and $Y(3S)$ states relative to $Y(1S)$ is consistent with the CMS result, but allows for additional suppression mechanisms. The $Y(1S)$ suppression through gluodissociation is in excellent agreement with the CMS data.

Summary:

We calculate the gluodissociation and screening of $Y(1S)$, $(2S)$, $(3S)$ and χ_b states at LHC energies, plus the subsequent radiative feed-down via the χ_b states. The weakly bound $3S$ state dissolves due to screening already at temperatures $T \approx 200$ MeV which are close to the critical value. For $2S + 3S$ relative to the $1S$ state we find a substantial

suppression due to screening, gluodissociation and feed-down that is consistent with the value reported by CMS when the experimental error bars are considered, but allows for additional suppression mechanisms of the excited states.

We obtain reasonable results for the suppression of the excited states relative to the ground state in PbPb collisions at LHC energies with an initial central QGP temperature of $500 \text{ MeV} < T_0 < 800 \text{ MeV}$, an effective gluon mass of $m_g \approx 0-1 \text{ GeV}$, and a central-collision interaction time of $\tau_{int} \approx 5-8 \text{ fm/c}$. Screening and gluodissociation are relevant suppression mechanisms in particular for the higher bottomium states. The consideration of the subsequent feed-down cascade via the χ_b states turns out to be an essential ingredient in calculating the suppression of the excited states relative to the ground state.

Although screening of the strongly bound $1S$ ground state is negligible, we find that its gluodissociation is sizeable due to the strong overlap of the $1S$ gluodissociation cross section with the thermal gluon distribution. Its observed suppression factor $R_{AA}(1S) \approx 0.62$ in minimum-bias PbPb collisions is mainly due to both direct gluodissociation of the $1S$ state, and to the melting and gluodissociation of the $\chi_b(1P)$ and $\chi_b(2P)$ states which partially feed the $1S$ state in pp, pbarp and $e+e^-$ collisions.

For a detailed comparison, one needs data with better statistics that is expected to become available from the 2011 PbPb run at the LHC. If it turned out to be possible to measure the populations of the $2S$ and $3S$ states very precisely, one could use this as a fairly accurate thermometer for the initial temperature T_0 of the quark-gluon plasma. On the other hand, substantial deviations from the experimental values might indicate that further mechanisms contribute to the suppression. It may, however, also turn out that the gluon distribution is not fully thermalized, in particular, in the longitudinal direction.

References:

- [1] S. Chatrchyan et al., CMS Coll., Phys.Rev.Lett. 107 (2011) 052302
- [2] F. Brezinski and G. Wolschin, Phys.Lett. B707 (2012) 534-538

Parallel IIIB: Jet quenching and energy loss / 12**Out of Medium Fragmentation from Long-Lived Jet Showers****Author:** Jorge Casalderrey-Solana¹**Co-authors:** Jose Guilherme Milhano²; Paloma Quiroga-Arias³¹ *U. de Barcelona*² *CENTRA-IST & CERN*³ *LPTHE***Corresponding Author:** jorge.casalderrey@ub.edu

We study the time structure of vacuum jet evolution via a simple uncertainty principle estimate in the kinematic range explored by current heavy ion collisions at the LHC. We observe that a large fraction of the partonic splittings occur at large times, of the order of several fm. We compare the time distribution of vacuum splittings with the distribution of path lengths traversed by jets in a heavy ion collision. We find that if no medium induced modification of the jet dynamics were present, a very large fraction (larger than 80% for inclusive jets) of the jet splittings would occur outside of the medium. We confront this observation with current available data on jet properties in heavy ion collisions and discuss its implications for the dynamics of jet-medium interactions.

Parallel IA: Quarkonia / 16**Improving the J/psi Production Baseline at RHIC and the LHC****Author:** Ramona Vogt¹**Co-author:** Randy Nelson¹¹ *LLNL and UC Davis***Corresponding Author:** vogt@lbl.gov

We assess the theoretical uncertainties on the inclusive J/psi production cross section in the Color Evaporation Model using values for the charm quark mass, renormalization and factorization scales obtained from a fit to the charm production data [1]. We use our new results to provide improved baseline comparison calculations at RHIC and the LHC. We calculate the fraction of J/psi production from B decays as a function of pT with these parameters. We also study cold matter effects on J/psi production at leading relative to next-to-leading order in the CEM within this approach [2].

[1] A. D. Frawley, R. Nelson and R. Vogt, in preparation.

[2] R. Nelson and R. Vogt, in progress.

Parallel IA: Quarkonia / 17**The relation between cross-section, decay width and imaginary potential of heavy quarkonium in a quark-gluon plasma.****Author:** Miguel Angel Escobedo¹

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Computations with weakly-coupled plasmas and some lattice results suggest that the heavy quarkonium potential has an imaginary part that is important in order to study dissociation. This imaginary part is due to the scattering with partons in the medium in a process called quasi-free dissociation. At temperatures much below dissociation another process that is known to be important is the gluon-dissociation. The aim of the talk is to clarify in a perturbative framework the relation of the different expressions for the quarkonium cross-sections that can be found in the literature with the quarkonium thermal width. Finally, with the use of effective field theories we evaluate the quasi-free and gluon-dissociation cross-sections in a wide range of temperatures ranging from the binding energy to the dissociation temperature.

Parallel IIIC: Electroweak Probes / 18

Measurement of electroweak boson production in PbPb collisions at 2.76TeV with CMS

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The unprecedented centre-of-mass energy available at the LHC offers unique opportunities for studying the properties of the strongly-interacting QCD matter created in PbPb collisions at extreme temperatures and very low parton momentum fractions. The Compact Muon Solenoid (CMS) is fully equipped to measure leptonic decays of electroweak probes in the high multiplicity environment of nucleus-nucleus collisions. Electroweak boson production is an important benchmark process at hadron colliders. Precise measurements of W and Z production in heavy-ion collisions can help to constrain nuclear PDFs as well as serve as a standard candle of the initial state in PbPb collisions at the LHC energies. The inclusive and differential measurements of the Z boson yield in the muon decay channel will be presented, establishing that no modification is observed with respect to next-to-leading order pQCD calculations, scaled by the number of incoherent nucleon-nucleon collisions. Measurements of the yield of W to $\mu\nu$ decays as a function of centrality and the W charge asymmetry as a function of rapidity show no modifications beyond isospin effects when compared to pp collisions. The status of the W and Z measurement in the electron decay channel will also be given. Results from the 2010 data taking period are reported and an outlook on the 2011 data analysis will be presented.

Parallel IIC: High pT suppression, Global Observables / 19

Measurement of charged hadron R_{AA} at high pT in PbPb collisions at $\sqrt{s}=2.76\text{TeV}$ with CMS

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The nuclear modification factor R_{AA} is one of the key signatures for the energy loss of fast partons traversing a QCD medium. Charged particle transverse momentum (p_T) spectra have been measured by CMS for pp and PbPb collisions at the same collision energy per nucleon pairs, $\sqrt{s_{NN}}=2.76$ TeV, corresponding to integrated luminosities of 230 nb⁻¹ and 150 ub⁻¹, respectively. Calorimeter-based high-transverse-energy jet triggers are employed to enhance the statistical reach of the high- p_T measurements. The pp results are compared to various generator tunes and also to an empirical scaling of different collision energies with $x_T=2p_T/\sqrt{s}$ over the p_T range up to 100 GeV/c. We have obtained R_{AA} in bins of collision centrality for the PbPb data sample dividing by the measured pp reference spectrum. In the range $p_T = 5-10$ GeV/c, the charged particle yield in the most central PbPb collisions is suppressed by up to a factor of 7. At higher p_T , this suppression is significantly reduced, approaching roughly a factor of 2 for particles with $p_T = 40 - 100$ GeV/c.

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One-loop Factorization for Inclusive Hadron Production in pA Collisions in the Saturation Formalism

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We demonstrate the QCD factorization for inclusive hadron production in pA collisions in the saturation formalism at one-loop order. We explicitly calculate both real and virtual gluon radiation diagrams and show explicitly that, the collinear divergences associated with the incoming parton distribution of the nucleon and the outgoing fragmentation function of the final state hadron, as well as the rapidity divergence with small- x dipole gluon distribution of the nucleus factorize into the splittings of the associated parton distribution and fragmentation functions and the energy (non-linear) evolution of the dipole gluon distribution function. The hard coefficient function is evaluated at one-loop order and contains no divergence.

Summary:

We carried out the single-inclusive hadron production in pA collision at one loop level. The proton is treated as a diluted system which, using collinear factorization, emits a quark or a gluon that eventually scatters off a dense target like a large nucleus. Here, the collinear factorization and the rapidity factorization enter on the same footing. It is then important to show that indeed the cross section can be written as a factorization of two pieces where each of them follows a different factorization scheme: one piece follows the normal collinear QCD factorization while the other one follows the small- x rapidity-factorization. This result represents a QCD factorization for hard processes in the saturation formalism at one loop.

Parallel IVC: Initial state and pA / 22

Di-hadron angular correlation as a probe of saturation dynamics

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Di-hadron angular correlations in the forward rapidity region of proton-nucleus collisions probe multi-gluon correlators (n-point functions of Wilson lines) in the

wave function of target nucleus at small x and thus, provide a more detailed picture of QCD dynamics at high energy (CGC). The Renormalization Group equations that govern the energy dependence of these n -point functions will be derived and their approximate solutions motivated. A connection to an alternative approach to high energy QCD, based on BJKP equation involving pomeron and Reggeon exchanges, will be made.

Parallel IA: Quarkonia / 23

Heavy-quarkonium suppression from medium-induced gluon radiation

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Quarkonium nuclear suppression in p-A collisions at large x_F can be accurately described in a model based on first principles (medium-induced gluon radiation) and depending on a single free parameter. Our results strongly support 'parton energy loss' as a dominant effect in quarkonium nuclear suppression, and moreover give some clue on the quarkonium hadroproduction mechanism.

Parallel IB: Jet quenching and energy loss / 24

Radiative Energy Loss in the absorptive QGP

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A firm knowledge of medium-induced energy loss mechanisms in the deconfined plasma state of QCD matter is essential for our understanding of phenomena such as strong jet quenching and high- p_T hadron suppression observed in high energy nuclear collisions at RHIC and LHC. Based on perturbative QCD calculations, it is commonly accepted that the radiative energy loss contribution is dominant, where heavy quarks radiate less than light partons. In these studies, however, possible damping mechanisms on bremsstrahlung gluons have so far been neglected.

In this talk it is argued that in an absorptive and polarizable plasma the radiation spectrum becomes significantly reduced, in particular, for charges with high initial energy [1]. This is because damping mechanisms in the absorptive medium may influence the formation of radiation, prominently, in the case of large formation times. Consequently, a suppression of the radiation spectrum has to be attributed to absorption rather than to coherence effects. Being quark mass independent, this new effect might provide a suitable explanation for the observed single electron puzzle. Moreover, as an imaginable damping mechanism, gluon bremsstrahlung from preformed radiation gluons could serve as a source for isotropic, low energy gluon radiation with a significant impact on phenomena studied at RHIC and even more at LHC.

[1] M. Bluhm, P. B. Gossiaux, J. Aichelin, Phys. Rev. Lett. 107, 265004 (2011).

Parallel IB: Jet quenching and energy loss / 25**Gauge invariant definition of the jet quenching parameter \hat{q}** **Authors:** Michael Benzke¹; Miguel Escobedo¹¹ *Technische Universität München (TUM)***Corresponding Author:** michael.benzke@tum.de

The jet quenching parameter \hat{q} describes the transverse momentum broadening of a high-energy parton moving through a thermal medium. In the past, several authors were able to relate this quantity to the expectation value of two light-cone Wilson lines. Recently, the results were re-obtained in a systematic way by employing effective field theory methods (Soft-Collinear Effective Theory). However, the calculations were only explicitly performed in a covariant gauge. General arguments were given, motivating the generalization of this result through the addition of transverse gauge links but the explicit derivation of this in effective field theory terms is missing. In this talk I will discuss how the adoption of a general gauge changes the picture and gives rise to a gauge invariant definition of the jet quenching parameter \hat{q} . Furthermore I will comment on practical applications of this result.

Plenary 1B / 26**Perturbative vs non-perturbative aspects of jet quenching: the role of color flow****Author:** Andrea Beraudo¹**Co-authors:** Guilherme Milhano¹; Urs Wiedemann¹¹ *CERN***Corresponding Author:** andrea.beraudo@cern.ch

Providing a unified description of the various “jet-quenching” observable nowadays available represents a deep challenge.

Several model calculations are available on the market, mostly based on the factorization between an energy loss occurring at the partonic level in the medium and a standard time-delayed non-perturbative hadronization stage taking place in the vacuum.

Two important features of QCD were so far ignored in the literature of jet-quenching, namely the correlations between successive gluon emissions (what is known in the vacuum as angular-ordering) and the analysis of color-flow.

I will briefly illustrate how the above features are essential to understand important QCD results in elementary collisions, so that studying how they are modified in the presence of a medium looks mandatory: this will be the main topic of my talk.

I will start reminding (very briefly) the audience recent findings on the “anti-angular ordering” of QCD antenna radiation in the medium. Then I will move to the problem of medium modification of color flow. I will show how radiative energy-loss calculations can be given a rigorous color-differential formulation and illustrate the implications of the modified color connections of the radiated gluons (with respect to a shower developing in the vacuum) at the hadronization stage. The phenomenological relevance for the interpretation of experimental results on quenching of hadron spectra and jet-fragmentation in AA collisions will be discussed.

Parallel IIIB: Jet quenching and energy loss / 27**The role of jet collimation in jet energy loss****Authors:** Jorge Casalderrey-Solana¹; Jose Guilherme Milhano²; Urs Wiedemann³¹ *Barcelona University*² *CENTRA-IST (Lisbon) and CERN-PH-TH*³ *CERN-PH-TH***Corresponding Author:** guilherme.milhano@cern.ch

The observation of a significant enhancement of the dijet asymmetry in PbPb collisions as compared to the pp reference case, compounded with the absence of modification of the azimuthal dijet distribution, led us to highlight the importance of medium induced transverse transport of soft quanta as a source of jet energy loss.

Here, we extend our analysis and explore the consequences of ‘jet collimation’ for more differential observables such as, but not restricted to, the dependence of jet energy loss on the leading jet energy as recently studied by CMS.

Parallel IVC: Initial state and pA / 28**Initial state and thermalization in the glasma****Author:** Francois Gelis¹**Co-authors:** Kevin Dusling²; Raju Venugopalan³; Thomas Epelbaum¹¹ *Institut de Physique Theorique*² *North Carolina State University*³ *Brookhaven National Laboratory***Corresponding Author:** francois.gelis@cea.fr

In the color glass condensate framework, the initial state of the system formed immediately after the collision of two heavy ions at high energy can be represented as a superposition of a classical color field and gaussian quantum fluctuations. This approximation is substantiated by results that show that all the leading logarithms of the collision energy are universal and can be factorized in distributions that represent each incoming nucleus. The fluctuating part of the initial color field results from a resummation of the modes that grow in the subsequent time evolution due to the Weibel instability.

We have carried out this resummation program fully for a simpler toy model that also exhibits similar instabilities, and we show that the instabilities drive the system towards local isotropy and thermal equilibrium.

References:

[1] Role of quantum fluctuations in a system with strong fields: Onset of hydrodynamical flow, K. Dusling, T. Epelbaum, F. Gelis, R. Venugopalan, 1009.4363 [hep-ph], Nucl. Phys. A 850, 69 (2011).

[2] Role of quantum fluctuations in a system with strong fields: Spectral properties and Thermalization, T. Epelbaum, F. Gelis, 1107.0668 [hep-ph], Nucl. Phys. A 872, 210 (2011).

Parallel IIB: Jet quenching and energy loss / 29**A probabilistic picture for in-medium jet evolution****Authors:** Edmond Iancu¹; Fabio Dominguez¹; Jean-Paul Blaizot¹; Yacine Mehtar-Tani¹¹ *IPhT (CEA-Saclay)***Corresponding Author:** yacine.mehtar-tani@cea.fr

We study the perturbative evolution of a jet via multiple gluon emissions induced by the interactions between the jet constituents and a dense QCD medium like a quark-gluon plasma. We focus on the typical medium-induced gluons emissions, for which the gluon formation time is much smaller than the overall size of the medium. We show that the typical time between two subsequent emissions is parametrically larger than the formation time for one gluon (in contrast to jet fragmentation in the vacuum, where these two scales get identified with each other). This separation of scales has a remarkable physical consequence: it implies that coherence phenomena are negligible and therefore successive emissions can be treated as independent from each other and ordered in time. This is important as it allows for a probabilistic interpretation of the in-medium jet fragmentation as a classical branching process, which is in particular suitable for implementation as an event generator.

Parallel IIC: High pT suppression, Global Observables / 30**Measurement of $dN/d\eta$ and $dET/d\eta$ in PbPb collisions at $\sqrt{s}=2.76\text{TeV}$ with CMS****Author:** Michael Murray¹**Co-author:** Collaboration CMS ²¹ *University of Kansas*² *CERN***Corresponding Author:** mjmurray@ku.edu

Measurements of the charged hadron multiplicity and transverse energy are presented for minimum bias PbPb collisions at a center-of-mass energy of 2.76 TeV per nucleon pair. The number of charged hadrons was obtained by two different methods based on the inner silicon pixel system of the CMS detector at the LHC. One technique involved counting the number of reconstructed single particle hits in the pixel detector, while the other formed hit pairs from the different detector layers. The two methods are in excellent agreement. For the transverse energy measurement, CMS has almost hermetic calorimetry with fine granularity and excellent resolution allowing to measure the energy over nearly the complete angular range. The measurements are performed as a function of pseudorapidity and centrality. The results are compared with heavy-ion results from earlier experiments, where a smooth dependence on the collision energy is observed. The centrality dependence of transverse energy production becomes steadily weaker as the pseudo-rapidity increases from 0 to 5.

Summary:

This work exploits the very large acceptance of CMS to measure the flow of energy and entropy over a very wide phase space.

Plenary 1B / 31**Advancing QCD-based calculations of energy loss**

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Co-authors: Carlos Salgado²; Yacine Mehtar-Tani³

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As a first step towards an understanding the physics of jet modifications in heavy-ion collisions, we analyze the radiation off a QCD antenna propagating through a quark-gluon plasma. The resulting spectrum is characterized in terms of the hardest scale of the problem. We show that this scale is either 1) the inverse size of the antenna as probed by the medium or 2) the maximal momentum transfer from the medium, given by the saturation scale of the QGP. In the former case, called the "dipole" regime, the antenna preserves its color correlation during the passage through the QGP and radiates coherently. In the latter situation, called the "decoherence" regime, which applies to the case of a dense medium, the antenna constituents de-cohere rapidly and the resulting spectrum is predominantly the superposition of the independent spectra off the two components. In both cases, however, vacuum coherence is restored for gluons emitted with transverse momenta larger than the hard scale of the associated regime. We explore the typical timescales relevant for emissions in both cases and discuss shortly about the implications for multi-gluon emissions in the QGP, relevant for jet studies in heavy-ion collisions.

References

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Inclusive jet measurements and unfolding studies in proton-proton collisions at $\sqrt{s} = 2.76$ TeV and 7 TeV with the ALICE experiment

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Jets, collimated sprays of particles associated with hard partons, are an invaluable tool in testing QCD and probing structure and properties of hot and dense nuclear matter created in high energy heavy-ion collisions. Jets enable us to study the evolution from hard-scattering through fragmentation to hadronisation and test modification of these processes in presence of nuclear medium with respect to measurements in vacuum. The unmodified baseline can be acquired from jet measurements in proton-proton collisions.

We have analysed data from proton-proton collisions at $\sqrt{s} = 2.76$ TeV and 7 TeV measured by the ALICE detector system at the LHC and reconstructed the inclusive spectra of charged particle jets using modern k_t and anti- k_t clustering algorithms at mid-rapidity. The measured jet spectra were corrected for detector effects using unfolding and we will present a detailed study of this procedure. In particular, we will make a comparison of the results obtained using Bayesian unfolding and unfolding utilising Singular Value Decomposition of the detector response matrix. The corrected results will be compared to fully reconstructed jets in ALICE using both charged and neutral particles as well as to other LHC experiments.

Parallel IVA: heavy flavour / 33**Open heavy flavor and J/psi at RHIC and LHC****Author:** Jan Uphoff¹**Co-authors:** Carsten Greiner ¹; Oliver Fochler ¹; Zhe Xu ²¹ *Goethe University Frankfurt*² *Tsinghua University, Beijing***Corresponding Author:** uphoff@th.physik.uni-frankfurt.de

Heavy flavors are important probes to study the early phase of ultra-relativistic heavy ion collisions at RHIC and LHC. We present results on the production and space-time evolution of heavy quarks and J/psi in the quark gluon plasma within the partonic transport model Boltzmann Approach to MultiParton Scatterings (BAMPS). Heavy quarks interact with the medium via binary and radiative scatterings with running coupling and a more precise Debye screening which is derived from hard thermal loop calculations. We compare our results on the elliptic flow and nuclear modification factor not only to experimental data of heavy flavor electrons at RHIC, but also to LHC data of heavy flavor electrons, muons, D mesons and non-prompt J/psi. The latter two are in particular sensitive on the mass difference of charm and bottom quarks. Furthermore, results on J/psi suppression are reported for central and non-central collisions, taking cold nuclear matter effects and the dissociation as well as regeneration of J/psi in the quark-gluon plasma into account.

Parallel IIIC: Electroweak Probes / 35**Measurement of isolated direct photons in lead-lead collisions at $\sqrt{s_{NN}}=2.76$ TeV with the ATLAS detector****Author:** Peter Steinberg¹¹ *Brookhaven National Laboratory***Corresponding Author:** peter.steinberg@bnl.gov

Direct photons are a powerful tool in heavy ion collisions. Their production rates provide access to the initial state parton distribution functions, which are expected to be modified by nuclear effects. They also provide a means to calibrate the expected energy of jets that are produced in the medium, and thus are a tool to probe the physics of jet quenching more precisely both through jet rates and fragmentation properties. The ATLAS detector measures photons with its hermetic, longitudinally segmented calorimeter, which has excellent spatial and energy resolution, providing detailed information about the shower shape of each measured photon. These capabilities provide powerful rejection against the background from neutral pions in jets. Rejection against jet fragmentation products is further enhanced by isolation criteria, which can be based on calorimeter energy or the presence of high pT tracks. First results on the rates of isolated direct photons from approximately 140 μb^{-1} of lead-lead data will be shown, as a function of transverse momentum, pseudorapidity and centrality, and their rates compared to expectations from perturbative QCD.

Parallel IC: Correlations / 36**Measurement of the coefficients and correlations between higher-order flow harmonics with the ATLAS detector****Author:** Jia JIANGYONG¹

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Recently, the study of harmonic flow coefficients v_n has been the focus of many experimental efforts in heavy-ion collisions at RHIC and the LHC. These coefficients are believed to be associated with the various shape components in the initial geometry, arising from fluctuations of the participating nucleons in the overlap region. The orientation of these harmonic flow (event plane or Ψ_n) are generally correlated due to the correlations between the original shape components in the initial geometry. We present detailed measurements of coefficients v_1 - v_6 , obtained from event plane, two-particle correlation and cumulant methods, as well as measurements of various event plane correlations involving Ψ_2 to Ψ_6 in Pb-Pb collisions. We discuss the implications of these results on our understanding of the nature of the initial geometry, and on the dynamical evolution of the medium.

Parallel IIIA: Heavy flavour / 38

Heavy quark studies in single-muon measurements from heavy ion collisions in ATLAS

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Heavy quarks are very important probes to study the hot, dense medium produced in heavy ion collisions. Heavy quarks are produced at a relatively early stage of the nucleus-nucleus collision and they may have a reduced level of gluon radiation due to a suppression of small angle gluon radiation known as the 'dead cone effect.' The first results on the suppression of the J/ψ as a function of the collision centrality were reported by the ATLAS experiment in 2011. Semi-leptonic decay muons from the heavy flavor hadrons can be employed as a proxy for the heavy flavor quarks by making use of the high precision and high efficiency of the ATLAS muon system. In this talk, we present the nuclear modification factor for the muons coming from the semi-leptonic decays of heavy flavor particles. The results are measured separately for the b and $c \rightarrow \mu$ decay channels as a function of the transverse momentum of the muon in the range from 4 to 14 GeV for different centralities of Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

Parallel IIIC: Electroweak Probes / 39

Measurements of the Z boson via the two-lepton channels in heavy ion collisions in ATLAS

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The color neutral Z boson is an excellent probe of the hot dense matter produced in heavy ion collisions. The products of the Z boson di-lepton decays do not interact with the dense color matter, thus, the Z boson allows us insight into the initial hard scattering that produced it and provides a clean test of our understanding of the collision. The ATLAS experiment has measured $Z \rightarrow e\bar{e}$ and $Z \rightarrow \mu\bar{\mu}$ in Pb+Pb collisions with $\sqrt{s_{NN}} = 2.76$ TeV in a data sample corresponding to 140 inverse microbarns of integrated luminosity. The measurement of Z boson production and their properties as observed in these interactions will be described.

Plenary 2A / 40**Jets and Jet-like Correlations in STAR****Author:** Alice Ohlson¹¹ *Yale University*

The propagation and modification of hard-scattered partons in the QGP can be studied using various types of jet and jet-like correlation measurements. The STAR detector with its full azimuthal and large pseudorapidity acceptance, as well as its wide transverse momentum coverage, is well-suited for these measurements. Correlations of neutral pions and jet-like clusters at forward rapidity in d+Au collisions are used to probe low x physics and the possible onset of gluon saturation effects. At mid-rapidity, azimuthal correlations of charged hadrons with the axis of a reconstructed trigger jet are used to study the modification of jet shapes and associated hadron yields from p+p to Au+Au. We also show results that take advantage of STAR's increased particle identification capabilities due to the Time-Of-Flight detector, such as particle ratios associated with reconstructed jets, and dihadron correlations with identified trigger particles. Such measurements will be used to explore the differences between jet-related and bulk-related particle production. The comprehensive set of STAR jet-quenching measurements can be used to further constrain theories of parton energy loss at RHIC.

Parallel IVC: Initial state and pA / 42**Small- x physics at the Large Hadron-electron Collider at CERN****Author:** Brian Cole¹¹ *Columbia University*

The Large Hadron-electron Collider LHeC is a proposed facility at CERN to collide electrons and positrons against the LHC beams at center-of-mass energies around 1 TeV per nucleon, with the aim of studying previously unexplored kinematical regions of the hadron and nuclear wave functions. After a brief physical motivation, I will present the project. Then I will focus on the opportunities for small- x studies, with special attention to the case of lepton-nucleus collisions. I will show the different opportunities for inclusive studies, exclusive and inclusive diffraction, and final states. For each observable, I will discuss the possibilities that it offers to establish the linear or non-linear behavior in small- x evolution, to determine the partonic structure of protons and nuclei at small x , and to investigate the dynamics of QCD branching and of hadronization.

Ref.: [cern/ch/lhec](http://cern.ch/lhec).**Parallel IVC: Initial state and pA / 43****Hadron and prompt photon production in pA collisions at the LHC from the Color Glass Condensate****Author:** Amir Rezaeian¹**Co-author:** Jamal Jalilian-Marian²¹ *Universidad Tecnica Federico Santa Maria*

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I will show the results of our recent investigation of the inclusive hadron and prompt photon production in proton (deuteron)-nucleus (pA) collisions at RHIC and the LHC within the Color Glass Condensate (CGC) framework. We investigate the contribution of inelastic and elastic processes to single inclusive hadron production in proton-proton and pA collisions at RHIC and the LHC. Using the hybrid formulation which includes both elastic and inelastic contributions, supplemented with the running-coupling Balitsky-Kovchegov equation, we get a good description of RHIC data. It is shown that inclusion of the inelastic terms makes the transverse momentum dependence of the production cross section steeper in the mid-rapidity region but does not affect the cross section in the very forward region. The inelastic processes also lead to a sharper increase of the nuclear modification factor R_{pA} with increasing p_T . For the inclusive (and semi-inclusive) prompt photon production, we divide the k_t factorized cross-section obtained in the CGC approach to the direct and fragmented part and investigate which part is more sensitive to the gluon saturation. We also investigate azimuthal photon-hadron correlations at the LHC and RHIC at various rapidities. We show predictions for the nuclear modification factor for both inclusive hadron and prompt (and isolated) photon production in pA collisions at the LHC at various rapidities. We will compare the predictions for R_{pA} for both inclusive hadron and prompt photon production coming from the collinear and the k_t factorization approach at the LHC. The forthcoming day-one LHC measurement of hadron multiplicity in pA collisions is a crucial test of the k_t factorization and gluon saturation based models. We provide quantitative predictions for the pseudorapidity distribution of charged particles produced in minimum bias pA collisions at the LHC based on the idea of gluon saturation in the CGC framework.

My talk is based on the following papers:

- 1: J. Jalilian-Marian and A. H. Rezaeian, "Hadron production in pA collisions at the LHC from the Color Glass Condensate", Phys. Rev. D85, 014017 (2012) [arXiv:1110.2810].
- 2: A. H. Rezaeian, "Charged particle multiplicities in pA interactions at the LHC from the Color Glass Condensate", Phys. Rev. D85, 014028 (2012) [arXiv:1111.2312].
- 3: J. Jalilian-Marian and A. H. Rezaeian, "Prompt photon production and photon-hadron correlations at RHIC and the LHC", To be published.

Parallel IIB: Jet quenching and energy loss / 44

Proton/pion ratios in relative azimuth with respect to a jet in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions at STAR

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Inclusive Proton/pion ratios show an enhancement at intermediate transverse momentum ($p_T \sim 1.5 - 4.0$ GeV/c) in central $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions compared to peripheral Au+Au and p+p collisions. This effect suggests a production mechanism, different from fragmentation, which is consistent with coalescence and recombination models. A high-ET trigger particle selects a surface-biased jet, which is measured to have a similar p_T distribution as a p+p jet. This jet is used to enhance the quenching effects of the recoiling, medium traversing one. We reconstruct the trigger jet using the FASTJET algorithm, with a ET (p_T) cut of 3.0 GeV/c on the towers(tracks) in order to reduce the heavy-ion collision background. The particle identification of tracks with p_T up to ~ 2.8 GeV/c is obtained by taking advantage of STAR TOF and TPC detectors with full azimuth coverage. Correlations in $\Delta\phi$ between jets and identified hadrons are presented, and the particle ratios in different regions of azimuth are measured. Particle ratios associated with the trigger jet vs. the recoil jet, and comparisons to inclusive particle ratios can help to distinguish between jet-related (vacuum and medium-modified) and bulk-related contributions to the ratios enhancement.

Parallel IVB: Jet quenching and energy loss / 47**Background subtraction and jet quenching on jet reconstruction****Authors:** Leticia Cunqueiro¹; Liliana Apolinário²; Néstor Armesto²¹ *Istituto Nazionale Fisica Nucleare*² *Universidade de Santiago de Compostela***Corresponding Author:** lilianamarisa.cunha@usc.es

In order to assess the ability of jet observables to constrain the characteristics of the medium produced in heavy-ion collisions at the LHC, we investigate the influence of background subtraction and jet quenching on jet reconstruction, with focus on dijet asymmetries as currently studied by ATLAS and CMS. Using two models for the background, a full simulation and a toy model, we examine the influence of different background subtraction methods on dijet momentum imbalance and azimuthal distributions. We compare the usual jet-area based background subtraction technique and a variant of the noise-pedestal subtraction method used by CMS. The purpose is to understand what are the differences between the two techniques, given the same event configuration. Also, we analyze the influence of the quenching effect with the aim of understanding quantitatively how these methods are able to handle these modifications of the hard part of the collision. It turns out that the two background methods show different sensitivity to background fluctuations and quenching.

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Investigating correlations between jets and the QGP geometry via jet v_n **Author:** Alice Ohlson¹¹ *Yale University*

A measurement of the correlation between the axes of reconstructed jets and the reaction plane of the bulk medium (known as jet v_2) and the higher-order participant planes (jet v_n) provides information on the pathlength dependence of medium-induced parton energy loss as well as biases in jet-finding methods. Additionally, knowledge of jet v_n and the ability to reconstruct the event plane in the presence of a jet are necessary in analyses of jet-particle correlations, which are used to study medium-induced jet shape modification.

A simple Monte Carlo Glauber model indicates that the average parton pathlength through the medium depends on the parton's relative angle to the n -th order participant planes, leading to a visible jet v_n . However, measurements of jet v_n are non-trivial because the presence of a jet can significantly bias the participant plane calculation, leading to an overestimation of jet v_n . A method is presented for calculating jet v_n and the event plane in an unbiased way, using knowledge of the azimuthal angle of the jet axis from full jet reconstruction.

Parallel VC: Initial state and pA / 49**The Future of Relativistic Heavy Ion Physics in the Forward Region in PHENIX****Author:** Richard Seto¹¹ *University of California, Riverside*

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The field of Relativistic Heavy Ion Physics has made great strides in the past decade with the establishment of the strongly interacting Quark Gluon Plasma (sQGP) in high energy collisions of heavy ions at the Relativistic Heavy Ion Collider (RHIC) and now at the LHC. Experience has taught us that large rapidity coverage, as well as careful measurements of cold nuclear matter will be important factors in giving us a quantitative understanding of the sQGP. I will outline plans for a upgrade aimed at covering a region $1 < \eta < 4$ and the contributions that such an upgrade can make to our understanding of the initial state, entropy production, parton energy loss, and long range correlations in the sQGP. I will also briefly indicate some of the spin measurements which such an upgrade will enable as well as its capabilities in an early phase of a possible electron-ion program. Inherent in this plan, is the capability of an sPHENIX detector, which together with the central region upgrade will cover a rapidity region between -1 and 4 units of rapidity with a capability to make the most critical measurements towards a comprehensive understanding of the sQGP.

Parallel IVB: Jet quenching and energy loss / 50

Reconstructed Jet Results in p+p, d+Au and Cu+Cu collisions at 200 GeV from PHENIX

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Jet reconstruction in heavy ion collisions at RHIC and the LHC is becoming a popular tool to explore medium effects including the energy loss and modified fragmentation of hard-scattered partons. In p+A and d+A collisions, reconstructed jets are important for evaluating cold nuclear matter effects such as the impact parameter dependence of nuclear parton distribution functions and initial state energy loss. We present current PHENIX results from p+p, d+Au, and Cu+Cu collisions at 200 GeV using the Gaussian filter and anti-kT algorithms. The systematic study of direct jet reconstruction across a variety of collisions systems at PHENIX will help to tell a coherent story of jet physics at RHIC.

Parallel IIB: Jet quenching and energy loss / 51

Data-driven analysis methods for the measurement of reconstructed jets in heavy ion collisions at RHIC and LHC

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We present new, data-driven analysis methods for the measurement of reconstructed jets over a broad kinematic range, in the complex environment of heavy ion collisions. We utilize simple model

calculations that contain the essential features of jet reconstruction in nuclear collisions at both energies, in order to assess systematic uncertainties of the methods due to large experimental backgrounds. Based on a Bayesian approach to unfolding of background effects, we establish criteria for systematically significant jet measurements over the full jet energy range at both RHIC and LHC. These criteria are satisfied only by specific choices of inclusive and coincidence observables, which have not been considered previously.

Parallel IIIC: Electroweak Probes / 52

Dielectron Production in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions at STAR

Author: Jie Zhao¹

¹ *Shanghai Institute of Applied Physics/ Lawrence Berkeley National Lab*

Dilepton production has been proposed to serve as a penetrating probe for the hot and dense medium created in high-energy nuclear collisions. Their small final-state interaction cross sections, let dileptons escape the interaction region undistorted. Since dileptons originate from all stages of a heavy ion reaction, their sources vary with the kinematic phase space under consideration: In the low mass region (LMR: $\text{mass} < 1.1 \text{ GeV}/c^2$), vector mesons and direct photons are the dominating source, while dileptons in the intermediate mass region (IMR: $1.1 < \text{mass} < 3 \text{ GeV}/c^2$) primarily stem from QGP thermal radiation and semileptonic decays of charmed mesons. In the high mass region (HMR: $\text{mass} > 3 \text{ GeV}/c^2$), heavy quark decays and Drell-Yan processes contribute the most to the dilepton spectrum. Due to the time-energy correlation, the higher the dilepton pair mass, the earlier the production. Therefore the dilepton distributions, especially in the IMR and HMR, provide information on early collision dynamics in heavy ion collisions. In this talk we will present STAR results on dielectron production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The results will be compared to hadron decay cocktails as well as theoretical calculations on vector meson in-medium modifications and the QGP thermal radiation. A systematic analysis of transverse mass distributions in the IMR region as a function of pair invariant mass will be discussed.

Parallel IIIB: Jet quenching and energy loss / 53

Calculating the jet quenching parameter \hat{q} in lattice gauge theory

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We present a framework where first principles calculations of jet modification may be carried out in a non-perturbative thermal environment. As an example of this approach, we compute the leading order contribution to the transverse momentum broadening of a high energy (near on-shell) quark in a thermal medium. This involves a factorization of a non-perturbative operator product from the perturbative process of scattering of the quark. An operator product expansion of the non-perturbative operator product is carried out and related via dispersion relations to the expectation of local operators. These local operators are then evaluated in quenched SU(2) lattice gauge theory.

Parallel VA: Quarkonia / 54

Upsilon Measurements at PHENIX

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The suppression of quarkonia in heavy ion collisions has long been thought to provide an indication of the temperature dependent Debye screening length of color charge in the quark gluon plasma. A large sample of d+Au and Au+Au collisions at $\sqrt{s_{NN}}=200$ GeV has been collected by PHENIX in 2008 and 2010. The large statistical sample allows for both the observation of Upsilon in the hot dense medium created by Au+Au collisions, but also a baseline measurement in d+Au. These baseline measurements aid the interpretation of the heavy ion suppression by separating the cold nuclear matter effects that result from using a nuclear target, but also add to our fundamental understanding of quarkonia production. In this talk, we will present measurements of Upsilon yields in hot and cold nuclear matter as observed by PHENIX at mid-rapidity in the di-electron decay channel and at forward rapidity in the di-muon decay channel.

Parallel IC: Correlations / 55

Two particle correlation measurements at PHENIX

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Measurements of two particle correlations are important tools to dissect the interplay of hard-scattered partons and the hot dense medium created by ultra-relativistic heavy ion collisions. One of important topic of correlation measurements in heavy ion collisions is to evaluate the path-length dependence of parton energy loss and to discern the medium response to it. Another topic is to analyze the contributions of higher harmonic flow, which result from fluctuations within the initial collision geometry, to long range rapidity correlations.

In this talk, we will present recent PHENIX measurements in Au+Au 200 GeV collisions of azimuthal correlations with trigger selections relative to the event plane for both high and mid transverse momenta. These produce measurements sensitive to the path-length dependence of parton energy loss and to the influence of medium effects respectively. Azimuthal correlations in which background from higher harmonic flow is removed will also be discussed.

Parallel IVA: heavy flavour / 56

Measurement of electrons from Heavy Quarks at PHENIX (for PHENIX collaboration)

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Heavy quarks are one of the most valuable probes for the matter produced in relativistic heavy ion collisions at RHIC. PHENIX experiment being designed specifically to study leptons, so electrons from the decay of heavy quarks acts as one of the most important tools in PHENIX for measurement of heavy quarks. Measurements of electron spectra at mid rapidity region has been done by PHENIX in broad p_T regions. Recent measurement in $p + p$ by PHENIX extends upto $p_T = 15$ GeV. After subtraction of photonic background electrons from the measured electron spectra, electrons from semileptonic decay of hadrons containing heavy quarks are left, which provides the measurement of heavy quarks.

Measurement of electrons from heavy quarks by PHENIX has been done for various collision species like $p + p$, $d + Au$, $Cu + Cu$ and $Au + Au$. In $Au + Au$ strong suppression of single electron compared with scaled $p + p$ is observed which challenges radiative energy loss models because heavy quarks are expected to radiate less. It is important to understand what happens when the collision species is asymmetric and has size in between $Au + Au$ and $p + p$. Measurements done in $d + Au$ collisions by PHENIX answer this question along with disentangling cold nuclear matter effect in heavy ion collisions. Also it is needed to know the situation when the collision species is symmetric and has size between $p + p$ and $Au + Au$. Measurements done in $Cu + Cu$ collisions by PHENIX provide the answer. Measurement of azimuthal anisotropy by using electrons from heavy quark decay has been done recently in PHENIX for $Au + Au$ at $\sqrt{s_{NN}} = 62.4$ GeV.

The techniques used by PHENIX for measuring electrons from heavy quarks and the latest results in collision species $p + p$, $d + Au$, $Cu + Cu$ and $Au + Au$ will be discussed in this talk.

Parallel VA: Quarkonia / 57

Measurements of Upsilon Production and Nuclear Modification Factor at STAR

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Thermal suppression of quarkonium production in heavy-ion collisions, due to Debye screening of the quark-antiquark potential, has been proposed as a clear signature of quark-gluon plasma (QGP) formation. At RHIC energies, the Υ meson is a clean probe of the early system that is not negligible level of enhancement from non-thermal suppression from co-mover absorption. We report on our measurement of e^+e^- cross-section for $Au + Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV. We compute a Nuclear Modification Factor by comparing these results to newly analyzed $p + p$ collisions from 2009 (21 pb⁻¹ compared to 7.9 pb⁻¹ in 2006). In order to have a complete assessment of both hot and cold nuclear matter effects on Upsilon production we also report on results from $d + Au$ collisions.

Plenary 1A / 58

Jet quenching and energy loss in CMS

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The energy loss of fast partons in hot and dense nuclear matter is studied in PbPb collisions at a nucleon-nucleon center-of-mass energy of 2.76 TeV with the CMS detector at the LHC. Detailed

studies of the dijet momentum balance and angular correlations are performed as a function of collision centrality and leading jet transverse momentum up to 350 GeV/c. Dijets in central collisions are found to be more unbalanced than the corresponding dijets in pp data up to the highest values of the leading jet transverse momenta studied. Concurrently, the dijet angular correlations in PbPb collisions remain consistent with the pp reference. Further, the transverse momentum balance in isolated photon-jet pairs is studied. Using the isolated photon as an unbiased measure of the initial parton energy, the ratio of the jet and photon transverse momenta is studied relative to a corresponding pp reference. A significant decrease of the jet to photon momentum ratio with increasing collision centrality is observed. Track-jet correlations and jet fragmentation functions are also studied. A large fraction of the momentum of unbalanced jets is found to be carried by low-pT particles at large radial distance from the jet axis, while the hard component of the fragmentation function evaluated with respect to the reconstructed jet momentum is not strongly modified in comparison to jet fragmentation in vacuum.

Parallel IVA: heavy flavour / 60

The measurement of non-photonic electrons in STAR

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Due to their large masses, charm and bottom quarks, are mostly produced during the initial phase of collisions via gluon fusion. Non-photonic electrons (NPE) are mainly produced by semileptonic decays of D and B mesons, hence the study of NPE in hadron-hadron and ion-ion collisions provides the information about heavy quarks production as well as the medium properties. In order to interpret NPE measurements it is important to determine the relative charm and bottom contribution to NPE spectrum. The measurement of azimuthal correlation between NPE and hadrons in Au+Au collisions can shed light on heavy flavor jet-medium interactions. NPE elliptic flow can be a good proxy to reveal heavy flavor collectivity, which can significantly improve our understanding of the medium thermalization.

This talk presents the recent STAR measurement of non-photonic electrons from p+p collisions at $\sqrt{s} = 200$ GeV, Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. We will also report the analysis status in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

Parallel IIIB: Jet quenching and energy loss / 62

Coherence and broadening effects in medium induced gluon radiation

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Radiative interferences in the multi-parton shower is the building block of QCD jet physics in vacuum. The presence of a hot medium made of quarks and gluons is expected to alter this interference pattern. To study such effects, we derive the gluon emission spectrum off an “asymptotic quark” traversing a hot and dense QCD medium at first order in the

medium density. The resulting induced gluon distribution gets modified when the new interference terms between the initial and final quark are included. We comment on the possible phenomenological consequences of this new contribution for jet observables in heavy-ion collisions.

Parallel VA: Quarkonia / 63

Measurement of bottomonium production in PbPb collisions at 2.76 TeV with CMS

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The Compact Muon Solenoid (CMS) is fully equipped to measure hard probes in the di-muon decay channel in the high multiplicity environment of nucleus-nucleus collisions. Such probes are especially relevant for studying the quark-gluon plasma since they are produced at early times and propagate through the medium, mapping its evolution. CMS has measured the nuclear modification factors of $Y(1S)$ in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. A suppression of $Y(1S)$ mesons is observed in PbPb collisions, compared to the yield in pp collisions scaled by the number of inelastic nucleon-nucleon collisions. Furthermore, a suppression of the excited Y -states has been measured with respect to the $Y(1S)$ state, expressed in a double ratio $[Y(2S+3S)/Y(1S)]_{PbPb}/[Y(2S+3S)/Y(1S)]_{pp}$ which is found to be $0.31^{+0.19}_{-0.15}(stat.) \pm 0.03(syst.)$. Results from the 2010 data taking period are reported and an outlook on the 2011 data analysis will be given.

Summary:

The LHC opens up a new era of precision measurements of the bottomonium family of states. We report the results of the first detailed Υ studies in heavy-ion collisions, obtained with the CMS experiment.

Parallel IIIB: Jet quenching and energy loss / 64

Transverse Momentum Broadening in Weakly Coupled Quark-Gluon Plasma

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We calculate $P(k_{\perp})$, the probability distribution for an energetic parton propagating for a distance L through a medium to pick up transverse momentum k_{\perp} , for a medium consisting of weakly coupled quark-gluon plasma. We use full or HTL self-energies in appropriate regimes, resumming each in order to find the leading large- L behavior. We estimate the jet quenching parameter and compare to results in the literature. And, we compare $P(k_{\perp})$ at weak coupling to the $P(k_{\perp})$ expected from holographic calculations that presume the quark-gluon plasma to be strongly coupled at all length scales. We find that the weak coupling and strong coupling results need not differ greatly at modest k_{\perp} , but we find that $P(k_{\perp})$ must be parametrically larger in a weakly coupled plasma than in a strongly coupled plasma at large enough k_{\perp} . By looking for rare large-angle deflections of the jet resulting from a parton produced initially back-to-back with a hard photon, experimentalists can find the weakly coupled quark and gluon short-distance constituents of the strongly coupled liquid quark-gluon plasma, much as Rutherford found the nuclei within atoms or Friedman, Kendall and Taylor found the quark within nucleons.

Parallel VB: Jet quenching and energy loss / 65**Jet Flavor Tomography at RHIC and LHC****Author:** Alessandro Buzzatti¹**Co-author:** Miklos Gyulassy¹¹ *Columbia University***Corresponding Author:** buzzatti@phys.columbia.edu

Jet Flavor Tomography is a powerful tool used to probe the properties of Quark Gluon Plasma formed in heavy ion collisions at RHIC and LHC. A new Monte Carlo model of jet quenching developed at Columbia University, CUJET1.0, was applied to predict the jet flavor and centrality dependence of some of the main phenomenological observables, the nuclear modification factor R_{AA} and the elliptic flow v_2 . The predictions for fragments $f = \pi, D, B, e$, derived from quenched jet flavors g, u, c, b in central and peripheral collisions at RHIC and LHC, exhibit novel features such as a level crossing pattern in R_{AA} over a broad transverse momentum range which can test jet-medium dynamics in quark gluon plasmas and help discriminating between current energy loss models.

Parallel IB: Jet quenching and energy loss / 66**LHC phenomenology of light quark jet quenching in AdS/CFT****Author:** Andrej Ficnar¹**Co-authors:** Jorge Noronha²; Miklos Gyulassy¹¹ *Columbia University*² *Universidade de São Paulo***Corresponding Author:** aficnar@phys.columbia.edu

In this talk, we explore phenomenological signatures of light quark jet quenching, modeled as falling strings within the AdS/CFT correspondence. In particular, we show that even in the simplest models, it is possible to obtain the correct qualitative behavior of the pion RAA at LHC, and we also present the quantitative predictions. We address the effect of the QCD conformal anomaly on this observable by exploring the behavior of falling strings in a non-conformal gravity dual, whose action is constrained by the lattice QCD data. In addition to this, we will also present results for falling strings in a geometry dual to a system experiencing a Bjorken expansion and investigate the effects of the expansion on the light quark jet quenching observables.

Parallel IVB: Jet quenching and energy loss / 67**Measurement of jet spectra in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV with the ALICE detector at the LHC****Author:** Marta Verweij¹¹ *Utrecht University***Corresponding Author:** m.verweij@uu.nl

We report a measurement of transverse momentum spectra of jets detected with the ALICE detector in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV. Jets are reconstructed from charged particles using the anti- k_T jet algorithm. The background from soft particle production is determined for each event and subtracted. The remaining influence of underlying event fluctuations is quantified by embedding different probes into heavy-ion data. The reconstructed transverse momentum spectrum is corrected for background fluctuations by unfolding. We compare the inclusive jet spectra reconstructed with $R=0.2$ and $R=0.3$ for different centrality classes and compare the jet yield in Pb-Pb and pp events.

Parallel IIB: Jet quenching and energy loss / 69

Measurement of inclusive jet cross section and jet fragmentation in pp collisions with ALICE experiment at the LHC

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Jet reconstruction and jet structure variables provide important information to study the interaction between hard scattered partons and the Quark-Gluon Plasma. This talk presents the measurement of the inclusive cross-section for fully reconstructed jets in pp collisions at $\sqrt{s}=2.76$ TeV, which provides an essential reference for jet measurements in Pb-Pb collisions at the same $\sqrt{s_{NN}}$. In addition, we report the inclusive cross section and jet structure measurements for charged particle jets in pp collisions at $\sqrt{s}=7$ TeV. These measurements utilize the ALICE central barrel tracking system to detect charged particles with good efficiency above 150 MeV/c, together with the Electromagnetic Calorimeter (EMCal). The jet cross section and structure measurements are compared to theoretical calculations.

Parallel IIB: Jet quenching and energy loss / 70

p/π ratio in jet and bulk region in heavy ion collisions

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An important open question regarding hadronization in heavy-ion collisions is to understand the baryon enhancement at intermediate pT observed at RHIC. In this work we analyze the p/π ratio in the associated yield (pT < 5.0 GeV/c) correlated to a high-pT trigger (pT > 5.0 GeV/c) in central Pb-Pb collisions. For this analysis we used Pb-Pb data taken by the ALICE detector at a center of mass energy of $\sqrt{s_{NN}} = 2.76$ TeV.

We measure the p/π ratio in the near-side jet peak, as well as in the near-side ridge region at large Δη, to distinguish between hadrons originating from hard partons and hadrons originating from the hot and dense QCD medium. We observe that at intermediate pT the p/π ratio in the jet peak is much lower than in the ridge region.

Parallel IC: Correlations / 71

Measurement of Fourier components of two-particle correlations in PbPb collisions at $\sqrt{s}=2.76\text{TeV}$ with CMS

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Measurements from the CMS experiment at the LHC of dihadron correlations for charged particles produced in PbPb collisions at a nucleon-nucleon centre-of-mass energy of 2.76 TeV are presented. The results are reported as a function of the particle transverse momenta and collision centrality over a broad range in relative pseudorapidity ($\Delta\eta$) and the full range of relative azimuthal angle ($\Delta\phi$). A Fourier harmonic decomposition analysis of the long-range azimuthal dihadron correlations is performed. The factorization relation between the extracted Fourier coefficients and a product of single-particle azimuthal anisotropies are studied and discussed in detail. These data provide important insight on the physical origin of the observed long-range dihadron correlations.

Parallel IVC: Initial state and pA / 72

Parton Energy Loss and Modified Beam Quark Distribution Functions in Drell-Yan Process in p+A Collisions

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Within the framework of generalized collinear factorization in perturbative QCD (pQCD), we study the effect of initial multiple parton scattering and induced parton energy loss in Drell-Yan (DY) process in proton-nucleus collisions. We express the contribution from multiple parton scattering and induced gluon radiation to the DY dilepton spectra in terms of nuclear modified effective beam quark distribution functions. The modification depends on the quark transport parameter in nuclear medium. This is similar to the final-state multiple parton scattering in deeply inelastic scattering (DIS) off large nuclei and leads to the suppression of the Drell-Yan cross section in $p+A$ relative to $p+p$ collisions. With the value of quark transport parameter determined from the nuclear modification of single-inclusive DIS hadron spectra as measured by the HERMES experiment, we calculate DY spectra in $p+A$ collisions and find the nuclear suppression due to beam parton energy loss negligible at the Fermilab energy $E_{\text{lab}}=800$ GeV in the kinematic region as covered by the E866 experiment. Most of the observed nuclear suppression of DY spectra in E866 experiment can be described well by parton shadowing in target nuclei as given by the EPS08 parameterization. The effect of beam parton energy loss, however, becomes significant for DY lepton pairs with large beam parton momentum fraction x' or small target parton momentum fraction x . We also predict the DY cross section in $p+A$ collisions at lower beam proton energy $E_{\text{lab}}=120$ GeV and show significant suppression due to initial state parton energy loss at moderately large x' where the effect of parton shadowing is very small.

Parallel IVB: Jet quenching and energy loss / 73

Dijet transverse momentum imbalance, fragmentation functions and jet-track correlations in PbPb collisions at $\sqrt{s}=2.76\text{TeV}$ with CMS

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Jet production in PbPb collisions at a nucleon-nucleon center-of-mass energy of 2.76 TeV was studied with the CMS detector at the LHC. Jets are reconstructed using the energy deposited in the CMS calorimeters and studied as a function of collision centrality. With increasing collision centrality, a striking imbalance in dijet transverse momentum is observed, consistent with jet quenching. Correlations of charged particle tracks with jets indicate that the momentum imbalance is accompanied by an excess of low transverse momentum particles over a large range in the hemisphere of the second most energetic, away-side jet. Jet fragmentation functions measured in PbPb collisions will also be presented, constructed with charged particle tracks with transverse momenta $p_T > 4\text{ GeV}/c$ in a sample of dijet events. Both the leading and subleading jets show a fragmentation pattern similar to that of a jet in vacuum, as seen by comparisons to pp data at 2.76 TeV.

Parallel IC: Correlations / 74

Measurement of charged hadron v_2 at high p_T in PbPb collisions at $\sqrt{s}=2.76\text{TeV}$ with CMS

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Measurements of the azimuthal anisotropy of charged hadrons are presented for PbPb collisions at $\sqrt{s_{NN}} = 2.76\text{ TeV}$ over an extended transverse momentum range. The data were collected with the CMS detector at the LHC. The anisotropy parameter (v_2) is extracted up to a significantly higher p_T region than previous achieved, by correlating charged tracks with respect to the event plane reconstructed using the energy deposited in forward-angle calorimeters. Dihadron angular correlations over wide pseudorapidity gap are also presented for the very high- p_T particles. These new data can impose quantitative constraints on the details of in-medium parton energy loss models, particularly the influence of the path length and the shape of the interaction region.

Parallel IIIC: Electroweak Probes / 77

Measurement of isolated photon R_{AA} at high p_T in PbPb collisions at 2.76TeV with CMS

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Isolated photon production is measured in pp and PbPb collisions at nucleon-nucleon center-of-mass energies of 2.76 TeV in the pseudorapidity range $|\eta| < 1.44$ and transverse energies E_T between 20 and 80 GeV with the CMS detector at the LHC. The measured E_T spectra are found to be in good

agreement with NLO perturbative QCD predictions. The ratio of PbPb to pp isolated photon ET-differential yields, scaled by the number of incoherent nucleon-nucleon collisions, is consistent with unity for all PbPb reaction centralities.

Parallel IC: Correlations / 78

Production anisotropy of h^\pm , π^\pm and protons at high- p_T in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV

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The ALICE collaboration has recently reported an observation of an enhanced intra-jet yield of charged particles associated with the high- p_T trigger particle in central Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV [Aamodt:2011vg]. There are several possible explanations of the origin of this enhancement: (i) modifications of the fragmentation function, (ii) bias on the p_T distribution of the outgoing partons due to the energy loss and (iii) possible change of the quark/gluon relative abundance due to the different coupling of quarks and gluons to the nuclear medium. An analysis of the transverse jet-fragmentation variation with collisional centrality may help to unravel the origin of the intra-jet charged particle yield enhancement. I will present the measurement of the centrality evolution of the transverse component distribution of the particles associated to the high- p_T particle in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV.

Parallel IIA: Heavy flavour / 80

D mesons suppression in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV measured by ALICE

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The production of the prompt charm mesons D^0 , D^+ , D^{*+} , and their antiparticles, in Pb-Pb collisions at the LHC, at a centre-of-mass energy $\sqrt{s_{NN}} = 2.76$ TeV per nucleon-nucleon collision, has been measured with the ALICE detector. The p_T -differential production yields in the range $2 < p_T < 16$ GeV/c at central rapidity, $|y| < 0.5$, were used to calculate the nuclear modification factor RAA with respect to a proton-proton reference obtained from the cross section measured at $\sqrt{s} = 7$ TeV and scaled to $\sqrt{s} = 2.76$ TeV. For the three meson species, RAA shows a suppression of a factor 3–4, for transverse momenta larger than 5 GeV/c in the 20% most central collisions. The suppression is reduced for peripheral collisions. Prospects for extending these measurements using the Pb-Pb data collected during the 2011 data taking period will also be discussed.

Azimuthal angular correlations between heavy flavor decay electrons and charged hadrons in pp collisions at 2.76 TeV in ALICE

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In ultra-relativistic heavy-ion collisions, heavy quarks, i.e. charm and beauty, are produced in the early stage by hard scattering processes and experience the full evolution of the strongly-interacting system. They therefore carry relevant information on the properties of the medium. In such collisions, heavy flavour hadrons can be measured from electrons produced in their semileptonic decays. The relative contribution of charm and beauty hadrons can be estimated from the study of the near side azimuthal angular correlations between these electrons and charged hadrons.

We present the azimuthal angular correlations between electrons and charged hadrons in pp collisions at 2.76 TeV measured with ALICE at the LHC. Electrons are identified using the electromagnetic calorimeter and the Time Projection Chamber and the charged hadrons are identified using Time Projection Chamber. The azimuthal angular correlation distributions from PYTHIA simulations are used to fit the data in order to extract the relative contribution of B-hadron decays to the yield of electrons from heavy flavour decays up to $p_T = 10$ GeV/c.

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Parallel IVB: Jet quenching and energy loss / 83

Measurements of Jets and Jet Properties in $\sqrt{s_{NN}}=2.76$ TeV PbPb Collisions with the ATLAS Detector at the LHC

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Jet quenching in the hot and dense medium created in ultra-relativistic heavy ion collisions is a well-established experimental phenomenon at RHIC. It has long been anticipated that the LHC heavy ion program would substantially advance the study of jet quenching by providing access to highly energetic jets and by measuring fully-reconstructed jets. Immediately following turn-on of the LHC in November, 2010, that expectation was fulfilled through the observation of large di-jet asymmetries that may indicate substantial jet quenching. In this talk we will present recent results from ATLAS aimed to provide further understanding of this phenomenon. Measurements of single jet production, di-jet correlations and jet fragmentation in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ -TeV will be presented. In addition to measurements from the 2010 data, results using the full 2011 run will also be presented, benefiting from a factor of 20 improvement in statistics.

Plenary 2A / 84

Modeling jet quenching effects

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High P_T measurements of hard hadrons or jets at RHIC and LHC appear contradictory and in some cases counter-intuitive, but upon closer investigation they represent a coherent picture of

jet-medium interaction physics which can be established with systematic comparisons of models against a large body of data. This picture is consistent with a perturbative QCD mechanism and does not require exotic assumptions. I outline how several key measurements each partially constrain shower-medium interaction physics and how from the sum of those the outlines of the mechanism of jet quenching can be deduced. I then explain how current jet results from LHC can be naturally understood in this picture and summarize the remaining open issues.

Plenary 1B / 85

High p_T identified particle production in ALICE

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The production of particles at high p_T in pp collisions can be described using perturbative QCD. In Pb-Pb collisions the observed yield of high p_T particles is much smaller than expected from binary scaling because of strong final state interactions with the surrounding dense medium. Experiments at RHIC have shown that this modification is very different for mesons and baryons.

In the ALICE experiment it is possible to identify particles with very high transverse momentum, $p_T \gg 3\text{-GeV}/c$. Charged pions and kaons+protons (together) can be identified from the dE/dx , measured in the Time Projection Chamber, thanks to the separation on the relativistic rise. K_s^0 and Λ can be identified from their V0 weak decay topology.

In this talk preliminary results from measurements in pp at $\sqrt{s} = 2.76\text{-TeV}$ and Pb-Pb at $\sqrt{s_{NN}} = 2.76\text{-TeV}$ for $3.0 < p_T < 20.0\text{-GeV}/c$ will be shown. The evolution of R_{AA} for identified particles with centrality and p_T will be discussed and compared to unidentified charged particles, theoretical predictions, and measurements at RHIC.

Parallel IA: Quarkonia / 86

J/psi elliptic flow measurement in Pb-Pb collisions at forward rapidity in the ALICE experiment

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J/psi suppression induced by color screening of its constituents quarks was proposed 26 years ago as a signature of the formation of a quark gluon plasma in heavy-ion collisions. Recent results from ALICE in Pb-Pb collisions exhibit a smaller suppression with respect to SPS and RHIC previous measurements. The study of azimuthal anisotropy in particle production gives information on the collective hydrodynamic expansion of the QGP. In particular, J/psi elliptic flow v_2 is important to test the degree of thermalization of particles containing heavy quarks. Together with the production yields, the elliptic flow is a powerful observable to address the question of suppression and regeneration of J/psi in QGP.

We present the first J/psi elliptic flow measurement obtained at forward rapidity and in the low transverse momentum region. v_2 is measured as a function of transverse momentum and as a function of rapidity in mid-central collisions. Comparison with recent STAR results is performed.

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Reconstruction of the charmed baryon Λ_c in pp collisions at $\sqrt{s} = 7$ TeV with ALICE

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A Large Ion Collider Experiment (ALICE) has been designed for the study of strongly interacting matter created in heavy-ion collisions at LHC energies. The measurement of heavy-flavour hadron production cross-sections in high energy proton-proton collisions provides interesting insights into QCD processes and is important as a reference for heavy-ion studies.

In ALICE, the production of several charm hadron species can be studied, at central rapidity and down to very low p_t , using particle identification and secondary vertex reconstruction techniques.

We present the status of the charmed baryon Λ_c analysis in pp collisions at $\sqrt{s} = 7$ TeV in the decay modes $\Lambda_c \rightarrow pK\pi$ and $\Lambda_c \rightarrow K0Sp$.

Parallel IIIA: Heavy flavour / 88

Measurement of heavy-flavour decay muon production at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ALICE experiment

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The main goal of the ALICE experiment is the study of the properties of the strongly-interacting matter at very high energy density which is formed in ultra-relativistic heavy-ion collisions at the LHC. Heavy-flavours (charm and beauty) have an important role in the investigation: being produced in the early stage of the collision, they are sensitive probes of the Quark-Gluon Plasma and allow one to study the parton-medium interaction.

The ALICE experiment measured heavy-flavour production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in different decay channels and rapidity ranges. After a short description of the ALICE muon spectrometer, the latest results of open heavy-flavour measurements in the semi-muonic decay channels at forward rapidities ($2.5 < y < 4$) will be presented. A particular emphasis will be placed on the measurement of the nuclear modification factor as a function of transverse momentum and centrality, with respect to a pp reference at the same center of mass energy.

Parallel IIA: Heavy flavour / 89

Open-charm meson elliptic flow measurement in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with ALICE at the LHC.

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A Large Ion Collider Experiment (ALICE) is one of the four major experiments at the Large Hadron Collider (LHC), and it is dedicated to the study of ultra-relativistic heavy ion collisions, with the goal of investigating the properties of the high-density state of QCD matter produced in these collisions. The study of D meson production azimuthal anisotropy and the measurement of their elliptic flow (v_2) can provide insight on the degree of thermalization of charm quarks in the medium and on the hadronization mechanism.

We present the measurement of the D^+ , D^0 and D^{*+} meson v_2 in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV at the LHC with ALICE. We discuss the details of the analysis and we show the results obtained from data samples collected in 2010 and 2011.

Parallel IIIA: Heavy flavour / 90

Quarkonium production in pp collisions with CMS

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Using large data samples of di-muon events, CMS has performed detailed measurements in the field of quarkonium production. Differential cross-sections of J/ψ , $\psi(2S)$ and $Y(nS)$ states in p_T and rapidity will be presented, separated in prompt and non-prompt contributions for the charmonium case: experimental results are compared with recent predictions in the context of NLO nonrelativistic QCD and the FONLL scheme. Studies of P-wave charmonia and bottomonia (χ_c , χ_b), using the decay mode $(J/\psi, Y) + \gamma$ where the photon converts in an e^+e^- pair inside the detector, will be also discussed.

Parallel IIC: High p_T suppression, Global Observables / 91

Charged particle production in Pb-Pb collisions at the LHC with the ALICE detector

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(on behalf of the ALICE Collaboration)

The ALICE experiment measured charged particle production in $\sqrt{s_{NN}} = 2.76$ -TeV Pb-Pb collisions at the LHC. We report on results on charged particle multiplicity and transverse momentum spectra. All the results are presented as a function of centrality, estimated with a Glauber Monte Carlo fit to multiplicity distributions reconstructed in various detectors. The applicability of the Glauber picture at LHC energies, the resolution of the centrality determination and the related systematic uncertainties will be discussed in detail.

Particles are tracked in the pseudorapidity window $|\eta| < 0.8$ with the silicon Inner Tracking System (ITS) and the Time Projection Chamber (TPC), allowing us to cover the range $0.15 < p_t \leq 50$ GeV/c. The low- p_t cut-off is further reduced in the multiplicity measurement using “tracklets”, reconstructed in the 2 innermost layers of the ITS.

The charged particle multiplicity is measured to be $dN_{ch}/d\eta = 1601 \pm 60$ in 0-5% most central Pb-Pb collisions, indicating an energy density a factor ~ 3 higher than at RHIC.

Its evolution with centrality shows a pattern strikingly similar to the one measured at RHIC. High transverse momentum particles are found to be strongly suppressed with respect to pp collisions, consistent with a large energy loss of hard-scattered partons in the hot and dense medium. The results are presented in terms of the nuclear modification factor R_{AA} and compared to theoretical expectations.

Parallel VB: Jet quenching and energy loss / 92

Measurement of isolated photon-jet correlations in PbPb collisions at $\sqrt{s}=2.76\text{TeV}$ with CMS

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Modification of jets transitioning through the quark–gluon plasma (QGP), or quenching, has been well established by the RHIC and LHC data, using particle correlation and recently, reconstructed jets. At LHC, the first measurement of the jet quenching employed dijets. However, the advantage of the large yield of dijets is offset by loss of the perturbative final state information, as both jets interact with the medium. This also causes the observed high p_T dijet to be predominantly emitted from the surface. These shortcomings can be addressed by measuring isolated photon–jet correlation, where the directly produced photons carries the kinematic information before interaction with the QGP. We describe the measurement of the momentum imbalance and azimuthal correlation of isolated photon–jet pairs from $\sqrt{s_{NN}} = 2.76$ TeV PbPb collisions at the LHC, and compare it to both the $\sqrt{s} = 2.76$ TeV pp collision data and PYTHIA calculations. We discuss the characterization of the in-medium parton energy loss using the results.

Parallel IC: Correlations / 93

jet-like near-side peak shapes in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV with ALICE

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In central heavy-ion collisions at the LHC hot and dense matter is formed in which outgoing partons suffer significant energy loss. The quenched energy seems to dominantly reappear at low and intermediate p_T , a p_T region where collective effects dominate and jet reconstruction is not feasible. To characterize in-medium energy loss in this p_T region, we analyse two-particle angular correlations of charged particles using the ALICE detector. Correlations having their origin in collective effects are subtracted using an eta-gap method. The shape and magnitude of the remaining jet-like peak are studied to characterize effects of energy loss occurring in the hot and dense medium. We compare results from central collisions with those from peripheral collisions and pp collisions at the same center-of-mass energy. Further, we compare to Monte Carlo models.

Parallel VA: Quarkonia / 95

Upsilon production in pp and pA collisions from RHIC to the LHC

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In the first part, I will discuss the impact of QCD corrections on the P_T differential cross section for Upsilon production in pp collisions at RHIC, Tevatron and LHC energies, as well as the behaviour of the differential cross section in rapidity. I will discuss the very good agreement between the parameter-free predictions of the Colour-Singlet Model and the first LHC data, especially in the region of low transverse momenta, which is the most relevant one for heavy-ion studies. I will also discuss predictions for the polarisation to be compared with the forthcoming LHC results. In the second part, I will discuss the nuclear-matter effects on Upsilon production at RHIC and the LHC in proton-nucleus and, by extension, in nucleus-nucleus collisions. We will argue that (i) the Upsilon break-up probability can be neglected in a first approximation, (ii) the gluon shadowing and antishadowing are not strong enough to describe forward RHIC data, (iii) the backward data hints at a gluon EMC effect, likely stronger than the quark one, (iv) fractional energy loss provides a very convincing explanation for the Upsilon suppression seen by PHENIX in the forward region. Following these discussions, outlooks for the LHC pPb run will be presented.

Parallel IIC: High p_T suppression, Global Observables / 99

Neutral meson production in pp and Pb-Pb collisions at LHC

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Identified hadron spectra are considered as a sensitive probe for transport properties of strongly interacting matter produced in heavy ion collisions. The ALICE detector at the LHC studies π^0 and eta meson production via their two-photon decays by two complementary methods, using electromagnetic calorimeters and the central tracking system for photons converted to e^+e^- pairs on the material of the inner ALICE detectors. Production spectra of π^0 and eta mesons were measured with ALICE in pp collisions at LHC energies at mid-rapidity in a wide transverse momentum range. The spectrum and the nuclear modification factor R_{AA} of the π^0 production measured in Pb-Pb collisions at different centralities, show a clear pattern of strong suppression in a hot QCD medium with respect to pp collisions. Azimuthal anisotropy v_2 of π^0 production measured with ALICE is consistent with v_2 for other hadron species. Comparison of the ALICE results on neutral mesons with the lower-energy experiments is discussed.

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Light vector meson productions at the LHC with the ALICE detector

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The measurement of light vector meson production (ρ, ω, ϕ) in pp collisions provides insight into soft Quantum Chromodynamics (QCD) processes in the LHC energy range. Calculations in this regime are based on QCD inspired phenomenological models that must be tuned to the data, in particular for hadrons that contain the u, d, s quarks.

Moreover, light vector meson production provides a reference for high-energy heavy-ion collisions. In fact, key information on the hot and dense state of strongly interacting matter produced in these collisions can be extracted measuring light meson production.

The ALICE experiment has taken data in 2010 and 2011 in p-p collisions at $\sqrt{s} = 2.76$ and 7 TeV, and in Pb-Pb collisions at 2.76 TeV.

Results will be shown for the ρ and ϕ differential cross sections in p-p collisions at $\sqrt{s} = 7$ TeV measured in the rapidity interval $2.5 < y < 4$.

Low mass resonances analysis in Pb-Pb collisions is ongoing and the prospects of this analysis will be presented in this poster.

Plenary 3B / 102

Quarkonia production in ALICE

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Heavy quarkonium states are expected to provide essential information on the properties of the high-density strongly-interacting system formed in the early stages of heavy-ion collisions. In particular the J/ψ suppression, in heavy-ion collisions, via color screening mechanism, can be seen as a direct effect of deconfinement.

During 25 years, the J/ψ suppression has been extensively studied at the SPS and at RHIC. It was indeed clearly observed but to a level surprisingly

similar despite the large difference in the center of mass energy at the two accelerators.

At the same time, new mechanisms of J/ψ regeneration via recombination of charm and anti-charm quarks were also proposed. The measurement of J/ψ suppression is especially promising at the Large Hadron Collider where the high energy density of the medium and the large number of charm quarks pairs produced in central Pb-Pb collisions should help to disentangle between the different suppression and recombination scenarios.

ALICE is the LHC experiment mainly dedicated to the study of nucleus-nucleus collisions. At forward rapidity ($2.5 < y < 4$), the J/ψ production is measured in the Muon Spectrometer, via the $\mu^+ \mu^-$ decay channel, down to zero transverse momentum.

After a brief description of the apparatus, the analysis of the inclusive J/ψ production in Pb-Pb collisions at a center of mass energy of $\sqrt{s_{NN}} = 2.76$ TeV will be discussed. Results on the nuclear modification factor (R_{AA}) dependence on the collision centrality will be shown.

Thanks to the large statistics collected in 2011, preliminary results on R_{AA} as a function of transverse momentum and rapidity will also be presented.

Parallel IA: Quarkonia / 103

Nuclear modification of J/ψ production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

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Heavy quarkonium states, such as the J/ψ , are expected to provide essential information on the properties of high-energy heavy-ion collisions where the formation of a Quark-Gluon Plasma is expected. The impact on the J/ψ production of such a hot and dense medium formed in the early times of the collision has been extensively studied at SPS and RHIC energies. It is expected that due to colour screening mechanisms J/ψ production is suppressed in a plasma of quarks and gluons. At LHC energies, however, charm is produced abundantly in central Pb–Pb collisions allowing for scenarios where originally uncorrelated charm and anti-charm quarks (re)combine at the phase boundary. Measuring the J/ψ production at LHC will help to disentangle between the different mechanisms.

ALICE is the dedicated heavy-ion experiment at the LHC. Due to the unique particle identification capabilities of the central barrel detectors ($|\eta| < 0.9$), J/ψ can be measured in the di electron channel in the very demanding environment of central Pb–Pb collisions at LHC. In addition J/ψ is measured at forward rapidity ($2.5 < y < 4$) with a dedicated muon spectrometer. ALICE is the only LHC experiment with a J/ψ acceptance that reaches down to $p_t = 0$ at both mid- and forward-rapidity. First results on the nuclear modification factor of the inclusive J/ψ production at mid-rapidity in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV will be presented. The mid-rapidity measurement is complemented with the results obtained at forward-rapidity.

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Quarkonium measurements in pPb collisions at the LHC with the ALICE experiment

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In heavy-ion collisions at the LHC, the ALICE experiment is studying nuclear matter at very high energy density where the formation of a Quark Gluon Plasma (QGP) is expected. Quarkonium production is an important probe to characterize the properties of the QGP as it gives access to the early stages of the collision.

In 2010 and 2011, the LHC provided Pb–Pb collisions at $\sqrt{s} = 2.76$ TeV per nucleon pair and pp collisions at $\sqrt{s} = 2.76$ TeV. It was found that the J/ψ production in Pb–Pb per binary nucleon-nucleon collision is suppressed as compared to its production in pp collisions. However, a part of the suppression may come from initial and/or final state nuclear matter effect. Large theoretical uncertainties on these effects does not allow us to quantify the amount of suppression as due to the deconfined state created in Pb–Pb collisions.

Measurement of J/ψ production in pPb and Pb–p collisions, foreseen for the end of this year, will reduce the uncertainties on these effects. Quarkonia can be reconstructed in the dimuon channel at forward rapidity and down to zero transverse momentum with the ALICE Muon spectrometer. We will report on the expected yields and measurements in pPb and Pb–p, based on MonteCarlo simulation studies, for quarkonium production at forward rapidity in ALICE.

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Azimuthal angular correlations between D^* mesons and charged hadrons in 7 TeV proton-proton collisions in ALICE

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As a consequence of their relatively high mass, heavy-flavour quarks, produced in heavy-ion collisions, are sensitive probes of the interaction dynamics inside the hot and dense QCD matter.

Since heavy quarks are produced in pairs during the initial stage of the collision, before the formation of the QCD medium, the measurement of heavy-flavour hadron production provides sensitive information on the properties of the medium itself.

A detailed understanding of the pair production mechanism in proton-proton collisions is interesting both as a QCD test tool and as a reference for future heavy-ion studies.

This particular physical process can be investigated using the angular azimuthal correlation between a reconstructed open-charm meson and the charged hadrons (or the kaons) produced in the collision. The azimuthal direction of charged hadrons (kaons) coming from a heavy-flavour decay, in respect to the $D^{*\pm}$, the “trigger” particle, is expected to be sensitive to the heavy quark production mechanism and can be compared to the perturbative QCD calculations.

The sample of reconstructed $D^{*\pm}$ mesons is highly pure because of its low background level. This feature makes them well suited candidates for correlation studies.

The status of the analysis, performed over the minimum bias proton-proton $\sqrt{s} = 7$ TeV data sample collected by the ALICE experiment in 2010, is presented.

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Parallel IVB: Jet quenching and energy loss / 107

What can we learn from the Dijets? A systematic study at RHIC and the LHC with VNI/BMS

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We present a systematic study of dijet suppression at RHIC and the LHC using the VNI/BMS parton cascade. We examine the medium modification of the dijet asymmetry A_J and the energy distribution within the dijets (jet-shape). Understanding the sensitivity of these observables to properties of the deconfined medium and to experimental factors is vital if dijets are to be useful for QCD tomography. VNI/BMS provides a controllable testbed with sufficient complexity to model jet modification without confounding results with fluctuations from hydrodynamics and hadronization. Dijets are examined under the modification of: the jet transport coefficient q_{hat} ; the path length of leading and sub-leading jets; cuts on the jet energy distributions; jet cone angle and the jet-medium interaction mechanism. We find that A_J is very sensitive to the distance traveled by the secondary jet and cuts applied to the leading jet energy, the jet shape is dominated by q_{hat} and the nature of the interaction mechanism.

Parallel VC: Initial state and pA / 108

Multigluon correlations in the Color Glass Condensate

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At high energy and/or for large atomic numbers the wave-function of a generic hadron is dominated by gluon modes with soft longitudinal momenta and high occupation numbers, which can reach the state of saturation. This state, known as the Color Glass Condensate (CGC), is universal and can manifest itself in any hadronic process involving small- x partons, like deep inelastic scattering and proton-proton, proton-nucleus and nucleus-nucleus collisions at the LHC. The CGC effective theory describes the ensemble of multigluon correlations at small x , which evolve with energy according to a renormalization group equation, the JIMWLK equation. After a quick review of the theory of the CGC, we focus on recent progress in solving the JIMWLK equation and thus obtaining explicit, analytic solutions for the multigluon correlations at high energy. Although approximate, these solutions are in fact very accurate, as demonstrated by their comparison to numerical solutions to the JIMWLK equation in all the cases where the latter are known.

Parallel VC: Initial state and pA / 109

Modeling the Impact Parameter Dependence of the nPDFs With EKS98 and EPS09 Global Fits

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The knowledge of the parton distribution functions (PDFs) is essential for interpreting any hard-process results from hadronic and nuclear collisions. The nuclear modifications of PDFs have been successfully determined through a global DGLAP analysis e.g. in the sets EKS98 and more recently EPS09. So far the nuclear PDFs (nPDFs) in the global fits have been taken to be spatially independent. However, it can be expected that the nuclear modifications vary when going from the dense center of a nucleus to its more dilute edge. In this work, using the A -dependence of the globally fitted nPDFs, we have been able to determine the spatial dependence of the nPDFs in terms of powers of the nuclear thickness functions. A routine for public use is released. For applications, we will discuss how one can then compute hard-process cross sections in different centrality classes of nuclear collisions. In particular, we consider the nuclear modification factor R_{dAu} for neutral pion production in deuteron-gold collisions at RHIC. Comparison with the PHENIX data in different centrality classes is also shown. In addition, predictions for the corresponding nuclear modification factor R_{pPb} in proton-lead collisions at the LHC are discussed. Both leading-order and next-to-leading order results are considered.

Parallel VC: Initial state and pA / 110

Suppression of high p_T hadron spectra in $p + A$ collisions

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Multiple hard and semi-hard parton scatterings in high-energy $p + A$ collisions involve multi-parton correlation in both momentum and flavor inside the projectile proton which will lead to modification of the final hadron spectra relative to that in $p + p$ collisions. Such modification of final hadron transverse momentum spectra in $p + A$ collisions is studied within HIJING 2.1 Monte Carlo model which includes nuclear shadowing of the initial parton distributions and transverse momentum broadening. Multi-parton flavor and momentum correlation inside the projectile are incorporated through flavor and momentum conservation which are shown to modify the flavor content and momentum spectra of final partons and most importantly lead to suppression of large p_T hadron spectra in pA collisions at both RHIC and LHC energies.

Summary:

We have studied the nuclear modification of hadron spectra in $d + Au$ and $p + Pb$ collisions at the RHIC $\sqrt{s_{NN}} = 200 \text{ GeV}$ and LHC energy $\sqrt{s_{NN}} = 4.4 \text{ TeV}$, respectively within both the HIJING 2.1 Monte Carlo model. collisions at the LHC is crucial to disentangle these cold nuclear effects from that caused by jet quenching in the hot quark-gluon plasma.

Parallel IVA: heavy flavour / 112

Heavy-flavour production in pp and AA collisions at the LHC

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A refined version of a multi-step calculation of heavy-flavour observables in pp and AA collisions has been developed, based on pQCD at NLO accuracy followed by parton shower evolution to describe heavy-quark production and on the relativistic Langevin equation to describe their stochastic evolution in the QCD plasma. Then, hadronization is modeled through an implementation of the available experimental data on heavy-quark fragmentation fractions and a set of pQCD fragmentation functions into pseudo-scalar and vector mesons.

Results of our calculations can be compared with some recent measurements performed at the LHC in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76 \text{ TeV}$: pT-differential spectra at mid-rapidity of heavy-flavour decay electrons and of exclusively reconstructed open-charm mesons at different centralities, as well as their nuclear modification factor RAA with respect to the pT spectra observed in pp collisions. In addition, predictions are given for the pT-differential elliptic-flow $v_2(pT)$ of open-charm mesons measured at mid-rapidity.

To test the validity of our setup for such studies, its predictions are also checked against the pT spectra measured in pp collisions at $\sqrt{s} = 2.76 \text{ TeV}$ and 7 TeV , considered as benchmark data samples.

Plenary 4B / 113

Global analysis of nuclear PDFs –latest developments

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I will present an overview of the nuclear parton distribution functions (nPDFs). I will first discuss the developments in the DGLAP-based global analysis during the last years. In the latter part of the talk, I will focus on the extraction of the spatial dependence of the globally analysed nPDFs, which has led to the new spatially dependent nPDFs called EPS09s and EKS98s ("s" for spatial). With these, one may now compute the nuclear hard-process cross sections in different centrality classes for the first time more consistently with the global analysis, and including also the spatially dependent versions of the error sets of EPS09. As an application, I will discuss the centrality dependence of the nuclear modification factor R_{dAu} for neutral pions in d+Au collisions at RHIC, compare with the data, and also present predictions for p+Pb collisions at the LHC.

Parallel IIIA: Heavy flavour / 116

Open Heavy-Flavour and J/psi production in proton-proton collisions measured with the ALICE experiment at LHC

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Open heavy-flavour and J/psi production measurements are powerful tools to test pQCD calculations in proton-proton collisions at the new LHC energy regime.

In addition, the measurement of open heavy-flavour and J/psi production in proton-proton collisions provides the necessary reference for the ALICE Pb-Pb program.

The ALICE experiment at the LHC collected proton-proton collisions at $\sqrt{s}=7$ and 2.76 TeV in 2010 and 2011. In this talk, the latest results of open heavy-flavour and J/psi production in proton-proton collisions measured by the ALICE experiment at both mid- and forward rapidity via their various hadronic and leptonic decay channels will be presented. These include, among other topics, the first LHC result on J/psi polarization, multiplicity dependence of J/psi production, D-meson measurement down to low transverse momentum and J/psi production from B-hadron decays. Comparisons with different theoretical models will be discussed as well.

Parallel IVA: heavy flavour / 117

Measurement of the nuclear modification factor of electrons from heavy-flavour decays in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with ALICE

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The medium-induced parton energy loss is expected to depend on its mass and colour charge. At the LHC, heavy quarks are copiously produced. This allows us to provide new constraints on partonic energy loss mechanisms in the medium produced in the heavy-ion collisions. The yield of electrons from semileptonic heavy-flavour decays has been measured at mid-rapidity $|y| < 0.8$ in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV by the ALICE experiment at the LHC in the transverse momentum range $1.5 < p_t < 6$ GeV/c. The p_t dependence of the nuclear modification factor R_{AA} at central rapidity has been calculated with respect to a pp reference obtained from the cross section measured at $\sqrt{s} = 7$ TeV and scaled to $\sqrt{s} = 2.76$ TeV. We present the spectra and the nuclear modification factor of electrons from heavy-flavour decays for different centrality classes. The production of electrons from beauty decays can be addressed using their displacement from the primary vertex. We discuss the status of this analysis in Pb-Pb

collisions, towards the measurement of the nuclear modification factor of electrons from beauty decays.

Parallel VC: Initial state and pA / 118

Azimuthal angle correlations in forward dihadron production in pA collisions

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Single inclusive hadron production in the forward rapidity region in deuteron-gold collisions is well understood in the Color Glass Condensate (CGC) framework. As a complement to single inclusive spectra, detailed information is obtained with two-particle correlations. Recent measurements of the azimuthal angle correlations at RHIC have shown that there is a strong suppression of the away side peak at forward rapidities. This is easily understood in the CGC framework: the produced partons are initially back-to-back in the transverse plane, but the interaction with the nucleus causes a momentum transfer of the order of the saturation scale. In forward dihadron production the small- x structure of the nucleus is probed, implying a large saturation scale.

We present on going work on calculating the dihadron correlation using the running coupling BK equation. We include the inelastic terms neglected in some of the previous literature and show that they naturally contain the double parton scattering part that has so far been treated as a separate contribution. We also use, for the first time in a phenomenological application, a Gaussian approximation of JIMWLK to go beyond the large- N_c limit.

Parallel VC: Initial state and pA / 119

Multigluon correlations in JIMWLK

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Multiparticle correlations, such as the “ridge” effect in pp and AA collisions and forward dihadron correlations in pA collisions, are an important probe of the strong color fields that dominate the initial stages of a heavy ion collision. We argue that the Color Glass Condensate framework provides the most natural way to understand them.

We describe recent progress in understanding two-particle correlations in the dilute-dense system, e.g. in forward dihadron production in deuteron-gold collisions. This requires computing the energy dependence of higher point Wilson line correlators from the JIMWLK renormalization group equation. We find that the large N_c approximation used so far in the phenomenological literature is not very accurate. On the other hand a Gaussian finite N_c approximation is a surprisingly close to the full result.

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Measurement of B meson production in pp collisions at $\sqrt{s} = 7$ TeV via displaced electrons in ALICE

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The measurement of the production cross-section of B mesons in pp collisions at LHC energies is important in two respects. First, it allows one to test perturbative quantum chromodynamics calculations. Secondly, it provides an essential reference for studies in heavy-ion collisions, in which a hot and dense medium, the quark-gluon plasma (QGP), is expected to be formed. When passing through this medium, quarks lose energy via the strong interaction. Since the amount of energy loss should depend significantly on the quark mass, beauty as the heaviest observable flavour is of particular interest for the exploration of QGP properties.

The presented poster will focus on methods and results of the analysis of displaced electrons from the B meson's semielectronic decay channels in ALICE, at pseudorapidities $|\eta| < 0.5$.

First, the electron identification in the ALICE central barrel, using the Time Projection Chamber (TPC) and Time Of Flight (TOF) detector will be outlined. The selection of electrons with a large displacement from the primary vertex will be detailed. This makes use of the larger B meson mean proper decay length ($\sim 500 \mu\text{m}$) in comparison to D mesons and other electron sources. The method for estimation of the remaining electron background in the selected sample will be presented, based on calculations using ALICE measured pt spectra of π^0 and D mesons. Finally, the pt spectrum of electrons from B decays measured in pp collisions at $\sqrt{s} = 7$ TeV will be shown.

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Study of the nuclear modification factor of electrons from B meson decays at mid-rapidity in Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV with ALICE

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Heavy quarks are relevant probes of the QCD medium produced in high-energy heavy ion collisions. Indeed, medium-induced energy loss is expected to depend on the parton mass and color charge. Charm and beauty quarks are created early in the collision and should thus traverse much of the QCD medium created. In 2010 and 2011, pp collisions at $\sqrt{s} = 7$ TeV and PbPb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV have been recorded by the ALICE experiment at the LHC. The electrons produced by the collision can be separated from the other particles via the excellent Particle Identification capabilities of ALICE. Due to the large proper decay length ($c\tau \approx 500 \mu\text{m}$) of beauty hadrons and a hard momentum spectrum, electrons from their decays have a wider impact parameter distribution compared to background electrons. By taking into account the different impact parameter distribution shapes, the p_t spectrum of electrons from beauty hadron decays can be obtained. We present a method to measure the p_t dependence of the nuclear modification factor R_{AA} of electrons from beauty hadron decays in Pb-Pb collisions using the central barrel ($|\eta| < 0.8$) of ALICE and discuss the current status of the analysis.

Open Heavy Flavor Production at Forward Angles in PHENIX

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Measurement of the production of heavy quarks in heavy ion collisions can be used to probe the early stages of the created medium, study hot and cold nuclear matter effects, and test theoretical predictions concerning quark energy loss and initial-state effects. This is a current area of active research in the field and it is important to extend such measurements to the forward region. PHENIX can measure the production of open heavy flavor at forward angles with subsequent semi-leptonic decay of heavy flavor mesons into muons. We report the nuclear modification factor for the production of muons from heavy flavor decay in Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV for three centrality intervals and compare to theoretical predictions concerning the suppression of heavy quark production which incorporate heavy quark energy loss and in-medium heavy meson disassociation. Additionally, we report the charm production cross section for p+p collisions at $\sqrt{s} = 200$ GeV and compare results to Fixed Order plus Next-to-Leading Log predictions.

Parallel IIA: Heavy flavour / 123

Open charm hadron production via hadronic decays at STAR

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Heavy quarks are a unique probe to study the medium produced in ultra-relativistic heavy ion collisions. The dominant process of charm quark production at RHIC is believed to be initial gluon fusion which can be calculated in the perturbative QCD. The upper limit of FONLL calculation seems to be in good agreement with charm cross section measurements at mid-rapidity in $p + p$ collisions at $\sqrt{s_{NN}} = 200$ GeV provided by STAR. The same measurement in Au+Au collisions at equal energy reveals the number of binary collisions scaling of charm cross section indicating that charm production is dominated by initial hard scattering.

This talk will present the measurements of D^0 , D^+ in $p+p$ and D^0 in Au+Au collisions at $0.6 \text{ GeV}/c < p_T < 6 \text{ GeV}/c$ and $|\eta| < 1$. Furthermore, we will present the analysis status on open charm measurement in $\sqrt{s_{NN}} = 500$ GeV $p + p$ collisions.

Parallel IB: Jet quenching and energy loss / 124

Probe the nuclear matter with jet productions at NLO

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Jets physics in heavy ion reactions is an important new area of active research at the Relativistic Heavy Ion Collider (RHIC) and at the Large Hadron Collider (LHC) that paves the way for novel

tests of QCD multi-parton dynamics in dense nuclear matter. At present, perturbative QCD calculations of hard probes in elementary nucleon-nucleon reactions can be consistently combined with the effects of the nuclear medium up to next-to-leading order (NLO). While such accuracy is desirable but not necessary for leading particle tomography, it is absolutely essential for the new jet observables.

With this motivation, We investigate the cold nuclear matter(CNM) effects on jet productions in high-energy nuclear collisions at LHC with the NLO perturbative QCD. The nuclear modifications for dijet angular distributions, dijet invariant mass spectra, dijet transverse momentum spectra and dijet momentum imbalance due to CNM effects are calculated by incorporating EPS, EKS, HKN and DS parametrization sets of parton distributions in nucleus . It is found that dijet angular distributions and dijet momentum imbalance are insensitive to the initial-state CNM effects and thus provide optimal tools to study the final-state hot QGP effects such as jet quenching.

Furthermore we present the results and predictions at NLO for productions of the single, the Z0 tagged jet, and double inclusive jet cross sections by including parton energy loss effect in the QGP to be formed in high-energy nucleus-nucleus collisions. We demonstrate how an enhanced di-jet asymmetry in central Pb+Pb reactions at the LHC, recently measured by the ATLAS and CMS experiments, can be derived from these results. We show quantitatively that a significant fraction of this enhancement may be related to the ambiguity in the separation between the jet and soft background medium and point to a suite of measurements that can help build a consistent picture of parton shower modification in heavy ion collisions at the LHC.

Parallel VB: Jet quenching and energy loss / 125

Jet-Tagged Back-Scattering Photons For Quark Gluon Plasma Tomography

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We investigate the correlations of photons produced by Compton back scattering and annihilation of fast quarks in quark gluon plasma with their away-side jets. Compton back scattering and quark annihilation into photons effectively act as jet-photon conversion mechanisms and were originally proposed as novel electromagnetic sources in heavy ion collisions in Phys. Rev. Lett. 90, 132301 (2003). The unique appeal of these processes lies in the fact that their photons carry information about both the medium via a $T^2 \log 1/T$ dependence of the yield, and about the energy loss of partons before the back scattering occurs. Attempts to identify these photons in experiment through inclusive direct photon spectra or direct photon v_2 measurements at intermediate PT at RHIC have been inconclusive so far. We show that the capability to measure jets in coincidence with photons at the upgraded STAR and SPHENIX experiments, or at one of the LHC experiments, offers a unique opportunity to identify back scattering photons at large photon momenta. Jet-triggered back-scattering photons can be distinguished from bremsstrahlung through their strong correlation with the given trigger ET, and they are set apart from prompt hard photons through the energy loss of their parent parton. We demonstrate with leading and next-to-leading order calculations that jet-triggered direct photon spectra and nuclear modification factors in nuclear collisions as a function of photon PT show a distinct feature around the trigger ET due to back-scattering photons. The height and width of this structure are correlated with the medium temperature and parton energy loss spectrum, respectively.

Plenary 2B / 126

Hadron correlations in CMS

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The measurements of the anisotropic flow of single particles and particle pairs have provided some of the most compelling evidence for the creation of a strongly interacting quark-gluon plasma (sQGP) in relativistic heavy ion collisions, first at RHIC, and more recently at the LHC. Using PbPb collision data taken in the 2010 and 2011 heavy ion runs at the LHC, the CMS experiment has investigated a broad scope of these flow phenomena. The v_2 elliptic flow coefficient has been extracted with four different methods to cross-check contributions from initial state fluctuations and non-flow correlations. The measurements of the v_2 elliptic anisotropy have been extended to a transverse momentum of 60 GeV/c, which will enable the placement of new quantitative constraints on parton energy loss models as a function of path length in the sQGP medium. Additionally, for the first time at the LHC, the CMS experiment has extracted precise elliptic anisotropy coefficients for the neutral pi meson (π^0) in the centrality range 20-80% and over a transverse momentum range 1.6 to 8 GeV/c. These results will be compared with both the π^0 results reported by the PHENIX detector at RHIC and with the inclusive charged particle anisotropy results reported from the LHC. Finally, the CMS experiment has mounted an extensive study of charged hadron pair azimuthal correlations using a Fourier harmonic decomposition to fit the data. The relationship between these pair coefficients and the single particle harmonic flow coefficients will be explored for its insight in the early dynamics of this viscous medium.

Parallel VB: Jet quenching and energy loss / 127

Realistic 3+1-dimensional modelling of QCD jets in heavy-ion collisions

Author: Clint Young¹

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The reconstruction of jets in heavy-ion collisions provides insight into the dynamics of hard partons in media. Unlike the spectrum of single hadrons, the spectrum of jets is highly sensitive to \hat{q}_\perp , as well as being sensitive to partonic energy loss and radiative processes. We use MARTINI, an event generator, to study how finite-temperature processes at leading order affect single jet, dijet, and photon-jet observables. While these observables are studied at the LHC, detector upgrades at RHIC may allow measurements of these observables at lower collision energies.

Parallel IIC: High pT suppression, Global Observables / 128

Neutral pion production in Au+Au collisions at RHIC

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Neutral pion production in $\sqrt{s_{NN}}=130$ and 200 GeV central Au+Au collisions at the Relativistic Heavy Ion Collider has been found to be strongly suppressed in comparison to the expectations from properly scaled p+p collisions [1], while data from d+Au collisions showed no suppression [2]. This observation was one of the first convincing signatures of a strongly interacting partonic medium created in high energy heavy ion collisions.

A study of the azimuthal anisotropy of π^0 production in the RHIC $\sqrt{s_{NN}}=200$ GeV Au+Au data from 2004 indicated that the azimuthal dependence of the nuclear modification factor R_{AA} is strongly correlated with the (approximately elliptical) geometry of the overlap region up to $p_T=10$ GeV/c [3]. The approximately 4 times higher integrated luminosity of 2007 Au+Au collision data, together with a reaction plane detector upgrade, allowed for a significantly improved determination of the dependence of R_{AA} on the reaction plane up to $p_T=18$ GeV/c. Recent results on the azimuthal anisotropy of π^0 production will be shown and compared to several theoretical models.

A 2005 RHIC energy scan with Cu+Cu collisions pointed out that π^0 suppression still exists in this lighter system at 62.4 GeV, while the 22.4 GeV Cu+Cu results showed an enhancement consistent with theoretical predictions [4]. Onset and evolution of the in-medium suppression with collision energy, centrality and system size will be presented, including the new results from Au+Au data collected in 2010 at $\sqrt{s_{NN}}=39$ and 62.4 GeV c.m.s. energies.

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Parallel VB: Jet quenching and energy loss / 131

Realistic medium-averaging in radiative energy loss

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There has been a lot of interest in testing radiative energy loss calculations against data from RHIC and the LHC. It is customary, as in the Gyulassy-Levai-Vitev (GLV) approach, to formulate the energy loss of a jet parton as a line integral from the production point along a straight-line trajectory. Calculations then account for variations in pathlength with jet origin and direction, and most recently also for fluctuations in the medium density (lumpiness), which give rise to fluctuations in energy loss that significantly affect high- p_T observables such as the nuclear suppression R_{AA} or the momentum anisotropies v_n .

These studies, however, ignore that the line integrals themselves represent an average over the location of possible interaction points (color sources in GLV) along the jet path. We will present results from a calculation with stochastically chosen interaction points for each jet, which gives additional fluctuations in energy loss. The influence of these fluctuations on RHIC and LHC observables will be discussed utilizing both medium density parameterizations and realistic medium evolution from bulk dynamics models, such as the parton transport MPC. A special advantage of using parton transport is that it conveniently provides the evolution of an ensemble of scattering centers.

Parallel IIA: Heavy flavour / 132**Recent results on heavy quark quenching in ultrarelativistic heavy ions collisions: the effect of gluon damping****Author:** Pol Bernard Gossiaux¹**Co-authors:** Aichelin J. ¹; Bluhm M. ¹; Gousset Th. ¹¹ *Subatech*

Recently, we have proposed a microscopic approach for the quenching and thermalisation of heavy quarks (HQ) in URHIC [1, 2, 3], assuming that they interact with light partons through both elastic and radiative processes evaluated by resorting to some parameterization of the running coupling constant, while those partons are spatially distributed along hydrodynamical evolution of the hot medium. This approach is able to explain successfully several observables measured at RHIC, such as the nuclear modification factor and the elliptic flow of non-photon single electrons. The diffusion coefficient of heavy quarks in the quark gluon plasma –a fundamental property of this state of matter –can thus be extracted and compared with recent lattice calculations. In this contribution at Hard Probes, we would like to discuss the predictions of our model [2] for D and B mesons production in URHIC at LHC energies and confront them with experimental results obtained so far by ALICE and CMS collaborations for Pb-Pb collisions at $\sqrt{s} = 2.76$ TeV.

Jointly, we would like to discuss the question of the influence of a possible gluon damping on the phenomenological consequences of radiative energy loss. In [5], we have indeed studied the effect of an absorptive medium on standard LPM [6] radiation in electrodynamics and have advocated that the large time needed for the photon formation in Bremsstrahlung from ultrarelativistic charges is not affordable if damping is taken into account. Similar effect manifests itself in QCD, as one of us (M. Bluhm) proposes to demonstrate at HP 2012 in another contribution. In our contribution, we would concentrate on the implications of such an effect on the quenching of particles in URHIC, discussing observables such as spectra, elliptic flow, azimuthal correlations, as well as the single electron puzzle.

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D+s production in pp collisions at 7 TeV and prospects for the Pb-Pb analysis with the ALICE detector**Author:** Innocenti Gian Michele¹¹ *Universita' di Torino - Italy*

The measurement of the charm production cross section in pp collisions at the LHC allows one to test the perturbative QCD predictions in a new energy regime. Furthermore, it provides a reference for charm measurements in Pb-Pb collisions in which heavy quarks are expected to be sensitive probes for the properties of the medium.

D+s mesons have been reconstructed at mid-rapidity with the ALICE detector through the decay channel $D+s \rightarrow K+K\pi^+$ in pp collisions at $\sqrt{s} = 7$ TeV. We present the pt-dierential cross section and we compare it to that of D0, D+ and D*+ mesons also measured with ALICE in the same

collision system. The status of the D+s analysis in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV is also discussed.

Parallel IB: Jet quenching and energy loss / 134

Shining a Gluon Beam through Quark-Gluon Plasma

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A holographic calculation of the quenching of a beam of gluons with typical momenta q shining through strongly coupled quark-gluon plasma shows that such a beam is attenuated rapidly over a distance of order $q^{-1/3} (\pi T)^{-4/3}$ as it propagates at the speed of light, shedding trailing sound waves with momenta of order (πT) . At larger and larger q , the trailing sound wave becomes less and less prominent. The outward-going beam of gluon radiation itself shows no tendency to spread in angle or to shift toward larger wavelengths, even as it is completely attenuated. In this regard, the behavior of the beam of gluons that we analyze is reminiscent of the behavior of jets produced in heavy ion collisions at the LHC that lose a significant fraction of their energy without appreciable change in their angular distribution or their momentum distribution as they plow through the strongly coupled quark-gluon plasma produced in these collisions. However, we know that quark-gluon plasma must be weakly coupled at short enough distance scales. This means that even if jet quenching typically occurs as in a strongly coupled plasma, there should be rare events in which a hard parton is scattered by a larger angle, picking up significant transverse momentum.

Parallel IIA: Heavy flavour / 135

Heavy flavor suppression: an interplay of electric and magnetic mass effects

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Reliable predictions for jet quenching in ultra-relativistic heavy ion collisions require accurate computation of radiative energy loss. While all available energy loss calculations assume zero magnetic mass –in accordance with the one-loop perturbative calculations –different non-perturbative approaches report a non-zero magnetic mass at RHIC and LHC. We generalized the dynamical energy loss formalism [1], to consistently include a possibility for existence of non-zero magnetic screening [2]. We show that this generalization indicates a fundamental constraint on electric to magnetic mass ratio, which appears to be supported by lattice QCD simulations. Jet suppression patterns, obtained from this newly developed generalization, will be compared with RHIC and LHC measurements. Interestingly, comparison with RHIC data indicates that the generalized dynamical energy loss formalism may provide a reasonable explanation of the “Heavy flavor puzzle at RHIC” [3].

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Parallel IB: Jet quenching and energy loss / 137**Weakness or Strength in the Golden Years of RHIC and LHC?****Author:** Horowitz Will¹¹ *Department of Physics University of Cape Town*

We present comparisons of the latest pQCD- and AdS/CFT-based energy loss models with the newest high-pT measurements from RHIC and LHC. Zero parameter predictions of energy loss from WHDG rigorously constrained to PHENIX π^0 RAA data show quantitative agreement with the measured azimuthal anisotropy and D meson suppression at LHC. pQCD predictions follow the qualitative trend of the LHC light hadron suppression, and we report on progress in including next-to-leading order effects which could provide the key ingredient needed for quantitative agreement. LHC D meson predictions from AdS/CFT are oversuppressed compared to data when constrained to RHIC non-photonic electron data, although due to the large experimental uncertainties, the method is not falsified. We also present for the first time theoretically controlled AdS/CFT predictions for light particle suppression, which also suggest that strong-coupling methods leads to a too-large suppression. Finally, we emphasize how the comparison of mass-dependent energy loss calculations to data provides a powerful tool for determining the dominant energy loss mechanism in heavy ion collisions.

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Transverse Momentum Spectra of Unidentified Charged Particles in pp Collisions at the ALICE experiment**Author:** Luettig Philipp¹¹ *Institut fuer Kernphysik Goethe-Universitaet*

The ALICE experiment at the CERN-LHC has accumulated data on pp and Pb–Pb collisions in the past two years. Designed for exploring the properties of hot and dense matter formed in heavy-ion collisions, the ALICE Time Projection Chamber (TPC) has the capability to measure the transverse momentum (p_T) of charged particles in a broad p_T range for $p_T > 150$ MeV/c. \\

The transverse momentum spectra of unidentified charged particles for pp collisions at $\sqrt{s} = 0.9, 2.76$ and 7 TeV are presented. The extraction of a pp baseline for the calculation of the nuclear modification factor R_{AA} at $\sqrt{s_{NN}} = 2.76$ TeV is discussed and compared to alternative approaches to construct a baseline. In addition, the dependence of the average transverse momentum of these spectra on center-of-mass energy is reviewed and compared to measurements by other experiments.

Parallel IVC: Initial state and pA / 139**Linear vs non-linear QCD evolution: from HERA data to LHC phenomenology****Author:** Paloma Quiroga-Arias¹**Co-authors:** Albacete Javier ²; Milhano Jose Guilherme ³; Rojo Juan ⁴¹ *LPTHE, Univ. Paris 6 and CNRS*² *IPN Orsay and IPhT CEA/Saclay*³ *IST/Lisbon and CERN*

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The forthcoming p+Pb run at the LHC will provide crucial information on the initial state effects of heavy ion collisions and on the gluon saturation phenomena. In turn, most of the saturation inspired phenomenology in heavy ion collisions borrows substantial empirical information from the analysis of e+p data, where abundant high quality data on the small-x kinematic region is available. Indeed, the very precise combined HERA data provides a testing ground in which the relevance of novel QCD regimes, other than the successful linear DGLAP evolution, in small-x inclusive DIS data can be ascertained. We present a study of the dependence of the AAMQS fits, based on the running coupling BK non-linear evolution equations (rcBK), on the fitted dataset. This allows for the identification of the kinematical region where rcBK accurately describes the data, and thus for the determination of its applicability boundary. It also sets important constraints to the saturation models used to model the early stages of heavy ion collisions. Finally we compare the rcBK results with NNLO DGLAP fits, obtained with the NNPDF methodology with analogous kinematical cuts. Further, we explore the impact on LHC phenomenology of applying stringent kinematical cuts to the low-x HERA data in a DGLAP fit.

Parallel IA: Quarkonia / 140

Measurement of charmonium production in PbPb collisions at 2.76 TeV with CMS

Author: Moon Dong Ho¹¹ Korea University

The Compact Muon Solenoid (CMS) is fully equipped to measure hard probes in the di-muon decay channel in the high multiplicity environment of nucleus-nucleus collisions. Such probes are especially relevant for studying the quark-gluon plasma since they are produced at early times and propagate through the medium, mapping its evolution. CMS has measured the nuclear modification factors of non-prompt J/psi (from b-hadron decays) and prompt J/psi in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. For prompt J/psi with relatively high pt ($p_T=6.5-30$ GeV/c), a strong, centrality-dependent suppression is observed in PbPb collisions, compared to the yield in pp collisions scaled by the number of inelastic nucleon-nucleon collisions. In the same kinematic range, a suppression of non-prompt J/psi, which is sensitive to the in-medium b-quark energy loss, is measured for the first time. Results from the 2010 data taking period are reported and an outlook on the 2011 data analysis will be given.

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Measurement of charm suppression and charm flow in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV via $D^0 \rightarrow K^+ \pi^-$ reconstruction in ALICE

Author: Cafarri Davide¹¹ Università degli studi di Padova

In ultra-relativistic heavy-ion collisions, heavy quarks are sensitive probes to test the medium properties, since they are formed at shorter time scale with respect to the deconfined state. These quarks can interact with the medium and lose energy via collisions and gluon radiation. The nuclear modification factor (RAA), obtained by comparing heavy flavour production yields in pp and heavy-ion collisions, allows to measure the effect of parton in-medium energy loss. The elliptic flow v_2 of D mesons compared to that of light hadrons is expected to bring insights into the degree of thermalization of charm quarks within the quark-gluon plasma. The ALICE experiment has collected Pb-Pb

data at $\sqrt{s_{NN}} = 2.76$ TeV and pp data at $\sqrt{s} = 7$ and 2.76 TeV. D^0 mesons have been reconstructed in their hadronic decay $D^0 \rightarrow K^+ \pi^-$ in the central rapidity region. The measurements of D^0 suppression at high momentum and the $D^0 v_2$, in Pb-Pb collisions will be presented.

Plenary 3A / 143

Quarkonia and heavy flavor production in CMS

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The Compact Muon Solenoid (CMS) is fully equipped to measure quarkonia in the di-muon decay channel in the high multiplicity environment of nucleus-nucleus collisions. Quarkonia are especially relevant for studying the quark-gluon plasma since they are produced at early times and propagate through the medium, mapping its evolution. CMS has measured the nuclear modification factors of non-prompt J/psi (from b-hadron decays), prompt J/psi and Y(1S) in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. For prompt J/psi with relatively high p_T ($6.5 < p_T < 30$ GeV/c), a strong, centrality-dependent suppression is observed in PbPb collisions, compared to the yield in pp collisions scaled by the number of inelastic nucleon-nucleon collisions. Such strong suppression at high p_T has previously not been observed at RHIC. In the same kinematic range, a suppression of non-prompt J/psi, which is sensitive to the in-medium b-quark energy loss, is measured for the first time. Also the low-pt Y(1S) mesons are suppressed in PbPb collisions. Furthermore, a suppression of the excited Y-states has been measured with respect to the Y(1S). During the 2011 data taking period the data sample has been increased by a factor twenty, which allows more detailed measurements of the observed quarkonia suppression patterns and opens the door to new observables. Results from the 2010 data taking period are presented and the status of the 2011 data analysis is reported.

Plenary 4A / 144

W,Z and photon production in CMS

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Electroweak gauge bosons, γ , W and Z, do not participate in the strong interaction, and thus constitute clean probes of the initial state of nucleus-nucleus collisions. The comparison of their production cross-sections in pp and in nuclear collisions provides an estimate of the nuclear parton distribution functions. Despite the low production cross section of weak bosons compared to other nuclear processes, the relatively clean signal of their leptonic decay channel allows their detection and reconstruction. The measurement of prompt photon production is challenging because of the presence of a large background coming from electromagnetic decays of neutral mesons, which is suppressed by photon isolation criteria. This talk will report measurements of isolated photons, as well as Z and W bosons, produced in PbPb and pp collisions at nucleon-nucleon $\sqrt{s} = 2.76$ TeV with the CMS detector.

Plenary 5A / 145

The di-lepton physics program at STAR

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Di-leptons are ideal probes of the strongly interacting hot, dense medium created at RHIC. They are not affected by the strong interaction once produced, therefore they can probe the whole evolution of the collision. In different mass regions, di-leptons can be used to probe vector meson in-medium modifications, Quark Gluon Plasma (QGP) thermal radiations, and color-screening features of QGP. In year 2010, the barrel time-of-flight detector was completed, which enables clean electron identification with full azimuthal coverage at mid-rapidity. In addition, the Muon Telescope Detector and Heavy Flavor Tracker Upgrades, to be completed in year 2014, providing clean muon identification and precise pointing resolution, will enable the precise measurements of correlated charm contribution to di-leptons, therefore, make it possible to measure QGP thermal radiation using di-leptons. In this talk, I will review recent di-electron results at STAR in p+p and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and discuss di-muon and e-muon physics capabilities with future detector upgrades.

Plenary 4A / 146

Measurement of the W,Z and photon production in lead-lead collisions at $\sqrt{s_{NN}} = 2.76$ TeV with ATLAS detector

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The color neutral bosons are an unparalleled probes of the hot and dense matter produced in relativistic heavy ion collisions at LHC. Because the decay products do not carry color charges, the W and Z bosons allows us insight into the initial hard scattering that produced it and provides a clean test of our understanding of the collision. In particular, the yield of bosons in heavy ion collisions is a sensitive test of binary scaling. The ATLAS experiment has measured W and Z boson yield via leptonic decay modes in Pb+Pb collisions with $\sqrt{s_{NN}}=2.76$ TeV in a data sample corresponding to 148 ub^{-1} of integrated luminosity. The measurement of W,Z boson production and their properties will be presented.

Plenary 4B / 147

Light vector meson production at the LHC with the ALICE detector

Author: Elisa Incani¹

¹ *CA*

Plenary 2B / 148**Holography and heavy ion collisions: promises and challenges****Author:** Derek Teaney¹¹ *Stony Brook University*

I review the application of the AdS/CFT correspondence to heavy ion collisions. The talk will first review and critique available holographic calculations of energy loss, with an emphasis on the parametric similarities and differences between perturbation theory and the strongly coupled theory. Then the talk will summarize the results of current AdS/CFT motivated energy loss models and their domain of applicability. In addition, several other results from the AdS/CFT correspondence of relevance to heavy ion collisions will be discussed. For example, recent results on the (strikingly fast) thermalization of holographic plasmas will be reviewed.

Plenary 2B / 149**Hadron Correlations in ATLAS****Author:** Soumya Mohapatra¹¹ *Stony Brook University*

Hadron correlations are important tools used to study the properties of the medium produced in relativistic heavy ion collisions. We present detailed measurements of flow harmonics v_2 - v_6 via di-hadron correlations in broad p_T , $\Delta\eta$ and centrality ranges using the 2010 Pb+Pb data from ATLAS. These measurements are compared to the corresponding values obtained via event-plane measurements. This result provides new insights on the origin of the long range “ridge” structure over broad p_T ranges. Measurements of the dipolar flow (v_1) associated with initial dipole asymmetry as function of p_T and centrality are also presented. Finally, the results of correlations between harmonic planes of different orders measured via two-plane and three-plane correlations are also discussed.

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Welcome**Plenary 1A / 151****No Pain, no Gain? Hard Probes of Quark-Gluon Plasma Coming of Age**

Author: Berndt Mueller¹

¹ *Duke University*

Hard QCD and QED probes hold the promise of providing controlled, rigorously calculable means of interrogating hot and dense QCD Matter, measuring its properties and determining its structure. While the RHIC has opened hard probes to experimental investigation, the LHC has extended the range of hard probe measurements by an order of magnitude. Data on jets, high-pT hadrons, quarkonia, photons, and lepton pairs over a wide kinematic range are now putting the challenge back into the theorists' court: Can we use these hard probes as hoped to characterize the quark-gluon plasma created in heavy ion collisions model independently and determine its structure? Related questions concern the investigation of the low-x parton structure on large nuclei and of the thermalization mechanism by means of hard probes. In my lecture I will review the status of experimental results and of theoretical efforts to understand and interpret them prior to Hard Probes 2012. I will also identify issues that need to be clarified before the full promise of hard probes for hot QCD matter can be realized.

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Welcome

Plenary 1A / 153

Jet quenching and heavy flavor production in ATLAS

Author: Aaron Angerami¹

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Measurements of inclusive jet and heavy quark jet suppression in relativistic heavy ion collisions are presented. The measurements were performed using Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ -TeV recorded with the ATLAS detector at the LHC during the 2010 Pb ion run. Results are obtained using calorimetrically reconstructed jets using the anti-kt algorithm with a per-event background subtraction procedure. Measurements of the single inclusive jet spectrum with jet radius parameters $R = 0.2, 0.3, 0.4$ and 0.5 , are presented. The spectra are unfolded to correct for the finite energy resolution introduced by both detector effects and underlying event fluctuations. Single jet production, through the central-to-peripheral ratio RCP, is presented as a function of jet pT, centrality and jet radius. Measurements of the single inclusive muons are also presented over the range $4 < pT < 14$ GeV, where the production is dominated by the semi-leptonic decays of open heavy flavor hadrons. The muon spectra and RCP are presented as a function of pT and centrality, which provide sensitivity to the quenching of heavy quarks.

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Hard Probes in Nuclear Collisions: where are we?

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Plenary 3A / 155**Recent developments in lattice studies for quarkonia****Author:** Olaf Kaczmarek¹¹ *Bielefeld University***Corresponding Author:** okacz@physik.uni-bielefeld.de

I will give a review on recent developments in lattice QCD studies for quarkonia in the quark gluon plasma medium. I will discuss recent progress in the extraction of spectral properties from lattice QCD calculations of hadronic correlation functions. Besides medium modifications of bound states and their dissociation in the plasma I will focus on transport coefficients, like heavy quark diffusion constants, extracted from different correlation functions on the lattice. Present limitations and future perspectives for studies of quarkonia and related transport coefficients on the lattice will be discussed.

Plenary 2A / 156**Hadron correlations in ALICE****Author:** Jan Fiete Grosse Oetringhaus¹¹ *CERN***Corresponding Author:** jan.fiete.grosse-oetringhaus@cern.ch

Particle correlations are a powerful tool to study collective effects and in-medium jet modification as well as their interplay in the hot and dense medium produced in central heavy-ion collisions. The talk presents measurements of two-particle correlations of inclusive charged and identified particles with the ALICE detector. We study the short-range correlation region and quantify the shape and particle content of the near-side peak. The results suggest strong modifications of the peak shape and particle ratios in central Pb-Pb collisions, compared to proton-proton or peripheral data. We compare to MC models and discuss the importance of the inclusion of collective effects in these models.

Plenary 2B / 157**Energy loss and hadron correlations in PHENIX****Author:** Justin Frantz¹¹ *Ohio University***Corresponding Author:** frantz@ohio.edu**Plenary 2B / 158****Future opportunities for jet physics at RHIC (with an eye at recent LHC results)****Author:** Brian Cole¹

¹ *Columbia University***Corresponding Author:** cole@nevis.columbia.edu**Plenary 3A / 159**

Heavy flavour production in ALICE at the LHC

Author: Silvia Masciocchi¹¹ *GSI Darmstadt***Corresponding Author:** s.masciocchi@gsi.de

Heavy quarks, charm and beauty, are excellent probes to investigate QCD processes in hadronic interactions, and to characterize the deconfined medium produced in high-energy heavy-ion collisions, the Quark-Gluon Plasma. They are produced dominantly through hard partonic scattering processes in the earliest stage of the hadronic collisions and thus they experience the whole history of the collision. ALICE at the LHC is the experiment dedicated to study the physics of nucleus-nucleus collisions, and particularly the physics of heavy quarks. High resolution tracking down to low transverse momentum, and good particle identification give access to many hadronic and semileptonic decay channels of heavy-flavour hadrons, both at mid- and at forwardrapidity. A selection of results from pp collisions at $\sqrt{s} = 2.76$ and 7 TeV, and from Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV will be presented. In proton-proton collisions, the high precision measurements provide an important test of perturbative QCD predictions. The precise vertex reconstruction together with the particle identification, allows the separation of the charm and the beauty components. Furthermore, the pp results are essential as a reference for the measurements in heavyion collisions. Nuclear modification factors were measured for D mesons, for electrons and for muons from heavy-flavour decays. Elliptic flow of D meson will be presented. The results provide information on the Quark-Gluon Plasma, via the energy loss of the heavy partons in the strongly interacting medium, and hints on the medium thermalization.

Plenary 3B / 160

Quarkonia production in effective field theory and potentials

Author: Alexander Rothkopf¹¹ *Institute for Theoretical Physics, University of Bern***Corresponding Author:** rothkopf@itp.unibe.ch**Plenary 3B / 161**

Quarkonia and open heavy-flavor production at STAR

Author: Manuel Calderon De La Barca Sanchez¹¹ *UC Davis***Corresponding Author:** mcalderon@ucdavis.edu

Heavy flavor production is a useful tool to study the medium produced in heavy ion collisions. We will present results on production of charm hadrons via the reconstruction of D0 and D* mesons,

and compare them to FONLL calculations. The nuclear modification factor of D mesons can then be used to study medium effects. We will also present results on charmonium and bottomonium production. By studying charmonium v_2 , one can estimate the amount of coupling between heavy quarks to the hot, flowing medium. The Upsilon nuclear modification factor, an important signature of deconfinement, will also be presented.

Plenary 3B / 162

Cold nuclear matter effects and heavy-quark production in PHENIX

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Measurements of cross section modifications for hard processes that take place in a nuclear target provide information about the modification of parton densities in nuclei at low Bjorken x . This is interesting because it illuminates the physics of QCD at high parton density, and also because it provides a baseline against which the modification of cross sections for hard processes in heavy ion collisions can be measured. PHENIX has now completed analysis of data from the 2008 d+Au RHIC run for production of quarkonia, open heavy flavor, and correlated high p_T π^0 production at forward rapidity. In this talk we will discuss these results and what they convey about cold nuclear matter effects, and their implications for hot matter effects in Au+Au collisions.

Plenary 4A / 163

Electromagnetic radiation in heavy ion collisions: Progress and puzzles

Author: Charles Gale¹

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I review the theory behind the emission of electromagnetic radiation in relativistic collisions. The rates for photon and lepton pair production are examined, both for a quark-gluon plasma and for a hadronic gas at finite temperatures and densities. A special emphasis is placed on the connection between electromagnetic spectra and the details of modern 3D hydrodynamic simulations of high-energy nuclear collisions. More specifically, the effects of a finite shear viscosity coefficient are examined, together with those of fluctuating initial states. I will summarize our current understanding of the relevant experimental data.

Plenary 4B / 164

How can we prove/disprove the relevance of CGC/saturation physics at LHC?

Author: Javier L Albacete¹

¹ *IPN Orsay*

The forthcoming LHC run on p+Pb collisions will offer a unique possibility to explore the small- x regime of QCD. I shall review the physics prospects for different observables within the Color Glass Condensate framework: from multiplicity distributions, and single inclusive spectra to two-particle correlations. I will discuss in detail the quantitative challenges for a precise discrimination of the CGC/saturation studies to other phenomenological approaches in Heavy ion collisions.

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Discussion on pA physics at the LHC

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Electromagnetic Radiation probing the Space-Time Evolution of Heavy ion collisions

Author: Axel Drees¹

¹ *Stony Brook University*

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Over the past years PHENIX has published multiple results on electron-positron pairs and direct photons from Au+Au collisions, which reveal a number of puzzling and not understood features. First measurements of direct photons at momenta below 3 GeV point towards a significant thermal yield consistent with initial temperatures well above the transition temperature. However, this thermal source shows large azimuthal momentum anisotropy, seemingly inconsistent with early emission. In addition, dilepton production below a mass of 1 GeV is significantly larger than can be attributed to the thermal source. These excess dileptons exhibit a soft momentum spectrum with an inverse slope of less than 100 MeV. In this talk we will present and discuss the latest results from PHENIX.

Plenary 5A / 167

Characterizing energy loss in ALICE

Author: Peter Jacobs¹

¹ *Lawrence Berkeley National Laboratory*

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This talk will present a global view of what has been learned to date from ALICE data about the interaction of jets with the hot medium generated in high energy nuclear collisions at the LHC. The discussion will incorporate measurements of inclusive charged and identified hadrons, hadron correlations, heavy flavor measurements, and first ALICE measurements of fully reconstructed jets, together with comparison to model calculations. I will also give a perspective on open questions in this area.

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Experiment summary

Author: Jorgen Schukraft¹

¹ *CERN*

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Theory summary

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Student lectures I / 171

Quarkonium production: experimental aspects

Author: Hermine Woehri¹

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Quarkonium production: theory aspects

Author: elena Ferreiro¹

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Student lectures II / 173

Jets: experimental aspects

Author: Mateusz Ploskon¹

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Student lectures II / 174

Jet quenching: theory

Author: Guilherme Milhano¹

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Discussion on pA physics at the LHC

Author: Carlos Salgado¹

¹ *Roma Univ. La Sapienza*

Plenary 4B / 176

Azimuthal angular correlations between heavy-flavour electrons and charged hadrons in pp collisions at $\sqrt{s} = 2.76$ TeV in ALICE

Author: Deepa Thomas¹

¹ *Utrecht University*

Plenary 4B / 177

Collision centrality and tau_zero dependence of the emission of thermal photons from fluctuating initial conditions

Author: Rupa Chatterjee¹

¹ *University of Jyväskylä, Finland*

Plenary 4B / 178

Direct photon measurements at PHENIX

Author: Baldo Sahlmueller¹

¹ *Stony Brook University*