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New insights on parton energy loss and fragmentation from a two-component analysis of PID p_t spectra to 12 GeV/c for Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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A two-component analysis of p_t and y_t spectra for identified pions and protons from 200 GeV Au-Au collisions is presented. The method is similar to an analysis of the n_{ch} dependence of transverse momentum p_t spectra from p-p collisions at 200 GeV [1], but applied to Au-Au centrality dependence [2]. The soft-component reference (longitudinal nucleon fragmentation) is a Lévy distribution on transverse mass m_t. The hard-component reference (transverse parton fragmentation) is a Gaussian on transverse rapidity y_t with exponential (p_t power-law) tail. Deviations of data from the reference are described by hard-component ratio r_{AA} which generalizes nuclear modification factor R_{AA}. The analysis reveals that the centrality evolution of the entire pion and proton spectra is dominated by changes in parton fragmentation extending to well below 1 GeV/c. The structure of r_{AA} suggests that parton energy loss produces a negative boost Δy_t of a large fraction (but not all) of the minimum-bias fragment distributions peaked at $p_t \sim 1$ GeV/c, and that lower-energy partons suffer relatively less energy loss, possibly due to color screening. The centrality dependence of parton energy-loss effects (e.g., suppression of R_{AA}) at larger p_t is closely correlated with pion and proton enhancements at smaller p_t/y_t. The analysis also suggests that the anomalous p/π ratio may be due to differences in the parton energy-loss process as manifested by the two hadron species. A search for evidence of radial flow in the data was unsuccessful.

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Characteristics of Parton Energy Loss Studied with High-p_{T} Particle Spectra from PHENIX

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Parton energy loss is characterized by studying its dependence on energy ($\sqrt{s_{\mathrm{NN}}}$), path length, and on the colliding species. As a starting point the latest results on the suppression of high-p_{T} π^0's (up to $p_{\mathrm{T}} = 20$ GeV/c) in Au+Au at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV will be presented. We extend this by presenting new results on the $\sqrt{s_{\mathrm{NN}}}$ dependence of the hadron suppression from Au+Au at 62.4 GeV, and Cu+Cu at 22.4, 62.4, and 200 GeV. Especially the lower-energy data sets shed light on the interplay between jet suppression and nuclear enhancement ("Cronin effect"). Moreover, the 22.4 GeV data allow a comparison to CERN SPS results. Except for $\sqrt{s_{\mathrm{NN}}} = 22.4$ GeV all p+p reference spectra were measured within PHENIX. Since the energy-loss depends both on the density of the medium and the path-length traveled by the parton, we also measure the suppression as a function of the angle w.r.t. the reaction plane in non-central Au+Au collisions. These results will be confronted with the path length dependence expected in parton energy loss models. Finally, the high-p_{T} hadron spectra are compared to prediction from parton energy loss models in a systematic way in order to extract medium properties such as the initial gluon density $\mathrm{d}N^{\mathrm{g}}/\mathrm{d}y$ and the transport coefficient $\hat{q}$.

ρ^0 Production at High-p_T in Central Au+Au and $p+p$ collisions at $\sqrt{s_{NN}} = 200$ GeV in STAR

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The ρ^0 ($\rho^0 \to \pi^+\pi^-$) has been measured in peripheral Au+Au and $p+p$ at low transverse momentum (p_T), where mass shifts of ~ 70 and ~ 40 MeV/c^2 were observed, respectively. Whether this behavior extends to high-p_T is of interest. In addition, the spectra of π, ρ^0, and $(\bar{p})p$ in $p+p$ and central Au+Au collisions can be used to study the effect of energy loss on fragmentation. The ρ^0 production at high-p_T ($5.0 \leq p_T \leq 10.0$ GeV/c) measured in minimum bias and central Au+Au, minimum bias d+Au, and $p+p$ collisions will be presented. The ρ^0/π ratios measured in $p+p$ will be compared to PYTHIA calculations as a test of perturbative quantum chromodynamics (pQCD) that describes reasonably well particle production from hard processes. The ρ^0 nuclear modification factors (R_{AA} and R_{dAu}) will also be presented. In $p+p$ collisions, charged pions and (anti-)protons are measured in the range $5.0 \leq p_T \leq 15.0$ GeV/c and the meson to meson and the baryon to meson ratios of these hadrons will be discussed.

First STAR results on π^0 production over an extended p_T range from 200 GeV Au+Au collisions

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We present the first STAR results for high p_T π^0 spectra and the nuclear modification factor in mid-rapidity in 200 GeV Au+Au collisions, using the large run-4 data sample. Two methods are used to reconstruct π^0s over a larger p_T-range (approx 1-12 GeV): 1. pairing two photons measured by the Barrel Electromagnetic Calorimeter (BEMC); 2. pairing one photon converting in the material inside the Time Projection Chamber (TPC) and the other one from the BEMC. Conversion photons are reconstructed from using TPC e^-/e^+ tracks. The clean sample of conversion photons gives a clear π^0 signal from below 1 GeV up to intermediate p_T, where backgrounds in the BEMC are large. Results from both methods are compared in the overlapping p_T-range and compared with previous pion measurements. The prospects for this analysis in the larger run-7 data sample with full BEMC coverage and a higher BEMC trigger threshold is discussed. This analysis is a first step towards direct photon spectra measurements in Au+Au collisions.

NUCLEAR MODIFICATION AT $\sqrt{s_{NN}} = 17.3\,\mathrm{GeV}$, MEASURED AT NA49

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Transverse momentum spectra up to 4.5 GeV/c around midrapidity of $\pi^\pm$, p, $\bar{p}$, $K^\pm$ in Pb+Pb reactions were measured at $\sqrt{s_{NN}} = 17.3\,\mathrm{GeV}$, by the NA49 experiment. The nuclear modification factors R_{AA} and R_{CP} were extracted and are compared to RHIC results at $\sqrt{s_{NN}} = 200\,\mathrm{GeV}$. The modification factor R_{AA} shows a rapid increase with transverse momentum in the covered region. This indicates that the Cronin effect is the dominating effect in our energy range. The modification factor R_{CP}, which contains only a reduced amount of the Cronin effect contribution, shows a saturation well below unity in the $\pi^\pm$ channel. The extracted R_{CP} values follow the 200 GeV RHIC results closely in the available transverse momentum range for all particle species. For $\pi^\pm$ above 2.5 GeV/c transverse momentum, the measured suppression is smaller than that observed at RHIC.

Why Does High–p_T Suppression Persist at Forward Rapidity?

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The nuclear modification factor has been seen to be remarkably constant for charged hadrons from mid-rapidity to the most forward experimentally accessible rapidities for Au+Au collisions at the top RHIC energy. Recent results from BRAHMS show that this is also true for identified particles. That is, the baryon meson difference seen at mid-rapidity persists to forward rapidites, despite the fact that the emitting source changes. This talk will present results of measurements of high transverse momentum identified particles at rapidities from

0 to 3.5. BRAHMS has carried out measurements for both Au+Au and p+p collisiions, allowing us to study the nuclear modification factor up to $p_T \approx 4$ over this broad range in rapidity. These results will be compared to model calculations in order to shed light on the relative contributions of the various effects (gluon saturation, partonic recombination, jet quenching) which conspire to give to the observed behaviour at forward rapidities.

Forward jets in p-p at 14 TeV: probing the gluon density in the proton at LHC energies

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The LHC will provide proton-proton, proton-nucleus and nucleus-nucleus collisions at $\sqrt{s_{NN}} = 14, 8.8, 5.5$ TeV, respectively. The range of fractional momenta of the colliding partons will be $x = 2p_T/\sqrt{s_{NN}} \approx 70$–30 times lower than equivalent collisions at RHIC, i.e. of the order $x \sim 10^{-3}$ at midrapidity. At forward rapidities, the relevant Bjorken x values can be as low as $x \propto e^{-y} \sim 10^{-6}$. In such low-$x$ regime, non-linear gluon-gluon processes – as described in the Color-Glass-Condensate picture – will likely dominate the parton structure and evolution of the wave function of the colliding hadrons. The Compact Muon Solenoid (CMS) experiment at CERN LHC has unparalleled capabilities for the measurement of particles in the forward hemisphere. The combination of the forward hadronic calorimeter HF ($3< |\eta| <5$) and the CASTOR sampling calorimeter ($5.1< |\eta| <6.6$) allows the measurement of forward jets in a kinematic region where the gluon densities in the proton are poorly known. We will present results on the expected performances of jet measurements in the CMS forward calorimeters.

Jet measurement in p+p and Pb+Pb collisions with the ALICE experiment at LHC

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The observation of the strong suppression of high p_T hadrons in ultra-relativistic heavy ion collisions has motivated a large experimental program using hard probes to characterize the deconfined medium created. A few selected results from RHIC which indicate a non negligeable interaction of high energy partons with a dense color medium before hadronization will be first discussed [1-3]. Despite many observables such as the nuclear modification factor, two and three particle azimuthal correlations have shown that partons lose energy in the dense medium by gluon radiations, the physical properties of the produced medium such as the value of the transport coefficient, $\hat{q}$, or the initial gluon rapidity density, are not yet fully characterized by the available models [4]. Moreover the center of mass energy available at RHIC has allowed a deep "leading particle physics" study which clearly presents some limitations. For instance, trigger bias induced by the steeply falling particle spectra and surface emission bias, which provides only a lower bound to the initial color charge density [5], limit strongly the conclusions that can be drawn and motivate the study of more penetrating probes.

The gain in the center of mass energy expected at the LHC will definitively help our understanding on how the energy is lost in the system but will also open a new major window of study in high p_T physics: the physics of jets on an event-by-event basis. I will concentrate on this topic and illustrate the new possibilities that the ALICE experiment will offer to first test pQCD and characterize the fragmentation function of the produced charged particles but also to better understand the medium created with the measurement of such observables [6]. Jet reconstruction in p+p and Pb+Pb collisions, improvements brought by the EMCal calorimeter [7] as well as some expected physics performances will be presented.

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Study of jets and their properties in PbPb collisions using the ATLAS detector at LHC

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The measurement of jets and their properties provides information about the jet quenching phenomenon that is predicted for heavy ion collisions and already measured at RHIC. At LHC energies where jets are well defined at the level of QCD, this phenomenon can be treated using the full jet reconstruction. The jet quenching means that a hard parton, before fragmenting into a jet of hadrons, deposits a fraction of its energy in the medium, leading to a change of jet energy distribution and particle multiplicity inside a jet. This allows us to investigate the properties of medium and its response to a traversing parton.

We present studies of the performance of a cone jet reconstruction algorithm with full GEANT simulation of the ATLAS detector. Simulated jets from PYTHIA are embedded to the heavy ion background from HIJING. The study shows results of the jet energy and position resolutions of the ATLAS calorimeter system for different centralities of the PbPb collision. The energy resolution of single reconstructed jets is better than 20% at 100 GeV. We also present ATLAS capability for measurement of jet energy profiles and j_T distribution.

Measurements of High p_T Identified Hadron Spectra and R_{cp}, from Run 7 Au+Au $\sqrt{s_{NN}} = 200\ GeV$ by the PHENIX Experiment

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One of the most striking observations in heavy ion collisions at RHIC is the large enhancement of baryons and antibaryons relative to pions at intermediate p_T 2-5 GeV/c. The PHENIX experiment has observed enhanced proton/pion ratios in central Au+Au collisions as compared to the expectation from parton fragmentation. The measurements were done using the Time-of-Flight (TOF) detector in the PHENIX East arm, which allowed pi/K and K/p separation up to pt = 2.5 and 4 GeV/c respectively. Particle identification (PID) to higher p_T (> 8 GeV/c) is needed to better characterize the hadron production mechanism at intermediate and high p_T to differentiate between competing theoretical descriptions. Measurements of the nuclear modification factor (central to peripheral ratios, R_{cp}) and high p_T PID pi/K/p/d spectra will be presented. These measurements should help us understand both energy loss and particle production mechanism in the transition from low to high p_T. This higher p_T data set is from the upgraded high-p_T PID system in PHENIX. A new TOF detector was installed in the West arm which allows a seamless track-by-track PID up to transverse momenta p_T of ≈9.0 GeV/c when used in conjunction with the Aerogel Cherenkov Counter. The large data set and new detector capabilities extend the momentum range well beyond the intermediate p_T region.

Quenching of light hadrons at RHIC in collisional energy loss scenario

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The nuclear suppression factor, $R_{AA}(p_T)$ for light hadrons has been calculated by taking into account the elastic energy loss with appropriate geometry of jet production and propagation within the system. The Fokker-Planck equation has been solved (initial momentum distribution for partons is taken from perturbative QCD calculations) to obtain the momentum distribution for the partons at any given instant. These distributions along with the fragmentation functions for light hadrons are used to obtain the hadronic spectra in heavy ion collisions at RHIC energies. The experimentally observed, $R_{AA}(p_T)$ at RHIC can be reproduced within the ambit of the present model with reasonable values of parameters, *e. g.* initial temperature, thermalization time and equation of state. It is observed that $R_{AA}(p_T)$ with collisional loss has a tendency to increase for higher p_T, indicating the importance of radiative loss in this domain. In light of these findings the theory of jet tomography is expected to change considerably.

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FINITE LIFE-TIME OF RECOMBINING PARTONS IN COLLISIONAL ENERGY LOSS PROCESSES

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We study the collisional energy loss mechanism for particles produced off mass-shell in a finite size QCD medium, in particular, the finite life-time of a jet parton that recombines with medium partons. We show that these effects reduce the energy loss as compared to the case when the particles are described as propagating on mass-shell. The effect is introduced by considering particles produced in wave packets instead of plane waves. The reduction of the energy loss is stronger as this scale becomes of the order or smaller than the medium size

Systematic Comparison of Jet Energy-Loss Schemes in a 3D hydrodynamic medium

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RHIC has generated a wealth of experimental data on high momentum hadron emission including, but not limited to, the nuclear modification factor R_{AA}, the elliptic flow v_2 at high p_T and a whole array of high-p_T hadron-hadron correlations. The emission of hadrons with large transverse momentum is observed to be strongly suppressed in central collisions of heavy nuclei, a phenomenon commonly referred to as *jet-quenching*. Computations of such jet modifications have acquired a certain sophistication as regards the incorporation of the partonic processes involved. However, the role of the medium has so far been relegated to the furnishing of an overall density and its variation with time. Even in this regard, most jet quenching calculations assume merely a one-dimensional Bjorken expansion.
The availability of a three-dimensional hydrodynamic evolution code [1] allows for a much more detailed study of jet interactions in a longitudinally and transversely expanding medium. The variation of the gluon density in such a medium is quite different from that in a simple Bjorken expansion. Over the past year we have utilized our evolution model to provide the time-evolution of the medium produced at RHIC for jet energy-loss calculations performed in the BDMPS/ASW [2], Higher Twist [3] and AMY [4] approaches. In each of the three projects, the inclusive as well as the azimuthally differential nuclear suppression factor R_{AA} of pions was studied as a function of their transverse momentum p_T. In addition, the influence of collective flow, variations in rapidity, and energy-loss in the hadronic phase were addressed for the selected approaches.

While the parameters of all three calculations by our group can be adjusted to provide a good description of inclusive data on R_{AA} versus transverse momentum, they differ in their predictions for the centrality- and azimuthal angular dependence of R_{AA} vs. p_T. Here, we will conduct a systematic comparison of the three jet energy loss approaches mentioned above. Since we use identical medium evolution in all three approaches we are in a unique position to isolate differences among the three calculations solely due to their energy-loss implementation. The aim of this work is to find discriminators, i.e. observables such as the centrality dependence of azimuthally differential R_{AA} versus p_T, which will permit the validation or falsification of the assumptions made in different jet energy loss models by means of a detailed comparison to data.

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Radiative and Collisional Jet Energy Loss in the Quark-Gluon Plasma at RHIC

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We calculate bremsstrahlung and collisional energy loss of hard partons traversing the quark-gluon plasma at RHIC [1] and compare the respective size of these contributions.
We employ the AMY formalism [2] for radiative energy loss and include additionally energy loss by elastic collisions. Our treatment of both processes is complete
at leading order in the coupling, and accounts for the probabilistic nature of jet energy loss. We find that a solution of the Fokker-Planck equation for the probability density distributions of partons is necessary for a complete calculation of the nuclear modification factor R_{AA} for pion production in heavy ion collisions. It is found that the magnitude of R_{AA} is sensitive to the inclusion of both collisional and radiative energy loss, while the average energy is not very affected by the addition of collisional contributions. We present a calculation of R_{AA} for π_0 at RHIC, combining our energy loss formalism with a relativistic (3+1)-dimensional hydrodynamic description of the thermalized medium
[1,3].
We also present calculations of R_{AA} vs. reaction plane at mid- and forward rapidity.

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Punching-through Jets in $A + A$ Collisions at RHIC/LHC Energy

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Based on previous study[1], punching-through jets are studied within a NLO pQCD parton model with jet quenching taken into account in high energy $A + A$ collisions. The spatial transverse distributions of the initial parton production points that contribute to the final high p_T single hadron/dihadron spectra are compared between RHIC and LHC energy. The fraction of the dihadron yield contributed by punching-through parton jets is found to increase with the transverse momenta of dihadron, especially at LHC energy. The azimuthal anisotropy v_2 of the dihadron spectra are studied in non-central $A+A$ collisions. It is found to be larger than the single hadron v_2. The dihadron v_2 is found to be also larger at LHC than RHIC energy because of the much more punching-through jets at LHC. Punching-through jets are created from the central system region where initial partons participating in strong interaction should be associated with stronger shadowing effects than those initial partons in the outer layer of the system, and therefore these punching-through jets also manifest a strong shadowing effect. These punching-through jets have a number fraction big enough to cause an observation of the difference of shadowing effects given by different shadowing parameterizations (EKS98[2], nDS[3], nPDF[4], Hijing[5]) in dihadron spectra at LHC energy, while a small number fraction of punching-through jets result in an absentation in dihadron spectra at RHIC and in single hadron spectra at RHIC/LHC.

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Towards a complete theory of pQCD jet modification

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The higher twist formalism of perturbative jet modification is extended via the resummation of a variety of all-twist contributions for different observables. In particular, we compute the elastic energy loss and transverse broadening of a hard jet in an extended medium. While the resummation of all twists leads to a two dimensional diffusion equation in transverse momentum, where the diffusion coefficient is related to the standard transport parameter $\hat{q}$, elastic energy loss is shown to have an extra separate contribution similar to a drag effect and depends on a somewhat different and new transport coefficient. Phenomenological consequences of this new coefficient are outlined. Comparisons to data on the single inclusive suppression are carried out including elastic energy loss in the higher twist formalism. The photon bremsstrahlung rate from a hard jet at all twist is calculated and its dependence on $\hat{q}$ and the transverse broadening is explicitly demonstrated. This is then applied to calculate the near side correlation between a high p_T hadron and a hard photon.

Jet-induced gauge field instabilities in the quark-gluon plasma

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We present the results of a study of the properties of the collective modes of a system composed by a thermalized quark-gluon plasma traversed by a relativistic jet of partons [1]. The aim is to provide a novel mechanism for the description of the jet quenching phenomenon (see [2] for reviews). We find that when the jet traverses the quark-gluon plasma unstable gauge field modes are excited and grow on very short time scales. As a consequence, the jet loses energy and degrades. In order to simplify the analysis we employ a linear response approximation, valid for short time scales. We assume that the partons in the jet can be described with a tsunami-like distribution function, whereas we treat the quark-gluon plasma employing two different approaches. In the first approach we adopt a Vlasov approximation for the kinetic equations, in the second approach we solve a set of fluid equations. We derive the expressions of the dispersion law of the collective unstable modes and compare the results obtained in the two cases.

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Characterizing Jets in Heavy Ion Collisions by Flow Method

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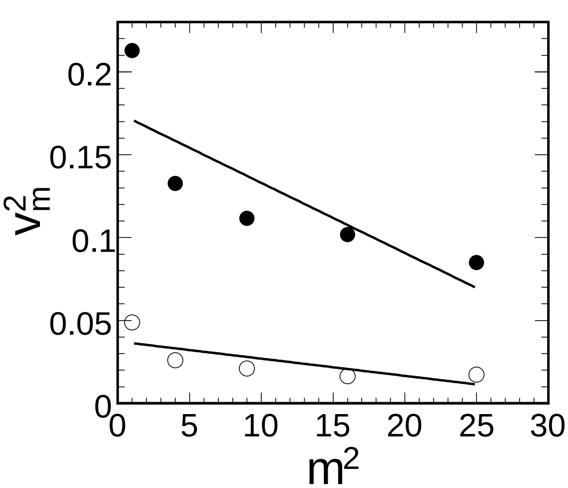
Identifying jets in heavy ion collisions is of significant interest since the properties of jets are expected to get modified because of the formation of quark gluon plasma. The detection of jets is, however, difficult because of large number of non-jet hadrons produced in the collision process.
Recently, we have developed a method[1] based on the the flow coefficients for events containing jets which allows one to identify the jet events, determine the jet opening angle and the associated number of particles in the jet in heavy ion collisions. Very recently, we have extended this method[2] by computing transverse momentum weighted flow coefficients. Using these flow coefficients, we are able to estimate the transverse momentum (p_T) of the jet as well as the jet opening angle(ϕ) and the number of jet particles(N_j).
The method is based on the fact that for particles(N) distributed uniformly in ϕ and the coefficients can be determined as

$$v^2_{m,p_T} = \frac{N_j^2 < p_T >^2}{N^2}\Big[j_0(m\Delta\phi/2)\Big]^2,$$

where $< p_T >$ is the average transverse momentum carried by a particle in the jet. Thus $N_j < p_T >$ gives the total transverse momentum of the jet.



A plot of v_m^2 *vs* m^2 for p_T cut of 0.75 GeV for background particles from HIJING event generator and 10 jet particles is shown. The closed (open) symbols are for with (without) p_T weight. This is the case of one jet with background particles. The extracted values of number of jet particles, jet p_T(GeV), opening angle are 11.60 ± 2.29, 18.17 ± 2.47, 0.46 ± 0.07 (with p_T) and 0.57 ± 0.008 (without p_T), respectively, for the corresponding inputs are number of jet particles 10, jet p_T(GeV) 18.26 and opening angle $\pi/6$, respectively.

We find in the figure that the flow coefficients are significantly larger than those obtained for an event without a jet. These type of plots will be discussed in the presentation for only background particles, only jet particles and jet with background particles. Also we will display the case like two Jets with background in the presentation.

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Jet-energy loss in heavy ion collisions - where does the energy loss lose strength?

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We analyzed the nuclear modification factor for pion production in $AuAu$ and $CuCu$ collisions at very-high transverse momenta, $p_T \geq 10$ GeV/c. Beyond this transverse momentum region the $R_{AA}(p_T)$ is affected by both the initial state nuclear modifications (e.g. EMC-effect) [1] and the non-Abelian jet-energy loss at the final state [2]. At this very high momenta both are strong enough to suppress the $R_{AA}(p_T)$ mostly below 1 at RHIC energies. We compare results using two different shadowing parameterization (HIJING [3] and HKN [4]) in our pQCD improved parton model [5].
We investigated a similar calculation for LHC energies in $PbPb$ collisions. We estimate larger opacity value, $L/\lambda = 8.0$ for the produced partonic matter in central collisions at the final state. This would result larger suppression at the high-momenta region, but results using HKN shadowing shown relatively small suppression at the 10 GeV/c $\leq p_T \leq$ 100 GeV/c momentum range.

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Tomography *of* Jets at the LHC

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For jets, with great power come great opportunities. The unprecedented center of mass energies available at the LHC open new windows on the QGP: we demonstrate that jet shape and jet topology measurements become feasible as a new, differential and accurate test of the underlying QCD theory [1]. We present a first step in understanding these shapes in nuclear collisions at the LHC. The QCD splitting kernels, Sudakov resummation and non-perturbative effects, calibrated with comparison to Tevatron data, determine jet structure in the vacuum [2]. Quantum coherence effects, such as the LPM (Landau-Pomeranchuk-Migdal) here calculated using the GLV (Gyulassy-Levai-Vitev) approach to radiative energy loss, map the 2D landscape in angle, r, and particle momentum, p_T, of the medium-modified energy distribution in the jet on the QGP properties. We present our predictions not for jet tomography but for tomography *of* jets [1], examine useful experimentally accessible observables [4] and discuss the effect of the inclusion of other energy loss mechanisms [5]. Our approach allows for detailed simulations of the experimental acceptance/cuts that help isolate jets in the high-multiplicity environment of heavy ion reactions with the goal of guiding this breakthrough measurement at the LHC.

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Jets and their rarer, harder collisions: Toward a quantitative understanding of jet quenching in the QGP

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To move beyond the qualitative discovery of jet quenching to quantitative jet tomography, we need to consider the full distribution and fluctuations of momentum transfers of jets with the medium. These distributions cannot be summarized in one 'q-hat' value or opacity parameterization. For applications to finite energy jets in realistic nuclear geometries, the rarer, harder collisions play a comparable role to multiple soft collisions. We will show how this affects different radiative energy loss formalisms, the magnitude of different orders in an opacity expansion, the interplay of collisional and radiative energy losses, and the mass dependence of energy loss. Only in this way will we be able to use jets to gain a quantitative understanding of the bulk medium, and eliminate the wild variation in input parameters currently used to 'fit' high momentum jet data.

Energy dependence of jet transport parameter and parton saturation in quark-gluon plasma

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We study the evolution and saturation of the gluon distribution function in the quark-gluon plasma as probed by a propagating parton and its effect on the computation of jet quenching or transport parameter $\hat{q}$. For thermal partons, the saturation scale Q_s^2 is found to be proportional to the Debye screening mass μ_D^2. For hard probes, evolution at small $x = Q_s^2/6ET$ leads to jet energy dependence of $\hat{q}$. We study this dependence for both a conformal gauge theory in weak and strong coupling limit and for (pure gluon) QCD. The energy dependence can be used to extract the shear viscosity η of the medium since η can be related to the transport parameter for thermal partons in a transport description. We also derive upper bounds on the transport parameter for both energetic and thermal partons. The later leads to a lower bound on shear viscosity-to-entropy density ratio which is consistent with the conjectured lower bound $\eta/s \geq 1/4\pi$. Implications on the study of jet quenching at RHIC and LHC and the bulk properties of the dense matter are discussed.

PARTON ENERGY LOSS WITHOUT TRANSVERSE MOMENTUM BROADENING?

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Perturbative descriptions of jet quenching indicate that the medium - induced energy degradation of leading partons is typically accompanied by a transverse broadening of the jet multiplicity and energy distributions. However, despite the strong quenching of single inclusive spectra at RHIC, signatures of the broadening of jets or jet-like correlations have not been observed so far outside the soft low-transverse momentum regime. We present results from a newly developed Monte Carlo parton shower. In the absence of medium-effects, this parton shower reproduces the known perturbative baseline. Comparing different implementations of parton energy loss on top of this baseline, we then delineate under which assumptions a significant parton energy loss does not imply a visible broadening of transverse jet-like distributions at sufficiently high transverse momentum.

Collisional Energy loss of Light partons in Anisotropic Medium

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One of the interesting findings at RHIC energies is the rapid thermalization of the system formed after two relativistic nuclei collide. The interpretation of the experimental data of anisotropic flow using ideal hydrodynamics requires a thermalization time of the order of 0.2 -0.3 fm/c [1]. Perturbative QCD calculation fails to infer such rapid thermalization. Plasma instabilities caused by anisotropic media may speed up the equilibration process [2]. The longitudinal expansion of the system formed in relativistic heavy ion collisions may lead to a strongly anisotropic momentum distribution before the thermalizaion sets in. The energy loss suffered by a jet in such anisotropic media might shed lights on the stronger broadening of di-hadron correlations in η space, the flow parameter (v_2) and the jet quenching. The underlying mechanism of thermalization and/or isotropization involve energy or momentum transfer during the collisions expressed in terms of drag (energy loss) and diffusion coefficients of the QCD plasma. In this work we calculate collisional energy loss (dE/dx) or the drag coefficient ($\eta = 1/E$ dE/dx) of light partons for different values of the anisotropy parameter (ζ). We also calculate the Debye mass (m_D) required to regulate the infra-red divergence appearing in $2 \rightarrow 2$ scattering
processes. It is important to note that in high temperature effective theory of QCD it is generally assumed that the coupling constant (α_s) is temperature dependent only. This is true when T >> Λ_{QCD}. However, when the momentum transfer in scattering processes is of same order as the temperature, one should take into account both momentum and temperature dependent coupling constant [3]. We have incorporated this aspect in our energy loss calculation.

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Enhancement of high P_T hadrons due to collapsing Z(3) walls in heavy-ion collisions

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We discuss enhancement of multiplicities of hadrons at high transverse momentum due to multiple reflections from collapsing Z(3) interfaces in the QGP produced in relativistic heavy-ion collisions. By modeling the dependence of effective mass of the quarks on the Polyakov loop order parameter, we evaluate the reflection of quarks from collapsing $Z(3)$ interfaces and determine the modification in their P_T spectra. We use the effective potential proposed by Pisarski for the Polyakov loop to determine the profile of the Z(3) interfaces and calculate the reflection probability for the quarks. In our earlier work we have shown that the expectation value of Polyakov loop is small at the middle of domain walls leading to a potential barrier for the quarks. The barrier is larger for heavier quarks leading to larger reflection coefficient. We discuss the formation of a network of these Z(3) walls in relativistic heavy-ion collisions, in the QGP phase. During the collapse of the walls, the quarks/anti-quarks undergo multiple scatterings inside the domain walls and pick up large transverse momentum before getting transmitted. We do a numerical calculation of the modifications in the transverse momentum distribution of quarks/antiquarks resulting from collapsing wall. We then use the recombination model to calculate the transverse momentum spectrum of final hadrons. Our results show enhancement of high P_T hadrons, with the enhancement being stronger for heavier quarks. Further, we find that due to larger reflection coefficient for heavier quarks, the density of strange and charm quarks/antiquarks increases inside the collapsing walls. This implies enhancement in the multiplicities of multi-strange and multi-charmed hadrons. We also discuss novel jet structures resulting from the reflection of quarks from collapsing walls.

Novel jet quenching observables in heavy ion collisions at the LHC

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Recent RHIC data on high-p_T particle production at $\sqrt{s} = 200\ A$ GeV are in agreement with the jet quenching hypothesis (medium-induced partonic energy loss in quark-gluon plasma). At LHC, a new regime of heavy ion physics will be reached at $\sqrt{s_{\rm NN}} = 5.5A$ TeV where hard and semi-hard particle production can stand out against the underlying soft events. The initial gluon densities in PbPb reactions at LHC are expected to be much higher than those at RHIC, implying a stronger partonic energy loss, observable in various novel channels.
We discuss such novel jet quenching observables at the LHC as direct measurements of medium-modified jet fragmentation function, nuclear modification factor and azimuthal

anisotropy for jets with finite cone size, B-tagged jets. The corresponding predictions obtained with PYQUEN partonic energy loss model [1,2] are presented. The experimental capabilities of LHC experiments to detect these phenomena are touched upon.

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