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Session : Particle production and Bulk properties

Charged Hadron Results from Au+Au Collisions at $\sqrt{s_{NN}} = 19.6$ GeV

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Results from a one day $\sqrt{s_{NN}} = 19.6$ GeV Au+Au test run at RHIC using the STAR detector are presented. The quality of these results from only 175,000 triggered events demonstrates some of STAR's physics capabilities for the upcoming beam energy scan at RHIC. From these 19.6 GeV Au+Au collisions, we have analyzed the transverse mass spectra of $\pi^{\pm}$, $K^{\pm}$, p, and $\bar{p}$ with $|y| < 0.5$ and $m_T - m_0 < 1.0$ GeV/c^2. The collision energy ($\sqrt{s_{NN}} = 19.6$ GeV) of this low energy Au+Au RHIC collider run is very close to that of the 158 AGeV fixed-target Pb+Pb runs at the SPS ($\sqrt{s_{NN}} = 17.2$ GeV). We present detailed comparisons between these STAR data and the spectra published by NA49 [1], NA44 [2], and WA98 [3]. Differences in rapidity, centrality, beam energy and beam size are taken into account. In most cases, the agreement is within the statistical and systematic errors of the measurements. We report radial flow parameters, multiplicity, particle ratios, and kinetic and chemical freeze-out conditions and compare these 19.6 GeV results to the energy systematics. There is agreement with the established trends. We have studied the very low p_T pion ratios and extract a Coulomb potential of the source to be 4.3 MeV. We have analyzed the directed and elliptic flow signals and we compare these results to the SPS results and the energy systematics. The RHIC program advisory committee has approved a fourteen week run to scan a series of energies ranging from $\sqrt{s_{NN}} = 4.6$ to 28 GeV in a search for the possible critical point and phase boundary in the QCD phase diagram. We will discuss the technical challenges faced during this test 19.6 GeV run and consider their solutions or ramifications for the upcoming energy scan in 2010, where we have proposed to measure at least five million events at each beam energy.

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Energy and centrality dependence of particle production at very low transverse momenta in Au+Au collisions

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The PHOBOS experiment at RHIC has a unique capability of measuring particle production at very low transverse momenta. New results on low-transverse momentum invariant yields of pions, kaons, protons and antiprotons produced in 200 GeV Au+Au collisions will be presented as a function of the collisions centrality for the 50% most central events. A comparison to the yields measured at 62.4 GeV will be shown. We will show that at the two energies similiar trends are observed in low transverse momentum particle production. The low transverse momentum yields agree with extrapolations from intermediate transverse momentum measurements. For all collision centralities a flattening of the transverse momentum spectra is observed and this effect depends on the particle mass, being stronger for heavier particles. This observation is consistent with a rapid transverse expansion of the system and does not confirm the hypothesis of transverse mass scaling postulated by the saturation models [1,2]. In contrast, in the environment of d+Au collisions, transverse mass scaling is confirmed.

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System Size, Energy, Centrality and Pseudorapidity Dependence of Charged-Particle Density in p+p, Cu+Cu and Au+Au Collisions at RHIC

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This work presents data from the PHOBOS experiment at RHIC for charged particle density distributions in Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}}$ = 19.6, 22.4, 62.4, 130 and 200 GeV as well p+p collisions at $\sqrt{s_{NN}}$ = 200 and 410 GeV as a function of collision centrality and pseudorapidity. The measurements of charged particle pseudorapidity density distributions in 22.4 GeV Cu+Cu and 410 GeV p+p collisions will be presented for the first time. These measurements were obtained in the same detector over a broad range in pseudorapidity, $|\eta| < 5.4$, allowing for a reliable systematic study of particle production as a function of energy, collision centrality, pseudorapidity and system size. Making a global comparison of Cu+Cu and Au+Au results, we find that the total number of produced charged particles and the rough shape (height and width) of the pseudorapidity density distributions are determined by the number of nucleon participants. More detailed studies reveal that a more

precise matching of the shape of the Cu+Cu and Au+Au pseudorapidity density distributions over the full range of pseudorapidity occurs for the same $N_{part}/2A$ value rather than the same N_{part} value. In other words, it is the collision geometry rather than just the number of nucleon participants that drives the detailed shape of the pseudorapidity density distribution and its centrality dependence at RHIC energies. The essential role of collision geometry when comparing pseudorapidity density distributions of charged particles between nuclear species will be demonstrated.

Rapidity distributions of $\pi^{\pm}$, $K^{\pm}$ and p ($\bar{p}$) in p+p and d+Au collisions at 200 GeV

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The rapidity density dN/dy of produced particles is strongly related to the energy density in the collision system[1]. Net-proton rapidity distribution are related to the baryon transfer process (stopping)[2].Rapidity densities of $\pi^{\pm}$, $K^{\pm}$ and p ($\bar{p}$) in two collision systems, p+p and d+Au collisions are presented. These system can be thought of as controls for Au+Au measurements[3]. The scaling of the rapidity density by the number of participants ($\langle N_{part} \rangle$) and number of binary collisions ($\langle N_{coll} \rangle$) involved in the collisions may reveal different physics at mid-rapidity and forward rapidities, e.g. comparison of the net-proton rapidity density in the central Au+Au collisions with smaller control systems such as p+p and d+Au will help us understand the baryon transport in these systems. Rapidity densities of identified charged hadrons ($\pi^{\pm}$, $K^{\pm}$ and p ($\bar{p}$)) and net-protons measured by the BRAHMS experiment in different systems are compared to each other and to model predictions[4,5,6]. Finally the centrality dependence of the rapidity density in d+Au collisions will be discussed.

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Stopping and longitudinal scaling from RHIC to LHC

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The unique rapidity coverage of the BRAHMS *experiment enables precision measurements of stopping at RHIC. These measurements show that the average rapidity loss saturate already at* $\sqrt{s_{NN}} = 62.4$ *GeV. Furthermore* $\sqrt{s_{NN}} = 62.4$ *GeV Au+Au* BRAHMS *data are used to predict the LHC net-baryon distribution and study longitudinal scaling of net-baryons.*

Stopping in heavy ion collisions has been measured by several experiments at different collision energies, in particular the AGS [1], SPS [2] and RHIC [3]. In this talk proton dN/dy distributions measured by the BRAHMS experiment in $\sqrt{s_{NN}} = 62.4$ GeV Au+Au collisions at RHIC will be presented. To quantify stopping the average rapidity loss is often used. It is defined as [4]:

$$\delta y = y_{beam} - \frac{2}{N_{part}} \int_0^{y_{beam}} y \frac{dN_{B-\bar{B}(y)}}{dy} dy \tag{1}$$

Here y_{beam} is the beam rapidity, N_{part} is the number of participating baryons. $\frac{dN_{B-\bar{B}(y)}}{dy}$ is the net-baryon rapidity density which must be derived from the measured net-proton distribution. The calculation of the rapidity loss will be presented and the result compared to measurements at AGS, SPS and RHIC. This comparison will be used to predict the rapidity loss of central Pb+Pb collisions at the Large Hadron Collider at CERN which will begin operation in the fall of 2008. A simple model will be used to obtain the net-baryon distribution at LHC and predict the energy loss available for particle production. From this an estimate will be given of the charged particle multiplicity at LHC. It has been conjectured that protons violate the energy dependence of longitudinal scaling [5]. In the talk this question will be revisited using the 62.4 GeV data, SPS data and the higher energy RHIC data.

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Systematic studies of global observables by PHENIX

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Systematic studies of global observables such as mean transverse energy $< E_T >$ and charged particle multiplicity in different collision systems are indispensable to map the location of the collision systems on the QCD phase diagram. Furthermore, fluctuations in these quantities can provide fundamental information relevant for the phase transitions. We will present scaling properties of charged particle multiplicity fluctuations in Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ and 200 GeV, and Cu+Cu collisions at $\sqrt{s_{NN}} = 22.5, 62.4,$ and 200 GeV, which will be compared to p+p data. The differential analysis of the multiplicity fluctuations as a function of pseudorapidity interval size will be presented. From these observations, we discuss the susceptibility of the density fluctuations in the logitudinal direction. Non monotonic increases of the susceptibility can be a direct signature of the phase transition based upon the Ginzburg-Landau framework[1]. Our data suggest a possible non monotonic increase of the susceptibility at $\epsilon_{BJ}\tau \sim 2.4$ GeV/(fm^{2}c) with a transverse area size of 60 fm^2 in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV[2]. The product of the energy density ϵ_{BJ} and the proper formation time τ can be deduced from measured $< E_T >$. Comparing to Cu+Cu collisions at the same collision energy, we discuss the behavior as a function of observed $< E_T >$ especially focusing on whether the increase can be seen at the same $\epsilon_{BJ}\tau$ even in the different collision system.

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THE STRING PERCOLATION SCENARIO FOR RAPIDITY AND TRANSVERSE MOMENTUM DISTRIBUTIONS AT HIGH ENERGY

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In saturation and percolation models the rapidity particle density and the moments of the transverse momentum distributions are related in a precise way. We explore this connection to describe, in the string percolation scenario, $dn/dy(dn/d\eta)$ and dn/dP_t^2 at all rapidities (pseudo-rapidities) in symmetrical, AA, and asymmetrical, AB, collisions. Predictions are given for LHC.

Polarization effects at RHIC

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Recently, the STAR collaboration has measured the Λ and $\overline{\Lambda}$ polarizations in 200 GeV Au-Au collisions [1]. These results can be understood in terms of a model, that we proposed recently, based on the hydrodynamical model, and taking into account the effect of the final-state interactions (that occur in the hadronic phase) between the hyperons and other produced particles. These final interactions are described in terms of chiral effective lagrangians, that consider many hadronic processes. This model describes quite well the antihyperon polarization data obtained in proton-nucleus collisions, and now we extended it to study nucleus-nucleus collisions, with a very good accord. Theoretical results obtained with other models will also be discussed.
The perspectives of hyperon polarization at LHC is another subject of interest.

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ANGULAR MOMENTUM CONSERVATION IN HEAVY ION COLLISIONS AT VERY HIGH ENERGY[1]

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The effects of angular momentum conservation in peripheral heavy ion collisions at very high energy are investigated. It is shown that the initial angular momentum of the quark-gluon plasma should enhance the azimuthal anisotropy of particle spectra (elliptic flow) with respect to the usual picture where only the initial geometrical eccentricity of the nuclear overlap region is responsible for the anisotropy. In hydrodynamical terms, the initial angular momentum entails a non trivial dependence of the initial longitudinal flow velocity on the transverse coordinates. This gives rise to a non-vanishing vorticity in the equations of motion which enhances the expansion rate of the supposedly created fluid compensating for the possible quenching effect of viscosity. A distinctive signature of the vorticity in the plasma is the generation of an average polarization of the emitted hadrons, for which we provide analytical expressions. These phenomena might be better observed at LHC, where the initial angular momentum density will be larger and where we envisage an increase of the elliptic flow coefficient v_2 with respect to RHIC energies.

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Dissipation in the very early stage of the hydrodynamical evolution in relativistic heavy ion collisions

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We propose a modification of the hydrodynamic modelling of the dynamics of ultrarelativistic nuclear collisions. The modification of the energy-momentum tensor at the initial stage describes the lack of izotropisation of the pressure. In the local comoving frame the pressure is driven towards the equilibrium isotropic form. Within the Bjorken scaling solution a bound is found on the decay time of the initial anisotropy of the energy-momentum tensor. For the strongest dissipative effect allowed we find a relative entropy increase is of about 30%, a significant hardening of the transverse spectra and no effect on HBT radia.

UNIVERSAL CHEMICAL FREEZE-OUT AS A SIGNATURE FOR THE QUARK-HADRON PHASE TRANSITION

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Using the dynamical freeze-out criterium introduced by Zimányi *et al.* [1] and previously exploited in [2,3] for relativistic heavy-ion collisions, it is shown that kinetic freeze-out in relativistic heavy-ion collisions invariably entails a non-trivial dependence of the freeze-out temperature on the collision centrality [4]. Using the successful ideal fluid dynamical model AZHYDRO [5] to model the expansion of the heavy-ion collision fireball, it is demonstrated that dynamical freeze-out quantitatively reproduces the observed centrality dependence of the thermal freeze-out temperature in Au+Au collisions at RHIC. The centrality *independence* of the chemical freeze-out temperature observed in the same collisions, however, is shown to be inconsistent with the hypothesis that hadron abundances decouple kinetically from inelastic hadron-hadron interactions [4]. On the other hand, it *is* found to be consistent with the alternate hypothesis that chemical decoupling is driven by the quark-hadron phase transition, and that the observed universal chemical freeze-out reflects its critical temperature, independent of the dynamical state of the collision fireball as it passes through the phase transition [4]. Our work emphasizes the sequential nature and conceptual difference between chemical and thermal freeze-out in high energy heavy-ion collisions. The consistency of chemical freeze-out data at RHIC with recent lattice results is discussed, and

predictions to test our theoretical framework for the interpretation of RHIC data at lower collision energies are presented.

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Fast Equilibration of Hadrons in an Expanding Fireball

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Due to long chemical equilibration times of hadrons in the hadron gas phase in relativistic heavy ion collisions it has been suggested that they are “born” into equilibrium. Here we develop a dynamical scheme in which possible Hagedorn states contribute to fast chemical equilibration times of baryon anti-baryon pairs (as well as kaon anti-kaon pairs) inside a hadron gas and just below the critical temperature. Within this scheme, we use master equations and derive various analytical estimates for the chemical equilibration times. Within a Bjorken expansion scenario, the kaons and baryons as well as the bath of pions and Hagedorn resonances can indeed quickly chemically equilibrate for both an initial overpopulation or underpopulation of Hagedorn resonances. Moreover, a comparison of our results to $(B+\bar{B})/\pi$ and K/π ratios at RHIC, indeed, shows a close match.

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SHEAR VISCOSITY OF A HADRONIC GAS MIXTURE

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We discuss in detail the shear viscosity coefficient η and the viscosity to entropy density ratio η/s of a hadronic gas of pions and nucleons. In particular, we study the effects of baryon chemical potential on η and η/s. We solve the relativistic quantum Boltzmann equations with binary collisions ($\pi\pi$, πN, and NN) for a state slightly deviated from thermal equilibrium at temperature T and baryon chemical potential μ. The use of phenomenological amplitudes in the collision terms, which are constructed to reproduce experimental data, greatly helps to extend the validity region in the T-μ plane. This is highly contrasted with the case with low energy effective field theories. The total viscosity coefficient $\eta(T,\mu) = \eta^\pi + \eta^N$ increases as a function of T and μ, indirectly reflecting energy dependences of binary cross sections. The increase in μ direction is due to enhancement of the nucleon contribution η^N while the pion contribution η^π diminishes with increasing μ. On the other hand, due to rapid growth of entropy density, the ratio η/s becomes a decreasing function of T and μ in a wide region of the T-μ plane. In the kinematical region we investigated $T < 180$ MeV, $\mu < 1$ GeV, the smallest value of η/s is about 0.3, thus it never violates the conjectured lower bound $\eta/s = 1/4\pi \sim 0.1$ as shown in the figure. (However, the results of the effective field theories violate the bound.) The smallness of η/s in the hadronic phase and its continuity at $T \simeq T_c$ (at least for crossover at small μ) implies that the ratio will be small enough in the deconfined phase $T \gtrsim T_c$. There is a nontrivial structure at low temperature and at around normal nuclear density. We examine its possible interpretation as the liquid-gas phase transition.

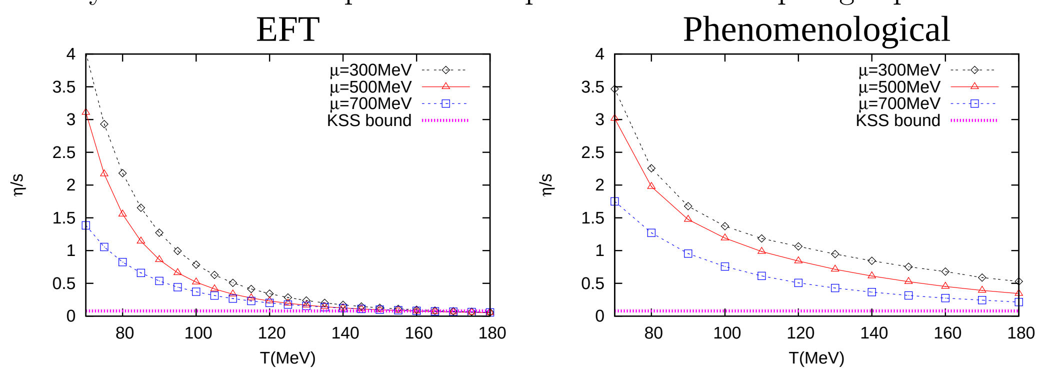

Figure 1: The ratio η/s as a function of temperature at different baryon chemical potentials $\mu = 300, 500, 700$MeV. Left panel is the results of the low energy effective field theories (EFT), and Right panel is the results of the phenomenological amplitudes.

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On the influence of the collision geometry on the dynamics of the relativistic nuclear collisions

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The reaction mechanisms of the $nucleus - nucleus$ collisions at relativistic energies are strongly related to the collision geometry. The so-called participants-spectators picture of these collisions is used by all mechanisms proposed for the description of their dynamics. Using a phenomenological geometric model[1,2], adapted for nucleus-nucleus collisions at colliders, too[3], we try to analyze the possible influences of the collision geometry on the collision dynamics. Symmetric and asymmetric nucleus-nucleus collisions at energies from a a few GeV per nucleon up to the hundred of GeV per nucleon are investigated. Considerations on the possible difference between dynamical behaviour of different nucleus-nucleus systems, at the same energy, but at different impact parameters which involve, however, the same number of participants (for example, $Au - Au$ and $Cu - Cu$ at $\sqrt{s_{NN}} = 200GeV$, but different impact parameters involving the same number of participants) are included.

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Longitudinal expansion and equation of state as observed in BRAHMS data

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Data collected by the BRAHMS Collaboration on pion rapidity distributions ($\mathrm{d}N/\mathrm{d}y(y)$) in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV [1] show good agreement with the Landau model [2] of full stopping. On the other hand, net proton distribution and the apparent saturation of average rapidity loss of the incoming nucleons for high beam energies [3] suggest applicability of the transparency scenario devised by Bjorken [4]. Measurements from BRAHMS experiment on Au + Au, Cu + Cu and p + p collisions will be used to obtain rapidity distributions for pions, kaons and antiprotons in several centrality classes. These results will be compared to hydrodynamical models that take into account longitudinal flow, like those presented in [5] or [6]. Comparison of the data at different colliding species, beam energies and collision centralities with theoretical expectations will give us insight into the

basic properties of the matter produced in heavy ion collisions: the equation of state or the initial energy density. It might also open the possibility of distinguishing between the Landau or Bjorken scenarios.

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The p/π ratio p_T-dependence in the RHIC range of baryo-chemical potential

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BRAHMS measurement of proton-to-pion ratios in Au+Au, Cu+Cu, p+p at $\sqrt{s_{NN}} = 62.4$ GeV and $\sqrt{s_{NN}} = 200$ GeV will be presented as a function of transverse momentum and collision centrality within the rapidity range $0 \leq y \leq 3$. The baryo-chemical potential, μ_B, for the indicated data spans from $\mu_B \approx 25$ MeV ($\sqrt{s_{NN}} = 200$ GeV, $y = 0$) to $\mu_B \approx 260$ MeV ($\sqrt{s_{NN}} = 62.4$ GeV, $y \approx 3$) [1]. The theoretical and experimental studies of the phase diagram in the $T(\mu_B)$ plane suggest that the gap between the temperature of the transition from the hadronic to the partonic phase, T_c, and temperature of chemical freeze-out increases with increasing μ_B. It was found [2] that at midrapidity region parton recombination model [3] provides a good description of p/π^+ ratios whereas the hydrodynamic model [4] fails in describing the shape of p/$\pi(p_T)$. However, for larger values of μ_B the pure recombination picture might be spoiled by the expected growth of the final-state hadron interaction. Eventually, this will lead to the behaviour reckoned for the expanding gas of hadrons. Comparison of the measured p/π ratios at different beam energies and rapidities with theoretical models [3,4,5] will allow to verify the above picture leading to better understanding of basic features of the phase diagram of strongly interacting matter.

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Landau Model for RHIC Rapidity Distribution - The Role of Viscosity

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It has been pointed out that the rapidity distribution of mesons for the central collisions of relativistic heavy ions can well be fitted by Gaussian distributions, and the energy dependence of the width seems to be in accordance with the simple Landau picture [1]. It is interesting to see if this fact really indicates certain validity of the Landau model in RHIC. However, a simple-minded Landau hydro-model with reasonable initial condition and freeze-out temperature does not correspond to this picture. To obtain the experimental rapidity distribution, the initial energy density should be very large, and when the system cools down to the expected freeze-out temperature, the flow profile approximates the Bjorken scaling solution in the sense that the final rapidity distribution presents a plateau rather than a Gaussian form near the central rapidity. As a matter of fact, even considering the transverse dynamics, it is not easy to reproduce the required rapidity width without forming a plateau within the framework of ideal hydrodynamics. In this work, we examine the effect of viscosity in relativistic hydrodynamics [2] and its consequence on the rapidity distribution. We found that the inclusion of the viscosity can transform the central plateau in the rapidity distribution into a Gaussian type, reproducing well the observed data for mesons. This might be a first indication of the importance of viscosity (non-equlibrium effects) in hydro scenario of relativistic heavy ion collisions. We also found that, even under the presence of viscosity, a relatively large relaxation time makes the fluid motion as if ideal while the velocity gradient is small. These results suggest a possible alternative scenario for the hydrodynamic motion of the colletive flow. It may well be possible that the apparent ideal fluid behavior in transverse motion is due to a relatively large relaxation time. A larger effective relaxation time may be understood due to the presence of non-equilibrium effects such as eddy turbulences.

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STATISTCAL MODEL PREDICTIONS FOR P-P COLLISIONS AT LHC

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The ALICE detector with its excellent efficiency for low momentum particles, its PID capability and high resolution of secondary vertices will provide high statistics data on systematics of strange particle production.
In this talk we present predictions of the statistical model for strange particle production yields at LHC energy. The statistical model is quite successful in describing particle yields

in heavy-ion and p-p collisions. However, in p-p interactions the phase space of strange particles is strongly suppressed and is controlled in the statistical model by the correlation volume.

We discuss how correlated strange-particle production might evolve towards LHC energies[1]. For p-p collisions we give predictions for two extreme scenarios possible within the statistical model concept. This will allow to test the validity of the statistical model concept and to shed light on the mechanism of strangeness equilibration and hadronization in elementary and heavy-ion collisions at LHC energy.

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The pp Minimum Bias Physics with ALICE

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The first step in the LHC physics programme will be to measure and understand the minimum bias p-p collisions, which will proceed in parallel with understanding of the detectors. The ALICE experiment will measure the properties of strongly interacting matter created in heavy ion collisions. Its design also makes it an excellent detector for minimum bias measurements in p-p collisions. In the initial low luminosity period ALICE has possibilities similar to the other p-p experiments, moreover it has the advantage of low p_T acceptance in the central barrel. ALICE will therefore play an important role in understanding the minimum bias p-p collisions at LHC energies.

This paper discusses the basic minimum bias measurements foreseen in the initial period of running. After brief description of the essential detectors needed for these measurements, i.e. triggering detectors (scintillator detector V0 and Silicon Pixel Detector-SPD) and tracking detectors (Time Projection Chamber-TPC and SPD), the initial trigger configuration is discussed. The proposed minimum bias trigger is sensitive to about 90 % of the total inelastic cross section and 99 % of the non diffractive cross section. The triggering detector V0 is able to suppress beam gas interactions efficiently. A procedure for an estimating of the trigger bias and trigger efficiency in the framework of the general correction scheme is presented. The corrections properly take into account the detector resolution of all sensitive variables in the analysis. The first physics measurements (e.g. momentum spectra, charged particle multiplicity) are analysed within the framework. The importance of trigger corrections for the precise luminosity measurement by the ALICE detector is emphasised.

Centrality dependence of pseudorapidity distributions of baryons in heavy ion collisions at RHIC

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Pseudorapidity distributions of inclusive baryons at RHIC energy have been obtained by the use of a method based on measured pseudorapidity distributions of charged particles, measured rapidity distributions of charged mesons and the observation of energy and centrality dependence of Limiting Fragmentation of pions [1, 2, 3, 4]
Pseudorapidity distributions of π^+, π^-, K^+, K^- measured for central AuAu collisions at $\sqrt{s}$= 200GeV, when transformed into (η - η_{beam}), were subtracted from scaled pseudorapidity distribution (with respect to η - η_{beam}) of charged particles at various centralities. Resultant distributions provide the scaled distributions for produced baryons and the beam remnants.
An estimate has been made about stopping at various centralities for scaled baryon disribution. At (η - η_{beam})$\sim$ 1.6, a crossover is found for baryon pseudorapidity disributions at various centralities. From the relative reduction of the area above crossover point, we make an estimate of rapidity loss of baryons.

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Kinetic Transport Equation for Freeze Out

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The Boltzmann Transport Equation (BTE) plays a key role in the physics of kinetic processes. In this presentation the basic limitations of the BTE approach for the very fast processes, which are actual nowadays for example in heavy ion reaction modeling, will be discussed, and modifications of BTE, which make description of such processes possible, will be presented.

The BTE is derived based on the following assumptions: (i) only binary collisions are considered, (ii) we assume "molecular chaos", i.e. that the number of binary collisions at position x is proportional to $f(x,p_1) \times f(x,p_2)$, (iii) $f(x,p)$ is a smoothly varying function on the mean free path (m.f.p.) scale. Therefore the usual structure of the collision terms in the BTE is not adequate for describing rapid process with characteristic length/time comparable with the m.f.p. Such sharp processes immediately contradict assumption (iii), and the assumption of "molecular chaos" gets also violated, because number of collisions is not proportional with $f(x,p_1) \times f(x,p_2)$, but it gets delocalized: $f(x_1,p_1) \times f(x_2,p_2)$, where x_k is the origin of colliding particles, i.e., the space-time point where the colliding particles were colliding last. This is an essential modification if the phase space distribution has a large gradient in the space-time. This gradient defines a 4-vector, characterizing the direction of the process, and neglecting changes in the other directions, i.e. along the hypersurface of the front, we can effectively consider such a process as 1-dimensional.
One of such rapid process, which can not be modeled with the standard BTE, is the freeze out in heavy ion collisions. It was shown in [1] that the basic assumptions of BTE are not satisfied during freeze out, because at the late stages of the process the characteristic length scale, describing the change of the distribution function, will always become smaller than the m.f.p.
To describe the phase space distributions, which change rapidly, faster than the m.f.p., BTE has to be modified. The first attempts to introduce Modified Boltzmann Transport Equation (MBTE) were done in Refs. [1]. In this presentation the further development of these ideas will be discussed.
Interestingly, the straight forward way to solve MBTE numerically is to follow the trajectories of each particles from one collision to the other, as it is done in the particle cascade kinetic models. Therefore the particle cascade models do actually solve MBTE, not BTE. Clearly, for the smooth processes these equations are the same, and there is no difference.

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Production of Light Nuclei and Antinuclei in Pb+Pb Collisions at CERN SPS Energies

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A comprehensive study of production of light nuclei and antinuclei in Pb+Pb collisions over a wide range of SPS energies was carried out in the NA49 experiment. Rapidity and transverse mass spectra of ^{3}He, tritons, deuterons and antideuterons as well as of protons and anti-protons were measured at beam energies of 20A, 30A, 40A, 80A and 158A GeV in centrality selected Pb+Pb collisions.
The large phase space coverage of NA49 allowed to obtain for the first time the total multiplicity yield of ^{3}He and its dependence on incident energy and collision centrality. A remarkable agreement is observed between the measured yields for ^{3}He and those predicted

by the Statistical Hadronization Model (SHM) [1].
The midrapidity invariant yield ratio of tritium to ^{3}He nuclei refelcts the neutron to proton density ratio at freeze-out. The measured result of 1.09 ± 0.05 contrasts with the ratio (A-Z)/Z=1.54 in nuclei, but is consistent with the yield ratio π^-/π^+ of pions produced in Pb+Pb collisions.
The dependence of the yield ratios and the inverse slope parameters of the transverse mass spectra on collision energy, centrality and mass number of the produced light nuclei will be shown and discussed within coalescence and statistical approaches. In particular the obtained coalescence parameters and $\langle m_T \rangle$ are compared to results from higher and lower energies. Moreover, the volume and nucleon density profile of the coalescence source is derived from the measured coalescence parameters and will be compared to results obtained from Bose-Einstein correlation analysis.

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Exploring the Charged Particle Multiplicity with the ALICE detector

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The charged particle multiplicity distribution $P(N)$, i.e. the probability P to measure an event with the charged particle multiplicity N, is one of the first measurements that ALICE will be able to perform. The knowledge of this basic property at a new energy is needed to configure Monte Carlo generators correctly with the aim of understanding the background of other, especially rare, processes including new physics. It allows to study the scaling behaviour and to verify model predictions. Furthermore, it provides a baseline for further studies and gives input for the trigger configuration.
The multiplicity distribution at low energy is well-described by KNO scaling, but broken at SPS energies ($\sqrt{s} = 540$GeV) [1]. Other explanations use negative binomial distribution (NBD) [2], a two component approach [3] or consider multi parton interactions [4]. One of the few predictions that can be tested in the realm of LHC's energy is based on the QGSM [5].
With ALICE, a broad region of phase space is accessible: $-3.4 < \eta < 5.1$ with the forward multiplicity detector (FMD) and the silicon pixel detector (SPD) in the central region ($|\eta| < 1.4$). The unfolding of the measurement is a non-trivial task due to the finite precision and acceptance of the detector. Solutions are based on χ^2 minimization or iteratively using Bayes' theorem.
The spectrum can be enhanced to very high multiplicities by exploiting the silicon pixel detector fast OR trigger. This trigger is based on the number of fired chips in the two layers of the SPD. Its 1200 chips allow sensitive triggering with an event rate up to 100 MHz.
We will present the two approaches to unfold the spectrum together with the associated systematic errors as they are expected today. Furthermore, the capabilities of the SPD fast OR trigger will be shown with their prospects for physics with ALICE.

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Study of Baryon Number Transport Mechanisms at LHC with the ALICE Experiment

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High-energy nucleon-nucleon and nucleus-nucleus collisions provide important insight about the carrier of the baryon number: valence quarks versus the gluonic field. Detailed analysis of the $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios and asymmetries at mid-rapidity allow to distinguish between these two scenarios.
The Large Hadron Collider LHC will provide p+p collisions at a center-of-mass energy of $\sqrt{s} = 14\,\text{TeV}$ and Pb+Pb collisions at $\sqrt{s_{\text{NN}}} = 5.5\,\text{TeV}$. The ALICE experiment, due to its excellent particle identification capabilities, will allow to study the proton and anti-proton yields at mid-rapidity ($|y| < 0.9$) with a wide transverse momentum coverage ($0.3 \leq p_T \leq 5\,\text{GeV}/c$) and high precision. Λs and $\bar{\Lambda}$s can be studied beyond $p_T = 0.4\,\text{GeV}/c$.
Since the two transport mechanisms for the baryon number produce only small differences in the observable baryon ratios and asymmetries, it is mandatory to understand in great detail the sources of systematic errors of these measurements. In this presentation the expected performance of the ALICE detector setup regarding the $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios will be discussed and limits for the systematic uncertainties of these measurements will be given.

Effect of finite chemical potential on QGP-Hadron phase transition in a statistical model of fireball formation

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We study the effect of finite chemical potential for the QGP constituents in the Ramanathan et al. statistical model (Phys. Rev. C 70, 027903, 2004). While the earlier computations using this model with vanishing chemical potentials indicated a weakly first order phase transition for the system in the vicinity of 170 MeV (Pramana 68, 757, 2007), the introduction of finite values for the chemical potentials of the constituents makes the transition a smooth roll over of the phases, while allowing fireball formation with radius of a few 'fermi' to take place. This seems to be in conformity with the latest consensus on the nature of the QGP-Hadron phase trnasition.

FIRST PHYSICS WITH ALICE: FROM pp TO Pb–Pb COLLISIONS

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The initial physics programme of the ALICE experiment at LHC will be discussed. ALICE[1] is the dedicated heavy-ion detector preparing for data taking with the first pp collisions at LHC, foreseen for the middle of 2008. The physics results will come progressively with the commissioning of the detector. The first few 10^4 minimum-bias pp events will be used for determination of the charged-particle density and multiplicity distribution. The same data sample will be used to align the tracking detectors in order to proceed with momentum measurements. The next results will be the p_{t} and pseudo-rapidity spectra, and the mean-p_{t} dependence on multiplicity. During the first month of running we aim to collect a few 10^7 pp events, the statistics needed for the calibration of different particle-identification systems. This data will be used to measure momentum spectra of different particle species, strange-particle production (also identified by decay topology), and the baryon–antibaryon asymmetry at mid-rapidity. The estimated statistical and systematic precision of these measurements will be presented and compared to the status of available predictions. In addition to the minimum-bias trigger we plan to collect data at high multiplicity (up to 10 times the average one) and to measure the particle composition and the p_{t}-spectra in such events, which may be affected by the parton saturation more than the average pp events. Early physics with the muon trigger in the forward region is also envisaged, we will measure the dimuon-mass spectrum and J/ψ yield. Finally, in the first pp run we want to trigger on photons with different energy thresholds in order to measure π^0- and direct γ-spectra.
After accomplishing the pp run we will be ready to record the first Pb–Pb data. We will benefit from pp running not only for the first physics results, but also from having well aligned and calibrated detectors, taking the advantage of low-particle density environment during commissioning. The heavy-ion programme will start with the determination of the basic event characteristics: charged-particle density, particle composition and spectra, and their

centrality dependence. A few days, even at very low luminosity $\mathcal{L} = 5 \times 10^{25}$ cm^{-2}s^{-1}, will be sufficient to obtain significant results for elliptic-flow measurement, two-particle correlations, resonance production, event-by-event fluctuations. We will take data both with the minimum-bias and for central Pb–Pb collision triggers. The first data sample will also make it possible to get an estimate of the charm-production rate thanks to the high significance of $D^0 \rightarrow K\pi$ signal and to measure the p_t-spectra of light hadrons up to 10 GeV/c. Data will be taken with the muon trigger aiming to measure the J/ψ yield in Pb–Pb collisions and to get an independent estimate for heavy-flavour production. The photon trigger will also be used to make a first measurement of π^0- and γ-spectra.

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Saturation of E_T/N_{ch} and Freeze-Out Criteria in Heavy-Ion Collisions

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The pseudorapidity densities of transverse energy, the charged particle multiplicity and their ratios, $(dE_T/d\eta)/(dN_{ch}/d\eta) \equiv E_T/N_{ch}$, are estimated at mid-rapidity, in a statistical-thermal model based on chemical freeze-out criteria, for a wide range of energies from GSI-AGS-SPS to RHIC. It has been observed that in nucleus-nucleus collisions, E_T/N_{ch} increases rapidly with beam energy and remains approximately constant at about a value of 800 MeV for beam energies from SPS to RHIC. E_T/N_{ch} has been observed to be almost independent of centrality at all measured energies [1]. The statistical-thermal model describes the energy dependence as well as the centrality independence, qualitatively well. The values of E_T/N_{ch} are related to the chemical freeze-out criterium, $E/N \approx 1\ GeV$ [2] valid for primordial hadrons. We have studied the variation of $< mass >, N_{decays}/N_{primordial}, N_{ch}/N_{decays}$ and E_T/N_{ch} with $\sqrt{s_{NN}}$ for all freeze-out criteria discussed in literature. These observables show saturation around SPS and higher $\sqrt{s_{NN}}$, like the chemical freeze-out temperature (T_{ch}) [3]. These observations along with the centrality independence of E_T/N_{ch} is consistent with the simultaneity of chemical and kinetic freeze-out at higher energies [4].

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Soft physics capabilities of CMS in pp at 14 TeV and Pb-Pb at 5.5 TeV

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The CMS experiment will provide good quality measurements of yields and spectra of identified charged and neutral particles, both in pp and heavy-ion collisions, thus contributing to the study of soft hadronic physics at the LHC energies.
The tracking of very low p_T charged particles will be possible down to about 200 MeV/c, with good relative resolution, good efficiency and a negligible fake rate, in the case of pp and p-nucleus collisions, thanks to the information present in the geometrical shape of the hit clusters observed in the silicon pixel layers. In the case of central Pb-Pb collisions the fake rate can be kept low for $p_T > 400$ MeV/c.
Charged hadrons with transverse momenta greater than 30 MeV/c will leave hits in the largely segmented first pixel layer of the tracker. The small occupancy (even in heavy-ion collisions) allows for the measurement of the pseudo-rapidity distribution of charged hadrons, by counting the number of reconstructed hits. Various corrections have to be applied to subtract contributions of secondary particles, looper particles, and non-functional channels. A sizeable fraction of V^0 decays can be measured by combining pairs of reconstructed charged tracks. Low p_T photons are also measurable by reconstructing conversions in the beam pipe and in the first pixel barrel layer. The analog readout of the silicon tracking layers (pixel and strip detectors) gives access to the energy lost by the charged hadrons, which enables their identification up to around 600 MeV/c total momentum, with 9-10% relative dE/dx resolution for minimum ionizing pions.

K/π identification by the kink topology in pp interactions at 14 TeV in the ALICE experiment

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The kink topology, reconstructed as a secondary vertex with the mother particle decaying into one (same)charged daughter particle plus neutral(s), is studied for K/π separation in pp interactions at 14 TeV in the ALICE experiment at LHC. The kinematical properties of the K/$\pi \rightarrow \mu + \nu_\mu$ decay are examined as a method for improving particle identification. The transverse momentun of the daughter particle and the kink decay angle (between mother and daughter) at a given momentum of the mother particle, will allow the K/π separation in a wide momentum range.The maximun q_T values (in the laboratory frame) of the daughter muons are 236 and 30 MeV/c for the K and the π, respectively. The decay angles (between mother and daughter) in the same system, at a given mother momentum, are different because of the mass difference between K and π. A combination of information from q_T and decay angle plots may provide information for K/π separation.
The analysis is based on 2$\times$ 10^6 simulated events at 14 TeV inside the ALICE detector and provides a list of selection criteria for the K/π separation in the real data samples.
The kaon yields via their kink topology will be compared with the ones identified by dE/dx with the ALICE-TPC. The sample of K's identified by their kink topology is expected to help the study of the intermediate p_T range ($1.5 < p_T < 6$ GeV/c), where the hard processes coexist with the soft ones. It is also expected to improve the signal extraction in the reconstruction of hadronic resonances including kaons in their decay products. Their signal in pp collisions will be the reference point for comparison with the corresponding signal in Pb-Pb interactions. As an example the effect on the extracted signal of $\Lambda(1520)$ will be discussed.

Global Features of Heavy Ion Collisions at the LHC using the ATLAS Detector

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While high p_T phenomena are of primary interest at the LHC, due to the expected increased rates of hard processes, the subsequent modification of jets and heavy quark transport will depend on the energy and gluon density of the medium, as well as its dynamical behavior reflected in the global properties of the "underlying event".

"Global" observables, which include the total and differential charged-particle yields ($dN/d\eta$), transverse energy ($dE_T/d\eta$) and charged particle spectra, are typically thought to be dominated by the non-perturbative soft processes observed in nucleon-nucleon interactions, with some contribution from hard processes. The interplay between the two reflects the nuclear collision geometry and beam energies, and leads to various proposed scaling laws that describe various aspects of the data. These have been studied at RHIC since the earliest Au+Au runs.

With the upcoming thirty-fold increase in energy and similarly large nuclei, Pb+Pb collisions at the LHC offer a powerful lever arm to test various scaling laws associated with the energy and impact-parameter dependence of bulk particle production. The ATLAS detector at the LHC has the means to do a comprehensive study of global observables both in p+p collisions (at full LHC energy) and Pb+Pb collisions (at $\sqrt{s_{NN}}$=5520 GeV) over a wide rapidity range ($|\eta| < 2.5$ for charged particles, and $|\eta| < 5$ for energy measurements). The collision geometry can be determined by a variety of variables, both energy and multiplicity, in comparison to Glauber models. The present status of physics performance studies will be shown in the context of theoretical expectations for the LHC based on RHIC data.

Antiparticle to particle ratios measured in Cu+Cu collisions using the PHOBOS detector at RHIC

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Antiparticle to particle ratio measurements provide direct information on the net-baryon content of the matter created in heavy-ion collisions. They are important for the understanding of the chemical freeze-out properties of strongly interacting matter. Heavy ion collisions at RHIC have provided us with an opportunity to study these ratios as function of system size and energy.
Antiparticle to particle ratio measurements made using the PHOBOS detector will be presented for pions, kaons and protons as a function of collision centrality for Cu+Cu collisions at the nucleon-nucleon center-of-mass energies of 62.4 and 200 GeV. A comparison with results obtianed for p+p, d+Au and Au+Au collisions, using the same detector, will also be discussed. No strong dependence of the anti-particle to particle ratios on collision centrality is found.
The strength of these experimental results on particle ratios stems primarily from two advantages of the PHOBOS detector. First, this measurement of antiparticle to particle ratios is unique at RHIC due to the two identical and symmetric spectrometer arms. PHOBOS can, by simply reversing the magnetic field systematically during data taking, measure particle ratios where all effects of acceptance and efficiency cancel. Second, the excellent collision vertex resolution of the PHOBOS Vertex detector allows for tight distance-of-closest-approach cuts on the identified particle's trajectories to aid in reducing the contributions from secondary and weakly decaying particles. The particle identification techniques used in the analysis will also be described.

STAR probe for the (strong interaction) parity violation effects in heavy ion collisions with three particle correlations

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In non-central relativistic heavy ion collisions, $P-$odd domains, which might be created in the process of the collision, are predicted to lead to charge separation (preferential same charge particle emission) along the system orbital momentum [1]. Since the direction of the separation may vary event to event in accord with the sign of the topological charge of the domain, the observation of the effect is possible only by correlation techniques. Such an observable, P-even, but directly sensitive to the charge separation effect, has been proposed in [2] and is based on 3-particle mixed harmonics azimuthal correlations. We report the STAR results obtained using this observable for Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}}$=200 and 62 GeV for different particle charge combinations as function of collision centrality. Studies of detector, and physics effects (besides parity violation) that might contribute to the signal are presented.

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Cosmic-ray Monte Carlo predictions for forward particle production production in Pb-Pb collisions at 5.5 TeV and p-Pb collisions at 8.8 TeV

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The origin and exact nature of cosmic ray (CR) primaries with energies above 10^{15} eV is unclear. Due to their low observed flux, only indirect measurements of CRs (thought to be protons and/or nuclei) are possible: current techniques measure the cascade of particles generated in the atmosphere in proton-nucleus (p-Air) and nucleus-nucleus (α-,Fe- Air) collisions. Determination of the primary energy and mass relies on Monte Carlo codes which describe the interactions of the primary (dominated by forward and soft QCD interations) in the upper atmosphere. Existing MC models predict energy and multiplicity flows differing by factors as large as three, with significant inconsistencies in the forward region ($|\eta| > 5$). The measurement of forward particle production cross-sections in p-A and A-A collisions at LHC energies (equivalent to $E_{lab} \approx 10^{17}$ eV) will provide strong constraints on these models and allow for more reliable determinations of the CR energy and composition at the highest energies measured on Earth. We will present and compare the predictions of various MC models (QGSJET-II [1], DPMJET [2], EPOS [3]) for the energy ($dE/d\eta$, $dE_T/d\eta$) and particle ($dN/d\eta$) flows in Pb-Pb and p-Pb collisions at $\sqrt{s}$ = 5.5, 8.8 TeV respectively, in the range covered by forward LHC detectors like CASTOR or TOTEM (5.2< $|\eta|$ <6.6 in the CMS interaction point) and ZDC or LHCf ($|\eta| >_{\sim}$ 8.1 for neutrals, in ALICE, ATLAS and CMS).

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Particle production as a nonlinear diffusion process

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Particle production in high-energy heavy-ion collisions is treated as a nonlinear diffusion process with the diffusion coefficient depending on rapidity density. The initial buildup of the distribution functions of produced particles occuring within $\tau_p \simeq 0.25$ fm/c in three sources during the colored partonic phase is modeled using analytical power-law solutions of the underlying nonlinear transport equation. In rapidity space $[y = 0.5 \cdot \ln((E+p)/(E-p))]$ it takes the form

$$\frac{\partial}{\partial t} R(y,t) = -\nabla_y \Big[J(y) R(y,t) \Big] + D_y \nabla_y R(y,t)^{\kappa} \nabla_y R(y,t).$$

For certain critical exponents κ, analytical solutions of the diffusive part of this equation can be obtained. In a two-step approach, the subsequent - mostly hadronic - evolution in pseudorapidity space during the interaction time of $\tau_{int} \simeq$ 7-10 fm/c (mean duration of the collision) is essentially linear as expressed in the Relativistic Diffusion Model [1] (RDM, $\kappa = 0$) with a drift term $J(y) = (y_{eq} - y)/\tau_y$ governed by the rapidity relaxation time τ_y and the equilibrium value of the rapidity y_{eq} , and a diffusion term $\propto D_y \frac{\partial^2}{\partial y^2} R(y,t)$. This yields excellent agreement with d+Au, Cu+Cu and Au+Au data at RHIC energies, including the detailed centrality dependence, and provides predictions at LHC energies.

Based on the RDM-evolution of the rapidity distribution functions in the three-sources model, the energy dependence of stopping and hadron production in high-energy heavy-ion collisions is investigated, and the time evolution towards statistical equilibrium is discussed. The transport coefficients are then extrapolated from Au + Au and Cu + Cu at RHIC energies ($\sqrt{s_{NN}}$=19.6 - 200 GeV) to Pb + Pb at LHC energies $\sqrt{s_{NN}}$= 5.52 TeV. Rapidity distributions for net protons, and pseudorapidity spectra for produced charged particles in central collisions are compared [2,5] to BRAHMS [3] and PHOBOS [4] data at RHIC energies, and discussed for several extrapolations [1,5] to LHC energies.

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