The Monte Carlo Dual Parton Model DTUNUC

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ABSTRACT

The Dual Parton Model provides a coherent picture for the description of hadron-hadron, hadron-nucleus and nucleus-nucleus collisions at high energies. Here we present further investigations of a Monte Carlo version of the DPM [1, 2] for the description of particle production in hA and AA collisions. Agreement is found with recent data on the stopping power in central S-S collisions; the model predictions for particle production at LHC energies are updated. In particular, we study the time development of the hadronic energy density for different projectile/target combinations as well as for different collision energies.

1. INTRODUCTION: Originally the Dual Parton Model provided a phenomenological description of the dominant features in soft hadronic interactions. However, experiments at p–$\bar{p}$ colliders demonstrate the intimate relation of soft non-perturbative and hard perturbative reaction mechanisms. A comprehensive formulation of a two-component DPM including soft hadronic processes (described by the supercritical pomeron) and semihard processes (described by perturbative parton scattering) was given by Aurenche et al. [3]. A Monte Carlo version of this model for hadron–hadron collisions has been realized with the event generator DTUJET: Interactions proceed via the formation of color neutral soft and hard parton–parton chains which are fragmented independently.

The extension of the Monte Carlo model to hadron--nucleus and nucleus–nucleus interactions – DTUNUC – includes the following main features [1]:

(1) Application of Glauber's multiple collision model; to allow for the application of the model at superhigh energies we introduced a parametrization for the energy dependence of the parameters describing the elastic scattering amplitude.
(2) Individual nucleon–nucleon collisions are described as in the DTUJET code.
(3) Formation time suppressed intranuclear cascade of created secondaries with spectator nucleons to all generations.
(4) Inclusion of Fermi momenta for nucleons together with a simple realization of Pauli's principle.

The actually released and documented model version DTUNUC 1.00 [2] does not yet include all the features of the two–component DPM as realized in the DTUJET code: Semihard parton–parton collisions (for the description of minijet production) and multiple pomeron interactions between individual nucleons are not treated in this version. These restrictions do not affect the results up to RHIC energies ($\sqrt{s} \simeq 200\ GeV$, $E_{lab} \simeq 20\ TeV$). A new release of the model is in preparation including the features important for the extrapolation to LHC energies.

2. RESULTS FROM DTUNUC: A first comparison of results from DTUNUC with data on hadron–production in hadron–nucleus and nucleus–nucleus collisions has been published [1, 4]. Good agreement was found for charged particle rapidity and grey–prong multiplicity distributions. Also the correlations between the rapidity distribution of fast secondaries and the number of grey particles are reproduced reasonably well.
Stopping power: In Fig. 1 we compare the proton rapidity distribution as obtained by DTUNUC with NA35 data from central S–S collisions at 200 GeV/c [5]. The agreement is satisfactory although the shape of the calculated distribution is rather sensitive to the actual sampling procedure applied for the parton x–values.

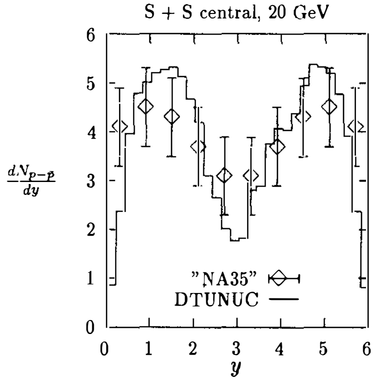

Fig. 1

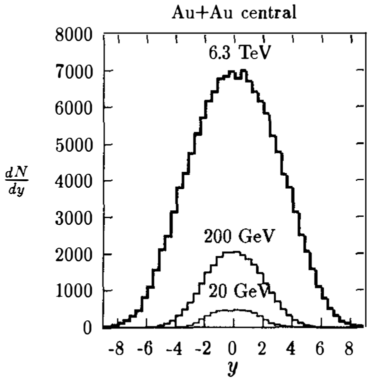

Fig. 2

Extrapolation to heavy ion collisions at LHC energies: As already mentioned the application of the Monte Carlo model beyond RHIC energies requires the inclusion of all features of the two-component DPM [3] into the DTUNUC code. As already discussed by J. Ranft at Quark Matter '91 [4] the semihard minijet component of the DPM yields about 25% of the multiplicity in central Au–Au collisions at the highest LHC energies whereas this contribution is negligible up to RHIC energies. Taking into account the multiple pomeron interactions (i.e. the possibility to form more then one pair of soft chains in individual nucleon–nucleon collisions) results in a further substantial increase of the multiplicities at LHC: The central rapidity density rises from about 5000 to roughly 7000 charged particles per rapidity unit at 6 TeV as shown in Fig. 2. This plateau value is in good agreement with analytical estimates of Capella et al. [6].

Hadronic energy density in central heavy ion collisions [7]: Sufficiently high energy densities of 2...5 GeV/fm^3 are considered to be a necessary condition for the formation of a quark–gluon plasma in nucleus–nucleus interactions.

In our approach the formation time τ_s is introduced to suppress the intranuclear cascade, i.e. during this characteristic time a hadron to be created cannot interact with other particles. Therefore, we assume that only secondaries which are already born will take part in the thermalization process of the hadronic matter, i.e. only these particles are taken into account in the calculation of energy and particle densities. This simplified description is motivated by the good agreement of our model with data on grey particle production.

Following this concept the evolution of the particle and energy densities in our model is straightforward: The Monte Carlo realization of the Glauber mechanism provides the impact parameter and all the nucleon positions as well as the assignment of interacting nucleon pairs for the actual heavy–ion collision. Furtheron, generated secondaries propagate along straight trajectories starting at the corresponding interaction points, and contribute to the densites after the actually sampled formation time.

To arrive at densities volume elements are defined by intervals of the space–time rapidity $y = arctanh(z/t)$ as longitudinal variable and three equidistant radial bins. The time development of the densities is considered as function of the eigentime of each volume element, i.e. by scoring the particles and their energies, resp., moving at a given eigentime within the corresponding space region.

In Fig. 3 we show the hadronic energy density ϵ for the inner radial bin as obtained in our model for central Au–Au collisions at three typical collision energies. The value $\tau = 4\ fm$ was chosen since the average formation time sampled for created hadrons is about 3 fm. Fig. 4 demonstrates that for central Au–Au collisions at RHIC the maximum value of ϵ stays for a time of about 5 fm/c above 2 GeV/fm^3 in the corresponding rest frame, the volume concerned is larger than 1000 fm^3.

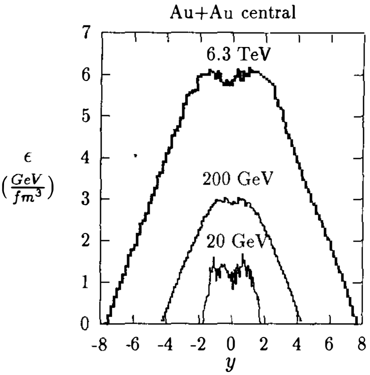

Fig. 3

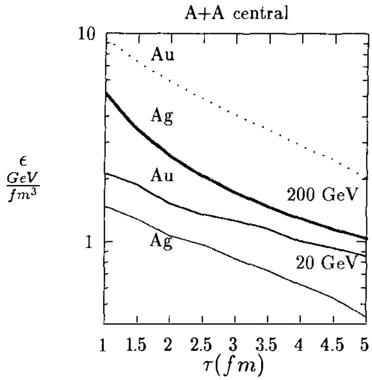

Fig. 4

3. SUMMARY: Our Monte Carlo Dual Parton Model DTUNUC describes successfully several important aspects of multiparticle production processes in hadron–nucleus and nucleus–nucleus collisions at presently available energies. Starting with heavy ion collisions at RHIC, both energy and particle densities reach values at which an independent fragmentation of chains becomes unlikely. New phenomena should show up as clear deviations from a straightforward extrapolation of our conventional model.

References

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