SCALING OF PARTICLE AND TRANSVERSE ENERGY PRODUCTION IN Pb+Pb COLLISIONS AT 158 A·GeV

WA98 Collaboration

(For a complete list of authors, see article "CERN WA98 Experiment.")

Heavy-ion collisions at ultrarelativistic energies probe nuclear matter at high temperatures and densities. A major goal of these studies is the search for a deconfined phase of nuclear matter. A necessary condition to reach such a phase transition is local equilibration which might be achievable through rescattering of produced particles. As the amount of rescattering should increase with the size of the reaction system, it is of interest to study these reactions over a wide range of centralities.

While a scaling with the number of collisions arises naturally in a picture of a superposition of nucleon-nucleon collision with a possible modification by initial state effects, the participant concept is more naturally related to a system with strong final state rescattering, where every participant contributes a similar amount of energy to particle production. The scaling behavior of particle production may therefore carry important information on the reaction dynamics.

Furthermore, there seem to be qualitative changes of the behavior in heavy-ion reactions once a certain system size is reached. The NA50 collaboration has observed an anomalous J/ψ suppression in central Pb+Pb collisions in contrast to peripheral reactions [1] where the J/ψ yield can be explained by the absorption in nuclear matter. Strangeness production is enhanced in S+S reactions compared to p+p, but seems to saturate for even larger nuclei (see e.g. [2]). Recent results from the WA98 experiment [3] show a significant change of the shape of the π^0 p_T spectrum in peripheral Pb+Pb collisions compared to p+p data. However, from semi-central Pb+Pb collisions with ca. 50 participating nucleons up to central reactions the shape remains unchanged. In this centrality range the π^0 production for $p_T > 0.4$ GeV/c has been found to follow a simple scaling as $\sim N_{part}^{1.3}$ with the number of participants and $\sim N_{coll}^{1.0}$ with the number of binary nucleon-nucleon collisions. It is therefore of interest to study in detail the centrality dependence of particle production and investigate its scaling properties with respect to the number of participants or collisions.

The dependence of the E_T, N_{ch} and N_γ pseudorapidity densities at midrapidity on the number of participants and collisions is shown in Fig. 1. A double logarithmic presentation has been chosen in order to look for scaling behavior as

$$\left.\frac{dX}{d\eta}\right|_{max} \sim N_{part}^{\alpha},\, N_{coll}^{\alpha}, \quad X = E_T,\, N_{ch},\, N_\gamma\,.$$

Indeed this functional dependence gives a reasonable description for $N_{part},\, N_{coll} > 50$. Within the errors the E_T, N_{ch} and N_γ scaling with N_{part} can be described by a universal exponent $\alpha = 1.09 \pm 0.02$. Alternatively, an equally valid scaling with the number of collisions as $N_{coll}^{0.85}$ is observed for $N_{coll} > 50$.

In simple multiple collision models a heavy-ion reaction is regarded as a sequence of independent nucleon-nucleon collisions which can be described as in free space [4, 5]. After a projectile nucleon suffers an inelastic collision the assumption of local baryon number

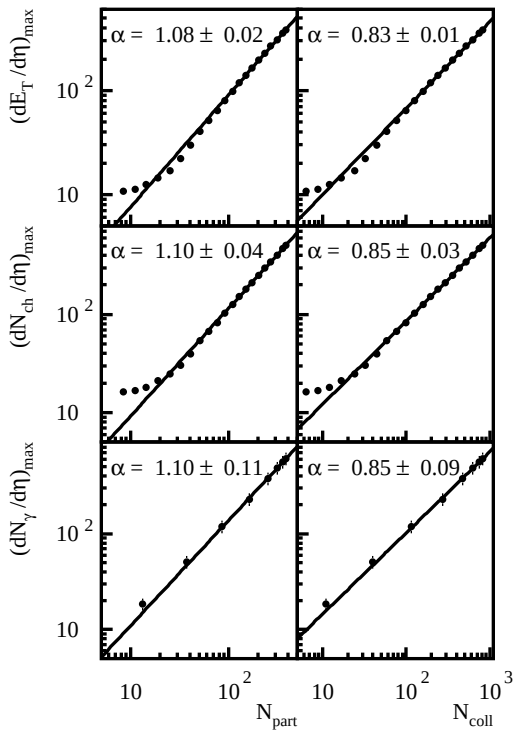

Figure 1: Pseudorapidity density of E_T, N_{ch} and N_γ at midrapidity as a function of the number of participants and binary nucleon-nucleon collisions. In each case the scaling exponent α obtained from a fit for $N_{part} > 100$ and $N_{coll} > 150$ are shown. The indicated errors are fit errors.

conservation assures that a baryon-like object is still present. This baryon-like object is assumed to contribute to the particle production in subsequent collisions with the same cross section as the initial nucleon. In this picture the contribution of each nucleon-nucleon collision is added incoherently which leads to a linear scaling of E_T and particle production with the number of binary collisions. If the energy degradation in each nucleon-nucleon reaction is taken into account a reasonable description of E_T and particle production can be obtained. The approximate scaling as $N_{coll}^{0.85}$ for the considered observables may be used to obtain information on the average energy degradation in a nucleon-nucleon collision. In case of the Wounded Nucleon Model the eventual fragmentation of an excited nucleon after an inelastic collision is not affected by further collisions with other nucleons no matter how many times it is successively struck. The observation of a stronger than linear increase with the number of participants indicates that this model can only give very crude estimates of E_T and particle production in Pb+Pb collisions

With the present data it is possible to determine the transverse energy per charged particle ($\langle E_T \rangle / \langle N_{ch} \rangle$), a quantity that can be seen as a measure of the global transverse momentum averaged over all particle species. $\langle E_T \rangle / \langle N_{ch} \rangle$ is plotted in Fig. 2 as a function of centrality, represented by the number of participants.

An increase of $\langle E_T \rangle / \langle N_{ch} \rangle$ is observed up to a system size of $N_{part} \approx 50-100$ which corresponds to an impact parameter of $b \approx 9$ fm. For more central collisions $\langle E_T \rangle / \langle N_{ch} \rangle$ levels

off at a value of 0.75. This value is slightly higher than the maximum $\langle E_T \rangle / \langle N_{ch} \rangle \approx 0.66$ observed in 200 AGeV S+Au and S+Al reactions [6]. A similar saturation with an increasing number of participants as observed here has been seen in the (truncated) mean p_T of neutral pions with $p_T > 0.4$ GeV/c produced in Pb+Pb reactions. A natural explanation of such a behavior would be the assumption that thermalization is reached once the system exceeds a certain minimum size.

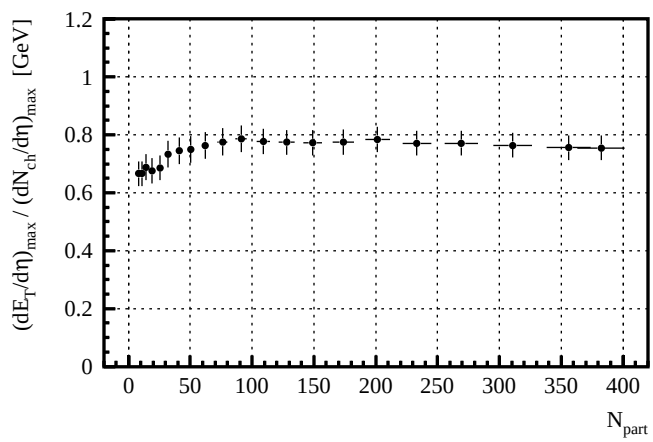

Figure 2: $\langle E_T \rangle / \langle N_{ch} \rangle$ at midrapidity as a function of the number of participants.

---

[1] NA50 Collaboration, M. C. Abreu et al., *Nucl. Phys. A* **638**, 261c (1997)

[2] J. Sollfrank et al., *Nucl. Phys. A* **638**, 399c (1997)

[3] WA98 Collaboration, M. Aggarwal et al., *Phys. Rev. Lett.* **81**, 4087 (1998)

[4] C. Y. Wong and Z. D Lu, *Phys. Rev. D* **39**, 2606 (1989)

[5] C. Y. Wong, *Phys. Rev. D* **32**, 94 (1985)

[6] WA80 Collaboration, R. Albrecht et al., *Z. Phys. C* **55**, 539 (1992)