

Inverse slope and asymmetry parameters as a function of the centrality for different particles in Ni+Ni collisions at a beam energy of 1.93 AGeV

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Particle production in heavy-ion collisions is an important diagnostic probe for the conditions inside the hot and dense reaction zone. Particle ratios measured at SIS energies can be described within a statistical model assuming chemical equilibrium [1]. On the other hand, the particle yields calculated with transport models depend on the elementary production cross sections which means that the equilibration is not complete [2]. Additional information on the properties of the fireball is contained in the phase-space distributions of the emitted particles.

We have measured the momentum distributions of pions, kaons and protons in Ni+Ni collisions at 1.93 A GeV as a function of the centrality at laboratory angles of $\Theta_{lab} = 32^\circ, 40^\circ, 50^\circ$ and 60° , for pions additionally at 70° . As an example we show in figure 1 the differential cross sections for the production of protons, pions, K^+ and K^- mesons for 5 centrality bins as a function of the laboratory momentum at $\Theta_{lab} = 40^\circ$. The reaction cross sections of the centrality classes were determined from the charged particle multiplicities measured at laboratory angles between 12° and 48° . We parametrize the spectral and angular distributions for kaons and protons as a function of E_{cm} by

$$\sigma = \left(1 + a_2 \cdot \cos^2(\Theta_{cm})\right) \cdot C \cdot E_{cm} \cdot e^{-\frac{E_{cm}}{T}}$$

with E_{cm} and Θ_{cm} being the energy and polar angle in the center-of-momentum frame, a_2 the asymmetry parameter and T the temperature. For pions we use a superposition of two Boltzmann distributions to describe both the low and high energetic part of the spectrum.

$$\sigma = \left(1 + a_2 \cos^2(\Theta_{cm})\right) \cdot E_{cm} \cdot \left[\left(C_1 \cdot e^{-\frac{E_{cm}}{T_1}}\right) + \left(C_2 \cdot e^{-\frac{E_{cm}}{T_2}}\right) \right]$$

The result of the fitting procedure at various laboratory angles is shown together with the data in figure 2. Note that the fit is performed simultaneously to all spectra of one particle species, so that the yield ratios are sensitive to the a_2 parameter only.

The resulting slope parameters T (in case of pions: high energy slope parameter T_2) and the corresponding asymmetry parameters a_2 are shown as a function of the number of participating nucleons A_{part} in figure 3 and figure 4. A_{part} is determined from the reaction cross section using a geometrical model.

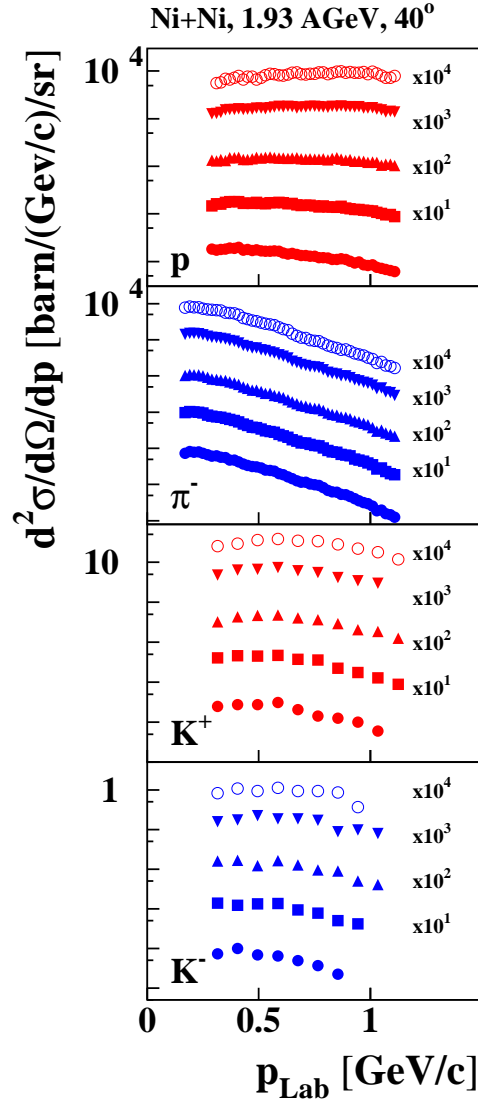


Figure 1: Differential cross section for the production of protons, pions, K^+ and K^- mesons in 5 centrality bins as a function of the laboratory momentum at $\Theta_{lab} = 40^\circ$. The non-scaled spectra correspond to peripheral collisions, central collisions are scaled by 10^4 . The yields depend on the size of the centrality bins which correspond to 5% (most central), 10%, 10%, 20%, 55% (peripheral) of the total reaction cross section.

The inverse slope parameters of protons (see figure 3) increase from $T = 130$ MeV to about $T = 170$ MeV with increasing centrality. These large values are an indication of the collective flow which influences the spectra of particles according to their masses. The inverse slope parameters of protons are substantially larger than those of

the K^+ mesons which are again larger than the ones of the K^- mesons and the high energy slope of the pions:

$$T(\text{protons}) > T(K^+) > T_2(\text{pions}) \geq T(K^-)$$

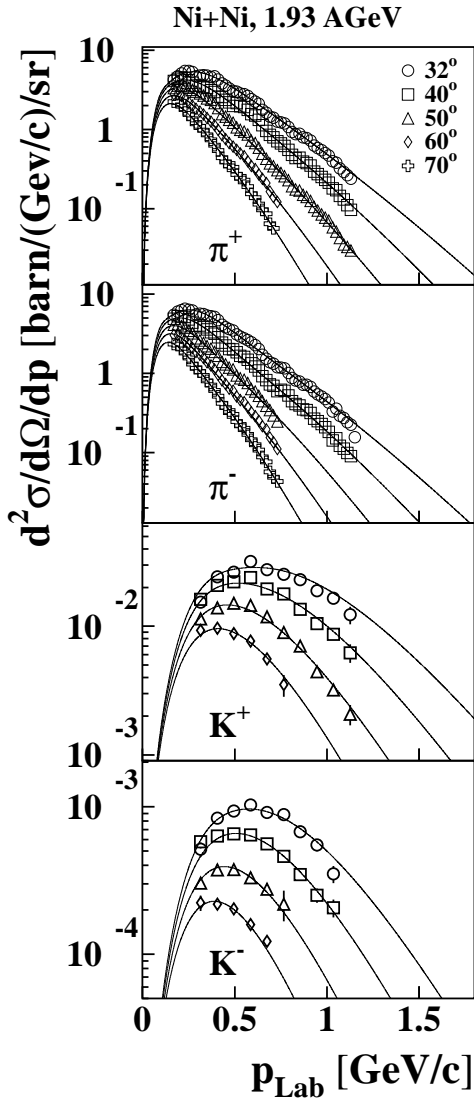


Figure 2: Double differential production cross sections for pions and kaons as a function of the laboratory momentum measured for inclusive Ni+Ni collisions at 1.93 A GeV. The data were taken at different laboratory angles (as indicated). The lines represent the functions (1) and (2) fitted to the kaon and the pion spectra respectively (see text).

This relation of the inverse slope parameters is at variance with the picture of a simultaneous decoupling of the particles from an expanding fireball. In this case the values of T should increase with increasing particle mass.

Moreover, the polar emission pattern of the particles is not isotropic, in particularly not for peripheral collisions. Figure 4 show the anisotropy parameters a_2 which decrease with increasing centrality. The proton angular distribution is strongly forward-backward peaked even for the most central collisions. The K^+ , K^- and π^\pm mesons emitted in central collisions, however, exhibit only small

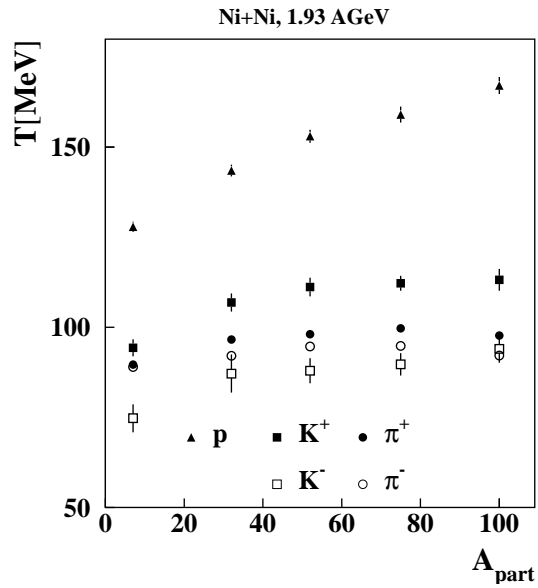


Figure 3: Inverse slope parameters for protons, kaons and h.e. pions (see text) as a function of the number of participating nucleons.

asymmetries which increase for more peripheral collisions. These observations indicate that the particles still remember the beam direction, in particular if they are created in non-central collisions.

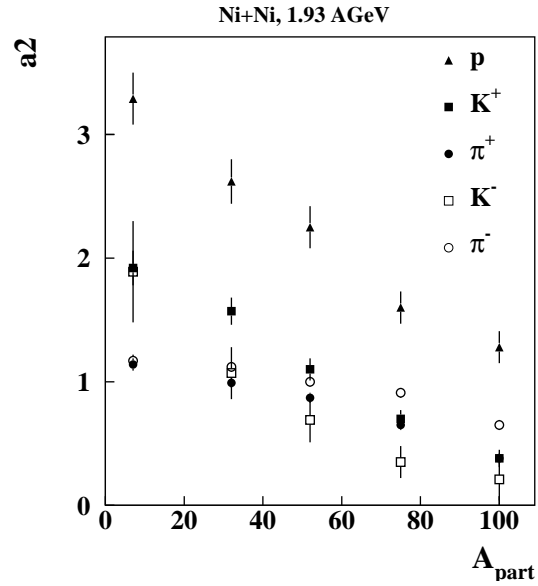


Figure 4: Anisotropy parameters for protons, kaons and pions as a function of the number of participating nucleons.

References

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