Pion Production at SIS Energies

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Pion production is the most important inelastic channel in relativistic heavy ion reactions. The yield of pions in the final state is connected, albeit through the population of intermediate nucleon resonances, to the temperature within the reaction zone. Thus, although not directly related to the Equation-of-State (EOS), pions are an integral part of the effort to determine the properties of nuclear matter. The available data on pion production in the full solid angle are sparse and partially controversial [1]. In order to improve this situation the systems $Ca + Ca$, $Ru + Ru$, and $Au + Au$ were studied at incident beam energies of 400 AMeV, 1000 AMeV and 1500 AMeV.

Pions were identified using the Central Drift Chamber (CDC) of the FOPI apparatus by combining the specific energy loss and the curvature of the tracks in the solenoidal magnetic field. For symmetric systems the acceptance covers more than 90% of the total solid angle.

The raw numbers have to be corrected for i) the geometrical acceptance ϵ_{geo} and ii) the tracking efficiency ϵ_{trk}. Both quantities were determined by means of GEANT based Monte Carlo studies employing IQMD as event generator [2]. ϵ_{geo} was found to be independent of centrality and amounts to $\epsilon_{geo} = 0.9 \pm 0.05$ slightly varying with the incident energy. ϵ_{trk} varies with centrality in the range 100%-60% for π^+ and 100%-80% for π^- and was determined for all measured systems individually. After applying the corrections a straight line was fitted to the sum of π^+ and π^- as function of A_{part}, the number of participants. The latter quantity was derived from the differential cross sections $d\sigma/dMUL$; for MUL several quantities like the forward wall multiplicity, the baryon multiplicity in the CDC acceptance and the total charged particle multiplicity were tested and gave the same results. The fit was restricted to a range $0.15 < A_{part}/A_{sys} < 0.85$ in order to avoid distortions due to the impact parameter selectivity of the apparatus.

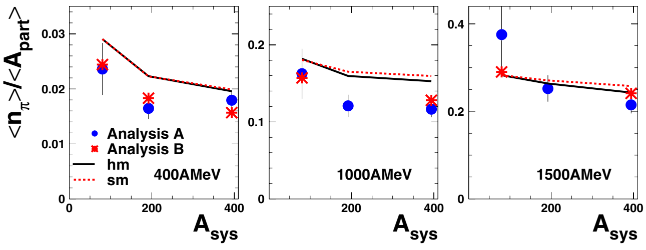

Figure 1: Total pion yield for different energies and colliding systems.

Figure 1 shows the total pion yield $< n_\pi >$ per participating nucleon, A_{part}, versus the system size, A_{sys}. An alternate, independent, analysis (B) give results in very good agreement with the first evaluation, see Fig. 1. In the alternate procedure, with a systematic error of about 10%, the effects of geometrical cuts and of transverse momentum thresholds were corrected by extrapolation of smooth fits to the measured data and the effects of track quality cuts were estimated by a systematic variation of the cuts and extrapolation to zero cuts. The relative π^-/π^+ efficiency was inferred from the data for ^{40}Ca+^{40}Ca, an isospin symmetric system. Differences between analysis A and B to former analysis [4] are currently under investigation.

At all energies a dependence of the normalized pion production with the system size is observed. Whether this decrease is connected to the system size or rather to the correlated change of the isospin content of the system is currently investigated by comparing the systems $Ru + Ru$ and $Zr + Zr$. The experimental results are compared in Fig. 1 with IQMD model calculations for different parameters of the equation of state (EOS), namely a soft (dashed line) and a hard (solid line) with the "standard" compressibilities of 200 MeV and 380 MeV, respectively. The IQMD events were analyzed with the same procedure as applied to the data. Calculating the pion production probability directly from the IQMD output allows to give a systematic error of procedure A. The results agree within 4%. The IQMD model describes the data with an accuracy of 20%. The pion yield is found to be independent from the stiffness of the EOS.

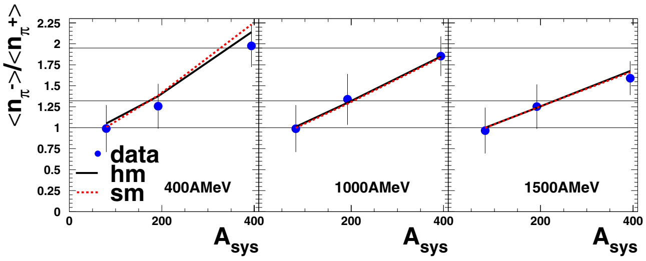

Figure 2: Ratio of charged pions for different energies and colliding systems. The lines indicate the predictions of the isobar model [3].

Figure 2 shows the π^- to π^+ ratio $R_\pi =< n_{\pi^-} > / < n_{\pi^+} >$ for the colliding systems and energies mentioned above. For the heaviest system, $Au + Au$, a strong energy dependence is observed. With rising energy the ratio, R_π, drops from 2.0 at 400 AMeV incident energy to 1.65 for the highest energy. The data are compared with the IQMD model. The measured ratios are perfectly described by the model including the observed energy dependence for the Gold system.

References

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