Antiproton, K^- and Hard π^- Production in Ne+NaF Collisions

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Extreme subthreshold particle production in heavy ion collisions is particularly sensitive to medium effects like the population of resonances, multiparticle correlations, or the reduction of effective masses in the dense medium. While the first two mechanisms help to exceed the required energy threshold at subthreshold beam energies, the latter effect reduces the effective threshold in the medium, enhancing the production of massive or energetic particles in all cases. In order to disentangle various contributions including reabsorption effects systematic studies are indispensable.

In a recent experiment $\bar{p}$, K^- and energetic π^- production in ^{20}Ne+NaF collisons at 0^o was investigated at the FRS at GSI with incident energies of 2 AGeV, 1.8 AGeV, 1.6 AGeV and 1.4 AGeV using the experimental setup described in ref. [1]. The mean beam energies in the target were 60 AMeV lower. The cm particle momenta were varied between 0.3 GeV/c and 1.0 GeV/c for $\bar{p}$, between 0.5 GeV/c and 1.1 GeV/c for K^- and between 0.1 GeV/c and 2.0 GeV/c for π^-. Thus also for π^- extreme subthreshold processes comparable to $\bar{p}$ production were studied [2]. Excitation functions for all particle species were measured for fixed cm momenta in order to keep the reabsorption effects unchanged.

The production of $\bar{p}$ and energetic π^- with $p_{cm} \sim 2$ GeV/c is still observed at the lowest incident energies $E_{beam} = 1.34$ AGeV. This demonstrates that even for a relatively small system like Ne+NaF, where thermal equilibrium is not expected to be reached in relativistic collisions, very high momenta of the participant nucleons and high mass baryonic resonances are populated.

As in the system Ni+Ni [3], a rough scaling of the invariant cross sections for all particles $\sigma_{inv} \propto exp[(E_{avail} - E_{prod})/E_0)]$ is observed with $E_{prod} = E_{thres} + E_{kin}^{cm}$ being the energy required for the production of the particle and E_{avail} the available nucleon-nucleon energy in the cm frame, and $E_0 \sim 80$ MeV. In spite of the smaller system size the deviations from this scaling relation are similar to those in the Ni+Ni system which were previously attributed to different reabsorption probabilities of the different particle species [3]. This indicates that other effects may also play a role as origin for the deviations.

The π^- cm kinetic energy spectra in a Boltzmann type representation are compared with thermal distributions in Fig. 1. The inverse slope constants range from ~ 80 MeV to ~ 95 MeV for projectile energies from 1.34 to 1.94 AGeV, ~ 5 MeV lower than for Ni+Ni at equal incident energy [2]. Deviations from a thermal behaviour are clearly visible in the ratio of the measured cross sections to the fitted values shown in Fig. 2. While the enhancement at ~ 0.3 GeV indicates contributions from Δ and $N^\star$ decay, the maximum at ~ 1.1 GeV is still unexplained.

Excitation functions for π^-, K^- and $\bar{p}$ production measured at various cm momenta are presented in Figs. 3 and 4. They are approximately described by an exponential dependence on the available energy in the nucleon-nucleon system $\sigma_{inv} \propto exp(\alpha{\cdot}E_{avail})$ and exhibit a systematic behaviour showing increasing slope constants α with increasing cm energy.

For the lowest π^- energies almost no dependence of the cross sections on the incident energy is observed, whereas for $\bar{p}$ and high energy π^- the slope constant is $\alpha \approx (50\text{ MeV})^{-1}$. The dependence of the slope constant α on the required production energy of the particle E_{prod} is consistent with a linear relation $\alpha \propto E_{prod}$ independent of the particle species. This behaviour is obtained in a simple thermal model which assumes that the energy of baryon-baryon collisions in the hot medium has a Boltzmann distribution, dependent on the incident energy, and that the particle production cross section is essentially given by the probability to populate energies above the threshold energy for the production of the particle with given kinetic energy.

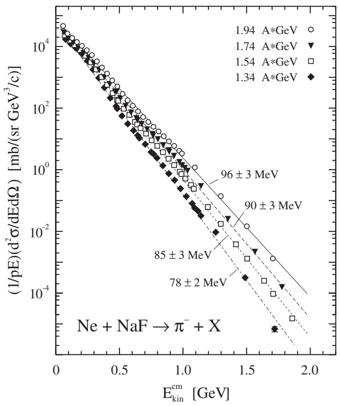

Fig. 1: π^- cm kinetic energy spectra. Thermal spectra follow exponential curves.

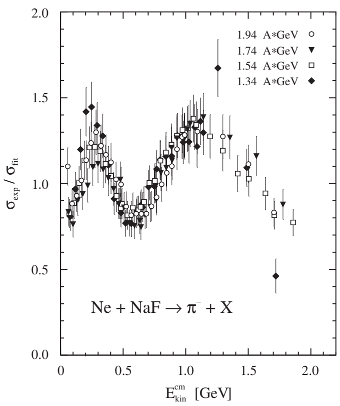

Fig. 2: Ratio of measured π^- production cross sections and the values from the exponential fits

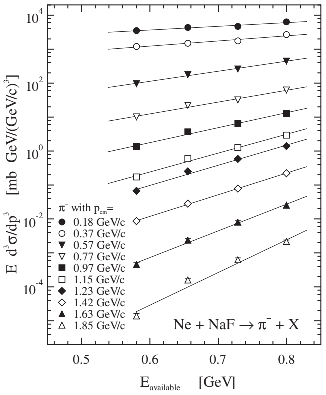

Fig. 3: Excitation function for π production for various cm momenta

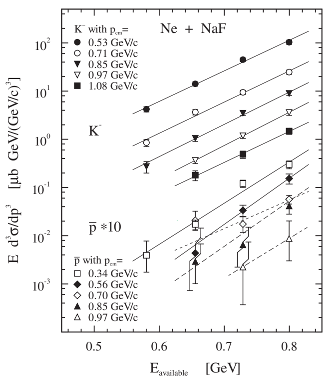

Fig. 4: Excitation function for K^- and $\bar{p}$ production for various cm momenta

References

[1] A. Schröter et al., Z. Phys. A 350 (1994) 101
[2] A. Gillitzer et al., Z. Phys. A 354 (1996) 3
[3] H. Gilg et al., Jahresbericht 1994, p.29