

## Isospin effects on particle production\*

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### Abstract

We investigate the Lorentz structure of the symmetry energy ( $E_{sym}$ ) at supra-saturation densities in Heavy-Ion Collisions (HIC) at SIS/GSI energies. It turns out that particle yields, and in particular, the *strangeness ratio*  $K^+/K^0$  presents a good probe in determining the high density isovector Equation of State (EoS).

HICs at intermediate relativistic energies (SIS/GSI regime, 0.1-2 AGeV) provide a unique tool to explore the nuclear EoS [1] under extreme conditions of density, temperature, and, particularly, of isospin-asymmetric nuclear matter (ANM). The density dependence of the isovector EoS is still unknown and theoretically differently predicted by various models [2]. On the other hand, its knowledge is important for the understanding of astrophysics, e.g. neutron stars [3].

In our work HICs are theoretically based on relativistic kinetic equations of Boltzmann type, i.e. the Relativistic Boltzmann Uhlenbeck Uheling (RBUU) transport equation. For the study of highly excited ANM matter we use the non-linear Walecka model (NL). The isovector part of the EoS is characterized by an isovector, vector  $\rho$  meson (NL $\rho$ ) or by a  $\rho$  and an isovector, scalar  $\delta$  fields (NL $\rho\delta$ ). The introduction of the  $\delta$  field changes the high density behavior of  $E_{sym}$ ; as in the isoscalar case (cancellation effects between strong repulsive vector  $\omega$  and attractive scalar  $\sigma$  fields), the  $\rho$  field rises linearly with increasing baryon density  $\rho_B$ , whereas the  $\delta$  meson is suppressed due to the saturation of the isospin scalar density at high  $\rho_B$ . Thus, in order to describe the same bulk asymmetry parameter  $a_4$  at saturation density, one has to increase the  $\rho$  meson coupling if the  $\delta$  meson is accounted for.  $E_{sym}$  becomes therefore stiffer going from the NL $\rho$  to the NL $\rho\delta$  model [4]. The effect between them increases in the dynamical situation due to the additional Lorentz currents. One expects important transport effects in HICs.

Fig. 1 shows the energy dependence of the ( $K^+/K^0$ ) and the ( $\pi^+/\pi^-$ ) ratios [5]. Here the standard free parametrizations of the elastic and inelastic cross sections were used and for the kaons no potential were applied, except for some cases (open triangles and stars). In the NL model one does not consider any isovector mesons in the nuclear mean field, and it serves as a reference. It is seen that the variable stiffness of  $E_{sym}$  (NL $\rho$ , NL $\rho\delta$ ) influences differently the pionic and strangeness ratios. In particular, the isospin effect on kaons is more pronounced with respect to that for pions. This is because of the strong secondary re-scattering effects of pions. On the other hand, kaons ( $K^{+,0}$ ) do not interact with the hadronic environment (large mean free path). Therefore they give directly

information on the high density phase. As in detail discussed in [6], the stiffness of  $E_{sym}$  considerably influences the threshold condition of particle production via the isovector scalar and vector components of the hadron self energy; with increasing stiffness of  $E_{sym}$  the  $K^0$  ( $K^+$ ) yield is enhanced (reduced). Their opposite behavior with respect to the model leads to the observed strong isospin effect. Furthermore, a preliminary study shows the robustness of the strangeness ratio against density modifications of the elastic cross sections (open triangles) and of the kaon potential (stars). We note that the strangeness ratio remains also stable against in-medium changes of the inelastic cross sections for resonance production.

In summary, we have investigated the possibility to set stringent constraints on the high density behavior of the isovector EoS from HICs. Possible candidates for such studies turn out to be particle ratios, and in particular the strangeness ratio between isospin states of the kaon. Future experiments with radioactive beams will be an important issue in determining the symmetry energy at high isospin density.

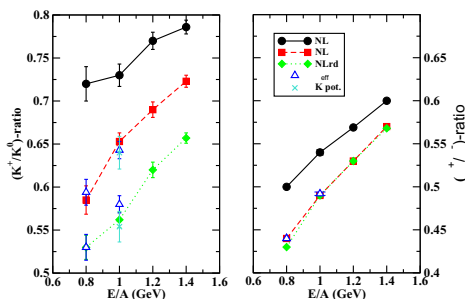


Figure 1: Energy dependence of the  $K^+/K^0$  (left) and  $\pi^+/\pi^-$  (right) ratios for central Au+Au collisions. Transport calculations with the NL (solid-circles), NL $\rho$  (dashed-squares) and NL $\rho\delta$  (dotted-diamonds) models are shown. In some cases calculations with in-medium elastic cross sections (open triangles) and with the kaon potential (stars) are presented.

### References

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