Signals of dense neutron-rich matter in high energy heavy ion collisions ?

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The production of neutron rich matter in relativistic nuclear collisions would give access to the information on the symmetry energy at high densities and thus on the isospin dependence of the equation of state at such densities. This information is crucial for understanding basic astrophysics aspects such as the origin of elements, the structure of rare neutron rich isotopes and neutron stars properties.

In this contribution we report new experimental and model calculation results which seem to evidence the possibility of producing neutron rich matter in high energy heavy ion collisions. FOPI [1] and EOS [2] Collaboration have evidenced in highly central Au + Au collisions systematically larger mean kinetic energy for ^{3}He relative to the ^{3}H fragments up to 400 A·MeV. Pure Coulomb repulsion, considered in microscopic transport models or hybrid hydrodynamical models, did not succeed to explain quantitatively this difference. Based on these facts, it was suggested that isospin effects could produce a radius dependence of the neutron/proton ratio within the fireball in the initial phase of the collision, with a direct concequence on the energy and yield distributions of ^{3}H and ^{3}He at the break-up moment [3].

Table 1: Experimental (right column) and theoretical values of kinetic energies of different light particles emitted in central collision Au+Au at 250 MeV/nucleon.

Particle	$< E_{kin}^{prim} >$ [MeV]	$< E_{kin}^{sec} >$ [MeV]	$< E_{kin}^{exp} >$ [MeV]
p	86.9	84.1	87±2
d	114.1	111.6	108±3
t	133.7	129.7	124±4
^{3}He	156.7	149.2	147±4
^{4}He	179.6	157.1	136±3

The main features of the evolution of compressed nuclear matter formed in heavy ion collisions can be rather well described as an initial isentropic expansion followed by clusterization [6]. We adopt this scenario and the parameters of the locally equilibrated source at the break-up time [6]. For the clusterization phase, a statistical multifragmentation model was inplemented [7] successfuly used to explain many experimental aspects of the multifragmentation process at intermediate energies. The relative neutron/proton population inside the fireball was parametrized as a function of radius in order to obtain good agreement of the isotopic yields and kinetic energies of elements $Z < 4$ with the experimental data obtained in Au+Au collisions at 250 A·MeV [1]. While the $dN/dZ(Z)$ and $< E_{cm} > /A(Z)$ distributions are almost insensitive to the isospin distribution inside the fireball, the kinetic energies of the light clusters have a dramatic dependence on the preferential fragment formation inside the fireball. Preliminary results of our studies indicate that a 20 MeV difference between the kinetic energies of ^{3}H and ^{3}He clusters (see Table 1) can be obtained assuming an N/Z distribuition decreasing from 4.3 in the core vecinity to approximative 0.8 near the surface, with an average value of 1.49.

Recently [4] we have observed a difference in the squeeze-out signals of ^{3}H and ^{3}He fragments in Ru+Ru collisions at 400 A·MeV.

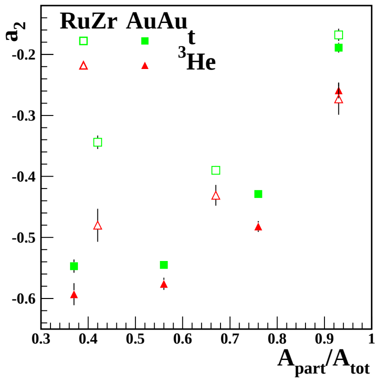

Figure 1:

By comparing experimental azimuthal distributions of mean kinetic energies (i.e. subdivided into a collective and a thermal part) with model predictions it was shown that it is possible to access different time intervals of the fireball expansion when looking in different directions of azimuth [5]. Thus, if the neutron/proton ratio within the fireball is dependent on the position, different values for the relative yield of ^{3}H and ^{3}He as a function of break-up time (azimuth) are expected.

Fig.1 shows the experimental results for the squeeze-out signal in Ru+Zr (the four Ru(Zr)+Ru(Zr) were summed up in order to increase the statistics, differences between them being neglected) and Au+Au at 400 A·MeV as a function of A_{part}/A_{tot}, for three centralities defined by A_{part}/A_{tot}. Systematically, ^3He has a larger squeeze-out signal relative to ^3H.

Estimates on the azimuthal distributions of ^{3}H and ^{3}He which are based on the correlation between break-up time and azimuthal angle [5] are in progress.

Recent hadronic transport calculations [8] reveal that n/p ratio of dense region is a snsitive probe of nuclear symmetry energy.

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