**Constraining the symmetry energy at supra-saturation densities with measurements of neutron and proton elliptic flow - the Microball at GSI**

P. Marini, P. Cammarata, L. Heilborn, L. May and S. J. Yennello for the ASY-EOS Collaboration

Understanding the equation-of-state of asymmetric nuclear matter is of fundamental importance and underpins our knowledge of many aspects of nuclear physics and astrophysics. The equation-of-state of asymmetric matter at supra-saturation densities has very few experimental constraints [1]. This is the domain with the greatest theoretical uncertainties and the largest impact on the understanding of neutron stars [2]. The behaviour of the symmetry energy at supra-saturation densities can only be explored in terrestrial laboratories by using relativistic heavy-ion collisions of isospin asymmetric nuclei.

A measure of the neutron and proton direct and elliptic flows, neutron-proton yield ratios and light-fragment flows and ratios in $^{197}$Au+$^{197}$Au, $^{96}$Ru+$^{96}$Ru and $^{96}$Zr+$^{96}$Zr at 400 MeV/u reactions has been conducted at GSI by the ASY-EOS collaboration. We focused on the difference between the neutron and proton flows, so that the influence of the isoscalar potential, which acts equally on neutrons and protons, is minimized, whereas the effects of the symmetry potential, which has opposite effects on neutrons and protons, are maximized. The experiment has been specifically designed to constrain the symmetry energy at density around 2-3 times the normal density and has been intended as a start of a program of measurements to constrain the equation of state of asymmetric nuclear matter using both stable and rare isotope beams at the present GSI facility and in the future at FAIR.

Neutrons and protons were detected and identified by LAND [3] while the modulus and the orientation of the impact parameter were measured by coupling the forward rings of CHIMERA[4] and the ALADIN-Time of flight wall [5]. Light fragments were detected by the Krakow telescope. The experiment was performed in air. Moreover, the Ru target was an oxide, thus the discrimination of the desired reactions versus those occurring on light elements was crucial for the analysis. The discrimination of reactions occurring in air from reactions occurring in the target was enabled by the Microball [6]. It was based on the backward emitted multiplicity, which is expected to be different in the two cases, according to a UrQMD simulation.

The Microball was located in a light-tight box, 40cm downstream of the beam-pipe end. The target was mounted inside the Microball, using a special target holder able to slide inside the detector, so that the Microball was covering angles from 60 to 172°. Only 4 rings of the Microball have been used during the experiment, in order not to shadow other detectors. A halo detector was located in front of the Microball to detect particles coming from upstream. Moreover, an aluminium shield was protecting the Microball from $\delta$ electrons produced by the interaction of the beam in air. The Microball also has a thin aluminium foil in the inner side shielding the detector from electrons produced in the target region. A lead shield was placed in front of the Microball, upstream and outside the box, 5cm downstream of the beam-pipe, to stop fragments produced upstream.

Data with and without a target have been collected during the experiment. A preliminary analysis performed online has shown that the detected multiplicity in the Microball is different in the two cases, as shown in fig. 1 giving us confidence in the capability of the Microball to discriminate the two reactions. The ratio of the number of events normalized to the beam current appears to be around 50%.

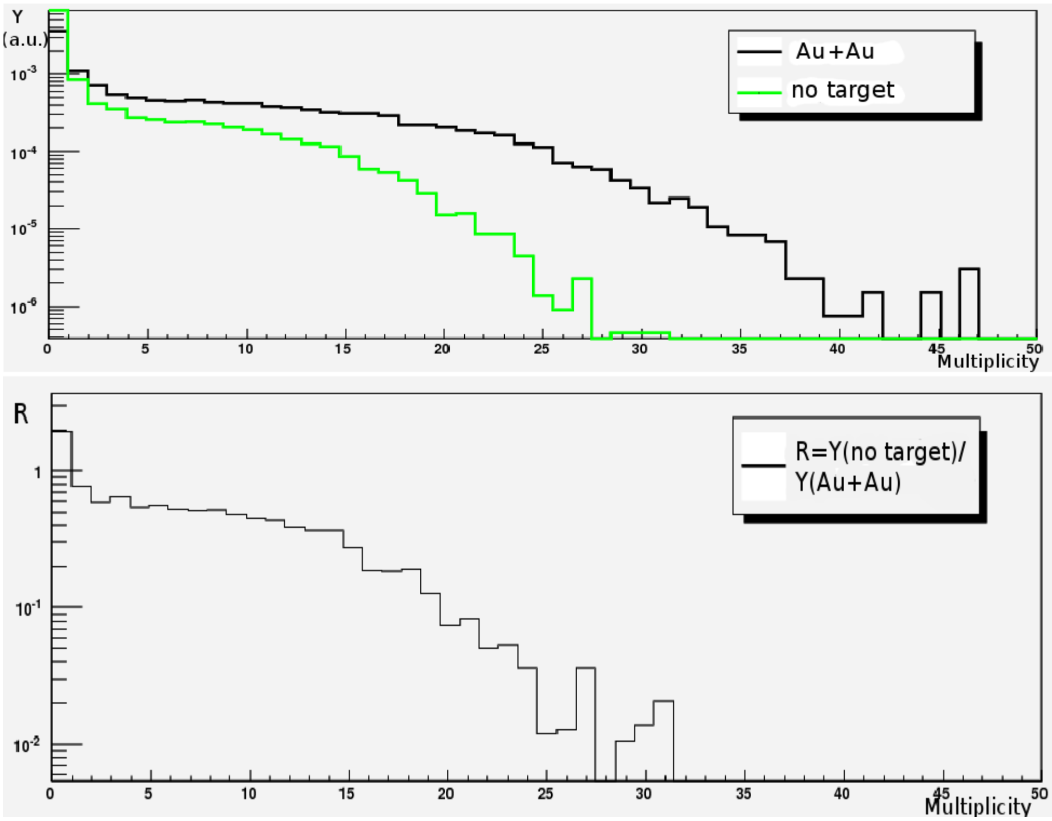


**FIG. 1.** Normalized multiplicity distributions for runs with (black) and without (green) target (top panel). In the bottom panel the ratio of the normalized yields is shown.

An even better discrimination of the two kind of reactions can be achieved looking at the multiplicity correlation with CHIMERA. Indeed events in which the reaction occurred in air present a much lower multiplicity in both the Microball and CHIMERA, as can be seen in fig. 2.

The unexpected high multiplicity observed in the Microball during runs with no target may be attributed to some noise in our detectors and/or to reactions occurring upstream. The off-line analysis will be able to compensate for these noise problems. The halo detector will provide a useful veto in our analysis to remove events in which particles hitting the Microball where produced upstream. Time-of-flight and energy measurements have also been performed in the Microball.

The calibrations of the detectors and the data analysis are now in progress by members of the ASY-EOS collaboration.

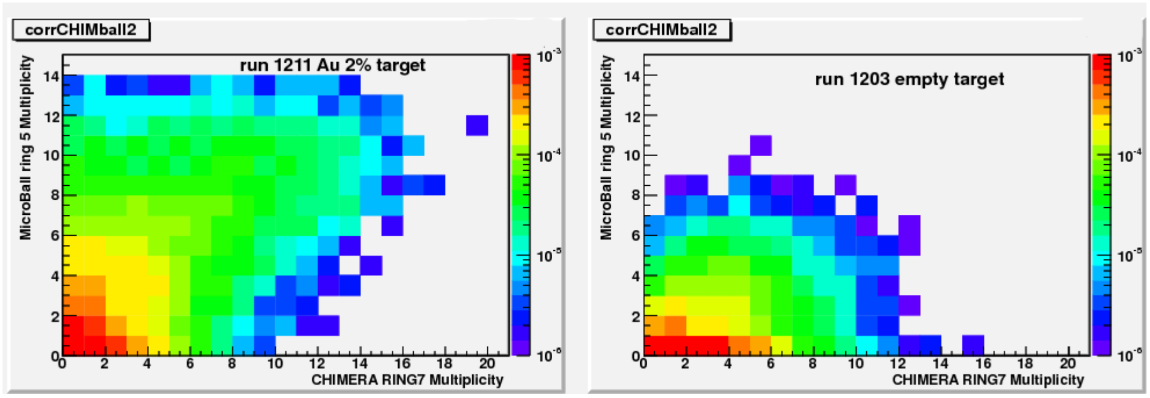


**FIG. 2.** Multiplicity correlations between CHIMERA and the Microball for runs with (left) and without (right) target.

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