Probing the symmetry energy at high energies with the ASY-EOS collaborations at GSI

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The nuclear equation of state (EoS) of asymmetric nuclear matter is also a quantity of crucial significance in understanding the physics of isolated and binary neutron stars, type II supernovae and neutron star mergers. Experimental information about the EoS can help to provide improved predictions for neutron star observables such as stellar radii and moments of inertia, crustal vibration frequencies and neutron star cooling rates [1, 2], which are currently being investigated with ground-based and satellite observatories. The symmetry energy is not well constrained at supra-saturation densities (Fig. 1). This is especially true in the range $\rho \geq 2\rho_0$ where there are the greatest theoretical uncertainties. The behaviour of the symmetry energy at supra-saturation densities can be explored in terrestrial laboratories by using relativistic heavy-ion collisions of isospin asymmetric nuclei. Elliptic neutron and proton flow, neutron-proton double yield and fragment ratios, as well as, flows in relativistic isospin-asymmetric heavy-ion collisions are predicted to be sensitive to the density dependence of the symmetry energy.

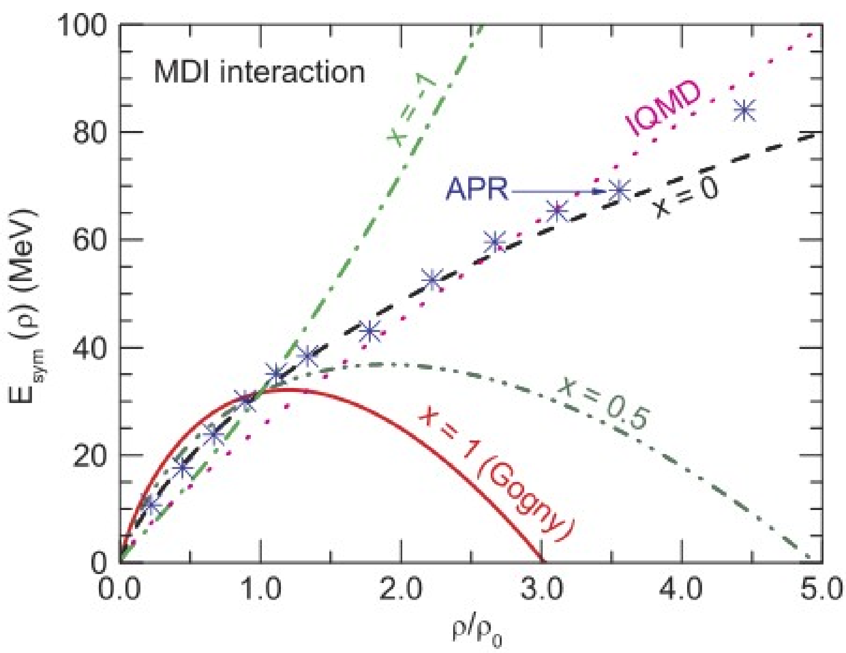

FIG. 1. Compilation of the theroetical symmetry energy vs normalized nuclear density [3].

For this experiment, the collaboration used reaction systems of ^{197}Au+^{197}Au at 800A MeV, ^{197}Au+^{197}Au , ^{96}Ru+^{96}Ru (RuO2) , and ^{96}Zn+^{96}Zn(ZnO_2) at 400A MeV. Detector arrays from around the world were set up to collect data in a common trigger. The CsI(Tl) Rings 4-8 of MicroBall [4] were installed around the target for multiplicity measurements to discriminate beam-target reactions from the reactions with lighter nuclei in air. Downstream (Fig. 2) CHIMERA [5] (Charge Heavy Ion Mass and Energy Resolving Array) was used for impact parameter determination and particle identification of reaction products from $7 - 20^\circ\ \theta$. To help veto reactions in air downstream of the target, a He pipe was installed before CHIMERA for the Ru and Zn systems.

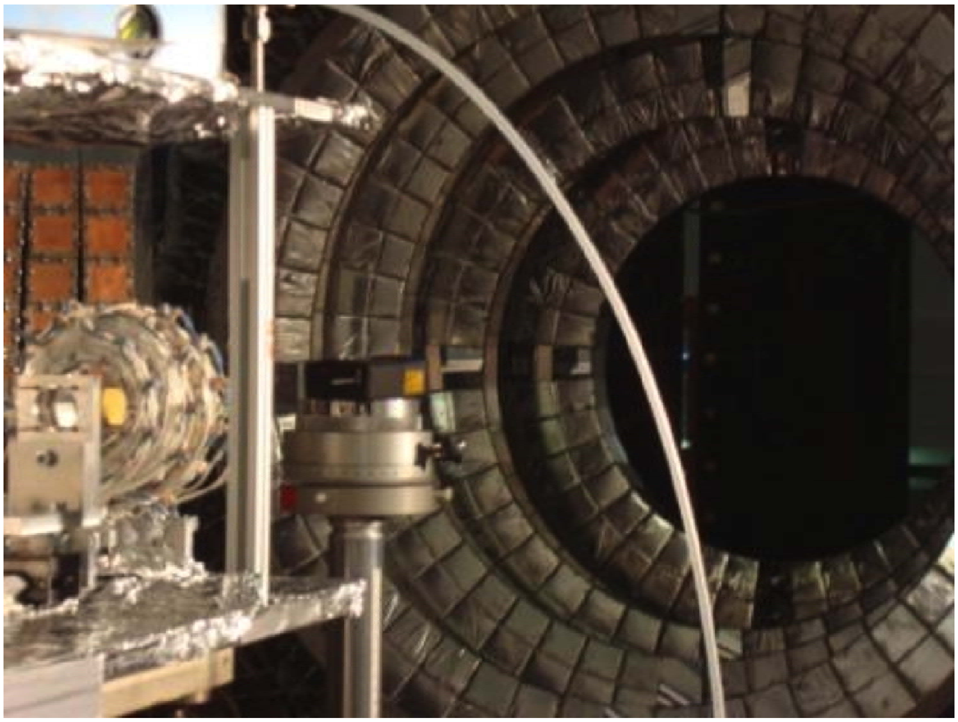

FIG. 2. MircoBall with CHIMERA downstream in the experimental configuration.

The ALADIN-ToF Wall [6] (Time of Flight Wall), constructed of dual-layered scintillator, was placed behind CHIMERA. The angular coverage of $0 - 8^\circ\ \theta$ overlapped with CHIMERA for particle identification of the reaction products. In addition, the Krakow PHOSwitch and LAND [7] (Large Area Neutron Detector) were placed at 60º and 45º off beam axis respectively. The PHOSwitch, located in close proximity to MicroBall and constructed of 35 Si-Si-Si-CsI stacked detectors, was used for mid-rapidity IMF (intermediate mass fragment) detection. LAND, constructed of plastic scintillator sandwiched Fe with 20 paddles per layer, was used to detect the neutrons in mid-rapidity complimentary to the IMFs in the PHOSwich.

The American contingent, was responsible for the setup and operation of the MicroBall detector during the experiment, along with, the data analysis scripting after the experiment to analyze the data. Initial data suggests that the MicroBall should be successful in detecting reactions in air vs reactions between the beam and target based on multiplicities collected during the initial calibration runs (Fig. 3). The green lines shows ^{197}Au+^{197}Au at 400A MeV with the target removed, thus yielding reaction products due to Au beam incident on air (N_2 and O_2).

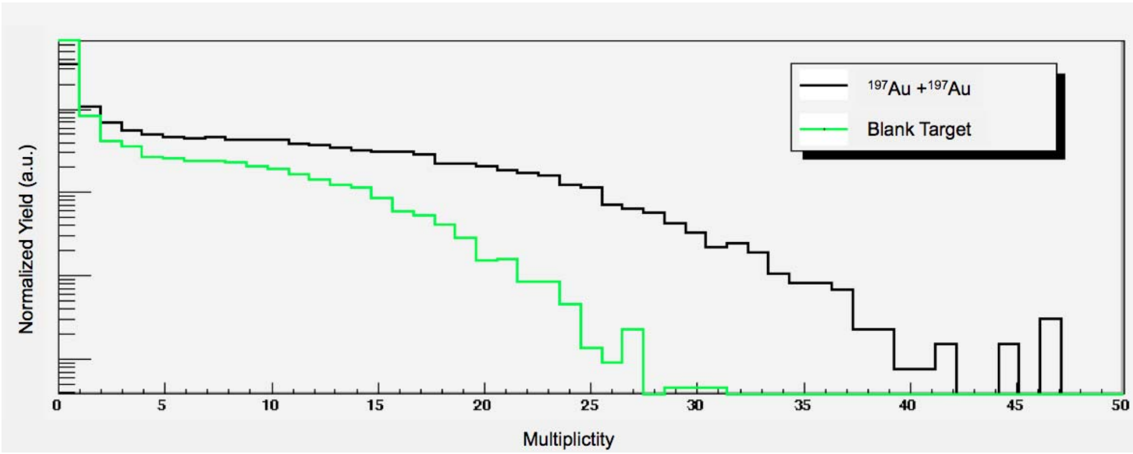

FIG. 3. Multiplicites from MicroBall calibration run. Green line shows mulitplicity of beam in air (target removed) and black shows beam on target.

The collaboration has completed the synchronization of the data from each detector and has set up a computational scheme to read in synchronized data for combined analysis. The calibration of CHIMERA has been successful. As of the date of this report, we are continuing to calibrate the remaining detectors this summer and hope to begin data analysis later this fall.

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