THE FAZIA DETECTOR AS A POWERFUL TOOL TO INVESTIGATE ISOSPIN DYNAMICS AROUND 40 MeV/u*

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The FAZIA (Forward A and Z Identification Array) is a charge- and mass-sensitive charged particle detector used mainly to investigate the evolution of isospin (N/Z) effects in heavy-ion collisions for excited quasi-projectiles (QP) formed in semi-peripheral collisions at Fermi energies. In the following text, there is a general discussion about FAZIA and plans for analysis and comparison of the data from ^{48}Ca + ^{27}Al at 40 MeV/u system from the recent FAZIA experiment performed at LNS (Catania) in February 2018 with the first assembled 6 FAZIA blocks.

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1. Introduction

Heavy-ion collisions offer unique possibilities to probe nuclear properties far from the ground state. The isospin flow during heavy-ion collisions is a subject of current investigation due to its link with the nuclear symmetry energy, $E_{\rm sym}$, whose behaviour is not fully known except at stable and ground-state conditions. More specifically, at incident energies around 20 to 100 MeV/u, it is possible to investigate the asymmetric nuclear matter with respect to its thermal and mechanical states. This has also a very high importance in the astrophysical context such as the formation of proto-neutron stars, *etc.*

The FAZIA [1] program is currently aimed at performing experiments using the new developed charge- and mass-sensitive charged particle detector for investigating the evolution of isospin (N/Z) effects in heavy-ion collisions for excited quasi-projectiles (QP) formed in semi-peripheral collisions at Fermi energies. Various observables (for *e.g.* isobaric ratios, mass fragment distributions, N/Z ratio of fragments, *etc.*) are measured from the data

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and used for tight model comparisons. The experiments are based on the excellent isotopic resolution of the FAZIA detector telescopes, permitted by the combined use of the ΔE–E and PSA (Pulse Shape Analysis) techniques along with fast digital electronics [2].

The need for powerful detector arrays, such as FAZIA, capable to identify reaction products also in mass, arises from the fact that the Nuclear Equation of State (EOS) is not well-understood far from the ground state. Figure 1 [3] gives an idea of the spread of model predictions about the behaviour of $E_{\rm sym}$ below and above the nuclear saturation density. In the Fermi domain, with FAZIA, we can well explore and gain more stringent information on the region below ρ_0. Although in the last decade (so after the paper of Ref. [3]), there have been various developments on the subject, still experiments with detectors with a large acceptance and high isotopic sensitivity are welcome in the community.

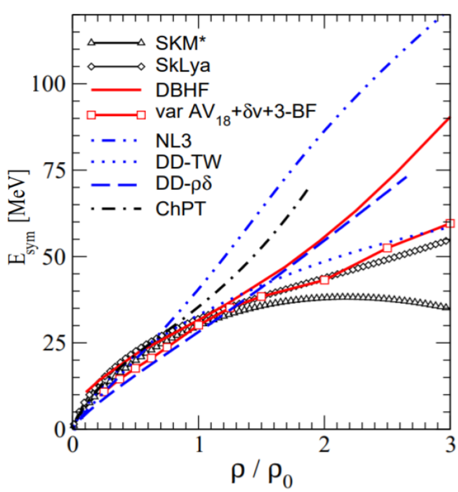

Fig. 1. Symmetry energy as a function of density as predicted by different models.

2. The FAZIA detector

The basic detection element is called a telescope (see sketch in figure 2) which is composed of three layers with active area of 20×20 mm^2: $\mathrm{Si}_1(300\,\mu\mathrm{m})$–$\mathrm{Si}_2(500\,\mu\mathrm{m})$–CsI(Tl) (10 cm). 16 such telescopes are mounted in a 4×4 matrix to make a single FAZIA block (see figure 3). Behind the detection module, there is the block frame which consists of 8 front-end electronic (FEE) cards (1 card per 2 telescopes), three cards for I/O data transfer and block operation (including PS and pulser generation), and the cooling plate because the block operates under vacuum.

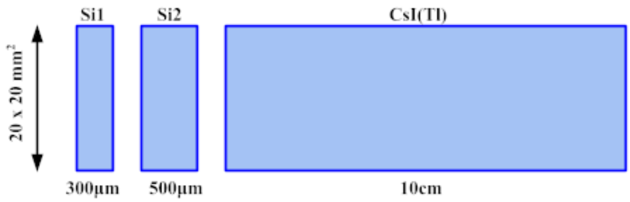

Fig. 2. Single detector telescope (Si-Si-CsI).

Fig. 3. Single FAZIA block.

3. The experiment

The last experiment performed in spring 2018 at the Laboratori Nazionali del Sud (INFN), Catania was done with 6 blocks of FAZIA like in an arrangement shown in figure 4. ^{40,48}Ca beams were impinging on thin ^{12}C, ^{40}Ca and ^{27}Al targets at 25 and 40 MeV/u. The main objective of the experiment was to understand the role of the possible larger fast (early) neutron emissions with increasing energies on the further isospin dynamics which occurs during the interaction phase. This study involves the investigation of the evolution of isospin effects in excited quasi-projectiles (QP) from semi-peripheral collisions comparing two bombarding energies (25 and 40 MeV/u) and data from systems with different initial neutron abundance.

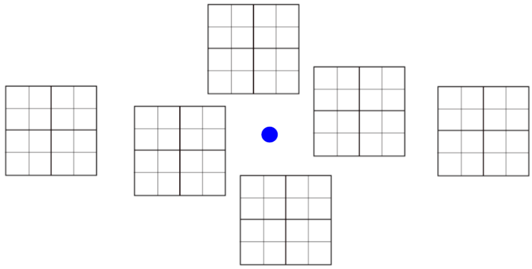

Fig. 4. 6 FAZIA block experimental setup.

4. Prospective analysis

Focusing on the specific system, ^{48}Ca + ^{27}Al at 40 MeV/u, the analysis will be done based on observables (energies, velocities, multiplicities, *etc.*) of fragments identified in Z and A. The particle identification and the data reconstruction will be performed using PSA and ΔE–E techniques for Si_1 and Si_2 detectors and Fast–Slow method for CsI crystals. The results can

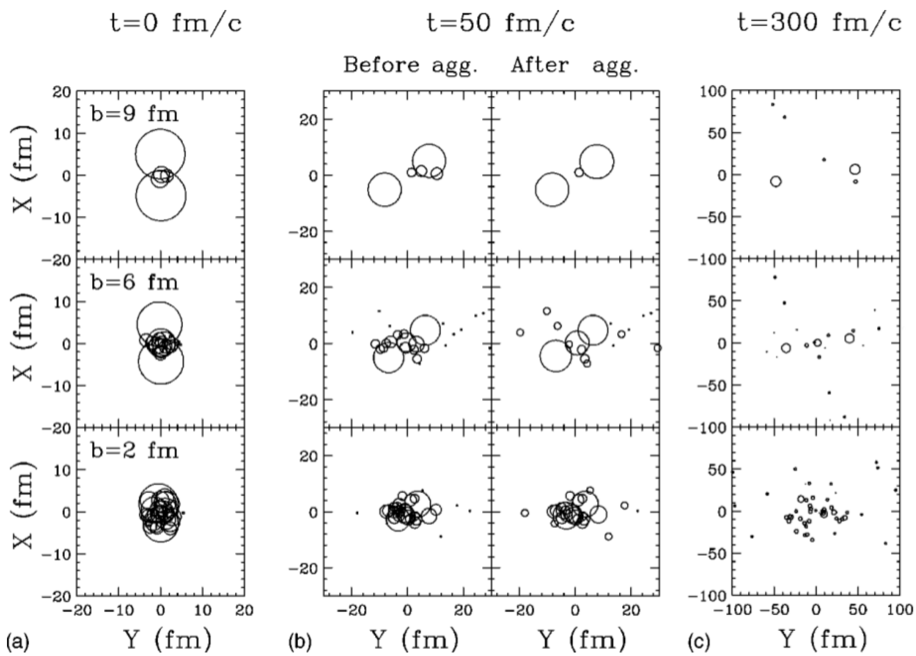

Fig. 5. Nuclear dynamics of a reaction simulated by HIPSE. From left to right figures correspond to the initial cluster configuration (a), the configuration before and after the re-aggregation (b), and during the de-excitation (c). Adapted from Ref. [4].

be later compared to the behaviour of other systems, for example, ^{48}Ca + ^{12}C at 40 MeV/u (comparison with respect to target) and ^{48}Ca + ^{27}Al at 25 MeV/u (comparison with respect to beam energy).

As for theoretical model calculations to be compared with the experimental data, HIPSE (Heavy-Ion Phase-Space Exploration) [4] will be used. HIPSE is basically an event generator for the description of nuclear collisions at an intermediate energy range. It can easily perform heavy-ion interaction simulations in the whole impact parameter range and thus it is a valuable tool for the description of the main reaction processes in peripheral and/or central collisions. It can simulate the whole reaction dynamics from initial phase, where the projectile approaches the target up to the final phase also called the after-burner phase (the decay of the initially formed excited species), as shown in Fig. 5.

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