HOTCT1

Study of reaction mechanisms induced by heavy ions at intermediate energies with the multidetector ARGOS.

Experiments performed at:

Laboratorio Nazionale del Sud (LNS) Catania, Italy

GANIL (Caen), France

^{40}Ar (44, 77 A.MeV), ^{36}Ar (95 A.MeV), ^{208}Pb (29 A.MeV) delivered at GANIL
^{58}Ni (45 A.MeV) delivered at LNS (Catania)
beam intensity: ≤ 1 nA, beam time resolution ≤ 1ns

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Physicists: Total of 13 researchers (8 from Italy)
INFN spokeperson: G. Lanzanò (e-mail: *lanzano@ct.infn.it*)

Research aims:

Nuclear fragmentation studies:

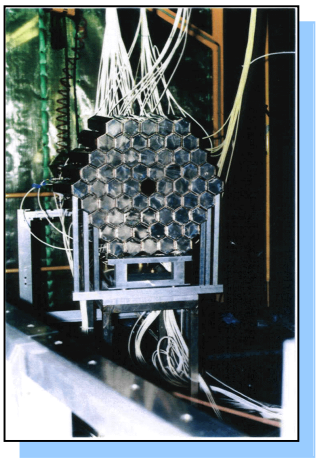
- ✓ Particle emission source identification.
- ✓ Isotopic distributions for projectile-like fragments.
- ✓ Sources temperature and excitation energy determination: caloric curve.
- ✓ Light charged particle and neutrons properties.
- ✓ Midrapidity source particle emission.
- ✓ Fermion interferometry, particle correlation functions.

Interdisciplinary topics:

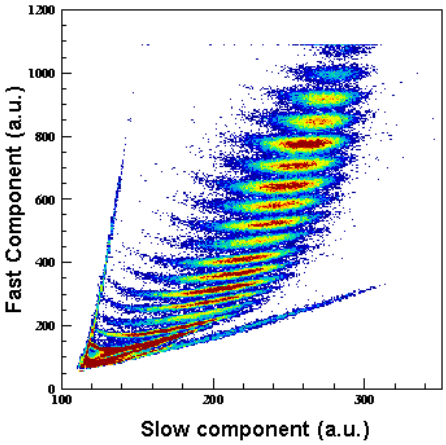
- ✓ Fast electron production induced by swift heavy ions.
- ✓ Binary encounter electrons and "*Fermi shuttle*" effect.

THE ARGOS MULTIDETECTOR

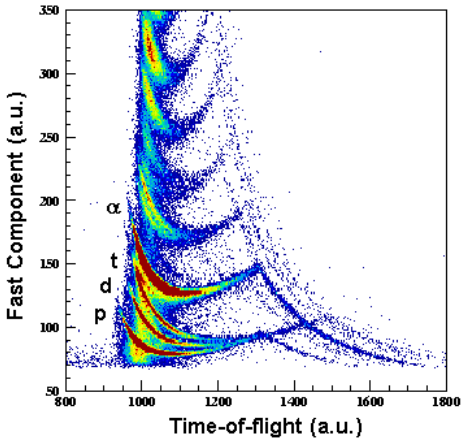
The multidetector consists of about 100 elements. Each element is a hexagonal shape BaF_2 crystal, 5 or 10 cm thick, with a cross-section of 25 cm^2, that may be modified in a phoswich just putting in front of the crystal a foil of plastic scintillator. In detecting a particle, the PM signal is charge integrated by two different gates, 40 and 300 ns wide respectively. These fast and slow components together with the time-of-flight information allow charge-identification for all detected particles, Z<30, and mass identification for light charged particles and light ions.



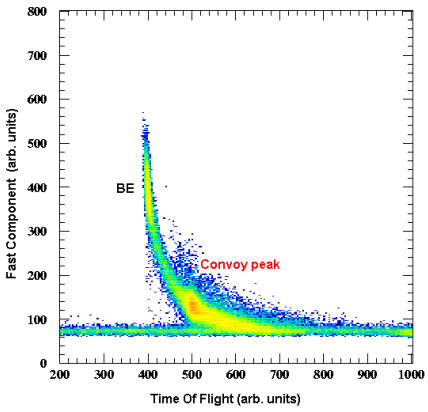
Due to the fast light response, timing characteristics of the detector are excellent, and time resolution (at the GANIL laboratory) as low as 300 psec have been obtained, comprehensive of the beam burst width. Therefore the neutron detection is also possible, with a measured efficiency between 5% and 20%, depending on the crystal thickness, neutron energy and electronic threshold. The elements can be assembled in different ways. In a typical geometry, the ARGOS detectors are distributed 60 in a forward and 18 in a backward walls, both honeycomb shaped and the other distributed at different angles along the horizontal plane.



A typical fast-slow component bidimensional plot to charge identify the nuclear products for the reaction ^{40}Ar (77 A.MeV) + ^{27}Al.



Fast component vs. Time-of-flight plot for the same reaction. Notice the Z=1 isotopic identification (p,d,t) in the lower part of the plot.

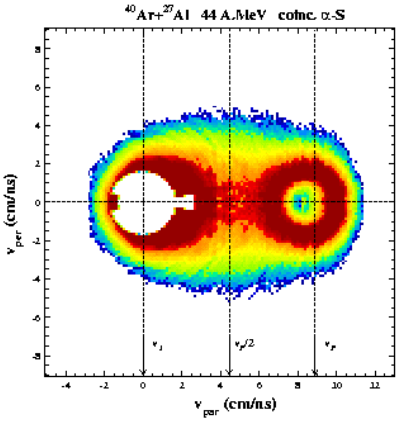


A typical Fast-Time plot for the detection of fast electrons. Note the convoy (v_e~v_{beam}) and the binary encounter BE (v_e~$2v_{beam}$) peaks. The reaction is ^{36}Ar (95 A.MeV) + Au.

The ARGOS multidetector presents a great versatility: from the mechanical point of view it can be assembled very easily in various geometrical ways depending from the experimental requirements. From the detection point of view it can, for example, be transformed in a powerful device to detect **electrons** by simple increasing the single module high voltage power.

Some significative Results:

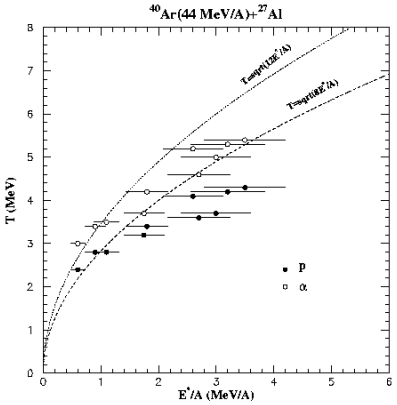
NUCLEAR FRAGMENTATION STUDIES



Lorentz invariant cross section for α particles in coincidence with a Z=16 projectile-like fragment. Two main sources of particles are clearly visible. However particles with velocity intermediate between the two are also present.

The study of coincidences between light charged particles and projectile-like fragment in projectile fragmentation at intermediate energies permits to have a comprehensive insight of the reaction scenario. In the study of the reaction ^{40}Ar + ^{27}Al at 44 A.MeV we have used a three sources analysis method that is very powerful in determining the fraction of particle that can be hardly associated with a source having the projectile or the target velocity.

Our main conclusion is that the collision gives origin primarily to a highly perturbated and high temperature zone of nuclear matter, from which particles or clusters of intermediate velocity escape. The presence of dynamical non-equilibrated processes in the overlap zone of the interacting nuclei prevents the formation of very highly excited nuclei (remnants of the projectile and target nuclei) in the exit channel at these intermediate energies.
(***published in Nucl. Phys. A683, 566, 2001***)



PLF "caloric curve" for the above reaction. The excitation energies are obtained by a calorimetric method and temperatures for protons and alpha particles from a three source fit performed simultaneously over an angle distribution from 1.5 to 172 degrees. Note that the extracted temperatures depend from the particle nature. The vicinity in phase space of the intermediate source could be the origin of this dependence.

FAST ELECTRON PRODUCTION INDUCED BY SWIFT HEAVY IONS.

Electron velocity spectra in the forward beam direction: two main components are observed:

- Binary encounterer electrons: due to a collision between the incident ion and an atomic electron. It produces electrons with almost twice the projectile velocity.
- Convoy electrons: they travel with a velocity close to that of the projectile.

An intriguing new result is the observation (with heavy target as Gold) of very fast electrons in the tail of the spectra that could be due to multiple collision sequences, also referred to "Fermi shuttle" mechanism (Phys. Rev. Lett. 83, 4518 (1999), Phys. Rev. A63, 032702, (2001).

Electron production has been studied in reactions induced by ^{40}Ar (77 A.MeV), ^{58}Ni (45 A.MeV) and more recently ^{36}Ar (95 A.MeV) and ^{208}Pb (29 A.MeV) beams.