The Joint Institute for Nuclear Astrophysics

Heavy Ion Detectors for Time of Flight Mass Measurements.

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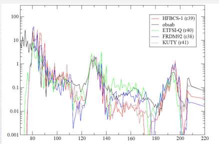
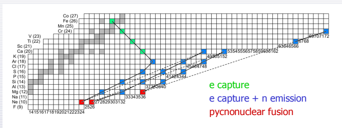
Astrophysical Motivation

Masses of very neutron rich isotopes are critical inputs for calculations of the r-process, and the nuclear processes in the crust of accreting neutron stars [1]. During most of the r-process an (n,γ)-(γ,n) equilibrium is reached, in which the abundance on each isotopic chain depends exponentially on neutron separation energies (Saha equation). In the crust of an accreting neutron star electron captures and pycnonuclear fusion will occur in a non-equilibrium way as matter is pushed into the star. Nuclear masses determine the depth where each reaction becomes energetically possible, thus affecting the observed signatures of the process (see poster by Sanjib Gupta).



Effect of different mass models on the classical r-process calculations [2]



Nuclear processes in the crust of an accreting neutron stars as described in reference [1].

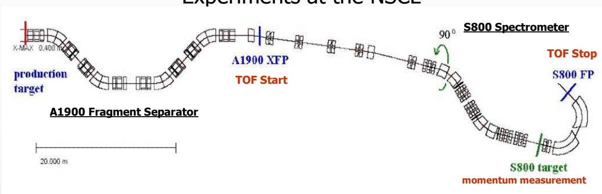
Time of Flight (TOF) Mass Measurements

- Mass derived from the measurement of the magnetic rigidity (Bρ) , and velocity of the beam particles:

$$B\rho = \frac{\gamma m}{q}\left(\frac{dx}{dt}\right)$$

- Fast fragment ion beams allow for the simultaneous measurement of several isotopes.
- Masses of very short lived isotopes (half life ~1 μs) can be measured.
- A mass precision of 200 keV can be achieved for the region of A ~ 100. This is a significant improvement compared with the predictions of mass models currently used for astrophysical calculations.

Experiments at the NSCL



- typical time of flight (TOF) ~ 500 ns.
- Path length = 58 m.
- Momentum dispersion at S800 target (dispersion matched optics) = 11 cm/%.

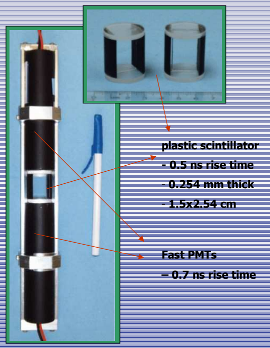
For this parameters of the experimental set up, a detector resolution of 1:10,000 is required to obtain the desired mass precision:

- time: ~50 ps.
- position: 1.0 mm at S800 target

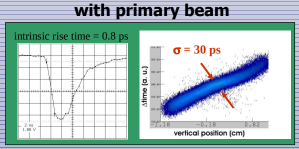
- Experiment 01035, in the region of ^{66}Fe, was completed in February 2006 (see poster by Milan Matos).

Timing Plastic Scintillator Detectors

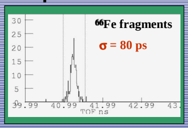
The timing detector is composed of a fast plastic scintillator attached to two fast photomultiplier tubes, which provide a short rise time signal. The small scintillator piece is designed to reduce the spread in the light collection time, as well as the energy and angular straggling of the beam.



Performance on Test Run with primary beam

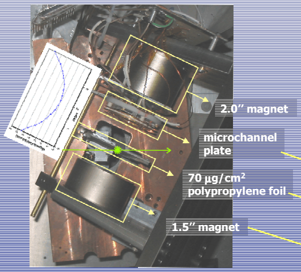


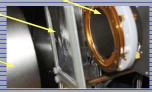
Performance on experiment 01035



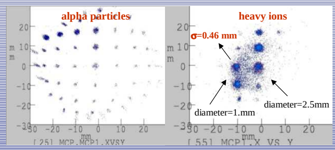
Tracking Detector for Heavy Ions

Microchannel plate (MCP) detectors [3] rely on detecting secondary electrons emitted from a thin foil on the path of the beam. To obtain 1 mm resolution with fast fragment beams, a strong magnetic field is applied to guide the energetic electrons from the foil surface to the microchannel plates. A thin gold coated polypropylene foil is used in order to minimize the beam straggling.





Mask Calibration



References: [1] P. Haensel and J.L. Zdunik, Astron. Astrophys. 229, 117 (1990)
[2] K.-L. Kratz et al., Ap. J. 403, 216 (1993)
[3] D. Shapira, et. al., NIM A 454, 409 (2000).

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