Charged Particle detectors for LEB-NUSTAR

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Introduction

In the scope of future slowed down beam campaign of low energy branch (LEB) in NUSTAR, major developments have been initiated for a charged particle detector setup for the slowed down beam studies. The detection system will consist of beam tracking detectors preceding the secondary target and a particle identification system for identifying the beam/secondary reaction products. The high energy beam from SFRS [1] (Super Fragment Separator) will be slowed down in a thick Al degrader to Coulomb energies. The resultant beam, which is poor in quality in terms of energy spread (3 MeV/u to 10 MeV/u) [2], angular spread and and spot size (~ 5 cm FWHM) will be utilized to perform multistep Coulomb excitation. Fig. 1 shows the extracted energy distribution (from TOF measurement) of the ^{64}Ni ions, after the degrader, slowed down from 250 MeV/u to 13 MeV/u.

The detection system has to meet following requirements: (i) event-by-event beam tracking capabilities to characterize the beam. (ii) Energy (*E*), nuclear charge (*Z*) and mass (*A*) identification of the reaction products. (iii) large solid angle coverage (~4π) to compensate for low intensities of secondary beam. (iv) high segmentation to achieve good angular resolution.

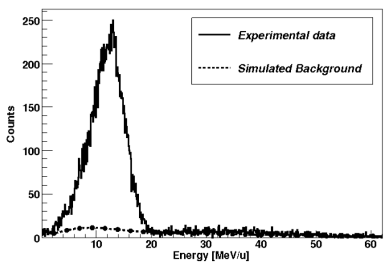

Fig. 1: Energy distribution of ^{64}Ni ions after slowing down in Al degrader [2].

Detector System

The beam tracking detectors will determine trajectory, mass and energy of all species using position information and time of flight (TOF) technique. This can be achieved by employing thin transmission type, position sensitive fast timing detectors at suitable positions. TOF will provide energy and mass information of beam species. This will help in reconstructing the kinematics of the secondary reaction products. It is desirable to have detectors which can provide timing resolutions ⩽100 ps, position resolution ~1 mm, have count rate handling capabilities ⩾10^6 pps with the highest transmission possible. TOF systems based on micro-channel plates (MCP) are the best solution. Requirements for the identification of reaction products can be fulfilled by employing detector telescopes using ΔE-E and TOF technique. Double sided silicon strip detectors (DSSD) based telescopes are ideal for such experiments as they provide good energy (∼100 keV), timing (~100 ps) and position (~1 mm) resolution. MCP detectors [3] are based on secondary emission of electrons knocked out by the detected particle from the conversion foil. An accelerating grid along with electrostatic mirror directs these secondary electrons into a Chevron MCP assembly. Position information is extracted using dual delay line anode. Three MCP detectors were tested : two rectangular with active area 60 x 40 mm^2, and a third (circular) with active diameter 150 mm. Single sided silicon strip detector (SSSD) and DSSD (design W from Micron Semiconductors, UK) with thickness of 20 µm and 40 µm, respectively and with active area of 50 x 50 mm^2 were used. The detectors are segmented in 16 strips. The detectors were thoroughly tested with radioactive alpha sources and in-beam measurements.

Measurements

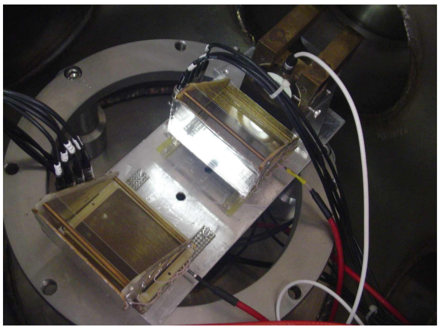

Fig. 2: Picture of MCP TOF system

Fig. 2 shows the picture of the setup with the rectangular MCP detectors. Their timing characteristics were evaluated by setting a TOF between them backed by a silicon detector for energy measurement. The flight path was set at 12 cm. The system was exposed to ^{229}Th α emitter.

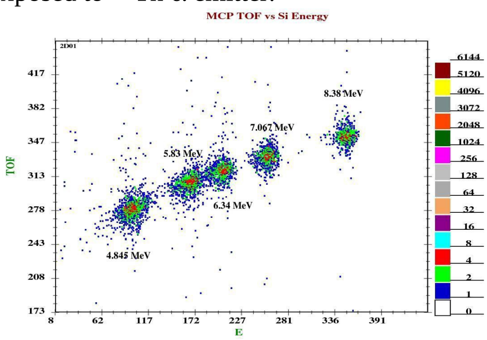

Fig. 3: Plot of TOF vs Si energy.

Fig. 3 shows the plot between TOF and energy from Silicon detector. A timing resolution of ~230 ps was observed for the 8.38 MeV transition. Assuming identical MCP, resolution of one MCP is estimated to be 160 ps. Further corrections are required to account for straggling in the foils (~ 250 μg/cm^2) acting as secondary electron emitter.

In order to evaluate timing performance of SSSD and DSSD, a 16 channel timing amplifier was designed and fabricated. The amplifier was connected to the front strips of SSSD/DSSD. Back strip/strips provided energy information through Mesytec charge sensitive preamplifier-amplifier combination. TOF was deduced between MCP (start) and DSSD (stop). A pixel resolution of 800 ps was observed for 5.48 MeV α for the 40 μm thick DSSD.

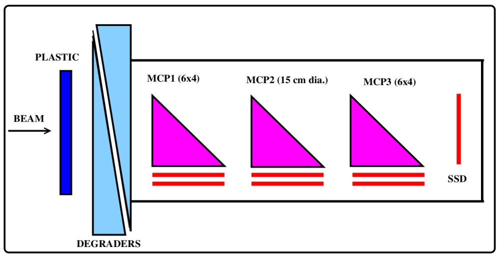

Fig. 4: Layout of detector system in CAVE'C'

The characterization of the detector system under realistic conditions was determined by performing test experiment at GSI in Cave C. Fig. 4 shows the schematic layout of the detector system. ^{124}Xe beam (10^5 pps) was accelerated to approximately 200 MeV/u using UNILAC and SIS18 synchrotron, and slowed down by the wedge shaped Al degrader. The fast timing plastic scintillator, at the entrance, provided reference timing for the all timing measurements. The test measurements were performed in two phases. In first phase a 300 μm thick Si detector (behind last MCP) was used to characterize the degrader. The thickness of the degrader is adjusted so as to have ~ 10 MeV/u Xe on the Si detector. Si detector is calibrated from TOF data of MCPs with respect to plastic. In the second phase, 20 μm thick SSSD was installed behind last MCP. All timing signals were fed to Phillips 715 and Ortec 935 CFD followed by VME based TDC. Position signals from MCP give the beam profile. Data is currently being analyzed to extract timing resolutions of MCPs and SSSD, and to study the characteristics of the beam in terms of energy spread, size, contamination etc. after degrader. Results will be discussed during the conference.

Future Perspective

In future, we plan to perform more measurements to study particle identification capabilities of SSD by performing secondary reaction after slowing down. Since secondary beam size from SFRS will be large, future measurements require large area (100 x 100 mm^2) beam tracking detectors.

References :

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[3] E. M. Kozulin et al., Exp. Tech. 51(2008)44