A hybrid detector telescope for the detection of light charged particles along the direction of fission fragment

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Introduction

Understanding the fission dynamics has been a subject of continued research interest, and in this context, the measurement of light charged particle (LCP) multiplicities in coincidence with fission fragments (FFs) during the fusion-fission process is a very useful probe [1]. In this type of measurement, the LCPs are intended to be measured in a wide range of relative angles from 0° to 180° with respect to the FF direction. The conventional method of using two separate detectors one for the FFs and another for the LCPs is not feasible to detect the LCPs along the direction of FF (in particular, θ_{rel} <20°).

The ΔE-E combination of gas-ionization-chamber [2] and large area thick CsI((Tl)-detector offers an excellent option for a versatile detector telescope which can be used for the simultaneous detection of a wide range of charged particles from Z=1 to the fission fragments (FFs). We have developed a hybrid detector telescope (HDT) consisting of trapezoidal shaped gas ionization chamber with anode plate segmented into two parts (ΔE_{gas} and E_{gas}) and two CsI(Tl)-Si(PIN) detectors mounted at the end of the gas-section. In this paper, we present the results of in-beam usage of the HDT. The potential advantages of the HDT for specific nuclear physics investigations are also demonstrated.

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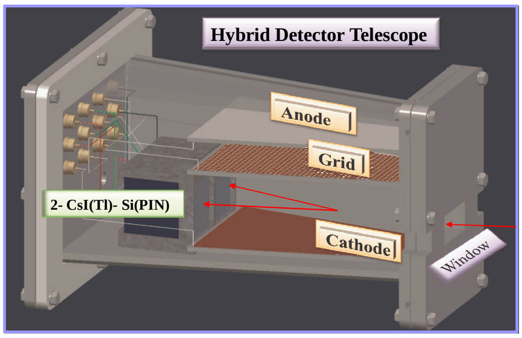

FIG. 1: Schematic diagram of the Hybrid Detector Telescope assembly.

Description of the Hybrid Detector Telescope

The gas-section of the Hybrid Detector Telescope (HDT) is of trapezoidal shaped parallel plate geometry. Main body of the detector is made of stainless steel, with a suitable mount to accommodate two CsI(Tl)-Si(PIN) detectors at the end of the gas-section. Fig.1 shows the schematic diagram of the HDT, consisting of three plates (cathode, a Frisch grid, and an anode) and two CsI(Tl)-Si(PIN) detectors. The anode plate is segmented into two trapezoidal parts; (i) the initial one of length 40 mm acting as ΔE_{gas} and (ii) the rear end of the length 60 mm acting as the E_{gas}. The separation between the cathode and grid was kept of 35 mm and the grid to anode of 15 mm. The active area of the window is (13.1 mm × 25.3 mm), which enables an angular coverage of 18.4° for the detector distance of 8.4 cm from the target. Each CsI(Tl) detector makes an angle of 3.5° with respect to the central point of entrance window, enabling thus to measure the LCPs having relative angles of less than 3.5° with respect to the FFs detected by the ionization chamber. The V-I characteristics of the ionization chamber were obtained for the FFs produced from ^{252}Cf source having two different mass and charge groups. The CsI(Tl)-Si(PIN) detector as individual has been characterized in detail in our earlier work [3].

In-beam use of the HDT

The HDT was employed to measure α particle yields in coincidence with FFs along the FF direction in ^{12,13}C + ^{232}Th reactions at different beam energies. The HDT was mounted in a 1-m dia scattering chamber at a distance of 8.4 cm from the target, subtending a solid angle of 55 msr. The telescope was placed in the reaction plane at 150° with respect to the beam direction. The gas pressure was maintained at fixed value of 150 ± 5 mbar throughout the experiment so that FFs are completely stopped in the ionization chamber and only LCPs along with the PLFs reach to the CsI(Tl) detectors. Applied bias voltages to the cathode, grid and anode were -100V, +125 V and +350V, respectively. The event trigger for data collection was generated from the ionization chamber signals.

The FFs are clearly separated from the PLFs by plotting partial energy loss in the ΔE_{gas} versus the energy loss in the E_{gas} as shown in Fig. 2(a) for ^{13}C(74 MeV) + ^{232}Th reaction. The inset in the Fig. 2(a) shows the X-projection of FF-group. Gain matching of the spectroscopic amplifiers corresponding to the ΔE_{gas} and E_{gas} was carried out using a pulse generator. If we plot the summed pulse heights of ΔE_{gas} and E_{gas} as a function of energy deposited in the CsI(Tl) detectors, the jumbled group of PLFs in the Fig. 2(a) is clearly separated into different parabolic bands of corresponding Z-values, as depicted in Fig. 2(b). The LCPs (mainly proton and α particles) are detected by the CsI(Tl)-Si(PIN) detectors and identified by employing the pulse shape discrimination (zero cross over) technique. Thus, using this hybrid telescope we are able to simultaneously separate the beam like particles, fission fragments and the LCPs. The α-particle multiplicity spectra in coincidence with FFs were obtained. Results in detail will be presented.

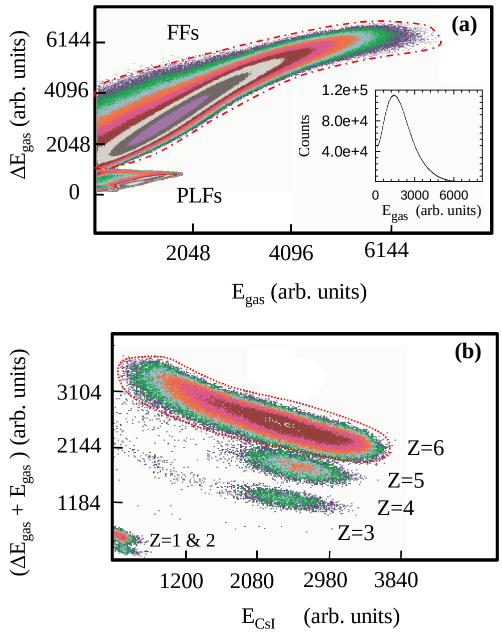

FIG. 2: (a) Two-dimensional plots obtained in the ^{13}C(74 MeV) +232Th reaction. (a) Partial energy losses in the ΔE_{gas} versus the E_{gas}. The inset in panel (a) is the X-projection of FF-group. (b) Summed pulse heights from ΔE_{gas} and E_{gas} as a function of energy deposited in one of the CsI(Tl)-Si(PIN) detectors.

Acknowledgments

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References

[1] Y. K. Gupta et al., Phy. Rev. **C 84**, 031603(R)(2011).
[2] D. C. Biswas et al., Nucl. Instrum. Meth. **A 340**, 551 (1994).
[3] Y. K. Gupta et al., Nucl. Instrum. Meth. **A 629**, 149(2011).