TEGIC: Concept and design parameters of a detector for beam species identification at FAIR-NUSTAR

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Introduction

We report the concept, design and developmental status of a Tilted Electrode Gas Ionization Chamber (TEGIC). This heavy ion detector is being developed as a beam diagnostic device for the identification of secondary beam species in the framework of FAIR-NUSTAR collaboration. The upcoming facility will have significantly increased secondary beam intensities with cocktail nature, and thus it is required to have faster detectors for identification of these species. The detector will provide high rate particle identification ($3 \leqslant Z \leqslant 92$) for high energy heavy ions (~100-500 MeV/A), and is expected to be operated at intensities of 10^6 pps. Nuclear charge (Z) identification will be realized using the standard technique of multiple differential energy loss measurements or ΔE-ΔE technique. The detector is proposed to be commissioned, in last quarter of 2018, at the exit of FRS for initial phase of NUSTAR campaigns from 2018-2022. The detector will be assembled and tested at IUAC, New Delhi before being shipped to GSI, Darmstadt.

Description

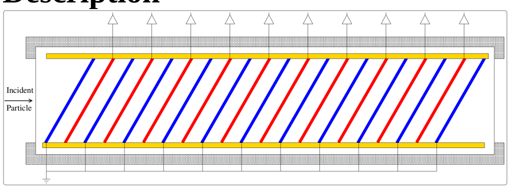

Fig.1: Cross-sectional view of TEGIC with electrode assembly

Fig.1 shows the schematic diagram of the TEGIC. The design is inspired from the earlier developed detector by Kimura et al., [1] with a tilted electrode geometry in axial field mode. The electrode planes are tilted 30° toward the center axis and the inter-electrode gap is 2 cm. The stacked electrodes with smaller inter-electrode gaps will provide faster charge collection. Conventional gas ionization chambers have a transverse field geometry with 3 electrodes: anode, frisch grid and cathode. Charge collection times in such a design are large, restricting the count rates to < 10^5 pps.

The active area of the detector is 20 x 8 cm^2 and the active depth is 40 cm. There are total of 21 electrodes: 10 anodes and 11 cathodes. As shown in the fig.1, the electrodes are stacked in such a fashion so as to have anode sandwiched between two cathodes and vice-versa. In other words anode and cathode are positioned alternately. This gives rise to 10 sets of cathode-anode-cathode ionization regions. All the electrodes will be made out of mylar foils stretched on a 3.2 mm thick FR4 printed circuit board frame. Mylar foils, 3 μm thick, are aluminized on both sides. First and last electrodes are cathodes.

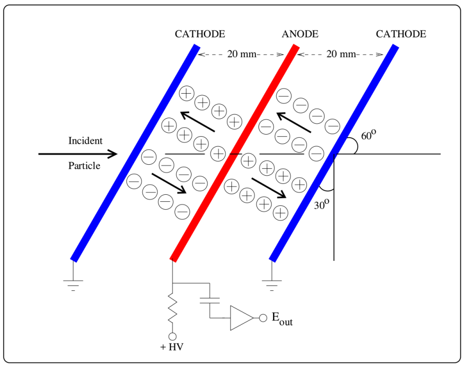

Fig.2: Schematic diagram illustrating TEGIC electrode configuration and movement of charge carriers.

Fig. 2 illustrates the operating principle of TEGIC along with the movement of charge carriers. When an ion passes through the active volume, it ionizes the detector gas liberating electrons and positive ions along the particle trajectory. They drift towards the respective electrodes under the influence of applied electric field. By tilting the electrodes, the liberated electrons and positive ions drift away from the original particle trajectories in opposite directions of each other. Chance of collision with each other and recombination probability is reduced to a large extent in such a case. Cathodes will be grounded, and positive potential at a reduced field of 0.5 - 1 V cm^{-1} $mbar^{-1}$ will be applied on the anodes.

The entire electrode assembly will be mounted inside an aluminum cuboid chamber. Fig.3 shows the isometric view of the electrode assembly. The electrodes are supported by frames on both sides which provides strength as well as the requisite gaps and angle at which the electrodes are tilted *w.r.t.* normal to the beam axis.

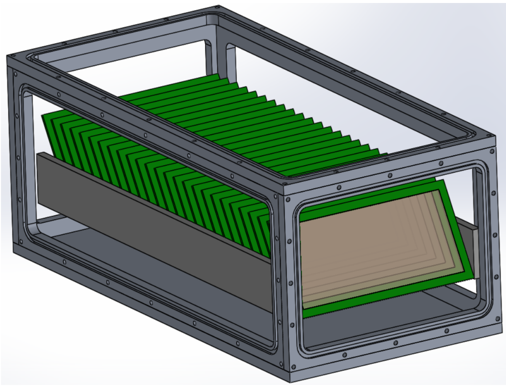

Fig.3: Isometric view of the CAD assembly of TEGIC chamber with electrodes.

As a standard practice, iso-butane gas is used in gas ionization chambers. It is proposed to use tetrafluoromethane or CF_4 as the counting gas for the TEGIC detector. The electron drift velocities for this gas is about 10 cm/µs for a modest field of 1 V cm^{-1} $mbar^{-1}$. This is twice as compared to iso-butane. At the same time mobility of positive ions (gas molecules) is also two times for CF_4 gas. These features will enhance the count rate handling capability of TEGIC detector. On the other hand, iso-butane requires 2.5 times less energy to create an electron-ion pair thus generating more charge. The stopping power of CF_4 gas is higher, since it has a density which is 1.6 times higher than iso-butane. Gas mixtures such as {90%Ar + 10%CF_4} and {90%Ar + 10%CH_4/CO_2} are the other possibilities being explored.

Signal processing

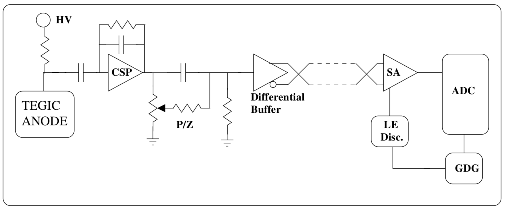

Fig.4: Signal processing scheme for TEGIC

Fig.4 shows the signal processing scheme for the TEGIC detector. Each anode signal will be processed by a charge sensitive preamplifier (CSPA). Custom designed CSPA units [2] are being developed which will be integrated with the anode inside the detector chamber. Each unit will process charge generated by 4 cm of active length. This quantity will be ion species (Li to U) dependent. Energy loss will vary from few 100 keV (for Li type) to ~ 300 MeV (for U region). It is planned to develop CSPA units with 3 different gains so as to avoid saturation (dynamic range ~ 1V) during detector operation. The CF_4 gas equivalent gains will be 1, 2 and 5 mV/MeV. Ten units for each gain are currently under development. These units will be developed as hybrids.

The differential output from CSPA will then be fed to Mesytec spectroscopy amplifier (SA) unit for the initial test runs. This will be replaced by waveform digitizers in future, which can handle higher count rates, and corrections for pile-up can be performed in the software using suitable algorithms,. It is proposed to perform test measurements in S4 experimental area (at the exit of FRS) using beams from UNILAC-SIS18 combination in the near future. For performance evaluation, a smaller detector has also been designed for performing test measurements with Pelletron-LINAC accelerator system at IUAC. In this case the electrodes will be prepared using wire frames (replacing mylar foils) for efficient detection of low energy heavy ions. Detailed description about the detector assembly and utilization will be presented.

References :

[1] Kimura et al., Nucl. Instr. and Meth. in Phys. Res. A 538 (2005) 608.

[2] A. Jhingan, Pramana J. Phys., Vol. 85, 2015, 483-495 .