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# First *in-beam characterization* of the new MAGNEX gas tracker

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**Summary.** — The MAGNEX gas tracker prototype underwent its first *in-beam* characterization at the 8UD Pelletron facility at the University of São Paulo (Brazil). Studies on the charge distribution width were conducted to understand the detector response as a function of the ion and rate; single-track analysis, resolution studies, and simulation of the charge distribution are also in progress.

## 1. – Introduction

An intense R&D activity is currently being carried out by the international NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) collaboration with the aim of upgrading the MAGNEX facility installed at INFN-LNS in Catania. The collaboration is trying to provide data-driven information on Nuclear Matrix Elements (NMEs) of neutrinoless double beta ($0\nu\beta\beta$) decay by studying Heavy-Ion induced Double Charge Exchange (HI-DCE) reactions [1, 2]. The new detection system has to withstand up to MHz

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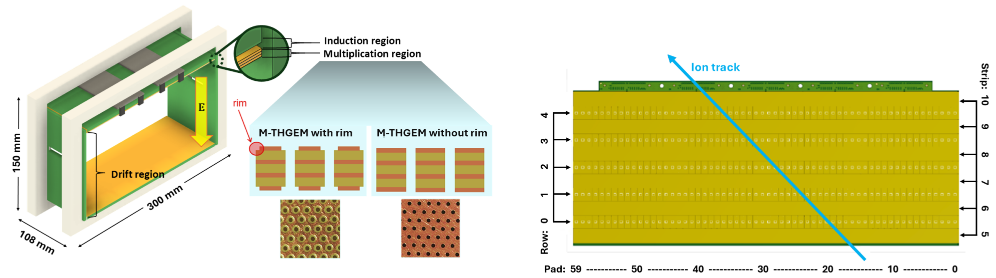
of ions and be sufficiently radiation-hard preserving the previous detection performances (mass $\Delta A/A = 1/300$ [3], angles $\Delta\theta = 0.3°$ (FWHM) and energy $\Delta E/E = 1/1000$ resolution) [4, 5]. After an important phase of stand alone characterization with radioactive $\alpha$-sources carried out at INFN-LNS, the gas tracker prototype underwent its first *in-beam* characterization during the IRRAD4 experiment at the 8UD Pelletron facility at the University of São Paulo (Brazil) [6]. The tests aimed to characterize the position and angle resolution of the gas tracker, the dependence of the performances on the angle and position of the incident beams, and the detector response to different energies and rates of the beams themselves.

## 2. – The gas tracker prototype

The gas tracker prototype (sketched in Fig. 1.(a)) has an active volume of $300 \times 108 \times 150$ mm$^3$ and is equipped with a Micro Pattern Gas Detector (MPGD), namely M-THGEM, designed to produce an electron avalanche by primary electrons obtained from gas ionization [7, 8]. The volume is filled with isobutane gas 99.95% pure at typical




(a) (b)

Fig. 1. – (a) The gas tracker prototype and M-THGEM(s) tested - Designed with AUTODESK® FUSION360™ - *Educational License* - (b) Picture of the segmented anode.

pressures ranging between 10 and 50 mbar. M-THGEM consists of a densely perforated printed circuit board (PCB) with holes smaller than 1 mm [7, 8]. The electric field **E** is adequately set along the vertical direction of the detector, which is divided into the following regions:

- *drift region:* here the incident ions produce tracks of electron-ion pairs. The drift electric field causes the electrons to drift toward the M-THGEM and the ions toward the cathode;
- *multiplication region:* within the cylindrical holes of the M-THGEM, this region is characterized by a multiplication electric field that is high enough to activate the electron avalanche. Two M-THGEMs have been tested, namely a triple-THGEM with rim and a triple-THGEM without rim (see Fig. 1.(a), the rim being a metal-free clearance ring surrounding the holes;
- *induction region:* between the M-THGEM and a segmented anode here an induction electric field drives the electrons from the M-THGEM to the anode [7, 8]. The anode is segmented into five rows and six strips, the row being pad-segmented strip containing 60 pads of size $5 \times 12$ mm$^2$, numbered from 0 to 59 [6] (see Fig. 1.(b)).

## 3. – The experimental methods and preliminary results

The experimental setup is sketched in Fig. 2. The ion beams $^{7}$Li at 24 MeV, $^{12}$C at

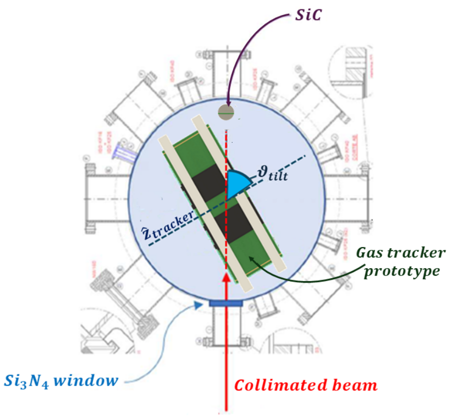



Fig. 2. – Experimental setup of the experiment IRRAD4 at the 8UD Pelletron facility.

45 MeV and $^{16}$O at 64 MeV have been accelerated by the 8UD Pelletron and transported to the chamber via the SAFIIRA beam line, which guaranties low angular divergence and small beam spot size at the detector [9]. Having crossed a silicon nitride ($Si_3N_4$) window, the beam reached the chamber and ionized the gas inside. The gas tracker prototype has been placed in the center of the chamber and rotated at an angle $\vartheta_{tilt}$ with respect to the direction of the collimated beam; downstream, a SiC detector stopped the beam, providing the timing signal for the measurement of the electron drift velocity and thus the vertical position.

Fig. 3 reports the experimental charge distribution widths for a specific angle $\vartheta_{tilt}$ for the runs acquired using M-THGEM with/without RIM. In addition, each panel shows

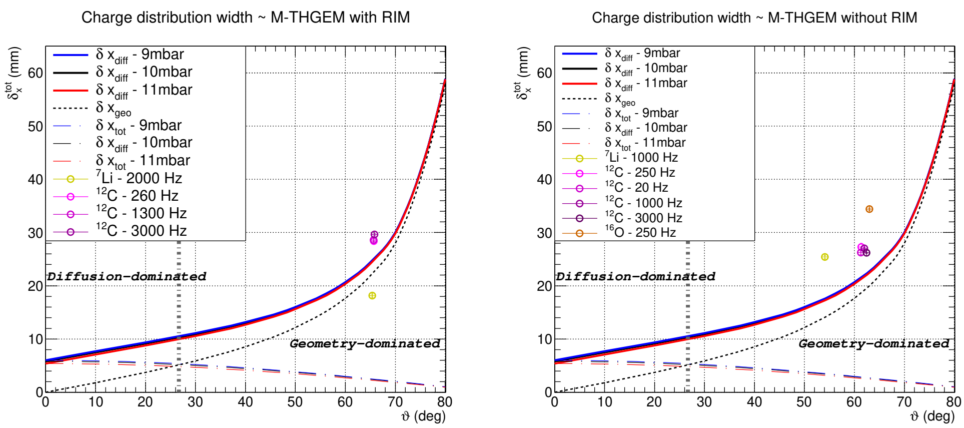



Fig. 3. – Predicted trend and experimental charge distribution widths obtained with ROW 2 of M-THGEM with/without RIM, respectively.

the expected trend in the charge distribution width, taking into account a simplified microscopic model of the charged particle drift and a geometric effect. In particular, the diffusion contribution was obtained projecting the transverse diffusion of electrons in i-$C_4H_{10}$ [10] on the pad plane, whilst the geometric one depends on the pad length and the angle $\vartheta_{tilt}$. This expected trend has been plotted for pressures 9, 10 and 11 mbar to appreciate pressure dependencies that, however, appear to be negligible. The experimental charge distribution widths qualitatively follow the predicted trend in both M-THGEM, ion beams, and rate changes, showing the dominant geometric effect present at high $\vartheta_{tilt}$.

## 4. – Conclusions and perspectives

The first *in-beam* characterization of the MAGNEX gas tracker prototype has been carried out at the 8UD Pelletron facility at the University of São Paulo (Brazil). The detector was irradiated using well collimated ion beams with the aim of characterizing its position and angle resolution, the dependence of the performance on the angle and position of the incident beams, and its response to different energies and rates of the ion beams. The results obtained are encouraging. To improve the quality of the reconstruction algorithm and for subsequent studies on resolution, a single-track analysis is being carried out in comparison with simulations to describe the charge distributions and the readout electronics, as well as the behaviour of the detector in future NUMEN experiments.

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