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Cosmic ray test of mini-drift thick gas electron multiplier chamber for transition radiation detector

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ABSTRACT

A thick gas electron multiplier (THGEM) chamber with an effective readout area of $10 \times 10\ cm^2$ and a 11.3 mm ionization gap has been tested along with two regular gas electron multiplier (GEM) chambers in a cosmic ray test system. The thick ionization gap makes the THGEM chamber a mini-drift chamber. This kind mini-drift THGEM chamber is proposed as part of a transition radiation detector (TRD) for identifying electrons at an Electron Ion Collider (EIC) experiment. Through this cosmic ray test, an efficiency larger than 94% and a spatial resolution $\sim 220\ \mu m$ are achieved for the THGEM chamber at -3.65 kV. Thanks to its outstanding spatial resolution and thick ionization gap, the THGEM chamber shows excellent track reconstruction capability. The gain uniformity and stability of the THGEM chamber are also presented.

1. Introduction

An Electron Ion Collider (EIC) is being considered as the next generation QCD facility to understand how the visible universe is built up [1]. More specifically, the EIC will probe with unprecedented precision the low Bjorken-x domain where gluons and sea quarks dominate for both nucleons and nuclei. A possible realization of the accelerator facility based on the (currently operating) Relativistic Heavy Ion Collider (RHIC), called eRHIC, has been proposed [2]. The Solenoidal Tracker at RHIC (STAR) detector, one of the two major experiments at RHIC, has been planned to evolve into eSTAR with a suite of upgrades optimized for the EIC physics program. The eSTAR detector performance and a broad range of flagship measurements, which have been identified as part of the EIC science case, have been studied through simulation. eSTAR has been found to be well suitable for an initial stage of eRHIC [3]. However, one of the major experimental challenges is to cleanly identify the scattered electron and to provide precise kinematics of the interaction. We have proposed a compact transition radiation detector (TRD) followed by an endcap time-of-flight (eTOF) detector with an additional converter [4]. Fig. 1 illustrates a schematic view of the detector configuration relevant to this proposal. The low-material time projection chamber (TPC) (and a possible inner tracker) in a solenoidal field in front of TRD provides tracking, momentum, dE/dx, and photon rejection. The combination of eTOF and TPC provides electron identification at electron momentum less than a few GeV/c [5]. Furthermore, eTOF provides hadron identification in the case that both hadrons and the scattered electrons strike the eTOF, as well as the collision time reference. The proposed TRD is similar to the ALICE TRD [6], providing dE/dx measurement in addition to the transition radiation (TR) signal and tracklet reconstruction capability, but with a readout stage based on thick gas electron multiplier (THGEM) chamber rather than the multiple wire proportional chamber (MWPC). The operation principle and design of the THGEM based TRD chamber is depicted in Fig. 2. The TRD serves two functions. Firstly, it provides additional dE/dx measurement with a Xe rich gas mixture at the entire momentum range. This is essential for small angle scattering, where only a small section of the particle trajectory falls within the tracking detector acceptance, resulting in few hits in the tracking detector and worse dE/dx resolution ($1/\sqrt{N}$ rule). Through the simulation [4], TRD with 300 μm spatial resolution is enough for tracking due to the thick TRD radiator and material in the TPC endcap. Secondly, it adds necessary TR signal to particles at

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high momentum. The TR threshold is around $\gamma > 1000$–2000. From a practical standpoint, only electrons provide such radiation into the ionization chamber in the TRD, boosting the effective electron dE/dx to even higher values from the existing relativistic rise.

Comparing with the gas electron multiplier (GEM) chamber first introduced in 1996 at CERN [7], the THGEM chamber is one of the most recently developed micropattern gas detectors [8]. The THGEM is a robust, high-gain gaseous electron multiplier, and has a hole-structure similar to the GEM [9]. It is manufactured economically by mechanically drilling sub-millimeter diameter holes in a thin printed-circuit board (PCB), followed by Cu-etching of the holes rim.

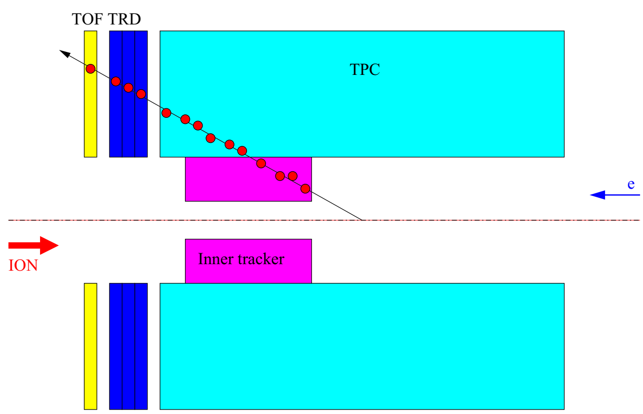

Fig. 1. A schematic view of the detector configuration at eSTAR. The proposed TRD+eTOF is placed between the pole-tip and the low-material tracking detectors.

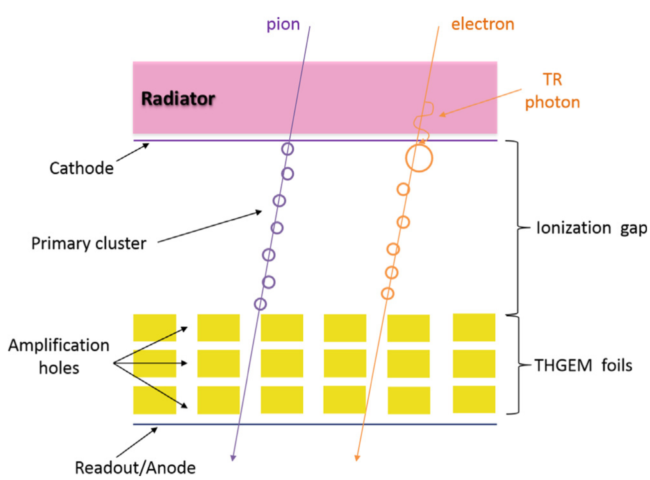

Fig. 2. Schematic of the THGEM based TRD.

Due to lack of Xe in laboratory, we used the Ar mixture instead of Xe mixture as the working gas of the THGEM chamber. Some experiments were carried out for comparing the THGEM or GEM chamber performance in large variety of gases [10–13]. The maximum gain measured with THGEM chamber operating in Xe is similar to that measured with THGEM chamber operating in Ar at atmospheric pressure [10]. Meanwhile, the maximum GEM chamber gains measured in Ar/CO_2 and Xe/CO_2 are comparable at atmospheric pressure [12]. Moreover, the results in [10] show the best energy resolution of the specified THGEM chamber reached in Ar with 5.9 keV X-rays is 30% FWHM while that reached in Xe is 27% FWHM. These previous experiment results illustrate that the results measured with the THGEM chamber operating in Ar mixture are able to provide a valid reference for that operating in Xe mixture.

In this paper, we focus on THGEM chamber's performance in various aspects such as detection efficiency, spatial resolution, gain uniformity and stability, especially the track reconstruction capability. The paper is organized as follows. Section 2 describes the THGEM chamber. The cosmic ray test system setup is presented in Section 3. Section 4 describes the performance of the THGEM chamber. Section 5 provides a concluding summary.

2. The THGEM chamber

The THGEM chamber in this study uses three THGEM foils in cascade. These foils are provided by the Institute of High Energy Physics (IHEP), China. The foil structure is shown in Fig. 3. The major parameters include foil thickness 300 μm, hole diameter 150 μm, and hole pitch 400 μm. The rim clearance region around the hole is ~50 μm. The effective readout area given by the foil is 10×10 cm^2. Fig. 4 depicts the readout board structure of the THGEM chamber.

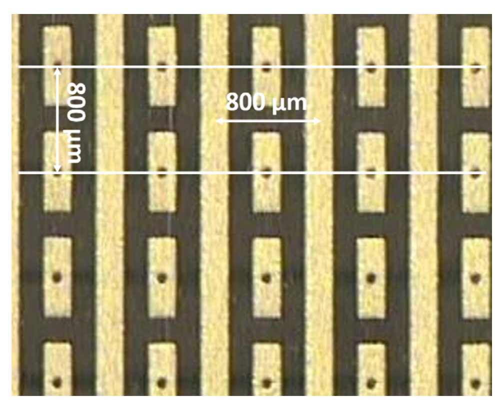

Fig. 4. The readout board structure of the THGEM chamber.

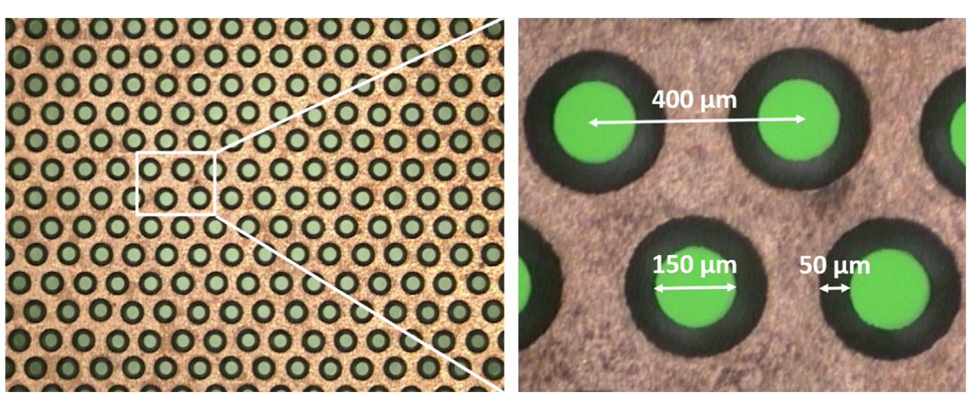

Fig. 3. The structure of the THGEM foil.