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TRICK: A tracking ring imaging CherenKov detector

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ABSTRACT

TRICK is a project funded by the INFN CSN5 Young grant 2020. It will use an innovative 5D technique to provide information about 3D position, time, and ID of the incoming particles. The proposed idea is based on the well-known technology of GEM-based TPC together with conventional Aerogel proximity focussing RICH in a single box. Both parts, TPC and RICH, will be read out simultaneously and instrumented with the same TIGER ASIC developed for the BESIII CGEM-IT detector. By combining information from both systems, the TRICK technique will improve the performance of each instrument: precise time information will help the extraction of the TPC position, while tracking will help the rings identification, by measuring the expected centre, also in a magnetic field. The TRICK-box prototype, instrumented with triple-GEM and Hamamatsu H12700 MA-PMT, aims to achieve a spatial resolution of 100 μm, time resolution below 1 ns, and 3σ separation for π/K up to 4 GeV.

This paper introduces the project and focuses on the initial studies with the prototype, the preparation of the first cosmic stand, and the next steps.

1. The idea

The TRICK (Tracking Ring Imaging CherenKov) project aims to find an innovative solution that exploits features of conventional detection techniques to improve the current state of the art and be better suited to the challenges of future detectors. In particular, TRICK combines a proximity focussing RICH (Ring Imaging CHerenkov) and a TPC (Time Projection Chamber) readout by triple-GEM (Gas Electron Multipliers) into a single volume to perform a 5D reconstruction, *i.e.* simultaneously providing three spatial coordinates, time of arrival, and particle ID. Two chips, based on TIGER (Torino Integrated GEM Electronics for Readout) ASIC, are used to read the TPC (TIGER-GEM [1]) and the RICH (TIGER-MED [2]) parts, respectively. Both share the same backend, so the information can be combined in the first part of the readout chain, the GEMROC readout card, prepared for the CGEM-IT project [3,4].

The demonstrator, called TRICK-box, is shown in Fig. 1 and it is based on these technologies: $9 \times 9 \times 2$ cm^3 hydrophobic aerogel with refractive index $n = 1.045$; four 5×5 cm^2 H12700 MA-PMTs (MultiAnode Photo Multiplier Tubes) by Hamamatsu, and a 10×10 cm^2 triple-GEM with 15 cm drift gap. The expected performance, with the current choice of detectors, are: a spatial resolution $\sigma_x \sim 100$ μm on all three coordinates, a time resolution $\sigma_t < 1$ ns (from the Cherenkov photons), and a $3\sigma\pi/K$ separation up to 4 GeV.

2. Status

The demonstrator development is divided into three main areas: mechanics, electronics, and software. Highlights are presented in the next sections.

2.1. TRICK-box mechanics

The prototype has already been designed and all the pieces are available at INFN-Ferrara. The TRICK-box will be based on PVC material to provide light insulation and gas tightness. To hold the aerogel, the PMT and the front-end electronics, special mechanical protrusions were designed on the front and back of the TRICK-box. The pillars, which hold the cathode at the proper distance, also serve as a support for the drift cage, which is going to be built with small wires to ensure good field uniformity and not to block Cherenkov photons trying to reach the PMTs. The TRICK-box will be placed on an XV anode with 650 μm strip pitch. The X strips are parallel to one of the box sides,

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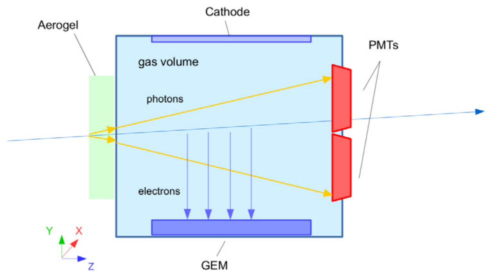

Fig. 1. Sketch of the TRICK working principle. The particles impinging from left to right first pass through the aerogel radiator, where the Cherenkov photons are emitted, and then through the gas, where the ionization happens. The photons cross the gas and are detected at the anodes of the PMTs, allowing the reconstruction of the rings. On the other hand, the electrons drift towards the triple-GEM, where they are amplified to reconstruct the passage of the particle.

while the V have a stereo angle of 30°. A dedicated black box with space for two external tracking stations based on planar triple-GEM prototypes has been prepared, and it will be used for cosmic data taking to begin the validation.

2.2. Software

The basic tools to test geometry and field configuration have been prepared. In particular, the basic geometry, consisting of the aerogel, the gas volume, the PMTs, and the pillars, has been prepared in GEANT4 [5]. This simulation is used to study the energy deposition in the gas, to be given as input to fast simulations, like PARSIFAL [6] to study the triple-GEM signal and to find a compromise between the wire spacing of the field cage, to ensure the uniformity, and the transmission of the Cherenkov photons to the photodetectors. It will also be used to test the reconstruction algorithm, that will be based on existing routines of CLAS12 RICH [7] and BESIII CGEM-IT [3,4] groups, to reconstruct and match tracks and rings to fully satisfy the TRICK idea. In parallel, an initial design of the field cage has been prepared with ANSYS [8], showing that about 10 wires are sufficient to achieve enough field uniformity for the project needs.

2.3. Electronics

The two ASICs, TIGER-GEM and TIGER-MED, have been developed as part of the BESIIICGEM project, funded by the European Commission for the readout of the BESIII CGEM-IT detector. TIGER-GEM has been extensively tested within that project, to read triple-GEMs and has a fully dedicated readout chain [9]. TIGER-MED has eight configurable gains to read different range of input charges, and was tested for the first time with MA-PMTs for single photon applications.

The validation has been performed in two steps with a special DAQ and a test board prepared by INFN-Torino. First, a test of the noise induced by the coupling between FEB (Front End Boards), mezzanine and PMTs was performed. This has shown that a dark count rate as low as ten Hz could be achieved, which perfectly met the requirements of the project. Later, a test was performed with a blue laser to verify the response of an external source mimicking the single photons. The laser was tuned to send a pulse with a 10 kHz frequency. Fig. 2 shows the results, where the time walk effect is clearly illustrated: when there is no charge difference between two consecutive hits, the time difference is close to the nominal value (about 20000 clock hits, 100 μs), while the interval increases (or decreases) when the charge difference increases (or decreases).

These measurements, combined with the experience gained with TIGER-GEM in the triple-GEM readout, validate the electronics for the next steps of the projects.

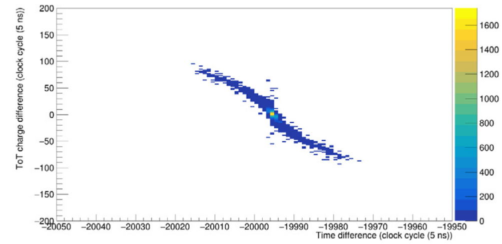

Fig. 2. Charge difference between two consecutive pulses in Time Over Threshold clock cycle with respect to the time interval between the two expressed in clock cycles. The laser was tuned at a 10 kHz rate. Positive (negative) charge differences correspond longer (shorter) intervals, since the pulses pass the threshold at different timestamps due to the time-walk effect.

3. Summary and next steps

The TRICK demonstrator aims to show that with the simultaneous readout of a TPC and a RICH it is possible to extend individual readout capabilities. On the one hand, the Cherenkov photons will provide a precise t_0 for reconstructing the time-projected coordinate; on the other hand, a standalone tracking system for the RICH will improve the matching with the rings and thus of the particle identification capabilities, reducing the tracking error.

A cosmic data taking will begin in the next months, and a test beam is planned before the end of 2022 to demonstrate the operation of TRICK in a controlled environment.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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