eRD22 GEM-TRD/T R&D Progress Report

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Abstract

Transition radiation detectors are widely used for electron identification in various particle physics experiments. For a high luminosity electron-ion collider a high granularity tracker combined with a transition radiation option for particle identification could provide additional electron identification/hadron suppression. Due to the low material budget and cost of GEM detector technologies, a GEM based transition radiation detector/tracker (GEM/TRD/T) is an ideal candidate for large area hadron endcap where a high flux of hadrons is expected at the EIC.

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1 Introduction

Identification of secondary electrons plays a very important role for physics at the Electron-Ion Collider (EIC). J/ψ has a significant branching ratio for decays into leptons (the branching ratio to electrons (e^+e^- pair) is similar to muons ($\mu^+\mu^-$ pair) and is at the order of 6%). The branching ratio of D-mesons is Br($D^+ \to e + X$) $\sim$ 16% and the branching ratio of B-mesons is Br($B^\pm \to e + \nu + X_c$) $\sim$ 10%. By using more sophisticated electron identification the overall J/ψ and open charm or beauty mesons efficiency could be increased and therefore statistical uncertainties could be improved. Electron identification is also important for many other physics topics, such as spectroscopy, beyond the standard model physics, etc. A high granularity tracker combined with a transition radiation option for particle identification could provide additional information necessary for electron identification or hadron suppression.

The scope of this project is to develop a transition radiation detector/tracker capable of providing additional pion rejection (>10-100).

2 PAST

- *What was planned for this period?*

  During this period we were planning to perform a test with pions coming from decays of ρ-mesons using the Glue-X detector. In the fall, Glue-X experiment planned to perform a commissioning run of DIRC detector (2 weeks in December). We were planning to install our prototype in front of the DIRC detector and integrate our GEM-TRD readout into the Glue-X data-acquisition system. This setup would allow us to use the GlueX physics analysis and reconstruction chain necessary for the pion extraction and would allow us to estimate the real e/π rejection factor for our GEM-TRD prototype.

- *What was achieved?*

2.1 Preparation and a joint Test run with GlueX and DIRC

As it was proposed in July, we were planning to have a joint setup with GlueX during the commissioning run of DIRC detector (2 weeks before Christmas break). The idea was to measure the response of the GEM-TRD module with pions, coming from decays of ρ, for example.

- **Prototype X-ray measurements at UVA**
  Before the installation in the joint setup with GlueX DIRC commissioning, we decided to investigate the issues that we experienced earlier with the GEM-TRD prototype during the 2019 test beam at JLab for the Hall D Spring 2019 run, where we were not able to acquire good signal in the detector because the chamber were preforming at an extremely low efficiency during the test beam. We suspected at the time, a problem with the HV power supply that would have caused a big discharge in the chamber and damage the GEM foils inside the prototype. We decided to investigate further to reproduce the problem in a different setting than the one we faced in Hall D the test beam at JLab. However tests with x-ray source as well as in the cosmic setup in the Detector Lab at UVa, performed after the Spring 2019 test beam, did not show any issue with the prototype. The chamber performed flawlessly as one can see on the plots of Fig. 1. On the top left of the figure is the GEM-TRD detector in a cosmic setup with a standard 10 cm $\times$ 10 cm COMPASS GEM and one 10 cm $\times$ 10 cm μRWELL detector used for this test as tracking detectors. The color 2D plot on the top right of Fig. 1 shows the charge sharing correlation plots of the XY readout layer of the prototype showing a good charges distribution between the x and y strips of the chamber. At the bottom left, the 2D distribution reconstructed position of the cosmic hit in the GEM-TRD prototype is shown and compared to the 2D hit map in the two references detectors the standard GEM and the μRWELL in the bottom center and the bottom right respectively. One can see from these hit map plots a good performance of the GEM-TRD prototype in the entire active area, as opposed to the problems we experienced in the test beam at JLab. The good performance during tests at UVa was also validated from tests performed in our x-ray setup before the cosmic tests. X-ray tests at UVa also did not reveal

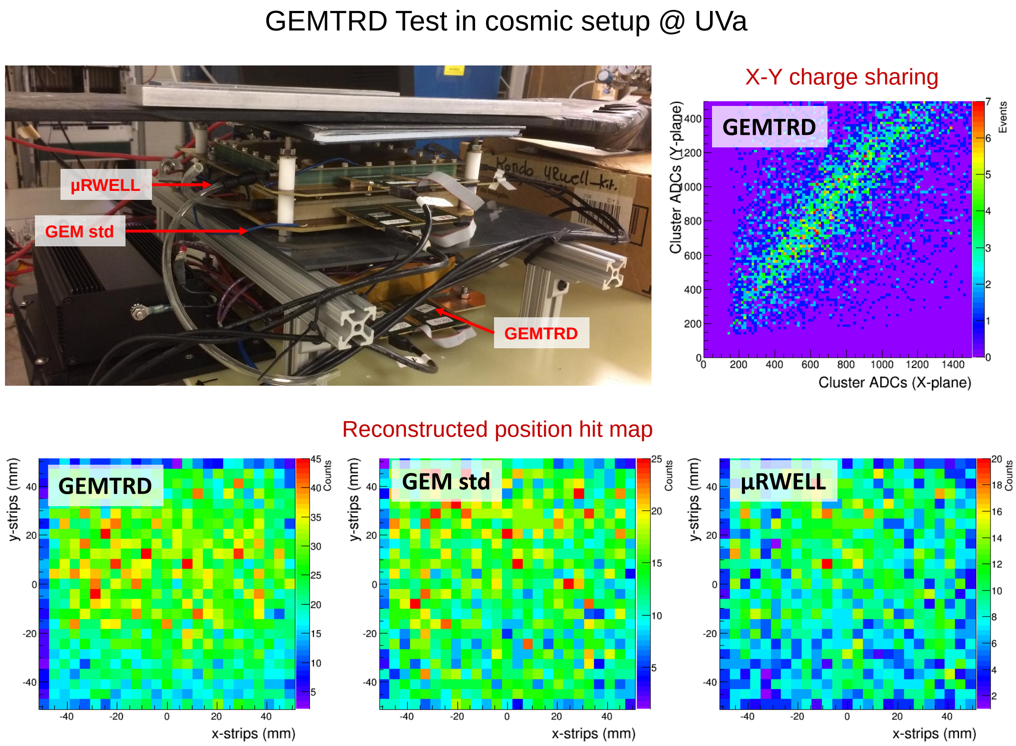

Figure 1: Test of the GEM-TRD prototype in a cosmic setup at UVa.

any issue with the prototype. The only significant difference between the cosmic and x-ray tests at UVa and the test beam at JLab where the readout electronics used to collect the data. At UVa, we used our standalone APV25-SRS readout electronics system whereas in the test beam, the prototype is equipped with JLab fADC125 and GASII preamplifier chip. After the successful cosmic and x-ray tests at UVa, the chamber was then moved to the JLab Hall D test beam setup in December 2019 for the Fall 2019 run. The preliminary analysis of the Fall 2019 data, however shows a return of the extremely low efficiency issues that we experiences during the spring 2019 run. It therefore seems like it will be extremely difficult for us to collect and extract some good quality data during that run until we understand better the problem and provide a fix for it.

- **Noise and Fe55 measurements at JLAB**

  After the tests at UVA, the prototype was installed in the Hall-D, for noise and pedestals measurements. On the left plot of Fig. 2 the baseline noise of the electronics alone with two carrier PCBs, each with 10 preamps, all powered (480 channels) are shown. The noise is nominally 9 mVpp and is the same as previously measured in the lab. Fig 2 shows the noise with one of the carrier boards attached to the detector X coordinate connector. The noise is similar at 11 mVpp. The Fig. 3 left shows the noise with with the two carrier boards attached to the detector X and Y coordinates. The noise increased considerably to 61 mVpp. These show that there is coupling on the detector between the X and Y strips. The long strips on the carrier boards, though shielded, may act as antennas but this needs further research to determine if the issue can be resolved via a new, more compact readout design or via a new detector re-design. The readout of Y coordinate was disconnected for the test until the further investigation.

  To estimate an amplification we performed measurements with Fe55 source. Those measurements were important for FlashADC calibration and pre-amplification chain gain measurements. Fig. 3 (right) shows Fe55 spectrum on the oscilloscope.

Figure 2: (a)- left- the baseline noise of the electronics alone with two carrier PCBs, each with 10 preamps, all powered (480 channels). (b)-right- one of the carrier boards attached to the detector X coordinate connector.

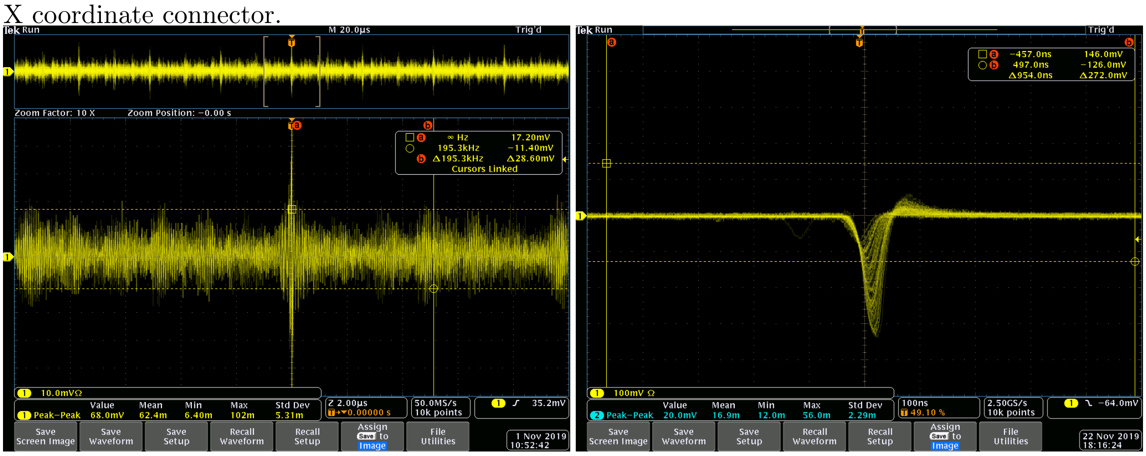

Figure 3: (c)-left- noise with with the two carrier boards attached to the detector X and Y coordinates. (d)-right- Fe55 measurements).

- **Gas system**
  The Gas system, which has been developed in Temple Uni. has been successfully installed in the Gas Room of the Hall-D (JLAB). All gas-pipes (?? m) have been installed and connected to the system. Many thanks to Scot Spiegel for his help with gas system installation and commissioning. The control and operation be done via computer interface (Fig. 4 left). Fig. 4 shows installation of the gas mixing system in Hall-D setup. Large bottles on the left are pure Argon and CO2 gases, respectively. The small bottle in front of the Gas Rock is a pure Xenon gas. During the operation we mixed Ar and CO2 gasses in the proportion of 75/25 respectively. Due to a high price of the Xe gas, we used it only during the dedicated TRD runs. The gas was mixed in the proportion of 80:20 (Xe/CO2).

Figure 4: Gas mixing system in Hall-D experimental setup).

  Before and after of the operation a quality of the gas mixture has been analyzed by the SRI 8610C gas chromatograph with a column 6' MS5a Helium 15 PSI carrier (Fig. 5(b).

  Fig. 5(a,c) shows an actual gas properties, such as percentage of Xe-C02 gas ratio as well as a contamination. We could resolve/measure a contamination down to 50ppm. We can not resolve Argon and Oxygen, but the total contamination is below 74ppm. The actual measured ratio of Xenon and $C0_2$ was 80.85 and 19.15 percent.

- **Experimental setup and alignment**

  The setup for this test had 5 modules (with 4 different tracking detectors technologies), counting from the target: Standard GEM plane,μRWELL, TRD Multi wire chamber (TRD-MW), GEM-TRD, Standard GEM plane. All 5 modules were mounted on a single aluminium stand. The alignment of all modules with respect to the reference frame (GlueX global system coordinate) has been performed. This tracking setup has been installed in front of the DIRC detector right after the exit from the GlueX solenoid.

  The upper left picture of the Fig. 6 shows sub-detectors mounted together. Middle and lower pictures of the Fig. 6 show how this setup was lifted up and also show its location in front of the DIRC detector after the solenoid exit. Readout electronics were kept closer to setup at the ground level, as shown on the upper right photo of the Fig 6.

  We would like to thank the GlueX team for their help with providing the mounting stand for the tracking modules, their alignment and installation. Especially, we would like to thank Tim Whitlatch for his help with installation.

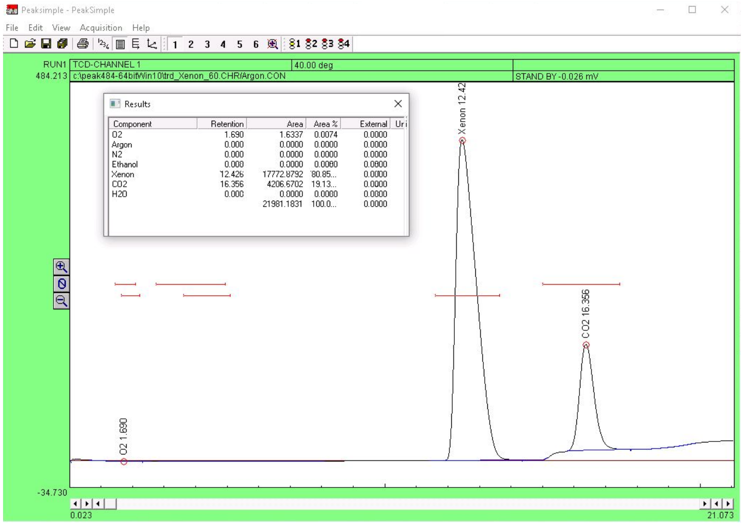

Figure 5: Gas quality measurements using a gas chromatograph).

- **Integration of GEMTRD to GlueX framework: DAQ, reconstruction** The readout of all tracking modules was integrated into the GlueX Data-Acquisition system. The special trigger setup was created which allowed to perform a joint run with GlueX, DIRC and TRD/tracking operations. Many thanks to Alexander Somov for providing a trigger setup.

  Our team would like to express our thanks to Justin Stevens for his help with integration of our tracking setup into GlueX data reconstruction framework. This would allow us to integrate GEM-based tracking setup into the track finding/fitting and to compare the track extrapolation with an actual position of the track in the area near the DIRC.

- **Experimental results**
  The main purpose of the joint test run with GlueX and DIRC was to estimate a performance of TRD with pions. Pions, comming from the decays of ρ-mesons could be identified by the GlueX detectors. The data are currently under the pre-processing.

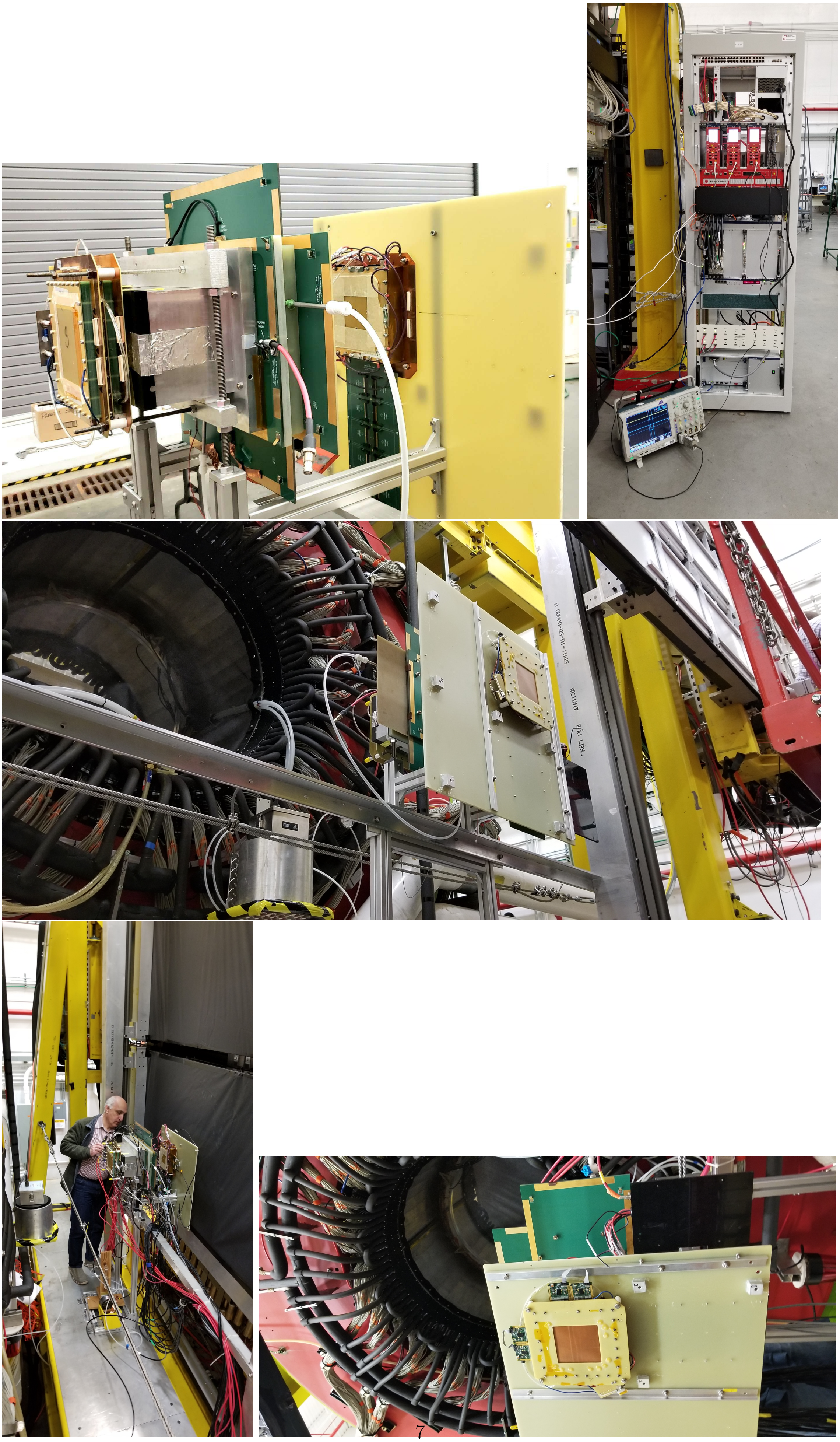

Figure 6: Test beam setup at Hall-D (CEBAF).

2.2 Integration into a global EIC software framework (g4e)

The Transition Radiation detector (TRD) has been integrated into the "*g4e*" setup (Fig 7). The transition radiation (TR) was included into the physics list. Different TR radiator materials were added into the material-database. The property of transition radiation was assign to a dedicated area only (the TRD detector only). Several options of TR radiator could be selected within the *g4e* (transparent or with a self-absorption). Histograms with an average energy deposition inside the slices of the drift area have been included into the output root-tree and could be used for the standard offline particle identification procedure. Further optimization should be performed, based on the actual needs and the global detector setup.

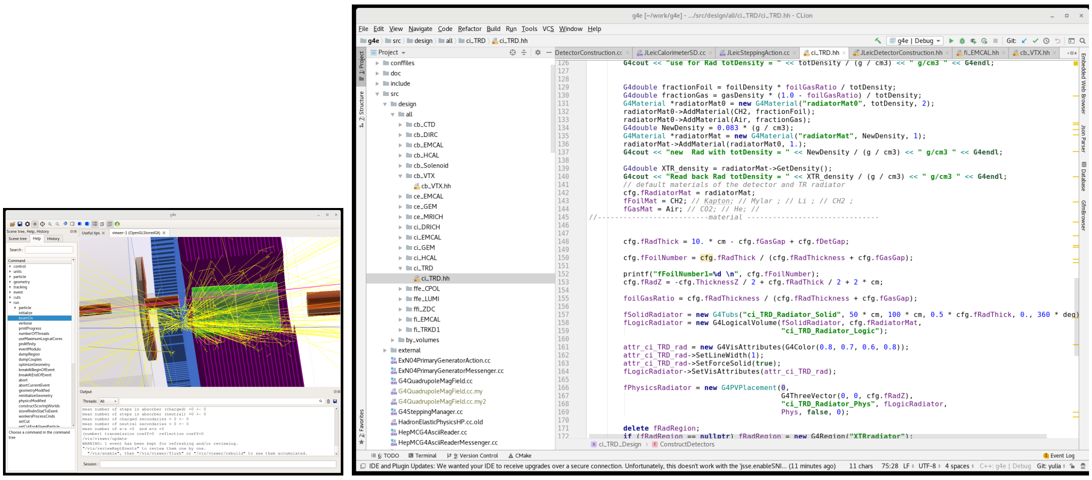

Figure 7: The g4e implementation of TRD (radiator and Xe-based volume).

3 PLANS

3.1 *What is planned for the next funding cycle and beyond? How, if at all, is this planning different from the original plan?*

Preparation for the Test-beam measurements in January:

- **Prototypes** As already we described in section 2.1, the first look at the Fall 2019 data seems to show that the extremely low efficiency issues that we saw with the prototype during the Spring 2019 are still present, even though extensive tests at UVa with cosmic and x-ray in between the two JLab test beam runs did not show any visible problem with the detector. We are planning to take the chamber out of the Hall D at JLab when we have an opportunity to investigate even further the problems and hopefully identify and fix it in time to re-install the detector in the setup in Hall D before the end of the Spring 2020 run. Initial investigations in Hall D during Fall 2019 run show that the fADC based electronics that we used to read out the detector readout strips can not possibly explain the issue that we are struggling with. So at this point, the only big difference between tests at UVa and at JLab is the particle rate in the chamber which is significantly higher in the Hall D at JLab than the conditions we tested the prototype in the cosmic and x-ray setup at UVa. We plan to re-test the chamber in the x-ray setup at UVa, but this time we will expose the chamber at a high particle rate to reproduce condition similar to the JLab Hall D setup. The goal is to reproduce the low efficiency performance and propose a fix.

- **Joint test beam mRICH and EMCAL**
  In January we are planning to move our GEM-TRD setup back into its original location, near the pair spectrometer. In addition to the tracking setup we are planning to install few modules of EMCAL (in collaboration with eRD1) and mRICH (in collaboration with eRD14) to perform a joint test run. The main goal of this test would be to evaluate the impact of the tracker resolution on the performance of EMCAL and mRICH detectors, as well as to estimate a global PID performance.

- **Test of different radiators**
  We are planning to perform a test of new materials, that are currently available for purchasing. Currently we identified 3 different radiator materials, which we would like to test for a Transition-radiation yield.

- **Test of different gas mixtures**
  Our gas mixing system is ready (see above). The first commissioning showed very good performance. Gas chromatograph would allow us to cross-check a quality and the actual percentage of the gas mix. We would like to perform a test with different Xe percentages.

- **Streaming and machine-learning application on FPGA for an online PID**
  our project got extra support from JLAB, and we are planning to work towards of implementation of online particle identification machine-learning application on FPGA. This project would allow us to also use different sub-detectors, such as calorimeters or rich detectors to provide global PID information in the early stage of data processing.

3.2 *What are critical issues?*

3.3 Publications

Please provide a list of publications coming out of the R&D effort. We are very proud to announce our first NIM paper: "A new Transition Radiation detector based on GEM technology" Nucl.Instrum.Meth. A942 (2019) 162356 (2019-10-21) DOI: 10.1016/j.nima.2019.162356

4 Acknowledgments

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