**Expression of Interest (EOI) – MPGD Trackers and TRD**

**Questionnaire**

**Please indicate the name of the contact person for this submission:**

Matt Posik

**Please indicate all institutions collectively involved in this submission of interest:**

* Florida Institute of Technology (FIT): Marcus Hohlmann
* Temple University (TU): Jeff Martoff , Jim Napolitano , Matt Posik, and Bernd Surrow
* University of Virginia (UVa): Kondo Gnanvo and Nilanga Liyanage
* Vanderbilt University (VU): Vicki Greene, Sourav Tarafdar, and Julia Velkovska

**Please indicate the items of interest for potential equipment cooperation:**

We would like to express our interest in developing central and forward/backward endcap tracking detectors based on Micro-Pattern Gas Detector (MPGD) technologies, in particular Gas Electron Multipliers (GEMs) and micro Resistive Well (RWELL), for the EIC. We will build on several years of R&D in those areas that we have conducted within the eRD6 consortium and eRD22 sponsored by the current BNL R&D program.

In the central detector region, we envision implementing thin cylindrical RWELL layers which will provide fast timing information and seed particle identification by providing precise track points and directional information for particles impacting a PID detector, such as a DIRC, near the RWELL layers.

For the forward and backward endcaps, we are interested in developing low-mass and large-area triple-GEM and RWELL planar trackers to aid in momentum reconstruction. A major benefit of employing large-area RWELL planar trackers over triple-GEM trackers is a significant reduction in the detector’s material budget. This can be particularly beneficial in the backward direction for electron reconstruction, which is more sensitive to the material budget.

Additionally, for the forward region, we are interested in developing very large-area triple-GEM and RWELL trackers which would be located behind the RICH detector. These trackers would provide fast timing and precise tracking information which would aid in reconstructing the seed particle used in the RICH ring reconstruction.

We plan to continue collaborating closely with our eRD6 colleagues from BNL (B. Azmoun, A. Kiselev, M. L. Purschke, and C. Woody) on these efforts as we have in the past years. In addition, we are interested in enhancing the capabilities of the triple-GEM and RWELL technologies in the forward/backward region by including capabilities for the detection of transition radiation. We plan to continue the close collaboration with our Jefferson Lab colleagues (F. Barbosa, C. Dickover, S. Furletov, Y. Furletova, L. Pentchev, and B. Zihlmann) from eRD22 on such an MPGD Transition Radiation Detector (TRD). Operating the MPGD portion of such a detector with a drift gap of several cm provides precise track points and allows for track segment reconstruction providing directional information. The TRD portion of the same detector provides pion-electron discrimination. This would be an ideal detector for detecting secondary electrons in the forward region, where hadrons will dominate.

**Please indicate what the level of potential contributions are for each item of interest:**

FIT offers person power, expertise and infrastructure for mechanical design, construction, and testing of detector components.

TU offers person power, expertise and infrastructure for mechanical design, construction, and testing of detector components. TU has sufficient space for cosmic-ray muon and source testing if applicable. The close proximity of TU to BNL allows easy access to BNL and actively participate with graduate students in the installation and commissioning of detector components.

UVa offers person power, expertise and infrastructure for construction, and testing of detector components.

VU offers person power, expertise and infrastructure for mechanical design, construction, and testing of detector components.

**Please indicate what, if any, assumptions you made as coming from the EIC Project or the labs for your items of interest:**

Our efforts will include

* Detector design activities

We are assuming that the following are going to be covered by the EIC project:

* Material costs
* Some engineering support

Specifically, TU assumes the same level of current DOE base funding, i.e. on average one postdoc and two graduate students. Additional support for one postdoc (50%) and two graduate students (50%) is provided by TU.

**Please indicate the labor contribution for the EIC experimental equipment activities:**

The expected labor contributions are summarized in this table:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Institution Name | Professor | Research Professor | Staff Scientist | Postdoc | Graduate Student | Undergrad. student | Engineer | Designer | Technician | **Total Sum** |
| FIT | 0.1 |  |  |  | 1.0 | 0.4 |  |  |  | **1.5** |
| TU | 0.3 | 0.2 |  | 0.5 | 1.5 | 0.8 | 0.25 |  | 0.25 | **3.8** |
| UVa | 0.1 | 0.3 |  | 0.5 | 1.0 | 0.4 |  |  |  | **2.3** |
| VU | 0.2 | 0.5 |  | 1 | 2 | 2 |  |  | 0.2 | **5.9** |
| **Total Sum** | **0.7** | **1.0** |  | **2** | **5.5** | **3.6** | **0.25** |  | **0.45** | **13.5** |

**FIT**: It is anticipated that the collaborative effort of FIT to cooperate on the EIC Project is to include (at an annual basis) 0.1 full-time equivalent FTEs of a professor, 1.0 FTEs of Ph.D. students, and 0.4 FTEs of under graduate students. We anticipate the duration of this collaborative effort to cooperate on the EIC Project to start at the DESIGN phase and to be for a period of FIVE years.

**TU:**  It is anticipated that the collaborative effort of TU to cooperate on the EIC Project is to include (at an annual basis) 0.3 full-time equivalent FTEs of a professor, 0.2 FTEs of an Assistant Research Professor, 0.5 FTEs of a postdoctoral researcher, 1.5 FTEs of Ph.D. students, 0.8 of undergraduate students, 0.25 FTEs of engineering, and 0.25 FTEs of technicians. We anticipate the duration of this collaborative effort to cooperate on the EIC Project to start at the DESIGN phase and to be for a period of FIVE years.

**UVa:** It is anticipated that the collaborative effort of UVa to cooperate on the EIC Project is to include (at an annual basis) 0.1 full-time equivalent FTEs of a professor, 0.3 FTEs of a Research Professor, 0.5 FTEs of a postdoctoral researcher, 1.0 FTEs of PH.D. students, and 0.4 FTEs of undergraduate students.

**VU**: It is anticipated that the collaborative effort of VU to cooperate on the EIC Project, contributed without requiring Project funds, is to include (on an annual basis) 0.7 FTE in senior personnel shared among 2 professors and one research professor, 1.0 FTE of postdoctoral fellow, 2.0 FTEs of graduate student work shared among 6 graduate students, and 2.0 FTEs of undergraduate researchers with research projects during the academic year and full time in the summer. Vanderbilt would also provide 0.2 FTE of a machine shop technician.

**Please indicate if there are timing constraints to your submission:**

FIT effort might ramp up after 2025 when GEM hardware contributions to the Phase 2 upgrades of the CMS detector at the LHC is complete.

TU effort will increase after 2022 when we have completed our obligations to the sPHENIX experiment.

VU group members have obligations on other experiments (sPHENIX, CMS), but the timing of those obligations has been considered in the labor estimates provided above, which is an estimate of the average time commitment to EIC-related research.

**Please indicate any other information you feel will be helpful:**

FIT, TU, UVa, and VU each possess experience related to MPGD detector development for experiments. FIT has been involved in the construction and quality control of large-area triple-GEM muon detectors for the CMS experiment. It was the production site for large-area GEMs in the initial phase of the CMS muon upgrade project, and is currently the detector-electronics integration site for large-area GEMs in the main phase of the upgrade project. TU was involved in the STAR Forward GEM Tracker and is currently building quadruple-GEM readout modules for the sPHENIX TPC. UVa has been developing large-area triple-GEM trackers for several experiments at Jefferson Lab, including PRad and Super BigBite, as well as future experiments MOLLER and SoLID and also served as the detector production site. VU has an established track record of successful detector design, construction, and operation (Pad Chambers and Time-of-flight for PHENIX), and is currently designated as one of the GEM factories for sPHENIX.

Through the EIC R&D program, FIT, TU, and UVa, have established a track record for working together to explore GEM and RWELL technologies as part of the eRD3, eRD6, and eRD22 projects. The three institutions collaborated to build and design a common GEM foil which could be used to assess different assembly procedures and readout schemes [1-10]. We are now working together to explore the use of RWELL technology in the EIC, which is the current focus of the eRD6 EIC R&D [11]. Together with colleagues from Jefferson lab, we have built and tested a triple-GEM based TRD prototype detector [12]. This served as a proof of principle that one can reconstruct tracking information as well as provide particle discrimination with GEMs.

Furthermore, TU and VU are currently collaborating to produce the quad-GEM readout modules for the sPHENIX TPC.

For the central and forward/backward MPGD trackers all four institutions would be able to provide fully equipped gas detector labs, clean rooms for detector assemblies, and access to University resources, such as machine shops. A more detailed contribution list for each institution can be found below.

**FIT**

**Gaseous-Detector Development Laboratory:** 600 sq. ft. with gas system infrastructure which includes:

* Gas quality monitor for O2 and H2O at the ppm level.
* Electronic leak hunter.
* Laminar flow hood capable of achieving class 10 or better.
* Basic analog electronic detector readout system with amplifiers and NIM modules.
* Cosmic ray muon tracking station with eight 30 cm x 30 cm triple-GEM detectors and associated electronics (12k ch.).
* Pico-ammeters for leakage current measurements for small and medium-sized GEMs under nitrogen flow.
* A variety of scintillation detectors (Nal and plastic scintillators) with PMTs and associated digital DAQ cards for providing coincidence triggers.
* Several computers for data analysis.
* A 3D printer.
* APV25-based Scalable Readout System with RD51 DAQ (DATE and AMORE for monitoring).
* ALTIUM software for PCB design.
* AutoCAD and Inventor design software suites.

**CMS GEM Detector Production & Quality Control site**: 1,000sq. ft. in high-bay experimental hall adjacent to tent clean room (see below), with

* Basic gas system infrastructure
* Laminar flow hood (12sq. ft., class 10 or better)
* Large optical table
* 3m × 2m × 1m lead-shielding box for large-surface x-ray exposure
* X-ray generator (Amptek)
* RD51 Scalable Readout System (4k ch.) with RD51 DAQ (DATE and AMORE for monitoring).
* NIM amplifiers, modules, and crates.
* Various CAEN HV modules (NIM & mainframe)
* Commercial Geiger counter for radiation monitoring

**Tent Clean Room:** 200sq. ft. in the high-bay experimental hall (class 1000) with

* Large optical table
* Laminar flow hood (class 10 or better)
* 1m × 0.5m Plexiglas box for N2 flushing of large GEMs
* Basic gas system
* Portable dust-particle monitor for monitoring cleanroom air

**Machine Shop:** Mechanical jobs can be done at the university machine shop for reasonable hourly fees ($35) or for free for a student project. Students can get trained by machinists on the use of standard machines in a dedicated 3-week training course before beginning work. Several students in Hohlmann's lab completed this course in the past.

**TU**

**Gaseous-Detector Assembly Laboratory:** 1,800 sq. ft. permanent class 1000 clean room which includes

* Two large N2 dry boxes (48 in x 12 in x 24 in).
* Large desiccant cabinet (413 L).
* Large (1000 cm x 80 cm) high resolution CCD scanner for GEM foil quality assurance.

**Gaseous-Detector Laboratory:** 800 sq. ft. with gas system infrastructure which includes

* A portable class 1000 clean room
* Portable dust-particle monitor for monitoring cleanroom air
* Cosmic ray stand based on scintillator detectors with PMTs and associated digital DAQ cards for providing cosmic ray coincident triggers
* APV25-based Scalable Readout System (256 ch.) with RCDAQ software
* Large ultrasonic bath
* Several CAEN HV power supplies, cosmic ray stand, and SRS readout
* MPOD HV power supplies (3 x 8 ch.)
* 8 ft x 6 ft optical table

**Machine Shop:** Can be used for machining of components. Our machine shop has lot of experience with machining and building components for experiments. Most recently the machine shop has produced components for the sPHENIX (TPC components) experiment and the STAR Forward upgrade (HCal components). Not to mention being heavily involved in past work at Jefferson Lab Halls A and C (Cerenkov detector components).

**Mechanical Engineer Support:** A dedicated mechanical engineer is expected to be available for design and assembly work.

**UVa**

**Gaseous-Detector Development Laboratory: 1**600 sq. ft. with gas system infrastructure which includes:

* Small cosmic ray stand with four 10 cm x 10 cm CERN “standard GEMs” for R&D
* Large cosmic ray stand for large MPGD detector (1000 cm x 50 cm) tests and characterization. The stand consists of plastic scintillation detectors with PMTs with associated digital DAQ cards for providing cosmic ray coincident triggers.
* Several readout electronics systems for MPGDs:
  + APV25-SRS (10k Ch): APV25-based Scalable Readout System with both RD51 DAQ (DATE and amoreSRS for monitoring) and Jefferson Lab DAQ (CODA and GEMView for monitoring).
  + APV25-MPD (2k Ch): Multi-Purpose Digitized with Jefferson Lab DAQ (CODA)
  + VMM3-SRS: VMM3-based Scalable Readout System with RD51 DAQ
* Pico-ammeters for HV testing and leakage current measurements of large GEMs under nitrogen flow.
* Lead-shielding x-ray box and x-ray gun for high particle rate exposure of large area MPGDs.
* Variety of scintillation detectors (Nal and plastic scintillators with PMTs) with associated HV power supplies.
* SoLIDWorks and Inventor design software suites.
* NIM crates and modules for trigger logic, CAEN HV PS modules, MPOD Wiener PS (> 8 channels).

**GEM Production and Quality Control for Jefferson Lab Experiments (PRad, SBS, SoLID, Moller)**

* Two fully equipped clean rooms for assembly of large triple GEM (150 cm x 55 cm) including
  + Large mechanical stretcher
  + 175 cm x 55 cm Nitrogen plexiglass box for HV tests and leakage current measurements.
  + Ultrasonic bath (60 cm x 50 cm x 40 cm) for cleaning of GEM components.
  + High resolution optical microscope for GEM foil and GEM readout inspection.

**University Machine Shop:** Mechanical machining jobs can be done at the University machine shop for reasonable hourly fees ($35) or for free for a student project. Students can get trained by machinists on the use of standard machines in a dedicated 3-week training course before beginning work. Several students in our lab have completed this course in the past.

**University Electronics Shop**

**VU**

**MPGD-Detector Laboratory :** 1500 sq. ft. ISO 6/class 1000 permanent clean room includes

* ISO 1 laminar flow table with inner dimension of 97” x 28” X 22.5” (wide x deep x high).
* Two 8’x8’ optical tables and one 8’x4’ optical table.
* Dry box of dimension 24”x 27.4”x25” (LxWxH) for storing MPGD detectors under low humidity condition.
* Two multichannel portable Particle counters.
* Hygrometer for humidity monitoring .
* In house built 3 gas mixing unit capable of mixing three different gases with 99.95% accuracy.
* 3’x3’x1.5’ (LxWXH) X-ray shielding box with X-ray tube interlock system for MPGD R&D.
* One triple GEM detector and one quadruple GEM detector using standard 10x10 GEMs assembled in VU MPGD lab for GEM R&D.
* 4 GEMs 24 x 17 cm2 (of different pitch and misaligned hole configuration) .
* 10 channel Zagreb picoammeter for IBF studies and also for HV testing of multisector GEMs under flow.
* Several Gas vessels for assembling GEM detectors using standard 10x10 cm2 GEMs and 24x17 cm2 GEMs.
* Mini X-ray tube with Ag target fixed inside X-ray shielding box for high rate of radiating MPGD detector.
* Fe-55 soft X-ray source.
* 256 channel X-Y strip COMPASS style readout board with 10 cm x10 cm active area.
* APV25 based SRS system (2048 channels) with RCDAQ and several computers for analyzing data and control module for hardware.
* One CAEN 4 channel HVPS NIM module and one 8 channel CAEN Desktop HVPS.
* Scope with the ability to histogram signal pulse.
* Several plastic scintillators with PMTs.
* NIM crates and modules (several shaping amplifiers, discriminators, trigger logic, fanout etc) along with standalone charge sensitive pre amplifier.
* Several sized stretching frames and gluing jigs for framing various sized GEMs.
* Ultrasonic bath (30 L) for cleaning clean room items
* Portable gas-leak detector
* 2’x 2’ N2 gas flow box for leakage current measurement under N2/dry air gas flow.

**Machine shop:** VU Physics department has machine shop which is quite experienced in machining and also designing different mechanical components for reasonable hourly fees.

**Cross-reference to other EoIs**

* ECCE, Electron ion Collider Consortium Expression of interest (using selected components of the sPHENIX Experiment), submitted by consortium including VU
* EIC Expression of Interest: Forward Silicon Vertex/Tracker Developments from Los Alamos National Laboratory is supported by TU

**References**

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[10] Gnanvo, K. et al. “Performance in test beam of a large-area and light-weight GEM detector with 2D stereo-angle (U–V) strip readout.” *Nuclear Instruments & Methods in Physics Research Section A-accelerators Spectrometers Detectors and Associated Equipment* 808 (2016): 83-92, doi: 10.1016/j.nima.2015.11.071.

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