Envisioned Jefferson Lab Micropattern Gaseous Detector Resource and Development Center

Background

Micropattern gaseous detectors (MPGDs) are charged particle detectors that utilize the ionization of a gas caused by the passage of high energy charged particles. They are based on thin printed circuit board (PCB) type foils with photolithography produced electronic elements/openings. The openings result in sub-millimeter distances between anode and cathode electrodes. When a voltage potential is applied the small openings enable *In situ* strong electrostatic fields. Ionizing radiation (i.e. high energy charged particles) interacting with the gas produce ionization electrons and ions that drift apart and are accelerated via the applied voltage potential. Electrons accelerated in the regions of strong electrostatic field in the gas create avalanches of additional electron-ion pairs in regions leading to their detection by readout electronics. See Figure 1 for example.

In the research fields of nuclear physics, high energy physics, astrophysics and beyond MPGDs are the choice for cost effective instrumentation of large area detection and for continuous tracking of charged particles with minimal detector material. The various types of MPGDs differ in the way the electrostatic field is created. Below is a list of MPGDs in use or under development:

- Gas Electron Multiplier (GEM)
- Micro-Mesh Gaseous Structure (MicroMegas)
- Thick GEMs (THGEMs), aka Large Electron Multipliers (LEMs)
- Resistive Plate WELL (RPWELL)
- GEM-derived architecture (μRWELL)
- Micro-Pixel Gas Chamber (μ-PIC)
- Integrated pixel readout (InGrid).

During the recent July 2022 Snowmass meeting, a ten-day international gathering of over 1000 particle physicists convened to discuss ways to advance the science [1]. The Snowmass meeting happens about every ten years. Associated with the meeting there were over 150 white papers submitted to be part of a larger report. Five white papers delt solely with MPGDs [2]. One of those white papers summarized the role of MPGDs in ongoing and future nuclear physics (NP) experiments and discussed the development needed to meet the challenges of future NP experiments [3].

In the white paper's section *4.4. Need for MPGDs R&D facility in the US for the Nuclear Physics community* it states:

> *As highlighted throughout this white paper, the MPGD requirements for future experiments at Jefferson Lab experiments require dedicated and sustained R&D effort to prepare for the challenges for large area, low mass, high spatial resolution and radiation hard MPGD technologies for tracking and PID in high rate environment. Having a facility in the US for the development, testing and dissemination of MPGD technologies will strongly benefit the development of MPGDs for Jefferson lab needs. Such US-based MPGD facility could be modeled on the Gaseous Detector Development (GDD) laboratory at CERN or the SiDet facility at FNAL dedicated for silicon detector technologies for HEP in the US.*

The nuclear physics community has also begun a periodic (every ~7 year) long range planning process for the field, which started first with a QCD "town meeting" held at the Massachusetts Institute of Technology. The concept of a US-based MPGD facility modeled on the GDD laboratory at CERN or the SiDet facility at FNAL was presented and met with resounding support. It is anticipated that this effort will be mentioned in both the white paper from this meeting and eventually also in the Long Range Plan for Nuclear Science this coming year.

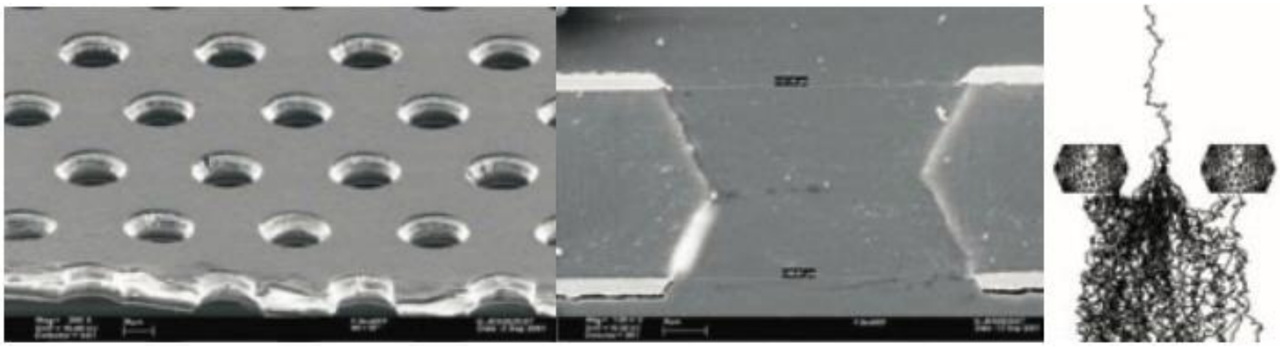

Figure 1: Electron microscope images of a GEM foil, and a simulated electron avalanche in a GEM hole [4].

There are over 40 US research institutions (see Appendix A for a partial list) involved in MPGD development or activities for experiments in different fields of physics that would benefit directly from a first of its kind US-based MPGD facility. Several of these institutions are members of the CERN-based RD51 collaboration which focuses on the advancement of MPGD technologies. The US institutions have benefited from the facilities offered by the CERN Gas Detector Development (GDD) lab and the Micro Pattern Technology (MPT) shop to perform initial R&D and optimization for MPGD technologies for their specific experiments. But, the community is growing swiftly and there is no such facility in the US to accommodate this need. We propose that such a facility with similar capabilities be located at Jefferson Lab.

Jefferson Lab MPGD Resource and Development Center

There are several opportunities for advancement of MPGD technologies by a US based center. As an example, resistive material use is the latest trend in the development of MPGD technologies. This could be one focus of the Jefferson Lab MPGD Development Center. Resistive electrodes allow better control of the spark rate and amplitude thus improving detector stability and robustness. One such novel resistive MPGD device is the Resistive Micro Well (μRWELL) detector that requires a thin layer Diamond-Like Carbon (DLC) material as the resistive layer of the detector stack. The DLC layer acts to quench discharges and enhance the spatial resolution performance of the device. Resistive Micro Mesh Gaseous Structures (Micromegas) using DLC have also been developed and operated over large area in experiments at Jefferson Lab. There is a similar, intense R&D effort to develop resistive GEMs as well.

Jefferson Lab development of resistive MPGDs such as μRWELL, or resistive GEMs, will be a huge boost for the MPGD community and establish the laboratory as one of the key international players in the field. It will support US based innovation in this novel detector technology, as well as US researchers in need of expert design and support for these systems. It will strongly benefit future high-profile experiments at Jefferson and other laboratories, for instance the tracking system for the detectors of the future EIC.

Jefferson Lab is an excellent location for a US-based MPGD facility for several reasons. MPGDs are essential for Jefferson lab's robust experimental nuclear program supporting high impact experiments (past, present and future) such as BoNUS12, Super Bigbite Spectrometer (SBS), PRad, MOLLER, SoLID, and PRad-II to name a few. Jefferson Lab is leading the detector development effort for the EIC detector which will have a significant need for specialized detector systems based MPGDs. Moreover, Jefferson Lab is home to the Radiation Detector and Imaging Group which already has leading experts in MPGD development in particular and other cutting edge nuclear physics detector technology in general. Finally, the Applied Research Center (ARC) on the Jefferson Lab campus will soon have ownership transferred from the City of Newport News to DOE. The ARC already has laboratory facilities and space which could perhaps be available for the envisioned Center. In any event there is land on the Jefferson Lab campus which could accommodate a new building.

We intend, on the outset, that the Center focus on the development of large area resistive MPGDs. The critical element of resistive MPGDs has been the DLC foil. Japan is the home of the one company worldwide able to reliably produce high-quality and large DLC foils. The Jefferson center could acquire the expertise in the fabrication of large area ~ ($1m^2$) DLC foils for the primary purpose of R&D activities on resistive MPGDs (µRWELL and resistive GEMs). A more comprehensive endeavor of the Center would be to take on the fabrication of complete resistive MPGD devices going beyond a single element such as the DLC layer.

In summary, the Jefferson Lab MPGD Resource and Development Center would provide expertise and support for researchers from several scientific disciplines developing MPGD instrumentation which includes design assistance, prototyping support, and testing facilities. Jefferson Lab would be creating a centralized location for the concentration of MPGD development resources to serve as an asset to the nation's scientific community.

Estimated Budget (burdened) $6M TOTAL

Appendix A

Nuclear Physics

- Thomas Jefferson National Accelerator Facility, Newport News, VA 23606
- Univ of Virginia Physics Department, Charlottesville, VA 22904
- Florida Institute of Technology, Melbourne, FL 32901
- Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824
- Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI 48824
- Temple University, Philadelphia, PA 19122
- Brookhaven National Laboratory, Upton, NY 11973
- Vanderbilt University, Nashville, TN 37240
- Hampton University, Hampton VA 23668
- Bates MIT, Middleton, MA 01949
- Stony Brook University, Stony Brook, NY 11794
- Yale University, New Haven, CT 06520

Dark Matter, Neutrinos and Physics Beyond the Standard Model

- University of Hawaii
- University of New Mexico
- Wellesley College
- Department of Physics, Duke University, Durham, NC 27708
- Triangle Universities Nuclear Laboratory, Durham, NC 27708
- University of Texas, Arlington, TX, 76019
- Department of Physics, North Carolina State University, Raleigh, NC 27695
- The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599
- Fermi National Accelerator Laboratory, Batavia, IL 60510
- Department of Physics, Enrico Fermi Inst., Kavli Inst. for Cosmological Physics, Univ. of Chicago, Chicago, IL 60637
- Mitchell Institute for Fundamental Physics and Astronomy, Texas A&M University, College Station, TX 77843
- Univ of Virginia Physics Department, Charlottesville, VA 22904
- Colorado State University, Fort Collins, CO 80523
- Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545
- Department of Physics, Occidental College, Los Angeles CA 90041
- Canisius College, Buffalo, NY, 14208
- Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720

High Energy Physics

- Florida Institute of Technology, Melbourne, FL 32901
- University of Texas, Arlington, TX, 76019
- Yale University, New Haven, CT 06520
- University of Wisconsin-Madison, Madison, USA
- University of Hawaii, Department of Physics and Astronomy, Honolulu, HI 96822
- Department of Physics, Carleton University, Ottawa, ON, K1S 5B6, Canada
- University of Michigan,
- Rice University
- University of California at Los Angeles
- Texas A&M
- Wayne State
- Harvard University
- Boston University
- University of California at Davis
- Brandeis University

References

[1] Physics Today **75**, 10, 22 (2022); https://doi.org/10.1063/PT.3.5097

[2] Report of the Instrumentation Frontier Working Group for Snowmass 2021, https://arxiv.org/abs/2209.14111v2 (accessed 4 Oct 2022).

[3] Snowmass 2021 Instrumentation Frontier (IF5 - MPGDs) – *White Paper 2: Micro Pattern Gaseous Detectors for Nuclear Physics*, 2203.06309.

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[4] Micropattern gas detector technologies and applications the work of the RD51 collaboration, S. D. Pinto, *IEEE Nuclear Science Symposium & Medical Imaging Conference*, 2010, pp. 802-807, doi: 10.1109/NSSMIC.2010.5873870.