Overview of EIC R&D Gas Tracking Projects

Matt Posik
Temple University
(For the eRD6 Consortium and eRD22)

1st EIC Yellow Report Workshop
Internet, the World
~~Temple University, Philadelphia PA~~
March 19-21, 2020

College of Science and Technology
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The eRD6 Consortium

- **eRD6**: *Tracking and PID detector R&D towards an EIC detector*
- Generic EIC R&D Program: https://wiki.bnl.gov/conferences/index.php/EIC_R%25D

Consortium Statistics

- Number of institutions/labs: 7
- Number of people: 29
- Number of publications: 23 (list in last slides)

R&D Focuses

- Central Tracker
- End Cap Tracker
- Particle ID

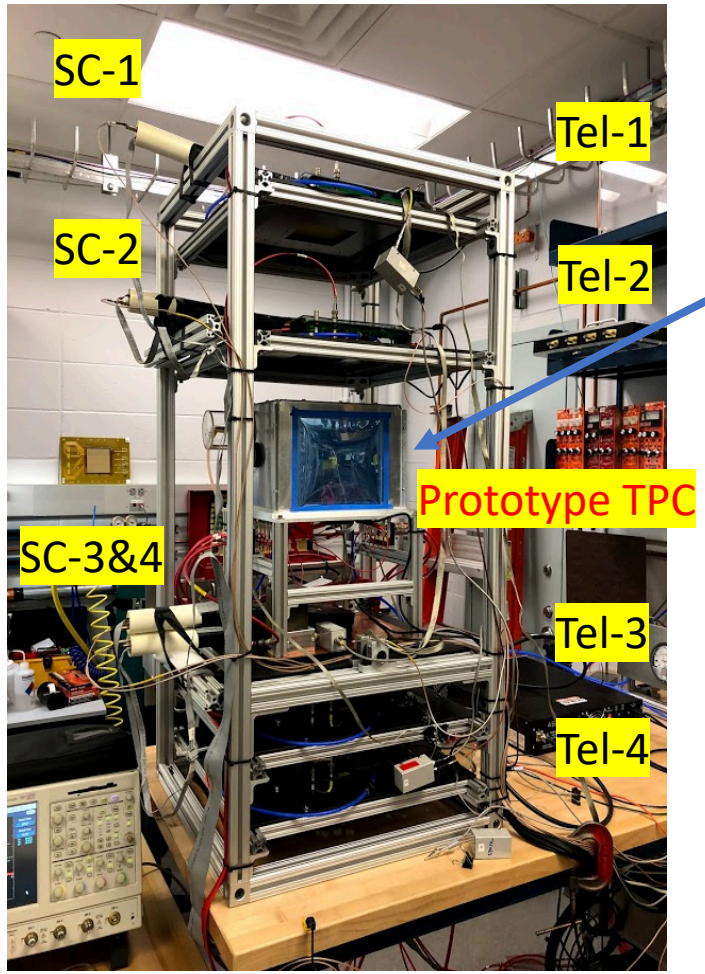
- Matt Posik will be serving as a link person between eRD6 and the tracking working group
  - Email: posik@temple.edu

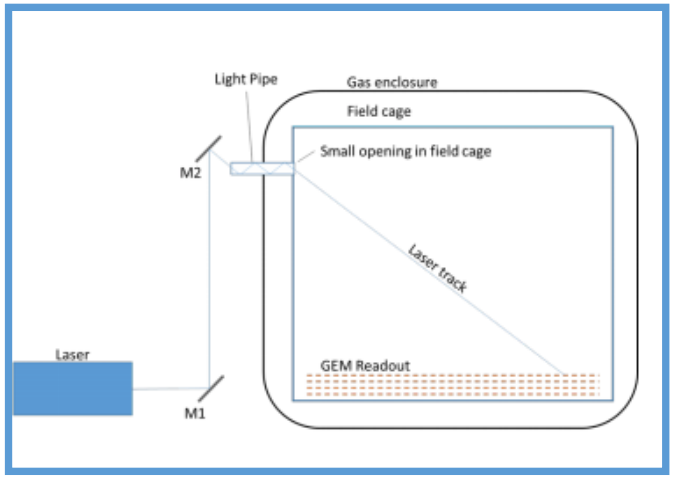
The eRD6 Consortium

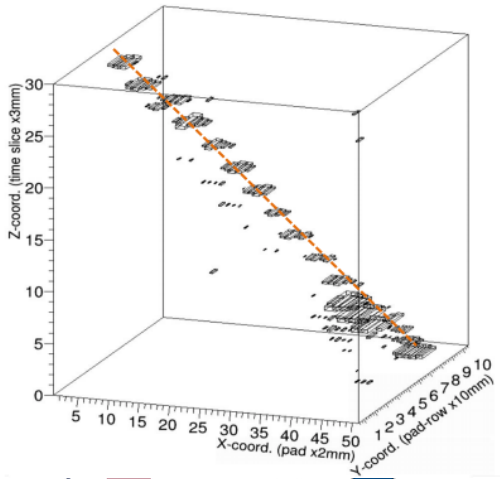
- **Brookhaven National Laboratory (BNL)**
  - **People**: E.C Aschenauer, B. Azmoun, A. Kiselev, M. L. Purschke, C. Woody.
  - **Central Tracker:** TPC and TPC/Cherenkov prototypes; zigzag pad readout, Avalanche structure readout.
- **Florida Institute Of Technology (FIT)**
  - **People**: M. Bomberger, J. Collins, M. Hohlmann.
  - **Central Tracker:** Cylindrical μRWELL; **End Cap Tracker:** Large area & low mass GEM with zig-zag readout.
- **INFN Trieste**
  - **People**: C. Chatterjee, D. D'Ago , S. Dalla Torre, S. Dasgupta, S. Levorato, F. Tessarotto, Triloki.
  - **Particle ID:** Hybrid MPGDs for RICH applications; New photocathode materials for RICH detectors.
- **Stony Brook University (SBU)**
  - **People**: K. Dehmelt, A. Deshpande, P. Garg, T. Hemmick.
  - **Central Tracker:** TPC-IBF; **Particle ID:** Short radiator length RICH, Large mirror coating, Meta Materials.
- **Temple University (TU)**
  - **People**: M. Posik, B. Surrow, N. Lukow, A. Quintero.
  - **Central Tracker:** Cylindrical μRWELL; **End Cap Tracker:** Commercial GEMs.
- **University Of Virginia (UVa)**
  - **People**: J. Boyd, M. Dao, K. Gnanvo, N. Liyanage, H. Nguyen.
  - **Central Tracker:** Cylindrical μRWELL; **End Cap Tracker:** Large area & low mass GEM with U-V readout.
- **Yale University (YU)**
  - **People**: D. Majka, N. Smirnov.
  - **Central Tracker:** Avalanche structure readout.

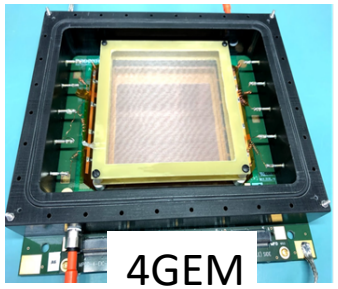
The eRD6 R&D Activities: Central Tracking (1)

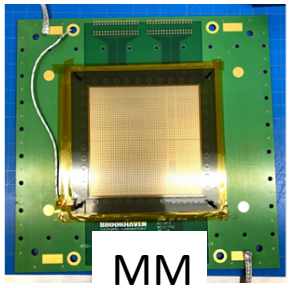
- **TPC** (BNL, SBU, Yale U)
  - Requires low mass ($\chi_0 \leq 5\%$), good momentum resolution, particle ID (dE/dx), ion back flow minimization
  - Tests of FE (SAMPA and DREAM) for TPC readout (BNL)
  - R&D of high intensity UV laser for TPC performance study
  - MPGD based avalanche structure with zigzag readout for TPC (BNL, Yale U)

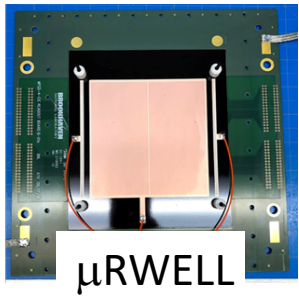


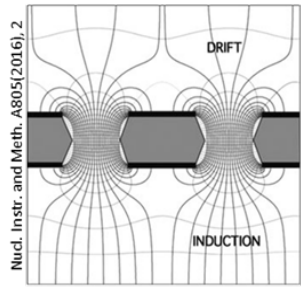


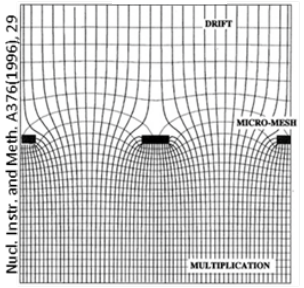


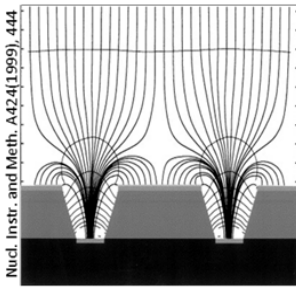

4GEM

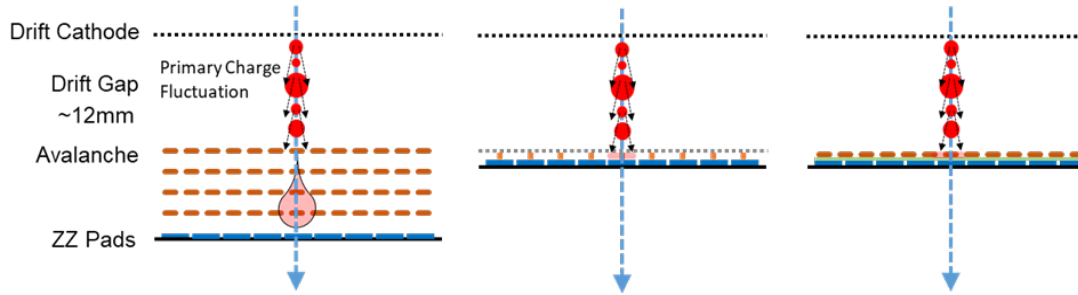

MM


μRWELL









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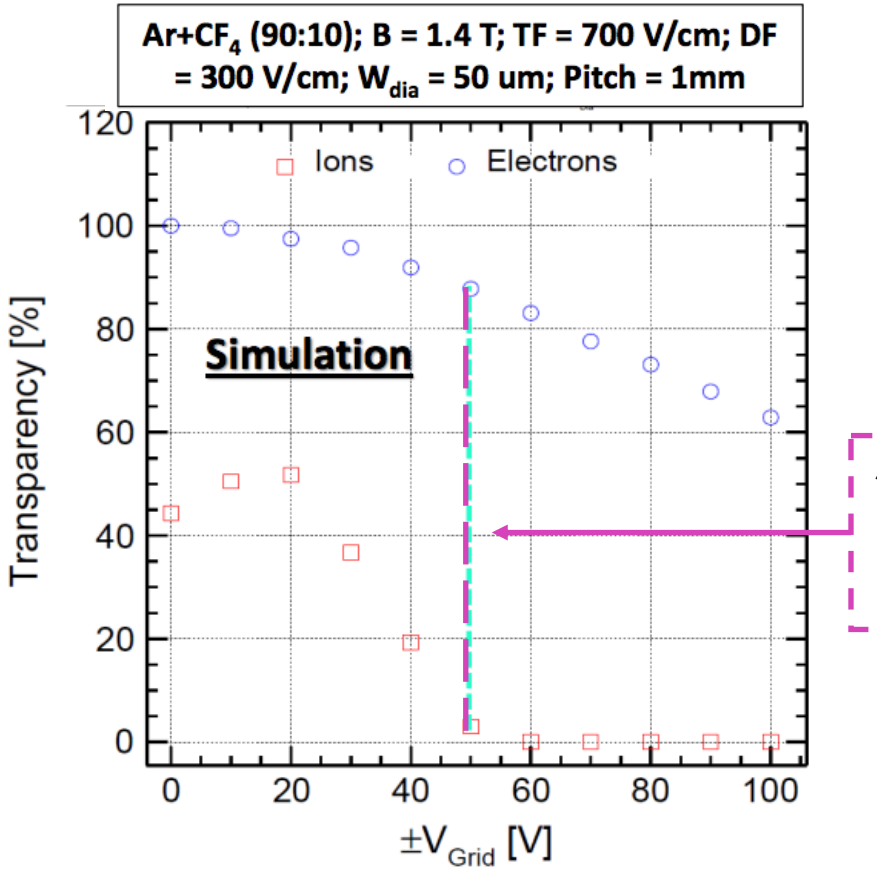
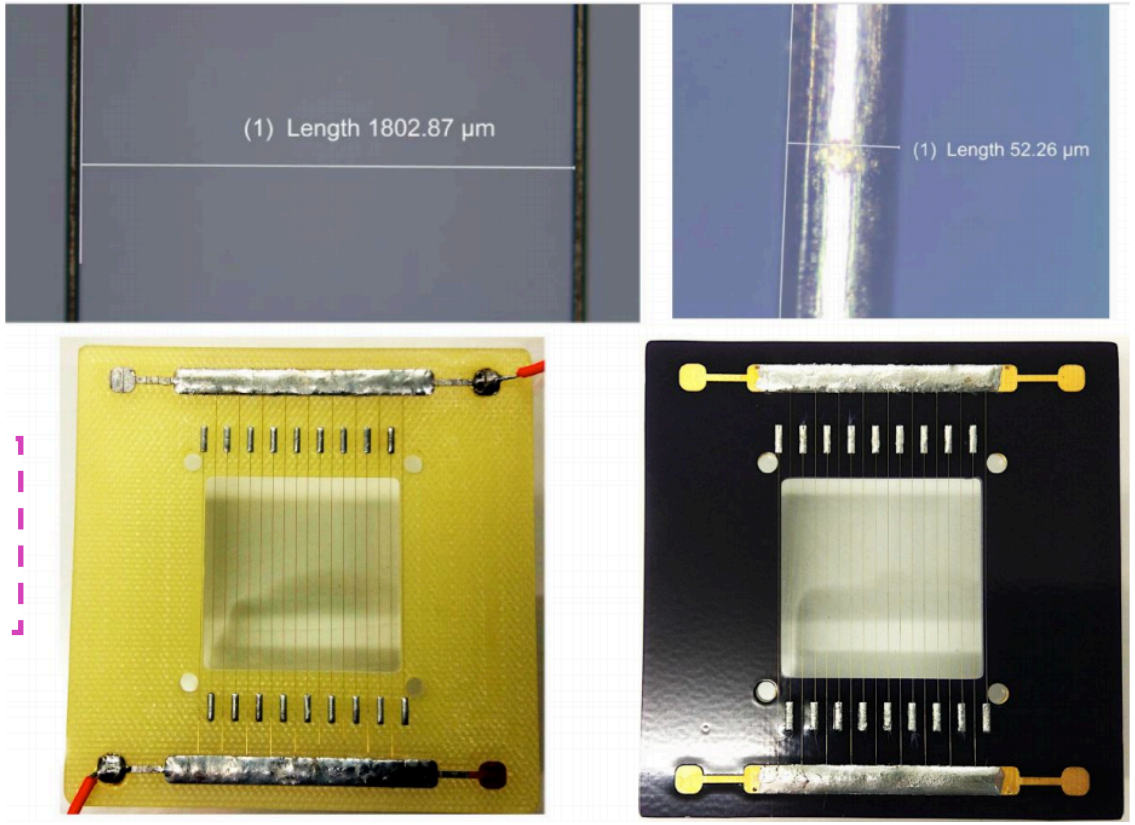
The eRD6 R&D Activities: Central Tracking (1)

❑ TPC (BNL, SBU, Yale U)

- Investigation to **minimize IBF** in MPDG based TPC readout (SBU)
  - Keep good dE/dx and momentum resolution
- Simulation results look promising
- 30 x 30 mm^2 prototype currently under study

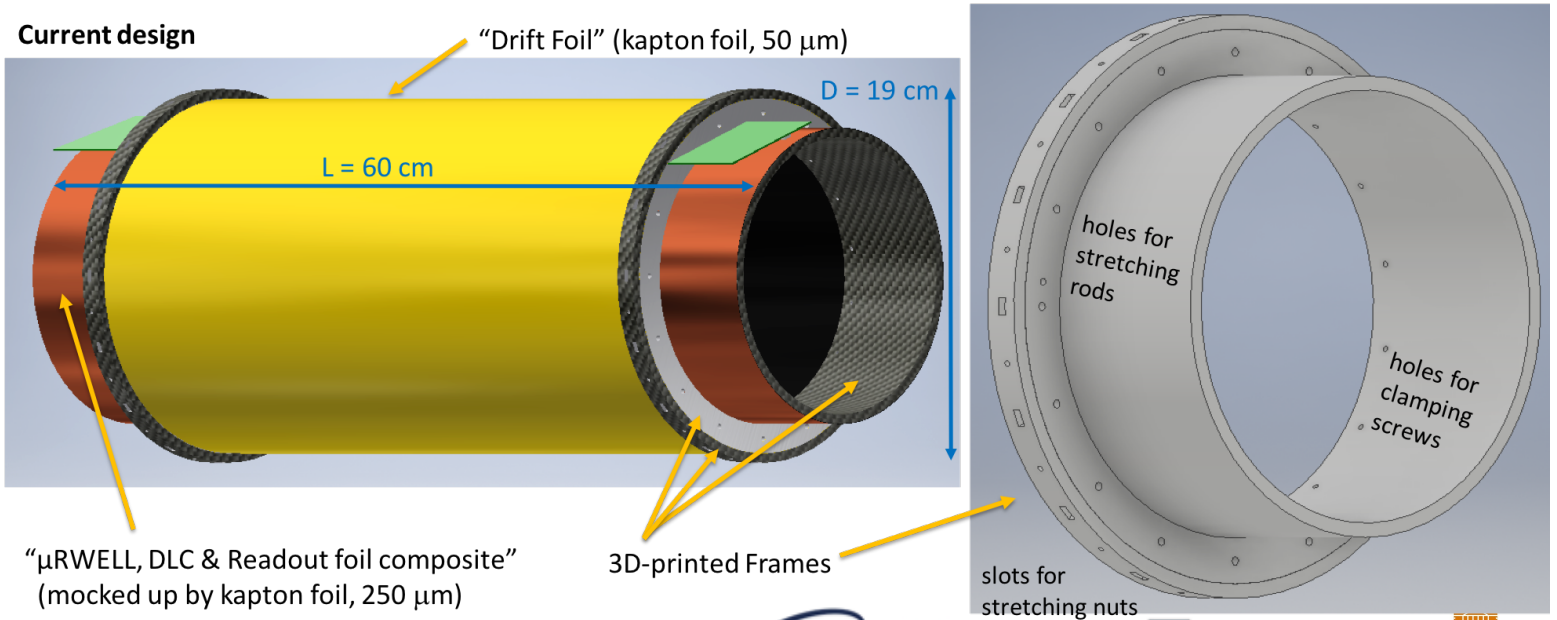


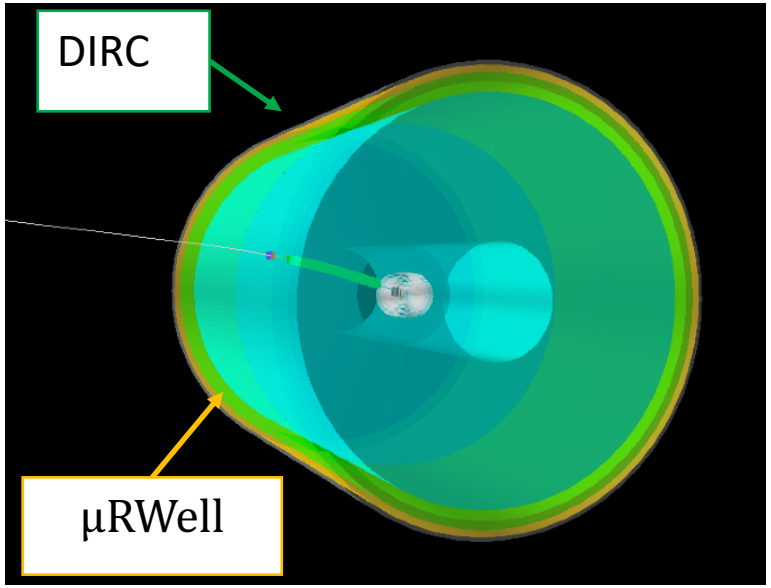
~ 90% e^- transparency
Vs.
< 5% ion transparency



The eRD6 R&D Activities: Central Tracking (2)

- **Cylindrical $\mu RWell$ prototype** (FIT, TU, UVa)
  - Cylindrical fast tracking MPGD layers
    - can be used to provide seed tracks correlated to bunch crossings
    - Operating in μTPC mode can provide additional track direction information to DIRC via tracklets
  - Design of prototype (FIT)
  - Simulation of prototype (TU)
  - Characterization of small planar prototype with 2D readout strips (Uva)
  - Design and characterization of prototype operating in $\mu RWell$ (UVa, TU)
  - Investigation of new tracking FE (VMM3-SRS) (UVa)



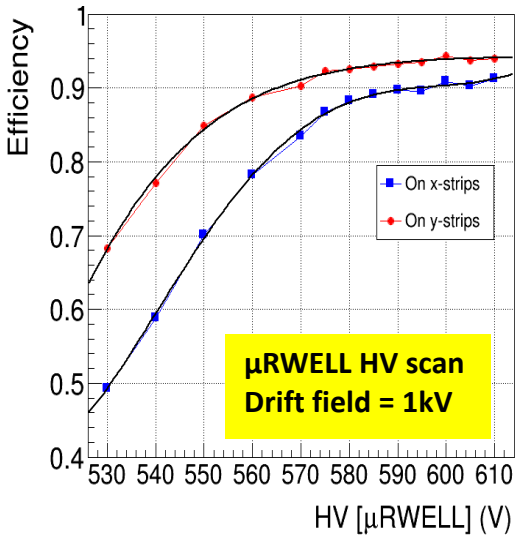


The eRD6 R&D Activities: Central Tracking (2)

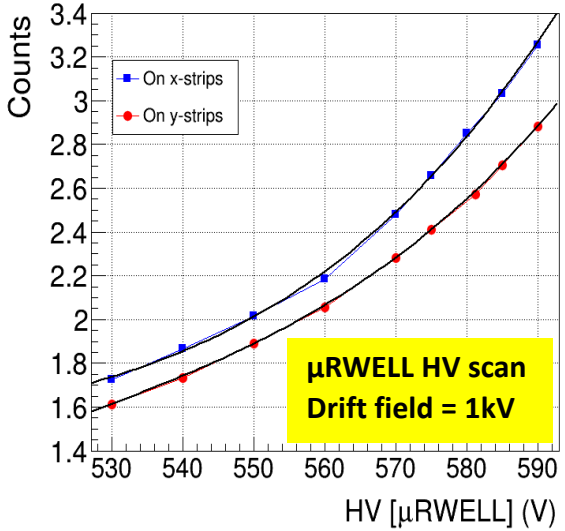
Cosmics

- **Planar $\mu RWell$ beam test**
  - 10 cm x 10 cm $\mu RWell$ tested by UVa in cosmics and FNAL proton beam
  - Tested in ArCO2 (70:30)
  - Used APV25 SRS readout
  - Good charge sharing X-Y correlation at 0.8
  - X-Y strip pitch = 400 μm
  - X (Y) strip width = 80 μm (340 μm)
  - Track residuals of 50 and 43 μm in X and Y

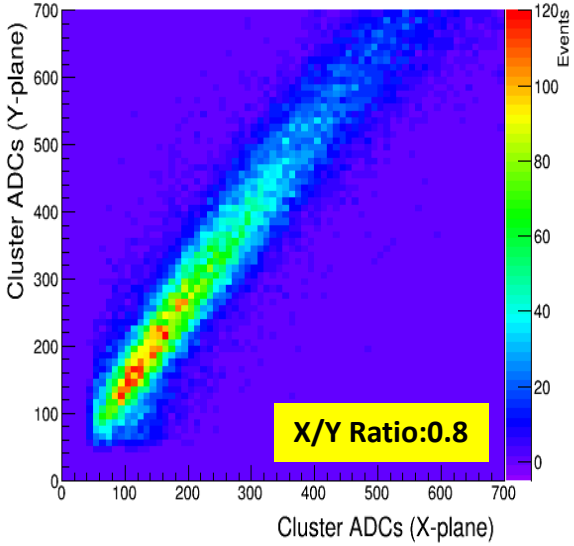
Efficiency vs. amplification



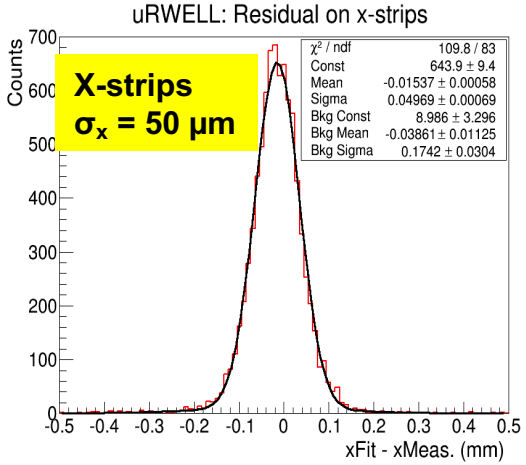
Cluster size vs. amplification

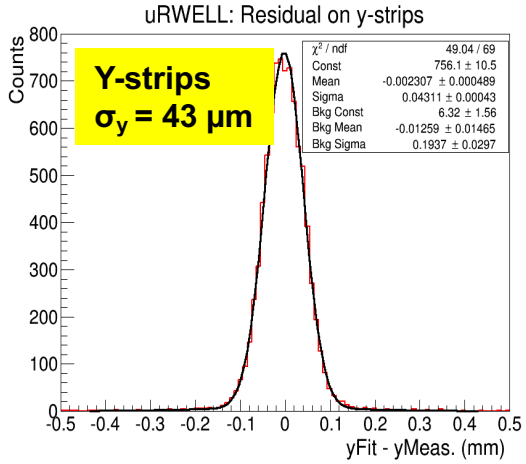


X-Y strips charge sharing



uRWELL position residuals from track fit with GEMs @FNAL





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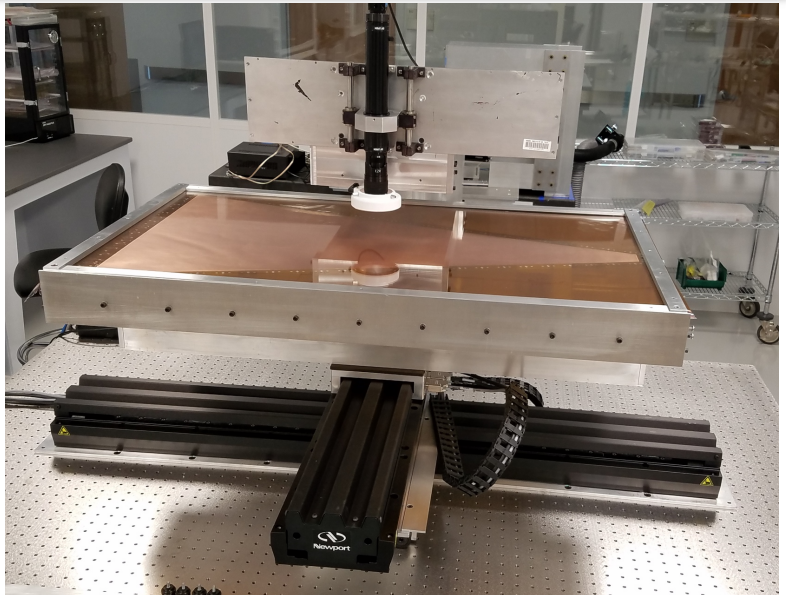
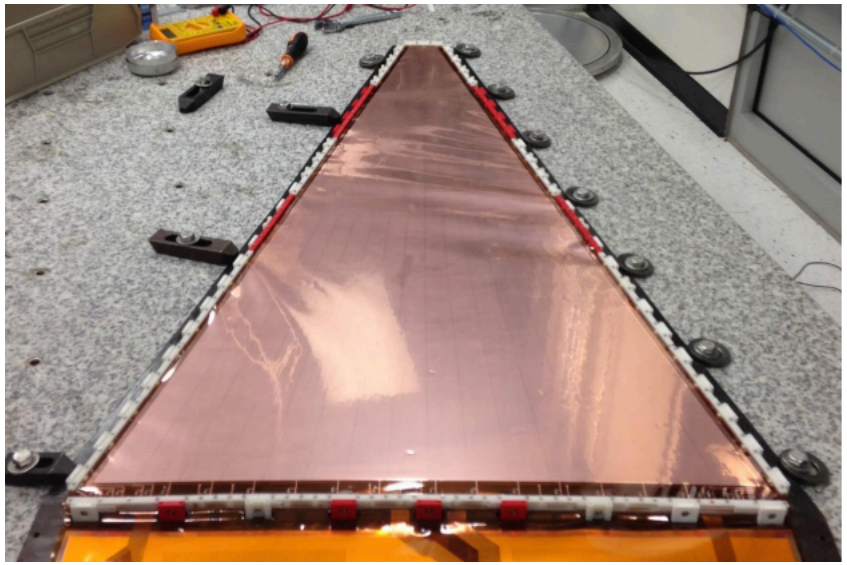
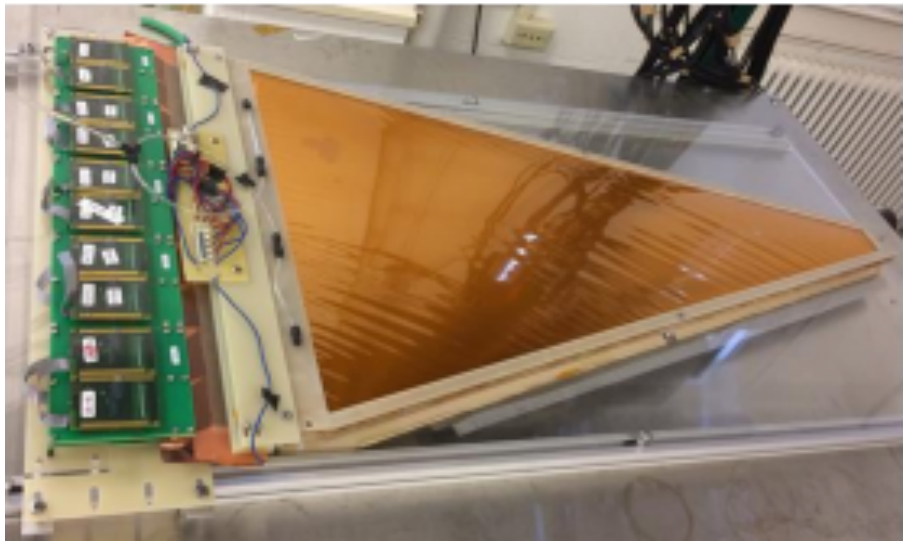
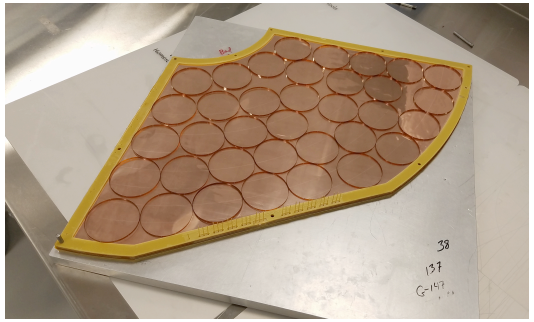
The eRD6 R&D Activities: End Cap Tracking

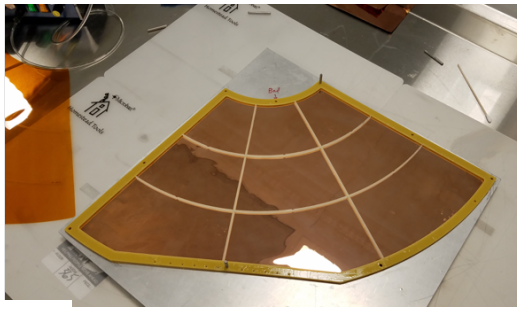
- **Low Mass Large Area GEM Tracker** (FIT, TU, UVa)
  - EIC requires low mass, large area, and good momentum resolution.
  - GEM tracker R&D investigations
    - Assembly: Mechanical stretching and glued frames
    - Spatial resolutions: Zig-Zag (1D), U-V, and $r - \phi$
    - Dead area in active area: Spacer grids, Kapton rings, none in the case of mechanical stretching
  - Simulation of endcap GEM trackers (FIT)
  - Characterization of large area GEM trackers (FIT, UVa)
  - GEM commercialization and optical foil QA (CCD Scanner) (TU)









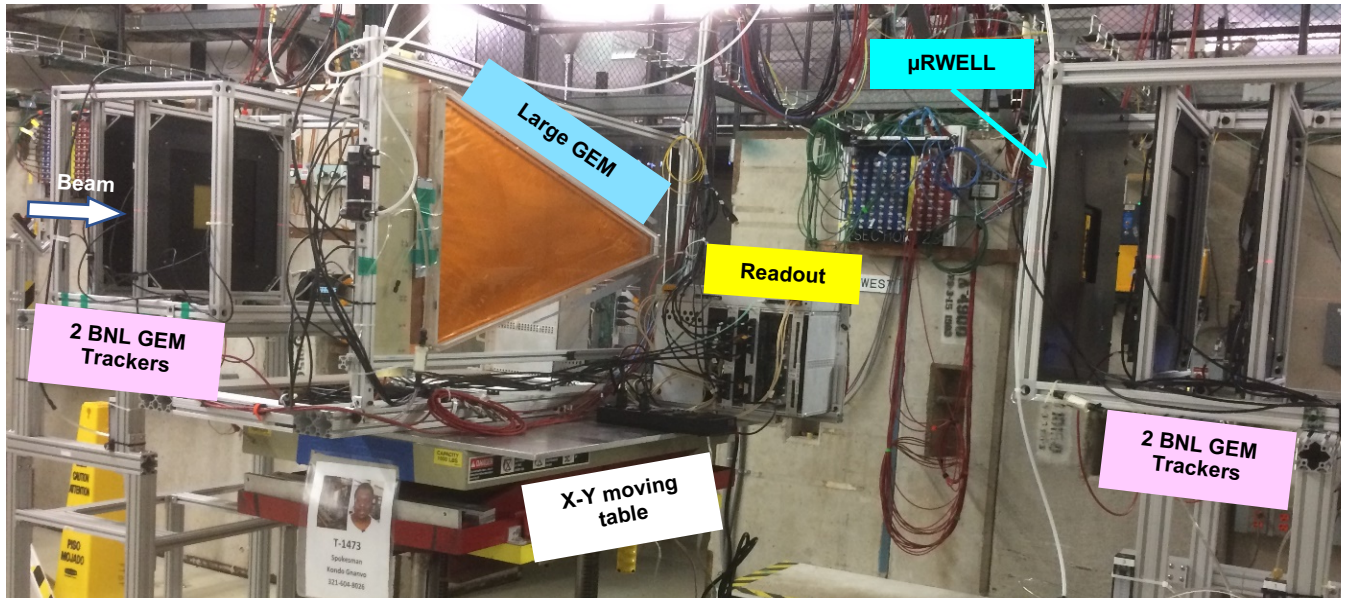


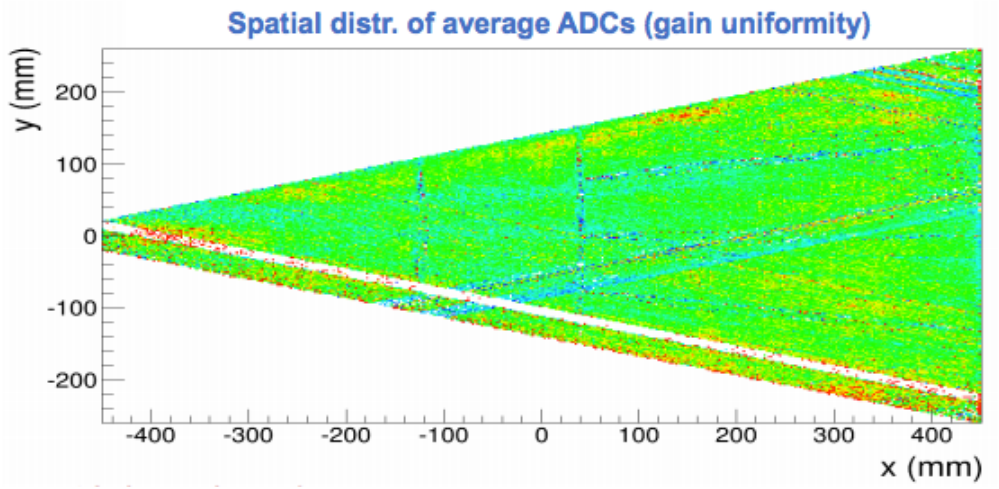
The eRD6 R&D Activities: End Cap Tracking

❑ Low Mass Large Area GEM Tracker Beam Test

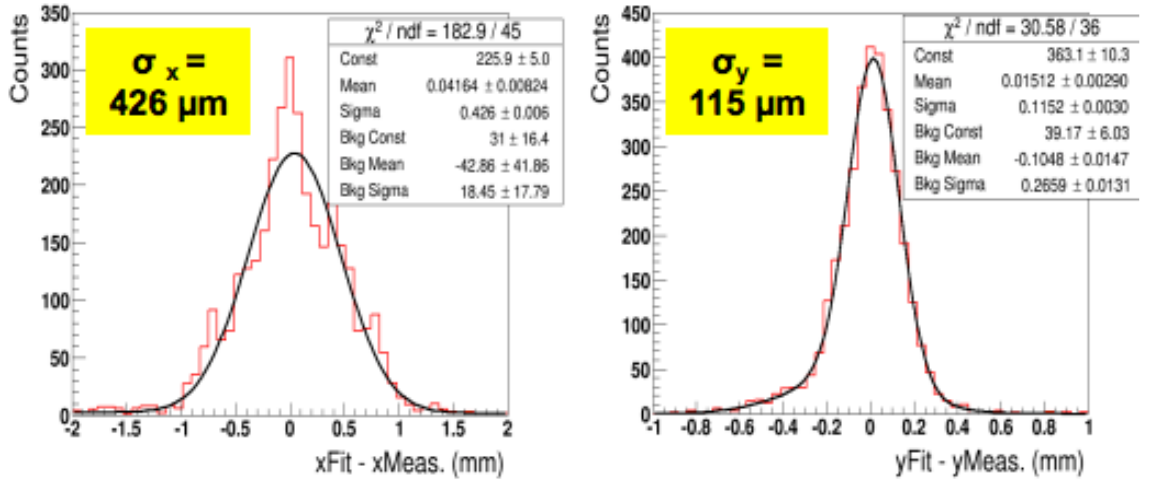
- UVa tested GEM tracker with FNAL proton beam
- Detector radiation length = 0.41%
- U-V readout strips with double-sided zebra connection
- Excellent X-Y resolution measured
  - $\sigma_x = 426\ \mu m$
  - $\sigma_y = 115\ \mu m$

Large GEM Setup in MT6.2b Area at FTBF (June-July 2018)





Spatial resolution with U-V strip readout (FNAL data)



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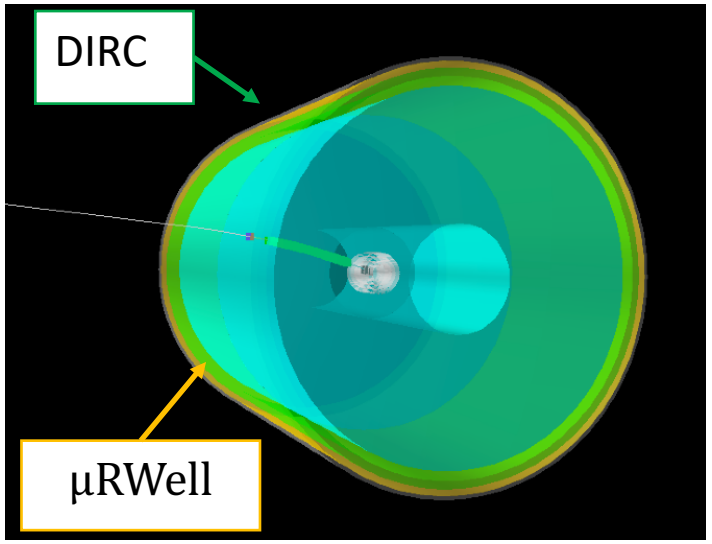
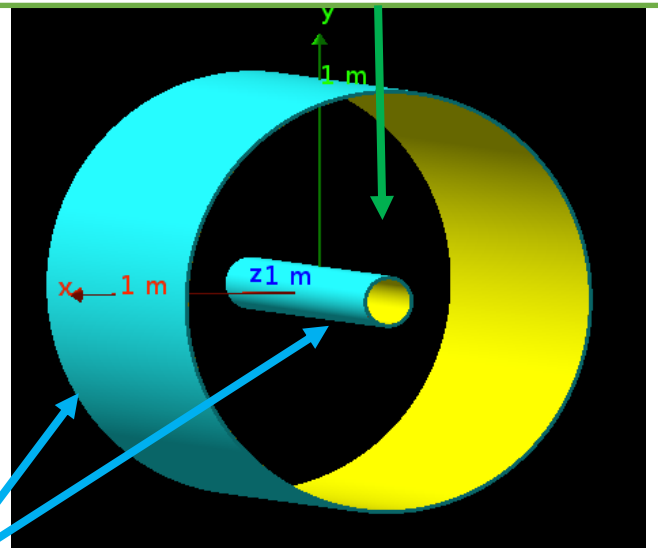
The eRD6 R&D Activities: Simulations

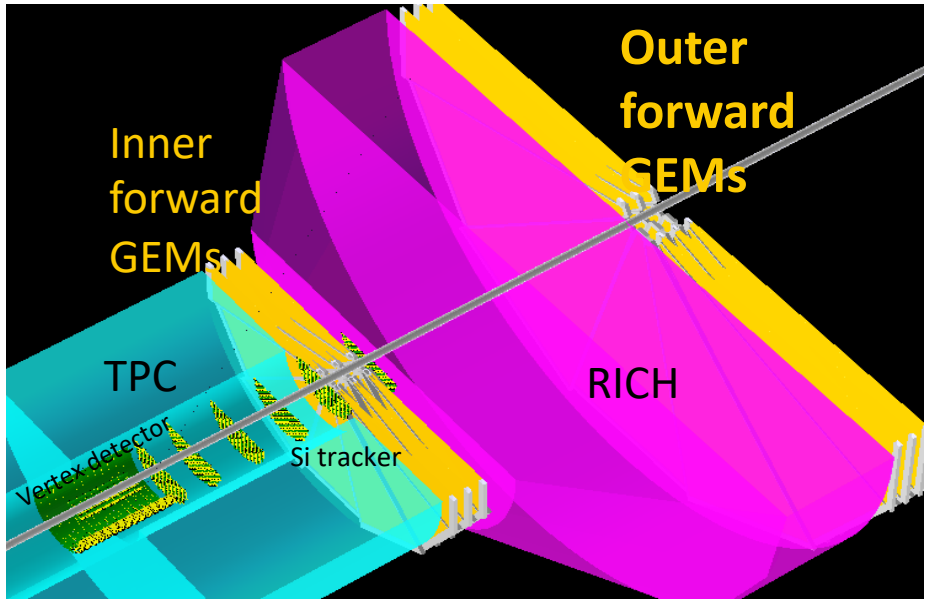
- **Simulations** (FIT, TU)
  - Actively involved in tracking performance studies of central and end cap regions
  - Fast $\mu RWell$ cylindrical trackers (TU)
    - Operate in μTPC mode
    - Provide information for DIRC as well as main central detector (e.g. TPC, Si) -> better PID
  - TPC in central region
  - GEM trackers in the forward region (FIT)
    - Outer forward GEMs would provide information to RICH -> better PID



Favorite central tracking detector
TPC, Silicon, …



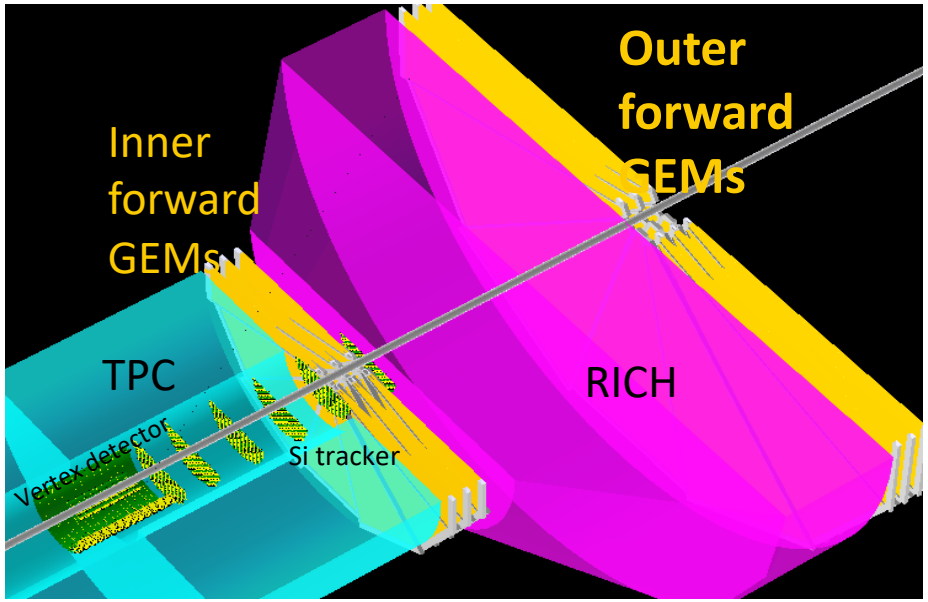
Fast $\mu RWell$
mini-drift trackers

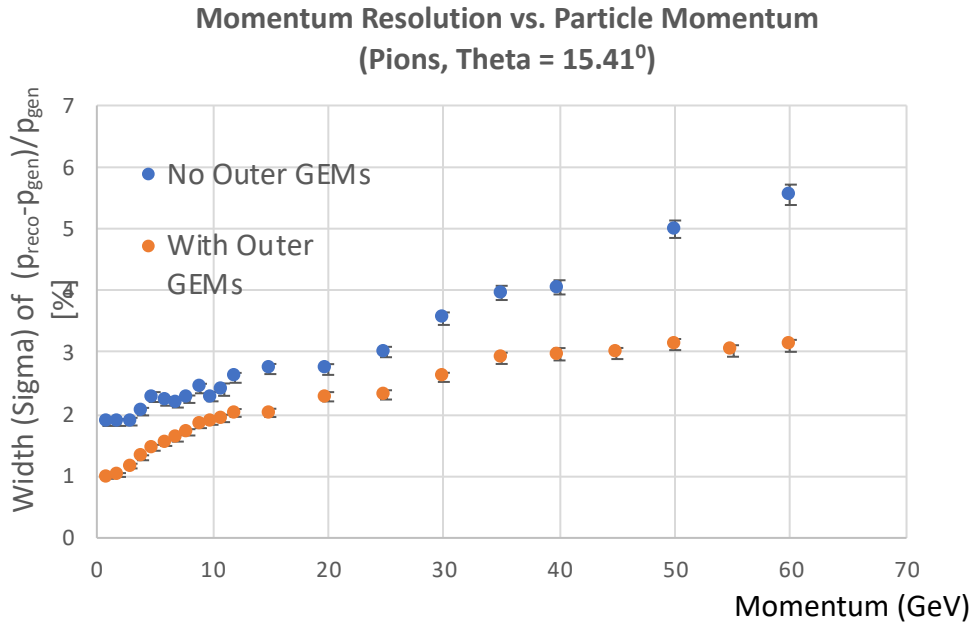


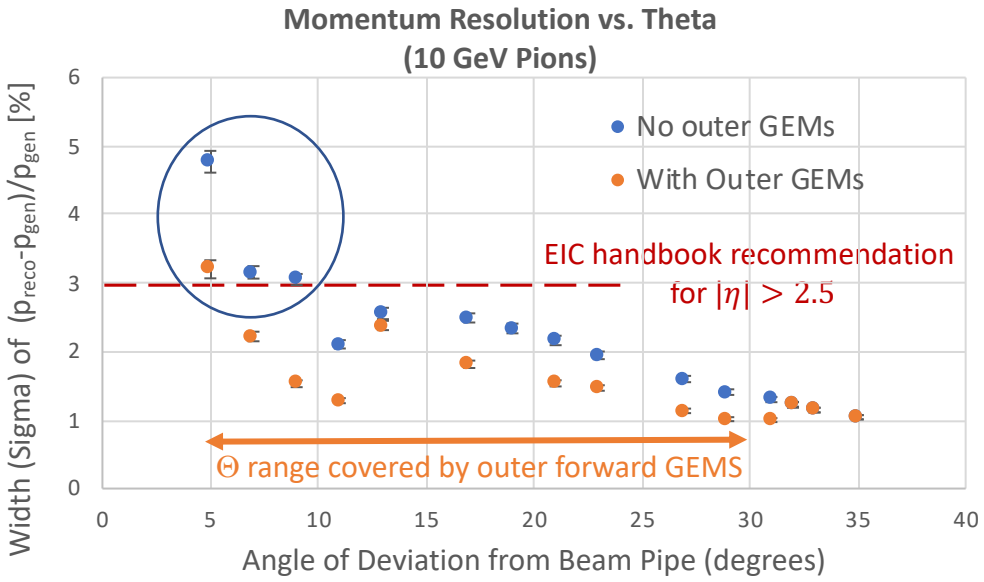
The eRD6 R&D Activities: Simulations

Outer Forward GEMs

- Impact of outer forward GEM trackers on RICH ring reconstruction still under investigation.
- Preliminary effects on momentum resolution have been studied.
  - Simulated detectors include
    - Vertex, silicon, and GEM trackers
    - TPC
    - RICH volume
    - Magnetic Field = 1.5 T







The eRD22 Team

- **eRD22**: *GEM-TRD/T*
- Generic EIC R&D Program: https://wiki.bnl.gov/conferences/index.php/EIC_R%25D

Project Statistics

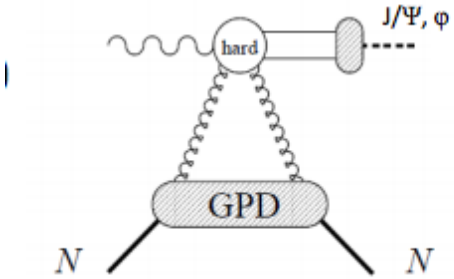
- Number of institutions/labs: 3 (Jefferson Lab, Temple University, and University of Virginia)
- Number of people: 11

R&D Focuses

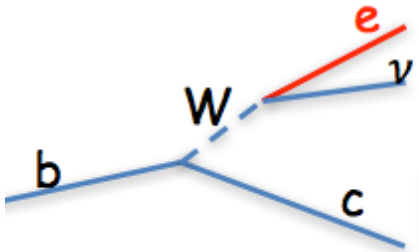
- GEM based transition radiation detector and tracker
  - F. Barbosa et al. "*A new Transition Radiation Detector Based on GEM Technology*". Nucl. Instrum. Meth. A 942, 162356 (2019). Doi: 10.1016/j.nima.2019.1

Electron Identification at EIC

- **Particle Decays**
  - J/ψ (spatial gluon distribution from photoproduction and DVCS, saturation)
  - Heavy quark (charm, beauty)
  - Spectroscopy
  - Beyond the Standard Model
- **Environment (Hadron endcap)**
  - Background: high multiplicity, large number of charged hadrons.
  - Large π^0 background
  - Electrons from particle delays will be boosted towards hadron endcap
- **A GEM TRD/Tracker**
  - TRD provides high e/h rejection for electrons in 1-100 GeV range.
  - GEM tracker functions as a μTPC (21 mm drift gap)
    - Provides high resolution tracking
    - Low mass
  - Located behind RICH detector would help with RICH ring reconstruction

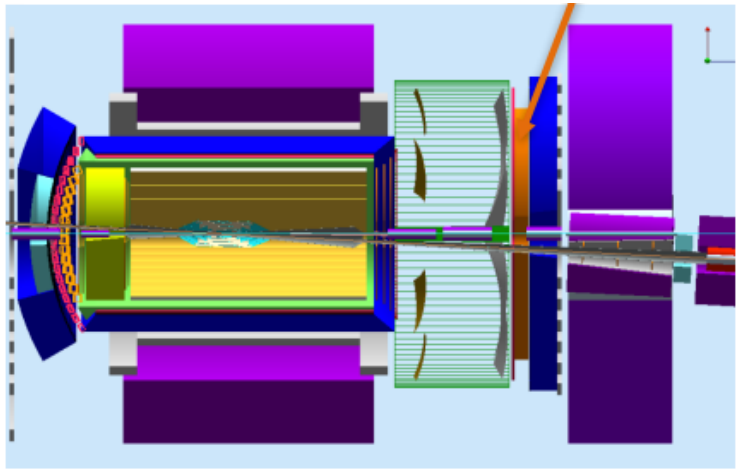


Br (J/ψ->e+e-) ~6%



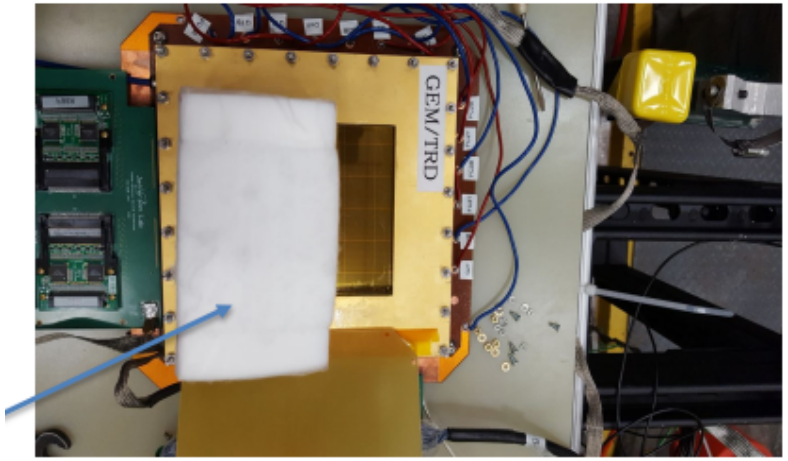
Br ($B^{\pm}$->e+ν+X_c) ~10%

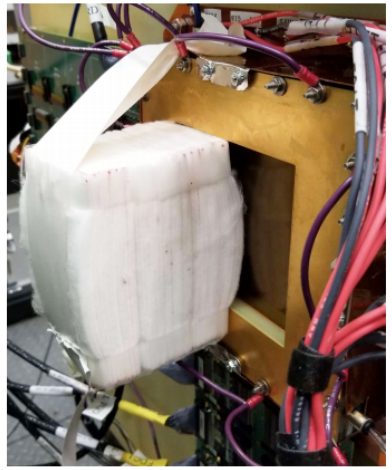
Br (D+ -> e + X) ~16%
Br (D0 -> e + X) ~ 6.5%

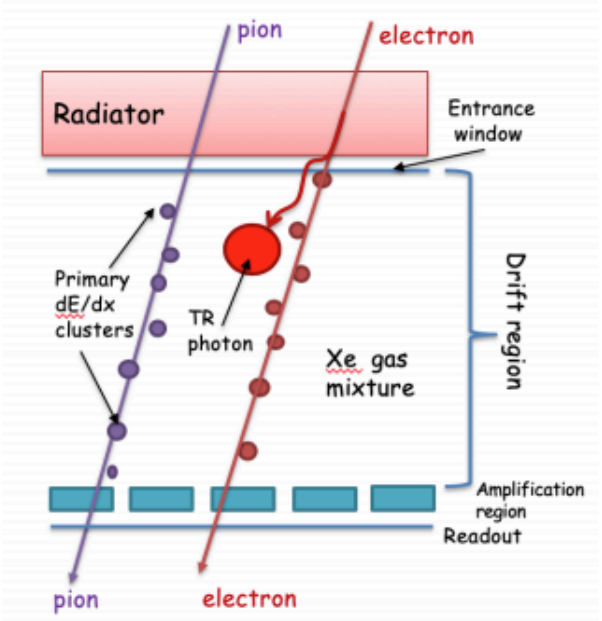


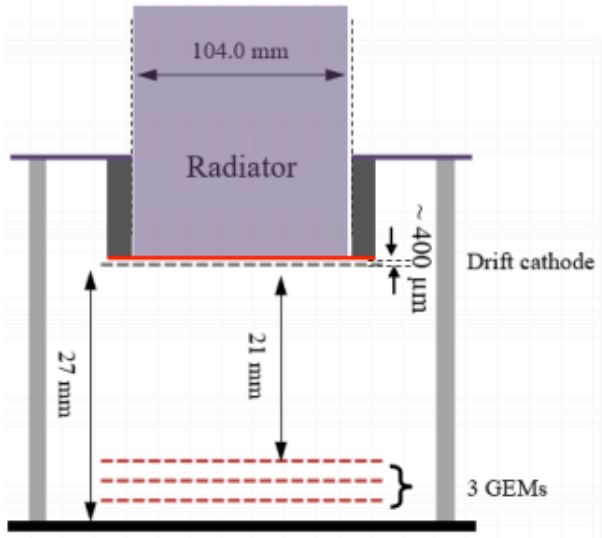
GEM TRD/T

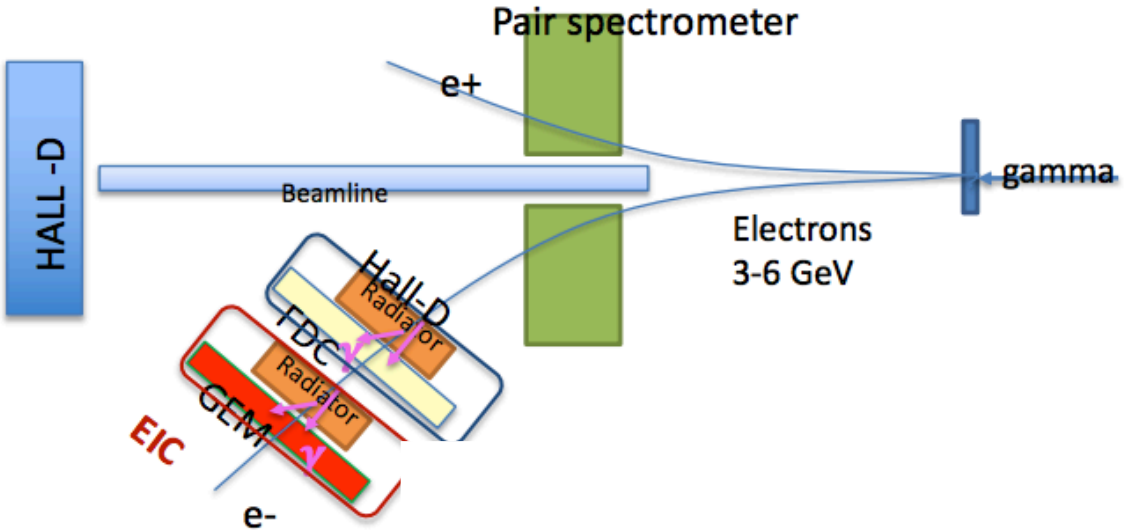
- **GEM TRD/Tracker Prototype** (JLab,TU, UVa)
  - $XeCO_2$ gas
  - Drift gap of 21 m
  - 10 cm radiator
  - Flash-ADC with VME based readout
    - work in progress for streaming readout mode







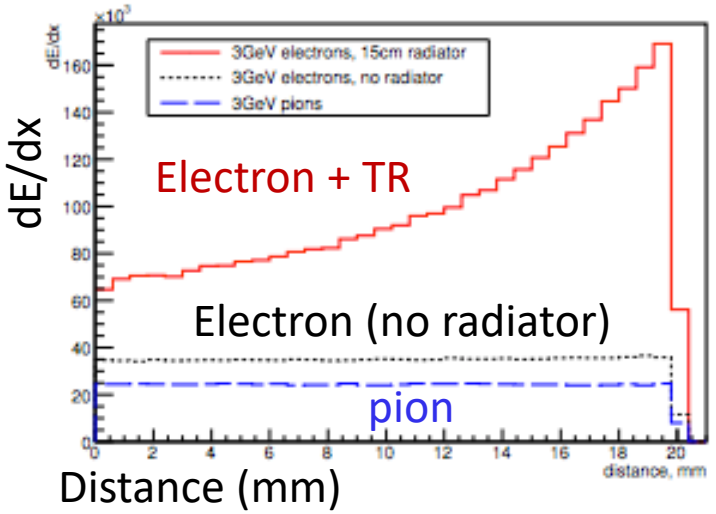


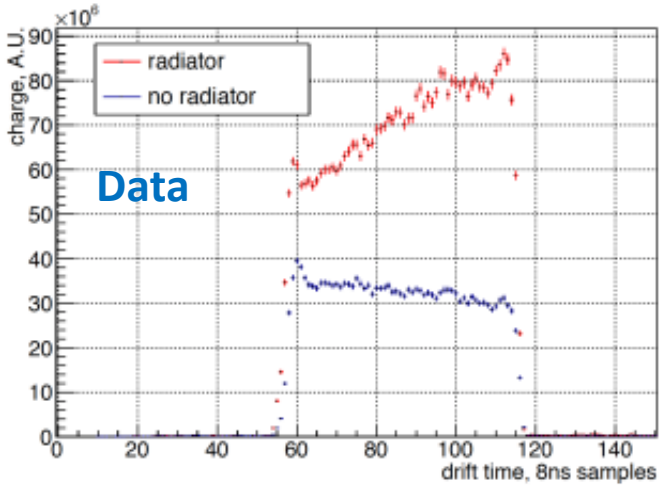


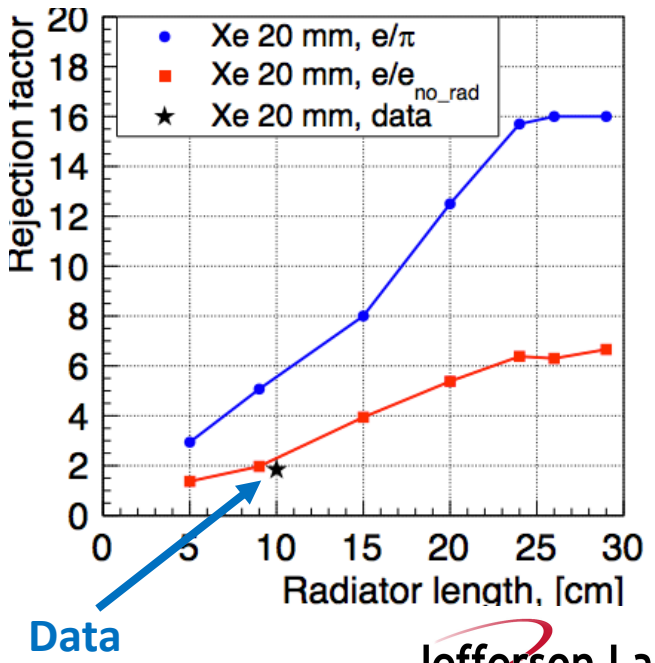
GEM TRD/T: PID

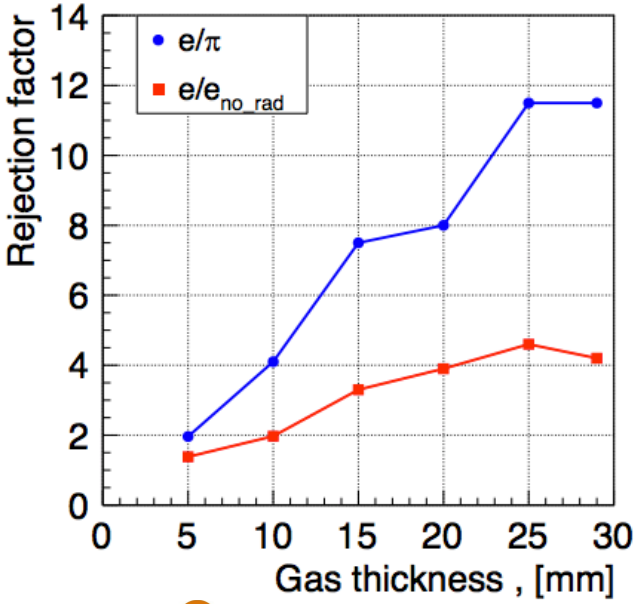
Nucl. Instrum. Meth. A 942, 162356 (2019).

- **PID of GME TRD/T**
  - Beam test ran in JLab Hall D with 3-6 GeV electron beam
  - e/π rejection can be assessed comparing dE/dx of electron with and without TR
    - Under estimates the true pion rejection factor
  - Good agreement between data and simulation
    - Several data analysis and machine learning (ML) approaches were used to estimate e/π rejection factor.



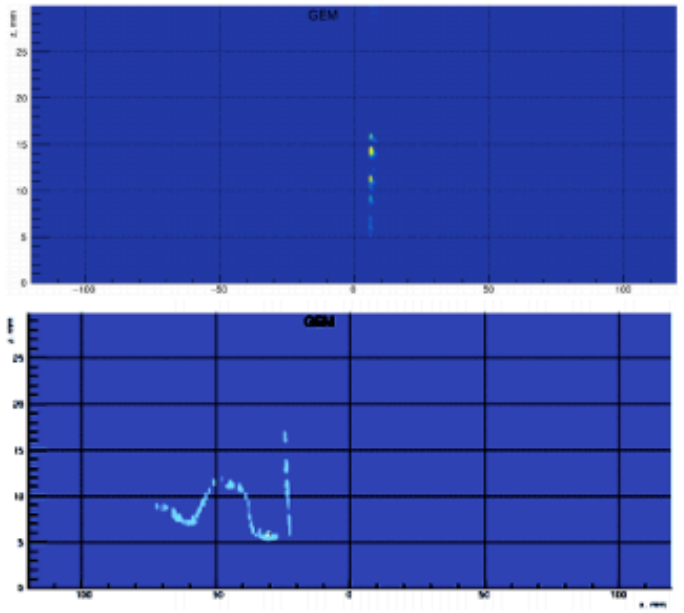




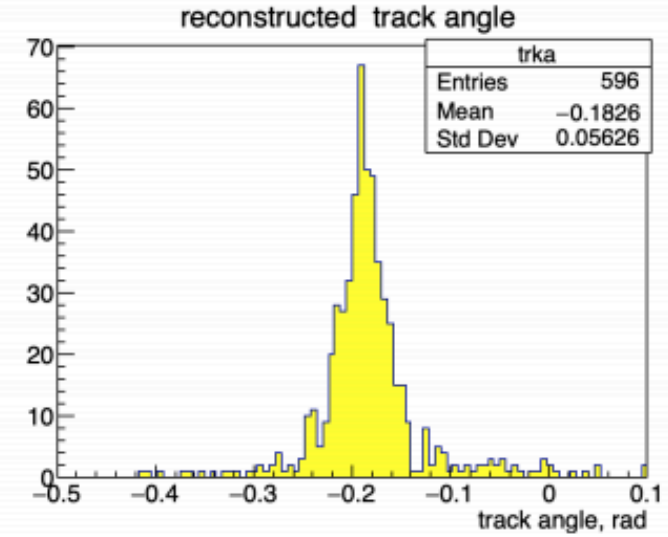


GEM TRD/T: Tracking

- **GEM TRD/T Tracking**
  - Triple-GEM readout can reconstruct X-Y hit locations
  - Operating with large drift gap in μTPC also allows for reconstruction of Z coordinate
- **GEM TRD/T has now been implemented into G4e software framework**
- **Flash-ADC is ideal, but investigating alternatives to reduce cost.**
- **Implemented ML in FPGA (Virtex5)**



Nucl. Instrum. Meth. A 942, 162356 (2019).



Angle of incoming electrons in the X plane

Thank You!

Thank You!

eRD6 Publications

- **BNL**
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  2. Maxence Vandenbroucke et al. “A Study of “Zigzag” Strip Readout for Micromegas Detectors”. In: 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference (2018 NSS/MIC). Nov. 2018, pp. 1–4. doi: 10.1109/NSSMIC.2018.8824702.
  3. B. Azmoun et al. “Design Studies for a TPC Readout Plane Using Zigzag Patterns with Multistage GEM Detectors”. In: IEEE Transactions on Nuclear Science (July 2018), pp. 1–1. issn: 0018-9499. doi: 10.1109/TNS.2018.2846403.
  4. B. Azmoun et al. “A Study of a Mini-Drift GEM Tracking Detector”. In: IEEE Transactions on Nuclear Science 63.3 (June 2016), pp. 1768–1776. issn: 0018-9499. doi: 10.1109/TNS.2016.2550503.
  5. Craig Woody et al. “A Prototype Combination TPC Cherenkov Detector with GEM Readout for Tracking and Particle Identification and its Potential Use at an Electron Ion Collider”. In: 2015. arXiv: 1512.05309 [physics.ins-det]. url: https://inspirehep.net/record/1409973/files/arXiv: 1512.05309.pdf.
  6. B. Azmoun et al. “Initial studies of a short drift GEM tracking detector”. In: 2014 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC). Nov. 2014, pp. 1–2. doi: 10.1109/ NSSMIC.2014.7431059.
  7. M. L. Purschke et al. “Test beam study of a short drift GEM tracking detector”. In: 2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (2013 NSS/MIC). Oct. 2013, pp. 1–4. doi: 10.1109/NSSMIC.2013.6829463.
- **INFN**
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  2. J. Agarwala et al. *“Study of MicroPattern Gaseous detectors with novel nanodiamond based photocathodes for single photon detection in EIC RICH"*. In: Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2019). issn : 0168-9002. doi : https://doi.org/10.1016/j.nima.2019.03.022 . url : http://www.sciencedirect.com/science/article/pii/S0168900219303213 .

eRD6 Publications

- **FIT**

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2. Aiwu Zhang et al. *"A GEM readout with radial zigzag strips and linear charge-sharing response"*. In:Nucl. Instrum. Meth. A887 (2018), pp. 184. arXiv: 1708.07931 [physics.ins-det].
3. Aiwu Zhang and Marcus Hohlmann. *"Accuracy of the geometric-mean method for determining spatial resolutions of tracking detectors in the presence of multiple Coulomb scattering"*. In: JINST 11.06 (2016), P06012. doi: 10.1088/1748-0221/11/06/P06012. arXiv: 1604.06130 [physics.data-an].
4. Aiwu Zhang et al. *"R&D on GEM detectors for forward tracking at a future Electron-Ion Collider"*. In: Proceedings, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC 2015): San Diego, California, United States. 2016, p. 7581965. doi: 10.1109/NSSMIC.2015.7581965. arXiv: 1511.07913 [physics.ins-det]. url: http://inspirehep.net/record/1406551/files/arXiv:1511.07913.pdf.
5. Aiwu Zhang et al. *"Performance of a Large-area GEM Detector Read Out with Wide Radial Zigzag Strips"*. In: Nucl. Instrum. Meth. A811 (2016), pp. 30. doi: 10.1016/j.nima.2015.11.157. arXiv:1508.07046 [physics.ins-det].

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- **TU**

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2. M. Posik and B. Surrow. *"Construction of Triple-GEM Detectors Using Commercially Manufactured Large GEM Foils"*. In: Proceedings, 2016 IEEE Nuclear Science Symposium and Medical Imaging Conference: NSS/MIC 2016: Strasbourg, France. 2016, p. 8069743. doi: 10 . 1109 / NSSMIC . 2016 .8069743. arXiv: 1612.03776 [physics.ins-det].
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- **UVa**

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2. Kondo Gnanvo et al. *"Performance in test beam of a large-area and light-weight GEM detector with 2D stereo-angle (UV) strip readout"*. In: Nucl. Instrum. Meth. A808 (2016), pp. 83. doi : 10.1016/j.nima.2015.11.071 . arXiv: 1509.03875 [physics.ins-det] .

- **Yale**

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