The GeN-RP Experiment and Neutron Electromagnetic Form Factor Measurements on the SBS at JLab

John Boyd

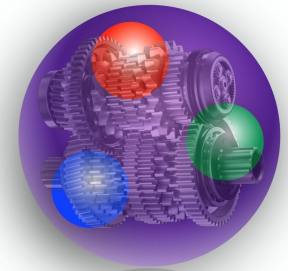
University of Virginia
Department of Physics

e-HUGS Seminar
June 17, 2021

Outline

- Motivation
- The Super BigBite Spectrometer
- GEn-RP Experiment on the SBS
- GEM Detectors
- UV Readout GEM Detectors

Motivation



Form Factors

- Important observables for characterization of the nucleon
- Describe the spatial distribution of electric charge and magnetization
- From $G_E(Q^2=0)$ and $G_M(Q^2=0)$ we can obtain the electric charge and magnetic moment
- From the slope of $G_E(Q^2=0)$ and $G_M(Q^2=0)$ we can obtain the electric radius and magnetic radius

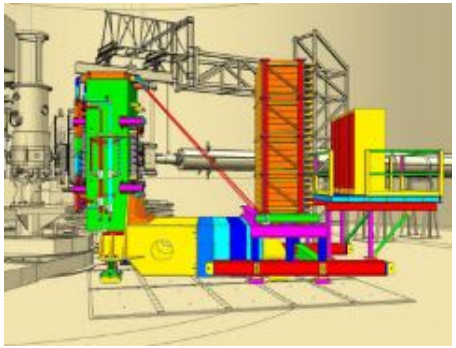
High Momentum-transfer Q^2 Measurements

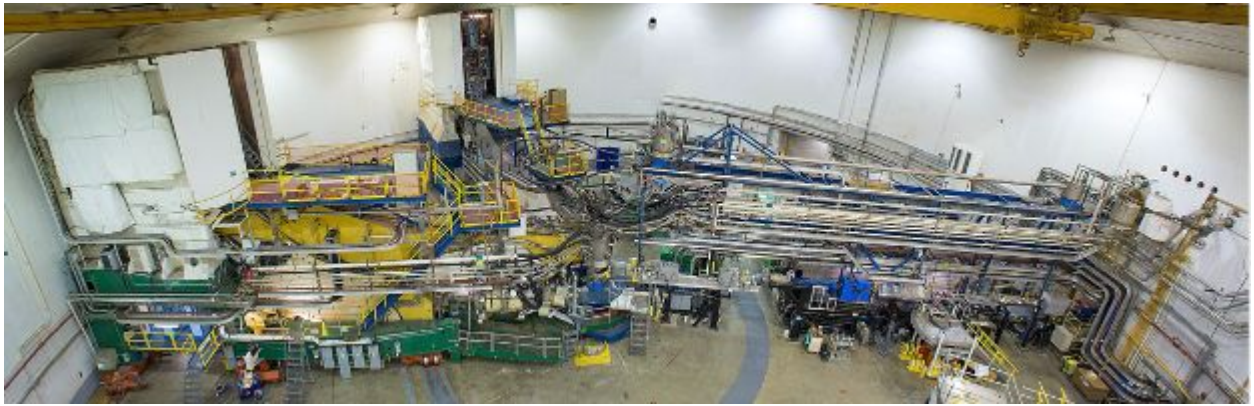
- Test the validity of predictions such as quark models and pQCD
- Comparisons to Lattice QCD
- Provide input to DVCS measurements
- Probing deeper into GPDs

The Super BigBite Spectrometer (SBS)

The SBS (Jefferson Lab's Experimental Hall A) is a large-aperture, high-acceptance detector package that will measure elastic electromagnetic form factors at the highest Q^2 momentum-transfer values and highest level of precision yet to be achieved.

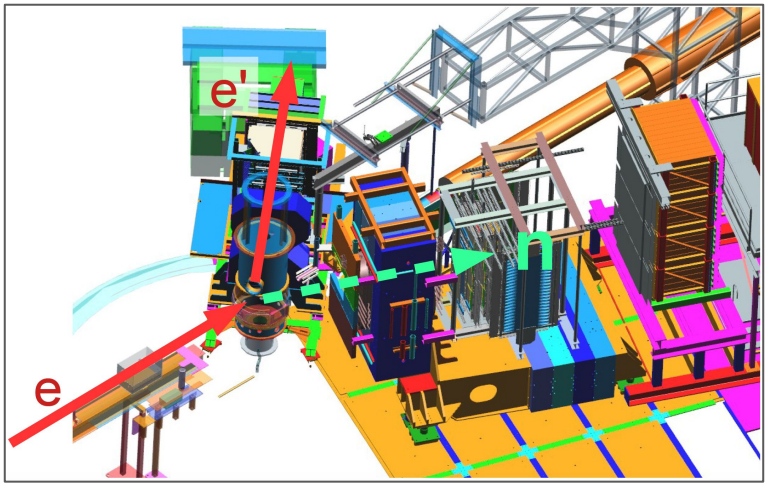
- Solid angle acceptance: **~75 msr**
- Designed for large amounts of particles and high background rates (**~1 MHz/cm^2**)
- Will be arranged for the following 12 GeV program experiments: G_M^n, G_E^n, G_E^n-RP, nTPE, and G_E^pV



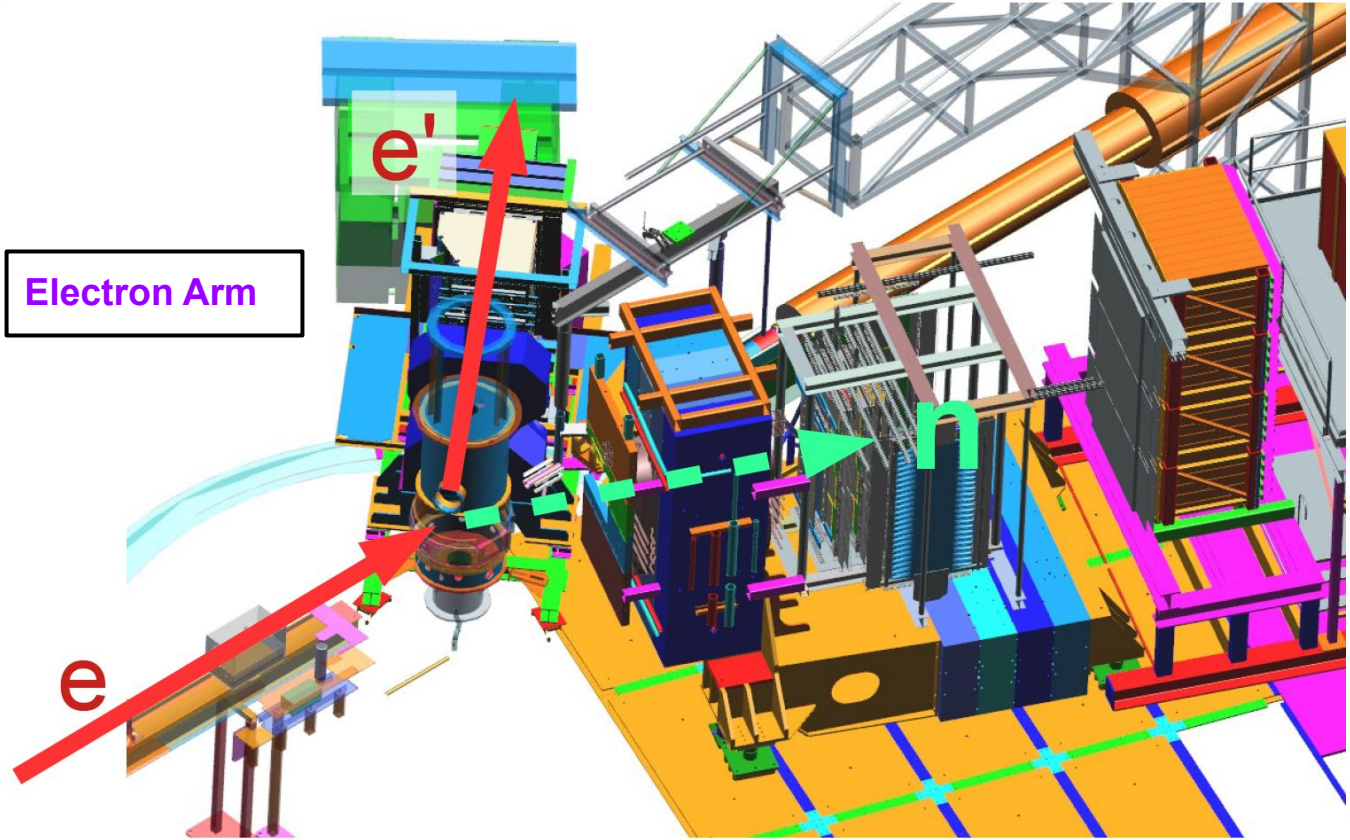


GEn-RP Experiment on the SBS at JLab

- GEn-RP (2021) will measure G_E^n/G_M^n using a polarized electron beam and an unpolarized deuterium target at a Q^2 of $4.5\ (\mathrm{GeV/c})^2$.
- Using two recoil polarimetry techniques:
  - ❏ Charge-Exchange $np \rightarrow pn$
  - ❏ Conventional: $np \rightarrow np$

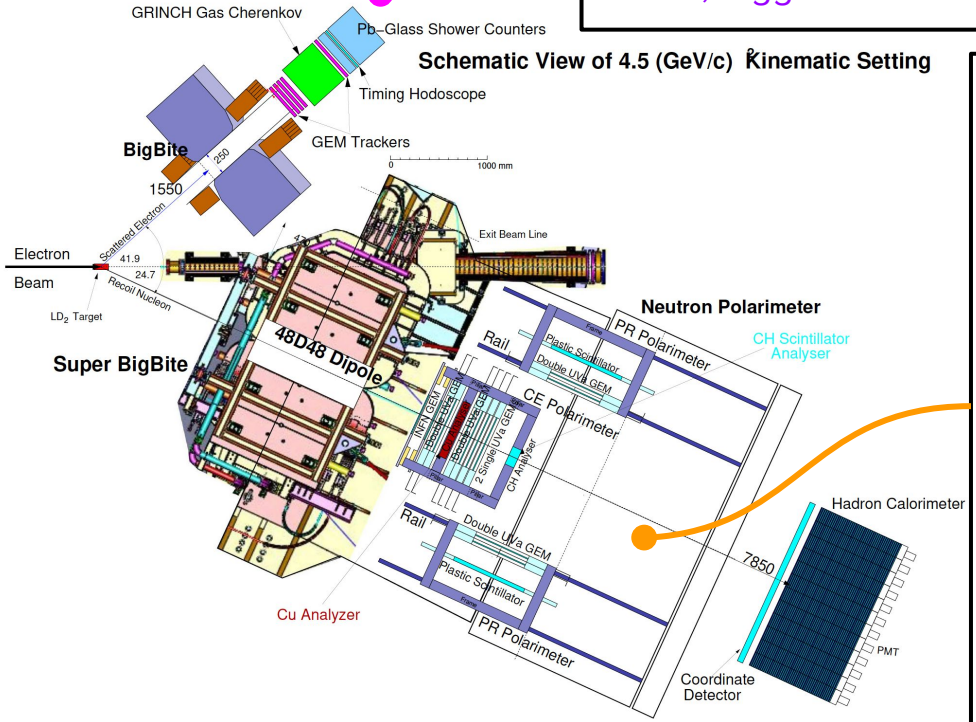


GEn-RP Experiment on the SBS at JLab



GEn-RP Experiment on the SBS at JLab

Scattered electron will be measured in BigBite (momentum, direction, reaction vertex, trigger time correlation)



Neutron arm/Polarimeter (position, time-of-flight, and spin precession for recoiling nucleon):

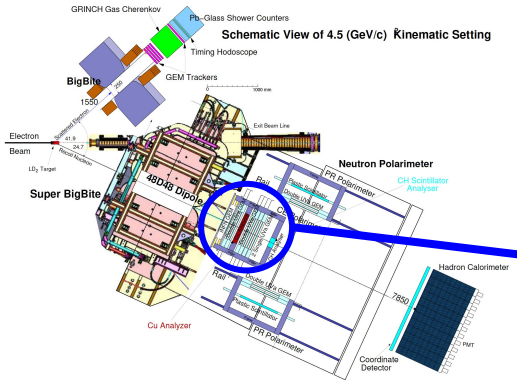
Charge-Exchange: $np \rightarrow pn$

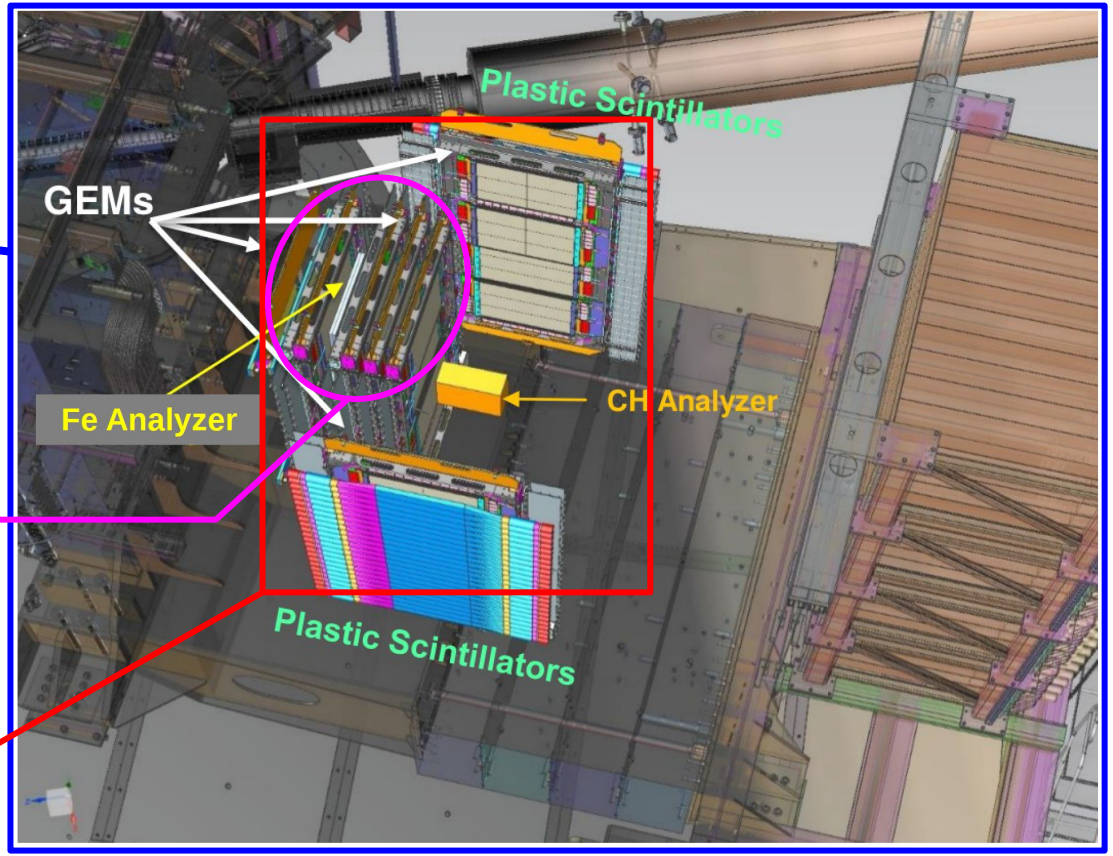
- Steel Analyzer (passive)
- GEM tracking and HCal measurement of forward protons
- GEM proton veto

Scattering: $np \rightarrow np$

- Plastic CH Analyzer (Active)
- Large-angle recoil protons ➔ side detectors
- Forward neutrons ➔ HCal

GEn-RP Polarimeter





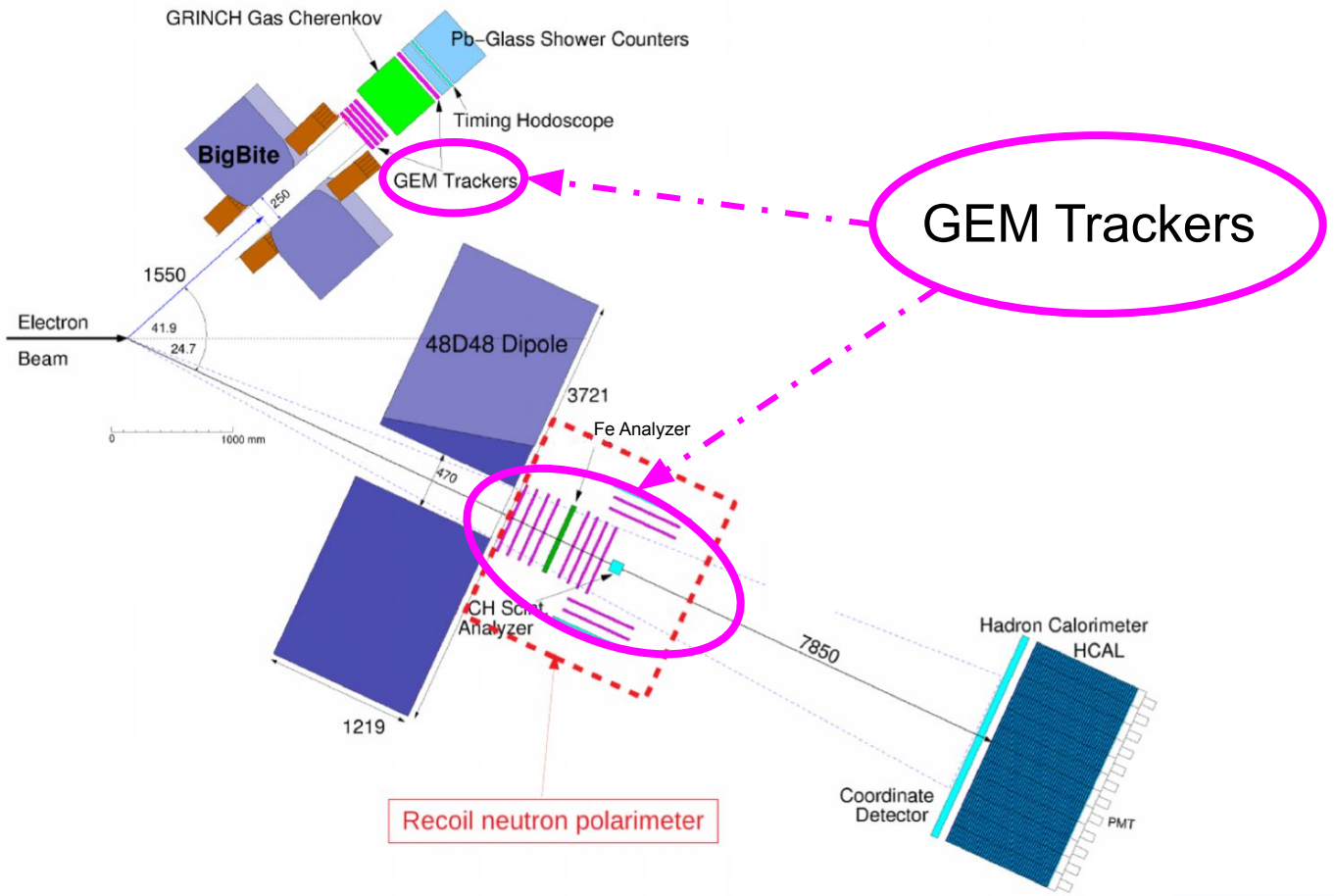
Charge Exchange Polarimeter
- 6 UVa GEMs
- 2 INFN GEMs
- Fe Analyzer

High momentum forward protons after charge exchange np → pn

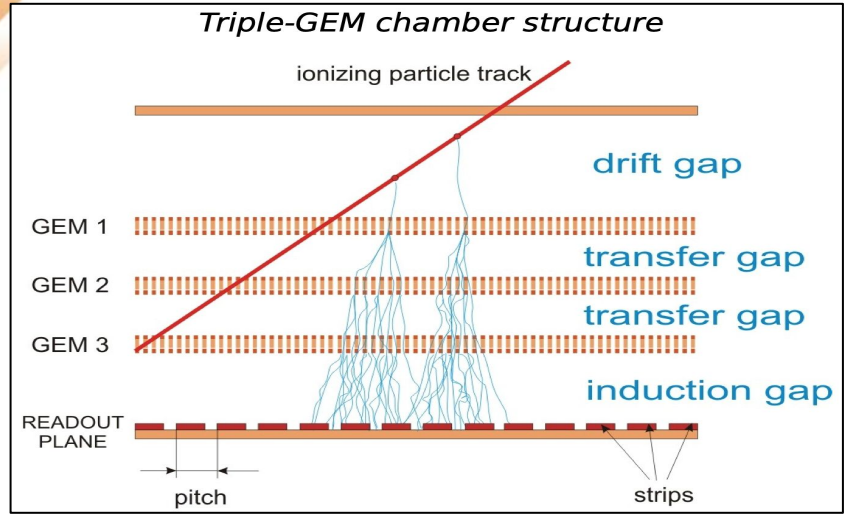
Proton Recoil Polarimeter
- Active CH Analyzer
- Front & side detectors

Low momentum, large-angle, recoiling protons after np → np

SBS Charged Particle Tracking With GEMs



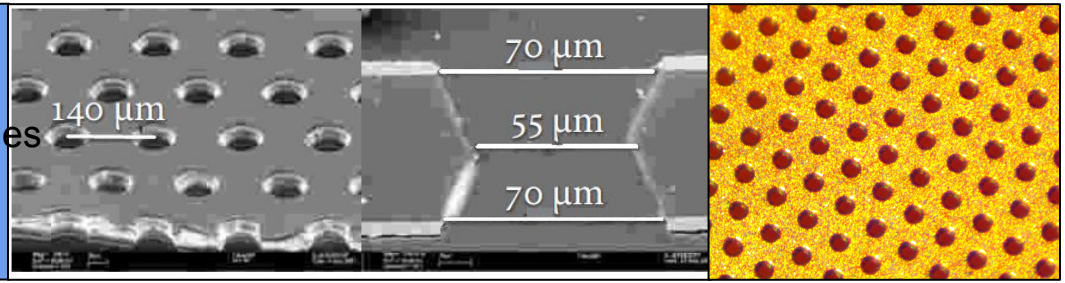
Gas Electron Multiplier (GEM) Detectors

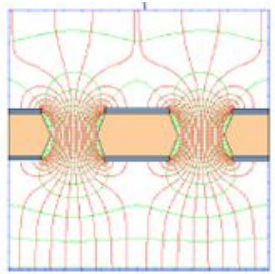


GEM detectors: cost effective solution for high resolution tracking under high rates over large areas.

- High-rate capability **(> 100s of MHz/cm^2)**
- High position resolution (**< 70 μm**)
- Large area coverage (**10 - 100's of m^2**)
- Low thickness (**~0.5% radiation length**)

GEM foil: 50 μm Kapton + few μm copper on both sides with holes & pitch, as shown

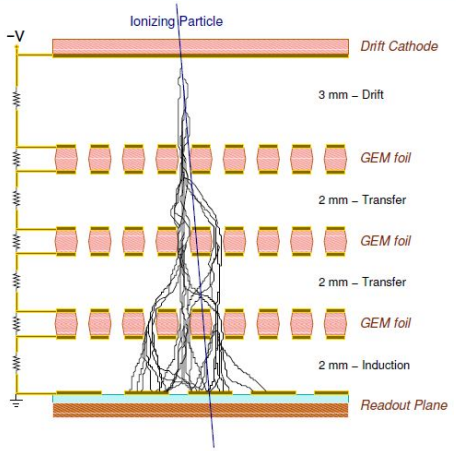




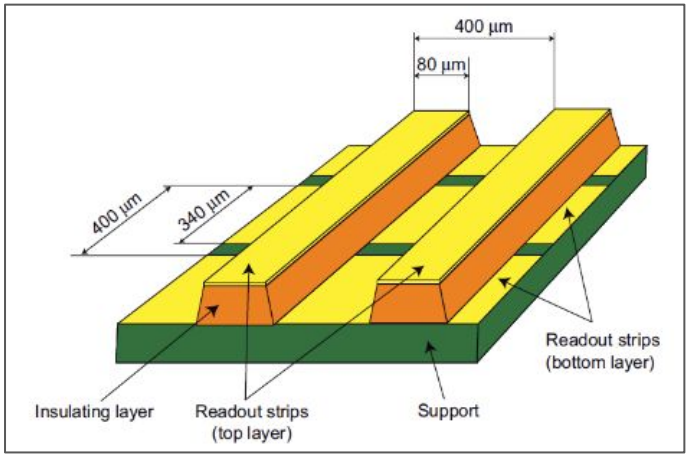
Strong electrostatic field in the GEM holes

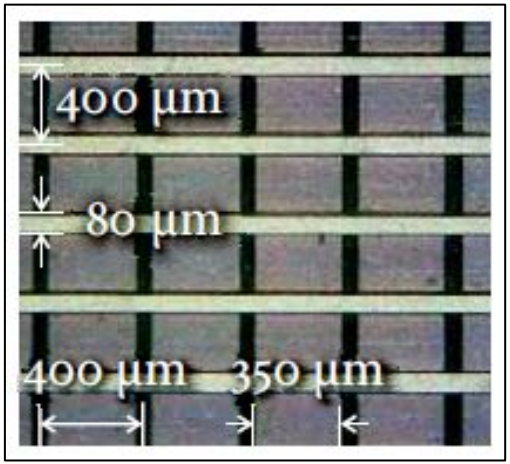
GEM Detectors - Readouts

- The avalanche cascades through the foil layers until it is read out on the **Readout Plane**.
- Readout plane consists of strips which detect incident particles.
- In an X-Y configuration the strips are orthogonal to each other.



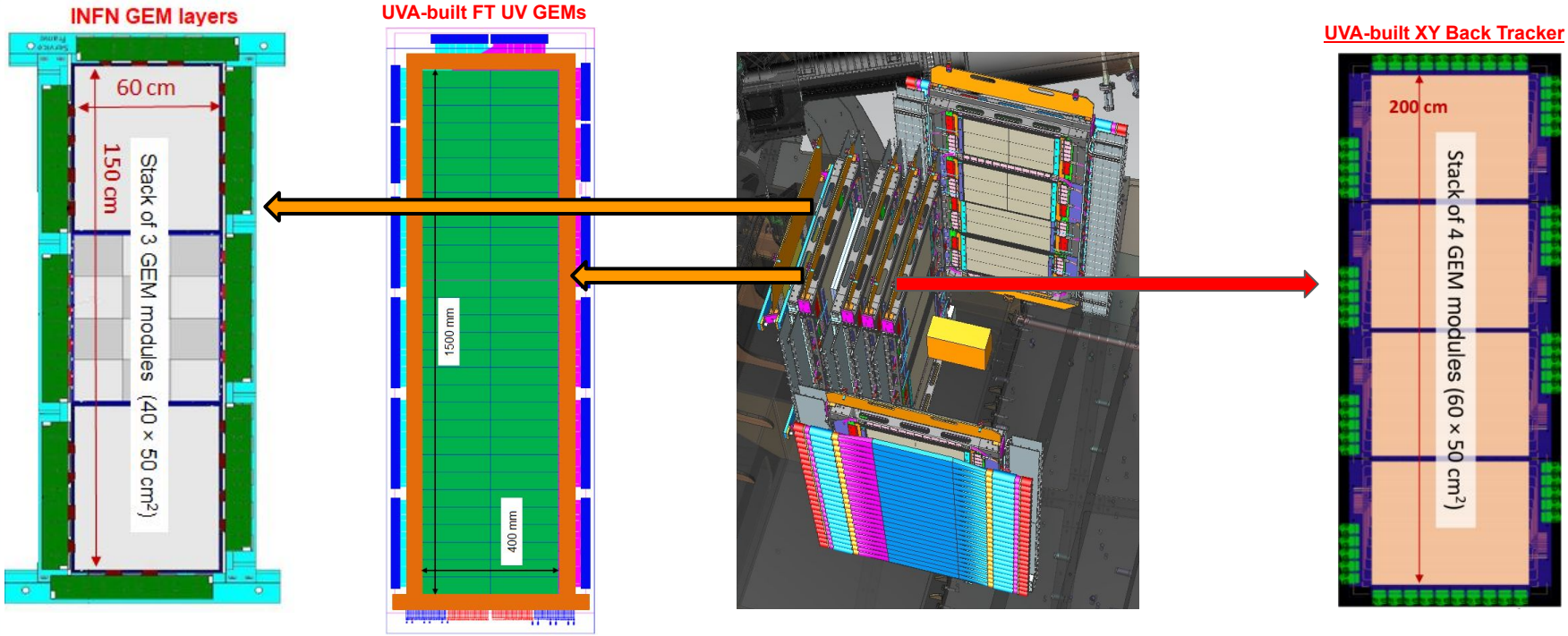
"Typical" X-Y Readout Planes





GEM Detectors on the SBS (GEn-RP)

Front and **Rear** GEM trackers are UVa-built triple-foil GEM modules.



A need for new & additional GEMs in the SBS

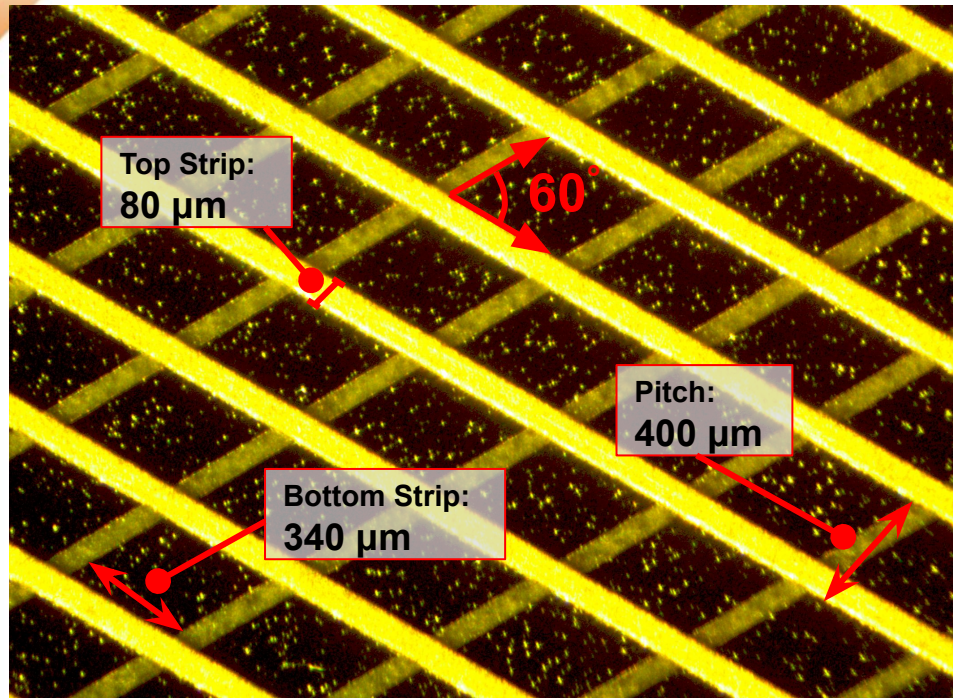
- SBS: high particle numbers and thus higher rates.
- Higher particle numbers & higher rates → harder parsing/analysis

A solution: additional GEMs with non "X-Y" readouts → "U-V" GEMs

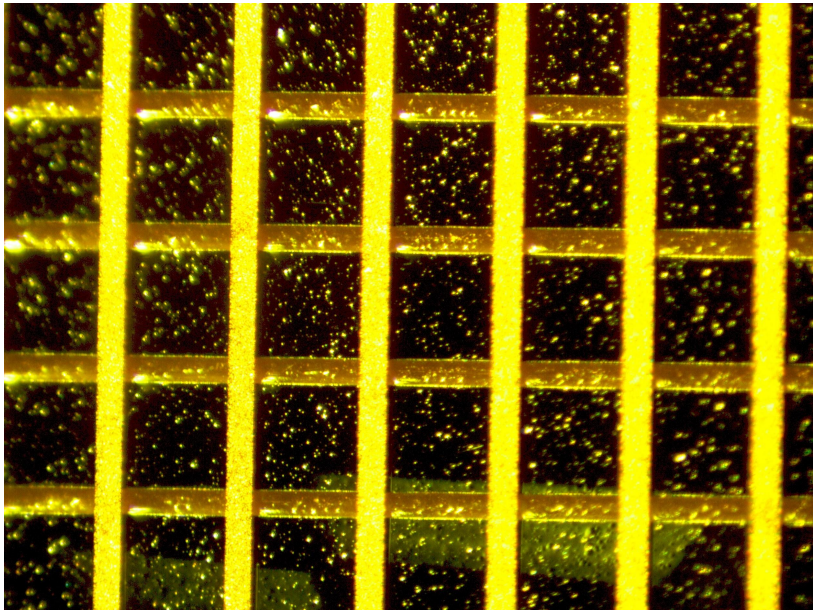
- Introduce trackers with a non-orthogonal readout plane.
- Coincidences must now correlate across readouts with orthogonal X-Y strips and non-orthogonal U-V strips.
- Thus, reducing combinatorics
- 4 U-V GEM modules being built at UVa to be installed at JLab

Comparison of UV and XY Readout Planes

"UV" Readout Plane



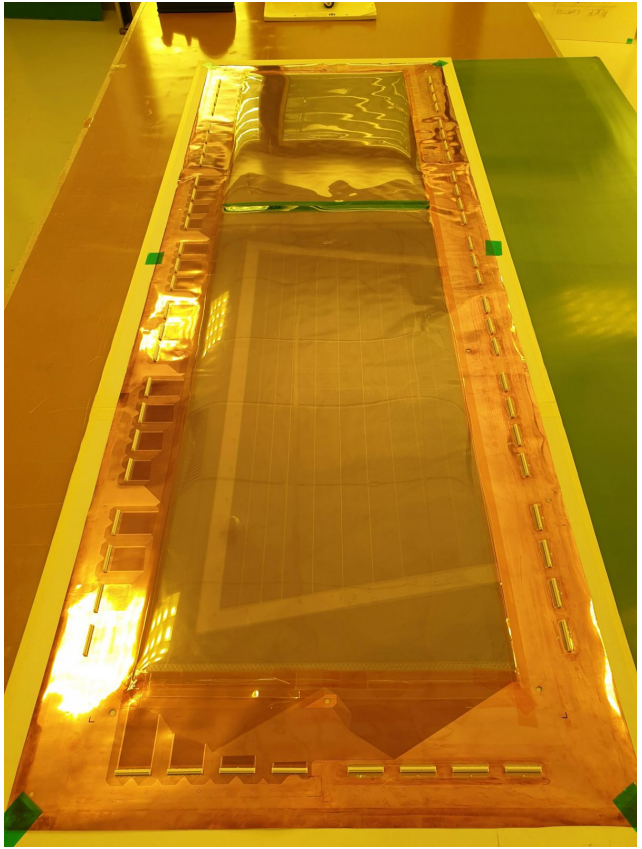
"XY" Readout Plane



GEM Components

UV GEM Foil

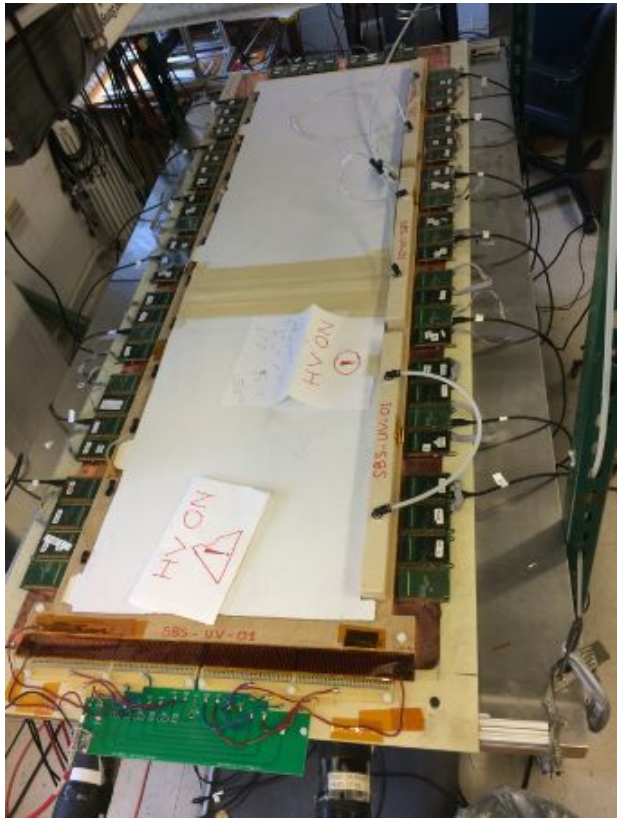
UV Readout Board



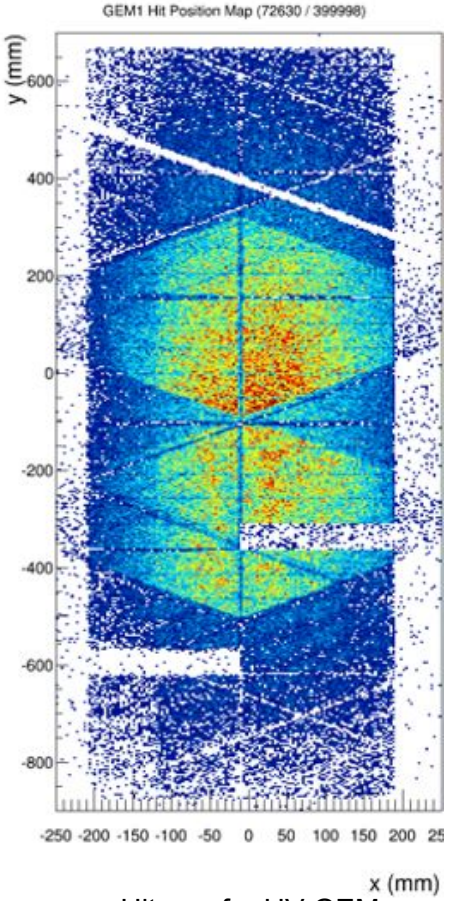
XY GEM Foil

*Manufactured by TS-DEM group at CERN, based on the UVa design

UV GEM Preliminary Data



Completed UV chamber on cosmic test stand



Hitmap for UV GEM

Summary

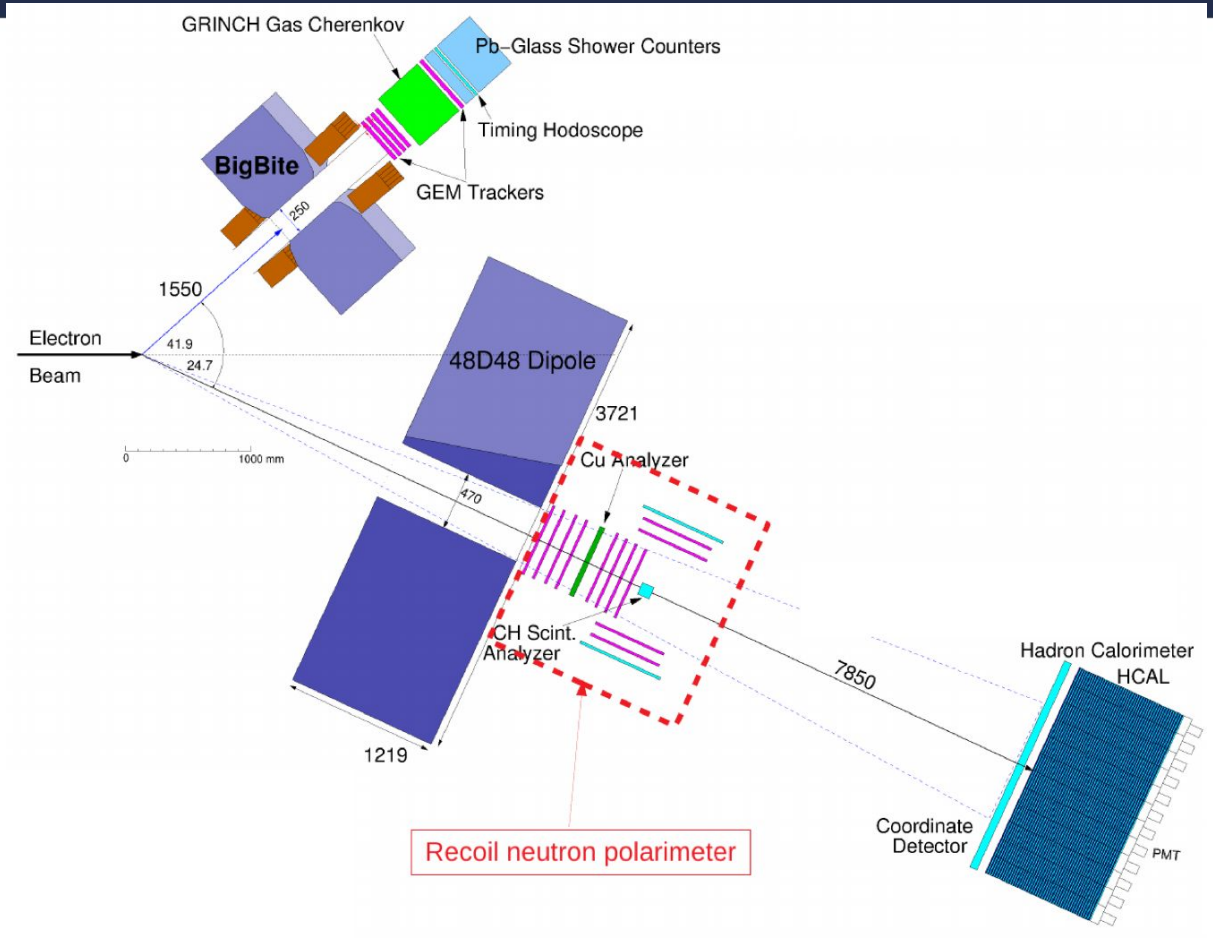
- EMFFs serve key roles in the investigation of nucleon structure and GPDs.
- Super Bigbite Spectrometer: Upcoming series of high Q^2 experiments to measure various form factors at highest levels of precision.
- GEM detectors are principal components for particle tracking/measurement.
- Two types of GEMs have been developed by our research team.
- In the final stages of development/test of the UV GEM set of detectors.
- SBS experiments set to begin later this year, starting with GMn in September

Acknowledgements

- My advisor Nilanga Liyanage
- Research scientists Kondo Gnanvo, Huong Nguyen
- Post-docs Xinzhan Bai and Salina Ali
- Graduate students John Matter, Siyu Jian, Anuruddha Rathnayake, Sean Jeffas, Bhashitha Thuthimal Dharmasena, and Vimukthi Gamage.
- The SBS Collaboration
- The Department of Energy

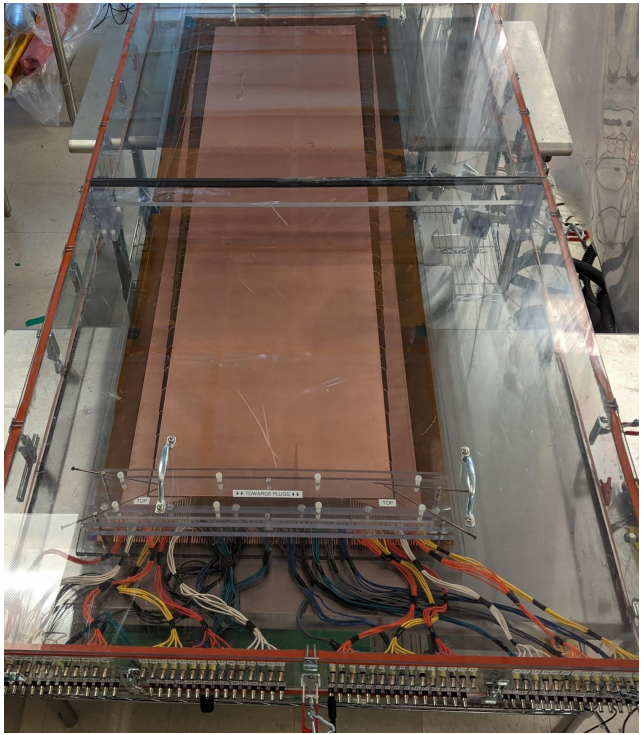
University of Virginia

Jefferson Lab

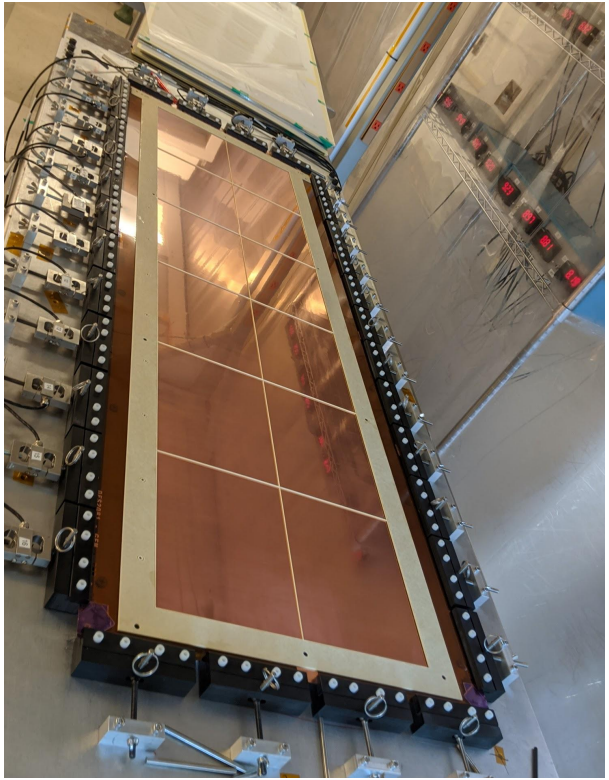

GRINCH Gas Cherenkov
Pb–Glass Shower Counters
Timing Hodoscope
BigBite
GEM Trackers
250
1550
Electron
Beam
41.9
24.7
48D48 Dipole
3721
0
1000 mm
Cu Analyzer
470
CH Scint.
Analyzer
7850
Hadron Calorimeter
HCAL
1219
Recoil neutron polarimeter
Coordinate
Detector
PMT

UV GEM Construction/Assembly/Test

U-V Frames Pre-Assembly

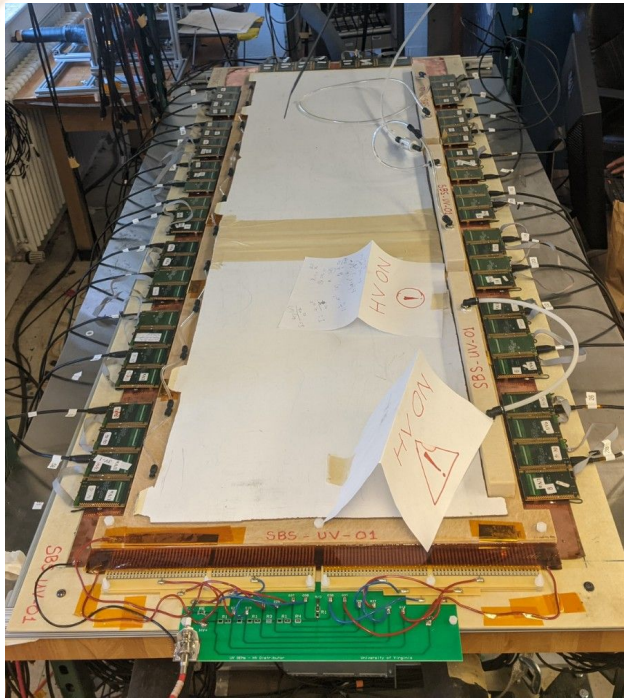


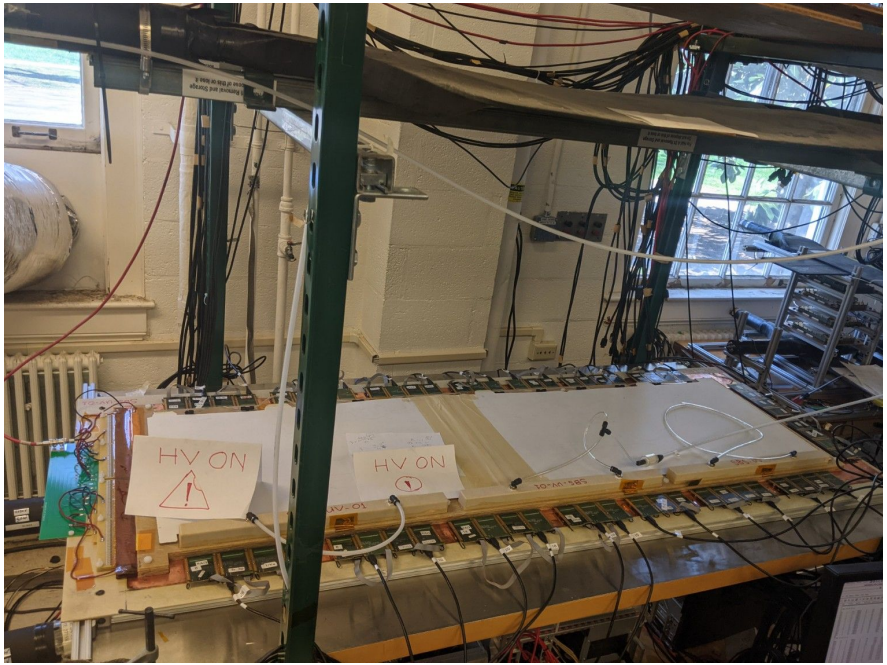
Testing a UV GEM foil under high voltage in a dry nitrogen environment



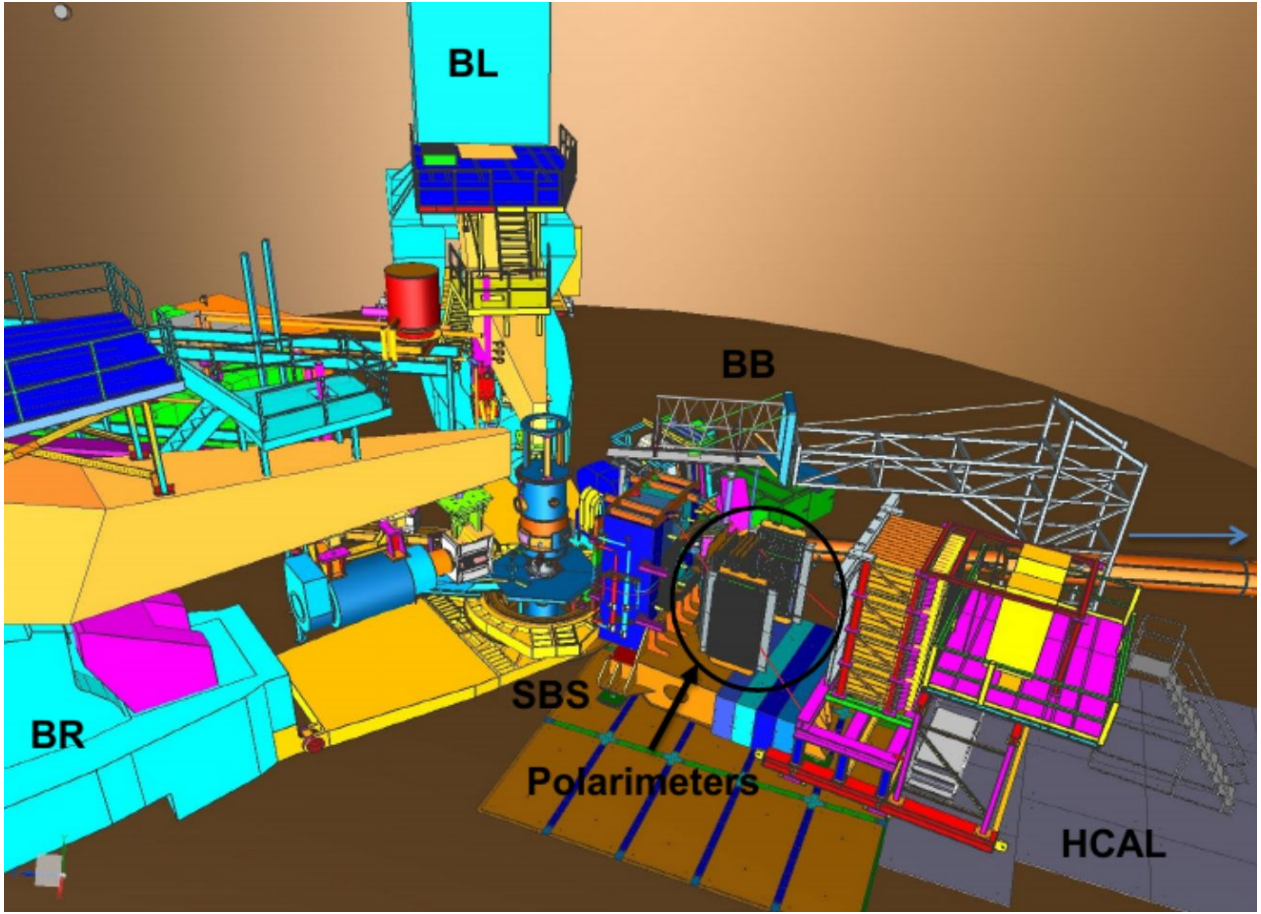
UV frame installed onto a mechanically-stretched GEM foil

UV GEM Construction/Assembly/Test





Assembled UV GEM Chamber on a cosmic test stand


BL
BB
SBS
BR
Polarimeters
HCAL