Design and production of GEM modules for the MOLLER experiment

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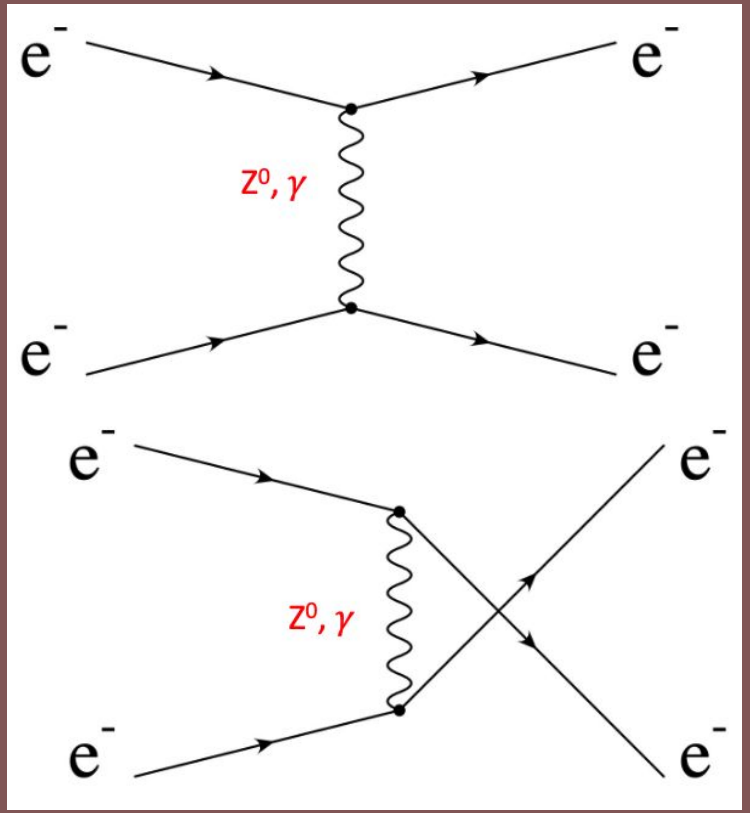
MOLLER experiment

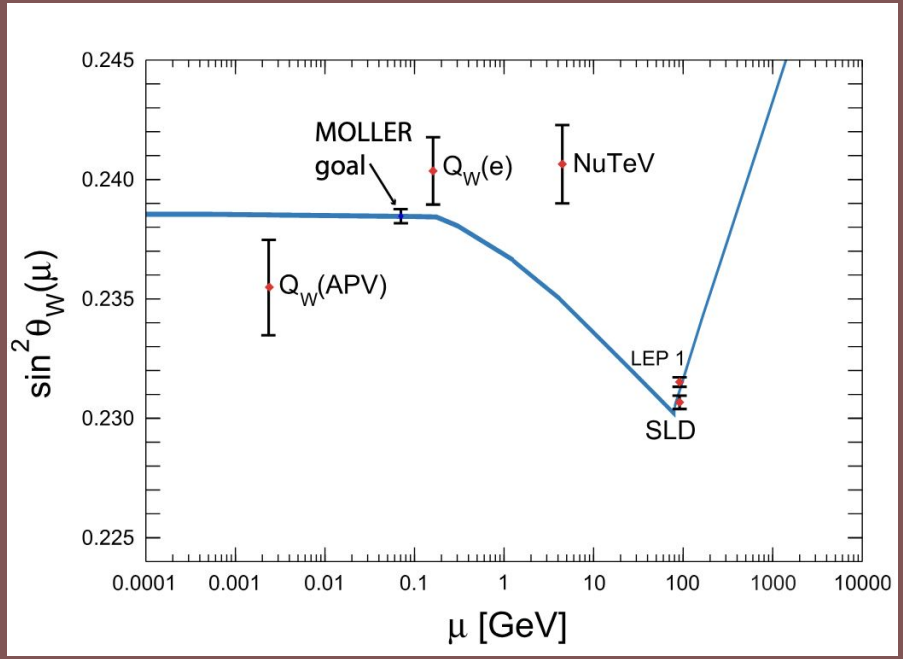
- Fixed target polarized e^- + e^- scattering
- Measure parity violation in Moller scattering
  - Interference between photon and Z



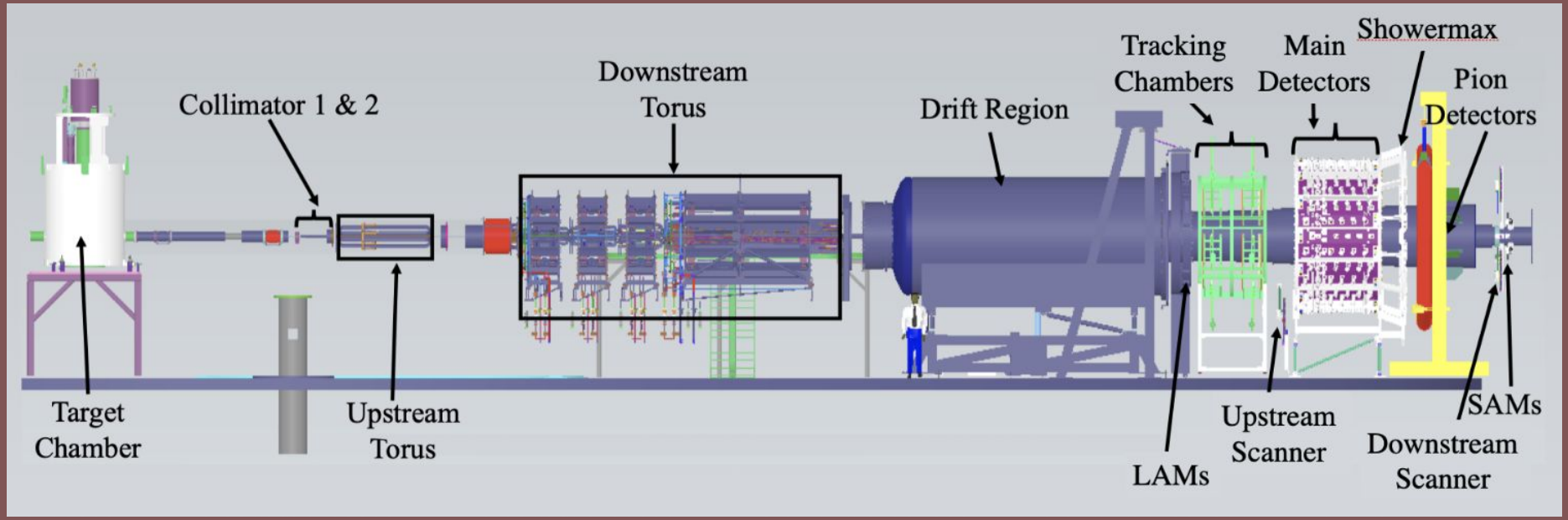
MOLLER experiment

$$\frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \equiv A_{PV} \propto \sin^2(\theta_W)$$

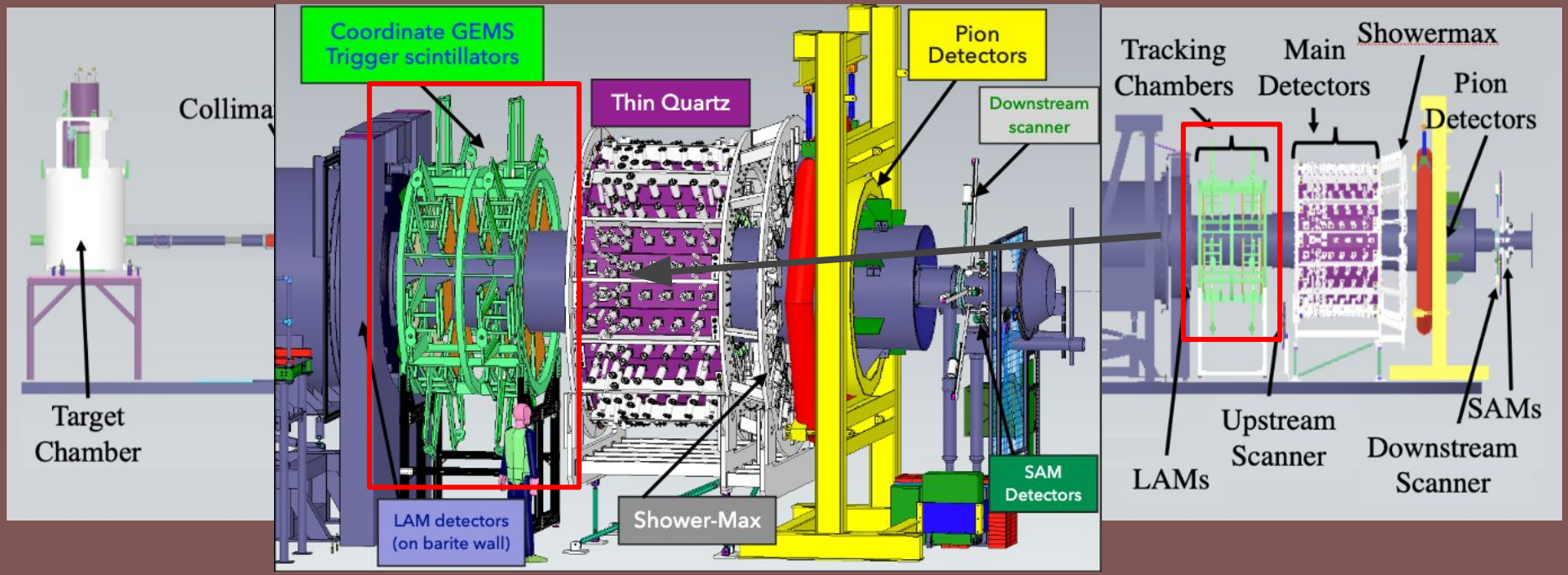
Unprecedented precision away from the Z-pole



MOLLER experiment



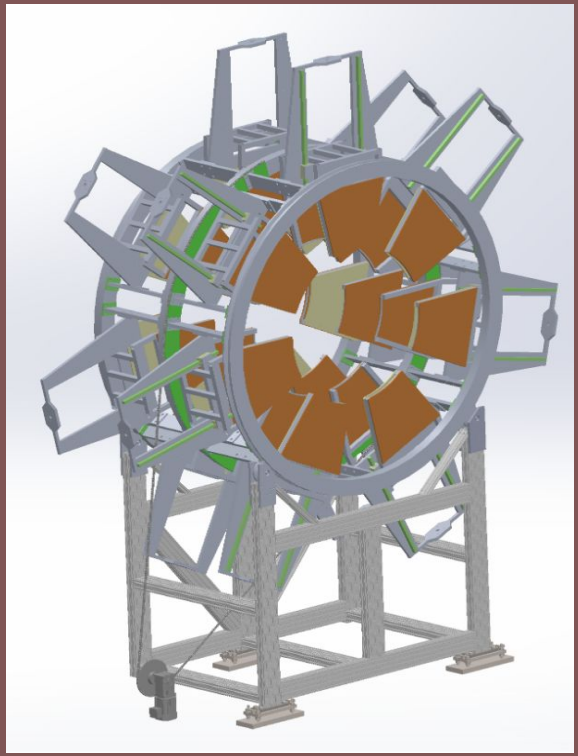
MOLLER experiment



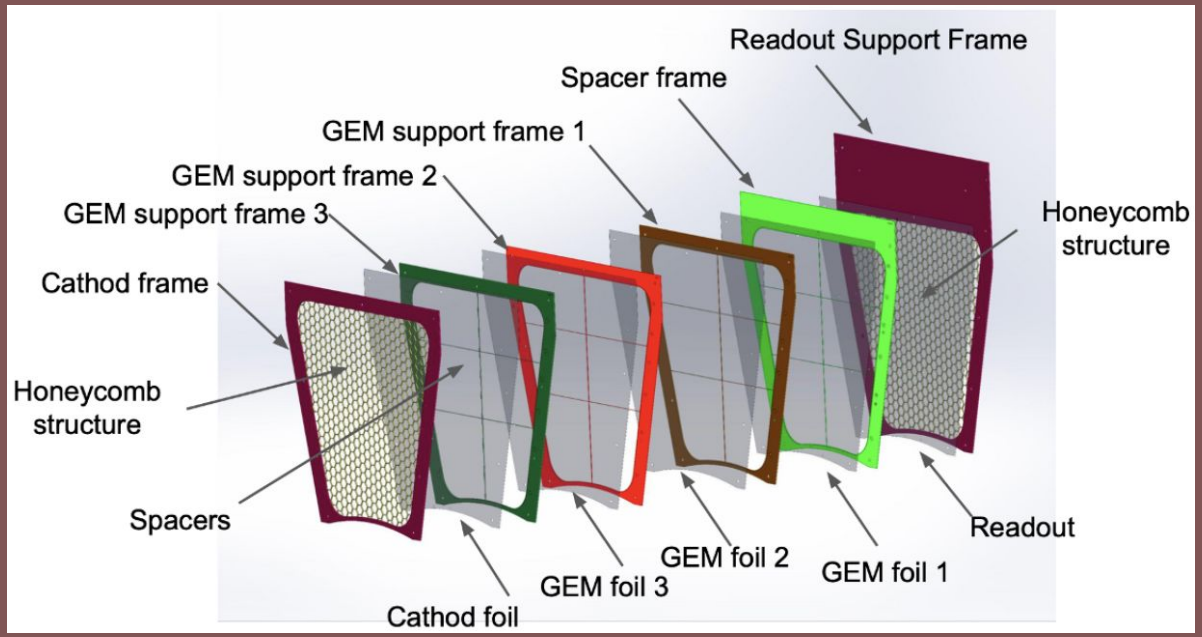
Tracking system

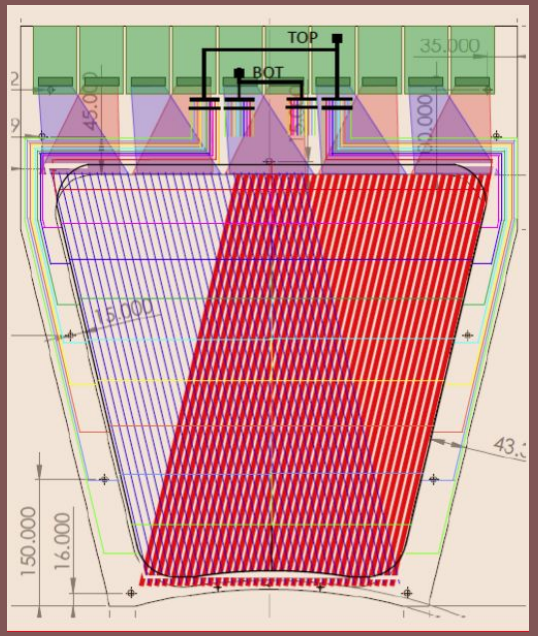
- Only low current
- Calibration of Cherenkov detectors
- Need 2π azimuth coverage
- Extraction of ‘kinematic factor’

$$\frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \equiv A_{PV} \propto \sin^2(\theta_W)$$



Design considerations

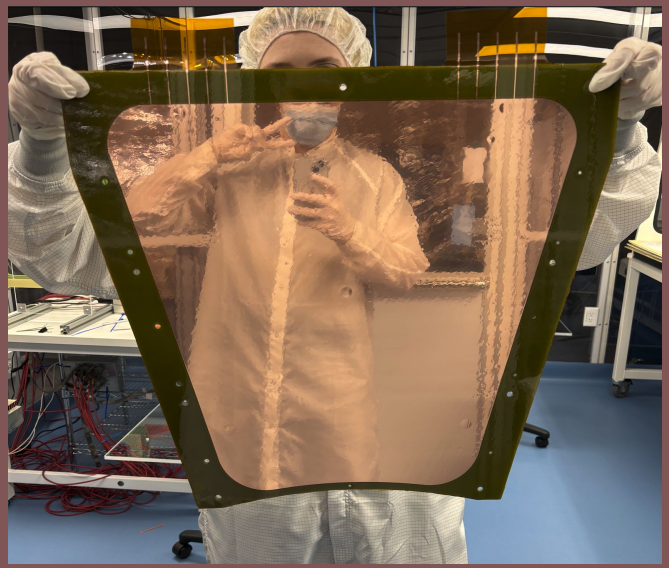




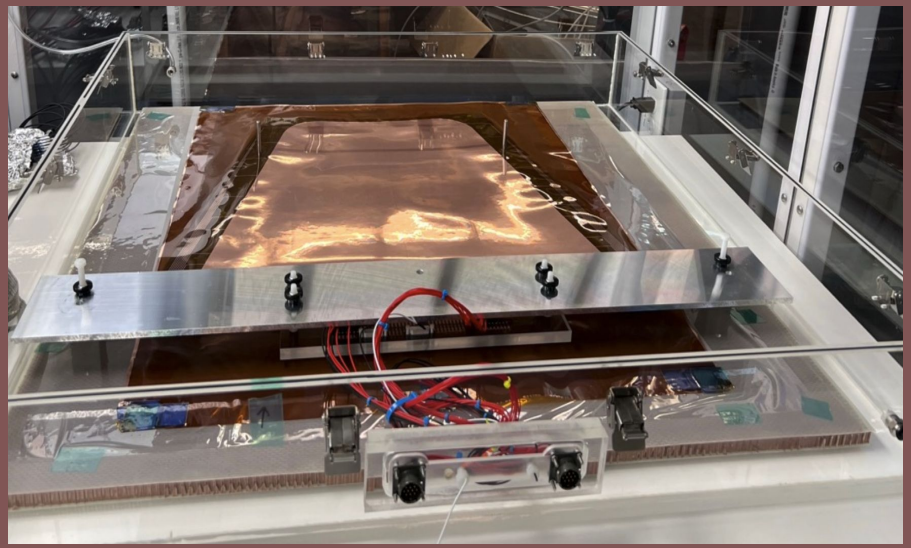
Read out via APV25

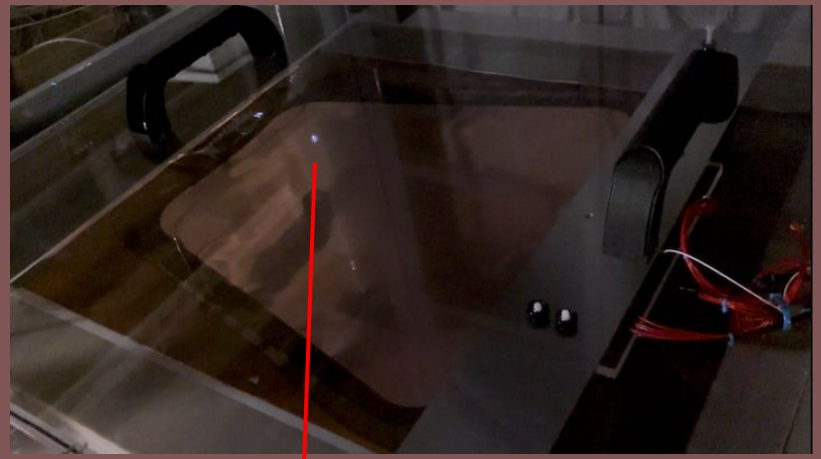
Starting from scratch: Grad student perspective

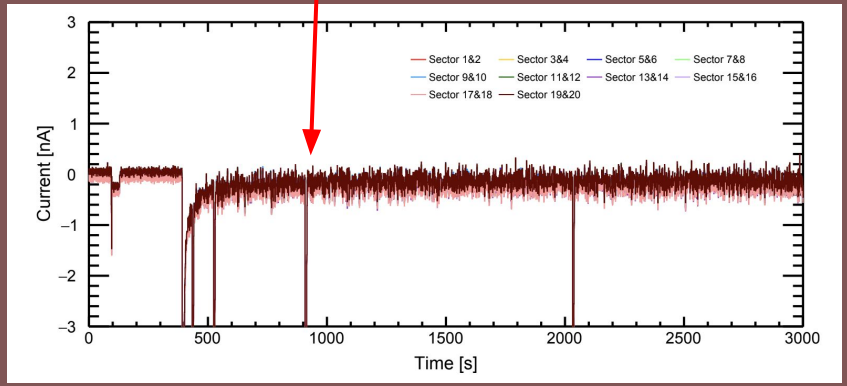
- We had people with experience (e.g. sPHENIX TPC, HBD, etc.)
- No clean room or procedures in place
- Making GEMs comparatively easy -> time burden



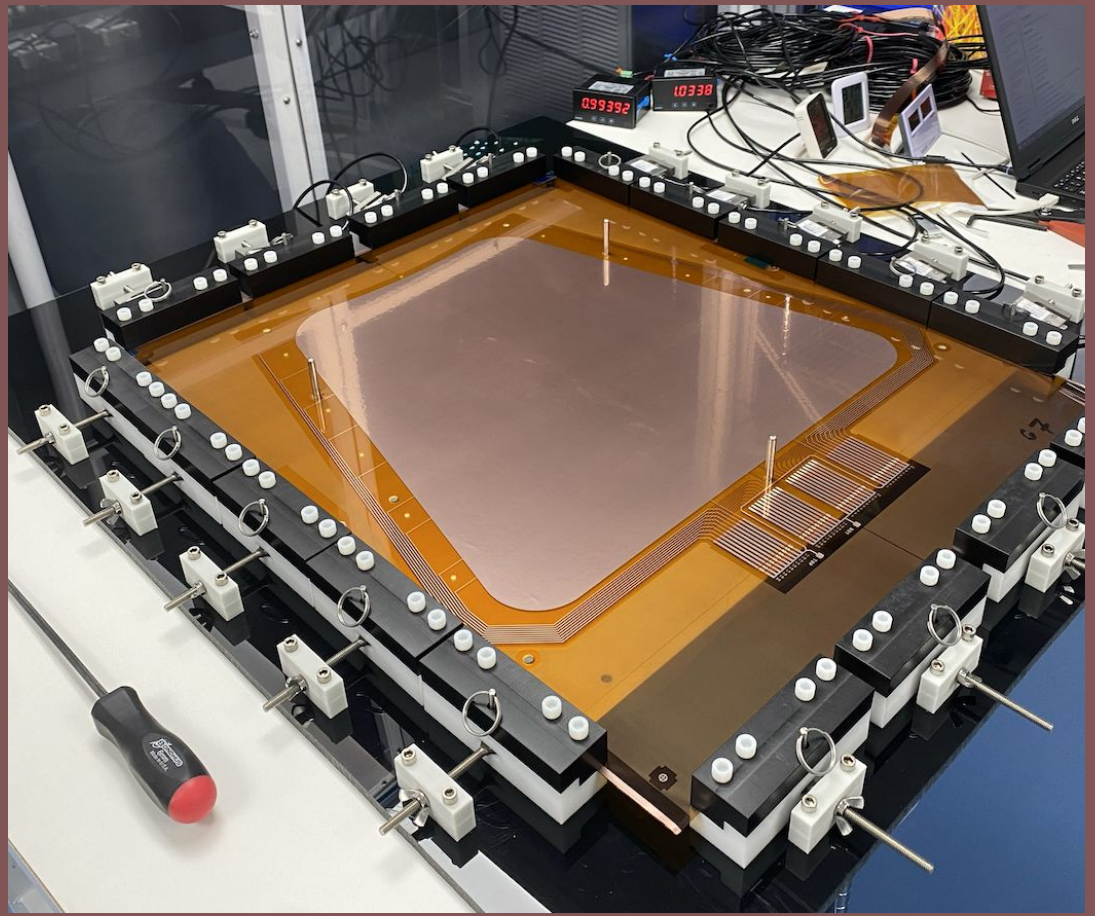
HV testing





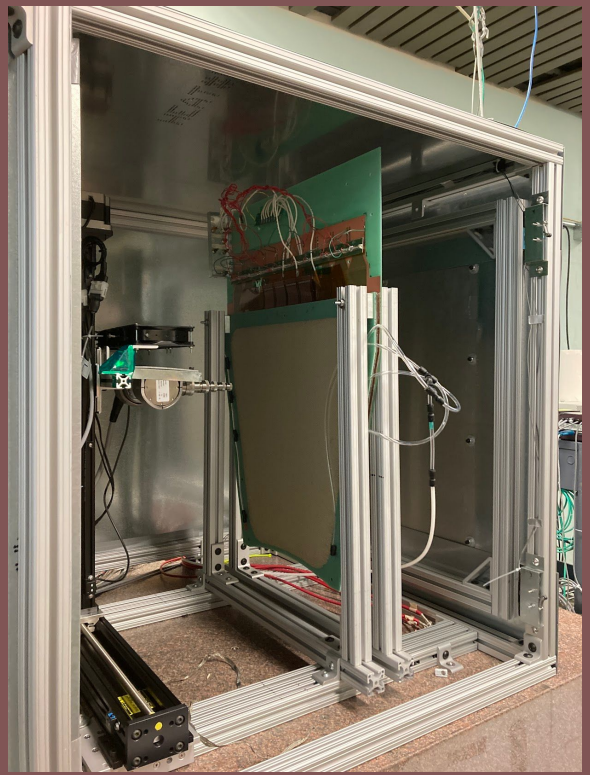

Sector 1&2
Sector 3&4
Sector 5&6
Sector 7&8
Sector 9&10
Sector 11&12
Sector 13&14
Sector 15&16
Sector 17&18
Sector 19&20
Current [nA]
Time [s]
3
2
1
0
−1
−2
−3
0
500
1000
1500
2000
2500
3000

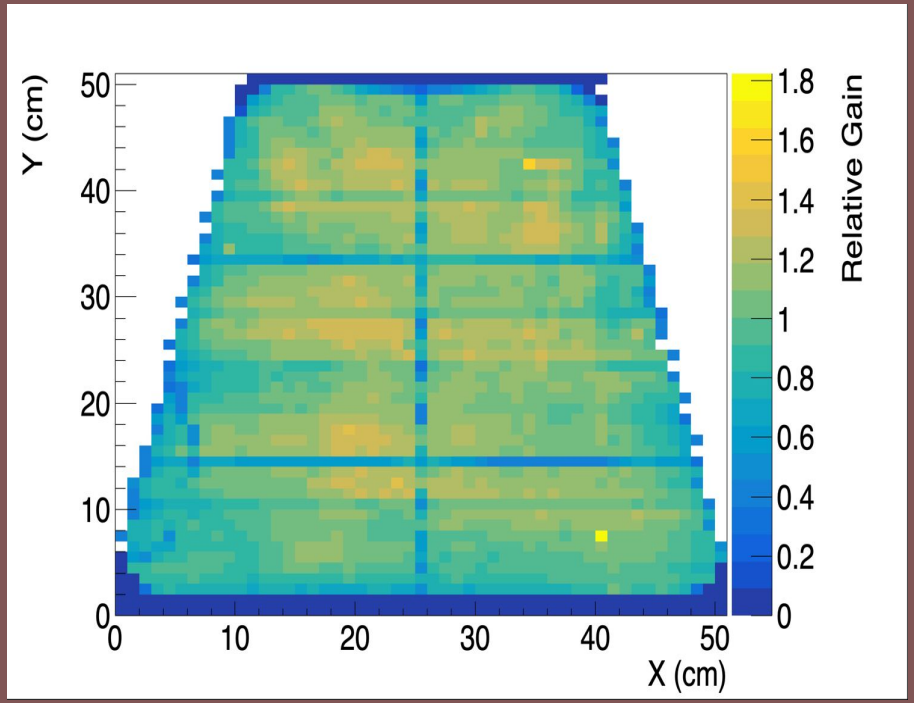
Stretching



Gain Uniformity

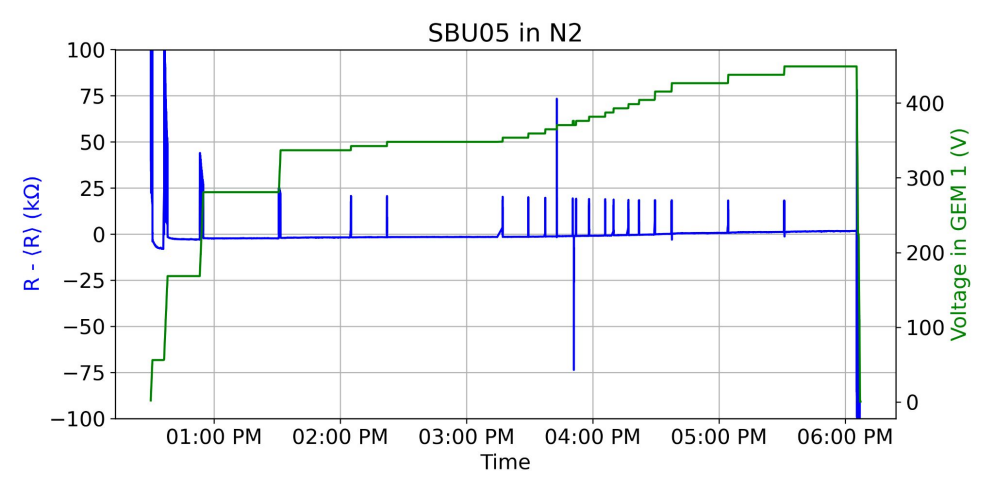
Charging up clearly observable



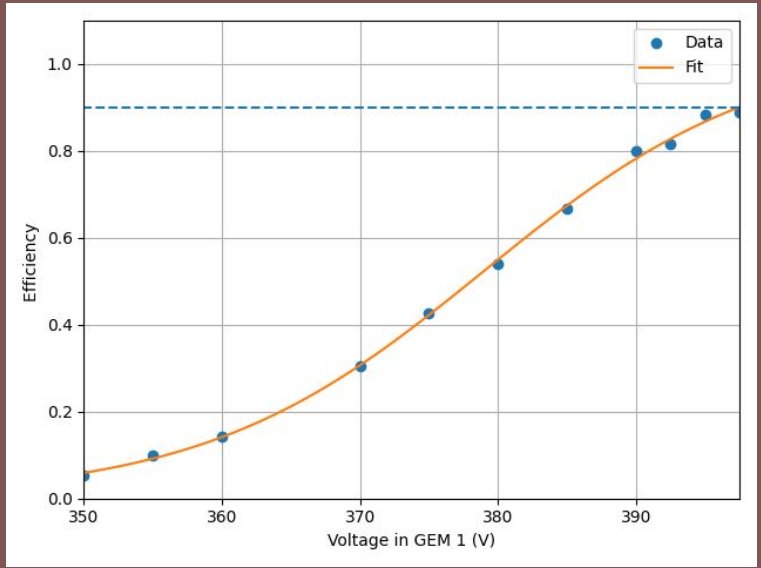


STD/Mean = 20.6%

Testing after assembly



HV stability in time



Efficiency vs voltage

What's next

- Modules were delivered to Jlab beginning of August
- Further testing to ensure stability of chambers after shipment
- Potential test beam -> translation system

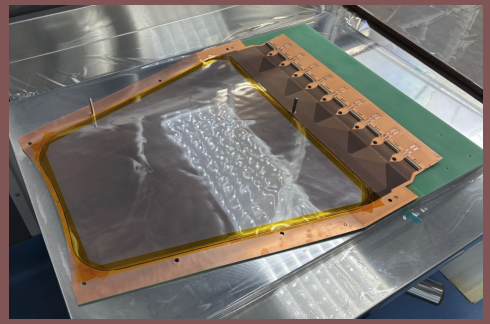
Summary + Outlook

- We built a cleanroom + testing apparatuses for study of large area GEM detectors
- We encountered lots of hurdles and roadblocks on the way
- We made 17 triple GEM detectors
- Minutiae is often missing

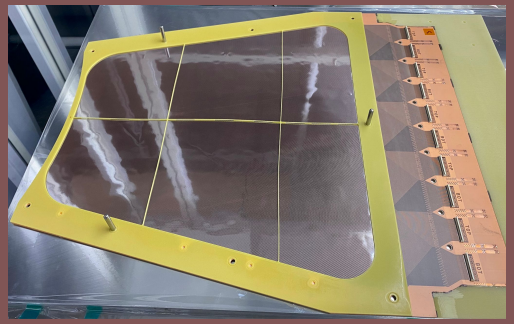
Acknowledgements

Thanks for your time!

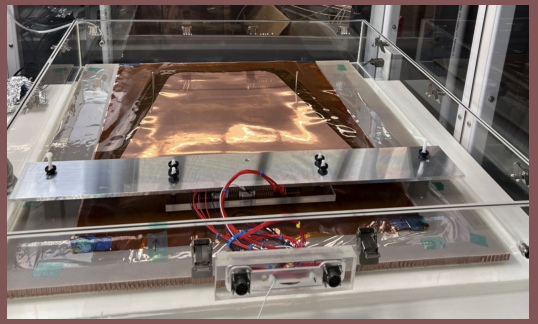
Backup/Annotations



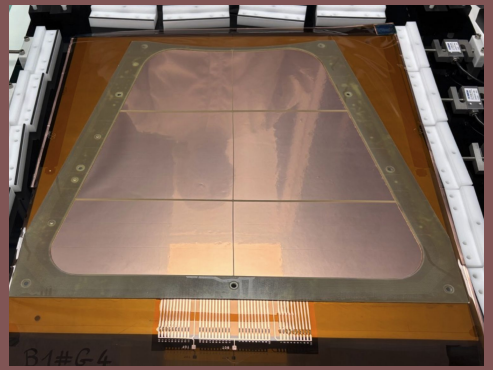
Glue Readout foil to honeycomb



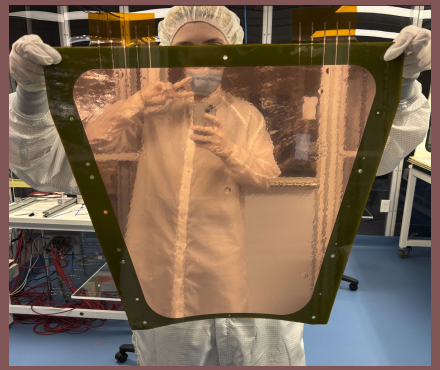
Glue spacer frame to RO



HV test of the GEM foils



Stretching and gluing a GEM foil



Drift cathode glued to support

Complete GEM module

Circa 2022

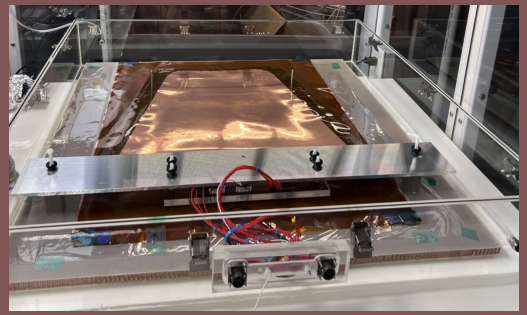
We had:

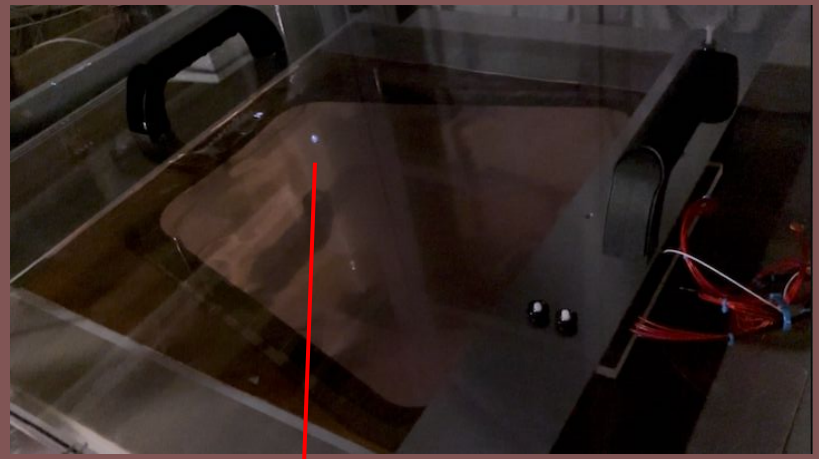
- Experience
- -> emphasize work with TPC/HBD GEMS

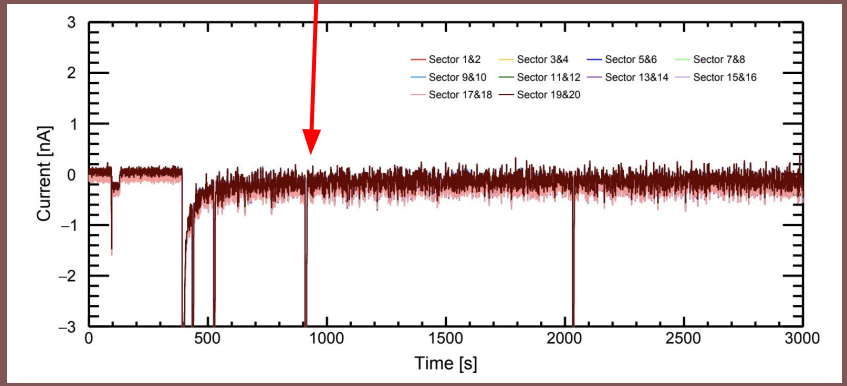
We didn’t have:

- A cleanroom
- Procedures
- Testing setups
- Infinite time

HV testing







Notes:

- Better to apply HV all at once
- Micron filter on gas line critical even for uhp gas
- We apply pogo pins individual to top traces, not to bottom
  - Don’t do this -> can’t isolate sparks, no correlation between sparks and sector

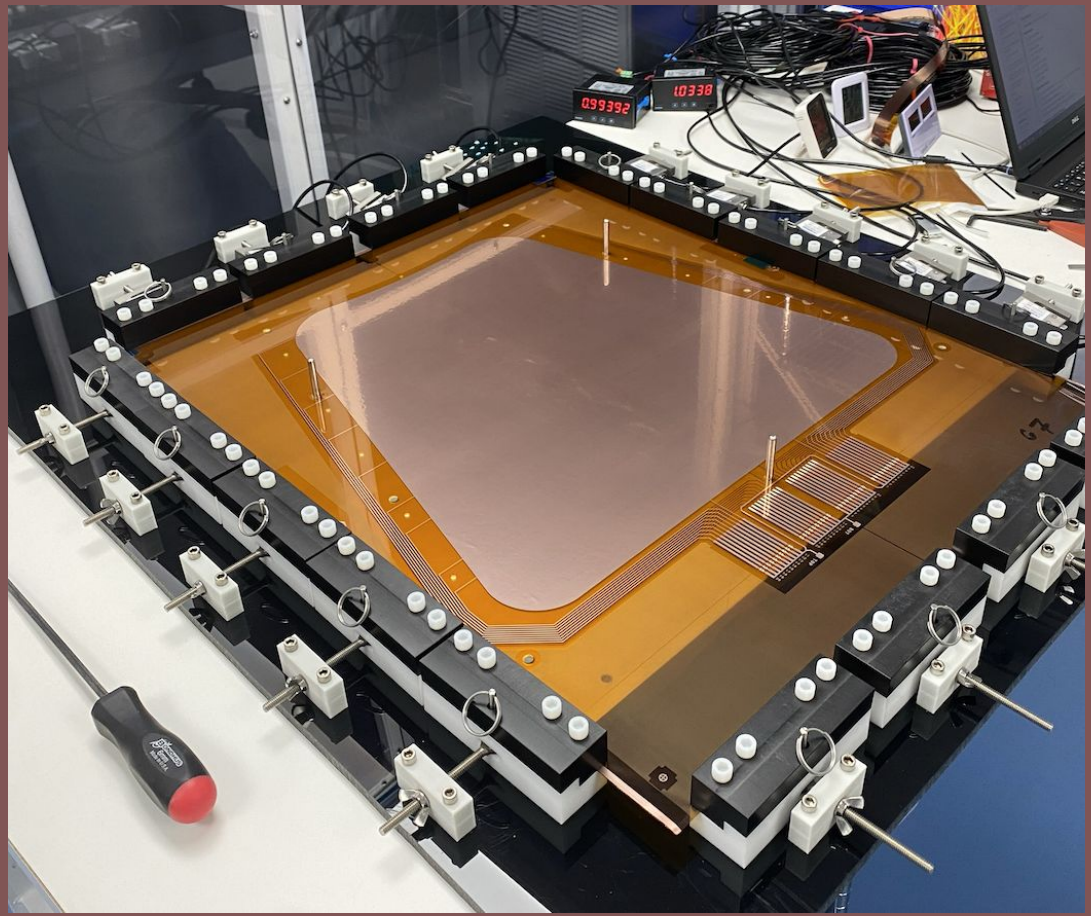
Stretching

Lots of back of envelope calculation about how much tension

Uniform tension very important in X, important NOT to apply equal tension along y, very narrow gap between bottom of GEM and drift pipe

Bowing occurs if too much tension there

Easy to cause twisting, need to tighten tension of opposite tensioners simultaneously,



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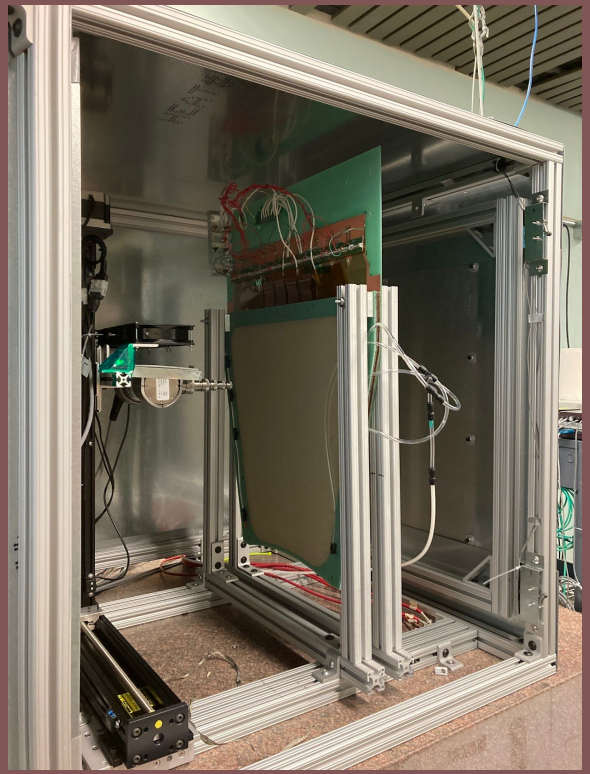

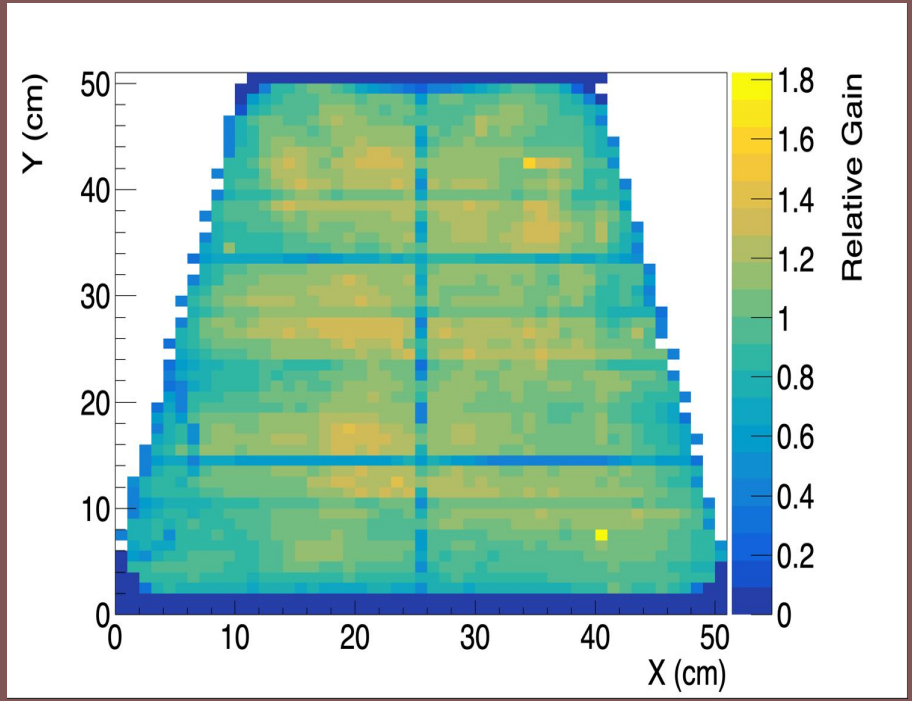

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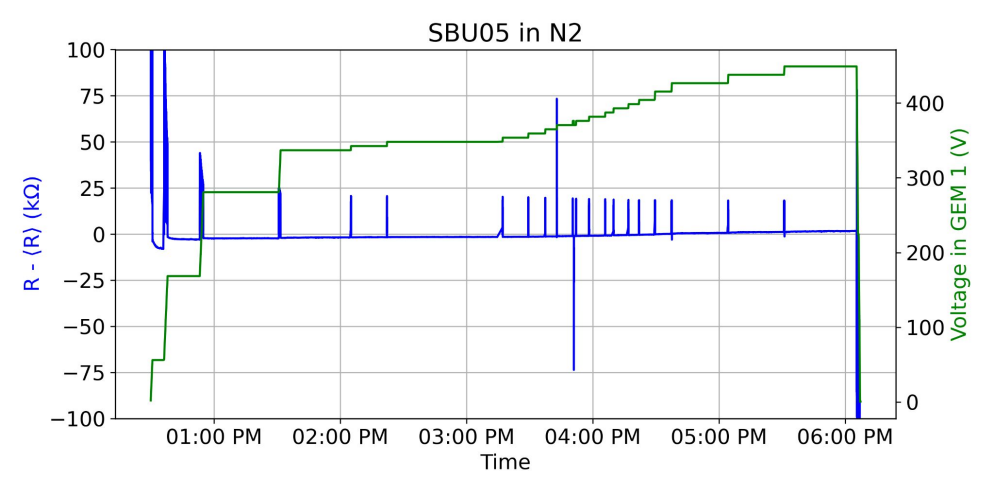

HV stability in time

We apply voltage in N2 to the detector first before ever applying voltage in counting gas and every time there has been a big gap (> 1 week) since last time it was at voltage in ArCO2

We apply voltage across the whole divider -> haven't experienced any issues with corona discharge ionizing electrons and leading to amplification

Summary + Outlook

- GEMs on their own are sensitive detectors, especially when being commissioned
  - As more advanced/complicated detectors are being developed and potentially using GEMs for a gain stage (e.g. combination gem/urwells, TPCs, etc.) they can't be taken for granted
- Many nuances, very few of these are written most are word of mouth (in my experience)