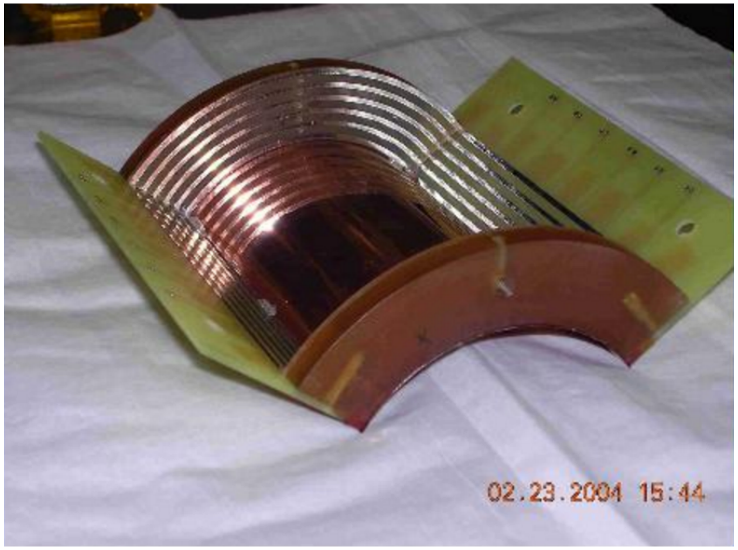
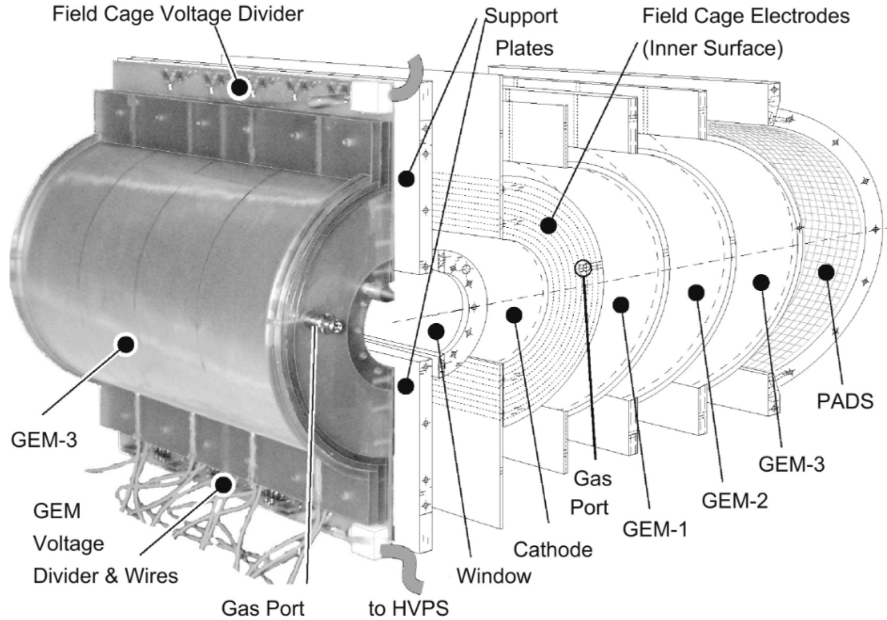
Applications of MPGD at BNL/Jlab and the future EIC.

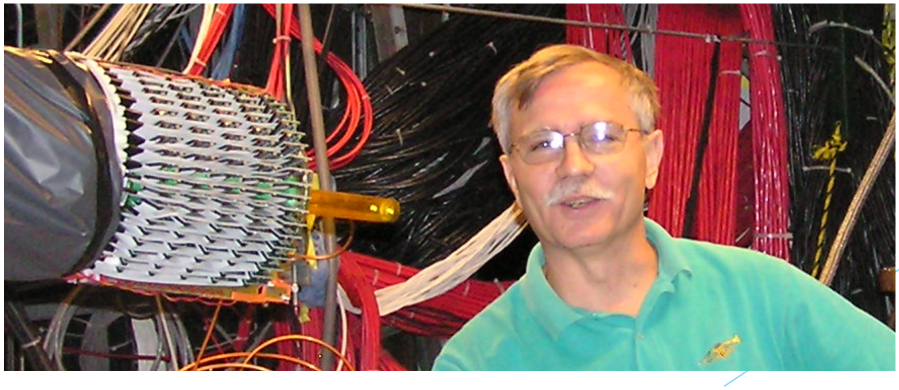
TK Hemmick

In recent years, we have seen a growing and impactful community participating in MPGD established in the US.
-- S. Dalla Torre, MPGD 2017

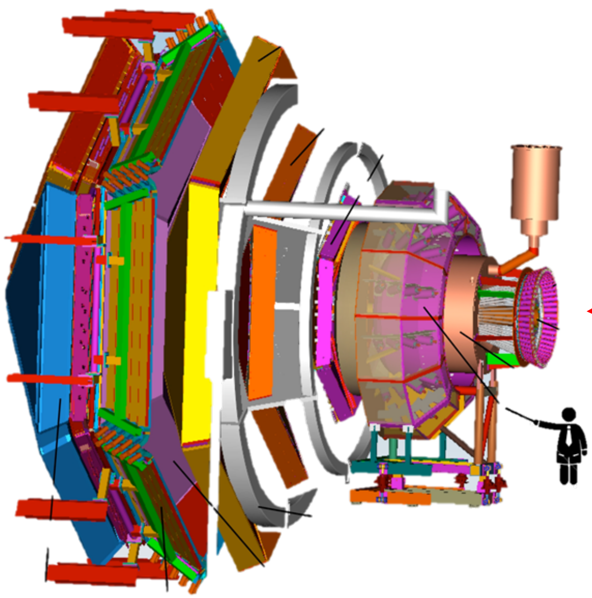
BoNuS (Barely Off-shell Nucleon Structure)



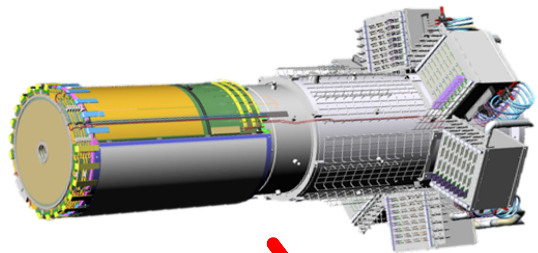


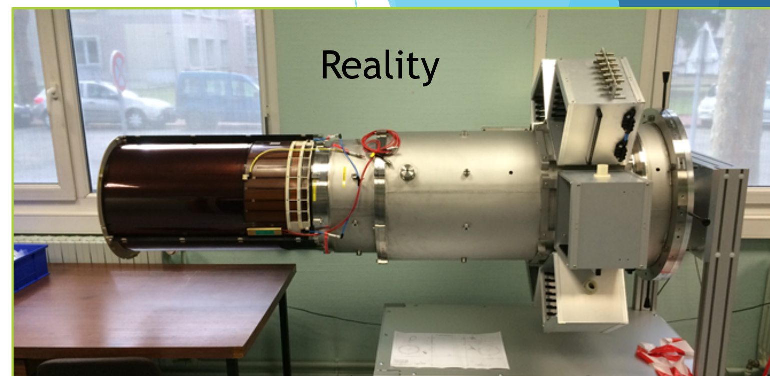


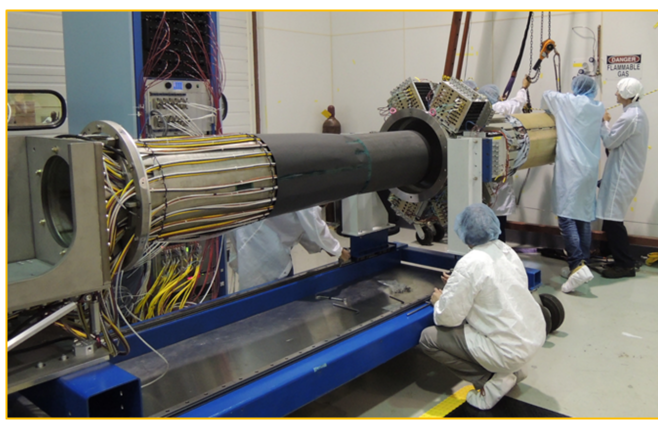
CLAS12 Barrel μMEGAS

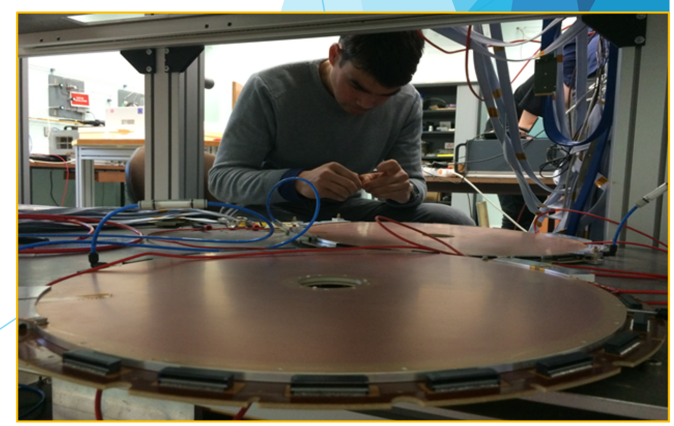


Dream

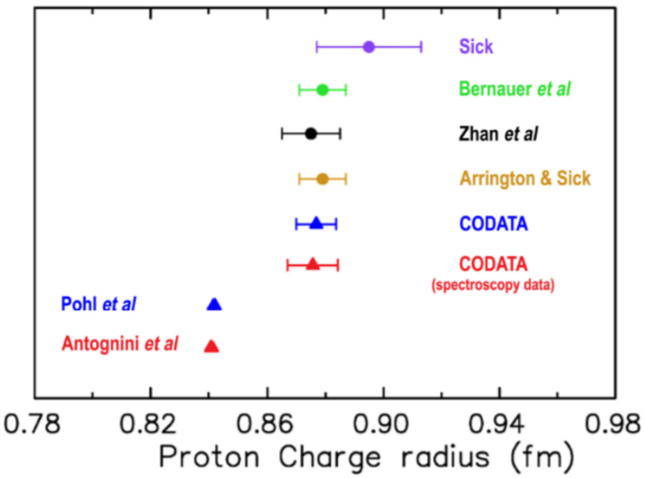


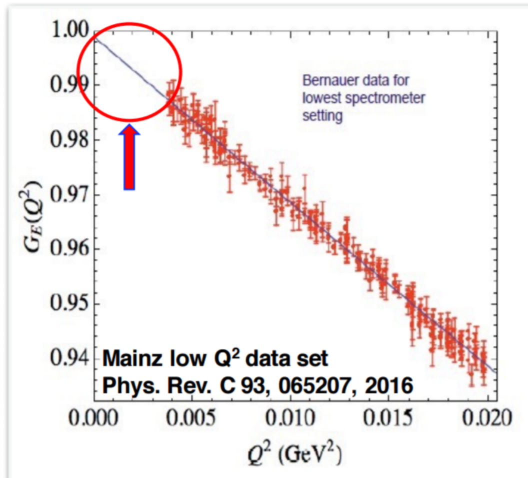


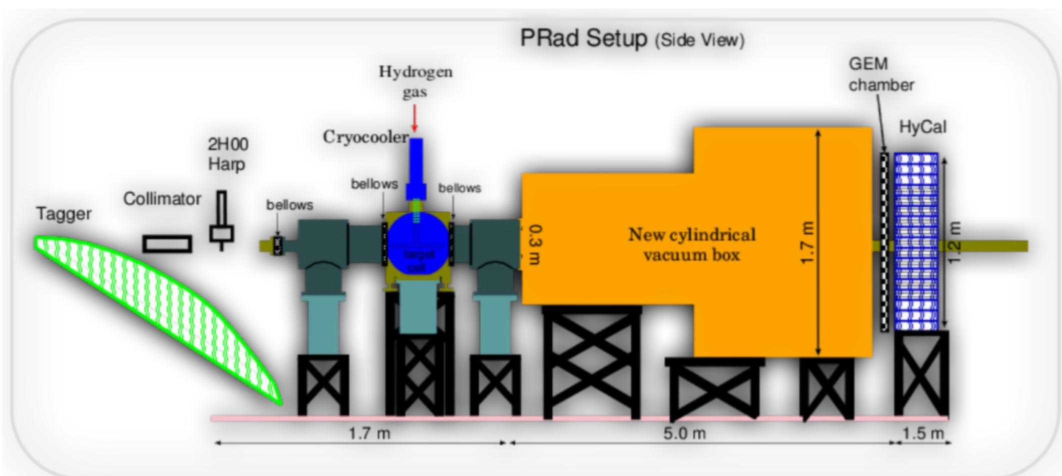


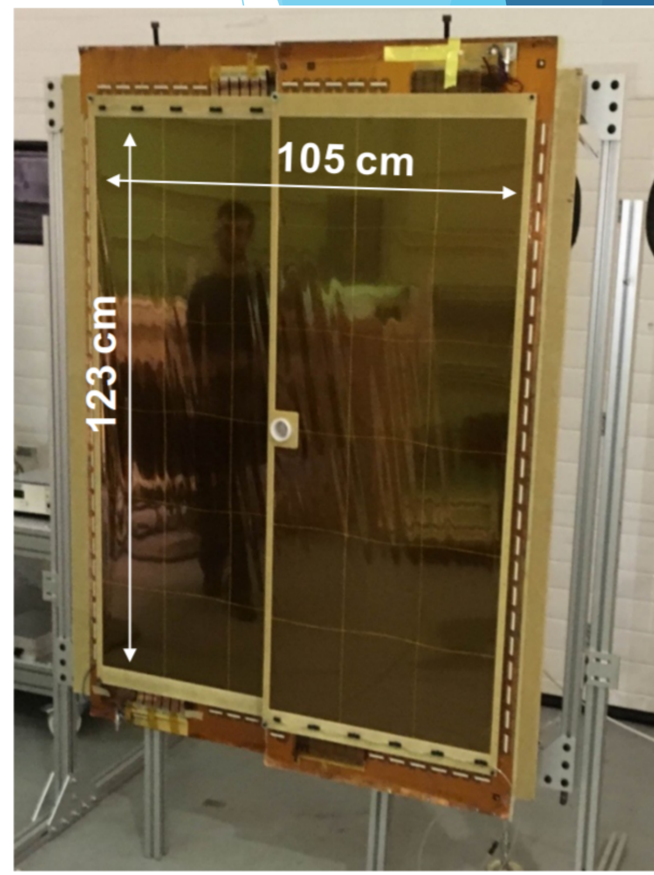


PRad


Sick
Bernauer et al
Zhan et al
Arrington & Sick
CODATA
CODATA
(spectroscopy data)
Pohl et al
Antognini et al
0.78
0.82
0.86
0.90
0.94
0.98
Proton Charge radius (fm)


1.00
0.99
0.98
0.97
0.96
0.95
0.94
$G_E(Q^2)$
Bernauer data for lowest spectrometer setting
Mainz low Q^2 data set
Phys. Rev. C 93, 065207, 2016
0.000
0.005
0.010
0.015
0.020
Q^2 (GeV^2)

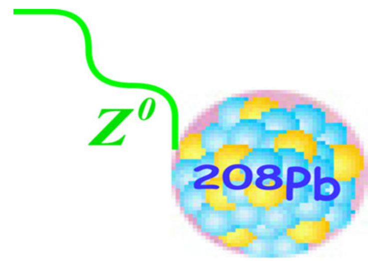

PRad Setup (Side View)
Hydrogen gas
Cryocooler
2H00 Harp
Collimator
Tagger
bellows
bellows
bellows
GEM chamber
HyCal
0.3 m
New cylindrical vacuum box
1.7 m
1.2 m
1.7 m
5.0 m
1.5 m

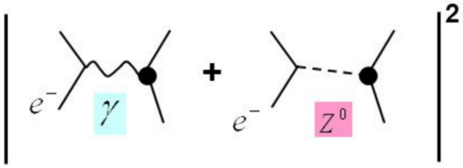

105 cm
123 cm

PREX/CREX

Lead (^{208}Pb) Radius Experiment : PREX

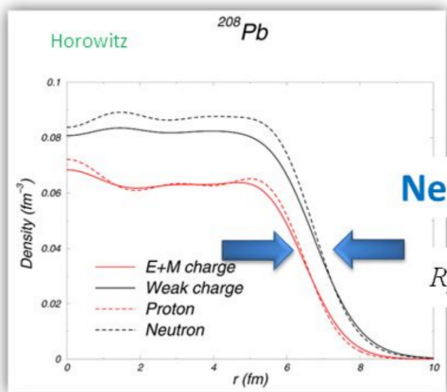
Lead (^{48}Ca) Radius Experiment : CREX



$\sigma \approx$ 

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim 10^{-4} \times Q^2 \sim 10^{-6}$$

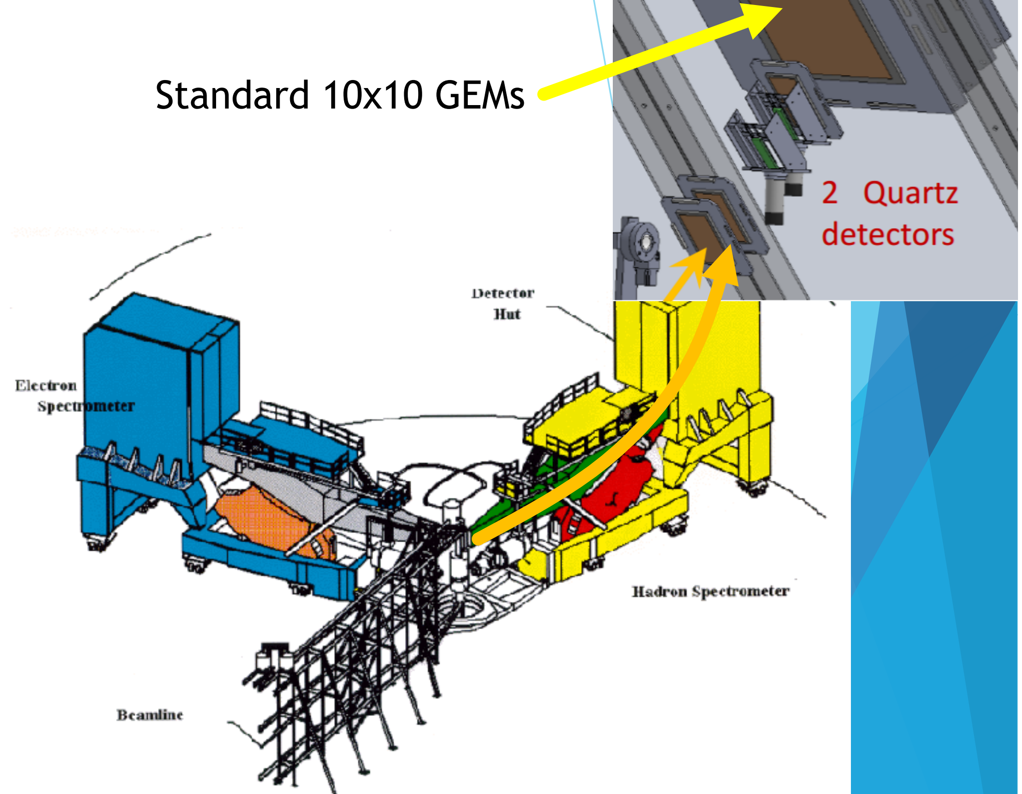
Electroweak Asymmetry in Elastic Electron-Nucleus Scattering :
A measure of the neutron distribution



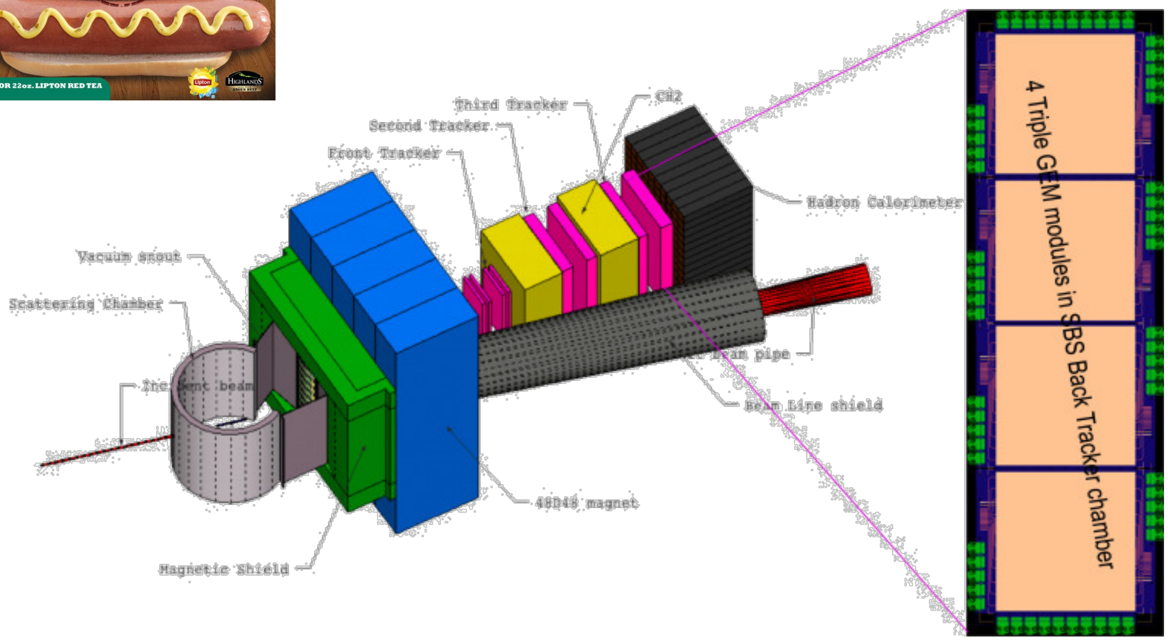
Neutron Skin

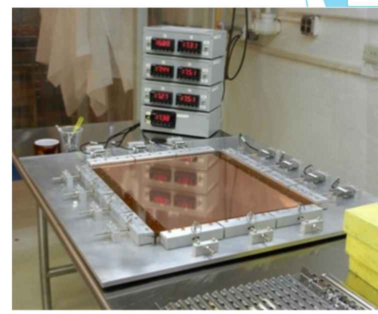
$$R_n - R_p = \sqrt{\langle r_n^2 \rangle} - \sqrt{\langle r_p^2 \rangle}$$

1/15



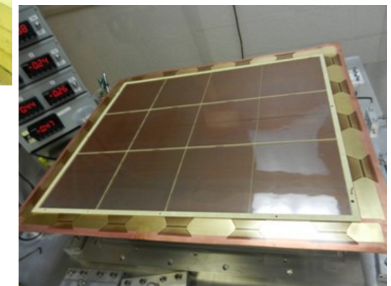
Super BigBite Spectrometer

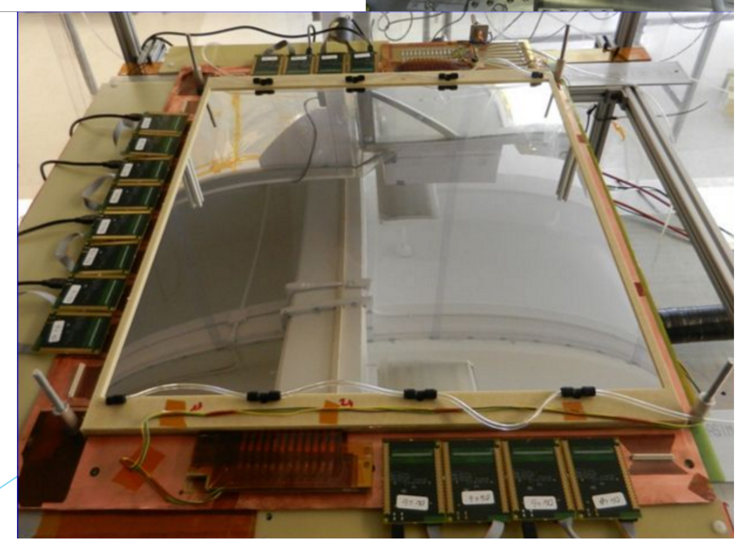




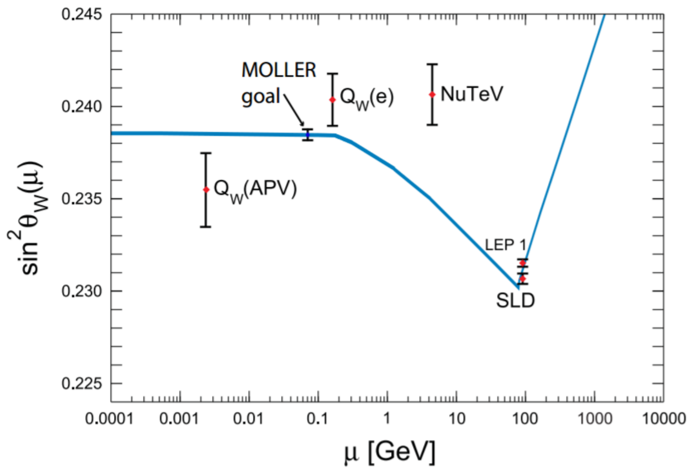
Stretching of GEM foils

Preparation of the readout board

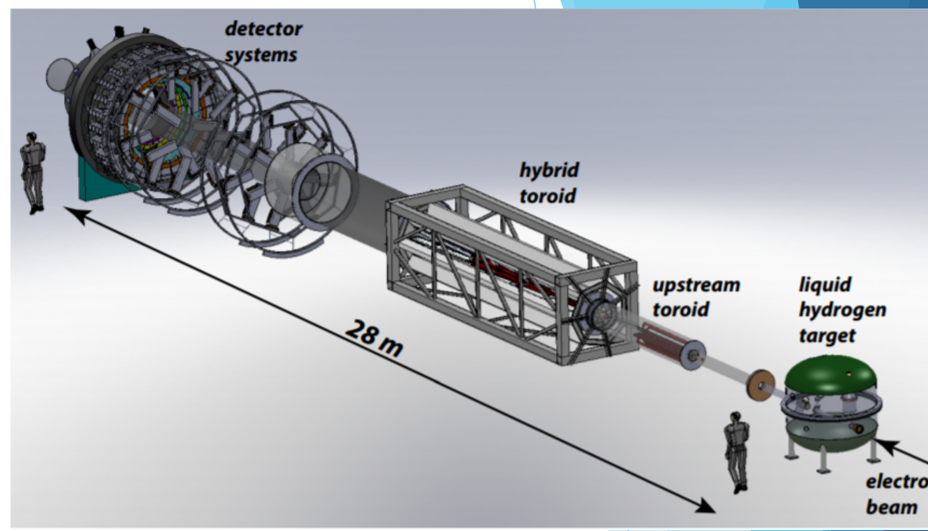




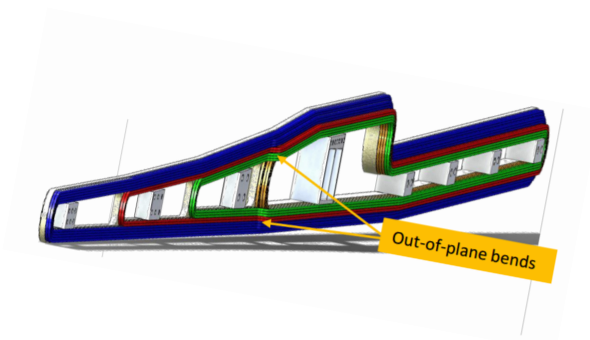
Moller



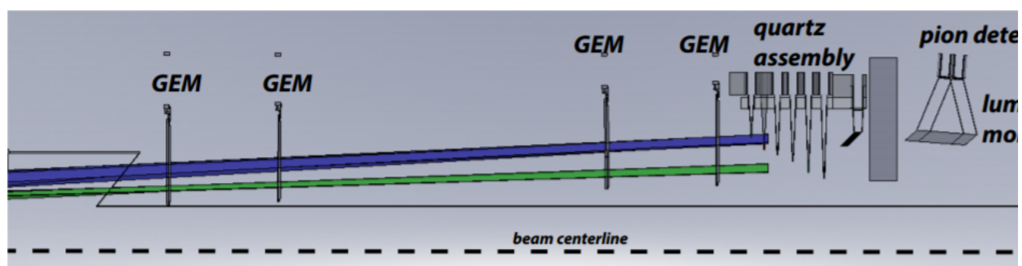
0.245
0.240
0.235
0.230
0.225
$\sin^2\theta_W(\mu)$
MOLLER goal
$Q_W(e)$
NuTeV
$Q_W(APV)$
LEP 1
SLD
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
μ [GeV]



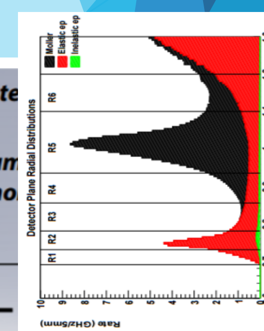
detector systems
hybrid toroid
upstream toroid
liquid hydrogen target
28 m
electron beam



Out-of-plane bends

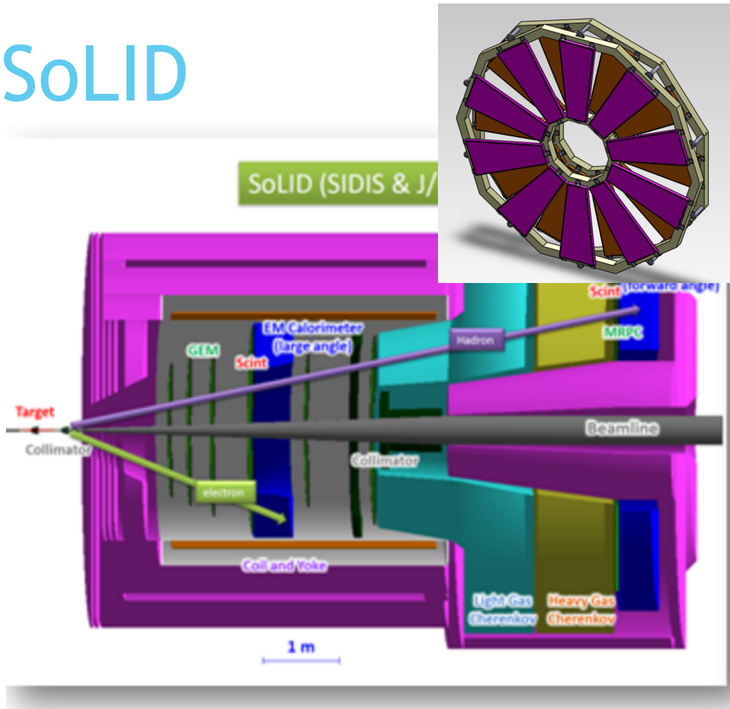


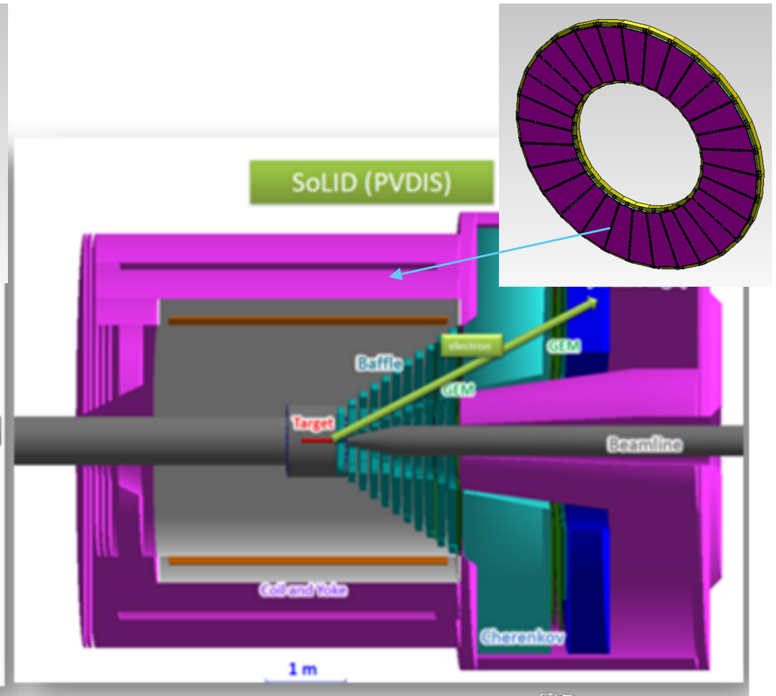
GEM
GEM
GEM
GEM
quartz assembly
pion dete
lum
mo
beam centerline

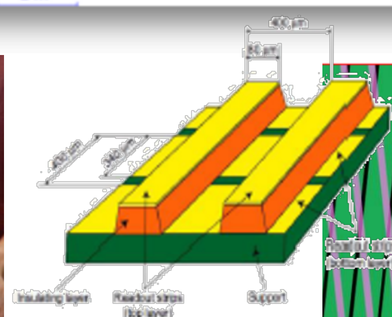


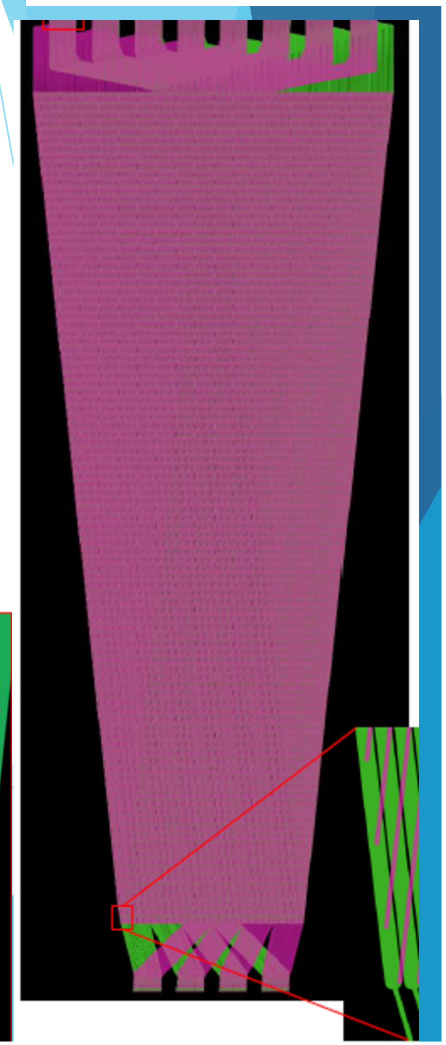
SoLID

Jefferson Lab









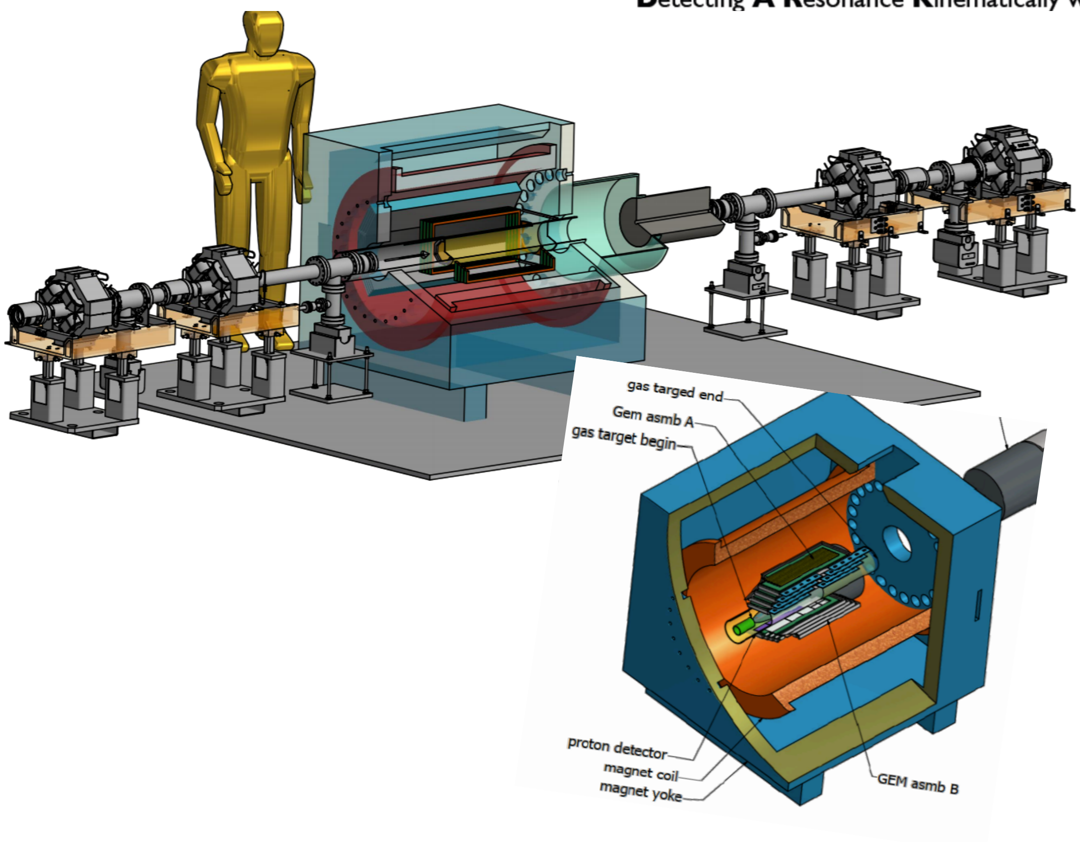
DarkLight

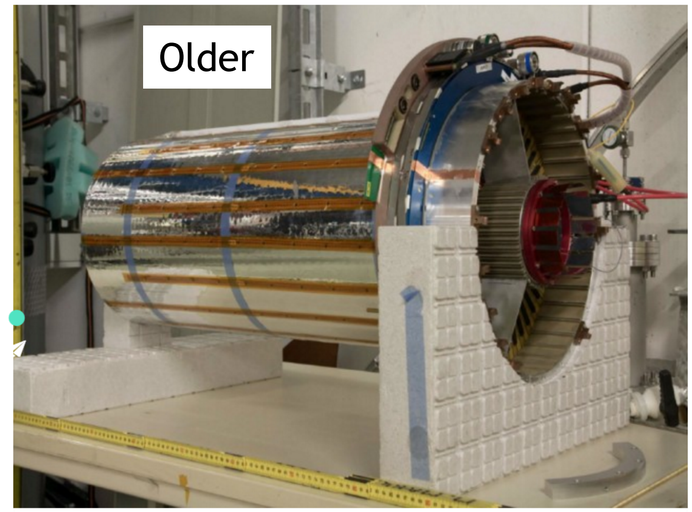
Jefferson Lab

DARKLIGHT

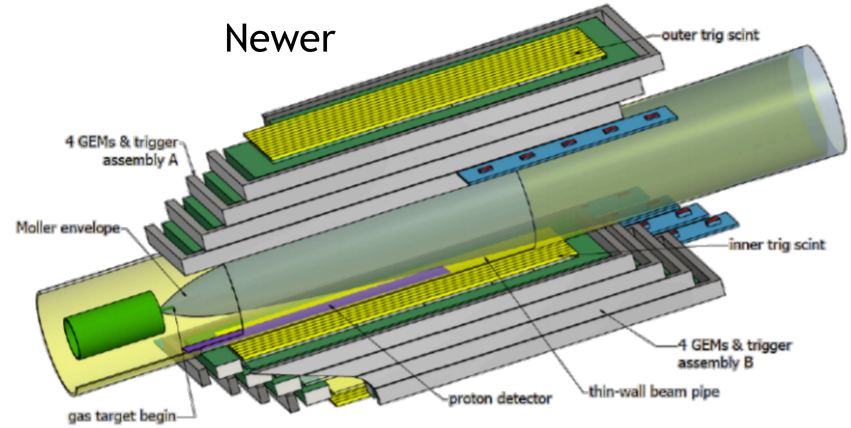
Detecting **A** **R**esonance **K**inematically with
'arget

Jefferson Lab





Photograph of the prototype constructed by the GEM-TPC collaboration. (C) MIT



LEGS

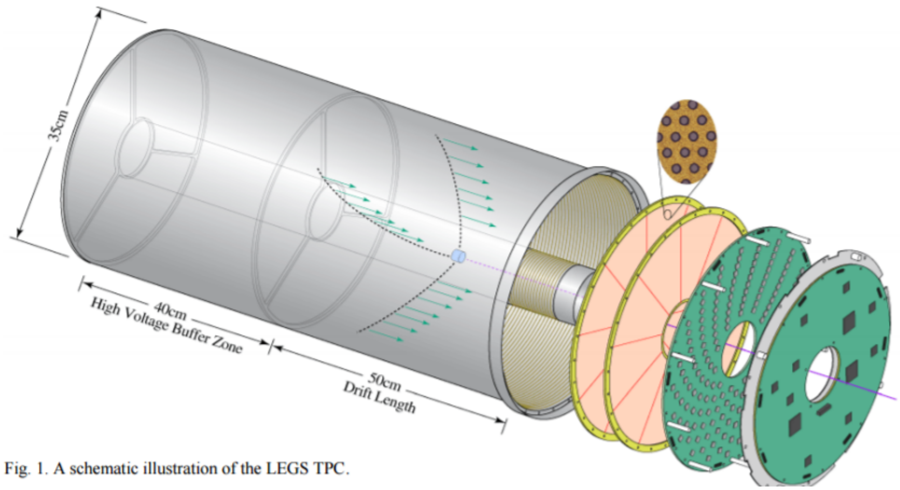


Fig. 1. A schematic illustration of the LEGS TPC.

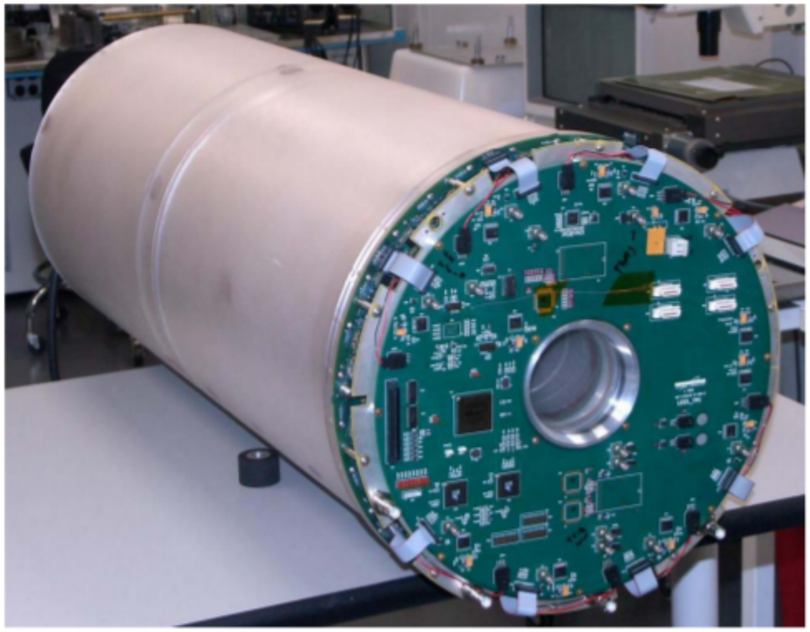
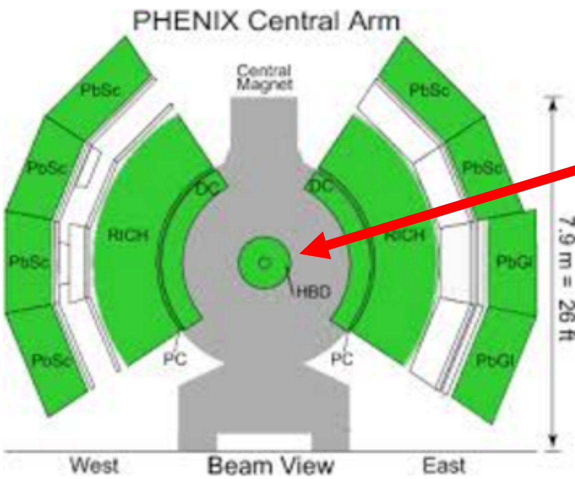
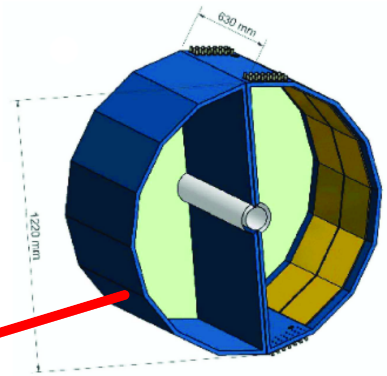


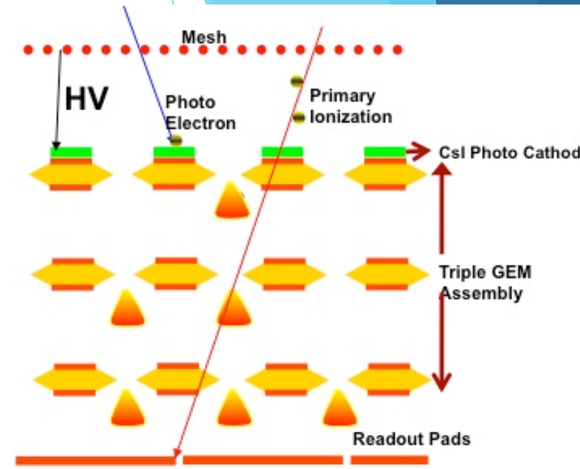
Fig. 5. The completed full size TPC with its readout electronics

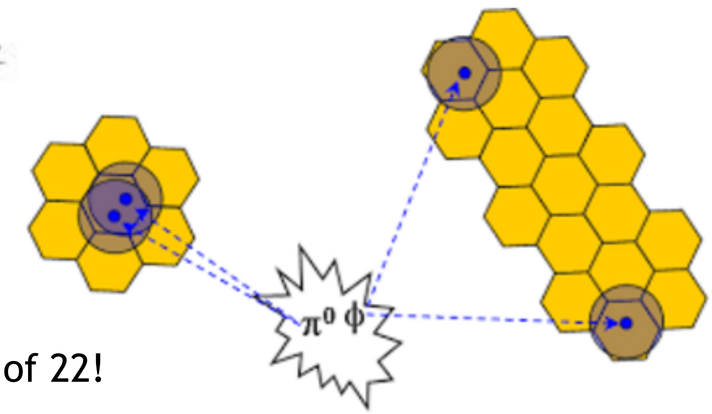
PHENIX HBD



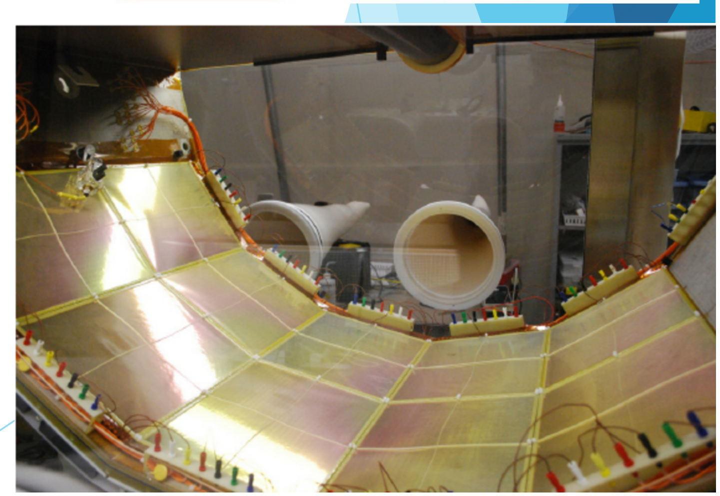


* Windowless Cherenkov detector
* Tripple GEM
* CSI photo-cathode
* Pure CF4: N0 = 322 cm-1
* 2.4% total radiation length.

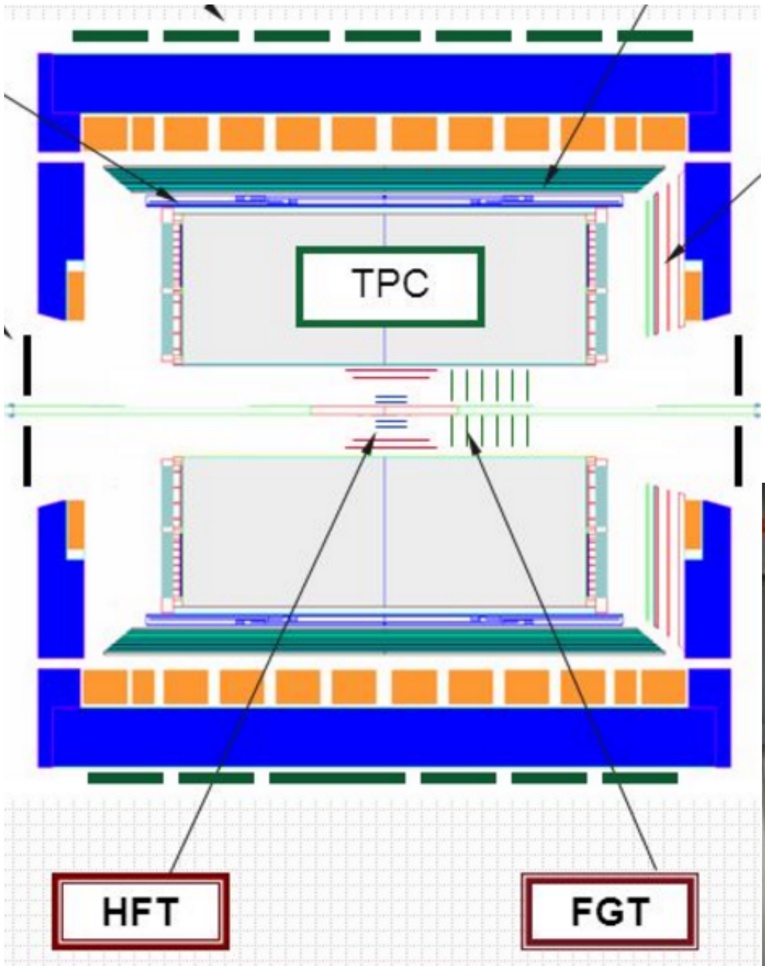


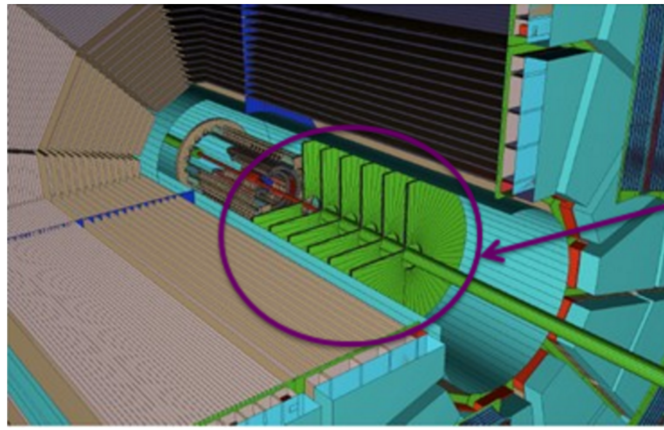


π^0 rejected,
45 photons instead of 22!

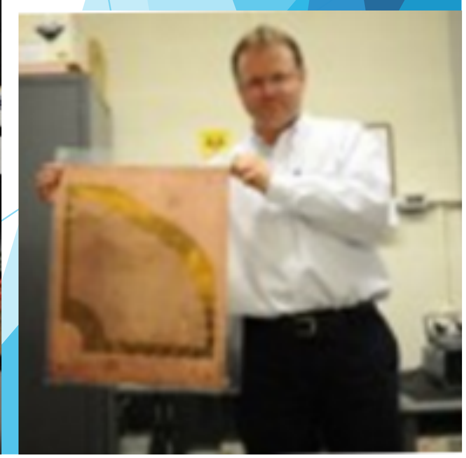


STAR FGT

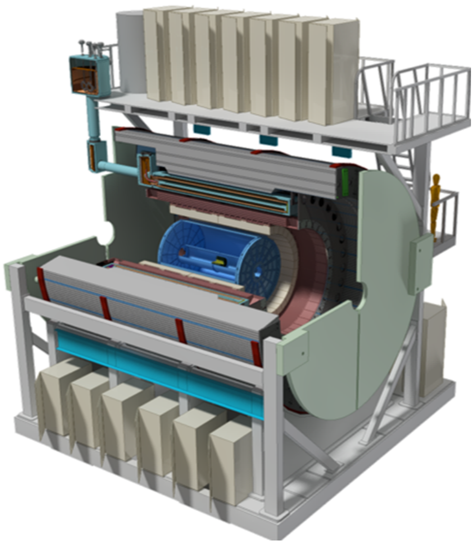


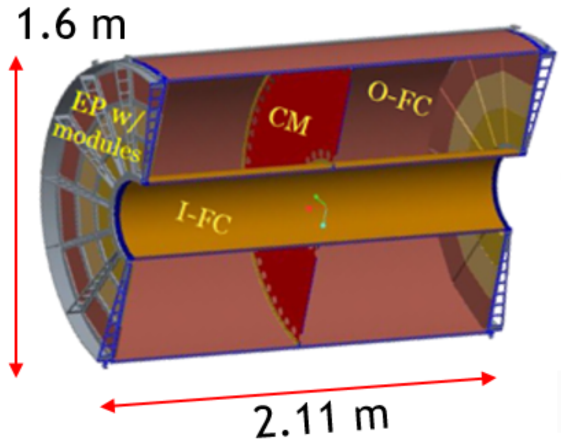


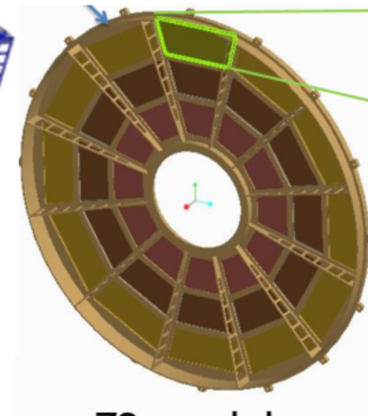
FGT installed inside STAR

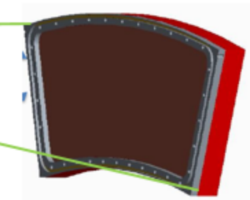


sPHENIX

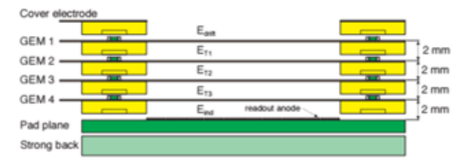




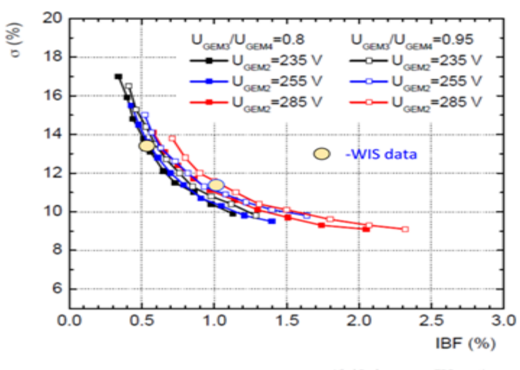


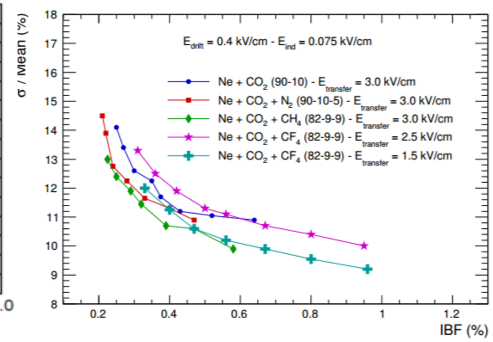


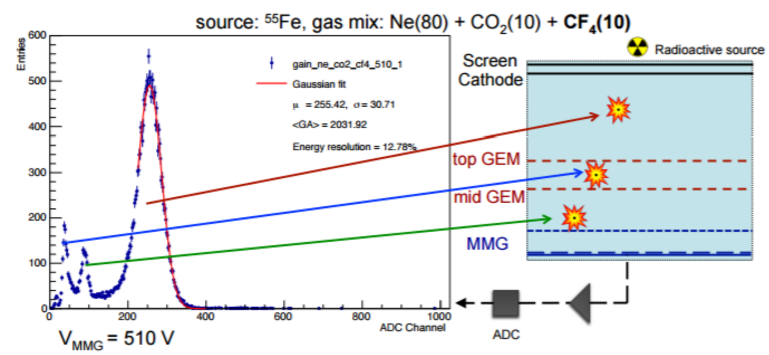
72 modules
2(z), 12(ϕ), 3(r)



Quad-GEM Gain Stage
Operated @ low IBF



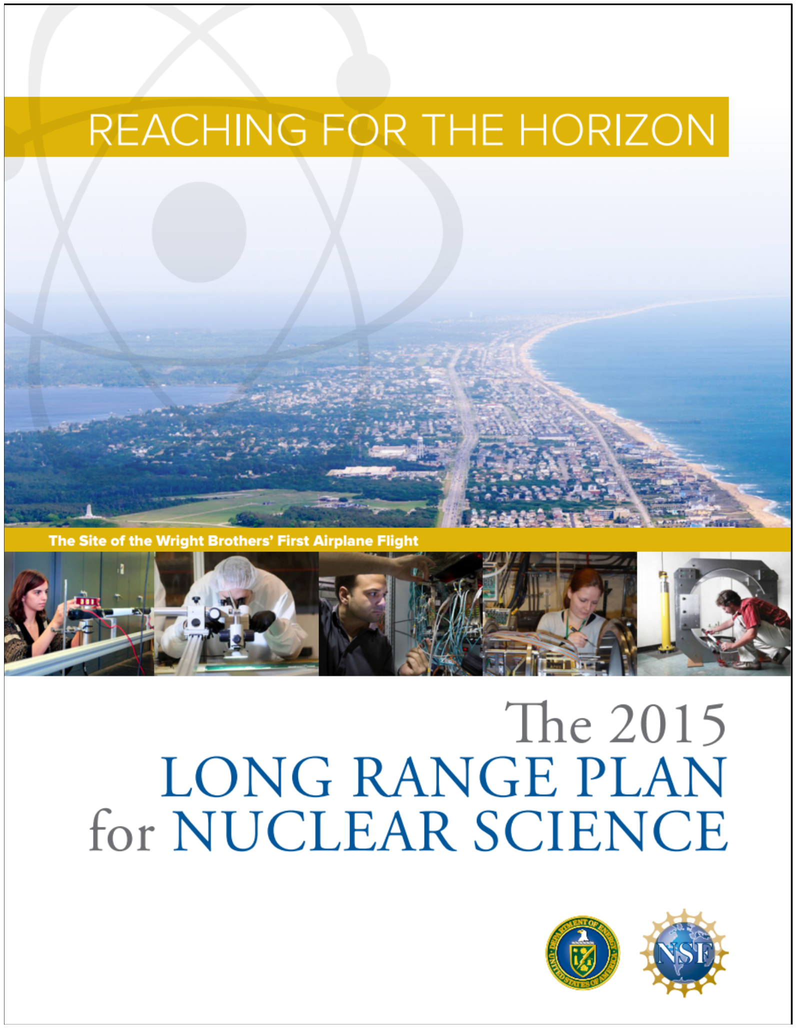




V_{MMG} = 510 V
ΔV^{top}_{GEM} = 260 V
ΔV^{mid}_{GEM} = 230 V

μMEGA Lower IBF

The Long Range Plan!



RECOMMENDATION III

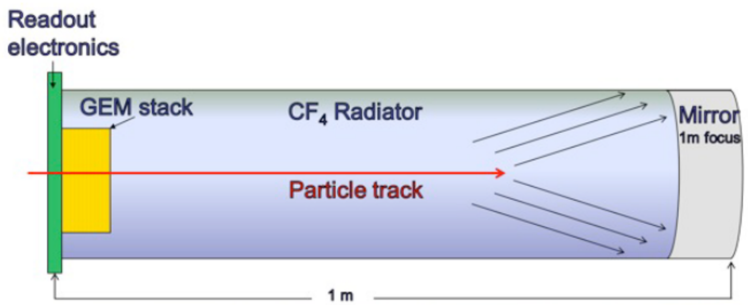
Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new electron ion collider (EIC), providing unprecedented precision and versatility. The realization of this instrument is enabled by recent advances in accelerator technology.

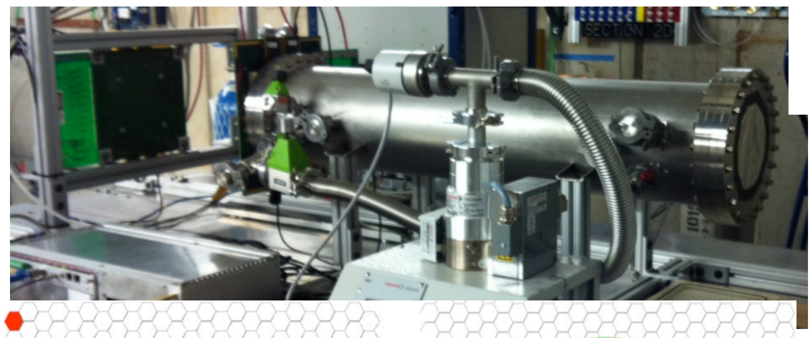
We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

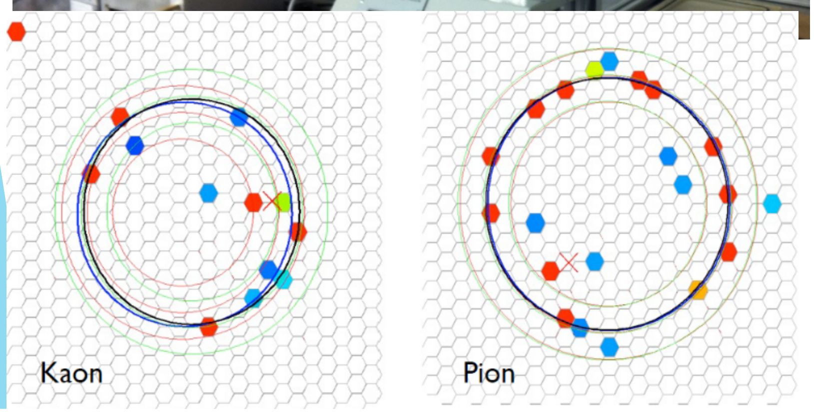
- What is the spatial mapping of quark and gluon fields in the nucleon AND nucleus.
- Is the missing spin to be found via quark orbital momentum?
- Are new phases of matter (Color-Glass Condensate) accessible at low x in nuclei?

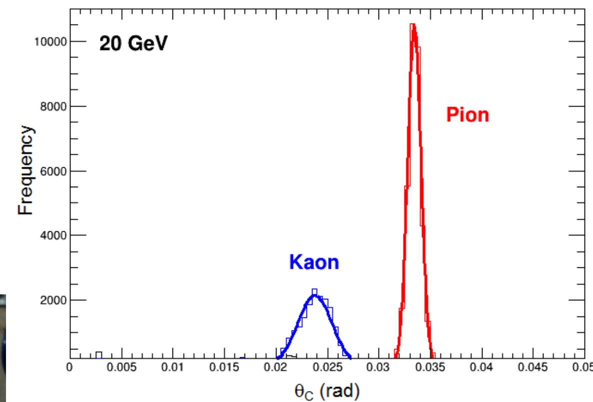
Site Competition
BNL & JLAB

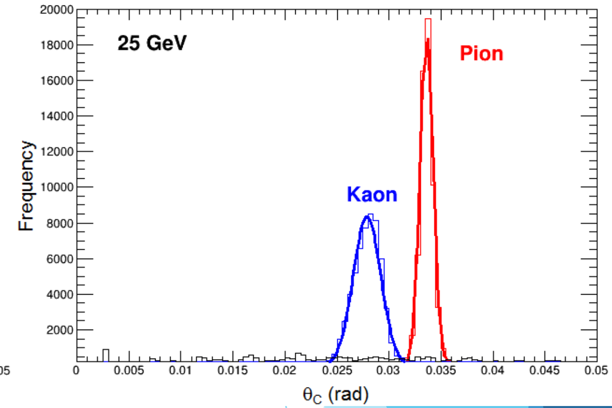
HBD-like RICH (Generic R&D)

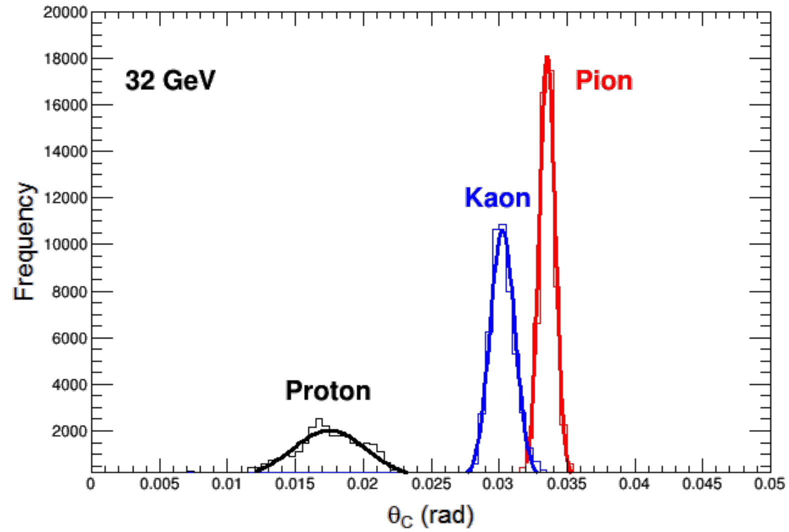












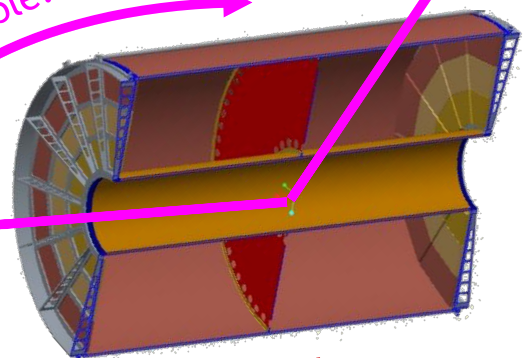
TPC-Cherenkov (Generic R&D)

How to extend eID as far as possible?

Primary electron nearly absent

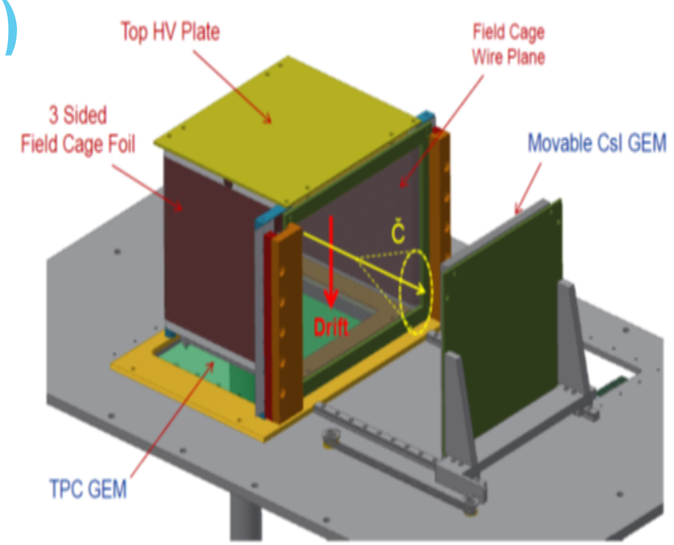
HBD

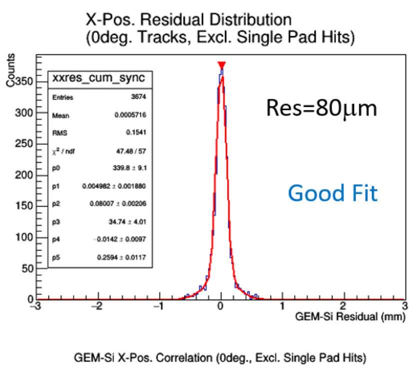
Primary Electron dominates



TPC Tracker

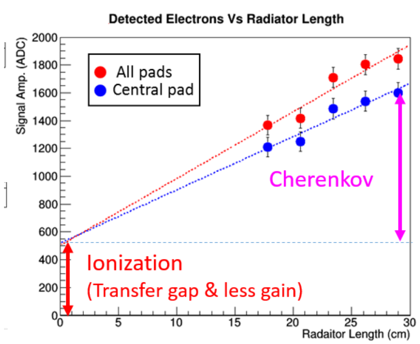
TPCC





Res=80μm

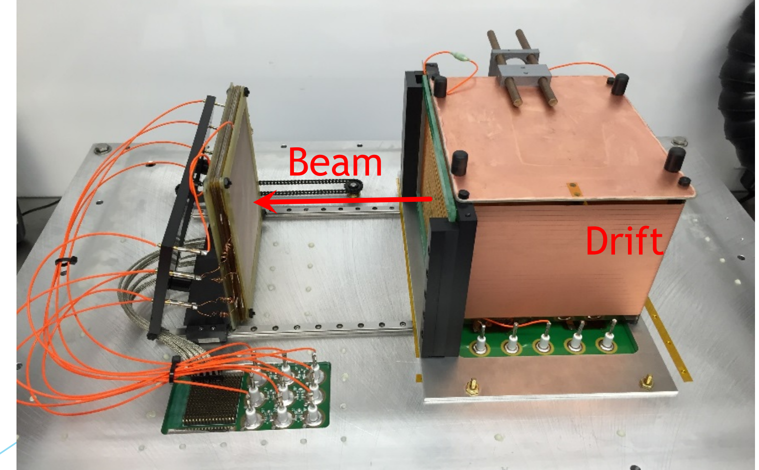
Good Fit



Cherenkov

Ionization
(Transfer gap & less gain)

30 pe @ full size



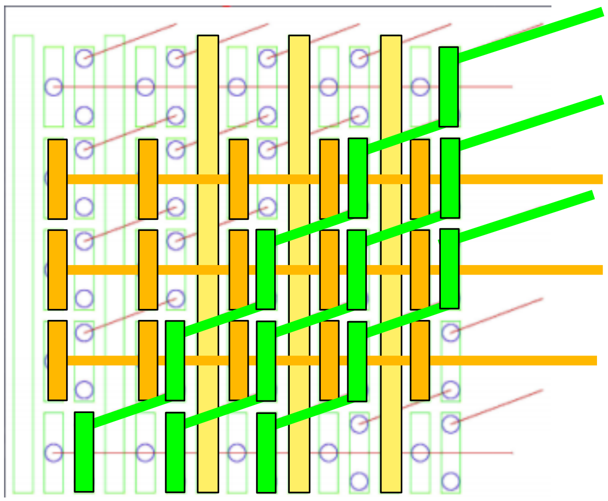
Cherenkov

TPC Field Cage

Beam

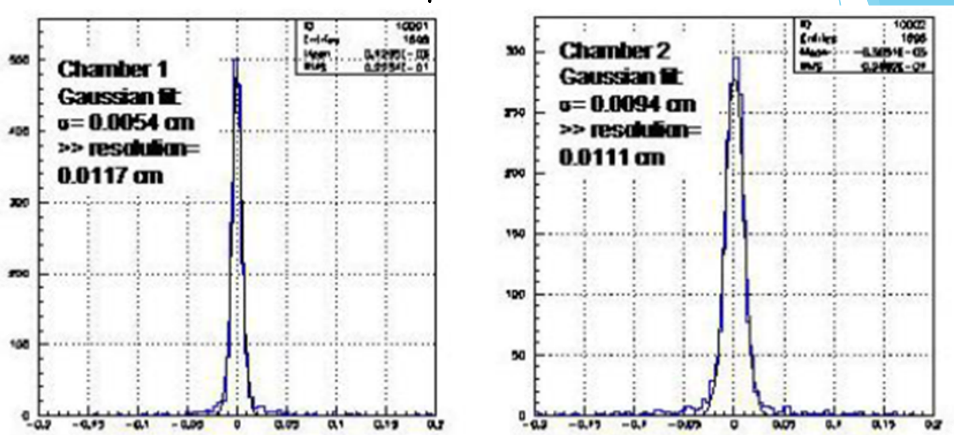
Drift

3-Coordinate Readout & ZigZags (Generic)

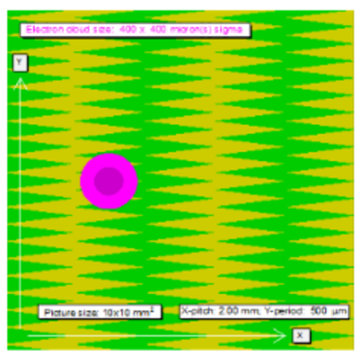


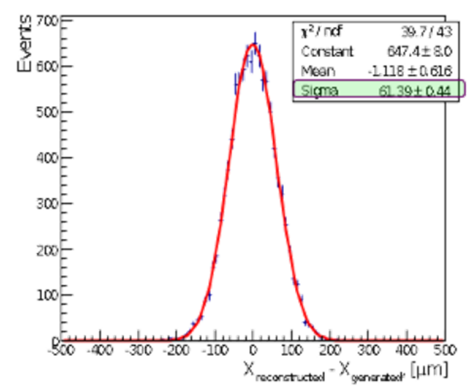
New 3-coordinate Readout
-Hit matching: GEOMETRY & CHARGE

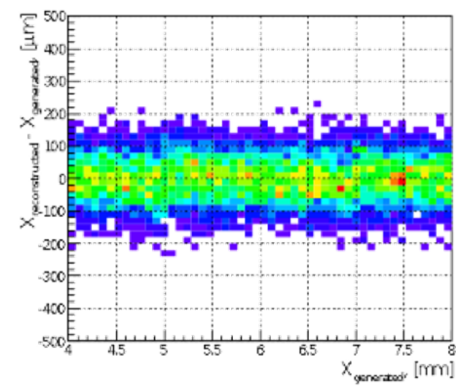
σ ~ 110-120 μm in each coordinate



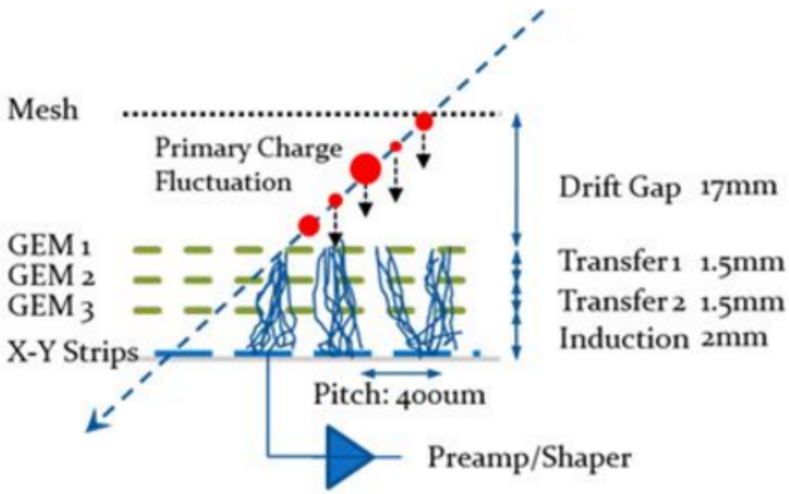
Theory leading R&D





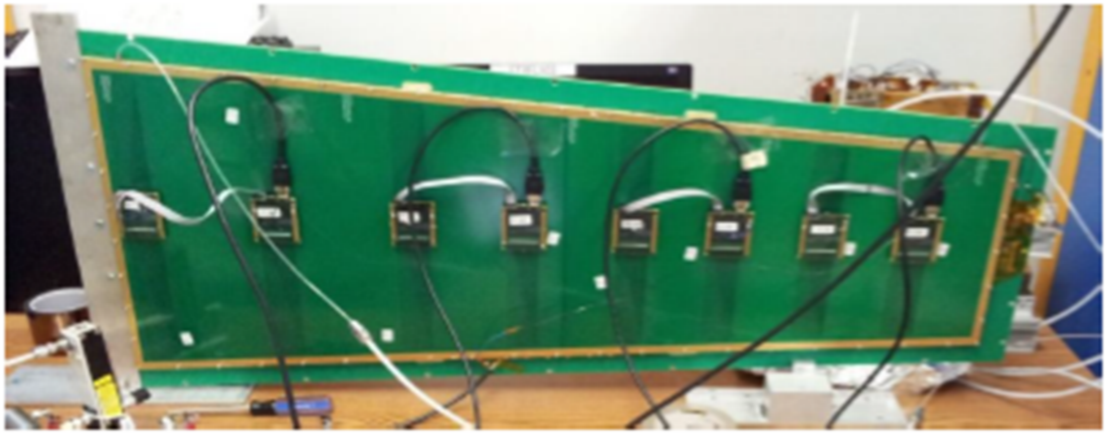


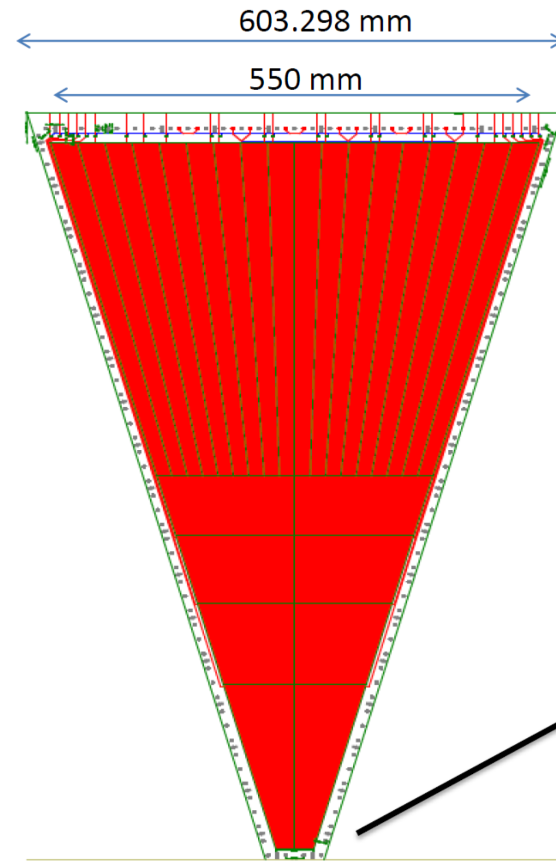
Minidrift (Generic)



- Planar GEMs lose position resolution dramatically wifor includes tracks.
- Significant improvement possible with short drift section.

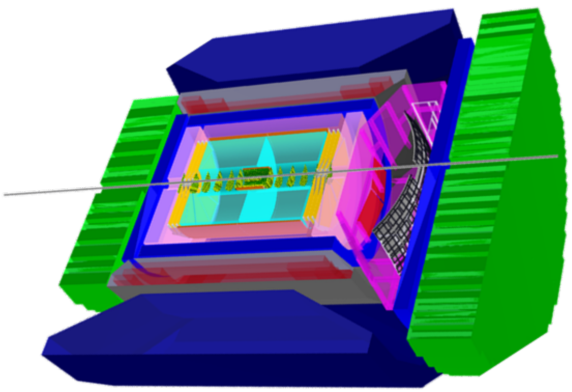
Large Area GEM Detectors (Generic)



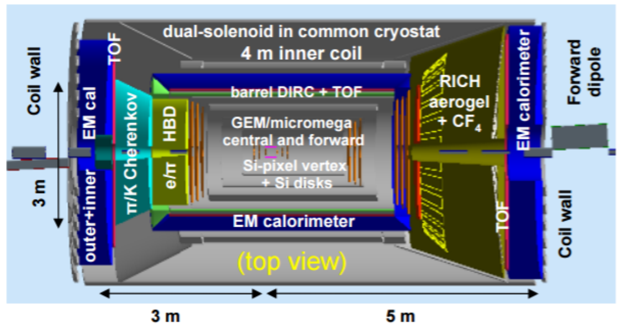


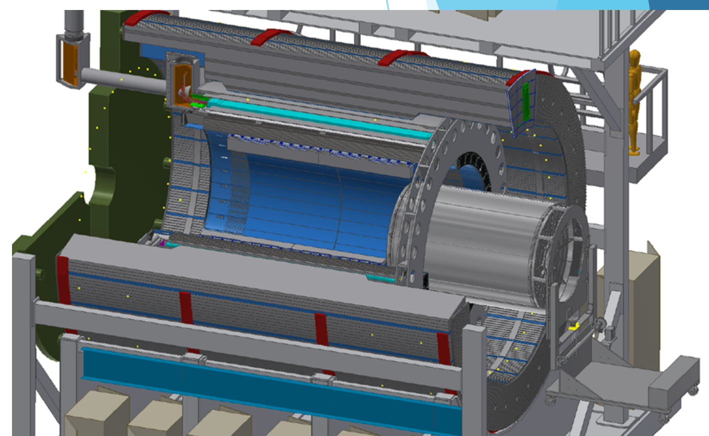
- Single pattern to drive R&D at 3 institutions:
  - FIT, UVA, TEMPLE
- Initial pattern from beam pipe to 1 meter.
  - Larger than most current EIC designs.

Era of directed R&D.

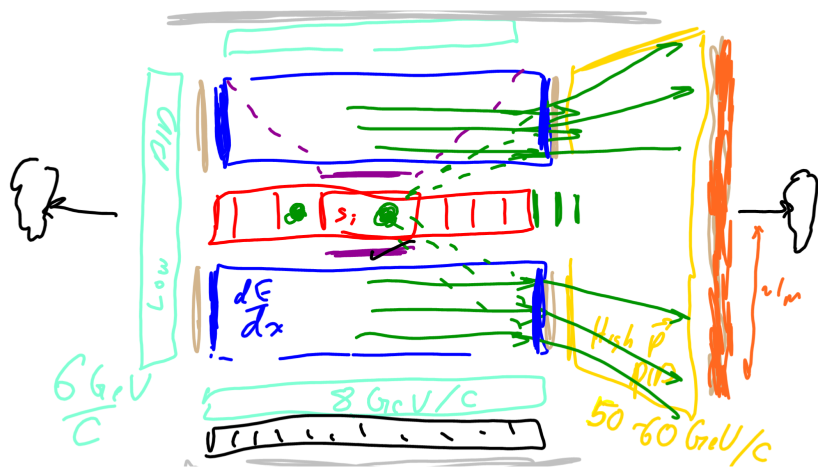


BeAST





Generic Model:

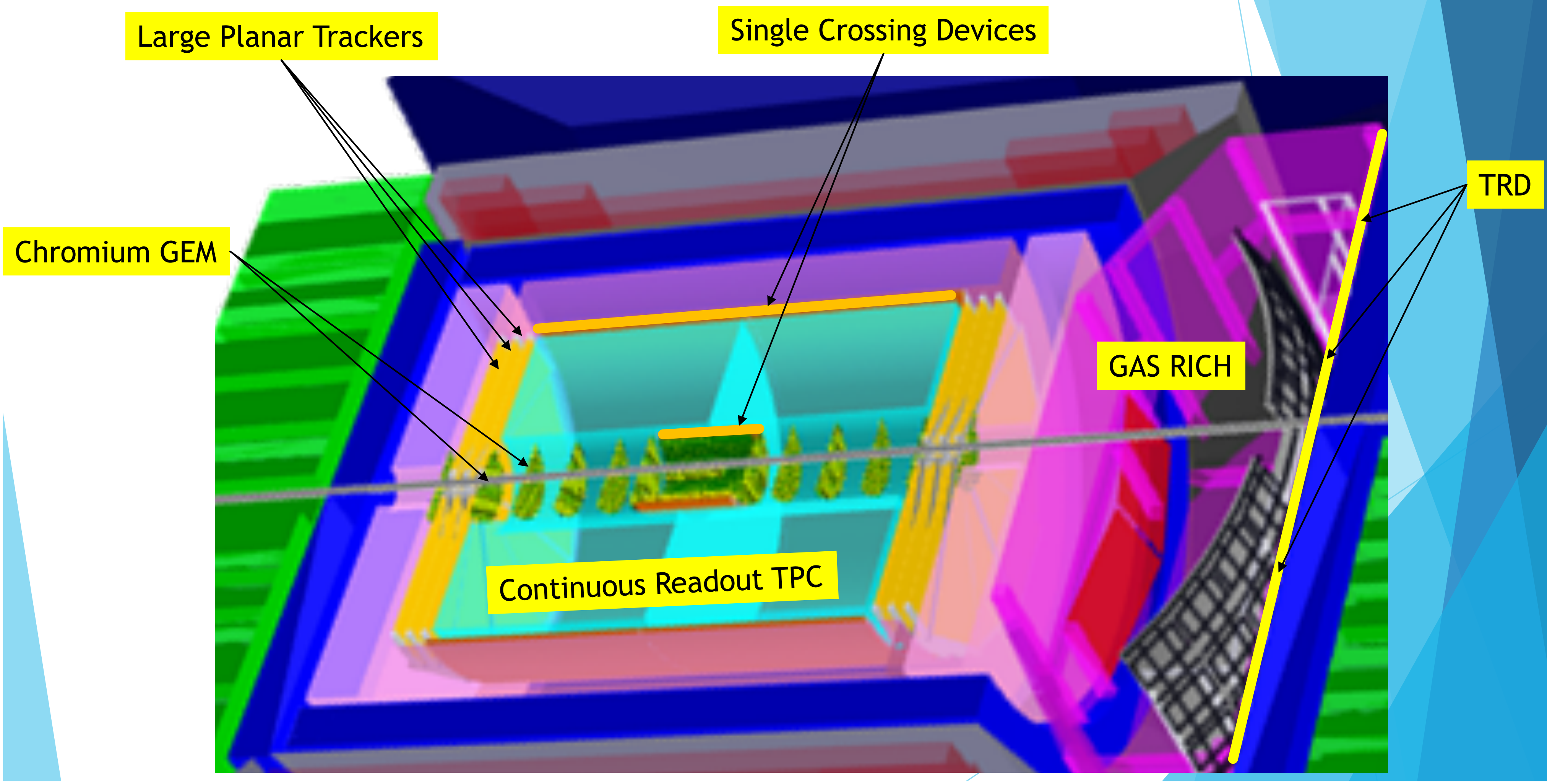


- Meeting prior to MPGD to establish R&D path forward into directed R&D.

Directed R&D Key Elements for MPGD app.

- TPC with Continuous Readout & IBF Suppression
  - Optimized for dE/dx rather than momentum resolution (unlike sPHENIX).
  - R&D into gain stages including proper minimization of IBF for:
    - High luminosity.
    - Possible high backgrounds (esp. Day 1).
  - Maximize dE/dx resolution:
    - High ionization density gas.
    - Instead look toward cluster-counter???
- Barrel Tagger
  - Fast (single crossing) device to verify tracks from slower trackers.
- TRD in hadron direction to study leptonic decays (e.gt. J/Y).
- Chromium GEM at forward angles to complement MAPS pixel sensors.
- Gas RICH as a technology follow-io to the COMPASS RICH UPGRADE.

Vision of directed R&D featuring MPGD @ EIC:



Summary

- Significant MPGD work has been done by the US community anticipating EIC.
- Much more work awaits in our future as MPDG find vast applications at EIC.
- One can only expect that the efforts will grow to meet the needs.
- I believe that the reception assertion is proved.

In recent years, we have seen a growing and impactful community participating in MPGD established in the US.
-- S. Dalla Torre, MPGD 2017

Q.E.D.