Status of Run Group F

- BONuS12

- DVCS on Neutron

Eric Christy

HAMPTON UNIVERSITY

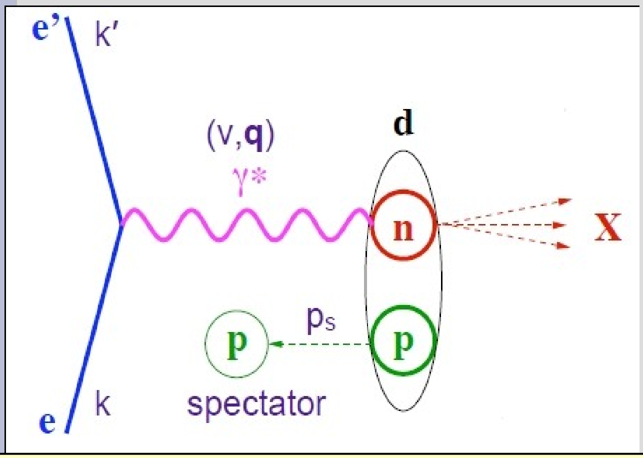
Jefferson Lab

CLAS Collaboration Meeting

November 13, 2019

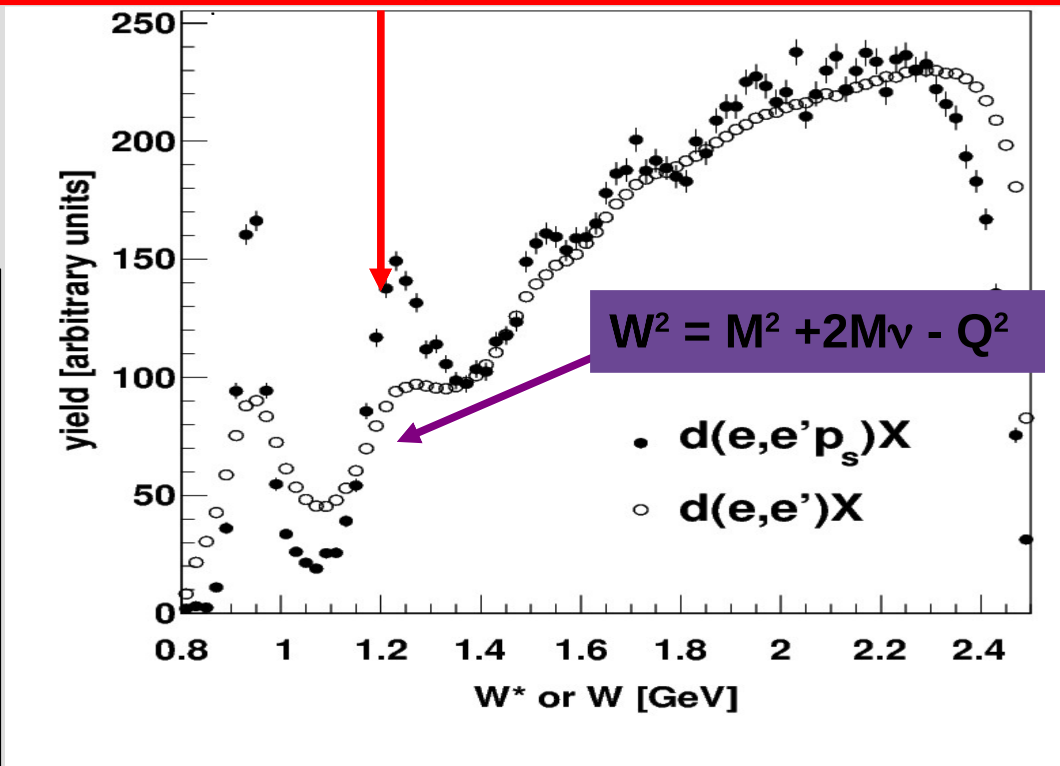
Neutron Structure from Spectator Tagging in the “Barely Off-Shell Neutron Structure” (BONuS) Experiment

$$p_S = \left(E_S, \vec{p}_S\right); \alpha_S = \frac{E_S - \vec{p}_S \cdot \hat{q}}{M_D/2}$$



$$W^{*2} \left(p_n + q\right)^2 = p_{n^\mu} p_{n_\mu} + 2\left(\left(M_D - E_s\right)\nu - \vec{p}_n \cdot \vec{q}\right) - Q^2$$

$$\approx M^{*2} + 2M\nu\left(2 - \alpha_S\right) - Q^2$$



PWIA Spectator Model:

- → Slow Backward proton is spectator
- → Neutron is *slightly* offshell
- → measured proton momentum from recoil in weakly bound d

=> correct for initial state neutron momentum

Select slow, backward protons to minimize:

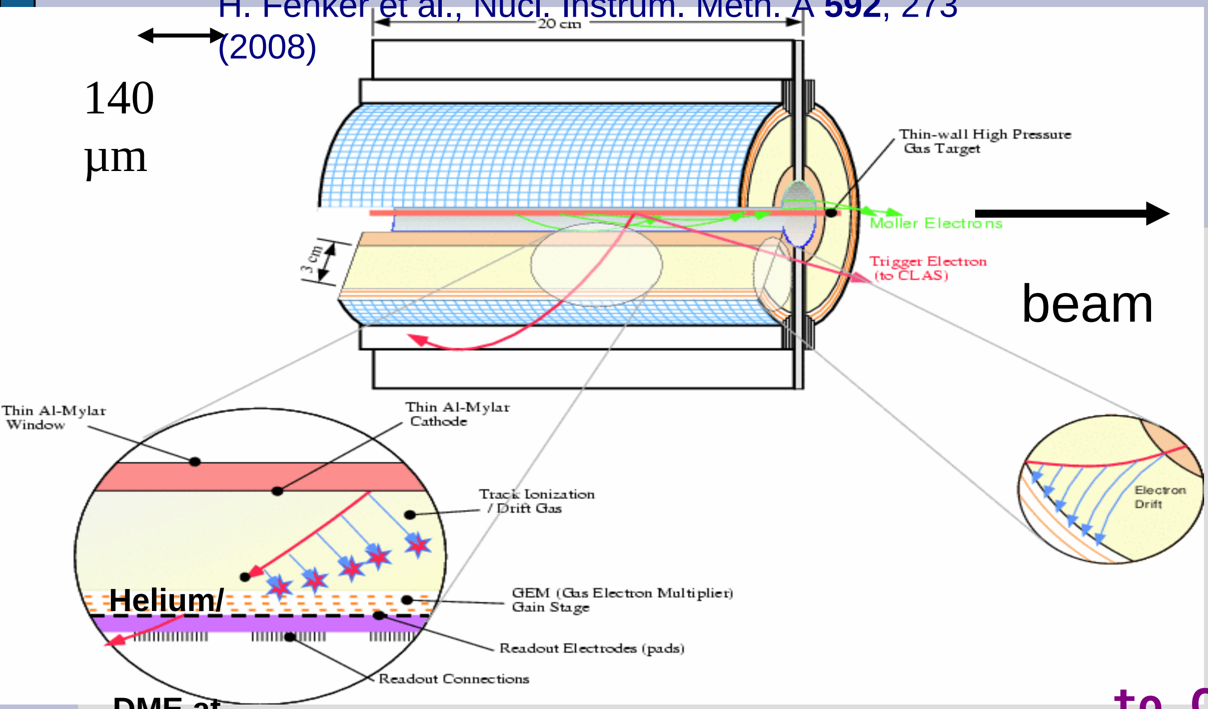
1. **Off-shell effects**

2. **Final state interactions**

3. **Enhancement to proton yield from target fragmentation**

Tag spectator proton in RTPC

H. Fenker et al., Nucl. Instrum. Meth. A **592**, 273 (2008)



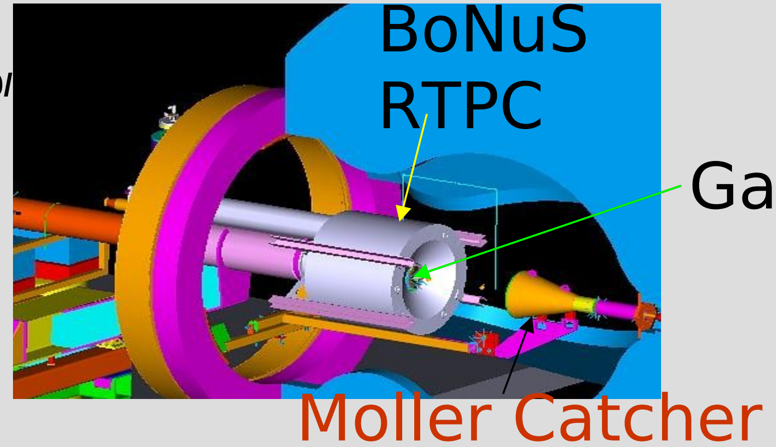
Fit RTPC points to determine helix of proton trajectory.

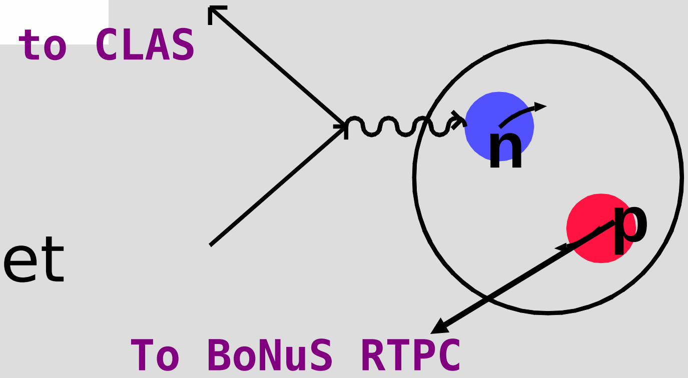
Momentum determined from track curvature in solenoid field.

dE/dx along track in RTPC also provides momentum information and PID.

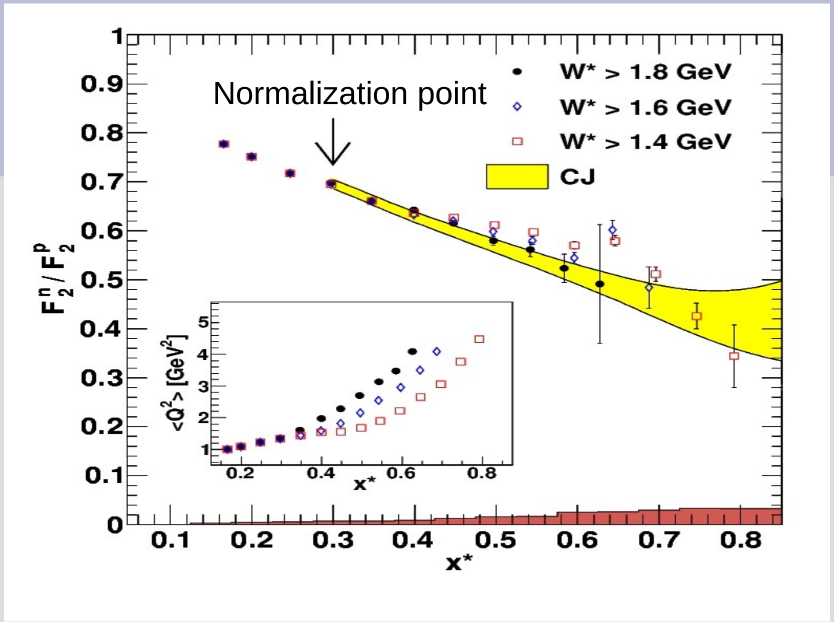
DME at

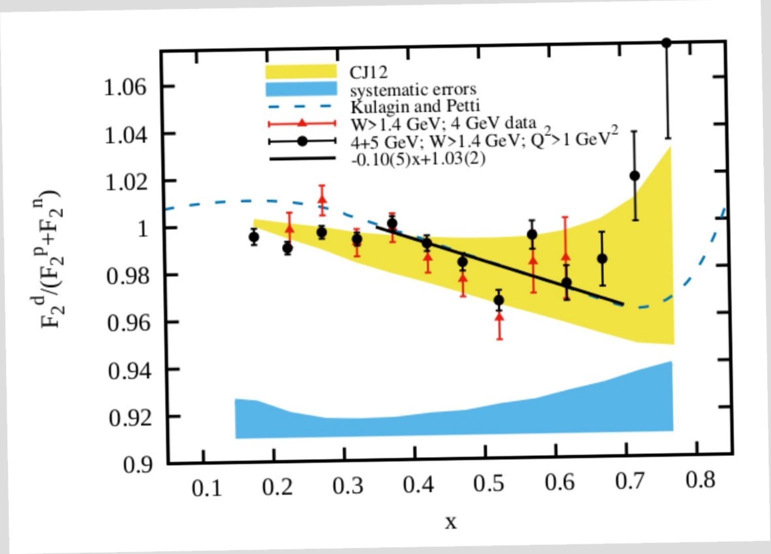
80/

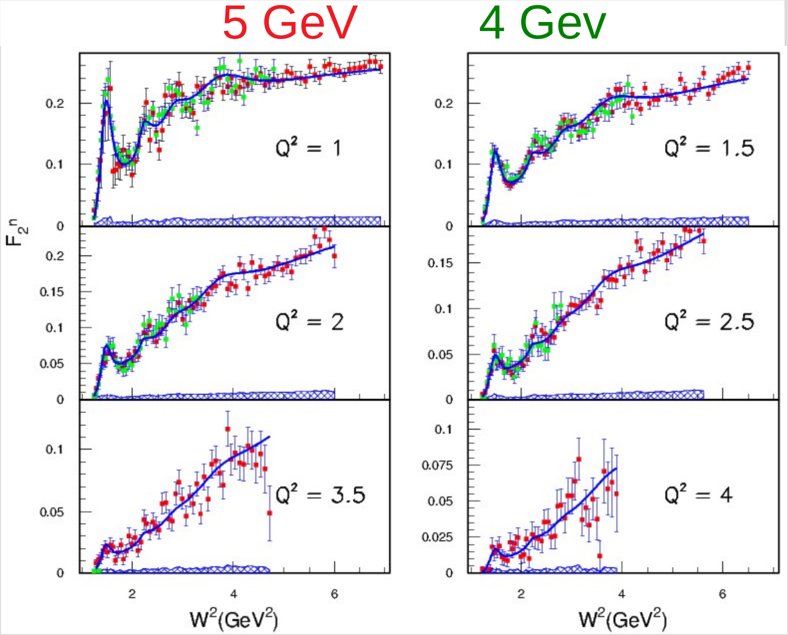




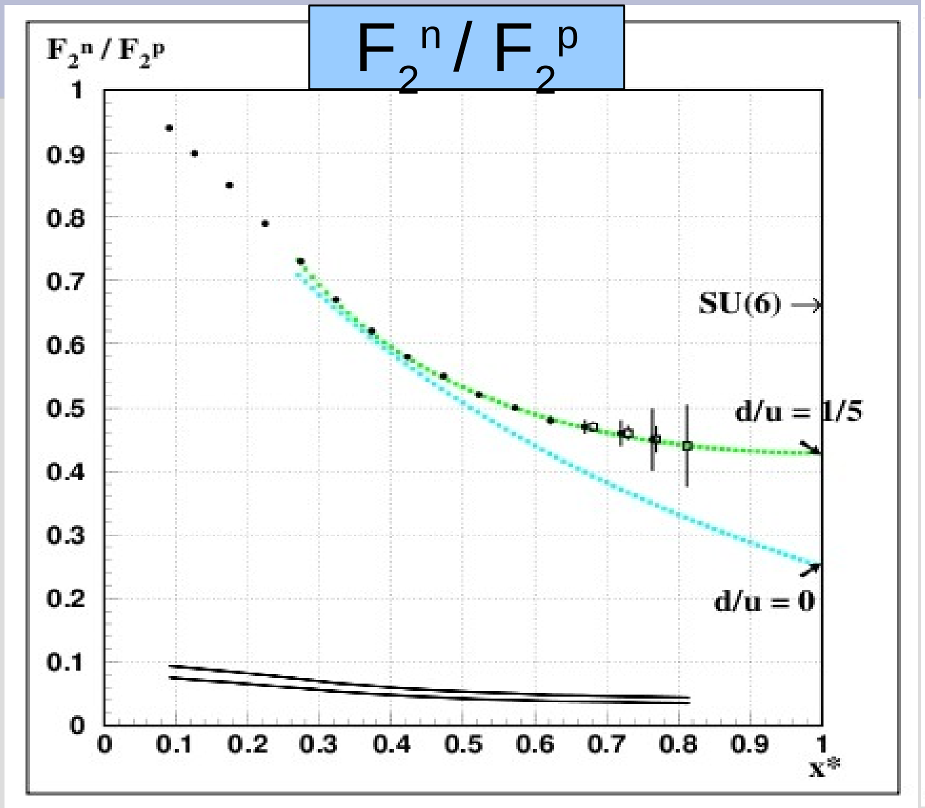
Lots of interesting results from 6 GeV

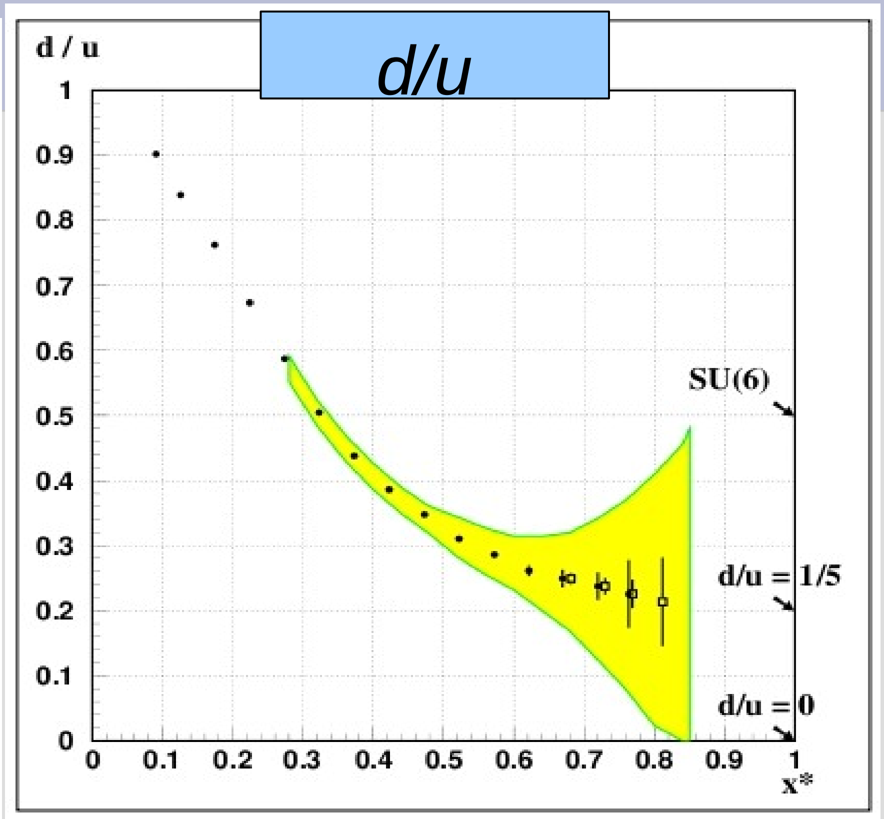






Expected BONuS12 precision

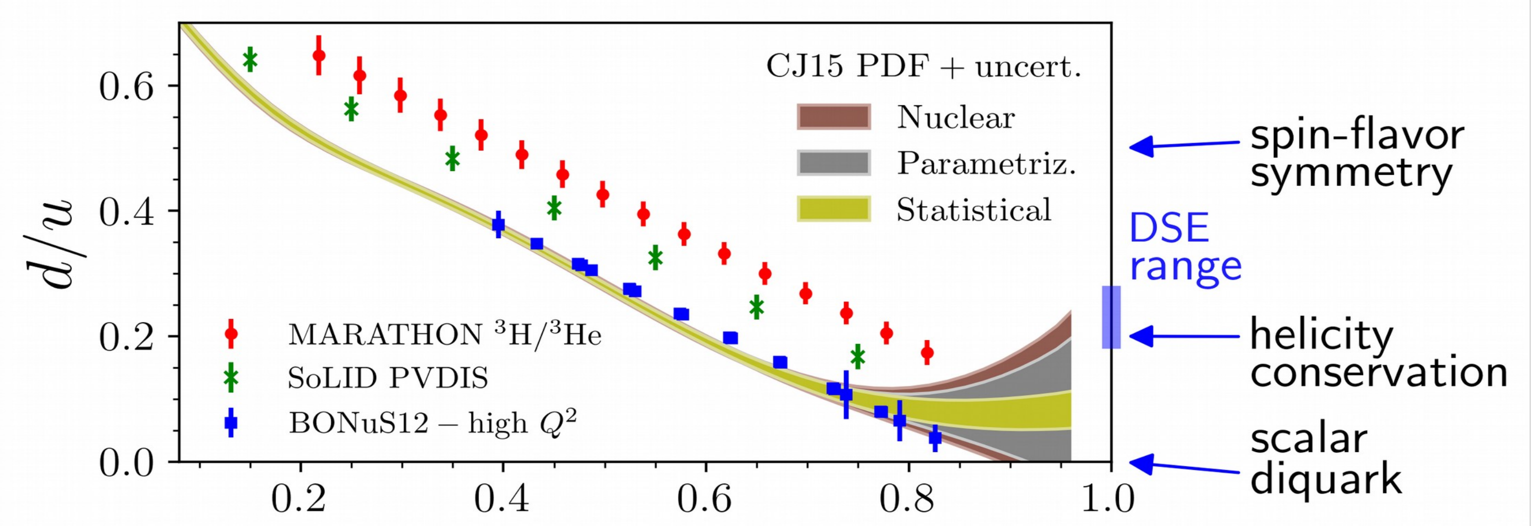




Multiple experiments in JLab 12 GeV era to determine *d/u* at high-*x*

With *different* systematics

- MARATHON - 3H / 3He mirror nuclei
- SoLID PVDIS
- BONuS12 – proton recoil tagging



A. Accardi

BONuS12 Experimental Setup

$e^- D \rightarrow e^- p X$

11 GeV

- Planned experimental setup:

- CLAS12 Forward Detector:

→ Superconducting Torus magnet.

→ 6 independent sectors:

→ HTCC

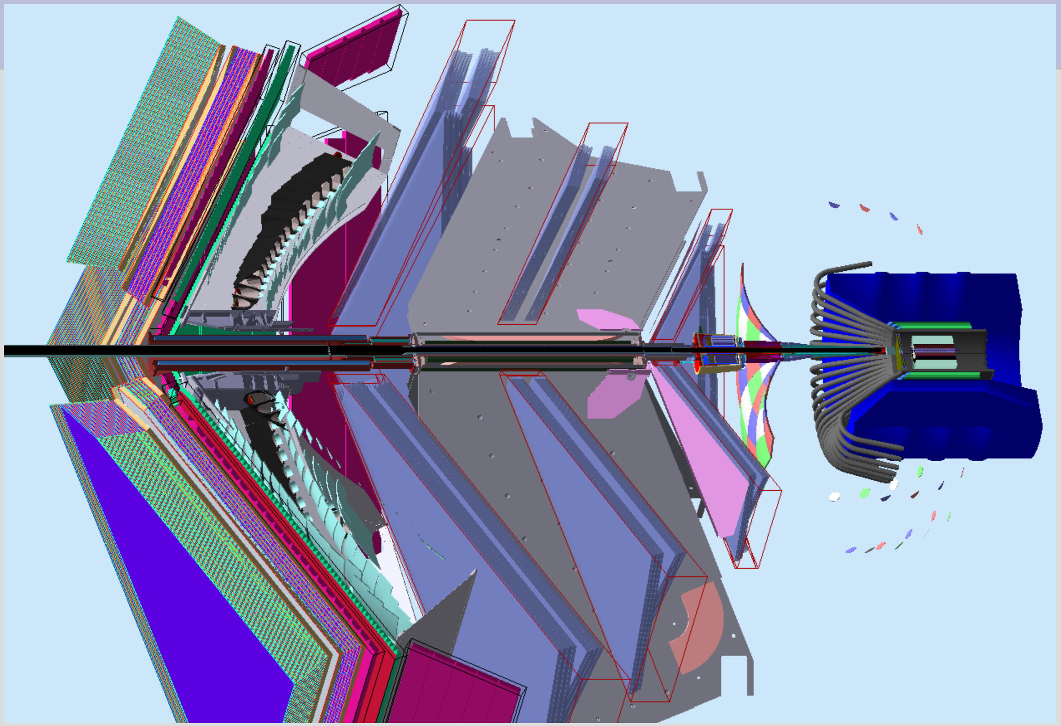
→ 3 regions of DCs

→ LTCC /RICH

→ FTOF Counters

→ PCAL and ECs

→ FT off



- Central:

→ Target: D gas @ 7 atm, 293 K

→ BONuS12 RTPC

→ FMT

→ Solenoid (5 T)

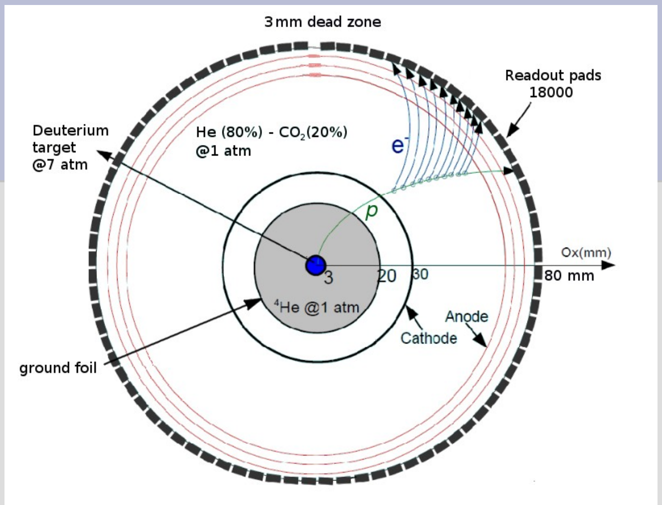
→ CTOF, and CND

35 days on D

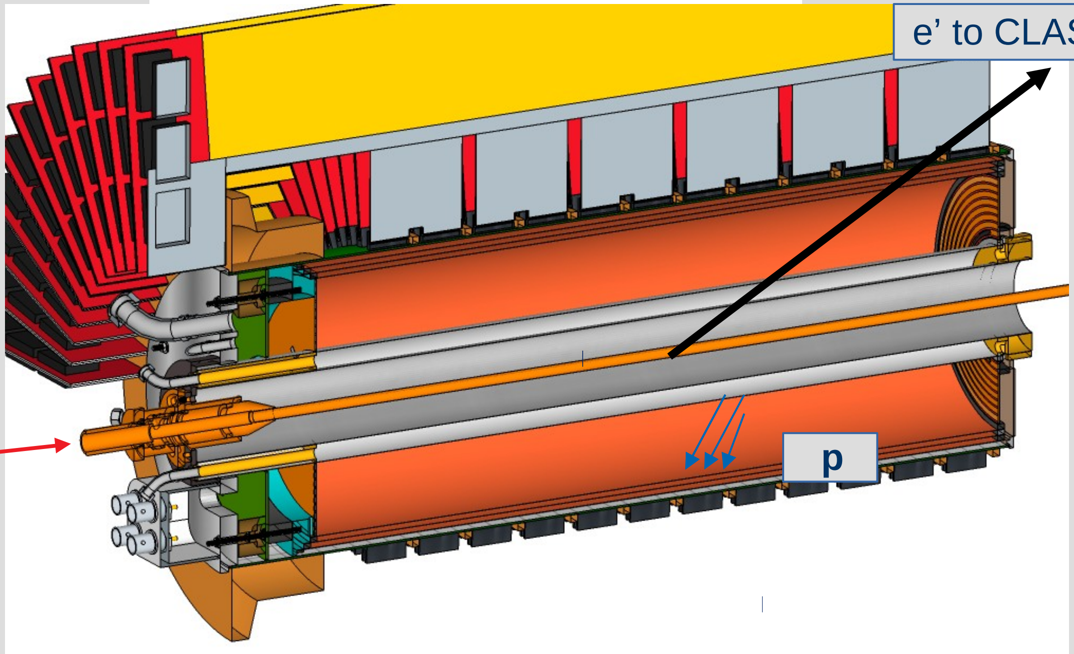
5 days on $^4He/H_2$

with $L = 2 \cdot 10^{34}$ cm^{-2} sec^{-1}

BONuS RTPC General Specifications



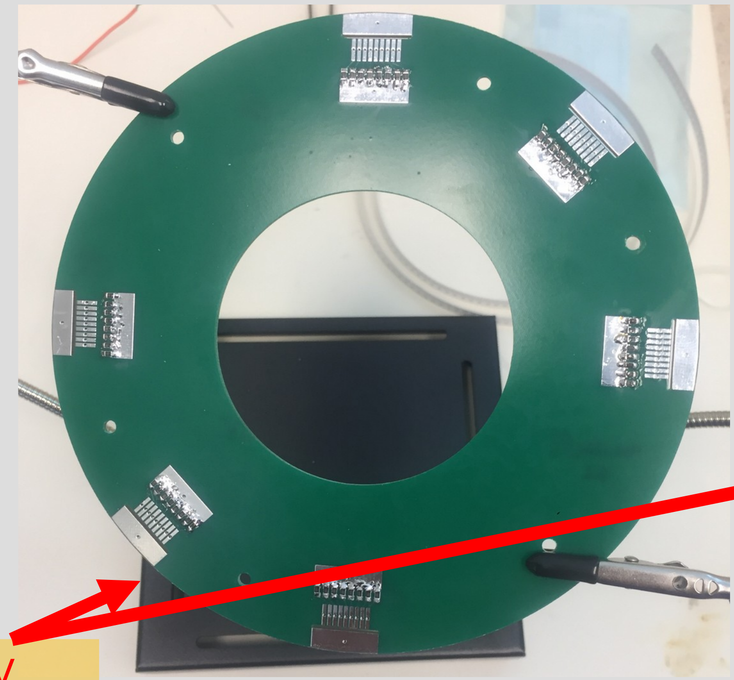
- → Active length: 40 cm
- → Radial drift distance: 4 cm
- → Drift gas He/CO_2 (80/20)
- → 3 GEM amplification layers
- → 16 HV sectors per GEM (Segmented in φ)
- → Pad readout: 2.8 mm x 4 mm
  => 17,280 channels

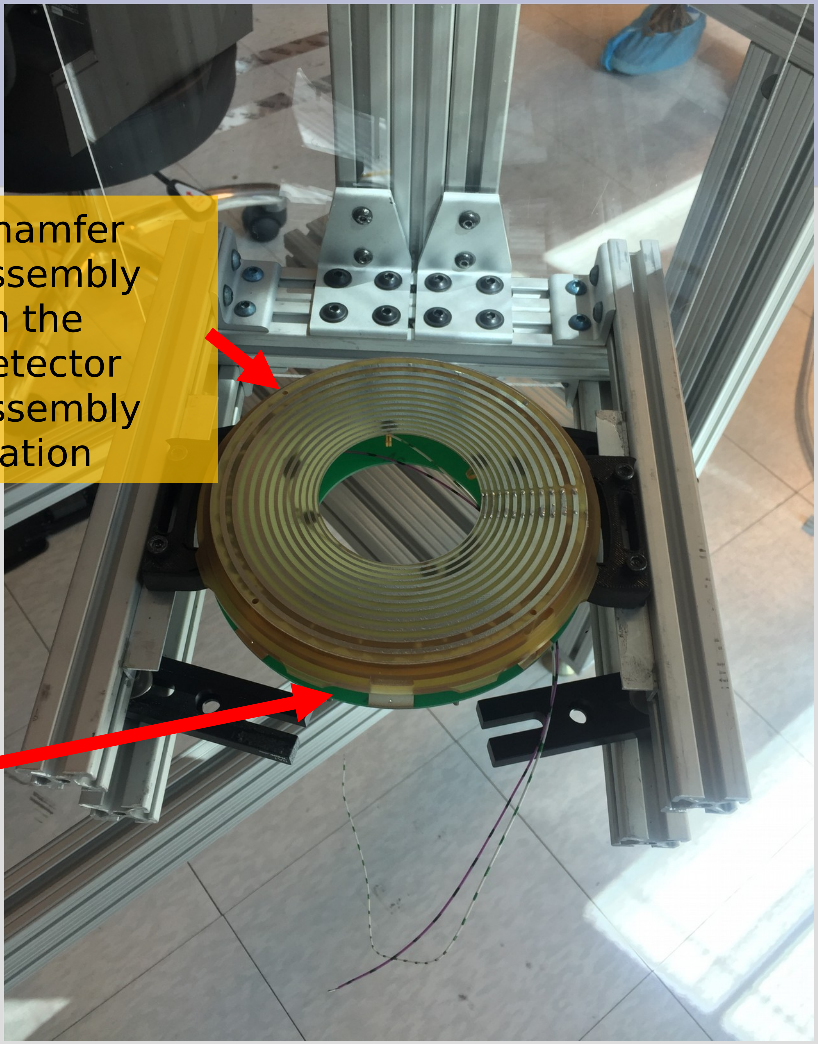


RTPC Construction at HU

Ibrahim Albayrak
Aruni Nadeeshani

Field cage + chamfer + high voltage board

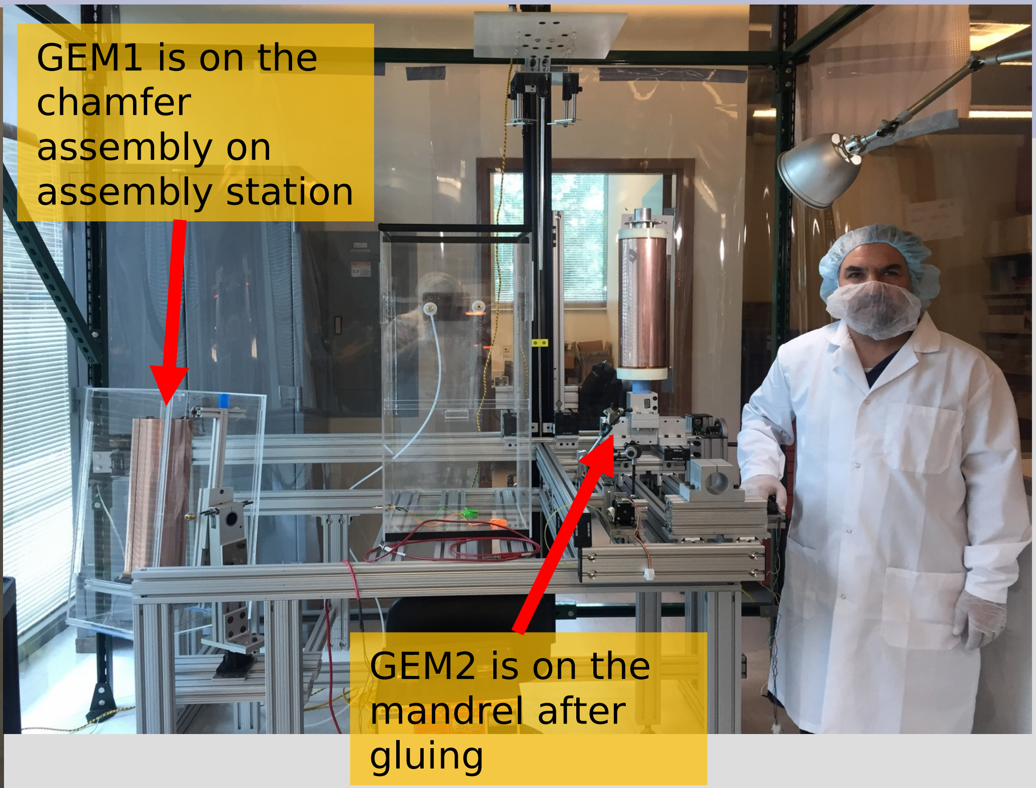




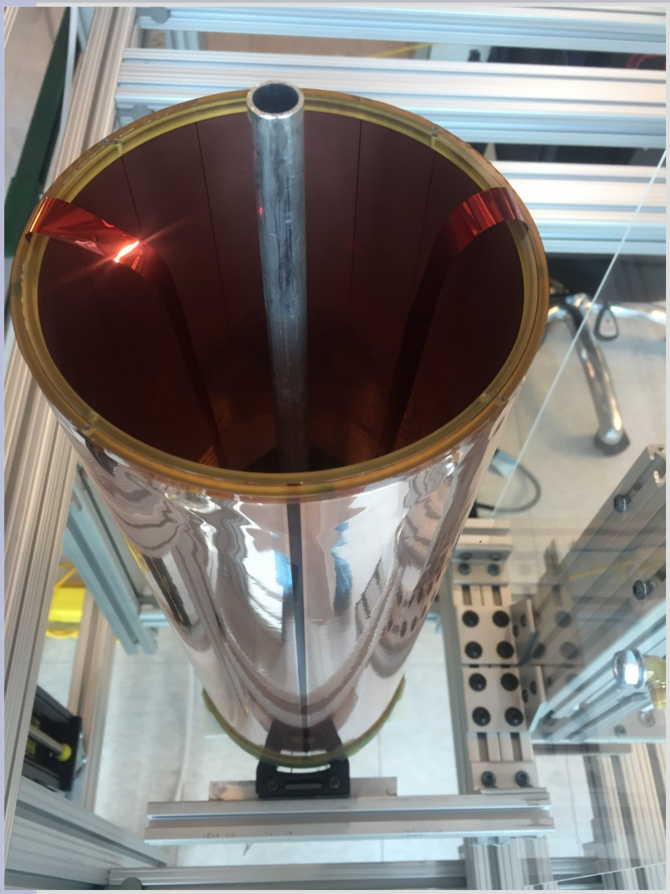
Chamfer assembly on the detector assembly station

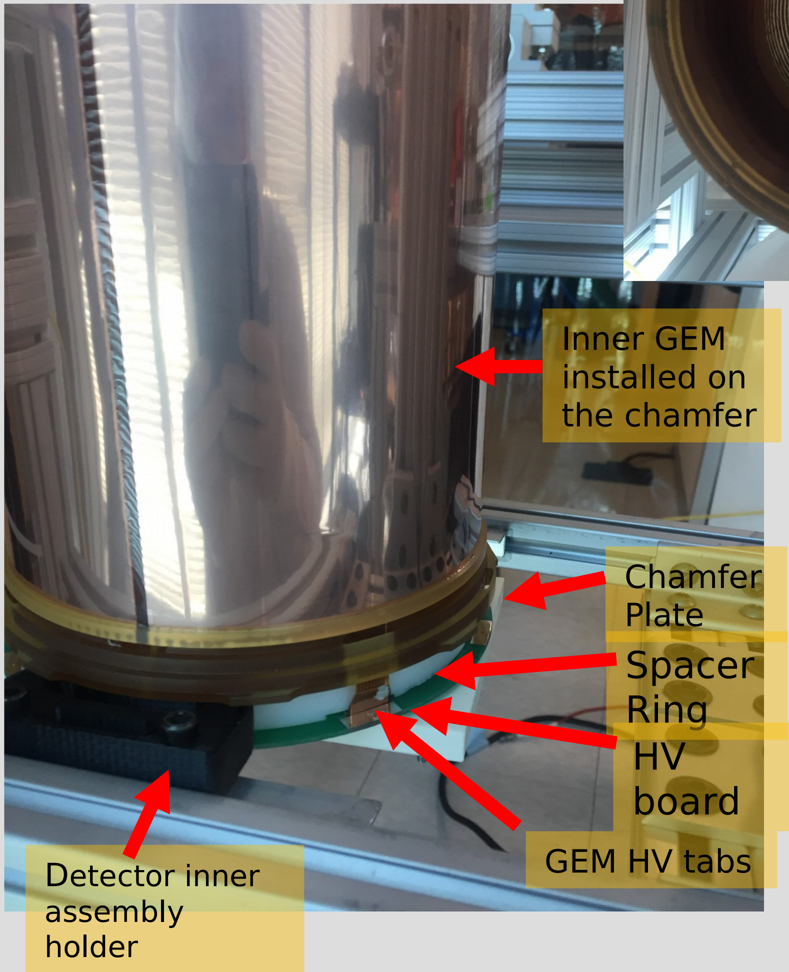
GEM HV Board

GEM Wrapping and Testing



GEM Installation





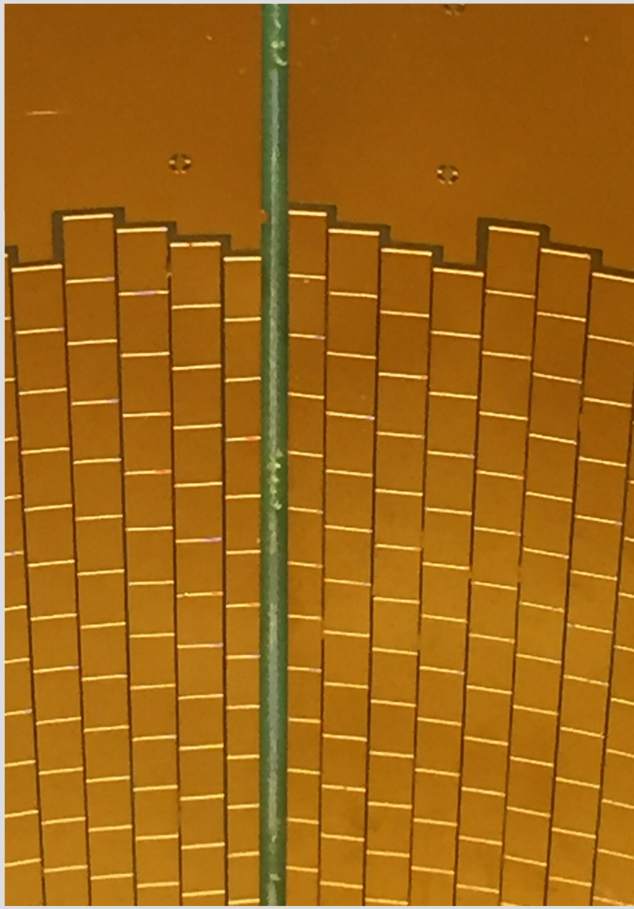
Padboard

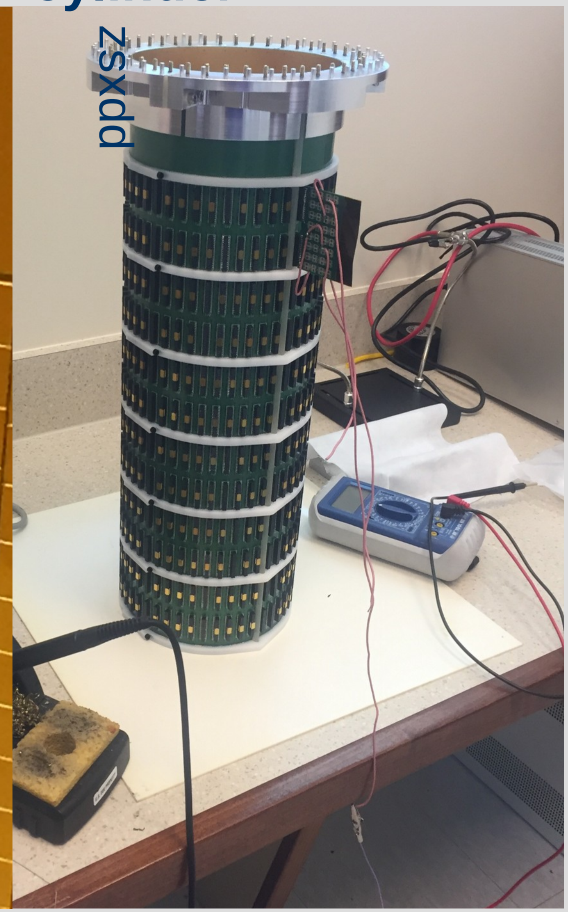
(Fast Electronics Group)

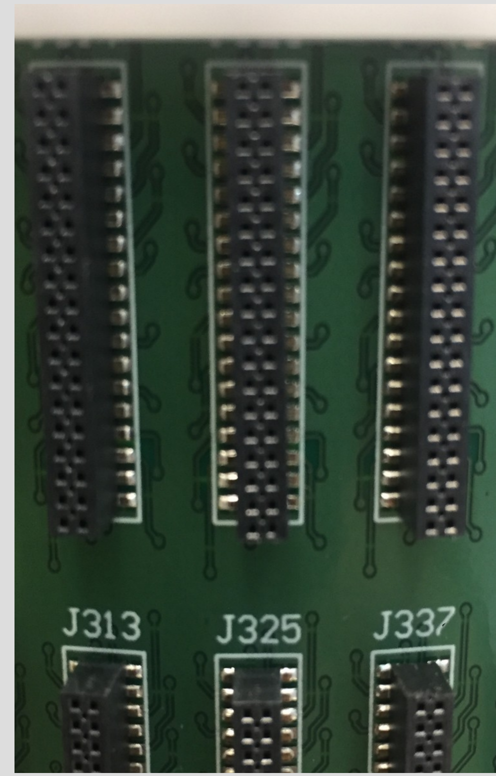
Inside Surface

Outside Surface After forming cylinder

Connectors

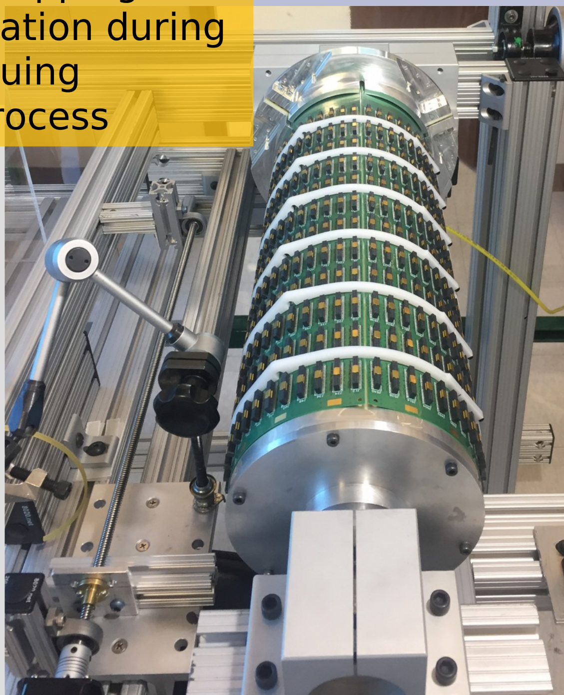




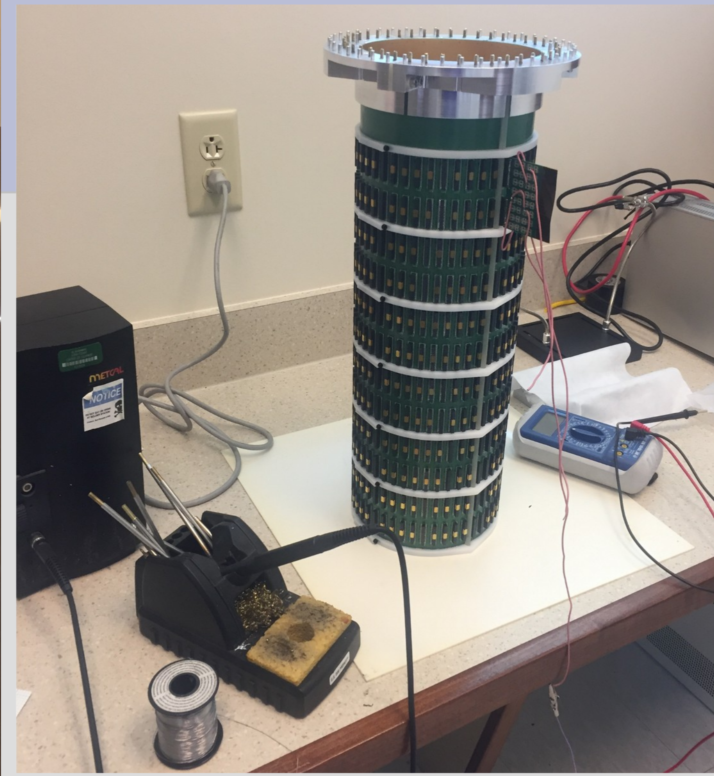


Padboard Wrapping

Pad board on wrapping station during gluing process



Pad board alignment cards for the rings

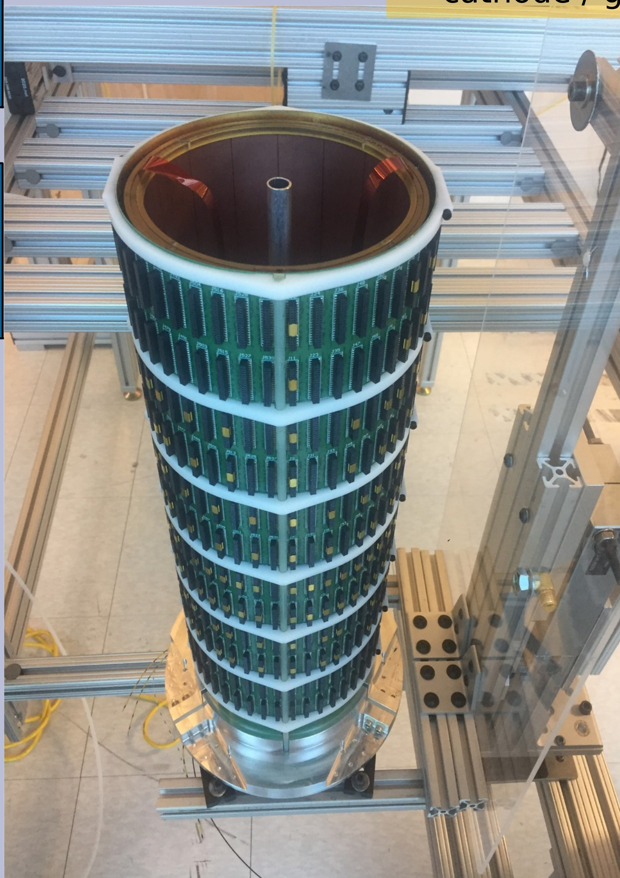


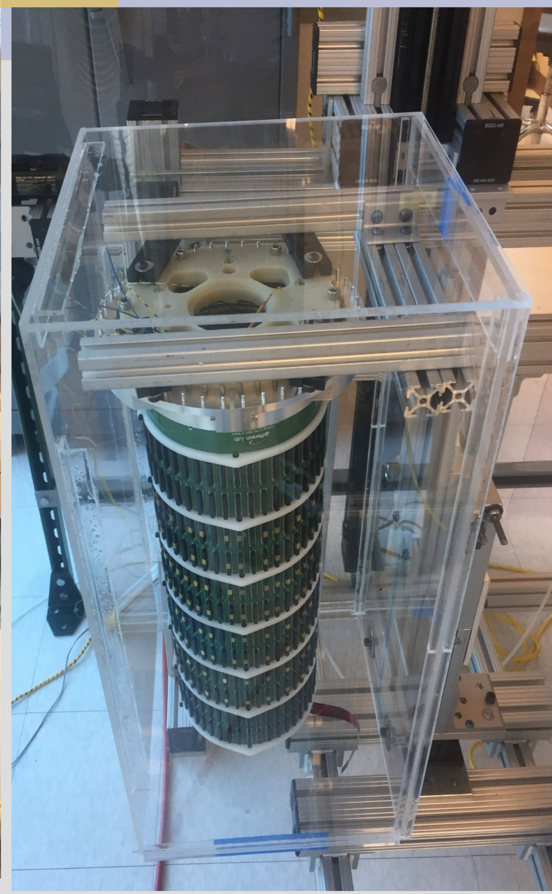
Final testing:

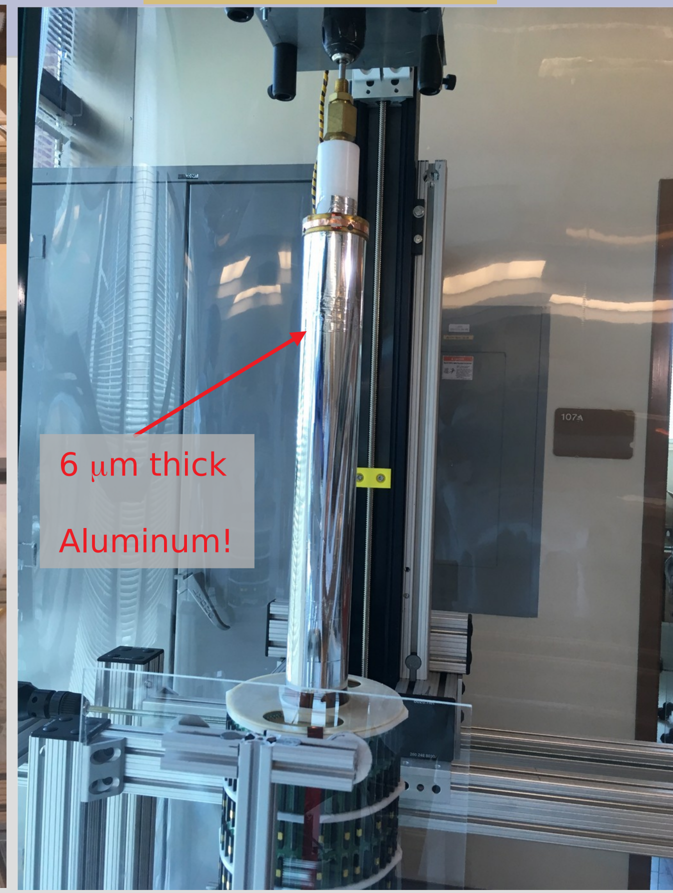
< 0.5% bad pad connections

Detector sans:
→ downstream fieldcage / plate
→ cathode / ground

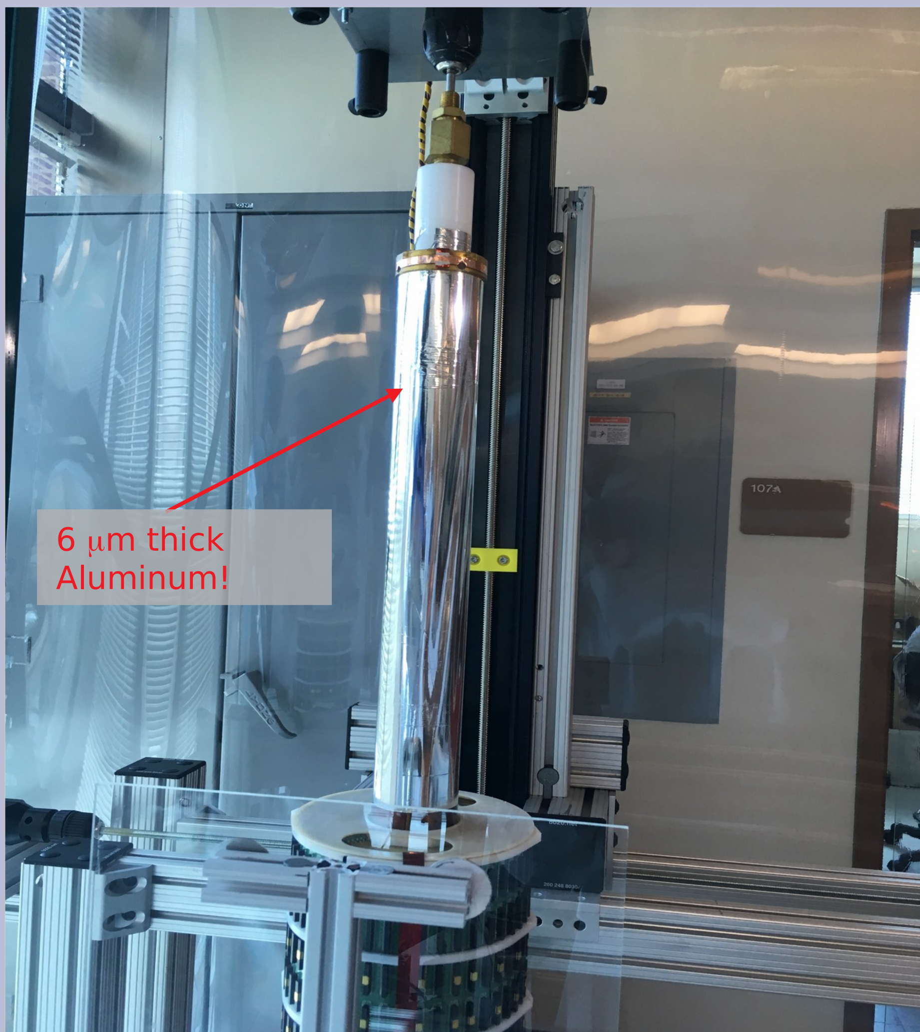
Cathode / ground assembly tension transfer test

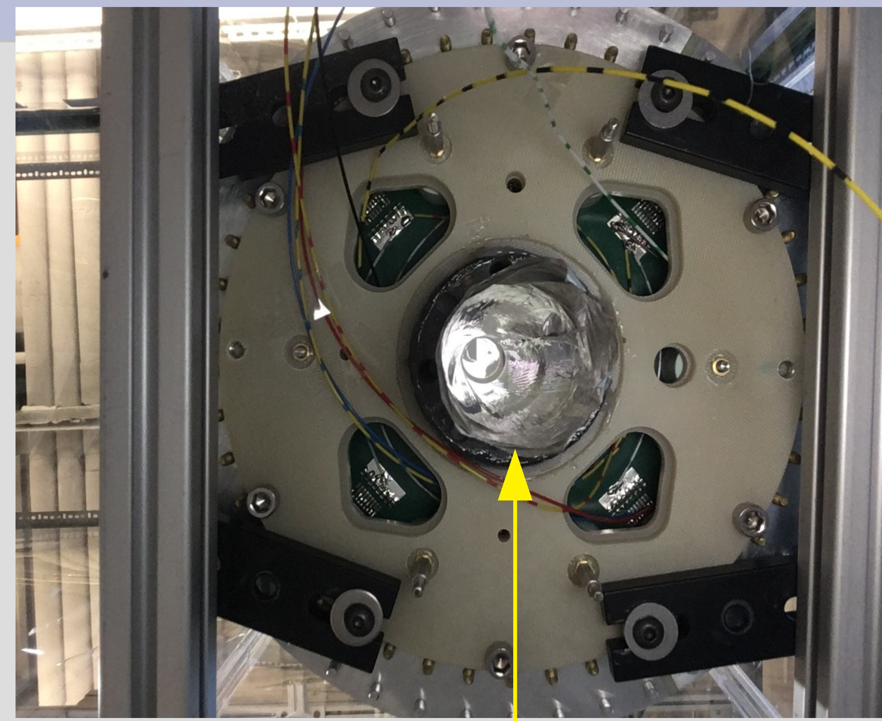




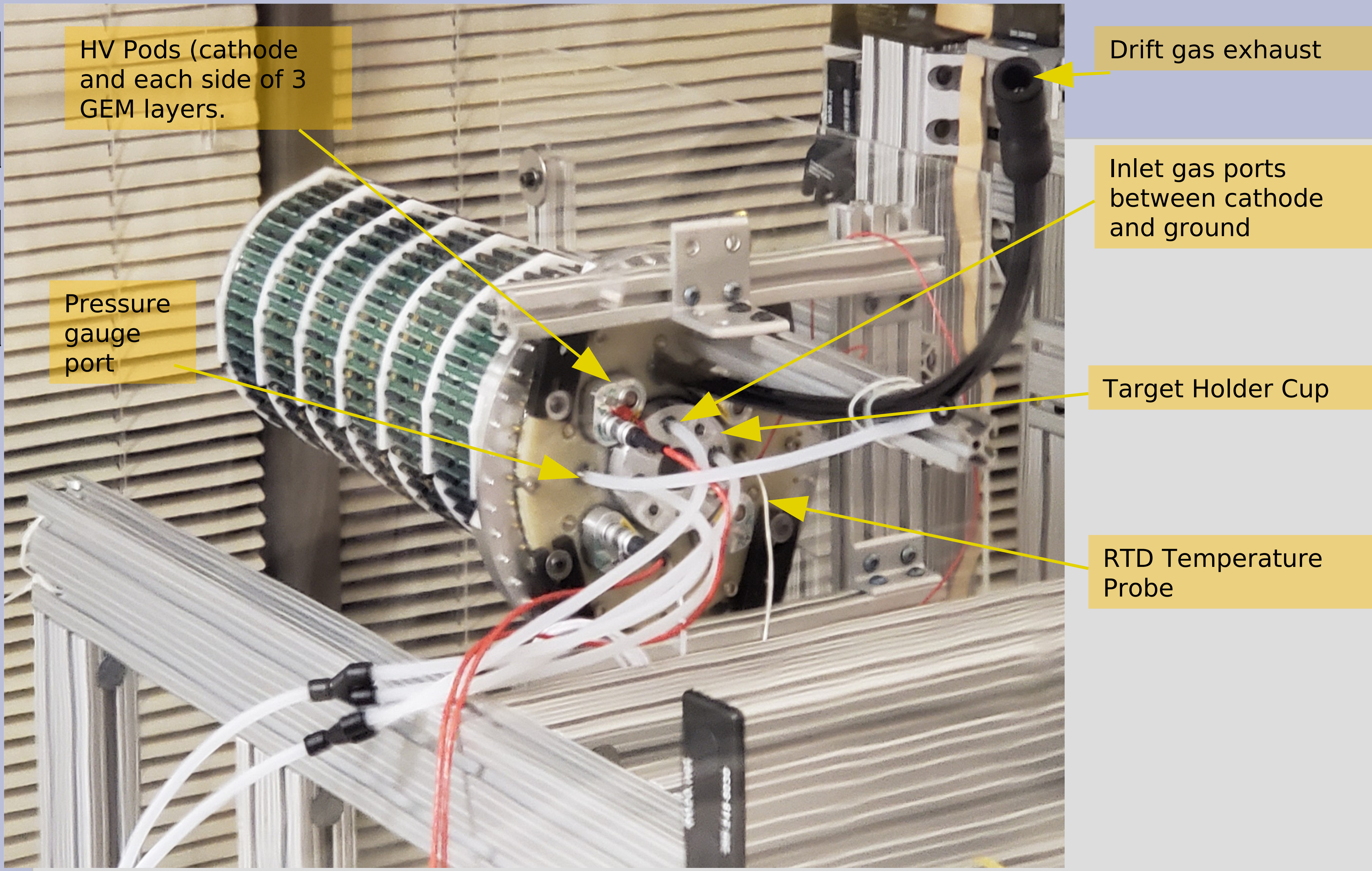


Cathode / Ground Assembly





Completed Detector



Detector / Testing Status

- 1st detector completed and tested with HV on cathode (-3000V) and both ground foil and padboard grounded and 1st GEM layer at -200 V

  => current draw consistent with resistance through field cages

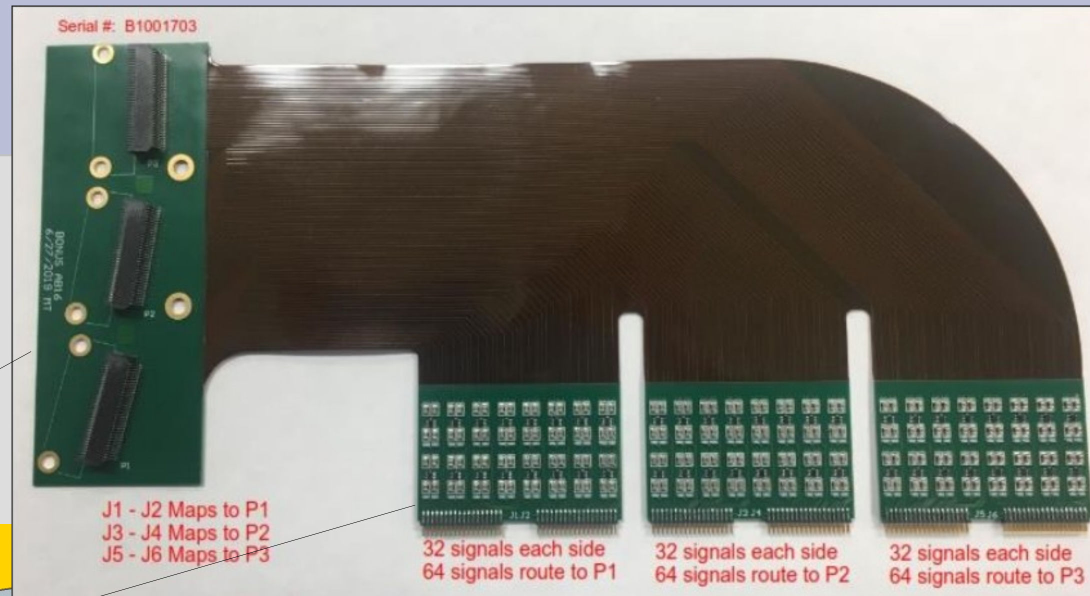
- Biasing of all GEM layers tested individually after forming cylinders

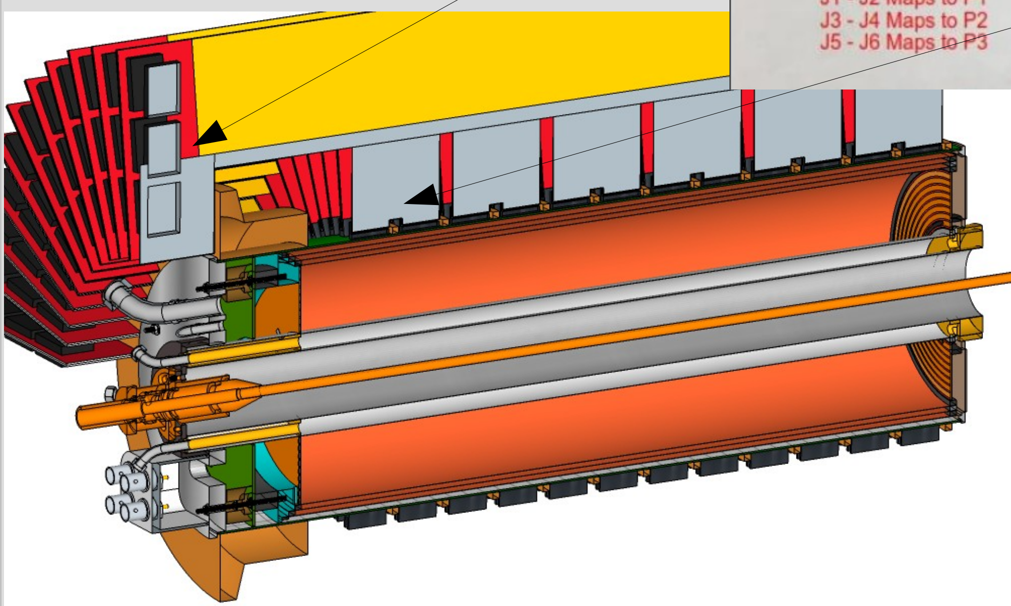
- Detector being transported to EEL for testing today.

- Waiting for SHV → LEMO HV cables (non-standard cable) to fully power all GEMs

Current limiting adapter boards

Current limiting adapter boards Protect FrontEnd Dream chip electronics





→ 5 prototypes in hand for testing

→ Production boards expected to arrive in 2 weeks.

BONuS12 Drift-Gas Panel and Slow Controls

Target

Buffer

Drift

- Gas system for drift and target regions in EEL, as part of test bench.
- Controllers and sensors for drift gas region run by slow controls.
- Drift gas region quantities have assigned EPICS variables and can be archived.
- Operation manual exists for this system as a live document.

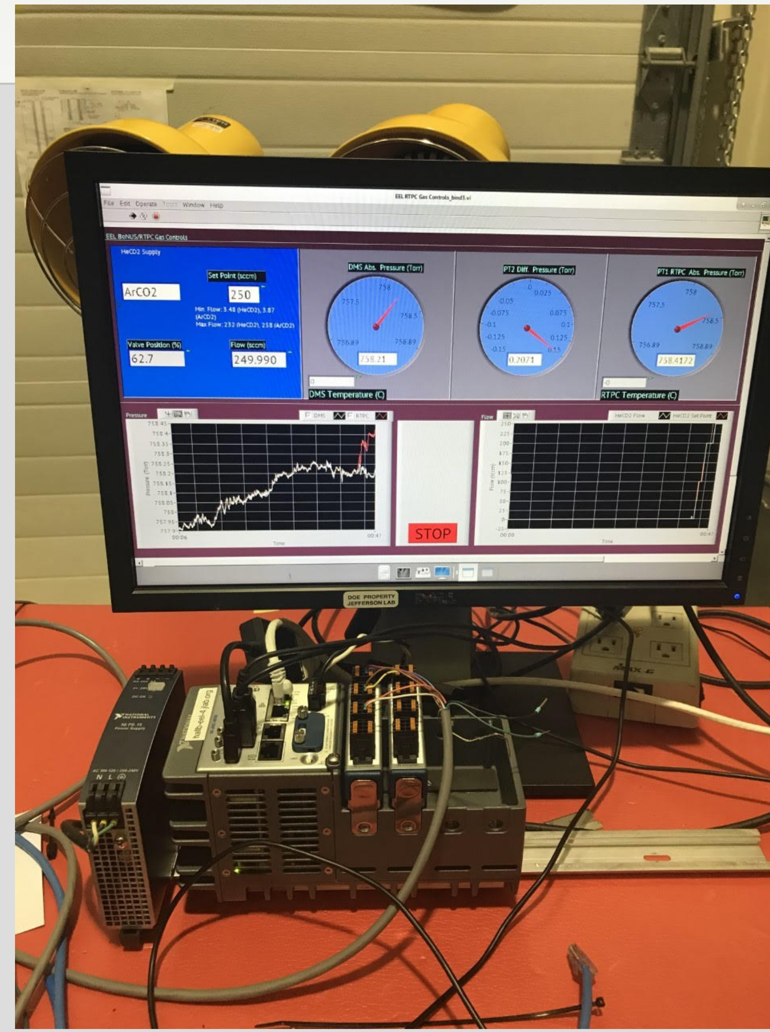
BONuS12 Drift-Gas Panel and Slow Controls

Target

Buffer

Drift

Gui operating in EEL test setup

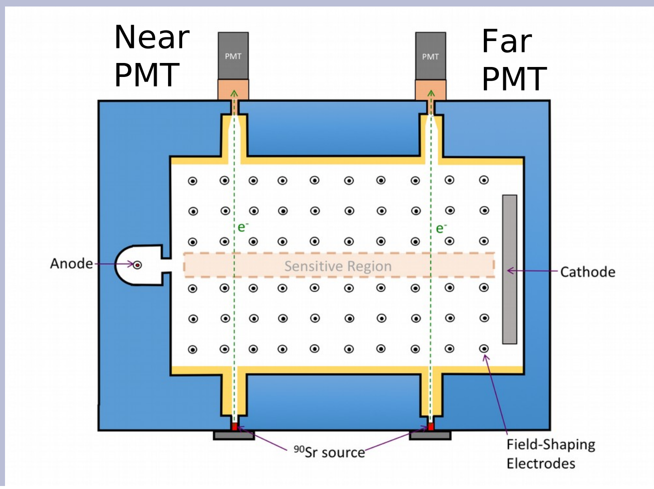


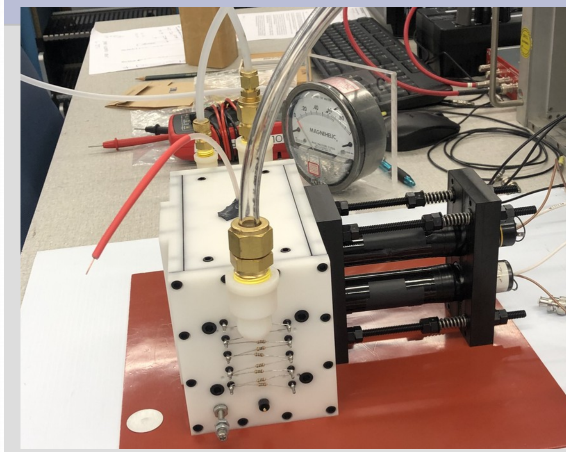
22

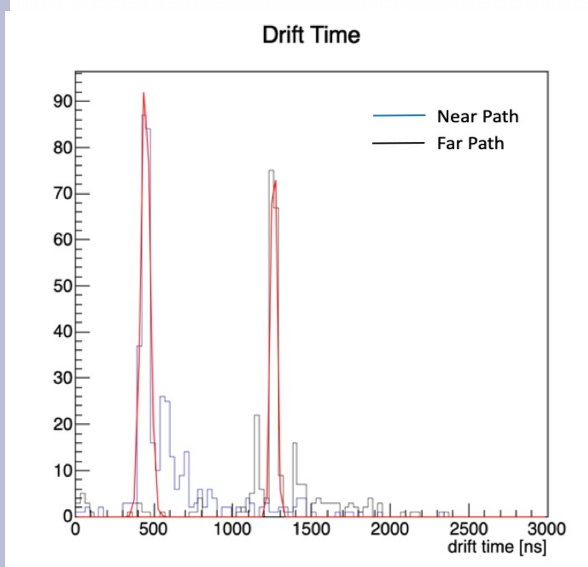
Drift-gas Monitoring System (DMS)

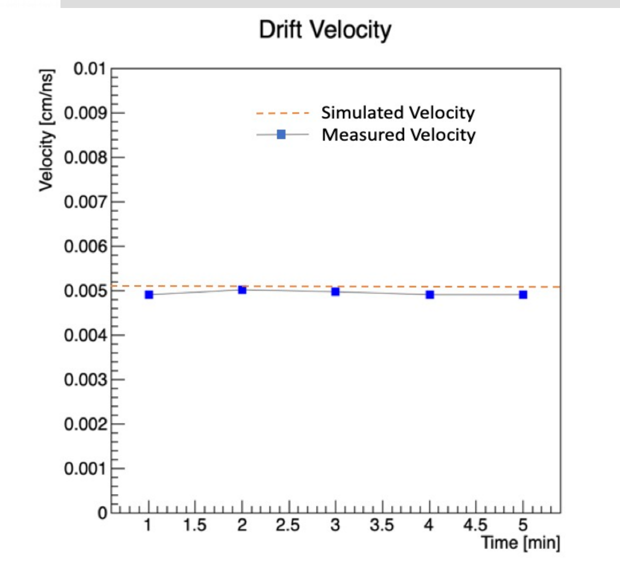
Nathan Dzbenski, ODU

Provides constant monitoring of changes in drift velocity due to changes in: Temperature, pressure, gas mixture









→ DMS built, tested, and shown to provide good precision for monitoring changes in gas affecting *drift velocity.*

→ Soon to be installed on Gas panel in EEL126

Test setup in EEL

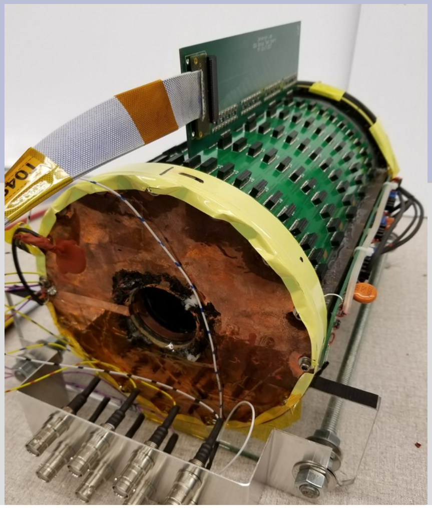
Setup in EEL126 to test:

- detector
- gas system
- full readout electronics chain
- DAQ
- Slow controls and monitoring

7 DREAM FEUs
→ utilize 6 for RTPC
3076 channels

Test setup in EEL

Jiwan Poudel, ODU
Mohammad Hattaway, ODU

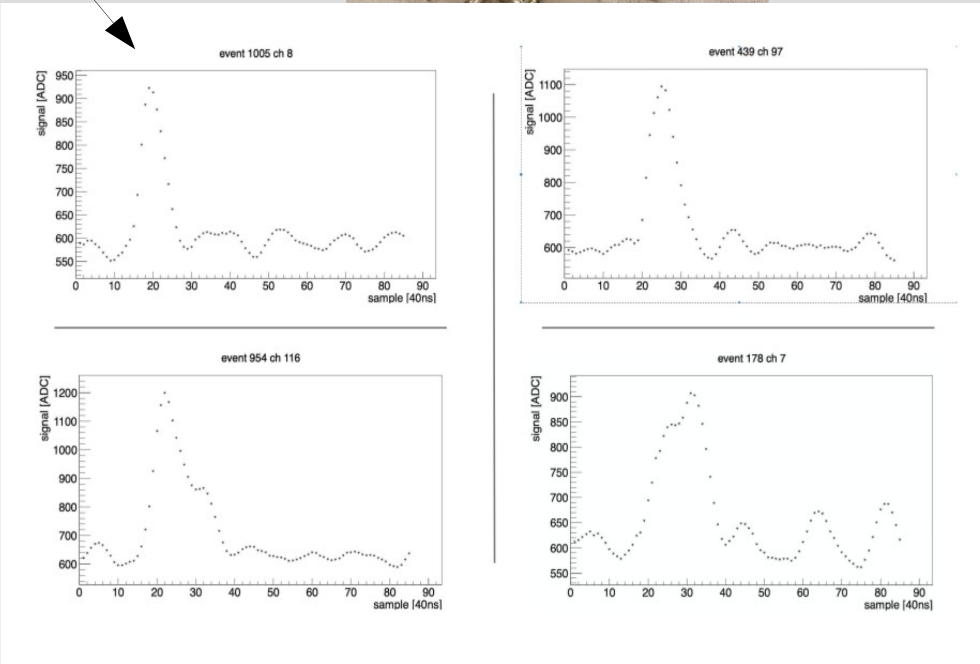


→ FEU firmware has been updated for and tested for RTPC operation.

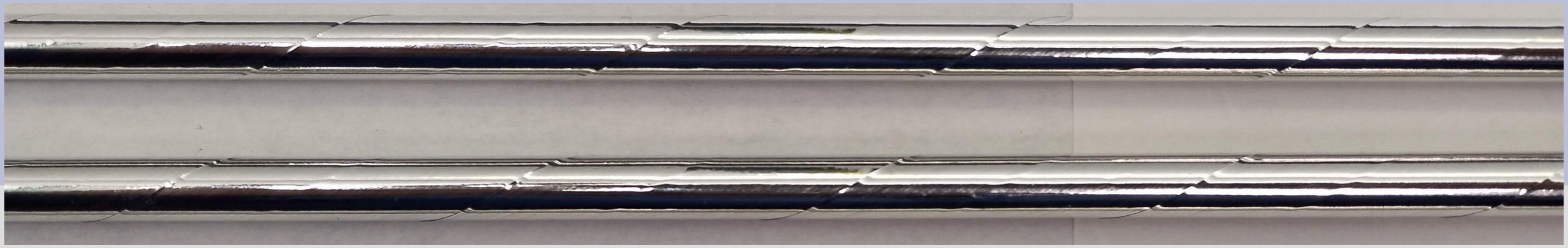
→ Signals from cosmics readout utilizing EG6 prototype RTPC

→ Everything in place for full CODA readout

→ Estimated time for full decoder and analysis software for cosmic ray tracking ~1.5 – 2 weeks.



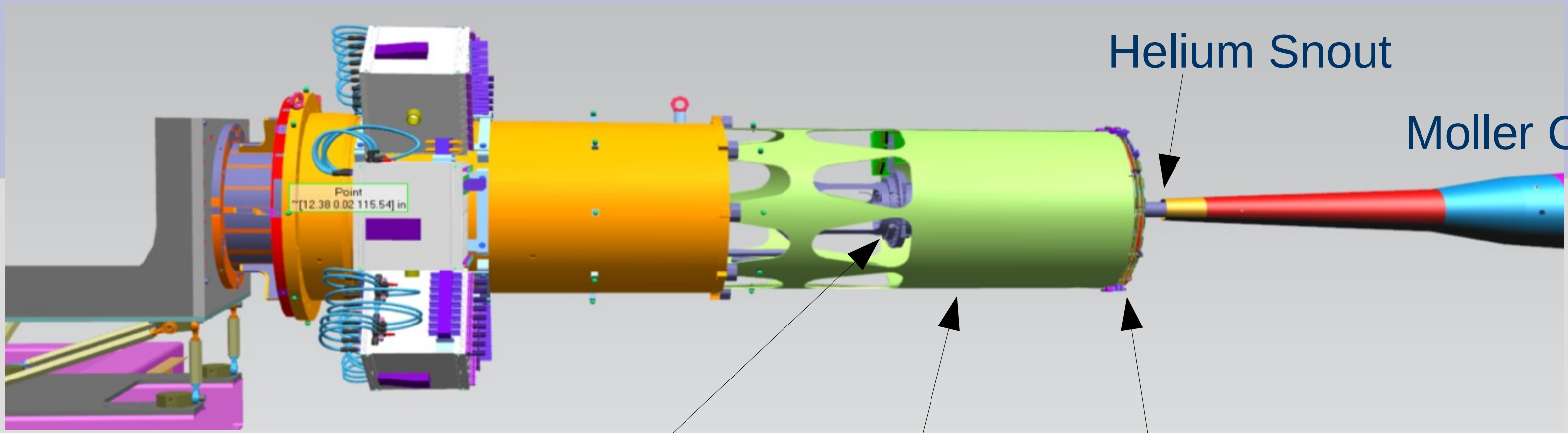
Status of Gas Target



- Received improved aluminized Kapton straws two weeks ago
  - 63 µm wall thickness
  - No gap between winding turns
  - Symmetric overlap of turns

- Presently testing in the lab
  - Long-term pressure stability and leak rate for nitrogen and helium gas
    - Pressure stable at 100 psi for 10 days
    - leak rate of about 1 psi of helium per hour at 95 psi pressure
  - Burst pressure at 120 psi

CLAS integration

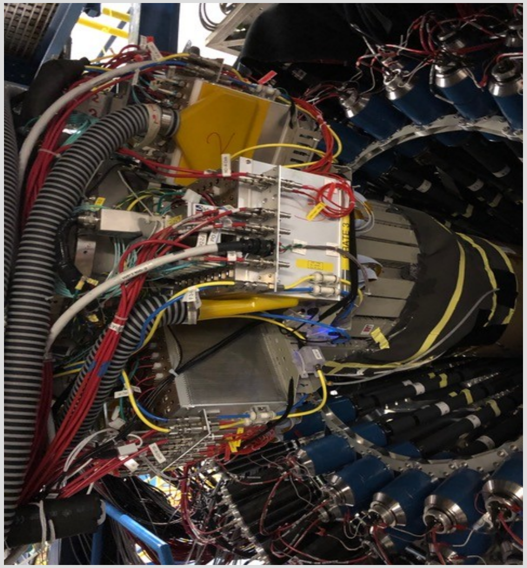


→ CVT replaced with RTPC and barrel support for FMT and cables

→ Utilize new 3 layer FMT

→ Utilize existing CVT electronics and cables for RTPC

→ Utilize existing CVT HV box for RTPC



Track Reconstruction (CLAS12 COATJAVA)

David Payette (ODU)

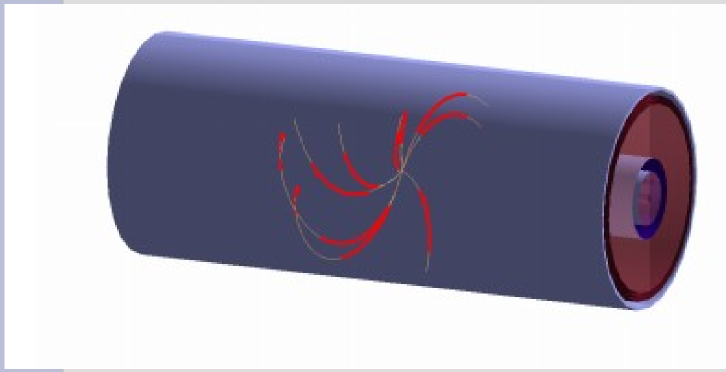
Software developed to data from
Digitized signal in DREAM format:

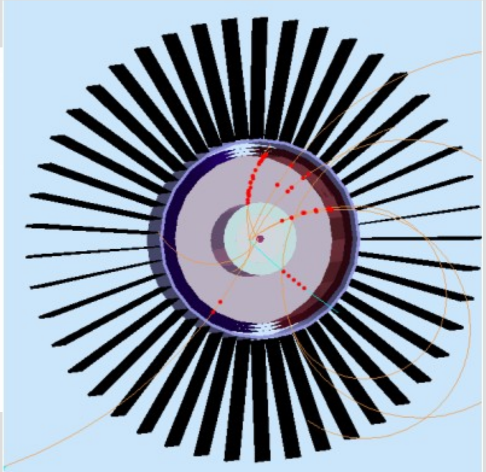
→ ADC for each pad in 120 ns time slices over entire time window (10000 ns).

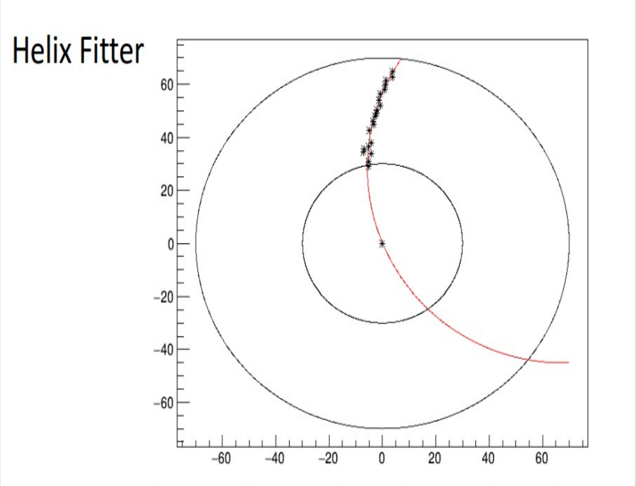
→ sort the signals on the readout pads into tracks

→ reconstruct the position of the ionization electrons which caused the signals

→ fit the tracks to calculate the momentum based on the curvature







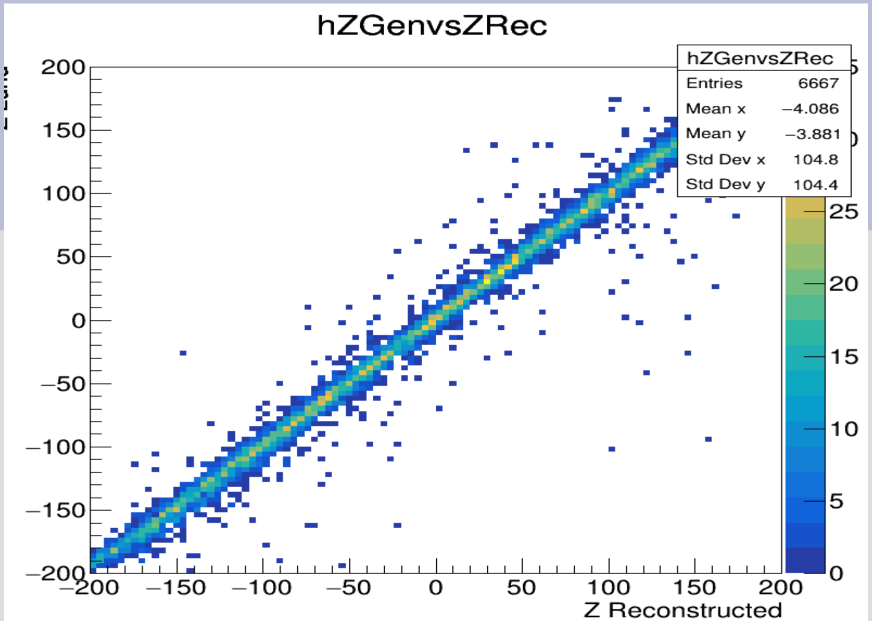
Reconstruction Resolutions: Monte Carlo

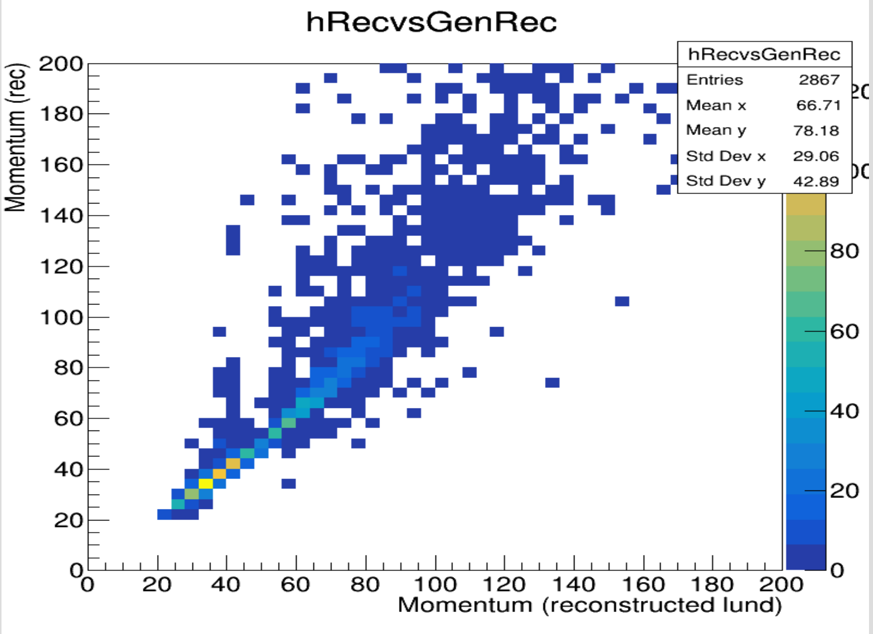
Analysis of MC data including with simulated signals and entire reconstruction chain.

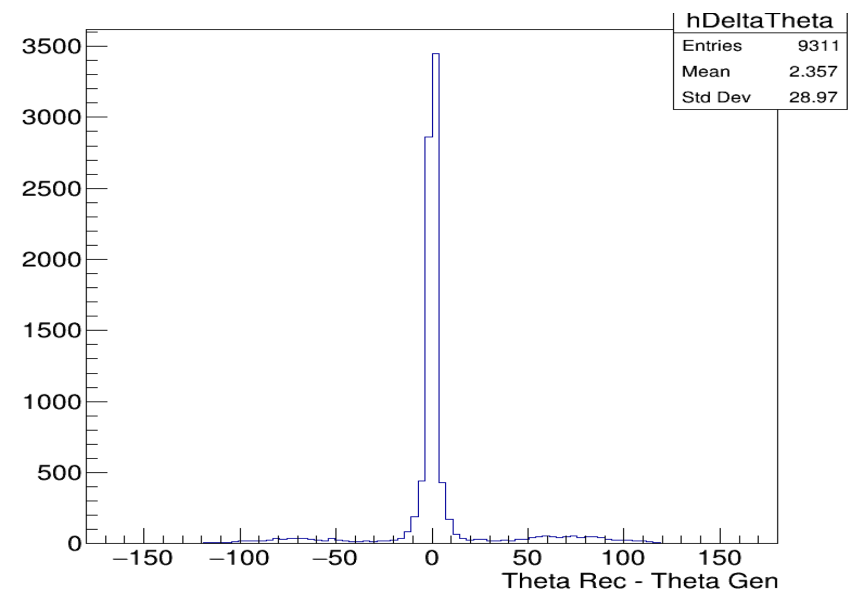
→ Resolutions on reconstructed

z_{vert}, θ, P_{proton}

already meet experiment requirements.







Beam Requirements

Parameter	Requirement	Comments
Energy (GeV)	10.6 (2.2)	A short run with 2.2 GeV, 1-pass beam at the beginning is needed for RTPC calibration
δp/p	$\sim 10^{-4}$	
Current (nA)	$200 - 400$	The production running will be at $\sim$ 200 nA, with up to 400 nA for empty target runs
Current stability	< 5 %	for $>$ 30 nA
σ_{xy} (μm)	< 300	As measured by 2H01A harp
Position stability (μm)	< 100	On 2H01 and 2H00 ($>$ 30nA) BPMs with feedback
Divergence (μrad)	< 100	
Beam Halo ($> \pm 5\sigma$)	$< 10^{-5}$	As measured by 2H01A harp
Charge asymmetry	$< 0.1\%$	Measured with SLM and halo rates, and controlled by hall
60Hz harmonics	$< 10\%$	of the total power, measured with SLM and halo rates

Schedule

11/15: First RTPC operational in EEL; begin of tests of all systems

12/1: Full tracking tests, DAQ and analysis operational.

12/15: 2nd RTPC completed, as well as target assembly and all installation hardware.

January: Routine operation in EEL with RTPC for experiment

January 30: Begin disassembly of RG-B, move of CVT into EEL

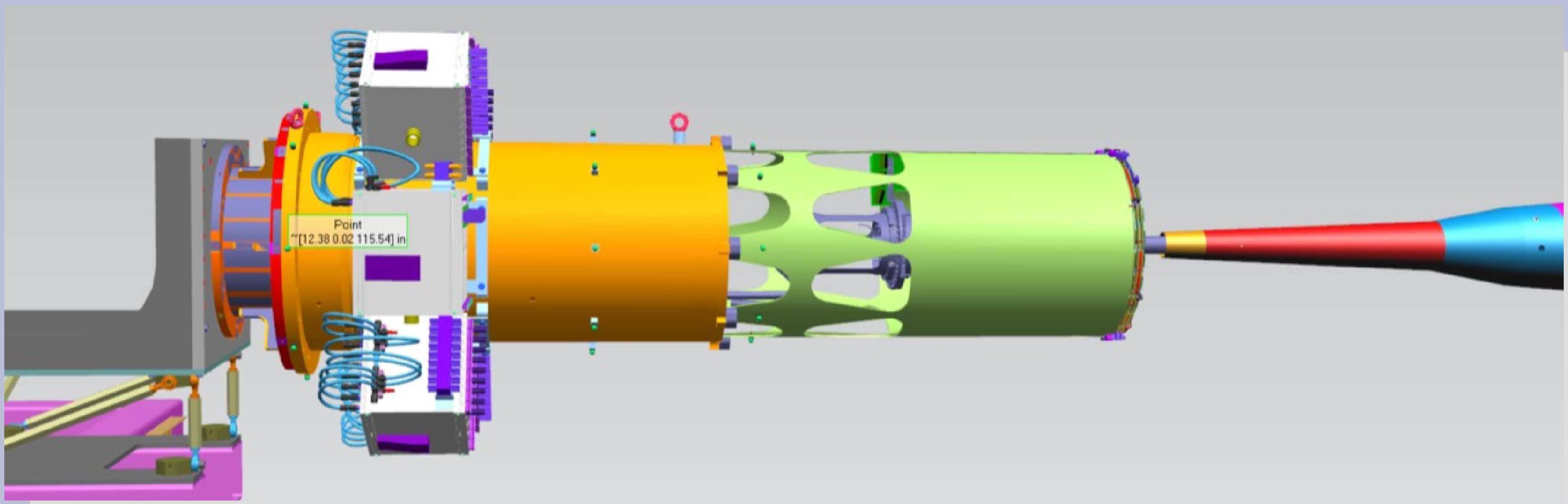
1/31-2/8: Radiation (neutron) test in Hall B; simultaneously deinstallation of BMT and SVT, and installation of RTPC and new FMT on insertion cart. If time, cosmic test with full electronics complement.

2/8-2/10: Installation of RTPC in Hall B.

2/12: Begin commissioning of RTPC at 1 pass (2.2 GeV)

2/16: Begin production running for BONuS12/RGF.

Thanks!



2 BEUs

Dream FEUs

270 Hitachi cables

17280 readout pads

BONuS12) was approved as a “high impact” experiment utilizing the upgraded CLAS12 spectrometer.

Additional approved experiment to measure DVCS on neutron will require High polarization and Moller runs about once per week.

→ **Improved gain uniformity**

Better momentum resolution

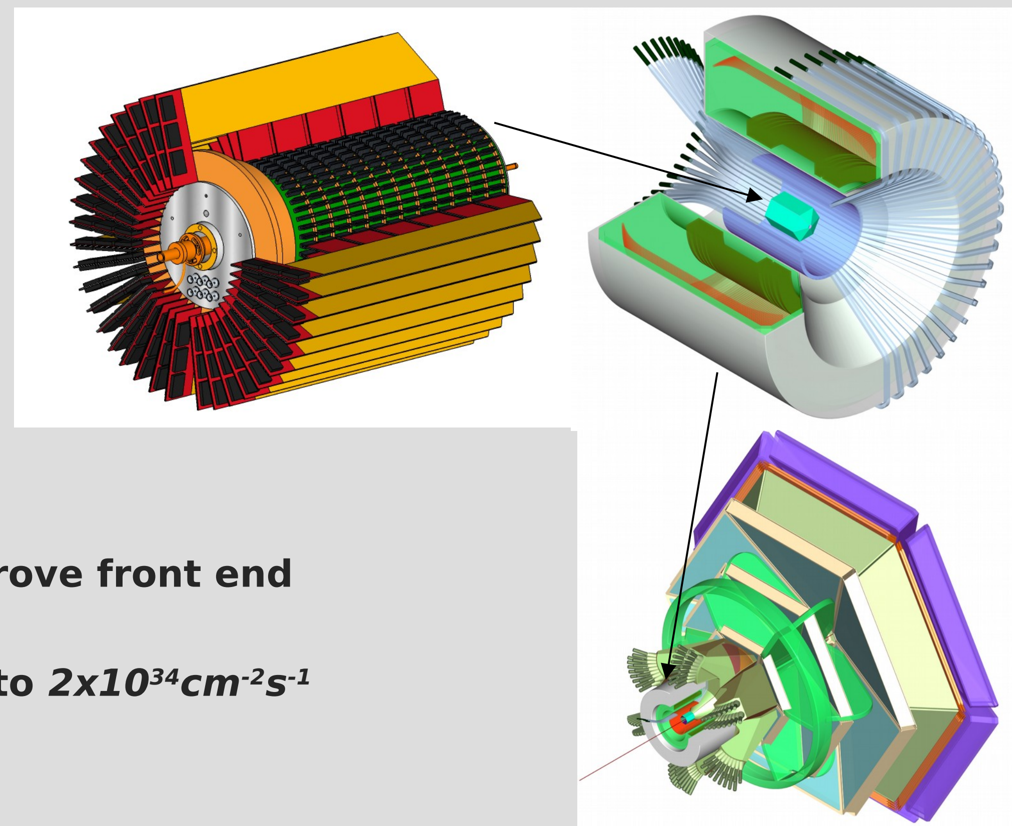
→ **Increased drift region 3cm → 4cm**

Better track sampling

→ **Improve ϕ acceptance**

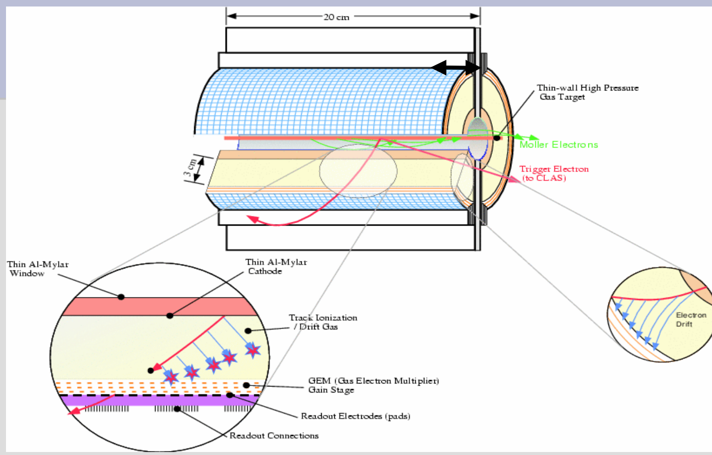
→ **Doubled detector length and improve front end**

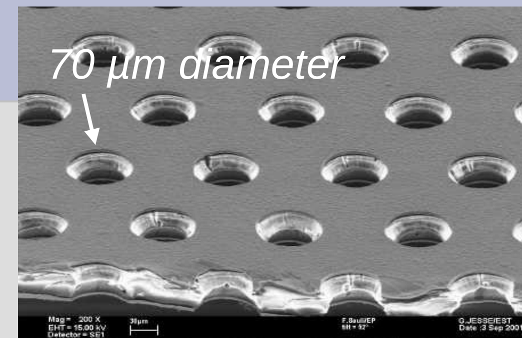
Electronics => increase luminosity to *$2x10^{34}cm^{-2}s^{-1}$*

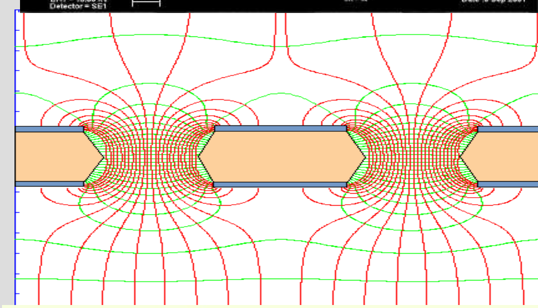


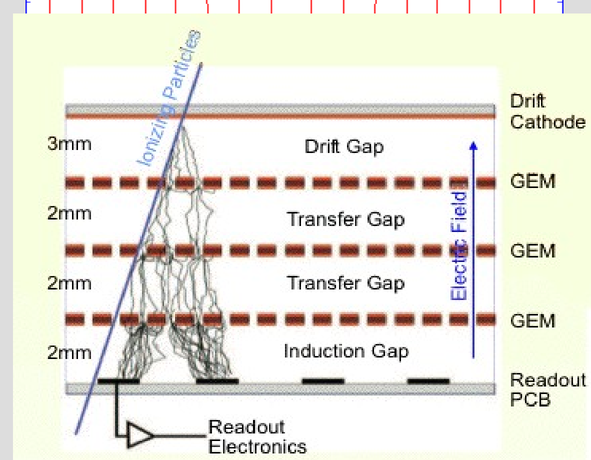
Charge Amplification using Gas Electron Multipliers (GEMs)

F. Sauli et al., NIMA 386 (1997) 531









- → Holes chemically etched in kapton layered front and back with copper.
- → Gas amplification due to large local field in holes.
- → More amplification from more GEM layers.
- → Can operate at very high rates.
- → Can conform to curved geometries

Ratio Method

First make experimental ratio:

$$R_{\exp} = \frac{N_{\text{tagged}}(\Delta Q^2, \Delta W^*, \Delta^{(\text{VIP})}\vec{p}_s)/A_e(Q^2, W^*)}{N_{\text{incl}}(\Delta Q^2, \Delta W)/A_e(Q^2, W)}$$

N_{tagged} is yield with VIP after accidental subtraction passing:

P_s < 100 MeV/c, θ_p > 110

A_e : electron acceptance in CLAS (*mostly cancels!*)

In terms of structure function ratio:

$$R_{\exp} = \frac{F_2^n(W^*, Q^2)}{F_2^d(W, Q^2)} \underbrace{\int_{\text{VIP}} d\alpha_s dp_s^{\perp} A_p S(\alpha_s, p_s^{\perp})}_{I_{\text{VIP}}}$$

A_p : tagged proton

Efficiency * Acceptance

→ Integral I_{vip} is largely independent of W* (x*) and Q^2

→ Determined from R_{exp} at x=0.3, where nuclear effects are small using F_2^n / F_2^d from CJ PDF fit.

Then $\mathbf{F_2^n / F_2^d = R_{exp} * I_{vip}}$