Future Applications of GEM Detectors at BNL

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RD51 Collaboration Meeting

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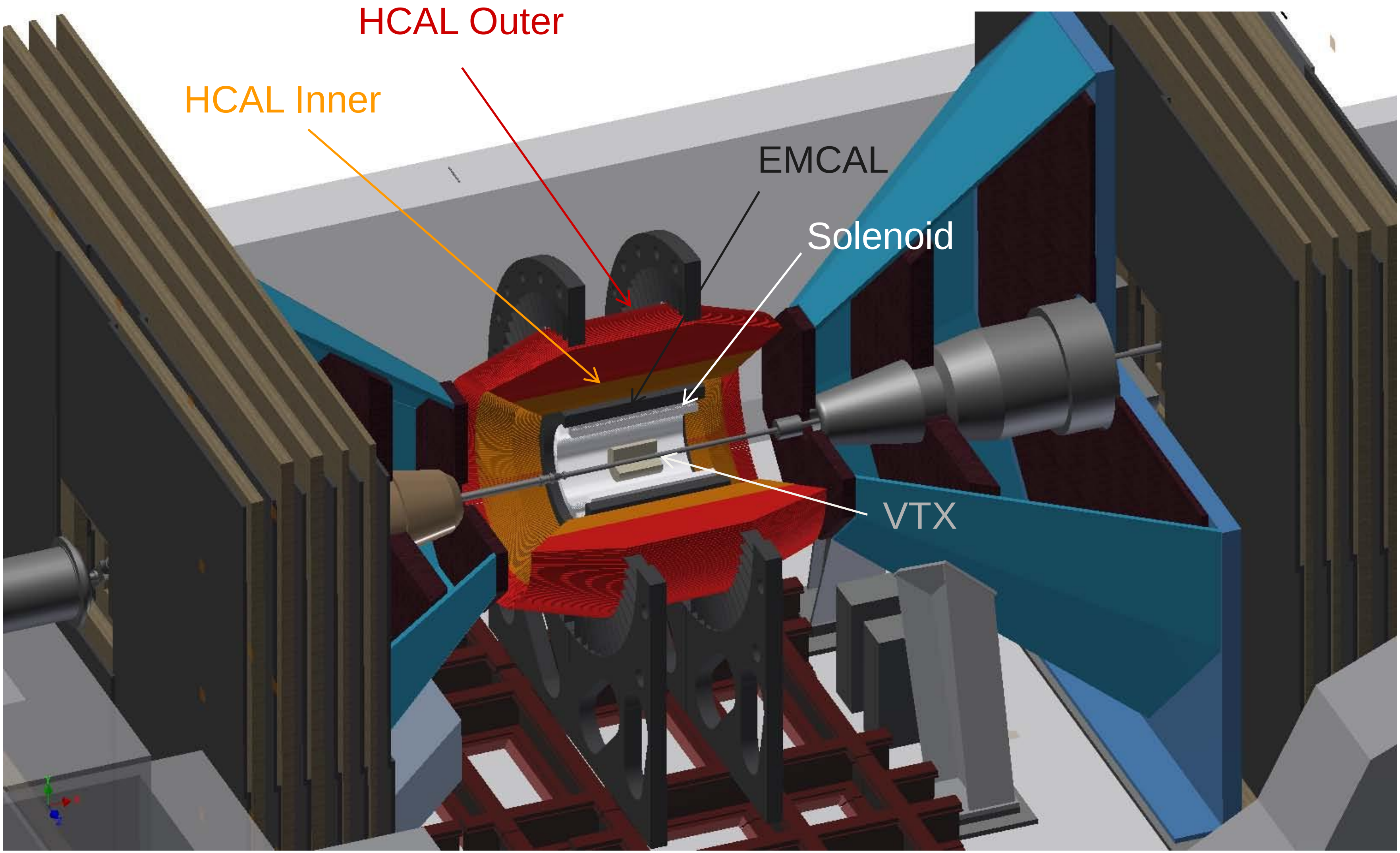
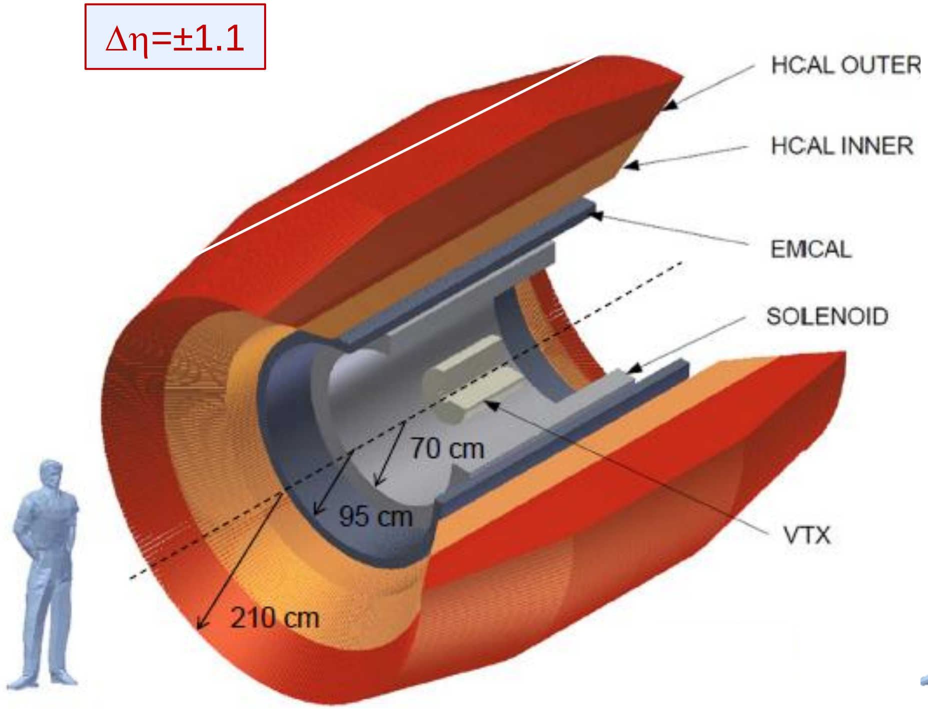
New Applications for GEM Tracking detectors at BNL

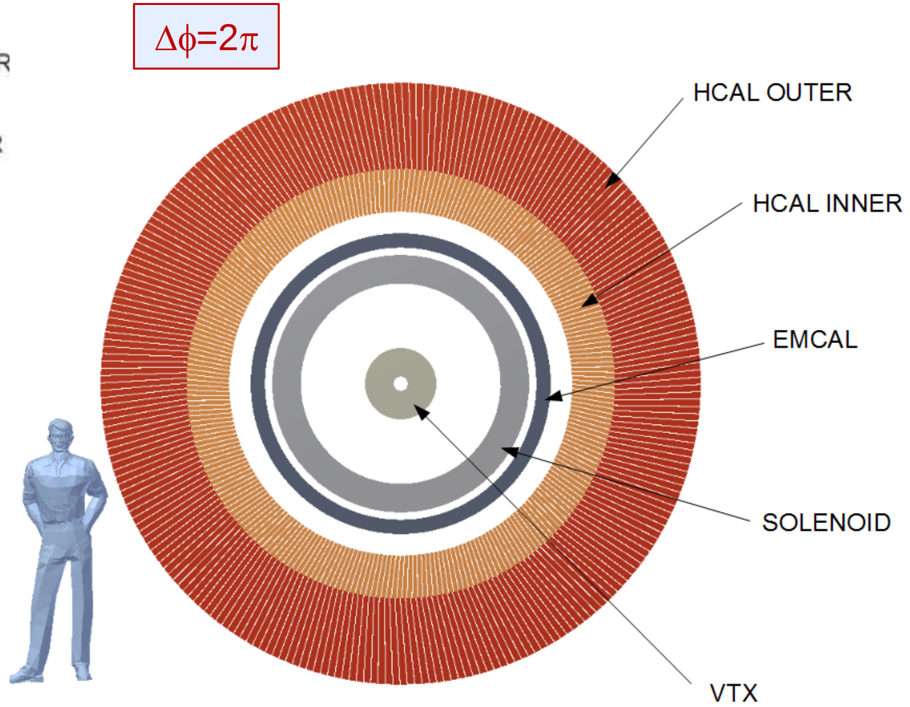
- Minidrift GEM detector
  - Application for sPHENIX
  - Future use in an EIC detector
  - Positron imaging for PET

- Fast, compact TPC with Cherenkov PID
  - Use for tracking and particle id at EIC

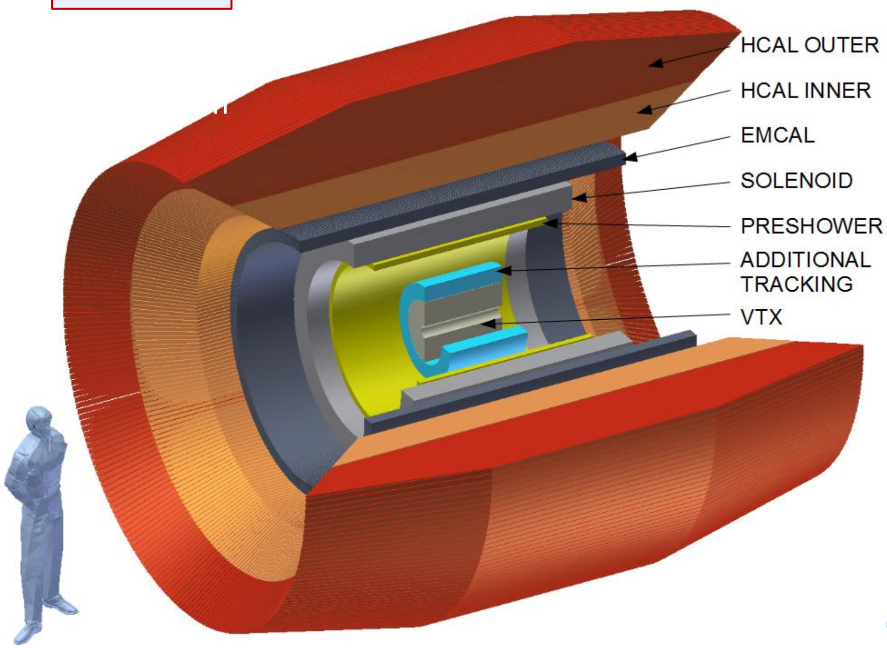
sPHENIX



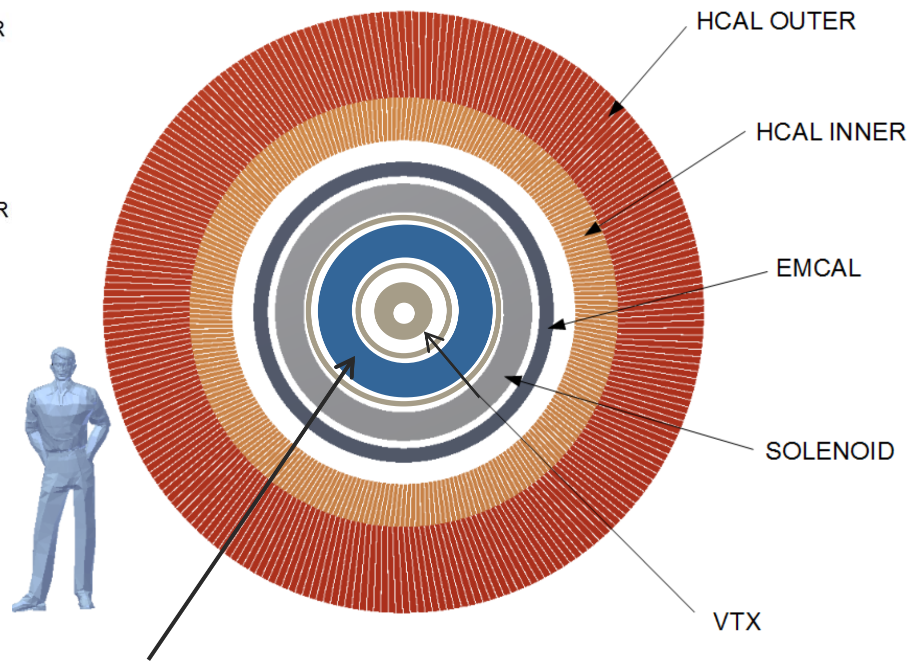

Δη=±1.1
HCAL OUTER
HCAL INNER
EMCAL
SOLENOID
VTX
70 cm
95 cm
210 cm


Δφ=2π
HCAL OUTER
HCAL INNER
EMCAL
SOLENOID
VTX

$\Delta\eta=\pm1.1$

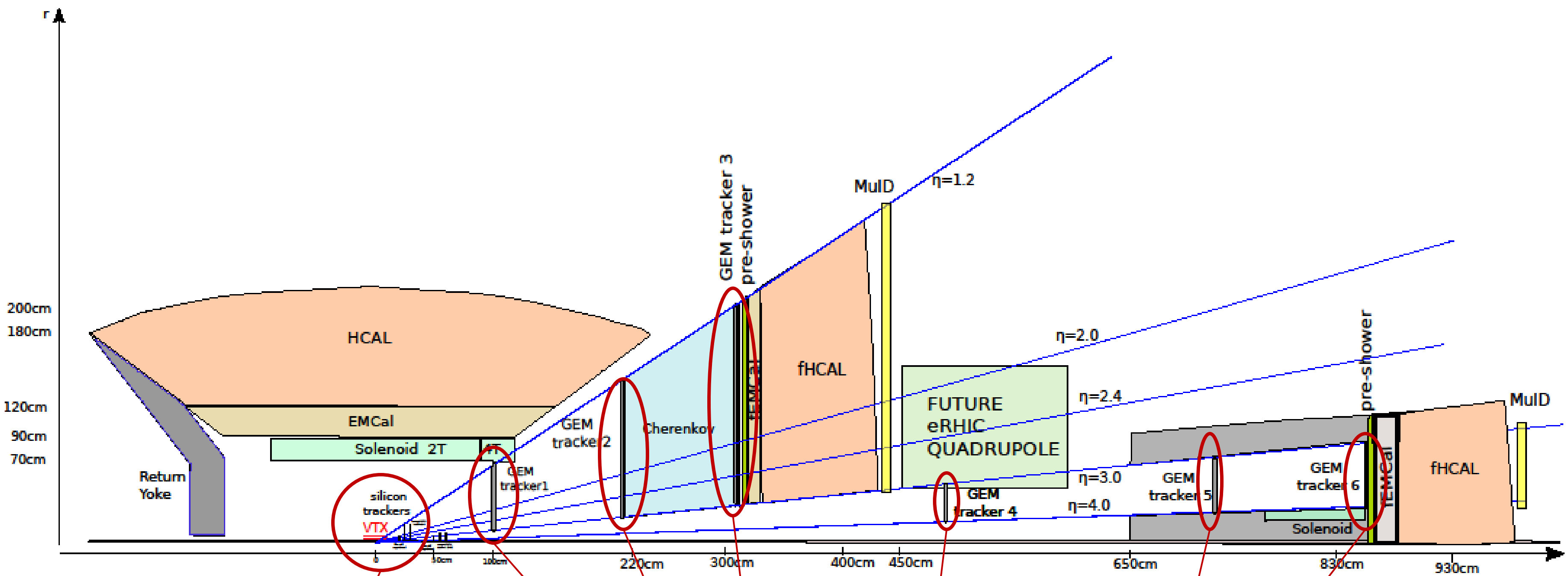


$\Delta\phi=2\pi$



Future additional tracking system
- Two additional layers of silicon tracking
- Cylindrical GEM tracker (possible radial minidrift)

Forward sPHENIX

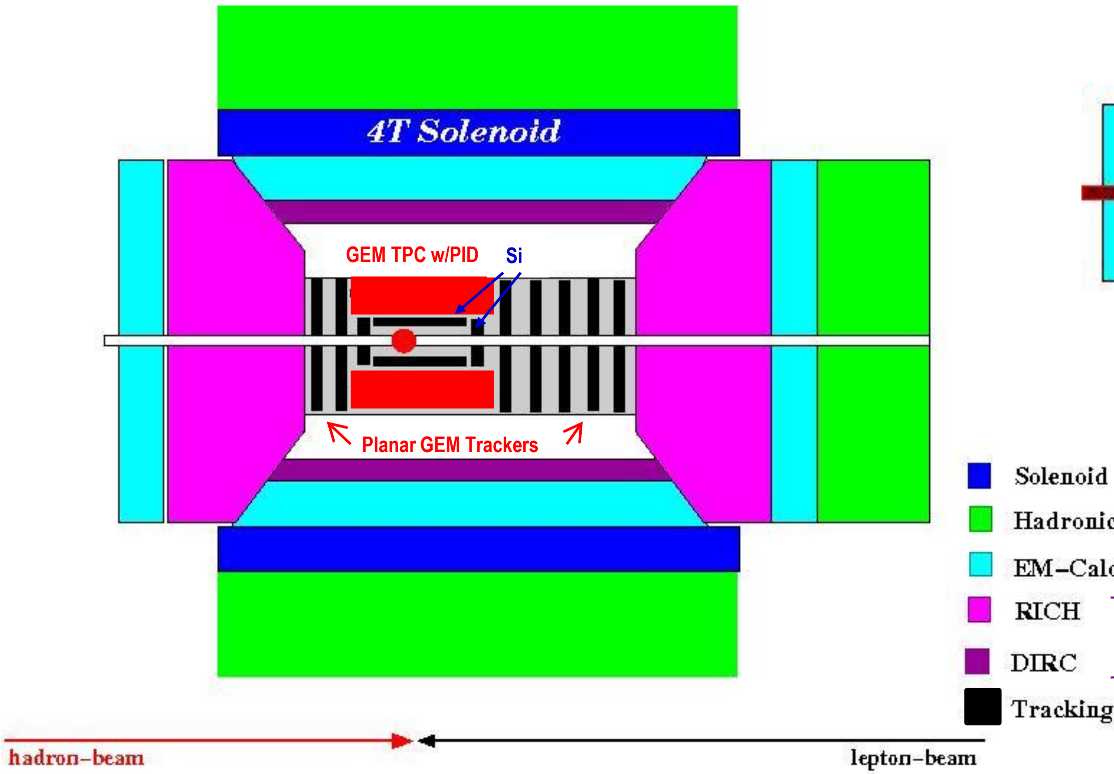


Current VTX and FVTX detectors

Forward GEM trackers

EIC Detector – Conceptual Design

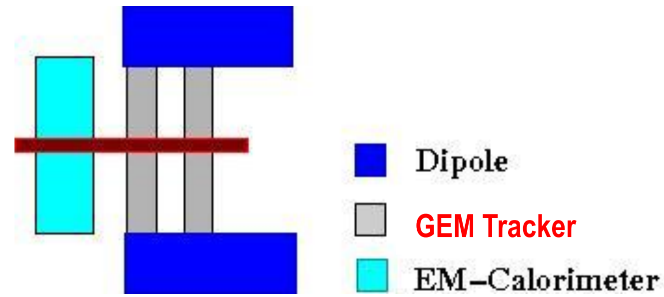
Central Detector



PID devices

Central TPC + Forward minidrift GEM Trackers

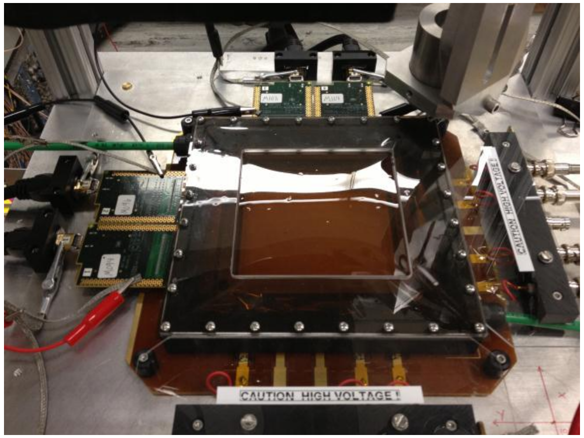
Forward/Backward Detectors



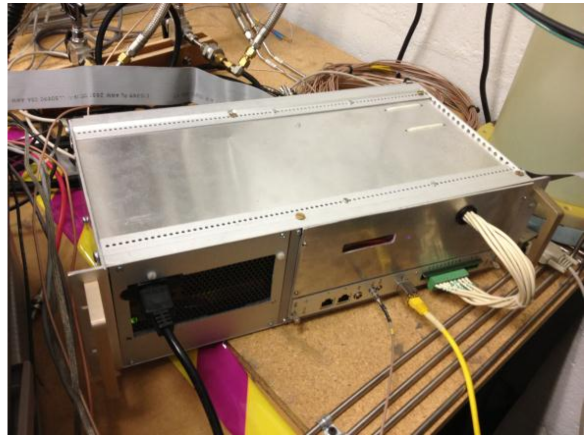
- Large acceptance: $-5 < \eta < 5$
- Asymmetric
- Nearly 4π tracking and EMCAL coverage
- HCAL coverage in central region and hadron direction
- Good PID
- Vertex resolution (< 5 μm)

- Electron is scatted over large range of angles (up to 165˚)
- Low $Q^2 \rightarrow$ low momentum (few GeV)
- Requires low mass, high precision tracking

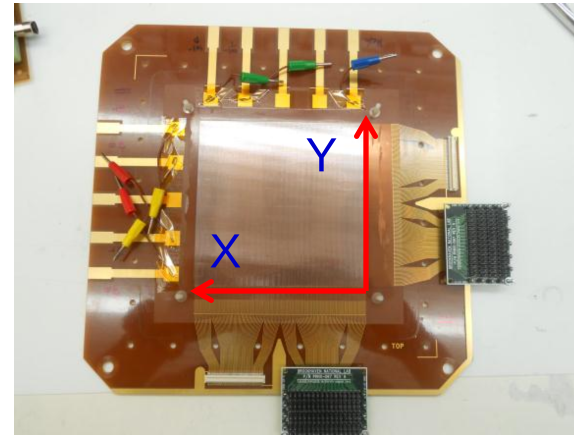
Minidrift GEM Detector with XY Readout



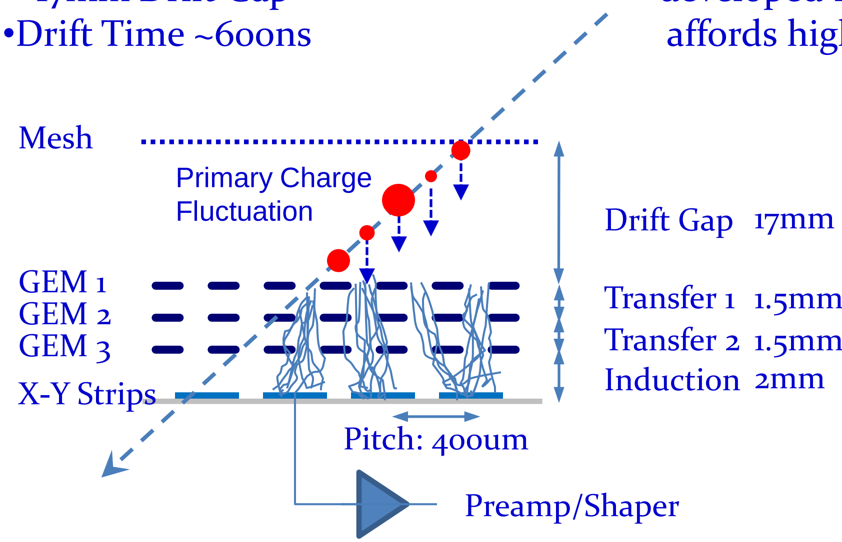
Std. 10x10cm CERN 3-GEM Det.
- $ArCO_2$ (70/30)
- Gain ~ 6500
- ~17mm Drift Gap
- Drift Time ~600ns



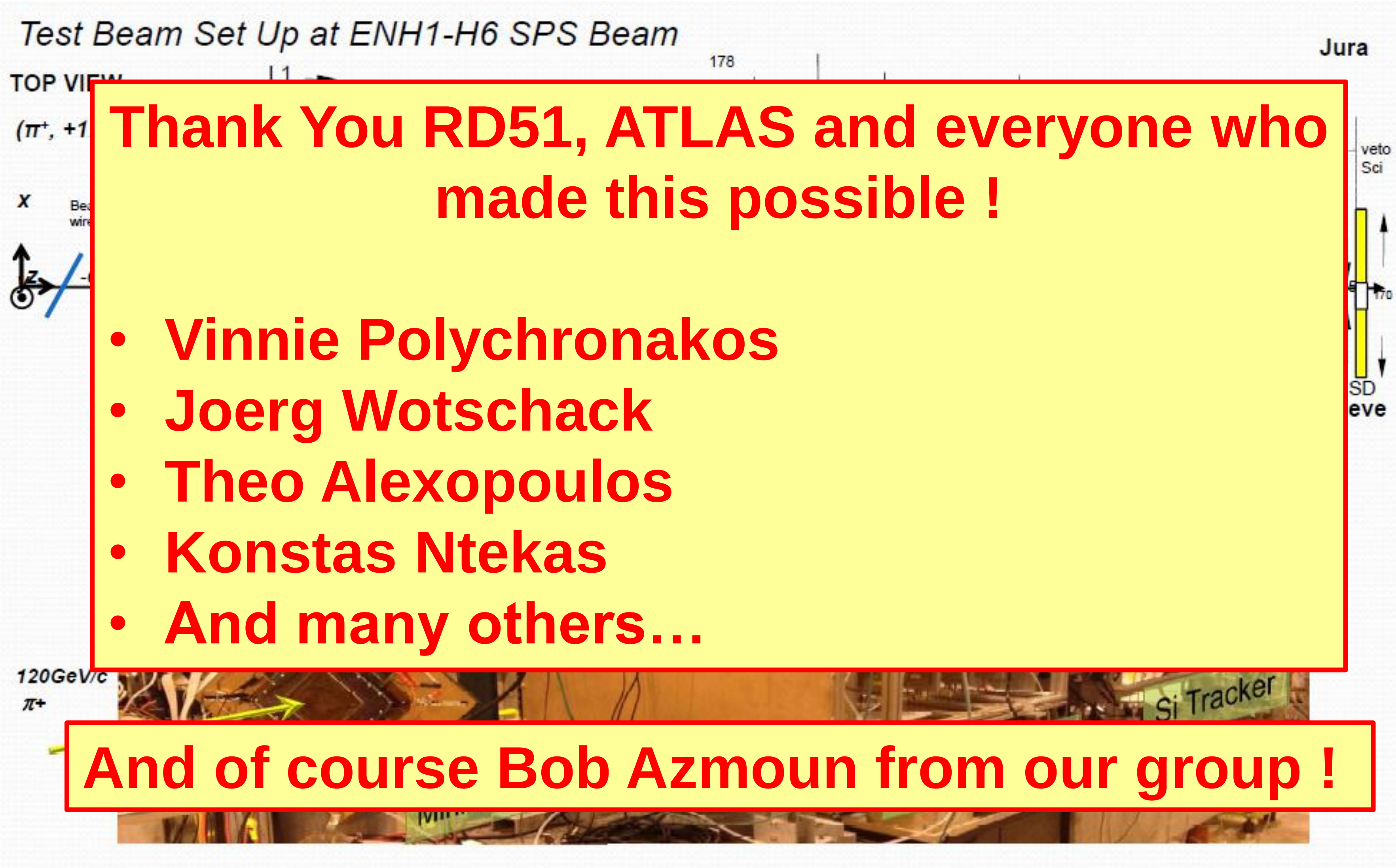
SRS /512 channels APV 25
- 30 x 25ns Time Samples
- Martin Purschke's newly developed RCDAQ affords high flexibility



COMPASS style Readout:
- 256 x 256 X-Y Strips
- ~10cm x 400um pitch



Beam Test in October 2012

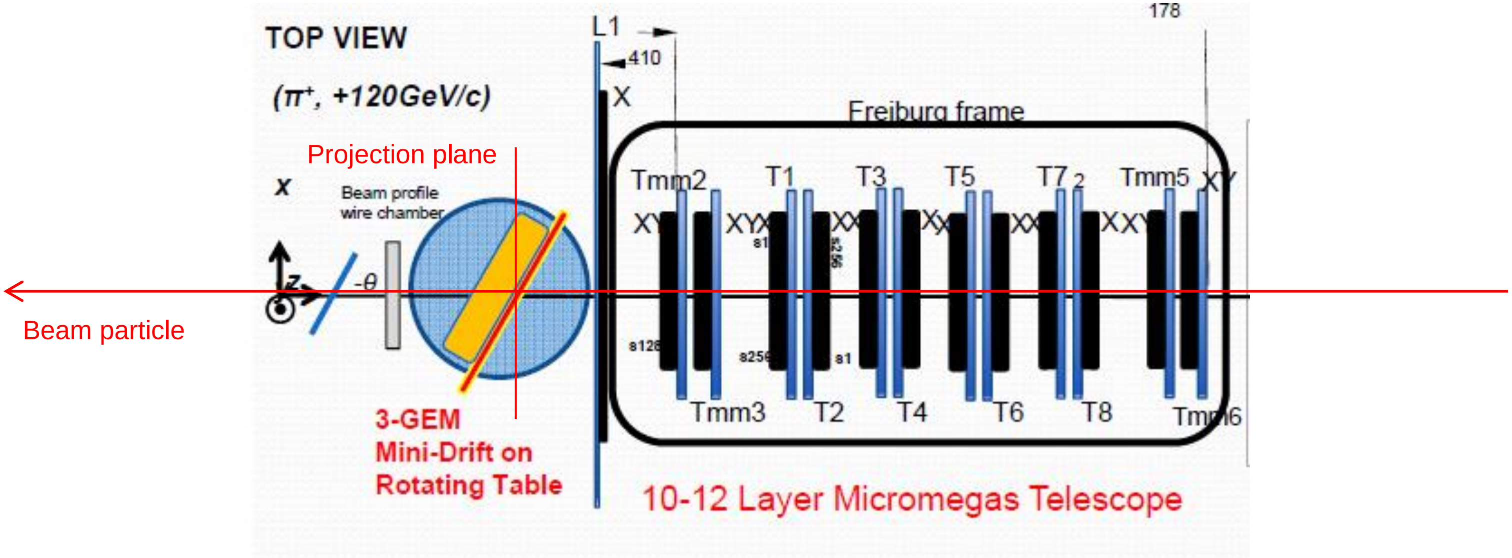


Thank You RD51, ATLAS and everyone who made this possible !

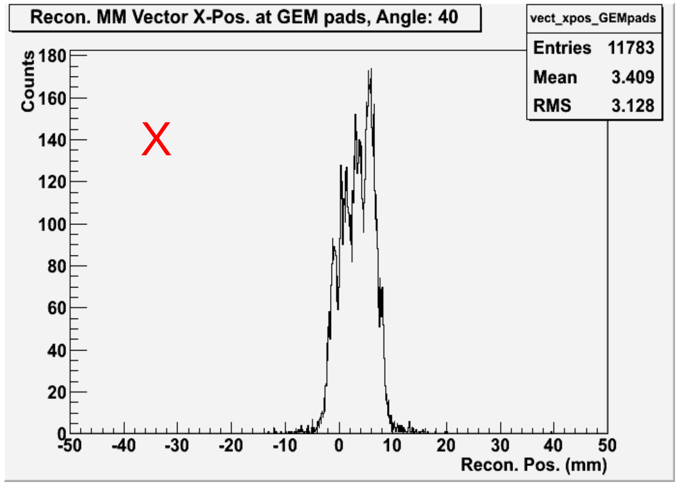
- **Vinnie Polychronakos**
- **Joerg Wotschack**
- **Theo Alexopoulos**
- **Konstas Ntekas**
- **And many others…**

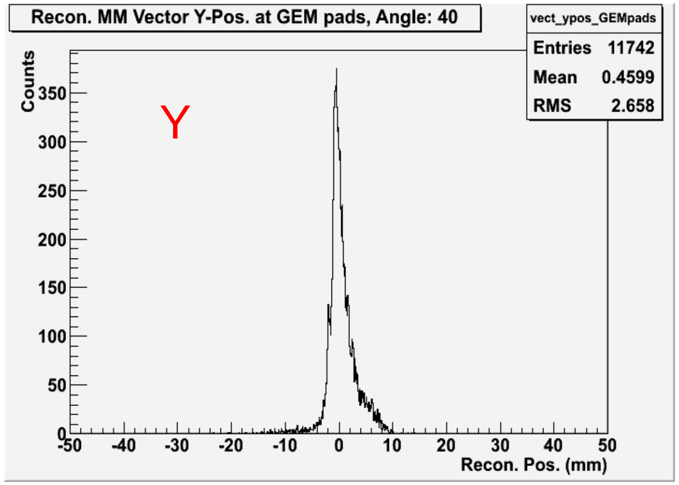
And of course Bob Azmoun from our group !

Test Beam Data – Micromega Detectors



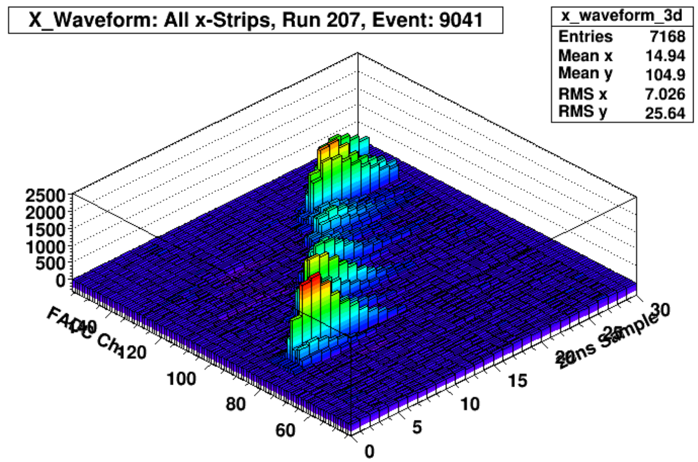
Beam Profile – Extrapolated Tracks from Micromegas



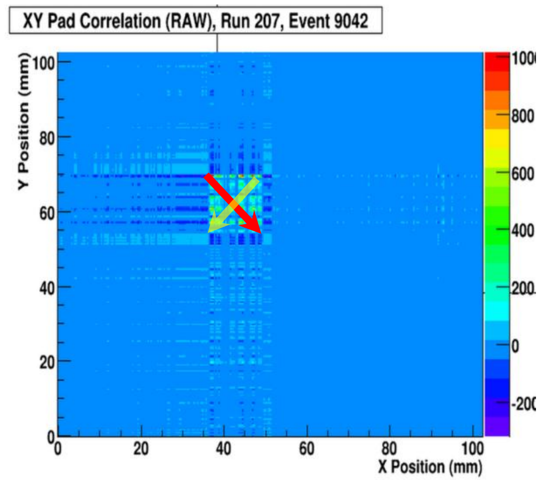


Vector Reconstruction in GEM Detector

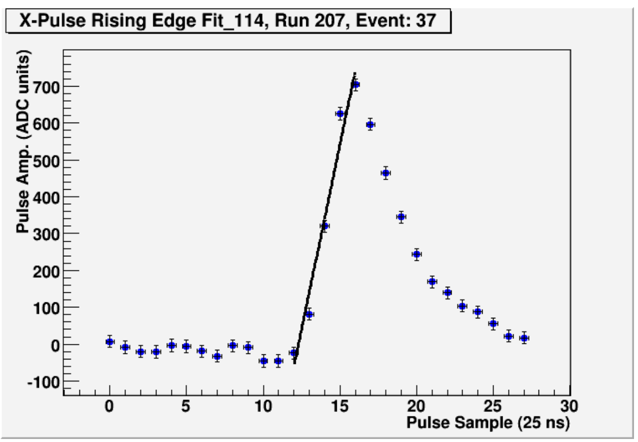
B. Azmoun



Raw Data: Waveforms in Time

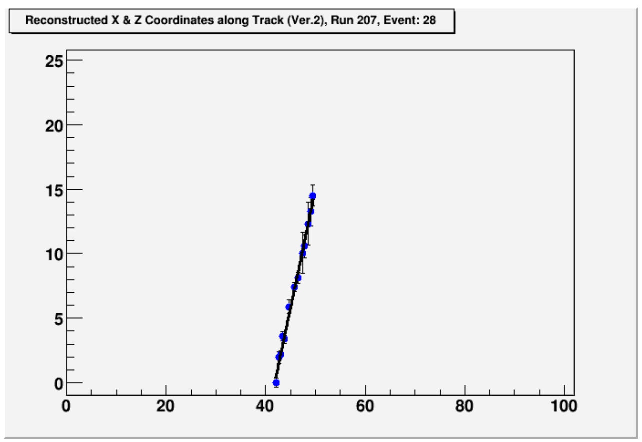


Vector Signature: “Charge square”



• Linear Fit to determine arrival time = x-int.

•30 samples x 25ns = 750ns window



Vector Recon:

•X -coord. = middle of pad

• Y-coord. = drift time * Drift Vel.

•Fit (x,z) points to line

Error on reconstructed vector

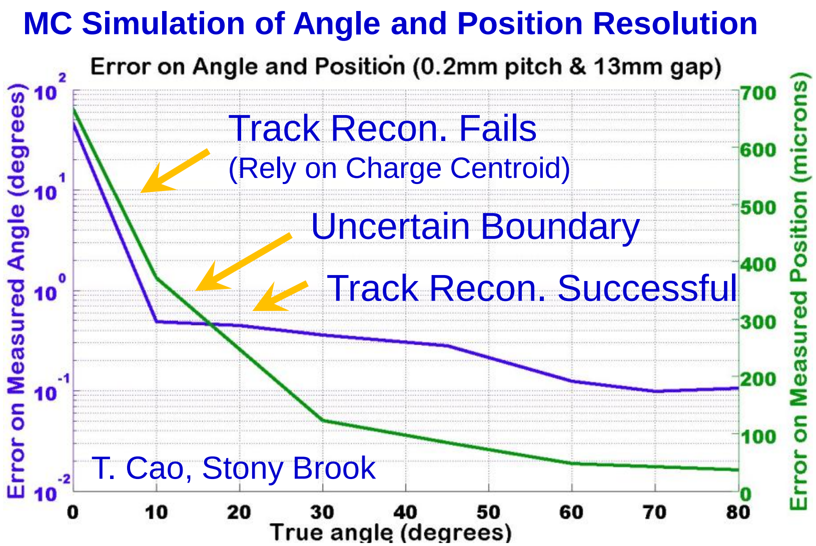
Error on arrival time: ~ ± -1.8ns

⇒ error on z-coordinate ~ 60 μm

⇒ error on reconstructed vector due to time resolution alone ~ 1 mrad (@ 40 degrees)

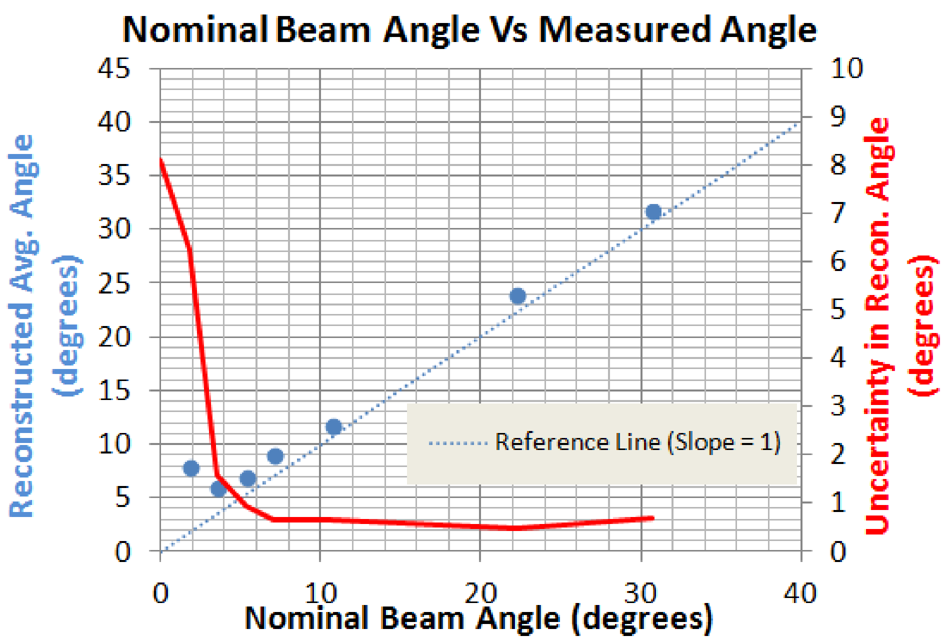
Main error on reconstructed vector is due to charge fluctuations

Angular Resolution



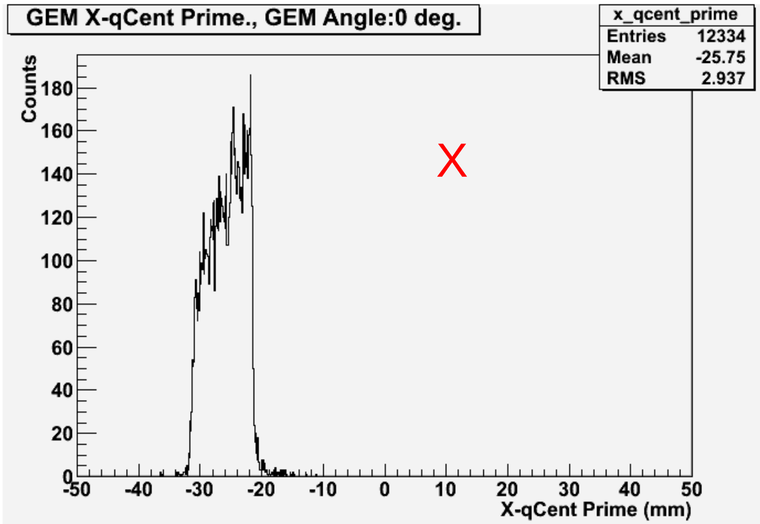
- At small angles, it is not possible to measure a vector and the best position information is obtained from the centroid of the charge distribution
- At angles > ~ 5 degrees, it is possible to determine a vector with an accuracy ~ 0.3 degrees (~ 5 mrad)

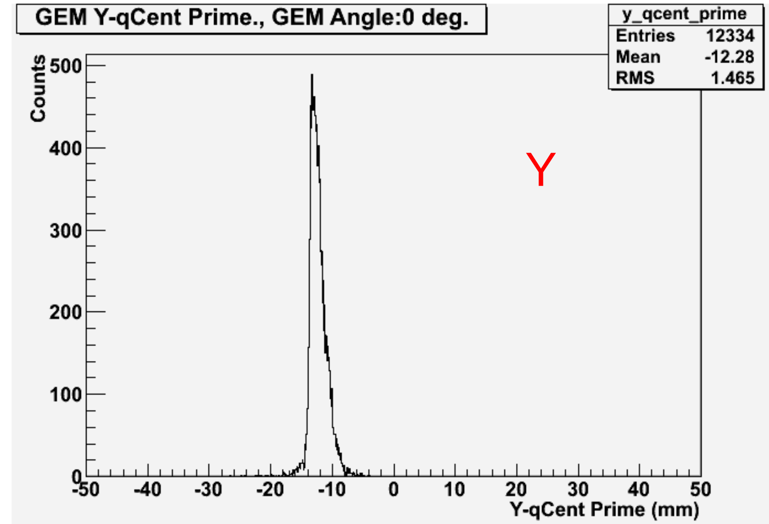
Reconstructed angle in GEM detector assuming beam track is at zero degrees with no divergence (not using MM data)



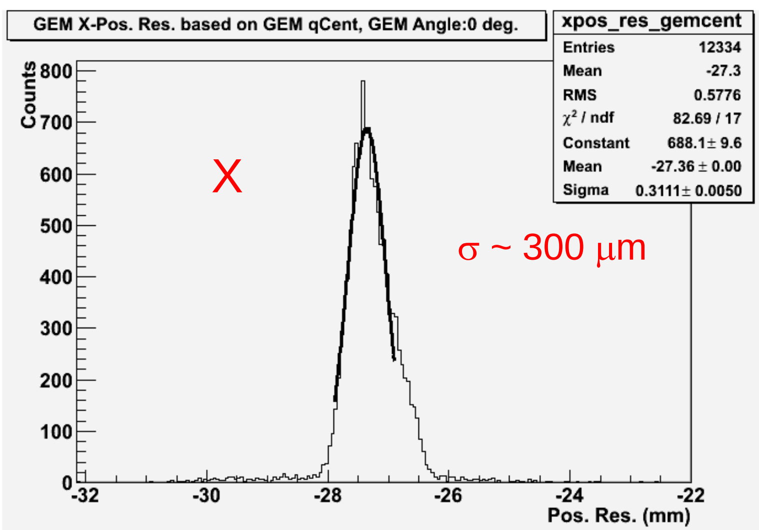
Test Beam Data – GEM Detector

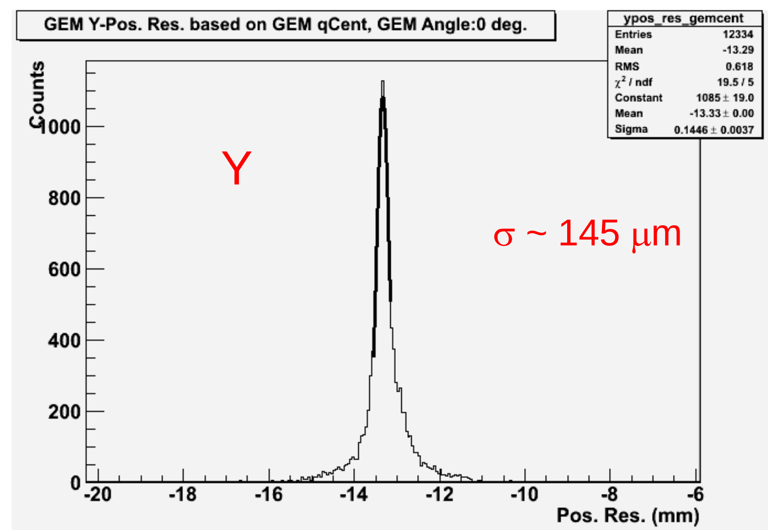
Beam Profile from GEM detector – Charge Centroid (0 degrees)





Difference in coordinate position (GEM Detector – Micromega Track Projection)



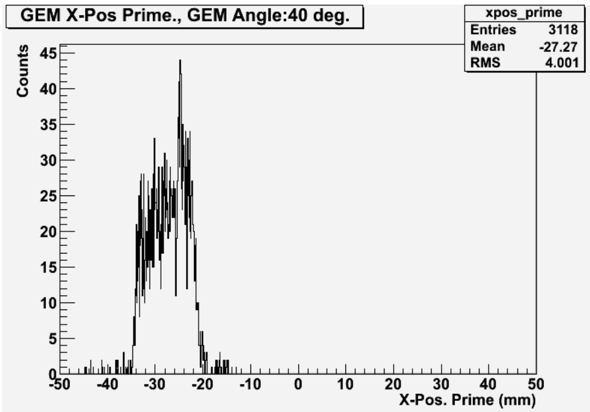


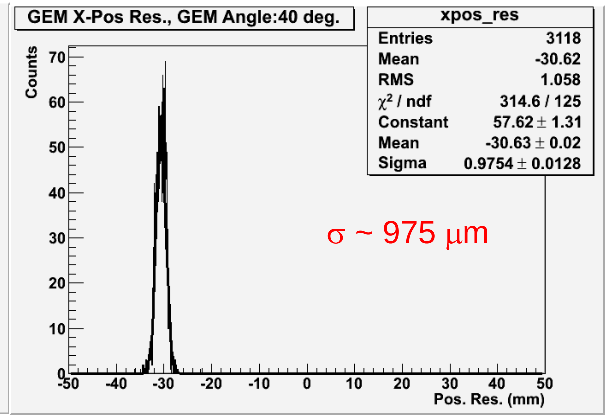
Test Beam Data – GEM Detector

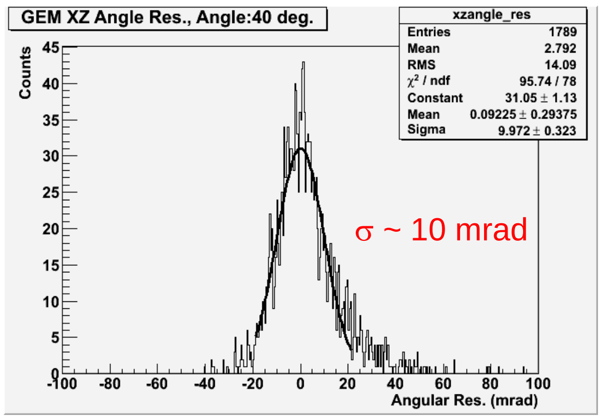
GEM detector – Vector Reconstruction (40 degrees)

	GEM position at projection plane	(GEM – MM) coordinate	(GEM – MM) angle

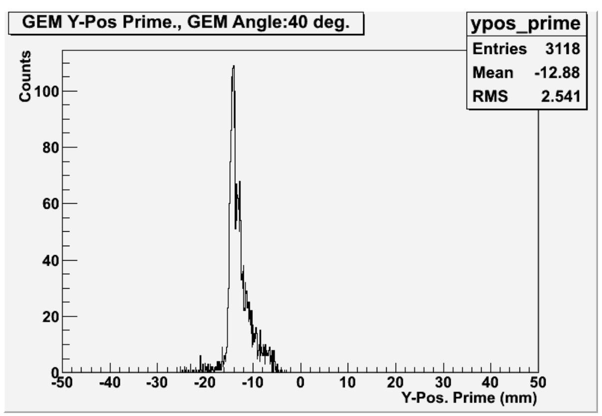
X

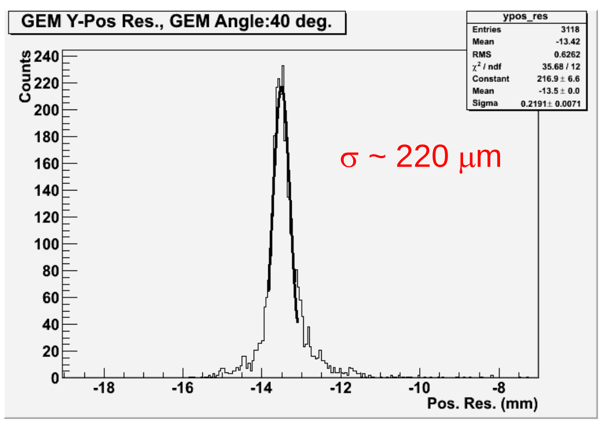


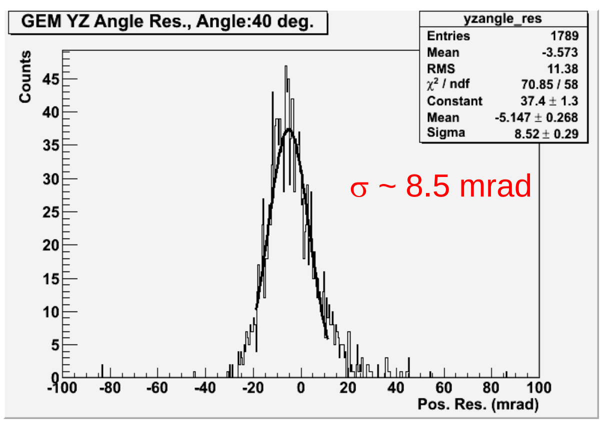




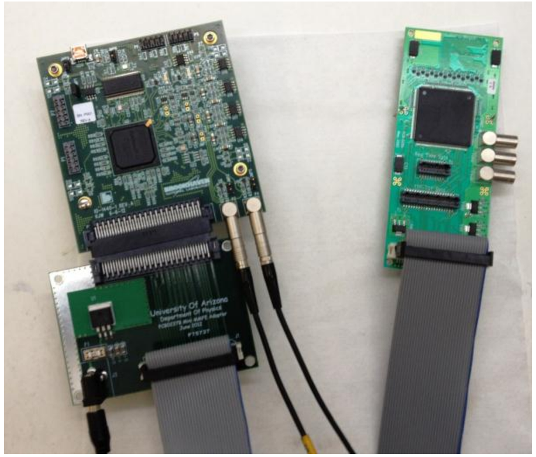
Y

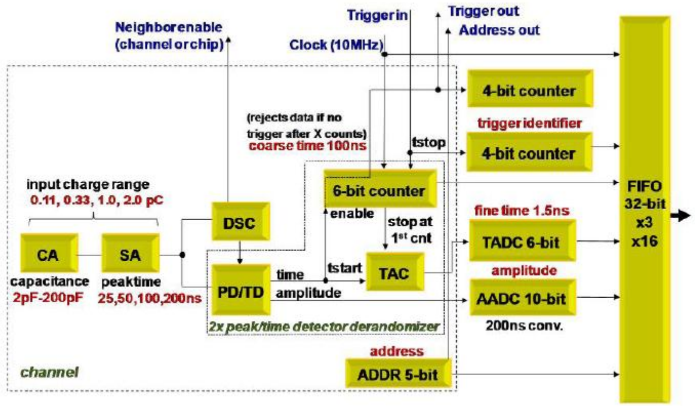


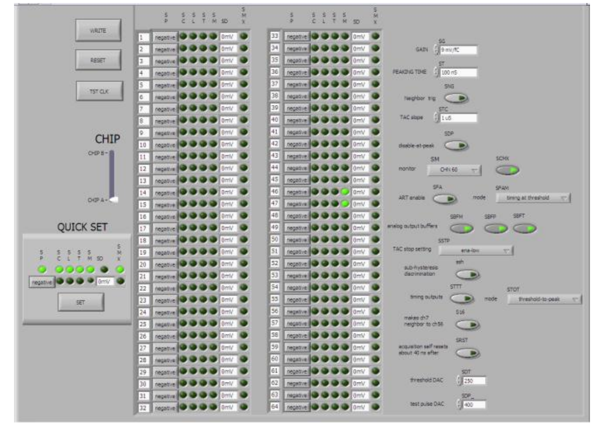




Minidrift GEM Detector with VMM1 Readout





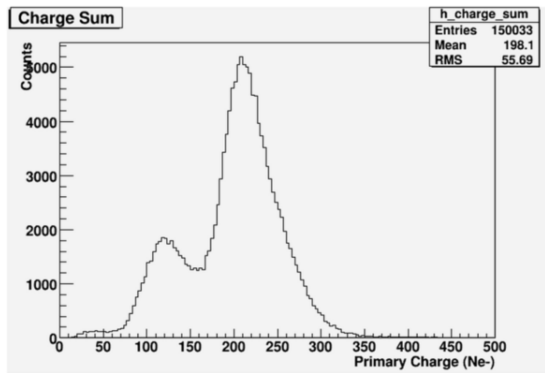


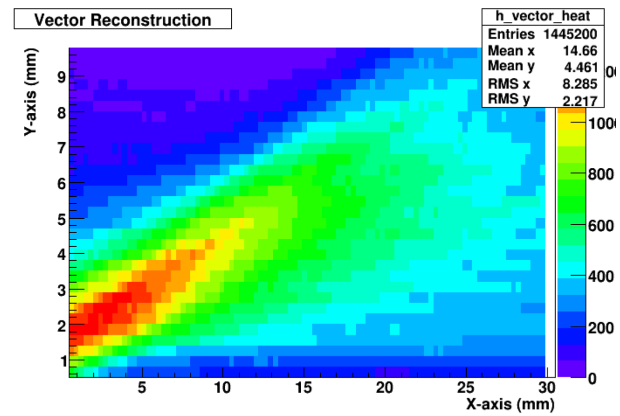
VMM1 Labview Control panel

VMM1 →FEC →USB→PC

Preliminary Results (64 ch.):

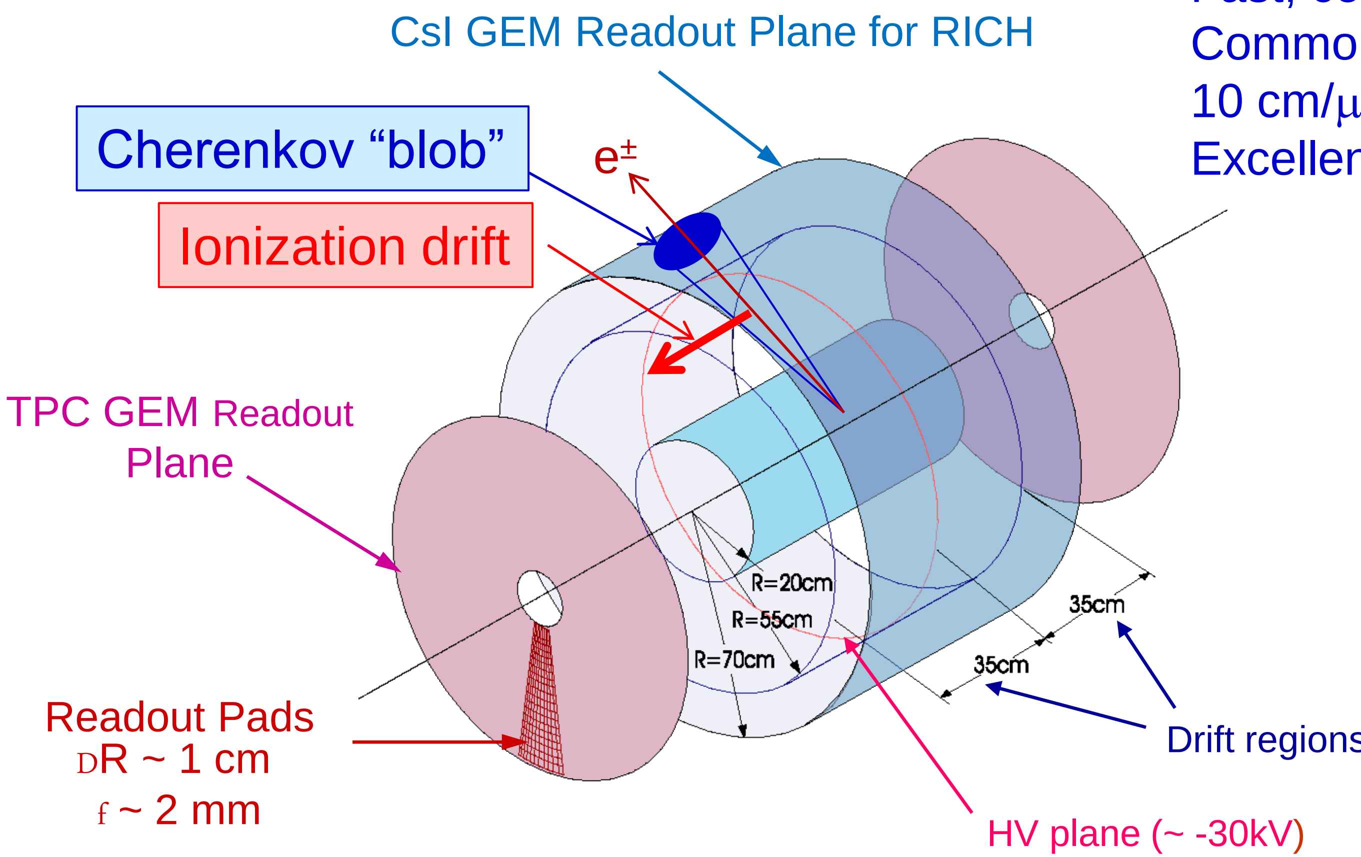
- Measured Fe55 spectrum
- Measured Sr90 vectors at ~35°





- Brief test (~ 1 day) of minidrift GEM with VMM1 readout at BNL
- Despite the very short time available, got the detector and readout up and running very quickly in the lab
- Unfortunately, no time to test in the test beam at CERN

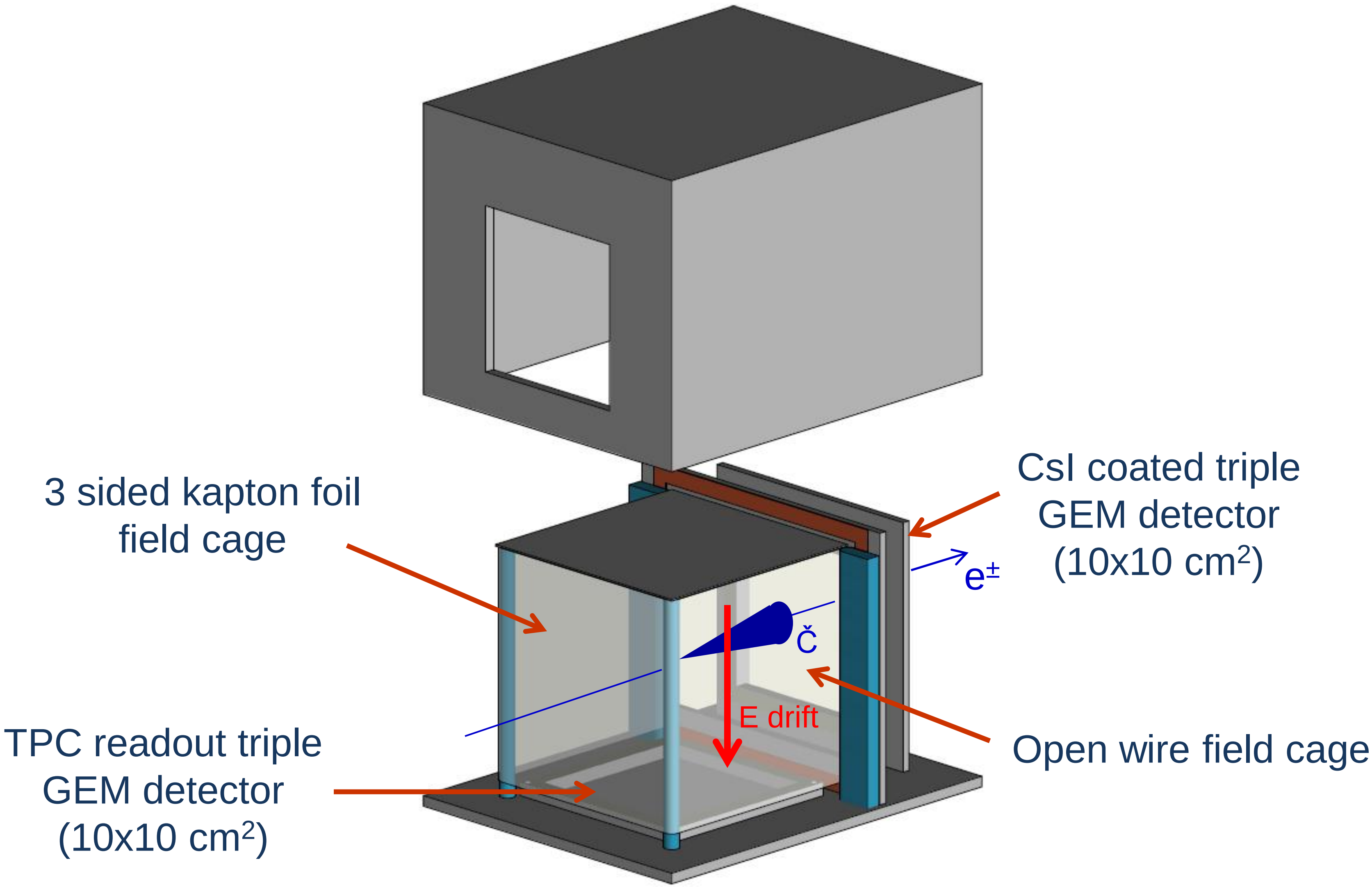
TPC with Particle ID (HBD)



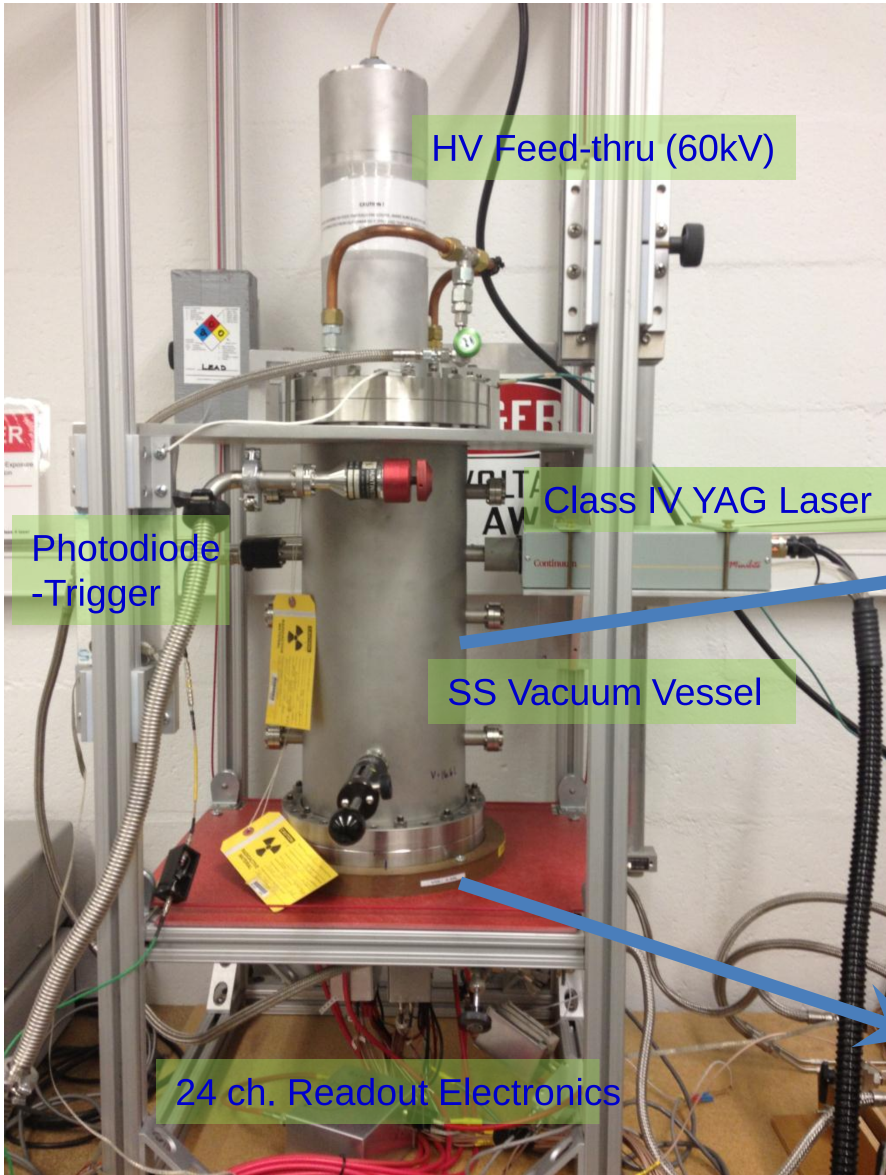
Fast, compact TPC
Common CF_4 gas (windowless)
10 cm/μsec
Excellent UV transparency

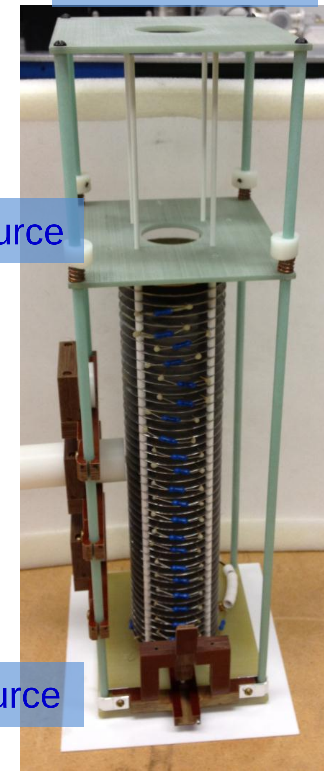
- Idea originally proposed for PHENIX (~ 2000)
- In the end decided to build just the HBD portion
- Idea now resurrected for EIC

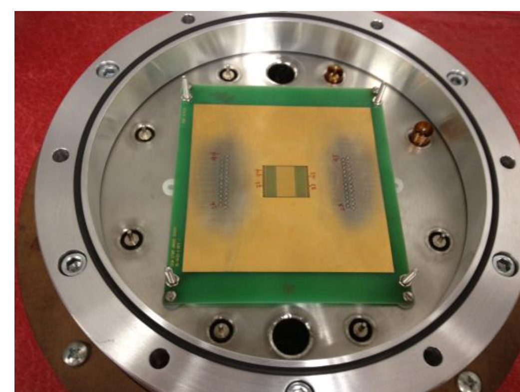
Prototype TPC/Cherenkov Detector



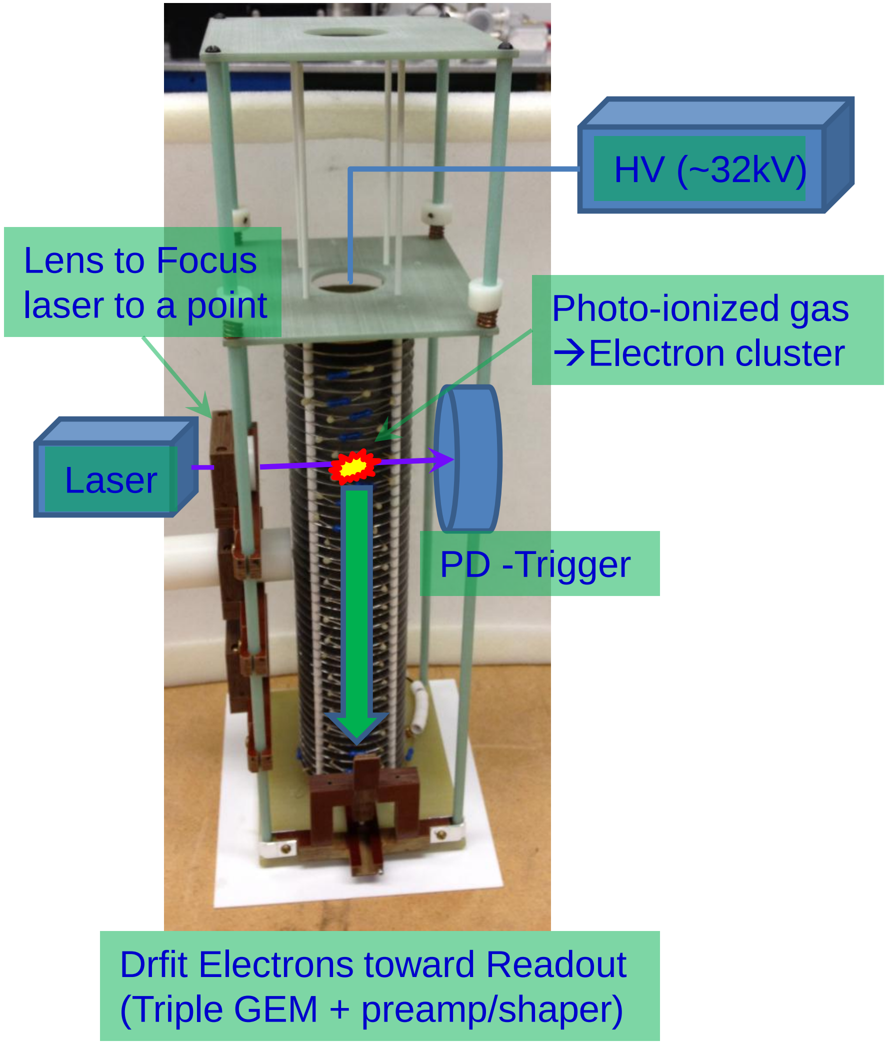
TPC Test Set Up



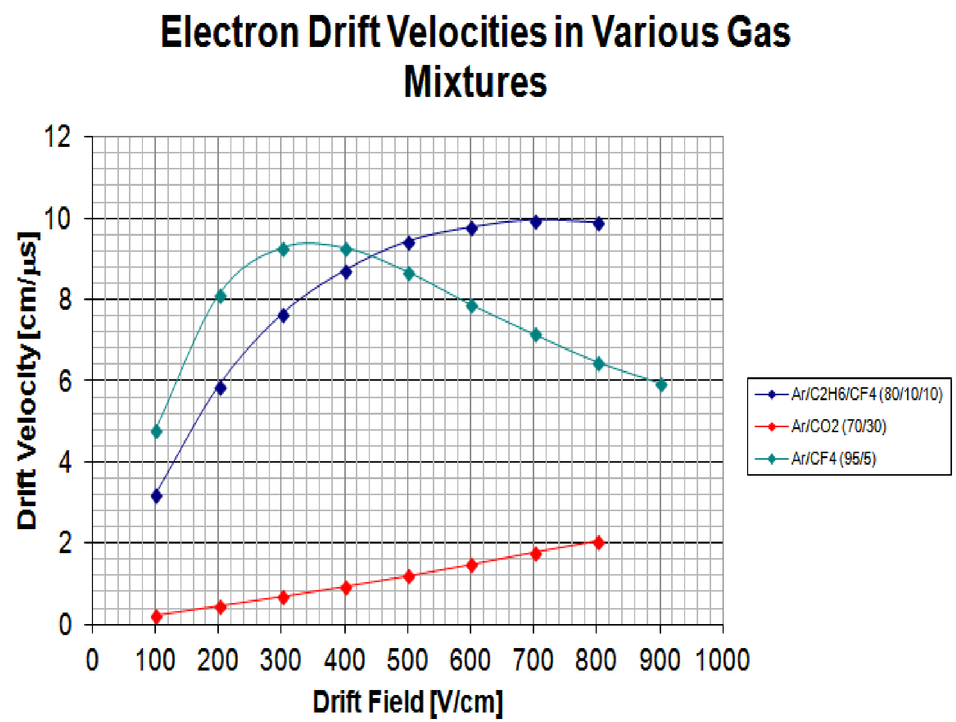




Drift Velocity Measurements

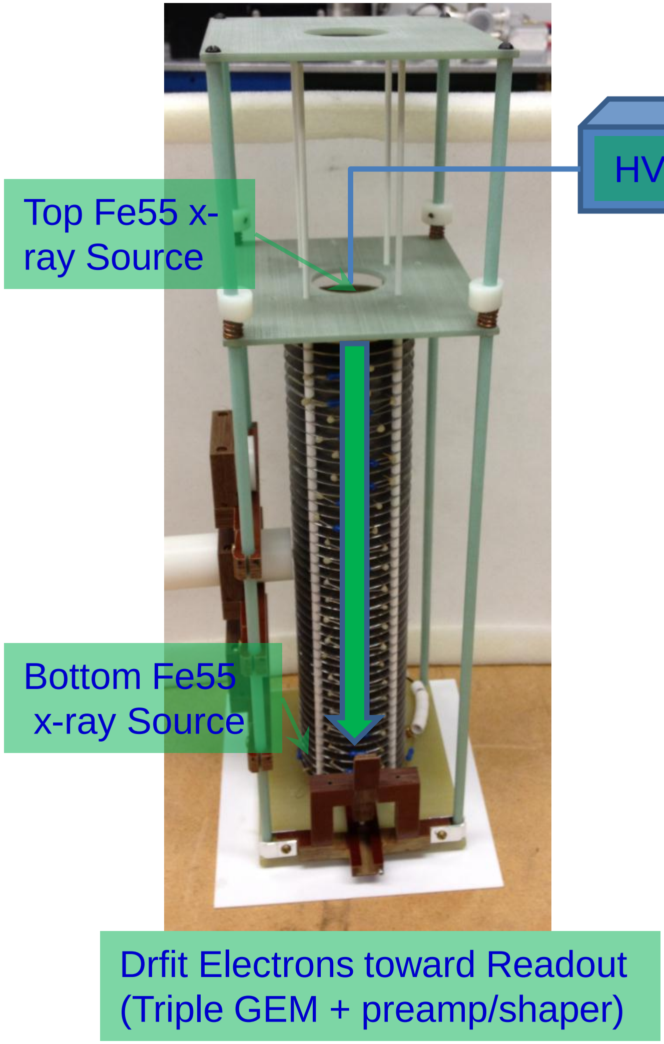


- Ionization "spot" produced by YAG laser
- Photodiode provides trigger
- Drift time is measured as the arrival time of the charge cluster at the readout plane

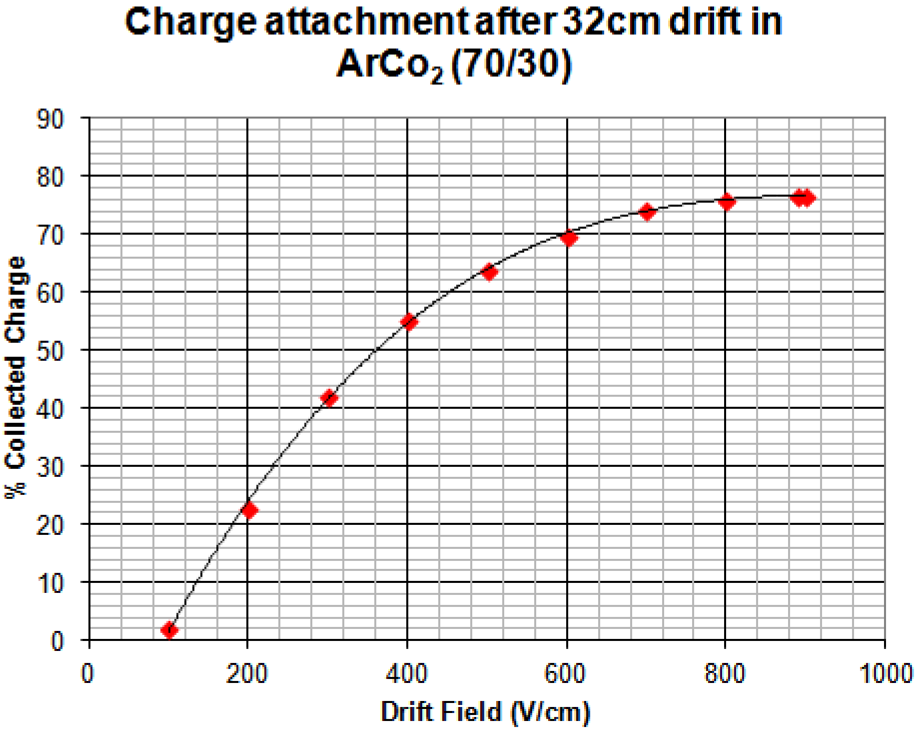


B. Azmoun

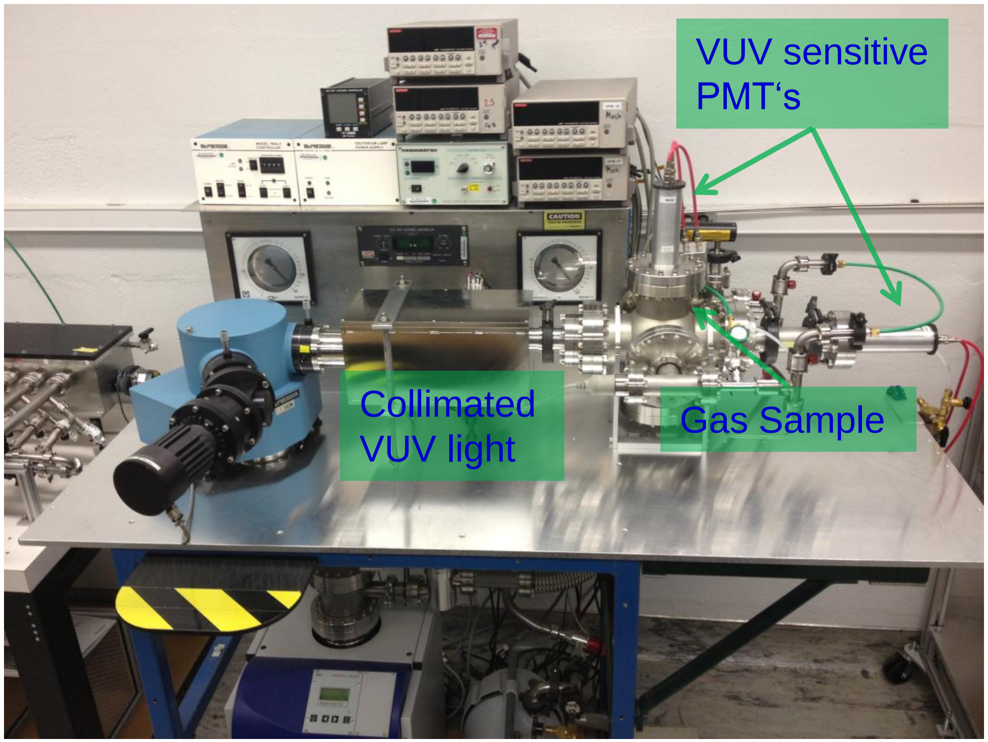
Charge Attachment Measurements



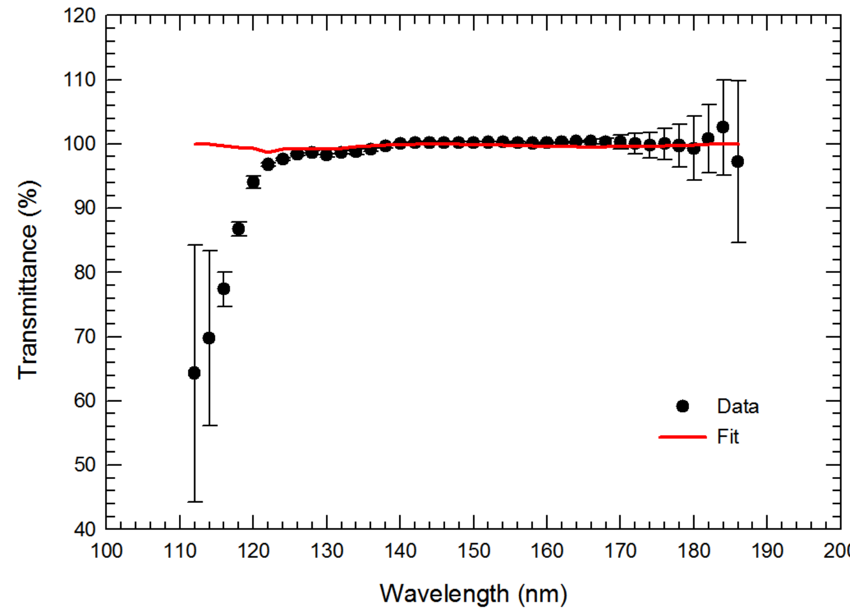
- Fe55 source deposits known charge at the top of the drift cell
- Charge is measured at the readout plane after 32 cm drift
- Ratio determines fraction of charge collected



Gas Transmittance Measurements



Transmittance of pure CF_4

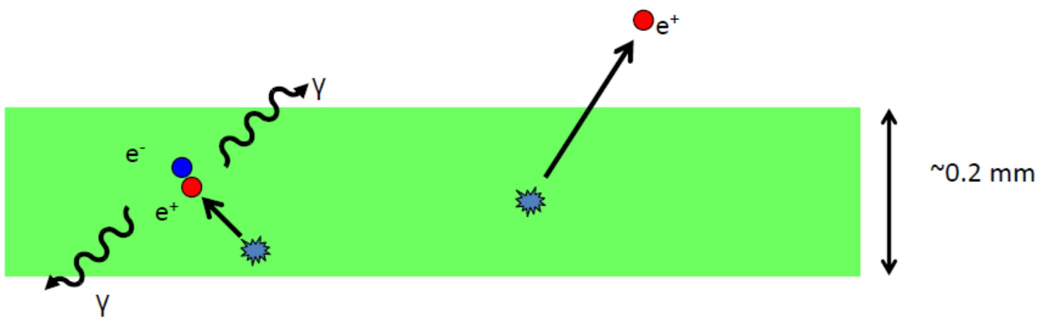


VUV Spectrometer for measuring transmission of gases down to ~ 120 nm

GEM Trackers for Positron Imaging

- Efficiency for conventional Positron Emission Tomography is very low for imaging thin objects such as skin, plant leaves, etc.
  - Large fraction of positrons escape without converting
- Range of positrons for PET isotopes is many cm in gas

Isotope	E_{max} β^+ (MeV)	Range in air (cm)
^{18}F	0.64	225
^{11}C	0.96	365
^{14}N	1.20	483
^{15}O	1.70	718

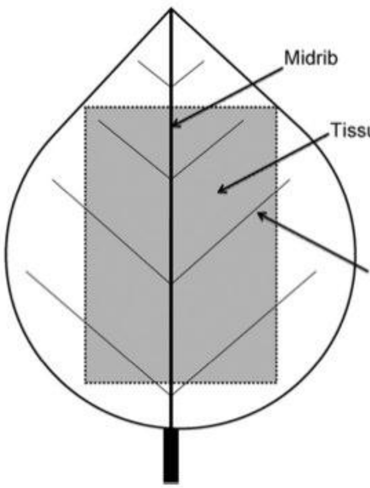


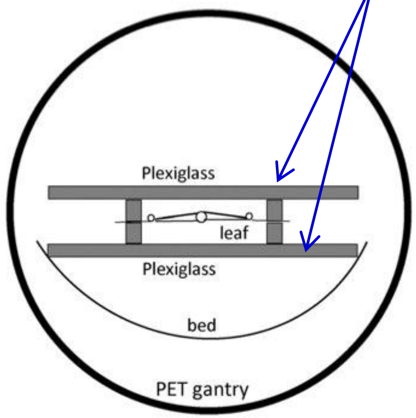
- It is therefore possible to track the escaped positrons, generating a line of response similar to the one produced by back-to-back gammas in conventional PET, and use this for image reconstruction
- Main problem is in multiple scattering of the positrons, primarily in the window of the detector

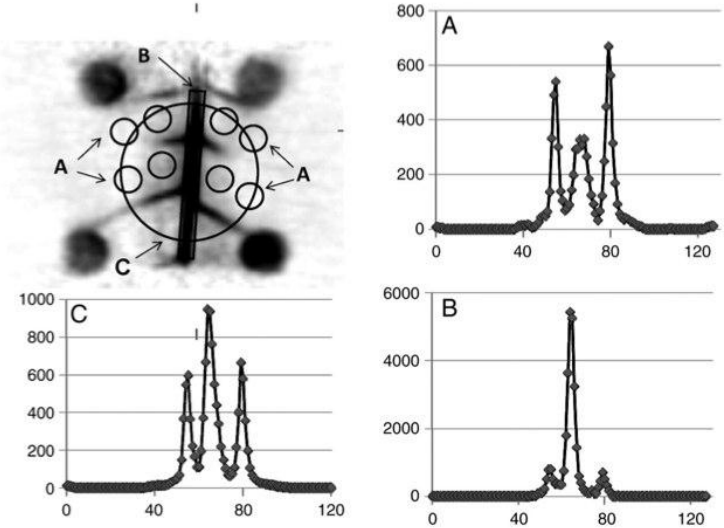
Positron Escape Probability

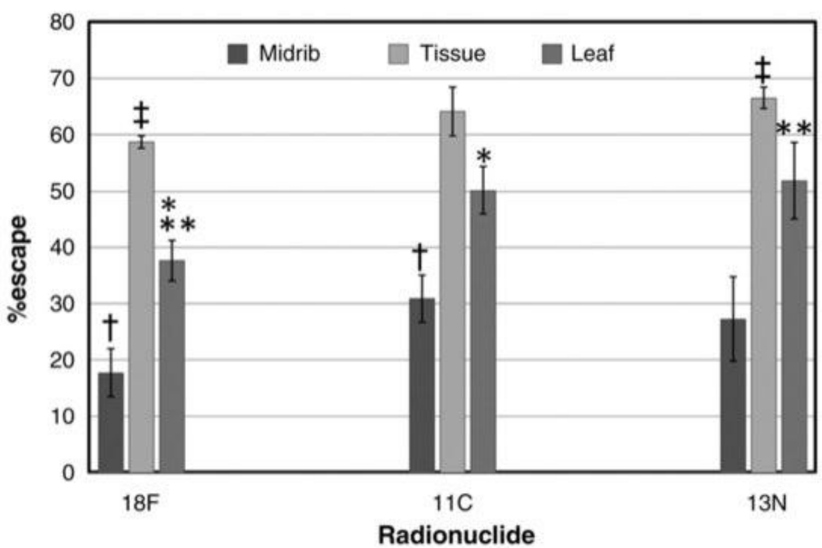
Leaf Experiment

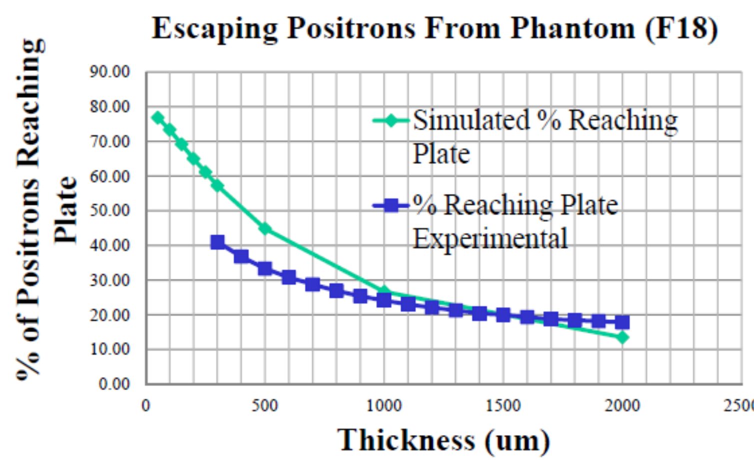
Plexiglass plates stop escaping positrons which are then imaged by PET



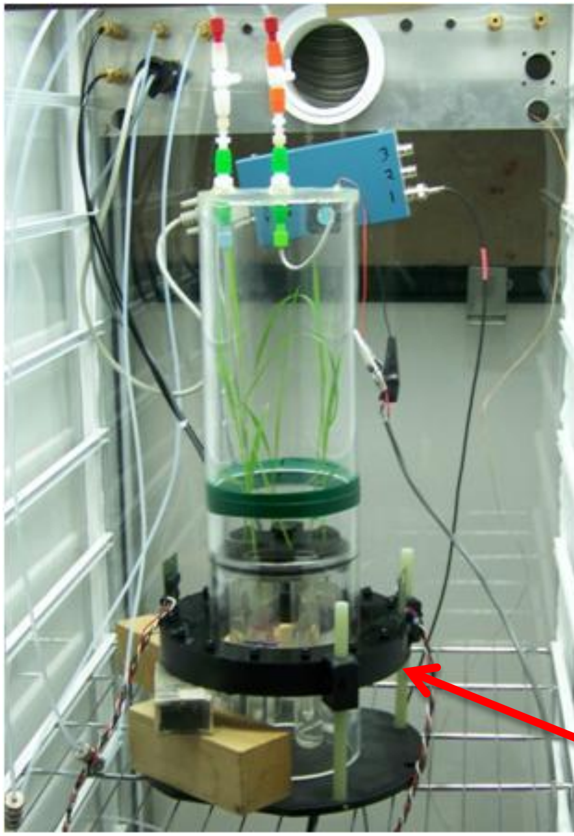


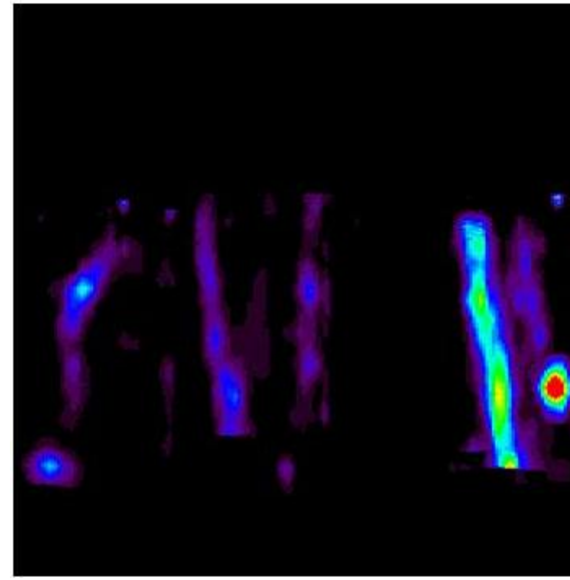






Positron Imaging Could be Complimentary to PET Imaging of Plants



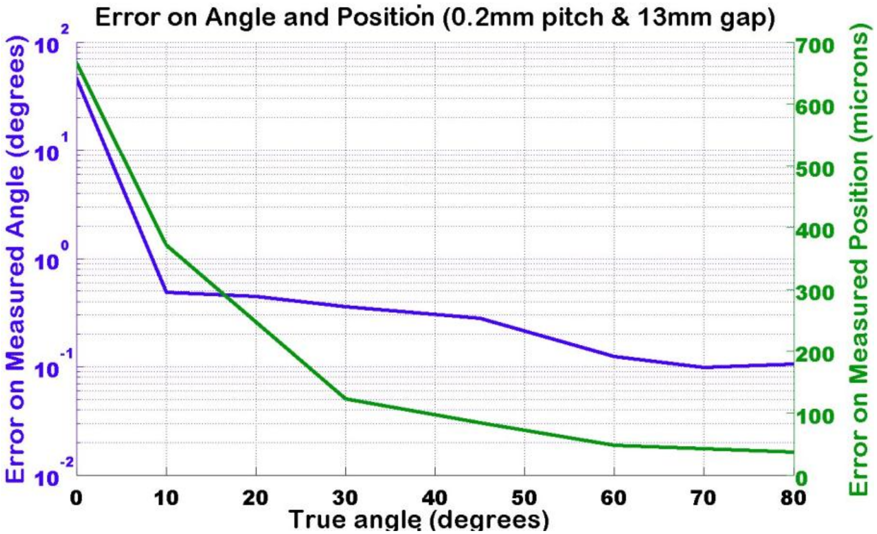


PET image of the stems of a corn plant

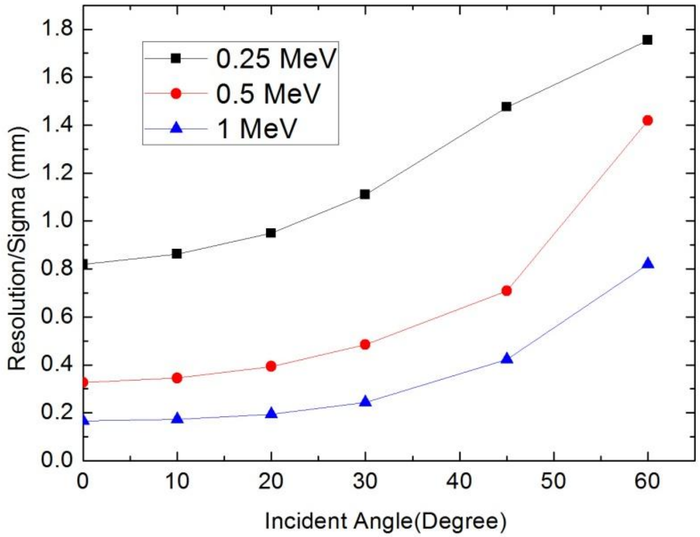
Two Ring Ratcap PET imager

Position and Angular Resolution for Measuring Escaped Positrons

Detector Resolution
(stand alone Monte Carlo)



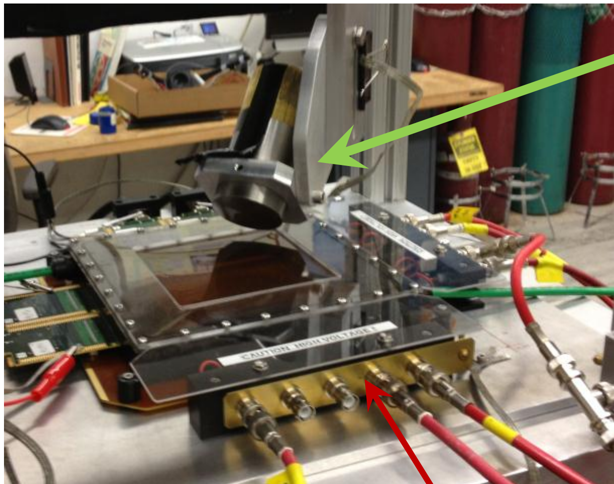
Spatial resolution due to multiple scattering in a 50 μm thick mylar window (Geant4)

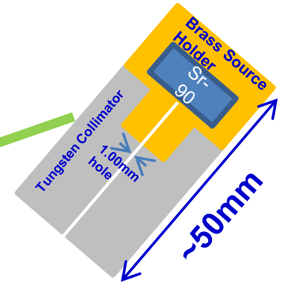


T.Cao, Stony Brook

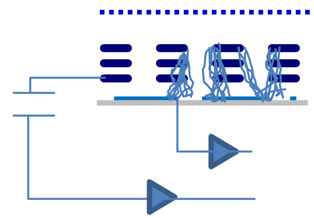
Position resolution is limited by scattering in detector window

Test with Collimated Beta Source





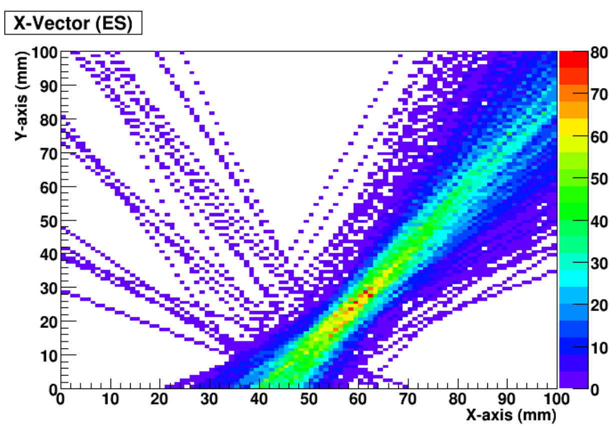
Trigger on bottom GEM

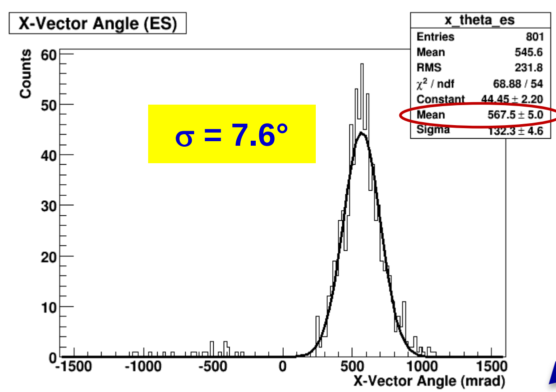


Preamp/Shaper Capacitively couped to bottom GEM electrode

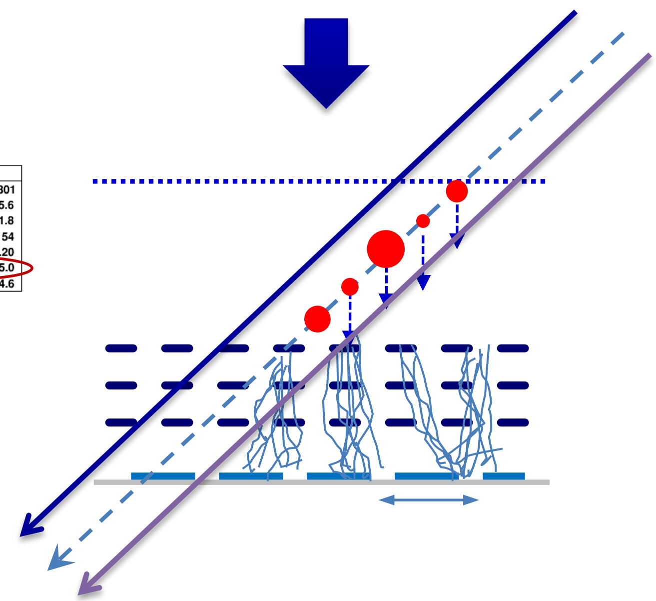
- ^{90}Sr source (e^-, E_{max} = 2.3 MeV)
- Tungsten collimator with 1 mm hole
- Need to reject background from γ conversions due to bremsstrahlung
- Trigger on bottom GEM
- Requires good single electron detection efficiency ($\Rightarrow$ high gain)

Trigger timing determines displacement of vector relative to track, although no influence on angular resolution.



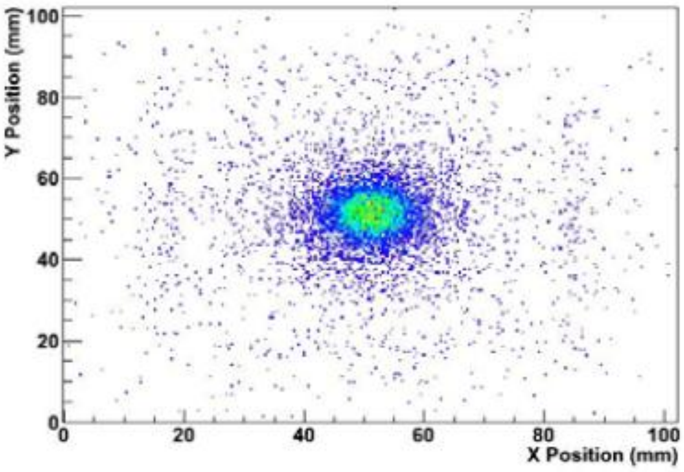


4.5° due to multiple scattering

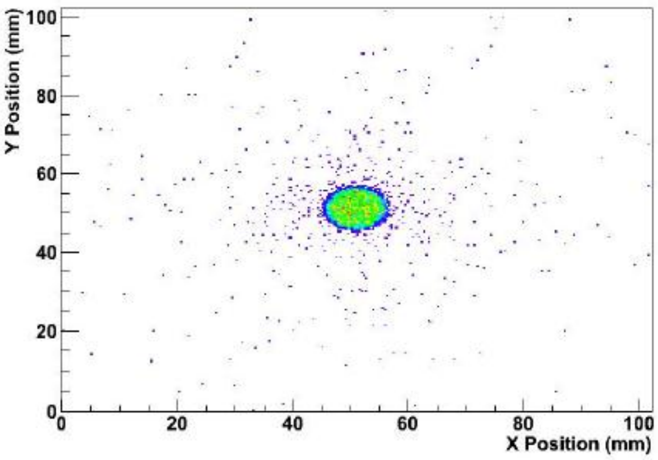


Planar Image vs Vector Reconstruction

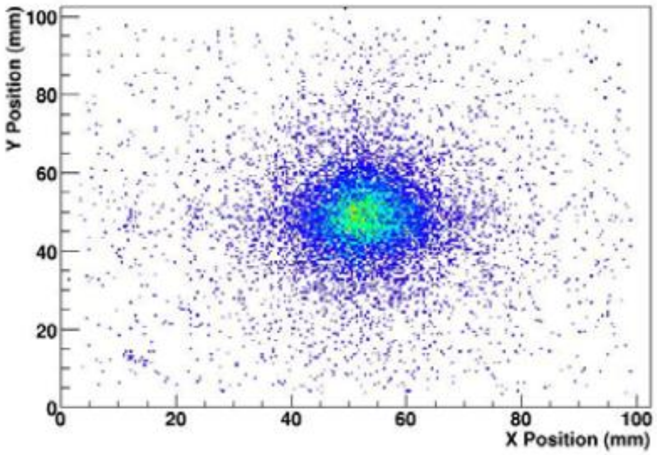
Monte Carlo simulation of image reconstruction of a 1 cm disc of FDG



Planar image using only position information

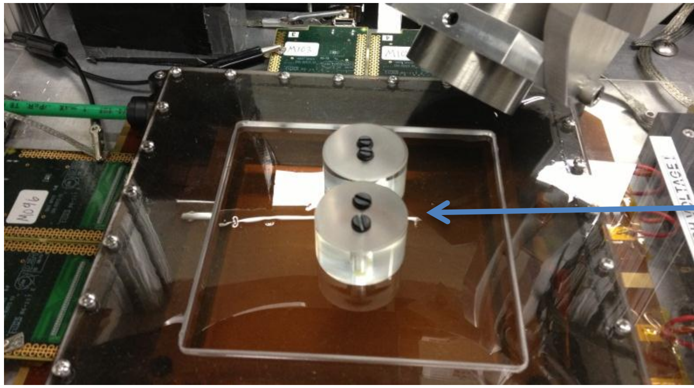


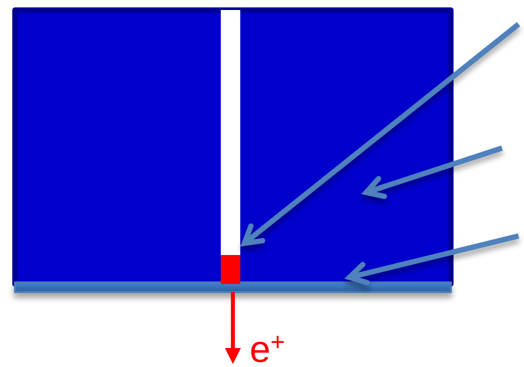
Same image using vector information



Planar image from actual data of a 1 cm disc of FDG

Imaging a Source Phantom

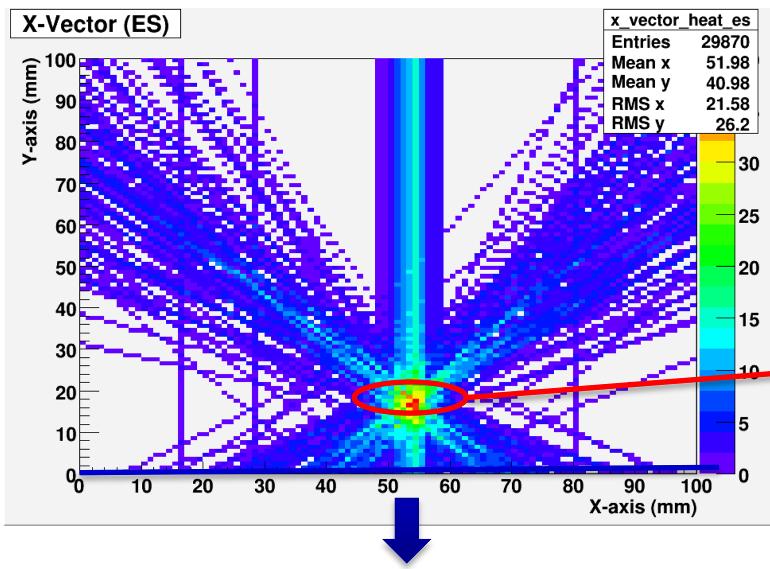


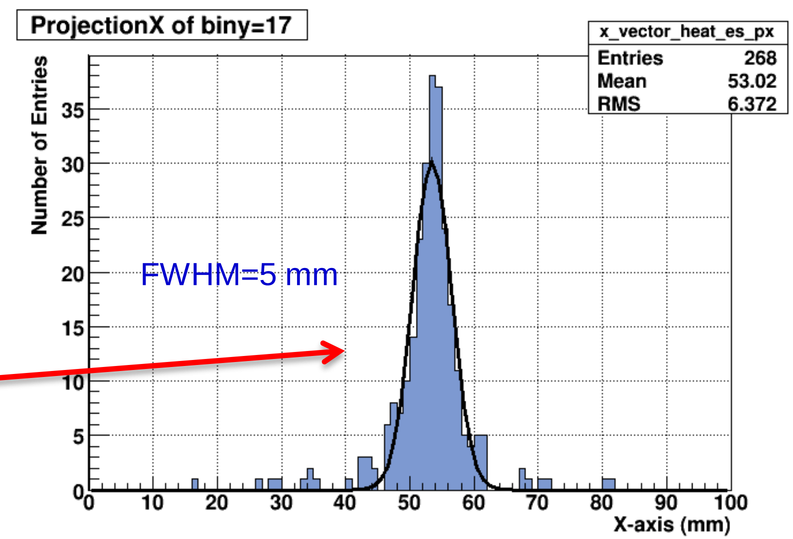


2 mm diameter hole partially filled with $^{11}C/^{18}F$ solution

Lucite cylinder

25 μm mylar window





Using only vertical tracks: collimator mode

Summary

- BNL is working on several new projects involving GEM detectors
  - Minidrift
    - Tracking for sPHENIX and EIC
    - Positron tracking for medical imaging
  - TPC/HBD
    - Tracking and particle id for EIC

- EIC tracking collaboration is also interested in large area GEM detectors for tracking (FIT, UVa), 3D readout (Yale) and RICH particle id (Stony Brook)