R&D on a Prototype TPC/Cherenkov Detector

Craig Woody
BNL

EIC Tracking R&D Workshop
Temple University

May 9, 2015

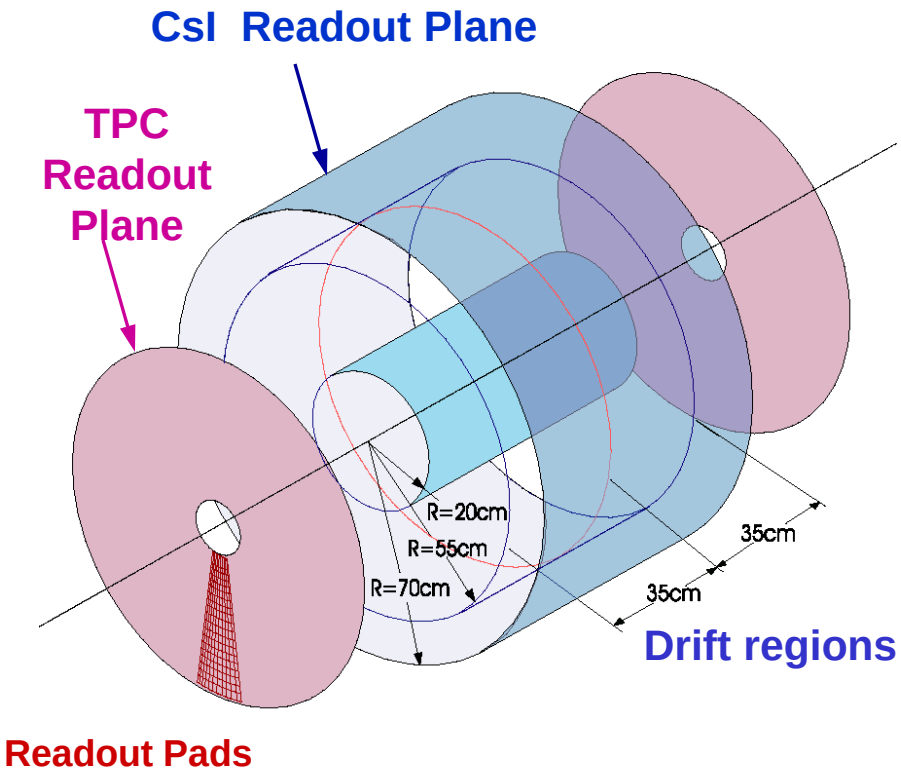
PHENIX Upgrade Workshop
Montauk, L.I.

March 21-23, 2001

A TPC Option for PHENIX

C. Woody
BNL

Original TPC/HBD Detector Proposal for PHENIX (circa ~ 2004)



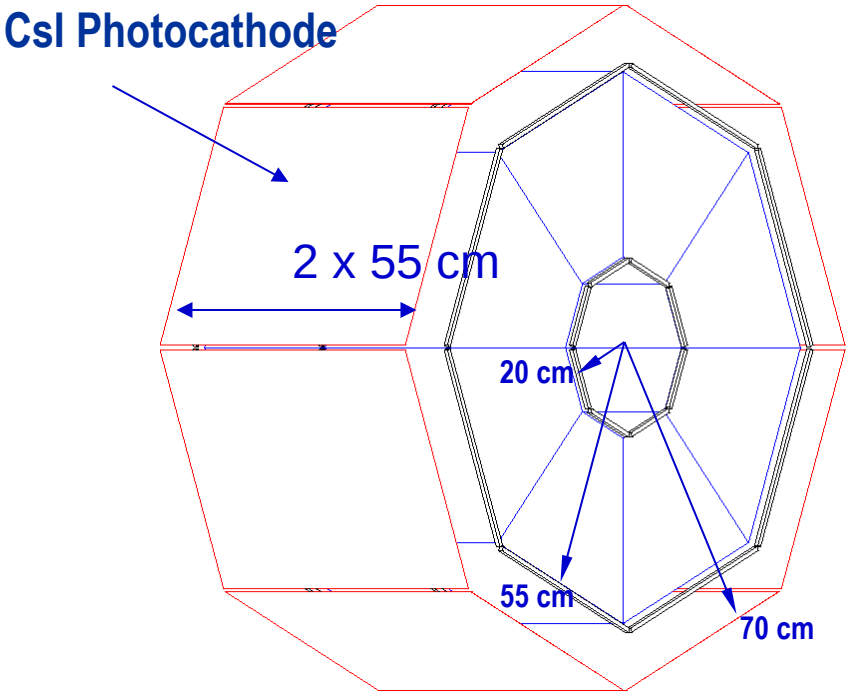
- TPC provides momentum measurement and particle id through dE/dx. Use ionization in gas volume to measure track trajectory.
- Cherenkov provides particle id as a threshold counter. Measure Cherenkov light produced in gas volume to identify high velocity particles (e.g., electrons)

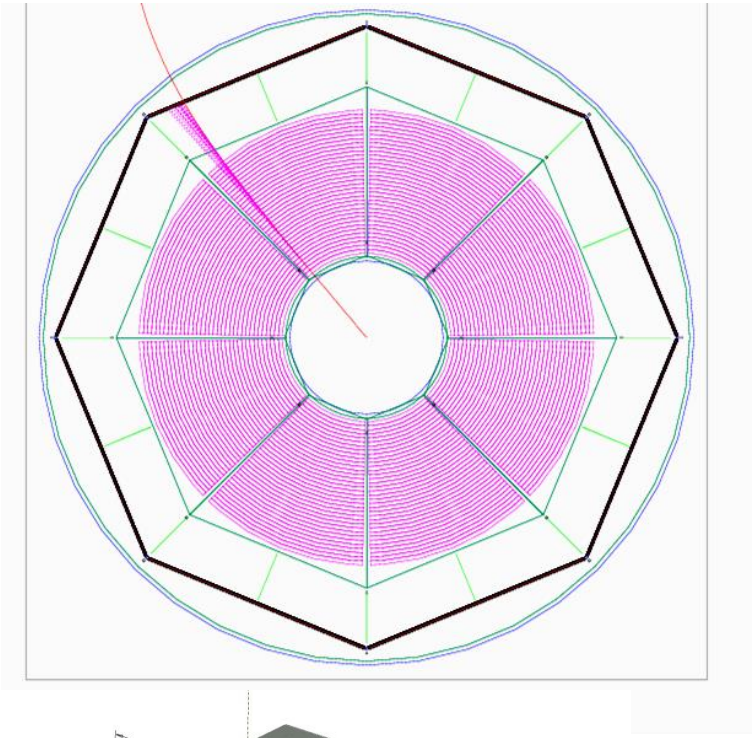
(could even be a RICH, but that becomes much more difficult)

Fast, Compact TPC

R<70 cm, L< 80 cm, T_{drift} < 4 μsec

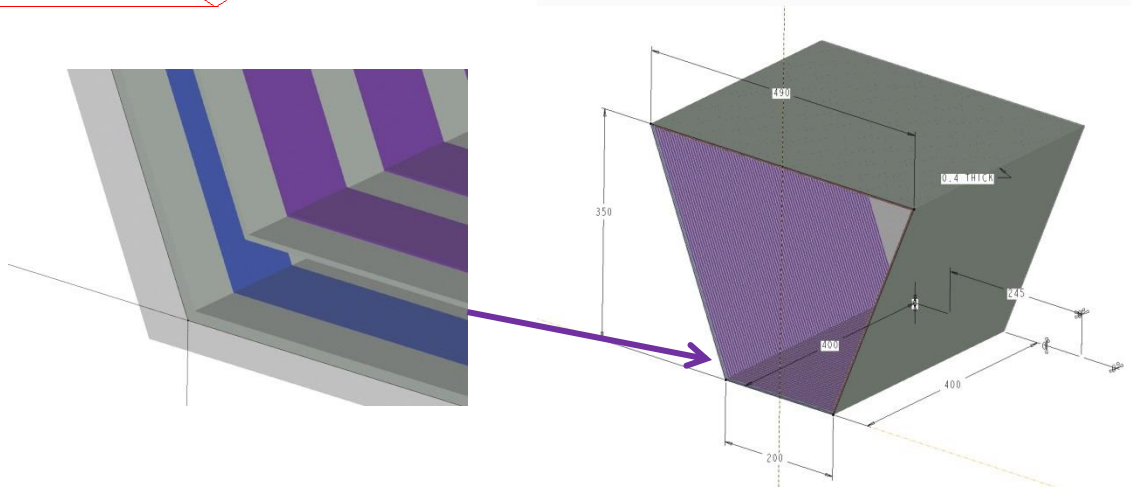
Previous Design Study





Field cage for sectors

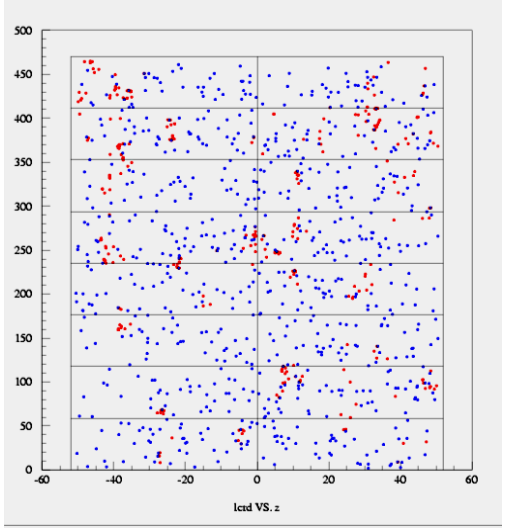
N. Smirnov



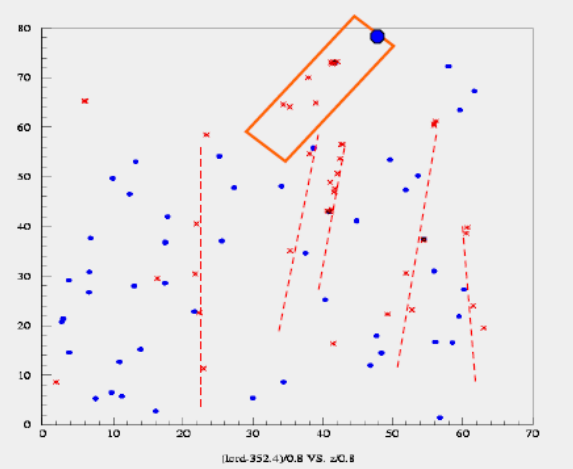
Previous Simulations

Finding electrons in central HIJING events using TPC to identify hits on Cherenkov plane

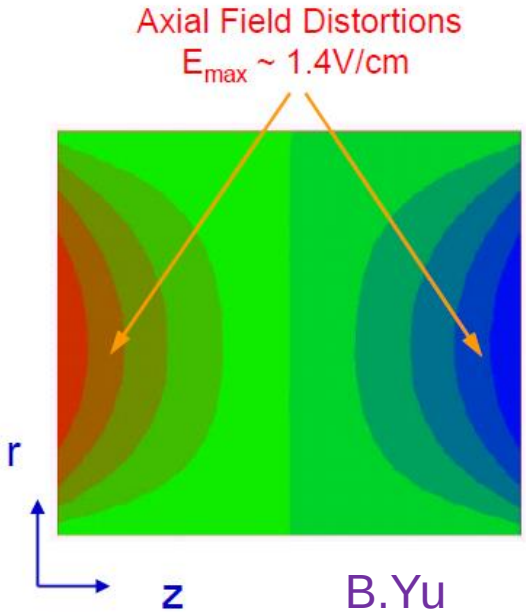
Rϕ All hits



Rϕ Cherenkov Hits

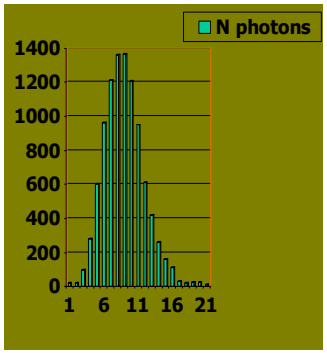


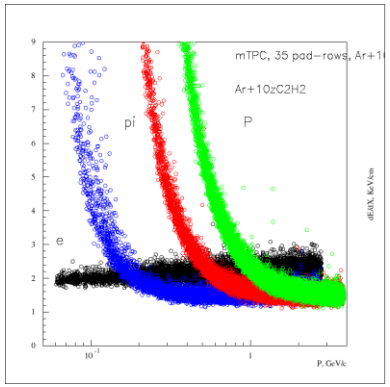
Space Charge Effects Central Au+Au

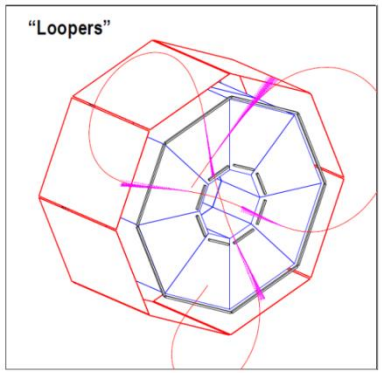


B.Yu

$\theta \sim 2.5 \times 10^{-3}$ rad
$\Delta x \sim 0.5$ mm for 40 cm drift





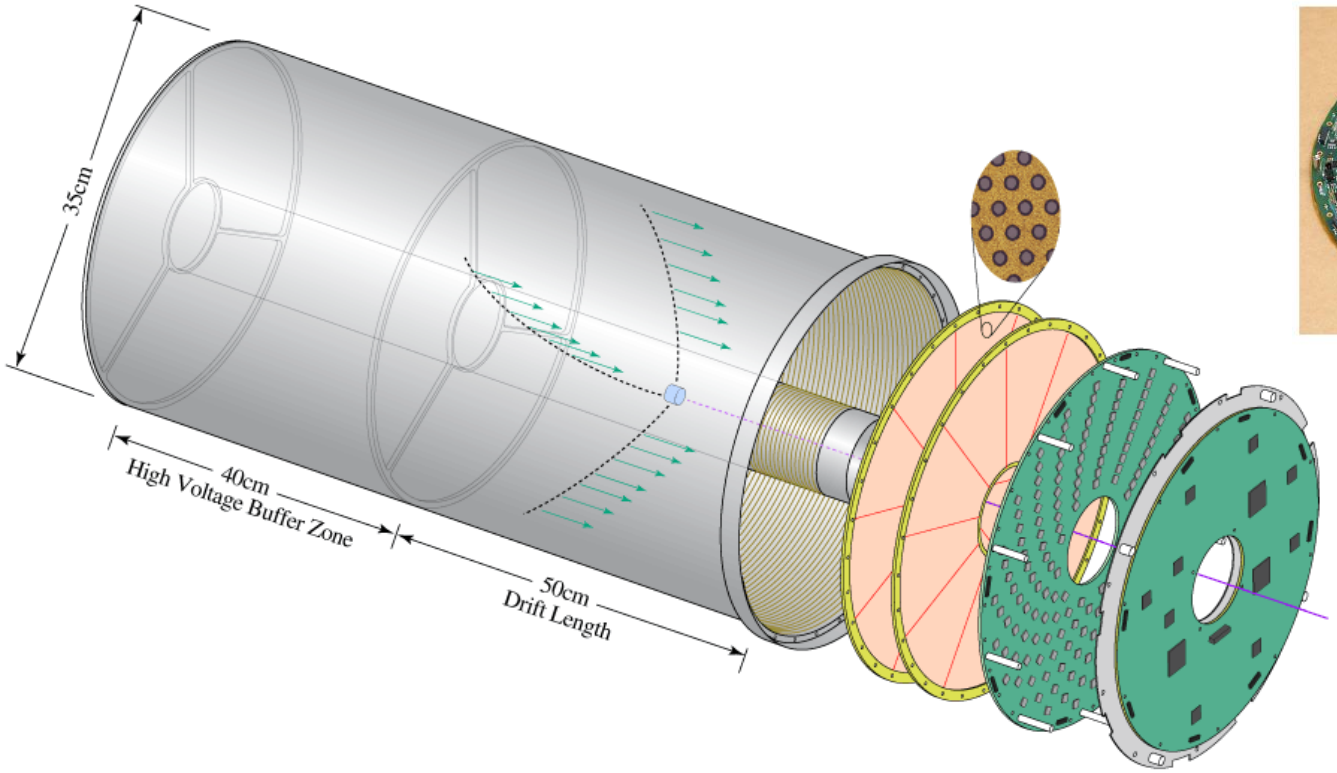


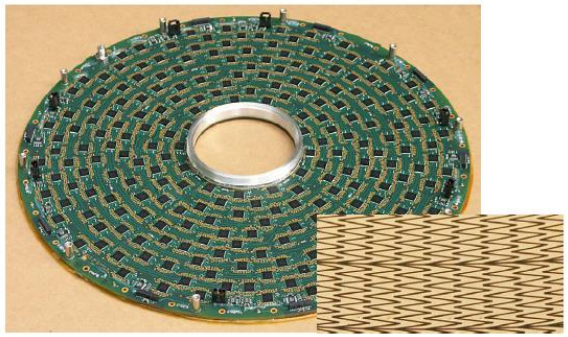
C.Aidala

N. Smirnov

LEGS TPC (circa ~ 2005)

- Designed for low rate (~kHz), low multiplicity (single sample per channel per trigger)
- Inner diameter ~9cm; Outer diameter ~35cm; Drift Length: 50cm



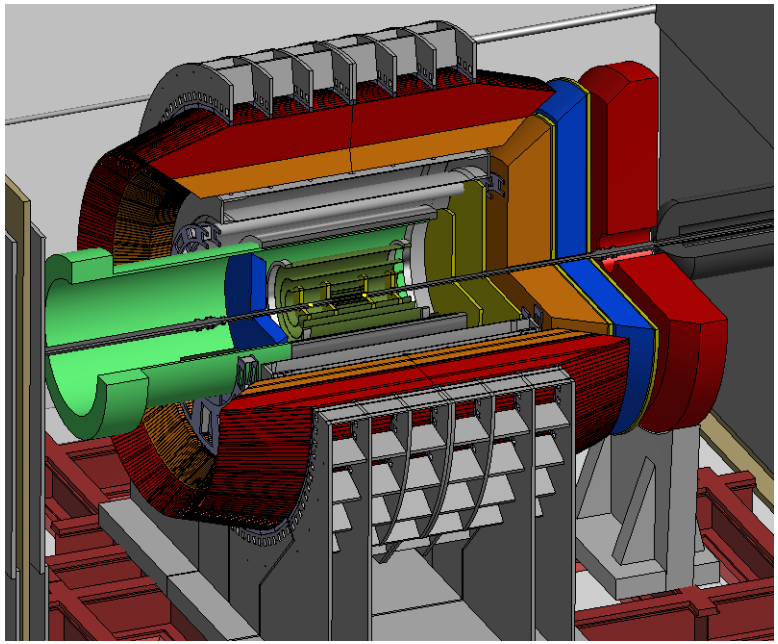


- Double GEM (G <1000)
- Drift field ~ 600V/cm (30kV HV)
- Drift time ~ 5μs

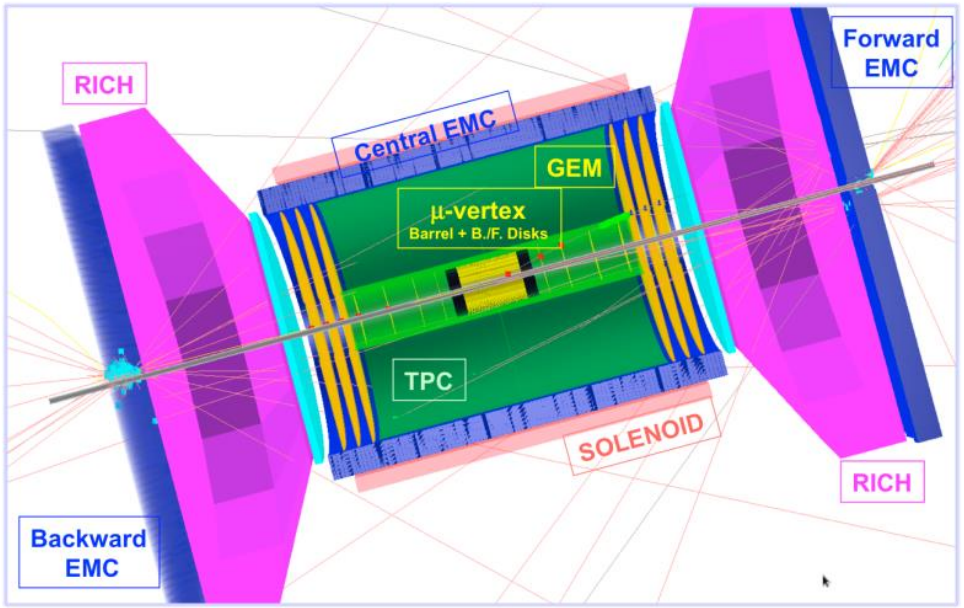
- Chevron pad readout (~ 200 μm resolution)
- ~ 7K Readout channels
- Custom ASIC
  32 channels per chip
  40mW per chip
- ENC < 250 e's
- 500ns peaking time
- Single peak time and amplitude measurement
- Timing resolution ~ 20ns

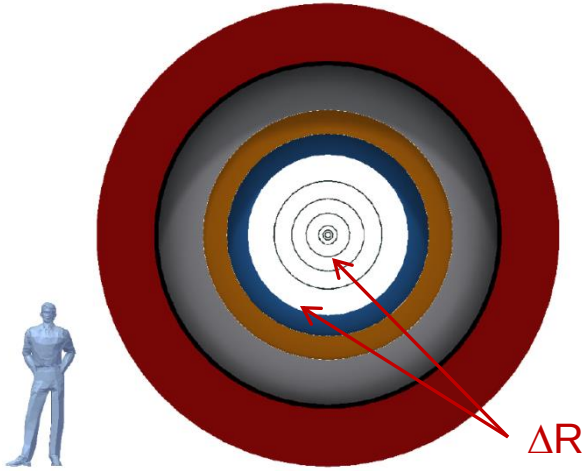
Use at RHIC and EIC

sPHENIX



BEAST





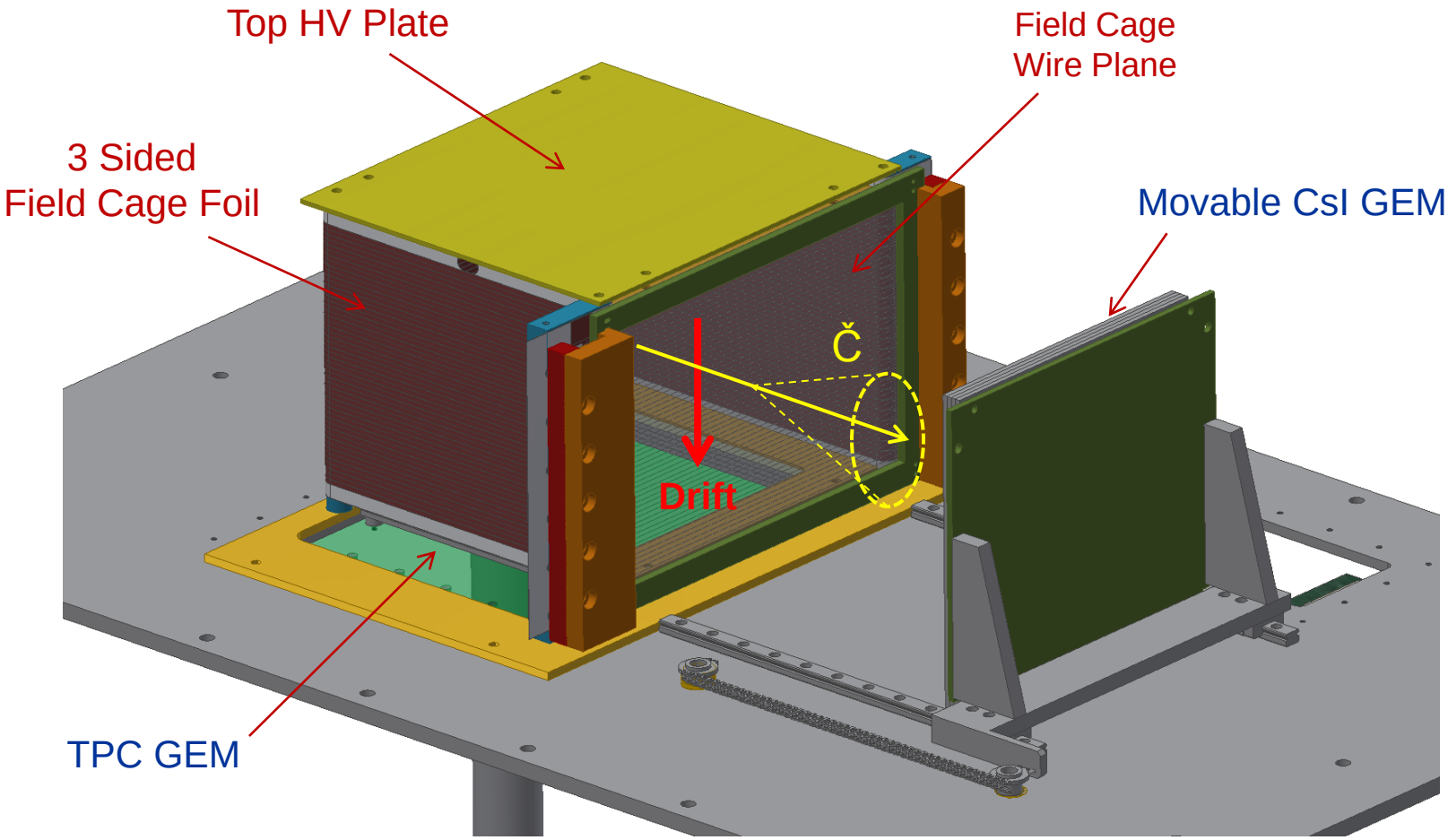
ΔR for TPC Tracking ~ 30-80 cm

- Could provide electron id for measuring Y's in sPHENIX
- Could help improve electron id in the central region at EIC

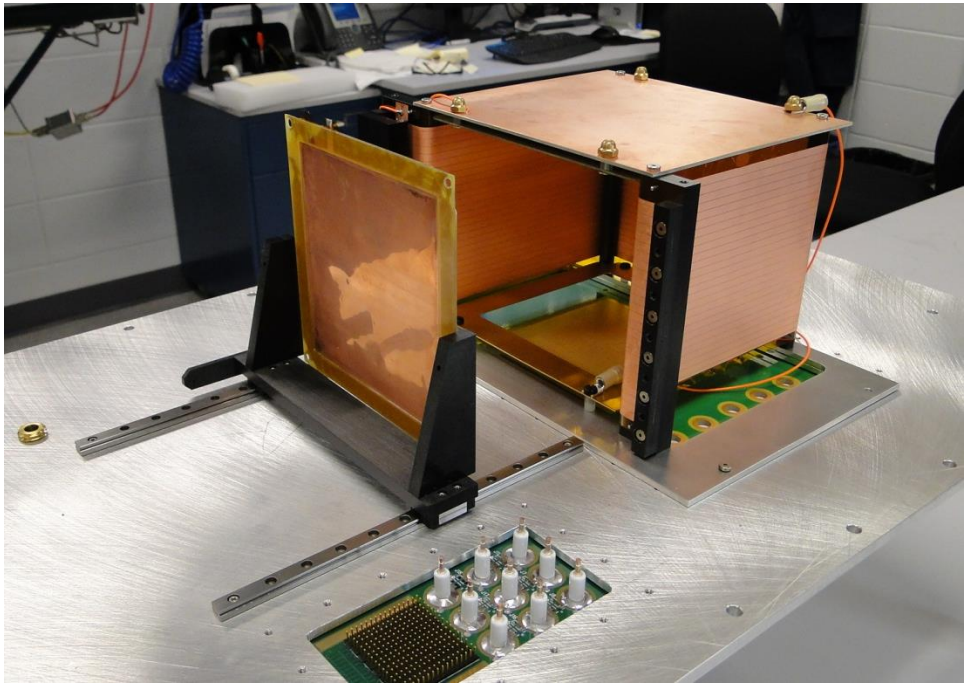
Detector Requirements

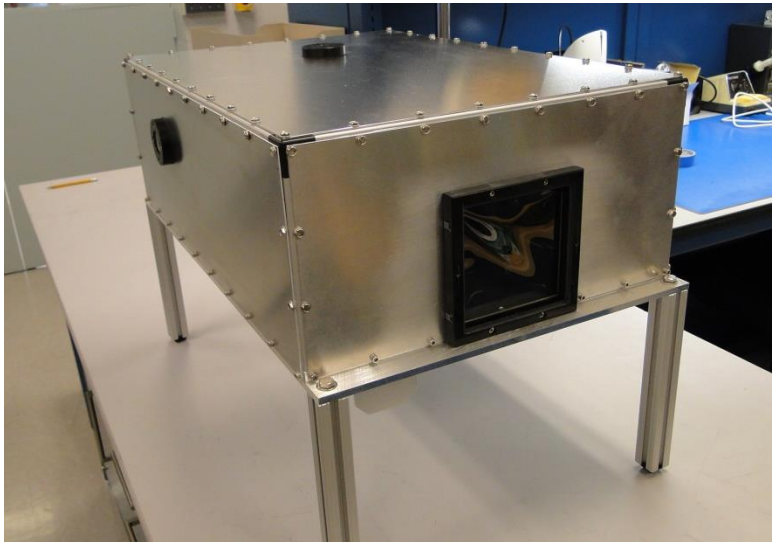
- Gas must be transparent to UV light $\longrightarrow$ CF_4 (like HBD)
- Want fast drift velocity ($\longrightarrow$ CF_4 or mixtures containing CF_4)
- Photosensitive GEM must operate near the HV plane of the field cage. Field cage must be optically transparent on its outer radius. How much radial space with it take up ?
- What are space charge limitations if used in HI collisions ?

3D Detector Model

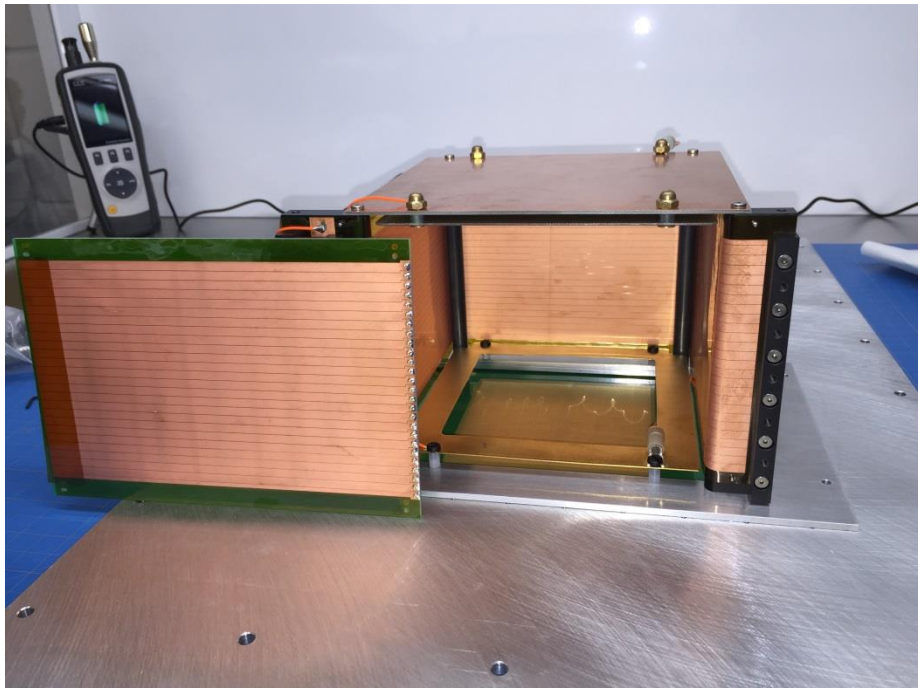


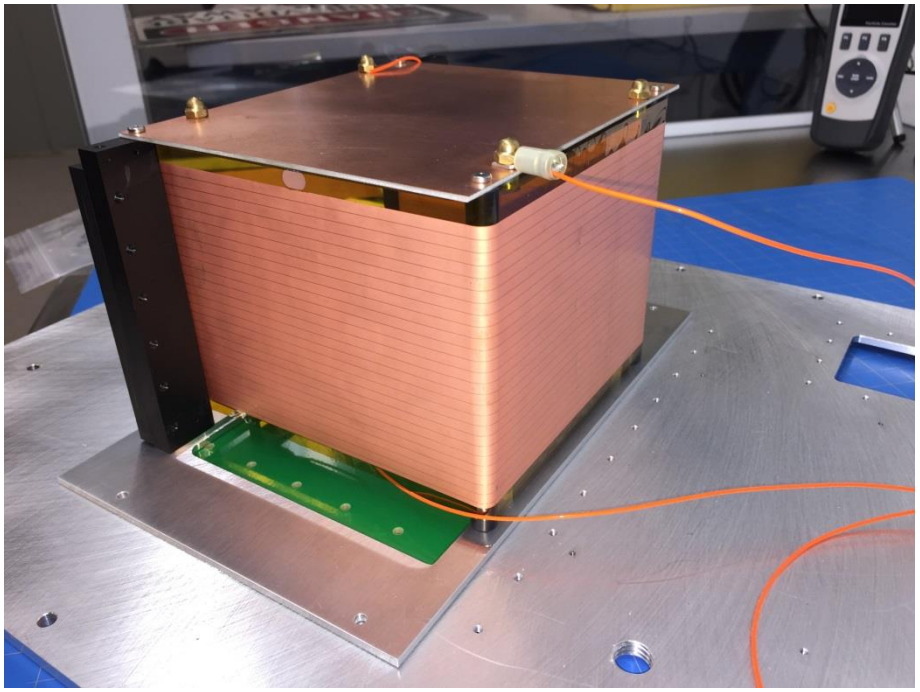
The Actual Prototype





3 Sided Field Cage + 1 Sided Foil

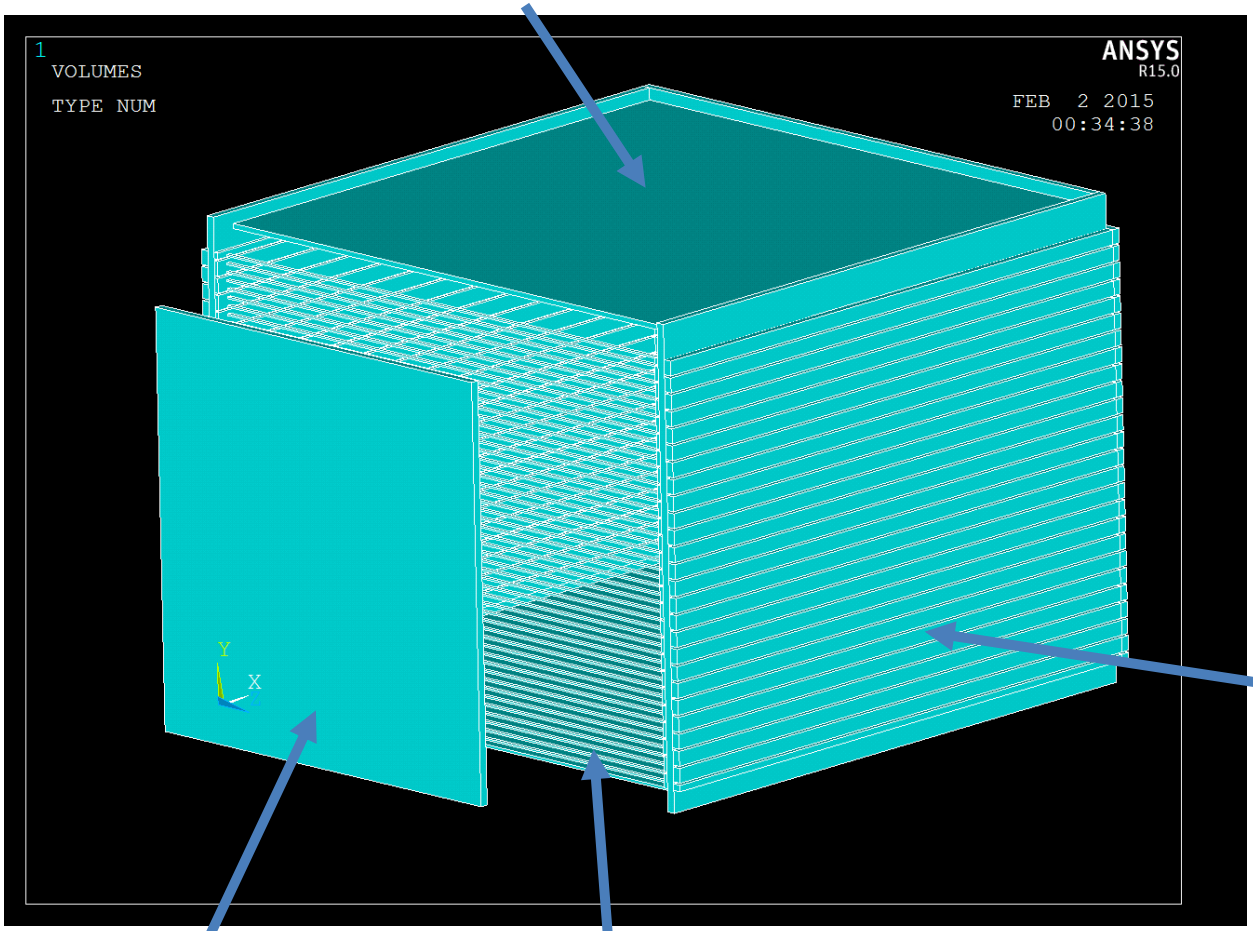




Kapton foil with 3.9 mm copper strips with 0.1 mm gaps
Tested to full operating voltage of 1 kV/cm

Electrostatic Simulation

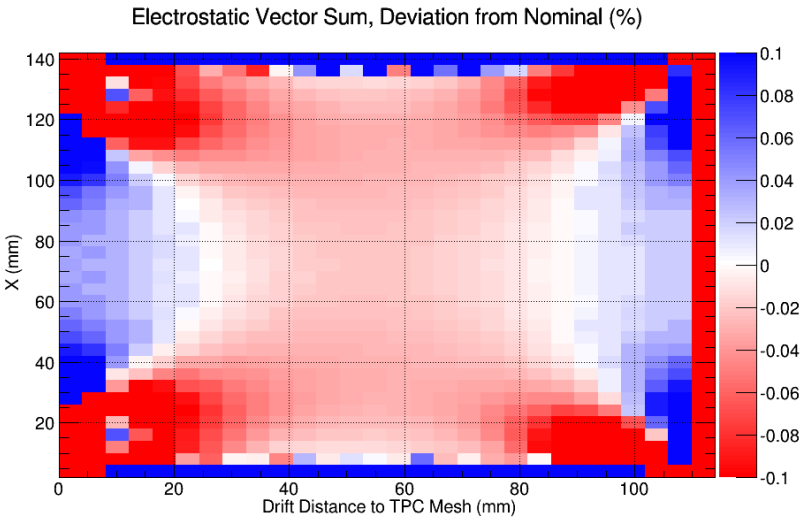
ANSYS



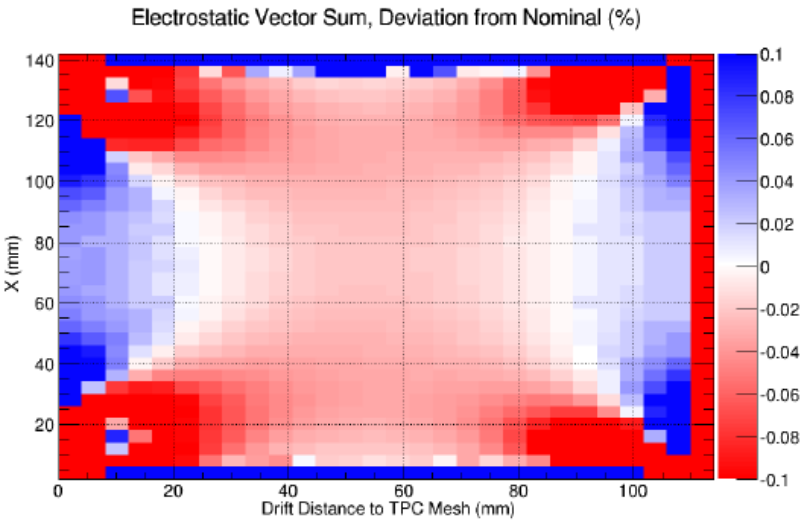
M.Phipps

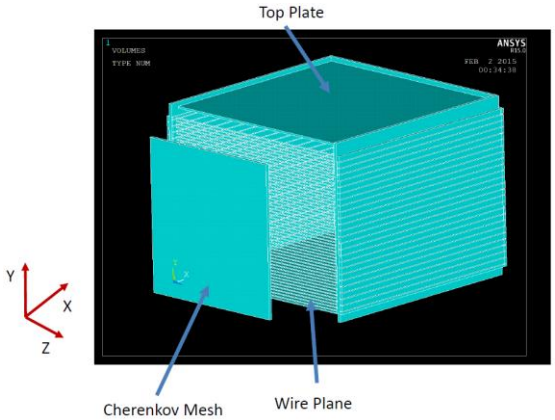
Field Distortions with One Plane of Wires for Field Cage

4 sides of strips



3 sides of strips + 1 side of wires





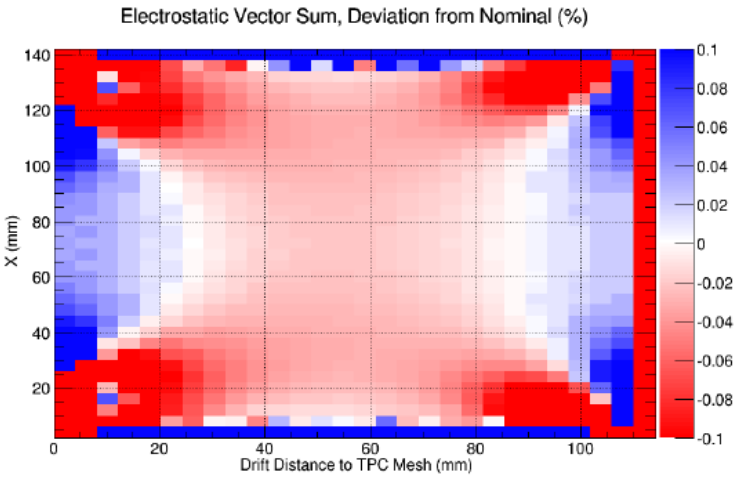
Slice in XY plane at mid Z
Wire plane is at X=0

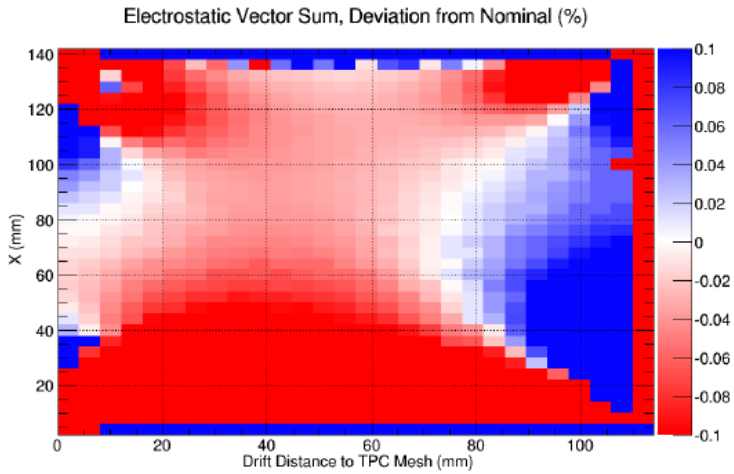
M.Phipps

Field Distortions with Addition of Cherenkov Mesh

Drift direction toward left. Slice is in XY plane in middle of Z
Note: wire plane along bottom of plot (low X)

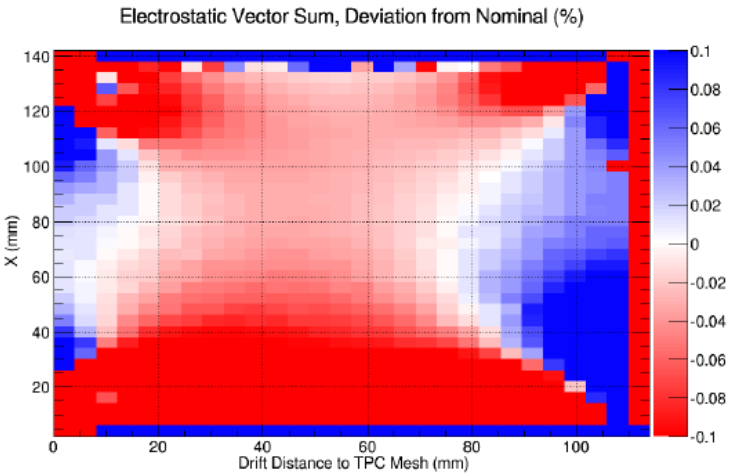
No Cherenkov mesh

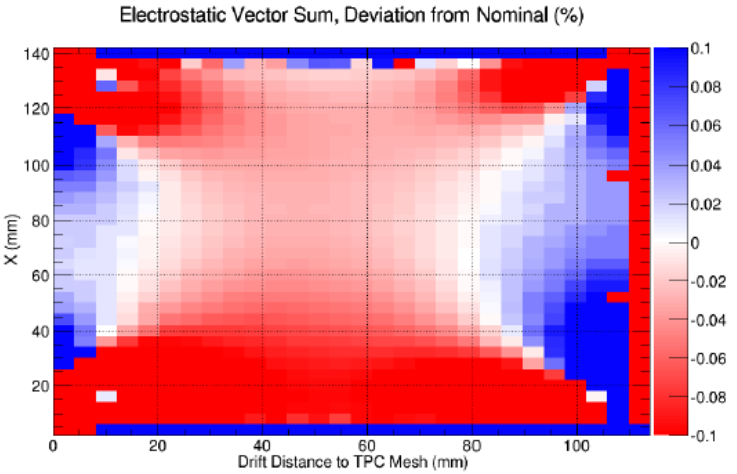




Cherenkov mesh @ -15 mm

Cherenkov mesh @ -25 mm

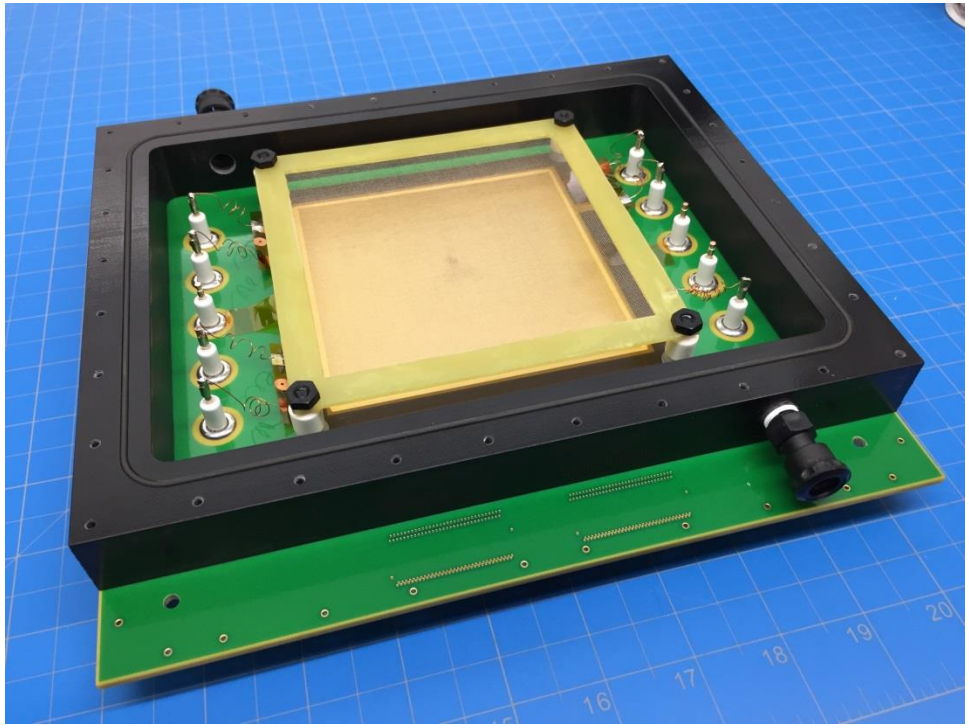


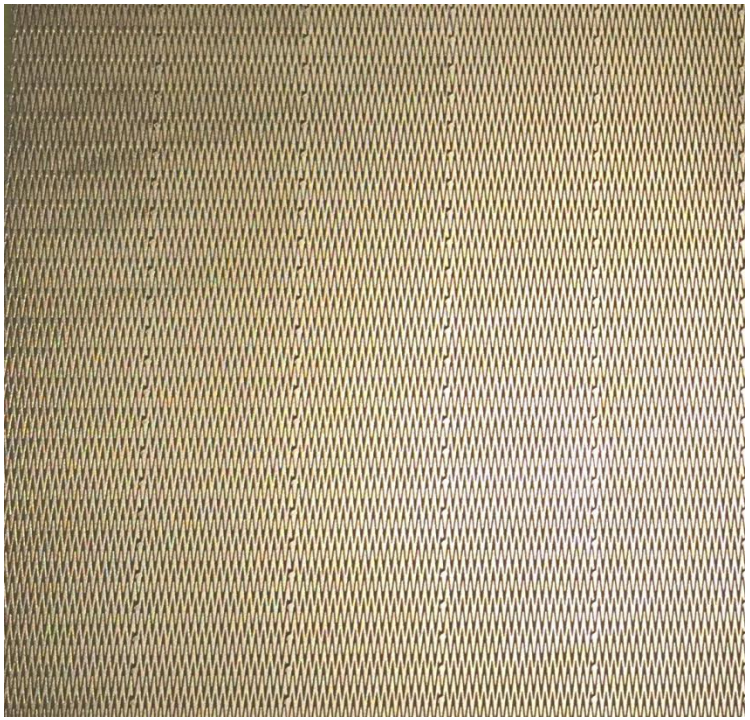


Cherenkov mesh @ -40 mm

M.Phipps

TPC GEM Detector with Chevron readout board

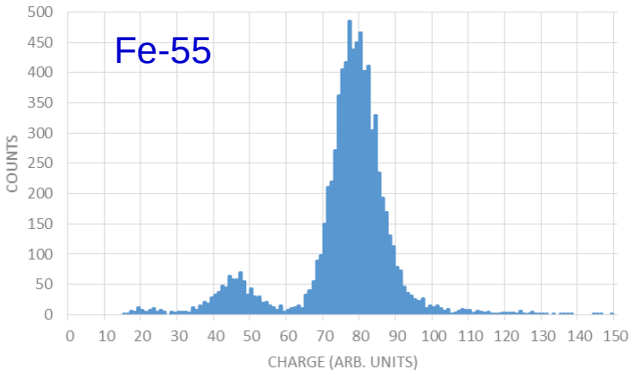




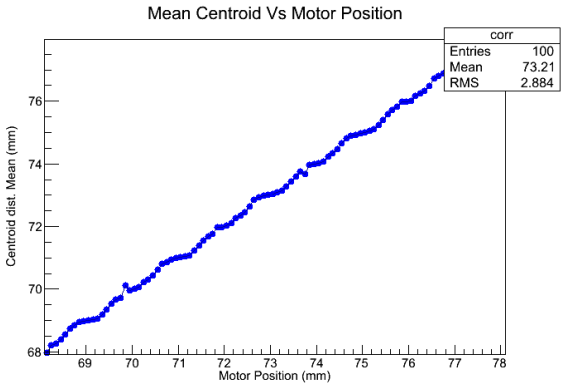
10x10 cm^2 Triple GEM

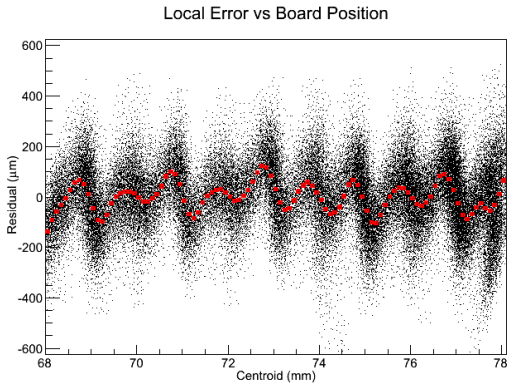
2 x10 mm Chevron Strips
0.5 mmm pitch

First Tests of the TPC GEM

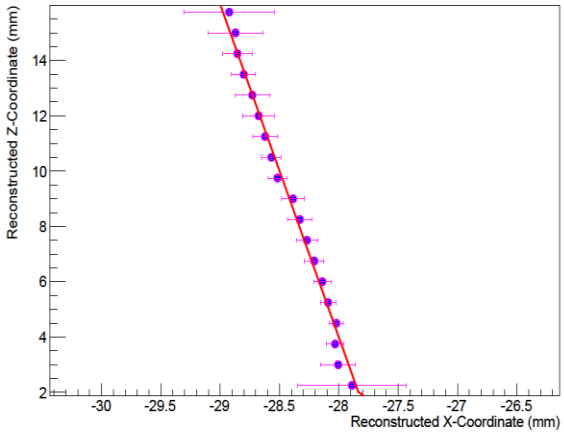


Scan across chevron pads with collimated X-ray source

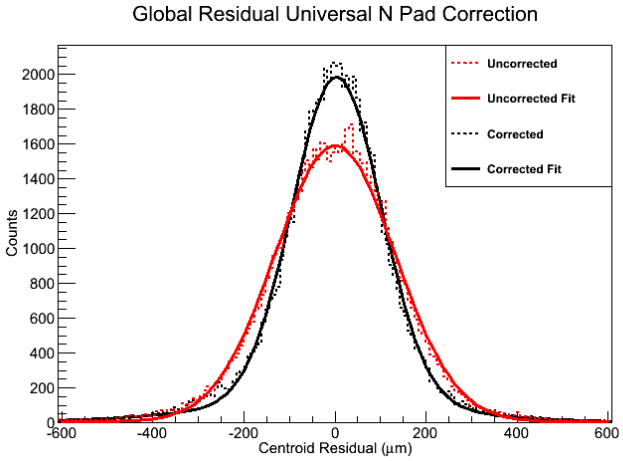




Reconstructed track with GEMs configured as a Minidrift Detector



Position Resolution



Uncorrected: 132 μm
Corrected: 98 μm

Electronics

Current readout options

- SRS : 1024 chs, 25 ns sampling
  28 samples → 700 ns drift time
- DRS4 : 128 chs, 1048 samples with selectable time resolution
  0.2 ns → 200 ns drift time
  1 ns → 1 μsec drift time
- Struck SIS3300 : 24 chs, 10 ns sampling, 10 μsec drift time
- VMM2 (derived from LEGS TPC chip)
  Single peak amplitude recorded, 1 μsec time buffer
- GET: General Electronics for TPCs
  General purpose TPC readout system developed at Saclay
  Used in many small to medium sized TPC systems in nuclear physics
- SAMPA
  Being developed for ALICE GEM TPC
  Time scale: needs to be ready by 2018
  → This is probably our best ultimate solution

Summary & Future Plans

- Assembly of the prototype TPC/Cherenkov is nearly complete
- Preliminary testing of the field cage and TPC GEMs look good
- Will test initially as a TPC only (no CsI GEM)
  This will really be a testing ground for learning how to operate a TPC
  Measure drift velocities, study ion feedback, reconstruct tracks, etc
- Add Cherenkov GEM (no CsI) and study HV effects
  How close can we bring the Č-GEM in proximity to the wire plane ?
- Add CsI GEM and study the Cherenkov detector
- Test entire detector in the test beam at Fermilab or SLAC
- FY16 budget request: $60K
  (parts & supplies, beam test, upgrade optics of VUV spectrometer)