WG5 Summary: MPGD

Kevin Black (University of Wisconsin–Madison)
Prakhar Garg (Stony Brook University)
Matt Posik (Temple University)

CPAD 2022

Stony Brook University

Nov. 29 to Dec. 2, 2022

Sessions

Tue 29/11

13:00				
	Ion Back Flow and Energy Resolution study for Quadruple GEM detector	*Sourav Tarafdar*	*Lecture Hall 1, Wang Center*	13:30 - 13:50
	Design and construction of the sPHENIX TPC	*Evgeny Shulga*	*Lecture Hall 1, Wang Center*	13:50 - 14:10
14:00				
	Spark Monitoring System for sPHENIX TPC GEMs	*Julian Driebeek*	*Lecture Hall 1, Wang Center*	14:10 - 14:30
	TPOT: Micromegas detectors to reconstruct distortions in the TPC for the sPHENIX experiment	*Audrey Francisco et al.*	*Lecture Hall 1, Wang Center*	14:30 - 14:50
	An overview of the MPGD Development for the EIC's ePIC Detector	*Matt Posik*	*Lecture Hall 1, Wang Center*	14:50 - 15:10
15:00				
	Particle Identification using GEM based TRD/T	*Sourav Tarafdar*	*Lecture Hall 1, Wang Center*	15:10 - 15:30

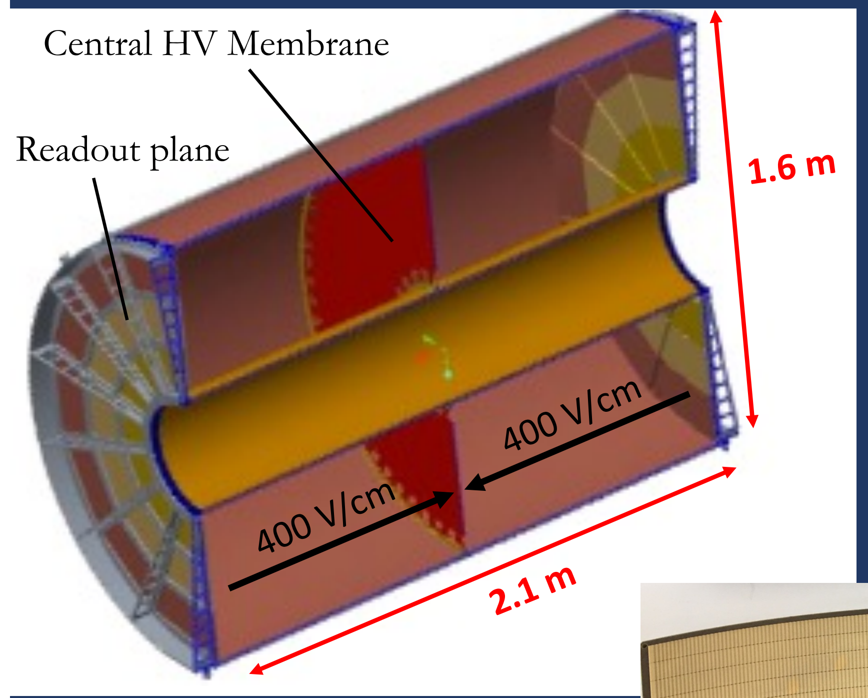
Wed 30/11

10:00				
	Recent Results from PICOSEC:Sub-25 Picosecond MPGD based charged particle timing	*Sebastian White*	*Room 201, Wang Center*	10:35 - 10:55
	First performance of Triple-GEM detectors in the CMS muon system with cosmic rays and LHC collisions	*Ilaria Vai*	*Room 201, Wang Center*	10:55 - 11:15
11:00				
	Detector and electronics integration for the CGEM Inner Tracker	*Ilaria Balossino*	*Room 201, Wang Center*	11:15 - 11:35
	A Gaseous Argon-Based Near Detector for DUNE	*Dr Tanaz Mohayai*	*Room 201, Wang Center*	11:35 - 11:55
	A tracker for PIONEER	*Jaydeep Datta*	*Room 201, Wang Center*	11:55 - 12:15
12:00				
	3D reconstruction of low-energy electron recoils in gas Time Projection Chambers with MPGD charge readouts	*Majd Ghrear*		

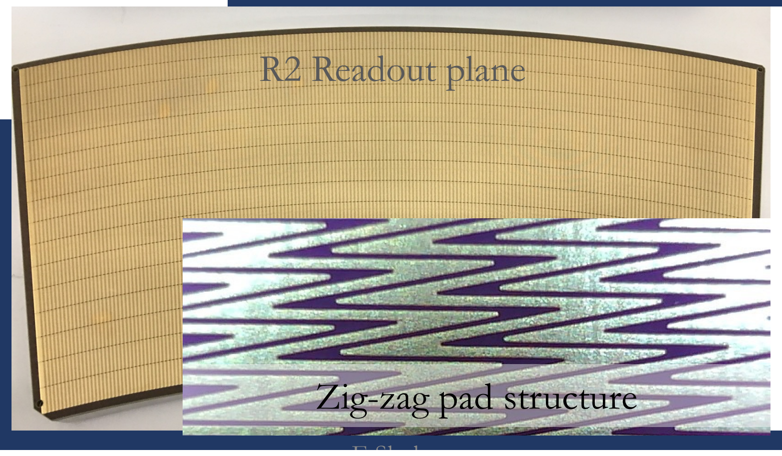
Online and in-person participation was almost equal

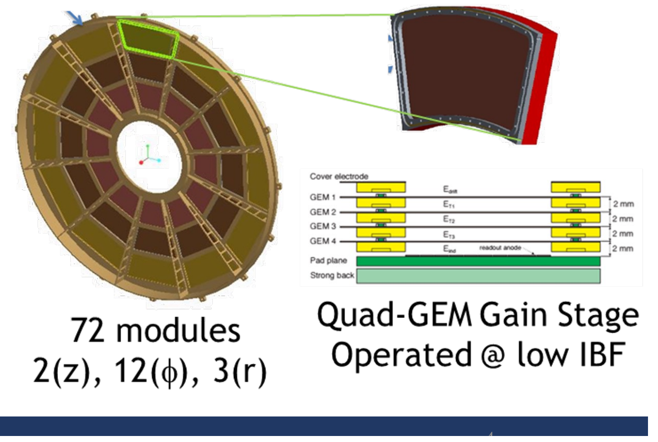
Evgeny Shulga, Stony Brook University

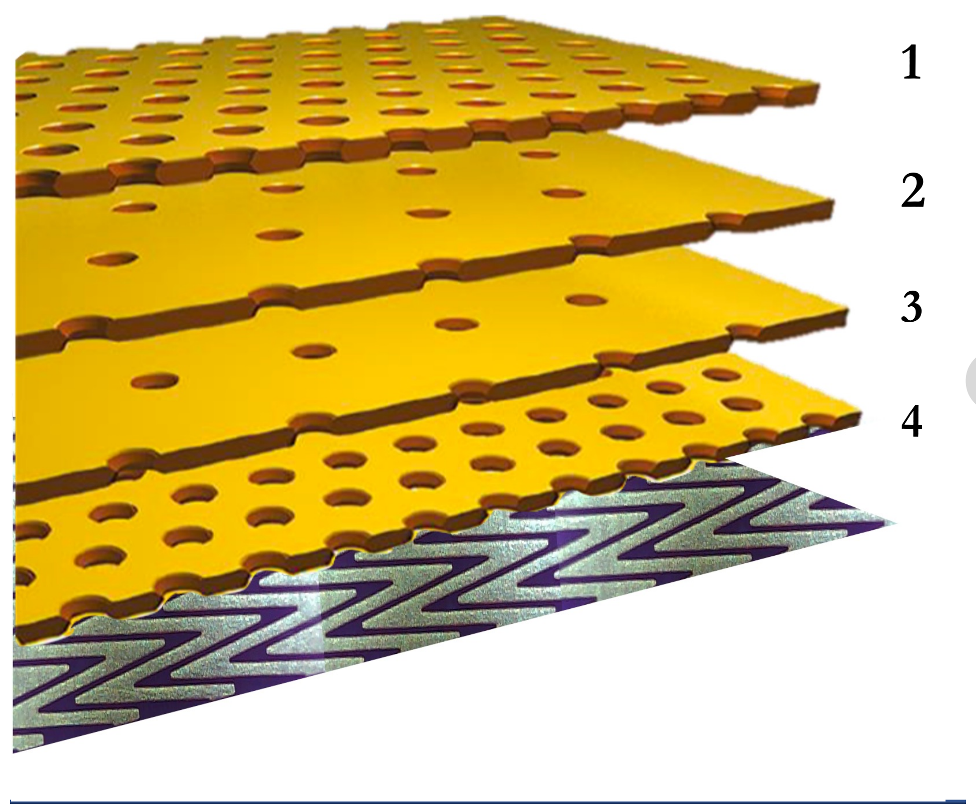
sPHENIX TPC



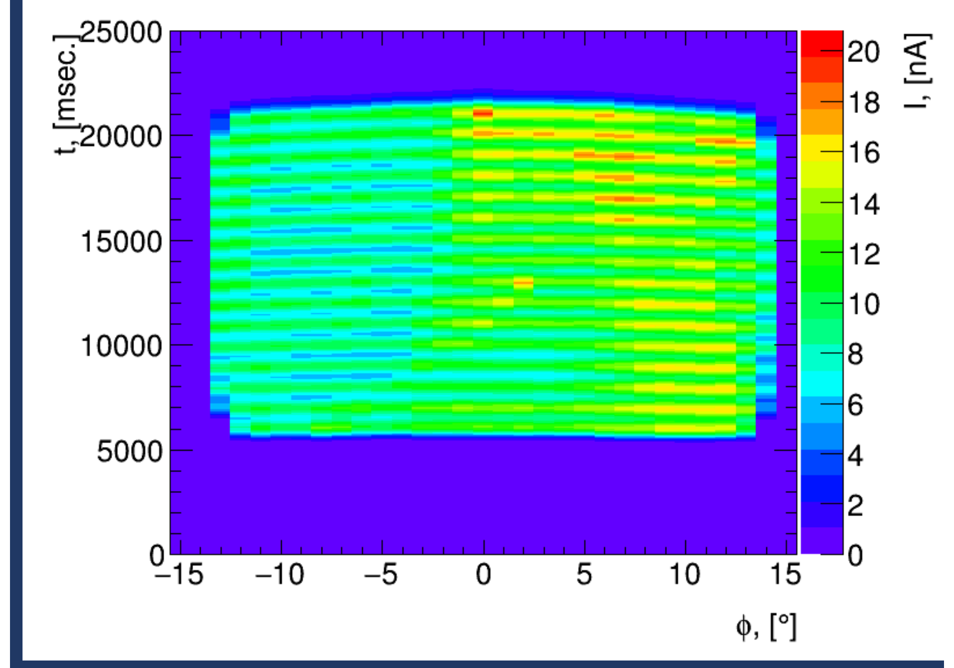
- Time Projection Chamber (TPC)
- Compact: 20 < r [cm] < 78 (active (>30cm)
- Gas: ~~Ne/CF$_4$~~ ⟹ Ar/CF$_4$
- Nominal drift field E = 400 V/cm and magnetic field B = 1.4 T along z
- Required spatial resolution: < 150 μm
- Charge collection via GEMs → ALICE SAMPA
- Gateless and continuous readout (GEMs for IBF suppression)

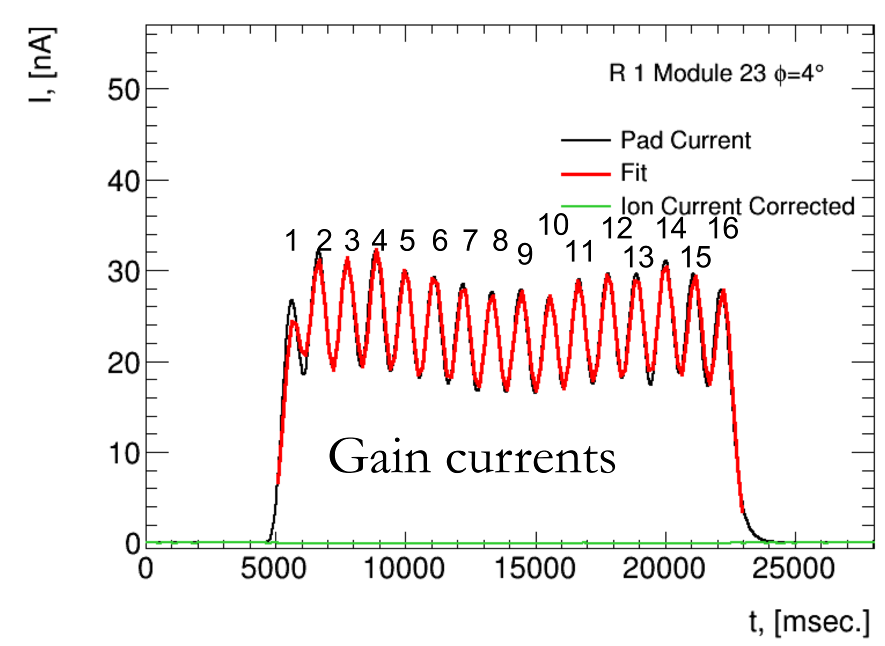




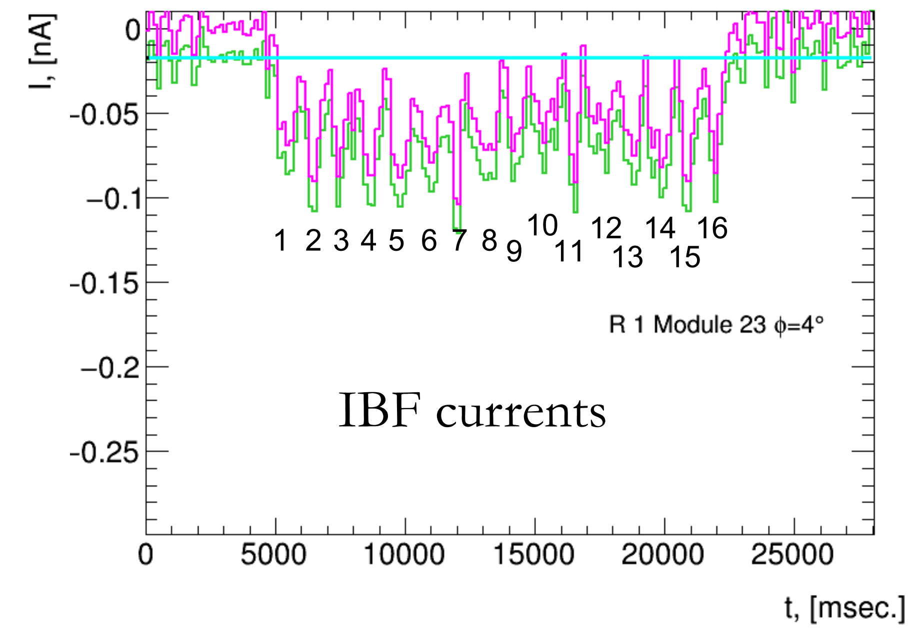


Gain & IBF measurements

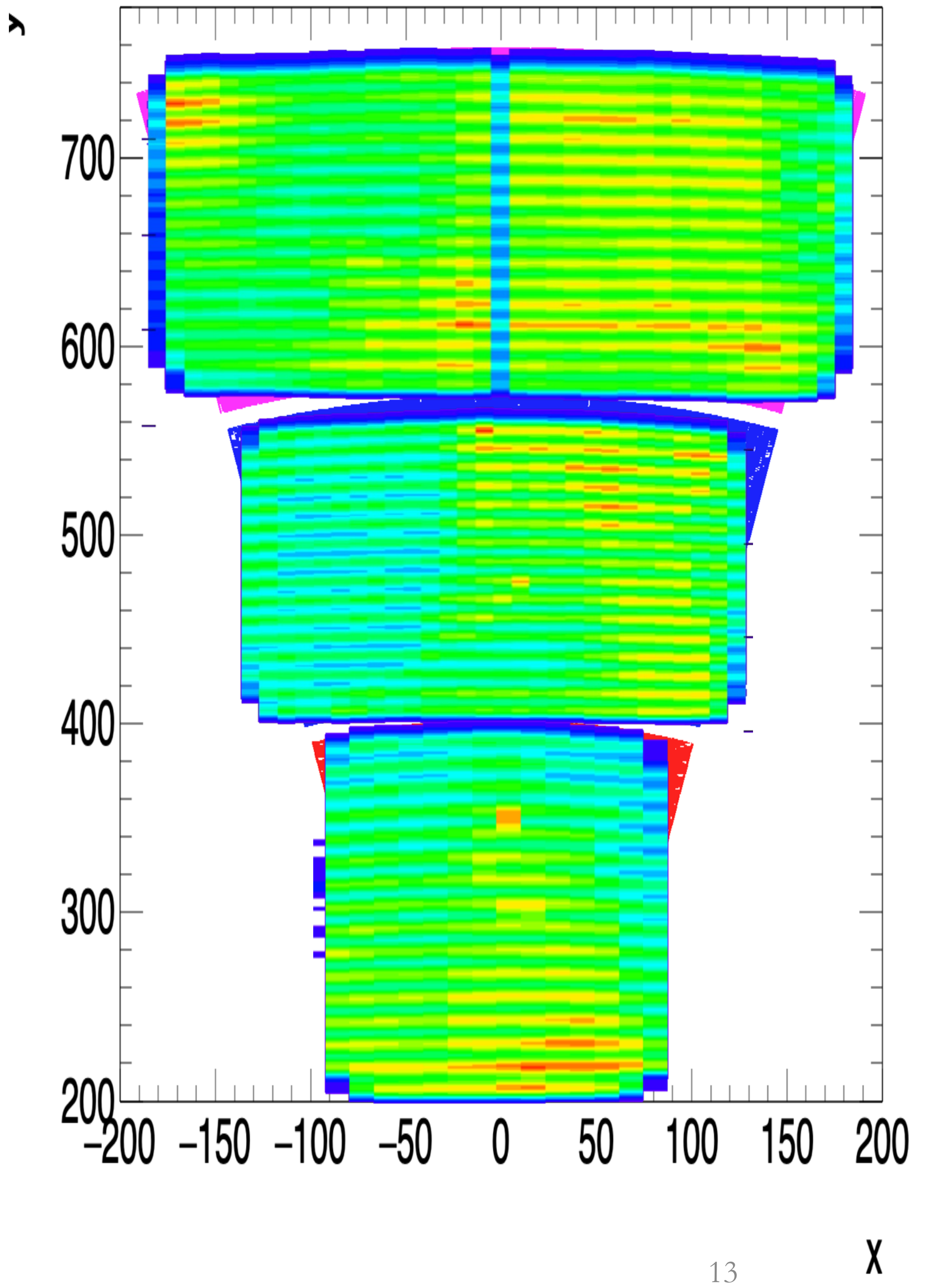




- All modules are scanned for Gain & IBF characterization
- IBF is correlated with gain
- Gain is uniform
- 0.3 % IBF is measured for all modules
- The scans are used for IBF values estimation for the digital currents



E Shulga

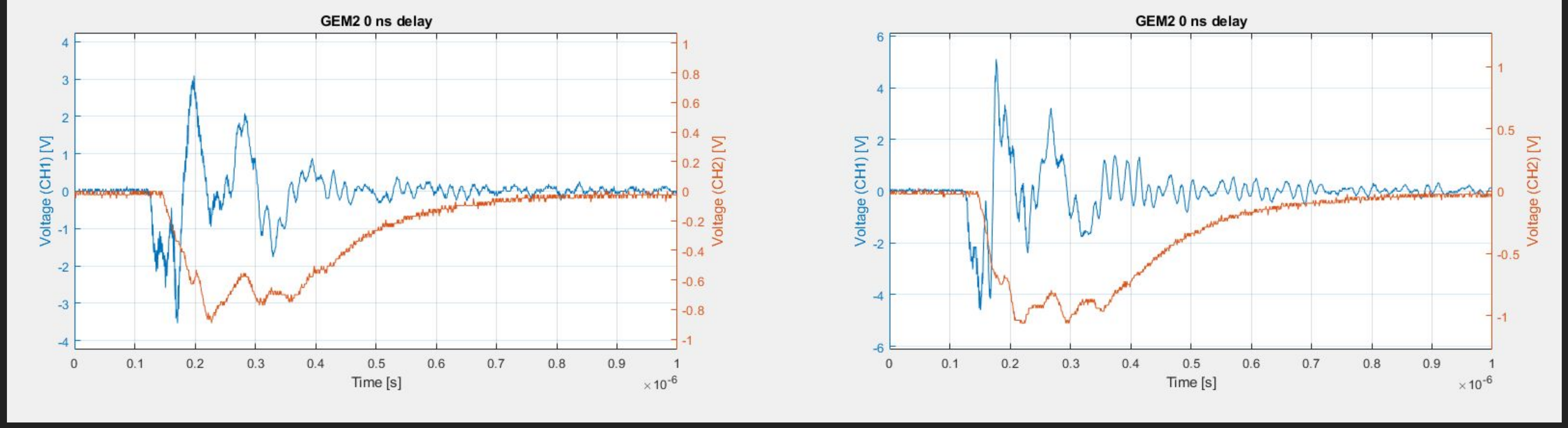


13

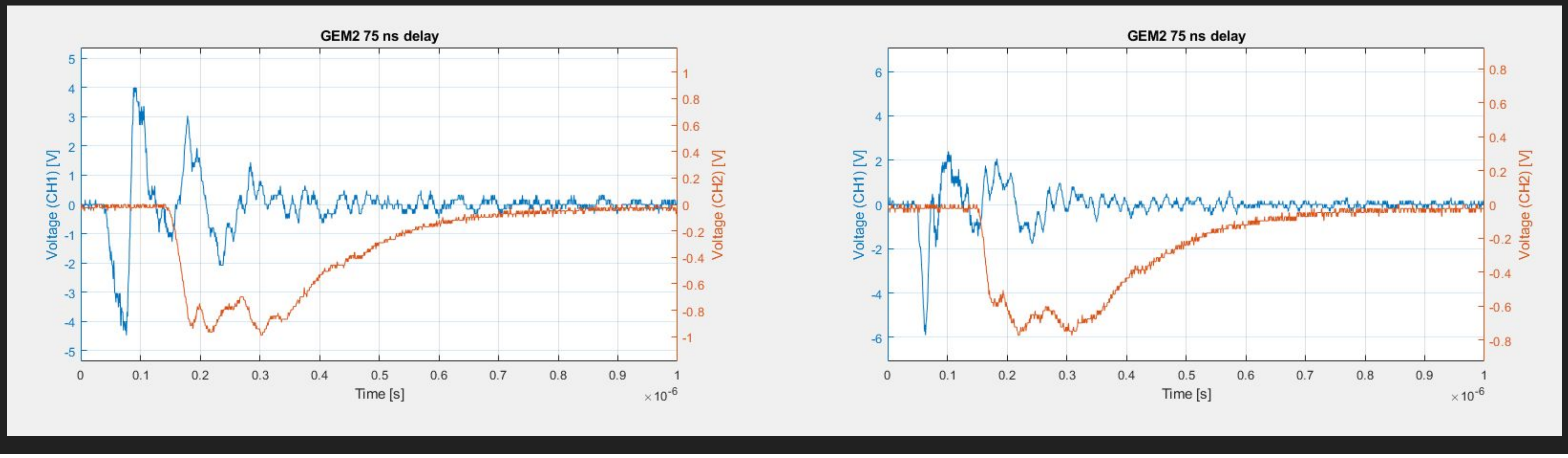
sPHENIX TPC is instrumented and awaiting its turn to be installed @ BNL

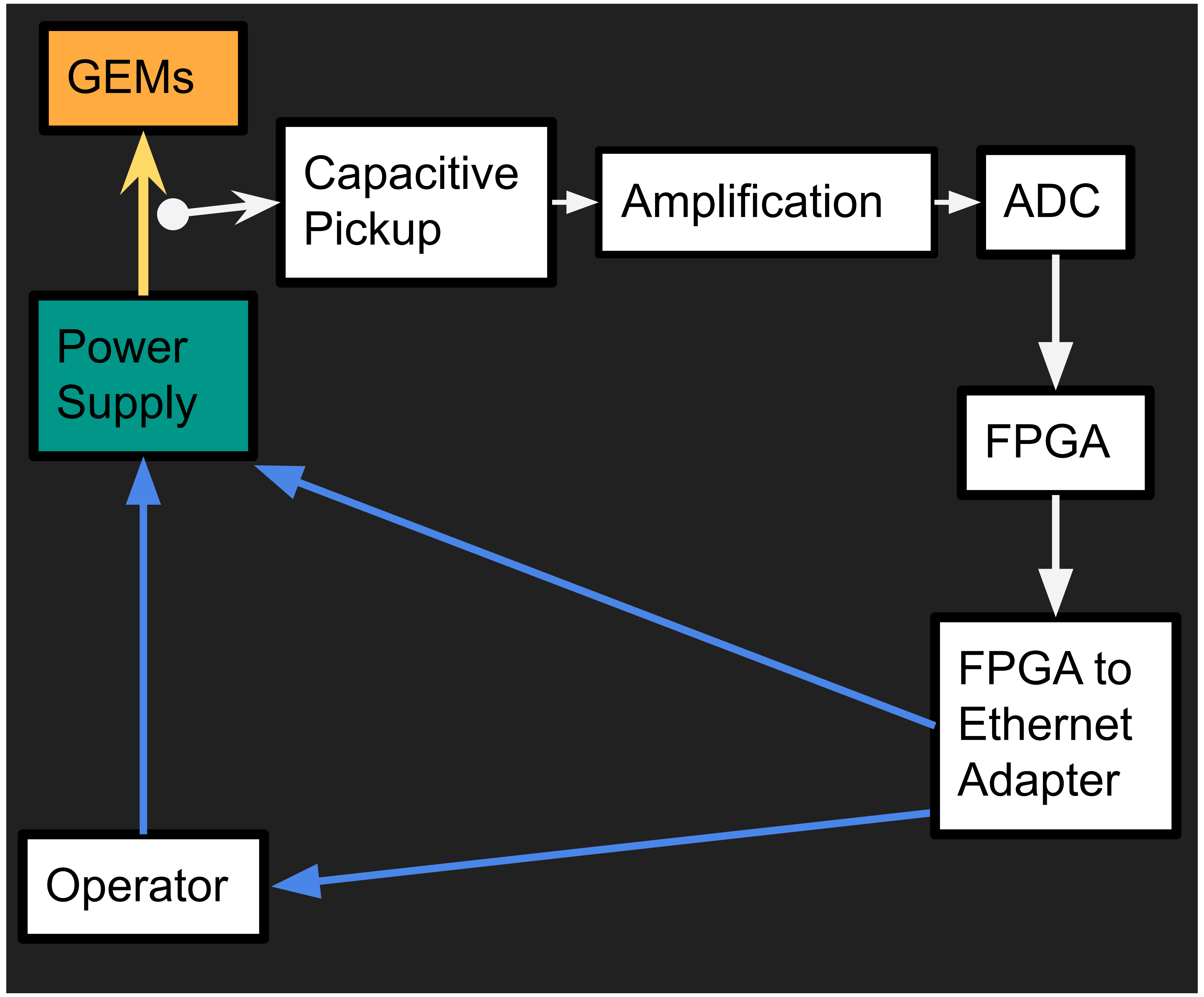
Julian Driebeek, Stony Brook University

Successful Performance of Integrated Absolute Value



After Delay Line





Sparks were larger and faster than expected, but a pre-amp sufficient for digitizing signals at 10 MHz has been demonstrated

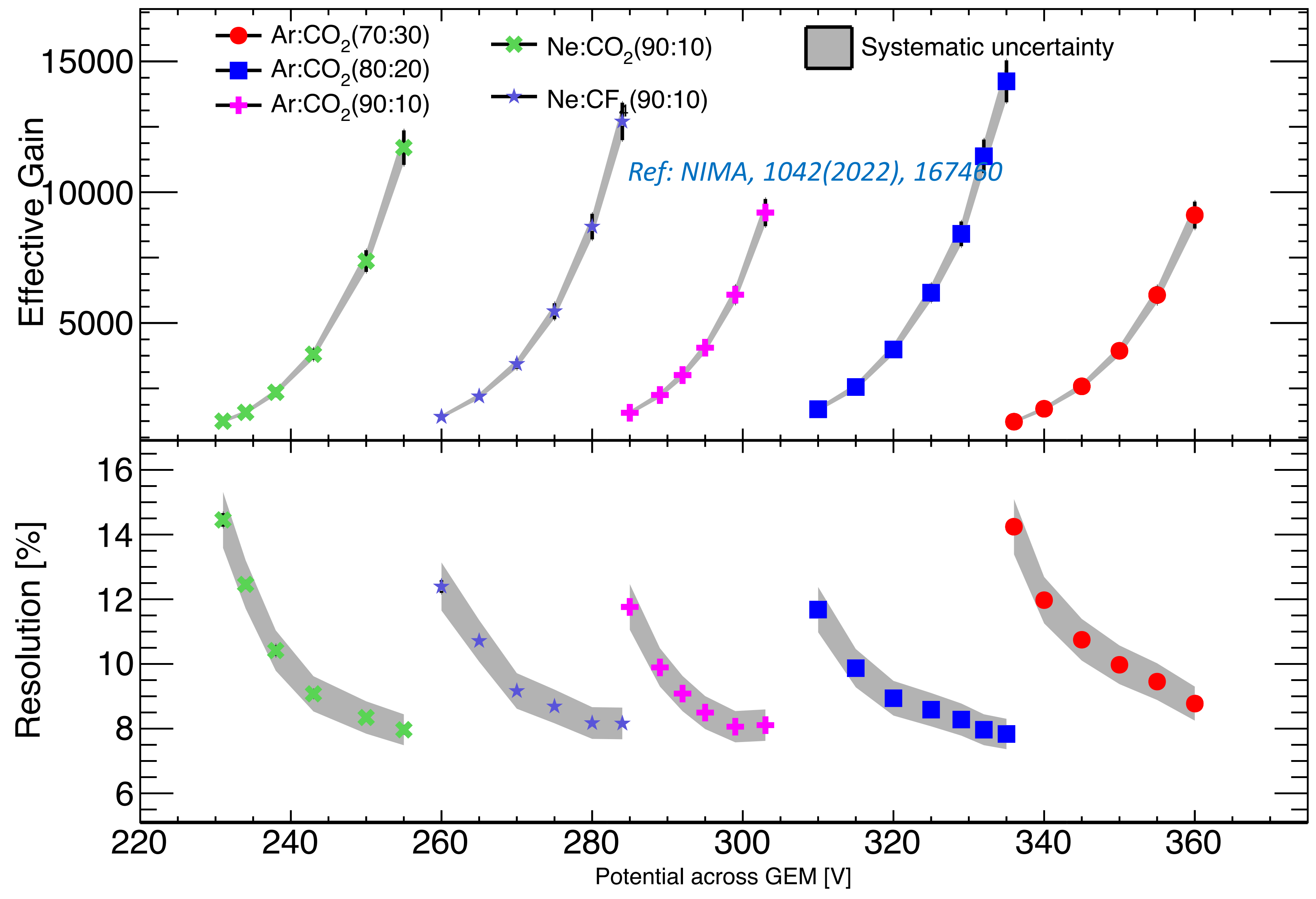
Sourav Tarafdar, Vanderbilt University

Ion Back Flow and Energy Resolution

- Ion Back Flow (IBF) $\frac{\text{Ions arriving at the cathode}}{\text{Electrons arriving at the anode}}$

In the presentation IBF $= \frac{I_{drift}}{I_{anode}}$

- Contributes to space charge density in drift volume.
- Lower IBF desirable for low space charge density for better tracking.



Ref: NIMA, 1042(2022), 167460

- Energy resolution $\frac{sigma\ of\ gaussian\ fit\ to\ energy\ spectra\ from\ monochromatic\ source}{Mean\ of\ gaussian\ fit}$

Good energy resolution for better Particle Identification

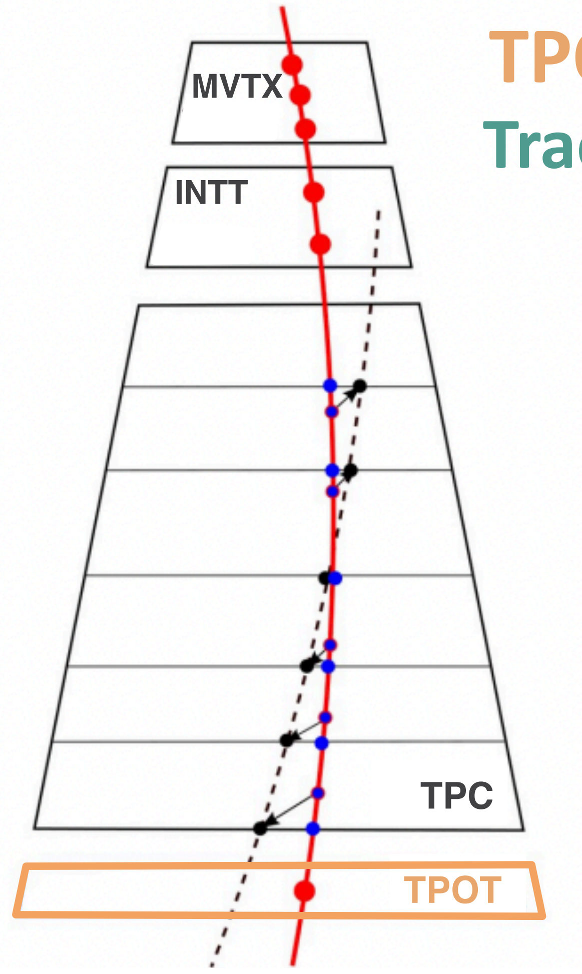
Ion Back Flow Suppression and energy resolution dependence on Transfer Gap, Drift Field and GEM voltages were also discussed.

Audrey Francisco, Saclay

OUTER TRACKER FOR THE TPC

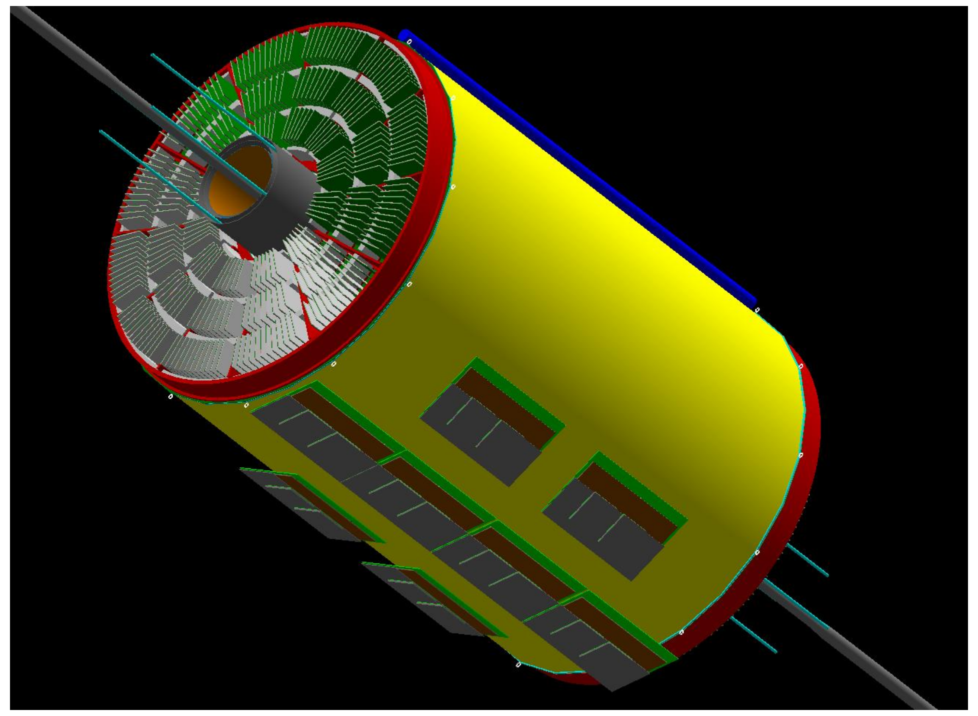
TPOT = TPc Outer Tracker

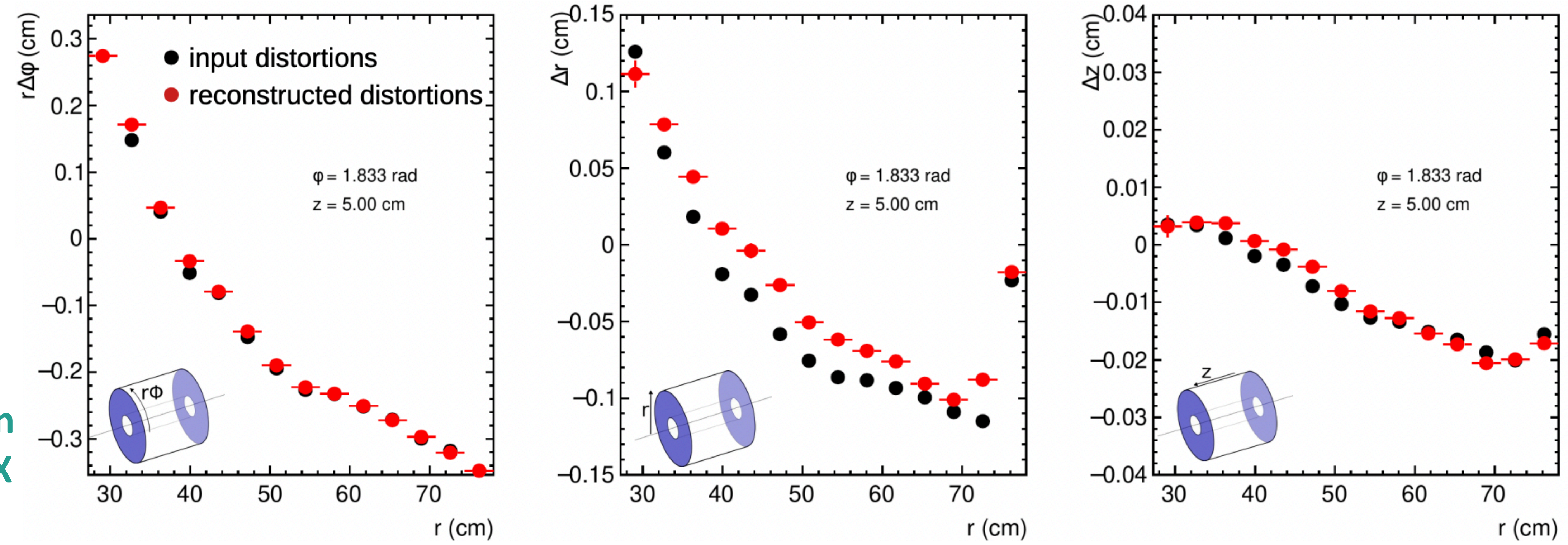
Track extrapolation with an additional space point outside the TPC

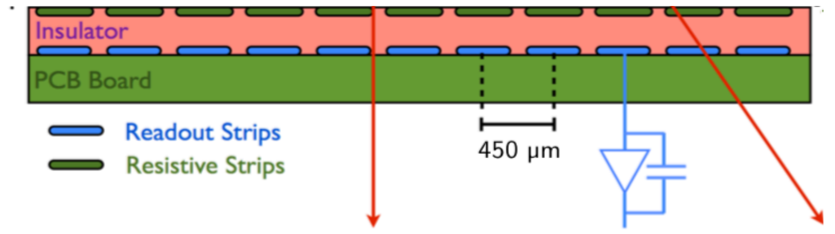


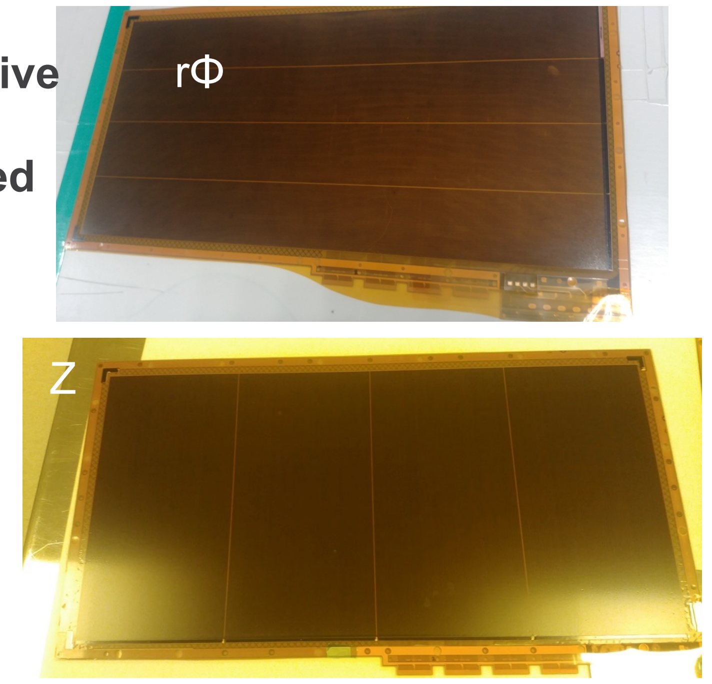
Partial TPC coverage

- Full z dependance
- ϕ dependance









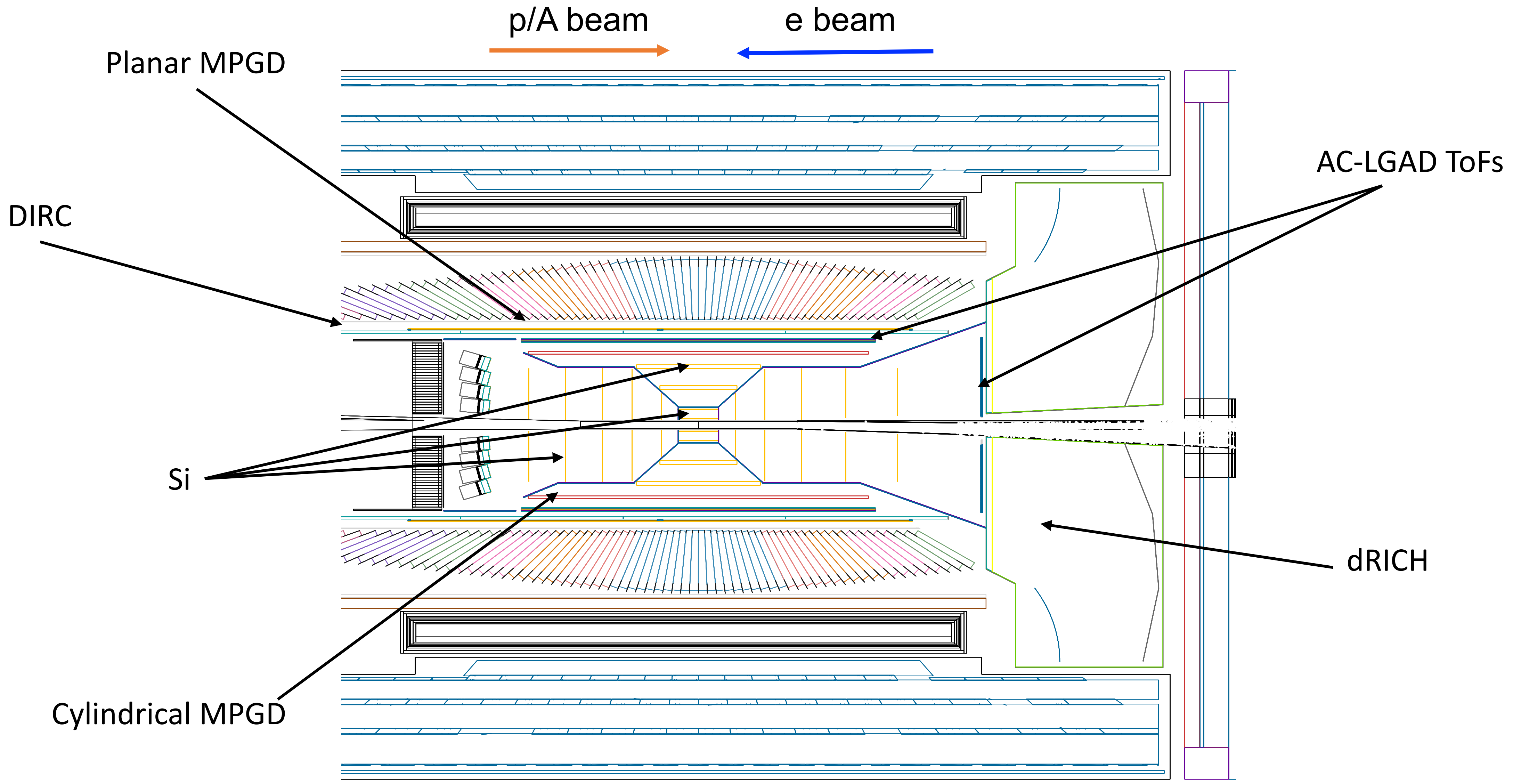
Serigraphy process

Collaboration with CERN for pressing the kapton layer on the PCB

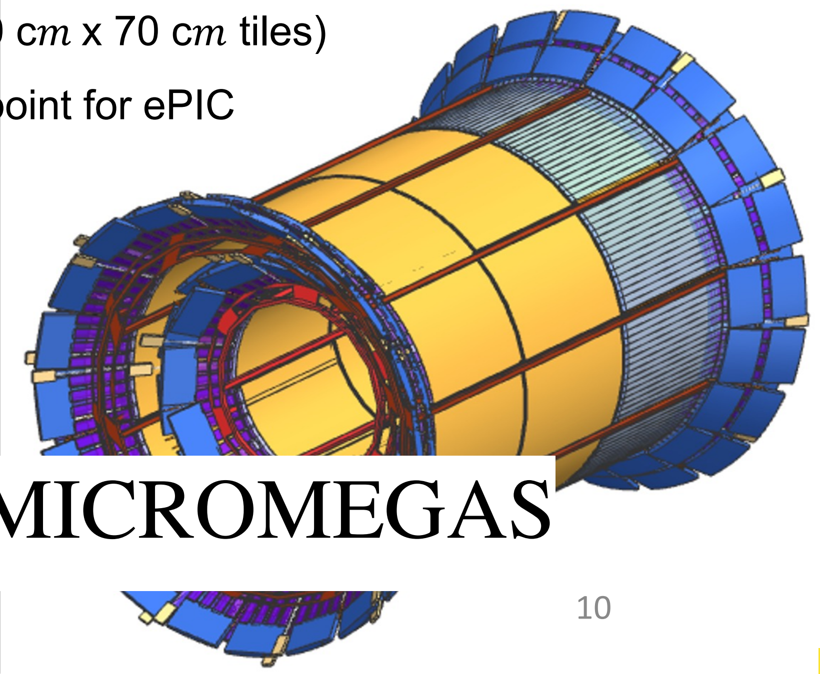
- 2021 — **Detector design**
- Nov 21 — **Green light from DOE**
- March 22 — **Prototypes validation**
- Spring 22 —
  - **Production** (serigraphy, bulk, assembly, metrology, validation) @ Saclay
  - **Mechanics for support structure** @ LANL
  - **Transportation and lifting** @ MIT/Bates
  - **Services** (Cooling, Gas systems, slow controls) @ BNL
- Aug 22 — **All detectors @ BNL**
- Fall 22 — **Assembly into sub-system and testing**
- Dec 22 — **Integration in sPHENIX**

Matt Posik Temple University

ePIC Reference Detector

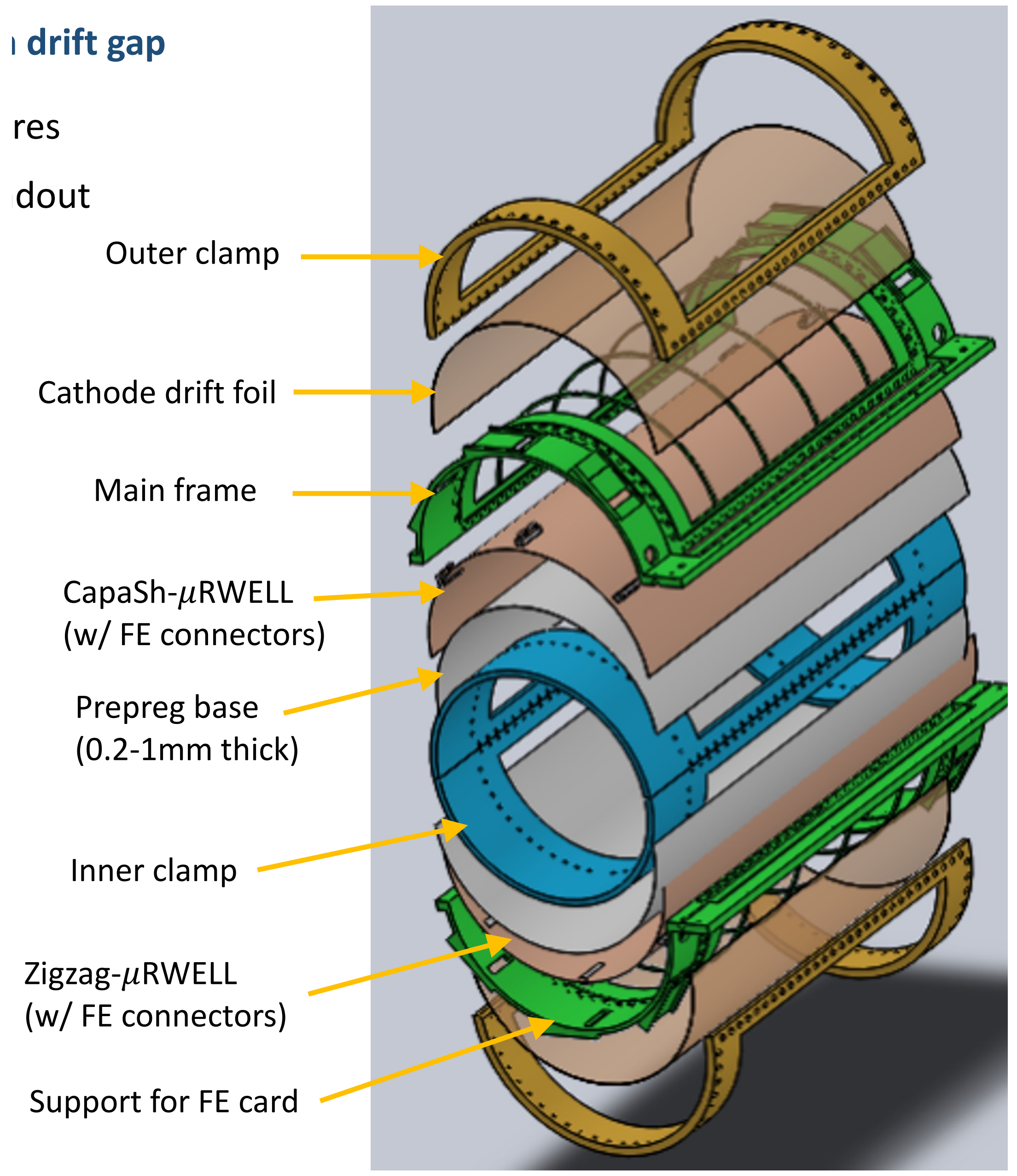


- First **CAD design** of the whole Micromegas tracker for the ATHENA proposal (50 cm x 70 cm tiles)
- Being used also as starting point for ePIC

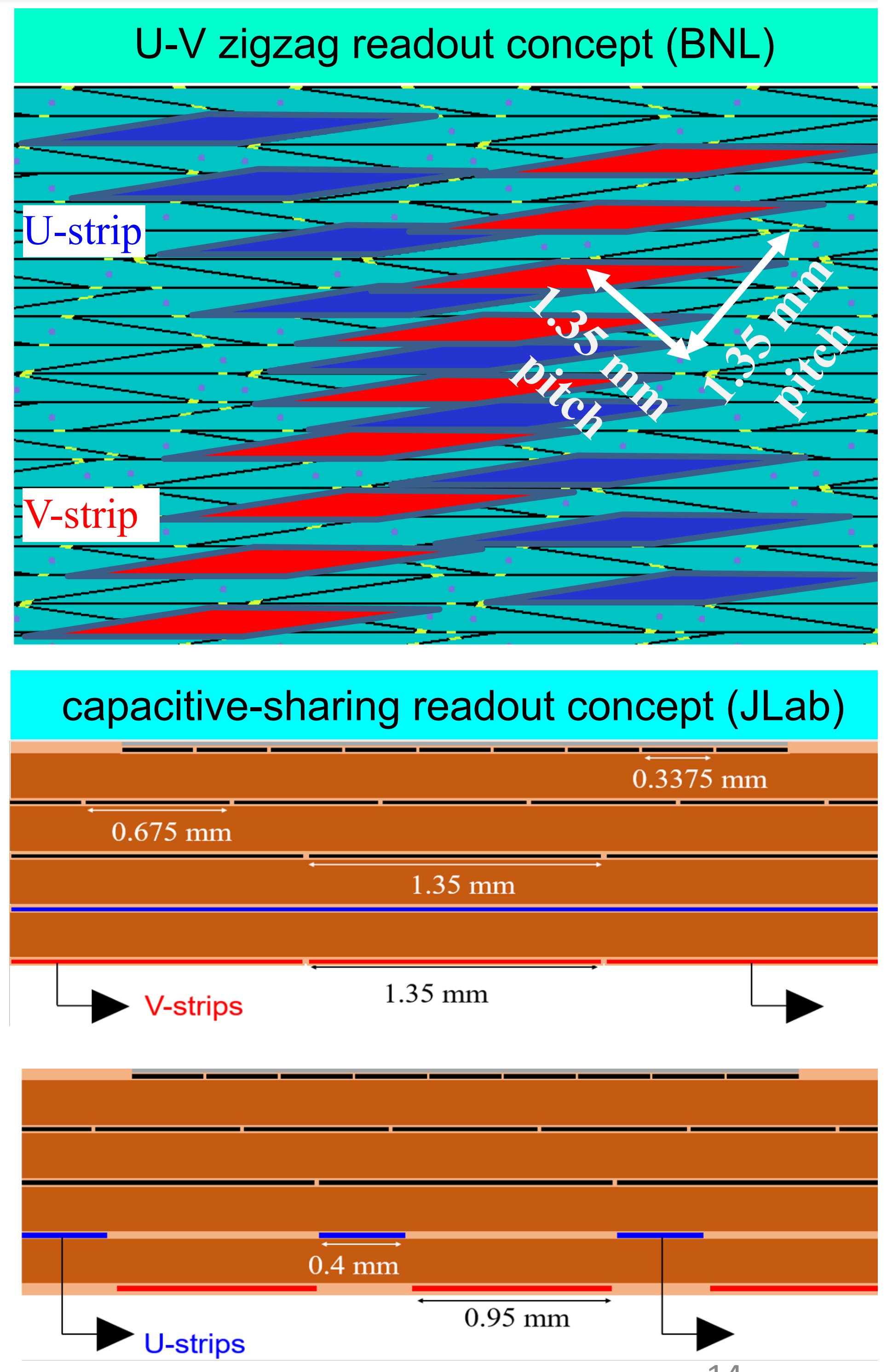


Cylindrical MPGDs: MICROMEGAS

10

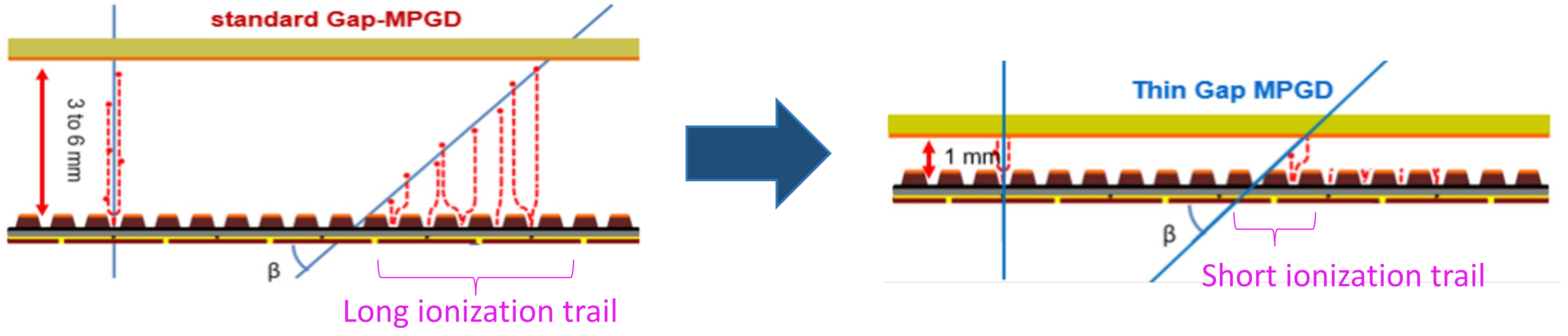


Cylindrical MPGDs: μRWELL



https://doi.org/10.1016/j.nima.2022.167782

14



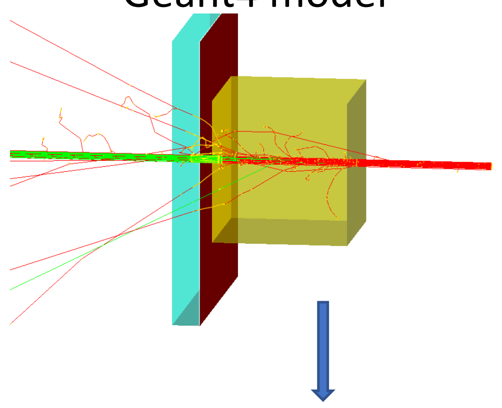
Sourav Tarafdar, Vanderbilt University

GEMs & GEM + MicroMegas Based TRD

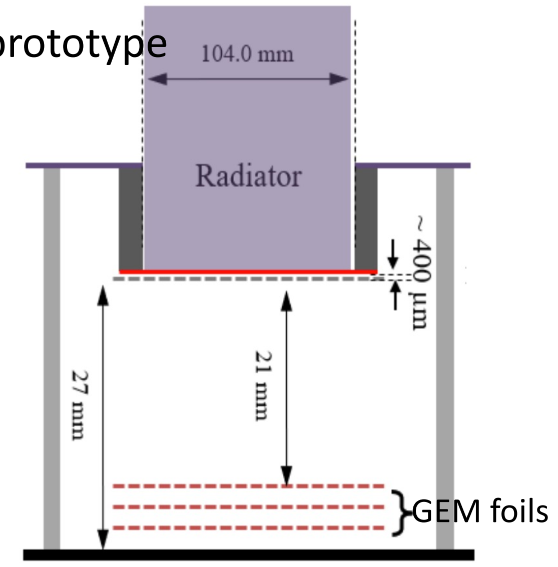
GEM based Transition Radiation Detector/Tracker

- First prototype based on triple GEM assembled at UVA.
- Drift gap was chosen as ~ 2.0 cm based on standalone Geant4 simulation.
  - ✓ Drift gap > 2 cm do not provide additional advantage in terms of TR yield
- Fleece Radiator length of 10 cm was used.
- Xenon gas was chosen.
- Two individual HVPS channels were used for biasing triple GEM via voltage divider and for independent biasing of drift cathode

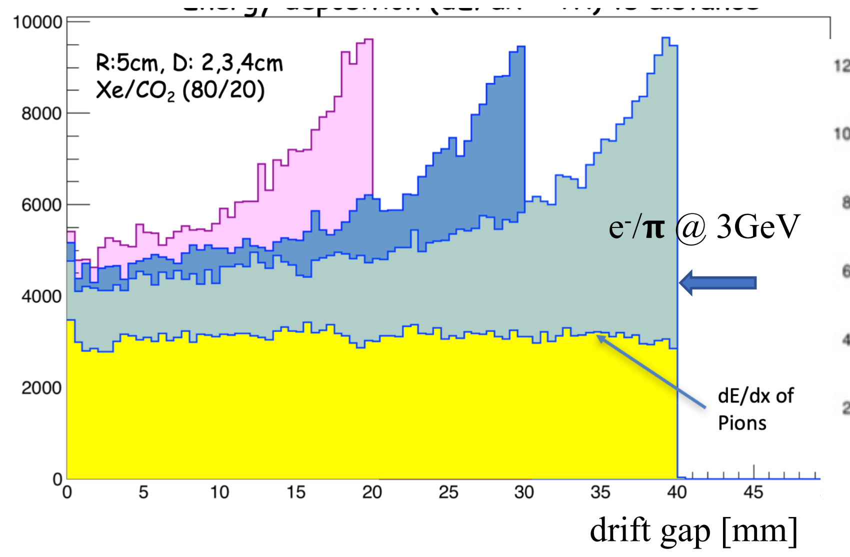
Geant4 model

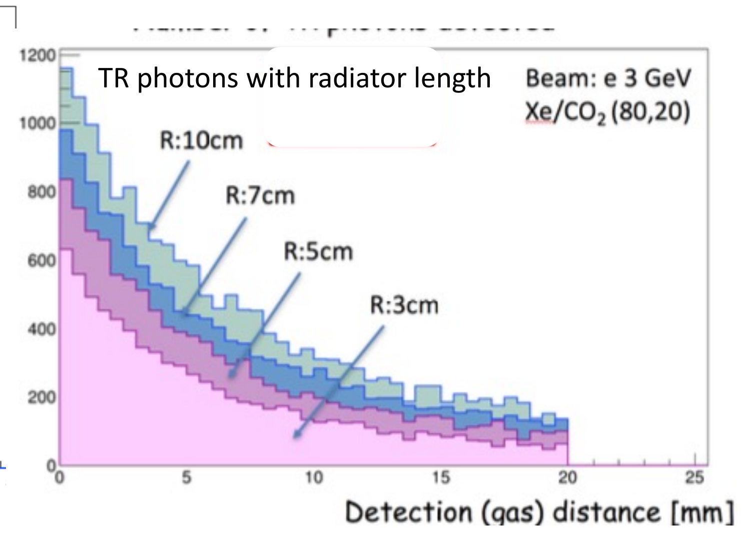


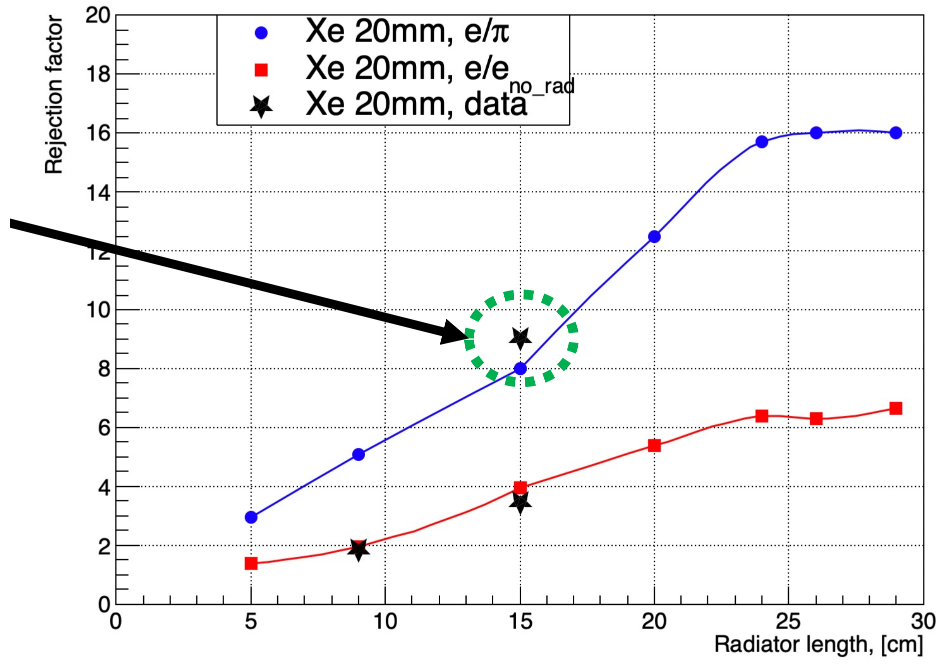
GEM-TRD prototype

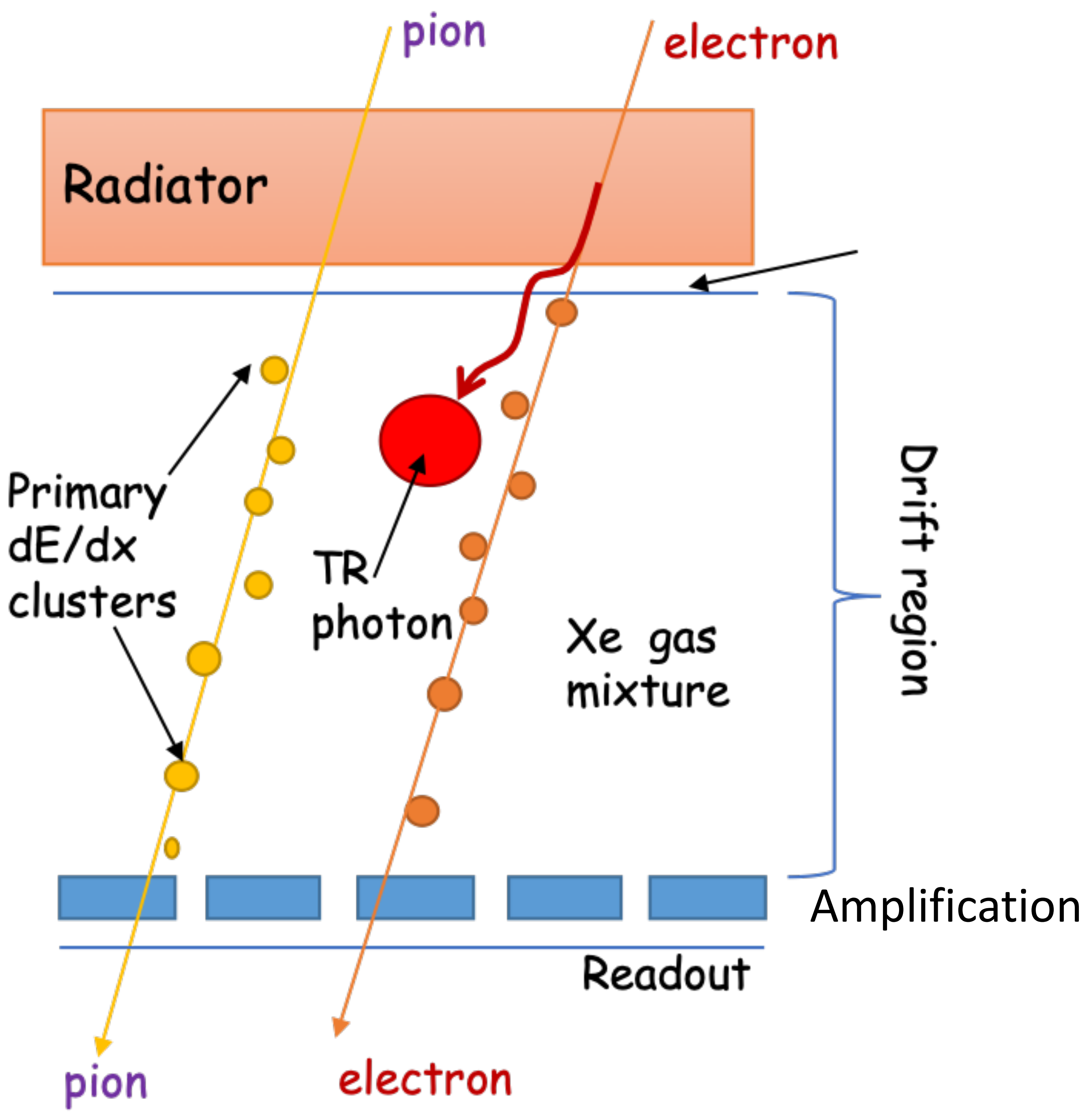


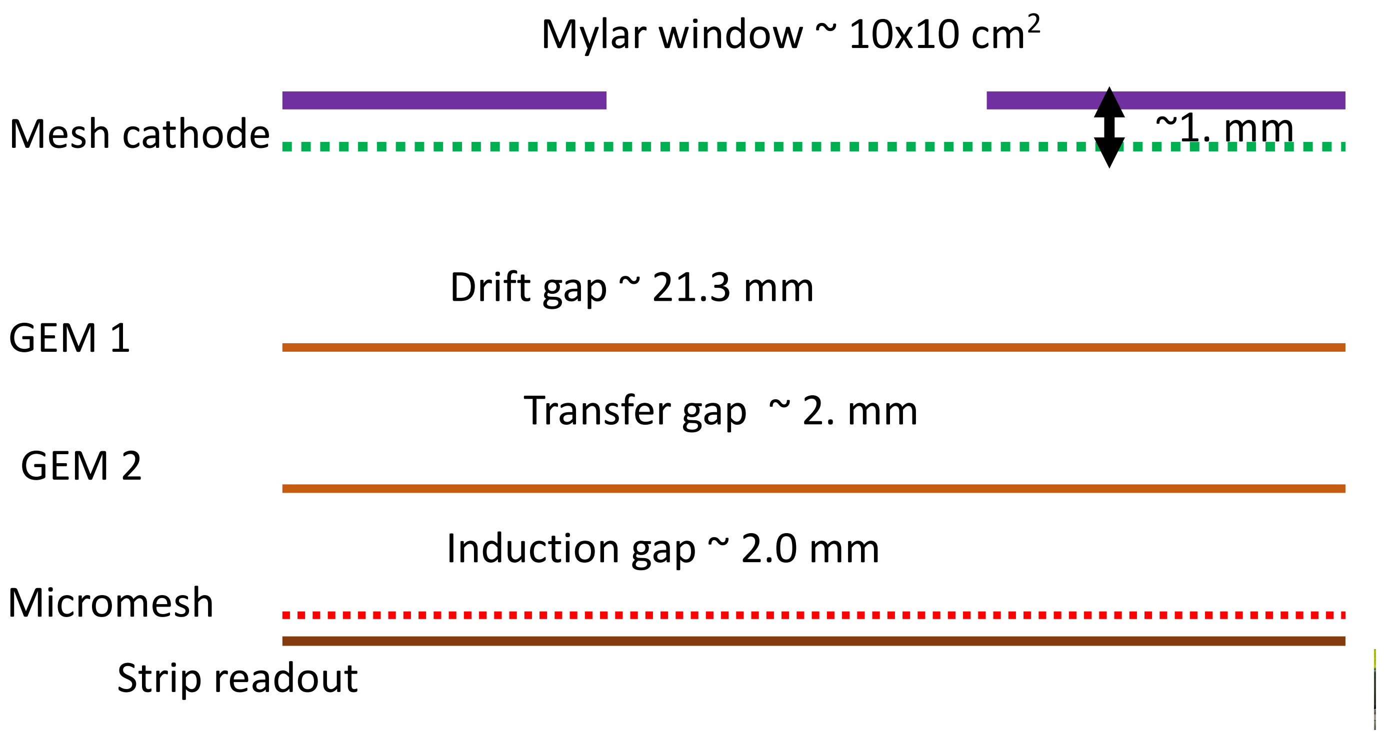
Energy deposition (dE/dx+TR) vs drift gap





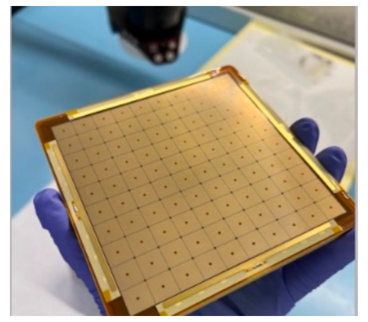


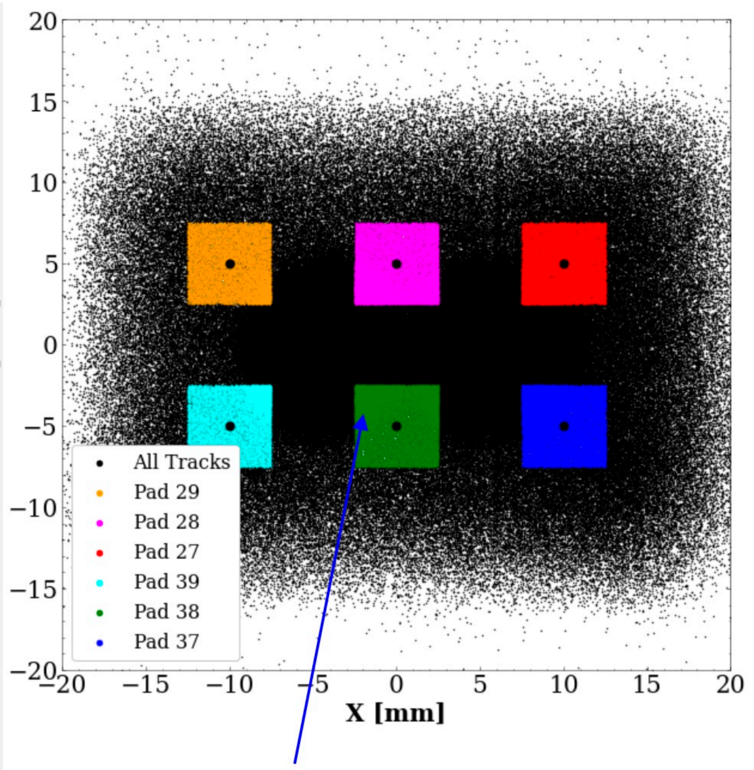




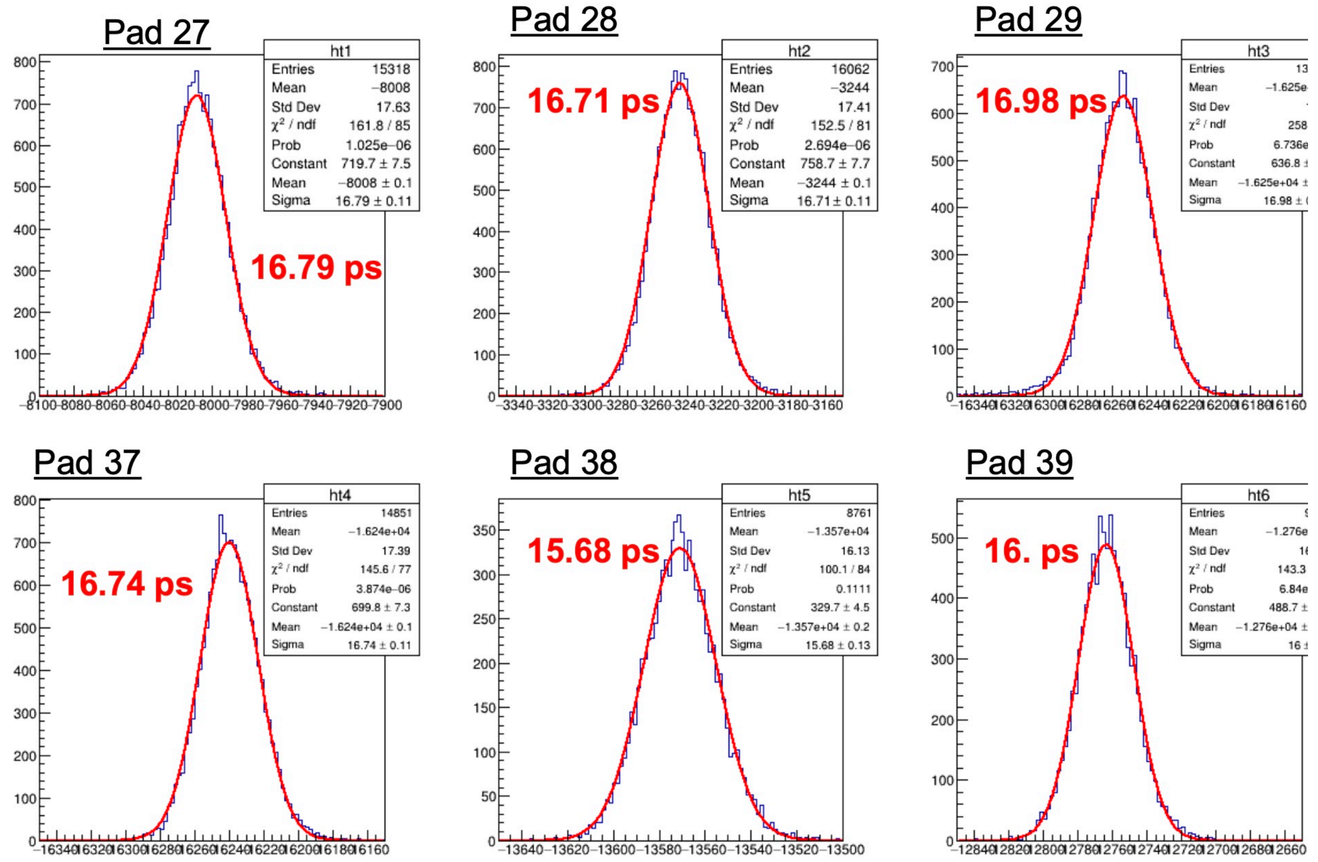
Sebastian White

Below: from recent AUTH analysis. Early results with SAMPIC (~6.4GSa/s) or charge sharing ~ 20 picosecond resolution.





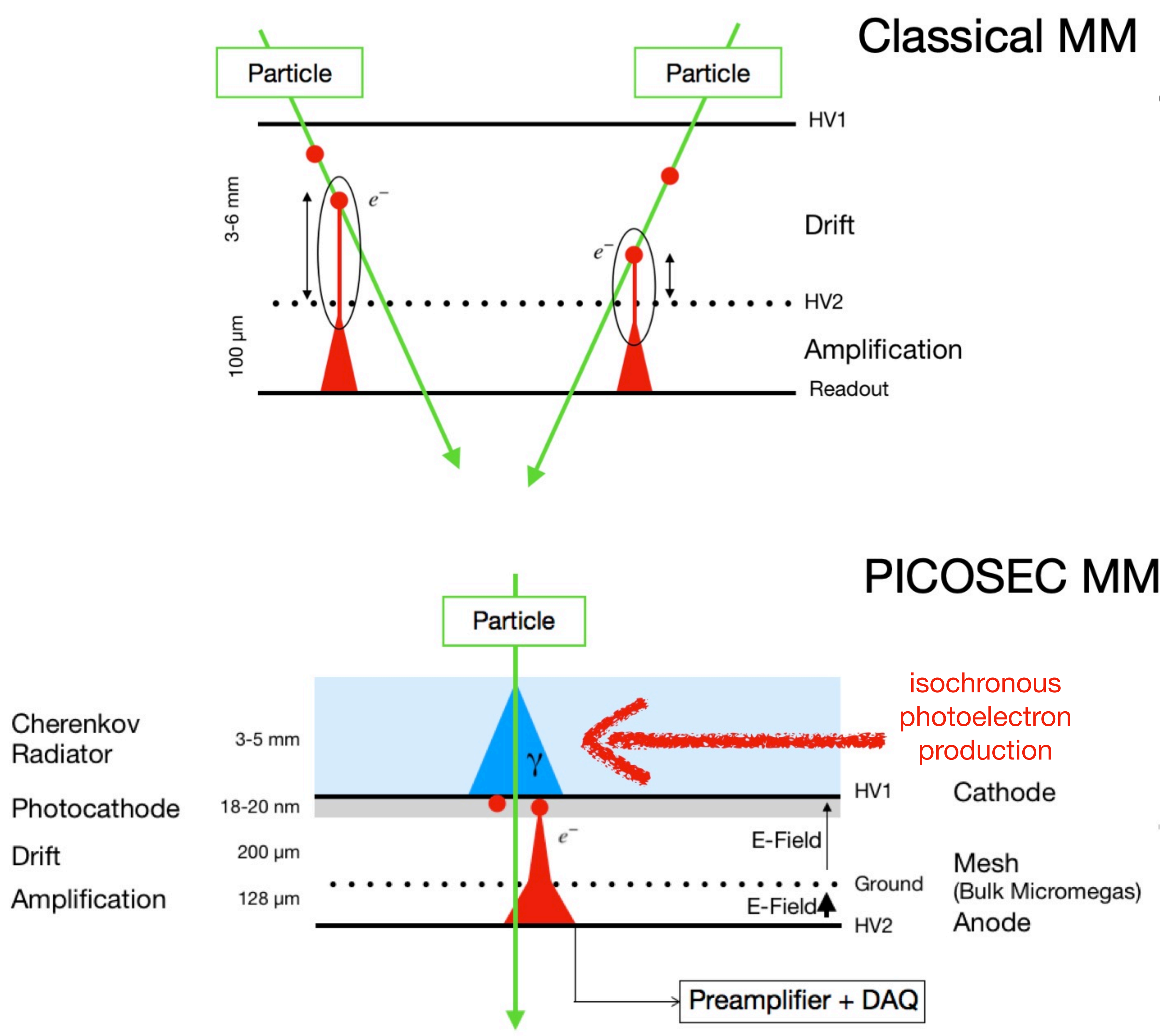
±2mm from each pad center

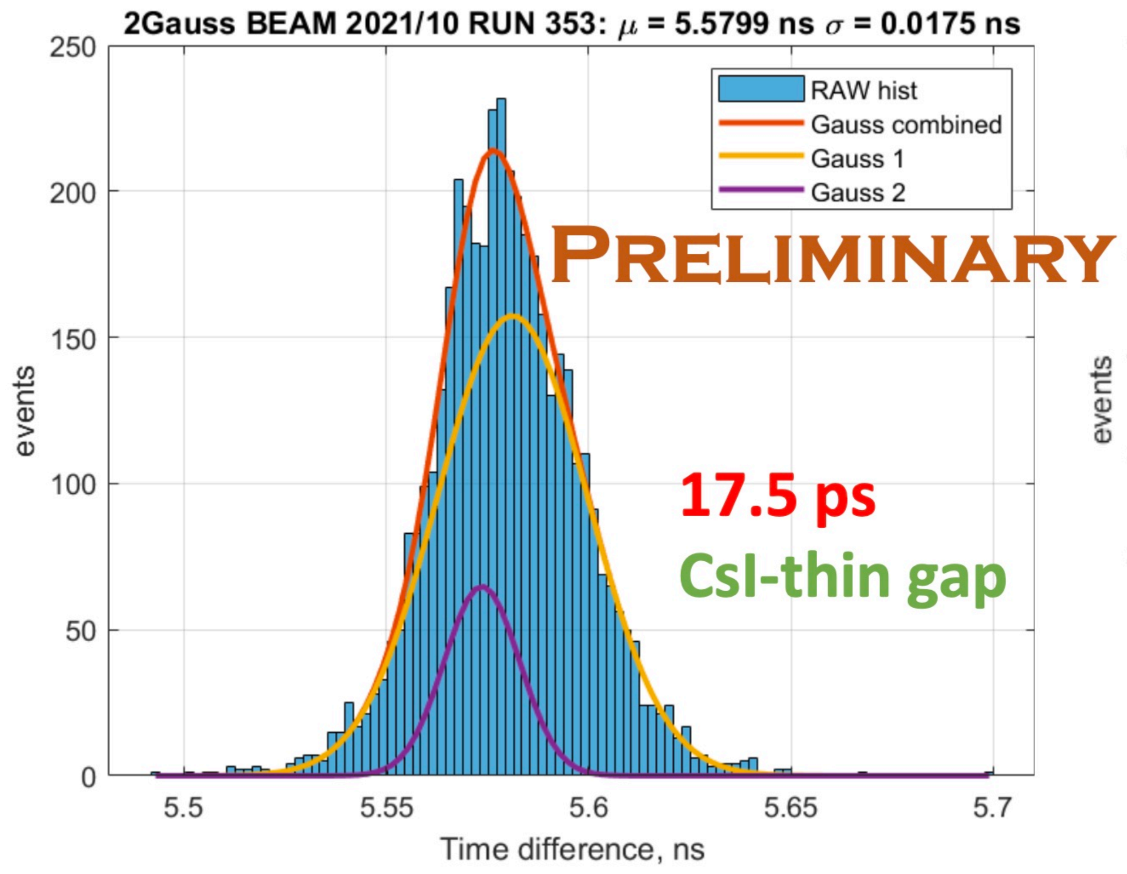


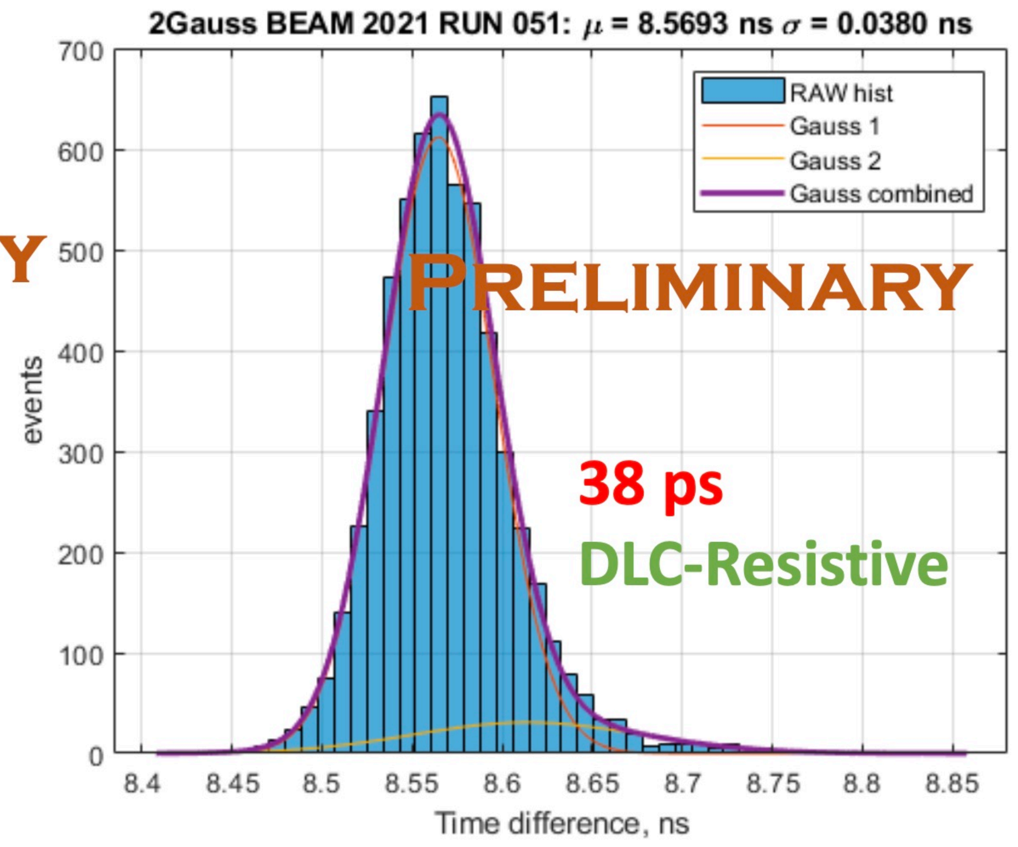
So far.. resistive multipad-> ~ 25 picosec

16

Observe **20.2 —>17 picosecond rms resolution** with preamp gap reduction (220->180 micron)
In the multipad PICOSEC, also encouraging results w DLC and resistive MM



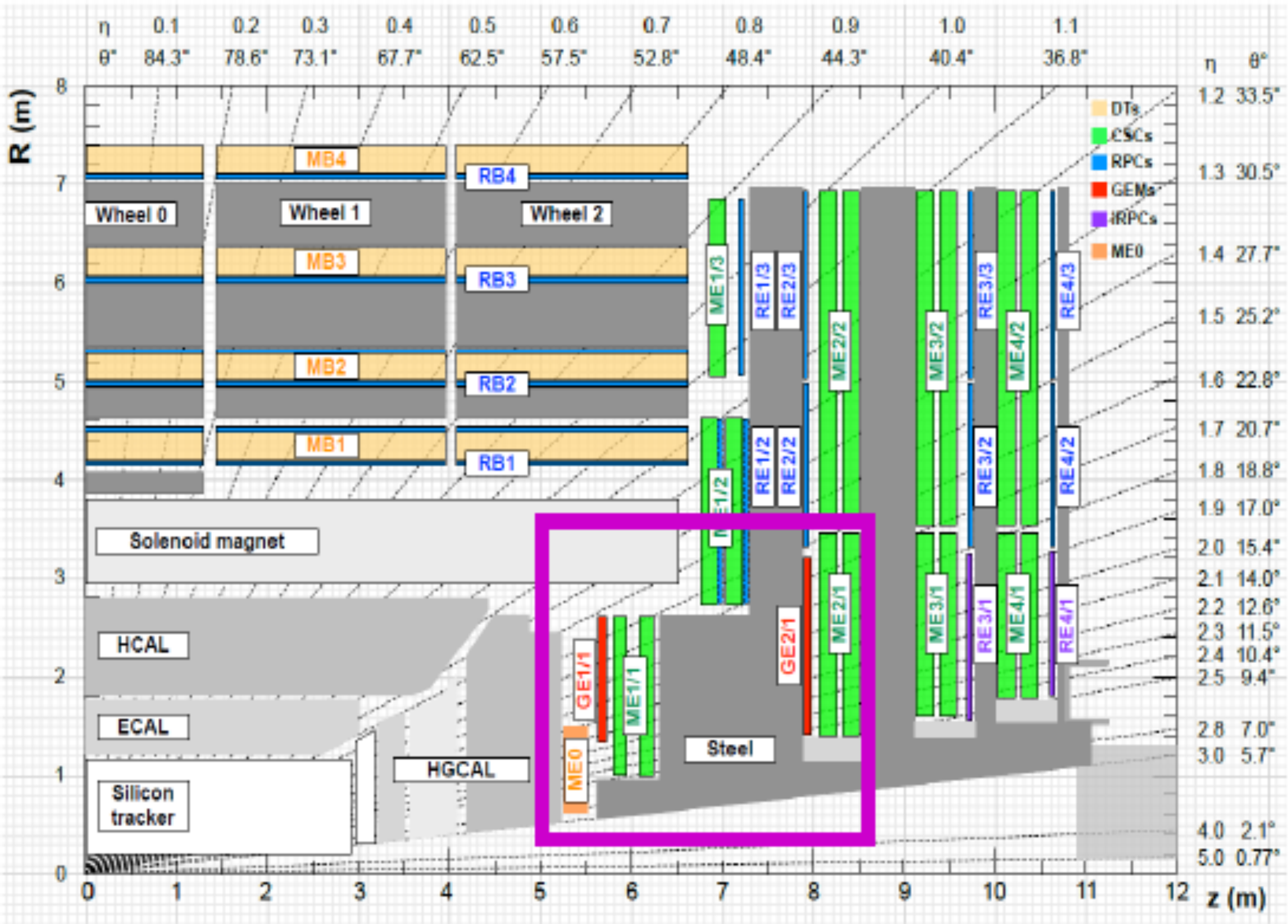




Scope for more digitizing schemes to sharpen the performance

Ilaria Vai on behalf of the CMS Muon Group

CMS Muon System Ugrade



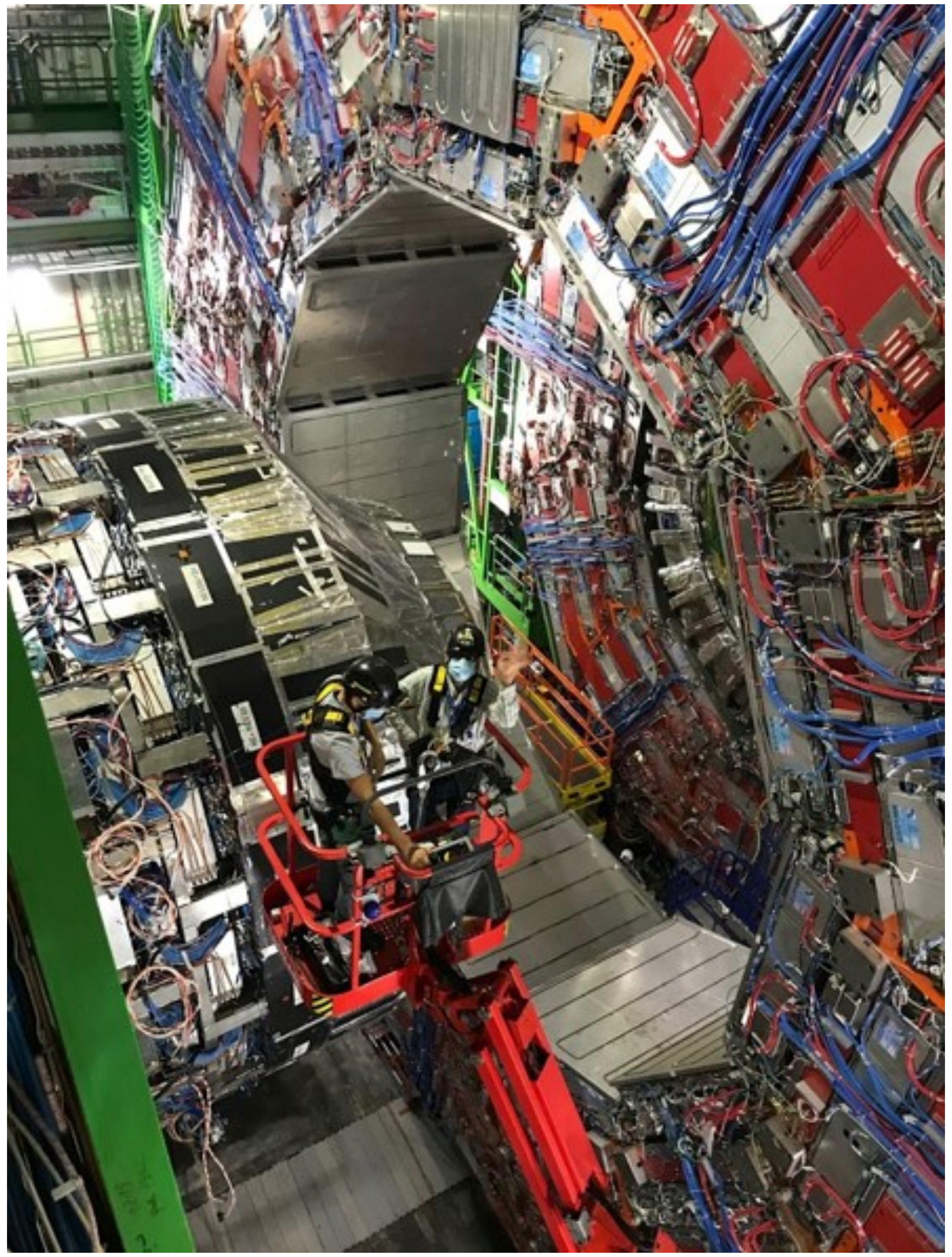
HL-LHC → New muon stations to:

- Improve the redundancy in the high η region
- Handle a rate of 10's of kHz/cm^2
- Survive to an intense background rate

Gaseous detectors technologies

- Drift Tubes (DT)
- Cathode Strip Chambers (CSC)
- Resistive Plate Chambers (RPC)
- Triple-Gas Electron Multiplier (GEM)

UNIVERSITÀ DI PAVIA INFN PAVIA Istituto Nazionale di Fisica Nucleare Sezione di Pavia CMS



- Triple-GEM is the new detection technology adopted for the CMS muon stations GE1/1, GE2/1 and ME0.
- GE1/1 station was installed in during the Long Shutdown 2.
- Currently under commissioning:
  - Operational experience of large size Triple-GEM detectors in magnetic field;
  - High granularity efficiency measured, fine tuning of the working point ongoing;
  - Track-based alignment ongoing, mandatory for triggering on muon.
- GE2/1 and ME0 stations will be installed during the Long Shutdown 3.

Installation in CMS

- Negative Endcap: completed in Oct. 2019
- Positive Endcap: completed in Sept. 2020

Ilaria BALOSSINO, INFN-IHEP Fellow

3

MDC 0.5% at 1 GeV/c

CsI(Tl) calorimeter 2.5% @ 1 GeV

BTOF 70 ps

ETOF 60 ps

dE/dx 6% e^- from Bhabha scattering

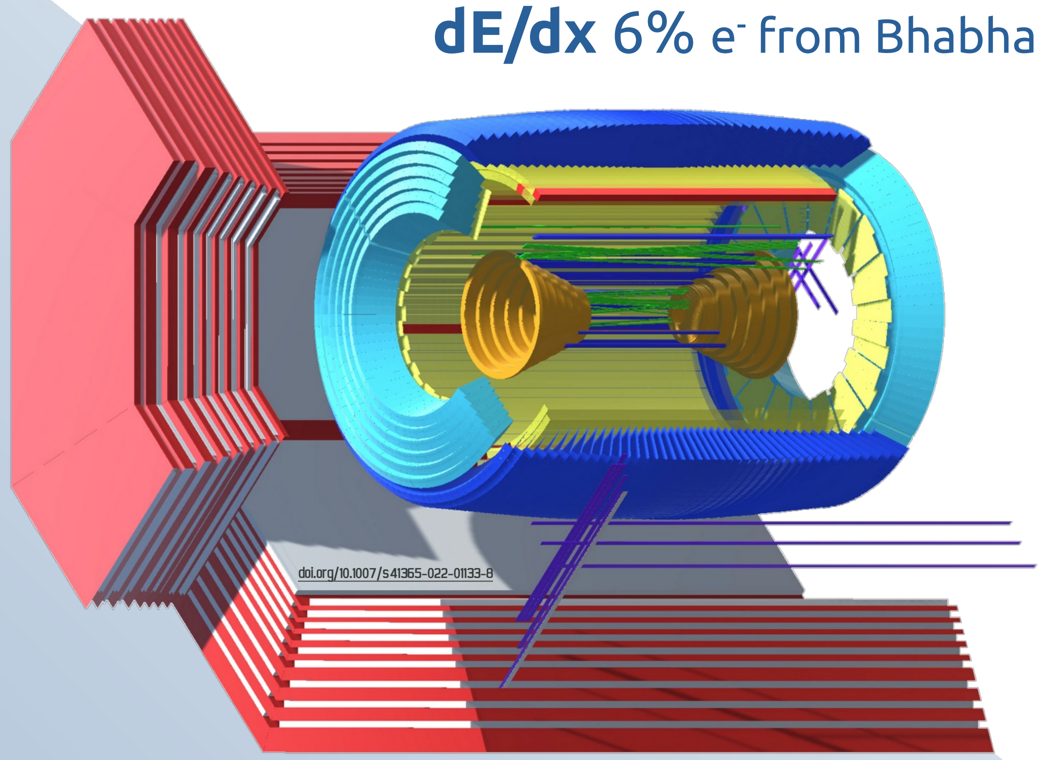
@BEPCII

e^+e^- collider

τ-charm factory

$E_{cm} = 2 - 4.95$ GeV

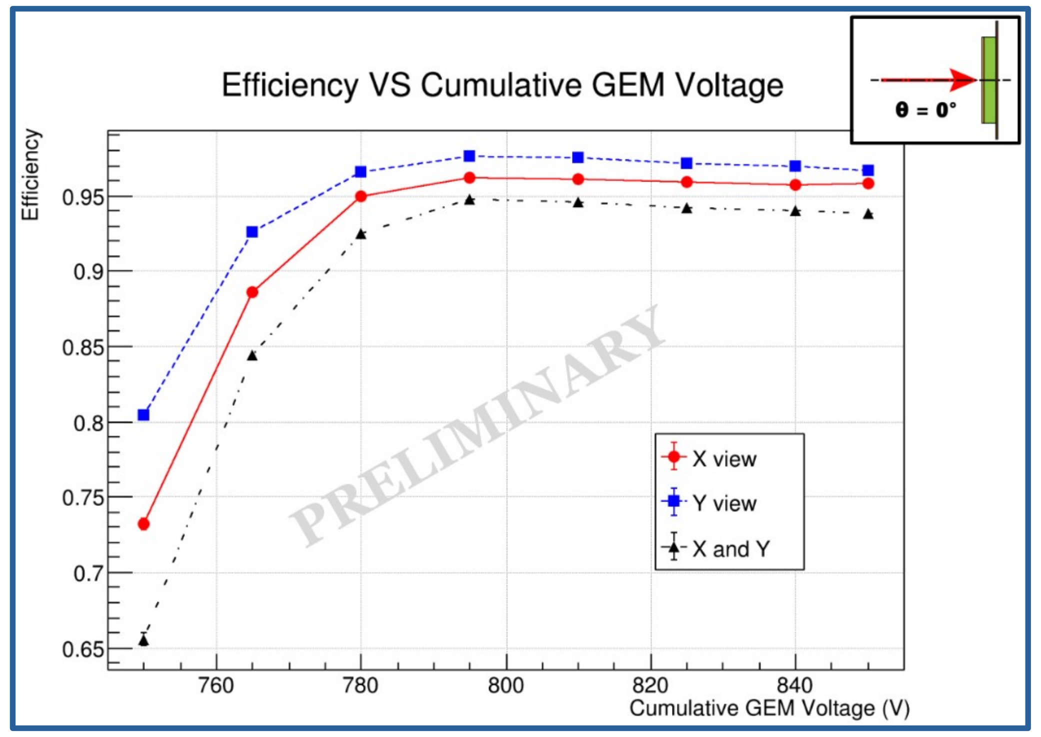
$L = 10^{33}$ /cm^{2}s



We have collected **10B of J/ψ !**

The world largest data sample

BESIII
@Institute of High Energy Physics, Beijing

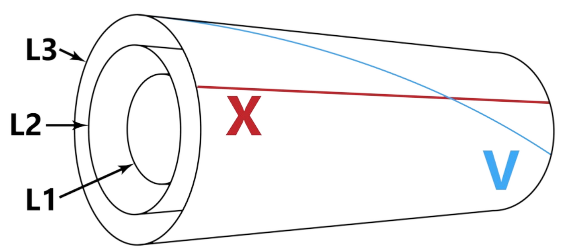


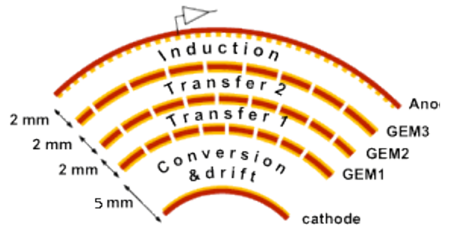
Grounding scheme and data buffering improvements are being upgraded to try to solve this efficiency losses

5

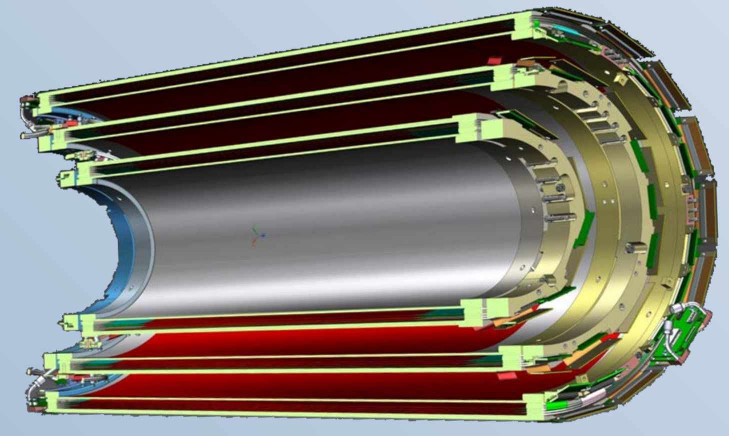
Cylindrical Triple GEM Inner Tracker

High Rate
High Radiation Hardness
93% Solid Angle Coverage
Low Material Budget <1.5% X_0





Triple GEM
X-V Anode Segmentation
Time and Charge Analogue Readout

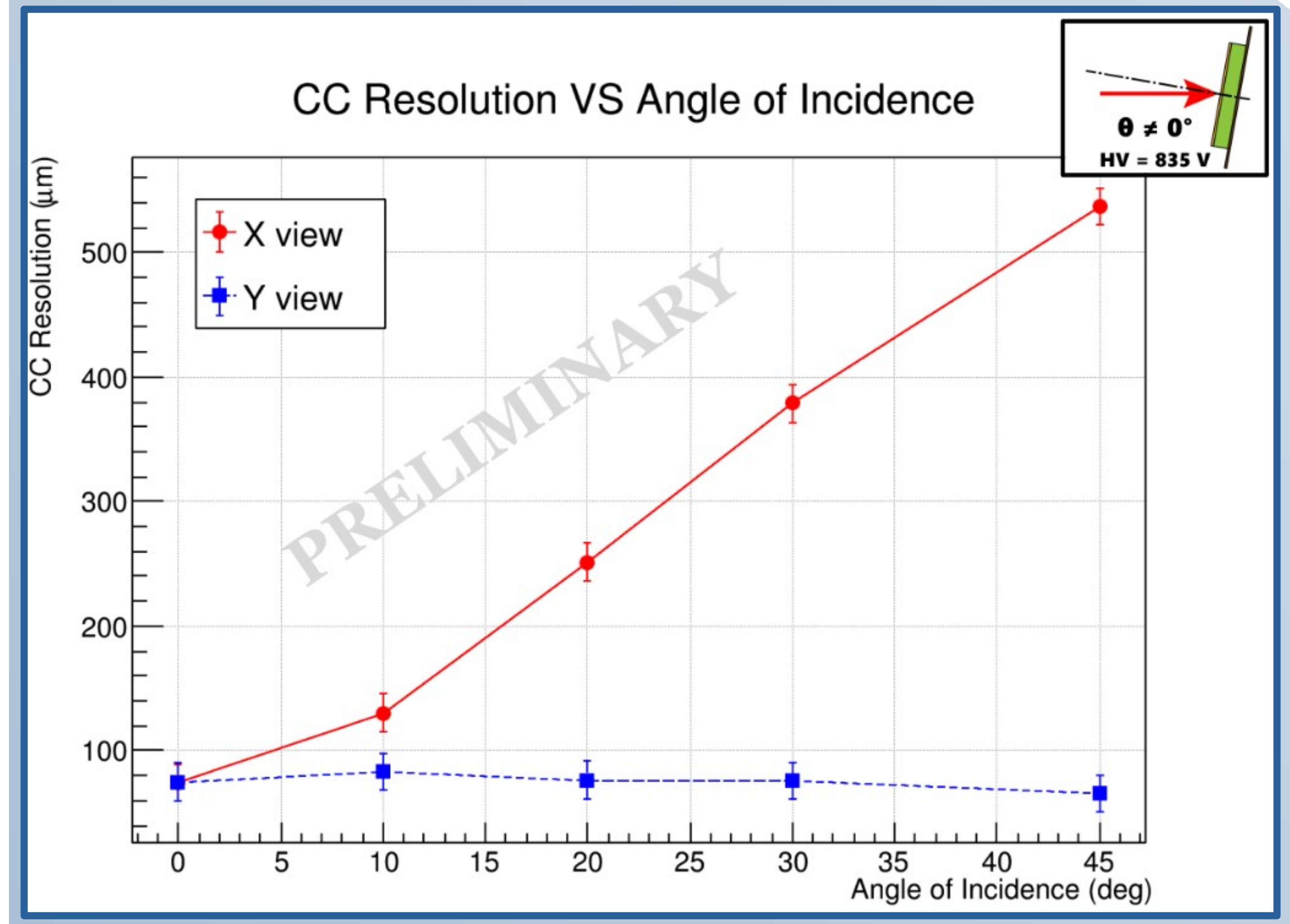


High Gain
Low discharge Probability
Improved spatial resolution
σ_z ~350μm
σ_{xy} ~130mm
σ_{pt} ~0.5% @1 GeV/c

DESIGN

www.mdpi.com/2073-8994/14/5/905

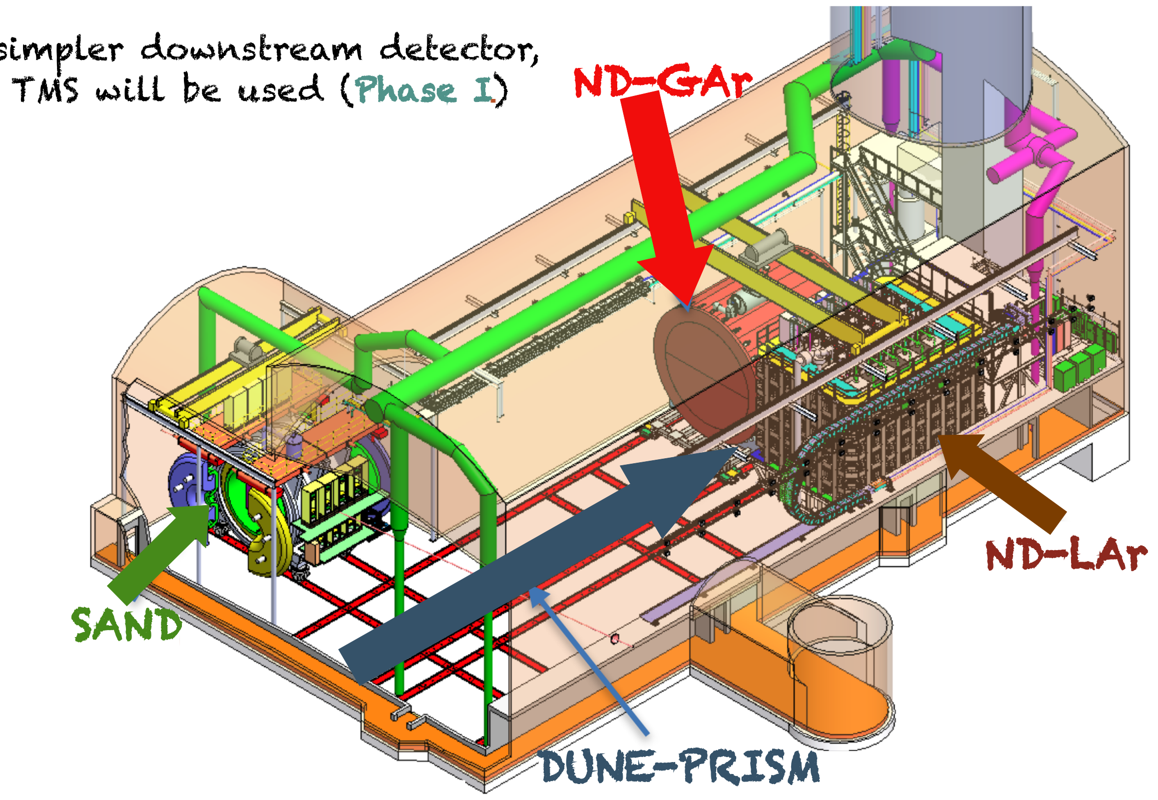
At θ = 0° about 60 μm
μ-TPC analysis in progress to improve resolution at large angles



Tanaz Mohayai, Fermilab

DUNE Near Detectors

in the early running, a simpler downstream detector, the muon spectrometer, TMS will be used (Phase I)



- An elaborate near detector complex:
  - ★ **ND-LAr** a liquid Argon time projection chamber, LArTPC
  - ★ **ND-GAr**, a gaseous argon-based time projection chamber
  - ★ **SAND**, system for on-axis neutrino detection

movable system enables the DUNE-PRISM program

Charge Readout Test Stand – MWPC

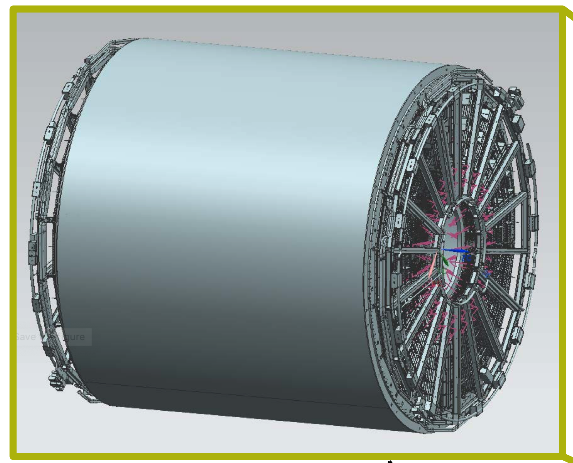
- **Pressure vessel** housing an **IROC**, aimed at calibrating the gain at various pressure set-points and amplification (anode) wire HV values

GOAT

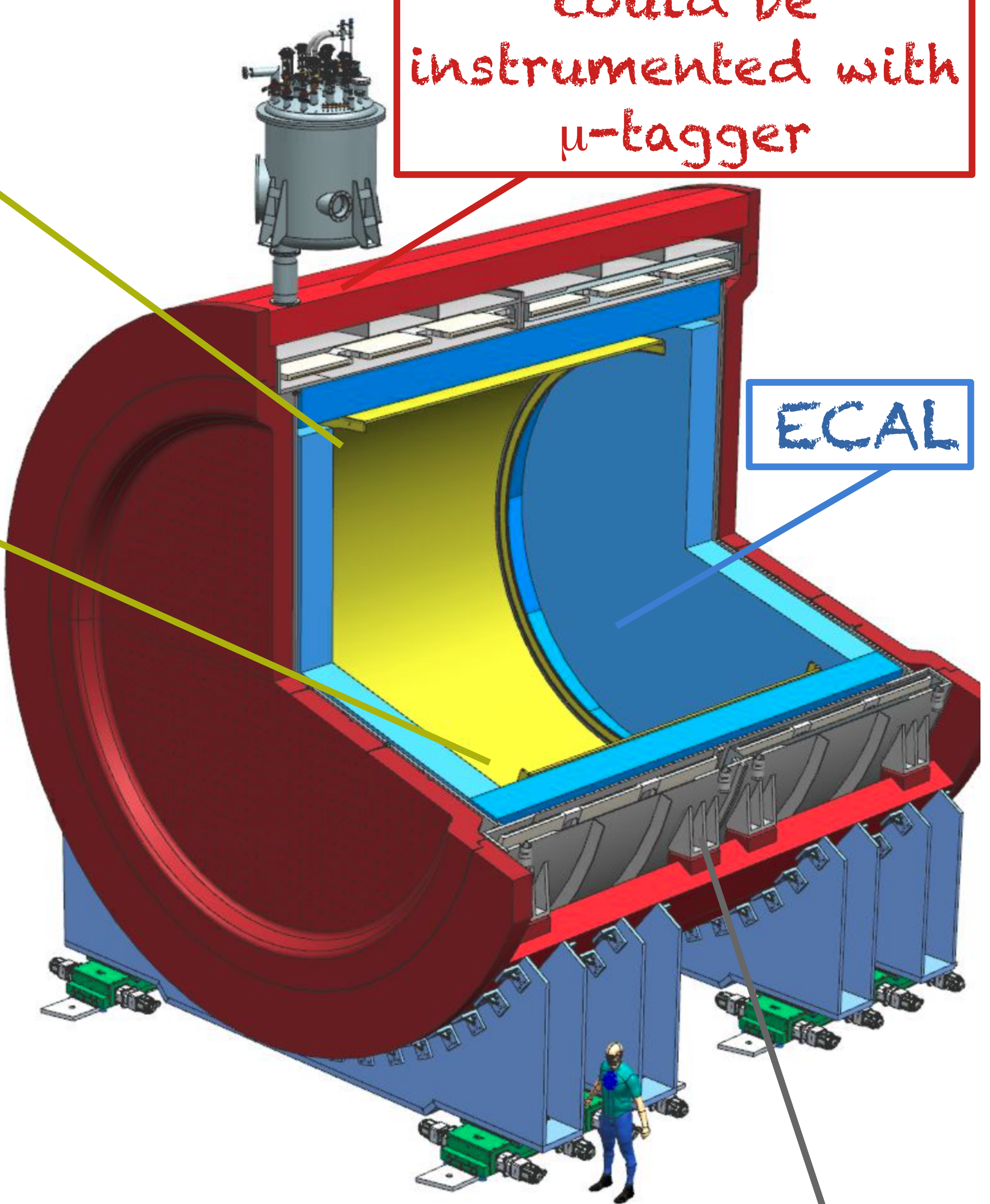
Fermilab, Colorado Boulder, Pittsburg

ND-GAr Near Detector Concept

HPgTPC



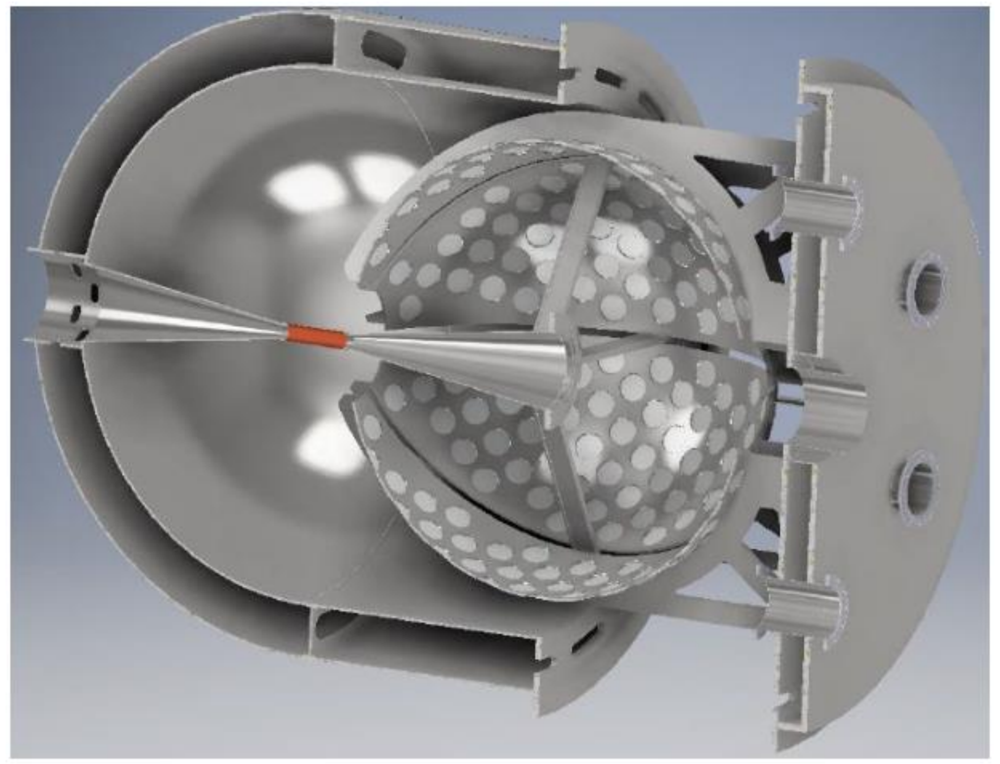
ALICE engineering drawing



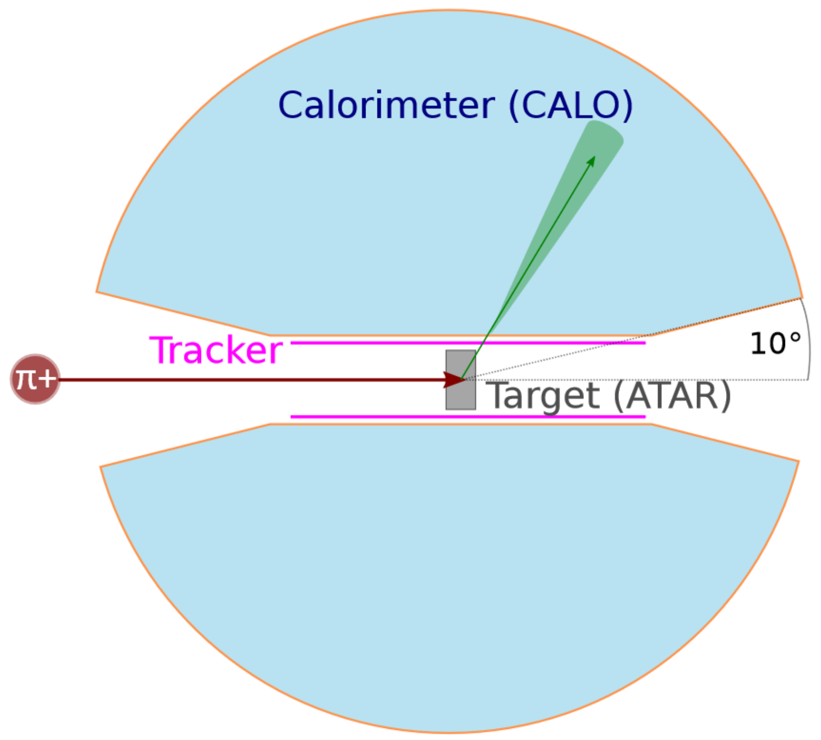
- A **magnetized High Pressure Gas Argon TPC (HPgTPC)** surrounded by **ECAL** and **μ-tagger**:
  - ★ Reference design repurposes ALICE multi-wire chambers
  - ★ Other designs under consideration, e.g. GEMs
- Key design capabilities:
  - ★ Excellent PID, tracking efficiency, momentum resolution
  - ★ 4π coverage
  - ★ Low threshold

Jaydeep Datta, CFNS, Stony Brook

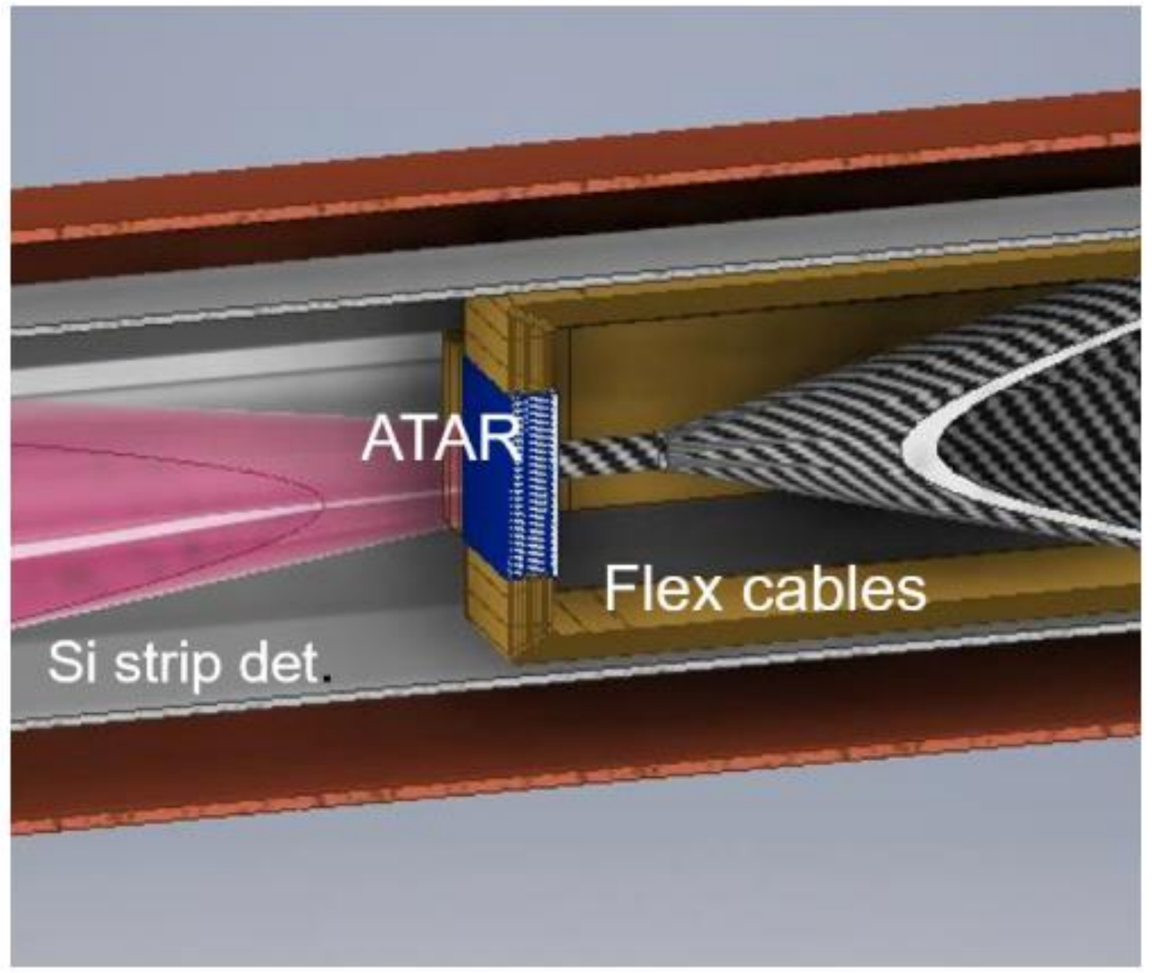
PIONEER Collaboration



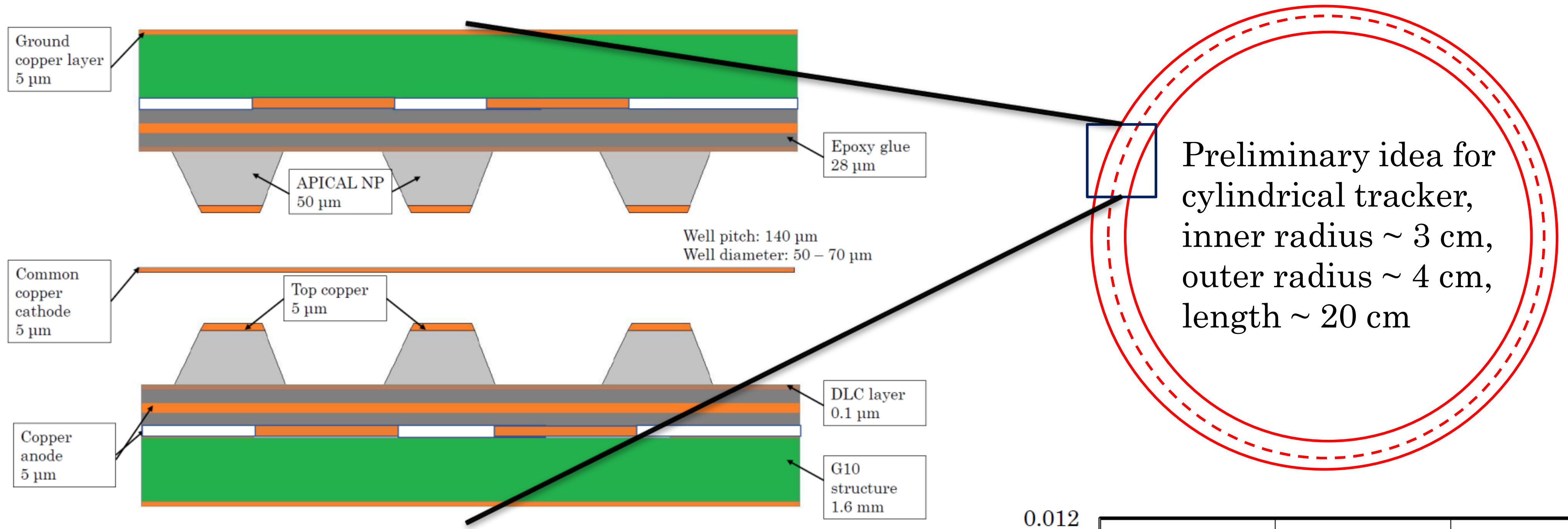
Conceptual design for the PIONEER experiment. Ref: arXiv:2111.05375



Simple schematic of the PIONEER experiment, with Liquid Xenon (LXe) calorimeter, Low Gain Avalanche Detector (LGAD) as Active TARget (ATAR) and cylindrical Tracker. (Ref: arXiv:2203.01981)

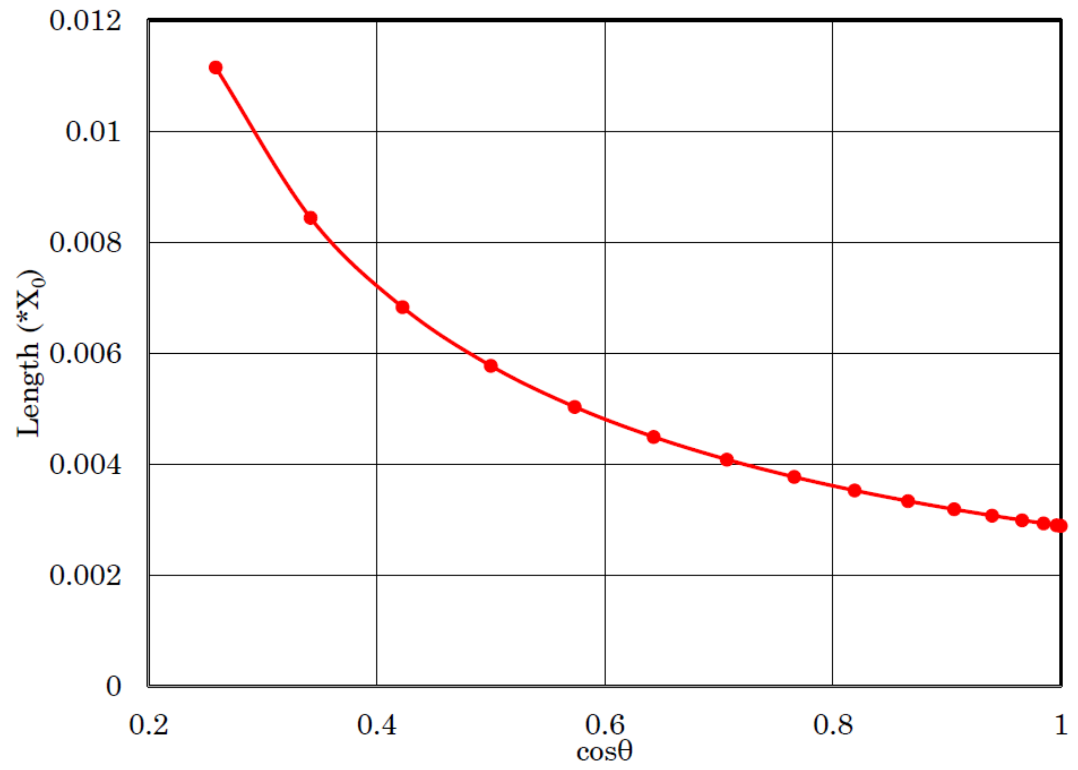


μ-RWell for tracker



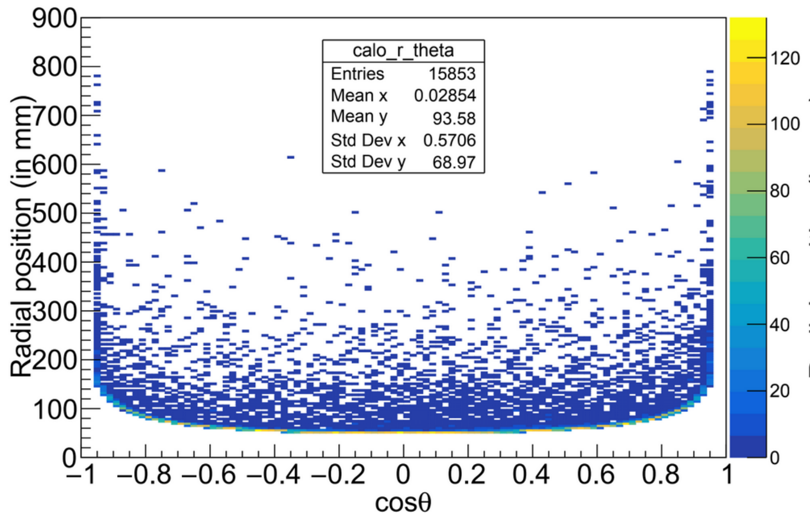
Detailed view of μ-RWell (not according to scale)

- High gain (~ 10^4)
- Good spatial resolution (<100 mum)
- Good time resolution (~ 5.7 ns)
- High rate capability (~ 1 MHz/cm^2)
- Ease of deployment

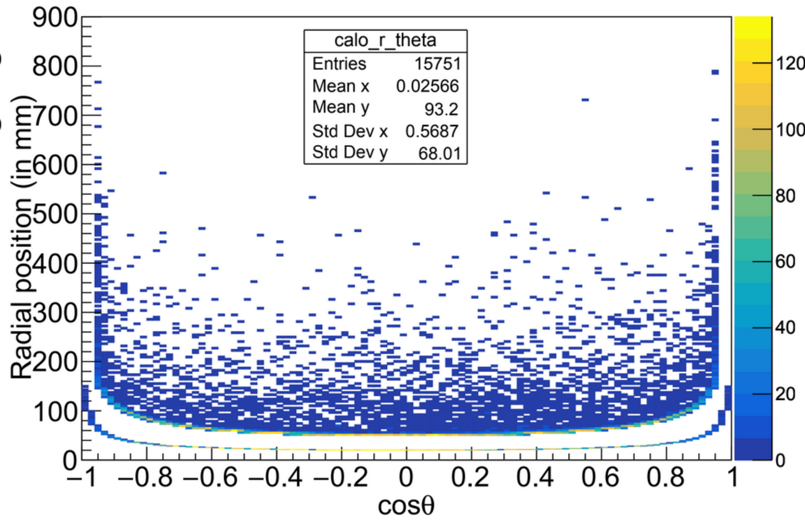


Material budget for proposed tracker

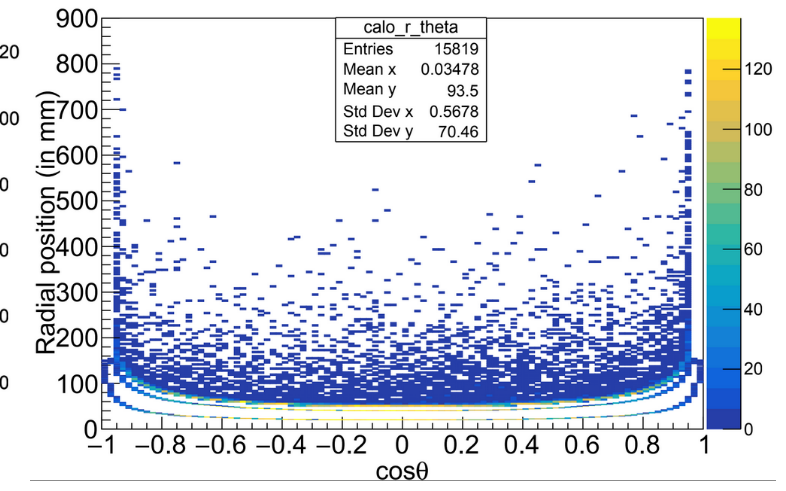
Energy deposition in detector



Energy deposition pattern without any tracker



Energy deposition pattern with one layer tracker



Energy deposition pattern with two layers tracker

Majd Ghrear, Jeff Schueler, Sven Vahsen,
University of Hawaii

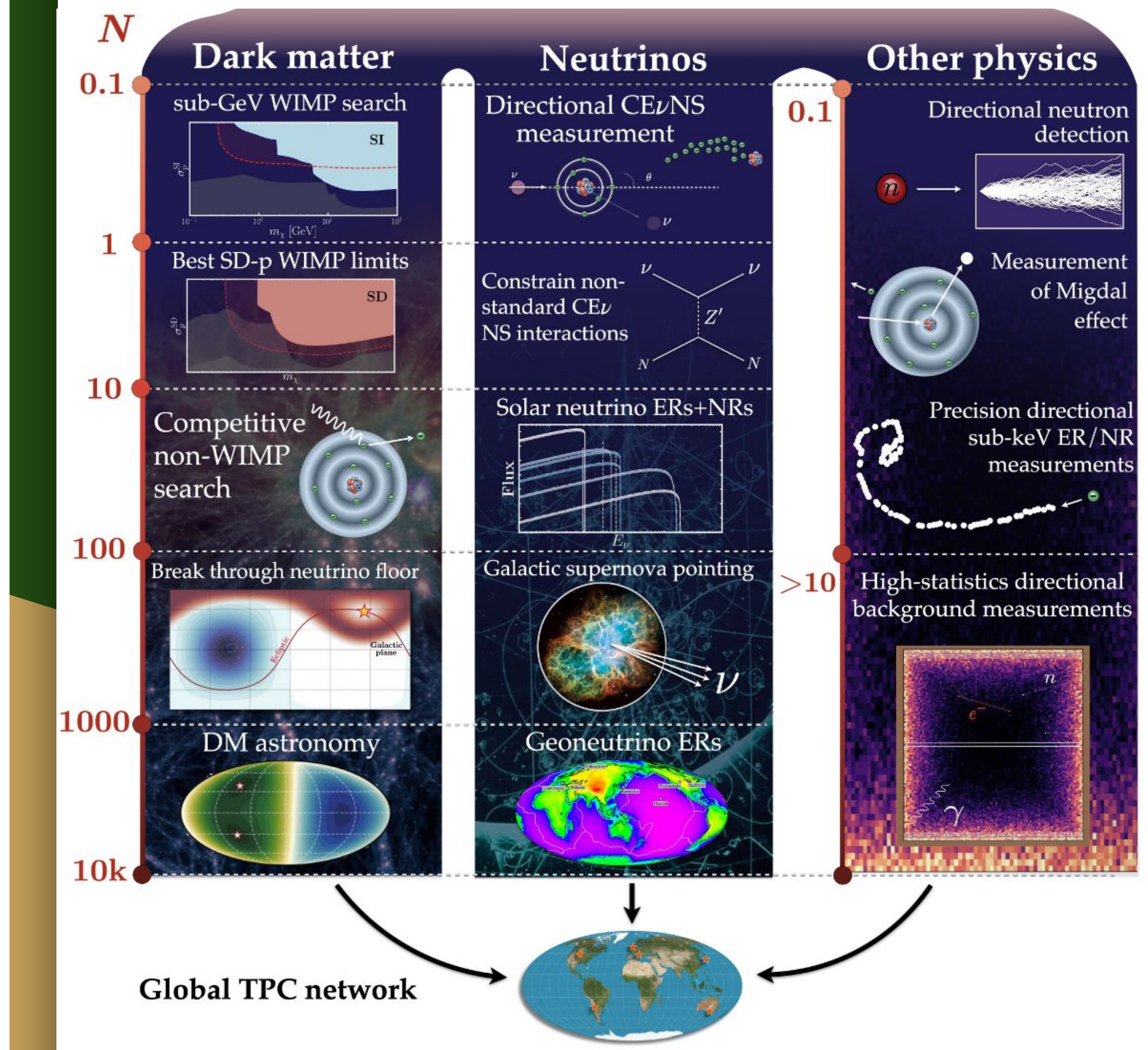
3D reconstruction of low-energy electron recoils

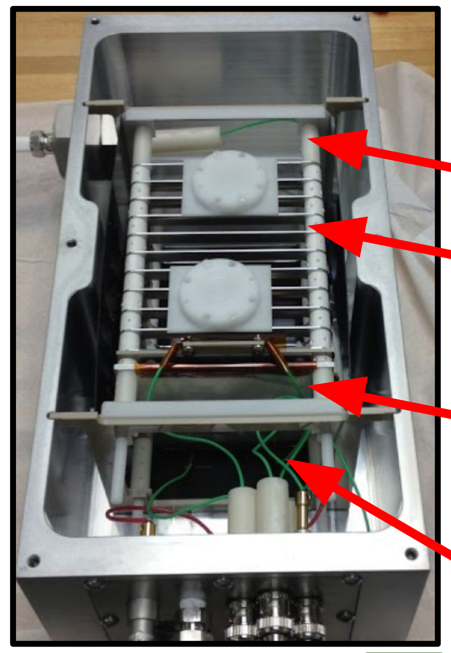
Improved the multiple scattering treatment,

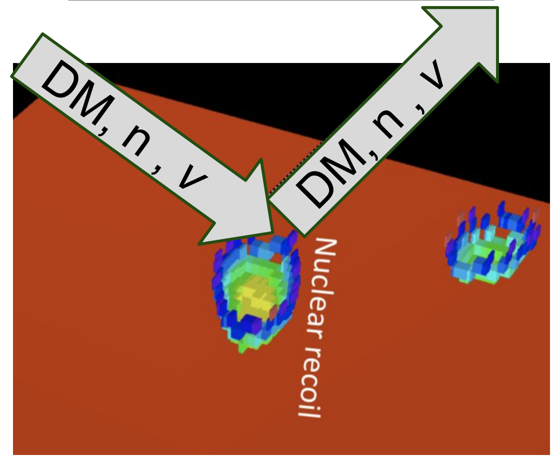
included leading detector effects

angular resolution of electron recoils in gas TPCs

Background



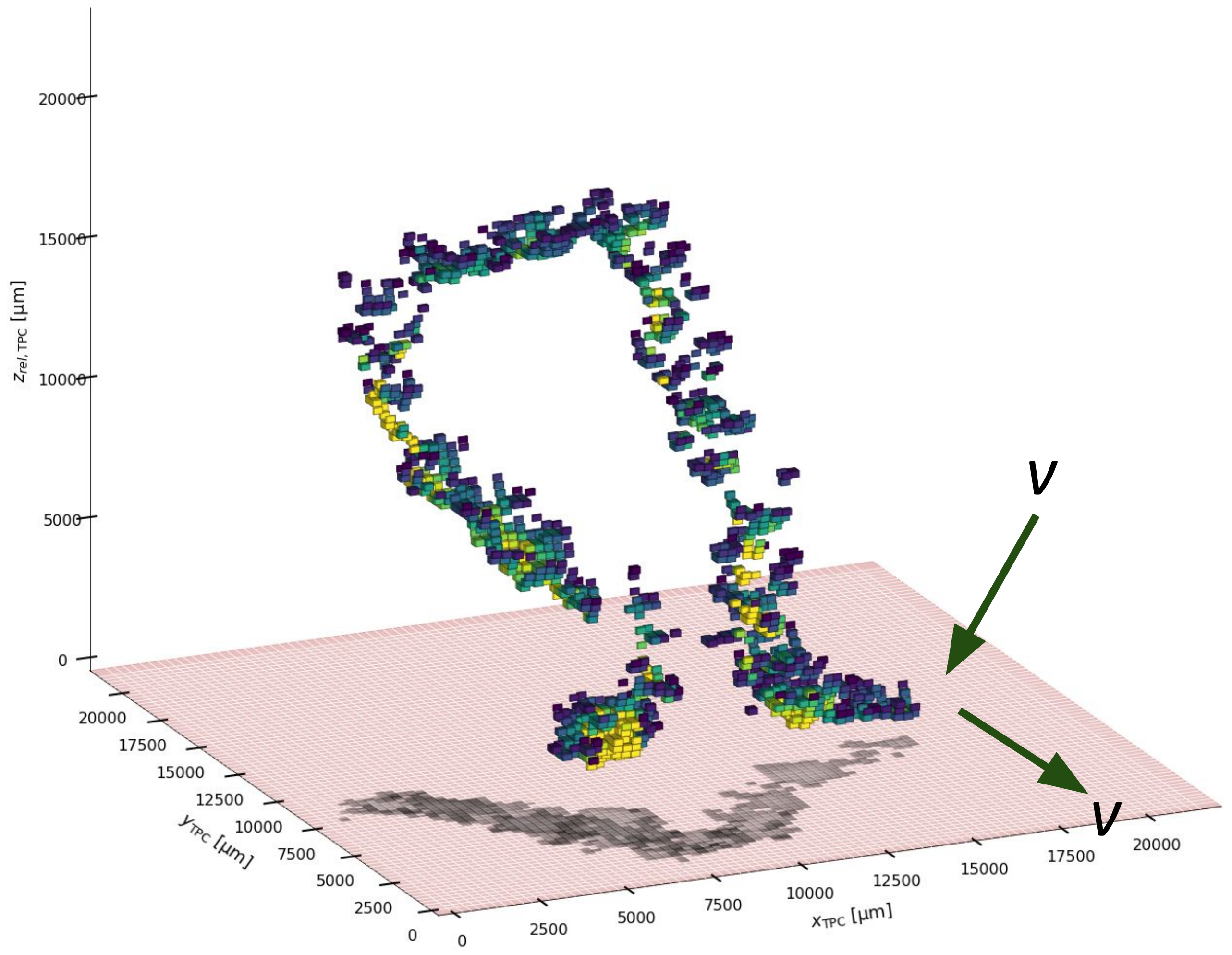




BEAST TPC

- 70:30 mixture of He:CO_2 at STP
- Cathode
- Field cage rings (~450 V/cm drift field => 220 μm / 25ns-time bin drift speed)
- Double GEM amplification capable of gains up to O(50,000)
- ATLAS FE-I4 pixel ASIC readout
- 80 x 336 grid of (250 x 50) μm^2 pixels
- 4-bit TOT charge quantization
- Noise floor ~100 electrons
- Single electron efficiency at ~20k gain

Directional Recoil Detection https://doi.org/10.1146/annurev-nucl-020821-035016
Compact, directional neutron detectors capable of high-resolution nuclear recoil imaging https://doi.org/10.1016/j.nima.2019.06.037



3D reconstruction of ~40 keV electron recoil in He : CO2 using BEAST TPC

Compact, directional neutron detectors capable of high-resolution nuclear recoil imaging, NIMA 2019.
https://doi.org/10.1016/j.nima.2019.06.037

Summary

- MPGDs are deployable in a wide rage of experiments.
- MPGDs as a fast timing devices (e.g. PicoSec) can open many other avenues for its application
- There is vibrant EIC R&D consortium pursuing MPGD related activities.
- Many ongoing R&D can benefit communities across different branches.