DE LA RECHERCHE À L'INDUSTRIE

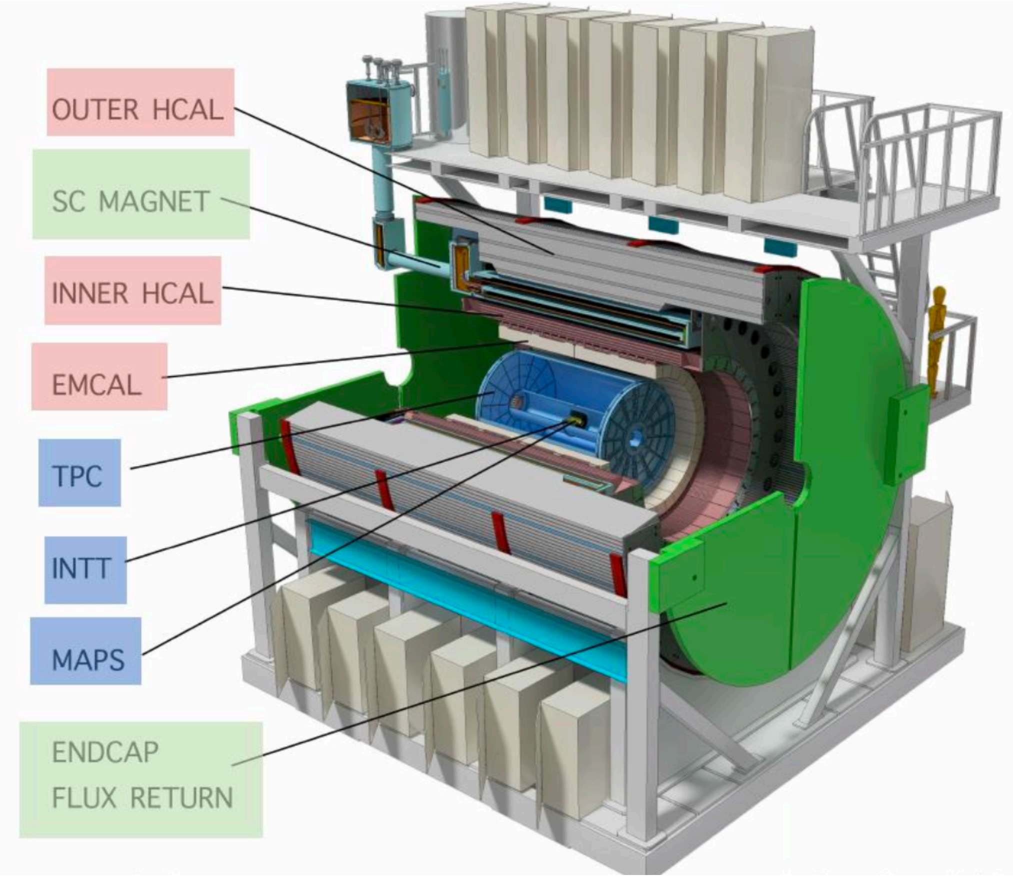
TPOT : TPC OUTER TRACKER

MICROMEGAS FOR SPHENIX

CPAD WORKSHOP 29/11/2022

Audrey Francisco
for the TPOT team

THE sPHENIX DETECTOR



Acceptance:

- full azimuth
- |η|~1
- 0.2 GeV/*c* < p_T < 40GeV/*c*

Babar 1.5 T super conducting solenoid magnet

MVTX: 3 layers of silicon pixels similar to that of ALICE ITS/MFT upgrade (ALPIDE)

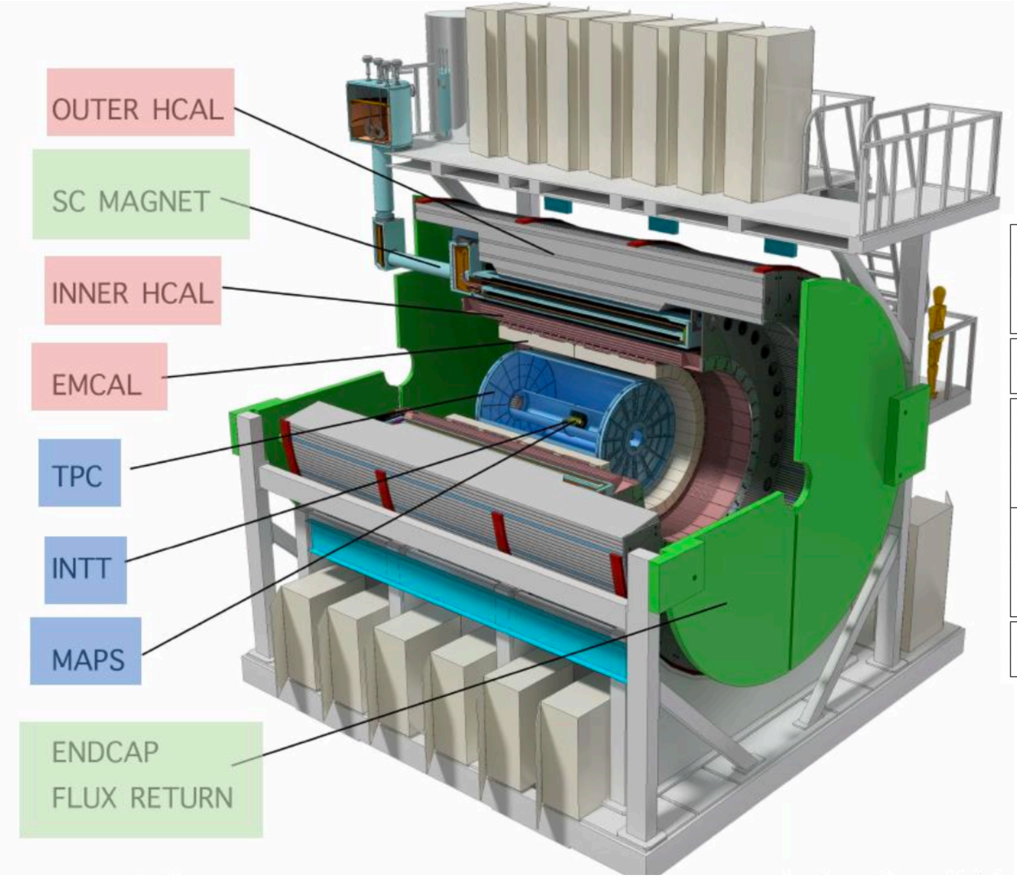
INTT: 2 layers of silicon strips, for tracking and possibly triggering

TPC: see next

Collision rate: 50kHz (Au-Au), 3MHz (pp)

Data acquisition rate: 15 kHz

THE sPHENIX DETECTOR

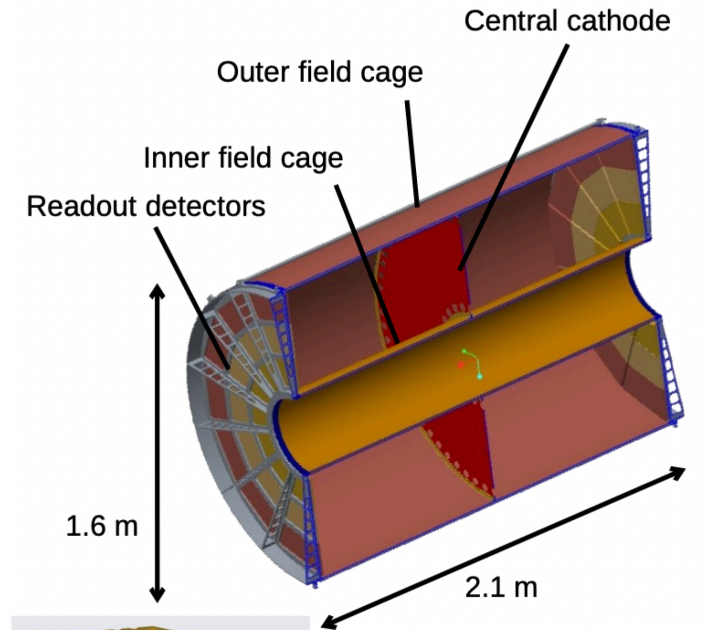


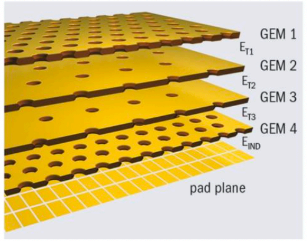
Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\|z\| <10$ cm	Samp. Lum. $\|z\| <10$ cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	4.5 (6.9) nb^{-1}
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5 kHz] 4.5 (6.2) pb^{-1} [10%-str]	45 (62) pb^{-1}
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5 kHz] 0.01 pb^{-1} [10%-str]	0.11 pb^{-1}
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

Main tracking instrument for sPHENIX

- Operated in continuous mode without gating grid
- 1m drift in Ar:CF4 60-40
- 50kHz collision rate in Au-Au
- **Read-out quadruple GEM** (upgrade ALICE)
  12 sectors with 3 detector layers

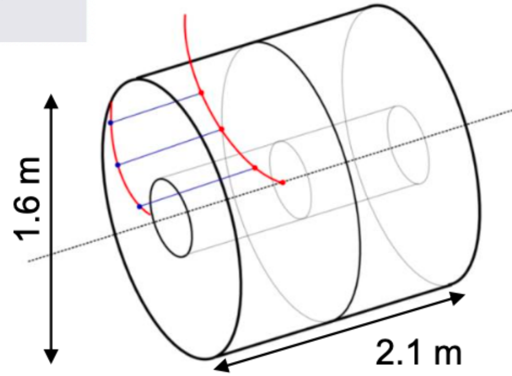
In an ideal TPC: longitudinal e- drift at constant velocity





Sources of distortions:

- **Static:** E,B inhomogeneities, alignement, etc.
  Scale : O(1cm)
  Mesured during commissioning, without beam 1x/year
- **Beam induced:** charges from primary ionisation and IBF
  → additional E field varying with time and position
  Scale : O(1mm) depends on luminosity and beam conditions, ~ 1/2h
- **Event by event fluctuations** of average distortions induced by the beam
  Scale : < 100µm, O(10ms)

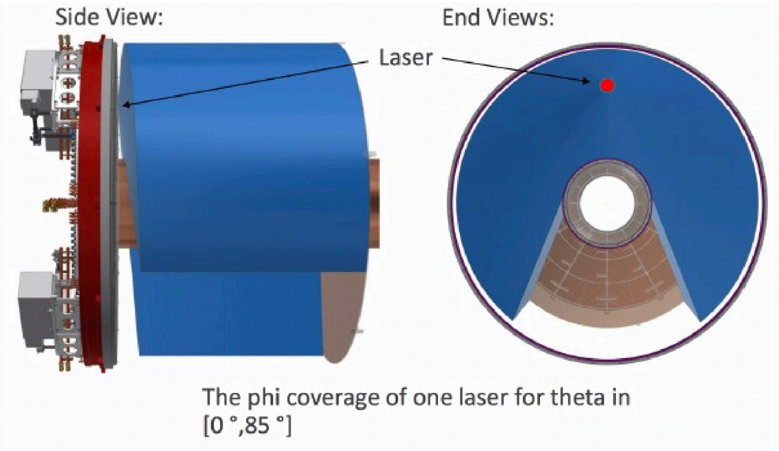


Must measure and correct these distortions with precision < 100 µm

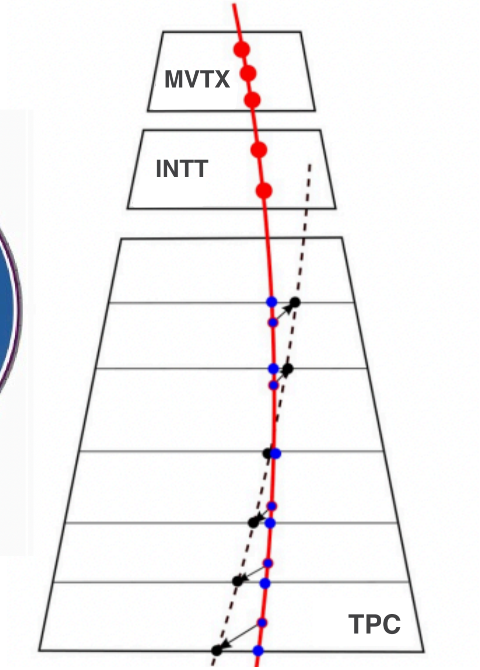
Tools to reconstruct distortions

1. **Direct lasers** → static distortions O(cm) during commissioning
2. **Tracks** → time-dependant distortions induced by the beam O(mm)
3. **Diffuse laser system** (and analog current reading) → event-by-event fluctuations (<100µm)

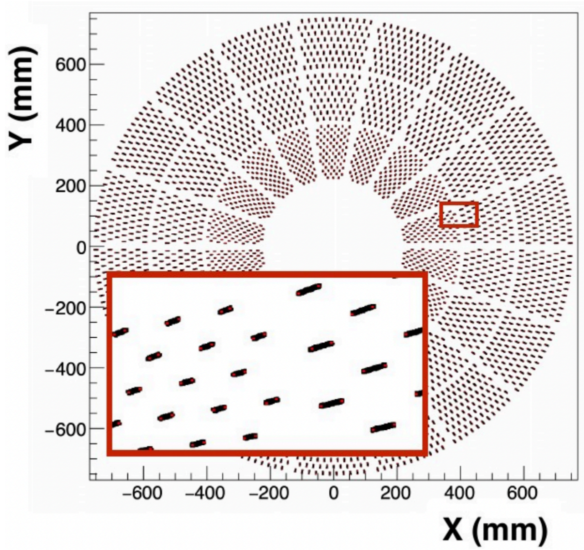
Need to use all **methods in cooperation**, to fully correct TPC distortions with the required precision of 100µm



Direct laser



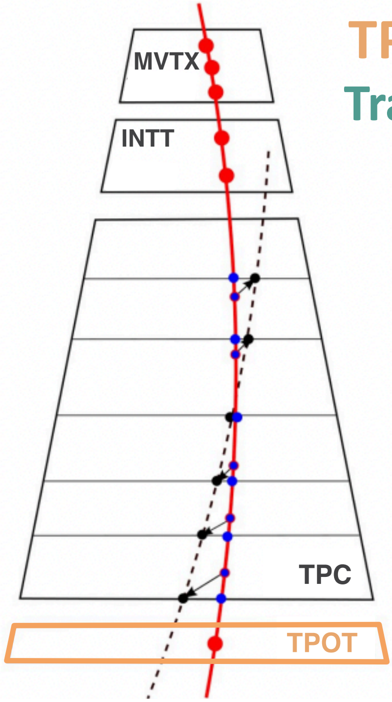
Track extrapolation



Pads on the TPC central membrane

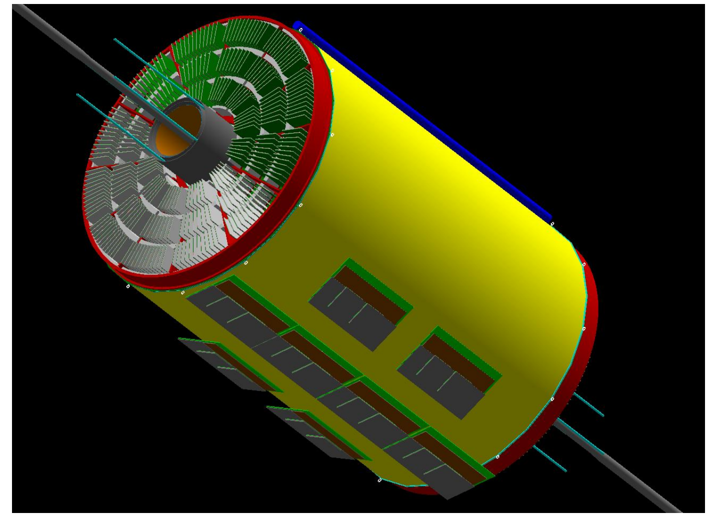
TPOT useful for the track extrapolation in the reconstruction of beam-induced distortions

OUTER TRACKER FOR THE TPC



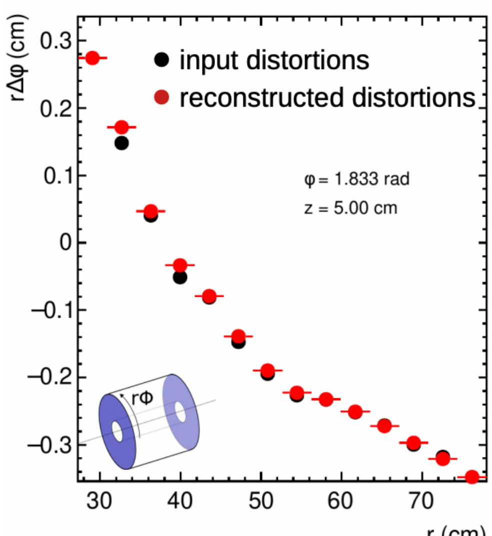
TPOT = TPc Outer Tracker

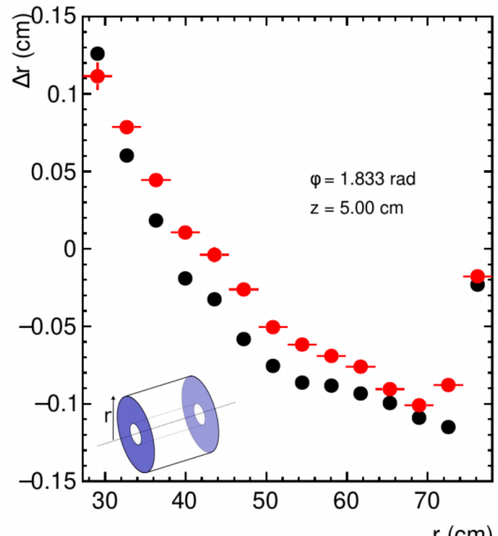
Track extrapolation with an additional space point outside the TPC

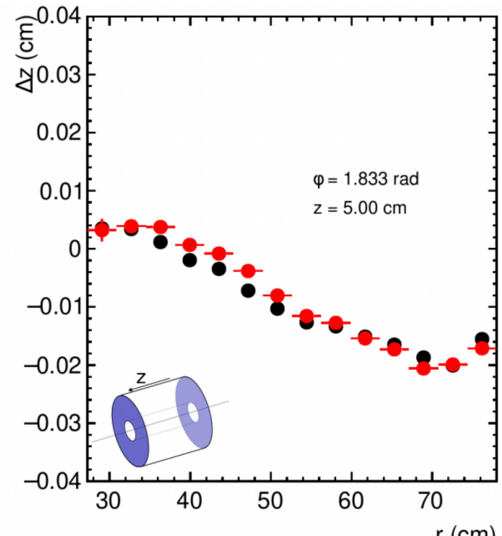


Partial TPC coverage

- Full z dependance
- ϕ dependance



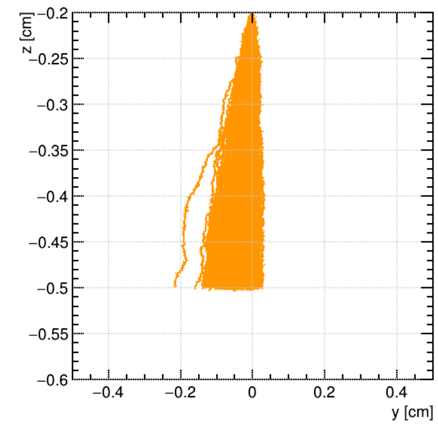




Outer Tracker for the TPC

- **Size:**
  - Thin detectors to fit between ECAL and TPC
    → *Micromegas amplification*
- **Environment:**
  - Magnetic field (1.4T): gas mixture to lower Lorentz angle, thin drift gap → *Ar/Iso 95/05*
  - Heavy ions physics → *resistive layer*
- **No access to detector:**
  - Max reliability with segmentation → *4 HV sectors per module*
  - No risk in detector design → *1D Micromegas*
- **Re-use of TPC services:** SAMPA FEE and cooling
- **(very compressed) schedule:**
  - Compatible with fast production → *standard PCB from industry, size* ***compatible with Saclay MPGD lab***
  - Compatible with DREAM electronics for cosmic rays and source characterisation at Saclay

Lorentz Angle simulation



→Micromegas = natural choice

Production (serigraphy, bulk, assembly, metrology, validation) @ Saclay
Mechanics for support structure @ LANL
Transportation and lifting @ MIT/Bates
Services (Cooling, Gas systems, slow controls) @ BNL

Green light from DOE

Integration in sPHENIX

2021 — Nov 21 — March 22 — Spring 22 — Aug 22 — Fall 22 — Dec 22

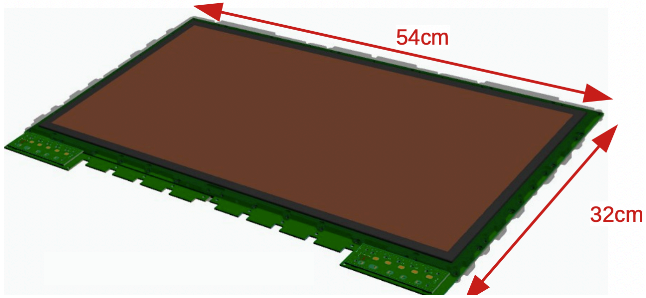
Detector design

Prototypes validation

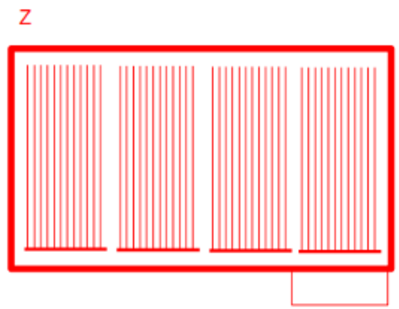
All detectors @ BNL

Assembly into sub-system and testing

Each TPOT detector (module) = **2 back-to-back 1D Micromegas layers**

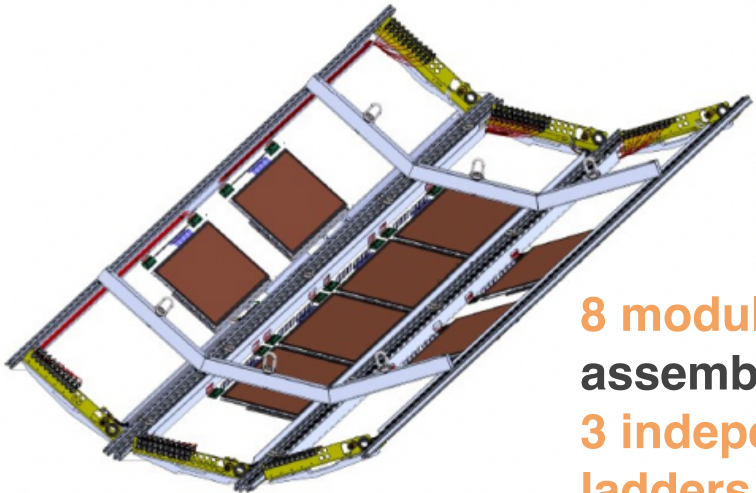


= 1Z + 1 rΦ detector

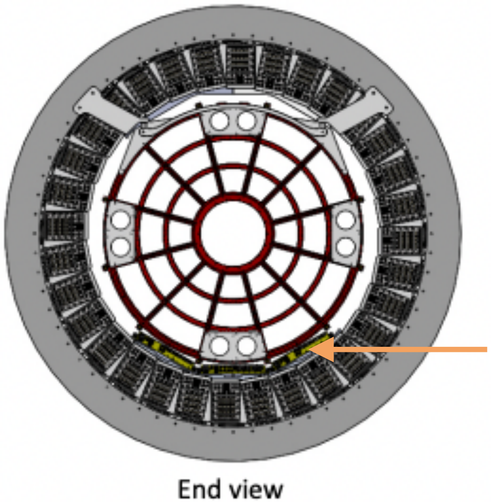
= 

+ 

Each layer is read by 1 FEE



8 modules assembled into 3 independant ladders

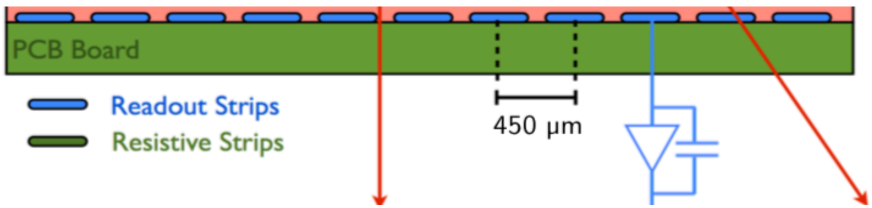


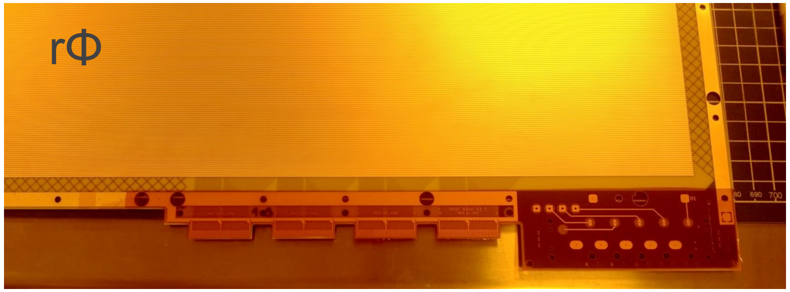
Inserted between TPC and EMCal

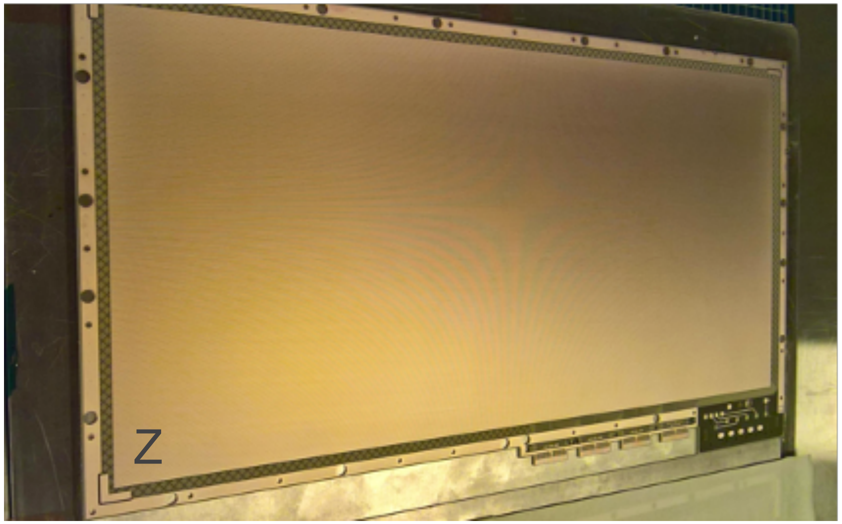
PCB

rΦ : straight strips (1mm pitch)
Z : **zigzag** strips (2mm pitch)

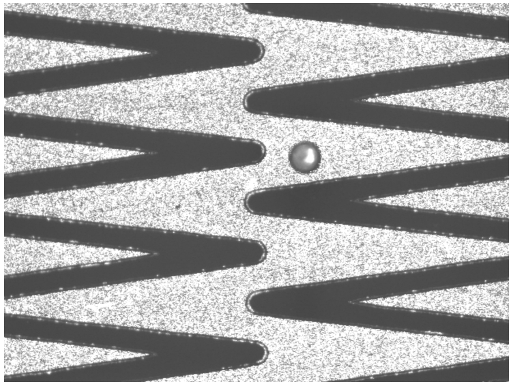
Standard PCB suppliers (SOMACIS, Italy and PCBelectronics, China)





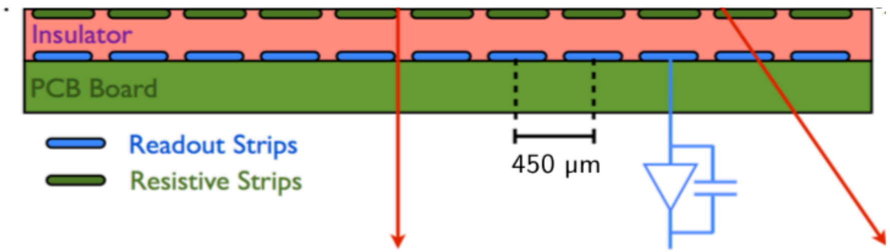


Zigzag strips on Z side (naked PCB)

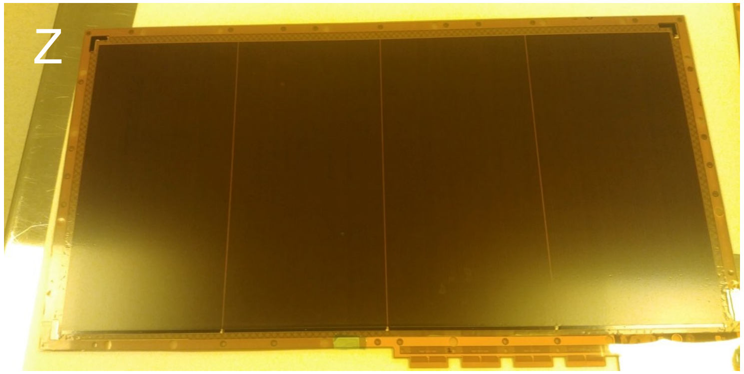


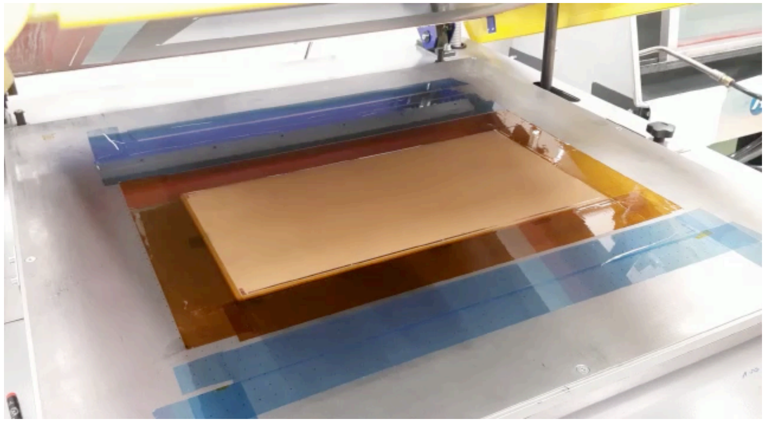
DETECTOR PRODUCTION @SACLAY

Resistive layer (straight strips)

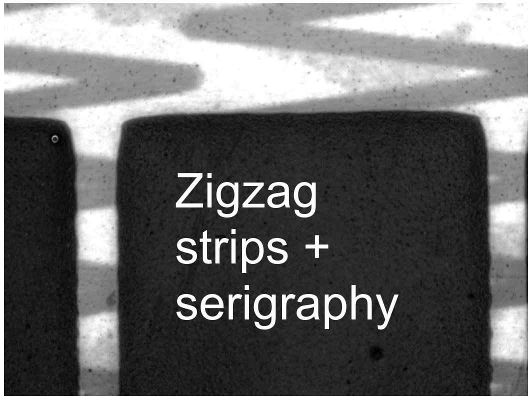


Resistive layers pressed on the PCB





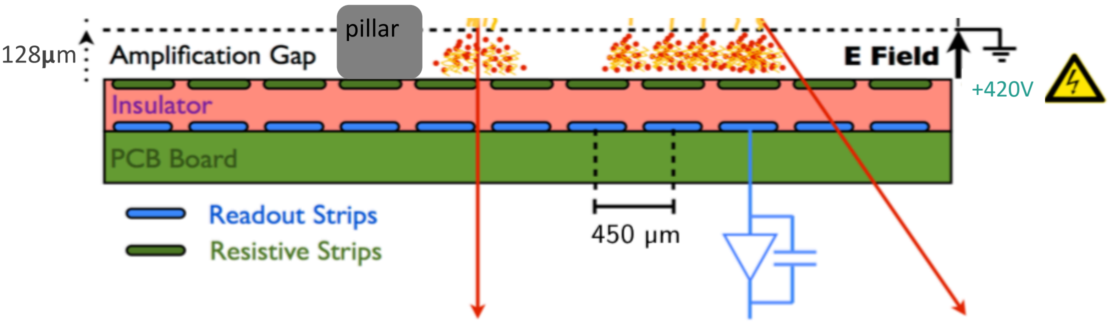
Serigraphy process

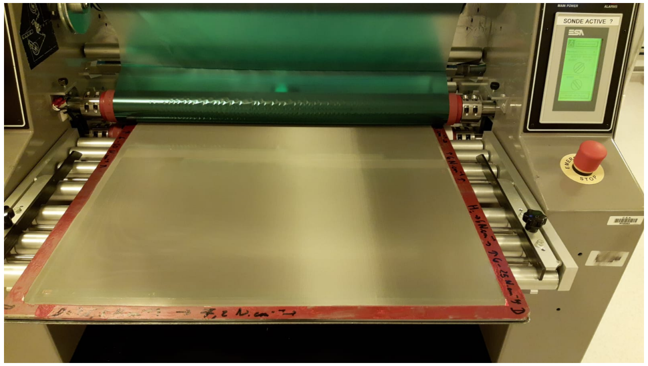


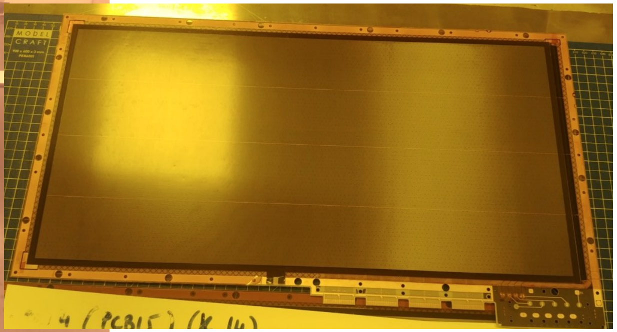
Collaboration with CERN for pressing the kapton layer on the PCB

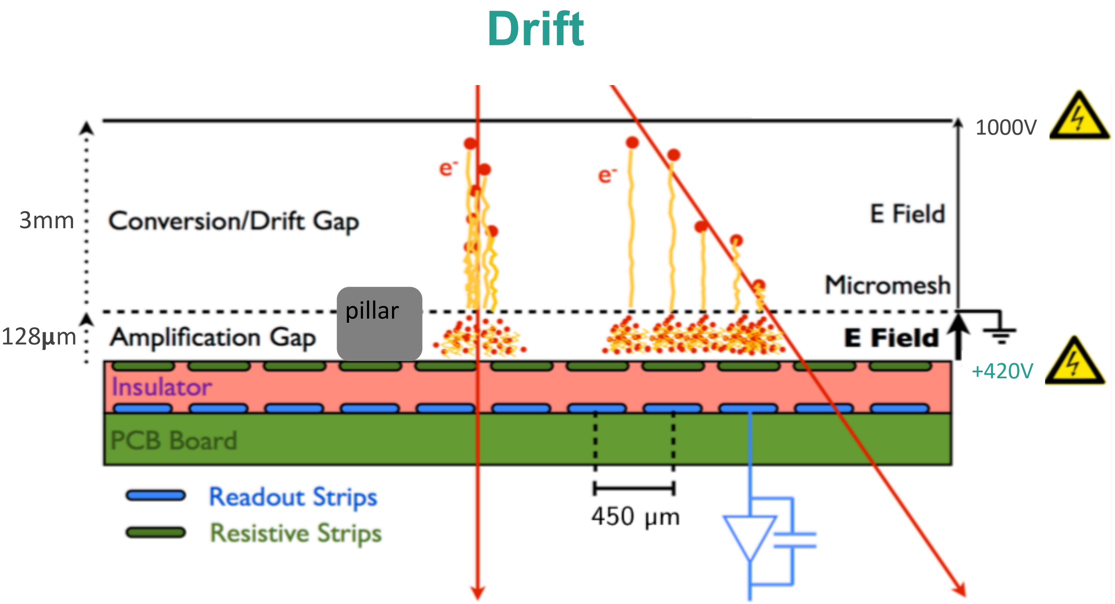
DETECTOR PRODUCTION @SACLAY

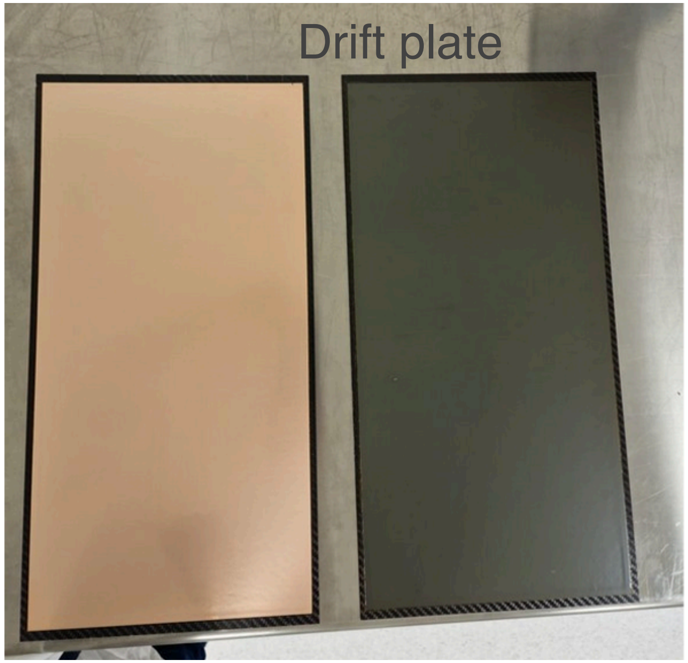
Bulk

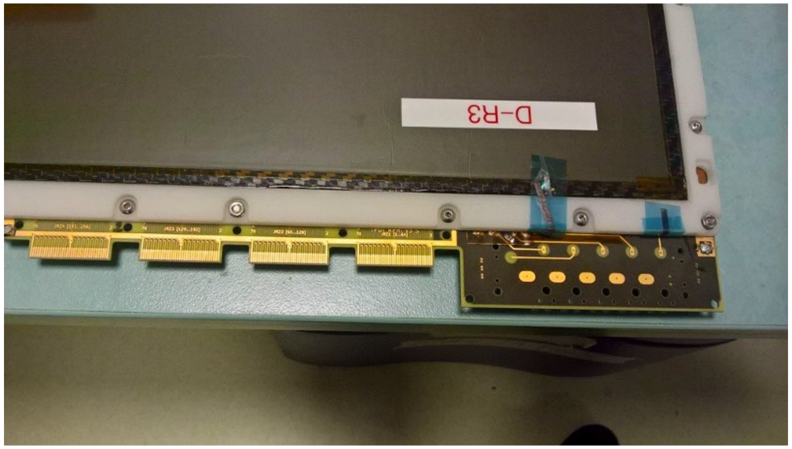


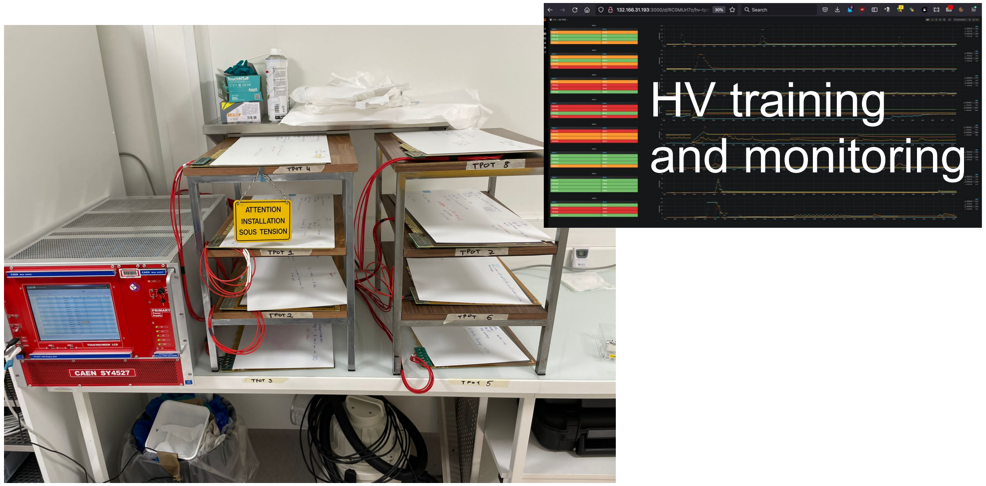





Drift
1000V
3mm
Conversion/Drift Gap
E Field
Micromesh
e-
e-
pillar
128µm
Amplification Gap
E Field
+420V
Insulator
PCB Board
Readout Strips
Resistive Strips
450 µm

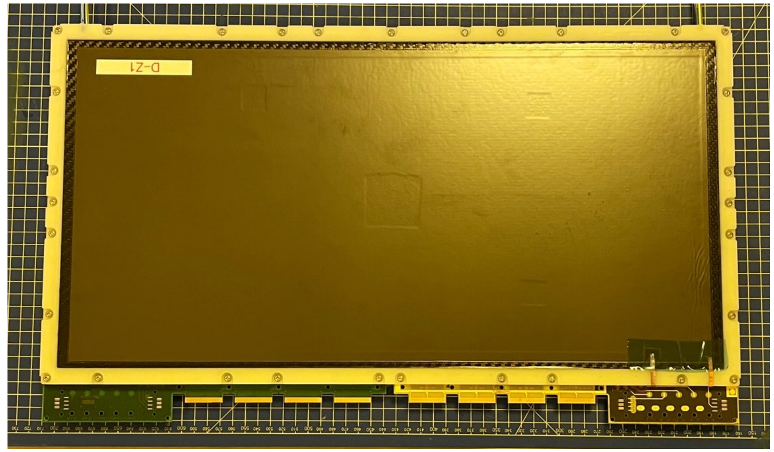

Drift plate

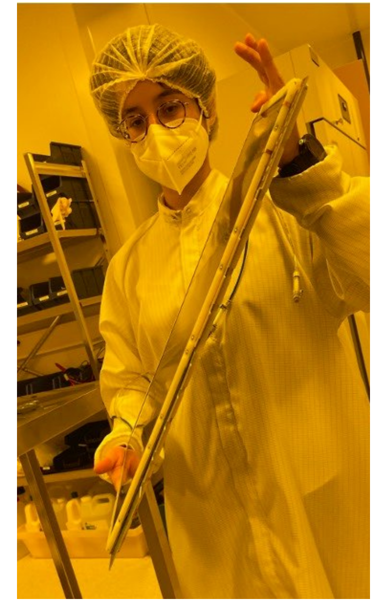

D-R3


HV training
and monitoring
ATTENTION
INSTALLATION
SOUS TENSION
CAEN SY4527

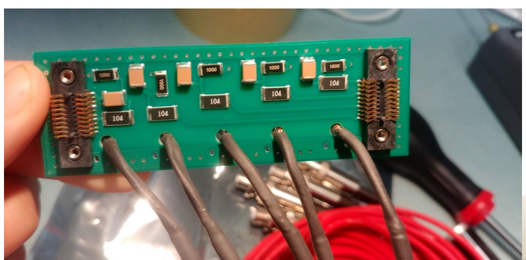
DETECTOR PRODUCTION @SACLAY

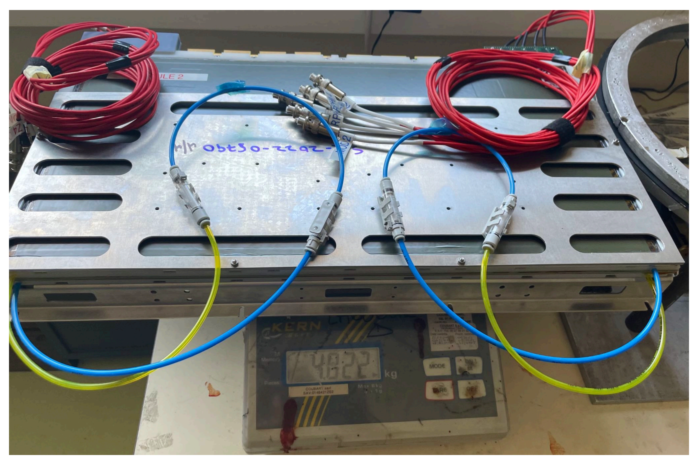
rΦ and Z assembled into 1 module





HV card

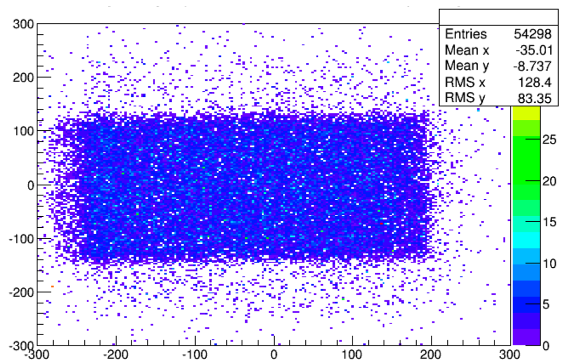


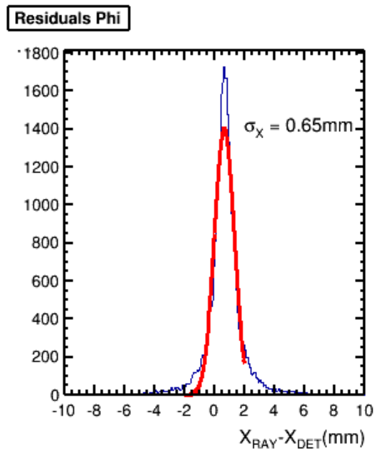


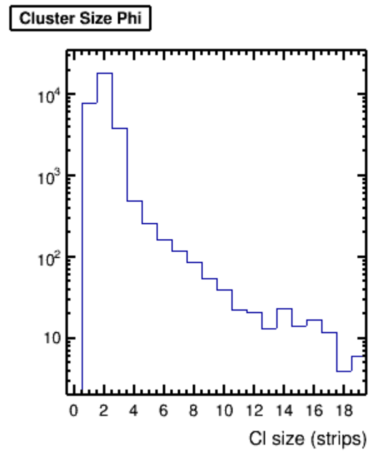
Full weight: 4.8kg without electronics

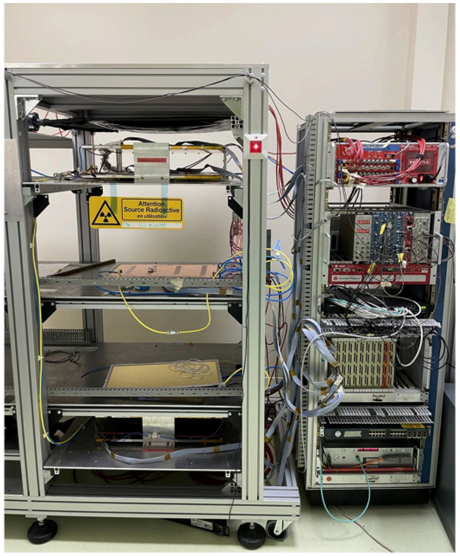
Detector performances with cosmic test bench @ Saclay using DREAM electronics

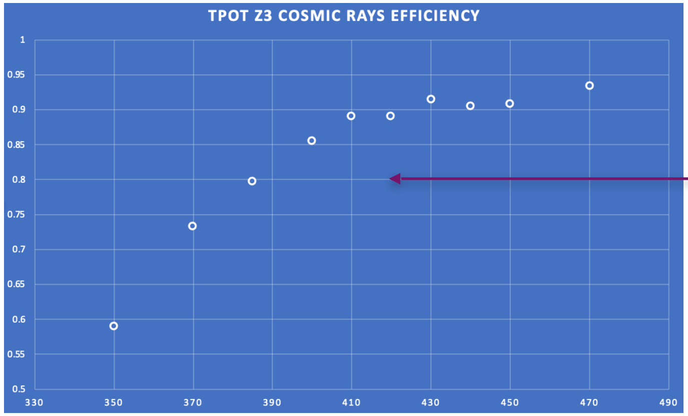
Hit map



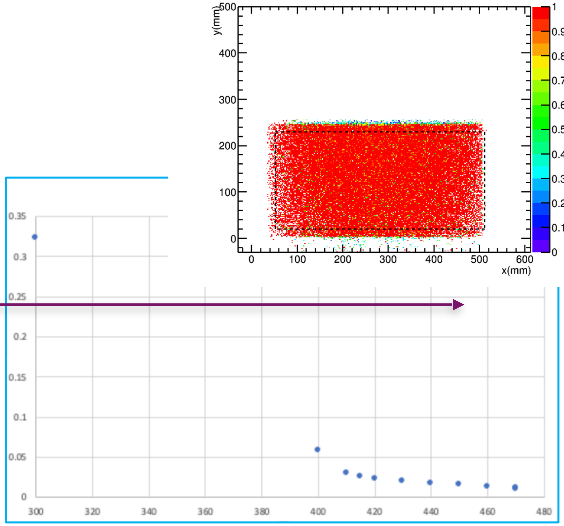




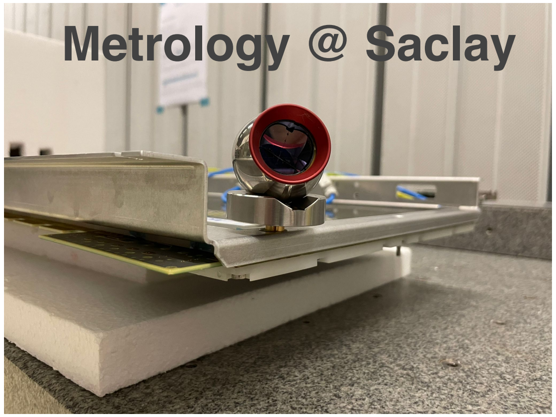




Efficiency plateau with cosmic rays



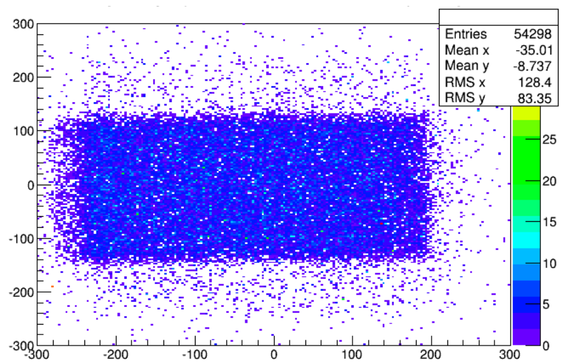
Efficiency curve with ^{55}Fe

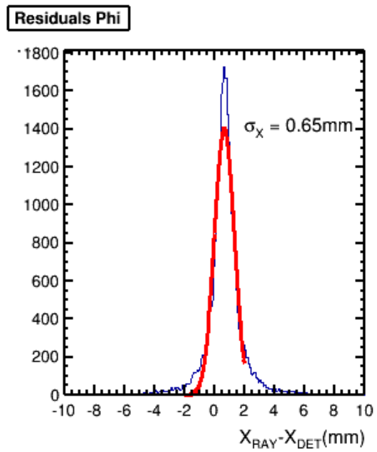


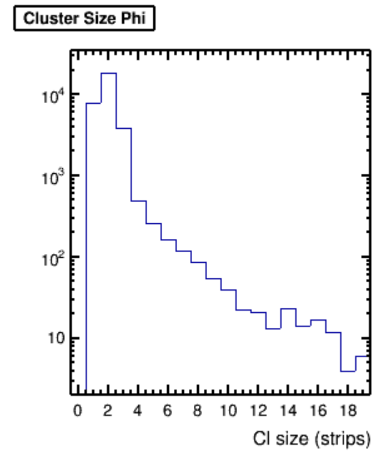
Detector performances with cosmic test bench @ Saclay using DREAM electronics

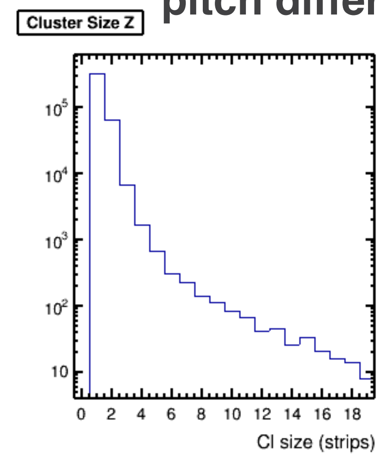
zigzag pattern compensates the pitch difference

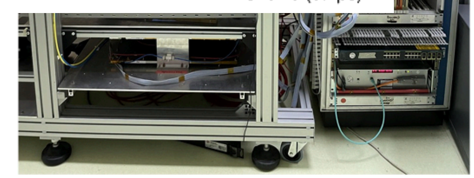
Hit map

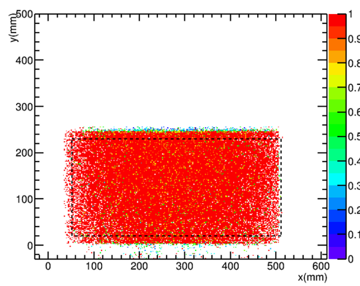


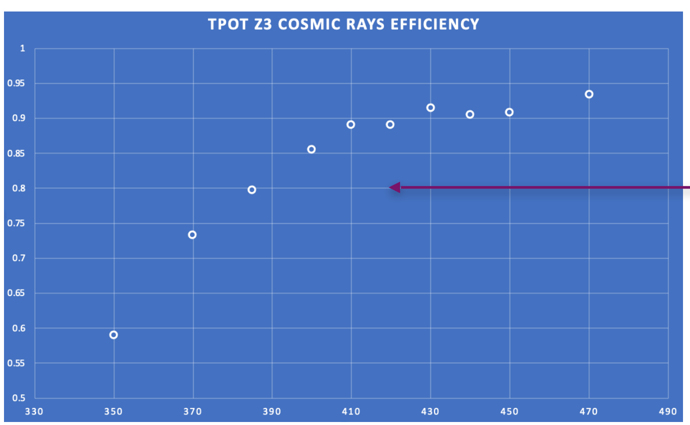




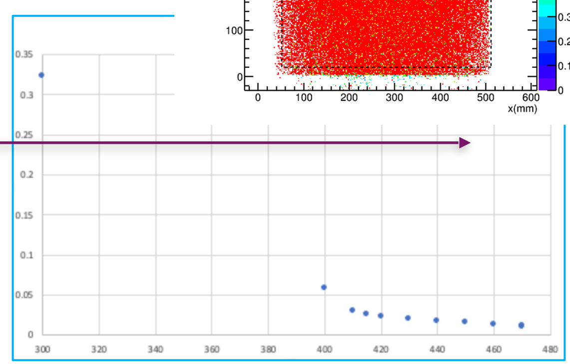




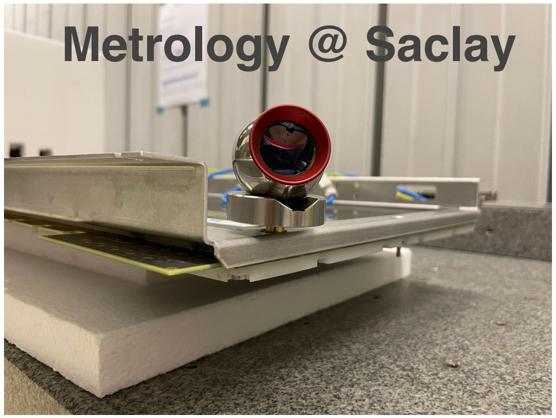




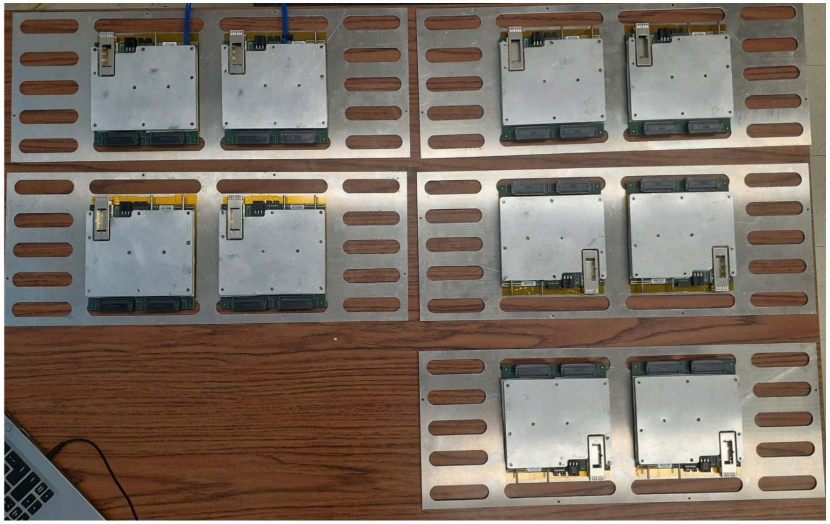
Efficiency plateau with cosmic rays



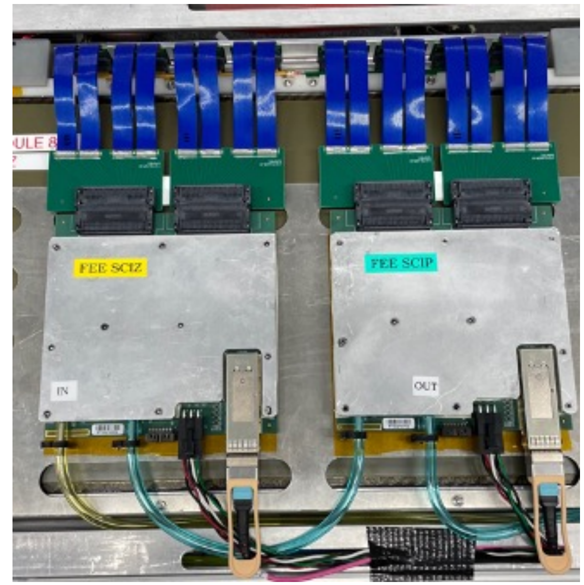
Efficiency curve with ^{55}Fe



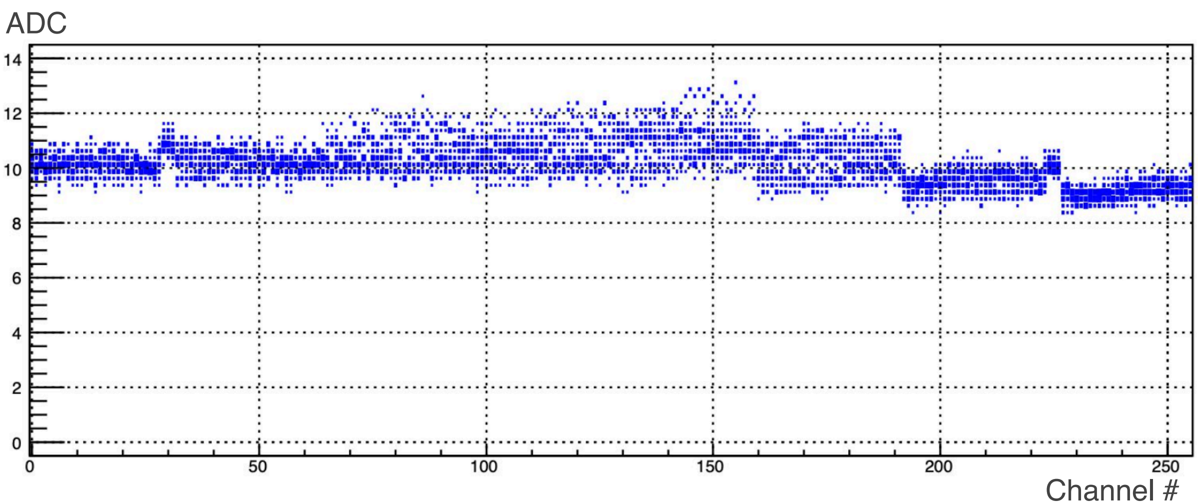
Assembled boards



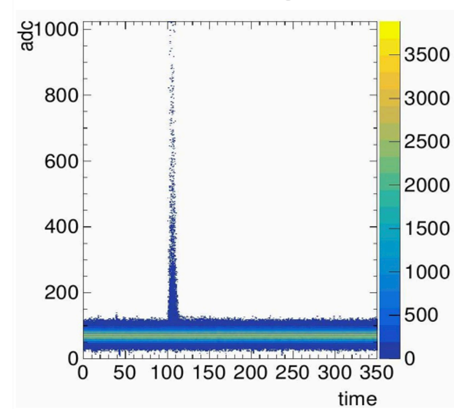
1 FEE per detector (2/module)
512 channels per module



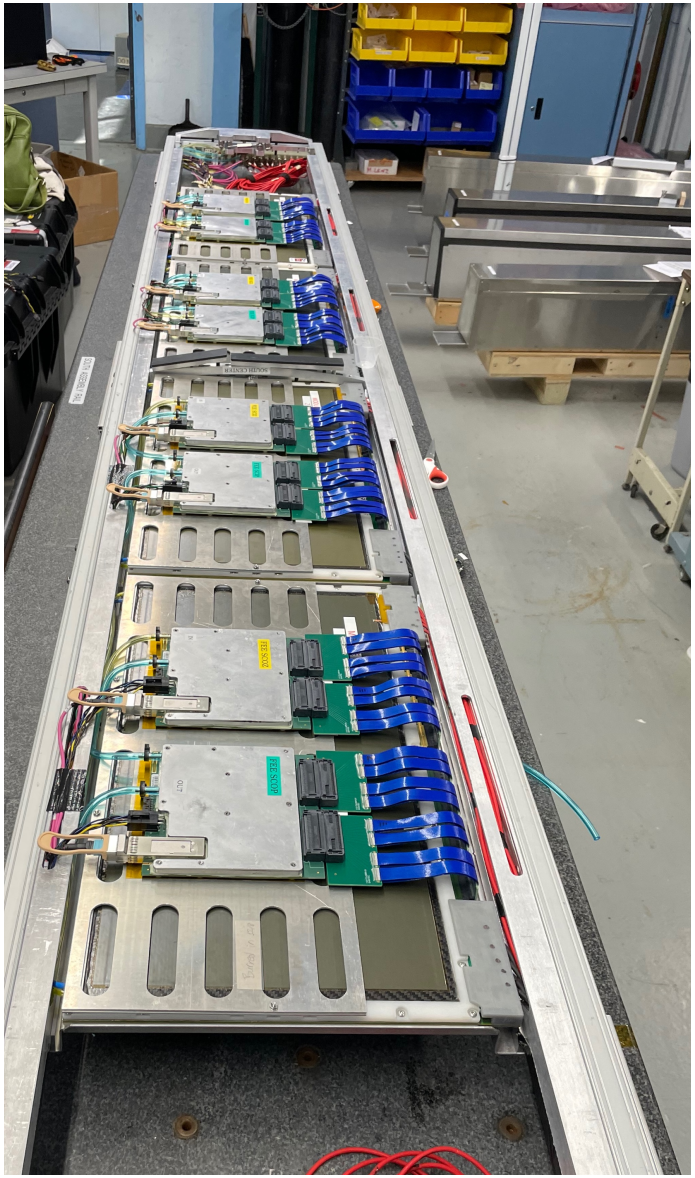
Noise measurements

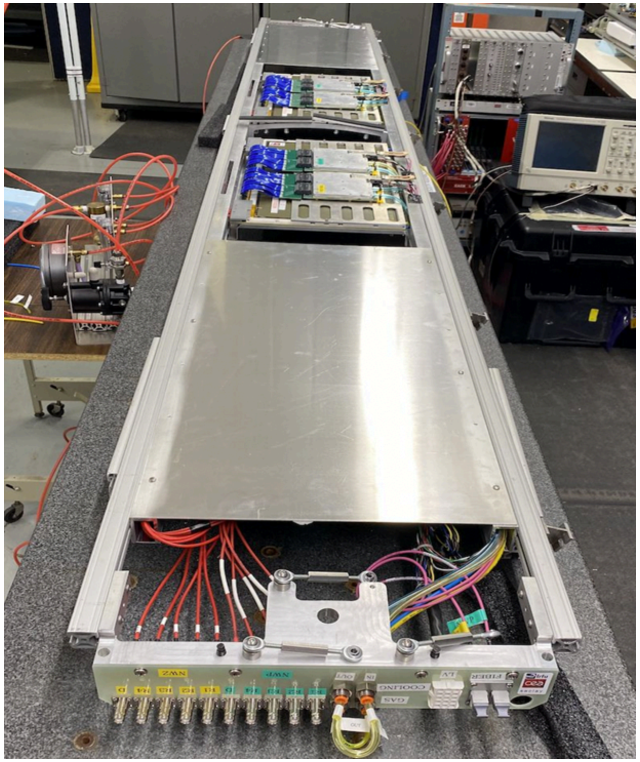


First signals

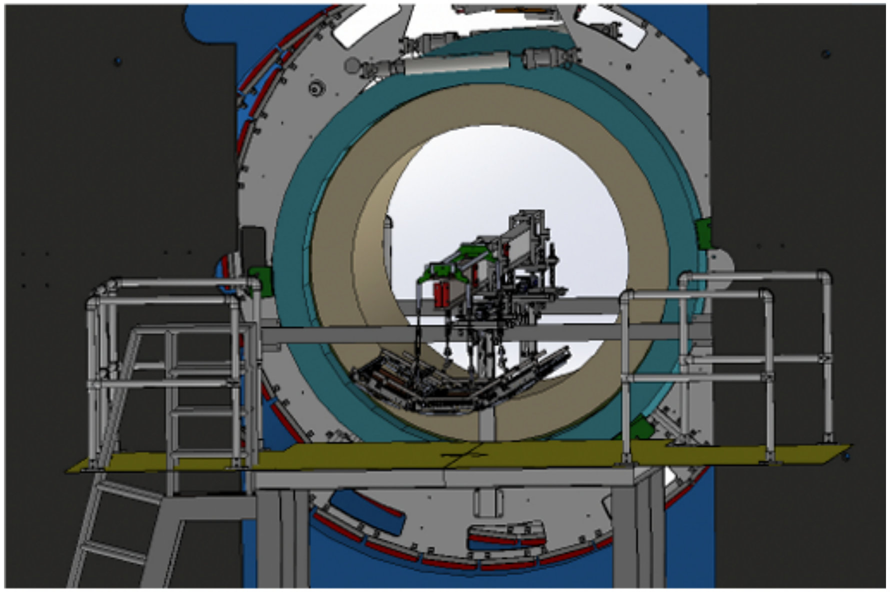


INSTALLATION ON LADDERS @ BNL

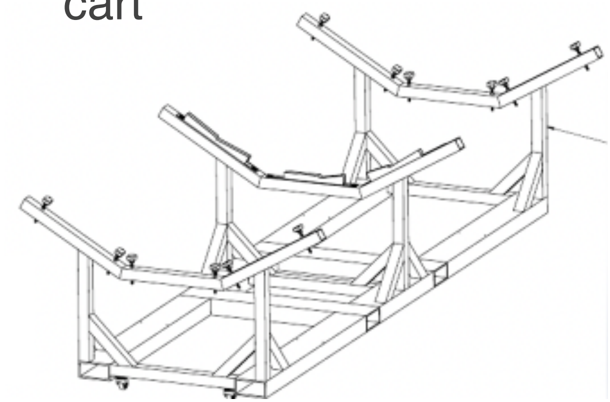


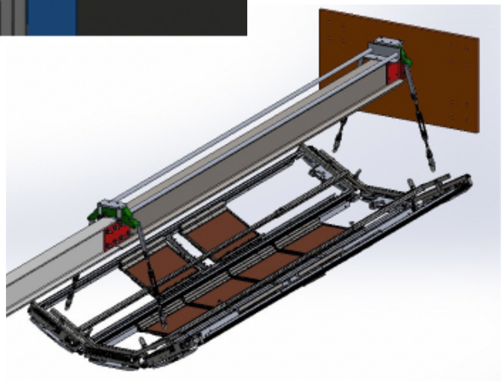


Insertion in sPHENIX in December…



Transportation cart

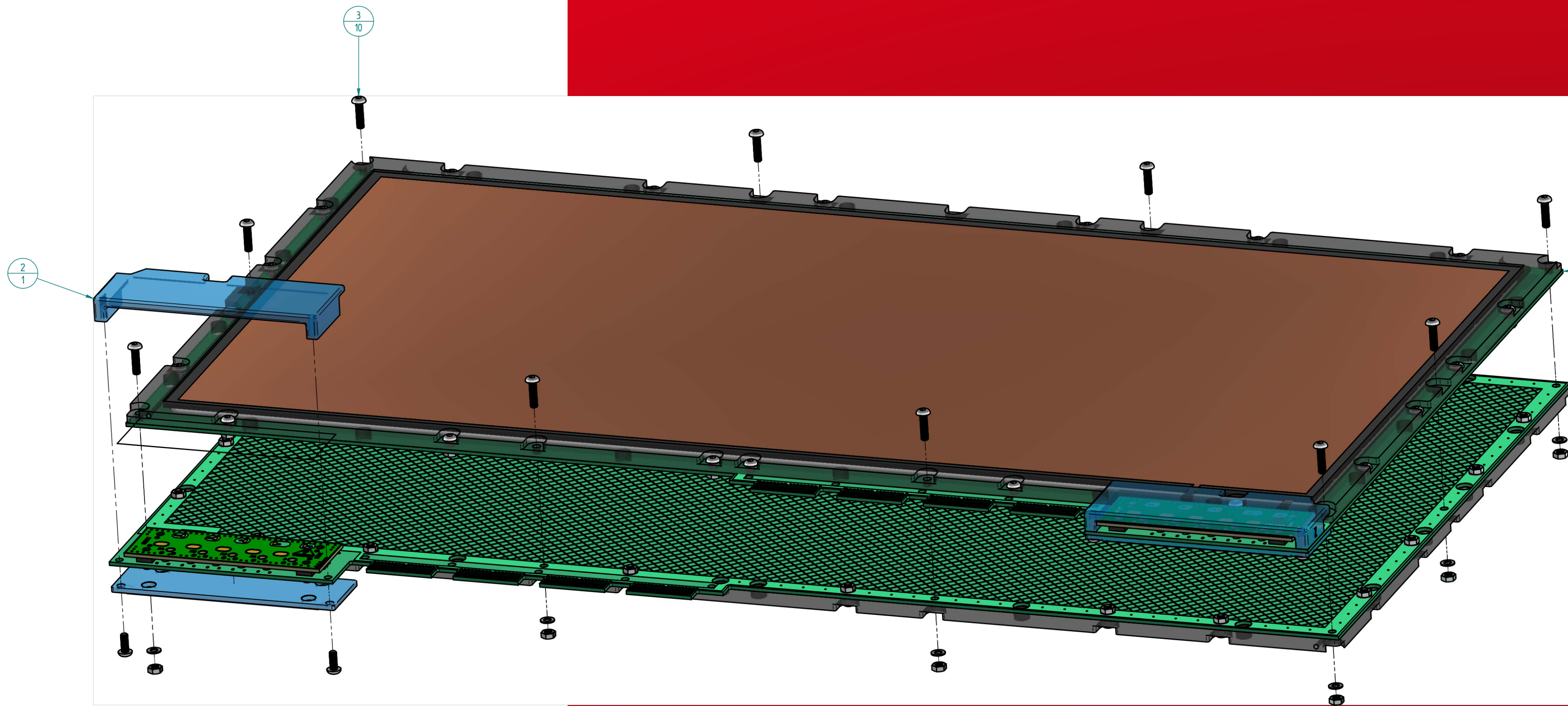


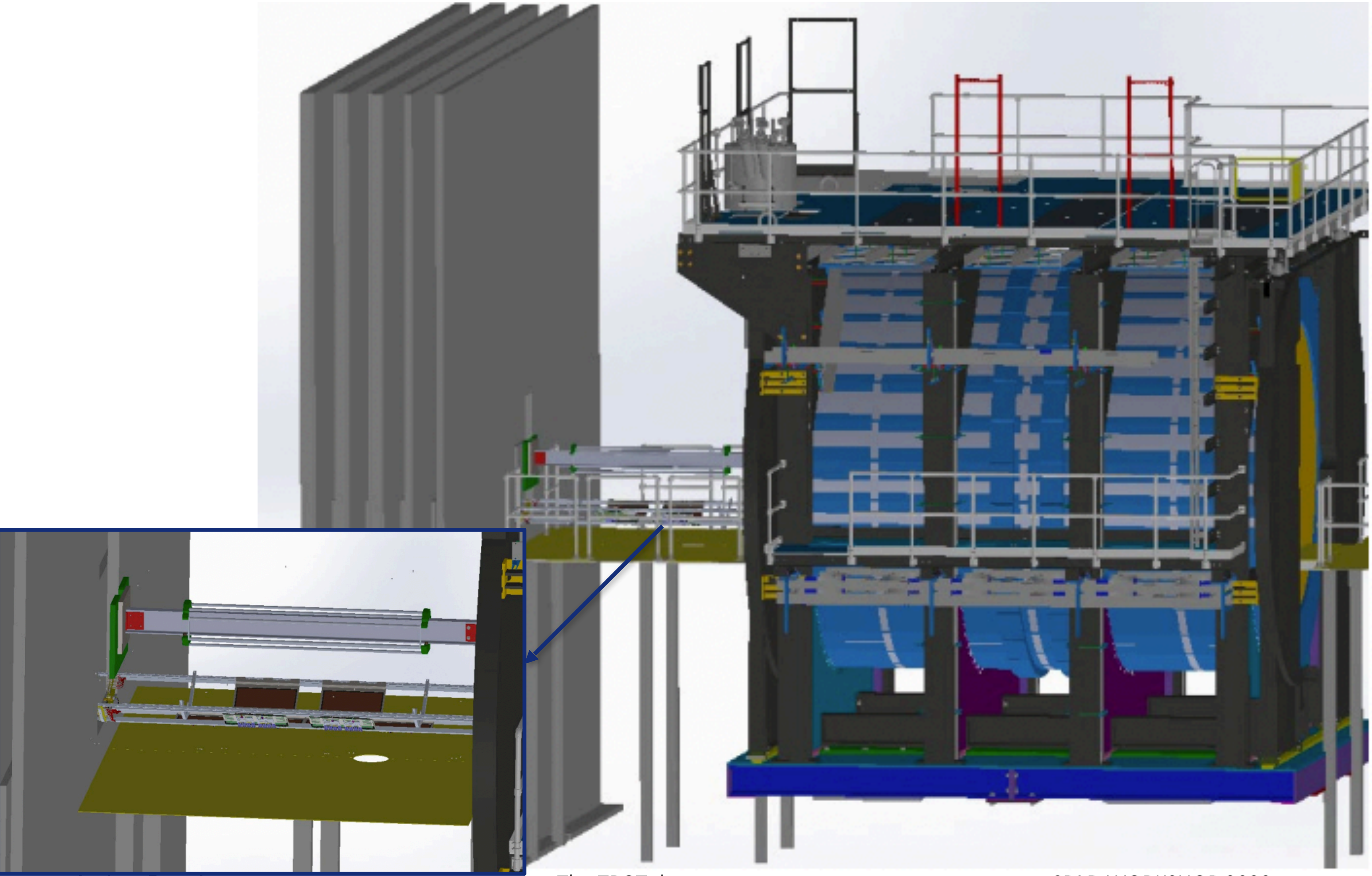


Followed by testing and commissioning!

Thank you for your attention

THANK YOU FOR YOUR ATTENTION

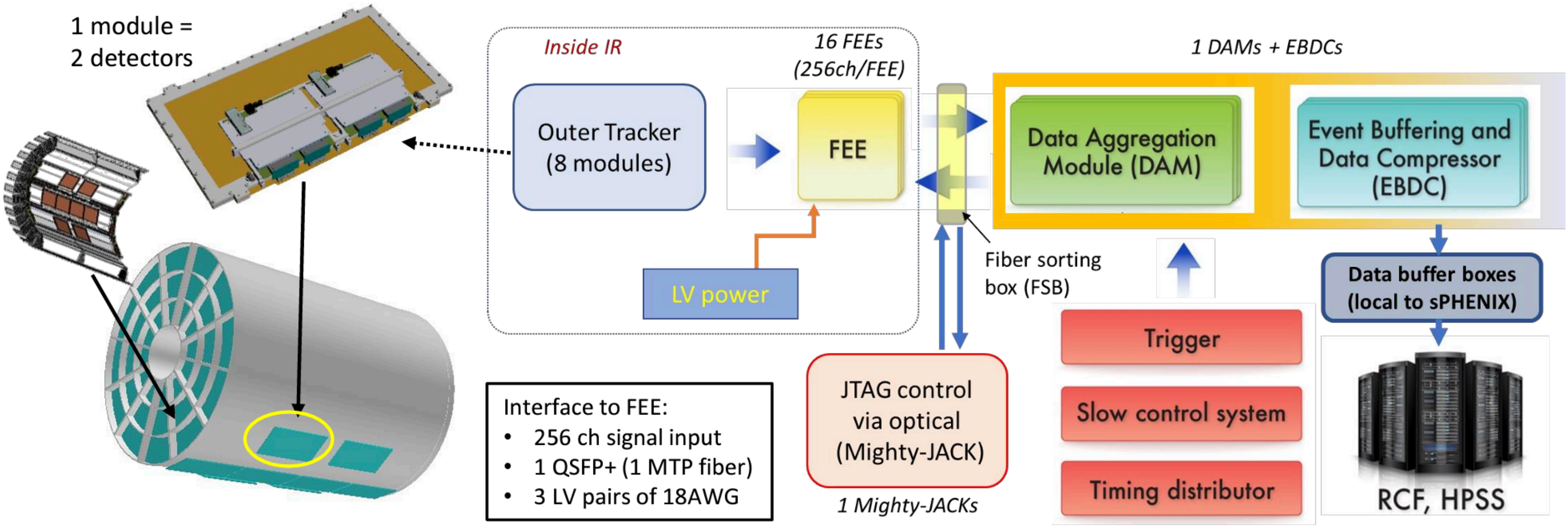




[BACK-UP] READOUT WITH SAMPA

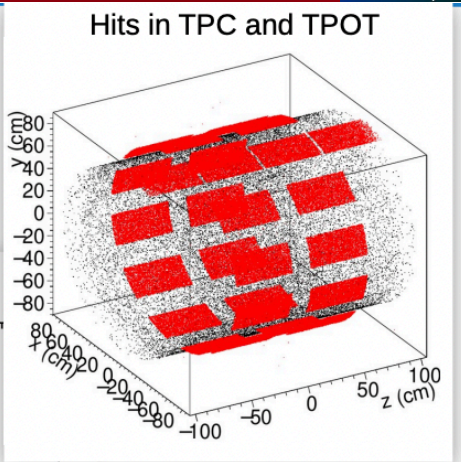
Readout scheme is the same as the one for TPC

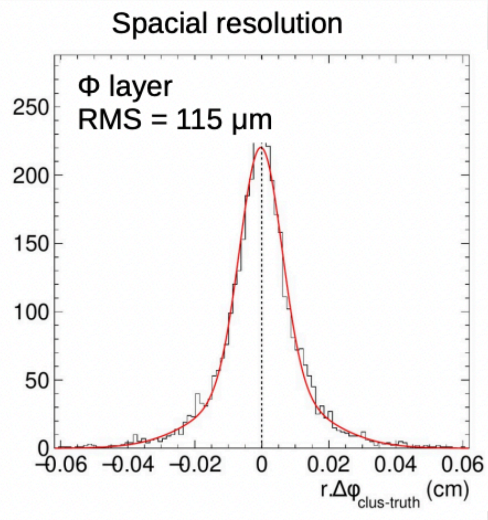
- Digitize analog signal from the detector, and send them to backend electronics (DAM) via optical cable
- 2 FEEs (512 channels) per module, 16 FEEs in total (vs 624 FEEs for the TPC), 1 DAM+EBDC
  - **Input capacitance (C_{det}) per channel (or strip): 150-200pF (vs 18pF for the TPC)**
- 1 JTAG control of FEE over optical cards (Mighty-JACK cards with fiber sort-out-box)

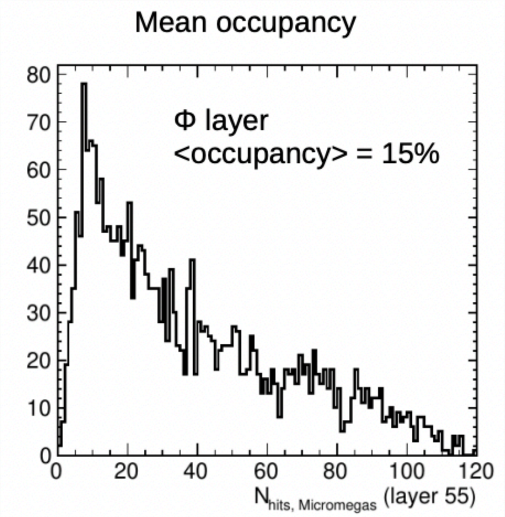


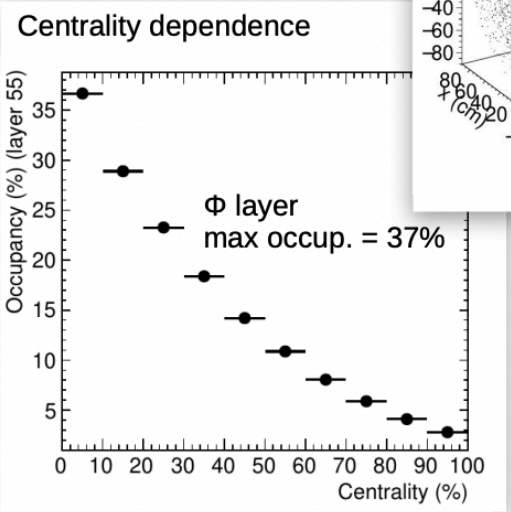
[BACK-UP] Occupancy TPOT

- Realistic description of the bare detector in sPHENIX GEANT4 simulation
- Complete integration in sPHENIX tracking
- First algorithm in place to estimate and correct for time-averaged distortions



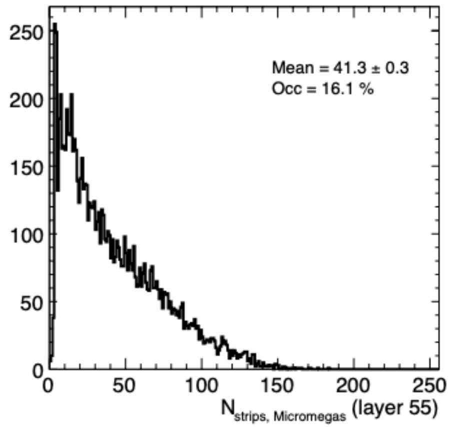


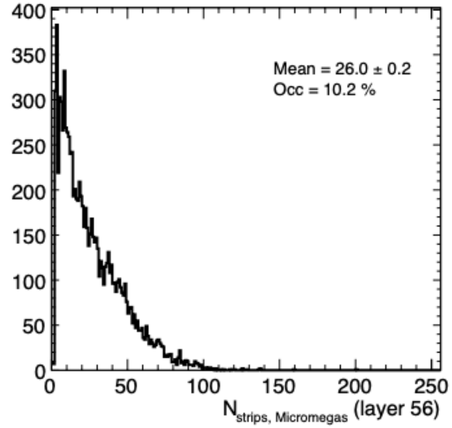


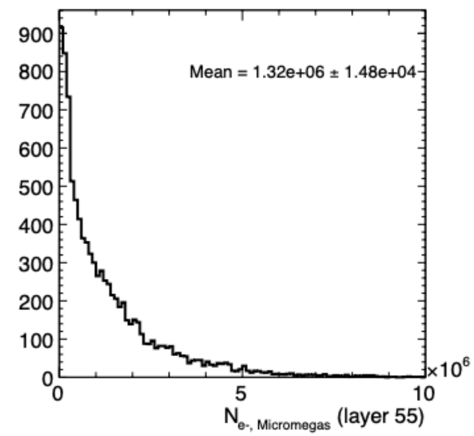


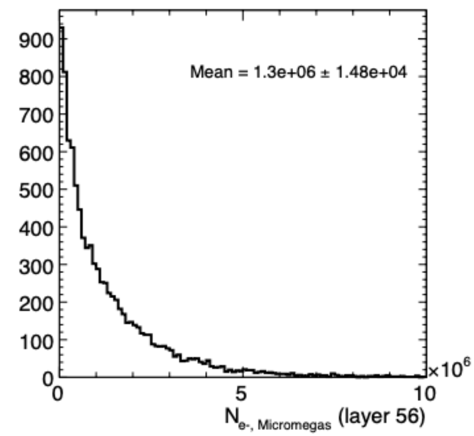
- RMS = 115µm probably too optimistic expect rather 200µm in Φ and 300µm in z
- High occupancy should not be a problem for the detector nor FEE, tracking can handle it

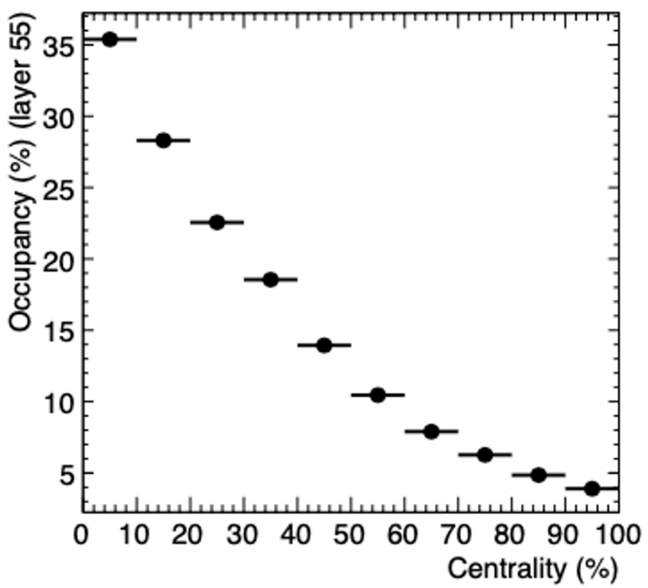
[BACK-UP] OCCUPANCY TPOT

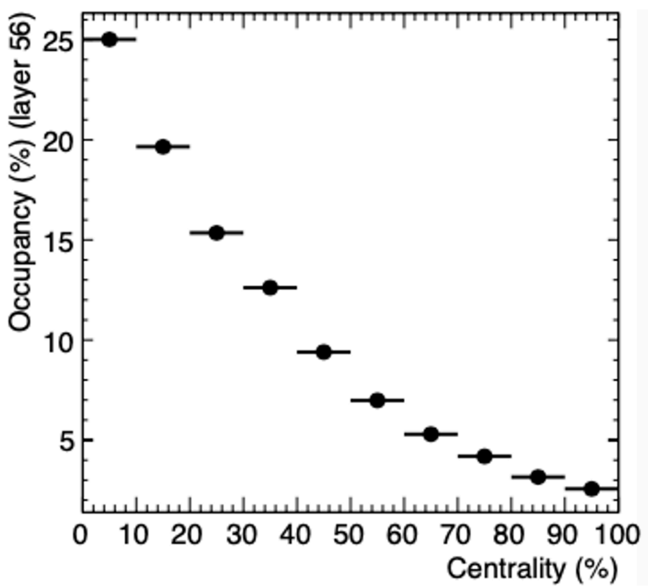






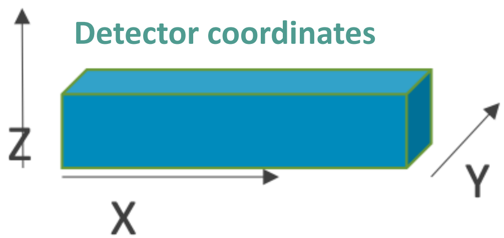


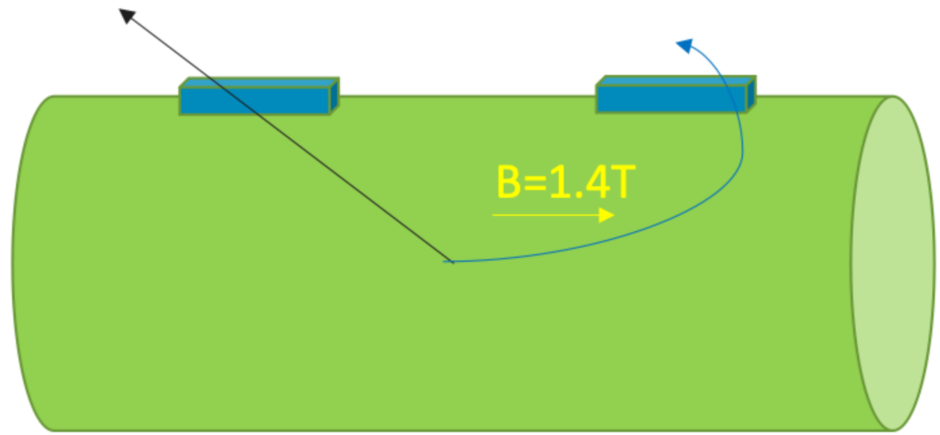




Angle de Lorentz

$$\tan(\theta_L) = \omega\tau = \frac{v_D B}{E}$$

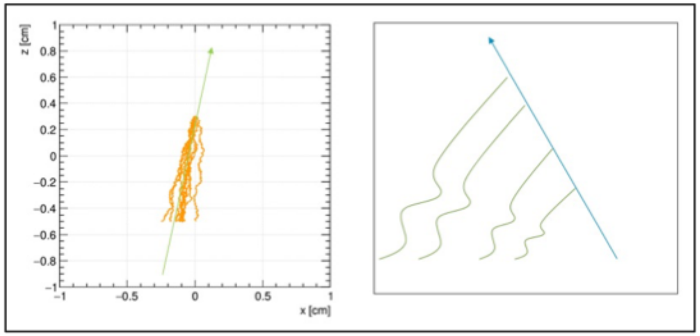




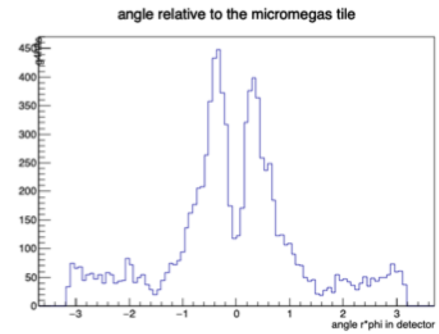
Donc B selon Xdet
=> Lorentz angle selon Ydet

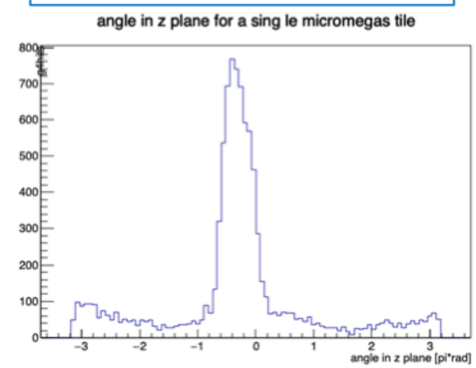
Angle R_Phi = ZY
=~ polarité de la particule

Angle Z = ZX
=~ coté de la TPC



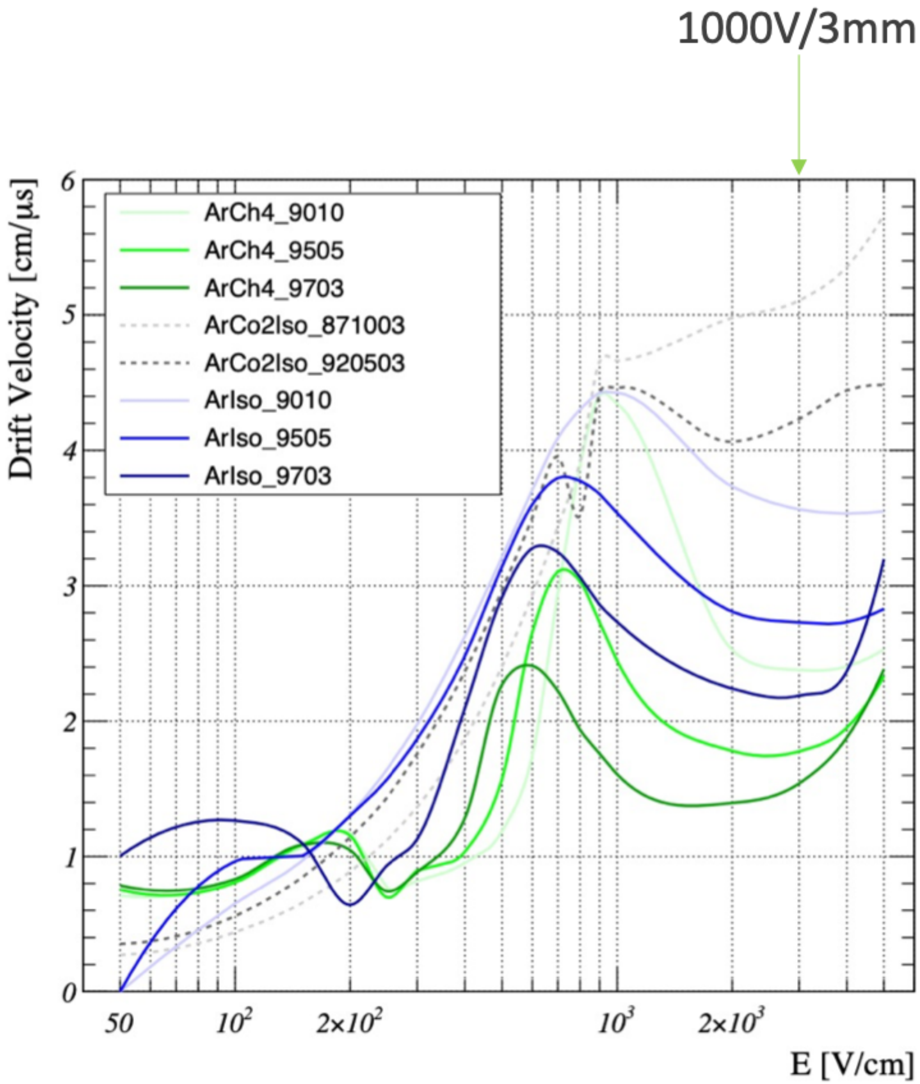
Effect of Lorentz angle along Y

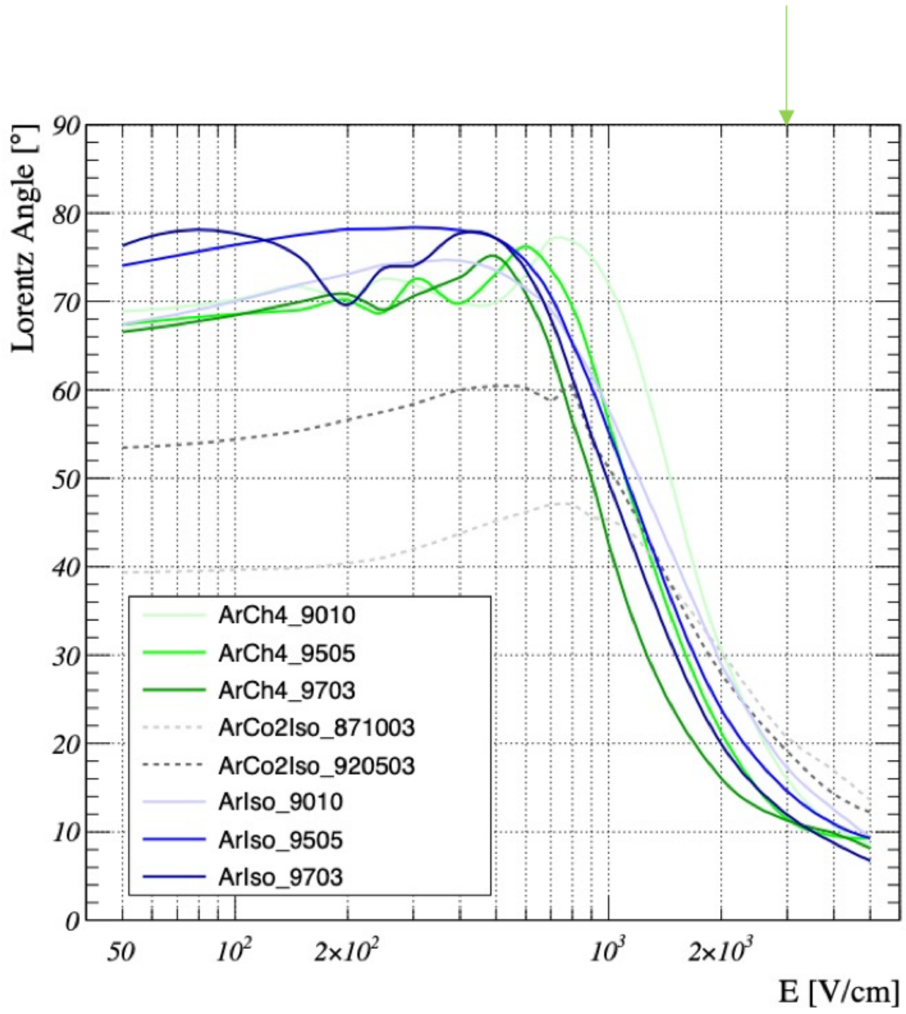




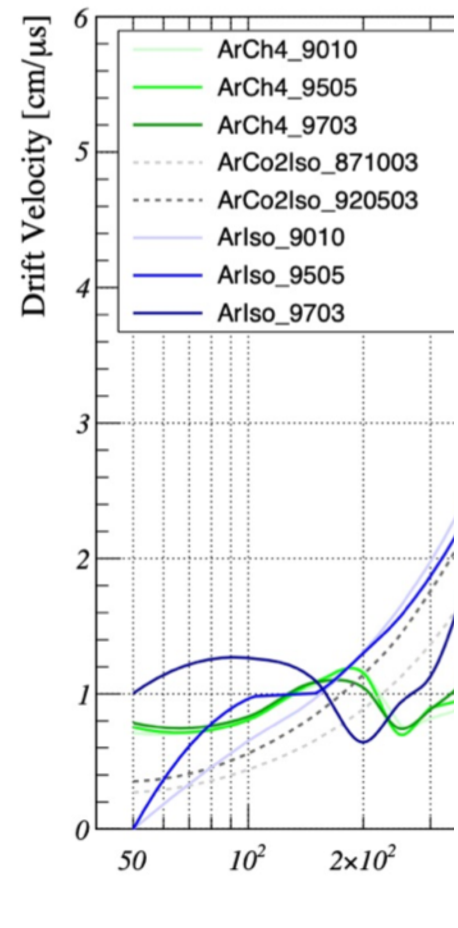
→Gas with low drift velocity at high E

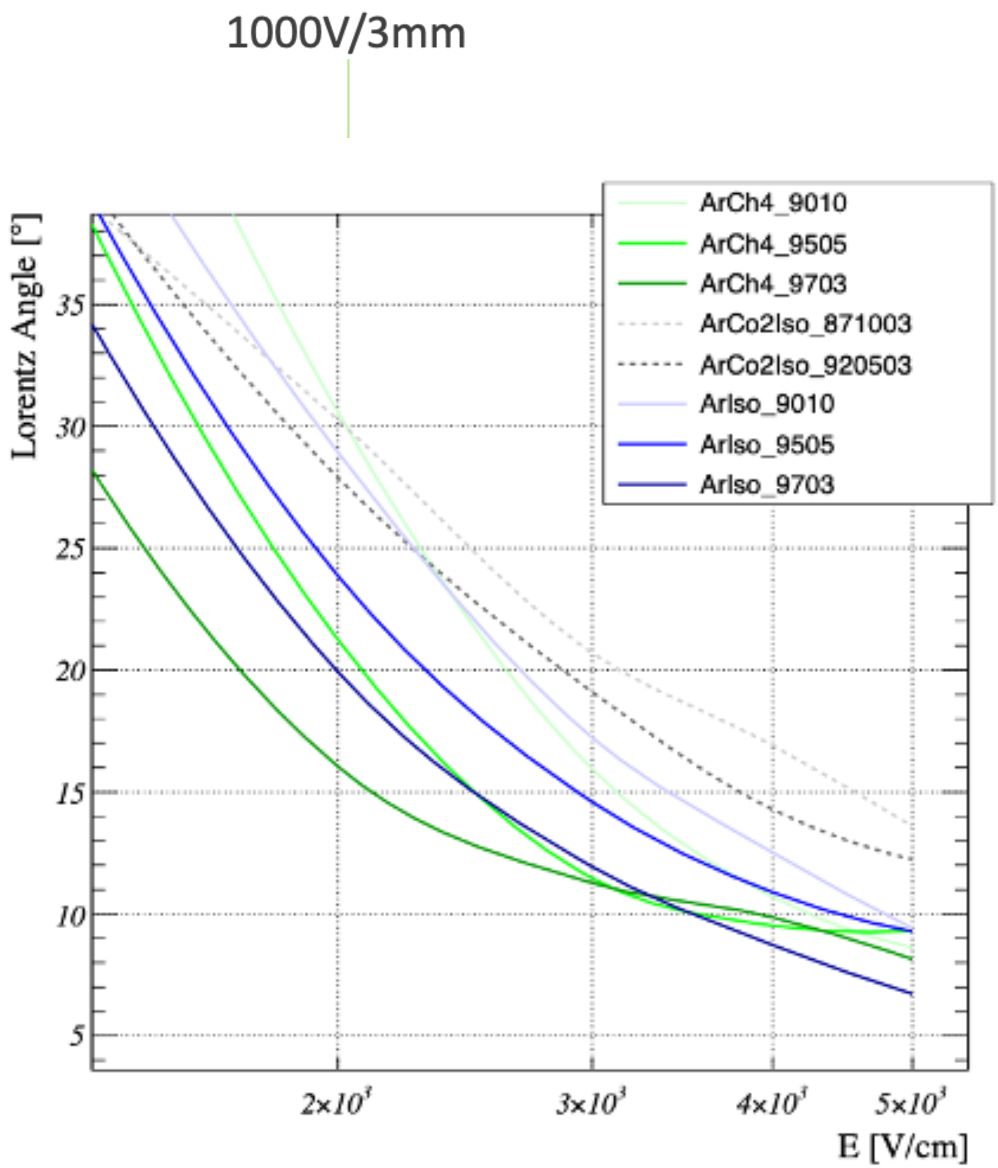
[BACK-UP] Gas choice

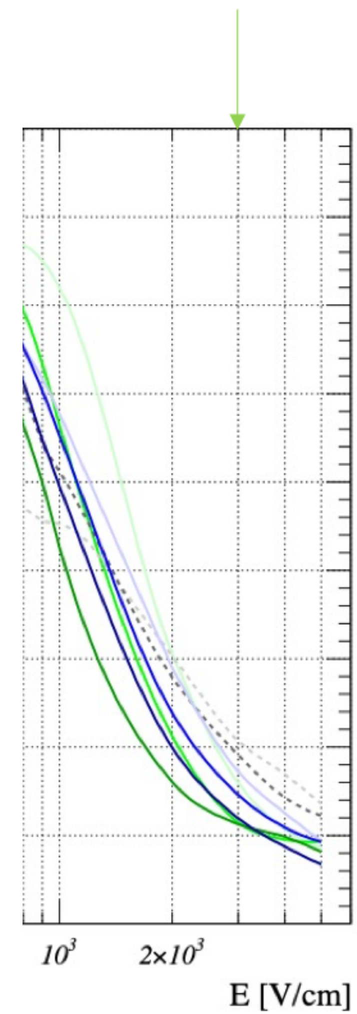




[BACK-UP] GAS CHOICE

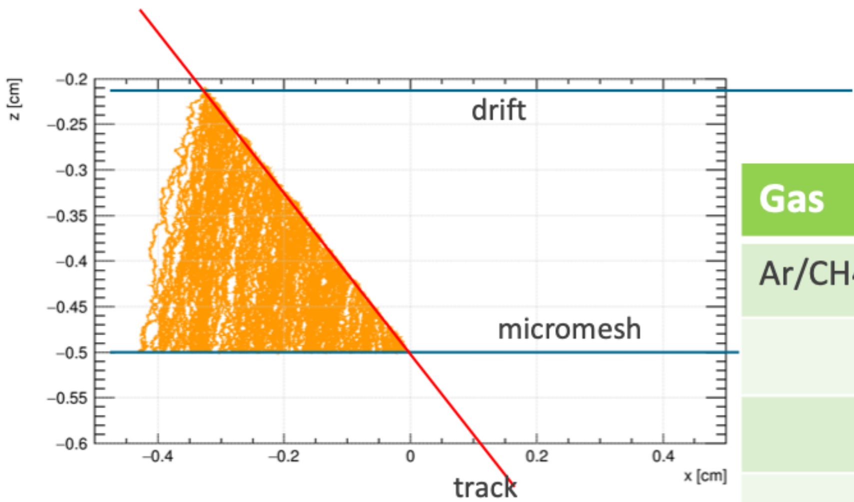






[BACK-UP] SIMULATIONS

Distributions from sPHENIX simulations + fit for MC



Gas	Condition		Std Dev (µm)
Ar/CH4 90/10	B=1.4T, E=1kV	X/Y	400/300
	1mm drift	X/Y	300/300
	Angle = 90deg	X/Y	200/300
	B=0T	X/Y	400/300
	B=OT Angle=90	X/Y	180/180
Ar/Iso 90/10		X/Y	8320/2550

⇒ With right gas, B effect small, dominated by angle
⇒ ~400/300um diffusion at readout level