DE LA RECHERCHE À L'INDUSTRIE

cea

sPHENIX and EIC tracker development

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RD51 collaboration meeting 15 of June 2021

Irfu

Outline

- EIC introduction
- Development to lower radiation length X_0 of micromegas
- Zigzag readout R&D for MPGD
- TPOT : sPHENIX TPC Outer Tracker monitoring with Micromegas

Electron Ion Collider (EIC)

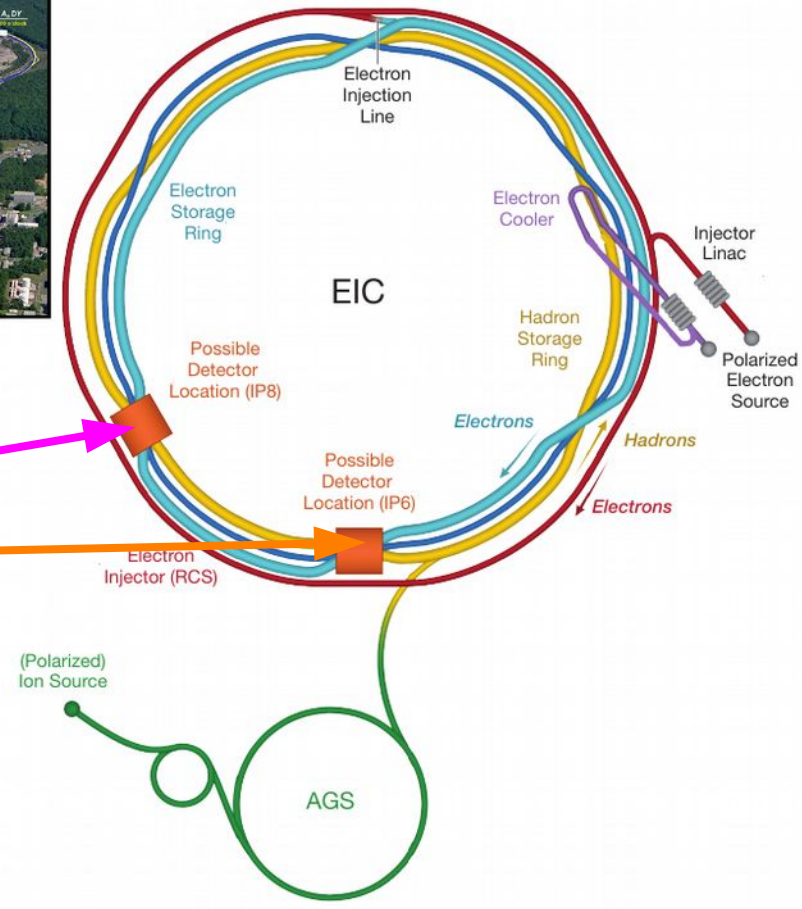
Brookhaven National Laboratory, NY, USA
Two polarized beams:

- **Electron** beam: 5-20 GeV
- **Ion** beam : 40-250 GeV
- e+p center-of-mass : 20-140 GeV
- Luminosity : 10^{33}-10^{34} $cm^{-2}s^{-1}$

Broad nuclear and hadron physics program :

- Nucleon structure, QCD, hadronization, spin physics…

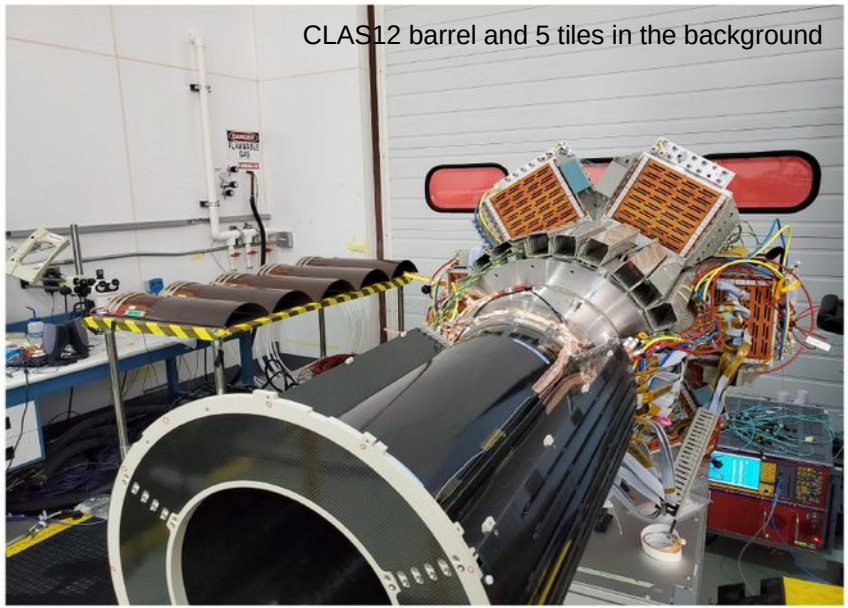
Two experiments located at **IP8**/**IP6**
Construction in 2025, **expected first beam 2030**
Today: CD-1 stage → targeting R&D starting now

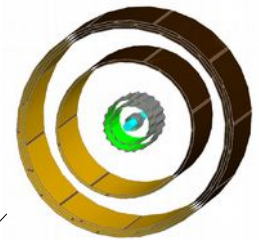


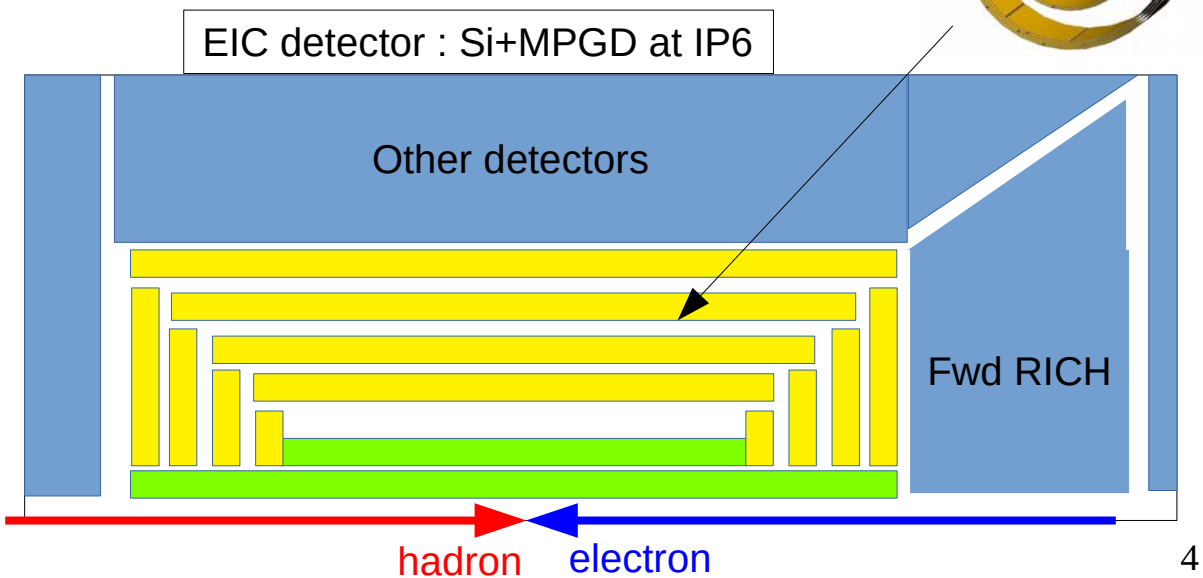
EIC : Proposal of a Micromegas tracker

Cylindrical tracker at CLAS12 (JLAB)
- 6 cylindrical Micromegas layers
- ~4m², 24k channels readout
- **Low momentum proton**
  → 0.4% of X_0 per layer

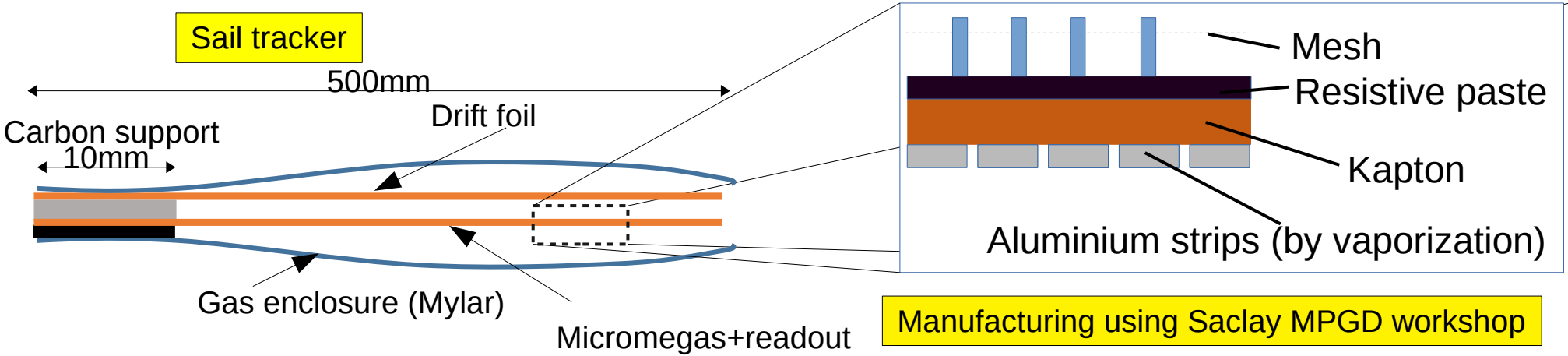
- **EIC → low momentum electrons**
- Require X/X_0 < 5% overall, **3% max** for 6 layers MPGD
- Micromegas as **Barrel**
- Barrel baseline: **5 Silicon layers + 6 Micromegas layers**
- Required **2D readout** (diamond like from zigzag


CLAS12 barrel and 5 tiles in the background





R&D on low X0 : Sail Tracker



Manufacturing using Saclay MPGD workshop

Challenging goal: Factor 10 from CLAS12 (0.4% → 0.04% X0)

Year	Barrel Micromegas Tracker (BMT)
2021	• Full simulation design • Stretch bulked Kapton demonstrator
2022	• Aluminium based strips • Thin aluminium mesh manufactured with laser ablation • Design of cylindrical Micromegas tracker structure within EIC detector
2023	• Prototype of ultralight Micromegas construction • Cylindrical 2D readout Micromegas construction

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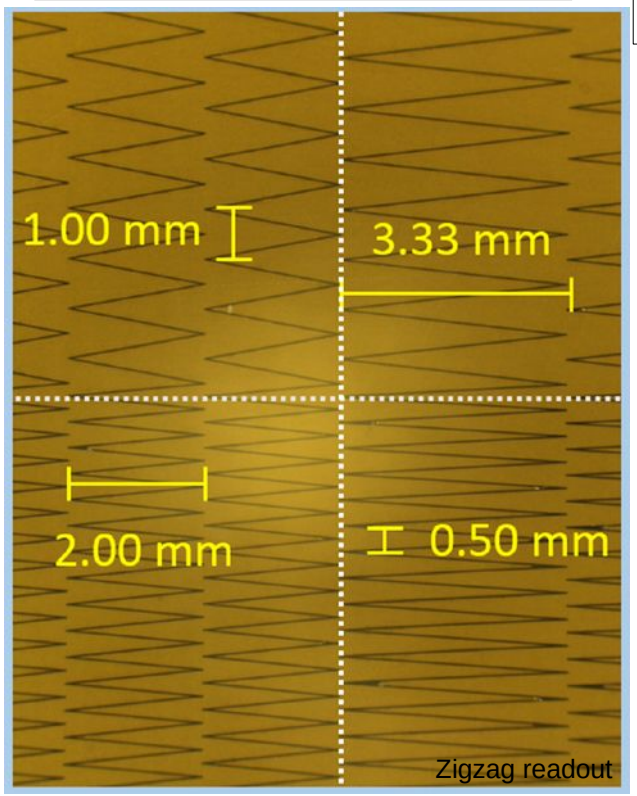
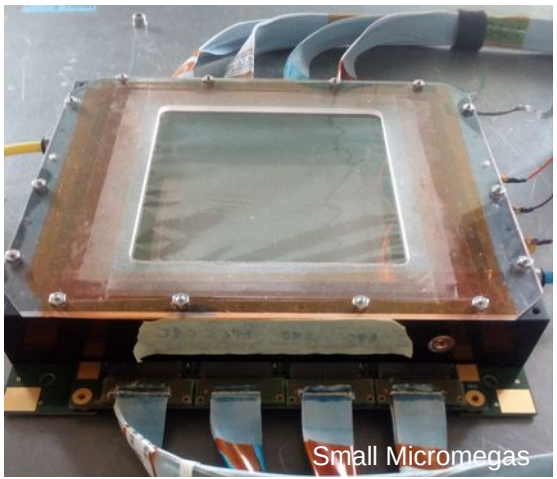
R&D : 1D zigzag readout R&D highlight

1. Zigzag patterns



2. 10x10cm² detectors with ~100 different patterns (**2019**)

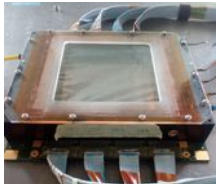


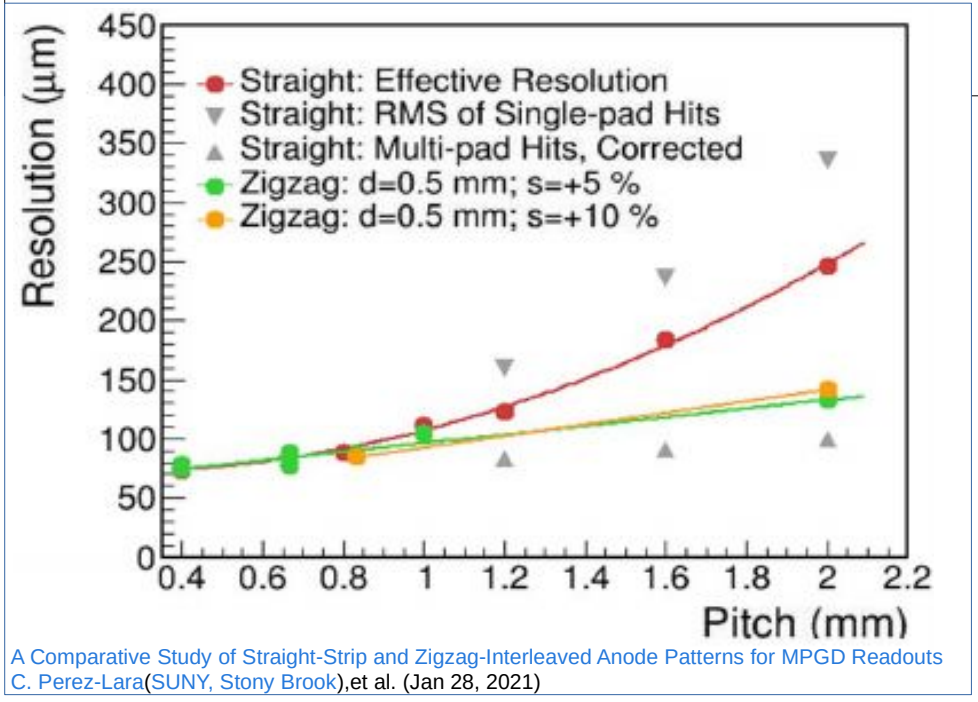
3. 40x40cm² full size zigzag Micromegas (**2021,** test beam ongoing). **Big Zigzag (BIZ)**.

This work was supported by the U.S. Department of Energy under Prime Contract No. DE ACO2-98CH10886

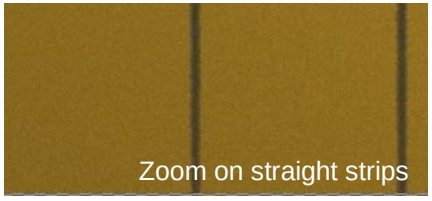
R&D LDRD : 1D zigzag readout results (test beam 2019) for Micromegas

- FNAL test beam **2019**:
- 10x10cm^2 active area
- 100 different zigzag patterns
- Ar:Iso(9505)
- Amplification E field of 31kV/cm

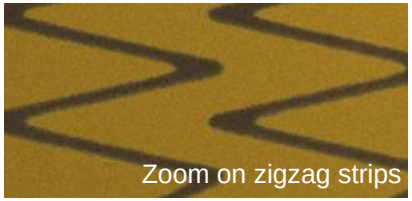




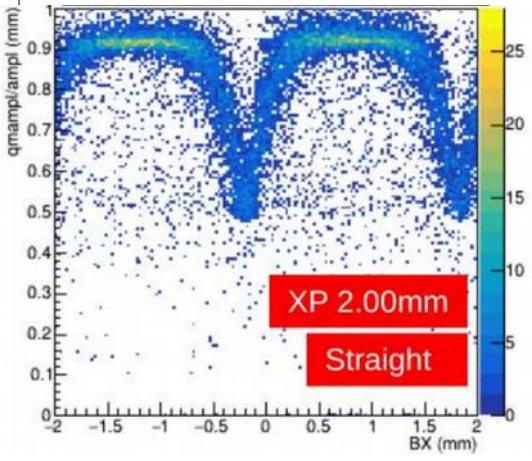
A Comparative Study of Straight-Strip and Zigzag-Interleaved Anode Patterns for MPGD Readouts
C. Perez-Lara(SUNY, Stony Brook),et al. (Jan 28, 2021)

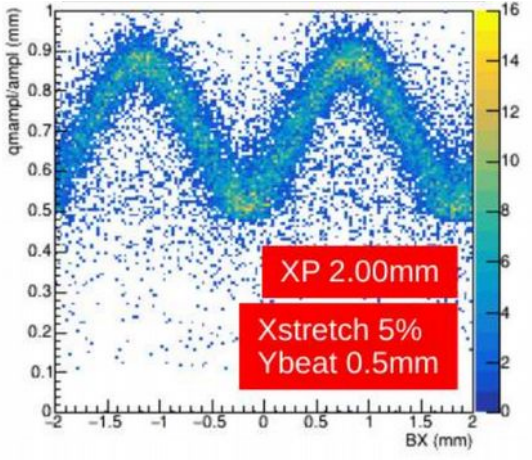


Almost no charge sharing for straight strips



Charge sharing improved for zigzag pattern





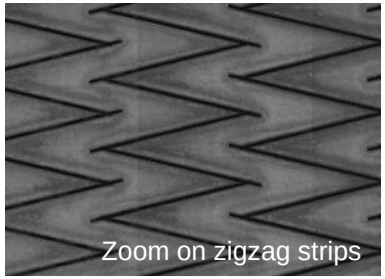
Max charge per total charge of cluster, along the strips

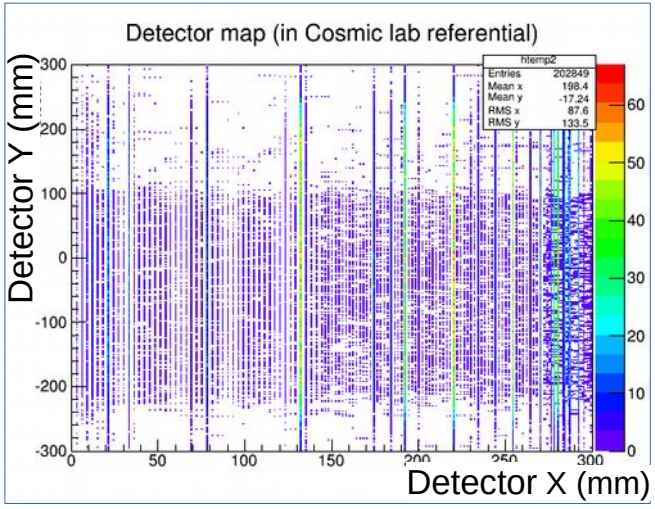
Spatial resolution less dependant wrt the pitch
Improvement for large pitch : 150µm with 2mm pitch

BIZ characterisation

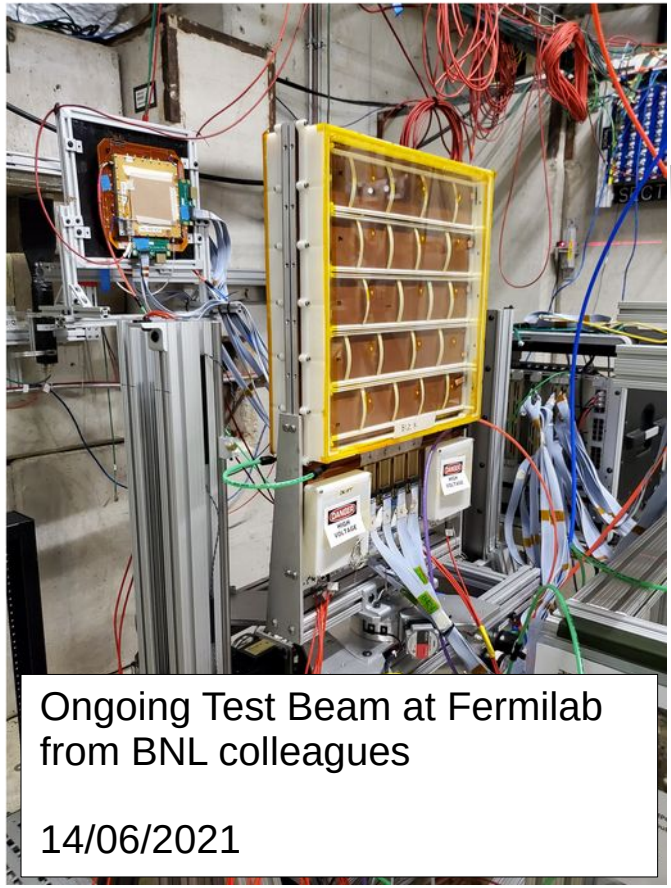
40x40cm BIZ detectors → capactiance test

Much larger capacitance than straight strips





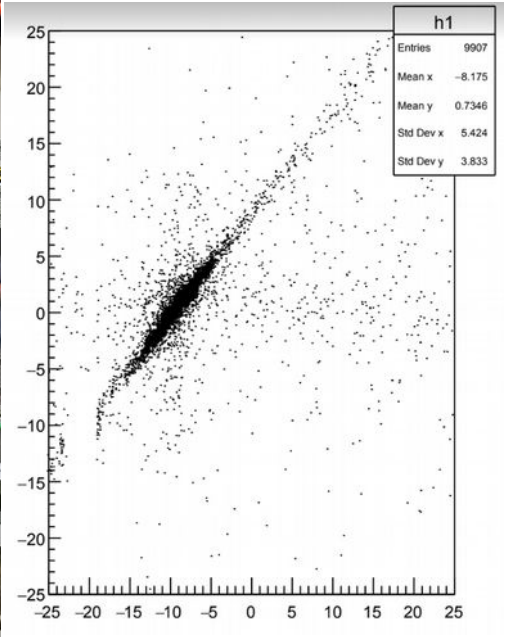
BIZ cosmic map



Ongoing Test Beam at Fermilab from BNL colleagues

14/06/2021

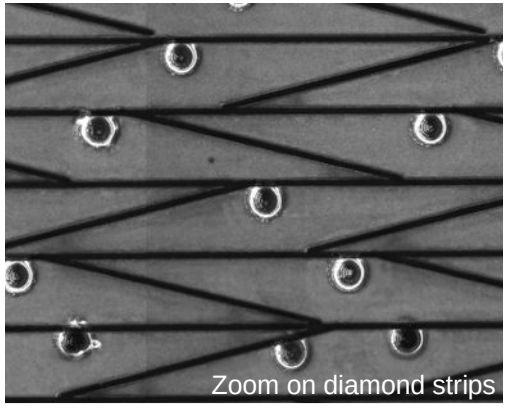
PRELIMINARY RESULTS

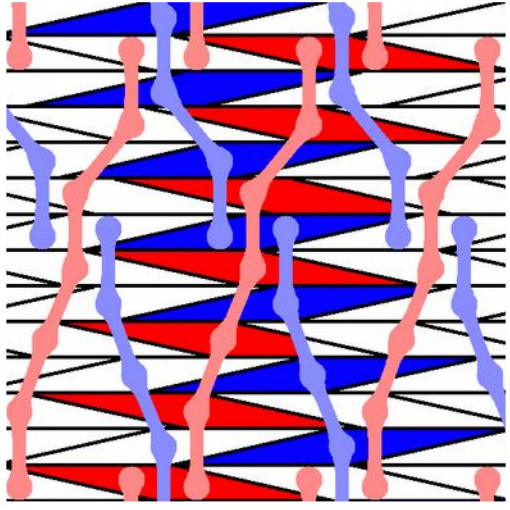


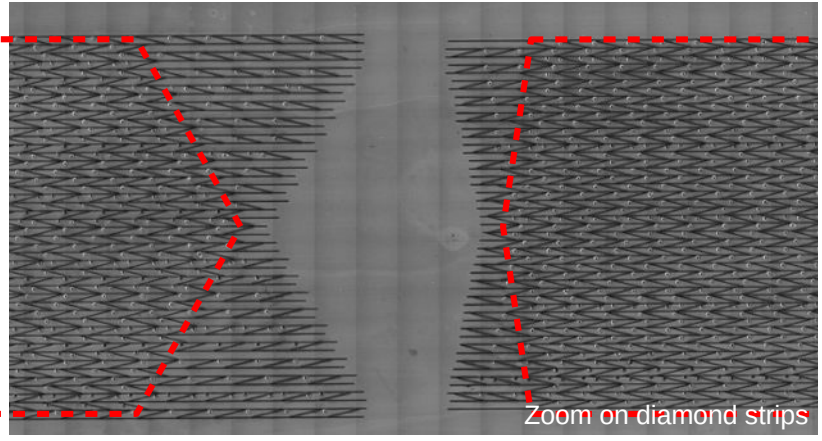
Tracks correlation

R&D LDRD : 2D patterns (u,v) readout

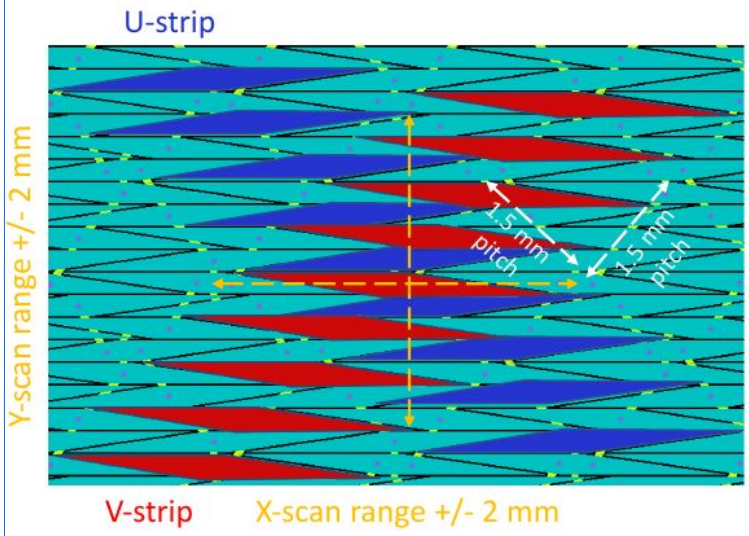
- 1x1cm² patterns on 10x10cm² detector
- Laser etched
- Different settings (angle, pitch…)
- Currently tested with proton beam at Fermilab







4-GEM tested with X-ray gun at BNL



- Residuals ~75µm
- Pitch of 1.5mm

Presented at TIPP 2021 by Alexander Kiselev

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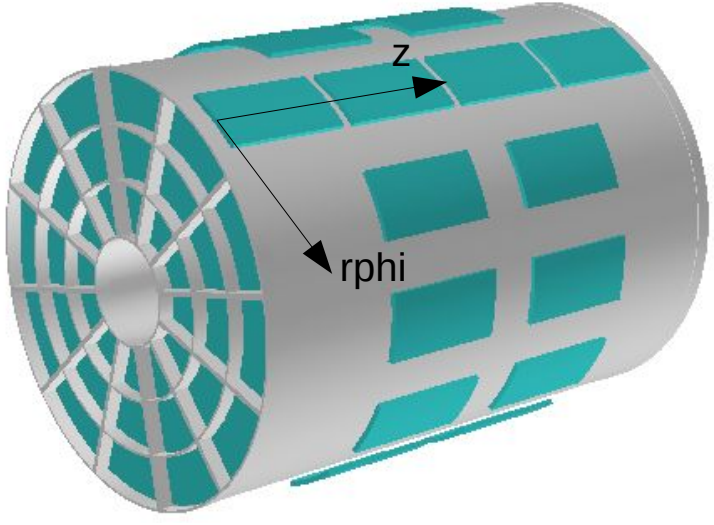
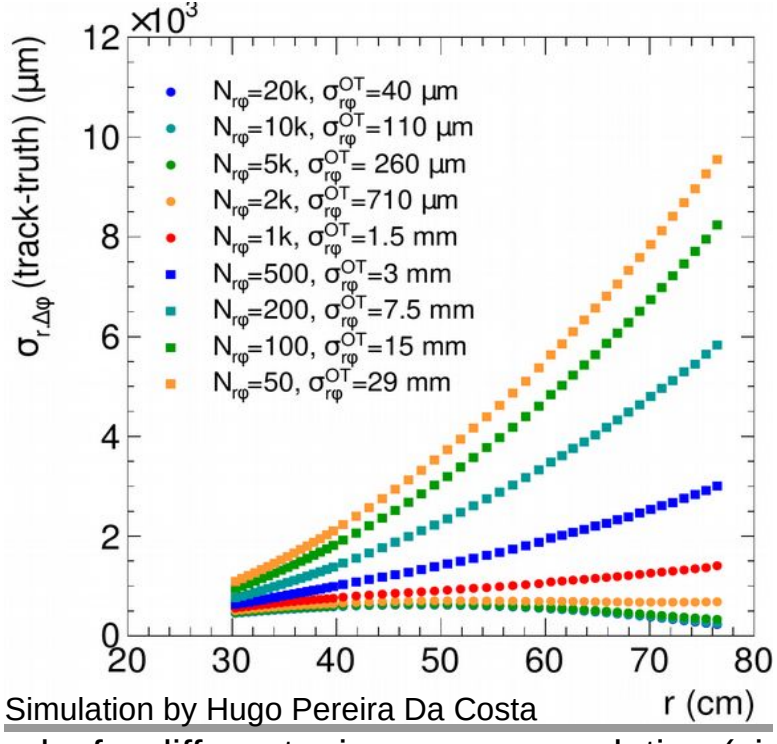
- Zigzag readout R&D for MPGD
- TPOT : sPHENIX TPC Outer Tracker monitoring with Micromegas

Sphenix : collaboration with BNL for monitoring

- Study the QGP in 200 GeV Au-Au collisions at RHIC
- Central tracking with TPC
- Distortions in TPC due to space charge
- Laser and digital current correction
- Monitoring with micromegas layer outside of the TPC
- 4 micromegas along drift coordinate
- 22 Micromegas along rPhi
- 50kHz collision rate → chalenging environment



Influence of Micromegas resolution on extrapolated position resolution in the TPC

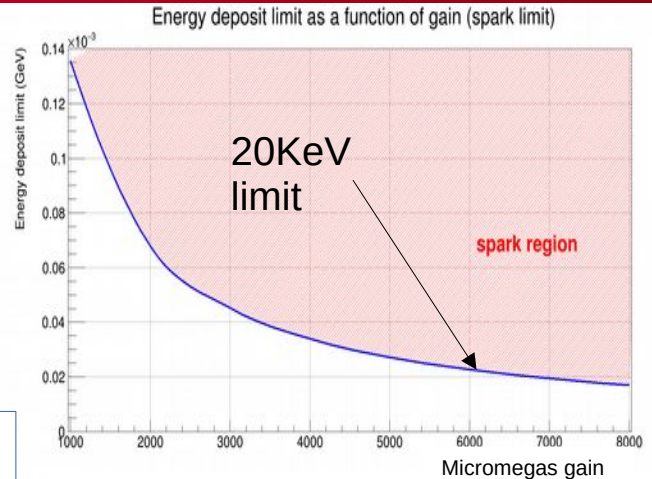


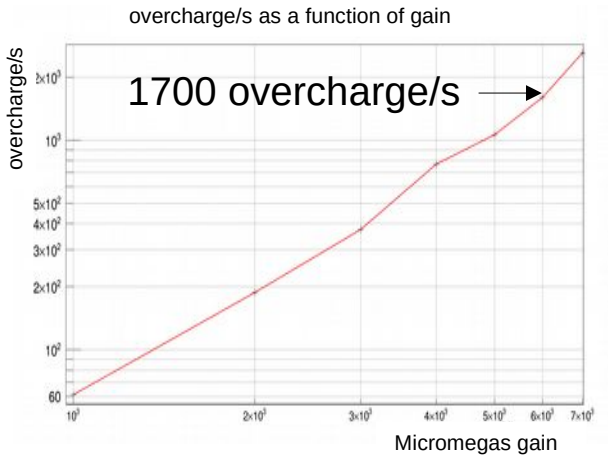
Simulation by Hugo Pereira Da Costa

Resolution of tracks for different micromegas resolution (simulation)
→ less than 500μm resolution requiered

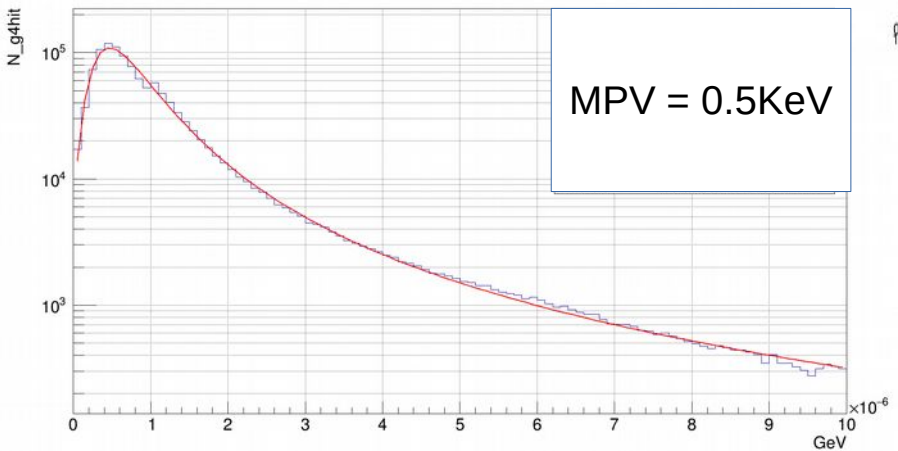
TPOT : estimation of potential sparks in micromegas

Charge density limit : Experimental*
limit of the electron density
= 2.10^9 e^-/mm^2
Proportional to gain and energy deposit





Energy deposit by G4hits in single micromegas layer



MPV = 0.5KeV

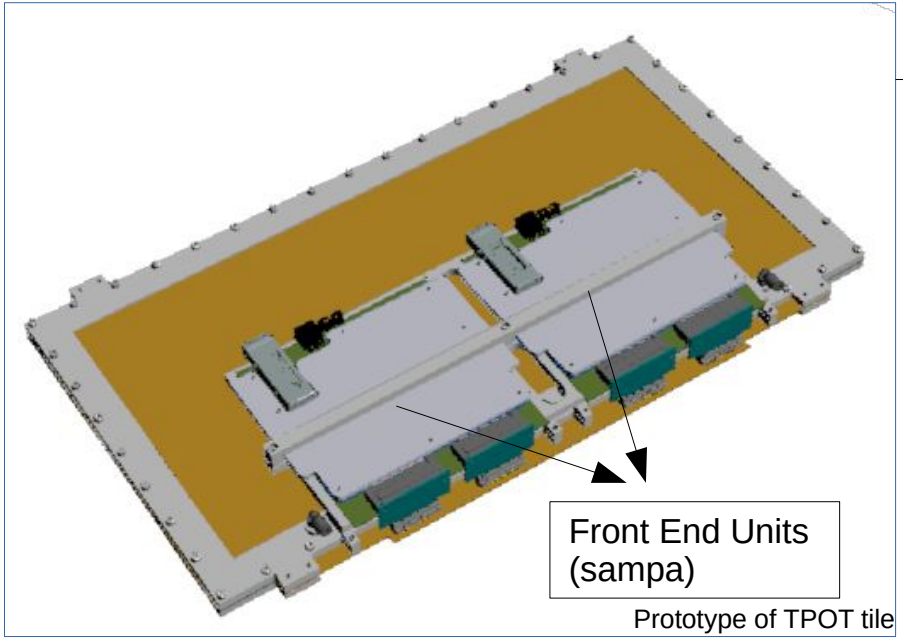
50k event/s, 7 particles/event,Gain of 6000 (SNR of 10)**

→ Resistive Micromegas required

** Origin and simulation of sparks in MPGD, S. Procureur et al, 2012, JINST 7 C06009*

***SAMPA Chip: the New 32 Channels ASIC for the ALICE TPC and MCH Upgrades,J. Adolfsson and al.*

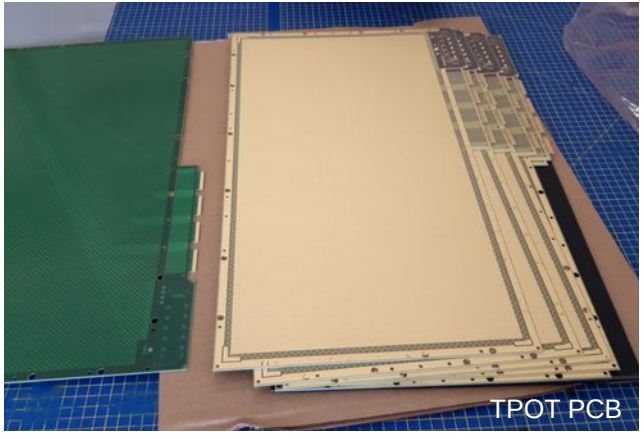
Sphenix : TPC Outer Tracker (TPOT) prototype

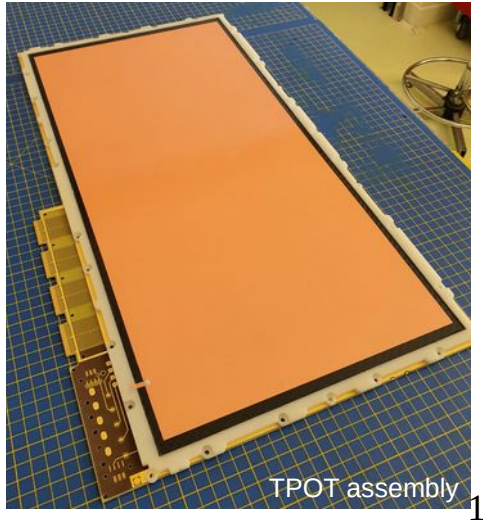


Prototype of TPOT tile

- **512x256mm** active area with 2 readout plane X/Y (1D)
- Strips of 1 and 2mm pitch
- 512 channels/detectors
- Expected resolution < 300µm
- Radiation length < 10% x_0
- 50kHz collision rate → resistive micromegas (next slide)

PCB delivered few days ago for prototype →


TPOT PCB


TPOT assembly

Conclusion

EIC :

→ **CLAS12**, expertise for cylindrical Micromegas tracker

→ **Low X_0 detector** with Kapton-based support

→ **2D readout** based on zigzag (diamond)

Zigzag readout:

→ **150µm spatial resolution** for 2mm pitch

→ 2D being tested on small detectors

→ **full-size 1D detectors** being tested

→ next step: analysis of test beam and construction of full-size 2D

sPHENIX:

→ **TPOT**, a monitoring tracker

→ Prototypes to be soon assembled and tested

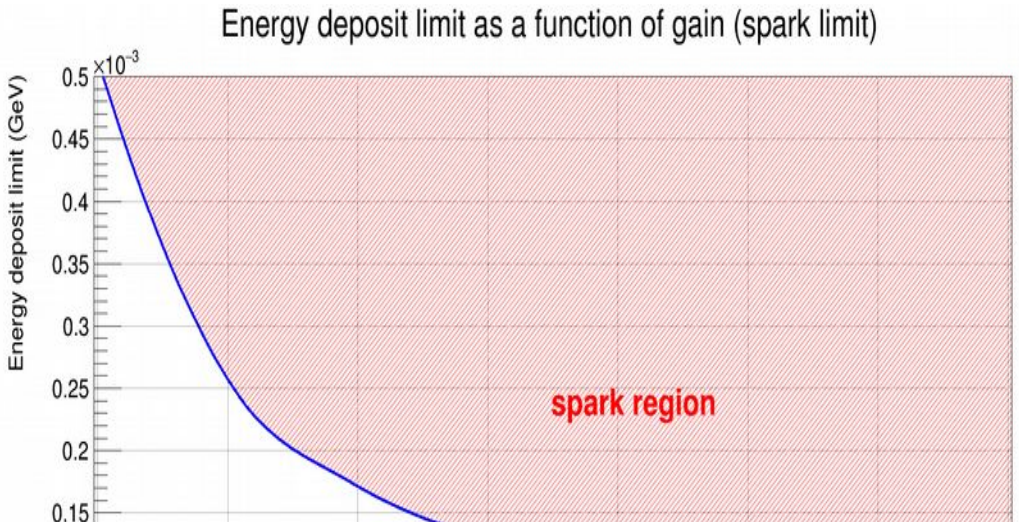
→ possible 52 resistive Micromegas detectors at CEA-Saclay MPGD workshop

Limits as a function of gain

Raether limit

Raether limit = 2.10^7 e^-

$$E_{dep} > \frac{w_i * 2 * 10^7}{Gain}$$

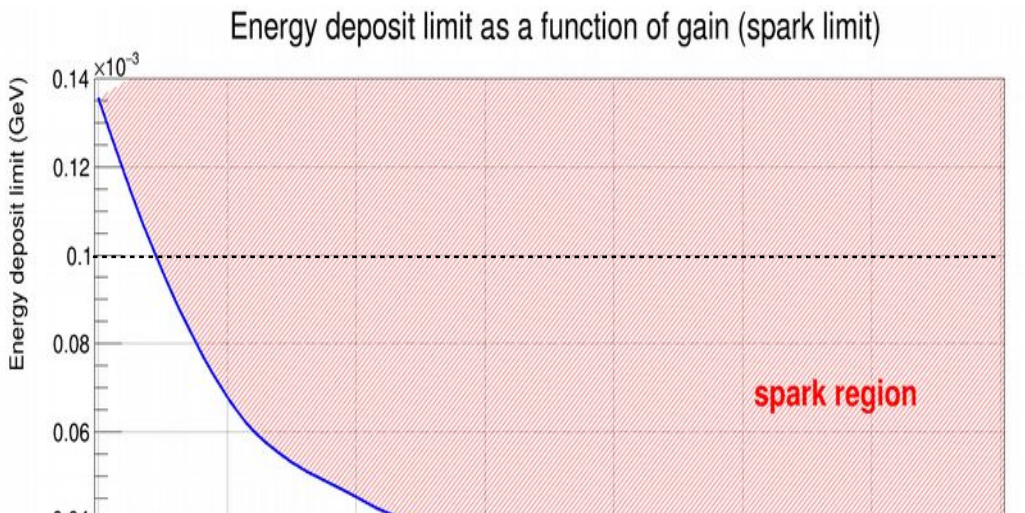


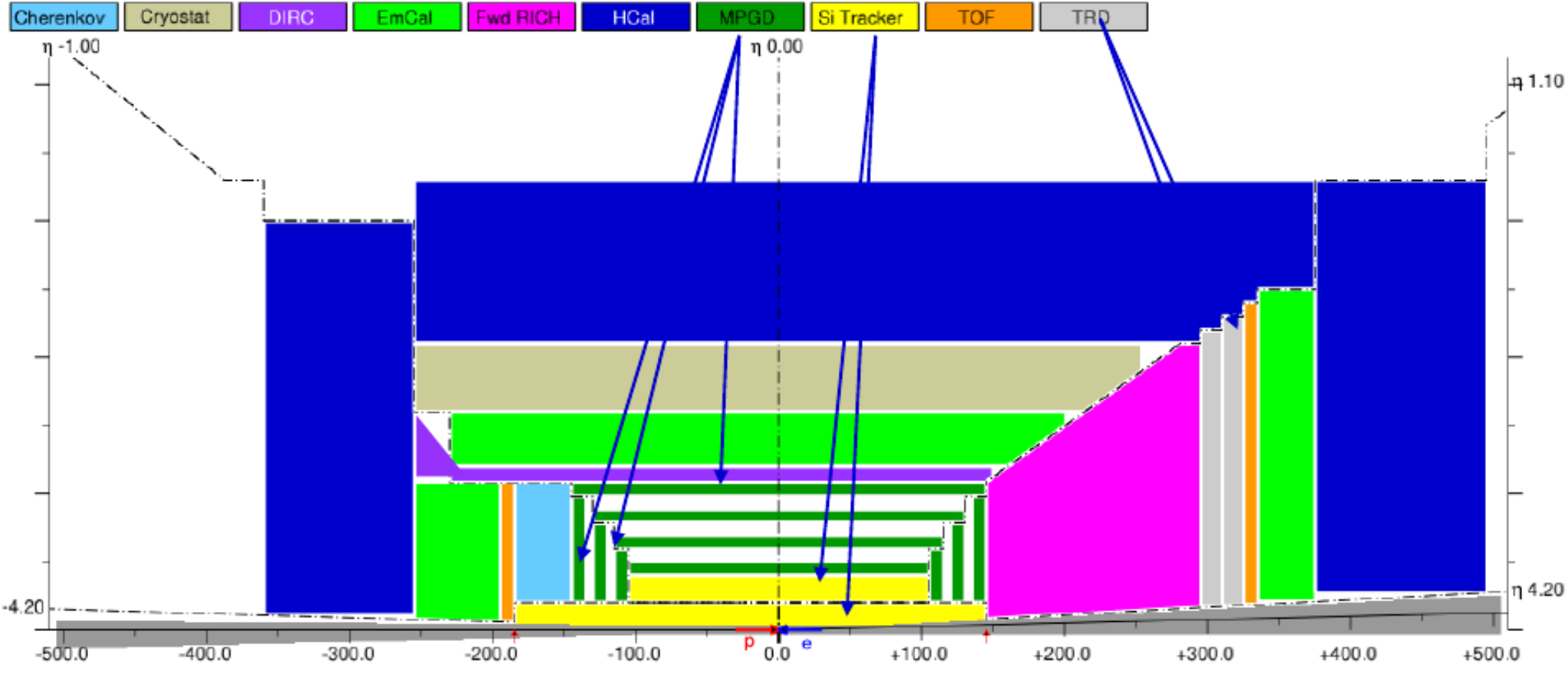
Charge density limit

Density limit = 2.10^9 e^-/mm^2

$$d_s = \frac{E_{dep}}{w_i} * Gain * \frac{4}{\pi * D^2}$$

$$D = diffusion * \sqrt{\frac{drift\ space}{2}}$$




Cherenkov
Cryostat
DIRC
EmCal
Fwd RICH
HCal
MPGD
Si Tracker
TOF
TRD
η -1.00
η 0.00
η 1.10
η -4.20
η 4.20
-500.0
-400.0
-300.0
-200.0
-100.0
0.0
+100.0
+200.0
+300.0
+400.0
+500.0
p
e

Electron Ion Collider (EIC) : 2 program

LDRD zigzag
2016-2021

- On readout pattern geometry (zigzag)
- Higher pitch without degrading performance
- Include Micromegas, GEM and µRWell
- Pronton Beam test at Fermilab

Tracker focus
2020 - now

- R&D on lowering X_0
- Zigzag resistive strip in micromegas