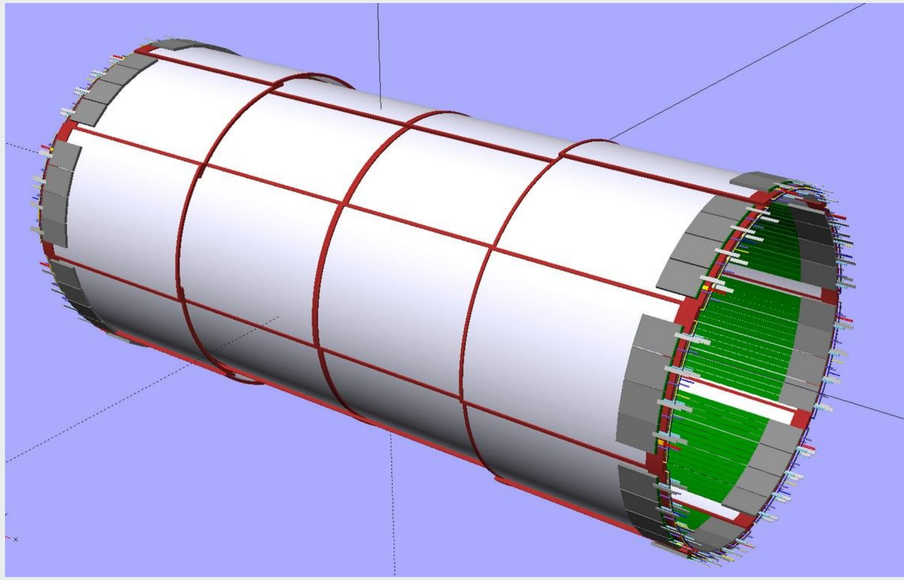
CyMBaL
Micromegas for EIC



Dylan Neff
CEA Saclay

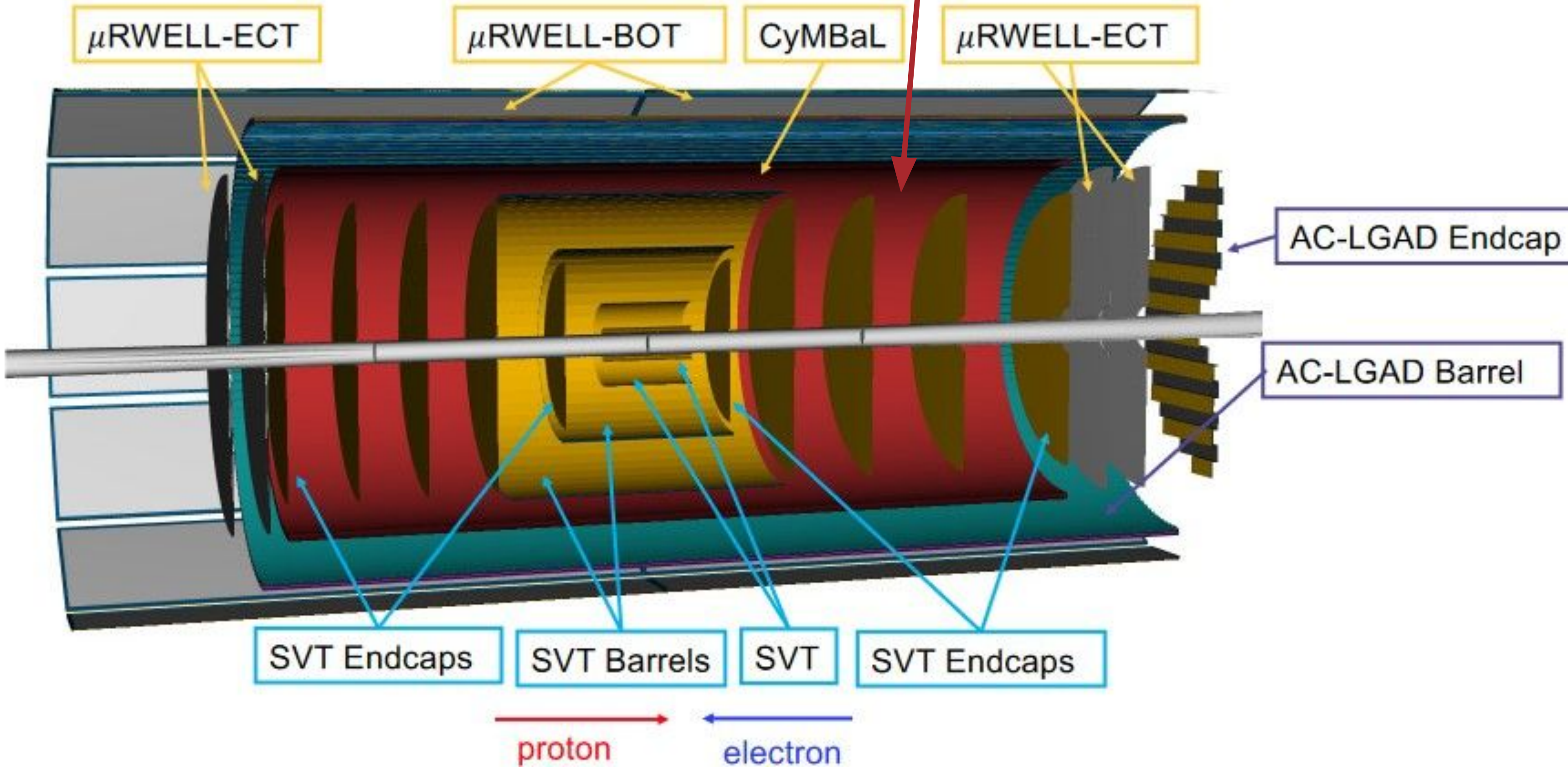
F. Bossù, A. Bonenfant, A. Francisco, C. Goblin, F. Jeanneau, C. Libourel, V. Maâch, I. Mandjavidze, D. Neyret, S. Polcher Rafael, M. Vandenbroucke

Cylindrical Micromegas Barrel Layer (CyMBaL)

- Tracking System (Barrel)
  - Silicon Vertex Trackers (SVT)
  - CyMBaL
  - Barrel Time of Flight (BTOF)
  - μRWELL-BOT

- What will CyMBaL do?
  - Fast tracklets for track seeding
  - Full hermetic coverage
  - Reliable redundancy

- CyMBaL Requirements
  - Spatial Resolution: ~150μm
  - Timing Resolution: ~10ns
  - Low Material Budget: ~0.5%X0

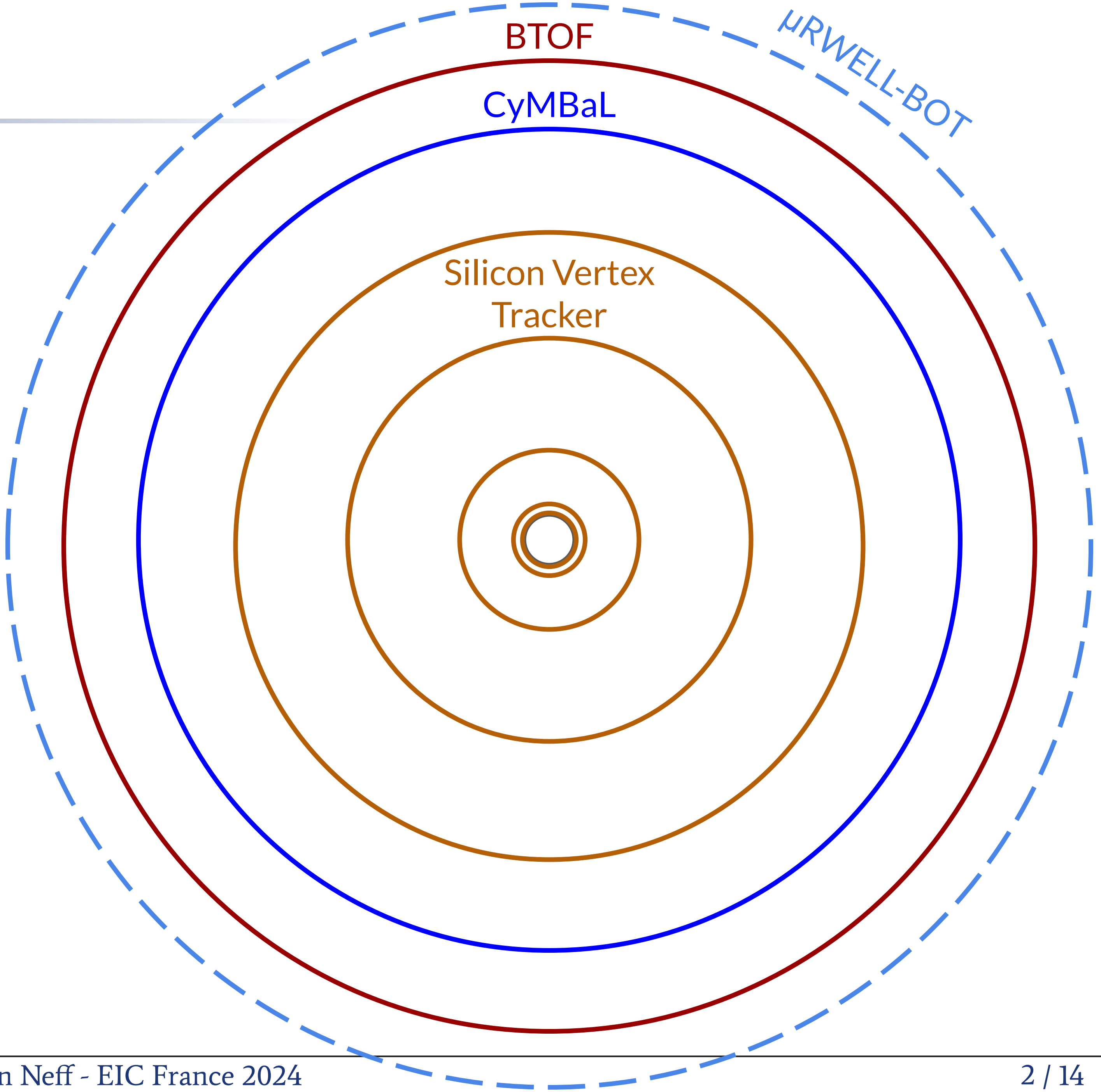


CyMBaL: Fast Tracklets

- Reconstruct tracklets with fast outer tracking detectors
  - CyMBal
  - BTOF
  - μRWELL-BOT

- Use these tracklets to seed tracks for the slower Silicon Vertex Tracker (SVT)
  - SVT integration time of 2-5μs
  - Events every ~2μs, expect some pile-up
  - Fast tracklets matched to SVT tracks give precise time information

- Micromegas lower in noise than silicon, provide reliable hits for track reconstruction



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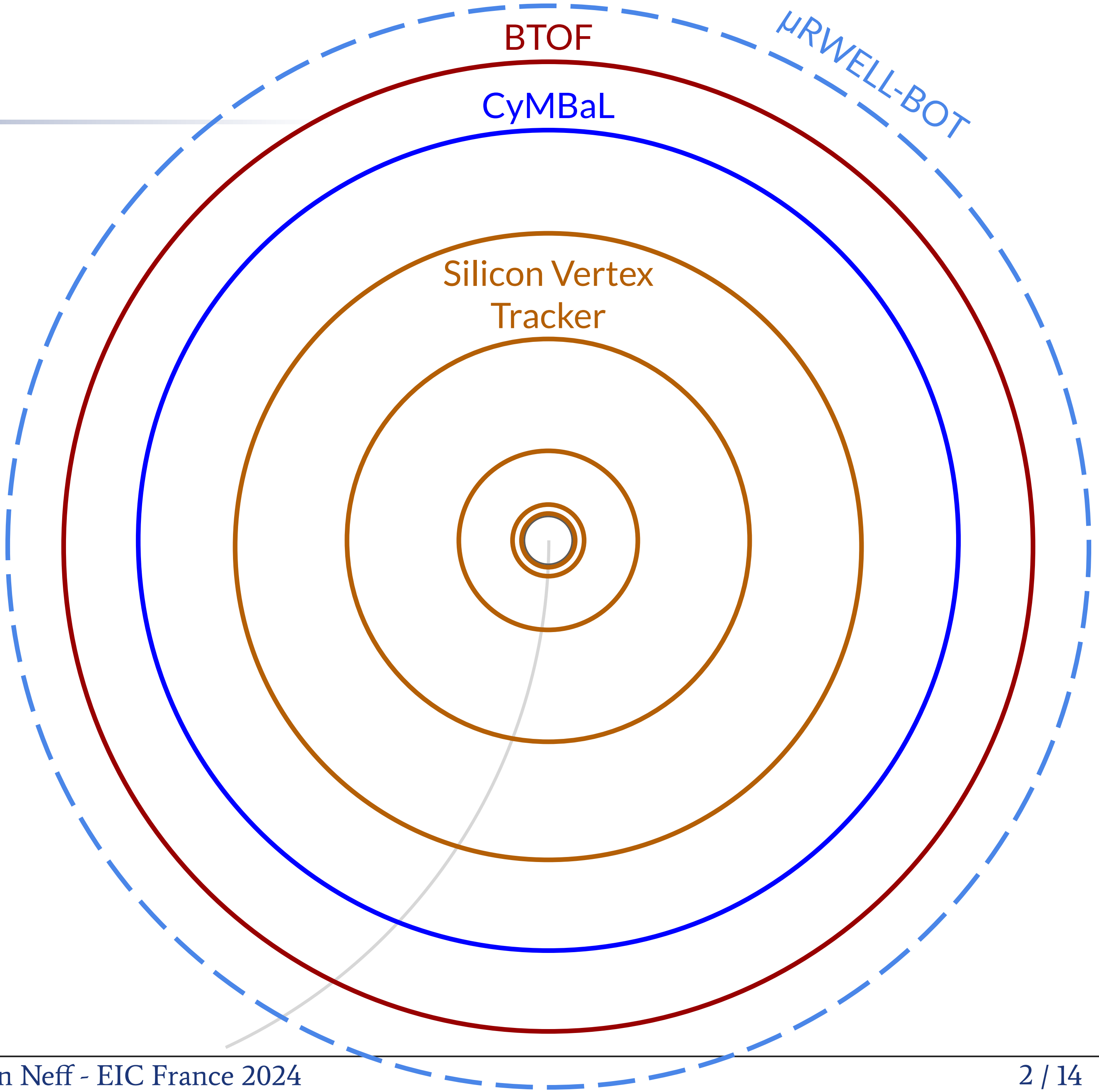

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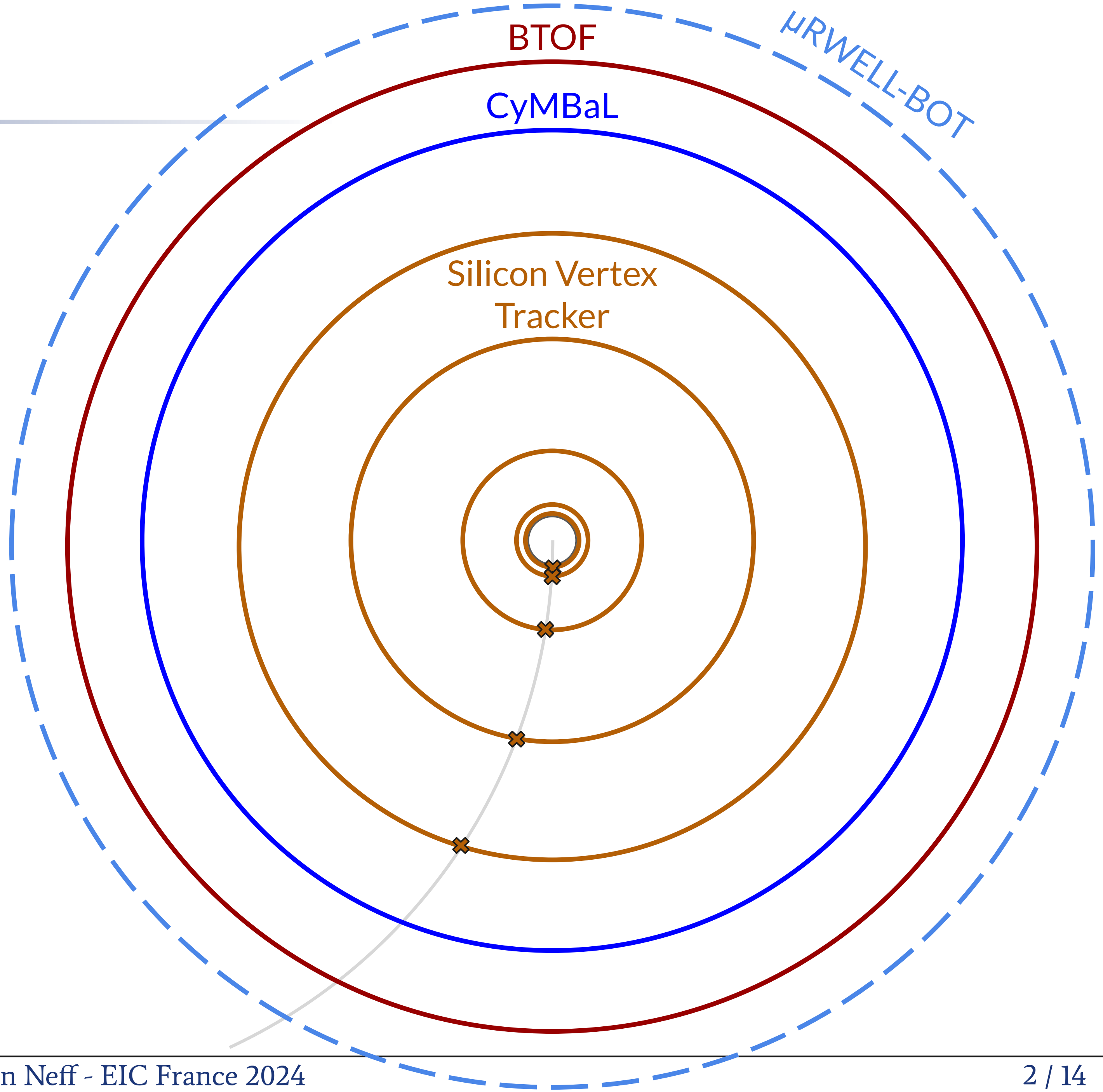

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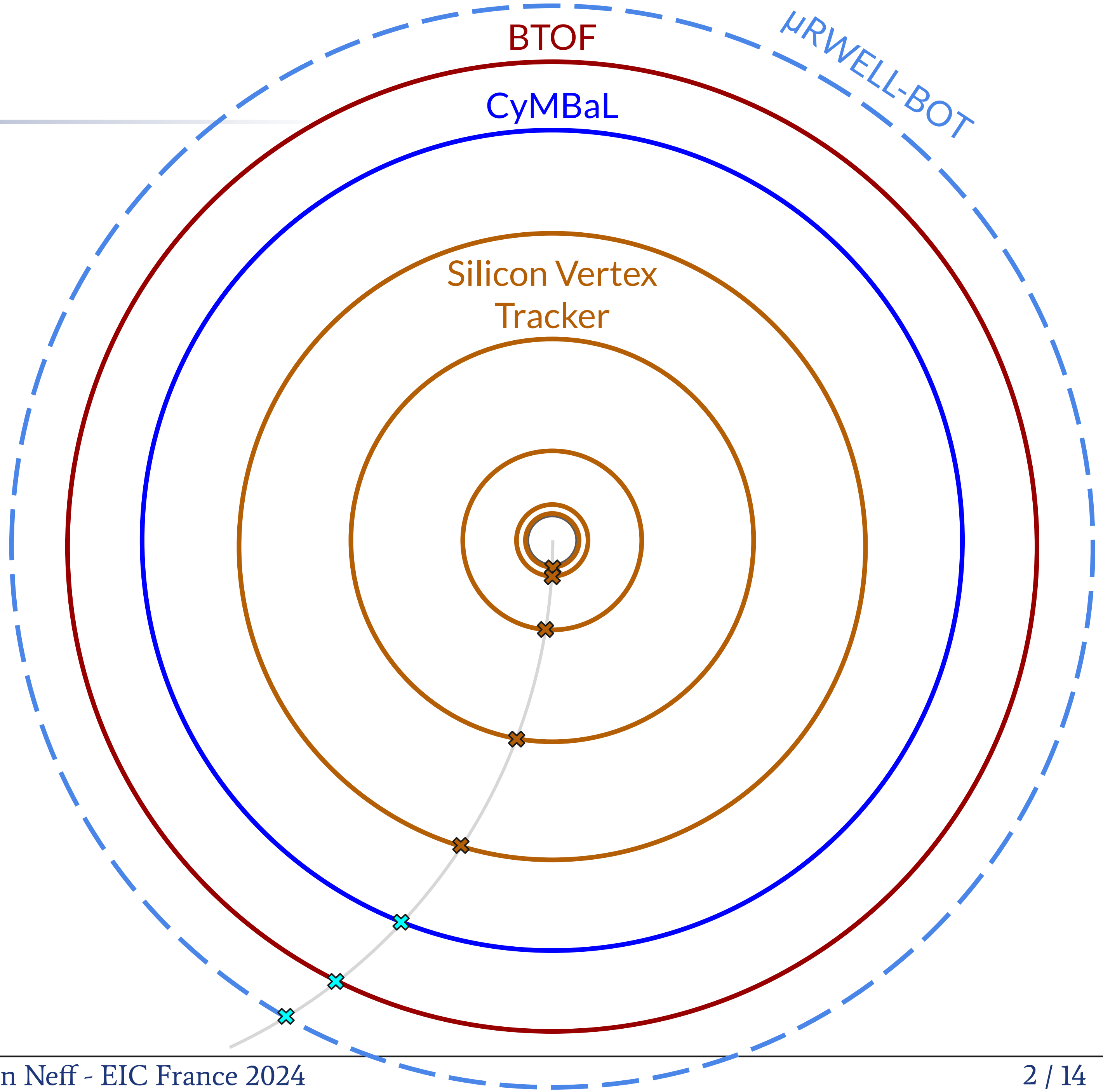

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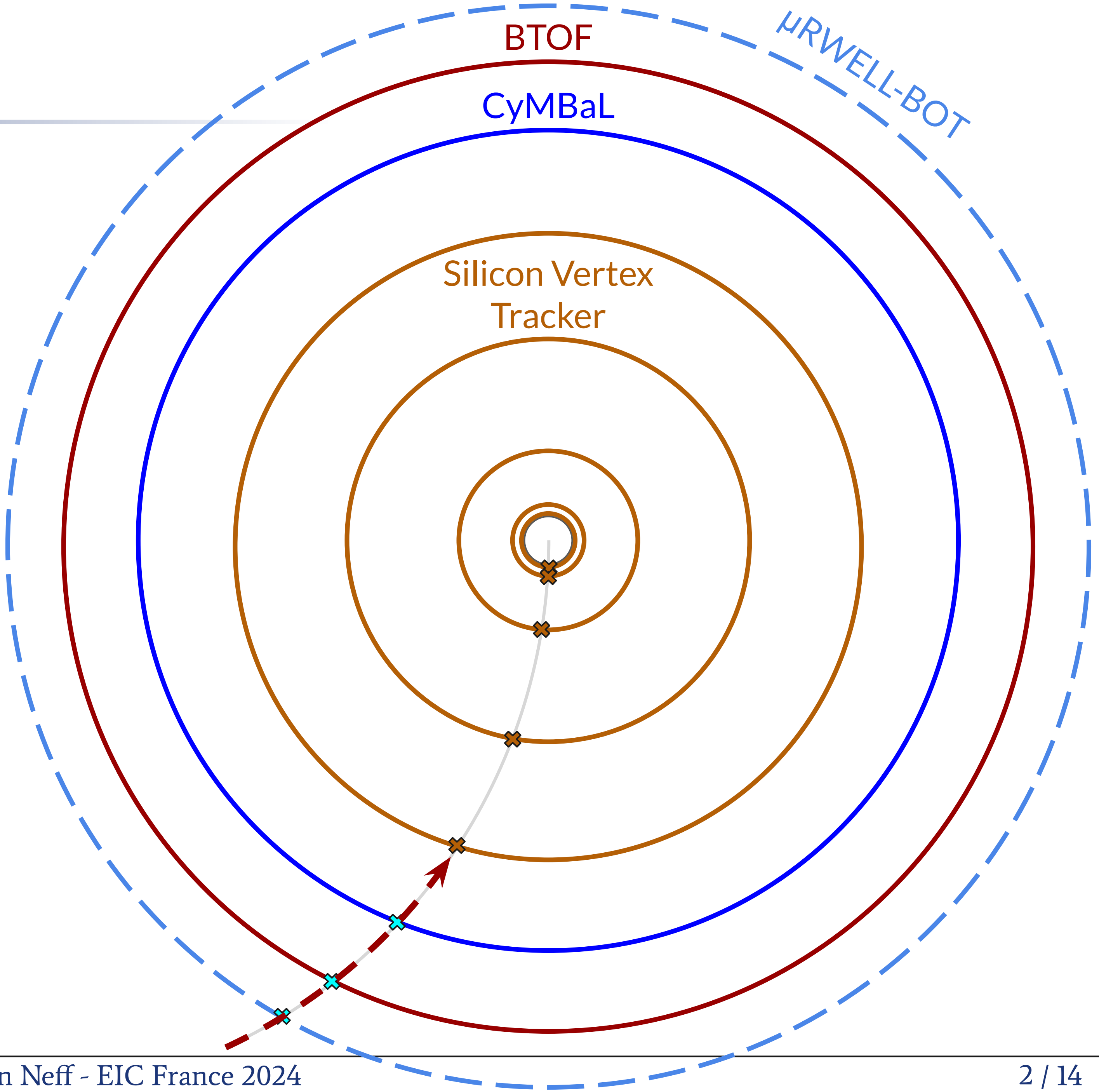
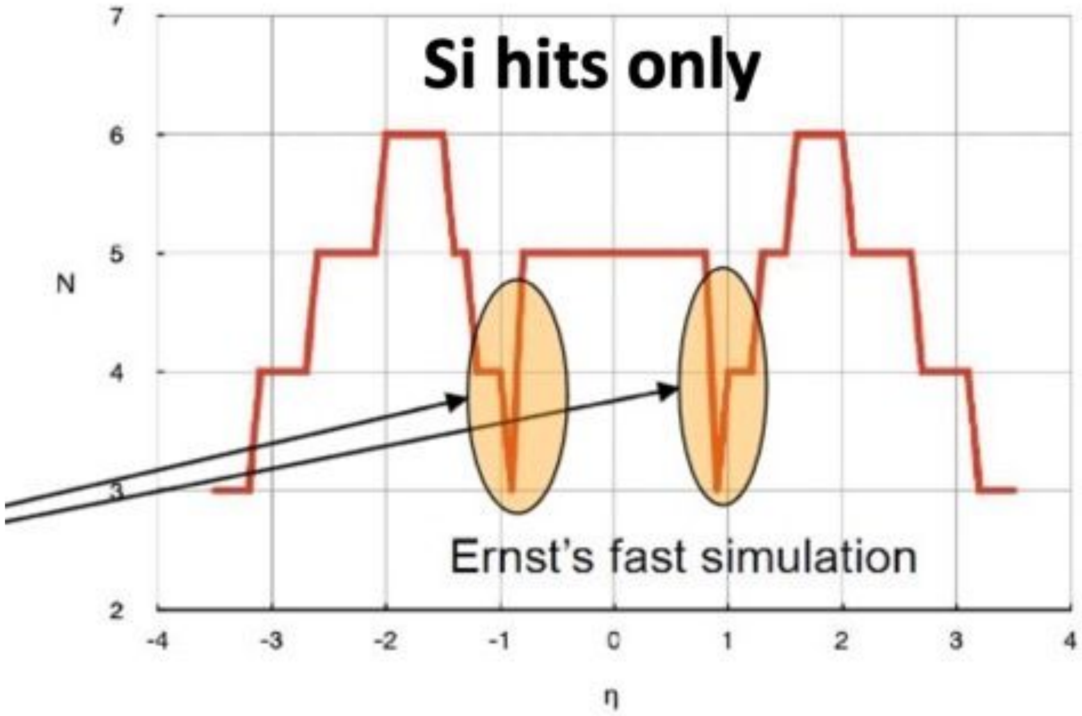
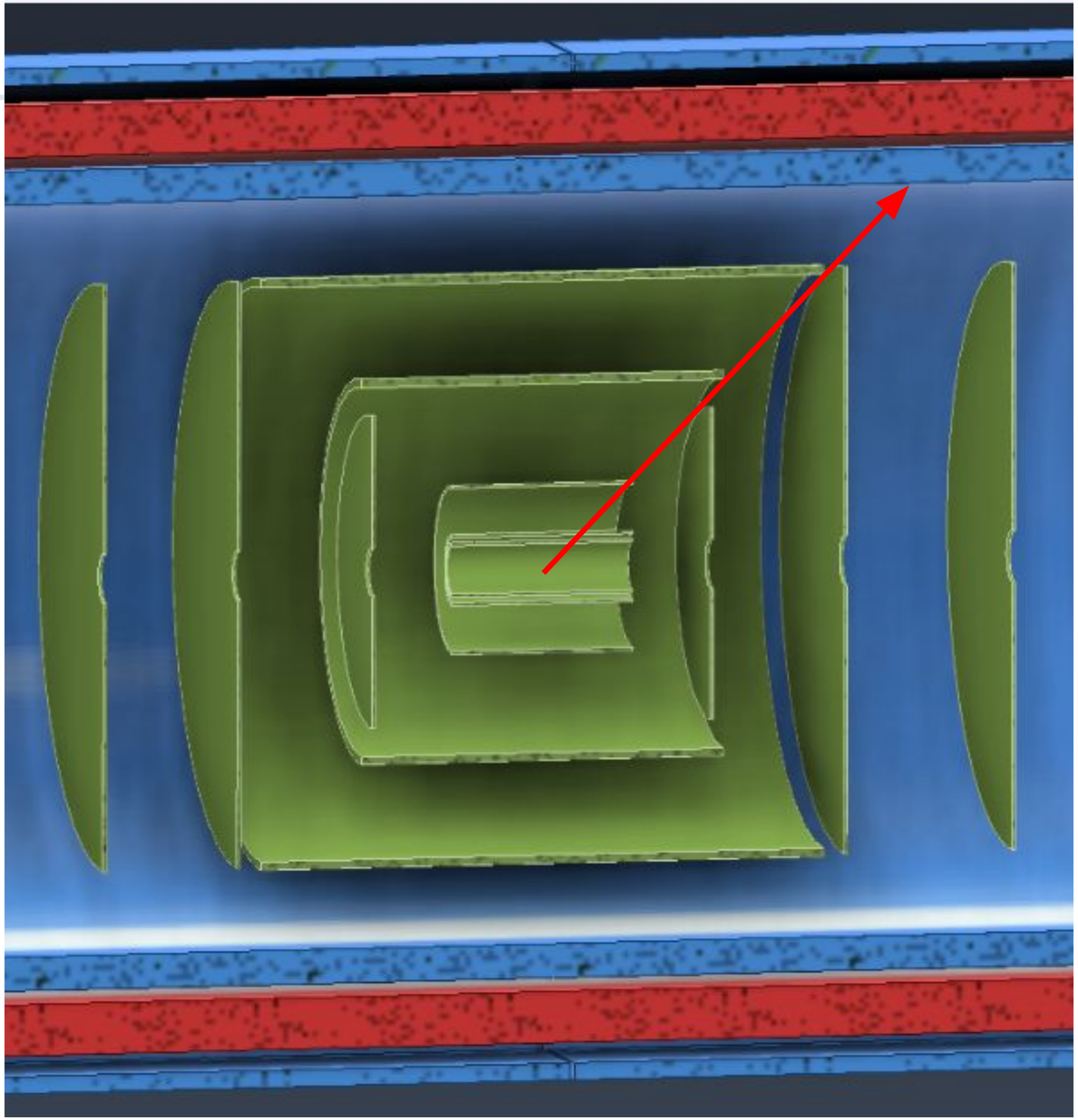


CyMBaL: Gap Coverage



- Silicon Vertex Tracker has a gap in rapidity between barrel and forward disks, as low as 3 hits max at η=1

- CyMBaL and BTOF cover this gap, bringing tracking back to 5 hits

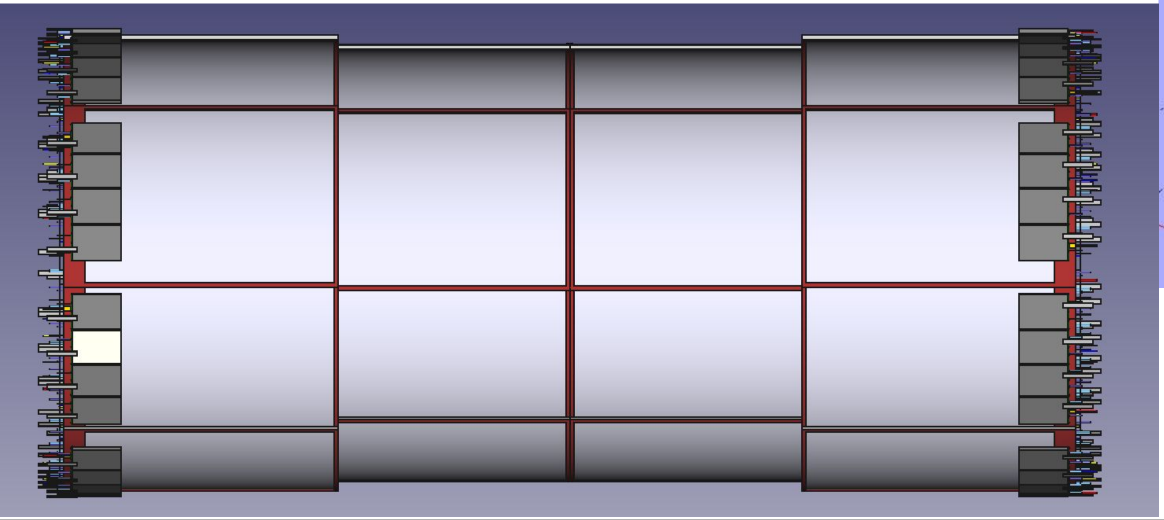


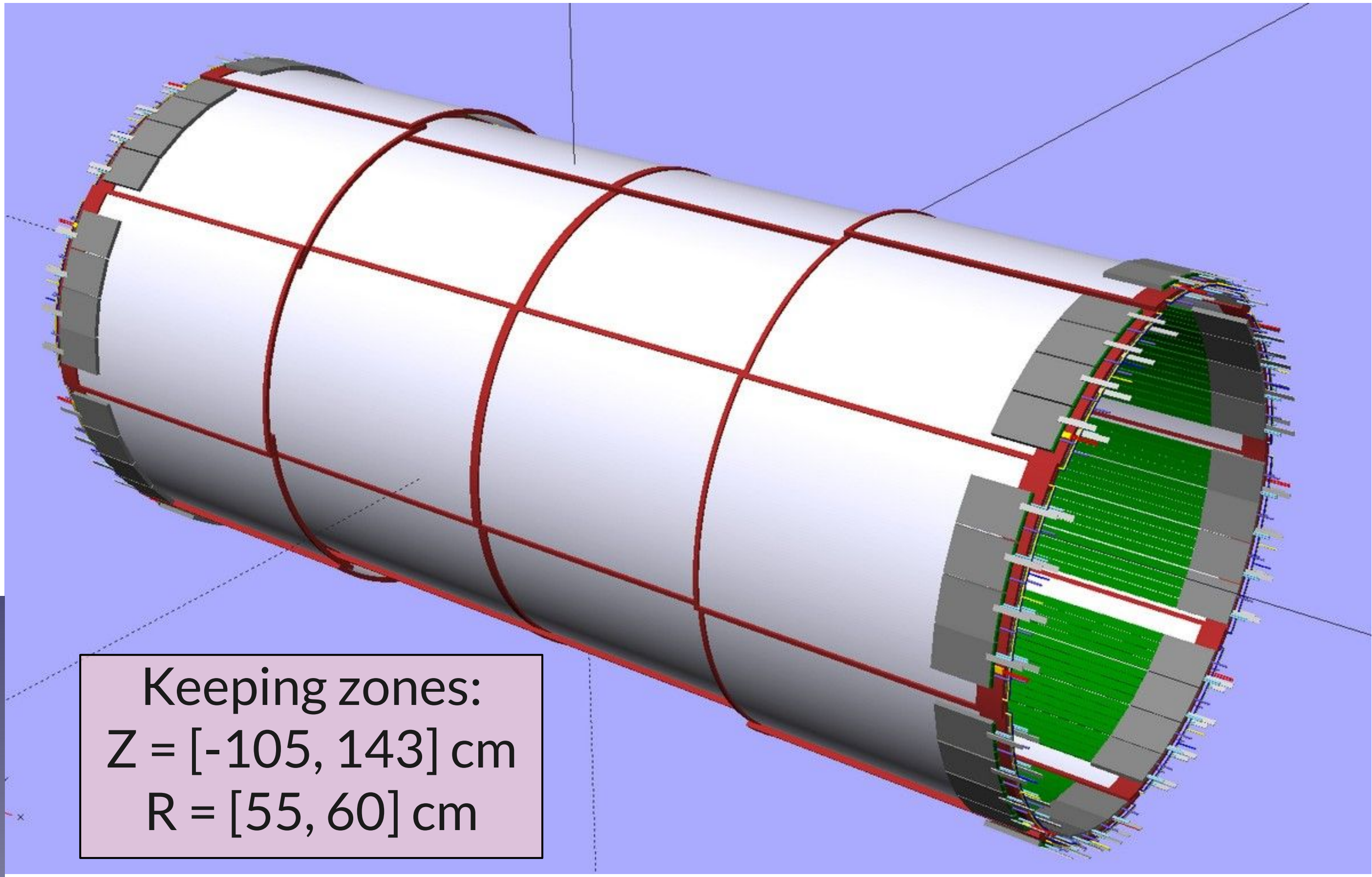
CyMBaL: Layout

- Fully hermetic: Overlap in phi and z

- Two curvature radii
  - Central cylinders: 50 cm
  - Forward cylinders: 55 cm

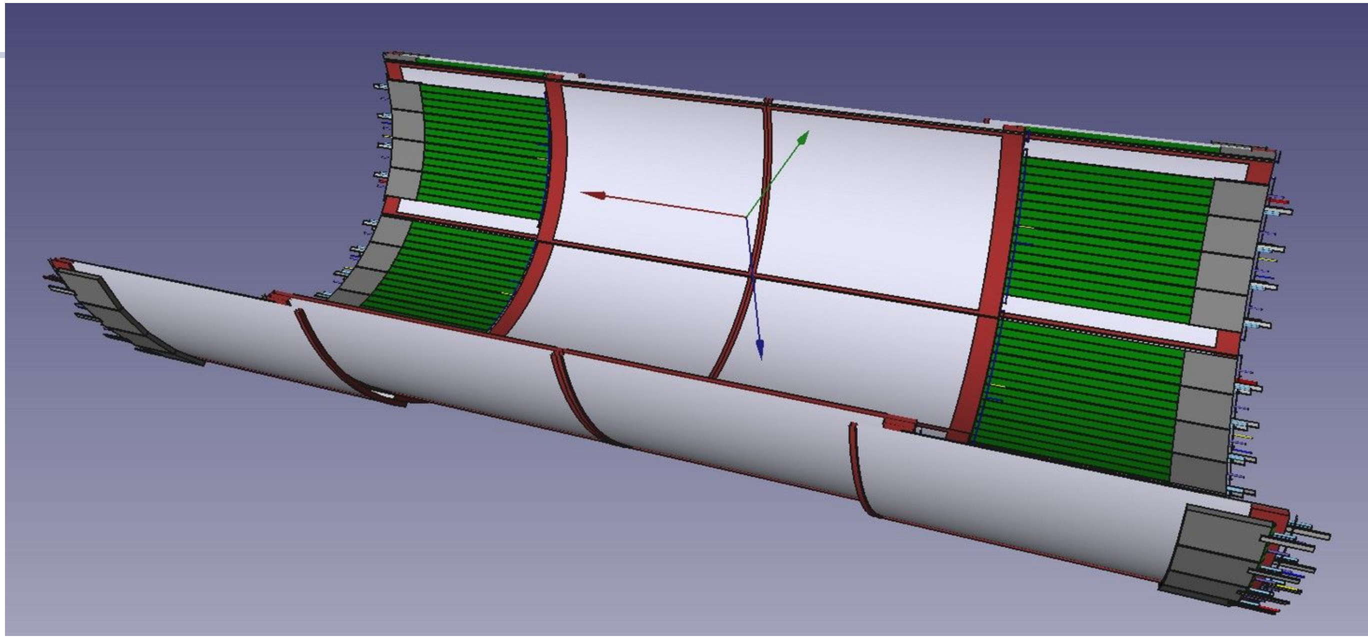
- 32 modules
  - 4 along z, 8 around azimuth
  - 1024 readout channels/module → 32k total

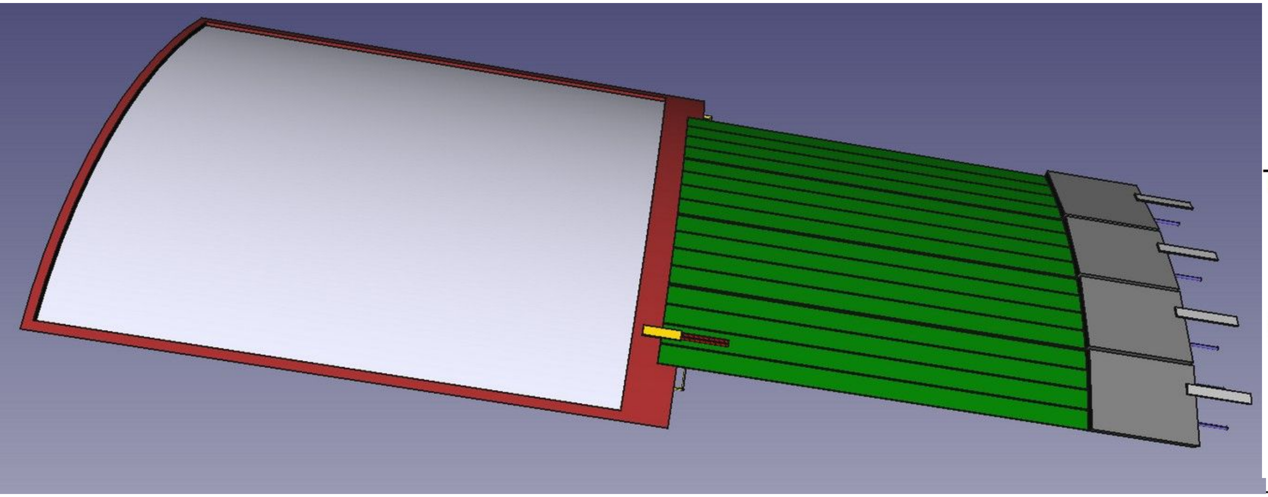


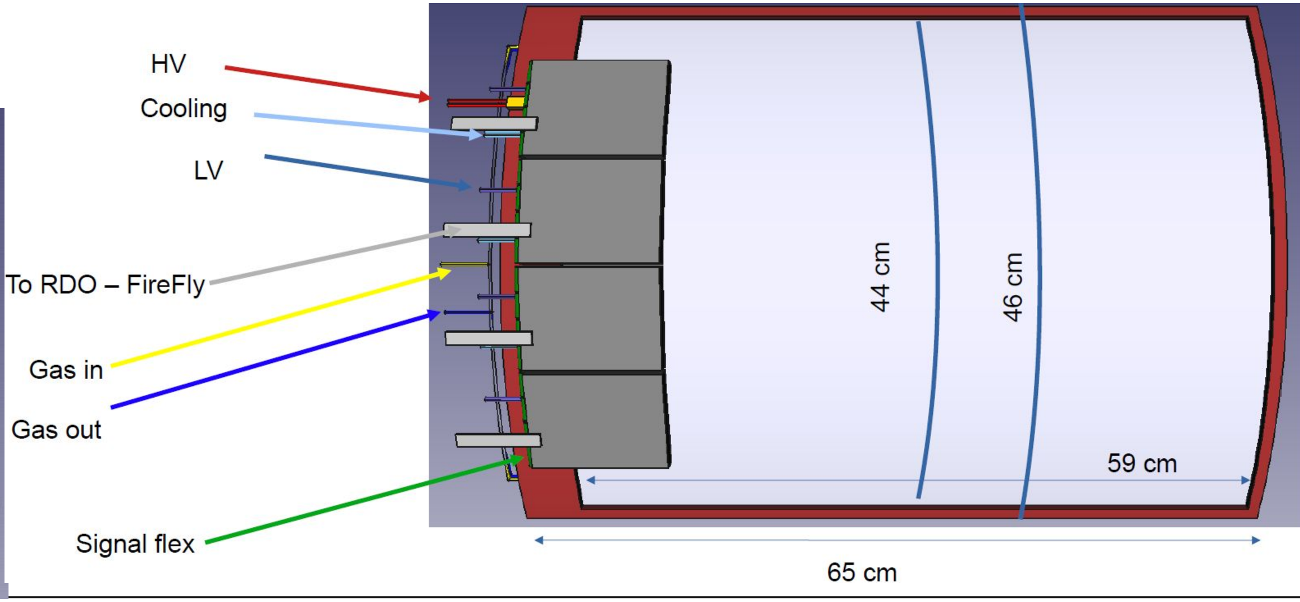


CyMBaL: Module

- Single module design with two curvature radii simplifies production and reduces cost
- Front end boards based on SALSA ASIC at edges of detector to reduce material budget
  - 50cm micro-coaxial cables connecting central modules
- 2D readout strips with pitch ~1 mm





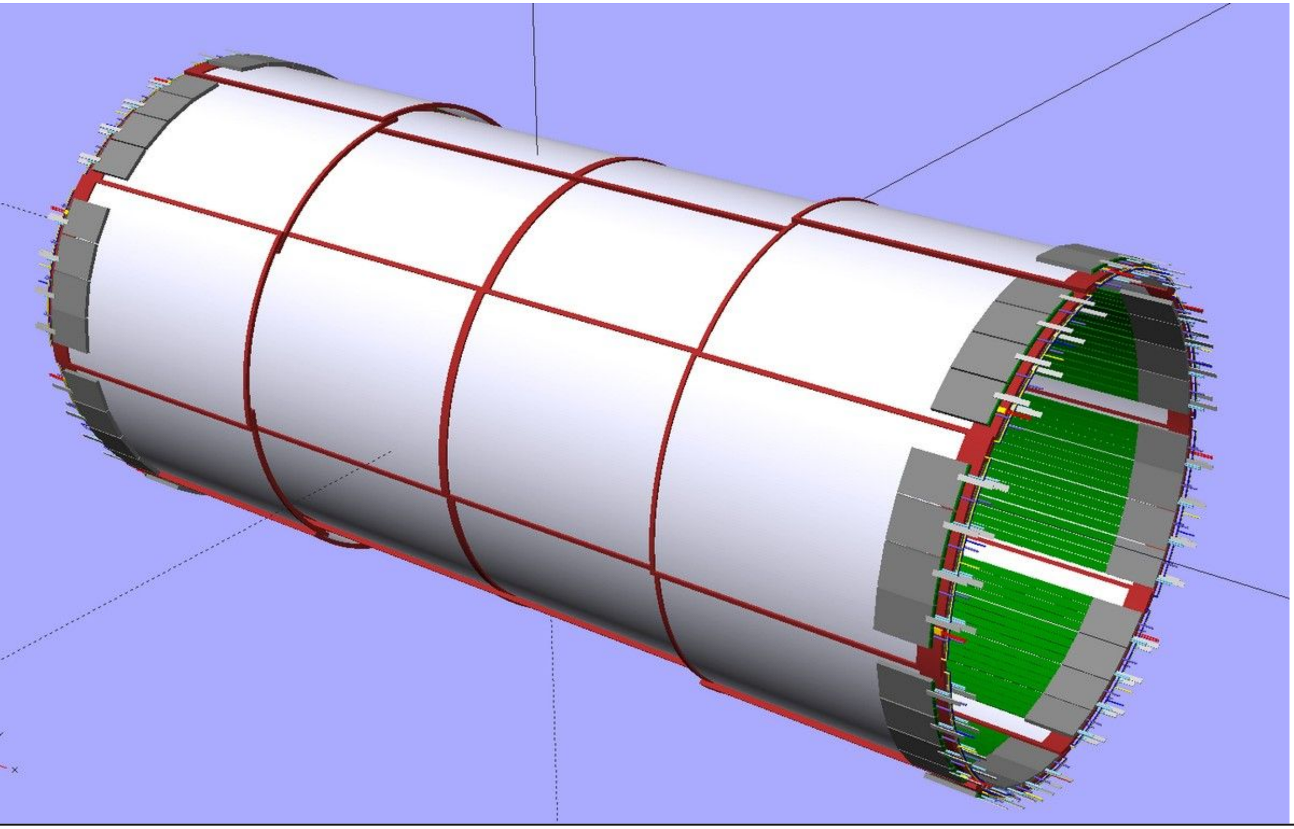


CyMBaL: Micromegas Design

CyMBaL Requirements

- Cylindrical shape
- ~2T magnetic field
- 5cm radial keeping zone → tight space!
- Low material budget

CyMBaL Design



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Saclay has experience building a detector that meets these requirements

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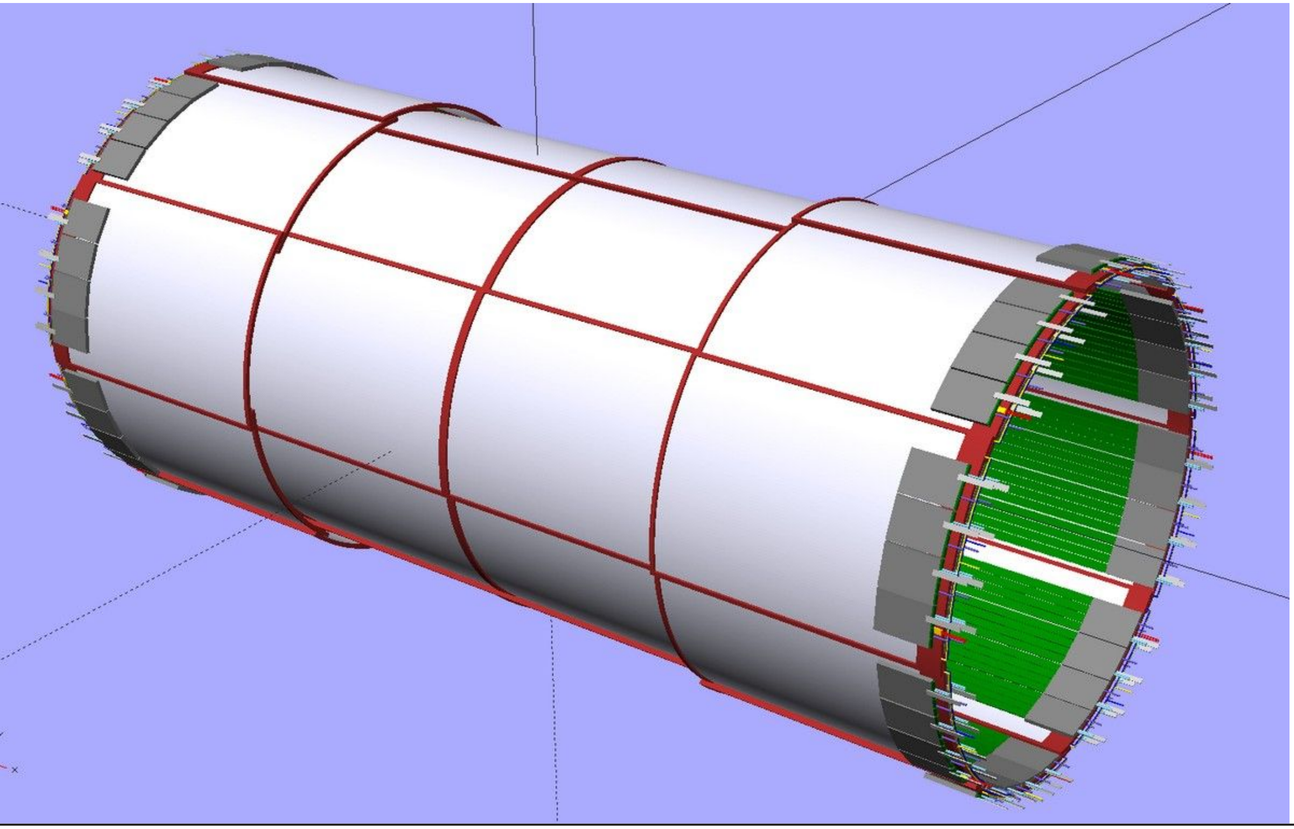
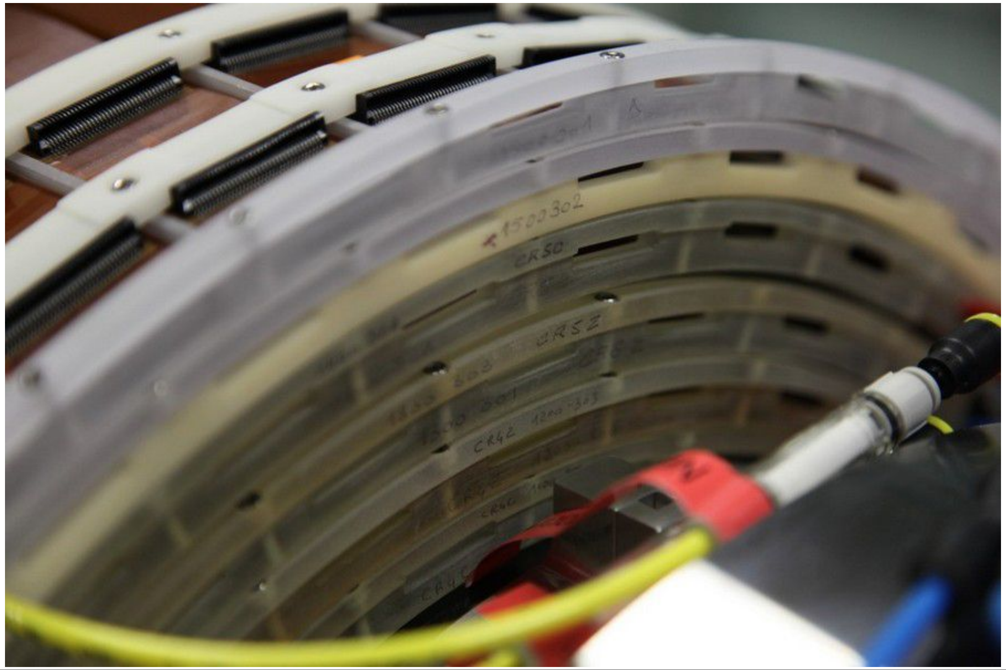


Cylindrical Micromegas built for the CLAS12 experiment at Jefferson National Lab

- Operates in 5T magnetic field
- Cylindrical shape
- Compact and light

CLAS12 Cylindrical Micromegas



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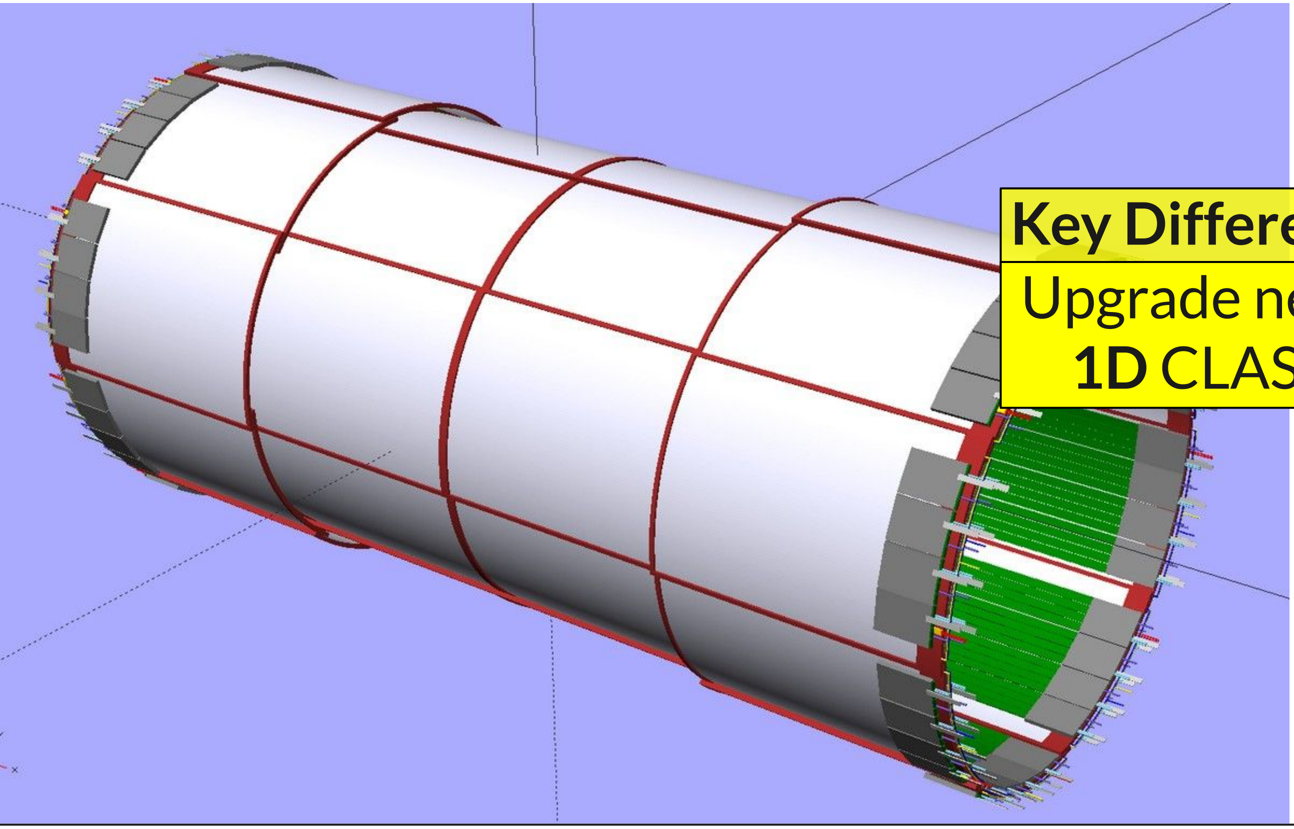

Key Difference:

Upgrade necessary for readout

1D CLAS12 → **2D** CyMBaL

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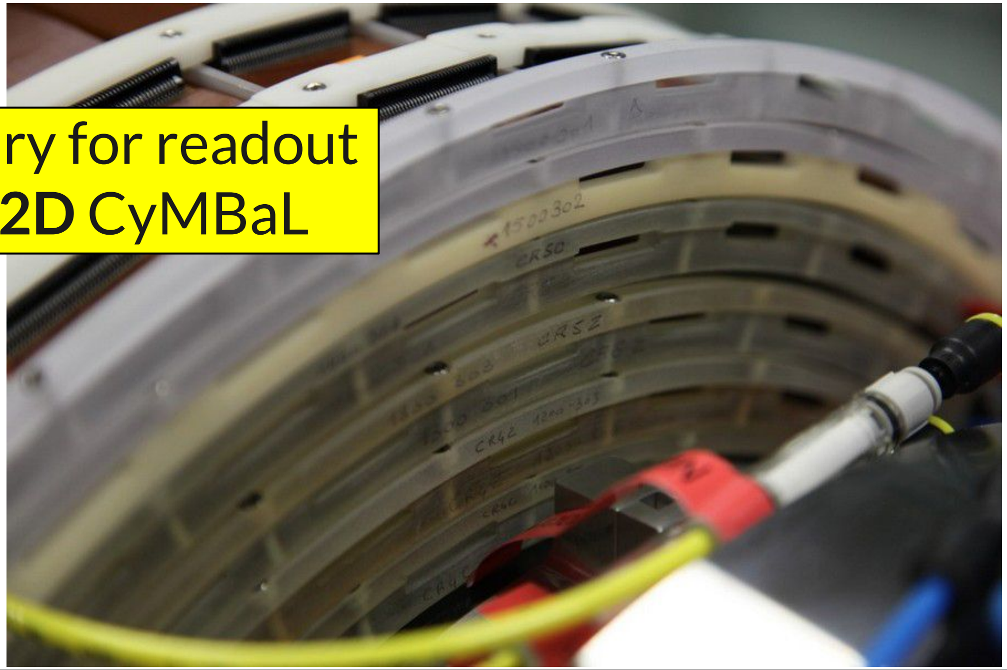
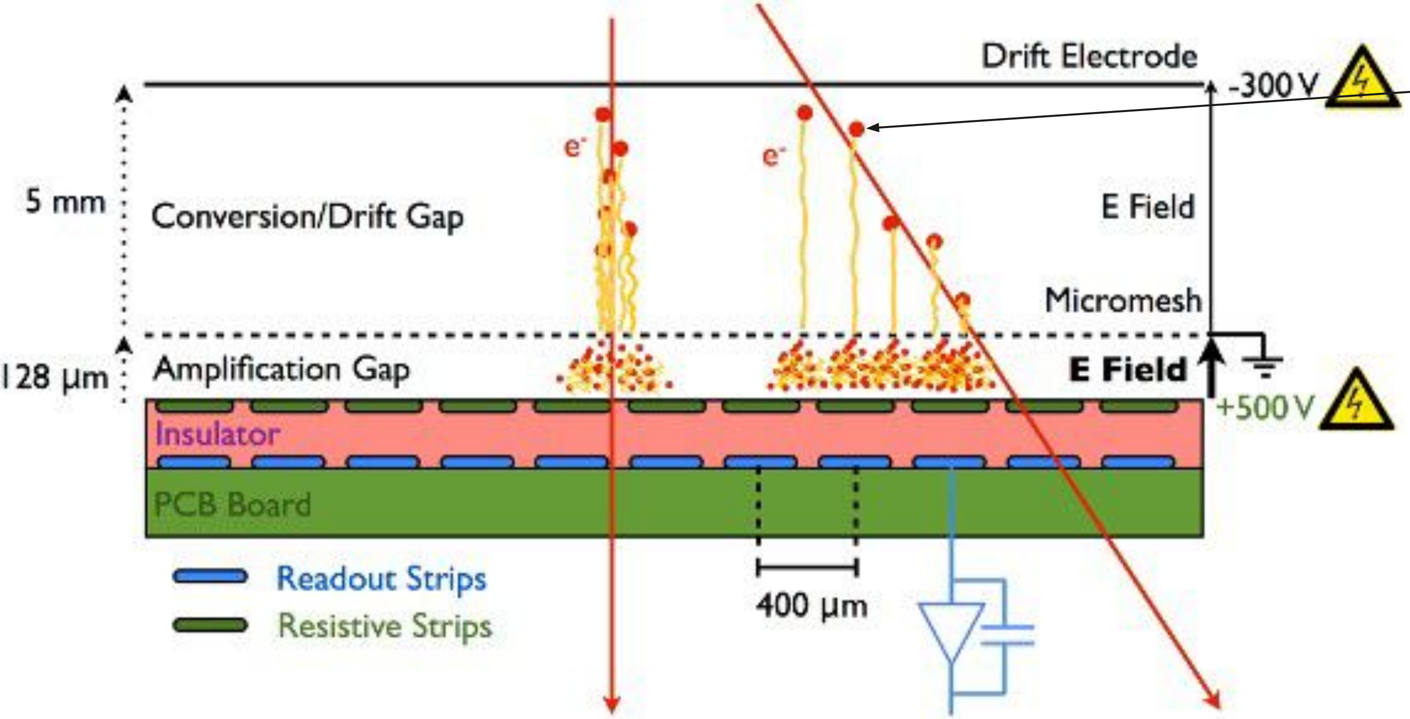
CLAS12 Cylindrical Micromegas

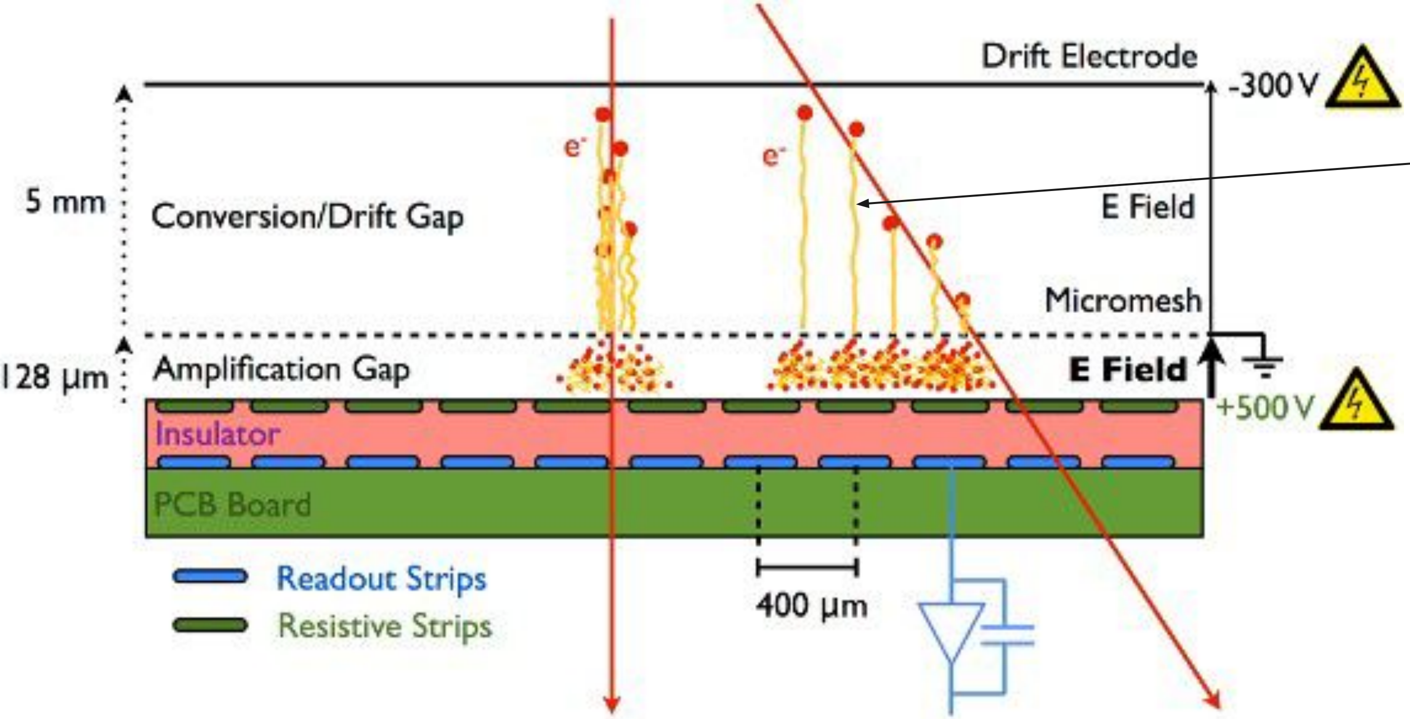


Micromegas Detectors



Gas ionized by incident particle

Micromegas Detectors



Gas ionized by incident particle

Electrons drift to mesh

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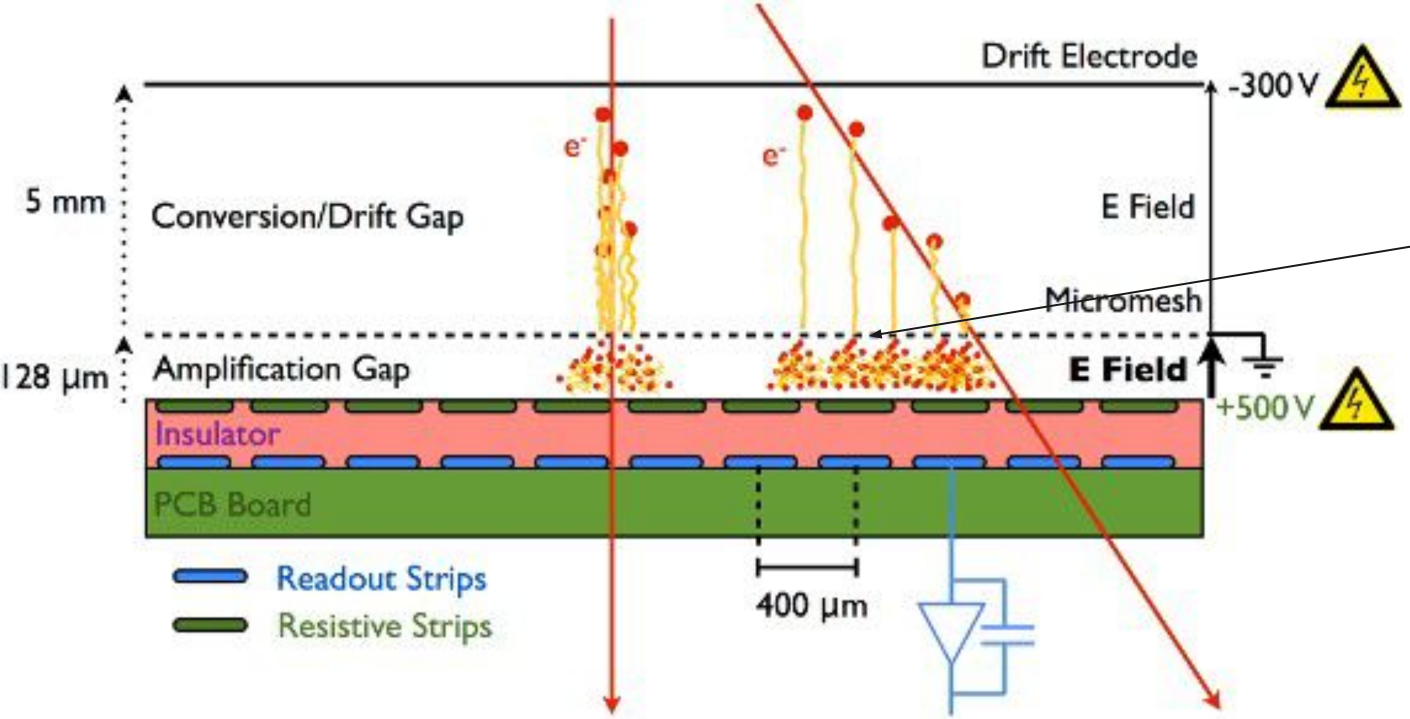
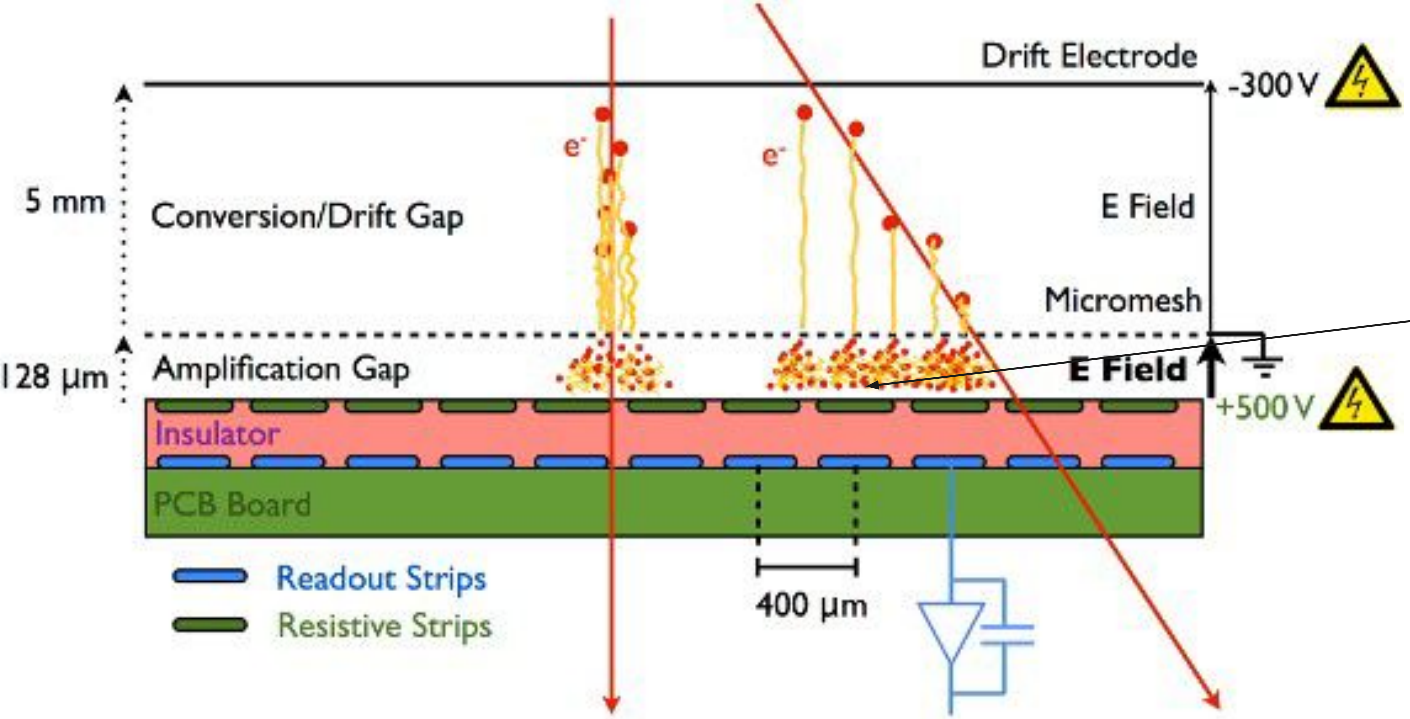


Gas ionized by incident particle

Electrons drift to mesh

Avalanche in amplification gap

Micromegas Detectors



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Charge spreads on resistive layer

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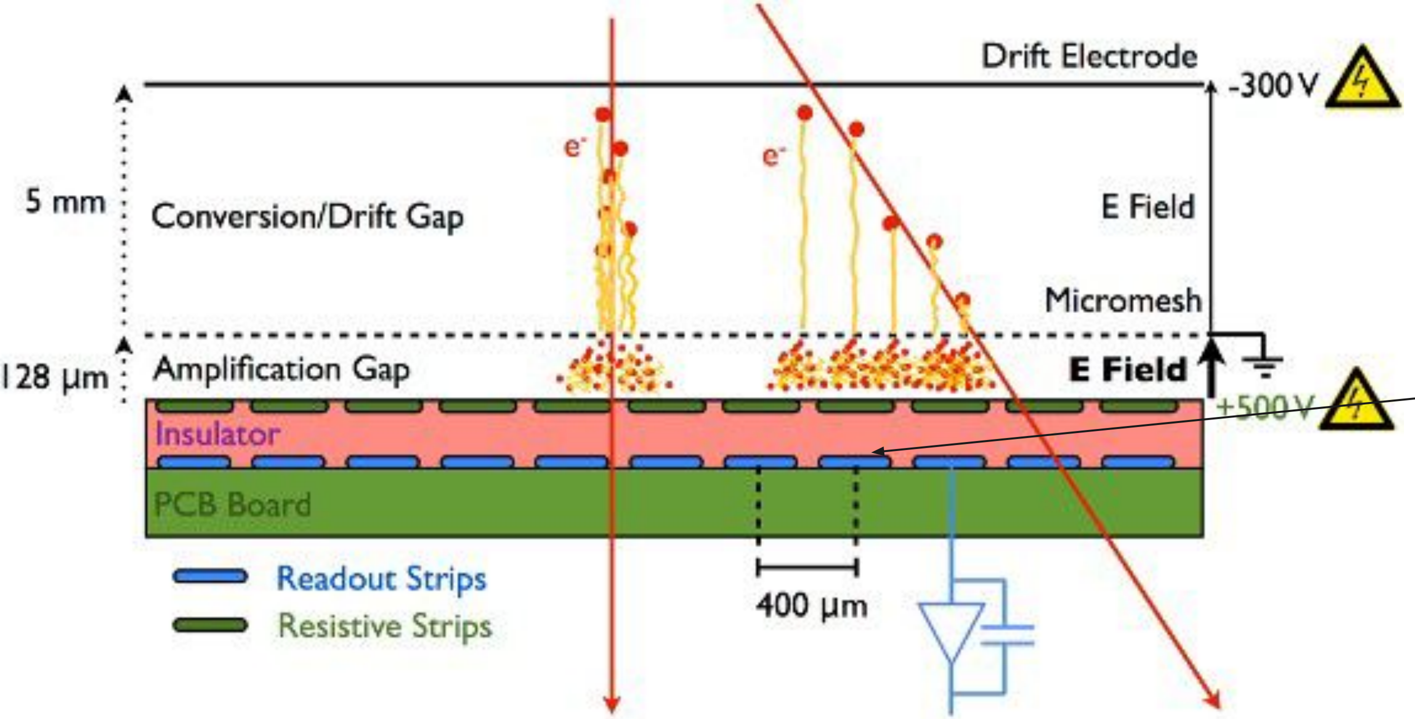

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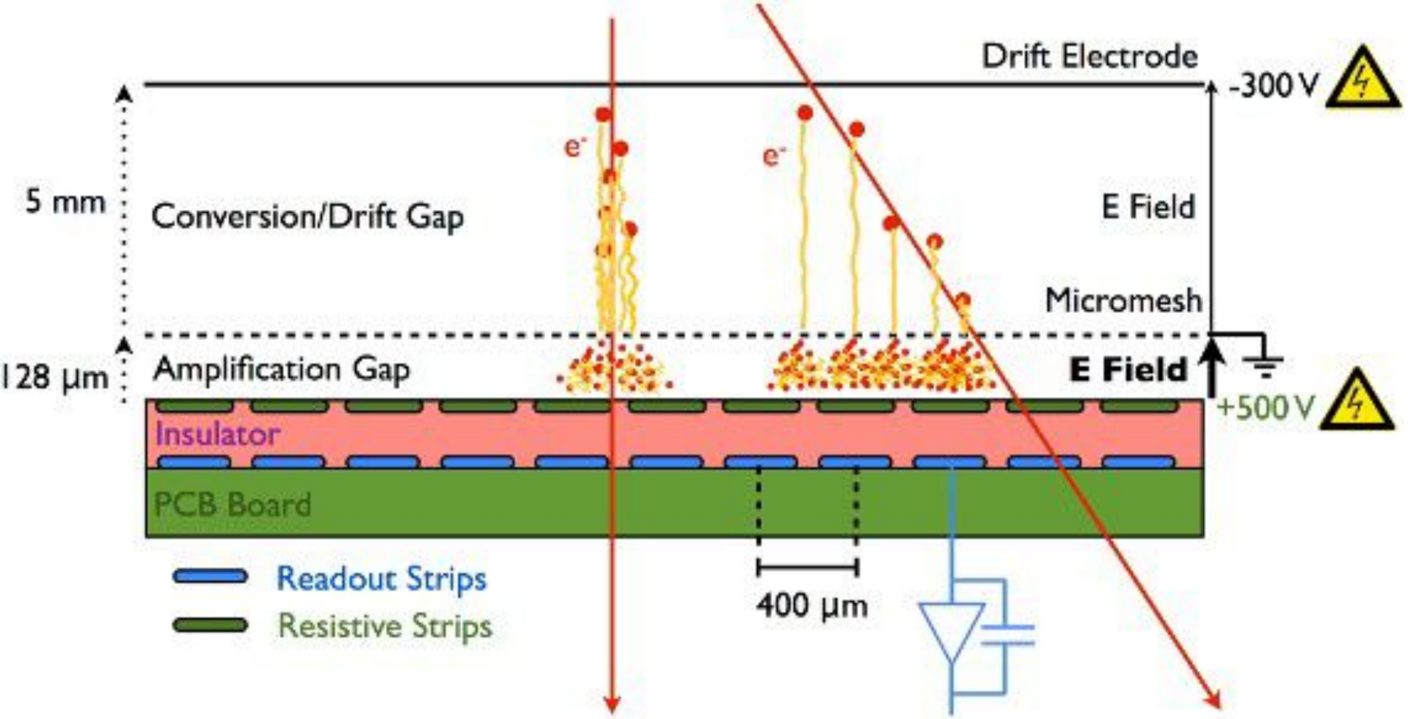
Avalanche in amplification gap

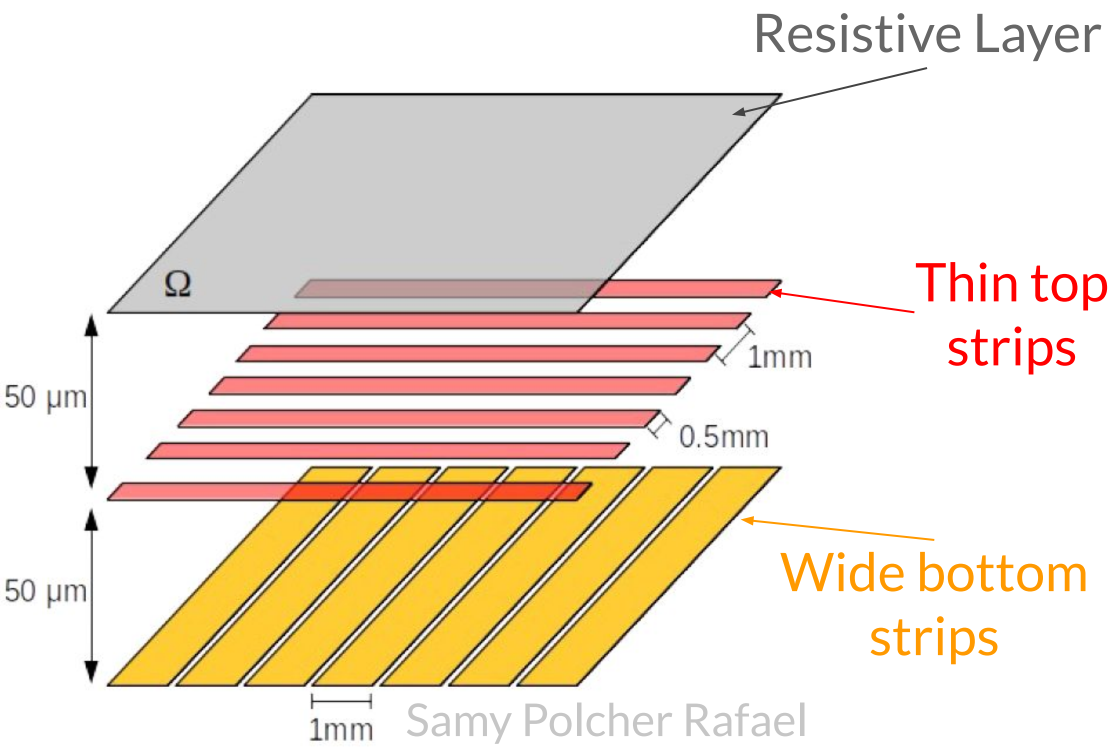
Charge spreads on resistive layer

Signal is induced on readout strips

Micromegas Detectors



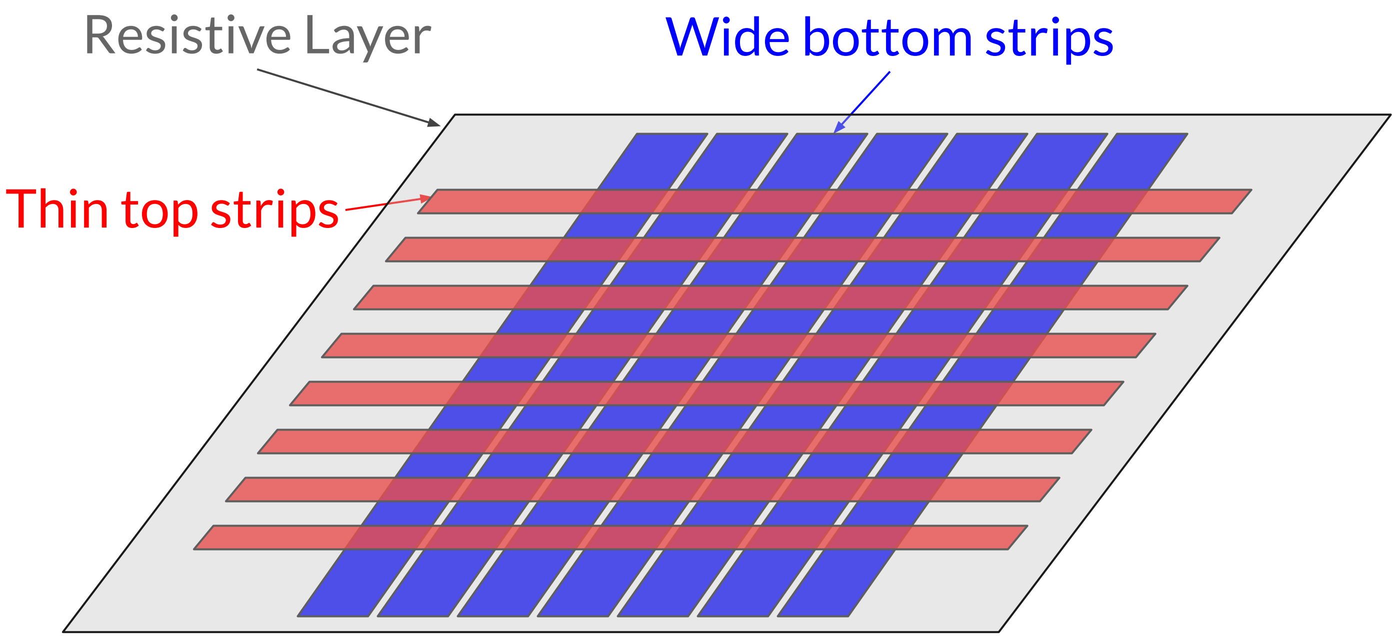
Gas ionized by incident particle
Electrons drift to mesh
Avalanche in amplification gap
Charge spreads on resistive layer
Signal is induced on readout strips



Design Goals

- Spread charge over multiple strips to improve spatial resolution by a weighted average
- Share charge equally between top and bottom strips

Developing and Optimizing 2D Detector Design



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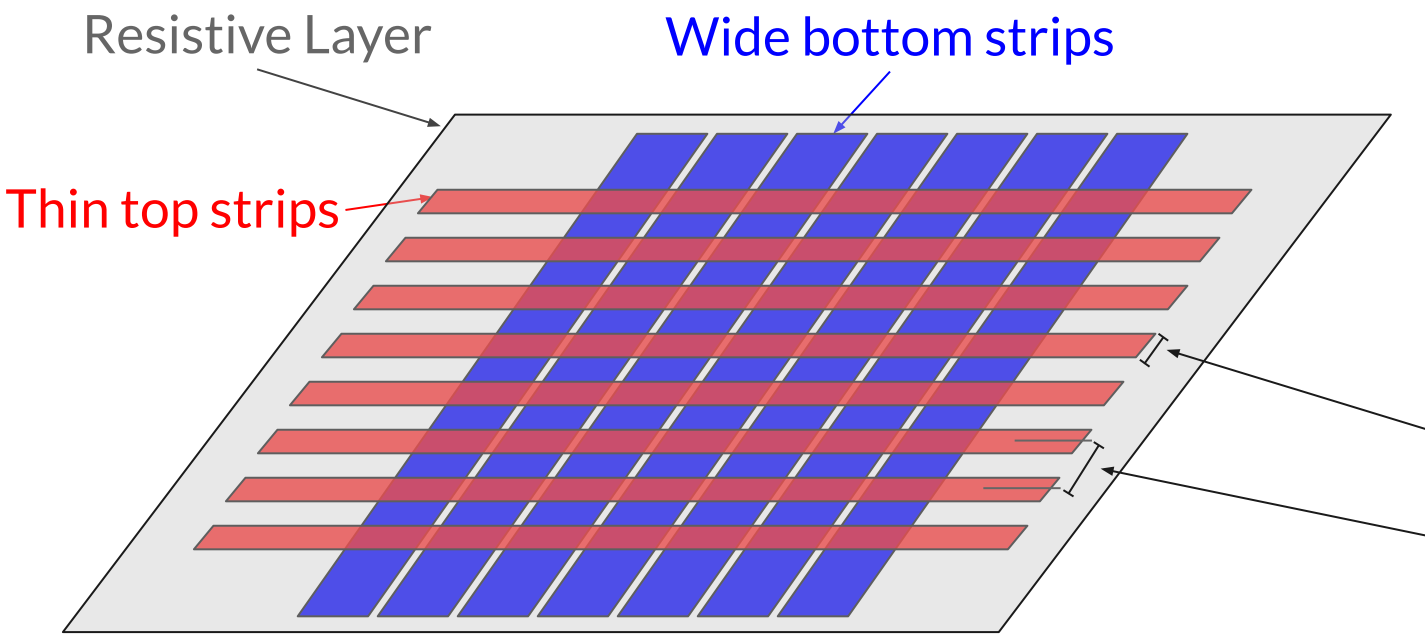
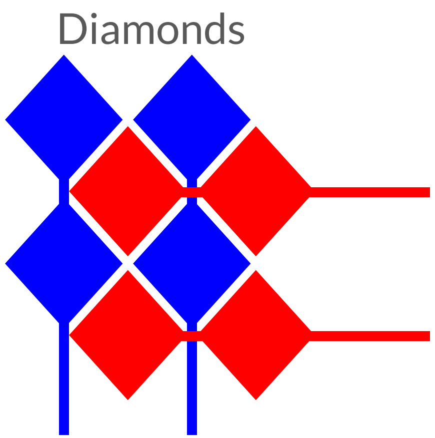
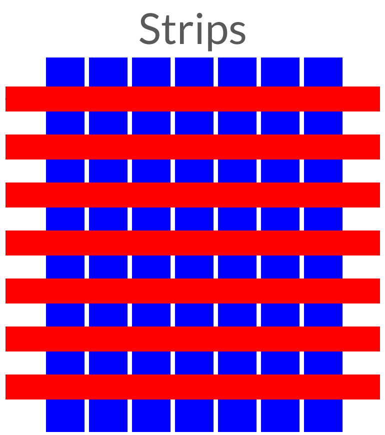


Strip Readout

- Strip design
  - Diamonds
  - Strips
- Strip width
- Strip pitch





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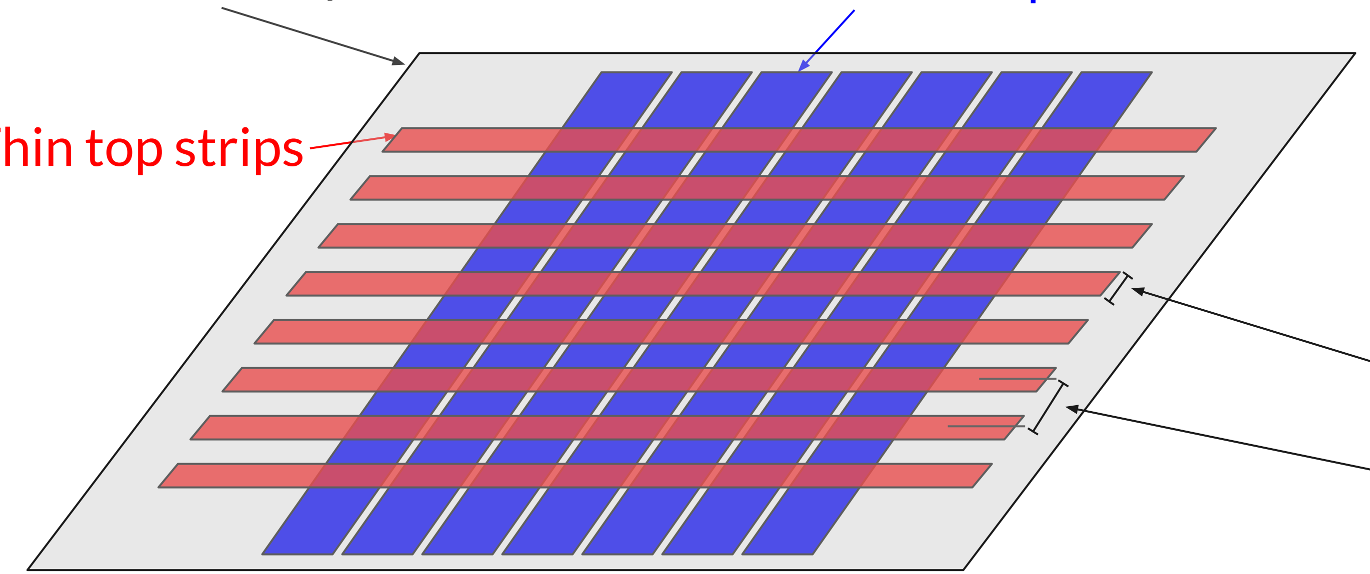
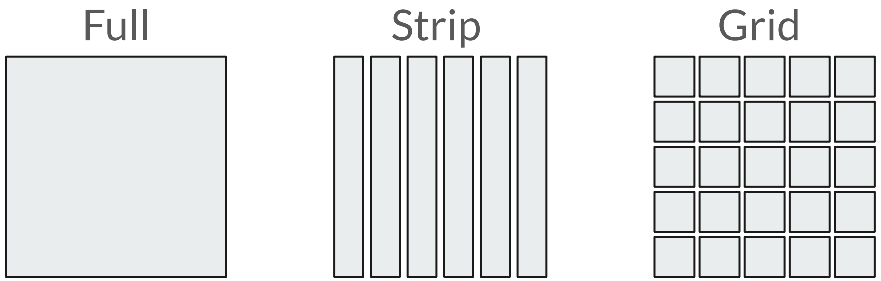


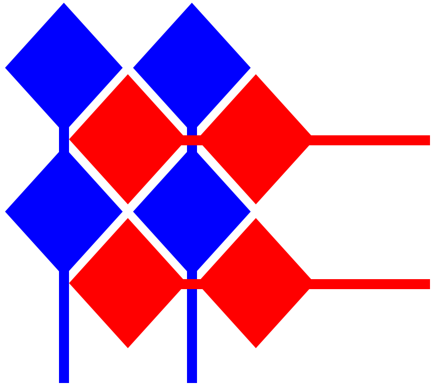
Strip Readout

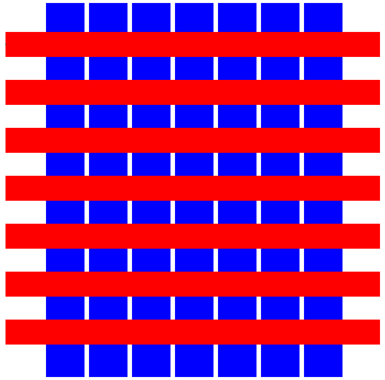
- Strip design
  - Diamonds
  - Strips
- Strip width
- Strip pitch

Resistive Layer

- Resistivity
- Pattern
  - Full
  - Strip
  - Grid





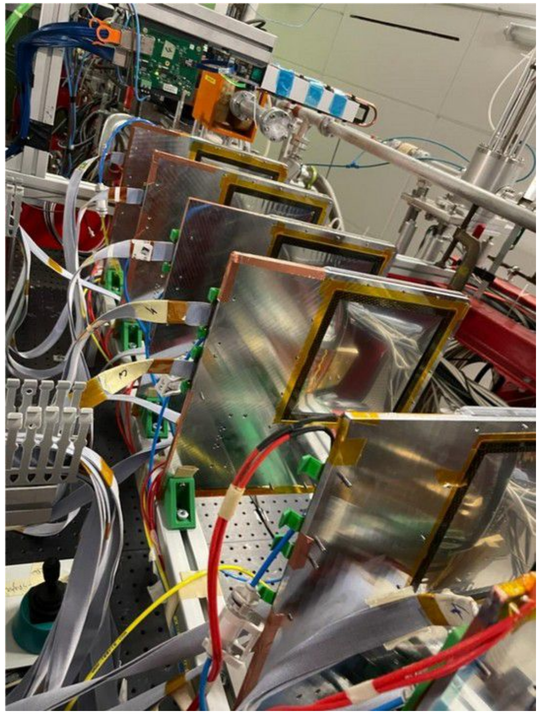


Developing and Characterizing Prototypes

Two Options for Testing Prototypes

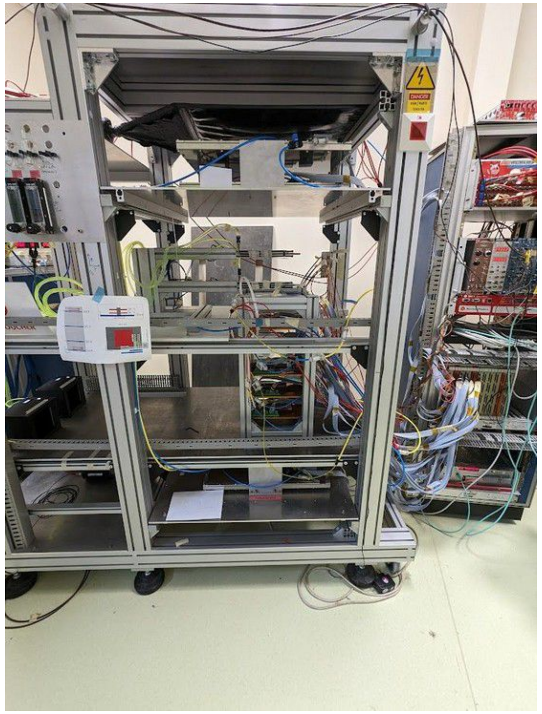
Beam Test	Key Measurements	Cosmics
✓	Time resolution	?
✓	Spatial Resolution	?
✓	Efficiency	✓
✓	Charge sharing	✓
✓	Cluster Size	✓
✓	Gain Curves	✓

Beam Test



- Mainz test in July 2023
  - Limited results due to multiple scattering
- Possible future test at CERN

Cosmics

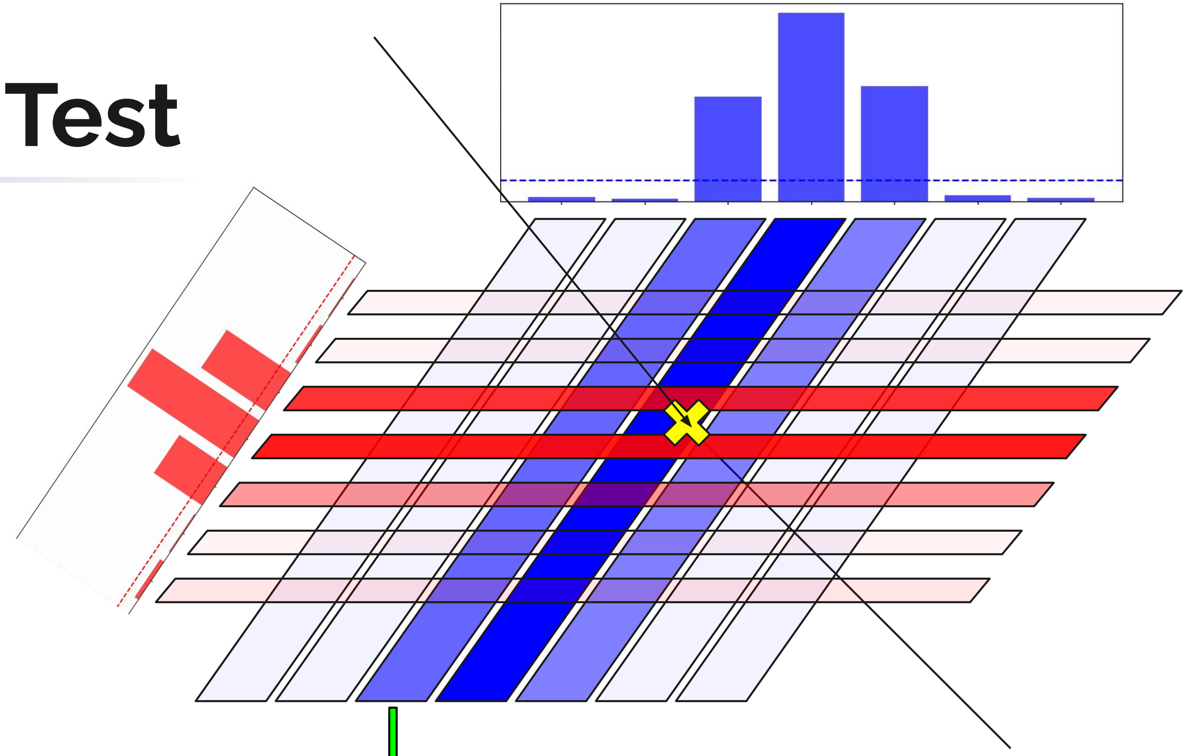


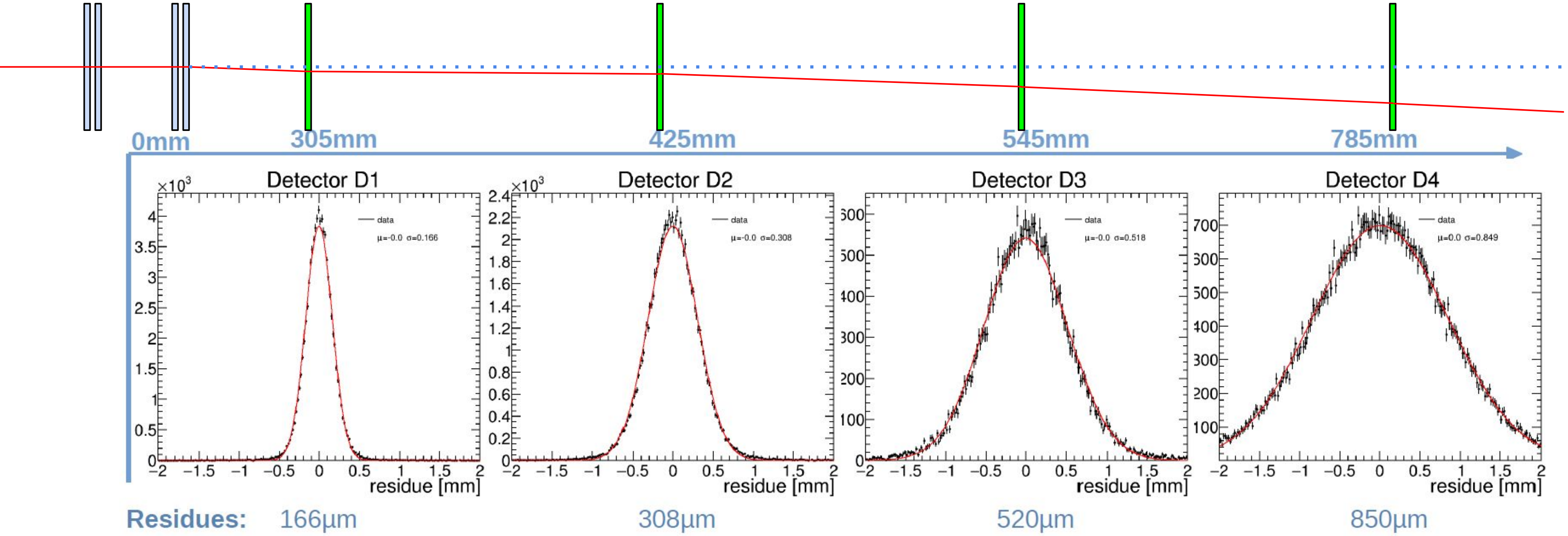
- Test bench set up at CEA-Saclay
- **Pro** Can quickly test new detectors
- **Con** Limited statistics for precise measurements

Results from the Mainz Beam Test

Measurements from beam test data

- Charge Sharing
- Cluster Size
- Spatial Resolution





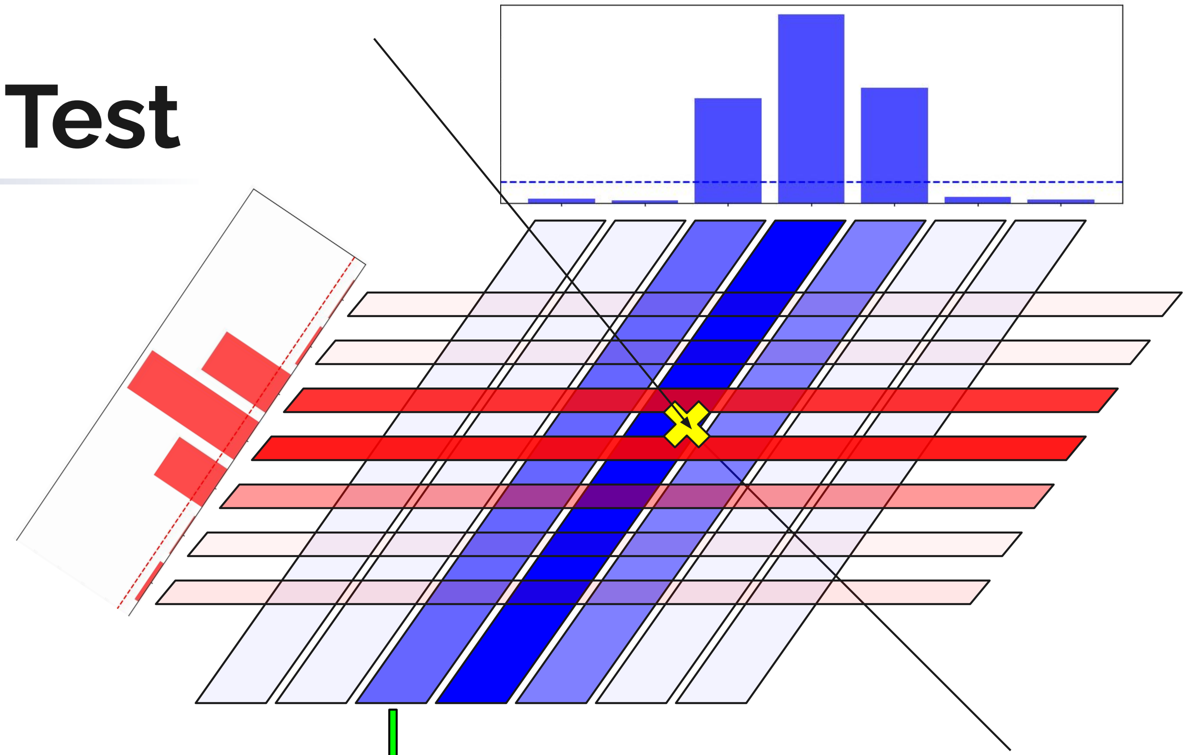
Analysis on most detectors was limited due to influence from multiple scattering

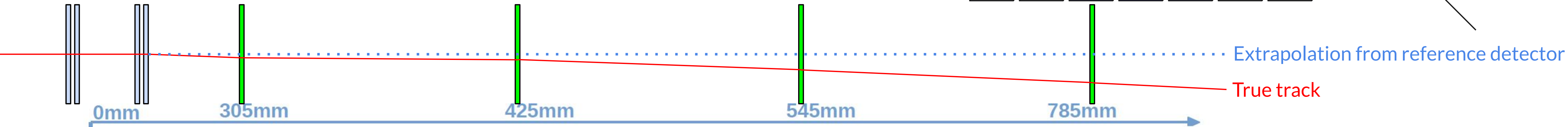
Results from the Mainz Beam Test

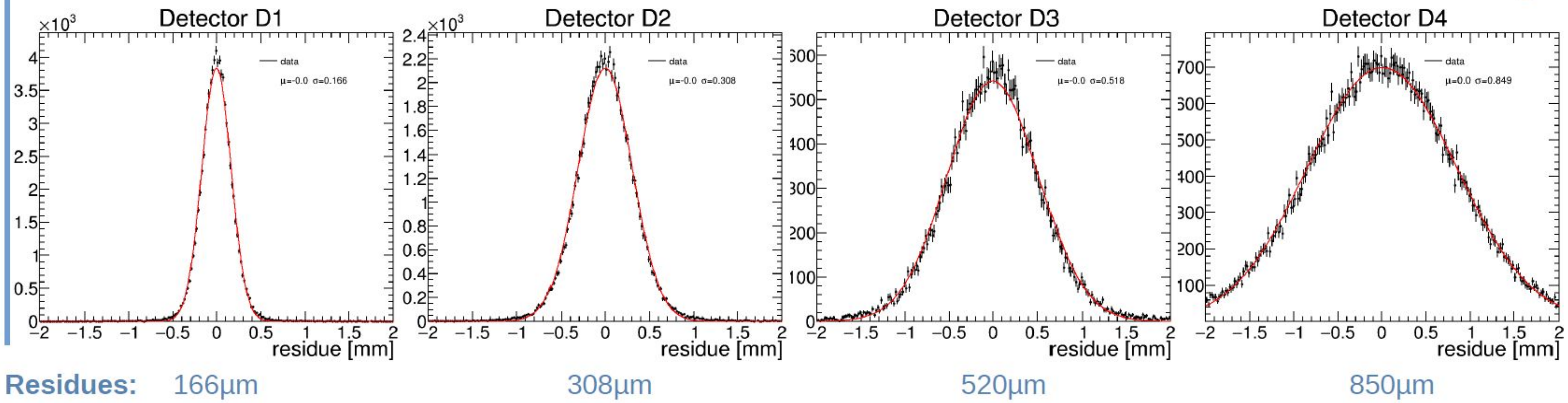
Measurements from beam test data

- Charge Sharing
- Cluster Size
- Spatial Resolution

Caveat:
D1, D2 μRWell, not micromegas







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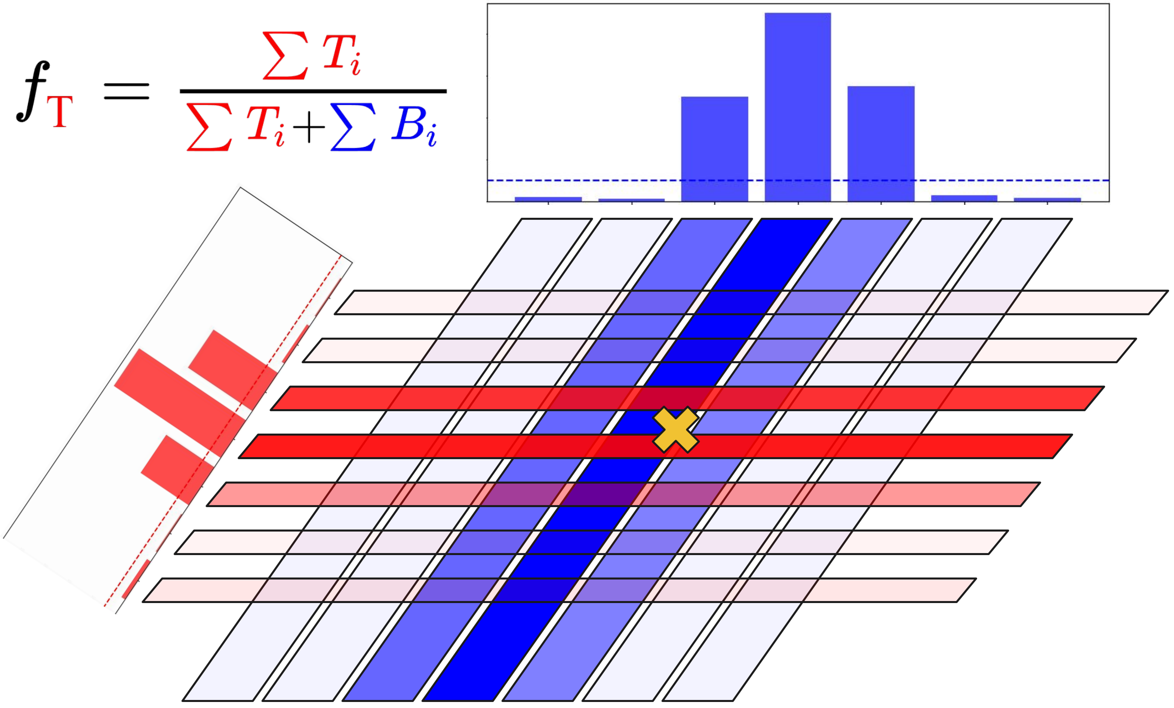
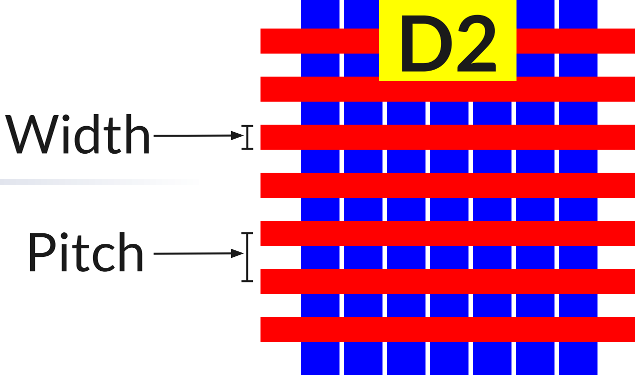
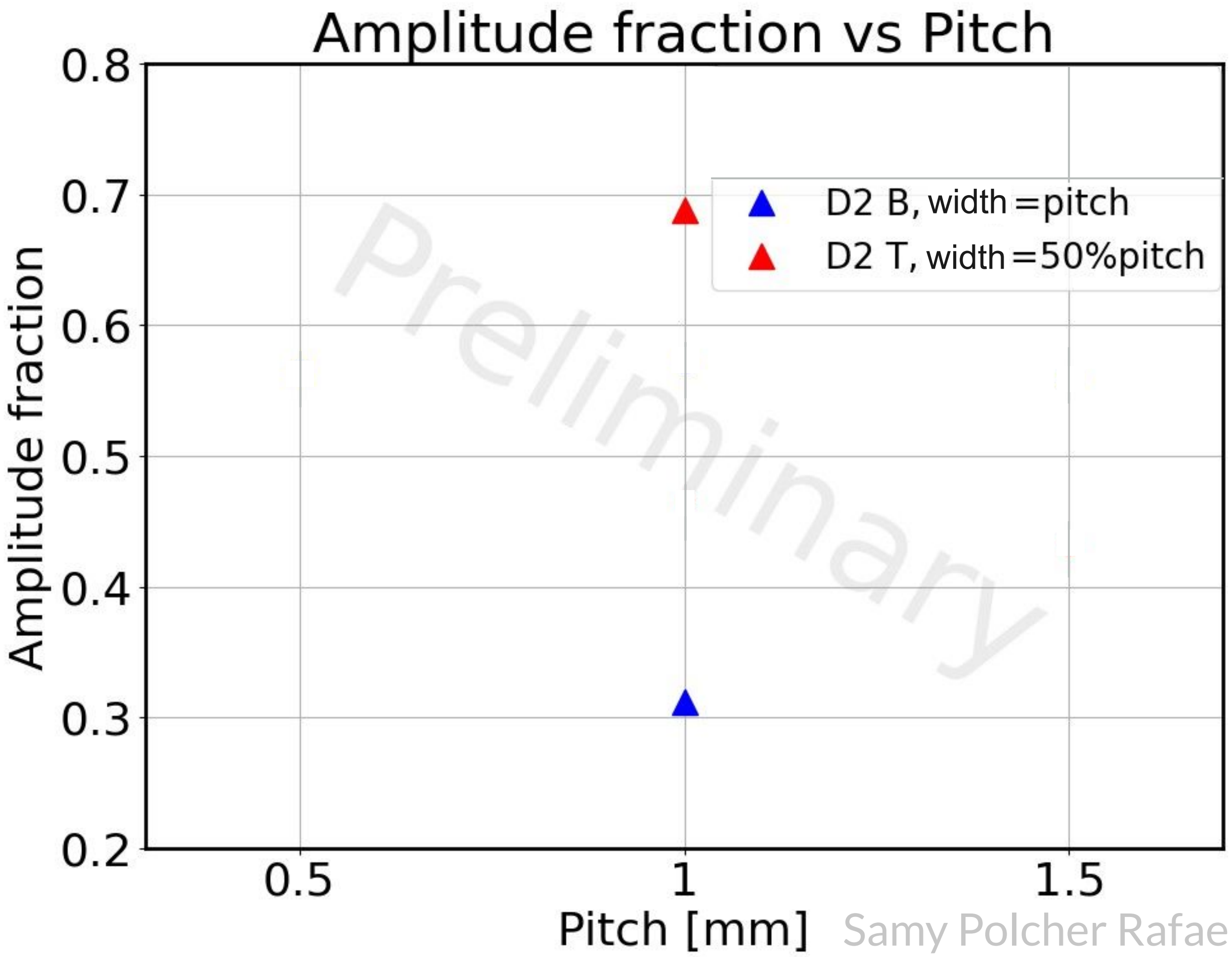
Charge Sharing

$$f_{\mathrm{T}} = \frac{\sum T_i}{\sum T_i + \sum B_i}$$







Samy Polcher Rafael

- What fraction of the charge is collected on the **Top** vs **Bottom** strips?
- Most of charge collected on **Top** strips for **D2**

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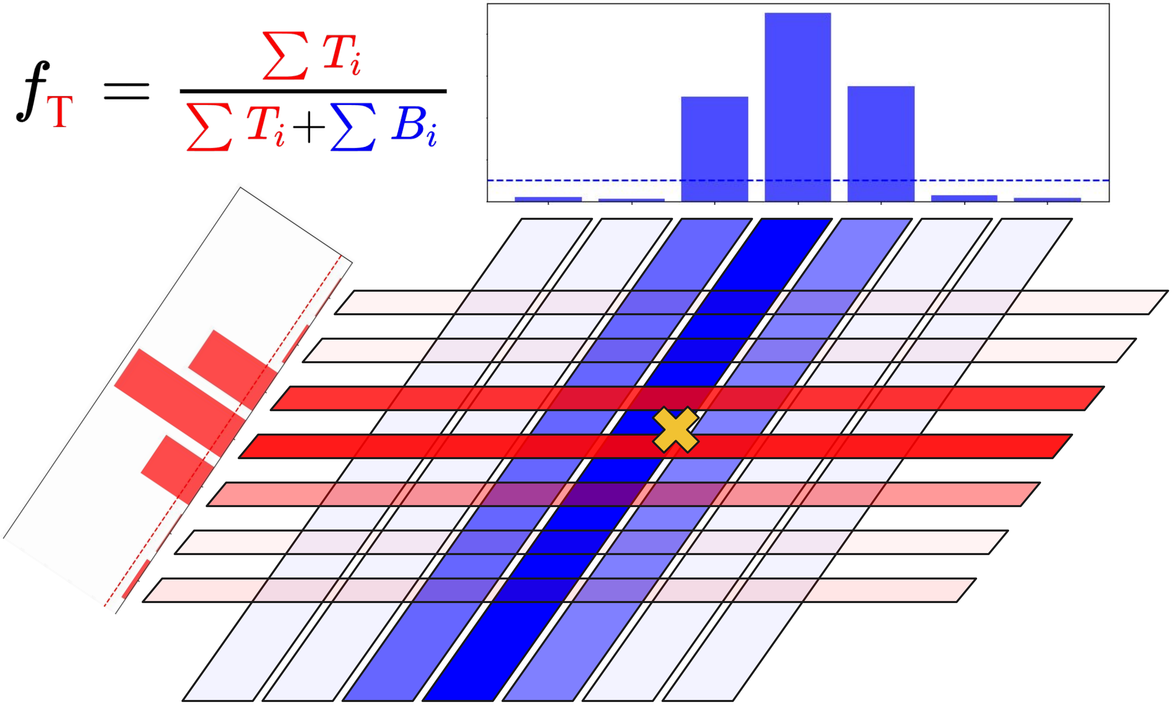
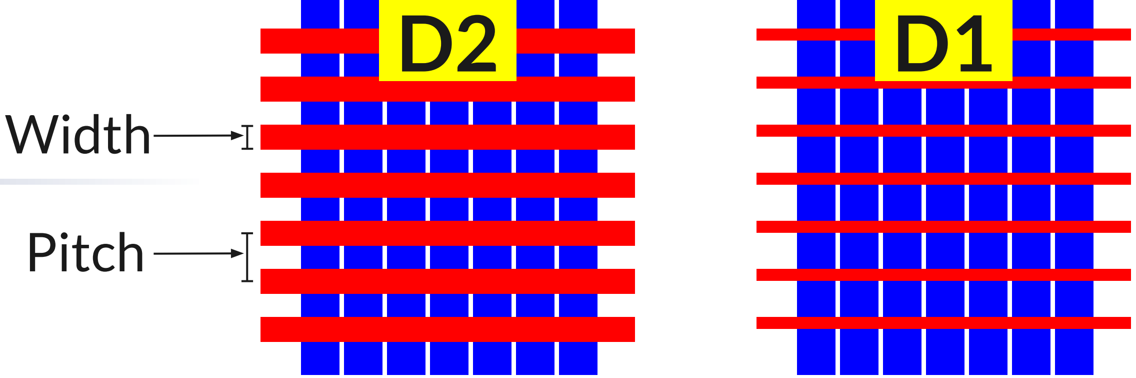
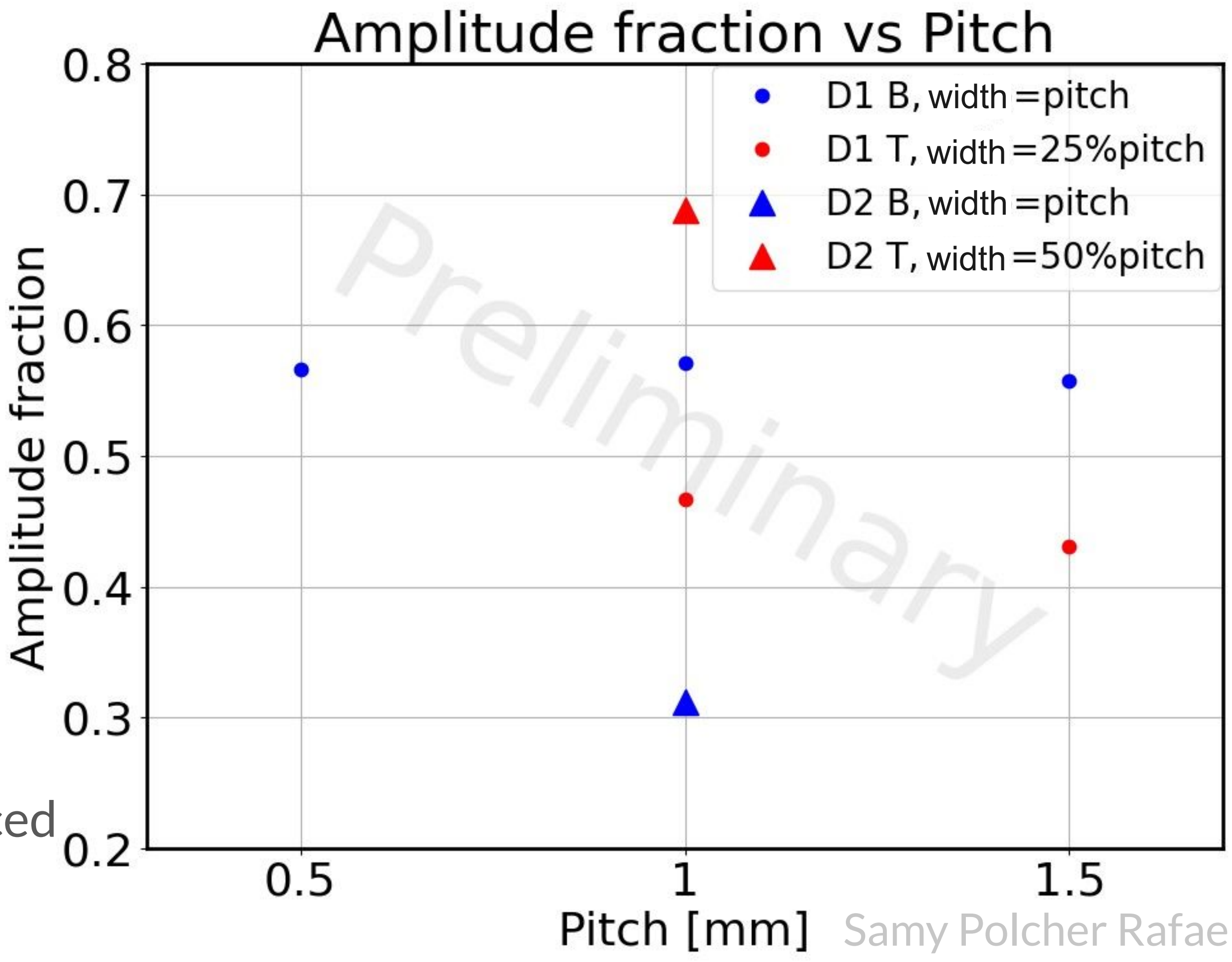


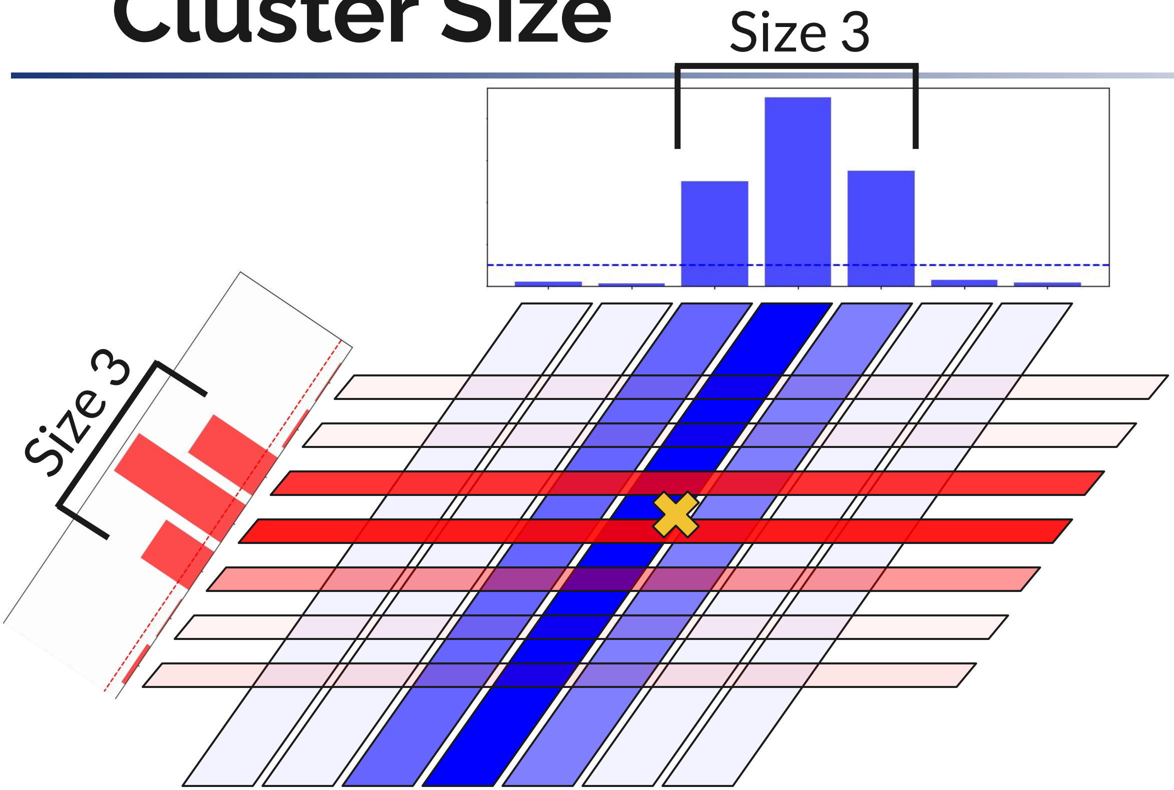


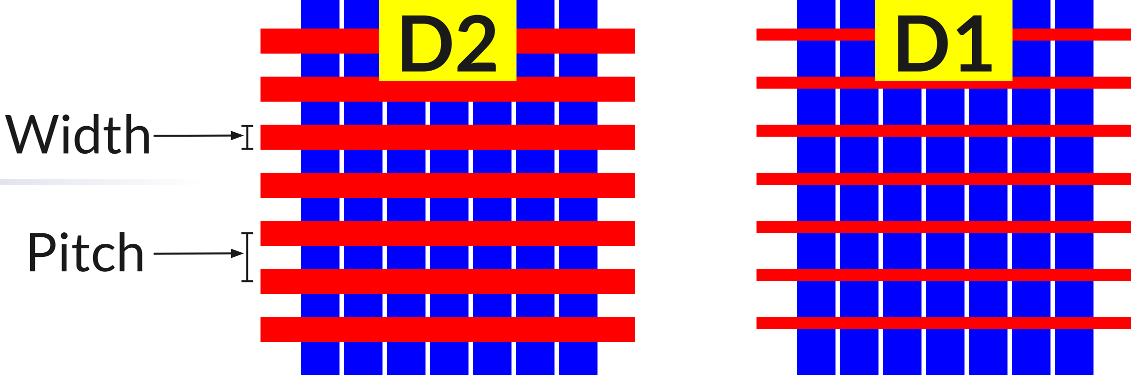


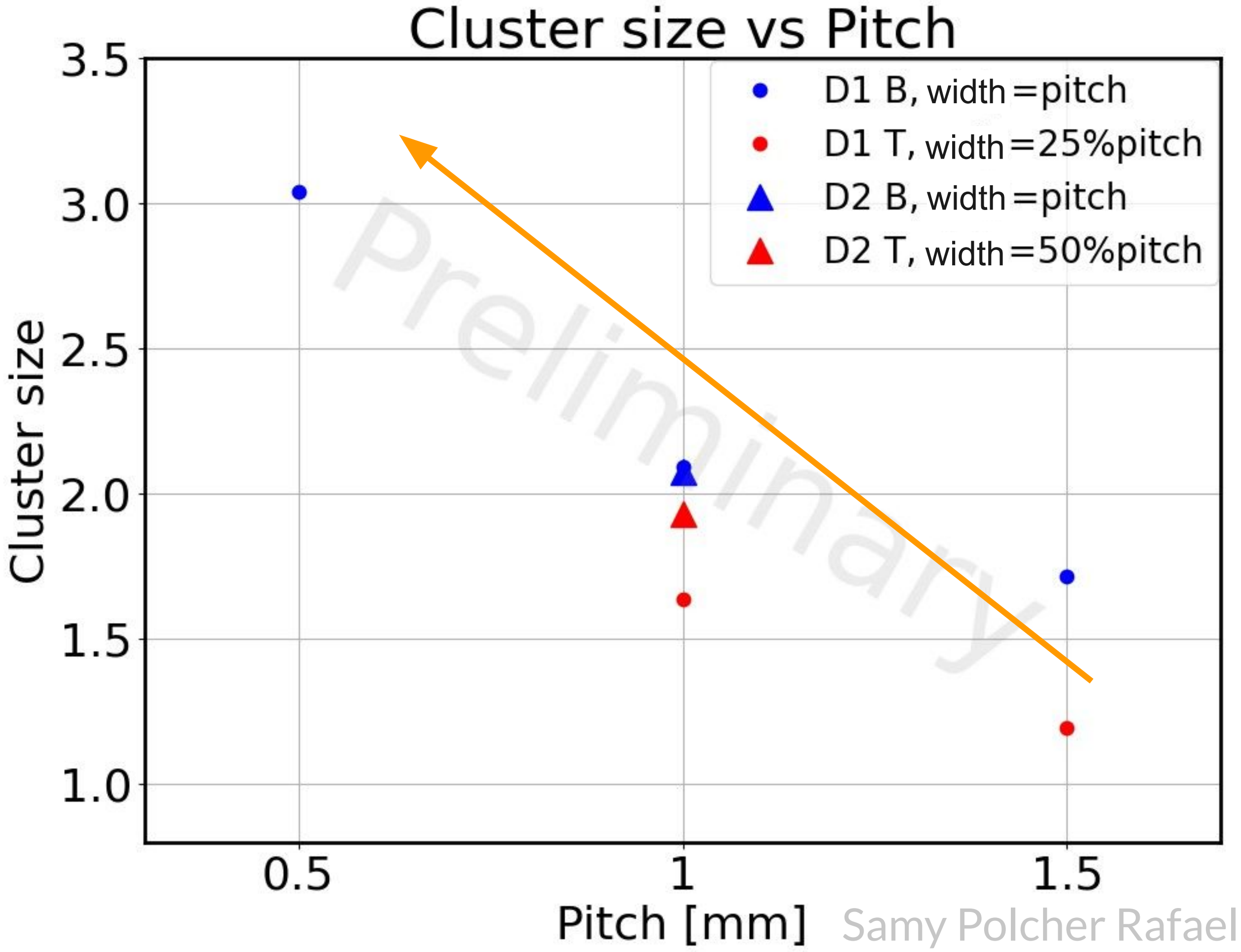
Samy Polcher Rafael

- What fraction of the charge is collected on the **Top** vs **Bottom** strips?
- Most of charge collected on **Top** strips for **D2**
- More equal sharing in **D1** where **Top** strip width reduced
  - Can tune **Top** strip width to optimize charge sharing

Cluster Size

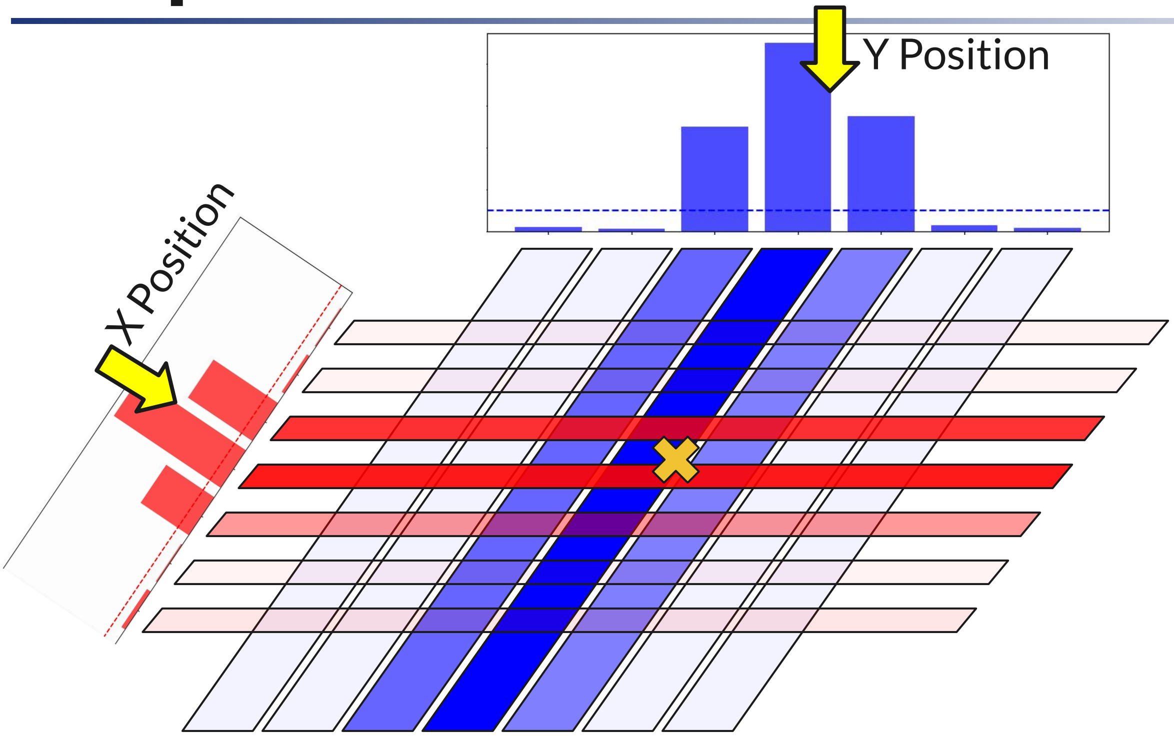


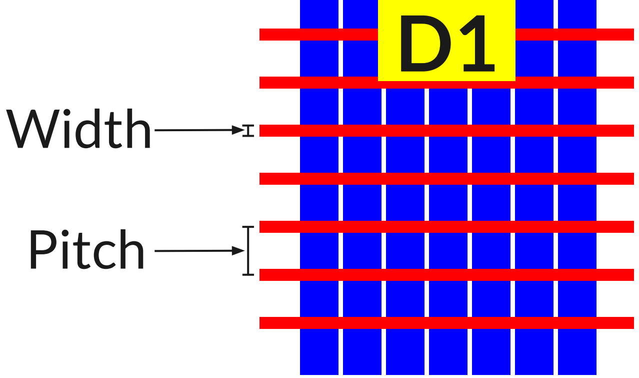




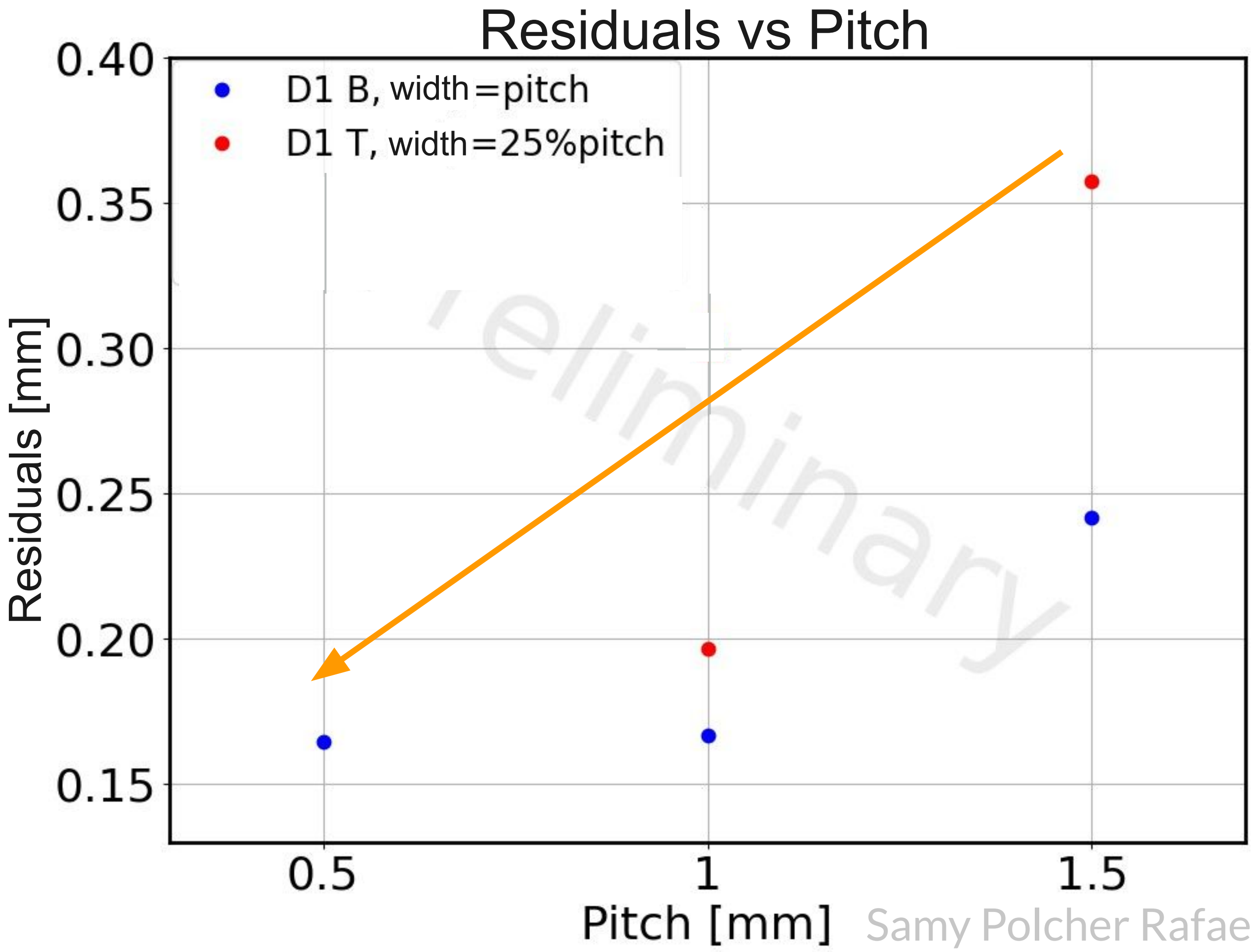
- Cluster Size: Number of adjacent strips above threshold
  - For cluster size > 2, a weighted average can improve spatial resolution. Larger cluster size desirable
- Smaller pitch increases cluster size
- Wider Top strips (**D2**) increase cluster sizes

Spatial Resolution





- Residuals: Difference between a track's true position and measured position
- Finer pitch gives better (smaller) residuals at the expense of more readout channels
- Residuals under **200μm** for 0.5 and 1.0 mm pitch



Summary

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- Work ongoing to characterize other prototype detectors and determine optimal 2D readout for CyMBaL

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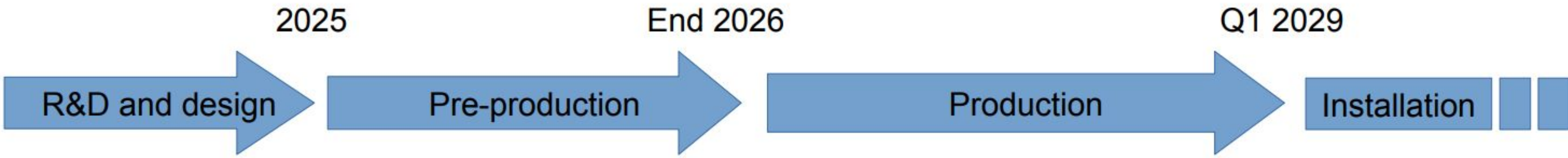
Thanks for your attention!

Backup

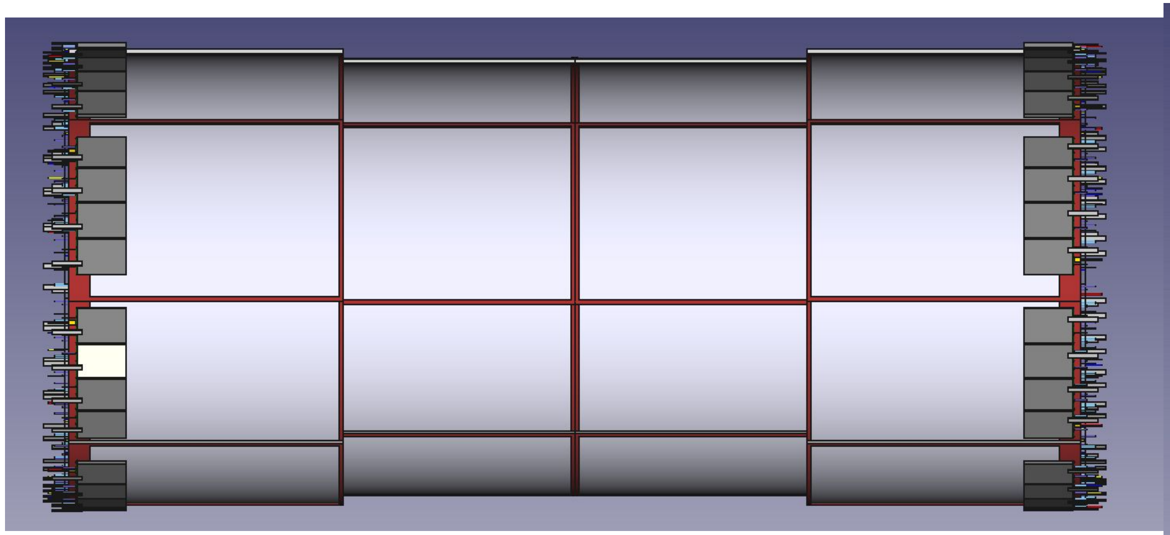
CyMBaL Timeline

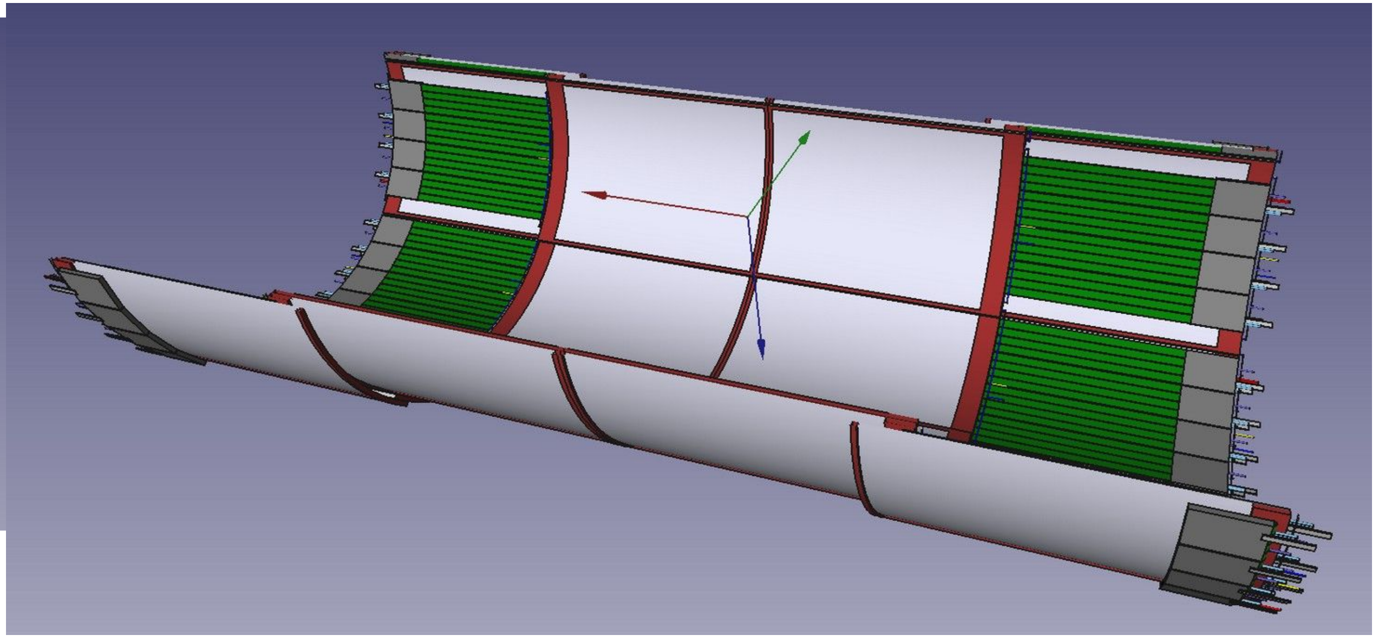


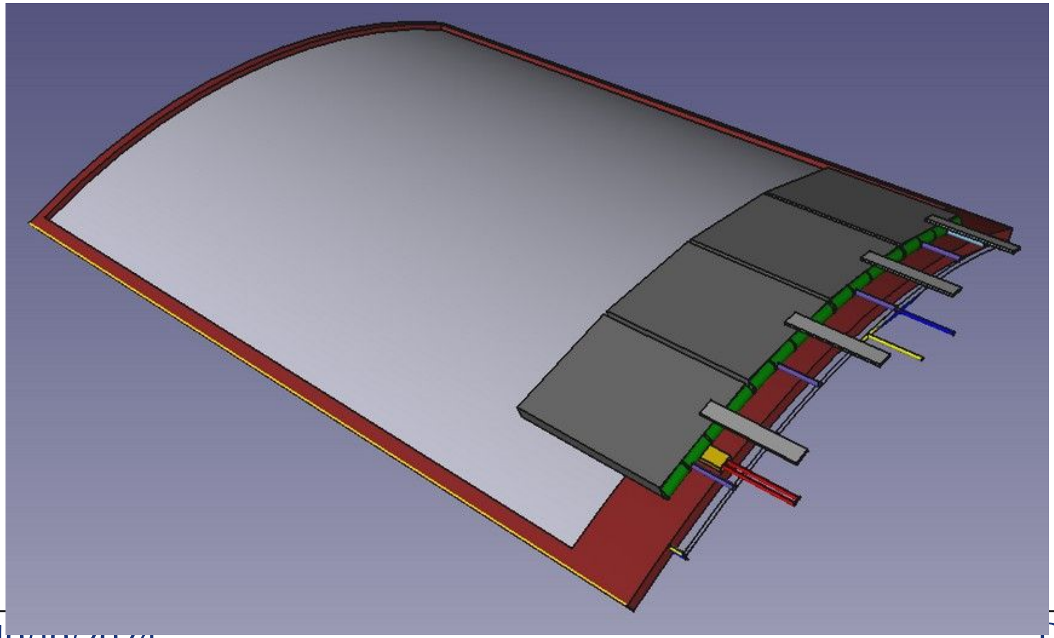
- Choice of the 2D readout pattern
- Large scale prototype
- Design of the final module

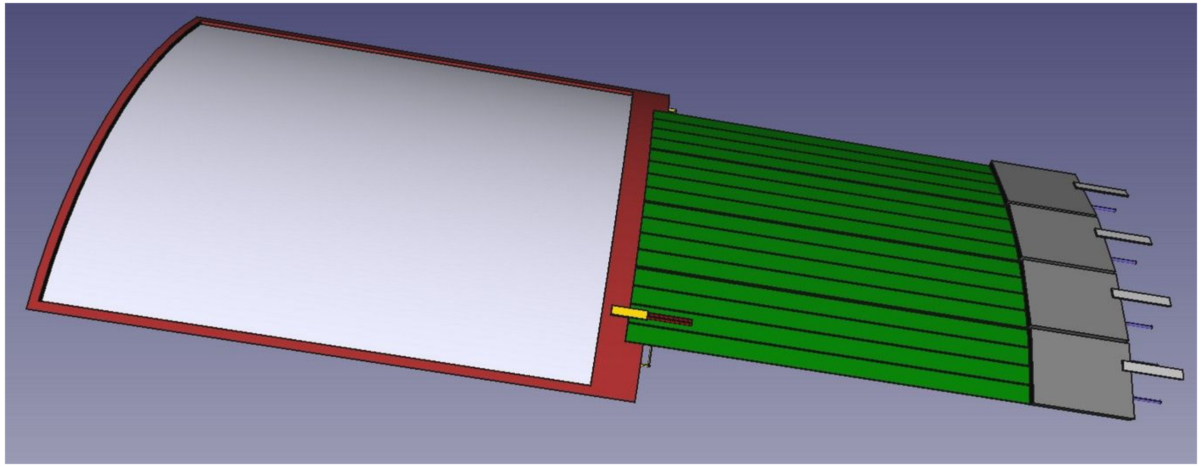
- First production of few modules
- Adjustment of the design
- Test of components from vendors
- Test of assembly line
- Start procurement for prod
- Validation of detector mechanics with ePIC support structure

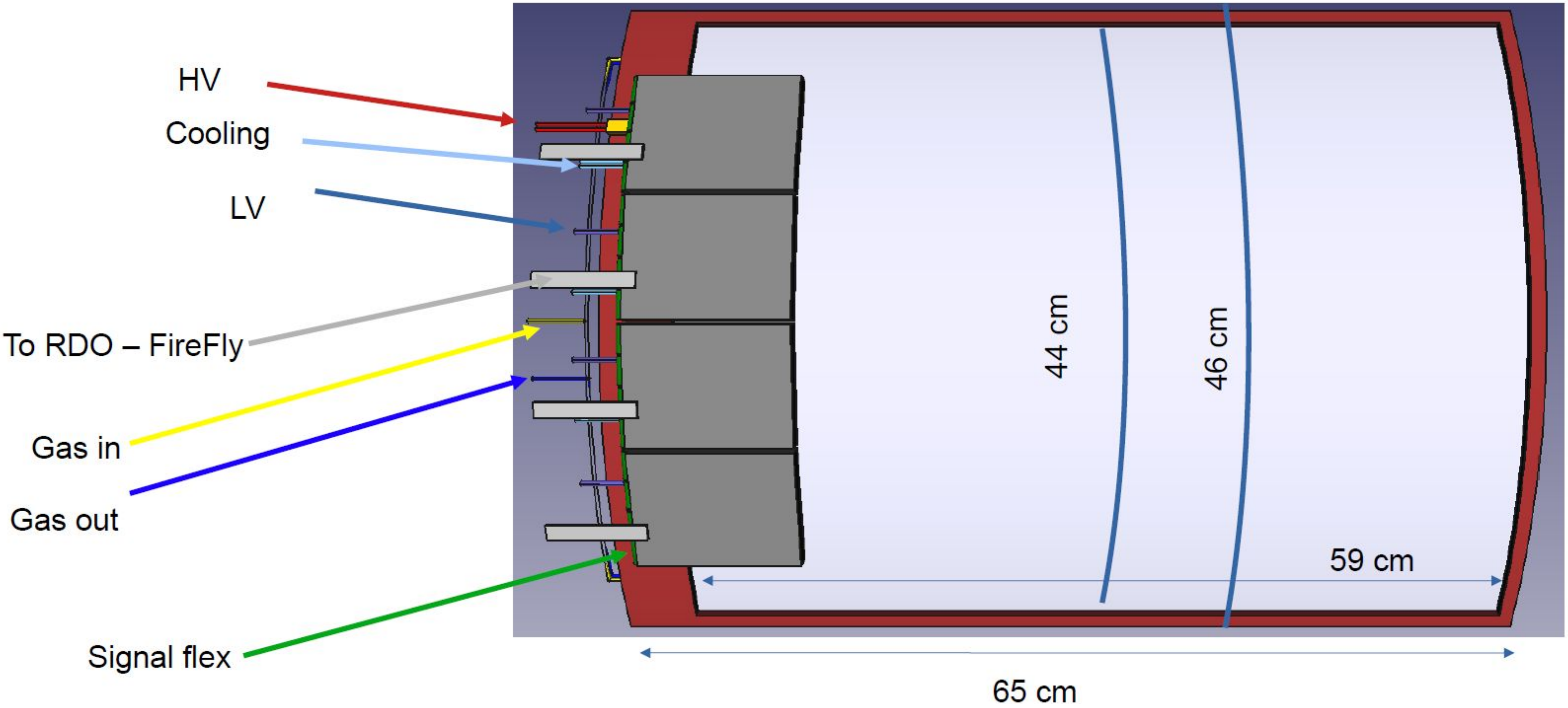
- Production of 32 modules
- Validation of modules with cosmics and with Fe55
- Shipments to BNL

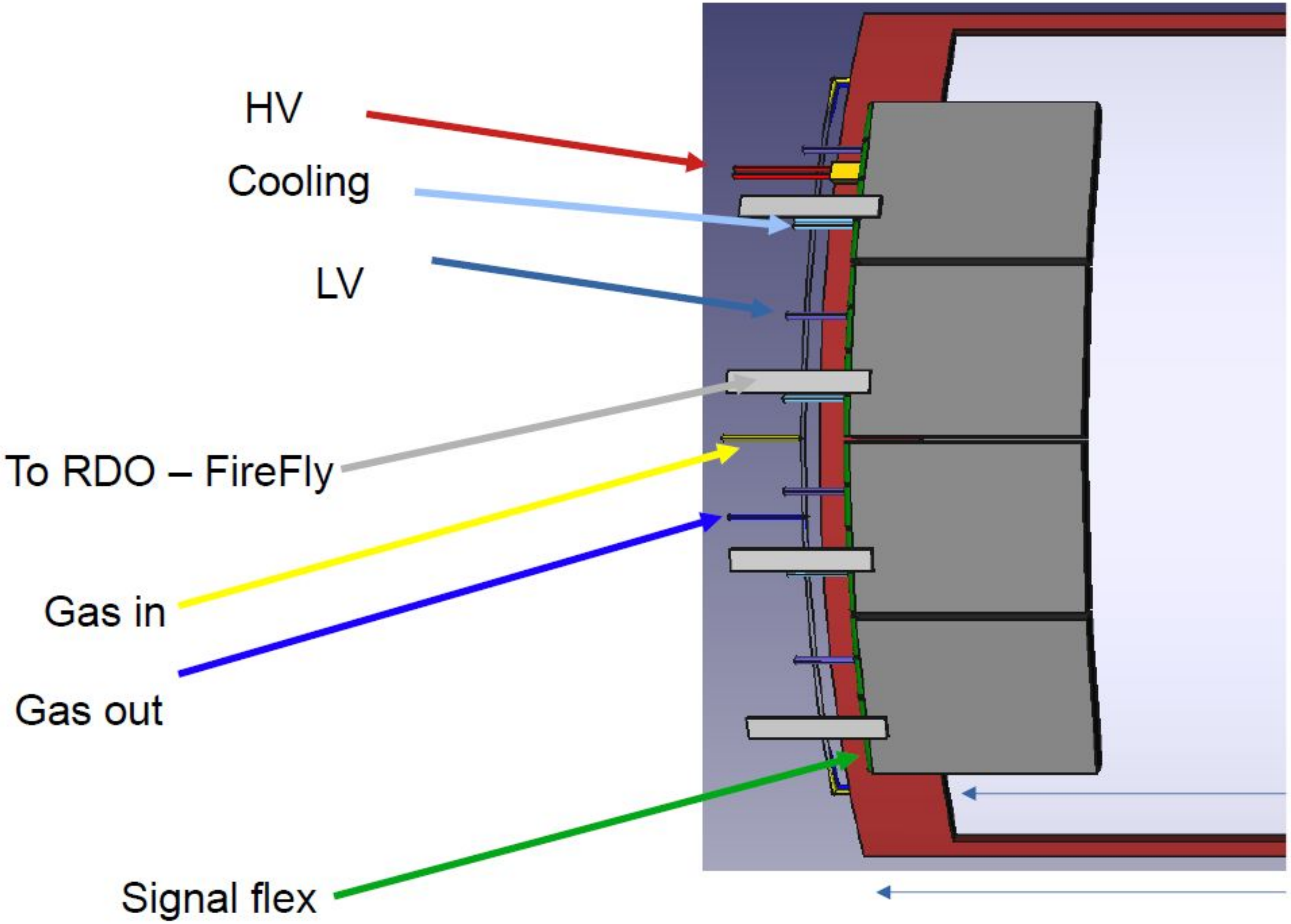









HV
Cooling
LV
To RDO – FireFly
Gas in
Gas out
Signal flex
44 cm
46 cm
59 cm
65 cm



Dimensions:

- Size: 65 x 46 cm^2
- Active area: 59x44 cm^2
- r/o strips: ~1 mm pitch in both directions
- Readout strips per module: 1024
- 32 channels per connector → 32 connectors

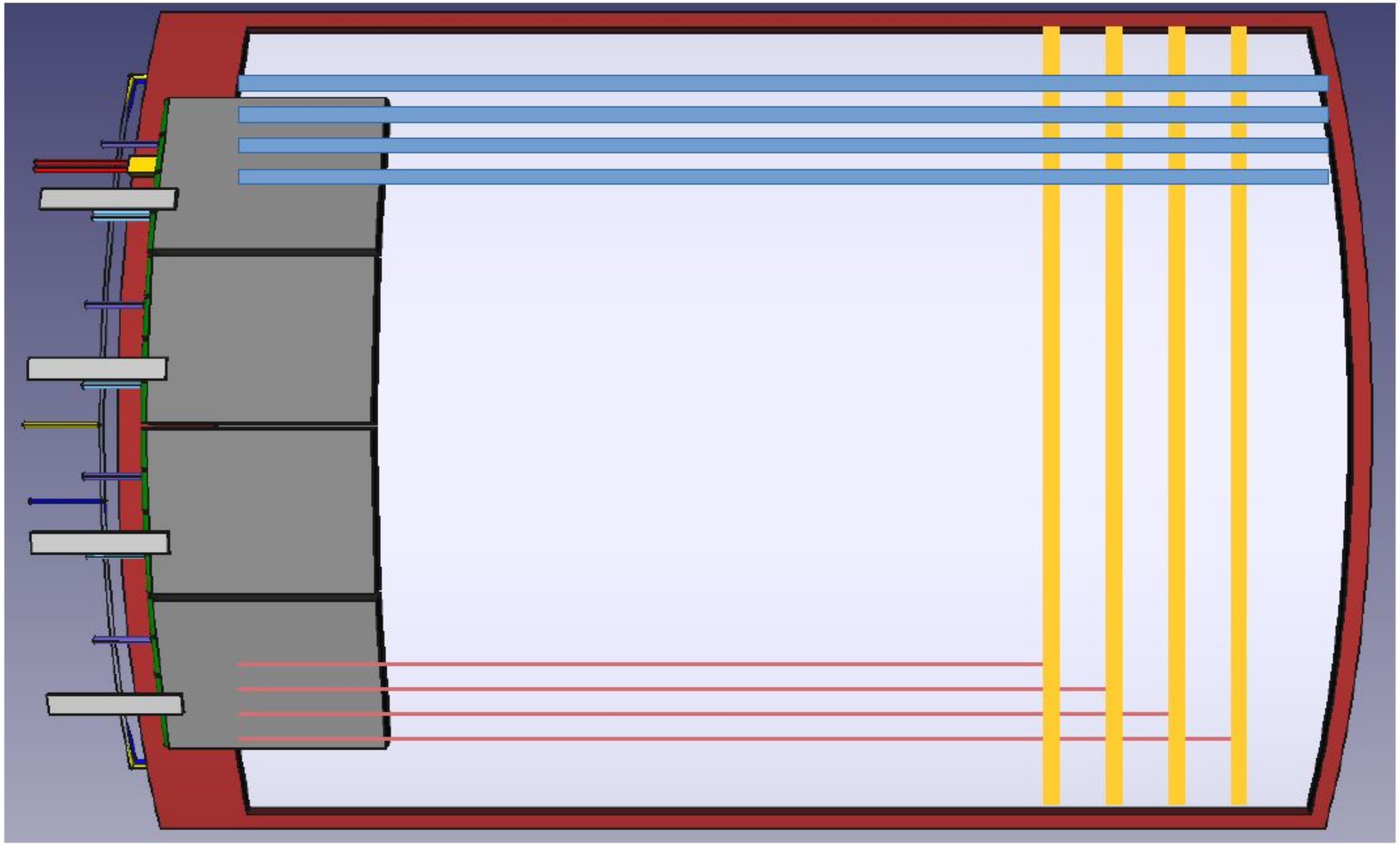
Services:

- HV: 2 channels (drift and resistive layer)
- Gas: 2 tubes (in and out)
  - Two tiles can be in series
- 4 FEBs per module
- 4 ASICs per FEB:
  - 1x8ch FireFly per FEB to the RDO or optical fiber FreFly
  - 2 short flex cables per ASIC
  - Low voltages: 2 voltages and 2 grounds
  - Cooling in and out, possibly in series

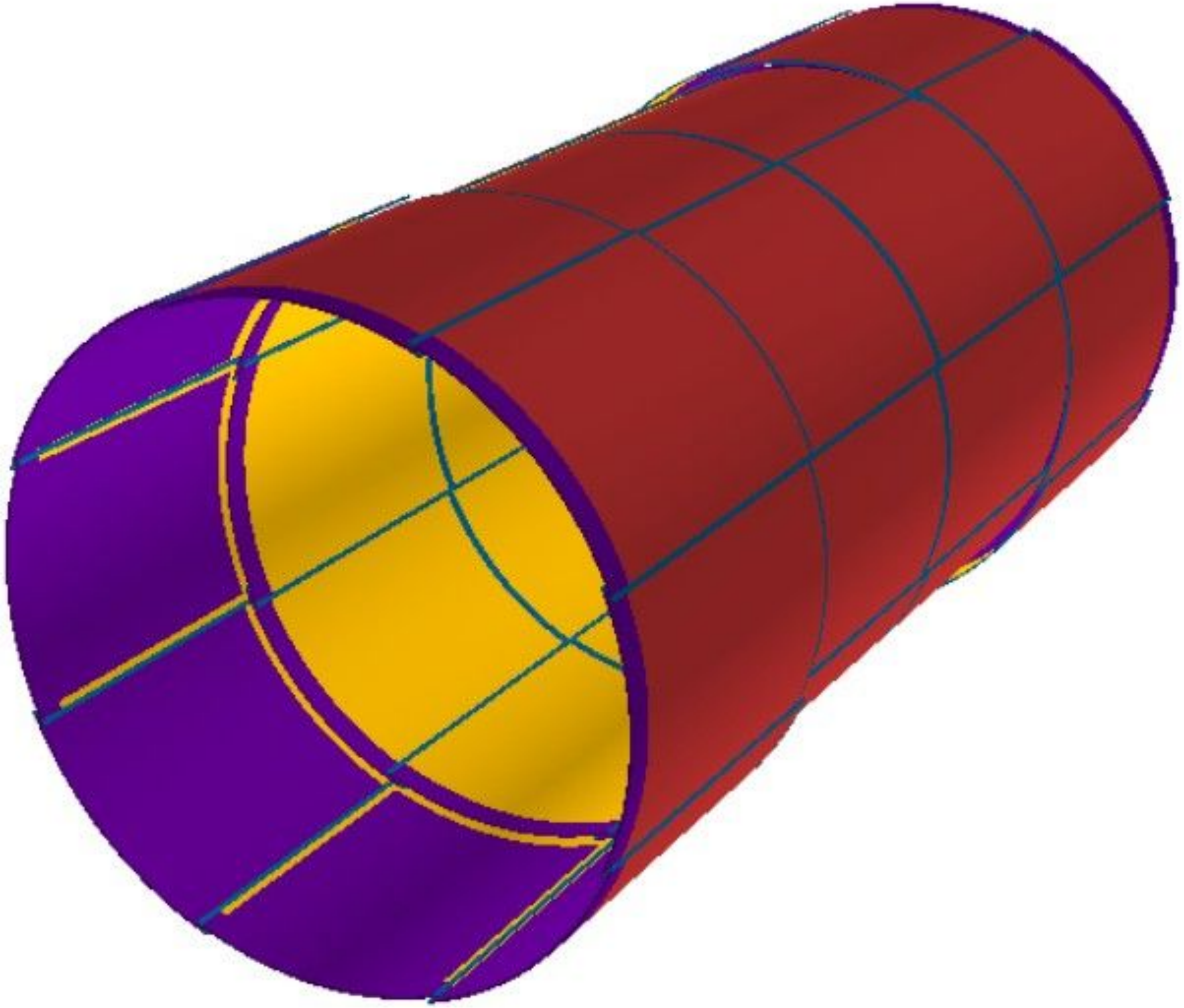
Z; (r phi)

C; (z)

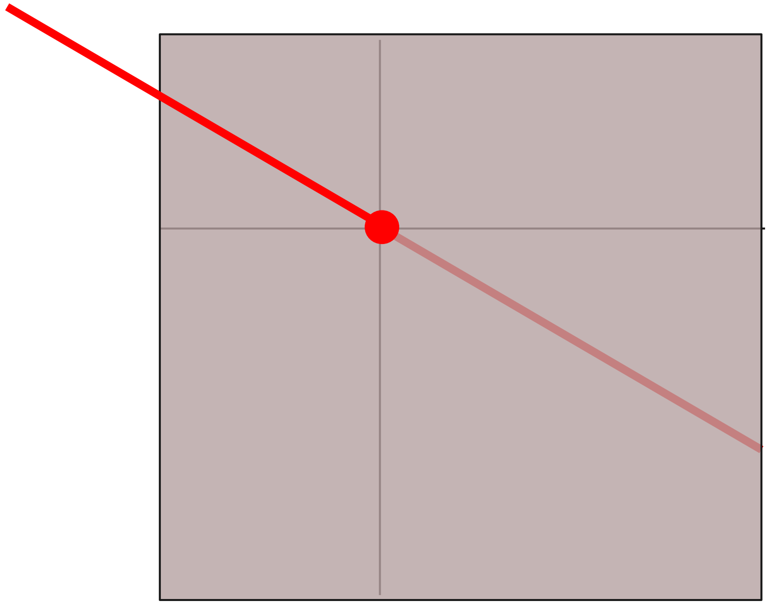
return trail for C strips

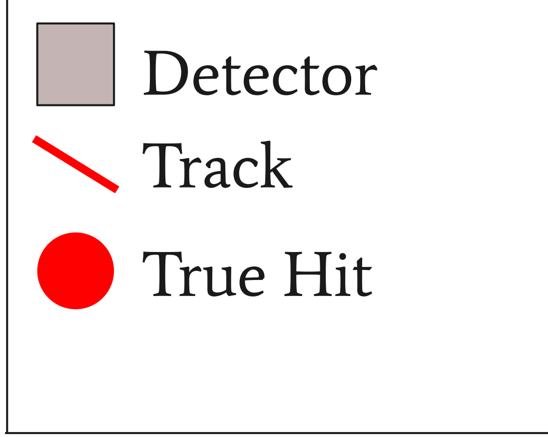


The final decision on the readout pattern design is pending the completion of the R&D



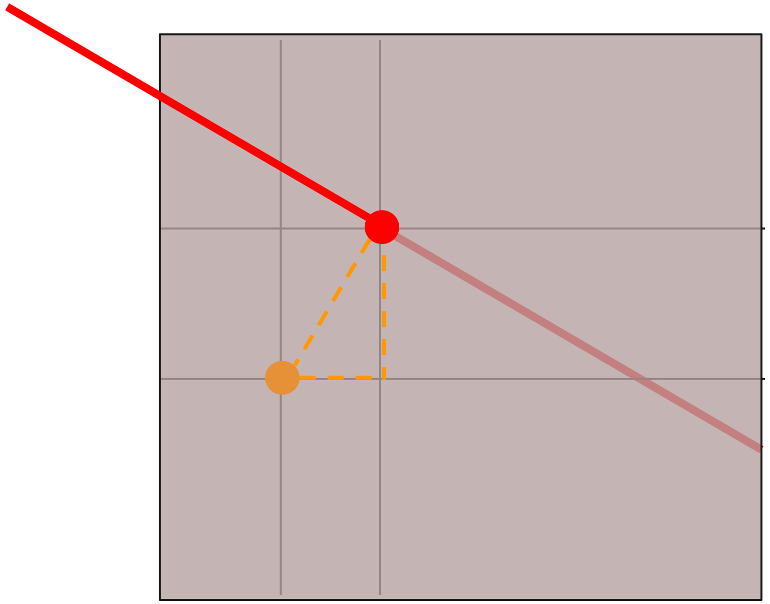
Measuring Tracking Resolution

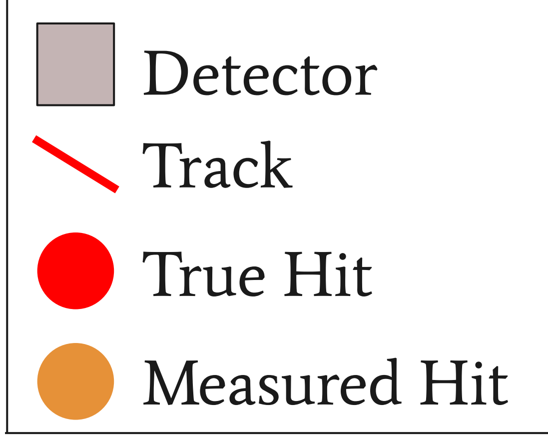




A track passes through (hits) a detector

Measuring Tracking Resolution



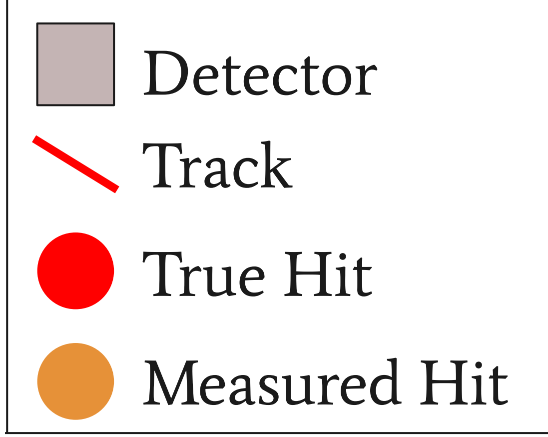


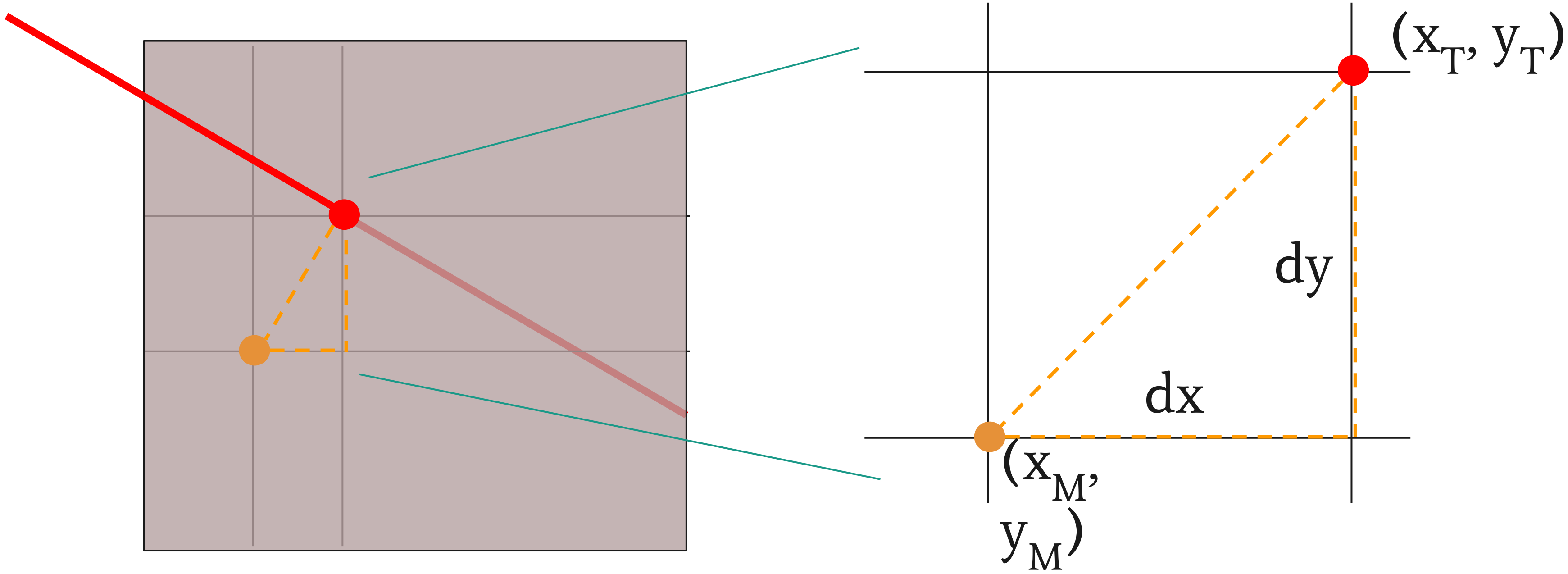
A track passes through (hits) a detector

The detector measures position of hit

Not necessarily in the true hit position

Measuring Tracking Resolution





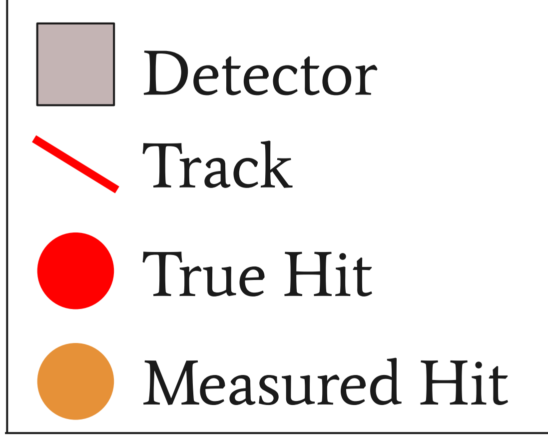
A track passes through (hits) a detector

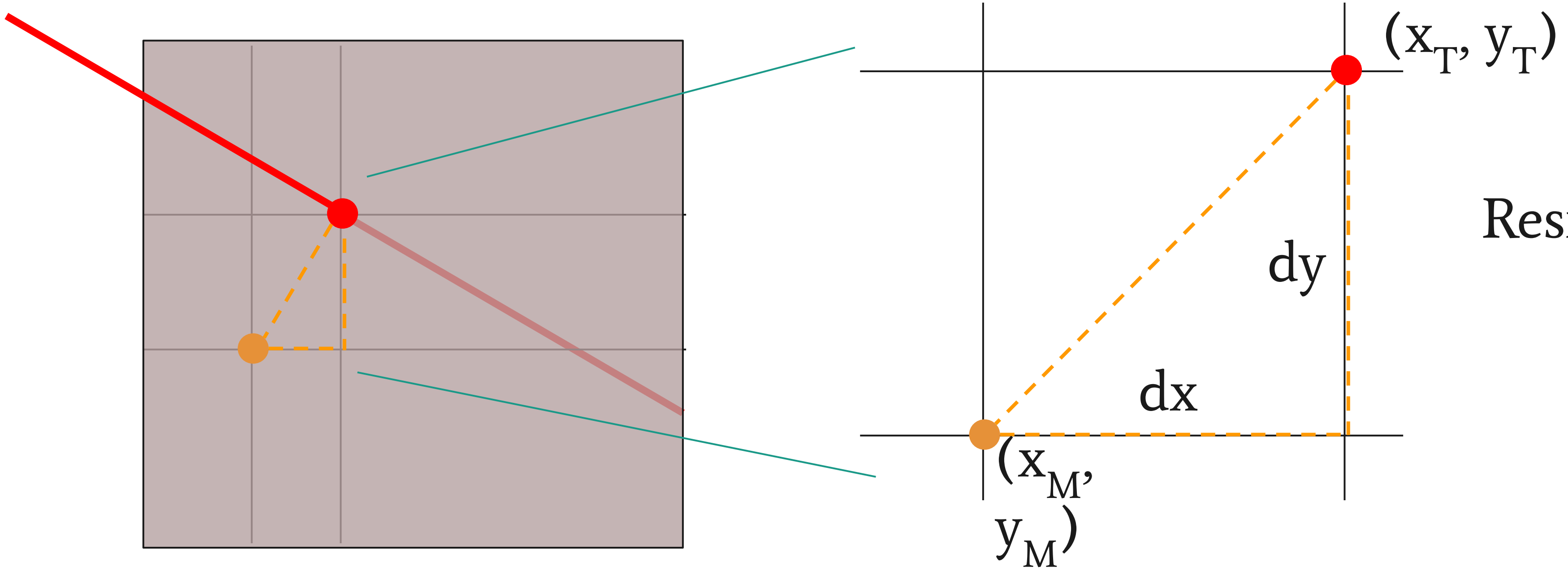
The detector measures position of hit

Not necessarily in the true hit position

Residual: Difference between true and measured hit position

Measuring Tracking Resolution



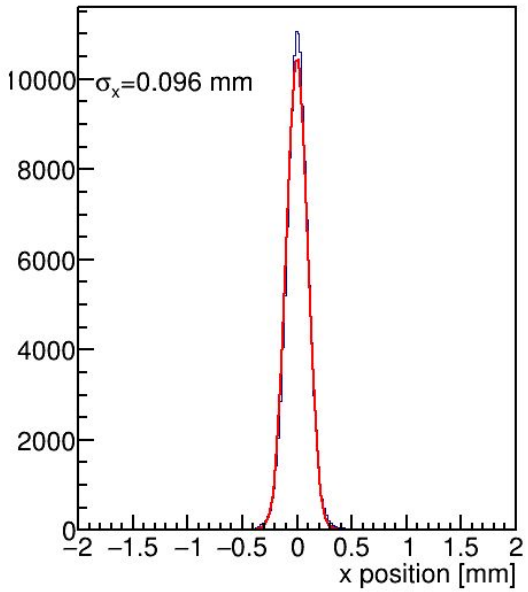


Residual distribution can tell us resolution of detector:
↪ precision of tracking

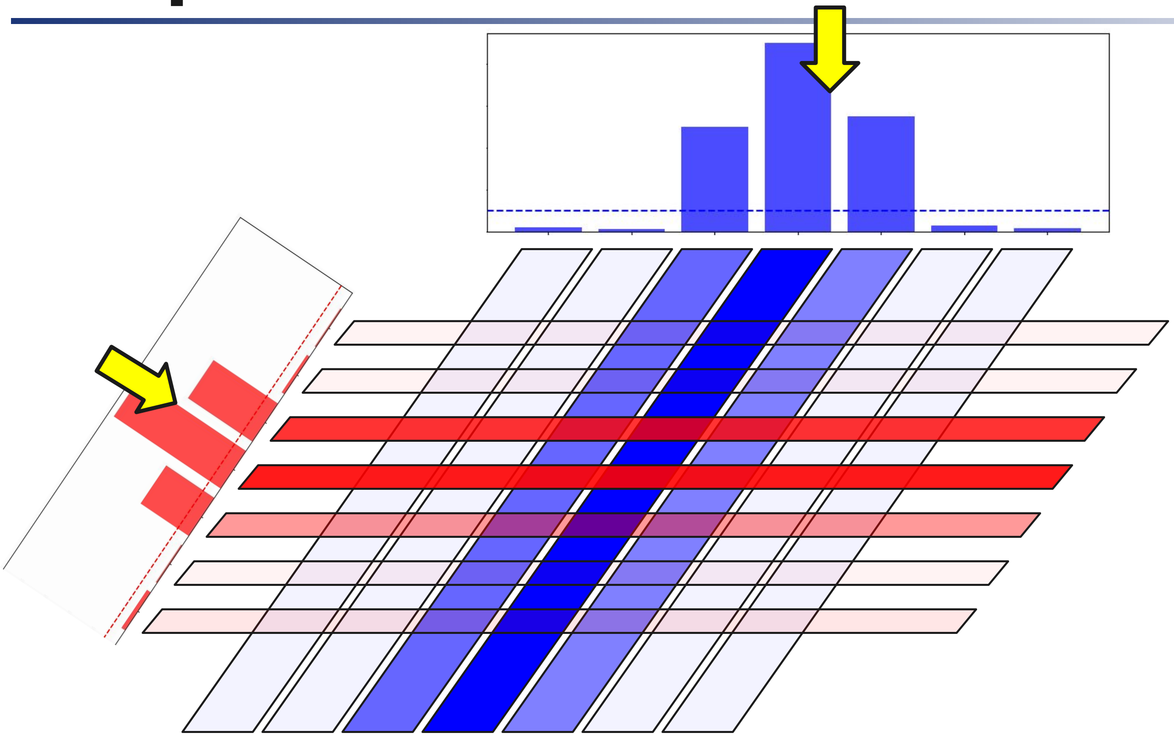
A track passes through (hits) a detector

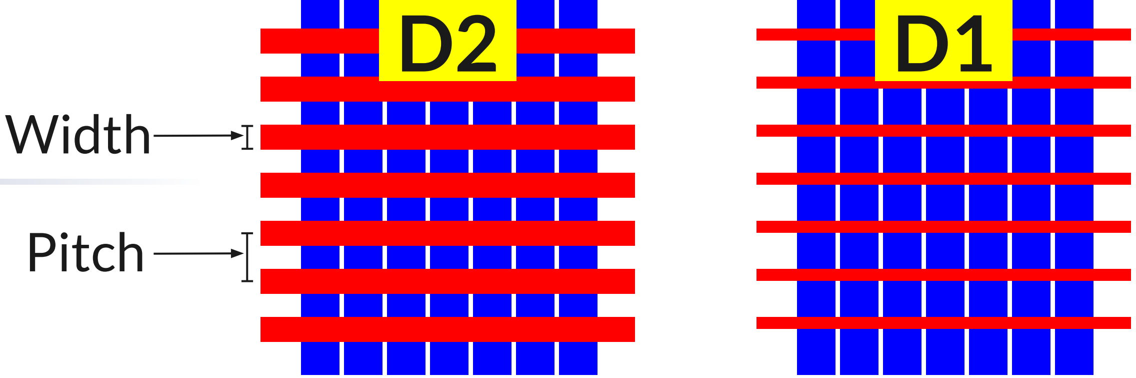
The detector measures position of hit
Not necessarily in the true hit position

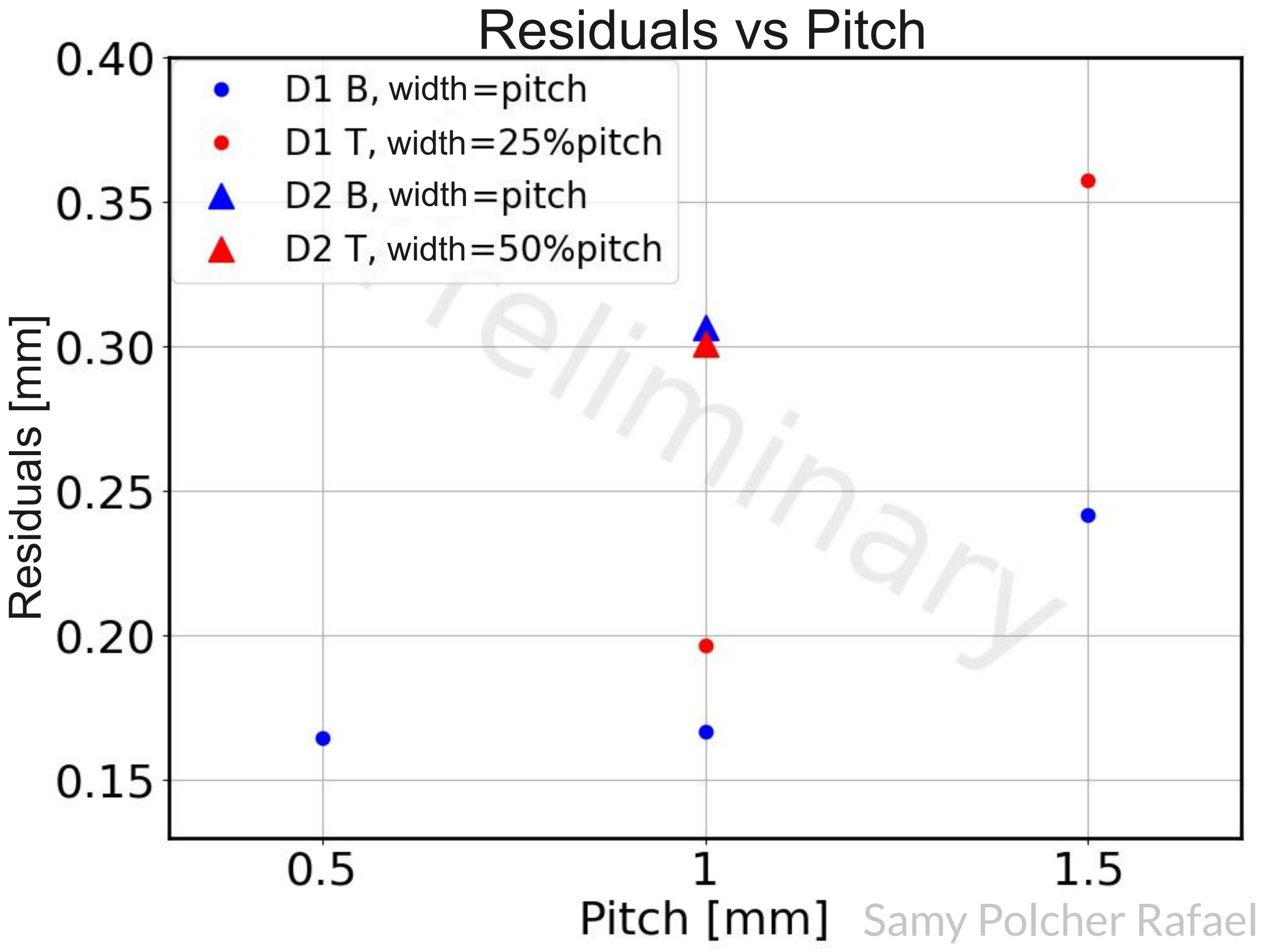
Residual: Difference between true and measured hit position



Spatial Resolution







Samy Polcher Rafael