More

EIC Tracking with Micromegas Detector Design Optimization

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CEA/IRFU/DPhN Saclay

Outline

- Optimizing detector design
  - Measuring Resolution
  - Problem with 2023 beam test
- Plans for 2023 beam test
- Cosmic muons
- Summary & Outlook

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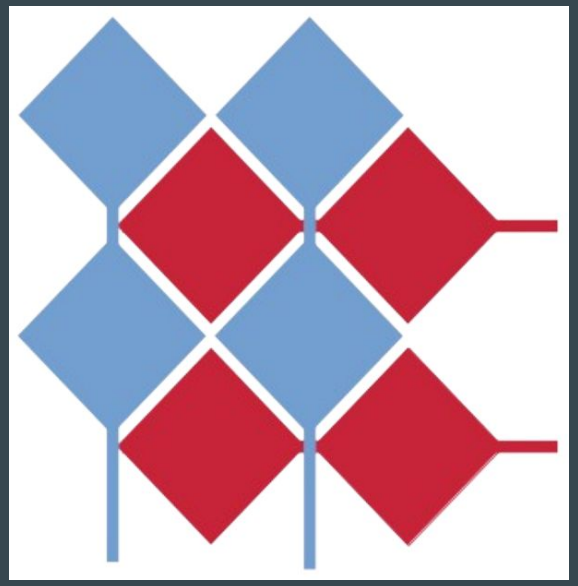
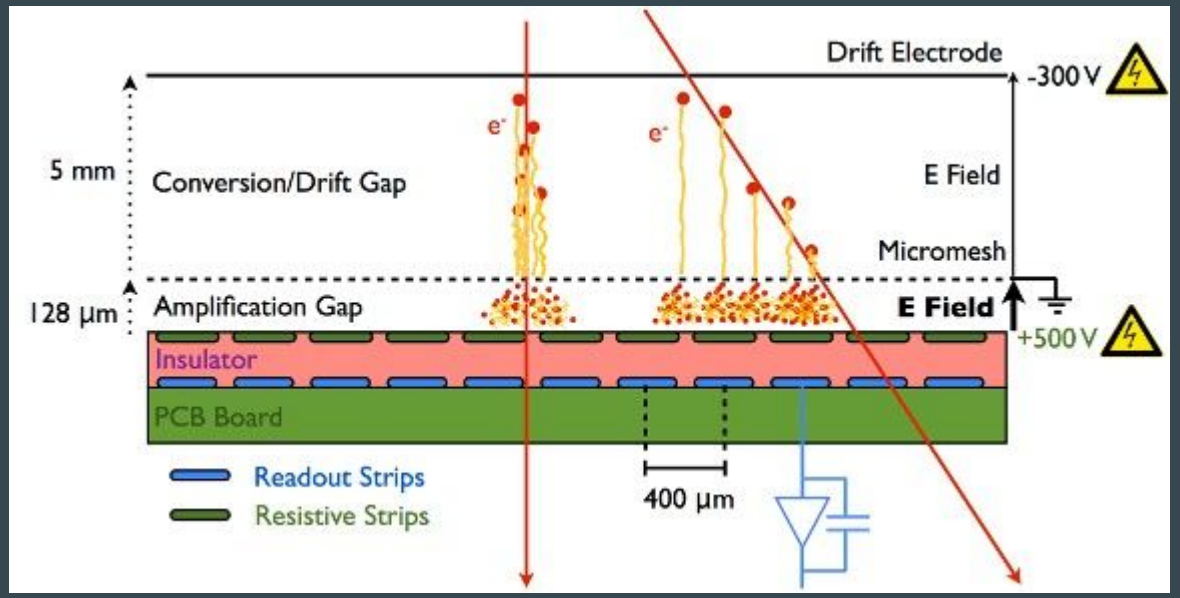
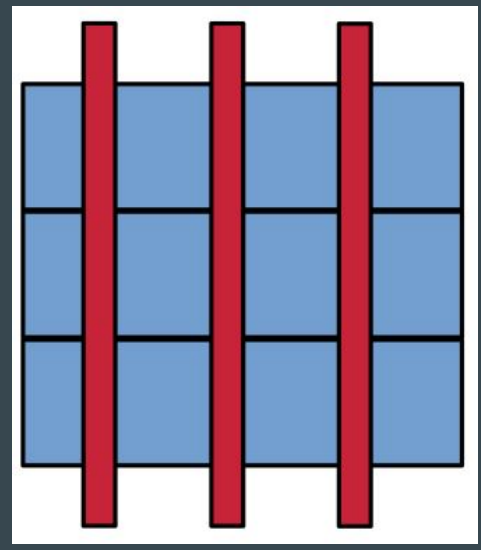
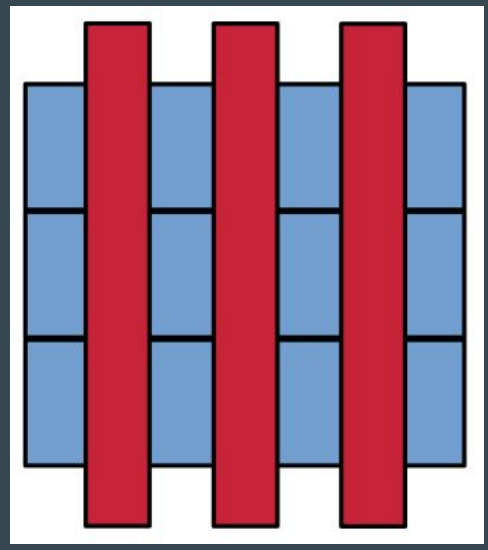
Goal: Select EIC Detector Design

- What is the optimal detector design for EIC?
- Design pattern parameters
  - Readout strips
  - Resistive layer
- Metrics to optimize
  - Tracking resolution
  - Detector efficiency/homogeneity
  - Charge sharing between layers









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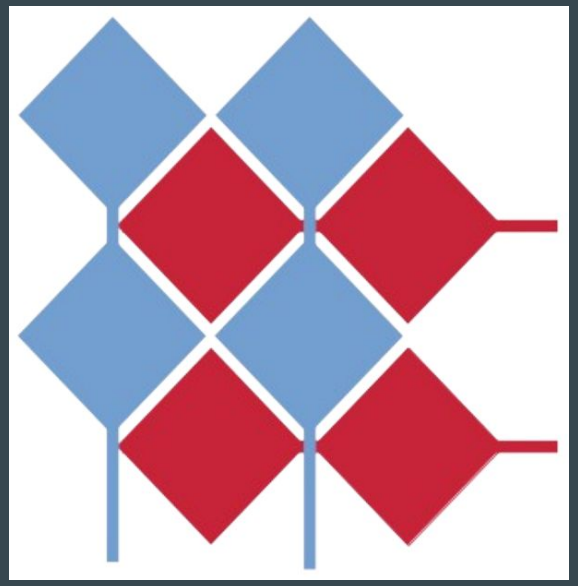
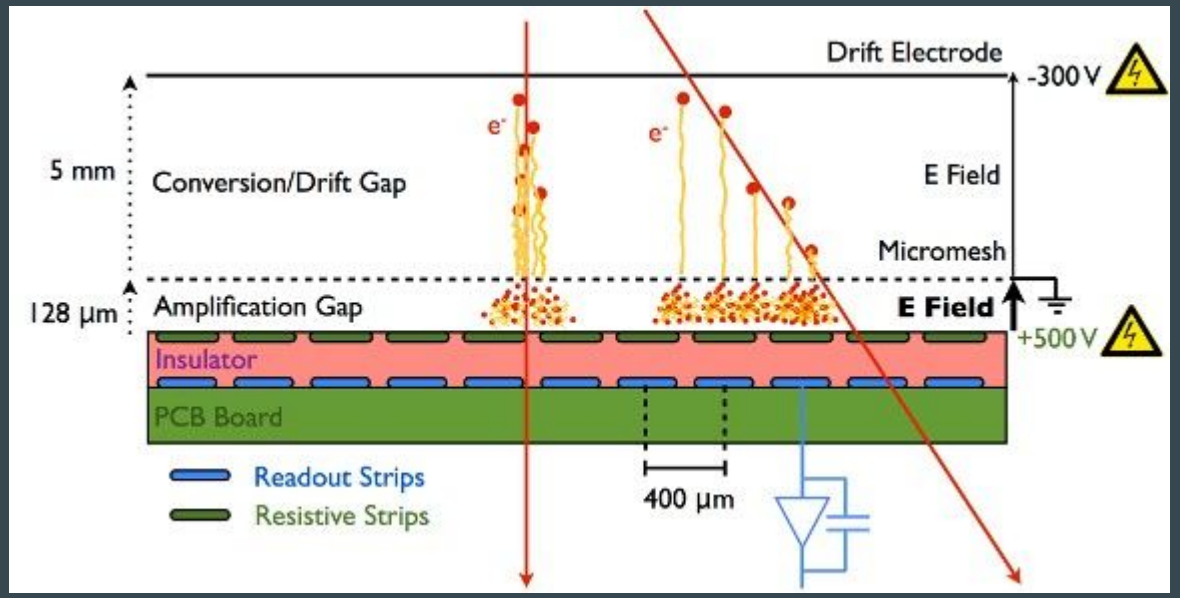
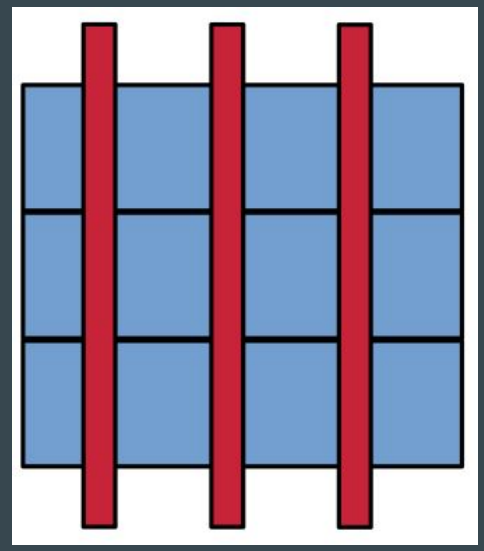
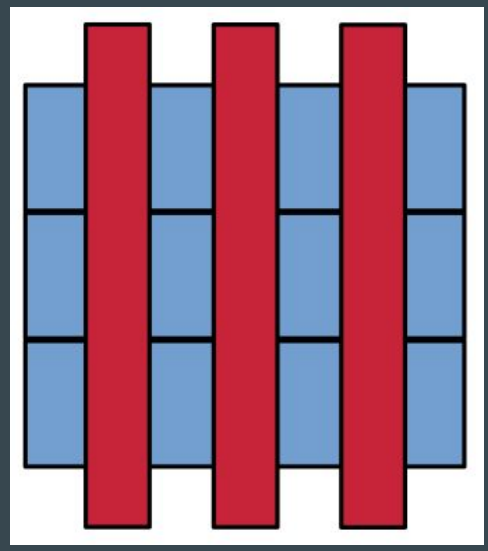
Focus here

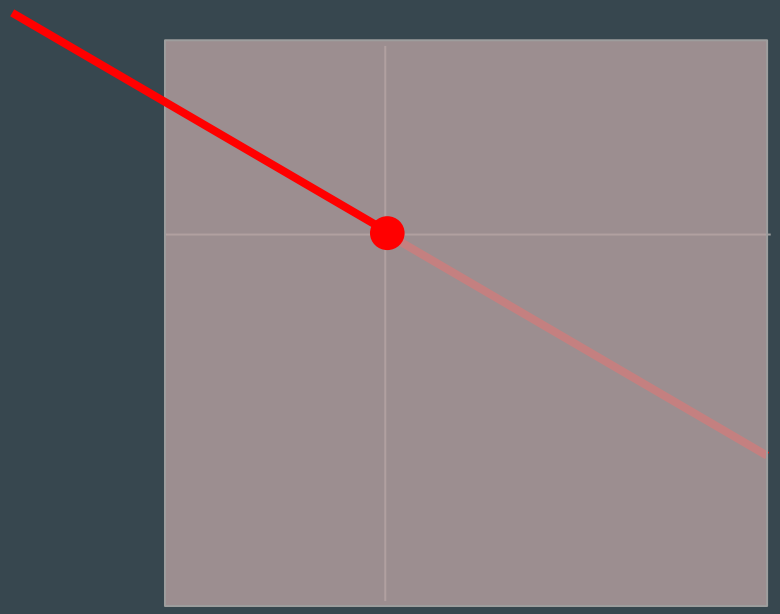






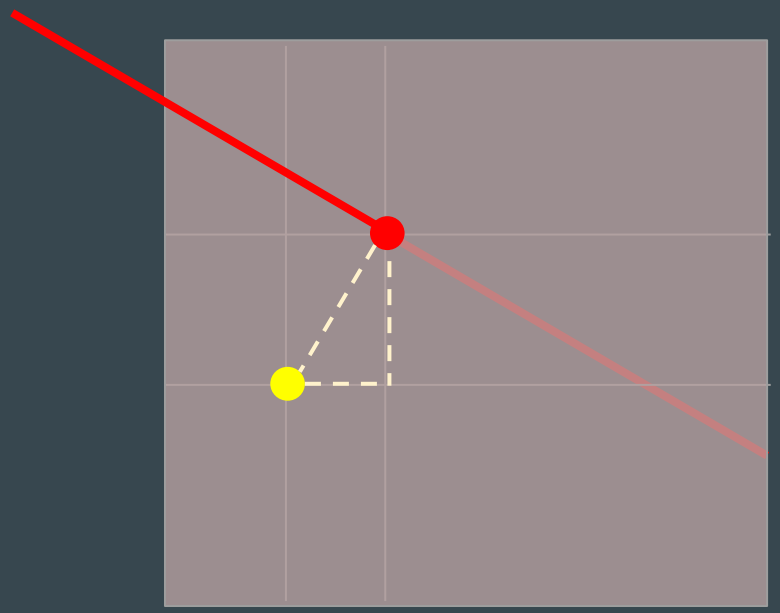


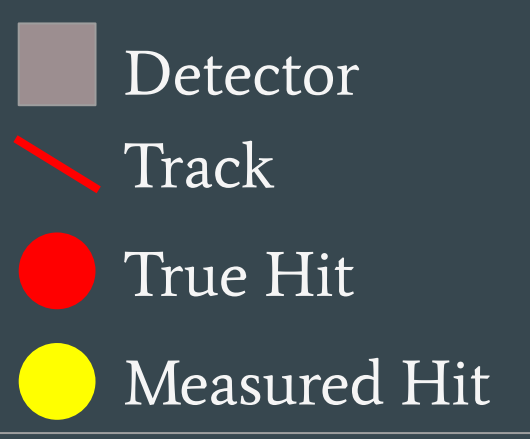
Measuring Tracking Resolution



A track passes through (hits) a detector

Measuring Tracking Resolution



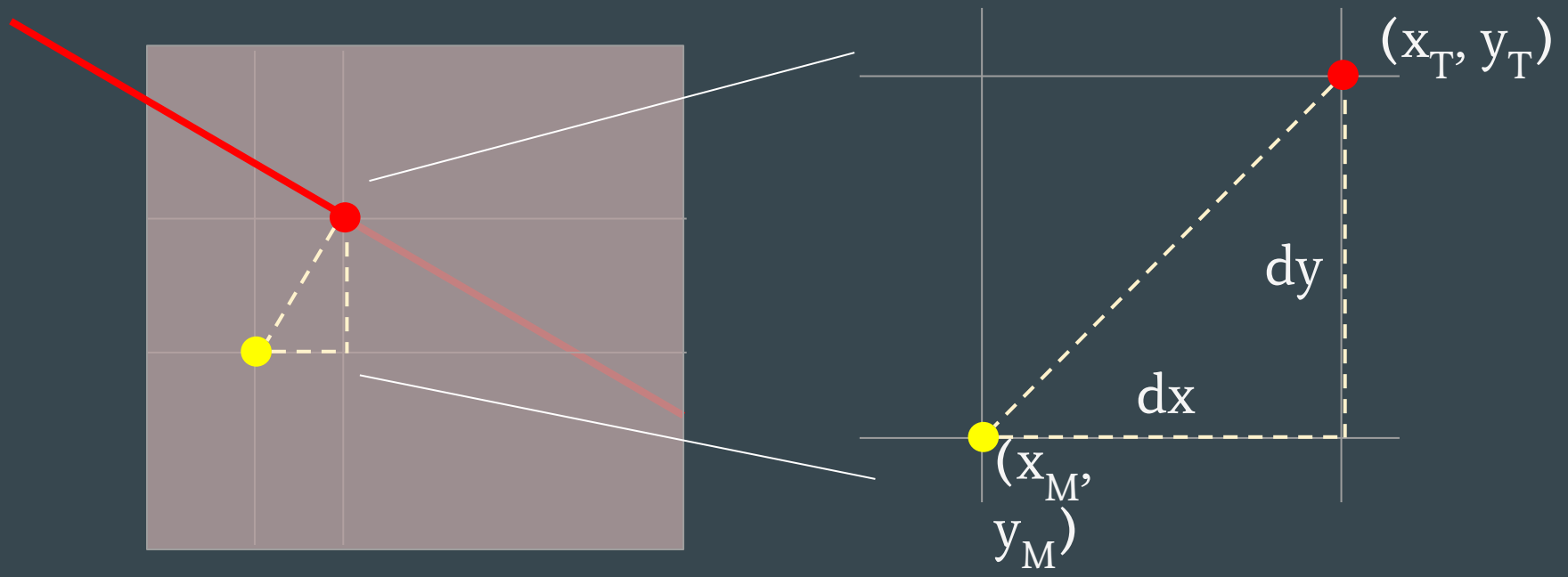


A track passes through (hits) a detector

The detector measures position of hit

Not necessarily in the true hit position

Measuring Tracking Resolution



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Residual: Difference between true and measured hit position

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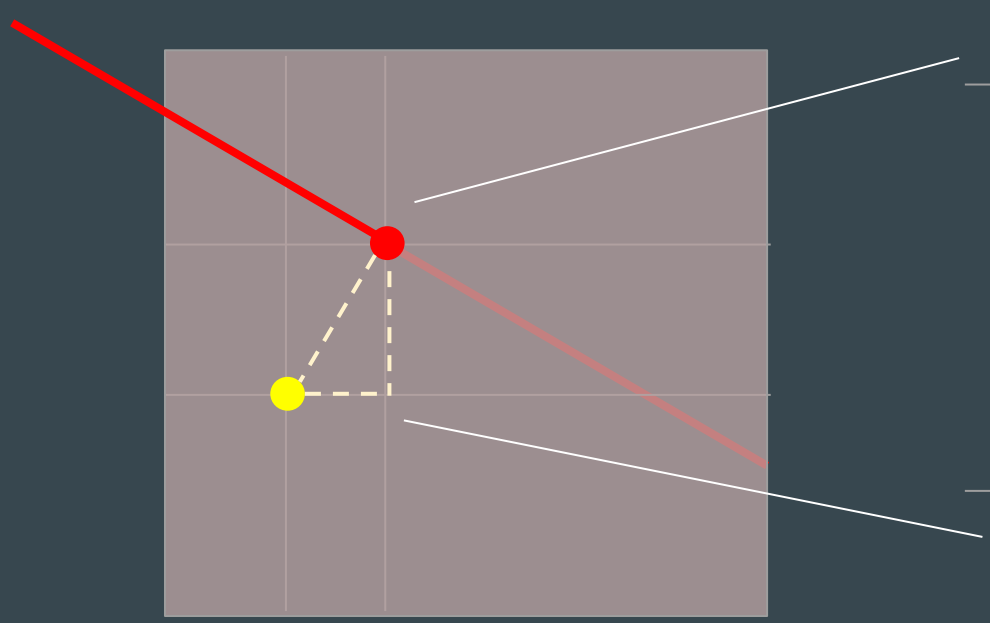
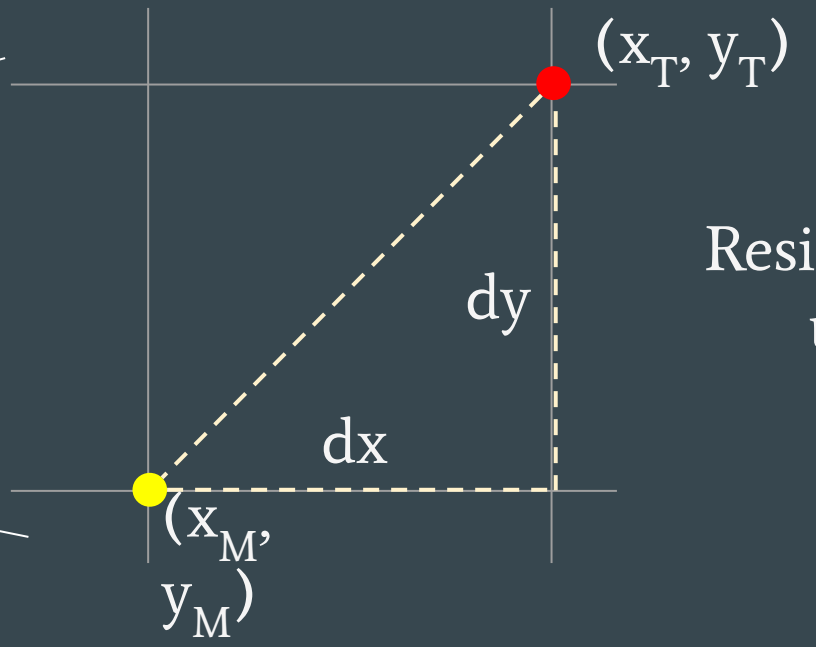
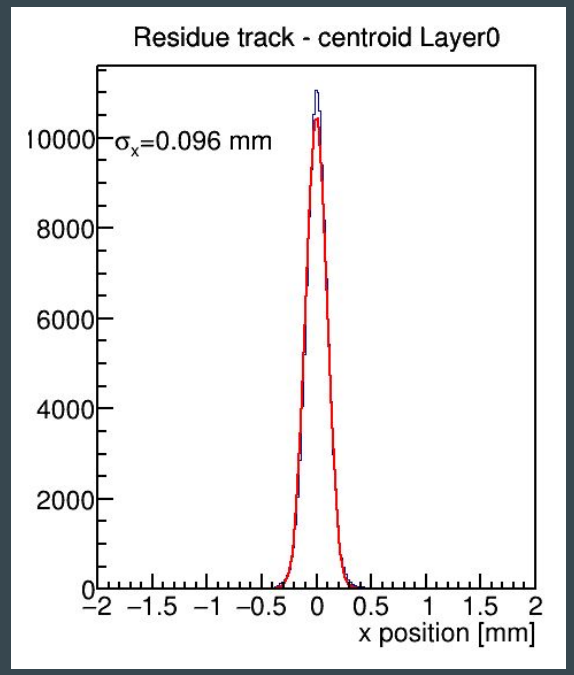




Detector
Track
True Hit
Measured Hit

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



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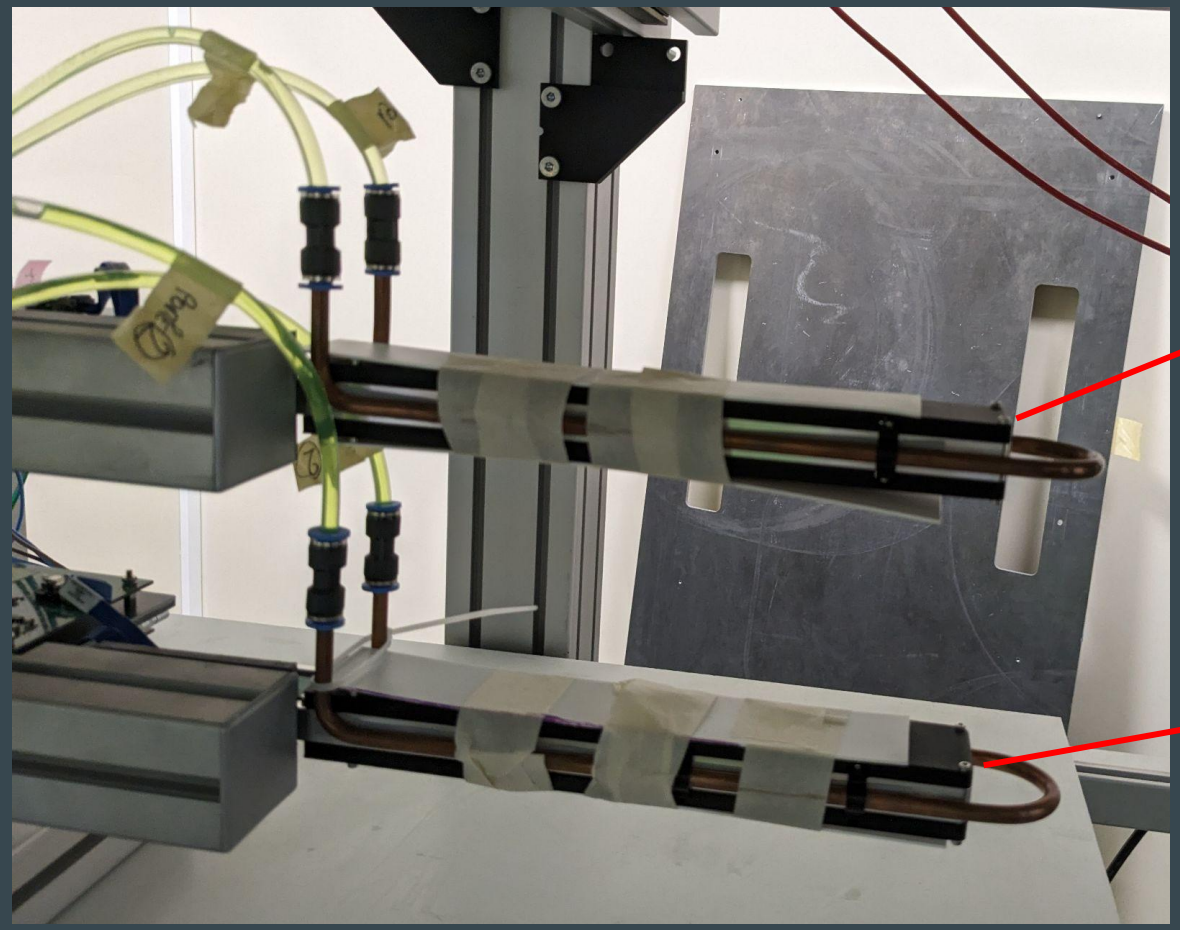
The detector measures position of hit
Not necessarily in the true hit position

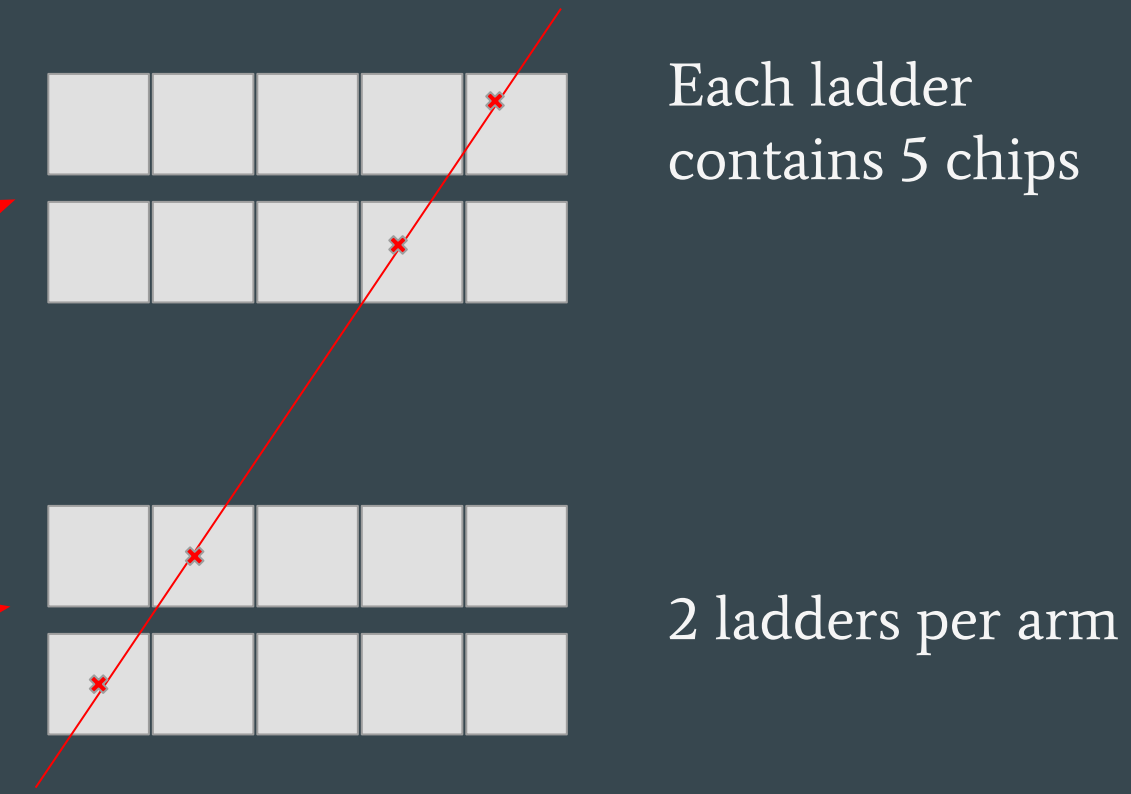
Residual: Difference between true and measured hit position

“Banco” MAPS Tracking Detector

- Silicon MAPS detector
- High spatial resolution

Allows us to reconstruct cosmic muon tracks with high precision
→ Use this to characterize the resolution of our test detectors





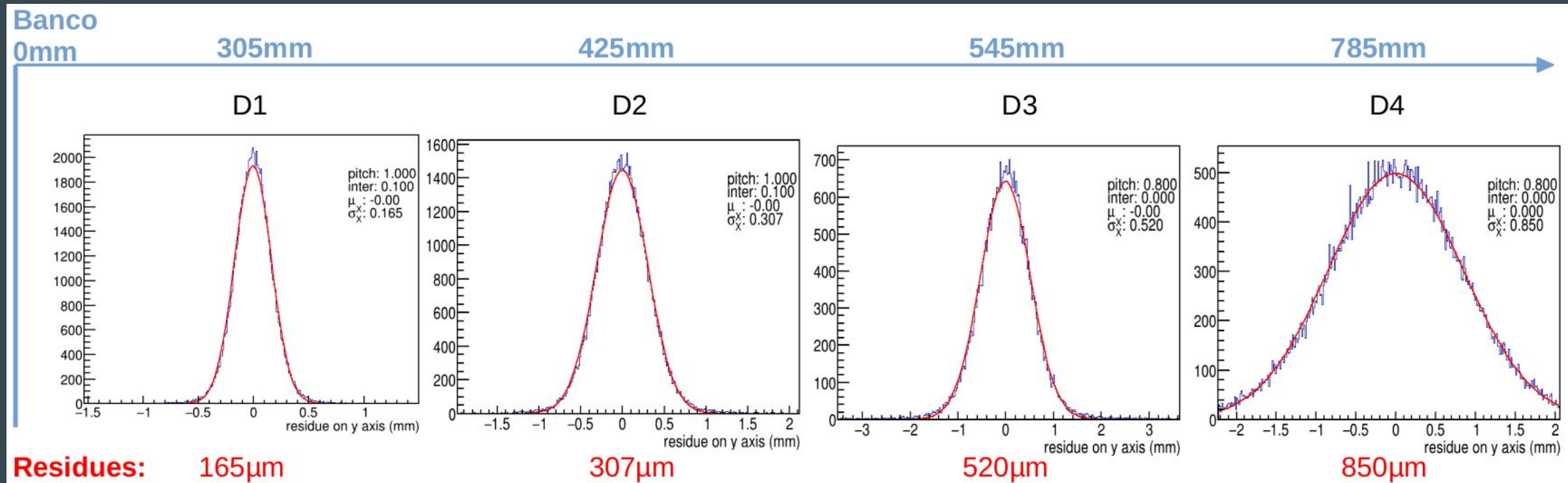
Each ladder contains 5 chips

2 ladders per arm

Problem with 2023 Test Beam

$$\sigma^2 = \sigma^2_{\text{detector}} + \sigma^2_{\text{tracking}} + \sigma^2_{\text{scattering}}$$

Multiple scattering of 880 MeV electrons was dominant contribution to residuals for most detectors!



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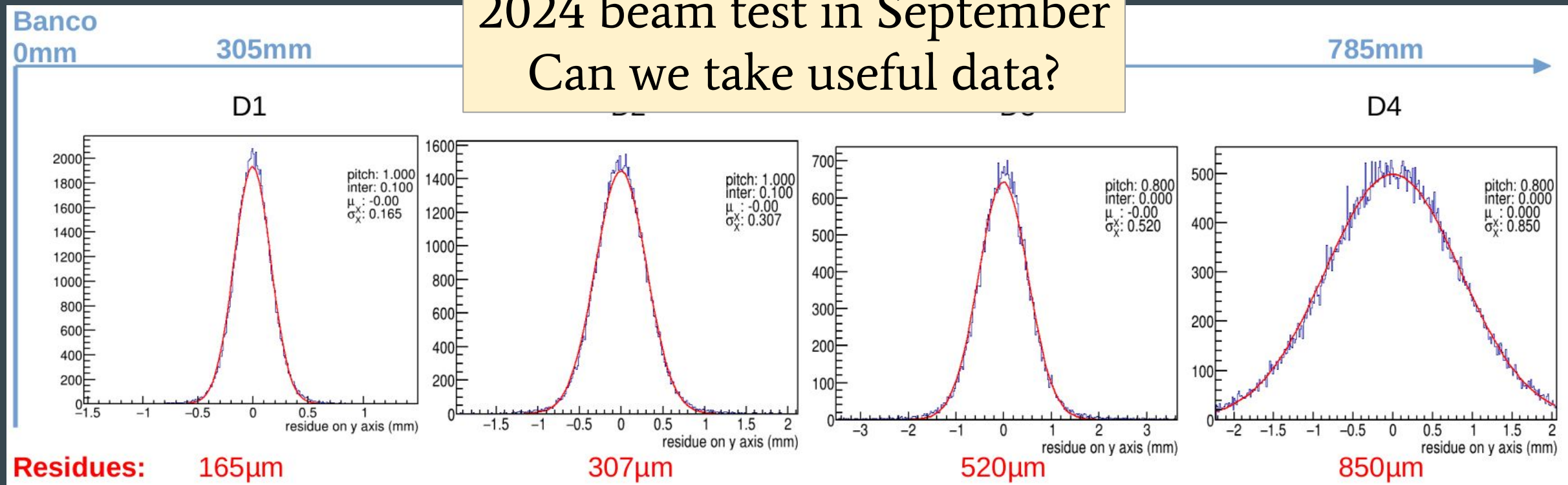
2024 beam test in September
Can we take useful data?



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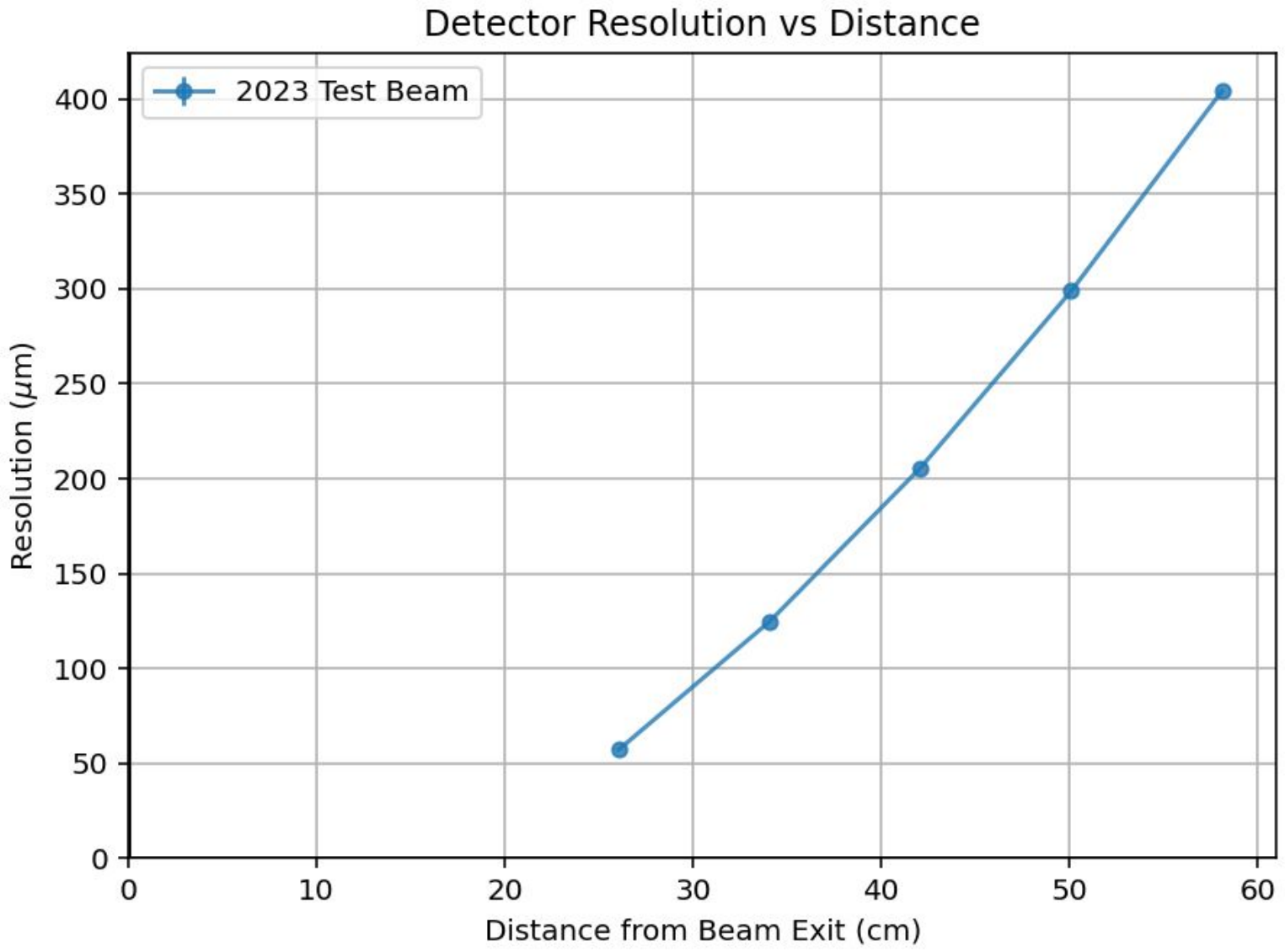
Model Beam Test Configuration

$$\sigma^2 = \sigma^2_{\text{detector}} + \sigma^2_{\text{tracking}} + \sigma^2_{\text{scattering}}$$

- Simulate multiple scattering and finite resolution of tracking detectors
  - Poor man's Geant4



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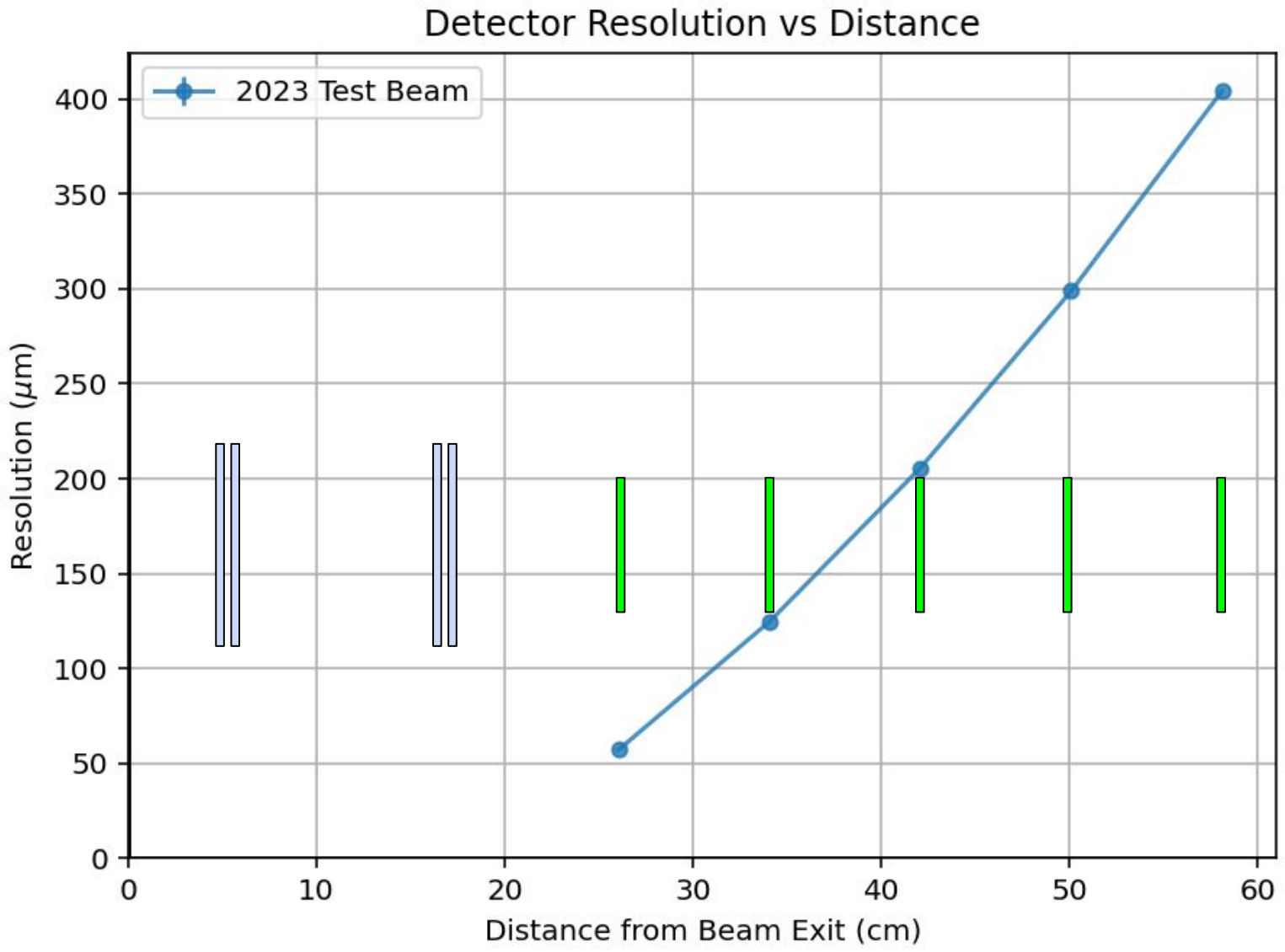

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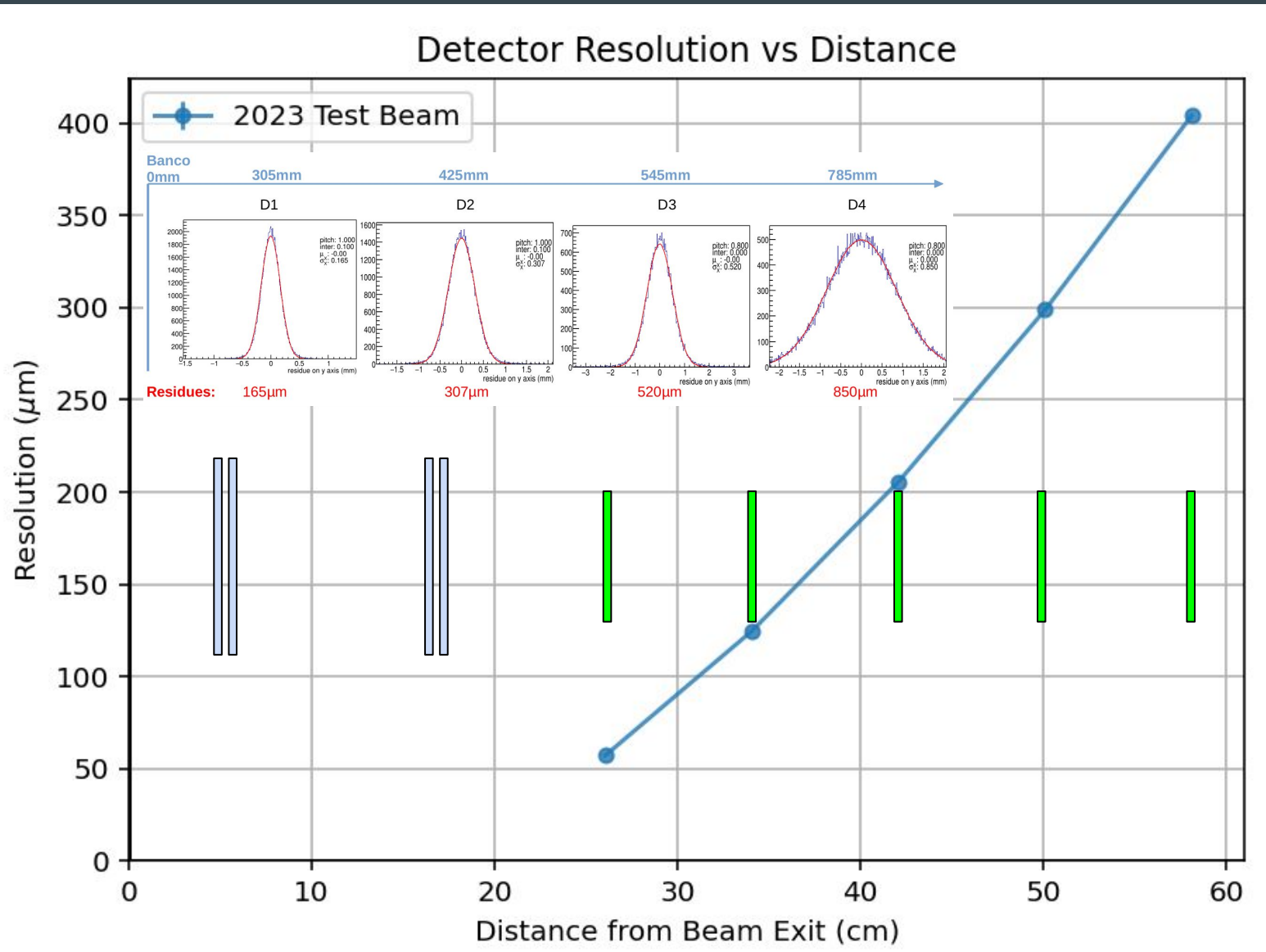
- Qualitatively reproduces Samy's Geant4 simulation along with beam test results
  - Careful geometry may make matching better



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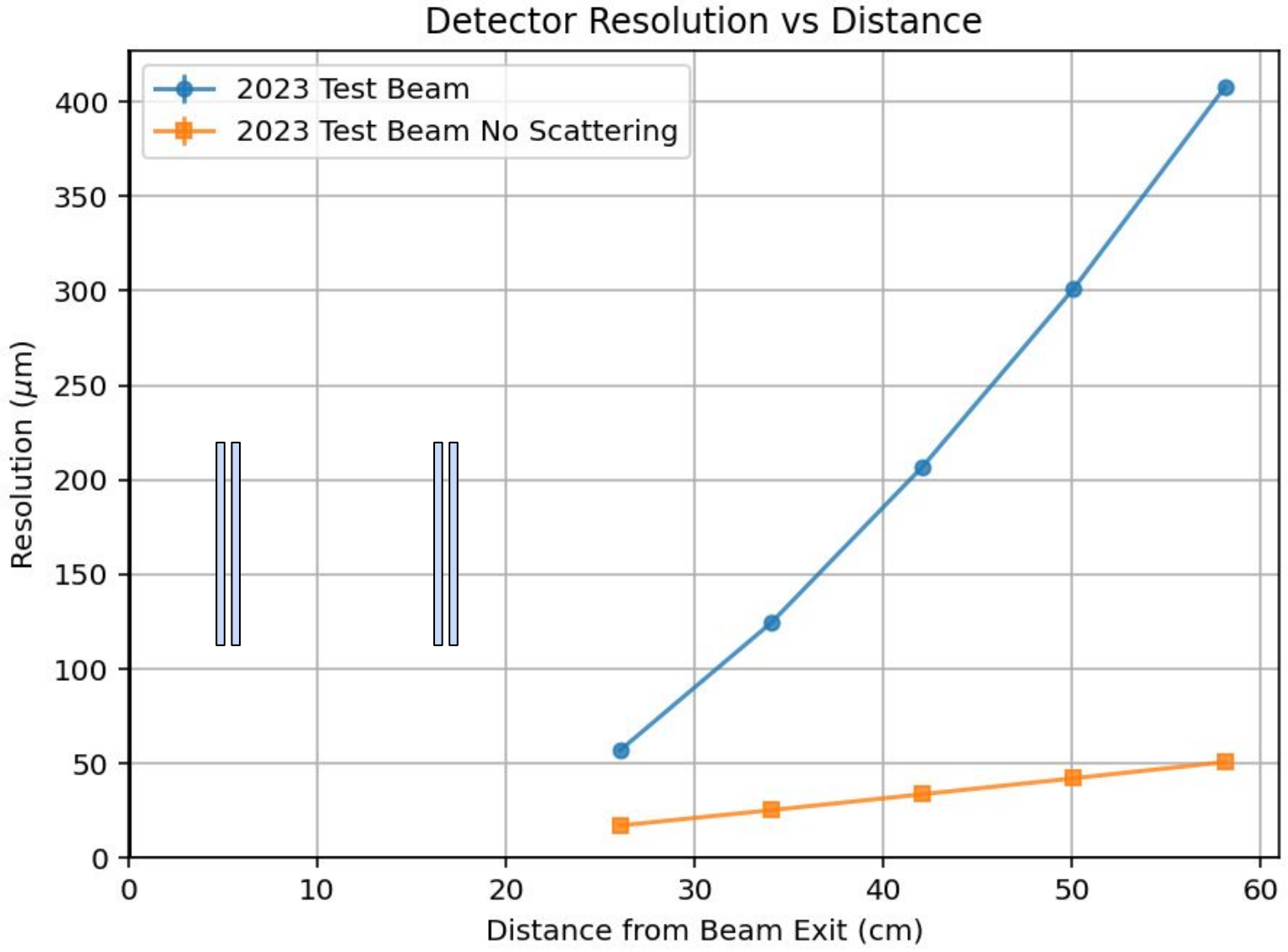
  Resulting resolution much lower (better)



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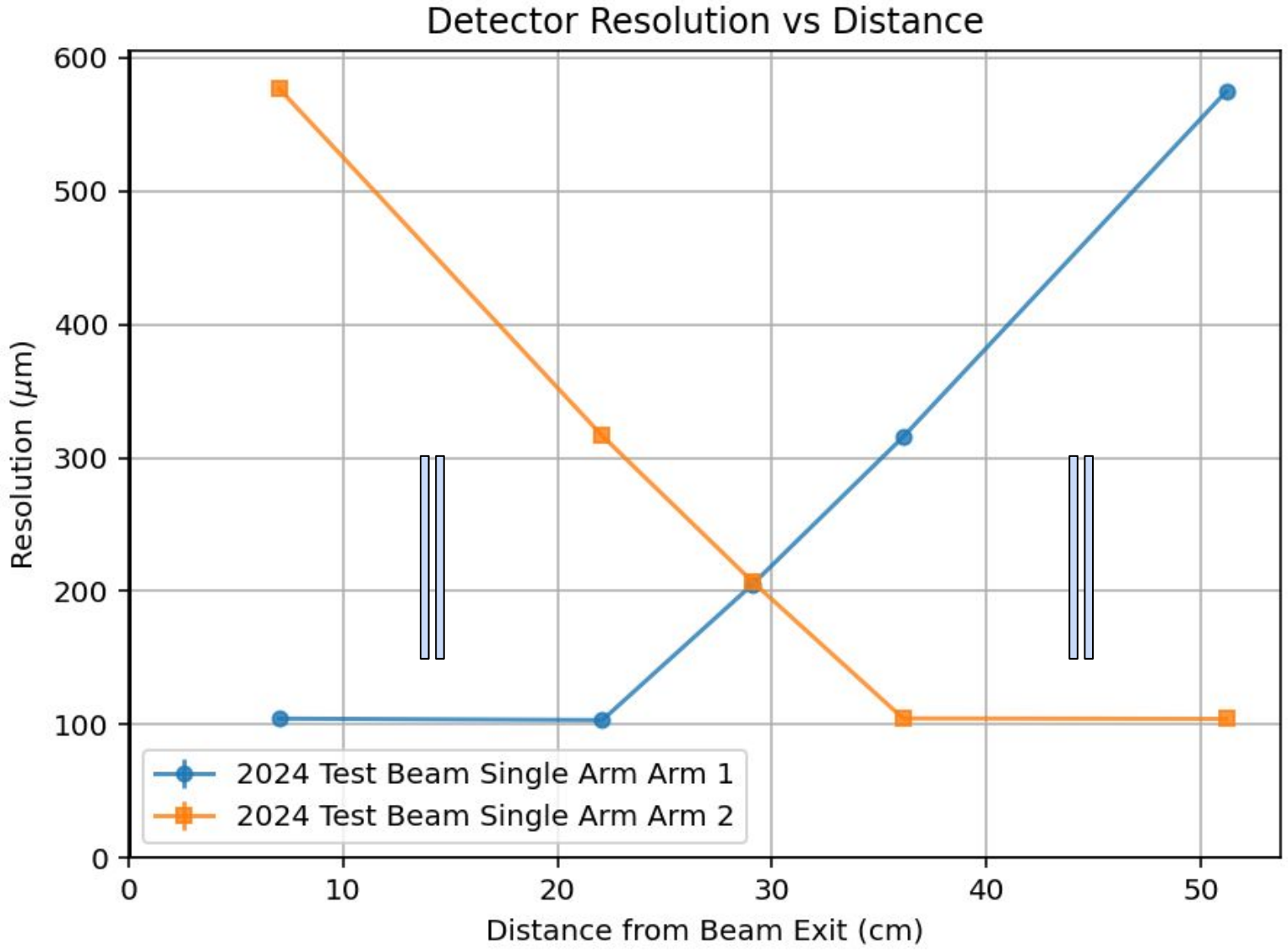
  - Most of the issue in this configuration is scattering

2024 Beam Test Configuration

$$\sigma^2 = \sigma^2_{\text{detector}} + \sigma^2_{\text{tracking}} + \sigma^2_{\text{scattering}}$$

- Want a better configuration for 2024
- One option is to use only a single arm for tracking → 4 detectors at once with good resolution



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- Slightly worse resolution than first detector in 2023

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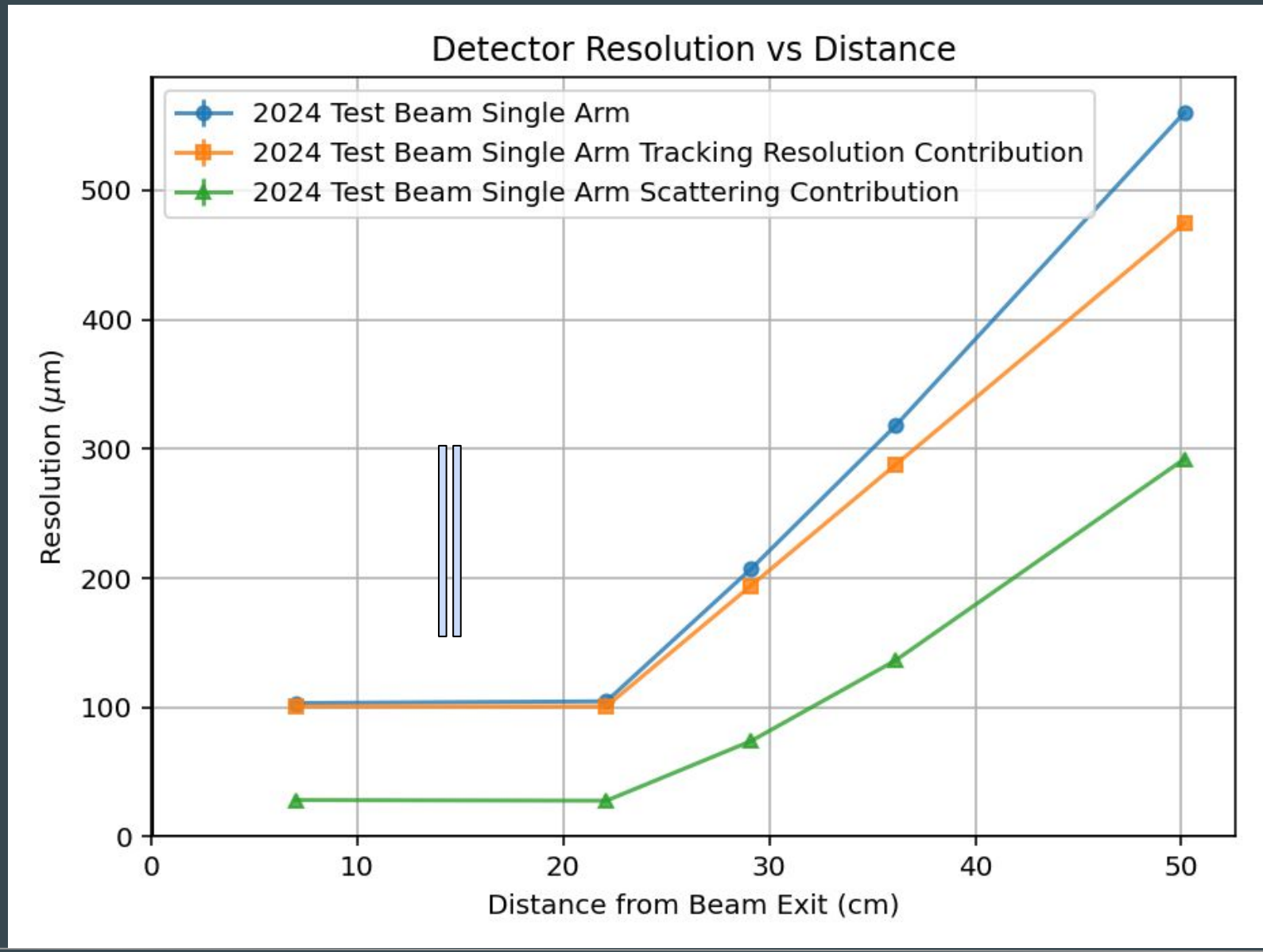

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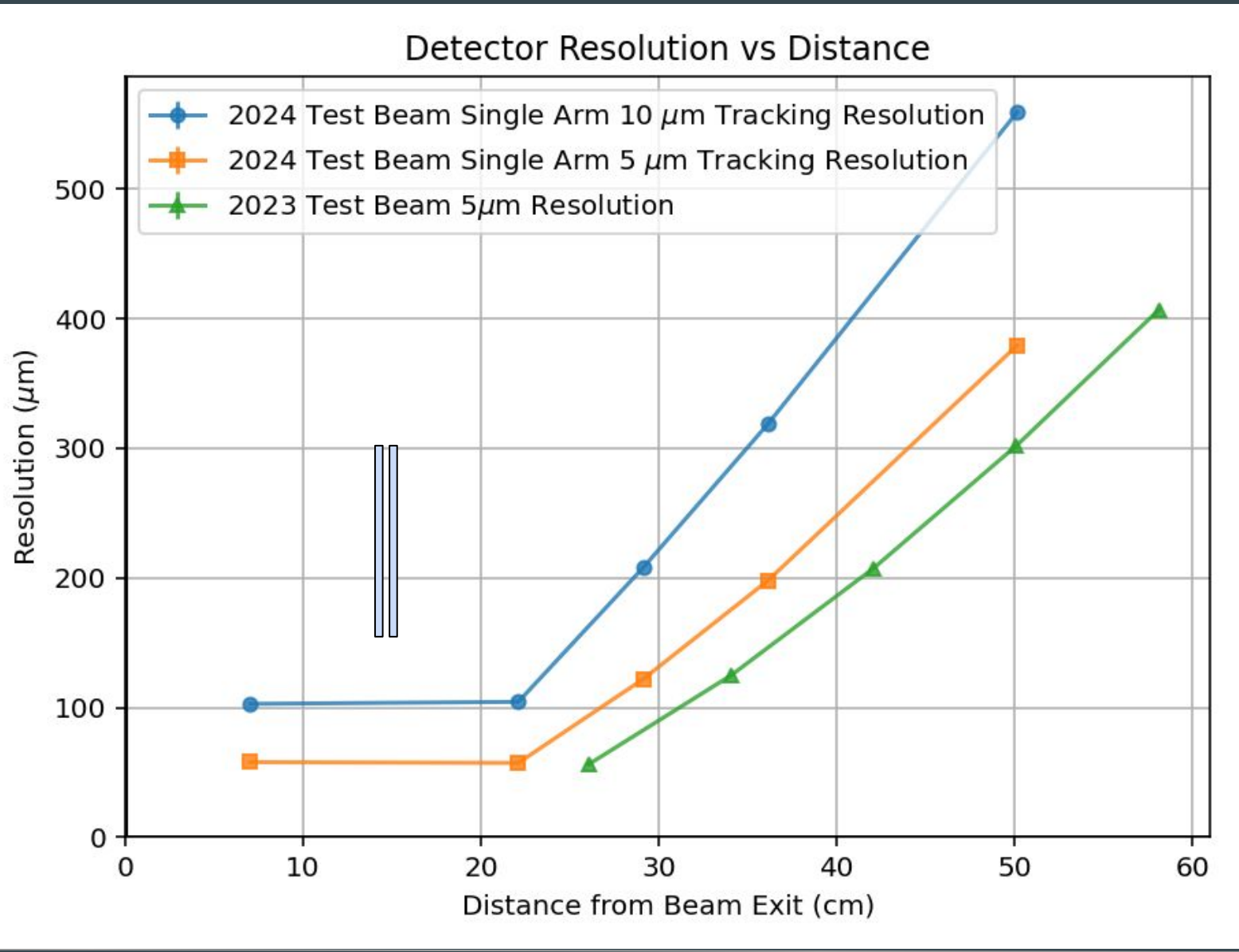

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Not sure if we can get 5 micron resolution on tracking detectors.
For this and more, we look to our cosmic muon setup

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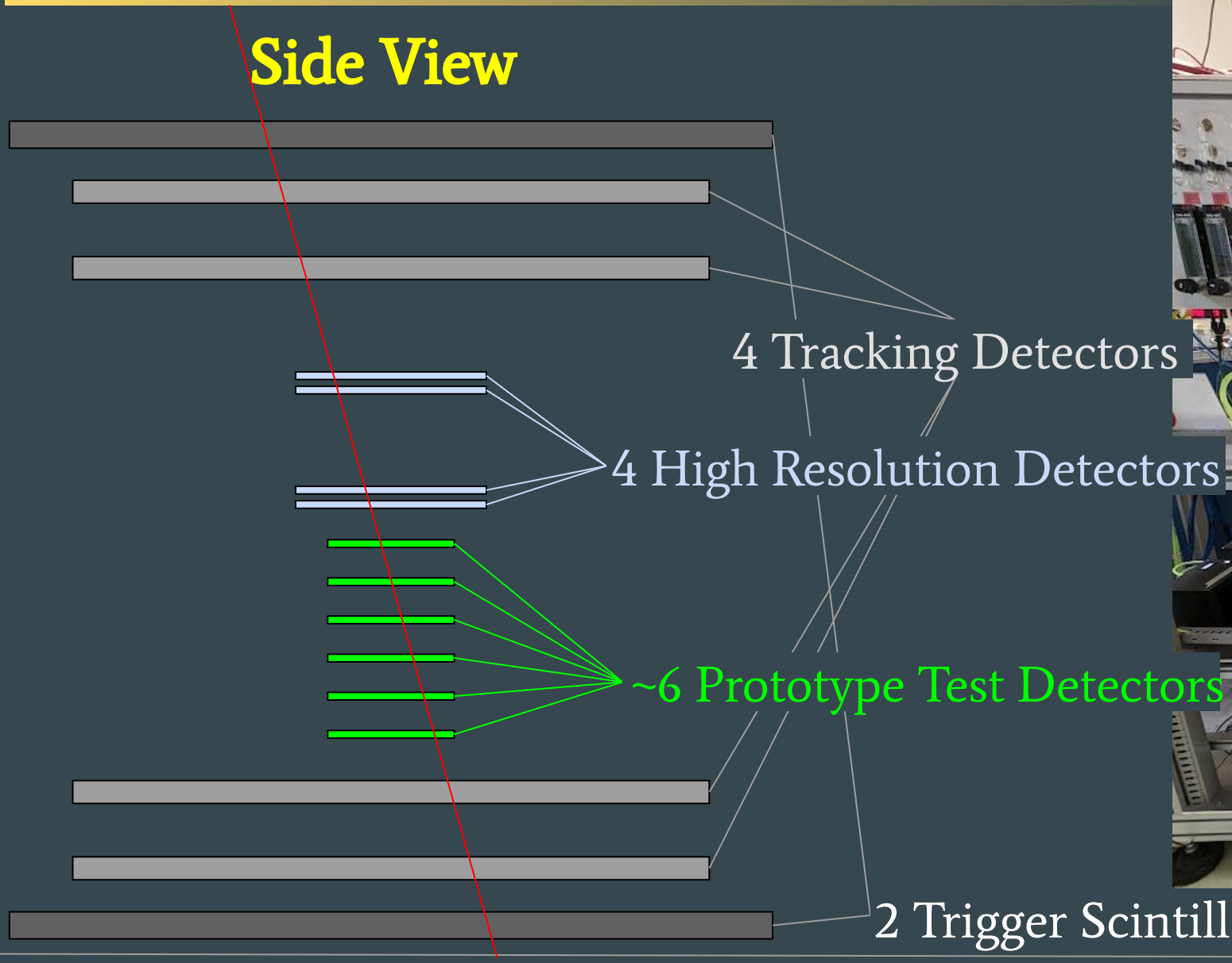
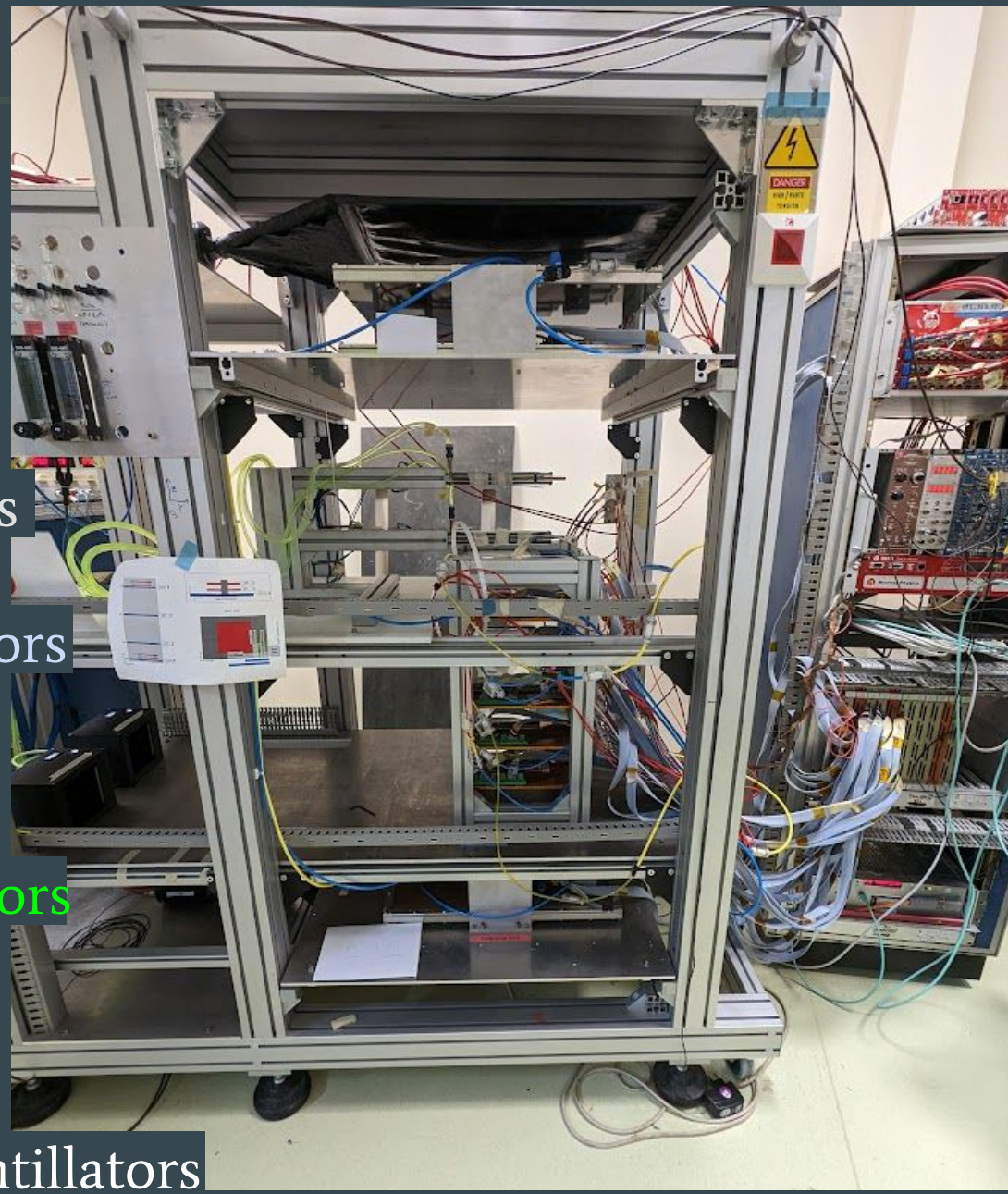
Cosmic Test Bench

Side View





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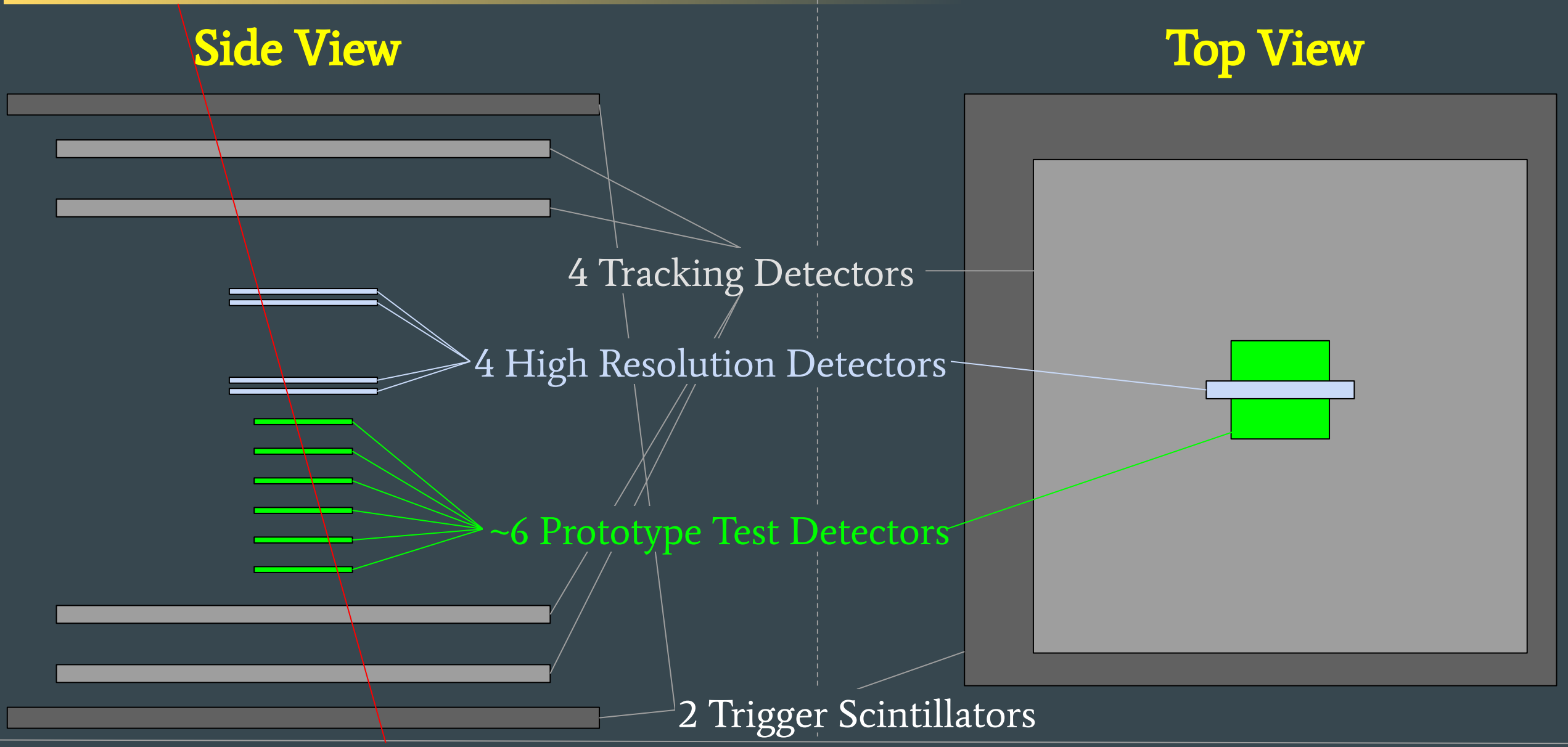

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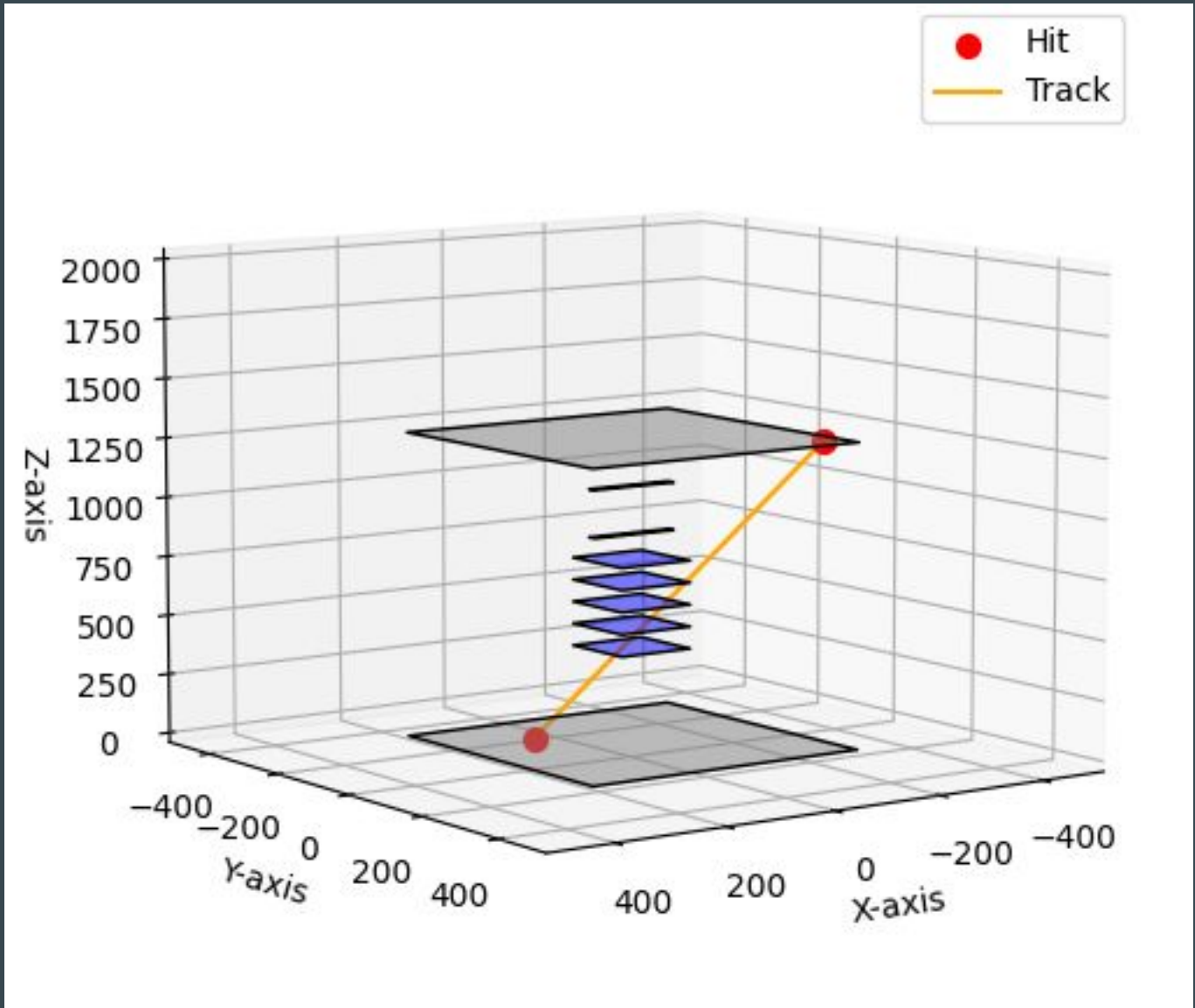
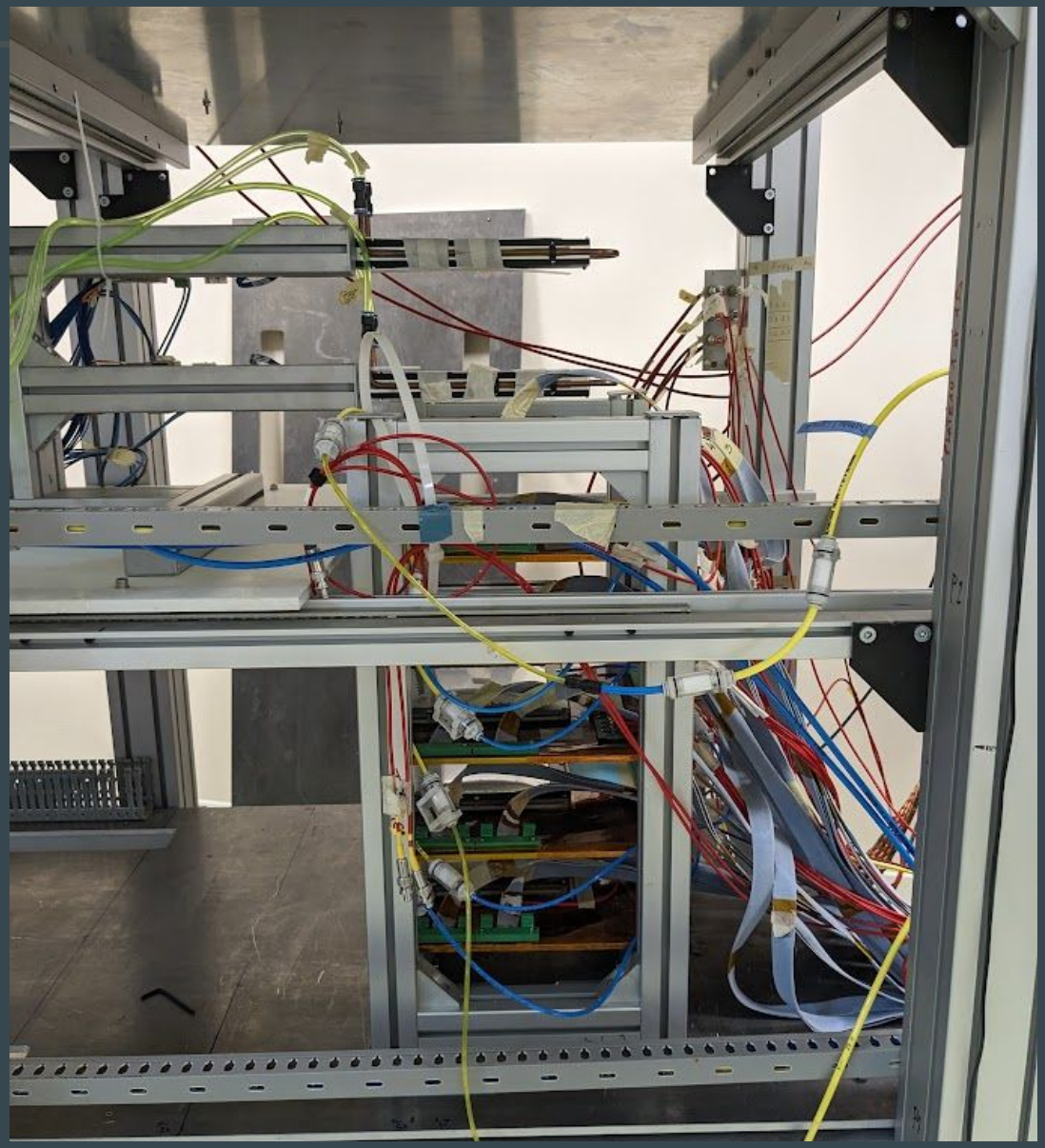
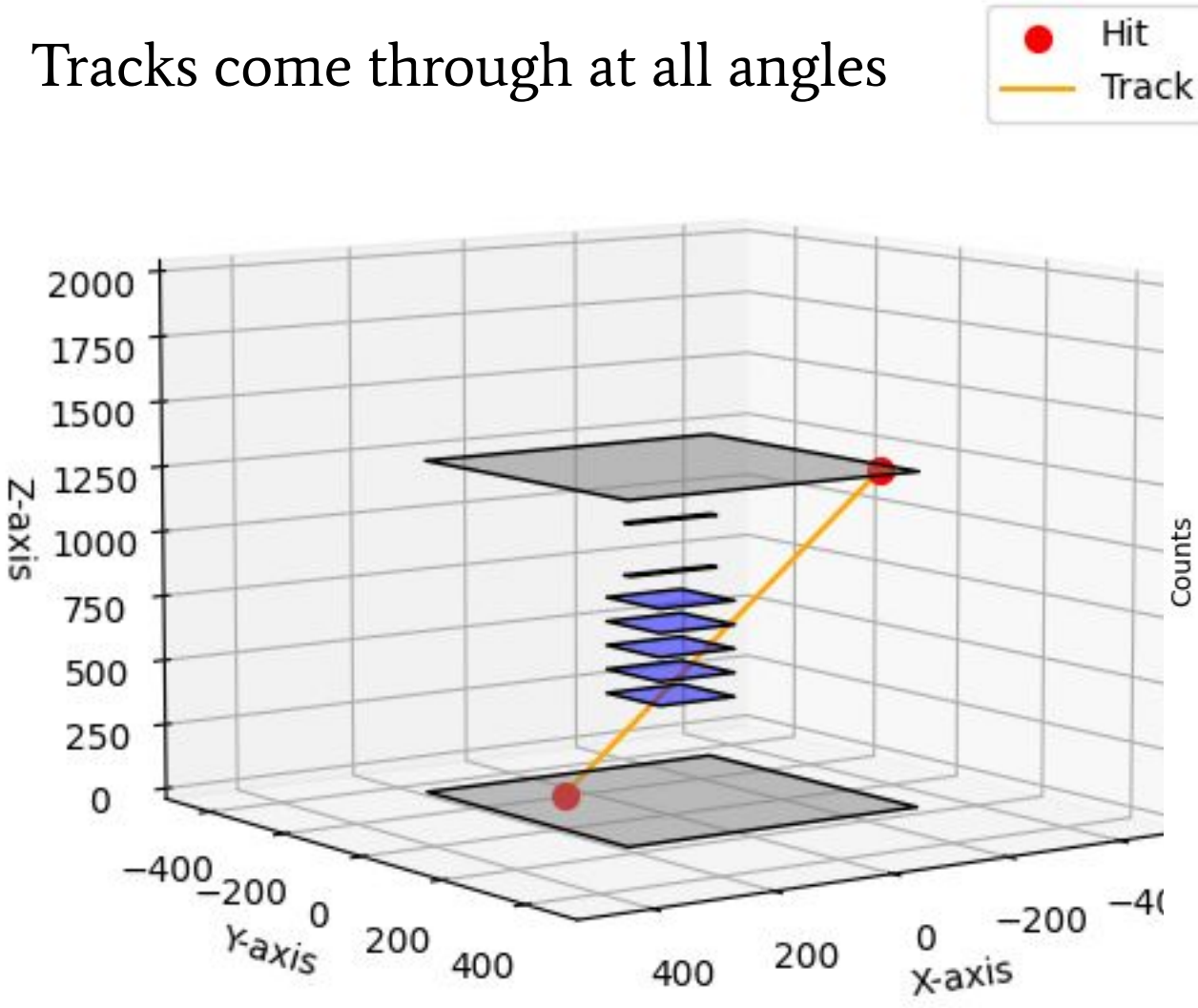
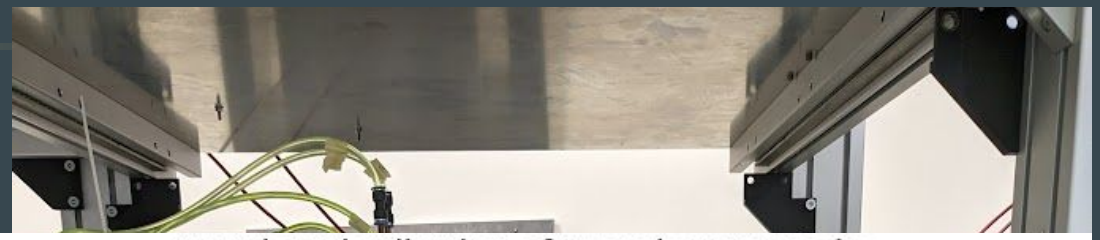


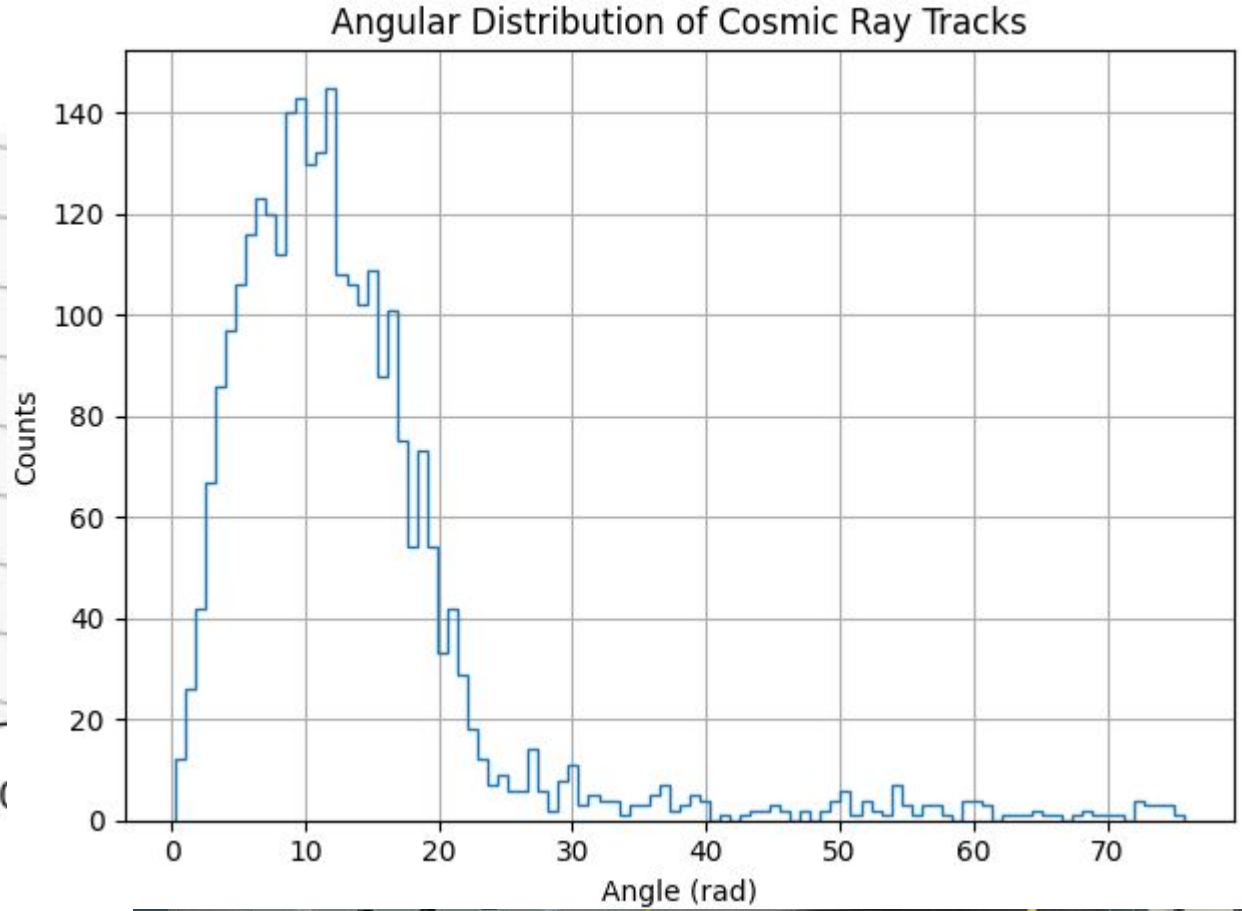


Cosmic Test Bench

Tracks come through at all angles

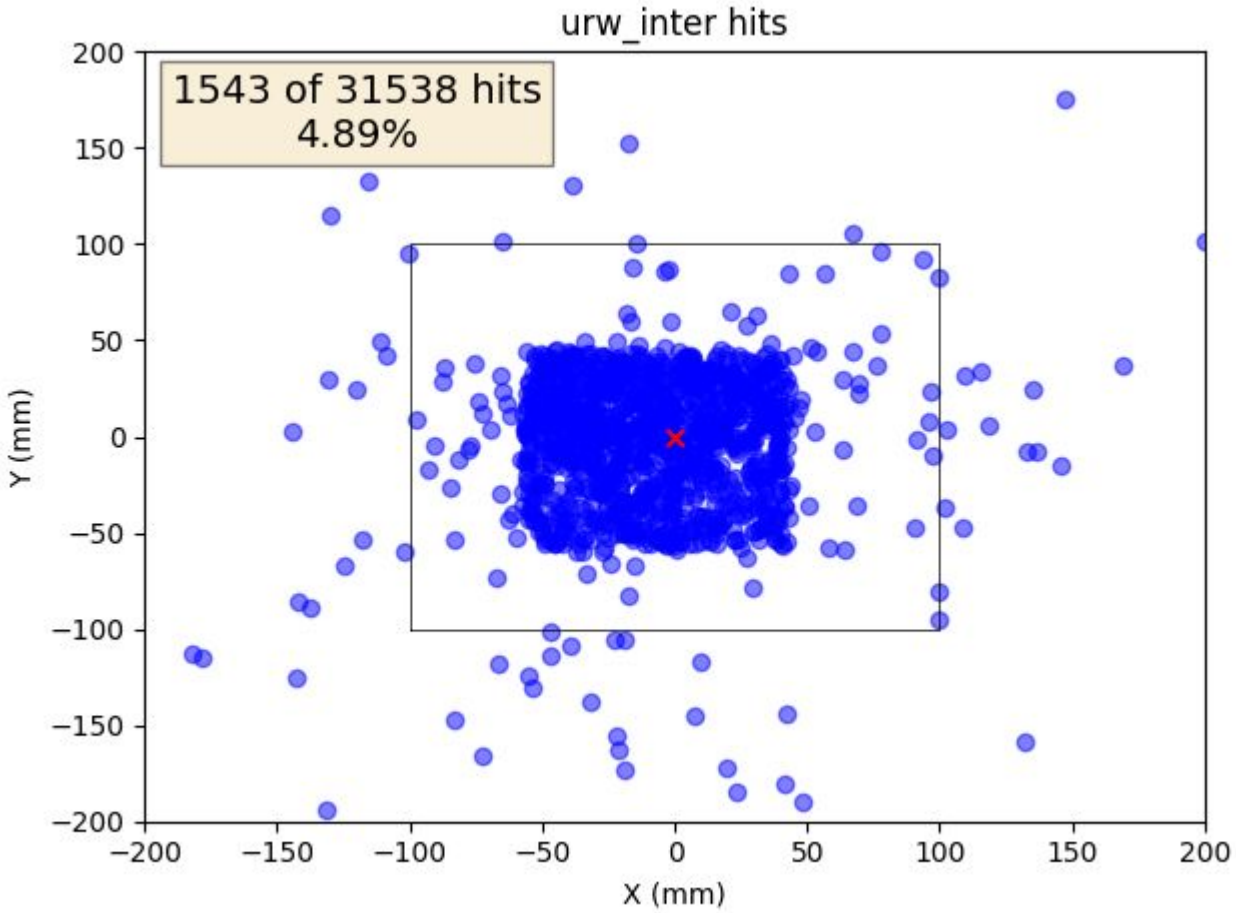


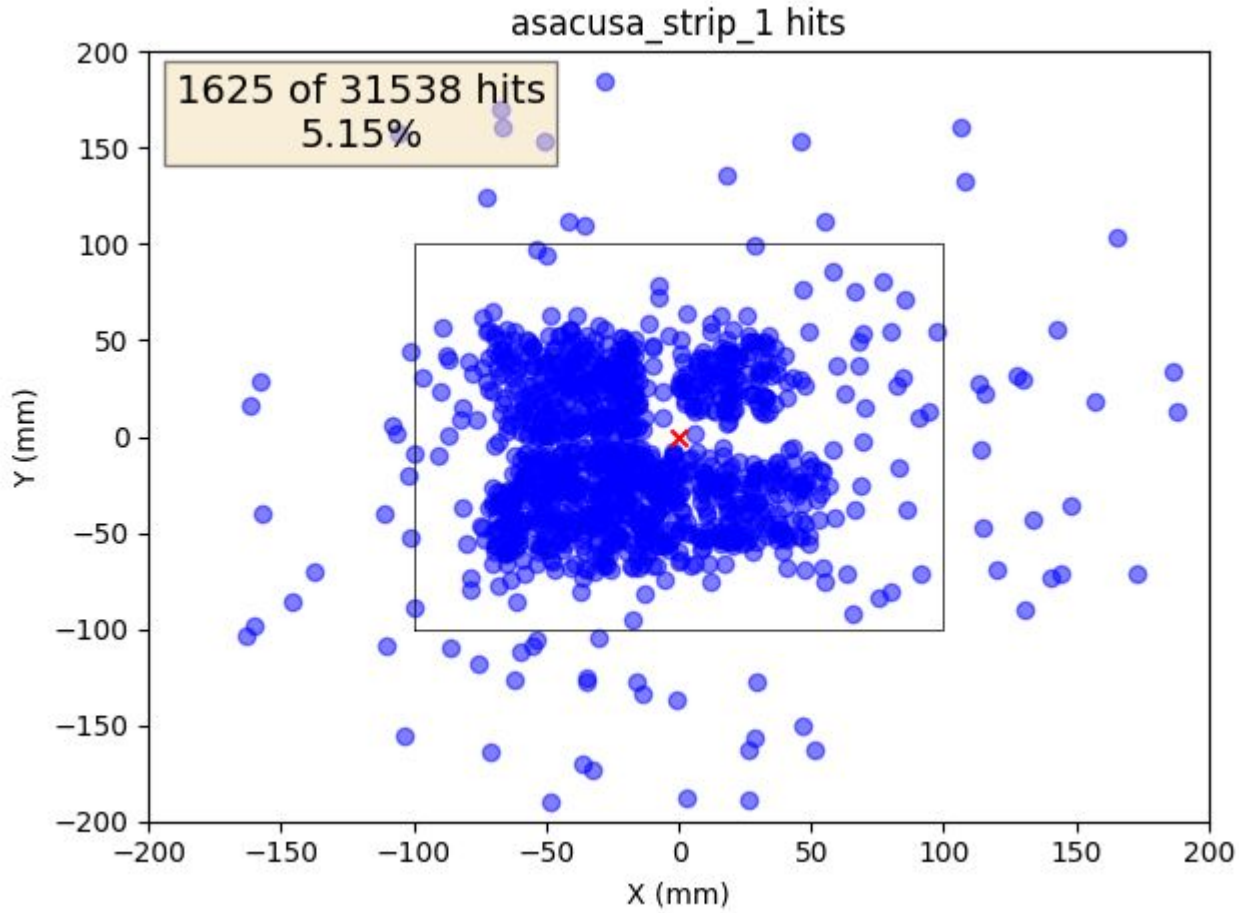




Cosmic Tracks in Prototype Detectors

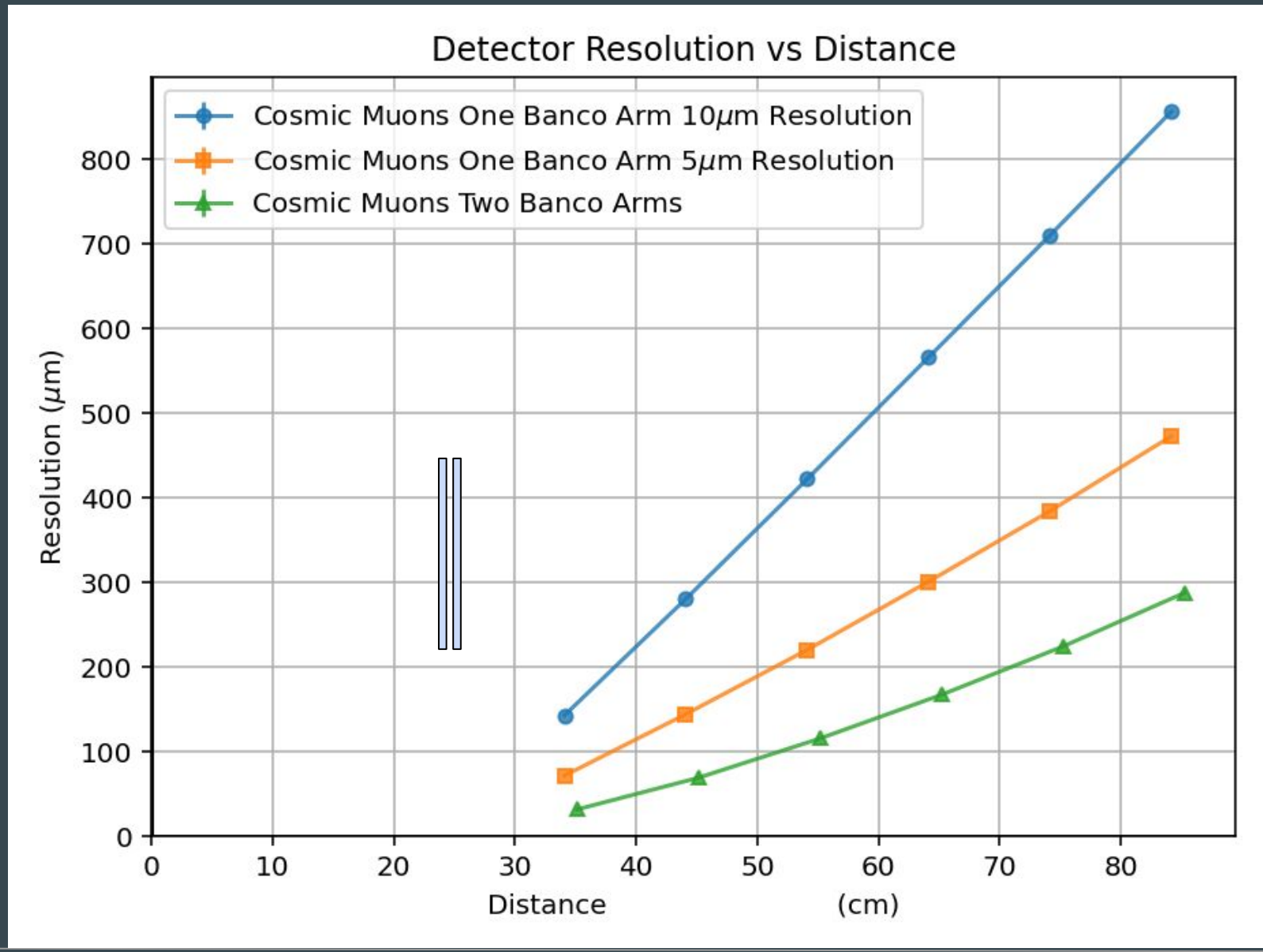
Sign of life for cosmic muon setup





Cosmic Configuration Resolution $\sigma^2 = \sigma^2_{\text{detector}} + \sigma^2_{\text{tracking}} + \sigma^2_{\text{scattering}}$

- Using two arms in coincidence we can should be able to get pretty good resolution on the first ~2 detectors



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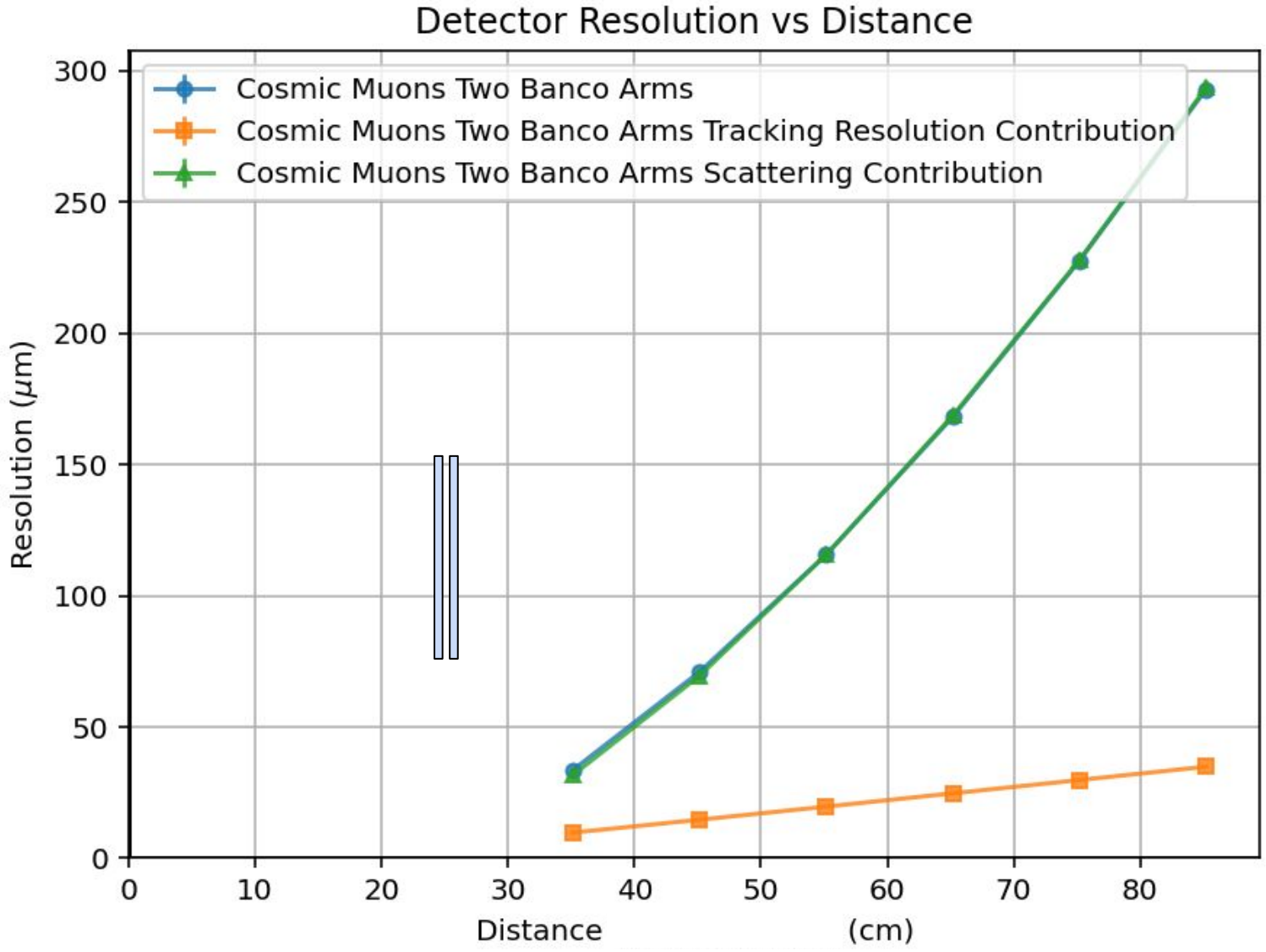
- Using two arms in coincidence we can should be able to get pretty good resolution on the first ~2 detectors
- Most of this resolution smearing still due to multiple scattering of 2 GeV muons
  - Need to double check simulation and cross-check with Geant4



Muon Rates

Low muon rate hitting small tracking detector.

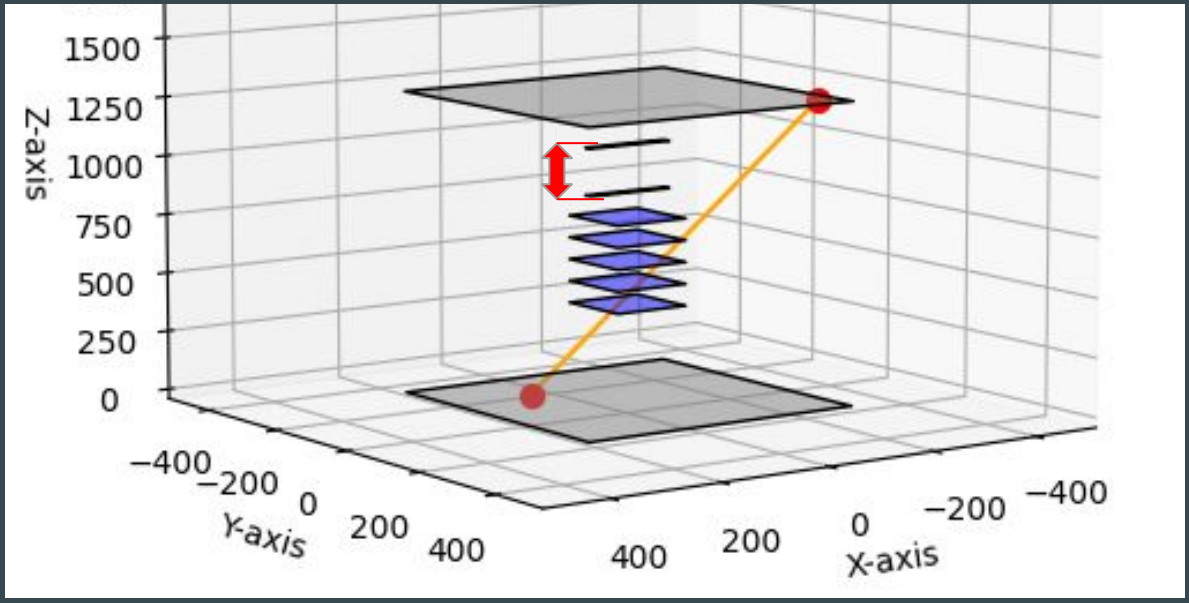
How many events do we need to characterize prototype resolution?

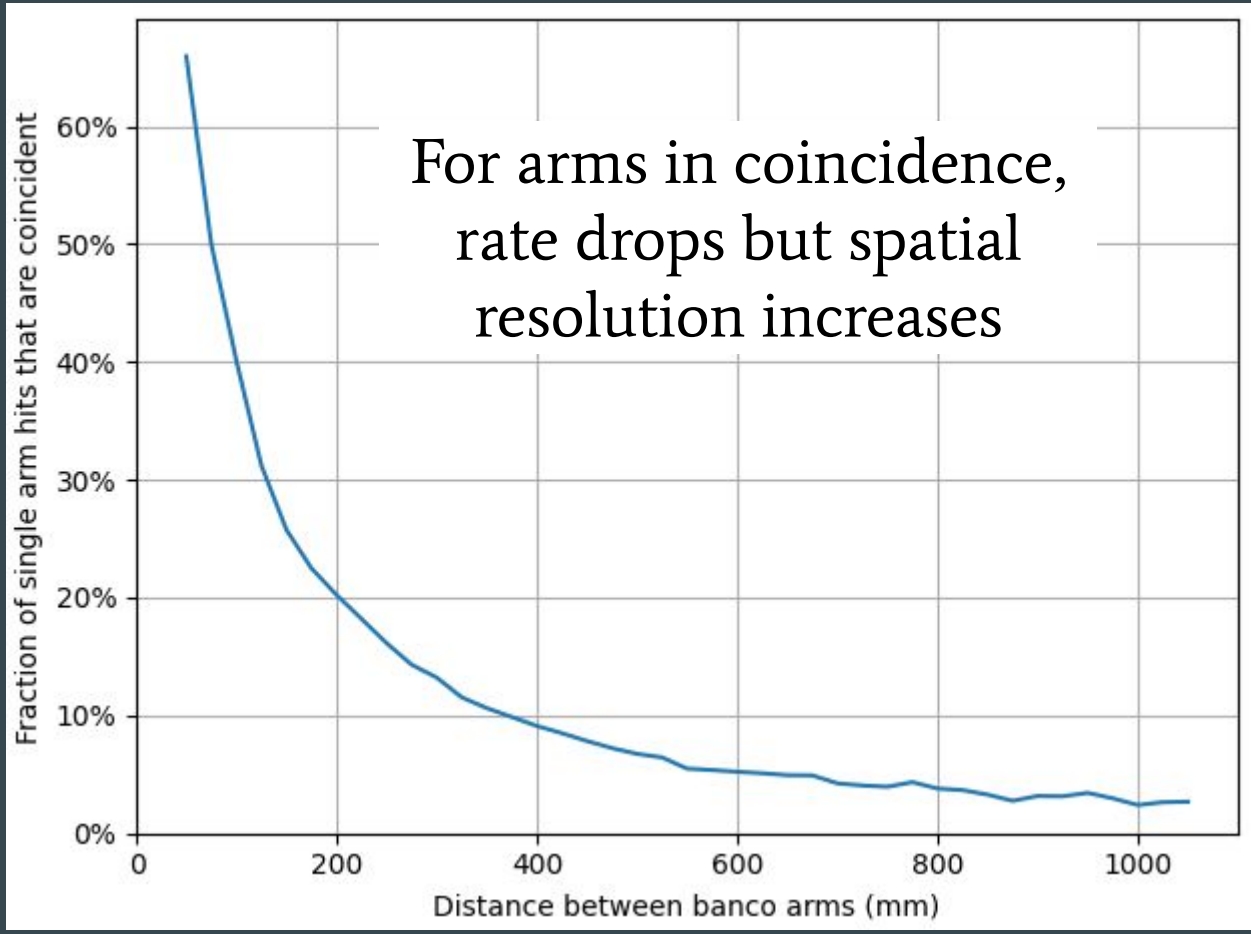
- 10cm: 40% → 1.2k/day
- 20cm: 20% → 600/day
- 30cm: 12% → 400/day
- 40cm: 9% → 300/day

Detector Rates

Reference detectors 500k/day

- 13x13cm: 30k/day
- 15x1.5cm: 3k/day





Correcting for Scattering and Tracking Resolution

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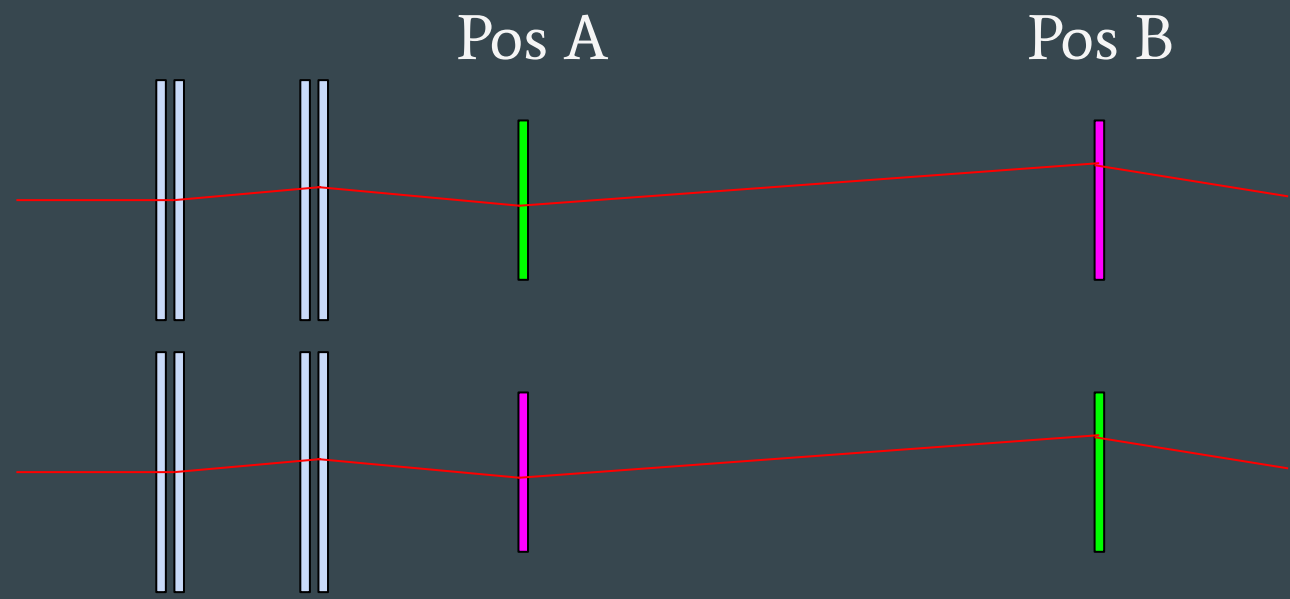

- Subtract tracking and scattering contributions directly using simulation
  - How much do we trust the simulations?
- Swap detector positions
  - If similar tracking and scattering smearing, may be able to measure relative resolution between detectors
  - Have to make sure we carefully swap

$$\sigma^2_{A1} = \sigma^2_{\text{detector 1}} + \sigma^2_{\text{position A}}$$

$$\sigma^2_{A2} = \sigma^2_{\text{detector 2}} + \sigma^2_{\text{position A}}$$

$$\sigma^2_{A1} - \sigma^2_{A2} = \sigma^2_{\text{detector 1}} - \sigma^2_{\text{detector 2}}$$

Summary & Outlook

- Need to decide on best detector design for EIC
- 2023 beam test could only characterize one detector
- Plans to characterize other designs
  - September 2024 beam test
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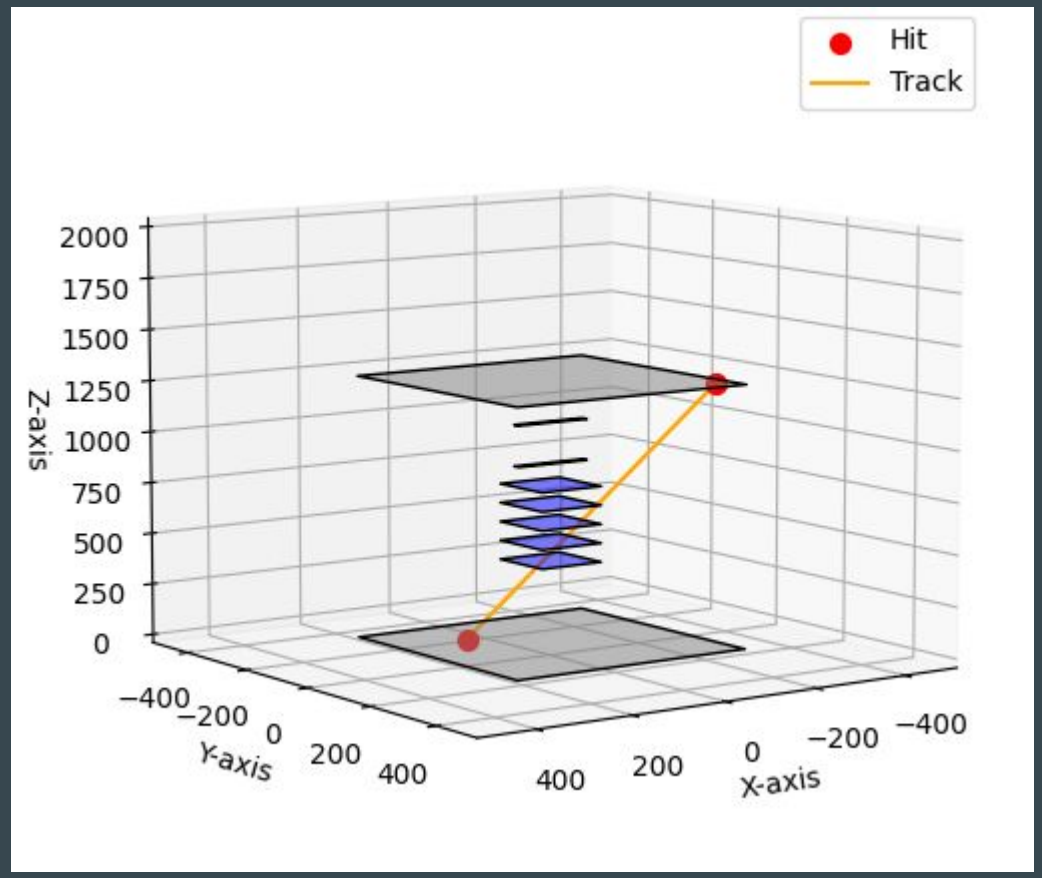
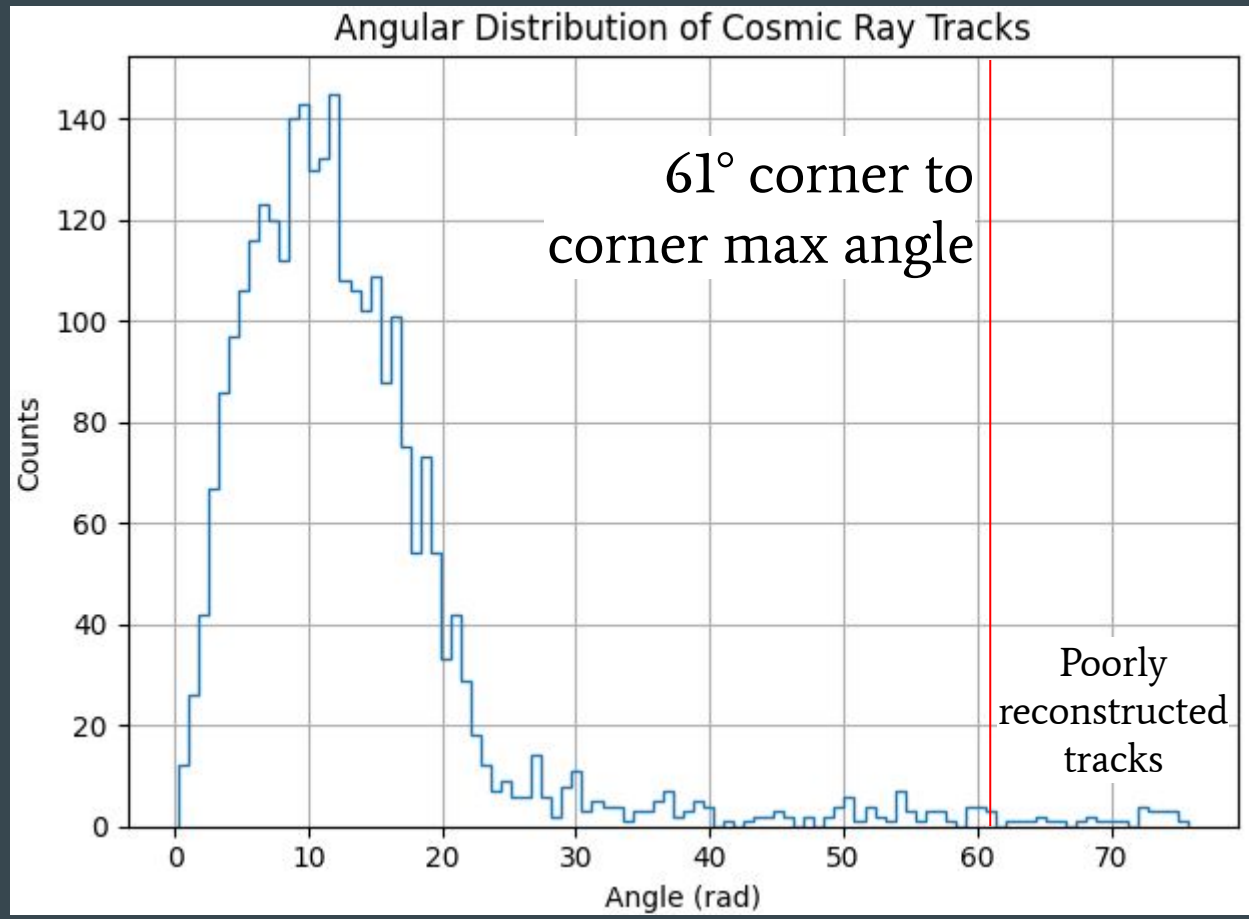
Thanks for your attention!

Backup

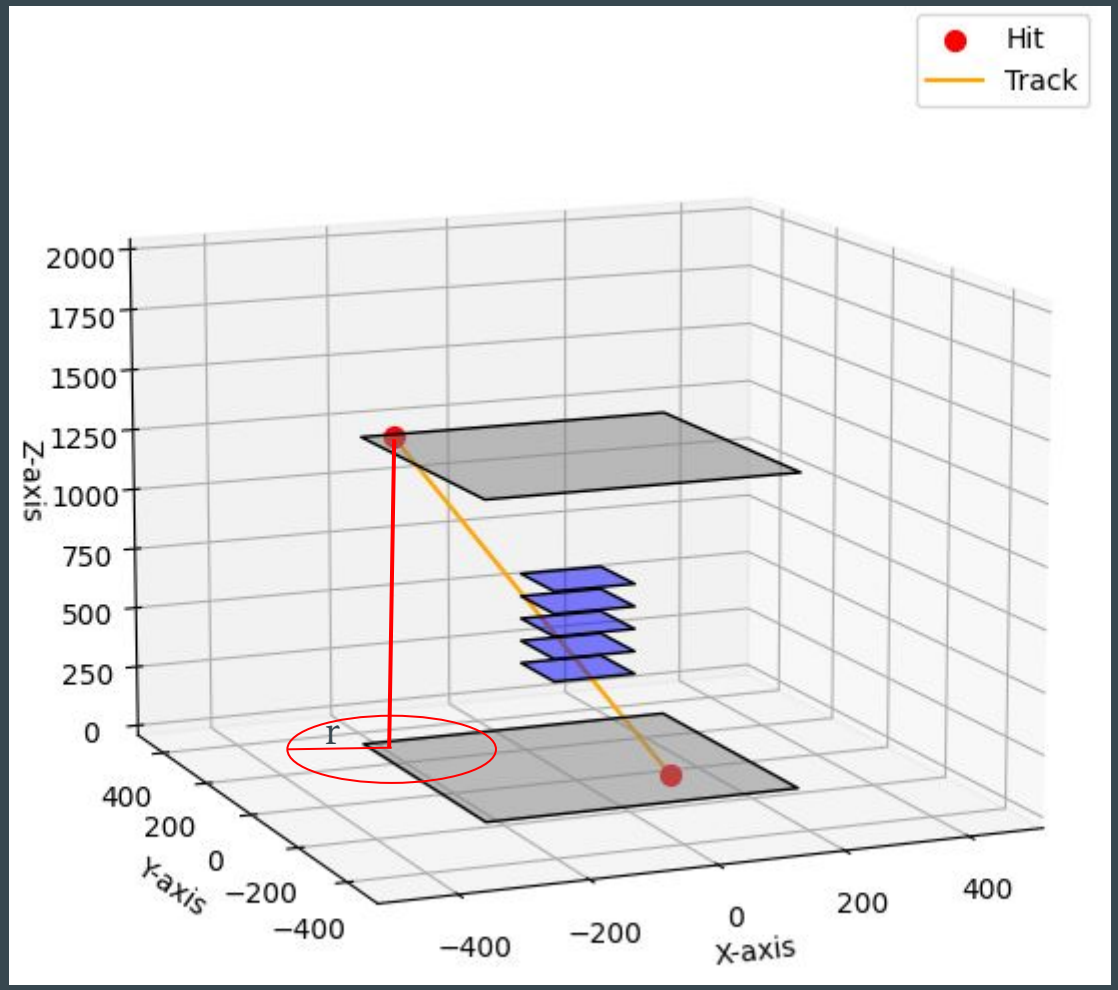
Muon Angular Distribution



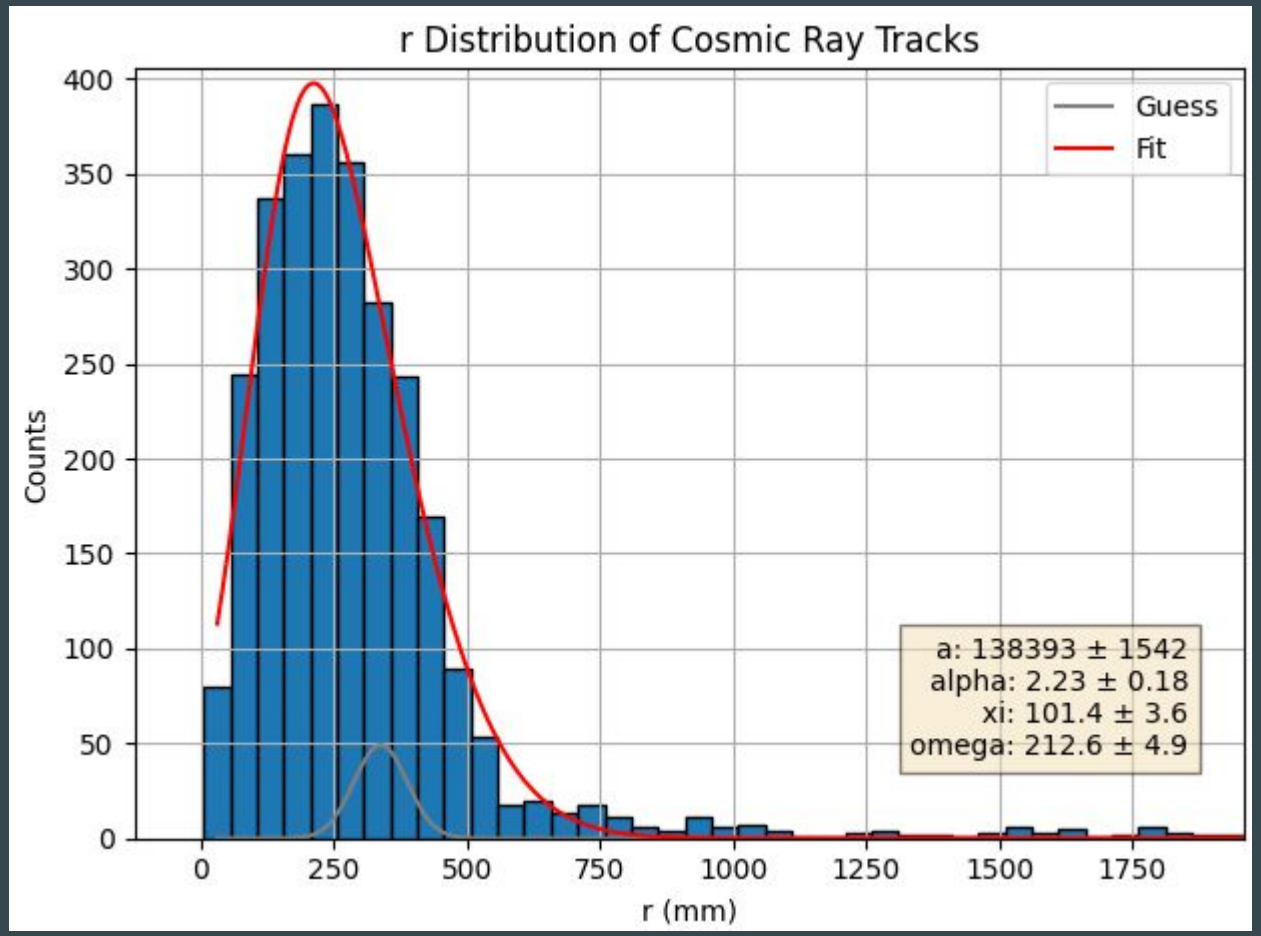


Muon Distribution

Random hits on top reference detector, bottom hit r distributed by distribution on right

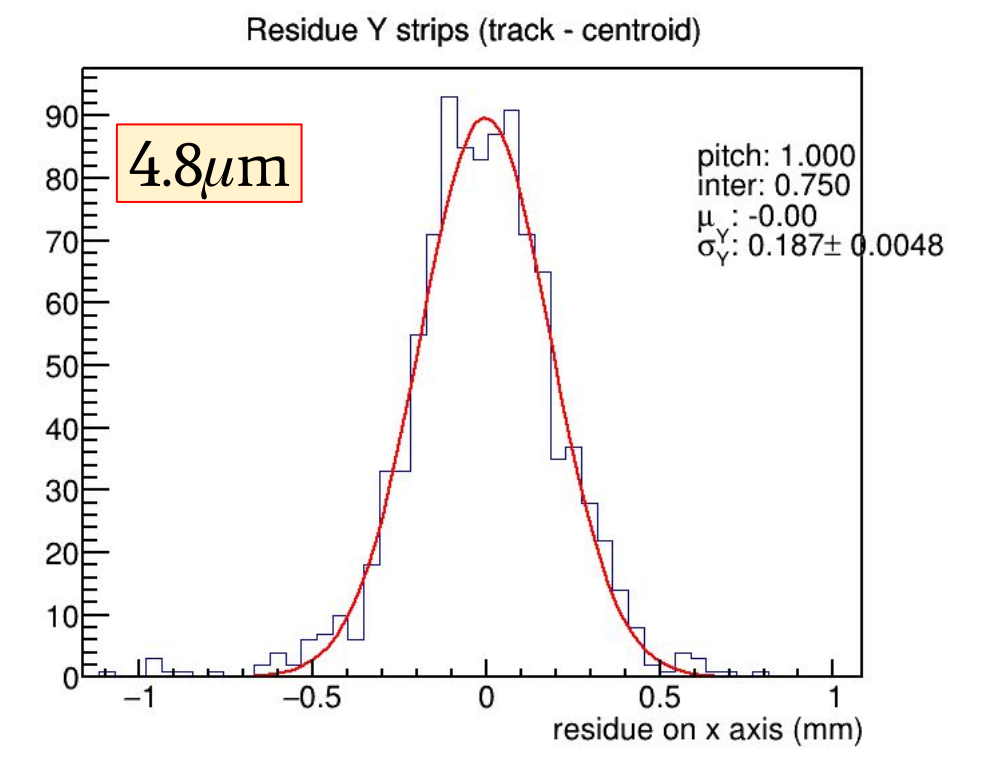


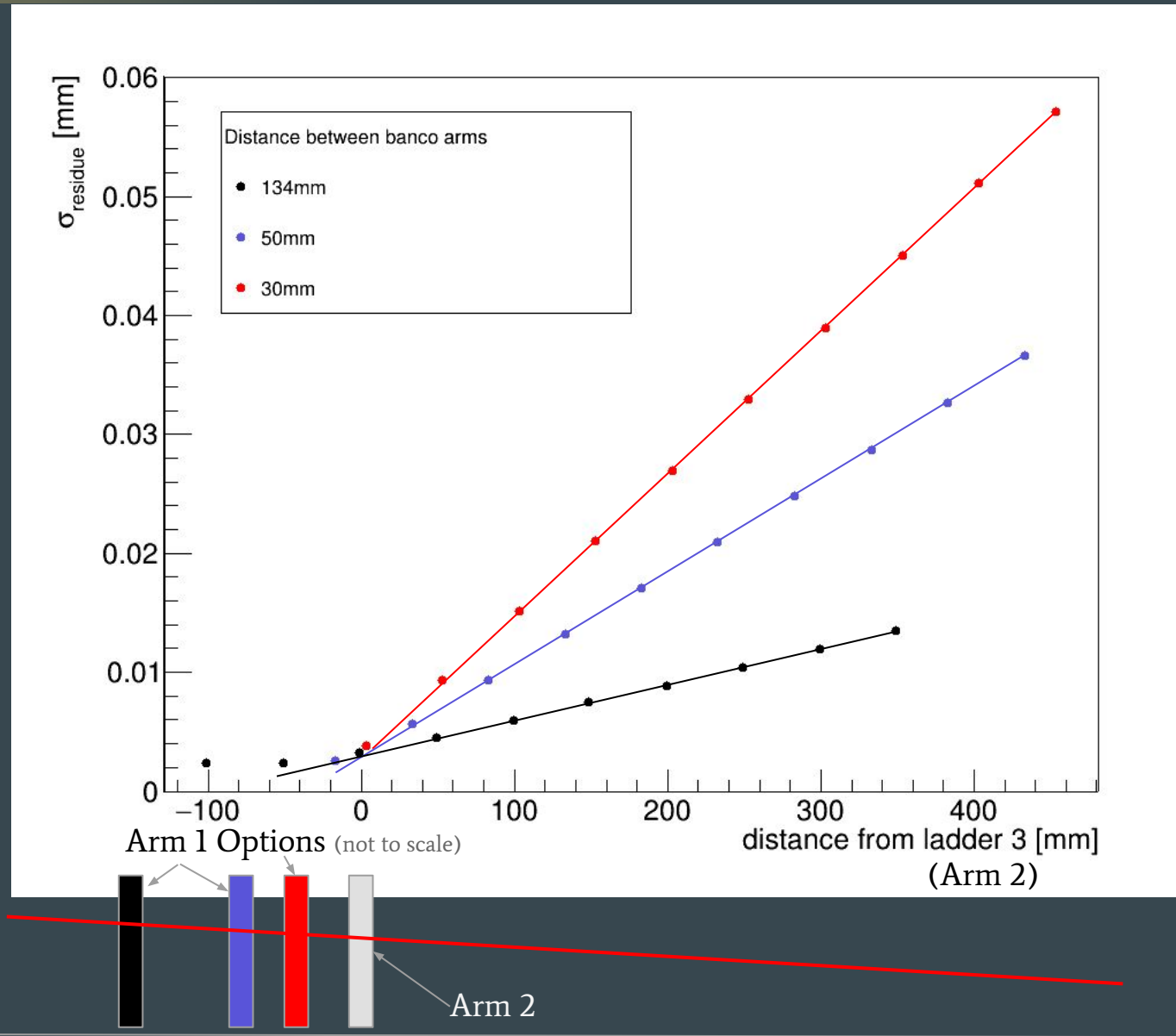
Model the angular distribution and simulate with detector geometry to get decent approximation of expected rate

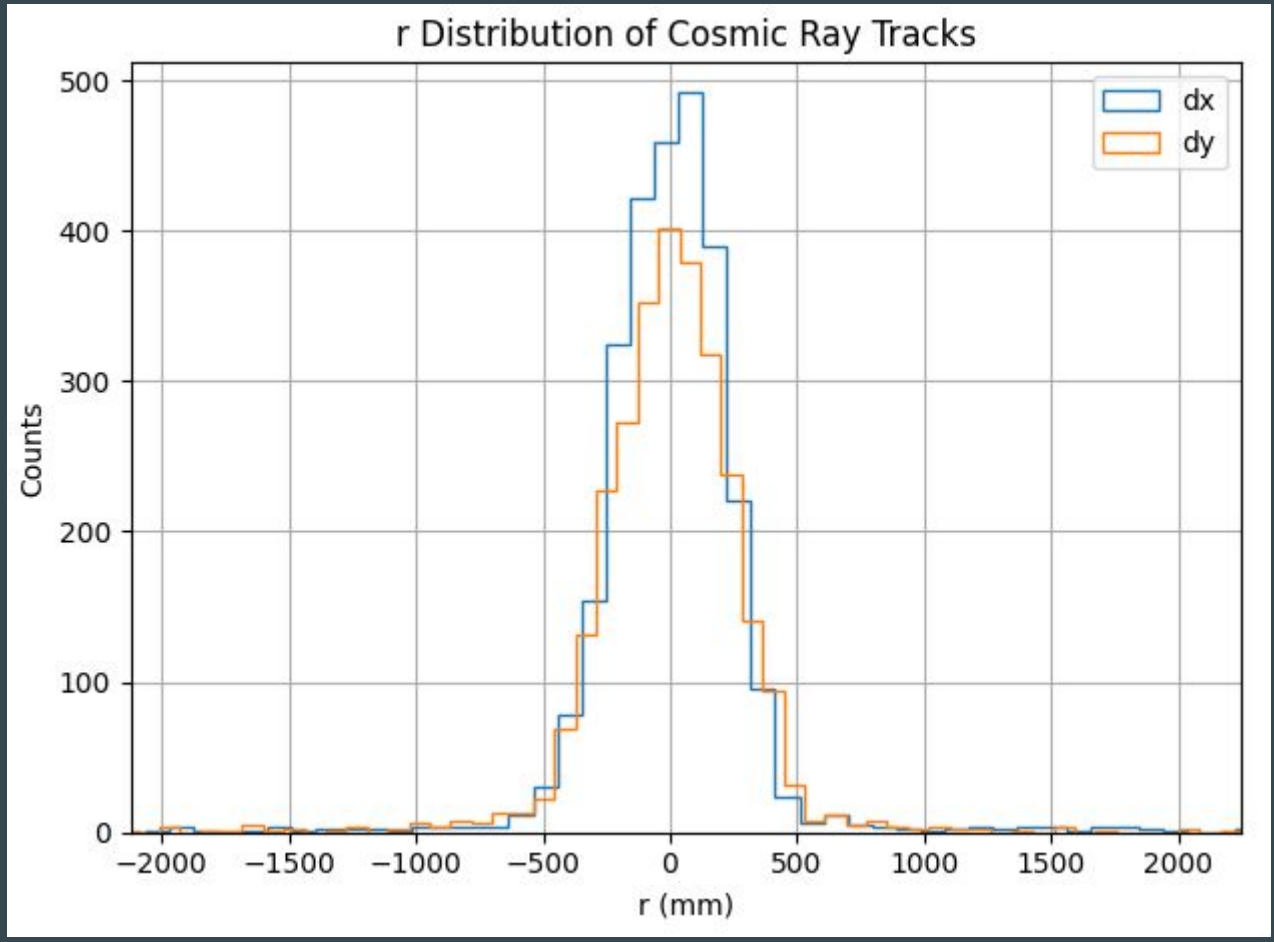


Samy's Resolution Study

- Samy calculated the naively expected banco resolution as a function of the distance from the arms and for various arm separations
- Also estimated uncertainty on resolution measurement with 10000 events






r Distribution of Cosmic Ray Tracks
dx
dy
Counts
r (mm)
500
400
300
200
100
0
−2000
−1500
−1000
−500
0
500
1000
1500
2000

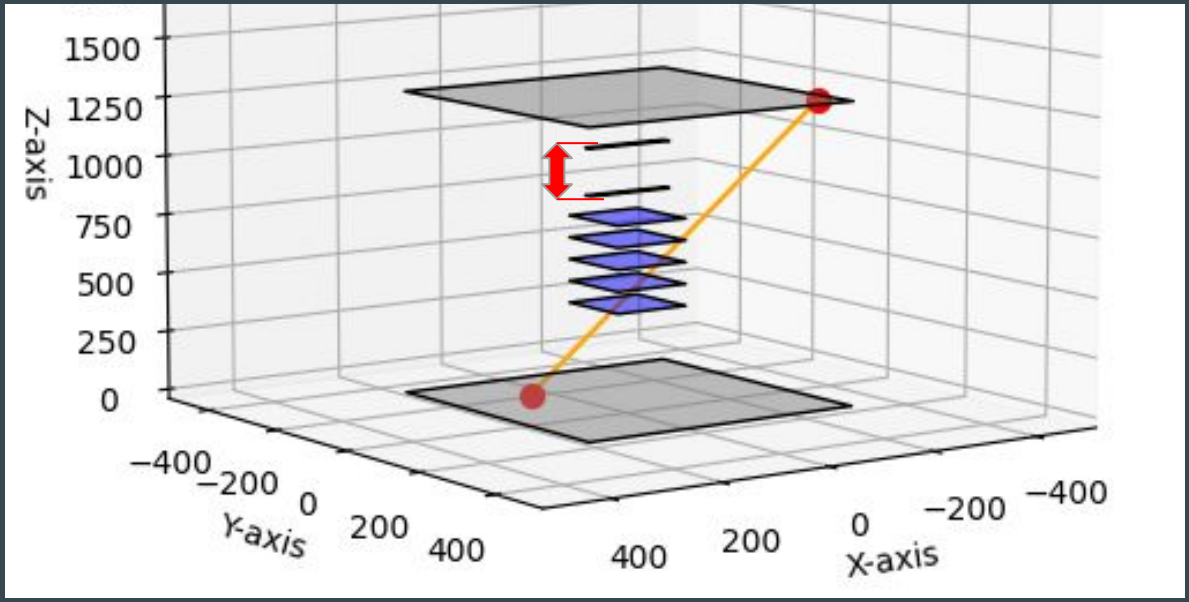
Rates

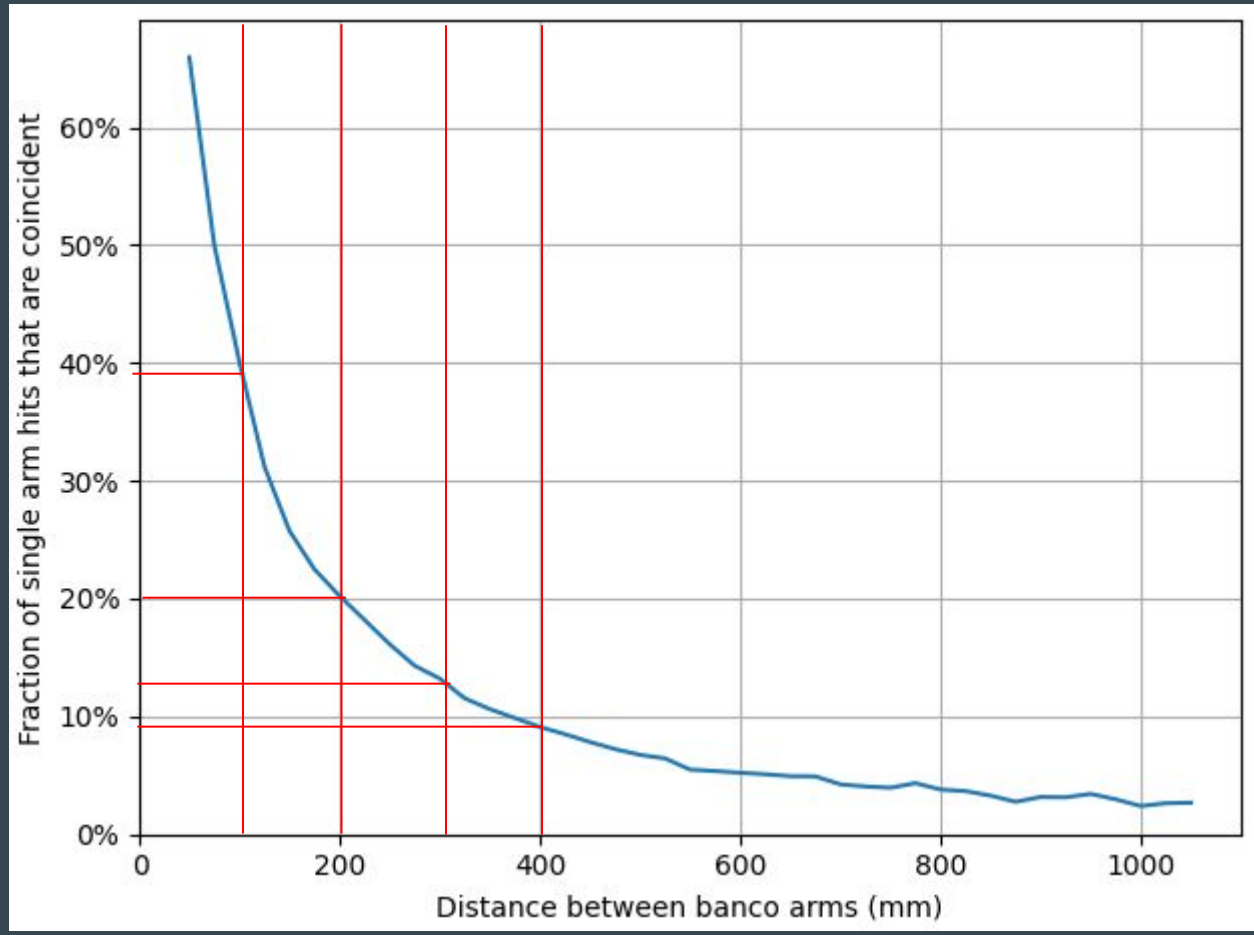
- 1 detector : 40% → 1.2k/day
- 2 detectors: 20% → 600/day
- 3 detectors: 12% → 400/day
- 4 detectors: 9% → 300/day

Detector Rates

Reference detectors 500k/day

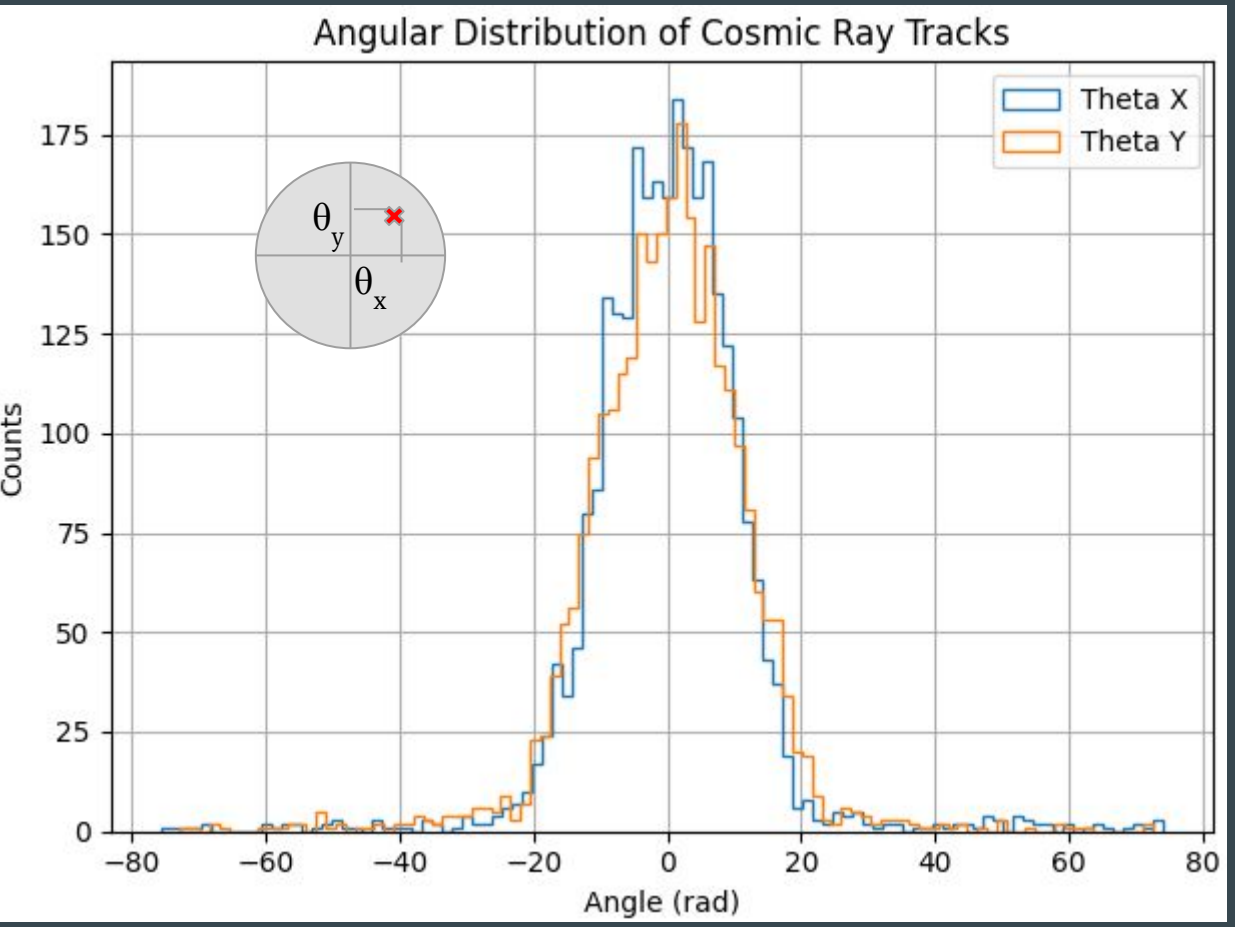
- 13x13cm: 30k/day
- 15x1.5cm: 3k/day



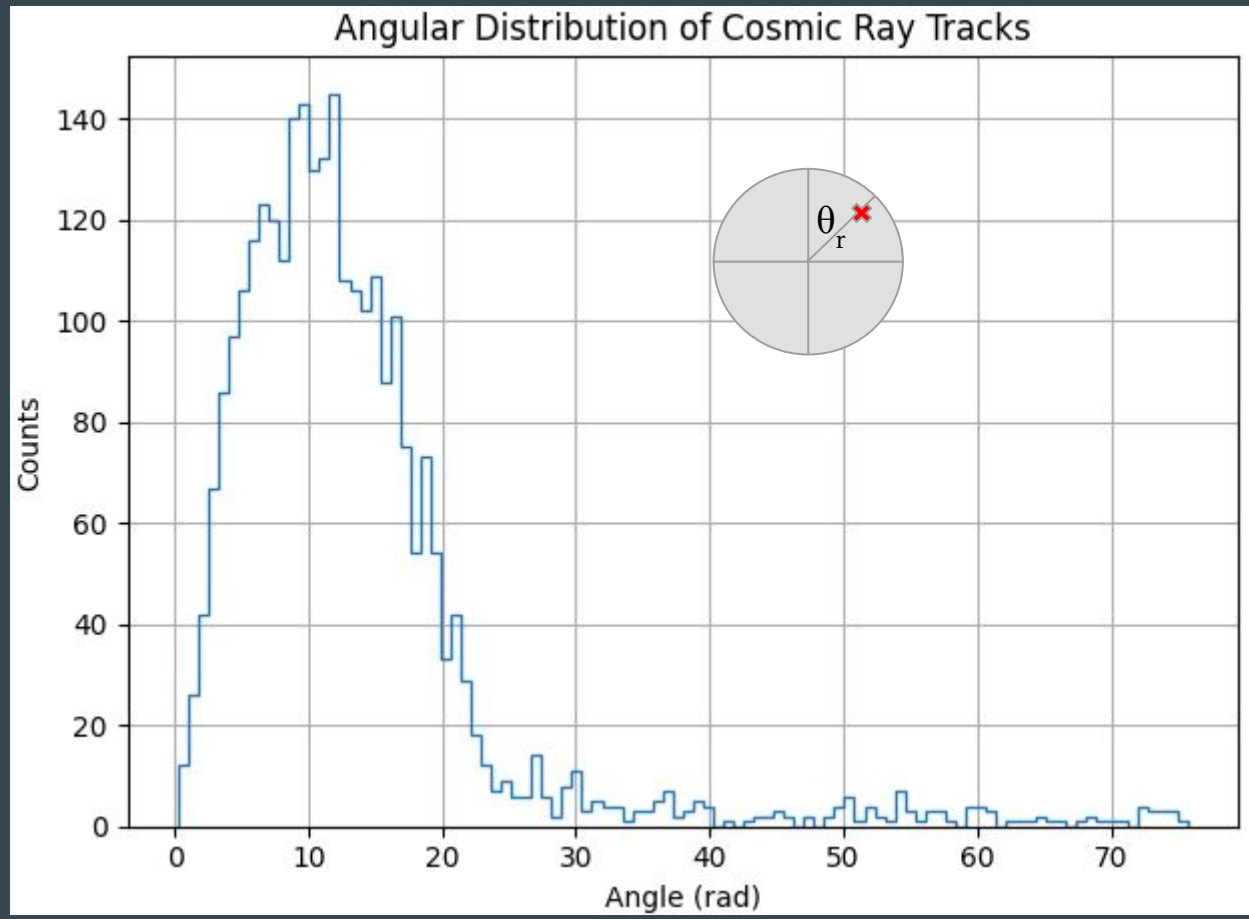


Muon Angular Distribution

X and Y Angles



Polar Angle?



Samy's Resolution Study

- Samy calculated the naively expected banco resolution as a function of the distance from the arms and for various arm separations
- Also estimated uncertainty on resolution measurement with 1000 events