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U.S. DEPARTMENT OF ENERGY
Office of Science

# Silicon Vertex Tracker Geometry and Simulation

**Shujie Li**

Tracking Workfest Session
ePIC January Collaboration Meeting @ ANL
Jan 10, 2024

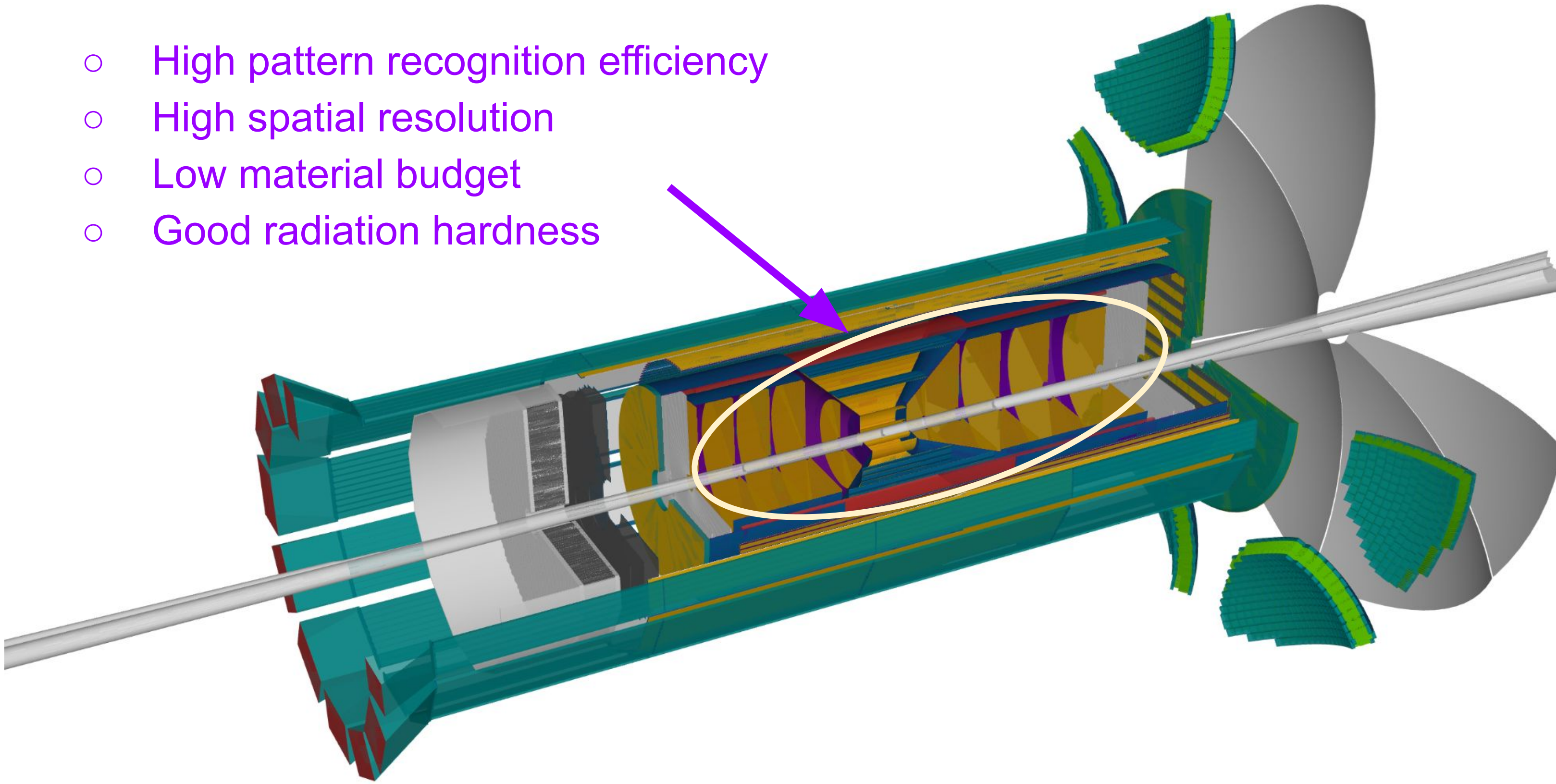
ePIC

See https://indico.bnl.gov/event/20126/ for craterlake tracking overview

# ePIC-Craterlake Configuration

Silicon Vertex Tracker with large area MAPS sensor:

- High pattern recognition efficiency
- High spatial resolution
- Low material budget
- Good radiation hardness



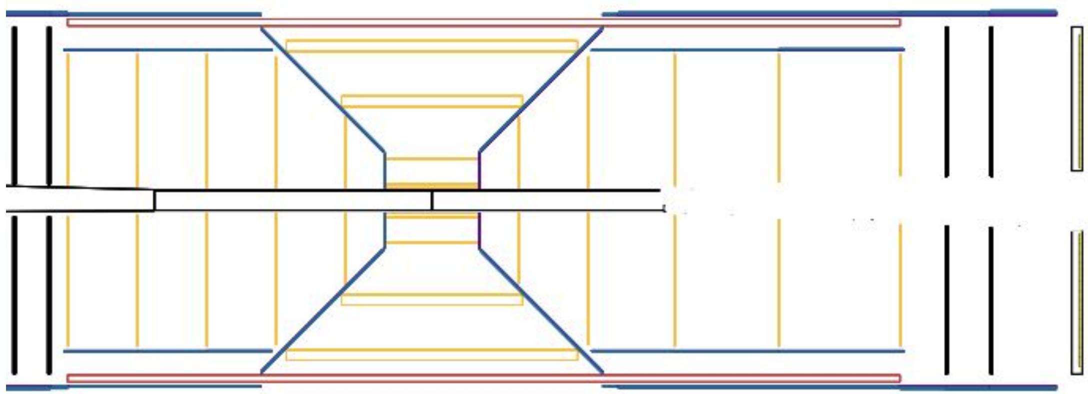
# SVT Tracker Geometry

SVT geometry on GitHub:

gitub.com/eic/epic/compact/**tracking**/

ePIC geometry database

eic.jlab.org/Geometry/Detector/Detector-20231031150001.html



- 3 inner vertex layers
  - ITS3
  - ~20x20um pixels
  - 0.05% X/X0
- 2 outer barrels
  - EIC-LAS staves
  - 0.55% X/X0
- 2x5 disks (forward/backward)
  - EIC-LAS
  - 0.24% X/X0
- Mechanical support structure and service cables

Epic-svt-l@lists.bnl.gov

# SVT Workfest / Work Package

Tue 09/01 | Wed 10/01 | Thu 11/01 | All days

Print | PDF | Full screen | Detailed view | Filter

08:00

**Welcome and introduction** — *Ernst Sichtermann et al.*
*A5000, APS Conference Center* — 08:00 - 08:05

**Radiation and rate environment** — *Laura Gonella*
*A5000, APS Conference Center* — 08:05 - 08:25

**MOSAIX and EIC LAS (remote)**
*A5000, APS Conference Center*

09:00

**EIC-LAS ancillary / support IC**
*A5000, APS Conference Center*

**Discussion on sensor and IC**
*A5000, APS Conference Center*

**Readout of the ePIC SVT (remote)**
*A5000, APS Conference Center*

11:00

**Discussion on readout of the ePIC SVT**
*A5000, APS Conference Center*

**Basics of serial powering and S-LDO**
*A5000, APS Conference Center*

**Serial powering for the ePIC SVT**
*A5000, APS Conference Center* — 11:25 - 11:45

**Discussion on serial powering for the ePIC SVT**
*A5000, APS Conference Center* — 11:45 - 12:00

12:00

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10:00

**Characterization of the SVT sensors and ancillary IC** — *Lukas Tomasek*
*B4100, APS Conference Center* — 10:15 - 10:45

**...rization for the SVT**
*B4100, APS Conference Center* — 10:45 - 11:05

**Inventory of SVT power dissipation**
*B4100, APS Conference Center* — 11:05 - 11:10

**Cooling of SVT layers and disks** — *Nicole Apadula*
*B4100, APS Conference Center* — 11:10 - 11:40

**Discussion on SVT cooling**
*B4100, APS Conference Center* — 11:40 - 12:00

12:00

See SVT workfest sessions on Tue/Wed for details on sensor, readout, power, cooling etc

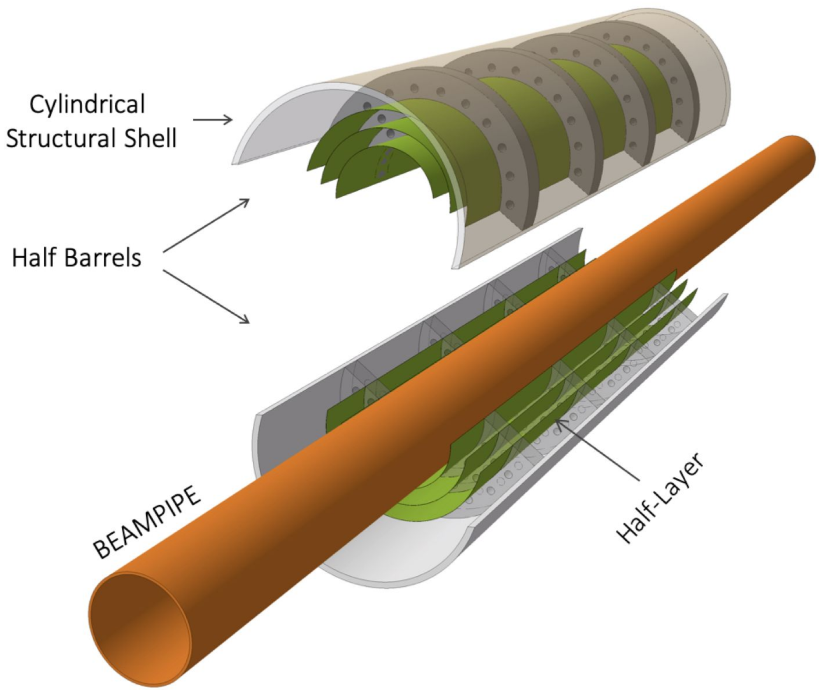
**Ongoing R&D:**

- eRD104: readout and power
- eRD111: mechanical structure and cooling
- eRD113: sensor characterization

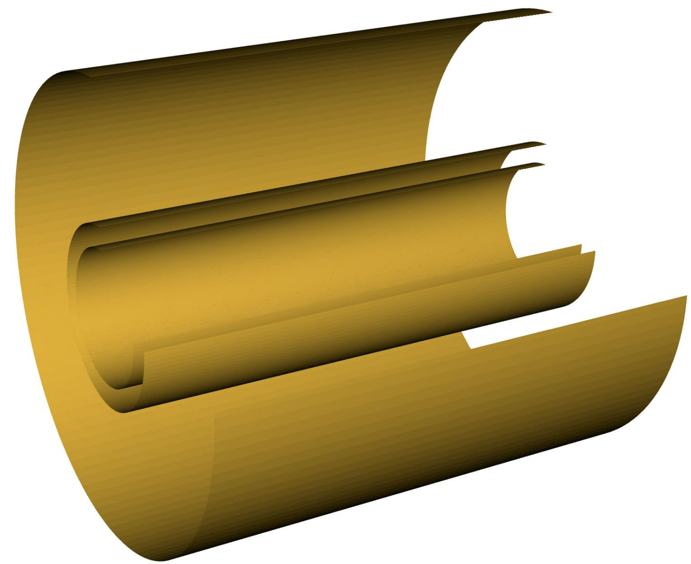
# Vertex Barrels

epic/compact/tracking/**vertex_barrel.xml**

ALICE ITS3 LOI

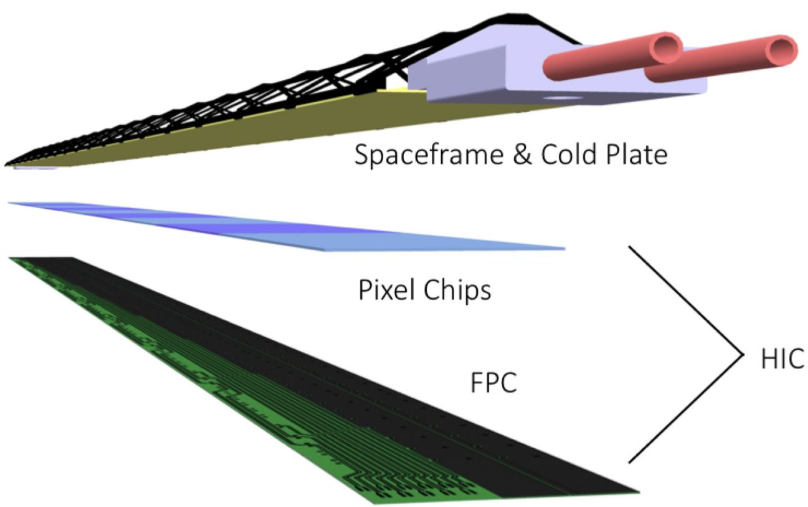



Current geometry in simulation:
3 ITS3 silicon layers (40um thick, r=3.6, 4.8, 12cm) approximated with 128 staves



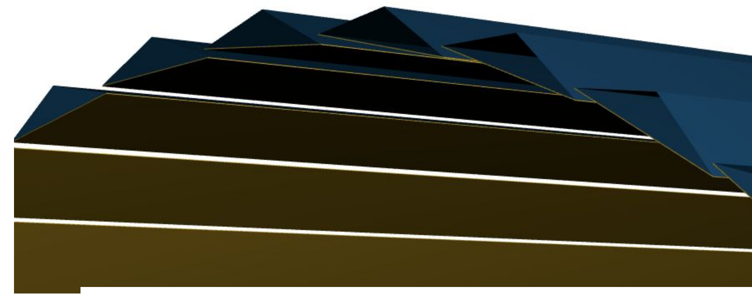
# Outer Barrels

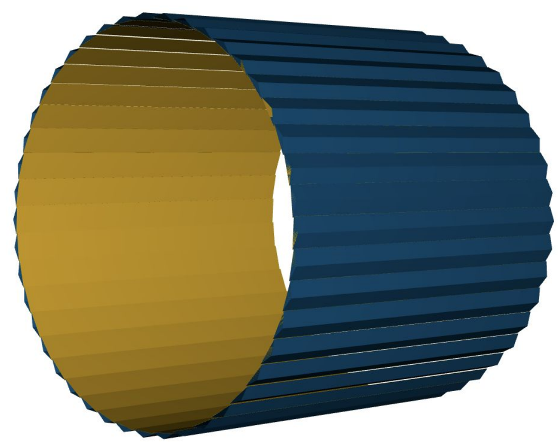
ITS2 barrel stave:




ePIC simulation:

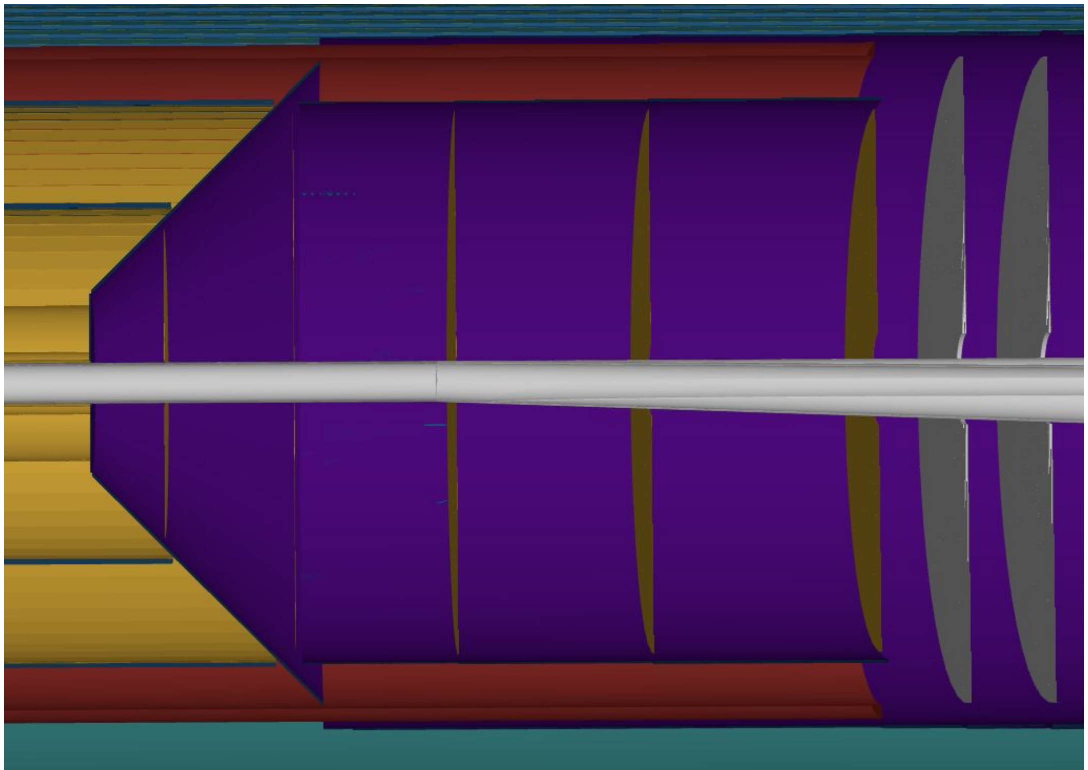
44 slightly tilt triangle staves (silicon + Al + carbon fiber plates)

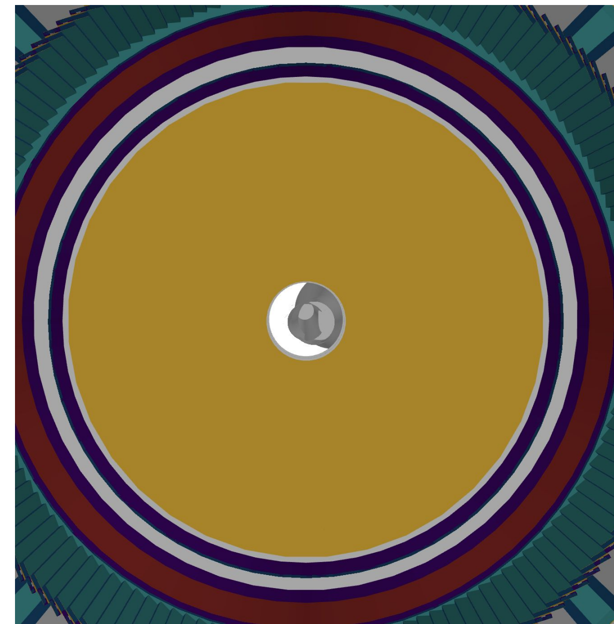




# Disks

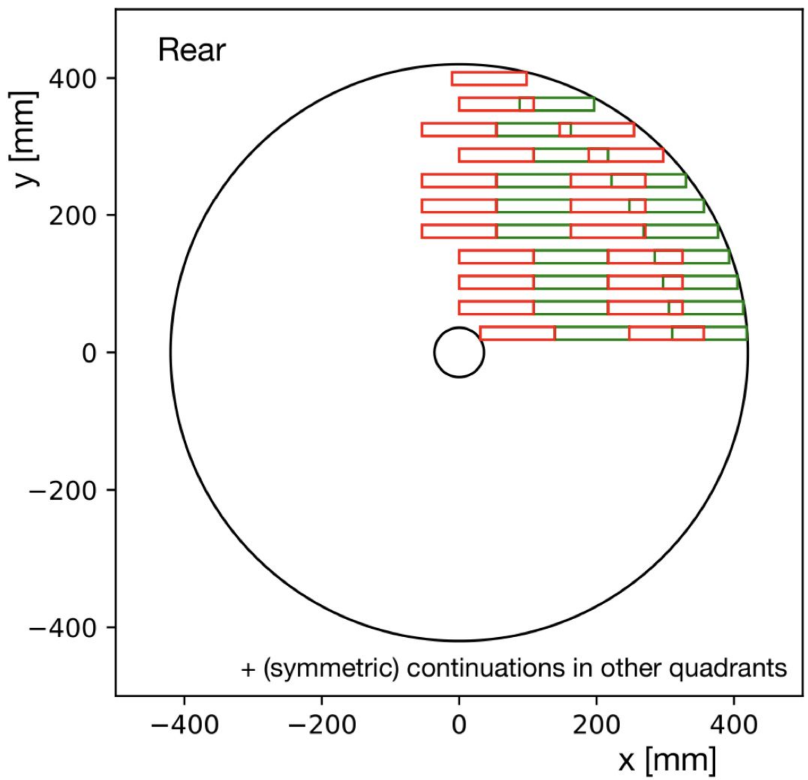
**In simulation**: use larger centered hole to accommodate beampipe fan-out



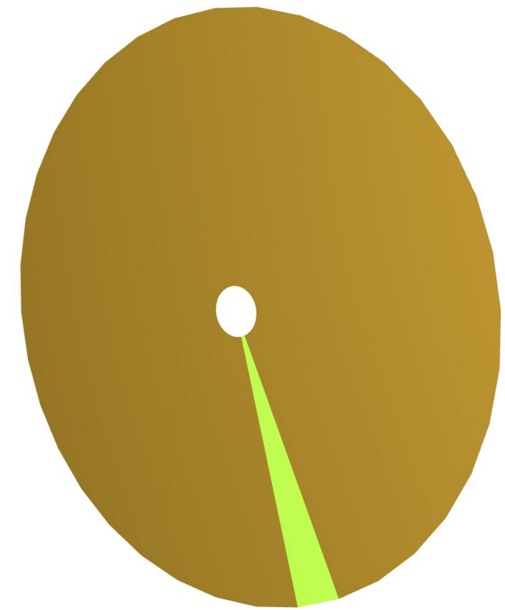


# Disks

**Design**: assemble disks with staves



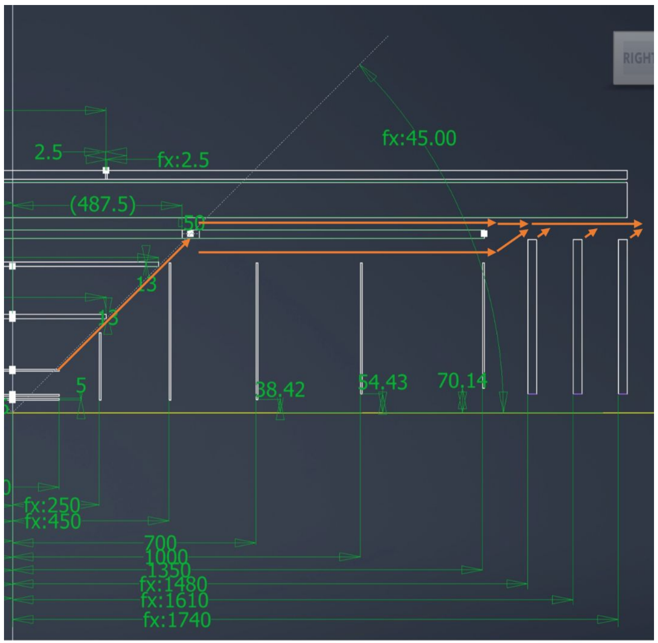

**Simulation**: disks from 36 trapezoid slices.



High-priority task: implement off-centered hole and staves to reflect the true acceptance.
See https://github.com/eic/epic/issues/118

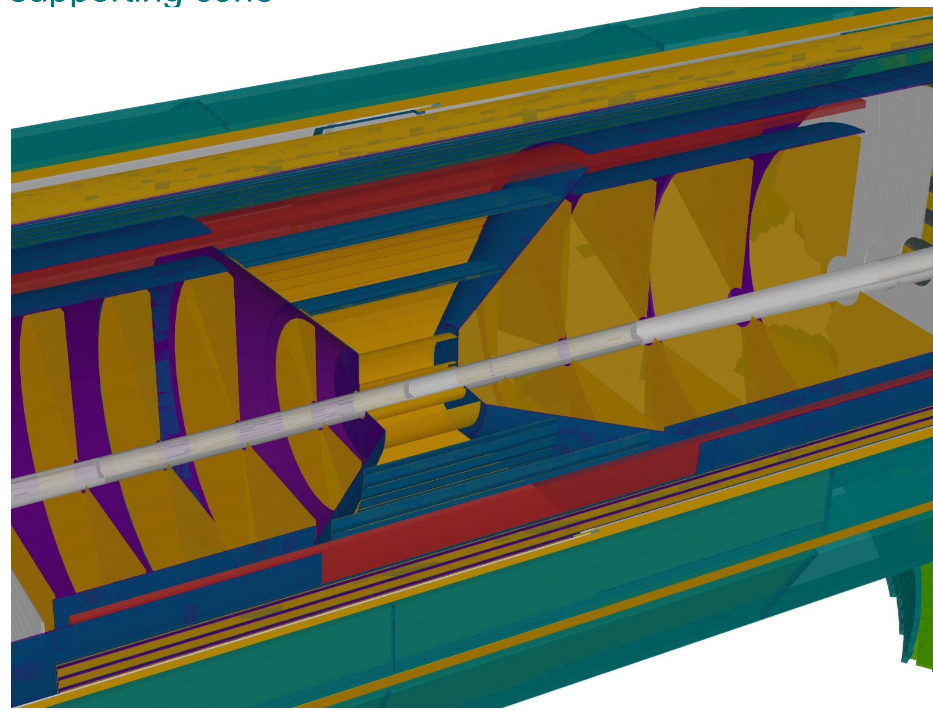
# Service cables and Supporting Structure

Planned cable routing



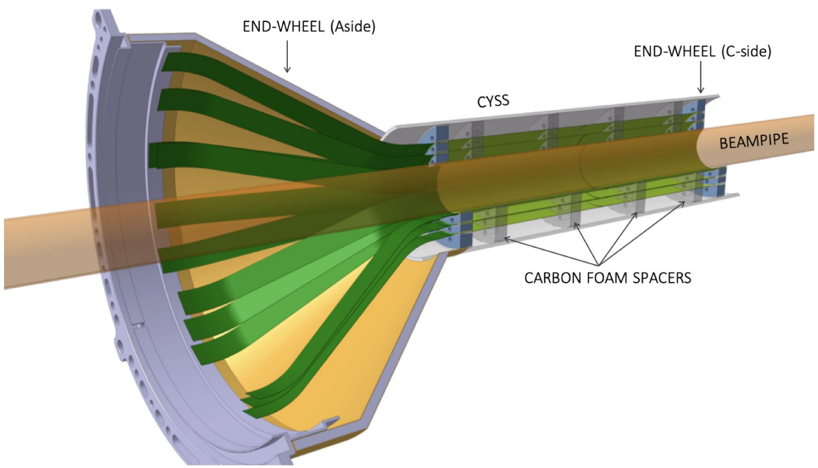

Courtesy of E. Sichtermann

Simulation: **Cables** guided out along the **carbon** supporting cone

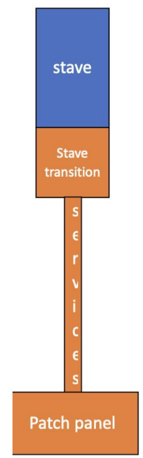


# Service cables and Supporting Structure

ALICE ITS3 LOI




Simulation: Cables treated as uniform aluminum layers with effective thickness proportional to silicon area size.




**Summary of ITS3 like Si tracking**

| | Stave X/X0 | Stave transition (per 100 cm^2 of Si surface)* | Services (per 100 cm^2 of Si surface)* | Patch panel (per 100 cm^2 of Si surface)* |
|---|---|---|---|---|
| ITS3 like vertexing | ~0.1% | 6.66 cm^3 of material with X/X0 of 0.0684 per traversed cm | 2.96 cm^2 cross section with X/X0 of 0.022 per traversed cm | 4.32 cm x 1cm x 1 cm with 0.102 X/X0 per traversed cm |
| ITS3 like barrel (up to 1.5m length) | 0.55 % | 4.286 cm^3 of material with X/X0 of 0.0684 per traversed cm | 1.905 cm^2 cross section with X/X0 of 0.022 per traversed cm | 2.778cm x 1cm x 1 cm with 0.102 X/X0 per traversed cm |
| ITS3 like disc (up to 60 cm diameter) | 0.24% | 6.66 cm^3 of material with X/X0 of 0.0684 per traversed cm | 2.96 cm^2 cross section with X/X0 of 0.022 per traversed cm | 4.321 cm x 1cm x 1 cm with 0.102 X/X0 per traversed cm |

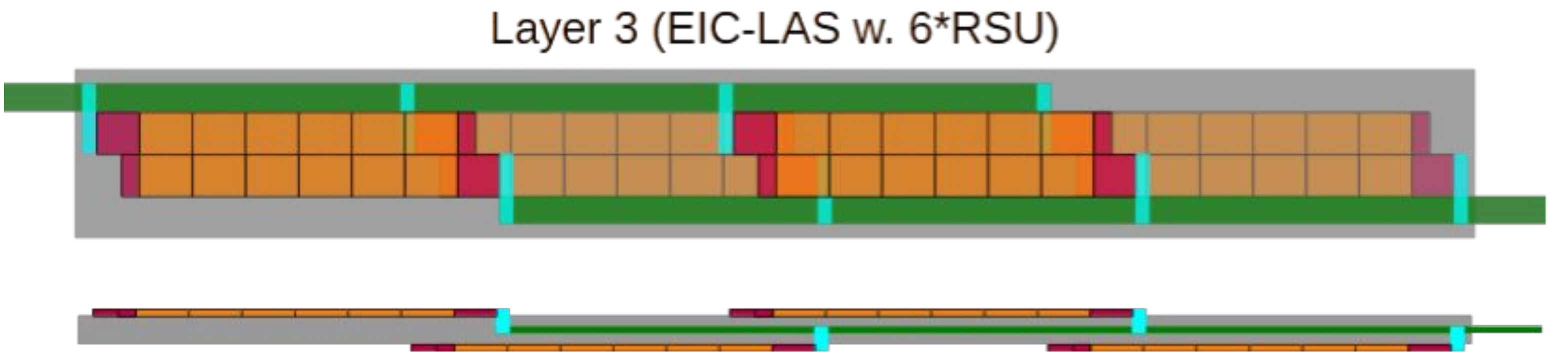
* Corrected 2021_03_13

DRAFT 2021_06_15_EIC_Si_material_projections LG 23

# Sensor Unit

Current stave design
Red = inactive areas

see J. Glover's talk on Tuesday

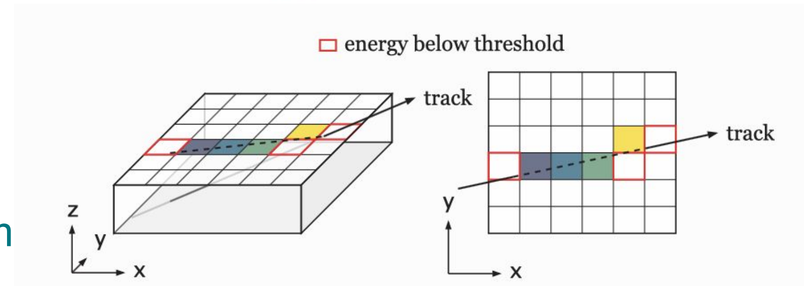



In simulation:
ALL parts are implemented as solid surfaces with segmentation size of 20x20um.
NO module, Periphery, or other mechanical details.
NO inactive areas, noise, deficiency.

# Digitization Scheme (ePIC digitization model )

1. Setup segmentation in geometry description file. Each SimHit has a cell ID on the detector surface

```
<readouts>
  <readout name="SiBarrelHits">
    <segmentation type="CartesianGridXY" grid_size_x="0.020*mm" grid_size_y="0.020*mm" />
    <id>system:8,layer:4,module:12,sensor:2,x:32:-12,y:-20</id>
  </readout>
</readouts>
```

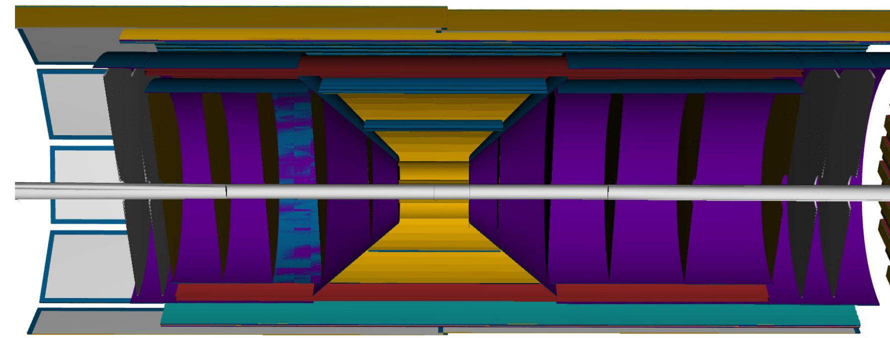


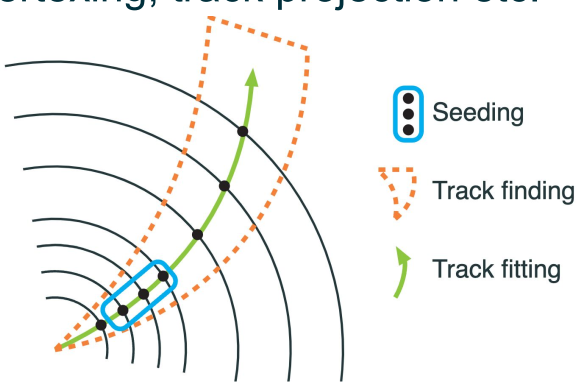

2. Digitization in EICrecon:
   1) read in SimHit ( cell ID, edep, tim
   2) apply energy threshold (0.54 keV)
   3) put hit at the center of each cell, resolution = pixel size / sqrt(12)
   4) Digitized hit → tracking measurement

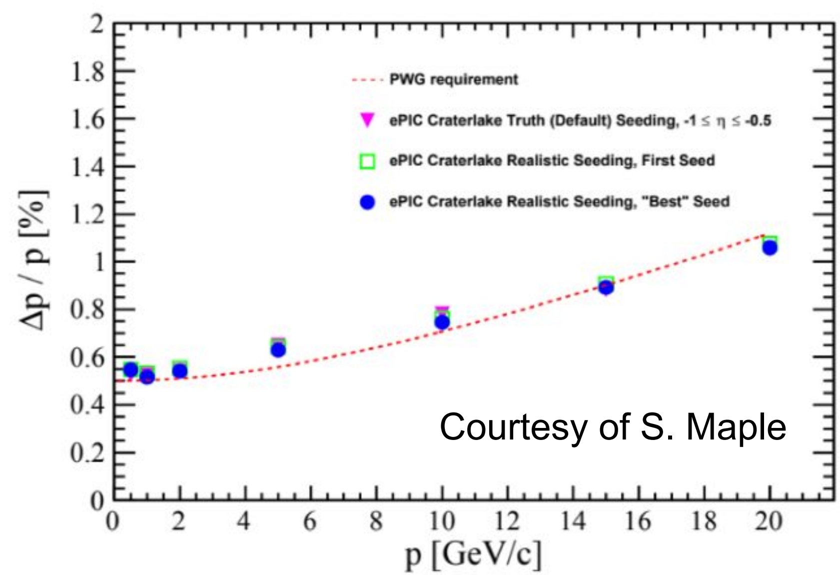
To do: add clustering algorithm, noise, and use timing info mailing list: eic-projdet-trk-recon-l@lists.bnl.gov

# Track Reconstruction Study

- geometry optimization
- access more tracking hits and time info via other tracking detectors
- check tracking performance (theta, phi, dp/p, DCA resolution) against physics requirements *see background/tracking session on Thursday
- Algorithm development: seeding, vertexing, track projection etc.





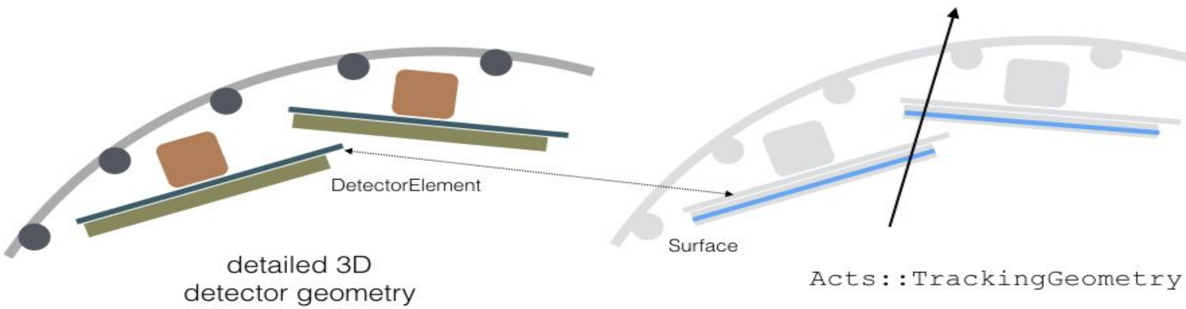
# Summary

- The ePIC SVT uses large area MAPS sensors with a combination of ITS2 and ITS3 technology, with several on-going eRD projects to decide detector specs.
- The current craterlake geometry is optimized to meet the physics requirements. It is implemented in DD4hep simulation with limited details. That serves the purpose of preliminary tracking study. Significant improvements will be needed for TDR.
- Digitization and reconstruction algorithm developments are on-going. Plenty of well-defined tasks are waiting for volunteers.

*Thank you!*

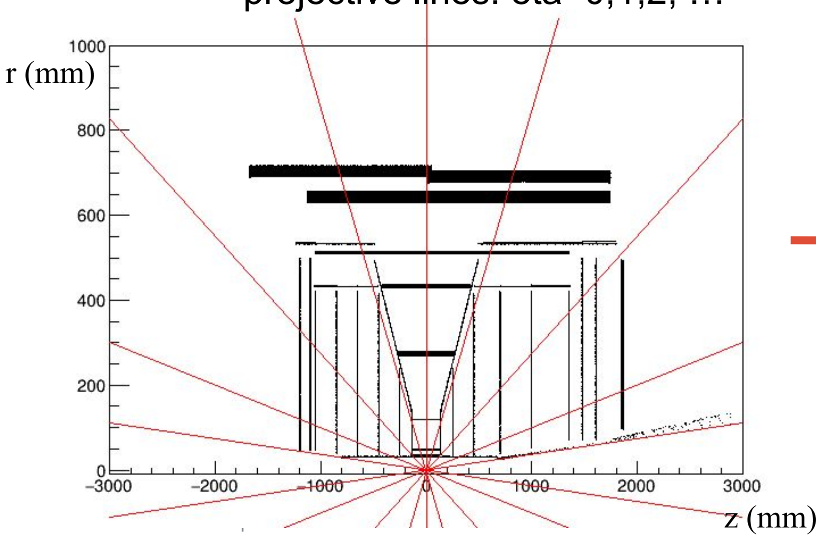
# Backup

# Simplified geometry in ACTS

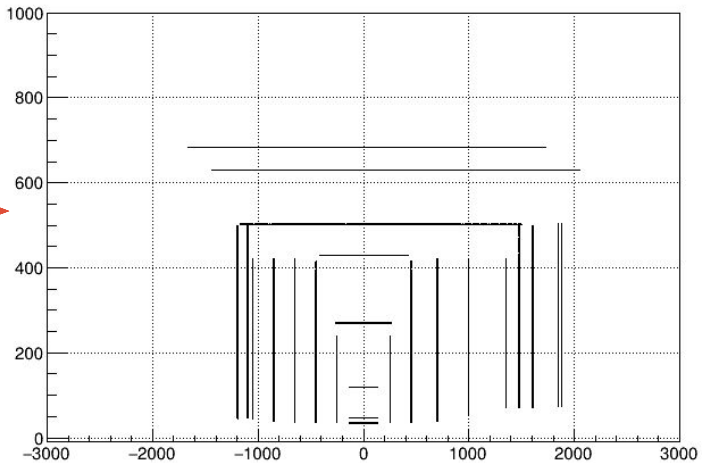



**Central tracker side view**

projective lines: eta=0,1,2, …



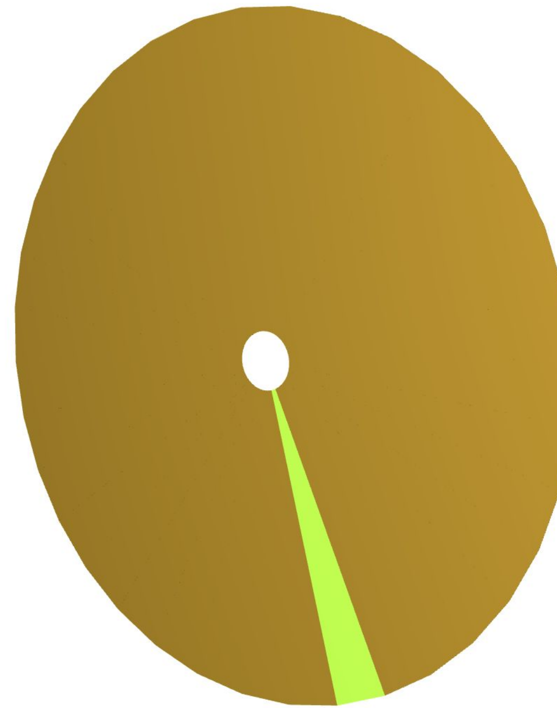

**Project materials to surfaces**



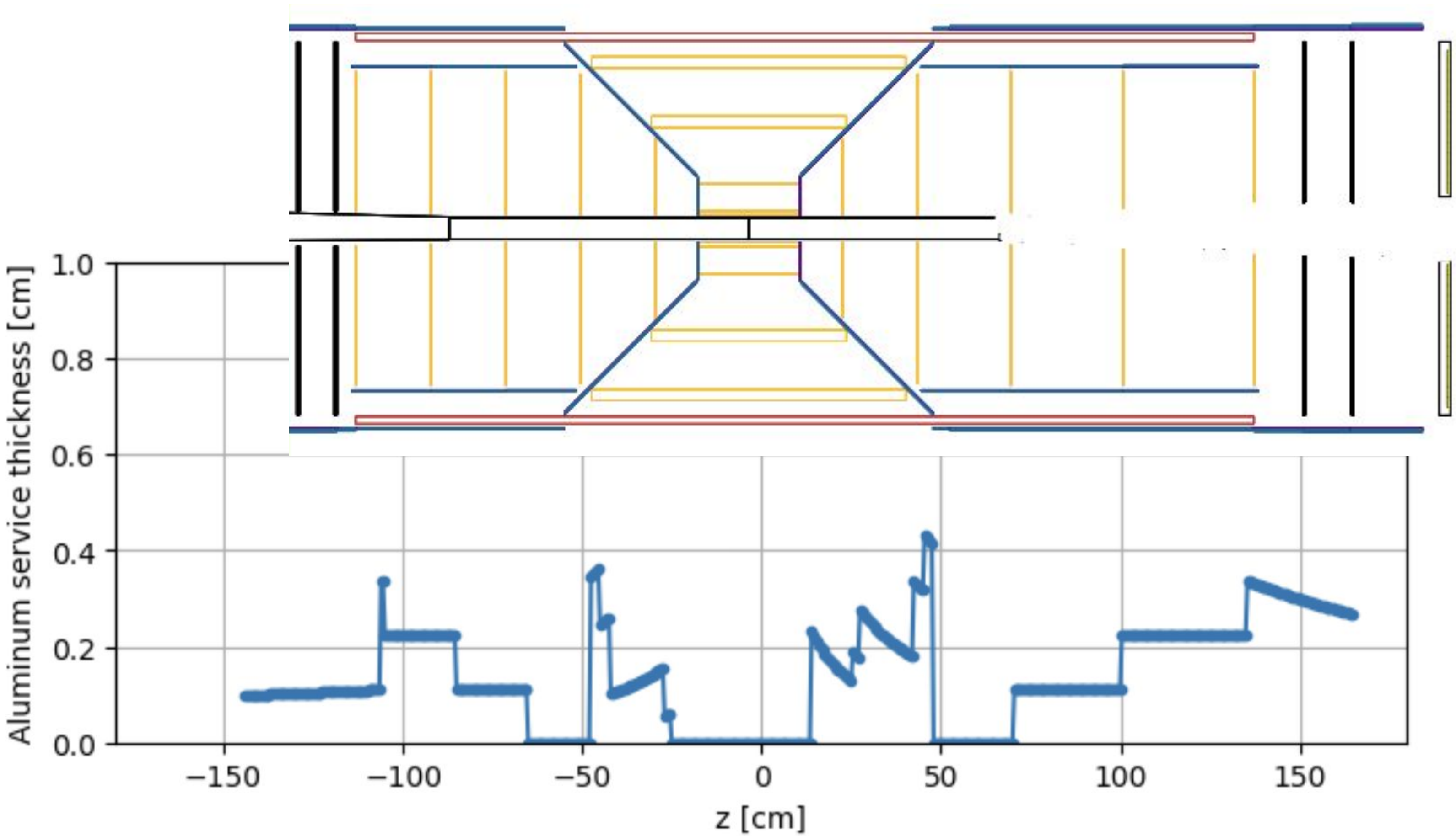
# Disks

| disk | Name in dd4hep | z pos (mm) | R_bpipe | x_offset | R_outer | R_inner_sym |
|---|---|---|---|---|---|---|
| 5n | TrackerEndcapNDisk4 | -1050 | 38.043 | -3.310 | 430 | 46.3529 |
| 4n | TrackerEndcapNDisk3 | -800 | 34.244 | -0.817 | 430 | 40.0614 |
| 3n | TrackerEndcapNDisk2 | -650 | 31.76 | 0 | 430 | 36.76 |
| 2n | TrackerEndcapNDisk1 | -450 | 31.76 | 0 | 430 | 36.76 |
| 1n | InnerTrackerEndcapN | -250 | 31.76 | 0 | 230 | 36.76 |
| 1p | InnerTrackerEndcapP | 250 | 31.76 | 0 | 230 | 36.76 |
| 2p | TrackerEndcapPDisk1 | 450 | 31.76 | 0 | 430 | 36.76 |
| 3p | TrackerEndcapPDisk2 | 700 | 32.86 | 0.6 | 430 | 38.42 |
| 4p | TrackerEndcapPDisk3 | 1000 | 40.58 | 7.85 | 430 | 53.43 |
| 5p | TrackerEndcapPDisk4 | 1350 | 49.12 | 16.02 | 430 | 70.14 |

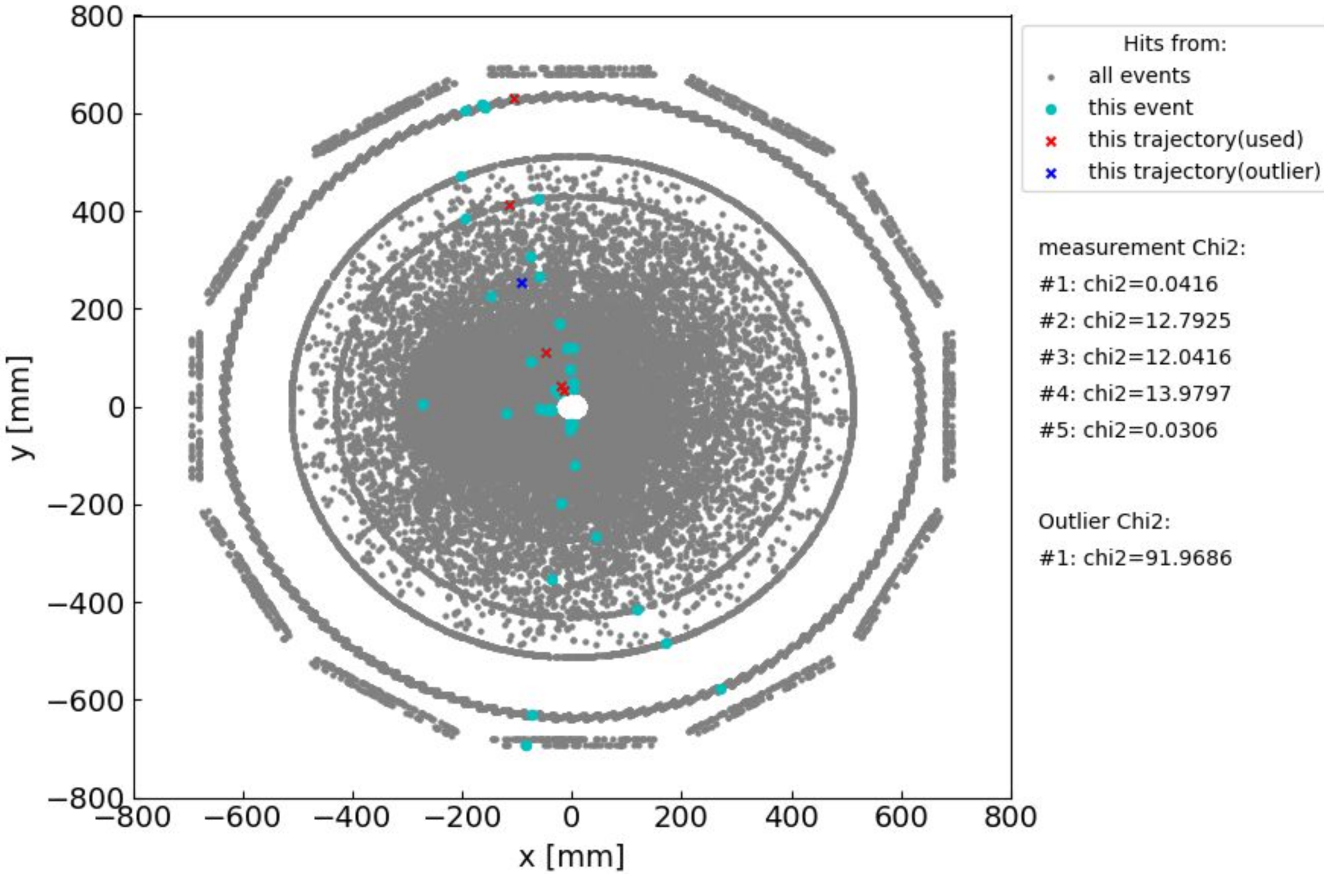
- X/X0=0.24%
- silicon + carbon fiber + aluminum plates
- 36 sections of



# Service cables and Supporting Structure



# Tracking Study with DIS Events




**on-going:**

- tracking performance study with background+DIS
- Dedicated study on number of hits and chi2

**to do:**

- use timing info for signal/background separation
- project trajectory to various detector surface/volumes