



UNIVERSITY OF
BIRMINGHAM

SCHOOL OF
PHYSICS AND
ASTRONOMY



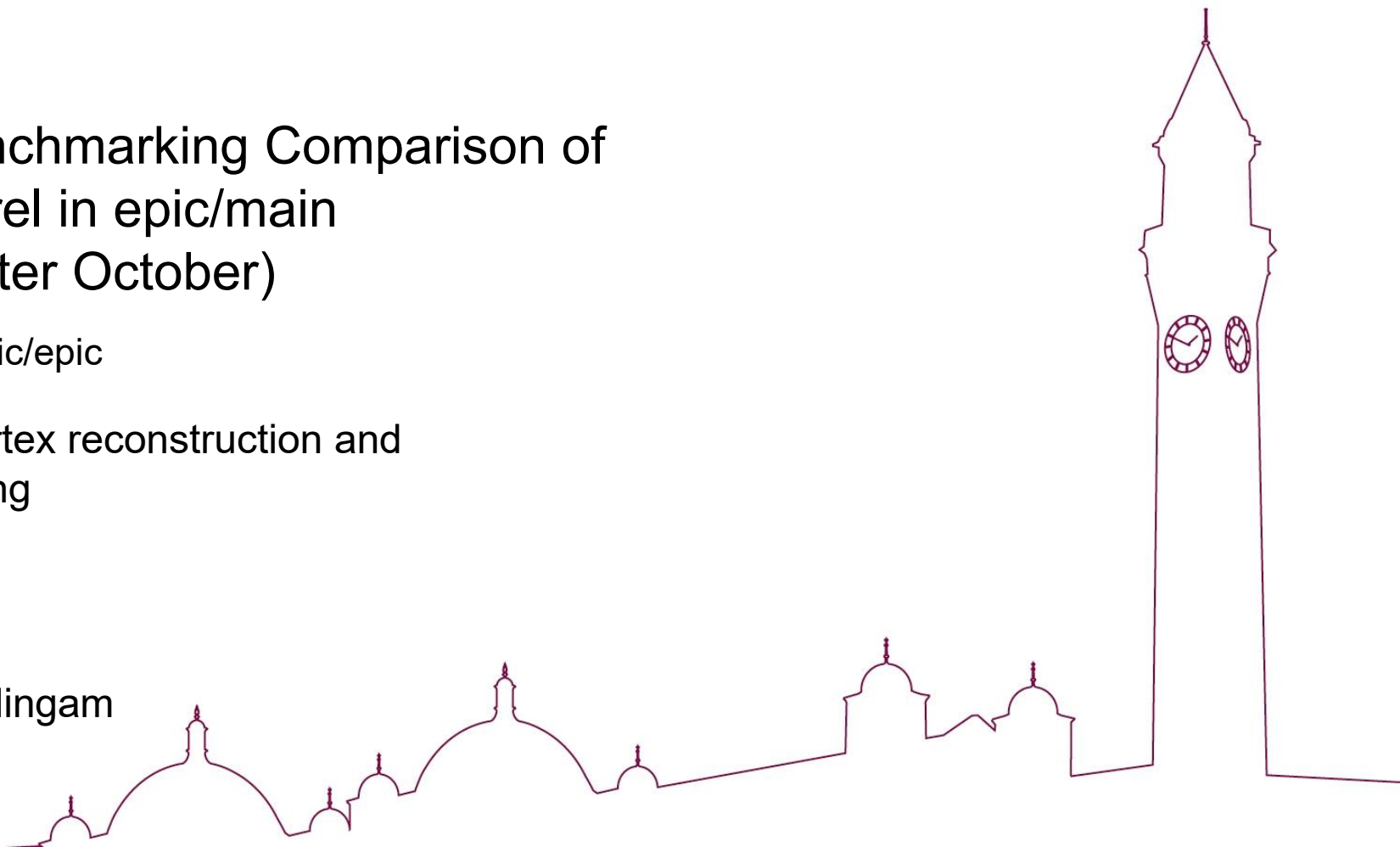
Geometry Benchmarking Comparison of the Outer Barrel in epic/main (before and after October)

<https://github.com/eic/epic>

Joint track and vertex reconstruction and
tracking wg meeting

11/12/2025

By Athavan Ramalingam



epic/main Outer Barrel Changes

- Merged flat_OB branch into main
 - Made by Sam Henry & Aditya
 - Initial attempt for a simple stave design close to the CAD design
 - Prev presentation from Sam of the July CAD design - <https://indico.bnl.gov/event/29542/>
- Purpose
 - Give a more appropriate estimate of material and geometry based on CAD designs of the staves
 - Based on the September CAD design of the staves - <https://indico.bnl.gov/event/29758/>
- This study
 - **Pre-merge OB**
 - Before flat_OB was merged (in eic shell 25.08.0 stable)
 - **Post-merge OB**
 - After flat_OB was merged (in eic shell 25.10.0-stable)



epic/main Outer Barrel Changes

- Merged flat_OB branch into main
 - Made by Sam Henry & Aditya
 - Initial attempt for a simple stave design
- Purpose
 - Give a more appropriate estimate of material and geometry based on CAD designs of the staves
 - Based on the September CAD design of the staves - <https://indico.bnl.gov/event/29758/>

Post-merge OB →

```
d66f231b8 (HEAD -> main, origin/main, origin/HEAD) Fixes stuck particles in far backward hadron beampipe (#903)
83aeabee6 Moved BT0F forward by 2.5 cm. (#965)
97e36e573 Change segmentation for the RP, and add LUTs for the RP polynomial re... (#966)
5fc9ff41c (tag: 25.10.1, tag: 25.10.0, origin/25.10) Update material map for 25.09.0 (#952)
d7053fb25 ForwardServiceGap_length increased by 2.8cm to move calo endcap (#960)
3e1ad24e8 SVT support/service update (#961)
dfc8b03a3 fix: tighter overlap tolerances (10 um) (#917)
b06e84c13 Flat ob (#933)
```

Pre-merge OB →

```
c42b63382 Add LightGuide and EndOfSectorBox lengths (#956)
c6439ab6d Add .github/release.yml (#949)
bbb53813e Implement curved RSU structure for the three layers of vertex barrel trackers (#803)
3188d2f5c Aerogel refractive index changed to 1.026 (#957)
5cc51e788 Updated-drch.lut (#958)
fc2eb7a5f (tag: 25.09.0) [pre-commit.ci] pre-commit autoupdate (#950)
```

Overview

- Visualisation of the outer barrel in geoviewer
 - Material
 - Layer geometry
- Hitmaps
 - Barrel region (active material)
- Materialscan
 - Barrel
 - Staves
- Resoluton plots
 - Updated material map
 - Momentum resolution
 - DCA_T resoluton

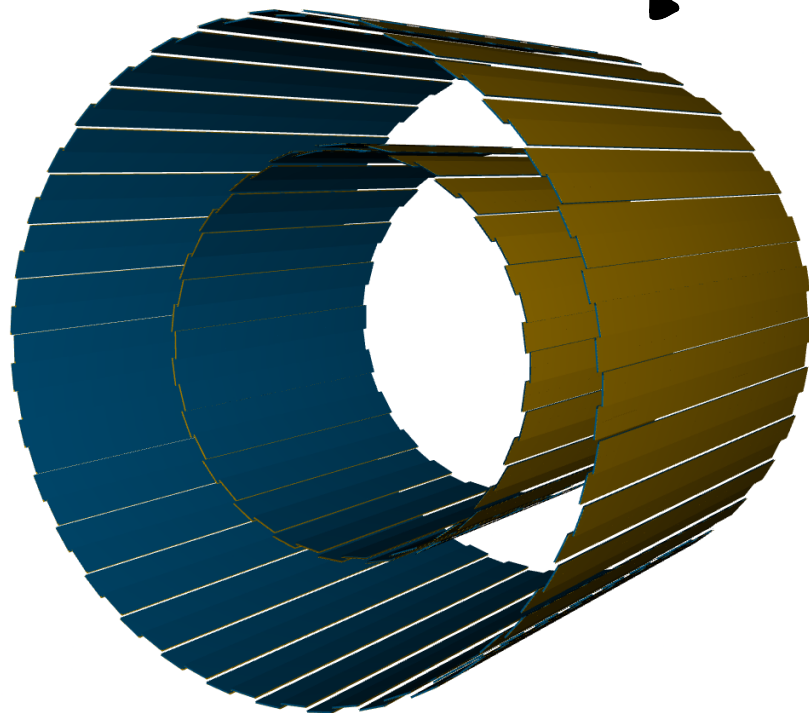
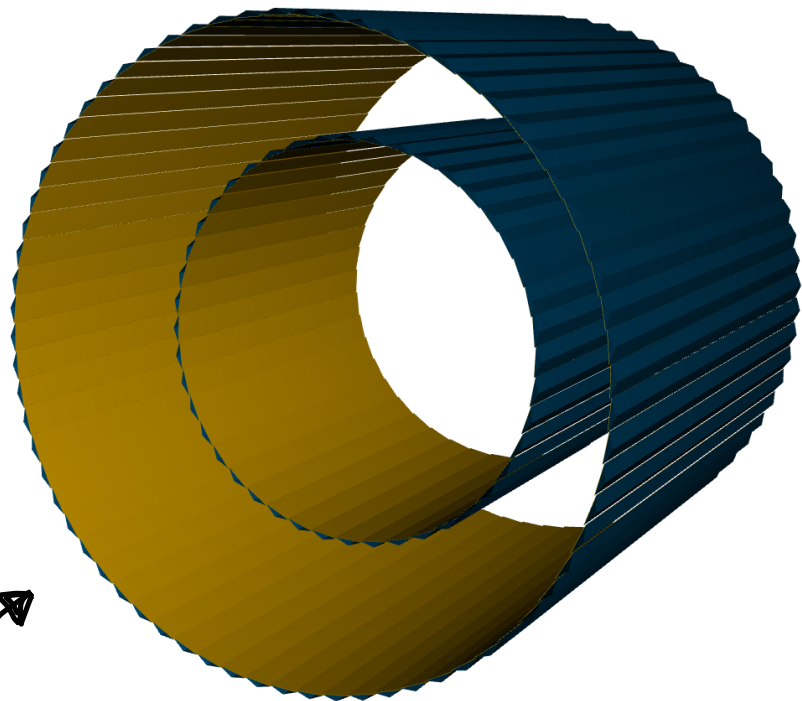


Geoviewer visualisation

Castellated single sided flat staves

Pre-merge

Post-merge



Tilted its2 like staves

Pre Merge - Stave structure L3

Silicon

Component: 0_1

Material: Si

L: 52cm, W: 4cm, D: 0.005cm (50 μ m)



Aluminum

Component: 1_2

Material: Al

L: 52cm, W: 4cm, D: 0.014 cm (140 μ m)



Carbon Fibre support

Module: 1_0

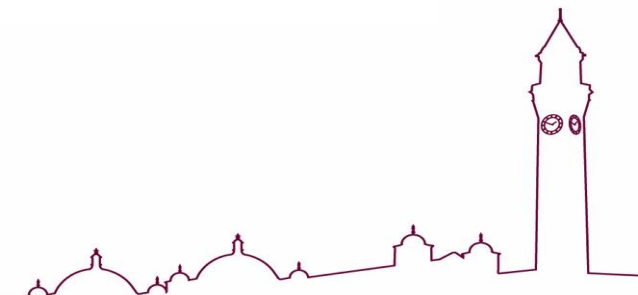
Material: Carbon Fibre

Left/right

L: 52cm, W: 4cm, D: 0.801cm (8010 μ m)



Total material $\sim 0.25\%$ X_0



Pre Merge - Stave structure L4

Silicon

Component: 0_1

Material: Si

L: 84cm, W: 4cm, D: 0.005cm (50 μ m)



Aluminum

Component: 1_2

Material: Al

L: 84cm, W: 4cm, D: 0.038cm (380 μ m)



Carbon Fibre support

Module: 1_0

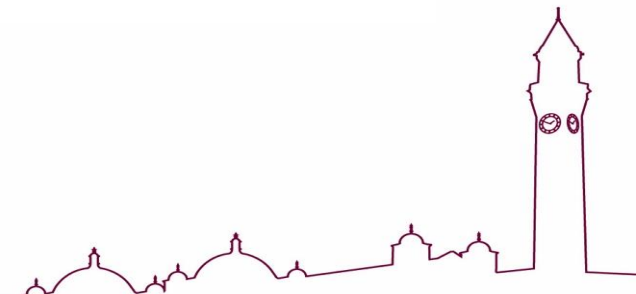
Material: Carbon Fibre

Left/right

L: 84cm, W: 4cm, D: 0.801cm (8010 μ m)



Total material $\sim 0.55\%$ X_0



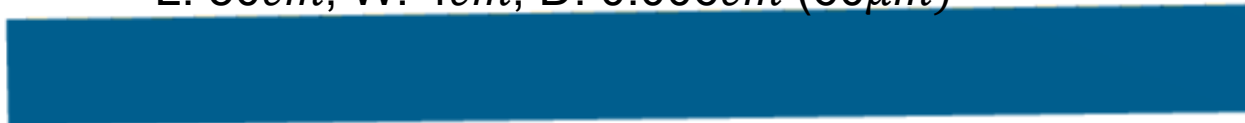
Post Merge - Stave Structure L3

Carbon Fibre stave

Components:0

Material: CHO

L: 50cm, W: 4cm, D: 0.006cm (60 μ m)

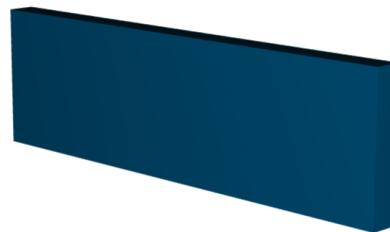


L: 1cm, W: 4cm, D: 0.2cm (2000 μ m)

Carbon Fibre support

Components:1-5

Material: CHO

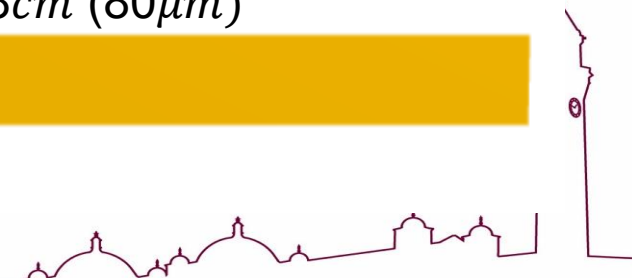


Kapton stave

Components:6

Material: CHNO

L: 50cm, W: 4cm, D: 0.008cm (80 μ m)



Post Merge - Stave structure L3

L: 50cm, W: 1.85cm, D: 0.01cm (100 μ m)

Active



(7)

Silicon

Components: 7-9

Material: Si

L: 50cm, W: 0.1cm, D: 0.01cm (100 μ m)

Dead



(8)

L: 50cm, W: 1.85cm, D: 0.01cm (100 μ m)

Active



(9)

Total average material at $\sim 0.25\%$ X_0 (with hotspots of ~ 0.8)

<https://eic.phy.anl.gov/geoviewer/>



Post Merge - Stave structure L4

Carbon Fibre stave

Components:0

Material: CHO

L: 80cm, W: 4cm, D: 0.012cm (120 μ m)

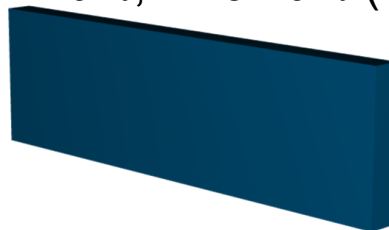


Carbon Fibre support

Components:1-9

Material: CHO

L: 1cm, W: 4cm, D: 0.2cm (2000 μ m)

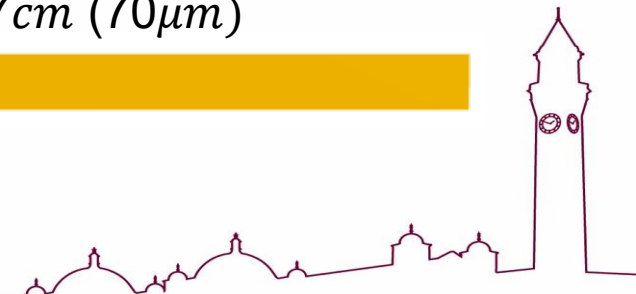


Kapton Stave

Components:10

Material: CHNO

L: 80cm, W: 4cm, D: 0.007cm (70 μ m)



Post Merge - Stave structure L4

L: 80cm, W: 1.85cm, D: 0.011cm (110 μ m)

Active



(11)

Silicon stave

Components: 11-13

Material: Si

L: 80cm, W: 0.1cm, D: 0.011cm (110 μ m)

Dead



(12)

L: 80cm, W: 1.85cm, D: 0.011cm (110 μ m)

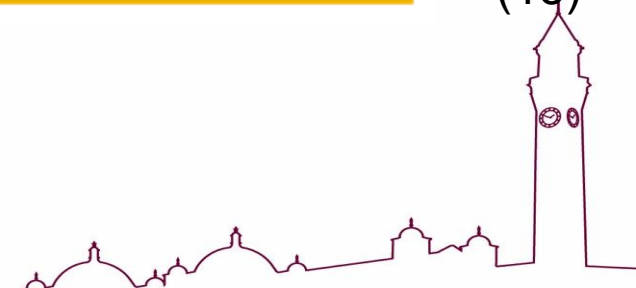
Active



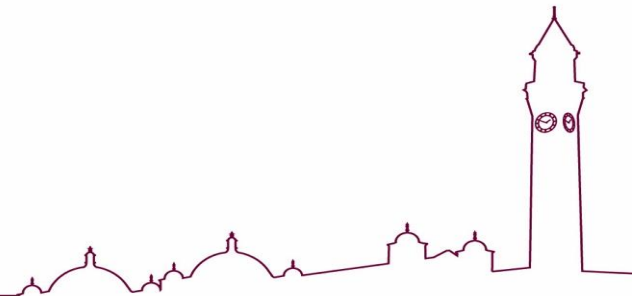
(13)

Total average material at $\sim 0.25\%$ X_0 (with hotspots of $\sim 0.8\%$)

<https://eic.phy.anl.gov/geoviewer/>



Hitmaps



Steering file for the hitmaps

Main focus is the barrel region ($|\eta| < 0.88$)

- π^- events
- 1 million single particle events
- Momentum $15\text{GeV}/c$

ddsim

--steeringFile steering.py
--compactFile \$DETECTOR_PATH/epic_craterlake_sb.xml
--numberOfEvents 1000000
--outputFile *name.root*

steering.py

```
1  from DDSim.DD4hepSimulation import DD4hepSimulation
2  from g4units import mm, GeV, MeV, deg
3
4  SIM = DD4hepSimulation()
5
6  # Configure particle gun
7  SIM.enableGun = True
8  SIM.gun.particle = "pi-"
9  SIM.gun.multiplicity = 1
10 SIM.gun.thetaMin = 45 * deg # Minimum angle
11 SIM.gun.thetaMax = 135 * deg # Maximum angle
12 SIM.gun.distribution = "eta" # Distribution type
13 #SIM.gun.momentumMin = 15 * GeV # Min momentum
14 #SIM.gun.momentumMax = 15 * GeV # Max momentum
15
```

Only silicon barrel

```
18 <documentation level="5">
19 | ## Electric and magnetic fields
20 </documentation>
21 <include ref="${DETECTOR_PATH}/compact/fields/marco.xml"/>
22
23 <documentation level="10">
24 | ## Central tracking detectors
25 </documentation>
26
27 <include ref="${DETECTOR_PATH}/compact/tracking/definitions_craterlake.xml"/>
28 <include ref="${DETECTOR_PATH}/compact/tracking/vertex_barrel.xml"/>
29 <include ref="${DETECTOR_PATH}/compact/tracking/vertex_barrel_support.xml"/>
30 <include ref="${DETECTOR_PATH}/compact/tracking/silicon_barrel.xml"/>
31 <include ref="${DETECTOR_PATH}/compact/tracking/mpgd_barrel.xml"/>
32 <include ref="${DETECTOR_PATH}/compact/tracking/support_service_craterlake.xml"/>
33 <include ref="${DETECTOR_PATH}/compact/tracking/mpgd_outerbarrel.xml"/>
34 <include ref="${DETECTOR_PATH}/compact/tracking/mpgd_forward_endcap.xml"/>
35 <include ref="${DETECTOR_PATH}/compact/tracking/mpgd_backward_endcap.xml"/>
36 <include ref="${DETECTOR_PATH}/compact/tracking/silicon_disks.xml"/>
37 <include ref="${DETECTOR_PATH}/compact/tracking/tof_barrel.xml"/>
38 <include ref="${DETECTOR_PATH}/compact/tracking/tof_endcap.xml"/>
39
40 <documentation level="11">
41 | ## Central beam pipe
42 </documentation>
43 <include ref="${DETECTOR_PATH}/compact/central_beampipe.xml"/>
44
45 <documentation level="11">
46 | ## Far forward detectors
47 </documentation>
48 <include ref="${DETECTOR_PATH}/compact/far_forward/default.xml"/>
49
50 <documentation level="11">
51 | ## Far backward detectors
52 </documentation>
53 <include ref="${DETECTOR_PATH}/compact/far_backward/default.xml"/>
54 </lccdd>
```

```
116 <documentation level="5">
117 | ## Electric and magnetic fields
118 </documentation>
119 <include ref="${DETECTOR_PATH}/compact/fields/marco.xml"/>
120
121 <documentation level="10">
122 | ## Central tracking detectors
123 </documentation>
124
125 <include ref="${DETECTOR_PATH}/compact/tracking/definitions_craterlake.xml"/>
126 <include ref="${DETECTOR_PATH}/compact/tracking/silicon_barrel.xml"/>
127 </lccdd>
```

epic_craterlake_sb.xml

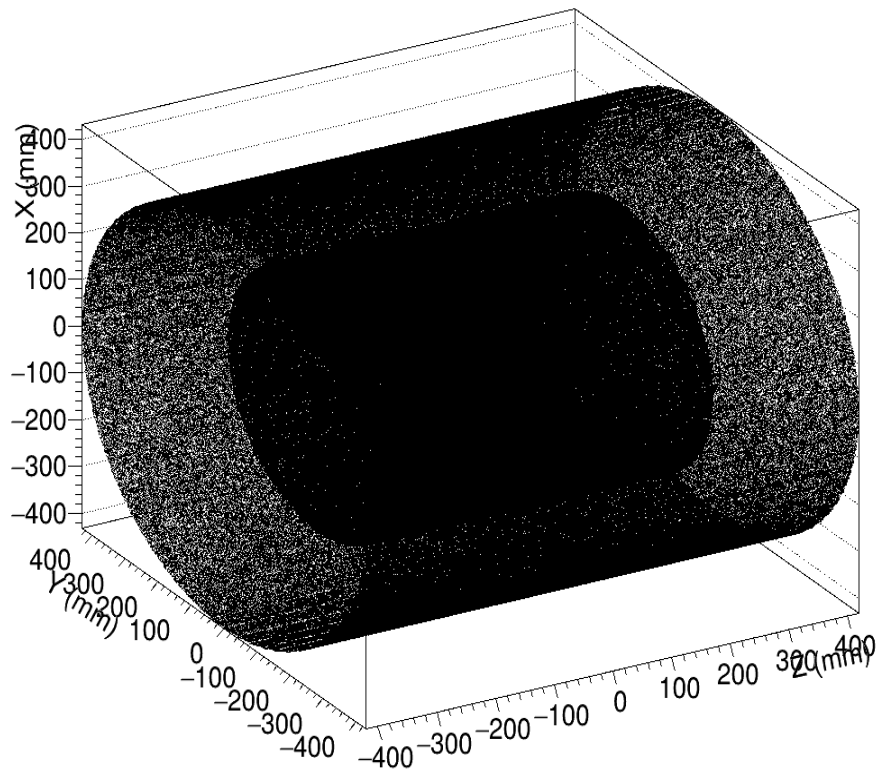
- **epic_craterlake_sb.xml** is a copy of **epic_craterlake_tracking_only.xml** with only the definitions and the silicon_barrel.xml as shown above.
- In install/share/epic/compact

epic_craterlake_tracking_only.xml

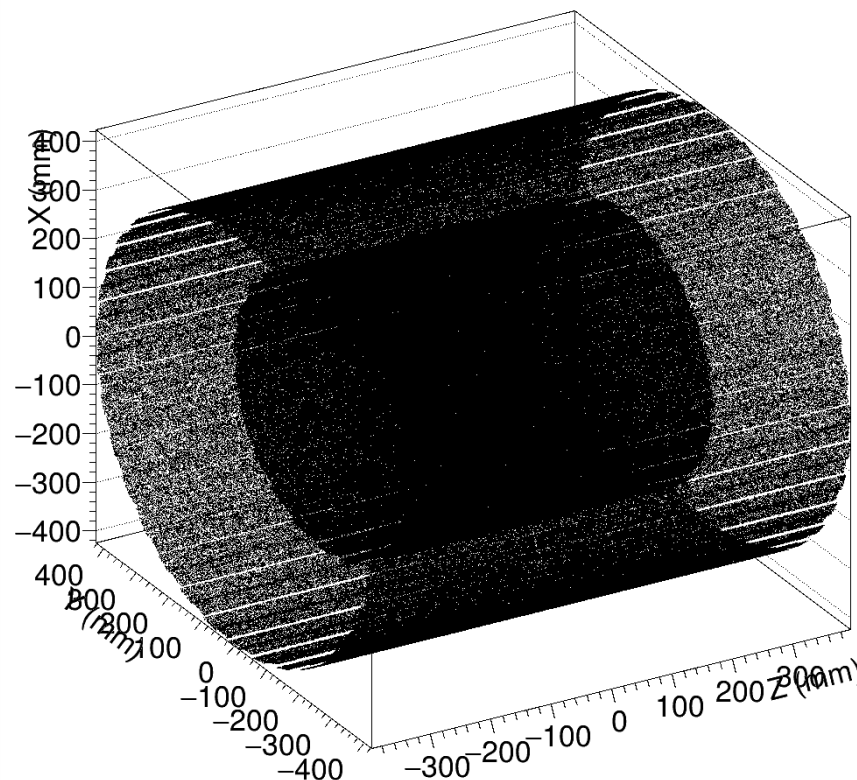
Outer Barrel Hitmaps

DDSIM
1 million events
 $p = 15\text{GeV}/c$
SiBarrelHit.position

Pre-merge

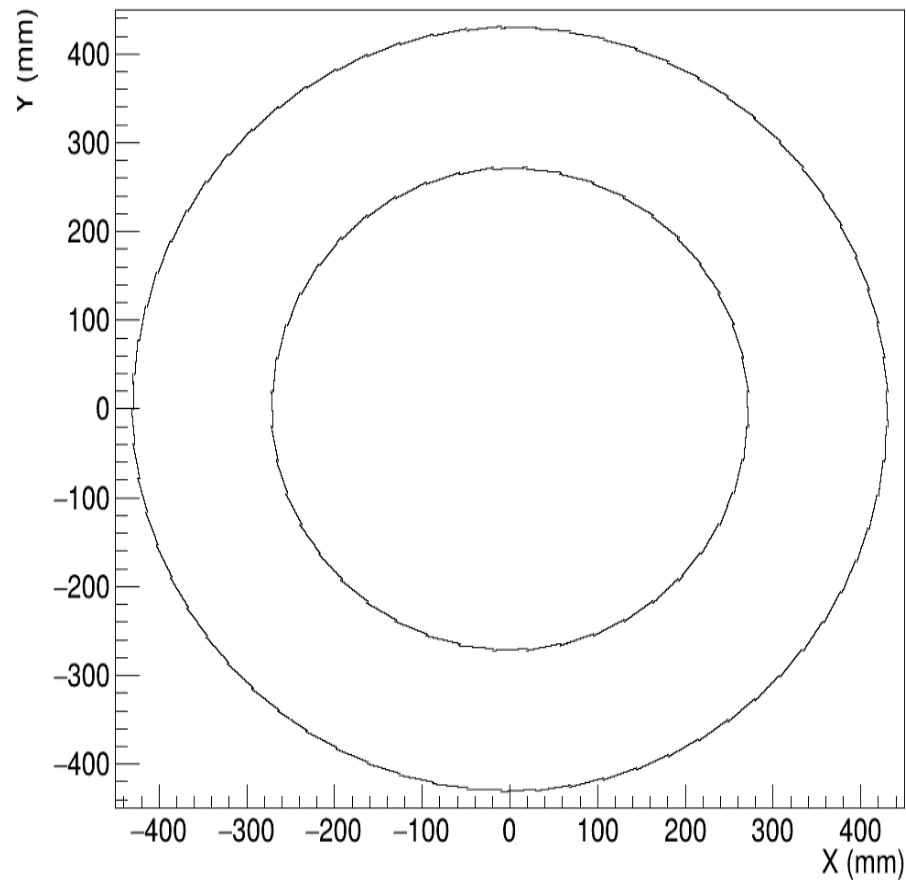


Post-merge

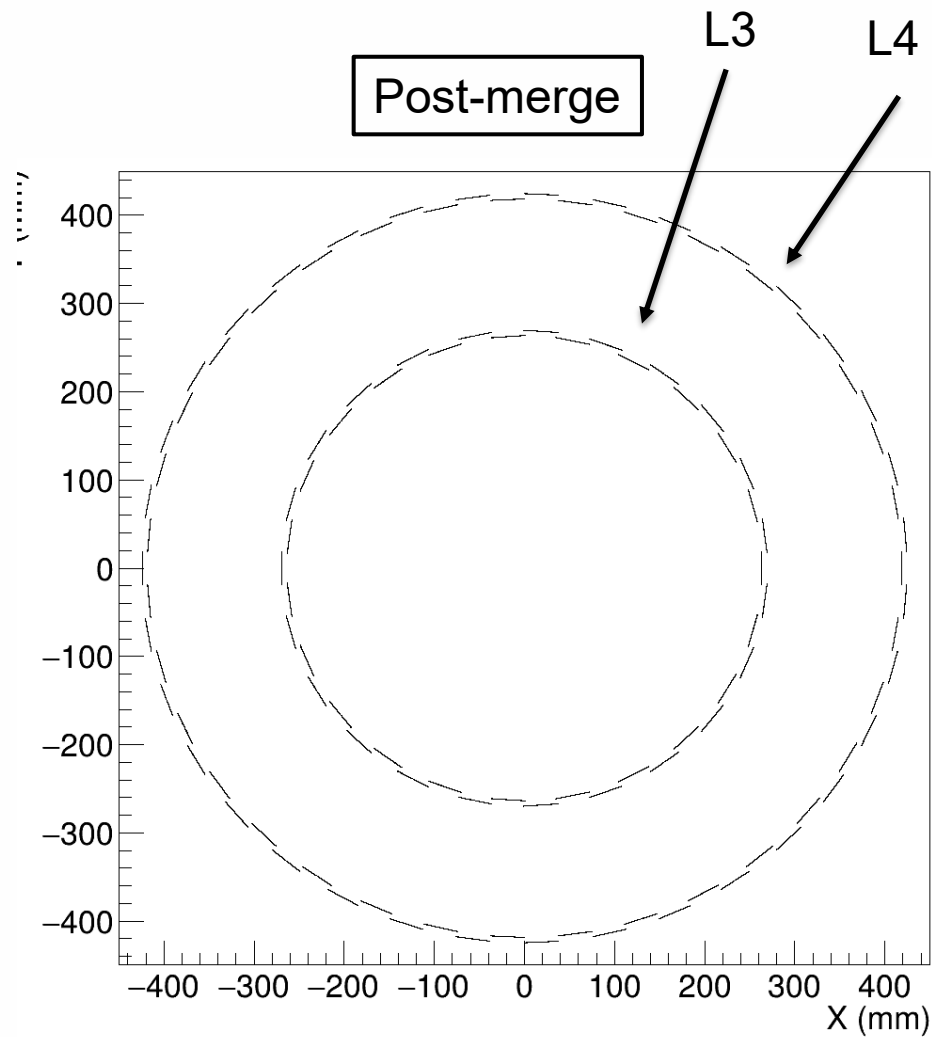


Outer Barrel Hitmaps

Pre-merge

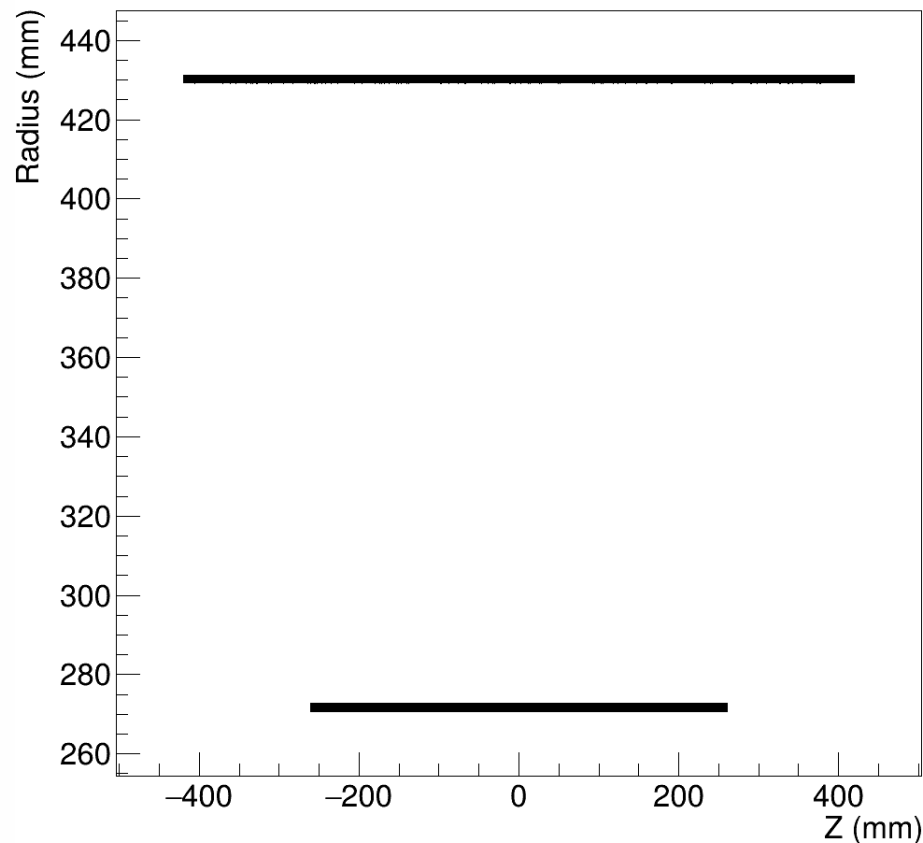


Post-merge



Outer Barrel Hitmaps

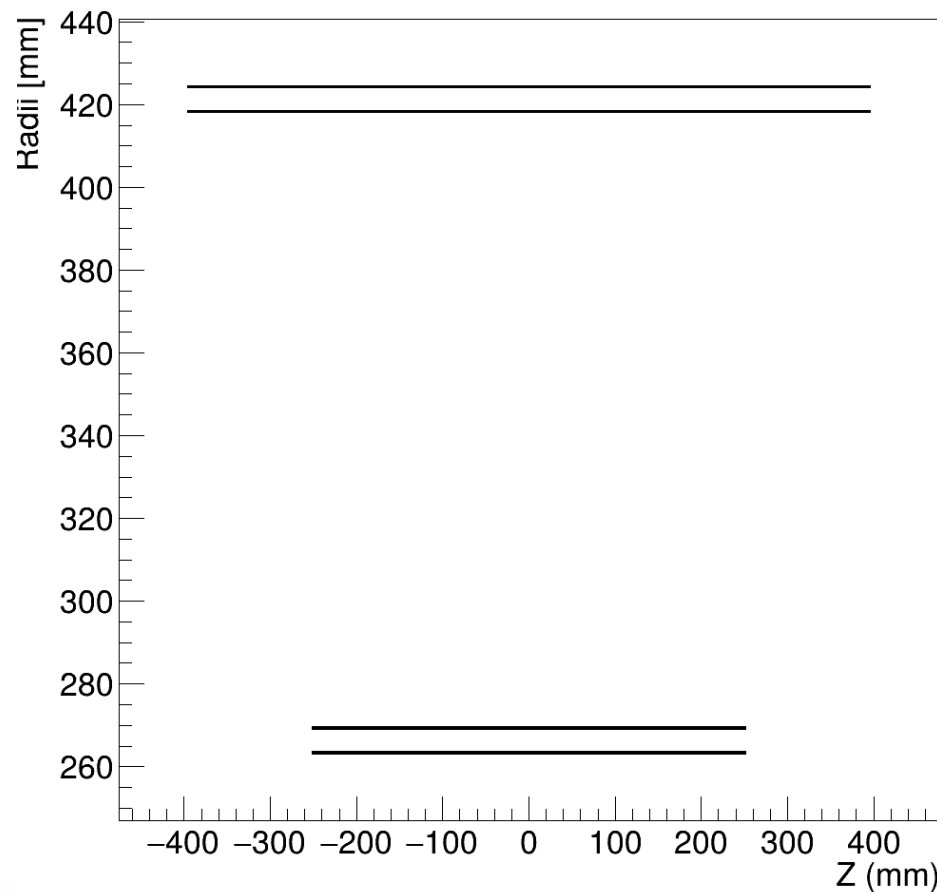
Radius vs Z



Pre-merge radii L3: 27cm, L4: 43cm

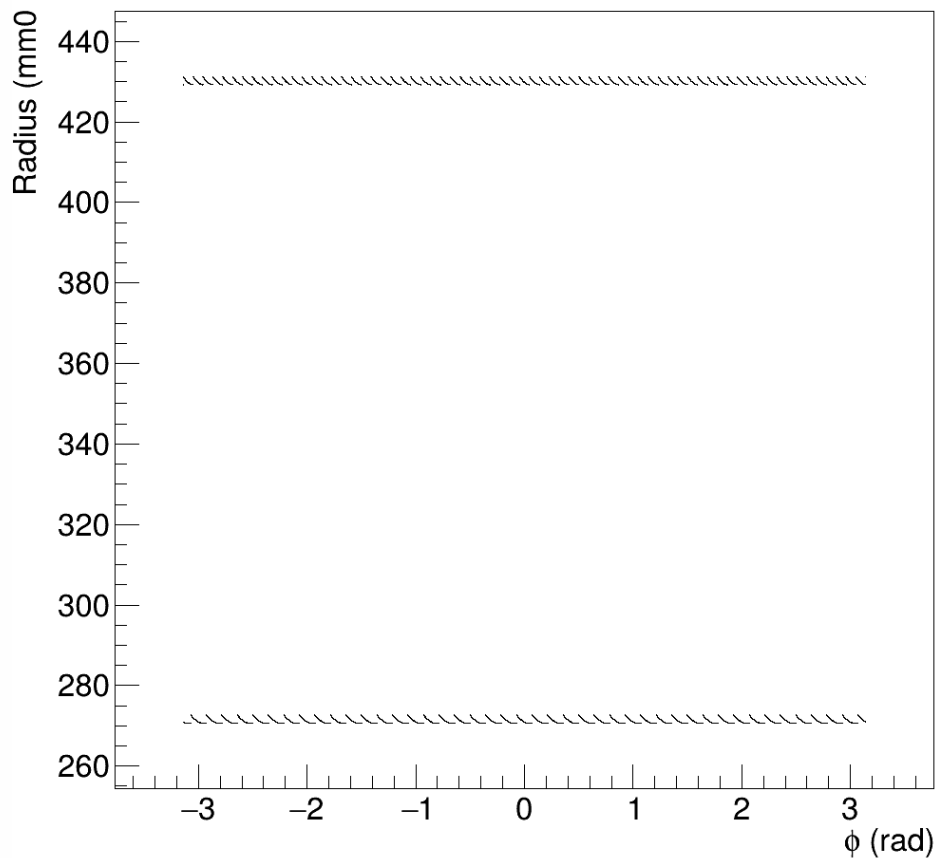
Post-merge L3: 26.5 cm, L4: 42cm

Radii vs Z



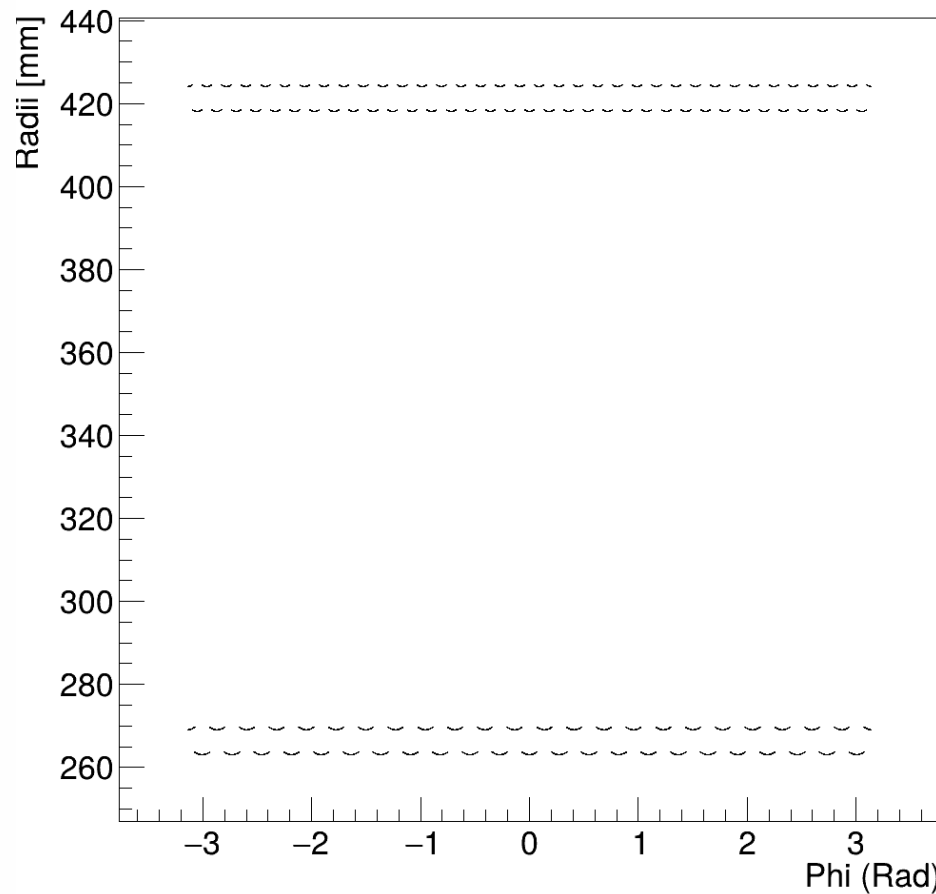
Outer Barrel Hitmaps

Radius vs ϕ



Pre-merge radii L3: 27cm, L4: 43cm

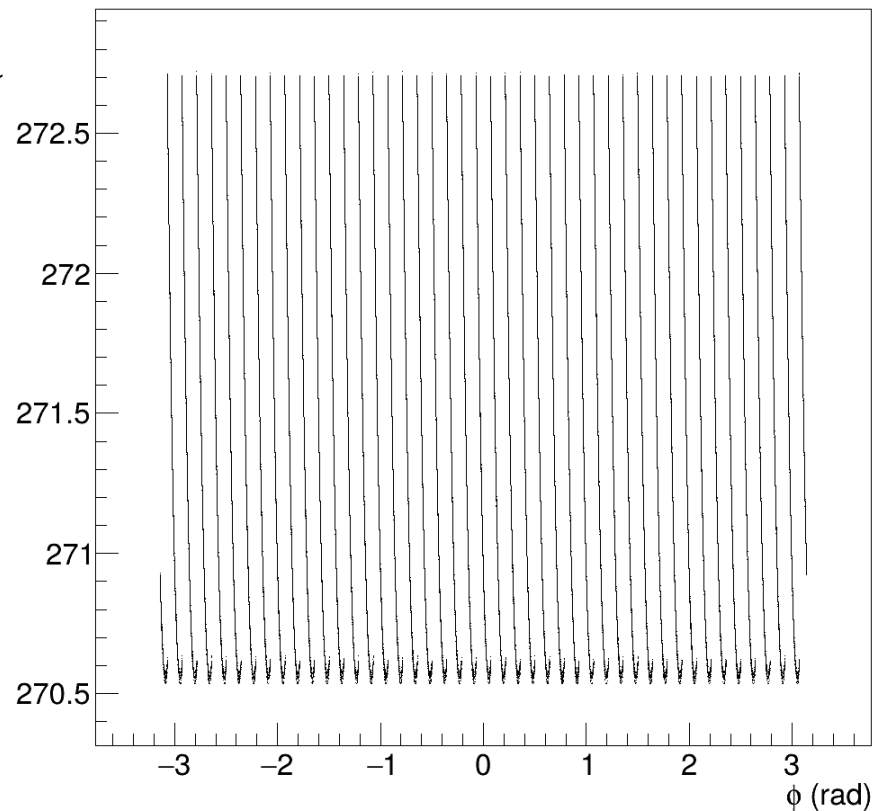
Post-merge L3: 26.5 cm, L4: 42cm



Outer Barrel Hitmaps

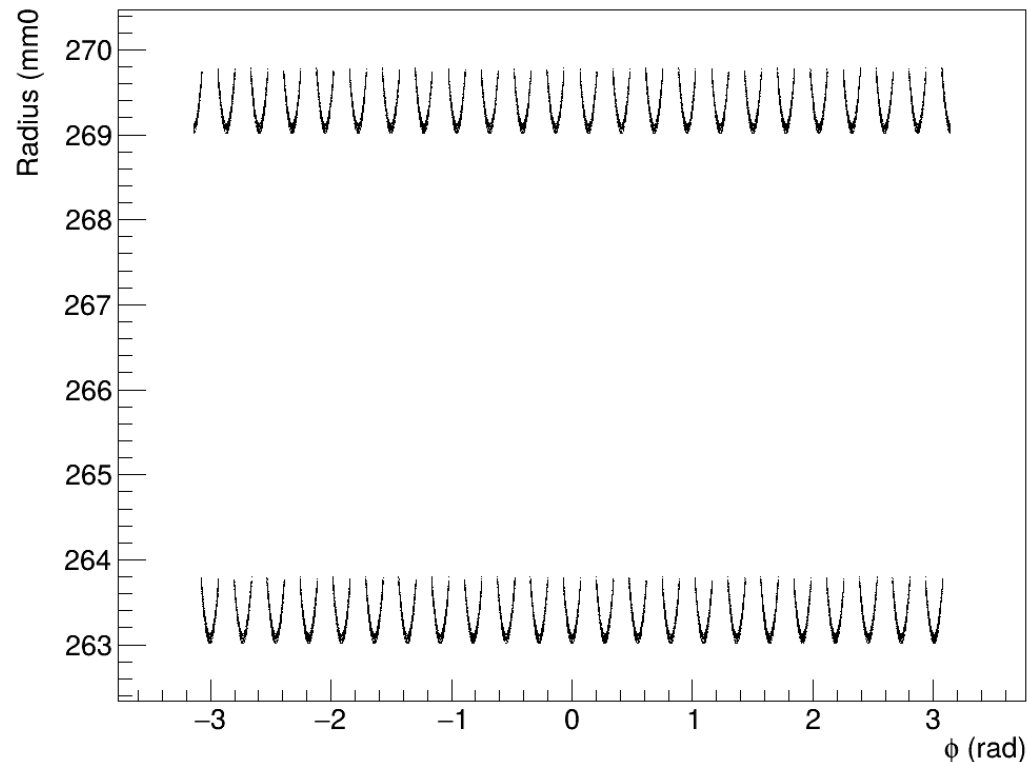
Pre-merge

L3 Radius vs ϕ



L3 Radius vs ϕ

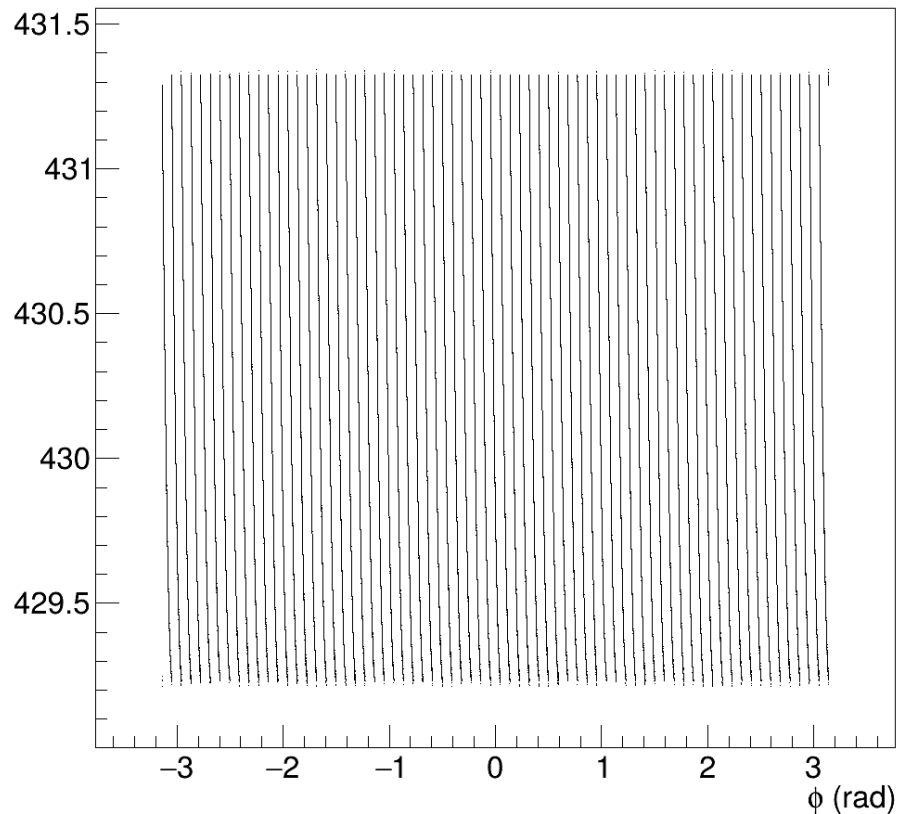
Post-merge



Outer Barrel Hitmaps

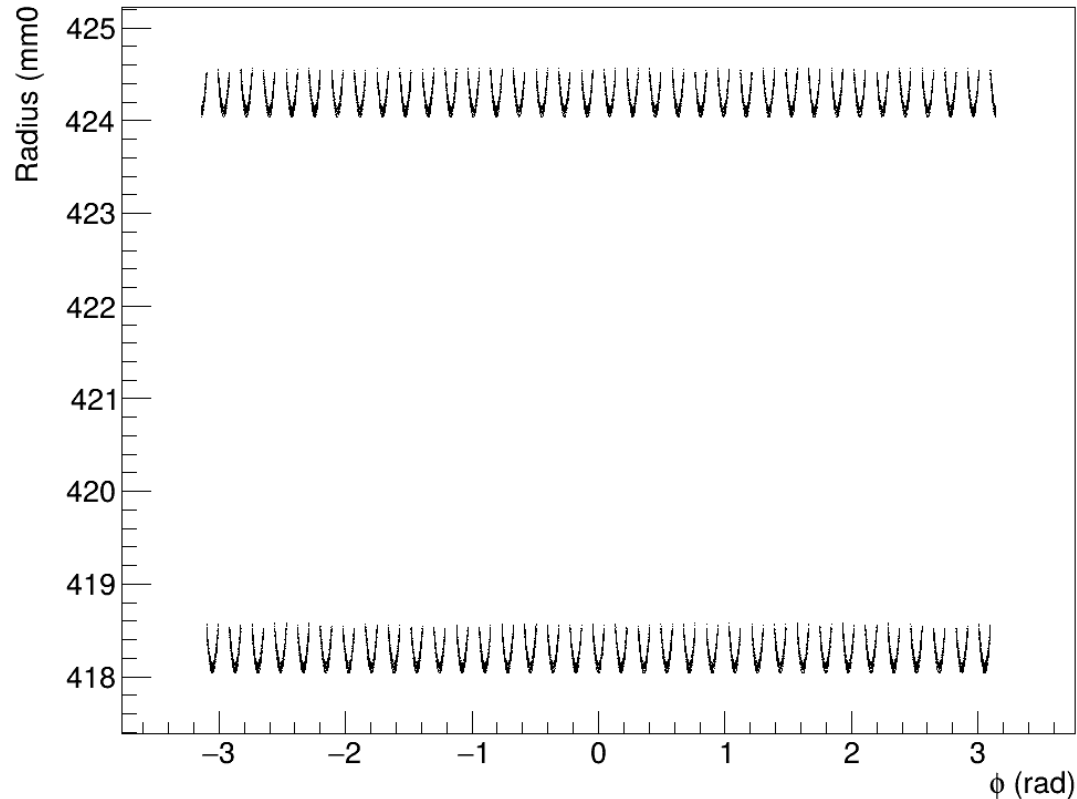
Pre-merge

L4 Radius vs ϕ



L4 Radius vs ϕ

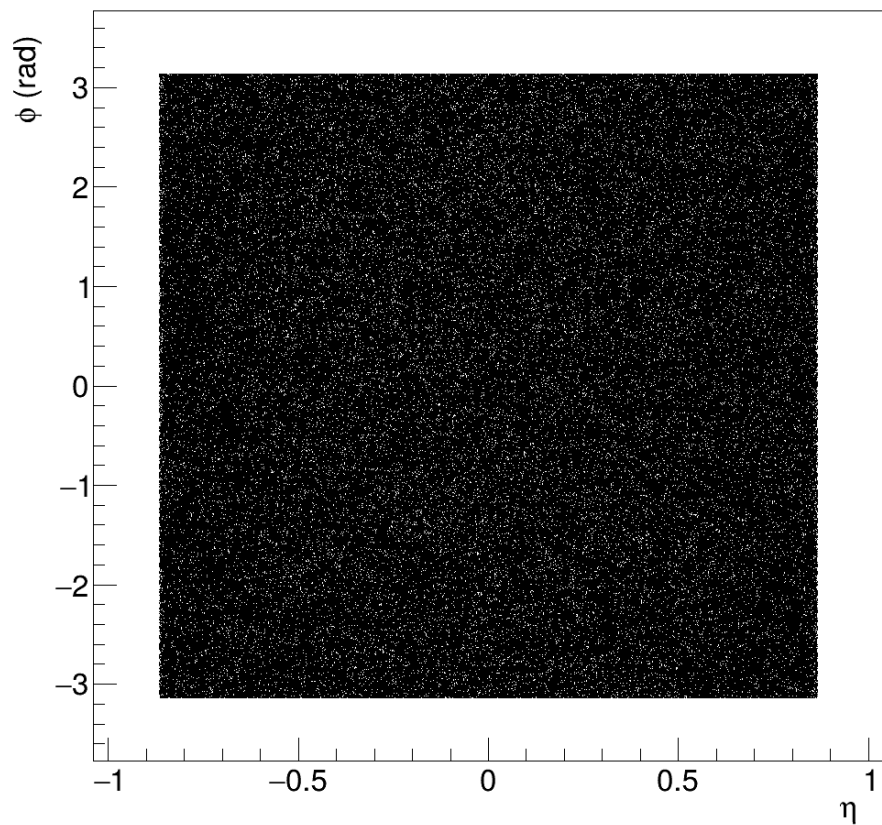
Post-merge



Hit map coverage

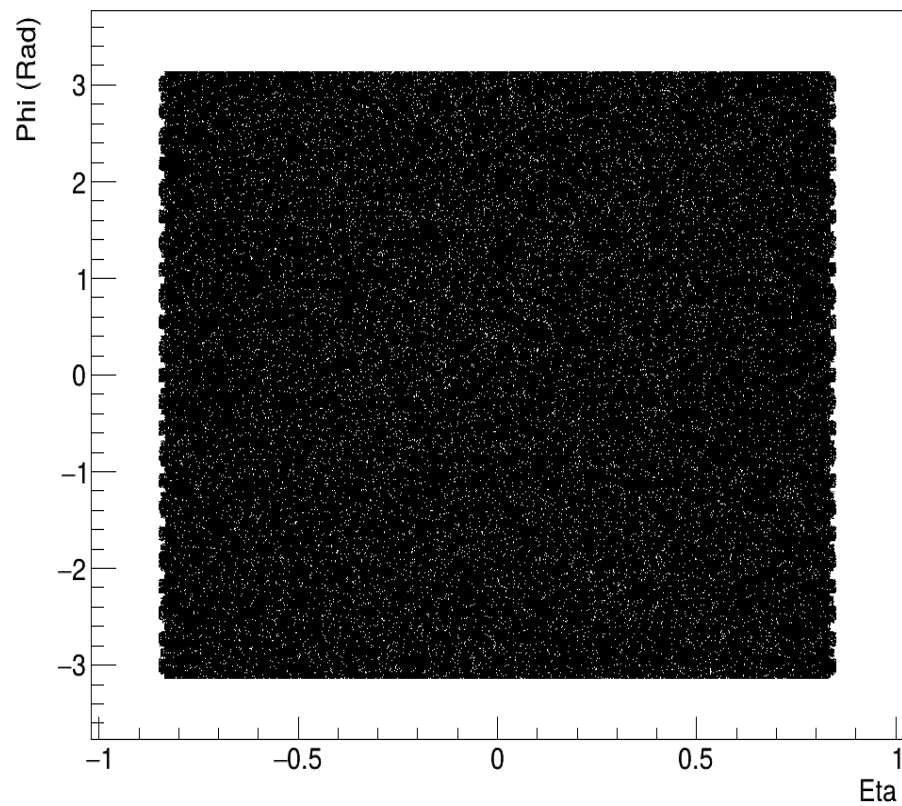
Pre-merge

ϕ vs η



Phi vs Eta

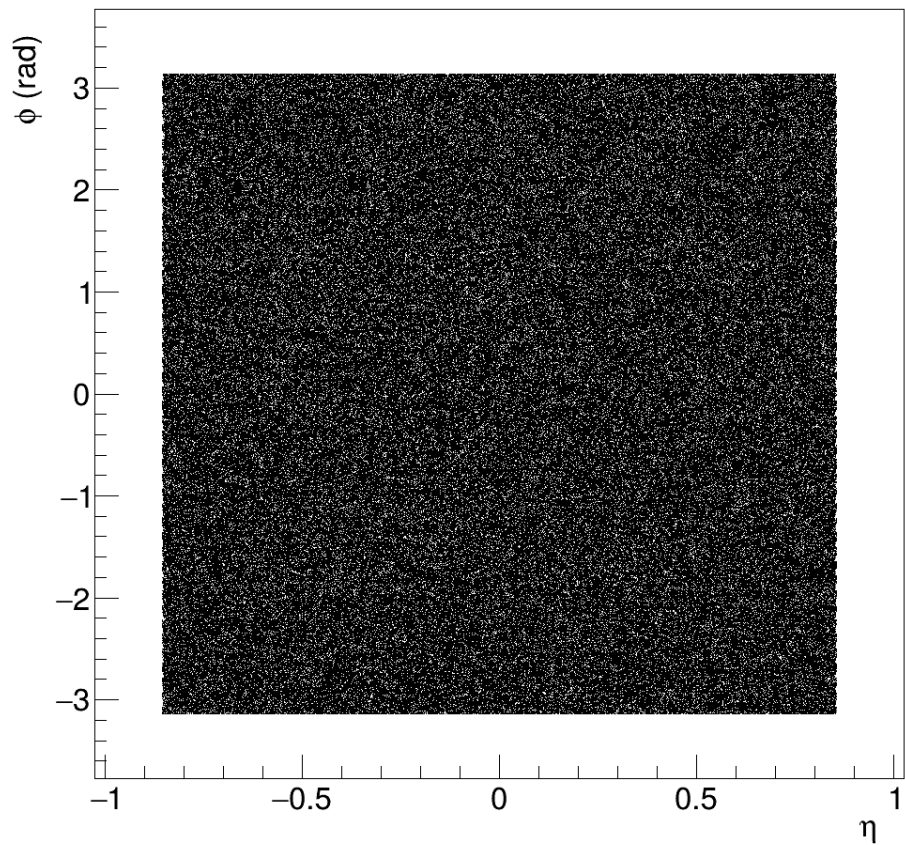
Post-merge



Hit map coverage

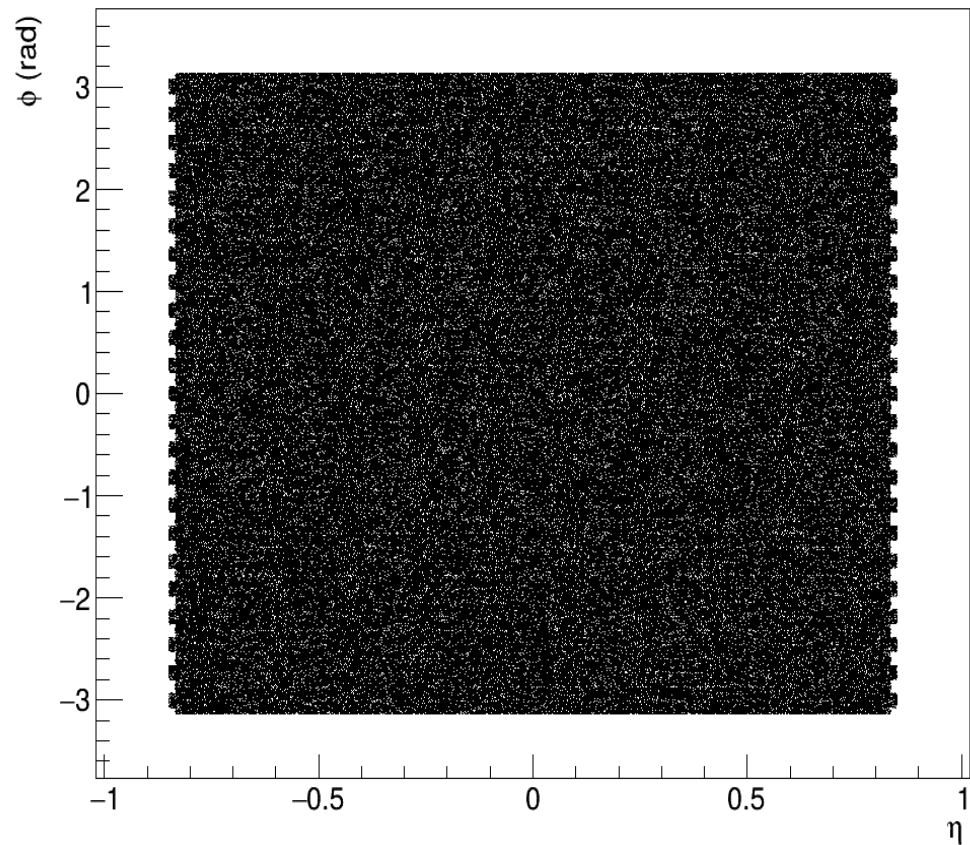
Pre-merge

L3 ϕ vs η



L3 ϕ vs η

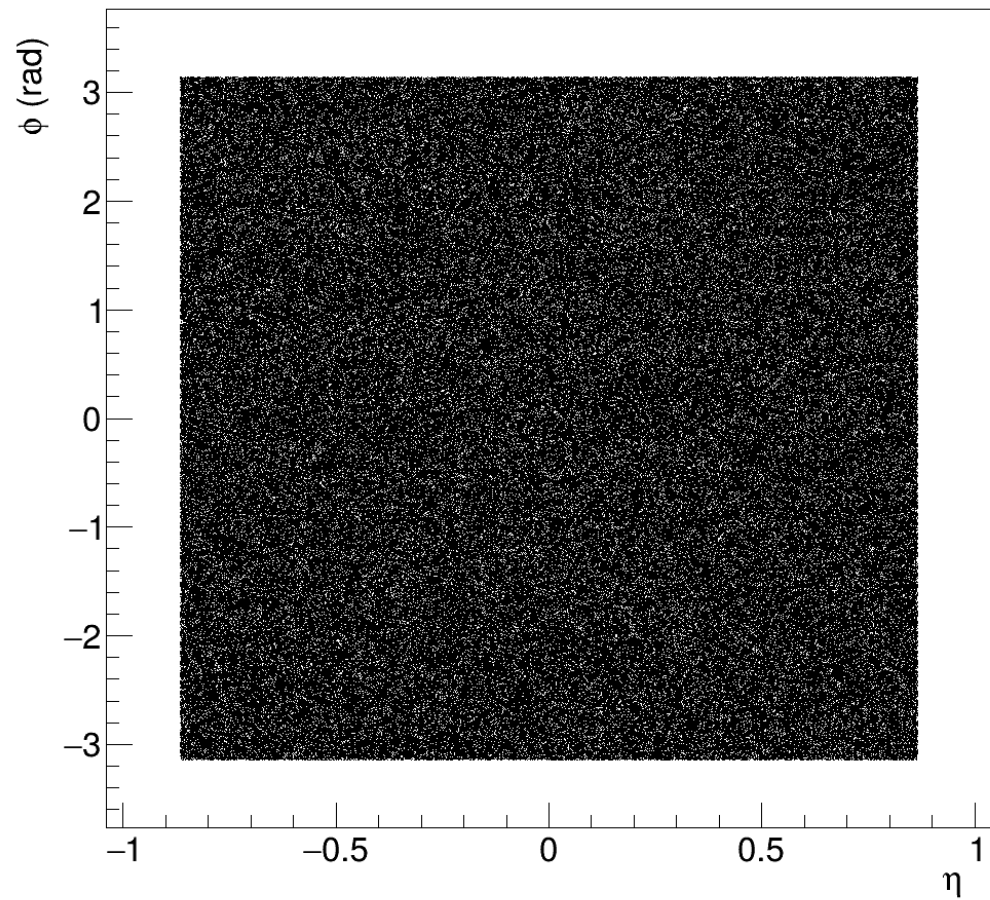
Post-merge



Hit map coverage

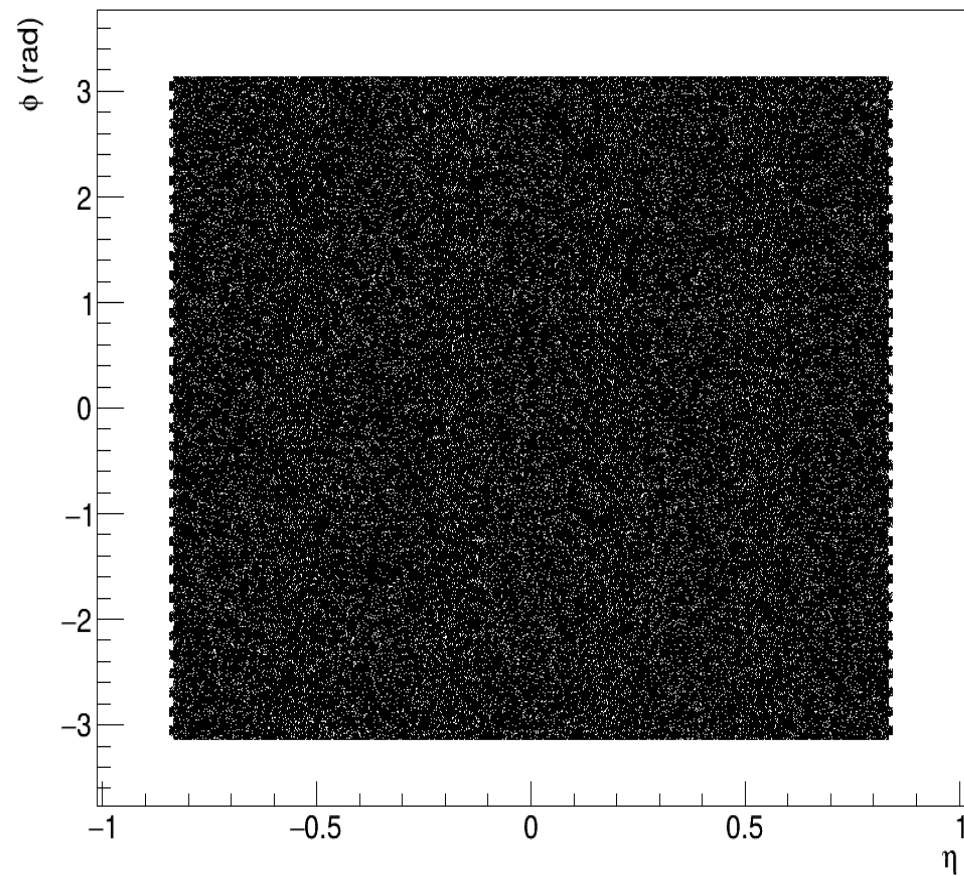
Pre-merge

L4 ϕ vs η

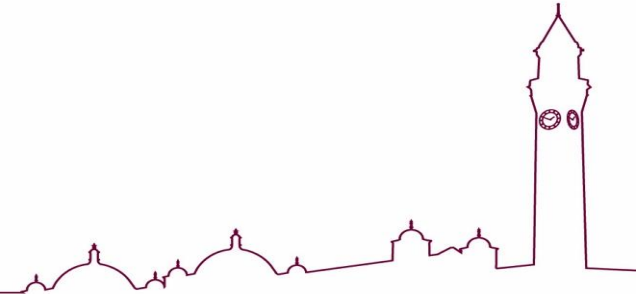


L4 ϕ vs η

Post-merge

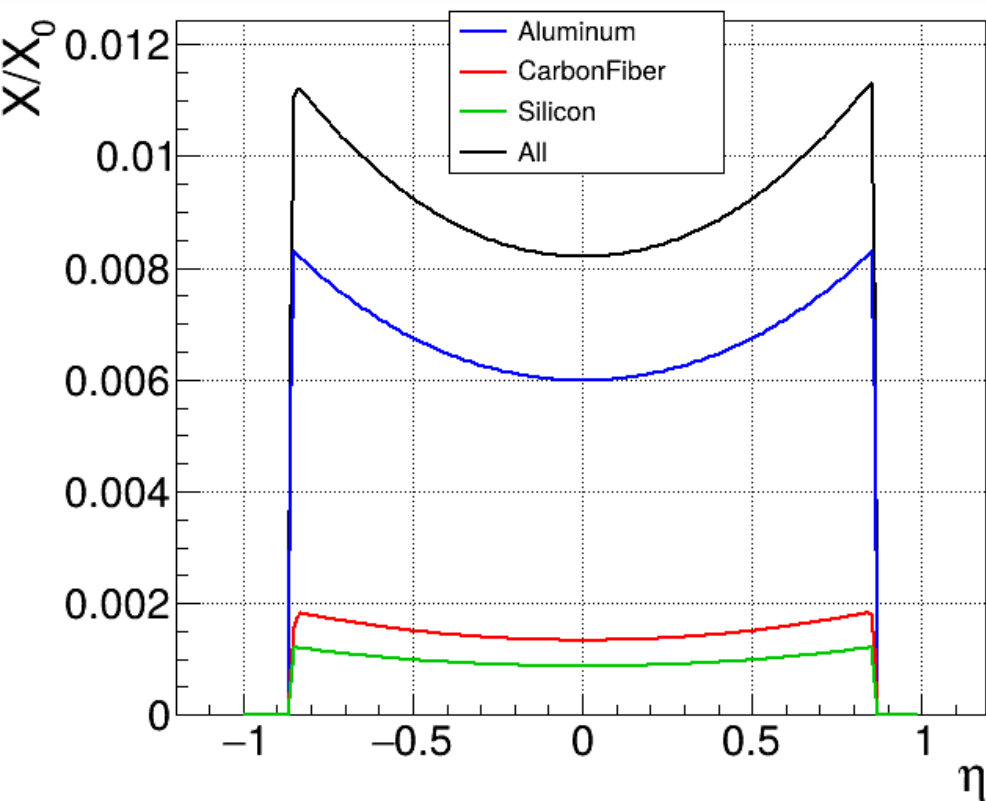


Material scans

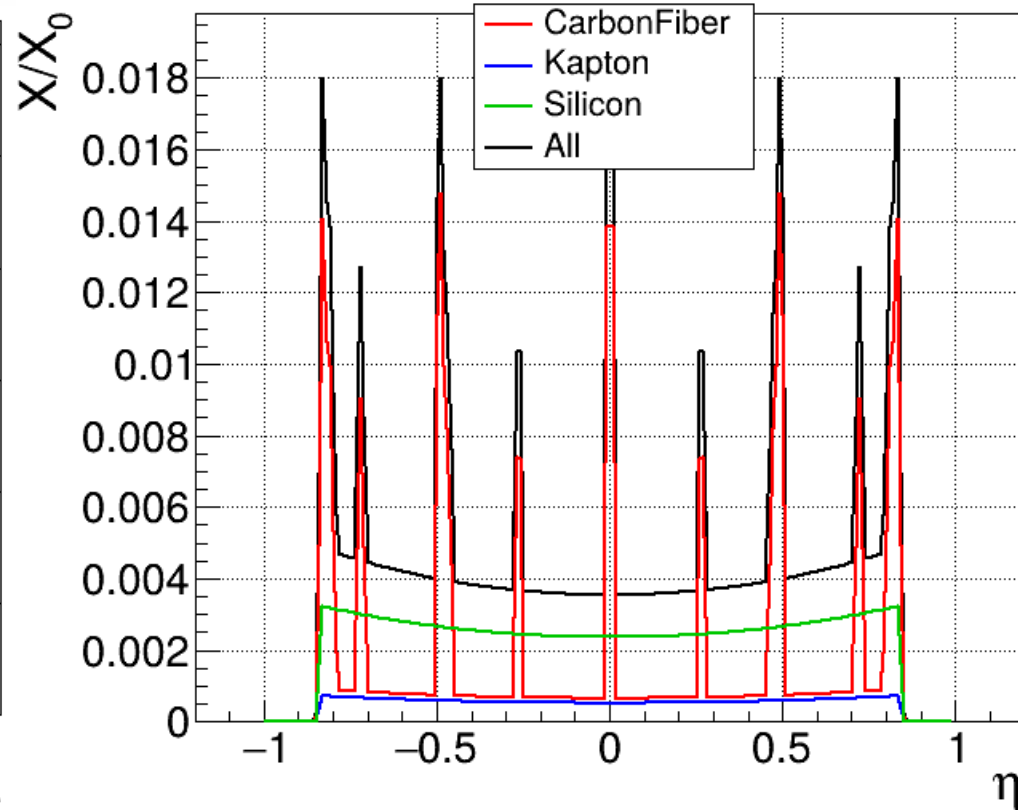


Material Scan Barrel

Pre-merge

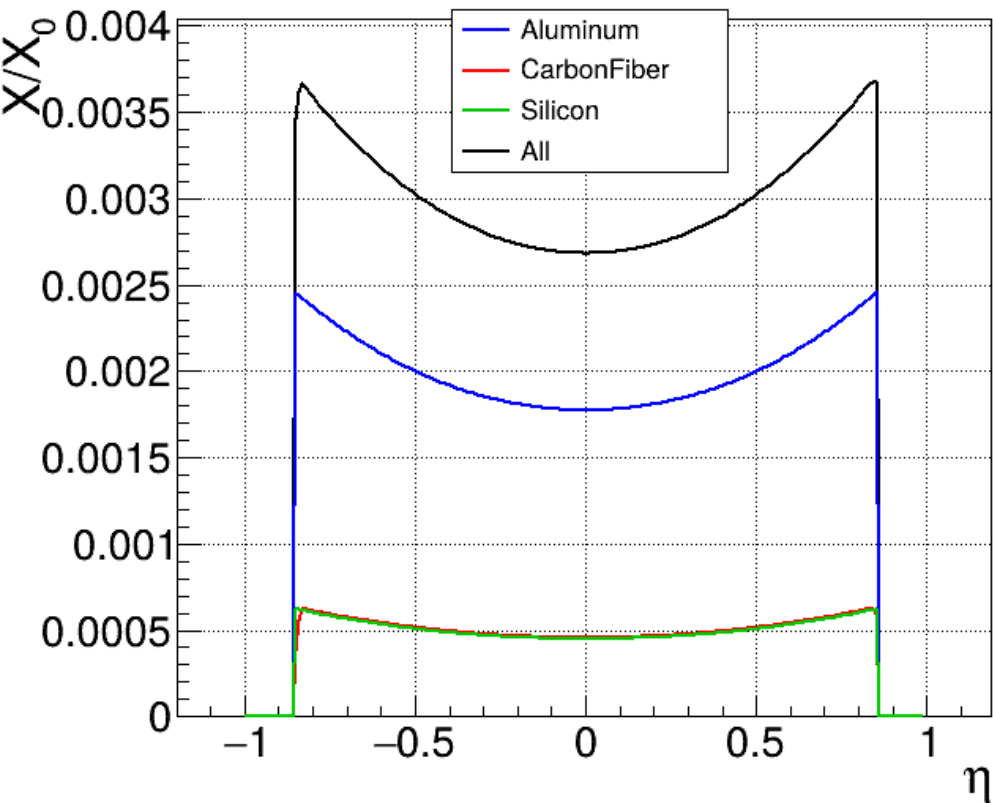


Post-merge

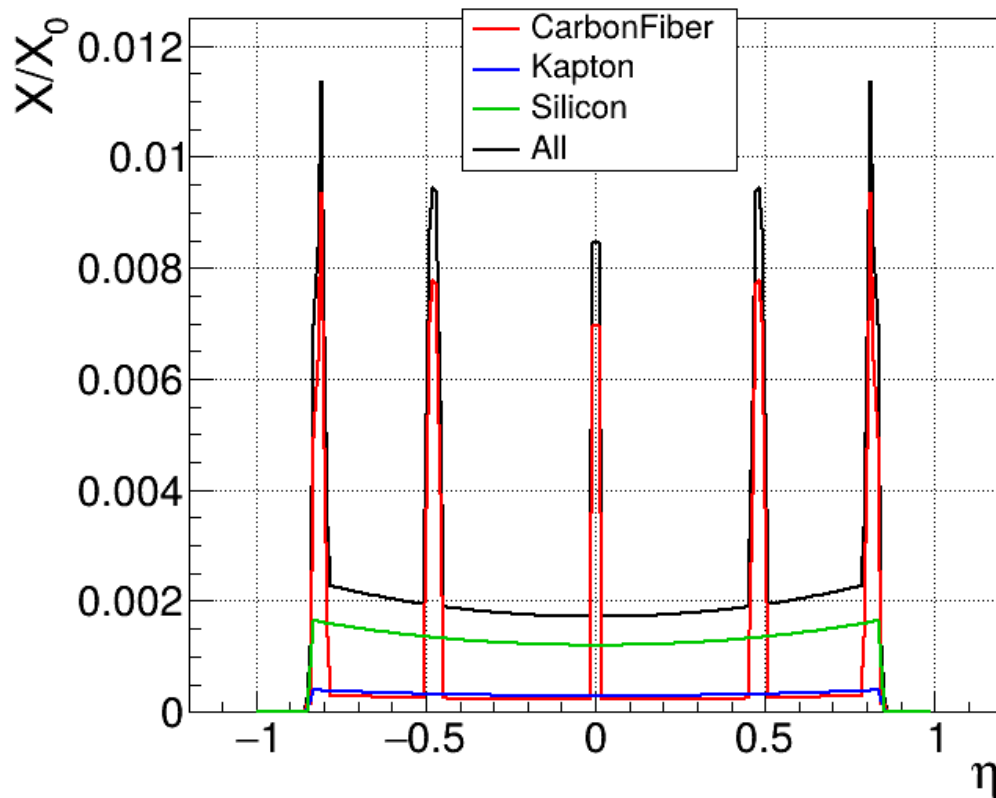


Material Scan Barrel – L3

Pre-merge

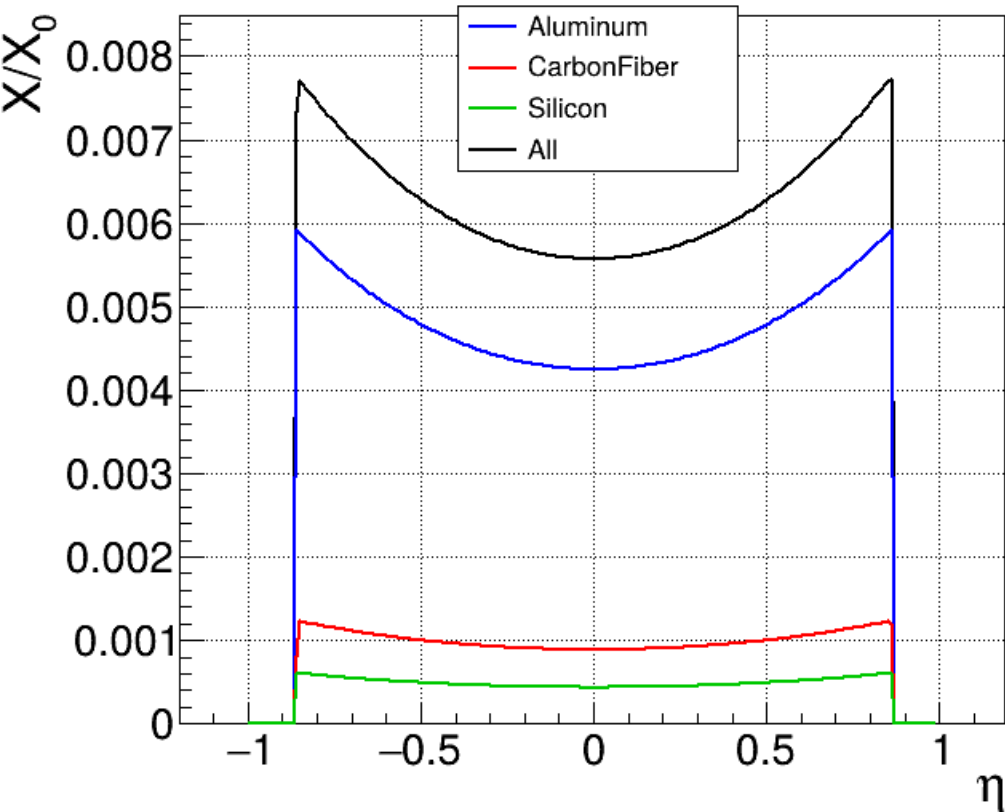


Post-merge

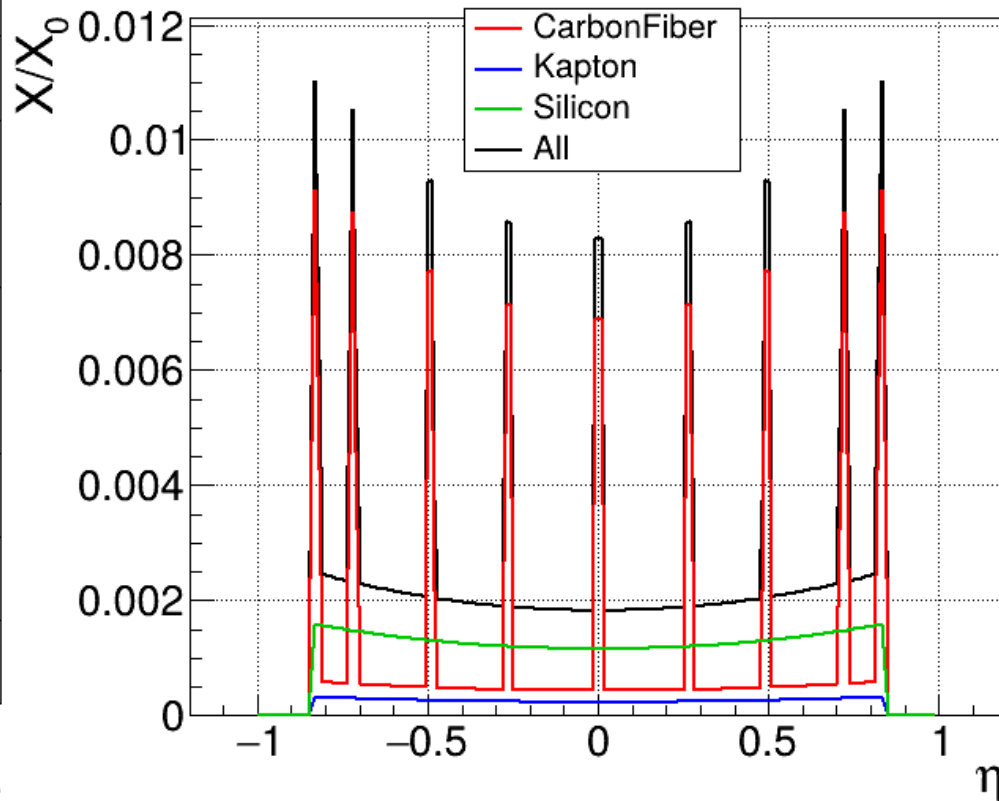


Material Scan Barrel – L4

Pre-merge

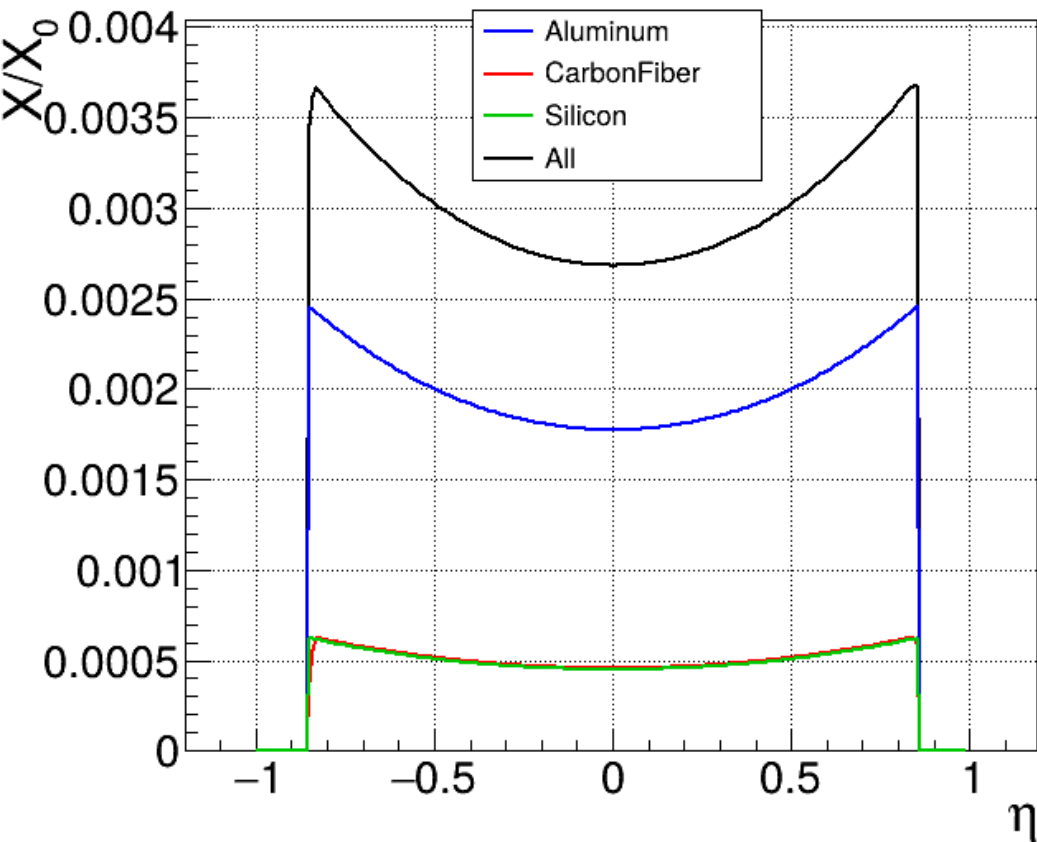


Post-merge

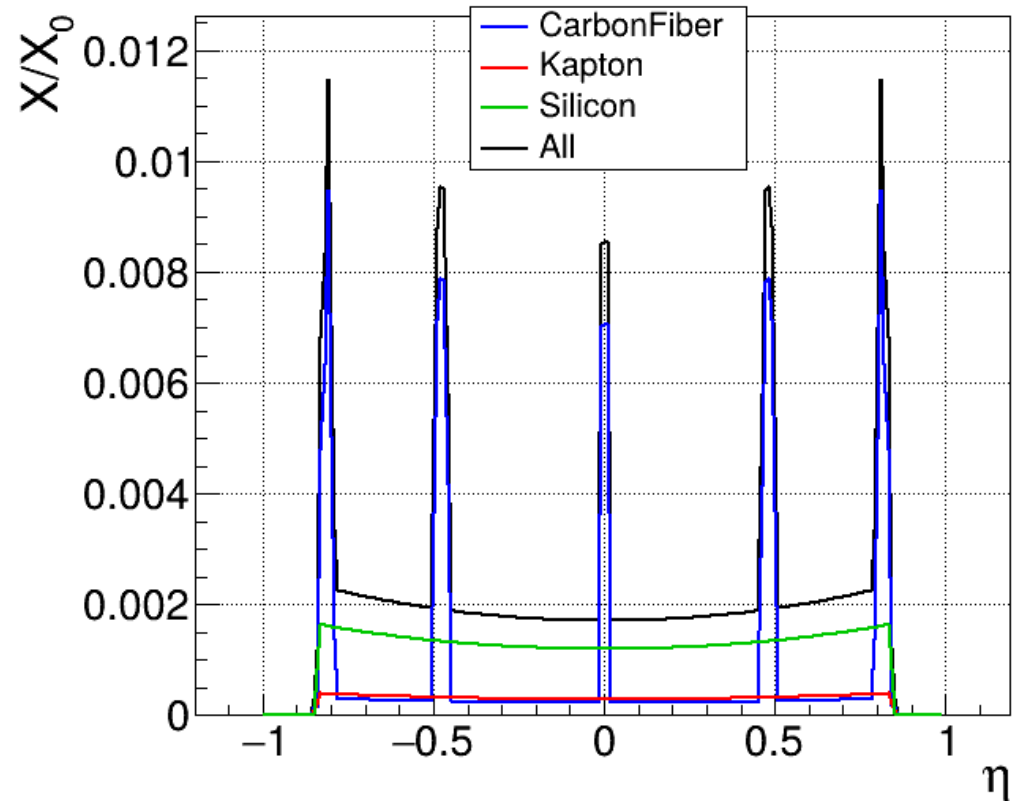


Material Scan Stave – L3

Pre-merge

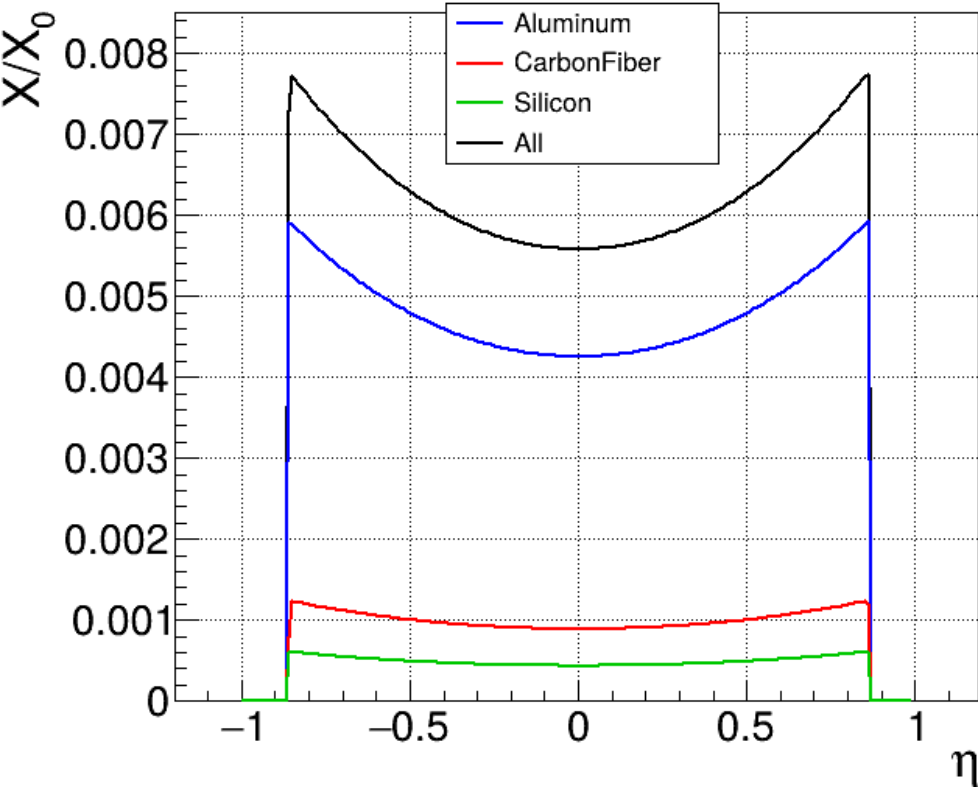


Post-merge

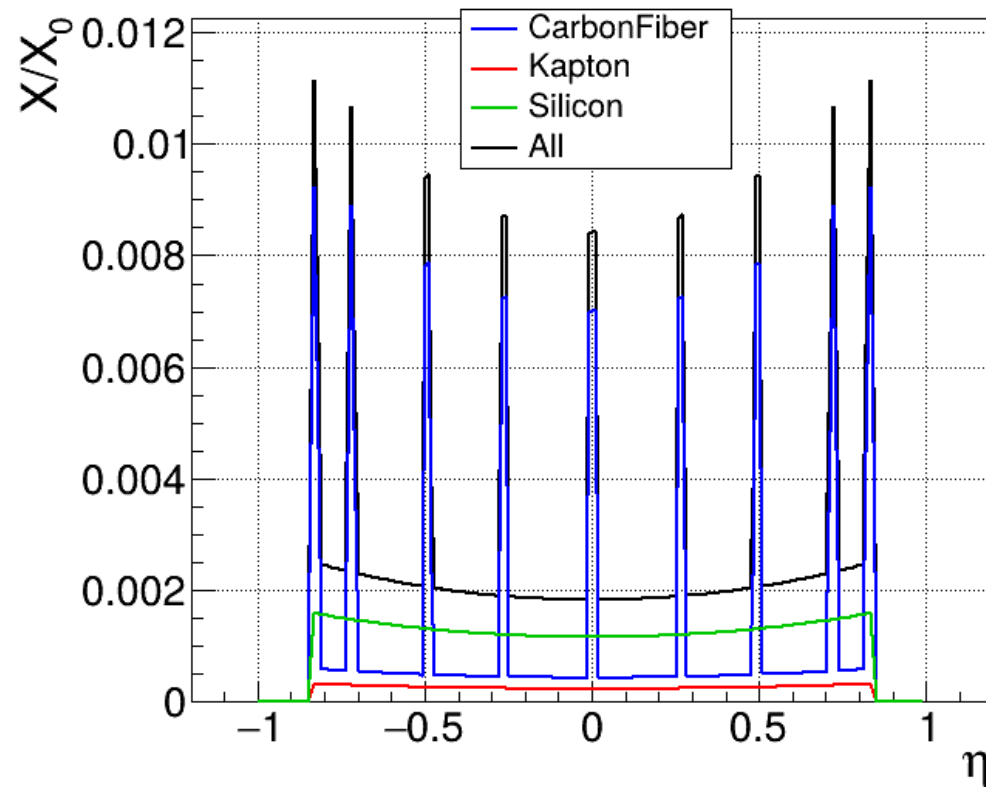


Material Scan Stave – L4

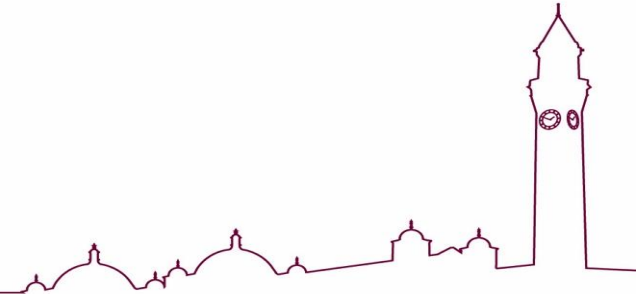
Pre-merge



Post-merge



Resolution Plots



Steering file for single particle simulations.

Main focus is the barrel region ($|\eta| < 0.88$)

π^- events

1000 events per momentum value

Particle distribution η

Momentum range $0.5\text{GeV}/c < p < 15\text{GeV}/c$

Steering.py

```
1  from DDSim.DD4hepSimulation import DD4hepSimulation
2  from g4units import mm, GeV, MeV, deg
3
4  SIM = DD4hepSimulation()
5
6  # Configure particle gun
7  SIM.enableGun = True
8  SIM.gun.particle = "pi-"
9  SIM.gun.multiplicity = 1
10 SIM.gun.thetaMin = 45 * deg # Minimum angle
11 SIM.gun.thetaMax = 135 * deg # Maximum angle
12 SIM.gun.distribution = "eta" # Correct distribution type
13 SIM.gun.momentumMin = 15 * GeV # Min momentum
14 SIM.gun.momentumMax = 15 * GeV # Max momentum
```

Updating Material Map for EICrecon

Default run

- `./run_material_map_validation.sh --nevents 1000 --nparticles 5000`
- Validation was failing

Instead:

- `./run_material_map_validation.sh --nevents 100 -nparticles 5000`
- Increase seed by nevents.
- Hadd geant4_material_tracks.root file1.root file2.root ... file10.root

Comment out the line, then run

- `./run_material_map_validation.sh --nevents 1000 --nparticles 5000`

Result:

- A .cbor file of the updated material map for EICrecon

Examples/Scripts/Python/material_recording.py

```
43 rnd = RandomNumbers(seed=228)
```

Examples/Scripts/Python/material_validation.py

```
34 rnd = acts.examples.RandomNumbers(seed=42)
```

```
120
121 echo "::group::----GEANTINO SCAN-----"
122 # output geant4_material_tracks.root
123 # The result of the geantino scan will be a root
124 # python material_recording_epic.py -i ${DETECTOR}
125 echo "::endgroup::"
126
127 echo "::group::----MAPPING Configuration-----"
128 # map geometry to geometry-map.json
```

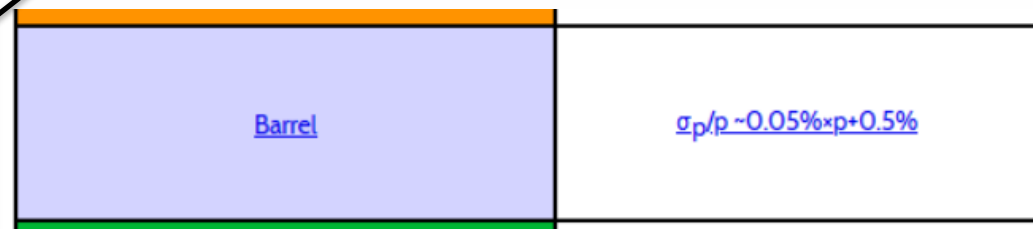
Comparison of geometries (pre merge vs post merge)

- Fixed seed
- Barrel region
- 1000 events per momentum value
- Black line – PWG requirement
- Blue line – best fit for momentum res.
- Green – multiple scattering term
- Orange – geometric/Sagitta term

Taking results from TrackAnalysis.C based on the eic analysis tutorial:

<https://eic.github.io/tutorial-analysis/03-analysis/index.html>

[preTDR_Version2.2](#)



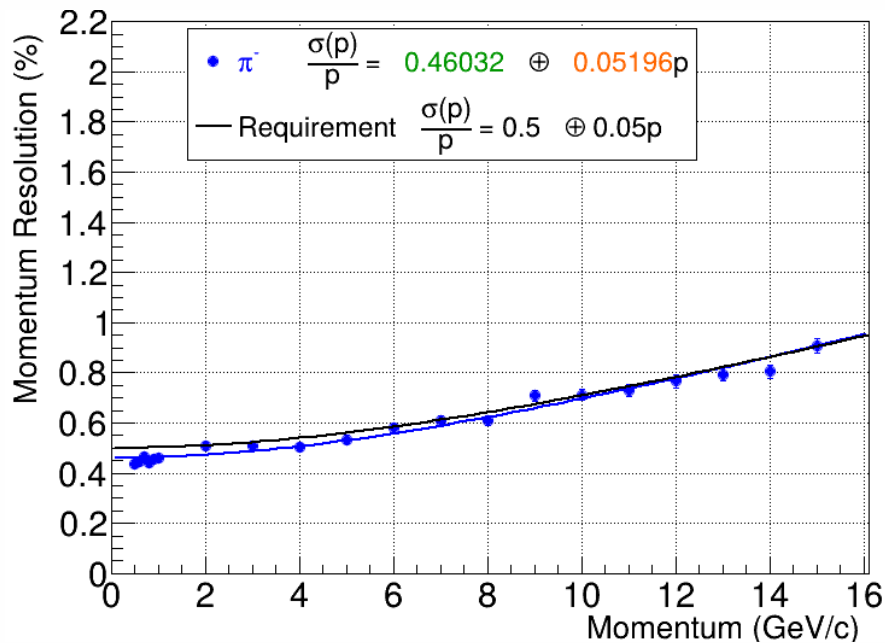
Average true transverse momentum:

$$\langle p_T \rangle = \frac{1}{N} \sum_{n=1}^{N=1000} p_x \oplus p_y$$

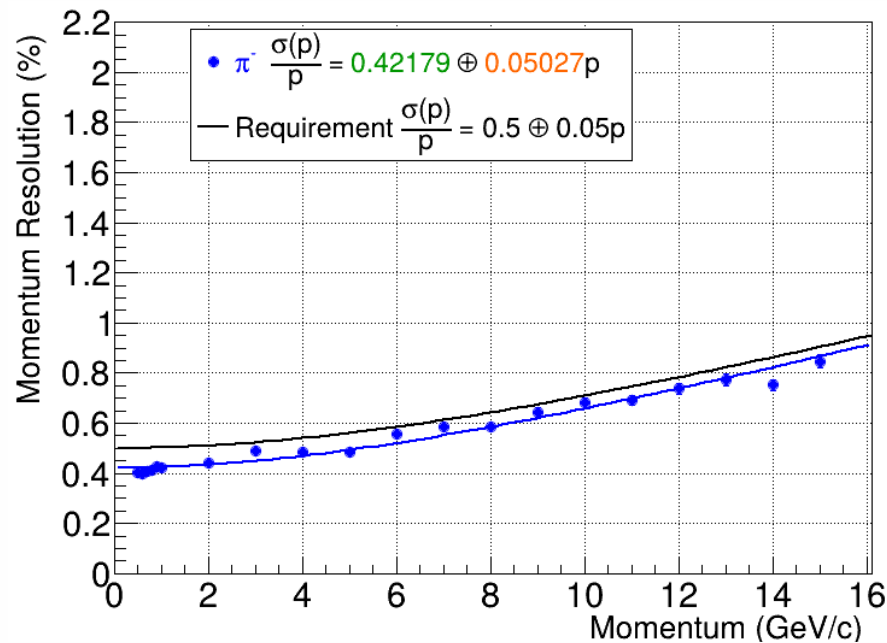
Total true momentum is set by the steering file.

Comparison of momentum resolutions

Pre-merge



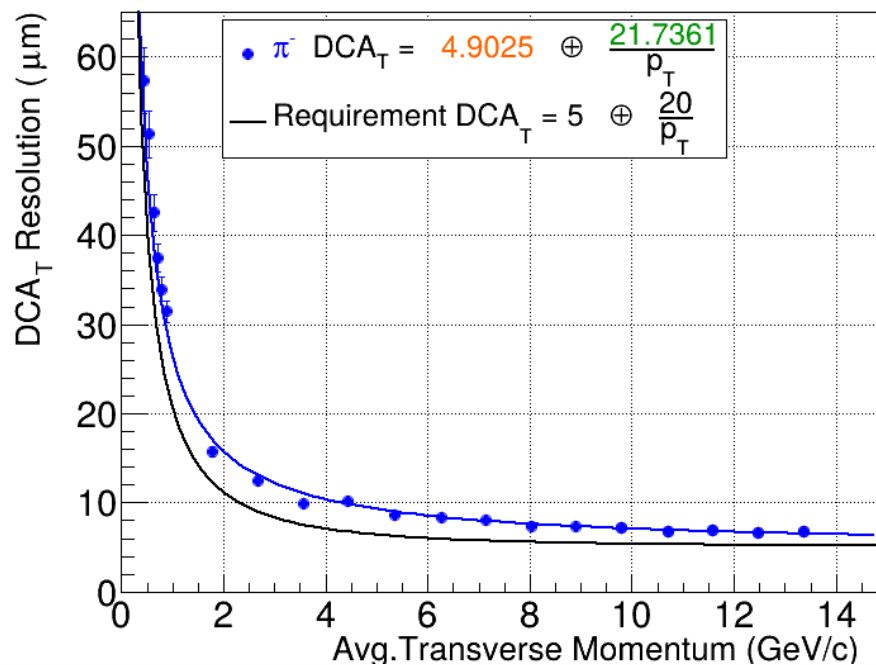
Post-merge



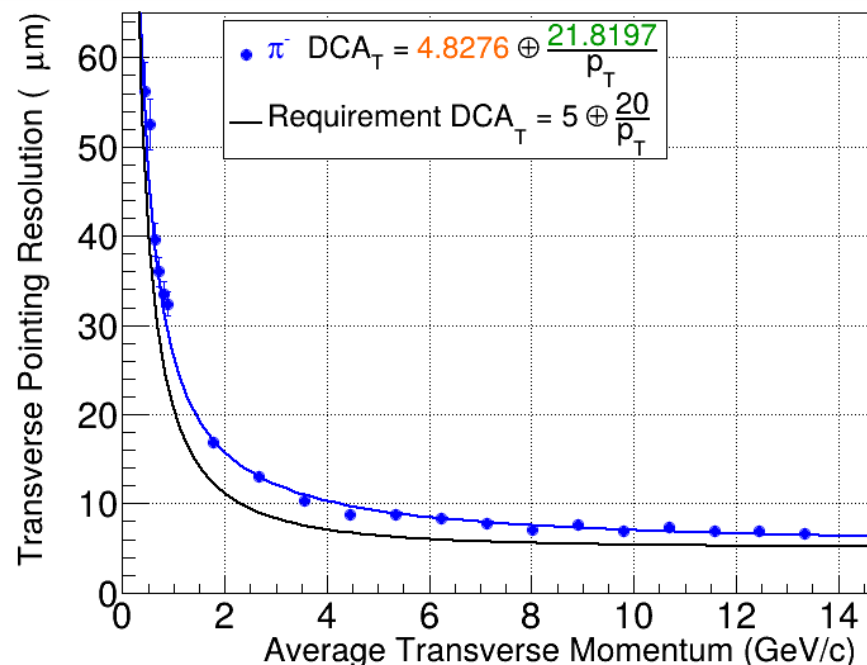
Pre merge has some momentum values above the requirement line.
Post merge has all the momentum values meet the physics set by WPG.

Comparison of momentum resolution

Pre-merge



Post-merge



Minimal differences in the MS term and the geometric term.
Makes sense as only the OB was changed.

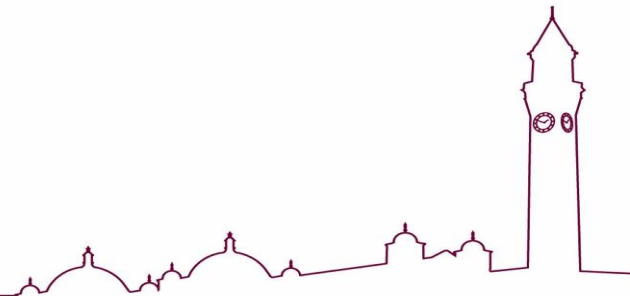
End

Any further questions/feedback or benchmarking requests?

More to do:

Efficiency comparison

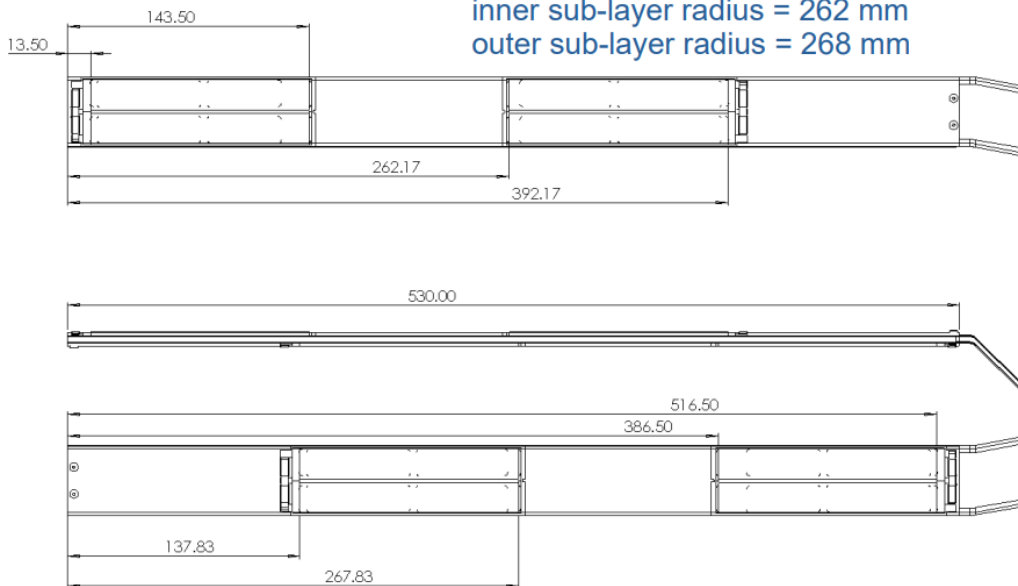
Bash file for material map



Sep CAD design:

OB L3

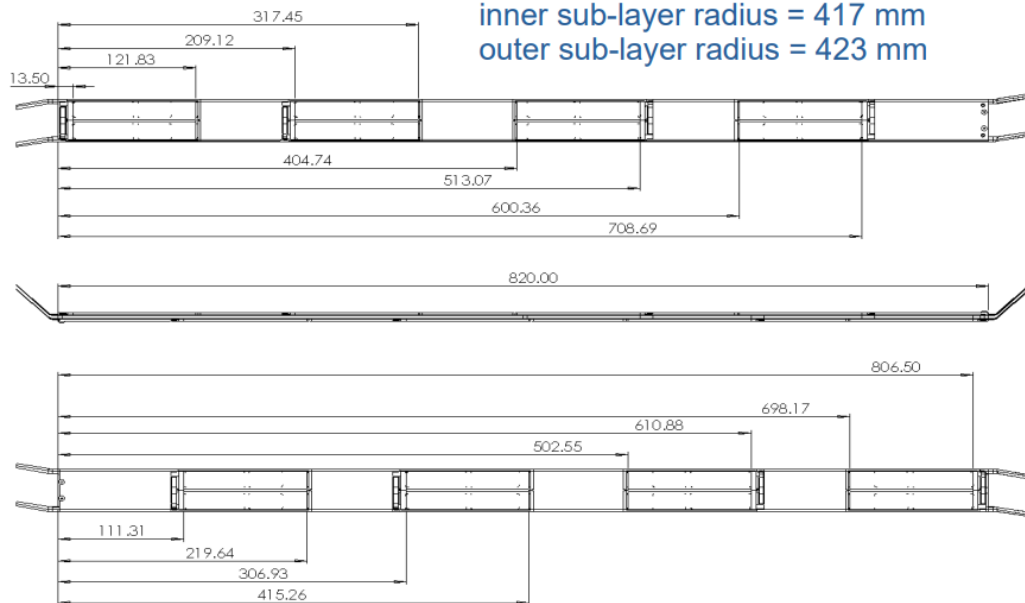
(Module = 2 × 6RSU-LAS, side-by-side)
44 staves per L3
inner sub-layer radius = 262 mm
outer sub-layer radius = 268 mm



Total active length = 503 mm

OB L4

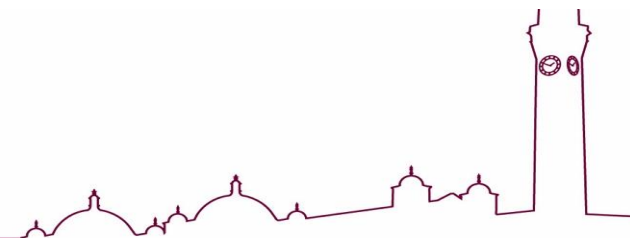
(Module = 2 × 5RSU-LAS, side-by-side)
70 staves per L4
inner sub-layer radius = 417 mm
outer sub-layer radius = 423 mm



Total active length = 793 mm

From ePIC SVT WP4 & WP6 joint meeting:

<https://indico.bnl.gov/event/29758/>



Bash file to run ddsim and eicrecon

ddsim

```
--steeringFile steering.py  
--compactFile $DETECTOR_PATH/epic_craterlake_tracking_only.xml  
--numberOfEvents 1000  
--outputFile ${filename.root}  
--gun.momentumMin "${MOMENTUM}*GeV"  
--gun.momentumMax "${MOMENTUM}*GeV"
```

eicrecon

```
-Pacts:MaterialMap=./scripts/material_map/material-map.cbor  
-Ppodio:output_file="${EICRECON_FILE}" "${DDSIM_FILE}"
```

dd_web_display

```
-o sb_geometry.root <-(optional)  
--export $DETECTOR_PATH/epic_craterlake_sb.xml
```

