



# Mighty Tracker and Simulation

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**on behalf of the Mighty Pix Simulation Team**

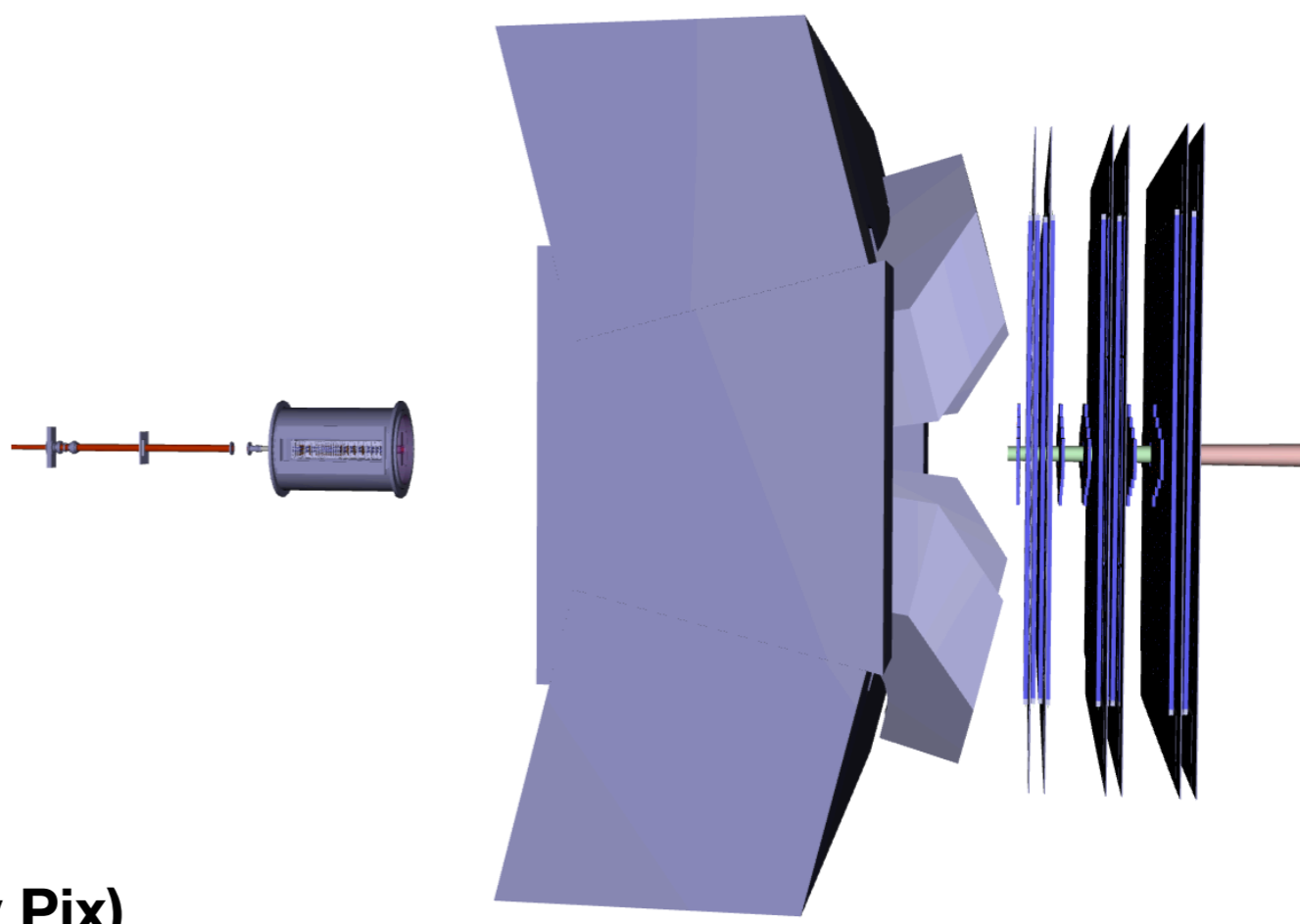
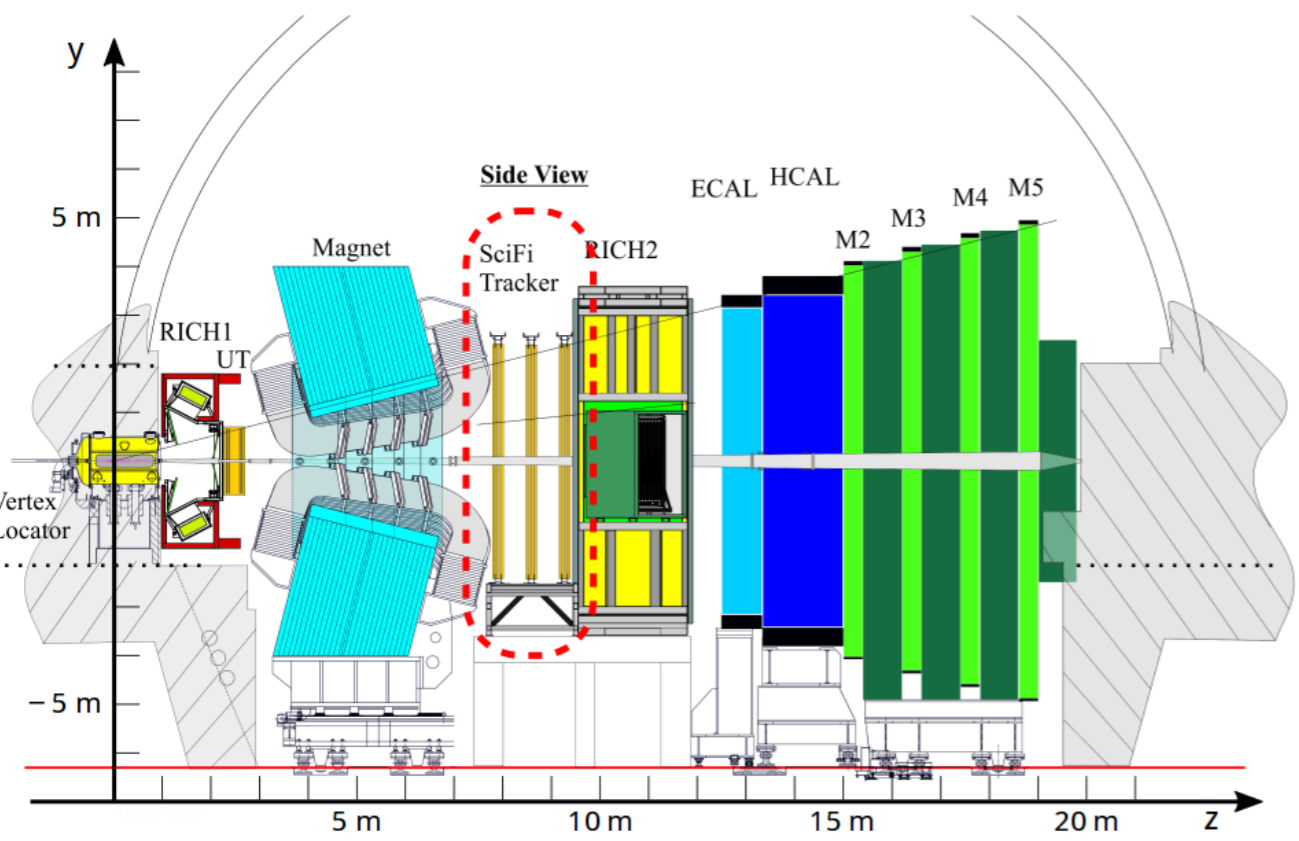
07/03/2024

LHCb Upgrade II Tracking Workshop  
Evian-Les-Bains

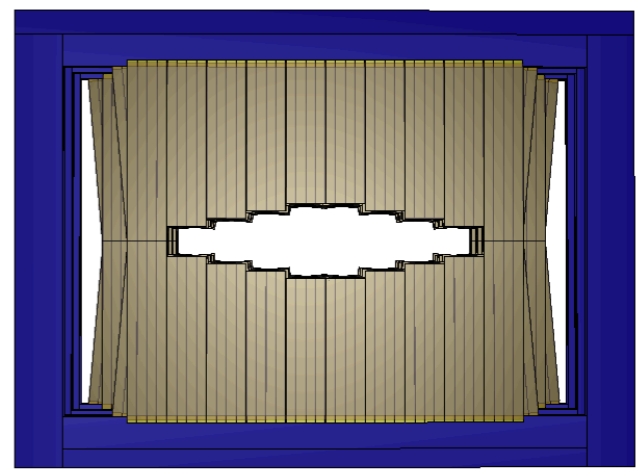
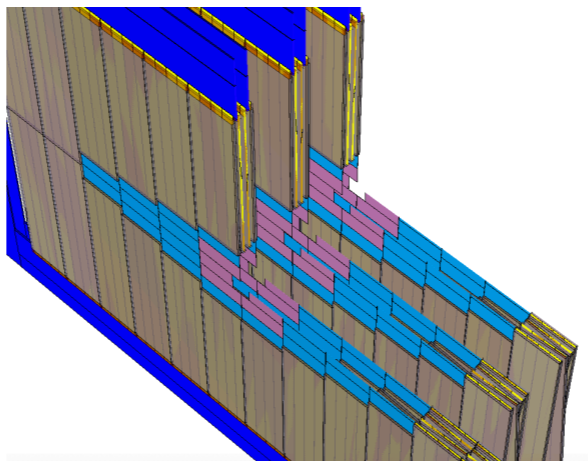
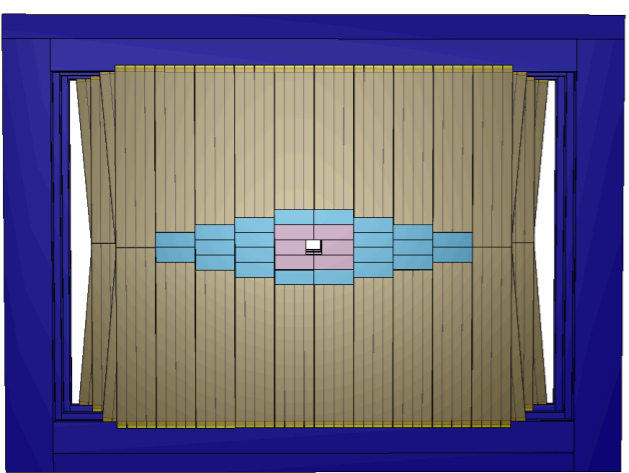


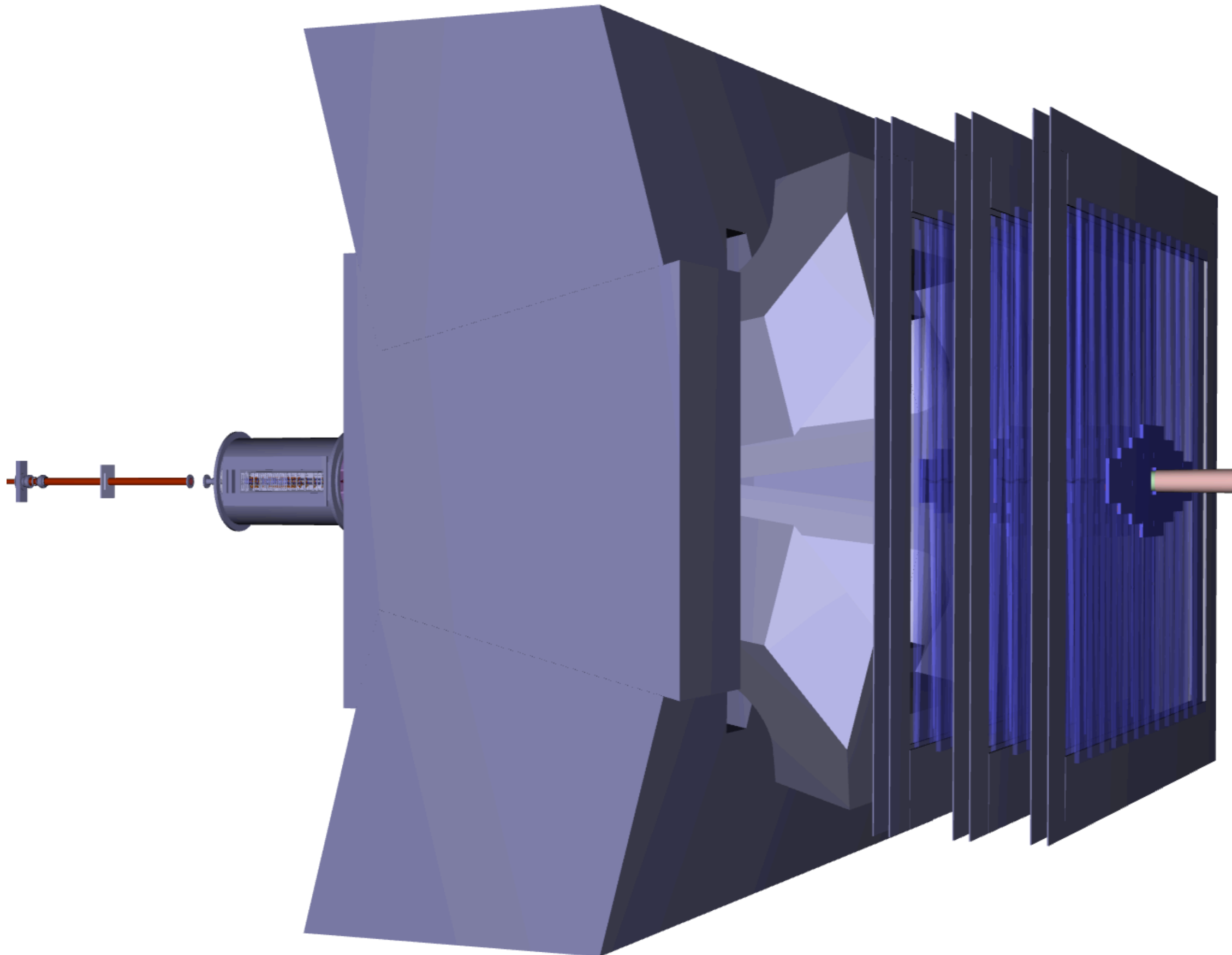
Science and  
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# Mighty Tracker



- \* Fibre Tracker (SciFi) + Pixel Tracker (Mighty Pix)
- \* Modify SciFi Tracker in the inner most area
  - \* 6 (or 5 layers) of Pixel layers in front and behind each SciFi stations
  - \* Possible to cut the same shape of hole of Mighty Pix in SciFi (in progress by Gary)
- \* Using DD4HEP toolkit as detector description for the geometry



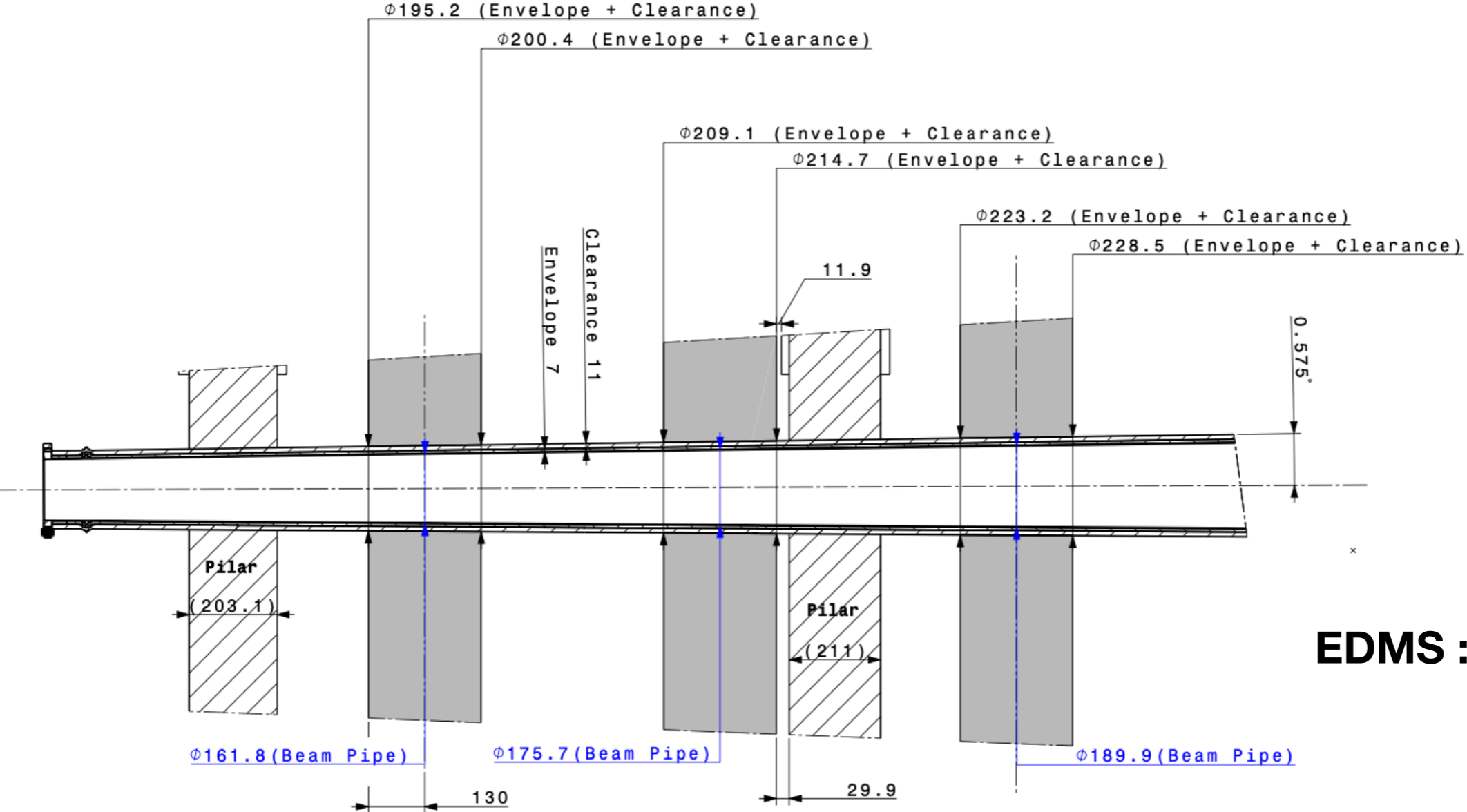


# Detector Geometry Simulation

- \* **Detector package is migrated from DetDesc + DDDB to DD4HEP**
- \* **Using DD4HEP to manage the data describing**
  - \* **the detector geometry,**
  - \* **the materials used when building the structures,**
  - \* **visualization attributes,**
  - \* **detector readout information,**
  - \* **basic conditions,**
  - \* **alignment,**
  - \* **calibration and environmental parameters**
- \* **All packages are modified with the existence of MightyPix:**
  - \* **Gauss - branch: mighty-tracker-20231019**
  - \* **LHCb - branch: mighty-tracker-20230815**
  - \* **Detector - branch: future\_upgrades\_structure\_MThackathon**  
(Gary pushed newest version of FT and MP coexisting in the same volume is now at [lhcb/Detector!463](#) )
  - \* **lhcb-conditions-database - branch: mighty-tracker-20231019**
  - \* **Thanks Gary and Manuel to rename and merge from the Master branch**
- \* **Simulation file (MCHits in .sim) can be produced with the other sub-detectors**
  - \* **In case the sub-detector is ready,**  
**we have currently test with “VP”, “FT”, “MP” and “Magnet”**
  - \* **One layer of sensitive material (silicon) with one layer of passive material are in the example shown in this presentation**

# Mighty Pix Geometry - Beampipe Opening (26 cm x 26 cm)

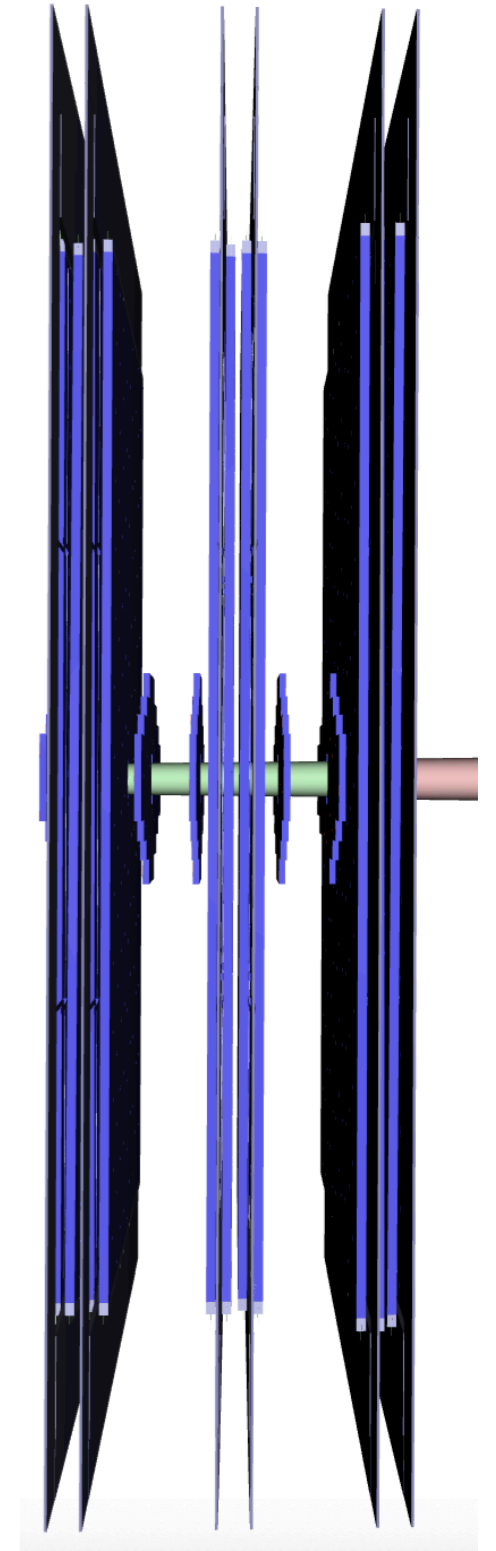
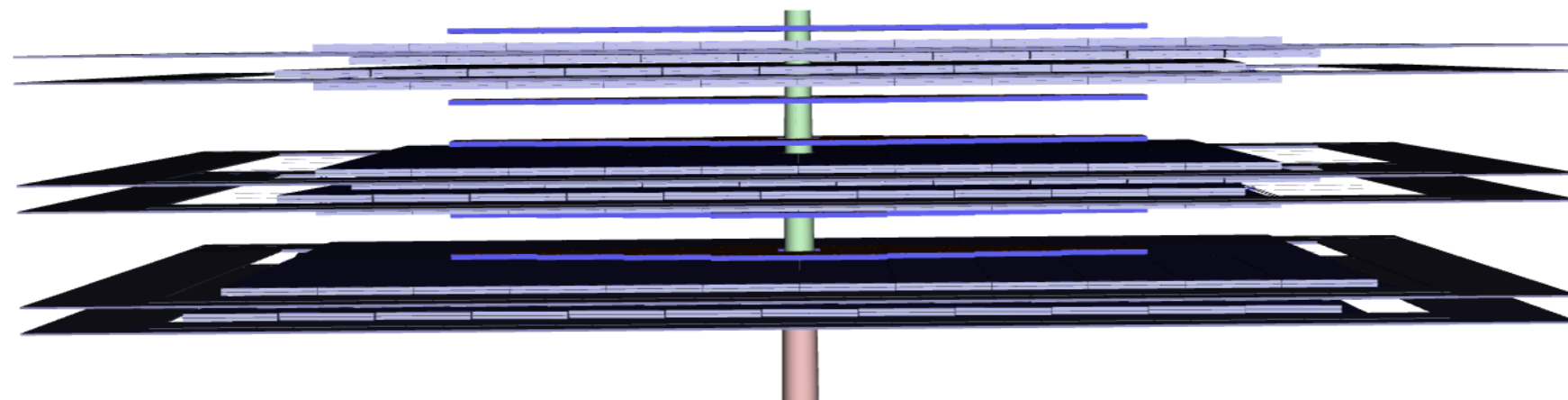
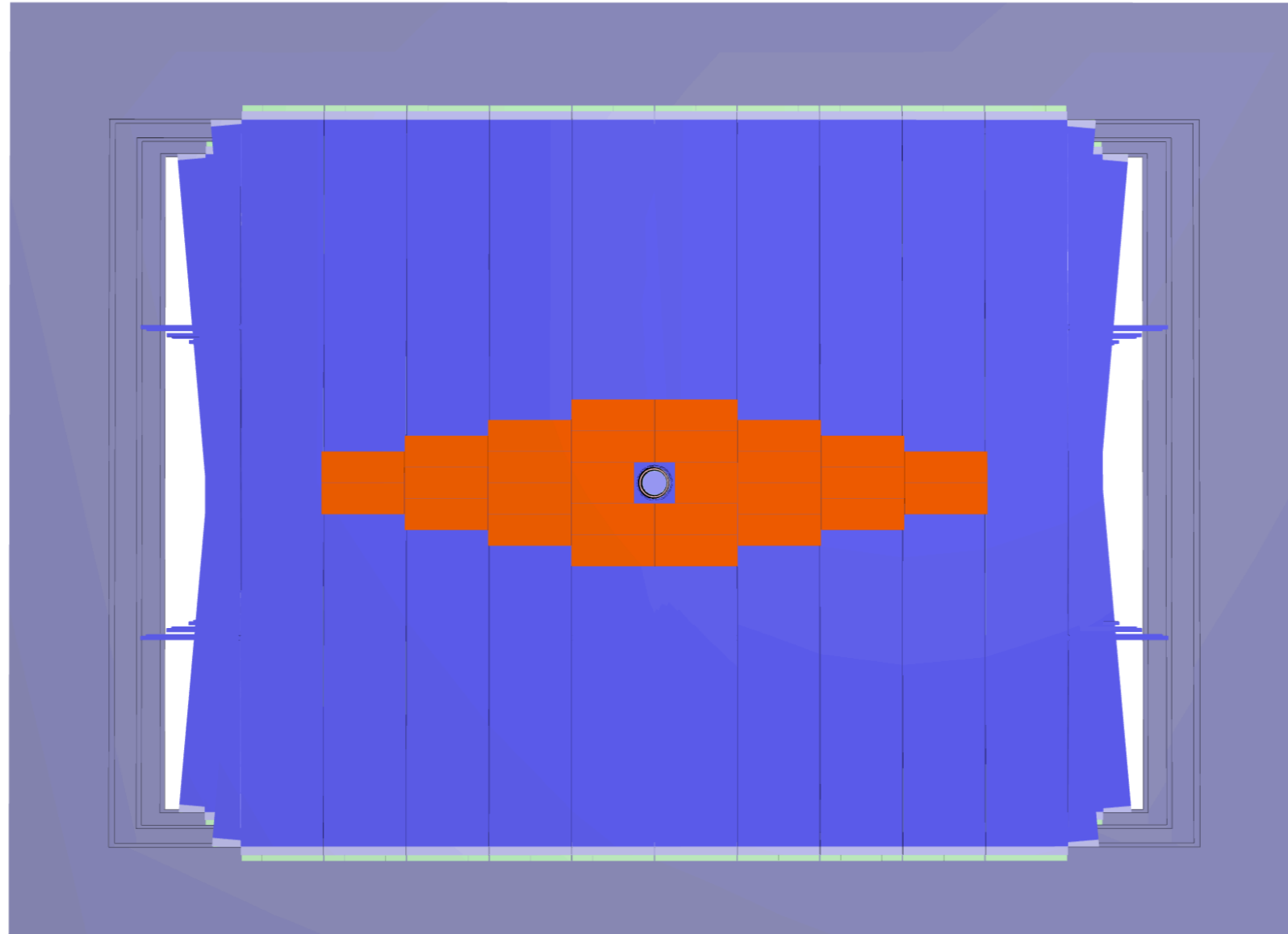
- \* Total Beam pipe clearance = Radius + 18 mm
- \* To stay all modules with the same beam pipe hole > 228.5 mm
- \* MightyPix modularity according to beam pipe hole constrain
  - \* Easier to increase the length in the unit of sensor chip than changing chip size
  - \* Change from 10 chips to 13 chips = 20 x13 = 260 mm
  - \* 228.5mm + 12.3mmx2 (Armacell for 0°C) = 253.1 mm
- \* [https://indico.cern.ch/event/1331920/contributions/5606680/attachments/2733196/4752037/MightyTrackerMechanicsMeeting\\_taihua231012.pdf](https://indico.cern.ch/event/1331920/contributions/5606680/attachments/2733196/4752037/MightyTrackerMechanicsMeeting_taihua231012.pdf)



EDMS : 1761168

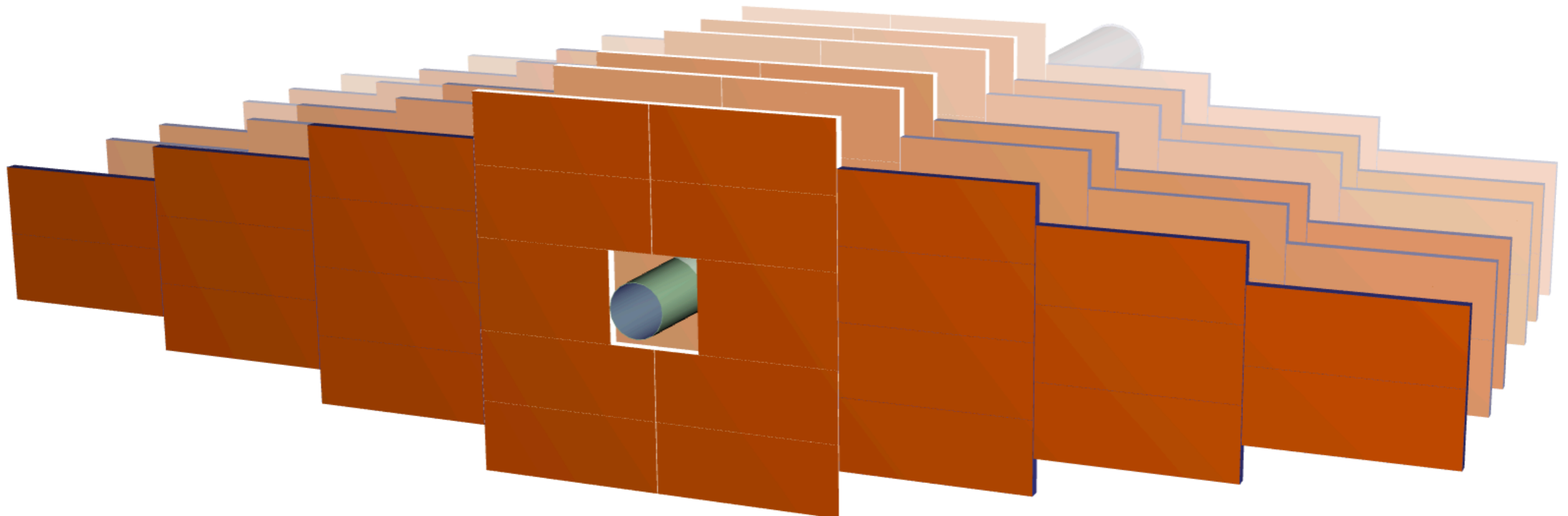
# Mighty Tracker Geometry

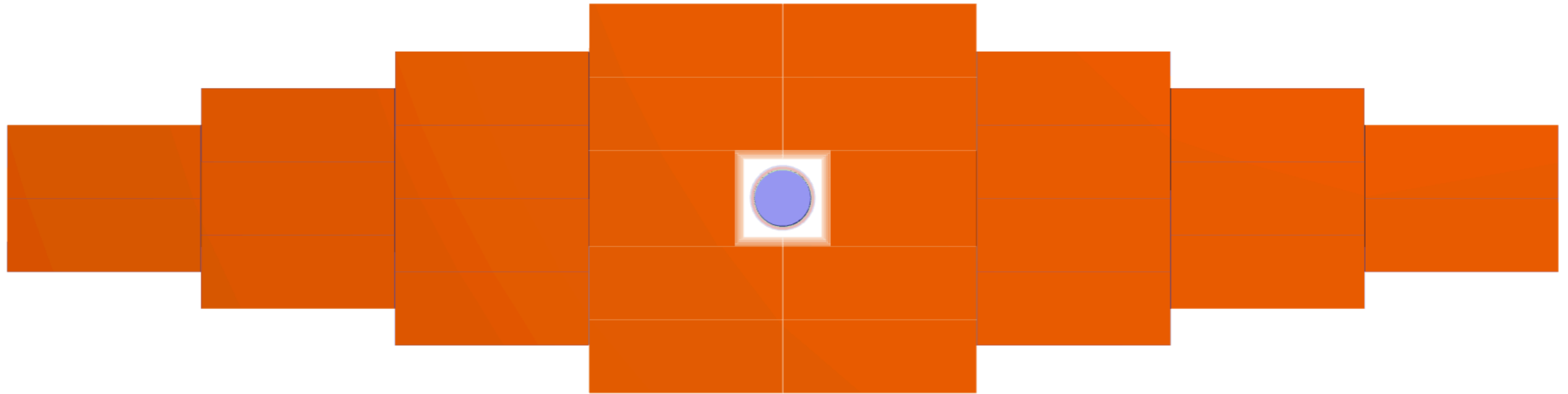
- \* Geometry visualisation in DD4HEP
  - \* SciFi + Mighty Pix



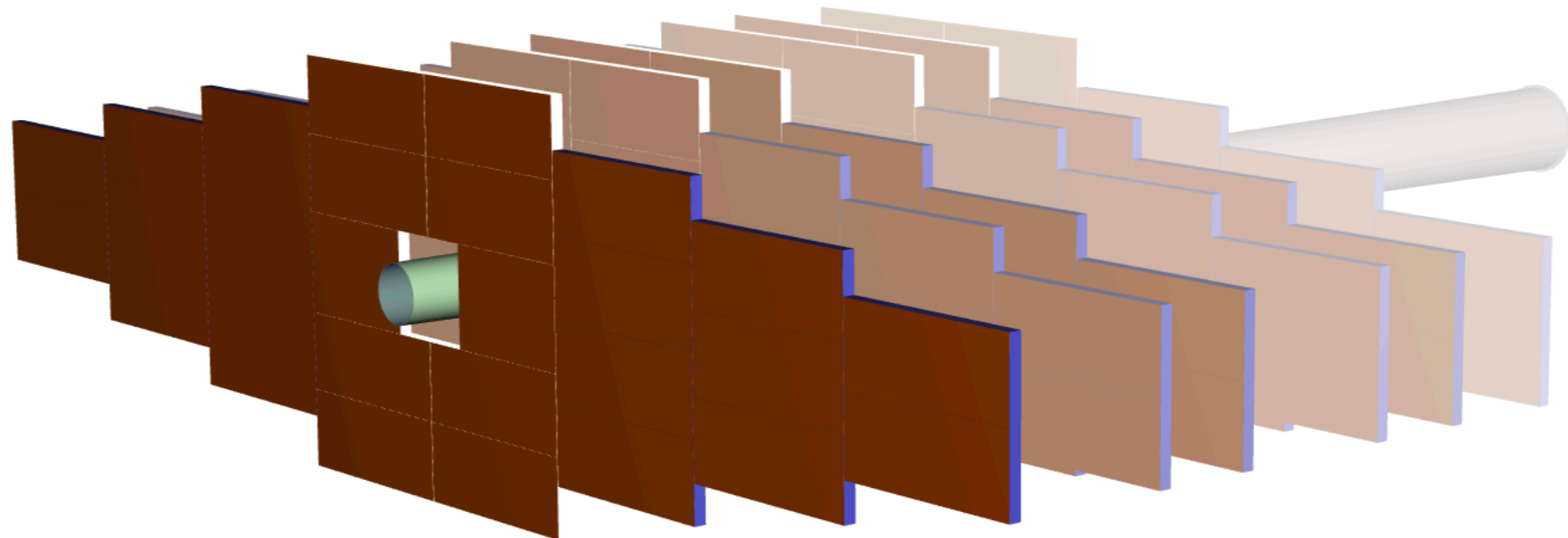
# Mighty Pix Geometry

- \* **Module X** = 528.0 mm
  - \* **Module Y<sub>(centre)</sub>** = 260.0 mm (beam pipe modules)
  - \* **Module Y<sub>(others)</sub>** = 200.0 mm (other modules)
  - \* **Module Z** = 31.73 mm (0.2 mm silicon + passive materials)
  - \* **Dead area** = 0.5 mm (related to the detection area)
  - \* **Module Gap** = 1 mm (related to the mechanical possibility)
  - \* **Module Pitch** = 530.0 mm (constrain by the geometry of Fibre Tracker)
- \* **All numbers are not final!**





- \* The short module with 13 chip in Y
  - \* With thickness 31.73mm
- \* The other modules with 10 chip in Y



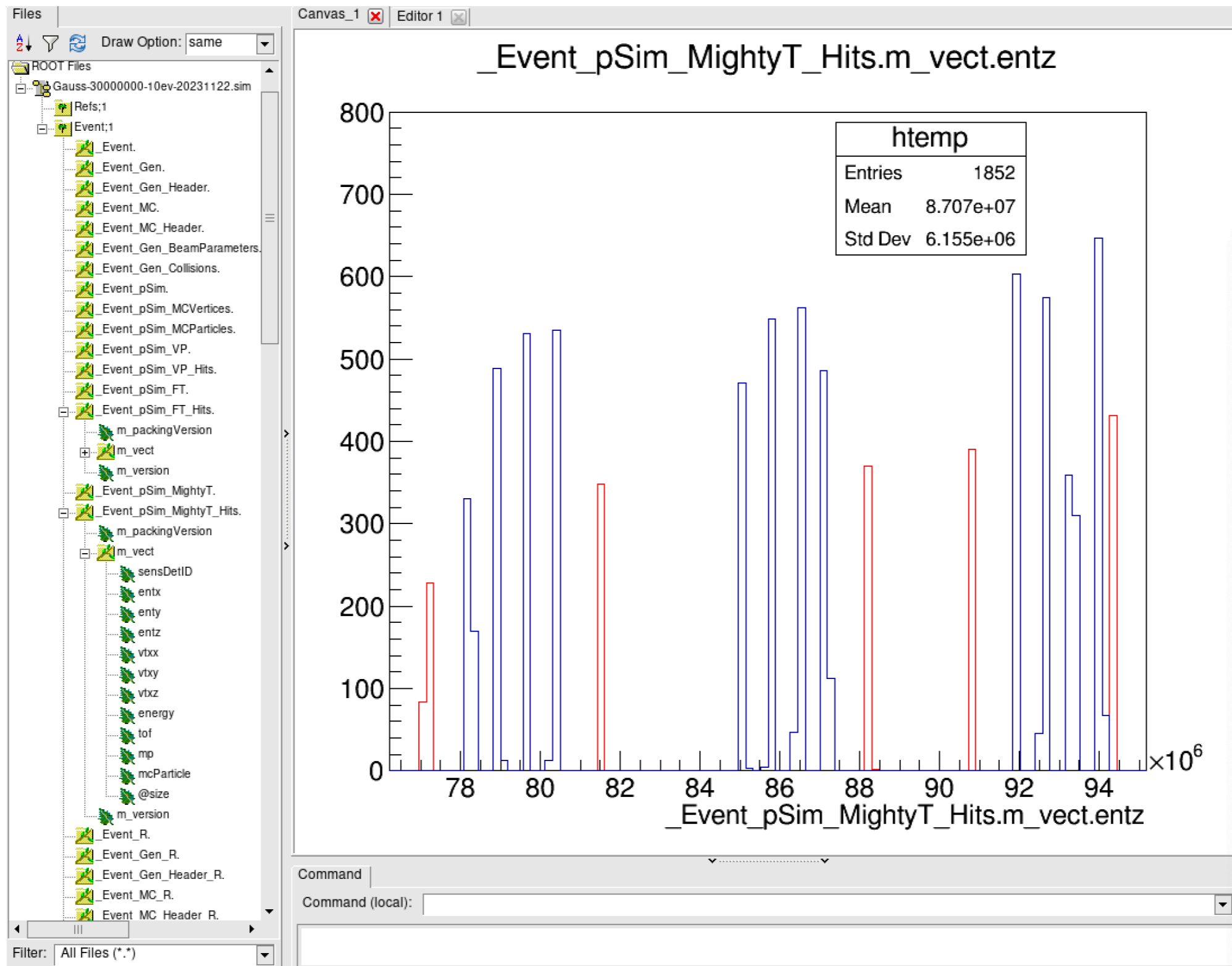


- ✱ Check the overlap with 'geometryvalidation' package using pyg4ometry
- ✱ The Mighty Tracker (Mighty Pix + SciFi) pass the overlap checking with 6 layers or 5 layers
- ✱ Overlap issue with Muon seems to appear with all other sub-detector, reported!
- ✱ Overview for passing the overlap check within the code:

```
(pyg4ometry) HEPDOCK138:geometryvalidation tai-hua.lin$ python pyg4ometry-scripts/showOverlaps.py data/lvMightyT+FT_GapTest0304.root
Info in <TGeoManager::Import>: Reading geometry from file: data/lvMightyT+FT_GapTest0304.root
Info in <TGeoManager::CloseGeometry>: Geometry loaded from file...
Info in <TGeoManager::SetTopVolume>: Top volume is world_volume. Master volume is world_volume
Info in <TGeoNavigator::BuildCache>: --- Maximum geometry depth set to 100
Info in <TGeoManager::CloseGeometry>: Voxelization retrieved from file
Info in <TGeoManager::CountLevels>: max level = 10, max placements = 14
Info in <TGeoManager::CloseGeometry>: 4724 nodes/ 145 volume UID's in Detector Geometry
Info in <TGeoManager::CloseGeometry>: -----modeler ready-----
LogicalVolume.checkOverlaps> world_volume
OVERLAP DETECTED> overlap with mother lvAfterMuon_0 34
1 overlaps detected
```

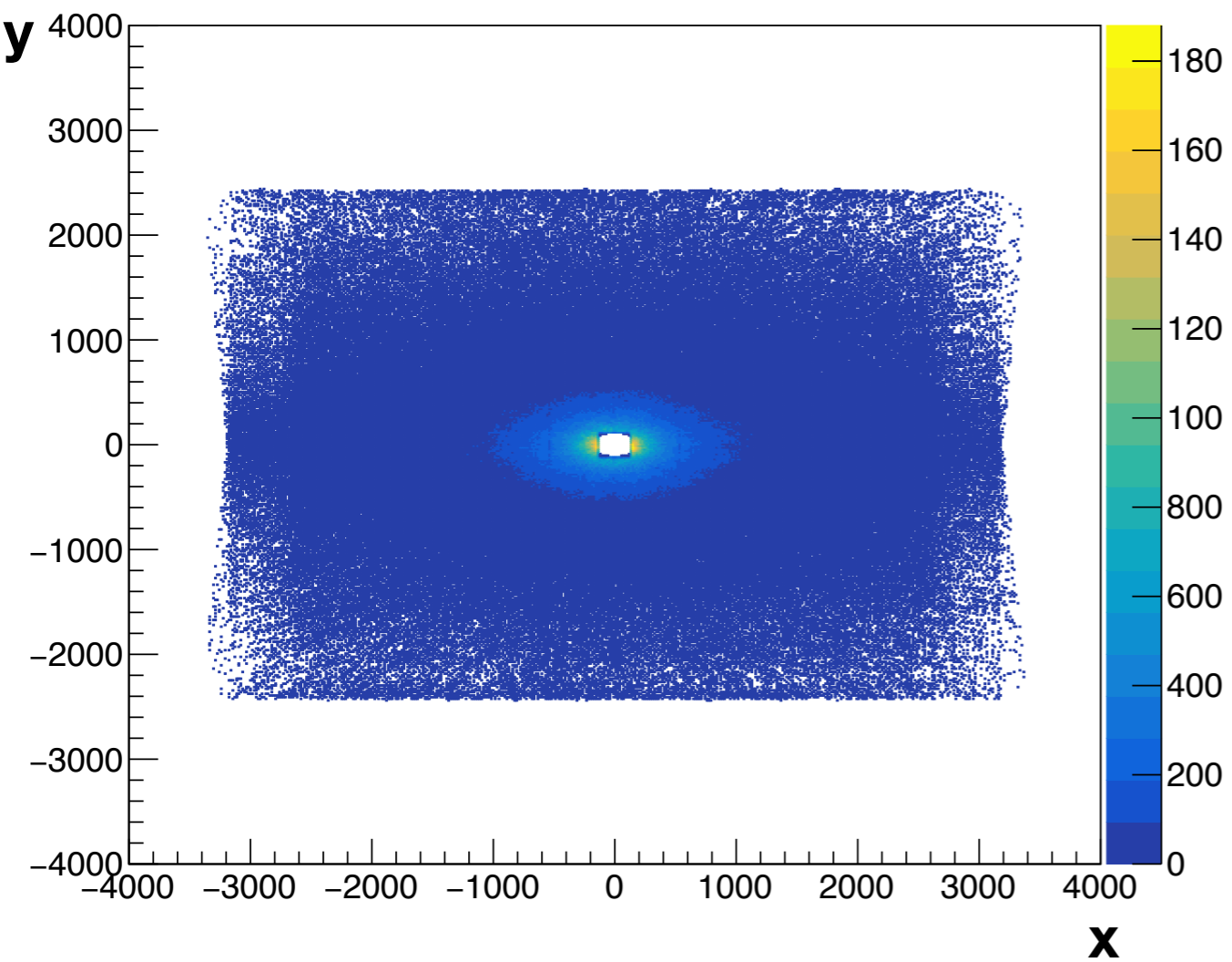
# MCHits in .sim

- “VP”, “FT”, “MP” and “Magnet” with MiniBias event by Pythia

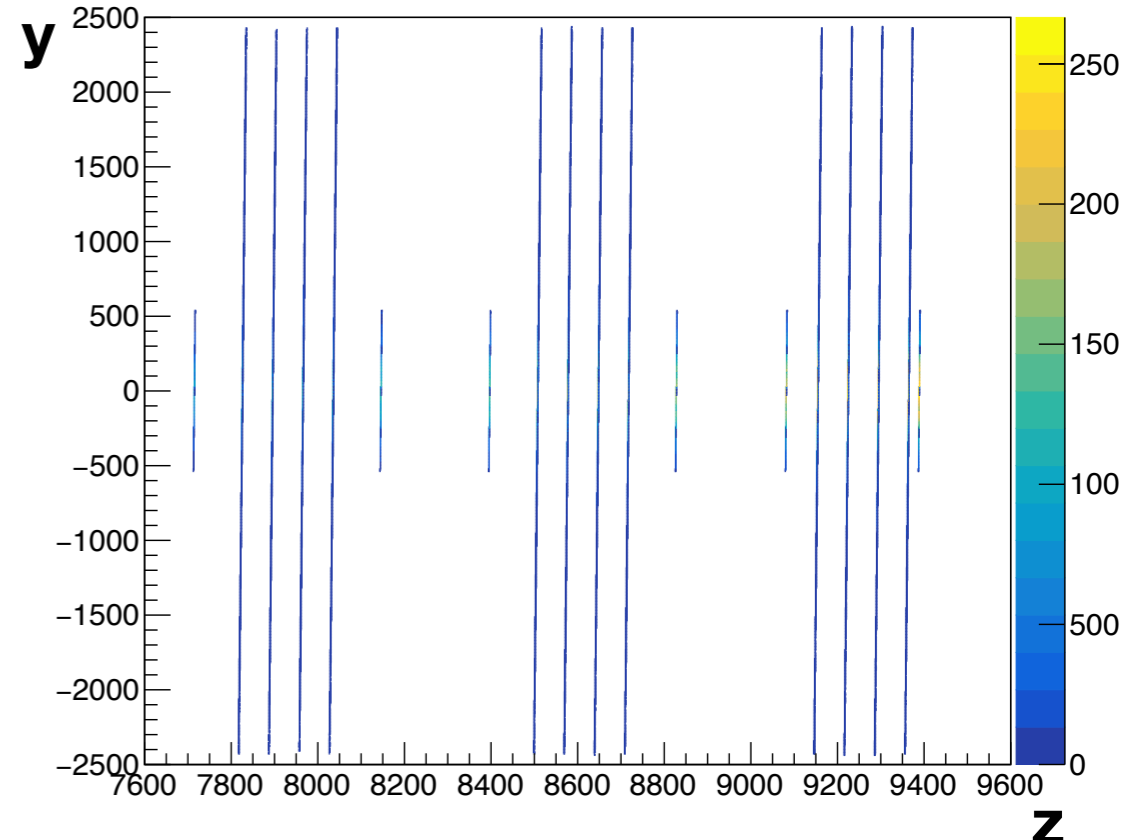
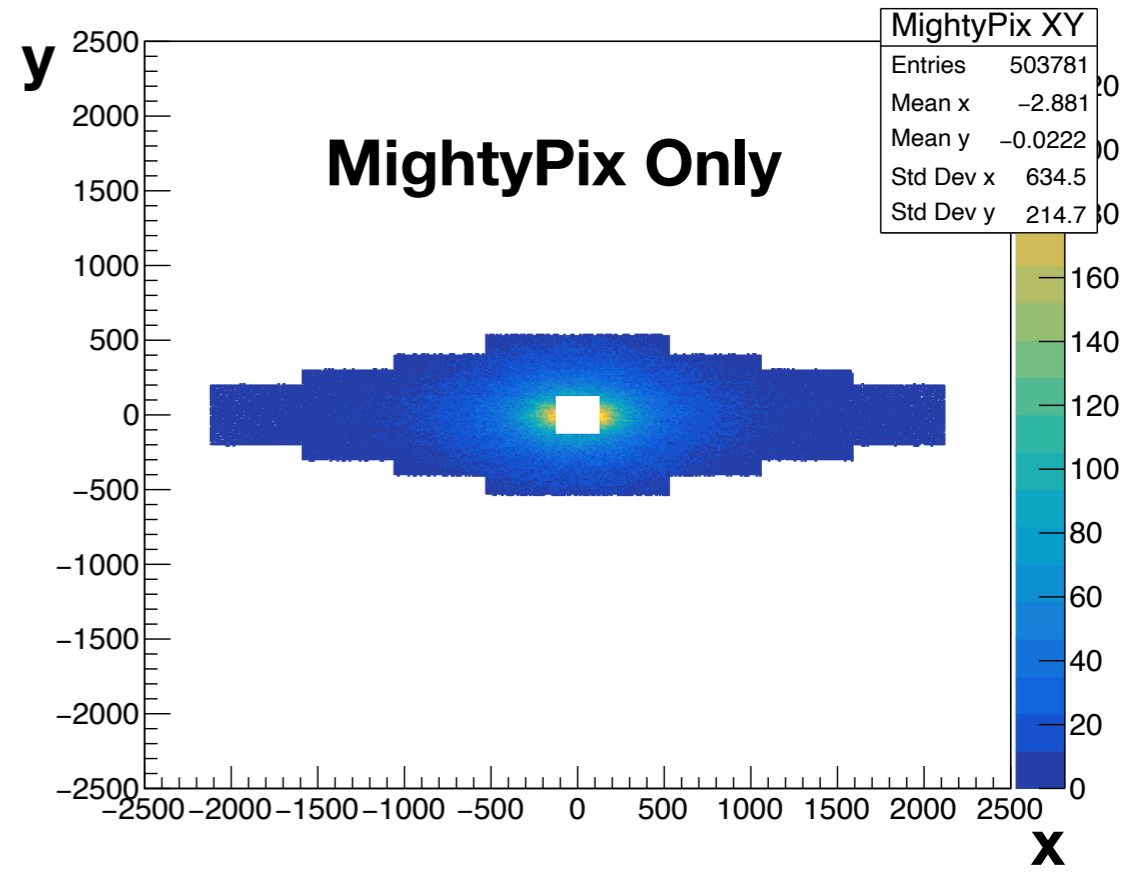


# MCHits for Mighty Pix Only and with SciFi

## SciFi + MightyPix



## MightyPix Only



# Old Mighty Pix Geometry - Position of Station w.r.t SciFi

## \* MightyPix

### Z position

- \* 7715.0 mm
- \* 8146.0 mm
- \* 8397.0 mm
- \* 8828.0 mm
- \* 9082.0 mm
- \* 9430.0 mm

## \* FT Z position (Global T station)

- \* 7931.0 mm
- \* 8613.0 mm
- \* 9298.0 mm

## Overlap with SciFi envelope

- \* Thinning the last layer
- \* Move the last layer of SciFi
- \* Move envelope backward
- \* Change envelop shape

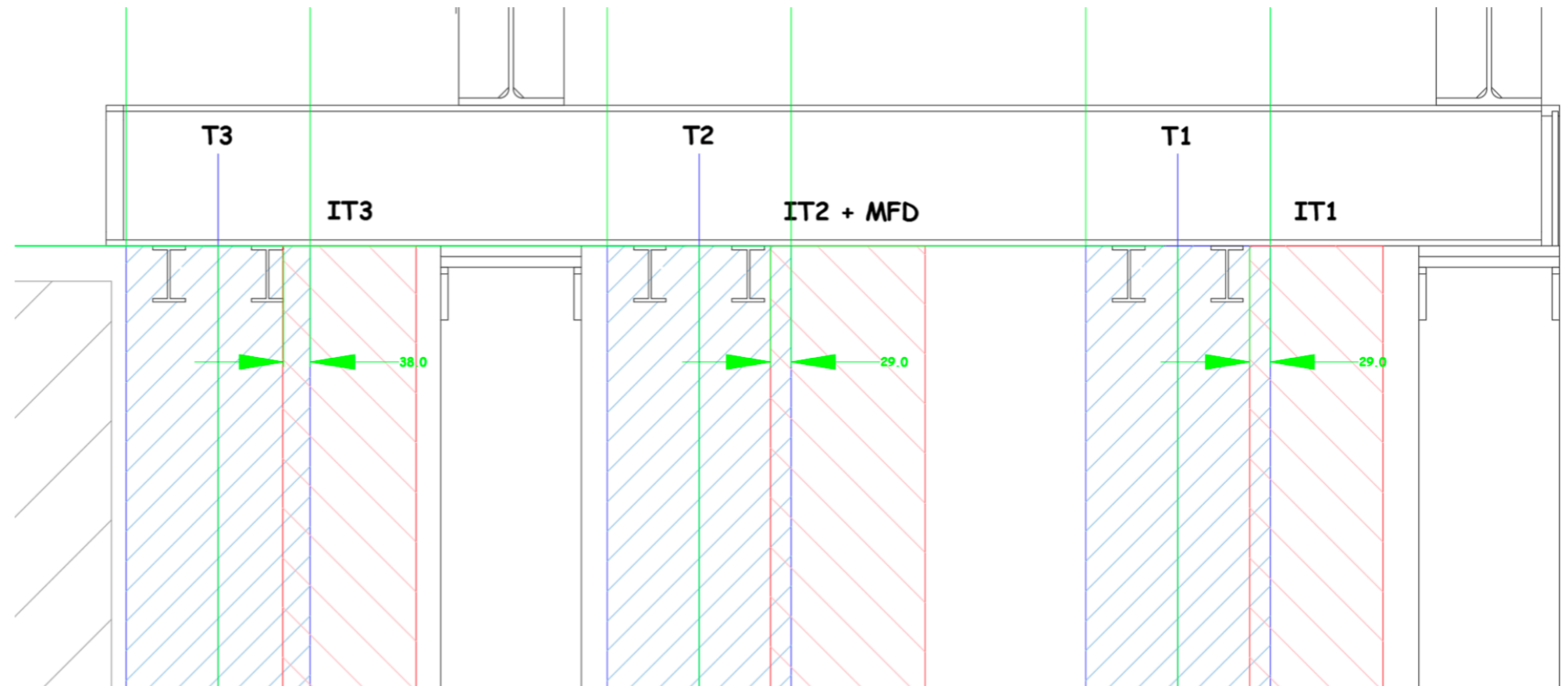


Figure 7. Envelope overlap – SciFi-IT

Given a clearance of 10 mm between the SciFi envelope and new IT envelope (as per EDMS 330689 v.2 -12/09/2016), the remaining space to allocate the new IT envelope is:

IT Station	mean - Y [mm]	$\Delta Y$ - Envelope [mm]	Y-start of total area [mm]	Y-end of total area [mm]	Z-mean envelope [mm]	$\Delta Y$ – mean position [mm]
IT1	7713.5	151	7789	7638	7180	0
IT2+MFD	8380.5	181	8471	8290	7180	667
IT3	9085.5	141	9156	9015	7180	705

Table 4. Size of the new IT envelopes in Y-direction

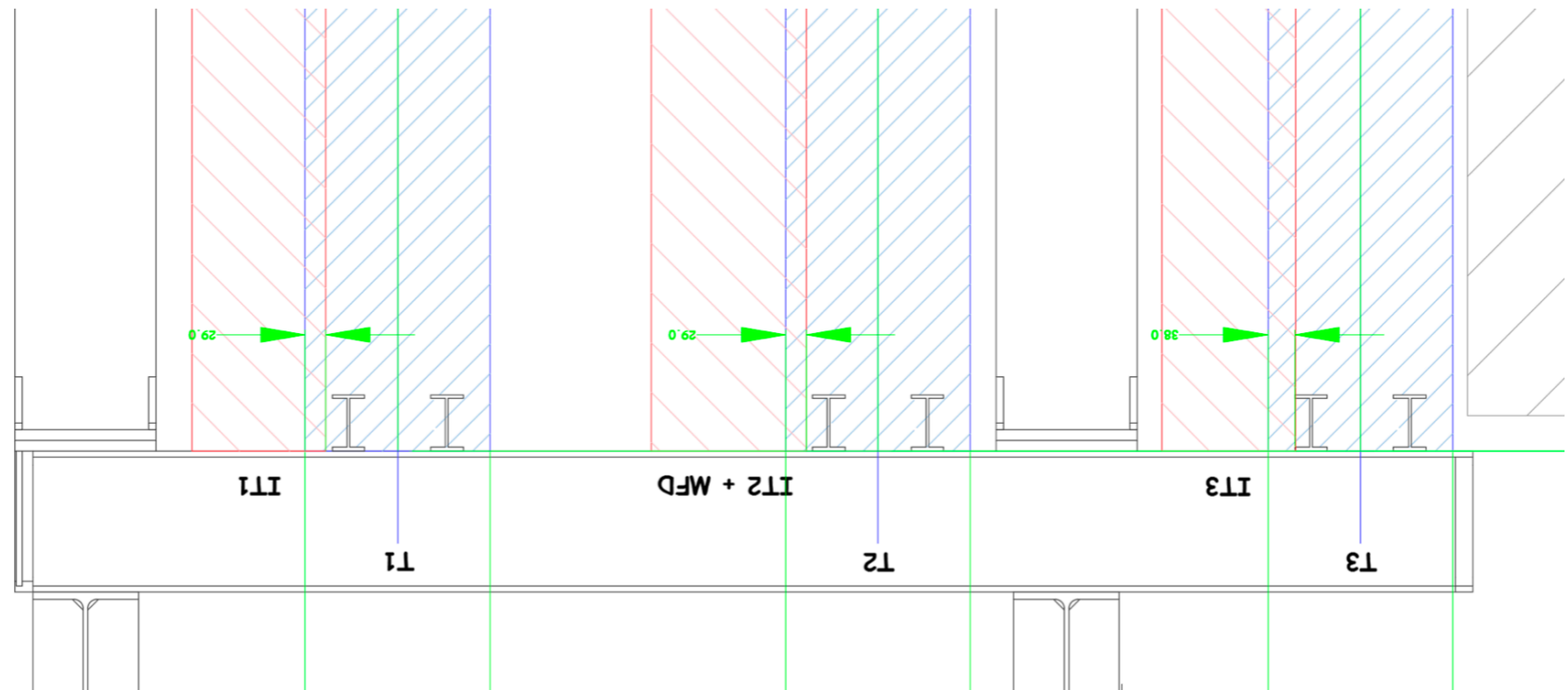
SciFi\_Project\_Envelope\_EDMS1792415\_V.3

# Mighty Pix Geometry - Position of Station w.r.t SciFi - with other possible to fine tune

- ✧ **Orig. MightyPix**

- Z position**

- ✧ 7715.0 mm
- ✧ 8146.0 mm
- ✧ 8397.0 mm
- ✧ 8828.0 mm
- ✧ 9082.0 mm
- ✧ 9430.0 mm



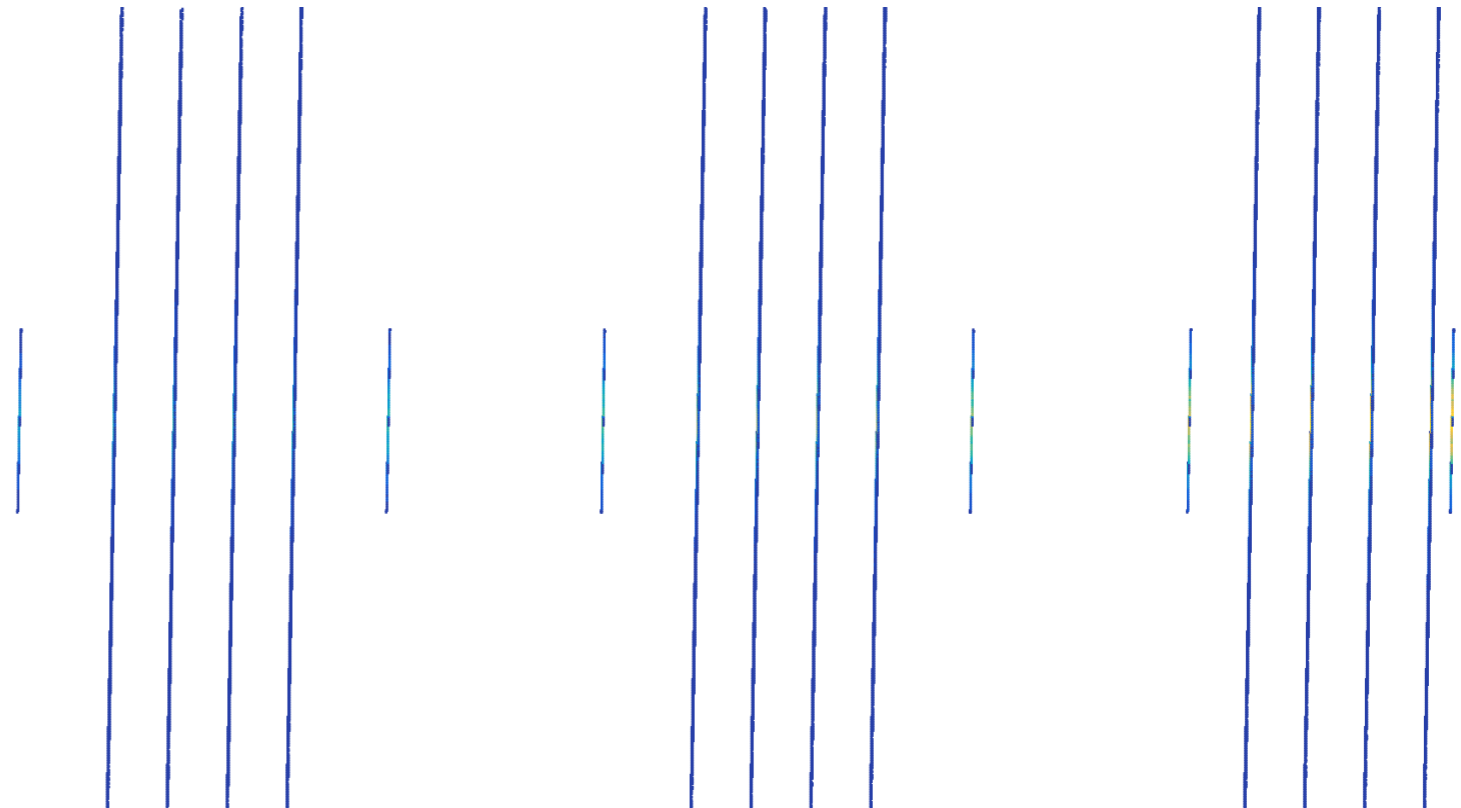
- ✧ **MightyPix last**
- Z position**

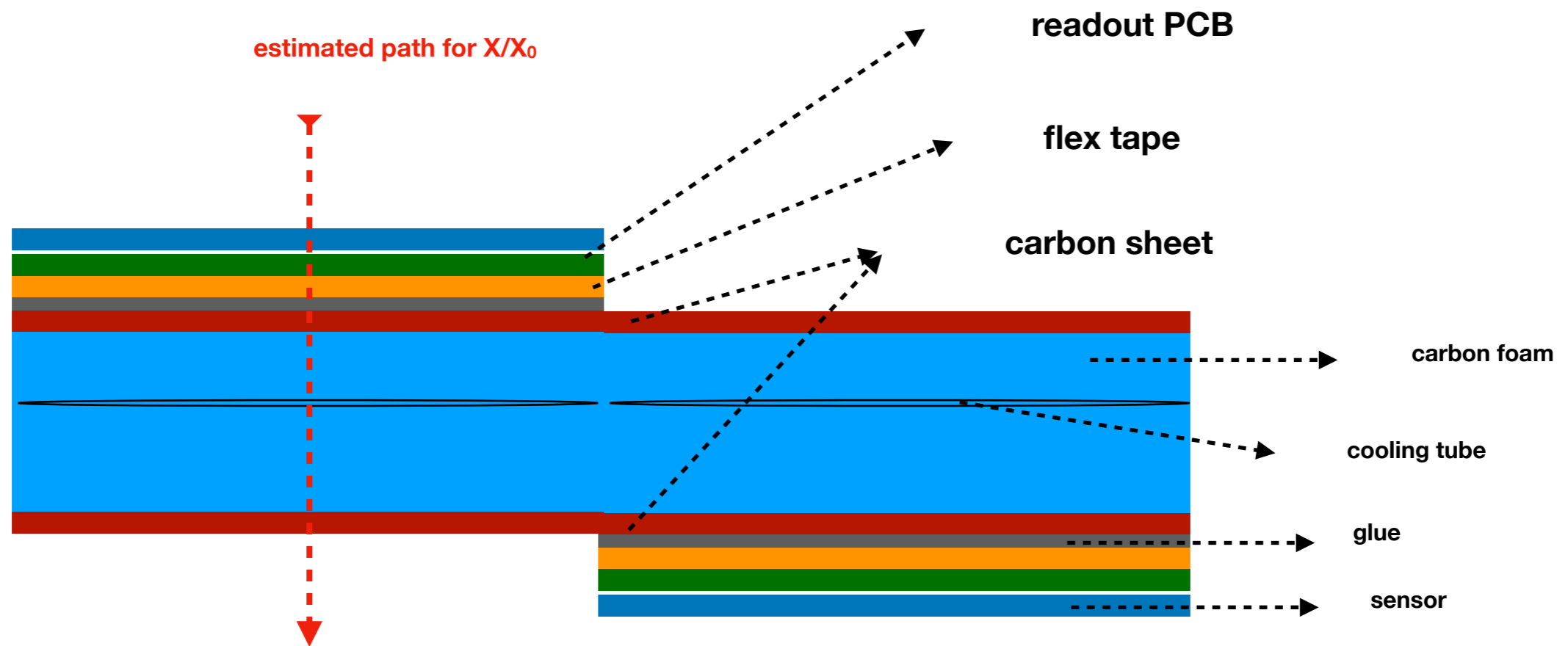
- ✧ **9389.0 mm**

Move 31 mm forward behind last layer,  
At 9405.0 with 3 overlaps

- ✧ **SciFi last**
- Z position**

- ✧ **From**
- 9298.0 mm**
- ✧ **To**
- 9260.0 mm**





- \* Silicon thickness - set as sensitive material

- \* 200  $\mu\text{m}$  or 150  $\mu\text{m}$  - Sensor design

- \* [https://indico.cern.ch/event/1345910/contributions/5666023/attachments/2755395/4797995/20231120\\_LHCb\\_Mighty\\_Tracker\\_EV.pdf](https://indico.cern.ch/event/1345910/contributions/5666023/attachments/2755395/4797995/20231120_LHCb_Mighty_Tracker_EV.pdf)



# Mighty Pix Geometry - Flex Tape Thickness

- \* Glue data is referenced from ALICE and ATLAS, more accurate estimation might be needed.

\* [https://indico.cern.ch/event/933783/contributions/3928160/attachments/2066791/3490827/MightyTrackerDD4Hep\\_taihua200701\\_correctPCBthickness.pdf](https://indico.cern.ch/event/933783/contributions/3928160/attachments/2066791/3490827/MightyTrackerDD4Hep_taihua200701_correctPCBthickness.pdf)

Product Code	Side 1 Copper Thickness $\mu\text{m}$ (oz/ft <sup>2</sup> )	Dielectric Thickness mil ( $\mu\text{m}$ )	Side 2 Copper Thickness $\mu\text{m}$ (oz/ft <sup>2</sup> )
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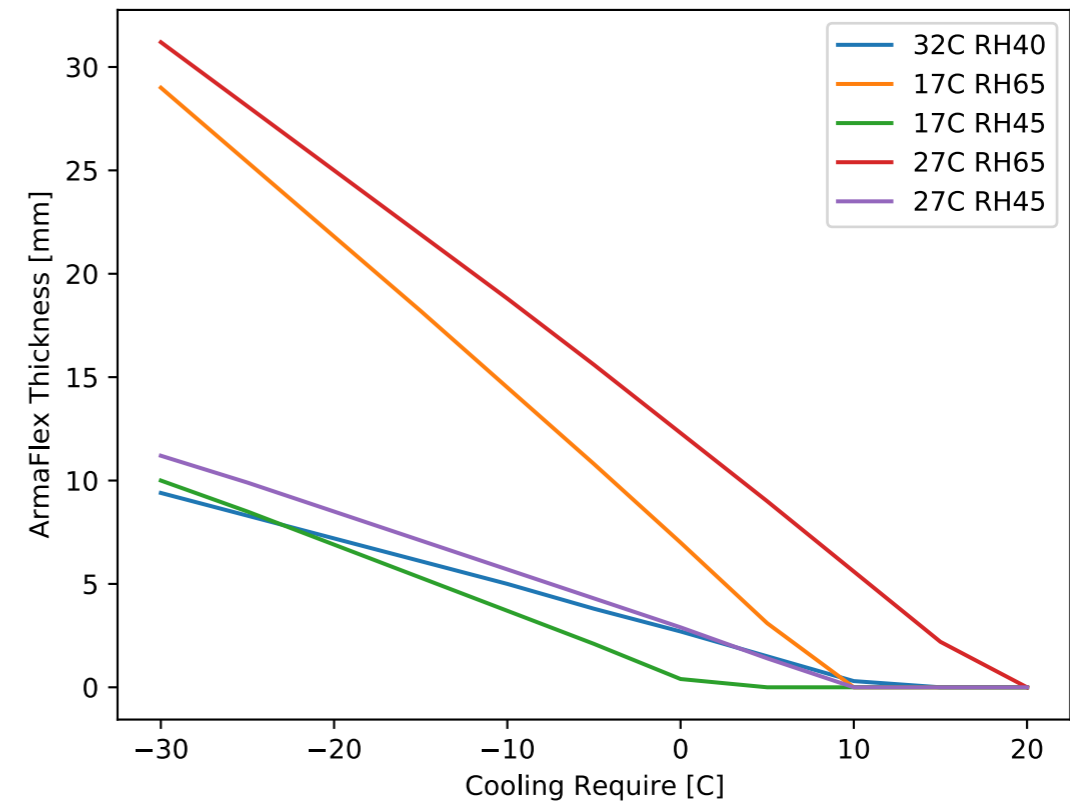
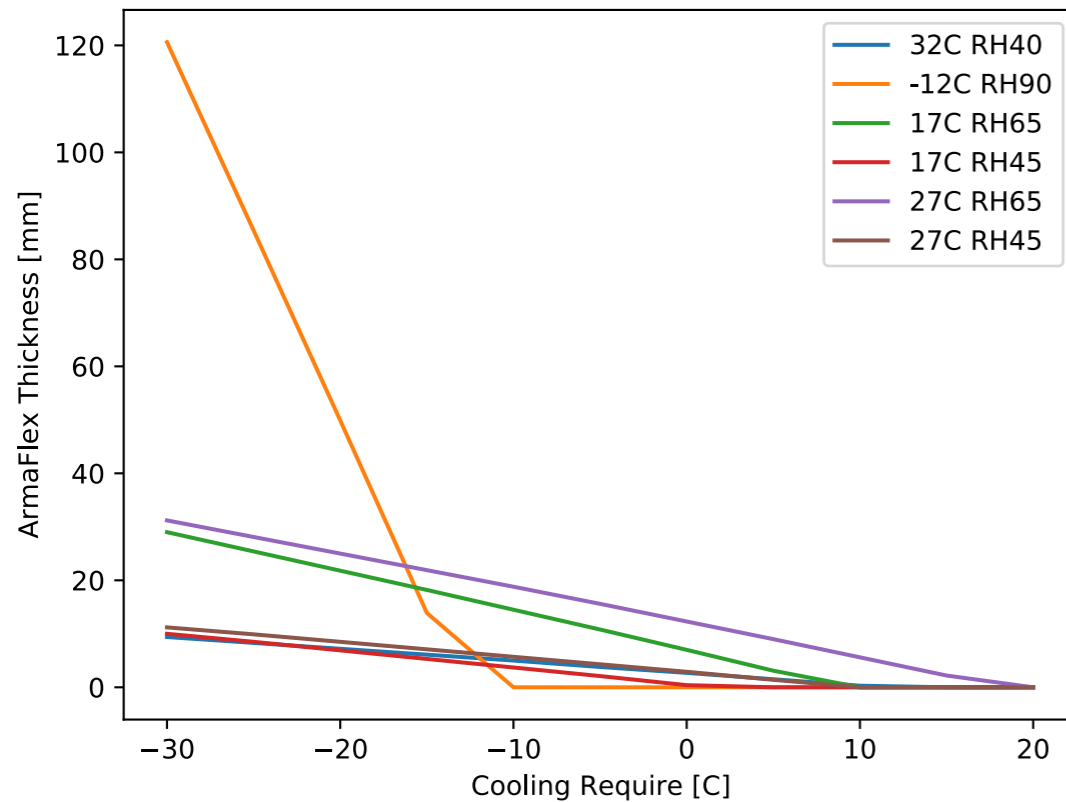
[https://www.dupont.com/content/dam/dupont/amer/us/en/products/ei-transformation/documents/PyraluxAPclad\\_DataSheet.pdf](https://www.dupont.com/content/dam/dupont/amer/us/en/products/ei-transformation/documents/PyraluxAPclad_DataSheet.pdf)

<https://www-physics.lbl.gov/~gilg/PixelUpgradeMechanicsCooling/Material/Radiationlength.pdf>

Material Unit	Thickness $\mu\text{m}$	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite composite
Flex Copper	18	2	1.44	0.25	Cu
Flex Dielectric	4	1	28.6	0.001	Dielectric Kapton
Flex FR4	300	1	17.0	0.176	FR4
Flex tape 1	340	1		0.428	Cu + Dielectric + FR4
Flex Copper	18	2	1.44	0.25	Cu
Flex Dielectric	4	1	28.6	0.001	Dielectric Kapton
Flex Polyimide	300	1	28.6	0.176	FR4
Flex tape 2	340	1		0.356	Cu + Dielectric + Polyimide

# Mighty Pix Geometry - Thermal Isolation Thickness

- ✱ **Armacell - using the manufacture simulation tool**
- ✱ **Assuming plastic inside the thermal box**



- ✱ **The object to isolated : copper, plastic (only small change)**
- ✱ **With cooling medium : Nitrogen (gaseous)**
- ✱ **Running in room temperature : no need for thermal box**
- ✱ **Take example of 27°C RH65% plastic**
  - Cooling required inside box of 15°C : thickness 2.2 mm**
  - Cooling required inside box of 0°C : thickness 12.3 mm**
  - Cooling required inside box of -30°C : thickness 31.2 mm**

[https://indico.cern.ch/event/1017512/contributions/4270360/attachments/2206573/3733531/MightyTrackerDD4Hep\\_taihua210311.pdf](https://indico.cern.ch/event/1017512/contributions/4270360/attachments/2206573/3733531/MightyTrackerDD4Hep_taihua210311.pdf)



- ✱ **Carbon Foram is chosen temporary as 4200 um will be confirmed with the gluing of the prototype**
- ✱ **DC-DC convertor and other on chip electronics are not included will have significant contribution for copper wire**
- ✱ **PCB is chosen with some default thickness from common manufacture will be nice to have some input from the experts**
- ✱ **Cooling tube will be changed if cooling method is different**

# Mighty Pix Geometry - Material Budget

- \* The number of this table is in the simulation
  - \* Thickness (Z): 3.17cm
    - limited space after SciFi for the last layer
  - \* SUM density is only with passive material

- \* The mass fraction is compared with Violain's table in DDDDB

\* <https://gitlab.cern.ch/lhcb-conddb/DDDB/-/blob/upgrade/violaine-dddb-20210218-newlayer-withrealcables-cutfibres-dcdc/materials/FTMaterials.xml>

	Thickness um	Layers	X0	X/X0	Filling factor	With Scifi	Density g/cm3	Mass /cm2	Mass fraction
<b>Silicon</b>	200	1	9.37	0.213	1				
<b>Cooling tube</b>	50	2	28.6	0.004	0.12		1.43	0.002	0.003
<b>Carbon form</b>	4200	1	185.65	0.226	1		0.23	0.097	0.168
<b>Carbon fibre</b>	300	2	23.70	0.253	1		2.2	0.132	0.229
<b>Flex tape</b>	340	1		0.356	1		1.71	0.058	0.101
<b>Glue</b>	120	1	35.49	0.034	1		1.17	0.014	0.024
<b>Armacell</b>	12300	2	801.27	0.307	1	19.266	0.08	0.197	0.341
<b>PCB</b>	1570	1	17.0	0.185	0.2	6.422	2.44	0.077	0.133
<b>SUM</b>	31730			1.578			0.182	0.577	0.999

- ✧ **Detector Geometry**
  - ✧ **Detector is modified to the latest new structure and rename from “MightyT” to “MP”**
  - ✧ **Temporary moved last SciFi layer in order to put full Mighty Pix in, to be discussed!**
  - ✧ **Adding detailed supporting structure (detailed passive materials, DCDC converter and cable curtain)**
  - ✧ **Adding the options in config file to be able to select which FTDR and other options**
  - ✧ **Cutting SciFi in the shape of Mighty Pix is in progress (by Gary)**
- ✧ **Gauss ( on Gaussino )**
  - ✧ **Got the MCHits from VP, FT, MP and magnet**
  - ✧ **Can add the other sub-detector if they are ready**
  - ✧ **Will discuss the numbering scheme for digitization**

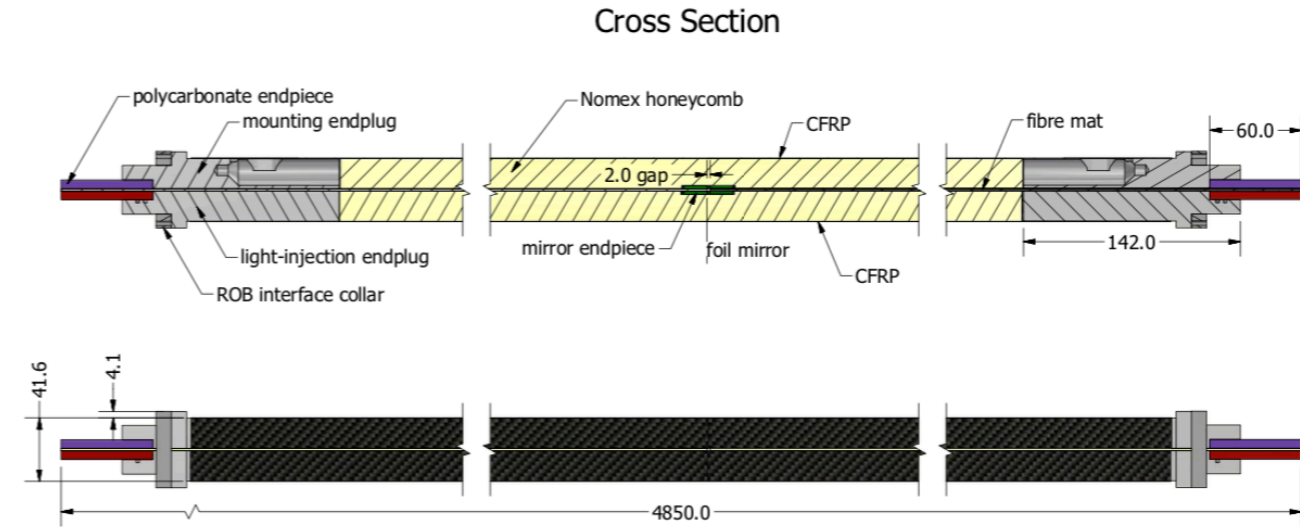
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# Back Up !

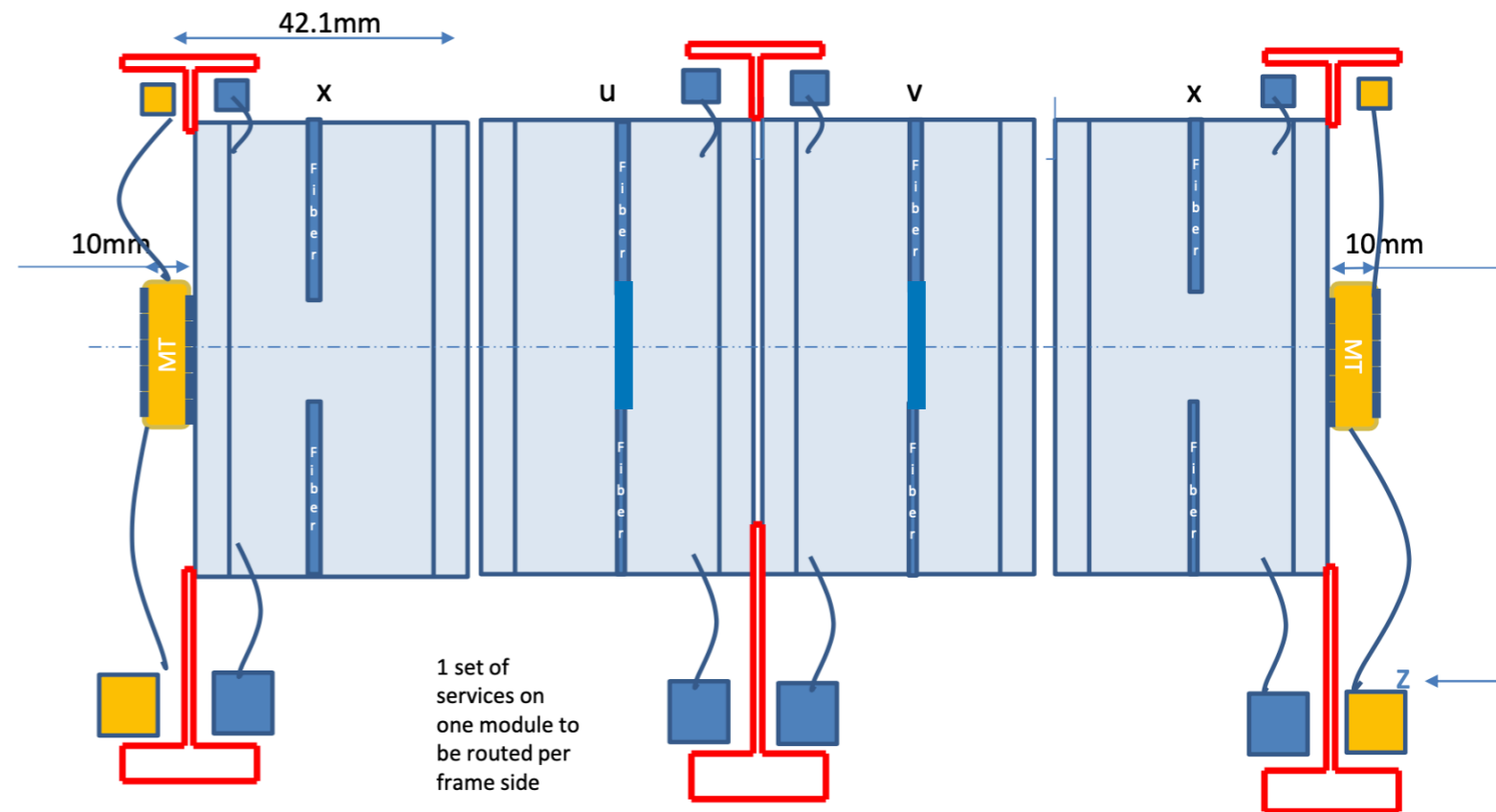
# SciFi - Fibre Tracker + Mighty Tracker

LHCb-PUB-2015-008 , p86 and p74

Material	Thickness( $\mu\text{m}$ )	Layers	$X_0(\text{cm})$	$X/X_0$ (%)
Nomex Core	20000	2	1310	0.305
CF skin	200	2	23.3	0.172
Panel assembly glue	75	4	36.1	0.083
Fibre mat	1350	1	33.2	0.407
Casting glue	120	2	36.1	0.066
<b>Total</b>	<b>42290</b>			<b>1.02</b>



Side View



\* **Mighty Tracker on the top of both outer side of the SciFi**

\* **One station is with 4 layers of fibre tracker and two layer of mighty tracker**

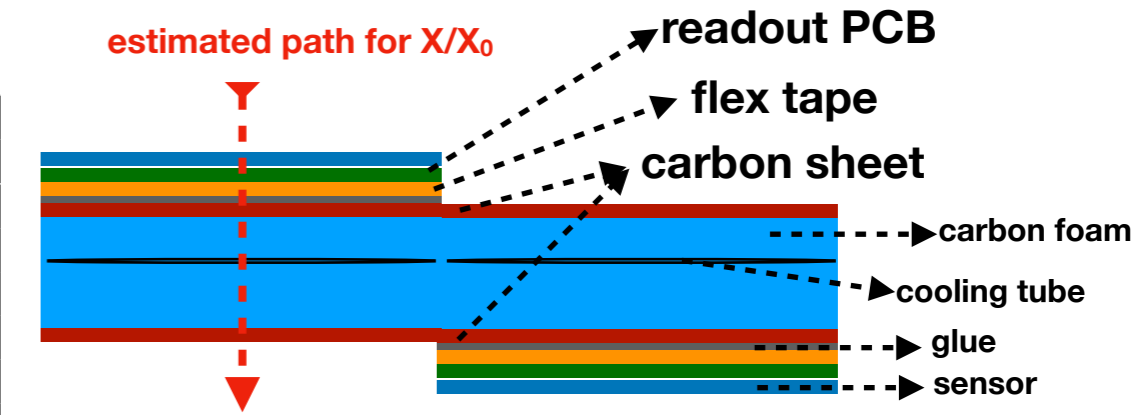
\* **The radiation of one station will be 9.60%, 6.96%, 5.77% for filling factors**

\* **For all combined (3 stations): 28.81%, 20.88%, 17.31%**

[https://indico.cern.ch/event/960971/contributions/4042022/attachments/2111918/3556494/LHCb\\_MT\\_Mechanical\\_17.09.2020\\_blakeaddition.pdf](https://indico.cern.ch/event/960971/contributions/4042022/attachments/2111918/3556494/LHCb_MT_Mechanical_17.09.2020_blakeaddition.pdf)

# Material Budget with options - per layer (apply filling factors)

Material Unit	Thickness $\mu\text{m}$	Filling Factor (%)	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite
Silicon	150	100	1	9.37	0.160	Si
Cooling tube	50	12	2	28.6	0.004	Kapton Polyimide
Carbon foam	4200	100	1	185.65	0.226	C, Allcomp K9 130pp
Carbon sheet	1000	100	2	23.70	0.843	C, K13C2U/EX1515
Flex tape	340	100	1		0.428	Cu + Dielectric + FR4
Glue	150	100	1	35.49	0.042	TenCate EX-1515
PCB	2360	20	1	17.0	0.278	FR4
Armacell	31200	100	2	801.27	0.779	-30 degree
SUM					2.761	



\* **Option 3**  
 \* **with total  $X/X_0 = 2.761\%$**

Material Unit	Thickness $\mu\text{m}$	Filling Factor (%)	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite
Silicon	120	100	1	9.37	0.128	Si
Cooling tube	50	12	2	28.6	0.004	Kapton Polyimide
Carbon foam	3200	100	1	185.65	0.172	C, Allcomp K9 130pp
Carbon sheet	300	100	2	23.70	0.253	C, K13C2U/EX1515
Flex tape	340	100	1		0.356	Cu + Dielectric + Polyimide
Glue	120	100	1	35.49	0.033	TenCate EX-1515
PCB	1570	20	1	17.0	0.184	FR4
Armacell	12300	100	2	801.27	0.307	0 degree
SUM					1.439	

\* **Option 2**  
 \* **with total  $X/X_0 = 1.439\%$**

Material Unit	Thickness $\mu\text{m}$	Filling Factor (%)	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite
Silicon	100	100	1	9.37	0.106	Si
Cooling tube	50	12	2	28.6	0.004	Kapton Polyimide
Carbon foam	2200	100	1	185.65	0.118	C, Allcomp K9 130pp
Carbon sheet	100	100	2	23.70	0.084	C, K13C2U/EX1515
Flex tape	340	100	1		0.356	Cu + Dielectric + Polyimide
Glue	100	100	1	35.49	0.028	TenCate EX-1515
PCB	780	20	1	17.0	0.009	FR4
Armacell	2200	100	2	801.27	0.055	15 degree
SUM					0.845	

\* **Option 1**  
 \* **with total  $X/X_0 = 0.845\%$**

\* For all combined (SciFi + Mighty Tracker):  
between 28.81% ~ 17.31%

\* Estimation of the material budget of the LHCb detector (LHCb note 2007-025)

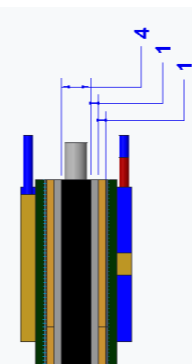
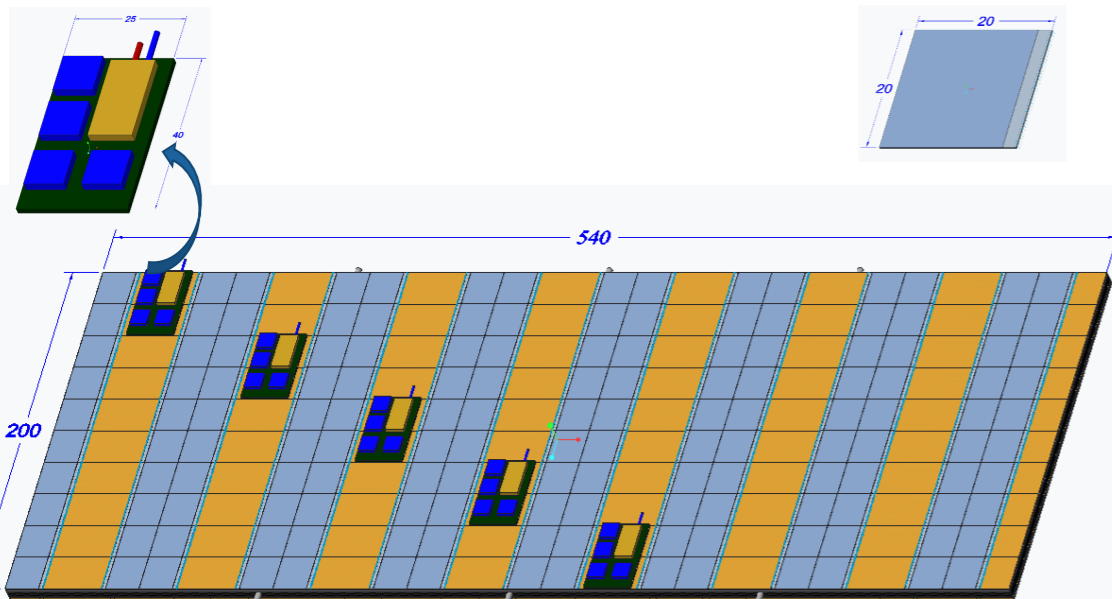
Region	$z_{min}/\text{cm}$	$z_{max}/\text{cm}$	$X_0/\%$
VELO	0	83	16.2
VELO-RICH1 interface	83.0	97.8	6.8
RICH1	97.8	225	9.5
TT	225	275	5.1
Magnet	275	760	5.3
T	760	930	17.8

\* **VELO upgrade : 20.9%**

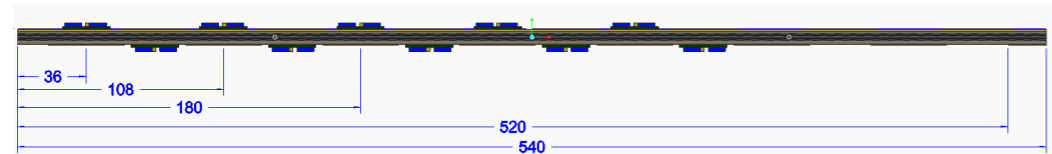
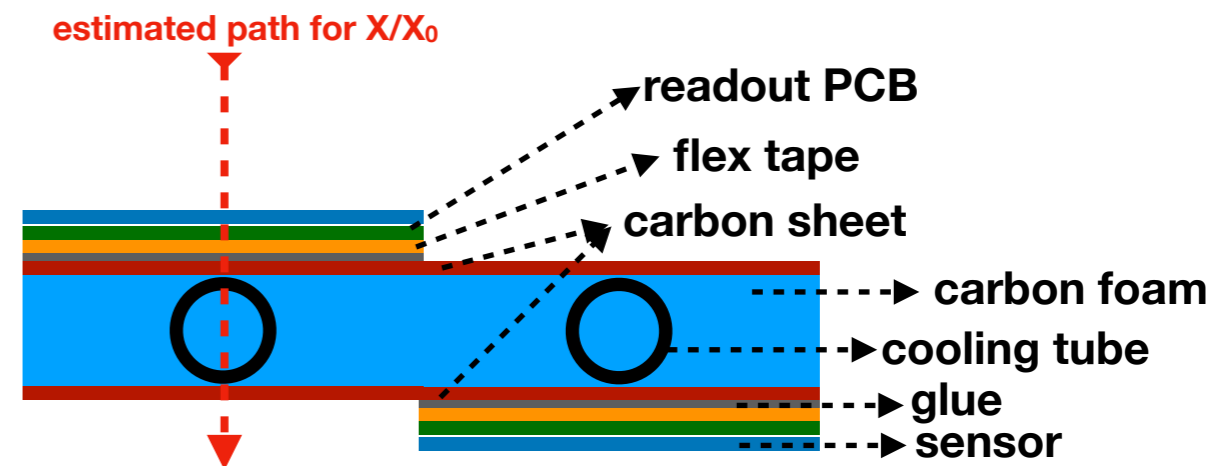
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# List of materials -

Part / Material	Density (g/cm <sup>3</sup> )	K (W/m <sup>o</sup> K)	Option 1	Option 2	Option 3
Cooling Tube (Kapton - Polyimide)	1.43	0.205	OD2mm(WT50 $\mu$ m)	OD3mm(WT50 $\mu$ m)	OD4mm(WT50 $\mu$ m)
Carbon Foam (Allcomp K9 130pp)	0.23	30	2.2mm	3.2mm	4.2mm
Carbon Sheets K13C2U/EX1515 [0/90/0)	2.2	K <sub>x</sub> = 206, K <sub>y</sub> = 103, K <sub>z</sub> = 1	100 $\mu$ m	300 $\mu$ m	1mm
Flex Tape	?	?	340 $\mu$ m	340 $\mu$ m	340 $\mu$ m
Chips (Silicon Sensors)	2.33	148	100 $\mu$ m	120 $\mu$ m	150 $\mu$ m
Glue (TenCate EX-1515)	1.17	0.169	100 $\mu$ m	120 $\mu$ m	150 $\mu$ m
Readout PCB	-	-	25x40x0.78mm	25x40x1.57mm	25x40x2,360mm

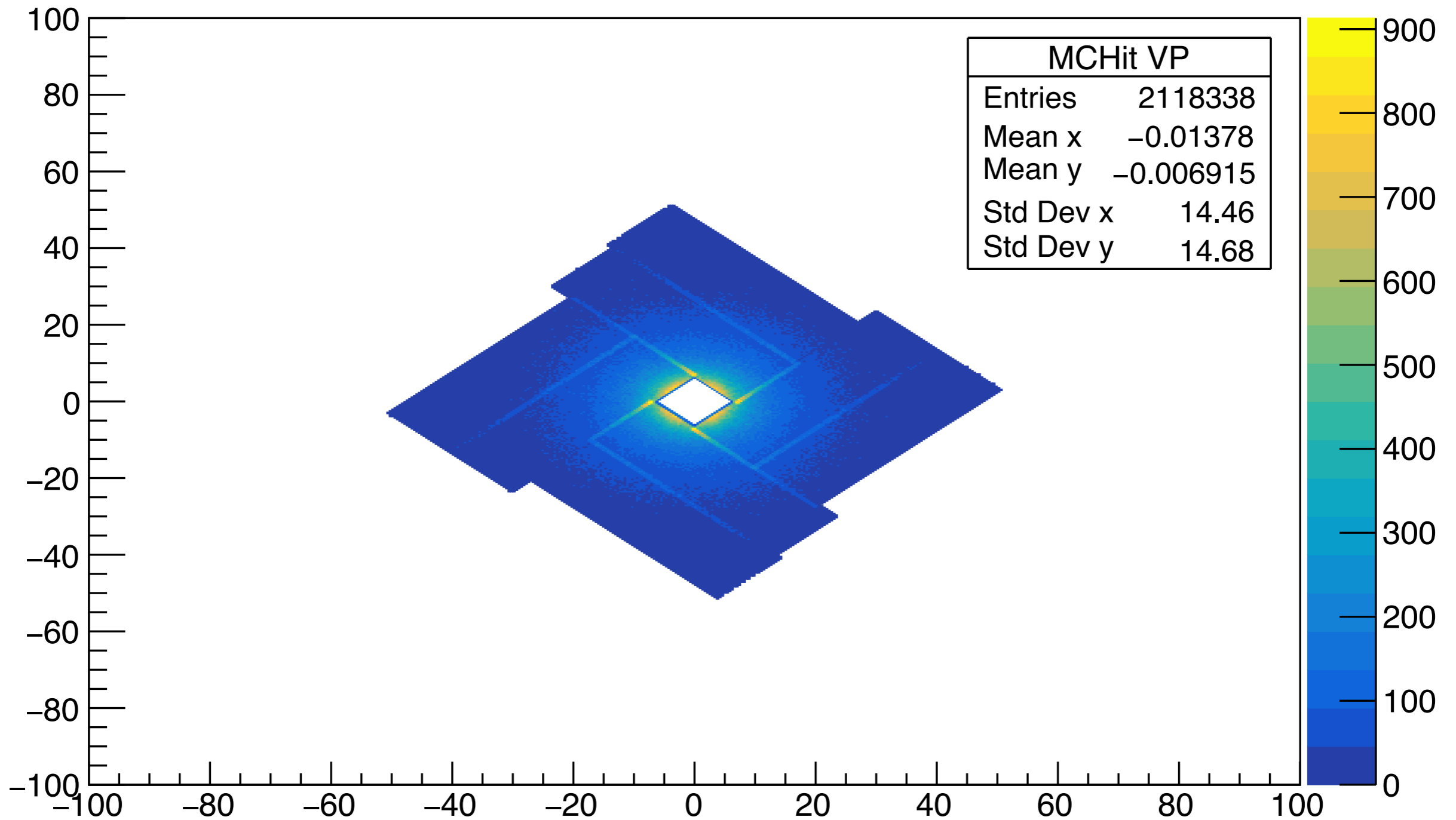


## Cross section view

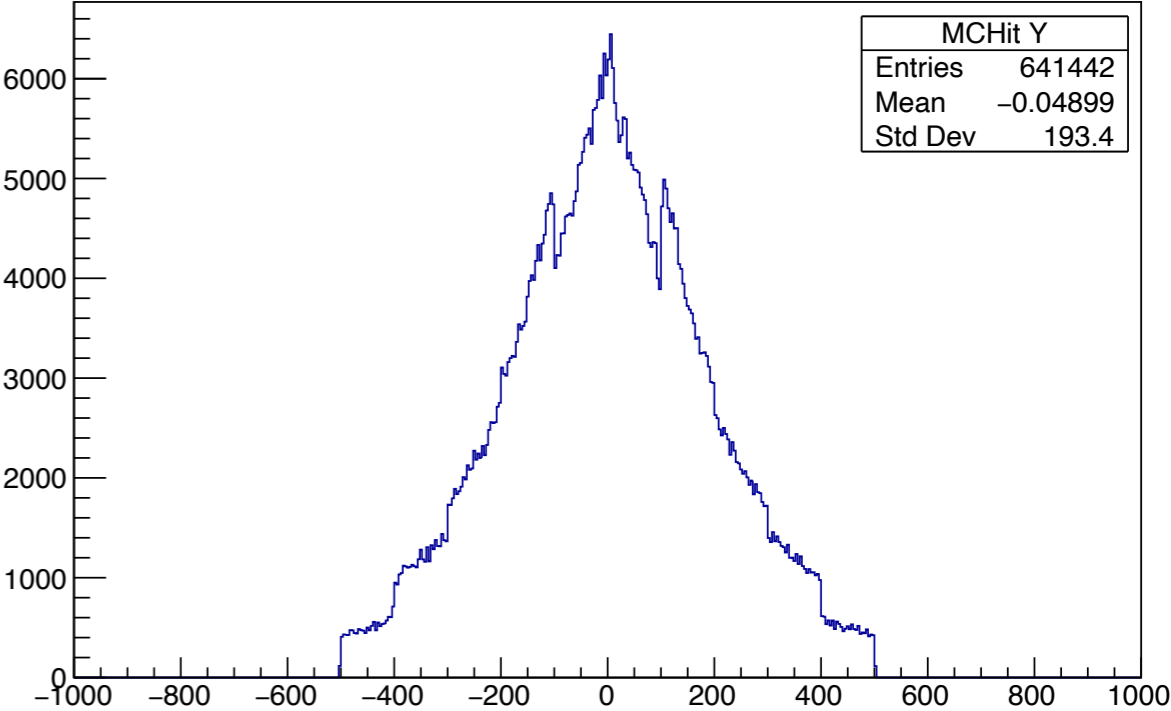
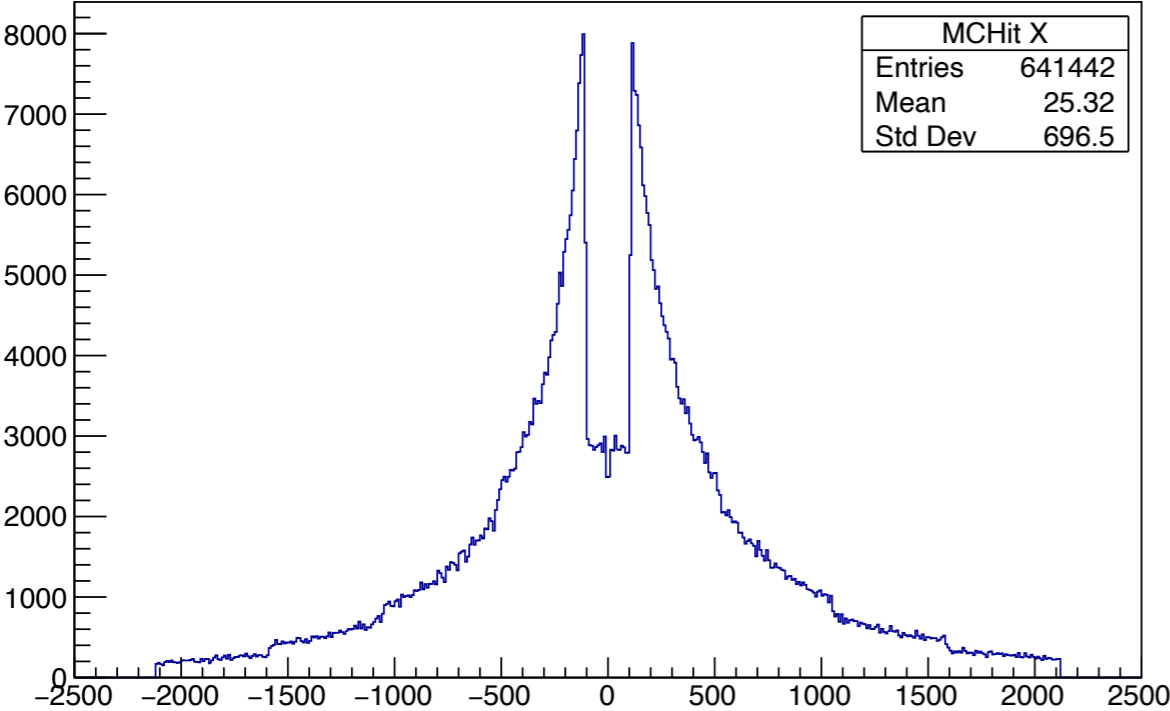




# Hit Map of Velo with magnetic field

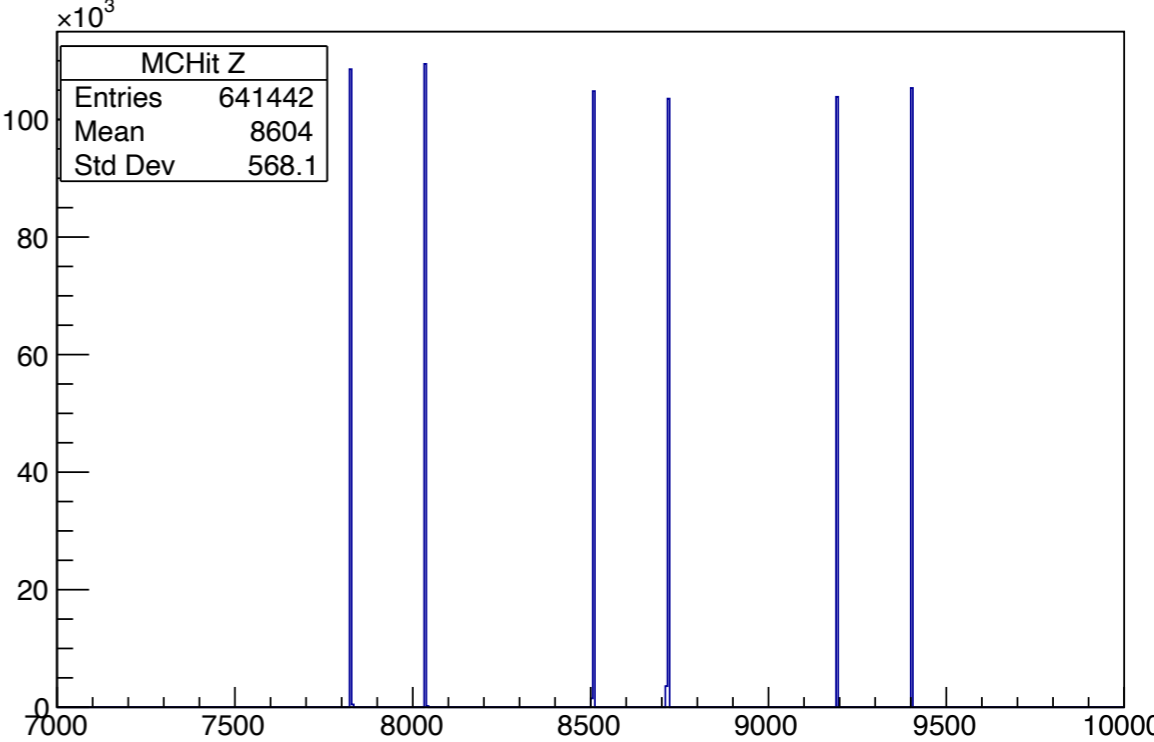


# Occupancy in X, Y and Z direction –Mighty Tracker



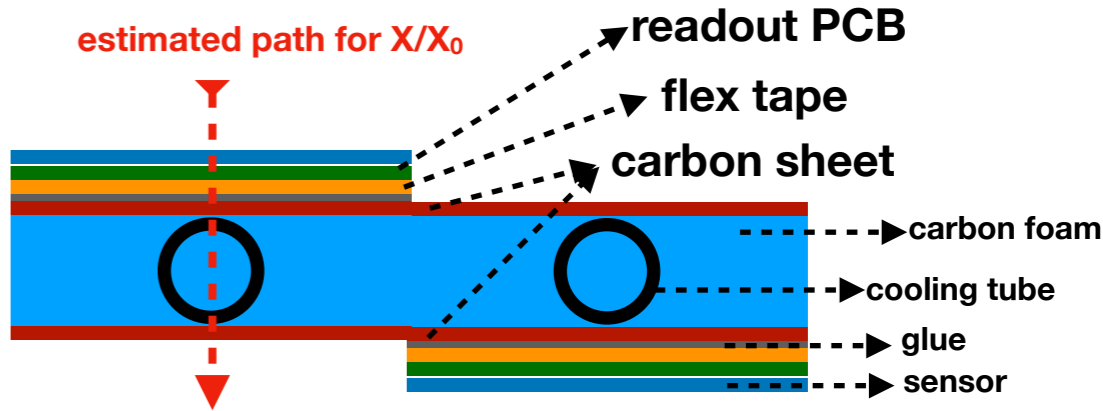
```

GenRndInit      INFO 1000 events processed
GenRndInit      INFO Measured event loop time (999) [ns]: 893503222760
GenRndInit      INFO Time per event: 0.893894 seconds.
GenMonitorAlg   INFO
===== Generators Statistics =====
=
= Number of particles generated: 3755299
= Number of events: 1000
= Mean multiplicity: 3755.3
=
= Number of pseudo stable particles generated: 1772059
= Number of events: 1000
= Mean pseudo stable multiplicity: 1772.06
=
= Number of charged stable particles generated: 541012
= Number of events: 1000
= Mean charged stable multiplicity: 541.012
=
= Number of charged stable particles in LHCb eta 112459
= Number of events: 1000
= Mean charged stable multiplicity in LHCb eta: 112.459
=
=====
    
```



# Material Budget - per layer (worst scenario)

Material Unit	Thickness $\mu\text{m}$	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite
Silicon	150	1	9.37	0.160	Si
Cooling tube	50	2	28.6	0.034	Kapton Polymide
Carbon foam	4200	1	185.65	0.226	C, Allcomp K9 130pp
Carbon sheet	1000	2	23.70	0.843	C, K13C2U/EX1515
Flex tape	340	1		0.428	Cu + Dielectric + FR4
Glue	150	1	35.49	0.042	TenCate EX-1515
PCB	2360	1	17.0	1.388	FR4
SUM				3.124	



\* **Option 3**  
 \* **with total  $X/X_0 = 3.12\%$**

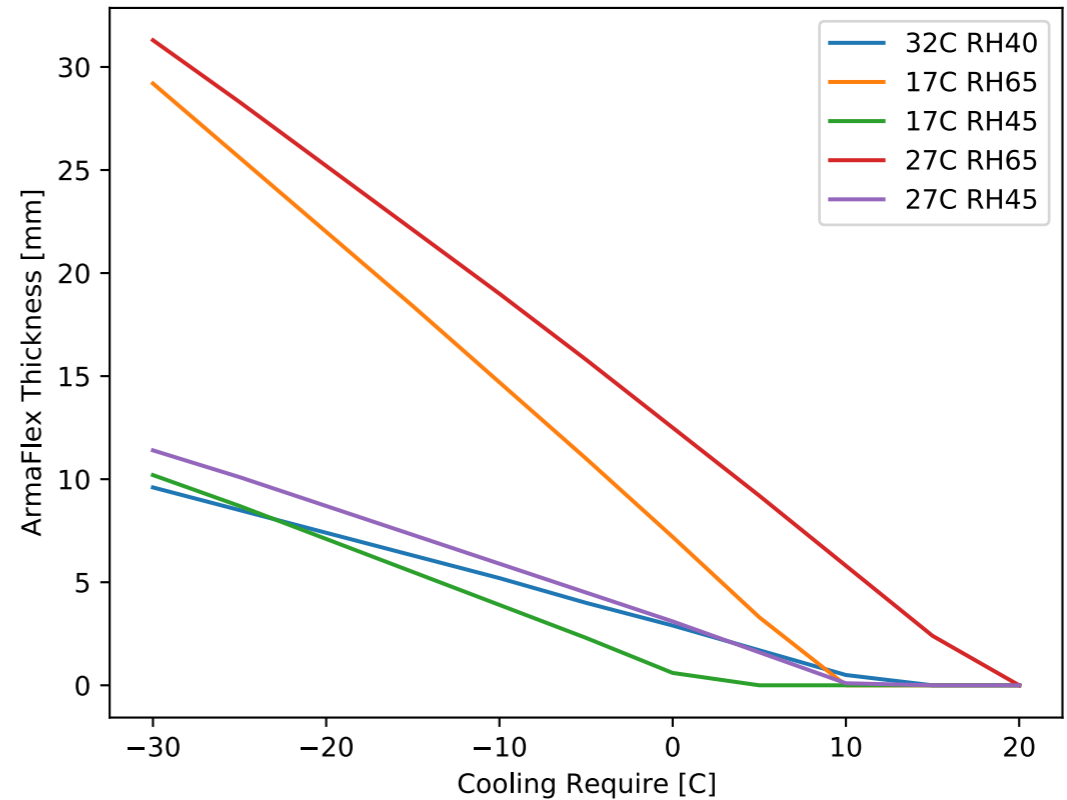
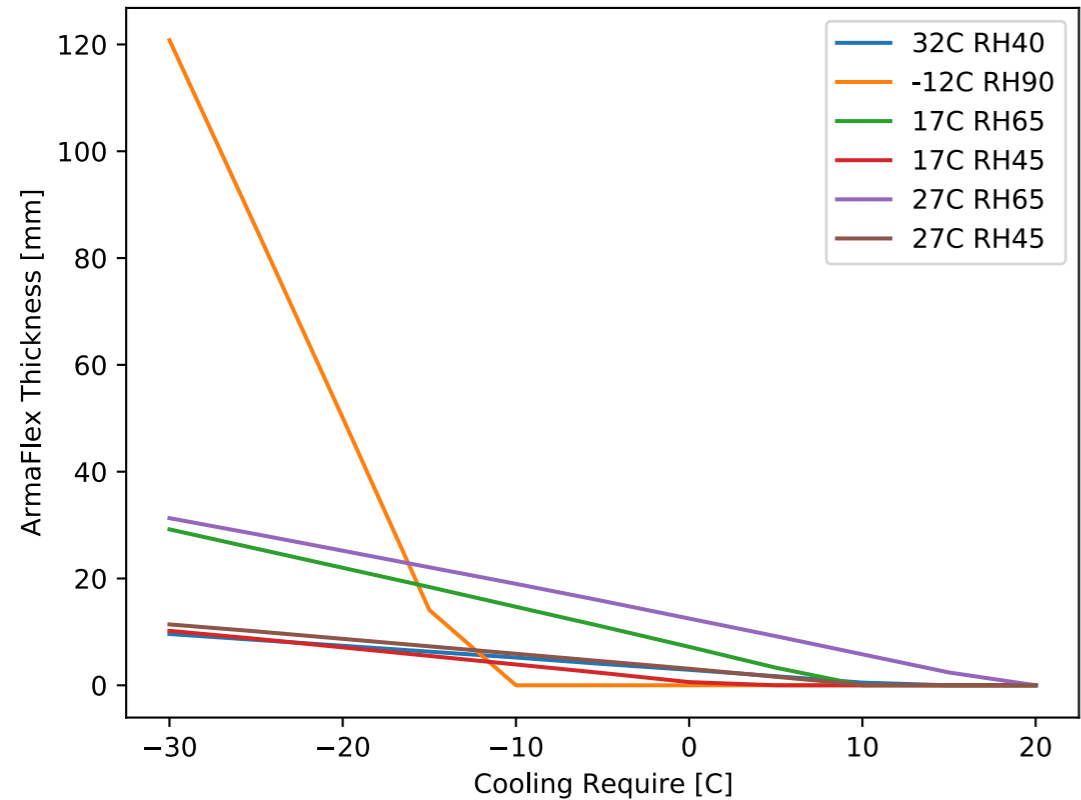
Material Unit	Thickness $\mu\text{m}$	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite
Silicon	120	1	9.37	0.128	Si
Cooling tube	50	2	28.6	0.034	Kapton Polymide
Carbon foam	3200	1	185.65	0.172	C, Allcomp K9 130pp
Carbon sheet	300	2	23.70	0.253	C, K13C2U/EX1515
Flex tape	340	1		0.356	Cu + Dielectric + Polymide
Glue	120	1	35.49	0.033	TenCate EX-1515
PCB	1570	1	17.0	0.923	FR4
SUM				1.902	

\* **Option 2**  
 \* **with total  $X/X_0 = 1.90\%$**

Material Unit	Thickness $\mu\text{m}$	Layers	$X_0$ (cm)	$X/X_0$ (%)	composite
Silicon	100	1	9.37	0.106	Si
Cooling tube	50	2	28.6	0.034	Kapton Polymide
Carbon foam	2200	1	185.65	0.118	C, Allcomp K9 130pp
Carbon sheet	100	2	23.70	0.084	C, K13C2U/EX1515
Flex tape	340	1		0.356	Cu + Dielectric + Polymide
Glue	100	1	35.49	0.028	TenCate EX-1515
PCB	780	1	17.0	0.458	FR4
SUM				1.188	

\* **Option 1**  
 \* **with total  $X/X_0 = 1.19\%$**

# Thermal Isolation Materials - assuming copper inside the thermal box



- \* **The thermal isolation materials : AF/Armaflex Class O (45 - 65 kg/m<sup>3</sup>)**
- \* **Estimating the thickness with ArmaWin providing from the manufacturer**
- \* **AIR CONDITIONING OF THE LHCb EXPERIMENTAL AND PROTECTED AREAS**
- \* **EXTREME OUTSIDE CONDITIONS:**  
**Summer: Dry bulb temperature Relative humidity +32°C 40%RH**  
**Winter: Dry bulb temperature Relative humidity -12°C 90%RH**
- \* **INDOOR CONDITIONS**  
**Supply air: dry bulb temperature +17°C dew point <+10°C**  
**Extraction air: dry bulb temperature <+27°C dew point <+12°C**

# Thermal Insulation Material

- \* The thermal insulation materials : AF/Armaflex Class O (45 - 65 kg/m<sup>3</sup>)
- \* UT uses AIREX + (ArmaFlex)
- \* Aerogel is also to be considered
  
- \* Take one of the synthetic rubber as example to calculate the radiation length: SBR (Styrene-butadiene rubber, 75% butadiene (CH<sub>2</sub>=CH-CH=CH<sub>2</sub>) and 25% styrene (CH<sub>2</sub>=CHC<sub>6</sub>H<sub>5</sub>)) with density 0.055 g/cm<sup>3</sup> .



Trade name: AF/Armaflex

Current version : 5.0.0, issued: 31.03.2017

Replaced version: 4.0.0, issued: 30.01.2017

Region: GB

## SECTION 3: Composition/information on ingredients

### 3.1 Substances

Not applicable. The product is not a substance.

### 3.2 Mixtures

#### Chemical characterization

reticulated foam based on synthetic rubber (elastomer)

#### Hazardous ingredients

This product does not contain substances to be mentioned according to EU Regulation No 1907/2006 (REACH), annex II.

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