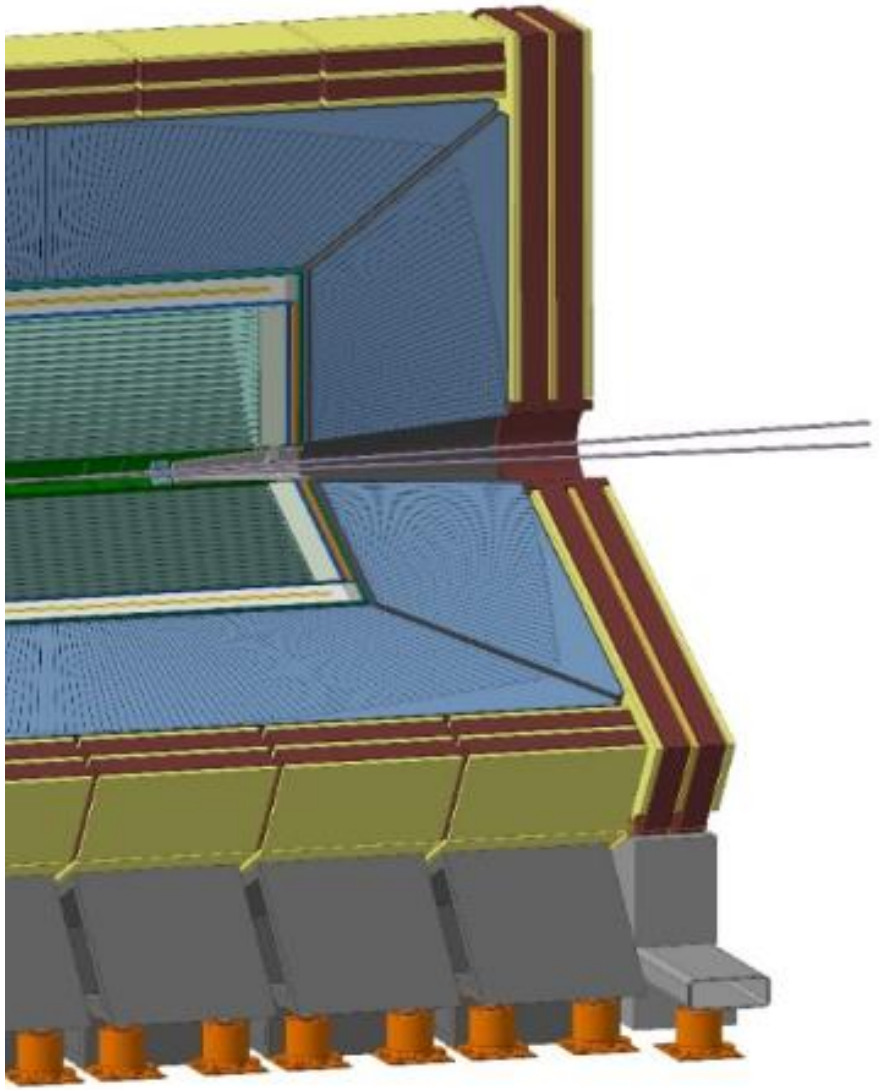
Mahmoud Ali

FULL SIMULATION OF IDEA MUON SYSTEM

7th FCC Physics Workshop, Annecy, 31 January 2024.



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UNIVERSITÀ DI BOLOGNA

INFN
Istituto Nazionale di Fisica Nucleare

FUTURE
CIRCULAR
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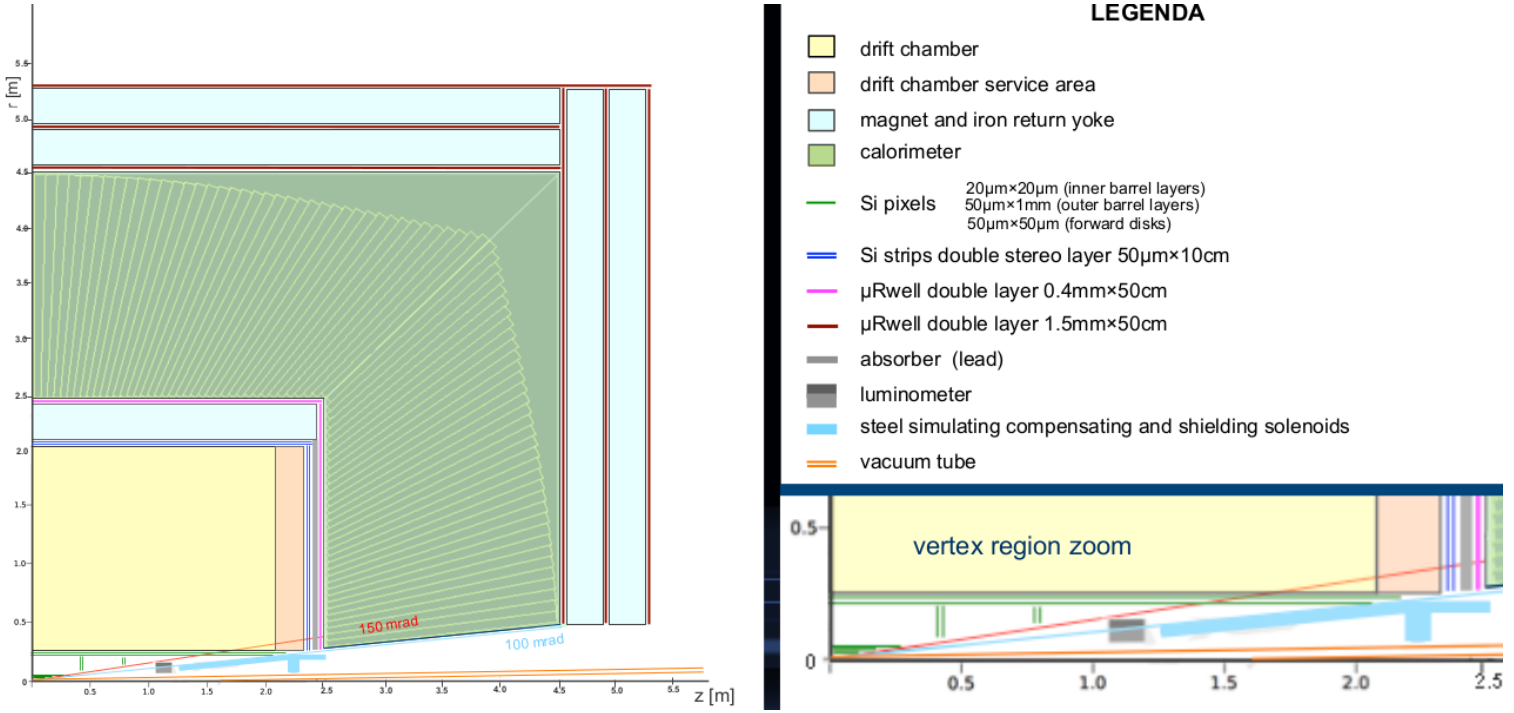
IDEA Muon system

IDEA detector concept foresees a muon detection system that would be realized using the μRWELL[1] technology.

Each station will consist of a large mosaic of 50 × 50 cm^2 μRWELL detectors.



IDEA detector layout

[1] JINST 10 (2015), P02008.

μRWELL detector technology

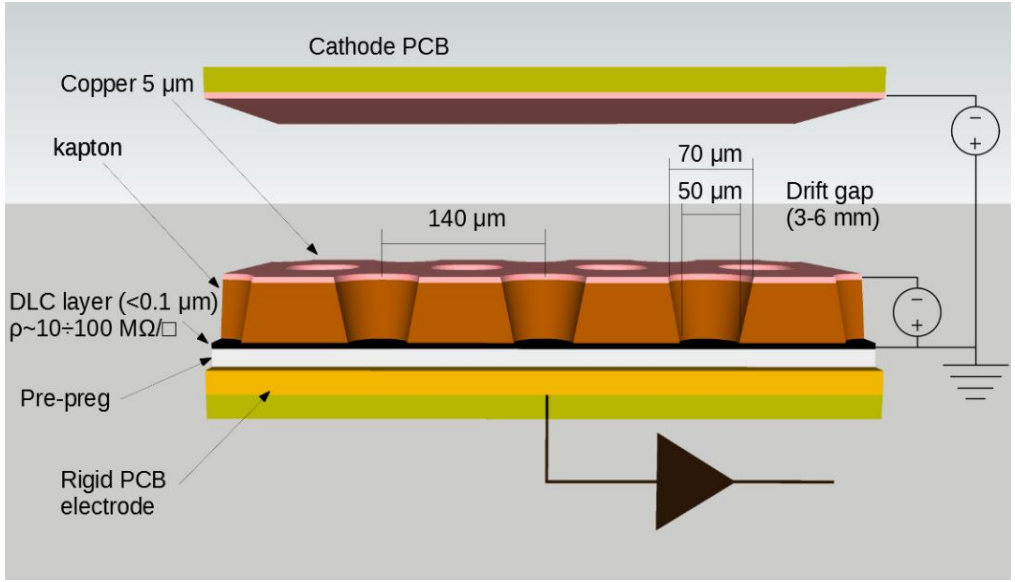
One promising detector technology that has gained attention in recent years is the micro Resistive-WELL (μRWELL) detector. The μRWELL detector offers several advantages, including excellent spatial resolution, fast response times, and radiation tolerance. It combines the advantages of **micro-pattern gas detectors** and **resistive plate chambers**, making it a promising candidate for various particle physics experiments.

The μRWELL is a single-amplification stage resistive MPGD. The baseline version of the μ-RWELL_PCB is composed of three layers:

1. A well-patterned single copper-clad polyimide foil acting as the amplification stage.

2. A resistive layer realized with a Diamond-Like-Carbon (DLC) film working as the discharge limitation stage.

3. A standard PCB for readout purposes.



Full-Sim of the muon system

IMPLEMENTATION OF THE MUON SYSTEM IN **DD4HEP**

The implementation of the muon system has been through two tracks:

1. As a first approach as a **simple cylindrical shaped**, which describe the muon system as layers of cylinders contains the different materials of our detector.
2. Then gradually a description of more complex and **detailed muon system**, which describe the mosaics of 50 × 50 cm^2 detailed μRWELL chambers.

The advantage of a simple description approach is to provide us with:

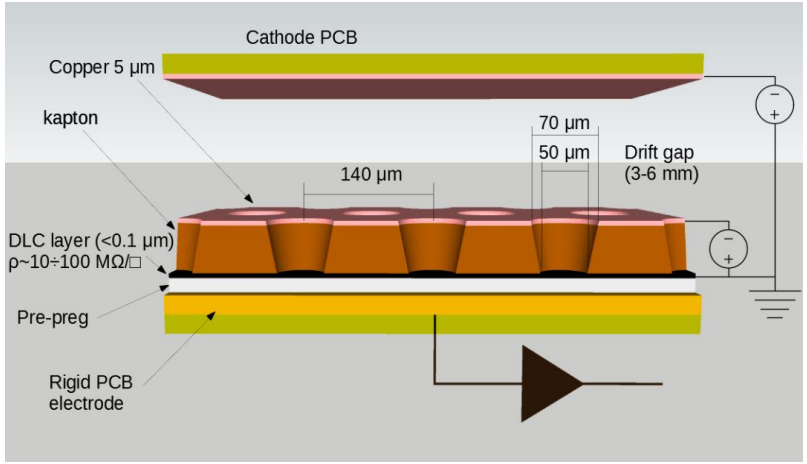
- A functional version in a short time, facilitating numerous pertinent physics investigations.
- It offers great adaptability, considering that the muon chamber, being the final detector in the sequence, is susceptible to adjustments necessitated by alterations in other sub-detectors.

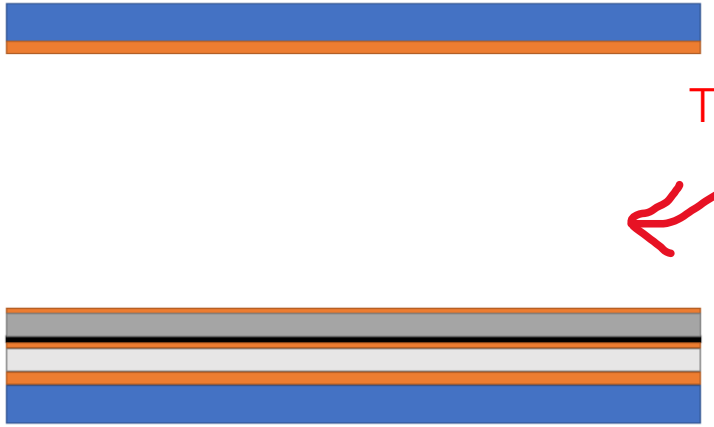
Full-Sim of the muon system

SIMPLE CYLINDRICAL SHAPED

- A complete description of the materials of the μRWELL and the geometry of the system has been done.

Component	Thickness of each layer	Material
	1.6 mm	FR_4
Cathode	35 μm	Copper
Gas gap	6 mm	$ArCO_2CF_4$
	5 μm	Copper
	50 μm	Kapton
	0.1 μm	DLC
μ-RWELL + readout PCB	35 μm	Copper
	100 μm	Film glue (same DLC density)
	35 μm	Copper
	1.6 mm	FR_4



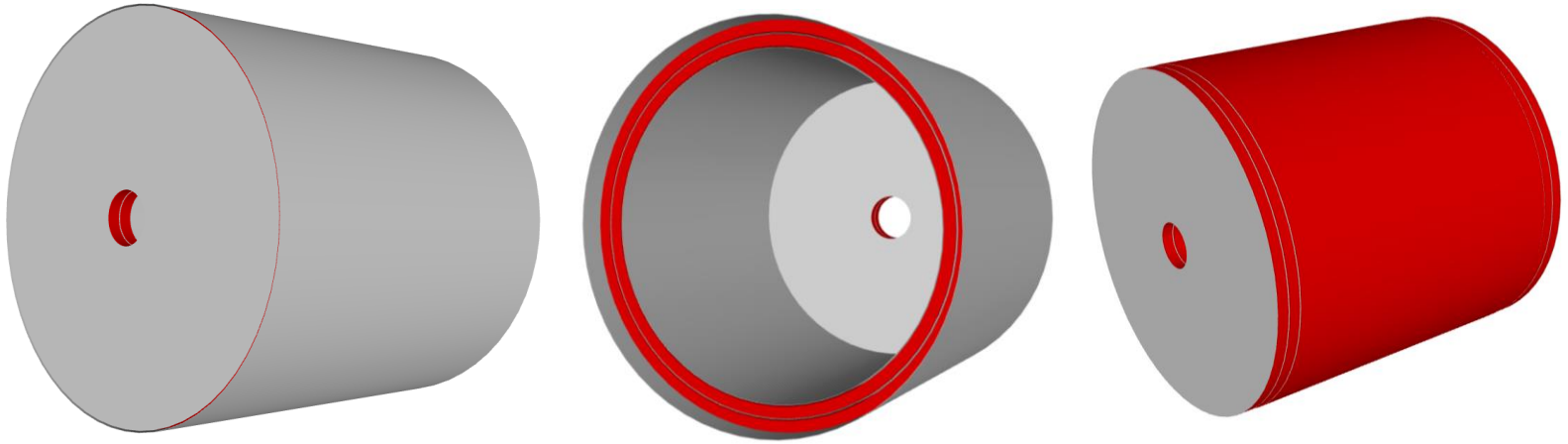


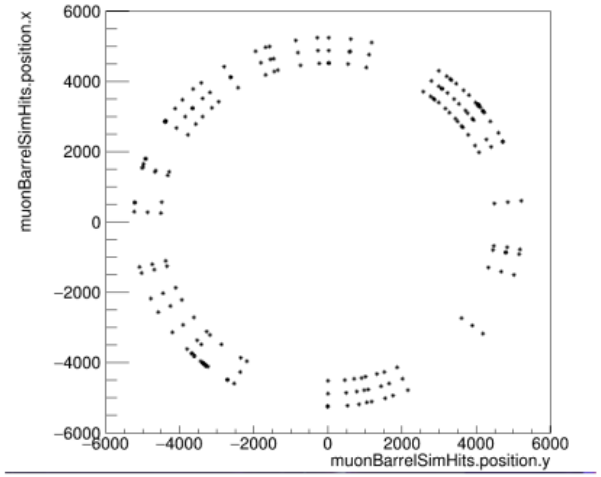
A schematic view of the various layers involved in the description of the μ-RWELL detector

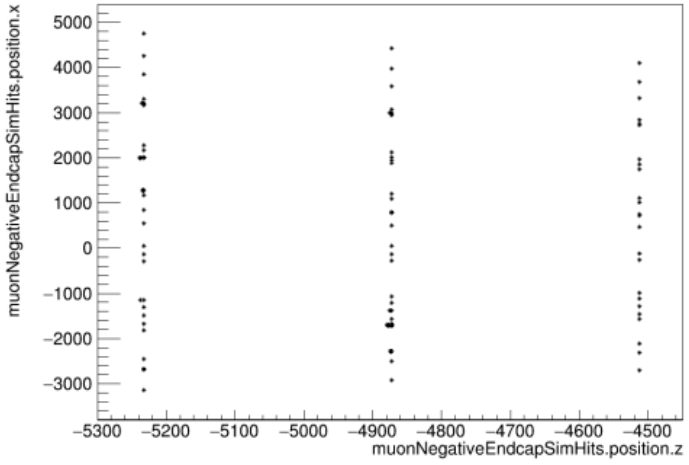
Full-Sim of the muon system

SIMPLE CYLINDRICAL SHAPED

- A complete description of the muon system as a simple cylindrical shape has been done.
- A readout system has been implemented for the cylindrical shape, with a segmentation in ϕ and θ direction to match the foreseen strip pitch.





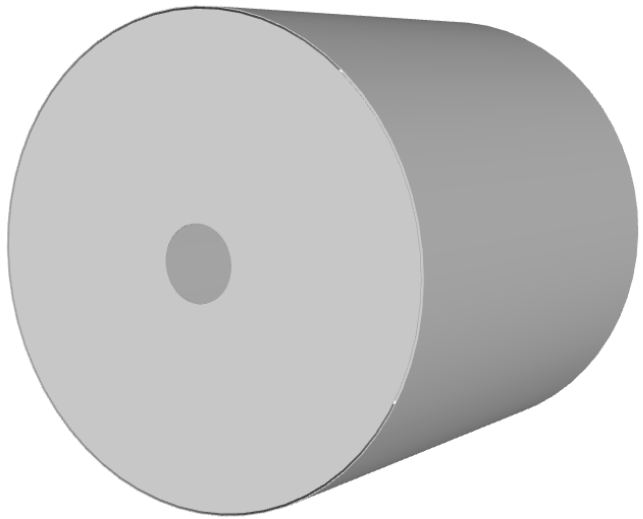


Left: SimHits from the barrel muon system. **Right:** SimHits from one of the endcap muon system.

Full-Sim of the Preshower

SIMPLE CYLINDRICAL SHAPED

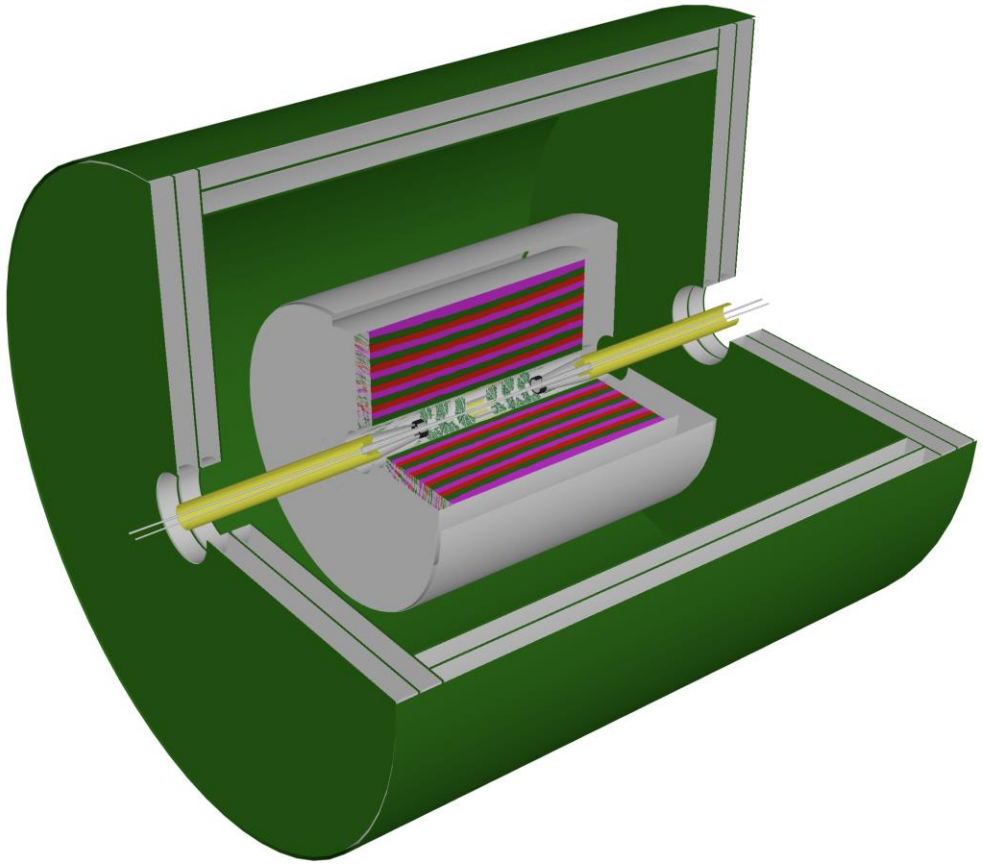
- Since the Preshower will be built with the same technology, the same code of the muon system can be used to describe the Preshower.
- A complete description of the Preshower as a simple cylindrical shape has been done.



IDEA Full Sim

SIMPLE CYLINDRICAL SHAPED

- The simple Muon System and Pre-shower have been included in the full IDEA DD4hep implementation.



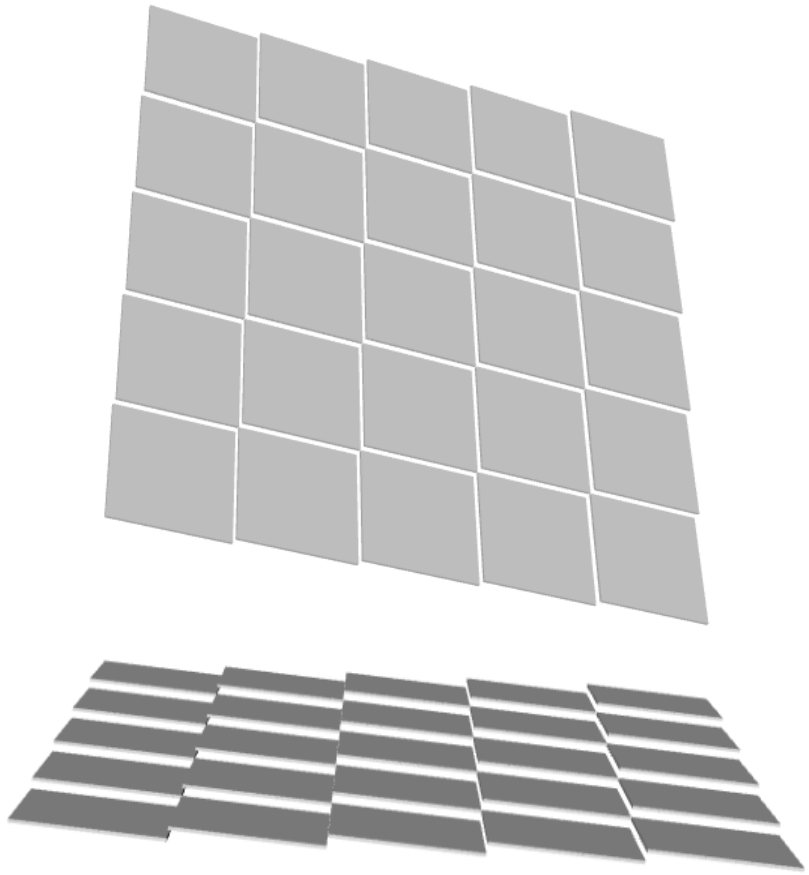
From Brieuc talk

Full-Sim of the muon system

DETAILED VERSION OF THE MUON SYSTEM

The aims:

- Building the muon system based on 50 × 50 cm^2 μRWELL chambers.
- Taking into account the overlap between the chambers in 2 dimensions (to minimize the dead area as much as possible).
- A readout system for every single chamber has been created (CartesianGridXY).



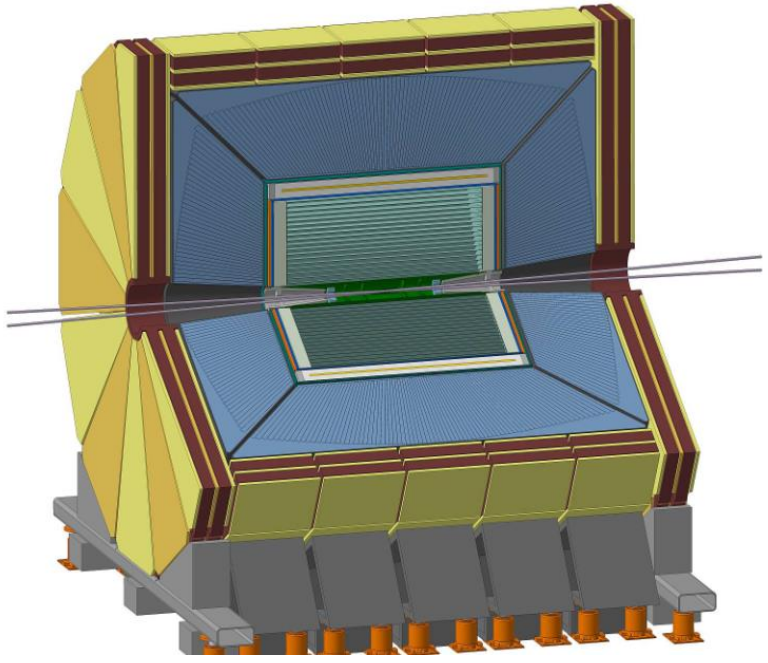
- **The structure of the detector starting from creating an envelope for the side volume, which contains an array of our μRWELL chambers.**
- **Then the envelope will be copied in different rotation angles to create the barrel part.**

Full-Sim of the muon system

DETAILED VERSION OF THE MUON SYSTEM

The aims:

• Making the design flexible, where the user can choose the number of sides of the shape (hexagon, octagon, ….), and automatically the builder will calculate the number and places of the copied chambers.



Full-Sim of the muon system

DETAILED VERSION OF THE MUON SYSTEM

The aims:

• Making the design flexible, where the user can choose the number of sides of the shape (hexagon, octagon, ...), and automatically the builder will calculate the number and places of the copied chambers.

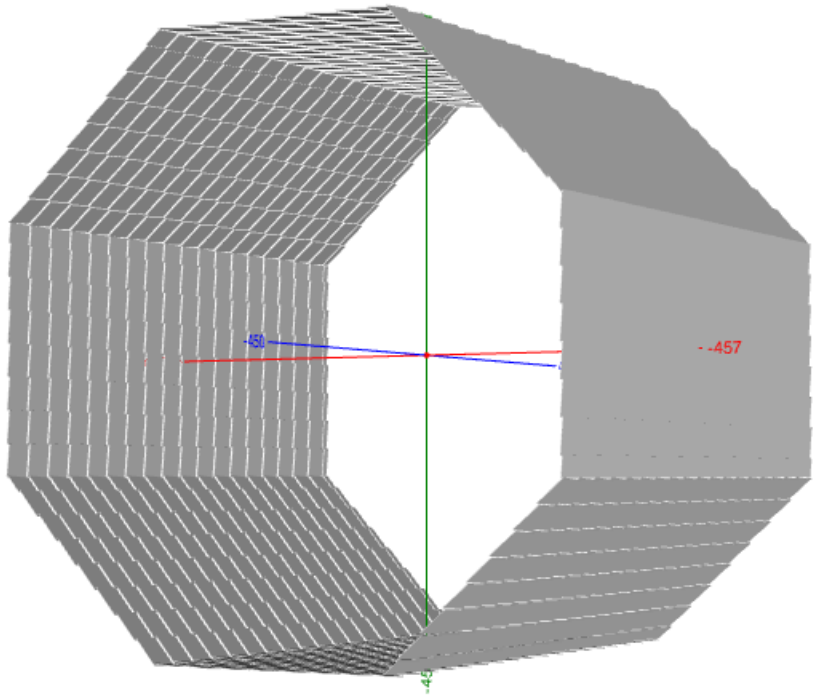
```
<!-- Specify the detector paramenters and the overlap -->
<detectorParameters radius="4520*mm" barrelLength="9000*mm" numSides="8" overlapY="1*cm" overlapZ="1*cm" />
```

The user only needs to enter in the xml file: the **inner radius**, his detector **barrel length**, and the **number of the detector sides** and his detector barrel will be ready.

DETAILED VERSION OF THE MUON SYSTEM

OCTAGON SHAPE AS AN EXAMPLE:

- An Octagon shaped **barrel** part of the muon system depending on 50*50 cm^2 chambers.

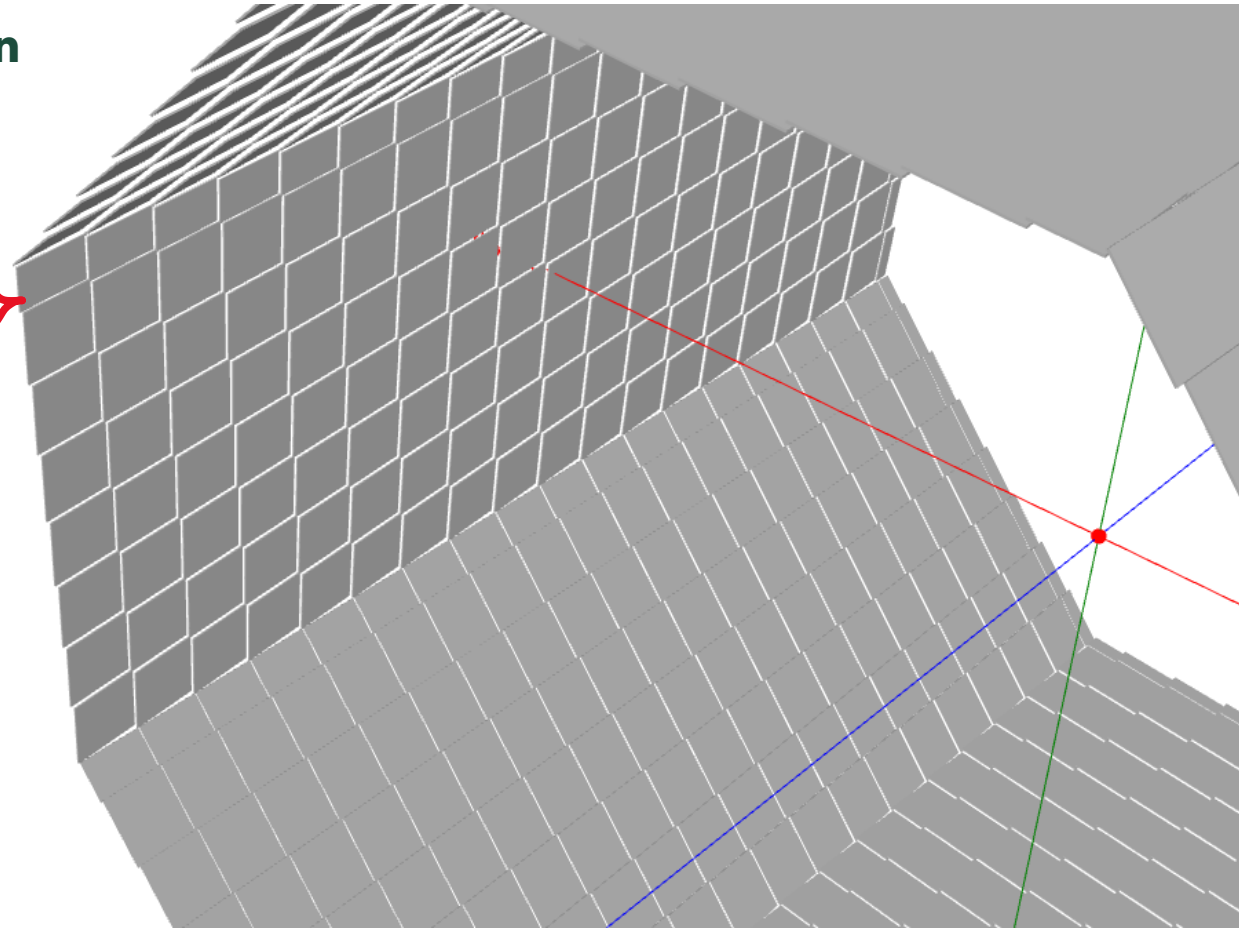


If the side length do not fit with an integer number of $50 \times 50\ cm^2$, the builder can make a chamber with unusual dimensions, which can fit the excess area at the end of the side (the R&D group makes this option available in manufacturing too).

Example:

08

Sides detector, depending on $50*50\ cm^2$ chambers.

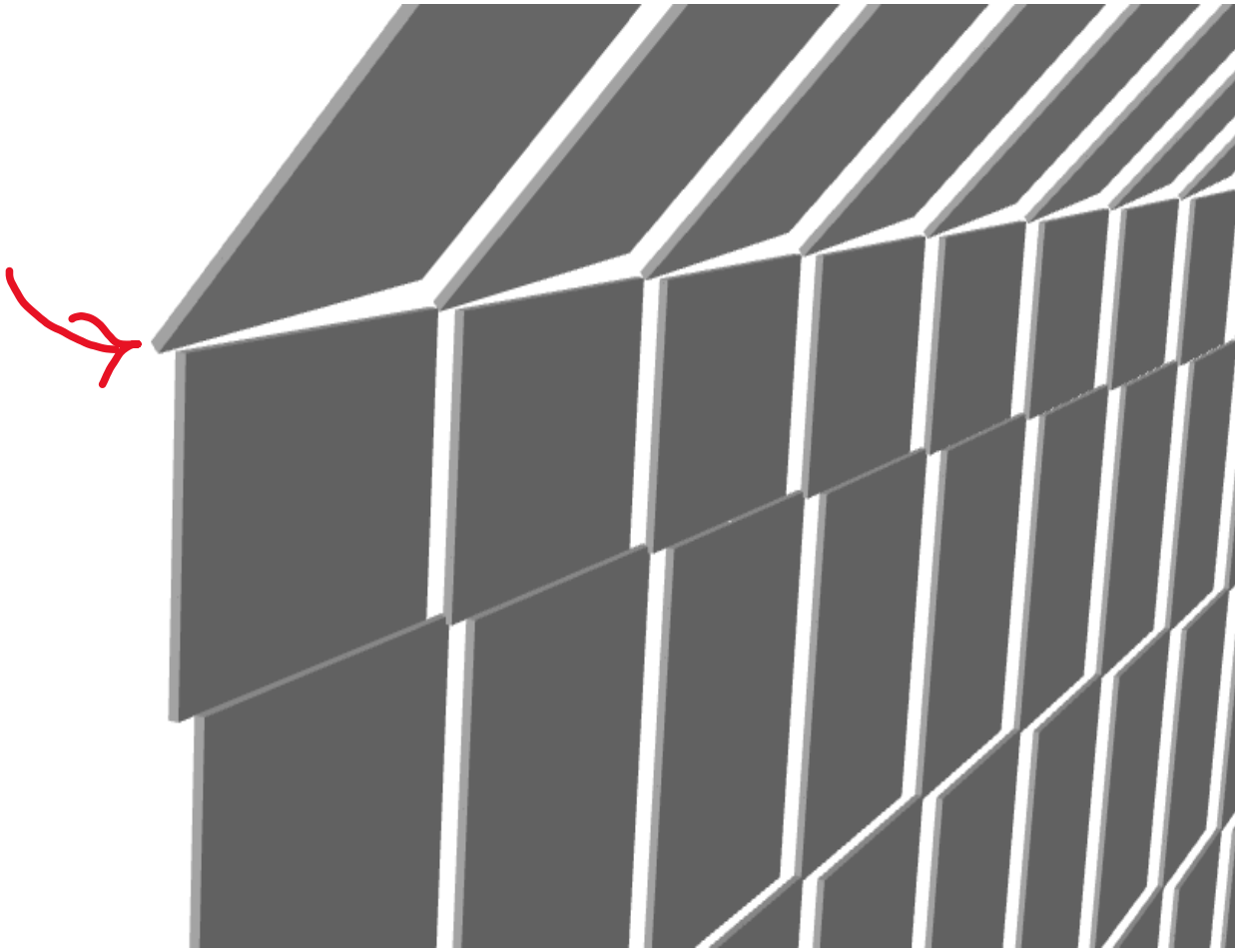


There is another idea of keeping the same chamber (PCB) size but changing (automatically) the overlapping area (Still not implemented).

The sides too have overlap with a slight rotation to avoid the intersection.

Example: 08

Sides detector, depending on 50*50 cm^2 chambers.

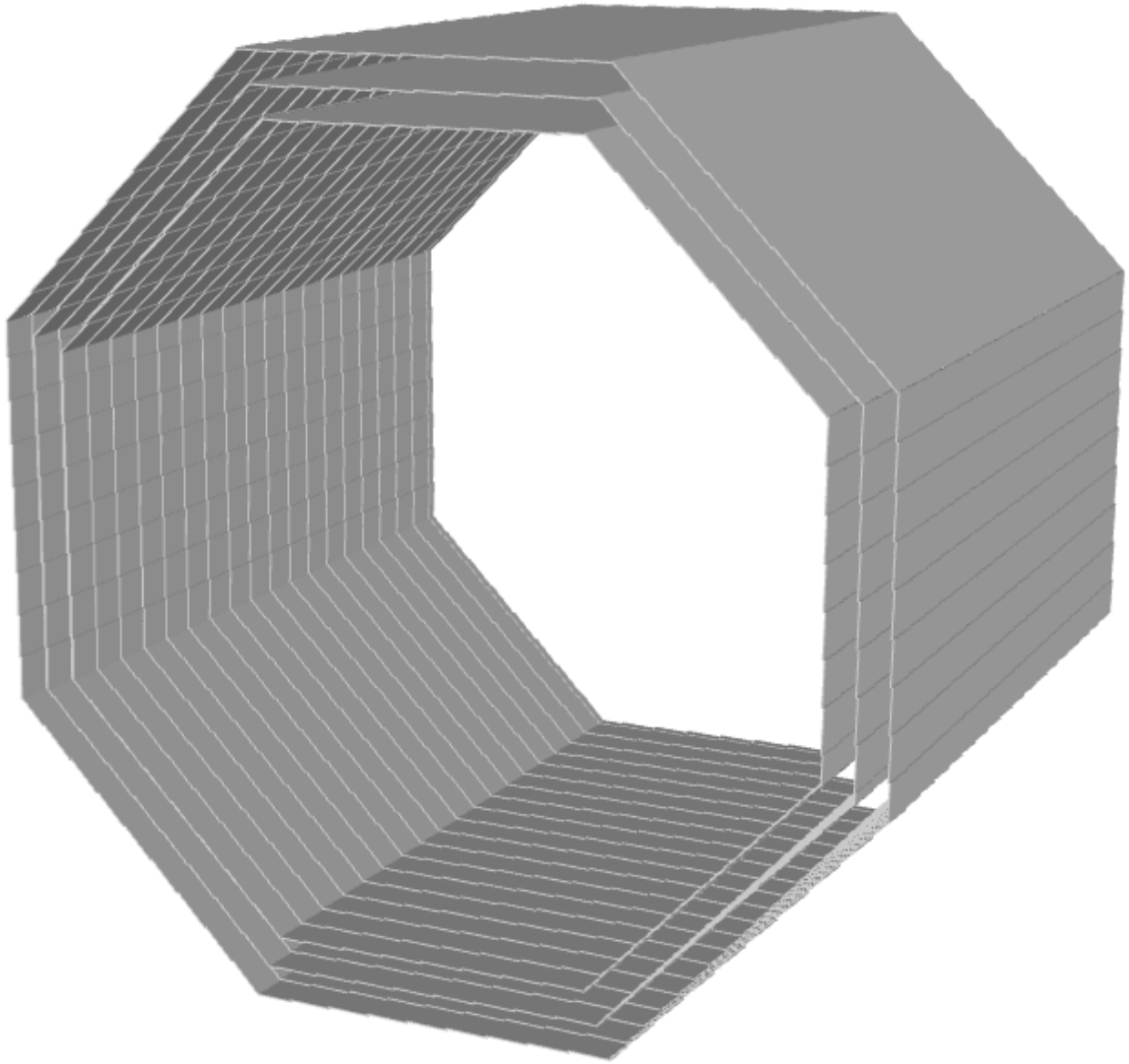


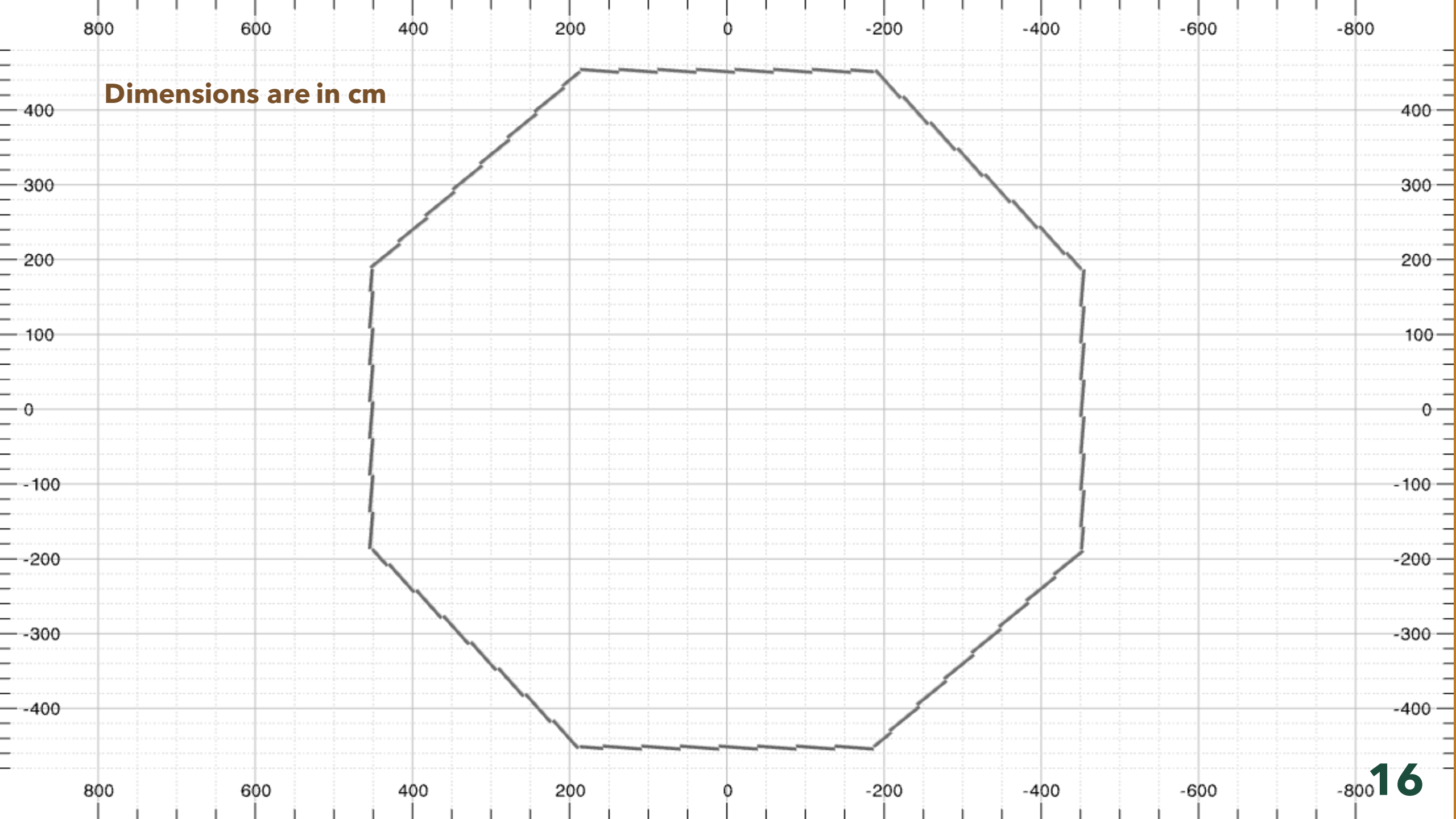
The availability to make multiple layers with different inner radius and barrel length.

Example:

08

Sides detector, depending on 50*50 cm^2 chambers.




Dimensions are in cm
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-600
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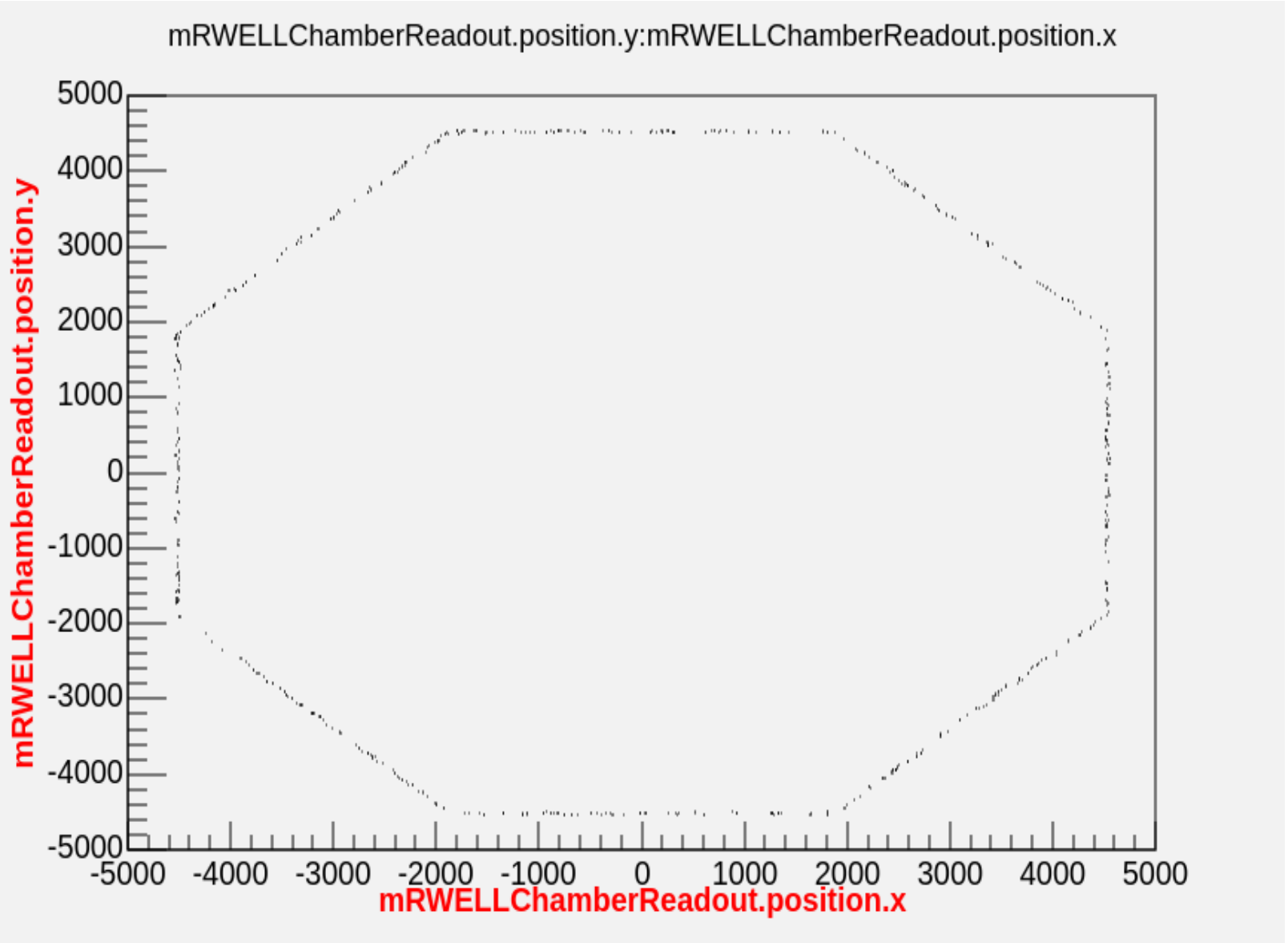
-300
-400

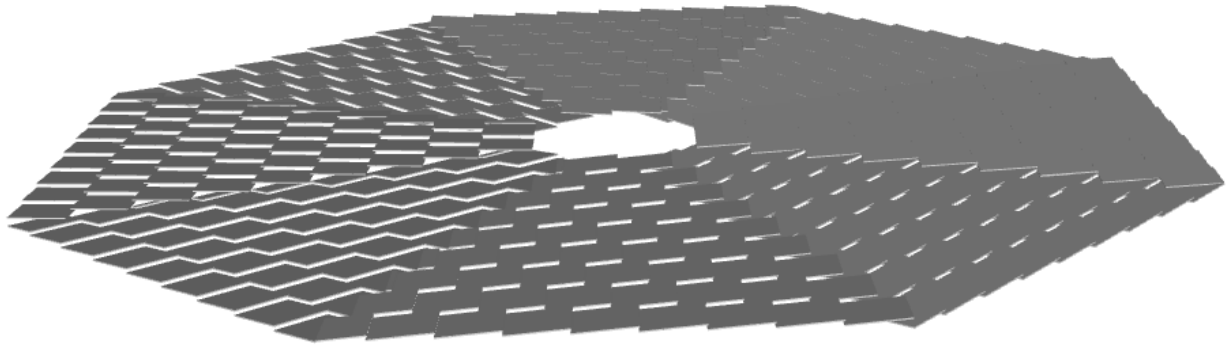
Simulation of 1000 muon hits as it appears in our chambers sensitive area for a single layer taking the octagon shape.

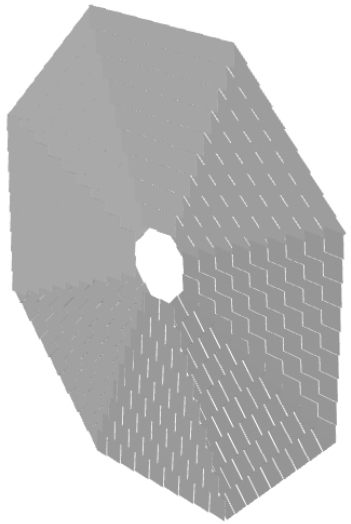


DETAILED VERSION OF THE MUON SYSTEM

OCTAGON SHAPE AS AN EXAMPLE:

- An Octagon shaped **endcap-**part of the muon system depending on 50*50 cm^2 chambers.
- Divided into 8-sides overlapping over each other.
- The same properties like the barrel: Creating chambers of unusual dimensions to fill the gaps.



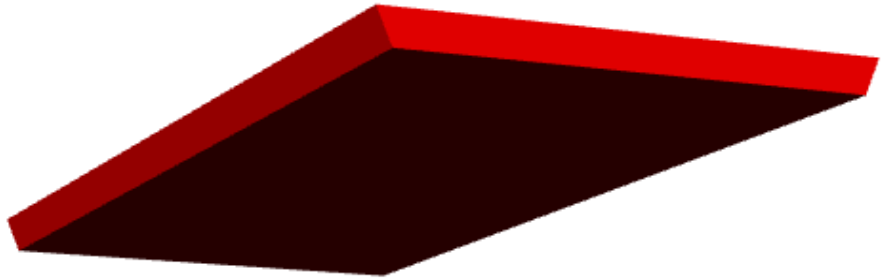


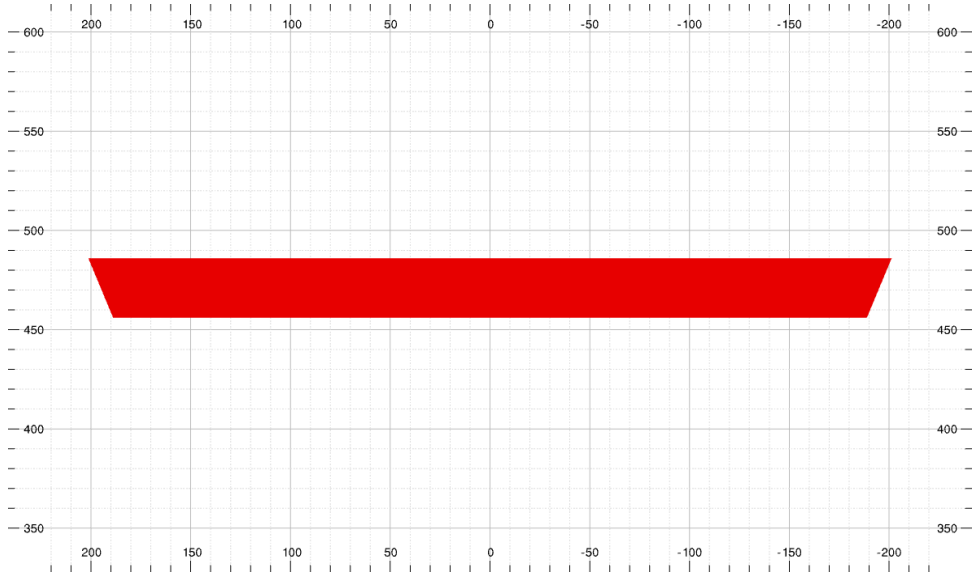
The code is very general, which can be used to describe any detector system made from repeated tiles, with having the capability to fill the gaps with unusual dimensions tiles.

Full-Sim of the muon system

IMPLEMENTATION OF THE IRON-YOKES

- I have described the yokes on the shape of trapezoid along Z-axis, taking the full length of the detector.
- The angle of the trapezoid is the same angle of the detector shape (octagon , hexagon, ...). That will assure they will perfectly meet at the corner without intersections.

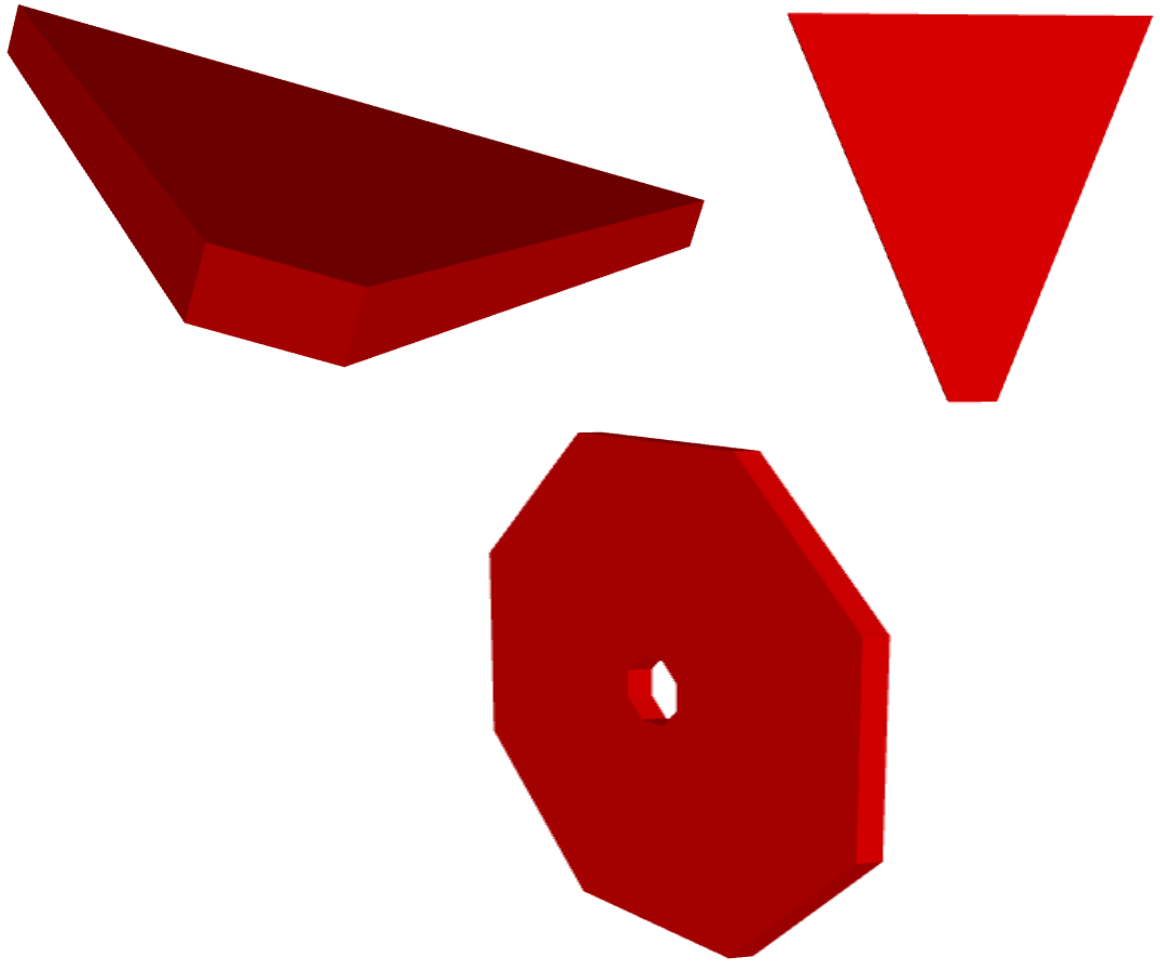




Full-Sim of the muon system

IMPLEMENTATION OF THE IRON-YOKES

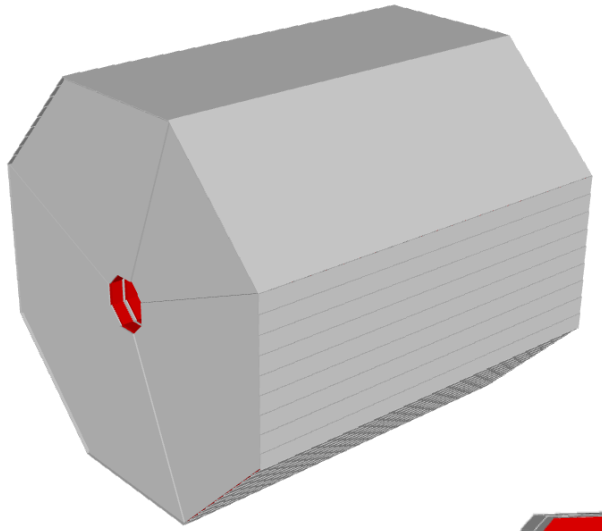
- In the endcap, I divided the yoke into # of parts = # of the shape sides.
- The angle of the trapezoid is the same angle of the detector shape (octagon , hexagon, ...). That will assure they will perfectly meet at the corner without intersections.

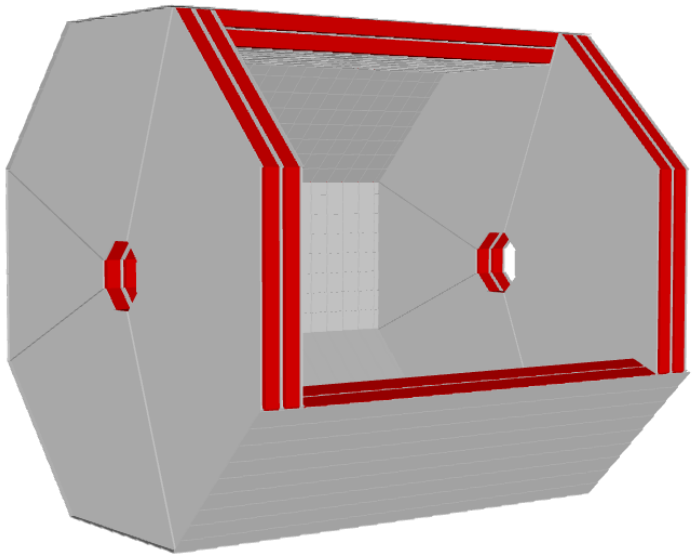


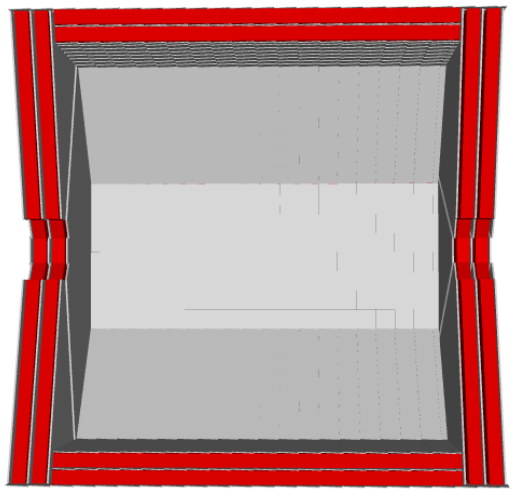
Full-Sim of the muon system

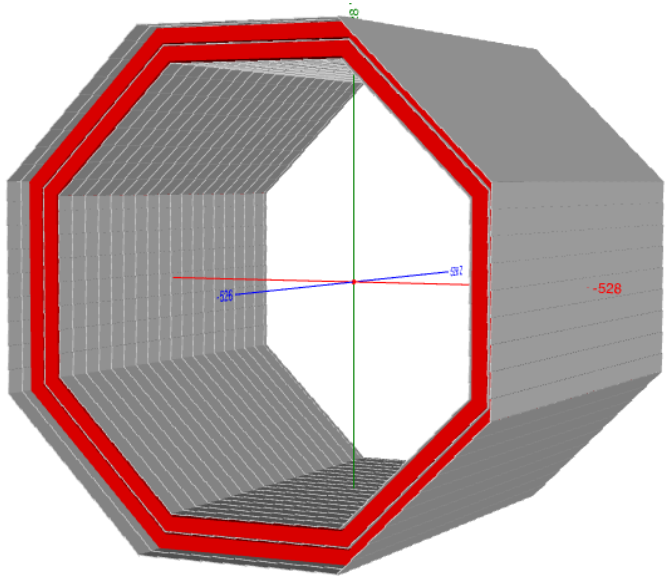
FULL MUON SYSTEM GEOMETRY

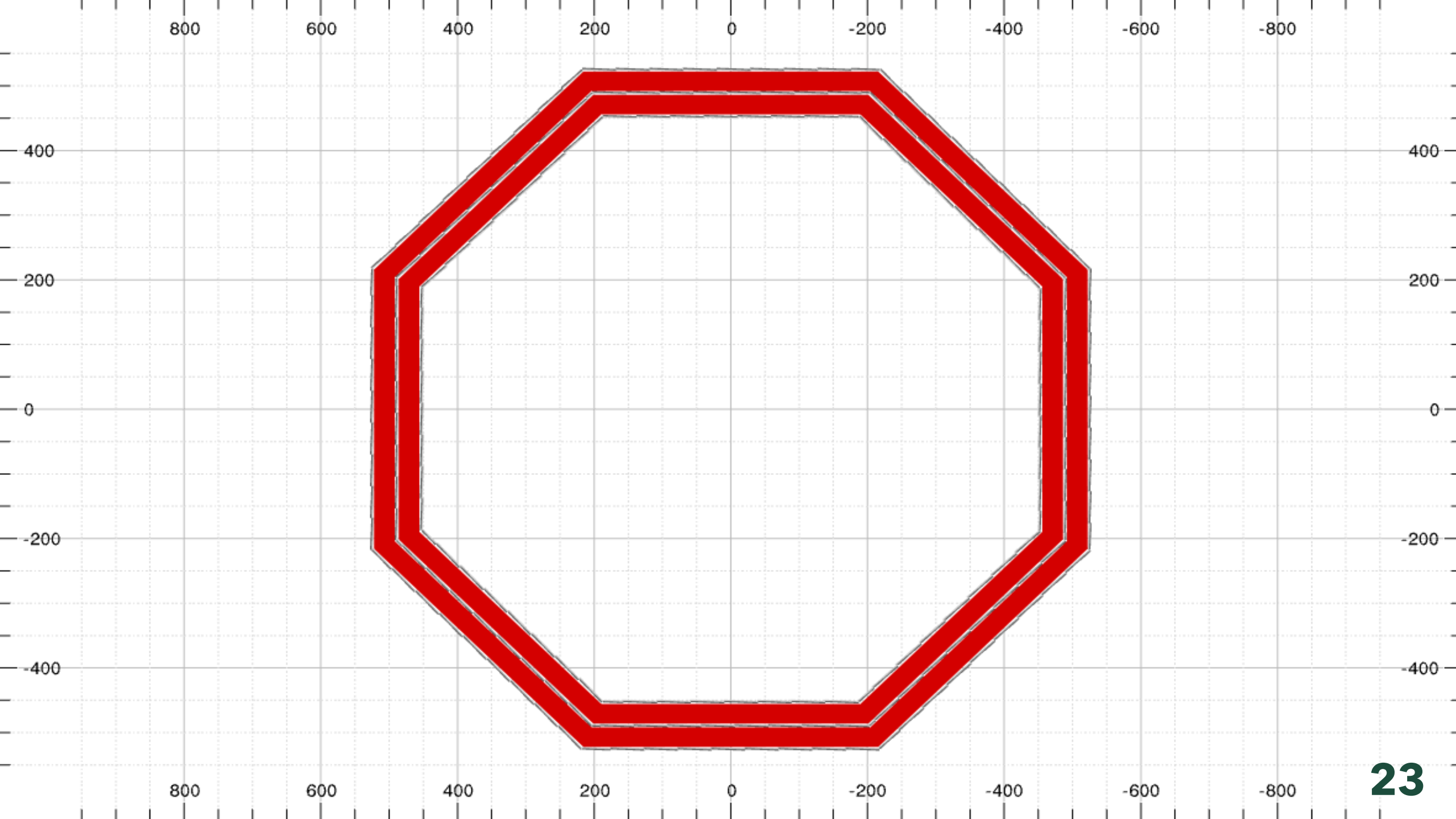
- A first draft of the **detailed version of the muon system** geometry implementation is ready.










800
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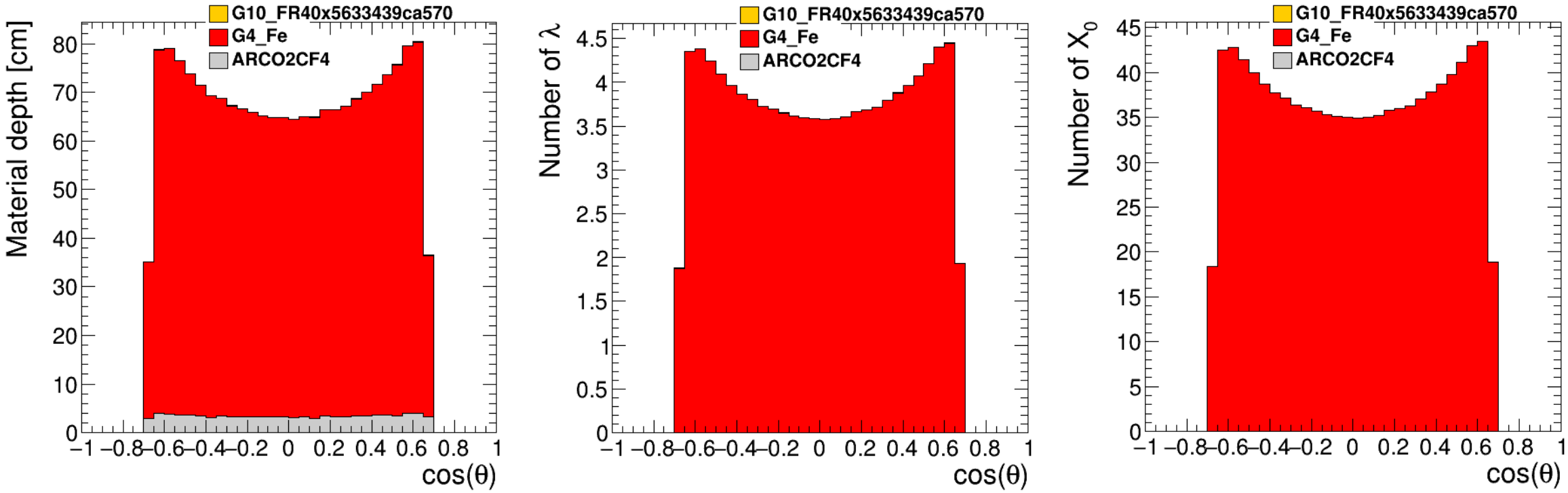
-200
-400

Full-Sim of the muon system

STUDY OF THE MATERIAL BUDGET OF THE MUON BARREL SYSTEM



Left: The depth of the material. **Middle:** # of interaction lengths. **Right:** # of radiation lengths.

Recall

Full-Sim of the muon system

DETAILED VERSION OF THE MUON SYSTEM

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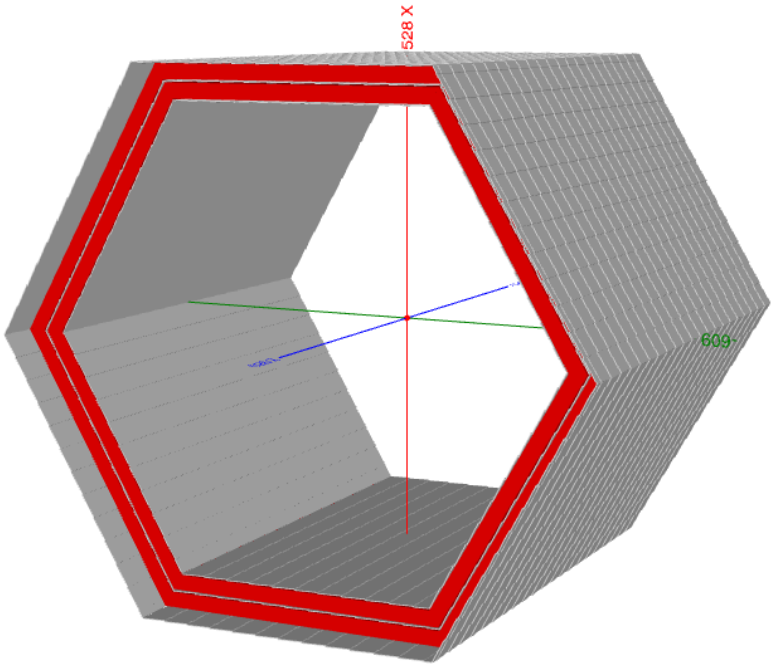
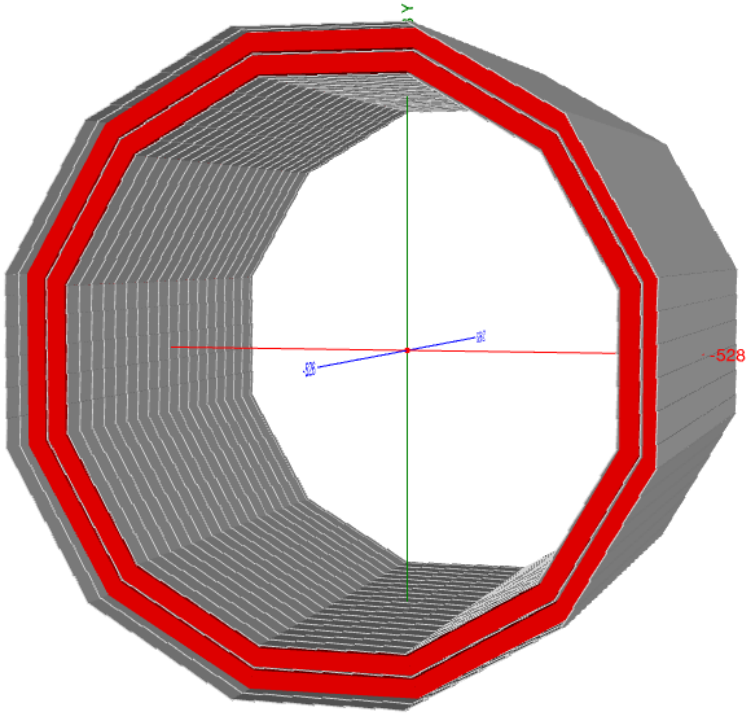
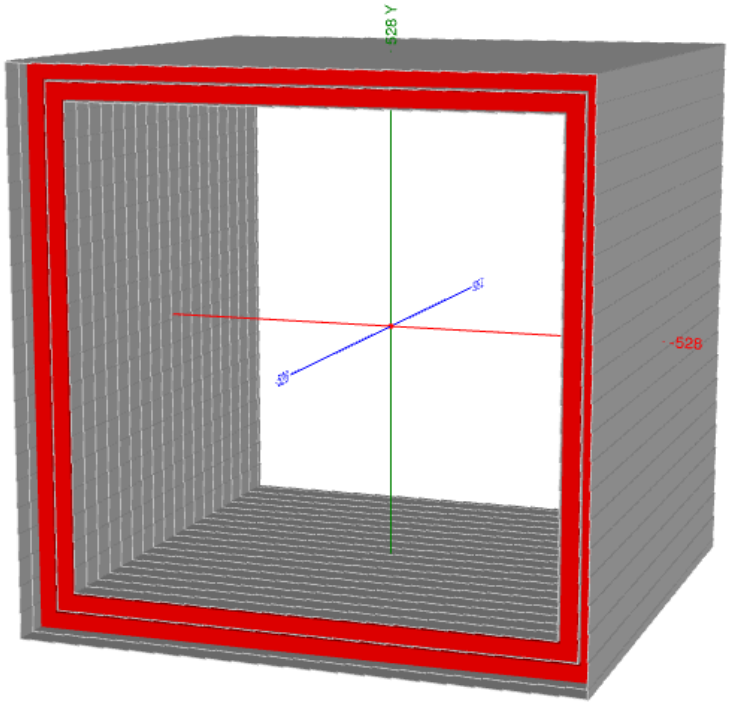
More different geometries made by the same builder (C++ code)



Hexagon



Dodecagon



Quadrilateral

Conclusion:

- The simple geometry description of the muon system and Preshower has been done, and both have been included in full IDEA DD4hep implementation.
- A detailed version of the muon system has been done.

Further developments:

- Implementation of a digitization algorithm(ongoing).
- Implementation of a muon reconstruction algorithms with and without the usage of the tracking system.
- Evaluation of the IDEA muon reconstruction performance.
- Evaluation of the physics reach for highly displaced “muon-like” signatures.

The code is available on FCCDetectors repository

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