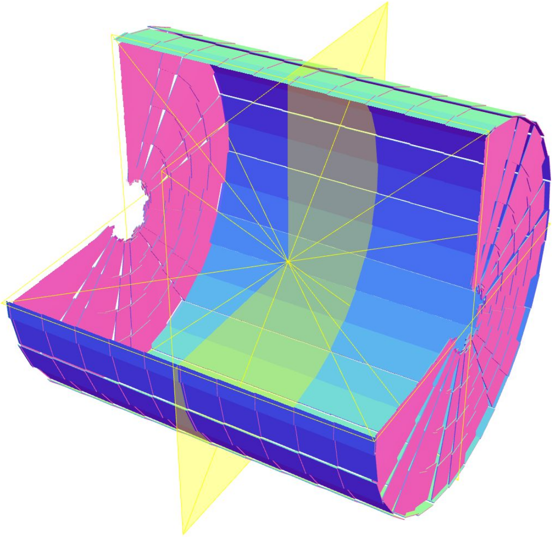
Preshower detector simulation for IDEA detector



N. Nitika

University of Udine

FUTURE CIRCULAR COLLIDER

CERN

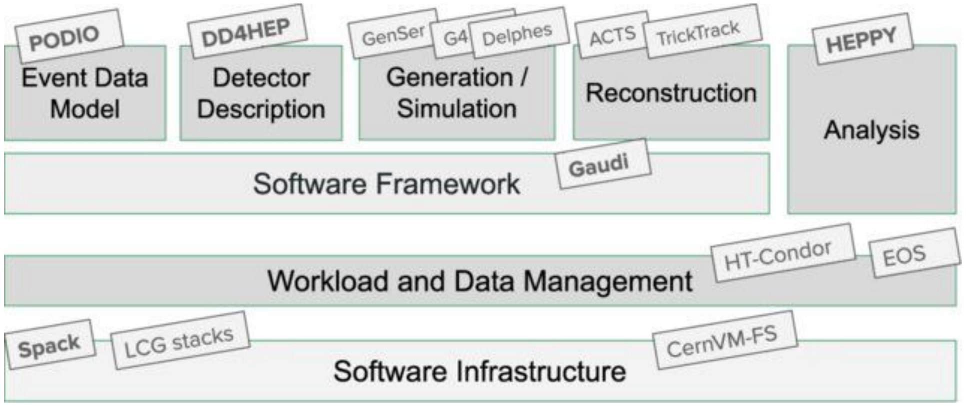
The Abdus Salam International Centre for Theoretical Physics

Key4hep & DD4hep

Key4hep

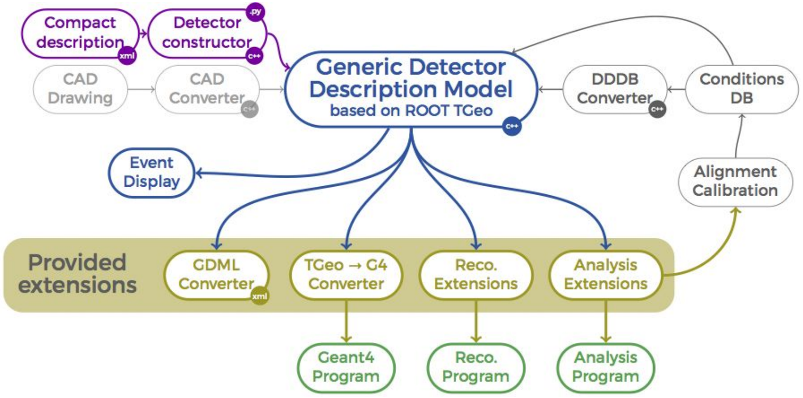
The turnkey software stack for FCC and all other future colliders

- ❖ The high-energy physics (HEP) community decided to create a software ecosystem that integrates the best software components in an optimal way, providing a ready-to-use, full-fledged solution for data processing in future collider experiments
- ❖ This effort involves contributions from various communities, including CEPC, CLIC, EIC, FCCee, FCChh, ILC, LUXE, Muon Collider.



DD4hep geometry toolkit

- ❖ supporting the full life cycle of the experiment
- ❖ this package serves as a single source of information for full simulation, reconstruction, alignment, visualization, and analysis used by CEPC, CLIC, CMS, EIC, FCC, ILC, LHCb, and other projects
- ❖ all future Higgs factory detector simulation models in one package https://github.com/key4hep/k4geo
- ❖ can use plug-and-play for sub detectors to study detector variants



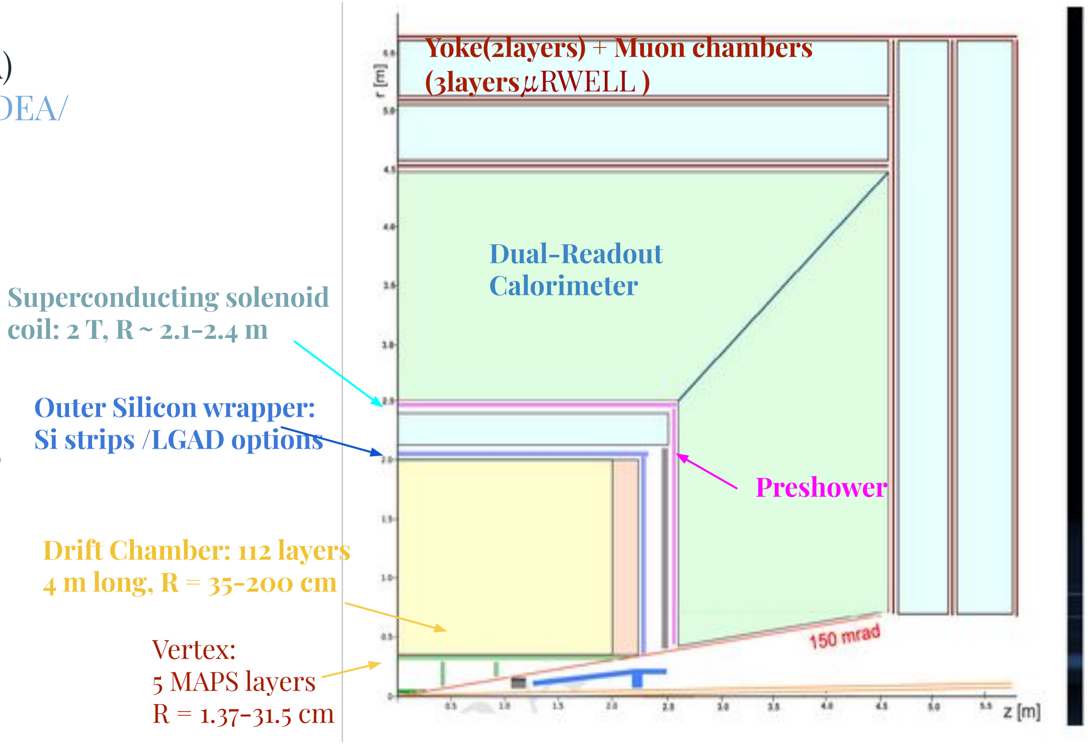
https://dd4hep.web.cern.ch/page/about/

IDEA

Innovative Detector for e+ e− Accelerator (IDEA)
https://fcc-ee-detector-full-sim.docs.cern.ch/IDEA/

IDEA detector concept consists of:

- Silicon pixel vertex detector.
- Large-volume extremely light drift wire chamber.
- Surrounded by a layer of silicon micro-strip detectors.
- Dual readout crystal calorimeter.
- Thin low-mass superconducting solenoid coil.
- Pre-shower detector based on μRWELL.
- Dual readout fiber calorimeter.
- Muon chambers based on μRWELL technology inside magnet return yoke.



IDEA Detector

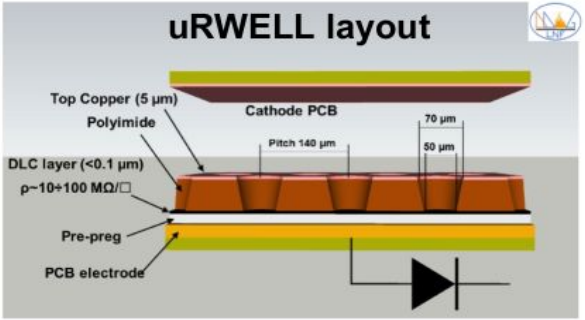
μRWELL technology

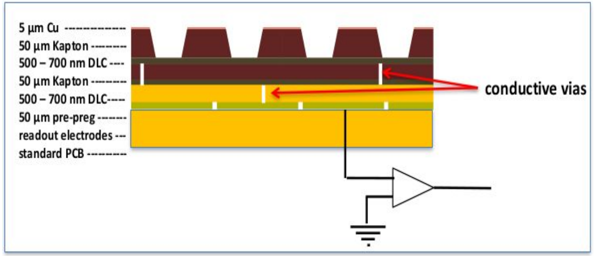
The μ-RWELL is a Micro Pattern Gaseous Detector (MPGD) composed of two elements:

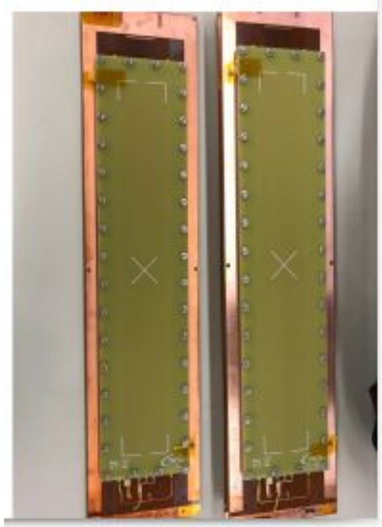
the μ-RWELL_PCB and the cathode.

The core is the μ-RWELL_PCB, realized by coupling three different elements:

- ❖ A WELL patterned kapton foil acting as amplification stage
- ❖ Resistive DLC layer (Diamond-Like-Carbon) for discharge suppression
- ❖ Standard readout PCB







μ-RWELL prototypes with 40 cm long strips

How it works-

- ➔ A charged particle ionizes the gas between the two detector elements
- ➔ Primary electrons drift towards the μ -RWELL_PCB (anode) where they are multiplied, while ions drift to the cathode or to the PCB TOP
- ➔ The signal is induced capacitively, through the DLC layer, to the readout PCB
- ➔ The two HV for the drift region and the amplification region.

Ongoing development
- Mass production
- Optimization of FEE channels/cost
- 50x50 cm² 2D tiles to cover more than 1650 m²

https://agenda.infn.it/event/39747/contributions/223705/attachments/119195/172716/20240507_IDEA_gaudio.pdf

Preshower

The IDEA detector includes a preshower system utilizing μRWELL technology.

-High resolution after the magnet to improve $\pi\pm/e\pm$ and 2γ separation.

-It allows the identification and measurement of electromagnetic showers that originate in the material of the solenoid before reaching the calorimeter.

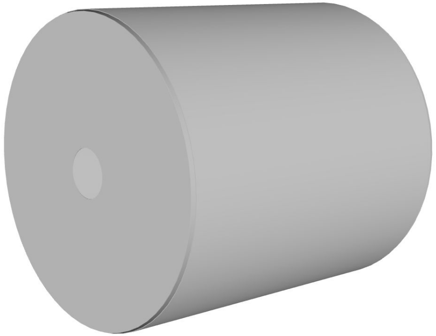
-to improve cluster reconstruction

Both the preshower and muon systems have a modular design.

```
<!-- %%%%%%                    microRWELL chamber different layers thicknesses                    %%%%%% -->
   <constant name = "psG10_FR4Thick"                    value = "1.6*mm"/>
   <constant name = "psCuThick"                         value = "0.035*mm"/>
   <constant name = "psGasLayerThick"                   value = "6*mm"/>
   <constant name = "psCu2Thick"                        value = "0.005*mm"/>
   <constant name = "psKaptonThick"                     value = "0.05*mm"/>
   <constant name = "psCarnonFiberThick"                value = "0.0001*mm"/>
   <constant name = "psCarbonFiber2Thick"               value = "0.1*mm"/>
   <constant name = "psSiThick"                         value = "1.6*mm"/>
   <constant name = "psMRWELLTotalThickness"            value =
"psG10_FR4Thick+psCuThick+psGasLayerThick+psCu2Thick+psKaptonThick+psCarnonFiberThick+psCuThick+psCarbonFiber2Thick+psCuThick+psSiThick"/> <!-- This sequense is the current order of
mRWELL (total 10 slices) -->
```

Simple sensitive layered cylindrical geometry: A functional version in a short time, facilitating numerous initial physics investigations. It offers great adaptability to adjustments requirement by alterations in other sub-detectors or new version of detector.

Simulation design vision (builder file + xml file): the flexible design, where user can choose the number of sides of the shape, layers, and automatically the builder will calculate the number and places of the copied chambers.



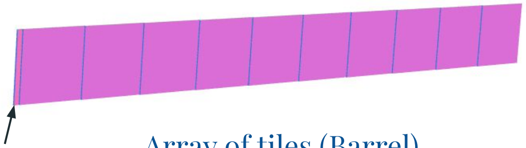
Simple sensitive layered cylindrical geometry

Preshower (detailed geometry)

For the detailed version of the preshower with μ-RWELL tiles, the specifications to be achieved :

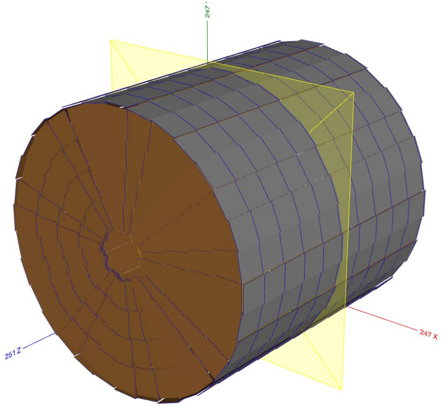
- ❖ Active area: 50×50 cm²
- ❖ Pitch between readout strips: 400 μm
- ❖ A readout system 2D (CartesianGridXY), for each individual chamber.
- ❖ Space Resolution < 100 μm
- ❖ 1.3 million channels

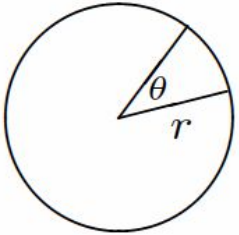
```
                                                    <!-- Barrel -->
<constant name = "psBarrelFirstLayerRadius"                     value = "2420*mm"/>         <!-- 1st Barrel microRWELL detector inner radius-->
<constant name = "psBarrelLength"                               value = "4900*mm"/>         <!--Barrel detector length,in description of detctor we always use half-length -->
                                                    <!-- Endcap -->
<constant name = "psEndcapFirstLayerZOffset"                    value = "2400*mm"/>         <!-- 1st Endcap microRWELL detector inner ZOffset -->
<constant name = "psEndcapLayersInnerRadius"                    value = "390*mm"/>          <!--Endcap detector inner radius, its start point of thicknesses of detector material -->
<constant name = "psEndcapLayersOuterRadius"                    value = "2420*mm"/>         <!--Endcap detector outer radius, its end point of thicknesses of detector material -->
<!-- End of Pre-shower Parameters-->
```



Unusual tile size

Array of tiles (Barrel)

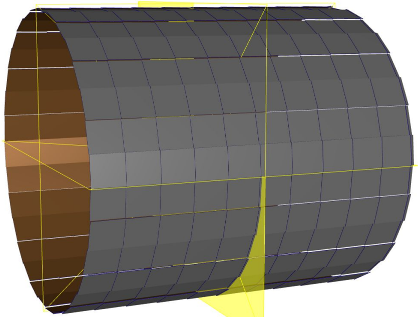




$n=2\pi/\theta$

https://fcc-ee-detector-full-sim.docs.cern.ch/IDEA/

Preshower Barrel

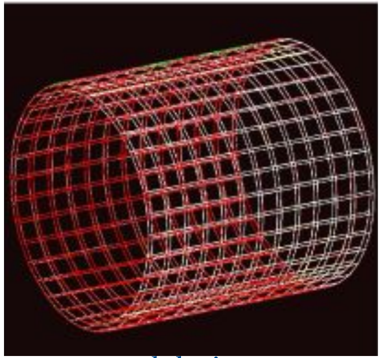


Barrel

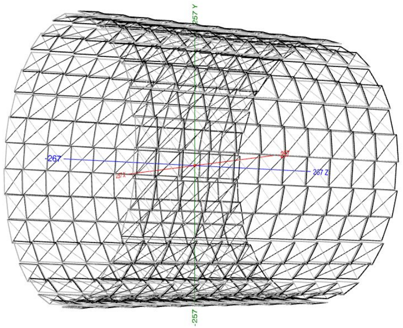
Layer	R [mm]	L [mm]	Thickness [mm]	Int. length	Pixel size [mm^2]
µRwell	2450	±2550	20 (two overlapping 10 mm		0.4×500

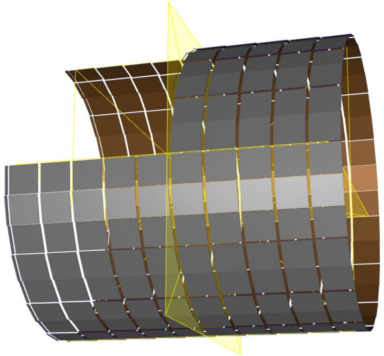
```
<!-- Pre-shower Parameters-->
<constant name = "psNumSides"                    value = "32"/>       <!-- The number of sides of the pre-shower -->
```

```
<!-- Specify the detector parameters and the overlap -->
<generalParameters numSides="psNumSides" overlapY="psOverlapingY" overlapZ="psOverlapingZ" clearance="psClearance"/>
<Barrel numDetectorLayers ="1"  rmin="psBarrelFirstLayerRadius" length="psBarrelLength" numYokes="0" yoke_Thickness="0*mm" yoke_Material="G4_Fe"/>
<constant name = "psOverlapingY"              value = "5*mm"/> <!-- the common distance between mRWELL chambers in Y direction -->
<constant name = "psOverlapingZ"              value = "5*mm"/> <!-- the common distance between mRWELL chambers in Z direction -->
<constant name = "psClearance"                value = "1*mm"/>  <!-- it's a small distance to be used to avoid overlapping between the different volumes ~ 1 mm -->
```



Expected design





Current design

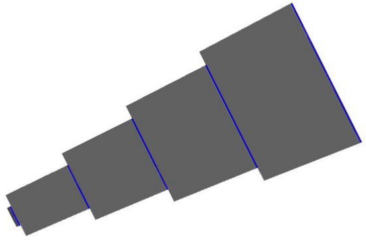
Preshower endcap

Endcap

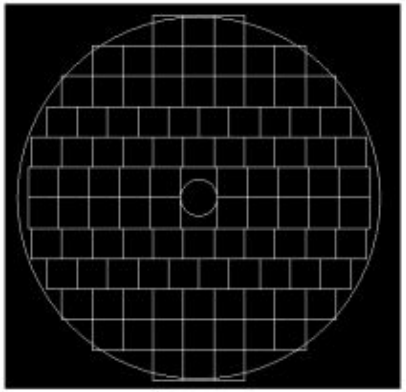
Disk	R^{in} [mm]	R^{out} [mm]	z [mm]	Thickness [mm]	Int. length	Pixel size [mm^2]
µRwell	390	2430	±2550	20 (two overlapping 10 mm PCB)		0.4×500

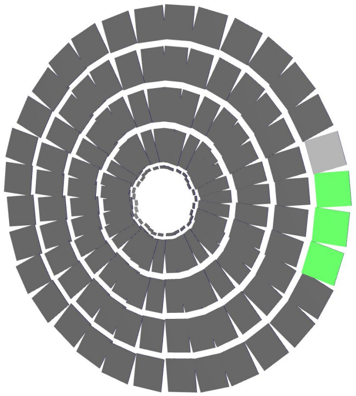
<!-- Specify the detector parameters and the overlap →

<Endcap numDetectorLayers="1" rmin="psEndcapLayersInnerRadius" rmax="psEndcapLayersOuterRadius" z_offset="psEndcapFirstLayerZOffset" numYokes="0" yoke_Thickness="0*mm" yoke_Material="G4_Fe" />

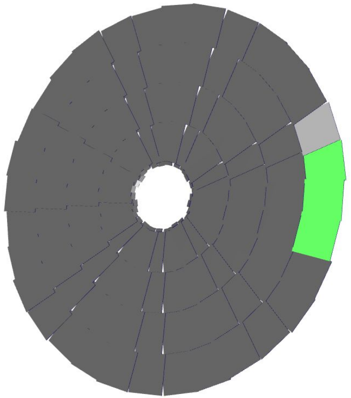


Array of tiles (endcap)



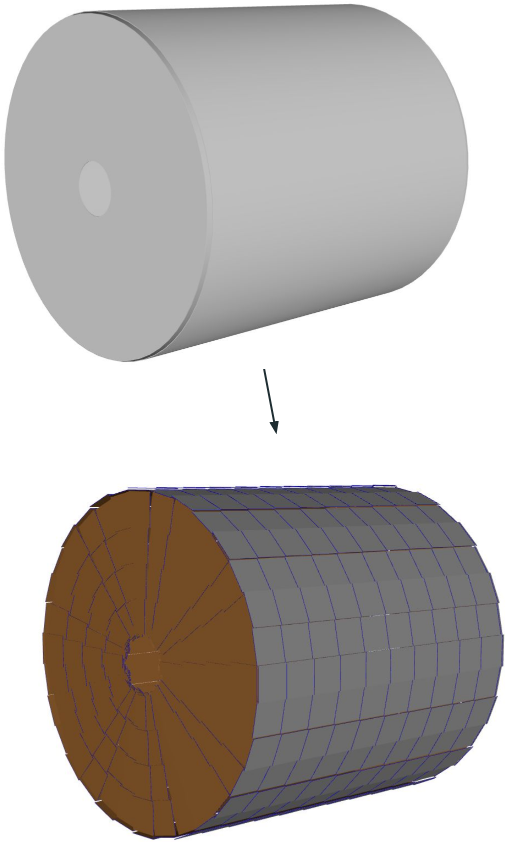


Current design

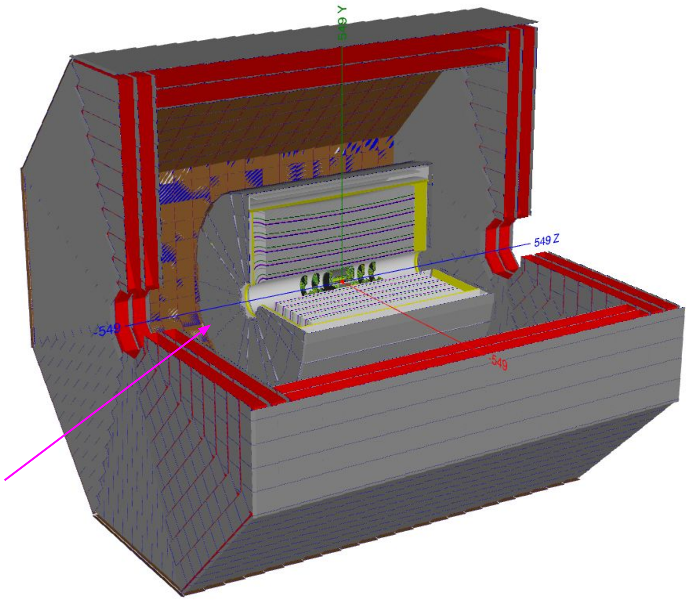


Endcap

Preshower at a glance.....



Simple sensitive layered cylindrical geometry with a readout system implemented for the cylindrical shape, with a segmentation in ϕ and θ direction to match the foreseen strip pitch.

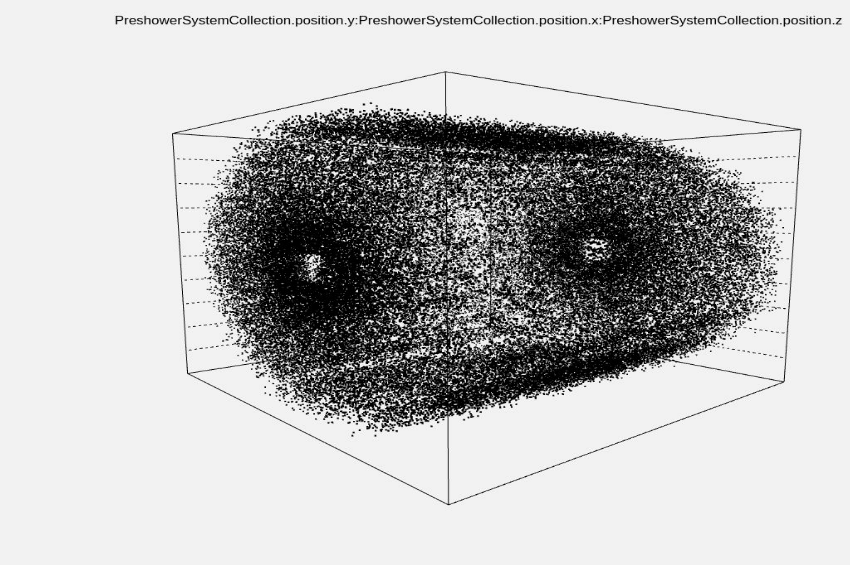


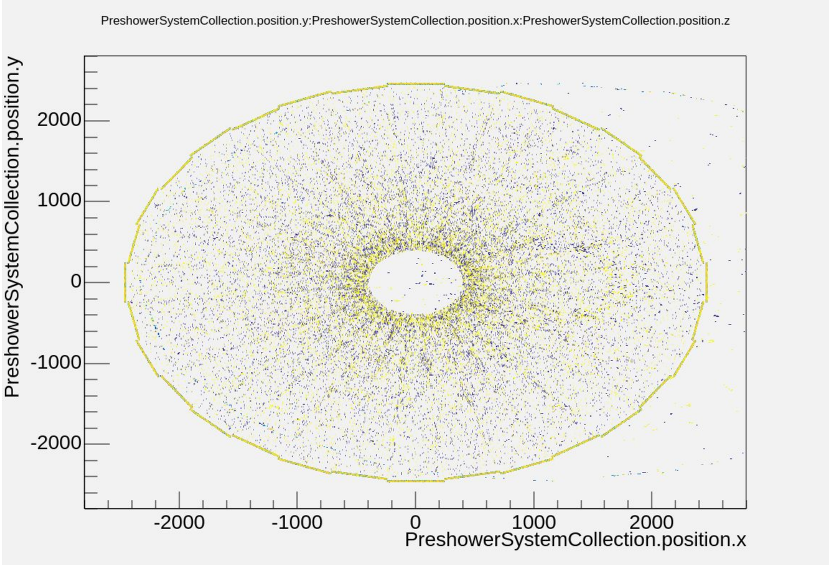
Detailed preshower geometry with a 2D (CartesianGridXY) readout system.

Preshower collection

A readout system has been implemented for every single chamber (CartesianGridXY) to match the foreseen strip pitch.

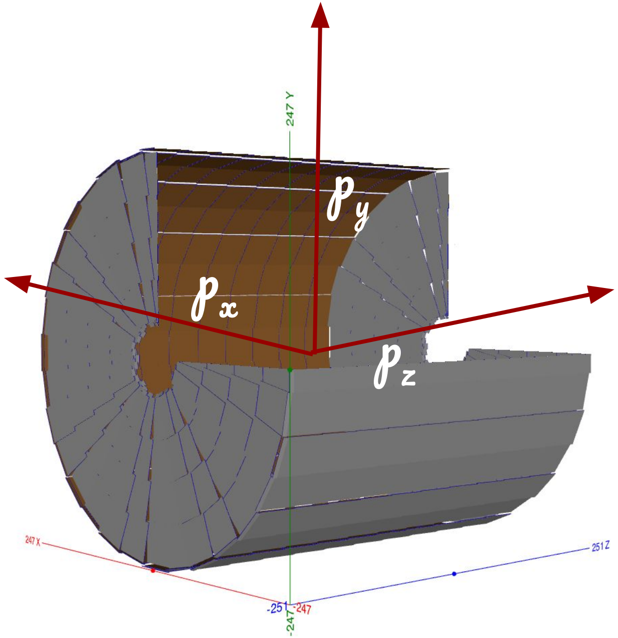
```
    <readout name="PreshowerSystemCollection">
     <segmentation type="CartesianGridYZ" grid_size_y="1.2*mm" grid_size_z="1.2*mm"/>   <!-- Depending on strip pitch 1.4 mm  -->
     <id>system:5,type:2,layer:4,chamber:15,slice:1,y:-10,z:-10</id> <!-- The bit field is divided into 2^5 systems(IDEA sub-detectors), 2^4 layers(Muon System layers"barrel and endcap layers"), 2^11 chambers(the number of muRWELL chambers in every layer), 2^1 slice(number of sensitive layers inside every chambers), and 2^10 y&z strips in every sensitive layer-->
  </readout>
```





Simulation of 100k events hits of muons, appeared from preshower chambers readout system having 32 sides.

Current work & next......



- ❖ Producing digitized hits using ddsim with the current version of Preshower collection to get the various info:

  MCParticles info- vertex, endpoint, momentum, momentumAtEndpoint, parents, daughters info. etc.

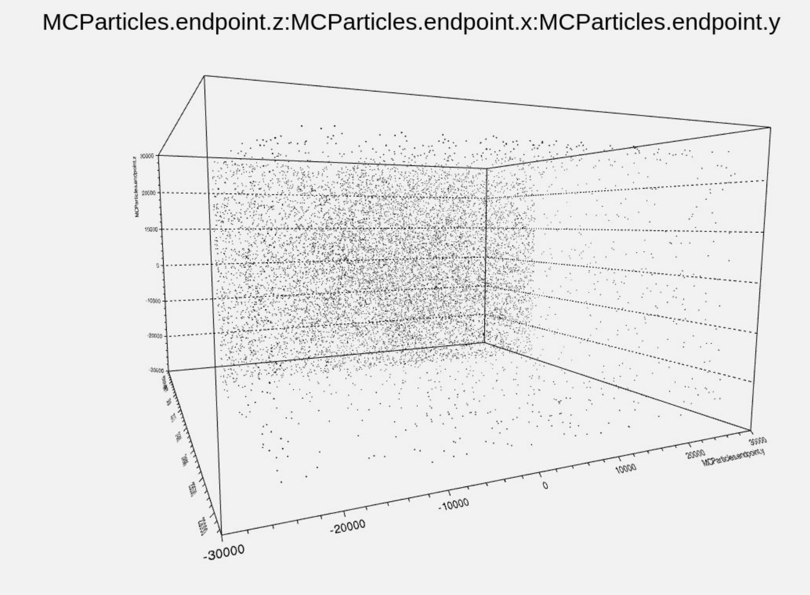
  PreshowerSystemCollection –cellID, energy deposition (eDep), time etc.

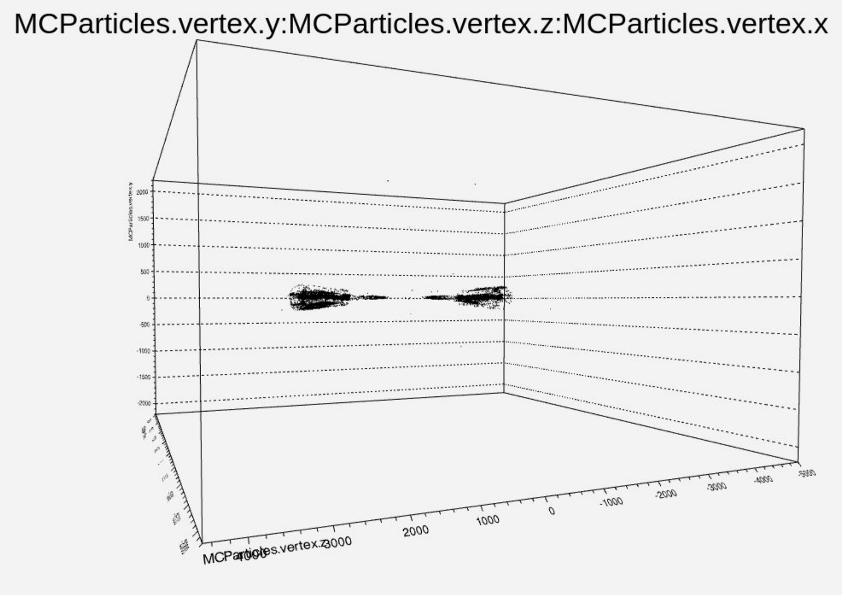
- ❖ This allows to see the info. related to the particle hits, hits position, including the cases when they end up in the same cell.
- ❖ Check on the momentum of the particle ↣ rate of the particle in barrel and end cap regions ↣ probability of particles in/towards specific subpart of detector.
- ❖ Information from MCParticles w.r.t. PreshowerSystemCollection can give an idea/estimation of particle conversion/decay and can get an idea readouts system efficiency including parent & daughter info.

```
ddsim --enableGun --gun.distribution uniform --gun.energy "10*GeV" --gun.particle gamma --numberOfEvents 100000 --outputFile 1_gun_1GeV_gamma_1000_Preshower.root --compactFile k4geo/FCCee/IDEA/compact/IDEA_o1_v03/IDEA_o1_v03.xml
```

```
events->Draw("MCParticles.endpoint.z:MCParticles.endpoint.x:MCParticles.endpoint.y", "", "");

events->Draw("MCParticles.vertex.z:MCParticles.vertex.x:MCParticles.vertex.y", "", "");
```





Thanks.....