IDEA muon system full simulation with DD4HEP

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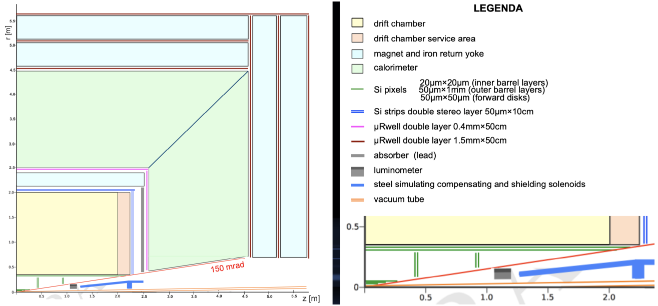
IDEA muon system

IDEA detector concept foresees a muon detection system that would be realized using the μRWELL technology. The muon detector would follow the IDEA geometry with a central cylindrical barrel region closed at the two extremities by two endcaps to ensure hermeticity. In the barrel, there will be three muon stations, at increasing radial distance from the interaction point, housed within the iron yoke that closes the solenoidal magnetic field.



IDEA muon system

Each station will consist of a large mosaic of μRWELL detectors. In order to profit from the industrial production capabilities of this technology, a modular design has been adopted. The basic μRWELL "tile" will have an active area of $50 \times 50\ cm^2$. The two layers of strips will both have a strip pitch of 1 mm, giving a total of 500×2 strips and consequently 1000 readout channels per tile.

IDEA muon system

Table: IDEA muon system parameters (Barrel and Endcap)

Barrel						
Layer	R [mm]	L [mm]	Thickness [mm]	Pixel size [mm^2]	Area [cm^2]	# of channels
μRwell	4520	$\pm$4500	20	1.5$\times$500	2.6M	341K
Iron	4560	$\pm$4500	300			
μRwell	4880	$\pm$4500	20	1.5$\times$500	3.0M	386K
Iron	4920	$\pm$4500	300			
μRwell	5240	$\pm$5260	20	1.5$\times$500	4.3M	462K

Endcap							
Disk	R^{in} [mm]	R^{out} [mm]	z [mm]	Thickness [mm]	Pixel size [mm^2]	Area [cm^2]	# of channels
μRwell	700	5200	$\pm$4520	20	1.5$\times$500	1.9M	227K
Iron	700	5200	$\pm$4560	300			
μRwell	700	5200	$\pm$4880	20	1.5$\times$500	1.9M	227K
Iron	700	5200	$\pm$4920	300			
μRwell	700	5200	$\pm$5240	20	1.5$\times$500	1.9M	227K

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 and energy 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.

Two layouts are under study:

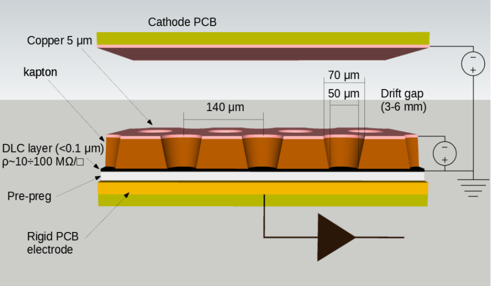
- Low-rate layout (FCC-ee)
- High-rate layout (LHCb)

μRWELL detector technology

The μRWELL is a Micro Pattern Gaseous Detector (MPGD) composed of only two elements: the μRWELL PCB and the cathode. The core is the μRWELL PCB, realized by coupling three different elements:

1. A WELL patterned kapton foil acting as amplification stage (GEM-like)
2. Resistive DLC layer (Diamond-Like-Carbon) for discharge suppression with surface resistivity $50 \div 100\ \mathrm{M}\Omega/\square$
3. Standard readout PCB

μRWELL detector technology



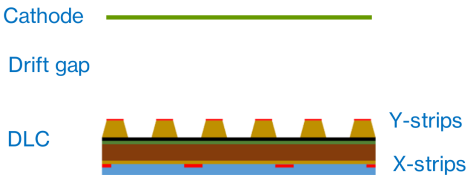


Figure: Baseline layout of the μ-RWELL.

Simulation of the muon system in DD4HEP

We started the implementation of the muon system in DD4HEP as a first approach as a simple cylindrical shaped, then gradually we went in more complicated and detailed description for the muon system.
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.

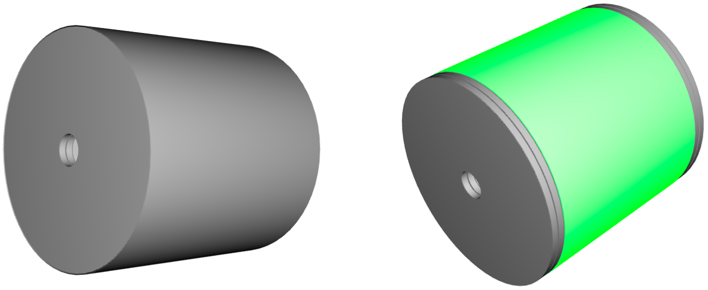
Simple Cylindrical shape

Our detector builder creates a factory for a shape from multiple cylinders, among theses cylinders you can specify the sensitive and non-sensitive layers of them. and the expected xml structure is like that:

```
  <detector type="
      SimpleSensitiveLayeredCylinder_o1_v00" ...>
  <dimensions rmin="..." rmax="..." dz="..."
      z_offset="...">
  <sensitive type="SimpleTrackerSD"/>
  <layer rmin="..." rmax="..." dz="..." z_offset="
      ..." material="...">
  ...
  <layer rmin="..." rmax="..." dz="..." z_offset="
      ..." material="..." sensitive="true">
</detector>
```

Simple Cylindrical shape

Our goal is to make the code flexible as much as possible, so it could be easily editable for the user.
We did the same in the XML file that describe the simple version, it's almost automated, in which the user only edit the main parameters at the beginning of the XML, and the code adjust the changes automatically to build the sensitive cylindrical layers.



Simple Cylindrical shape

```xml
<!---                          Muon System Parameters                          -->

  <constant name = "BarrelInnerRadius"              value = "4500*mm"/>  <!--Barrel envelope inner radius -->
  <constant name = "BarrelOuterRadius"              value = "5280*mm"/>  <!--Barrel envelope outer radius -->
  <constant name = "BarrelFirstLayerRadius"         value = "4520*mm"/>  <!-- 1st Barrel microRWELL detector i
  <constant name = "BarrelFirstYokeRadius"          value = "4560*mm"/> <!-- 1st Barrel Return-Yoke inner radi
  <constant name = "BarrelSecondLayerRadius"        value = "4880*mm"/>
  <constant name = "BarrelSecondYokeRadius"         value = "4920*mm"/>
  <constant name = "BarrelThirdLayerRadius"         value = "5240*mm"/>
  <constant name = "BarrelLength"                   value = "9000*mm"/> <!--Barrel detector length, in the des
  <constant name = "BarrelThirdLayerLength"         value = "10520*mm"/> <!-- The third layer is longer than t

  <constant name = "EndcapInnerRadius"              value = "685*mm"/>  <!--Endcap envelope inner radius -->
  <constant name = "EndcapOuterRadius"              value = "5220*mm"/> <!--Endcap envelope outer radius -->
  <constant name = "EndcapLayersInnerRadius"        value = "700*mm"/> <!--Endcap detector inner radius, its t
  <constant name = "EndcapLayersOuterRadius"        value = "5200*mm"/> <!--Endcap detector outer radius, its 
  <constant name = "EndcapLength"                   value = "760*mm"/>
  <constant name = "EndcapZOffset"                  value = "4880*mm"/> <!--  The offset is = the barrel halfl
  <constant name = "microRWELLVolumeThick"          value = "40*mm"/> <!--The thickness of the detector layer 
  <constant name = "YokeVolumeThick"                value = "320*mm"/> <!--The thickness of the return-yoke (3
```

Figure: Muon system XML file structure.

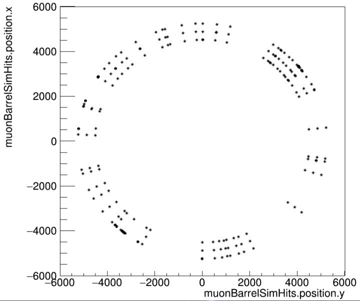
Simple Cylindrical shape

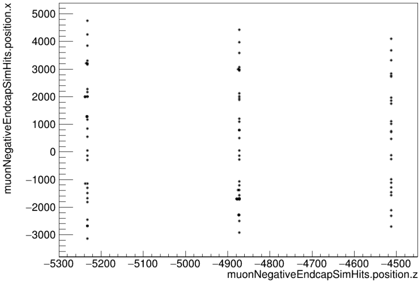
```xml
<!-- %%%%%%               microRWELL chamber different layers thicknesses               %%%%%% -->

  <constant name = "G10_FR4Thick"                         value = "1.6*mm"/>
  <constant name = "CuThick"                              value = "0.035*mm"/>
  <constant name = "GasLayerThick"                        value = "6*mm"/>
  <constant name = "Cu2Thick"                             value = "0.005*mm"/>
  <constant name = "KaptonThick"                          value = "0.05*mm"/>
  <constant name = "CarnonFiberThick"                     value = "0.0001*mm"/>
  <constant name = "CarbonFiber2Thick"                    value = "0.1*mm"/>
  <constant name = "SiThick"                              value = "1.6*mm"/>

<!-- %%%%%%               Return yoke thickness               %%%%%% -->

 <constant name = "YokeThick"                             value = "300*mm"/>
```

Figure: Muon system XML file structure.

Linking with Gaudi

A simple readout system have been implemnted with a segmentation in Phi and Theta.
The following plots are for the hits positions in the barrel and one side of the endcap detectors for 100 events for have been simulated for 10 GeV muons.





Muon system detailed builder

The detailed version of the muon system is under construction now, with the goals:

- Building the muon system based on 50 $\times$ 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).
- 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.

Figure: Overlap in 1 direction

Muon system detailed builder

- If the side length won't be 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 make this option available in manufacturing too).
- Developing a digitizer in parallel, where we are tuning the efficiency and the resolution of the detector with the R&D results.

Thanks!