IDEA Physics and Software meeting

Muon Detector Simulation

studies and plans

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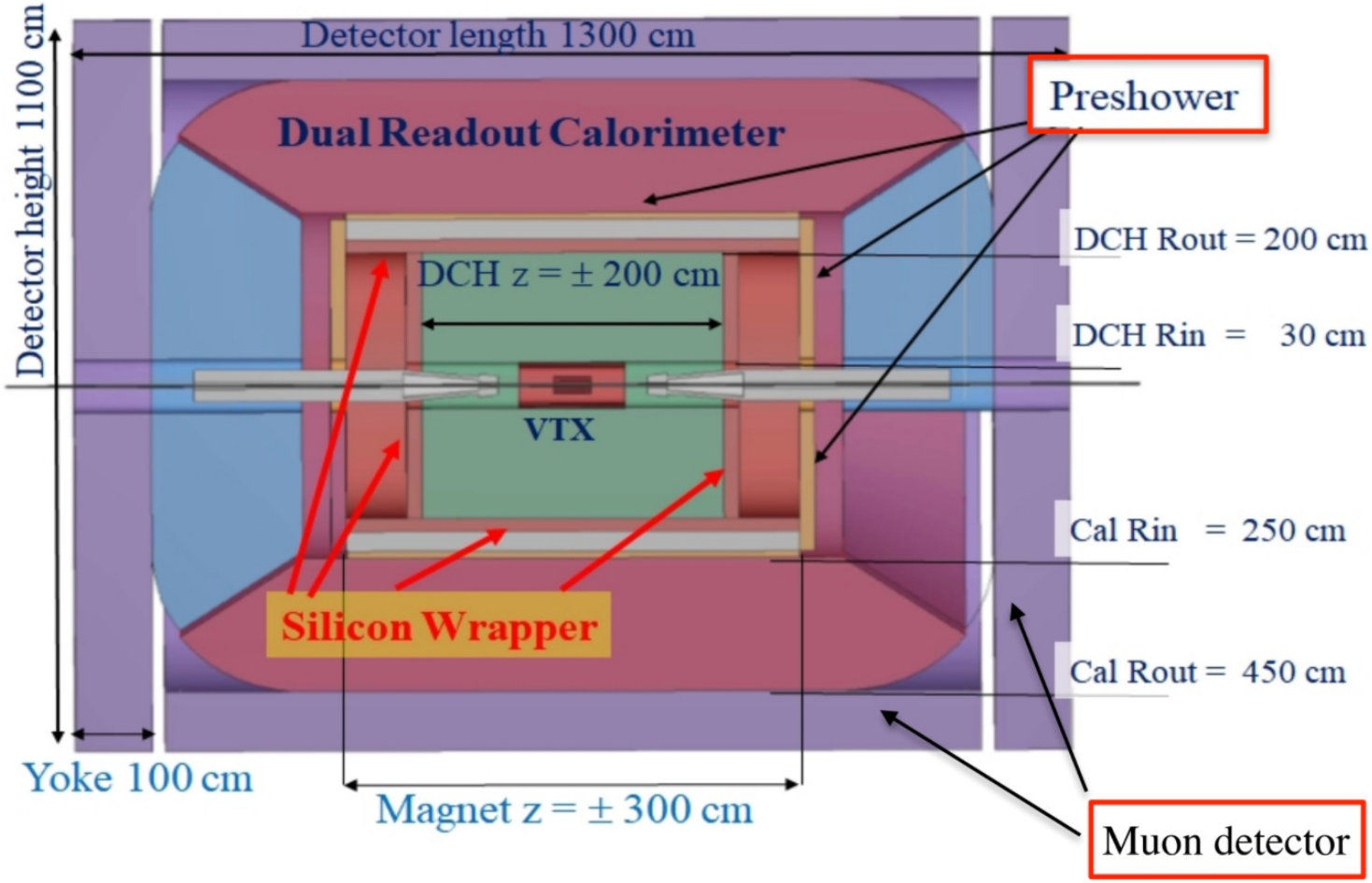
The IDEA Detector



Preshower and the muon detection system are designed with the μRWELL technology

The Muon Detector: reference dimension

- Version 1: we simulate the barrel only
  - box with the following dimension
  - Only barrel (for beginning)

Barrel

Layer	R [mm]	Length [mm]	Thickness [mm]	int. length	pixel size [mm]	area [cm²]	# of channels
μRwell	4520	±4500	20		1.5×500	2.6M	341K
iron	4560	±4500	300	1.5			
μRwell	4880	±4500	20		1.5×500	2.8M	368K
iron	4920	±4500	300	1.5			
μRwell	5240	±5260	20		1.5×500	3.5M	462K

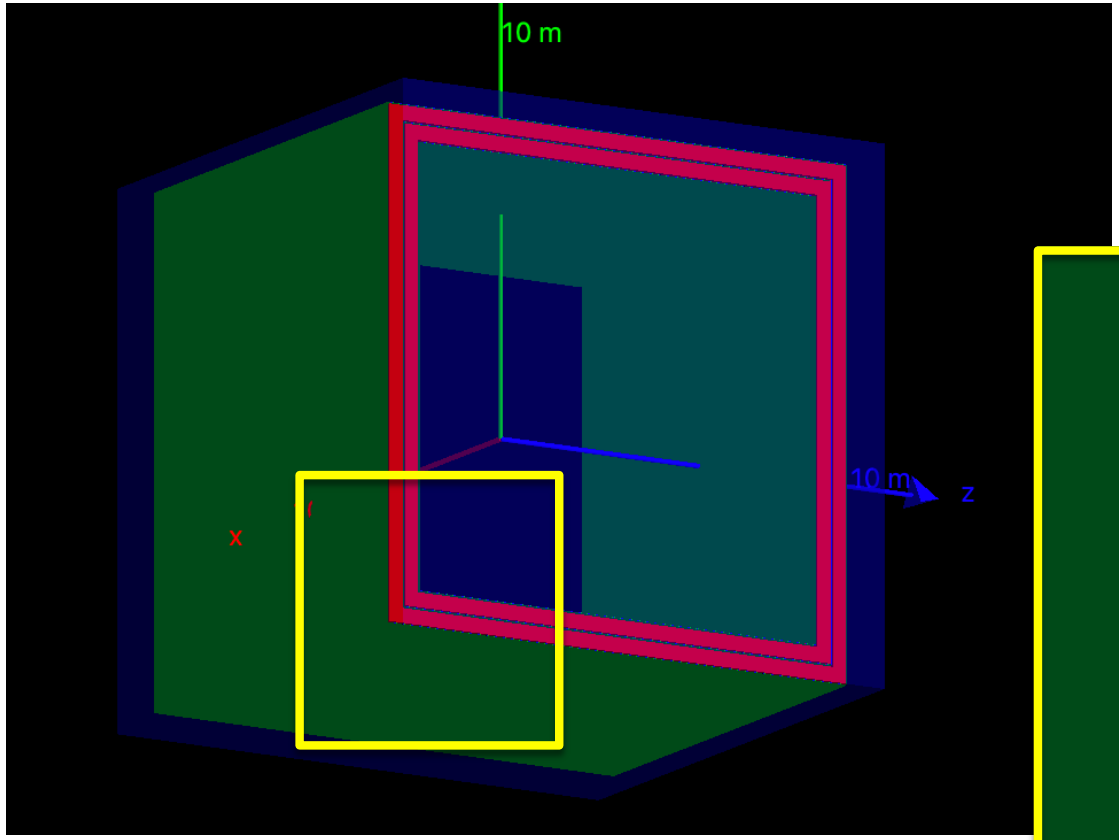
50x50 cm²
strips 50 cm
pitch 1.5 mm

Endcap

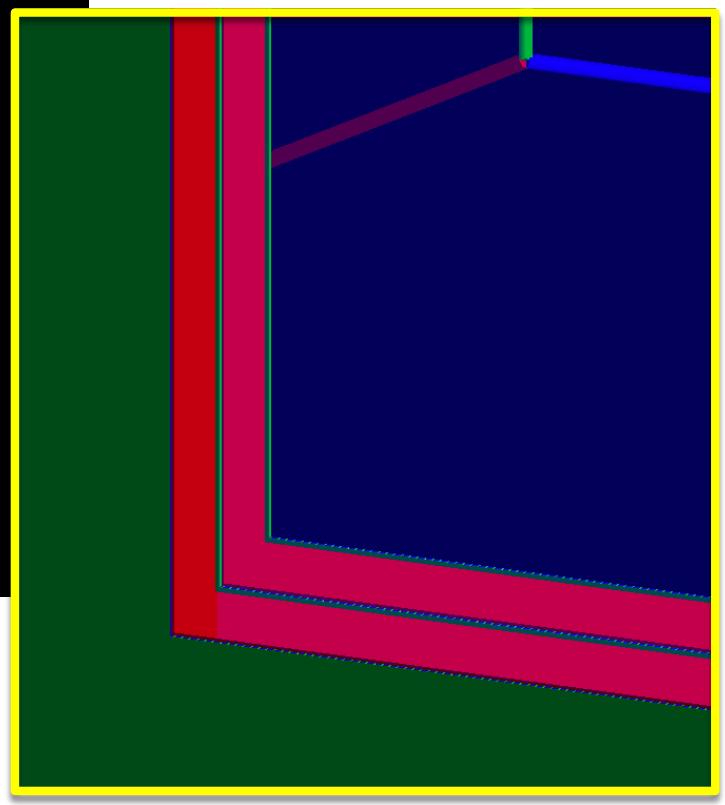
Disk	R_{in} [mm]	R_{out} [mm]	z [mm]	Thickness [mm]	int. length	pixel size [mm]	area [cm²]	# of channels
μRwell	454	5220	±4520	20		1.5×500	1.7M	227K
iron	454	5220	±4560	300	1.5			
μRwell	454	5220	±4880	20		1.5×500	1.7M	227K
iron	454	5220	±4920	300	1.5			
μRwell	454	5220	±5240	20		1.5×500	1.7M	227K

From G. Cibinetto talk on microRWELL-based IDEA subdetectors (14/10/2020)

Starting Point: Standalone Simulation



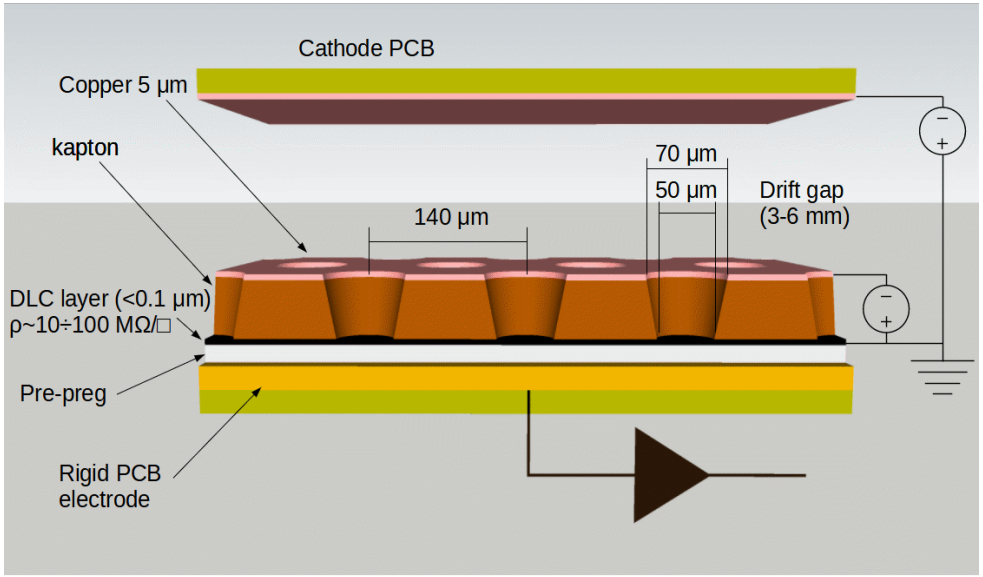
- **2 layers of steel**
- **3 layers of sensitive detector**



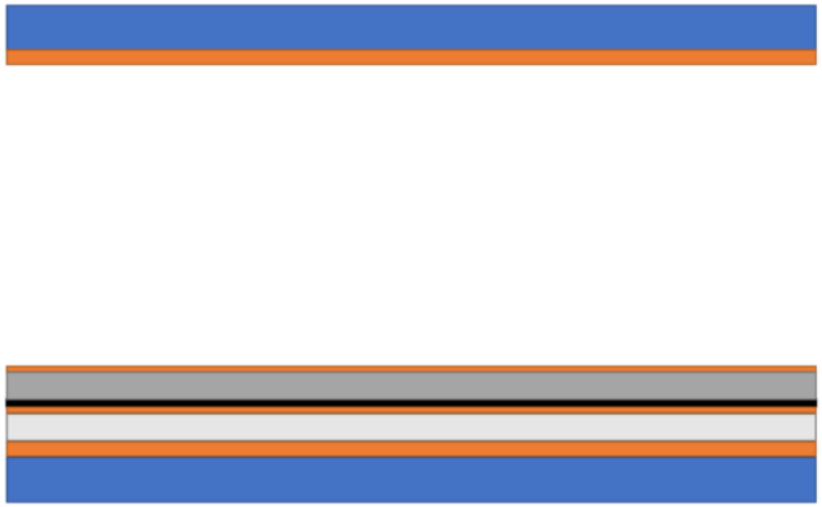
```
G4Material* materials[numlayer]={m_FR4,m_Cu,m_gasDet,m_Cu,m_Kapton,m_DLC,m_Cu,m_DLC,m_Cu,m_FR4};
G4double CStratification[numlayer]={1.6*mm,0.035*mm, 6*mm, 0.005*mm, 0.050*mm, 0.0001*mm, 0.035*mm, 0.1*mm, 0.035*mm, 1.6*mm};
```

The μRWELL detector

- μRWELL: chatode, drift gap, μRWELL_PCB



μRWELL stratification



- see R. Farinelli and M. Poli Lener talks for more details on μRWELL concept
  - https://agenda.infn.it/event/28676/contributions/145373/attachments/87079/116206/General_Meeting_2021-12-15_urwell.pdf
  - https://agenda.infn.it/event/28676/contributions/145393/attachments/87090/116219/20211215_μRWELL_TB_Preliminary.pdf

The μRWELL stratification

*from E. Fontanesi PhD thesis

μ-RWELL component	Thickness of each layer	Material
Cathode	1.6 mm	FR_4
	35 μm	Copper
Gas gap	6 mm	ArCO2CF4
	5 μm	Copper holes
	50 μm	Kapton holes
	0.1 μm	DLC
μ-RWELL + readout PCB	35 μm	Copper Strips
	100 μm	Film glue (same DLC density)
	35 μm	Copper Strips
	1.6 mm	FR_4

Holes and strips: effective density as first option

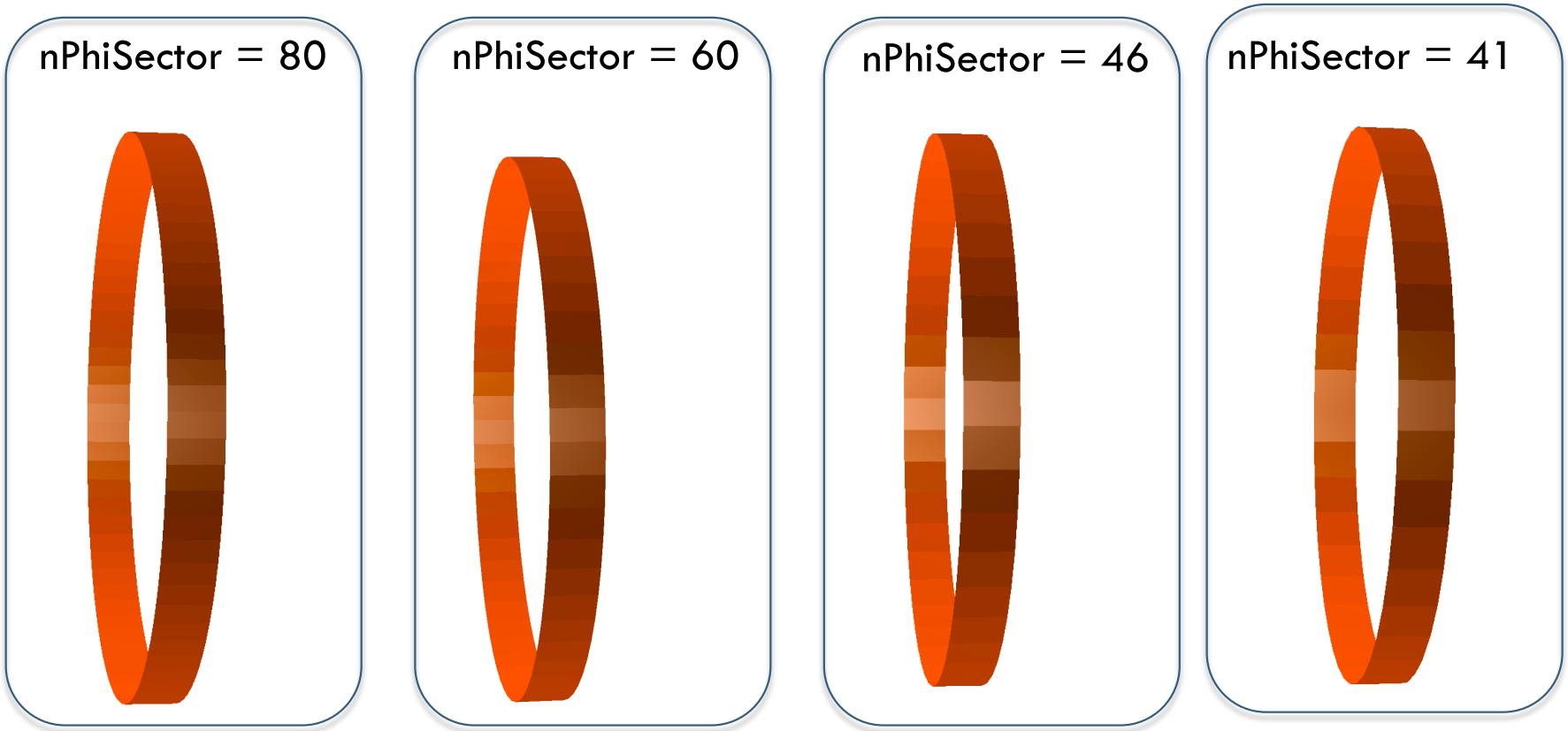
News about the geometry

- Version 2: IDEADetectorSIM
  - Only barrel (for beginning)
  - MUSPC folder
    - Study of the code (from G. Tassielli)
    - config file for muon detector: only one layer of μRWELL

```
// Barrel MUSPC parameters

int    muspc.Brl.nLayers                    = 1;
vector<double> muspc.Brl.LayersInRad        ={4500} //mm
vector<int> muspc.Brl.nPhiSectors           = {xxx}; //number of planes in phi
vector<int> muspc.Brl.nLaddersPerSector     = {45}; // number of plane in the z direction
vector<double> muspc.Brl.LaddersHalfLength  = {50};
vector<double> muspc.Brl.LaddersThickness   = {10
vector<int> muspc.Brl.ROTypes               = {1}; //1: Pixel; 2: strip
vector<double> muspc.Brl.ROfirstSideDim     = {0.07}; // to be updated
vector<double> muspc.Brl.ROfirstSideInsul   = {0.0005}; //to be updated
vector<double> muspc.Brl.ROSecondSideDim    = {0.07}; // to be updated
vector<double> muspc.Brl.ROSecondSideInsul  = {0.0005}; // to be updated
vector<double> muspc.Brl.ROangle            = {0.0}; // Per Layer

// First Barrel Layer Ladder description
int    muspc.Brl.l1.ld.nShells =      10;
vector<string> muspc.Brl.l1.ld.ShellsMaterial = { "G10_FR4",
"G4_Cu","C_19_H_20_O_4","G4_Cu","Kapton","CarbonFiber","G4_Cu","CarbonFiber", "G4_Cu", "G10_FR4"};
vector<double> muspc.Brl.l1.ld.ShellsThickness = { 1.60, 0.035, 6.0, 0.005, 0.05, 0.0001, 0.035, 0.1, 0.035, 1.60};
int    muspc.Brl.l1.ro.nShells =      1;
vector<int> muspc.Brl.l1.ro.ShellIds = { 0 };
```

nPhiSector

- Starting from the pre-shower configuration



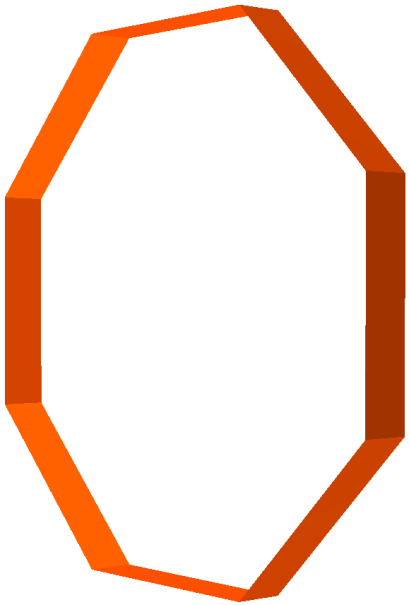
- ERROR when nPhiSector <41 ➔ due to the maximum number of RO channels

MUSPCMaker.cc

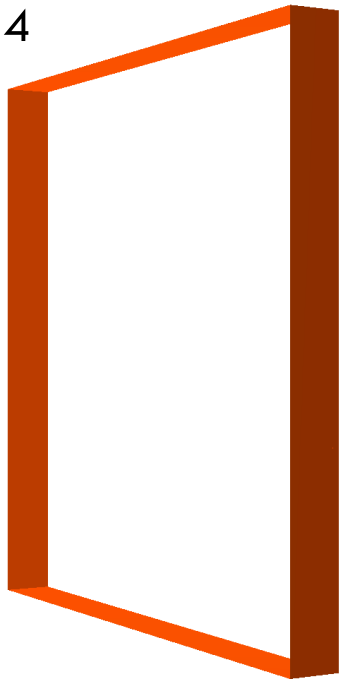
```
      if (nROFstSdperLad>10000 || nROSndSdperLad>10000) {
        /       throw cet::exception("GEOM") <<"Using GDML file option is temporarily
disabled\n";
exc::exceptionG4 e("GEOM","Fatal Error in Argument",1);
        e<<"MUSPC: Maximum number of Channels allowed per X or Y per Ladder is
10000!\n";
e.error();
```

TO DO: Optimize the strips and pitch dimension in order to satisfy this control

nPhiSector = 8



nPhiSector = 4



Ladders stratification

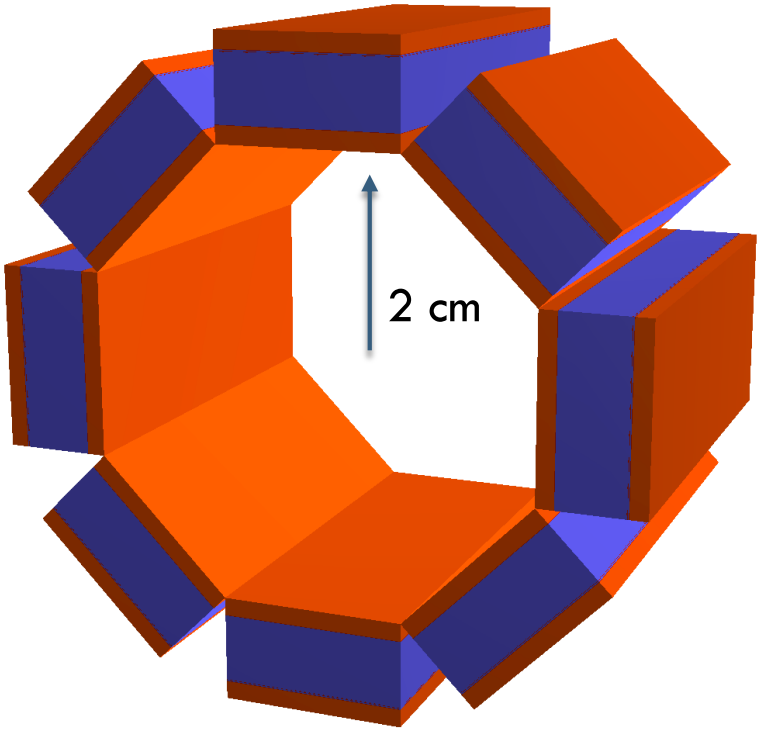
```
// First Barrel Layer Ladder description
int     muspc.Brl.l1.ld.nShells =       10;
vector<string> muspc.Brl.l1.ld.ShellsMaterial = { "G10_FR4",
"G4_Cu","C_19_H_20_O_4","G4_Cu","Kapton","CarbonFiber","G4_Cu","CarbonFiber",
"G4_Cu", "G10_FR4"};
vector<double> muspc.Brl.l1.ld.ShellsThickness = { 1.60, 0.035, 6.0, 0.005, 0.05,
0.0001, 0.035, 0.1, 0.035, 1.60};
int     muspc.Brl.l1.ro.nShells =       1;
vector<int> muspc.Brl.l1.ro.ShellIds = { 0 };
```

Few materials to be updated

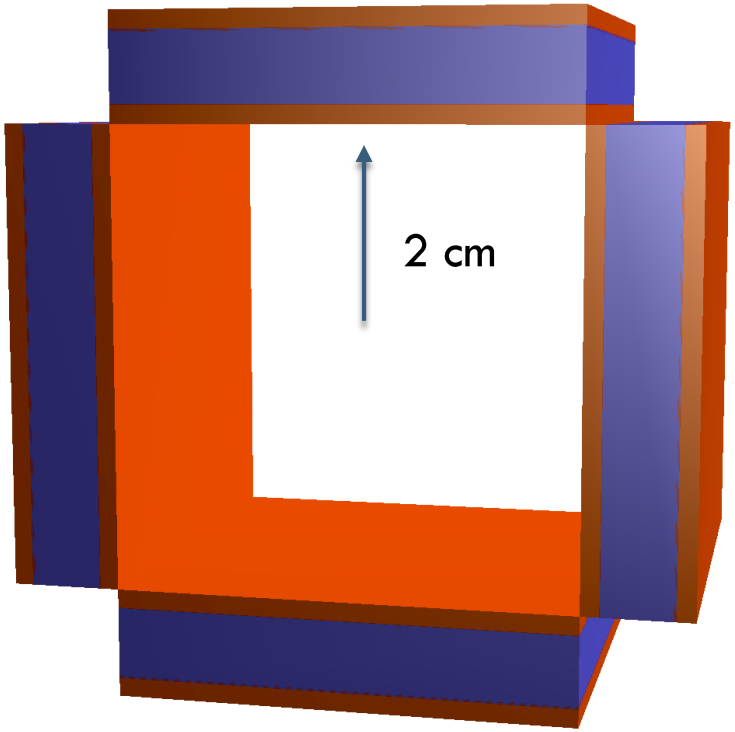
μ-RWELL component	Thickness of each layer	Material
Cathode	1.6 mm	FR_4
	35 μm	Copper
Gas gap	6 mm	$ArCO_2C_4$
	5 μm	Copper
	50 μm	Kapton
	0.1 μm	DLC
μ-RWELL + readout PCB	35 μm	Copper
	100 μm	Film glue (same DLC density)
	35 μm	Copper
	1.6 mm	FR_4

Ladders stratification

```
vector<double> muspc.Brl.LayersInRad      = {20};  //mm
```



nPhiSector = 8

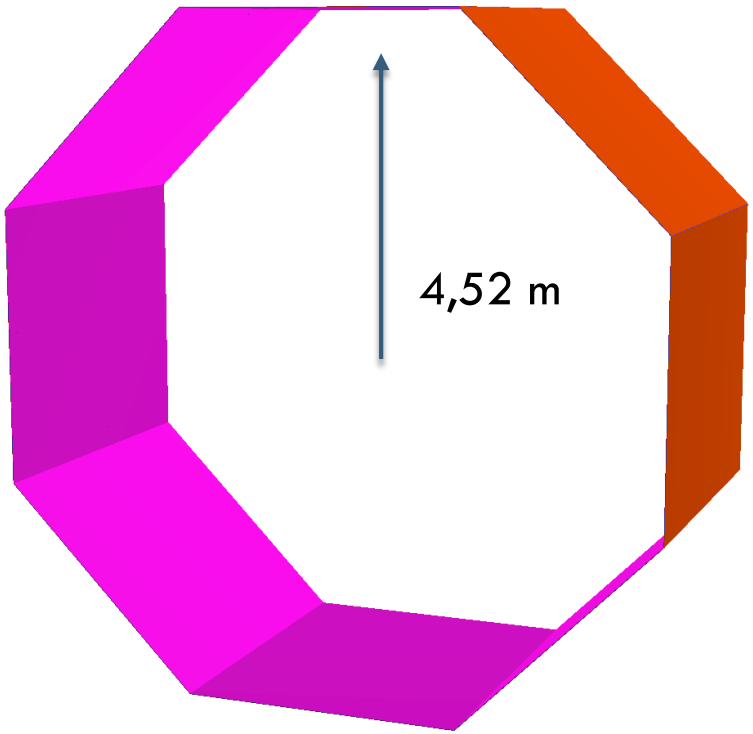


nPhiSector = 4

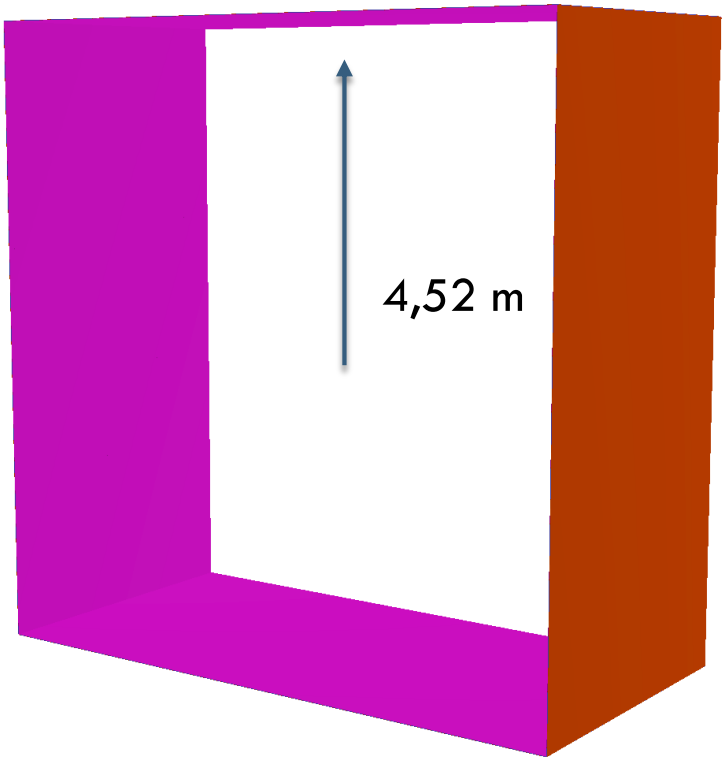
Ladders stratification

```
vector<double> muspc.Brl.LayersInRad      = {4520};  //mm
```

nPhiSector = 8



nPhiSector = 4



Conclusion and PLANS

- Version 0: Standalone simulation (barrel) done!

- Version 1: Muon detector simulation in the official framework
  - Study the already existing code (from G. Tassielli)
  - First layer of muRWELL detector implemented (easy to change the geometry configuration)
    - Ladder Stratification

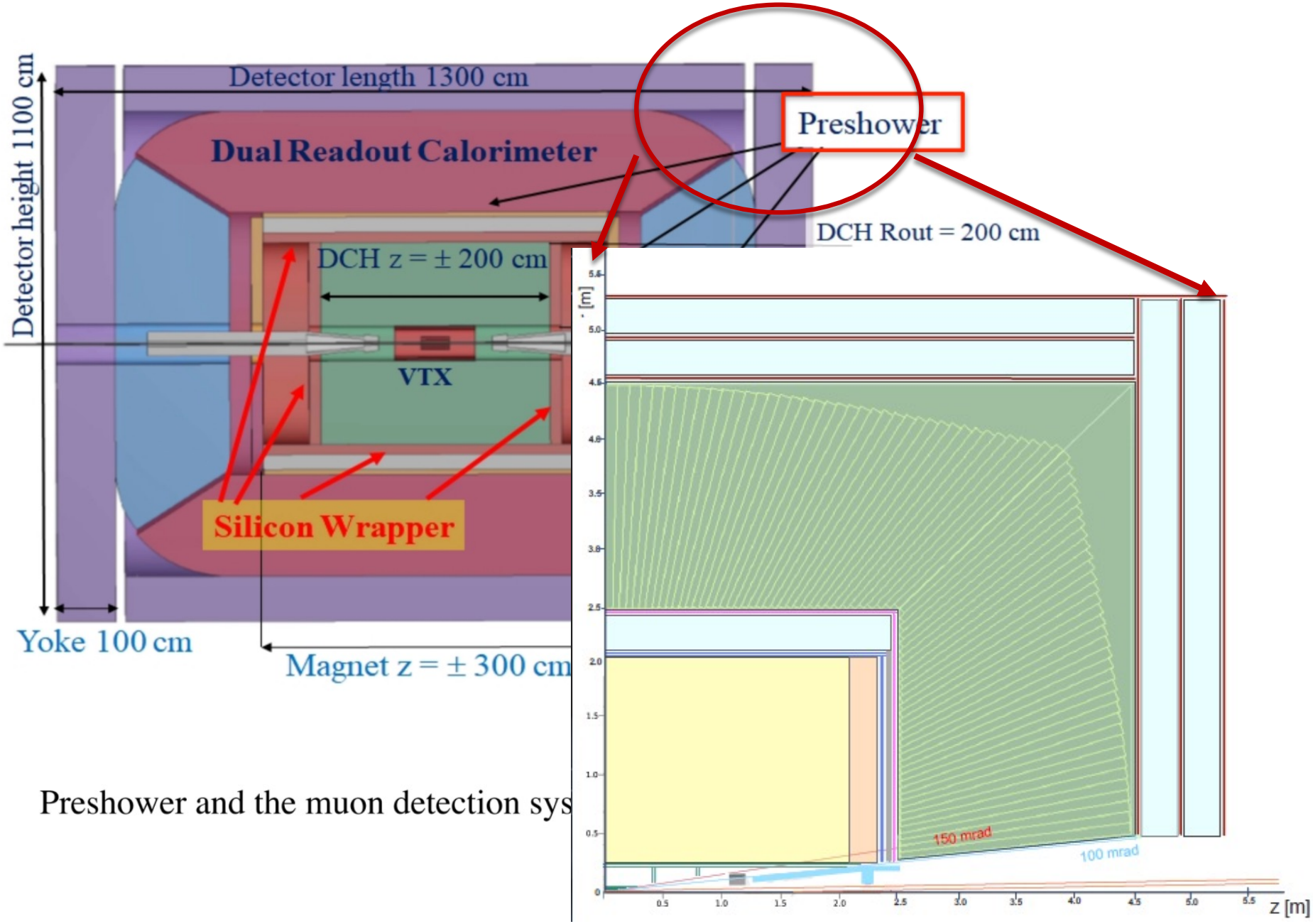
- NEXT STEPS:
  - Implementation of the Radiators (two layers of steel)
  - Construction of the other 2 layers of muRWELL
  - Check the right material
  - Check dimensions and pitch of strips
  - Simulate the full IDEA geometry and overlaps check

Many thanks to G. Tassielli and Walaa for the help

Thanks for your attention

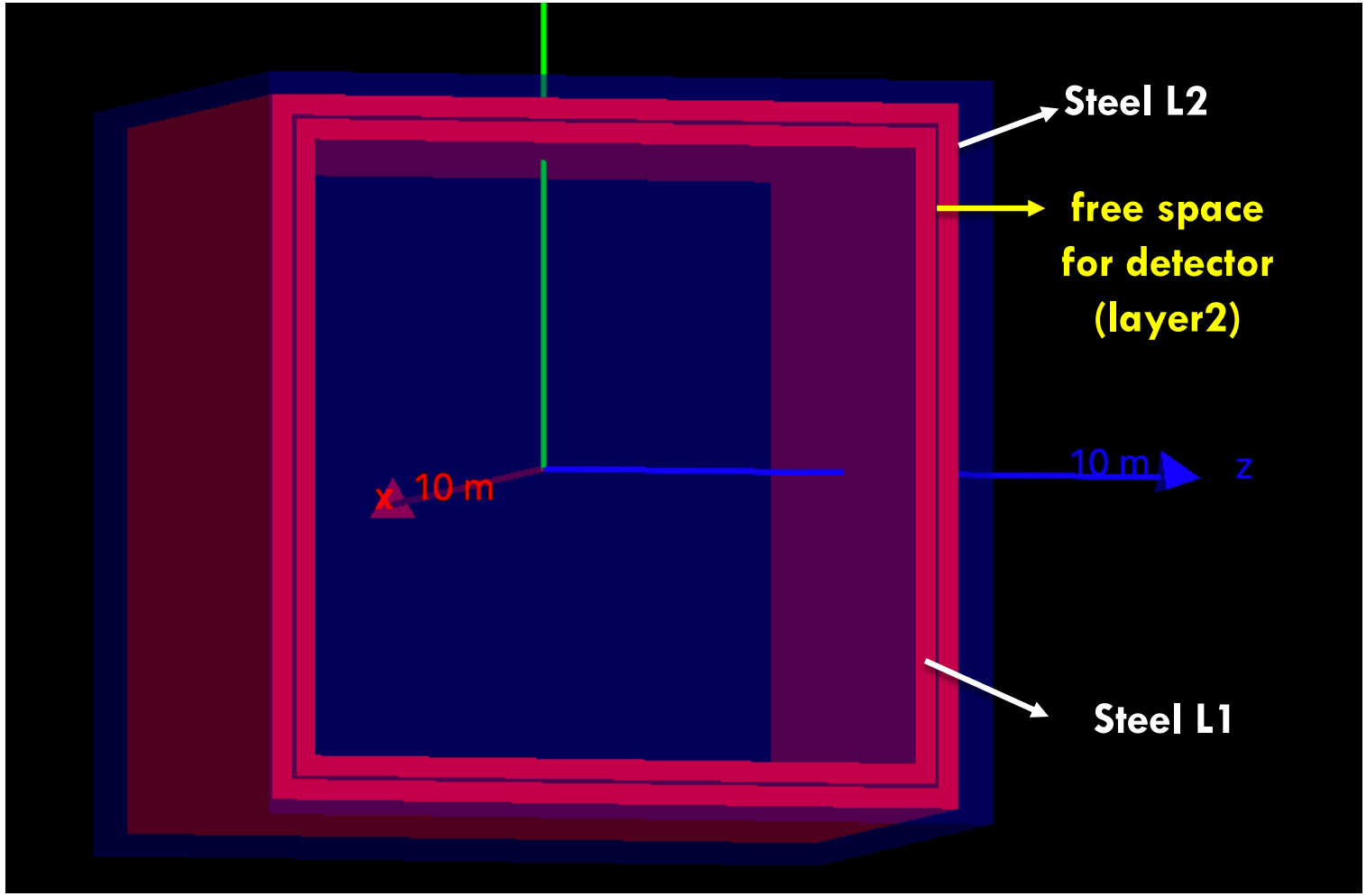
```
.....
.....
.....
You have successfully registered the following user vis actions.
Run Duration User Vis Actions: none
End of Event User Vis Actions: none
End of Run User Vis Actions: none


Some /vis commands (optionally) take a string to specify colour.
"/vis/list" to see available colours.


-------- EEEE ------- G4Exception-START -------- EEEE -------
*** G4Exception : Fatal Error in Argument
      issued by : GEOM
MUSPC: Maximum number of Channels allowed per X or Y per Ladder is 10000!


*** Fatal Error In Argument *** core dump ***
 **** Track information is not available at this moment
 **** Step information is not available at this moment


-------- EEEE -------- G4Exception-END --------- EEEE -------




*** G4Exception: Aborting execution ***
Aborted (core dumped)
[igarzia@lxplus7104 instal_dir]$
```

The IDEA Detector



Preshower and the muon detection sys

The Muon Detector: reference dimension

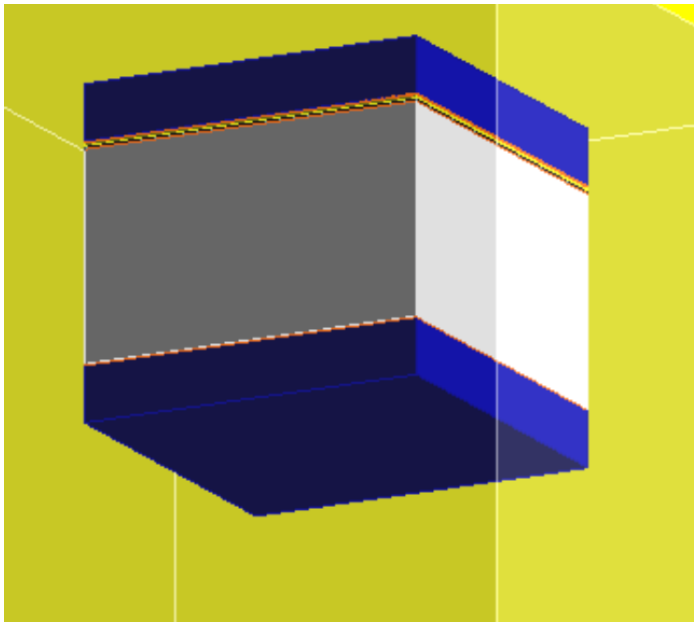


The μRWELL materials and implementation

- Goal: construction of a parametric code for simulation

```
G4double CStratification[numlayer]={1.6*mm,0.035*mm, 6*mm, 0.005*mm, 0.050*mm, 0.0001*mm, 0.035*mm, 0.1*mm, 0.035*mm, 1.6*mm};
G4Material* materials[numlayer]={m_FR4,m_Cu,m_gasDet,m_Cu,m_Kapton,m_DLC,m_Cu,m_DLC,m_Cu,m_FR4};
```

- Two function for steel layers and sensitive detectors
  - CreateSteelLayer(logicEnv, La, r1_steel, thickness_steel, checkOverlaps);
  - DetAssembly(logicEnv, mat, La, radius, CStratification[i],color[i], checkOverlaps);



The μRWELL materials and implementation

- ConstructMaterial();

- From G4NistManager:
  - m_Cu = nist->FindOrBuildMaterial("G4_Cu");
  - m_Kapton = nist->FindOrBuildMaterial("G4_KAPTON");
- DLC:

```
////DLC material (carbonio amorfo)
mat_name    = "DLC";
mat_density = 2.00*g/cm3;  ///should be checked (used for CGEM simulation)
n_element = 1;
m_DLC = new G4Material(mat_name,mat_density,n_element = 1);
m_DLC->AddMaterial(m_Cu, 1);  //fraction mass
```

- FR4:

```
mat_name    = "FR4";
mat_density = 1.97*g/cm3;  ///should be checked (used for CGEM simulation)
n_element = 2;
m_FR4 = new G4Material(mat_name, mat_density, n_element);
m_FR4->AddMaterial(m_FiberGlass,0.6);
m_FR4->AddMaterial(m_Epoxy,0.4);
```

The μRWELL materials and implementation

- ConstructMaterial();

- From G4NistManager:
  - m_Cu = nist->FindOrBuildMaterial("G4_Cu");
  - KAPTON");

-
```
mat_name    = "FiberGlass";
mat_density = 1.99*g/cm3;
n_element = 4;
m_FiberGlass =  new G4Material(mat_name, mat_density, n_element);
m_FiberGlass -> AddMaterial(SiO2, 0.6);
m_FiberGlass -> AddMaterial(B2O3, 0.05);
m_FiberGlass -> AddMaterial(Al2O3, 0.13);
m_FiberGlass -> AddMaterial(CaO, 0.22);
```

- FR4:

```
mat_name    = "Epoxy";
mat_density = 1.2*g/cm3;
n_element = 2;
m_Epoxy =  new G4Material("epoxy", mat_density, n_element=2);
m_Epoxy->AddElement(elC, n_natoms=2);
m_Epoxy->AddElement(elH, n_natoms=2);
```

```
mat_name    = "FR4";
mat_density = 1.97*g/cm3;  ///should be checked (used for GEM simulation)
n_element = 2;
m_FR4 = new G4Material(mat_name, mat_density, n_element);
m_FR4->AddMaterial(m_FiberGlass,0.6);
m_FR4->AddMaterial(m_Epoxy,0.4);
```

The μRWELL materials and implementation

- ConstructMaterial();

- ArCO2CF4:

```
G4Material* _CO2 = nist->FindOrBuildMaterial("G4_CARBON_DIOXIDE");
mat_name = "CF4";
mat_density = 3.78*kg/m3;
n_element = 2;
G4Material* _CF4 = new G4Material(mat_name, mat_density, n_element = 2);
_CF4->AddElement(elC, n_natoms=1);
_CF4->AddElement(elF, n_natoms=4);
//build gas for the muon detector
mat_name    = "gasDet";
mat_density = 2.94*kg/m3;  ///should be checked (used for CGEM simulation)
n_element = 3;
m_gasDet = new G4Material(mat_name,mat_density,n_element = 3);
m_gasDet->AddElement(elAr, 0.295);  //fraction mass
m_gasDet->AddMaterial(_CO2, 0.109);  //fraction mass
m_gasDet->AddMaterial(_CF4, 0.596);  //fraction mass
```

from G4NistManager

new material