Pre-shower and Muon system for IDEA

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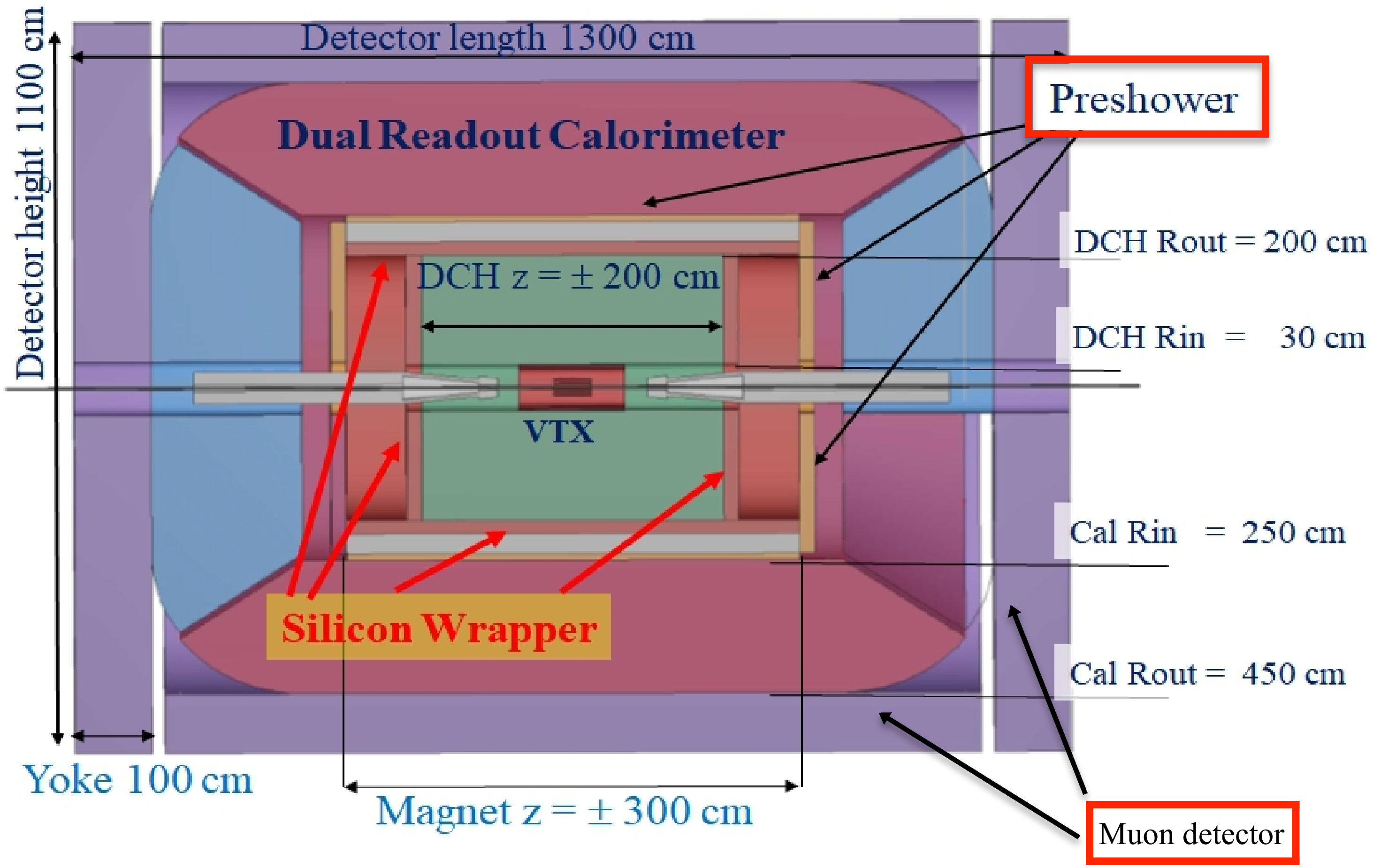
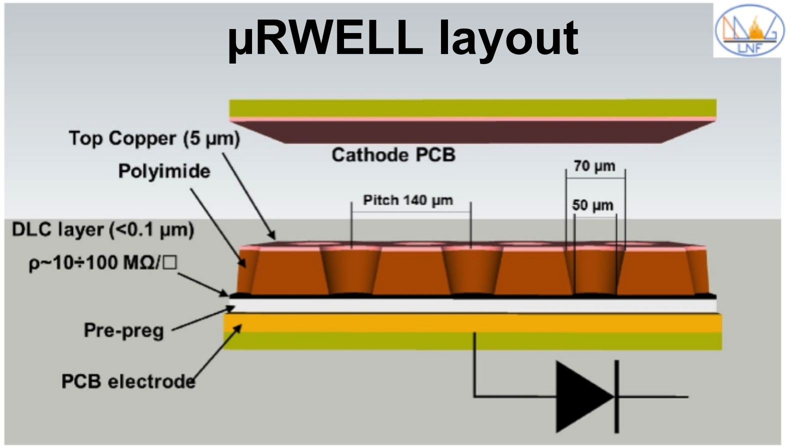
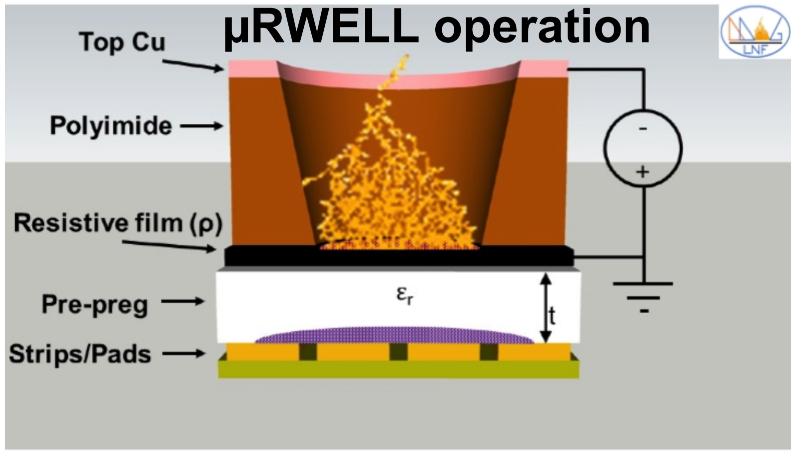
IDEA detector layout

IDEA detector is a general purpose detector designed for experiments at future e+e- colliders such as CEPC



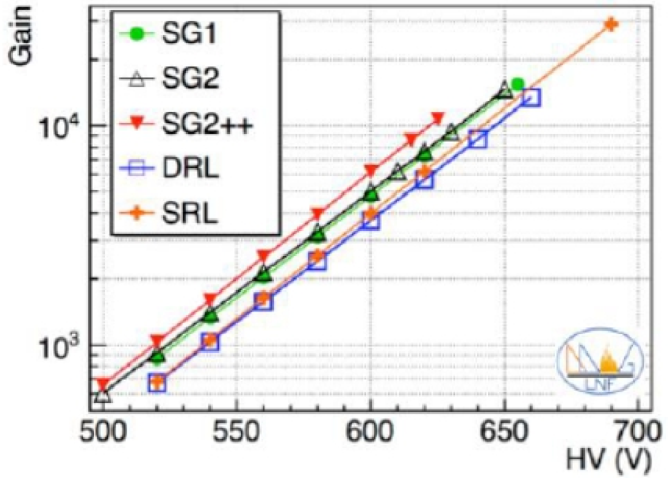




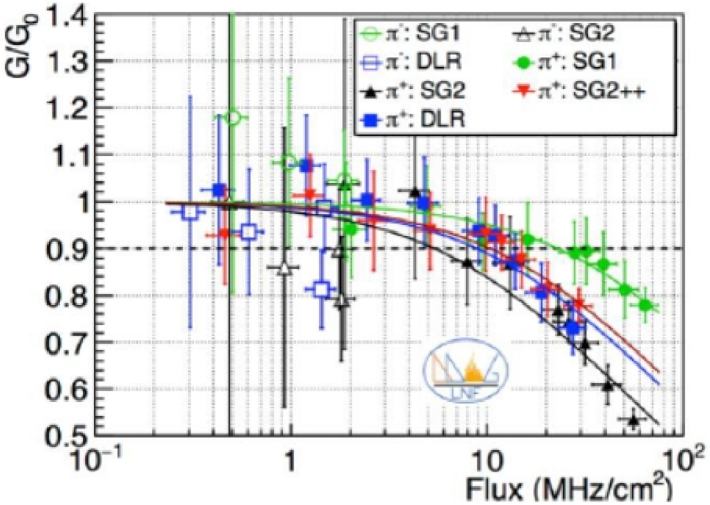
Pre-shower and the Muon Systems are designed with the µRWELL technology

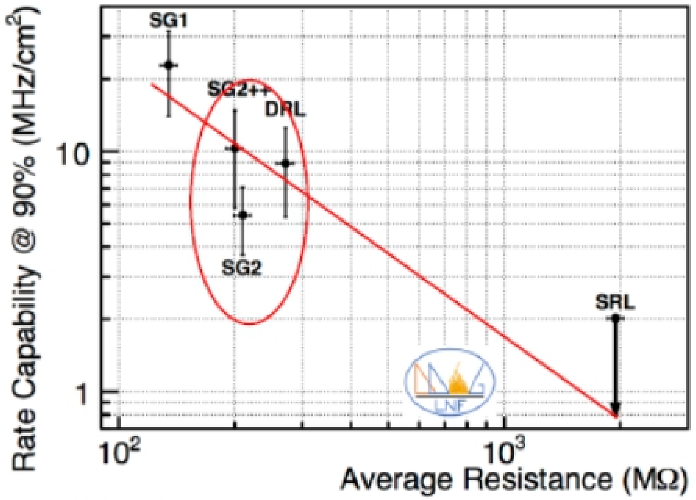
Current state of art of µRWELL

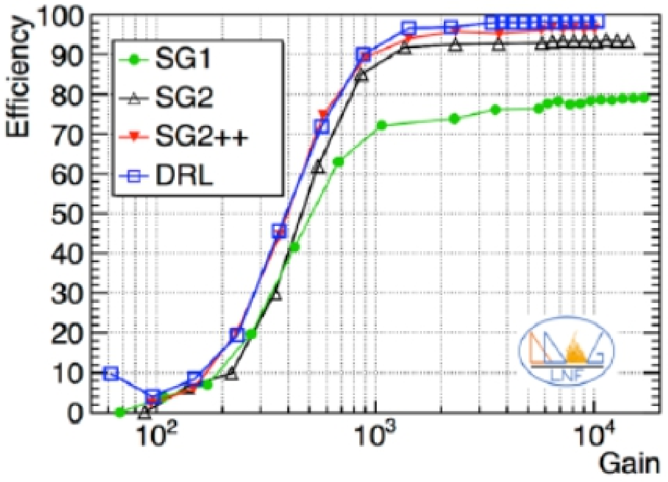
Gain up to ~ 10^4

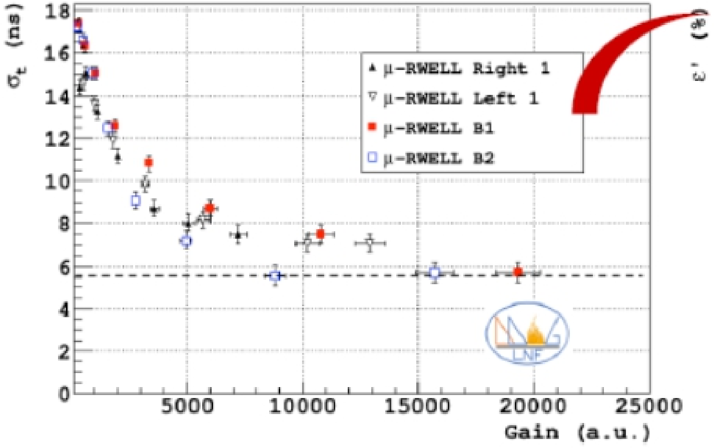


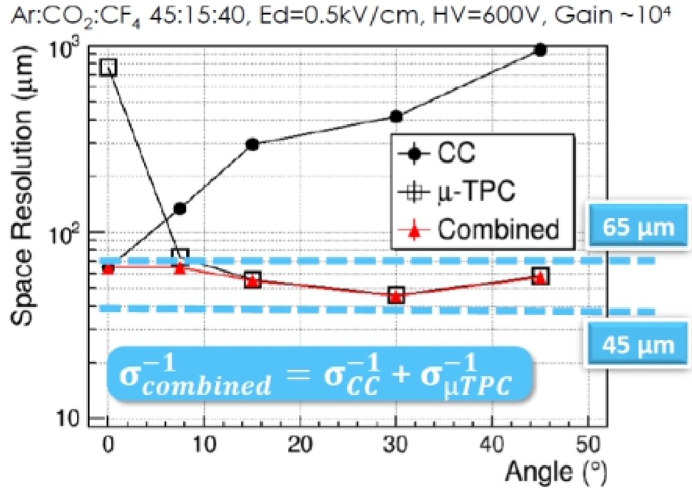
Rate capability (@ G = 5000) ~ 5-10 MHz/cm^2











Efficiency ~ 98%

σ_t ~ 5-6 ns

Space resolution in u-TPC-mode

IDEA pre-shower detector dimensions

Barrel

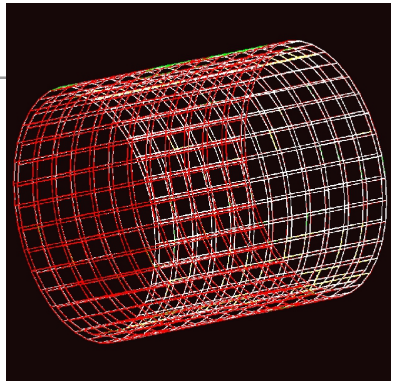
R [mm]	Length [mm]	Thickness [mm]	pixel size [mm]	area [cm^2]	# of channels
2460	±2480	20	0.4×500	768K	384K

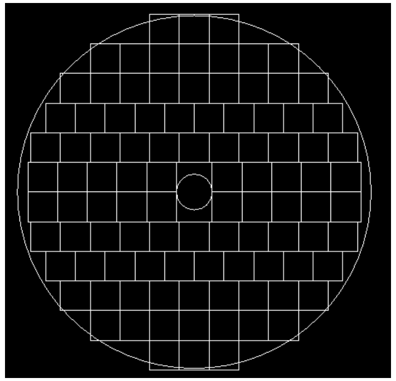
Endcap

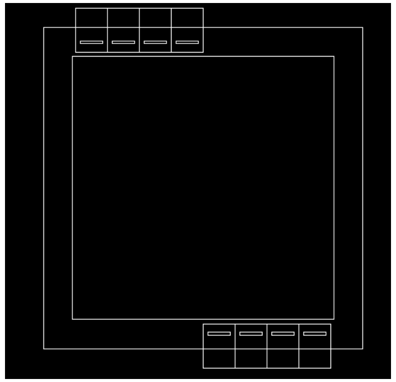
R_{in} [mm]	R_{out} [mm]	z [mm]	Thickness [mm]	pixel size [mm]	area [cm^2]	# of channels
248	2440	±2460	20	0.4×500	370K	185K

IDEA's Pre-Shower detector would have in total:
- ~ **225 m2 total**
- ~ **1.5 M channel in total**

Tiles: 50x50 cm^2 with X-Y readout
Strip Length: 50 cm
Strip pitch: 0.4 mm
Input FEE capacity (Cap_{inp})~70 pF







IDEA Muon detector dimensions

Barrel

Layer	R [mm]	Length [mm]	Thickness [mm]	int. length	pixel size [mm]	area [cm^2]	# 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

Endcap

Disk	R_{in} [mm]	R_{out} [mm]	z [mm]	Thickness [mm]	int. length	pixel size [mm]	area [cm^2]	# 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

IDEA's Muon detector would have in total:

~ **2800 m2 total**

~ **4M channels in total**

~ **3 stations**

Tiles: 50x50 cm^2 with X-Y readout
Strip Length: 50 cm
Strip pitch: 1.5 mm
Input FEE capacity (Cap_{inp}) ~270 pF

Questions to be solved

How to optimize the detector design to the CEPC physics program?

How to reduce the input FEE capacity in the muon system?

How to built more than 3000 m2 of μRWELL detectors?

Activities on 2021

The activities for this years are divided in four main topics:

- Design and construction
- Simulation and reconstruction software
- Development of front-end electronics
- Test and integration

Hardware activities on 2021

The 2021 program is centered mainly on the following activities:

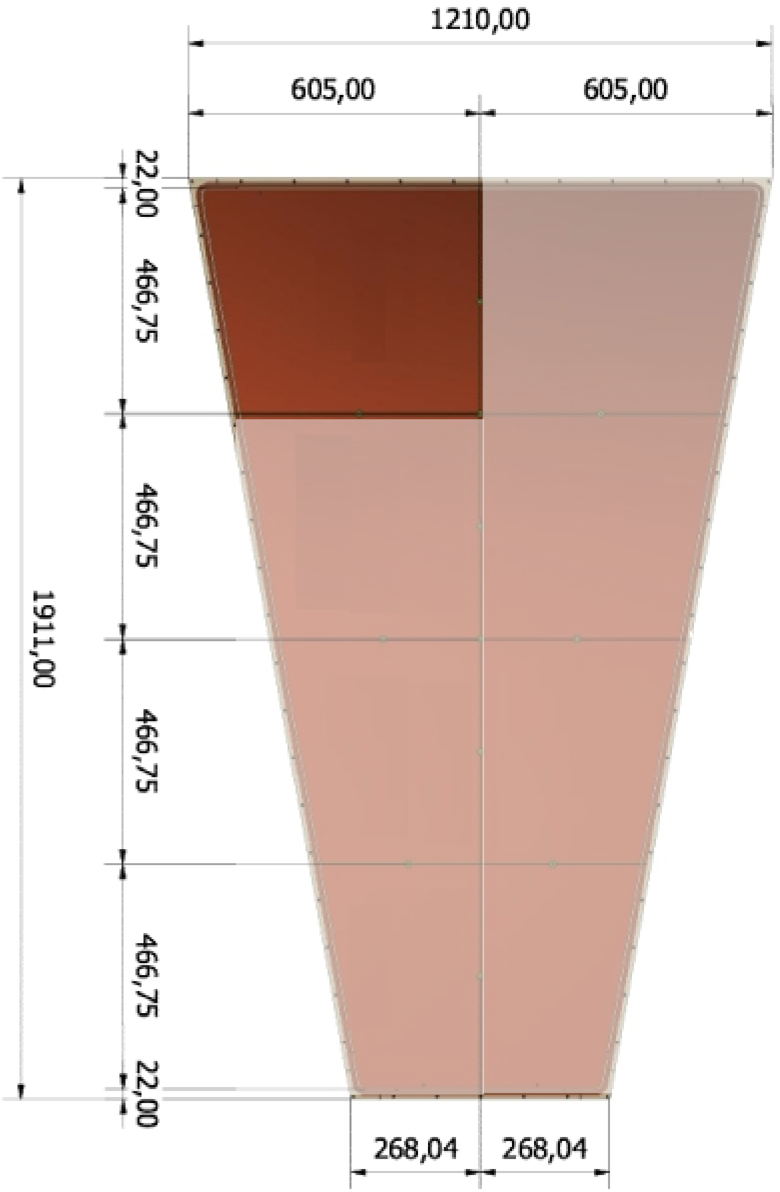
1. test of large size μ**RWELLs** with TIGER-GEMROC readout
2. construction of a large size μ**RWELL** at ELTOS (TT)
3. *optimization studies on DLC resistivity and pitch size*

Built and test a large area µRWELL

A first large area µRWELL has been built at CERN in Rui's workshop

Size: 606.5 x 498.5 x 1 mm
Active area: 559.6 - 480 (w) x 450 (h) mm
373 radial strips
strip pitch 1.29 - 1.5 mm
strip length ~ 22 cm

This first detector will tested with a cosmic-ray stand and readout with TIGER-GEMROC technology developed by INFN within the CGEM-IT BESIII frame.

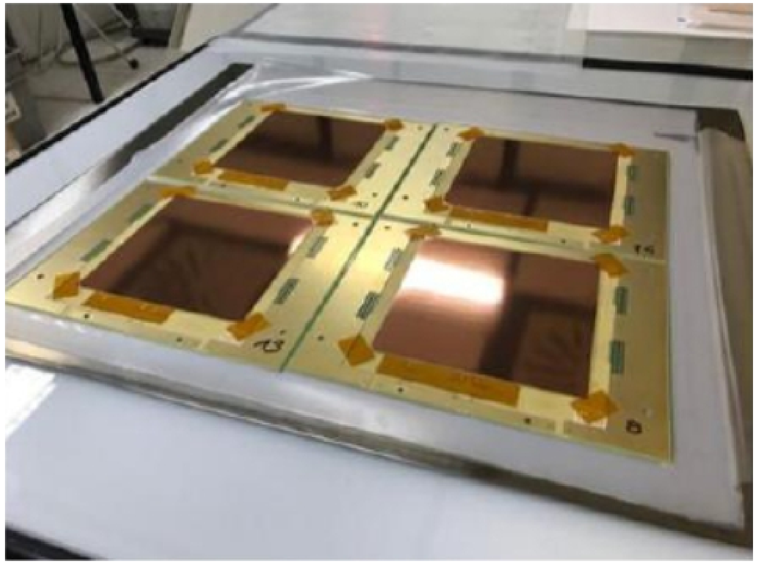


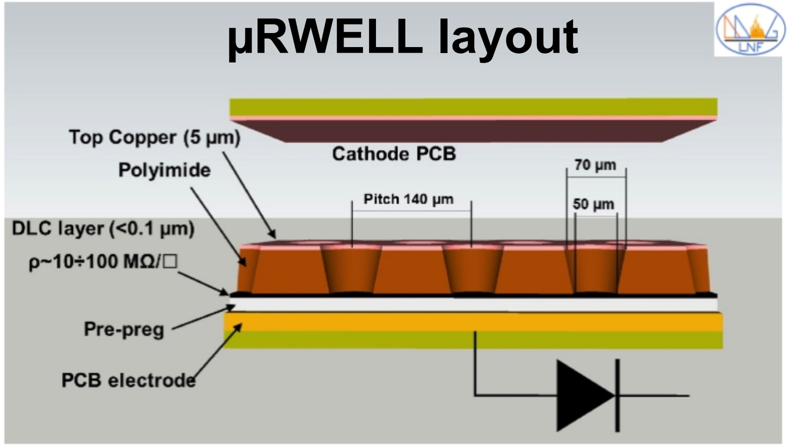
Built a second large area µRWELL: technological transfer

A second large area µRWELL of 500 x 500 mm2 will be developed together with ELTOS, an Italian industry that performs the coupling of the DLC-foil with the PCB (only for low rate layout)

The max size of the µRWELL-PCB that can be produced by ELTOS is about 600x700 mm2.

Up to 8 PCBs of such a size can be manufactured at the same time. The manufacturing procedure is slightly different from the one used by Rui but works fine. The etching is done at CERN.

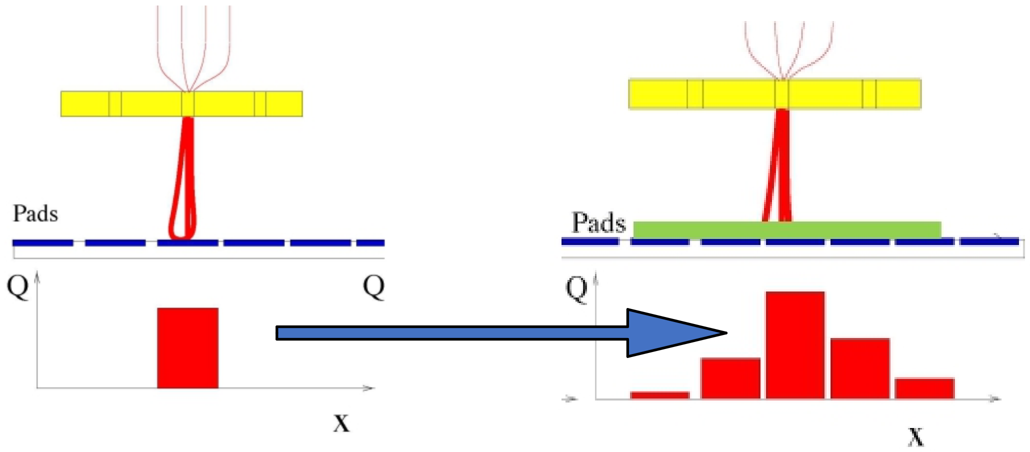




Built a second large area μRWELL: DLC sputtering

A proposal for a DLC sputtering facility is under discussion between CERN and INFN. A DLC sputtering machine will allow to study DLC production for large area surfaces and to optimize the resistivity of the foils as a function of their purpose. The scientific interest for the DLC is central for the MPDG technologies and their developments.

Optimization of resistivity and pitch size: charge dispersion

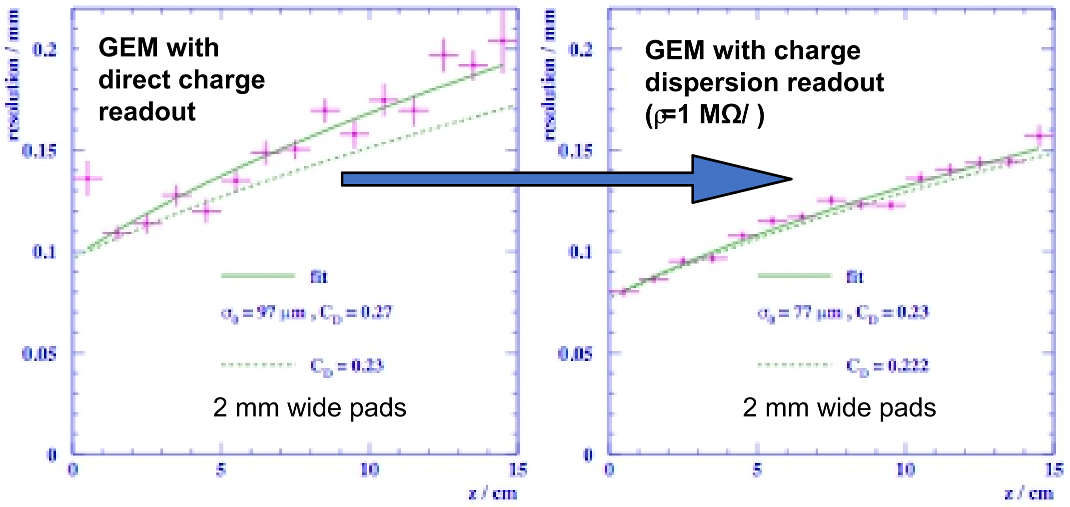


Modified GEM anode with a high resistivity film bonded to a readout plane shows the improvement introduced by the charge dispersion with respect to a design without a resistive film.

If a large pitch size is used then limitations of the spatial resolution may occurs. The charge dispersion technique allows the signal to reach more strip/pad.

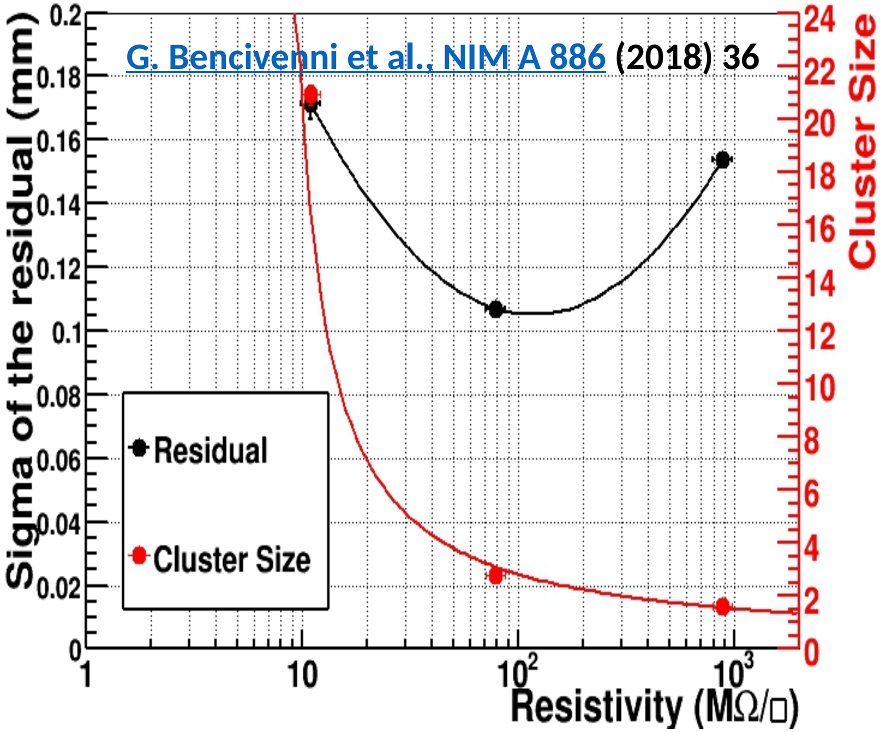
R.K.Carnegie et.al., NIM A538 (2005) 372

K. Boudjemline et.al., NIM A574 (2007) 22

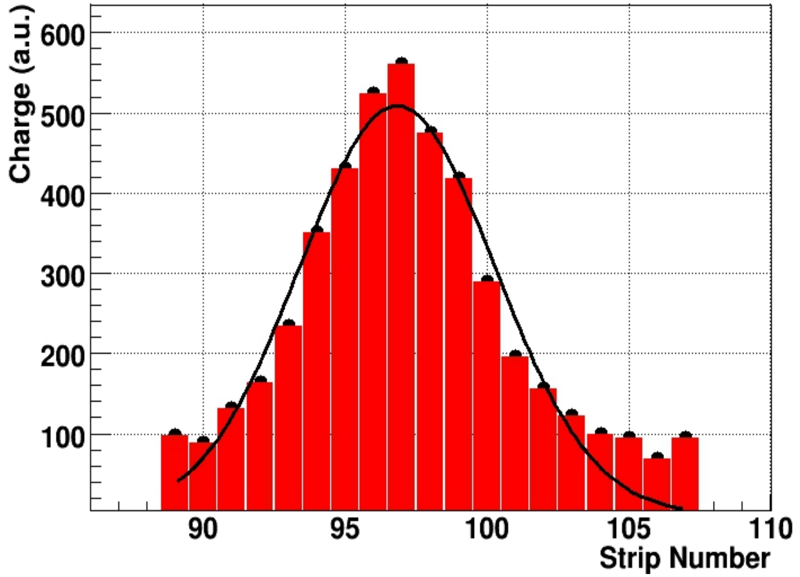


Optimization of resistivity and pitch size: μRWELL studies

APV & 400 um strip pitch & Cinp=15 pF



Charge collected by the APV on the strip readout (resistivity 10 MΩ/)



The use of **low resistivity increases the charge spread** (cluster size) on the readout strips and then **σ is worsening.**

At **high resistivity** the **charge spread is too small (Cl_size → 1)** then the Charge Centroid method becomes no more effective **(σ → pitch/√12).**

Optimization of resistivity and pitch size: the plane

Built and test 10 μRWELL detectors low-rate configuration with active are of 50x16 cm^2

N.5 μRWELL for the Pre-shower
Strip pitch 0.4 mm, strip length 50 cm (C_{inp}~70 pF)

N.5 for the Muon detector
Strip pitch 1 mm, strip length 50 cm (C_{inp}~180 pF)

The proposal measures the charge distribution for 5 resistivity on the DLC 10-20-50-100-200 MOhm/square.

Hardware and software simulations will test different pitch sizes: i.e. 0.4-0.8-1.2 mm for the pre-shower configuration and 1-2-3 mm for the muon chamber configurations.

The characterization of these configurations will be performed with a test beam with APV electronics at SPS-CERN

Software activities on 2021

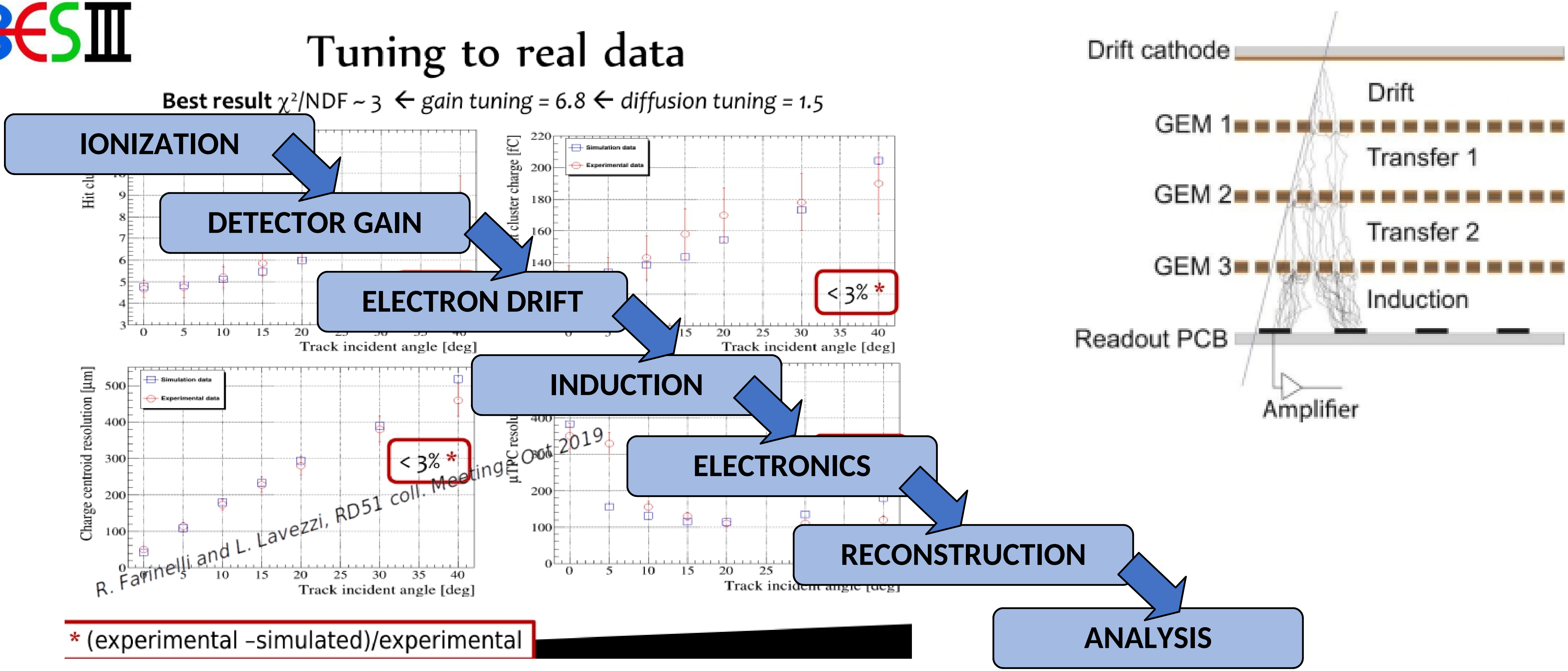
The 2021 program is centered mainly on the following activities:

1. development of a μRWELL detailed simulation
2. description of the IDEA pre-shower and muon system in the DD4HEP framework within the Key4HEP environment

These task is needed for futher software studies:

3. *Development of ML algorithms for the μRWELL signal reconstruction*
4. *Performance studies with pre-shower and muon system (design optimization, Long Living Particles "case studies")*

Detailed μRWELL simulation: the triple-GEM experience



A triple-GEM parametric simulation which take into account diffusion, transparency, gain, induction and readout electronics has been developed within the CGEM-IT BESIII frame. The simulated data has been tuned to the experimental results of charge, multiplicity and spatial resolution (CoG and μTPC)

Detailed µRWELL simulation: charge dispersion

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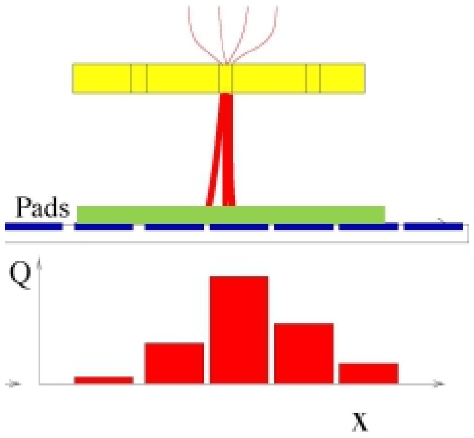
CREMLIN PLUS Connecting Russian and European Measures for Large-scale Research Infrastructures

- IONIZATION
- DETECTOR GAIN
- ELECTRON DRIFT
- RESISTIVE
- INDUCTION
- ELECTRONICS
- RECONSTRUCTION
- ANALYSIS



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Simulating the charge dispersion phenomena in Micro Pattern Gas Detectors with a resistive anode

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$$\rho\left(x,y,t\right)=\frac{Nq_e}{2\pi\left(2ht+w^2\right)}exp\left[-\left(x^2+y^2\right)/\left(2\left(2ht+w^2\right)\right)\right]$$

$$\rho\left(x,t\right)=\frac{q}{\sqrt{2\pi}\left[\sigma_0\left(1+\frac{t-t_0}{\tau}\right)\right]}exp\left[-\frac{\left(x-x_0\right)^2}{2\sigma_0^2\left(1+\frac{t-t_0}{\tau}\right)^2}\right]\Theta\left(t-t_0\right)$$

Time-dependent model adapted to a one-dimensional readout

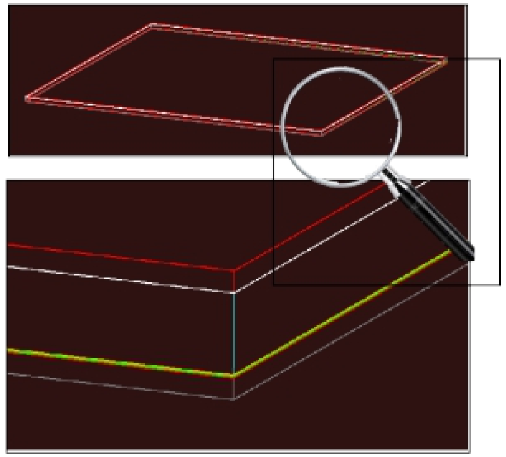
IDEA pre-shower and muon system simulation

The detailed simulation of a μRWELL will be implemented with the DD4HEP framework using Geant4

The simulation has to run with Key4HEP and to use it in the CEPC software

Once the full IDEA detector will be simulated, it will be possible to optimize the detector geometry (strip size, spatial resolution, etc...) as a function of the CEPC physics program.

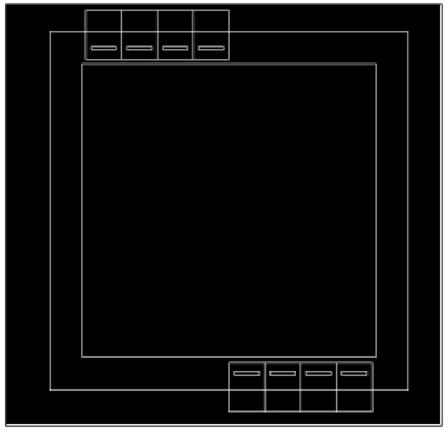
A high spatial resolution muon system impact can be studied system New Physics researches, such as the detection of Long Lived Particles

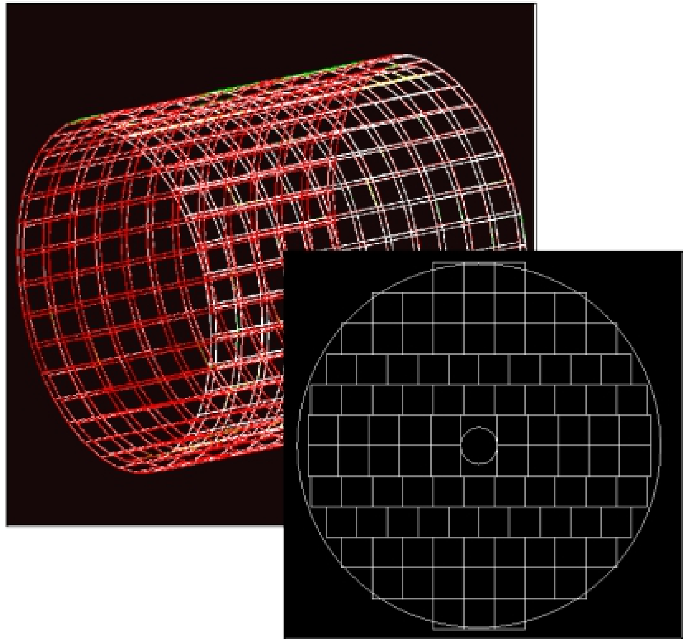


Chamber thickness: 9.4601mm
- Cathode thickness: 1.635mm
- Driftgap: 6mm
  - μ-RWELL+readout thickness: 1.8251mm

The cathode points to the IP

First considered chamber size:
500 mm x 500 mm





2022-2024 program on the μRWELL

- Define the best resistivity of the DLC for both μRWELL fundamental tiles and built the 50x50 cm2 prototypes for the pre-shower and muon system
- Optimize the engineering mass construction process together with the ELTOS industry
- Develop a custom-made ASIC for the μRWELL with the experience obtained from the TIGER chip and to test the μRWELL prototypes
- Develop a new reconstruction algorithm, ML-based, to improve the resolution of μRWELL
- Simulation of the CEPC decay channels of interest to optimize the detector design with special emphasis on Long Lived Particles to show the impact of a performing tracked in the muon system instead of a tagger

Conclusion

- The test of resistivity/pitch size relationship will optimize the detector and will provides information for the the µRWELL detector simulation

- The pre-shower and muon system simulation will be developed to describe the full IDEA detector in the CEPC software

- A road map up to 2024 is defined starting from the construction, simulation and test activities ongoing. An international cooperation would boost these activities

Thanks