CEPC Detector and Physics meeting
06/11/2019

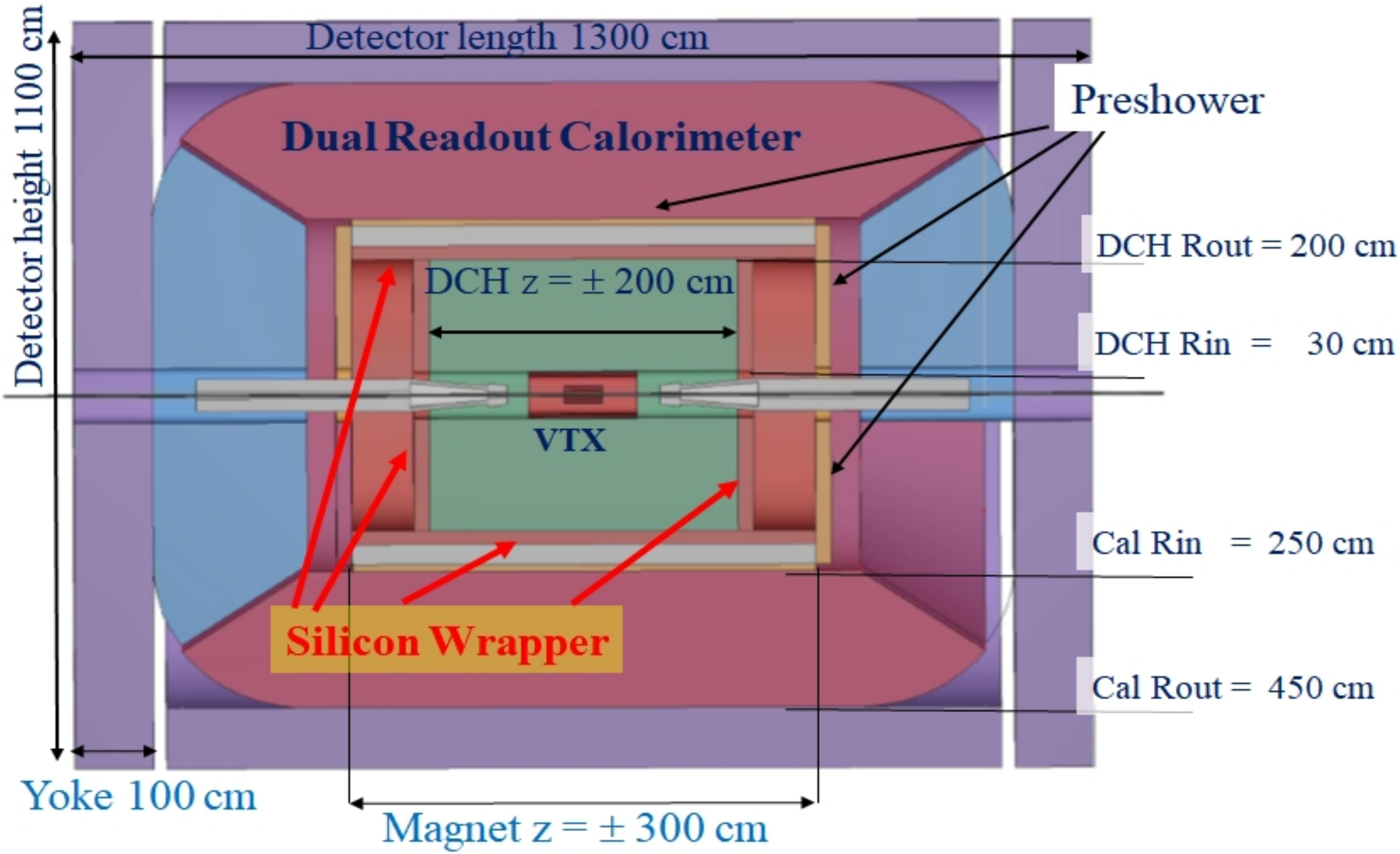
IDEA's drift wire chamber, Preshower and Muon detectors

Paolo Giacomelli
INFN Bologna

Overview

- The drift wire chamber
  - Wire length problem
  - Envisaged solutions
- The IDEA Preshower and Muon detector
  - The μ-RWELL detector
  - R&D in 2019
  - R&D foreseen in 2020
- Conclusions

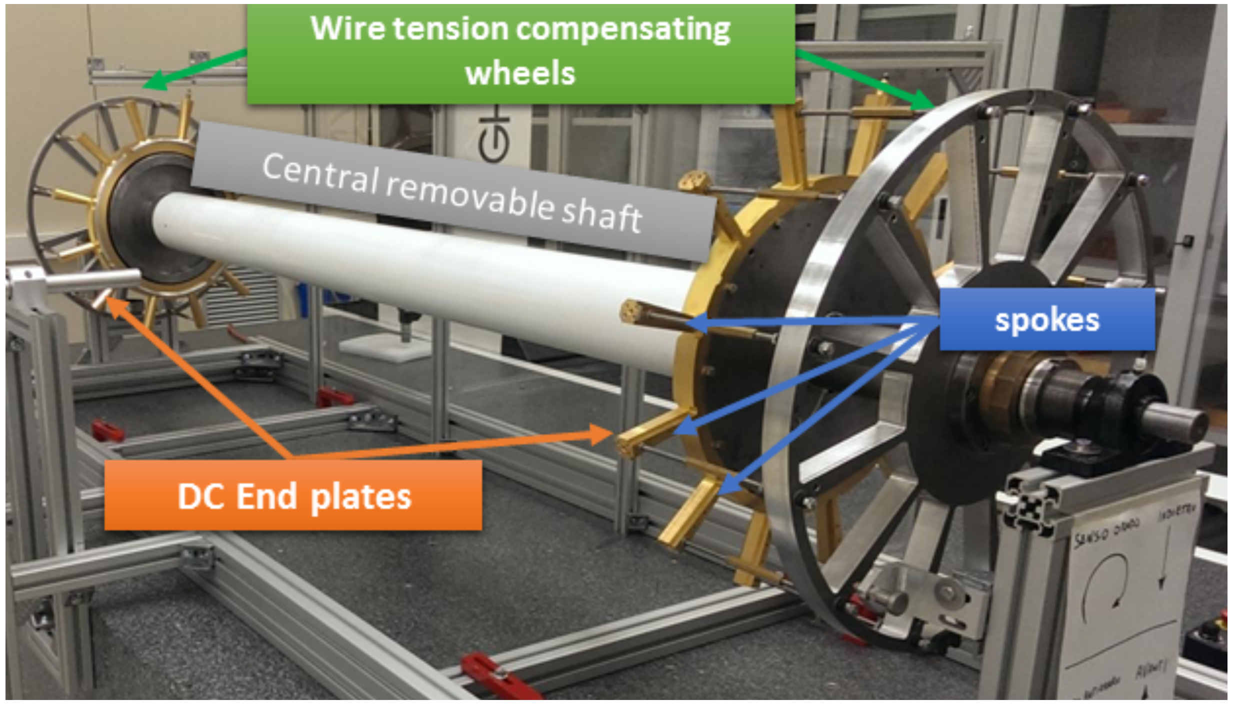
IDEA detector layout



Detector for circular lepton collider

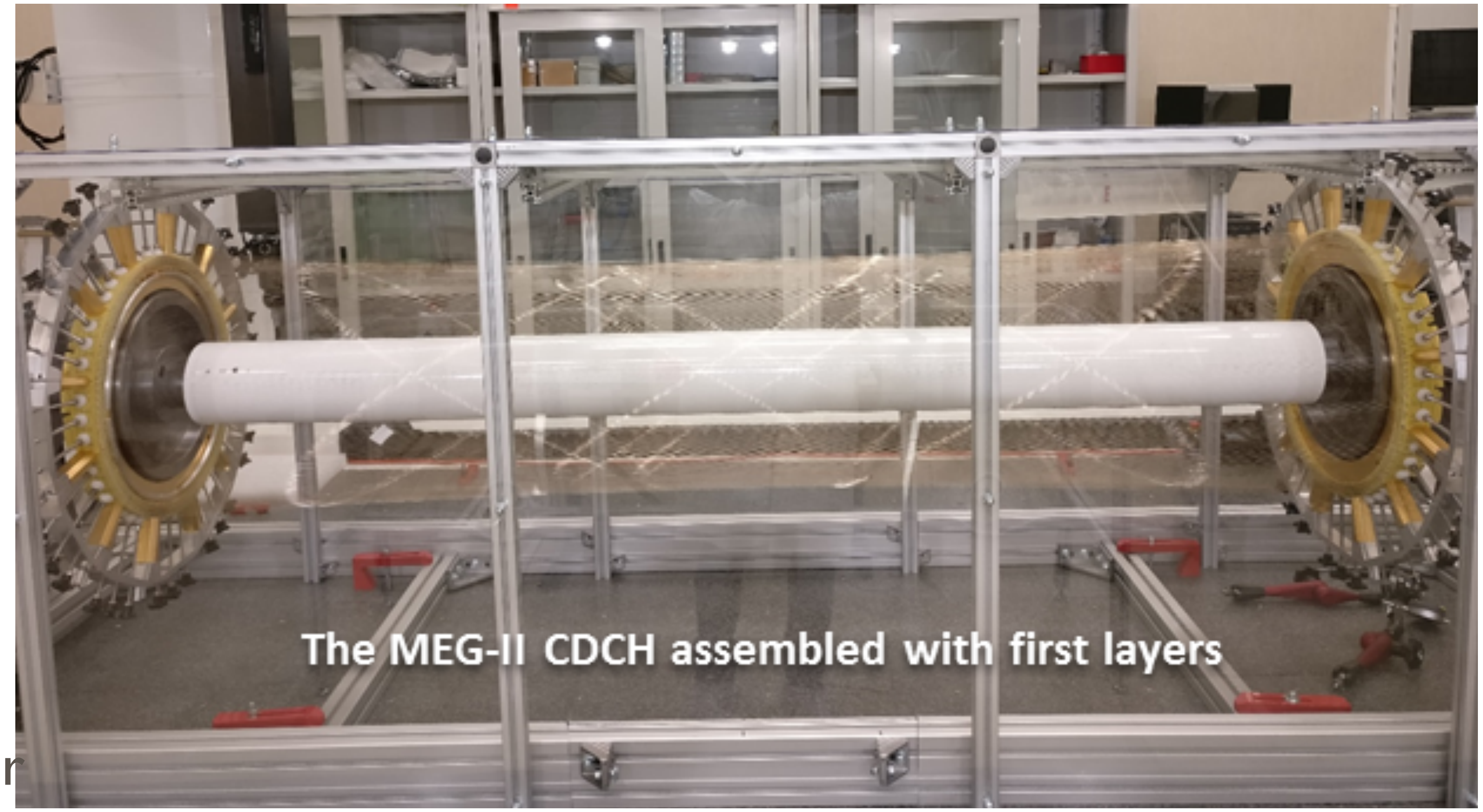
Drift wire chamber

IDEA wire chamber



"Naked" chamber

MEG II chamber with first layers of wires

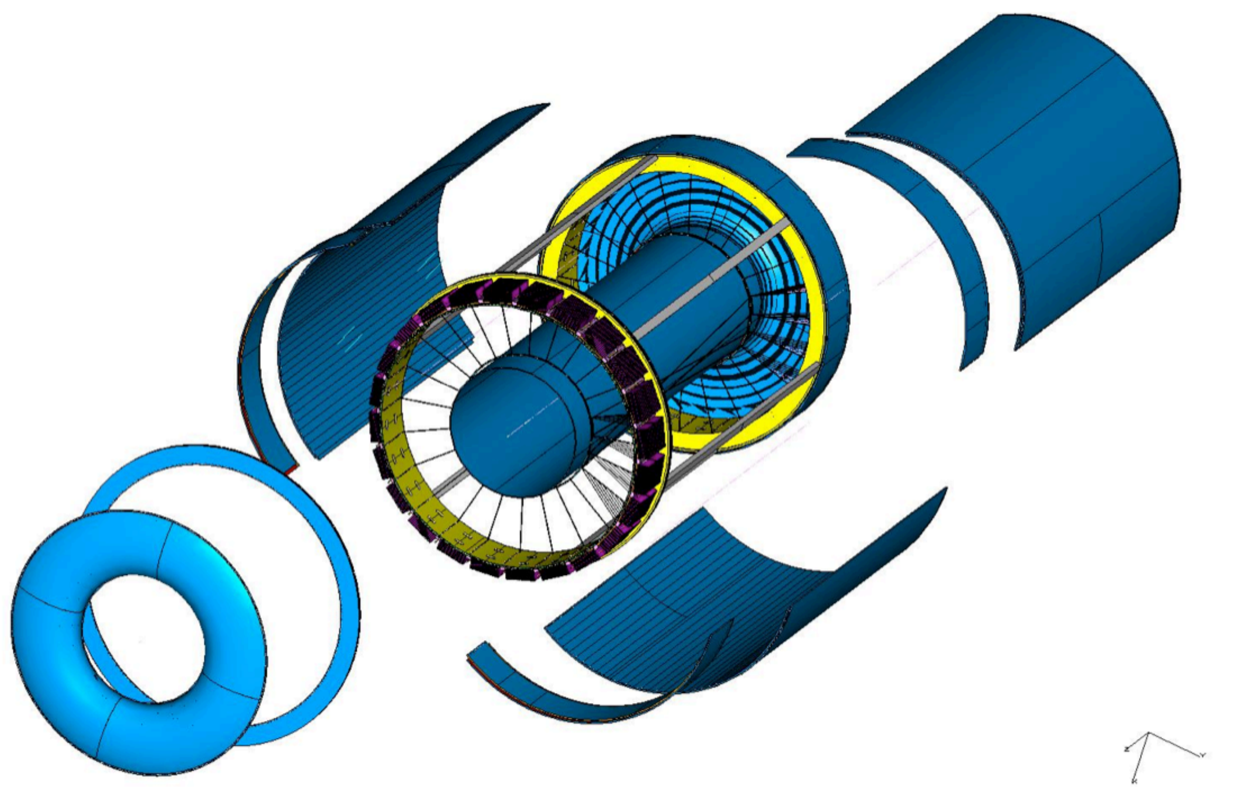


Dimensions of the MEG II chamber:

- L = 193 cm
- R_{in} = 17 cm
- R_{out} = 30 cm
- 10 layers for each 30° azimuthal sector

IDEA wire chamber

MEG II's BIG BROTHER is being proposed as the main tracker of IDEA:

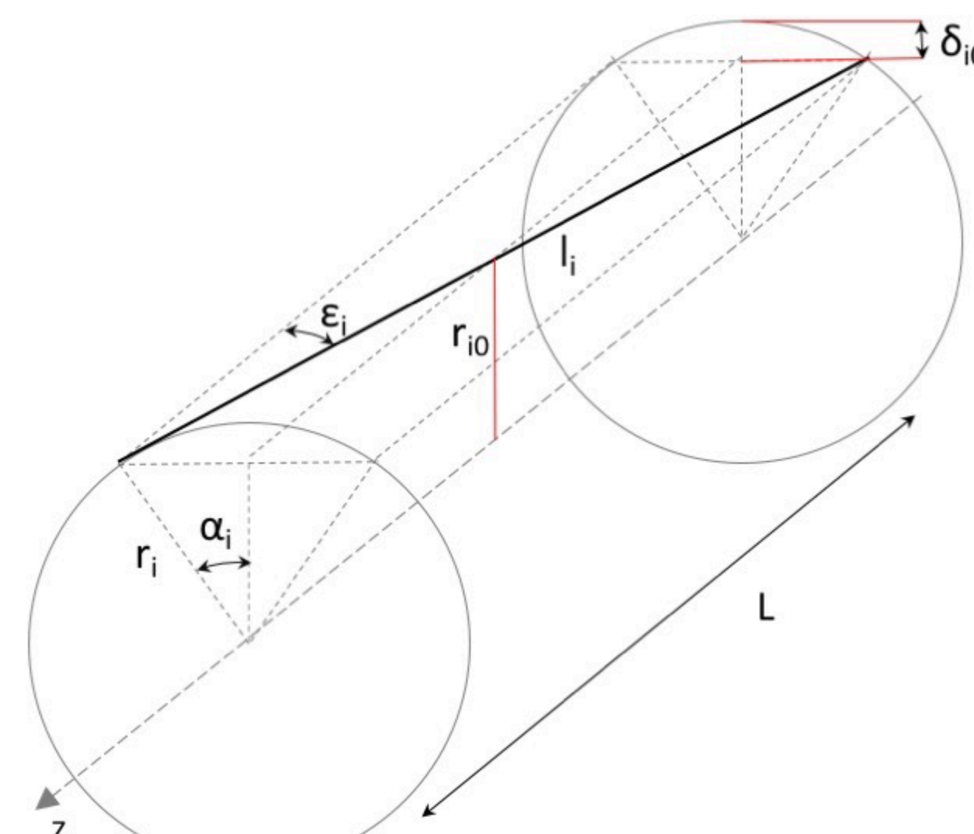


The IDEA drift chamber by numbers:

- $L =$ 400 cm
- $R_{in} =$ 35 cm
- $R_{out} =$ 200 cm
- 112 layers for each 15° azimuthal sector
- 56 448 squared drift cells of about 12-13.5 mm edge
- max drift time: 350 ns in 90%He-10%iC_4H_{10}

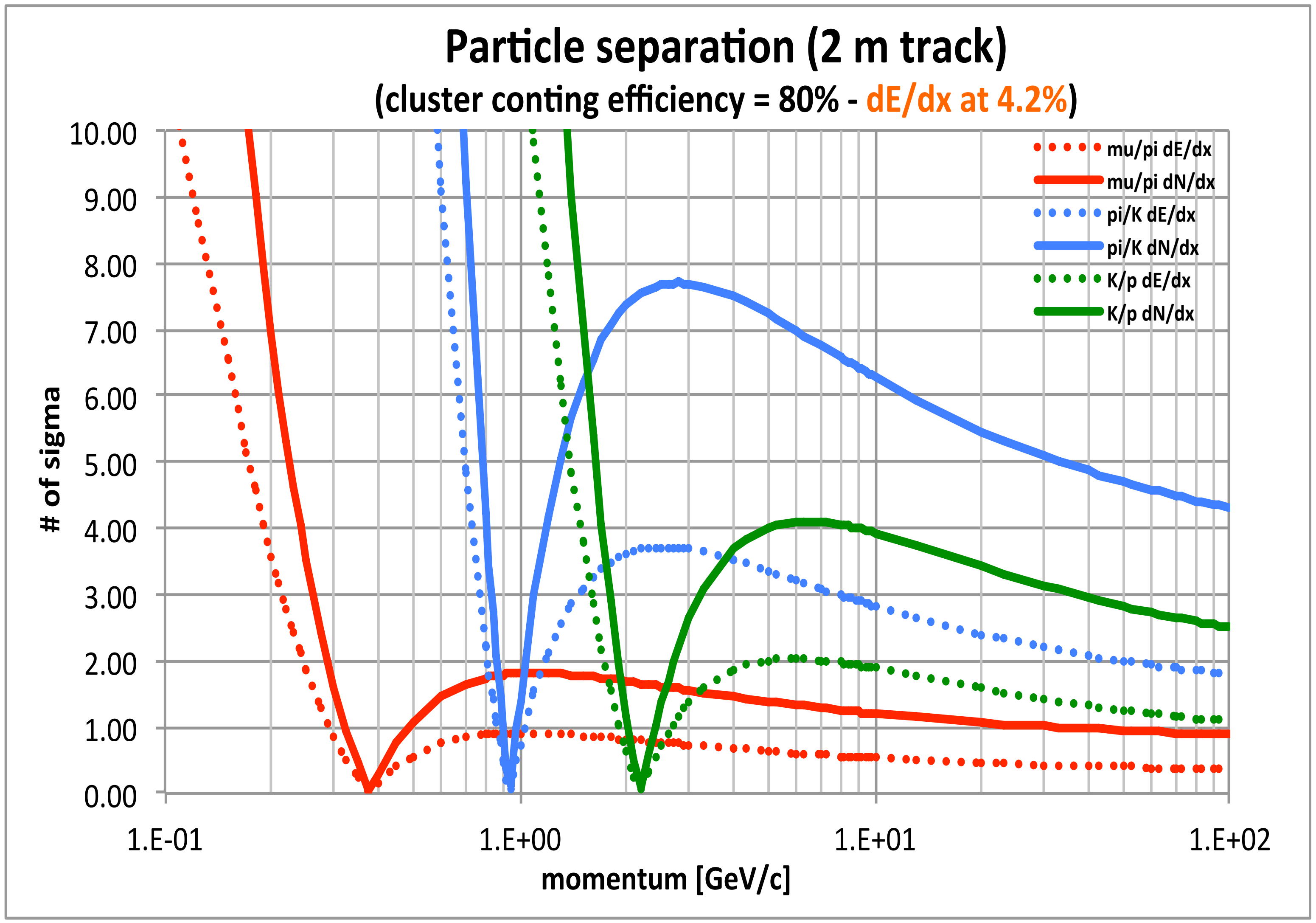
The "wire cage" and the "gas envelope" are decoupled

- The stereo angle α is generated stringing the wire between spokes @ 2 sectors (30°) distance
- $\alpha \in$ [20 mrad (1.1°); 180 mrad (10.3°)], increasing with R
- the electrostatic stability is achieved when the wire tension is about 25g, for a total load of about 7,7 tons!



IDEA wire chamber

- cluster counting for improved particle identification: it is essentially based on the well known method of measuring the [truncated] mean dE/dX but it replaces the measurement of an ANALOG information with a DIGITAL one, namely the number of ionisation clusters per unit length:



Wire length problem

Electrostatic stability condition $T > \dfrac{C^2 V_0^2 L^2}{4\pi\varepsilon w^2}$

T = wire tension
C = capacitance per unit length
V_0 = anode-cathode voltage
L = wire length, w = cell width

IDEA Drift Chamber: **C = 10 pF/m, V_0 = 1500 V, L = 4.0 m, w = 1.0 cm**

T > 0.32 N

- 20 µm W sense wire (Y.S. ≈ 1200 MPa): **T_{max} = 0.38 N** (marginal)
- 40 µm Al field wire (Y.S. ≈ 300 MPa): **T_{max} = 0.38 N** (marginal)

=> **shorten chamber** (loss of acceptance)
=> **widen cell size** (increase occupancy)
=> **increase wire diameter** (increase multiple scattering and endplate load)

or,

=> replace 40 µm Al with **Titanium** (Y.S. ≈ 550 MPa): **T_{max} = 0.70 N**
but Ti G5 (90%Ti-6%Al-4%V) hard to draw in such sizes ("galling phenomenon")
=> replace 40 µm Al with **35 µm Carbon monofilament**
(Y.S. > 860 MPa): **T_{max} > 0.83 N**

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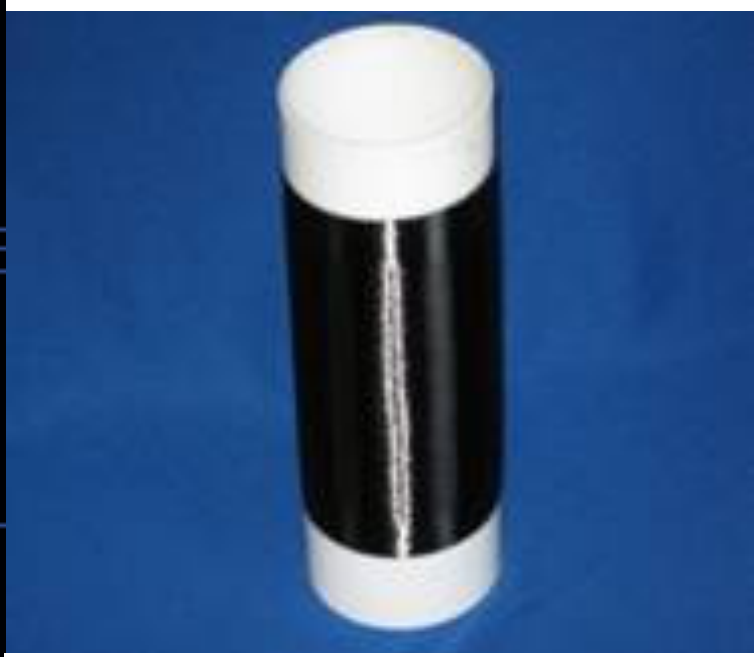
New wires: Carbon monofilaments

SPECIALTY MATERIALS, INC.

Manufacturers of Boron and SCS Silicon Carbide Fibers and Boron Nanopowder

CARBON MONOFILAMENT



TYPICAL PROPERTIES

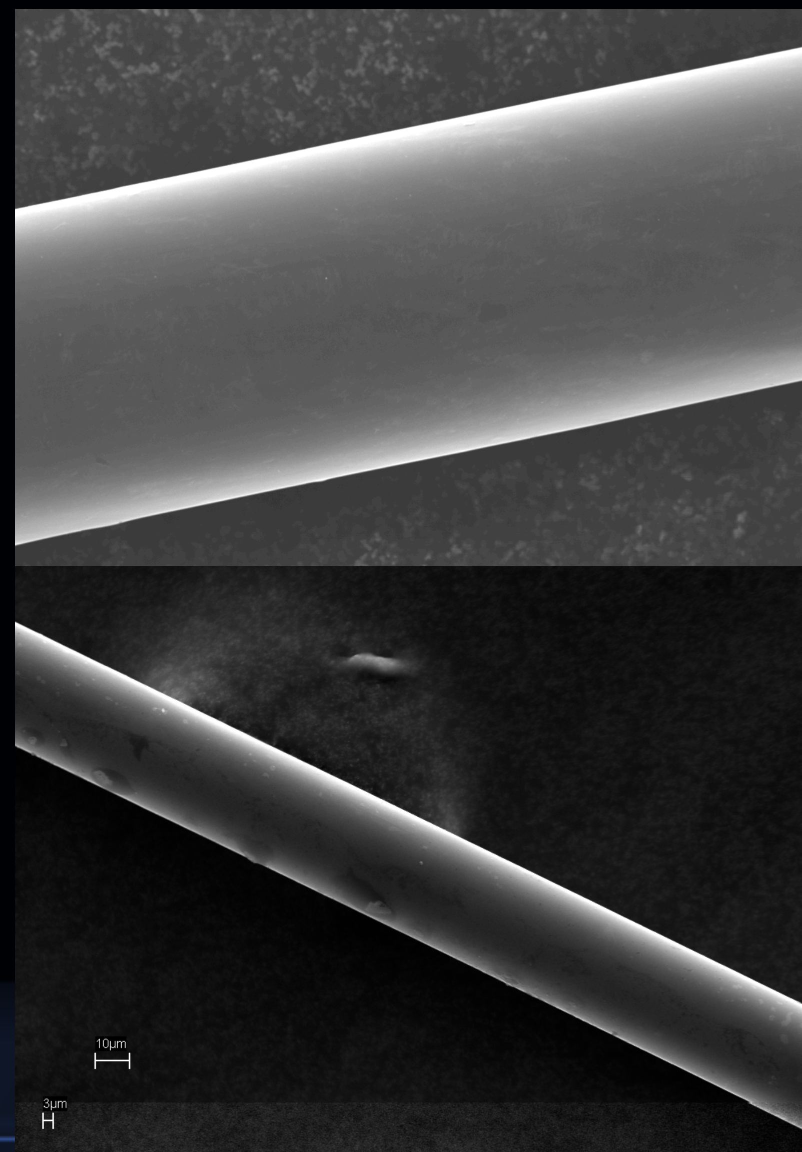
Diameter:	**0.00136 +/- 0.0001" (34.5 +/- 2.5 µm)**
Tensile Strength:	**125 ksi (0.86 GPa)**
Tensile Modulus:	**6 msi (41.5 GPa)**
Electrical Resistivity:	**3.6×10^{-3} ohm cm**
Density:	**1.8 g/cc**

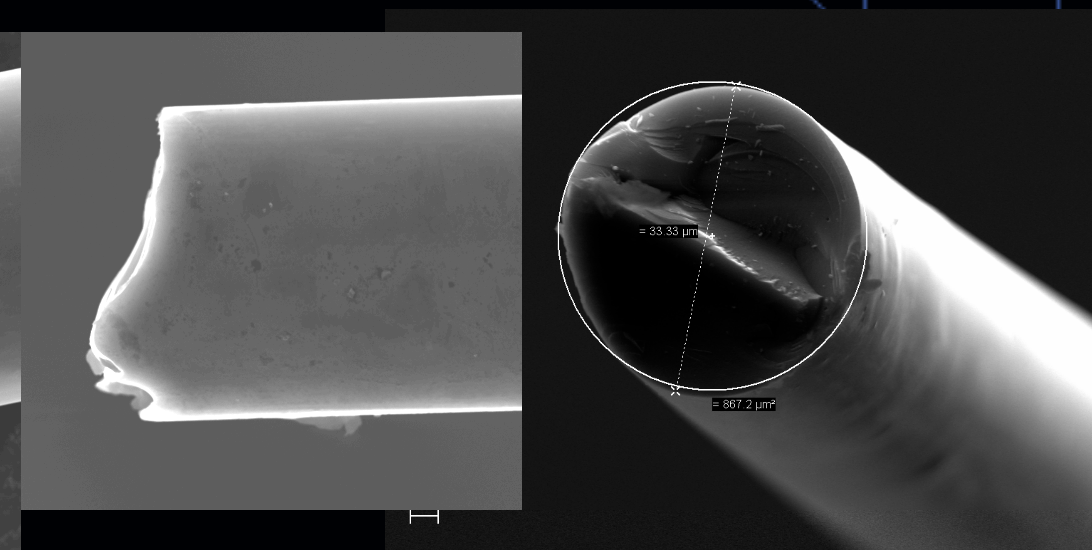
Specialty Materials, Inc.
1449 Middlesex Street
Lowell, Massachusetts 01851

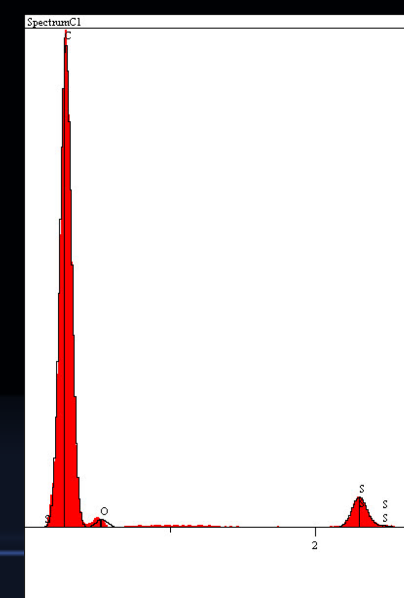
Phone: 978-322-1900
Fax: 978-322-1970

CARBON MONOFILAMENT PRODUCT PRICE LIST
Effective October 1, 2017

Product	Quantity	Price LF
CARBON MONOFILAMENT	1 Million LF	$0.02
	500,000 LF	$0.03
	1,000 LF	$0.93







Component	Type	Mole Conc.	Conc.		
O	Calc	5.592	7.248	wt.%	
C	Calc	93.865	91.340	wt.%	
S	Calc	0.543	1.412	wt.%	
		100.000	100.000	wt.%	Total

Elt.	Line	Atomic %	Conc		
C	Ka	93.865	91.340	wt.%	
O	Ka	5.592	7.248	wt.%	
S	Ka	0.543	1.412	wt.%	
		100.000	100.000	wt.%	Total

kV	20.0
Takeoff Angle	35.0°
Esc	On
Sum Peak	On

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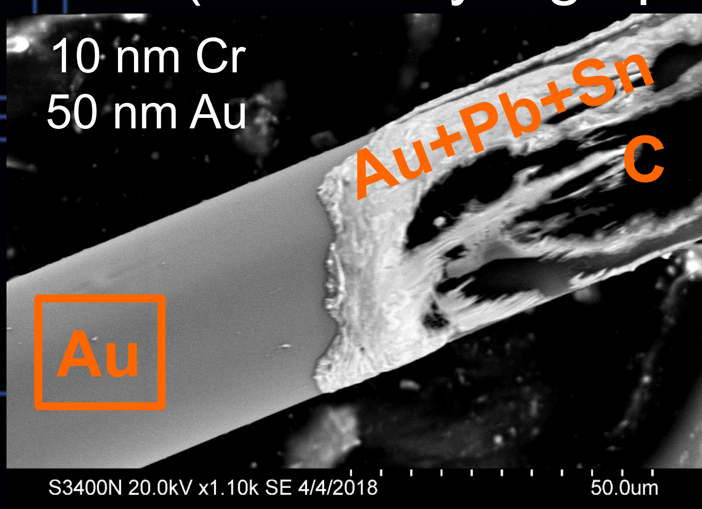
C wire metal coating

BINP
A. Popov
V. Logashenko

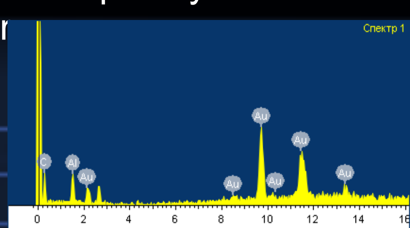
HiPIMS: High-power impulse magnetron sputtering

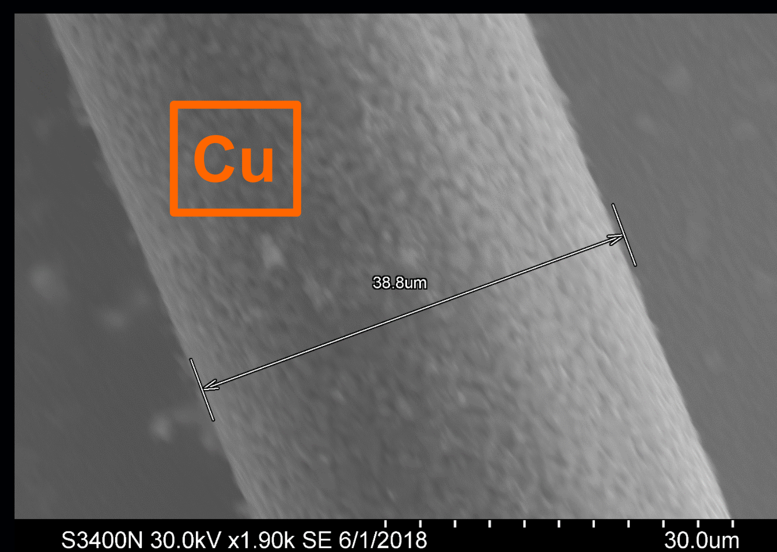
physical vapor deposition (PVD) of thin films based on magnetron sputter deposition
(extremely high power densities of the order of kW/cm² in short pulses of tens of
cyc



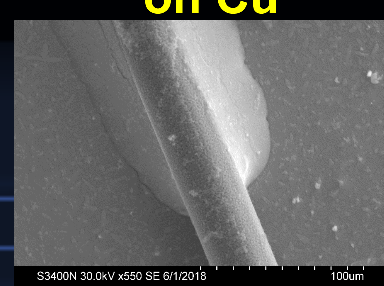
soldering attempt

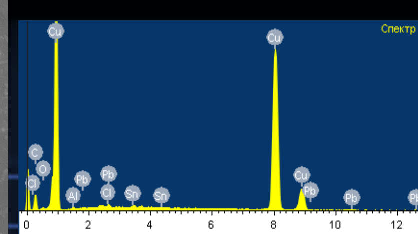
Lead forms intermetallic compound with gold and completely dissolves the 50 nm Au layer

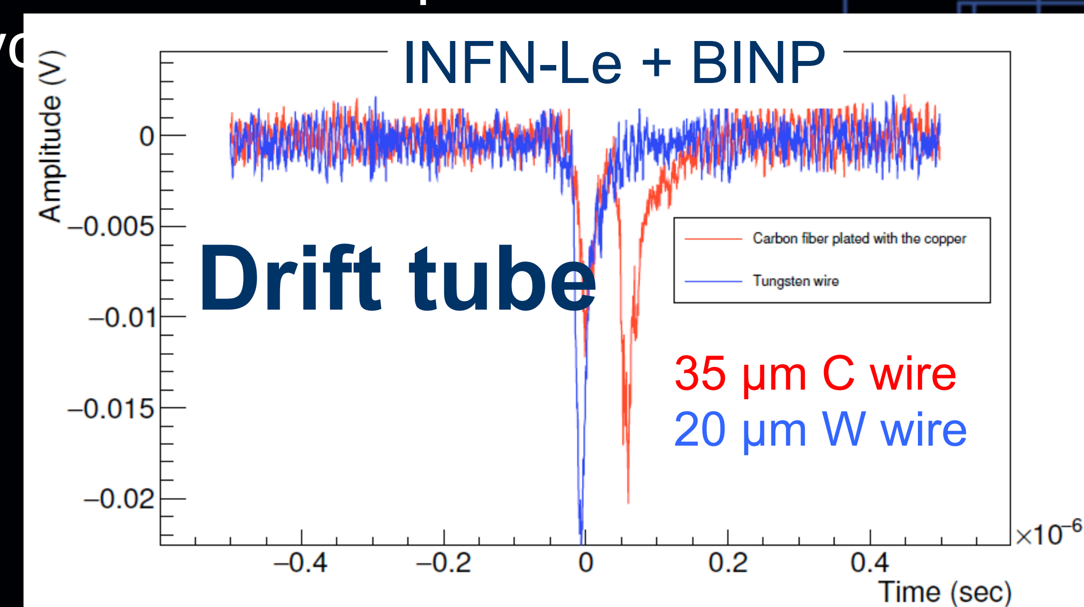


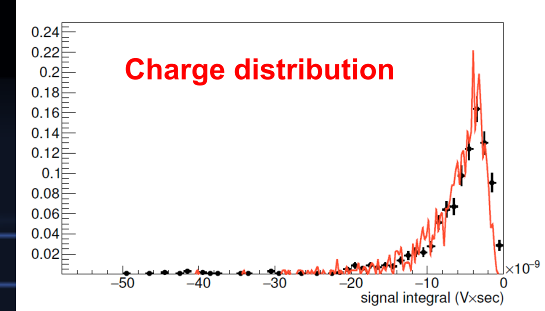


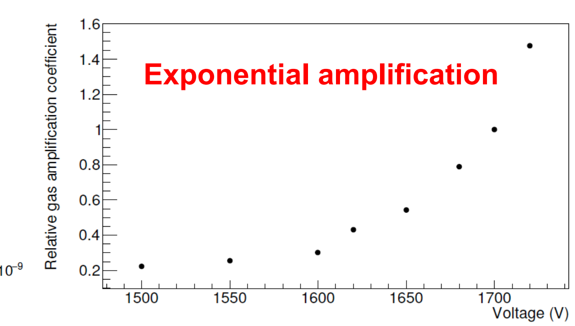
good solder wettability on Cu











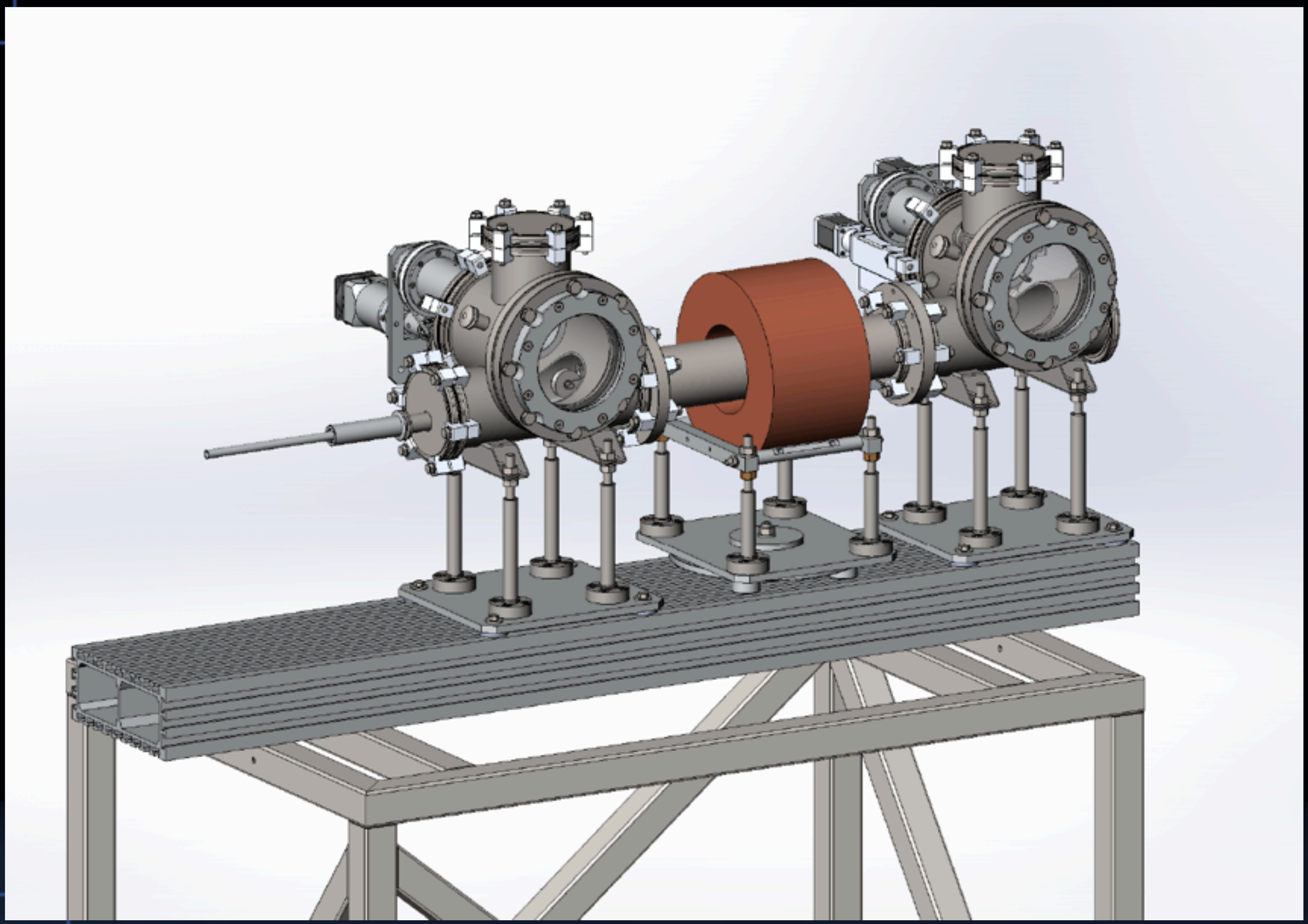
C wire metal coating

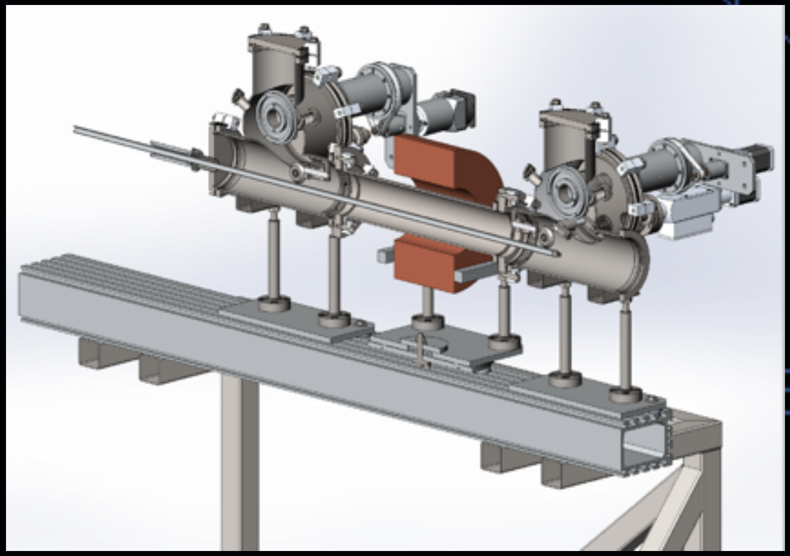
Considerations:

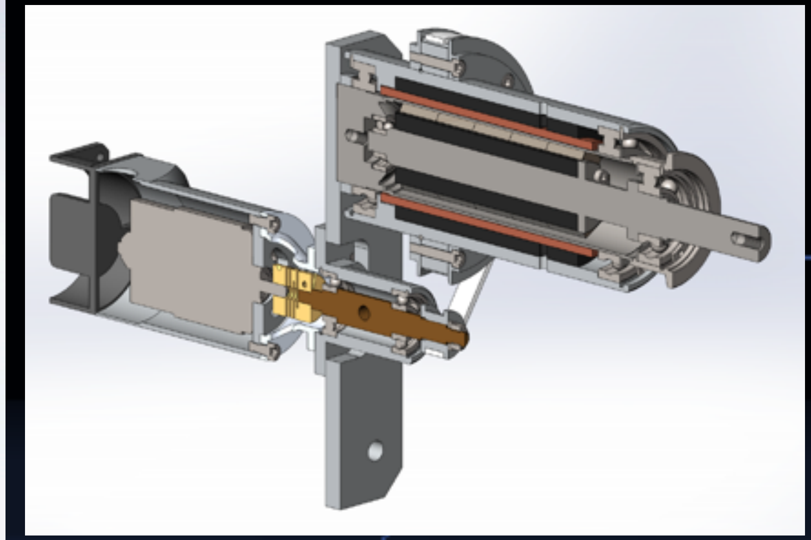
- Cu coating test of 35 µm carbon monofilament very successful on short samples with HiPIMS at BINP, Novosibirsk
- Investigation of magnetron sputtering facilities elsewhere (INFN LNL?)
- Industrialization of process for coating continuous spooled monofilament under study
- **Alternatives?**

C wire metal coating: BINP proposal

BINP
A. Popov
V. Logashenko







C wire soldering **without** metal coating

Soldering of Carbon Materials Using Transition Metal Rich Alloys

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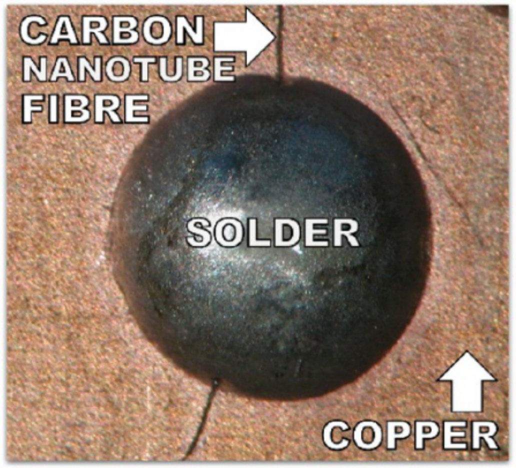
ABSTRACT Joining of carbon materials *via* soldering has not been possible up to now due to lack of wetting of carbons by metals at standard soldering temperatures. This issue has been a severely restricting factor for many potential electrical/electronic and mechanical applications of nanostructured and conventional carbon materials. Here we demonstrate the formation of alloys that enable soldering of these structures. By addition of several percent (2.5—5%) of transition metal such as chromium or nickel to a standard lead-free soldering tin based alloy we obtained a solder that can be applied using a commercial soldering iron at typical soldering temperatures of approximately 350 °C and at ambient conditions. The use of this solder enables the formation of mechanically strong and electrically conductive joints between carbon materials and, when supported by a simple two-step technique, can successfully bond carbon structures to any metal terminal. It has been shown using optical and scanning electron microscope images as well as X-ray diffraction patterns and energy dispersive X-ray mapping that the successful formation of carbon—solder bonds is possible, first, thanks to the uniform nonreactive dispersion of transition metals in the tin-based matrix. Further, during the soldering process, these free elements diffuse into the carbon—alloy border with no formation of brazing-like carbides, which would damage the surface of the carbon materials.



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C wire soldering **without** metal coating

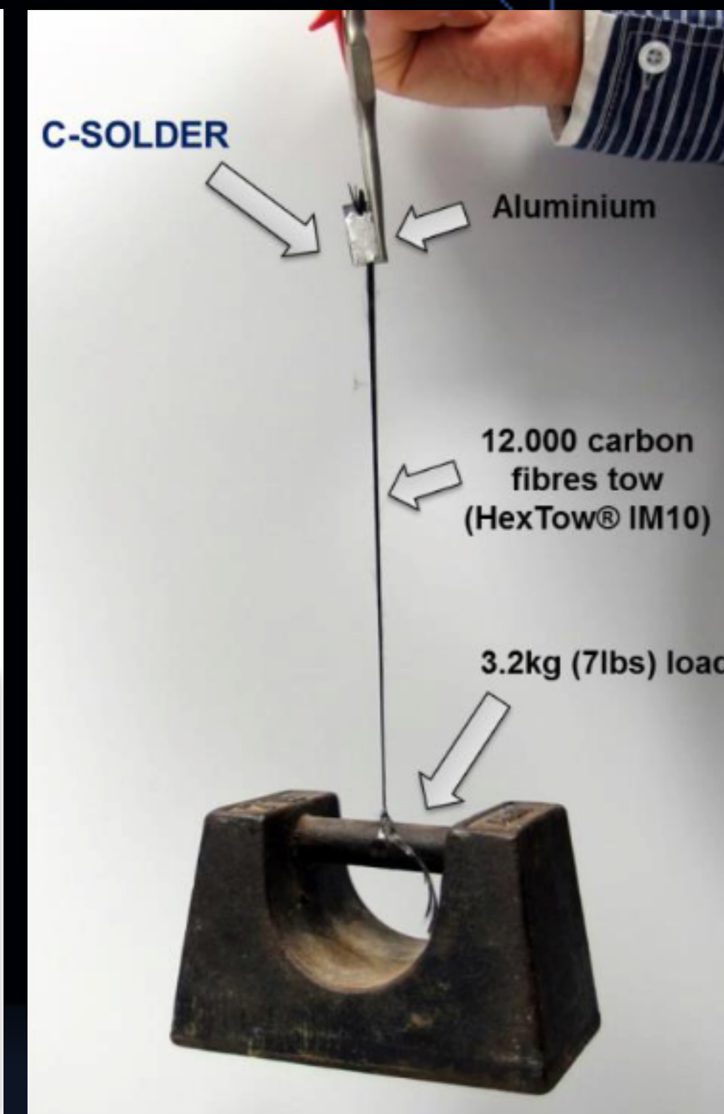
Up to now it has not been possible to apply soldering to graphitic materials as they are not wetted by the commercially available alloys.

C-SOLDER is a trade name for a group of new tin-based lead-free low-temperature soldering alloys which enable joining of various carbon materials including carbon fibres or carbon nanotube fibres in both carbon-carbon and carbon-metal arrangements.

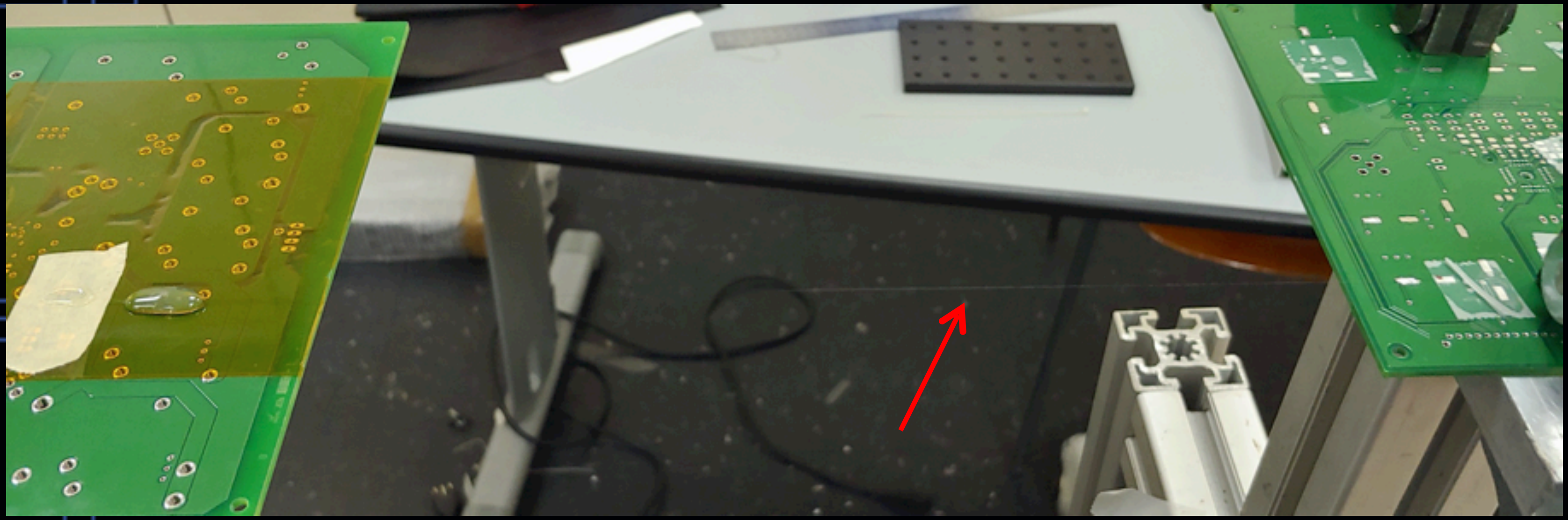
The use of these alloys allows fast formation of mechanically strong bonds which are electrically conductive simultaneously.

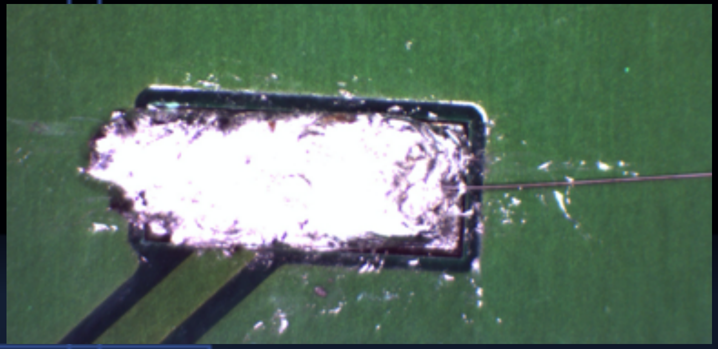
C-SOLDER Type: SAC-1B:

- Excellent wetting of carbon materials: graphite, carbon fibres, carbon nanotube fibres, graphene, etc.
- Suitability for bonding in carbon-carbon and carbon-metal systems.
- Soldering temperatures below 450°C.
- Good mechanical and electrical properties.
- Lead free.
- Flux free.

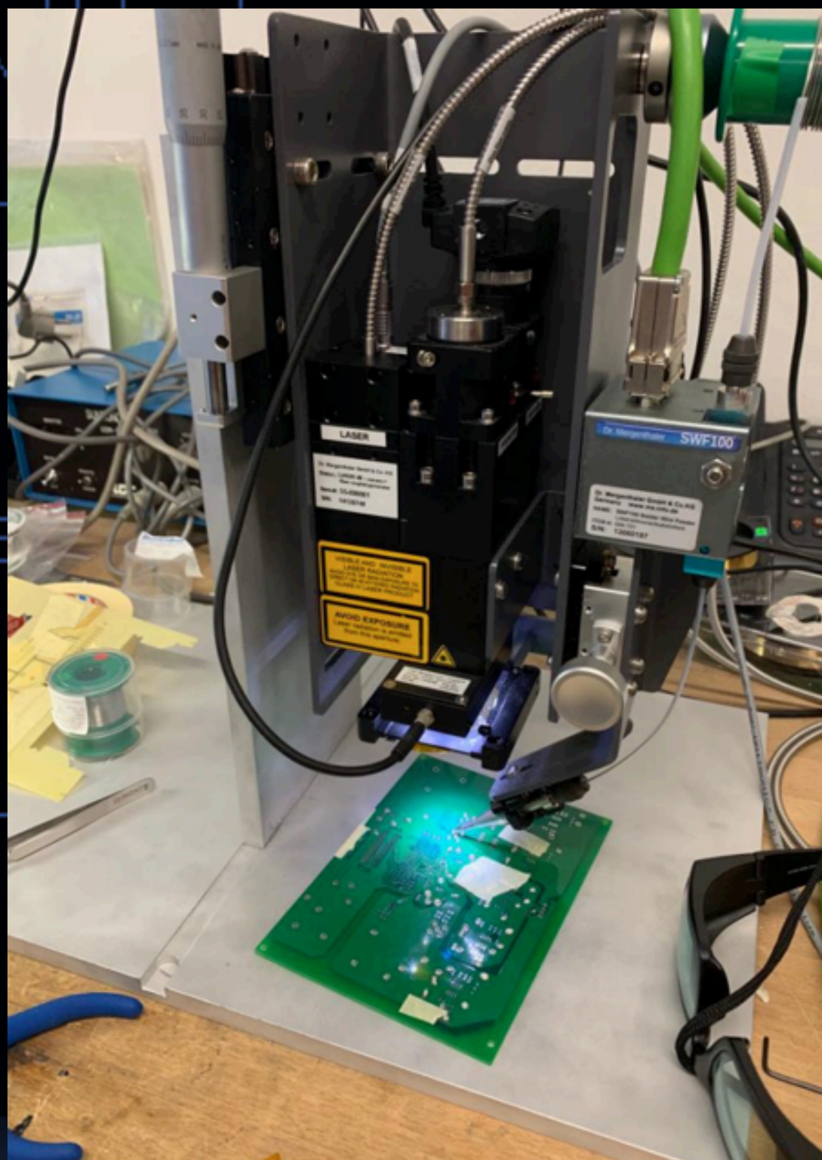


C wire **without** metal coating: **manual** soldering





C wire **without** metal coating: **laser** soldering



The Infrared laser system of the MEG2 wiring robot makes use of 0.5 mm soldering wire

For 3Kg we will make 0.5 mm. We can also give it a try to go below 0.5 mm with no extra fee.

2-3 Kg at the cost ~ £1500/500g (4 times cheaper as compared to £122.00/10g offered by Goodfellow).

Preshower and Muon detector

IDEA preshower and muon detector

The µ-RWELL detector

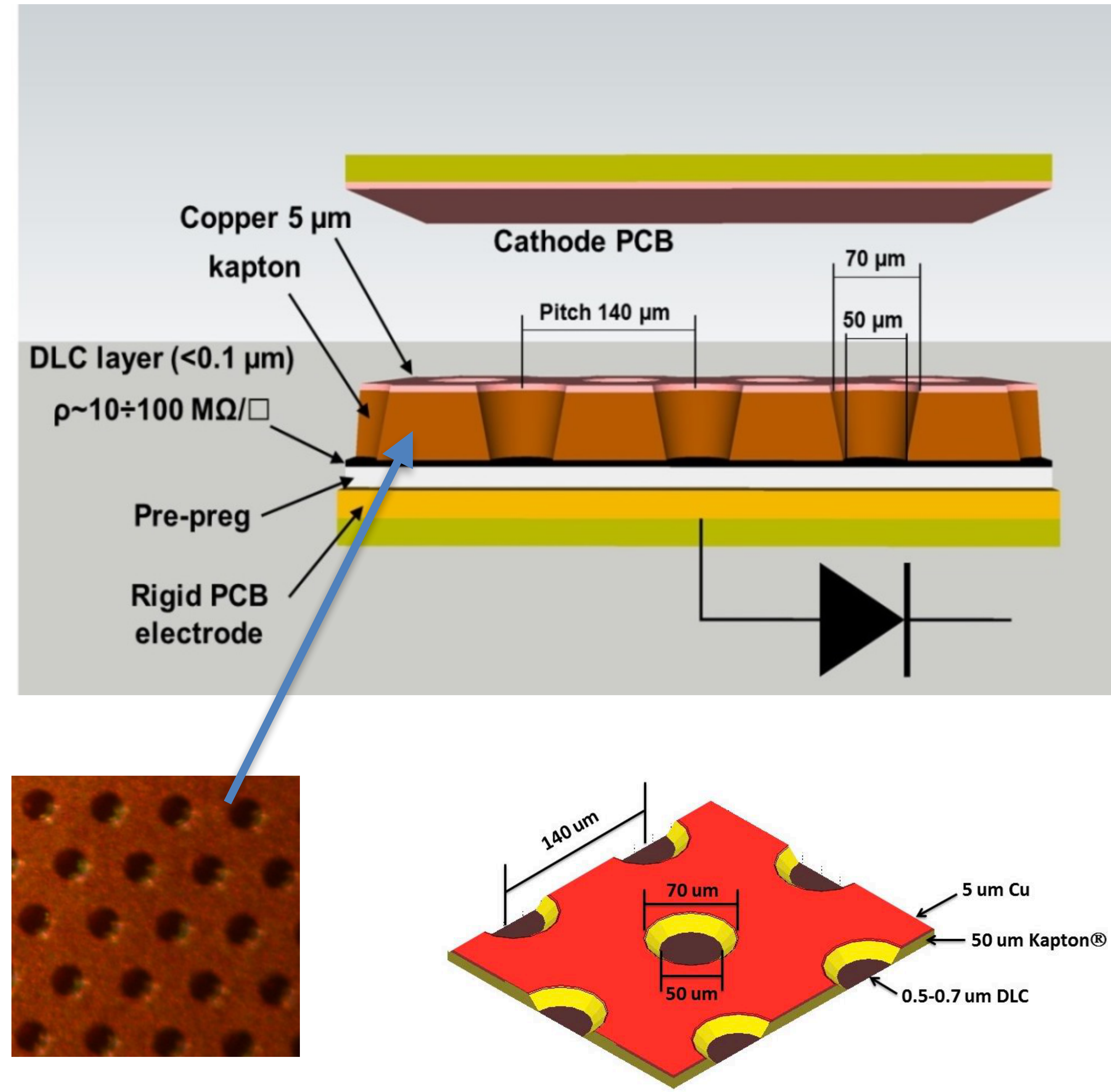
The µ-RWELL is composed of only two elements:

- µ-RWELL_PCB
- drift/cathode PCB defining the gas gap

µ-RWELL_PCB = amplification-stage ⊕ resistive stage ⊕ readout PCB

Similar in operation to a drift tube:

- HV is applied between the Anode and Cathode PCB electrodes
- A charged particle ionises the gas between the two detector elements
- Electrons drift towards the µ-RWELL_PCB (anode), while ions drift to the cathode

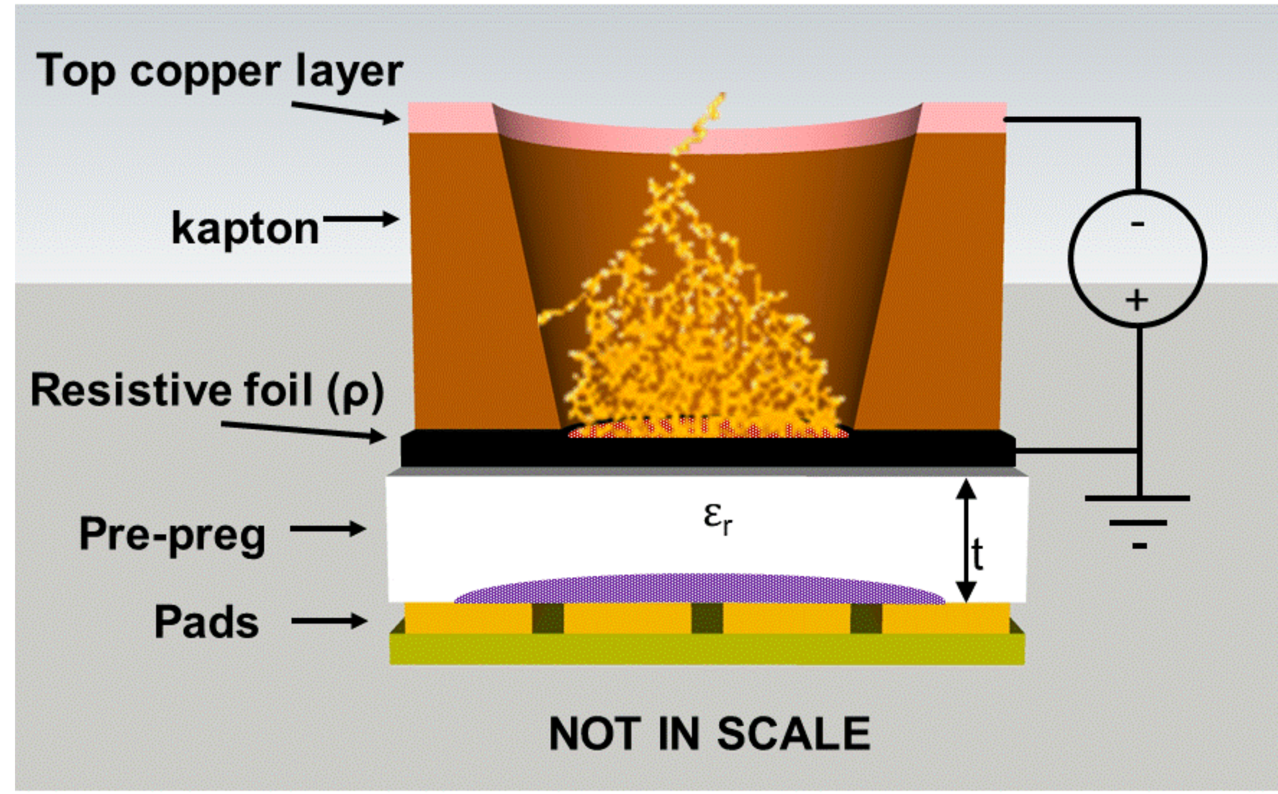


IDEA preshower and muon detector

The µ-RWELL detector

What is different with respect to a drift tube:

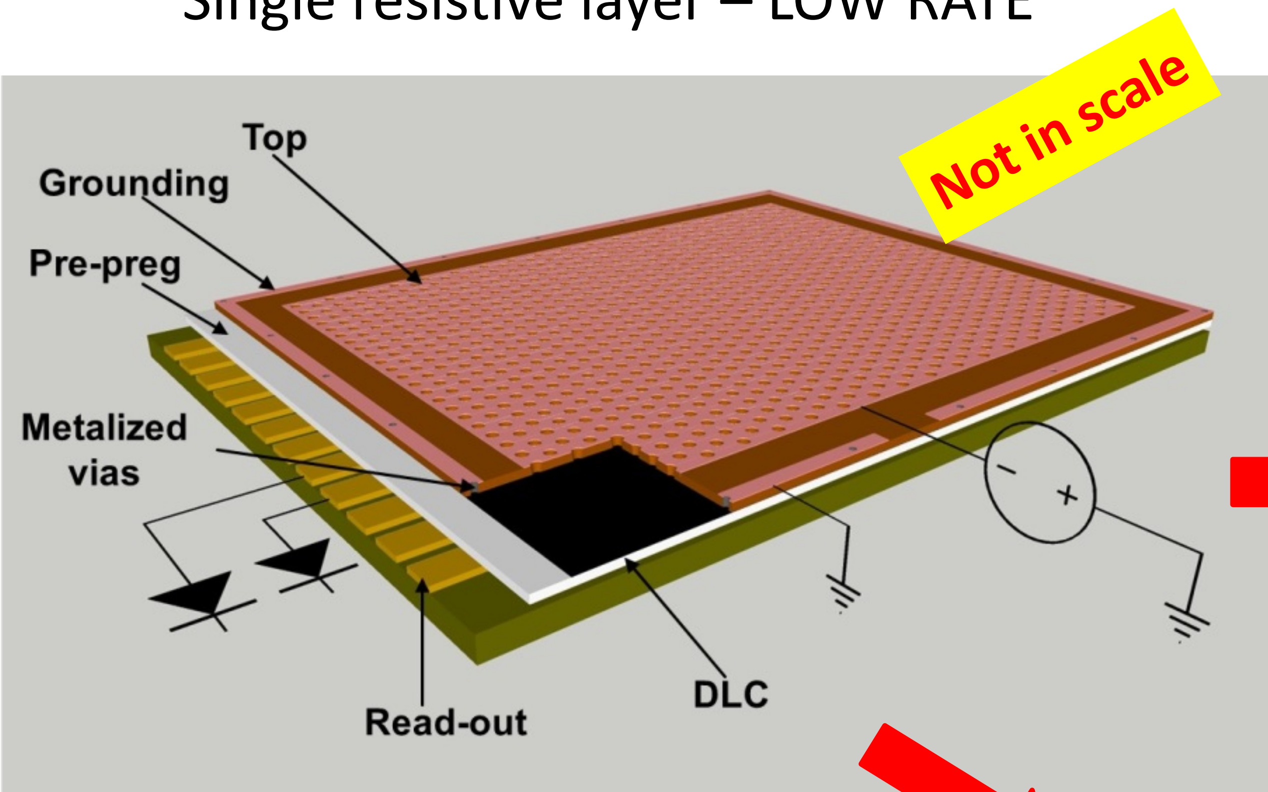
- µ-RWELL_PCB provides an amplification stage applying a separate HV to the faces of this layer
- The "WELL" acts as a multiplication (~4000 times) channel for the ionization produced in the gas of the drift gap
- The charge induced on the resistive layer is spread with a time constant, $\tau \sim \rho \times C$



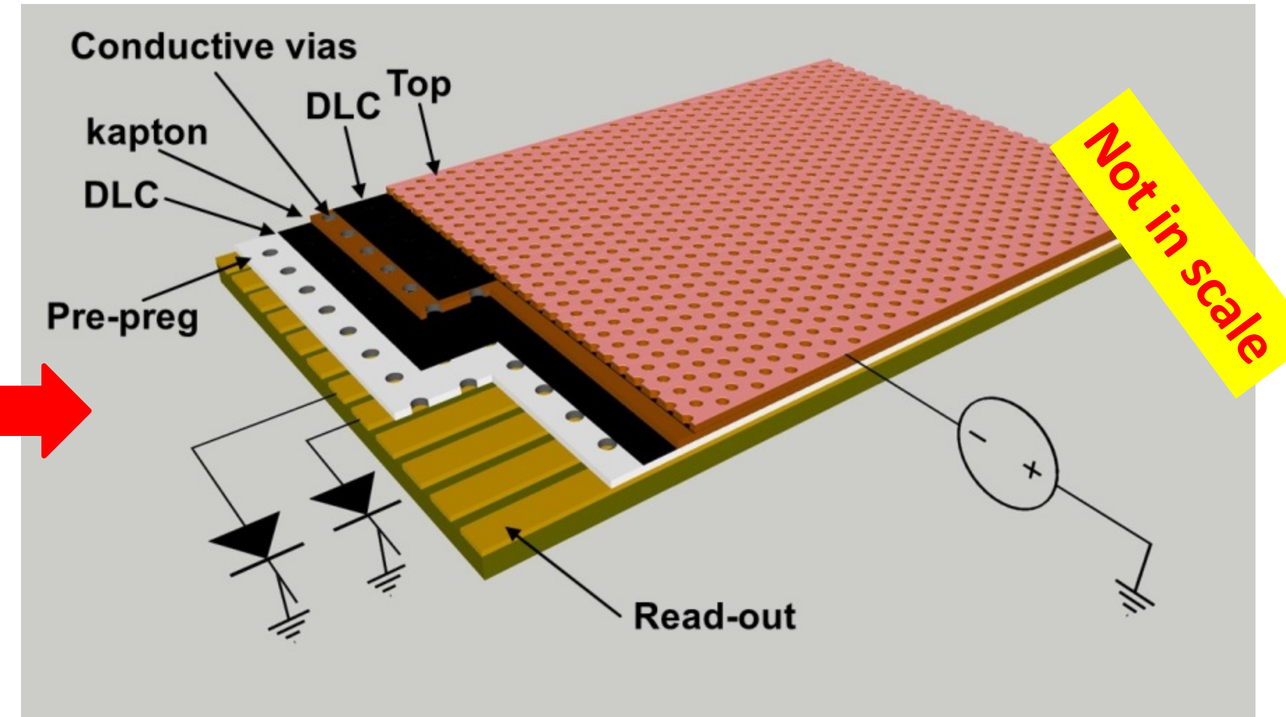
$$C = \varepsilon_0 \times \varepsilon_r \times \frac{S}{t} \cong 50\ pF/m$$ (pitch-width 0,4 mm)

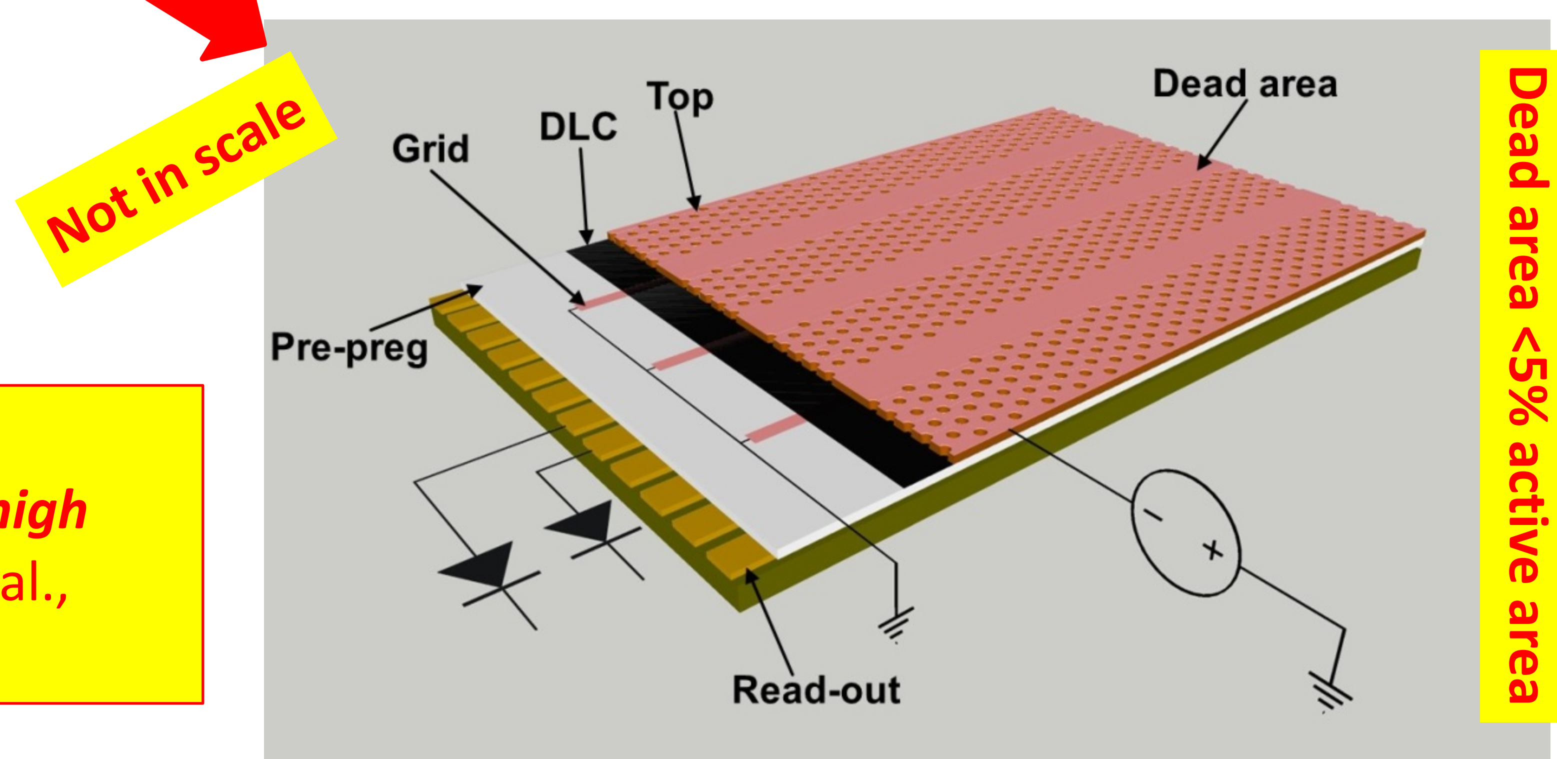
IDEA μ-RWELL layout

Single resistive layer – LOW RATE



Double resistive layer – HIGH RATE



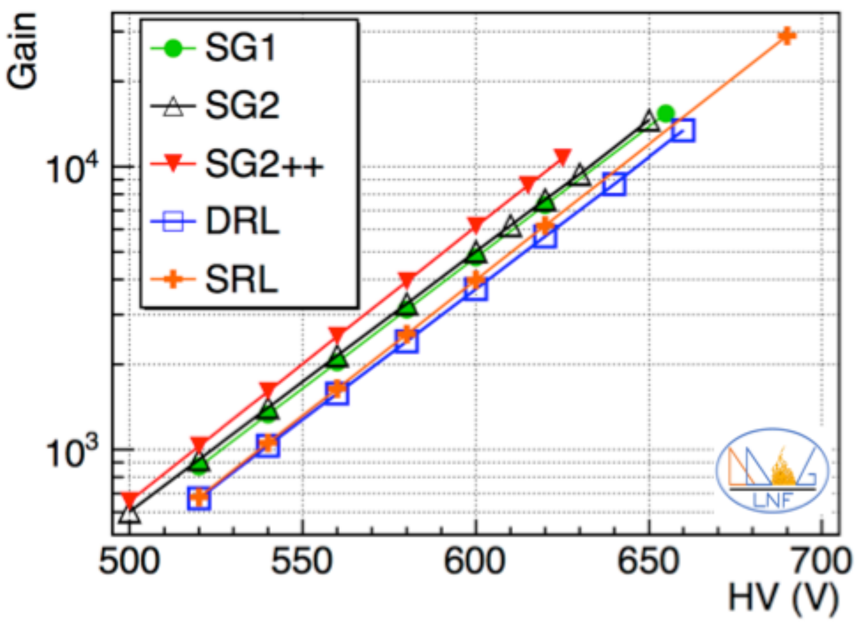


Detailed description in:
The micro-RWELL layouts for high particle rate, G. Bencivenni et al., 2019_JINST_14_P05014.

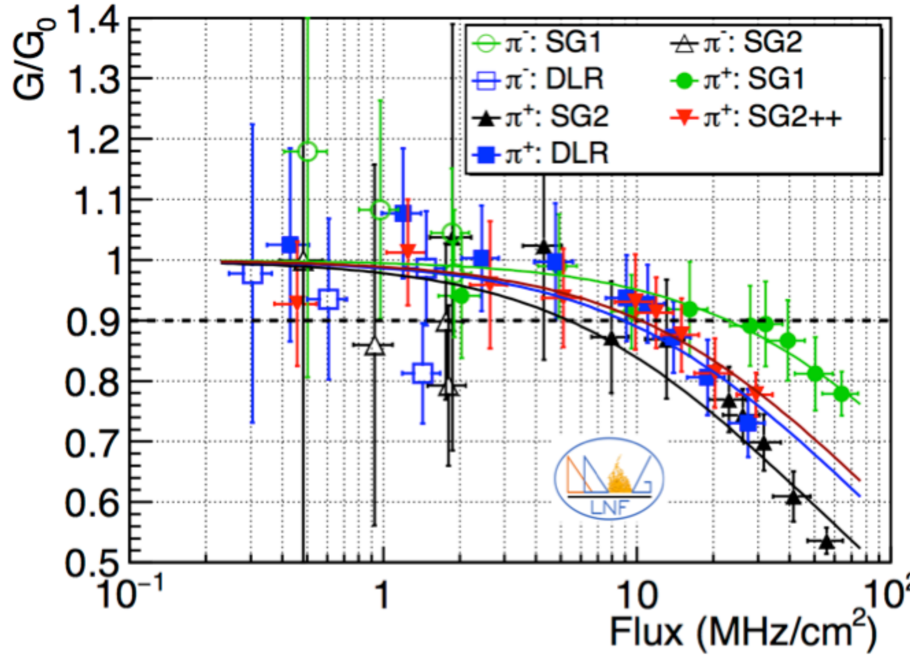
Single resistive layer with dense grid grounding – SIMPLIFIED HIGH RATE

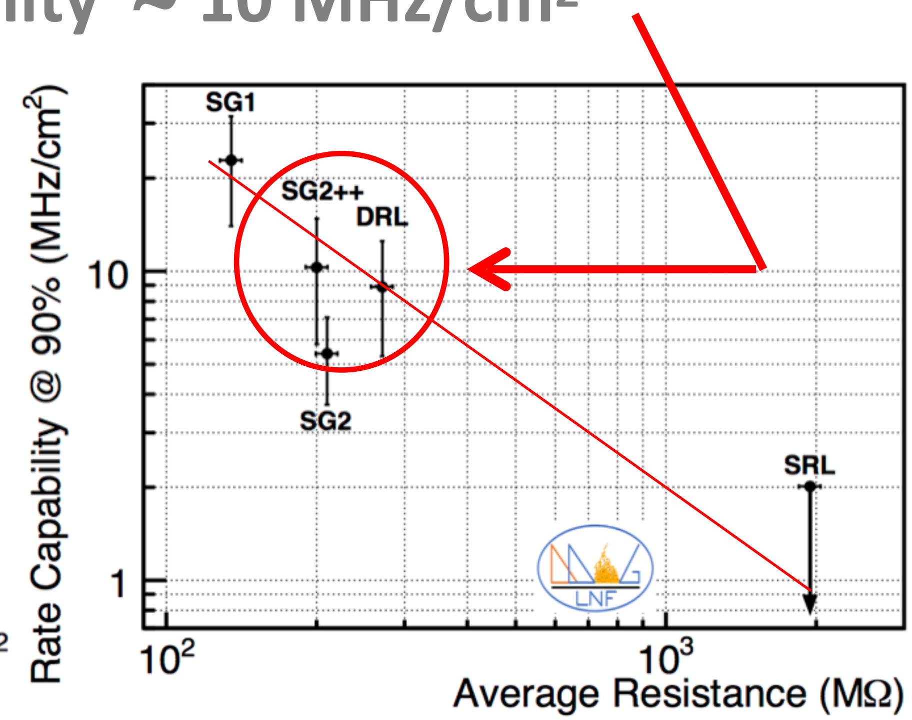
Detector performance

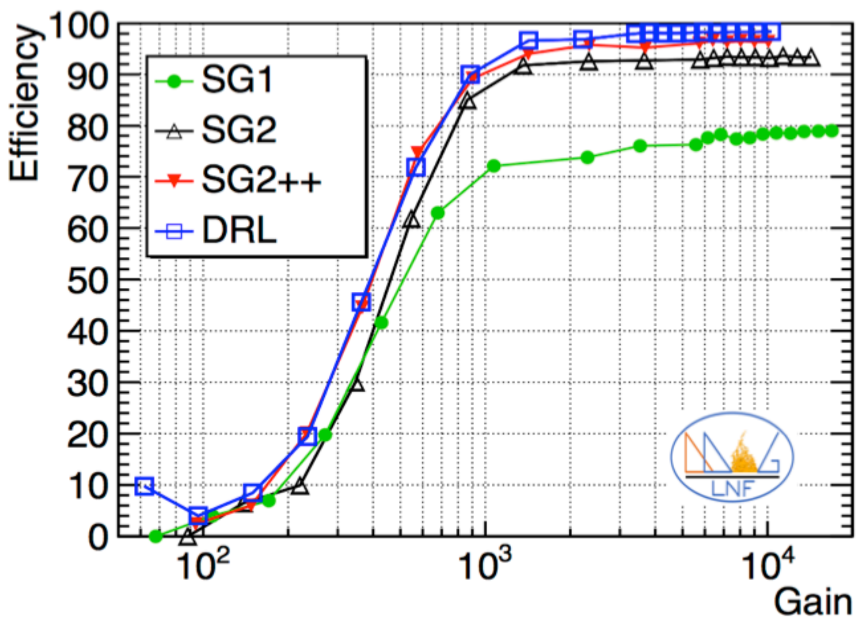
$G \sim 10^4$

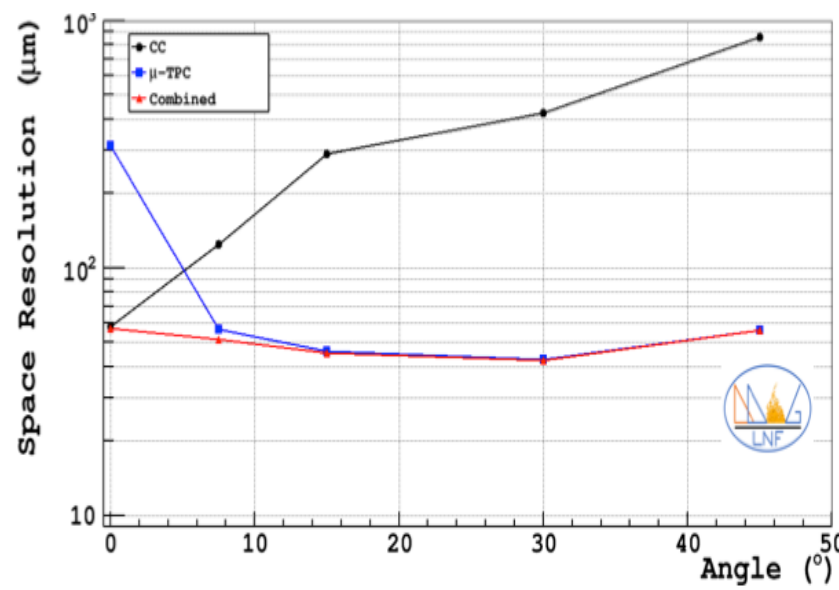


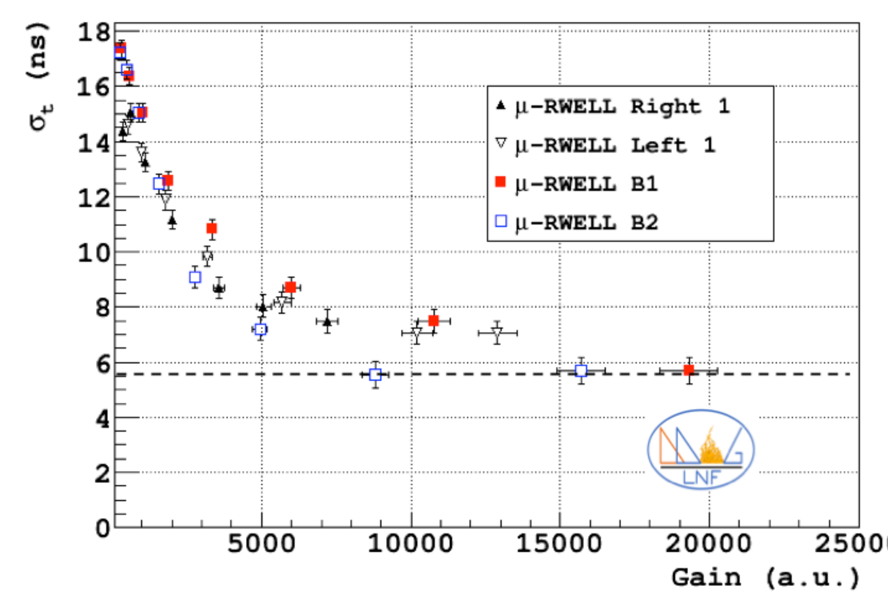
Rate capability $\sim 10\ MHz/cm^2$











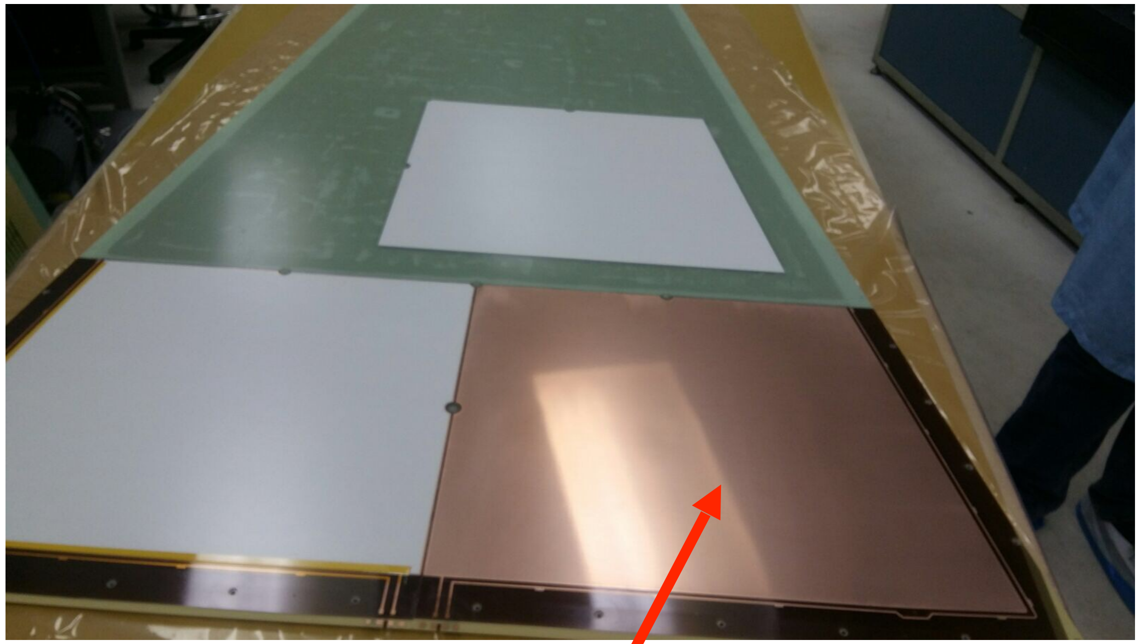
Efficiency ~ 98%

$\sigma_x \sim 40 - 60\ \mu m$

$\sigma_t \sim 5\text{-}6\ ns$

IDEA μ-RWELL prototypes

GE2/1 20^0 sector with 2 M4 μRWells
(2 m height, 1.2 m base)



M4 μ-RWELL prototype is a trapezoid of ~55-60x50 cm^2
Largest μ-RWELL ever built and operated!

M4 μ-RWELL

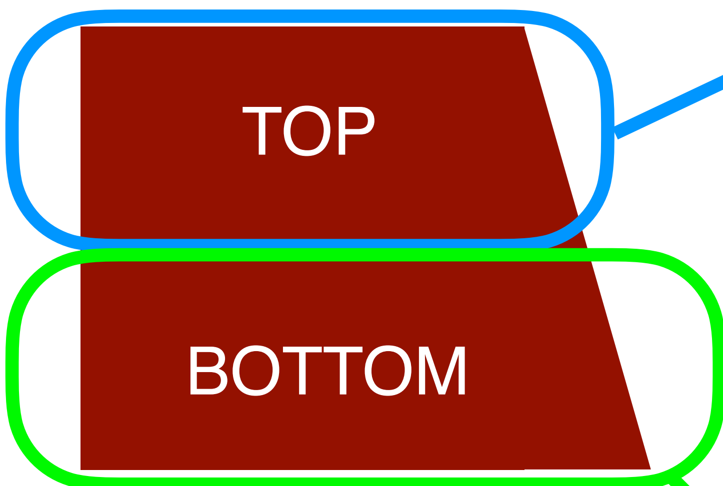
CMS M4 μ-RWELL: homogeneity

Efficiency = # hits (Tracker 1 & Tracker 2 & M4 right) / # hits (Tracker 1 & Tracker 2)

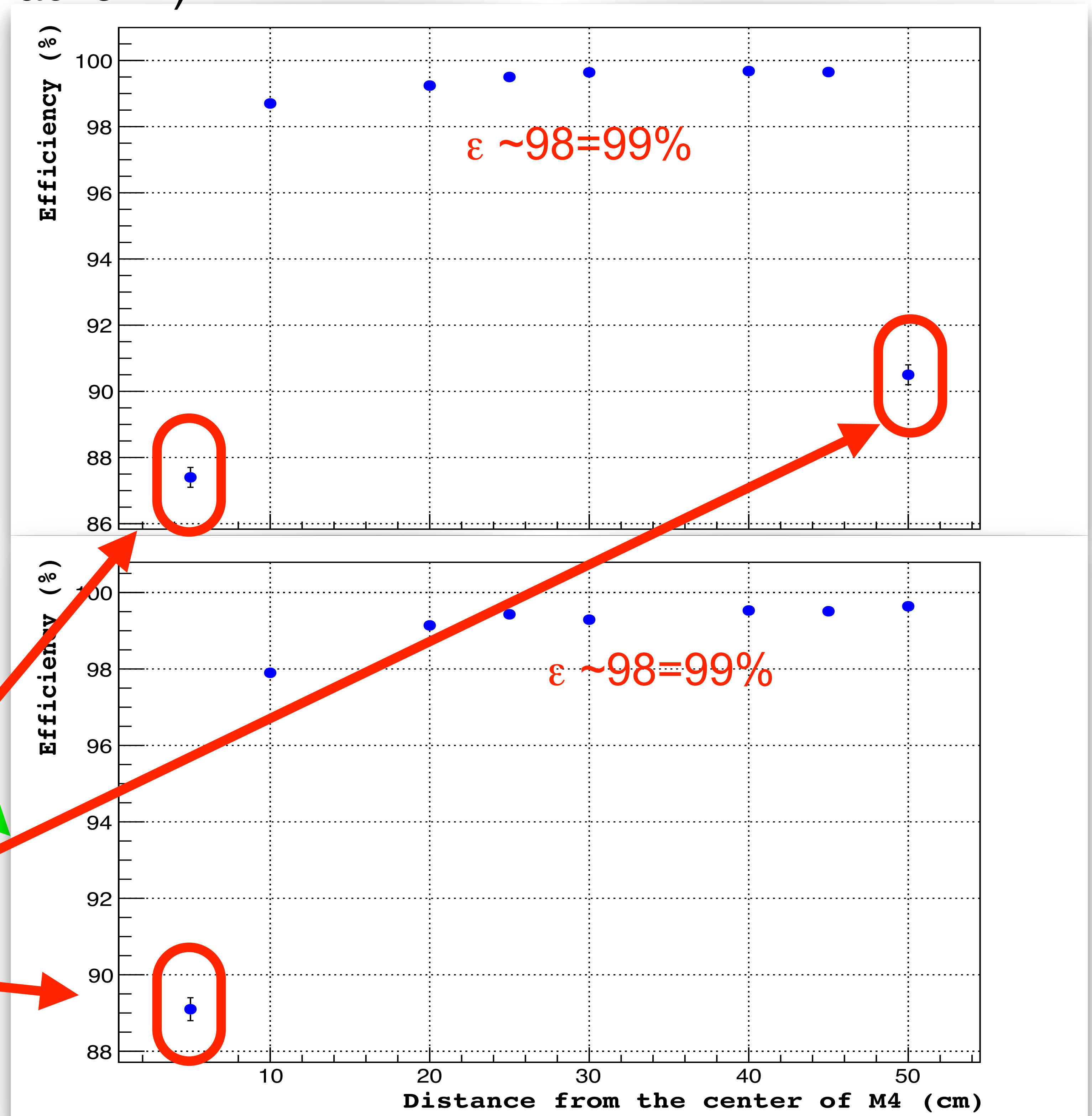
Muon beam

M4 right side:

- Drift Field = 3.0 kV/cm
- $V_{\mu\text{-RWELL}}$ = 530 V



M4 right scheme



Beam on the edge of the detector
NOT inefficiency!!

R&D status 2019 (I)

I. **WP7.1.0** - **Technology Transfer (ELTOS+TECHTRA): ongoing, excellent results** on the realisation of **small area (10x10 cm^2) prototypes.** Work is continuing with the realisation **at ELTOS + TECHTRA** of the **first 10x10 cm^2 high rate** (**SG2++ type) prototypes, realised with DLC+Cu (made in Cina - next point).**

II. **WP7.1.1** - **R&D on improved DLC+Cu sputtering (Common Project RD51): collaboration with USTC of HEFEI (PRC) ongoing, excellent results**. The first **high rate detectors of type SG2++** built (at CERN) and tested successfully obtaining a rate capability of 10 MHz/cm^2 with a 97% efficiency. A new batch **of fogli DLC+Cu sufficient for the production** of the **first 16-20 high rate prototypes made by ELTOS (previous point) is being delivered**

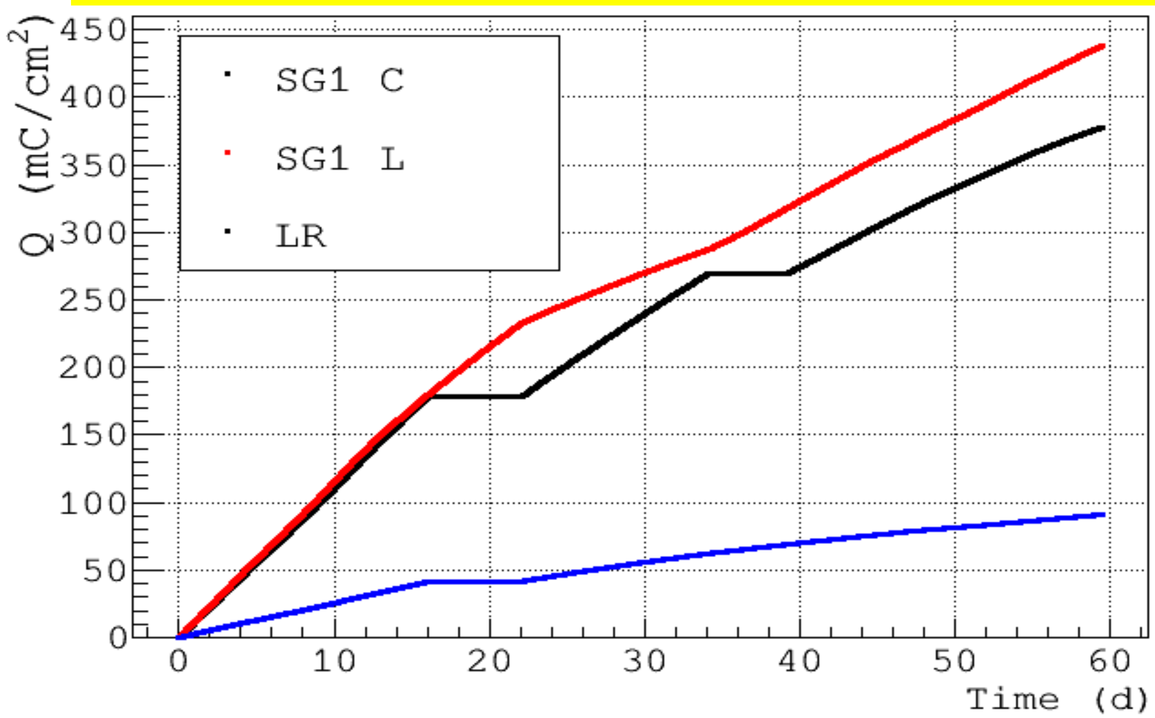
III. **WP7.2.1** - **Construction of μ-RWELL 2D readout:** The first prototype μ-RWELL 2D (XY) has been **realised at CERN**

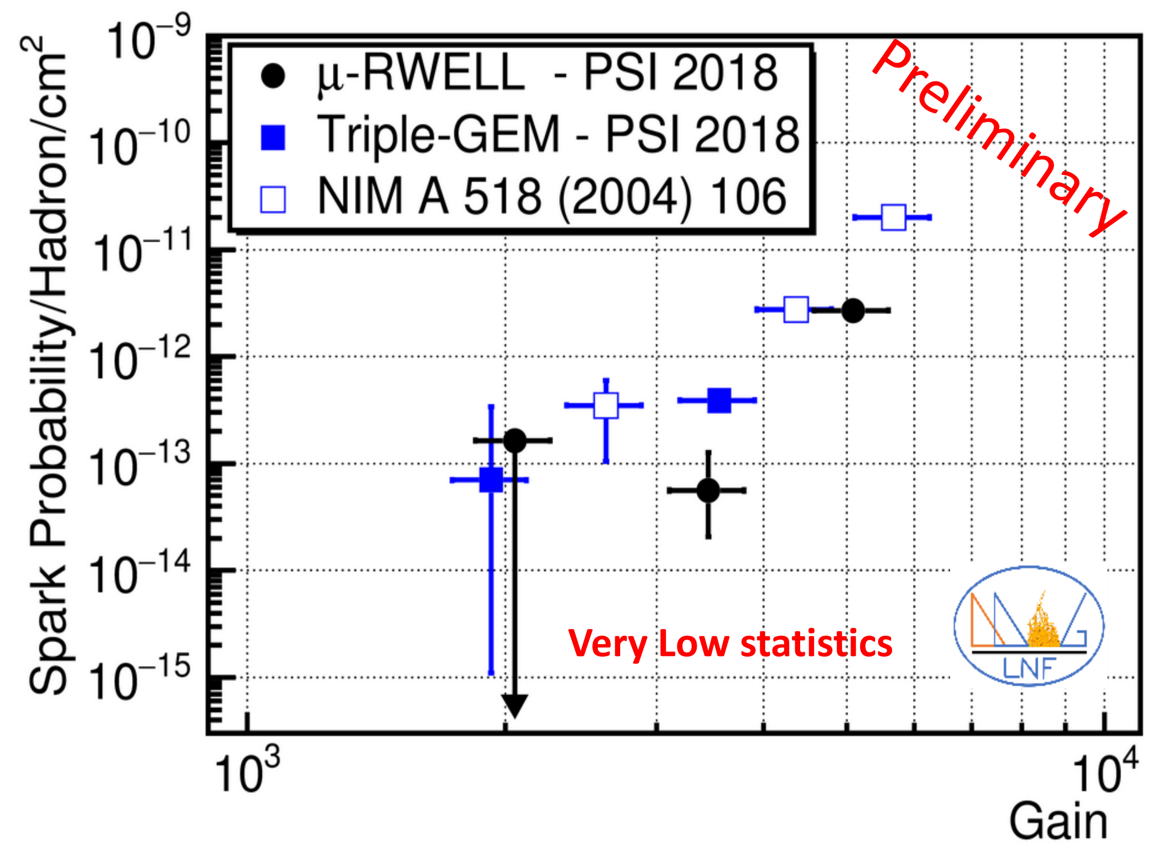
R&D status 2019 (II)

For what concerns the characterisation of the µ-RWELL prototypes (High rate e Low rate) the situation is the following:

1 – Stability measurements of the DLC and of the ageing ongoing at LNF with X rays and dedicated tests of "current drawing" on DLC

X-Ray ageing - spot 50 cm^2 flux ~ 5 MHz/cm^2





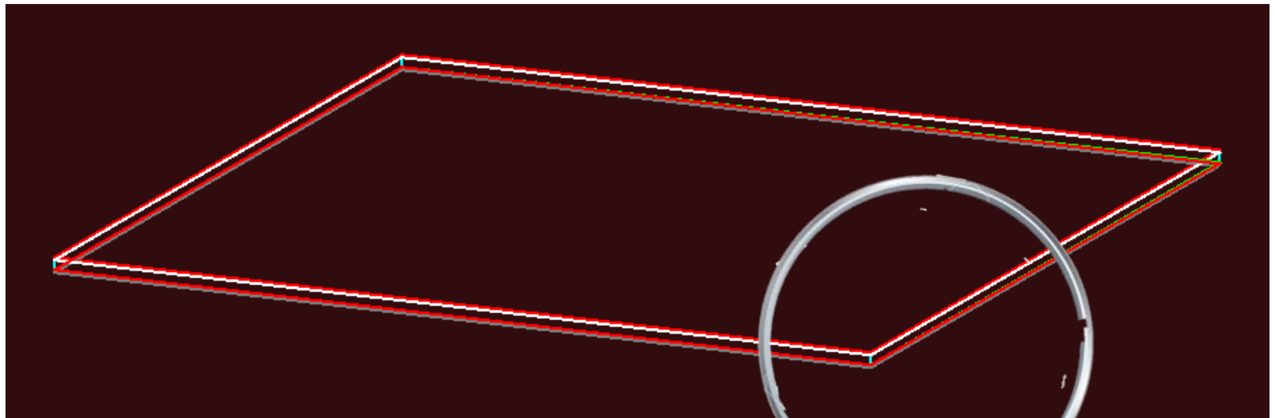
2 – High statistics study ad elevata statistica of sparks with µ-RWELL high rate at PSI (TB done 22/09 – 06/10/2019). Not conclusive for sparks, excellent ageing test instead

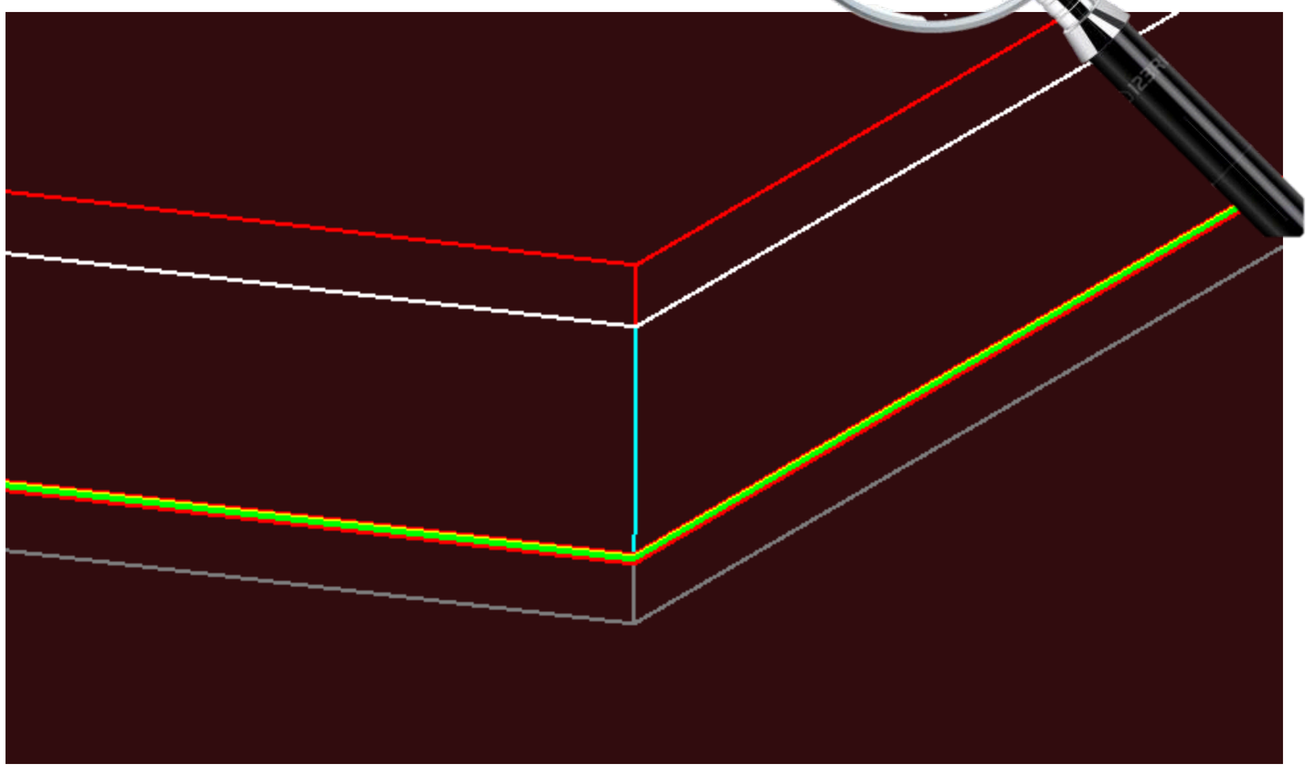
Preliminary R&D program 2020

The 2020 R&D program is centred mainly on the following activities:

1. realisation at ELTOS/TECHTRA (**Technology Transfer**) of **medium/large** size **High Rate** *(technology very similar to the LR, since it is based on single resistive layer)* μ-RWELLs (**300x250 ÷ 600x250 mm^2**)
2. design, construction and characterisation of RWELL for **detection of thermal neutrons** (**ATTRACT – uRANIA small dimensions , borated cathodes**)
3. design, construction and characterisation of a **cylindrical μ-RWELL** (**CREMLIN2 will start in March/April 2020**)

IDEA full simulation of preshower

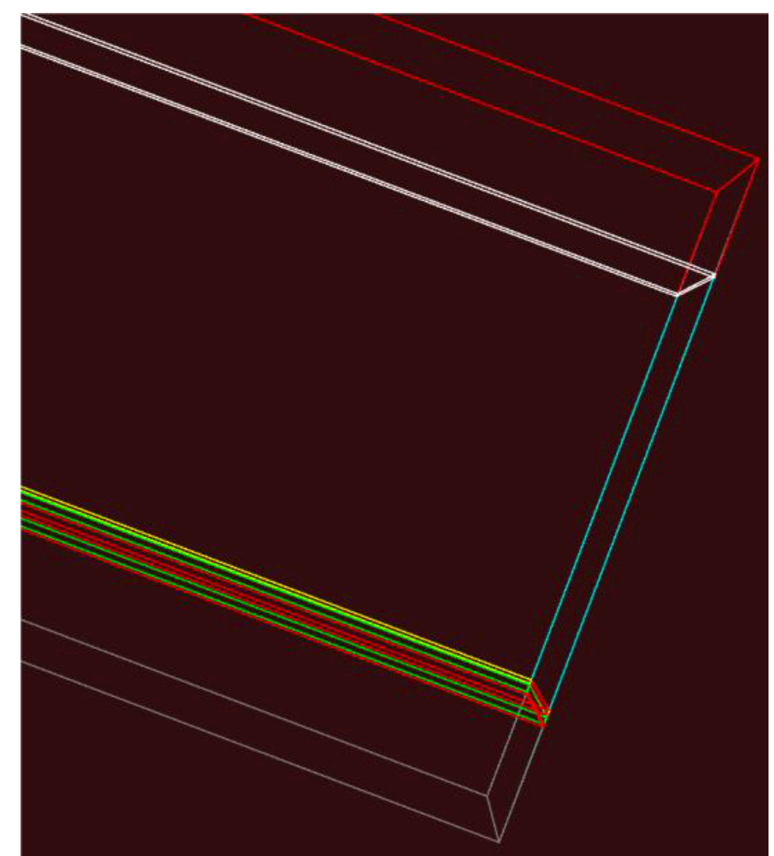




Chamber thickness: 9.4601mm

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

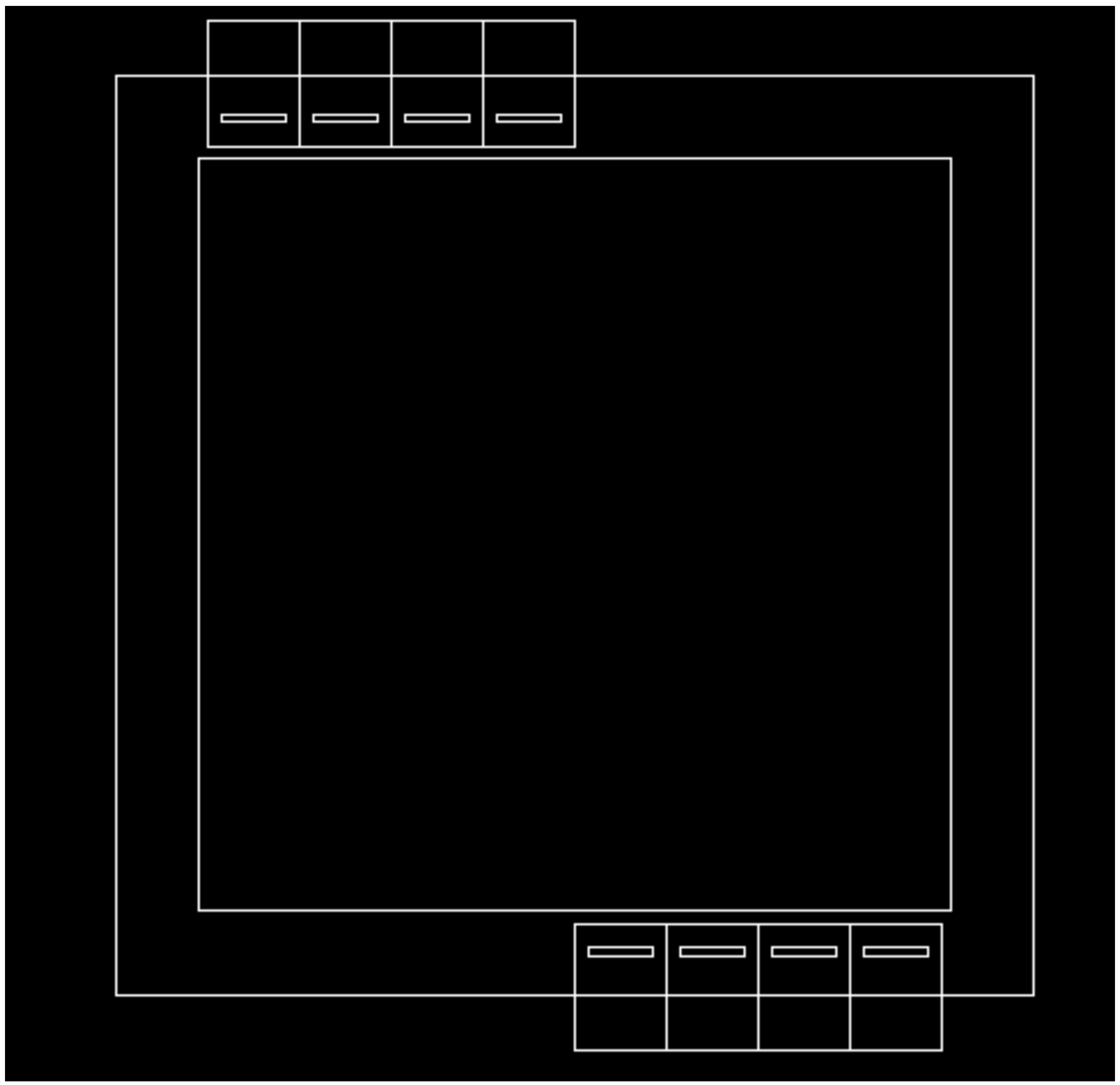
The cathode points to the IP



All the materials and dimensions of a HR μ-RWELL HR-SG2++ have been considered

Full simulation of IDEA's Preshower

First considered chamber size:
500 mm x 500 mm



Need to evaluate the realistic ACTIVE AREA of the detector:

- HV cables
- 8 APV25 (128 channels):
  50 mm x 68 mm x 1.6 mm
- Panasonic connectors (perpendicular to strips):
  35 mm x 4.2 mm x 7mm

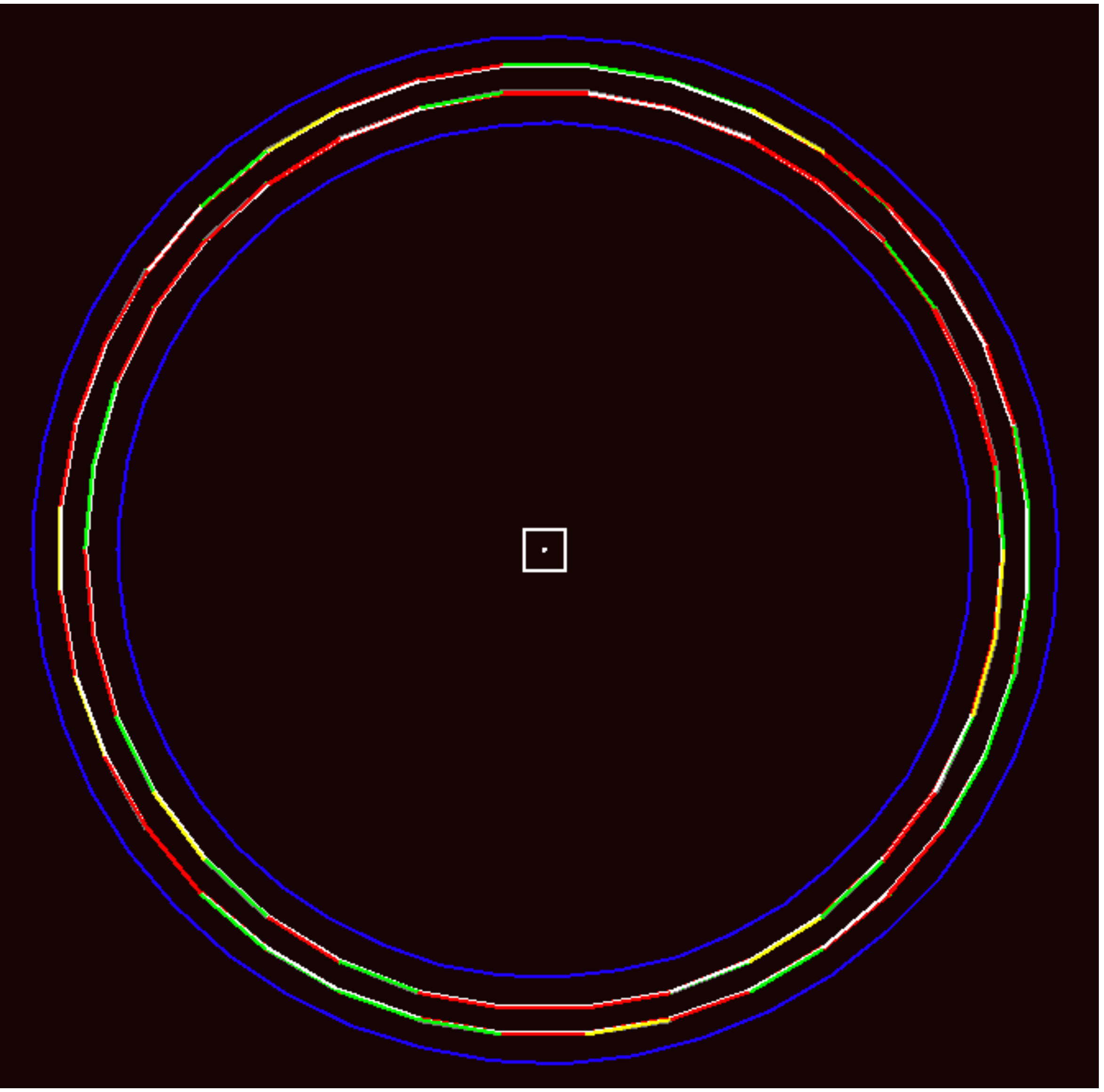
ACTIVE AREA = 410 mm x 410 mm

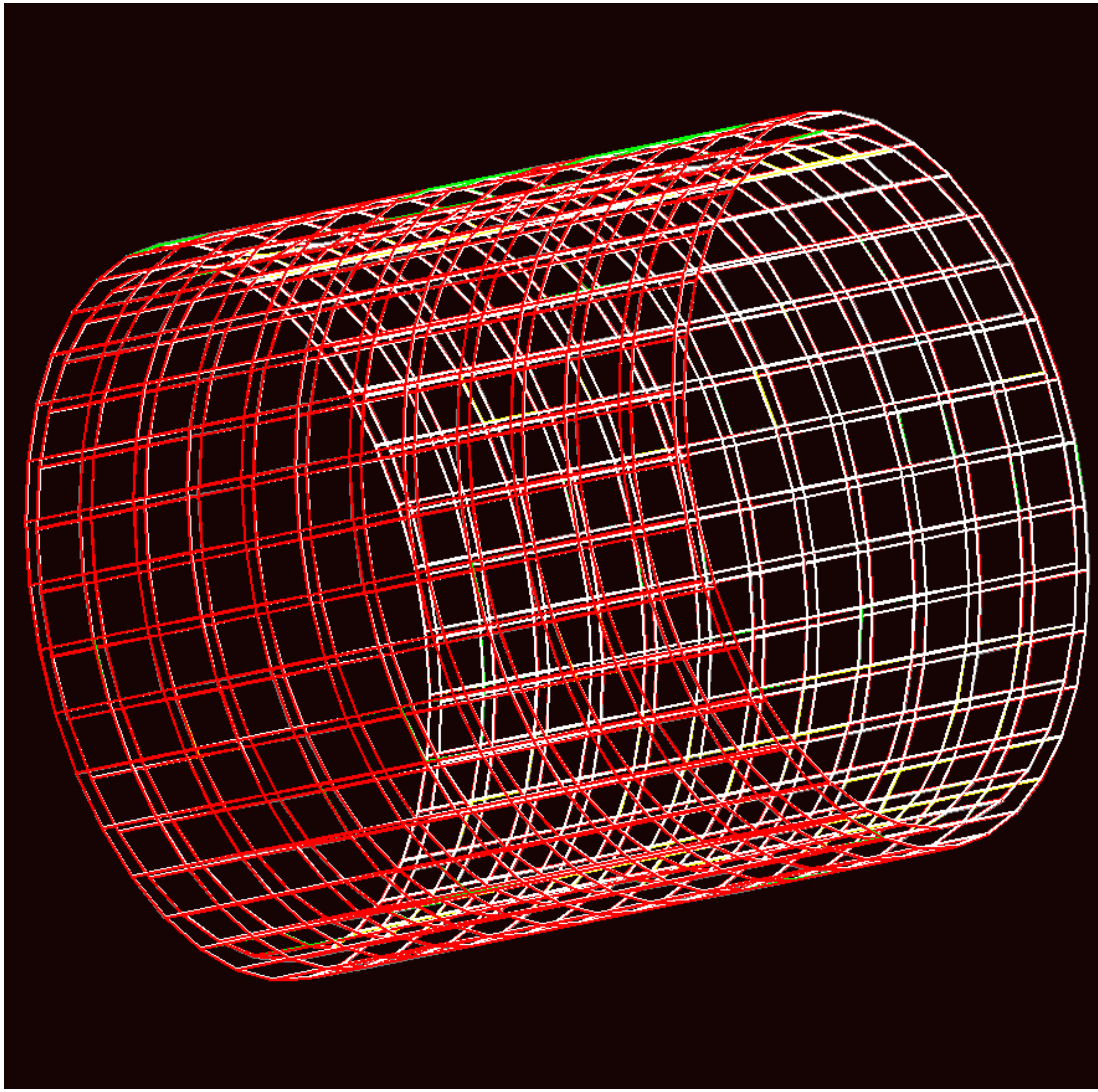
Pitch: 400 μm=> 1025 strip
(they will be reduced to 1024,so that they can be read by 8 APV25 (128 channels)

Description of a μ-RWELL (HR layout–SG2++) detector implemented

IDEA full simulation of preshower

Barrel preshower

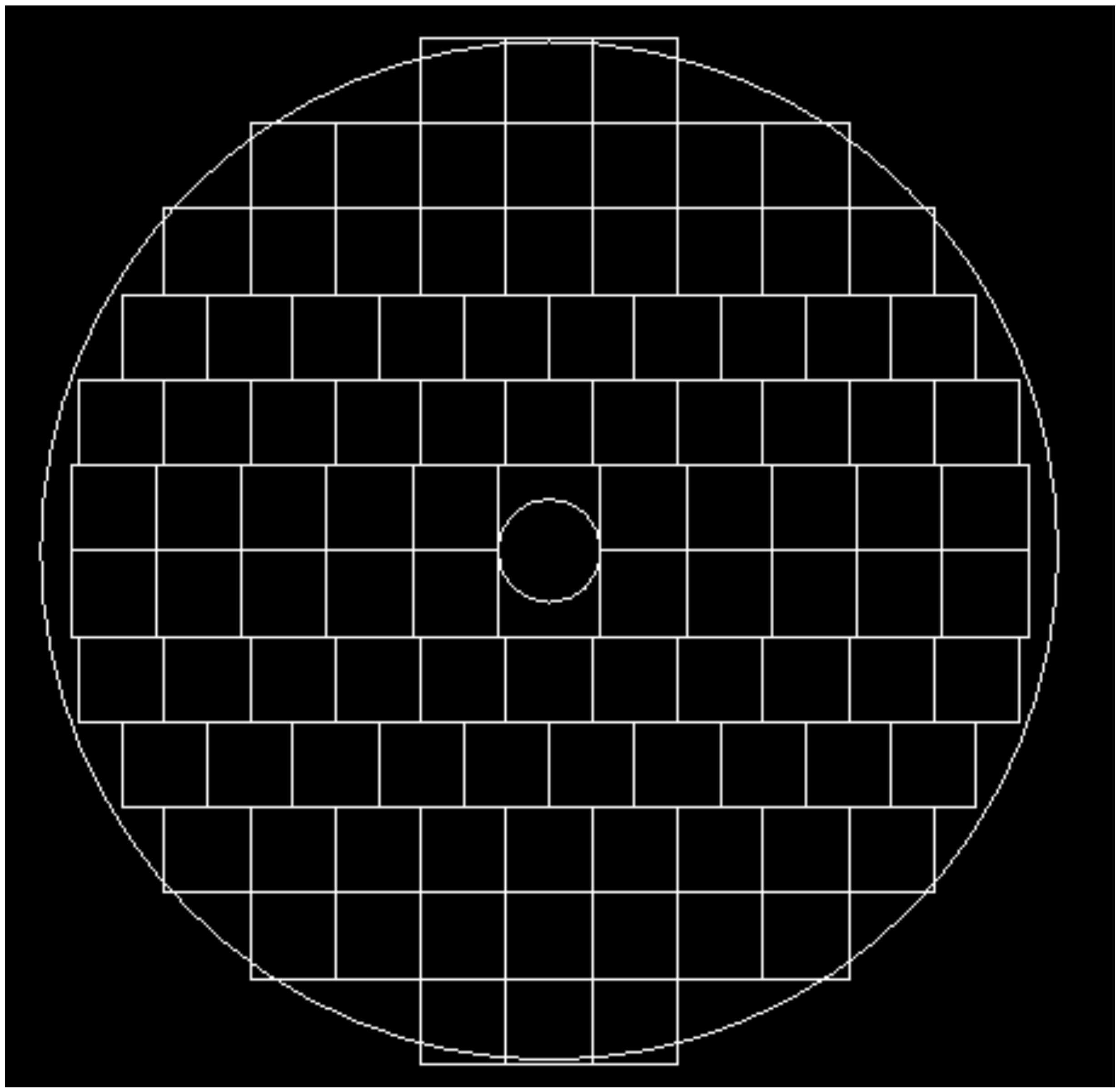




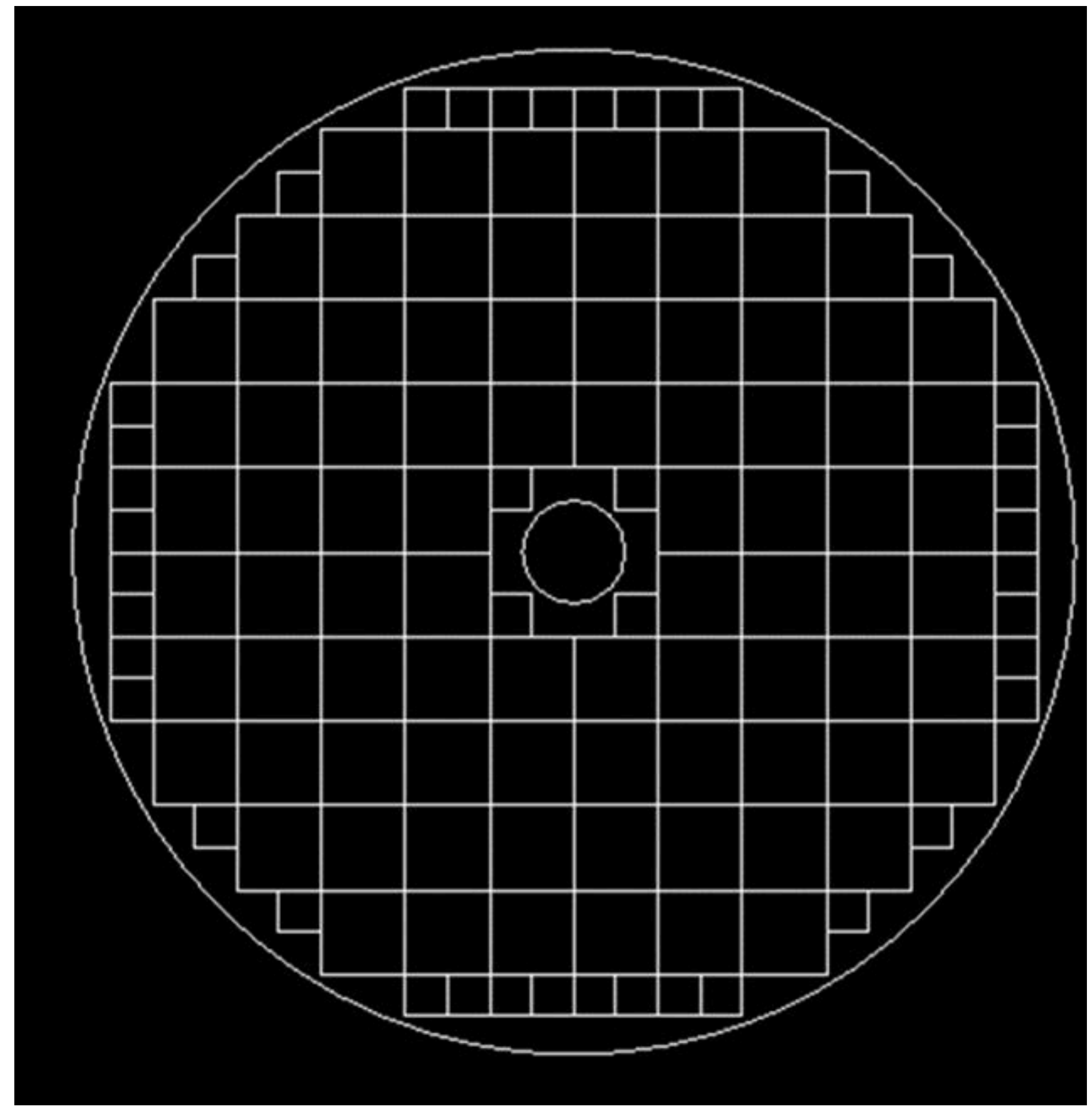
IDEA full simulation of preshower

Endcap preshower

Option 1



Option 4



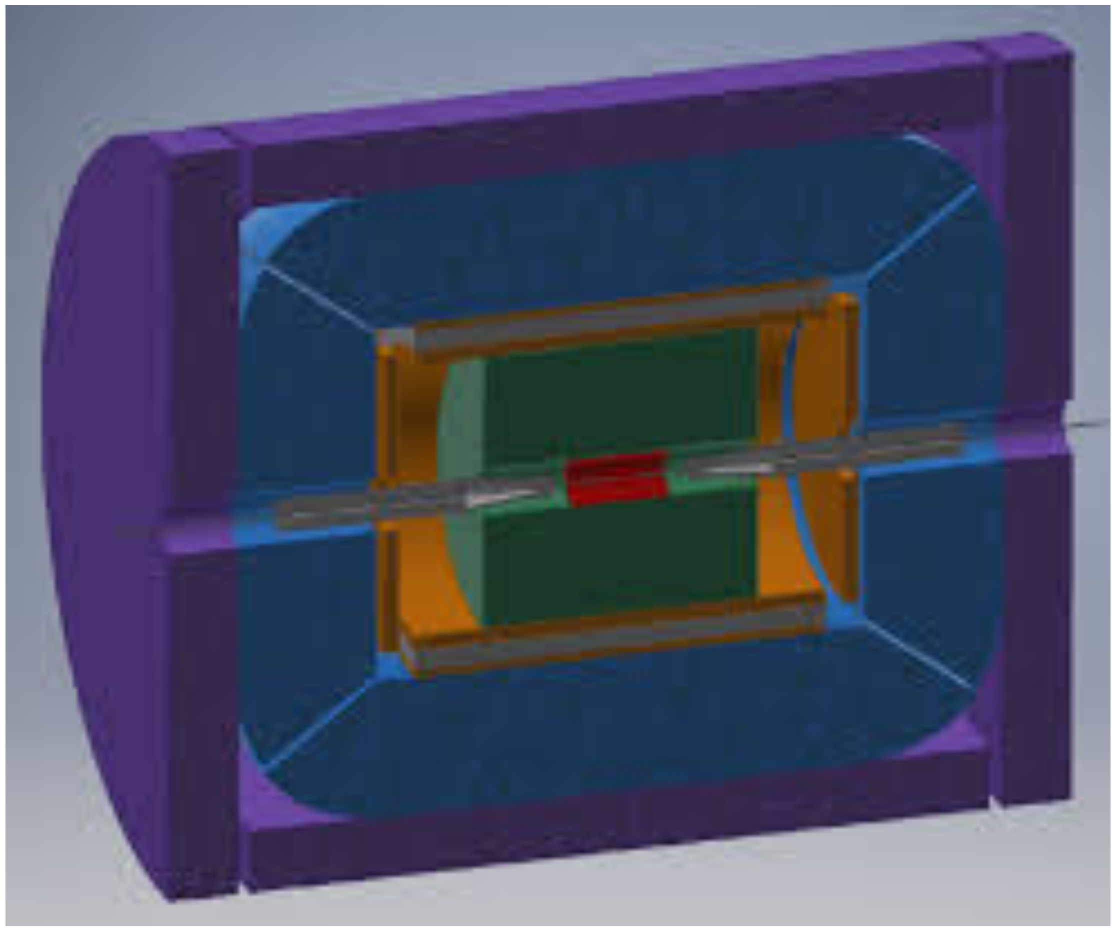
Conclusions

- The central tracker of IDEA, the large wire chamber, calls for significant R&D, especially for the 4 m long wires needed
- The IDEA preshower and muon detector are sought to be realised with the same detector technology: the μ-RWELL
  - An exhaustive R&D program is being pursued to optimise this detector for IDEA's characteristics (and not only)
  - This R&D is done in close contact with a couple of industries, ELTOS and TECHTRA, and therefore an importante Technology Transfer is present.
- The R&D on the wire chamber and on the μ-RWELL will be partly financed by a few European projects, among which AIDA++.

Backup

Circular colliders: FCC-ee detectors

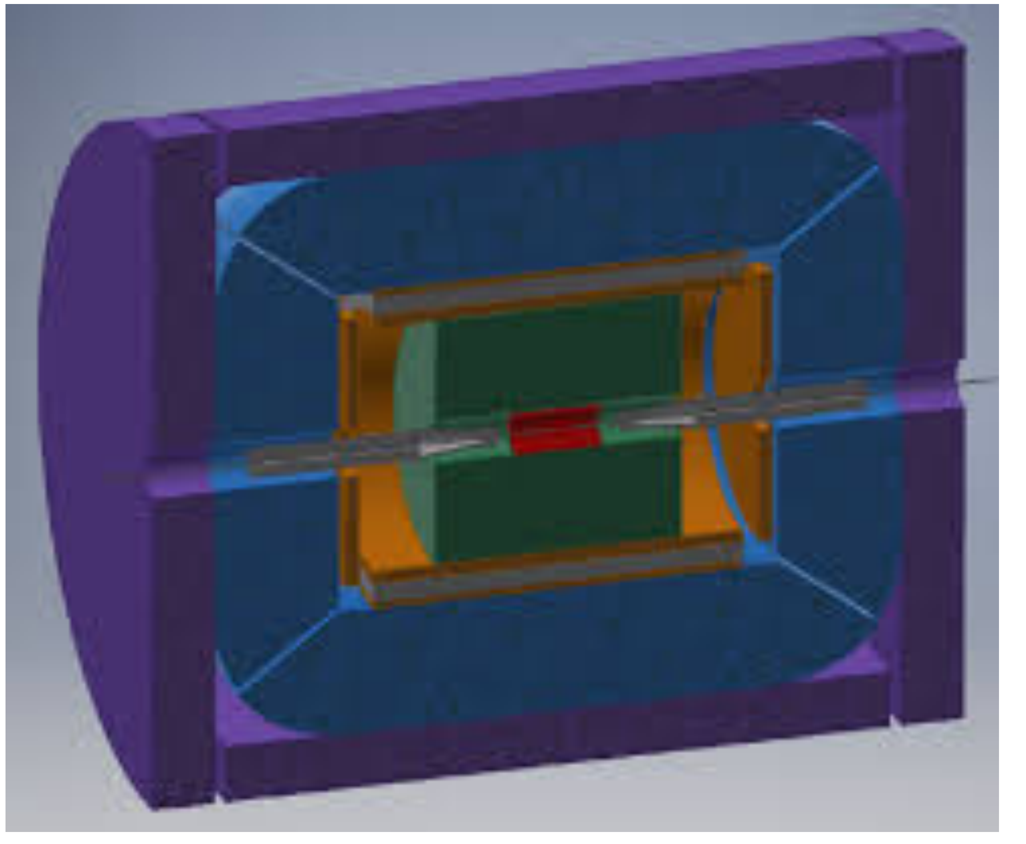
IDEA

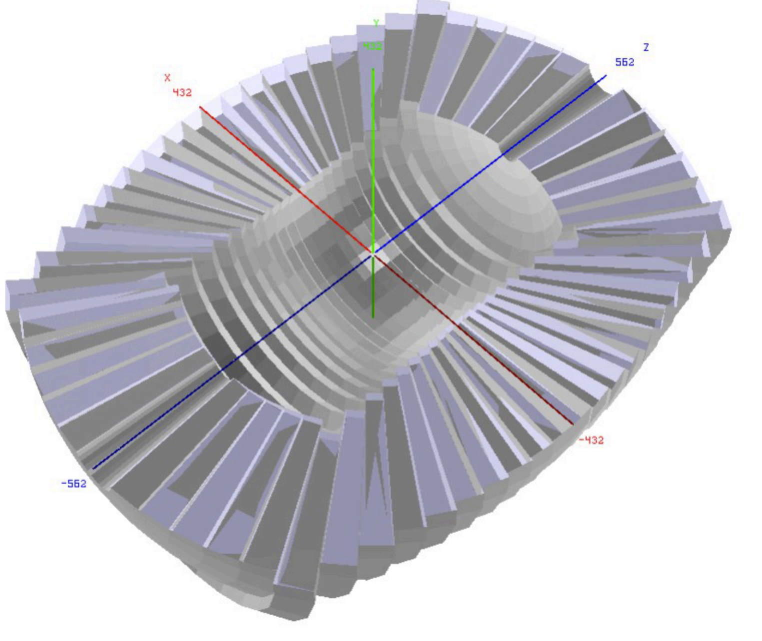


2 T thin solenoid
Si vertex
Wire chamber
Dual Readout calorimeter
MPGD-based Muon detector

Circular colliders: CEPC detectors

IDEA





IDEA detector concept

- IDEA's strong points:
  - Wire chamber with >= 100 position and dE/dx measurements on each track
    - Extremely transparent (more transparent than air)
  - Very thin superconducting coil of 2 T
  - Dual readout calorimeter
    - Best EM and hadronic jets energy resolution
    - Preshower with high spatial resolution to precisely measure the position of showers initiated before the calorimeter
  - Veri high efficiency muon detector with very good position resolution
    - Standalone measurement of the muon tracks
    - Useful for long lived particles
  - Last but not least…it is considered both for FCC-ee and CEPC!
    - Described in both Conceptual Design Reports