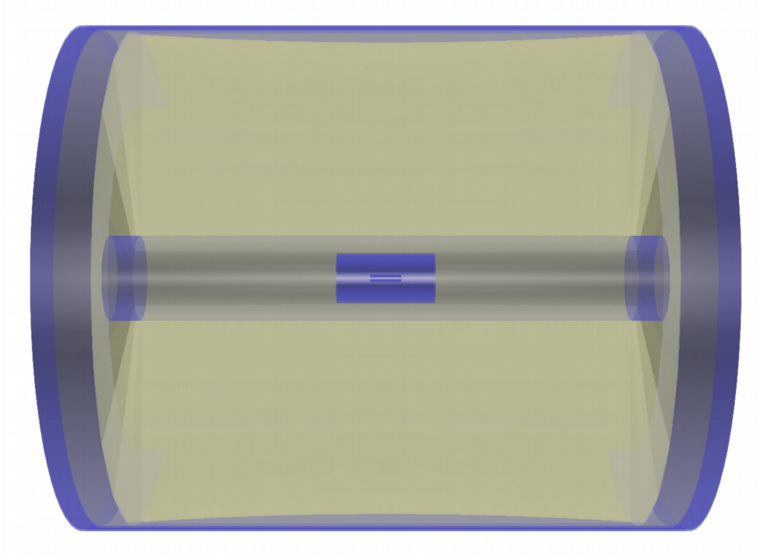
IDEA Drift Chamber



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FCC Week April 2018, Amsterdam

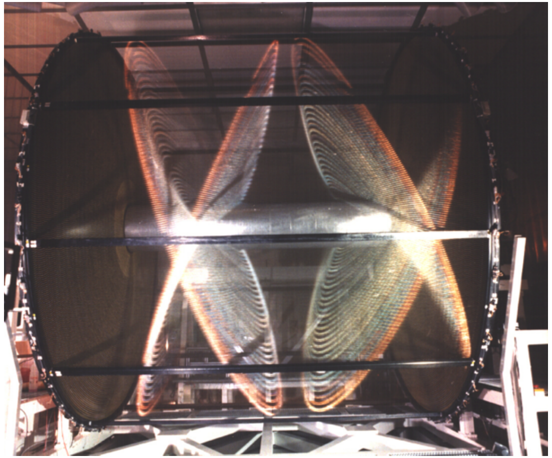
Outline

- IDEA Drift Chamber
  - Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DC to IDEA DC)
  - Geometrical parameters
  - Cluster Counting/Timing and P.I. expected performance
- IDEA tracking system (DC+SVX+PSHW)
  - Possible layouts
  - Simulation
  - Expected IDEA tracking performance
  - Impact on the Higgs recoil mass
- Summary

Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DC to IDEA DC)

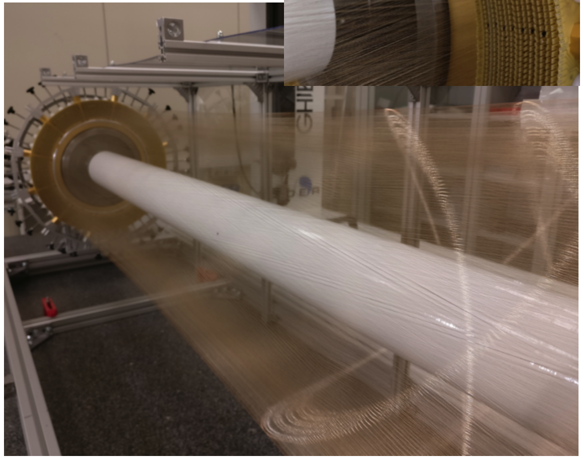
- Ancestor chamber: **KLOE** at INFN LNF Daϕne φ factory (commissioned in 1998 and currently operating)
- **CluCou** Chamber proposed for the **4th-Concept** at ILC (2009)
- **I-tracker** chamber proposed for the **Mu2e experiment** at Fermilab (2012)
- **DCH** for the **MEG-II upgrade** at PSI (under commissioning)

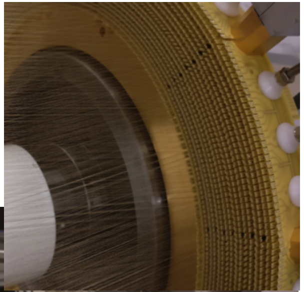
KLOE DCH



	KLOE	**MEG-II**
stereo	**Fully (~ 80 mrad)**	**Fully (~120 mrad)**
diameter	**4 m**	**0.6 m**
length	**3.3 m**	**2.0 m**
structure	**C-fiber**	**C-fiber**
Gas (He-iC$_4$H$_{10}$)	**90% - 10%**	**85% - 15%**
Sense wires	**12000**	**2000**
Total wires	**52000**	**12000**
Weaker wire	**80 μm Al**	**40 μm Al**
cell size	**2x2 - 3x3 cm^2**	**0.7x0.7 - 1x1 cm^2**
Wire density	**~0.4 wires/cm^2**	**~12 wires/cm^2**

MEG-II DCH

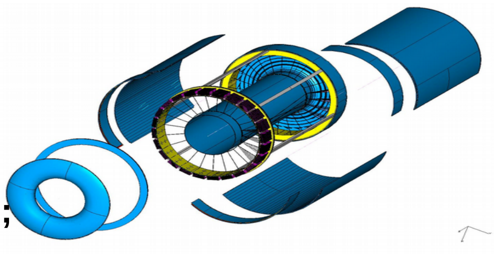




High wire densities prevent the use of feed-through, needing novel approaches to the wiring procedures

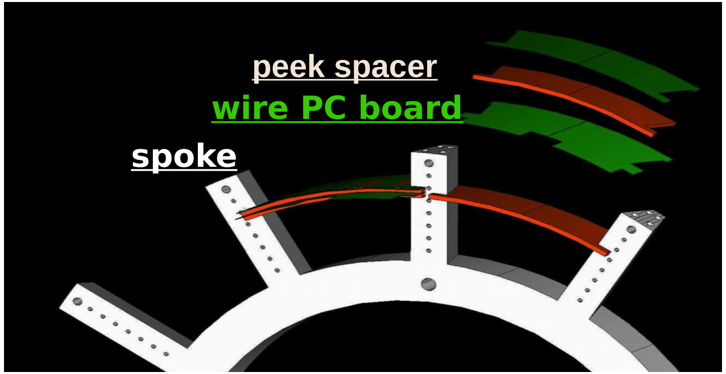
Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DC to IDEA DC)

- **Separate the end-plate function: mechanical support for the wires and gas sealer;**
- **Find a feed-trough-less wiring procedure.**



- **end-plates numerically machined from solid Aluminum (mechanical support only);**
- **Field, Sense and Guard wires placed azimuthally by Wiring Robot with better than one wire diameter accuracy;**
- **wire PC board layers (green) radially spaced by numerically machined peek spacers (red) (*accuracy < 20 µm*);**
- **wire tension defined by homogeneous winding and wire elongation (*ΔL = 100µm corresponds to ≈ 0.5 g*);**
- **Drift Chamber assembly done on a 3D digital measuring table;**
- **build up of layers continuously checked and corrected during assembly;**
- **End-plate gas sealing will be done with glue.**

The solution adopted for MEG II:



Novel approach at construction technique of high granularity and high transparency Drift Chambers (From KLOE DC to IDEA DC)

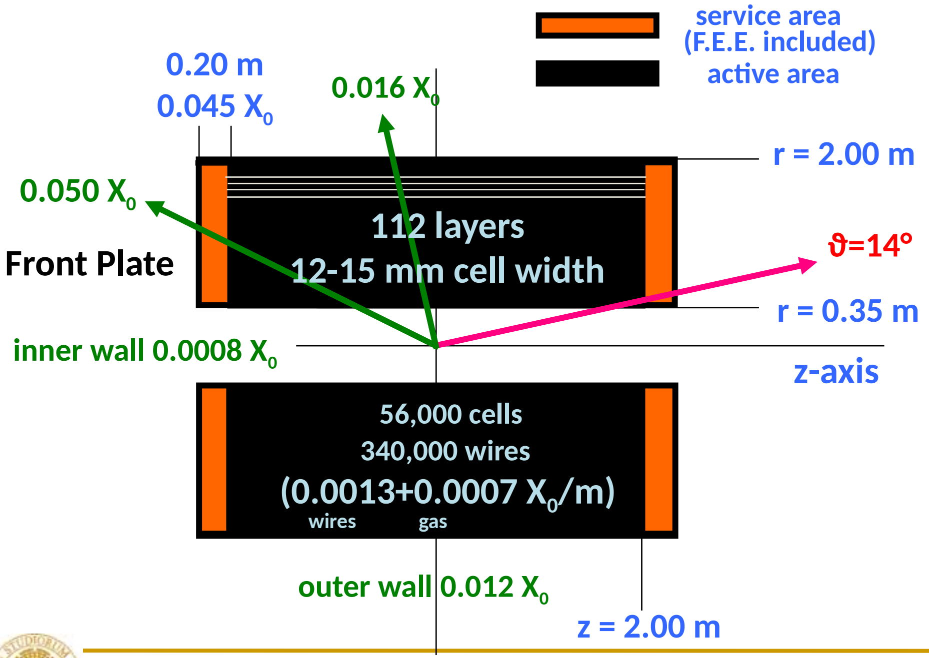
Based on the MEG-II DCH new construction technique the *IDEA DCH* can meet these goals:

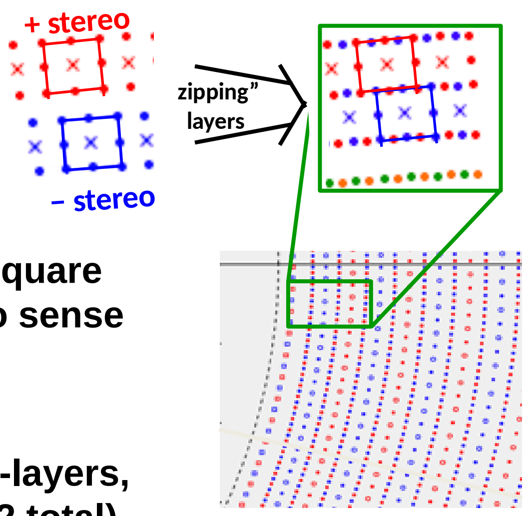
- Gas containment – wire support functions separation
  - allows to reduce material to ≈ 10^{-3} X_0 for the inner cylinder and to a few x 10^{-2} X_0 for the end-plates, including FEE, HV supply and signal cables (Mu2e proposal design: 1.5×10^{-3} X_0 and 8×10^{-3} X_0, respectively)
- Feed-through-less wiring
  - allows to increase chamber granularity and field/sense wire ratio to reduce multiple scattering and total tension on end plates due to wires (by using thinner wires)
- Cluster timing
  - allows to reach spatial resolution < 100 μm for 8 mm drift cells in He based gas mixtures (such a technique is going to be implemented in the MEG-II drift chamber under construction)
- Cluster counting
  - allows to reach dN_{cl}/dx resolution < 3% for particle identification (a factor 2 better than dE/dx as measured in a beam test)

Geometrical parameters

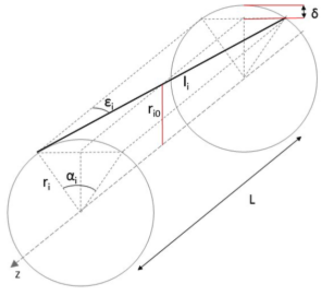
tracking efficiency ε ≈ 1
for ϑ > 14° (260 mrad)
97% solid angle

0.016 X_0 to barrel calorimeter
0.050 X_0 to end-cap calorimeter

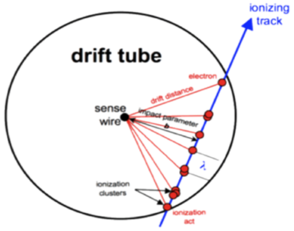




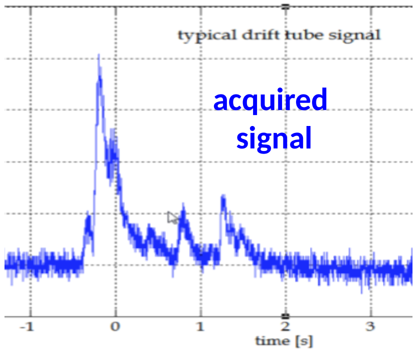
- 12÷15 mm wide square cells 5 : 1 field to sense wires ratio
- 56,448 cells
- 14 co-axial super-layers, 8 layers each (112 total) in 24 equal azimuthal (15°) sectors (Ni = 192 + (i – 1) × 48)
- alternating sign stereo angles ranging from 50 to 250 mrad



Cluster Counting/Timing and P.I. expected performance



From the ordered sequence of the electrons arrival times, considering the average time separation between clusters and their time spread due to diffusion, reconstruct the most probable sequence of clusters drift times: $\{t_i^{cl}\} \quad i = 1, N_{cl}$



dE/dx

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 0.41 \cdot n^{-0.43} \cdot (L_{track}[m] \cdot P[atm])^{-0.32}$$

from *Walenta parameterization (1980)*

truncated mean cut (70-80%) reduces the amount of collected information n = 112 and a 2m track at 1 atm give

σ ≈ 4.3%

Increasing P to 2 atm improves resolution by 20% (σ ≈3.4%) but at a considerable cost of multiple scattering contribution to momentum and angular resolutions.

dN_{cl}/dx

$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl} \text{¿} dx)} = (\delta_{cl} \text{¿} L_{track})^{-1/2}$$

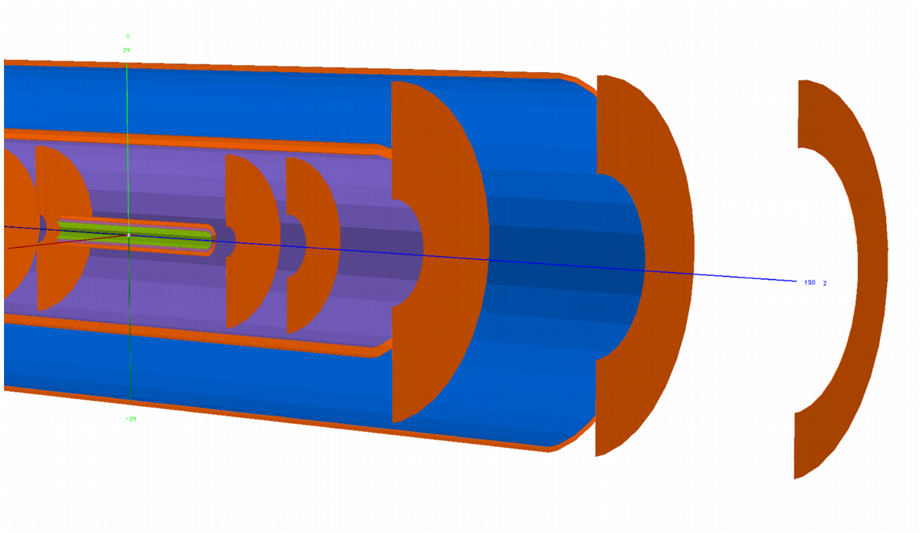
from *Poisson distribution*

δ_{cl} = 12.5/cm for He/iC_4H_{10}=90/10 and a **2m track** give

σ ≈ 2.0%

A small increment of iC_4H_{10} from 10% to 20% (δ_{cl} = 20/cm) improves resolution by 20% (σ ≈1.6%) at only a **reasonable** cost of multiple scattering contribution to momentum and angular resolutions.

IDEA tracking system (DC+SVX+PSHW)



Summary

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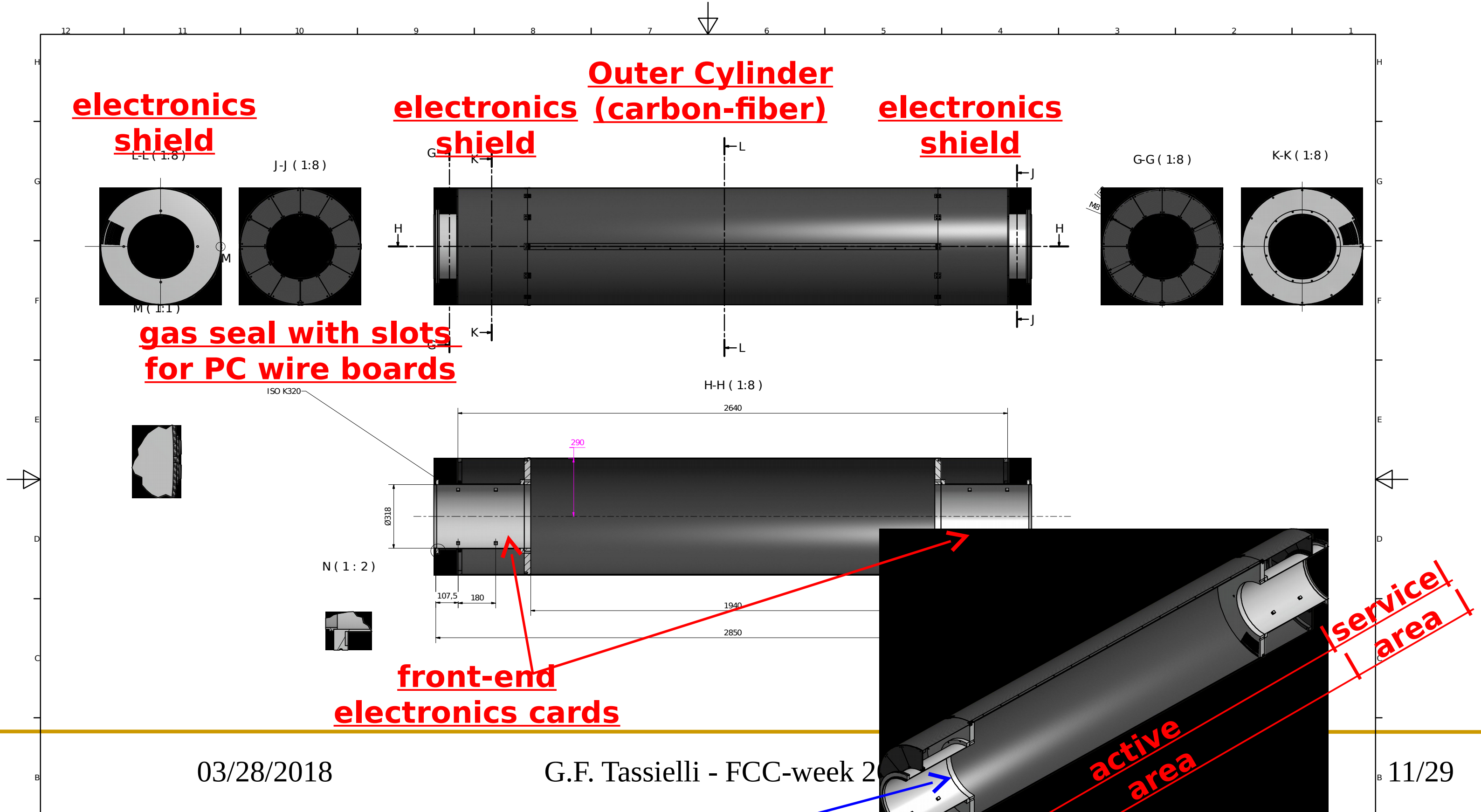
Backup

MEG-II DC: the novel way

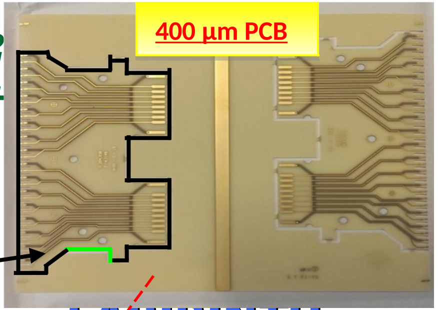
The carbon fiber outer cylinder is the only mechanical structure supporting the wire tensio



MEG-II DC: stringing (*the Wi* *Robot)*

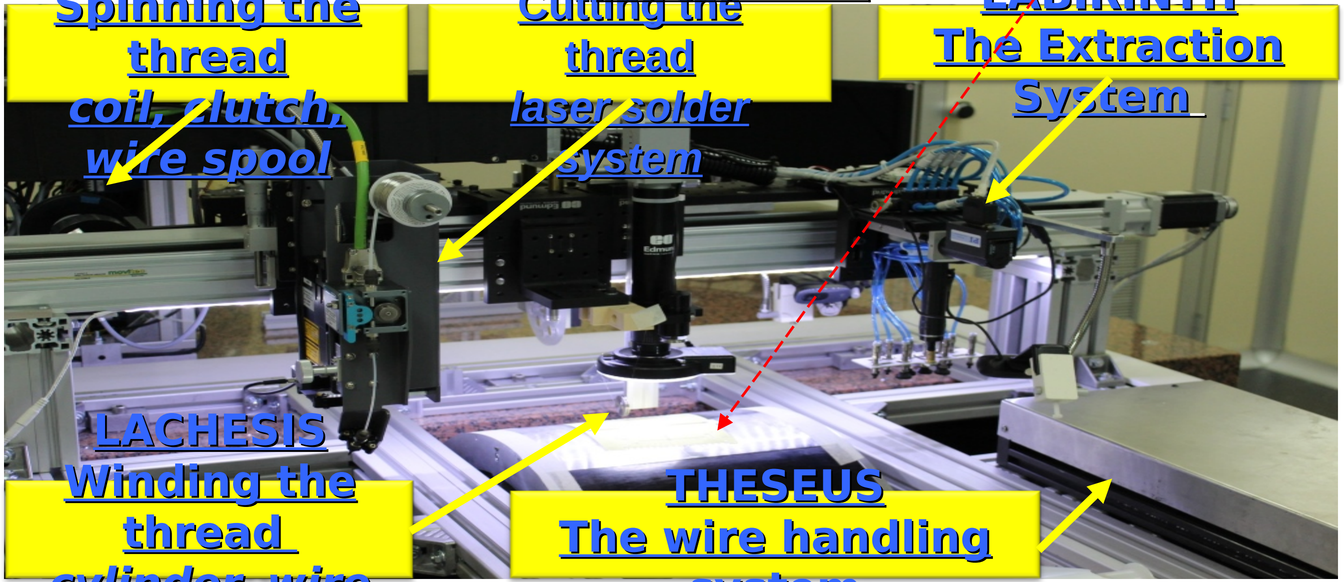
The tasks of the wiring robot are:

- the wiring of a multiwire layer made of 32 parallel wires;
- settable wire tension (±0.05g);
- 20µm of accuracy on wire position.

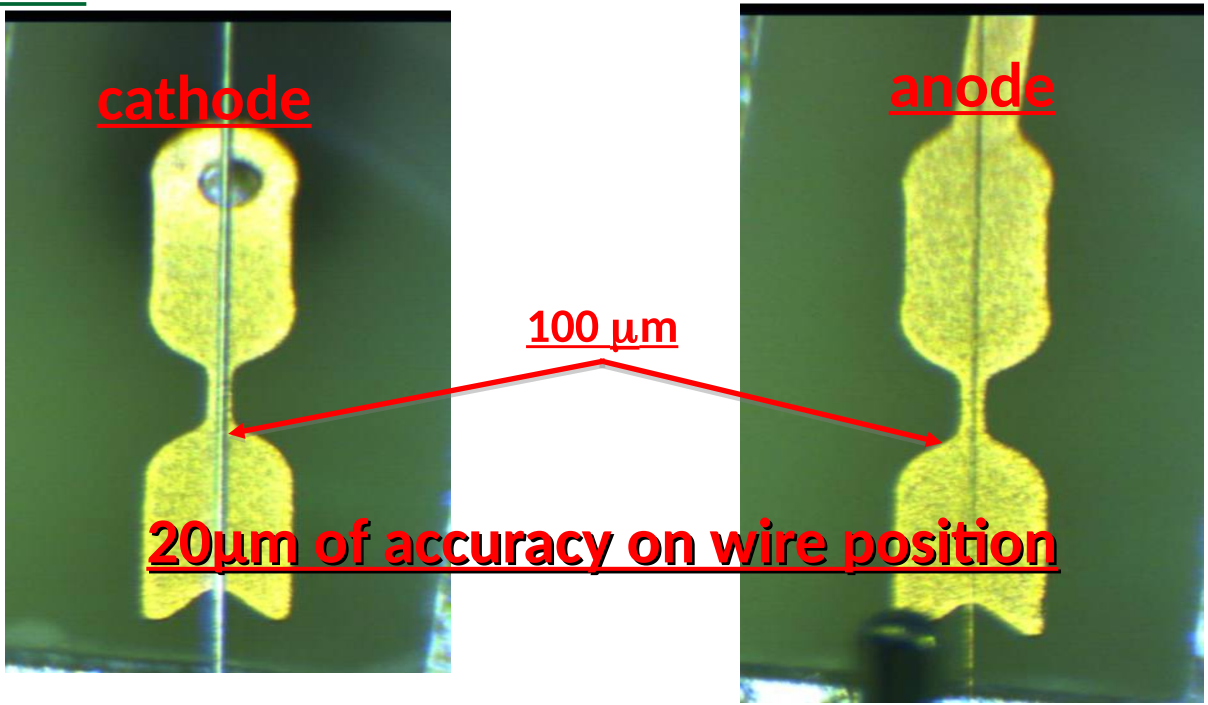


Its main parts are:

- a winding drum;
- an electromagnetic brake;
- a system of pulleys;
- a strain gauge;
- an high resolution camera;
- 5 linear synchronized axes;
- a CompactRIO controller;
- a contactless soldering

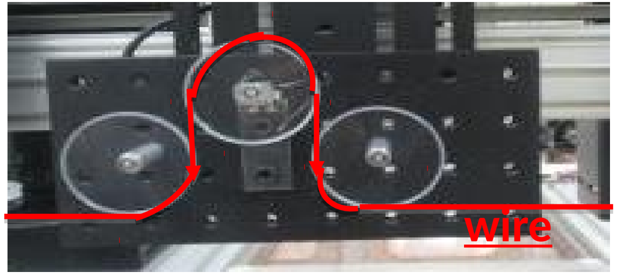


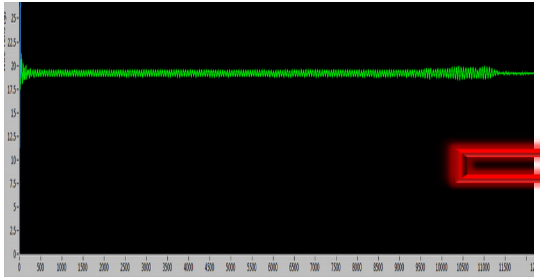
WIRING SYSTEM (*Klotho and Lachesis*): wire position

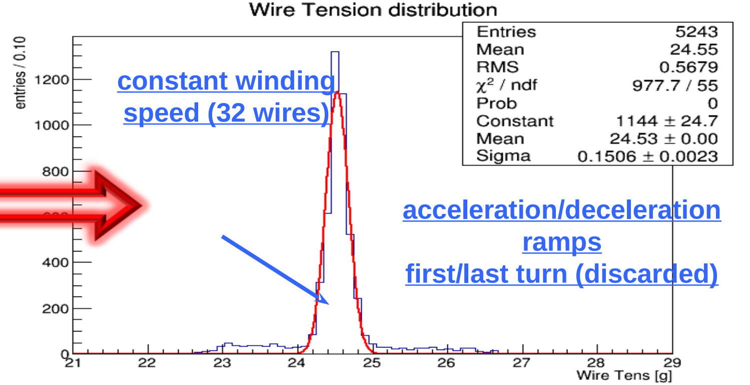


WIRING SYSTEM (*Klotho and Lachesis*): wire tension

The wire mechanical tension is delivered by an electromagnetic clutch and its on-line monitored by a high precision strain gauge, a real-time feedback system correct any variation.

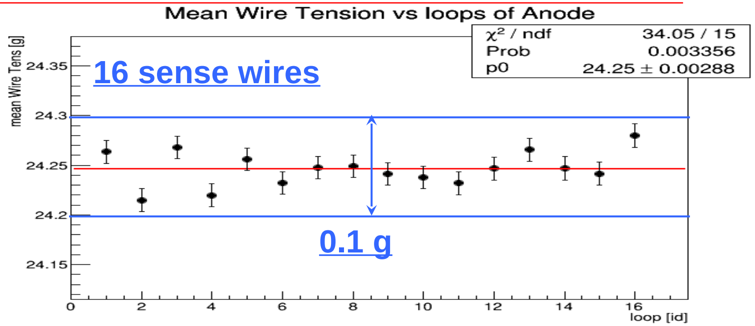


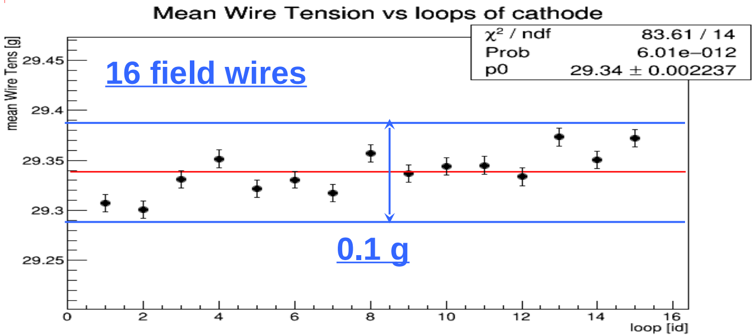




mean wire tension is stable at the lev

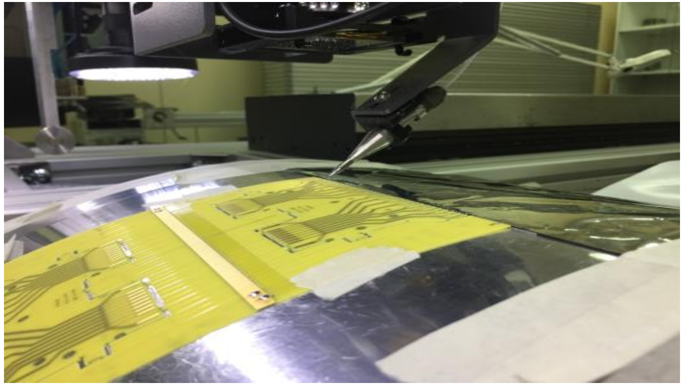
For single wire (turn):

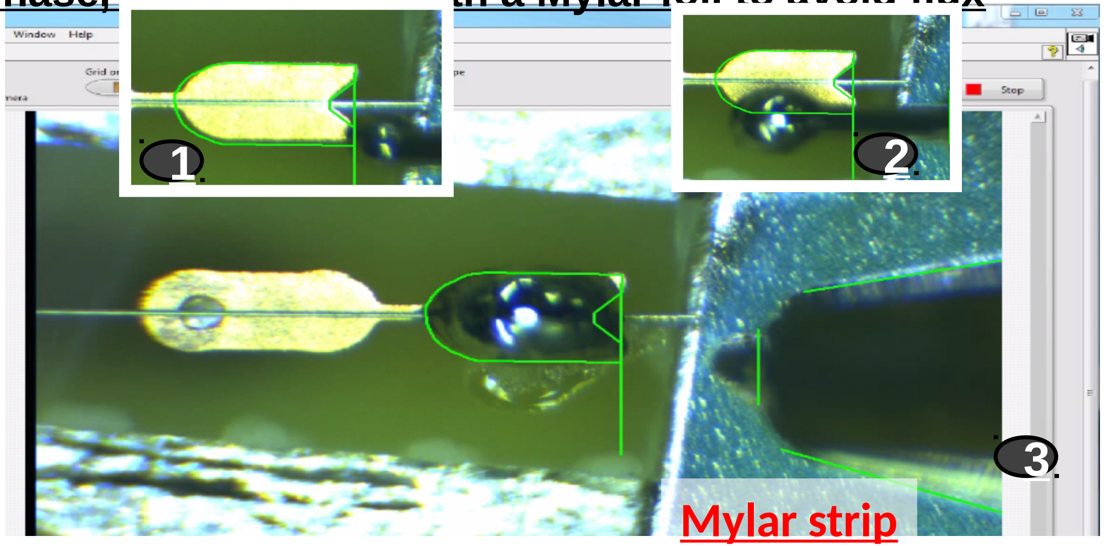




SOLDERING SYSTEM (*Atropos*)

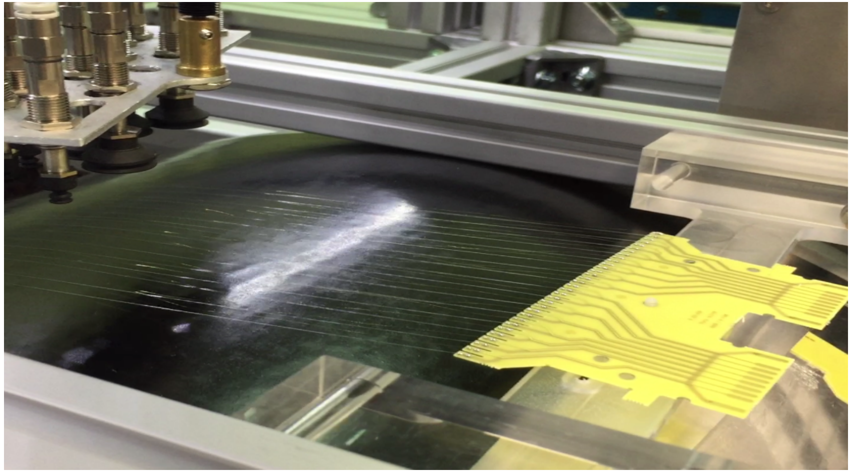
- **The soldering phase is accomplished by an LASCON 501 IR laser soldering System using a low temperature (180 °C) melting tin.**
- **The laser system is controlled by the NI CompactRIO and is synchronized with the positioning system.**
- **The wires, during the soldering phase, are protected with a Mylar foil to avoid flux splashing.**

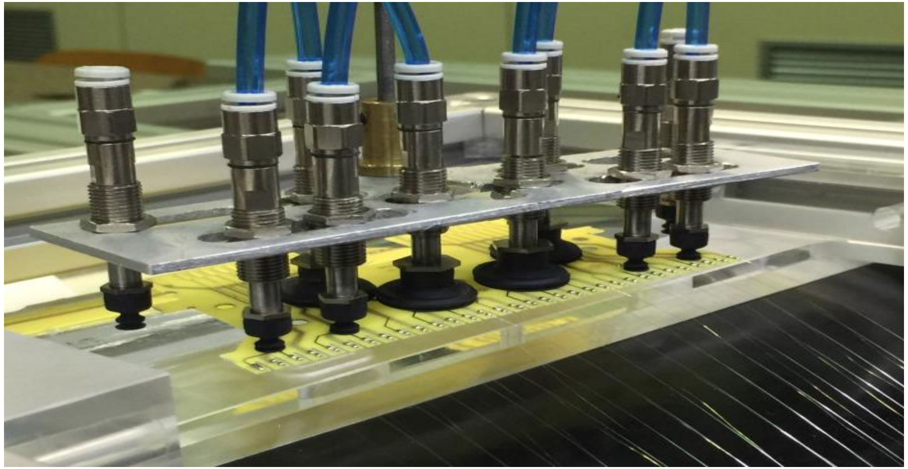




EXTRACTION SYSTEM (*Labirinth and Theseus*)

- The wound layer of soldered wires must be unrolled from the winding drum and de-tensioned for storage and transport to the assembly station at INFN Pisa.
- The wire PCBs are lifted off from the cylinder with a linear actuator connected to a set of vacuum operated suction cups.



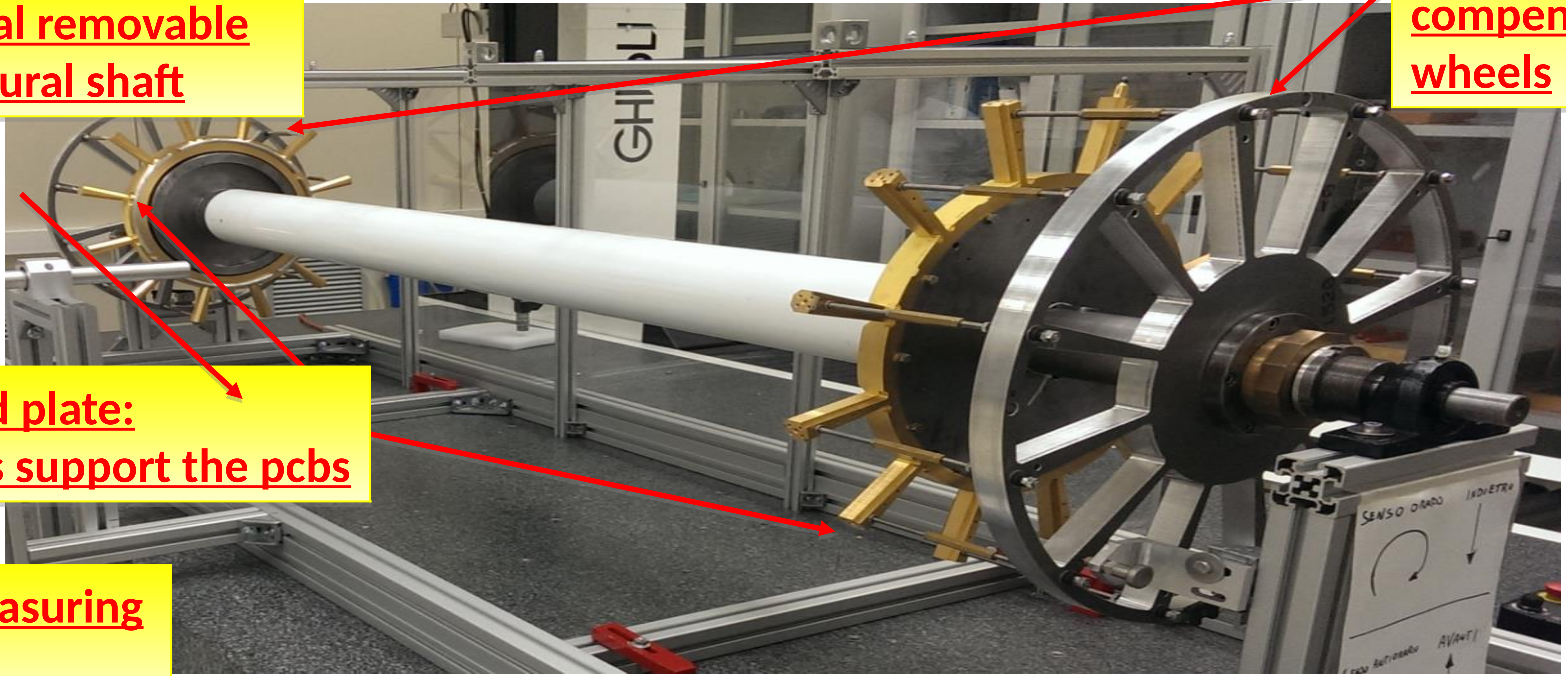


MEG-II DC: assembly-I

- **During the assembly phase, the endplates are placed at a shorter distance than nominal to avoid stressing the wires**

Central removable structural shaft

wire tension compensating wheels

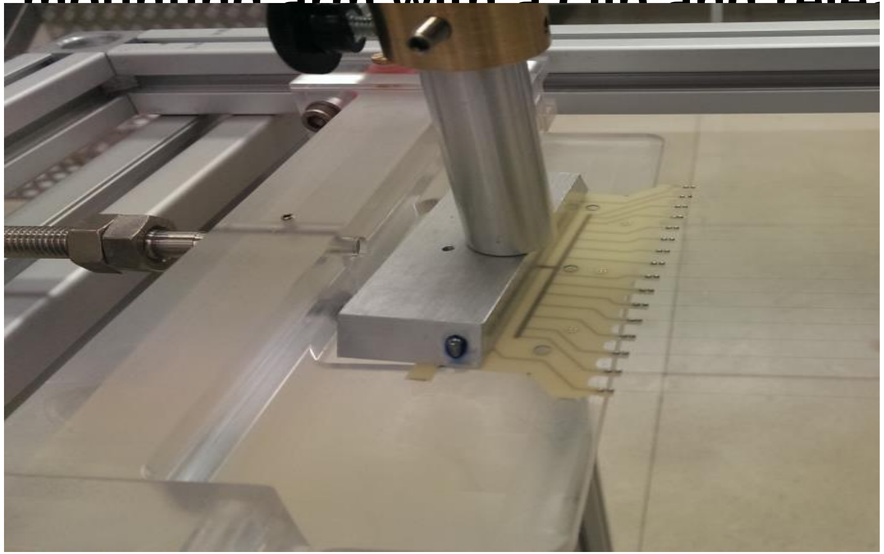


DC End plate: spokes support the pcbs

3D measuring table

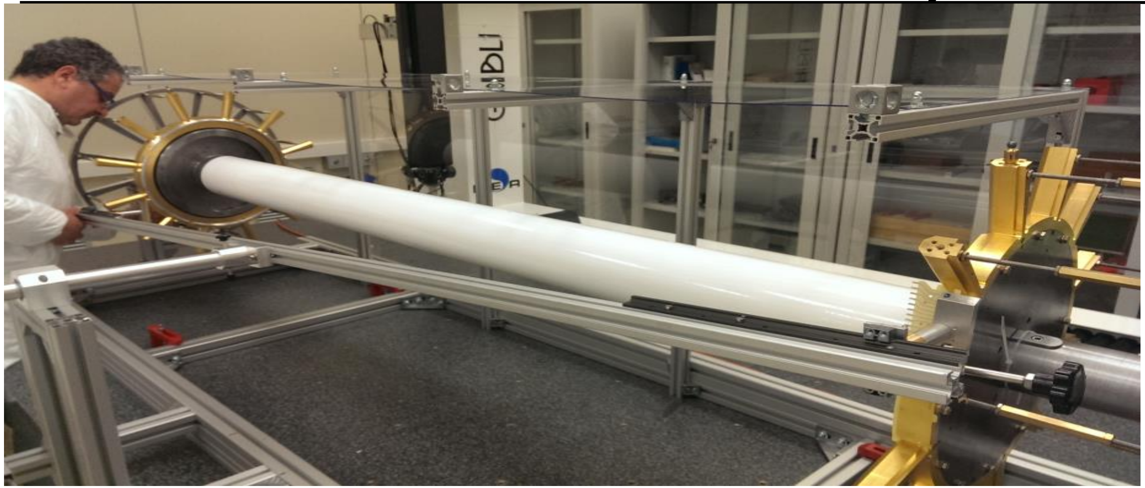
MEG-II DC: assembly-II

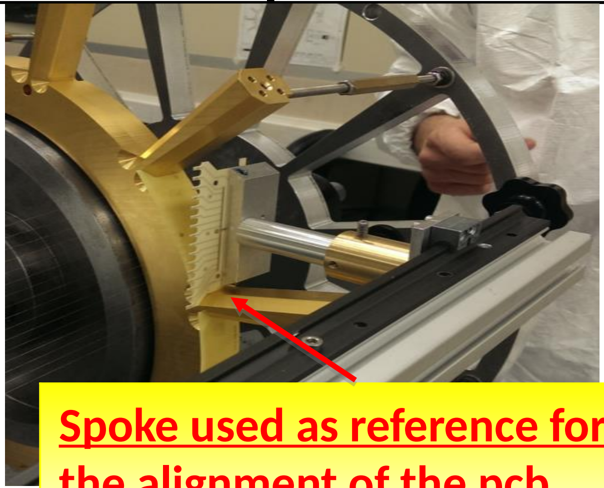
- **The mounting procedure is performed with an adjustable arm and a flipping arm (used only for flipped layers);**
- **The wire-PCBs, fixed on the transport frame, are anchored to the mounting arm with a clip and relea[illegible] frame.**



MEG-II DC: assembly-III

- **The mounting arm (with the multi-wire layer) is then placed next to the end plates for the engagement procedure.**
- **The mounting arm is fixed to a support structure to prevent damaging the wires.**
- **This structure transfers the multi-layer wire on the end plates between**

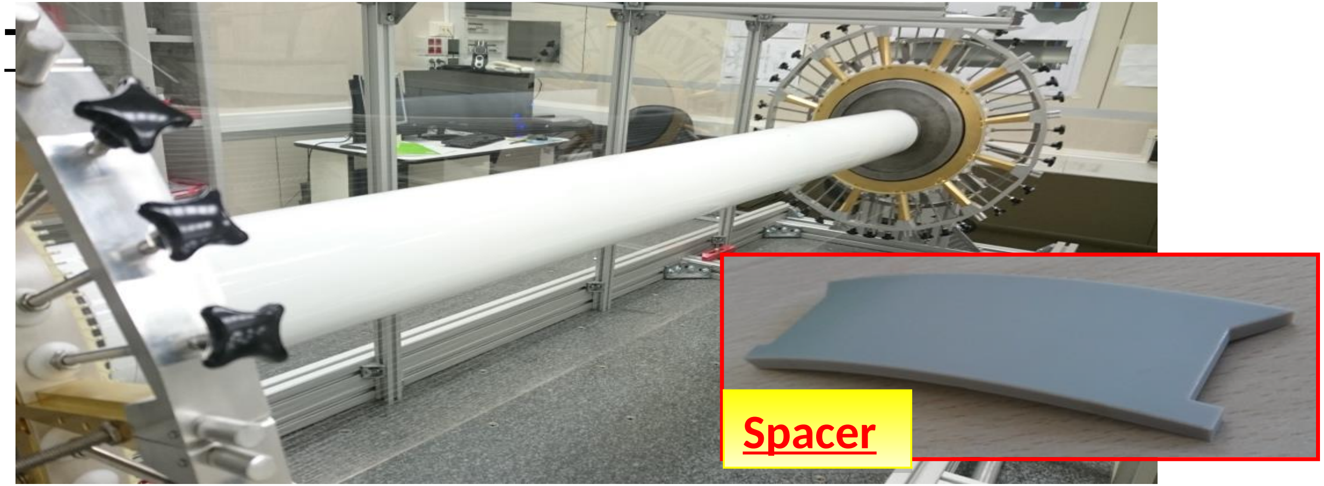


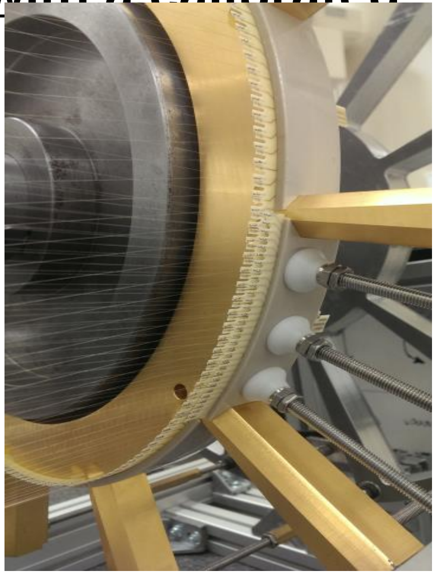


Spoke used as reference for the alignment of the pcb

MEG-II DC: assembly-IV

- This procedure is repeated for each of the 12 sectors.
- After completing the installation of one layer, a survey is performed on the radial layer position.
- Half cell spacers are pressed and glued in position with a calibrated pressure-sensitive film.



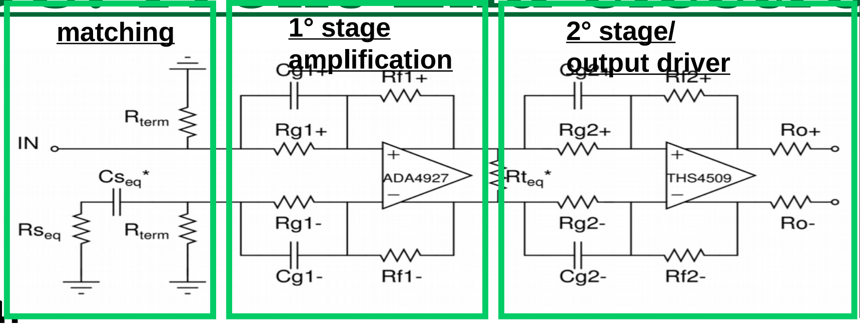


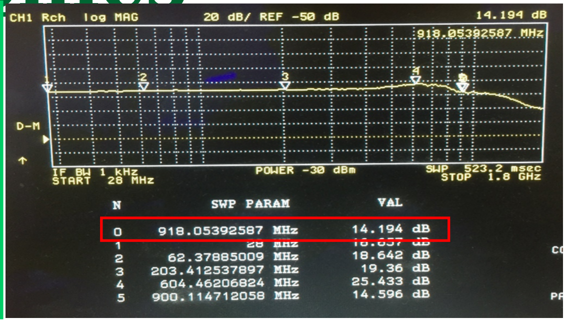
MEG-II DC: assembly-V

- **After assembling all layers, the DC is closed with the carbon fiber outer panels.**
- **The DC will be put vertically to seal the end plate (wire-pcb and spacer).**
- **After sealing, the mechanical supports and the extender structure for the front end electronics will be mounted.**
- **The inner mylar cylinder will be mounted after shipping the DC to PSI.**

All mounting procedure, together with the DC insertion in the COBRA magnet has been successfully tested with a Mock-up chamber mechanically identical

MEG-II DC: Front End electronics





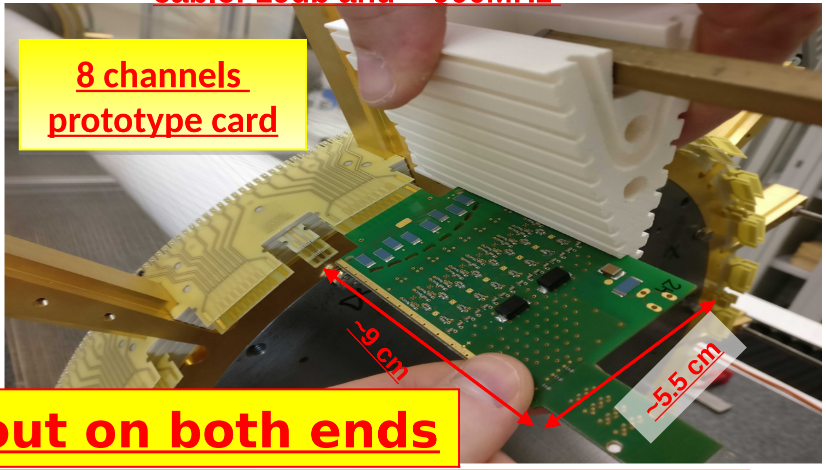
Requirements:

- **High bandwidth >700 MHz**
- **Good gain: ~10**
- **High density < 7mm channel width**
- **Fully differential**

analog gain and Bandwidth after 5m cable: 19db and ~ 900MHz

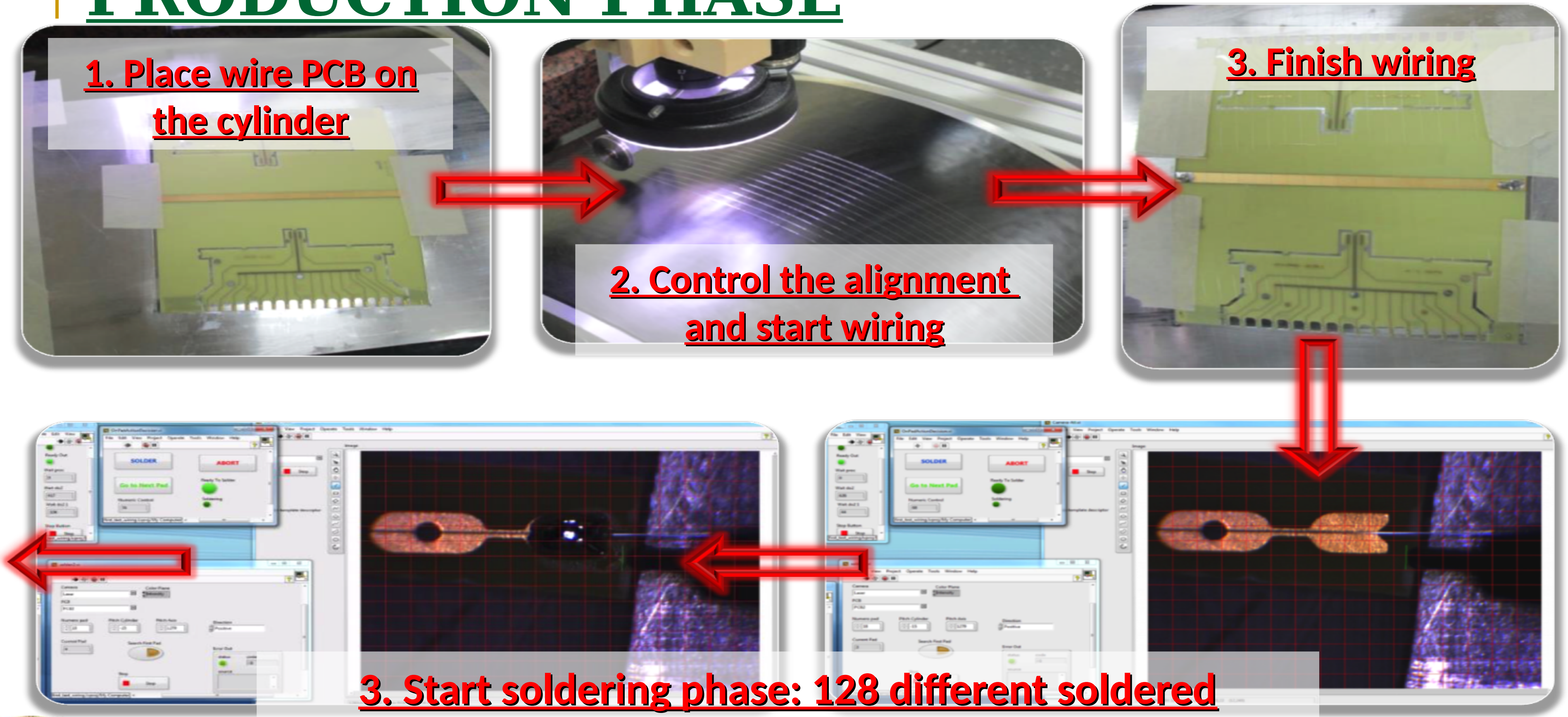
Layout:

- **2 stage amplifiers based on commercial devices:**
  - **ADA4927 (AD) Ultralow distortion current feedback**
  - **THS4509 (TI) Wideband low noise fully differential amplifier**
- **Pre-emphasis implemented on both stages in order to balance the attenuation of output**
- **High overall (after 5m of cable) bandwidth (FE input to DRS WaveDream input): ~1GHz**
- **Low power: 50mW @ +2.5V**

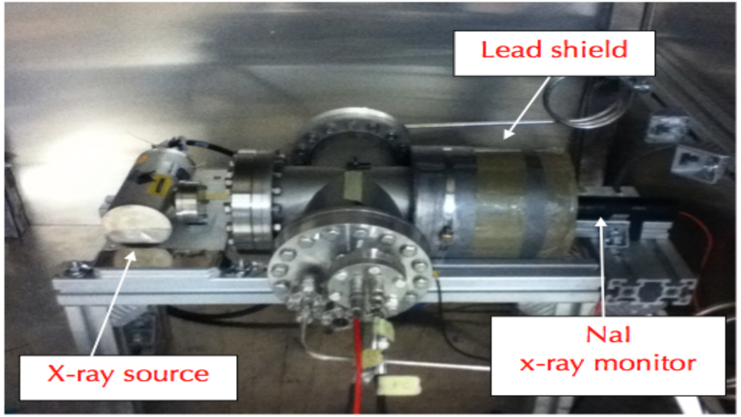


1280 out of 1920 channels (2/3) readout on both ends

PRODUCTION PHASE



MEG-II DC: aging



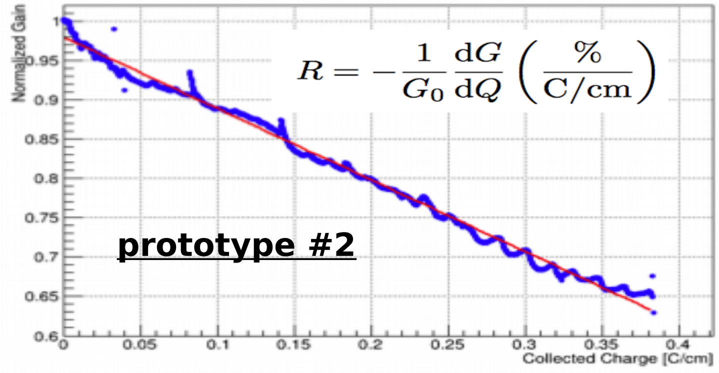
@ 7×10^{7} μ/s and 10^{5} gas gain

expect ≈ 6 nA/cm in the hottest point

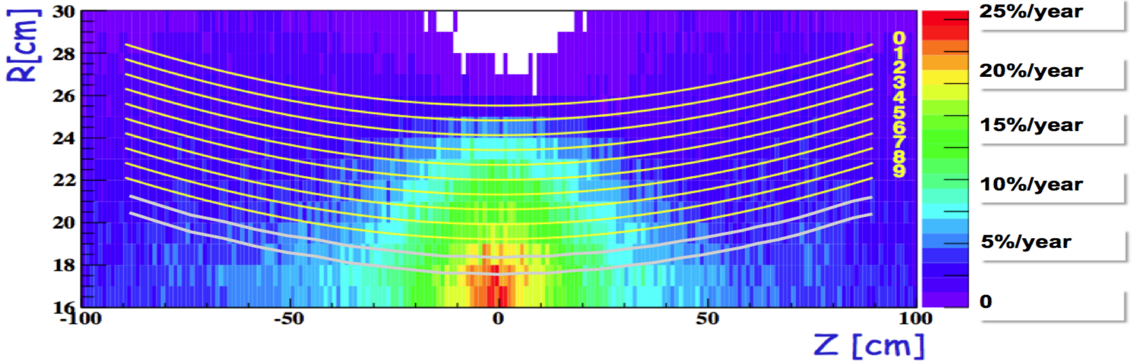
≈ 0.32 C/cm

integrated over 3 years data taking

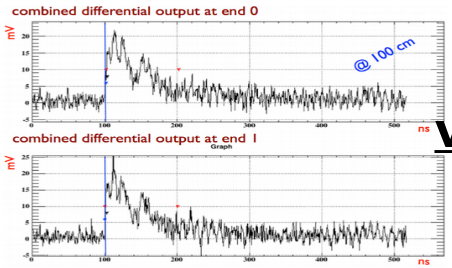
(however, @ G = 10^{5}, dG/dV ≈ 3-4%/Volt)



gain drop



MEG-II DC: single hit resolution

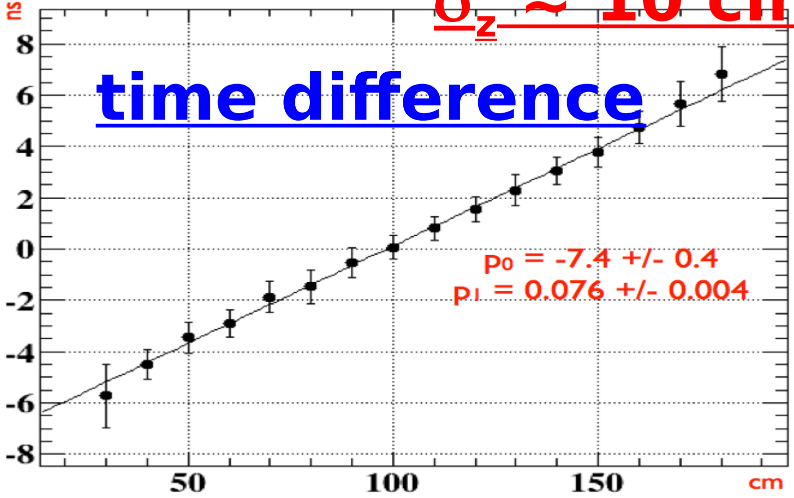


v_s = 13.2 cm/ns

$\sigma_{\Delta t} \approx$ 0.5 ns

$\sigma_z \approx$ 10 cm

time difference

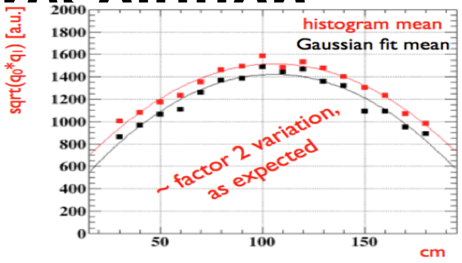


Longitudinal resolution

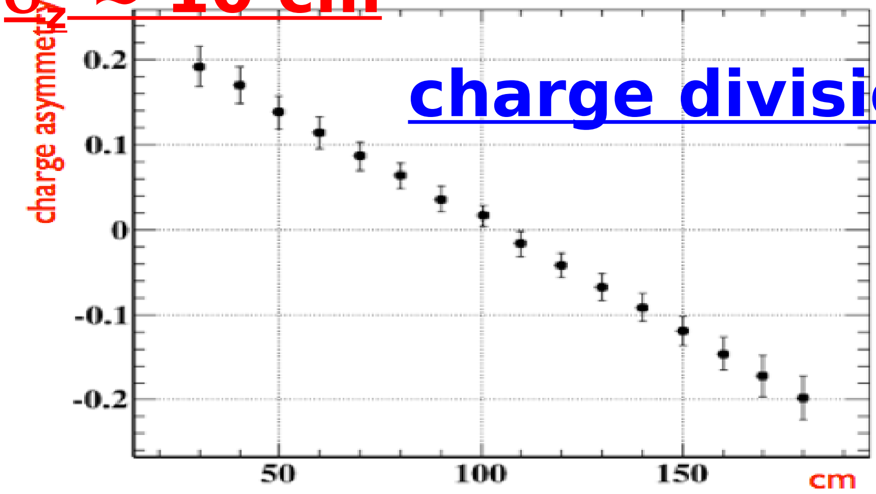
R_w = 150 Ω/m

20 μm W wire

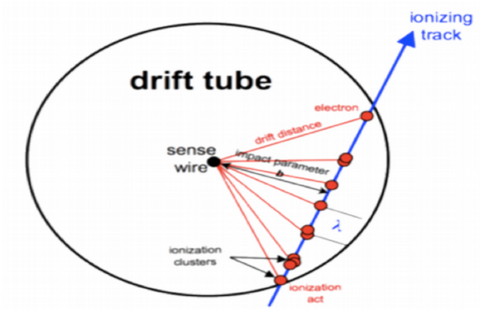
$\sigma_z \approx$ 10 cm



charge division



Cluster Timing



From the ordered sequence of the electrons arrival times, considering the average time separation between clusters and their time spread due to diffusion, reconstruct the most probable sequence of clusters drift times: $\{t_i^{cl}\}$ $i=1,N_{cl}$

For any given first cluster (FC) drift time, the cluster timing technique $\{t_i^{cl}\}$ exploits the drift time distribution of all successive clusters to determine the most probable impact parameter, thus reducing the bias and the average drift distance resolution