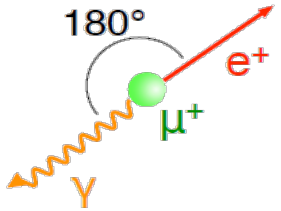
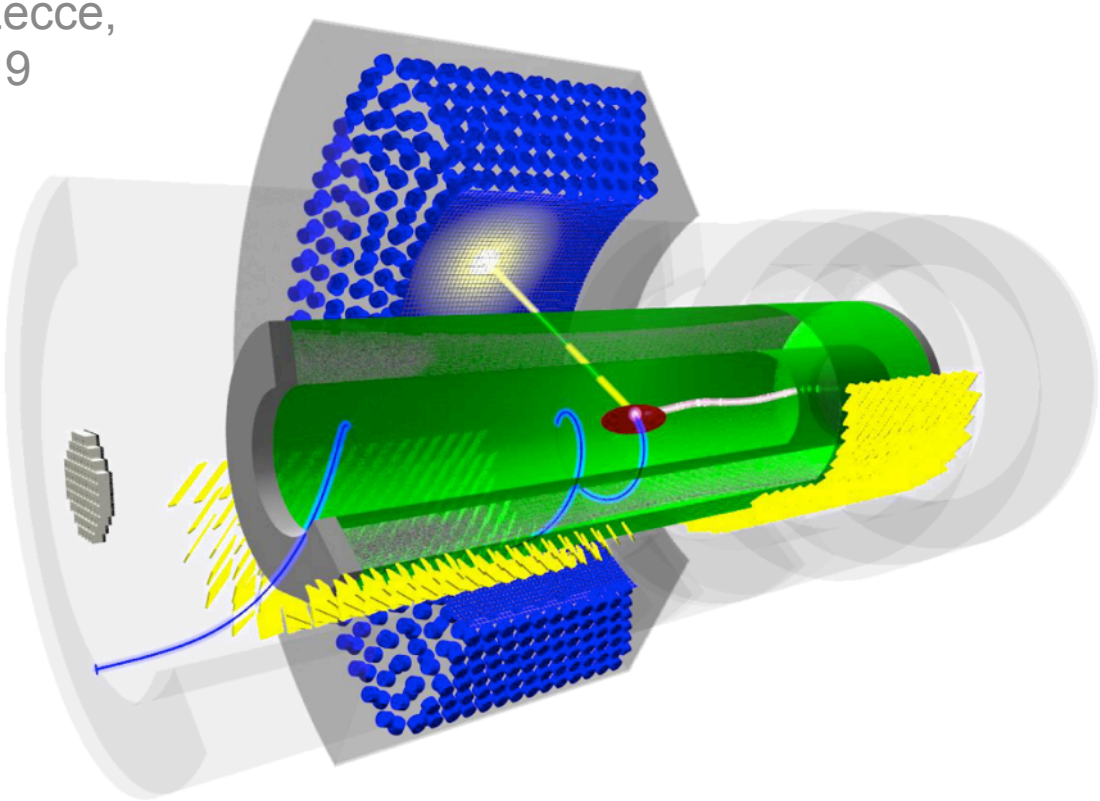
# The MEG2 Drift Chamber Experience

**F. Grancagnolo** INFN Lecce,
IHEP, November 18, 2019




$t_e = t_\gamma$
$E_e = E_\gamma = 52.8$ MeV
$\theta_{e\gamma} = 180°$



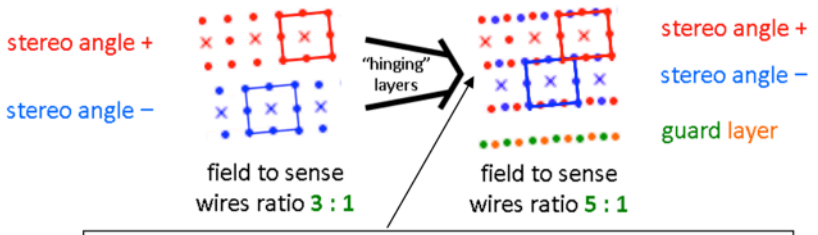
Best world limit (MEG):
*Eur.Phys.J. C76 (2016) 434*

$$BR(\mu^+ \to e^+\gamma) < 4.2 \times 10^{-13} \ @ \ 90\% \ CL$$

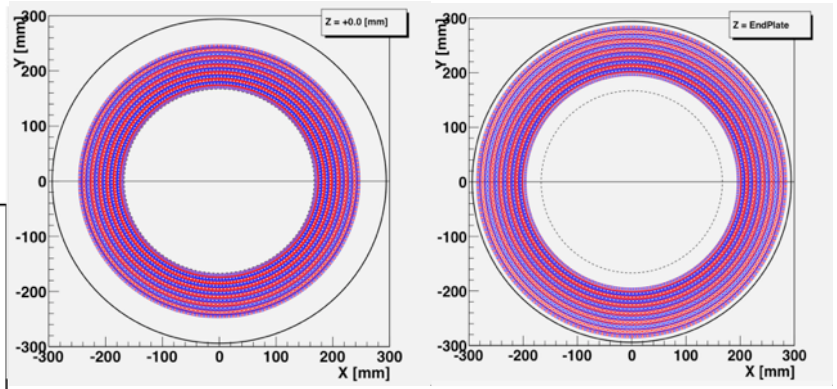
# General Layout

**Chamber characteristics:**

- $r_{in}$~ 16cm $r_{out}$~ 30cm
- L ~ 2m
- 10 layers
- 12 cylindrical sectors
- 16 cells per sector
- full stereo with large stereo angles **(102÷147 mrad)**
- small square cells **(5.8÷7.8 mm at z=0, 6.7÷9.0 at z=±L/2)** (see pictures:)



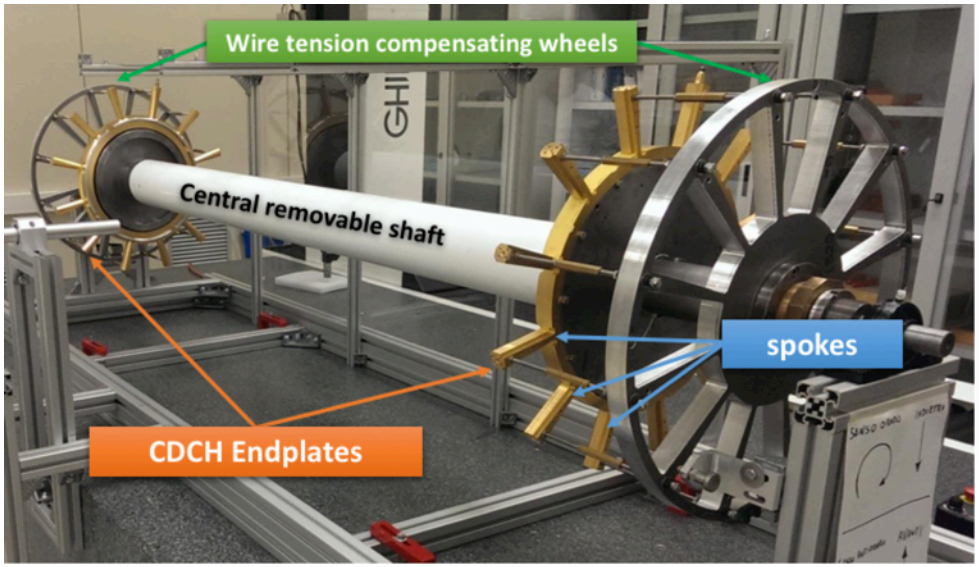

The wire net created by the combination of + and – orientation generates a more uniform equipotential plane



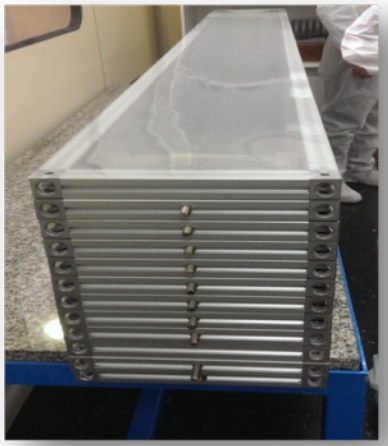

**1920** sense wires: *W(Au) 20 μm*
**7680** field wires: *Al(Ag) 40 μm*
**2688** guard wires: *Al(Ag) 50 μm*
**12288 wires in total**
**(~ 12 wires/cm²)**

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

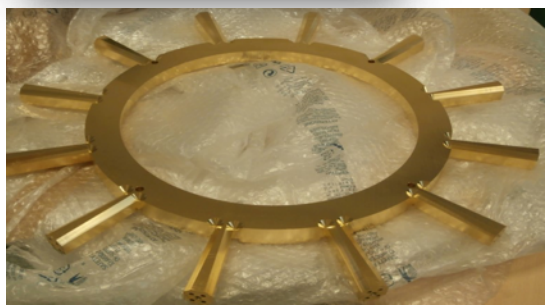
# Wire Support




support structure



wire frames



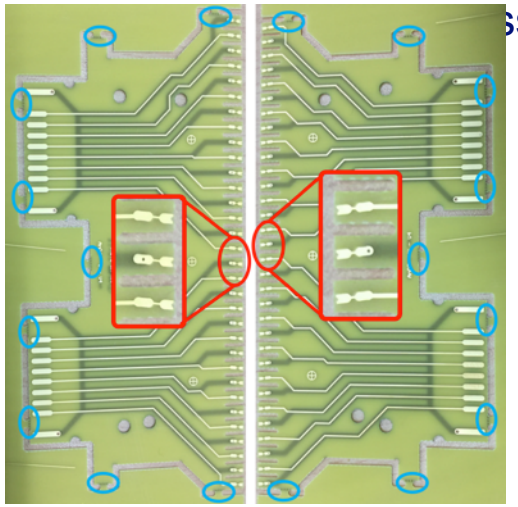
End-plates numerically machined from solid Al and Au plated

# The wire PCB's

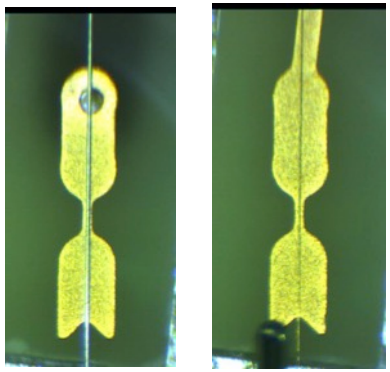
The wire PCBs are made of 400 µm thick FR4 board with 35 µm gold plated copper traces.

All wire pads are oriented along the stereo angle

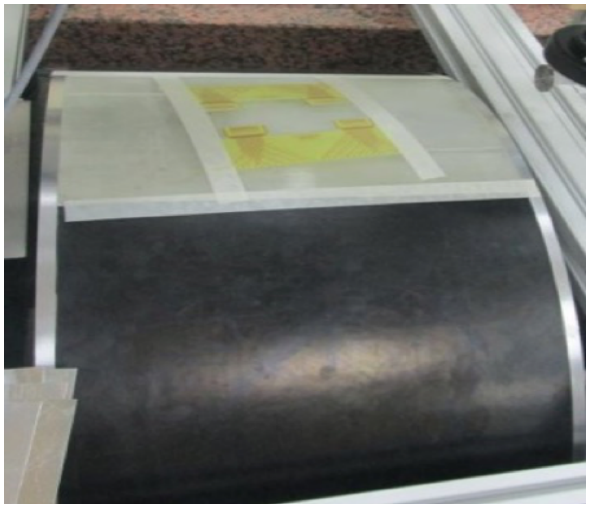
US and DS wire PCB are coupled together in a single FR4 board for a precise alignment during the wiring procedure



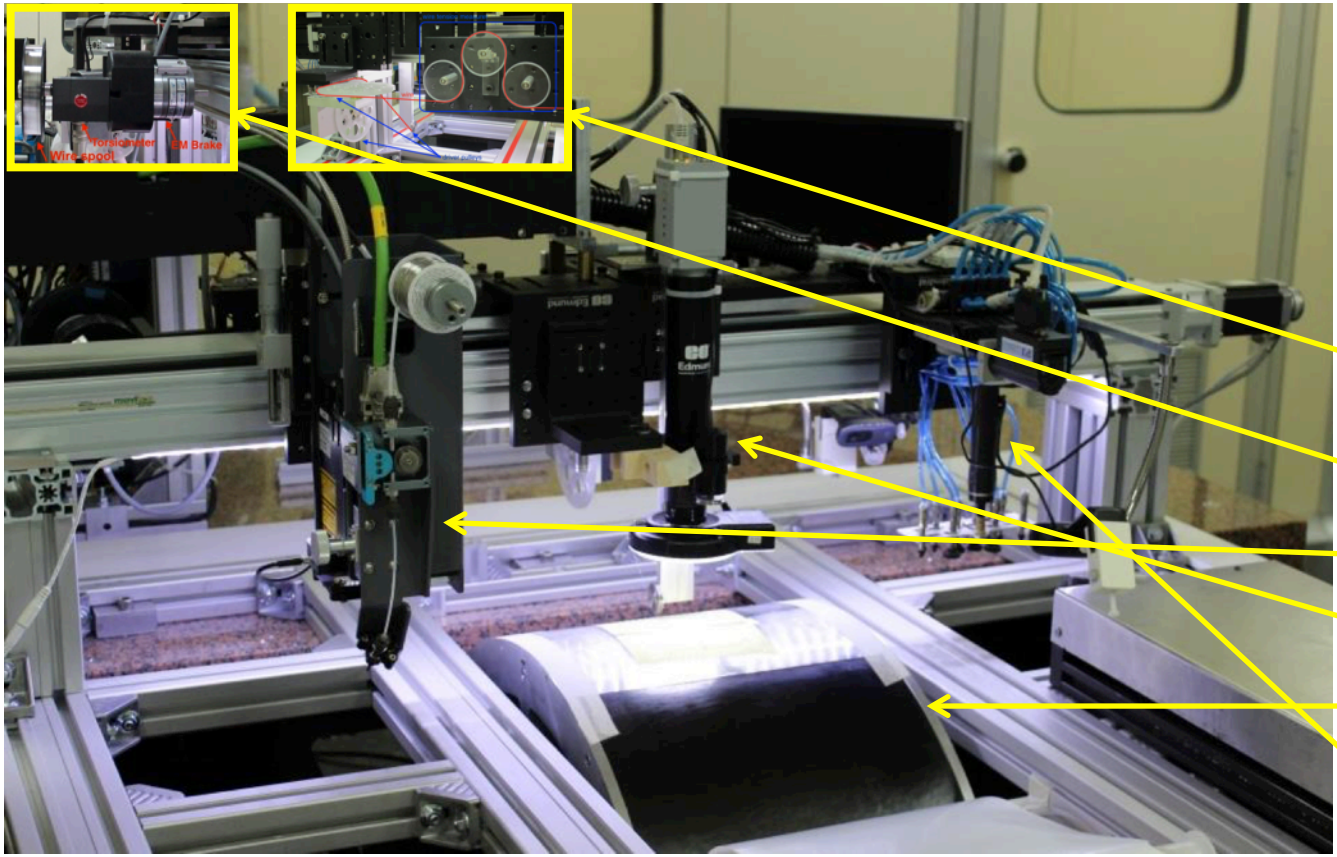
ss than its diameter




**winding drum**



# The wiring robot




**accomplishes wire**:

- positioning,
- tensioning,
- soldering,
- layer extraction

wire spool
e.m. brake
torquemeter

wire tension measurement

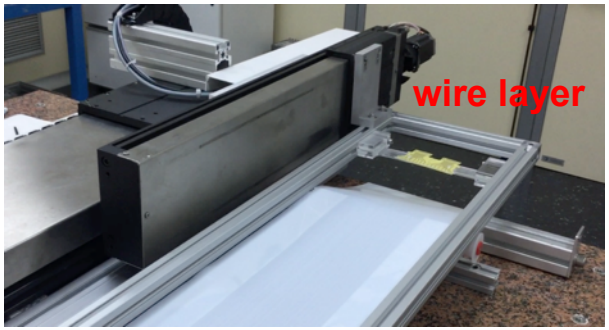
IR laser soldering

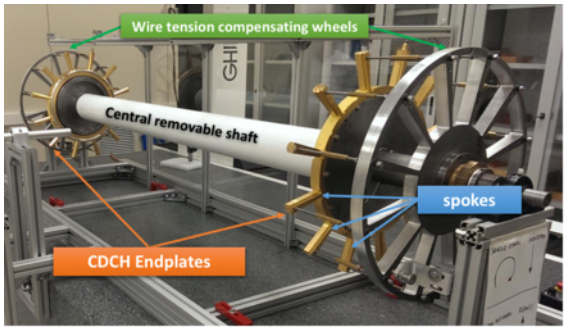
wire positioning camera

winding drum

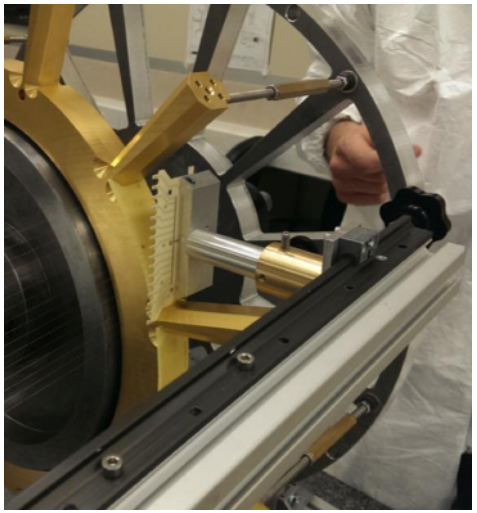
wire layer extraction system

# Stacking the wire layers



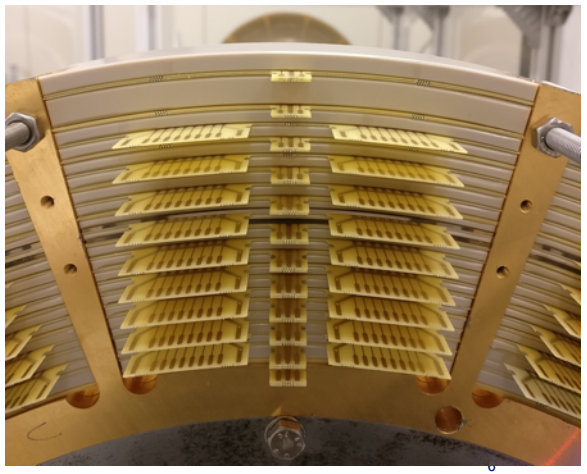




During the assembly phase, the endplates are placed at a shorter distance than nominal to avoid stressing the wire



The multi-wire layer is placed next to the end plates for the engagement procedure and stretched between two spokes on one side and the corresponding ones on the other side.

This procedure is repeated for each of the 12 sectors.
After completing a layer, a survey is performed on the radial position.
Spacers, to separate the adjacent layers, are built accordingly and are pressed and glued in position.
The multi-wire layer placing procedure is repeated for all 10 layers



# A short history of wire problems

A short history of wire related problems

1. March 2016 (wiring started Nov. 2015)
   many field wires mounted on the chamber, found broken due to unsuspected extreme sensitivity to humidity. Detailed analysis revealed a corrosion pattern.
   September 2016 restarted wiring and assembly from scratch
2. October 2016 human error caused a few wire breakings.
   Procedures revised and wiring and assembly resumed in December 2016.
3. July/August 2017 14 wires found broken inside the chamber. Removed. Improved environmental conditions and air dryness. Assembly resumed in September 2017. Decided to limit wiring to 9 layers with a slightly de-tensioned (-1 mm) chamber to avoid excessive stress to weak wires.
4. Wiring and assembly completed in December 2017.
5. October 2018, found a broken cathode during operation. Again due to earlier initiated corrosion.
6. After partial engineering run in Nov. 2018, extract chamber from COBRA. Chamber reopened and extra-tensioned (+1.2 mm) to eliminate wires with corrosion process in progress. 49 more wires eliminated. All showed clear signs of corrosion. Chamber kept under extremely low humidity for the whole summer at extra-tension. No sign of further damage ever since. Tension partly released. Chamber closed.

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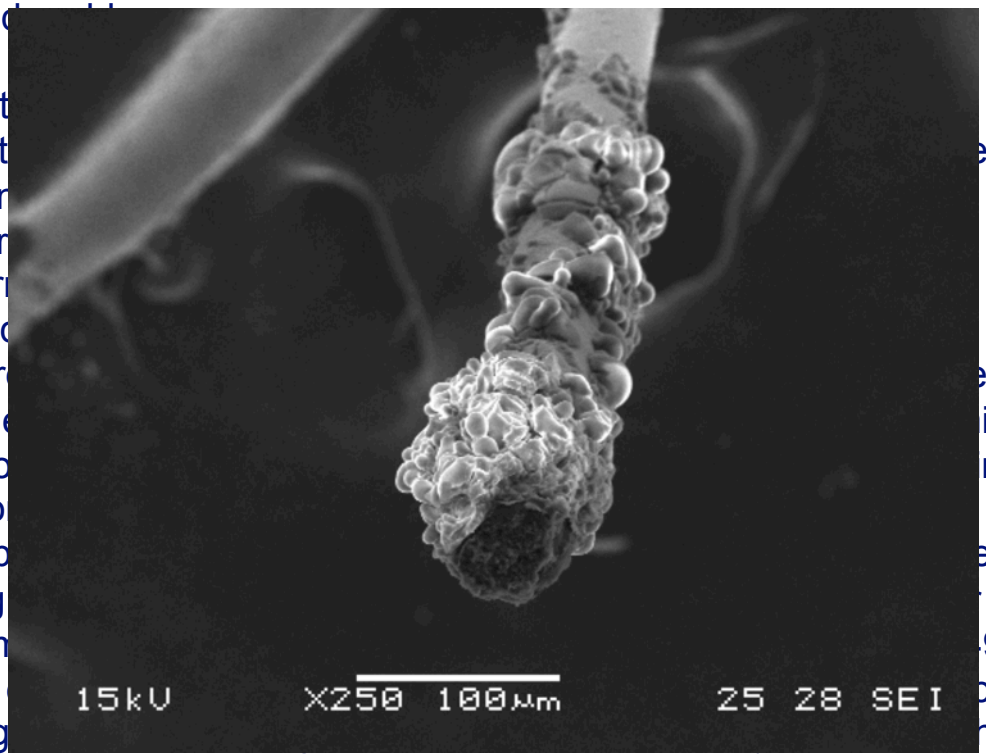

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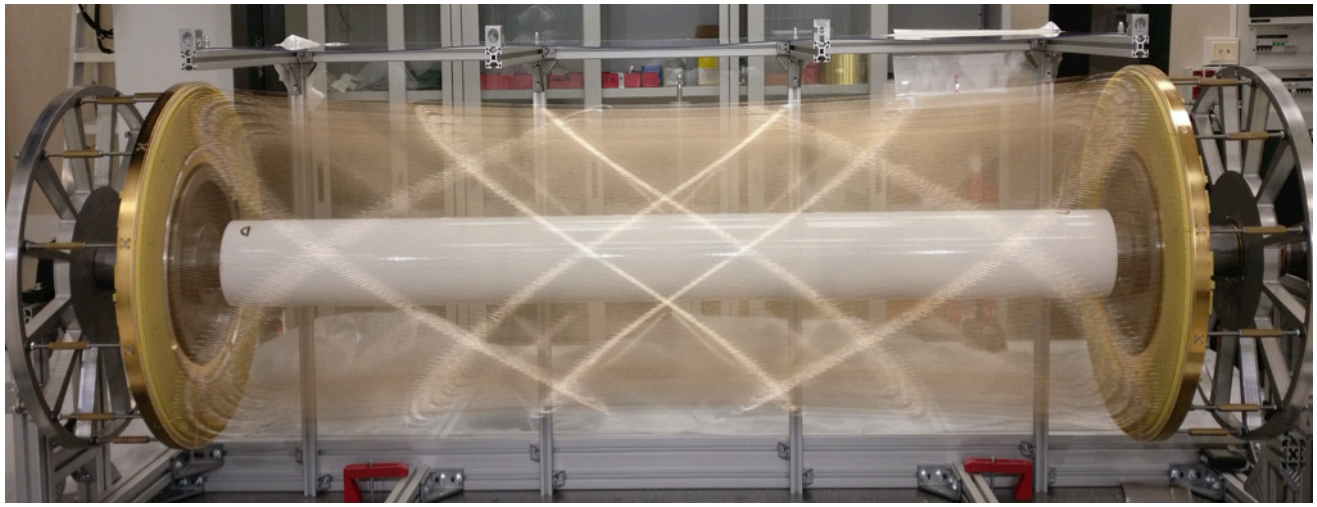
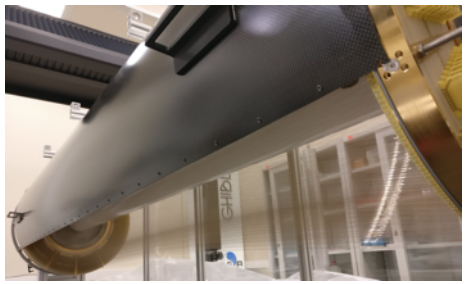
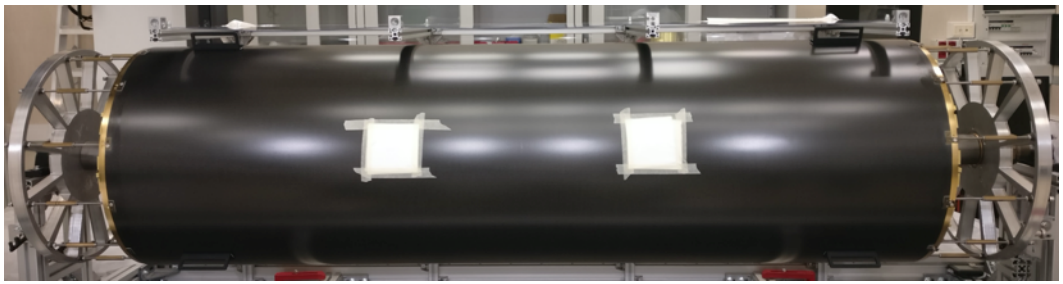
# Wiring completed

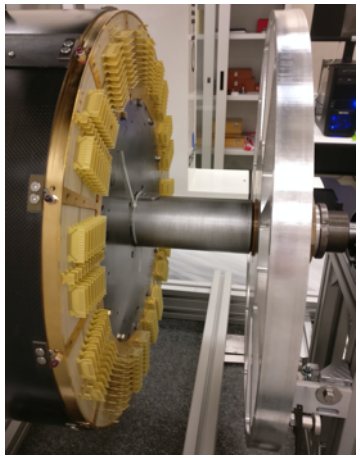


Closing with two half cylinder carbon fiber shells

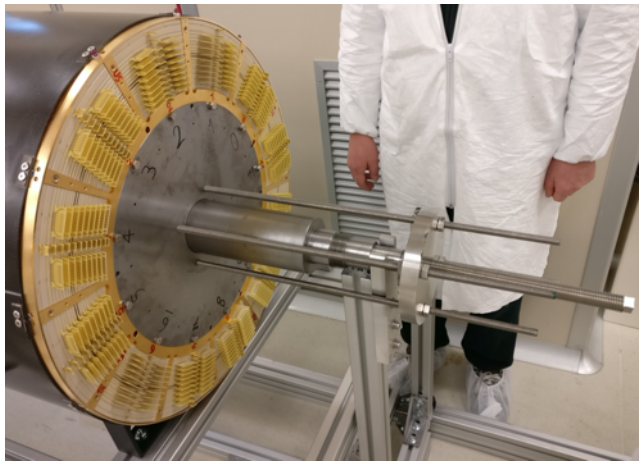




# Measured geometrical tolerances

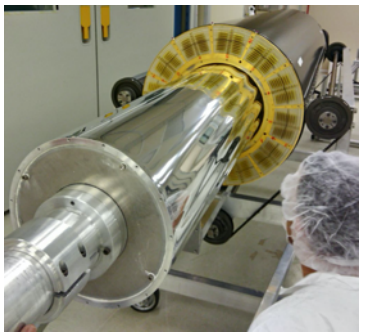


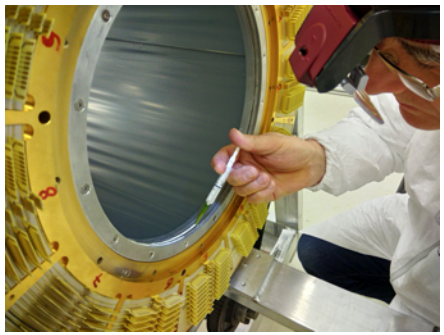
**End-flanges removal**: turnbuckles are removed and the chamber is disengaged from the support structure on the granite table used for wiring



**Central shaft removal**: turnbuckles are removed and the chamber is disengaged from the support structure on the granite table used for wiring

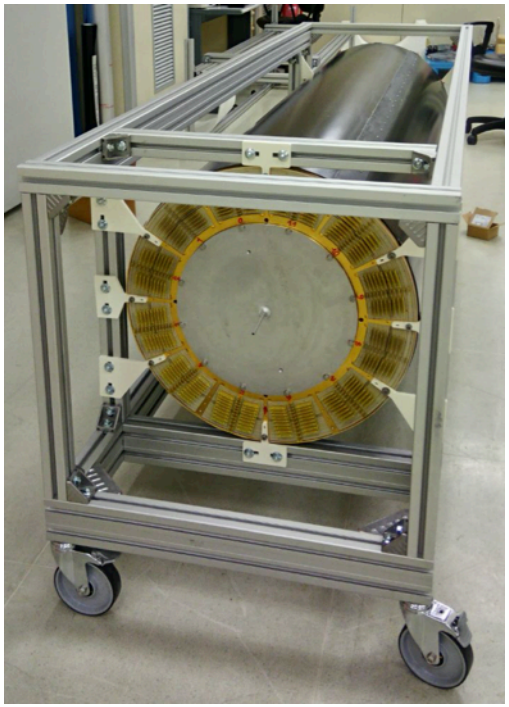
Innner 20 μm mylar foil inserted

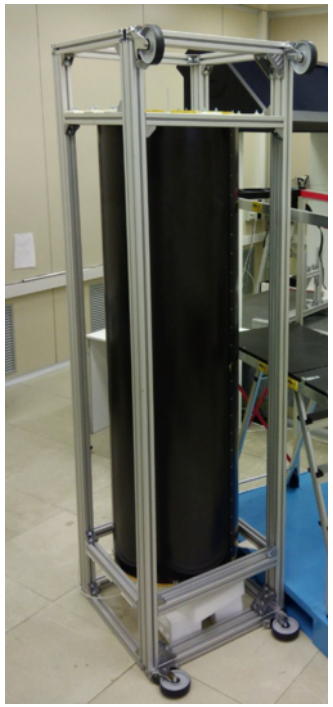




**Distance** between the average endplate planes: **1992.840 mm** (**+4.840 mm**)
Endplates **planarity**: **40 μm** (**US**), **30 μm** (**DS**)
**Parallelism** between the average endplate planes: **80 μm**
Relative **azimuthal tilt** of endplates: **0.001°**
Radial deformation of endplates:
**60 μm** (**US**), **55 μm** (**DS**)

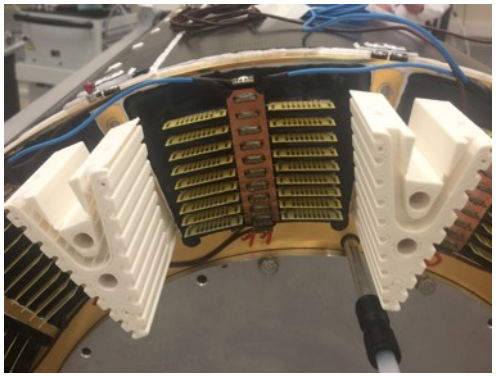
# Gas sealing and ground connection





ThreeBond

Stycast



All the 40/50 µm cathode wires are grounded together

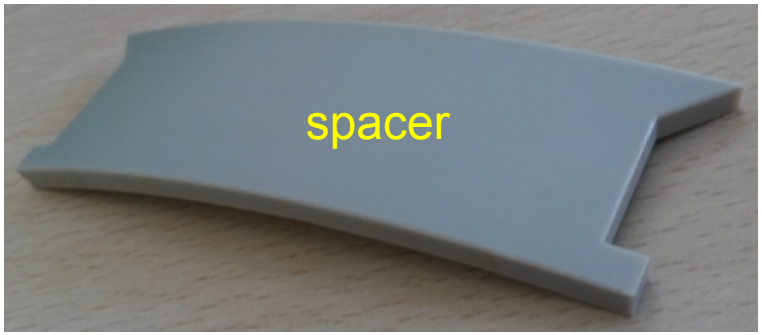
all the inner guard wires (HV1)
all the outer guard wires (HV2)
are connected together

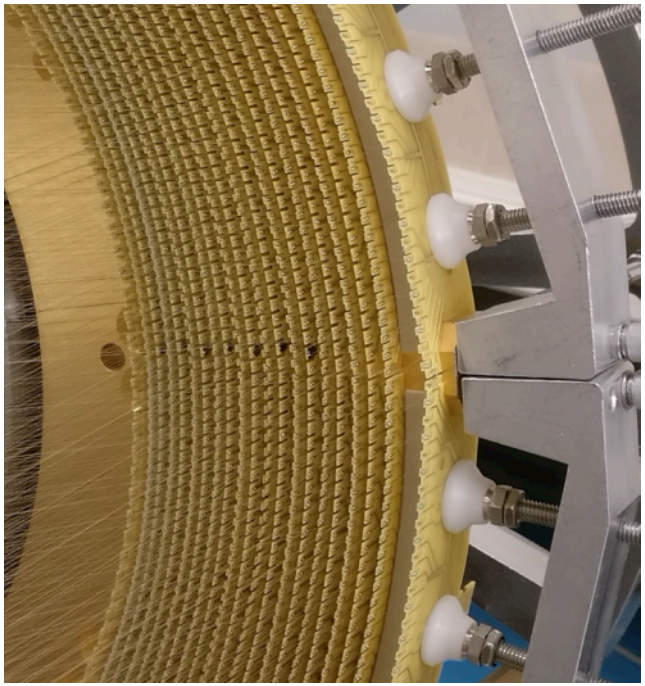
FE cards holders and tube cooler holders

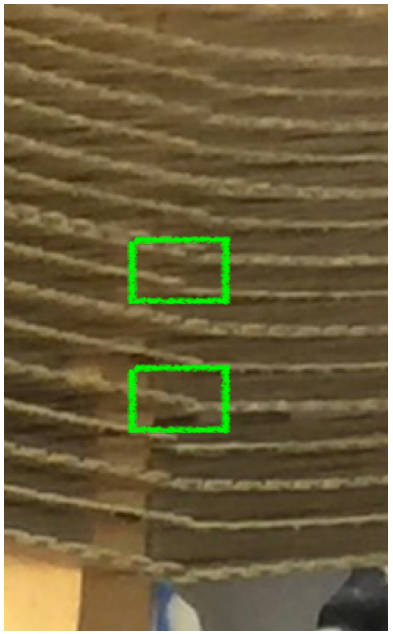
# A weak point

Discovered a critical aspect responsible for a weakness of some drift cells between two adjacent sectors

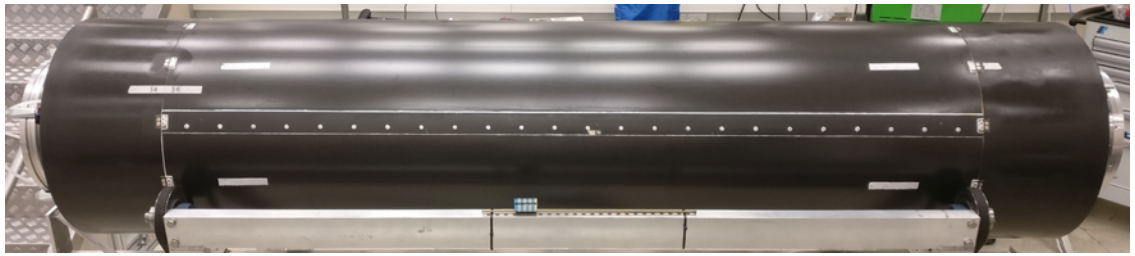
Deformations O(≈100 μm) have been spotted, sufficient to cause this problem



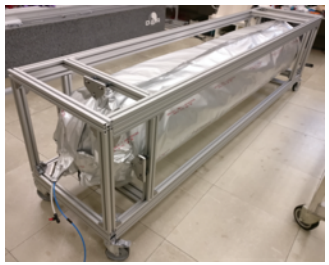





# Packing and shipping to PSI

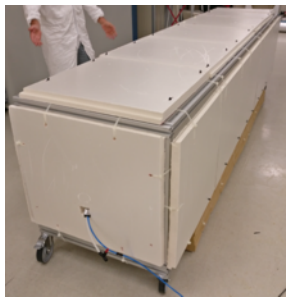


mounting end-plates extensions
wrapping in controlled atmosphere



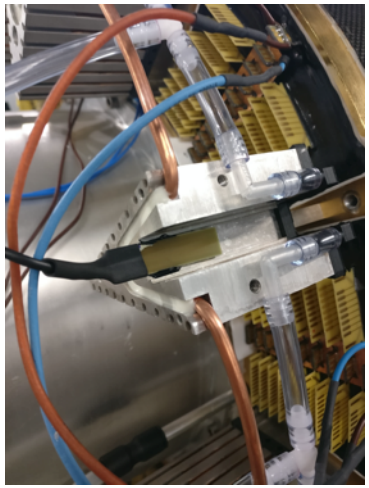
mounting in shipping structure

second wrapping

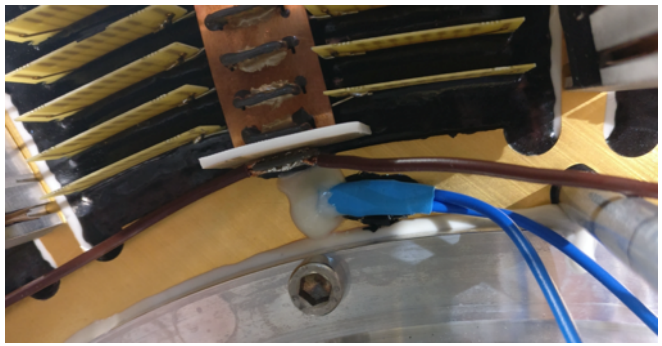


thermal shield

# End-plates dressing: cooling and sensors



The **water cooling** system to cool the electronics and a **dry air system** to keep the humidity low inside the extension



24 temperature sensors directly connected to the FE holders

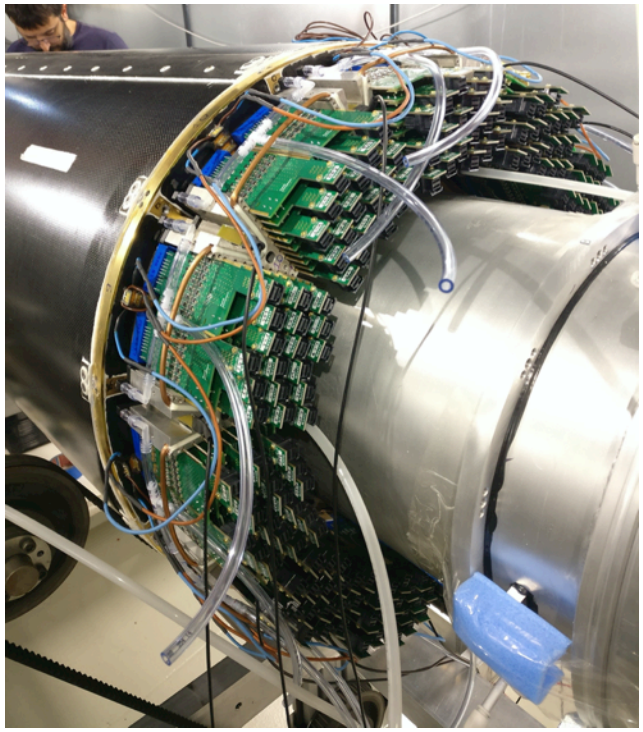
4 humidity sensors

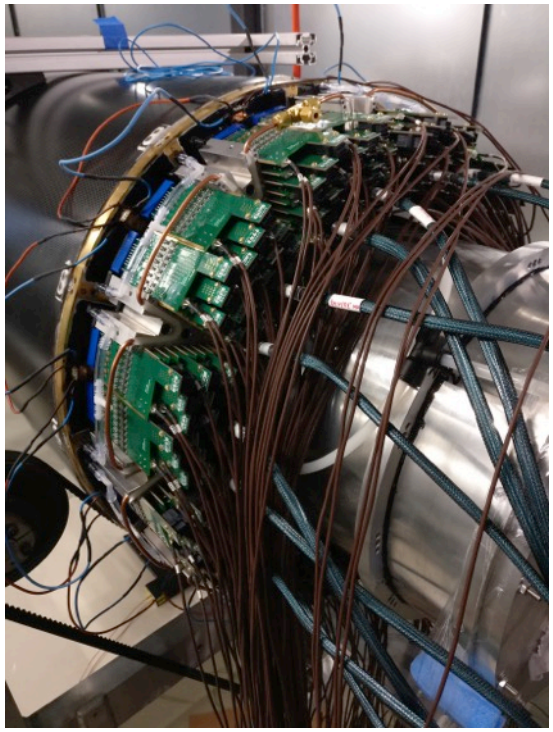
4 PT1000 (cooling tubes and endplates)

have been mounted to control **the temperature and humidity inside the extensions**

Also sensors to measure the gas inlet temperature

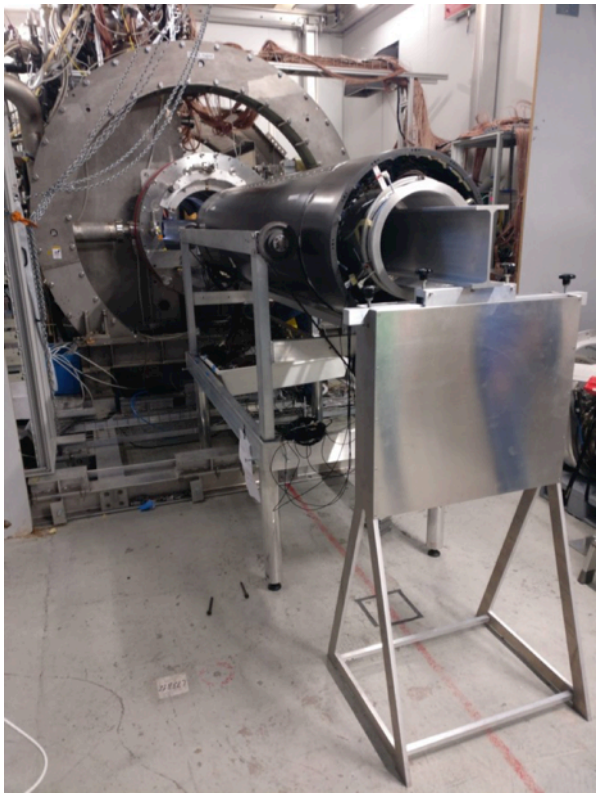
# End-plates dressing: front end cards





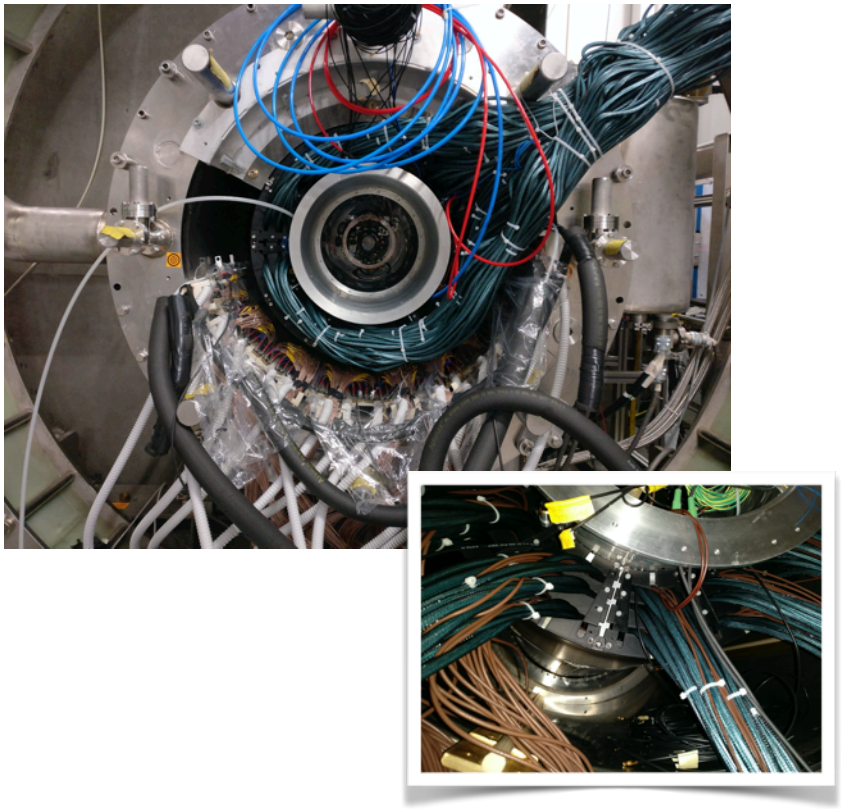
Mount all DS and US FE cards (532)

# Insertion in COBRA magnet

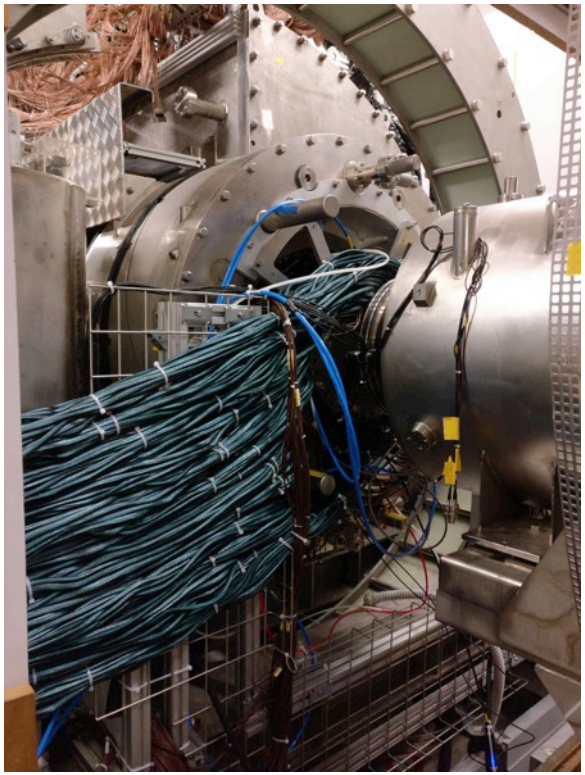


# Final cabling

US



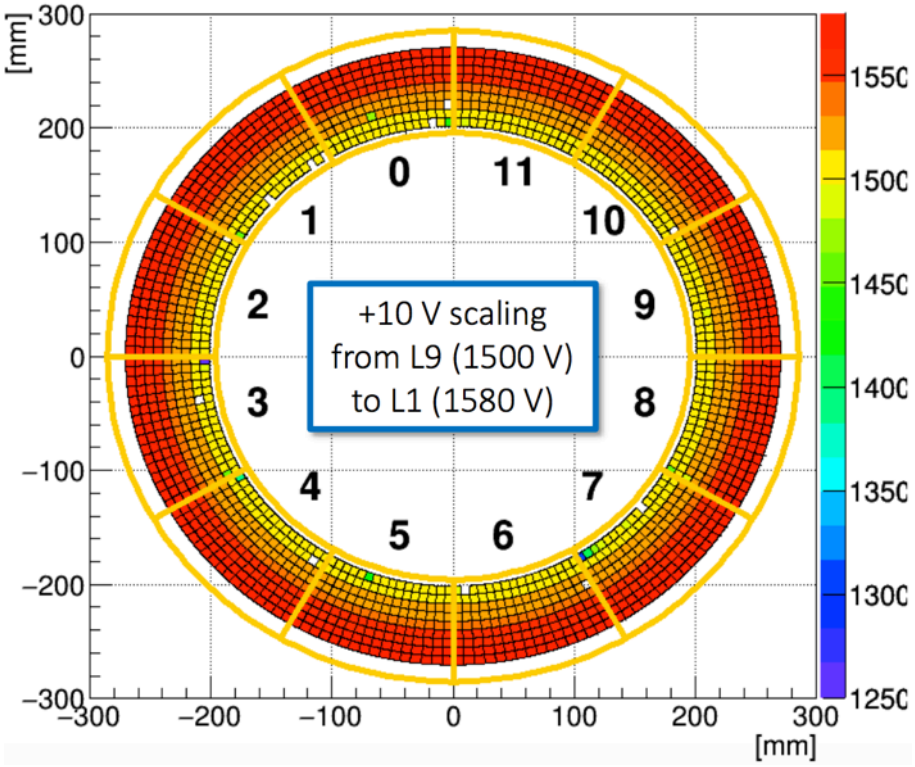




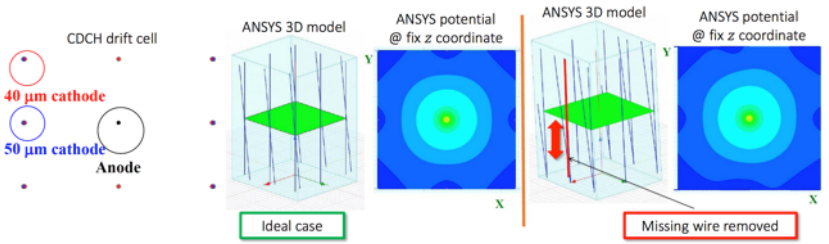
DS

# Commissioning

FINAL LENGTH @ +5.6 mm CONFIRMED




## Missing wires effect




- CDCH has a mesh of criss-crossing cathode wires between anode planes
- Used Garfield and ANSYS to simulate the electric field in a $6 \times 6\ \mathbf{mm^2}$ representative drift cell + $B_z = 1.26\ \mathbf{T}$
- The aim is to study the effect of a missing wire on isochrones and so on positron recostruction

- The effect of the missing cells has been simulated in high statistic MC runs
  - 100k signal events, and 1000k background
  - removed 21 wires on L9 and 10 wires on L8)
- The number of missing cells is so far only 0.8%

**missing cell effect**

Positron efficiency in cascade

| | ε(Acceptance) % | ε(DCH fake) % | ε(prop.cut) % | ε(tail cuts) % | ε(matching) % | ε(SPX fake) % | ε (time cut) % ±0.2 |
|---|---|---|---|---|---|---|---|
| standard | 91.3 | 87.6 | 81.5 | 67.1 | 65.4 | 65.4 | 63.4 |
| usable wires | 91.3 | 87.4 | 81.1 | 66.3 | 64.6 | 64.5 | 62.6 |

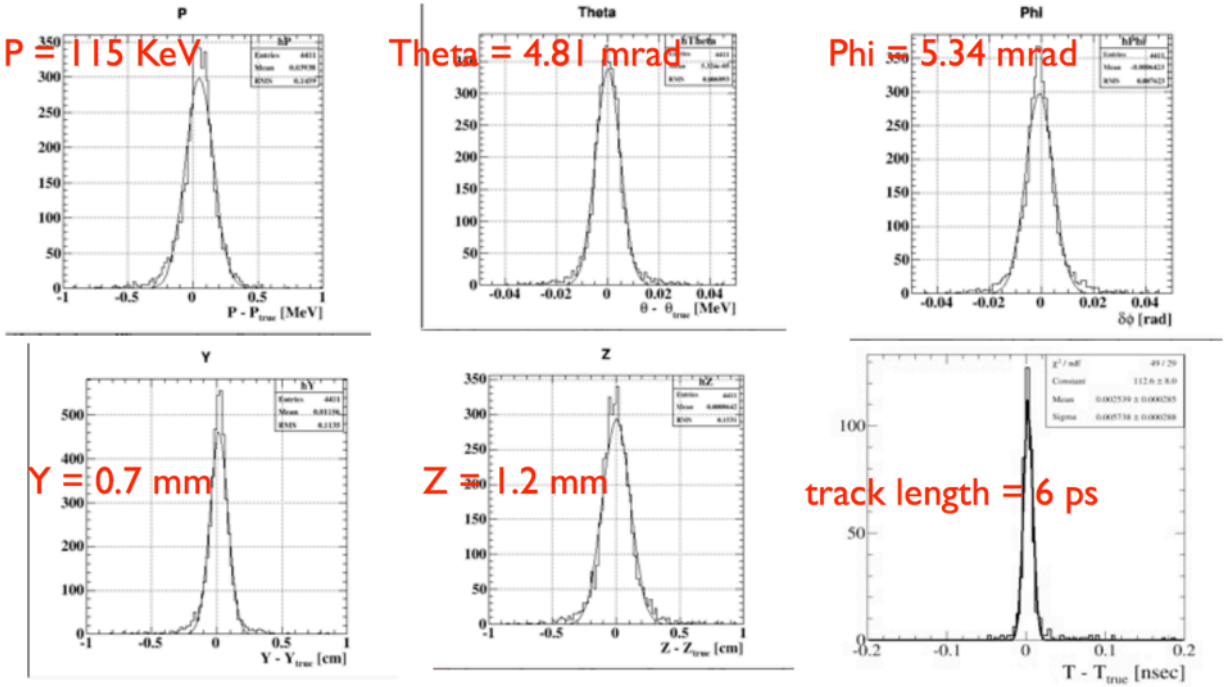
Resolutions

| | σθ/RMSθ (mrad) ±0.03 | σφ /RMSφ (mrad) ±0.03 | σp/RMSp (keV) ±0.4 | σz/RMSz (mm) ±0.006 | σy/RMSy (mm) ±0.006 |
|---|---|---|---|---|---|
| standard | 6.217/6.876 | 5.766 /6.514 | 87.5/103.6 | 1.379/1.590 | 0.728/0.828 |
| usable wires | 6.221/6.879 +0.04% | 5.822/6.585 +1% | 88.0/103.9 +0.3% | 1.384/1.601 +0.7% | 0.736/0.837 +1% |

**Marginal effect due to the missing cells**

# Expected Performance

Z = 90 cm  Impact parameter smeared **120 μm**




88.5% of events with SPX hit are tracked
86.1% of them, are also SPX-matched

# Expected Performance

| | MEG drift chamber | | MEG2 drift chamber | |
|---|---|---|---|---|
| **Single hit resolution** | | | | |
| • $\sigma_R$ (mm) | .250 (core) | .300 (RMS) | .100 (core) | .130 (RMS) |
| • $\sigma_Z$ (mm) | .700 (core) | 1000 (RMS) | .700 (core) | .900 (RMS) |
| **Track resolution** | | | | |
| • $\sigma$ (p) | 310 KeV (core) | | 115 KeV (core) | |
| • $\sigma(\phi)$ | 7. mrad | (at $\phi$ = 0, 10 mrad aver.) | 5.3 mrad | |
| • $\sigma(\theta)$ | 11. mrad | | 4.8 mrad | |
| • $\sigma$(Y) | 1.3 mm | | 1.2 mm | |
| • $\sigma$(Z) | 3.0 mm | | 0.7 mm | |
| **TC – DC reconstruction** | | | | |
| • DC-TC matching eff. | 45 % | | 88% | |