Studio dell'invecchiamento e delle prestazioni di prototipi di camere a deriva per l'upgrade dell'esperimento MEG

Marco Venturini

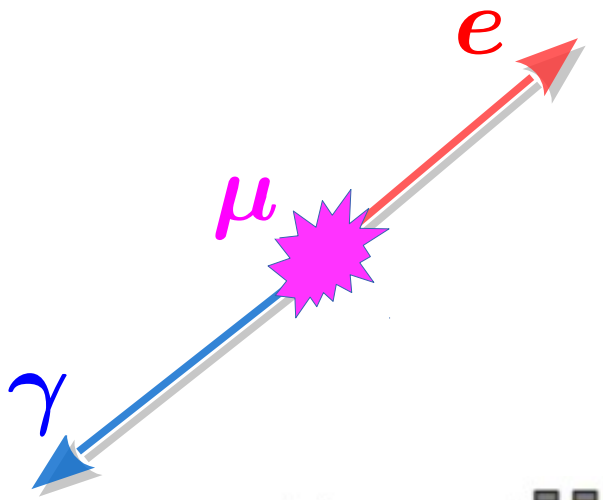
Scuola Normale Superiore,

INFN Sezione di Pisa

IFAE 2014, 10 Aprile – LNGS

The MEG experiment

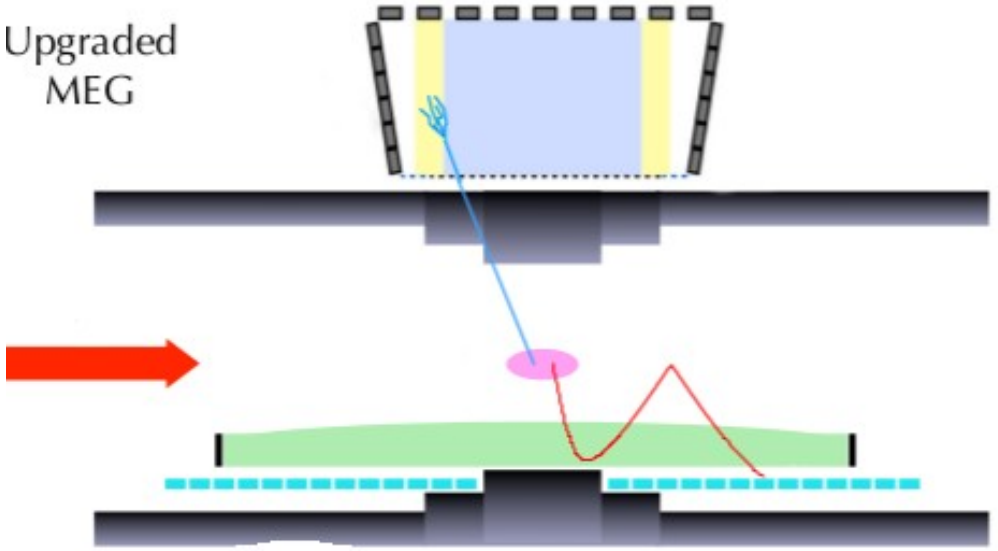
Search for the Lepton-Flavour-Violating decay $\mu^+ \to e^+\gamma$



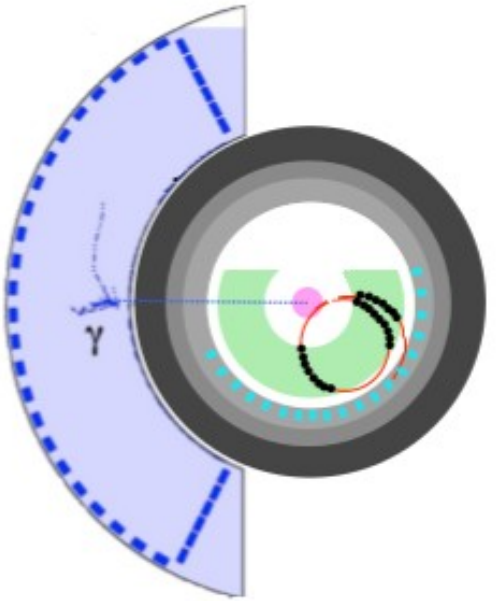
Clear kinematic signature:

1) $E_\gamma = 52.83\,\mathrm{MeV}$
2) $E_e = 52.83\,\mathrm{MeV}$
3) $\delta\vartheta_{e\gamma} = 180^\circ$
4) $\delta t_{e\gamma} = 0$

High-performance positron tracking is mandatory

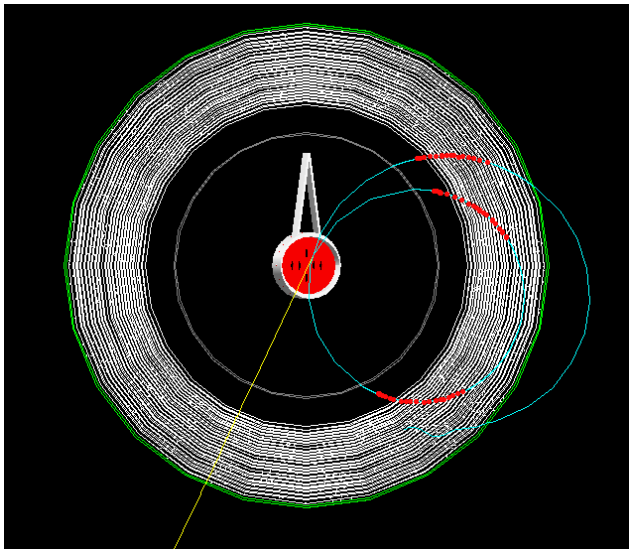


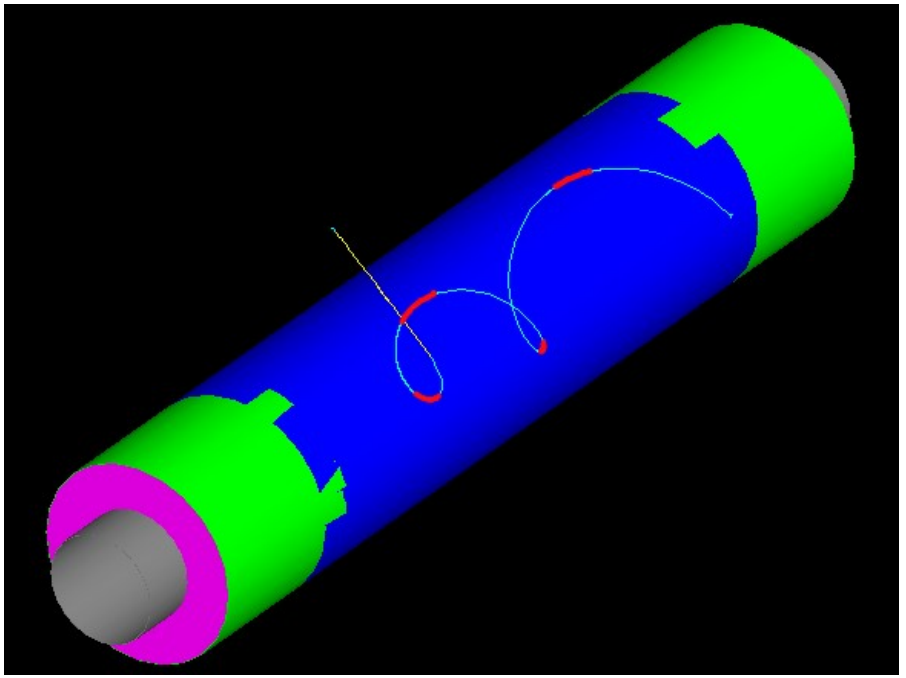
Baldini et al., ArXiv e-prints (2013), 1301.7225.

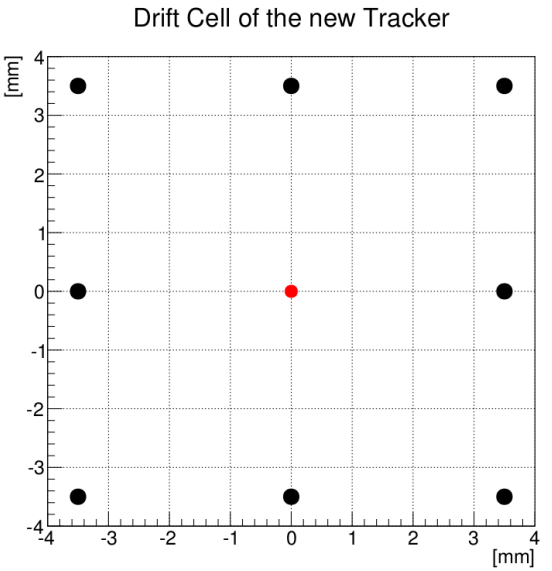


A new Drift Chamber

- Hyperbolic Drift chamber with stereo angles ±7°÷8°.
- 10 layers with alternating **stereo angles**.
- Drift cells with approximately squared shape 7x7 mm^2.
- **Low mass** gas mixture with helium and isobutane 85:15.

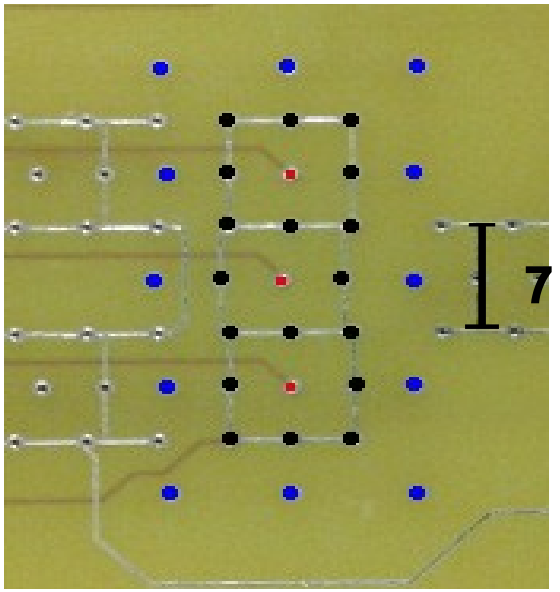


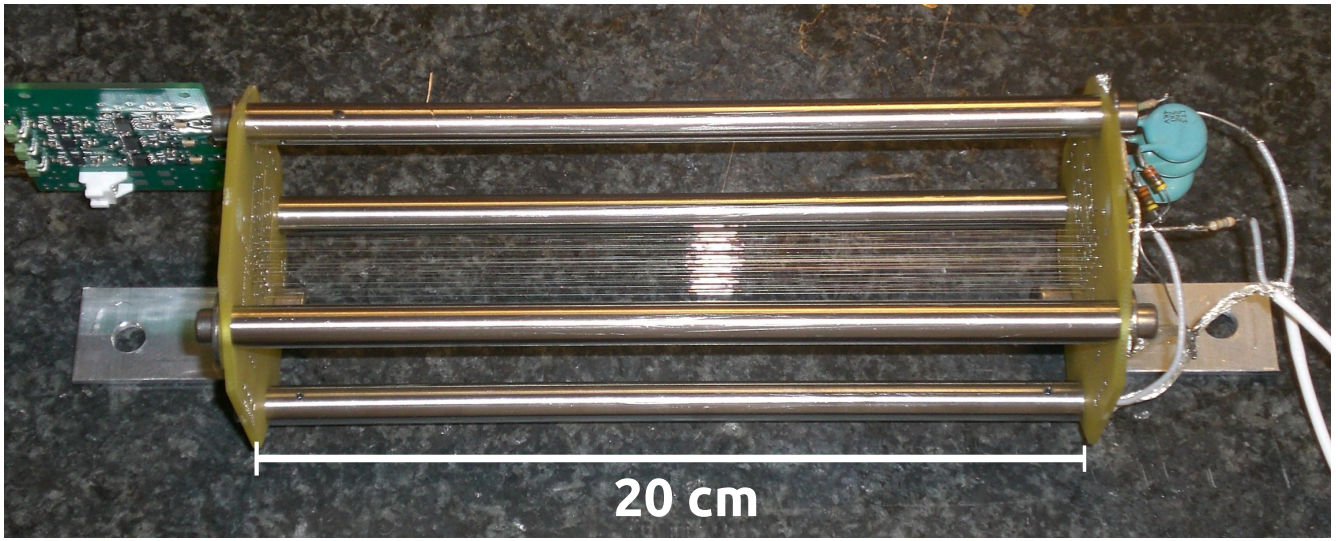




Three-cell prototype realization

- Wire configuration implemented on two **FR4** PCBs.
- 20-µm **Gold**-plated **Tungsten** anodes;
- 80-µm **Silver**-plated **Aluminum** cathode and guard wires;
- Central anode **staggered** by 500 µm;
- 4 aluminum rods stretching the wires to a length 20 cm
- Wiring performed in Pisa INFN **clean room**.



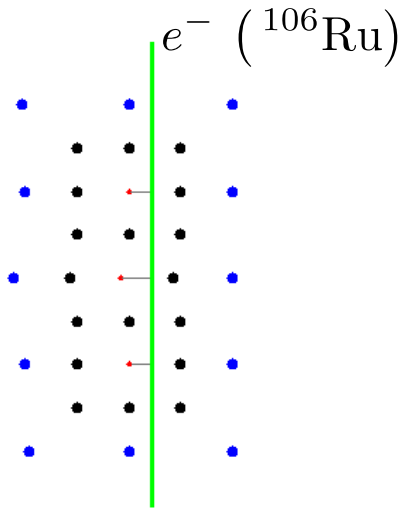


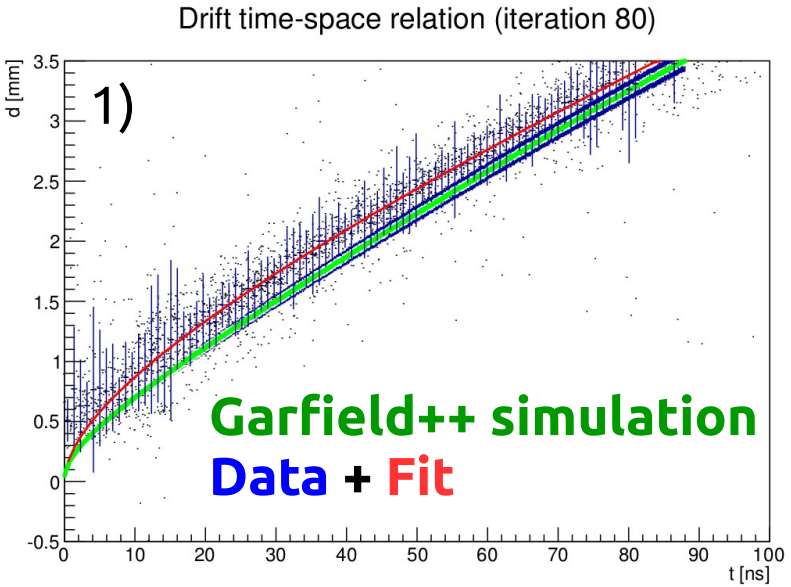
Simple tracking

Comparing drift distances measured in different cells it is possible to:

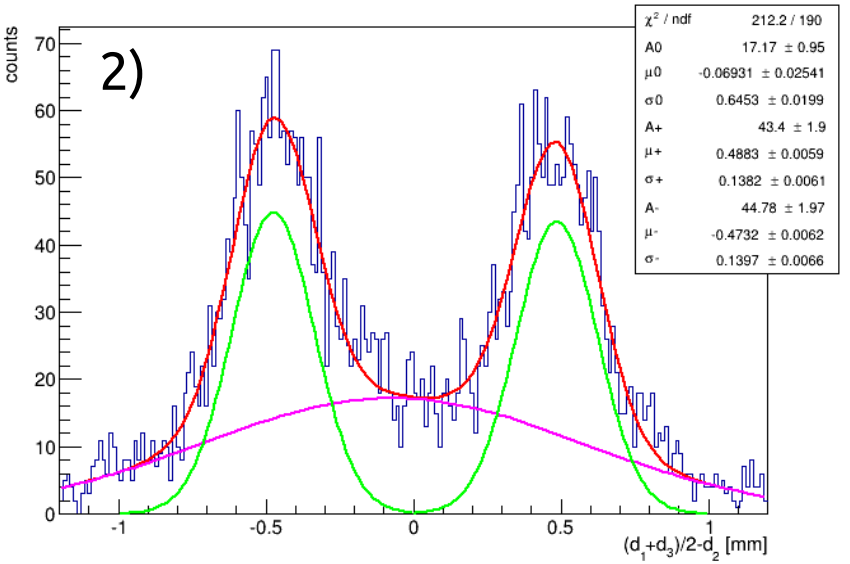
1)Determine **drift time-to-distance relations**

2)Estimate the **single-hit resolution**





$$\langle v_{\mathrm{drift}} \rangle \simeq 3.5 \mathrm{cm}/\mu\mathrm{s}$$

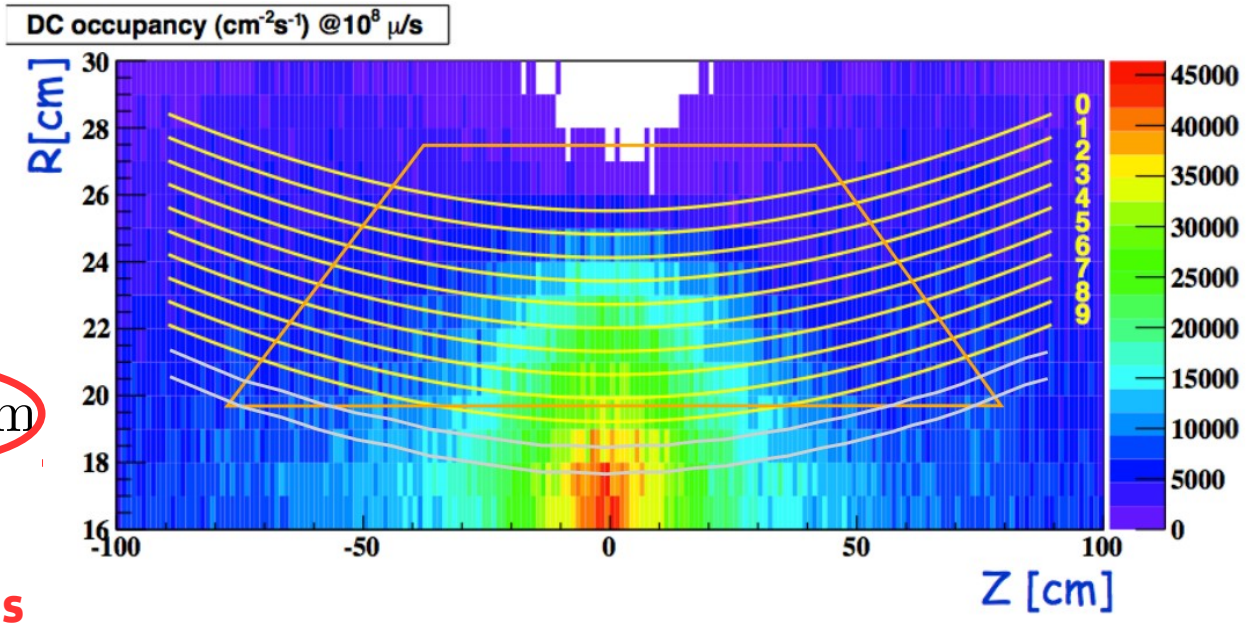


$$\sigma_d \simeq 120 \mu m$$

Ageing issues

MEG2 drift chamber will undergo a **very intense rate** of Michel positrons
⇒it is necessary to measure its robustness to ageing effects

$$I \simeq 10\,\mathrm{nA/cm} \longrightarrow \sim 0.5\ \mathrm{C/cm}$$
3 DAQ years

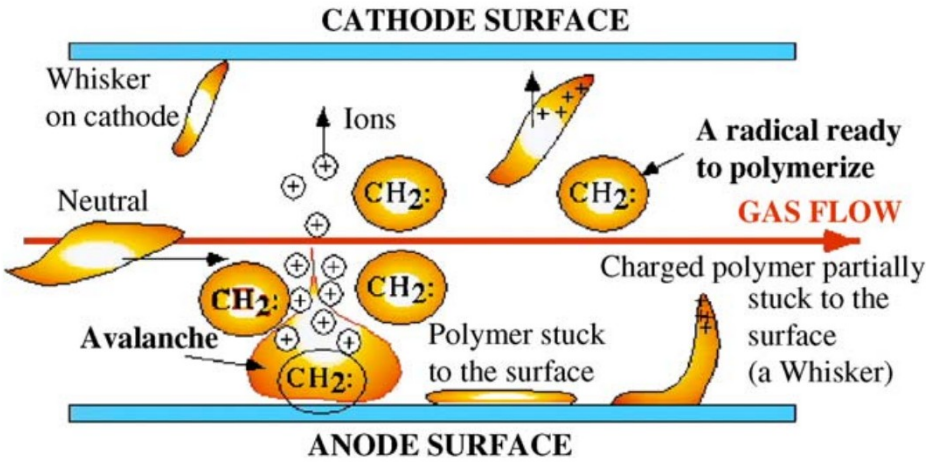


Drift chamber loss of performances

- **Gain loss**.
- Loss of response uniformity.
- **Electrical instability** and dark currents.
- Self-sustained discharges.

Ageing causes

- Gas molecules fragmentation (iC_4H_{10})
- **Free radicals** formation.
- Polymer **deposits** on wire surfaces.



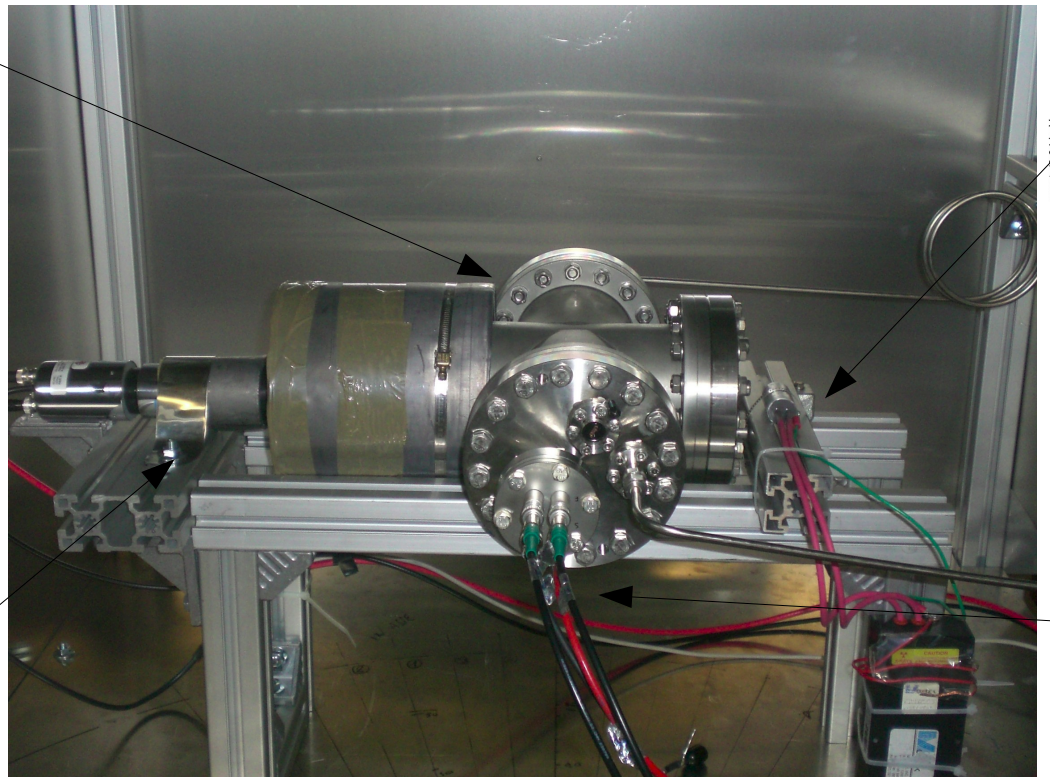
Kadyk, Nucl.Instrum.Meth., A300:436-479, 1991
Niebuhr, Nucl.Instrum.Meth., A566:118-122, 2006

Ageing tests

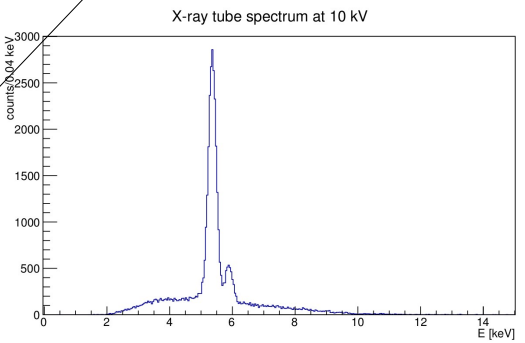
- Measurable quantity: gain loss
- **Accelerated** laboratory test with intense sources
- Gain monitored from anodic current

$$\mathcal{R} = -\frac{1}{G_0}\frac{\mathrm{d}\,G}{\mathrm{d}\,Q}\left(\frac{\%}{\mathrm{C/cm}}\right)$$

Test Chamber



X-ray tube

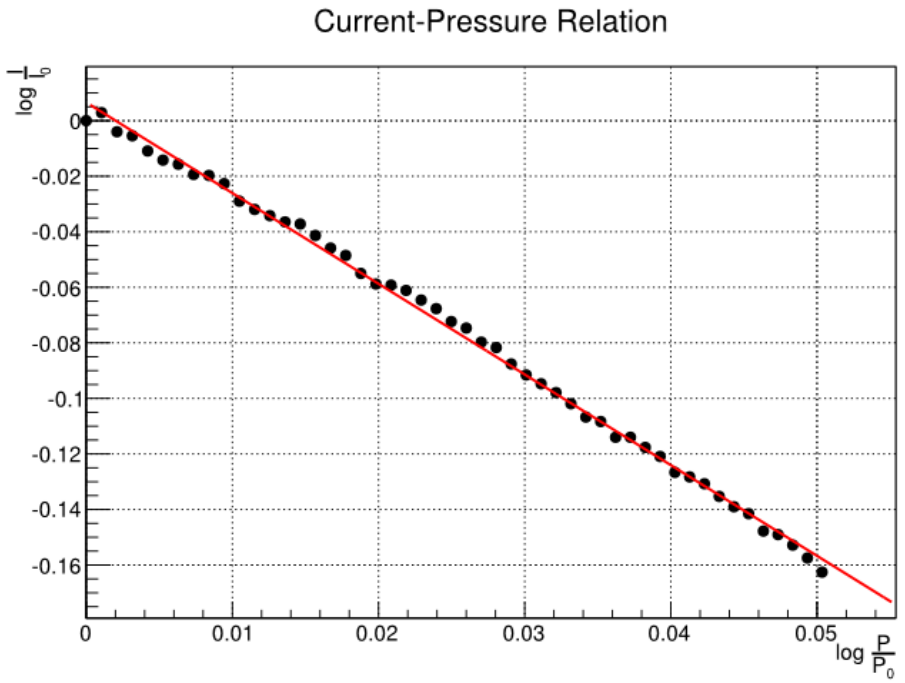


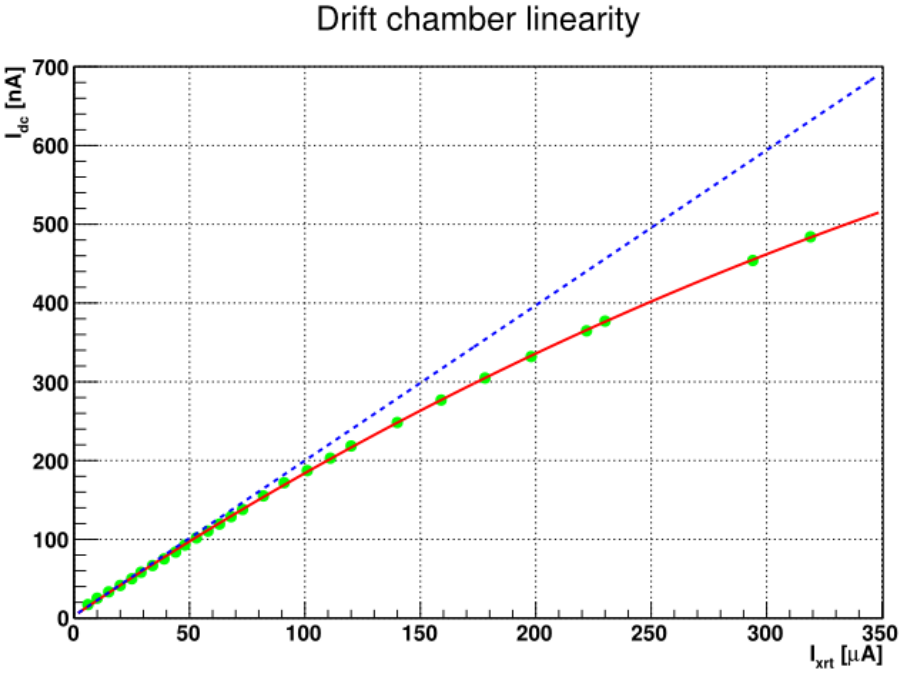
Readout to pAmmeter Keithley 2635A

X-ray monitor NaI

Preliminary measurements

Gas gain varies with temperature and saturation, potentially mimicking ageing effects





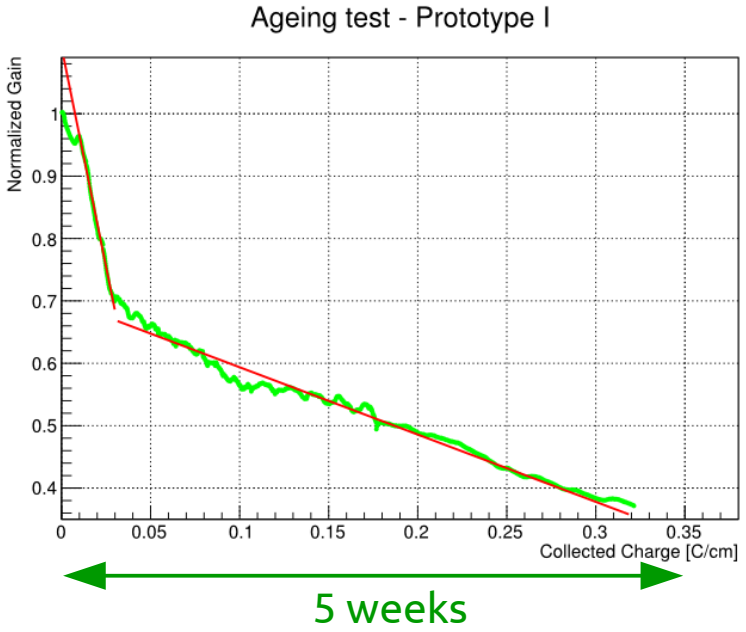
$$\left(\frac{G'}{G}\right) = \left(\frac{T'}{T}\right)^{\alpha}_{P} = \left(\frac{P'}{P}\right)^{-\alpha}_{T}$$

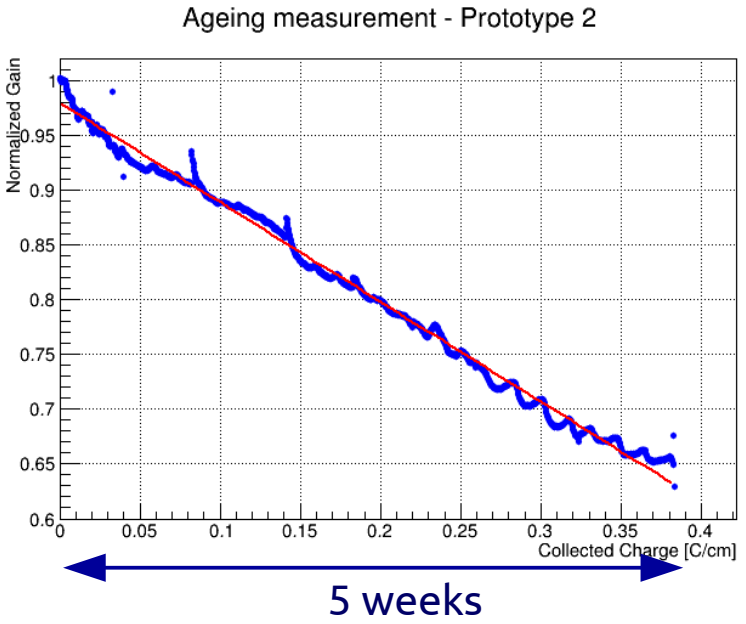
$$I = RG\, e^{-kRG}$$

Saturation can lead to a valuable underestimate of the gain loss!

Ageing test Results

Two tests were performed on single-cell prototypes.





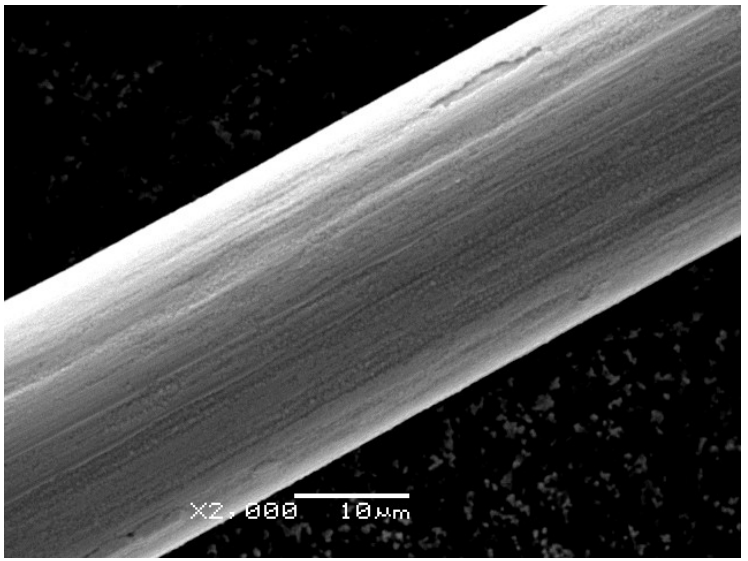
$$\mathcal{R} = \begin{cases} 1408\,\%/\,(\mathrm{C/cm}) \\ 108\,\%/\,(\mathrm{C/cm}) \end{cases}$$

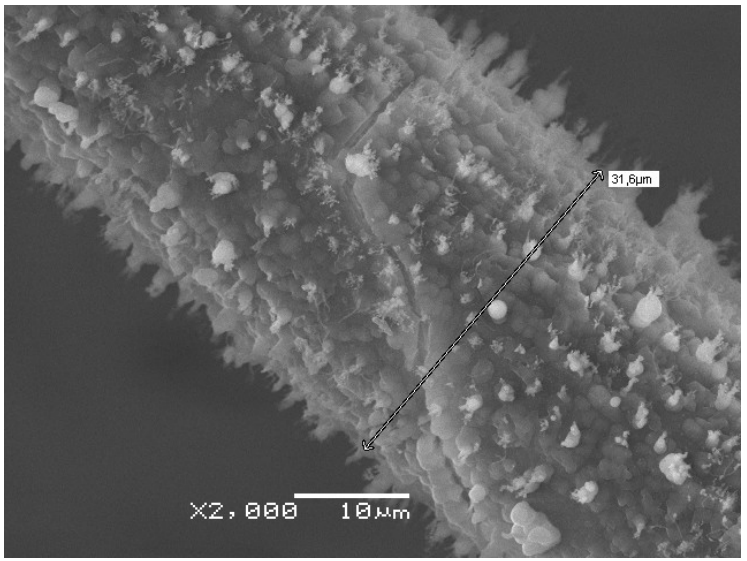
$$\mathcal{R} = 91\,\%/\,(\mathrm{C/cm})$$

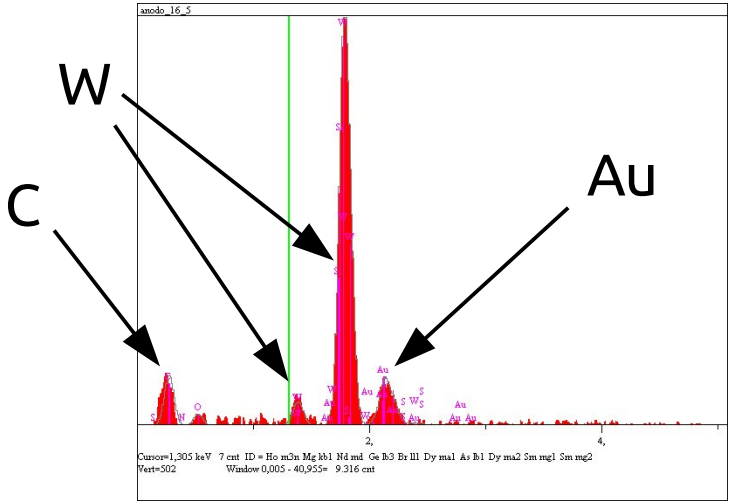
The measured ageing rates predict a **16% gain loss/year** in the hottest region of the chamber

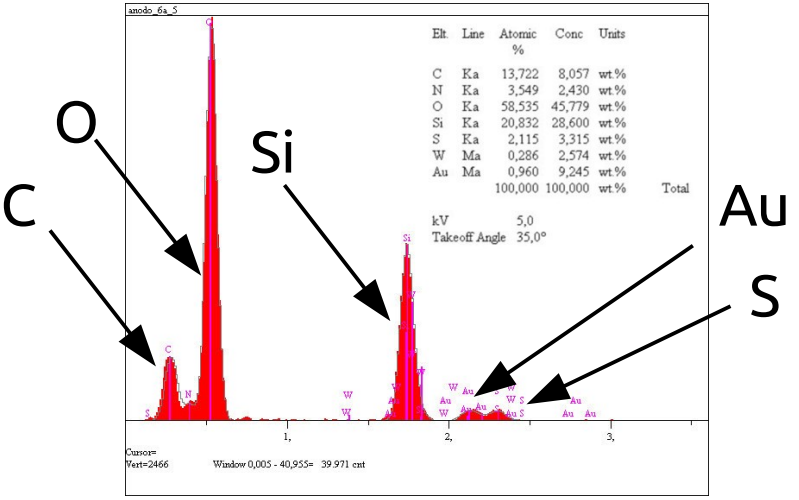
Microscopy of Aged Wires

Aged wires were analyzed at the SEM/EDX facility @ INFN Lecce

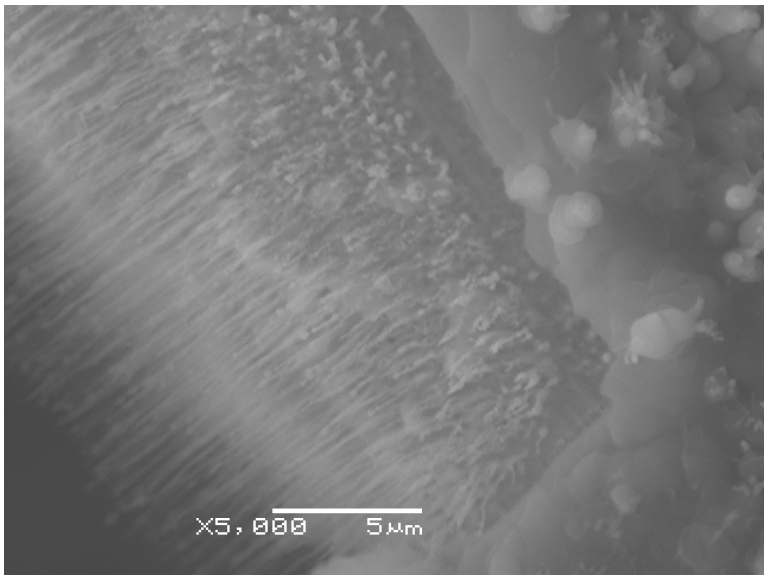


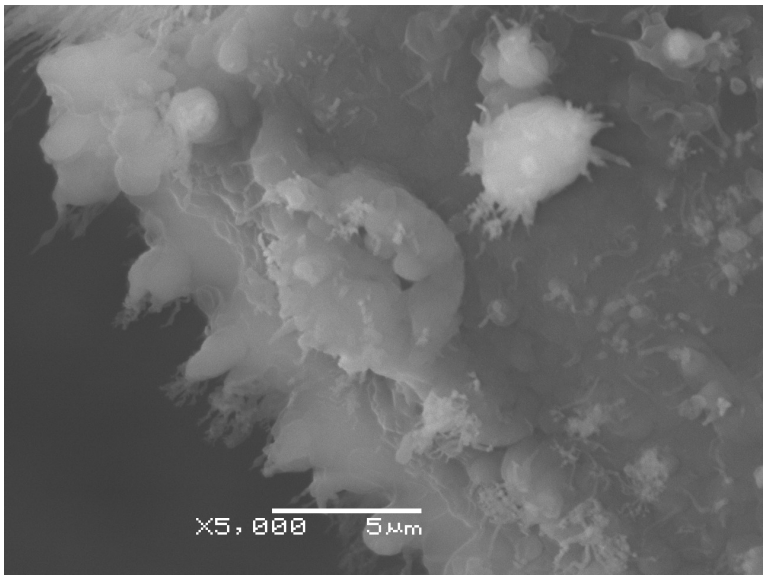


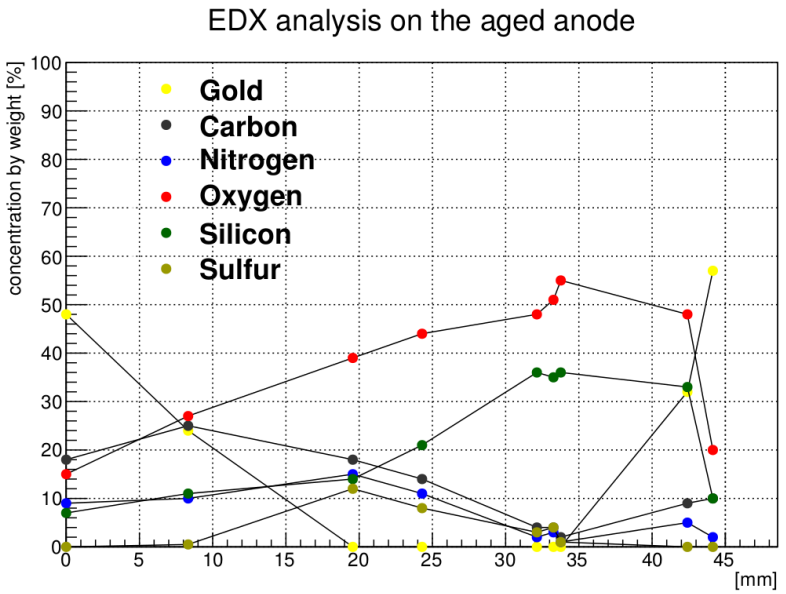




Microscopy of Aged Wires







From EDX analysis a coated area with length ~ 3 cm is clearly visible.

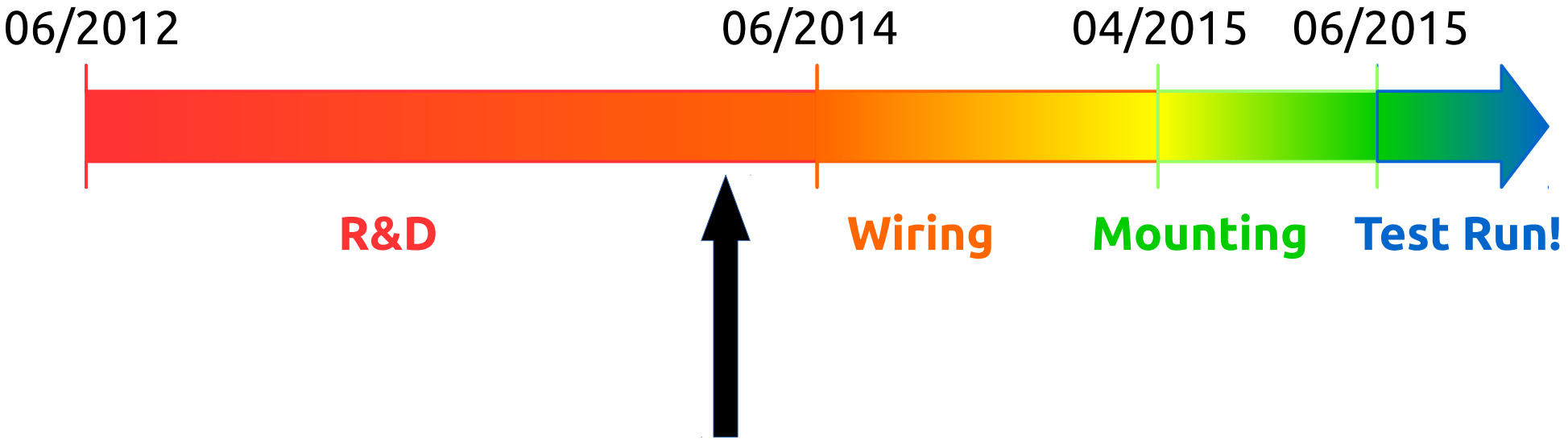
Conclusions

With the first tests performed on drift chamber prototypes we obtained

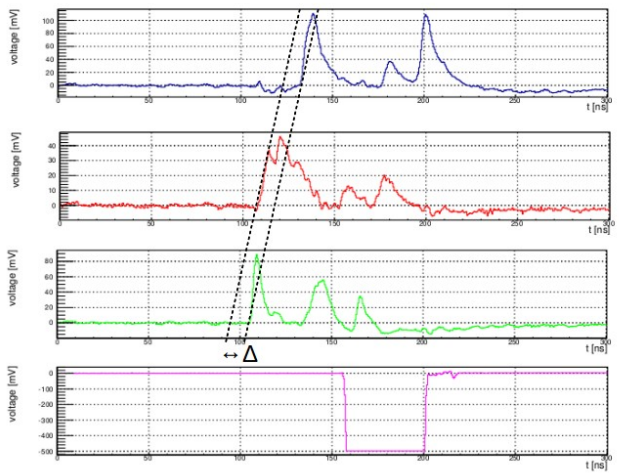
1)An estimate of the **single-hit resolution** of the drift chamber

2)An evaluation of gain loss due to **ageing** of the detector

Both results were **promising** and allowed to go on with the R&D for the final drift chamber.



Spare



	Prototype I	Prototype II
Cell parameters:		
Anode	25 m W (Au)	20 m W (Au)
Cathodes	80 m W (Au)	80 m Al (Ag)
Gas mixture	90:10 - 85:15	85:15
Gas flow rate	40 sccm - 5 sccm	15 sccm
Cell gain	$\sim 1 \times 10^4$	$\sim 3 \times 10^4$
Irradiation spot	2.5 cm - 1.8 cm	3 cm
Accelerating factor	$\times 17$ - $\times 26$	$\times 10$ - $\times 20$