

Development of μ TPC Micromegas for Directional Detection of Rare Event : D2S2 (MIMAC)

D2S2 : Directional Detection of dark matter and neutrons for
Science and Society

LPSC (Grenoble) : D. Santos, F. Malek
- M. Marton, N. Sauzet, O. Guillaudin (G. Bosson, J. Bouvier),
O. Bourrion, E. Lagorio, C. Houaro, Ilias Ourahou (PhD LPSC)

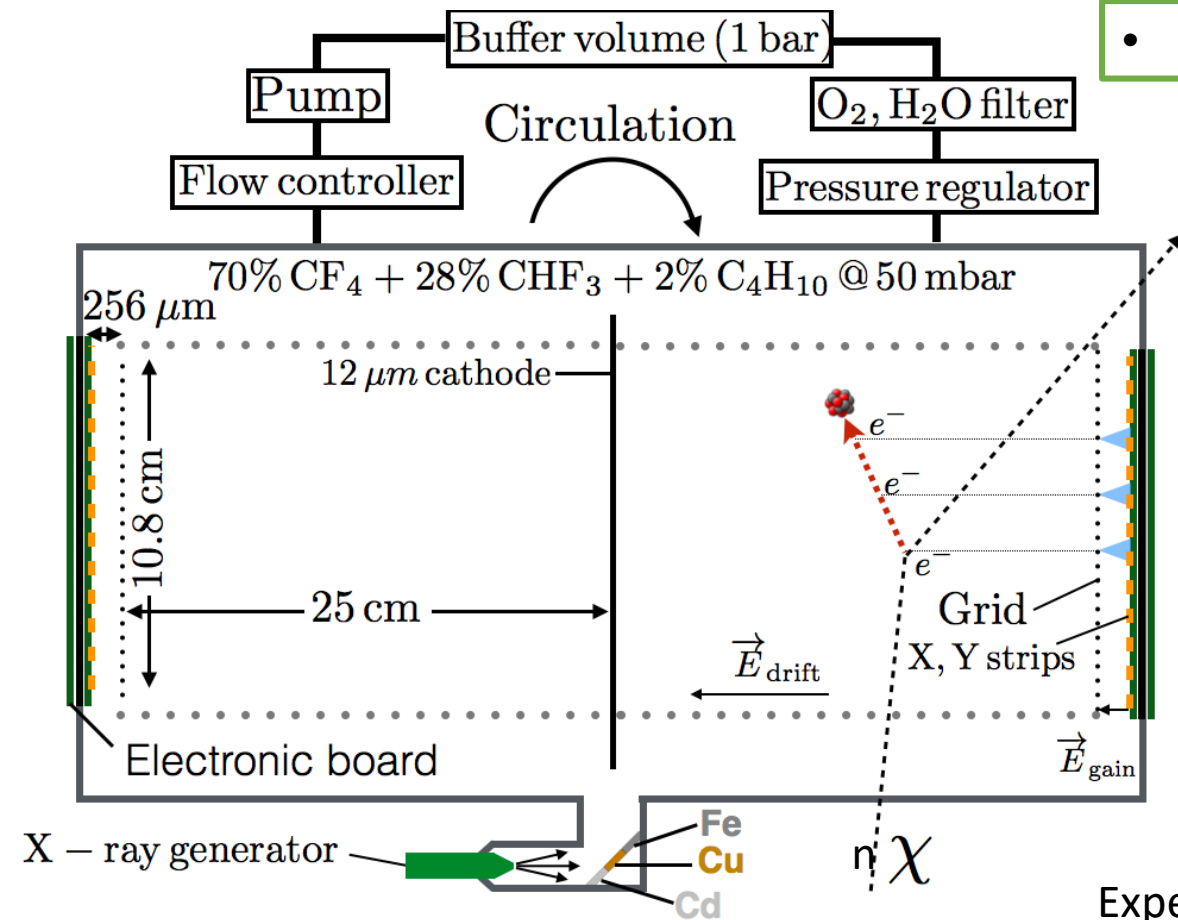
CPPM (Marseilles) : C. Tao , J. Busto

USTC (Hefei) : Z. Zhang,

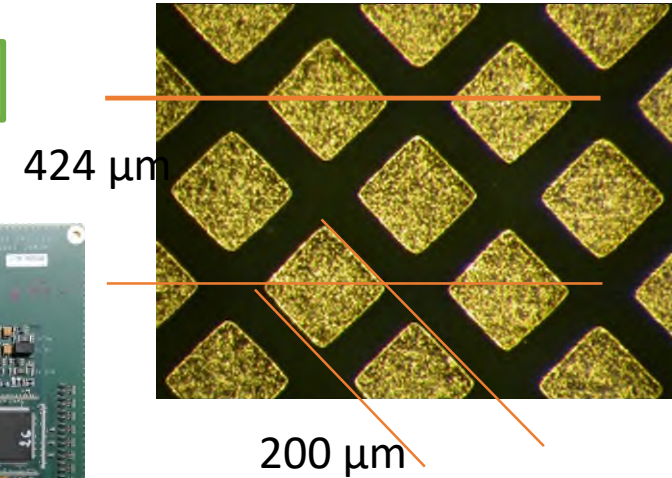
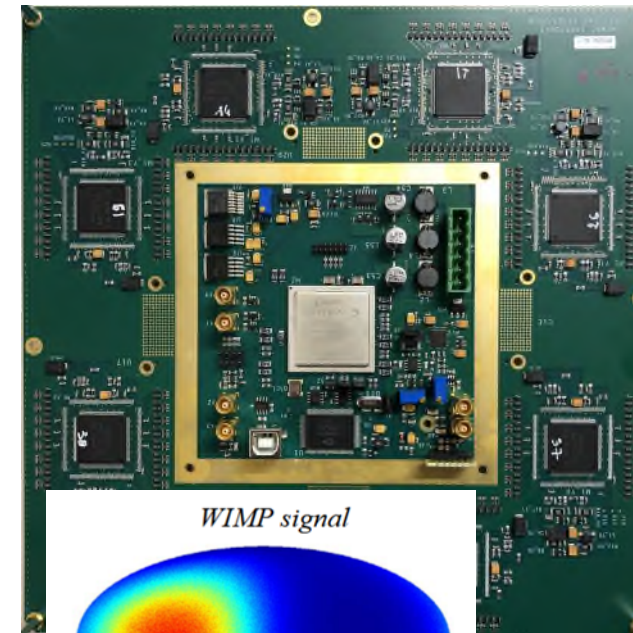
CERN / GDD : Rui de Oliveira



How directional detection can be done?



- Energy threshold (Mesh) < 1keV



- 512 channels → 65000 pixels
- Frequency : 20 ns (50 MHz)
- Energy (mesh) : ADC (50 MHz)
- External clock

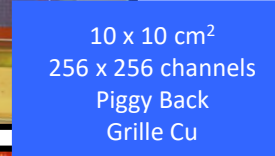
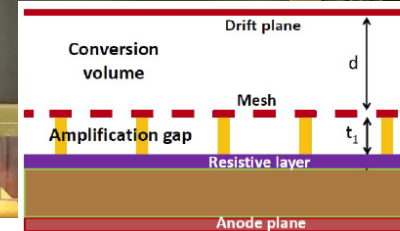
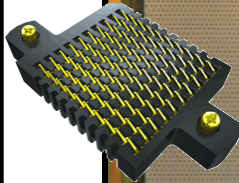
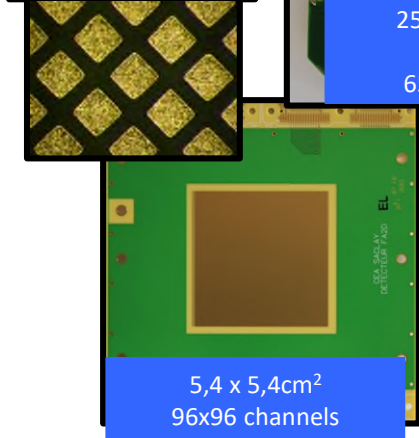
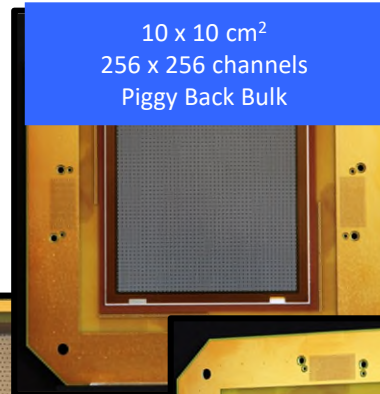
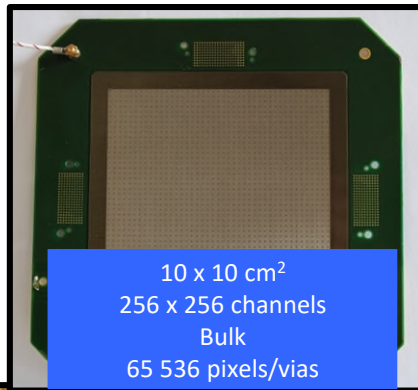
Gap 256 à 512 μm

Micromegas μ TPC Development

256 to 512 μ m amplification gap

Materials

- PCB or Kapton
- DLC ou Ge
- Cu ou stainless steel
- PMMA
- ~ 802 816 pixels / via



Materials

- PCB / Cu
- Stainless steel mesh

Materials

- Kapton / Cu
- DLC
- PMMA

2007

2009

2011

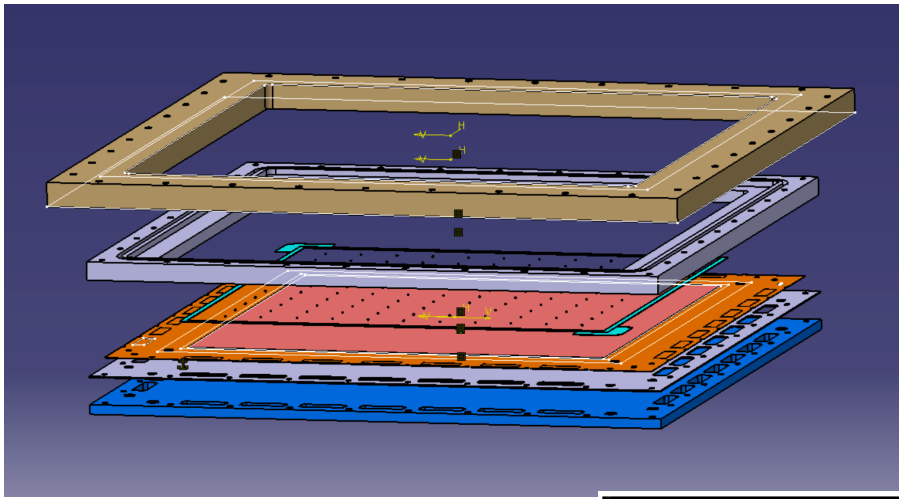
2012

2016

2022

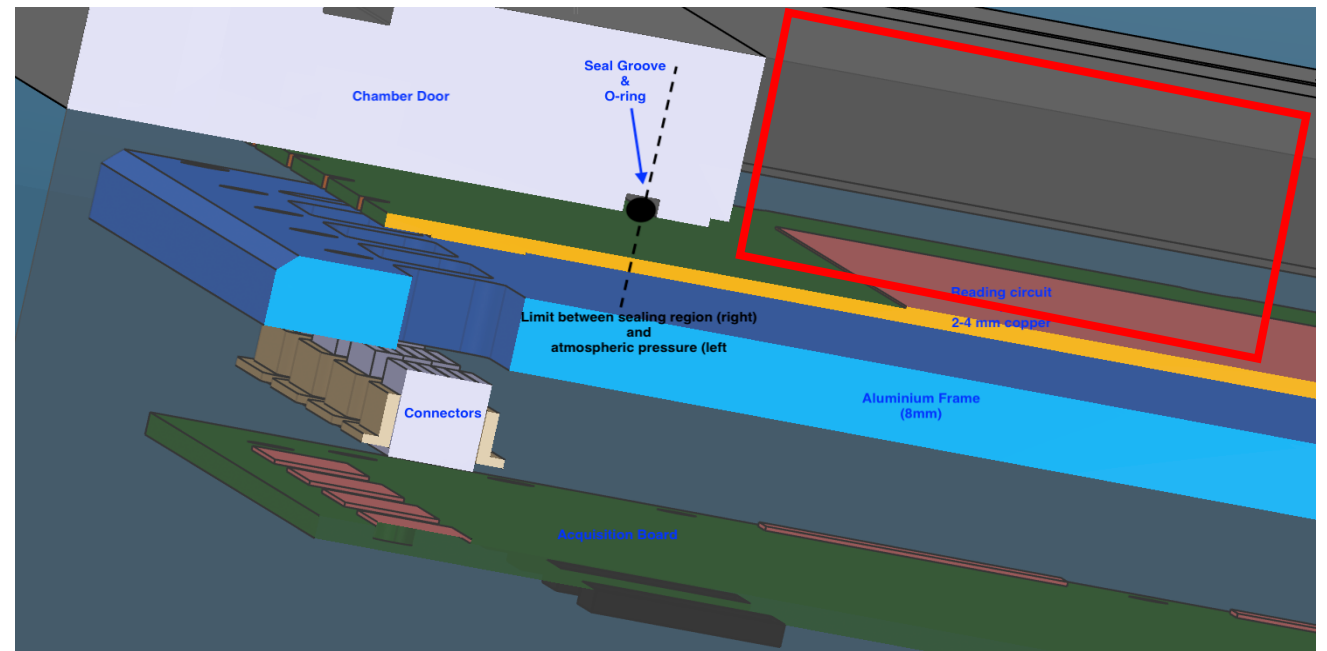
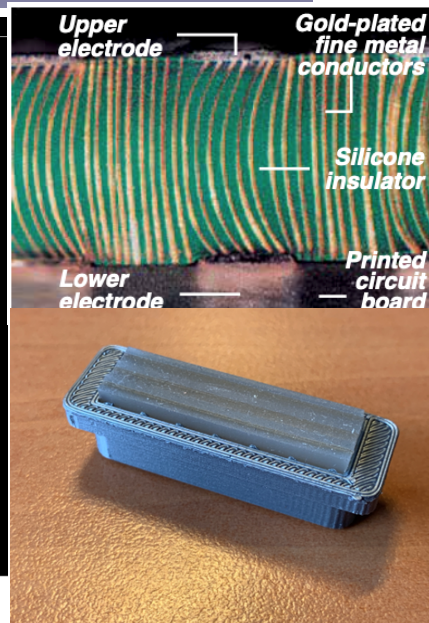
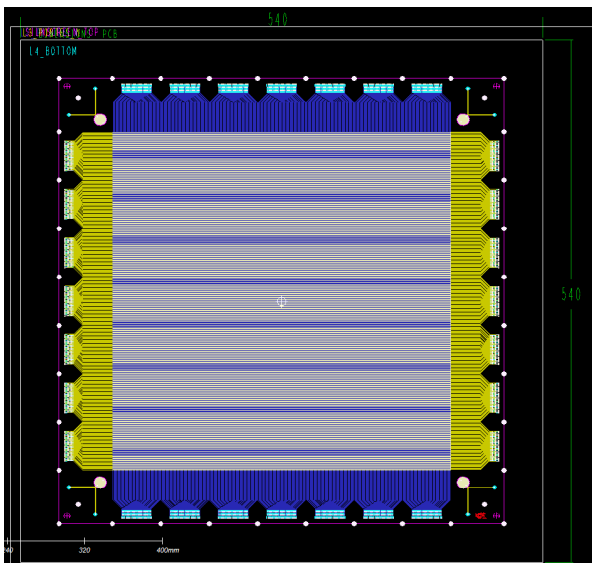
2026

μ TPC 3D Model of 35 x 35 cm

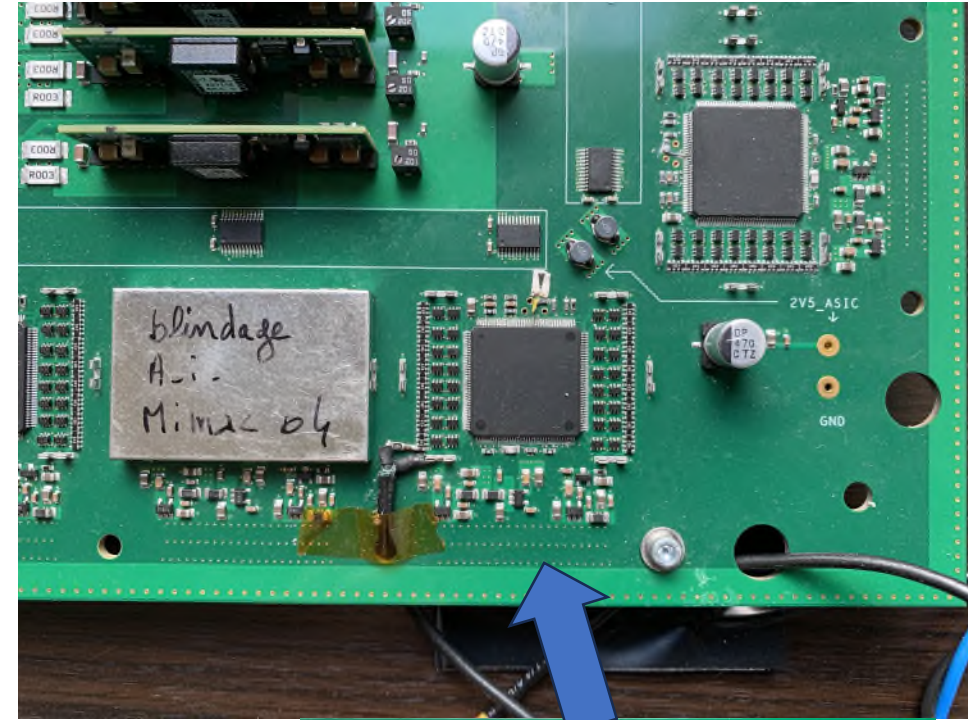
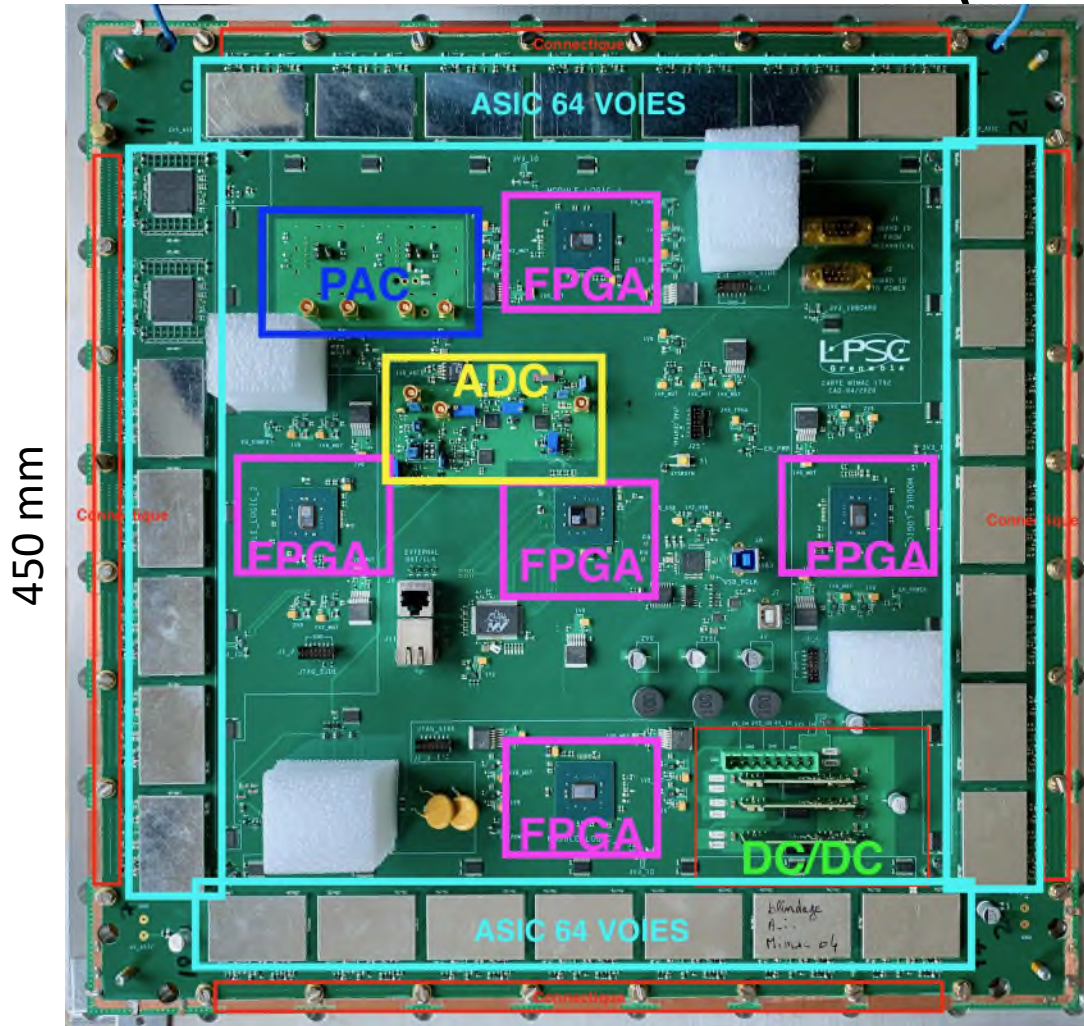


Spécifications

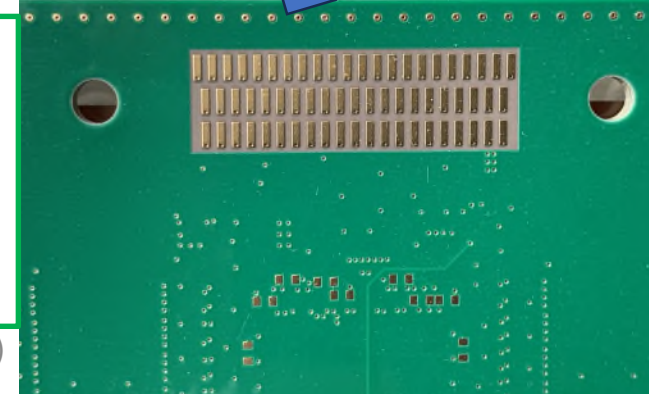
- Vacuum resistance: Operation at 30–50 mbar with low leakage rate
- Custom connector: Zebra (elastomeric connector)
- Low Insertion/compression force: easy assembly
- Custom Holder
- Contact alignment: 1792 pads aligned in a single operation
- Main challenge: Perfect matching between detector/mechanic/board



The electronic board 1792 channels (LPSC) + ASIC MIMAC (LPSC)

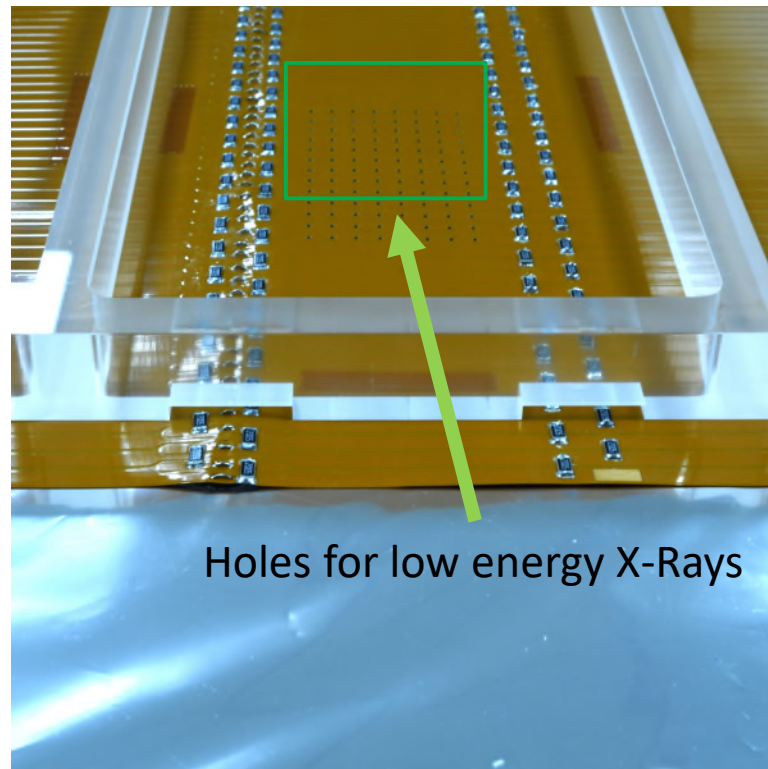
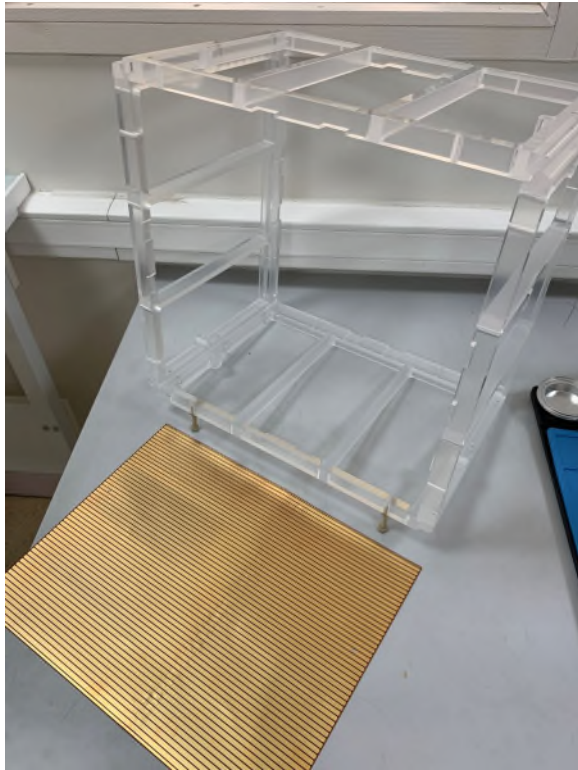


- 28 ASIC s(64 chs)
- 5 FPGAs
- 2 ADCs
- 3 DC/DCs
- 2 PACs

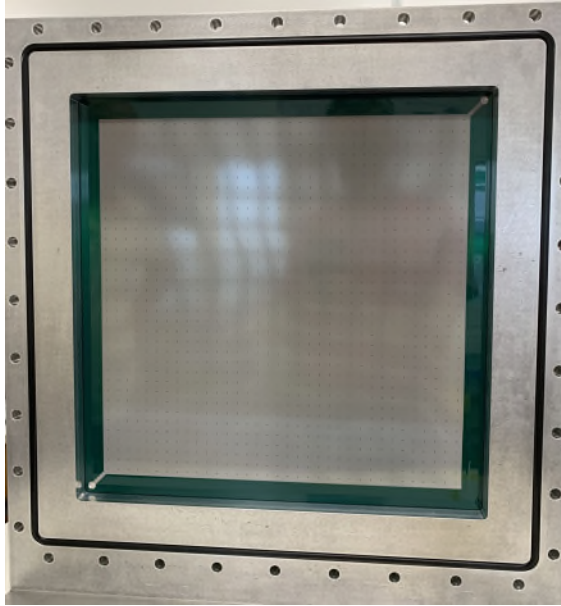


Field Cage

- Uniform electric field
- Radiopure materials : PMMA / Kapton / Cu
- 300 resistors ($10\text{ M}\Omega$,)



2 Detector Layout



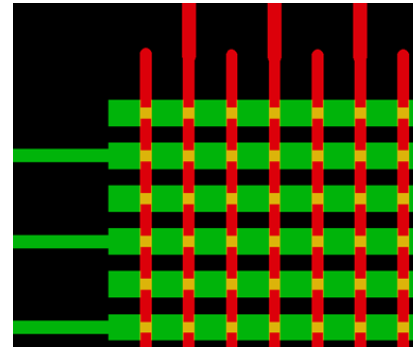
-  PCB
-  Kapton
-  Copper
-  Inox
-  Colle

Gap 500 μm

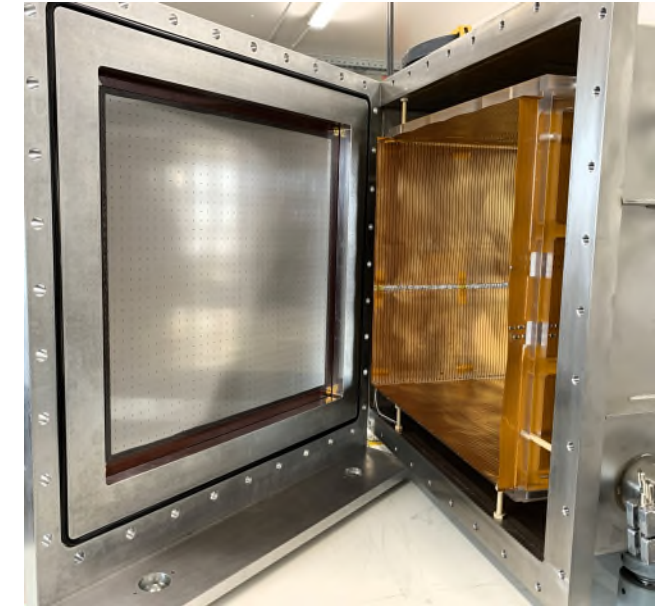
Grille : Inox 18/25

Résistif : DLC / Ge

- Kapton DLC : 30 - 50 $\text{M}\Omega/\square$
- Ge : 100 – 200 $\text{M}\Omega/\square$



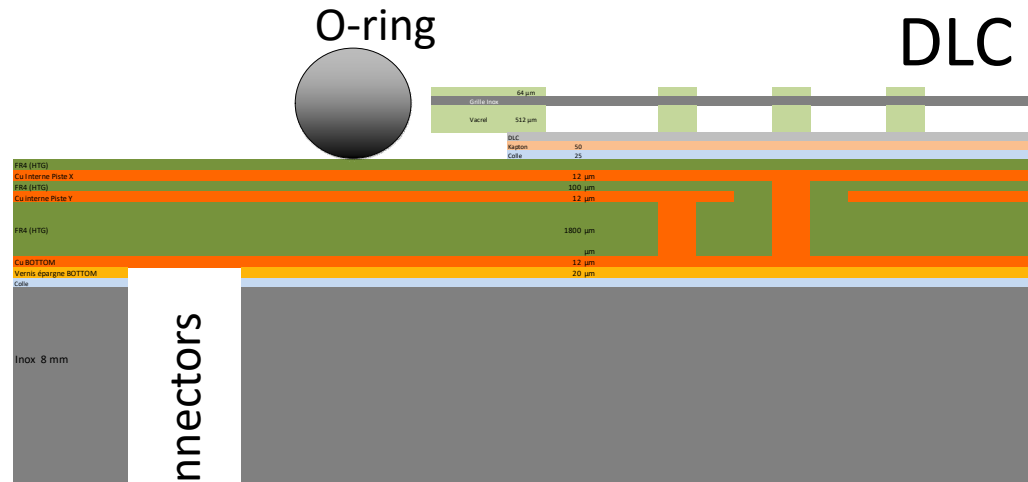
Readout pattern



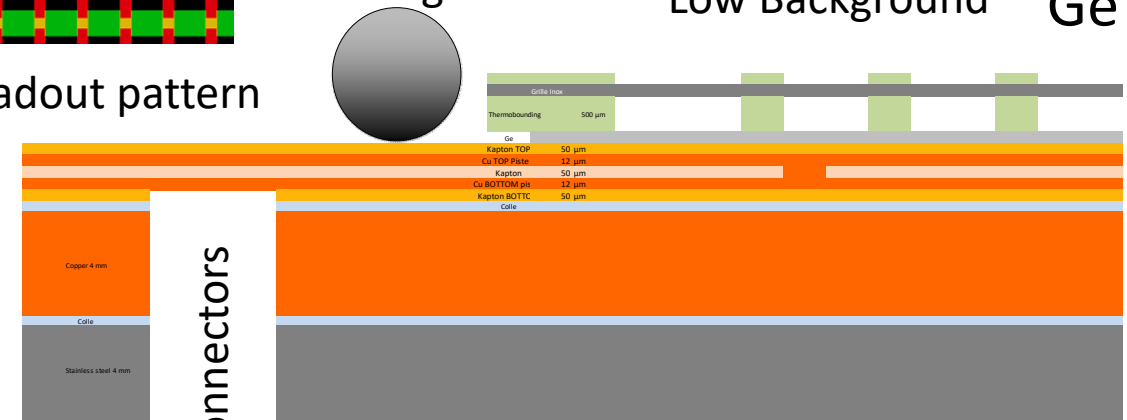
Thermal bonding Micromegas

O-ring

Low Background Ge



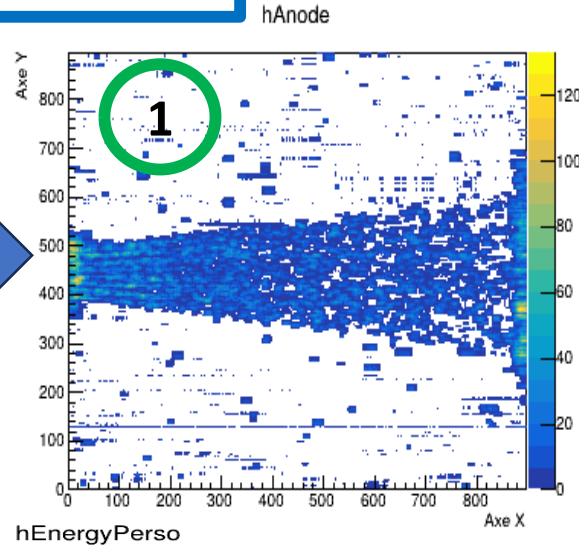
PCB (CERN - GDD)



Kapton / Cu
(USTC – Hefei, China)

Characterization Kapton version : Gas gain, drift speed, ...

Kapton / Cu Version

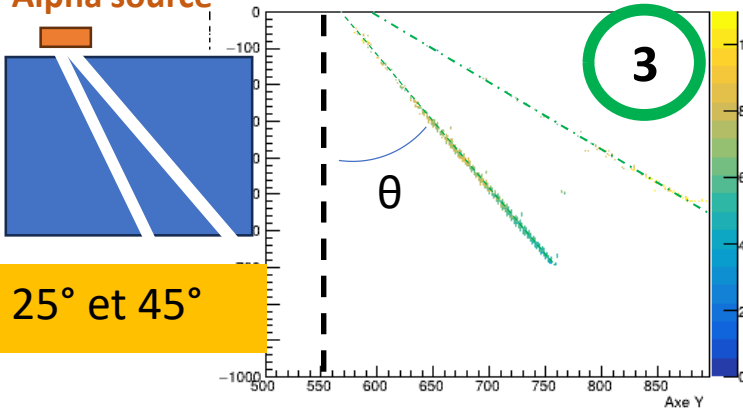


X generator

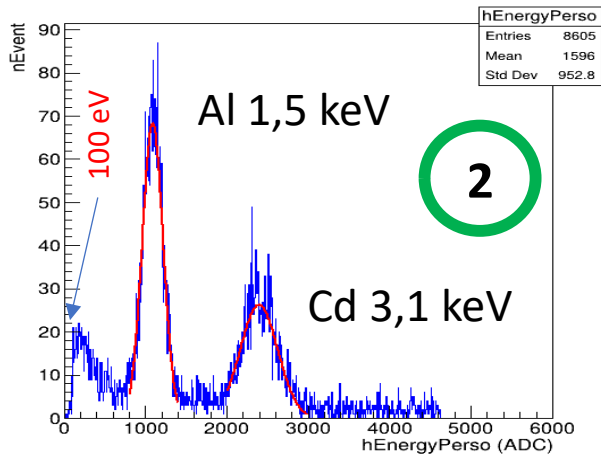
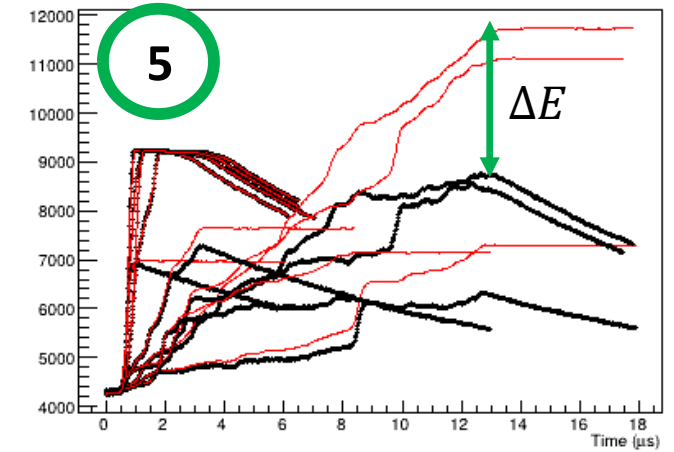
Alpha source

25° et 45°

hTrackYZ



Raw Flash and Corrected



C4H10/CHF3 30 mbar

Resolution :

1.5 keV : 27,4 % (FWHM)
3.1 keV : 22,6 % (FWHM)

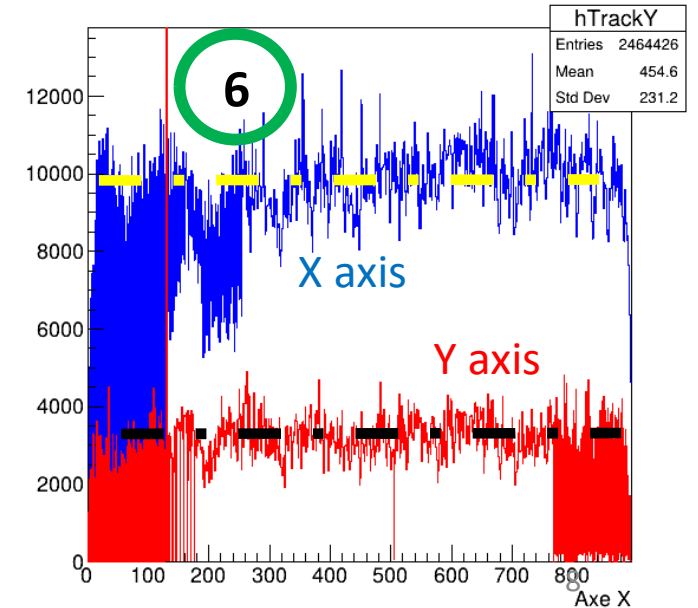
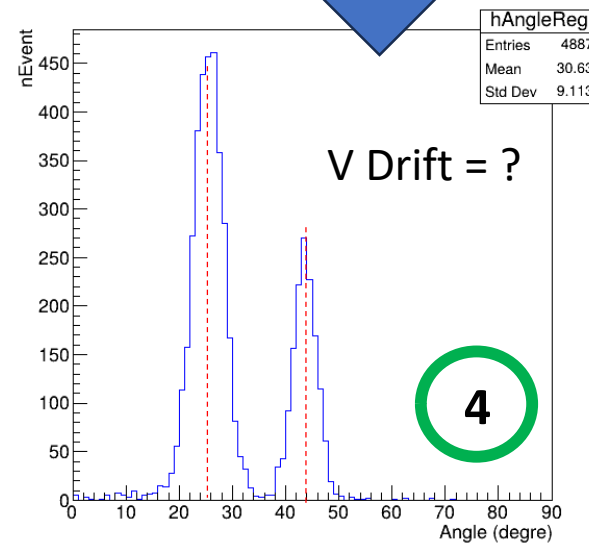
Gain ~ 30 000

~ 1,3 eV/bin

Energy range : 5,8 keV

Threshold : 100 eV

Reconstruction of angles
with respect to the z-axis



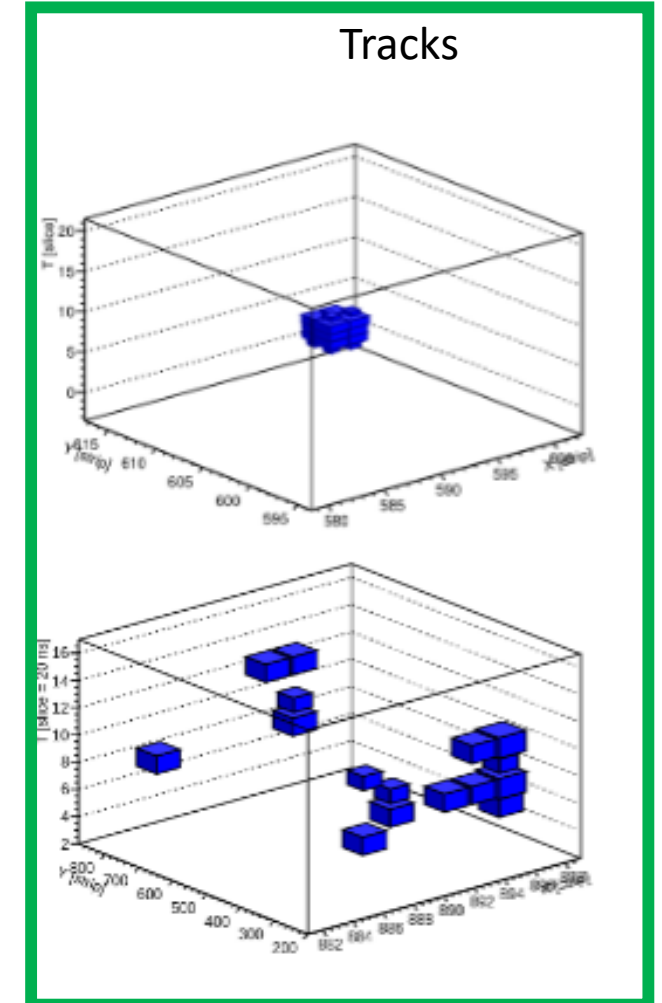
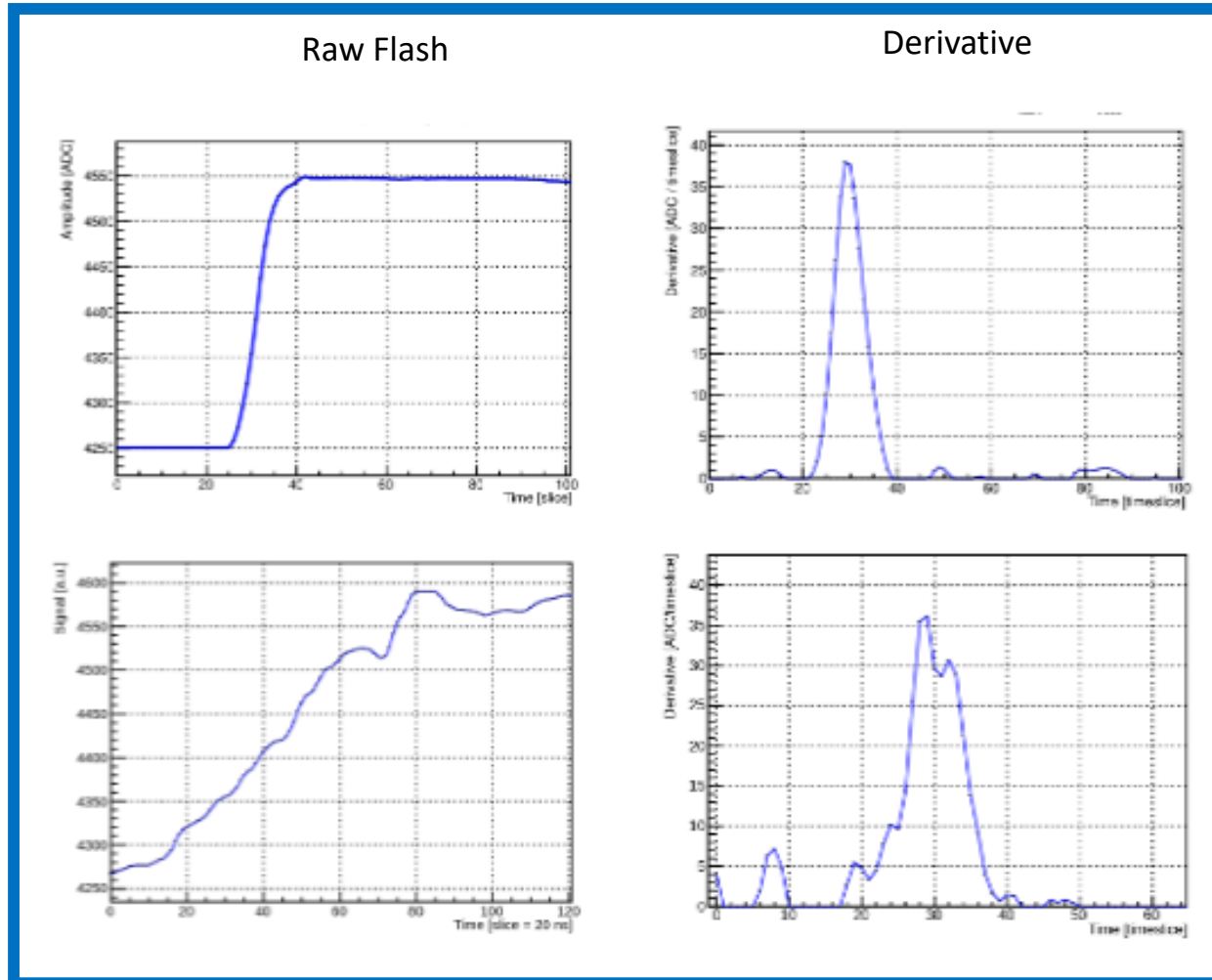
FCCPN/L,

Event discrimination

Flash energy analysis (I. Ourahou)

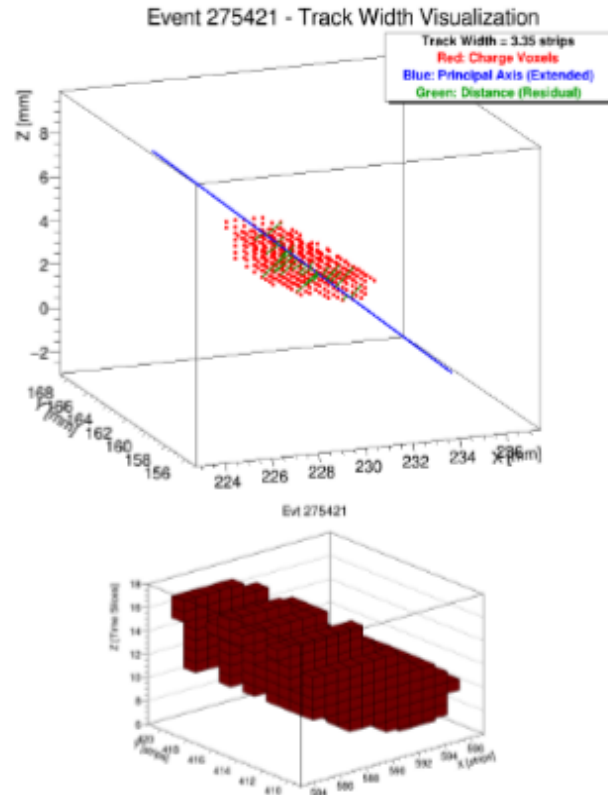
Nuclear Recoil

Electron

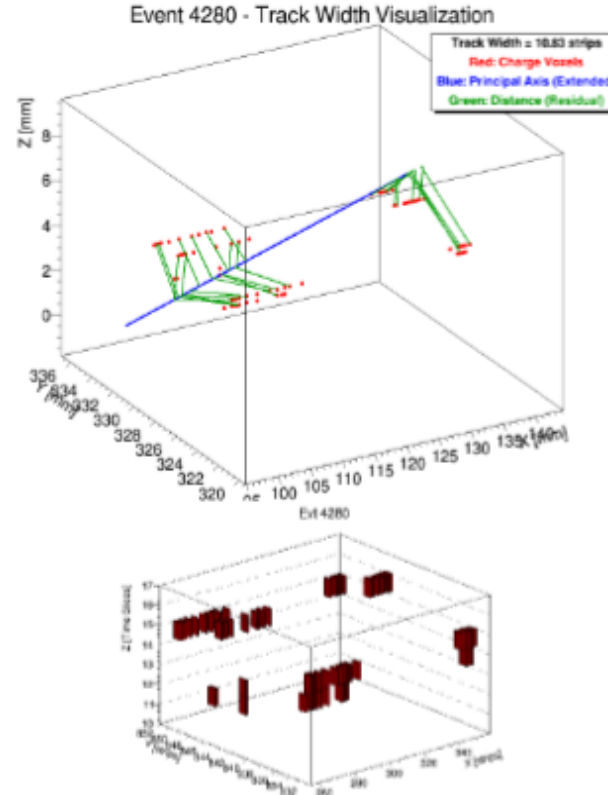


Event discrimination

Track Width (w)

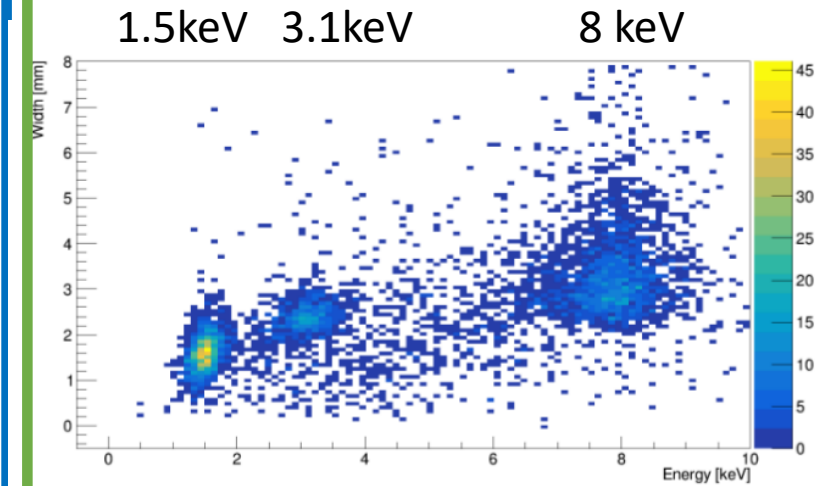


(a) Nuclear Recoil Candidate (4.09 keV)



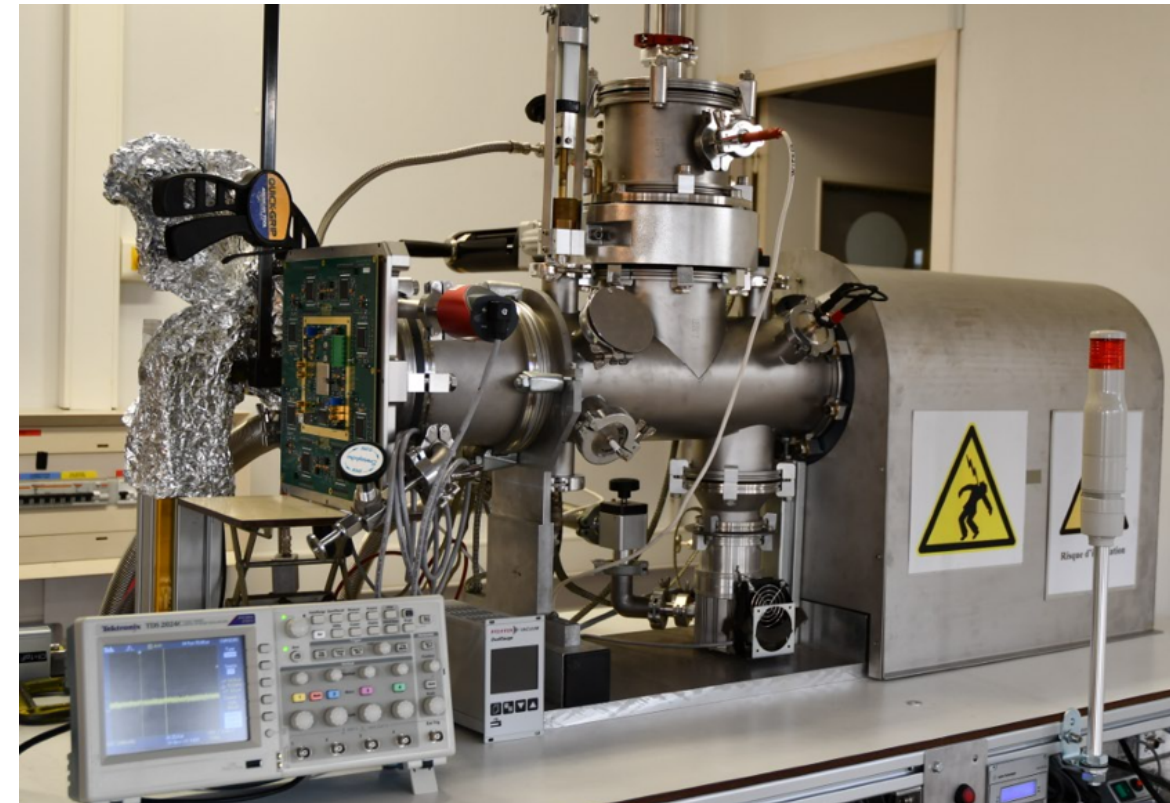
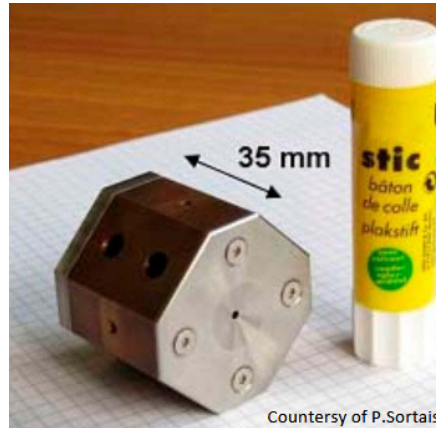
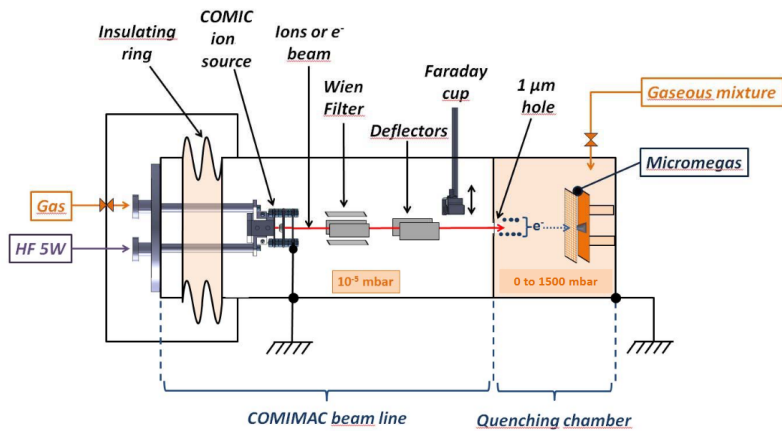
(b) Electron Recoil Background (4.59 keV)

Distribution of track widths
for calibration electrons



Discrimination training : A low energy table top ion/electron beam facility for gaseous detector calibration (COMIMAC)

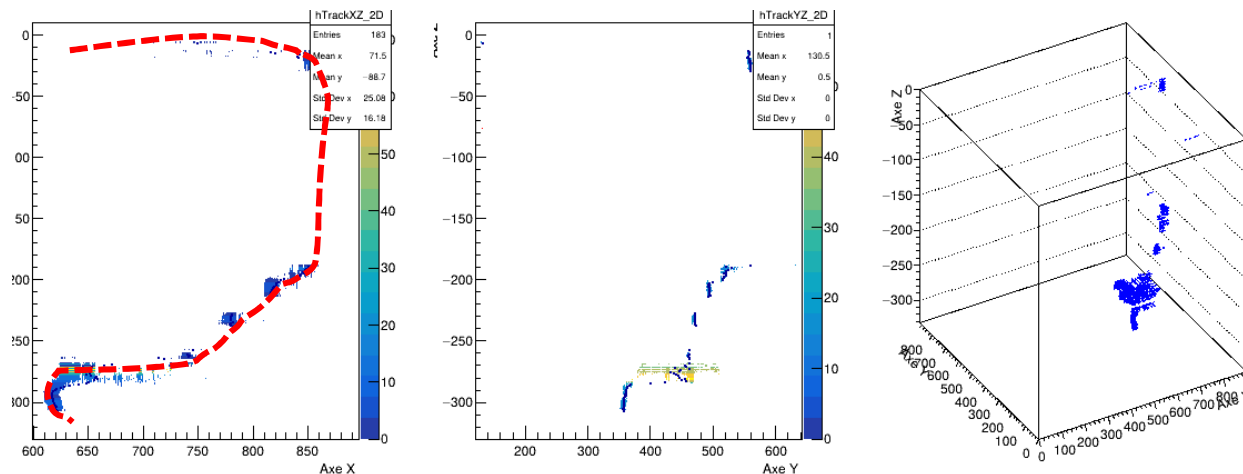
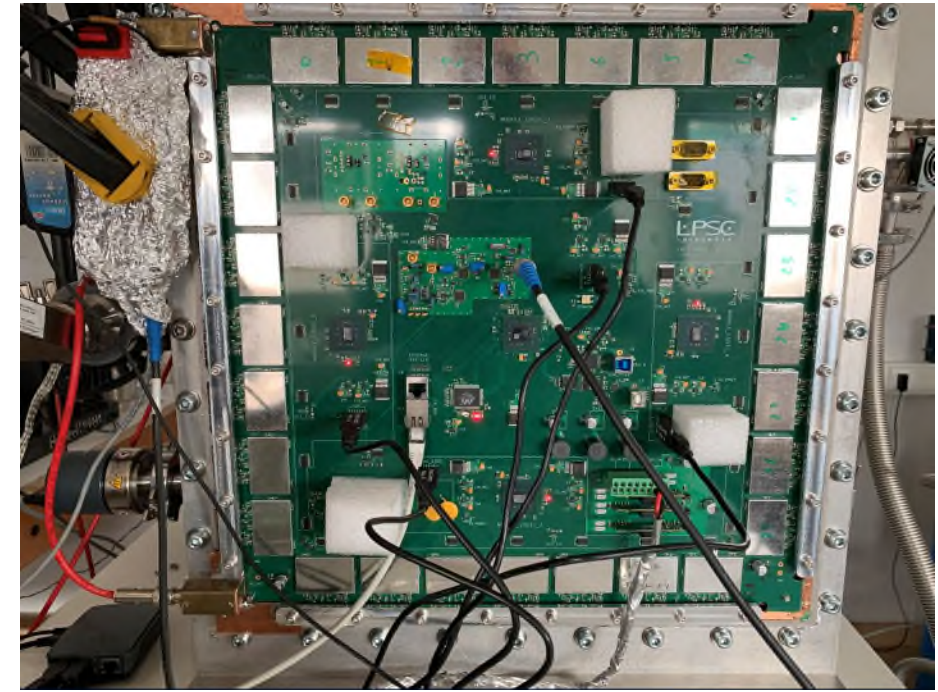
A table-top ion and electron beam facility for ionization quenching measurement and gas detector calibration (J.F. Muraz)



- Highly Miniaturized Source
- Energy range : 0 to 50 keV
- Ion and electron beam.
- Stainless steel interface with $\varnothing 1 \mu\text{m}$ hole
- μTPC with 512 channels

Outlook / Conclusion

- New μ TPC ($35 \times 35 \times 29 \text{ cm}^3 \times 2$), 70 L, 3600 channels
- Dark matter (C_4H_{10} / CHF_3) (2027 @ LSM)
- Exploring Coherent directional neutrino detection (He/CF_4)
- Fast neutron spectrometry (He/CO_2 at 1 bar)
 - Metrology and spectrometry of neutron fields
 - Nuclear waste characterization
 - Neutron background in underground laboratories (C_4H_{10} / CHF_3)



Thank you for your attention