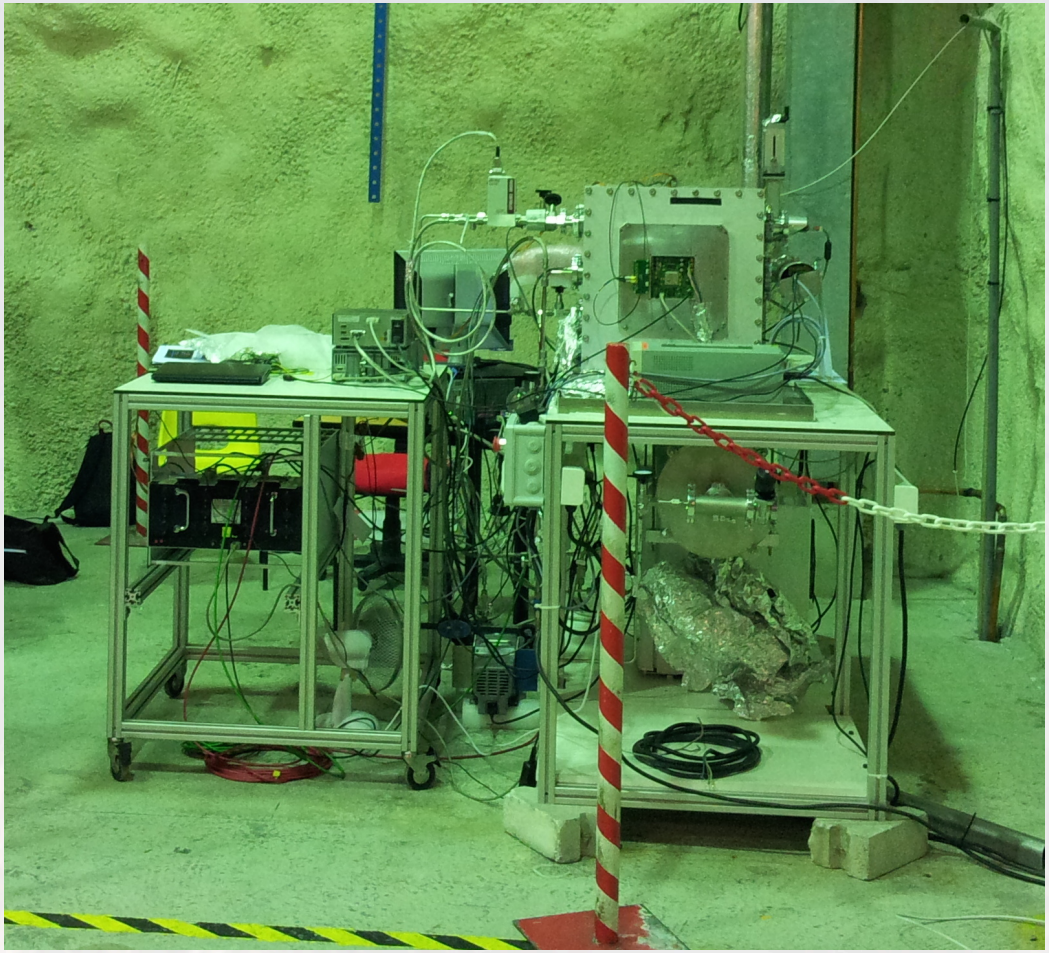
MIMAC

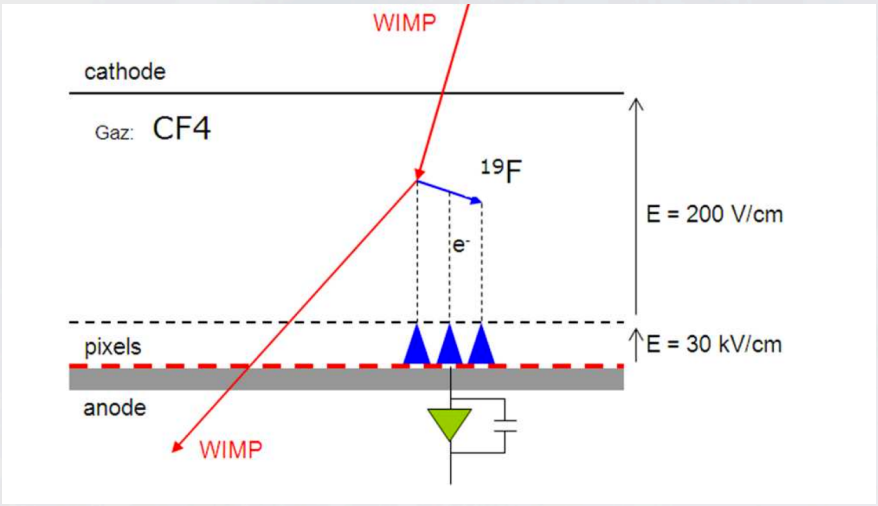
a low pressure µTPC example



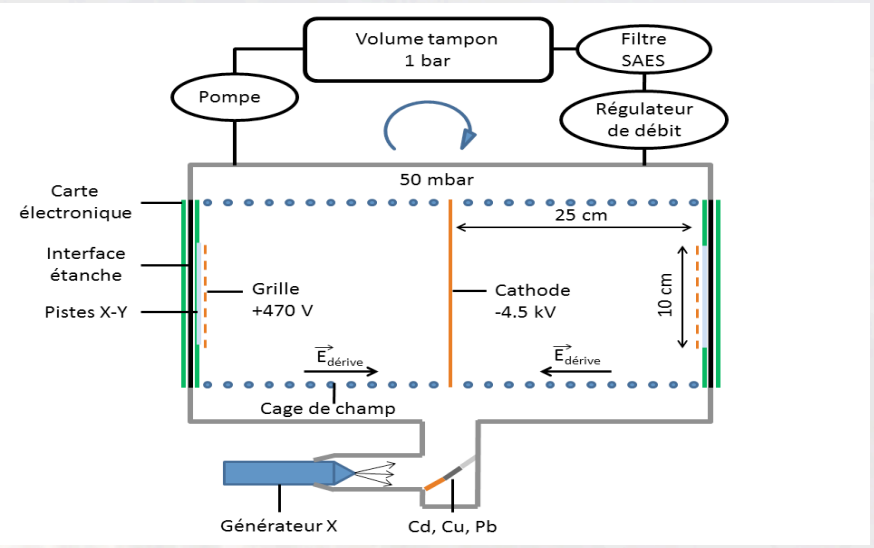
Olivier Guillaudin
LPSC
Instrumentation Days on gasous Ddetector

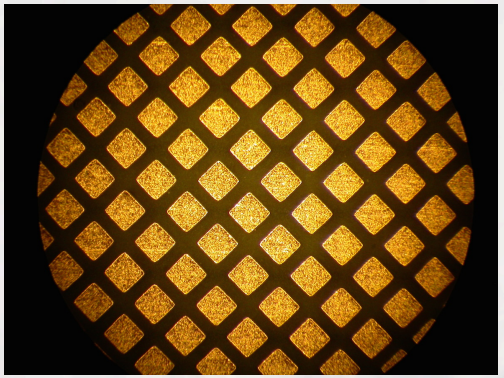
The MIMAC Project

A low pressure detector prototype for directionnal dark matter search and …



- Energy and 3D Track measurements
- Recoil : 1 to 100 keV
- Micromegas technology (256 µm gap)
- ^{19}F Target (CF4 at 50 mbar)
- Bi-chamber module prototype
  - 2 x 2,5 liters (Drift : 25 cm)
  - Pitch ~400 µm (65000 pads)
  - 512 channels (**20 ns**)





Drift Velocity : introduction

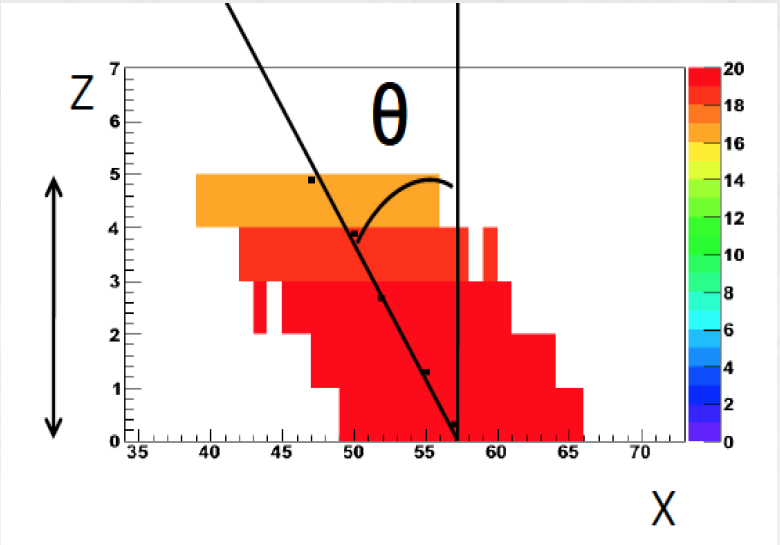
- 3D Track reconstruction requires a precise knowledge of the electron drift velocity

$$\Delta Z = \Delta T \times Vd$$

Magboltz simulations give good result for pure CF4

But differences with real life

- Gas mixture
- Impurities??
- Field inhomgeneities

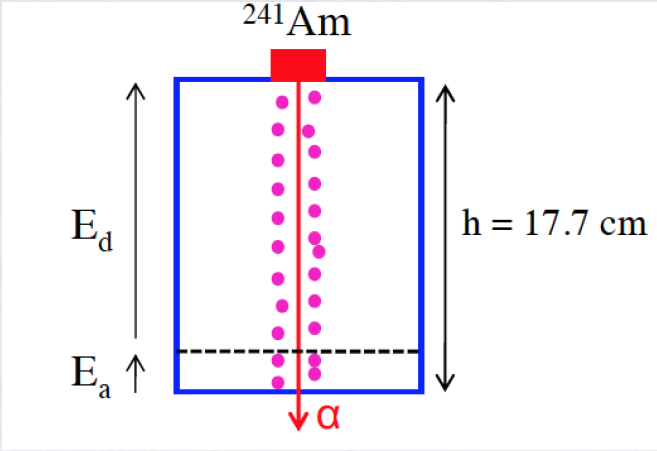


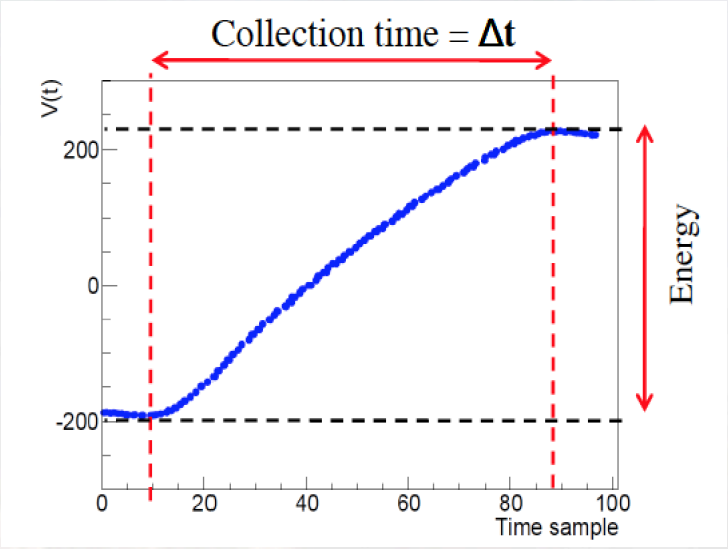
Measure the electron drift velocity with our directional setup

Drift velocity measurement setup

Use of an 5.47 alpha source (241Am)

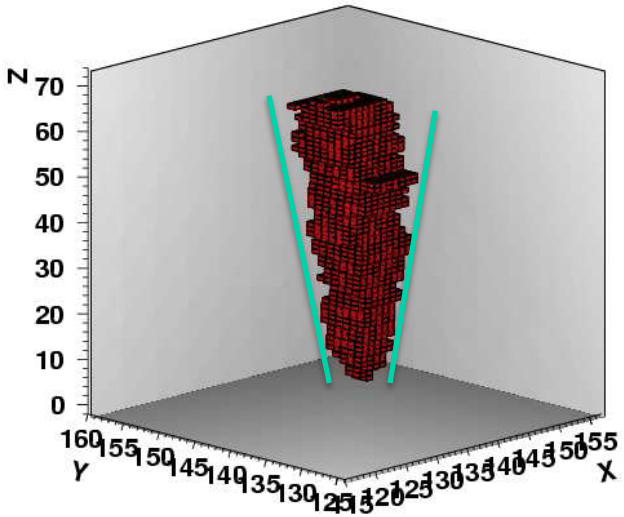
- Alpha particles go through the entire drift chamber
- Measurement of the 3D tracks and charge profile
- A starting and an ending point





$$Vd = \frac{d}{\Delta t}$$

3D reconstruction of one track crossing the whole drift space



Data analysis strategy based on a profile likelihood method

(J Billard *et al* 2014 *JINST* **9** P01013)

Drift Velocity : CF4

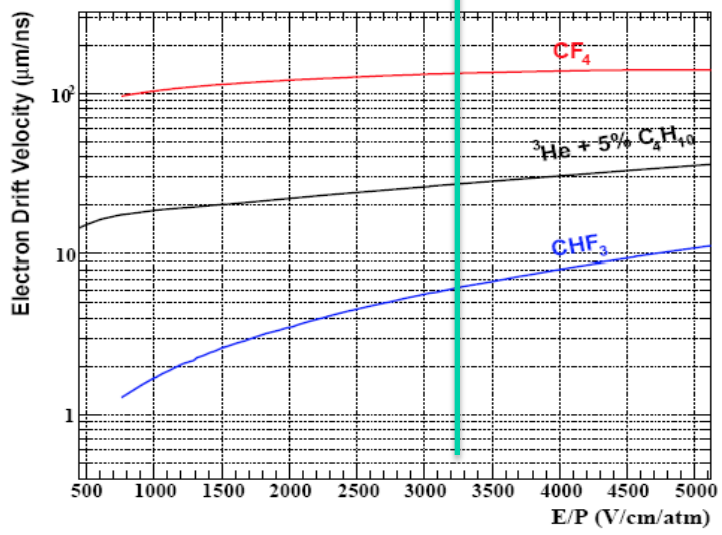
Fluorine Recoil of 100 keV

- Track : ~ 3 mm at 50 mbar (SRIM)
- Vd : ~ 120 µm/ns (pure CF4)
- Drift lenght→ 2,4 mm in 20 ns (2 slices with MIMAC electronic)

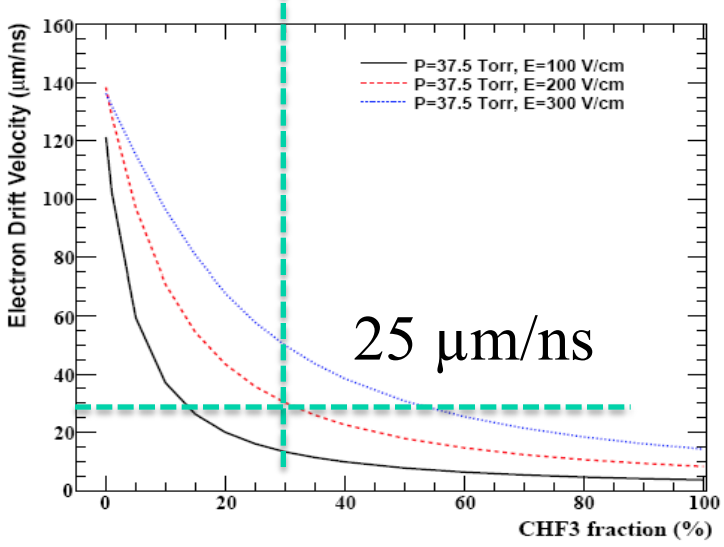
TOO FAST!!!

The addition of CHF3 lowers the electron drift velocity

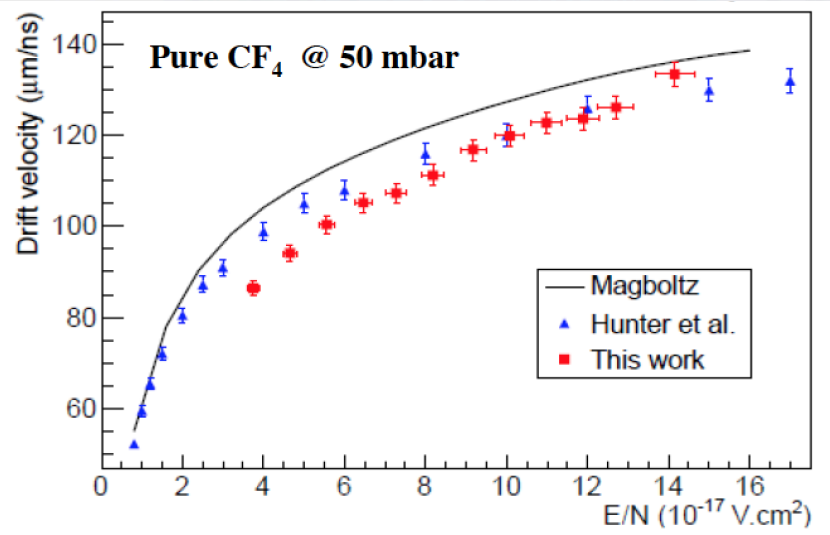
160 V/cm

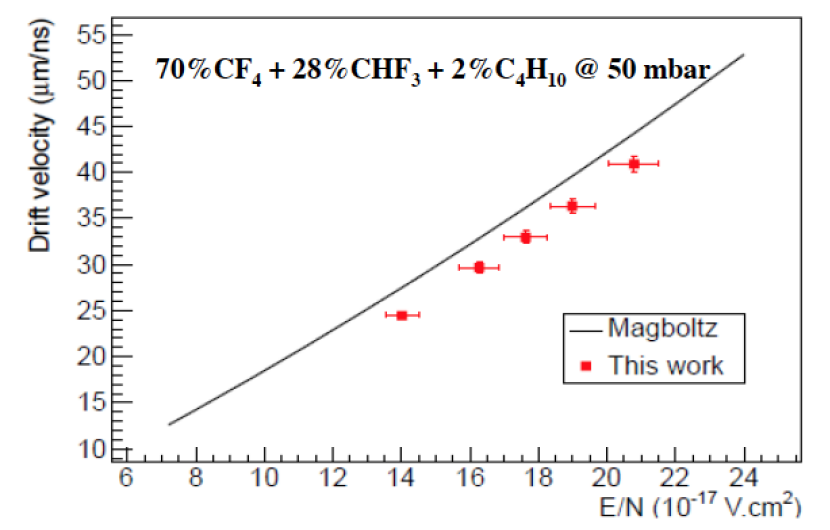


160 V/cm



Drift Velocity : results





J Billard *et al* 2014 *JINST* **9** P01013

- Fair agreement (up to 10%) with the Magboltz simulation
- The addition of CHF3 lowers the electron drift velocity while keeping a large Fluorine content : 5 times lower than in the pure CF4 case (key point for 3D track)
- Validation of the charge collection all along the drift chamber

→Golden gas mixture for MIMAC (low drift velocity and large fluorine fraction)

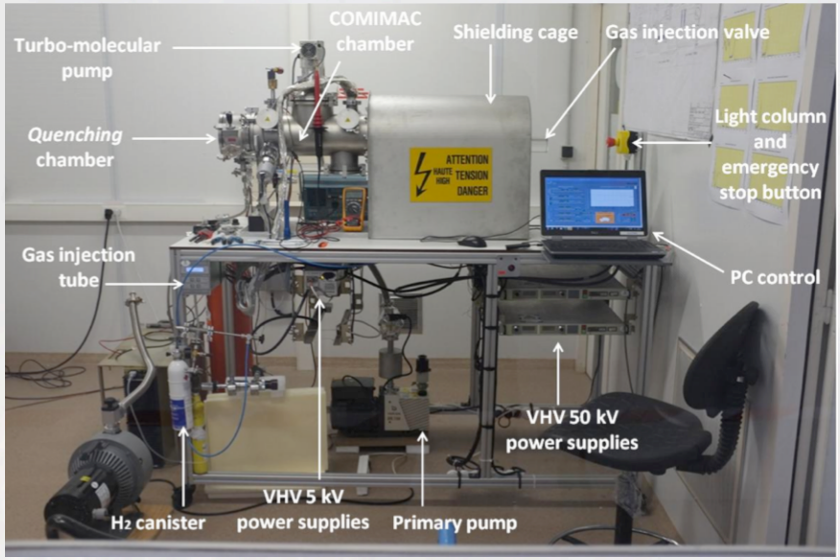
70% CF4 + 28 % CHF3 + 2 % C4H10

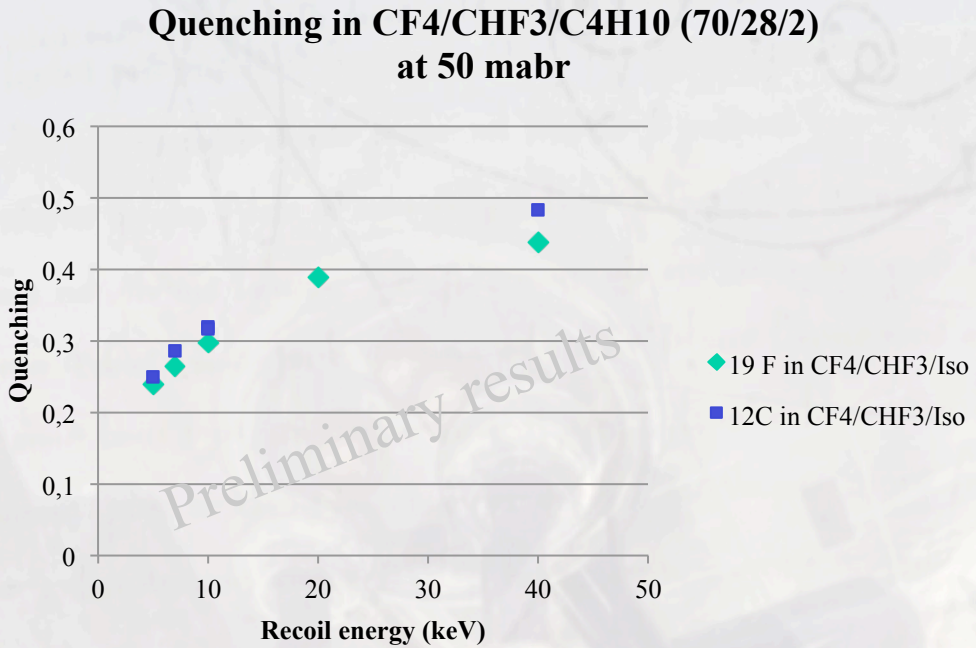
MIMAC : energy measurements

- Ionization Quenching factor

$$Q = \frac{E_{ionization}}{E_{recoil}}$$

- Quenching factor is predicted by Lindhard theory
  - **… but has not yet been measured !**
- Key point for Dark Matter to compute recoil kinetic energy
- **→ COMIMAC**

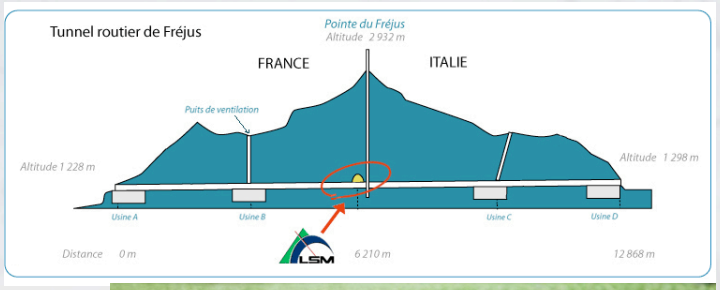




Gas System

CF4, CHF3 and C4H10 :

- Greenhouse gas
- Expensive gas ($$$)
- Modane underground laboratory (gas rejection)



Estimation : 80l/h at low pressure

Several m3 per year of operation

- Recovering and reprocessing (flammable gas mixture)
- Compliance with environmental standards

Prototype : compact, clean, simple gas system.

- Closed loop
- Online filtering
- Small volume gas buffer

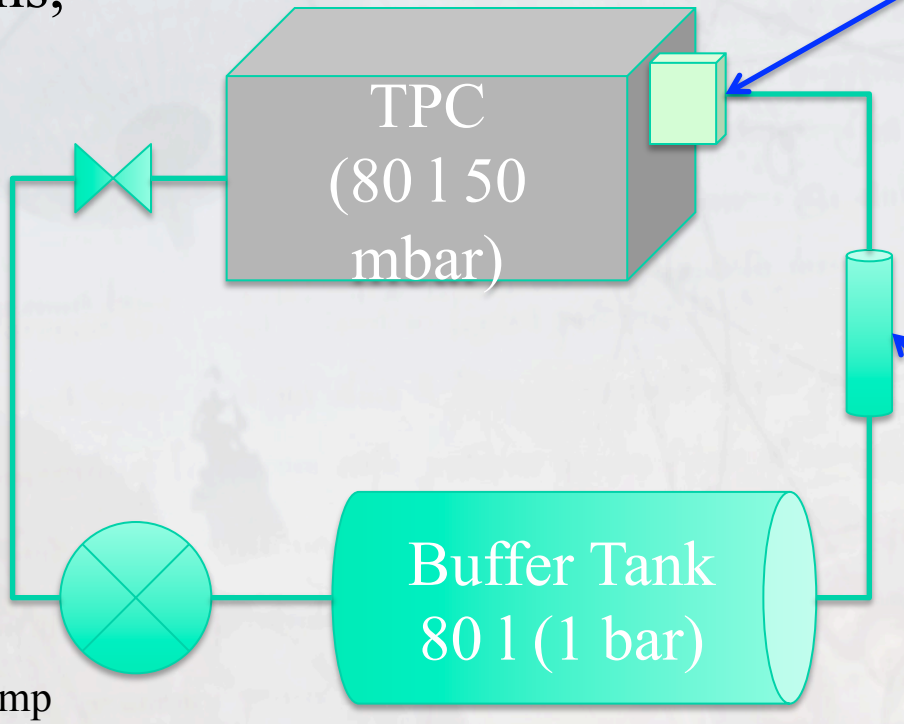
Closed loop design

Full metal system :

- Pipe,
- Connexions,
- Valves

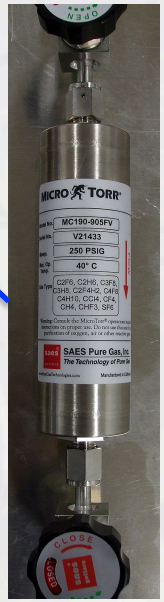
Absolute Pressure Controller

Custom Dry scoll Pump



Crucial element

- Ultimate pressure (<1mbar)
- Leak rate (<10^{-6} mbar.l/sec)



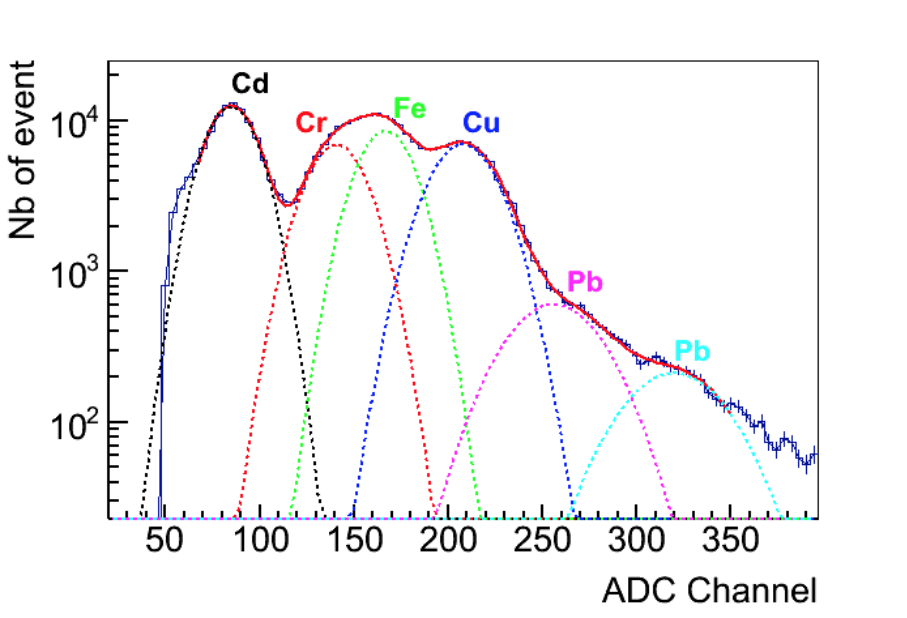
Gas purifier

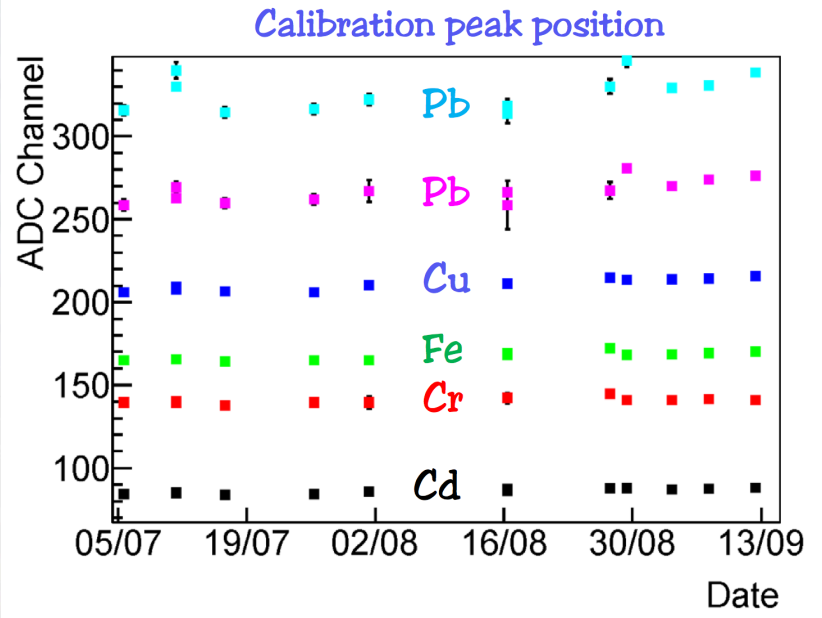
MIMAC Calibration

(70% CF4 + 28 % CHF3 + 2 % C4H10)

X-Ray generator and fluorescence target

Stable operation during first 3 months

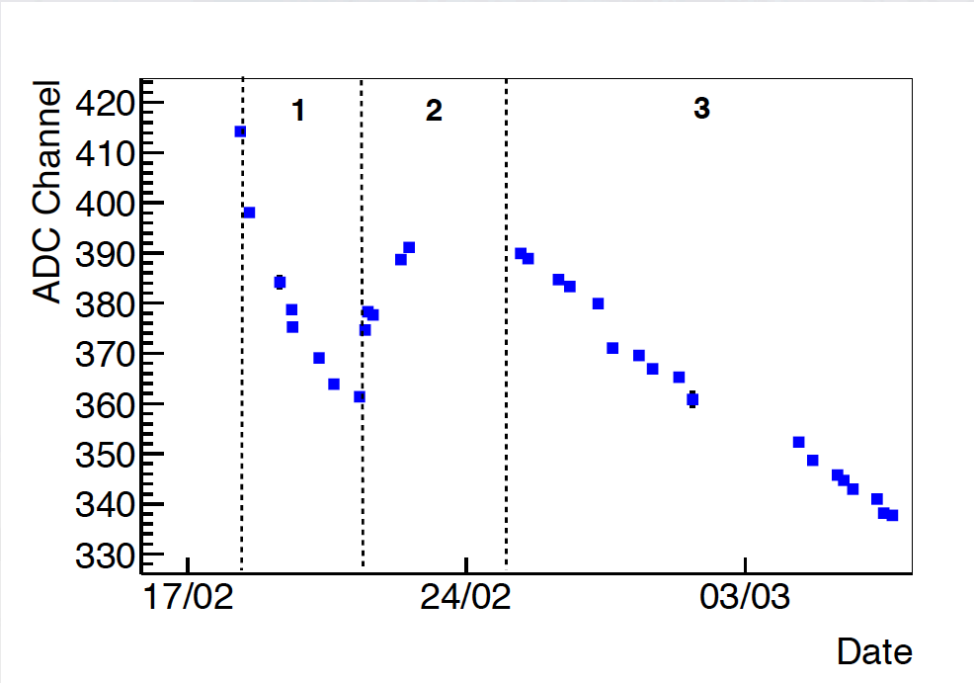


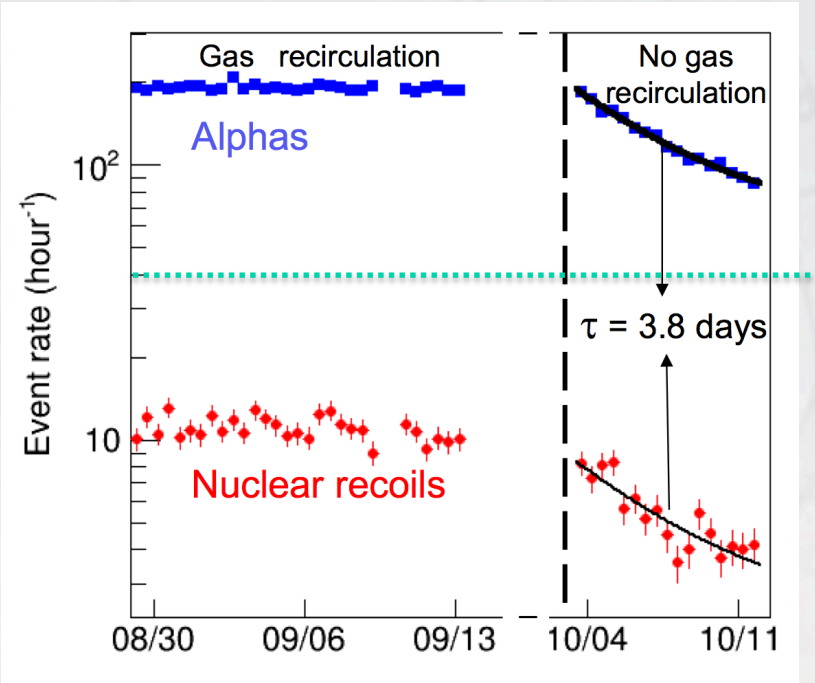


The same charge of gas is used since June 2013

→ No gain variation after one year

Gas circulation (LSM Modane)





8 keV copper peak (ADC)

- 1 = circulation without SAES getter
- 2 = circulation with SAES getter,
- 3 = without circulation

BAD PUMP !!!

Leak rate : 210^{-4} mbar.l/sec

3,8 days : compatible with ^{222}Ra half-life

Now (LSM) : ~4 10^{-5} mbar.l/sec

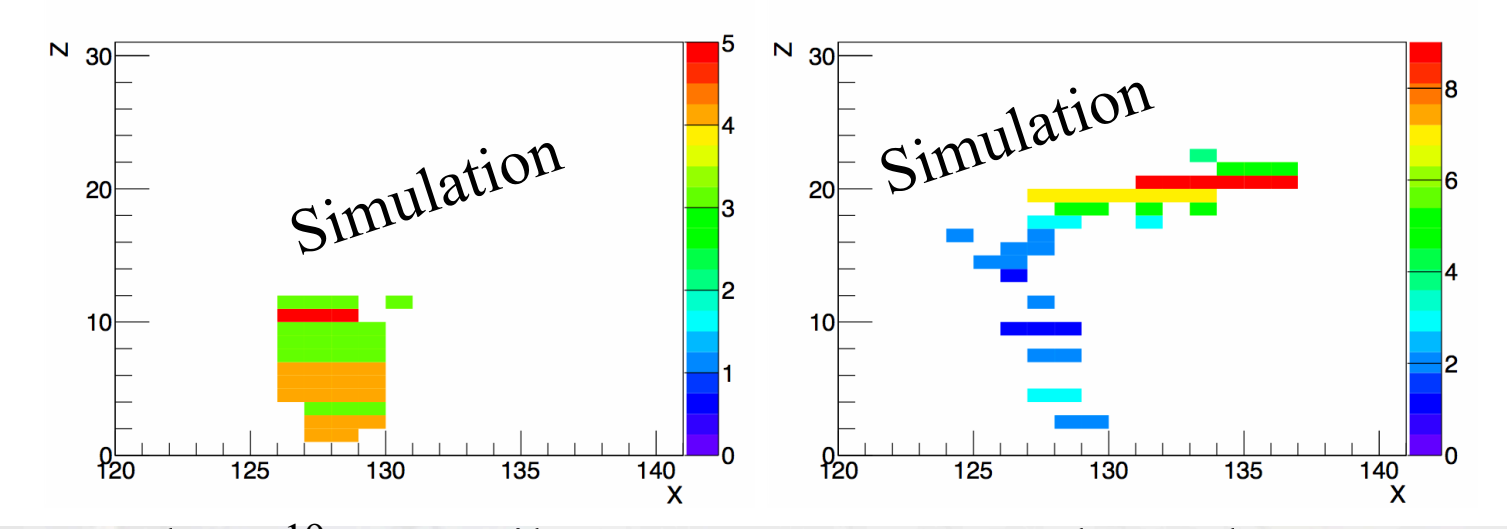
Conclusion

- A new measurement method of the electron drift velocity
- A golden gas mixture for MIMAC
  - **70%CF4 + 28%CHF3 + 2%C4H10 @ 50 mbar**

    → low electron drift velocity & large Fluorine fraction
- Quenching factor measurement setup
- MIMAC bi-chamber module has been installed at Modane Underground Laboratory in June 2012
- Stable operation during one year with only 80l (NPT) of gas mixture

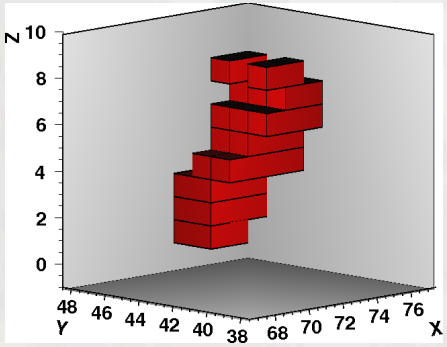
Some track examples

70% CF4 + 28 % CHF3 + 2 % C4H10 at 50 mbar

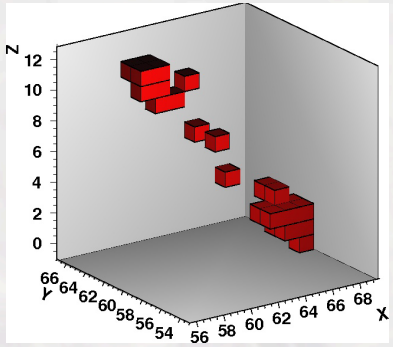


100 keV ^{19}F Recoil

10 keV electron



Data



Track lenght in

70% CF4 + 28 % CHF3 + 2 % C4H10 at 50 mbar