MIMAC

MIcro-tpc MAtrix of Chambers

($^3He + CF_4$)

A Large TPC for non baryonic Dark Matter search

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MIMAC:
(Micro-tpc MAtrix of Chambers)

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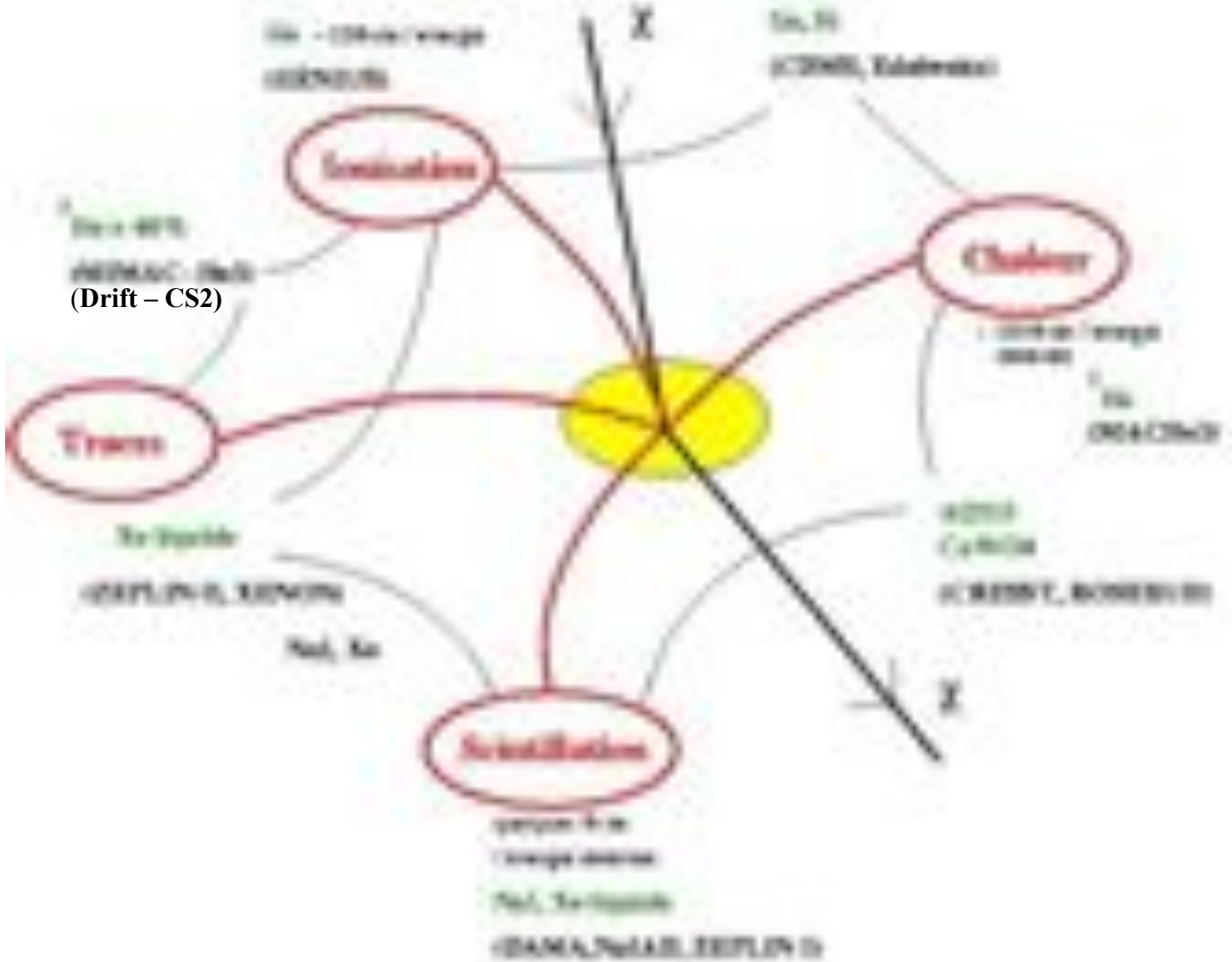
Technical Coordination : O. Guillaudin
- Electronics : O. Bourrion, G. Bosson, J-P. Richer
- Gas detector : A. Pellisier, O. Zimmermann
- Data Acquisition: F. Pancher
- Mechanical Structure : Ch. Fourel,
- Ion source : T. Lamy, P. Sole

CEA-Saclay (Dapnia): I. Giomataris, P. Colas, D. Attié, A. Giganon, E. Ferrer, J. Pancin

ILL (Grenoble) : B. Guerard, G. Manzin

Direct detection strategies



Why do we think we need a large TPC?

- Axial interaction and Scalar interaction
- Mass dependence cross section (modularity)
- Directionality
- Two different operating modes (pressure)
- Low energy threshold detection (~ 300 eV)

^{3}He for axial detection of non-baryonic dark matter

- spin 1/2 nucleus $\Rightarrow$ axial interaction
- high "signal/noise" ratio : energy range ~ 1-5 keV
- sensitive to M (WIMP) > 6 GeV
- neutron capture signature: $n + {}^3He \rightarrow p + {}^3H + 764$ keV
- very low sensivity to γ-rays
- in a gas form, the possibility to share a "patchy" matrix with other gases to follow the A cross section function

CF_4 as a quencher and target

- Axial interaction
- Odd in proton
- Ionization (~20%) : E < 7.5 keV (in ^{3}He: E< 5 keV)
- The volume needed to have the same number of nuclei that we have in 10 kg of ^{3}He is the 20 m^3 at 1 bar.
- Discrimination electron- recoil by tracks even better.

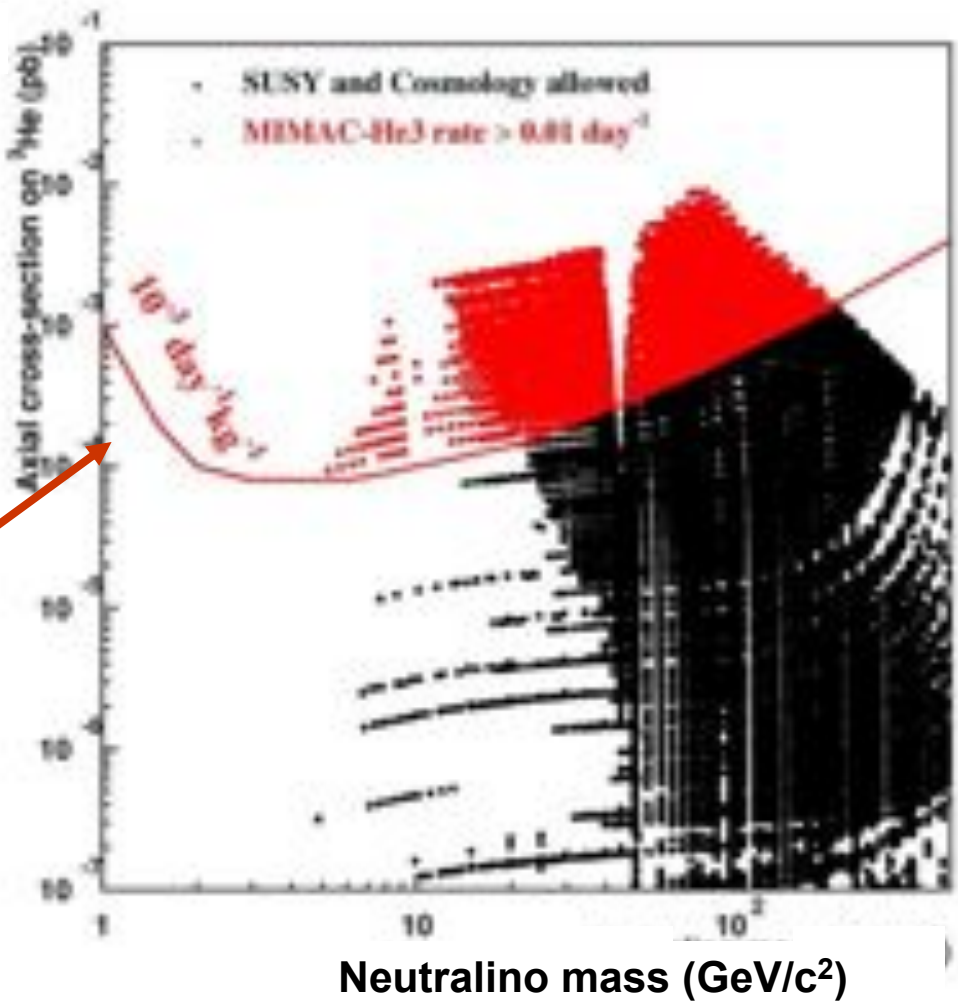
Spin contributions to the axial interaction

Nucleus	Z	Odd nucleon	J	$\langle S_p \rangle$	$\langle S_n \rangle$
^{3}He	2	n	1/2	-0.05	0.49
^{19}F	9	p	1/2	0.44	-0.11
^{27}Al	13	p	5/2	0.34	0.03
^{129}Xe	54	n	1/2	0.03	0.36

Cross section ^{3}He-χ and event rate in MIMAC-He3 (10kg)

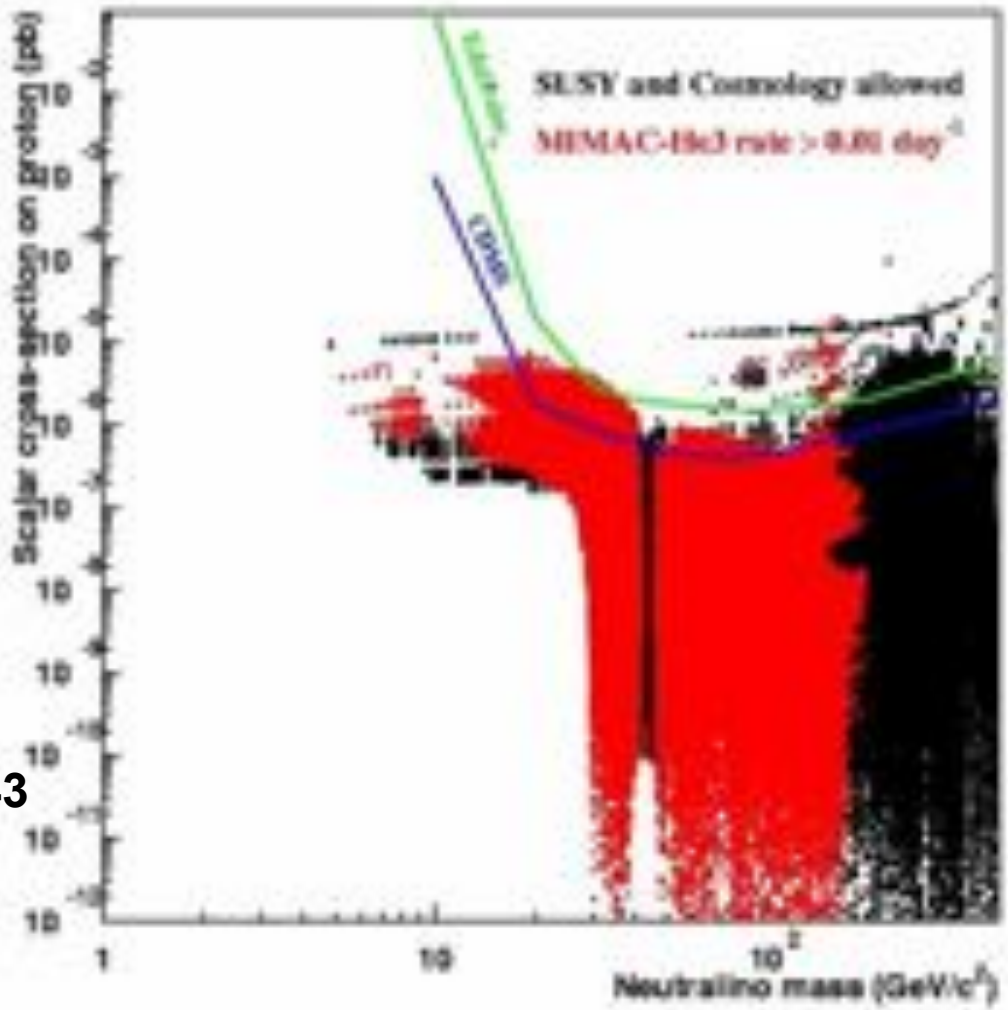
- $0.02 < \Omega_\chi h^2 < 0.15$
- Accelerator constrains

Exclusion curve for background 10^{-3} kg^{-1}jour^{-1}



Complementarity with scalar detection

σ_{SD} and σ_{SI} not correlated

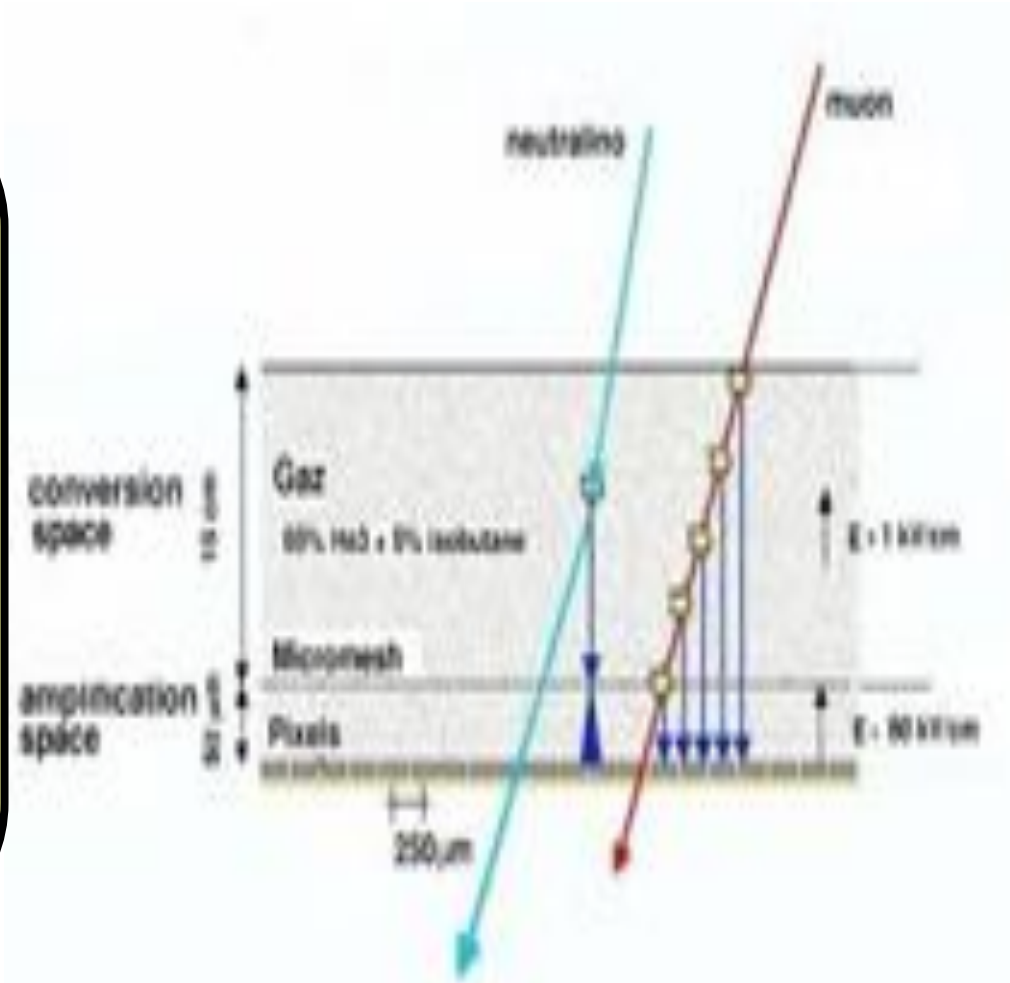


E. Moulin et al, PLB 614 (2005)143

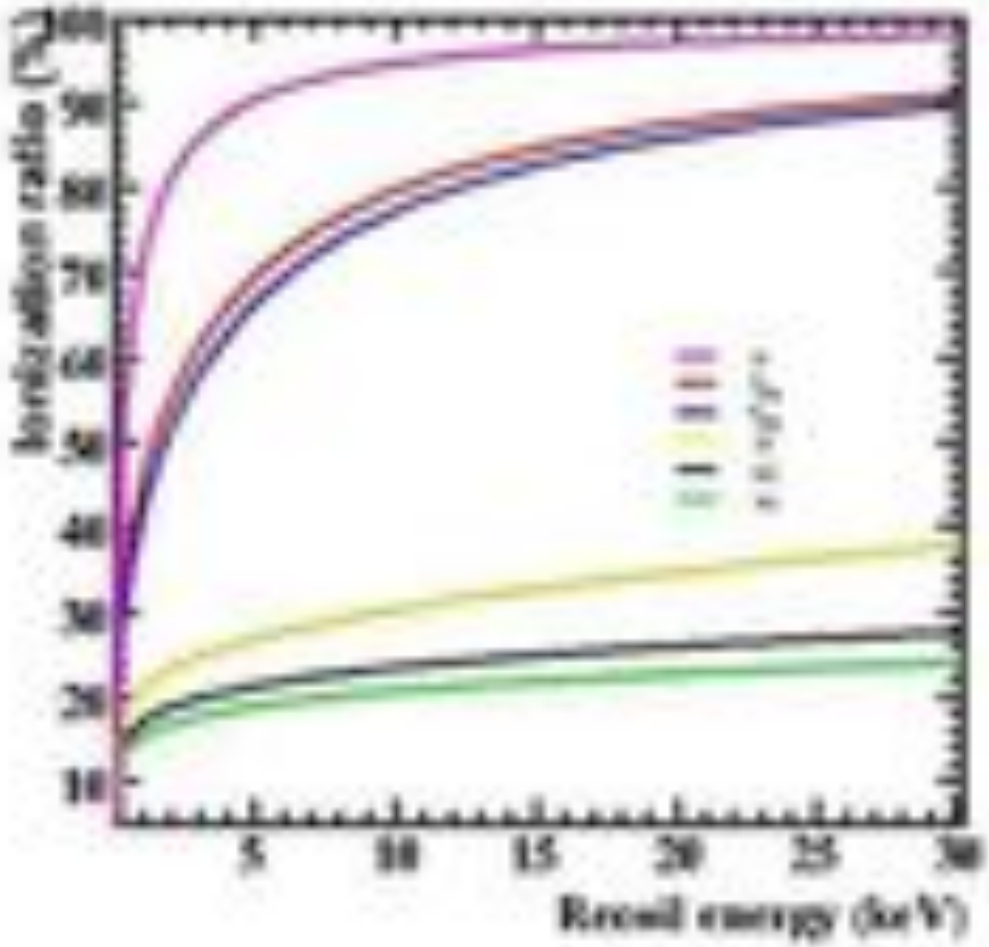
MIMAC-He3:
(Micro-tpc MAtrix of Chambers of He 3)

{ spatial
temporal } resolution
energetic

⇒ recoil track
⇒ energy threshold ~ 200eV
⇒ electron/recoil discrimination



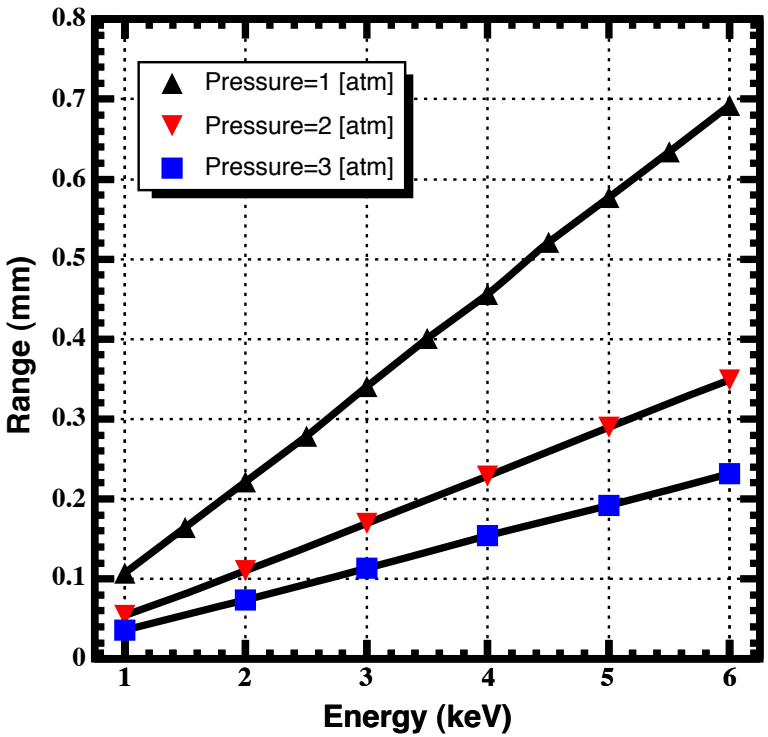
Quenching factor calculation
(Lindhard theory)



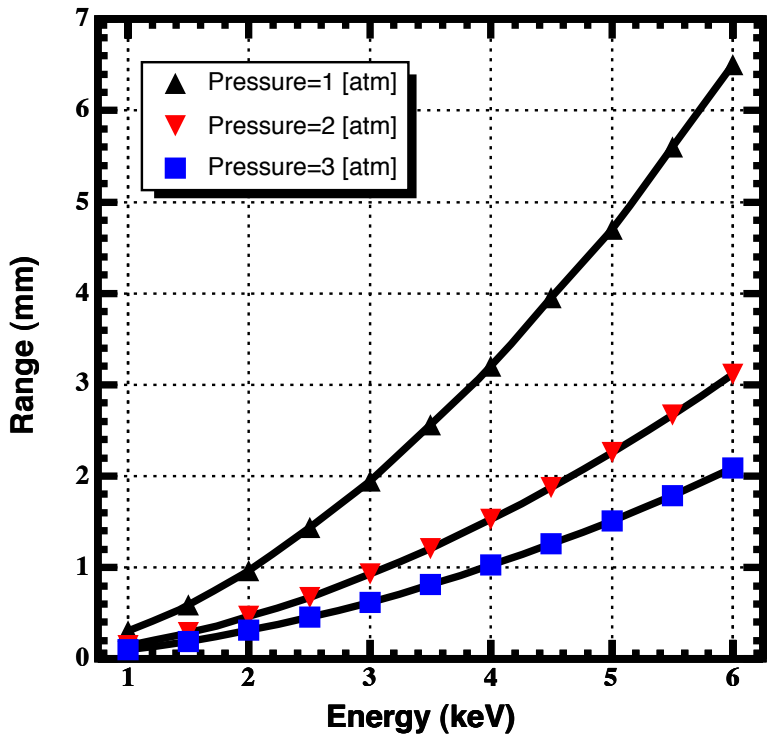
F. Mayet (2006)

Range vs. Energy

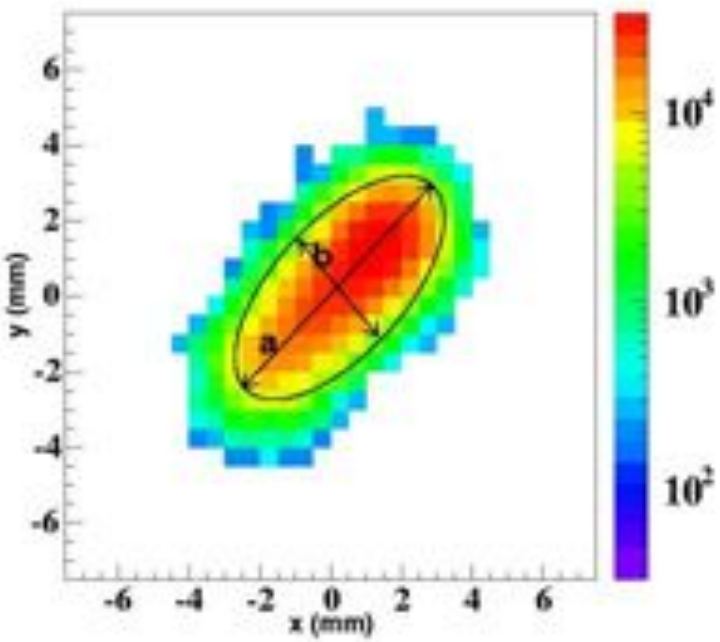
He3 recoils

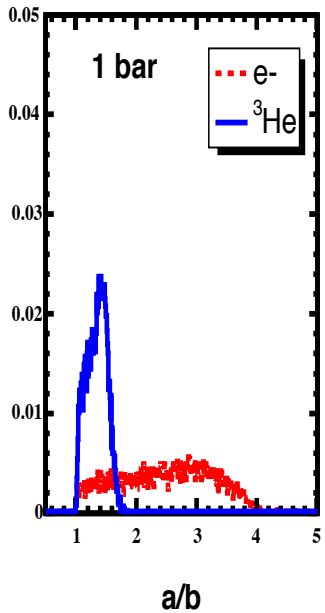


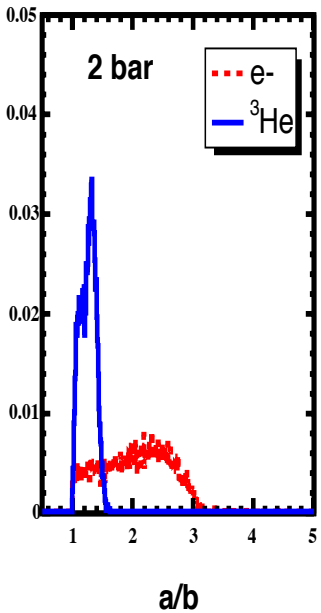
Electrons

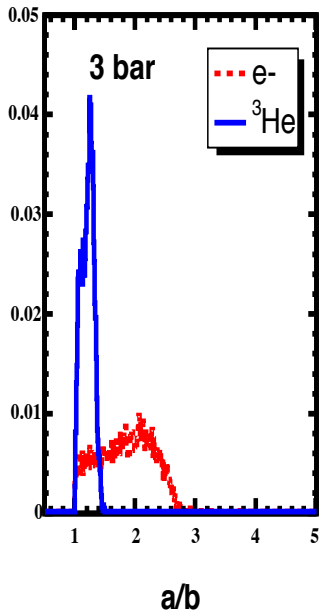


a/b ratio = f (pressure)
L~10 cm

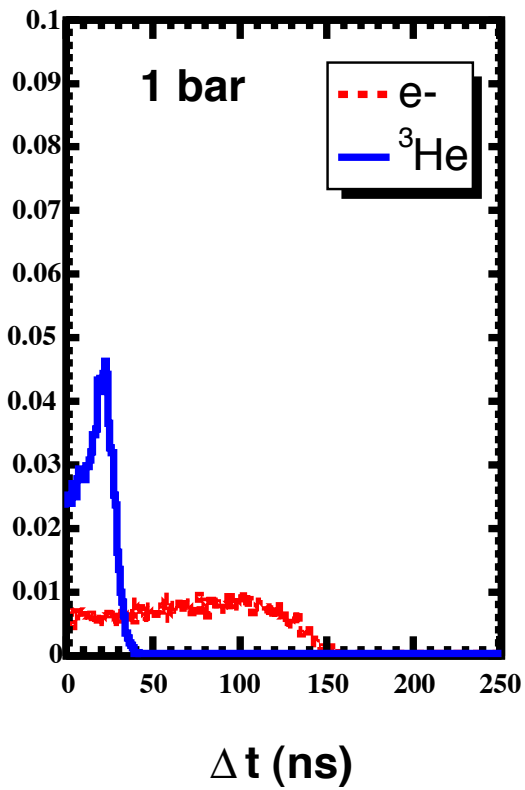


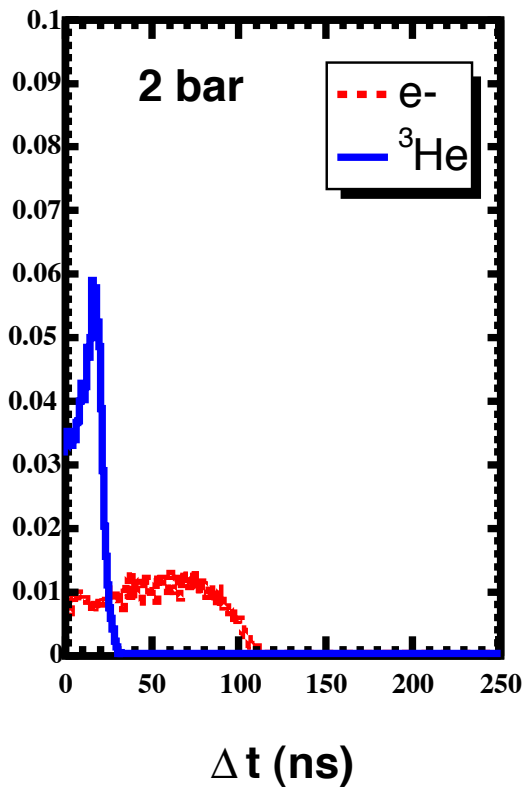


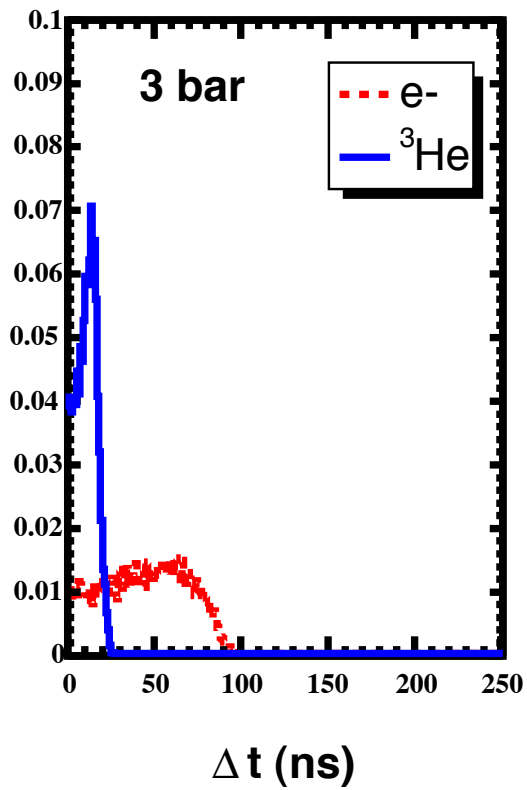




Time collection = f(pressure)

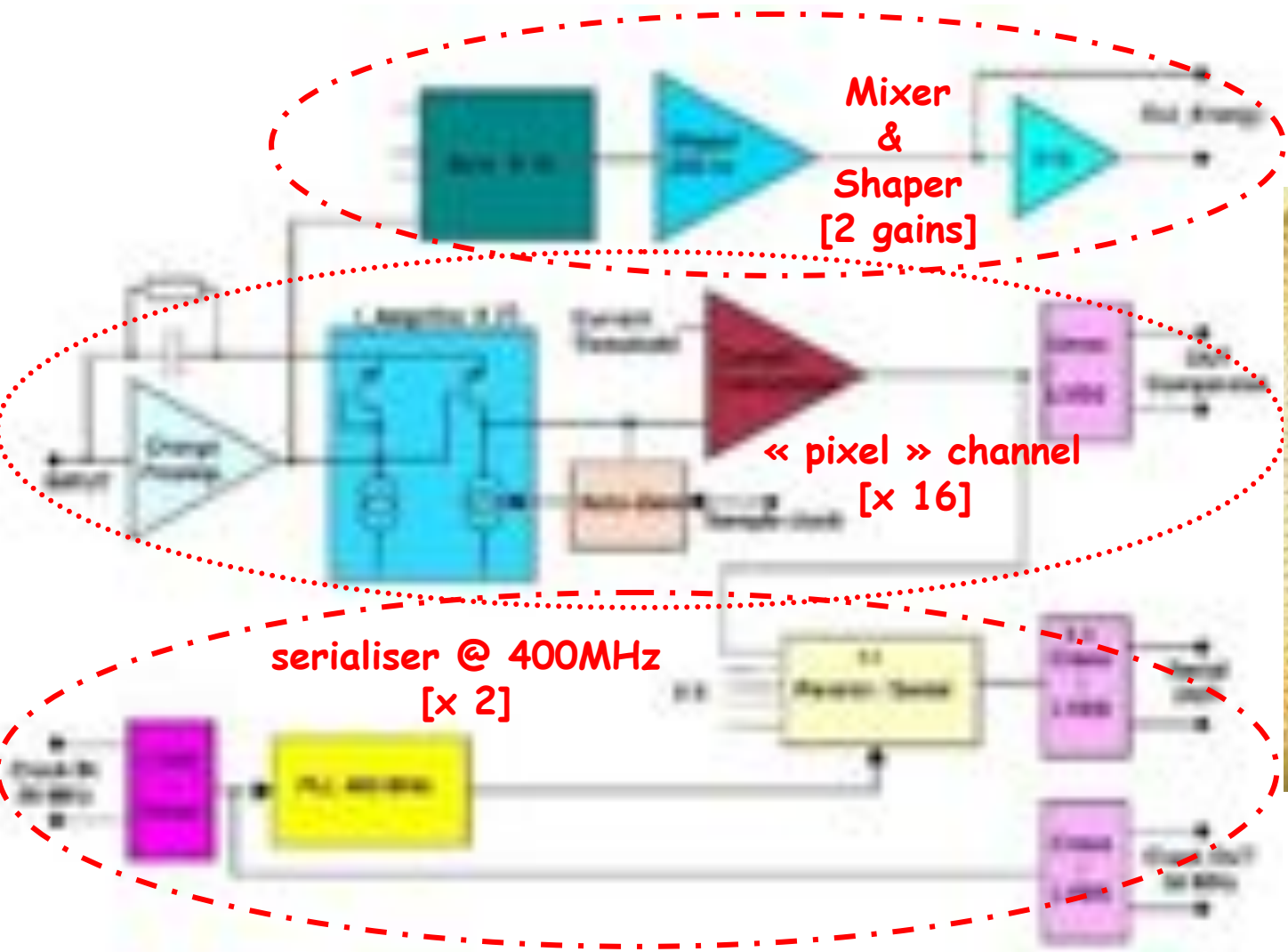






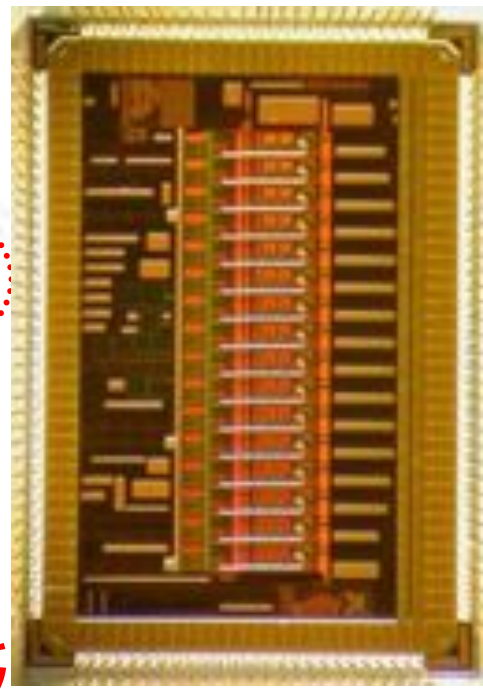
ASIC MIMAC

16 « pixel » channels + mixer & shaper [energy] + double serialiser

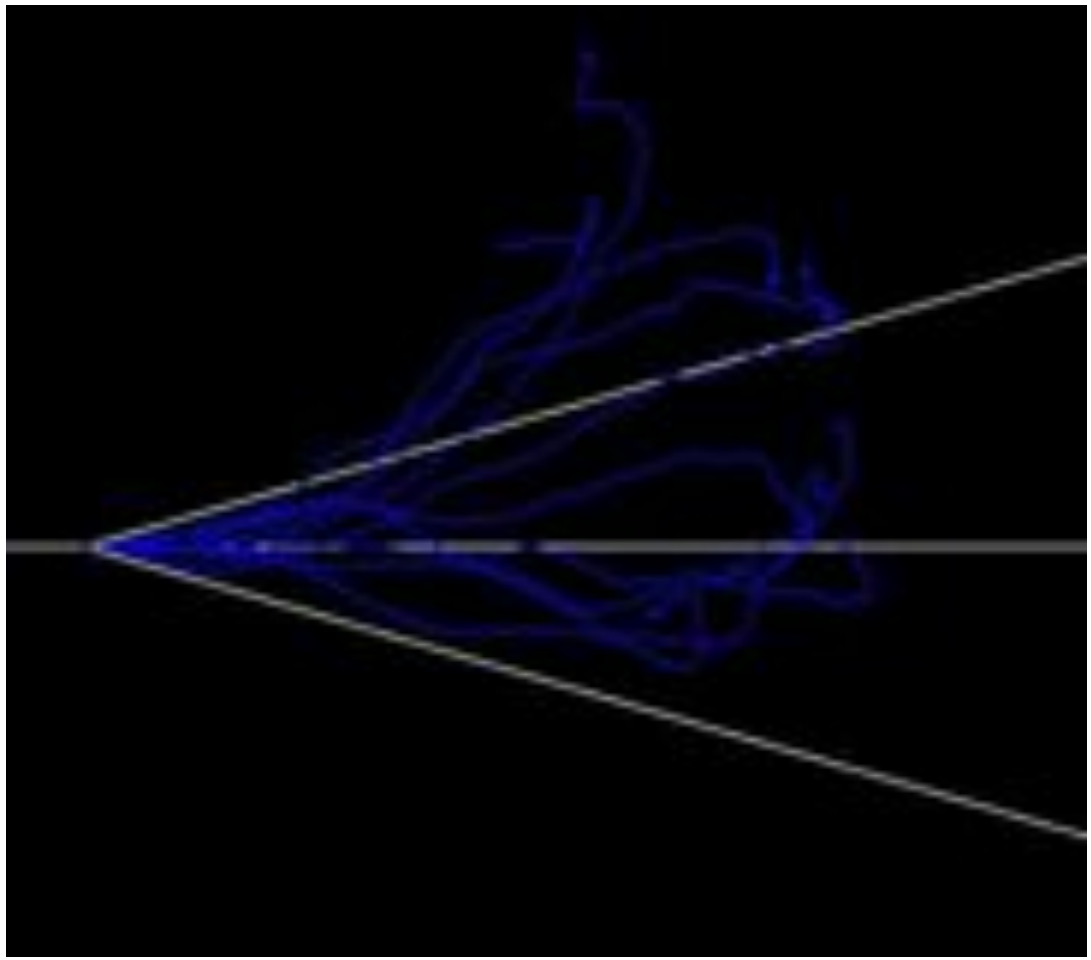


Process

BiCMOS-SiGe 0.35µm

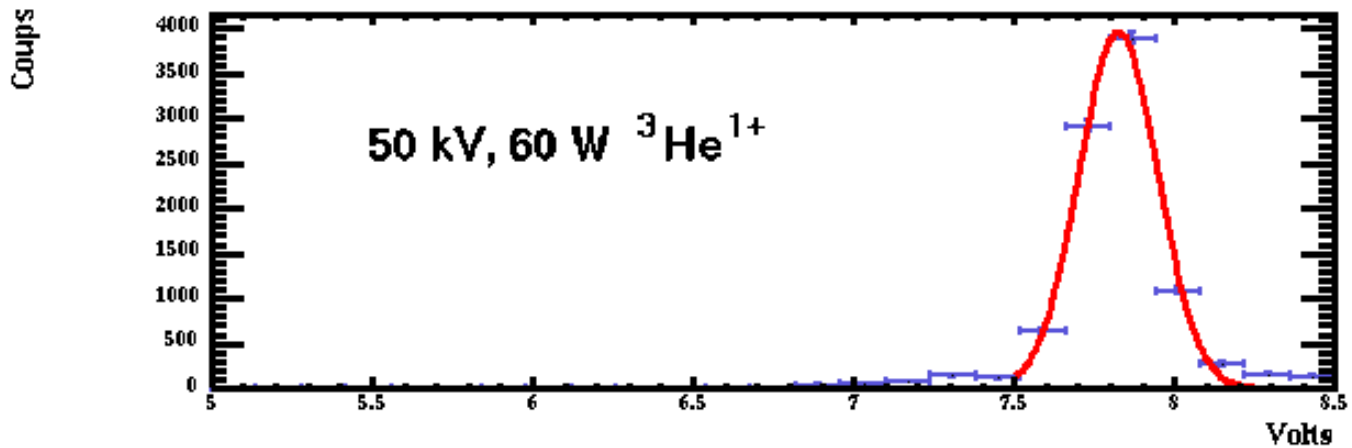


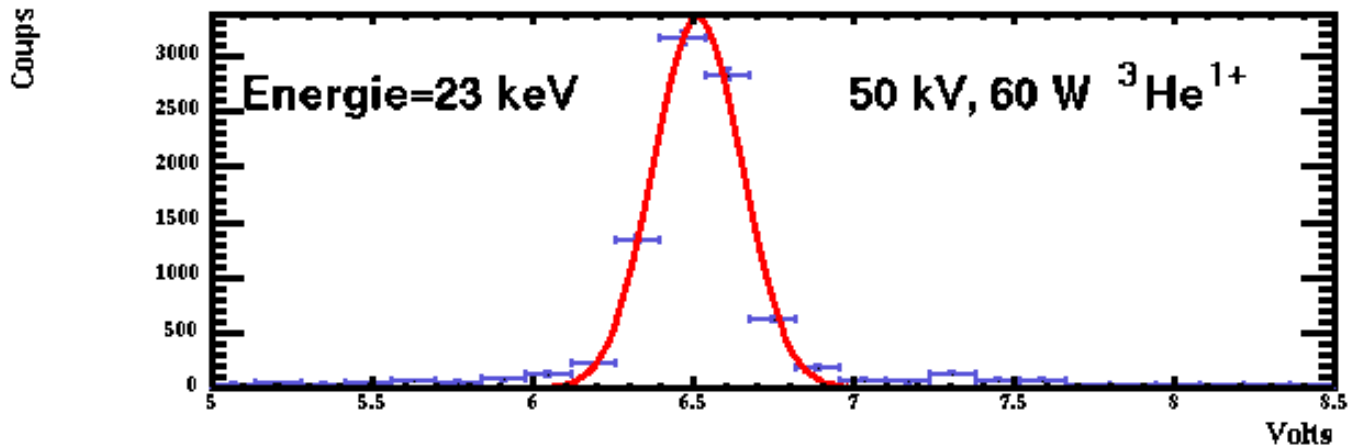
^{4}He (6 keV) in ^{4}He (100mbar)
range ~ 4mm



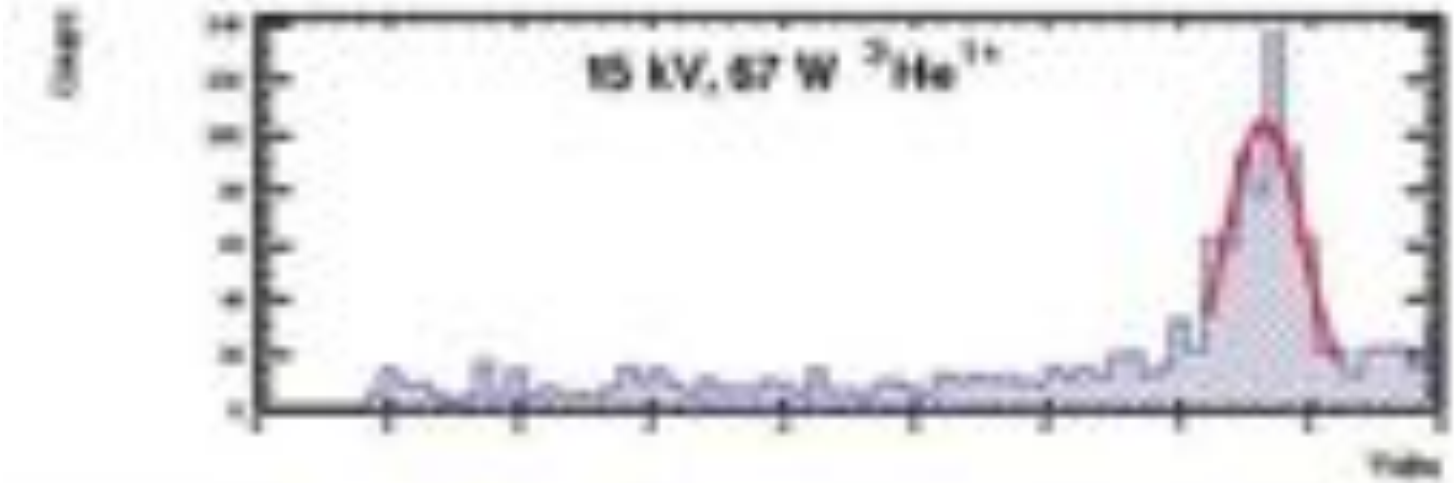
Source ^{3}He, ^{4}He, ^{1}H, (…)
(LPSC-Grenoble)

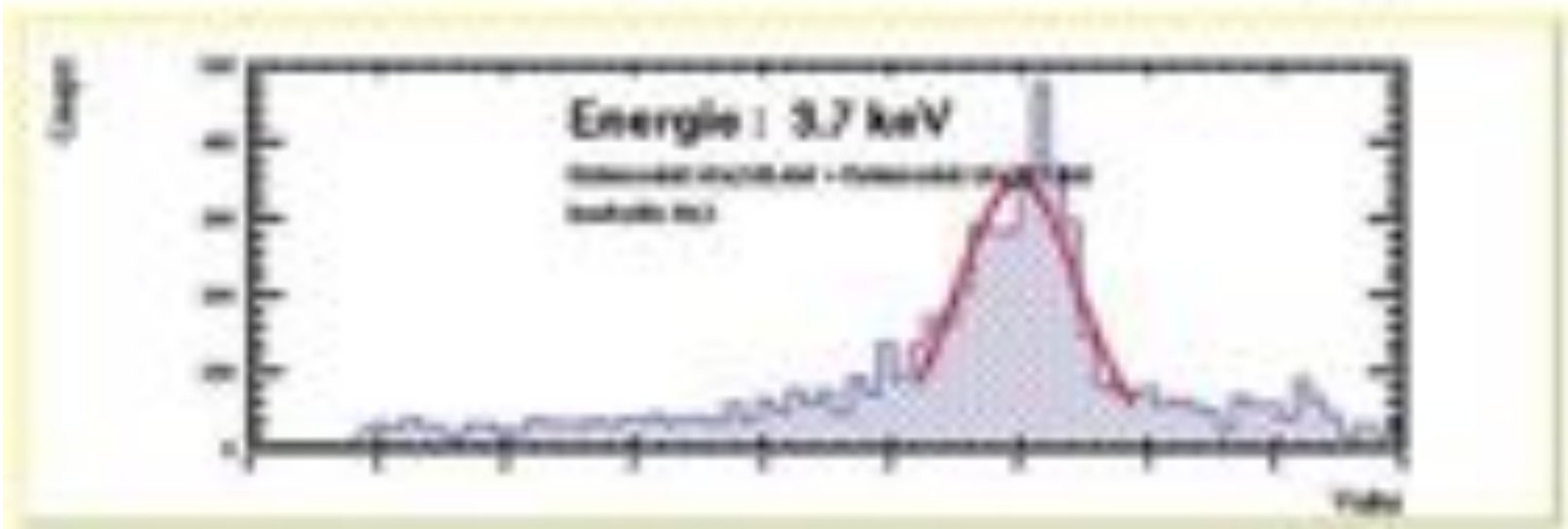
Time of flight measurement of the ion coming out of the MIMAC source at 50 kV

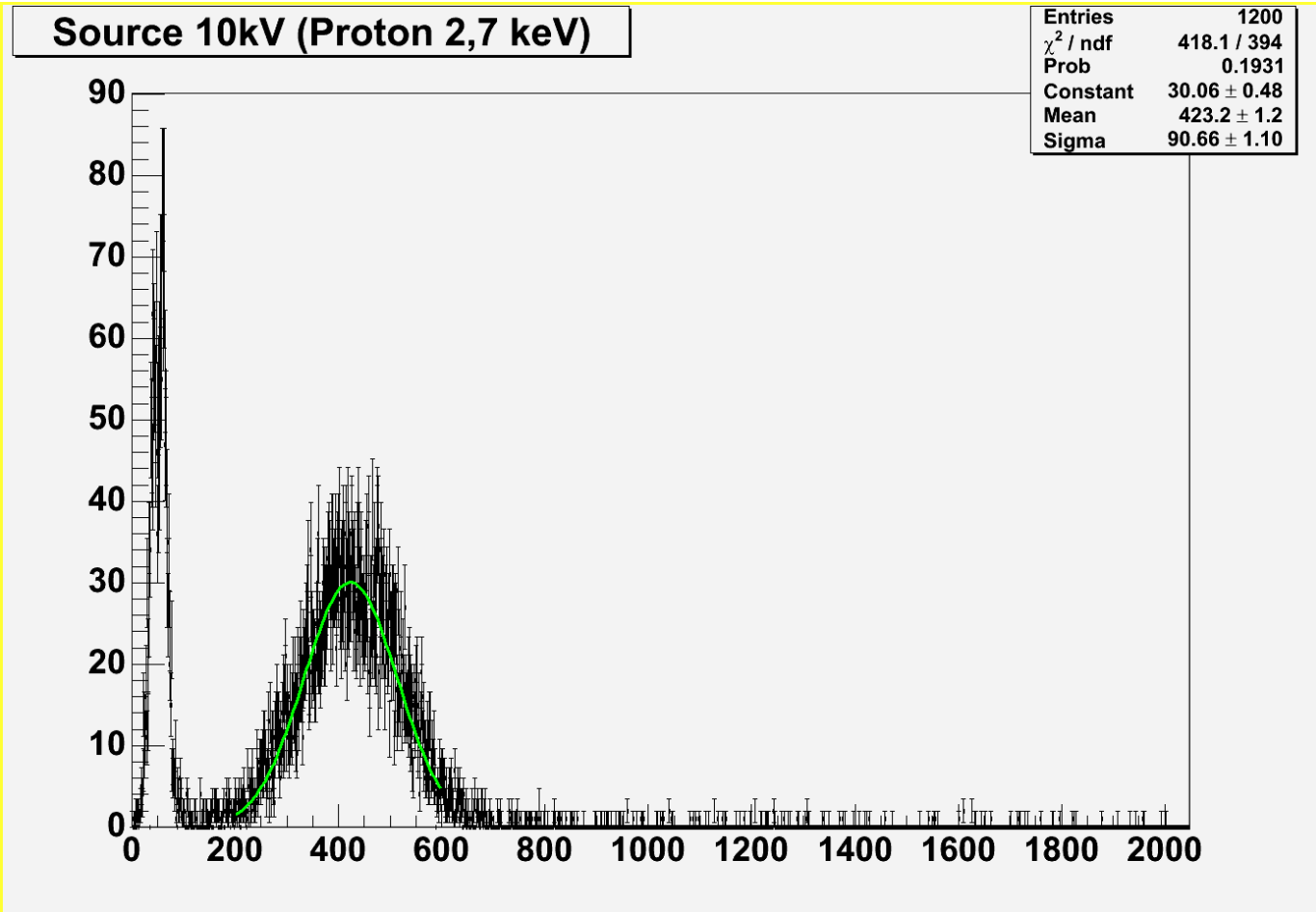




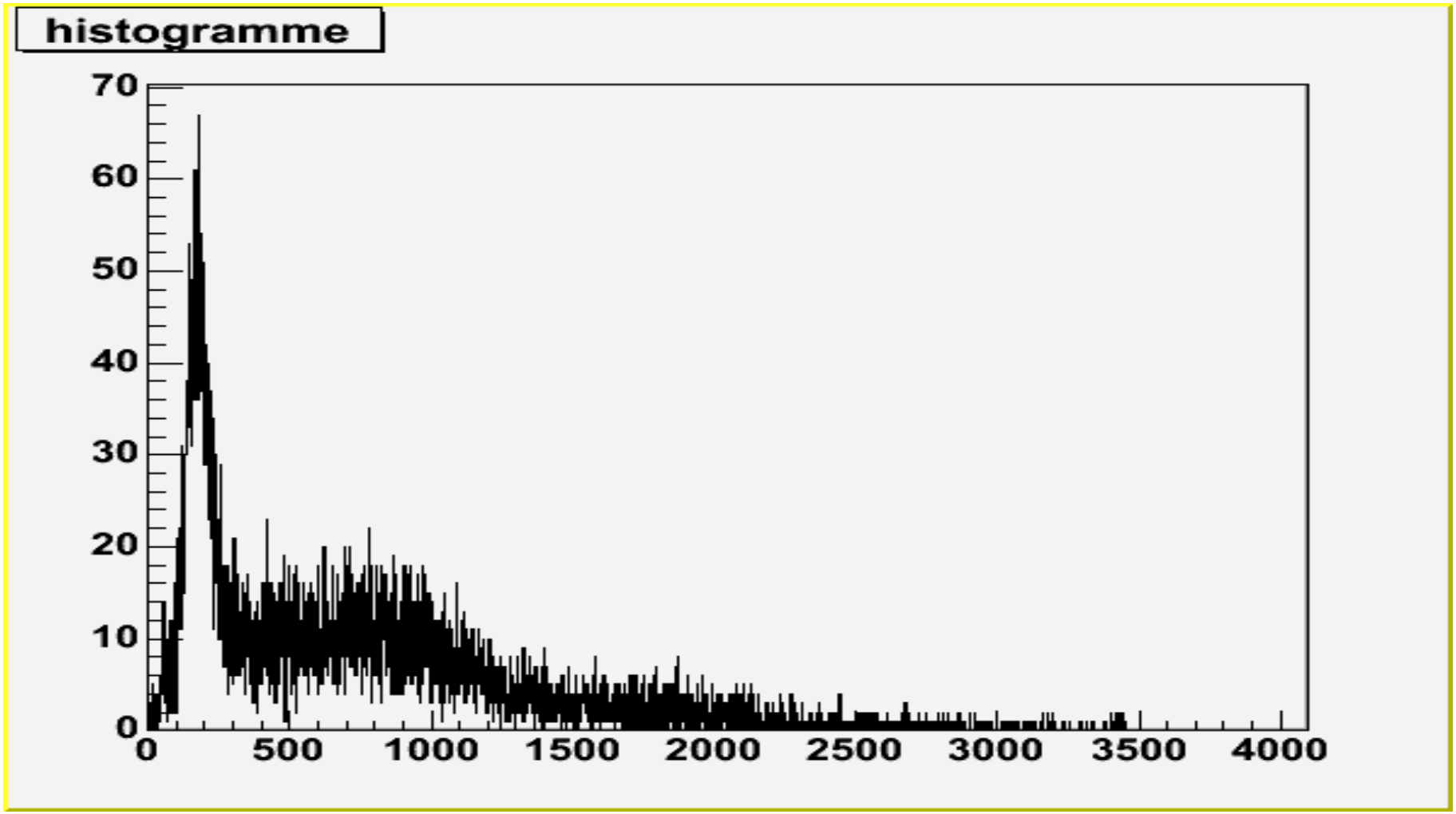
He3 -TOF measurement



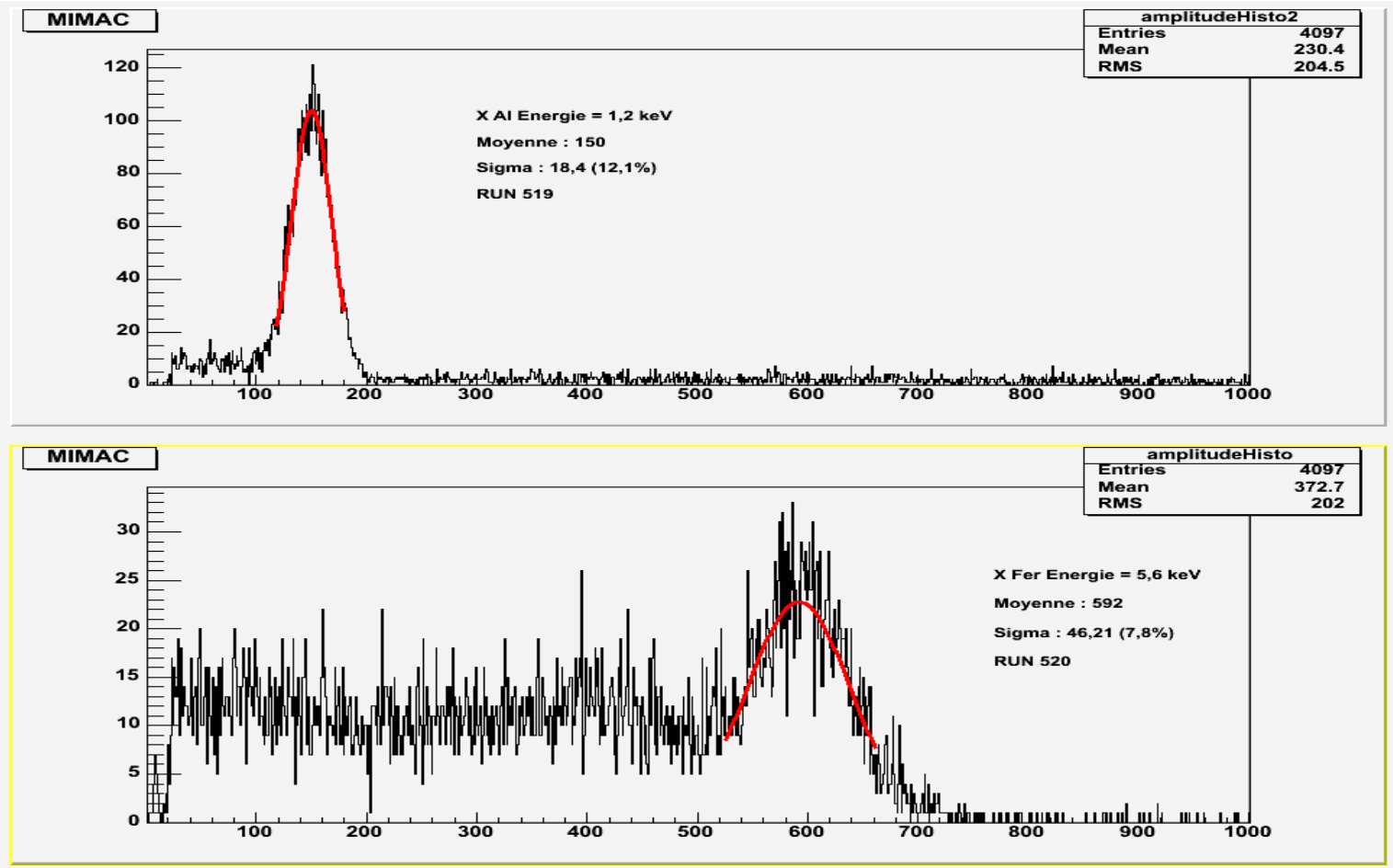



Source 10kV (Proton 2,7 keV)
Entries 1200
χ^2 / ndf 418.1 / 394
Prob 0.1931
Constant 30.06 ± 0.48
Mean 423.2 ± 1.2
Sigma 90.66 ± 1.10
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000

He3 (1.1 keV) + e^- (Co57)



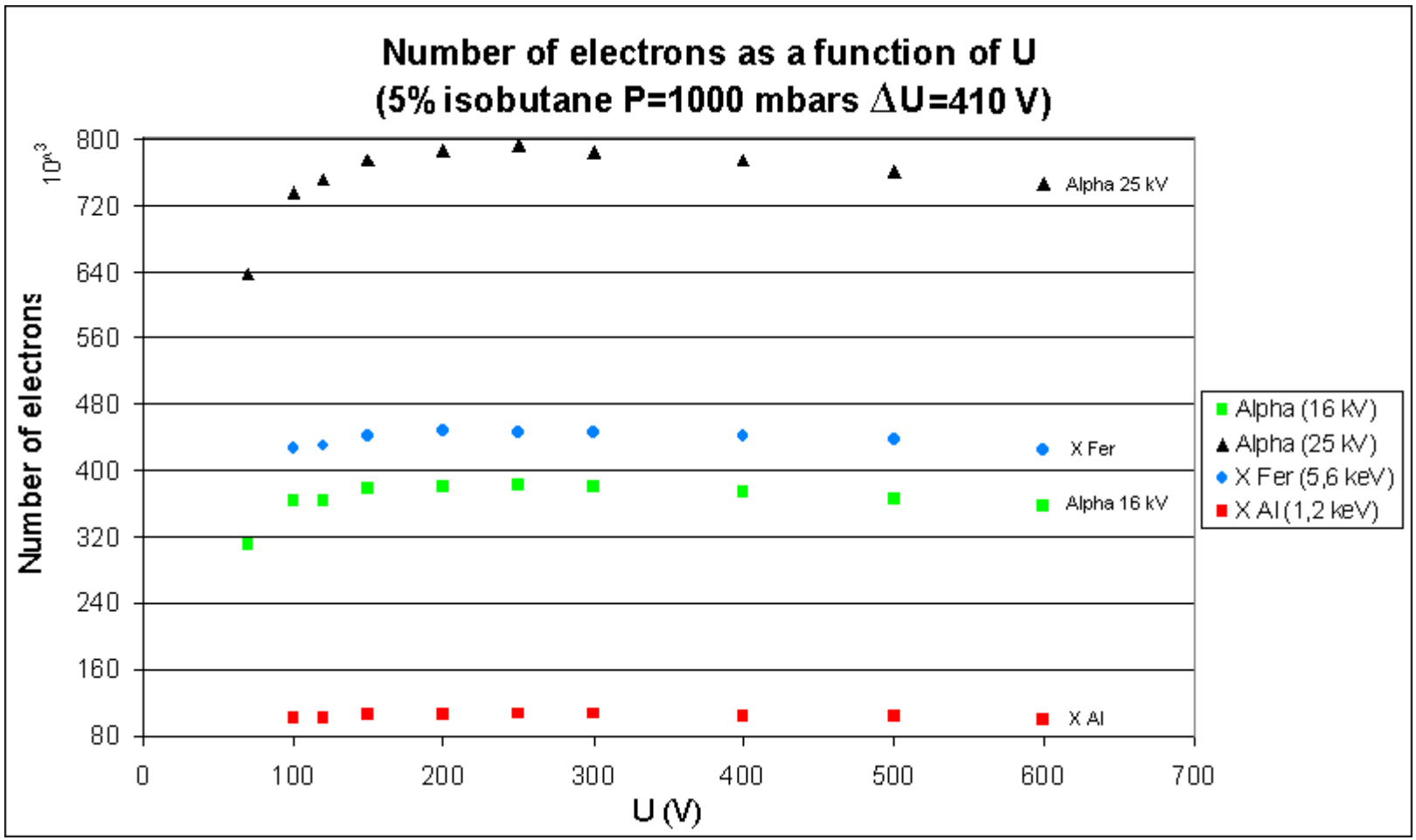
X-rays (e^-) detection : 1.5 keV and 5.9 keV in ^{4}He



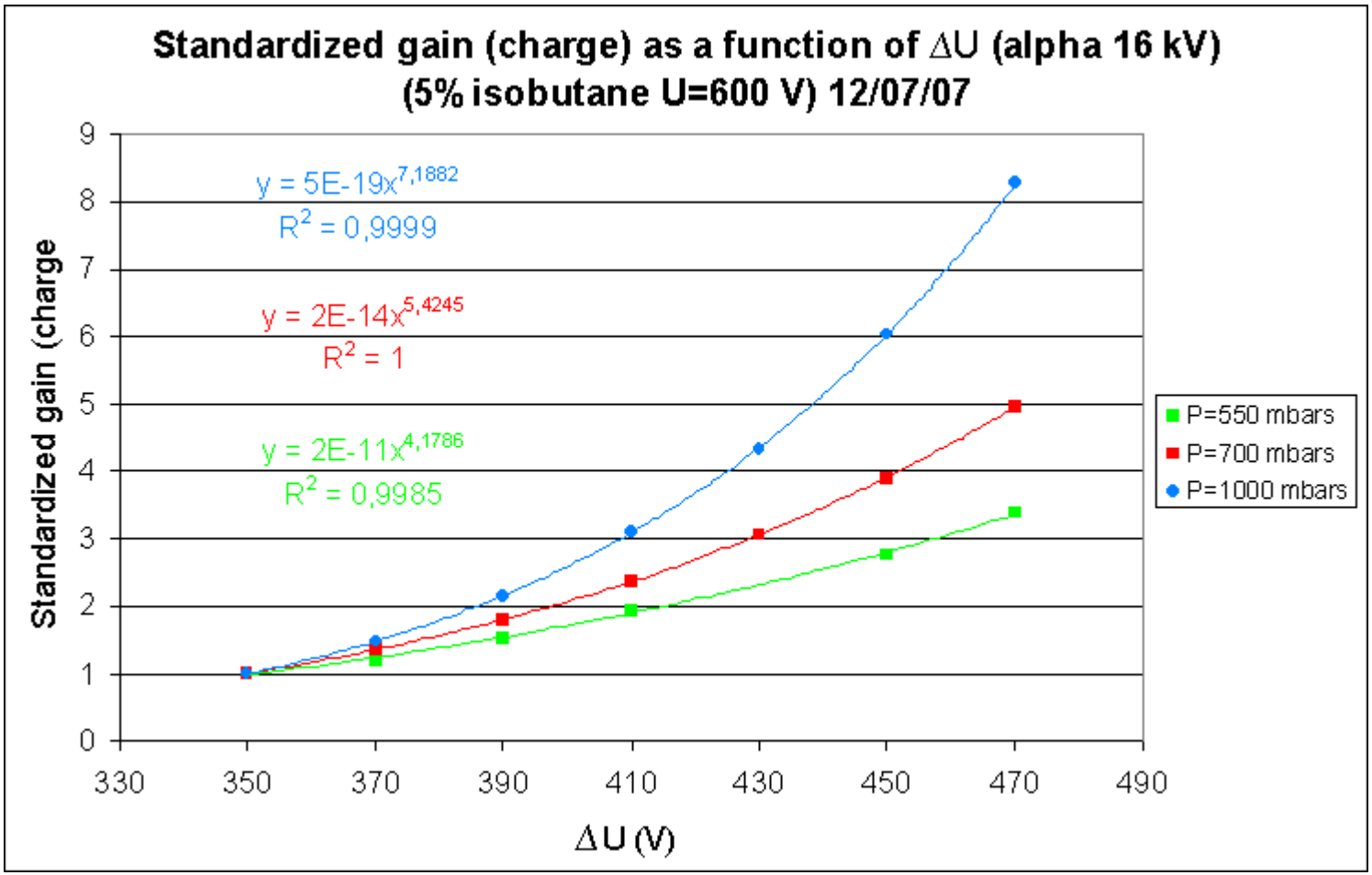
Boulby (U.K.), July 23rd 2007

D. Santos

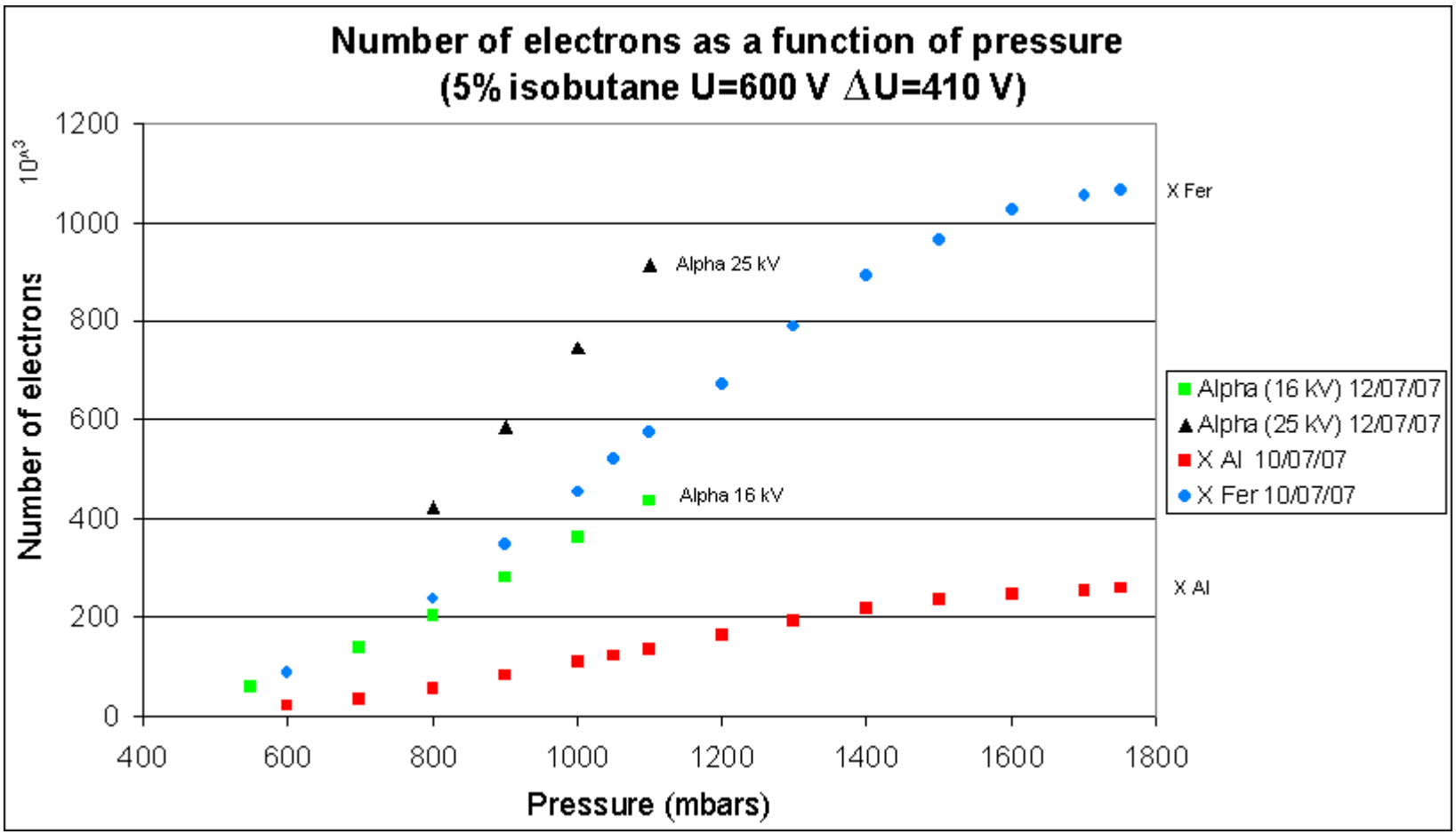
Ionization energy measured as a function of the Mesh voltage (drift)



Gain as a function of anode voltage for different pressures (550,700, 1000 mbars)



Gain as a function of pressure



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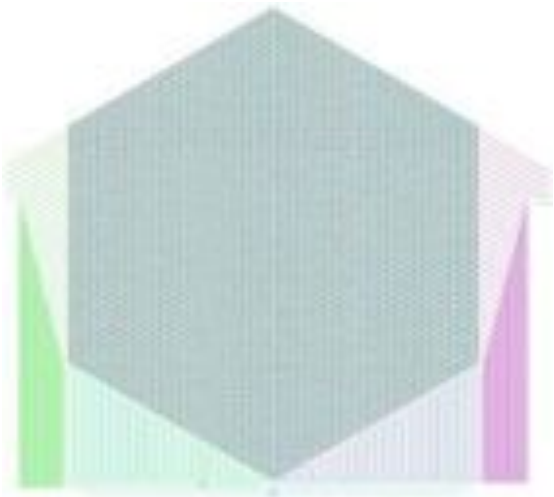
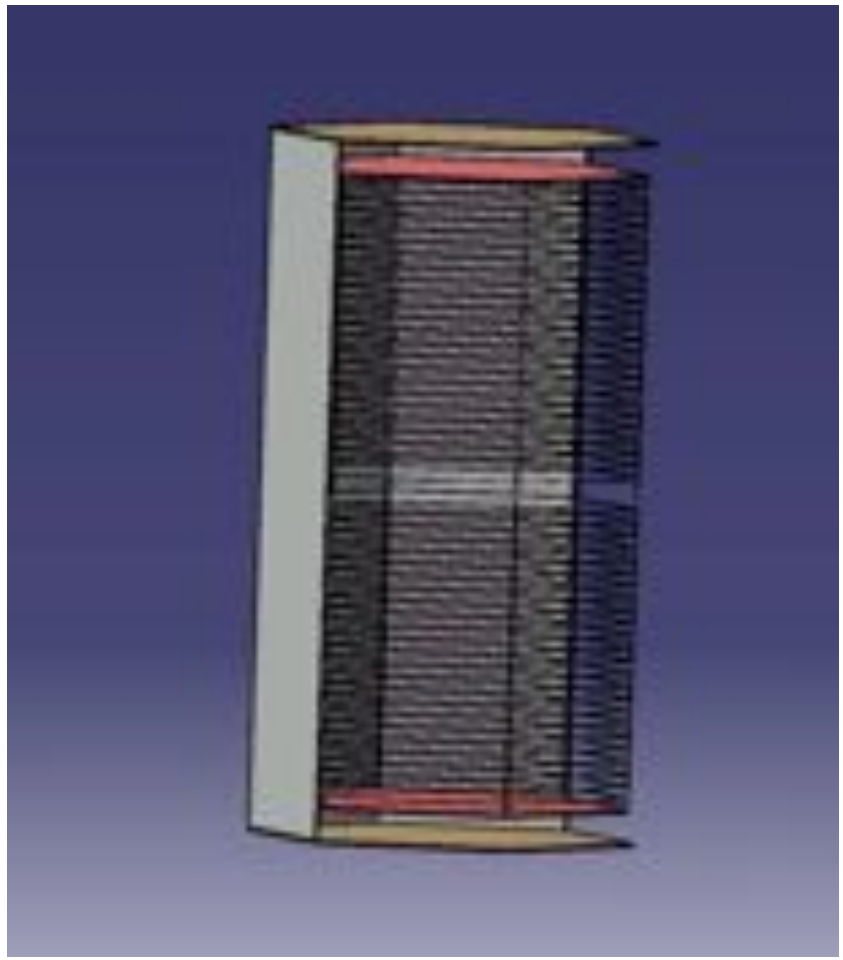
Hexagonal Module (bi-chamber)

Diameter : 30 cm
Chamber (vol) : 14.625 l





AMANDE facility (IRSN-LPSC collaboration) (to validate the recoil track measurements)

CYGNUS (DRIFT + MIMAC+…) Grenoble-Saclay-Sheffield-Zaragoza-…

- Common interest in the definition of a Large TPC for non-baryonic dark matter
- Common efforts in:
  - simulation studies
  - read-out electronics
  - optimization of micromegas detector (100 mb up to 2000 mb)
  - Pixellized anode design