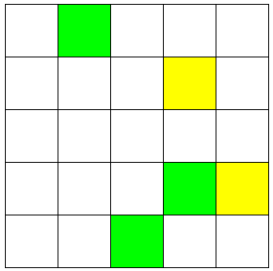


MIMAC

MIcro-tpc MAtrix of Chambers

A Large TPC for directional non baryonic Dark Matter detection

Daniel Santos

Laboratoire de Physique Subatomique et de Cosmologie

(LPSC-Grenoble)

(UJF Grenoble 1 -CNRS/IN2P3-INPG)

MIMAC:
(MIcro-tpc MAtrix of Chambers)

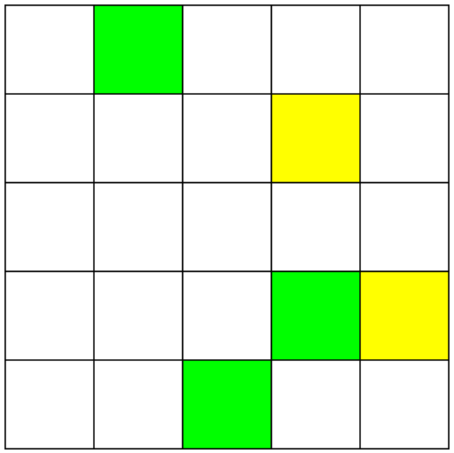
LPSC (Grenoble) : J. Lamblin, F. Mayet , D. Santos
J. Billard (Ph.D) (left in July 2012**), Q. Riffard (Ph.D)** (started in October 2012)

Technical Coordination :	**O. Guillaudin**
- Electronics :	**G. Bosson, O.Bourrion, J-P. Richer**
- Gas detector :	**O. Guillaudin, A. Pellisier**
- Data Acquisition:	**O. Bourrion**
- Mechanical Structure :	**Ch. Fourel, S. Roudier, M. Marton**
- Ion source (quenching) :	**P. Sortais, J-F. Muraz**

CEA-Saclay (IRFU): I. Giomataris, E. Ferrer (micromegas detectors)
Joined in 2012:
CCPM (Marseille): J. Busto, Ch. Tao, D. Fouchez, J. Brunner (Radon filtering)

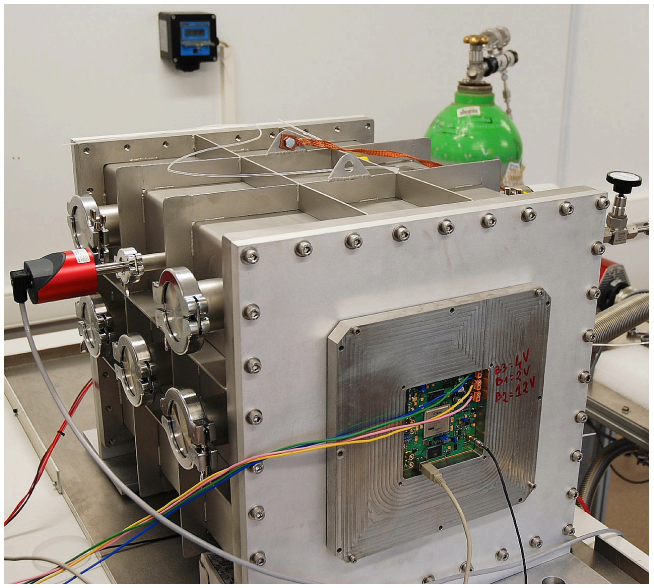
Neutron facility (AMANDE) :
IRSN (Cadarache): L. Lebreton, D. Maire (Ph. D.), J. Médard (CDD-1year)

The MIMAC project



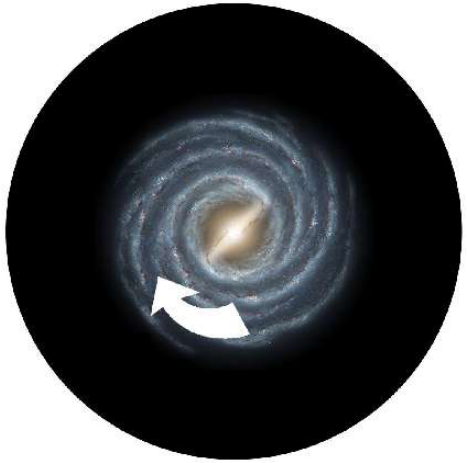
A low pressure multi-chamber detector

- Energy and 3D Track measurements
- Matrix of chambers (correlation)
- µTPC : Micromegas technology
- CF_4, CHF_3, and ^1H : σ(A) dependancy
- Axial and scalar weak interaction
- **Directionnal detector**



Bi-chamber module
2 x (11x11x25 cm^3)

Strategy:
- direct detection
- Energy (Ionization) AND 3D-Track of the recoil nuclei
- Prove that the signal "comes from Cygnus constellation"

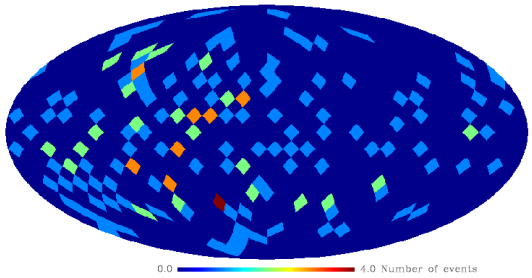


Phenomenology: Discovery

J. Billard *et al.*, PLB 2010
J. Billard *et al.*, arXiv:1110.6079

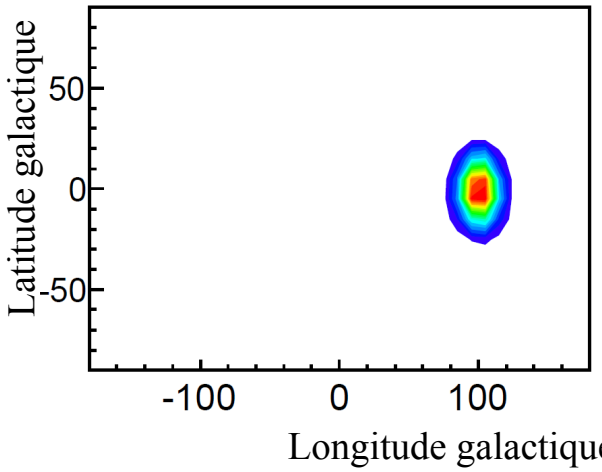
Proof of discovery: **Signal pointing toward the Cygnus constellation**

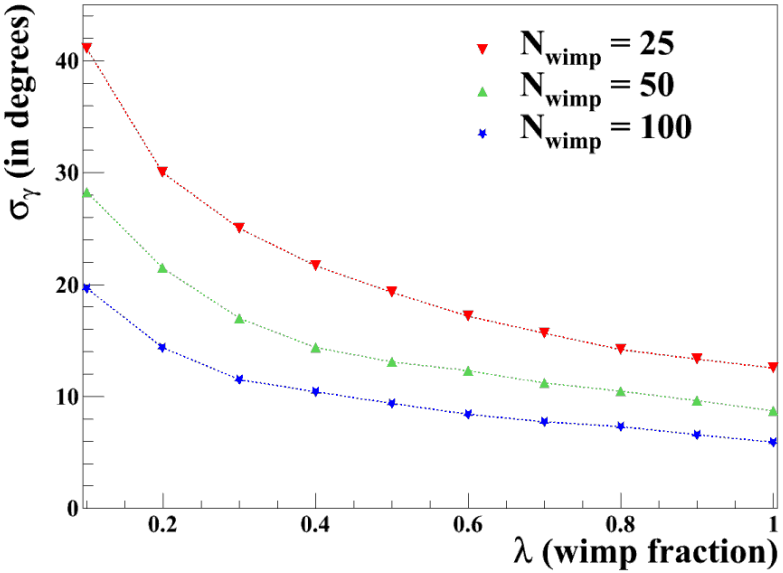
Blind likelihood analysis in order to establish the galactic origin of the signal



100 WIMP + 100 BKG

$$\mathscr{L}(\ell, b, m_\chi, \lambda)$$





Strong correlation with the direction of the Constellation Cygnus even with a large background contamination

Phenomenology: Identification

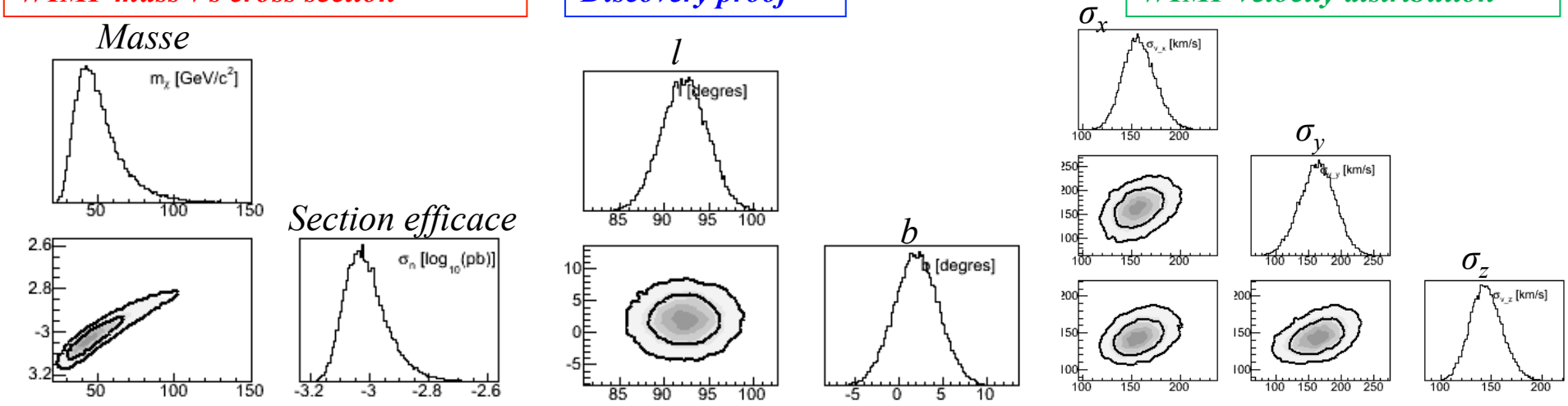
J. Billard *et al.*, PRD 2011

The eight parameters are strongly constrained with only one directional data set.

WIMP mass Vs cross section

Discovery proof

WIMP velocity distribution



	m_χ (GeV/c^2)	$\log_{10}(\sigma_n$ (pb)	$\ell_\odot$ (°)	$b_\odot$ (°)	σ_x (km.s^{-1})	σ_y (km.s^{-1})	σ_z (km.s^{-1})	β	R_b (kg^{-1}year^{-1})
Input	50	-3	90	0	155	155	155	0	10
Output	$51.8^{+5.6}_{-19.4}$	$-3.01^{+0.05}_{-0.08}$	$92.2^{+2.5}_{-2.5}$	$2.0^{+2.5}_{-2.5}$	158^{+15}_{-17}	164^{+27}_{-26}	145^{+14}_{-17}	$-0.073^{+0.29}_{-0.18}$	10.97 ± 1.2

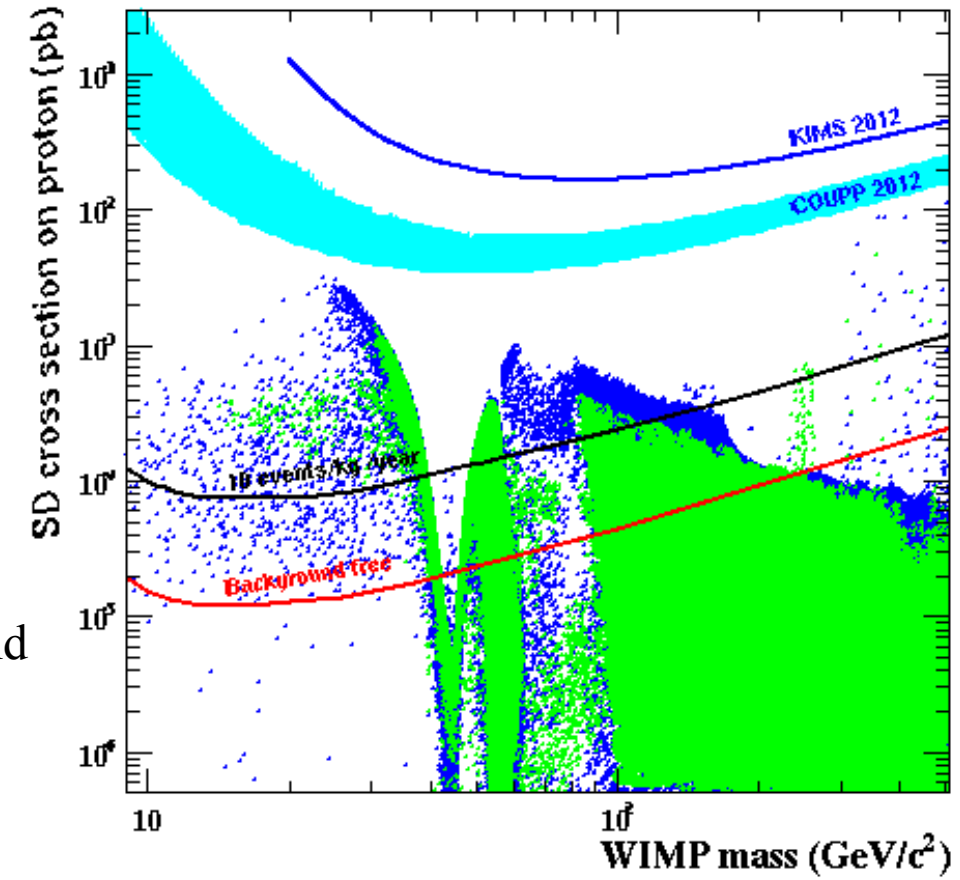
MIMAC Phenomenology: Discovery

Estimation of the discovery potential

MSSM
NMSSM
} *D. Albornoz-Vasquez et al.*, ***PRD 85***

MIMAC characteristics
-10 kg CF_4
- DAQ : 3 years
- Recoil energy range [5, 50] keV

Discovery at 3σ
- With BKG (300)
- Without BKG



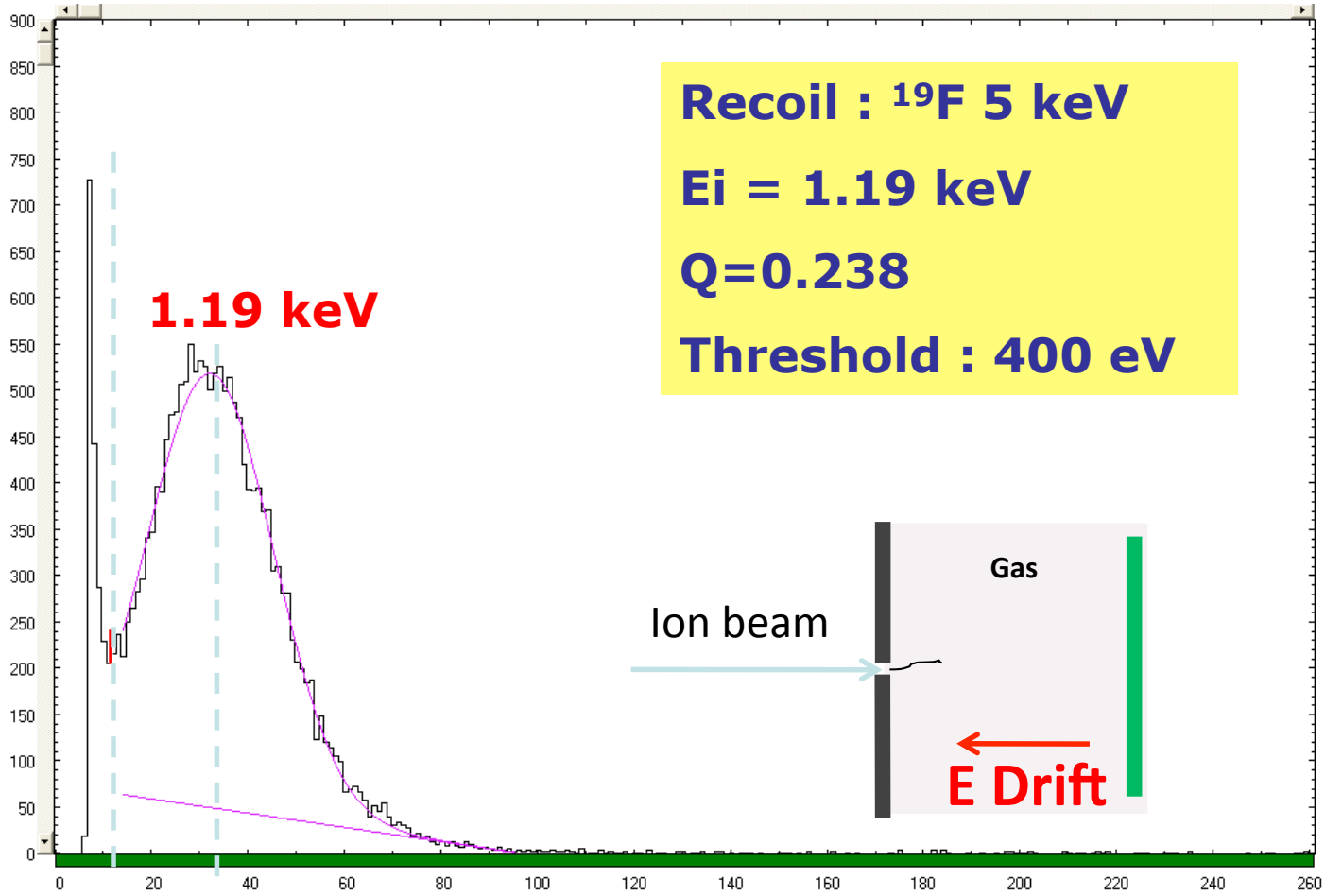
→ Even with a large number of background events, discovery is still possible

→ Only low number of WIMP events are required at low masses

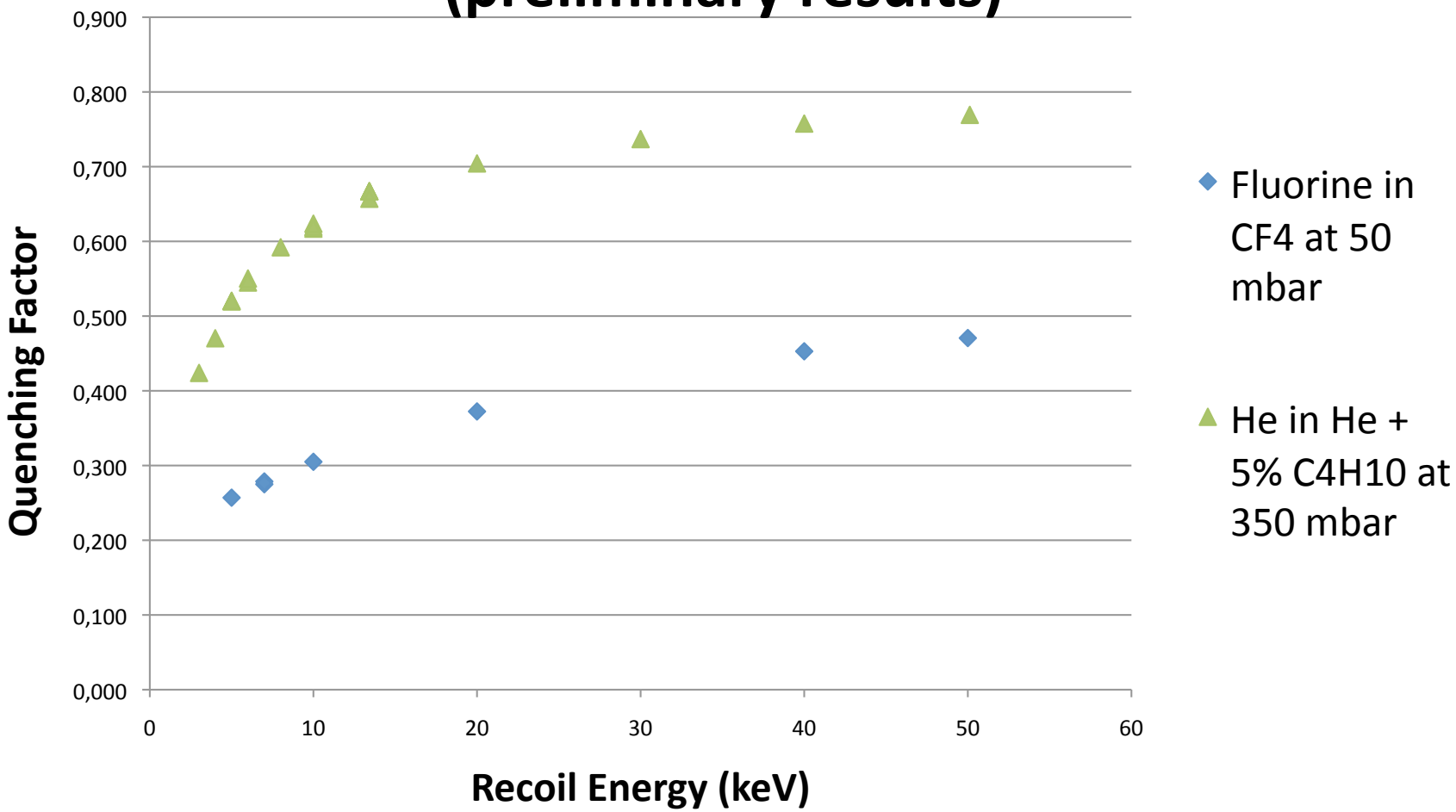
→ ***A discovery (>3σ@90%CL) with BKG*** is possible down to ***10^{-3}-10^{-4} pb***

Ionization Quenching Measurements: 5keV ^{19}F Recoil in 60 mbar

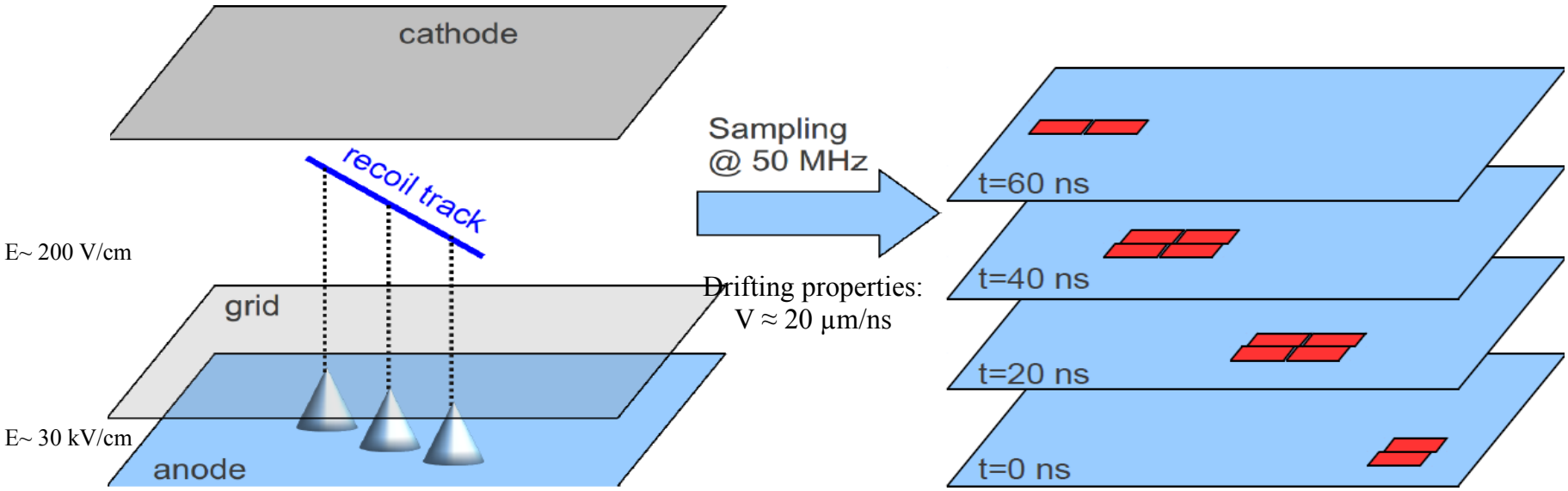
40mbar CF_4+16.8mbar CHF_3+1.2 mbar Isobutane



Ionization Quenching Factor for Fluorine in pure CF4 at 50 mbar (preliminary results)



MIMAC: Detection strategy

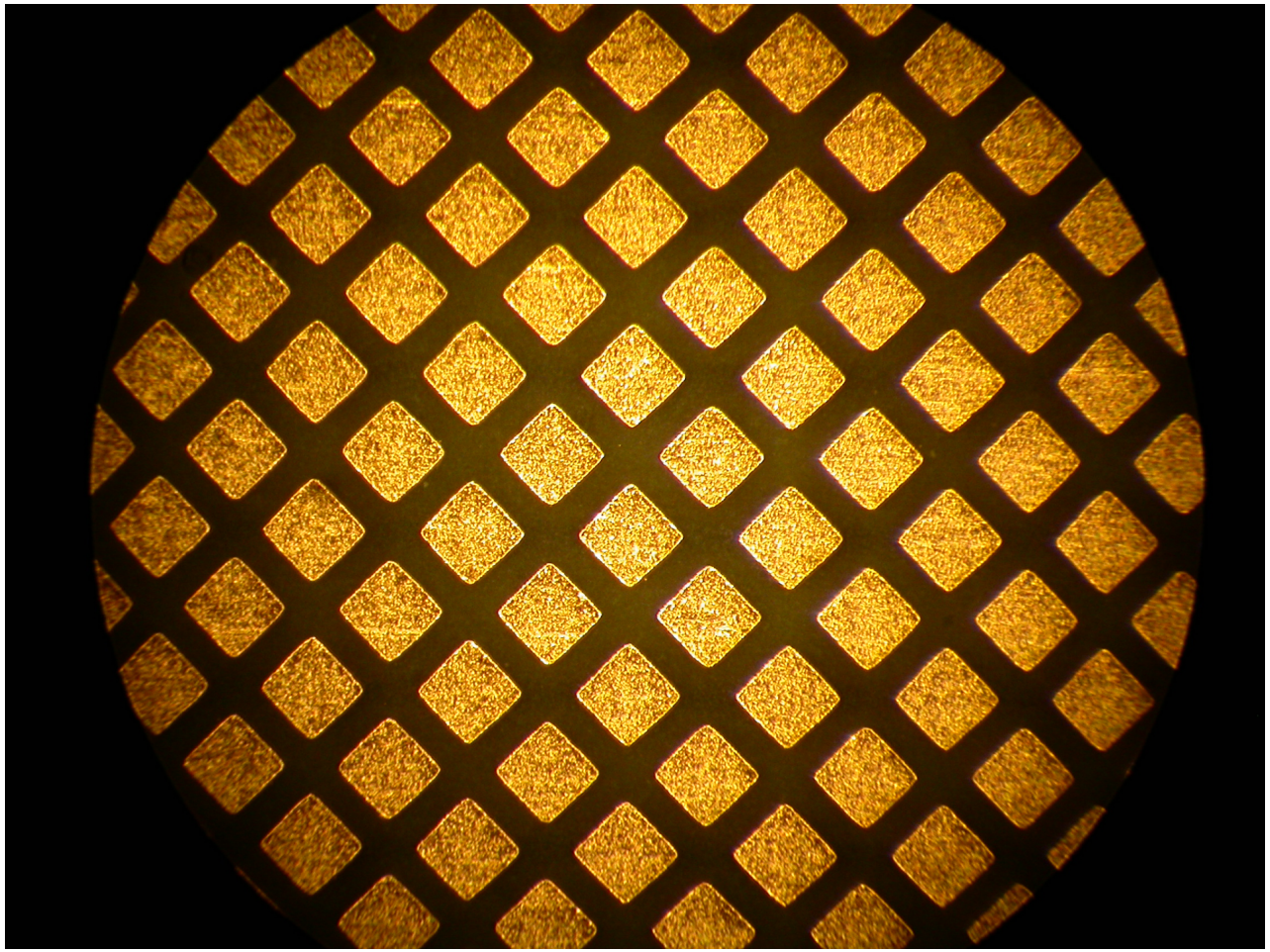


Scheme of a MIMAC µTPC

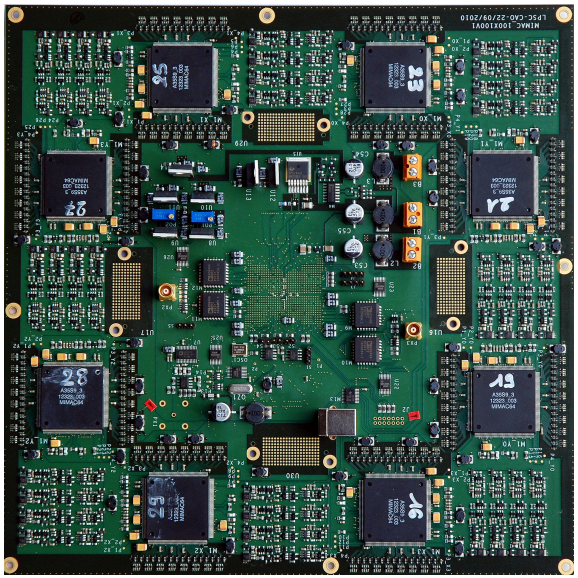
Evolution of the collected charges on the anode

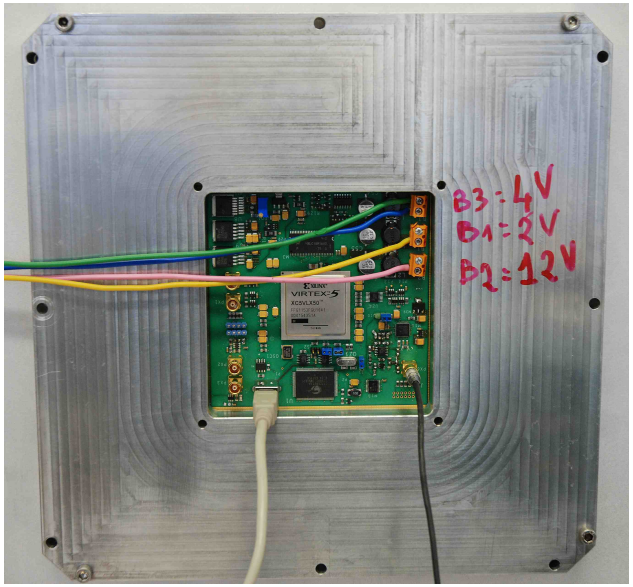
Measurement of the ionization energy: Charge integrator connected to the grid

MIMAC 100x100 mm^2(v2)
(designed by IRFU- Saclay (France))



MIMAC electronics (512 channels)





Entirely developed (ASICs included) by the MIMAC team at the LPSC-Grenoble (France)

V1: 2007 (192 channels for the 3cm x3cm)
ASIC-Mimac (16 channels)

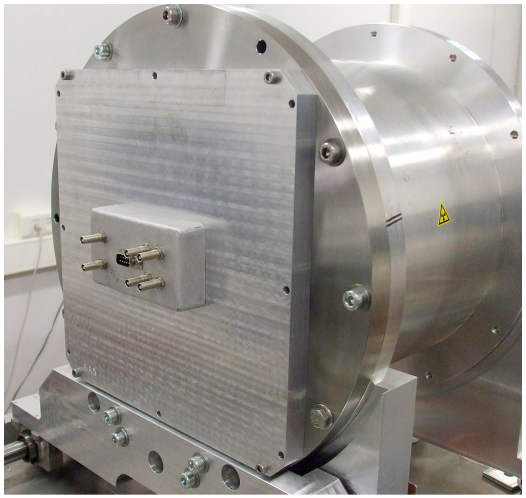
V2: 2009 (512 channels for the 10cmx10cm)
ASIC-Mimac (64 channels)

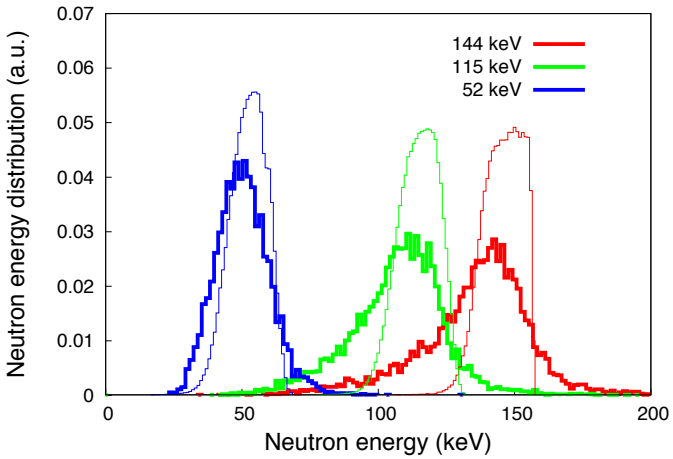
V3: 2011 (upgraged version) 512 channels

MIMAC : nuclear recoil track measurements

Amande facility @ IRSN Cadarache

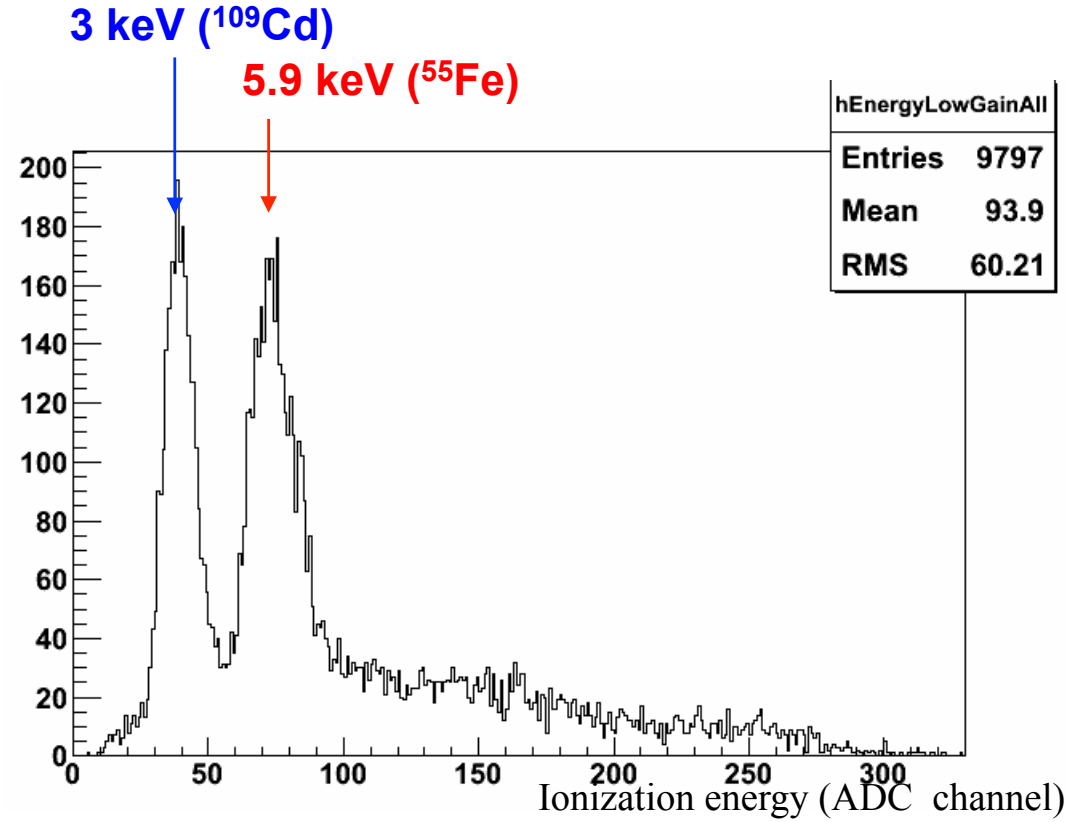
- Neutron field with energies down to a few keV





D. Santos (LPSC Grenoble)

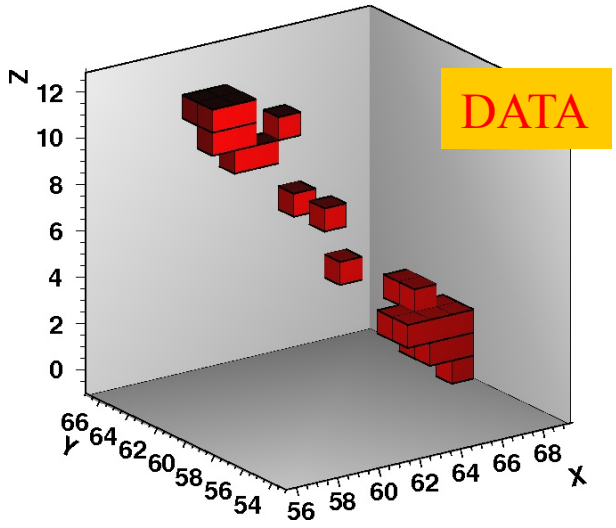
MIMAC: Performance at low energies



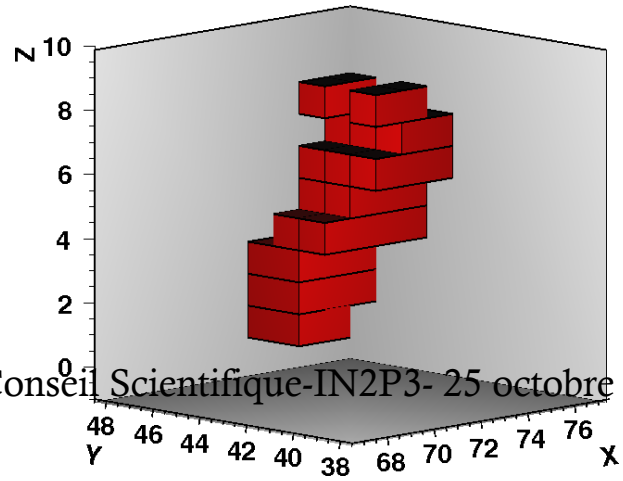
CF_4+ 28%CHF_3

(+2% C_4H_{10})

50 mbar



One electron track (6 keV)



Fluorine candidate
@ 50 keV ionization
Produced with a
monochromatic neutron
field (AMANDE)

D. Santos (LPSC Grenoble)

Recoils from 144 keV neutrons

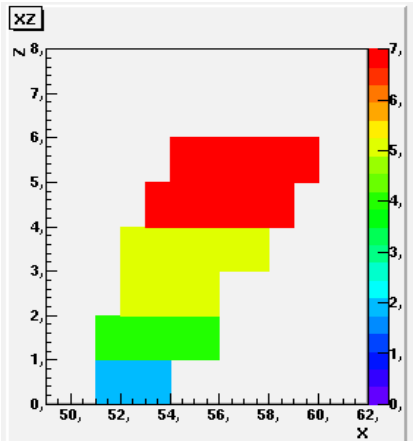
Pure isobutane

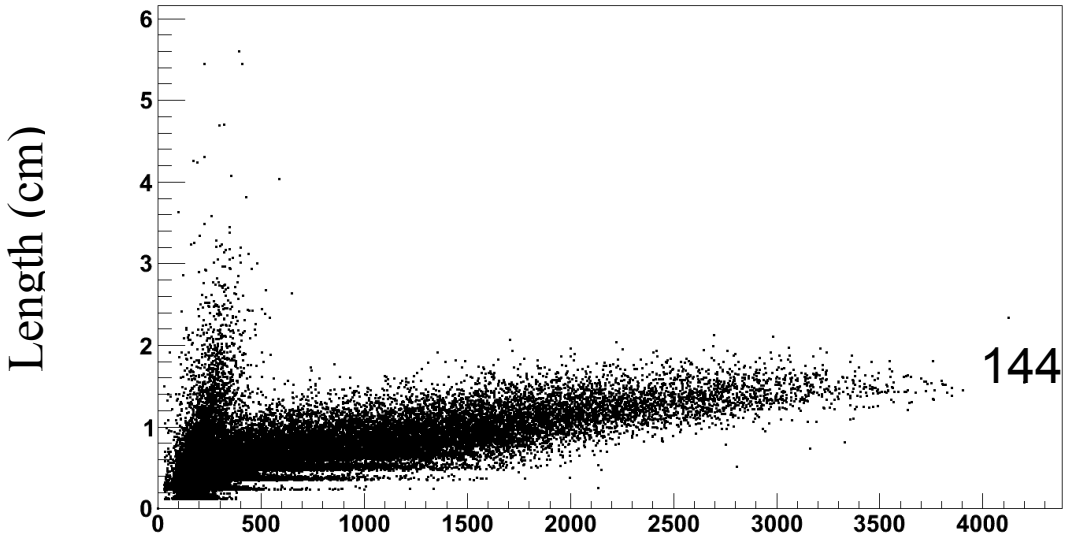
100 mbar

150 V/cm

Amande facility @ IRSN Cadarache

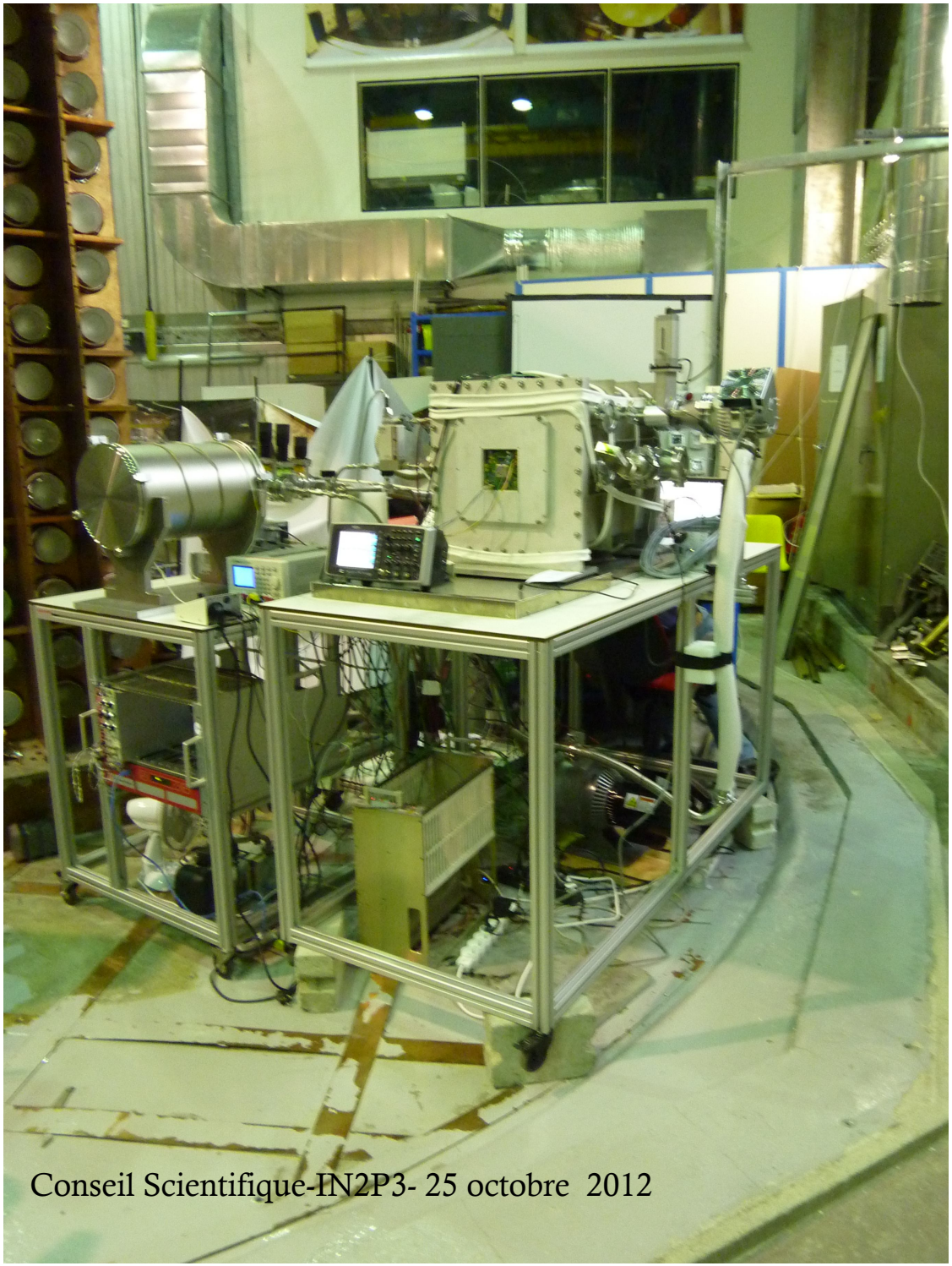
-> Neutron field with energies down to a few keV





Raw data
(no cuts)

- **Possibility to have H as a target**
- **Background discrimination from recoils**



MIMAC (bi-chamber module)at Modane Underground Laboratory (France)
since June 22nd 2012

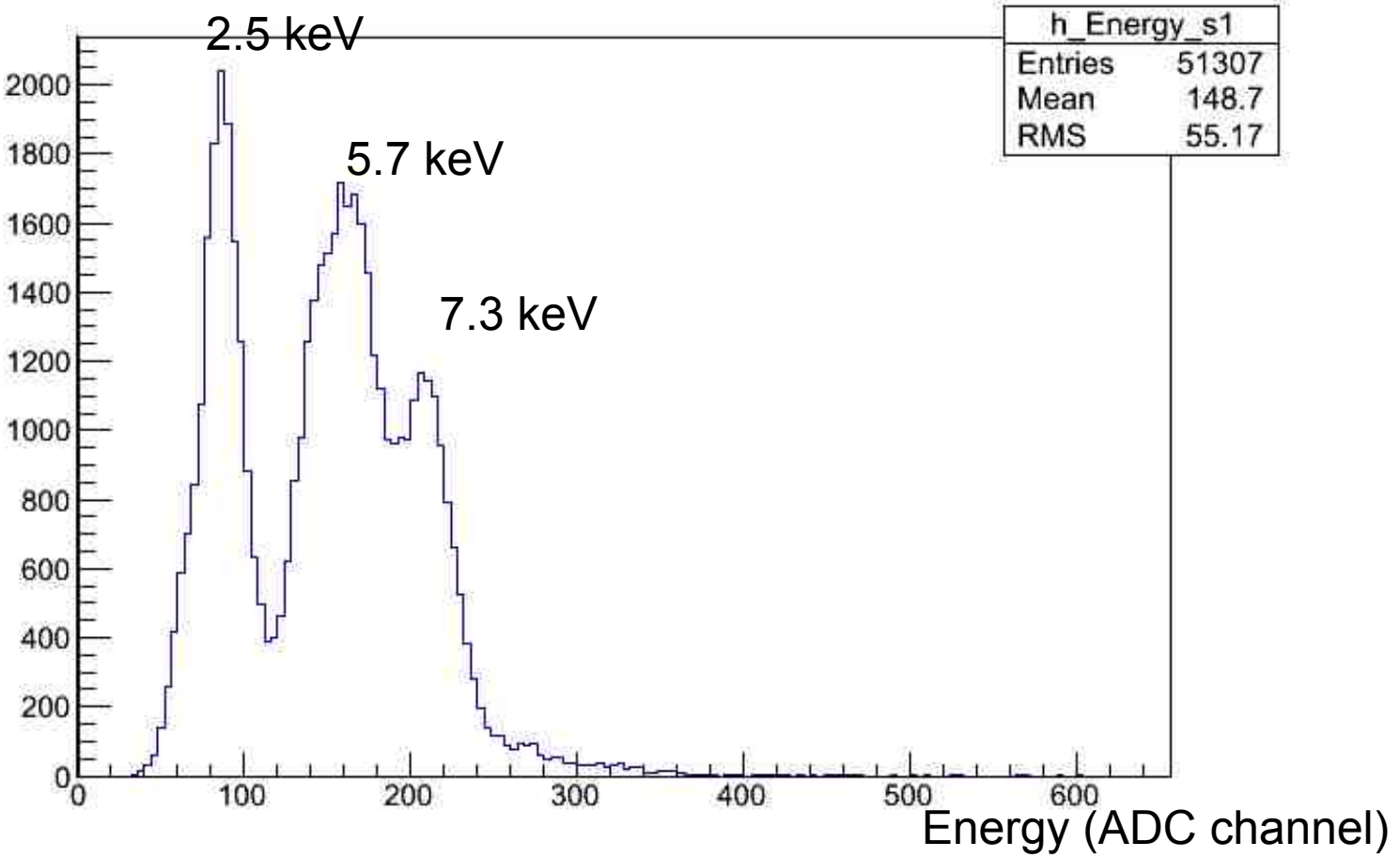
-working at 50 mbar
(CF_4+28% CHF_3 + 2% C_4H_{10})

-in a permanent circulating mode
-Remote controlled and commanded
-Calibration control twice per week

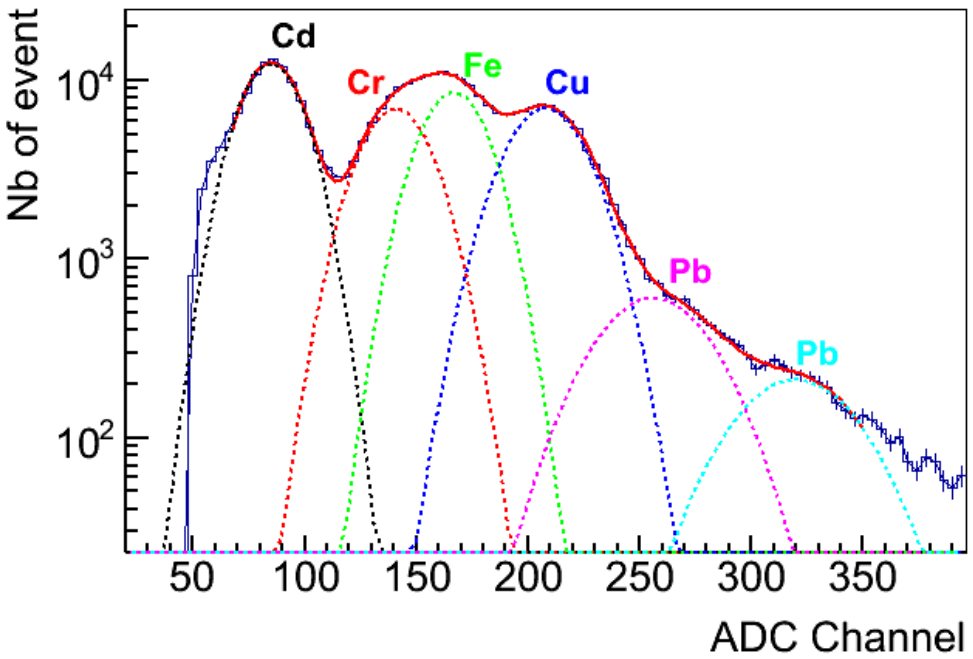
Many thanks to LSM staff

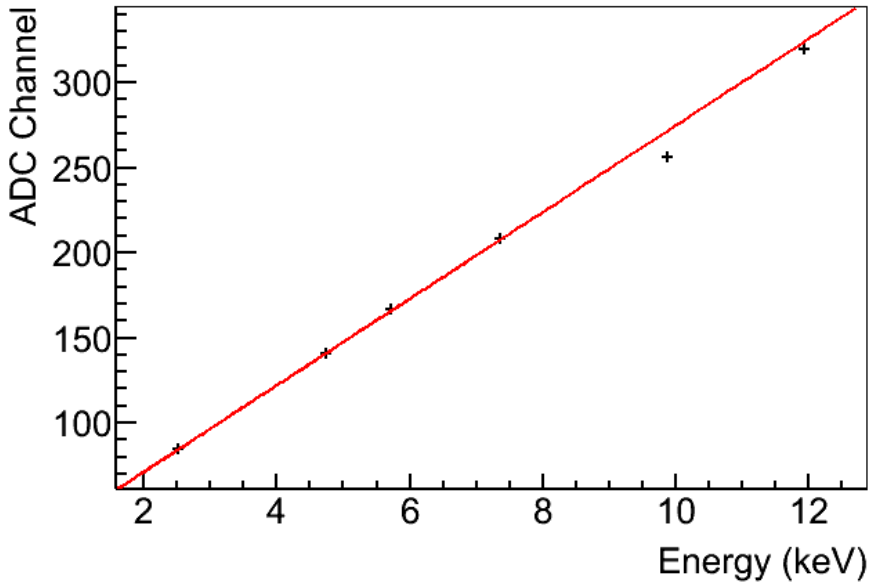
D. Santos (LPSC Grenoble)

Calibration – Chamber2 (at Modane)
fluorescence of Cd-(Cr-Fe)-Cu
(binding energy of ^{19}F ~ 0.7 keV)

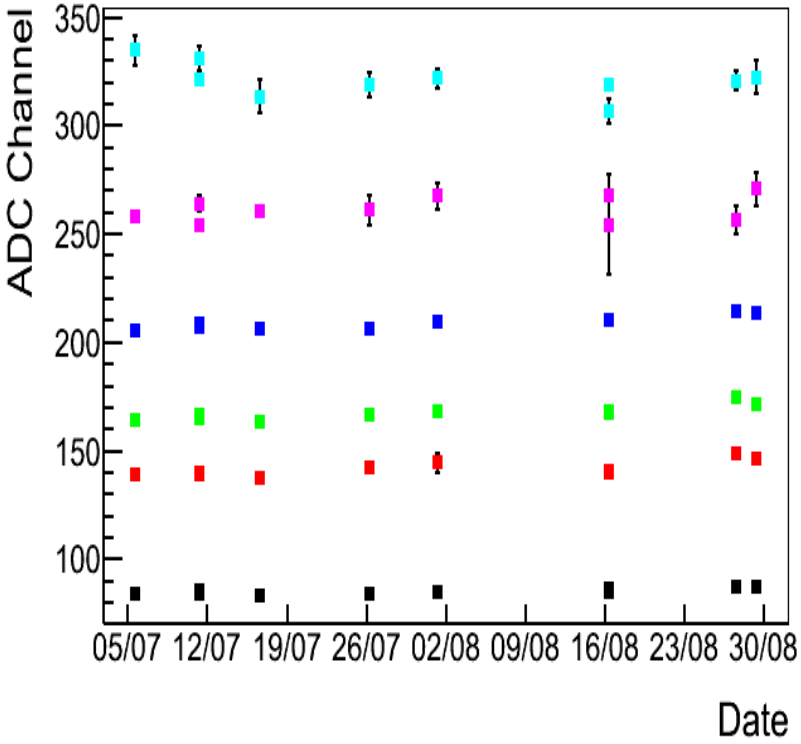


MIMAC Calibration at Modane (by fluorescence + X-ray generator)



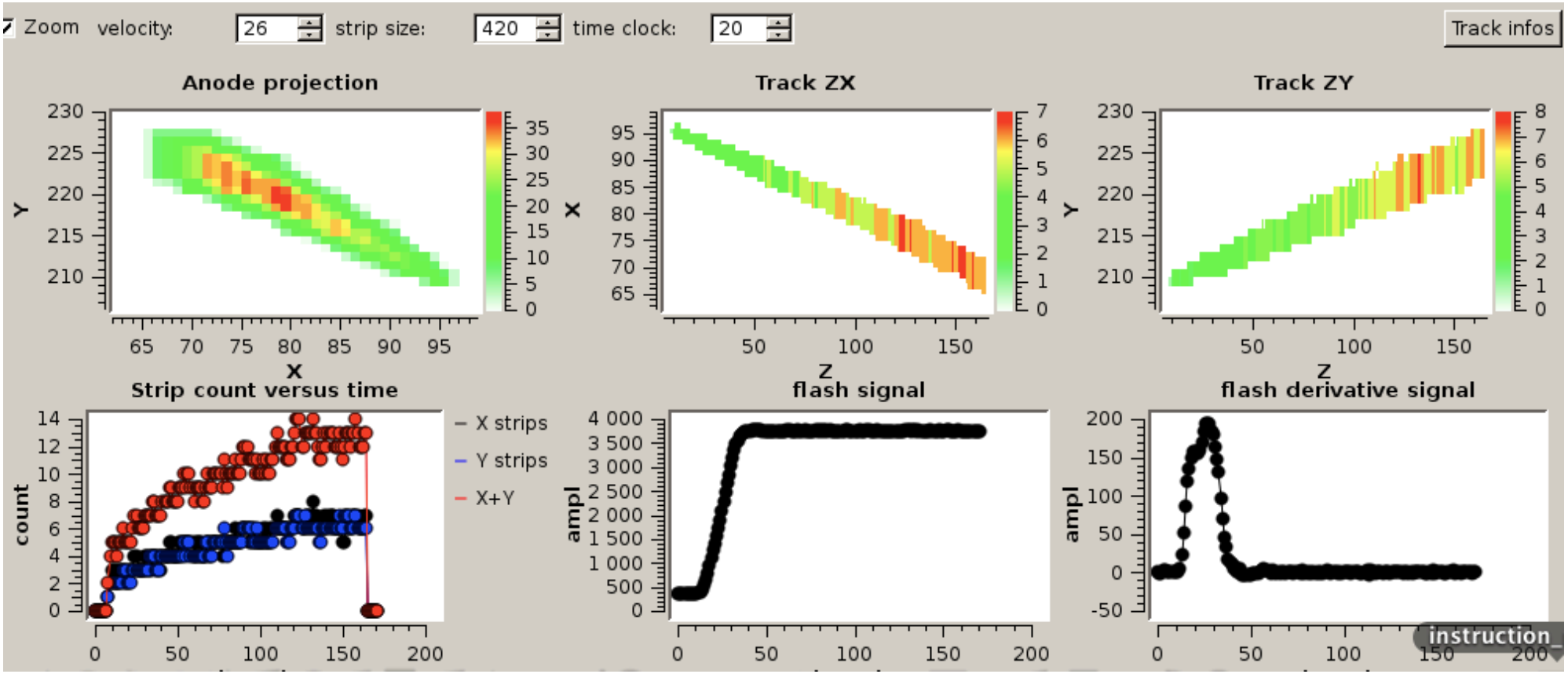


Gain stability (Peak_channel vs. time(days))

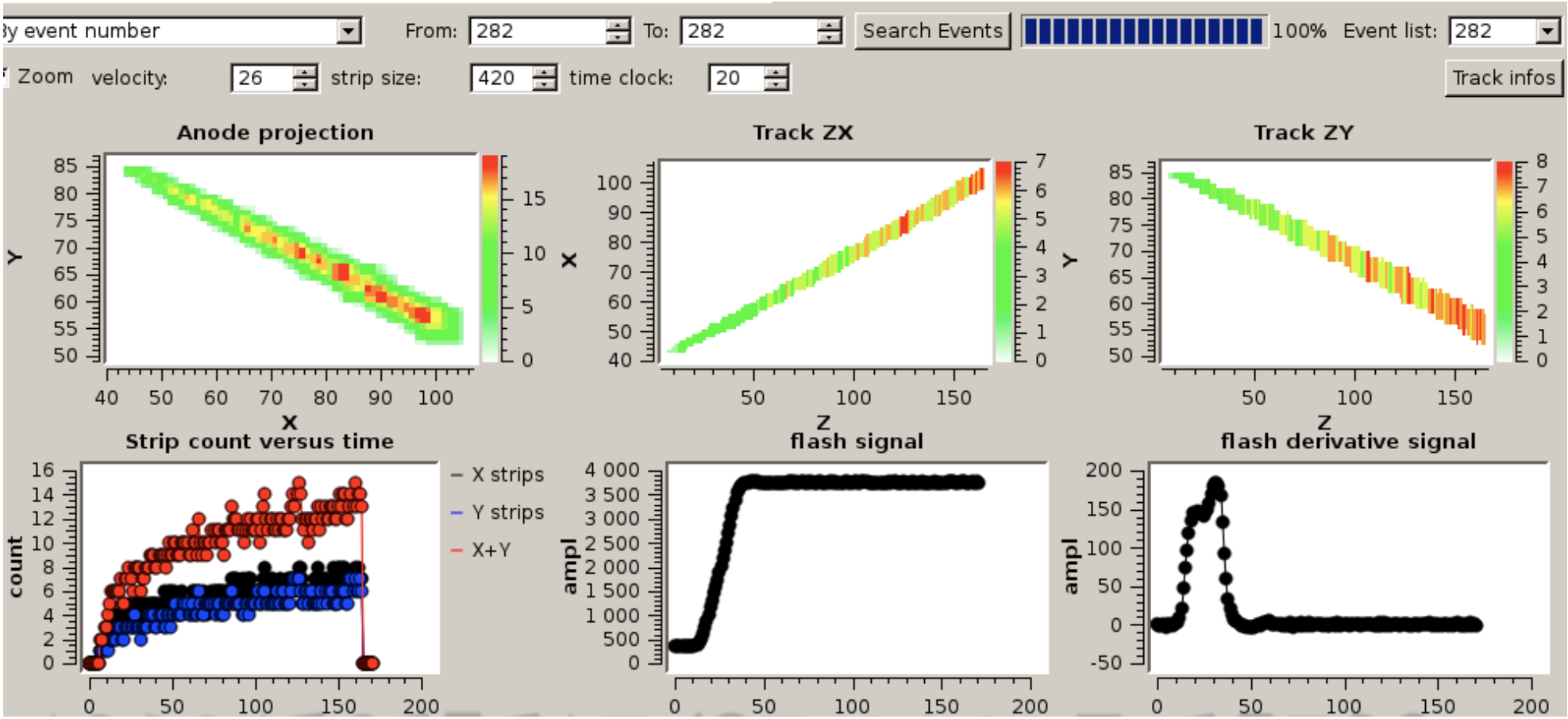


An alpha particle crossing the detector
(as an illustration of the MIMAC observables)

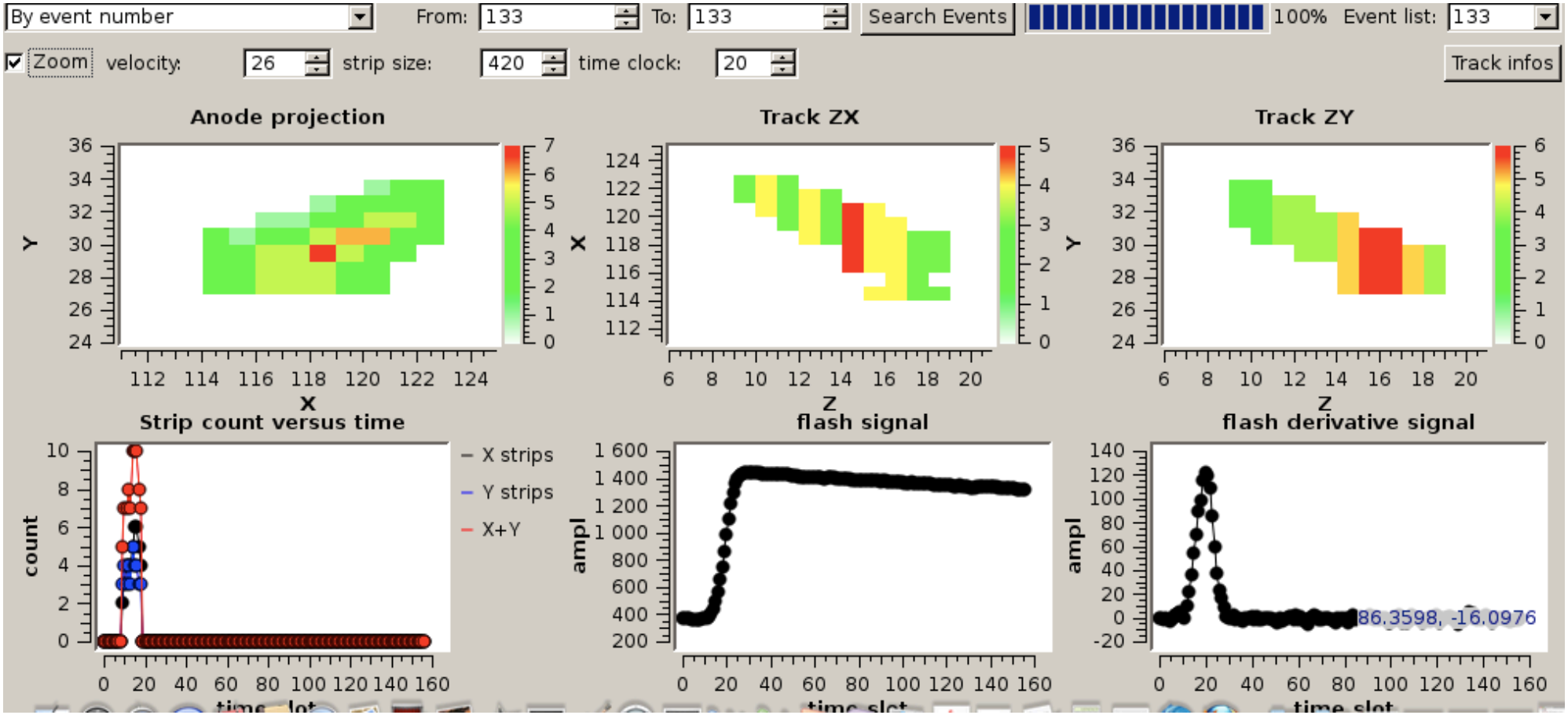
X-Y (anode) X-Z(t) Y-Z(t)



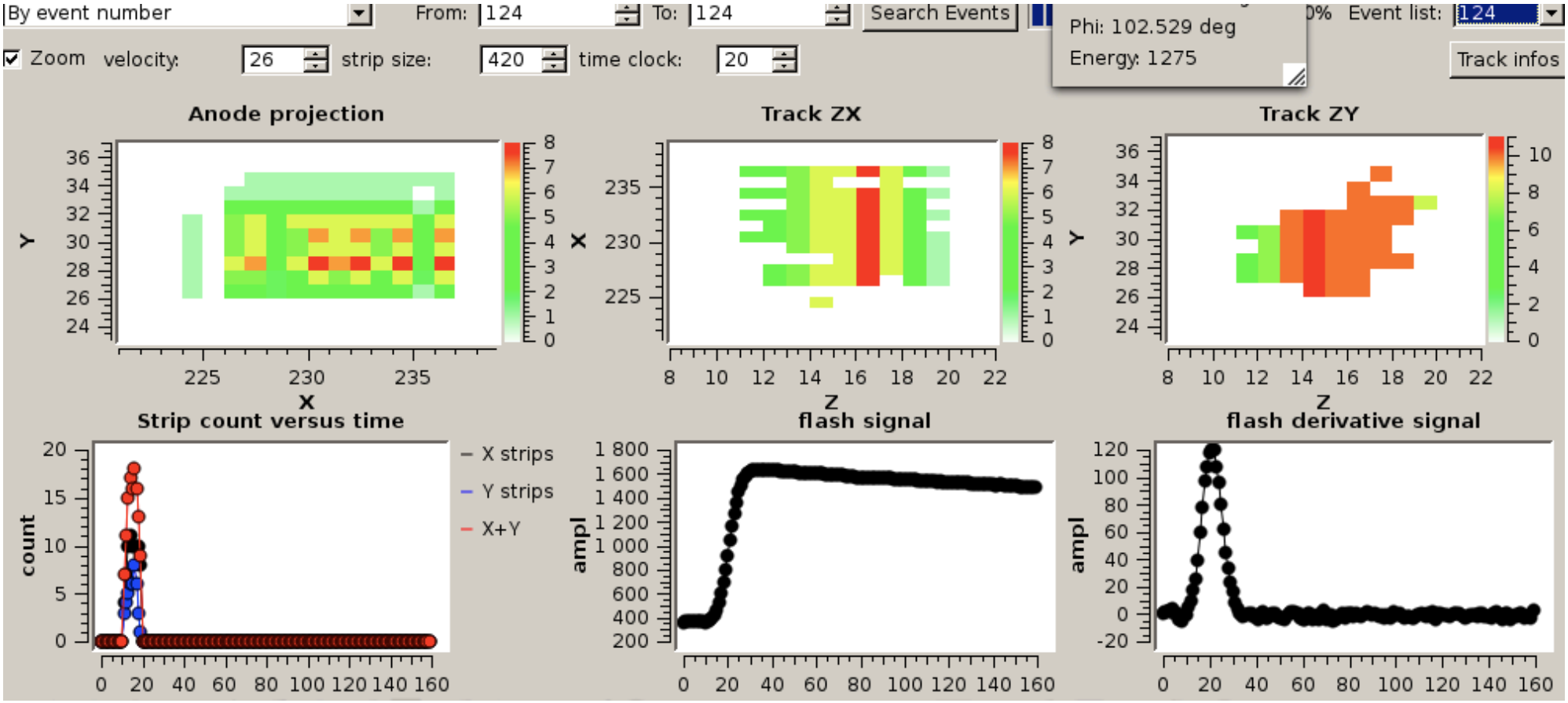
An other alpha particle crossing the detector



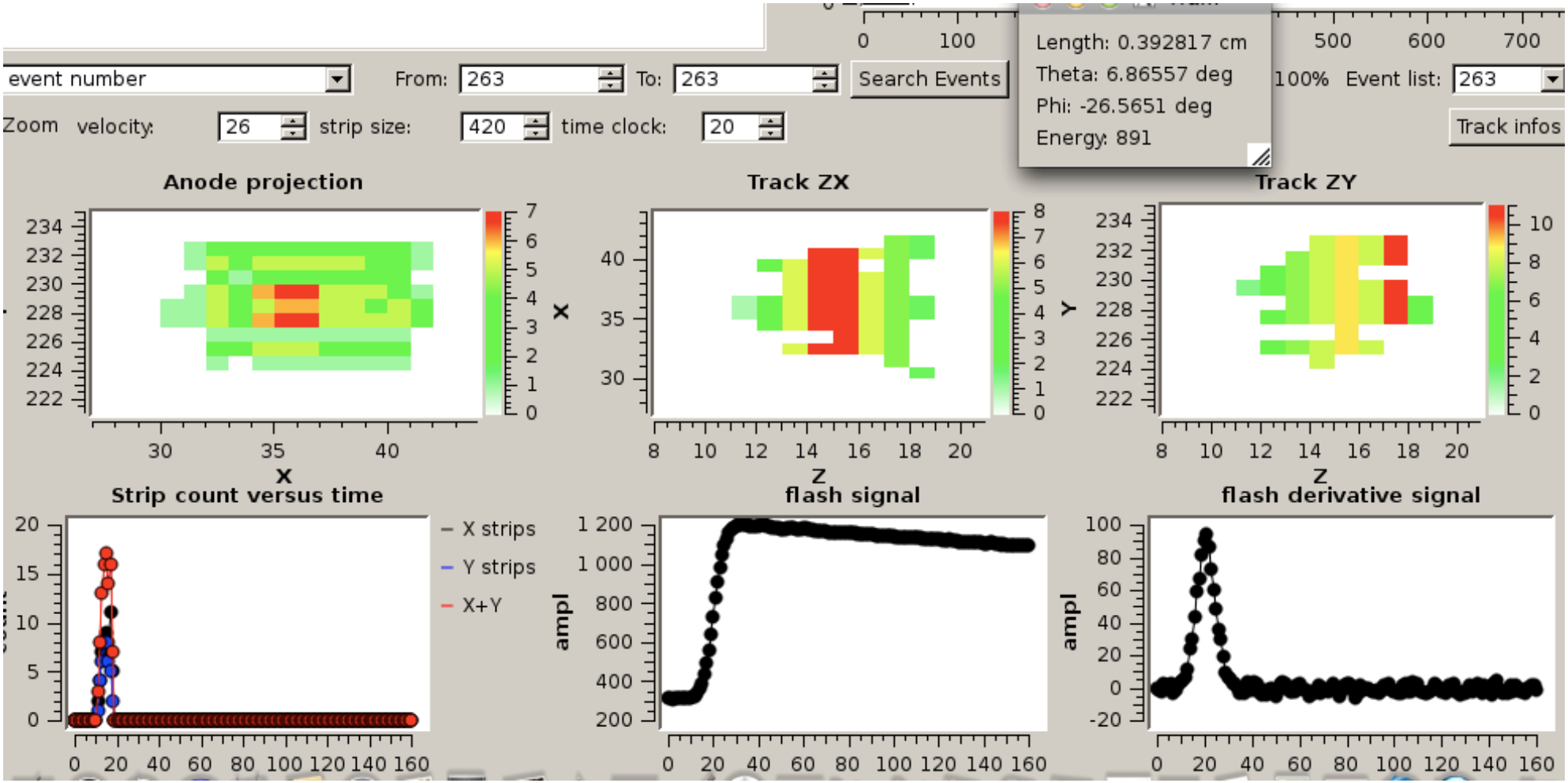
(preliminary analysis): A “recoil event” (~ 34 keVee)



(preliminary analysis): A “recoil” event (~ 40 keVee)



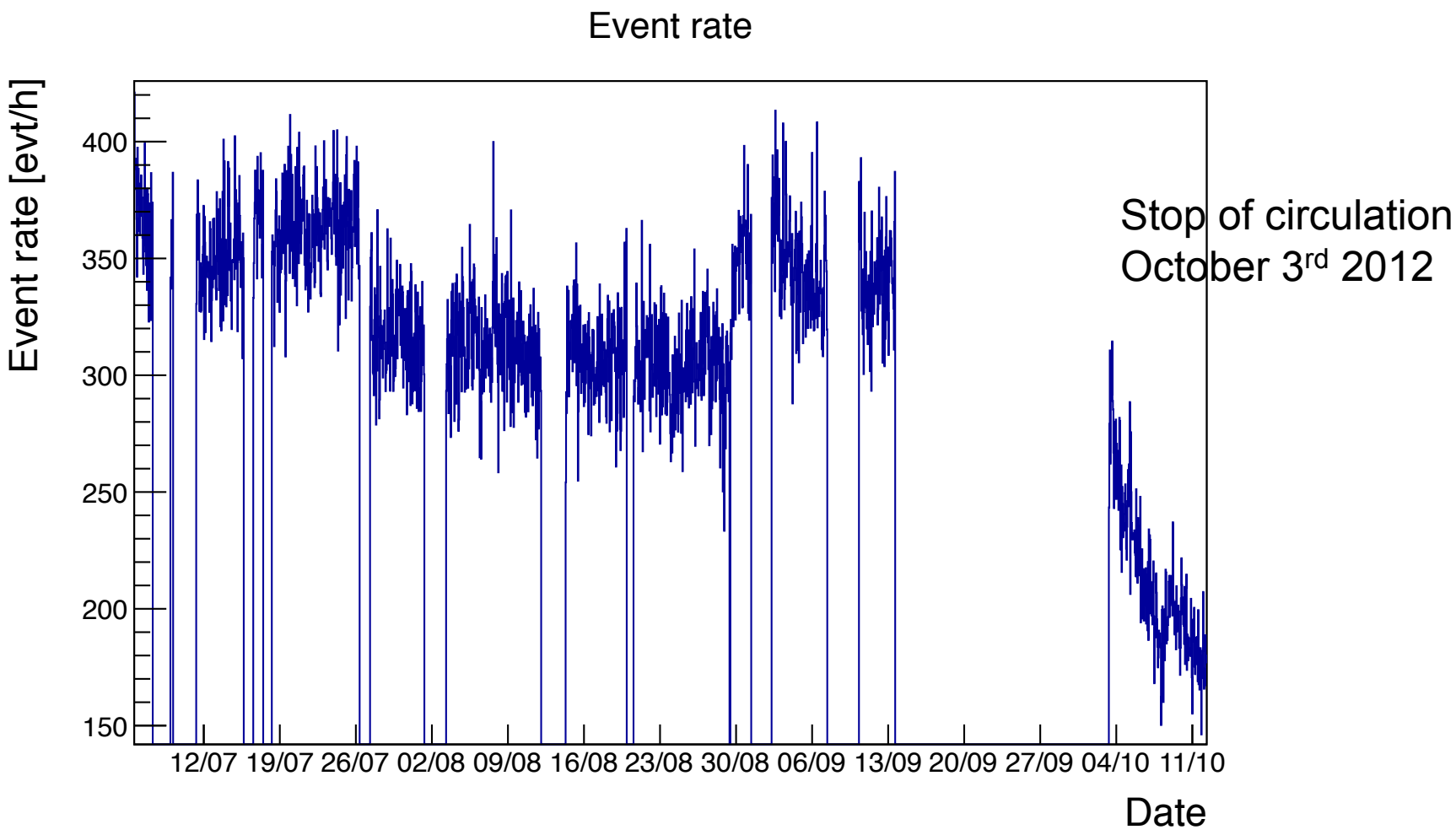
(preliminary analysis): A “recoil” event (~ 28 keVee)



Total event rate at Modane in Ch2

(threshold 1 keVee, at 470V) (no cuts !)

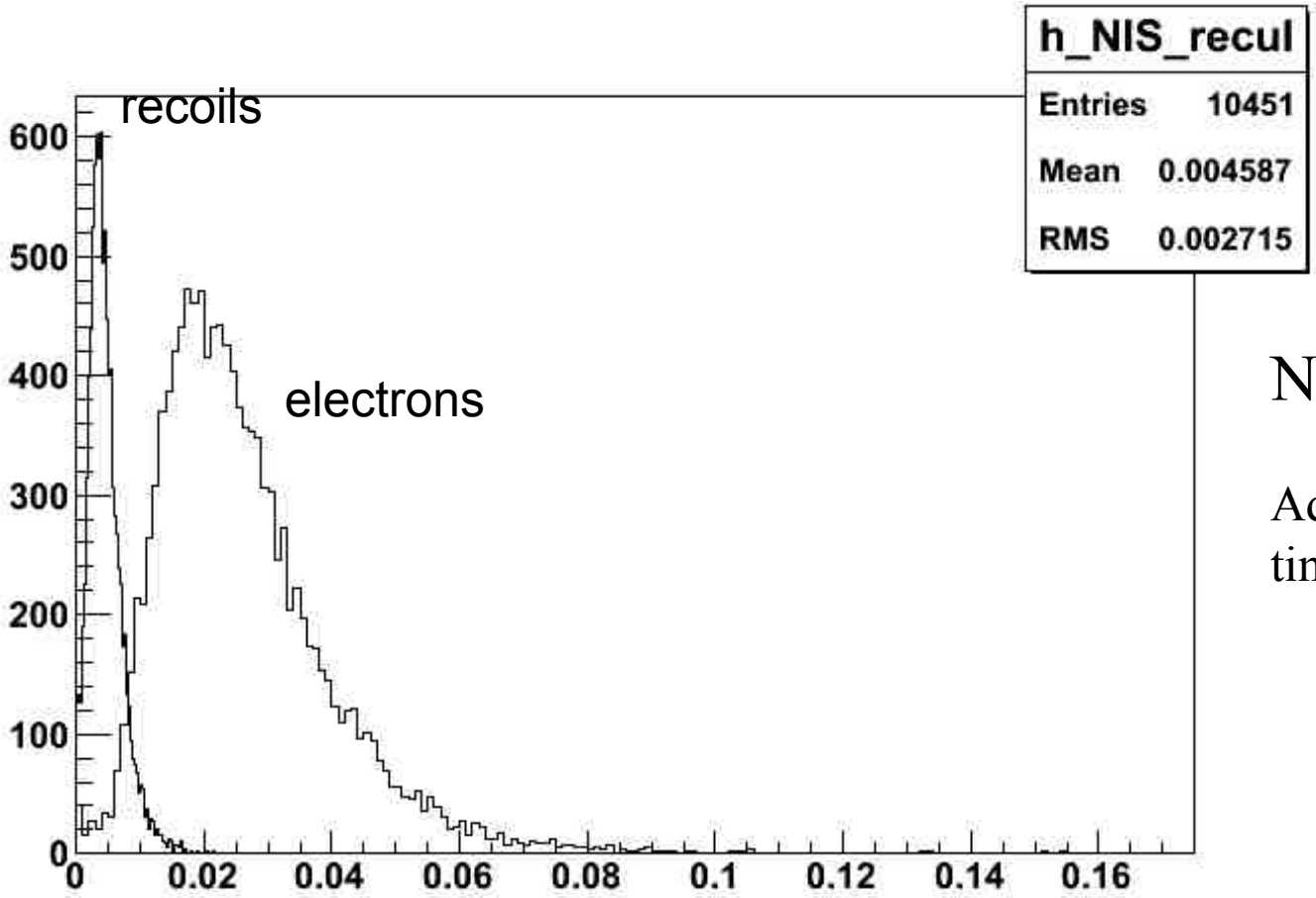
(validation of the source of alphas (Rn))



Normalized Integrated Straggling (NIS)

(a new degree of freedom for e-recoil discrimination)

(The adition of partial deflections along the measured track, normalized by its total (ionization) energy)



$NIS = \Sigma (\Delta\theta_i) / E$

Addition over all the time samples of a track

« MIMAC – observables »

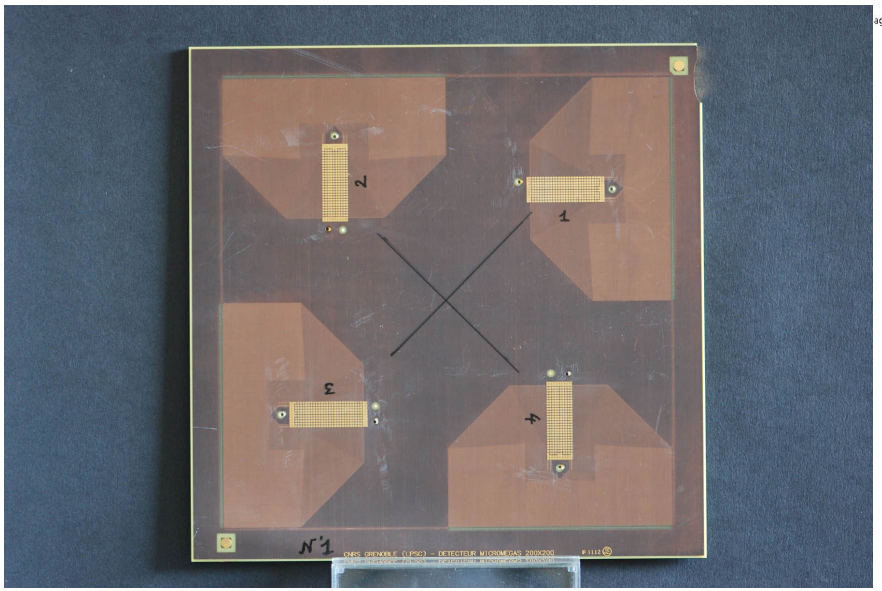
- Ionization energy (+ quenching factor)
- Track length and 3D track
- NIS (Normalized Integrated Straggling)

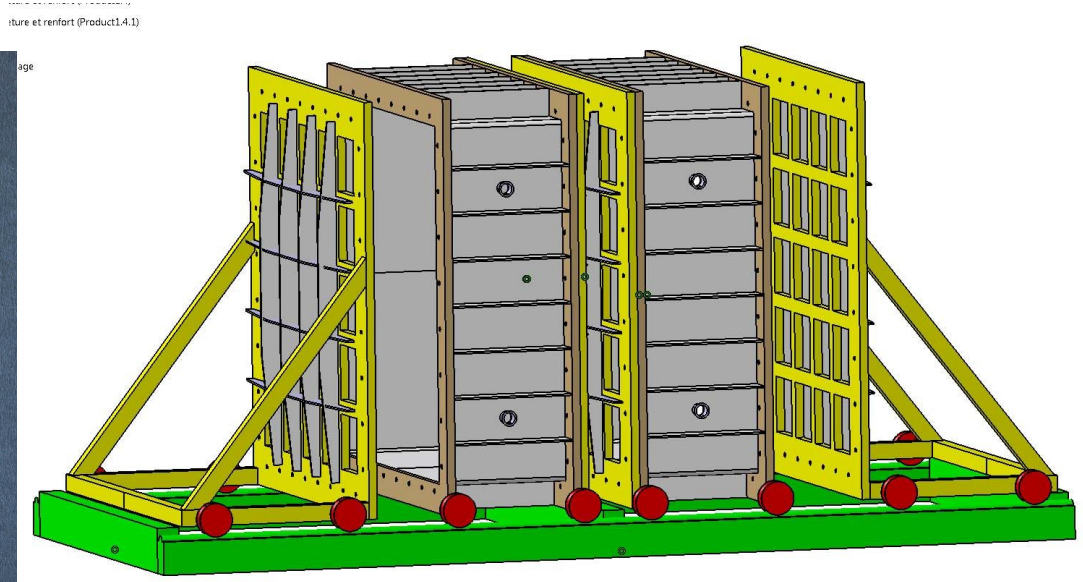
  Low energy electron/recoil discrimination for directional Dark Matter detection, J.Billard et al. (JCAP 07(2012) 020

- Delta T= (Flash-ADC time – Time slots) [20ns] = f(drift)
- dE/dx asymmetry as a function of t
- Track topology (number of holes)

MIMAC – $1m^3$ = 50 bi-chambers ($20x20x25\ cm^3$)

i) New technology anode 20cmx20cm (piggy-back) (already tested in 10cmx10cm)
ii) New electronic card (1024 channels)
iii) Only two big chambers (25 bi-chambers each)





New 20cmx20cm pixellized anode

Budget $1m^3$

-Electronics (100x 1024 channels) + Acquisition:	335 k€	(150 k€ of ASICs)
-Detectors (piggy back)	150 k€	
-HT (power supply)+ cables	40 k€	
-Mechanical structure and Shielding	85 k€	
-Calibration (X-ray generators, sources)	15 k€	
-Gas circulation and control system + vacuum	75 k€	
-Total equipement:	700 k€	
-1 Post-doc (3 years)	135 k€	
- Missions (+ logistic) (4 years)	40 k€	
-Total :	875 k€	

Previous funding: ANR-Blanc (1/2008- 11/2010) : 400 k€

Conclusions

i) A new directional detector of nuclear recoils at low energies has been developed giving a lot of flexibility on targets, pressure, energy range…

ii) Quenching measurements allow to define the recoil energy threshold.

iii) Phenomenology studies performed by the MIMAC team show the impact of this kind of detector.

iv) MIMAC bi-chamber module is running at Modane Underground Laboratory since June 22nd 2012.

v) For the first time 3D nuclear recoil tracks are available from 1keVee.

vi) New degrees of freedom are available to discriminate electrons from nuclear recoils to improve the DM search for.

vii) The 1 m^3 will be the validation of a new generation of DM detector including directionality (the ultimate signature for DM)