

MIMAC

Micro-tpc MAtrix of Chambers

A Large TPC for directional non baryonic Dark Matter detection

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(UJF Grenoble 1 -CNRS/IN2P3-INPG)



MIMAC: (Micro-tpc Matrix of Chambers)

LPSC (Grenoble) : J. Lamblin, F. Mayet , D. Santos

J. Billard (Ph.D) (leaving in July 2012), Q. Riffard (Ph.D)

Technical Coordination :

- Electronics :

- Gas detector :

- Data Acquisition:

- Mechanical Structure :

- Ion source :

O. Guillaudin

G. Bosson, O.Bourrion, J-P. Richer

O. Guillaudin, A. Pellisier

O. Bourrion

Ch. Fourel, M. Marton

P. Sortais, J-F. Muraz, J. Médard

CEA-Saclay (IRFU): I. Giomataris, E. Ferrer, F.J. Iguaz, J-P. Mols

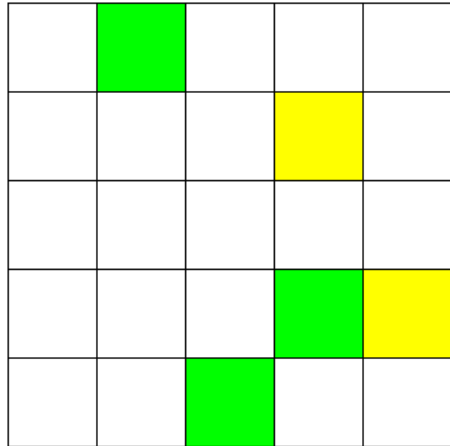
Joining :

CCPM (Marseille): J. Busto, Ch. Tao, D. Fouchez, J. Brunner

Neutron facility (AMANDE) :

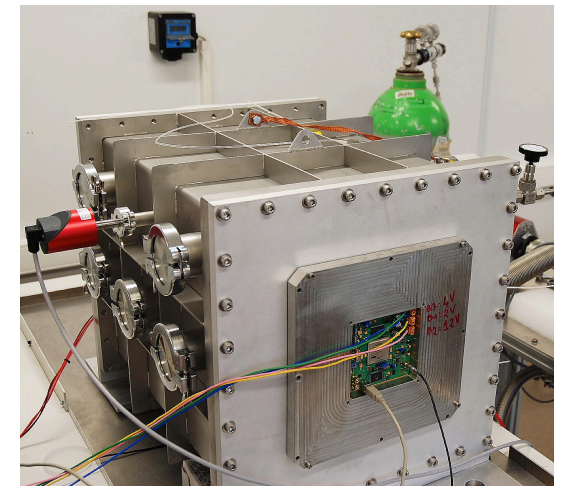
IRSN (Cadarache): L. Lebreton, D. Maire (Ph. D.)

The MIMAC project



A low pressure multi-chamber detector

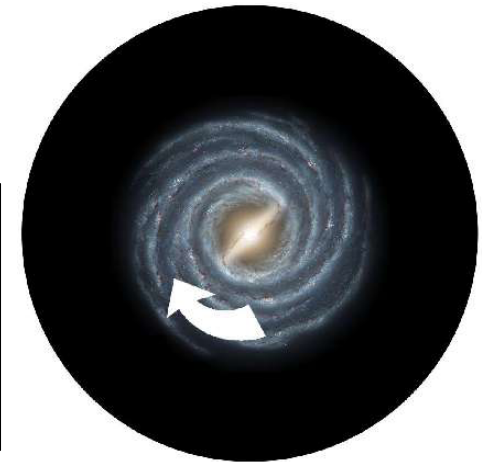
- Energy and 3D Track measurements
- Matrix of chambers (correlation)
- μ TPC : Micromegas technology
- CF_4 , CHF_3 , and ^1H : $\sigma(A)$ dependency
- Axial interaction
- Directional detector



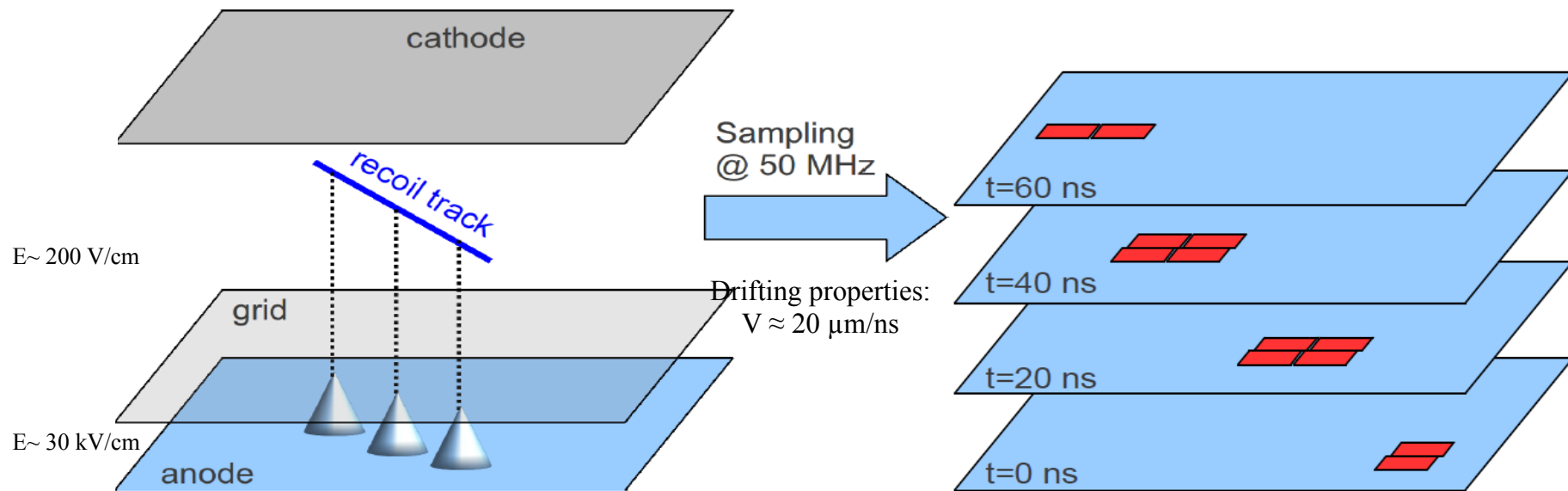
Bi-chamber module
2 x (11x11x25 cm³)

Strategy:

- direct detection
- **Energy AND 3D-Track** of the recoil nuclei
- Prove that the signal “comes from Cygnus”



MIMAC: Detection strategy

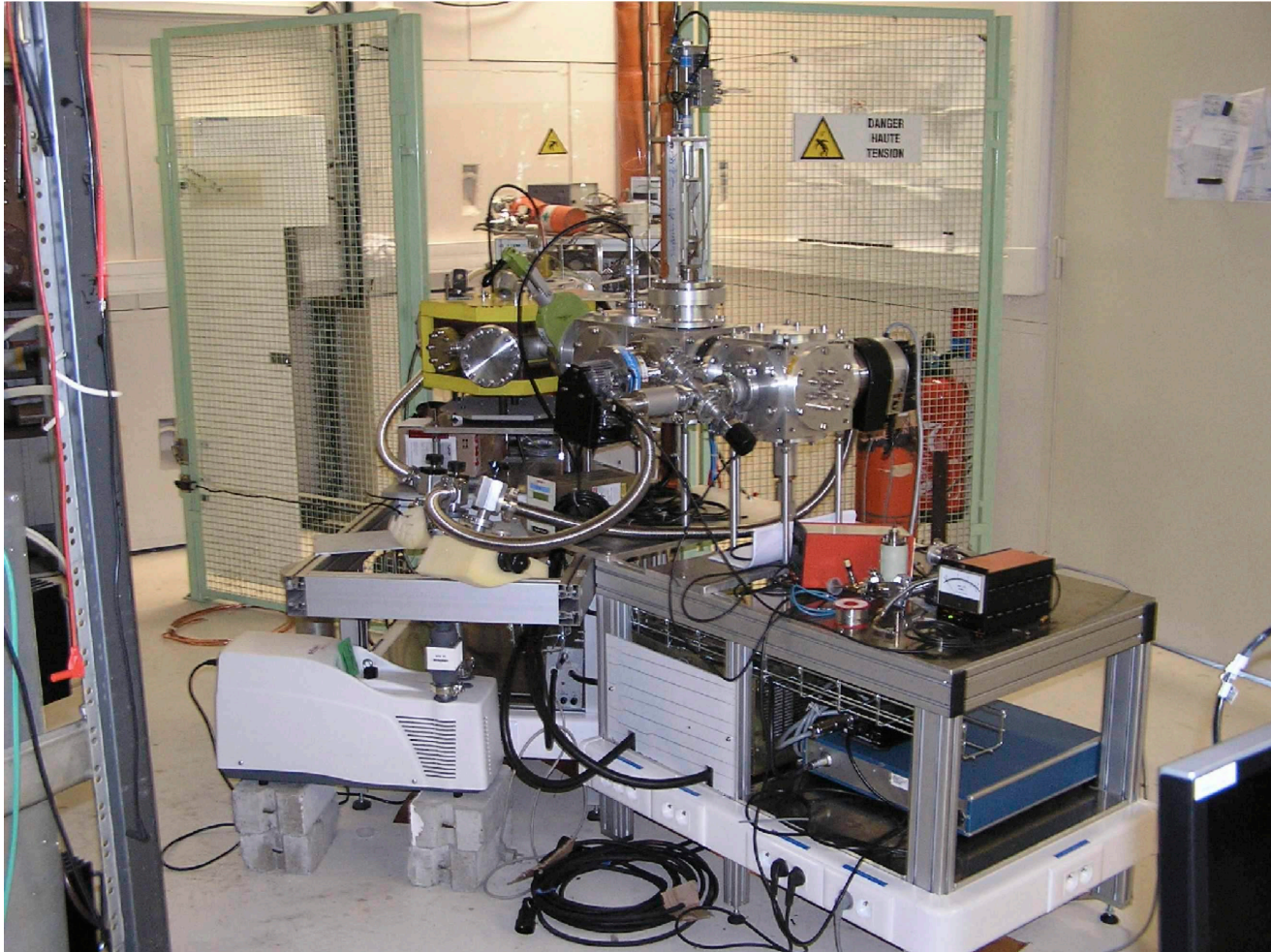


Scheme of a MIMAC μ TPC

Evolution of the collected charges on the anode

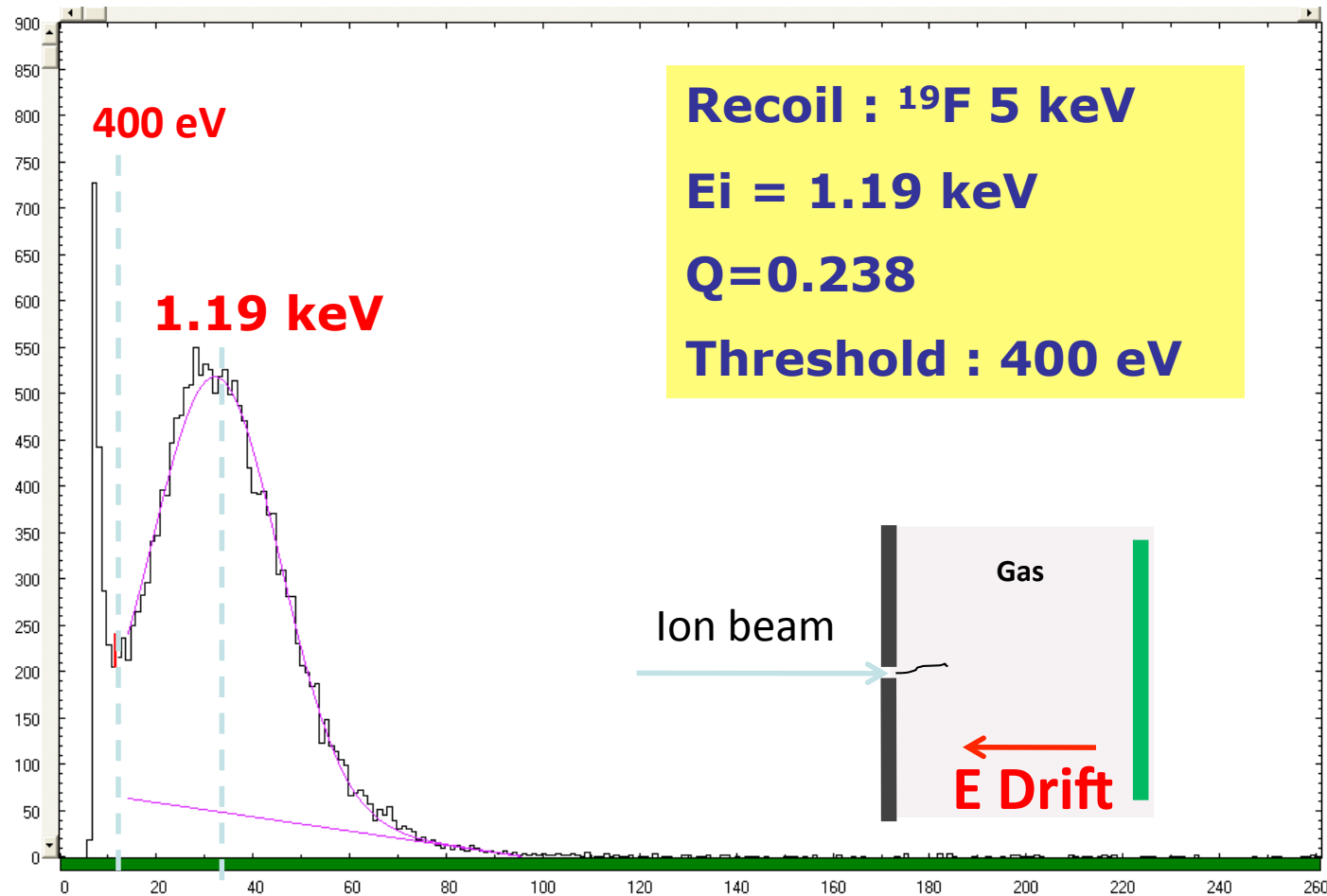
Measurement of the ionization energy: Charge integrator connected to the grid

Ionization Quenching Facility at LPSC-Grenoble

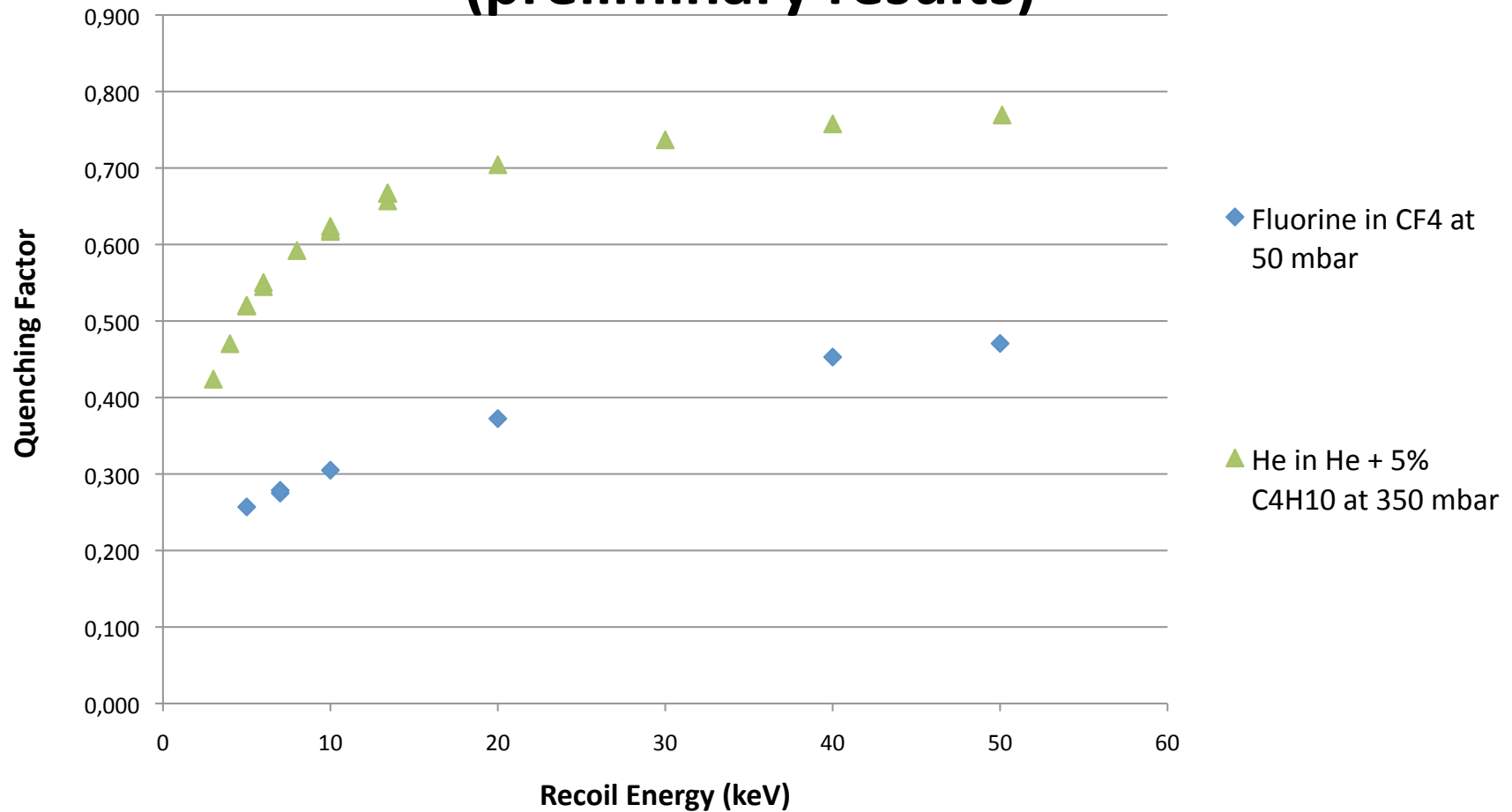


- **Low energy ion source
1 to 50 keV**
- **Developped @LPSC**

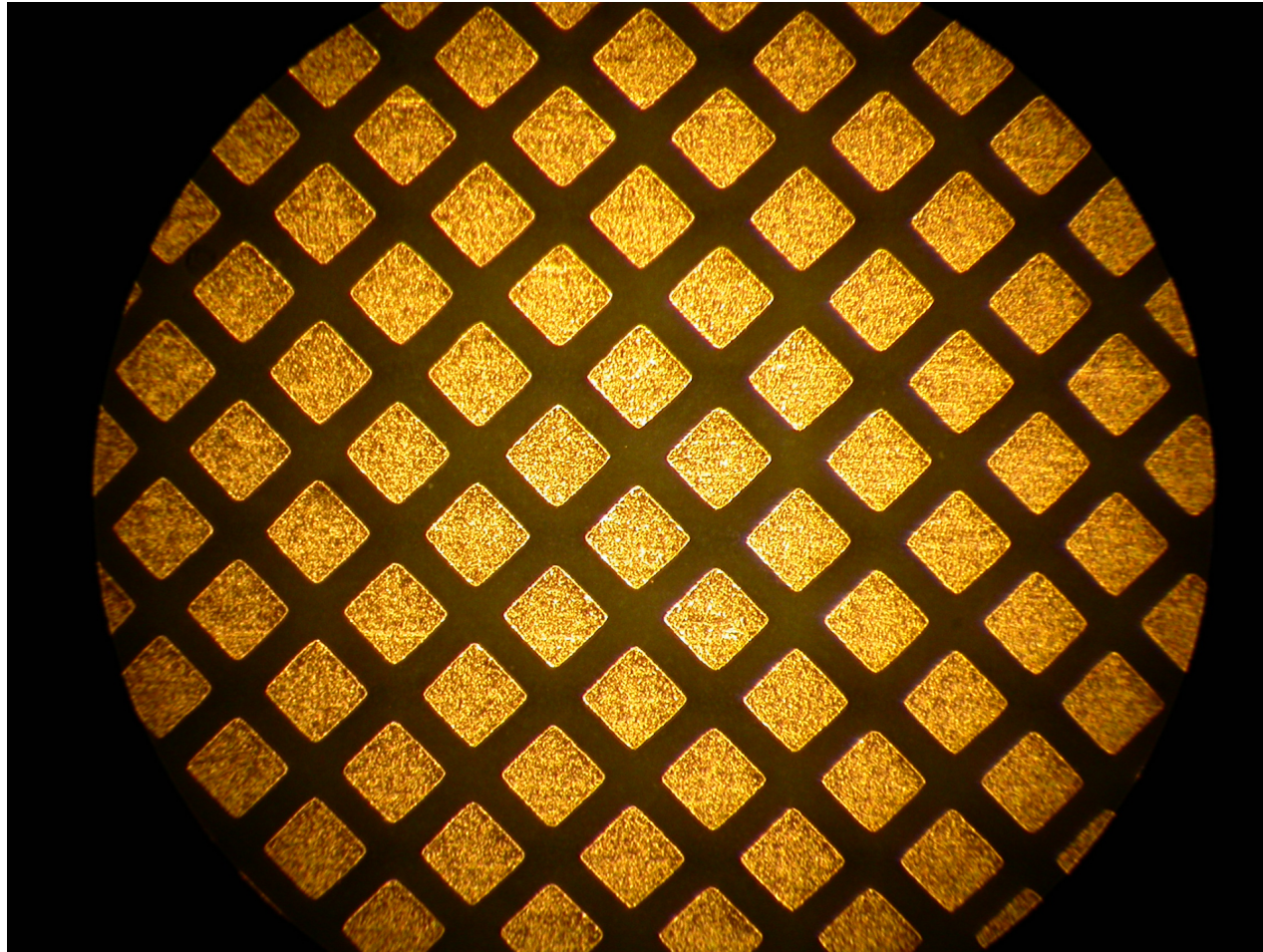
Ionization Quenching Measurements: 5keV ^{19}F Recoil in 60 mbar 40mbar CF_4 +16.8mbar CHF_3 +1.2 mbar Isobutane



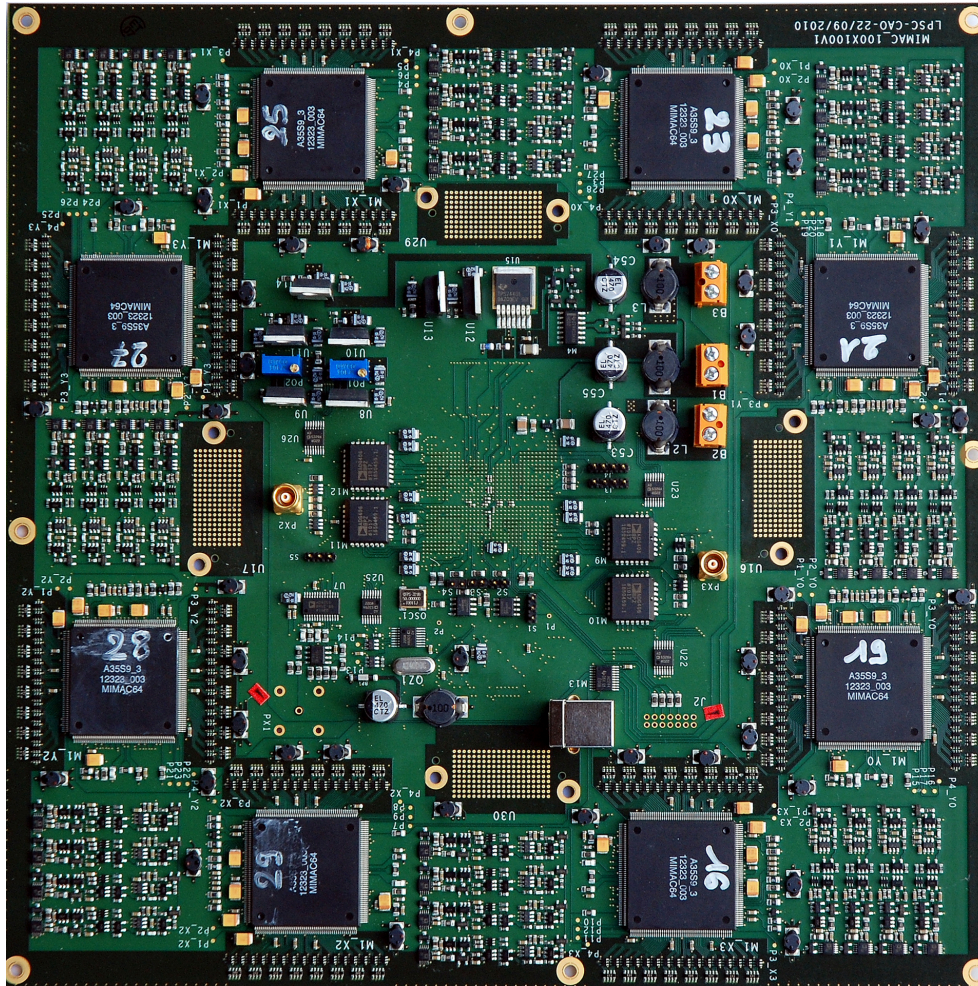
Ionization Quenching Factor for Fluorine in pure CF₄ at 50 mbar (preliminary results)



MIMAC 100x100 mm²(v2) (designed by IRFU- Saclay (France))

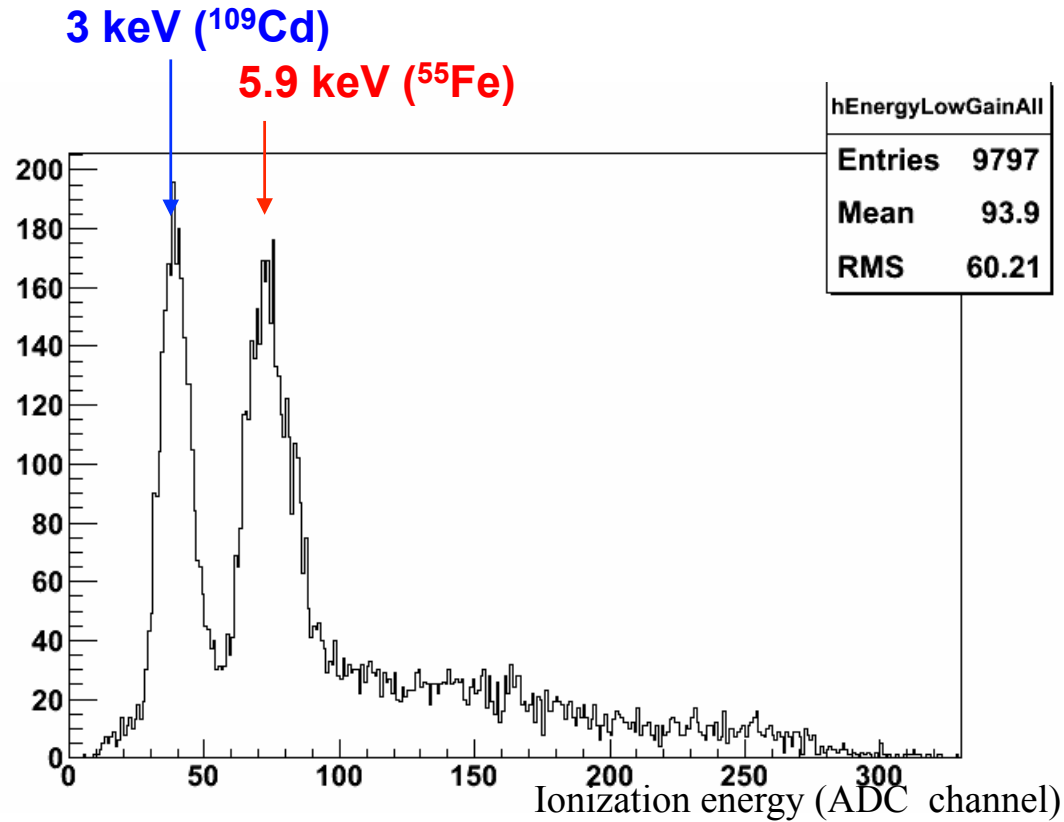


New MIMAC electronics (512 channels)

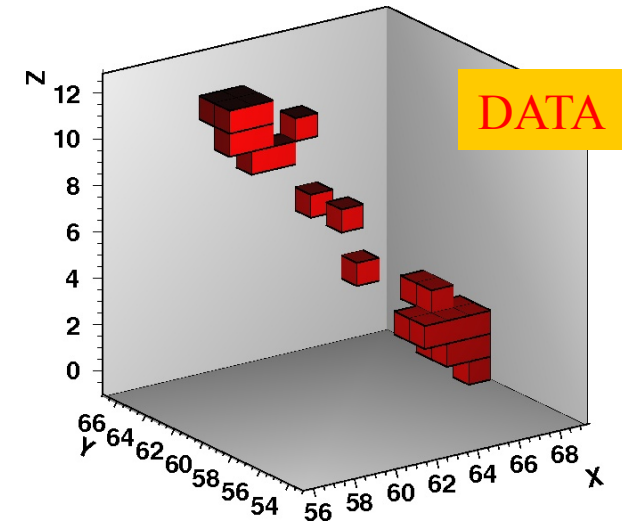


Entirely developed
(ASICs included) by the
MIMAC team at the
LPSC-Grenoble
(France)

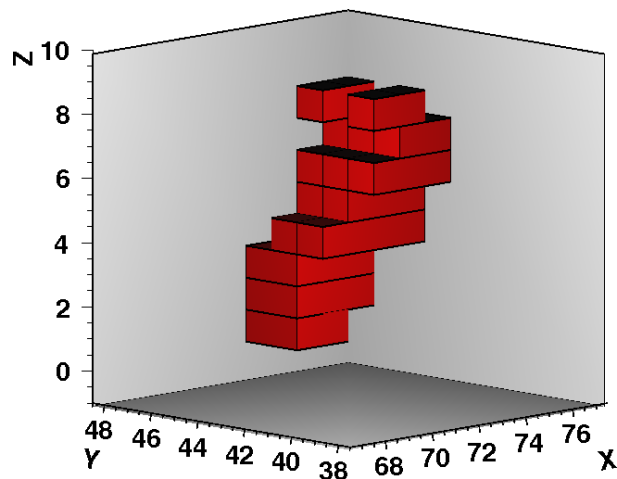
MIMAC: Performance at low energies



$\text{CF}_4 + 28\% \text{CHF}_3$
(+2% C_4H_{10})
50 mbar



One electron track (6 keV)



D. Santos (LPSC Grenoble)

MIMAC : nuclear recoil track measurements

April 2009

@ IRSN Cadarache

and May 16th, 2011 !!



Amande facility :

- Neutron field with energies down to a few keV

Recoils from 144 keV neutrons

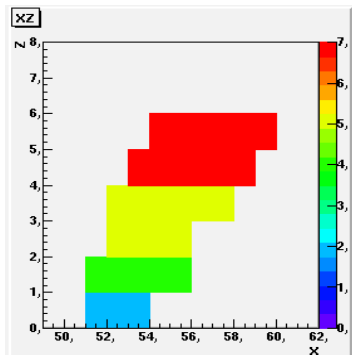
Pure isobutane

100 mbar

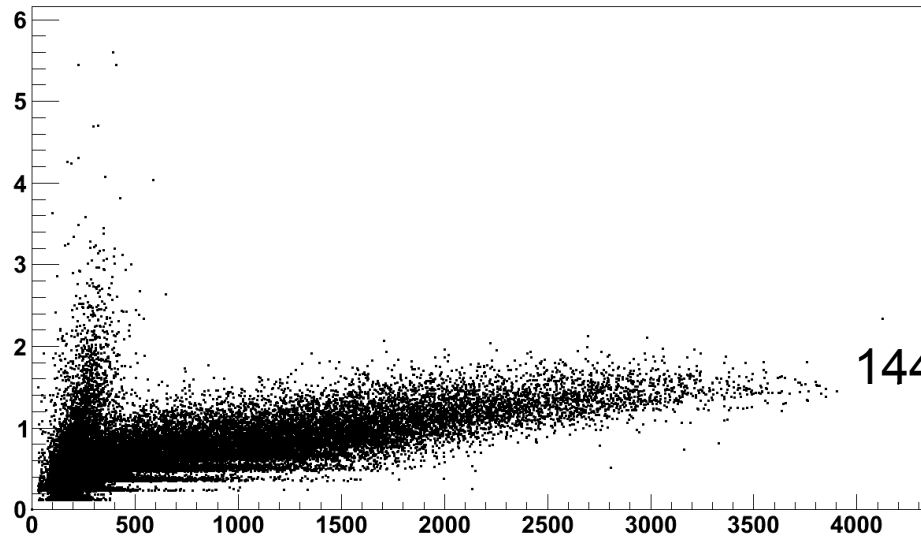
150 V/cm

Amande facility @ IRSN Cadarache

-> Neutron field with energies down to a few keV



Length (cm)



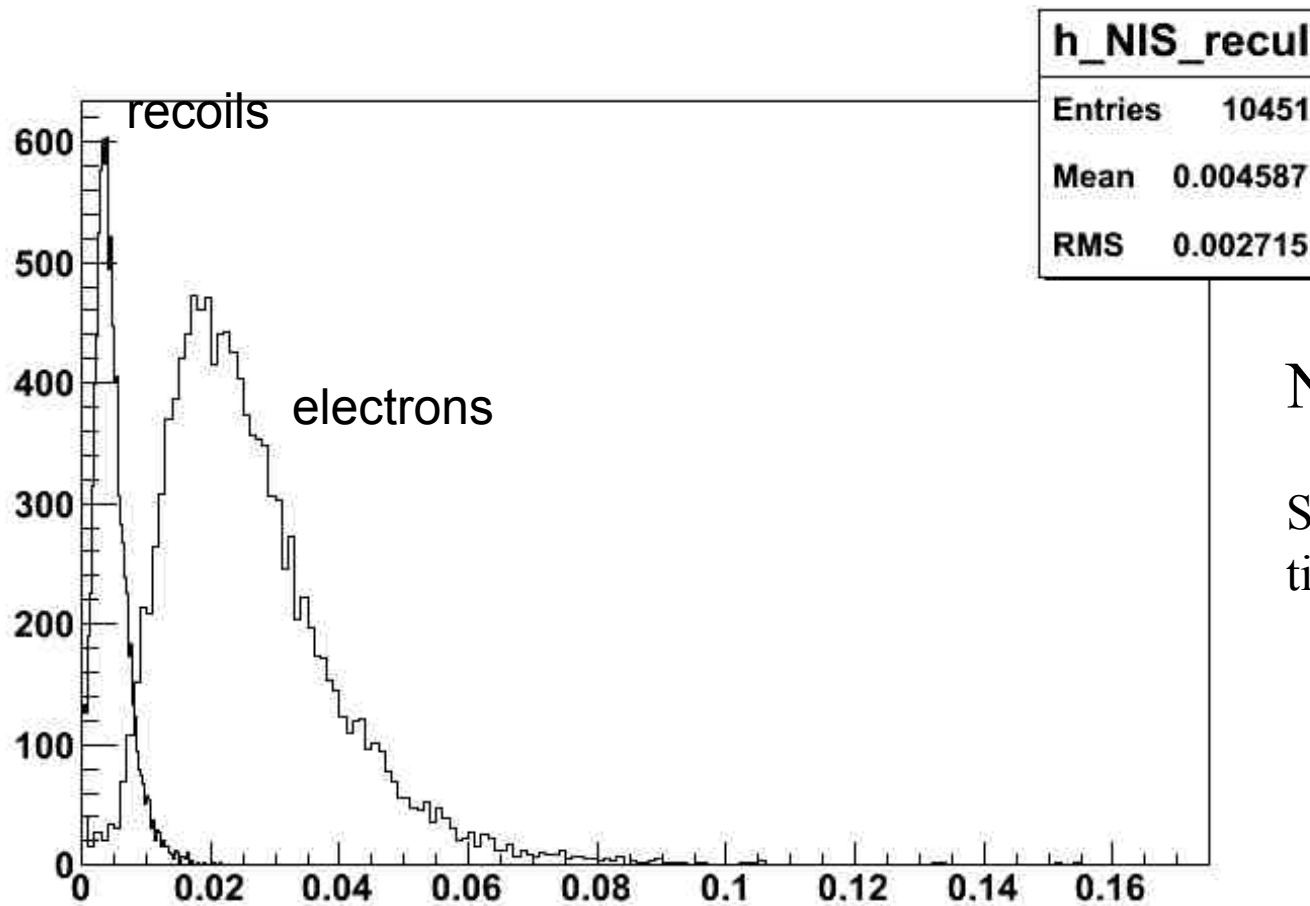
Energy (ADC)

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

Normalized Integrated Straggling (NIS)

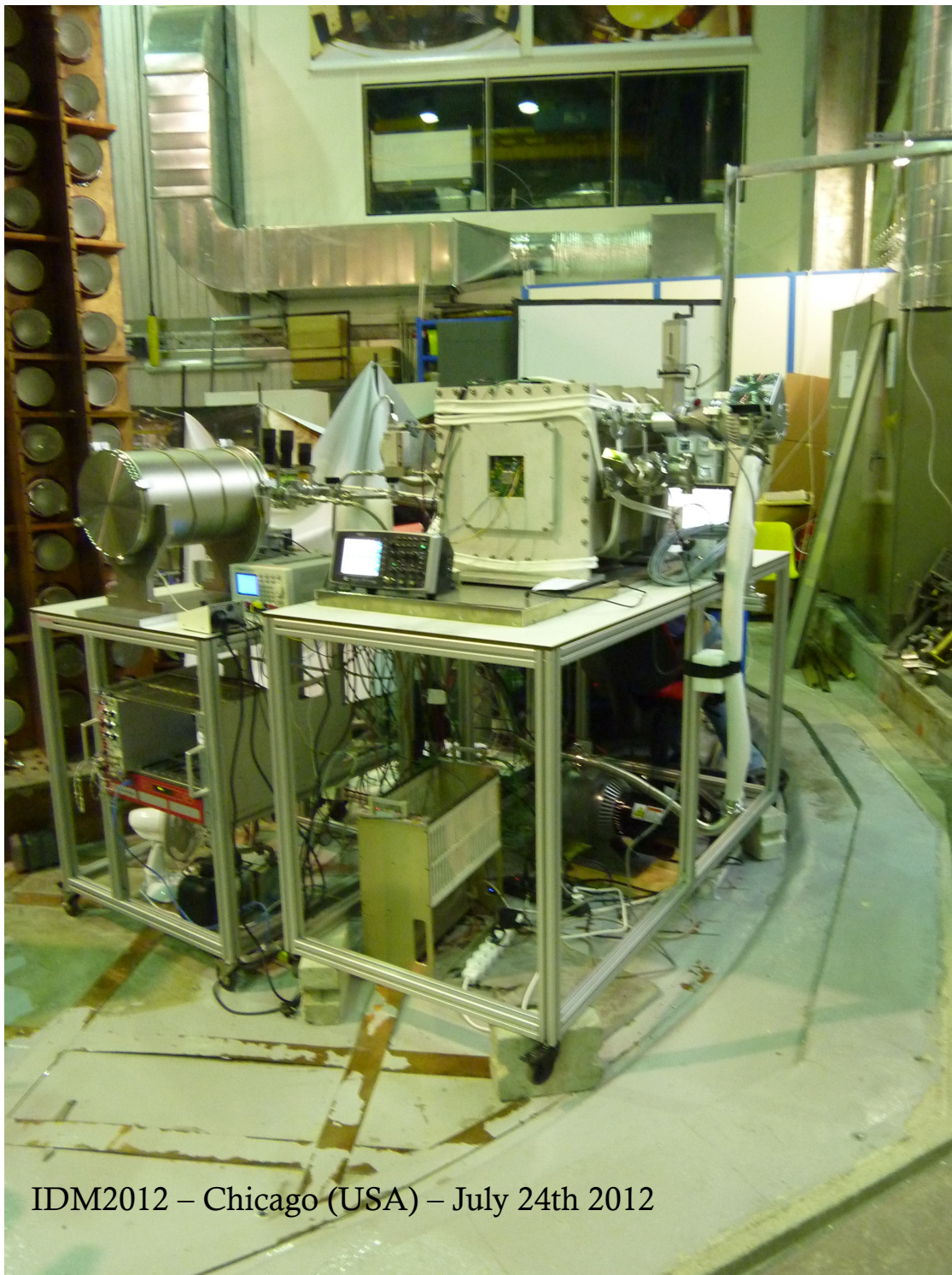
(a new degree of freedom for e-recoil discrimination)

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



$$\text{NIS} = \Sigma (\Delta\theta_i) / E$$

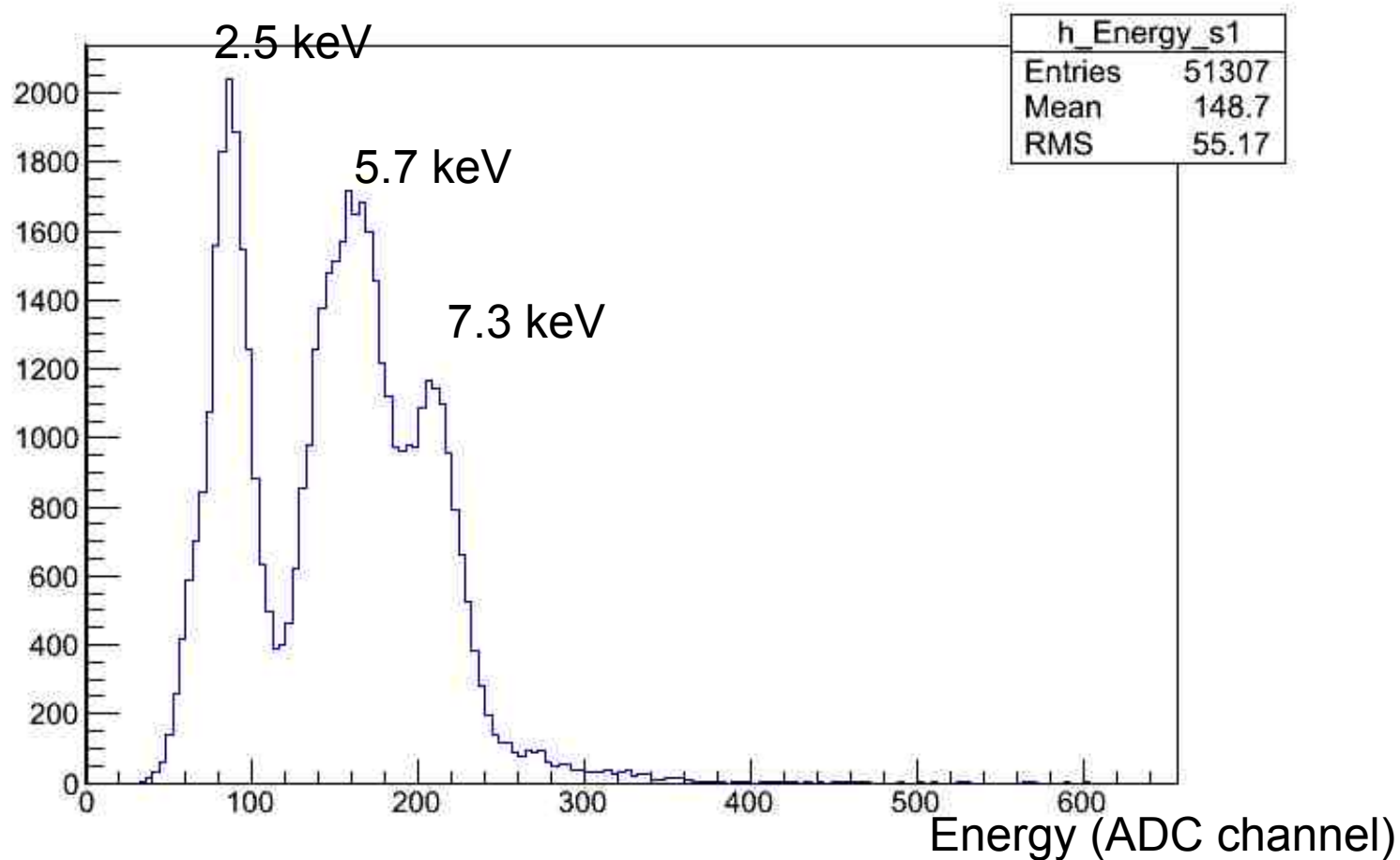
Summed over all the
time samples of a track



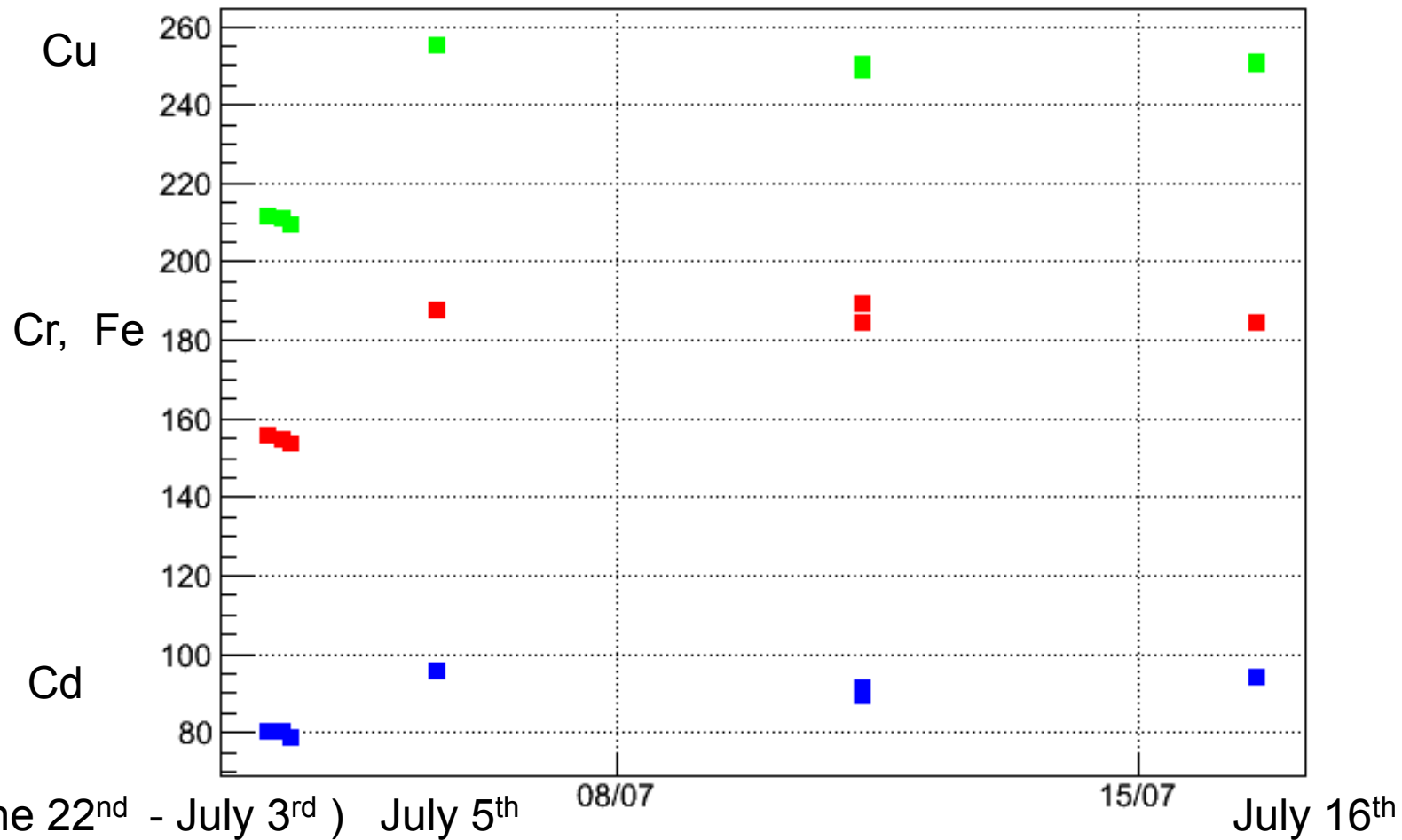
MIMAC (bi-chamber module)
at Modane Underground
Laboratory (France)
since June 22nd 2012 working at
50 mbar ($\text{CF}_4 + 30\% \text{CHF}_3$) in a
permanent circulating mode

Laboratoire Sousterrain de Modane
(LSM) IN2P3 (CNRS) – CEA
FRANCE

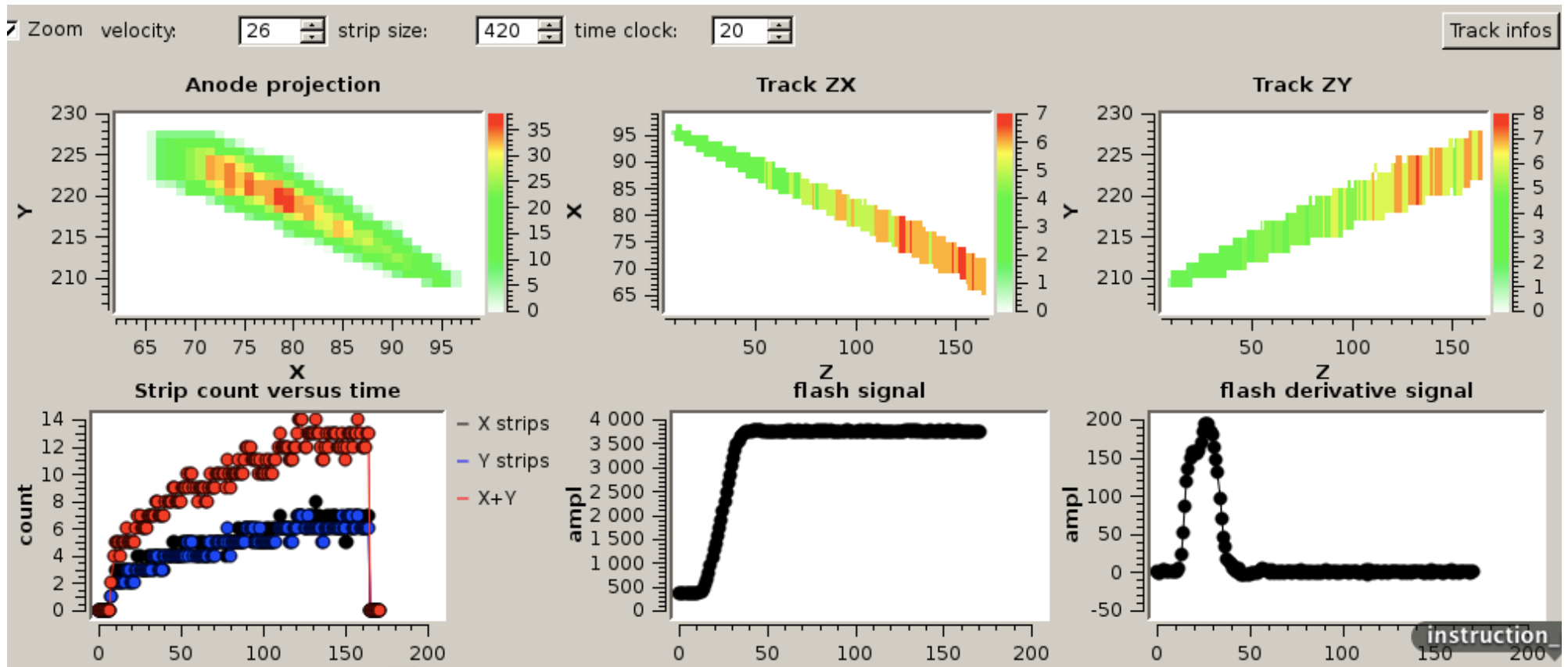
Calibration – Chamber2- Cd-(Cr-Fe)-Cu (binding energy of ^{19}F \sim 0.7 keV)



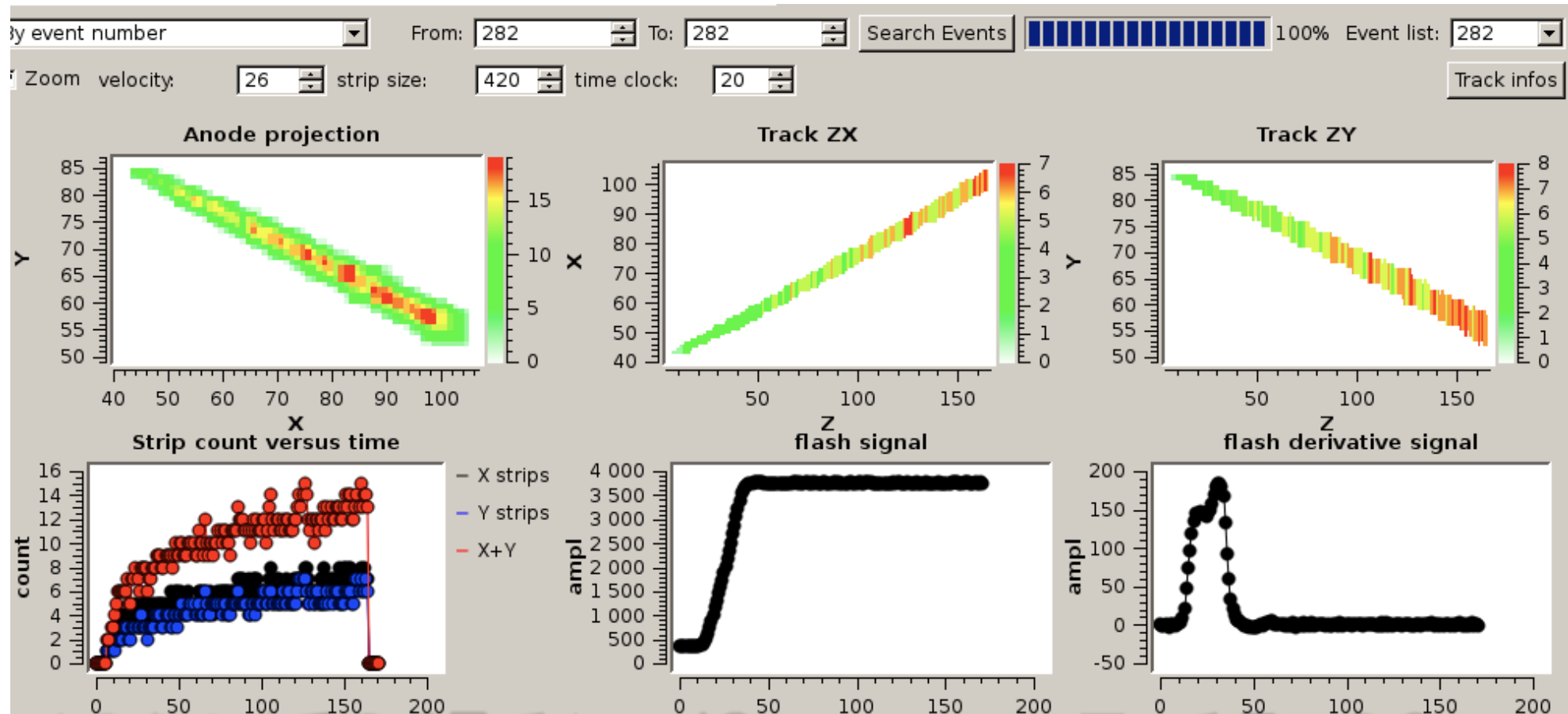
Gain stability (Peak_channel vs. time(days))
in Chamber1(X-ray generator)
2.5 keV (blue), 5.7 keV (red), 7.3 keV (green)
(June 22nd to July 3rd with different conditions)



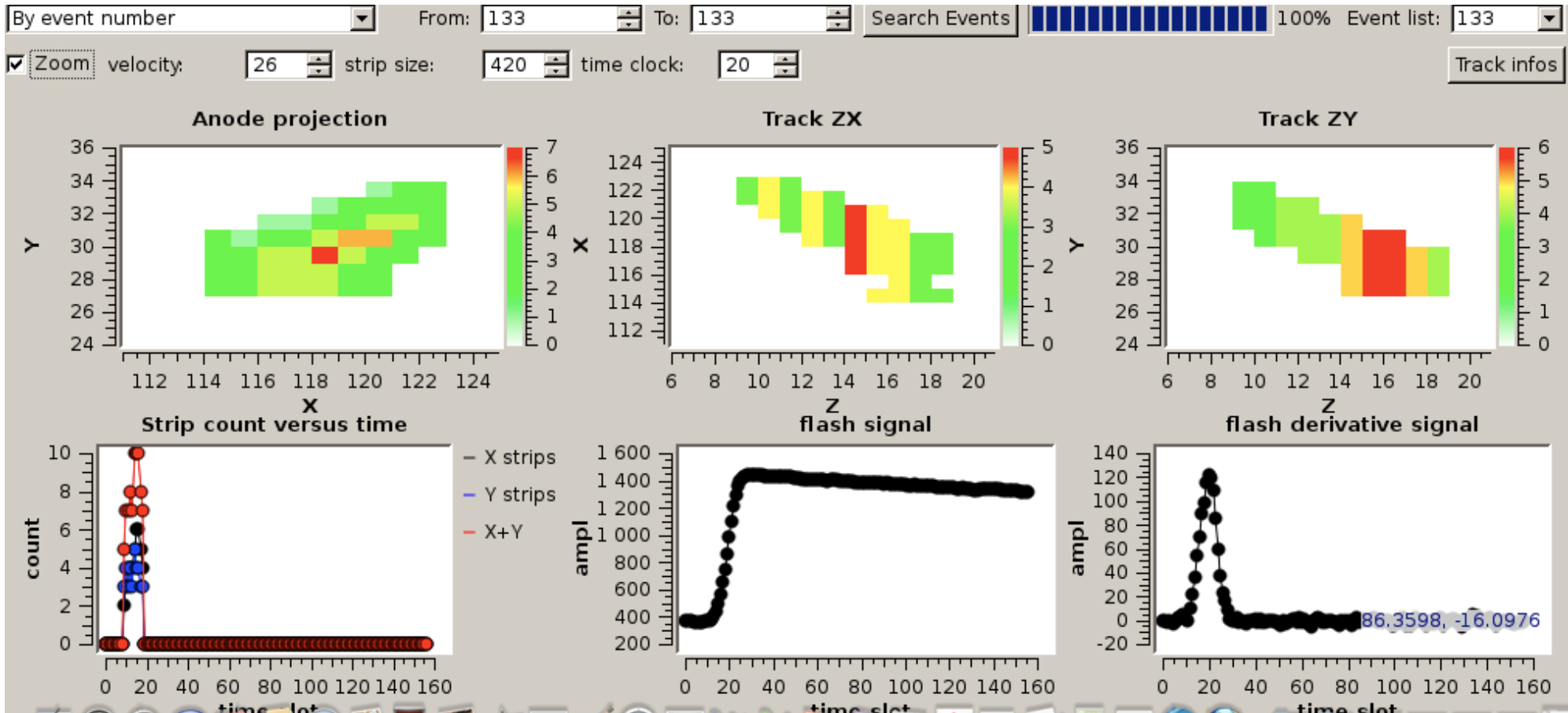
An alpha particle crossing the detector



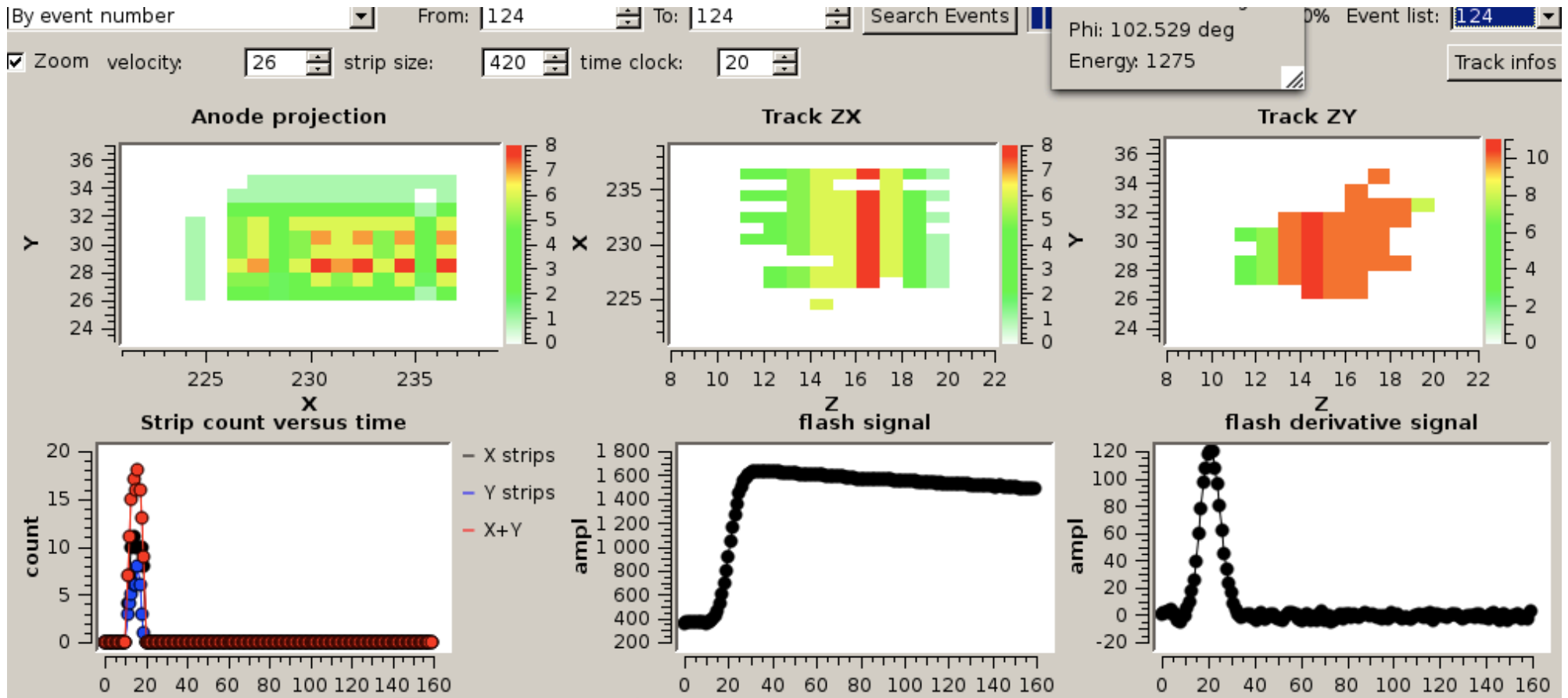
An alpha particle crossing the detector



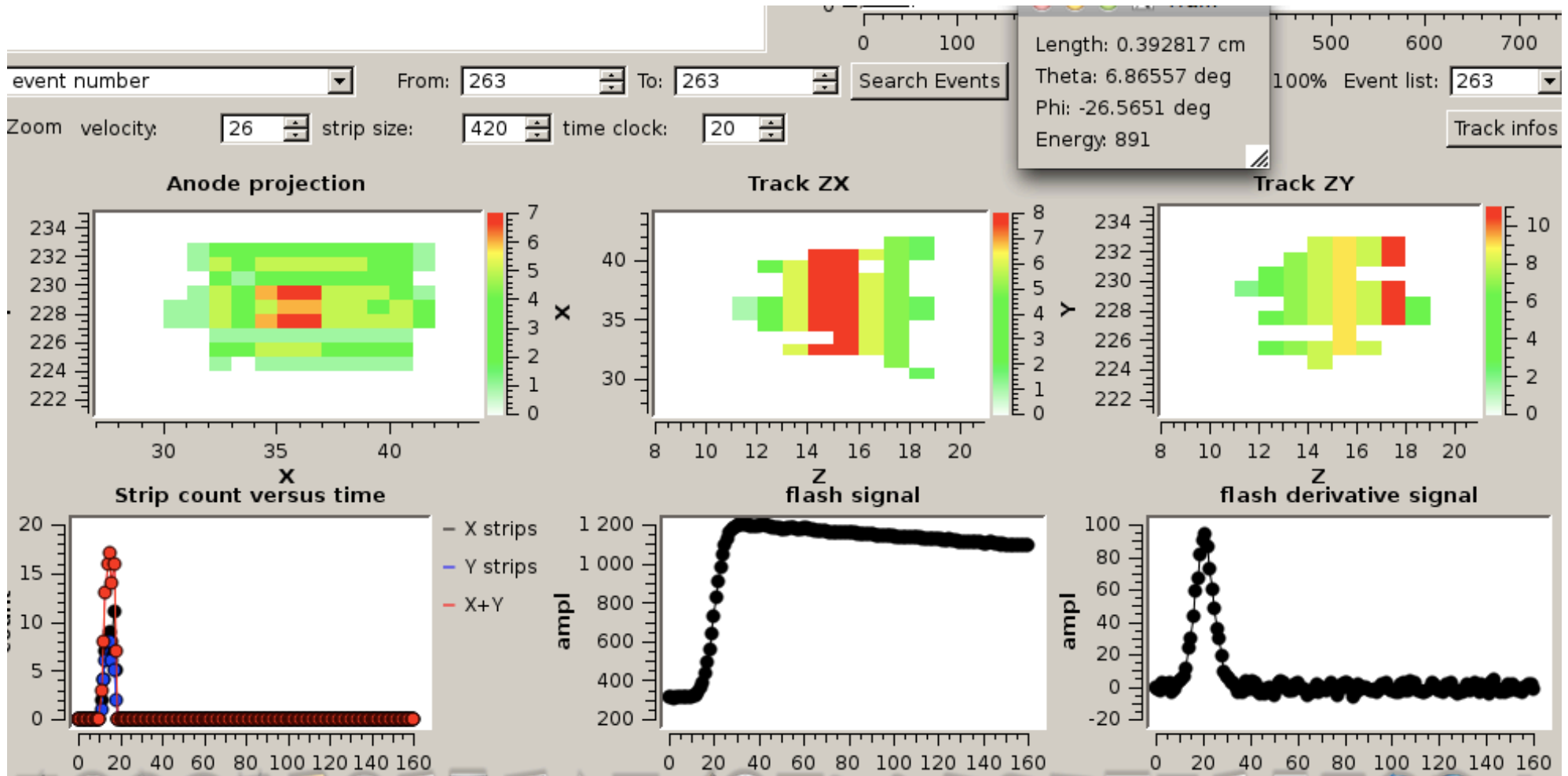
A recoil event (~ 34 keVee)



A recoil event (~ 40 keVee)



A recoil event (~ 28 keVee)

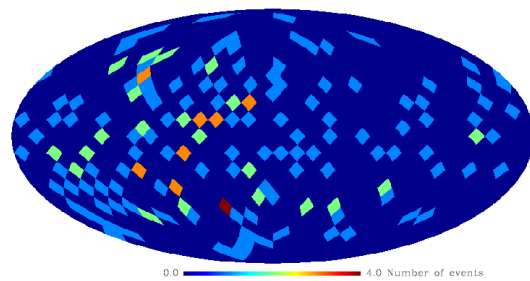


Phenomenology: Discovery

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

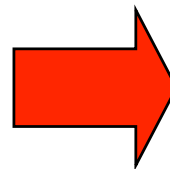
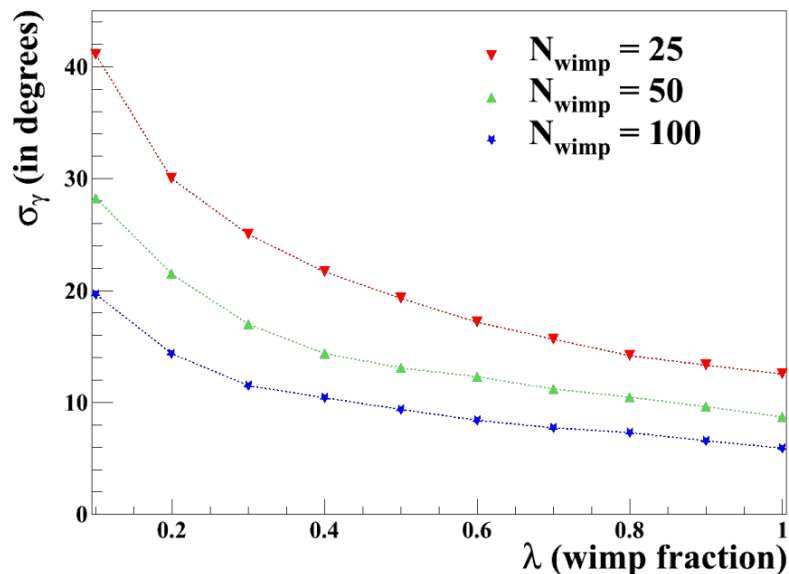
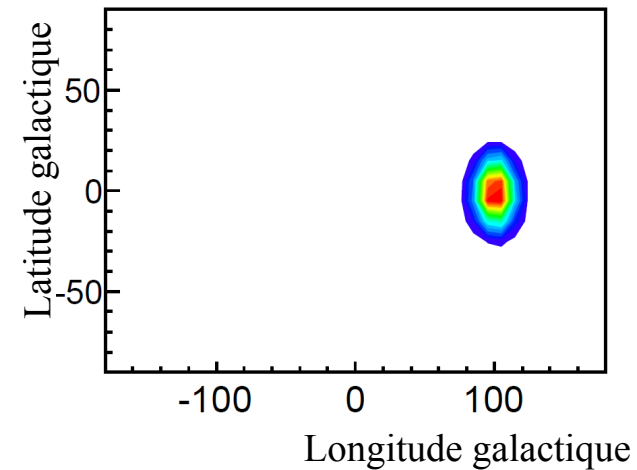
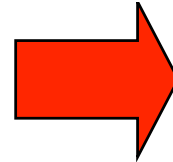
Proof of discovery: **Signal pointing toward the Cygnus constellation**

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



100 WIMP + 100 BKG

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



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

D. Santos (LPSC Grenoble)

Phenomenology: Identification

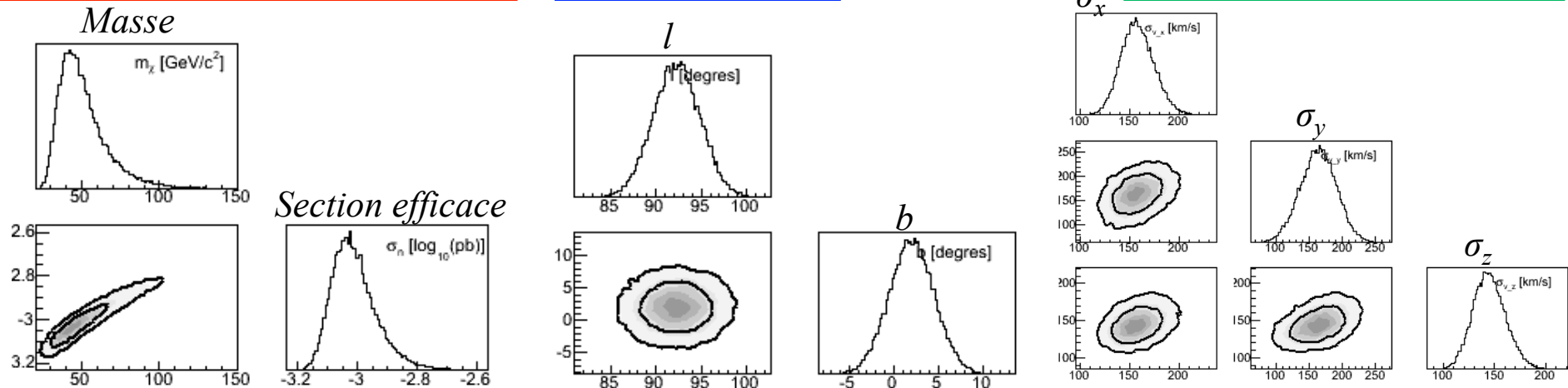
J. Billard *et al.*, PRD 2011

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))	l_\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

MIMAC characteristics

- 10 kg CF₄
- DAQ : 3 years
- Recoil energy range [5, 50] keV

Discovery at 3σ

With BKG (300)

Without BKG

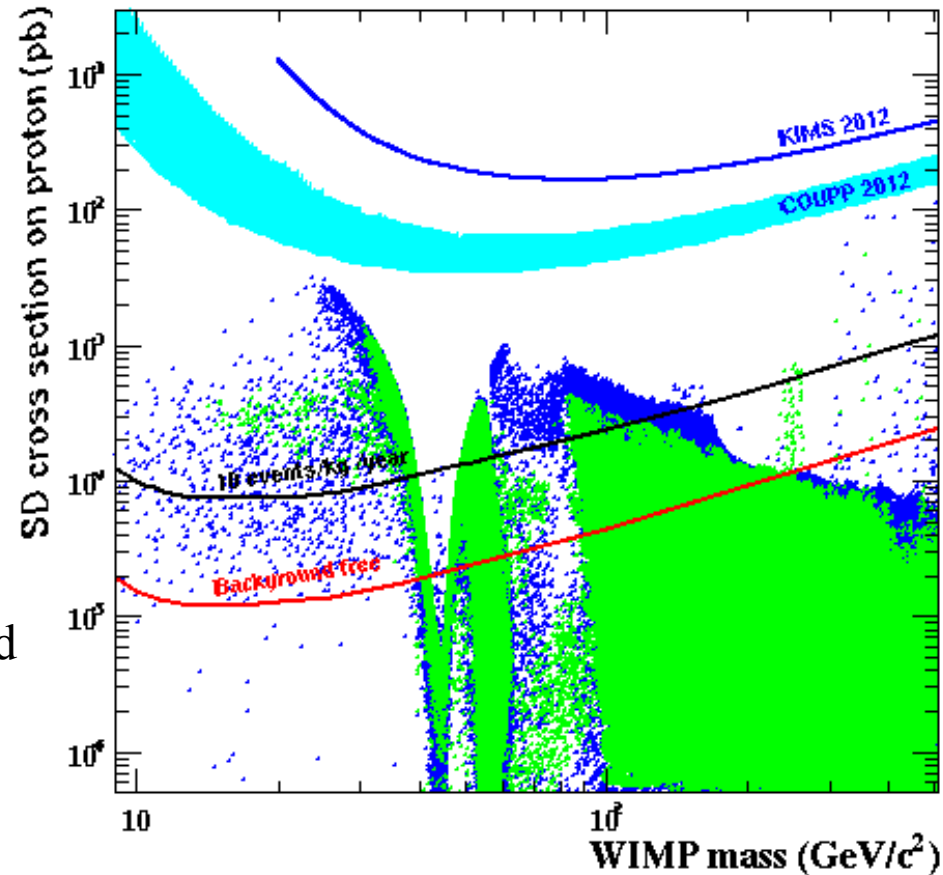
→ Even with a large number of background events, discovery is still possible

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

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

MSSM
NMSSM

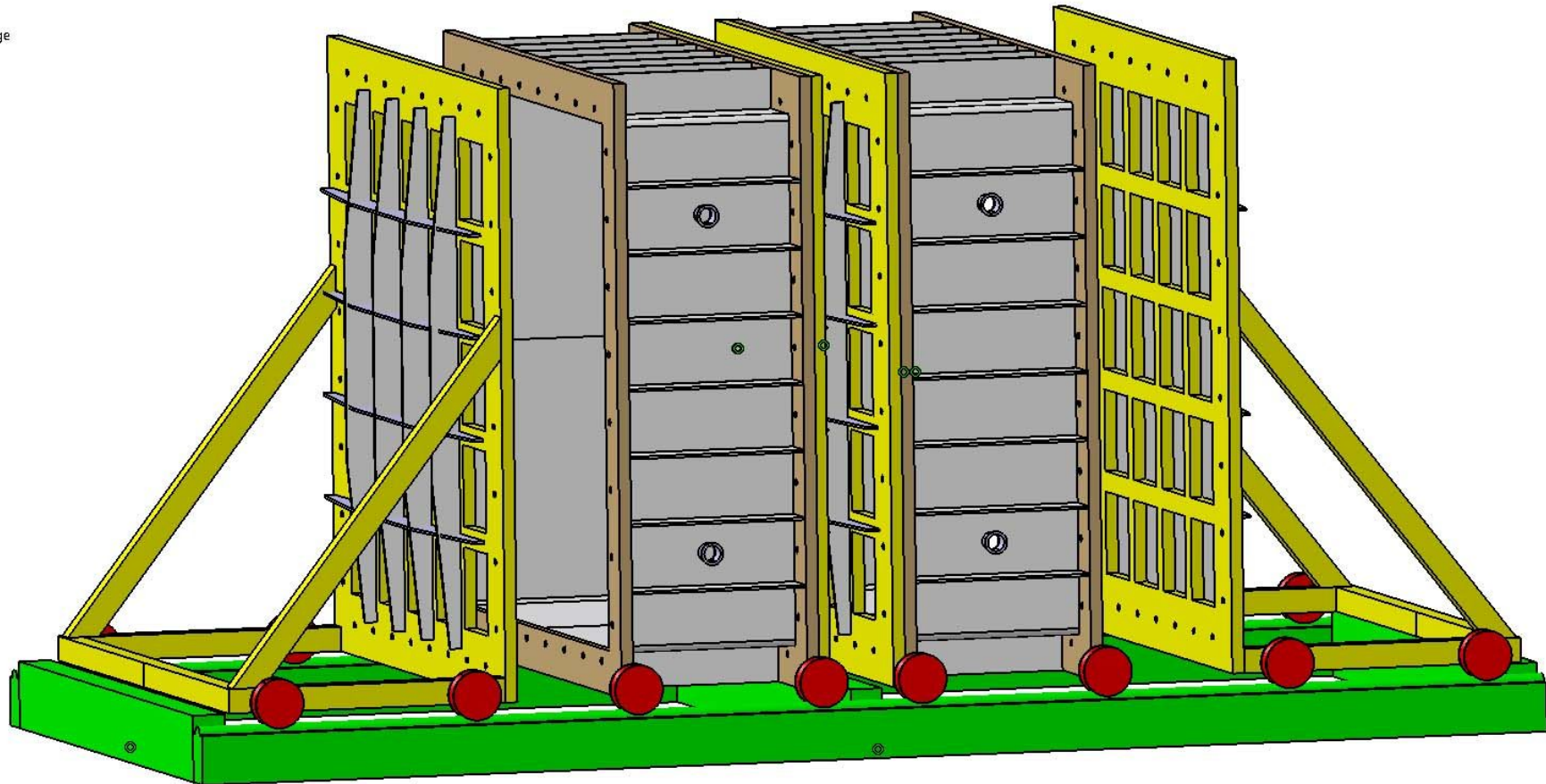
D. Albornoz-Vasquez et al., PRD 85



MIMAC – 1m³

Structure et renfort (Product1.4.1)

blage



Conclusions:

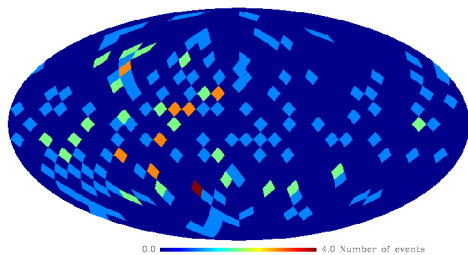
- i) **MIMAC** bi-chamber module is running at Modane Underground Laboratory since June 22nd 2012.
- ii) For the first time 3D nuclear recoil tracks are available between 1keVee and 100 keVee to characterize fast neutron background
- iii) New degrees of freedom are available to discriminate electrons from nuclear recoils to improve the DM search for.
- iv) The directional detection at low energies is possible !
- v) A lot of work to be done... You are all welcome !

MIMAC : Dark Matter discovery/exclusion

J. Billard *et al.*, PLB 2010

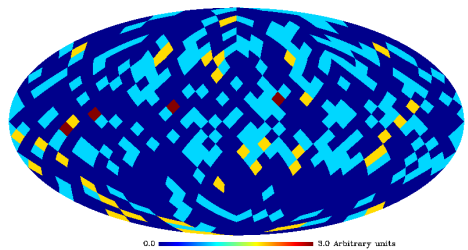
J. Billard *et al.*, PRD 2010

• **discovery (5σ)**
Up to 10^{-4} pb

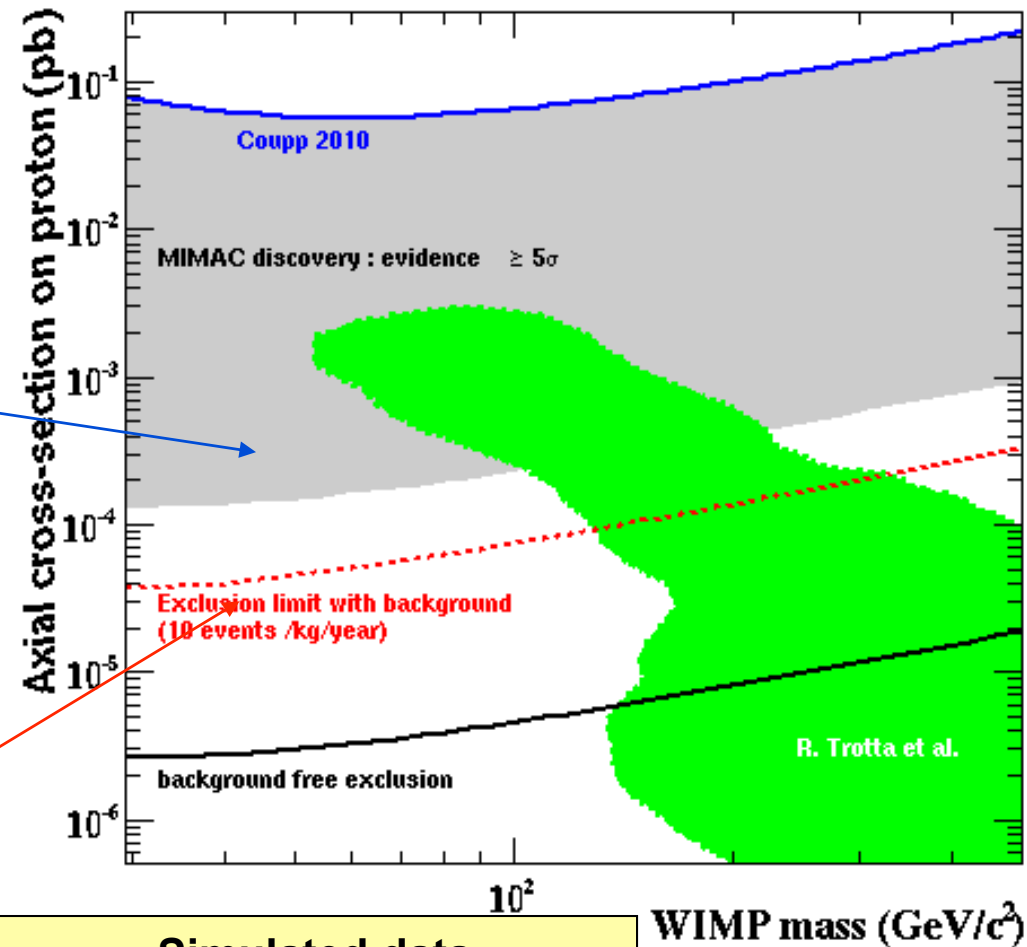


100 WIMP, 100 bkg

• **exclusion**
Up to 10^{-6} pb



0 WIMP, 300 bkg



Simulated data

- 30 kg.year CF_4
- Recoil energy [5, 50] keV
- Angular resolution : 15°