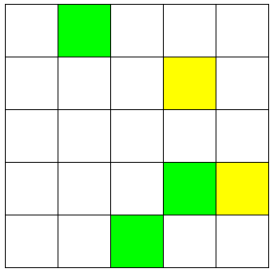


MIMAC

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)

LPSC Grenoble

cnrs IN2P3 Les deux infinis

MIMAC:
(MIcro-tpc MAtrix of Chambers)

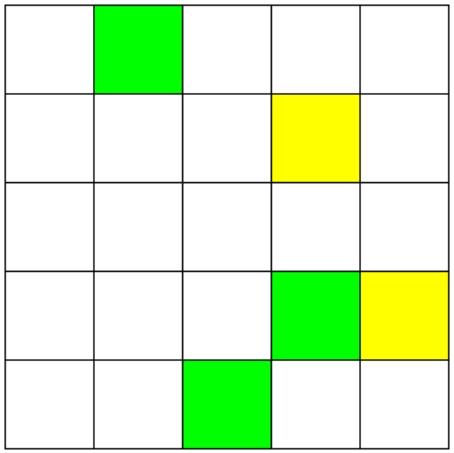
LPSC (Grenoble) : J. Lamblin, F. Mayet , D. Santos
J. Billard (Ph.D) (left in July 2012**), Q. Riffard (Ph.D)** (started in October 2012)

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) :	**J-F. Muraz, J. Médard (CDD-1year)**

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

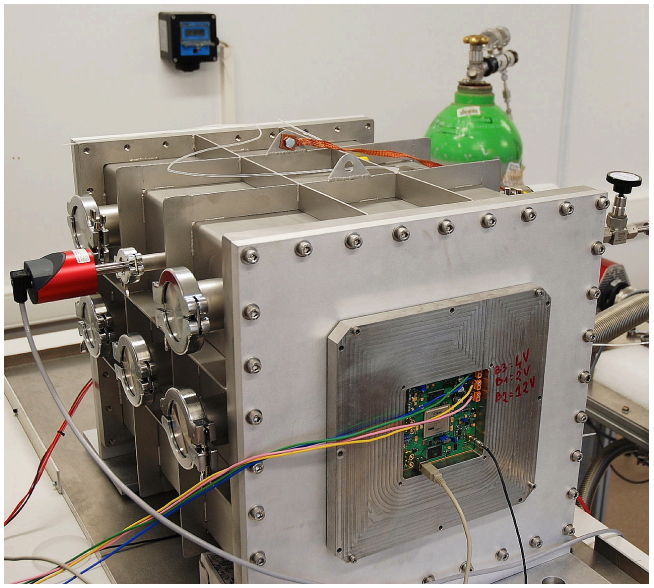
Neutron facility (AMANDE) :
IRSN (Cadarache): L. Lebreton, D. Maire (Ph. D.)

The MIMAC project



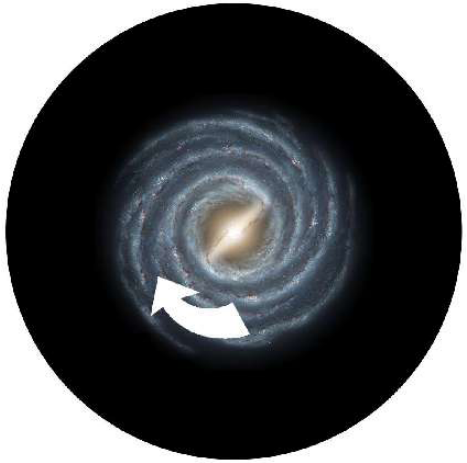
A low pressure multi-chamber detector

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



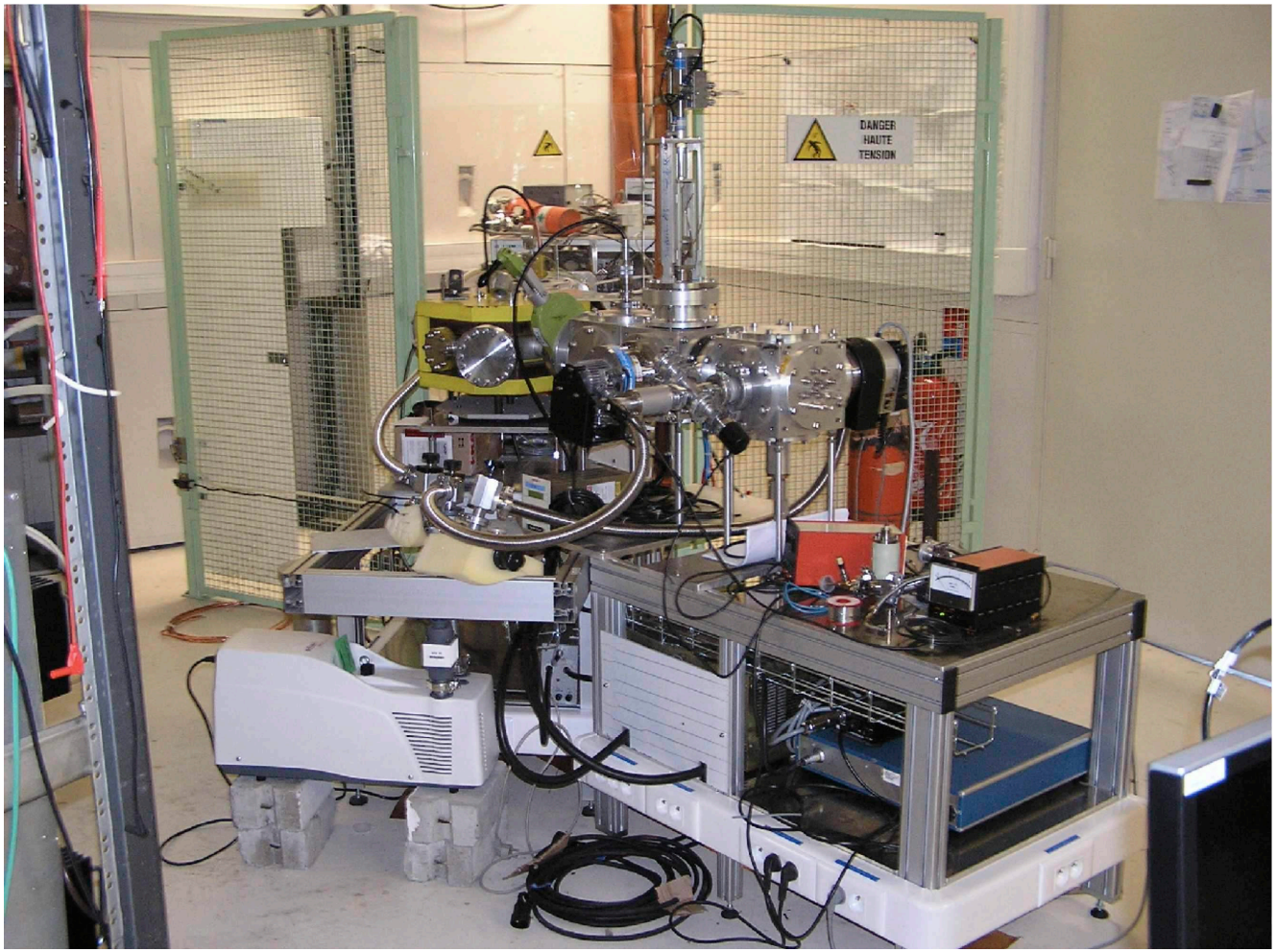
Bi-chamber module
2 x (10.8x 10.8x 25 cm^3)

<u>Strategy:</u> (see Fréd Mayet's talk)
- Directional direct detection
- Energy (Ionization) AND 3D-Track of the recoil nuclei
- Prove that the signal "comes from Cygnus "



D. Santos (LPSC Grenoble)

Ionization Quenching Facility at LPSC-Grenoble



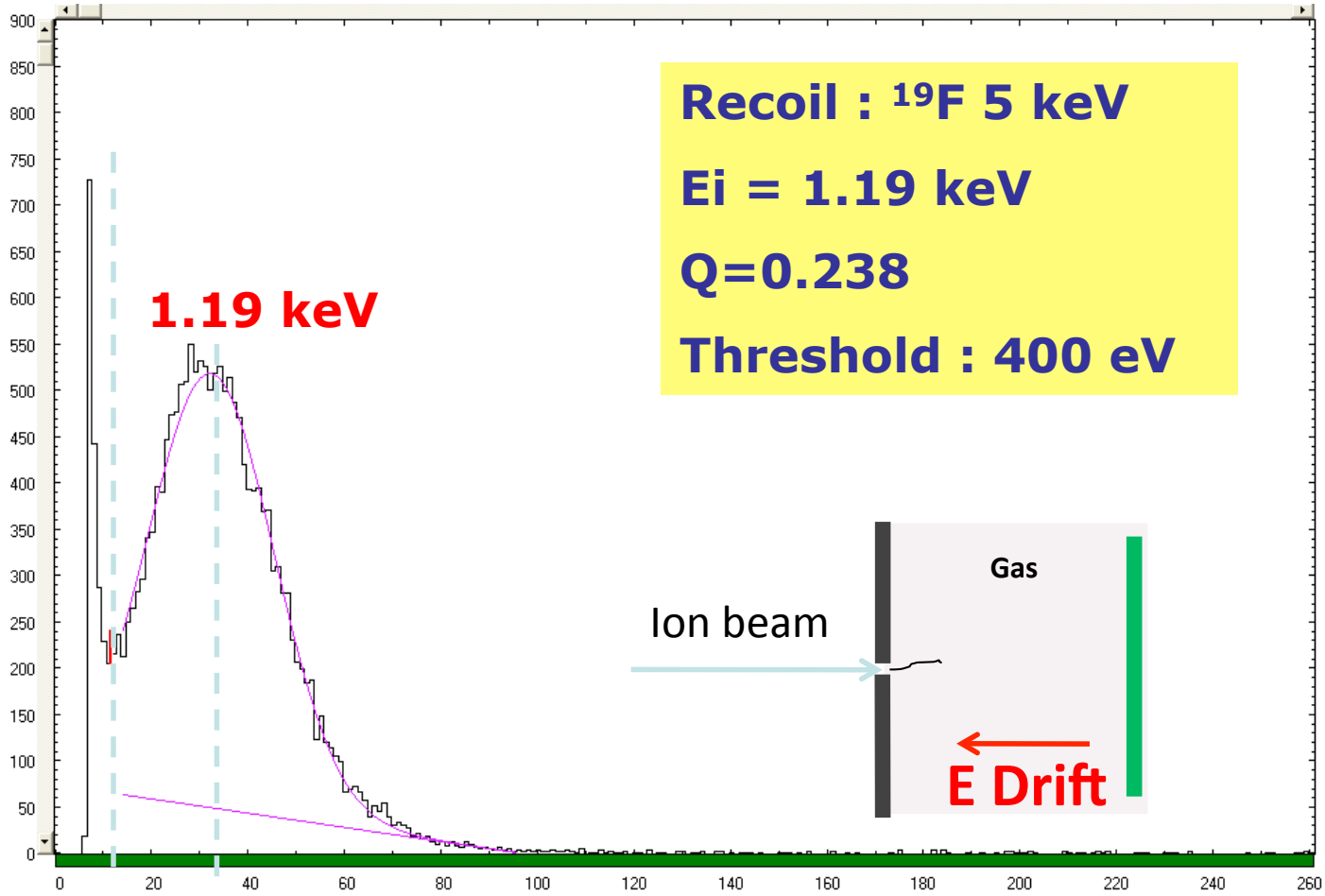
- **Low energy ion source**

  1 to 50 keV

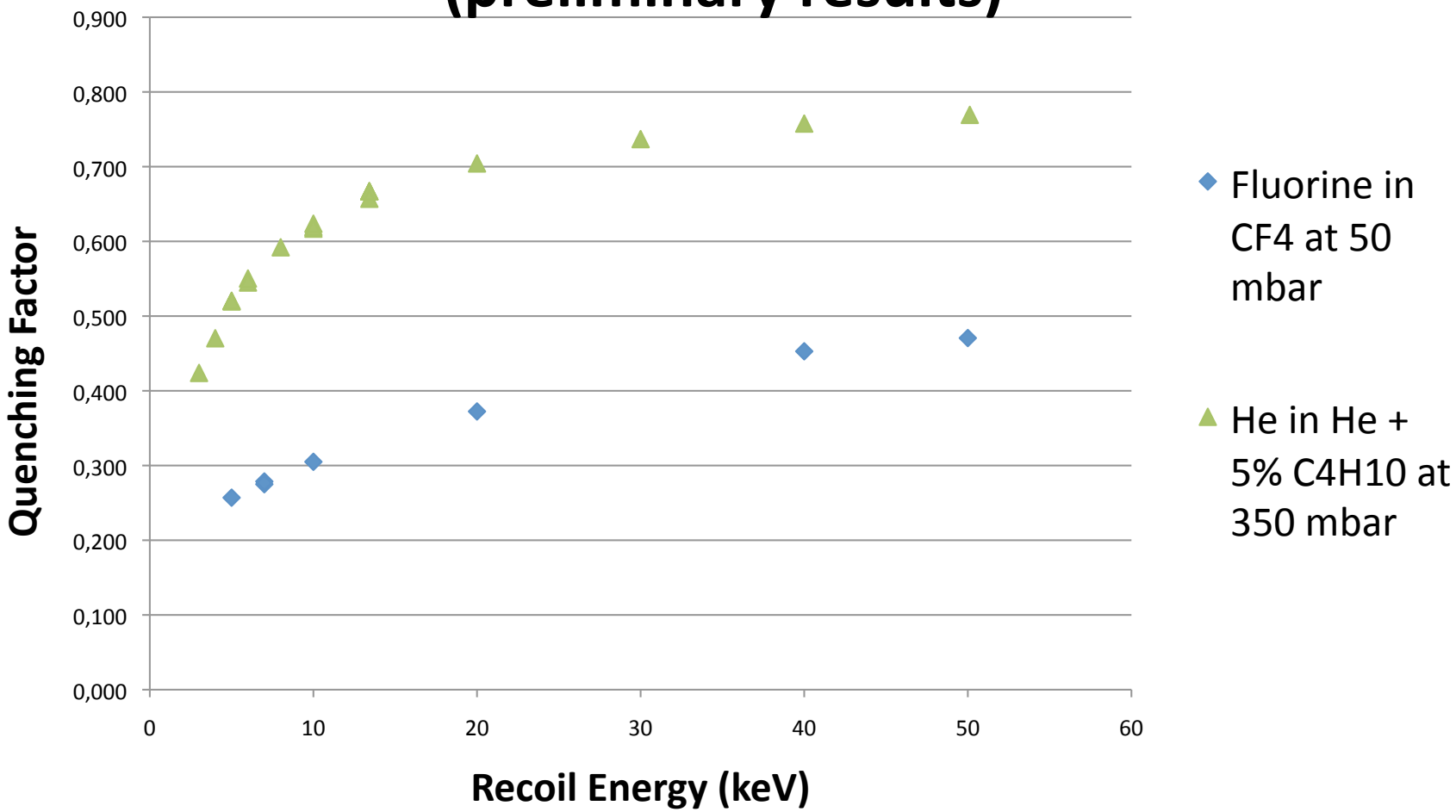
- **Developped @LPSC**

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

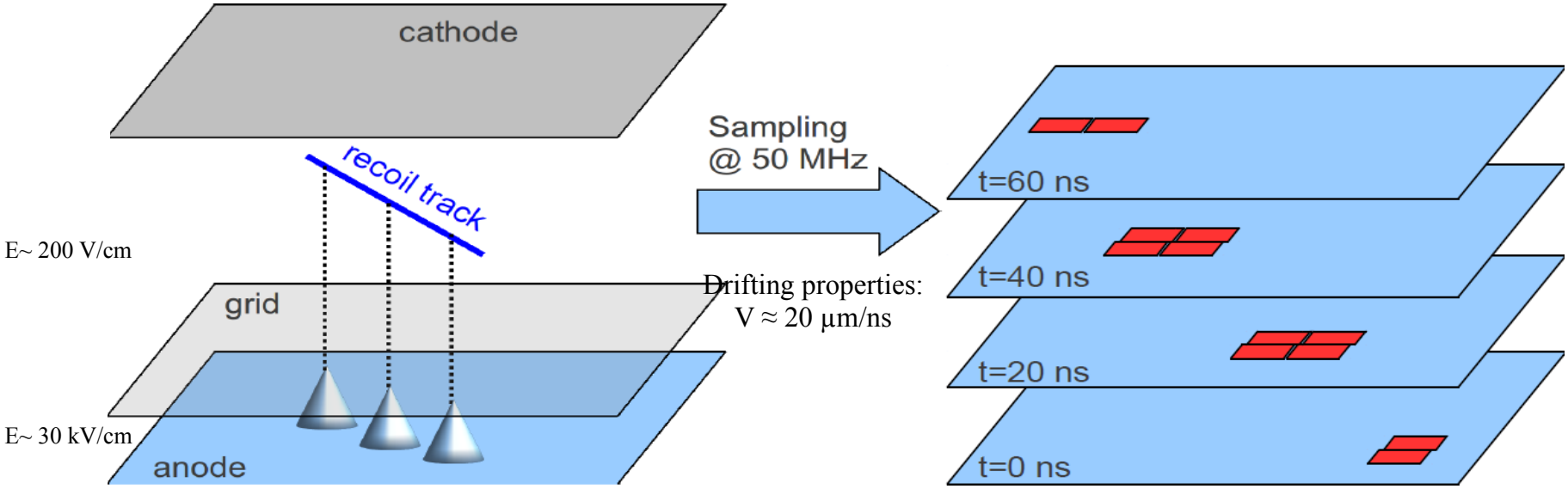
40mbar CF_4+16.8mbar CHF_3+1.2 mbar Isobutane



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



MIMAC: Detection strategy

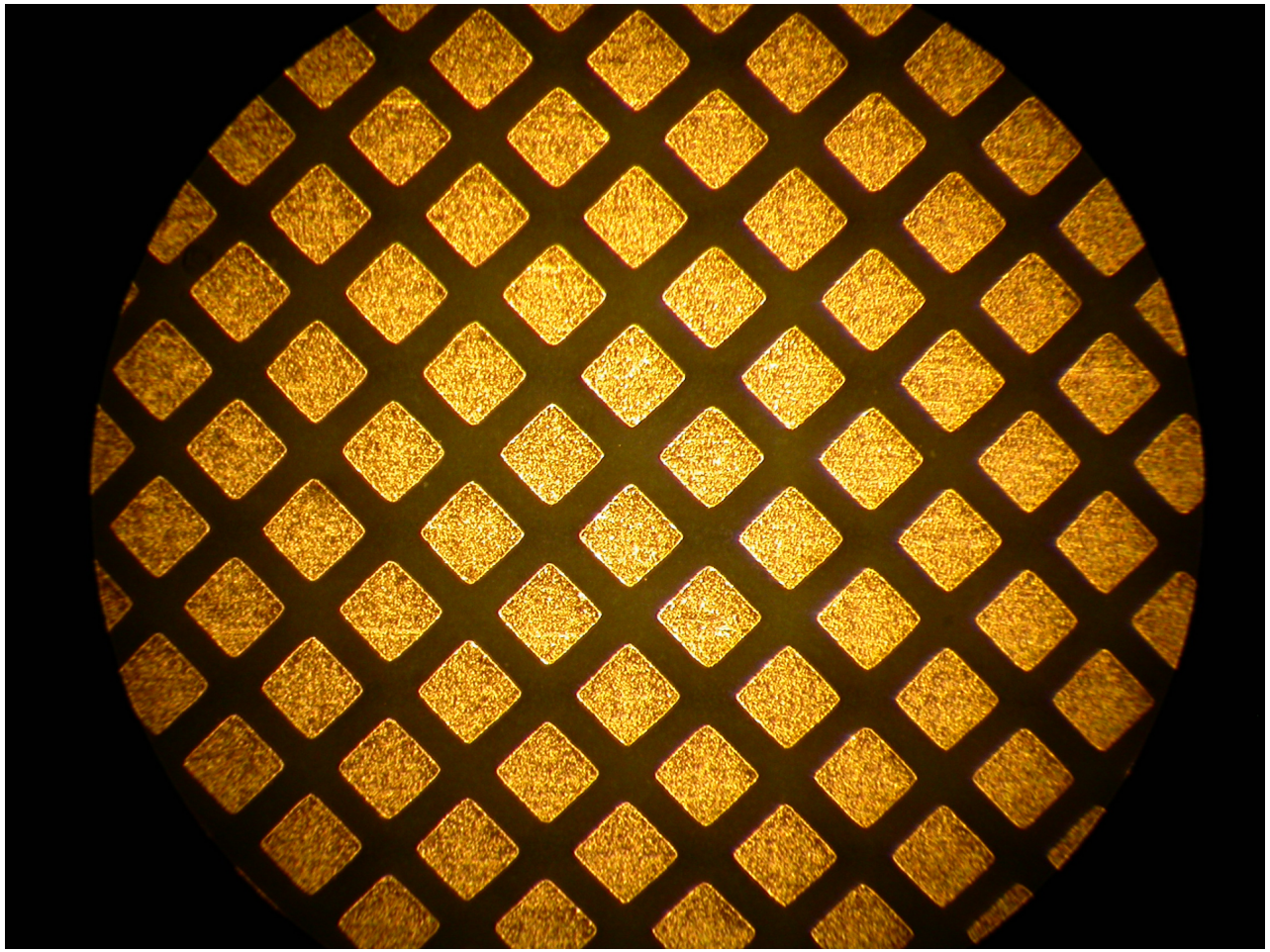


Scheme of a MIMAC µTPC

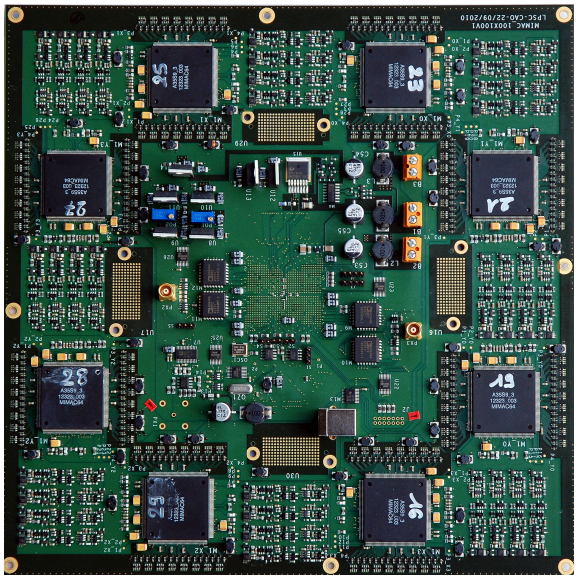
Evolution of the collected charges on the anode

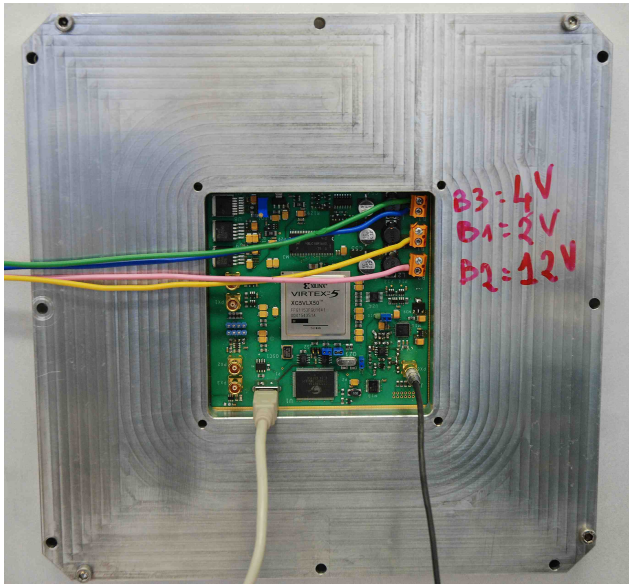
Measurement of the ionization energy: Charge integrator connected to the grid

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)

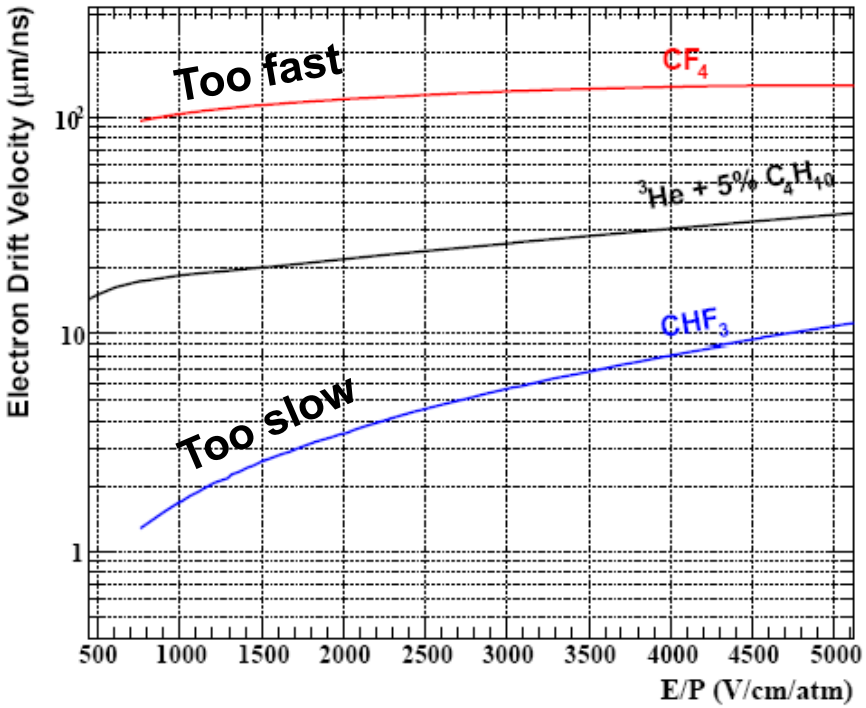
V1: 2007 (192 channels for the 3cm x3cm)
ASIC-Mimac (16 channels)

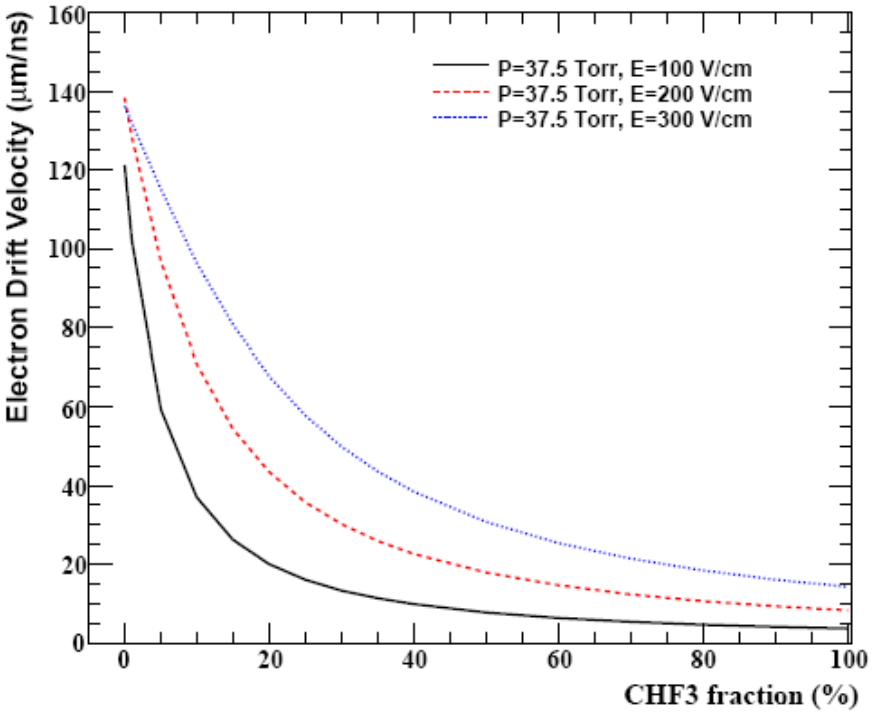
V2: 2009 (512 channels for the 10cmx10cm)
ASIC-Mimac (64 channels)

V3: 2011 (upgraged version) 512 channels

3D Tracks: Drift velocity

Magboltz Simulation





- New mixed gas MIMAC target : CF_4 + x% CHF_3 (x=30)

MIMAC validation with neutrons

Neutron monochromatic field:

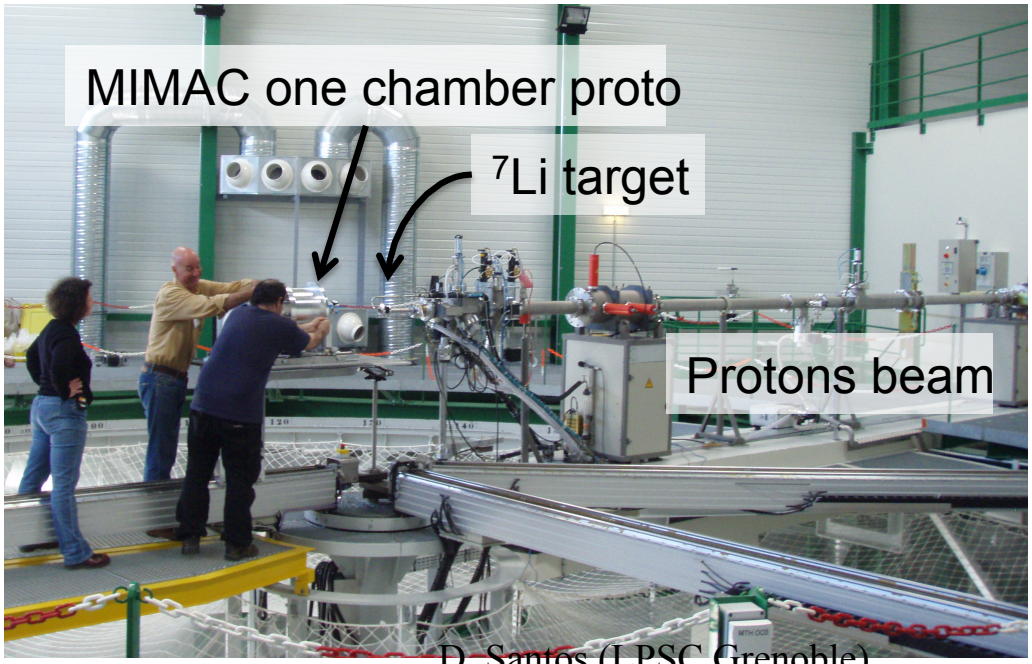
AMANDE facility at IRSN of Cadarache

– Neutrons with a well defined energy from resonances of ^{7}Li by a (p,n) reaction

$$E_{\mathrm{Re}coil} = 4\frac{m_n m_R}{\left(m_n + m_R\right)^2} E_{neutron} \cos^2\theta$$

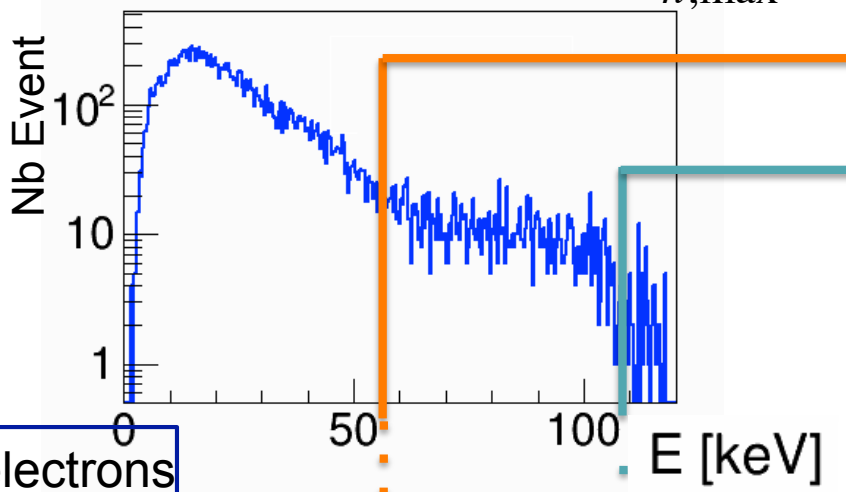
Calibration:

^{55}Fe (5.9 keV) and ^{109}Cd (3.1 keV) sources



Measurement of the ionization energy and the 3D track

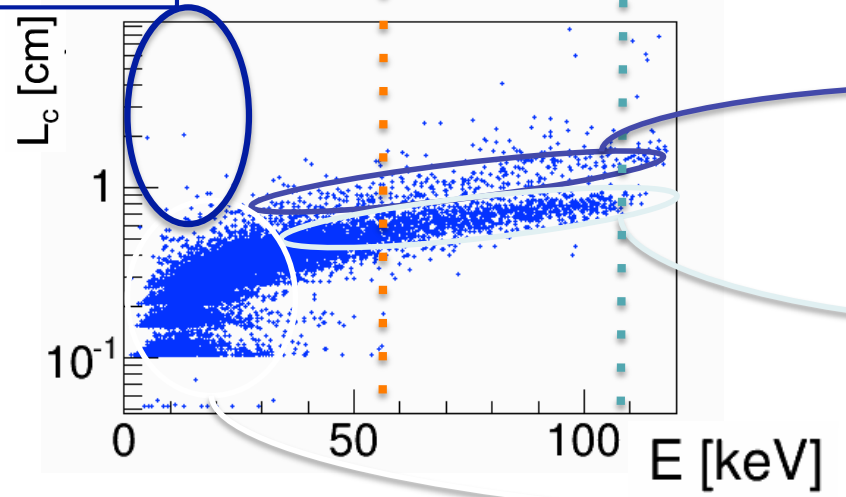
Max neutrons energy: $E_{n,\max} = 565$ keV



Fluorine end-point × Q_{ion}

Carbon end-point × Q_{ion}

No electrons



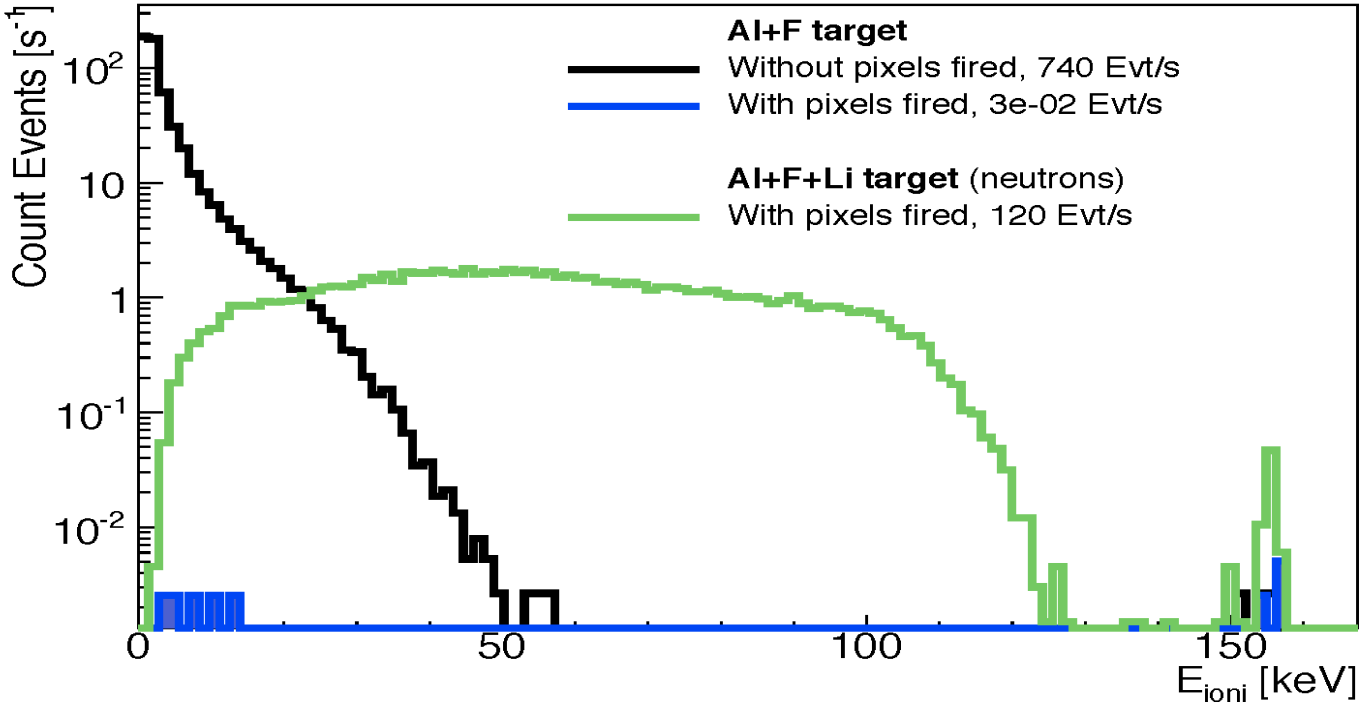
Proton « arm »

Fluorine + Carbon

Fluorine + Carbon +Proton)

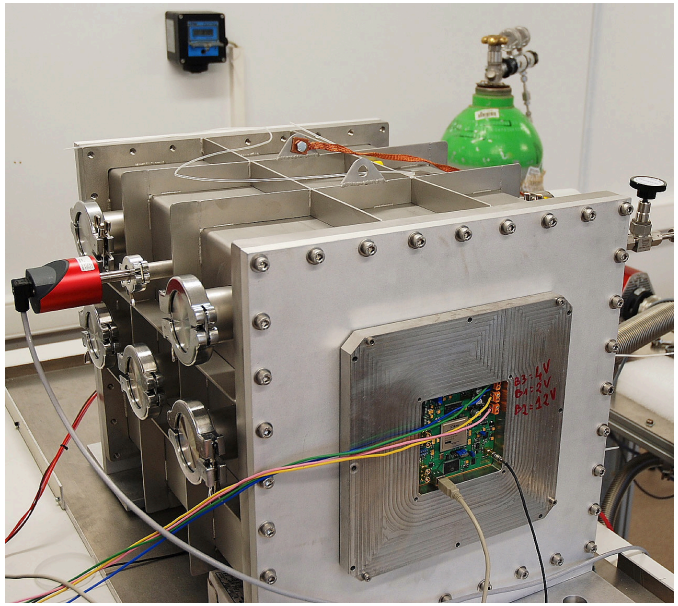
« Gamma rejection »

from the background of an in beam proton (2.5 MeV) reaction

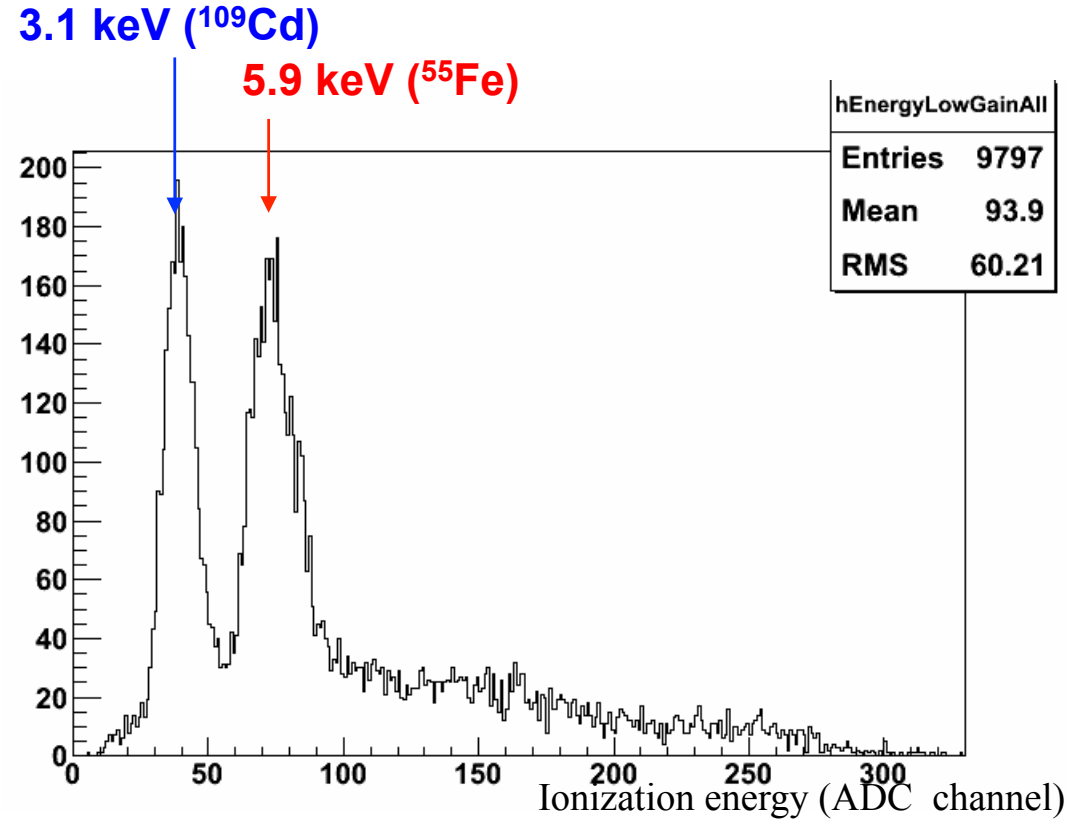


MIMAC bi-chamber module

- Two detectors with a common cathode (mylar 24um, 12um)
- Active volume = 2x(25x10.8x10.8) cm^3 ~ 5.8 l
- Gas mixture 70% CF_4 + 28% CHF_3 + 2% C_4H_{10} at 50 mbar
- Gas circulation system with a buffer volume, a pressure regulator and a O_2 filter (+ charcoal filter)
- On-line calibration system with a X-ray generator (by fluorescence)



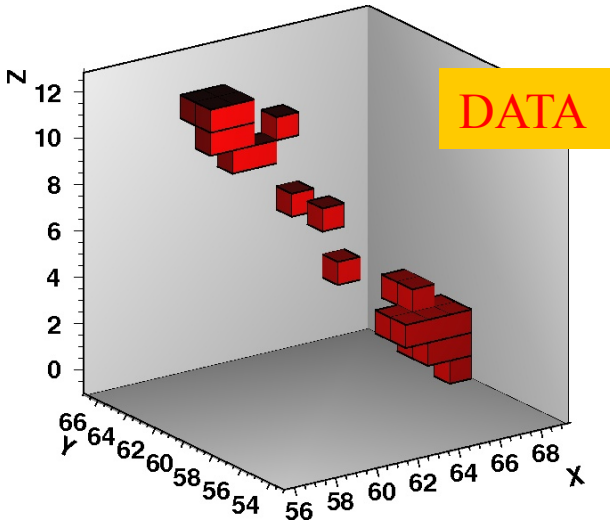
MIMAC: Performance at low energies



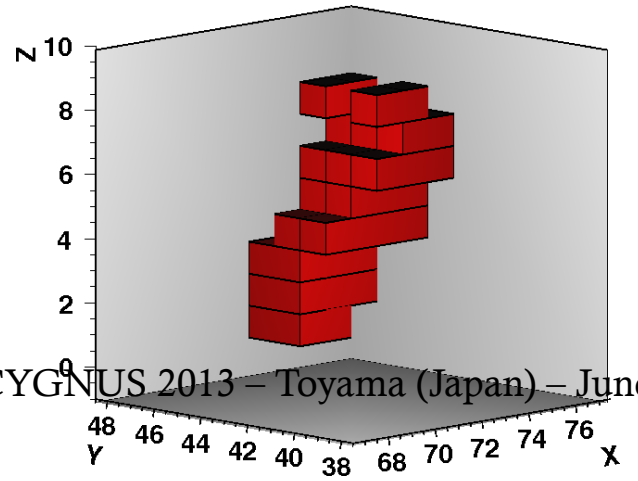
CF_4+ 28%CHF_3

(+2% C_4H_{10})

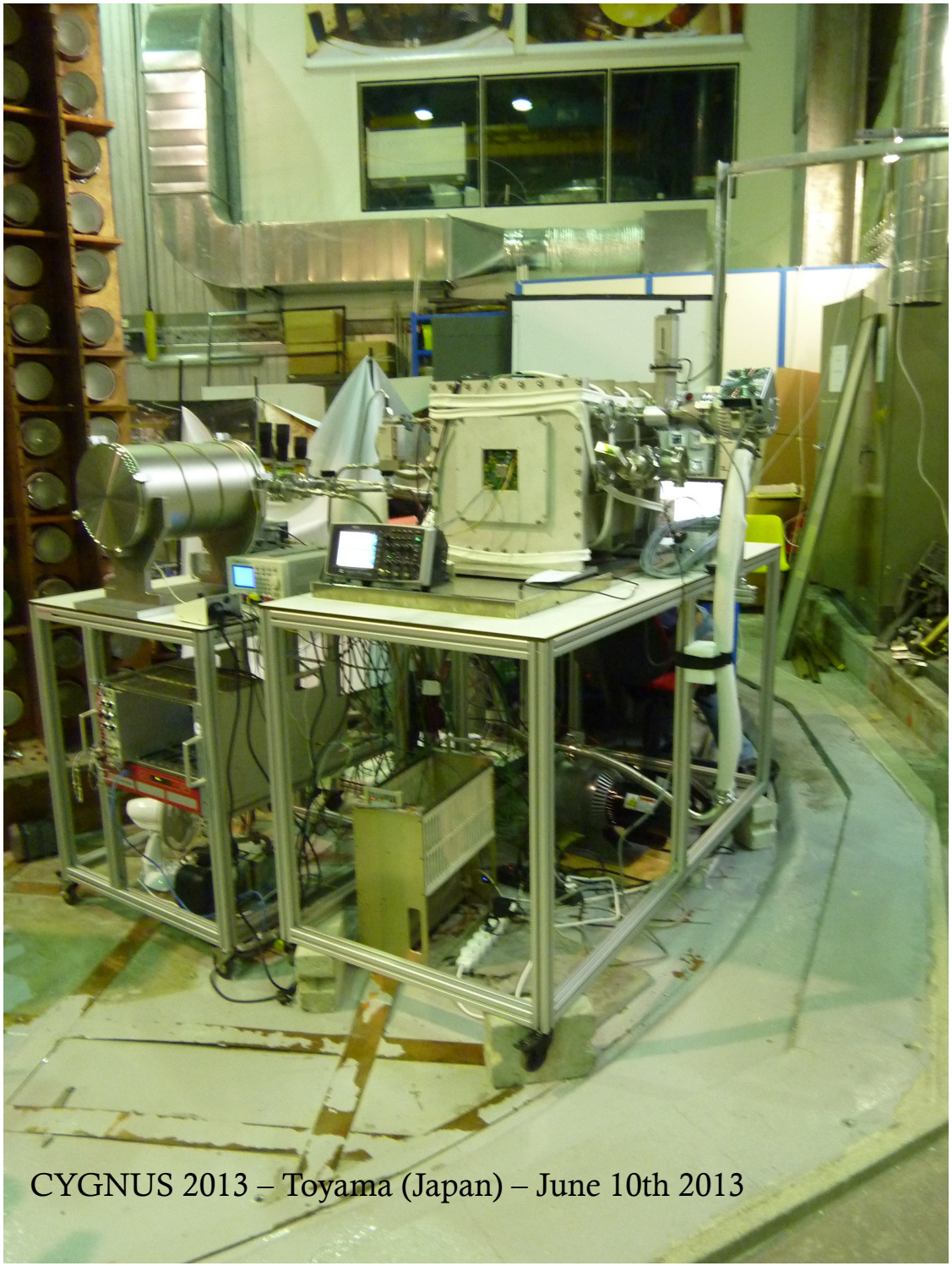
50 mbar



One electron track (6 keV)



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



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

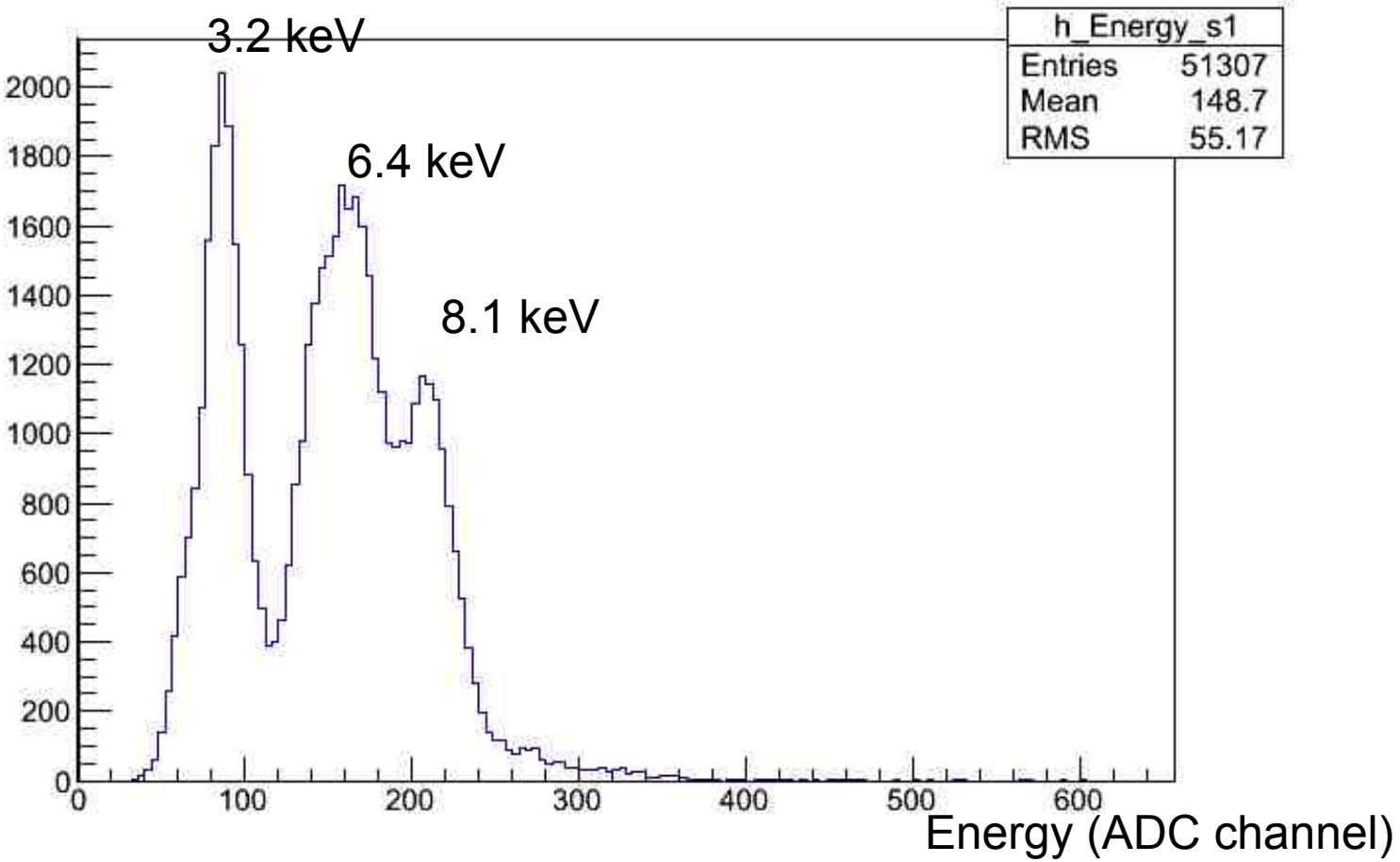
-working at 50 mbar
(CF_4+28% CHF_3 + 2% C_4H_{10})

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

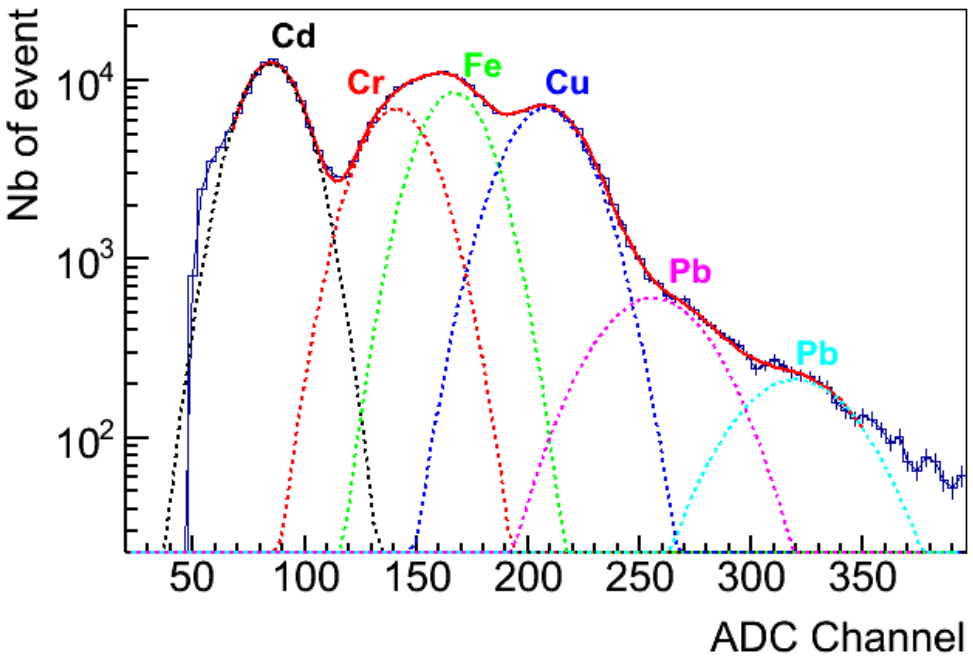
Many thanks to LSM staff

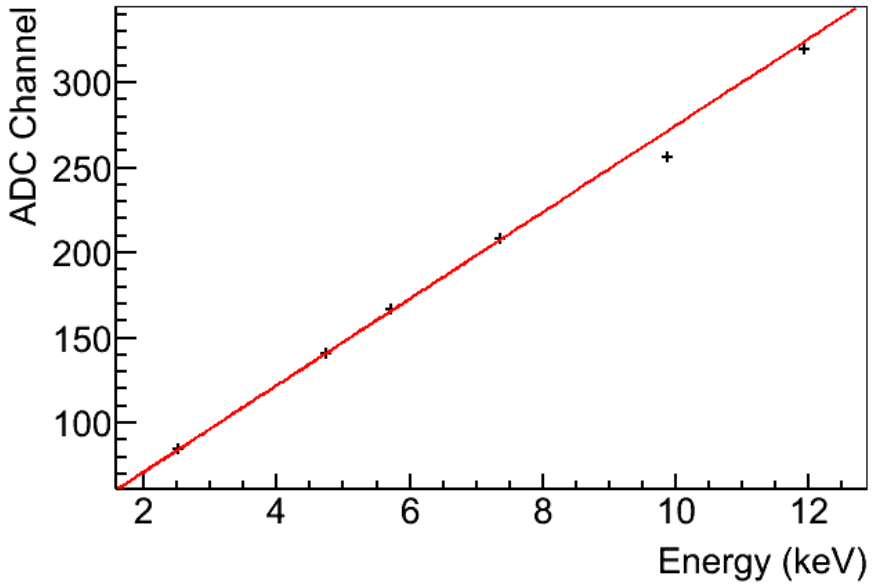
D. Santos (LPSC Grenoble)

Calibration – Chamber2 (at Modane)
fluorescence of Cd-(Cr-Fe)-Cu

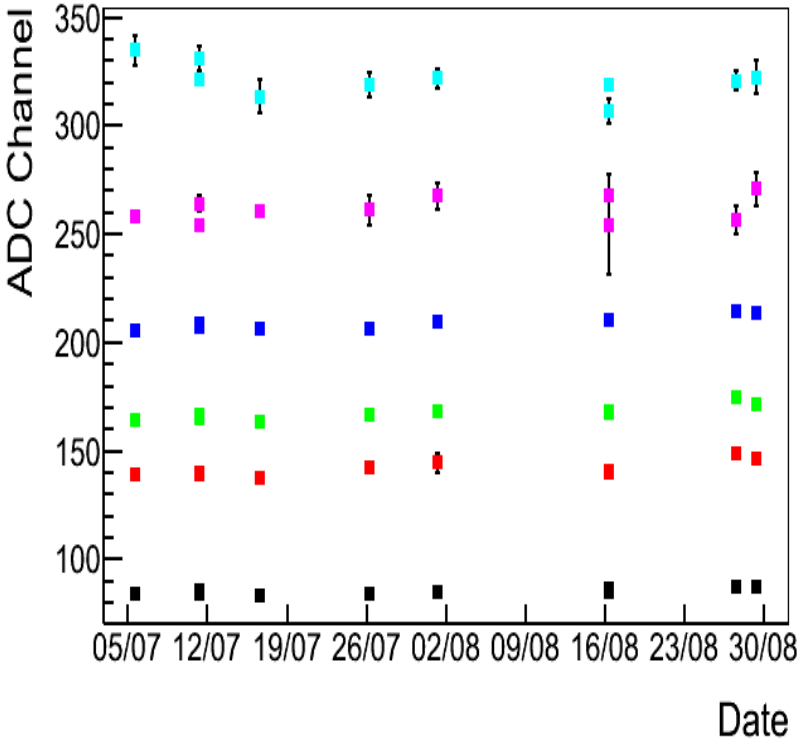


MIMAC Calibration at Modane (by fluorescence + X-ray generator)



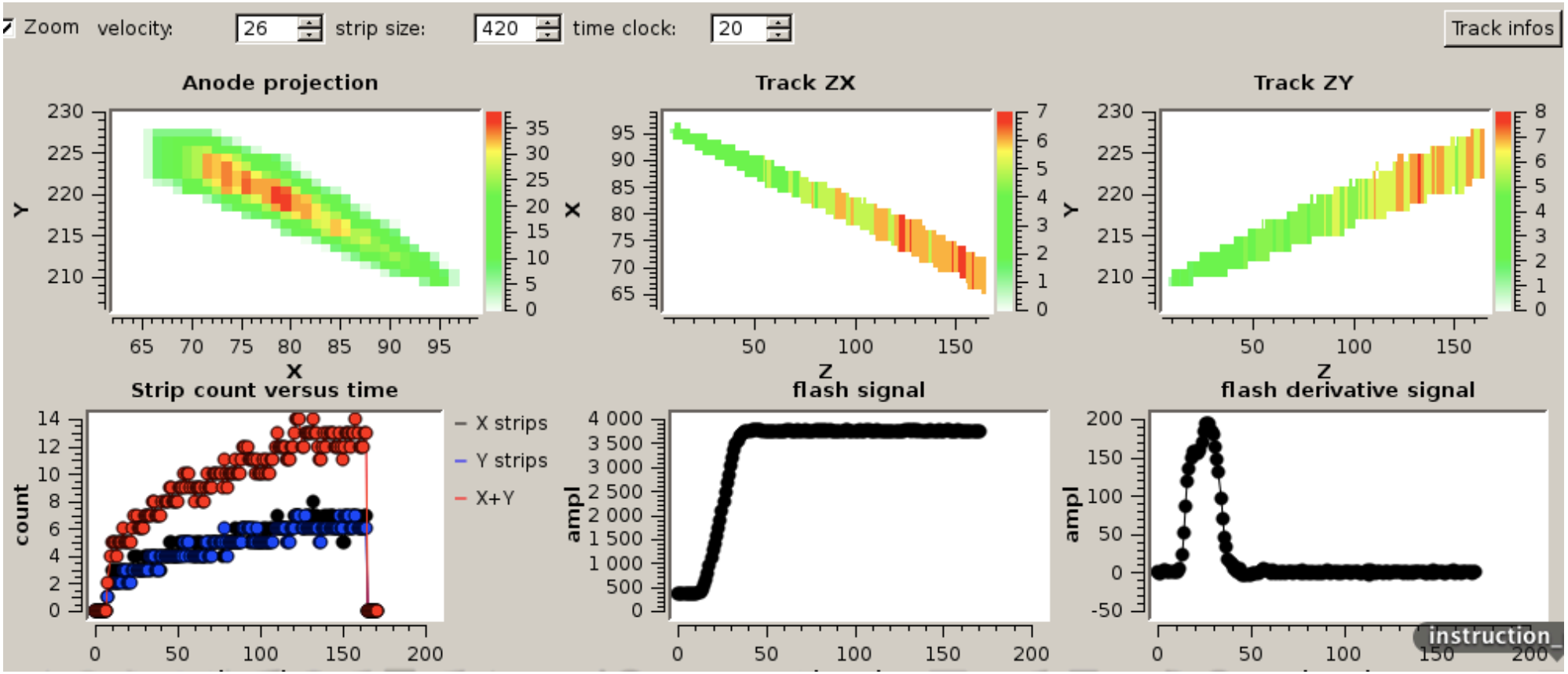


Gain stability (Peak_channel vs. time(days))

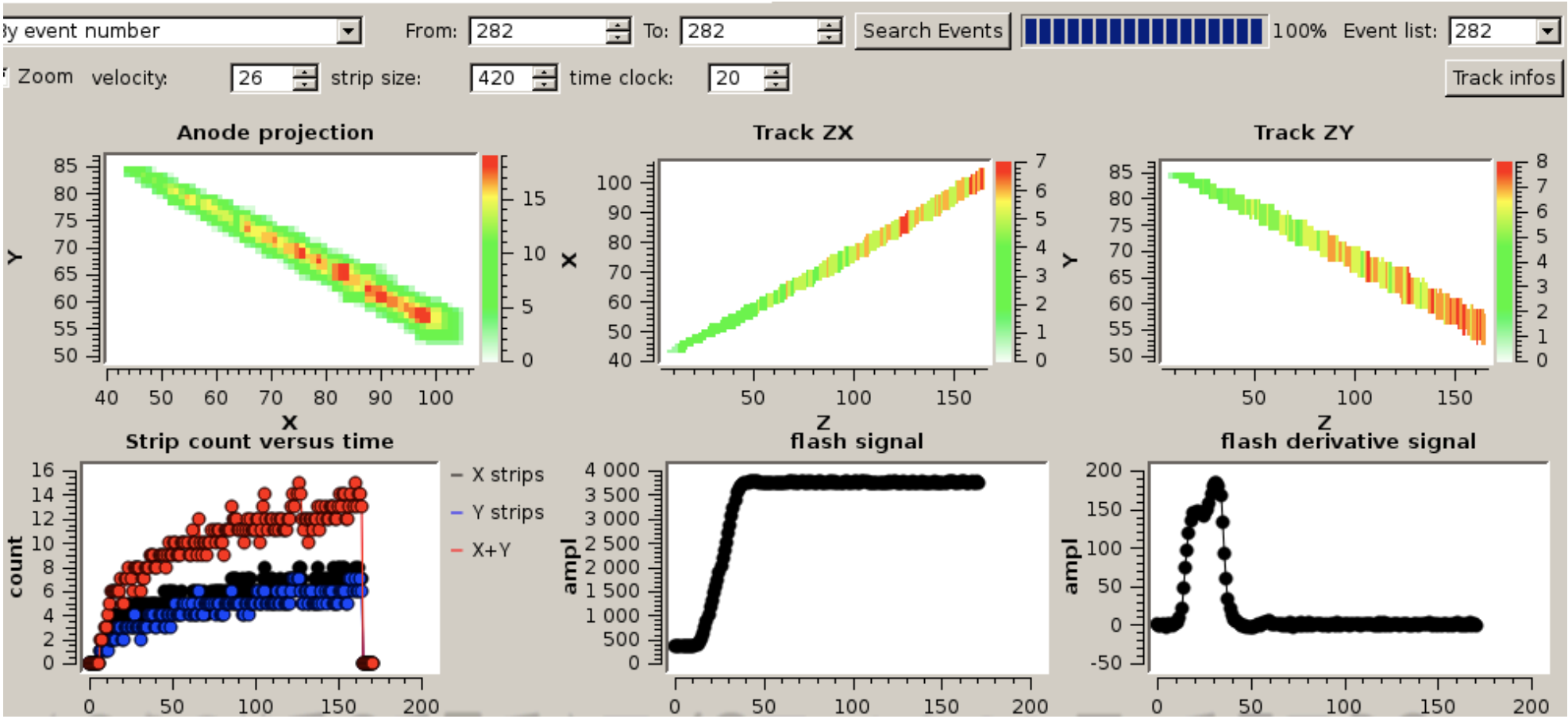


An alpha particle crossing the detector
(as an illustration of the MIMAC observables)

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



An other alpha particle crossing the detector



« 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 observables

– Ionization Energy: E_{ioni}

– flash ADC length: L_{ADC}

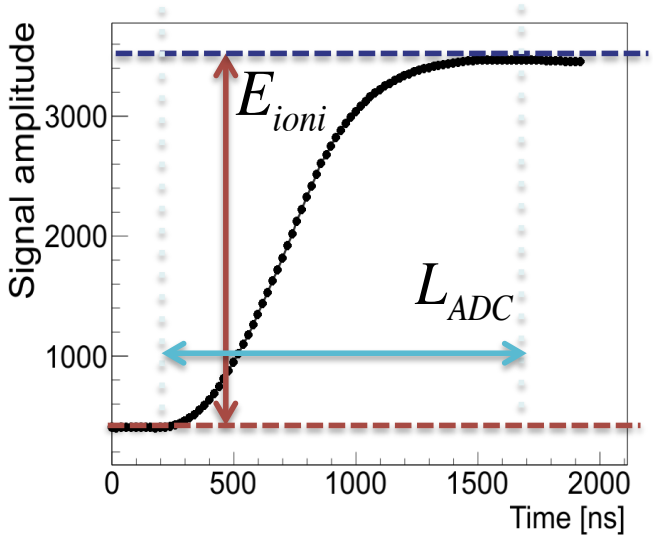
– Track length:

$$L_C = \sum_i \Delta L_i$$

- Normalized Integrated Straggling

$$NIS = \frac{1}{E_{ioni}} \sum_i \theta_i$$

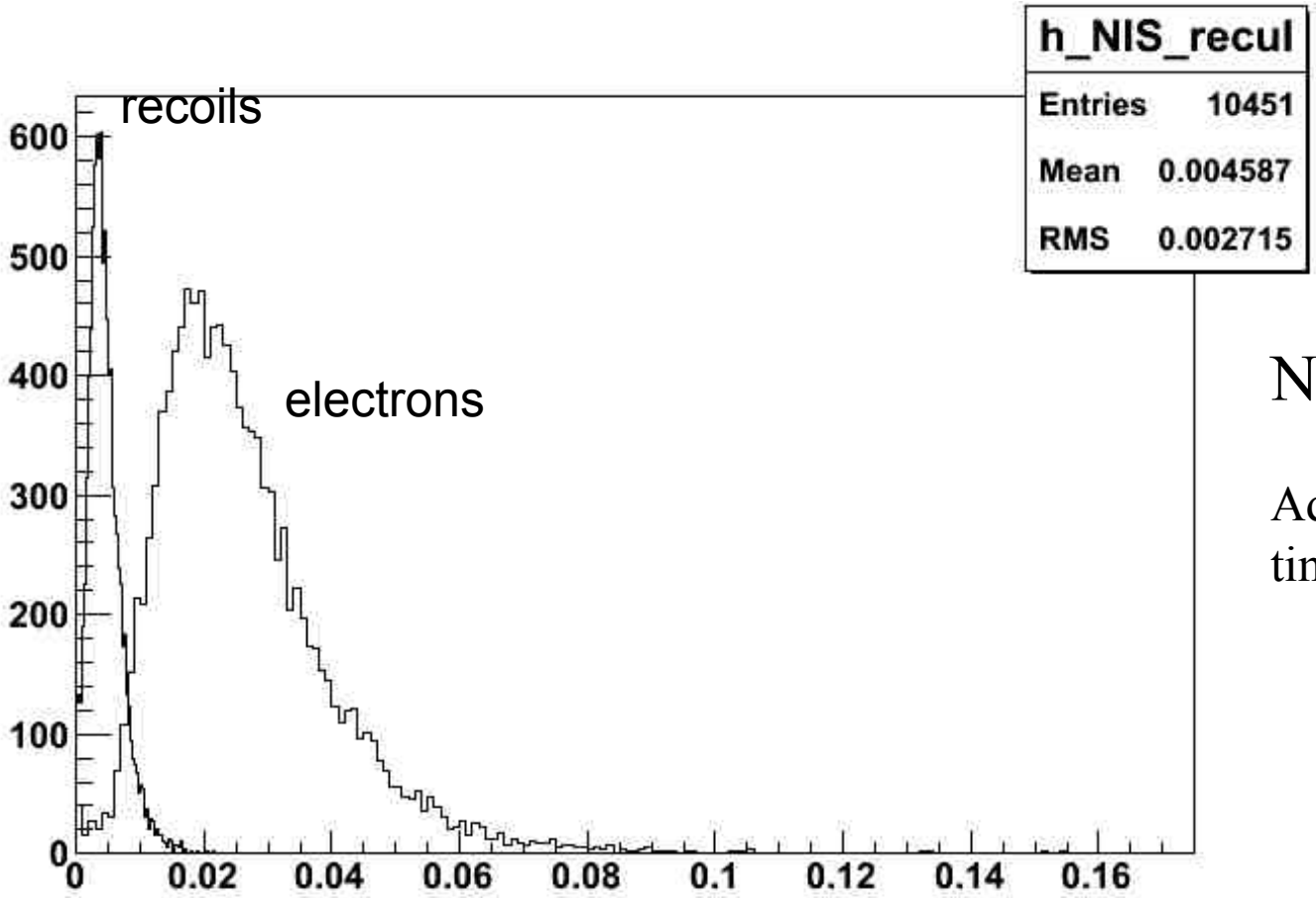
Strong Correlation between $L_{ADC} \leftrightarrow L_C$



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)

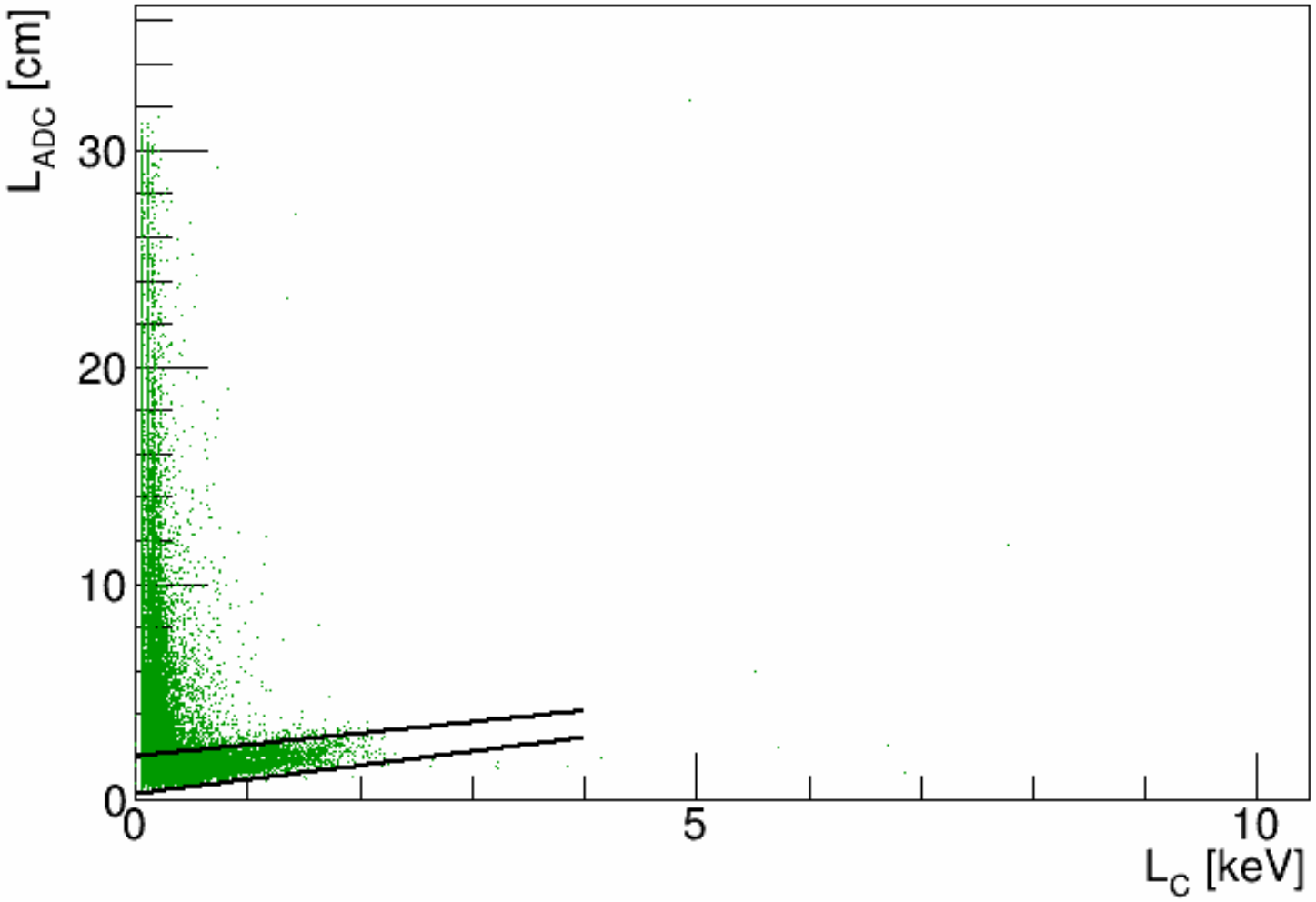


$$NIS = \Sigma (\Delta\theta_i) / E$$

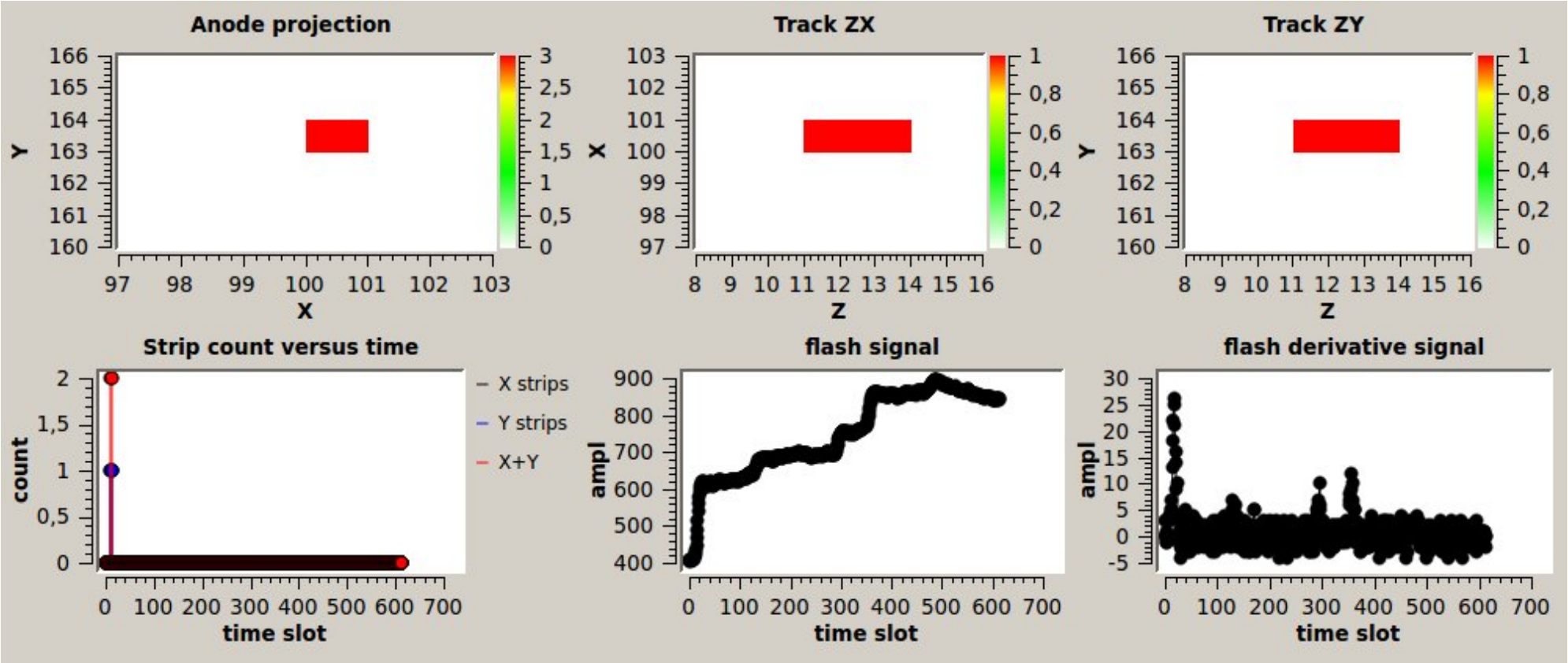
Addition over all the time samples of a track

Correlation between the 3D track lengths of events observed at Modane

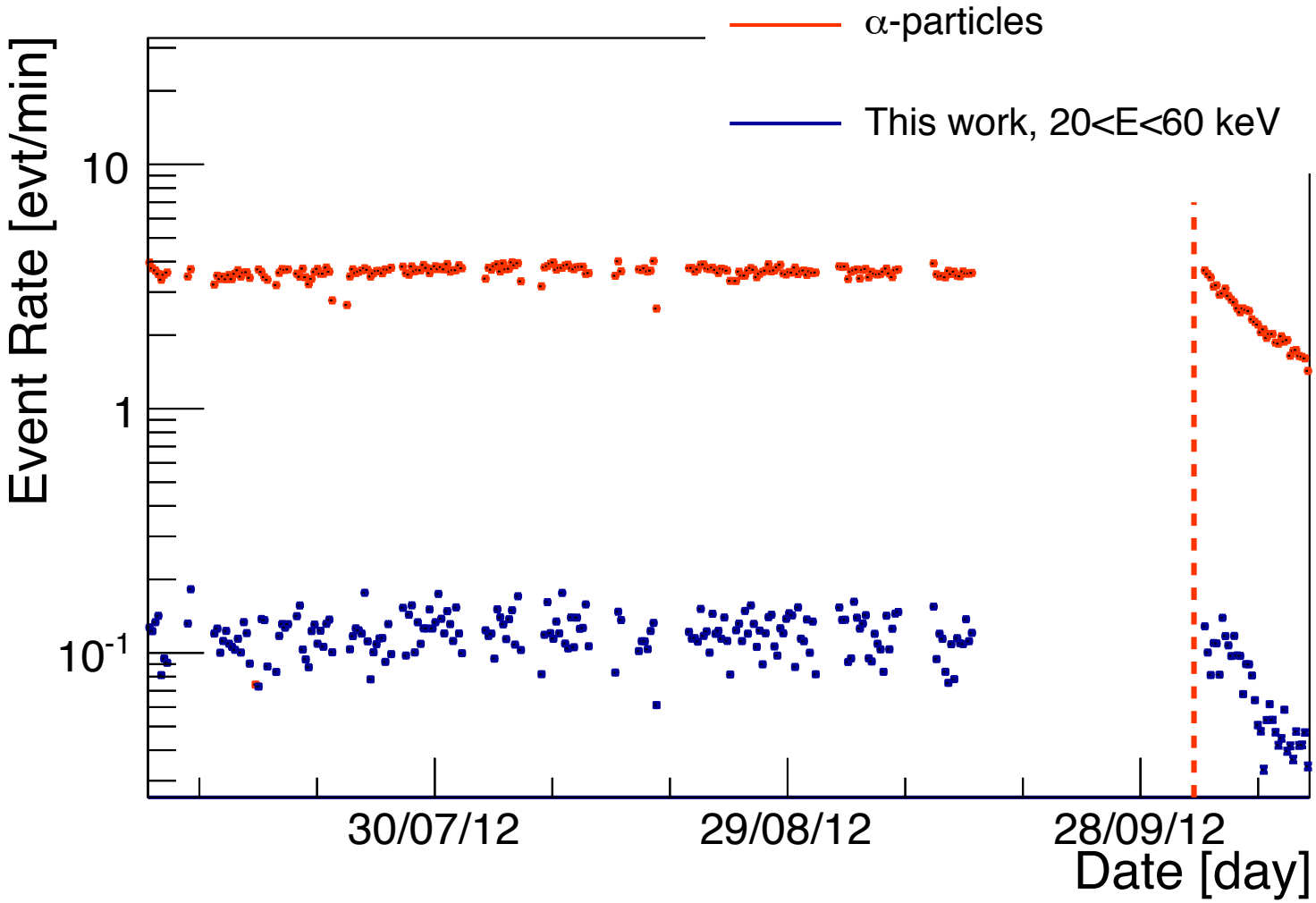
(to improve the electron-recoil discrimination)



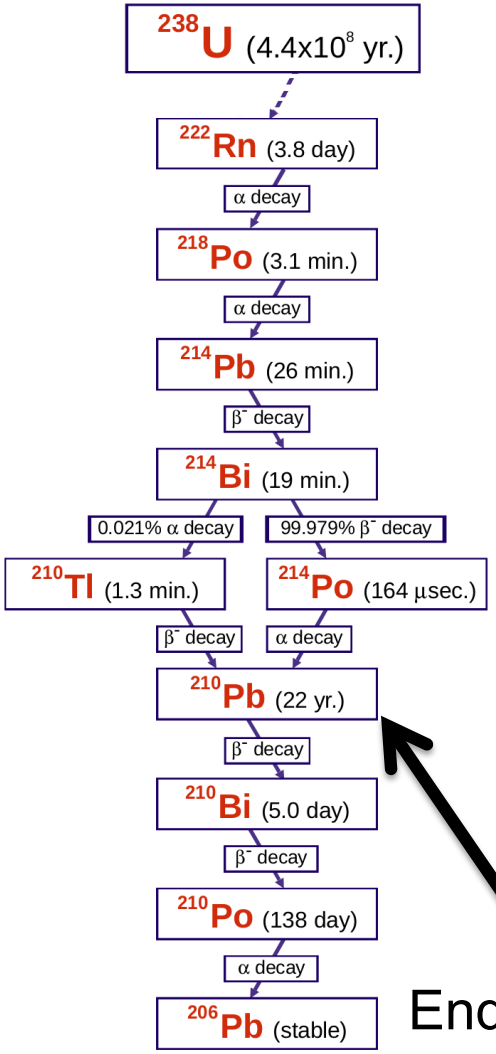
Electron track (18 keV)

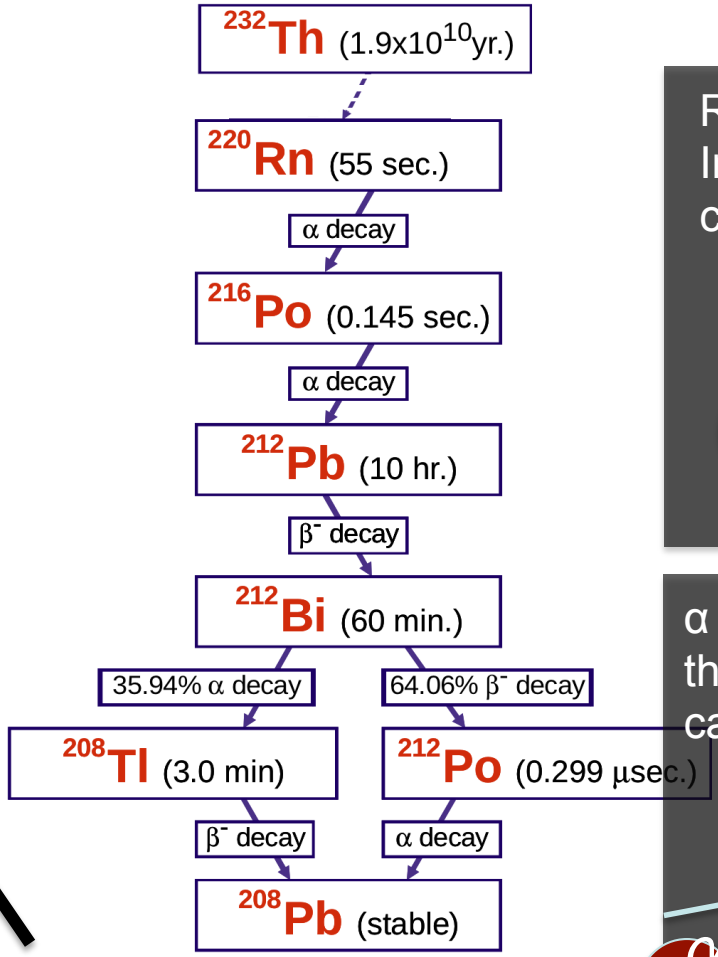


Event rate of alphas at Modane in Ch2 (validation of the source of alphas (^{222}Rn))

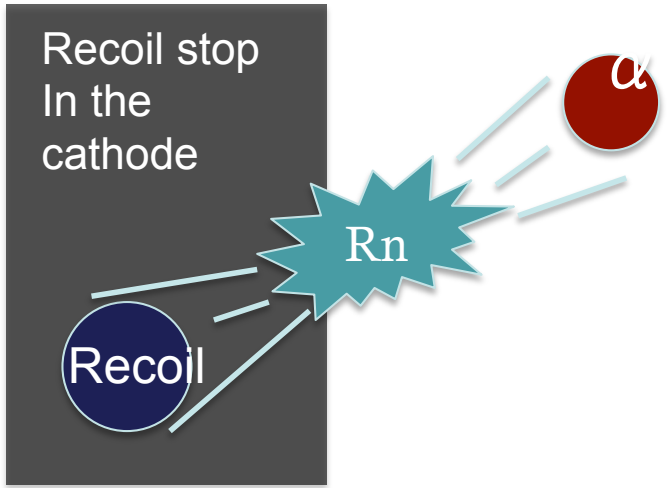


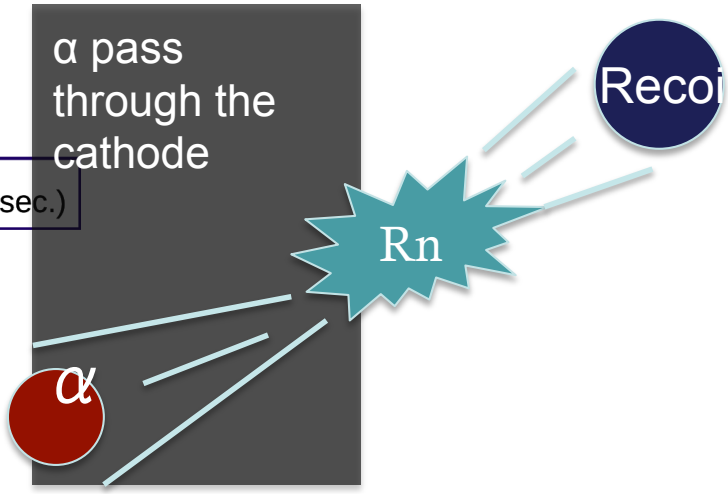
Rn progeny events



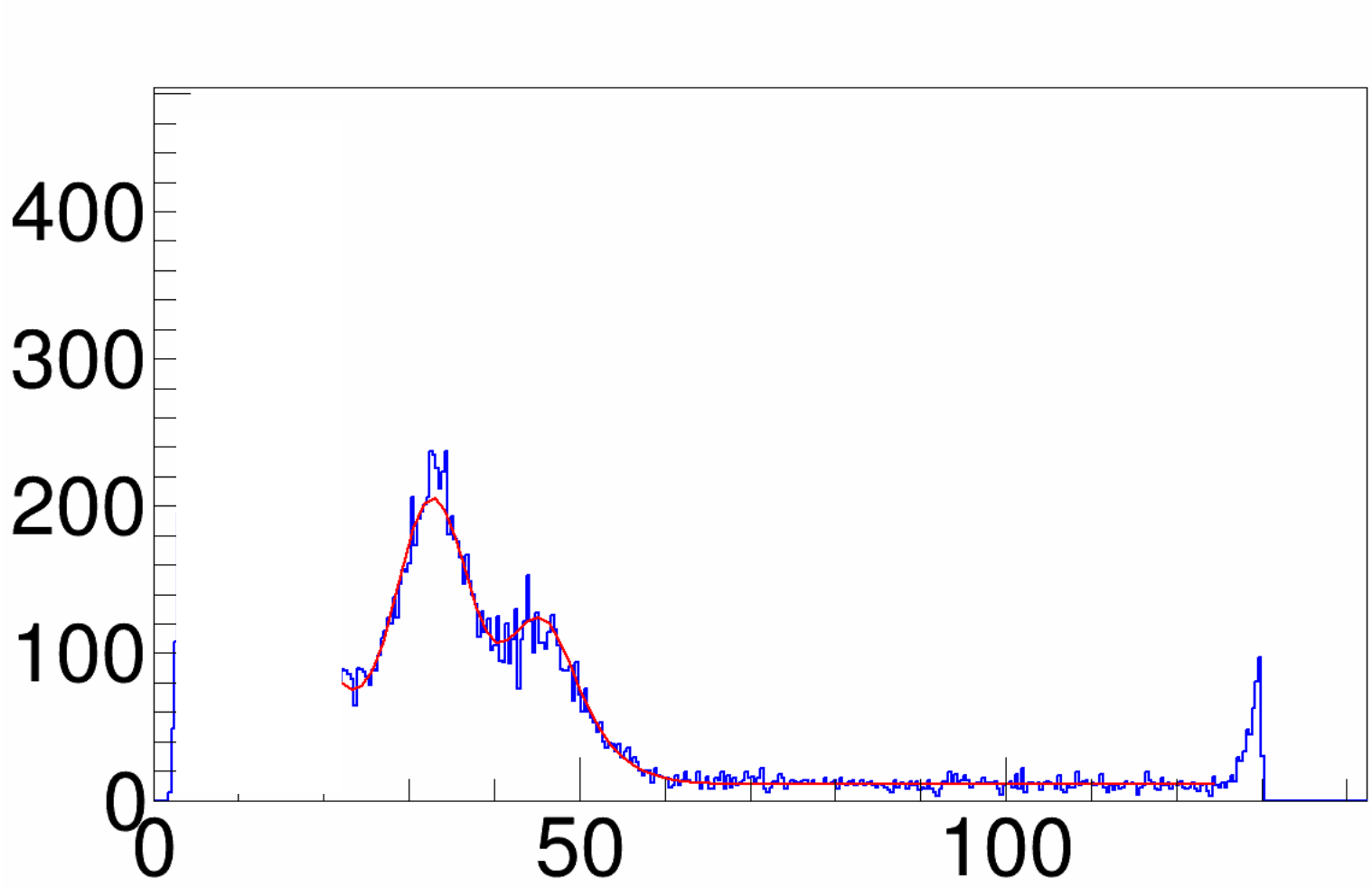


End of chain





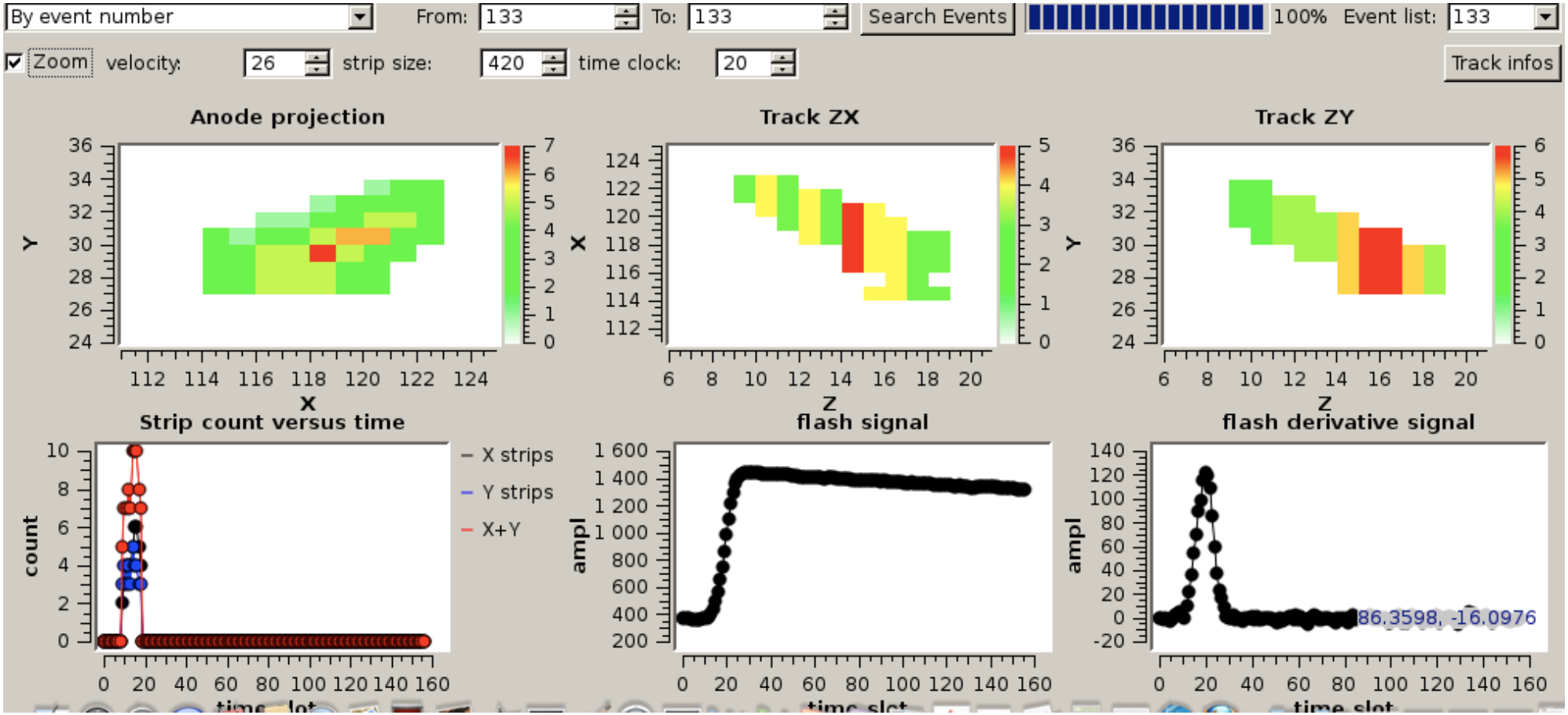
Spectrum of nuclear recoil tracks detected at Modane (coming from the ^{222}Rn chain decay, surface events) and the alpha particles through the cathode…



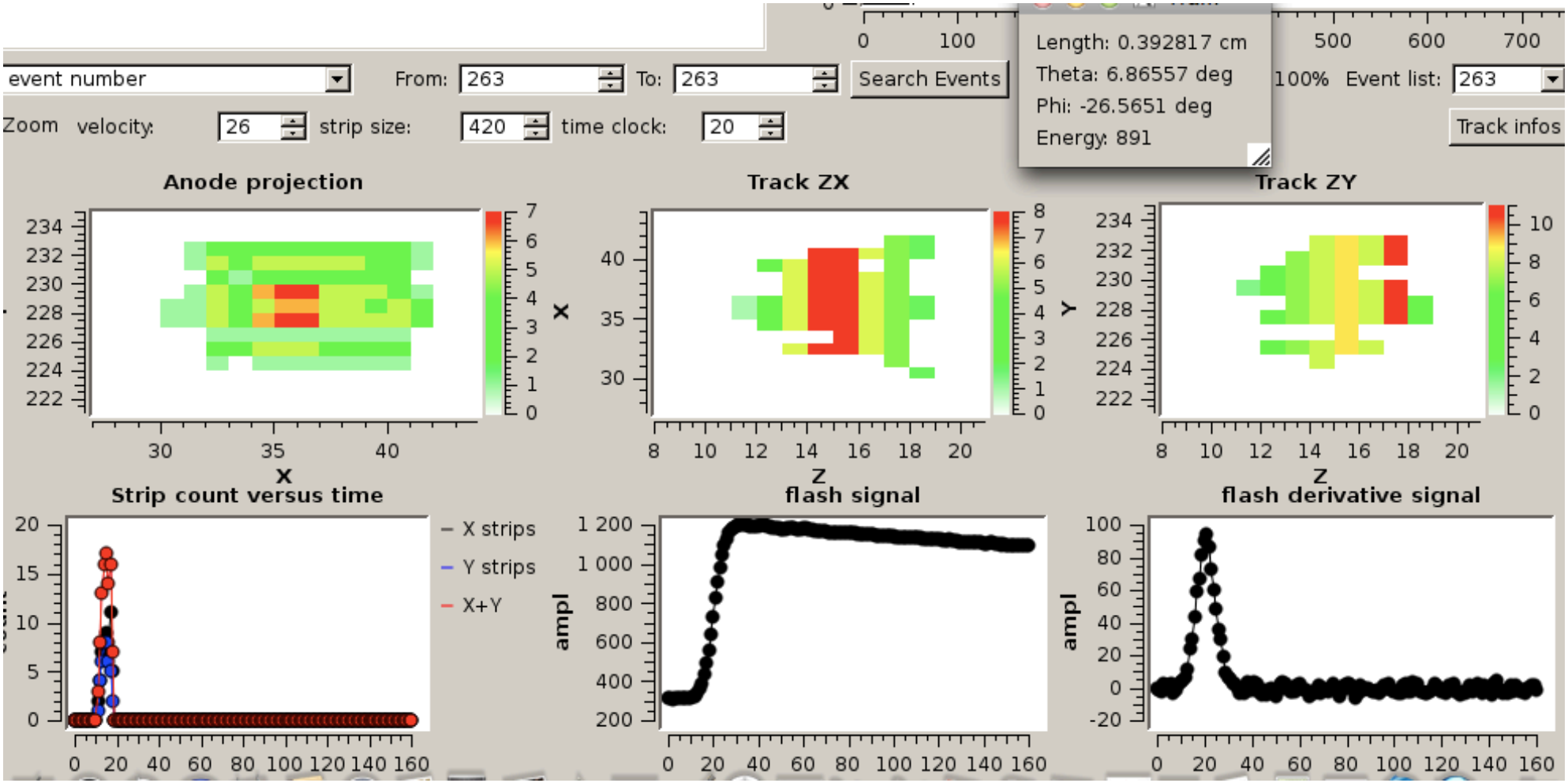
^{222}Rn progeny events in ionization energy (MIMAC)

Recoil	Recoil Energy [keV]	Ionization Quenching factor (SRIM) [%]	Ionization Energy (SRIM) [keV]	Ionization Energy measured [keV]
^{218}Po	100.79	37.93	38.23	32
^{214}Pb	112.27	39.10	43.90	34
^{210}Pb	146.52	40.12	58.78	45

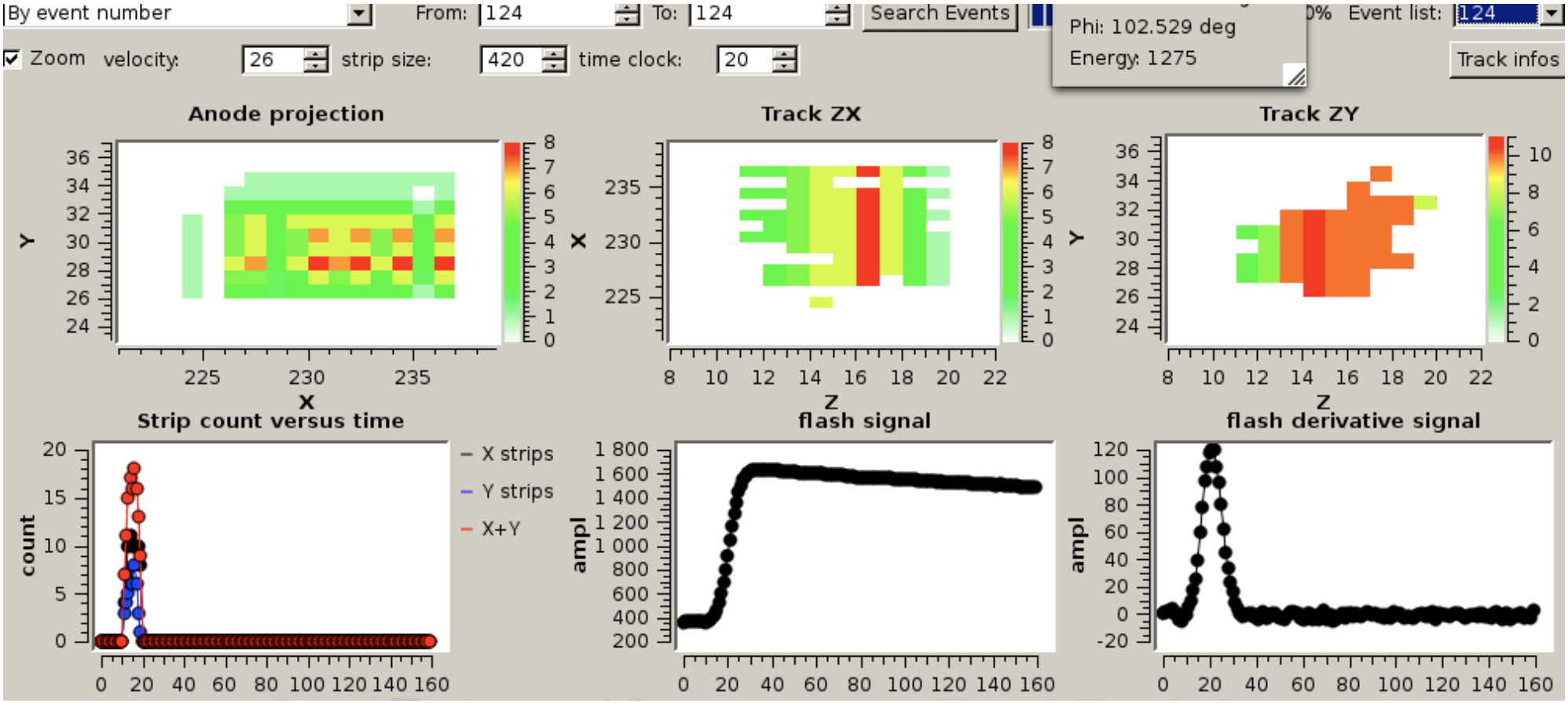
A radon progeny “recoil event” (~ 34 keVee)



A radon progeny “recoil” event (~ 28 keVee)

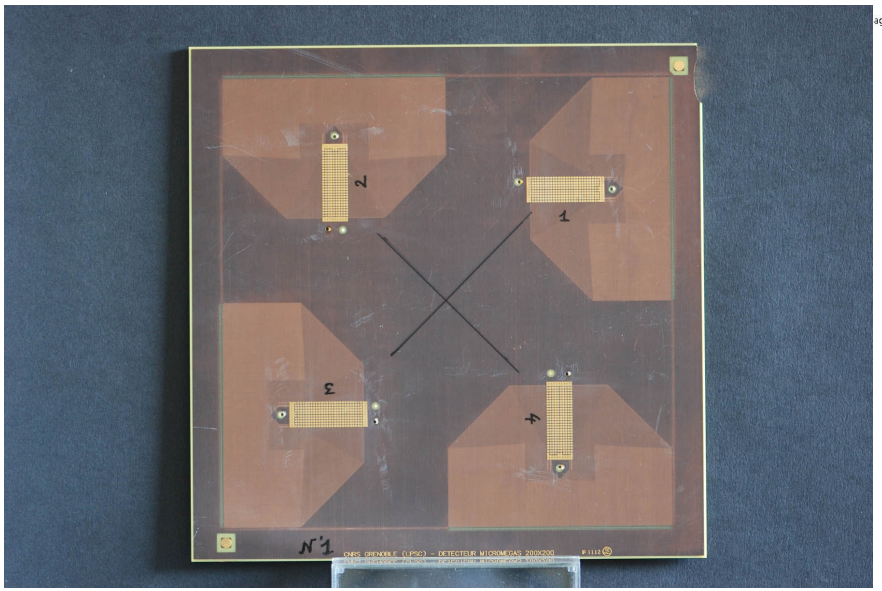


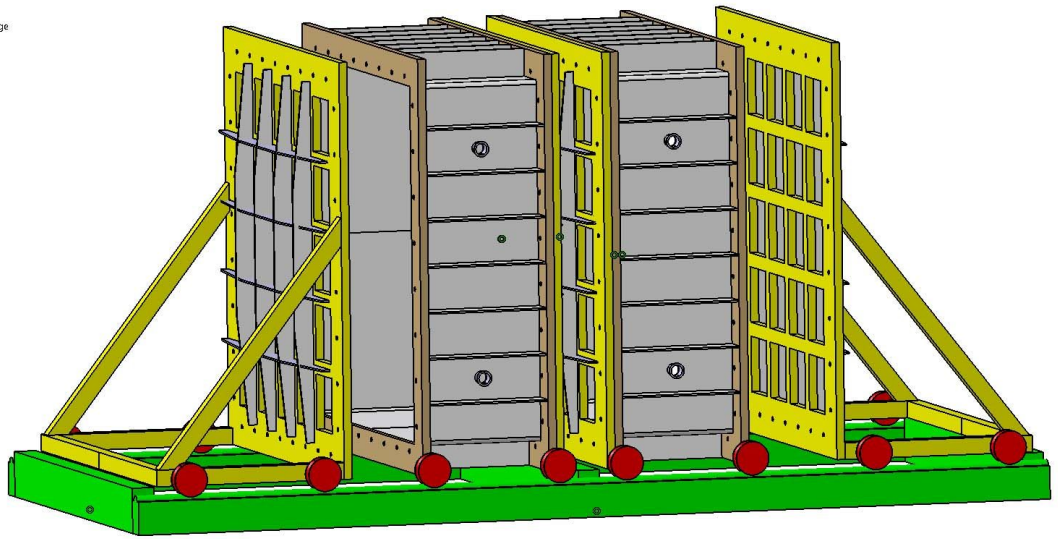
A radon progeny “recoil” event (~ 40 keVee)



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

MIMAC Phenomenology: Discovery

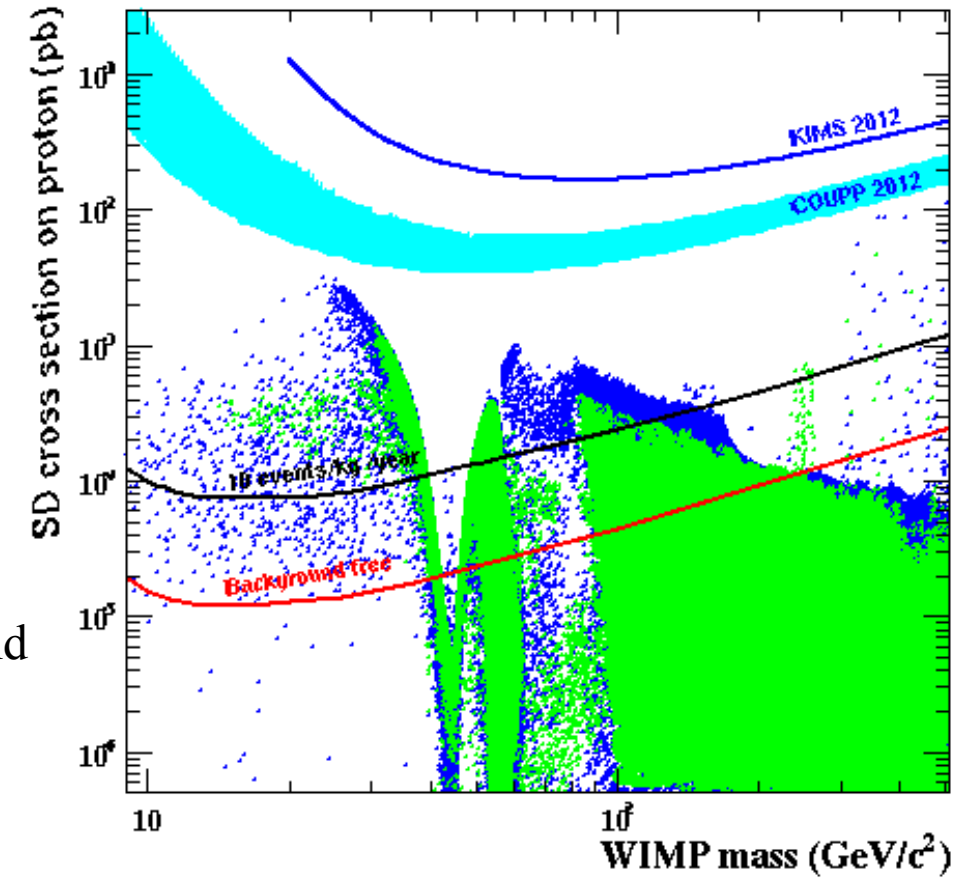
(see F. Mayet's talk)

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***

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) Ionization quenching factor measurements have determined experimentally the recoil energy threshold.

iii) Phenomenology studies performed by the MIMAC team show the impact of this kind of detector (see F. Mayet's talk)

iv) MIMAC bi-chamber module has been installed at Modane Underground Laboratory in June 2012.

v) For the first time the 3D nuclear recoil tracks from the Rn progeny have been observed.

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)