MIMAC

MIcro-tpc MAtrix of Chambers

A Large TPC for directional non baryonic Dark Matter detection

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(LPSC-Grenoble)

(UJF Grenoble 1 -CNRS/IN2P3-INPG)

MIMAC:
(MIcro-tpc MAtrix of Chambers)

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J. Billard (Ph.D)

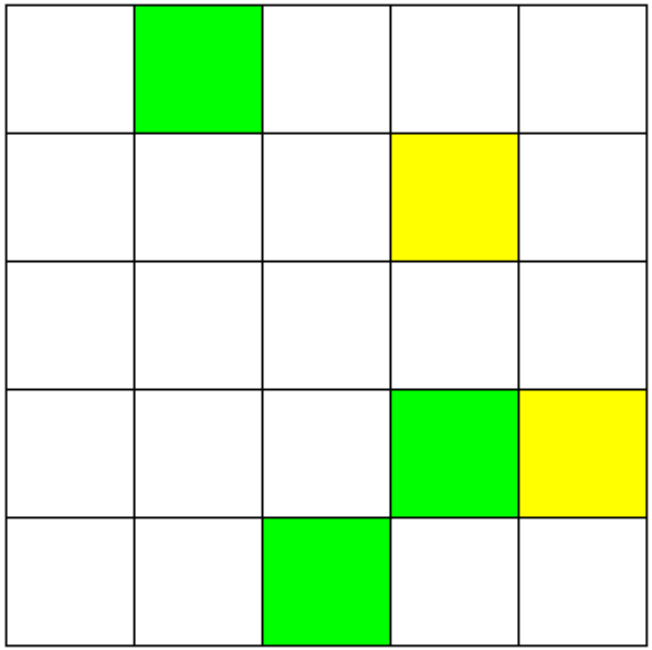
Technical Coordination :	O. Guillaudin
- Electronics :	G. Bosson, O.Bourrion, J-P. Richer
- Gas detector :	O. Guillaudin, A. Pellisier
- Data Acquisition:	O. Bourrion
- Mechanical Structure :	Ch. Fourel
- Ion source :	T. Lamy, J. Angot, P. Sortais

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

IRSN (Cadarache): L. Lebreton, C. Golabek

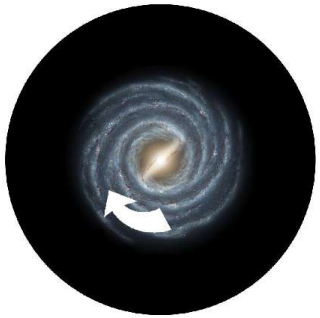
CCPM (Marseille): J. Busto

The MIMAC project



A low pressure multi-chamber detector

- Track-Energy measurements
- Matrix of chambers (correlation)
- μTPC : Micromegas technology
- CF_4, ^3He, and ^1H : $\sigma(A)$ dependancy
- Axial interaction
- Directionnal detector



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

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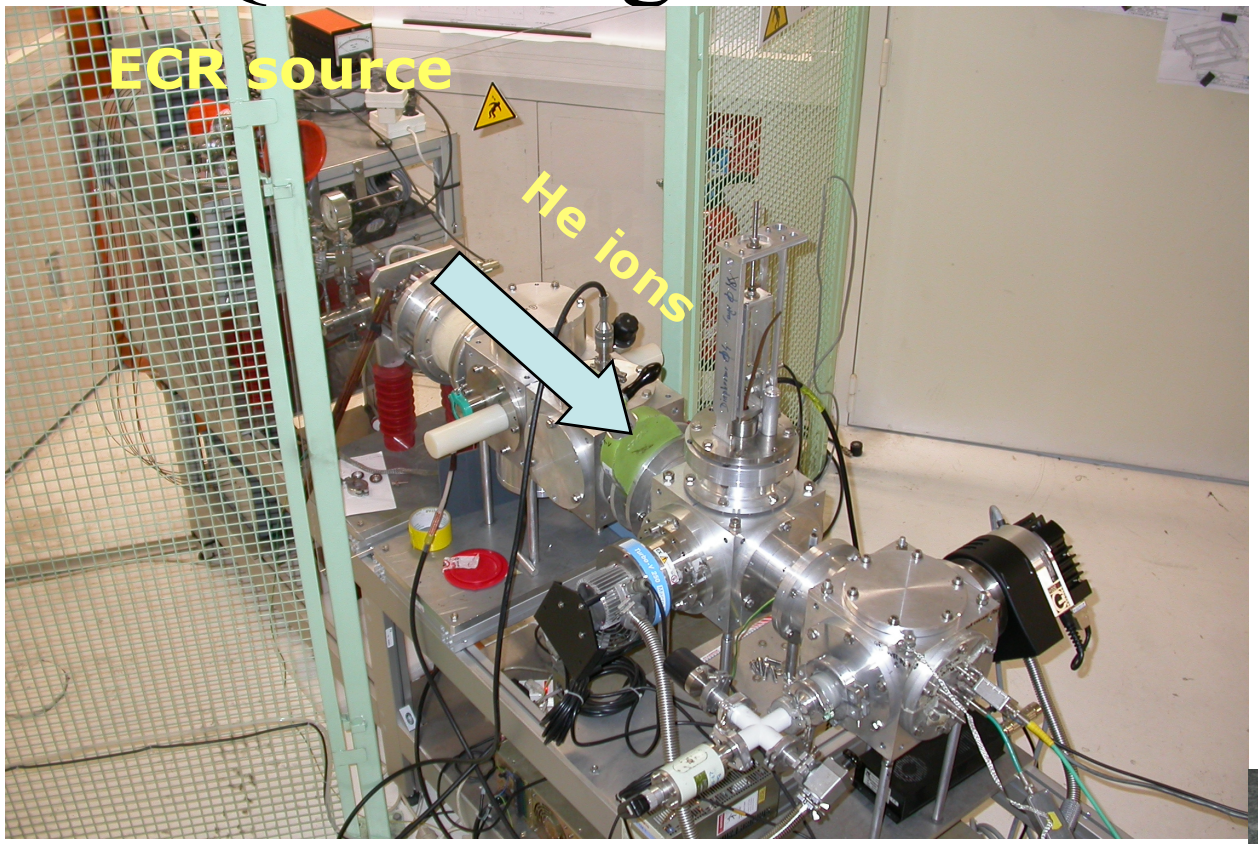
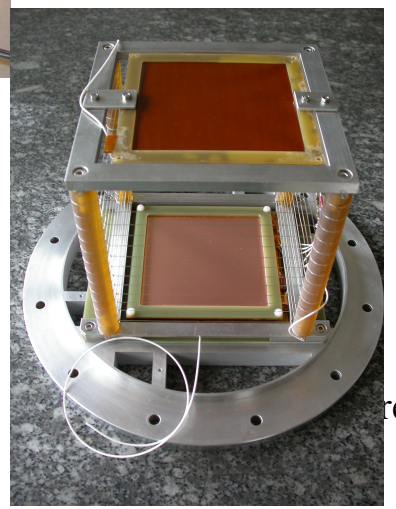
Quenching factor measurement



- **Low energy ion source**

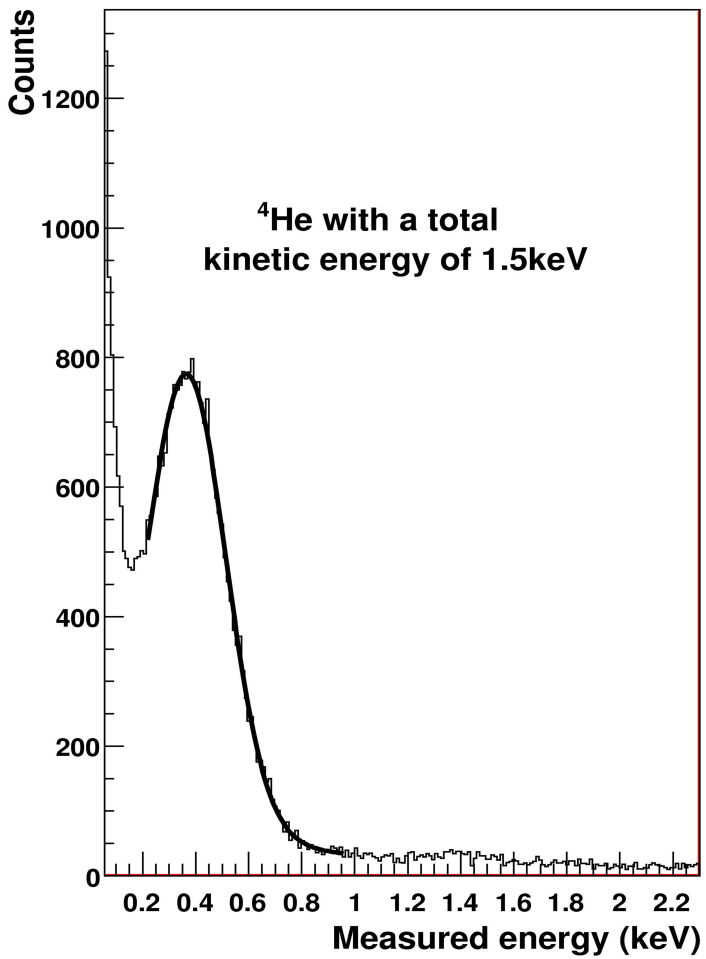
  1 to 50 keV

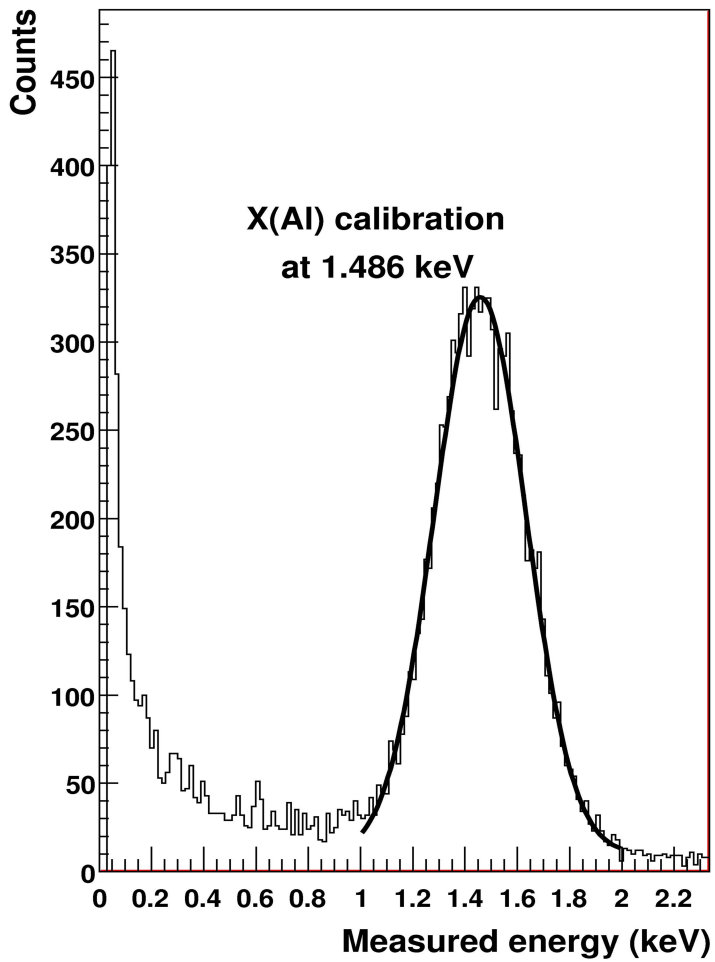
- **Developped @LPSC**



Micromegas µTPC

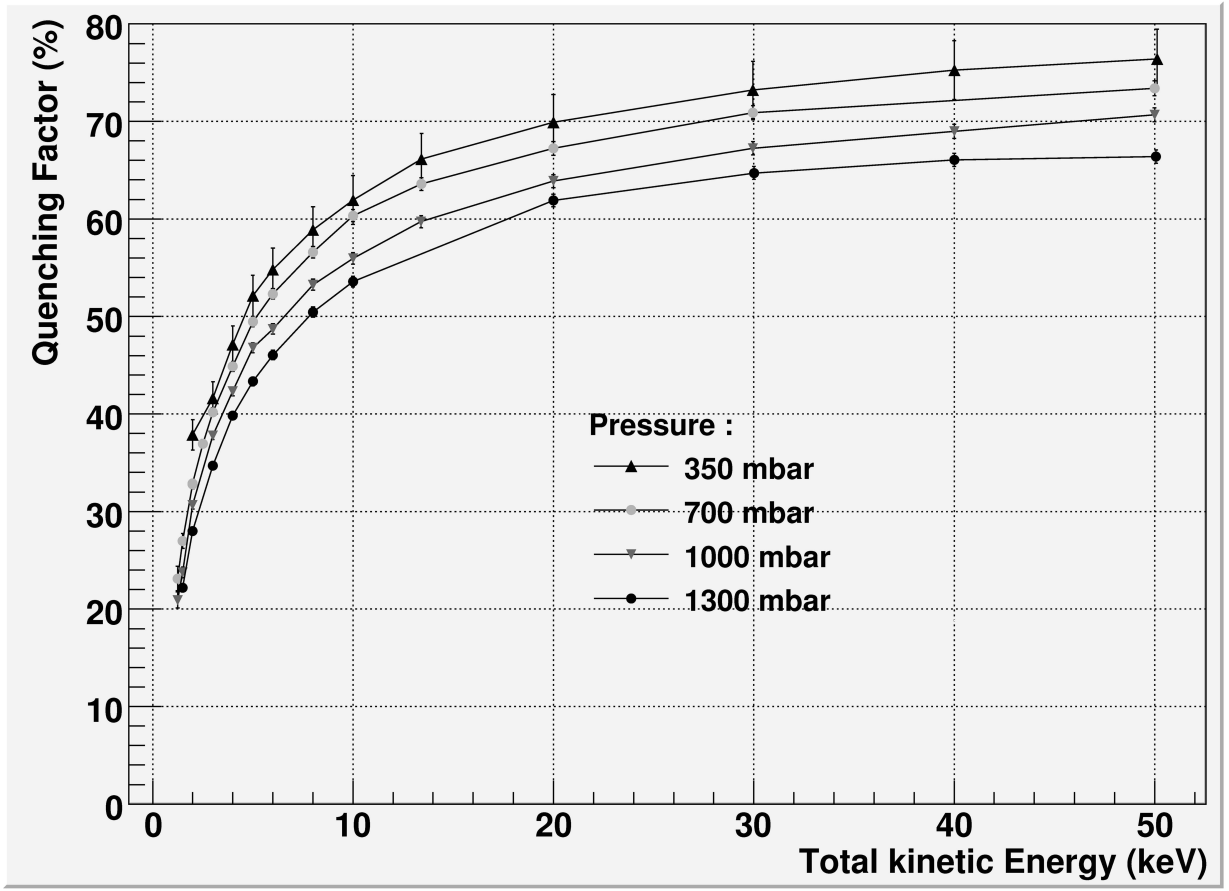
Detection of ^{4}He (recoils) of 1.5 keV !!
(95% ^{4}He + 5% iso) at 700mbars





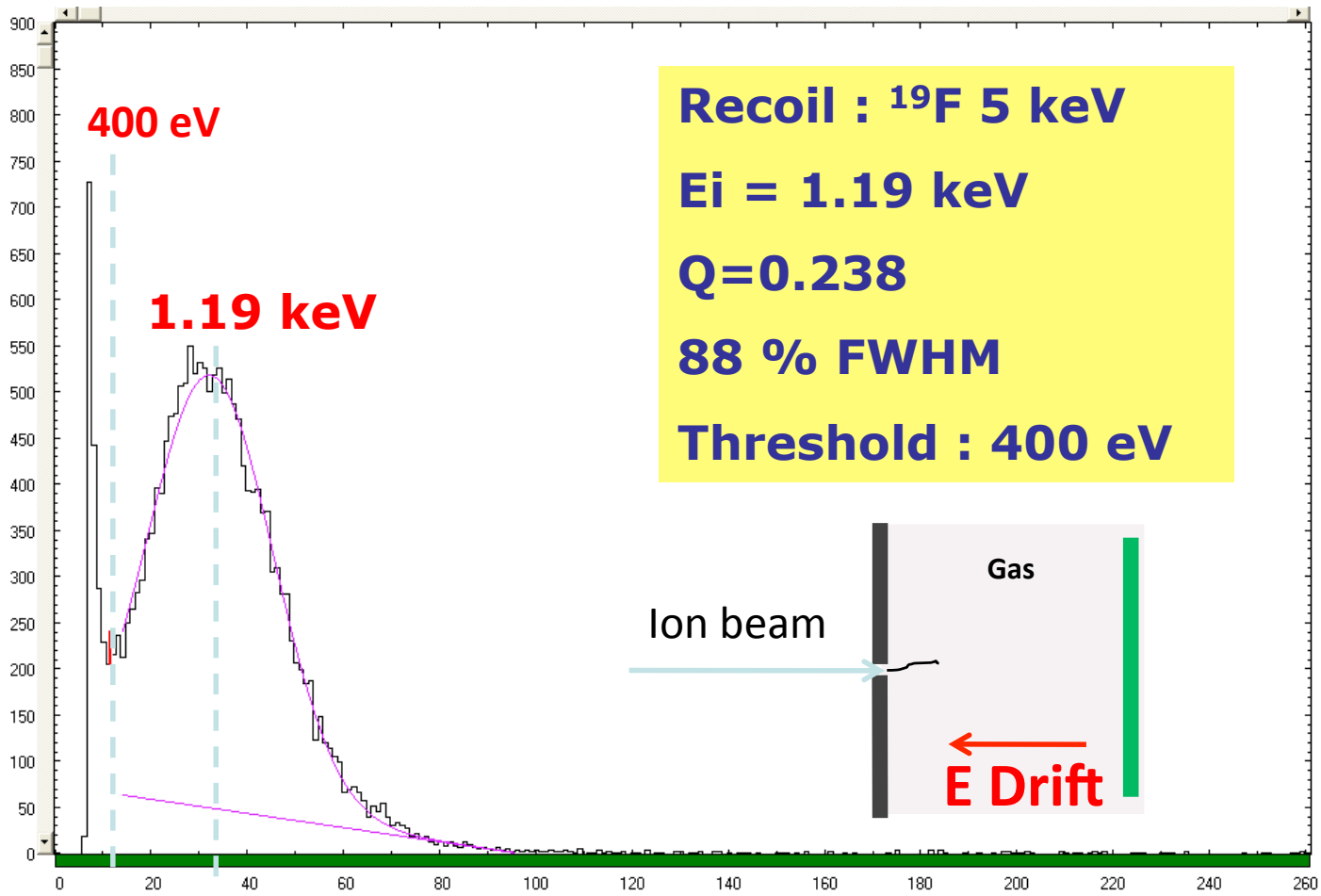
IQF Measurement of ^4He in 95% ^4He + 5% C_4H_{10} as a function of the pressure

D. Santos et al. arXiv:astro-ph0810.1137

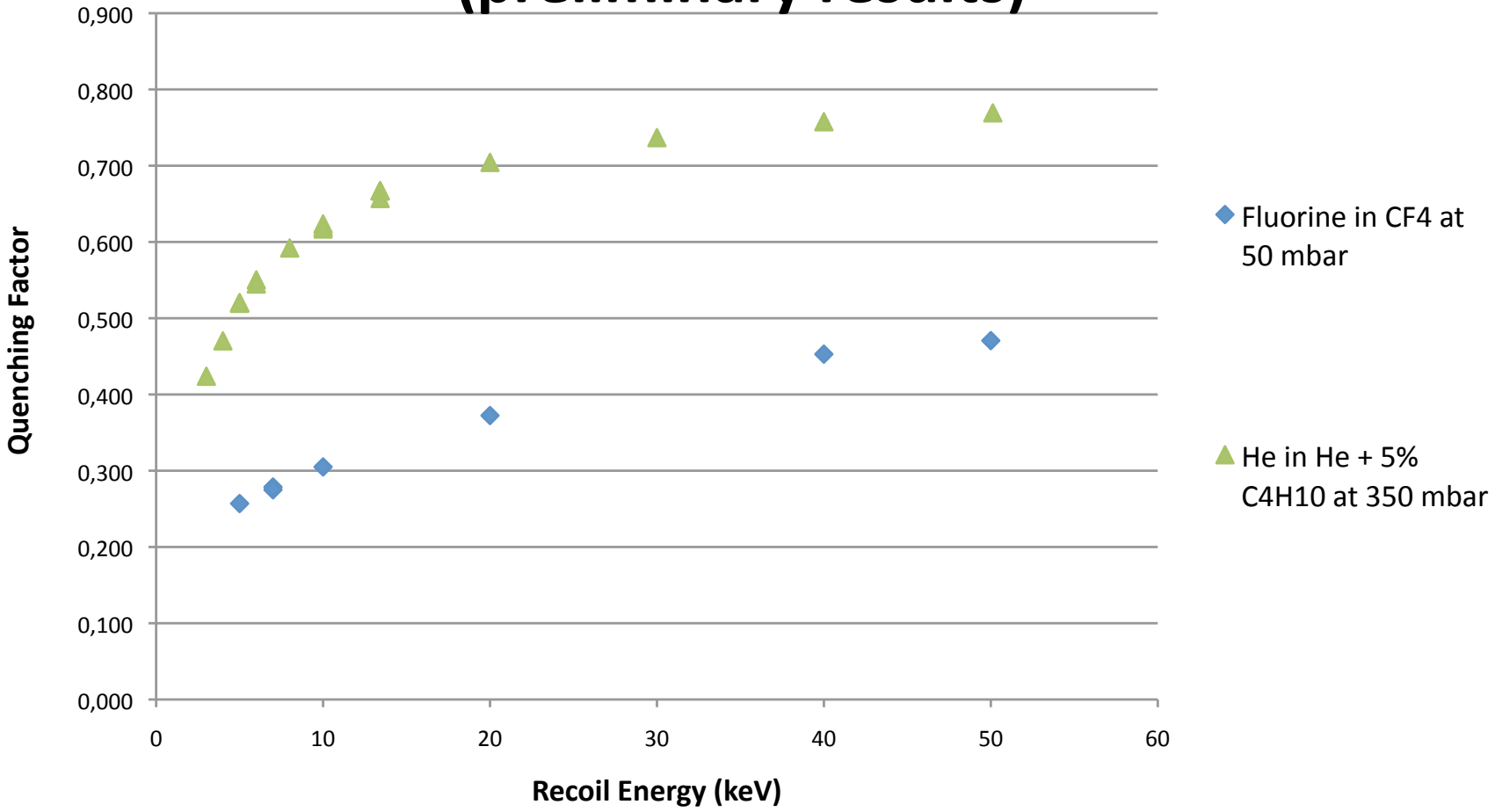


5keV ^{19}F Recoil in 60 mbar

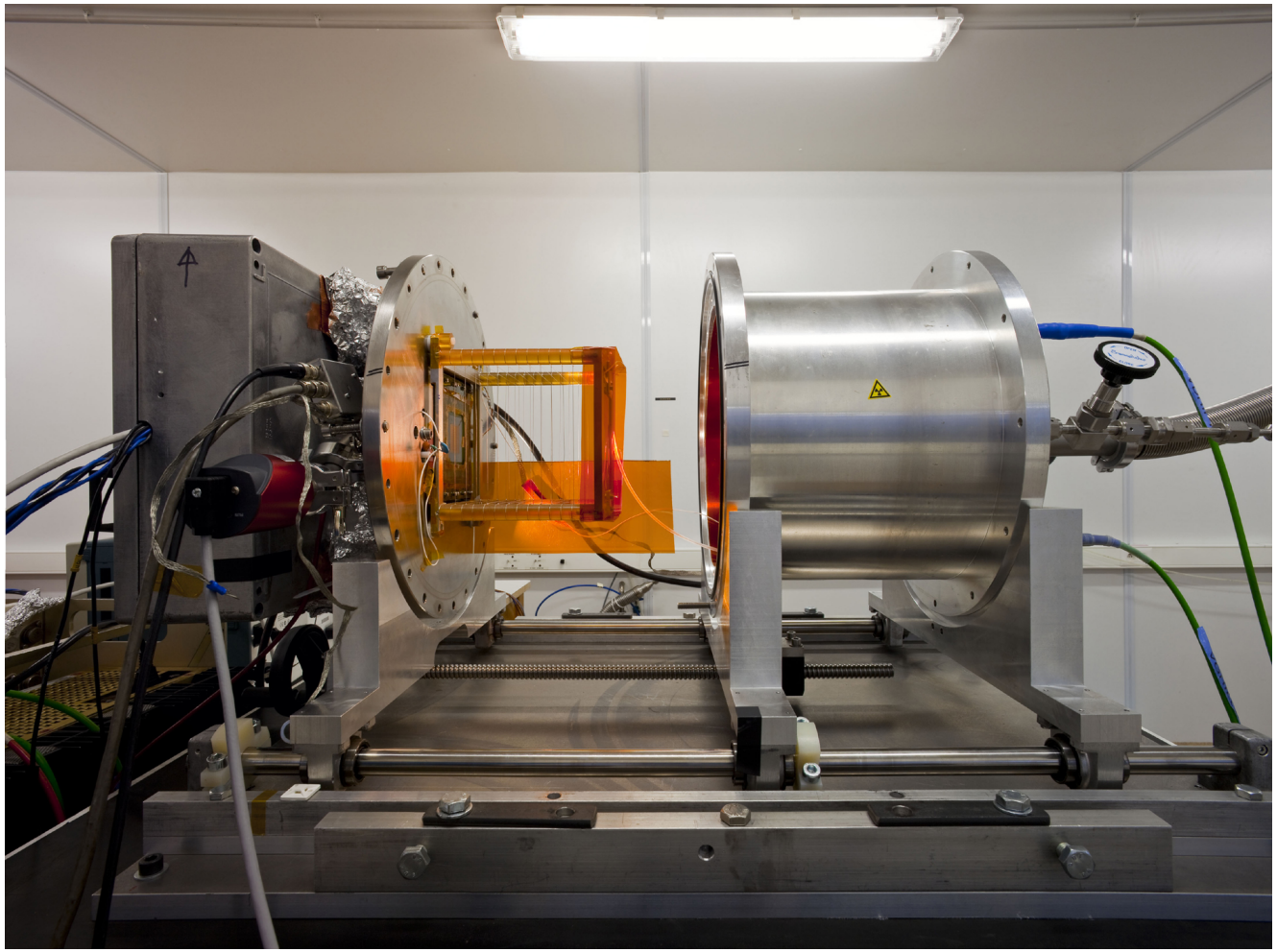
40mbar CF4+16.8mbar CHF3+1.2 mbar Isobutane



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



MIMAC Prototype Chamber



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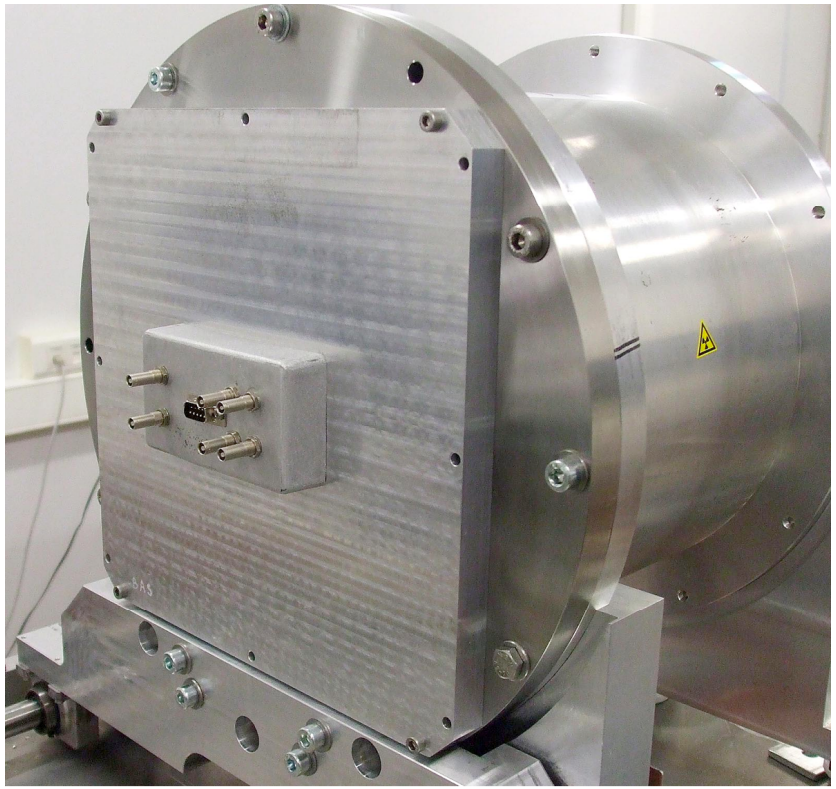
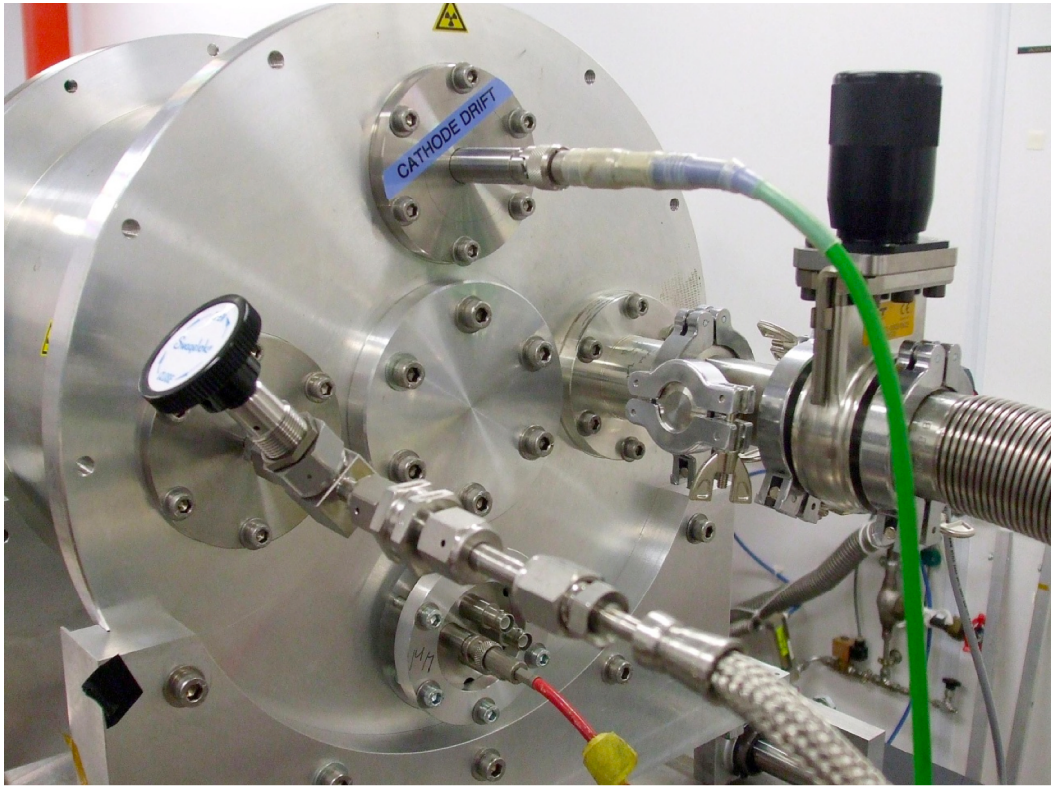
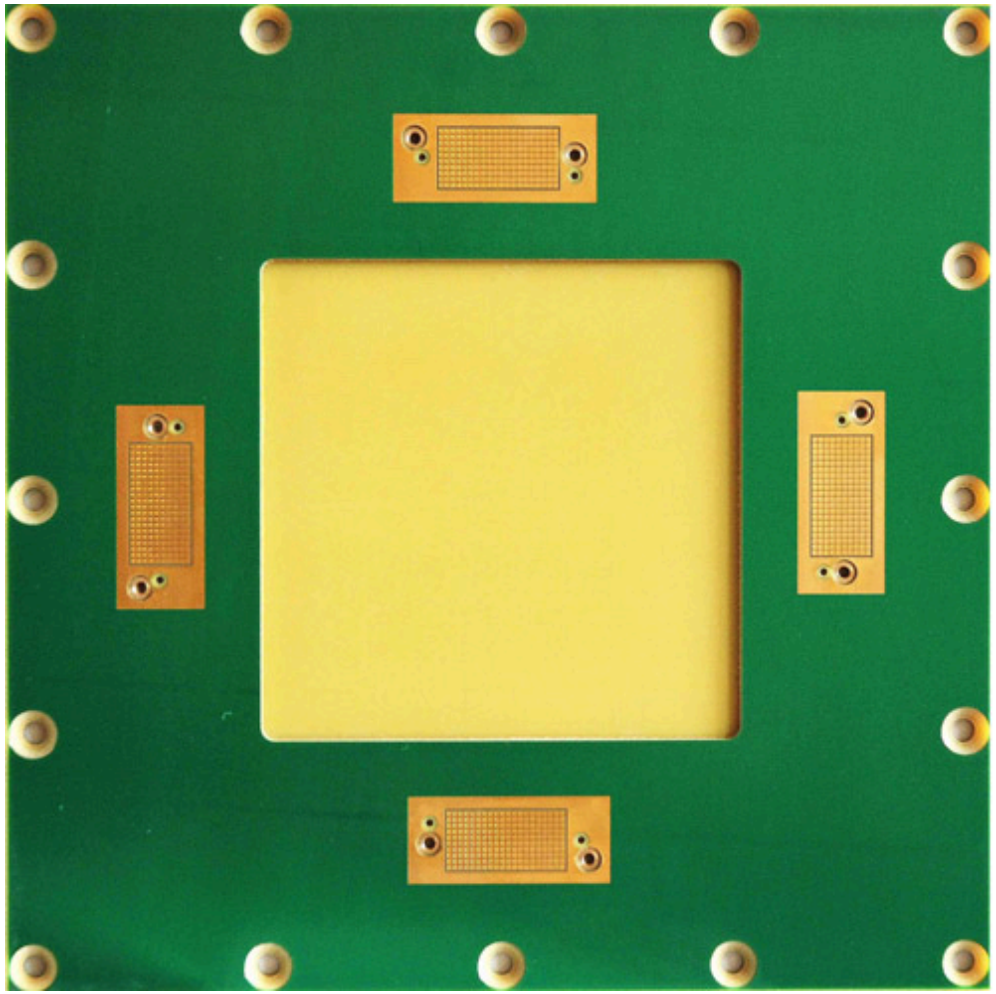
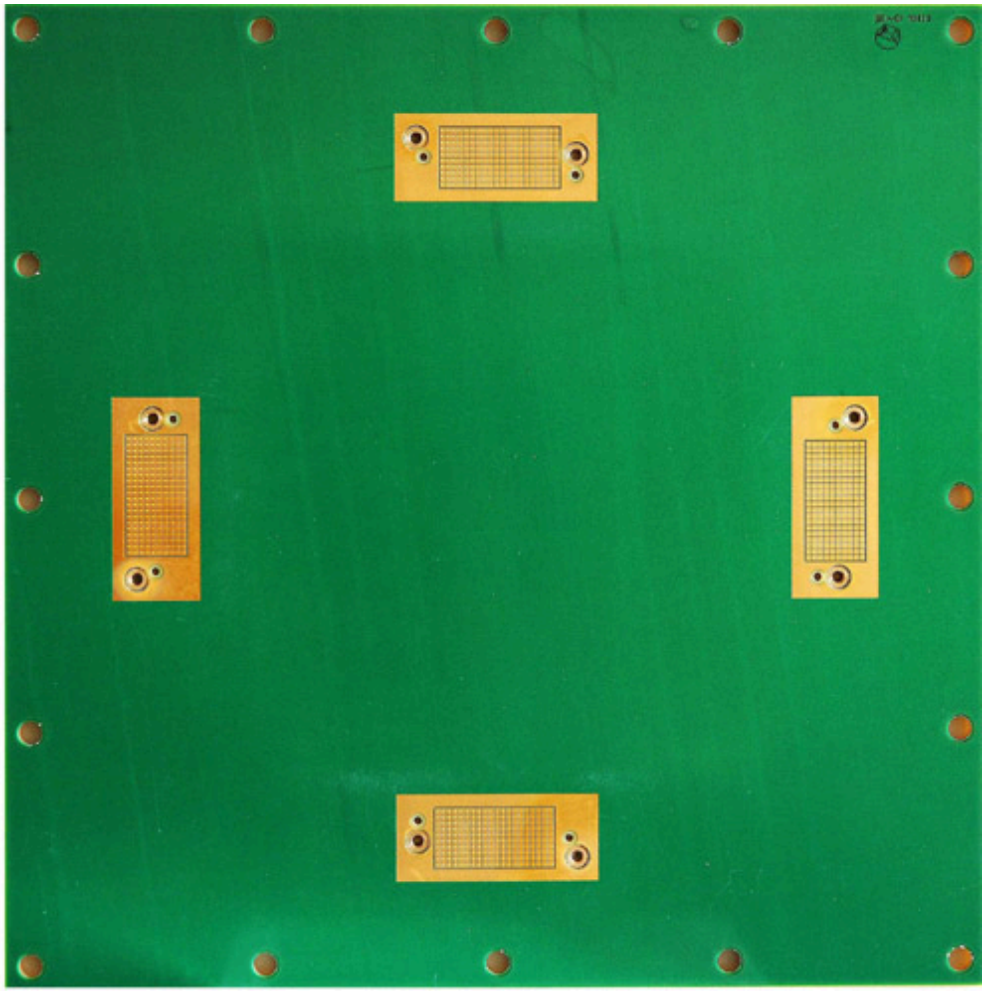
MIMAC prototype – 10x10x18 cm^3



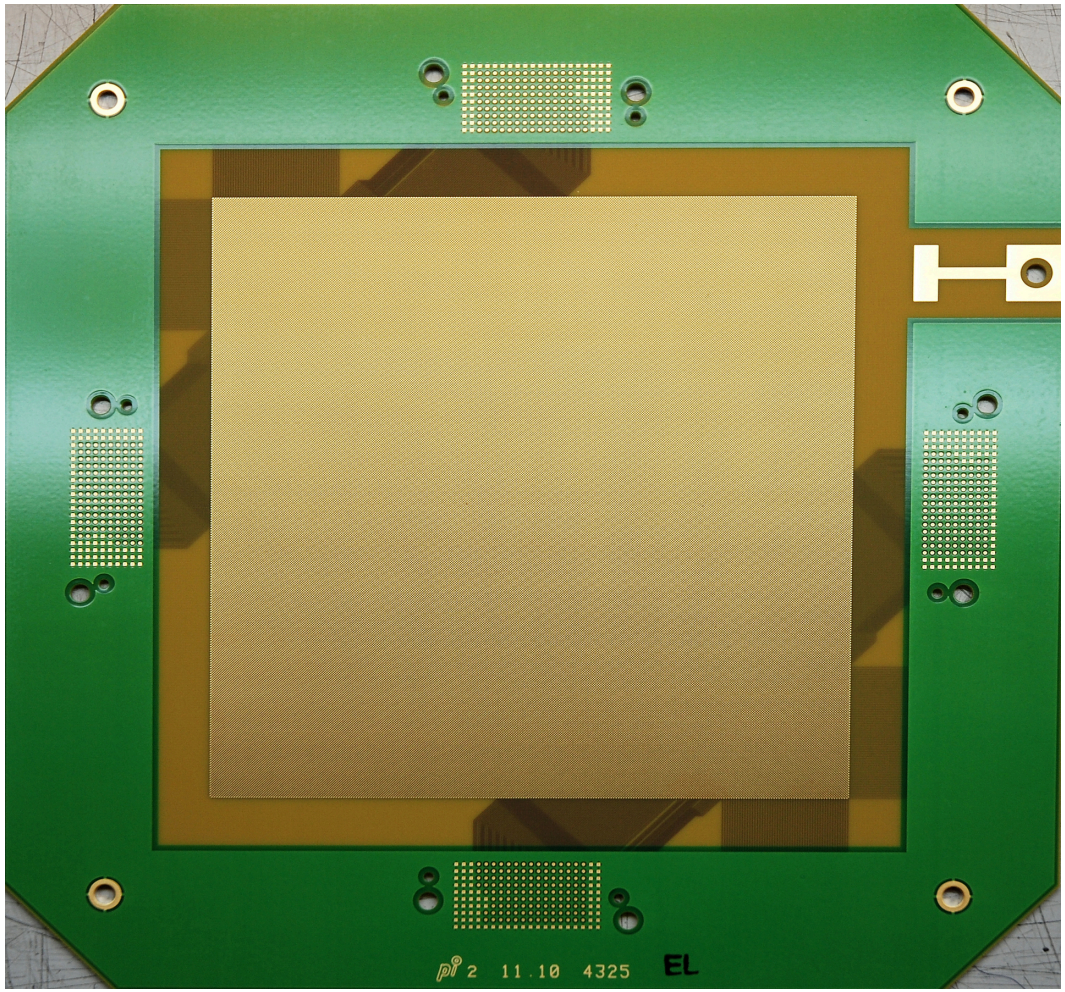


10x10 cm^2 - Interface

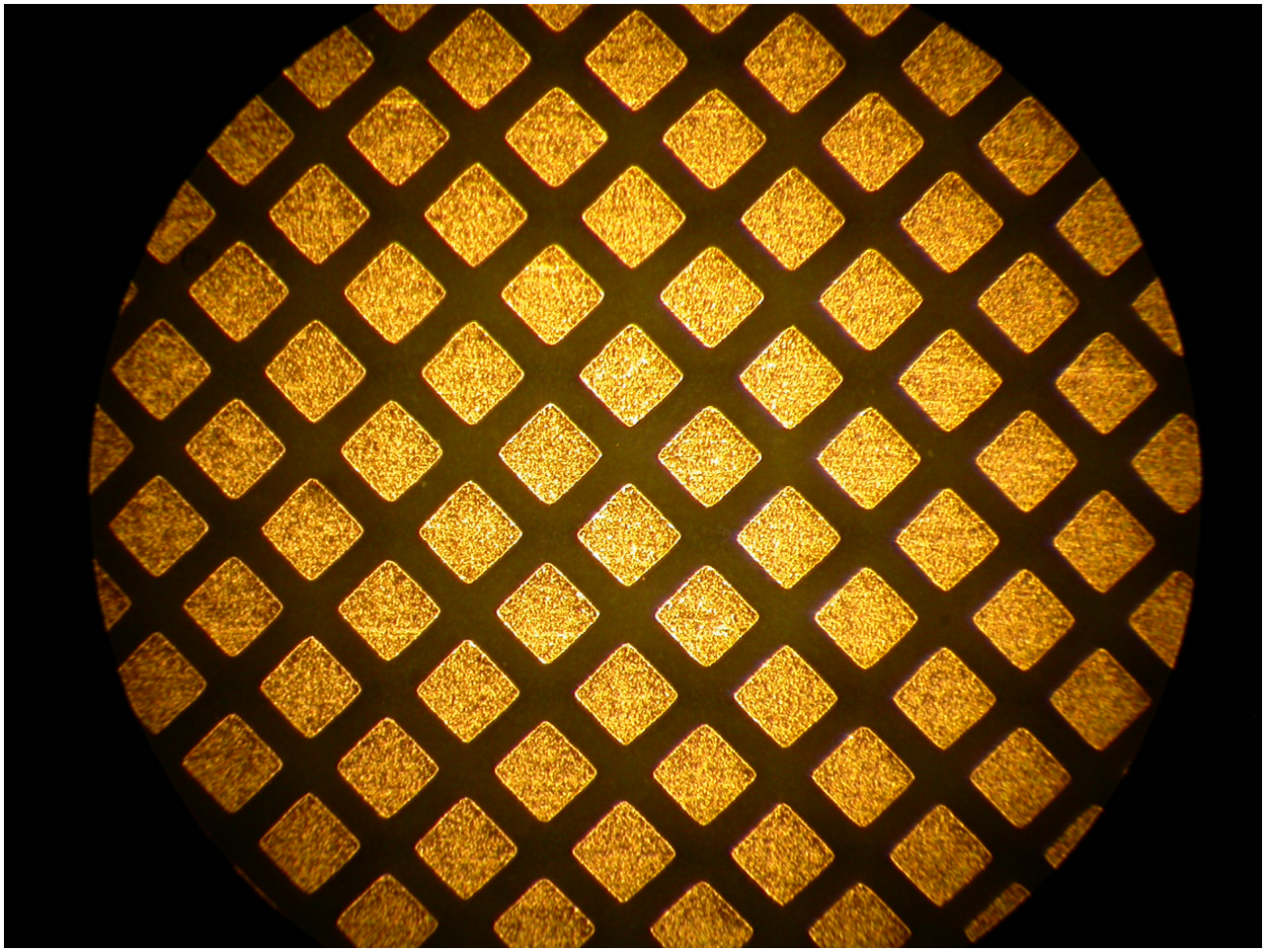




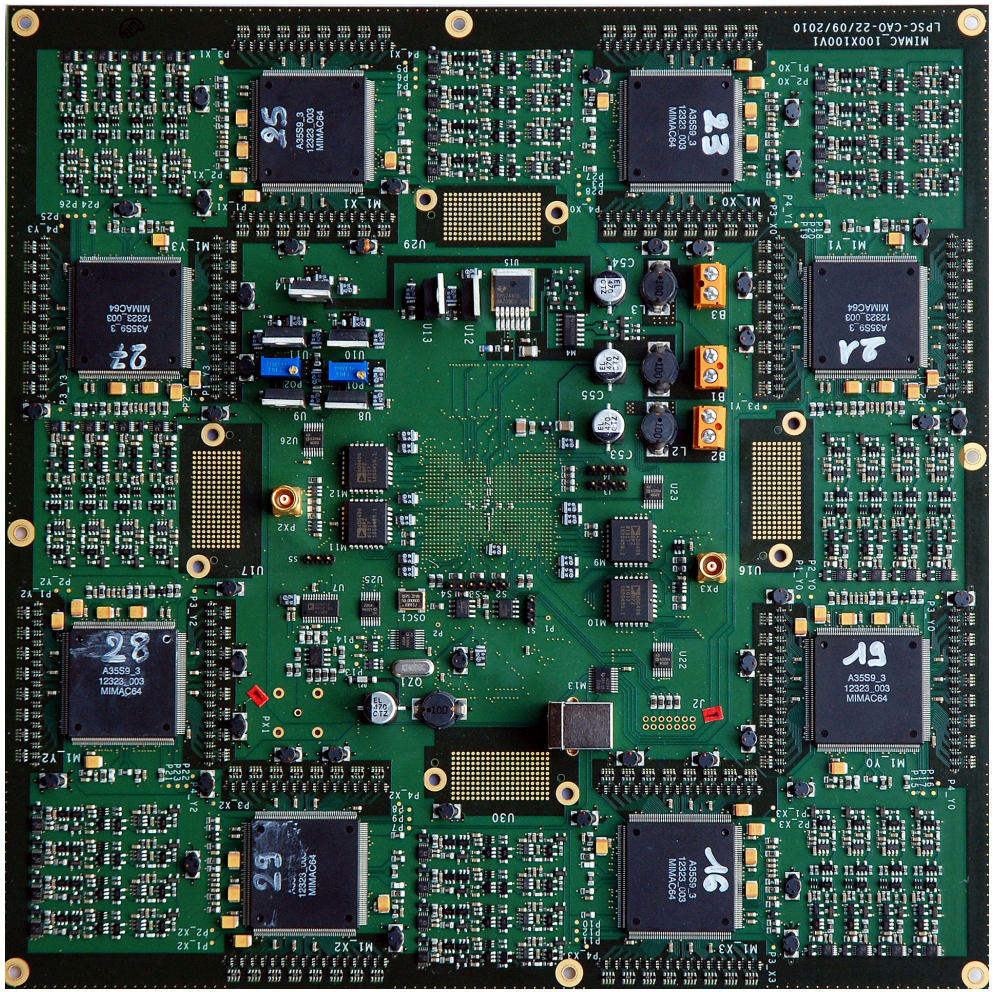
The MIMAC-micromegas 100x100 (bulk)



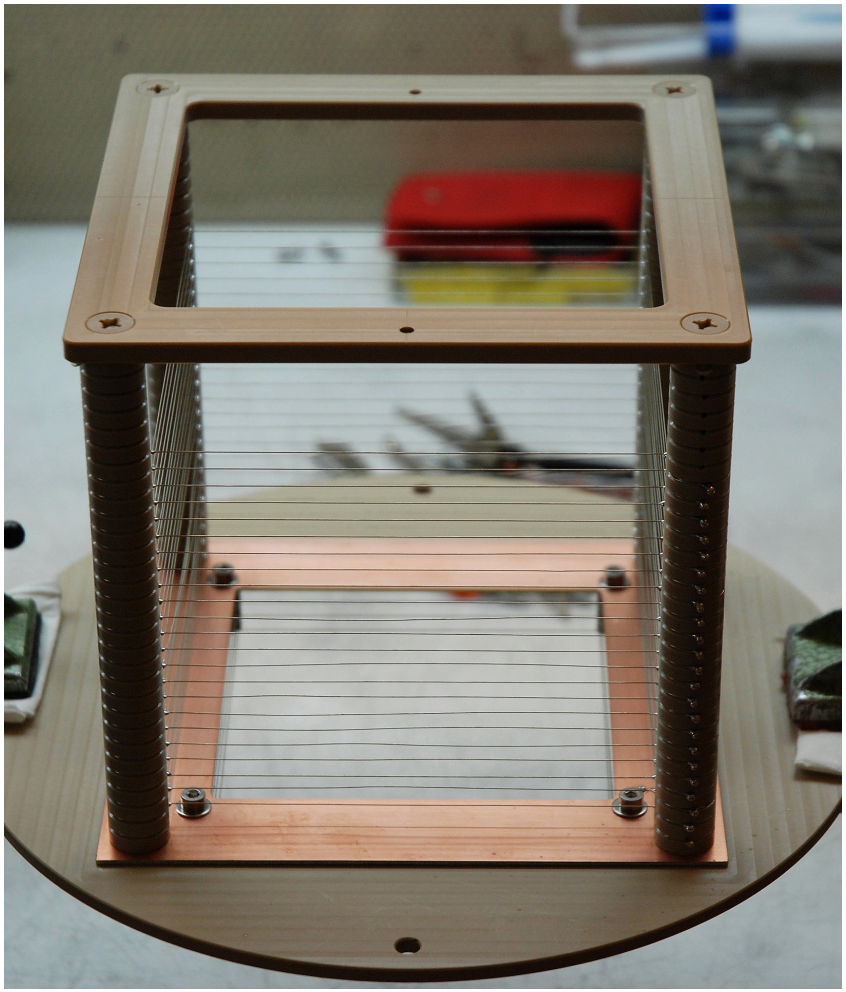
MIMAC 100x100 (v2)



New MIMAC electronics (512 channels)



Drift volume – charge collection



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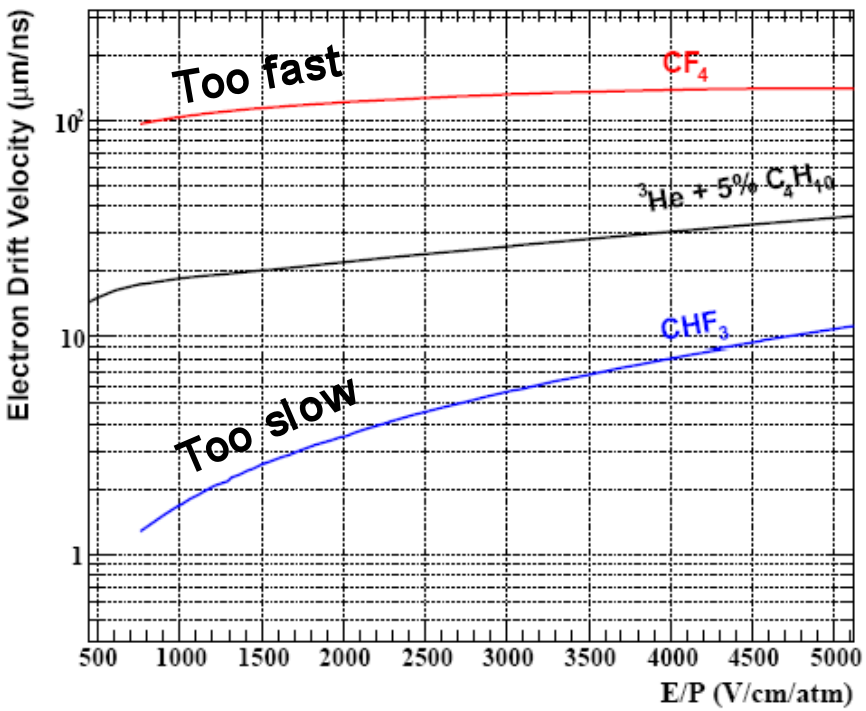
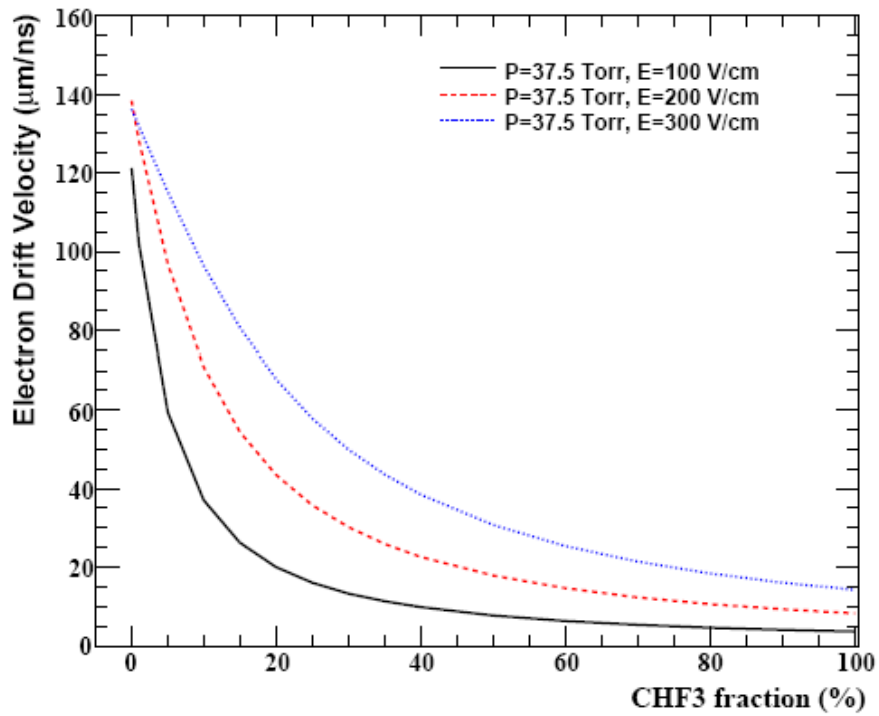
3D Tracks: Drift velocity

Magboltz Simulation





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

MIMAC : recoil track measurements

April 2009

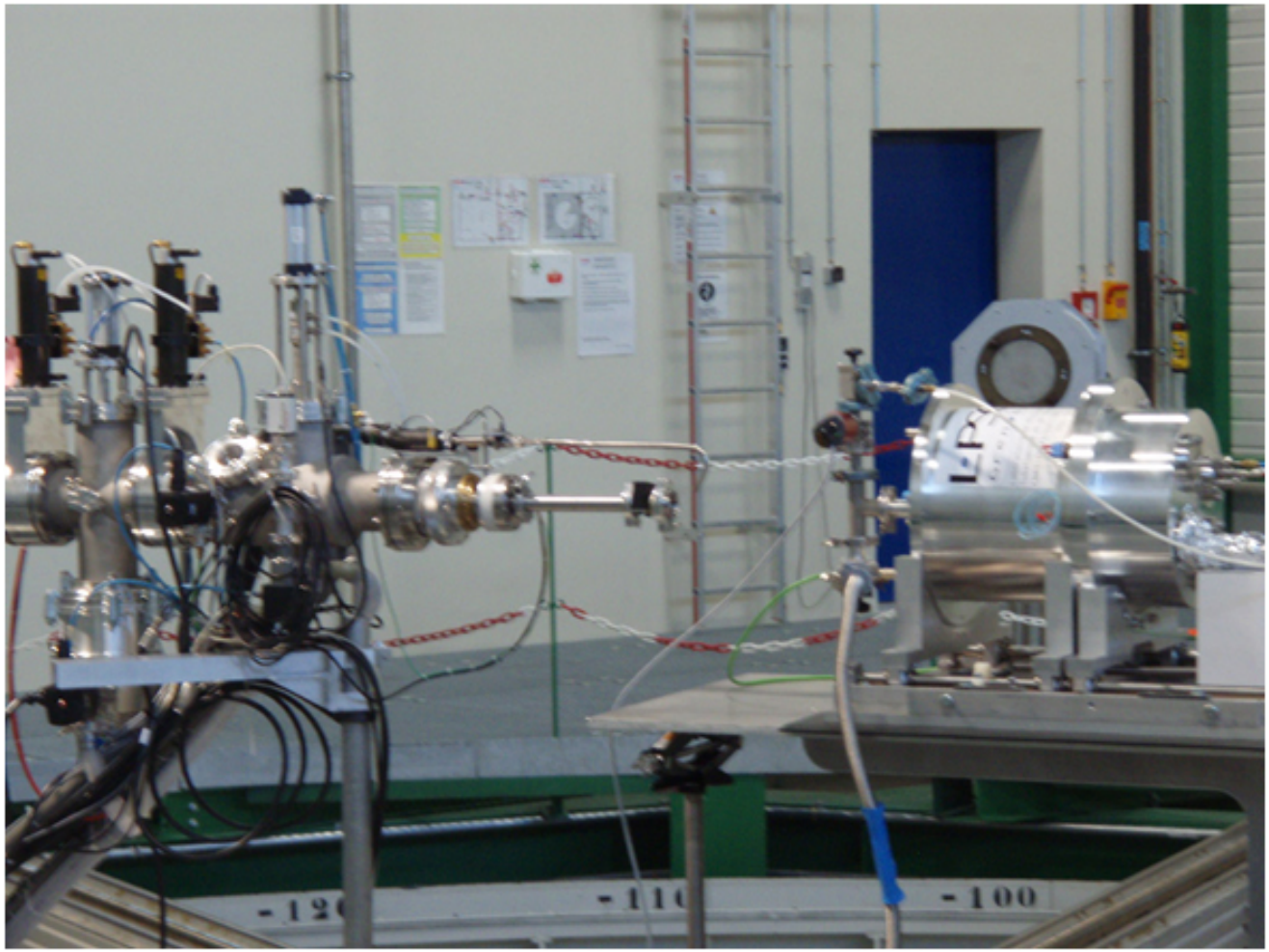
@ IRSN Cadarache

and May 16th, 2011 !!

Amande facility :

•Neutron field with energies down to a few keV

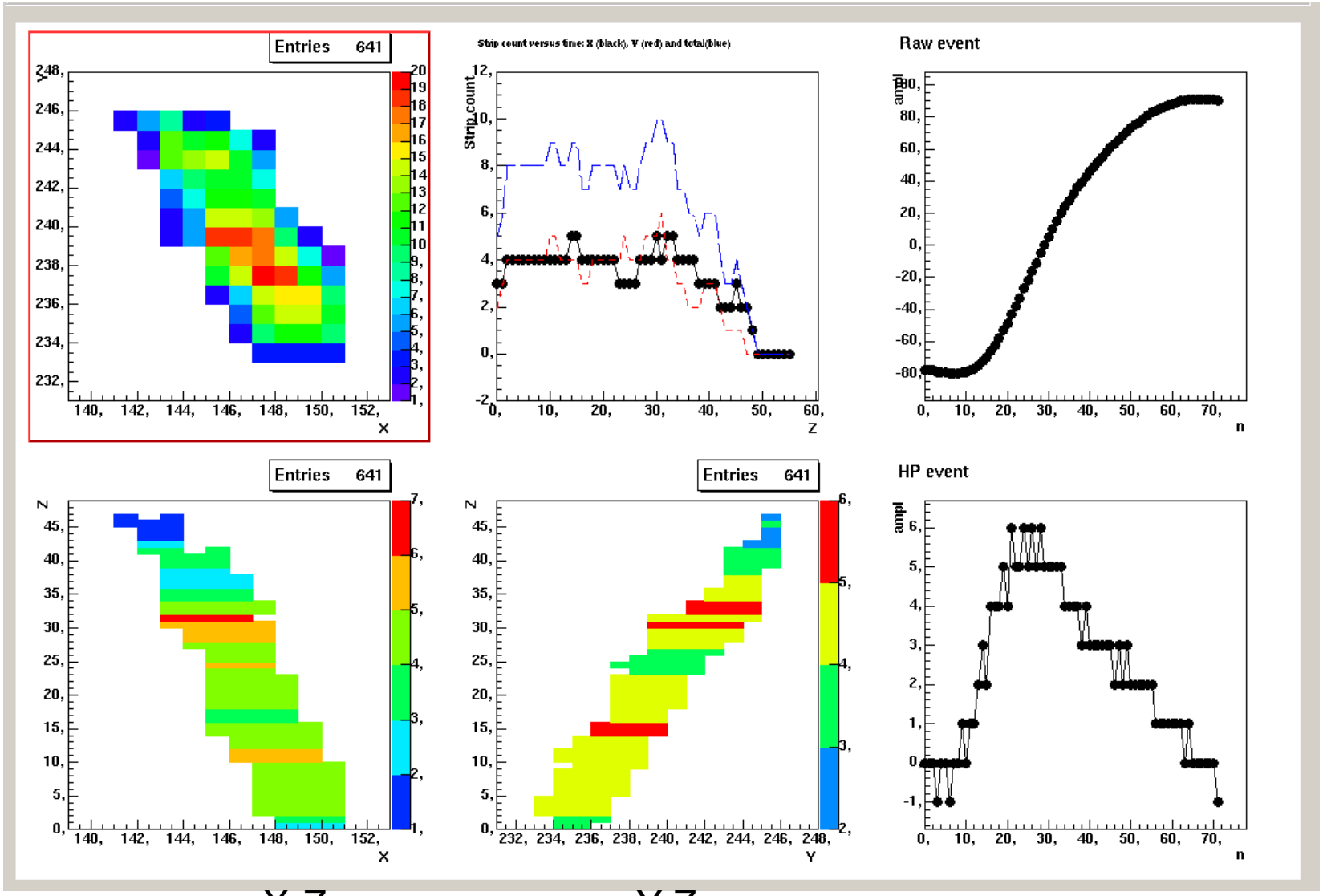
MIMAC prototype at Cadarache (detecting neutrons by nuclear recoil)



MIMAC – (512 channels) 10x 10 x18 cm^3

X-Y, X-Z and Y-Z projections, of a ^1H (60 keVee) 3D-recoil track produced by a neutron (565keV)(Amande-Cadarache). Flash-ADC (sampled every 20ns) giving its stoping power dE/dx

X-Y

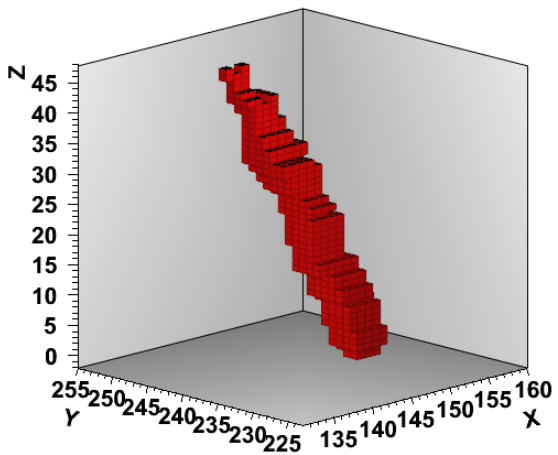


FADC

dE/dx

X-Z

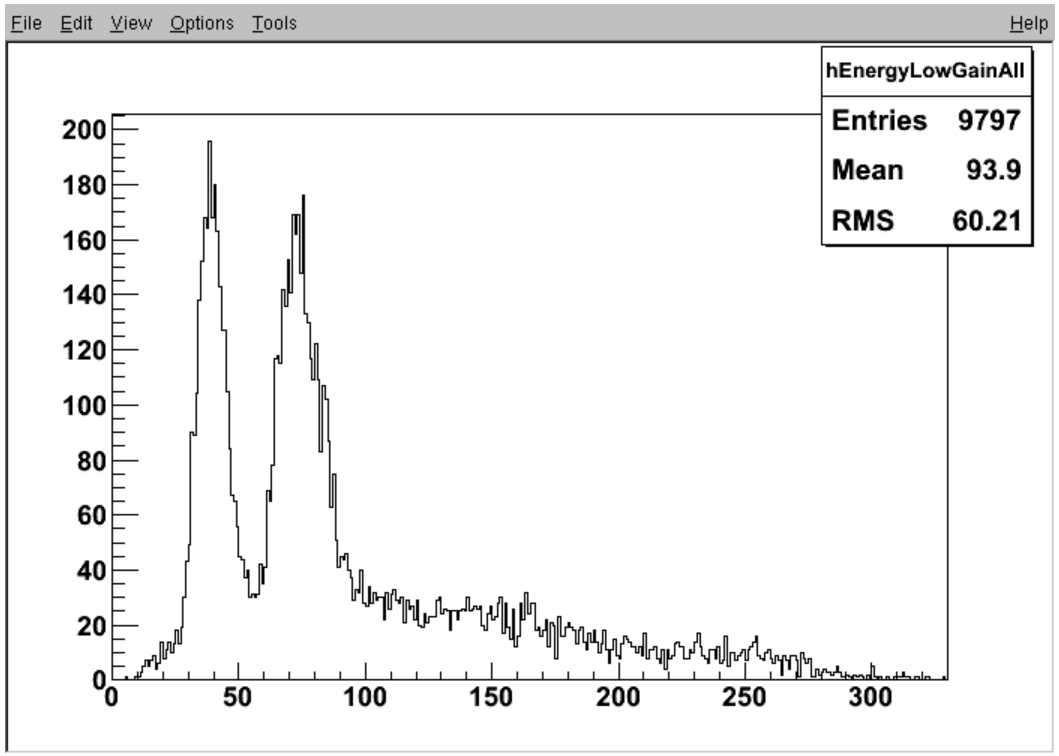
Y-Z



Trace en 3D : ^{1}H en 50mbar : 35mbar CF_4 + 14 of CHF_3 + 1mbar of C_4H_{10} !!!

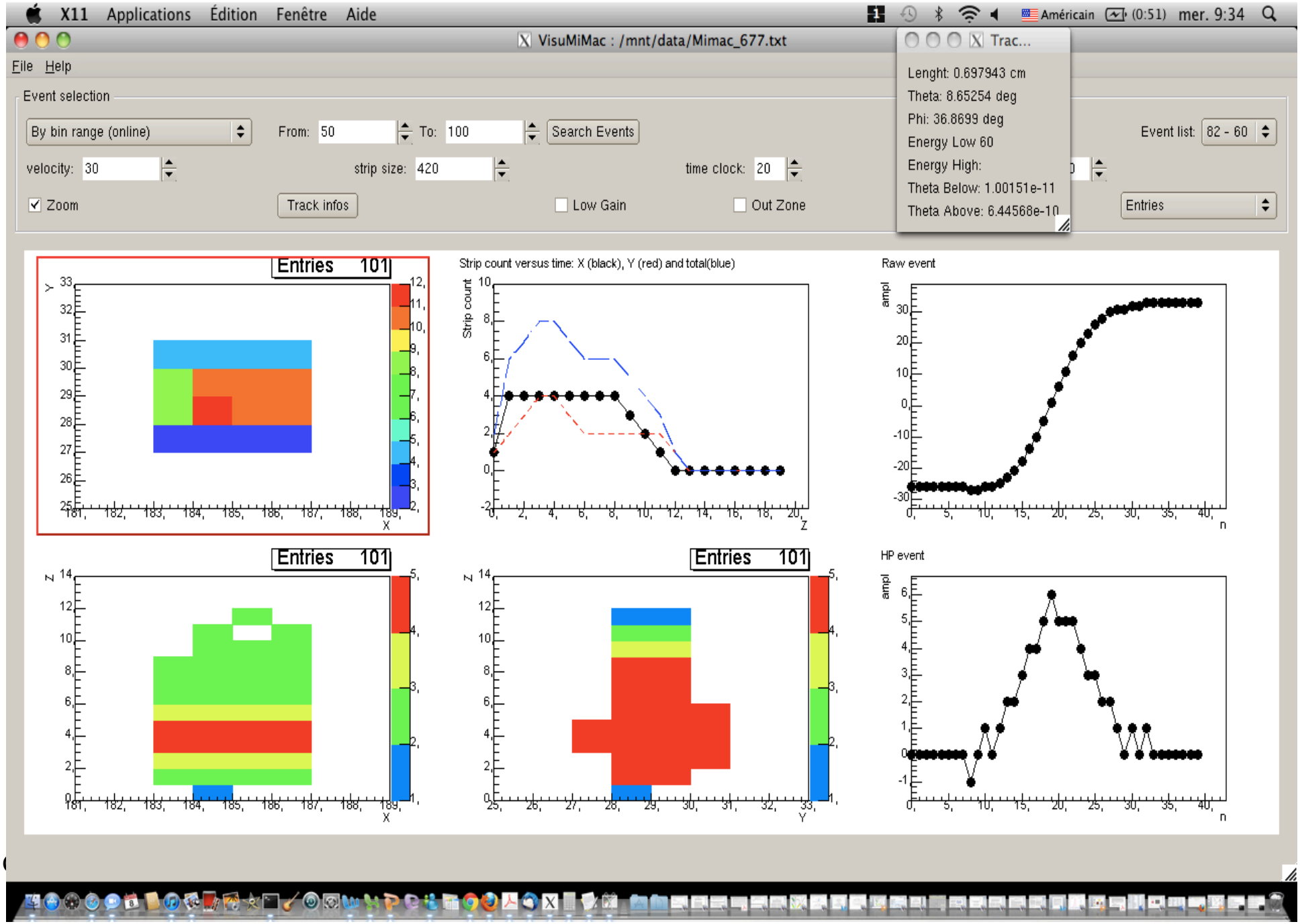
~57 keV (ionization), ~3 cm

Calibration from X rays: 3.05 keV (^{109}Cd) et 5.96 keV (^{55}Fe)

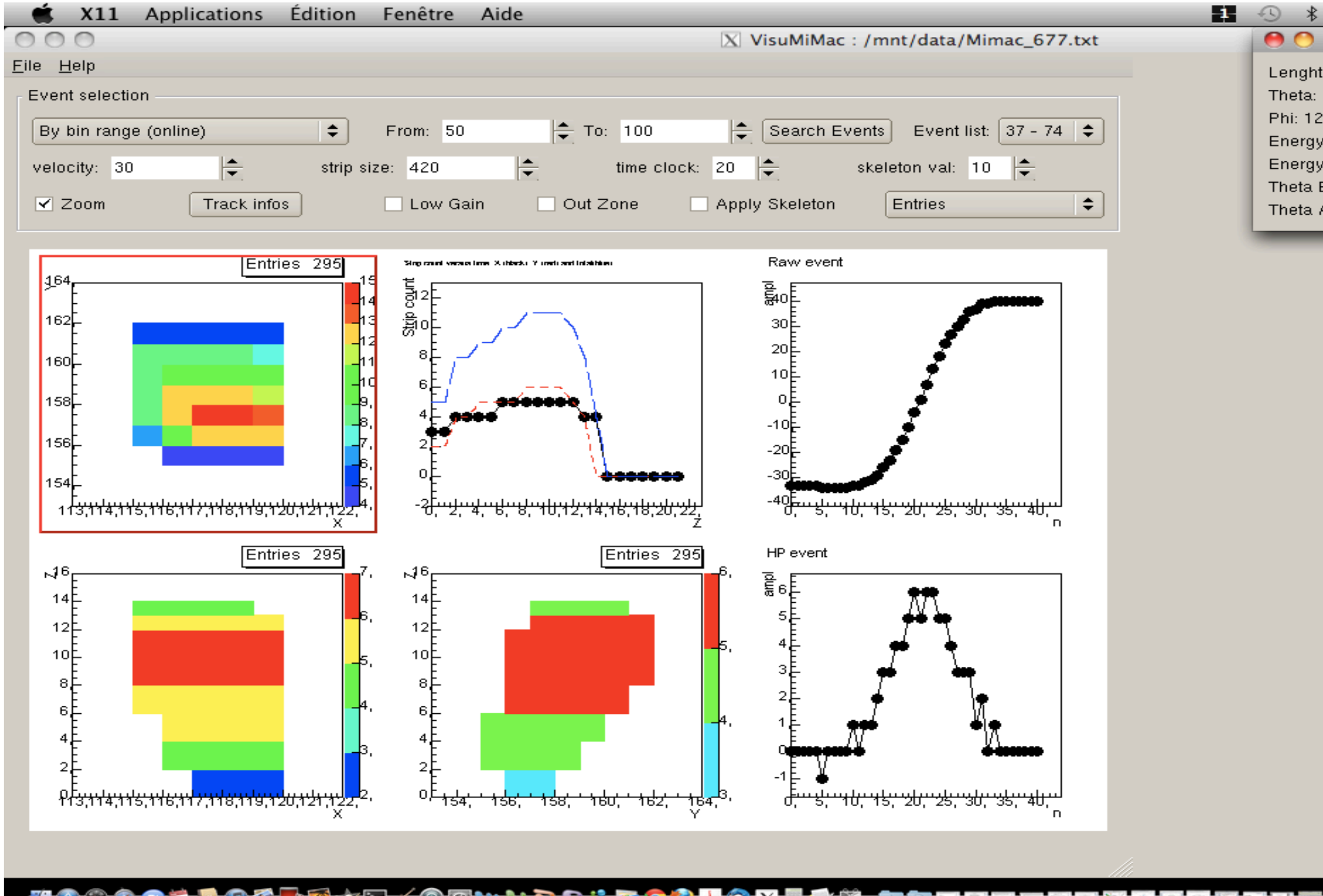


Each event has its associated track…

X-Y, X-Z and Y-Z projections, of a ^{19}F (~40 keVee) 3D-recoil track in CF_4+CHF_3

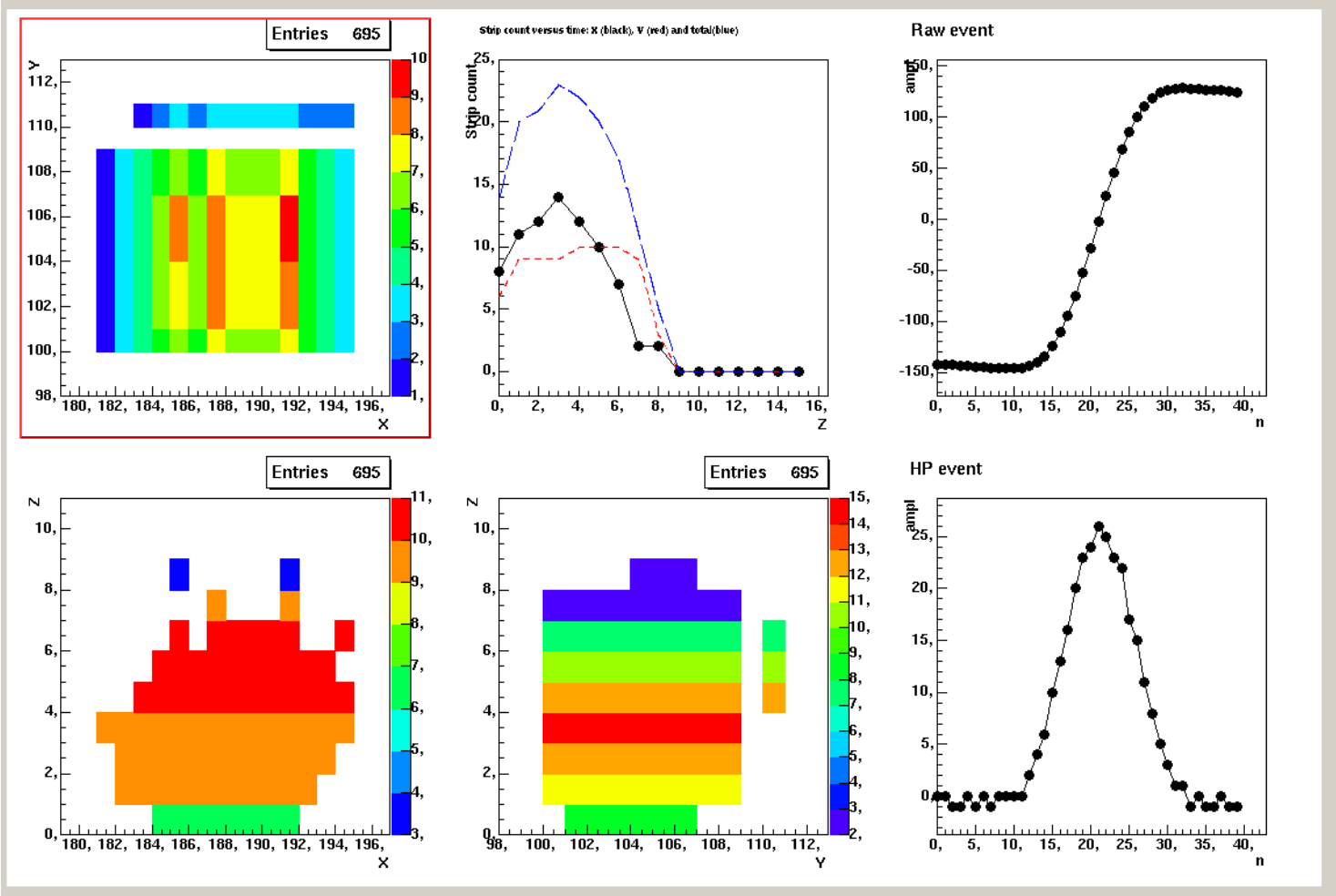


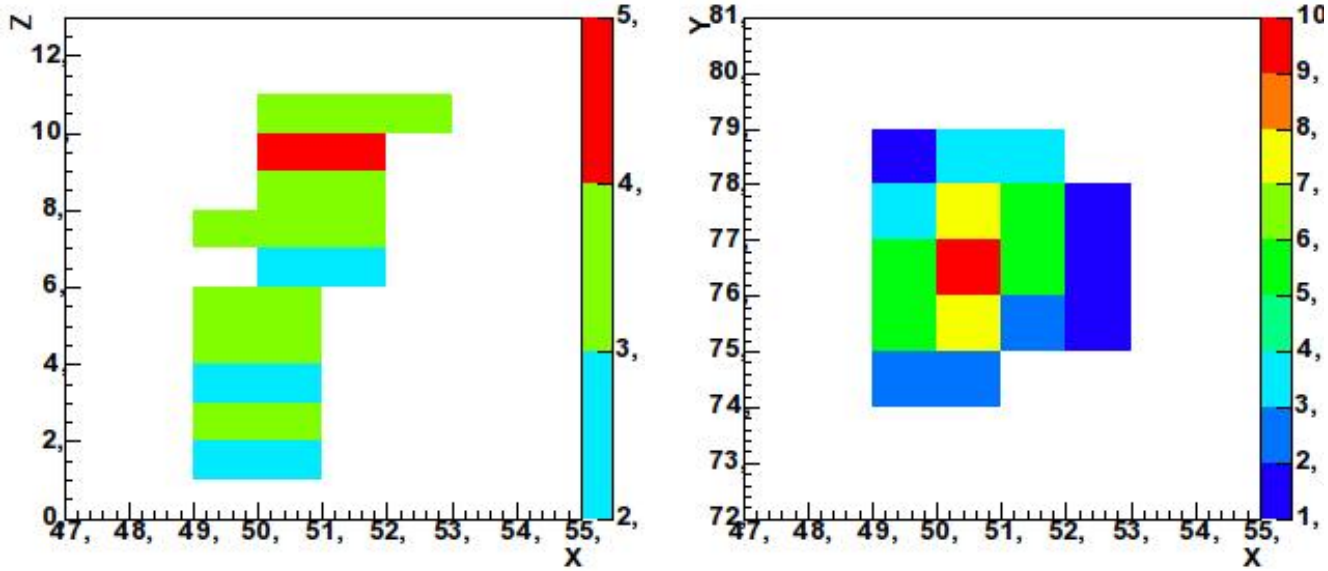
X-Y, X-Z and Y-Z projections, of a ^{19}F (~50 keVee) 3D-recoil track in CF_4+CHF_3



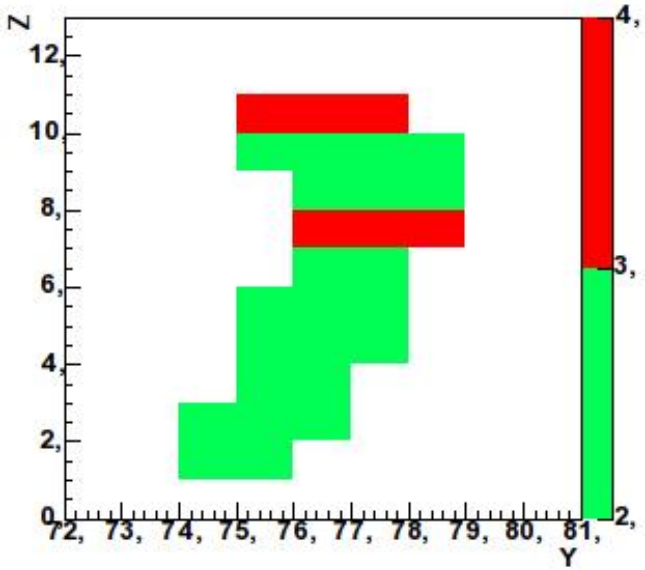
MIMAC – (512 channels) 10x 10 x18 cm^3

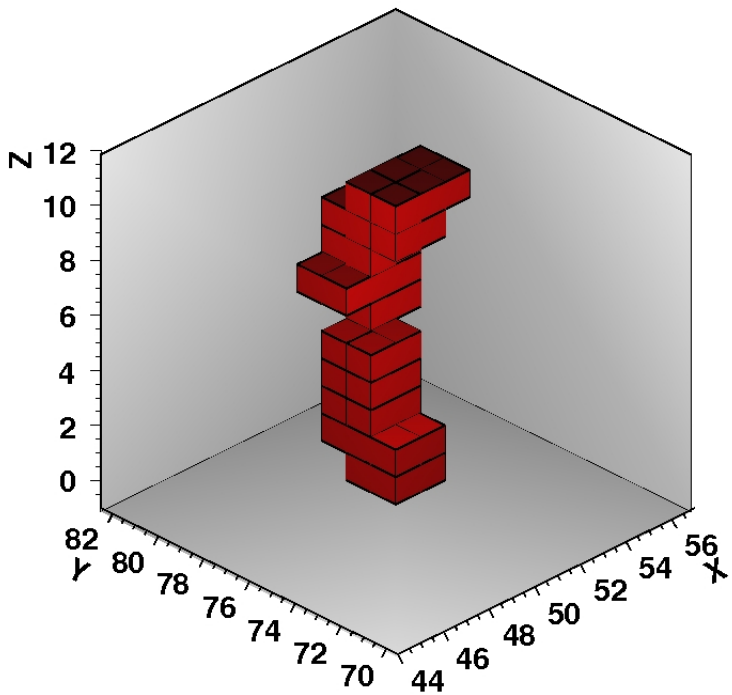
X-Y, X-Z and Y-Z projections, of a ^{19}F (50 keV ee) 3D-recoiltrack produced by a neutron (565keV)(Amande-Cadarache). Flash-ADC (sampled every 20ns) giving its stoping power dE/dx





Recoil of 19F
(E_{ion}~40 keV)
in 50 mbar of
CF4 + CHF3 (30%)



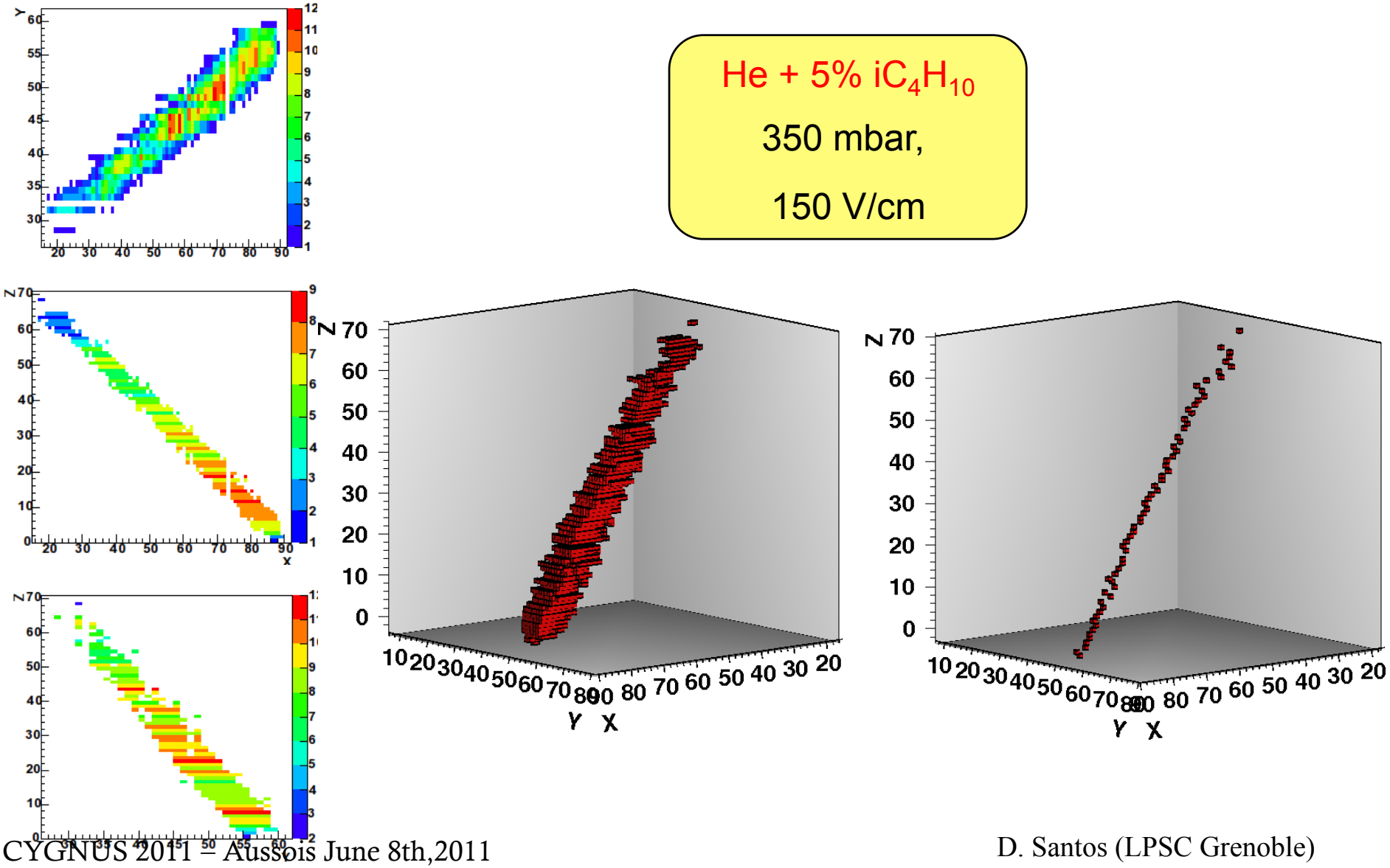


3D track : **Alpha 5,5 MeV** (^{222}Rn)

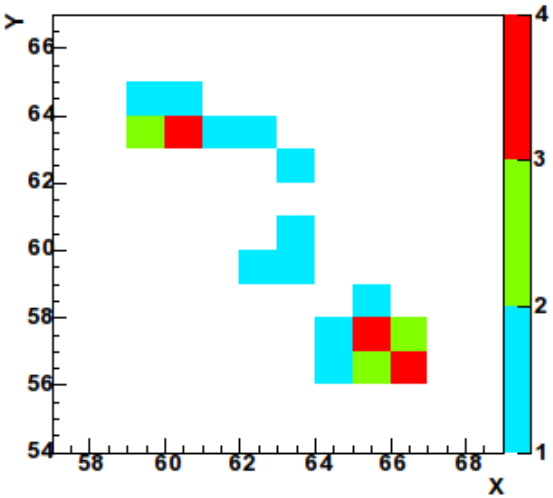
He + 5% iC_4H_{10}

350 mbar,

150 V/cm



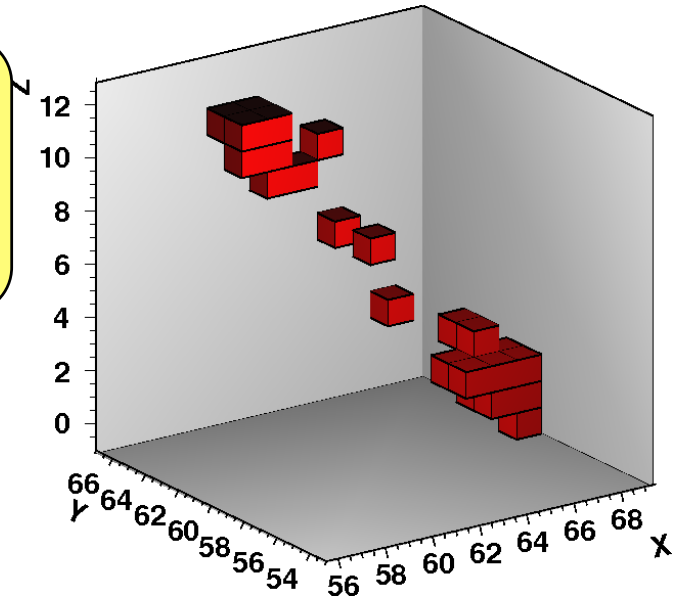
3D Track : 5.9 keV electron (^{55}Fe)

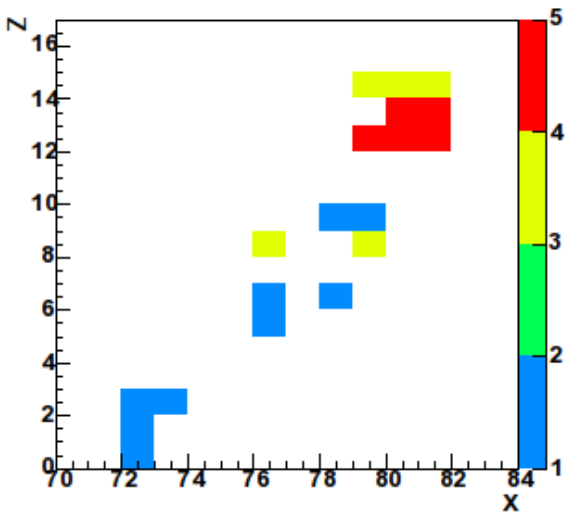


He + 5% iC_4H_{10}

350 mbar,

150 V/cm

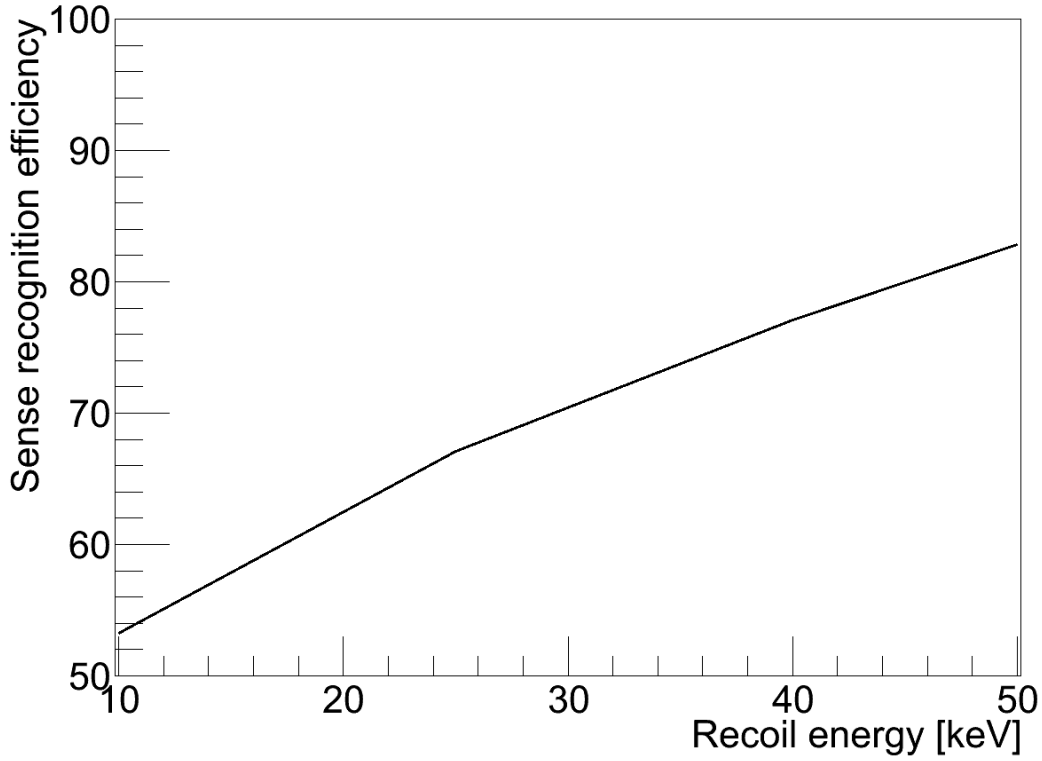




Typical background in DM detection

Head-tail discrimination in MIMAC

(measured for protons)



For ^{19}F full simulation including de response of the detector gives similar results, not yet obtained experimentally

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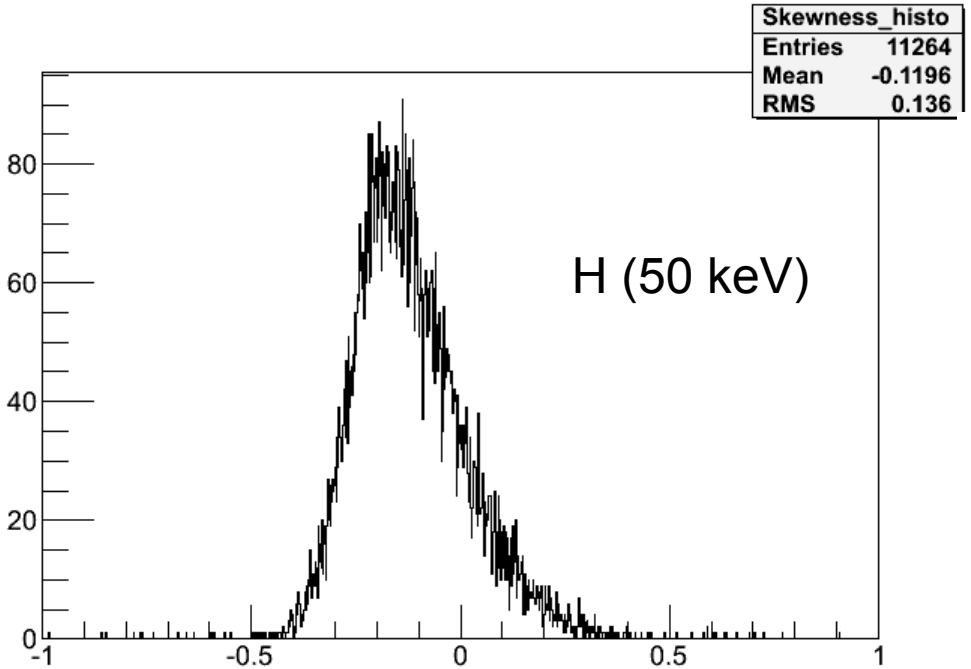
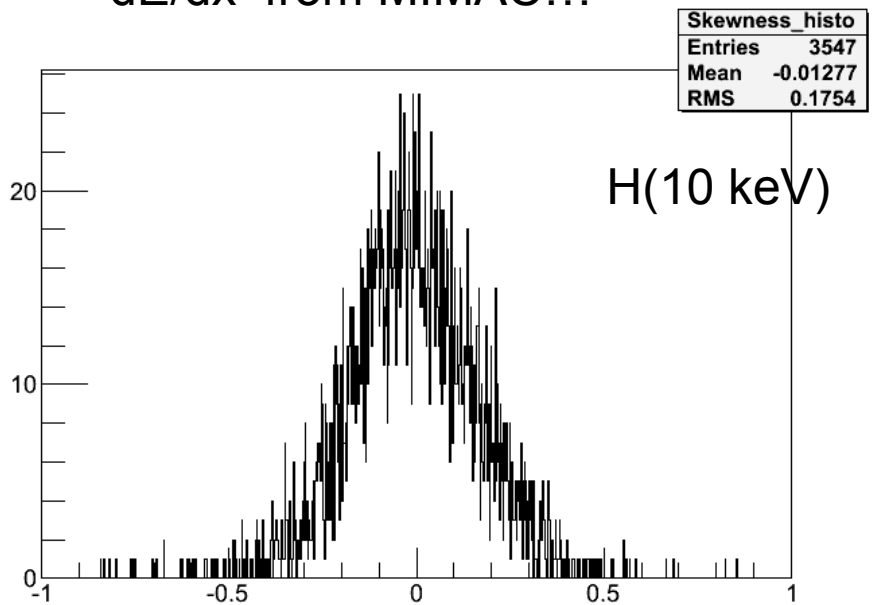
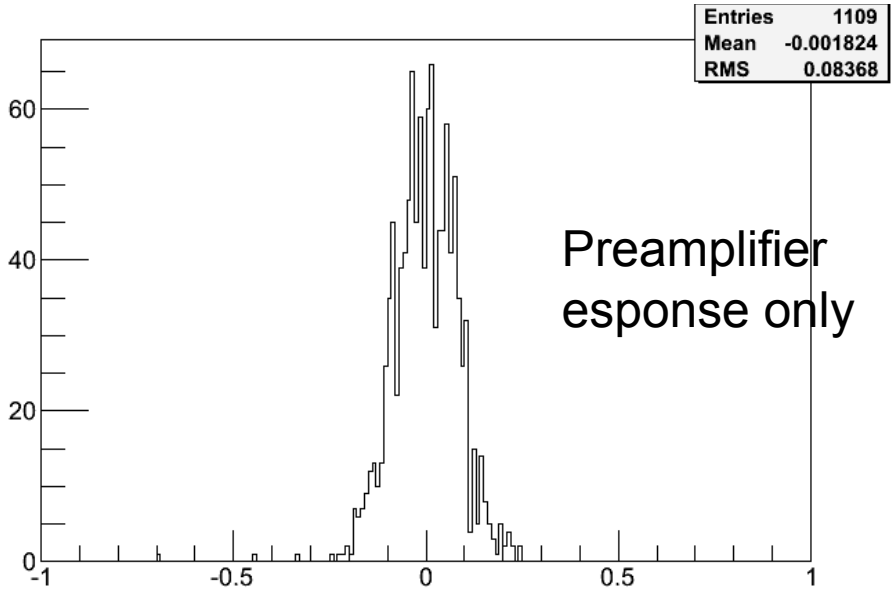
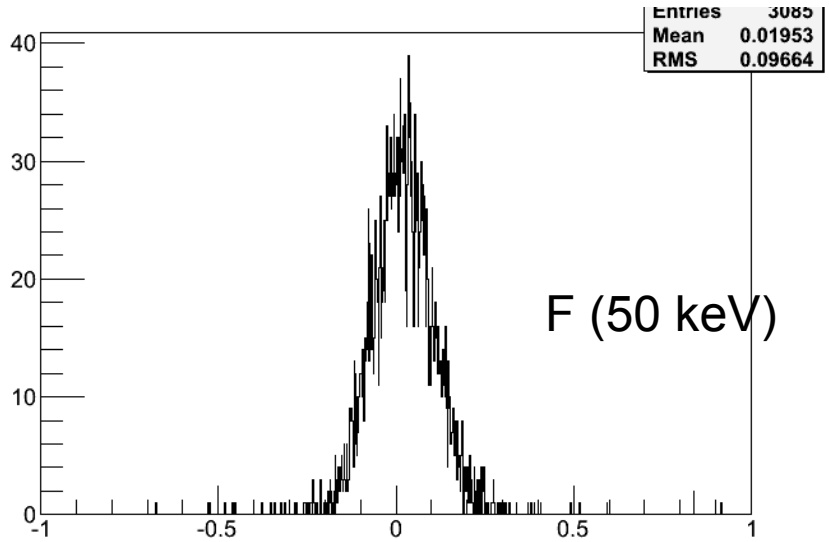
dE/dx from MIMAC…

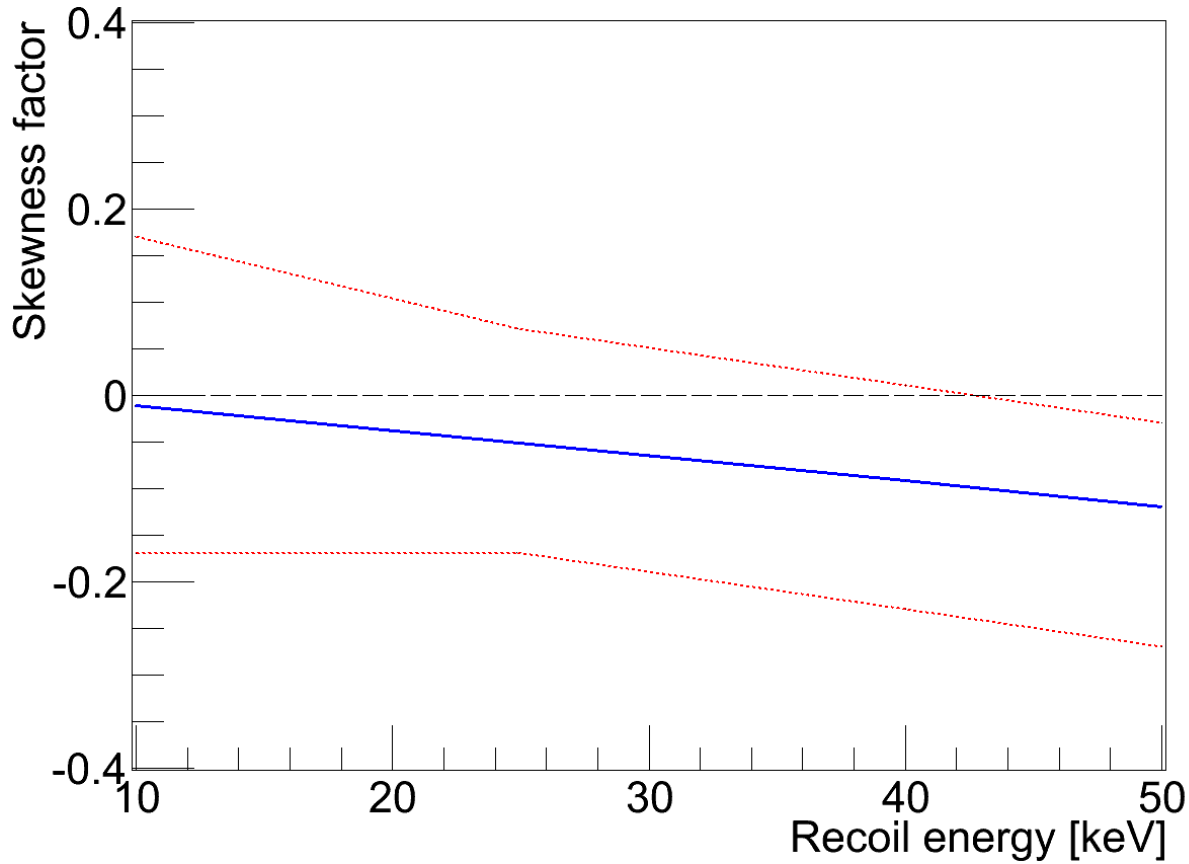








Asymmetry of dE/dx (for protons) in MIMAC



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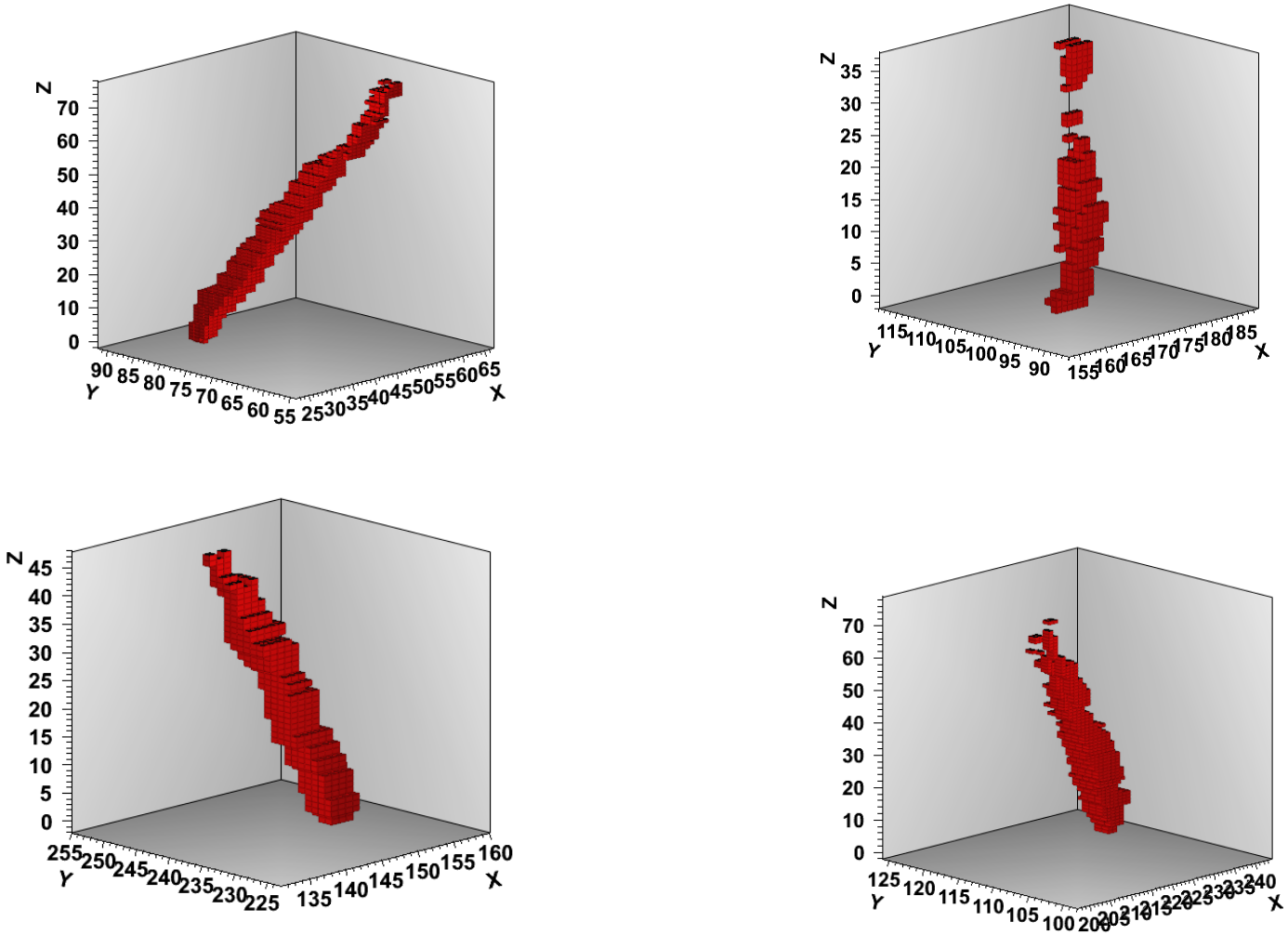
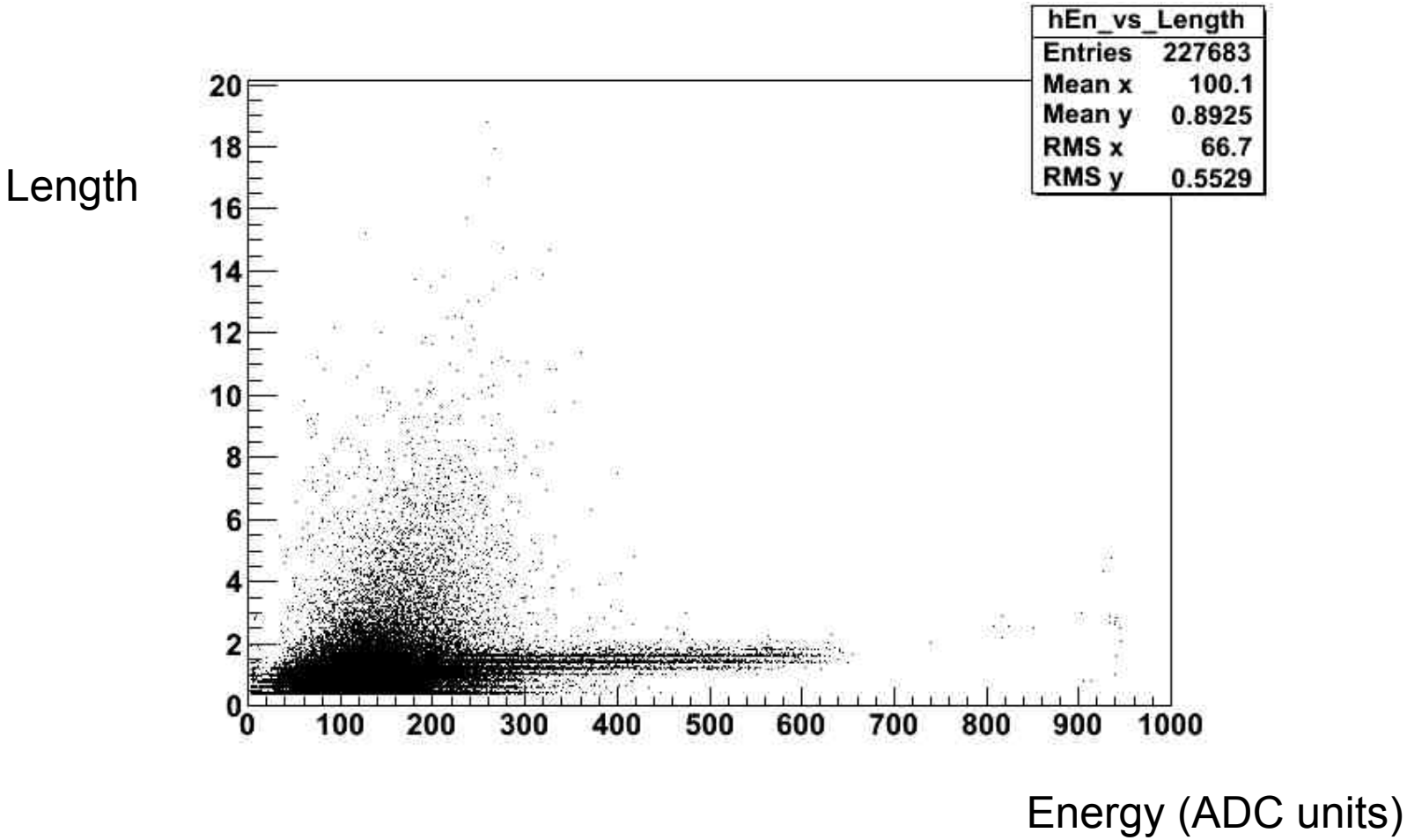
3D-Tracks in 50 mbar (CF_4+30%CHF_3)



Total Length vs. Energy (in CF_4)

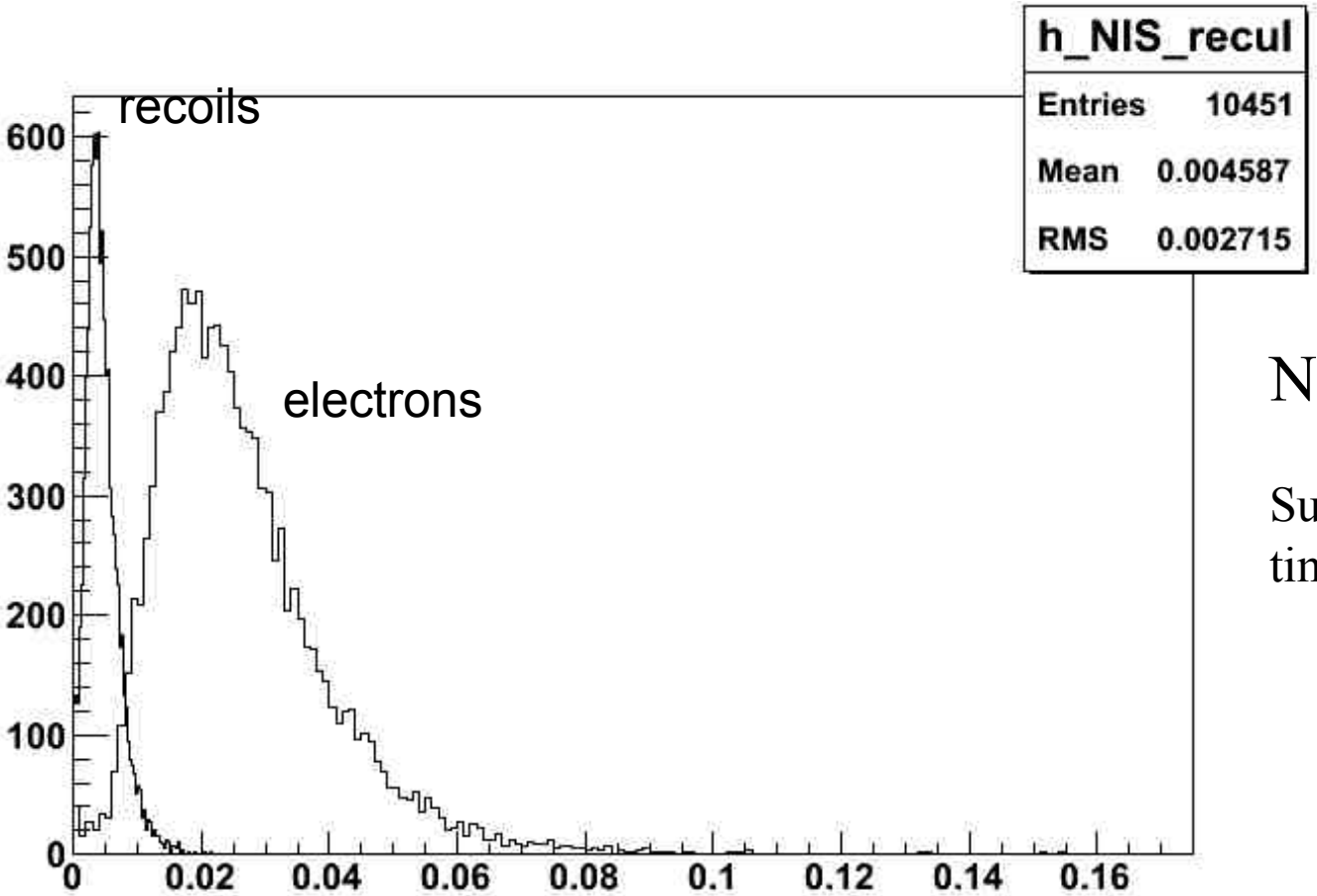


D. Santos (LPSC Grenoble)

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 energy)

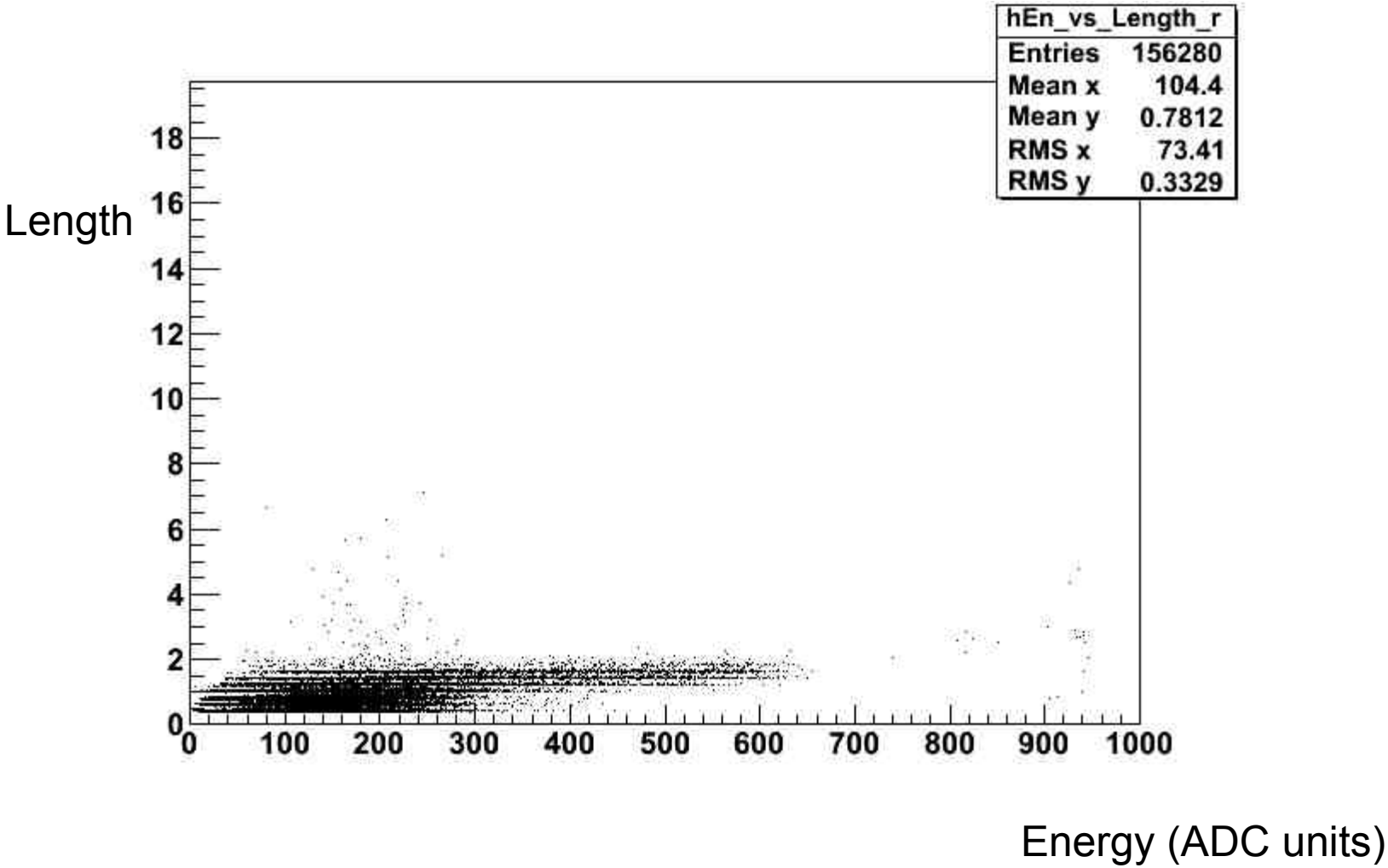


$$NIS = \Sigma\,(\Delta\theta_i) / E$$

Summed over all the time samples of a track

D. Santos (LPSC Grenoble)

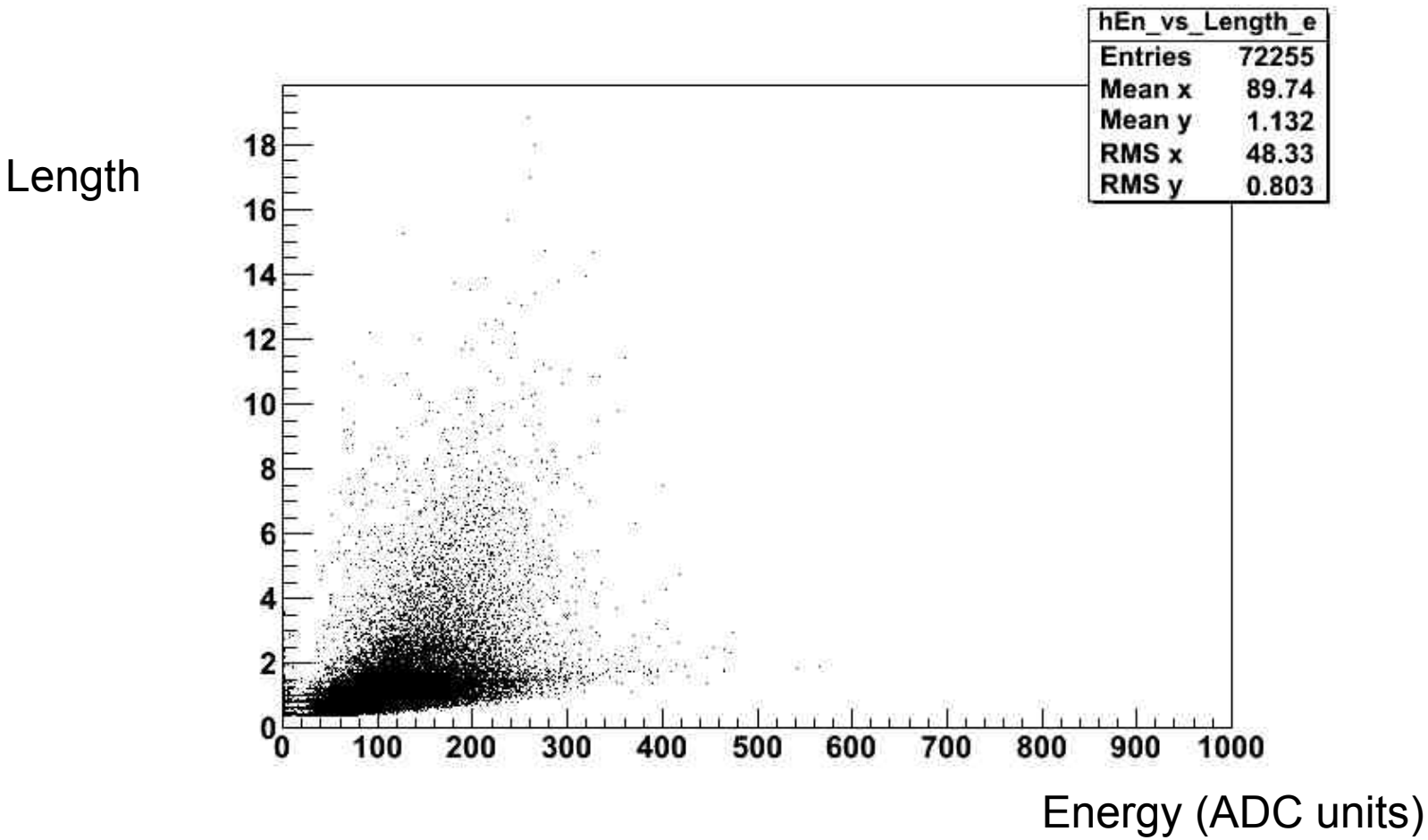
Length vs. Energy (with NIS cut)



D. Santos (LPSC Grenoble)

Length vs. Energy (with NIS cut)

selecting electrons…



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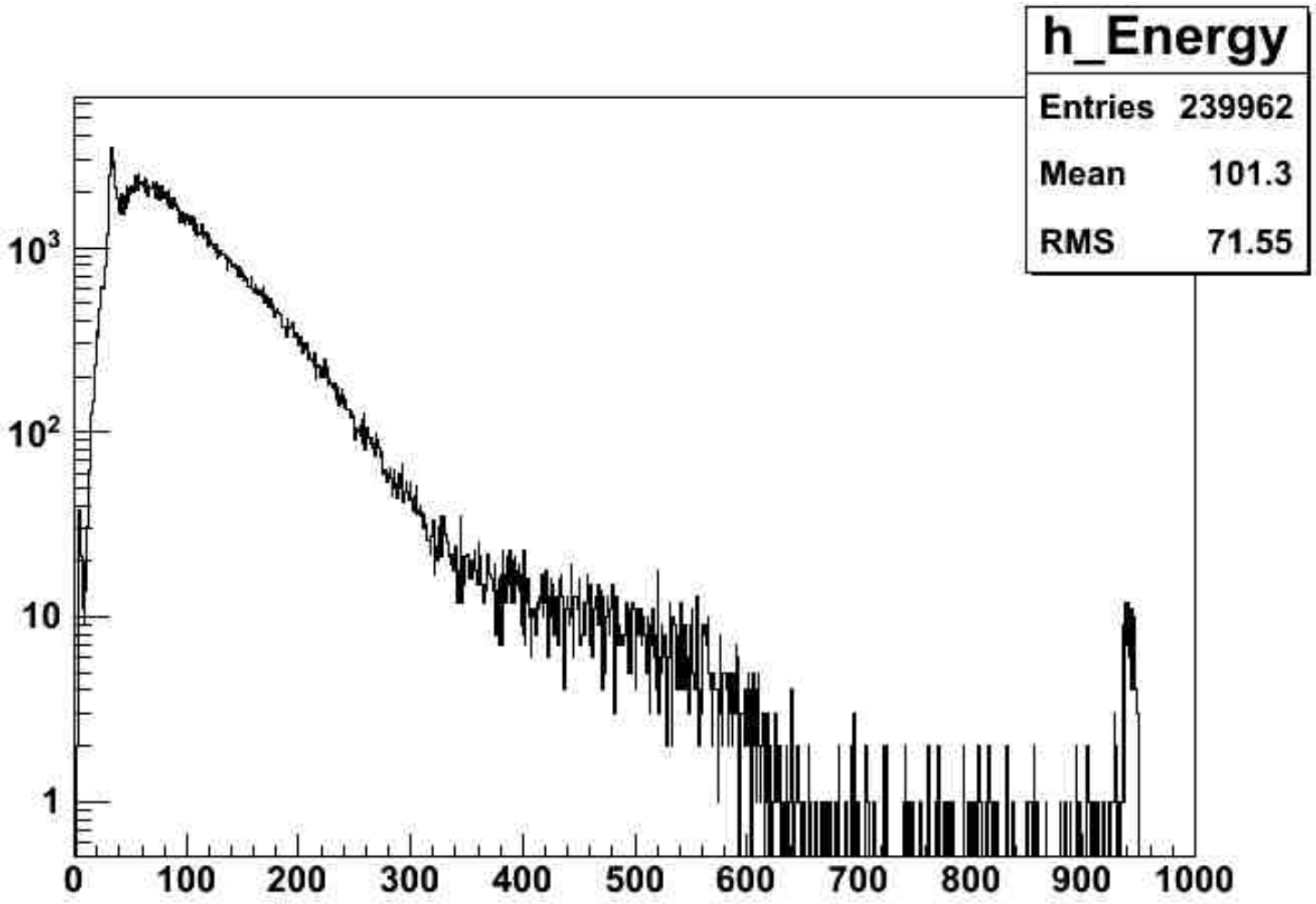
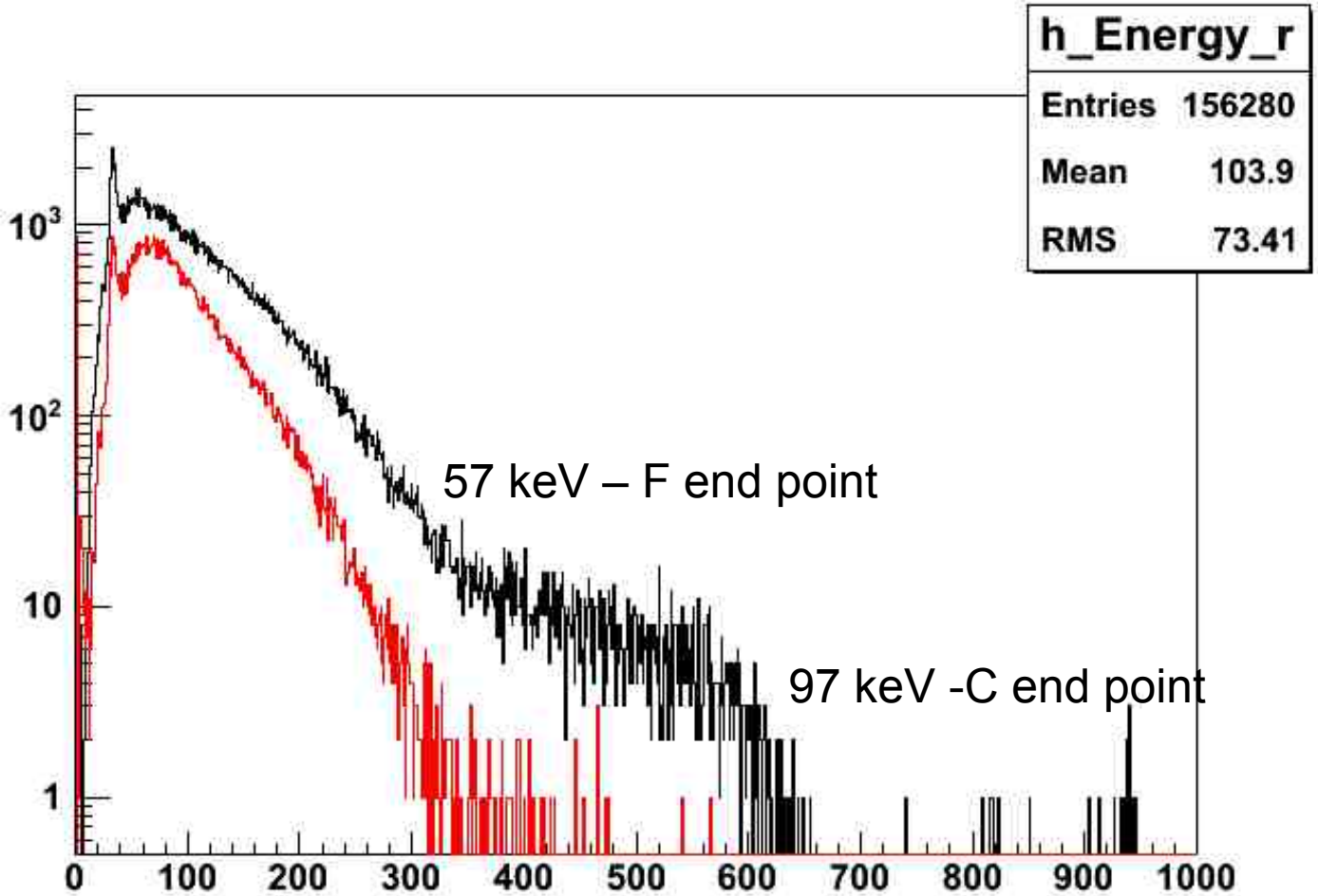
Total Energy Spectrum from $^{7}Li(p,n\ (565keV))$

(50 mbar of CF_4)

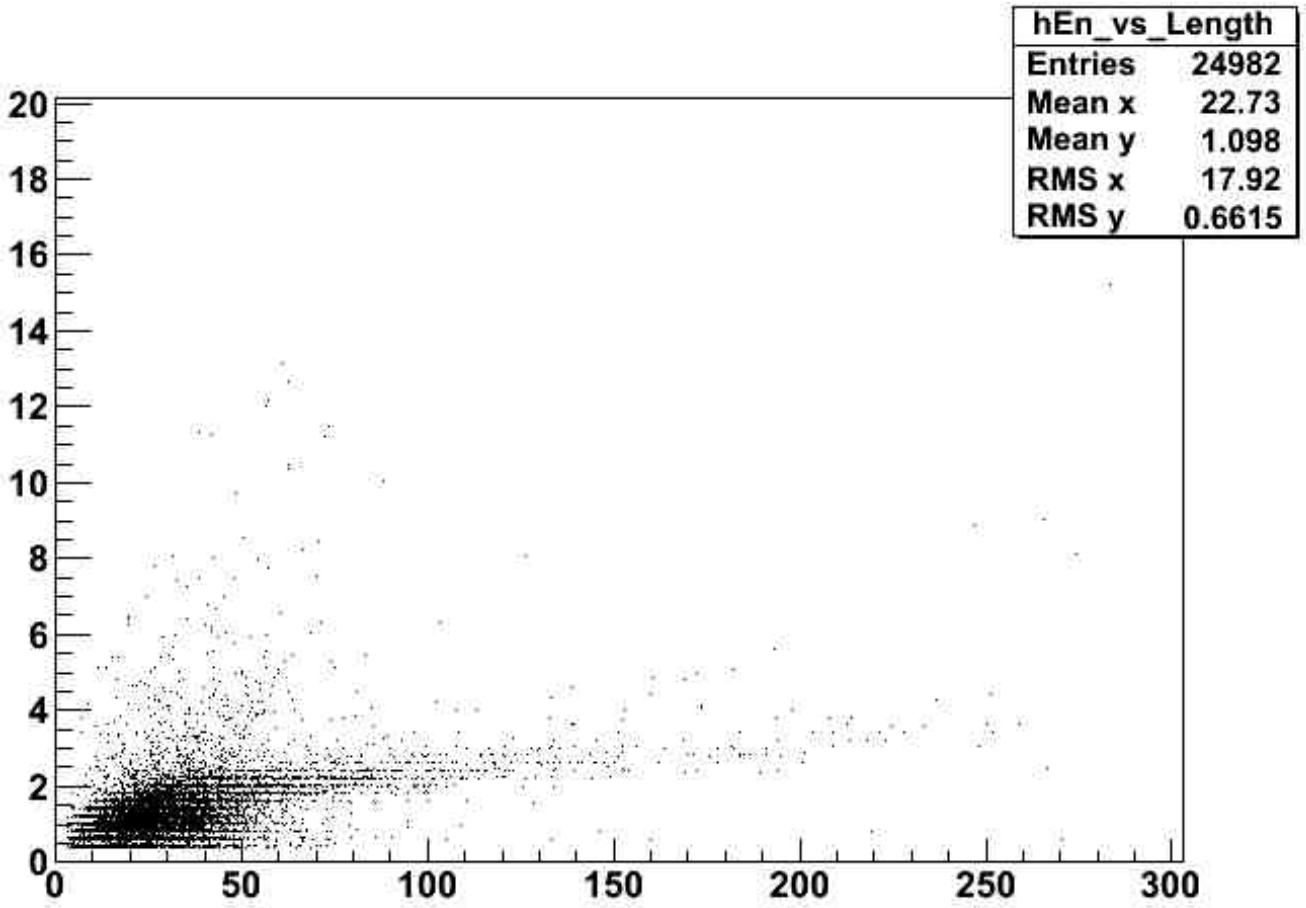


With only a NIS cut on the Energy spectrum

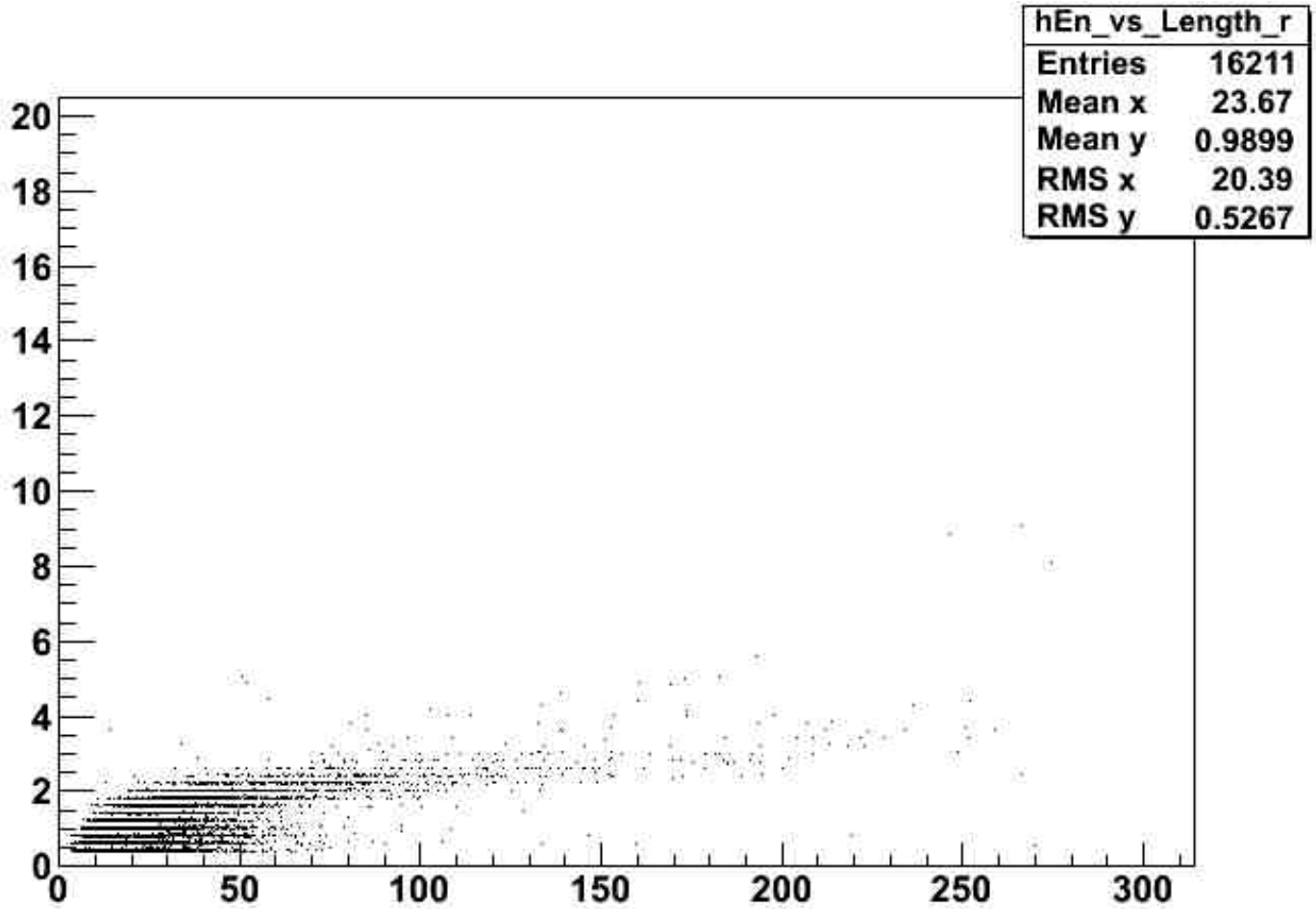


D. Santos (LPSC Grenoble)

Total Length vs. Energy (in $CF_4 + CHF_3$)

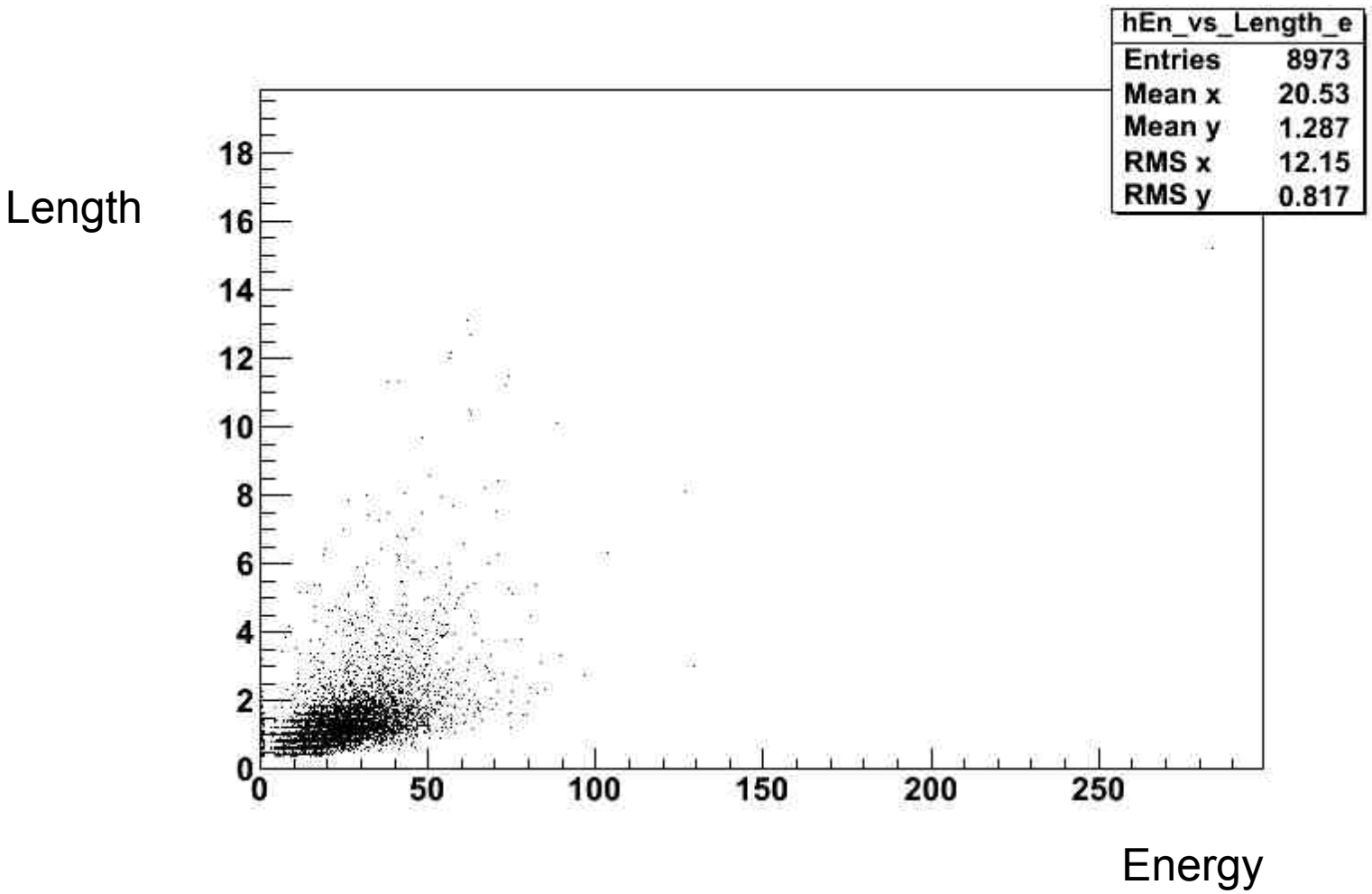


Length vs. Energy (with NIS cut)



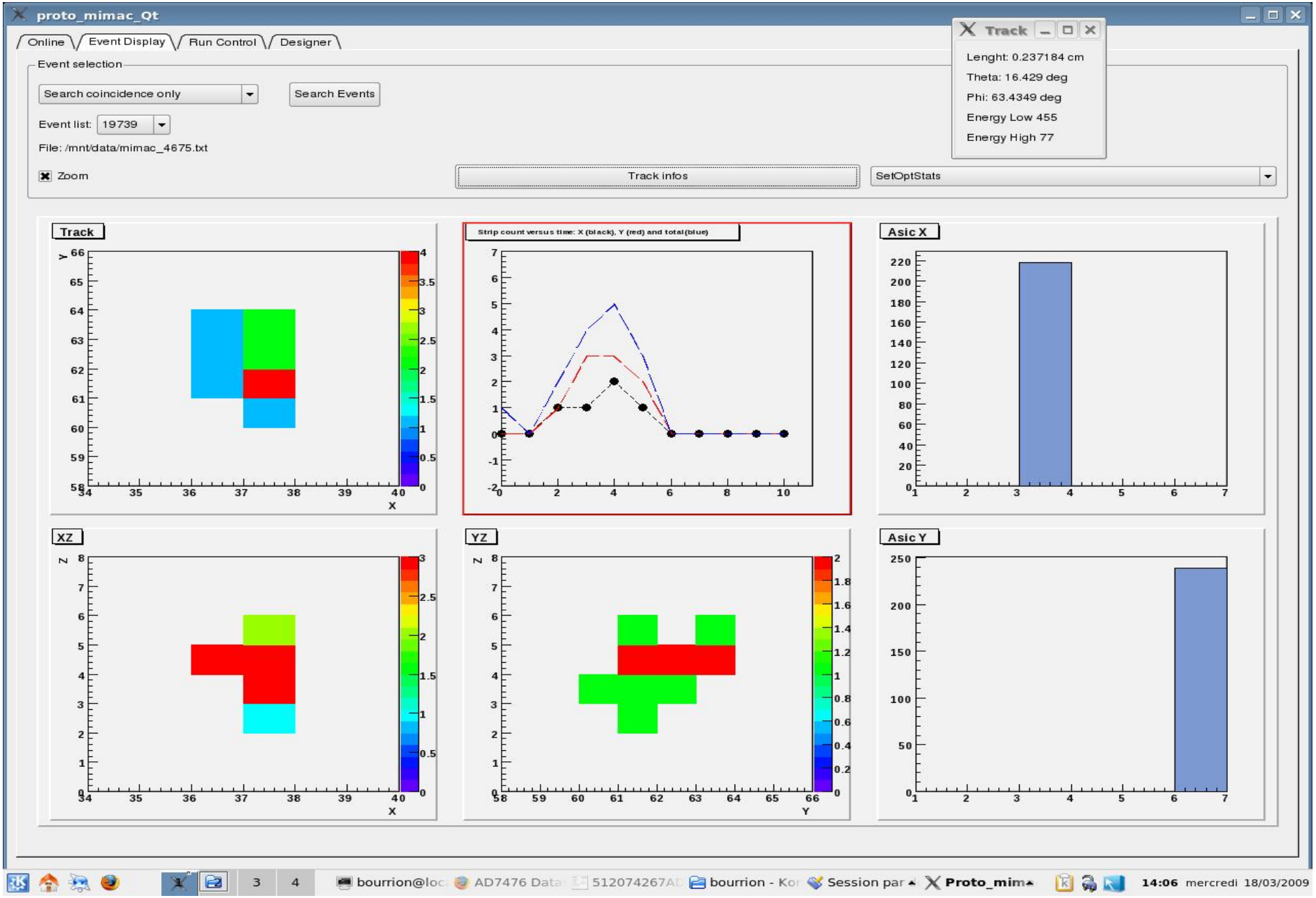
Length vs. Energy (with NIS cut)

selecting electrons…



D. Santos (LPSC Grenoble)

3D track measurement of an electron of 1.5 keV (X(Al))



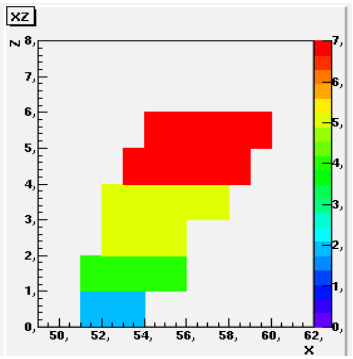
Recoils from 144 keV neutrons

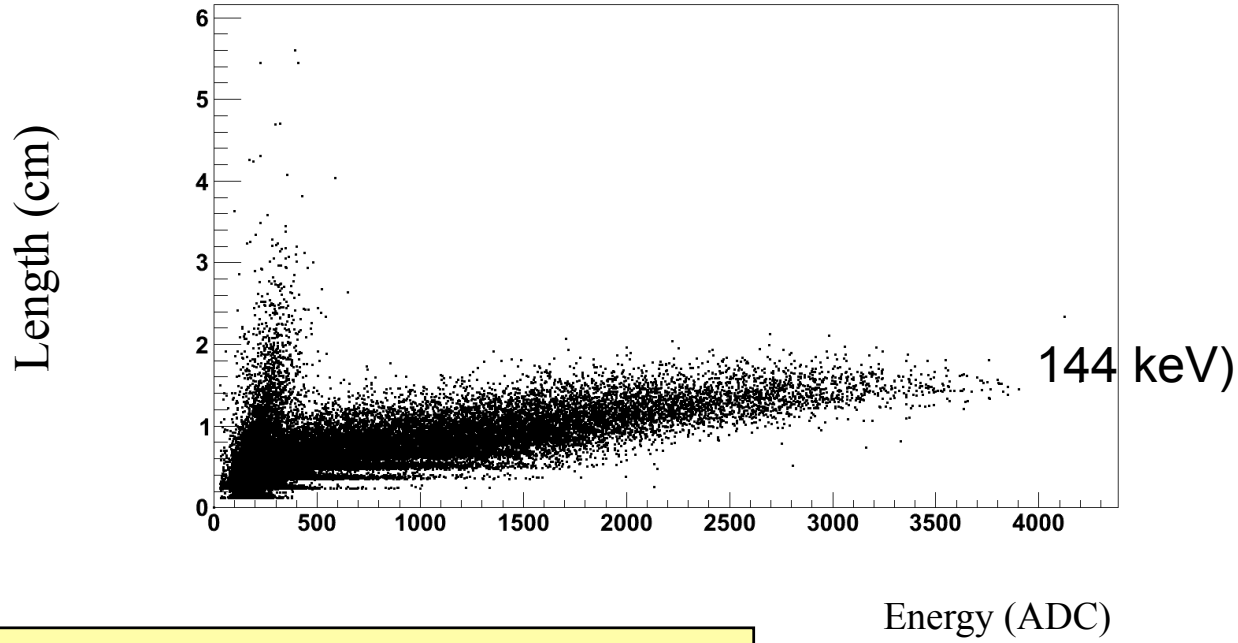
Pure isobutane

100 mbar

150 V/cm

Amande facility @ IRSN Cadarache
-> Neutron field with energies down to a few keV

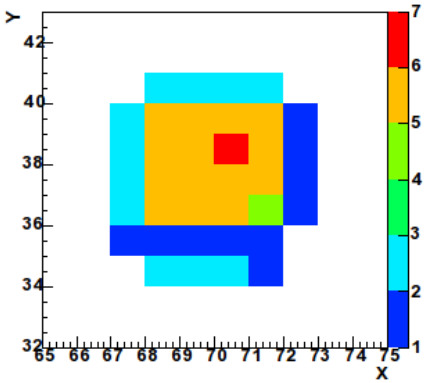


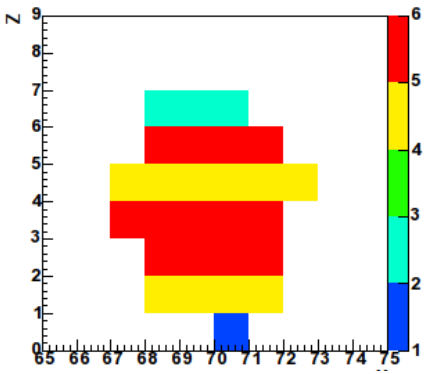


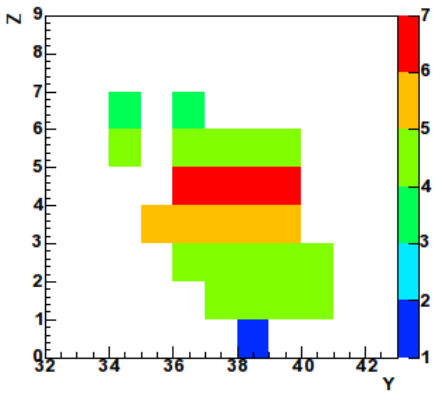
- **Possibility to have H as a target**
- **Background discrimination from recoils**

D. Santos (LPSC Grenoble)

3D Track: proton 8 keV in He + 5% iC_4H_{10}



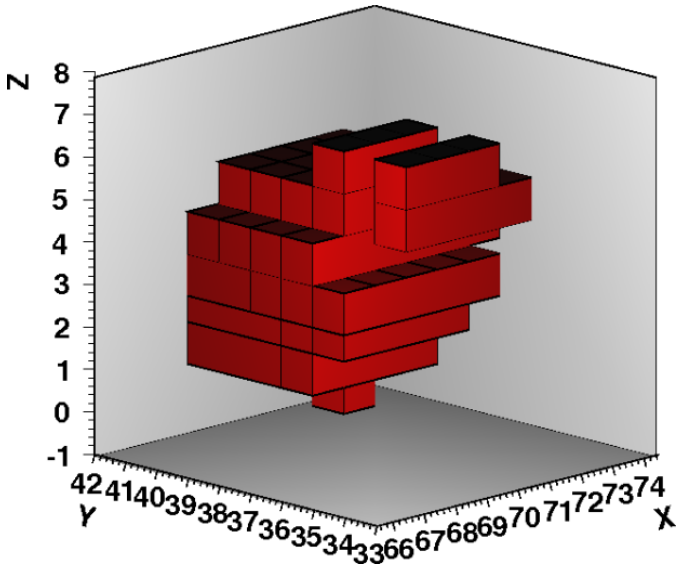


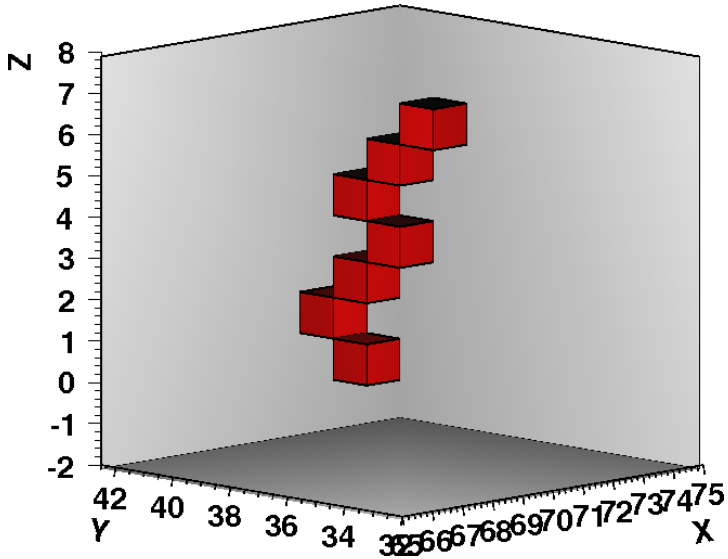


He + 5% iC_4H_{10}

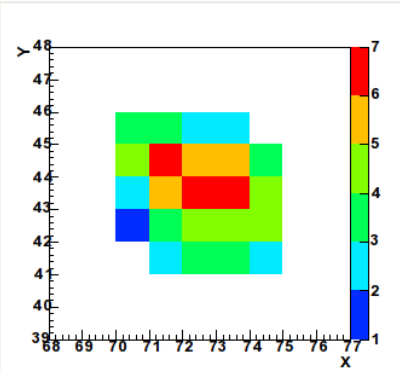
350 mbar,

150 V/cm





Trak in 3D : ^{19}**F** in 70 % CF_4 + 30% CHF_3 !!!

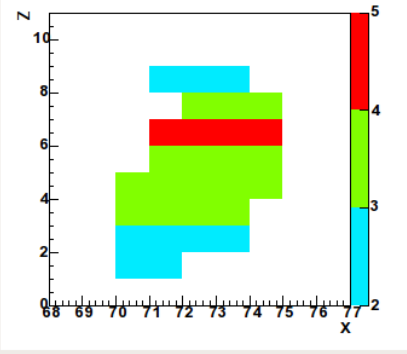


X-Y (anode)

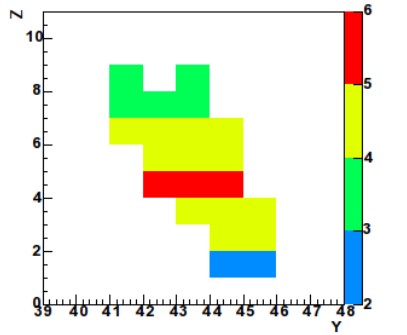
70 % CF_4 + 30% CHF_3

55 mbar,
170 V/cm

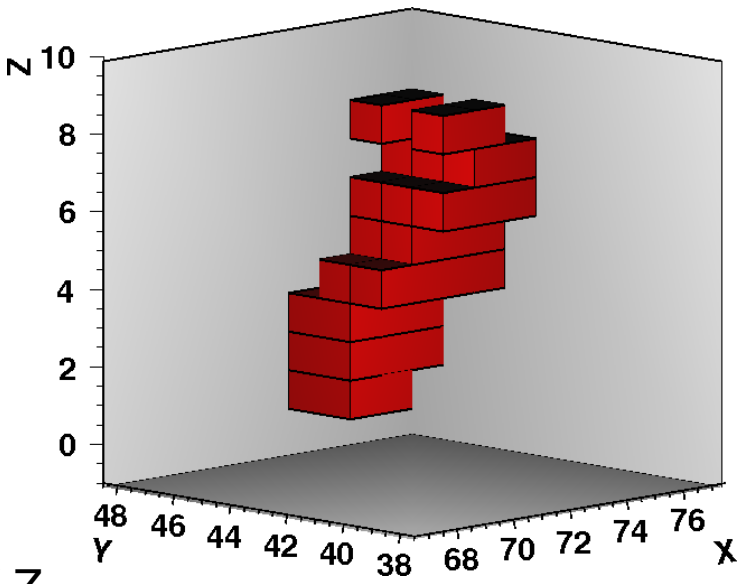
~40 keV (ionization), ~3 mm

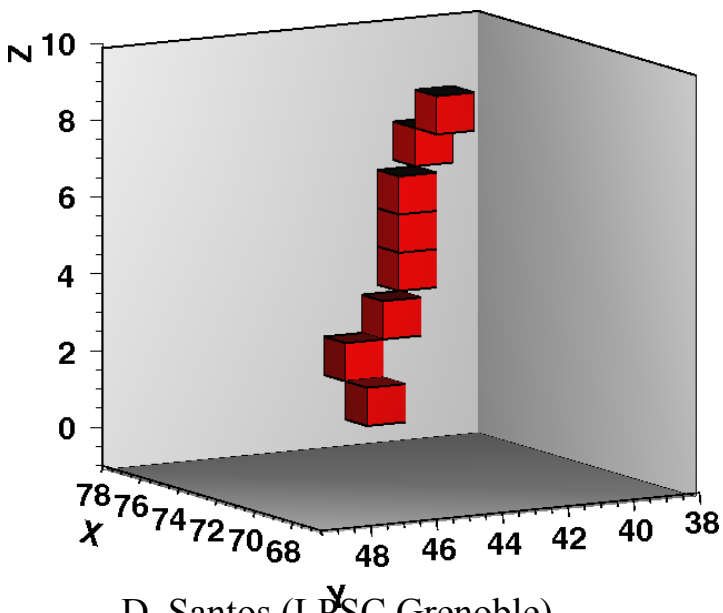


X-Z



Y-Z

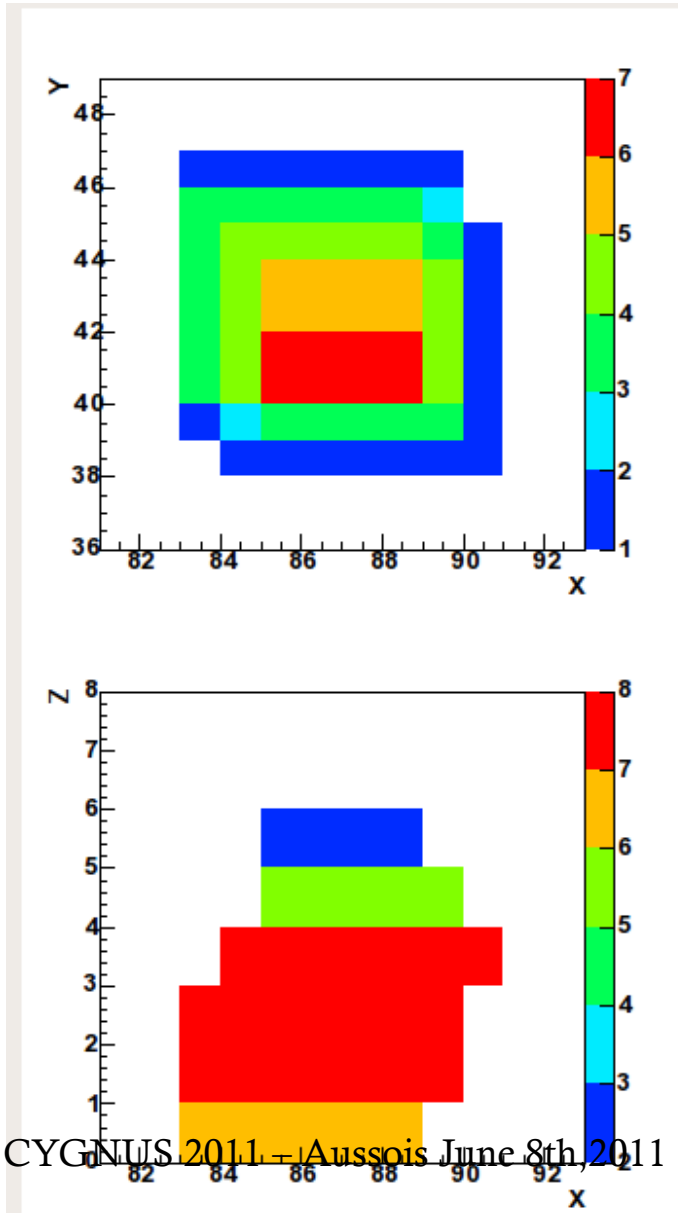




100% iC_4H_{10}

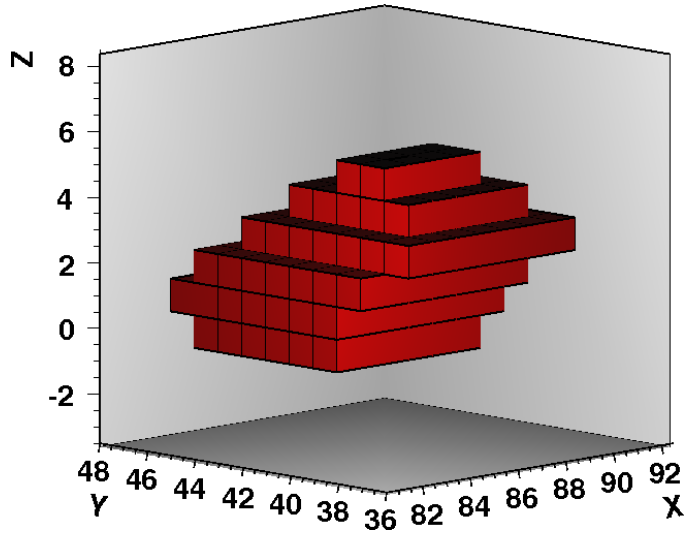
50 mbar,

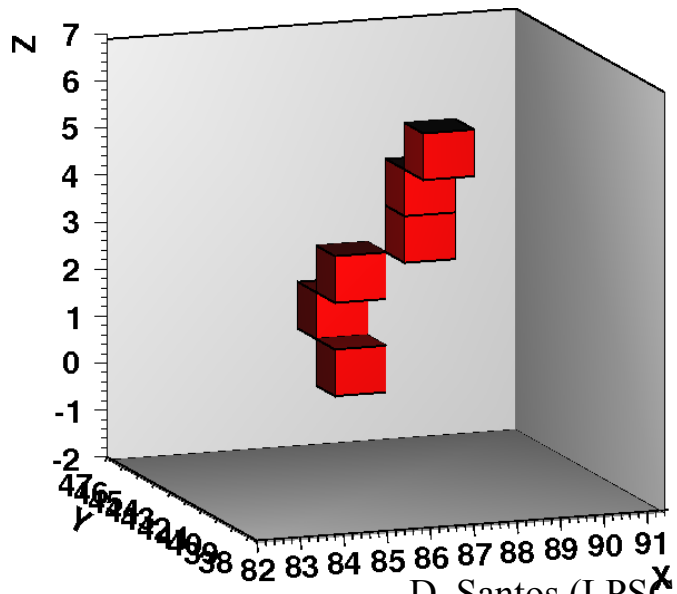
Proton recoil in isobutane



3D reconstruction

30 keV



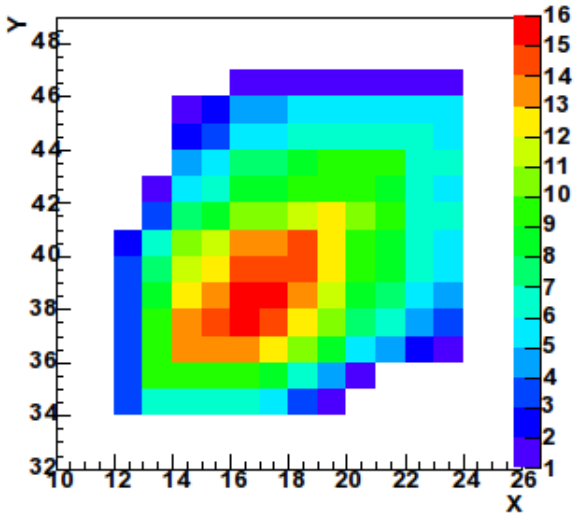


D. Santos (LPSC Grenoble)

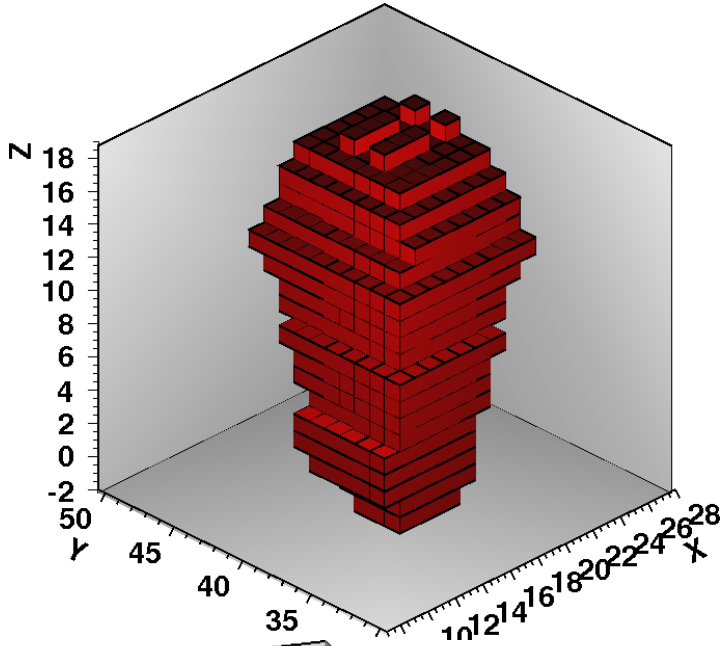
100% iC_4H_{10}

50 mbar,

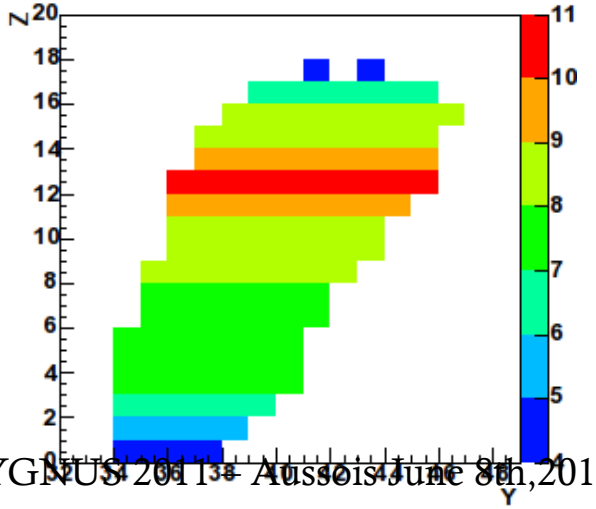
Proton recoil in isobutane

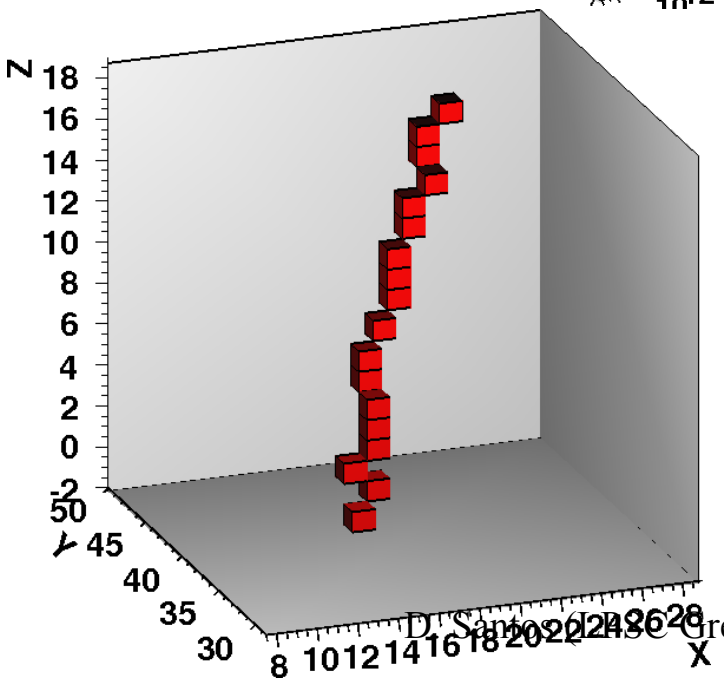


3D reconstruction

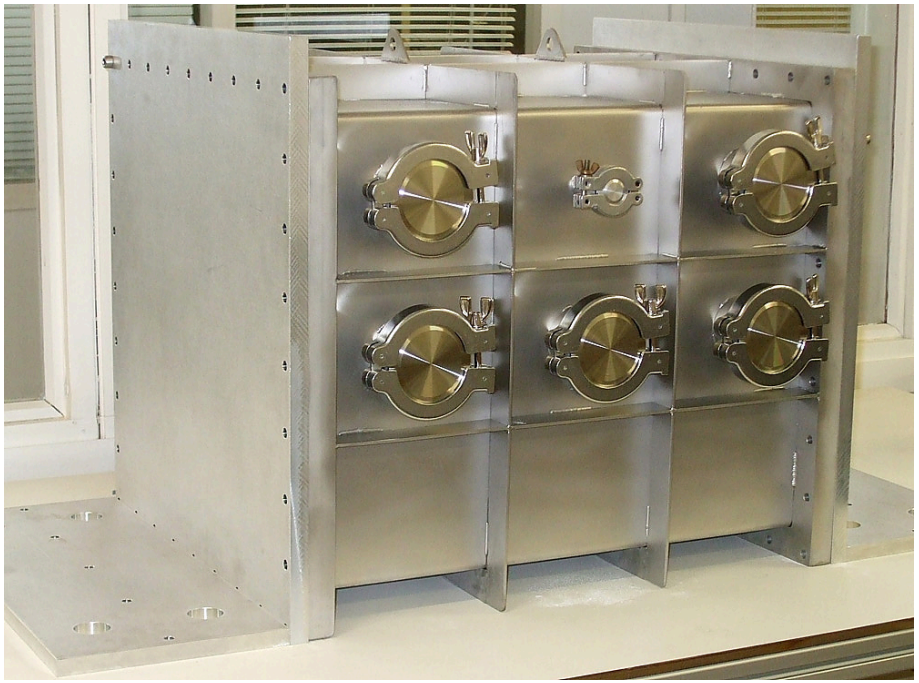


180 keV recoil



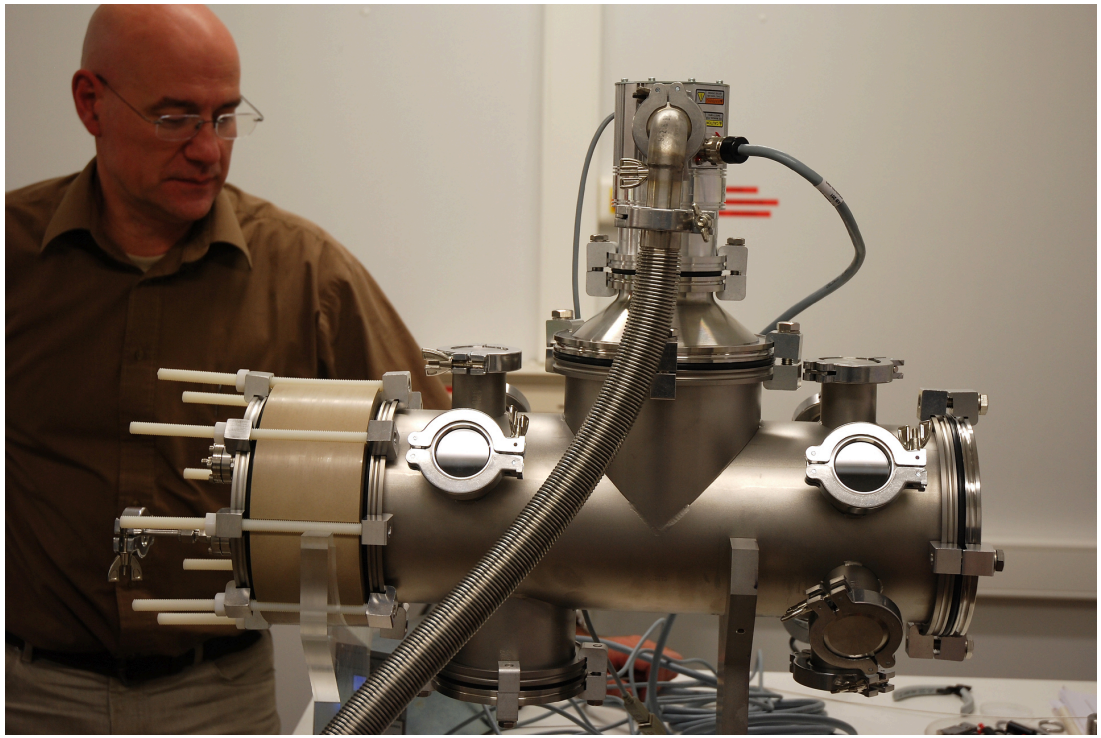


Bi-chamber module (Modane)
2x (10x10x25 cm^3)
(November 2011 !)



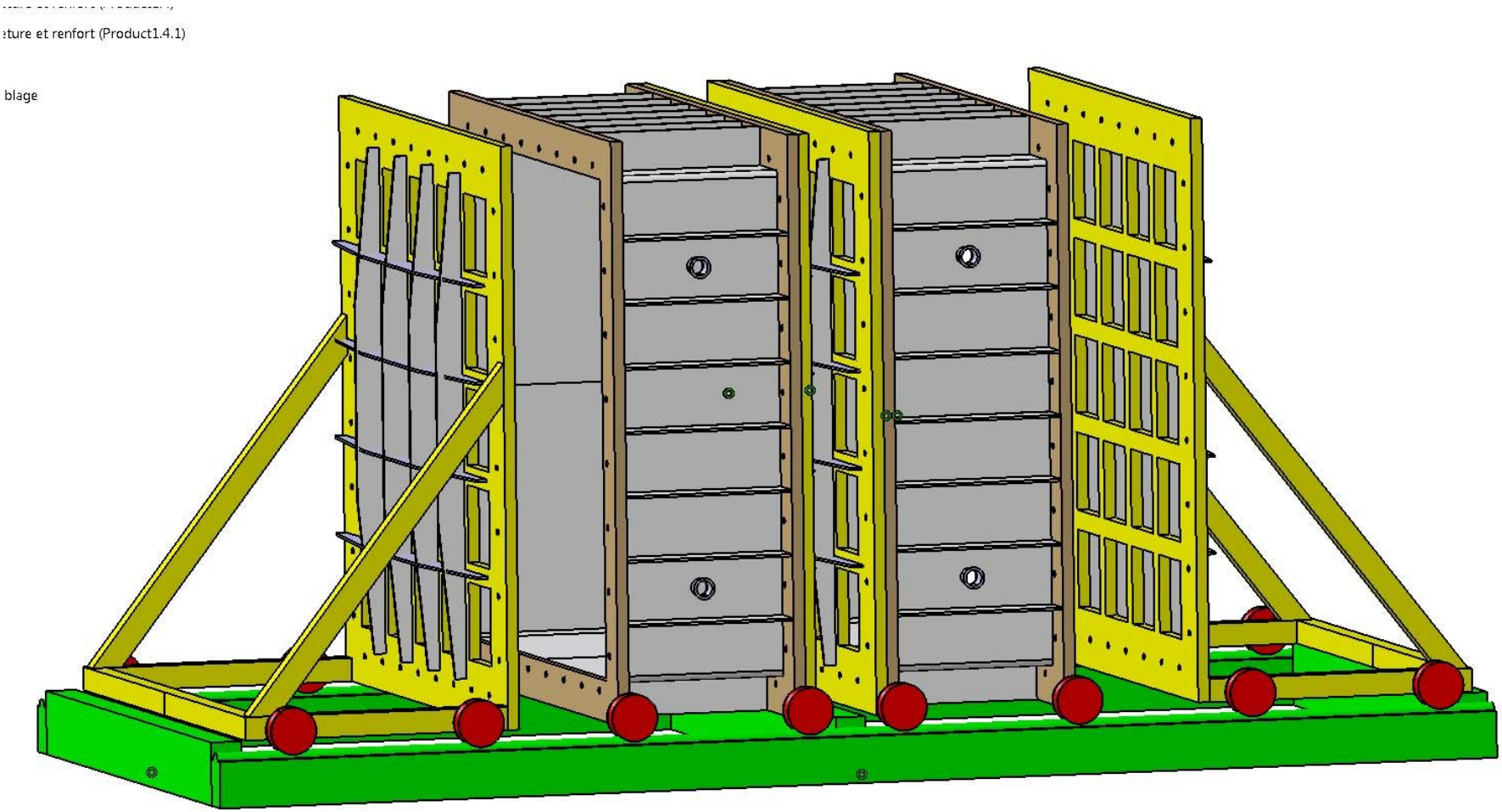
D. Santos (LPSC Grenoble)

New Ion Source for calibration (quenching) purposes (COMIMAC)



D. Santos (LPSC Grenoble)

MIMAC – 1m^3

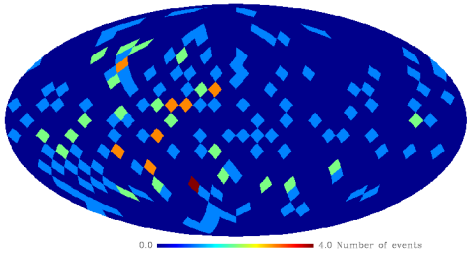


MIMAC : Dark Matter discovery/exclusion

J. Billard *et al.*, PLB 2010

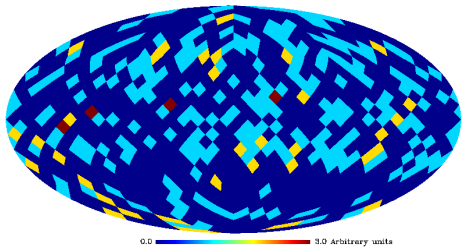
J. Billard *et al.*, PRD 2010

- ***discovery (5σ)***
  Up to 10^{-4} pb

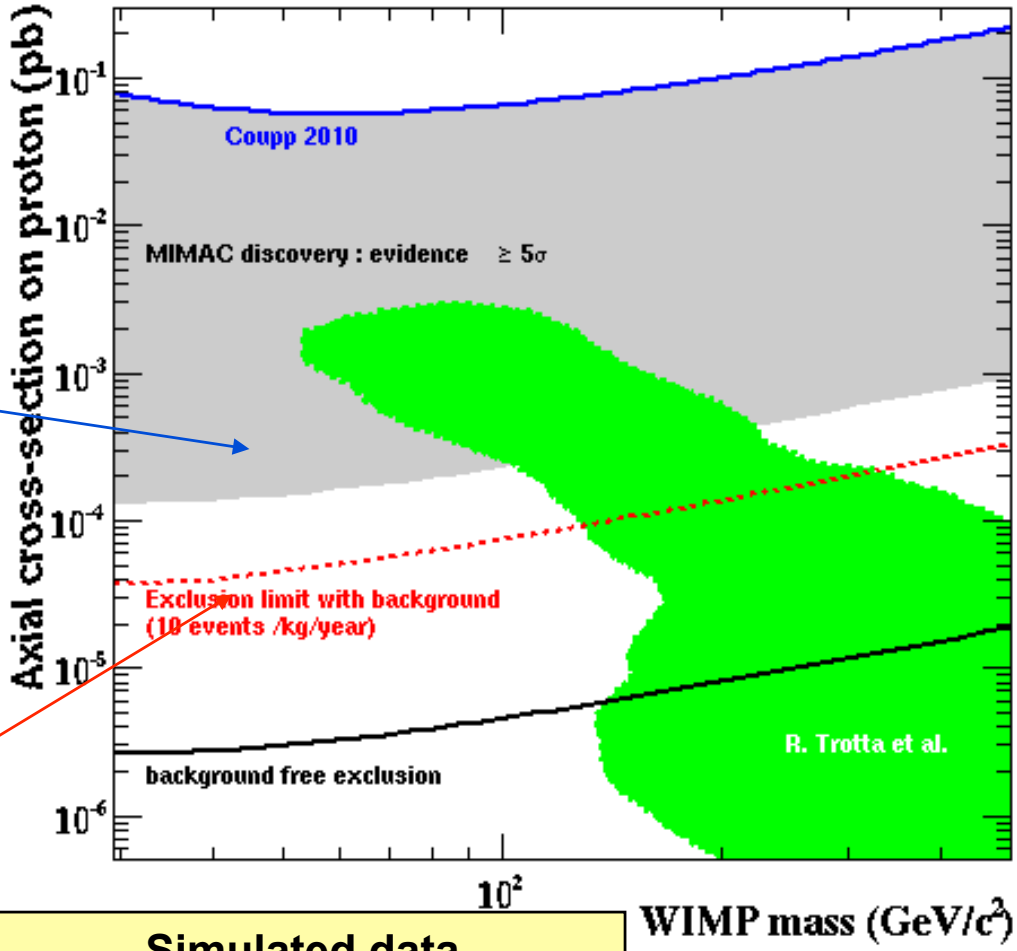


100 WIMP, 100 bkg

- **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°