

MIMAC

Micro-tpc MAtrix of Chambers

A Large TPC for directional non baryonic Dark Matter detection

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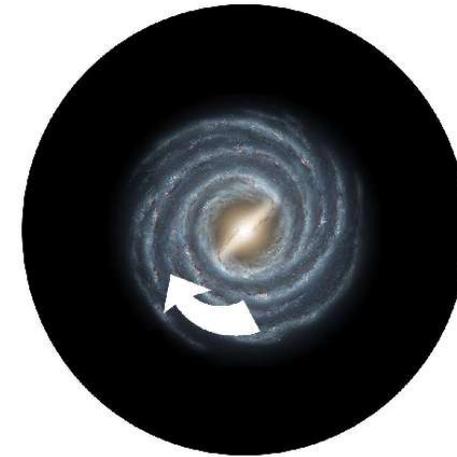
Directional Detection of Dark Matter

Direct detection requires high rejection factor against background, which need to be very precisely understood (radiopurity of materials, neutrons, ...)

Directional Detection

gives a clear and unambiguous signature for WIMP

The solar system rotates around the center of the Galaxy, through a halo of WIMPs, and towards the Cygnus constellation.

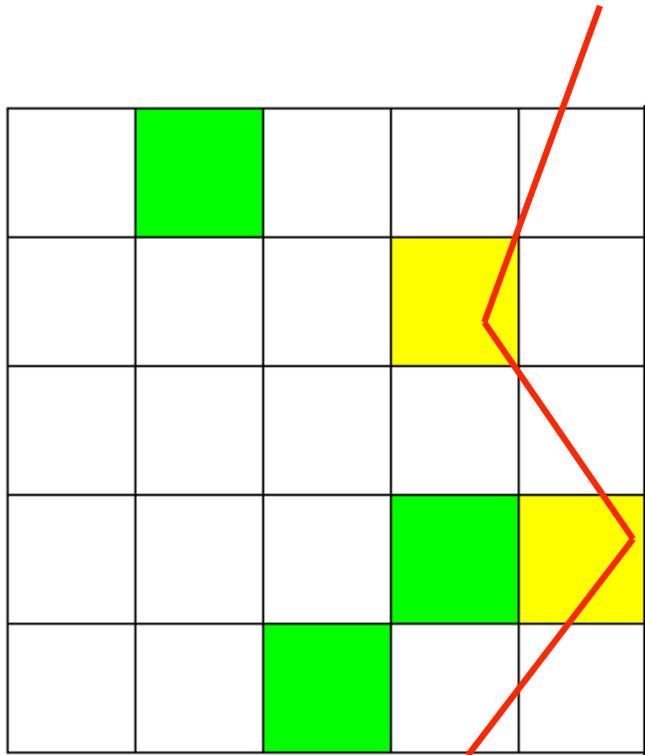


Background can not mimic such genuine events

Strategy:

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

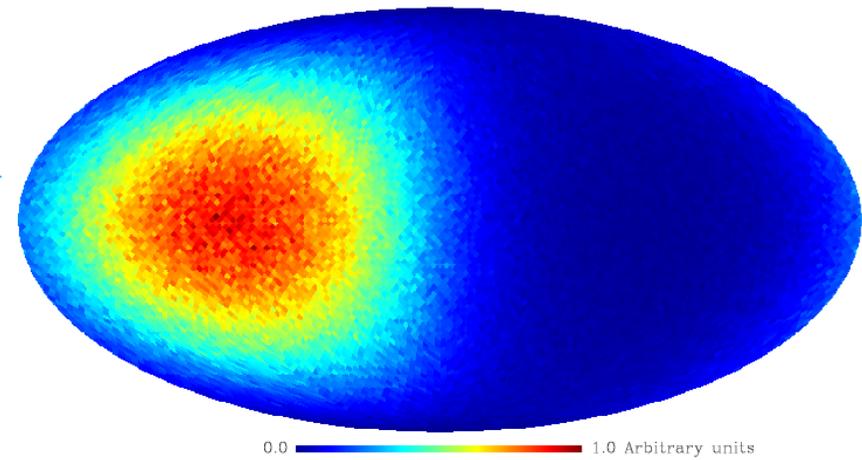
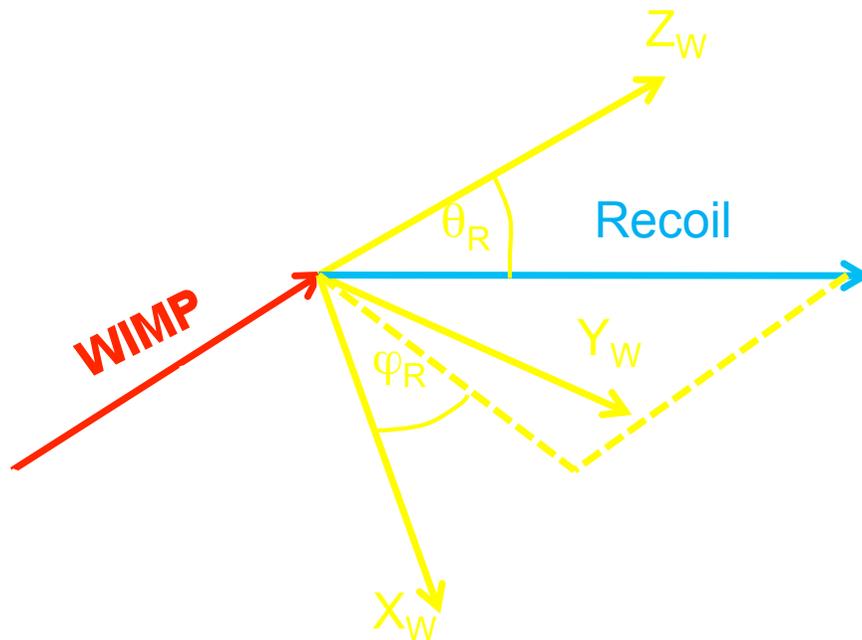
The MIMAC project



A multi-chamber detector

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

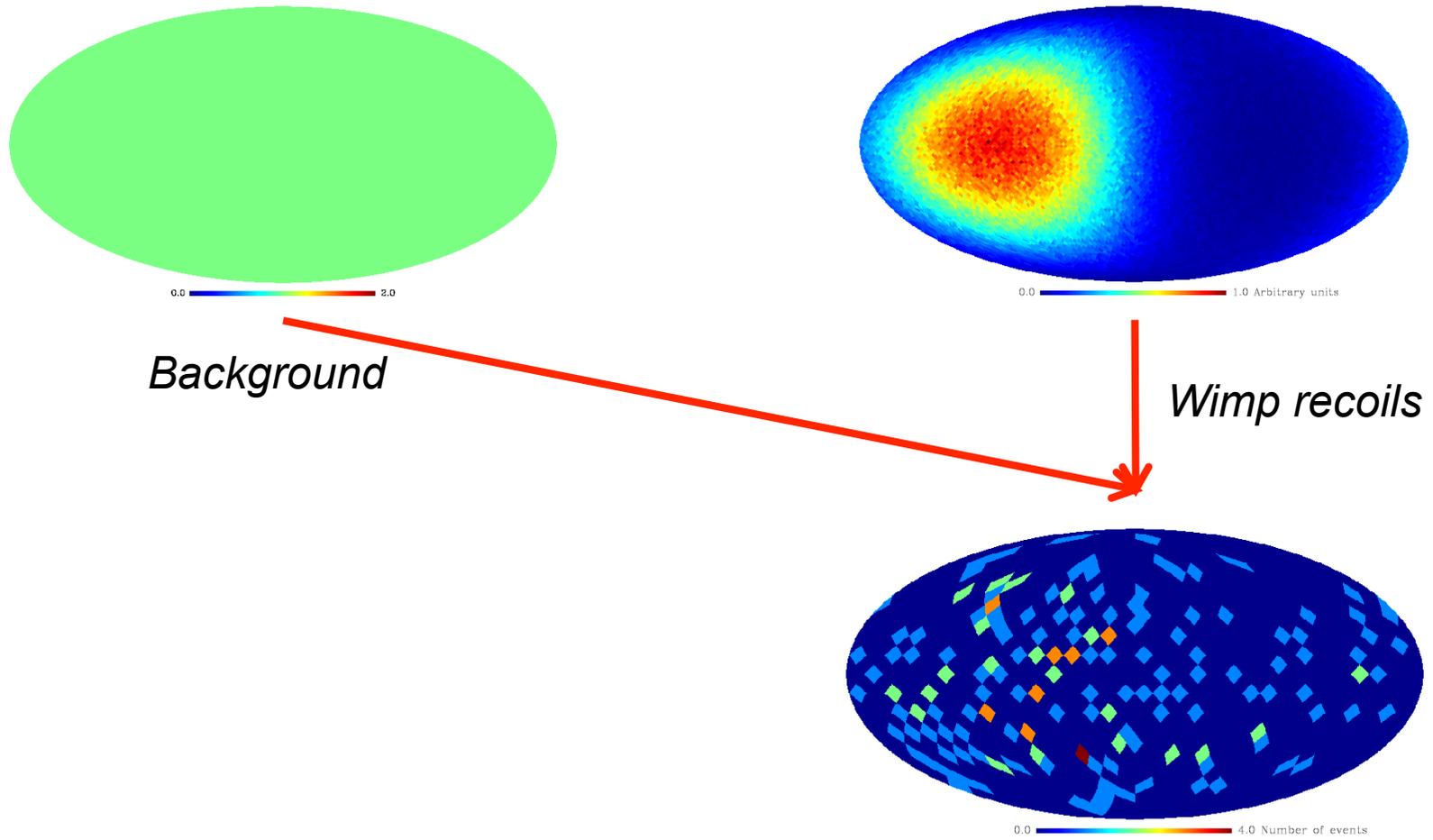


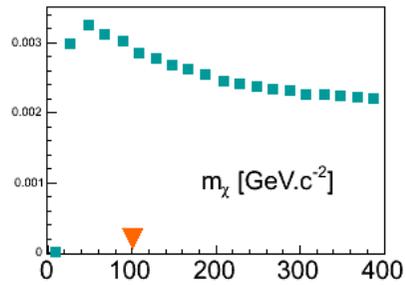


Map of recoils in galactic coordinates (HealPix)

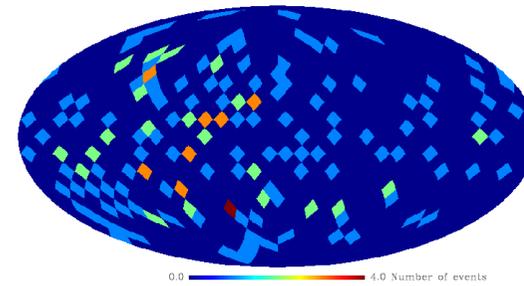
10^8 Events with $E_R = [5, 50]$ keV

Example of a MIMAC map measurement:
100 WIMP evts + 100 Background evts



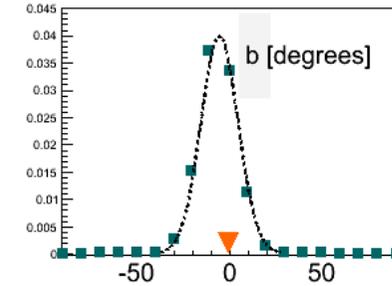
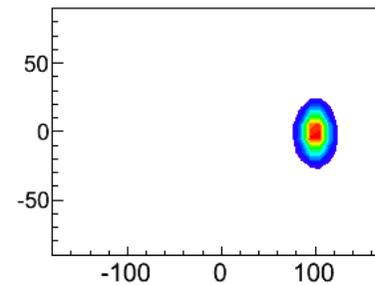
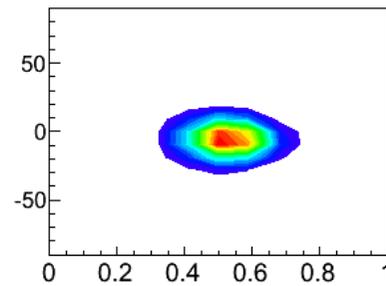
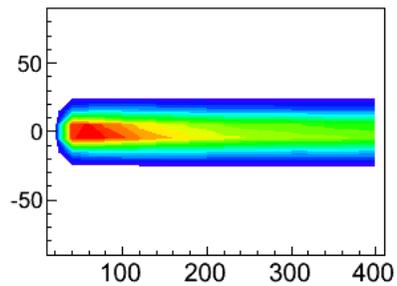
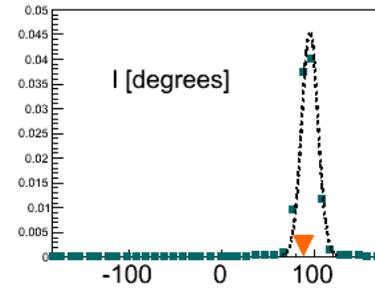
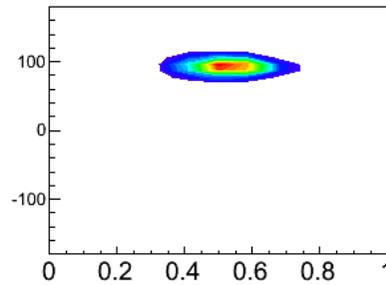
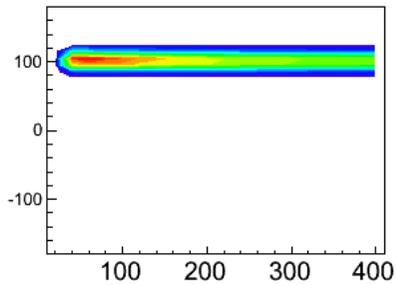
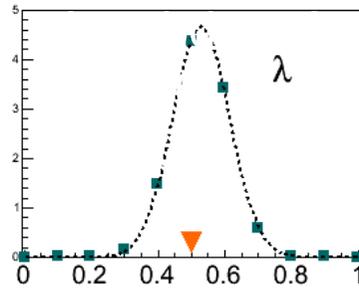
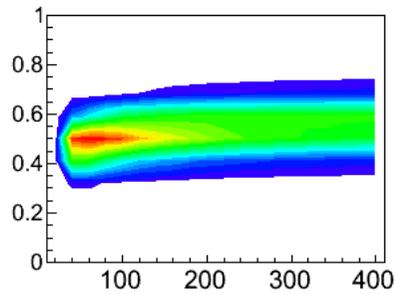


Input:



Likelihood analysis

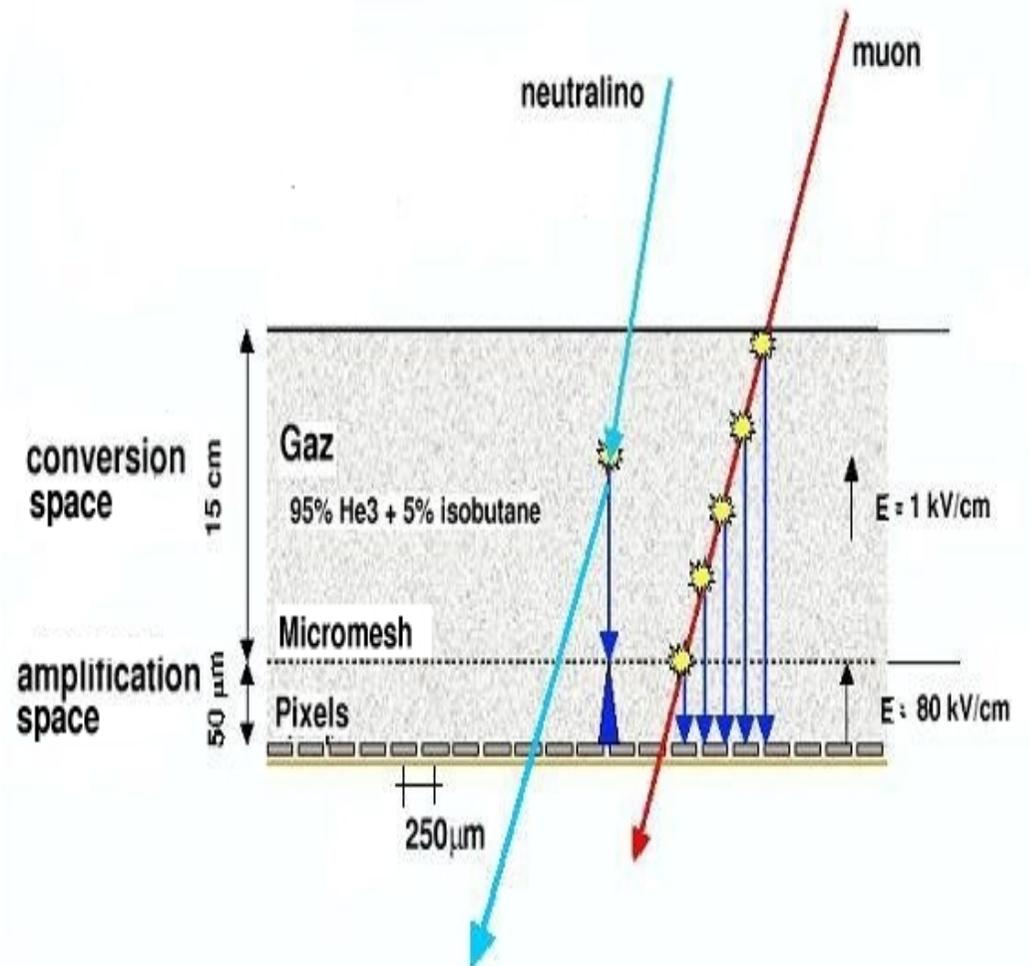
WIMP mass: $m_\chi > 10 \text{ GeV}\cdot\text{c}^{-2}$
 WIMP fraction: $\lambda = 0.53 \pm 0.085$ (1σ CL)
 Galactic latitude: $l = 95^\circ \pm 10^\circ$ (1σ CL)
 Galactic Longitude: $b = -6^\circ \pm 10^\circ$ (1σ CL)



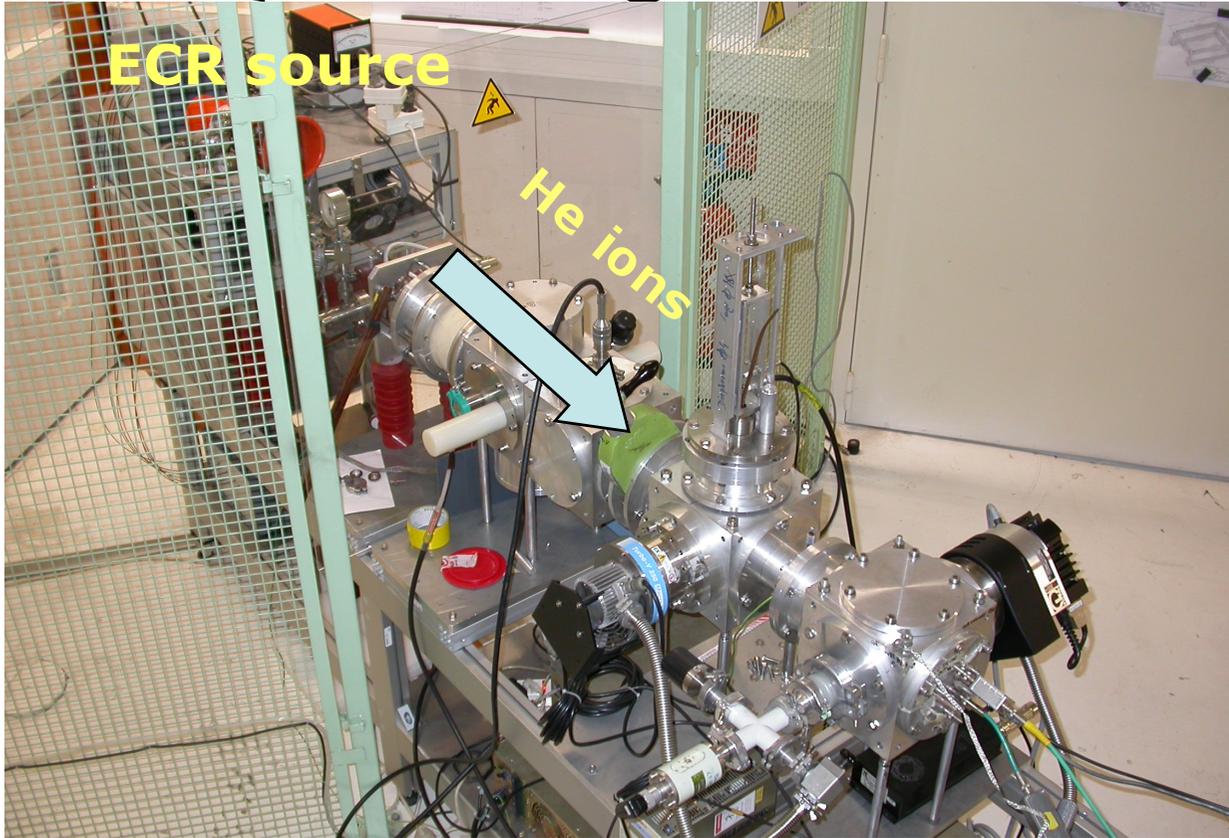
MIMAC: (Micro-tpc Matrix of Chambers)

{ spatial
temporal
energetic } resolution

- ⇒ recoil track
- ⇒ energy threshold $\sim 200\text{eV}$
- ⇒ electron/recoil discrimination



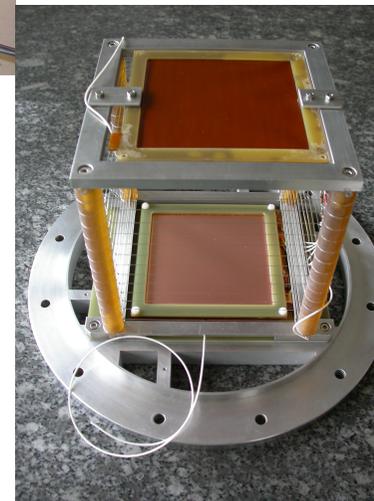
Quenching factor measurement



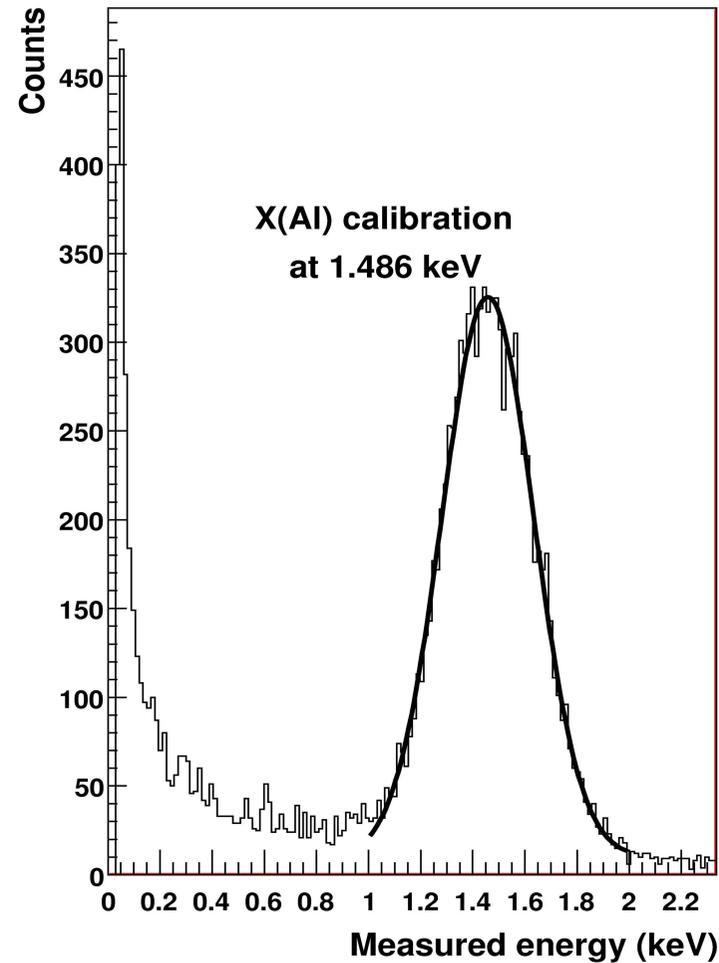
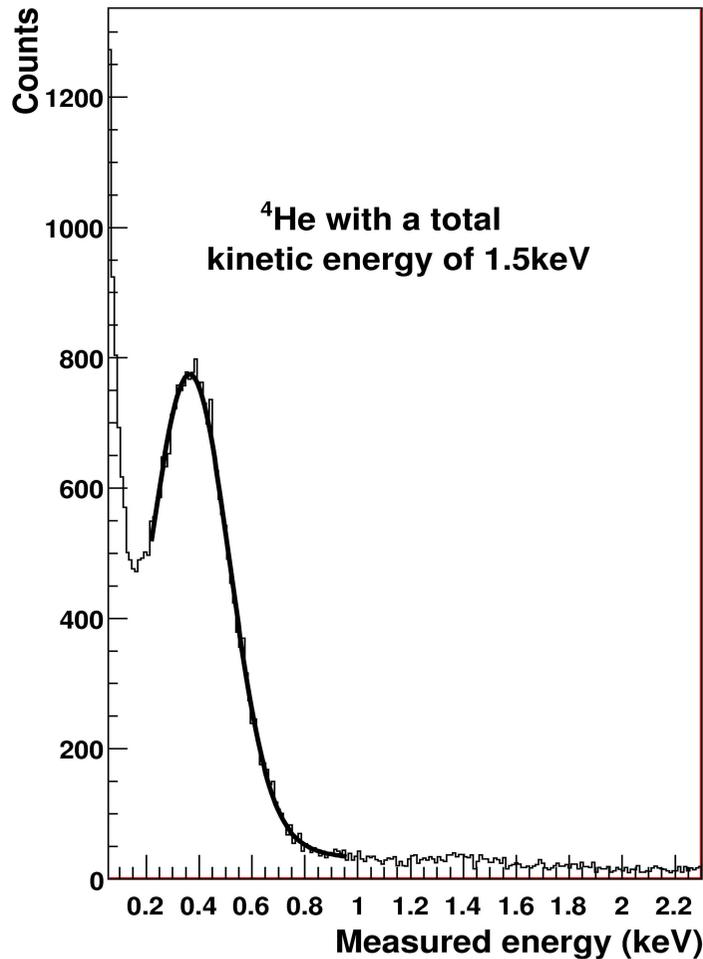
- **Low energy ion source**
1 to 50 keV
- **Developped @LPSC**



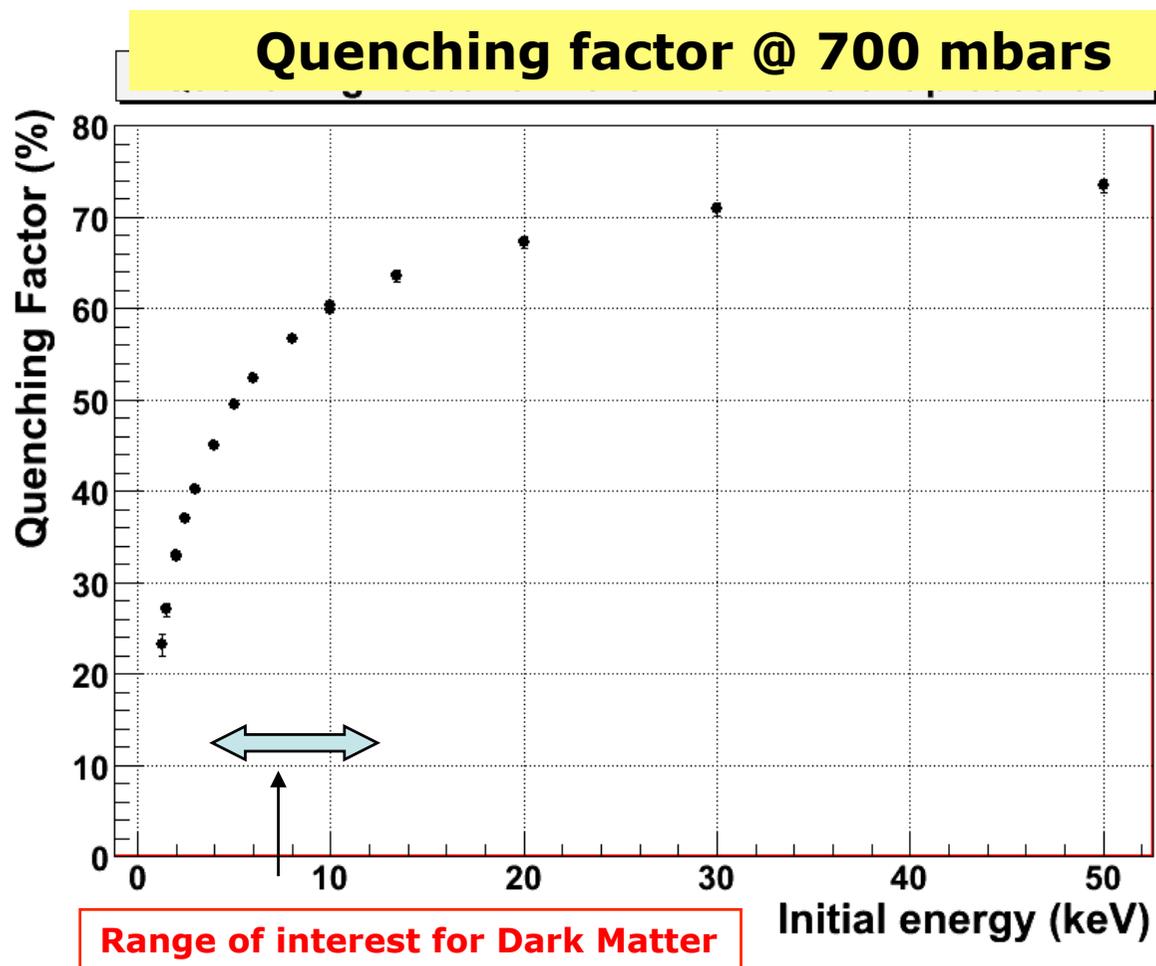
Micromegas μ TPC



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



QF measurement !!

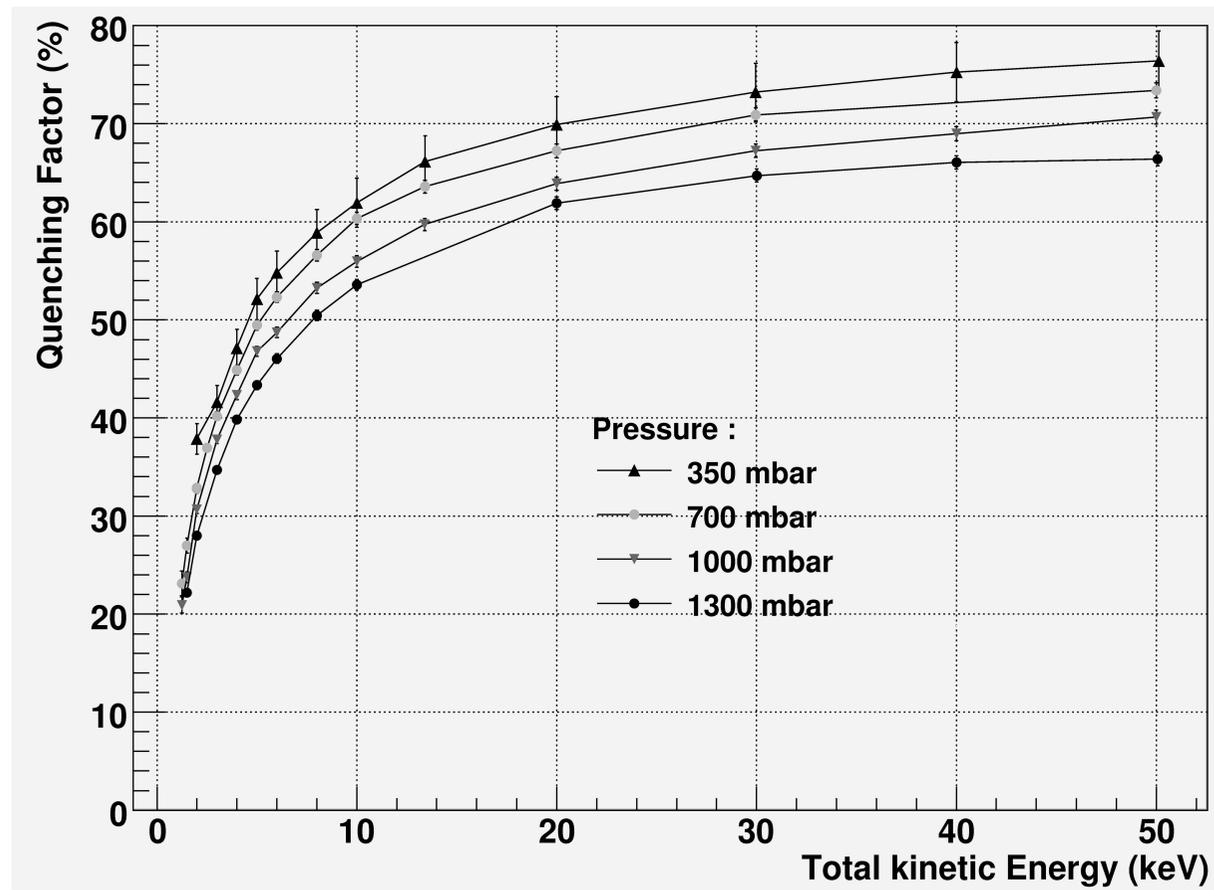


Measurement of ${}^4\text{He}$
in 95% ${}^4\text{He}$ + 5% C_4H_{10}

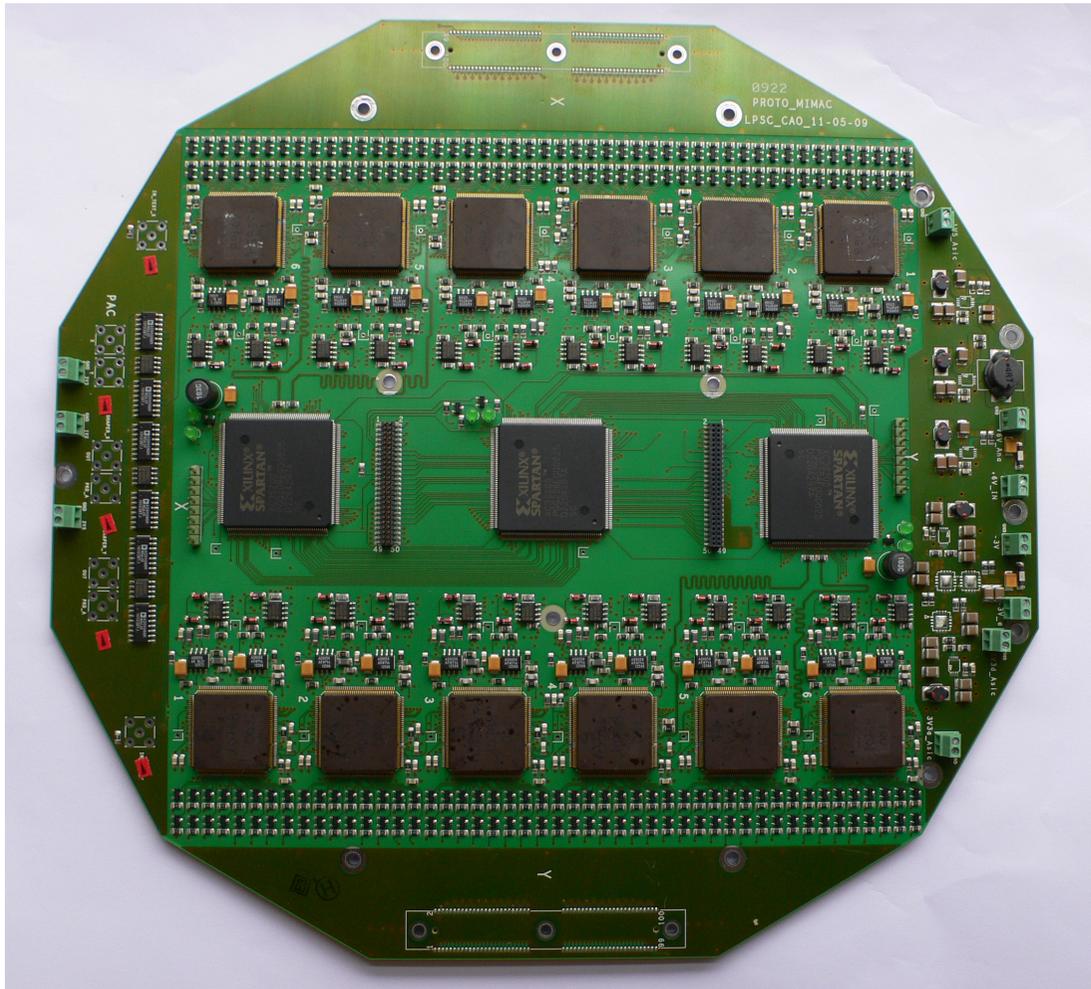
- Threshold : 300 eV (ioni.) or 1 keV (recoil)
- The response of this ${}^4\text{He}$ detector is fully understood from 1 to 50 keV
- Dark Matter range : covered

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

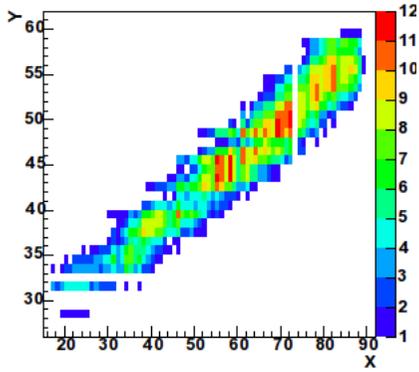


MIMAC chips integrated in the electronics of the prototype

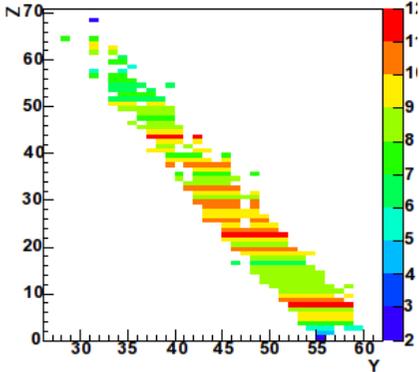
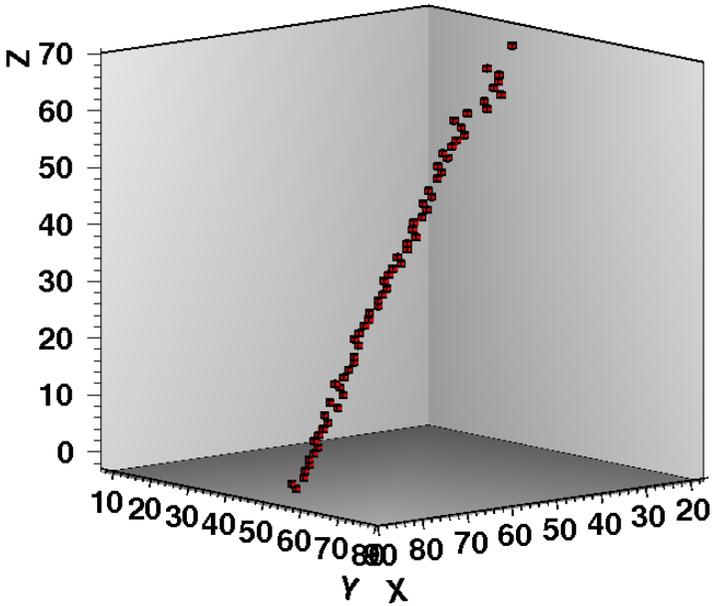
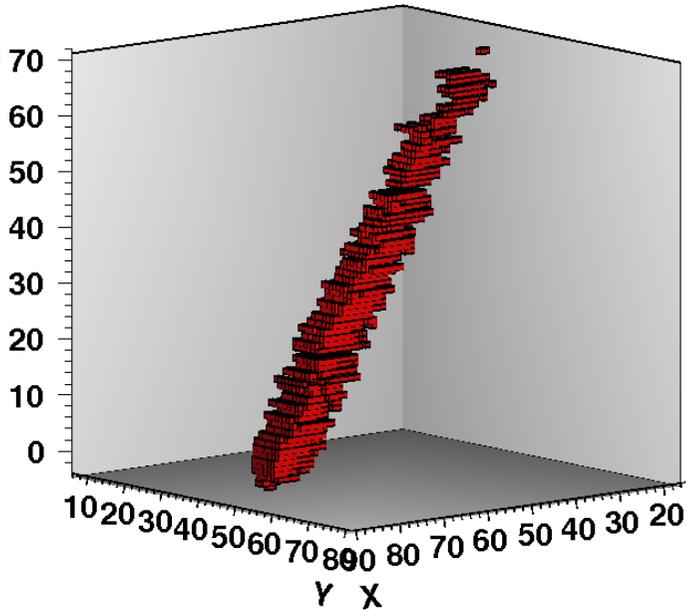
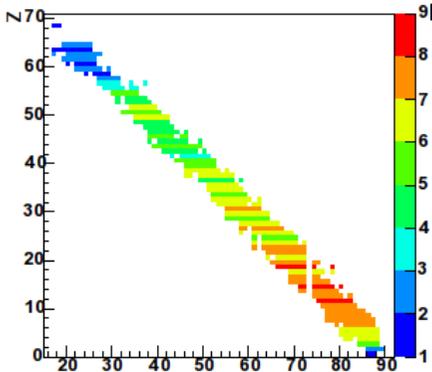


96+96=192 channels
Covering 3x3 cm²
Autotriggered
Reading it every 25ns

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



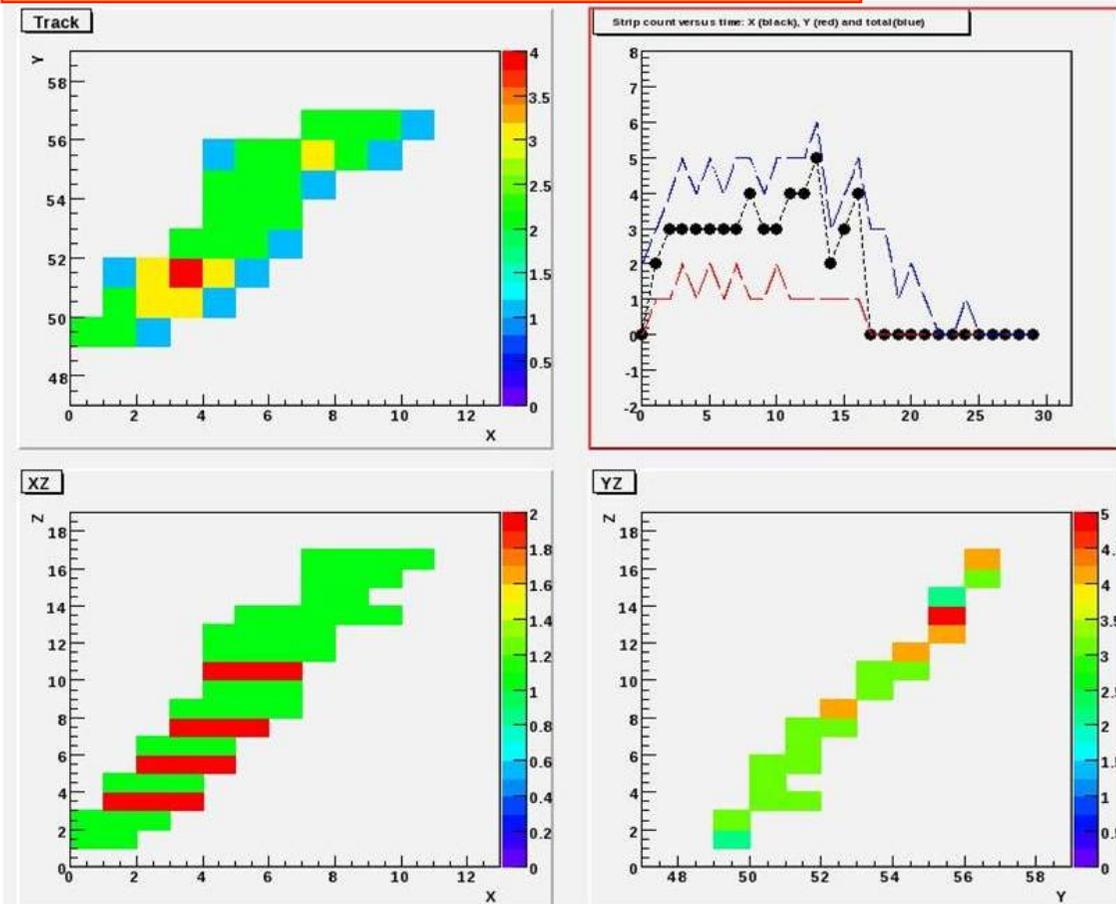
He + 5% $i\text{C}_4\text{H}_{10}$
350 mbar,
150 V/cm



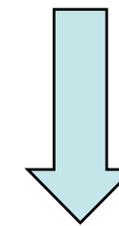
What about the low energies?

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

MIMAC Event display



With the
3D reconstruction



$E=200$ V/cm
 $P=350$ mbar
 $v = 16$ $\mu\text{m/ns}$

Track 45

$\phi = 41.6$ deg

$\Theta = 39.2$ deg

$L = 8$ mm

First 3D track of ~ 6 keV electron !!

MIMAC : recoil track measurements

April 2009

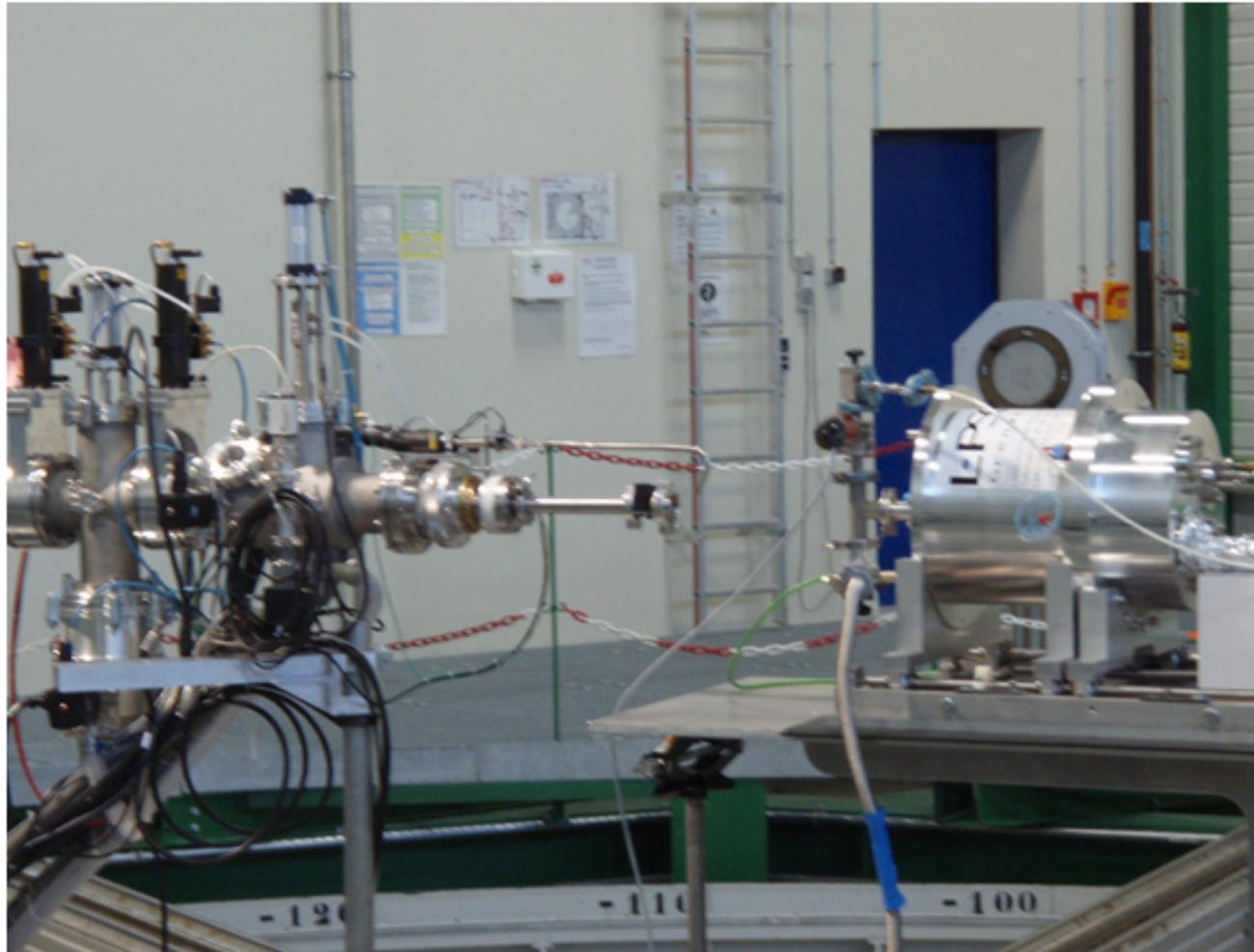
@ IRSN Cadarache



Amande facility :

- Neutron field with energies down to a few keV

MIMAC prototype at Cadarache (detecting neutrons by nuclear recoil)



Recoils from 144 keV neutrons

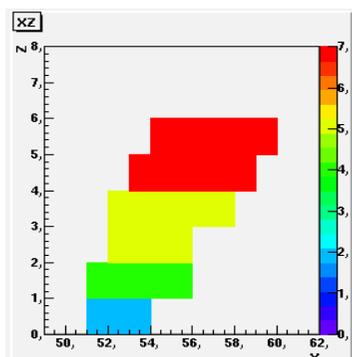
Pure isobutane

100 mbar

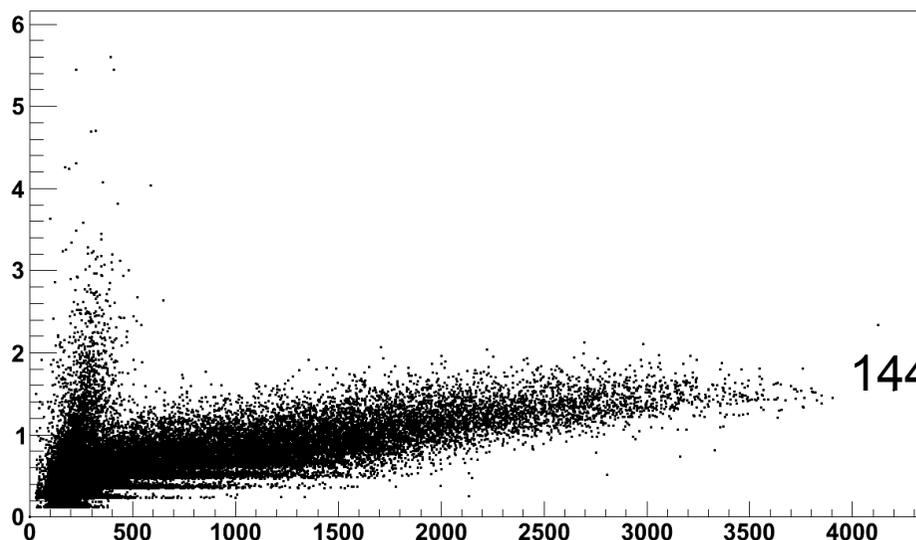
150 V/cm

Amande facility @ IRSN Cadarache

-> Neutron field with energies down to a few keV



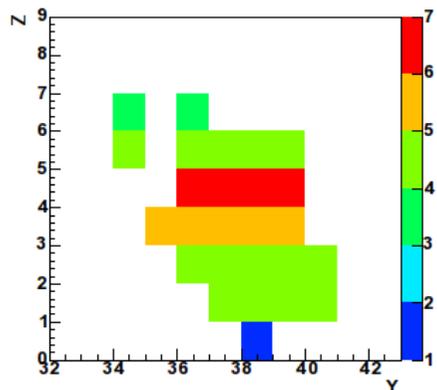
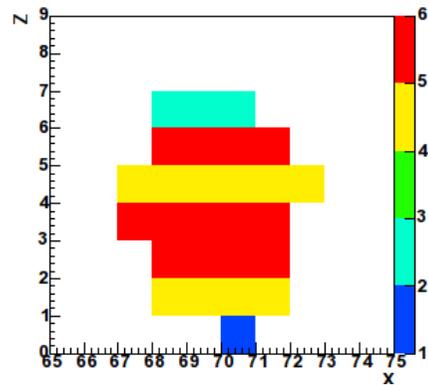
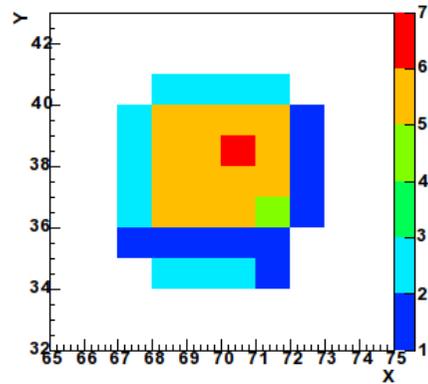
Length (cm)



Energy (ADC)

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

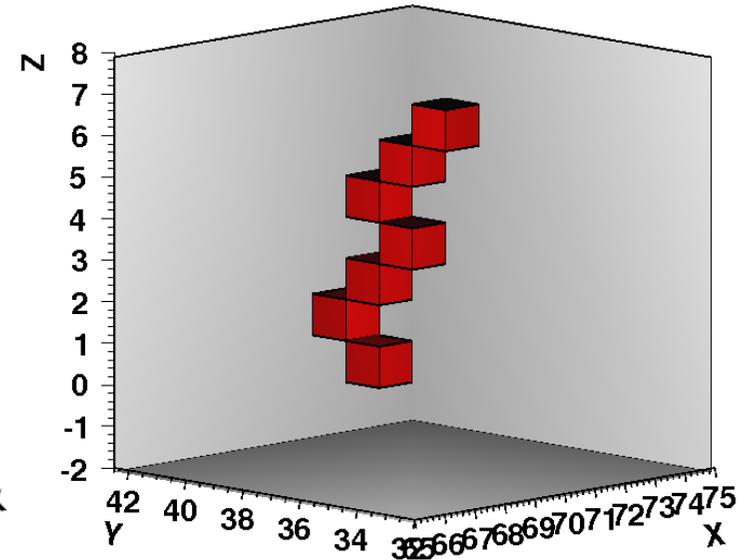
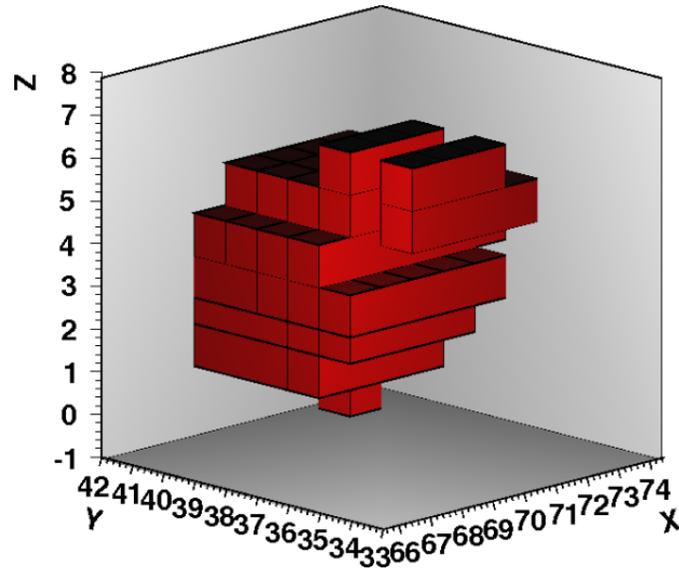
3D Track: proton 8 keV in He + 5% iC₄H₁₀



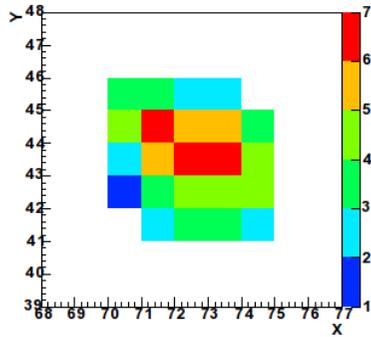
He + 5% iC₄H₁₀

350 mbar,

150 V/cm



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

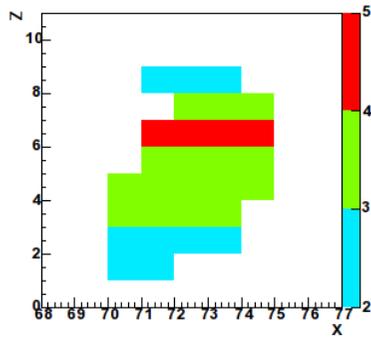


X-Y (anode)

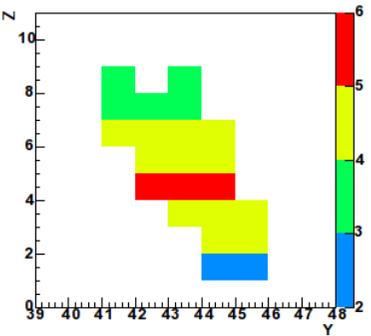
70 % CF_4 + 30% CHF_3

55 mbar,
170 V/cm

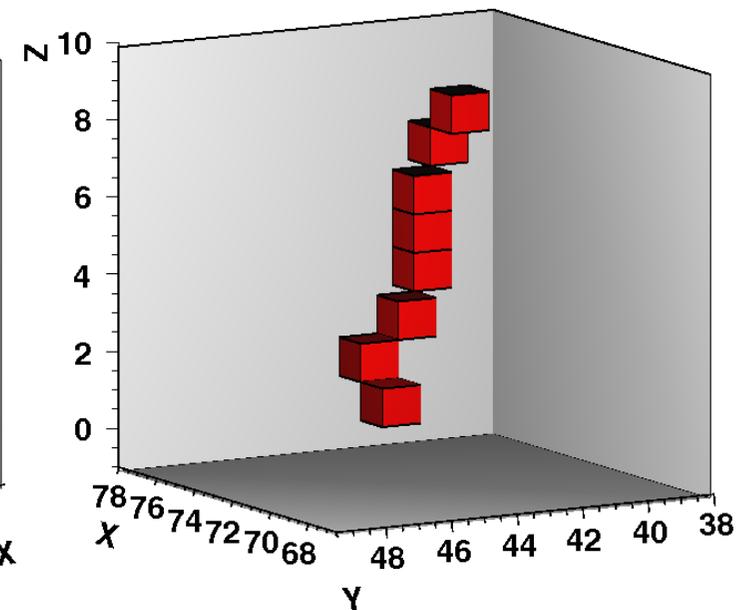
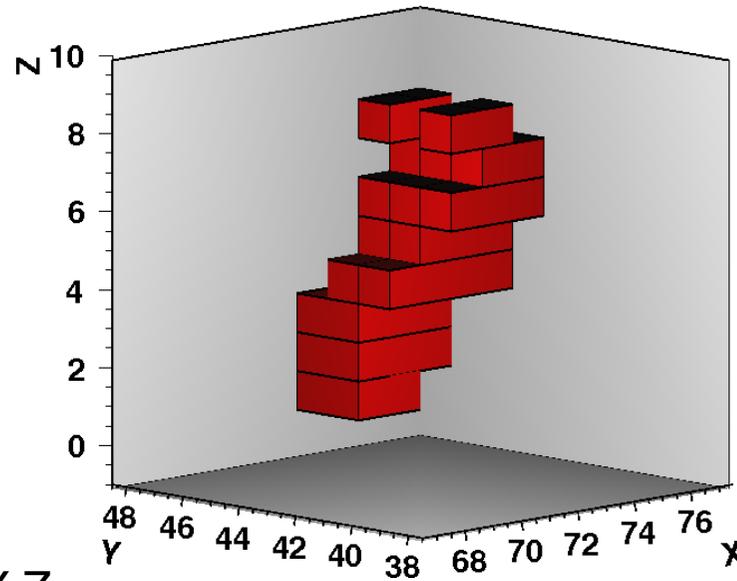
~40 keV (ionization), ~3 mm



X-Z



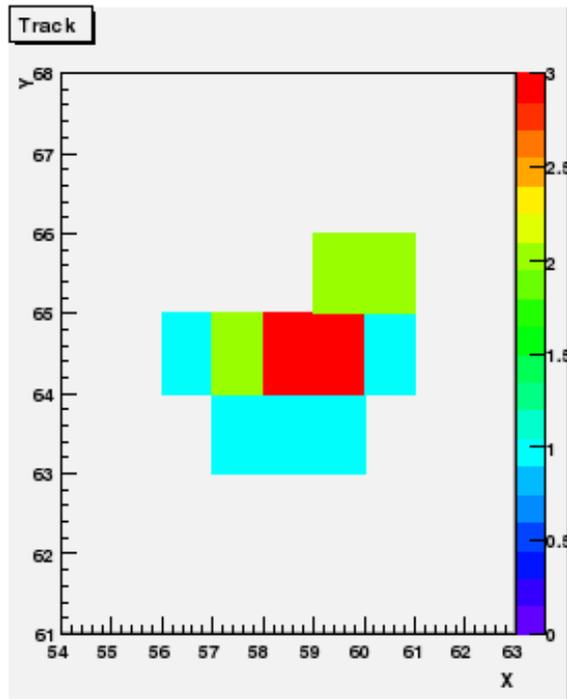
Y-Z



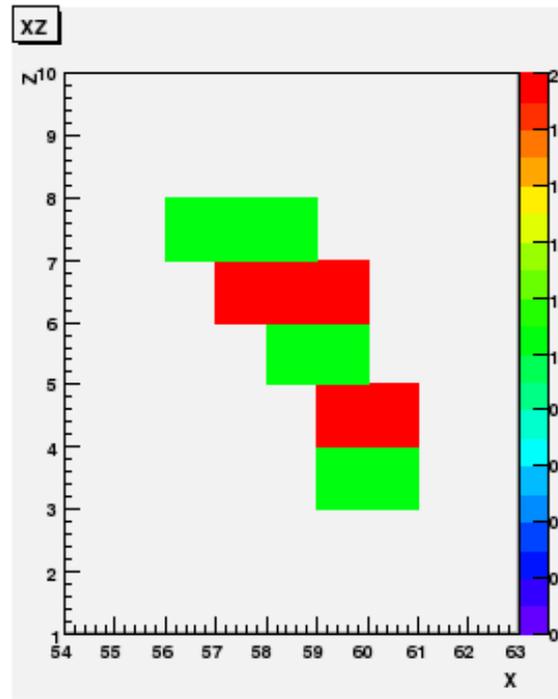
6 keV recoil track (^4He) projections

300 mbar (95% of ^4He , 5% of C_4H_{10})

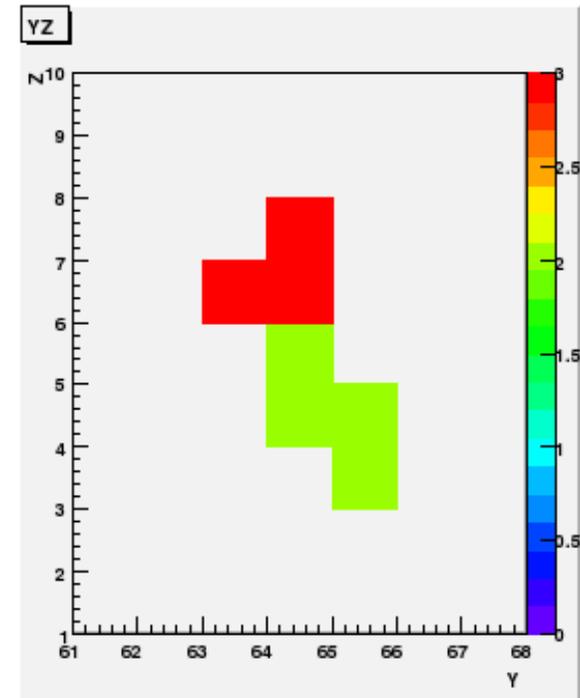
X-Y

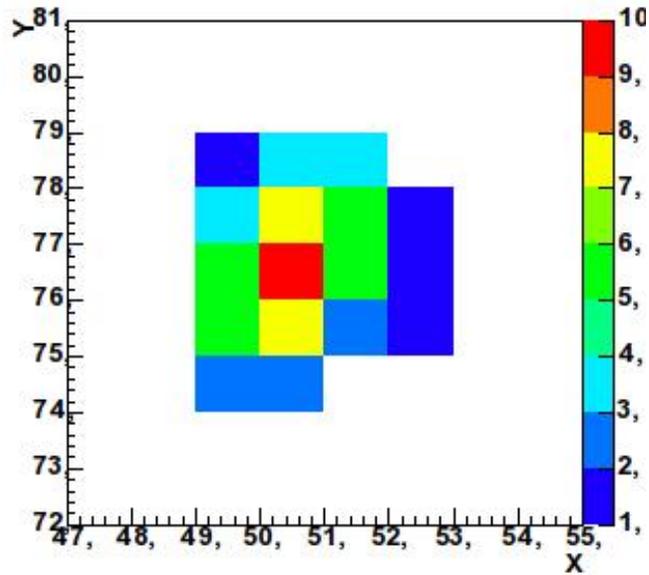
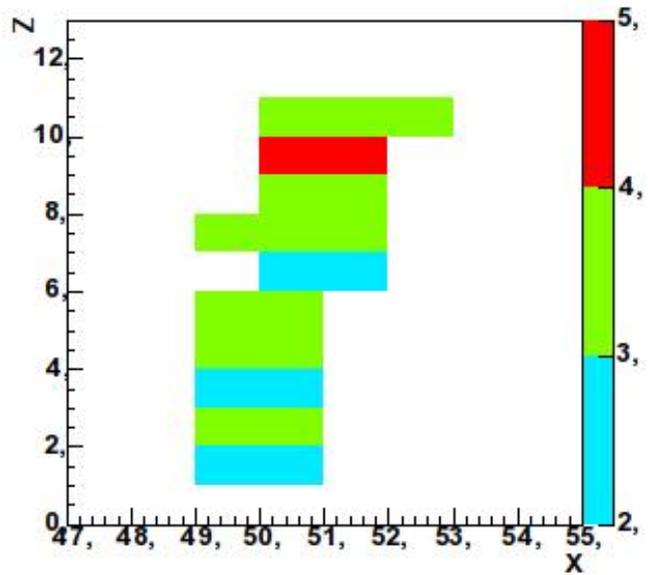


X-Z

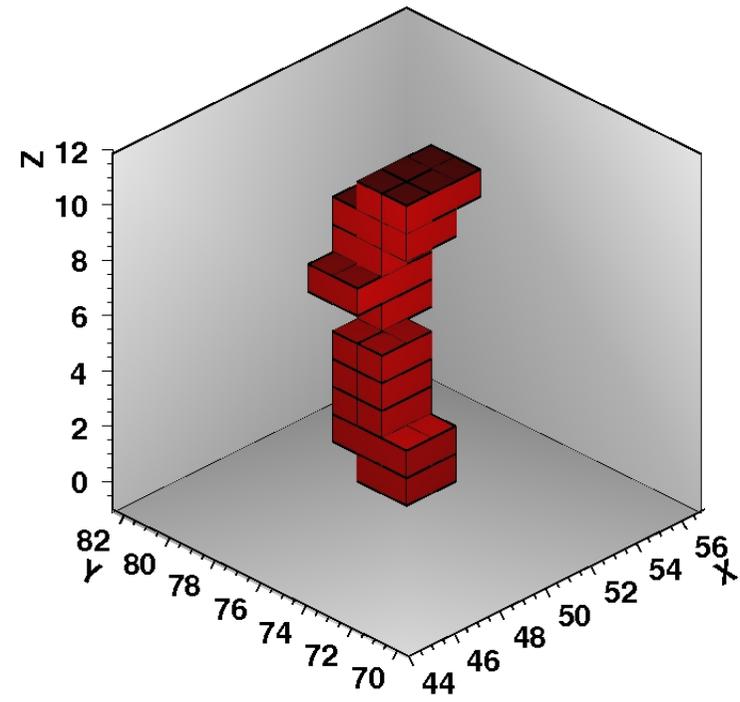
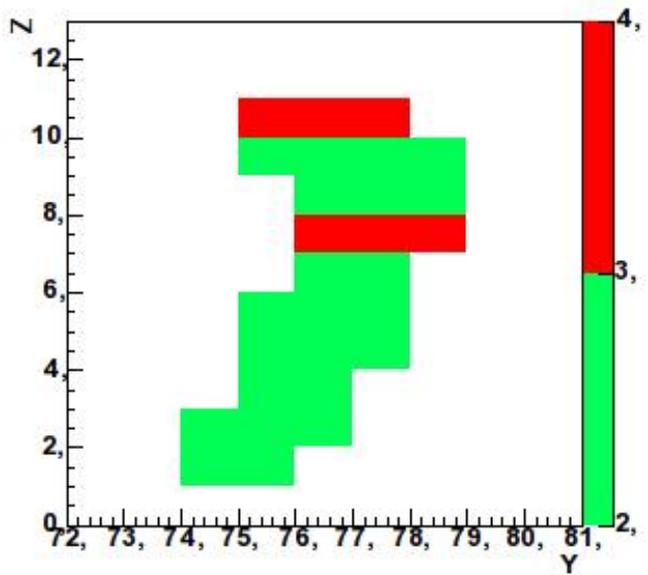


Y-Z

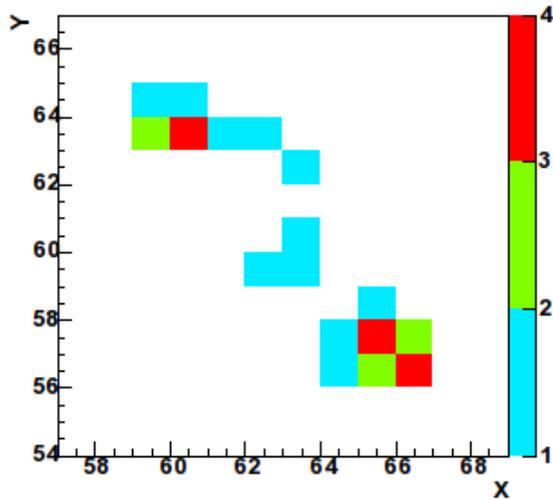




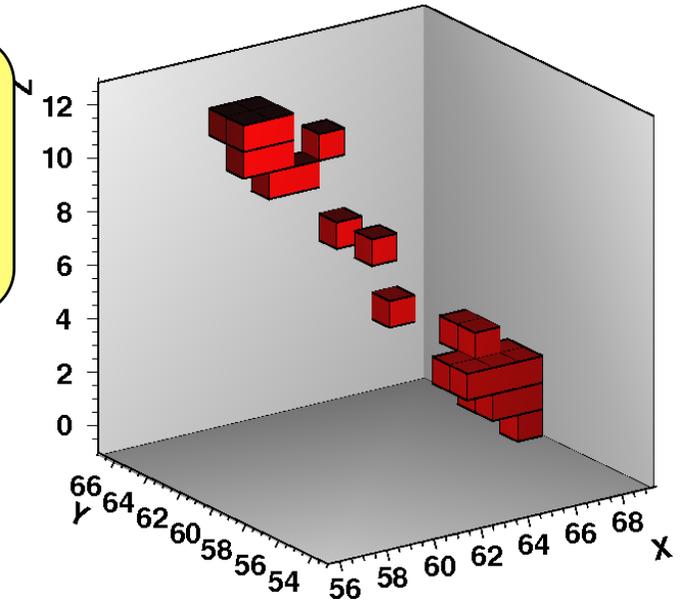
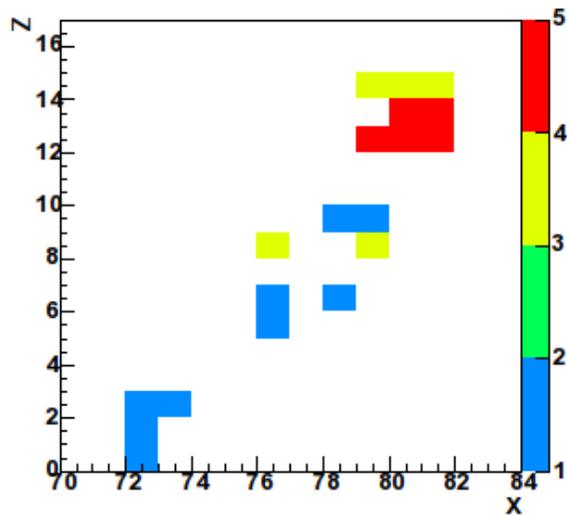
Recoil of ^{19}F
 ($E_{\text{ion}} \sim 40 \text{ keV}$)
 in 50 mbar of
 $\text{CF}_4 + \text{CHF}_3$ (30%)



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

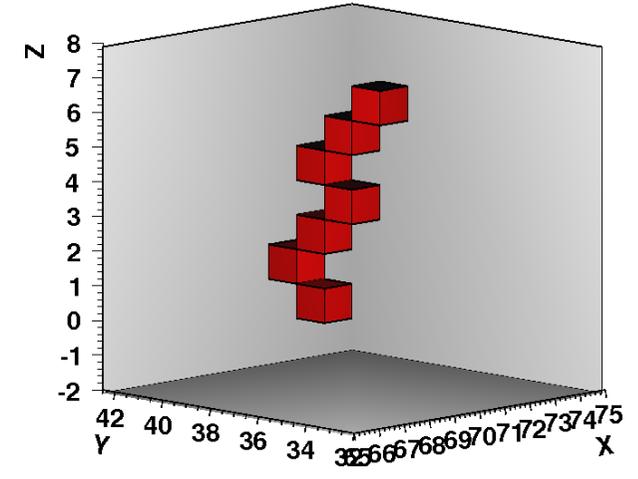
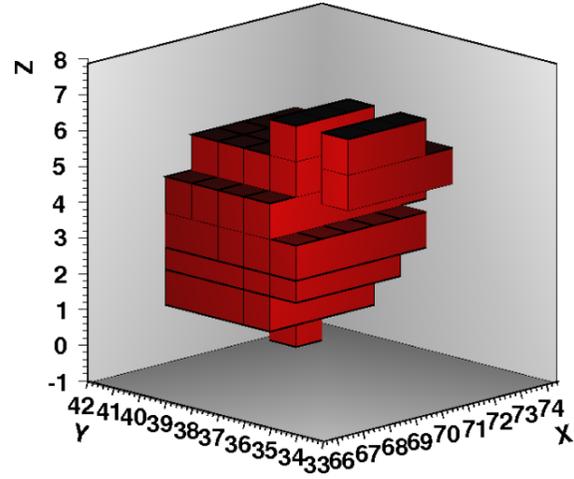
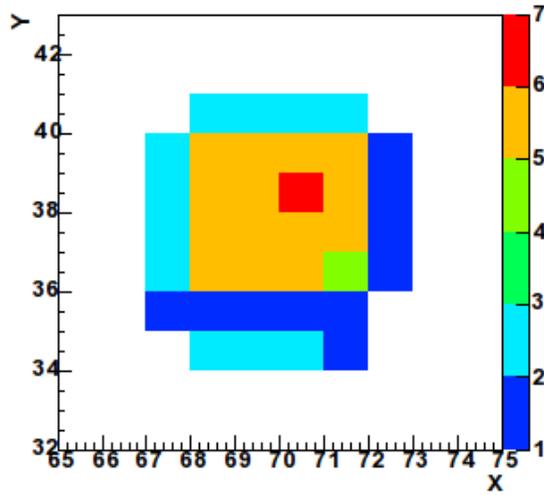


He + 5% $i\text{C}_4\text{H}_{10}$
350 mbar,
150 V/cm

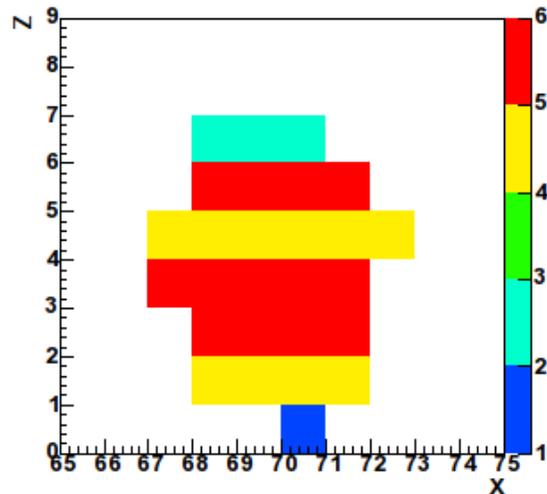


**Typical
background in
DM detection**

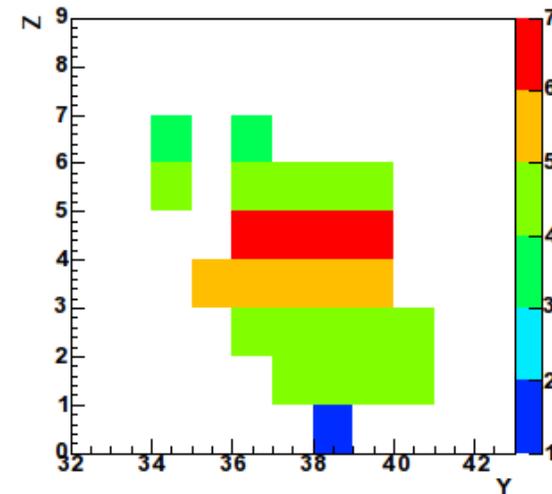
Proton recoil in He + isobutane



8 keV recoil



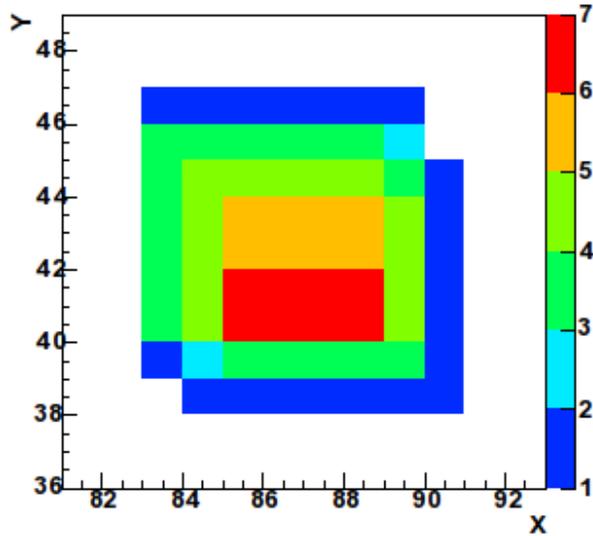
He + 5% iC_4H_{10}
350 mbar,
150 V/cm



100% iC_4H_{10}

50 mbar,

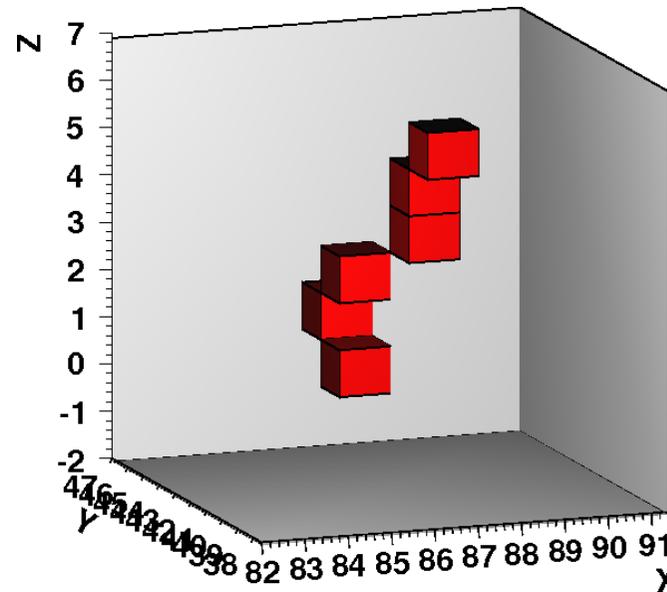
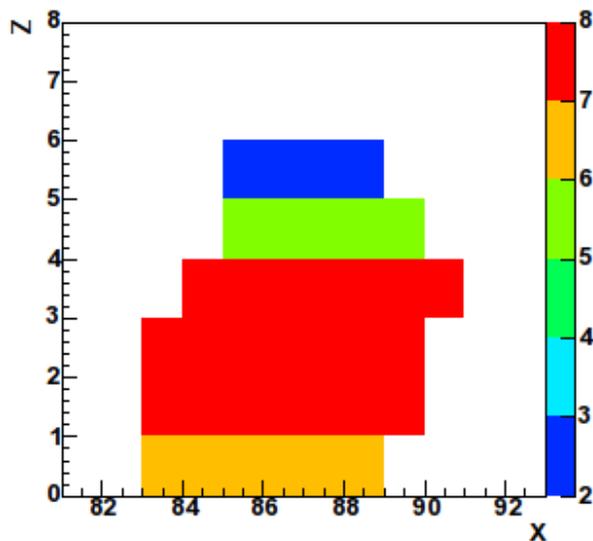
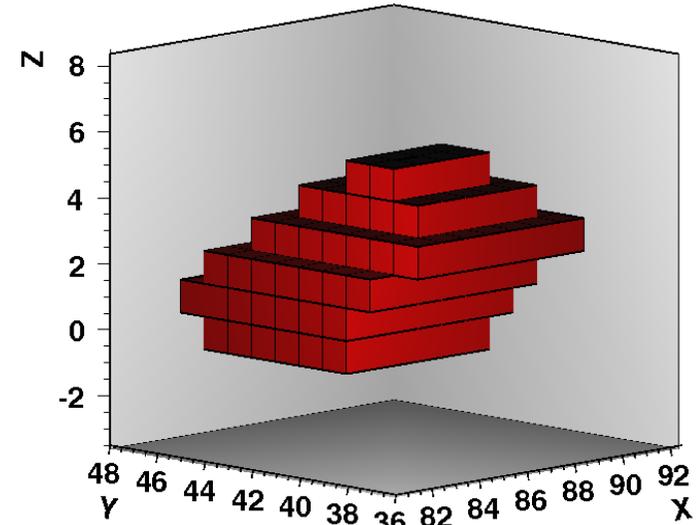
Proton recoil in isobutane



3D reconstruction



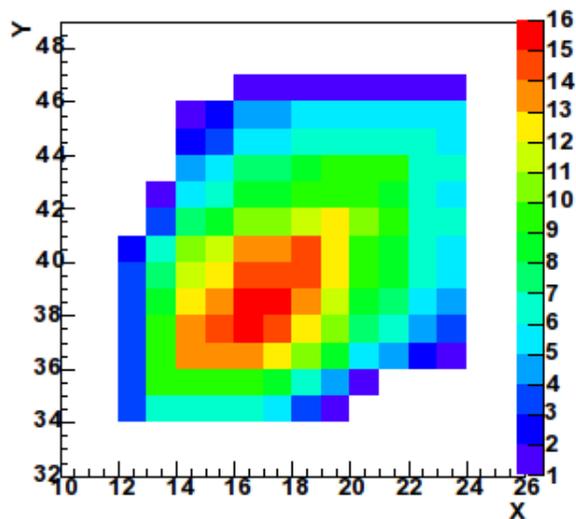
30 keV



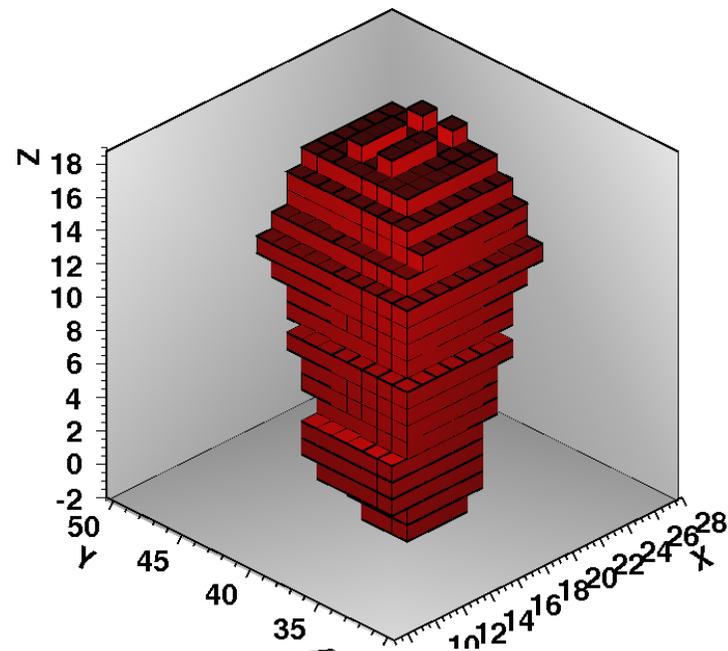
100% iC_4H_{10}

50 mbar,

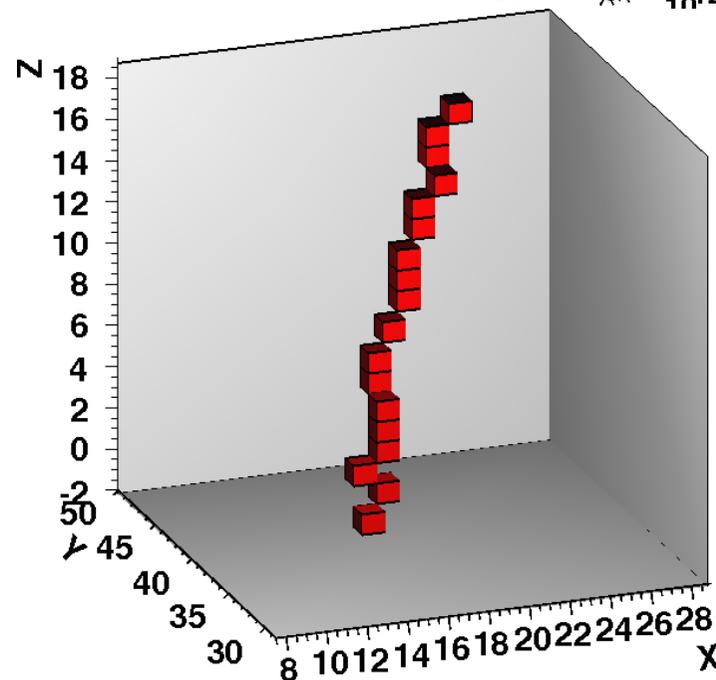
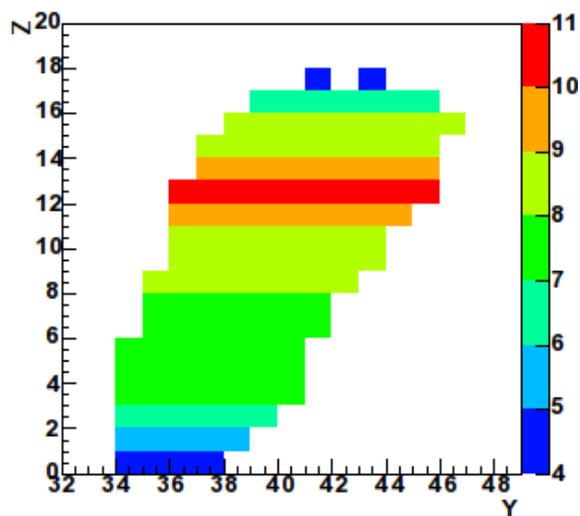
Proton recoil in isobutane



3D reconstruction

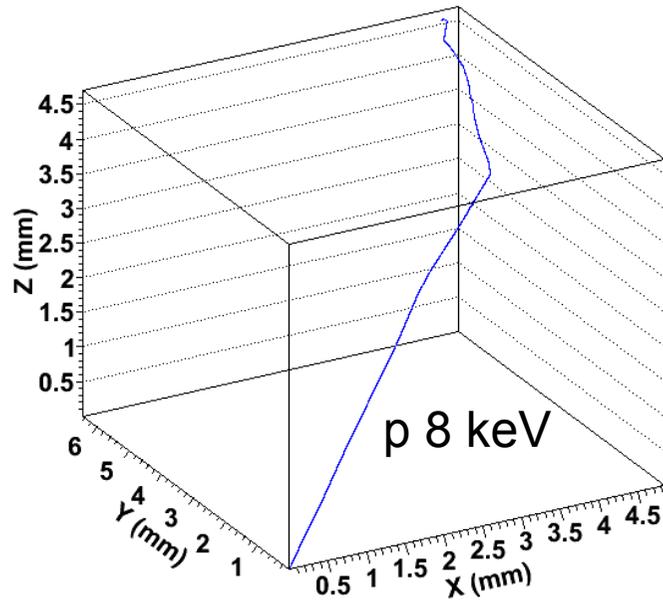


180 keV recoil

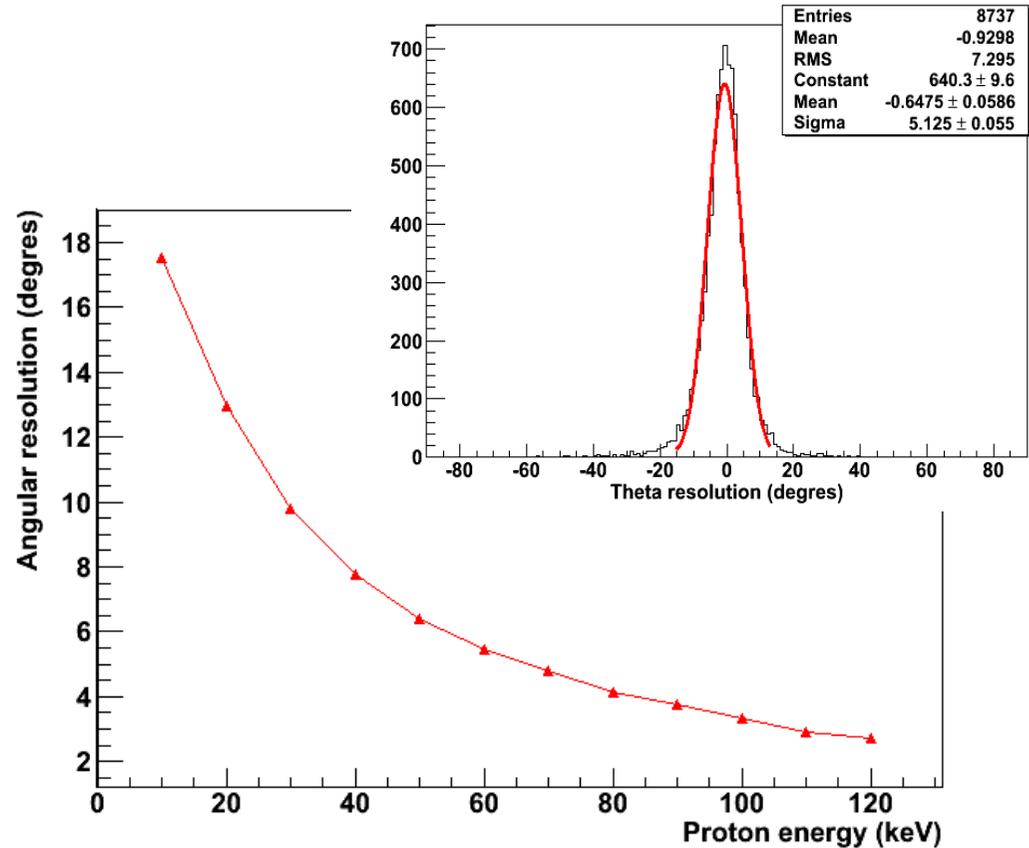


3D Tracks: Reconstruction & simulation

SRIM + Magboltz (electron diffusion) + detector response simulation (DAQ ...)



He + 5% iC₄H₁₀
100 mbar,
60 V/cm

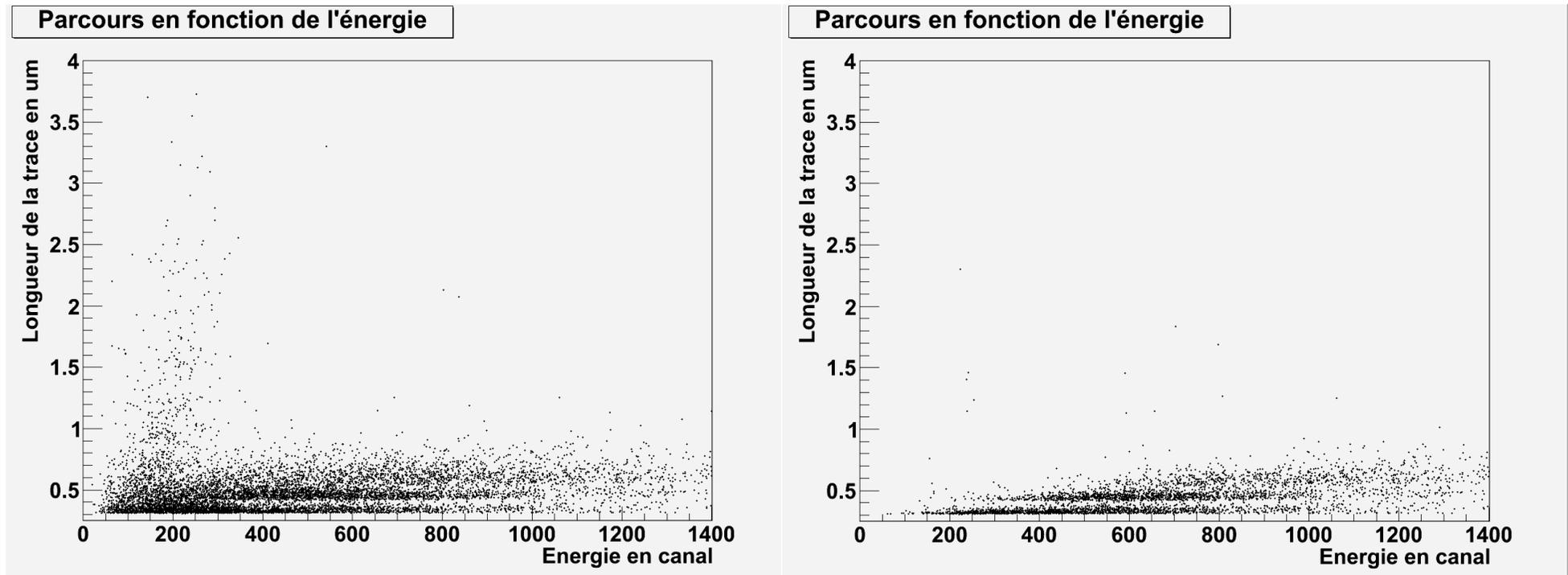


C. Grignon et al, 2010

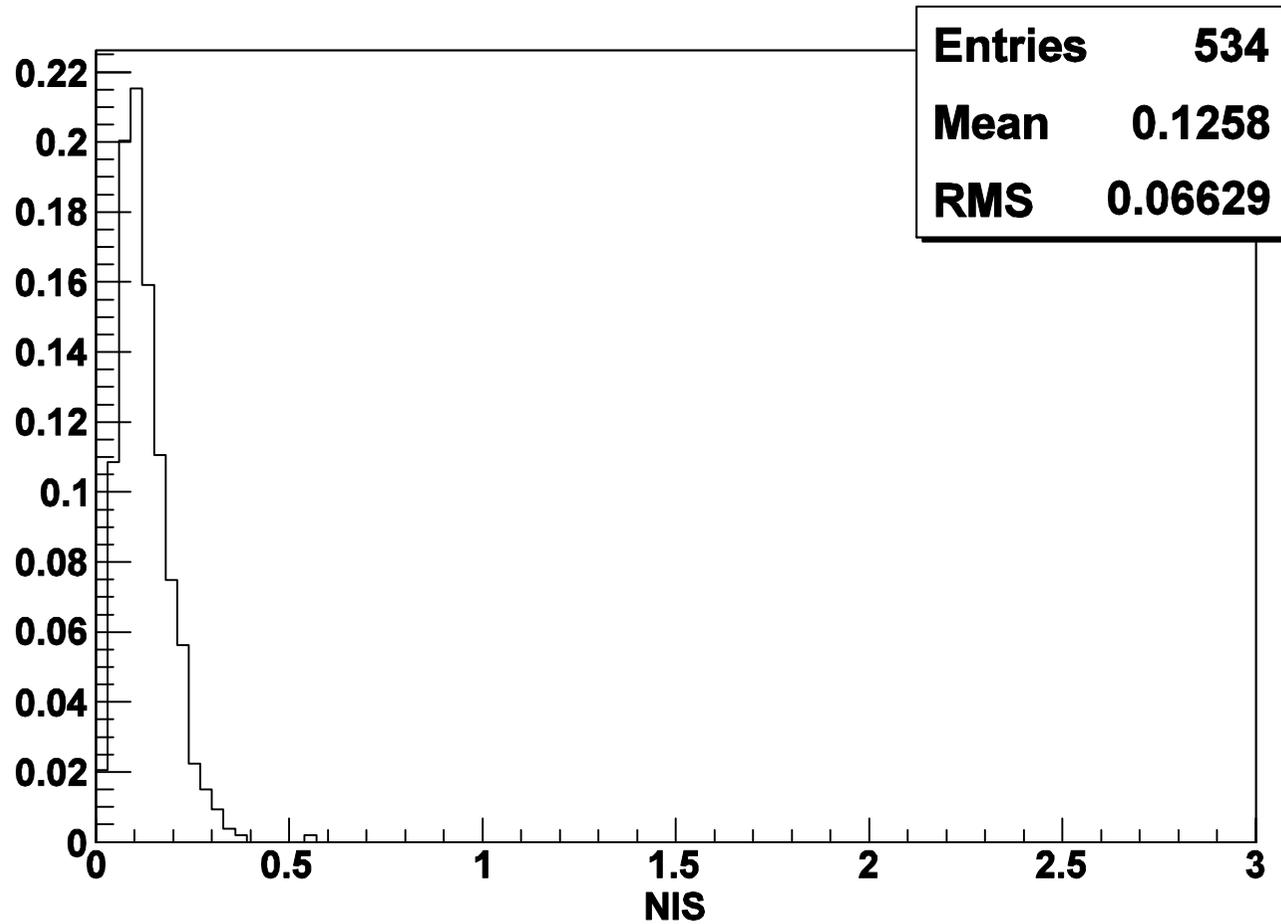
New degree of freedom to discriminate recoils from electrons from 3D tracks

Normalized Integrated Stragglng (NIS)

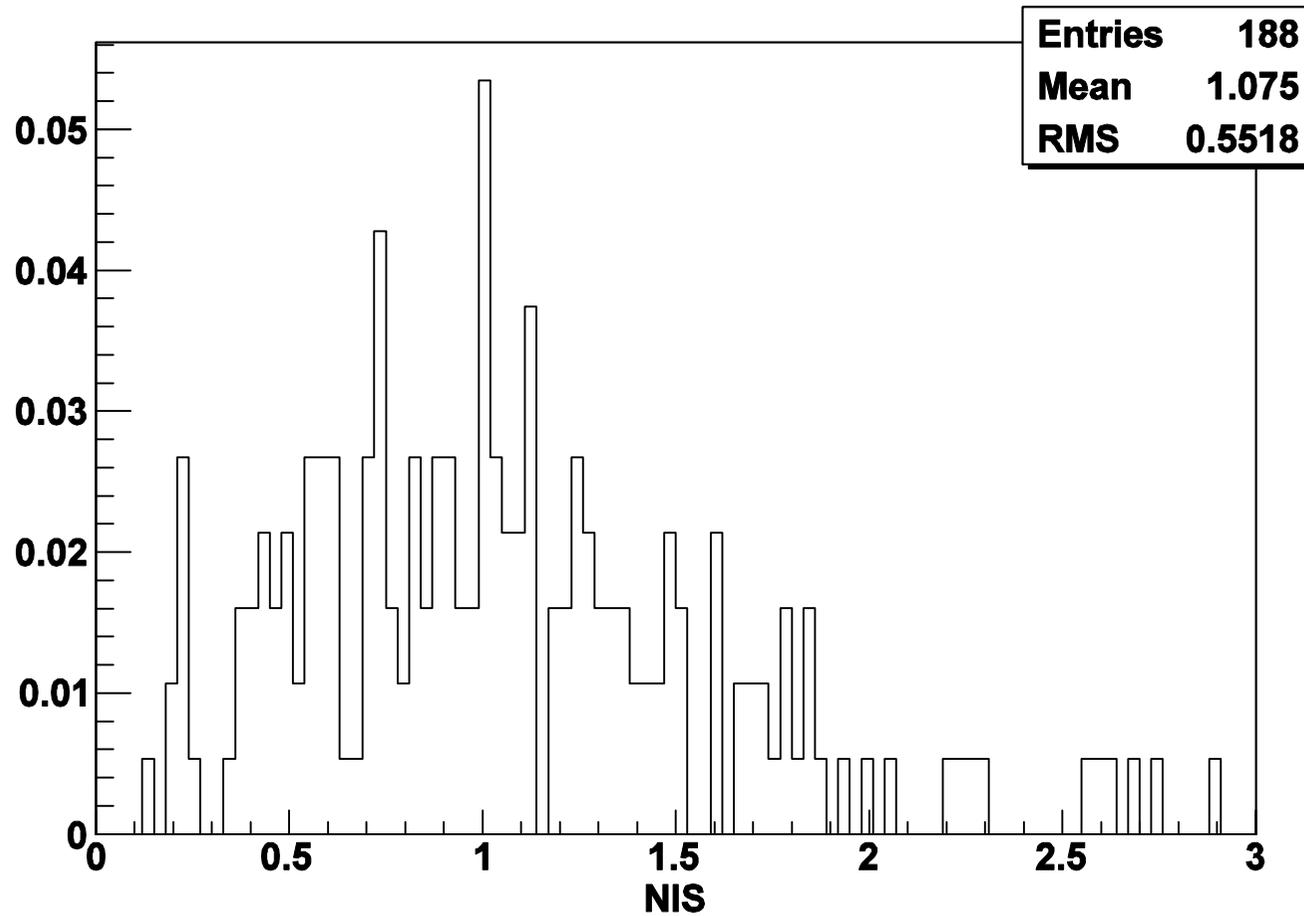
(Sum of partial deflections along the measured track, normalized by its total energy)
(J. Billard et al. (2010) in preparation)

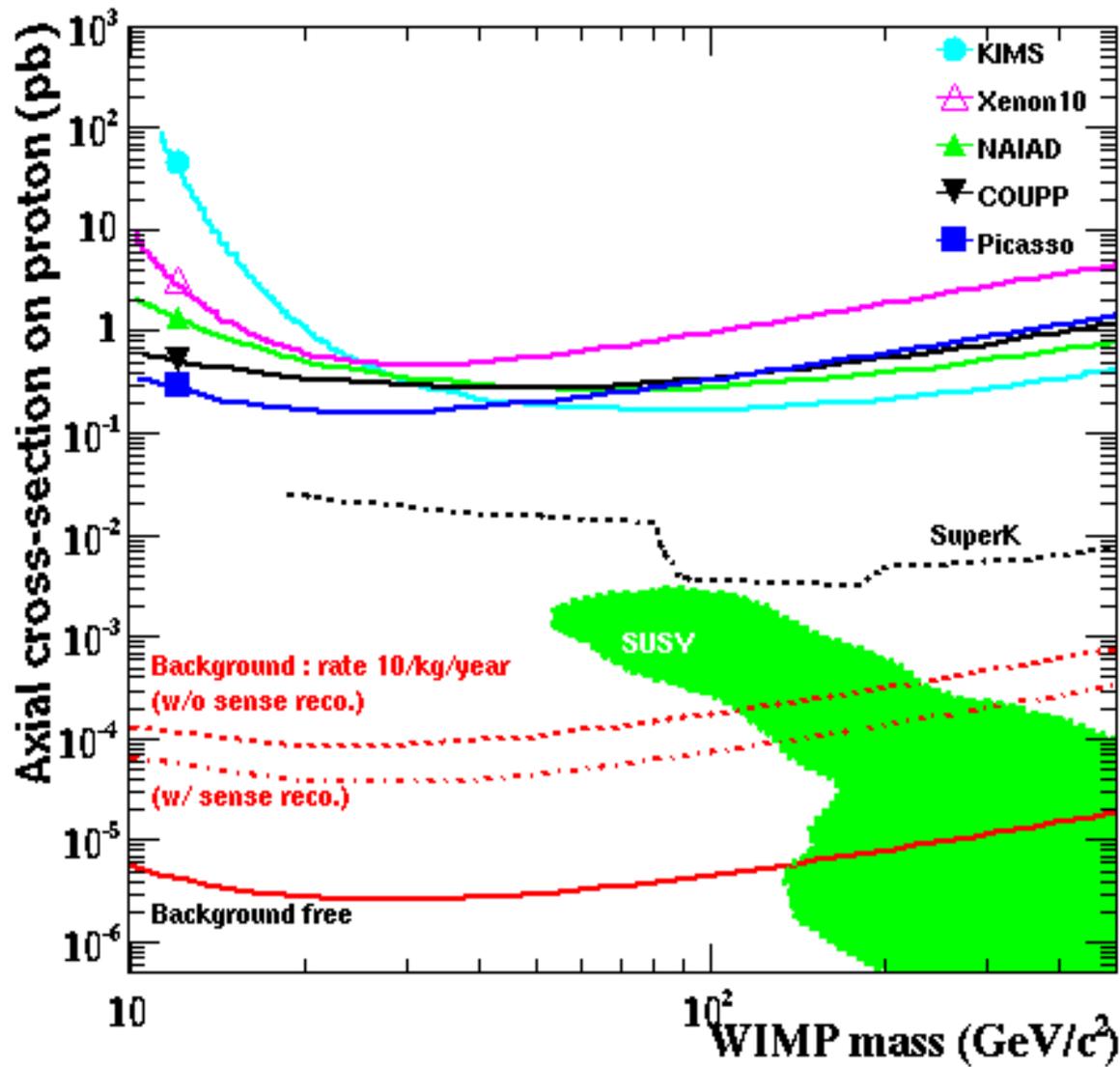


NIS (for recoils)



NIS(for electrons)





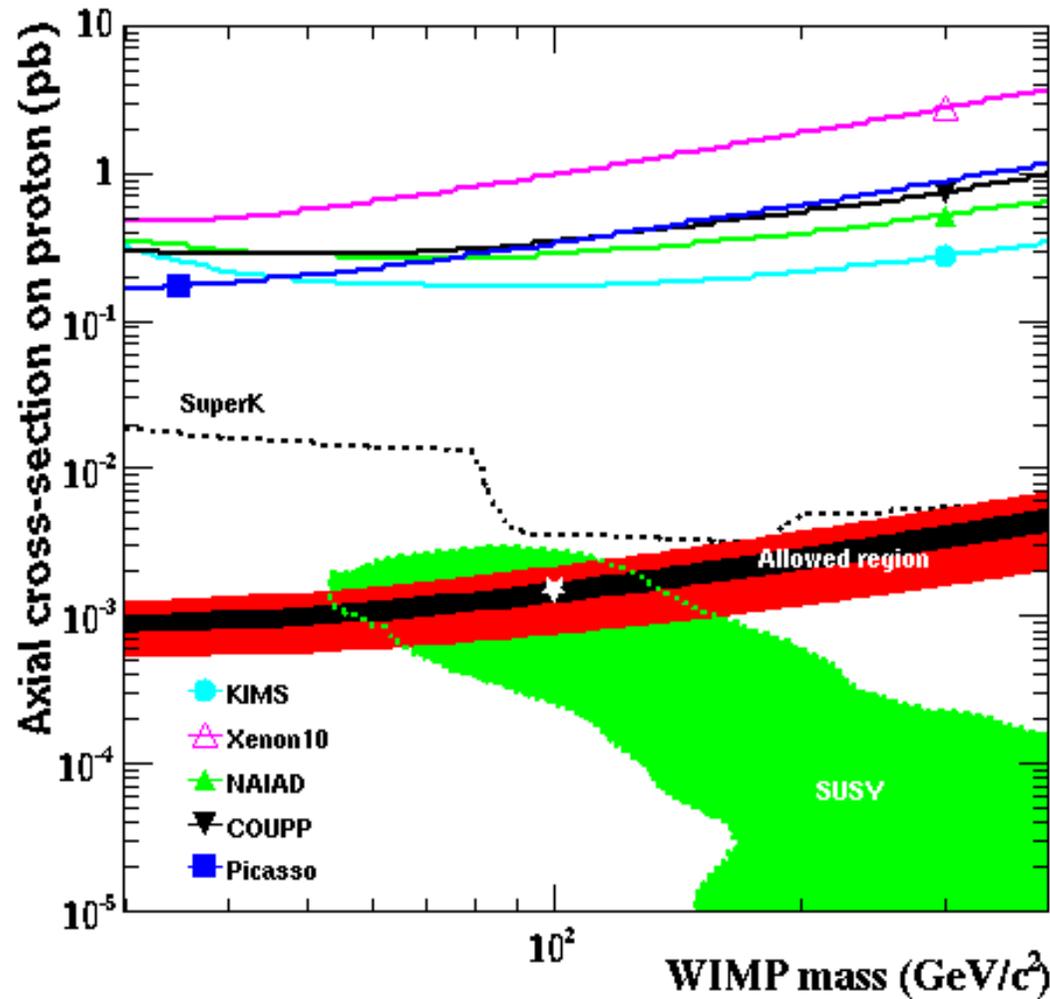
Exclusion plot for directional detection

J.Billard, F.Mayet ,D.S.
(2010) submitted to PRD

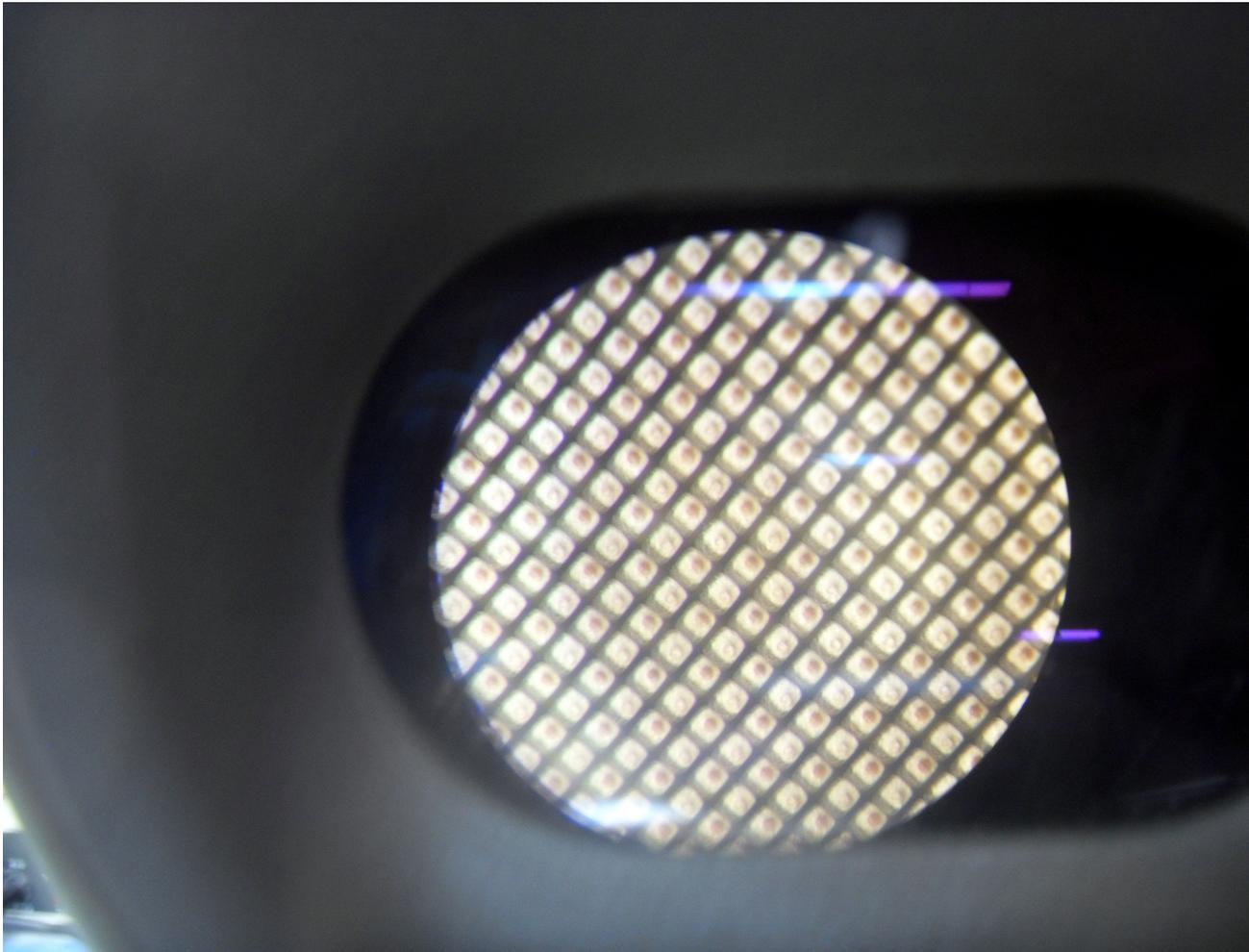
Discovery plot

(significant number of Wimp events (~ 50))

J.Billard, F.Mayet et D.S. PRD (2010)

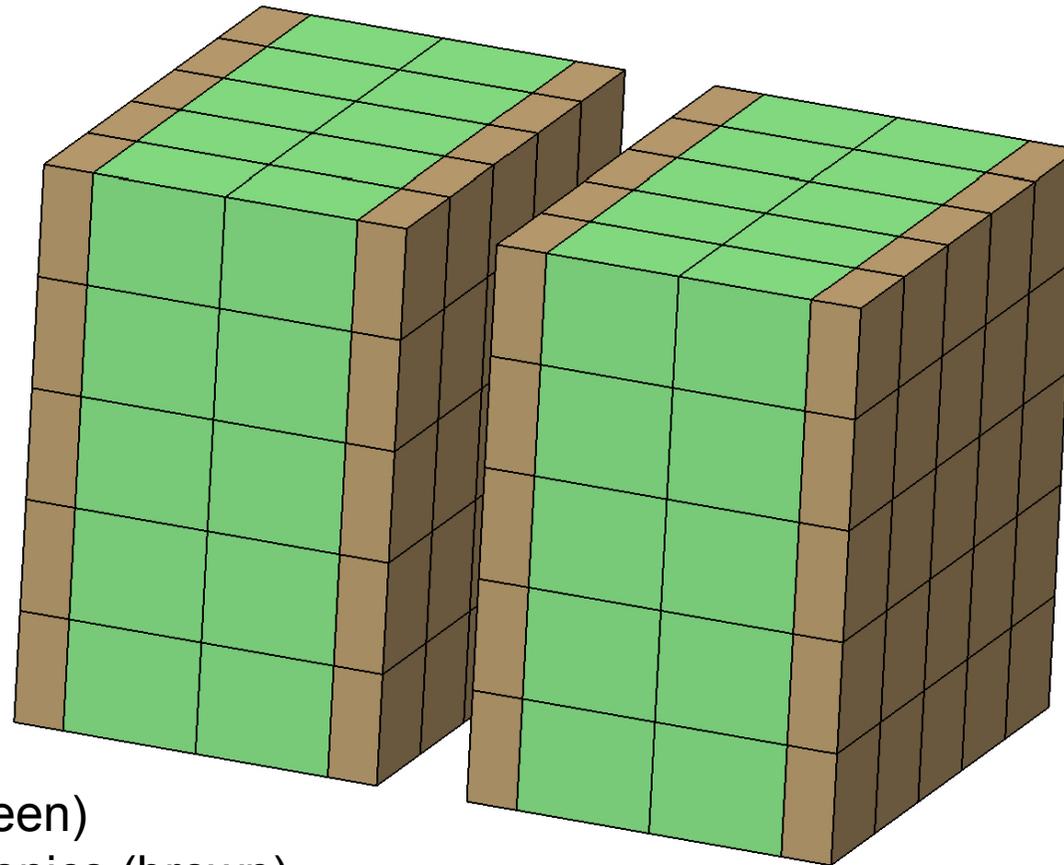


A small part of the 10x10 cm² pixelized anode (Saclay-MIMAC)



J-P. Mols et al.
October 2009

MIMAC unit (1m³) in 2013...



Chambers (green)
MIMAC Electronics (brown)

MIMAC: (Micro-tpc Matrix of Chambers)

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