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)

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J. Billard (Ph.D)

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

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

IRSN (Cadarache): L. Lebreton, A. Allaoua

CYGNUS (CosmoloGY with NUclear recoilS)
A large Scale Directional Dark Matter Detector

List of Participants for the ASPERA call (June2009) (alphabetic order) [partner's number]

France

CNRS/IN2P3/UJF/Laboratoire de Physique Subatomique et de Cosmologie de Grenoble (LPSC) [1]

CEA/Saclay/Institut sur les Lois Fondamentales de l'Univers (IRFU) [5]

Germany

University of Technology Darmstadt [4]

Spain

University of Zaragoza [3]

United Kingdom

University of Sheffield [2]

University of Edinbourgh [6]

Why do we think we need a large TPC?

- Directionality

  (correlation with galactic halo)
- Axial interaction (^{1}H ,^{3}He, ^{19}F)

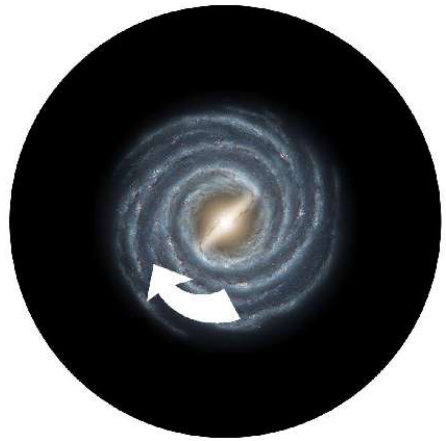
  (complement of scalar (coherent) search)
- Mass dependence cross section (modularity)
- Two different operating modes

  (high and low pressure)
- Low energy threshold detection (< 300 eV)

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.

More precisely the Deneb star

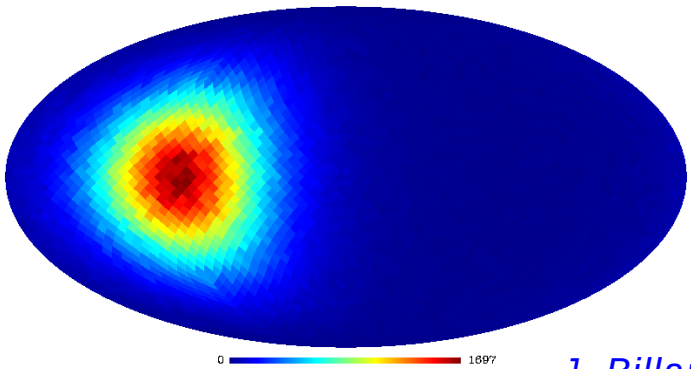
Background can not mimic such genuine events

WIMPs events should point towards Cygnus constellation (a wind of WIMPs)

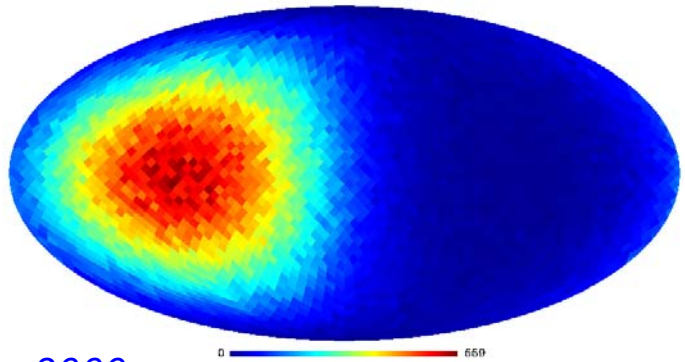
Strategy:
- use direct detection
- reconstruct Energy AND Track of the recoil nuclei
- Prove that the signal "comes from Cygnus"

Directional DM detection
(isothermal spherical halo)

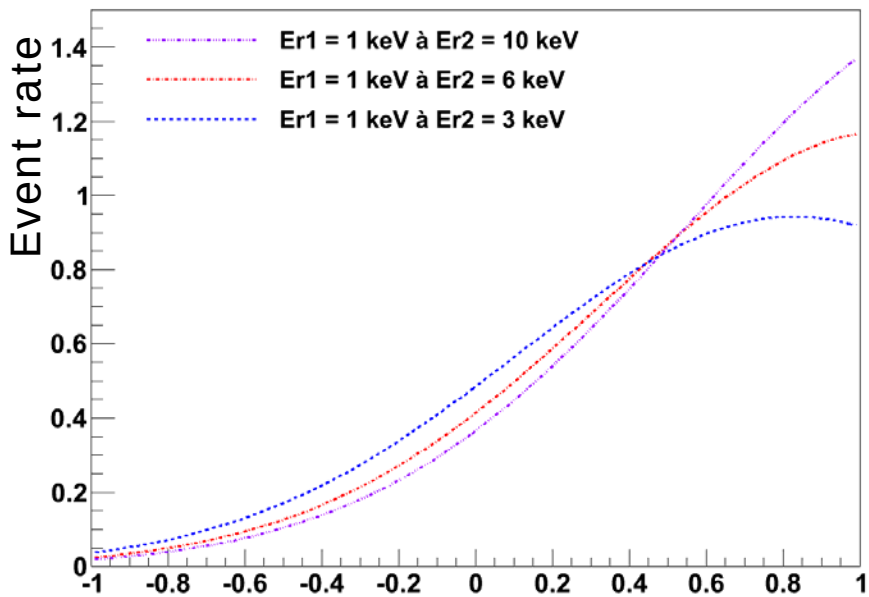
WIMP flux



Recoil events (He, M=20 GeV)



J. Billard et al., 2009

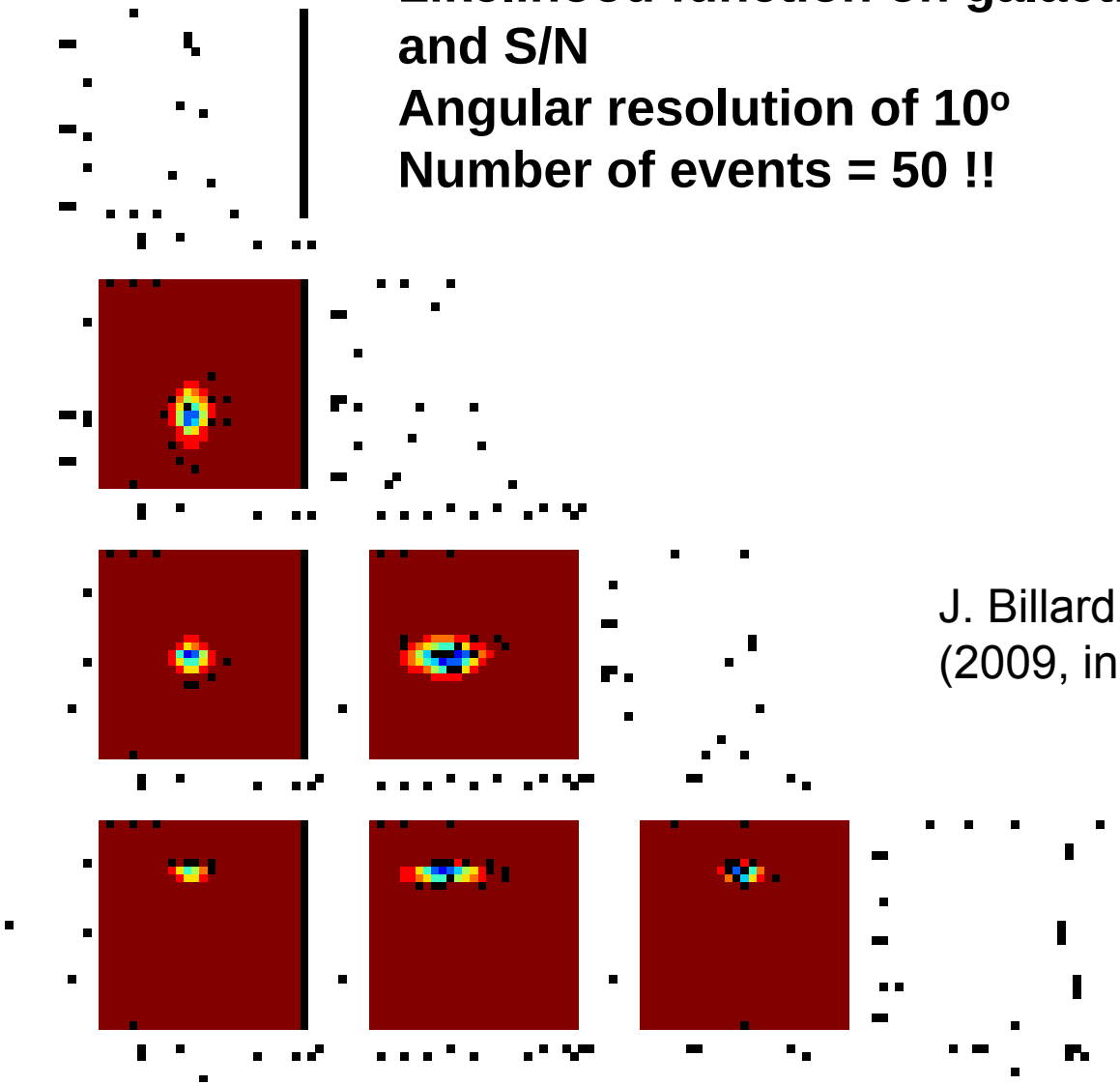


Both the WIMP flux and the recoil events show a strong direction dependency towards Cygnus constellation

$$(\ell = 87.5°, b = 1.3°)$$

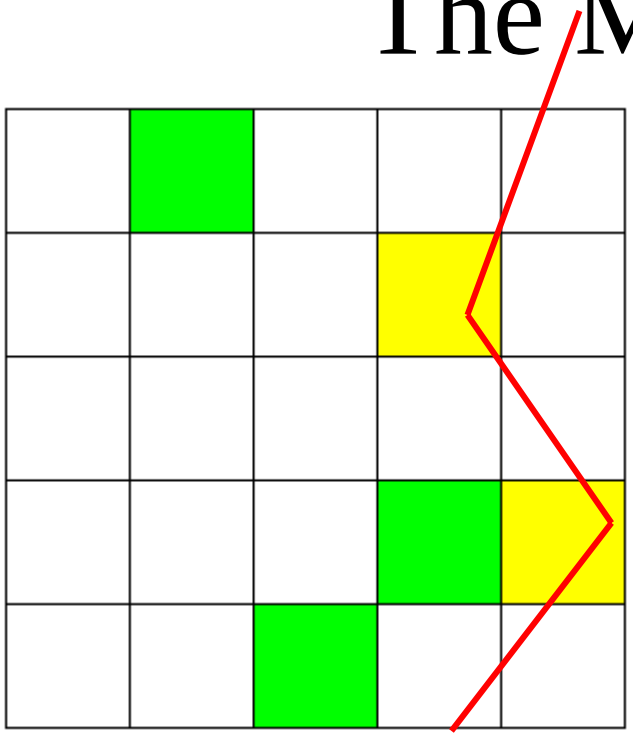
Strong forward / backward asymmetry

Likelihood function on galactic coordinates (l,b) and S/N
Angular resolution of 10º
Number of events = 50 !!



J. Billard, F.Mayet et al. (2009, in preparation)

The MIMAC project



A multi-chamber detector for Dark Matter

- Track-Energy measurements
- Matrix of chambers (correlation)
- µTPC : Micromegas technology
- ^{3}He and CF_4 gaz : $\sigma(A)$ dependancy
- Axial interaction
- High or low pressure regime
- Directionnal detector

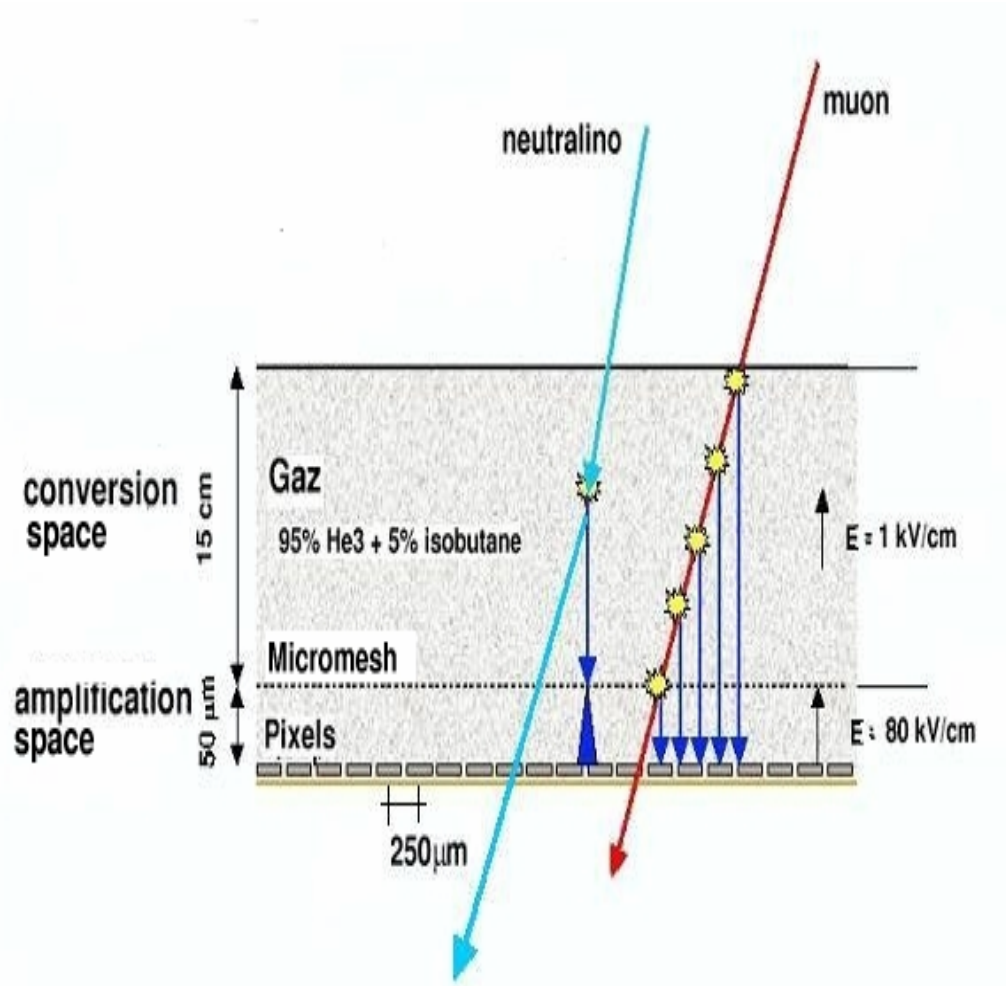
Rejection of background events :

- ✓ **Energy (ionization)**
- ➢ **Track**
- ➢ **Direction (Cygnus)**

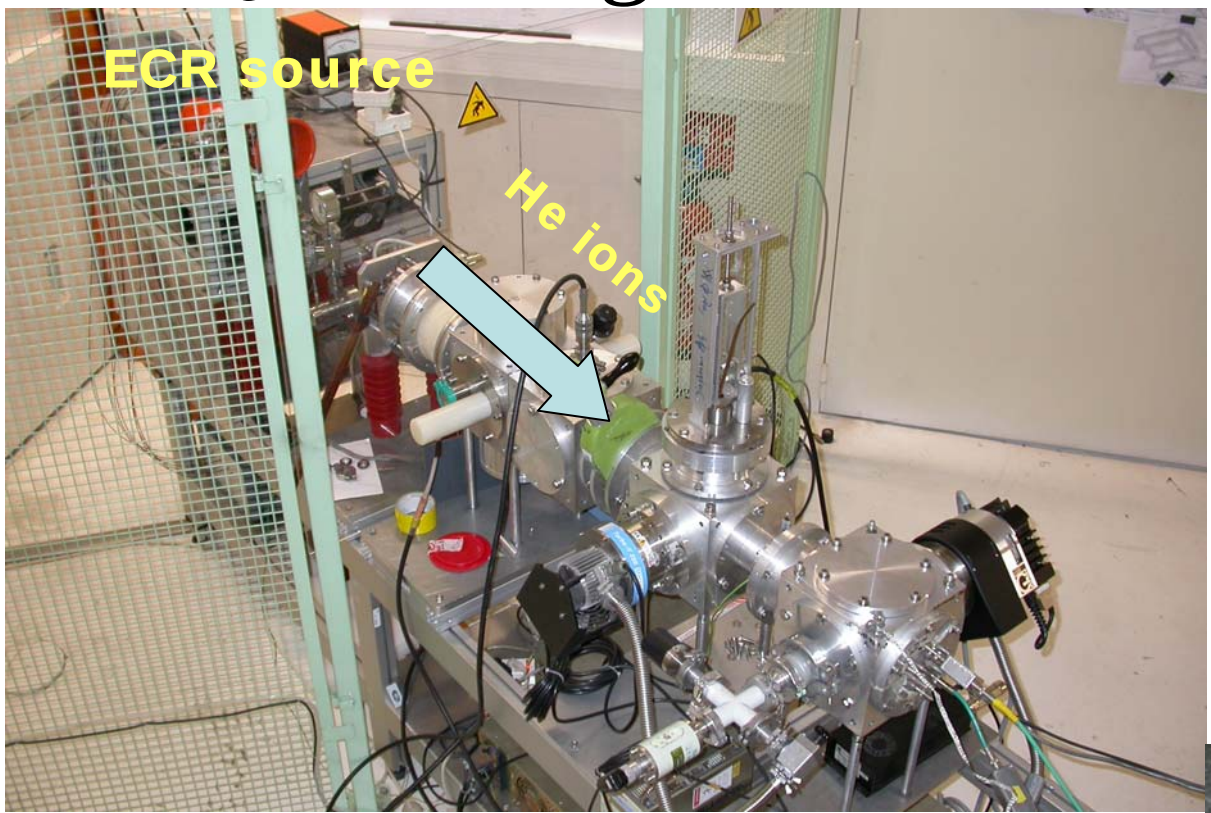
MIMAC:
(Micro-tpc MAtrix of Chambers)

{spatial, temporal, energetic} resolution

⇒ recoil track
⇒ energy threshold ~ 200eV
⇒ electron/recoil discrimination



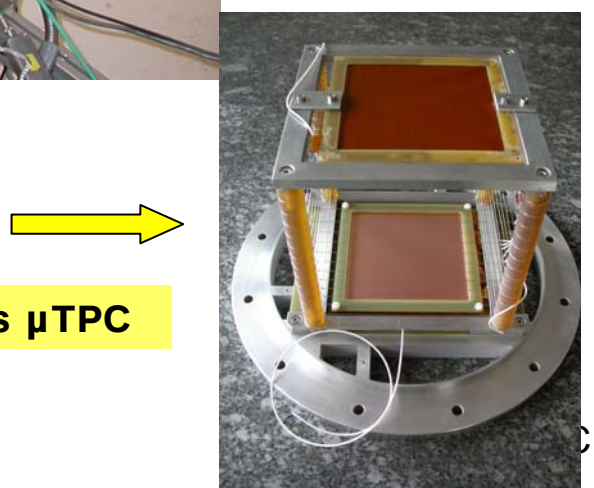
Quenching factor measurement



- **Low energy ion source**

  1 to 50 keV

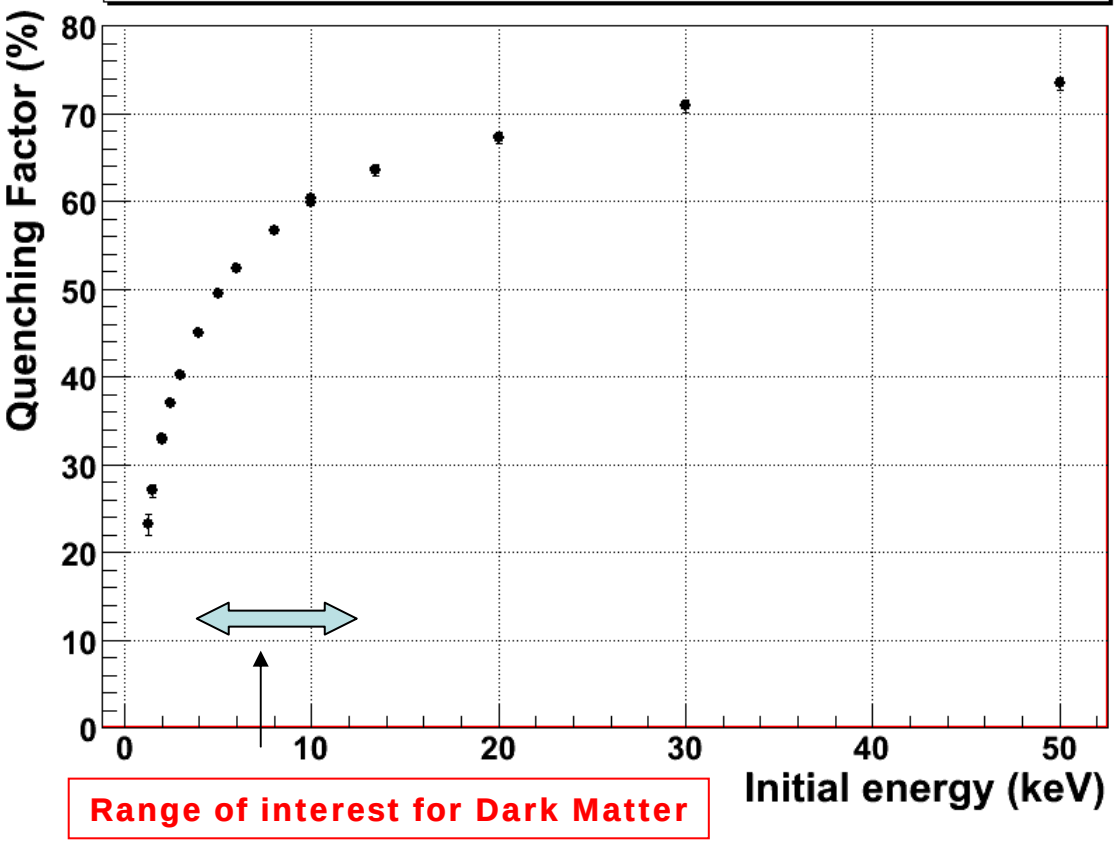
- **Developped @LPSC**



Micromegas µTPC

QF measurement !!

Quenching factor @ 700 mbars



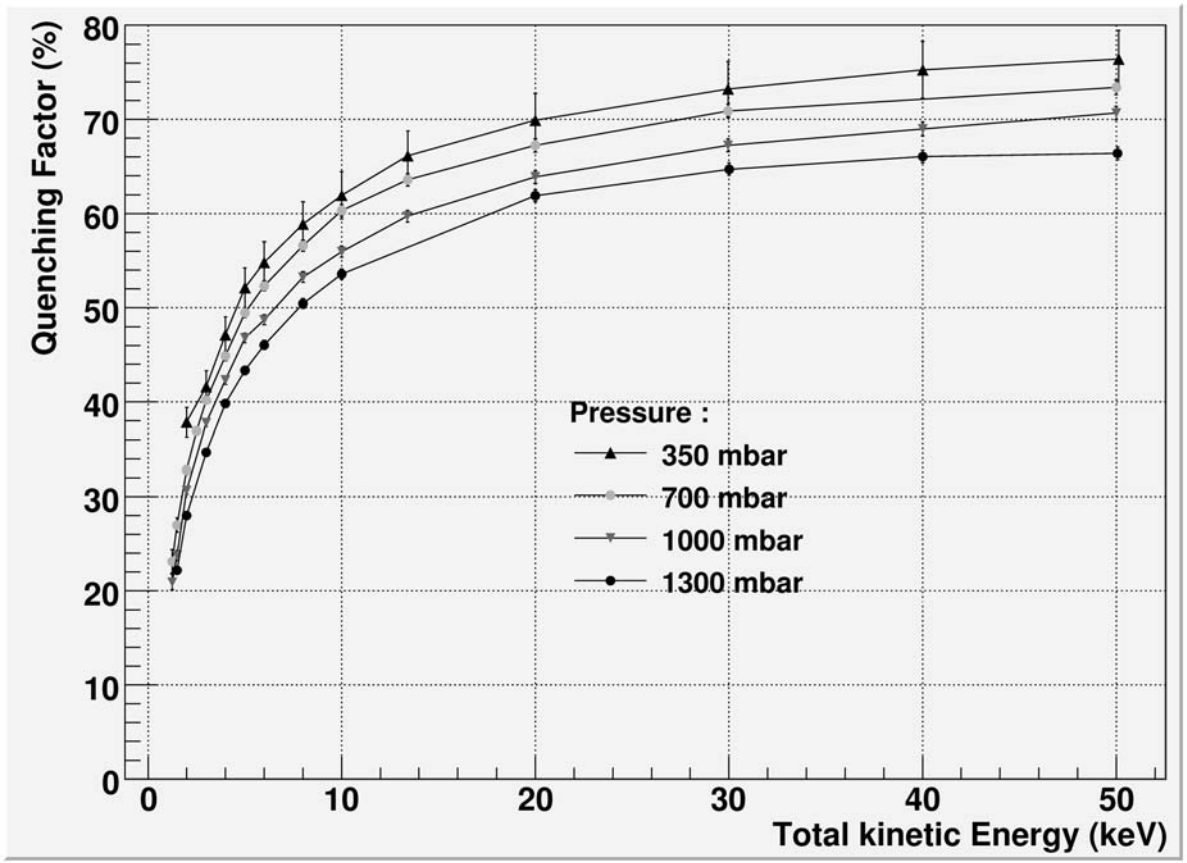
Measurement of ^4He

in 95% ^4He + 5% C_4H_{10}

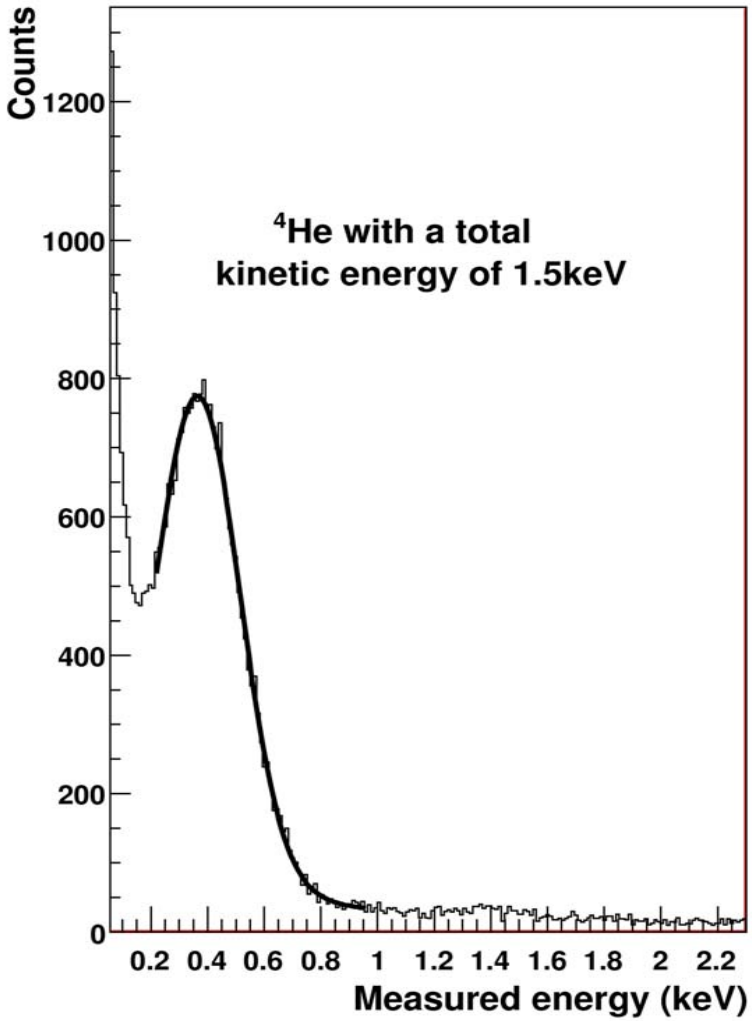
- Threshold :300 eV (ioni.) or 1 keV (recoil)
- The response of this ^4He detector is fully understood from 1 to 50 keV
- Dark Matter range : covered

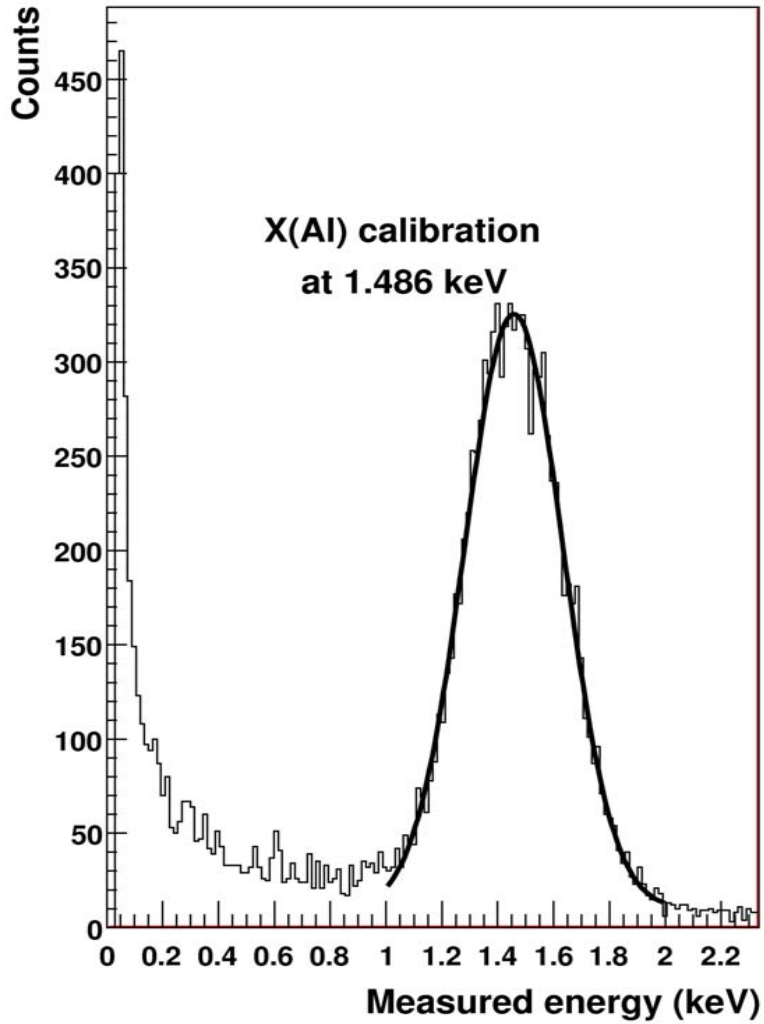
IQF Measurement of ^4He in 95% ^4He + 5% C_4H_{10} as a function of the pressure

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

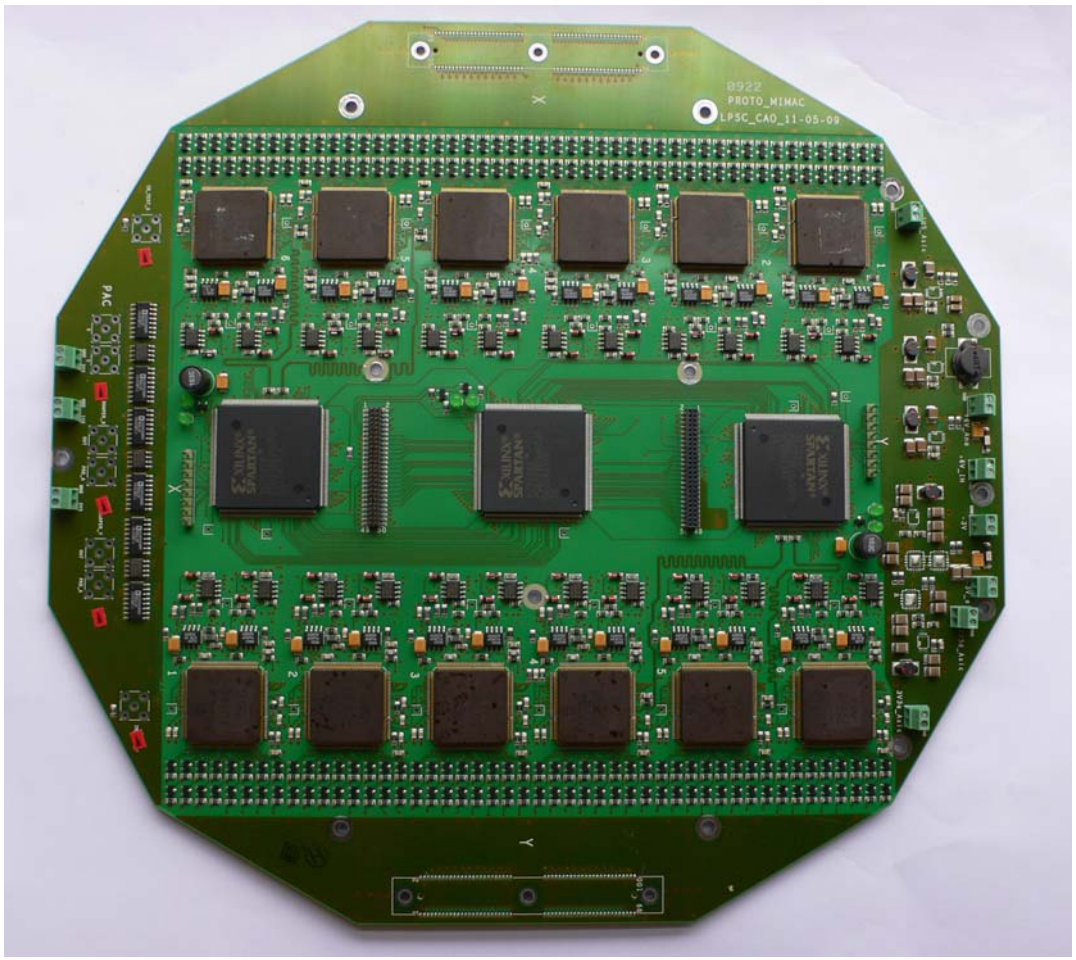


Detection of ^{4}He (recoils) of 1.5 keV !!
(95% ^{4}He + 5% iso) at 700mbars



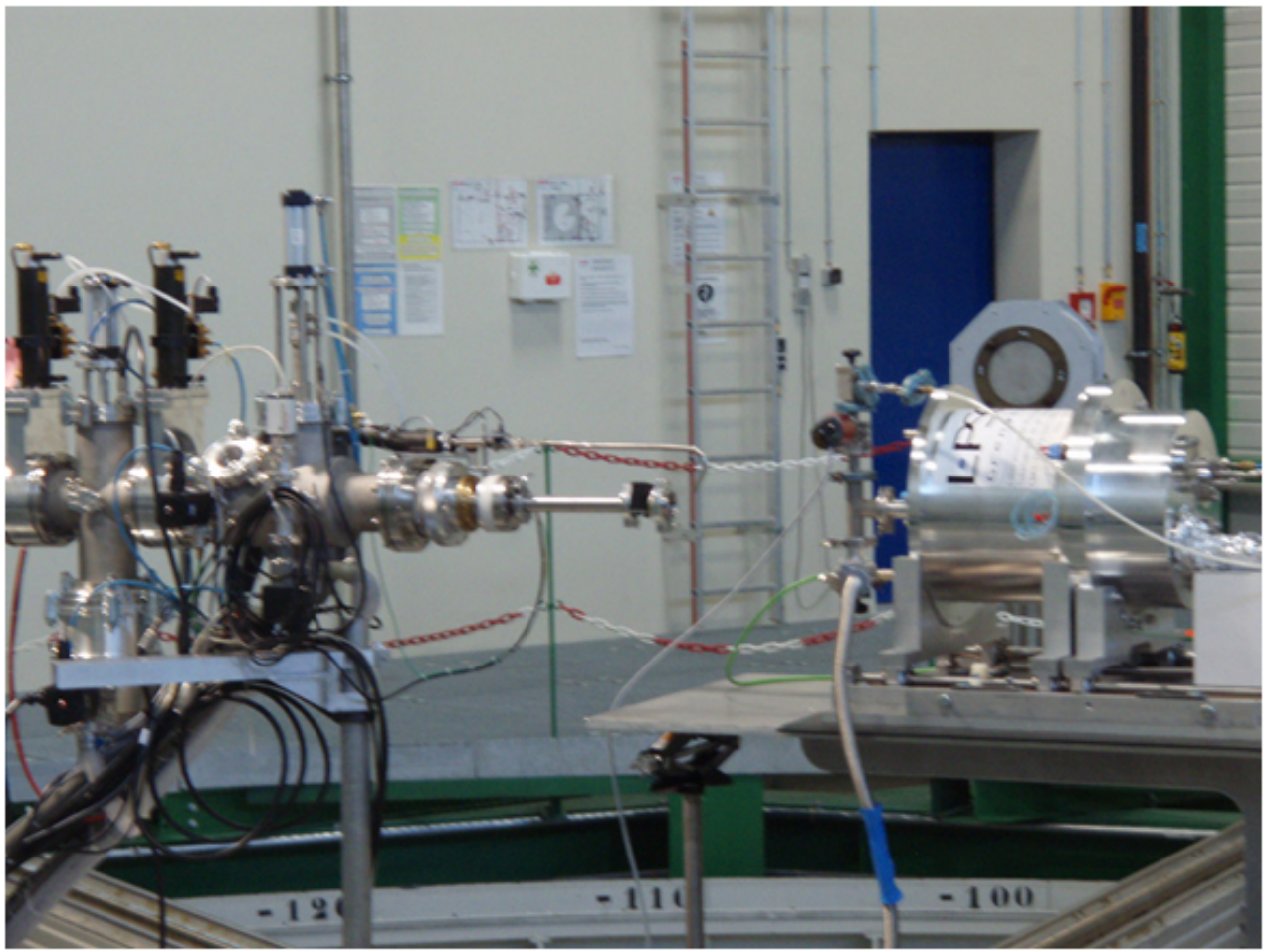


MIMAC chips integrated in the electronics of the prototype



96+96=192 channels
Covering 3x3 cm^2
Autotriggered
Reading it every 25ns

MIMAC prototype at Cadarache (detecting neutrons by nuclear recoil)



MIMAC : recoil track measurements

April 2009

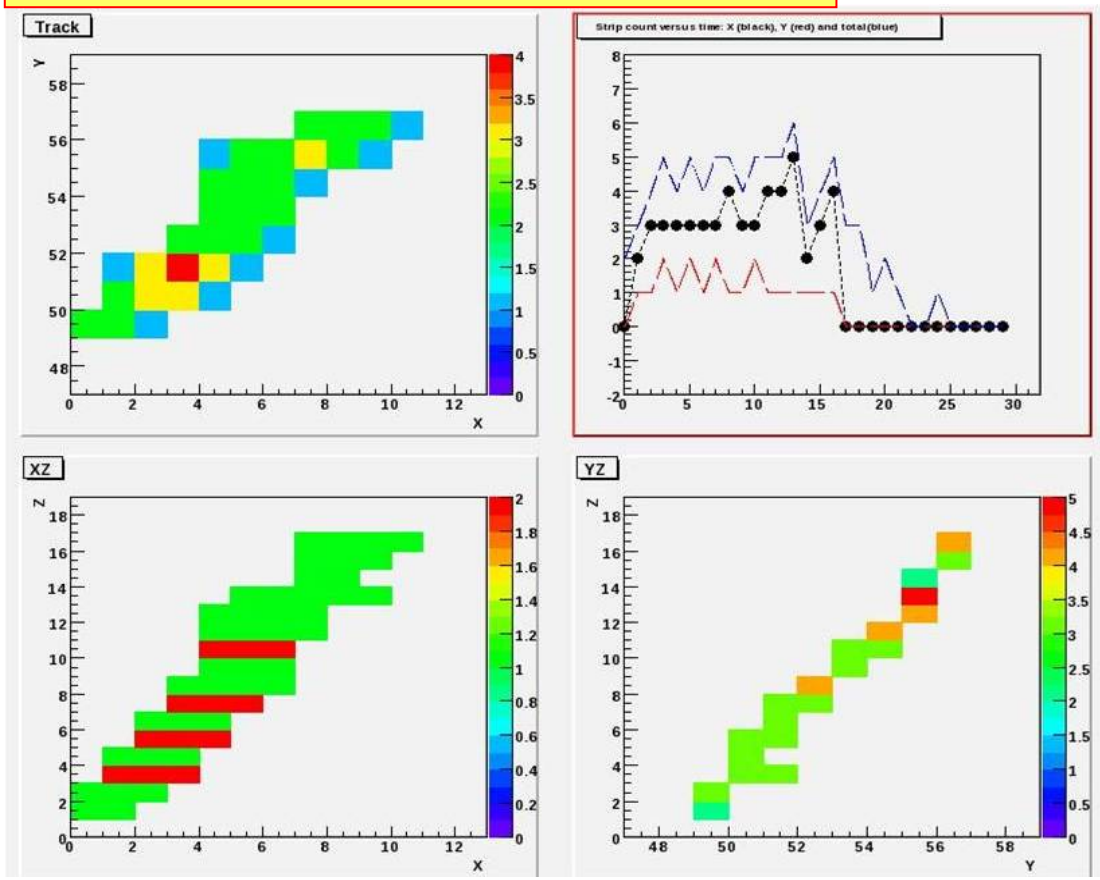
@ IRSN Cadarache

Amande facility :

- Neutron field with energies down to a few keV

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 µm/ns

Track 45

ϕ = 41.6 deg

Θ = 39.2 deg

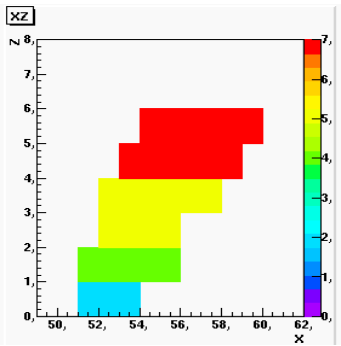
L = 8 mm

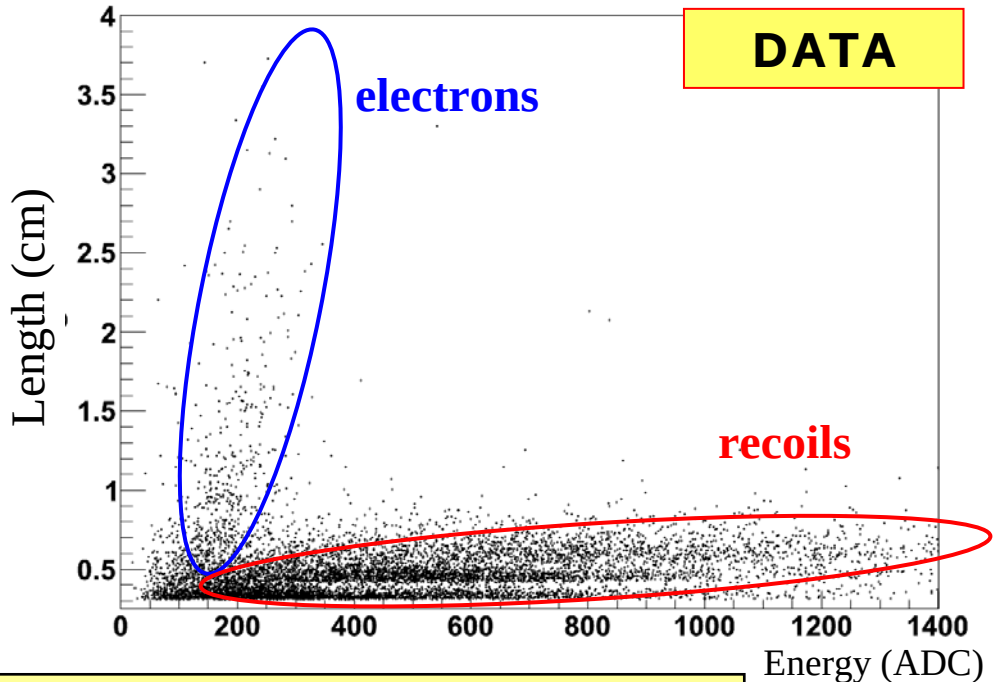
First 3D track of ~6 keV electron !!

Recoil from 144 keV neutrons

Preliminary results!

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





Pure isobutane

100 mbar

150 V/cm

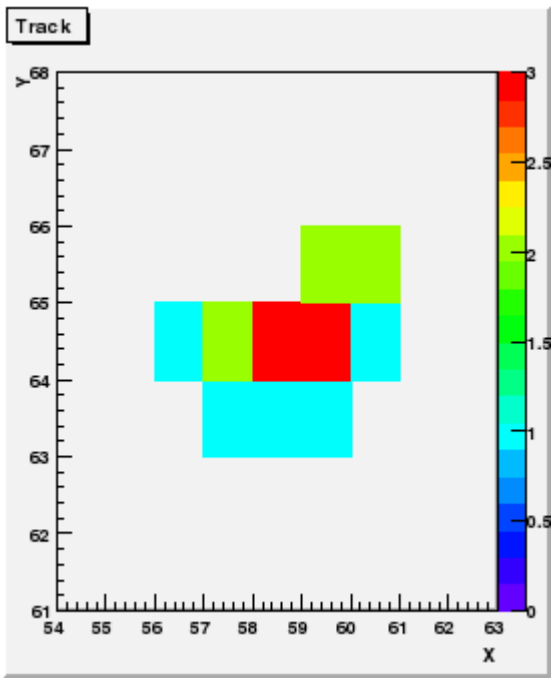
(same results in pure methane)

- **Possibility to have H as a target**
- **Separate background from recoils**

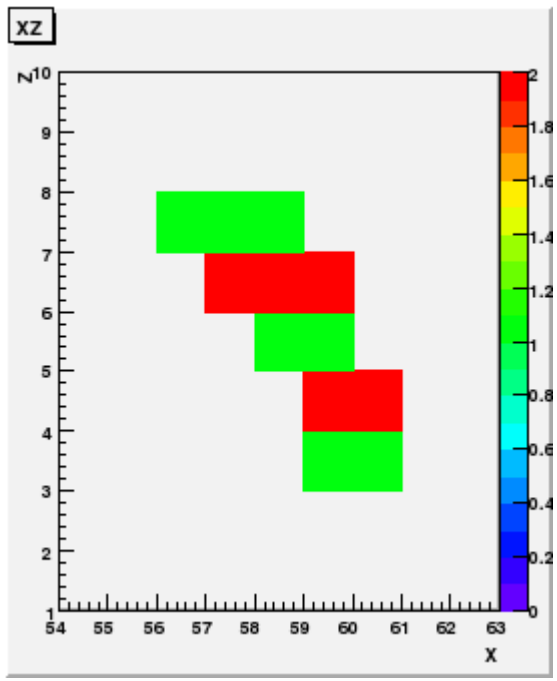
6 keV recoil track (^{4}He) projections

300 mbar (95% of 4He, 5% of $C_4 H_{10}$)

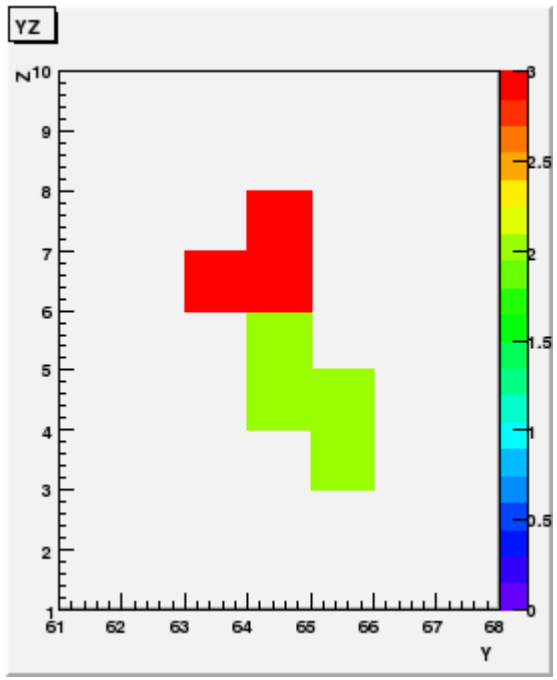
X-Y



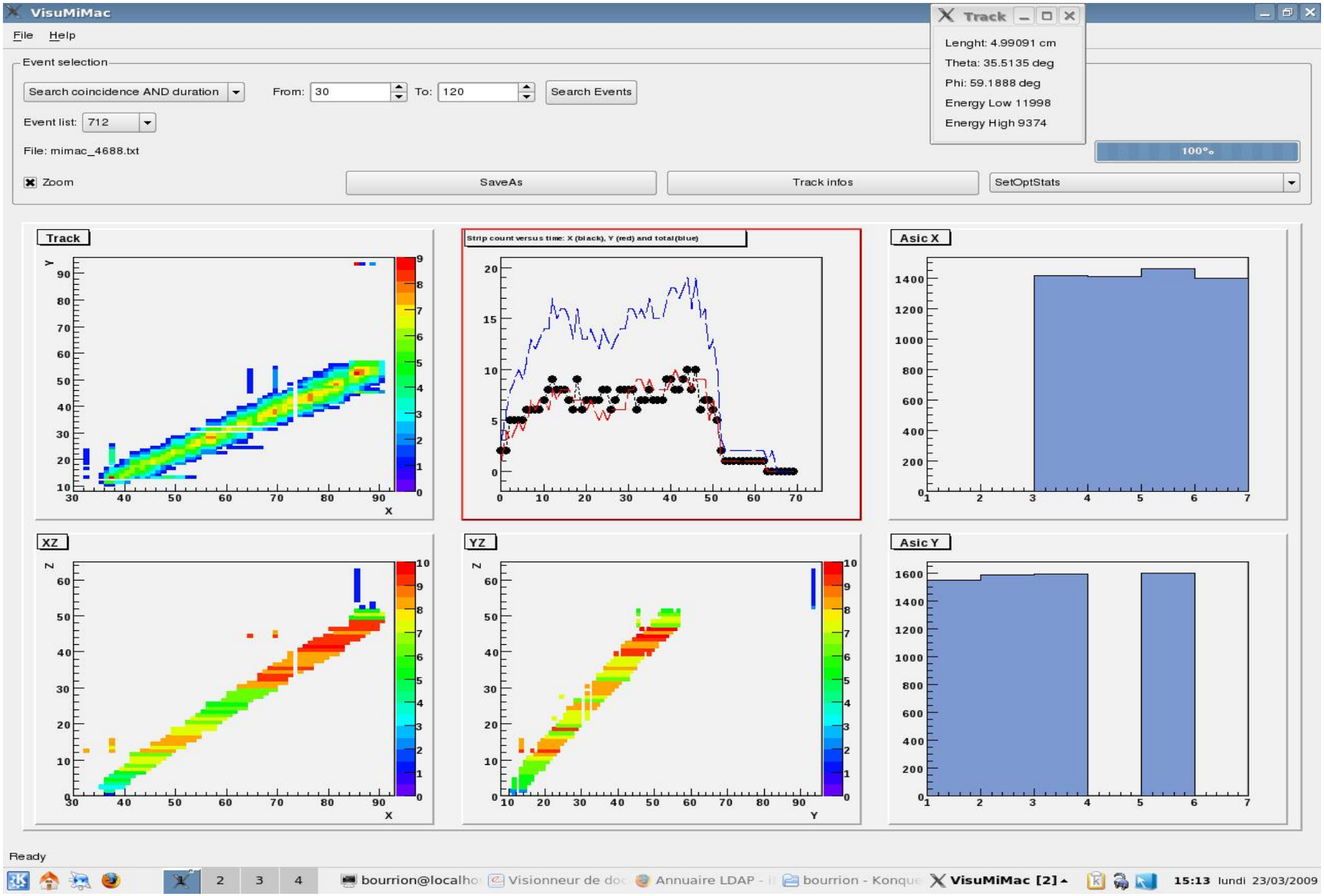
X-Z



Y-Z



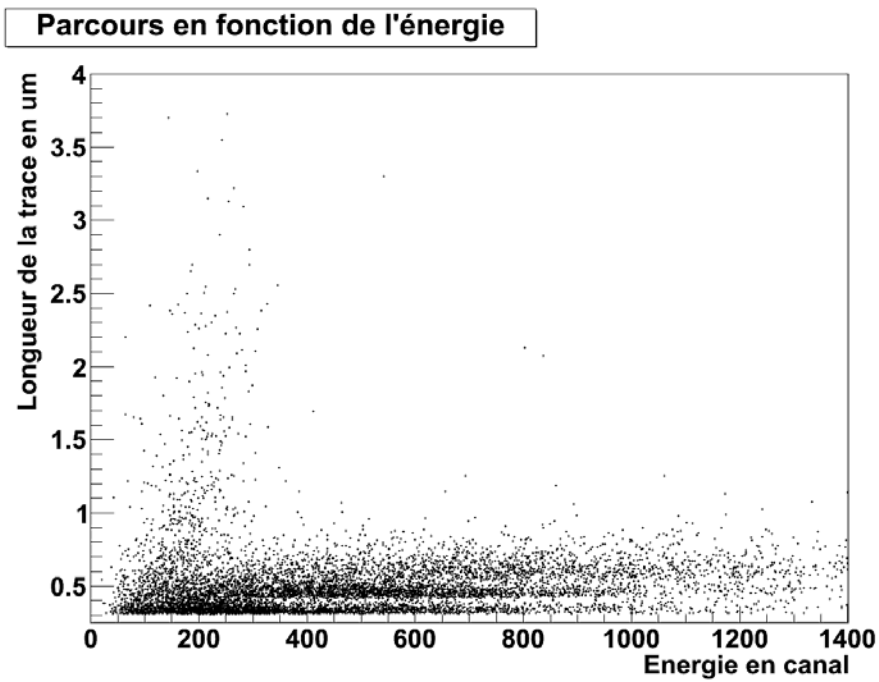
3D track alpha (radioactivity)

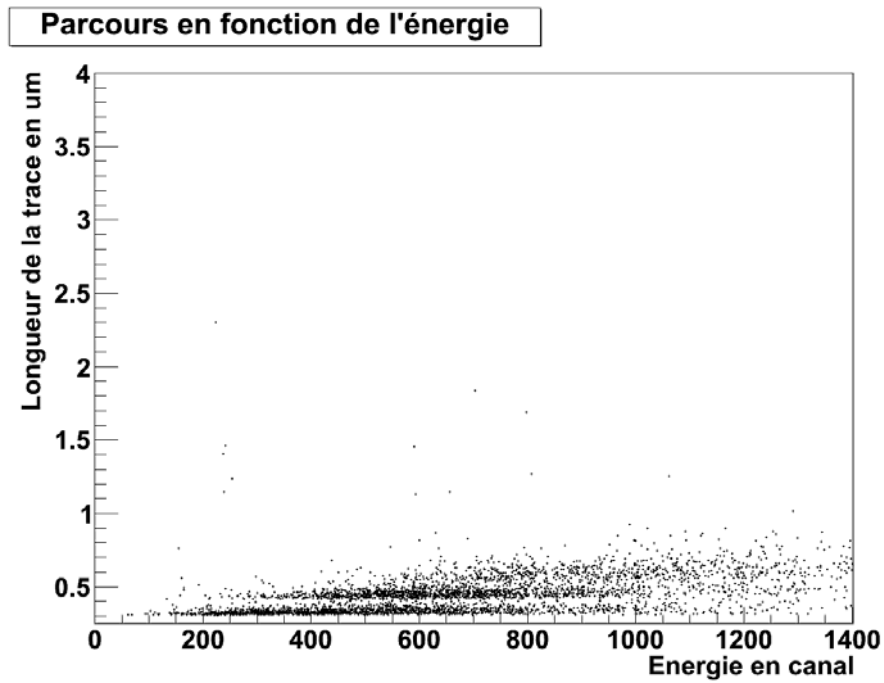


New degree of freedom to discriminate recoils from electrons from 3D tracks

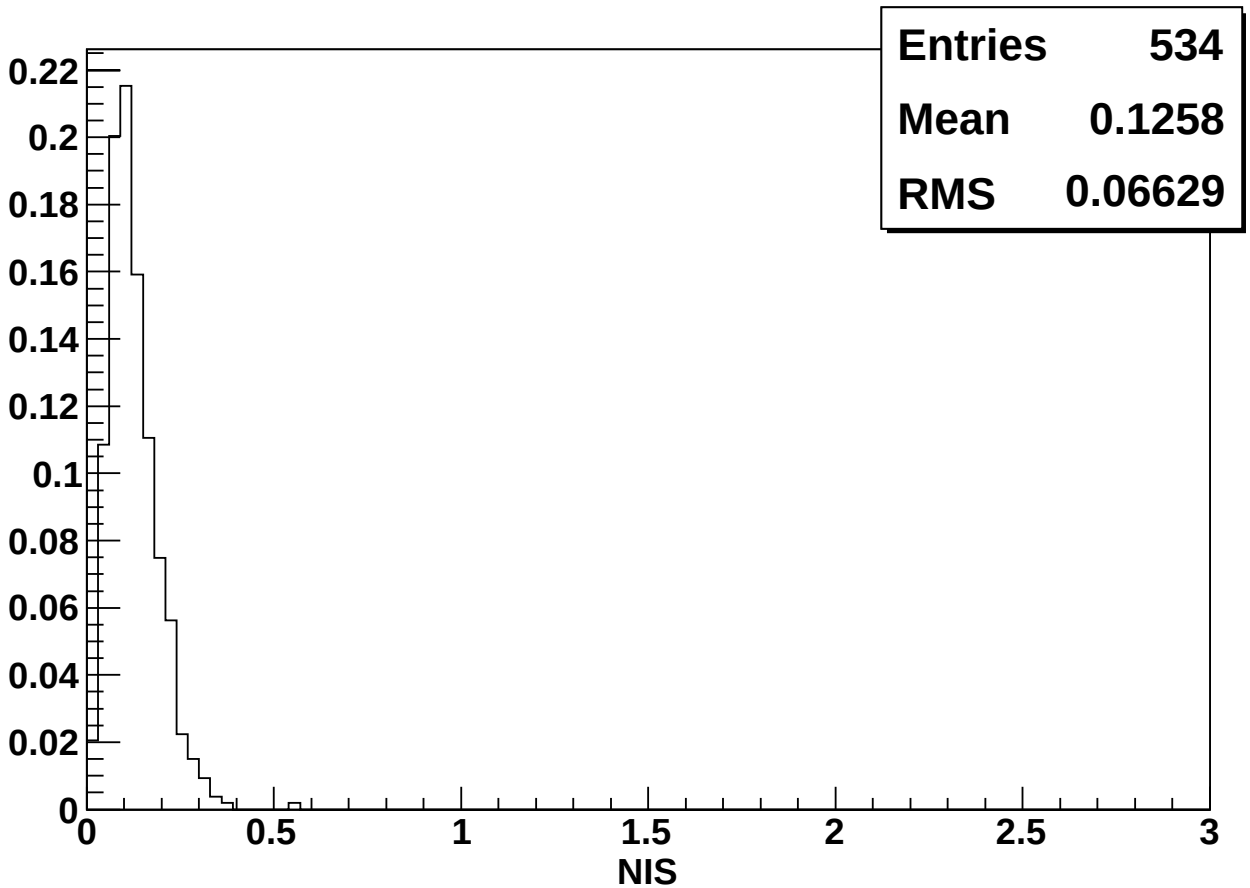
Normalized Integrated Straggling (NIS)

(Sum of partial deflections along the measured track, normalized by its total energy)
(J. Billard et al. (2009) in preparation)

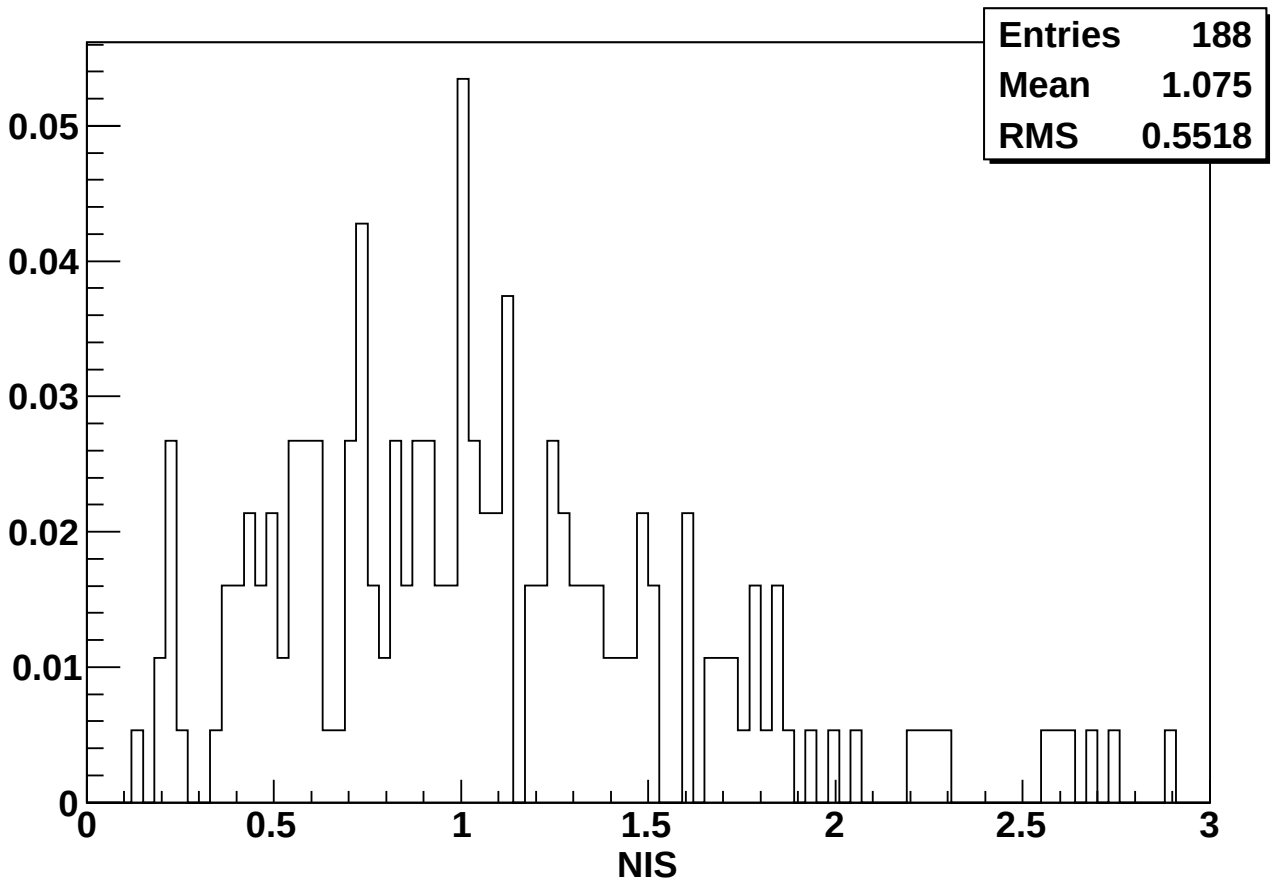




NIS (for recoils)



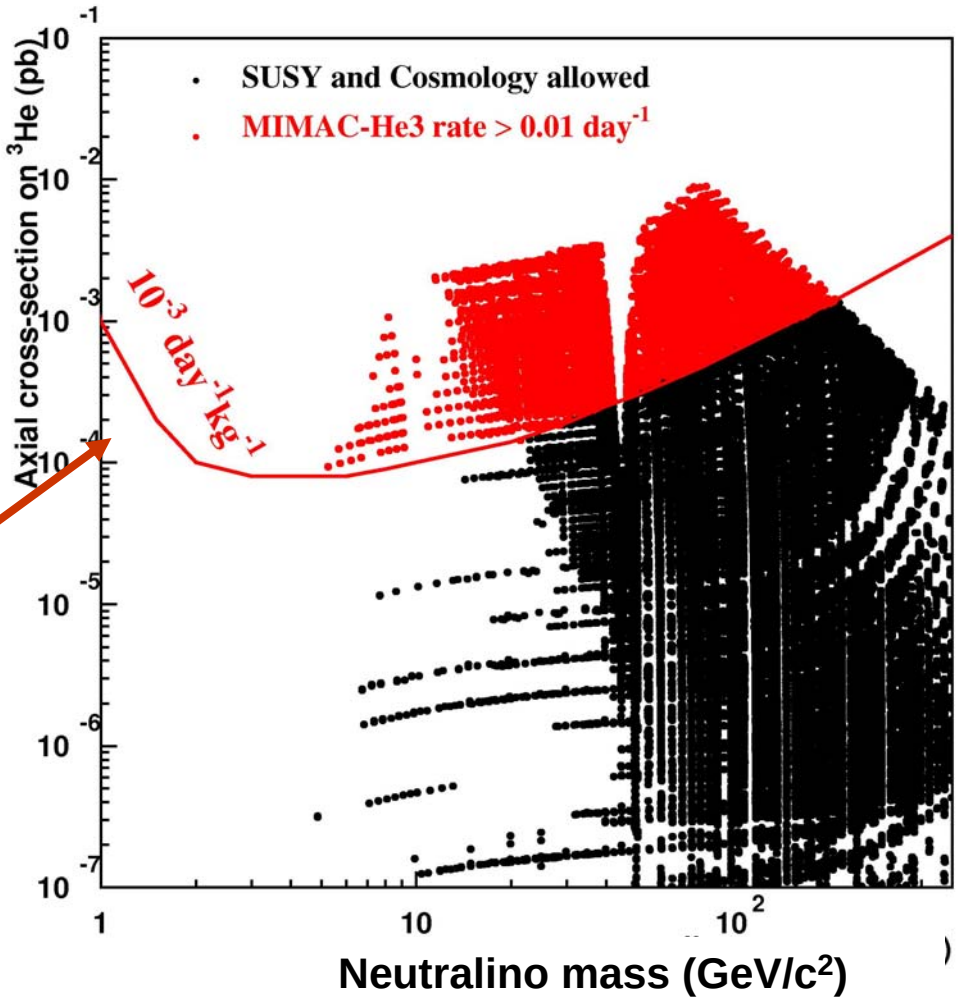
NIS(for electrons)



Cross section ^{3}He-χ and event rate in MIMAC-He3 (10kg)

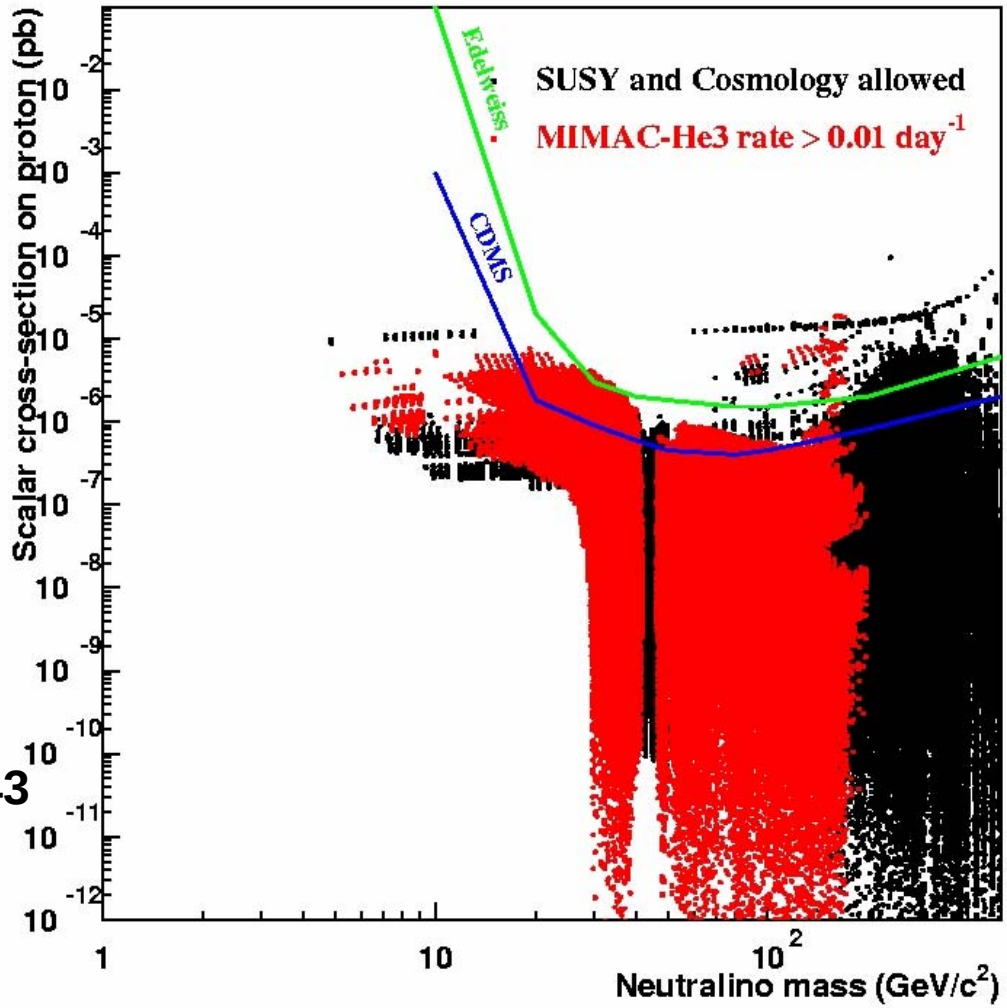
- $0.02 < \Omega_\chi h^2 < 0.15$
- Accelerator constrains

Exclusion curve for background 10^{-3} kg^{-1}jour^{-1}



Complementarity with scalar detection

σ_{SD} and σ_{SI} not correlated



E. Moulin et al, PLB 614 (2005)143

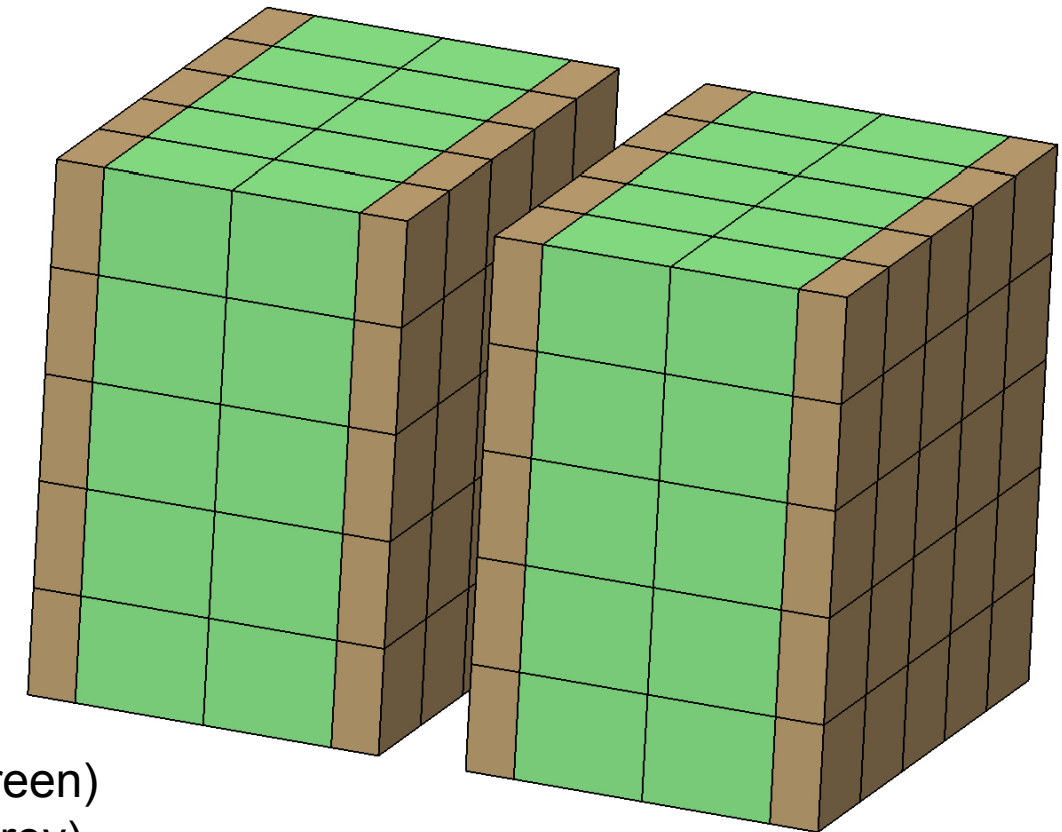
MIMAC-CYGNUS

(to have 50 evts in 3 years at 10^{-3}evts/(kg day))

- The number of nuclei in 10 kg of ^{3}He = 3333 N_A
- In CF_4 to have the same number of ^{19}F we need 74 kg
- The axial cross section follows a A^2 dependence (factor 40 wrt ^{3}He)
- We need 50 m^3 of CF_4 at 50mbar
- The tracks of 30 keV ^{19}F are roughly 1mm long at 50mbar.

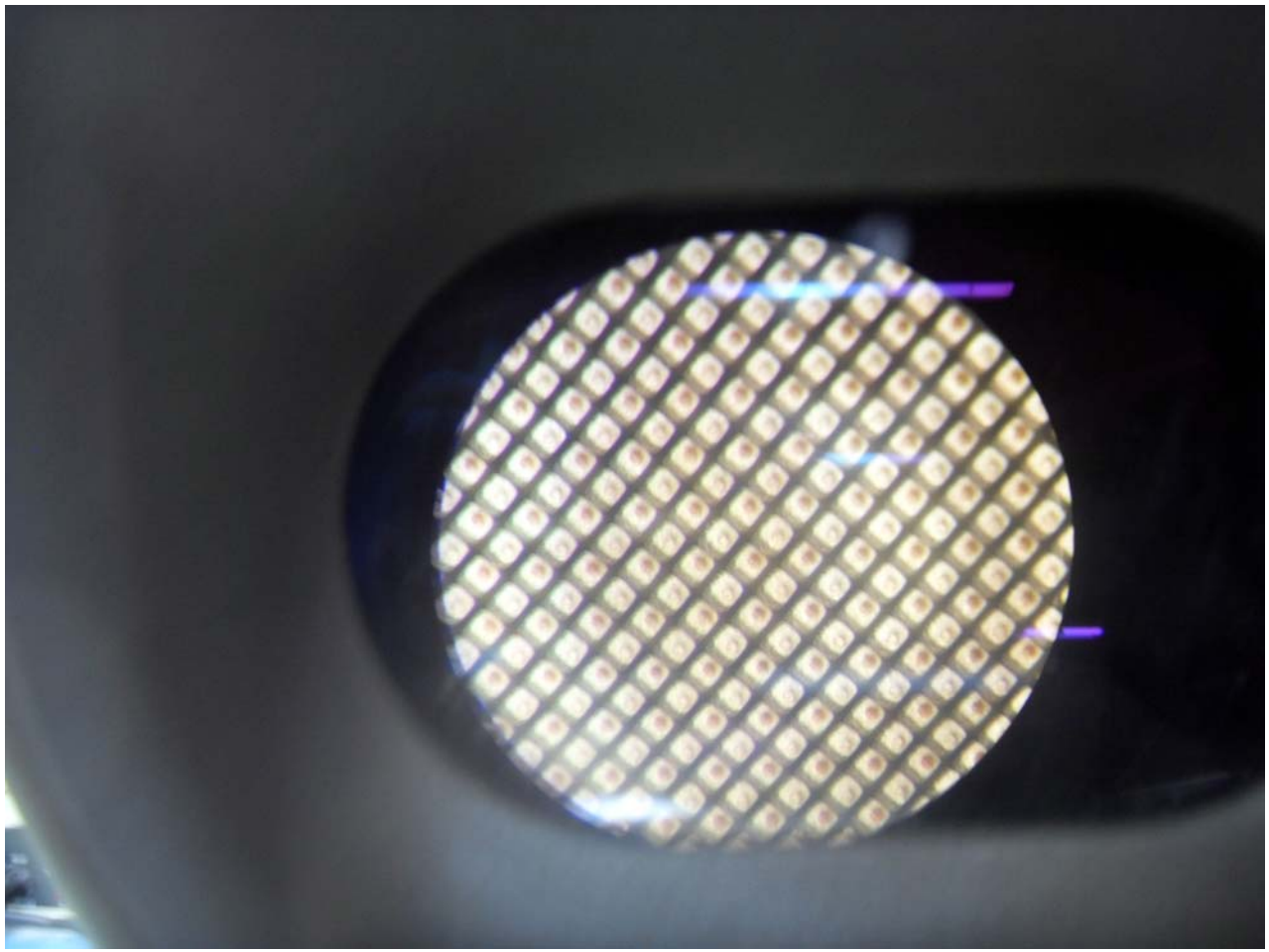
Possible to have other or alternative target as (^{1}H, ^{3}He, ^{4}He or ^{20}Ne) without change the detector !!

MIMAC unit ($1m^3$)



Chambers (green)
Electronics (grey)

A small part of the 10x10 cm^2 pixelized anode (Saclay-MIMAC)

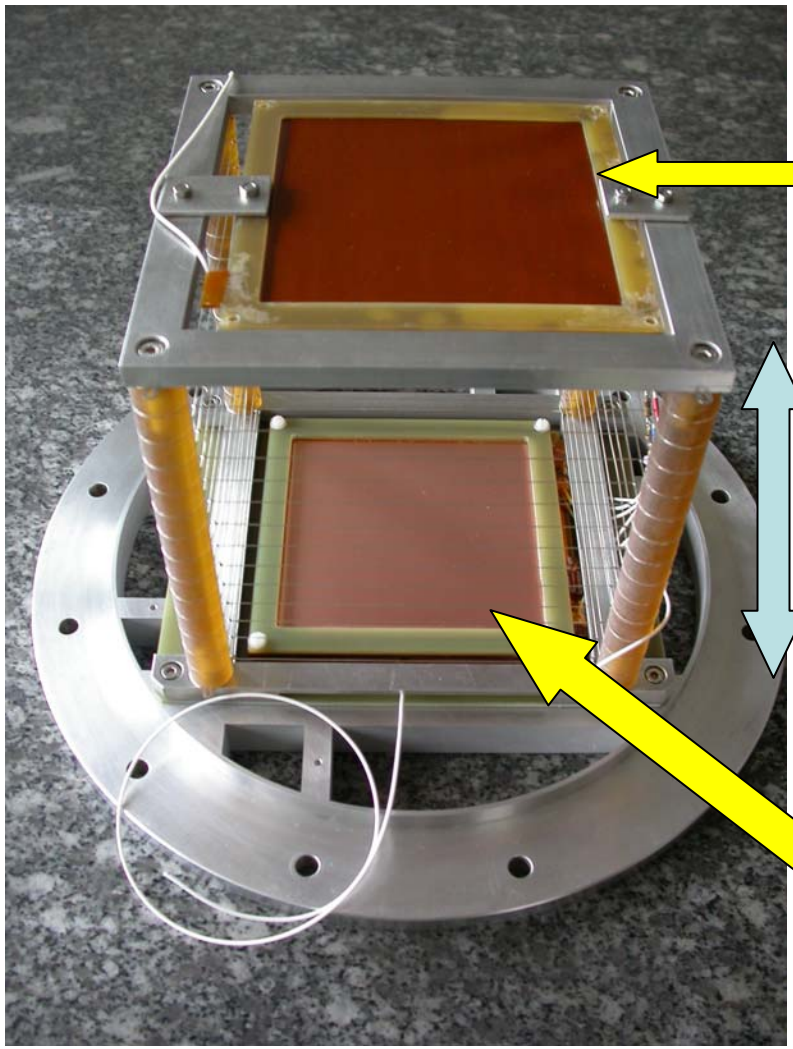


J-P. Mols et al.
October 2009

Provisional Timetable

- The ANR-MIMAC project has to show the elementary module of the 3D-Matrix working by the end of 2010.
- The CYGNUS design study has as the main purpose to define the 1 m3 by the end of 2012.
- These milestones will give us the design of the 50 m3 detector by 2013.
- The electronic chip necessary to read-out the pixel-anode will be defined by the end of 2010.
- The modular design will give us the possibility to run intermediate volumes during the mounting of the final detector with previous defined phases of extensions.
- The construction of the detector can be done relatively fast having no blocking problems in the design as it has been shown thanks to the ANR-Blanc Project that allow the Saclay and the Grenoble teams work together to define the elementary chamber.

MIMAC : µTPC chamber



Real size prototype

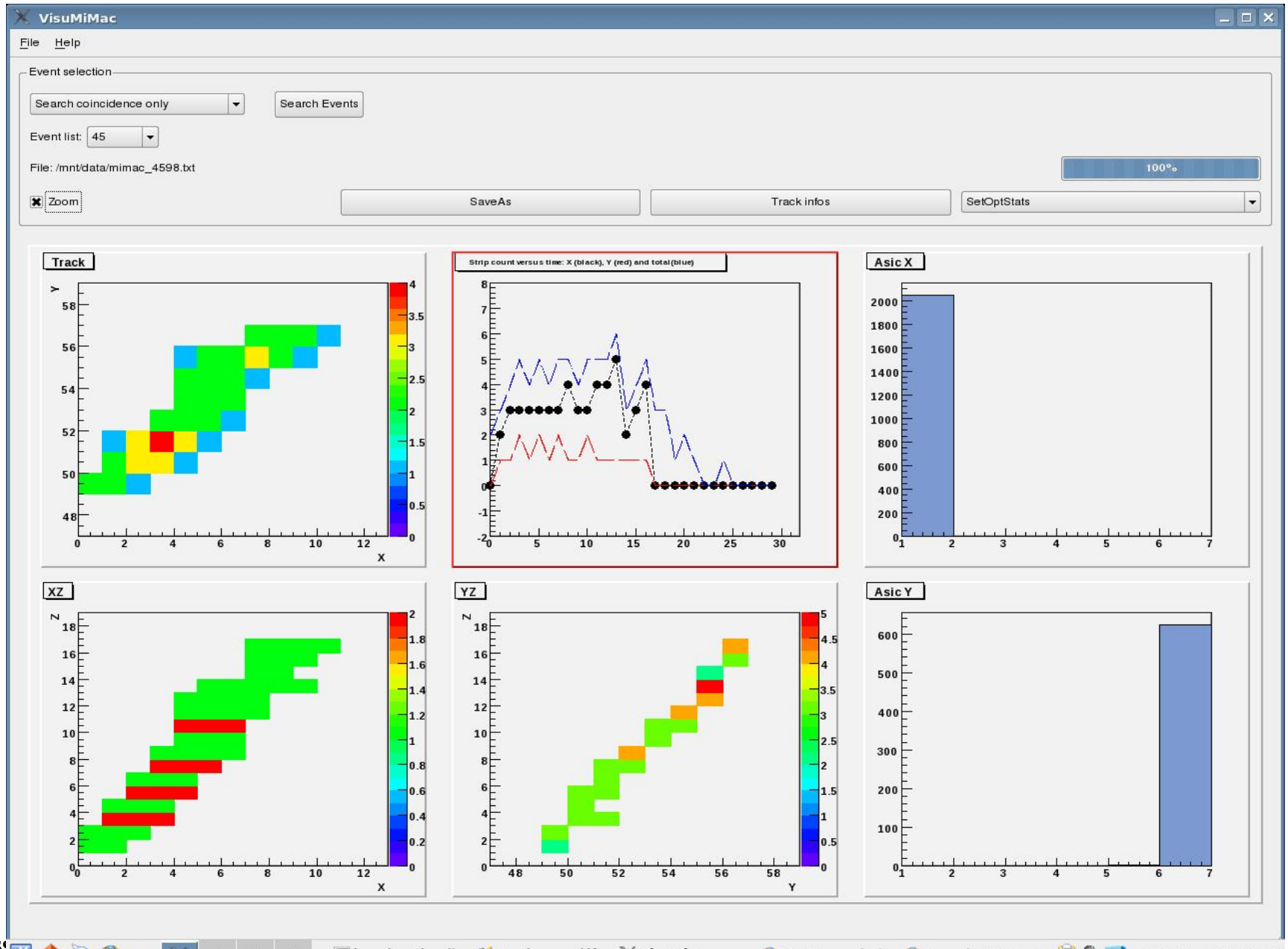
cathod

Drift space : 15 cm

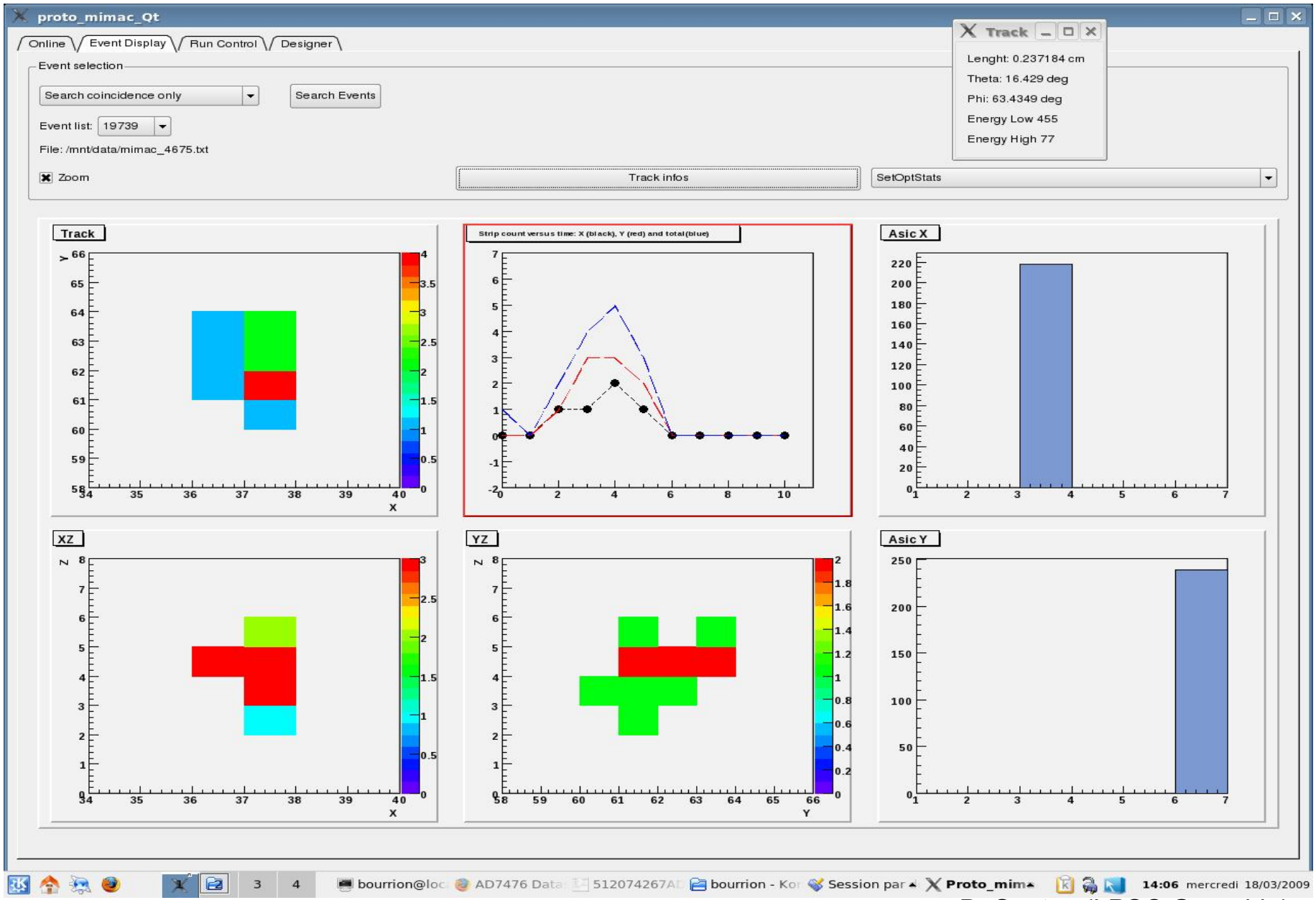
Micromegas

+pixellized anod (x,y)

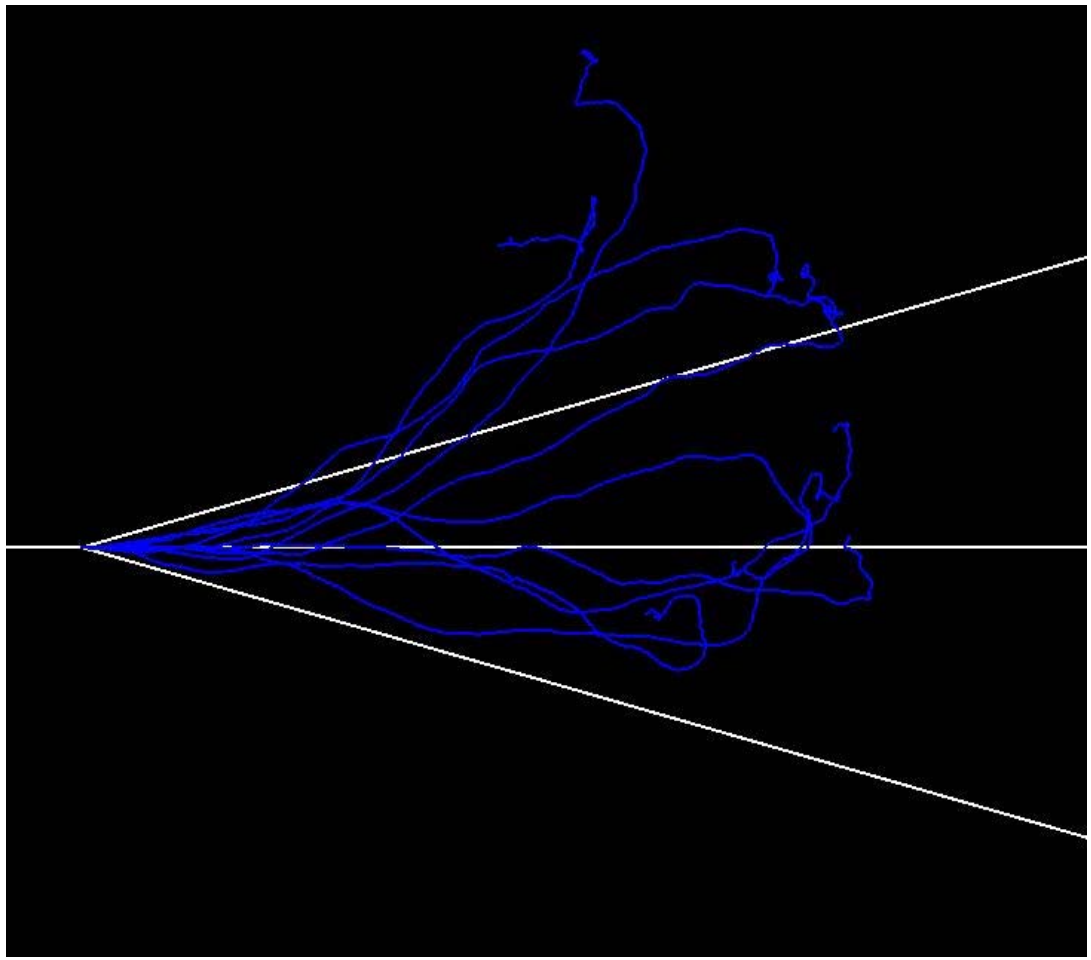
3D track measurement of an electron (5.9 keV, 350mbar)



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



^{4}He (6 keV) in ^{4}He (100mbar)
range ~ 4mm



Directionality of recoils measured in 3D (E ~ 120 keV)