A portable and directional neutron detector MIMAC-FASTn

Nadine Sauzet
Laboratoire de Physique Subatomique et de Cosmologie
(LPSC-Grenoble)
(UJF Grenoble 1, CNRS/IN2P3, Grenoble INP)

LABEX ENIGMASS – Valorisation MIMAC

Project objectives

- Fast neutron detection, with electron/recoil discrimination,
- Neutron energy spectrum measurement,
- Neutron emitter location,
- A mobile and portable solution.

Project roots

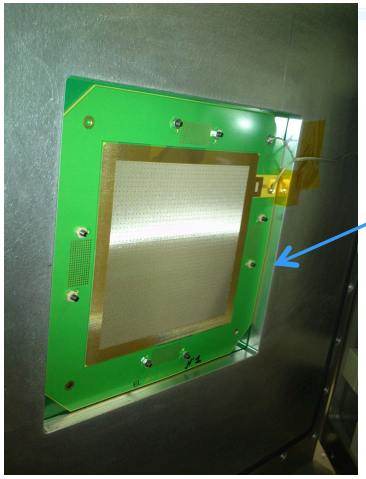
- MIMAC project (MIcro-TPC Matrix of Chambers) :
  - Instrumentation dedicated to directional non baryonic dark matter detection,
  - Developed at LPSC-Grenoble (electronics, gas system, data acquisition, mechanical structure, quenching measurements),
  - Can be adapted for fast neutron detection.

- Instrumentation solution and originality :
  - Coupling of a specifically designed fast and self-triggered electronics, to a micro-patterned detector with a pixelated anode,
  - Coupling thanks to a specific tight interface,
  - System performance : very low electronic noise.

LPSC Grenoble

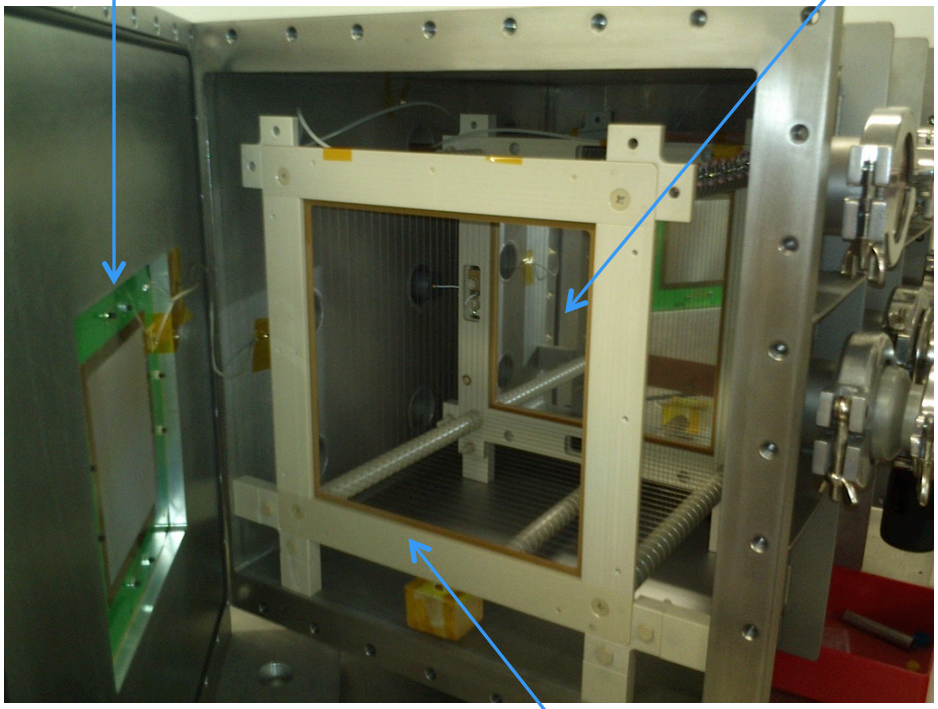
cnrs IN2P3 Les deux infinis

MIMAC instrumentation solution



MicroMégas (CEA/Saclay)
10cm x 10cm

Cathode

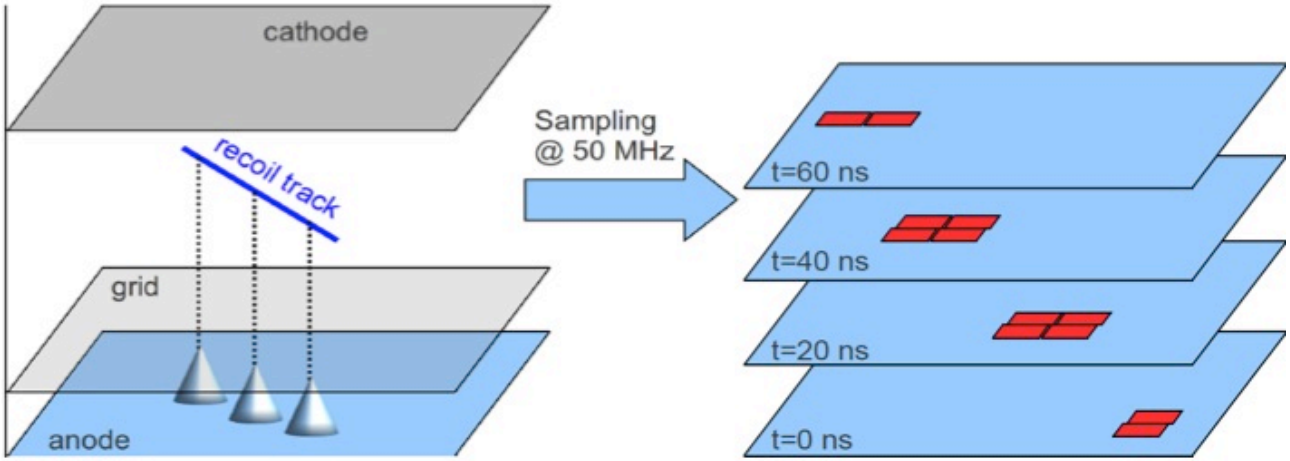


Electronic board

Field cage / 25 cm drift

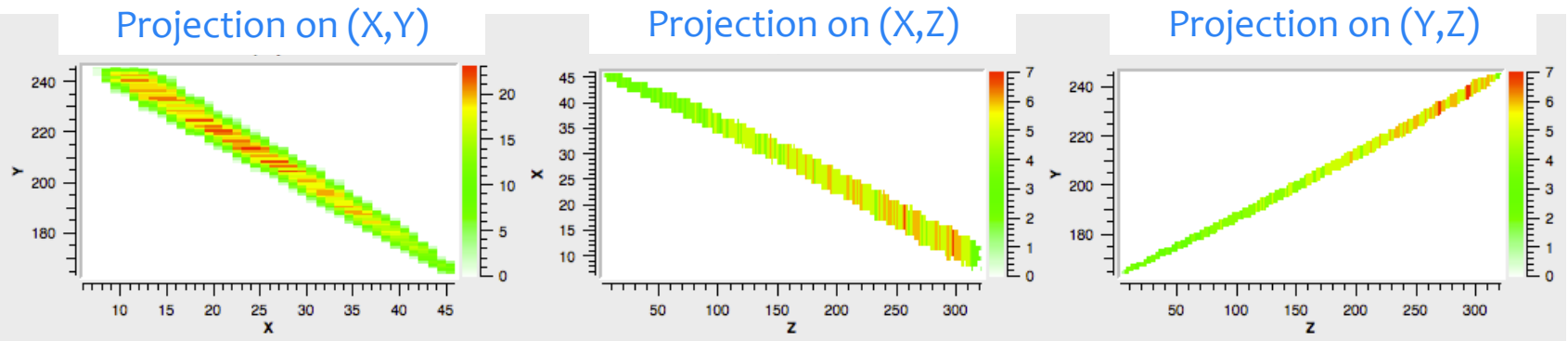
Detection principle

- Detection based on a nuclear recoil tracking, that results from the interaction between a neutron and a gas nucleus.
  - Drift in a ionization chamber,
  - Gas amplification in a MicroMegas,
  - Readout on a pixelated anode, sampled at 20 ns.

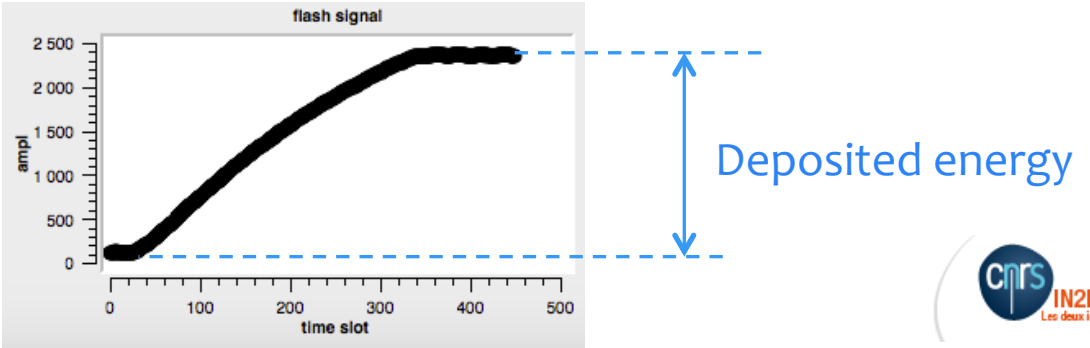


System outputs

- Nuclear recoil tracks :
  - Length, angles
  - Example of track projections (*α track with a He / CO2 (5 %) mixture at 900 mbar*) :



- Ionization energy read on the mesh (*α track with a He / CO2 (5 %) mixture at 900 mbar*) :



Flexibility

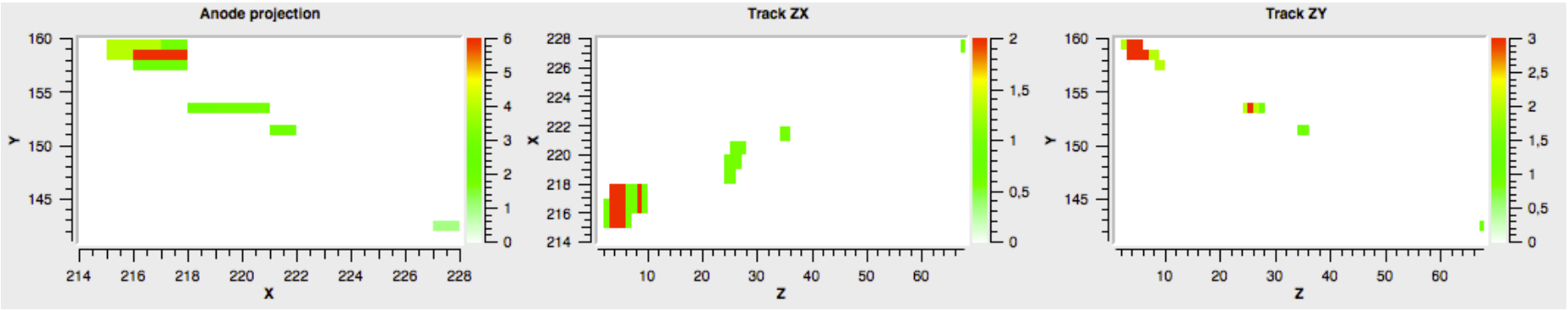
- Adaptable parameters depending on the performance targeted :
  - Gas nature
  - Gas pressure
  - MicroMegas gap

- Examples of adaptation :

Gas composition	Gas pressure	Micromegas gap	Neutron energy range
CF_4 / CHF_3 (28 %)/C_4H_{10} (2%)	50 mbar	256 µm	[5 keV ; 565 keV]
C_4H_{10} / CHF_3 (40 %)	50 mbar	256 µm	[8 keV ; 250 keV]
He / CO_2 (5 %)	900 mbar	128 µm	[100 keV ; 8 MeV]

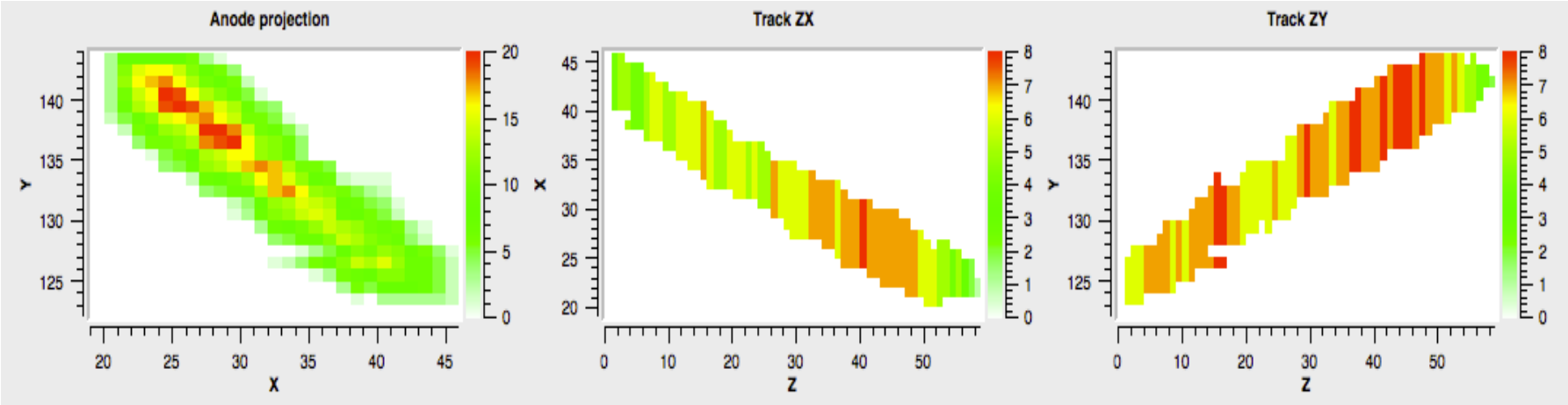
Electron/recoil discrimination : electrons

- **Electrons** let clusters in the gas
- Example of electron track in a He / CO2 (5 %) mixture at 900 mbar :



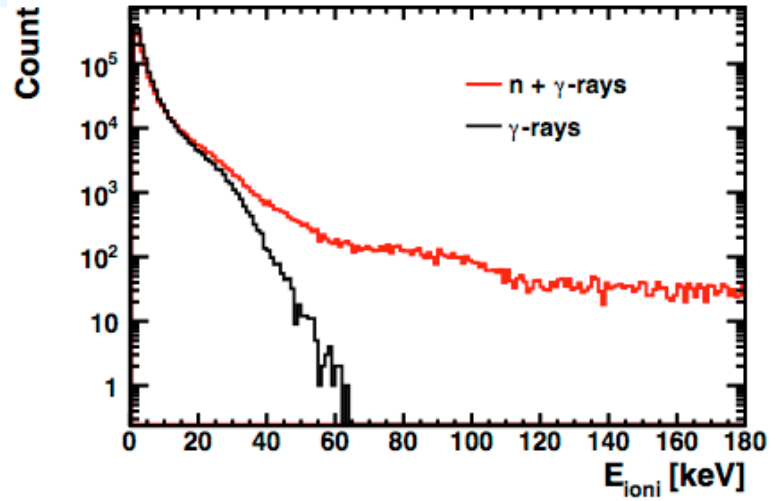
Electron/recoil discrimination : recoils

- **Recoils** let very dense tracks
- Example of recoil track in a He / CO2 (5 %) mixture at 900 mbar :

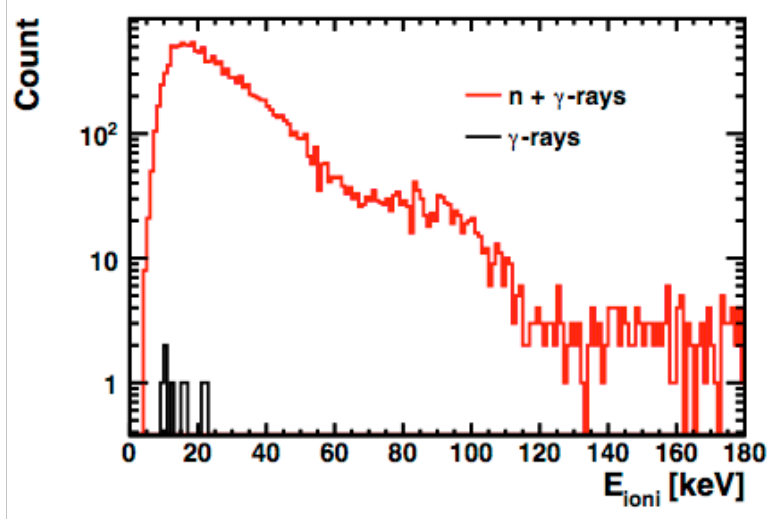


Electron/recoil discrimination for low neutron energies

- In CF_4 / CHF_3 (28 %) /C_4H_{10} (2%) at 50 mbar
- $^7Li(p,n)^9Be$
- Neutron energy = 565 keV
- With or without ^7Li target



- After electron rejection with a BDT multivariate analysis :

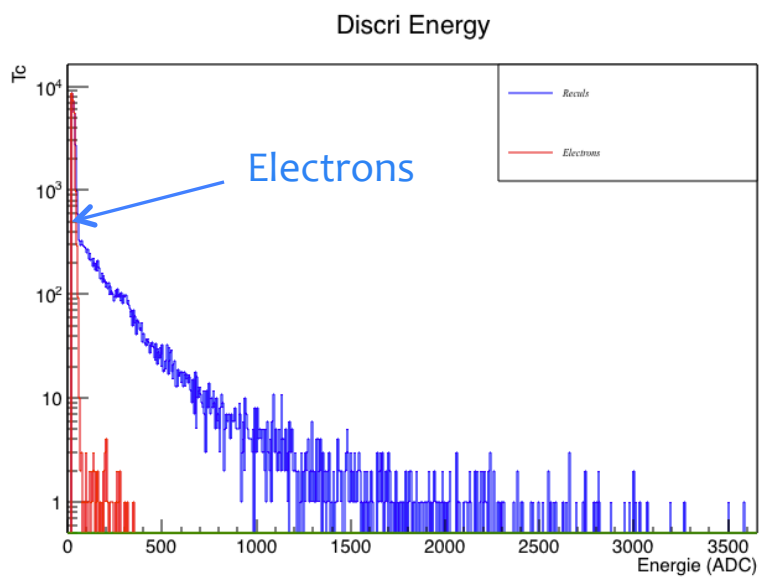


Q.Riffard *et al. To be published*

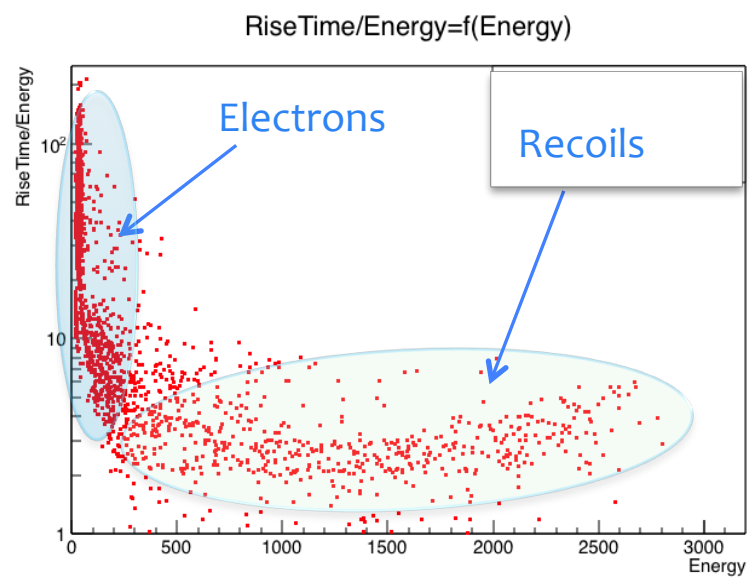
Electron/recoil discrimination for high neutron energies (a few MeV)

- In a He / CO2 (5 %) mixture at 900 mbar
- Preliminary results :

Energy spectrum :

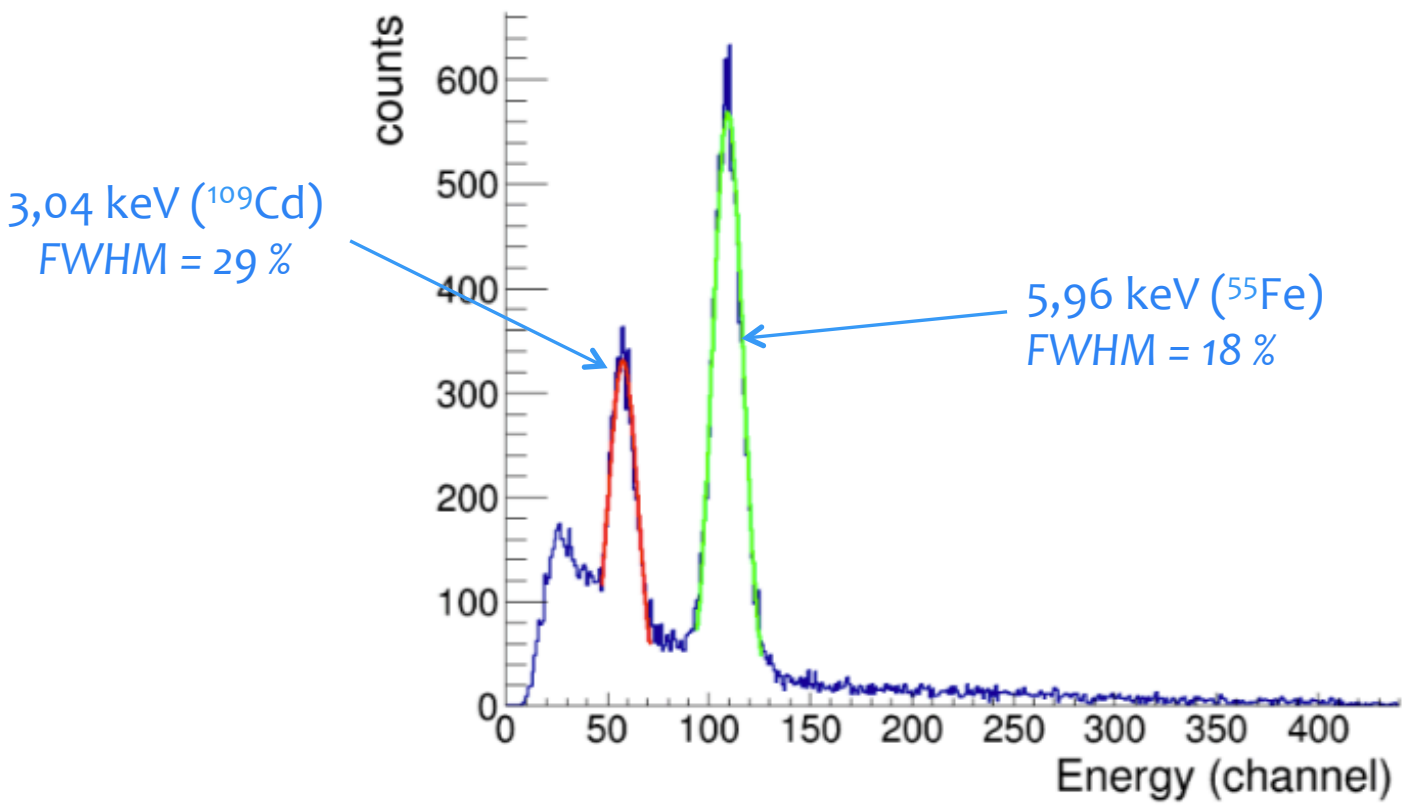


Risetime/Energy = f(energy):



Calibration for the range [8 keV ; 250 keV]

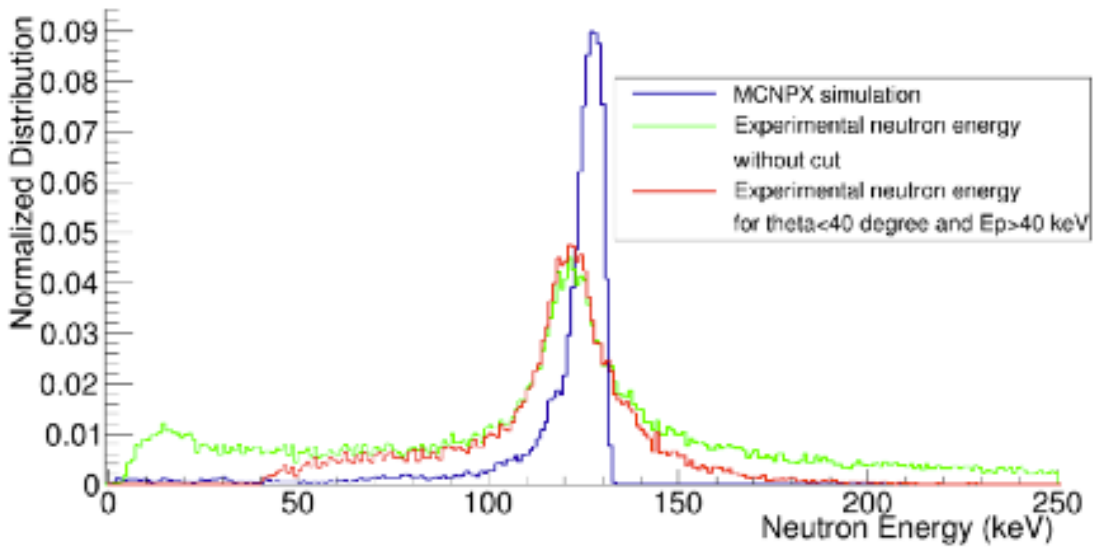
- Example of energy calibration, with ^{109}Cd and ^{55}Fe, in a C_4H_{10} / CHF_3 (40 %) mixture at 50 mbar :



D.Maire *et al.*, IEEE transactions on nuclear science, vol. 61, no. 4, august 2014
arXiv:1310.6837

Measure of a 127 keV neutron field

- With a C_4H_{10} / CHF_3 (40 %) mixture at 50 mbar,
- Measurement on AMANDE installation,
- $^7Li(p,n)^9Be$,
- Monoenergetic neutron beam : energy = 127 keV
- Neutron energy spectrum, by reconstruction from the nuclear recoils :



D.Maire *et al.*, IEEE transactions on nuclear science, vol. 61, no. 4, august 2014
arXiv:1310.6837

Configuration for higher energies

- Tests performed with a He / CO_2 (5 %) mixture at 900 mbar.
- Energy range targeted = [100 keV ; 8 MeV].
- Electric fields adapted to get dense tracks and complete charge collection.

Features with a He/CO_2 mixture

- Charge drift velocity is quite low : 10 µm/ns
- $\sigma_{\text{Eff elastic collision n/He}}$ = [1 barn ; 10 barn]
- Charge collection time max ≈ 10 µs

- Track lengths related to the recoils energy :

Neutron energy	He recoil energy	He track length
7 MeV	4,48 MeV	13,3 cm
5 MeV	3,2 MeV	8,2 cm
3 MeV	1,92 MeV	4,4 cm

LPSC Grenoble

cnrs IN2P3 Les deux infinis

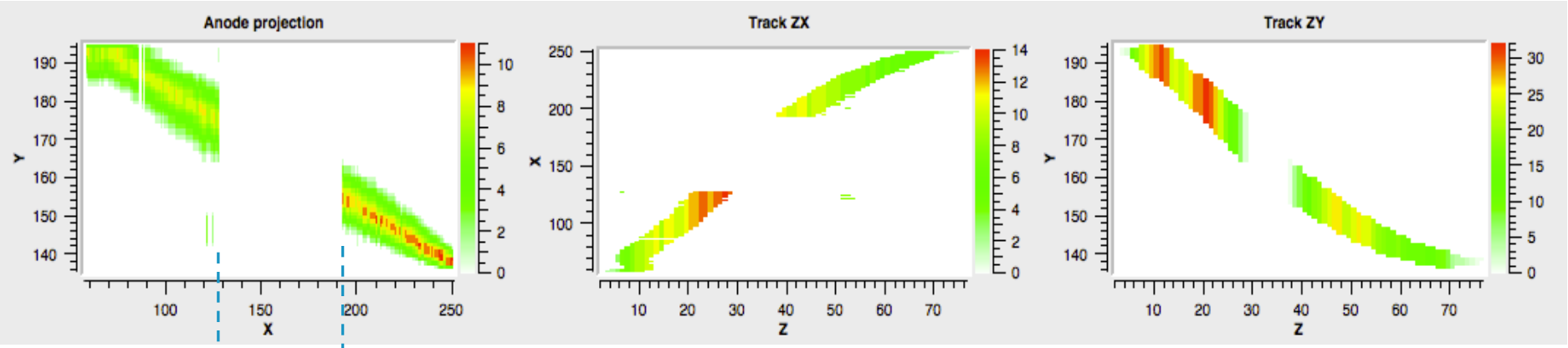
Calibration strategy with a natural boron layer (1)

- Use of a natural boron layer (estimated thickness = 1 µm), on aluminium plate :
  - Plate inside the cage field,
  - At 2 cm from the front of the cathode,
  - At 23 cm from the mesh.
- Exposition to neutrons from an AmBe source thermalized, at 50 cm of the detector :
  - $^{10}B(n,\alpha)$

Particule	Energy	Track length
α	[1,12 MeV ; 1,78 MeV]	[2,8 cm ; 4,1 cm]
Li	[515 keV ; 1,16 MeV]	[1,7 cm ; 2,5 cm]

Calibration strategy with a natural boron layer (2)

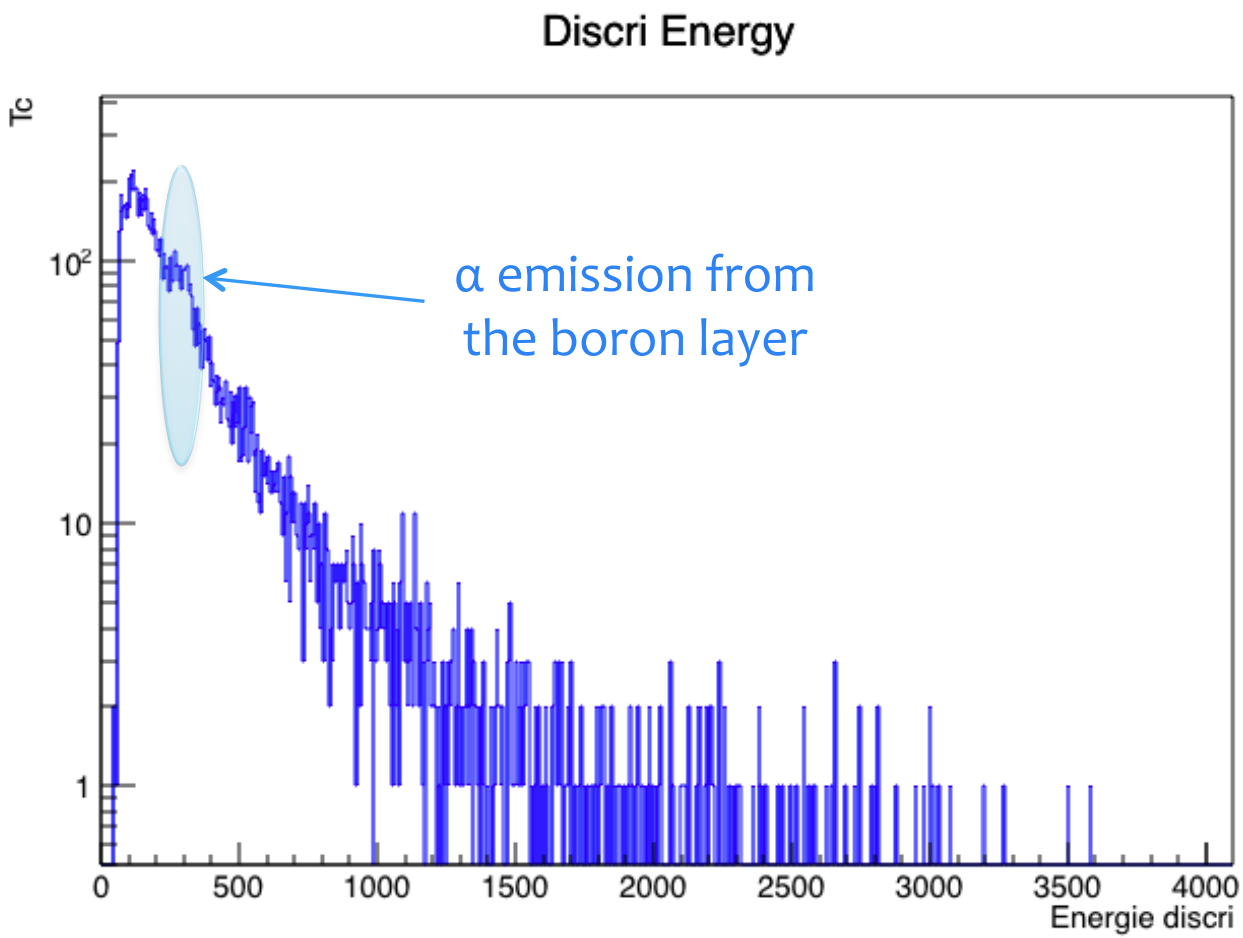
Track behind the boron deposit



Boron width

Calibration strategy with a natural boron layer (3)

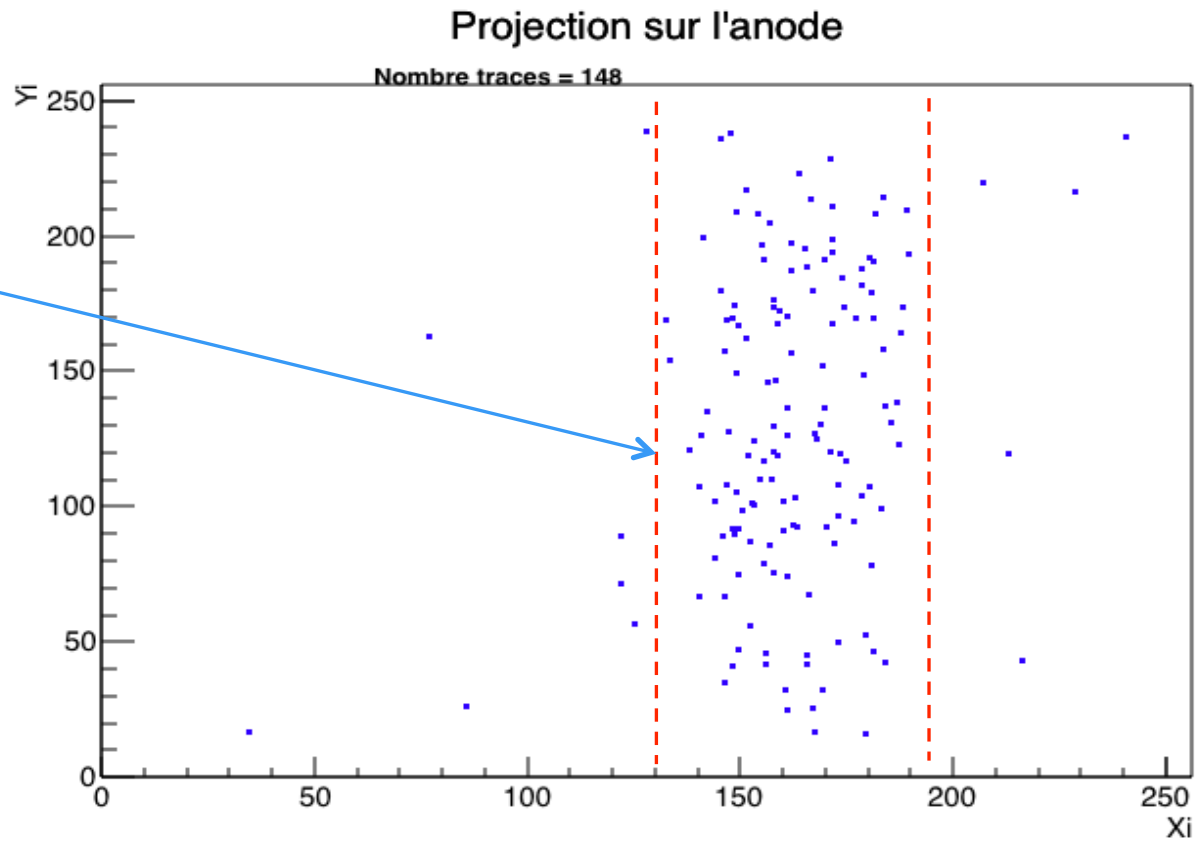
Energy spectrum with thermal neutrons :



Calibration strategy with a natural boron layer (4)

- Reconstruction of the boron layer location inside the detector :
  - 1st interaction inside the drift volume
  - Projection on the anode (axis in pixels) :

Boron layer

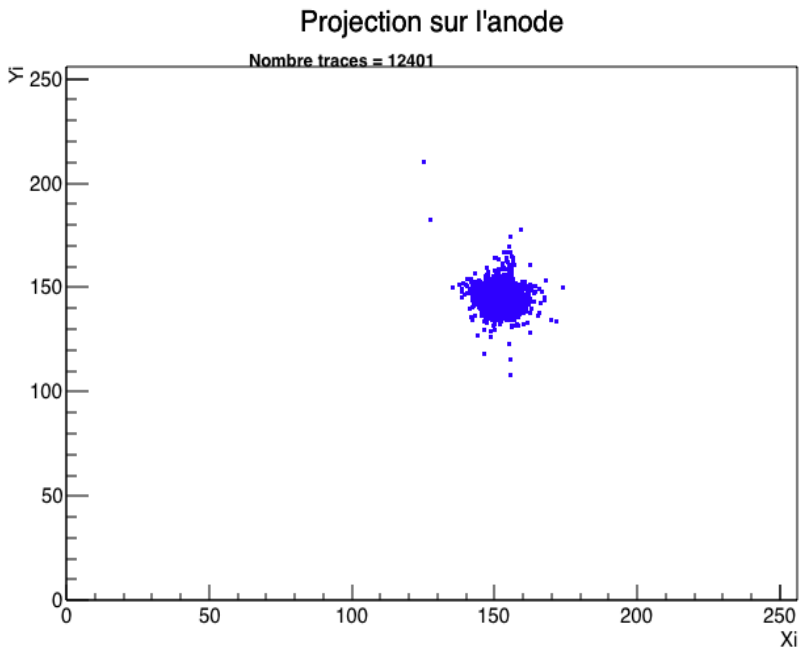


Directionnality analysis (1)

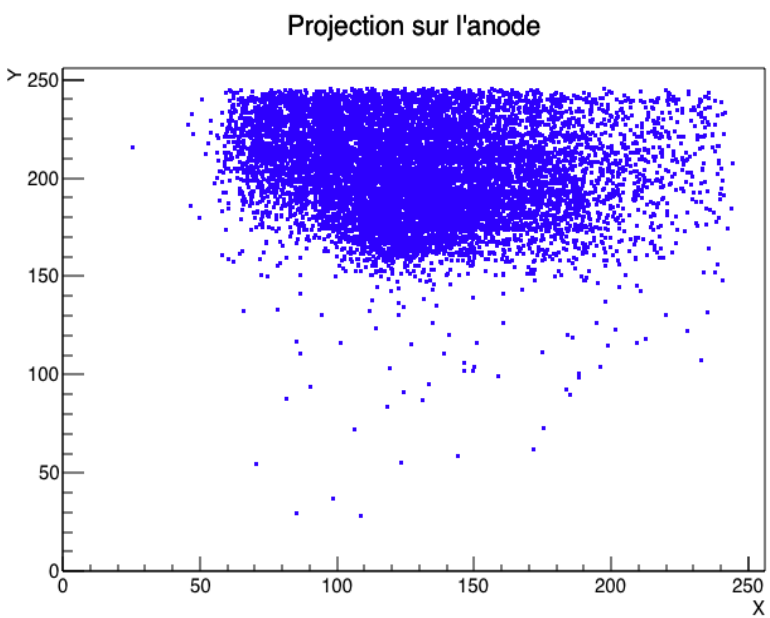
- Measurement with a ^{244}Cm source, collimated behind a thin aluminium foil (120 um, with a hole of 1,5 mm),
- The source is placed inside the detector, in the middle, at 2 cm in front of the cathode,
- Reconstruction of the α emitter location, from the recoil tracks data.

Directionnality analysis (2)

First interaction in the volume *(axis in pixel)* :

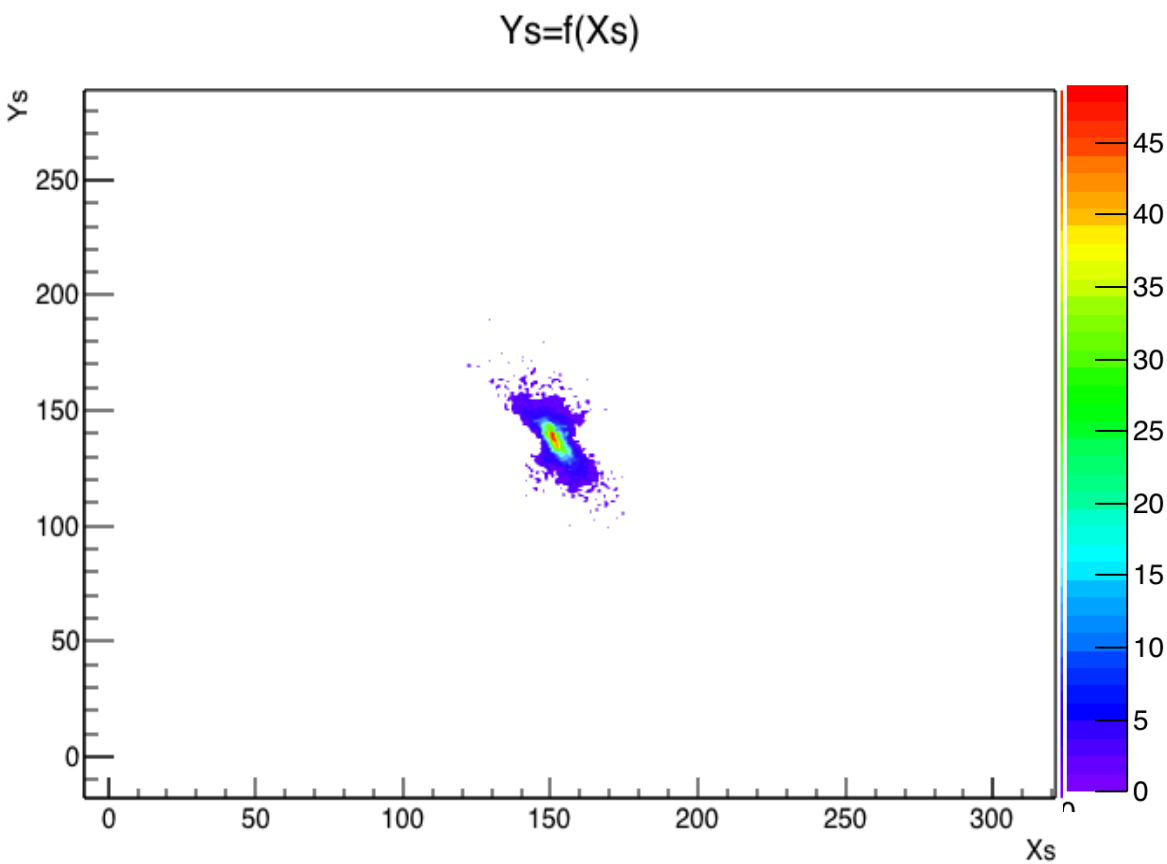


Last interaction in the volume :



Directionnality analysis (2)

- Projection of the α emitter location on the anode :
  - The emitter is behind a collimator



Conclusion and perspectives

- Flexibility to reach different energy ranges.
- The electron/recoil discrimination has been performed for low neutron range energy, in CF_4 / CHF_3 (28 %) /C_4H_{10} (2%) at 50 mbar.
- On-going work for energies above 1 MeV.
- The neutron spectrum reconstruction ability has been demonstrated in a hydrogenated gas mixture, at 127 keV level.
- The directionality ability has been demonstrated.
- Thermal neutron captures on boron have been detected and located : to be used for calibration.
- Very promising data, with on-going tests for neutron energies above 1 MeV.

LPSC Grenoble

cnrs IN2P3 Les deux infinis