A portable and directional fast neutron detector MIMAC-FASTn

An application : AB-NCT

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LABEX ENIGMASS – Valorisation MIMAC

Summary

1. **Strategy for fast neutron detection with MIMAC**
2. Electron/Recoil discrimination
3. Detection of thermal neutrons
4. Energy calibration
5. Detection of a few MeV neutrons

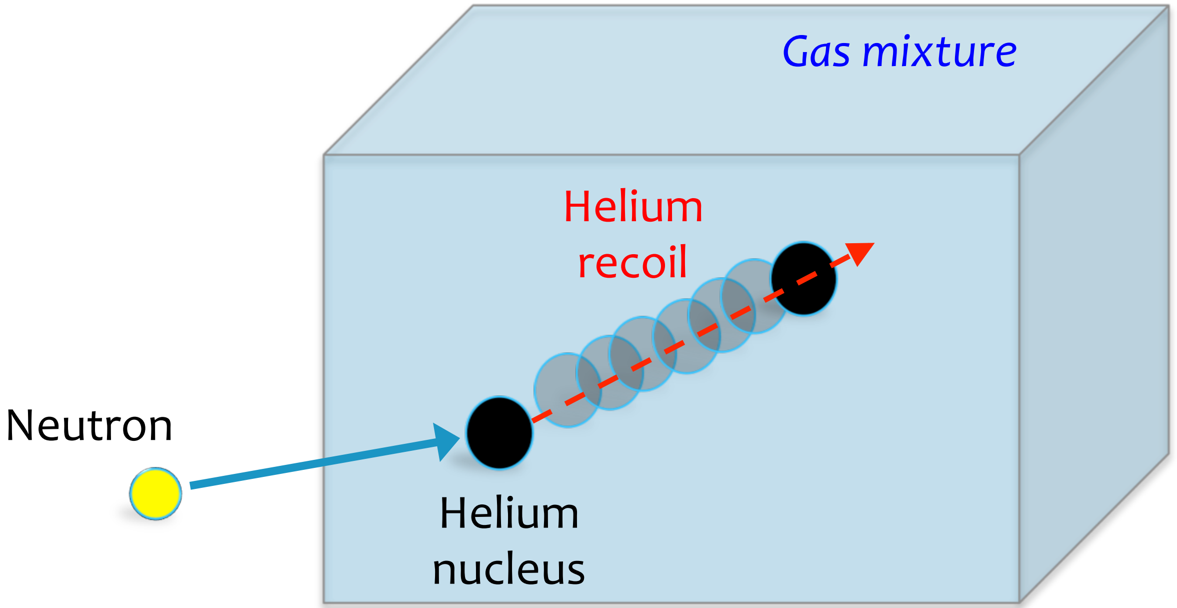
Project roots

- 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.

Detection principle (1)

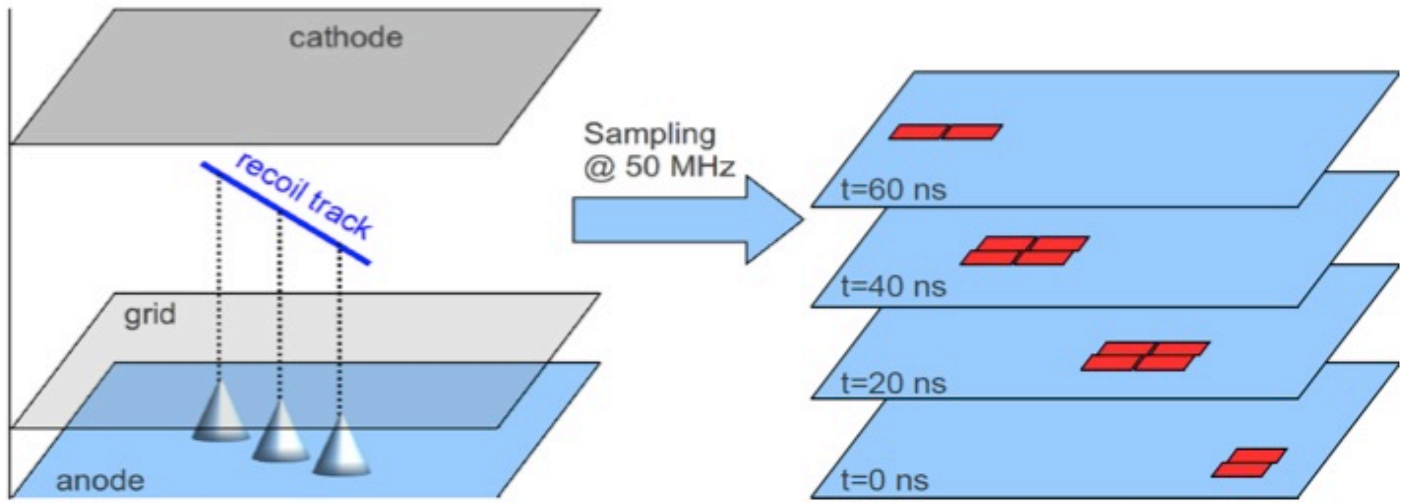
- Detection based on a nuclear recoil tracking, that results from the interaction between a neutron and a gas nucleus.



Recoil $_{\text{Energy max}}$ = 64 % $_{\text{Neutron Energy}}$

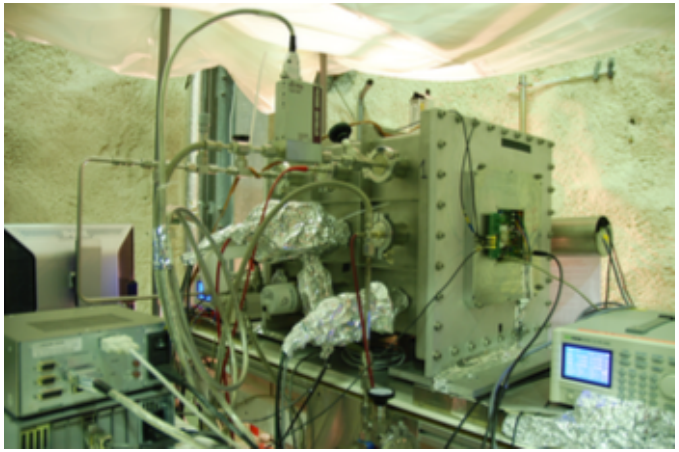
Detection principle (2)

- Drift in a ionization chamber,
- Gas amplification in a MicroMegas,
- Readout on a pixelated anode, sampled at 20 ns.



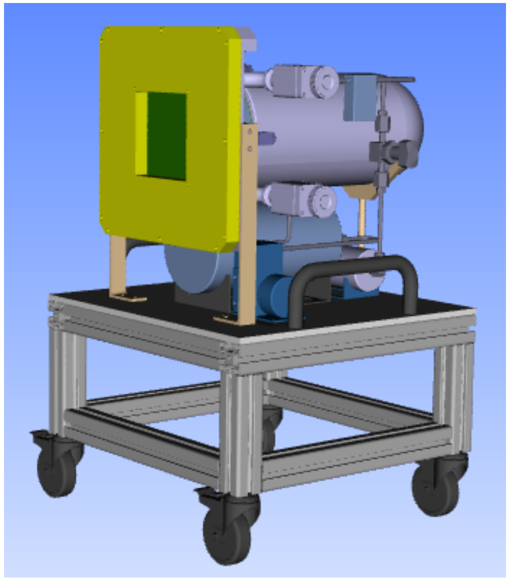
Detector preview

MIMAC detector



1st prototype IRSN detector

MIMAC-FASTn



DIRE prematuration program

Operational parameters

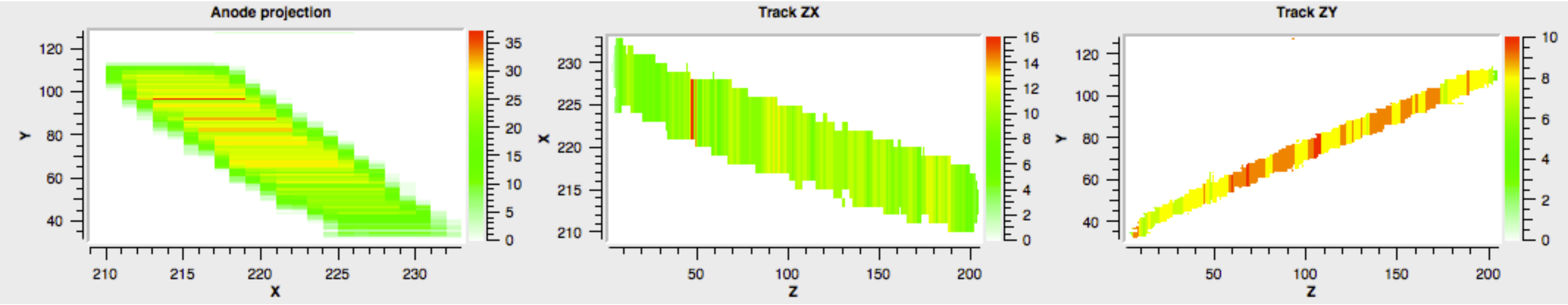
- Operational parameters adapted for high energy neutrons detection :
  - An inert gas mixture : He / CO_2
  - Gas pressure : around atmospheric pressure

- Typical neutron energy range = [120 keV ; 6 MeV]

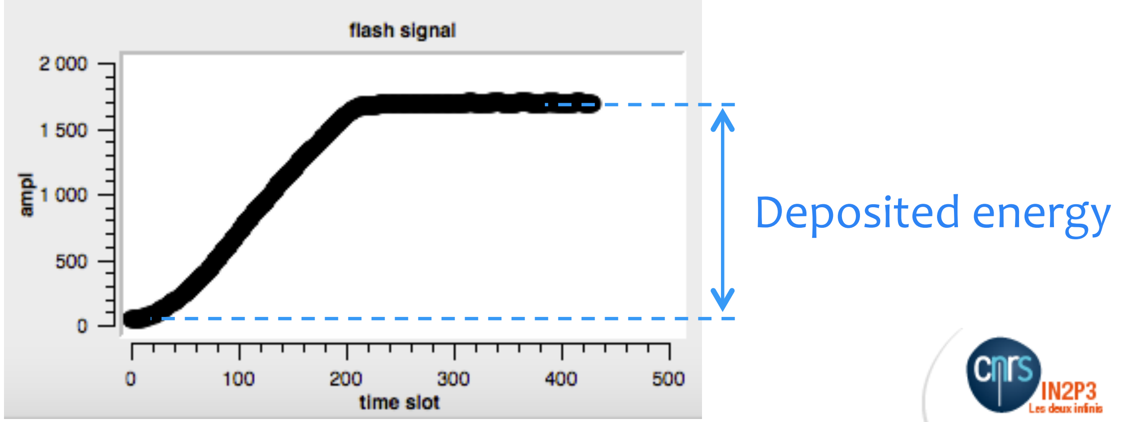
- Flexibility to cover different energy scales.

Nuclear recoils signature

- Example of a recoil track in a He / CO_2 mixture :



- Associated energy :



1. Strategy for fast neutron detection with MIMAC
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Electron/recoil discrimination

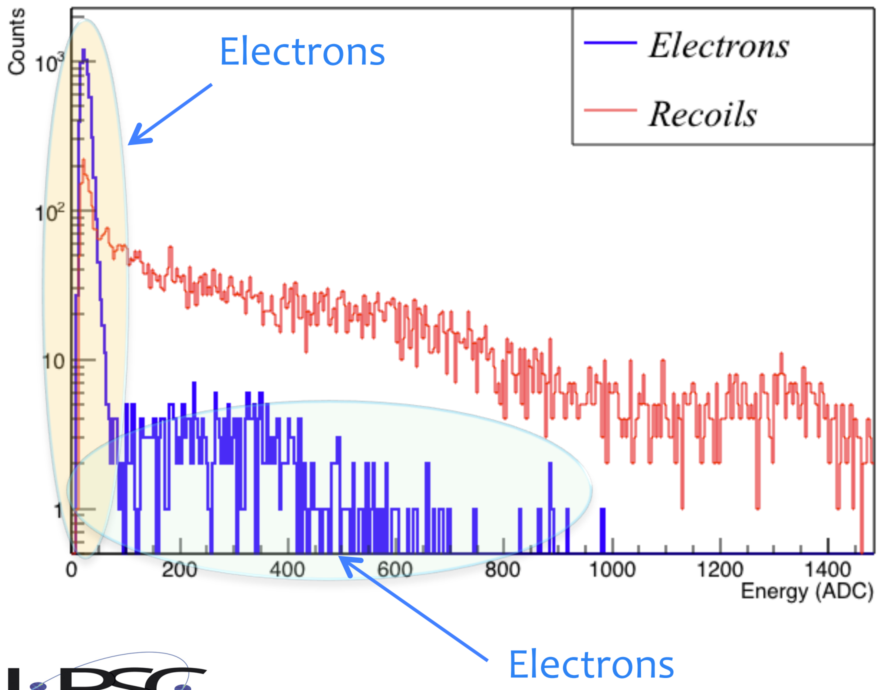
- **Objective :**
  - Discriminate recoils (resulting from neutron/gas nucleus interaction), from electrons

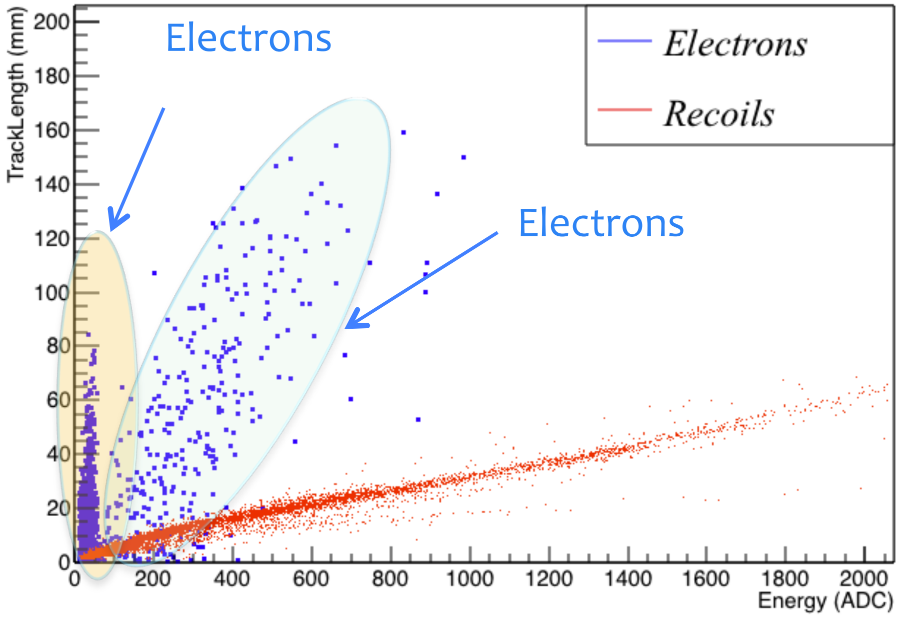
- **Origin of electrons :**
  - Compton electrons resulting from gamma rays interaction with the detector walls,
  - β desintegration of nucleii intrinsic to the detector.
  - Cosmic rays : muons, protons.

Electron/recoil discrimination for a few MeV neutrons

- **Measure with a thermalized AmBe source**

- Energy spectrum : Track length=f(Energy) :





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Thermal neutrons detection (1)

- Exploitation of the neutron capture reaction : $^{10}B(n,\alpha)$
  - with thermal and epithermal neutrons

$^{10}B + n \longrightarrow {}^{7}Li^{*} + \alpha \longrightarrow {}^{7}Li + \alpha + \gamma$ *(94 %)*

$^{10}B + n \longrightarrow {}^{7}Li + \alpha$ *(6 %)*

- Secondaries energies and estimated tracks' lengths :

Particule	Energy	Track length
	94 %	
α	[1,12 MeV ; 1,47 MeV]	[3,4 cm ; 4,13 cm]
Li	[515 keV ; 840 keV]	[2,2 cm ; 2,8 cm]
	6 %	
α	[1,43 MeV ; 1,78 MeV]	[4,2 cm ; 5,2 cm]
Li	[835 keV ; 1,16 MeV]	[2,8 cm ; 3,3 cm]

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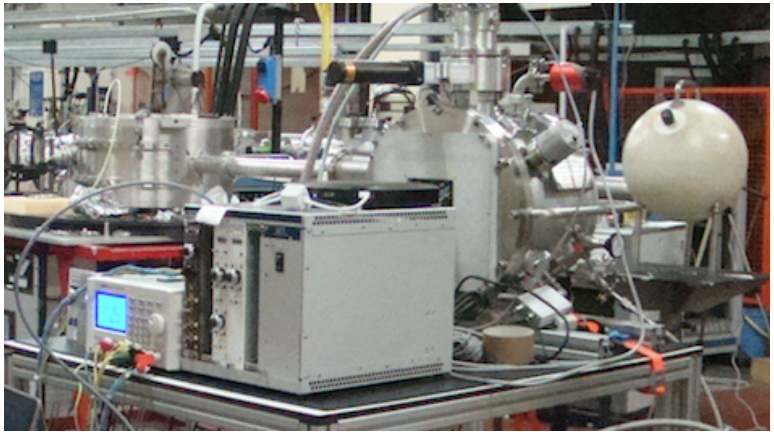
Thermal neutrons detection (2)

- Experiment performed at INFN / Legnaro
  - In collaboration with Buenos Aires, Grenoble, Cadarache, Legnaro, Sevilla

- Principle :
  - Deuteron beam of 1,45 MeV
  - A thin ^{9}Be target of 10 µm
  - Neutron detector : first prototype (IRSN), adapted for operation with He/CO_2 gas mixture.



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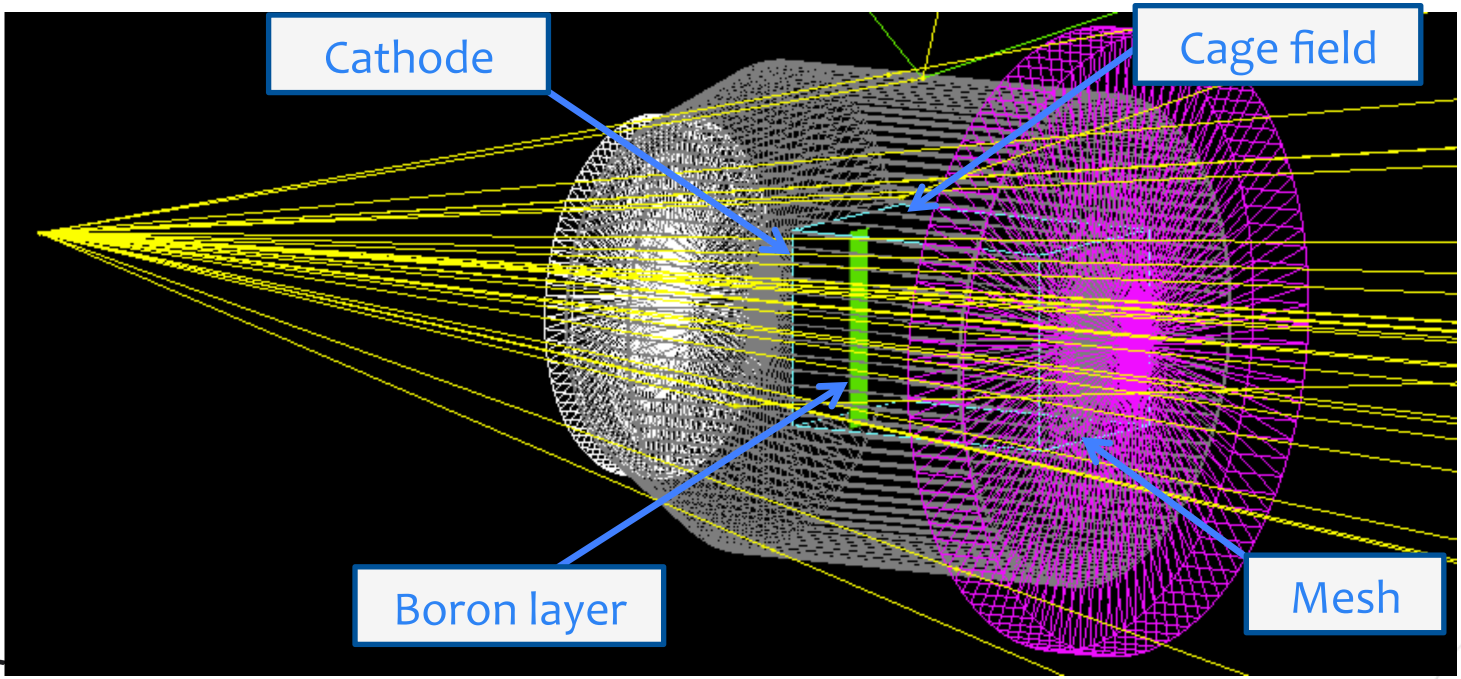
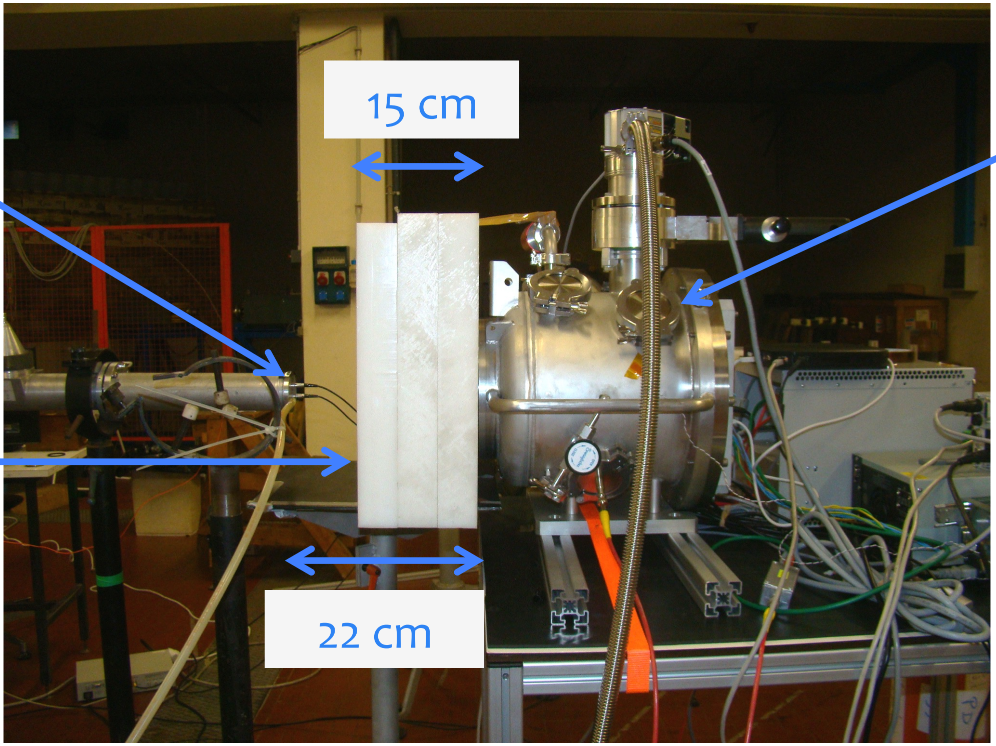
Thermal neutrons detection (3)

- Integration of a natural boron layer, inside the neutron detector :
  - Aluminium plate holder inside the cage field,
  - At 3 cm from the front of the cathode, and 14 cm from the mesh.



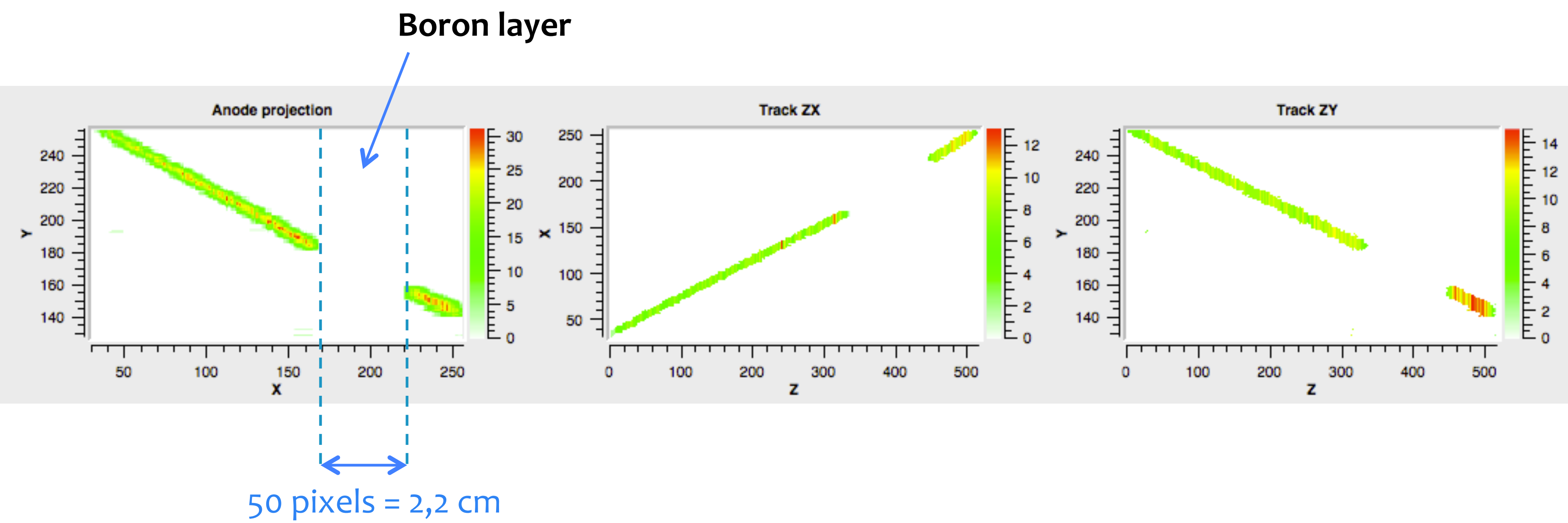
Thermal neutrons detection (4)

- Configuration of the experiment :
  - Moderation of neutrons with polyethylene plates
  - Deuteron beam current ≈ 60 nA
  - Count rate ≈ 30 c/s



Thermal neutrons detection (5)

- Check of the boron layer location :
  - Example of a track behind the boron layer :

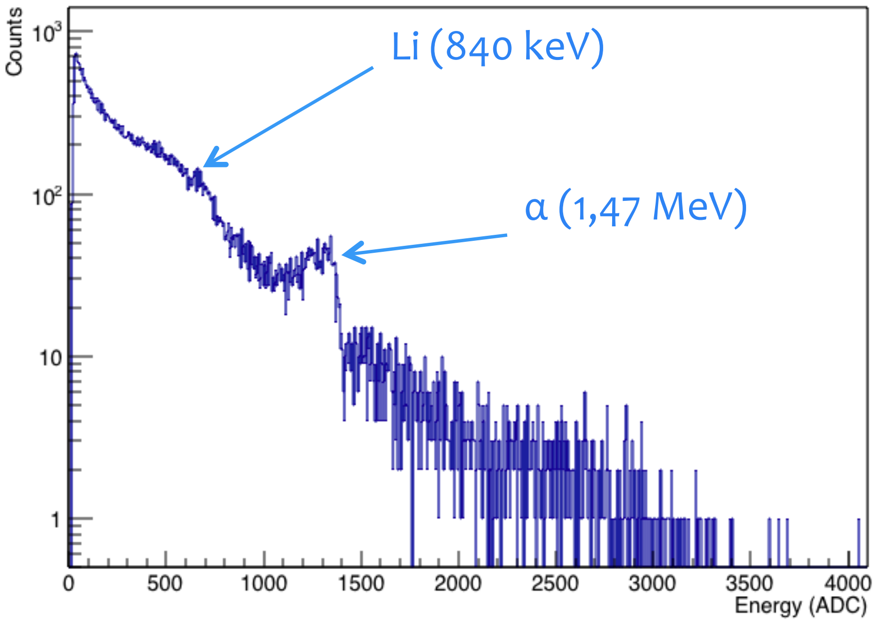


→ No electrical field distortion

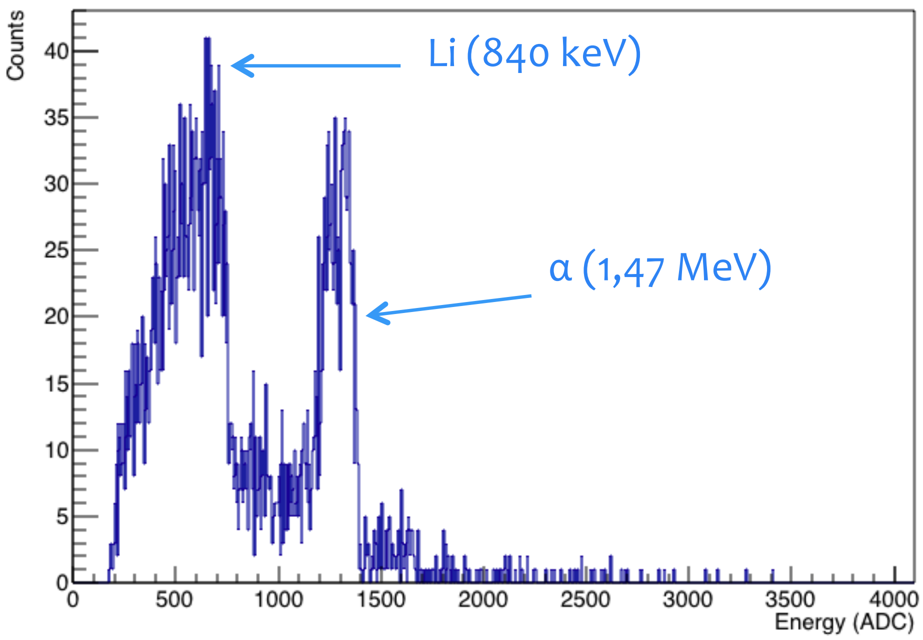
Thermal neutrons detection (6)

- Energy spectrum with thermal neutrons :

Raw spectrum, after minimal cuts :

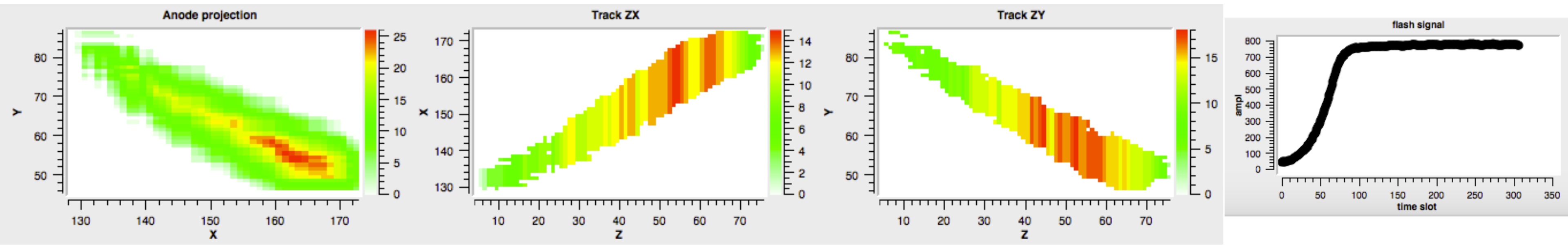


After data selection :

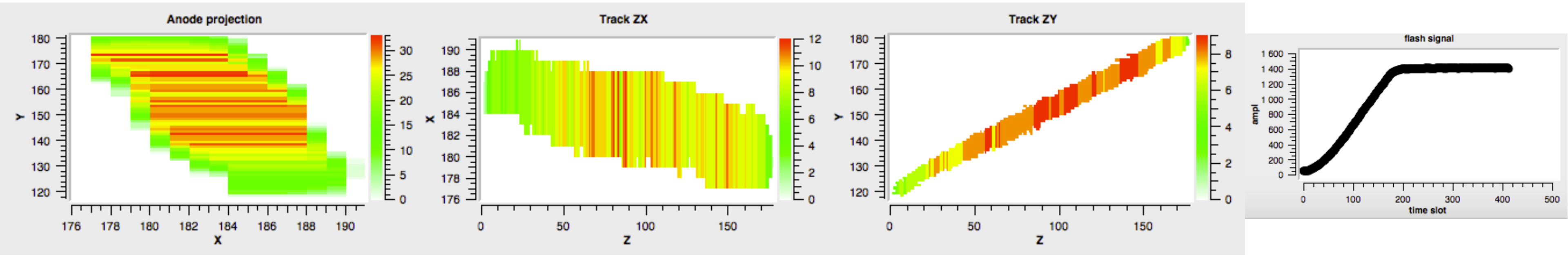


Thermal neutrons detection (7)

- Lithium track and energy :

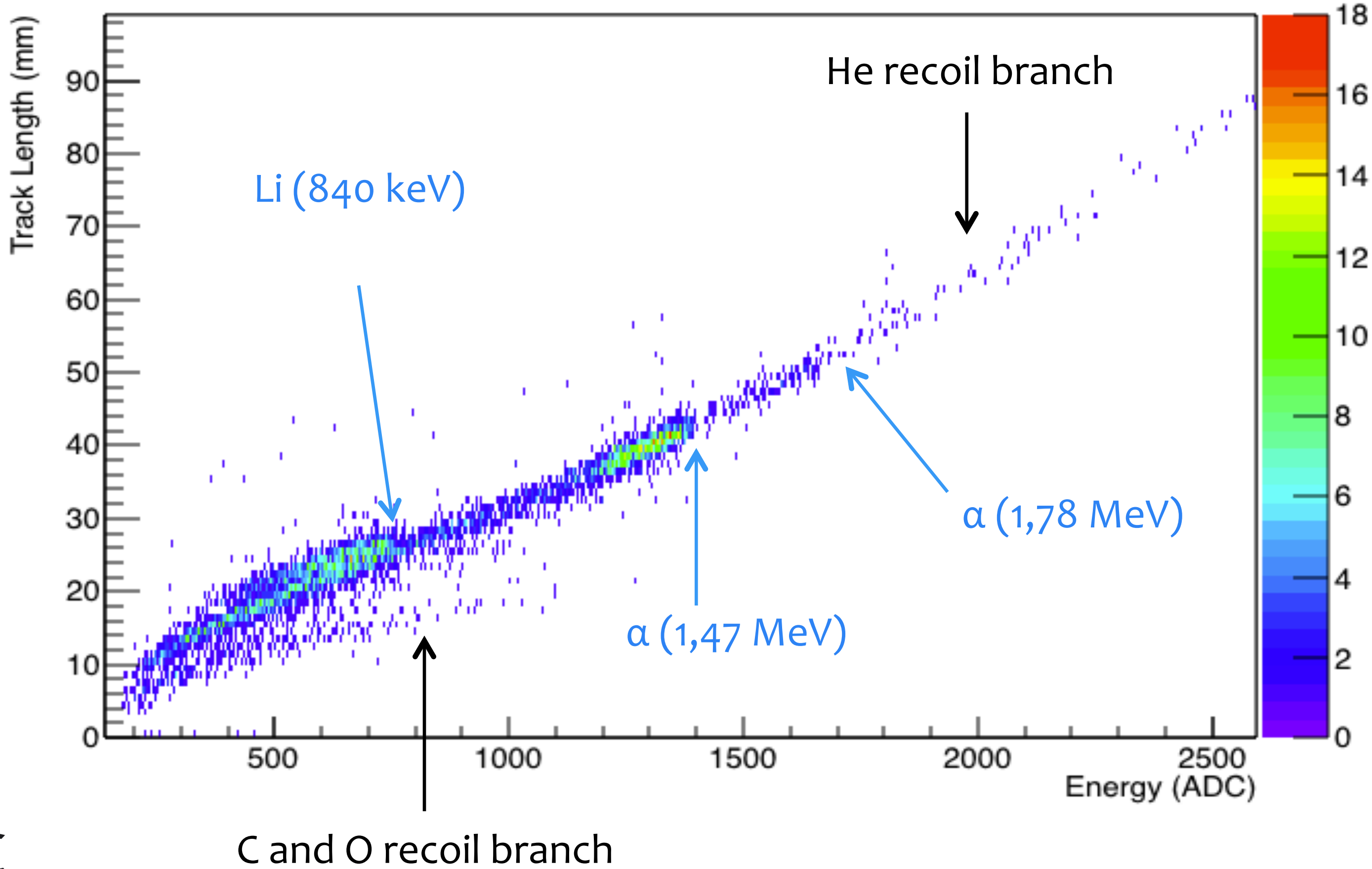


- Alpha track and energy :



Thermal neutrons detection (8)

- Track length = f(Energy) :



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Energy calibration

- Strategy :
  - Exploitation of the thermal neutrons detection principle.
  - Identification of the end-points of α and Li particles distributions.
  - Definition of a few observables, relevant to identify the end-points.

- Example of resulting energy range :
  - [120 keV ; 6 MeV]
  - [70 keV ; 3,8 MeV]

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5. **Detection of a few MeV neutrons**

Detection of a few MeV neutrons (1)

- Objective :
  - Faisability to build a fast neutron spectrum in the range [120 keV ; 6 MeV]

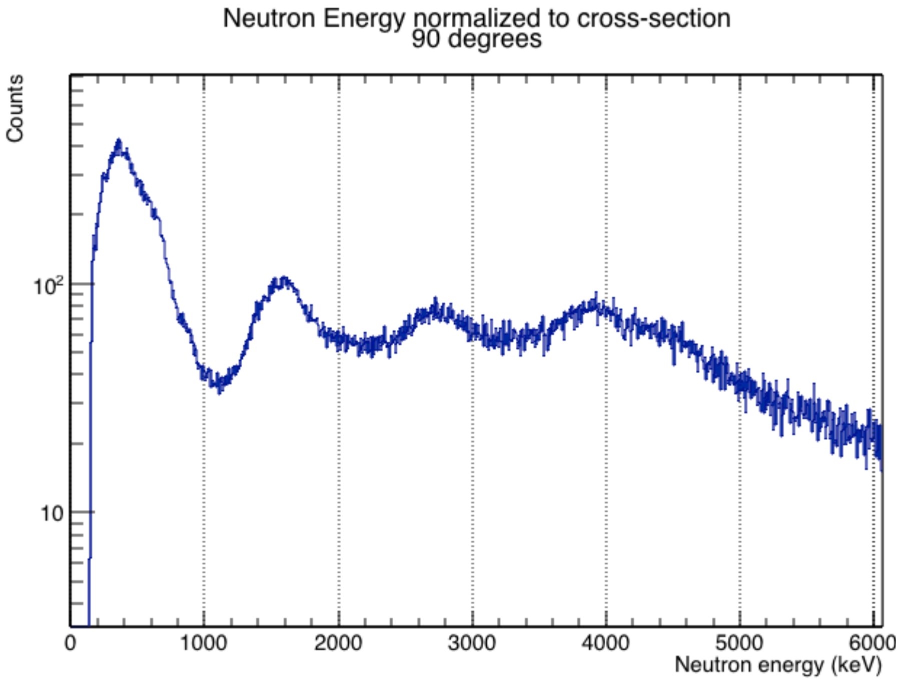
- Principle :
  - Fast neutrons from the reaction $^{9}Be(d,n)$
  - Same protocol as for the thermal neutrons detection, without polyethylene plates.
  - Detector at 90° and 35° of the target plan.

- Present results :
  - Preliminary state

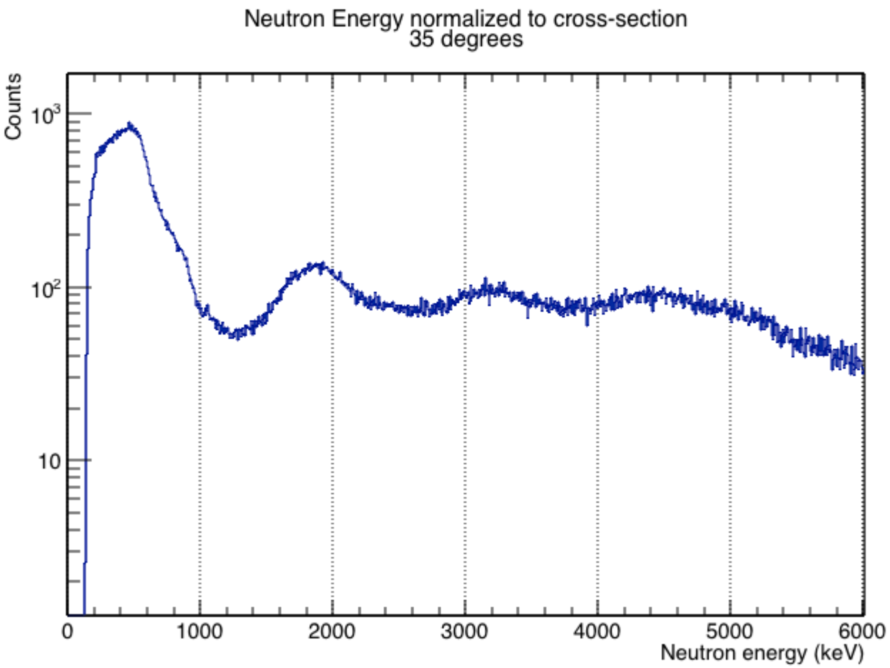
Detection of a few MeV neutrons (2)

- **Preliminary spectra** with $^{9}Be(d(1,45\ MeV),n)$:

At 90°



At 35° :



→
- Structures emerge
- Quantitative analysis to perform

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Perspective

- Purpose of MIMAC-FASTn : characterization of fast neutron fields :
  - For AB-NCT subsets sizing,
  - For AB-NCT daily operation.

- Integration of a moderator and of a boron coating :
  - To detect thermal neutrons,
  - to estimate the fast neutrons dose in the patient.

- Manufacturing of a demonstrator.

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