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INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

μ-TPC: a future standard instrument for low energy neutron field characterization

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Context

In the framework of associated laboratory to the French standard laboratory LNE, IRSN (French Institute for Radioprotection and Nuclear Safety) develops tools to produce neutron fields but also must develop instruments and methods to characterize the neutron fields. In order to measure energy of neutron fields, with energy ranging from 8 keV to 1 MeV, a new primary standard is being developed at the IRSN. This future standard, μ-TPC (Micro Time Projection Chamber), developed in collaboration with the LPSC (Laboratory of subatomic physics and cosmology), is a gaseous detector of recoil nuclei.

LNE – Le progrès, une passion à partager

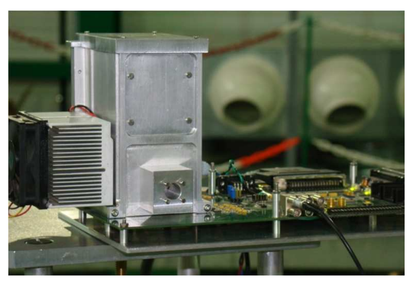
LPSC Grenoble – Laboratoire de Physique Subatomique et de Cosmologie

In continuous mode, the aim is the determination of energy and fluence using a primary reference measurement procedure (VIM 2008), i.e. the measurand must be obtained without relation with a measurement standard of the same kind.

AMANDE facility

AMANDE facility:
- ✓Mono-energetic neutron fields from 2 keV to 20 MeV.
- ✓Neutron scattering is minimized:
  - •experimental hall at 6m from the floor
  - •Metallic walls and ceiling
- ✓A fully automated transport system allows: detectors at any distance between 0.5 and 6m and any angle between -150° and 150°

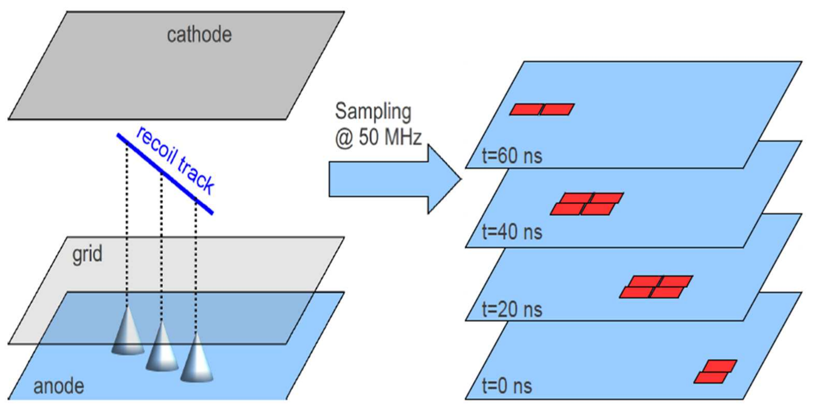
TPR-CMOS
J. Taforeau



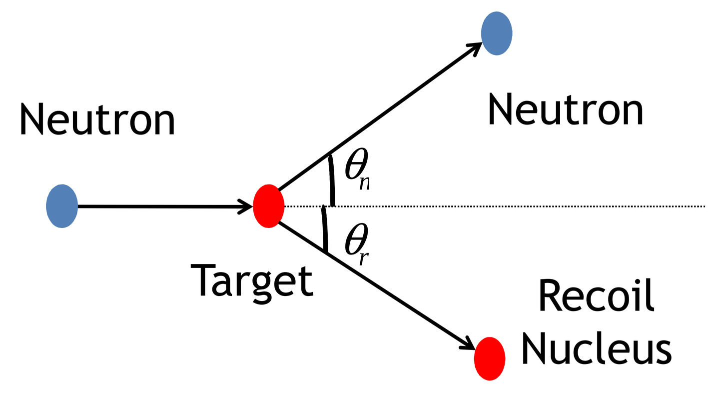
Two detector systems are under development to cover mainly the energy range of neutron produced by AMANDE:
- ✓ TPR-CMOS (ATHENA) from 5 MeV to 20 MeV
- ✓ μ-TPC from 8 keV up to 1 MeV

The detector μ-TPC [6],[7]

I. Detection Principle



Detection principle of the μ-TPC



Elastic scattering between an incident neutron and a recoil target of the medium in the detector.

For neutron energy measurement

Direct measurement of neutron energy

$$E_n = \frac{(1+A)^2}{4A} E_r / \cos^2\theta$$

Scattering angle

Recoil nucleus Energy

For low energy threshold

gas as converter and detection technique

For good detection efficiency

Hydrogen as recoil nucleus (highest elastic cross section, no resonance, highest maximum recoil energy)

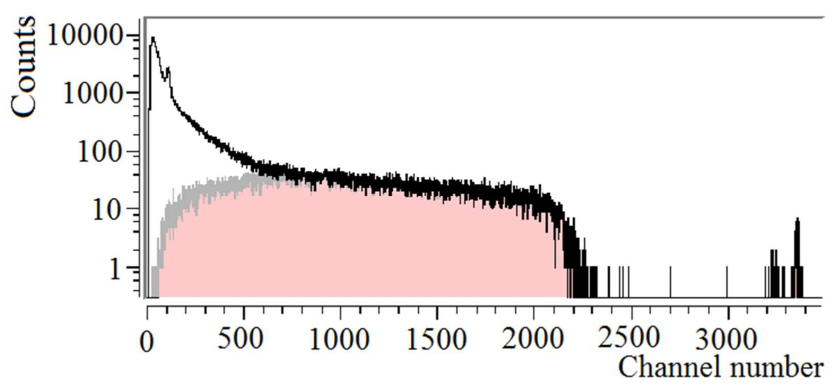
Gas mixture composed of hydrogen atoms: C_4H_{10}

Measurement of E_p and θ to reconstruct E_n:

$$E_n = \frac{E_p}{\cos^2(\theta)}$$

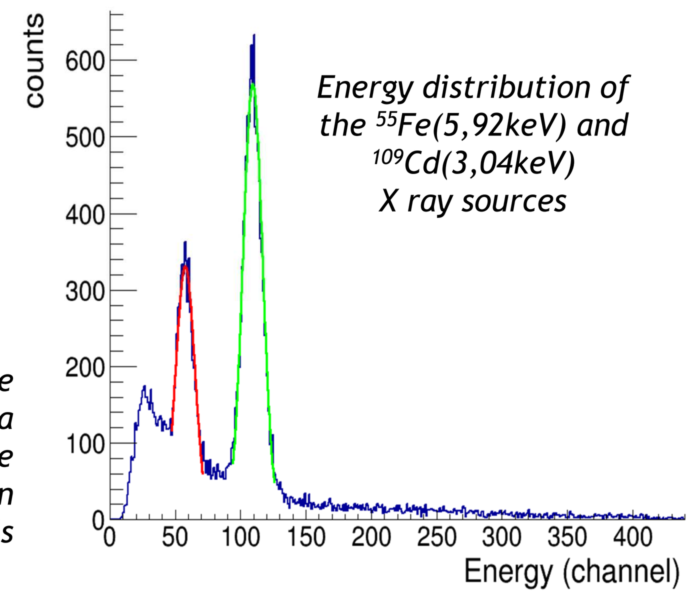
II. Measurement of the proton recoil energy

1. Measurement of ionisation electrons collected on the grid: q_{ion}

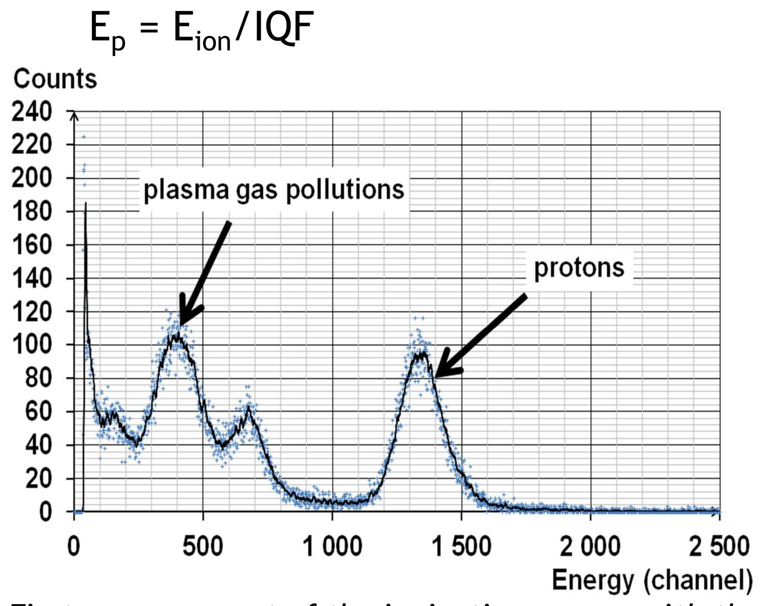


Energy distribution from the flash ADC obtained by the charge collection on the grid (black curve) when a neutron field is produced by AMANDE. The gray curve (pink area) corresponds to the energy distribution obtained when a coincidence between strips of pixels (anode) and the grid is required (coincidence mode).

2. Ionization energy obtained by the calibration with electrons (^{55}Fe, ^{109}Cd, COMIMAC): $E_{ion} = a*q_{ion}+b$

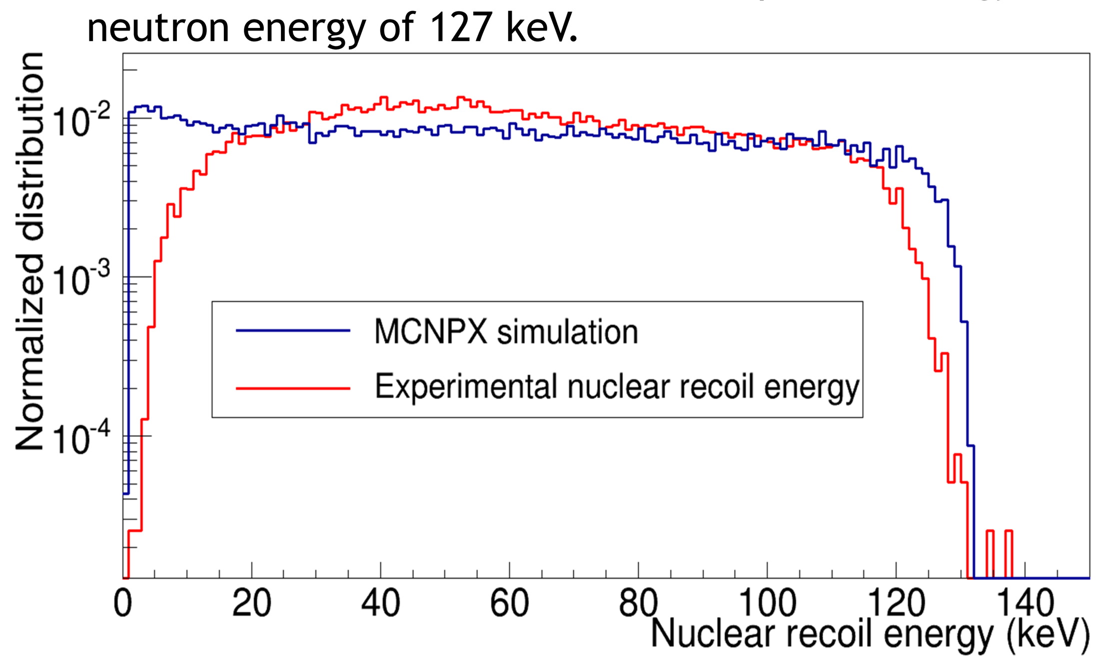


3. Estimation of the proton ionization quenching factor (SRIM, COMIMAC) [9]: $E_p = E_{ion}/IQF$



First measurement of the ionization energy with the COMIMAC device

4. Simulation and measurement of the proton energy for a neutron energy of 127 keV.

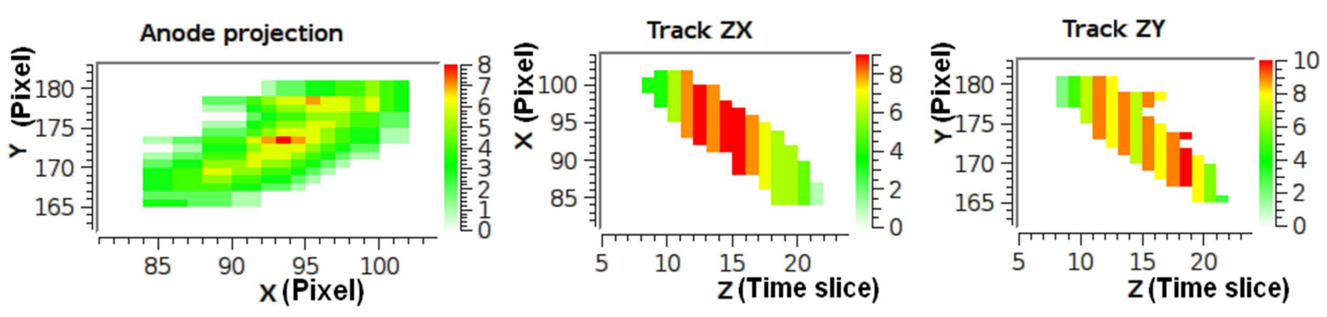


Nuclear recoil proton energy distribution at En=127 keV.

III. Estimation of the initial angle of recoil proton (measured at AMANDE facility)

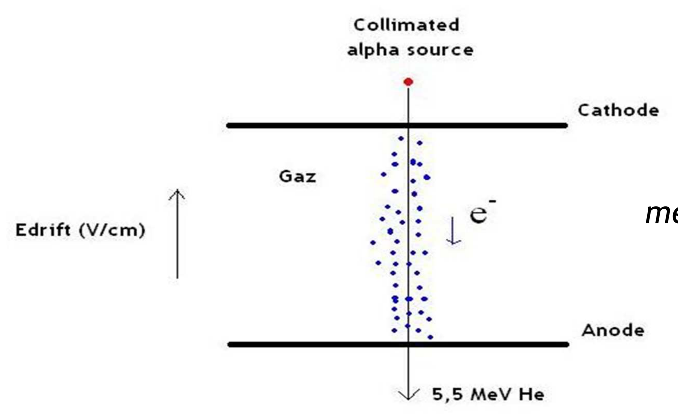
Recoil proton track reconstruction:

1. Micromegas pixelised anode for 2D projection of the track [11] associated with fast electronics (50 MHz) [10] for the time sampling of the anode (third dimension)

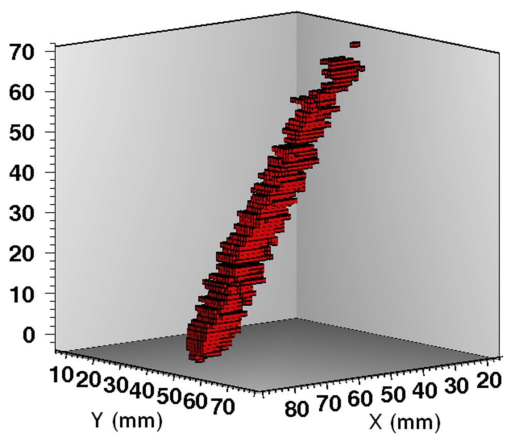


Three projections of a measured recoil nucleus compatible with a proton of 100keV

2. Drift velocity measurements or calculations (MAGBOLTZ code) to get the third spatial dimension

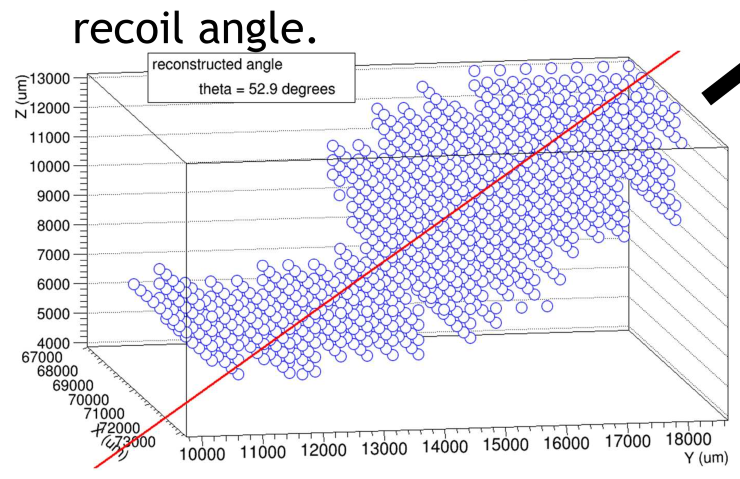


Drift velocity measurement principle in the μ-TPC



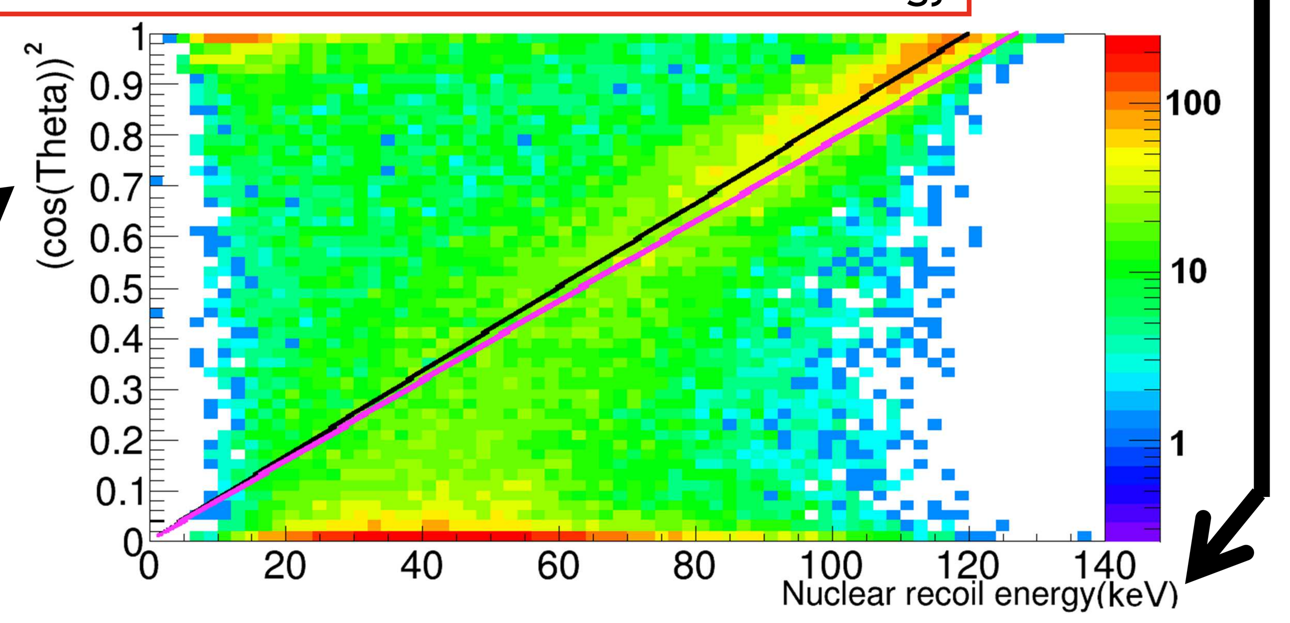
Experimental 3D cloud of pixels of an alpha particle crossing the chamber

3. Algorithm fitting a straight line to the cloud of pixels in order to reconstruct the initial proton recoil angle.

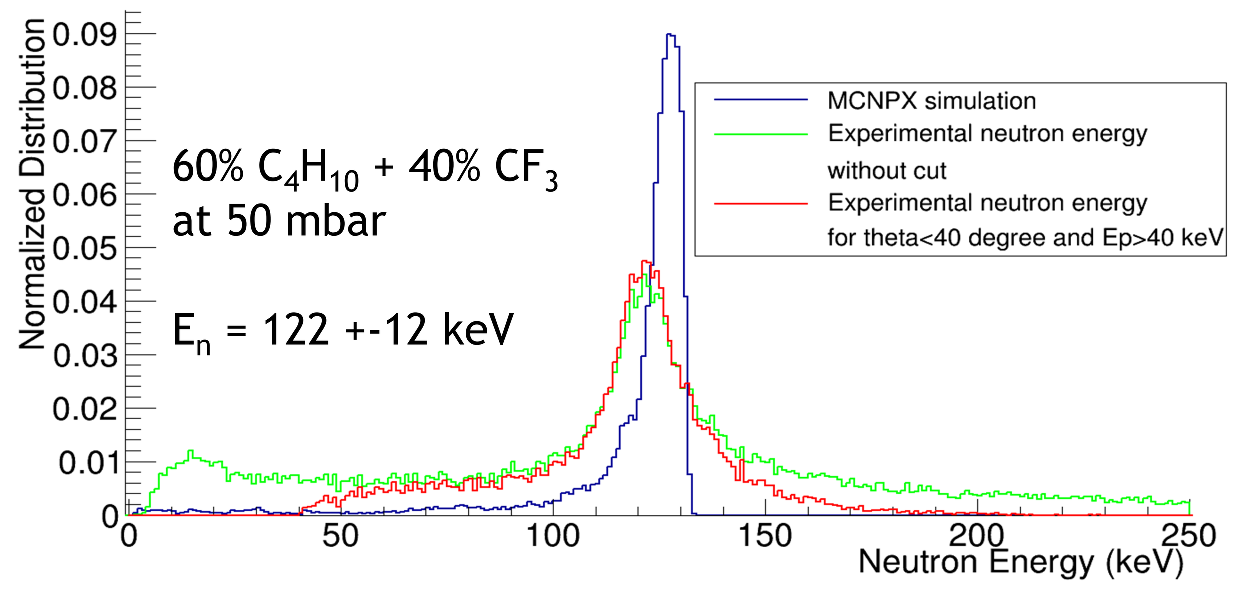


Experimental 3D cloud of pixels fitted by a straight line to estimate the scattering angle

IV. Results: Reconstruction of the neutron energy



Square of the cosine of the reconstructed angle vs the recoil energy. The black and the pink curves correspond to the theoretical equation for a neutron energy of respectively 120 keV and 127 keV. The points represents the data obtained with a neutron field of an expected energy of 127 keV.

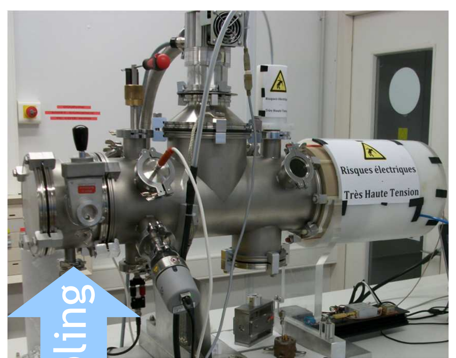


Simulated and experimental neutron energy distribution at an expected neutron energy of 127 keV.

Conclusion and perspectives

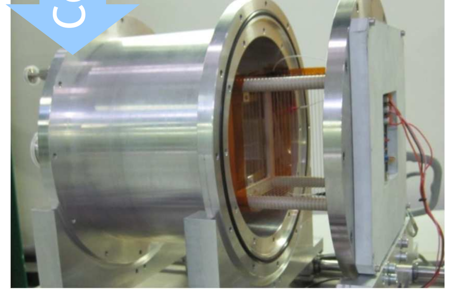
- ✓ First experimental reconstruction of the neutron energy in a primary way with the μ-TPC.
- ✓ High discrimination between photoelectrons and nuclear recoils.
- ✓ First tests of COMIMAC device.

- ➢ Improvement of the calibration with the COMIMAC device.
- ➢ Measurement of the proton ionization quenching factor up to an initial proton energy of 50 keV with the COMIMAC device.
- ➢ Measurement of the electron drift velocity in this gas mixture.
- ➢ Characterization of the reconstruction algorithm.
- ➢ New chamber to limit neutron scattering in the detector walls.
- ➢ Coupling between the COMIMAC device and the μ-TPC.



COMIMAC device

Coupling



The μ-TPC : opened

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[10] O. Bourrion et al., arXiv:1109.2002v2.

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