MIMAC and SEDINE(News-G)at LSM

Directional Dark Matter Detection with MIMAC and non-directional with SEDINE(News-G)

Daniel Santos

LPSC-Grenoble

GDR-DUPHY, October 2022

What does it mean to perform a directional detection of nuclear recoils?

If you wounder about your detector is able to perform a directional detection …

- You have to put your detector in a mono-chromatic neutron field knowing where is the source.

- You try to get the energy of the mono-energetic neutron field detecting each nuclear recoil with its angle with respect to the neutron direction producing such recoil !

- If you are interested in the low energy range (keV range) you can choose a 27 or even 8 keV mono-chromatic neutron field…

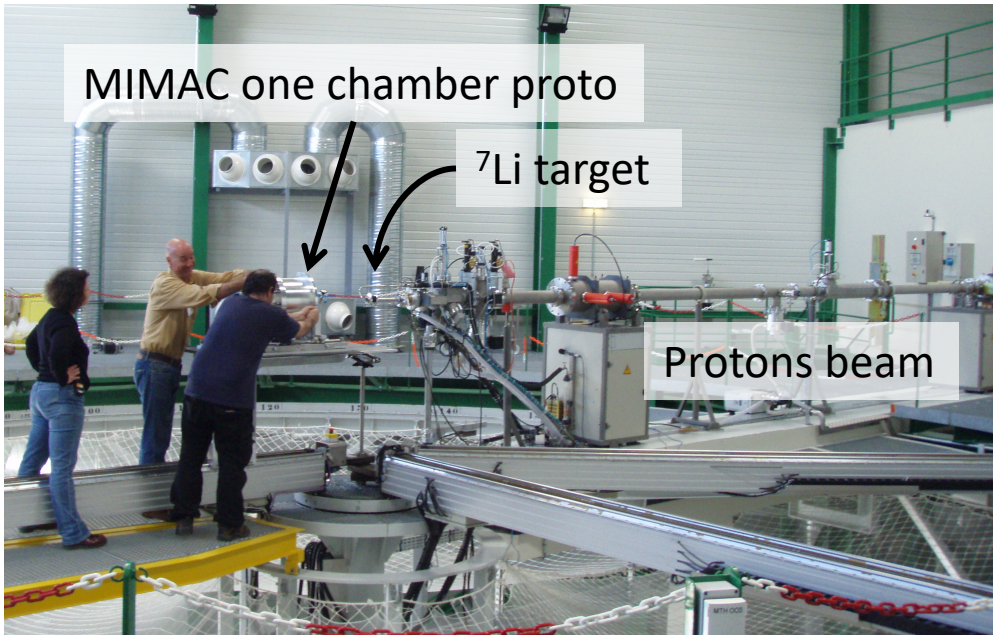
Nuclear recoil calibration with neutrons

Neutron monochromatic field:

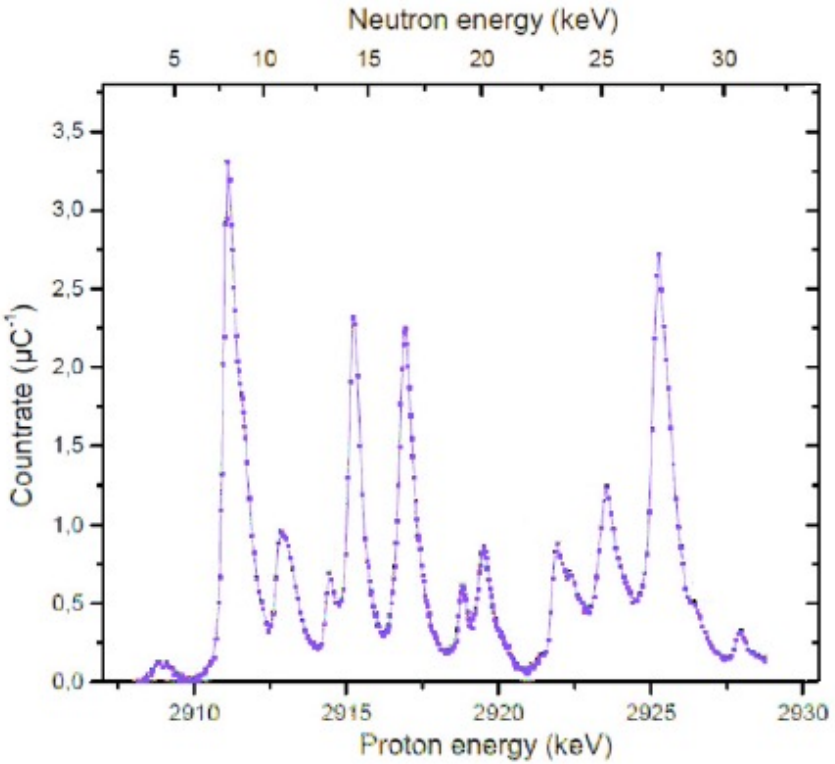
AMANDE facility at IRSN of Cadarache

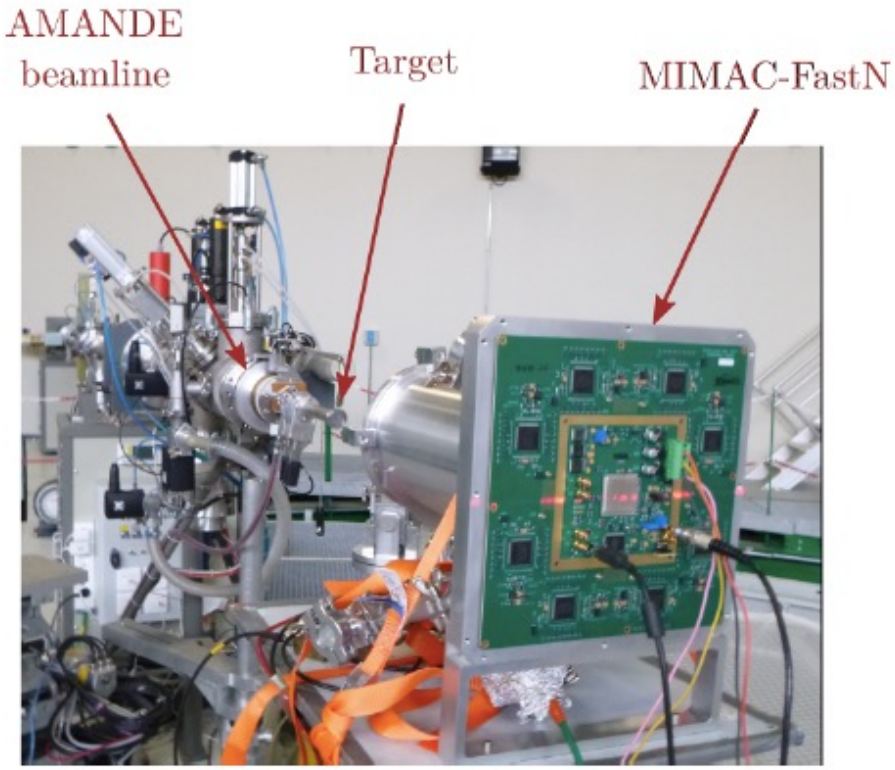
- **Neutrons with a well defined energy from resonances of nuclear reaction**

$$E_{\mathrm{Re}coil} = 4\frac{m_n m_R}{\left(m_n + m_R\right)^2} E_{neutron} \cos^2\theta$$



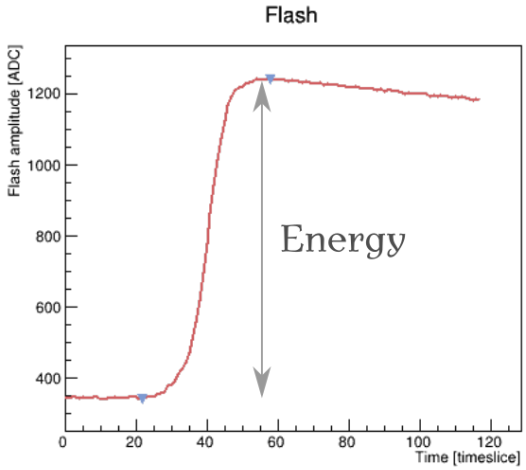
Low energy (8 and 27 keV) mono-energetic neutron detection

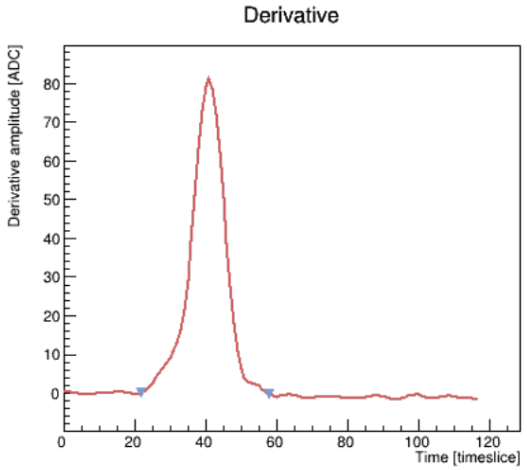


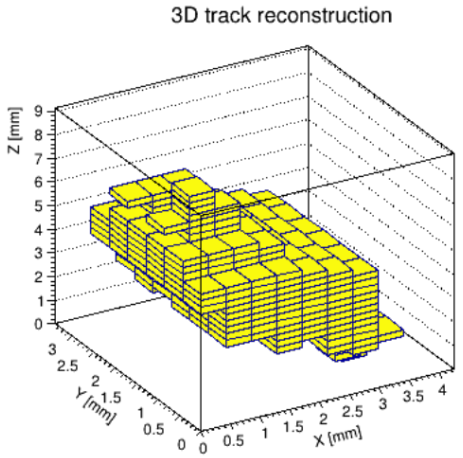


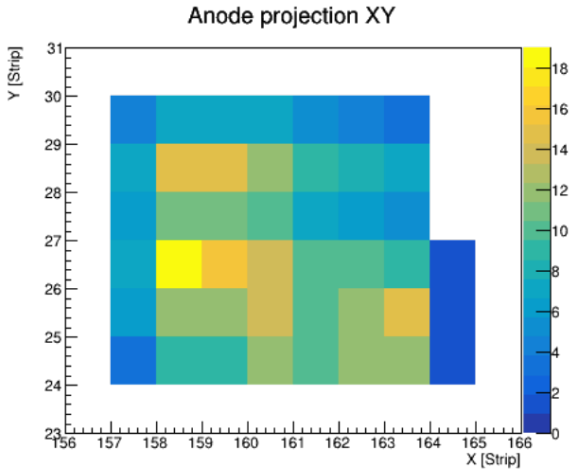
^{45}Sc(p,n) neutron resonances

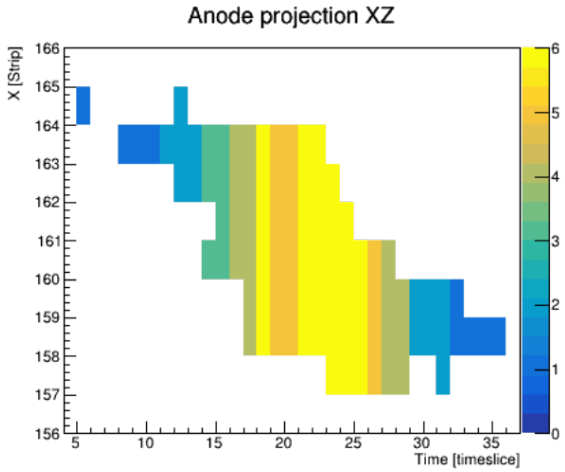
Example of a proton recoil of 6 keV_{ee} (8.6 keV_{nr})

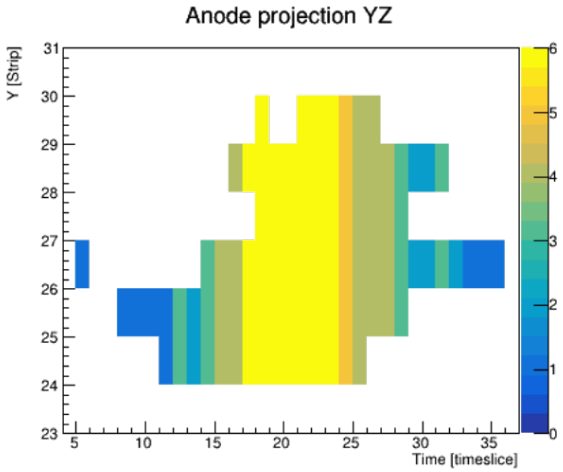








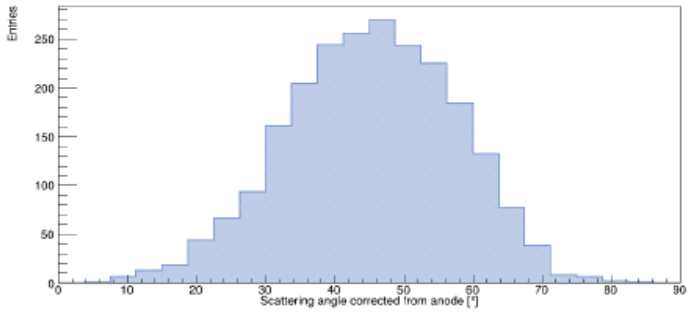


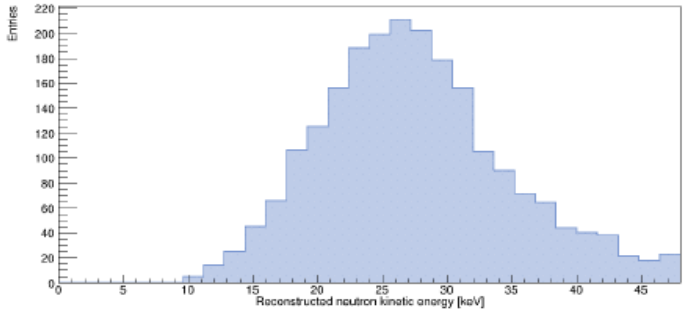


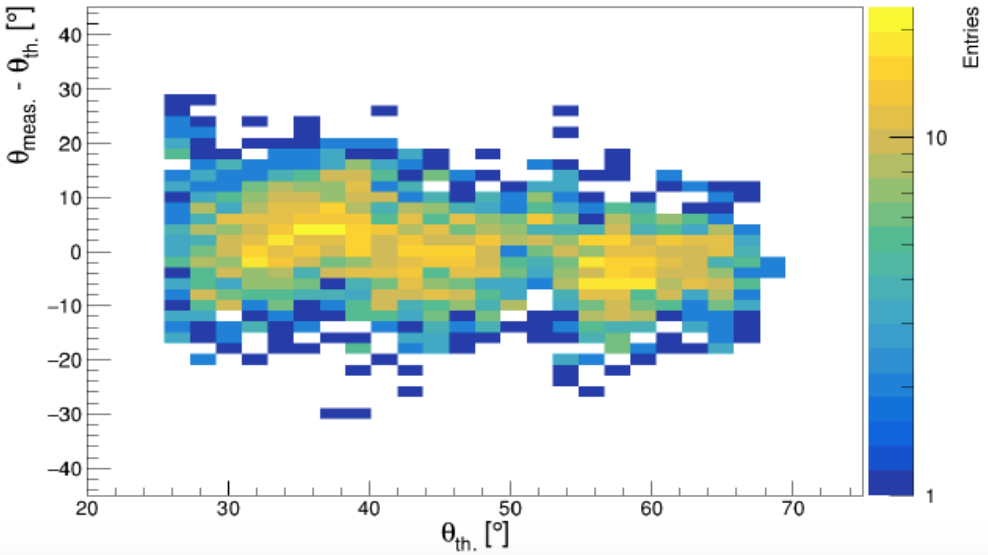
– → Sampling at 50 MHz (20 ns)

Proton recoil Angular Distribution produced by 27 keV neutrons in C_4H_{10} + 50% CHF_3 (30 mbar)

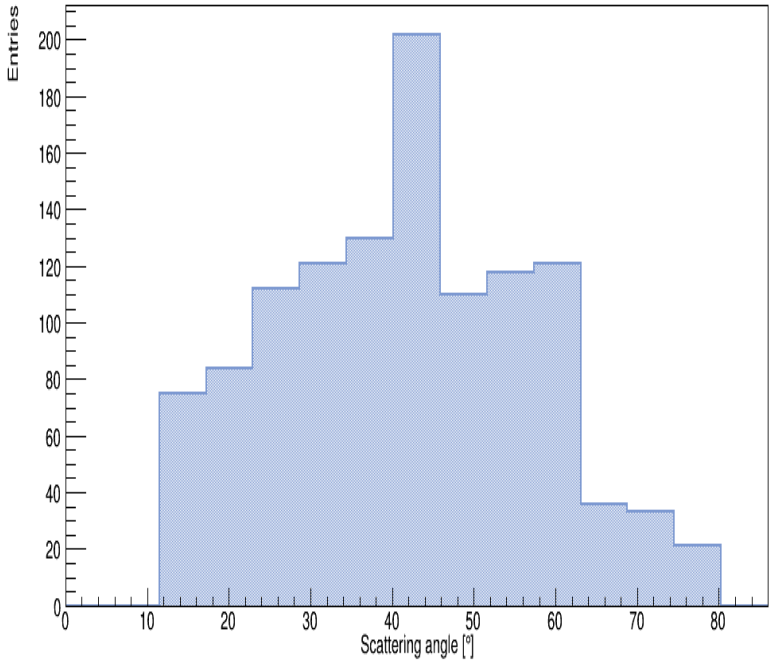
Cyprien Beaufort et al, https://arxiv.org/abs/2112.12469



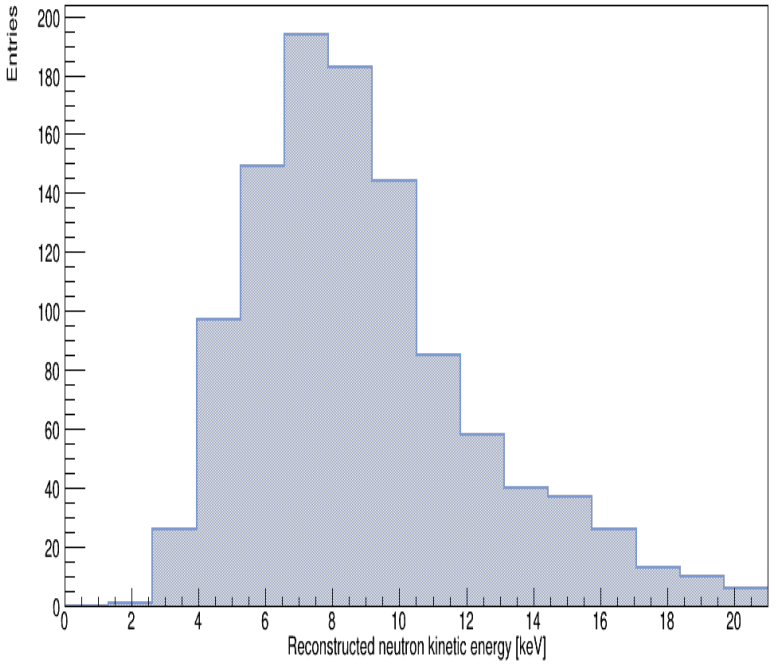




Directionality – **First Neutron spectrum at 8 keV from proton recoils**



Angular distribution



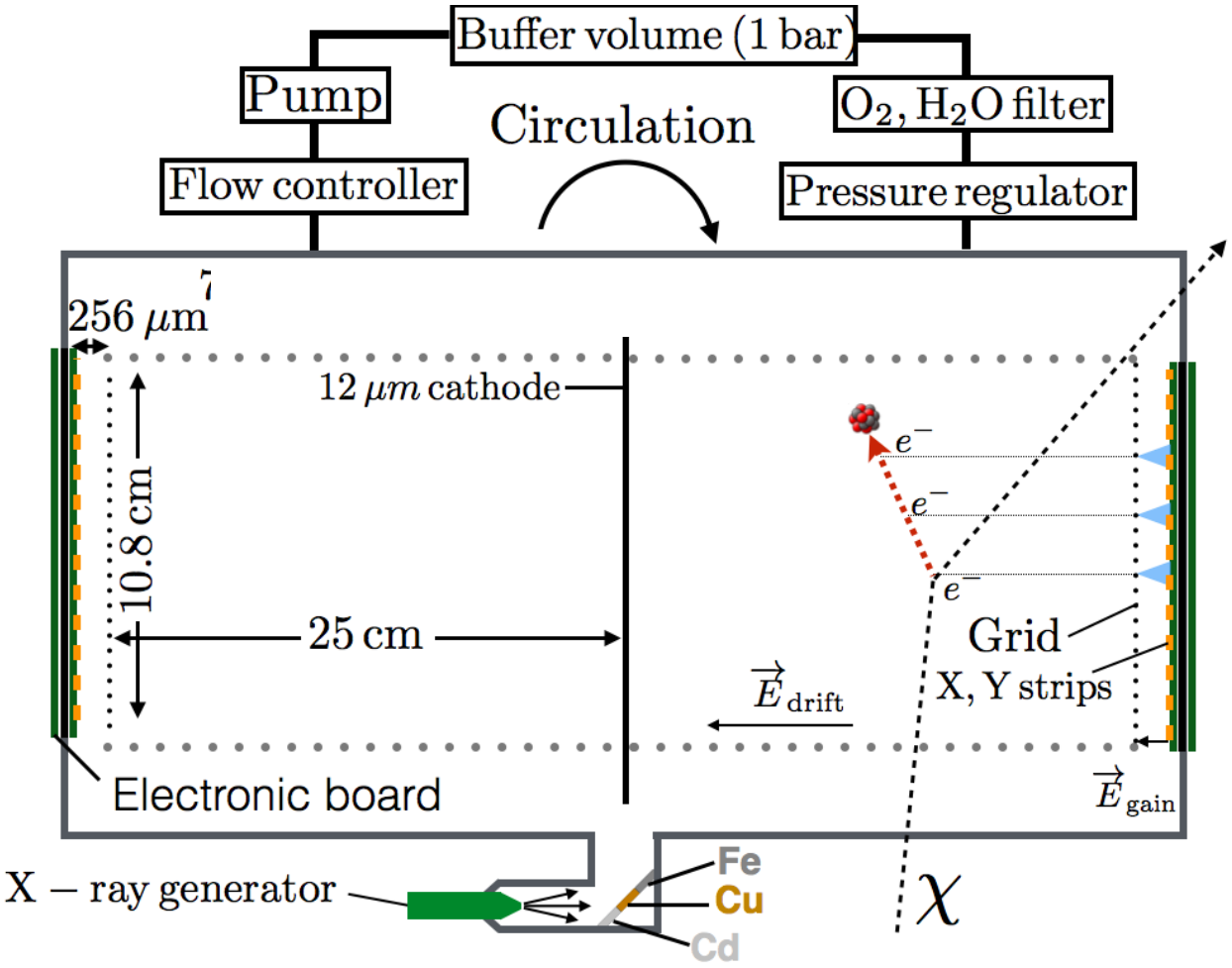
Reconstructed spectrum

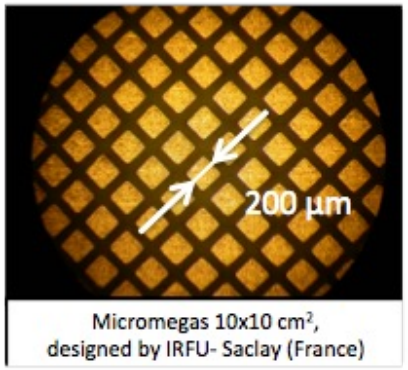
Directional performances at $8\,\mathrm{keV}$:

- Energy reconstructed agrees within 4.0% and angular resolution better than 15°

Remark: this approach for directionality from the deconvolution of the ionic contribution is **complementary** from the standard one from 3D track reconstruction

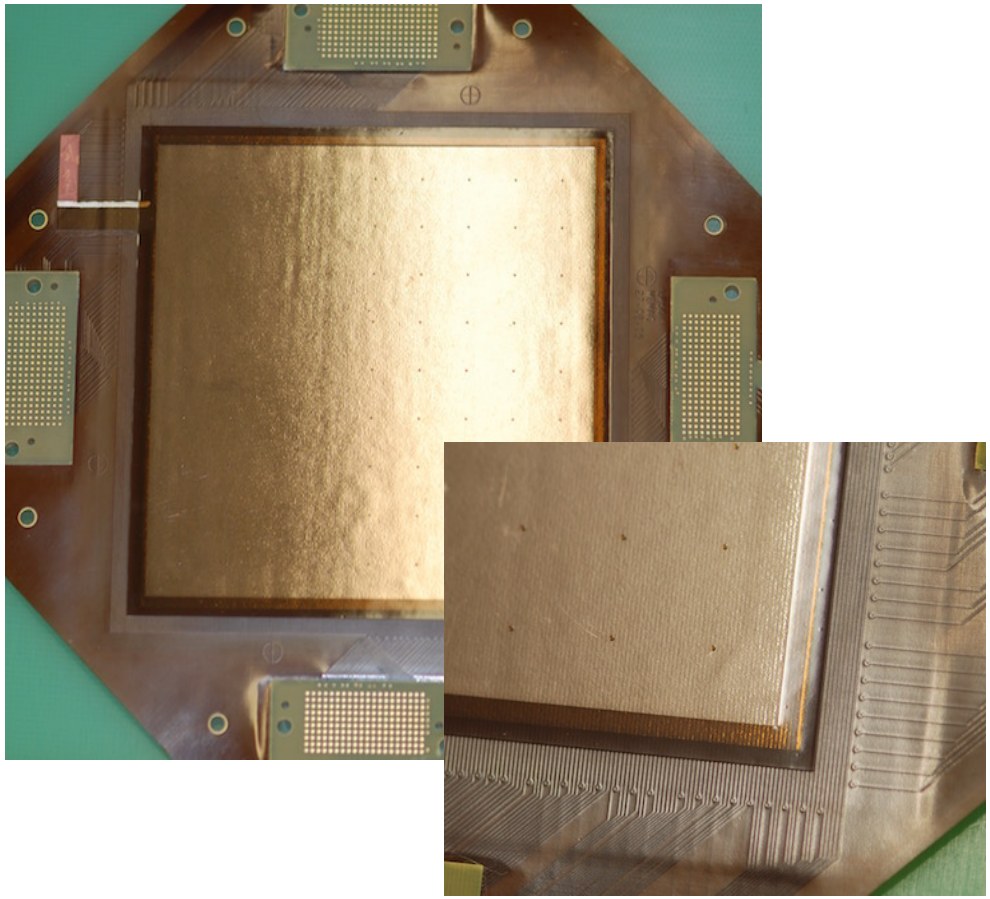
MIMAC-bi-chamber module prototype



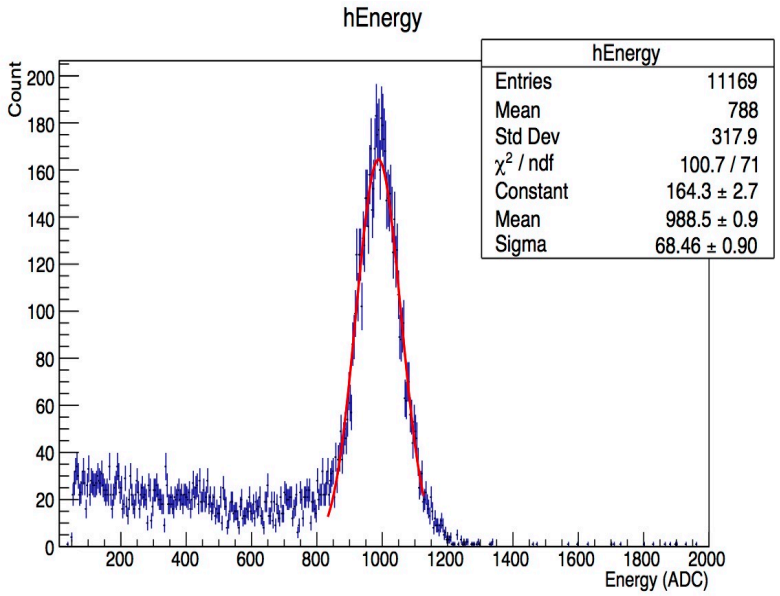


MIMAC Target: ^{1}H, ^{12}C, ^{19}F

New MIMAC low background detector



Kapton micromegas readout
Piralux Pilar



Gaz : MIMAC 50 mbar
HT grille : -560 V
Drift field : -150 V/cm

16,3 % FWHM (6 keV)
Gain ~25 000
Energy threshold <1 keV

Cathode Signal to place a 3D-track

- The cathode signal is produced by the primary electrons. It is produced before the anode signal produced by the avalanche.

C. Couturier, Q. Riffard, N. Sauzet, O. Guillaudin, F. Naraghi, and D. Santos.

Journal of Instrumentation, 12(2017):P11020,.

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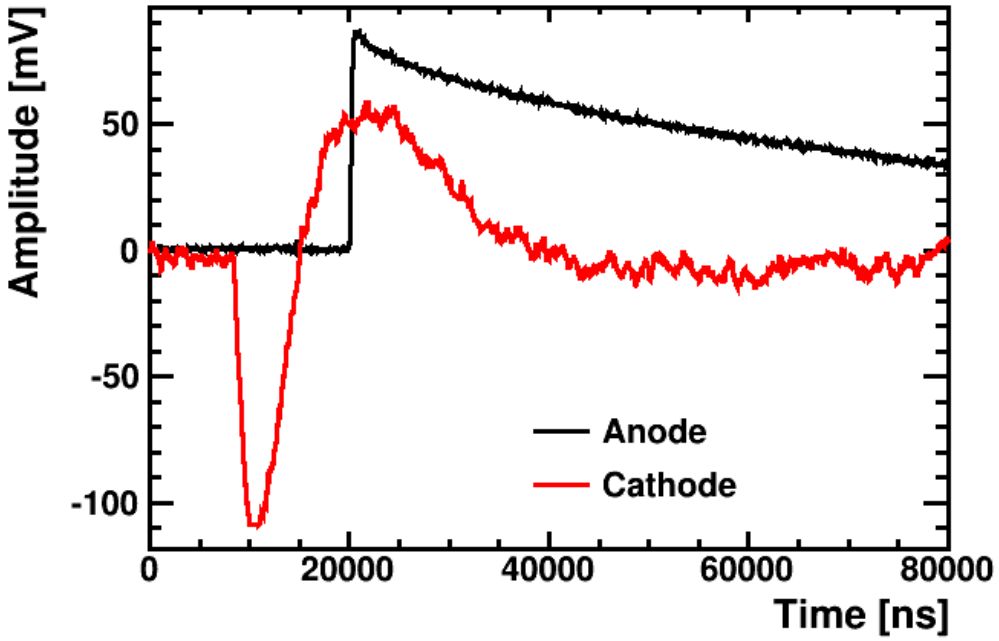
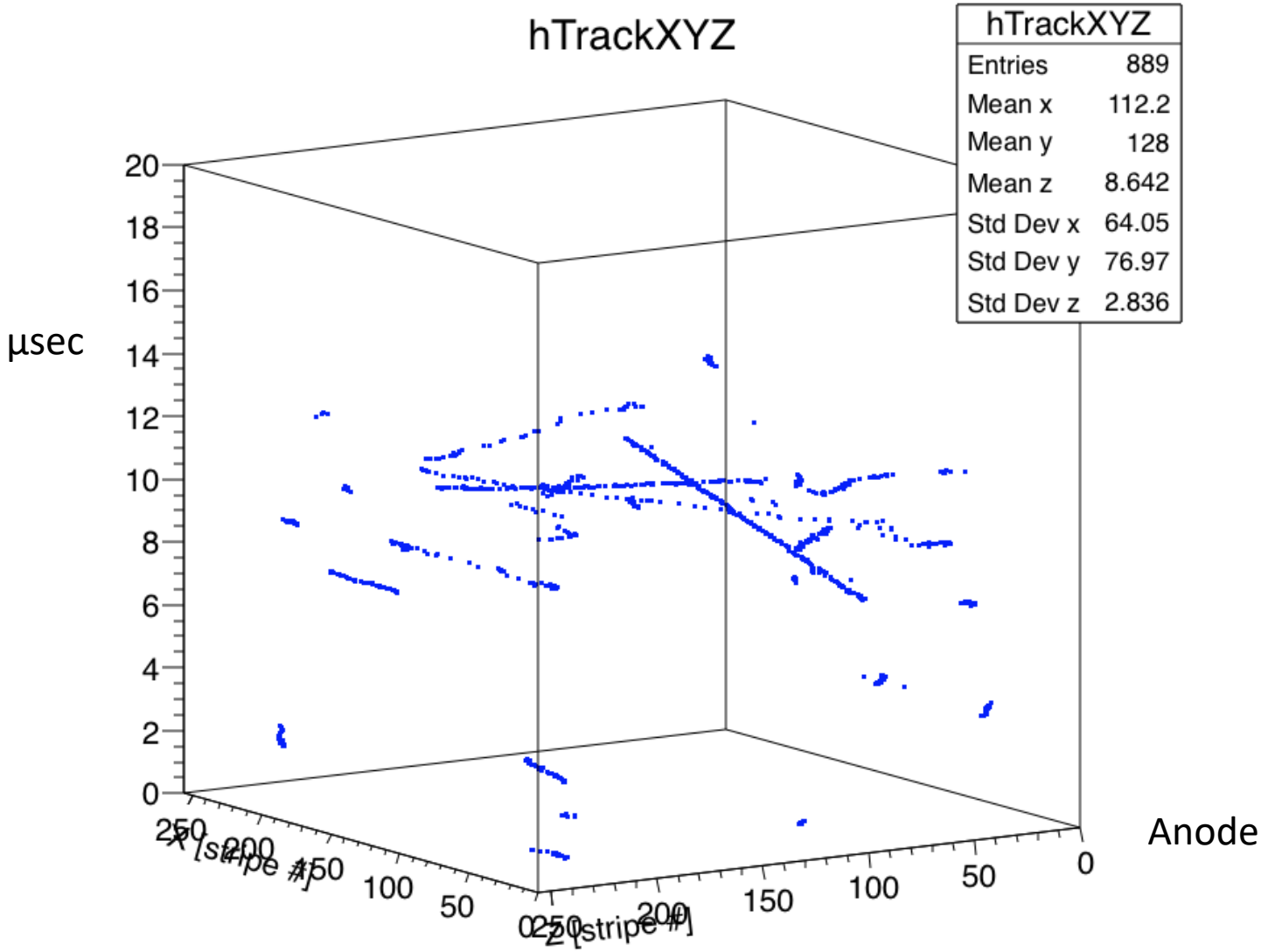


Measurement in a MIMAC chamber of an alpha passing through the active volume parallel to the cathode at 10 cm distance.

3D event-localization in MIMAC by means of the cathode-signal



Bi-chamber module (with the Cathode Signal and the new low background 10 cm detectors) (November 2022)

MIMAC (bi-chamber module)at Modane Underground Laboratory (France)

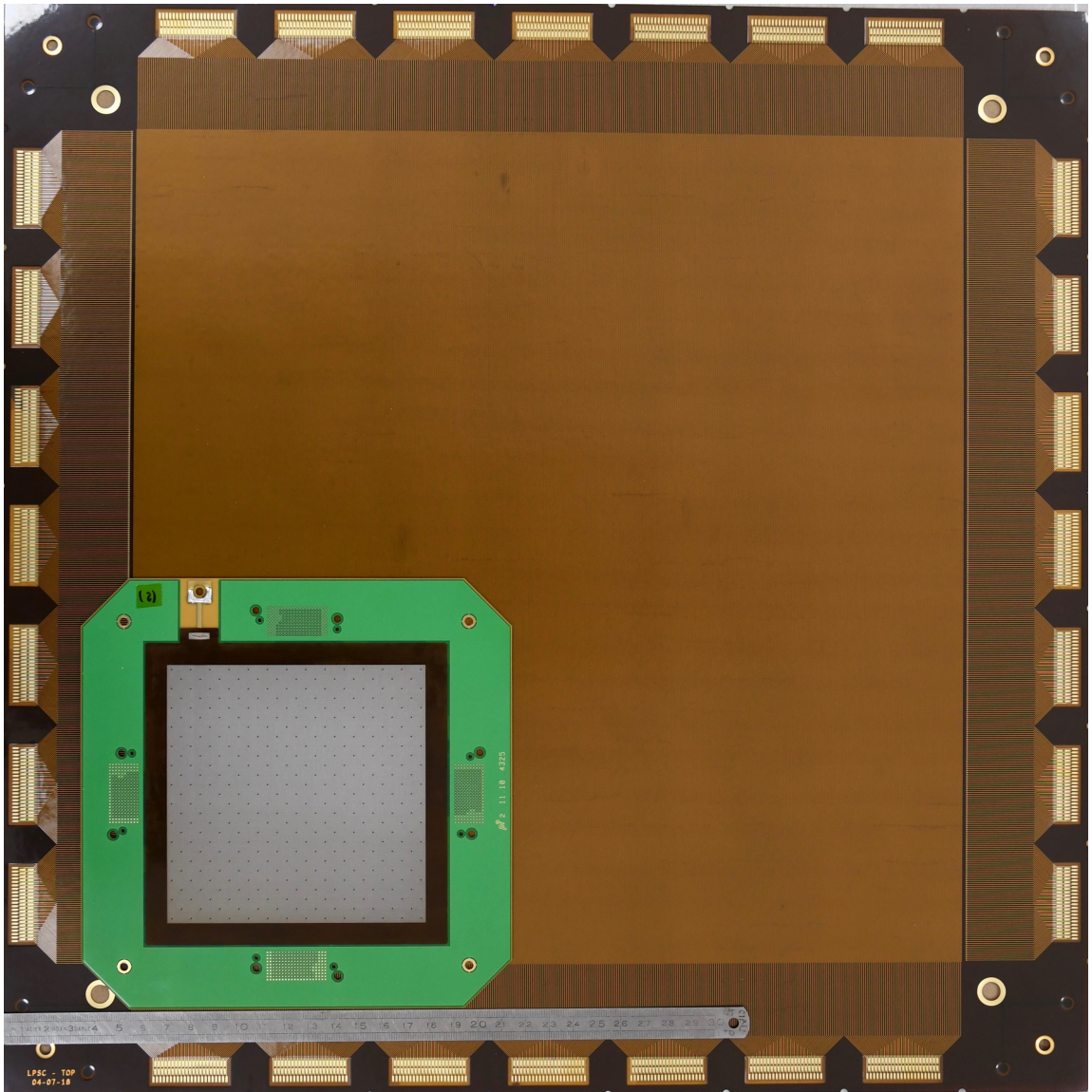
-working at 30 mbar (C_4H_{10}+50% CHF_3)

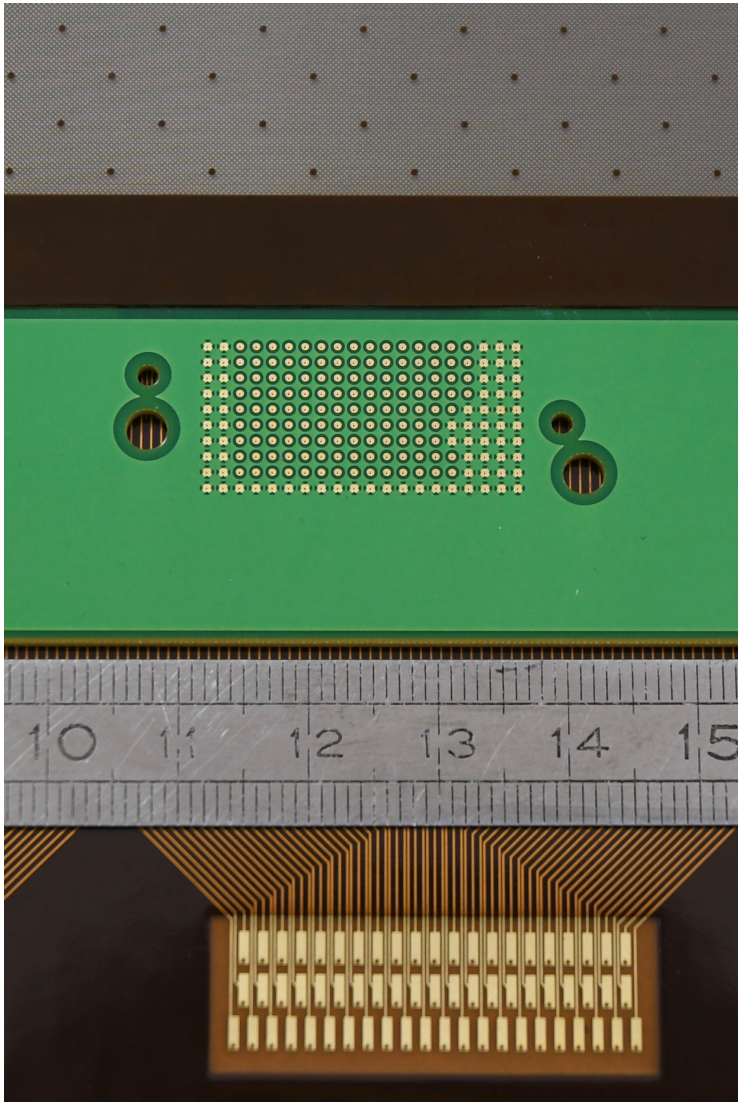
-Permanent circulating mode

-Remote controlled and commanded

- A calibration control per week

The new 35 cm “new technology” MIMAC detector compared to the old one





New MIMAC Bi-chamber module 35x35x25 cm^3

- Installation at Modane on July 2023 with the same gas system than the 10 cm Bi-chamber module
  Run background without lead shielding (1 month)

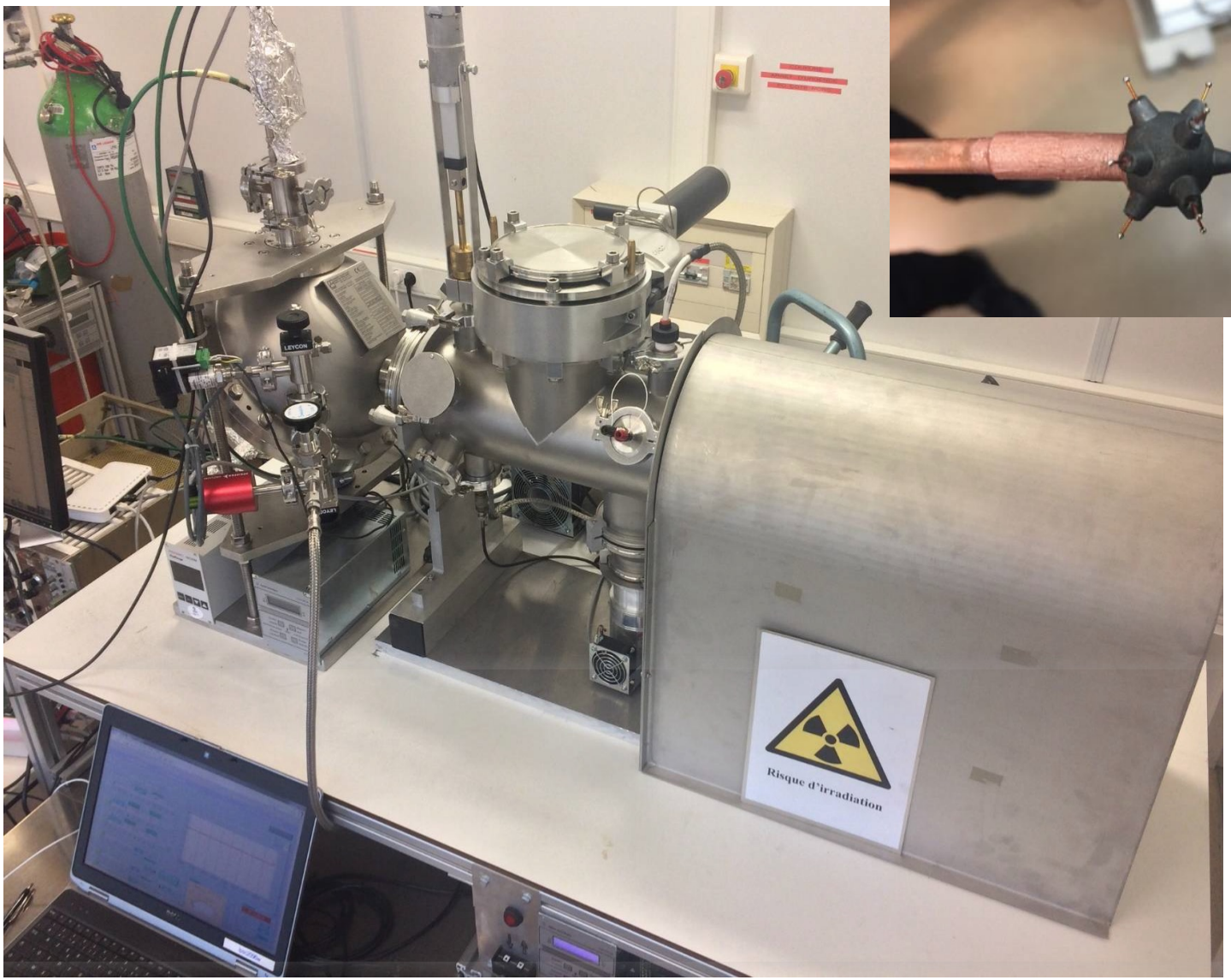
- Lead shielding installation (October 2023)

- 1st Physics Run: November 23- June 24

NEWS-G (Sedine) at LSM

A. Dastgheibi-Fard, F. Vazquez de Sola and D. Santos
on behalf of NEWS-G collaboration

S30 coupled to COMIMAC



Ionization Quenching Factor Measurements with COMIMAC
(NEWS-G collaboration, arXiv 2201.09566 to be published in ERJ-C)

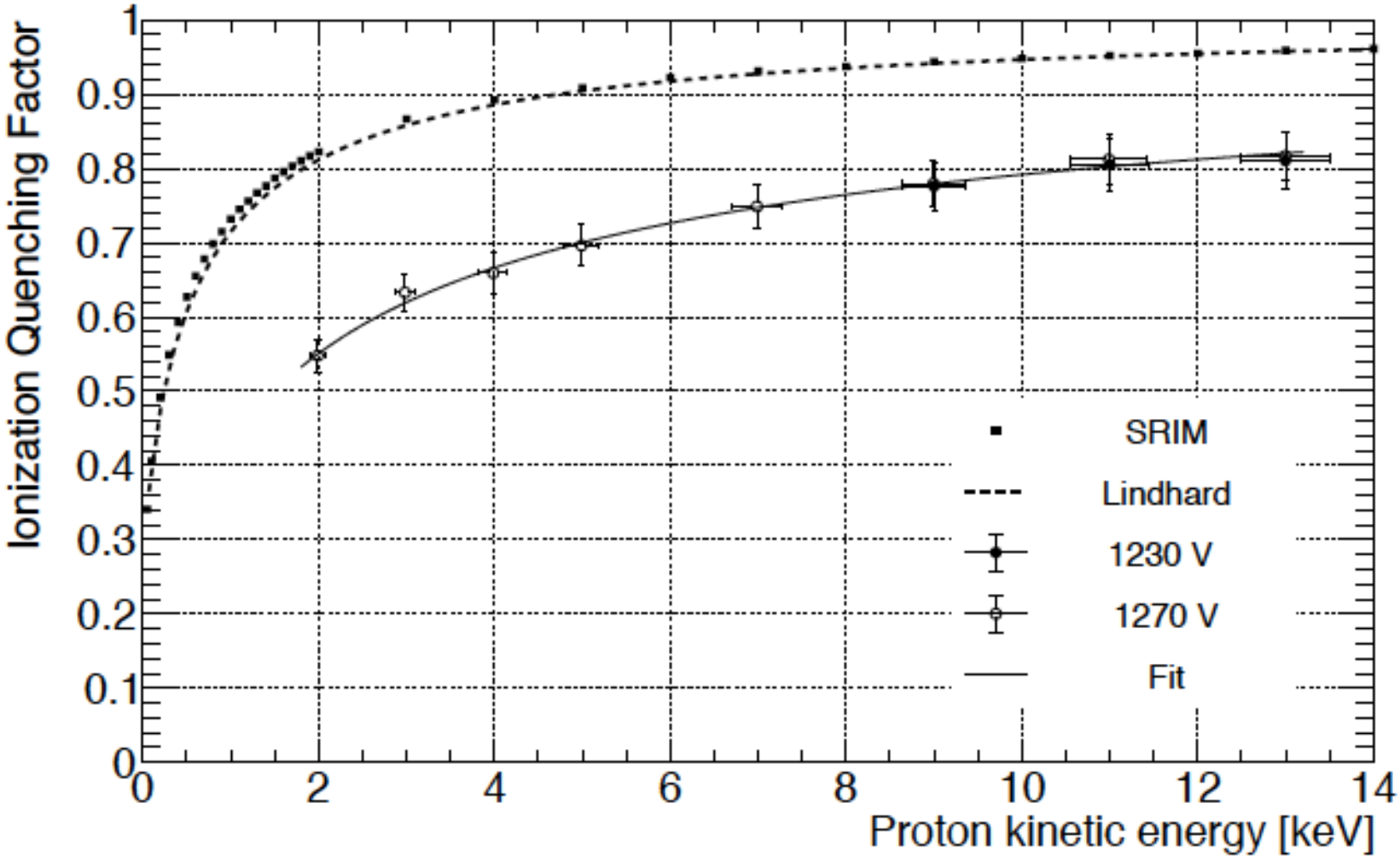
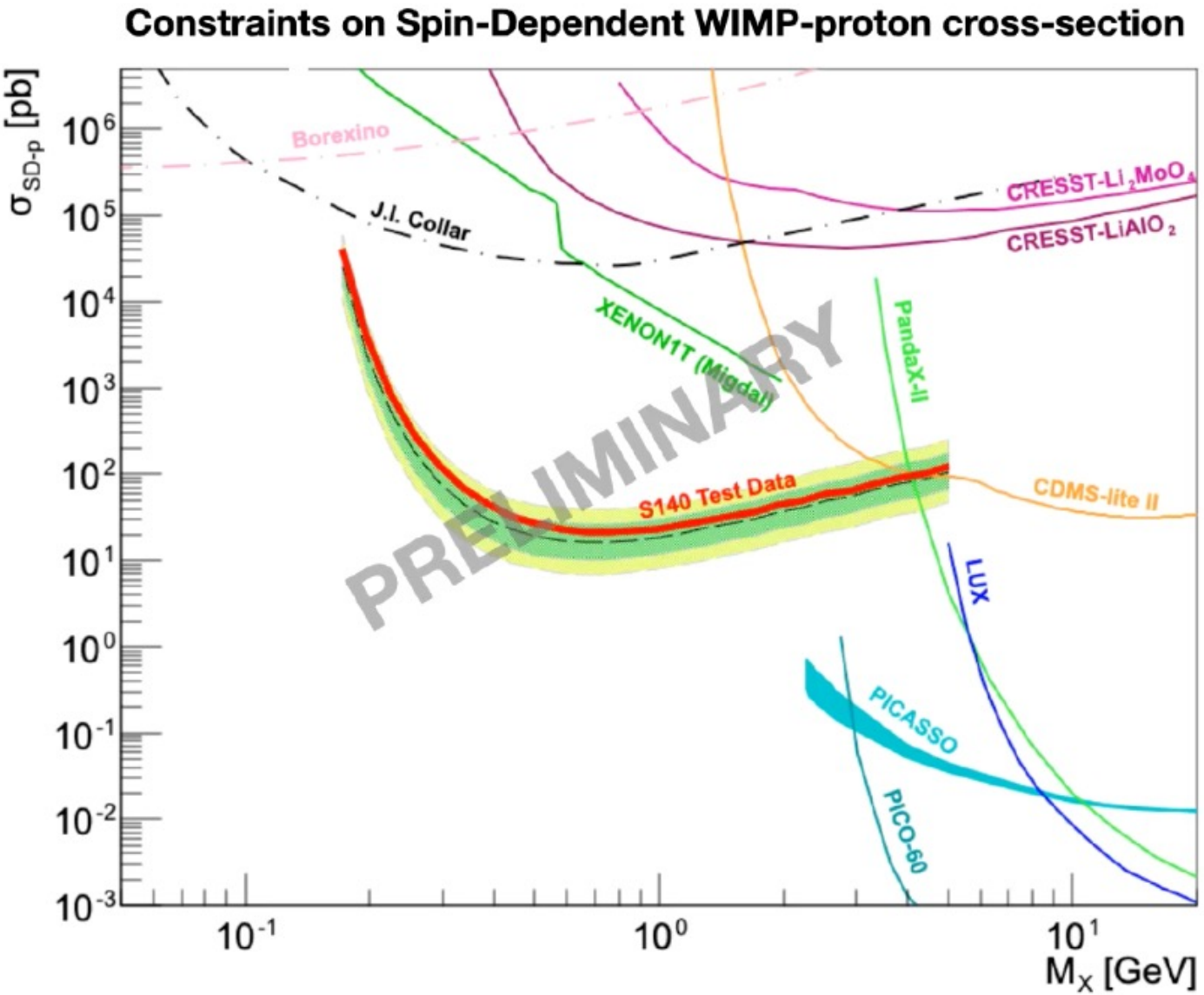


Fig. 9: Ionization Quenching Factor for protons in 100 mbar of methane. The measurements at 1230 V and 1270 V are respectively presented with black dots and white dots. Comparisons with SRIM and with the Lindhard theory are also shown.

S140 at Modane during 15 days at 135 mbar CH_4



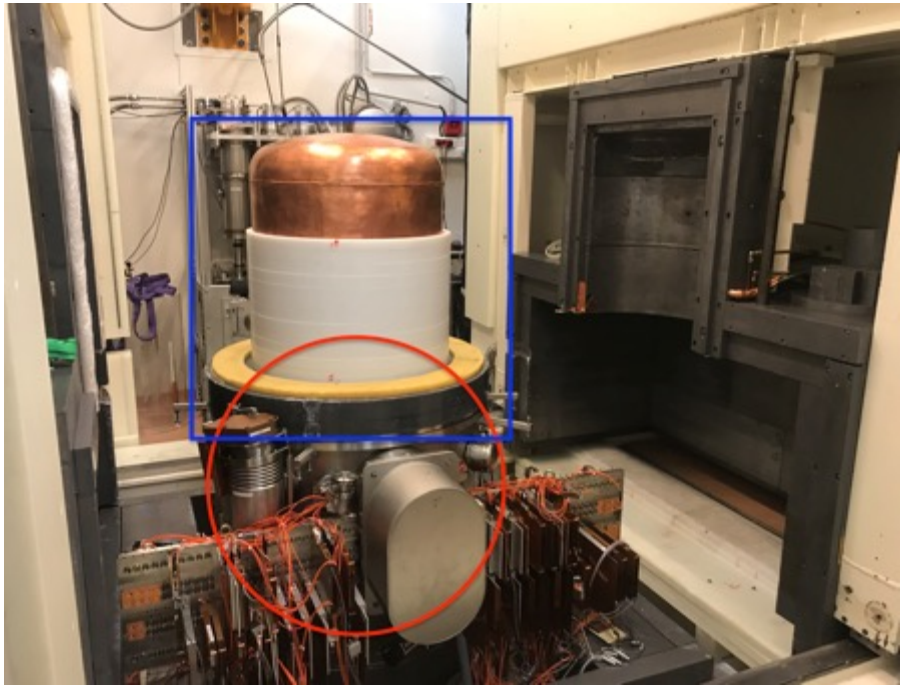
Presented by F. Vazquez de Sola on October 19th 2022

Possible New runs with SEDINE in EDELWEISS shielding

- **Runs**
  - CH4 (safety proceeding) + Achinos 11 balls

- **Edelweiss Shielding**

Poly	30 cm	=>	40 cm
Lead	15 cm	=>	25cm (including the Roman lead)



Sedine (NEWS-G)

- Sedine, the first low background detector fabricated with 5N Copper (purity of 99.999%)
- To profit of the work done on NEWS-G (S140) at Modane and Snolab understanding the background and signals in the sphere.
- To profit of the possibility to run an experiment with CH_4 at pressure less than 800 mbar (5.9 times the pressure of S140 run at Modane) and having the IQF measured at Grenoble
- To profit of the Edelweiss shielding at least 6 months

We'll get a nice opportunity to improve the exploration at low Wimp masses…even better than present limits

MIMAC (MIcro-tpc MAtrix of Chambers)

LPSC (Grenoble) : D. Santos, C. Beaufort (CDD), F.Naraghi , O. Guillaudin, N. Sauzet,

- Electronics : **G. Bosson (r), J. Bouvier (r), J.L. Bouly, L.Gallin-Martel, F. Rarbi, Cairo Caplan (CDD)**
- Data Acquisition: **T. Descombes**
- COMIMAC (quenching) **: J-F. Muraz**

CCPM (Marseille): J. Busto, C. Tao

IRSN- LMDN (Cadarache): M. Petit, T. Vinchon
(spectroscopie neutronique métrologique)

Prototype hosted in **IHEP (Beijing-China)**: **ZhiminWang , Changgen Yang**

First detection of 3D tracks of Rn progeny

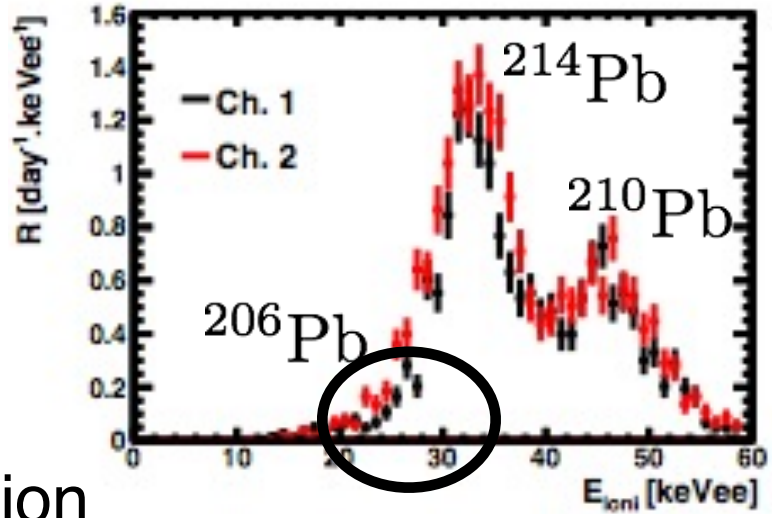
Electron/recoil discrimination

Mesure: $\begin{cases} E_{ioni}(^{214}\mathrm{Pb}) = 32.90 \pm 0.16\,\mathrm{keVee} \\ E_{ioni}(^{210}\mathrm{Pb}) = 45.60 \pm 0.29\,\mathrm{keVee} \end{cases}$

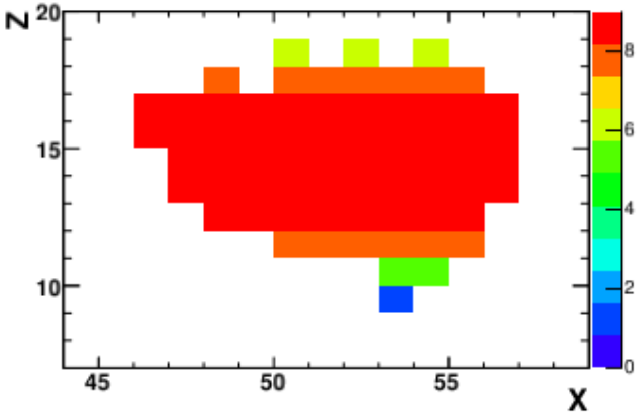
First measurement of 3D nuclear-recoil tracks coming from radon progeny

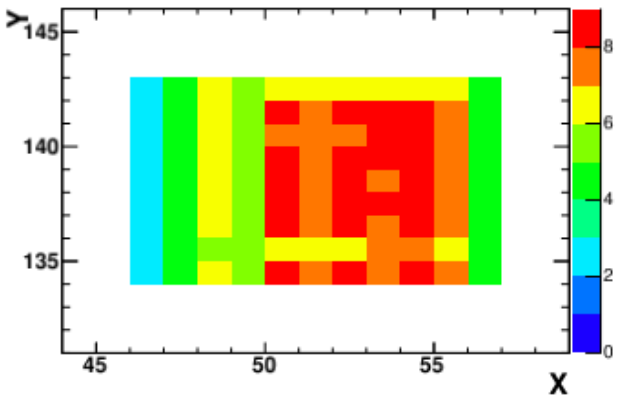
→ MIMAC detection strategy validation

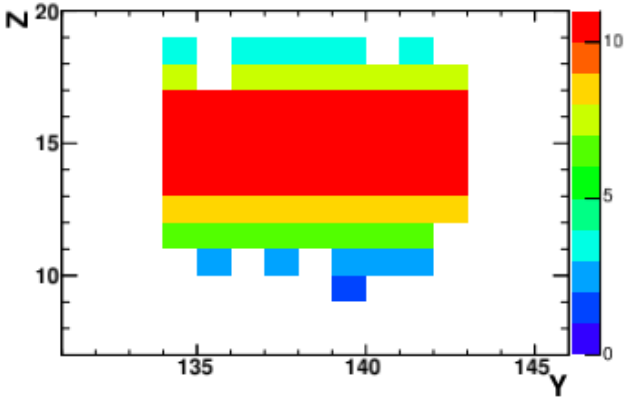
Nuclear recoil spectra



$R_{^{206}\mathrm{Pb}} \sim 0.25\,\mathrm{day}^{-1}.\mathrm{keVee}^{-1}$





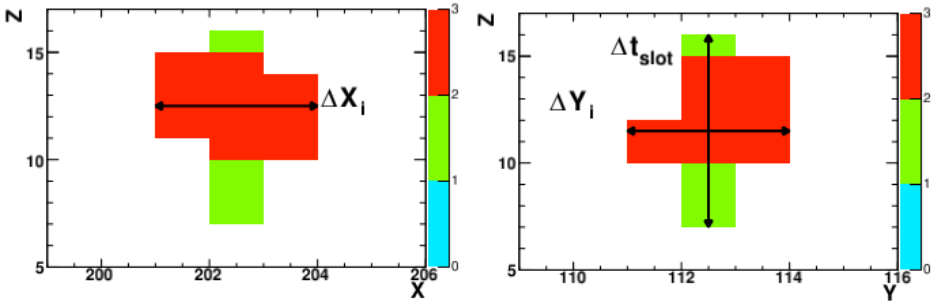


RPR events occur at different positions in the detector…

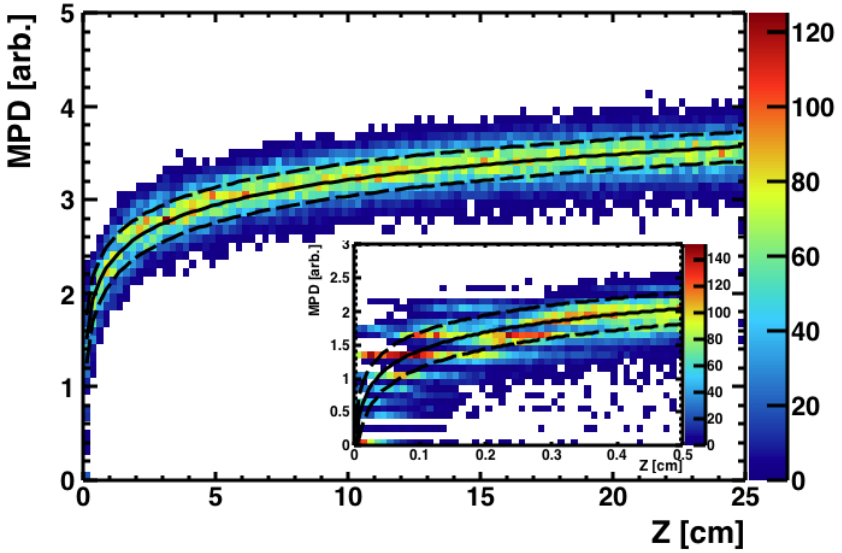
$$z_0 \longleftrightarrow \text{Diffusion}$$

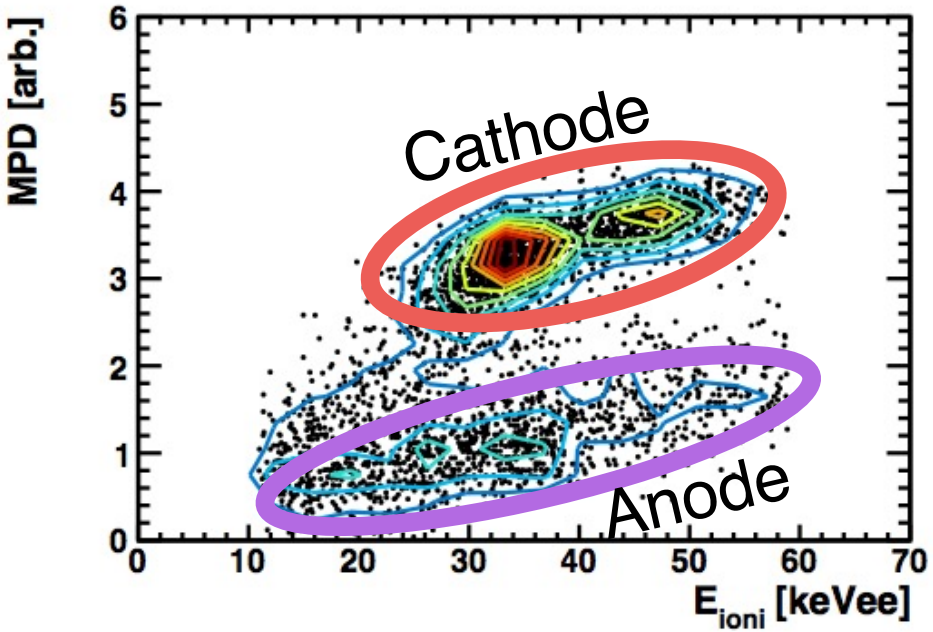
$$\begin{cases} D_T = 237.9\,\mu\text{m}/\sqrt{\text{cm}} \\ D_L = 271.5\,\mu\text{m}/\sqrt{\text{cm}} \end{cases}$$

« Grid » event



Mean Projected Diffusion: $\overline{\mathcal{D}} = \ln\left(\overline{\Delta X} \times \overline{\Delta Y}\right)$





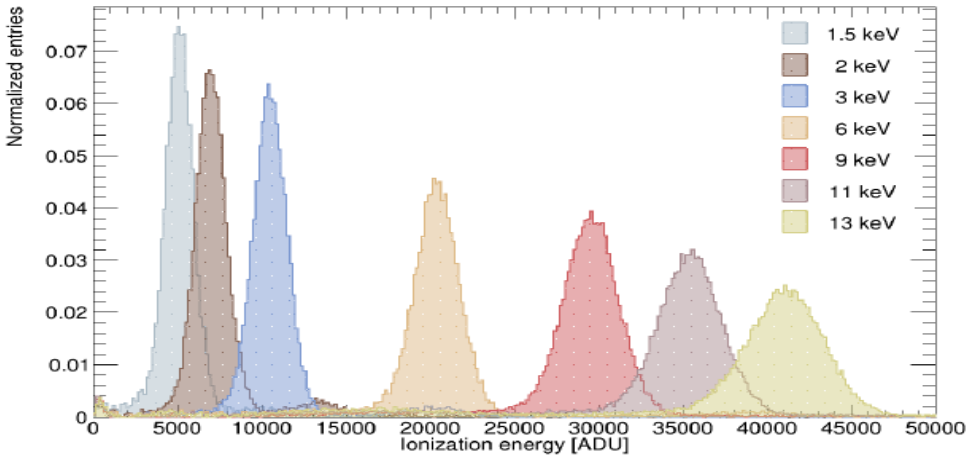
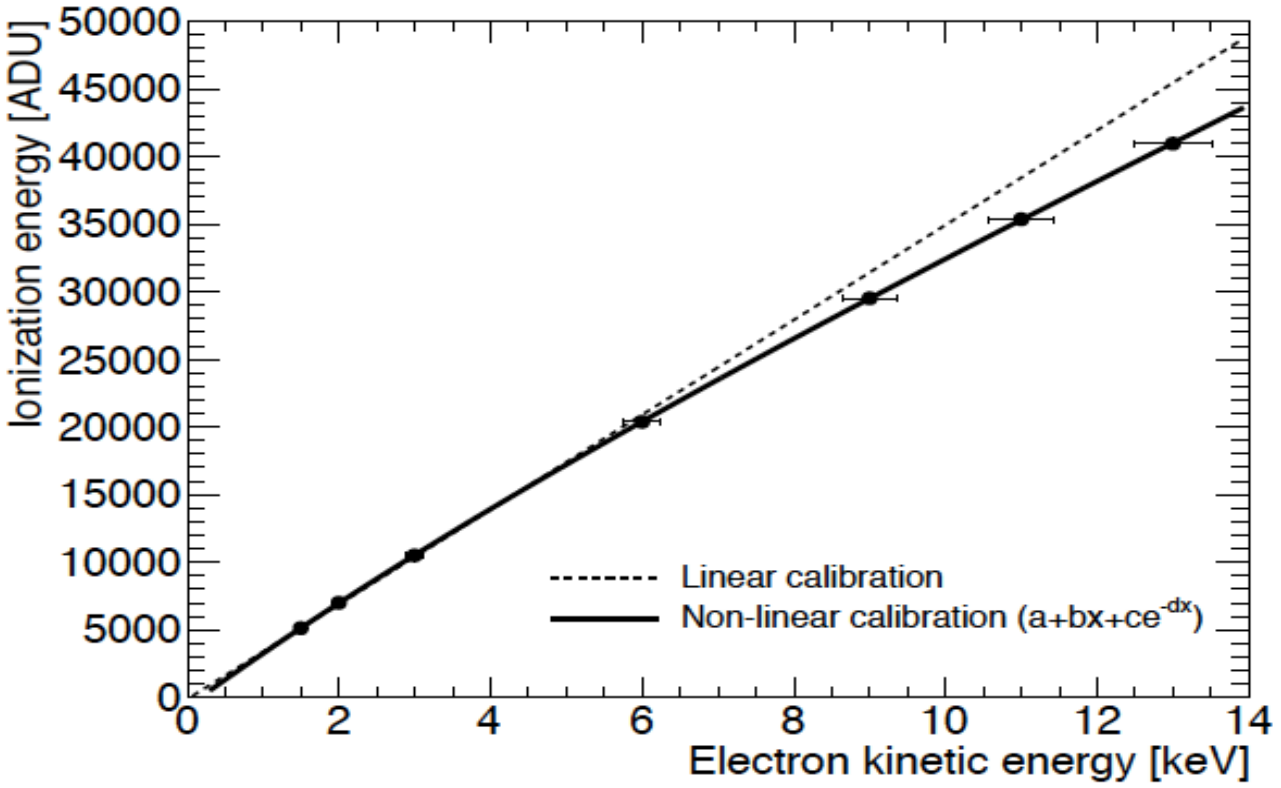


Fig. 5: Complete set of energy spectra used for the calibration of the detector response. The kinetic energy is determined by the Comimac facility. The cosmic background has been subtracted but no cut is applied.

Electron Calibration with COMIMAC of a 30 cm diameter Sphere with an akinos sensor

Non-linearity at energies higher than 4 keV probably due to screening charge effect of previous avalanches on the primary electron avalanches.

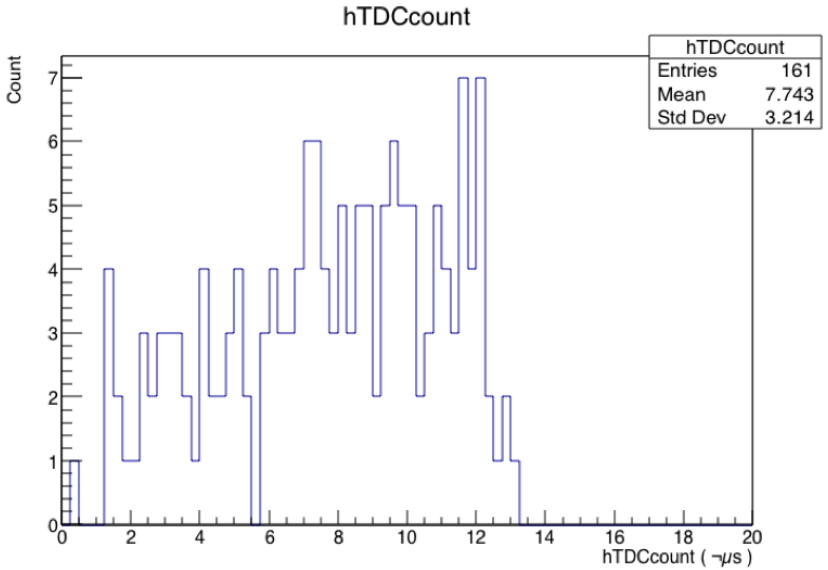
(NEWS-G collaboration, arXiv 2201.09566 to be published in EPJ-C)



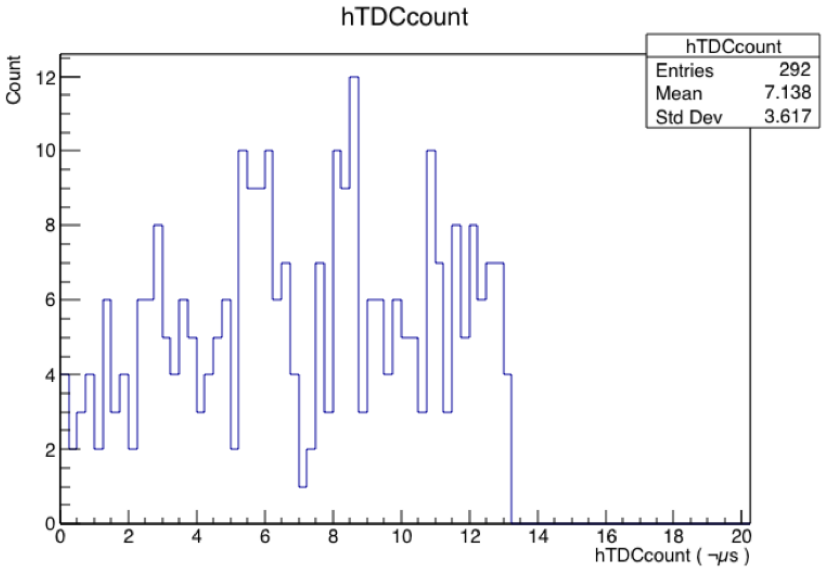
First Cathode Signals from the MIMAC bichamber background

(O. Guillaudin, D.S. et al.)

Chamber 1



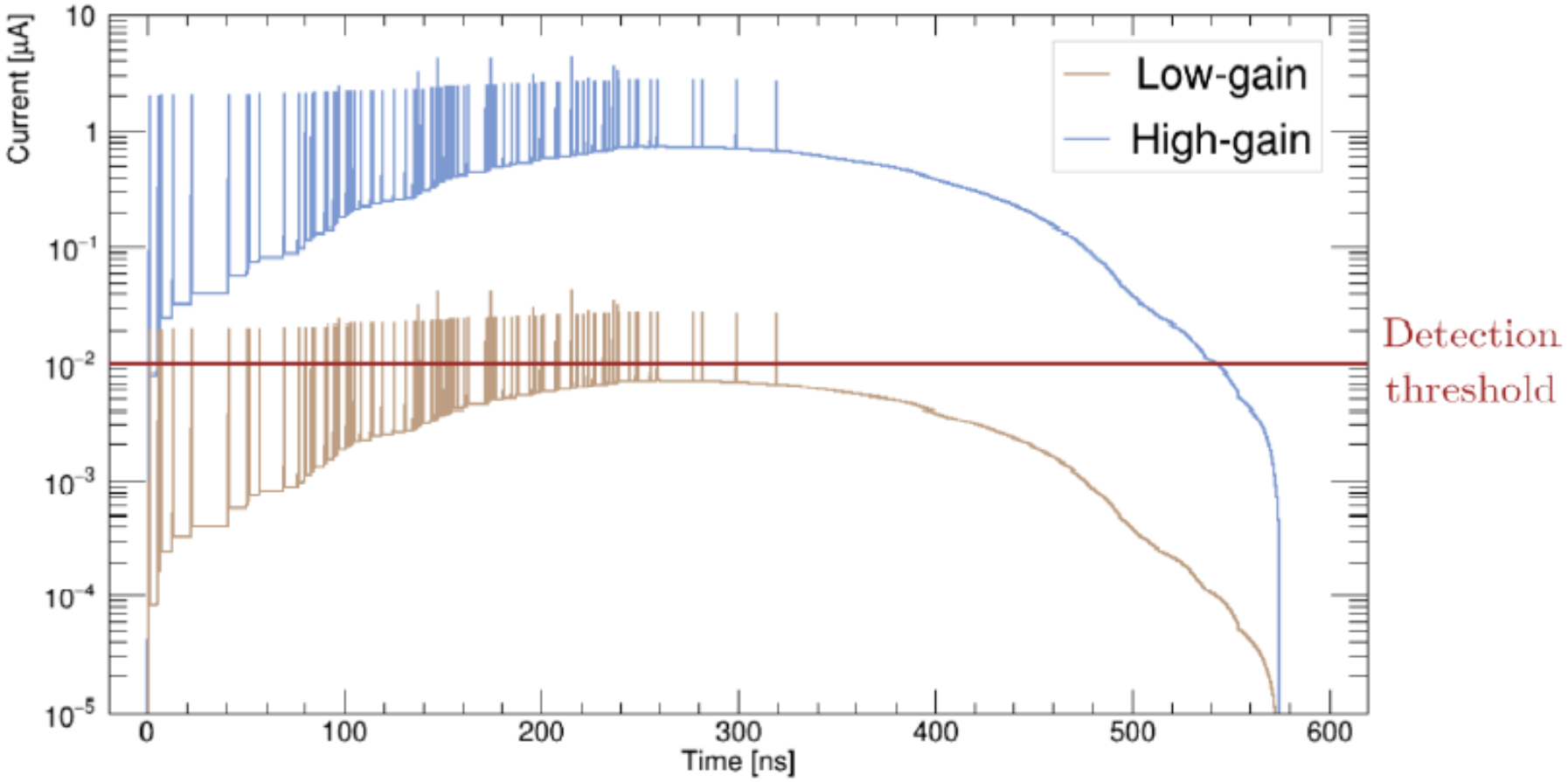
Chamber 2



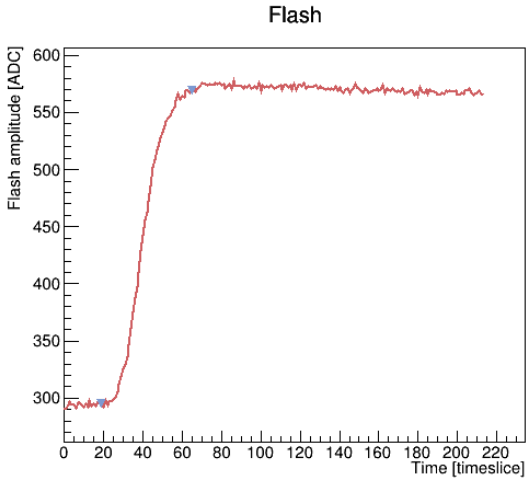
Measuring the time between the “event production” and the avalanche signal !!
Covering the 26 cm drift distance (13 us x 20 um/ns) !!

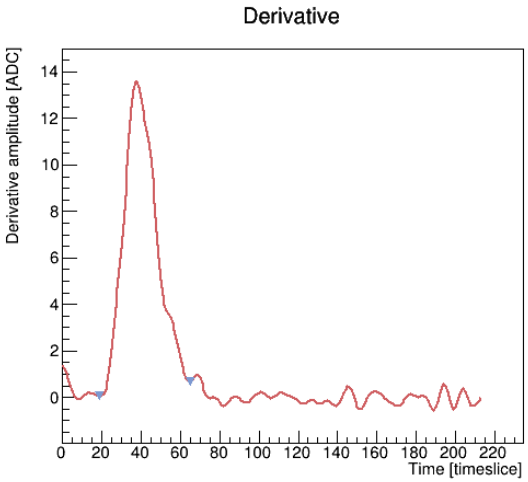
Signal contributions at high-gain (primary electrons and secondary ions)

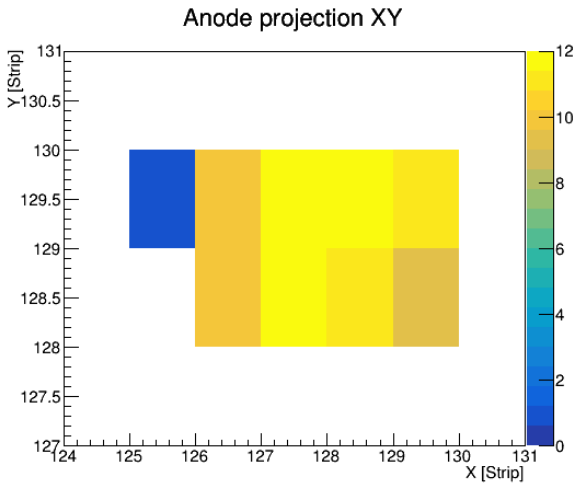
Cyprien Beaufort et al. arxiv.org/2112.12469

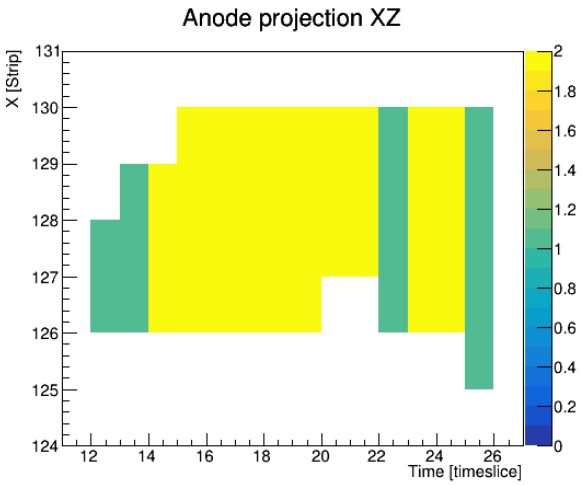


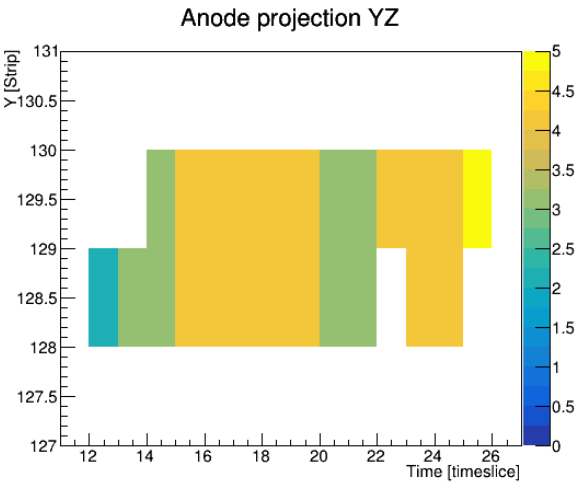
150 eV 3D- Electron track produced by COMIMAC detected by one MIMAC chamber (C_4H_{10}+50% CHF_3) at 30 mbar





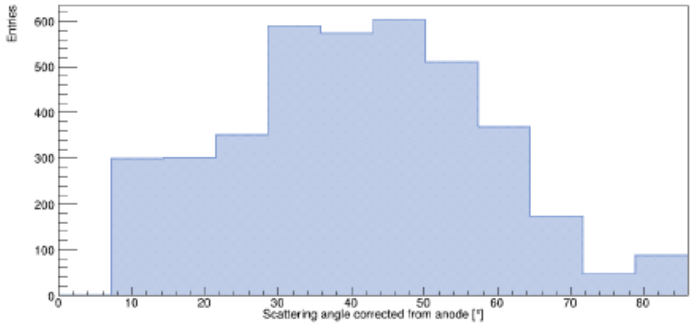


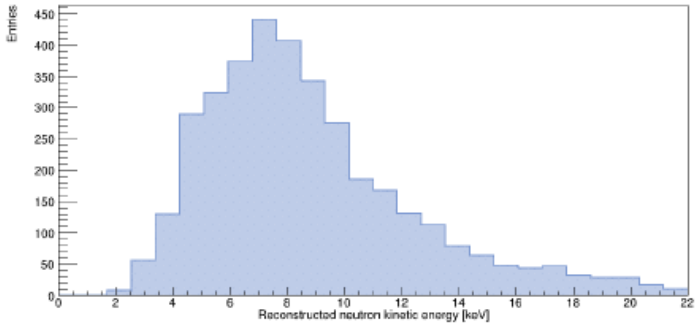


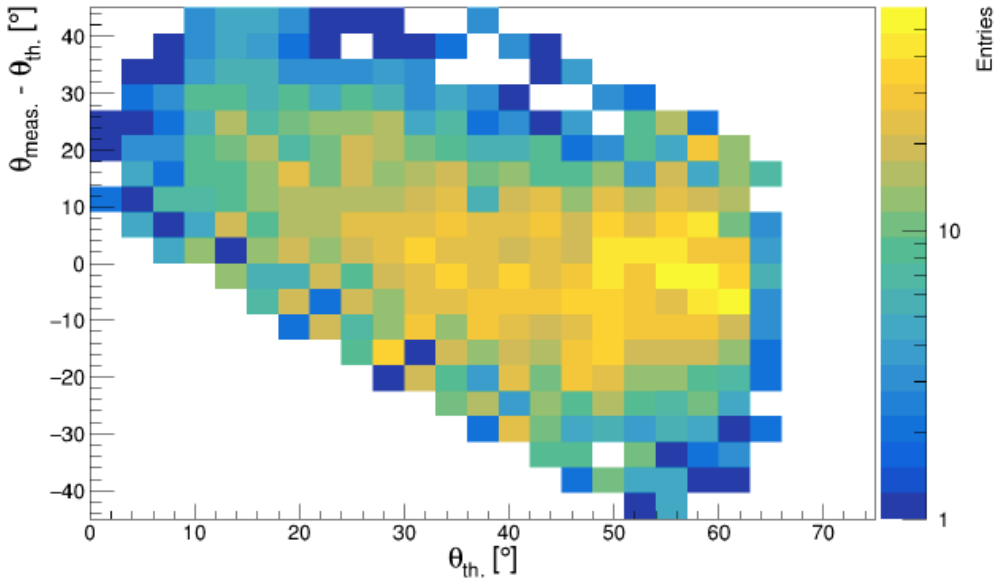


Proton recoil Angular Distribution produced by 8 keV neutrons

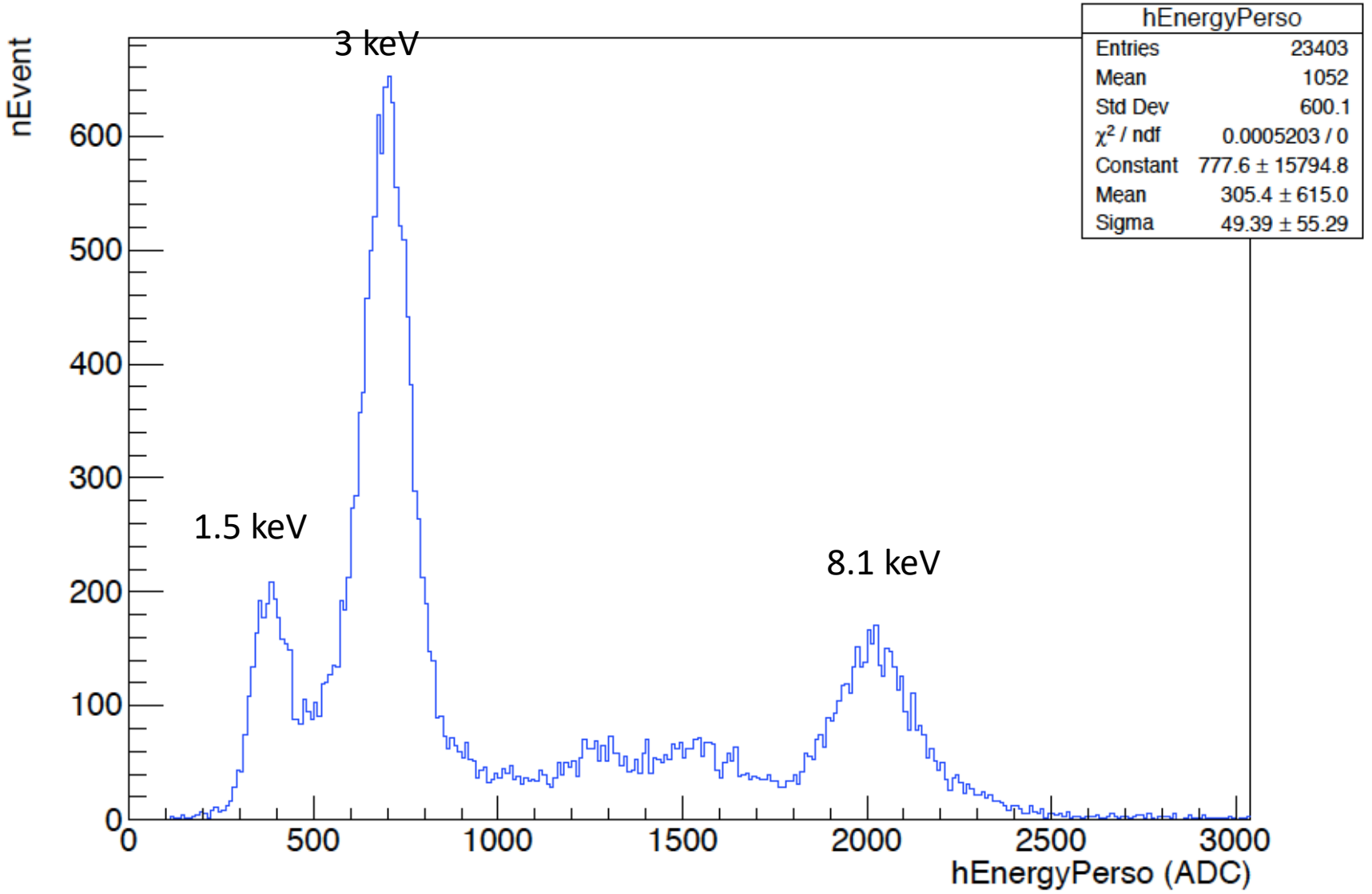
Cyprien Beaufort et al.,arxiv.org/2112.12469





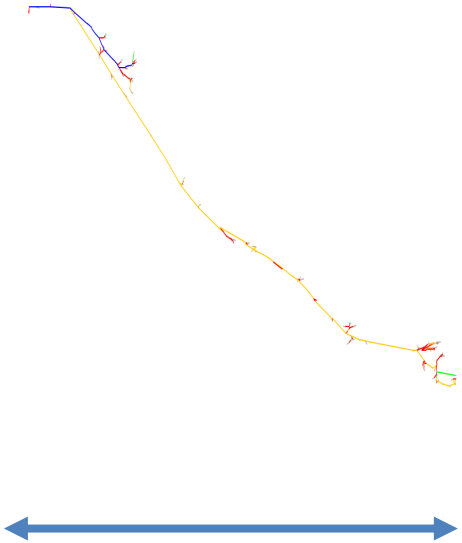


X-ray Calibration of the new detector Bi-chamber Module at 500 V, 3000V drift



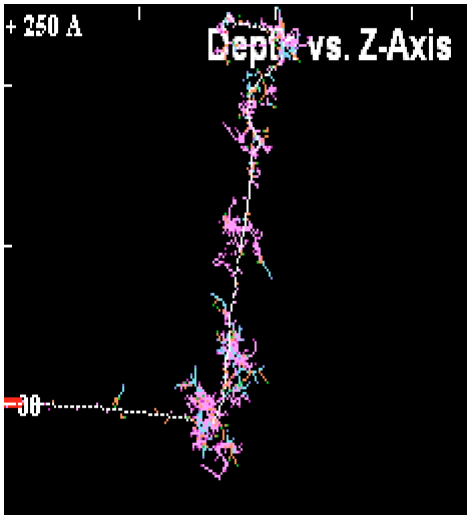
Directional detection: comparison of strategies

- Emulsion layers



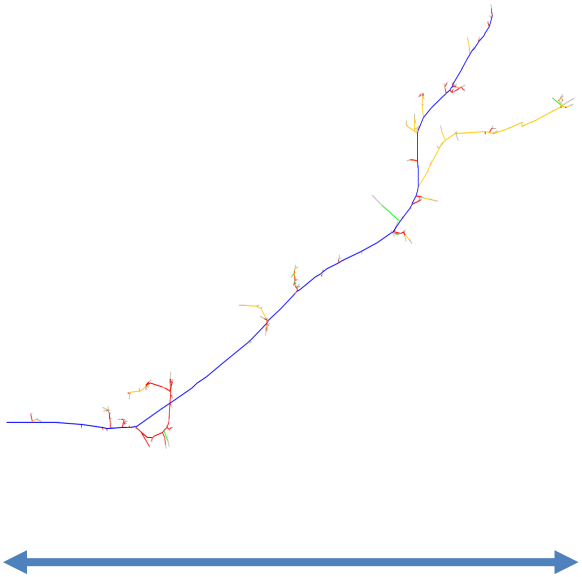
~100 nm

- Anisotropic crystals



~10 nm

- Low pressure TPCs



~1 mm
(10^5 times longuer !!)

(SRIM simulations)

MIMAC – $2m^3$ = 16 bi-chamber modules (2x 35x35x52 cm^3)

New technology anode 35cmx35cm

Stretched thin (12 um) grid at 512um.

New electronic board (1792 channels)

Only one big chamber