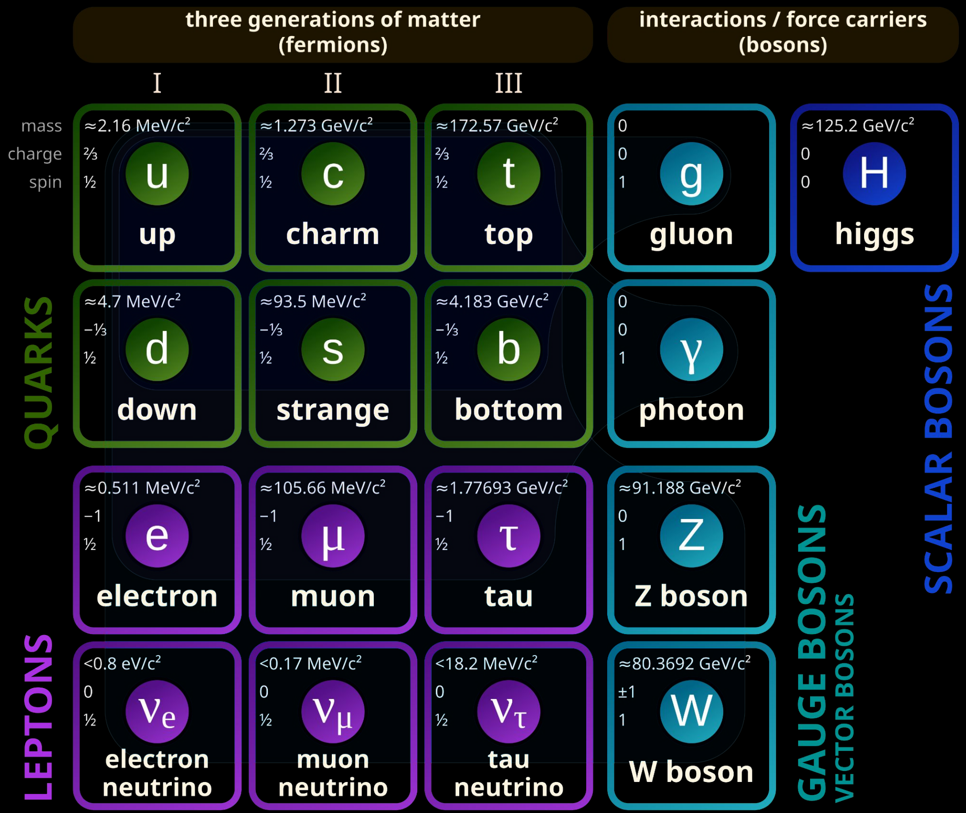
Measuring the CENNS with the cryogenic RICOCHET experiment : status and prospects

Romain FAURE
Supervised by Leïla HAEGEL and Jules GASCON

24/04/2026

The *Standard Model*



- ➔ **Foundation of particle physics**
- ➔ **Quantum description of 3 out of the 4 fundamental forces (not gravity but )**
- ➔ **Tested, retested, and reretested …**
- ➔ **Explains almost everything we know**

Theoretical and experimental success for a very large set of predictions and parameters 🎉🎉

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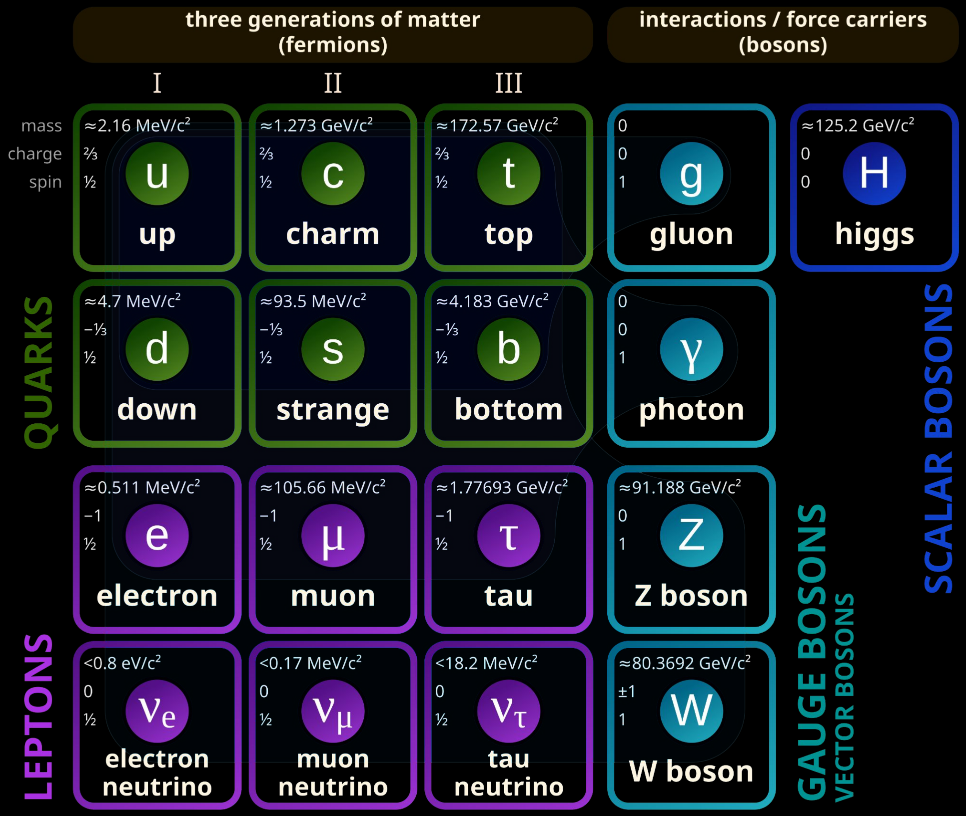

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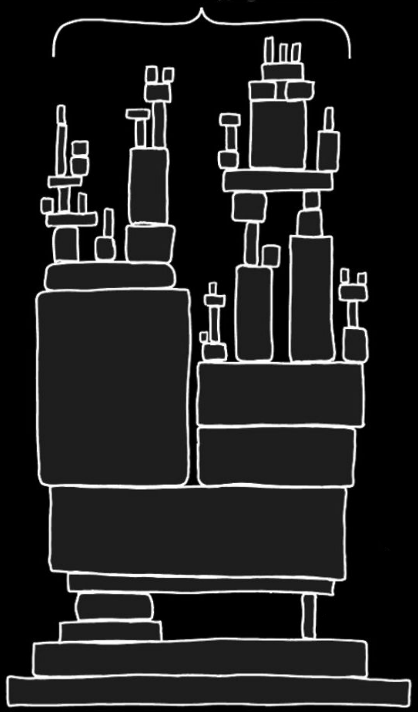
almost

yes, almost

The *Standard Model*

The Standard Model of Particle Physics



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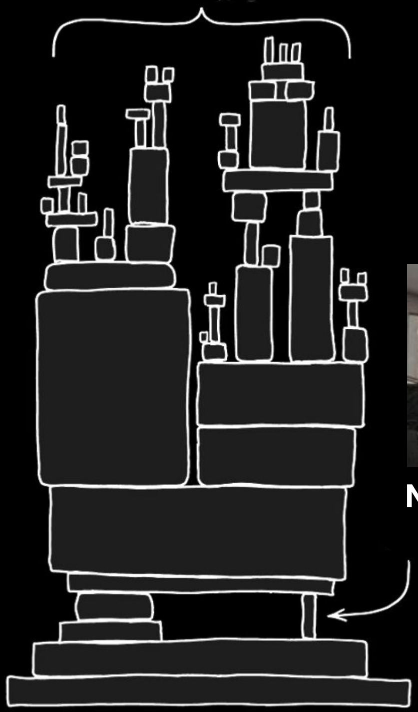

Neutrinos have no mass

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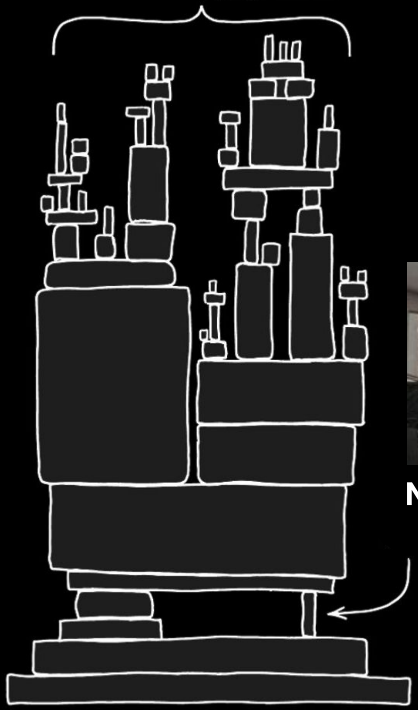


~~Neutrinos have no mass~~

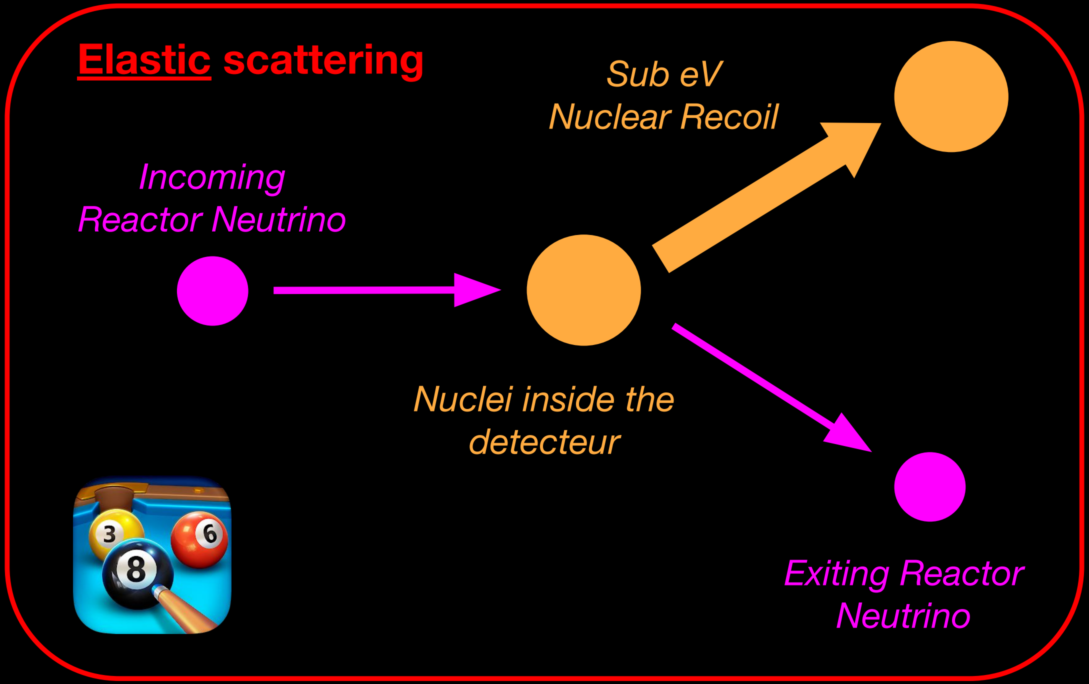
★ In 1998, T2K and SNO proves that neutrinos *oscillate*, and therefore have a mass !

➔ The Standard Model is not the ultimate model, we need to go beyond it

★ Examples of other phenomena not accounted for in the Standard Model :
- Dark Matter
- Why only 3 families ?
- Gravitation ?

Probing the Standard Model with CENNS

Coherent Elastic Neutrino-Nucleus Scattering



Why search the CENNS ?

- ➔ **Low energies aren't fully understood (eV - keV region)**
- ➔ **To measure the Weinberg angle, a free parameters of the SM**
- ➔ **CENNS is sensitive to new physics theories, that might answer the problems of the SM**

D. Z. Freedman. « Coherent effects of a weak neutral current ». Phys. Rev. D 9, 5 1974, p. 1389-1392. doi : 10.1103/PhysRevD.9.1389.

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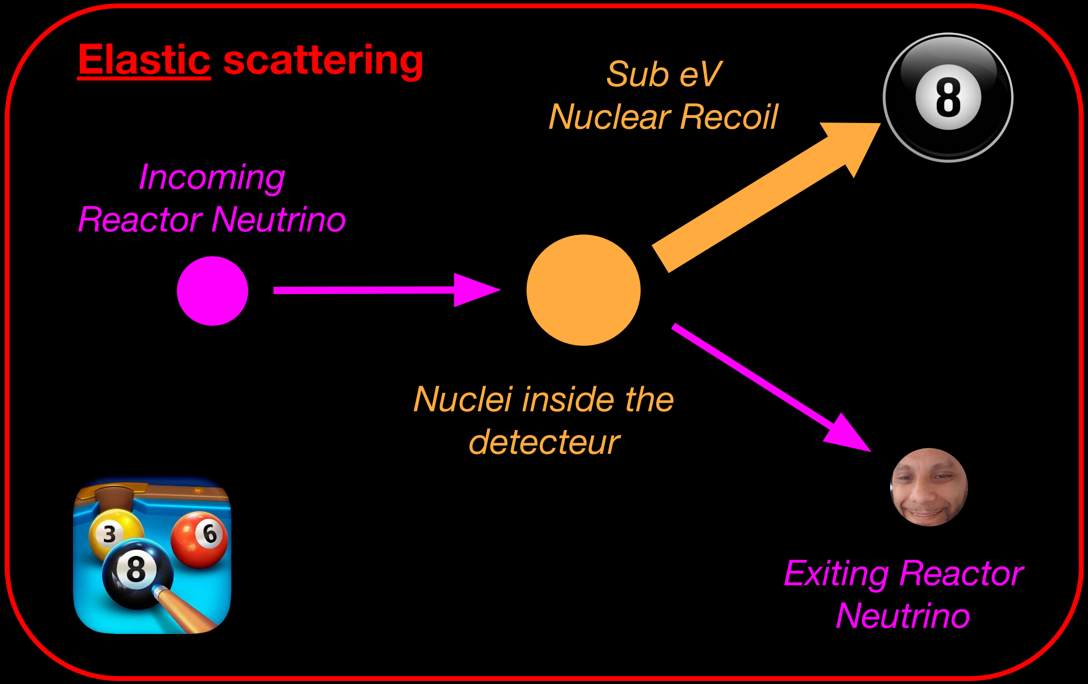

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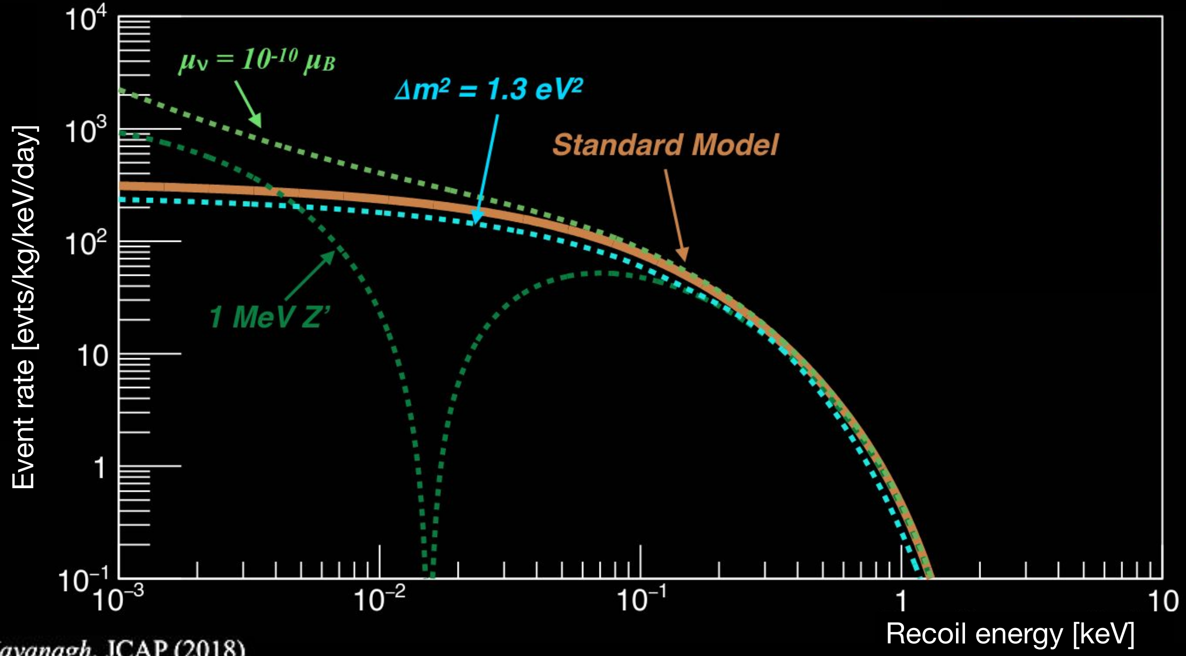
Probing the Standard Model with CENNS

Excellent probe for new physics

Recoil energy distribution

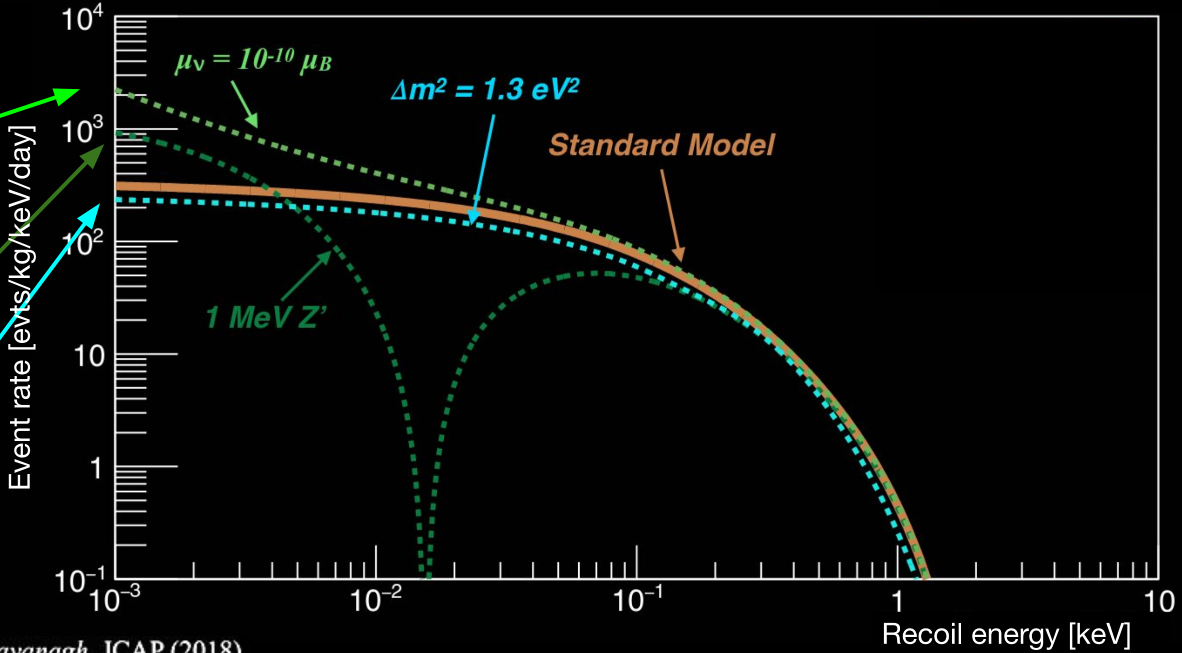


J. Billard, J. Johnston and B. Kavanagh, JCAP (2018)

Excellent probe for new physics

Deviation = New physics models !

Recoil energy distribution



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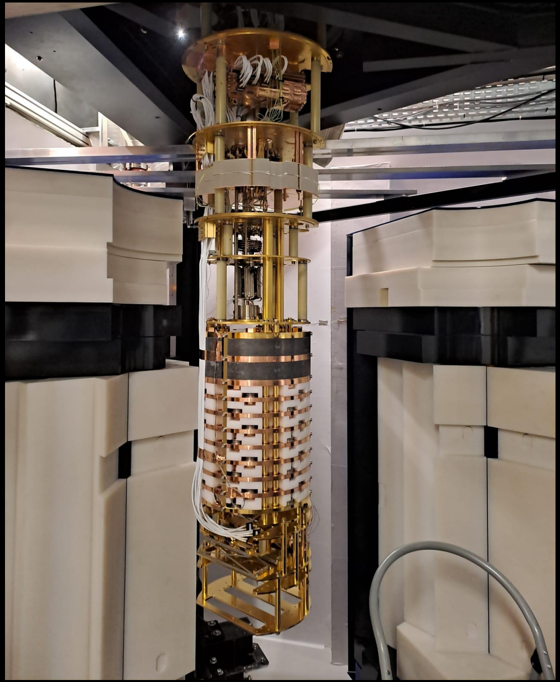
Detecting CENNS with RICOCHET



A Coherent Neutrino Scattering Program

Signal :

- ➔ Neutrino source : Institut Laue Langevin nuclear reactor (ILL), at Grenoble, 8.8m from the detectors
- ➔ Cryogenic detectors : Semiconductor Germanium with ionisation and heat readout

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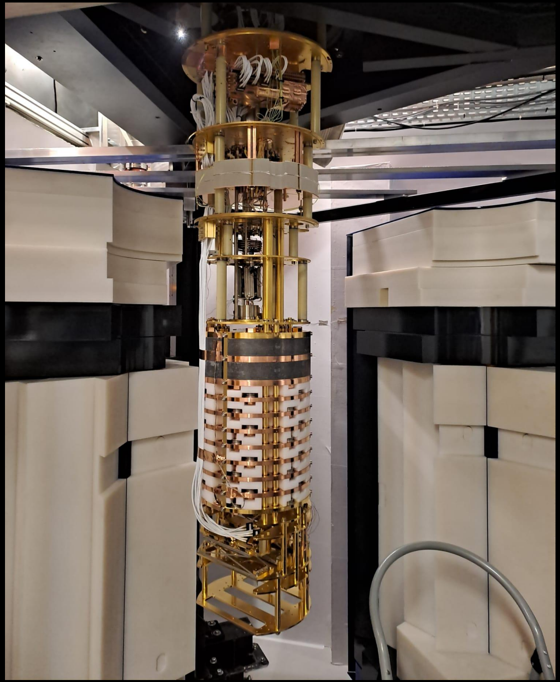

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Backgrounds :

➔ Radiogenics, reactogenics et cosmogenics

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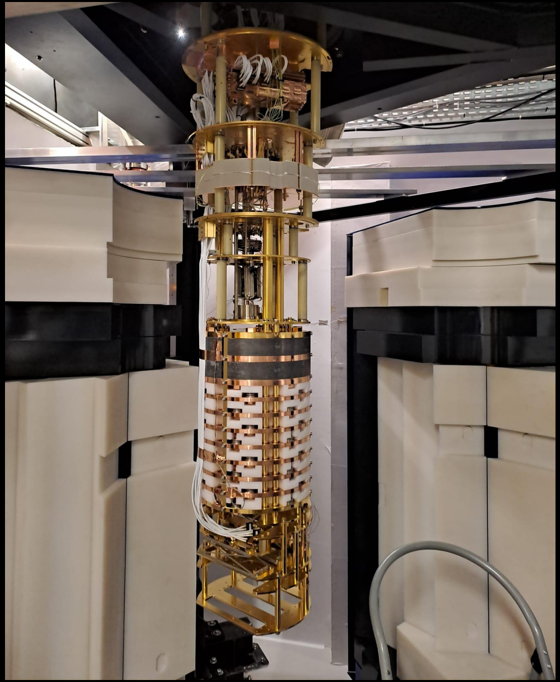

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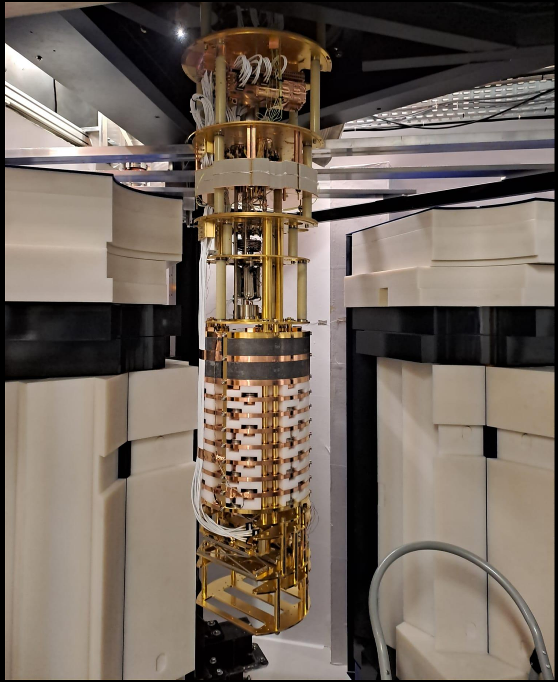
Need some shielding !

Detecting CENNS with RICOCHET



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Mitigation  **:**

➔ Passive shielding (20 t) : lead, polyethylene and overburden of 15 m.w.e

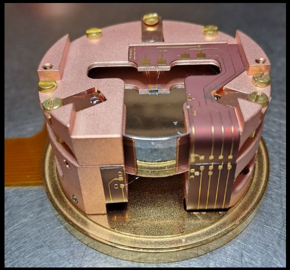
➔ Active shielding : muon veto

➔ Discrimination between electronic recoils (background, the bad ones) et nuclear recoils (signal, the good ones) by the detectors

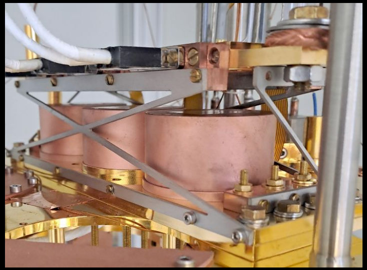
Detectors

Cryocubes :

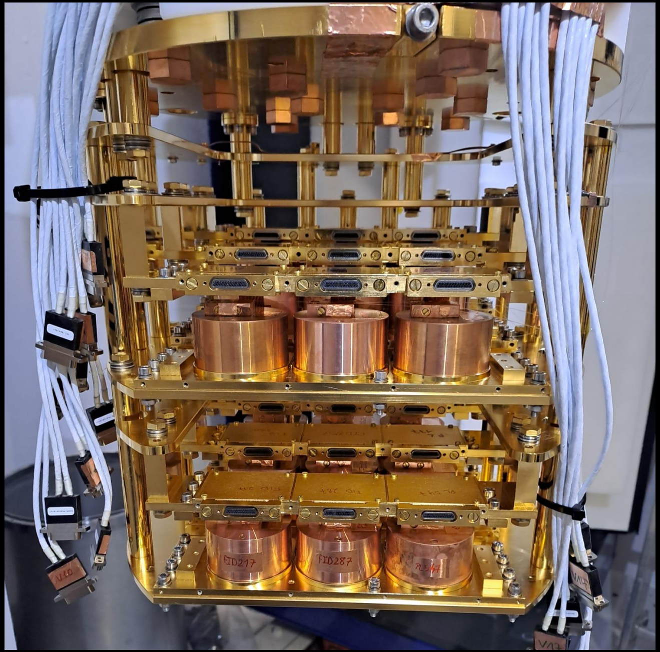
- ➔ 42-g semiconductor Germanium crystal
- ➔ Dual readout of ionisation and heat 
- ➔ 18 detectors currently installed
- ➔ Science phase started in July 2025 !



Germanium detector

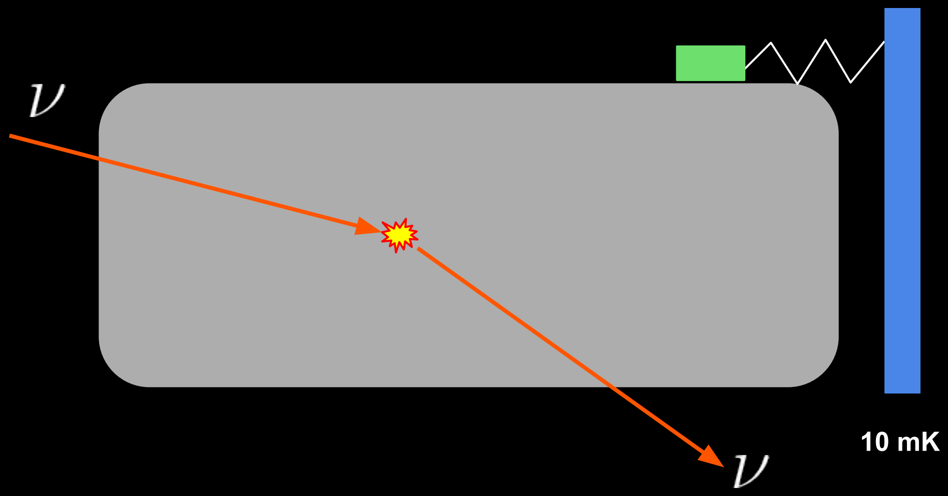


MiniCryoCube



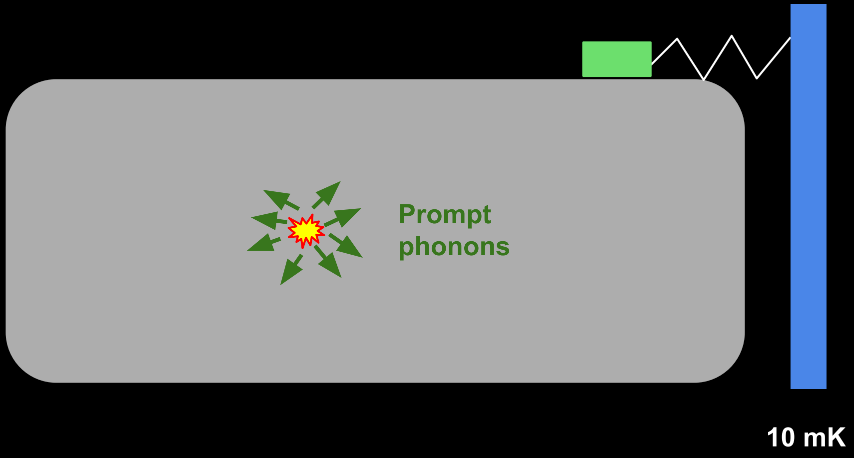
CryoCube detectors for RICOCHET at Institut Laue Langevin, 18 Ge detectors

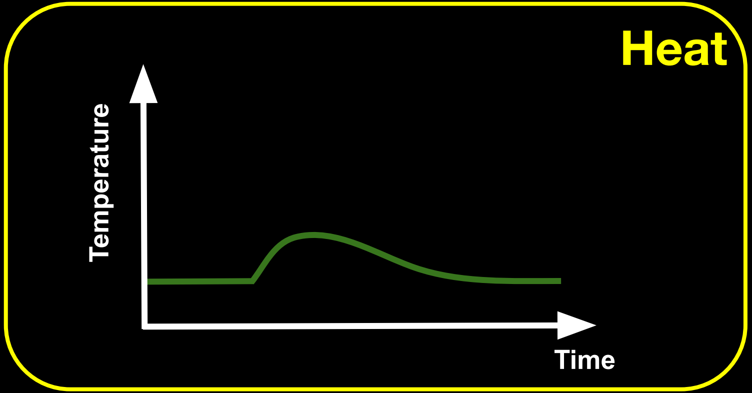
Double readout : Heat and Ionization



- Germanium crystal
- Thermal bath
- Thermal sensor

Double readout : Heat and Ionization





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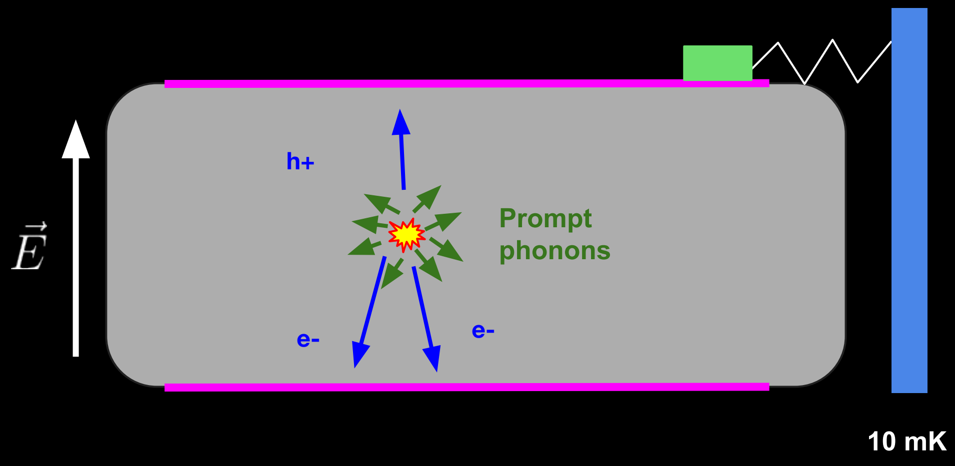

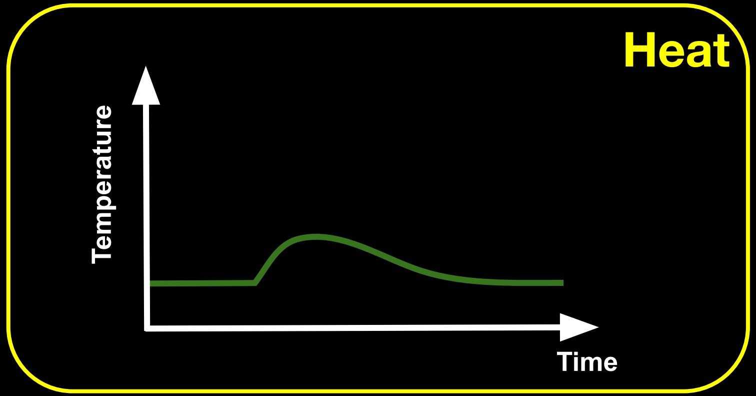

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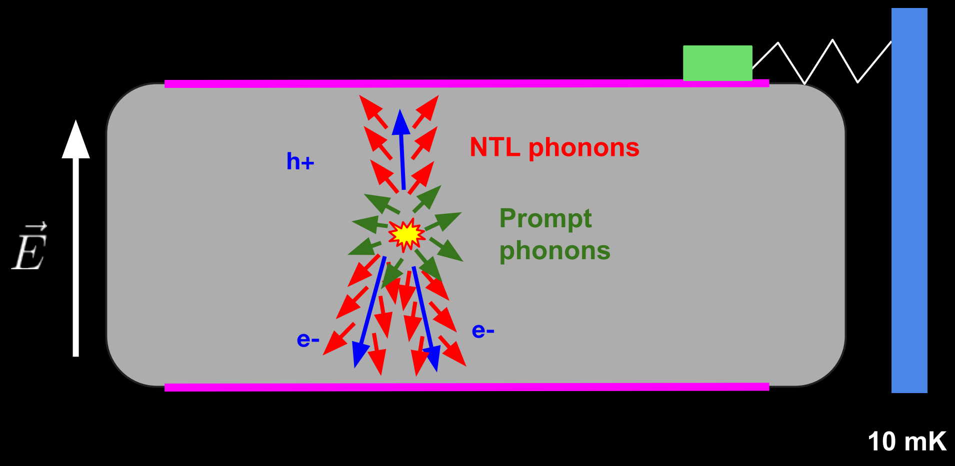

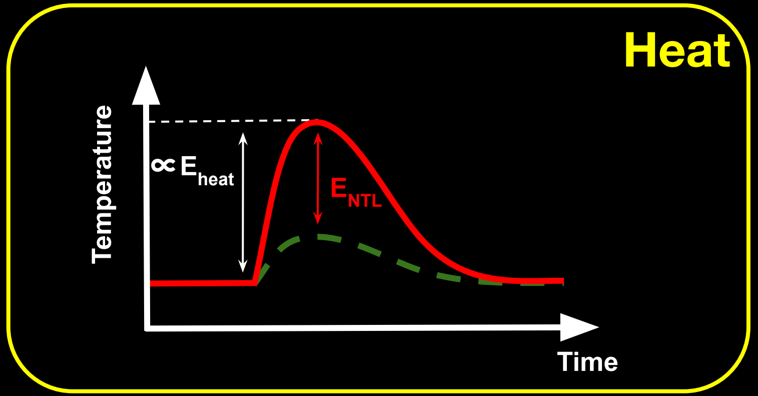

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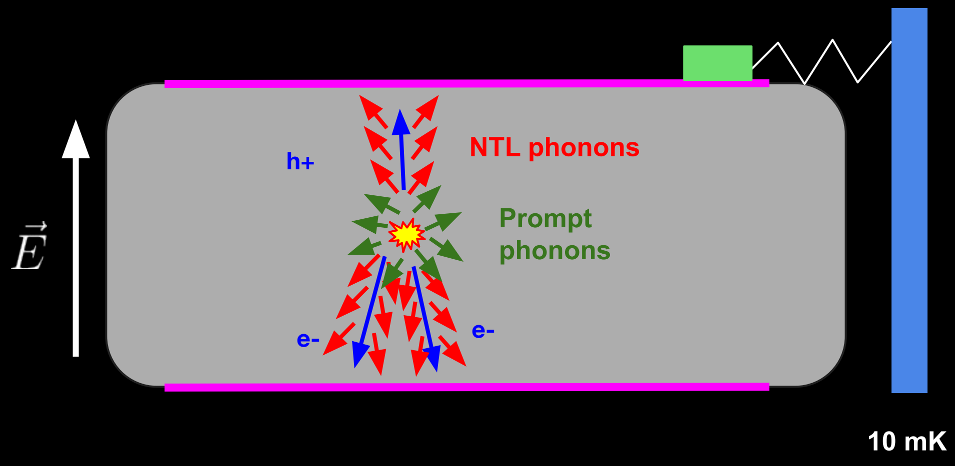

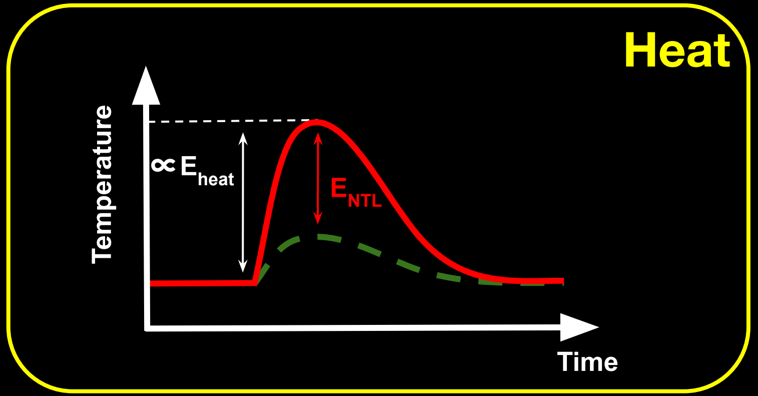

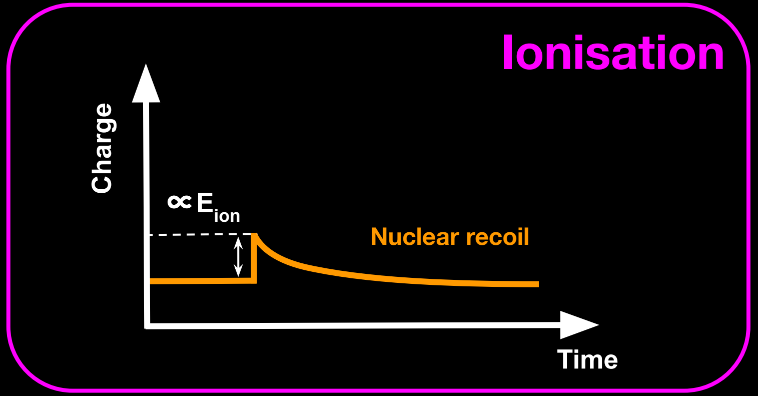

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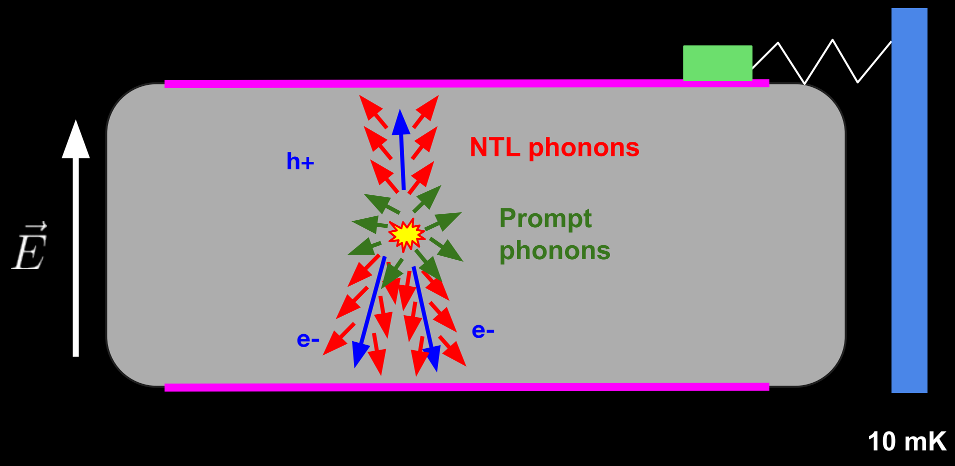

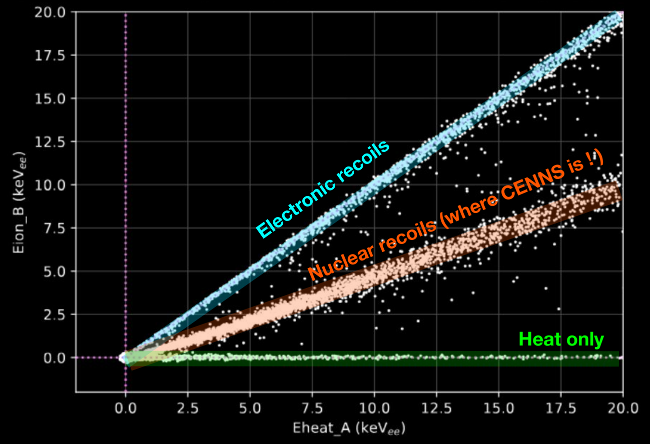

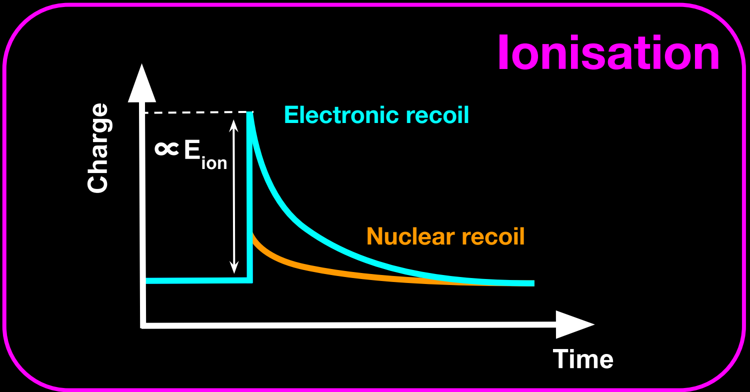

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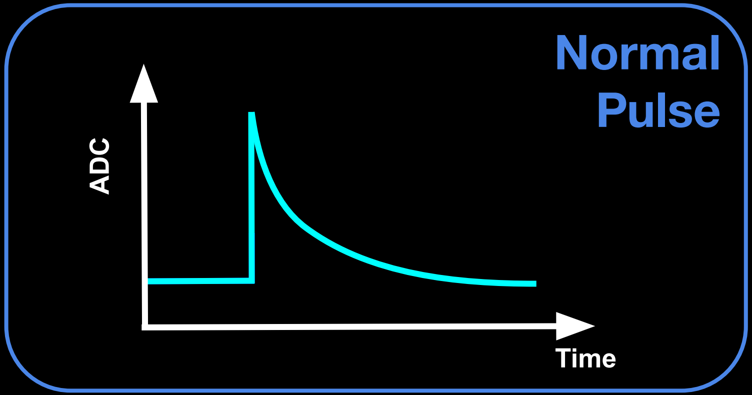
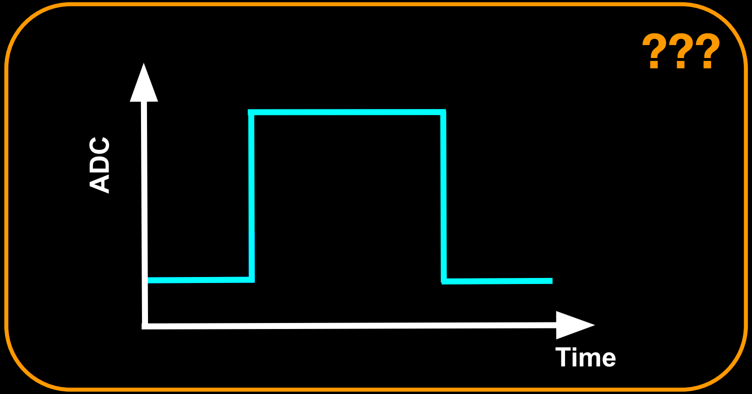
Guess the event !

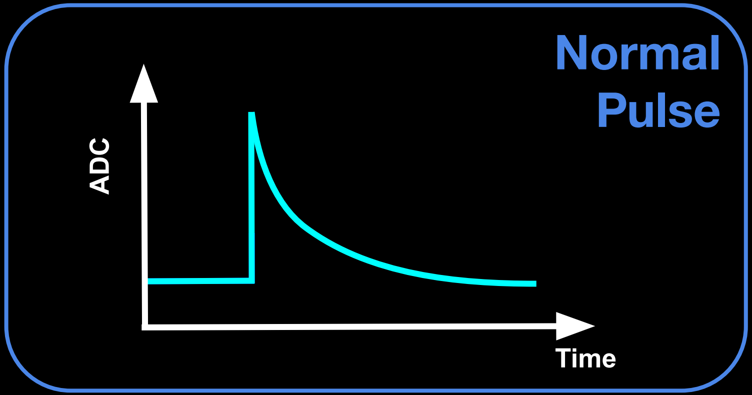


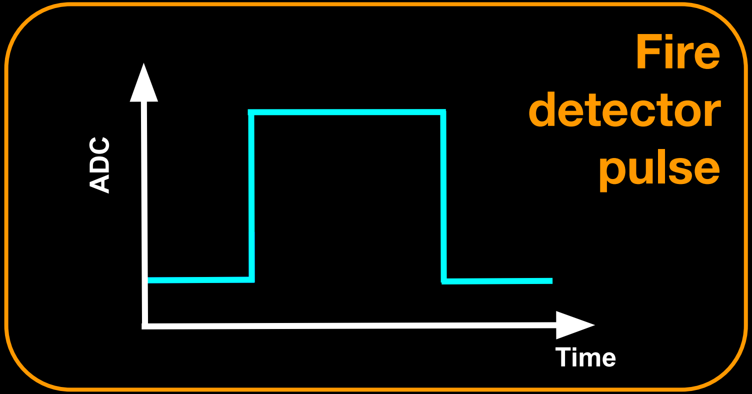


What is this square pulse ?

1. The meowing of the cat next door
2. The fire detector above the experiment
3. The coffee machine of the technical local
4. The guard playing Subway Surfer

Guess the event !





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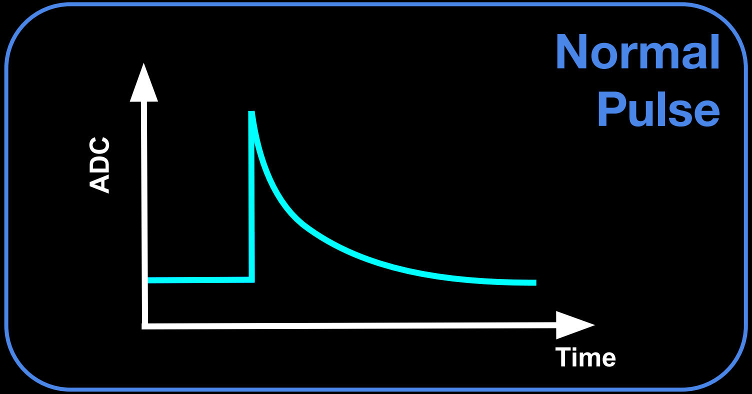

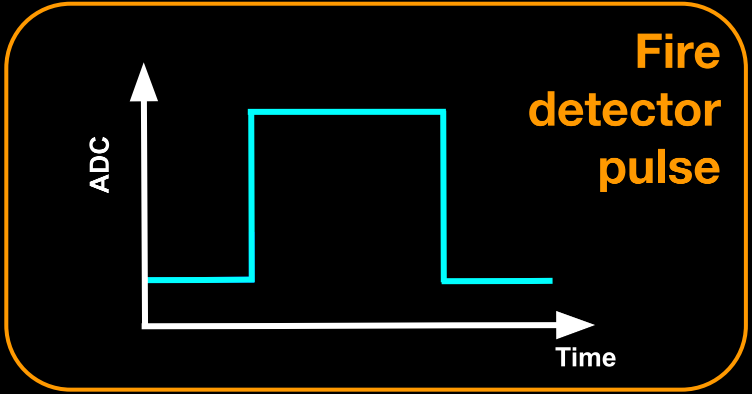

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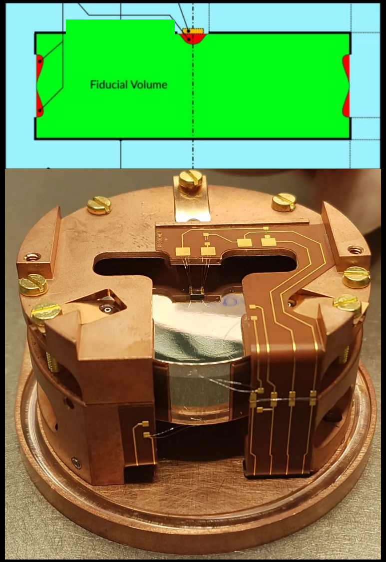
→ We are very, *very*, sensitive

Detectors

Two different types of electrodes configuration



Planar configuration (PL)

- Two electrodes
- Greater uniformity of the electric field
- 99.2 % fiducial volume

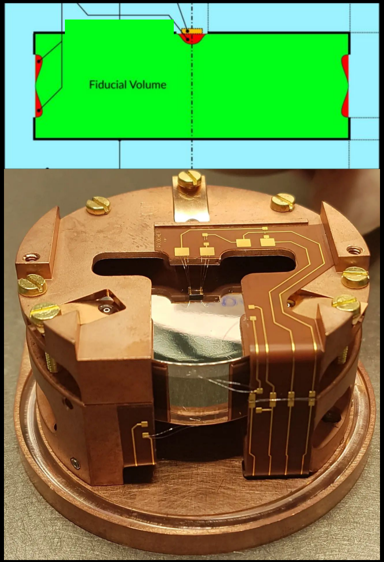
But :

- No discrimination of the surfaces events

J.Low Temp.Phys. 211 (2023) 5-6, 398-406

Detectors

Two different types of electrodes configuration



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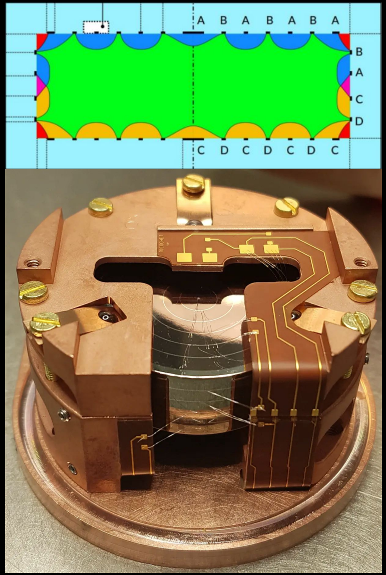

Fully interdigitated configuration (FID)

- Four electrodes, creating different volumes of detection
- Identification of surface events

But :

- Reduced fiducial volume (50-70%)

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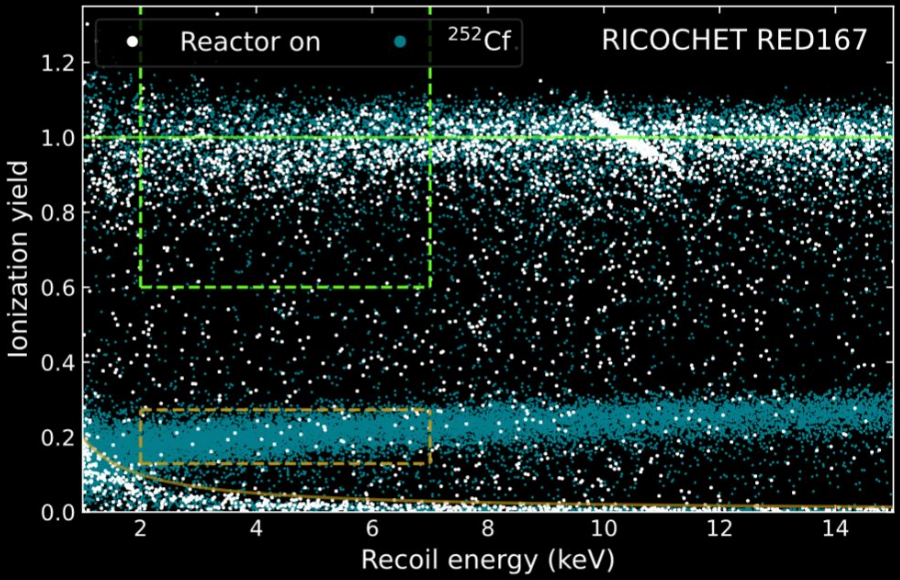
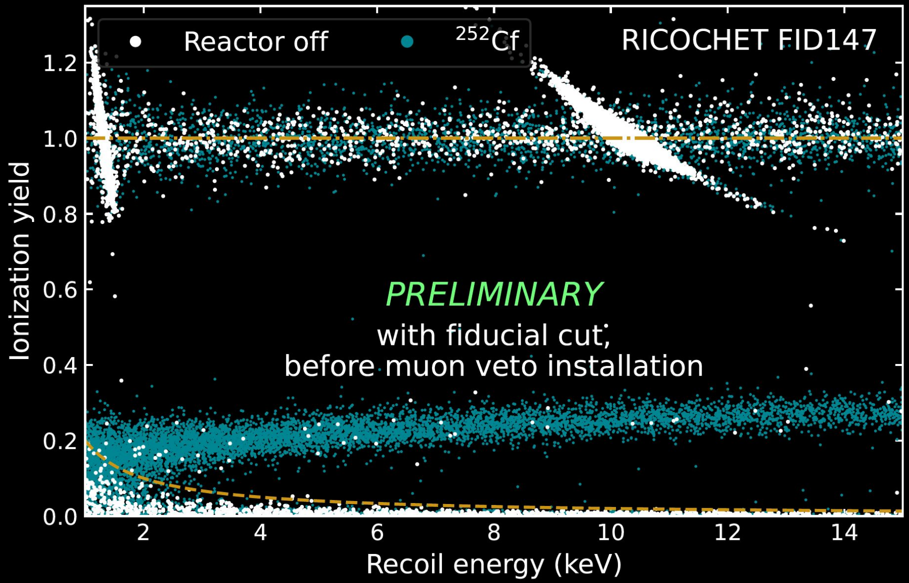
FIDs

The fiducial configuration allows to cut off the surface events





https://arxiv.org/pdf/2507.22751

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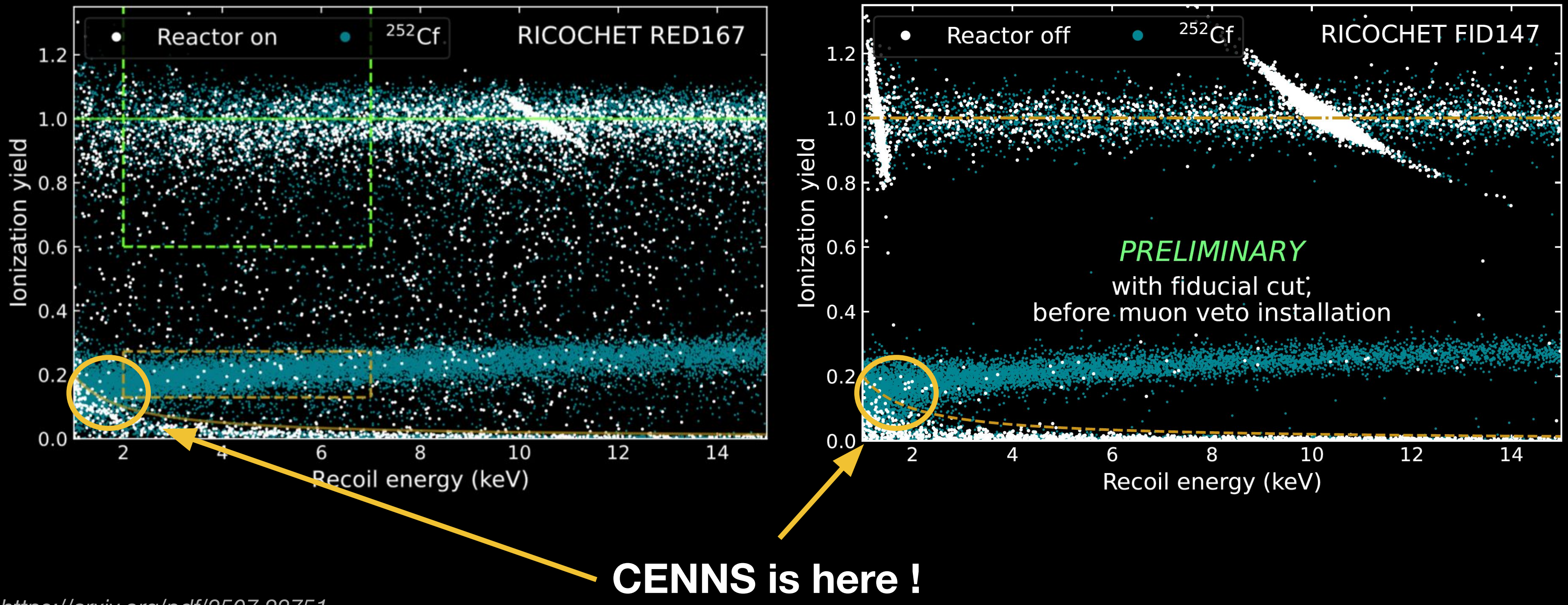

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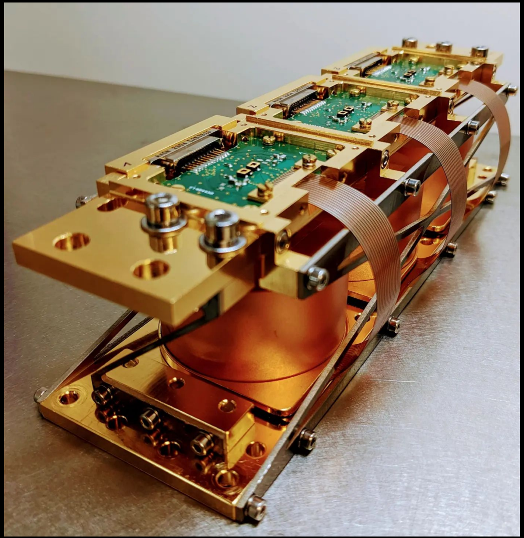
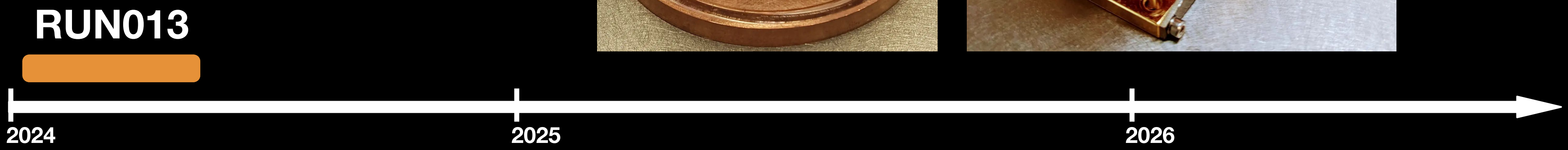
Runs @ ILL

A run is a long data taking period at the ILL
ILL has an alternating cycle on OFF and ON period of the reactor

- **RUN013 - 2024**
  - ➔ First data taking at ILL
  - ➔ 3 planar detectors in one miniCryocube





Runs @ ILL

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- RUN013 - 2024
- RUN014 - 2024
  - ➔ Same 3 detectors than in RUN13
  - ➔ Installation of the outer muon veto
  - ➔ Installation of the laser for calibration and removal of electron trapping

Runs @ ILL

A run is a long data taking period at the ILL
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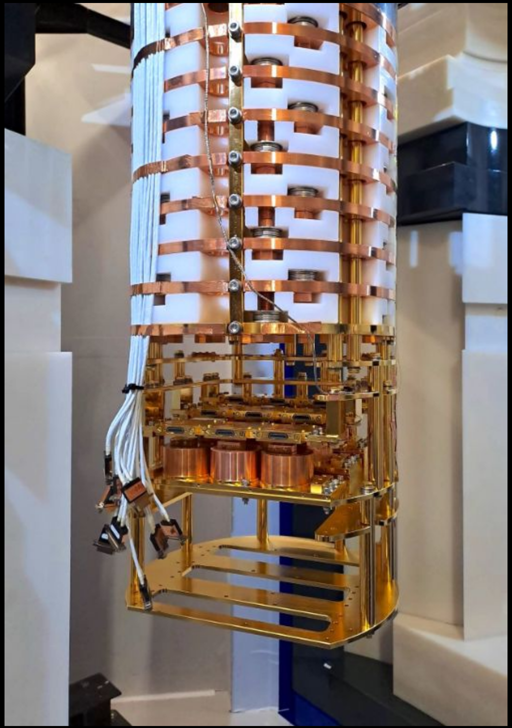
- **RUN013 - 2024**
- **RUN014 - 2024**
- **RUN015 - 2025**
  - ➔ **9 detectors : 3 planar / 6 FID**
  - ➔ **Ionisation resolution of 40 eVee**
  - ➔ **Phonon resolution of 30 eVee !**



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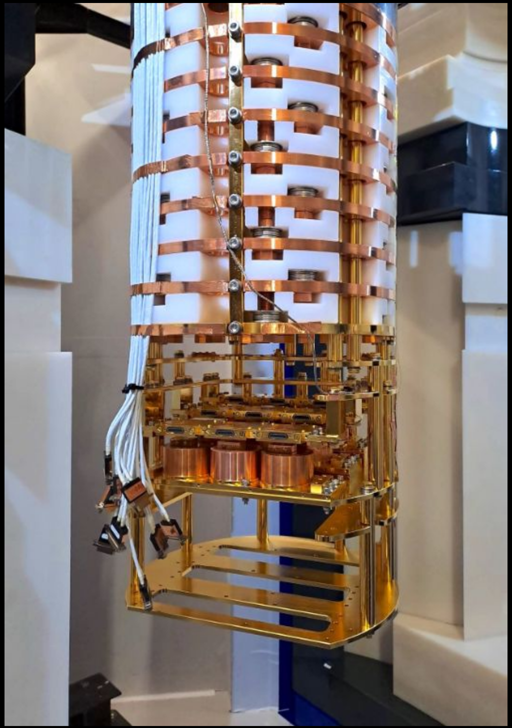

Runs @ ILL

A run is a long data taking period at the ILL
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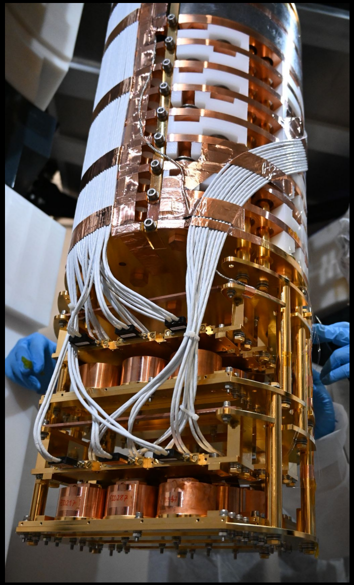
- **RUN013 - 2024**
- **RUN014 - 2024**
- **RUN015 - 2025**
- **RUN016 - 2025 / 2026**
  - ➔ **First science Run with the whole payload !**
  - ➔ **18 detectors in total : 9 planar / 11 FID**
  - ➔ **Analysis ongoing**



Runs @ ILL

A run is a long data taking period at the ILL
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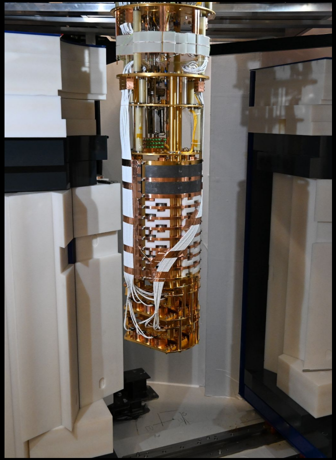
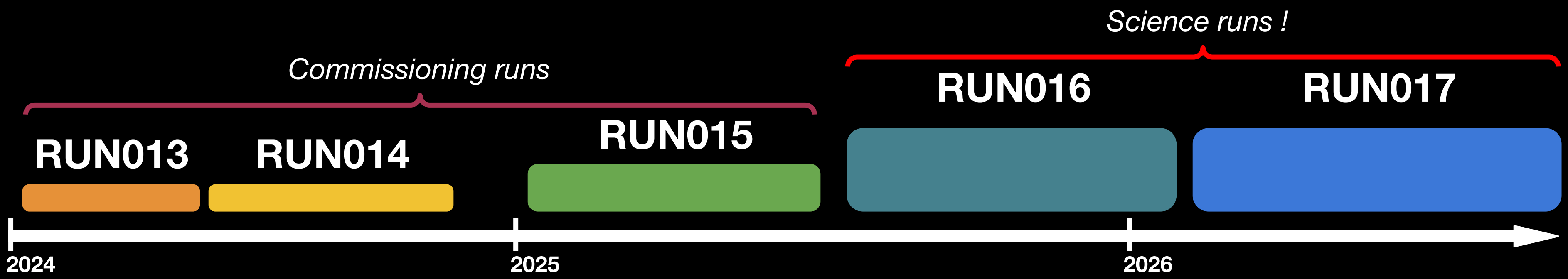
- RUN013 - 2024
- RUN014 - 2024
- RUN015 - 2025
- RUN016 - 2025 / 2026
- RUN017 - 2026
  - ➔ Change of the heat preamplifier
  - ➔ Same detectors as in RUN16
  - ➔ Taking data right now !





Conclusion

RUN017 until end of 2026 !

- Currently in its science phase
- Taking data as of right now
- Characterization of performance
- Ready for a first CENNS measurement !

Conclusion

RUN017 until end of 2026

- **Currently in its science phase**
- **Taking data as of right now and analysis on the way**
- **Characterization of performance**
- **Ready for a first CENNS measurement !**

But not only !

Ricochet is in R&D for a phase II !

- **Other semiconductors targets (see *Tatiana*'s talk just after this one !)**
- **Improvement of the readout**

Lots of physics, analysis and instrumentation to come !

Back up

L'angle de Weinberg et la constante de Fermi

Théorie : $\sin^2\theta_W \simeq 0.23$

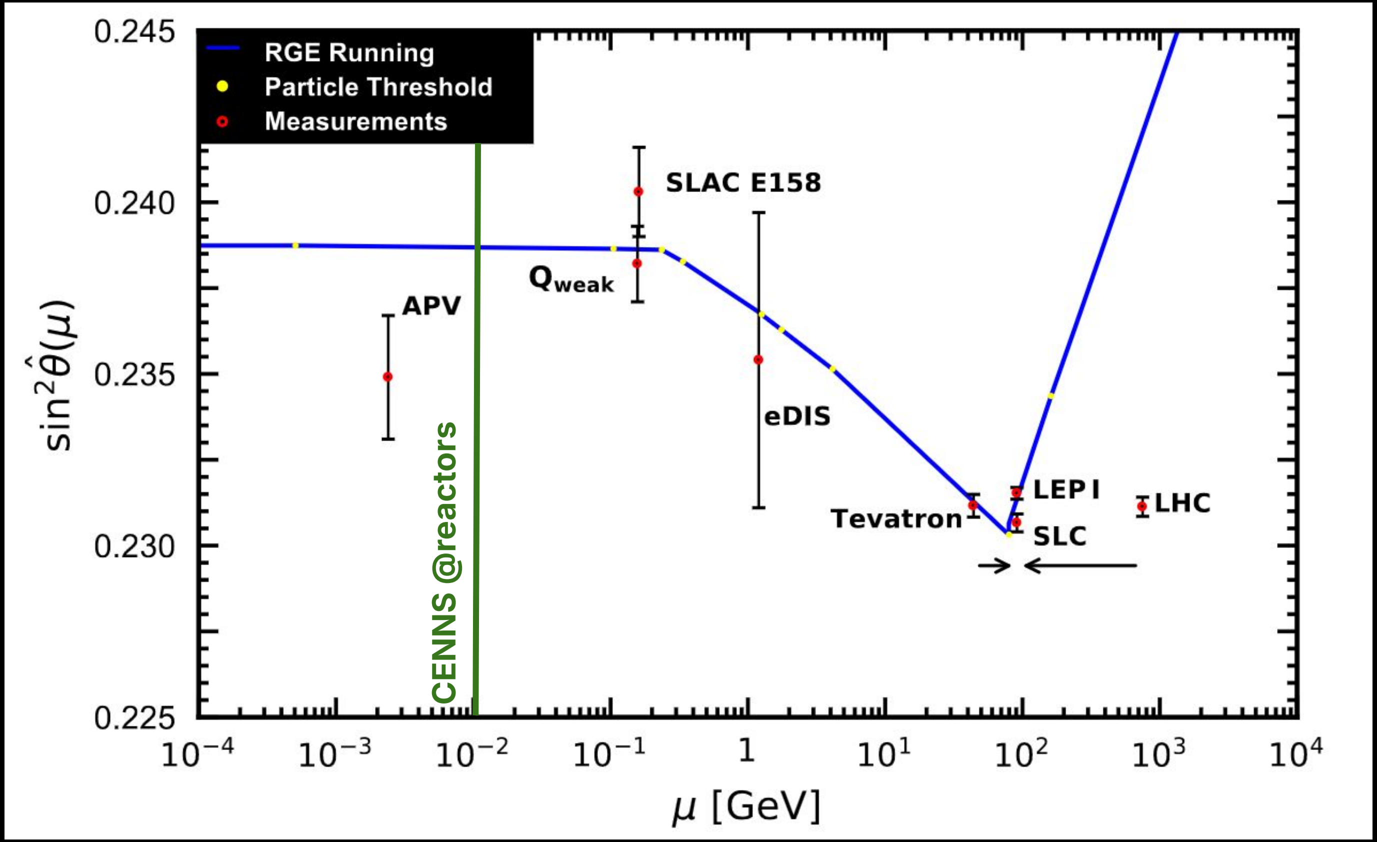
Expérimentalement : $\sin^2\theta_W = 0.23146 \pm 0.00012$

$$\Rightarrow \boxed{\theta_W \simeq 30^\circ}$$

CENNS = Tests de précision du Modèle Standard à basses énergie dans le secteur électrofaible

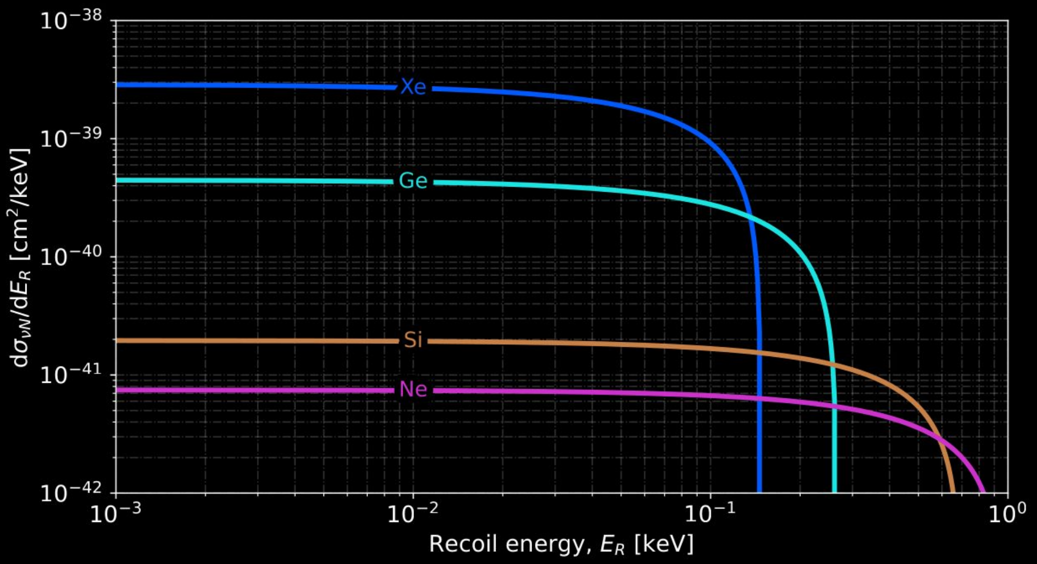
$$G_\mathrm{F} = \frac{\sqrt{2}}{8}\left(\frac{g_\mathrm{W}}{m_\mathrm{W}c^2}\right)^2(\hbar c)^3 \qquad \frac{G_\mathrm{F}}{(\hbar c)^3} = 1{,}166\,378\,7(6)\times 10^{-5}\ \mathrm{GeV}^{-2}$$

Weinberg



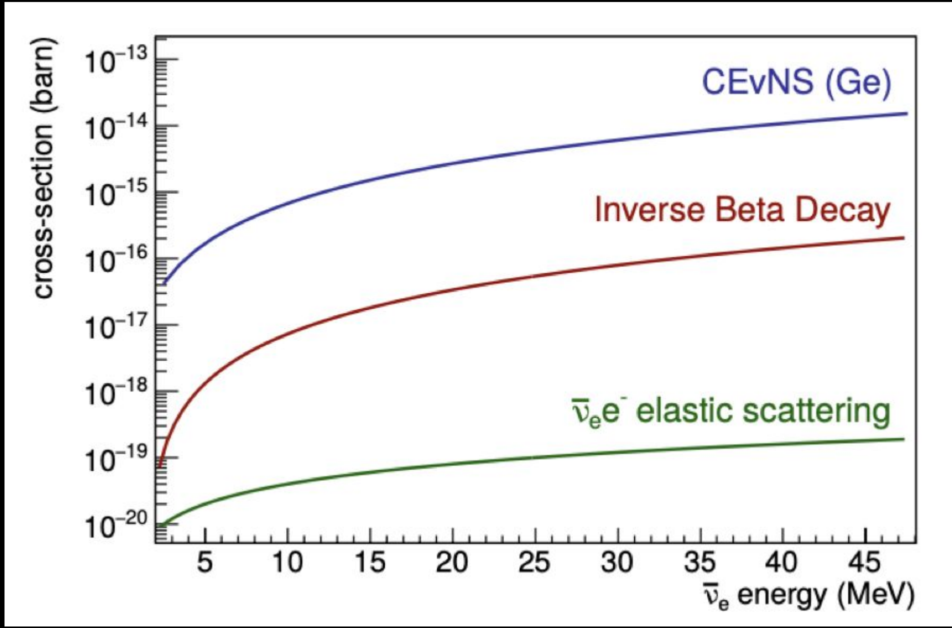
RGE Running
Particle Threshold
Measurements
SLAC E158
Q_{weak}
APV
eDIS
CENNS @reactors
LEP I
SLC
Tevatron
LHC
$\sin^2\hat{\theta}(\mu)$
μ [GeV]
0.245
0.240
0.235
0.230
0.225
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
10^{1}
10^{2}
10^{3}
10^{4}

Pourquoi du Germanium ?



Section efficace différentielle du CENNS dans le cadre du Modèle Standard

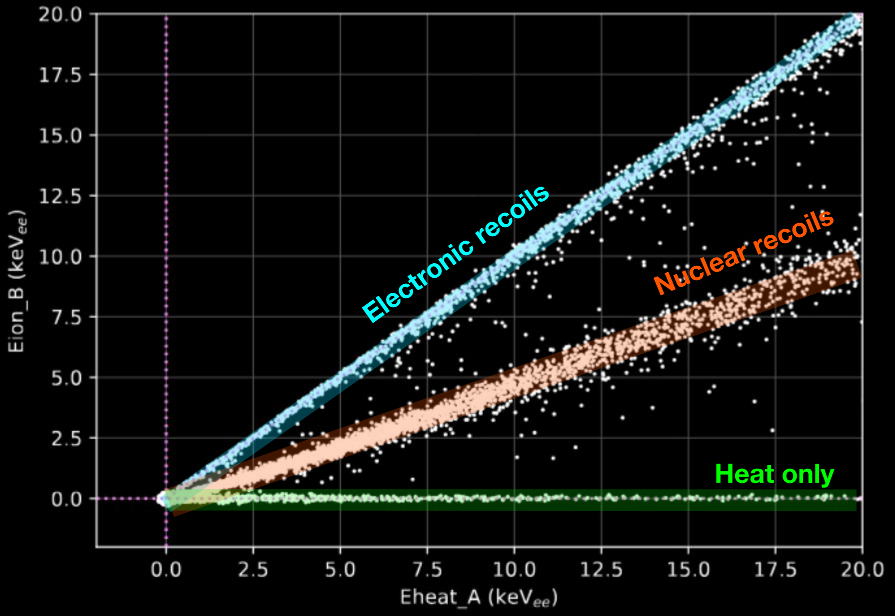
Section Efficace



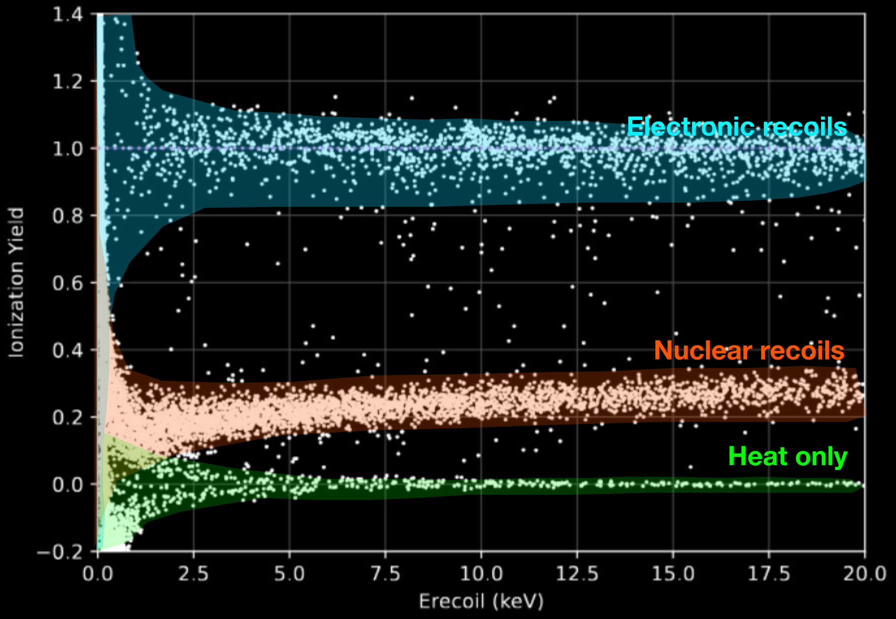
Section efficace totale en fonction de l'énergie du neutrino pour différents processus d'interaction

Double readout : Heat and Ionization

Typical CryoCube detector's data. Exposition to a neutron (AmBe) source



(E_{heat}, E_{ion}) plan

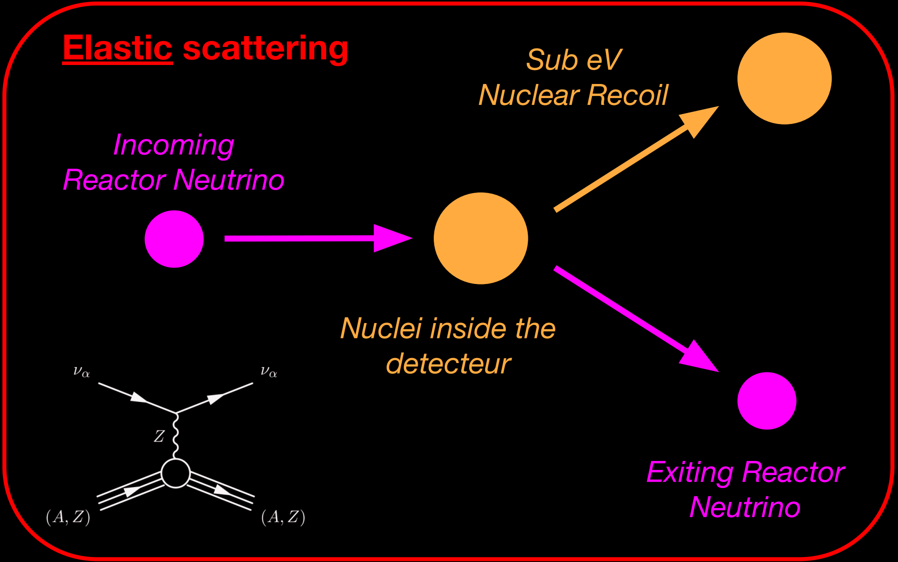


(E_R, Q) plan

N. Martini

Probing the Standard Model with CENNS

Coherent Elastic Neutrino-Nucleus Scattering



Signal : $E_R^{max} \sim \dfrac{2E_\nu^2}{m_N}$

$$\underbrace{\frac{d\sigma(E_\nu, E_R)}{dE_R}}_{\text{Section efficace différentielle}} = \underbrace{\frac{G_f^2}{4\pi} Q_W^2}_{\text{Théorie électro-faible}} m_N \underbrace{\left(1 - \frac{m_N E_R}{2E_\nu^2}\right)}_{\text{Cinématique}} \underbrace{F^2(E_R)}_{\text{Facteur de forme}}$$

$$Q_W = N - Z(1 - 4\sin^2\theta_W)$$

Mesure de l'angle de Weinberg à basse énergie

L'angle de Weinberg

Angle de mélange résultant de l'unification de la théorie électrofaible
Il y a dans le Modèle Standard deux bosons neutres (Z^0 et Aμ) qui sont décrit dans la théorie électrofaible par deux nouveaux bosons neutres, Bμ et W3μ, associés à une nouvelle symétrie de jauge U(1)Y

$$A^\mu = B^\mu \cos\theta_W + W_3^\mu \sin\theta_W$$
$$Z^\mu = -B^\mu \sin\theta_W + W_3^\mu \cos\theta_W$$

Cet angle représente la rotation effectuée lors de la brisure spontanée de symétrie sur le plan des bosons Bμ et W3μ lorsqu'ils produisent un boson Z et un photon Aμ. La valeur de $\sin^2\theta$w dépend de l'énergie (!) et peut être obtenue théoriquement par le rapport des constantes de couplages αW et αEM

Théorie : $\sin^2\theta_W \simeq 0.23$ **Expérimentalement :** $\sin^2\theta_W = 0.23146 \pm 0.00012$

$\Rightarrow$ $\theta_W \simeq 30^\circ$

CENNS = Tests de précision du Modèle Standard à basses énergies dans le secteur électrofaible