Status of the RICOCHET experiment at ILL

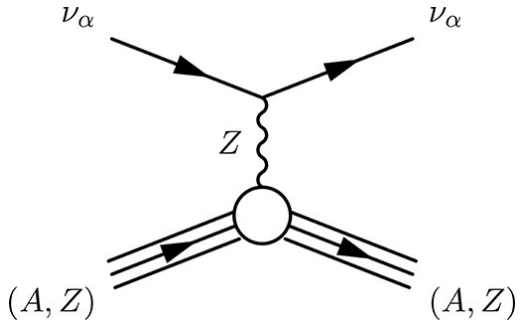
Louis Bailly-Salins on behalf of the RICOCHET collaboration

IRN neutrino meeting, Lyon, 13/06/2025

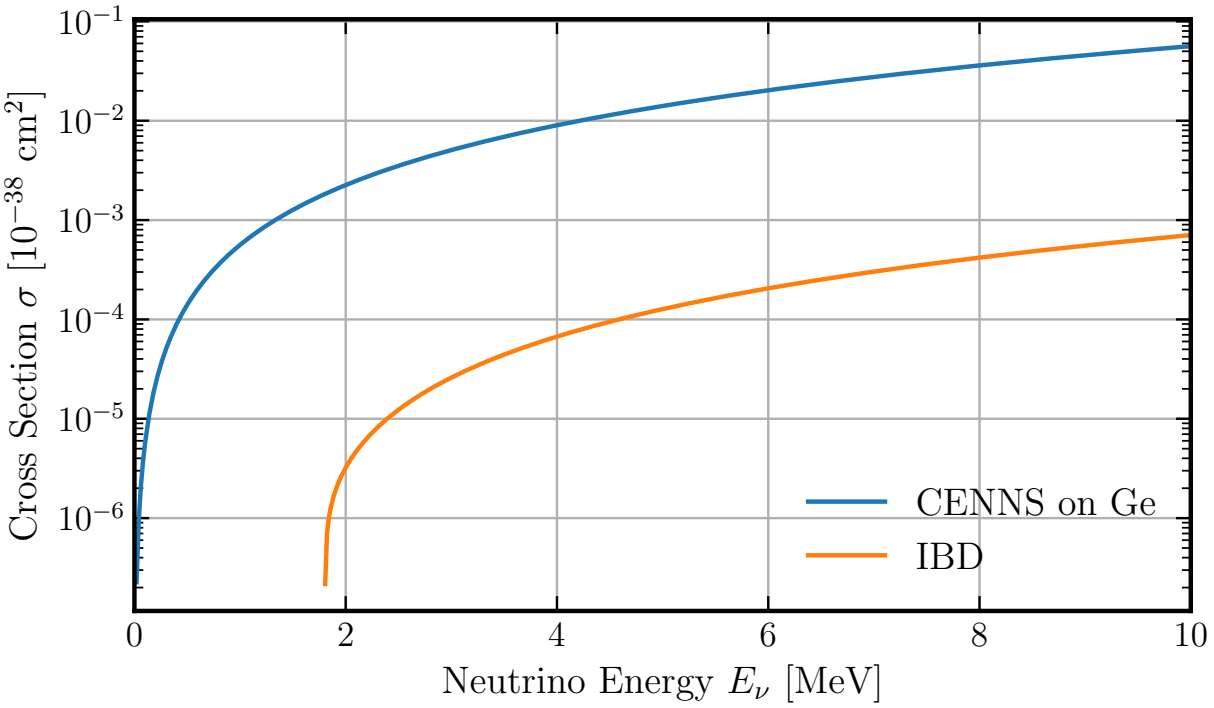
CENNS

Coherent **E**lastic **N**eutrino-**N**ucleus **S**cattering

Prediction (Freedman): 1974 → 1st observation (COHERENT): 2017



[Papoulias, Kosmas, Kuno, 10.3389/fphy.2019.00191]



Large cross-section but induce <keV nuclear recoils for MeV neutrinos

CENNS Physics

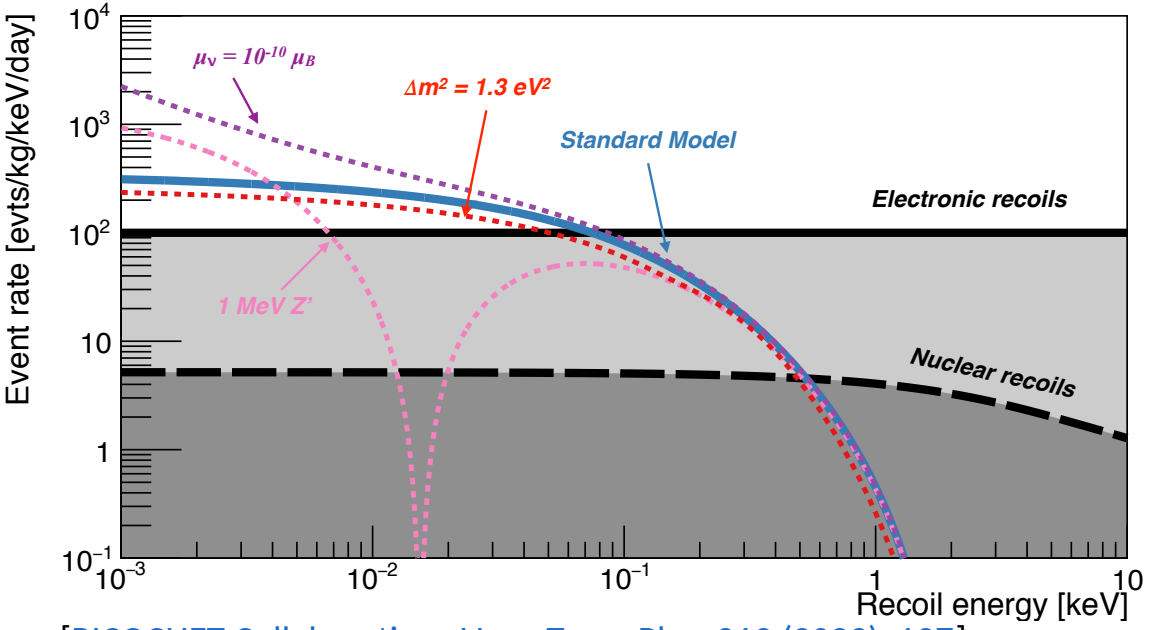
Weak nuclear charge

$$\frac{d\sigma}{dE_r} = \frac{G_f^2}{4\pi} Q_W^2 m_A \left(1 - \frac{m_A E_r}{2E_\nu^2}\right) F(E_r)^2$$

Form factor ~1 for MeV neutrinos

$$Q_W = N - Z(1 - 4\sin^2\theta_W) \quad \sim 0.23$$

1) Standard model: Measurement of the weak mixing (Weinberg) angle



[RICOCHET Collaboration, J Low Temp Phys 212 (2023), 127]

2) BSM signatures on E_r spectrum: ν magnetic moment μ_ν, new massive boson mediators (Z'), sterile ν, etc.
Need low-energy threshold O(10 eV)

3) Solar/atmospheric ν = ultimate background for direct DM detection

RICOCHET @ ILL

8.8m from reactor core: $\phi_\nu \approx 10^{12}$ cm^{-2}s^{-1}

⇒ **High CENNS statistics: ~11 evts/day/kg in [50 eV, 1 keV]**

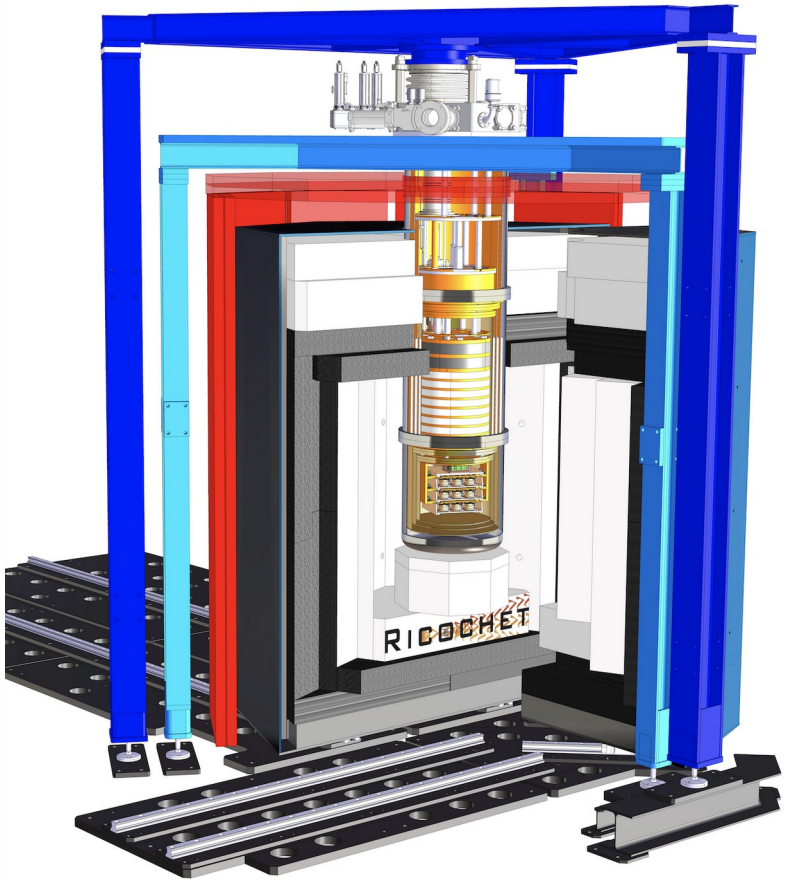
But substantial background: reactogenic, cosmogenic

Background mitigation:

- Shielding: Borated PE + Lead + Soft iron
- Muon veto
- Three 50-days reactor ON cycles /year: ON – OFF subtraction

Neutron background characterized: expect **S/B~1** in [50 eV, 1 keV] (depend on threshold !)

[RICOCHET Collaboration, EPJC 83 (2023), 20]

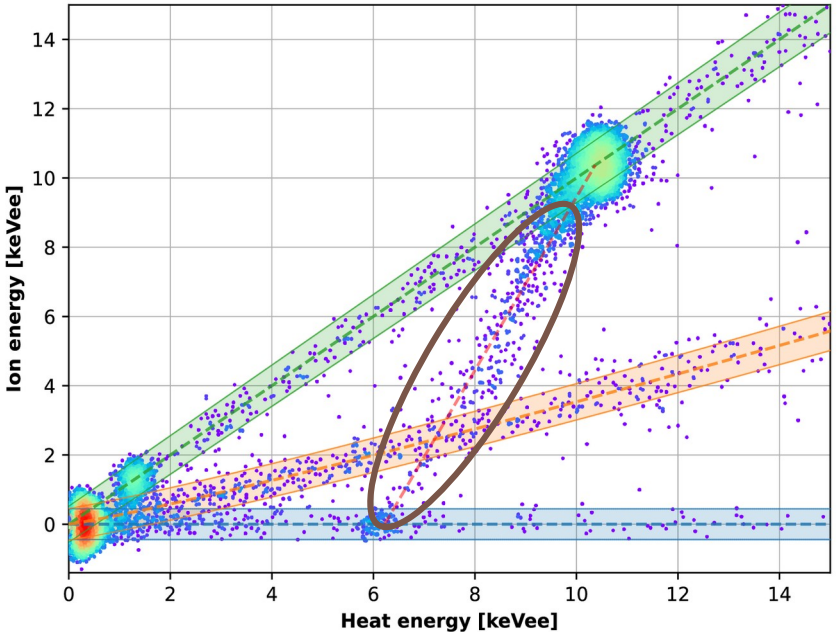


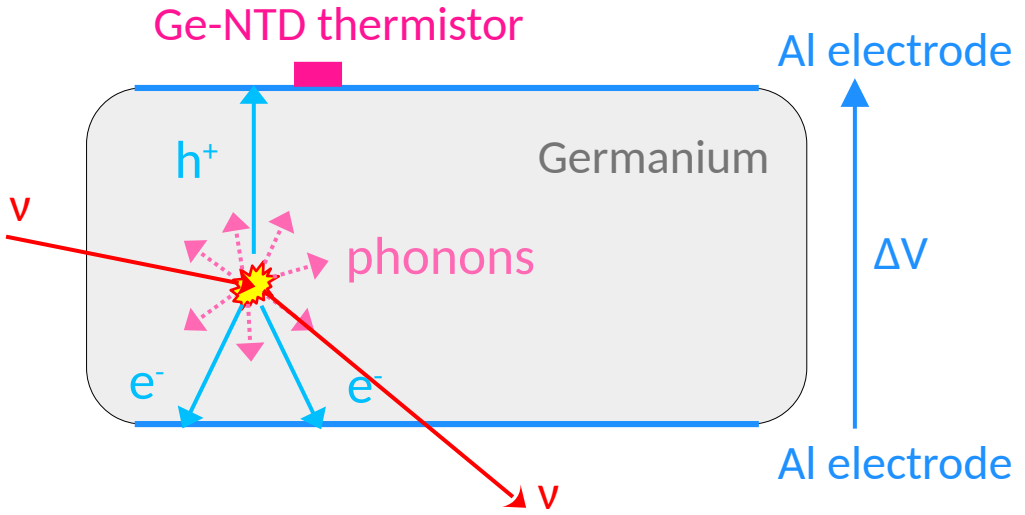
CryoCube detectors principle

Assembly of Ge semiconductor cryogenic (~10 mK) calorimeters

Simultaneous ionization + heat measurement ⇒ E_{recoil}

[J Low Temp Phys 211 (2023), 398]





Particle ID by measuring ionization yield $\mathbf{Q=E_{ion}/E_{recoil}}$:

- electronic recoil (**ER**) from γ,β (Q=1)
- nuclear recoil (**NR**) from **CENNS**, neutrons (Q≈0.3)
- Heat-only (Q=0)
- + Surface events: incomplete charge collection

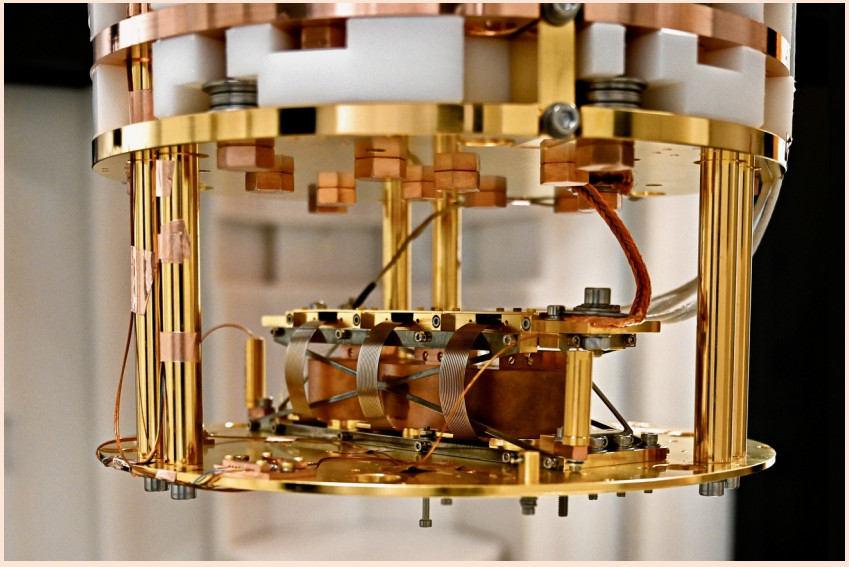
CryoCube detectors

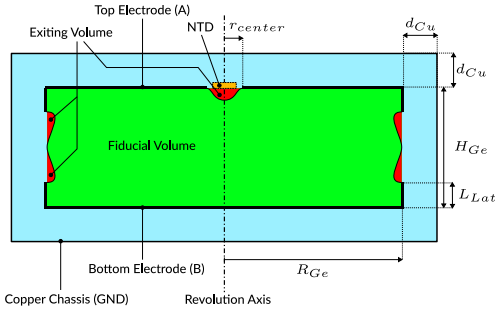
Planar

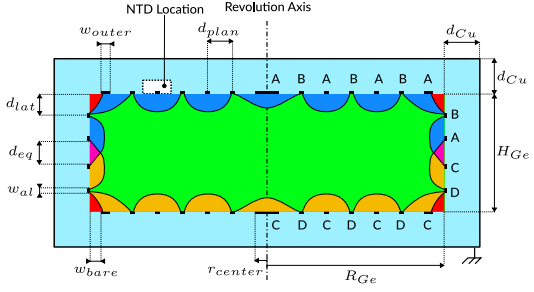
Fully Inter-Digitized

Height: 10 mm, Ø: 30 mm, Weight: 42 g

MiniCryoCube = 3 detectors + electronics
Cryocube = 2 x 3 MiniCryoCube
Full payload: 18x42g ⇒ **kg-scale**







Fiducial volume ~ 99%

✗ No surface events rejection

Fiducial volume ~ 65%

✔ Surface events rejection

RICOCHET commissioning @ ILL

Commissioning started Fall 2023 @ ILL:

- Cryogenics validation
- Outer muon veto
- Vibration mitigation
- Laser (calib + neutralization)
- **May-October 2024 (RUN014): 3 (2) planar detectors**

⇒ First reported in-situ measurements of detector performances and background event rates

Article in preparation !

Baseline energy resolutions:

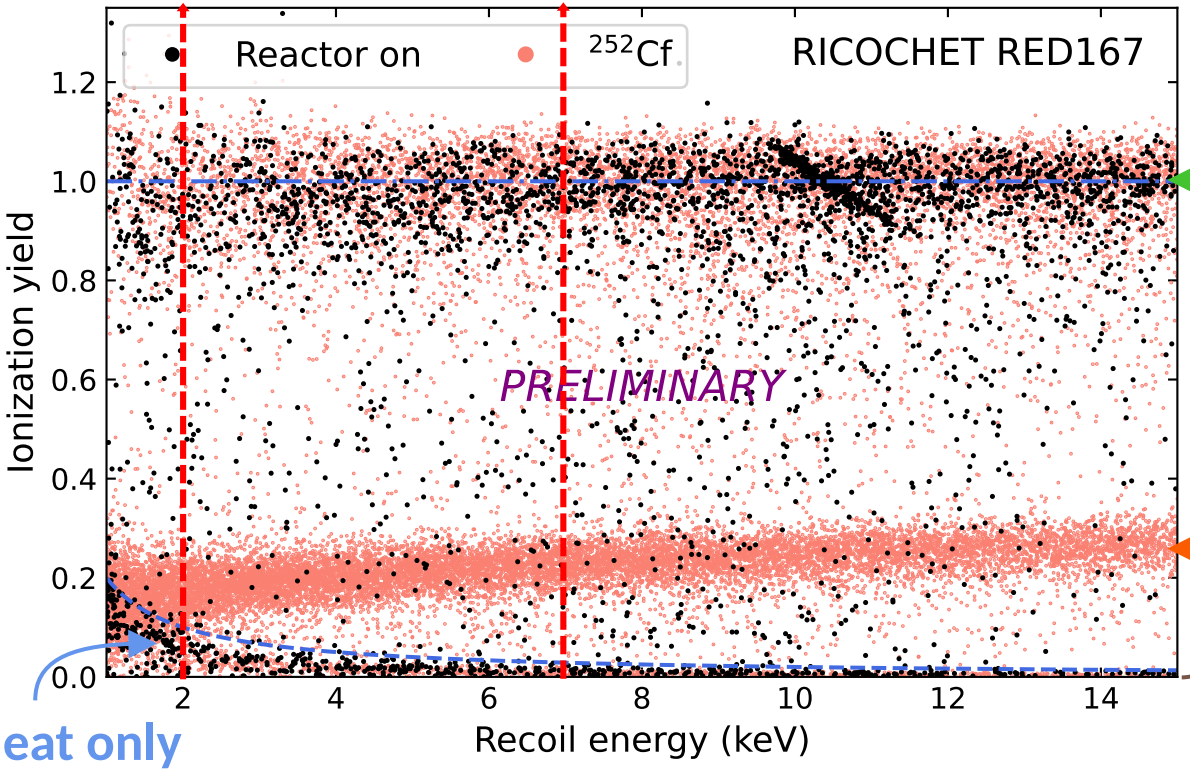
Ionization: 40 eV_{ee}
Phonon: 50 – 80 eV

RUN014 Background event rates

- Reactor ON (155 h)
- ^{252}Cf neutron calibration (253 h)

} μ veto coincidence cut

Ionization yield $Q=E_{ion}/E_{recoil}$



Heat only

Electron recoil

Surface events

Nuclear recoil

Measure background nuclear recoil rates in $E_{recoil} \in$ [2, 7] keV

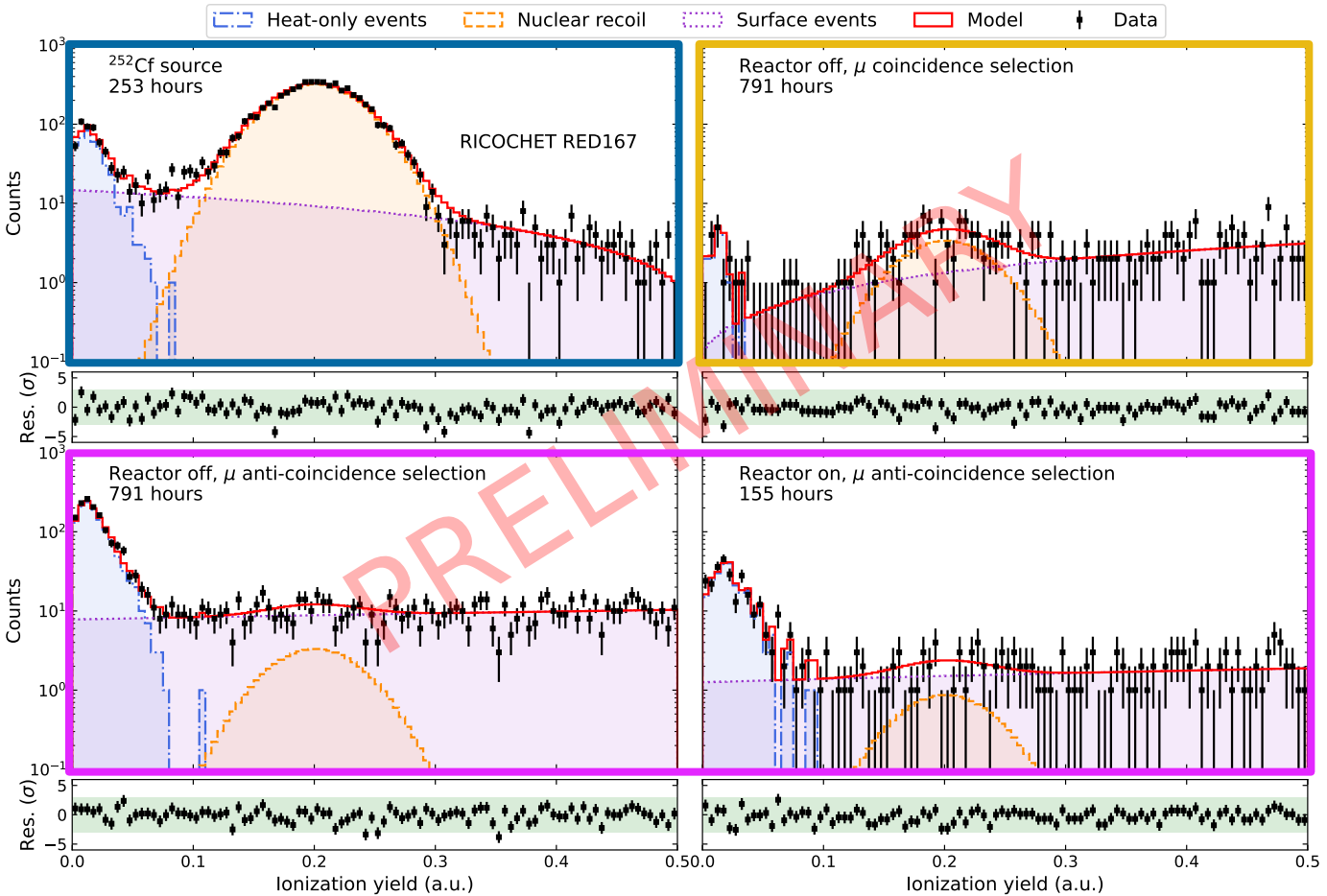
RUN014 NR background event rates $E_{recoil} \in [2, 7]$ keV

1) Fit Cf data to calibrate NR peak center/width

2) Fit other samples by scaling Cf result:

μ coinc: **rate ≈ simulations** (~15 evts/day/kg)

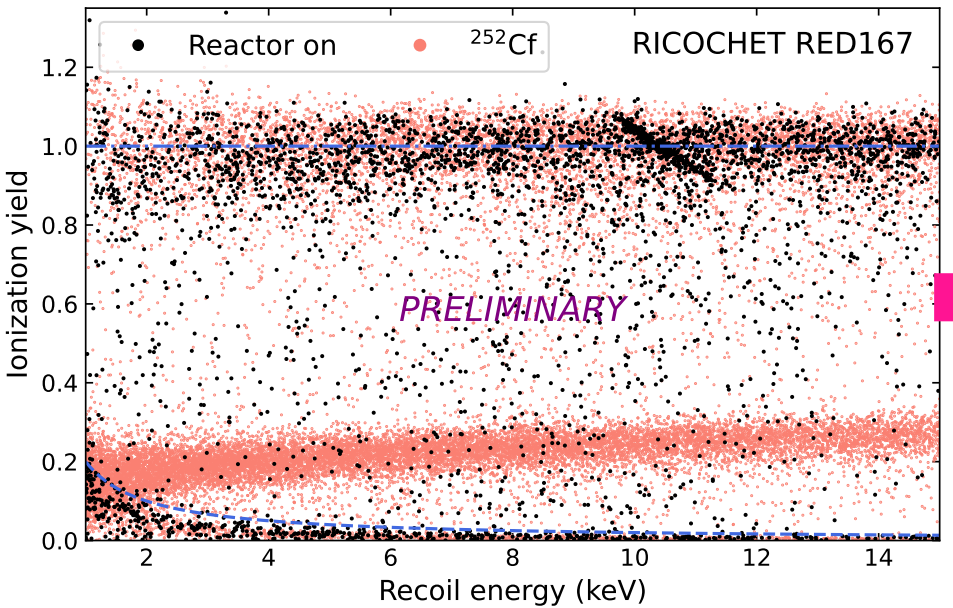
μ anti-coinc: **dominated by surface events**, only upper limit <20 evt/day/kg in both ON/OFF



RUN015: Preliminary FID performance

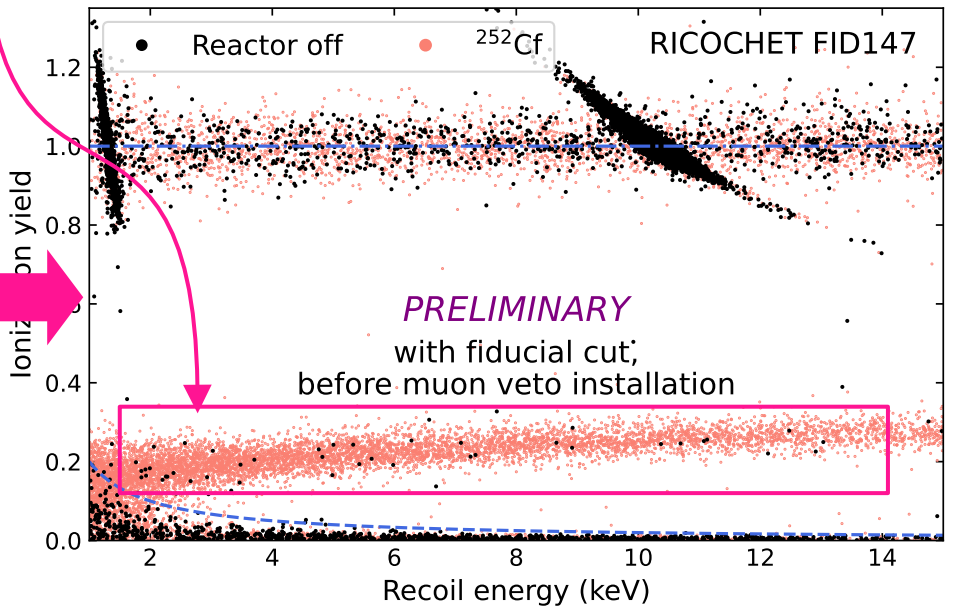
RUN015: Jan-June 2025, 9 detectors including 4 FID with surface event rejection ⇒ **can see nuclear recoils !**

Planar detector (RUN014)



155h reactor ON, 252h Cf reactor OFF,
μ veto cut

FID detector (RUN015)



277h reactor OFF, 102h Cf reactor OFF,
no μ veto cut

Summary

- RICOCHET successfully operating at ILL
- Baseline resolutions: 40 eV_{ee} (ion), 50-80 eV_{ph} (phonon) (*FID: 30 eV_{ph} !*)
- Background NR rates validating simulation

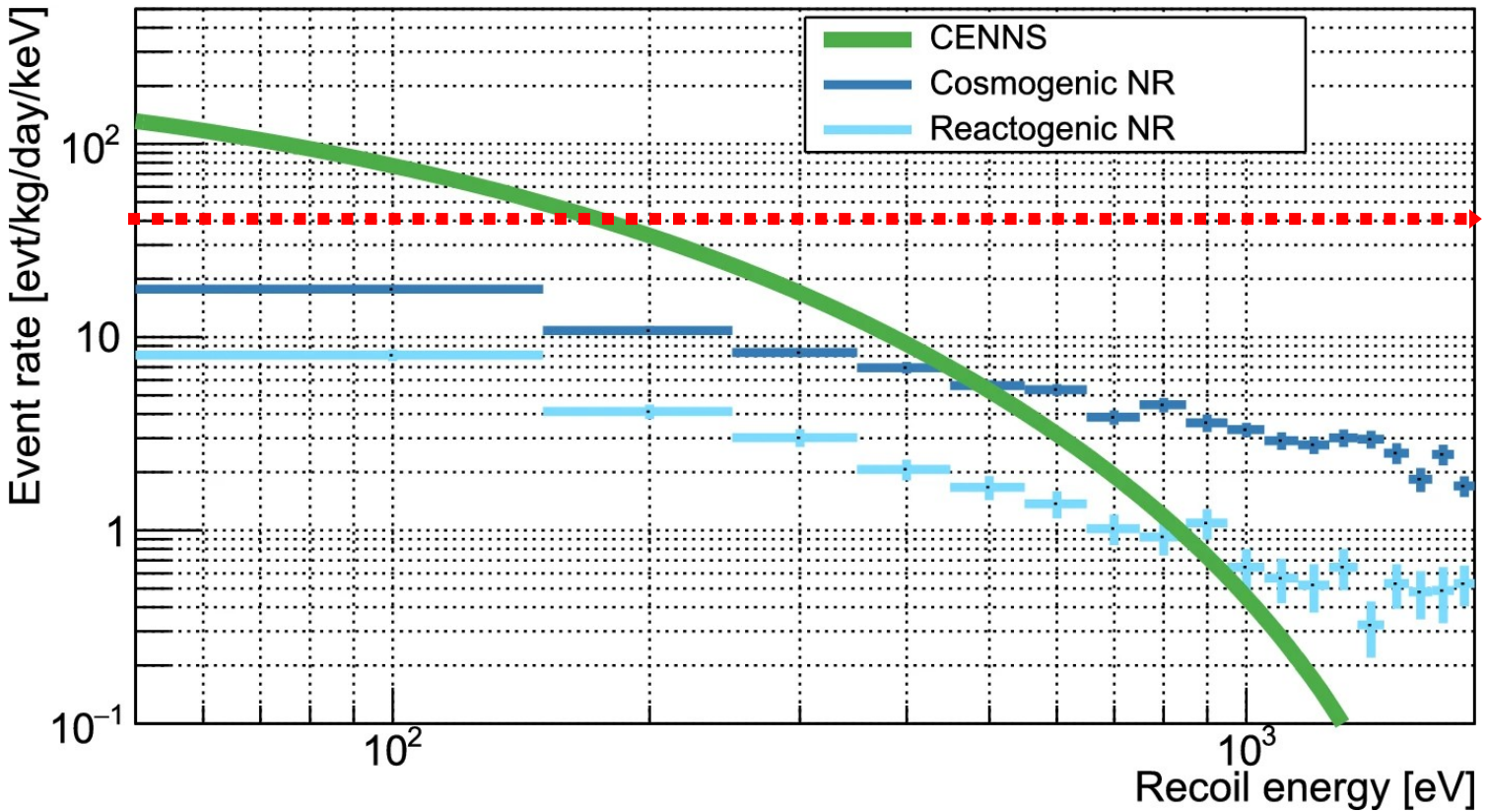
- RUN015 (9 detectors including 4 FID) just finished: FID commissioning results soon (background NR rate without surface events)
- RUN016: first science run with full 18 detectors payload (+ cryogenic μ veto) to start in July: **Getting closer to CENNS !**

Thank you !

Backup

Expected signal vs background

[RICOCHET Collaboration, EPJC 83 (2023), 20]

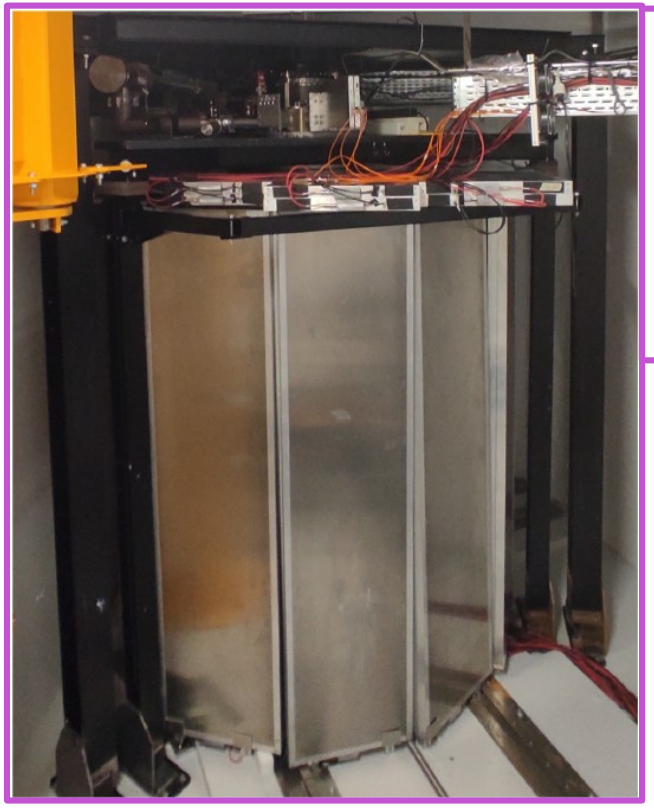


Cosmo. + reacto γ ER

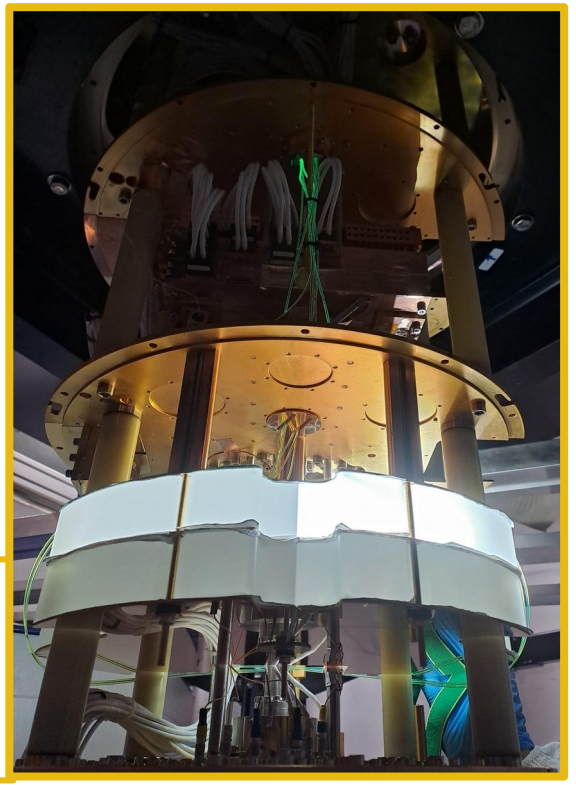
Neutron background characterized: expect **S/B~1** (depend on threshold !)

Muon veto setup

Goal: reject muon-induced neutrons with minimum dead time



External veto: 34 3 cm-thick plastic scintillator panels arranged by pair, 1 PMT/panel. 6 top pairs & 11 side pairs



Cryo veto: 2x3 cm-thick plastic scintillator @ 4K stage, SiPM

Synchro board: common clock with bolometers

CryoCube detectors principle

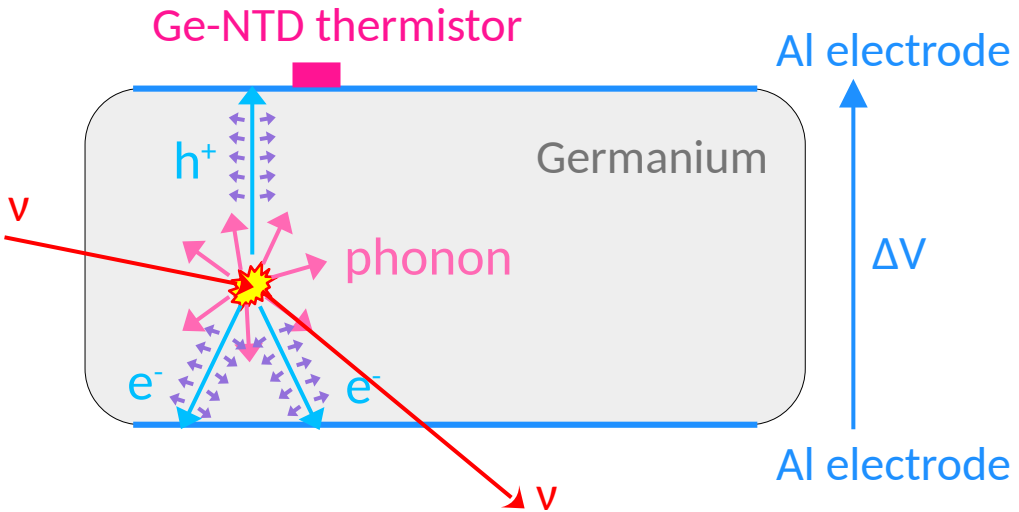
Simultaneous ionization + heat measurement ⇒ $\mathbf{E_{recoil}}$

Neganov-Trofimov-Luke: 2ndary phonons from drifting charges

$$E_{ph} = E_{recoil} + E_{NTL} = E_{recoil} + E_{ion}\frac{e\,\Delta V}{\epsilon}$$

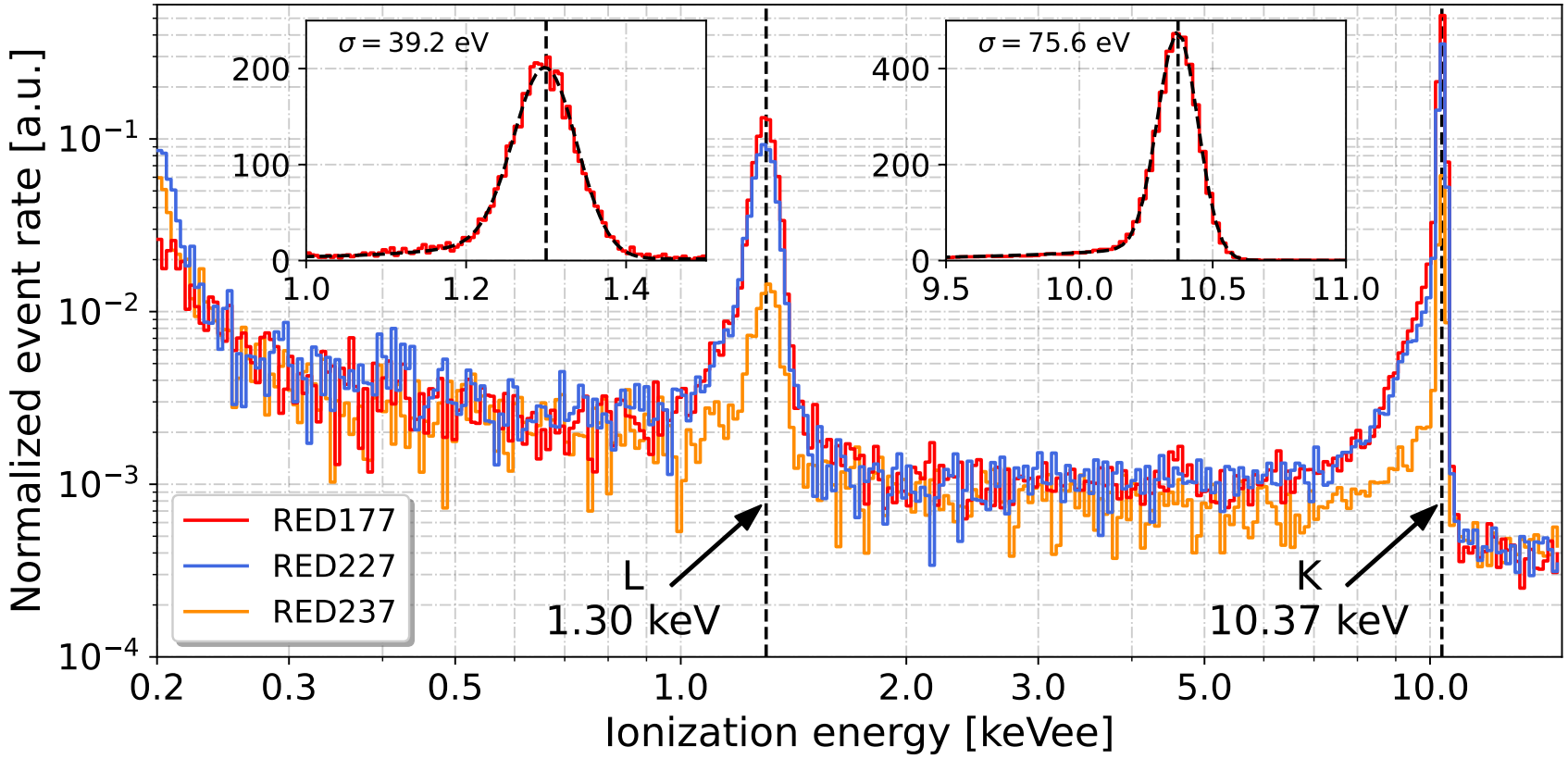
ΔV = 4 V

e^-/h^+ pair creation energy in Ge ϵ=3 eV



Ge detector energy calibration

^{71}Ge electron capture K/L shells



[EPJC 84 (2024), 186]