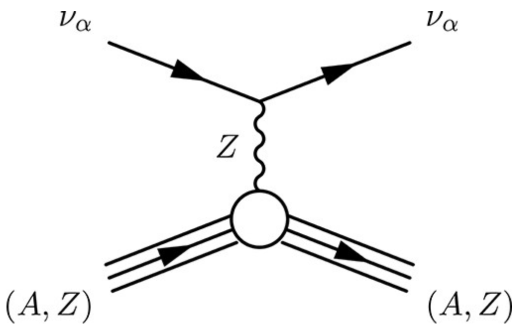
Status of the RICOCHET experiment at ILL

Louis Bailly-Salins on behalf of the RICOCHET collaboration
EPS-HEP, Marseille, 08/07/2025

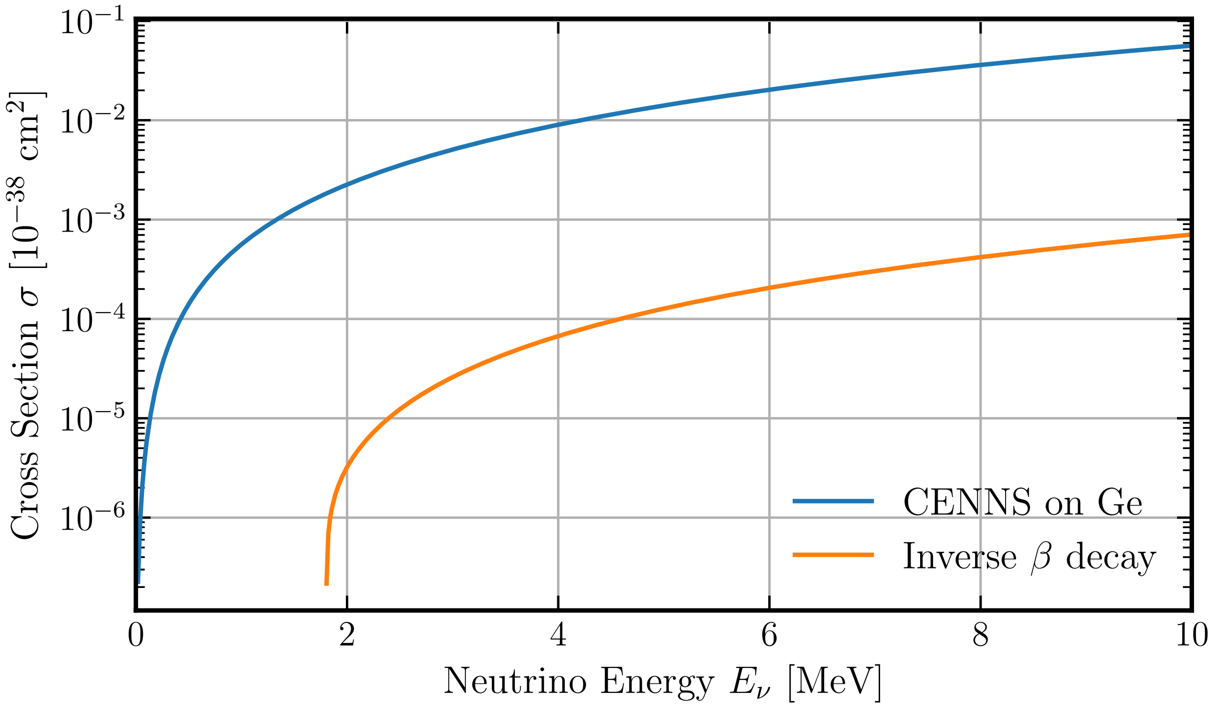
CENNS

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 nuclear recoils with energies below a few keV for MeV neutrinos

CENNS Physics

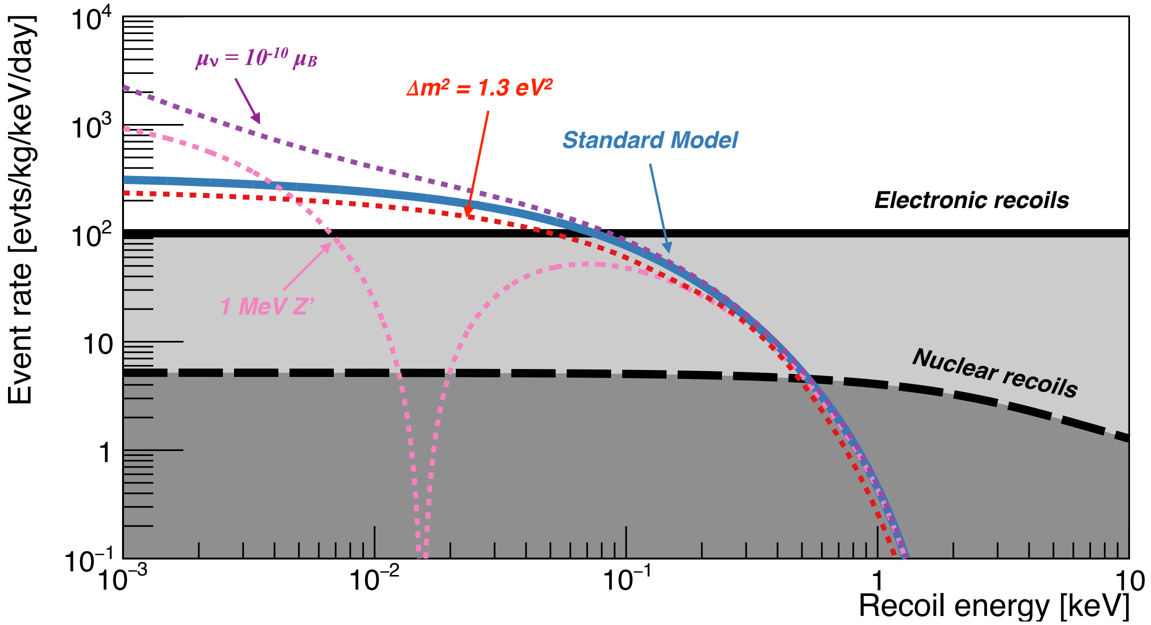
Weak nuclear charge

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

Form factor ~1 for MeV neutrinos

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

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



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

2) Beyond the Standard Model signatures on recoil energy (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 bkgnd for direct dark matter detection

RICOCHET @ ILL

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

⇒ **High CENNS interaction rate**

But background: reactogenic, cosmogenic

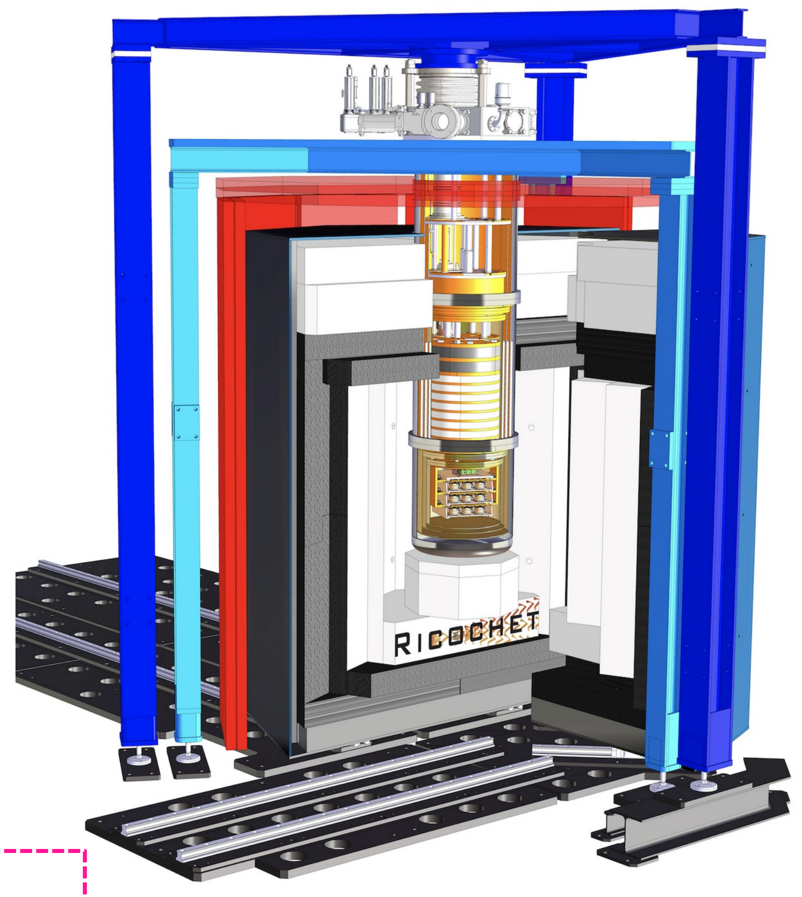
Background mitigation:

- 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** (depends on low-energy threshold !)

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

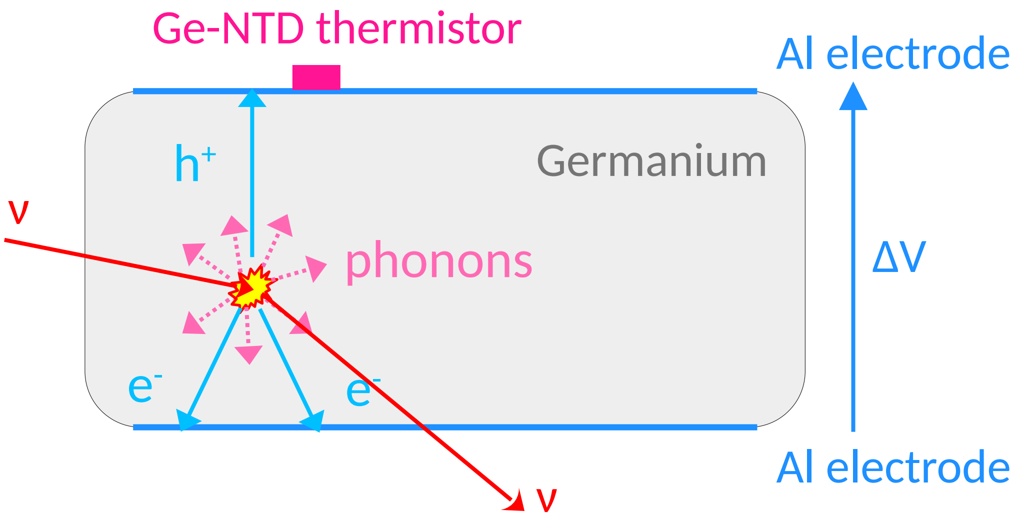
+ Gamma background: see poster #666 by R. Serra (tomorrow @ 18:00)



CryoCube detectors principle

Array of Ge semiconductor cryogenic (~10 mK) calorimeters

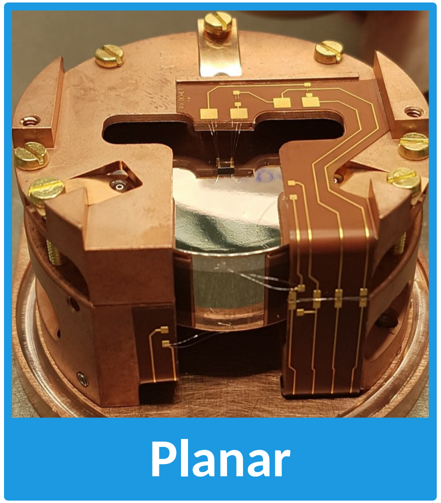
Simultaneous ionization + heat measurement



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

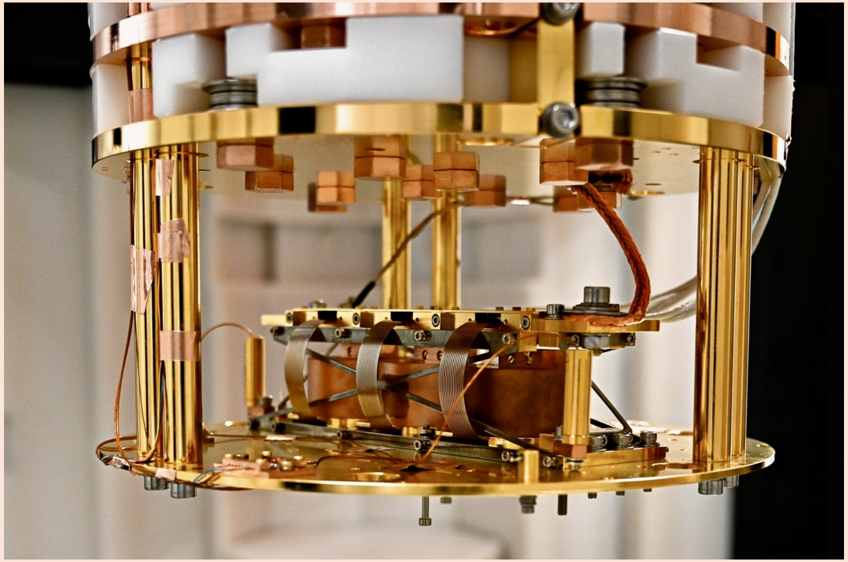
- electronic recoils (**ER**) from γ,β (Q=1)
- nuclear recoils (**NR**) from **CENNS**, neutrons (Q≈0.2)
- Heat-only/low-energy excess (LEE) (Q=0)

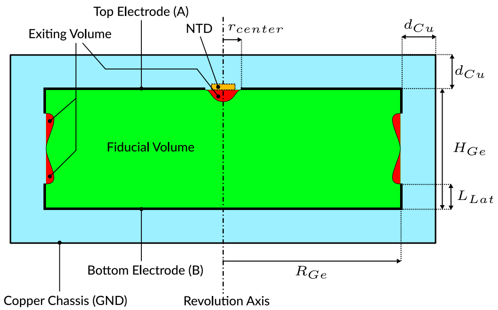
CryoCube detectors

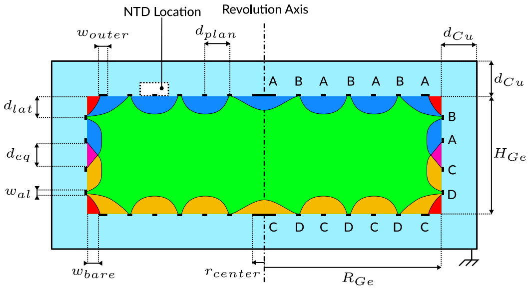


Height: 10 mm, Ø: 30 mm, Weight: 42 g

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 Februray 2024 @ ILL:

- Cryogenics
- Detectors (operation, vibration mitigation)
- Background (inner shielding, outer μ veto)
- Laser (calibration)
- **May-October 2024 (RUN014): 3 planar detectors**

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

Article in preparation !

Baseline energy resolutions:

After setup optimization

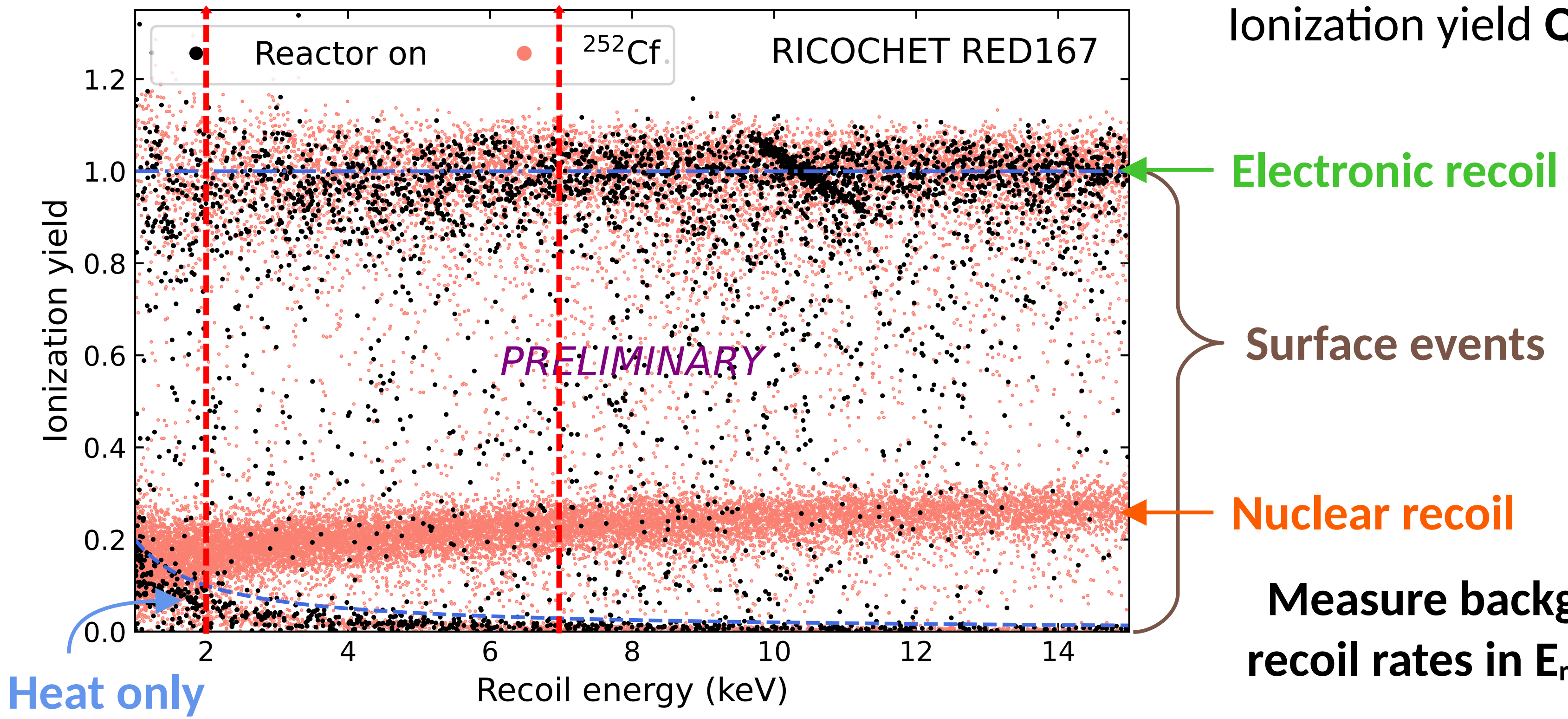
Ionization: 40 eV_{ee}

Phonon: 50 – 80 eV_{ph}

RUN014 Background event rates

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

} µ veto anti-coincidence selection



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

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

RUN014 NR background event rates

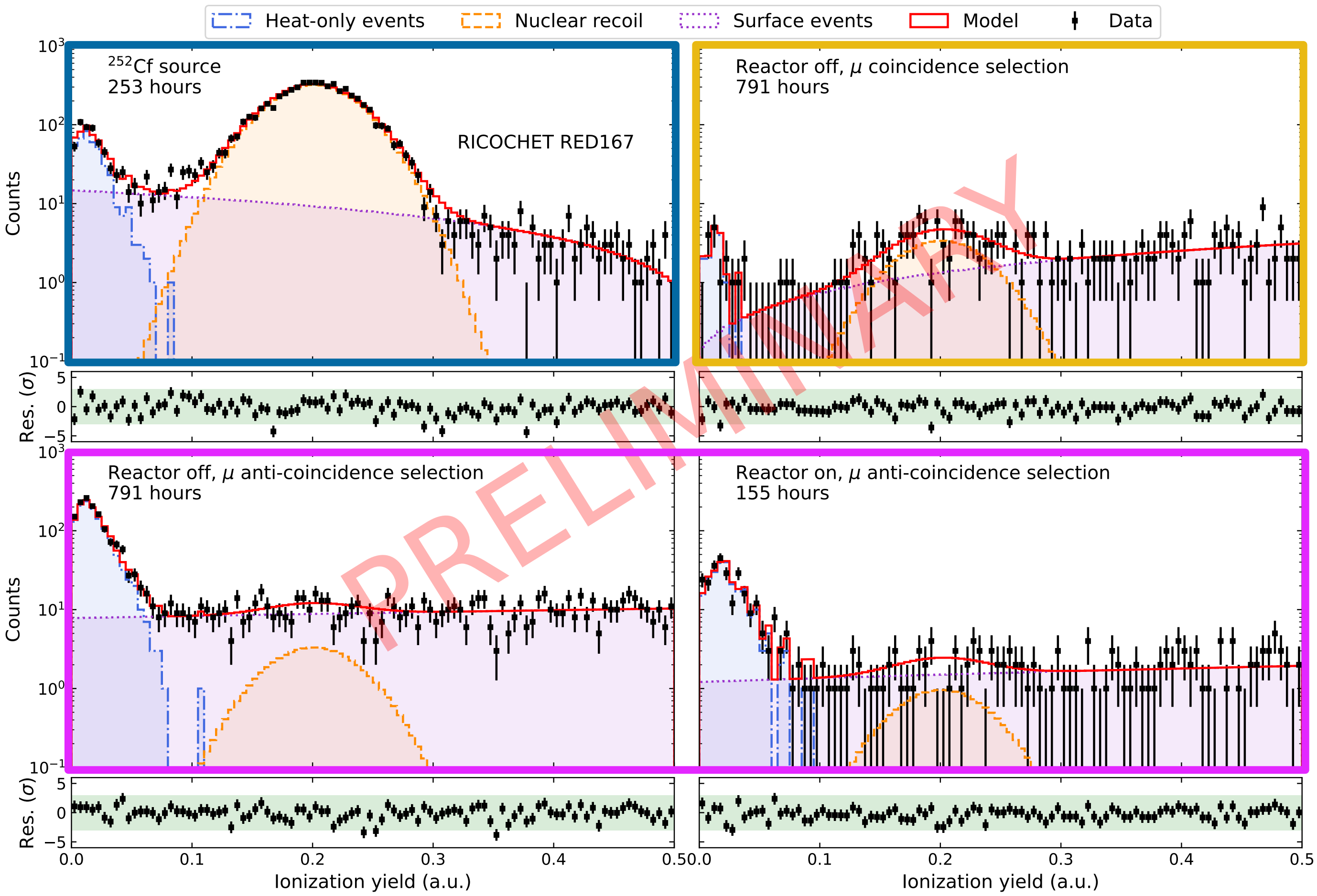
$E_{recoil} \in$ [2, 7] keV

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)

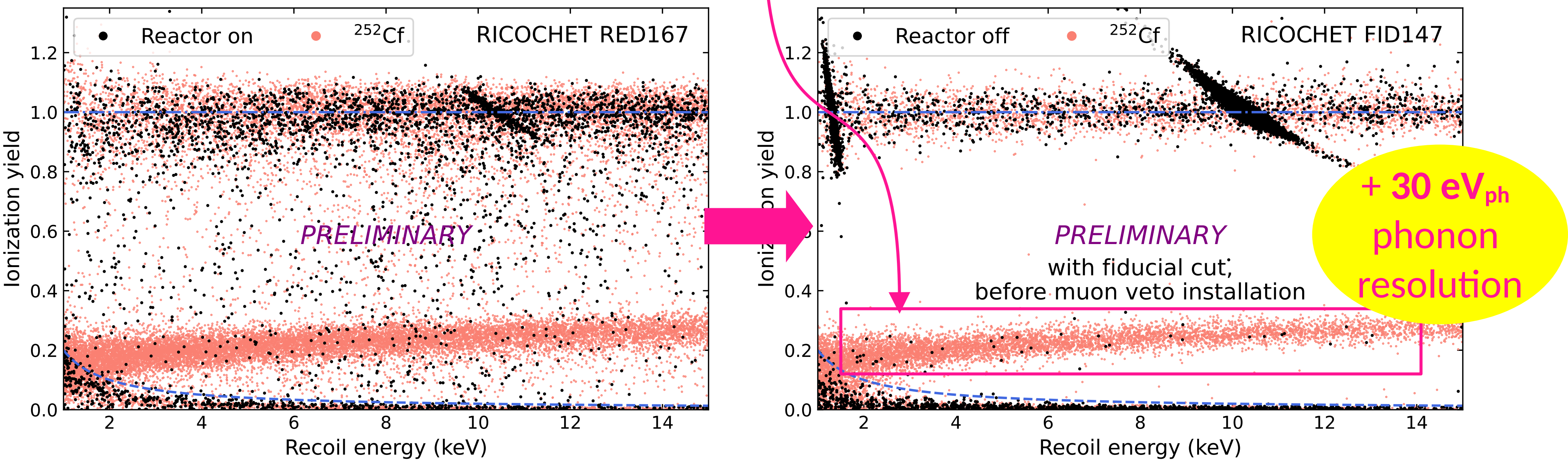
μ anti-coinc: **dominated by surface events**, only upper limit <20 evt/day/kg in both ON/OFF



RUN015: Preliminary FID performance

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

Planar detector (RUN014) **FID** detector (RUN015)



155h reactor ON, 252h Cf reactor OFF, µ veto anti-coincidence selection

277h reactor OFF, 102h Cf reactor OFF, **no µ veto anti-coincidence selection**

Summary & outlook

- RICOCHET successfully operating at ILL
- RUN014 Baseline resolutions: 40 eV_{ee} (ion), 50-80 eV_{ph} (phonon)
- RUN014 Background NR rates validating simulation

- RUN015 (9 detectors including 4 FID) finished: FID commissioning results soon (background NR rate without surface events) + 30 eV_{ph} phonon resolution

- RUN016: science run with full 18 detectors payload (+ cryogenic μ veto) to start in July: **Getting closer to observing CENNS !**

Thank you !

iP2i LES 2 INFINIS LYON

LPSC GRENOBLE | MODANE

IJCLab Irène Joliot-Curie

ill NEUTRONS FOR SOCIETY

NÉEL institut

C2N

UNIVERSITY OF TORONTO

MIT

UNIVERSITY OF MASSACHUSETTS 1863

NORTHWESTERN UNIVERSITY QUAECUMQUE SUNT VERA 1851

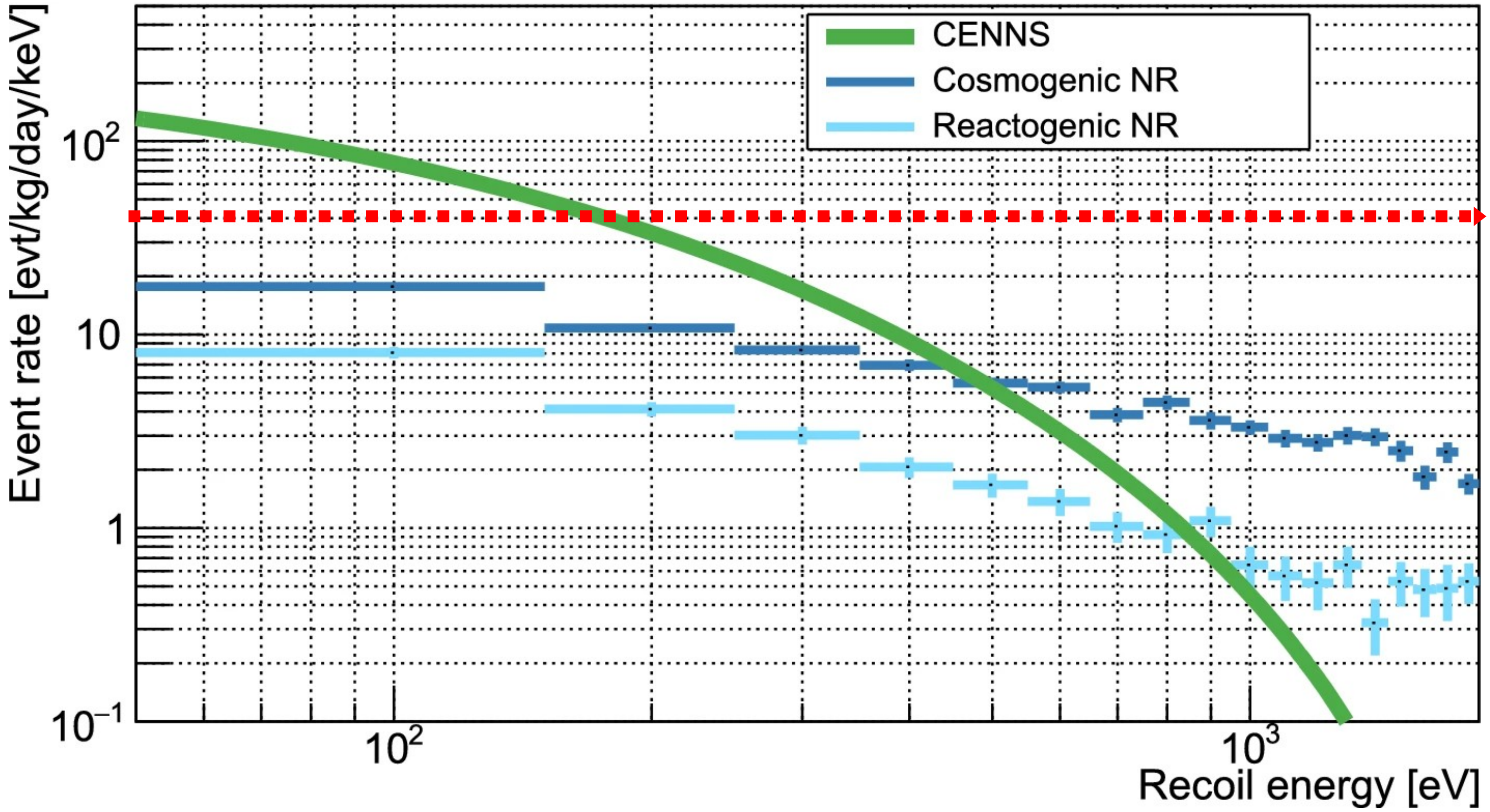
SCHOOL OF MINES 1874 COLORADO

COLORADO SCHOOL OF MINES

Backup

Expected signal vs background

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

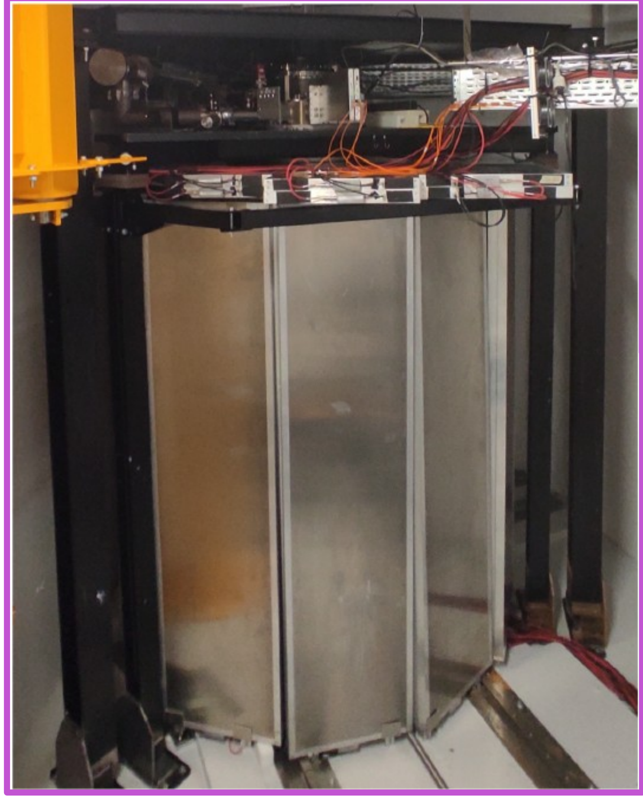


Cosmo. + reacto γ ER

Neutron background characterized: expect **S/B~1** (depending 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

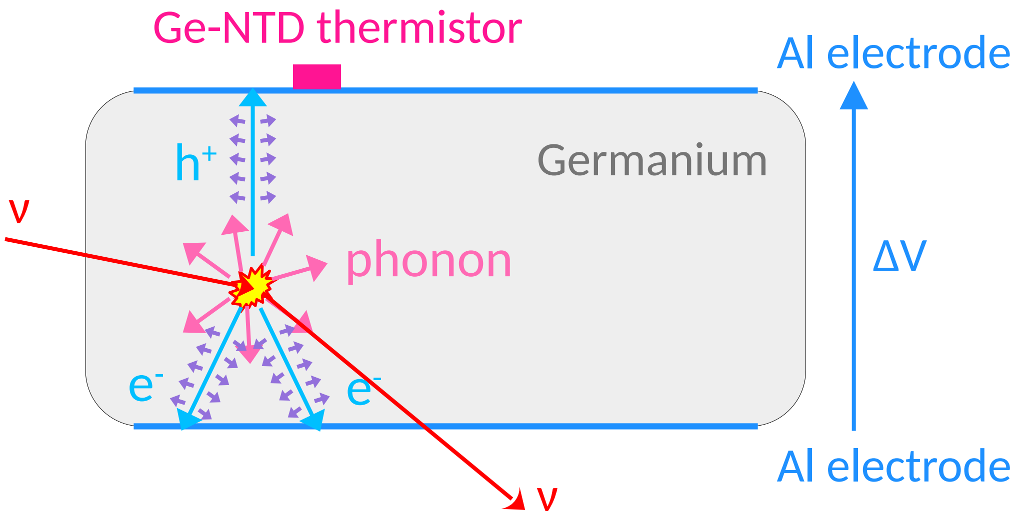
Simultaneous ionization + heat measurement ⇒ $\mathbf{E_{recoil}}$

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

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

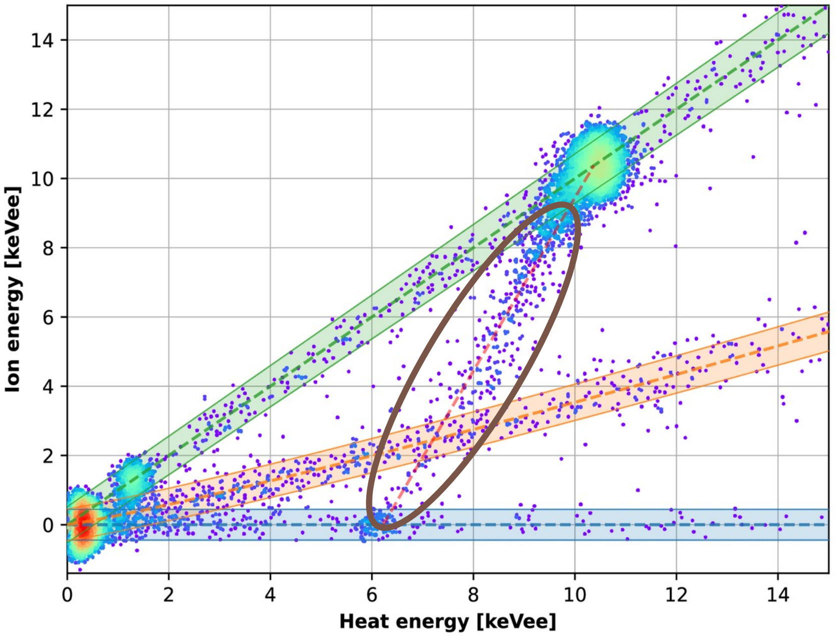
ΔV = 4 V

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



CryoCube particle ID

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

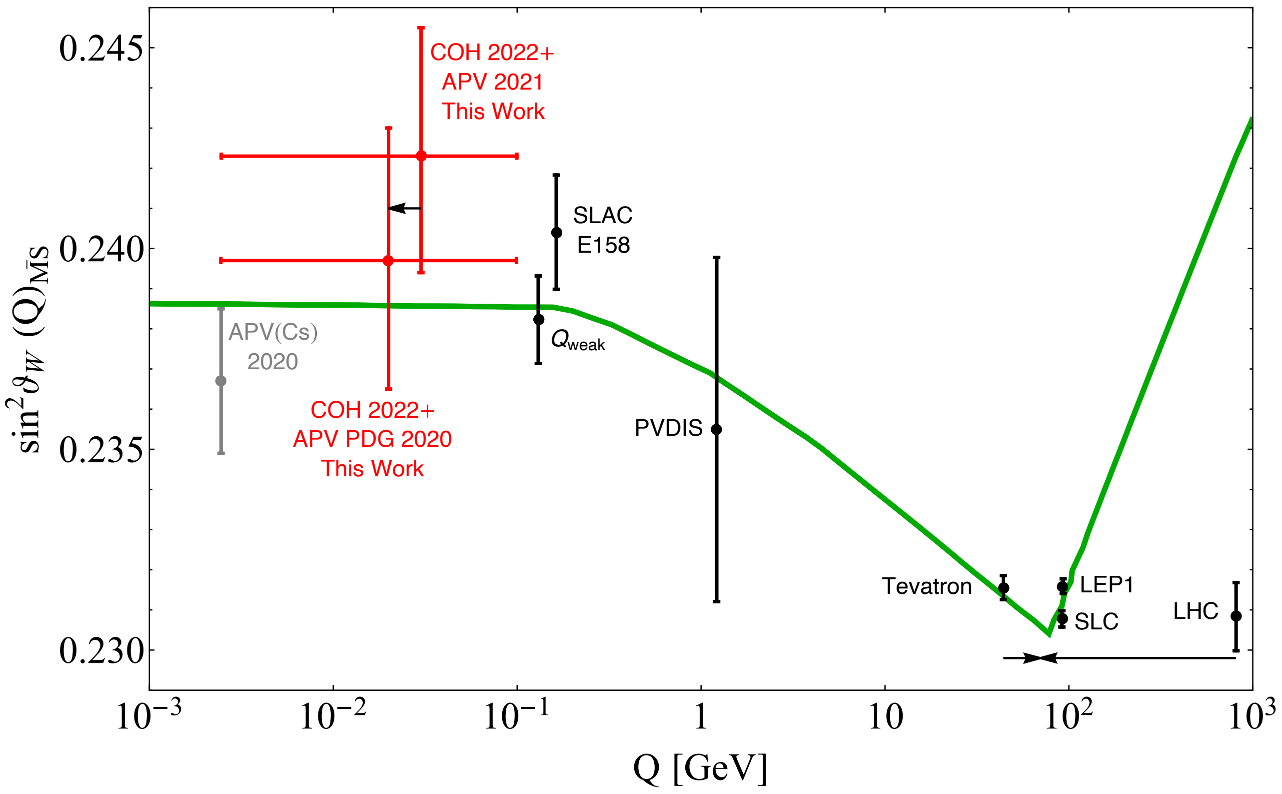


Particle ID by measuring ionization yield **$Q=E_{ion}/E_{recoil}$** :

- 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

Weak mixing angle

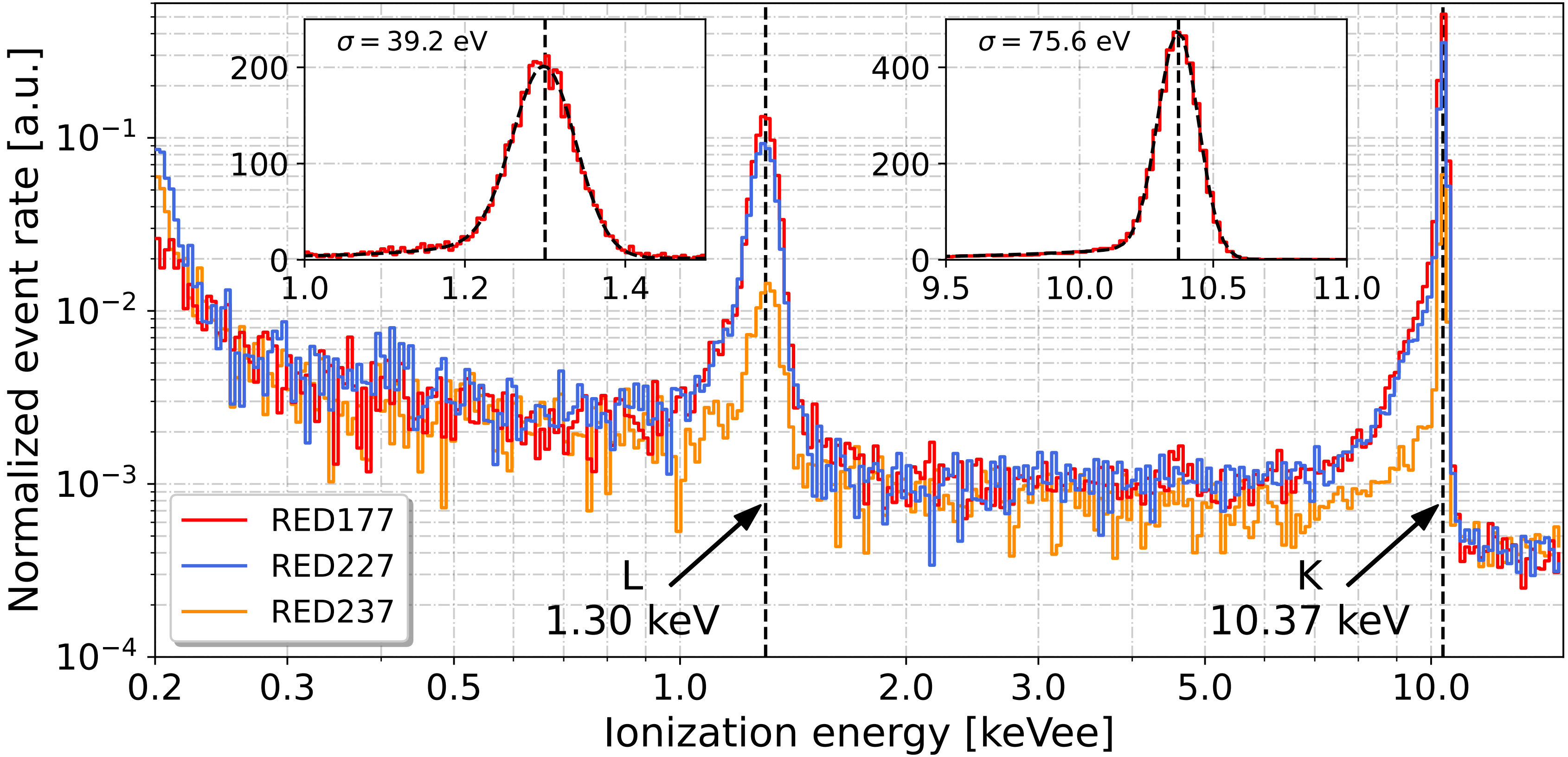
[Eur. Phys. J. C (2023) 83: 683]



From COHERENT + atomic parity violation data

Ge detector energy calibration

^{71}Ge electron capture K/L shells



[EPJC 84 (2024), 186]