Status of the Ricochet Experiment

RICOCHET
A Coherent Neutrino Scattering Program

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Coherent Elastic Neutrino(ν)-Nucleus Scattering (CEνNS)

$$\frac{d\sigma}{dE_r} \cong \frac{G_F^2}{2\pi}\frac{Q_W^2}{4}F^2(q)\left(2-\frac{ME_r}{E_\nu^2}\right) \propto N^2$$

First theorized by D. Freedman in 1974 [1] and first measured by COHERENT at the spallation neutron source (SNS) at Oak Ridge National Laboratory [2].

- CEνNS spectrum can be used to probe the Standard Model and search for new physics (Fig. 1).
- CEνNS has a larger cross section than other neutrino interactions but is in a lower energy regime
  - ⟹ Nuclear Form Factor (F(q)) ~ 1
  - ⟹ Fully coherent interaction

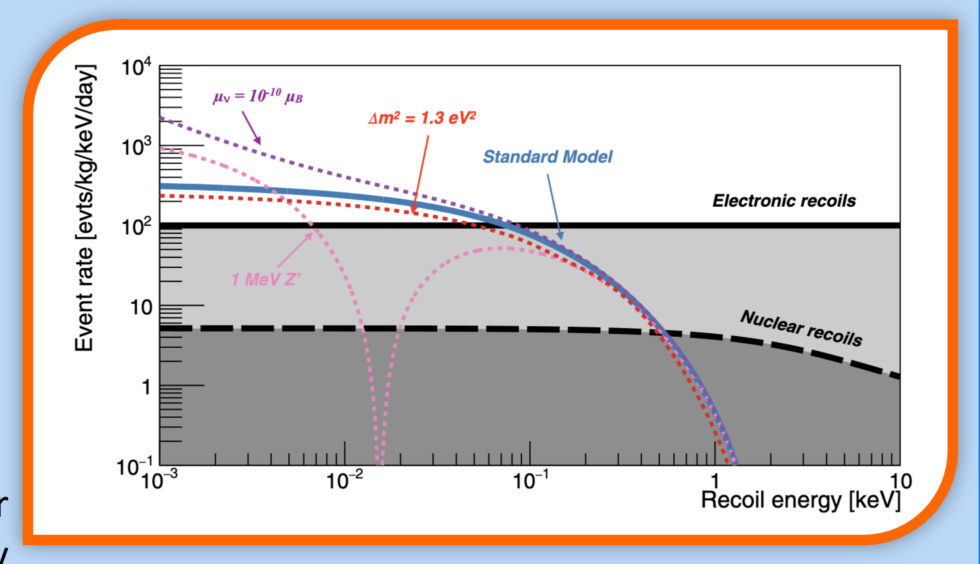

Figure 1: Changes to the CEνNS spectrum based on different beyond the standard model physics [3]

The Ricochet Experiment at ILL

Ricochet is located **8.8 m from the core** of the research nuclear reactor at the Institut Laue-Langevin (ILL)

- Nominal thermal power **58 MW**
- Frequent reactor-on and reactor-off cycles for monitoring of non-reactor backgrounds
- Overburden of **~15 m water equivalent** for cosmic rays
- The ILL provides **4 orders of magnitude higher neutrino flux** than the SNS

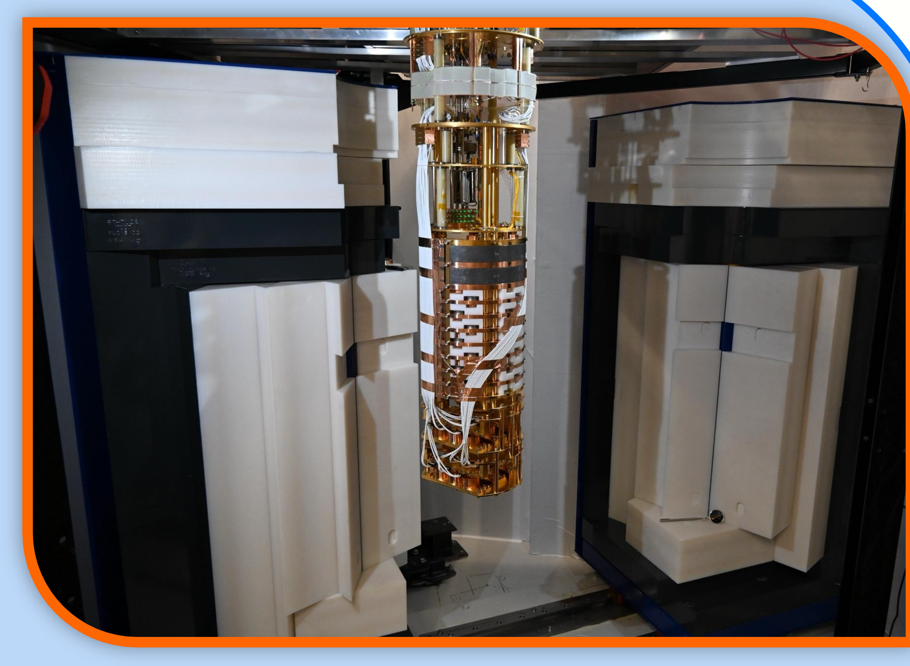

Figure 4: Ricochet internal and external shielding on site

Ricochet's CryoCube consists of **18 x 42 g germanium cryogenic calorimeters** (*Fig. 3*) with both heat and ionization readout

- Dual readout allows us to distinguish between electron and nuclear recoils
  - Phonon channel readout with germanium neutron-transmutation-doped (Ge-NTD) thermistor
  - Ionization channel read out via aluminum electrodes deposited directly on target surface
- High-density polyethylene (HDPE) and lead shielding (*Fig. 4*)
  - Internal shielding has alternating copper layers for thermalization
- Double layer of plastic scintillator panels surrounding cryostat to veto muon events
  - Hole in top of shielding covered by a cryogenic muon veto

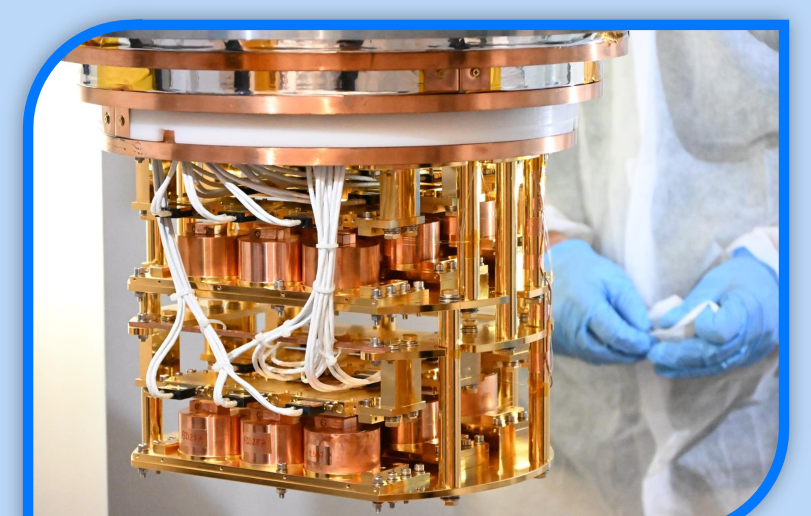

Figure 3: Full CryoCube payload installed at the Ricochet experimental site

Results of Ricochet Commissioning Runs

Ricochet commissioning results obtained using germanium detectors in the planar configuration (*Fig. 5*) during 2024 [5]

- 2 of the 3 detectors were operated (RED167 and RED237)
- Operating temperatures: 12 – 15 mK
- Improvements in decoupling the detectors from the vibrations
  - Dampening pads between cryostat frame and pillars
  - Damping polyurethane foams between the bellows and the pulse-tube frame
- **Baseline resolutions achieved**, RED167 (RED237):
  - Ionization: **40 eVee** (40eVee)
  - Phonon: **50 eVph** (80eVph)

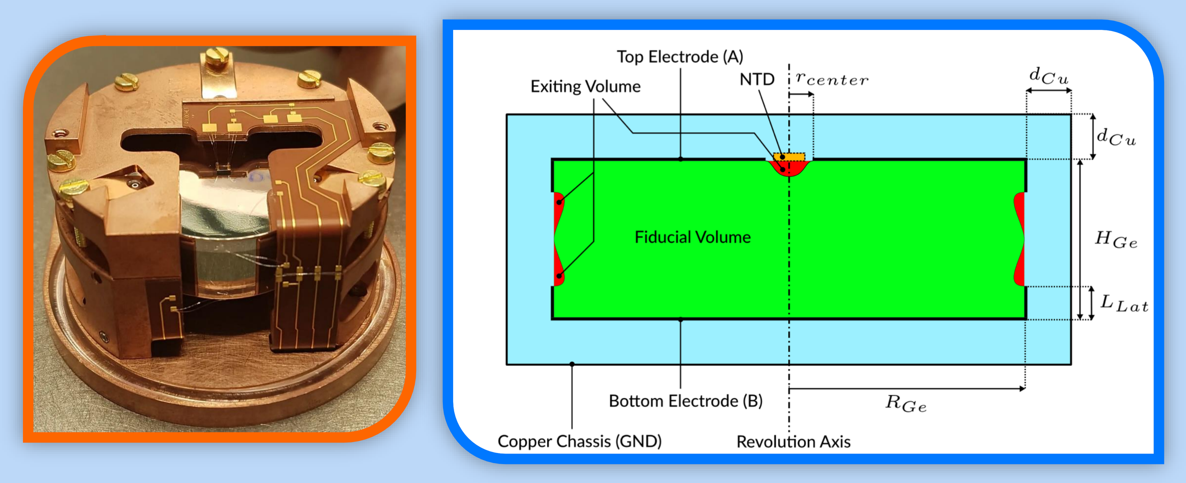

Figure 5: Photo of planar detector along with a simplified illustration of its fiducial volume [4]

Particle identification can be achieved by looking at the ionization yield (Q) distribution of all events (*Fig. 6*).

$$Q = \frac{E_i}{E_r} = \frac{E_i}{E_h - \frac{E_i \Delta V}{\epsilon}}$$

Background rates were measured in DRU (events per kg per day per keV) and results quoted in *Table 1*

- Rates were compared to Ricochet's GEANT4 simulation for cosmogenic (cosm. sim), and reactogenic backgrounds (react. sim.)

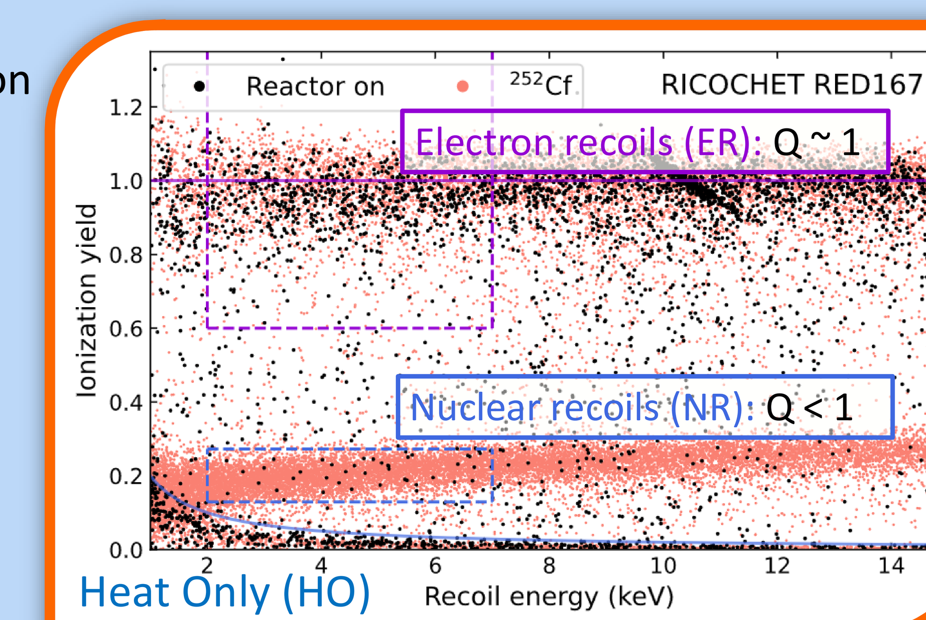

Figure 6: Ionization yield as a function of the recoil energy for the reactor-on data in anticoincidence with the muon veto [5]

Reactor status	Detector	HO (DRU)	ER (DRU)		NR estimate (DRU)		
		data	data	cosm. sim	data	cosm. sim	react. sim
ON	RED167	707(110)	1115(172)	23(2)	< 25	4.6(8)	0.4(1)
	RED237	784(122)	1200(184)	23(2)	< 9	4.6(8)	0.4(1)
OFF	RED167	642(97)	135(21)	23(2)	< 15	4.6(8)	...
	RED237	611(92)	123(19)	23(2)	< 21	4.6(8)	...

Table 1: Background rates anticoincidence with muon events in the range from 2 – 7 keV . Nuclear recoil estimates from likelihood fit model described in Ref. [5]. Systematic and statistical uncertainties are quoted in the parenthesis

Ricochet Science Phase

Ricochet now has installed Fully-Inter-Digitized (FID) detectors (*Fig. 7*)

- **FID detectors are capable of rejecting the problematic "surface event" background** that is visible detectors with the planar configuration

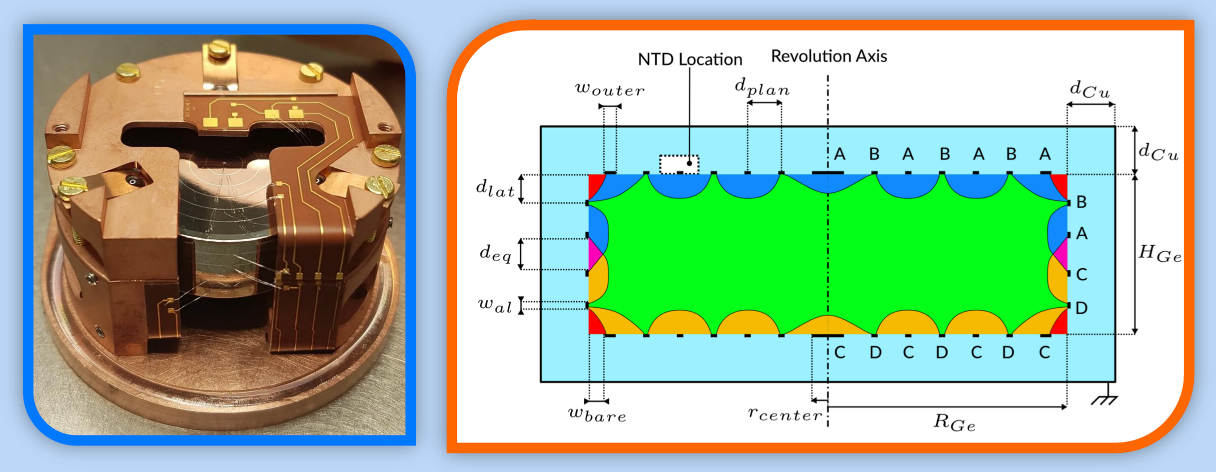

Figure 7: Photo of FID detector along with a simplified illustration of its fiducial volume [4]

Ricochet started its science phase in July of 2025

- Full payload of 18 detectors with a total germanium mass of 0.75 kg
  - **11 FID detectors**
  - **7 Planar detectors**
- Improvements in sealing of the outer shielding to mitigate reactor-correlated ^{41}Ar backgrounds
- Surface etching on planar detector holders to help with "surface event" background
- Black paint added to copper cans to improve charge collection in the detectors

There is a paper coming describing the data pipeline of Ricochet and the process of injecting pulses into our data, which can be used to validate/test detector performance and CEνNS sensitivity.

Analysis of science data is ongoing and paper is in preparation. *Stay tuned!*

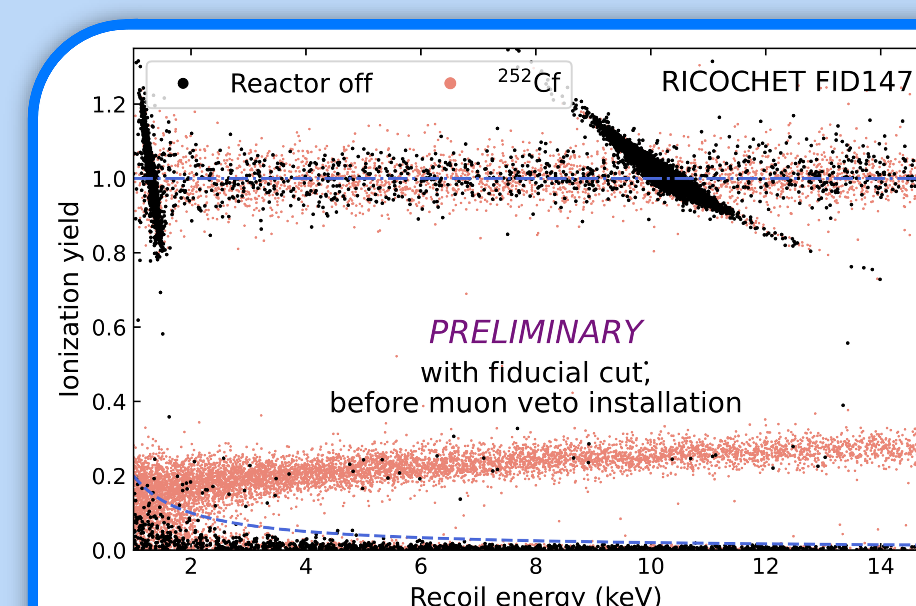

Figure 8: Ionization yield plot after removing surface events in an FID detector

References:

[1] D. Z. Freedman, Coherent effects of a week neutral current, *Phys. Rev. D* **9**, 1389–1392 (1974)
[2] D. Akimov *et al.*, Observation of coherent elastic neutrino-nucleus scattering. *Science* **357**,1123-1126 (2017)
[3] Augier, C., Beaulieu, G., Belov, V. *et al.* Ricochet Progress and Status. *J Low Temp Phys* **212**, 127–137 (2023)
[4] Salagnac, T., Billard, J., Colas, J. *et al.* Optimization and Performance of the CryoCube Detector for the Future Ricochet Low-Energy Neutrino Experiment. *J Low Temp Phys* **211**, 398–406 (2023).
[5] Ricochet Collaboration, Armatol A. *et al.* Characterization of mini-CryoCube detectors from the RICOCHET experiment commissioning at the Institut Laue-Langevin *Phys. Rev. D* **112** 112019 (2025)

Ricochet Collaboration

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