The Ricochet Experiment

Current Status and Future Directions

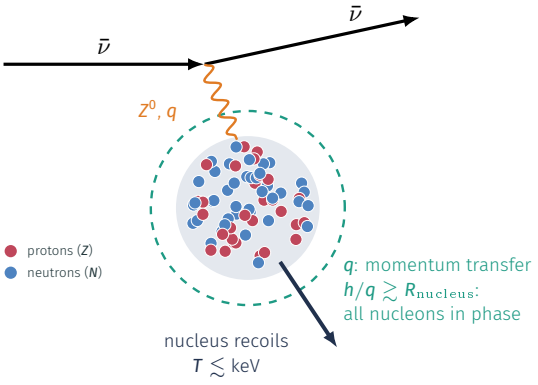
Wouter Van De Pontseele on behalf of the Ricochet collaboration

CPAD 2026 • RDC 7 Low-Background Detectors • Seattle, 20 October 2026

Colorado School of Mines wouter.vandepontseele@mines.edu

Coherent elastic ν–nucleus scattering (CEνNS) at a reactor

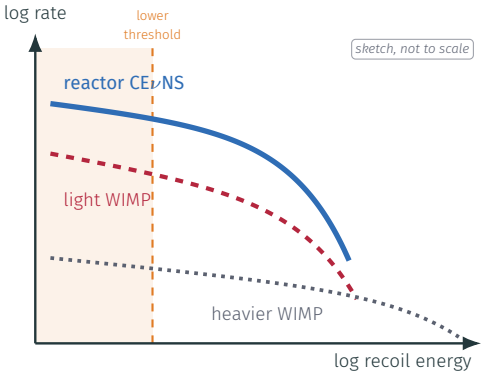
CEνNS in one slide



$$\frac{\mathrm{d}\sigma}{\mathrm{d}T} = \frac{G_F^2 M}{4\pi} \underbrace{\left[N - (1 - 4\sin^2\theta_W)Z\right]^2}_{\approx N^2} \left(1 - \frac{MT}{2E_\nu^2}\right) F^2(q)$$

- **Largest** ν cross section at MeV energies, flavour-blind, *predicted by the SM*
- **Tiny recoil**: $T_{\max} \simeq 2E_\nu^2/M$
  reactor $E_\nu < 8$ MeV $\Rightarrow$ Ge recoils < 2 keV
- Proposed in 1974 [PRD 9, 1389], observed in 2017 at a π-DAR source [Science 357, 1123], at a reactor in 2025 [Nature 643, 1229]
- Reactor + sub-keV threshold: fully coherent ($F \simeq 1$), **precision & new physics**: μ_ν, light Z', NSI, sterile ν [JCAP 11 (2018) 016]

Same signature as a light-WIMP search … a very different game

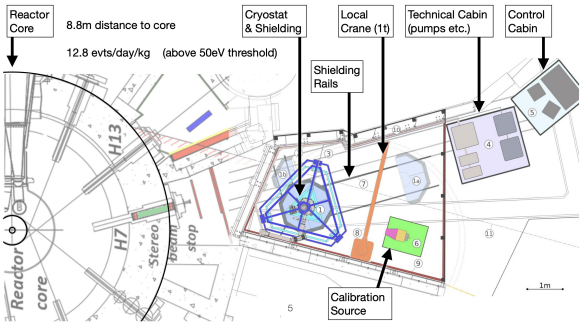


Same observable: a sub-keV nuclear recoil
[J. Billard, HDR 2021]

	NR dark-matter search	Reactor CEνNS (Ricochet)
Signal	unknown m_χ, σ	SM-predicted, known flux
Rate	$\lesssim$ events / kg / yr, higher for light DM	$\mathcal{O}$(events / kg / **day**)
Site	deep underground	**surface**, 8.8 m from a core
Backgrounds	radiogenic, cosmogenic, LEE	cosmogenic n, reactor γ/n, LEE
Handle	shielding, radiopurity, (ER/NR ID)	**reactor ON/OFF**, μ veto, shielding, ER/NR ID
Goal	discover / exclude	**precision spectrum**

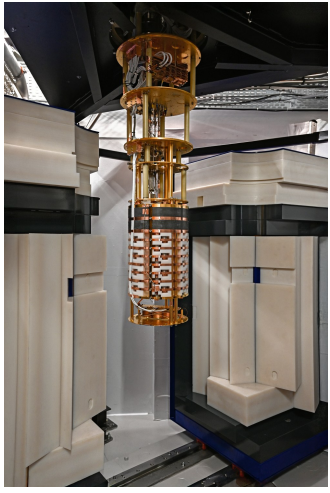
Your neutrino fog is our signal [PRL 127, 251802]

Ricochet @ ILL: a reactor neutrino observatory

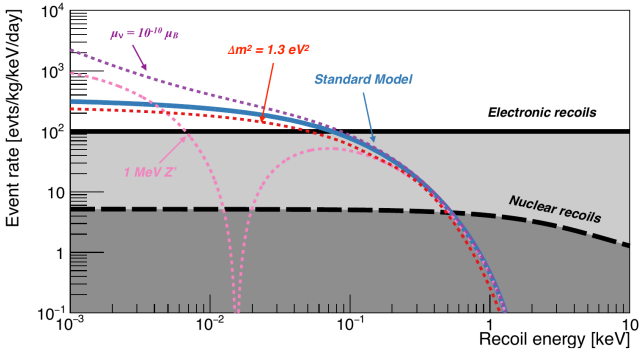


Ricochet site layout at the ILL

- 58 MW research reactor, highly enriched ^{235}U; typically three 2-month cycles / yr $\Rightarrow$ built-in ON/OFF
- 8.8 m from the core, 15 m.w.e. overburden; 22 t passive shielding (Pb, borated PE, soft iron) + μ vetoes outside & inside the cryostat



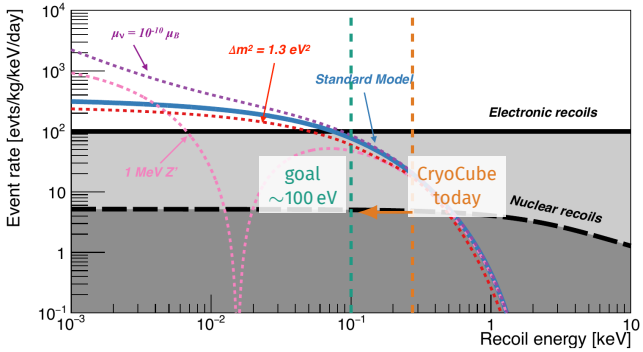
cryostat in its shielding at the ILL
[PRD 112, 112019]



Expected CEνNS signal and backgrounds at the ILL; annotations added
[J. Low Temp. Phys. 212, 127]

- Signal lives **below ∼1 keV** in Ge
- New physics shows up as **spectral distortions** at the lowest energies
- Electron recoils ≫ nuclear recoils
  ⇒ $\mathcal{O}$(100 eV) threshold
  + ER/NR identification

⇒ cryogenic calorimeters with particle identification



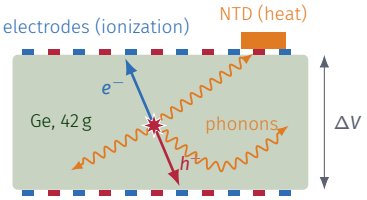
Expected CEνNS signal and backgrounds at the ILL; annotations added
[J. Low Temp. Phys. 212, 127]

- Signal lives **below ~1 keV** in Ge
- New physics shows up as **spectral distortions** at the lowest energies
- Electron recoils $\gg$ nuclear recoils
  $\Rightarrow$ $\mathcal{O}$(100 eV) threshold
  + ER/NR identification

$\Rightarrow$ cryogenic calorimeters with particle identification

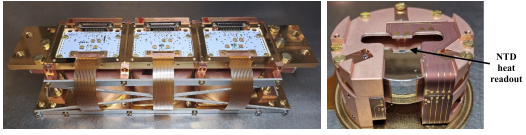
Ricochet CryoCube

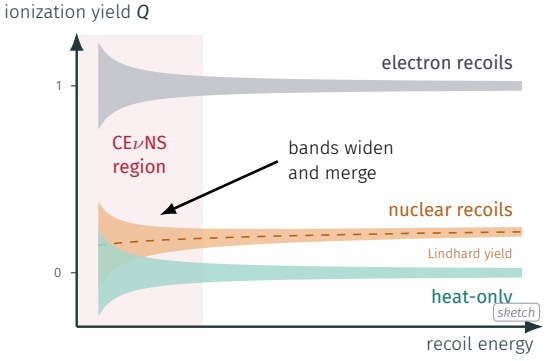
CryoCube: telling nuclear from electron recoils



$$E_{\text{heat}} = E_r + \frac{q\,\Delta V}{\varepsilon} E_{\text{ion}} \quad \text{(Neganov–Luke)}$$

$Q \equiv E_{\text{ion}}/E_r$: ER Q=1 NR Q≈0.2 heat-only Q=0





Particle ID is the crux: CEνNS lives **below 2 keV**, where the bands merge

CryoCube status: 18 detectors in physics mode at the ILL

R13–14: 2–3 planar → PRD 112, 112019

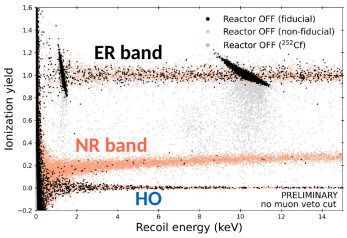
R15: 9 det. 4 FID, cryo μ veto

R16: full 18 Ge final electronics

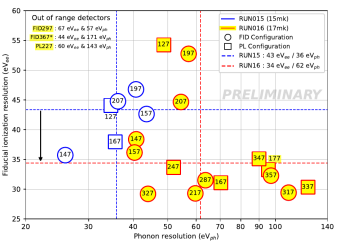
R17: FETs decoupled → better heat res.

Phase I ends end of 2027

2024 · 2025 · 2026 · now · 2027 · 2028



R15, FID detectors, reactor OFF + ^{252}Cf [Ricochet, preliminary]

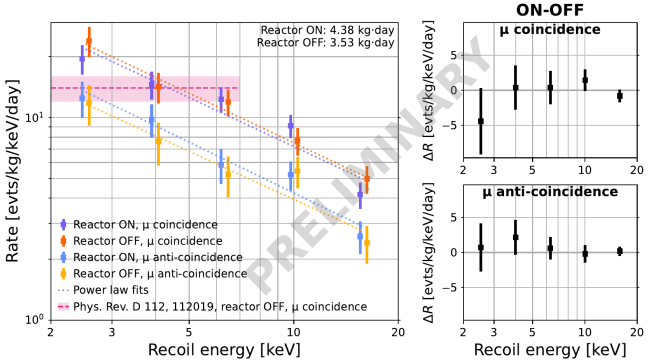


baseline resolutions, R15 vs R16 [Ricochet, preliminary]

- **R16 median**: 34 eV_{ee} ionization, 62 eV_{ph} heat (best: 27 eV_{ph})
- FID electrodes reject surface events → clean NR band
- **Vibrations** from the reactor hall: key for the heat channel

▶ **#101** *Vibrational Noise in a Dry Dilution Refrigerator*
J. Fisher, Thu 4:30 pm, RDC 7

Backgrounds: the reactor is quiet in nuclear recoils

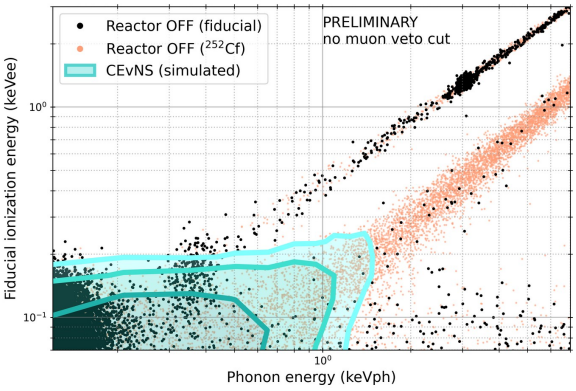


NR rates, 2–20 keV, four FID detectors of R15 [Ricochet, preliminary]

- μ-coincident NR rate (OFF, 2–7 keV): 14(3) /kg/keV/day, **as predicted** by Geant4: 15(2) [PRD 112, 112019]
- **No significant ON–OFF excess** in anti-coincidence above 2 keV

Reactogenic NR background under control: the ON–OFF subtraction works

CryoCube aims: a first look at reactor CEνNS by the end of 2027



simulated CEνNS injected into R15 FID data (68/95/99 % contours)
[Ricochet, work in progress]

Threshold today: median 250–300 eV$_{nr}$
$\Rightarrow$ 1.4–1.8 CEνNS/day

Phase I (to end 2027):
7 reactor-ON cycles
$\Rightarrow$ $\sim$1–2σ hint

What limits us at low energy

- heat-only events / LEE below $\sim$1 keV
- ionization res. $\rightarrow$ ER/NR & NR/LEE
- cosmogenic neutrons (same signature!)
- reactor-hall vibrations & noise

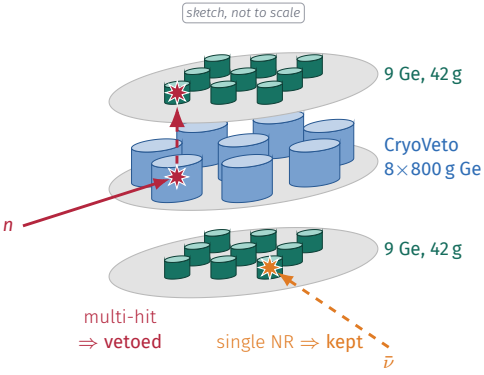
Phase II (ANR-funded since fall 2026, data 2028–2031): **CryoVeto** + Si + improved ionization (goal 20 eV$_{ee}$) $\Rightarrow$ **4–7σ** (Ge+Si)

Next step: CryoVeto

a germanium cryogenic veto (Phase II, ANR-funded)



Geant4 geometry
[Ricochet,
design in progress]

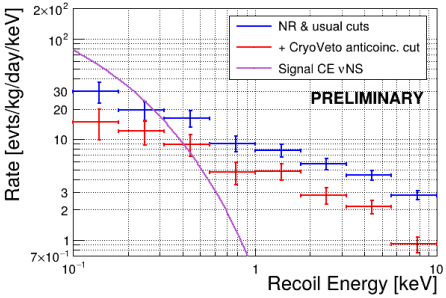


- **8 × 800 g Ge** (EDELWEISS FID800), between the two CryoCube layers at 10 mK
- Each crystal is **heavier than the whole CEνNS payload**
- Ionization readout, threshold ∼250 eV$_{ee}$
- Anti-coincidence tags **neutrons** (multiple scatters) and γ's

G. Soum-Sidikov, Ricochet poster
[Ricochet, work in progress]



Geant4 geometry
[Ricochet,
design in progress]



cosmogenic NR background with and without the CryoVeto, simulation
[Ricochet, work in progress]

- 8×800 g Ge (EDELWEISS FID800), between the two CryoCube layers at 10 mK
- Each crystal is **heavier than the whole CEνNS payload**
- Ionization readout, threshold $\sim$250 eV$_{ee}$
- Anti-coincidence tags **neutrons** (multiple scatters) and γ's
- Simulation: cosmogenic NR **halved**, reactogenic ***n*** NR —20–25 %, CEνNS significance **+25 %**

G. Soum-Sidikov, Ricochet poster
[Ricochet, work in progress]

What can the future hold?

Beyond Phase II: three directions we are exploring

Lower thresholds & more channels
for reactor CEνNS *and* light dark matter

1. Smaller absorbers

lower threshold ↔ lower mass:
eV-scale pixels, many of them

NIST Sidecar platform at Mines

2. Read out many sensors

microwave SQUID multiplexing:
one coax line, many TESs

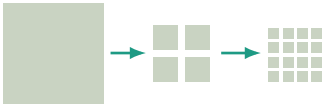
Al μMUX · QICK readout

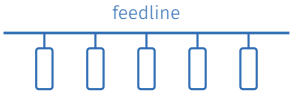
3. Know the energy scale

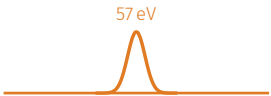
nuclear-recoil calibration
at tens of eV

implanted ^{7}Be, pioneered by the BeEST collaboration

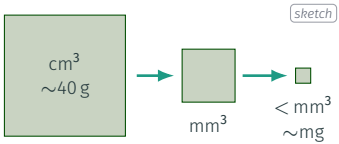
g → mg pixels







1. Lower threshold ↔ lower mass

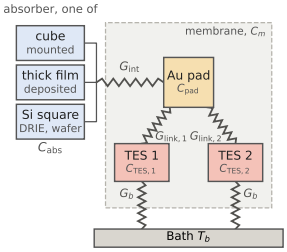


$\sigma_E \propto T\sqrt{k_B C}, \quad C \propto \text{mass}$

better resolution, lower threshold

more pixels for the same mass

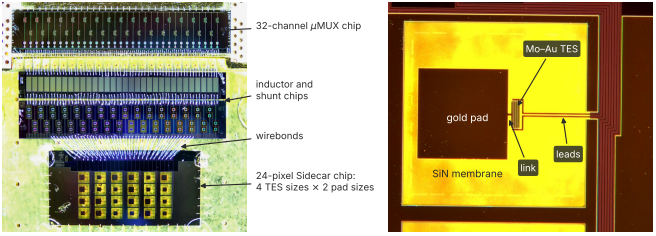
eV-scale resolution means **many small pixels**
⇒ multiplexing is not optional



thermal readout of a small absorber through a gold pad on a membrane, two TESs per pad

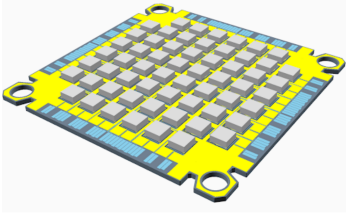
- **Thermal**: absorber on a Au pad, TES link defined lithographically → **NIST Sidecar**, next slide
- **Athermal**: collect phonons before they thermalize

▶ **#56** *Modeling and Design of HONEYCOMB*
E. Figueroa-Feliciano, today 3:20 pm, this session



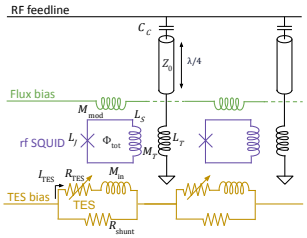
our first test chip and 32-channel μMUX, assembled at NIST, Sept. 2026

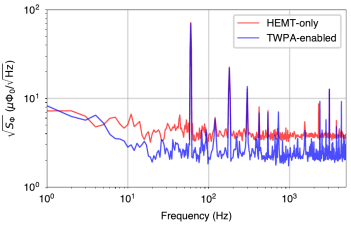
- **24-pixel test chip**: 4 TES sizes × 2 Au pads, read out by a 32-channel μMUX
- **Next**: first cooldown at Mines; ^{55}Fe & laser; then target cubes on the pads



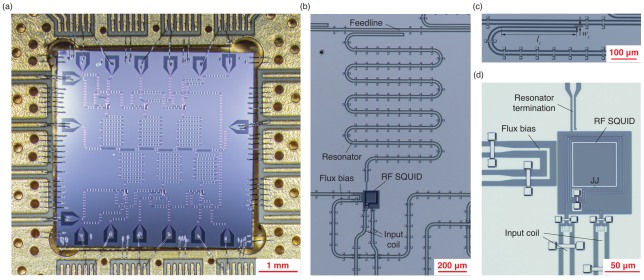
concept: a target cube on every Au pad (render)

- **Any target**: Ge, Si, superconductors; implanted before mounting
- **Risk**: cube–pad heat link
  Fix: electroplate the absorber, up to 40 μm





flux-ramp noise, with / without JTWPA



(a) chip, (b) one channel, (c) coupler, (d) rf SQUID

- 6-channel aluminum μMUX for Ricochet TES readout
- Flux ramp: **24–33 pA**/$\sqrt{\text{Hz}}$ at the TES input
- JTWPA as first stage: T_{sys} **3.6 K** $\rightarrow$ **0.6 K**

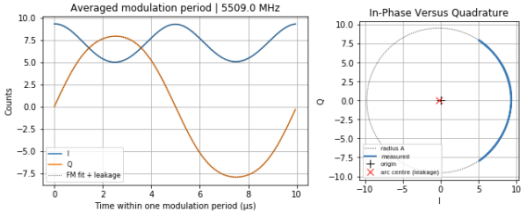
J. Yang, W. Van De Pontseele *et al.* (Ricochet), Supercond. Sci. Technol. **39**, 105010 (2026)

- **AMD ZCU216 RFSoC** in a QICK box
  16 DACs at **9.85 GS/s**, 16 ADCs at **2.5 GS/s**
- **Open source** (Fermilab), widely used for qubit control & readout [RSI 93, 044709]
- Building on a QICK-based **MKID readout**
- Regular meetings with the **Fermilab QICK** team and the **NIST μMUX** group

Goal on **one board**: tone generation, resonator tracking, flux-ramp demodulation, pulse reconstruction



our QICK box in the lab at Mines



first multi-tone loopback test: demodulated tone over one modulation period

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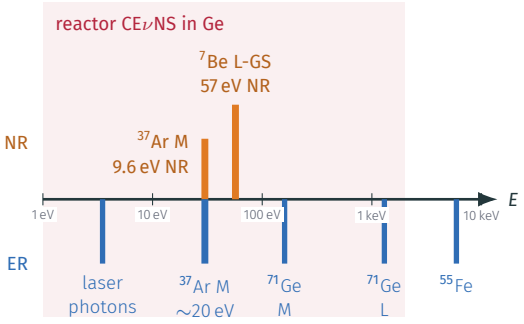
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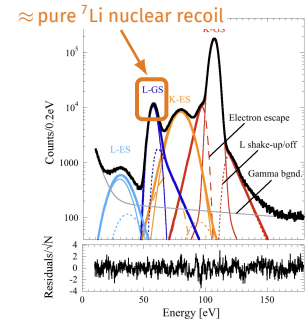
our QICK box in the lab at Mines

▶ **#95** *Time-Domain Simulation of Microwave SQUID Multiplexers*
L. Wanner, Thu 2:20 pm, RDC 11

▶ **#97** *SMuRF and SPECTRA: Scalable Superconducting-Sensor Readout*
Z. Ahmed, Thu 3:20 pm, RDC 4



- Sub-keV NR energy scale relies on **neutron calibrations** & quenching models
- **Mono-energetic NR lines** below 100 eV are rare

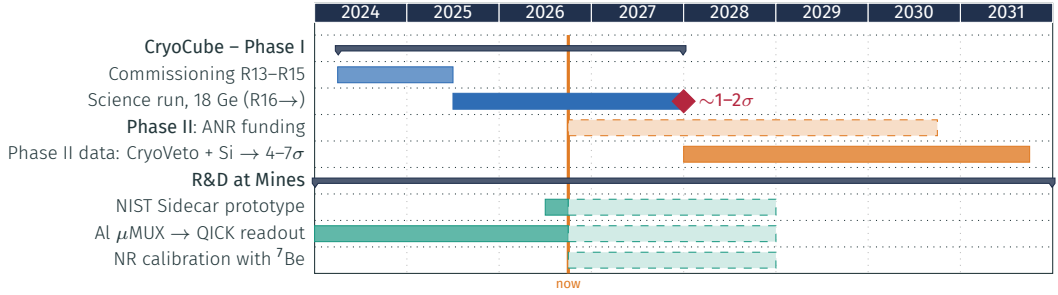


^{7}Be EC in Ta STJs, BeEST collaboration; annotation added
[PRL 125, 032701]

Plan: implant ^{7}Be into a Sidecar target cube → an **internal 57 eV NR line** in the CEνNS region

▶ Next two talks: **NR calibration with neutrons**

Roadmap & Summary



- **CryoCube**: 18 Ge detectors in physics mode, ~35 eV_{ee} / ~60 eV_{ph}; reactogenic NR background under control
- **CryoVeto** + Si (Phase II, ANR-funded) → **4–7σ** CEνNS
- **Beyond**: segmented pixels (NIST Sidecar), multiplexed TES readout (Al μMUX, QICK), NR calibration at 57 eV (BeEST)
- All Ricochet papers: ricochet-experiment.github.io/publications

Join us: Quantum Technologies at the Sensitivity Frontier



the group, underground at CURIE (Edgar Mine)

▶ **CURIE status**: L. Wanner, Wed 12:45 pm, Facilities

QTSF
Quantum Technologies at the Sensitivity Frontier

Superconducting sensors & readout for rare-event physics: CEνNS, μMUX, TES, STJs, quasiparticle & phonon physics, underground R&D at CURIE

RICOCHET
A Coherent Neutrino Scattering Program

BeEST

CURIE

COLORADO SCHOOL OF MINES

We are hiring a postdoc!

At the intersection of

- **BeEST**: STJ sensors, ^{7}Be electron capture
- **NIST TES** sensors & calorimetry (Sidecar)
- **μMUX** tests & RFSoC (QICK) readout

Surface & underground (CURIE) cryogenic platforms; close links to NIST, MIT, Fermilab, LLNL and Queen's.

Talk to me this week, or email
wouter.vandepontseele@mines.edu

qtsf.mines.edu

Thank you!

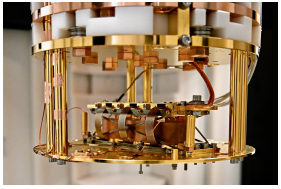
Questions?



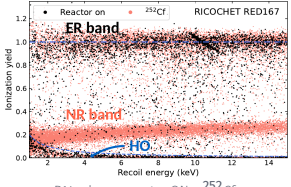
the Ricochet collaboration

Backup

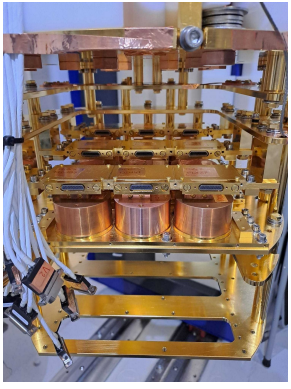
Backup: the CryoCube payload & commissioning data



mini-CryoCube on the 10 mK stage
[PRD 112, 112019]



R14, planar, reactor ON + ^{252}Cf
[PRD 112, 112019]



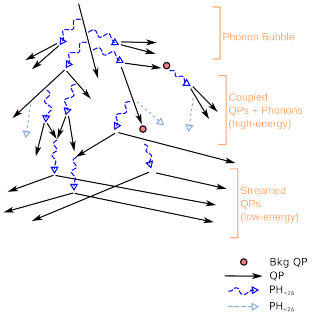
18-detector CryoCube
[Ricochet]

NR rate, 2–7 keV	[/kg/keV/day]
OFF, μ-coinc.	14(3) (sim. 15(2))
ON, μ-anticoinc.	$<$ **9** (90 %CL) (sim. 5)

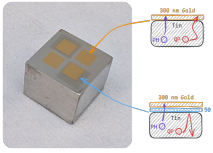
planar detectors, R14
[PRD 112, 112019]

- 30 eV$_{ee}$ ionization resolution demonstrated [EPJC 84, 186]
- Commissioning paper: PRD 112, 112019 (2025)

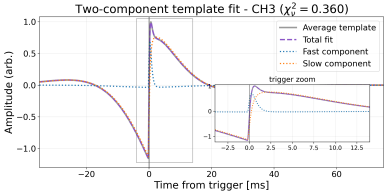
Backup: superconducting absorbers & quasiparticle modeling



down-conversion cascade in a superconducting absorber
[M. Li, ASC 2026]



Sn cube with Au collection pads, direct contact vs. SiO_2 barrier



two-component pulse fit, direct-contact dataset
[M. Li, ASC 2026]

- Gap $2\Delta_{\mathrm{Sn}} = 1.13$ meV vs. ∼eV in Ge: $\sim 10^3\times$ more quanta
- Direct Au contact: **fast + slow** pulse components
- SiO_2 barrier: **no fast component** ⇒ fast part from quasiparticles entering the pad
- Cascade simulation (work in progress): fast/slow partition vs. energy, pad geometry, recoil type

Backup: dielectric vs. superconducting absorber



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