CEvNS detection with Ge-Mini

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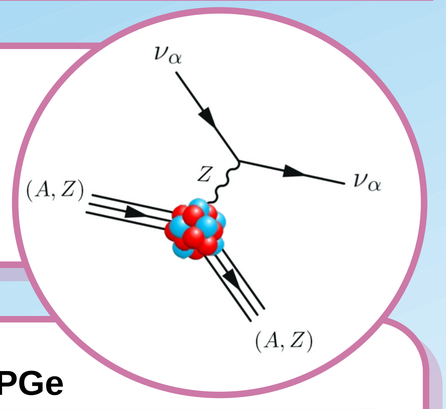
Poster #155

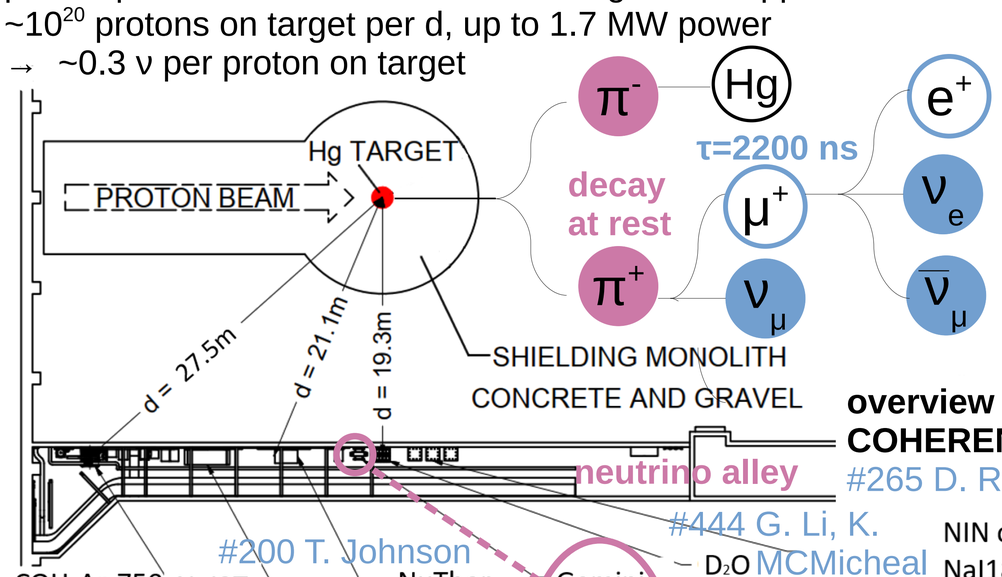
Coherent elastic neutrino nucleus scattering (CEvNS)

- neutral current neutrino interaction with all nucleons in a nucleus at once → **enhancement of cross section** σ~(#neutrons)^2
- **Standard Model process** predicted by Freedman (1978) [1], first detection by COHERENT (2017) with CsI scintillating crystals [2]
- **coherency condition:** DeBroglie wavelength of momentum transfer > size of target atom → upper limit on neutrino energy ≤50 MeV
- **signature of interaction:** recoil of nucleus hit by the neutrino → need detectors with sub-keV sensitivity for nuclear recoils



Spallation Neutron Source (SNS)

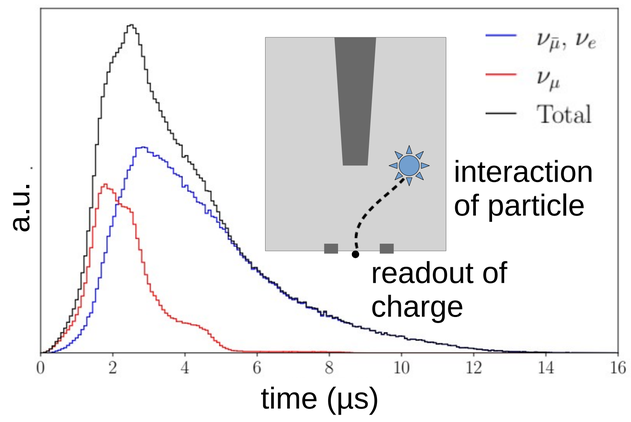
Pion-decay-at-rest source at Oak Ridge national laboratory, USA:
- pulsed proton beam with 60 Hz → background suppression
- ~10^{20} protons on target per d, up to 1.7 MW power
  → ~0.3 ν per proton on target

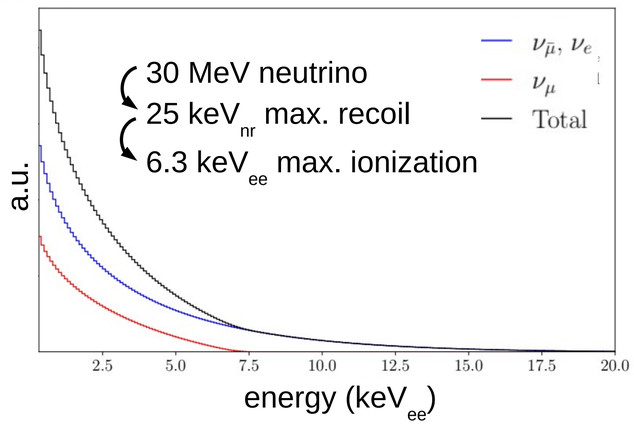


overview COHERENT
#265 D. Rudik
#444 G. Li, K. MCMicheal
#200 T. Johnson
#96 S. Hedges
#453 V. Da Silva
Cryo CsI #422 C. Prior
Lead glass #568 N. Ogoi

Detector response

expected SNS neutrino time and energy spectra in HPGe





drift time evaluated by:
- pulse shape simulations with Siggen (D. Radford, github.com/radforddc/icpc_siggen)
  → homogeneous interactions in diode
- measurement with fast-responding (ns) coincidence detector and ^{228}Th source
  → includes response of electronics

=> **most signal read out <14 μs**
=> successful beam correlation

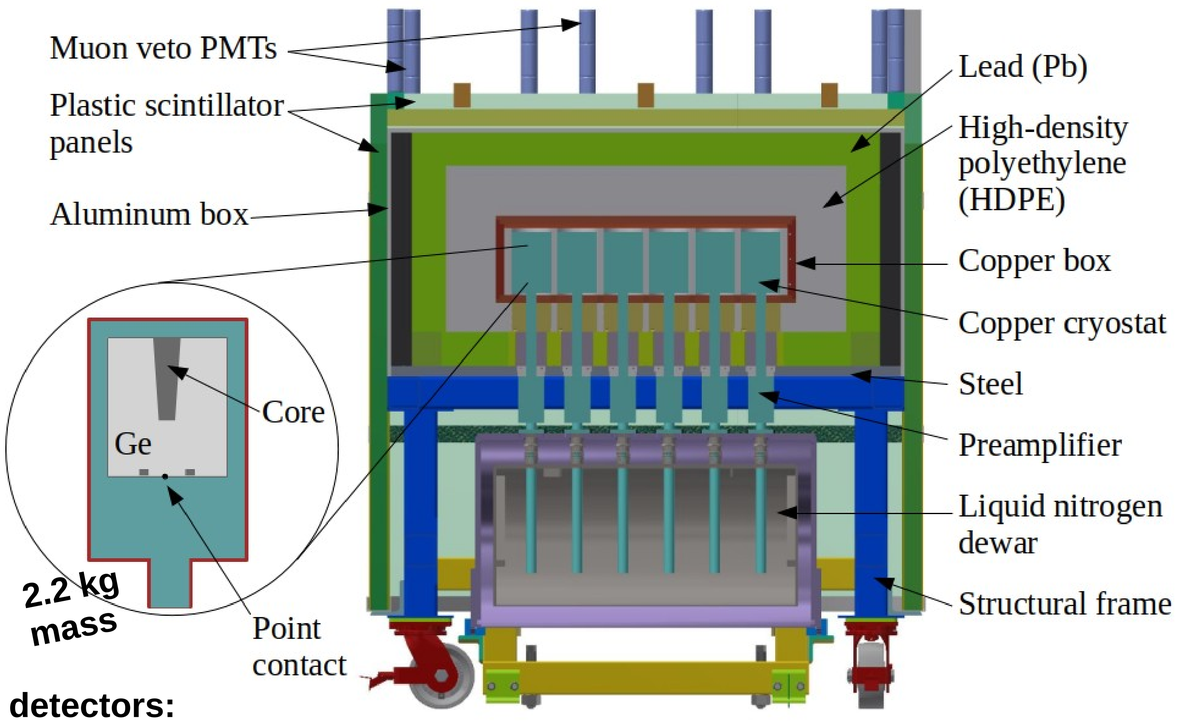
quenching: **detectable by HPGe**
recoil → **ionization energy** + **phonons**
described by Lindhard theory [3] with k=0.157±0.004 [4]

form factor: ~shape of nucleus
→ ~32% reduction of the rate

excellent energy resolution:
→ minor impact on CEvNS spectrum

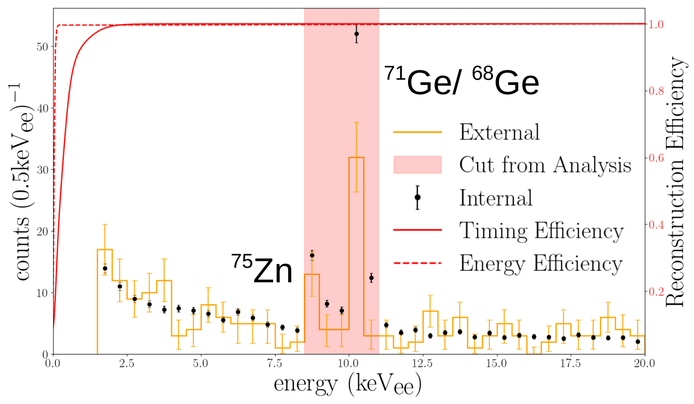
- **active mass:** outer layer of diode is dead → about 4% loss of total mass
- **energy scale calibration:** linear, two point calibration

Ge-Mini



detectors:
- eight high-purity point contact Germanium spectrometers (HPGe)
- **large-sized** crystals, inverse coax design
- low electronics noise with trapezoidal reset preamplifier (TRP)
- **energy resolution**: 220-280 eVee$_{ee}$ full-width-half-maximum at 10.37 keV

Campaign-2



physics run: summer 2023
five stable detectors
total exposure: **10.22 GWhkg** (after all cuts)
background reduction:
- by shield: ~10^3-10^4
- by beam corr.: ~10^3

} **sig./bkg ~1**

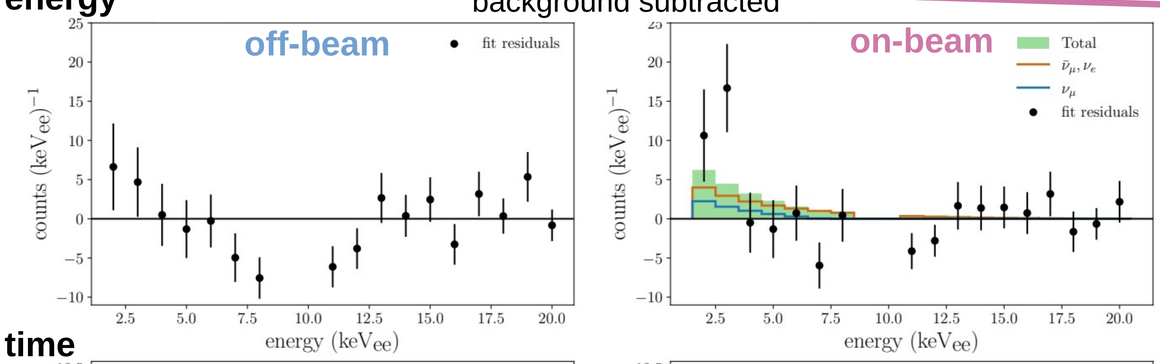
(0.19±0.03) d^{-1}kg^{-1} in [1.5,20] keV$_{ee}$
Beam-related neutrons: negligible

CEvNS results

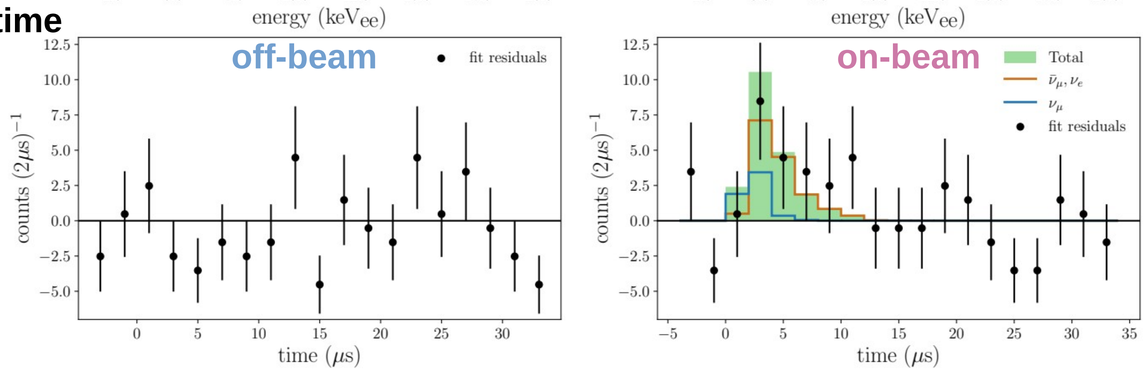
Publication on the way! Talk by M. Green

- unbinned 2-dimensional likelihood fit in time and energy

energy background subtracted



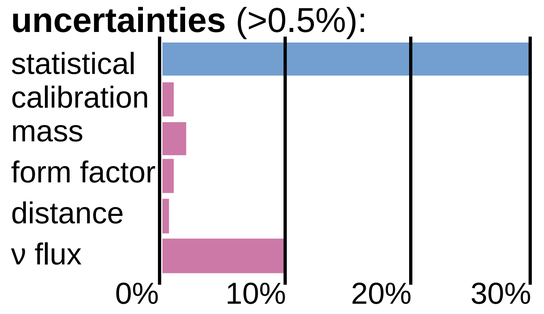
time



First detection of CEvNS on germanium!

fit result:
null hypothesis rejected by **3.9 sigma**!
CEvNS signal: 20.6 -6.3 +7.1 (stat)
beam-related neutrons: 0.7 ± 0.3 (input)
steady-state bkg: 161.7 -9.1 +9.5 (stat) (40 μs window)
Standard model prediction: 35.1 ± 3.6
agreement within 2 sigma!

uncertainties (>0.5%):

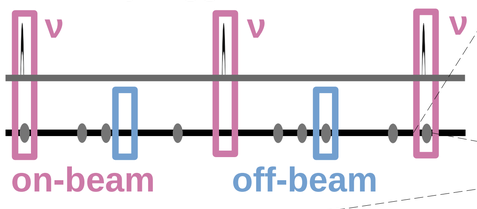


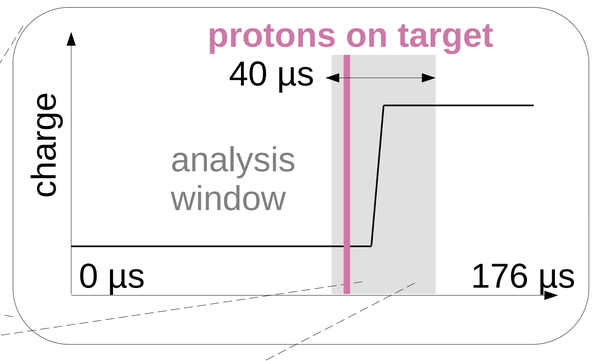
→ result is statistically limited, next beam time starting this summer!

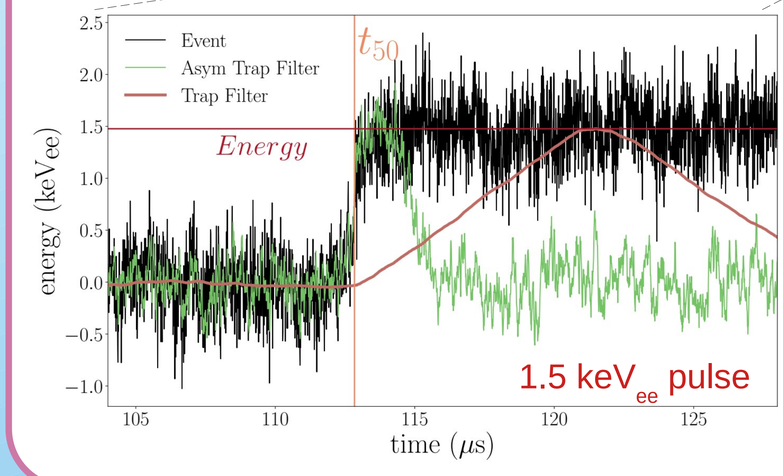
Triggering and detector performance

externally triggered: 120 Hz

internally triggered: calibration







energy reconstruction:
- symmetric trap. Filter
  → accurate at >200 eV$_{ee}$

timing reconstruction:
- asymmetric trap. Filter
  → accurate at >2 keV$_{ee}$
  → small efficiency loss within [1.5,2] keV$_{ee}$

cuts on:
- noise: LN fills, TRP,...
- muon-tagged events

Literature: [1] D.Z. Freedman, Phys. Rev. D 9, 1389 (1974), [2] D. Akimov et al. (Coherent), Science 357, 1123 (2017), [3] J. Lindhard, Jens. Mat. Fys. Medd. Dan. Vid. Selsk 34.14 (1965): 1-64., [4] A. Bonhomme et al. (CONUS) EPJC 82, 815 (2022)

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