COHERENT Results and Status

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On behalf of the COHERENT Collaboration

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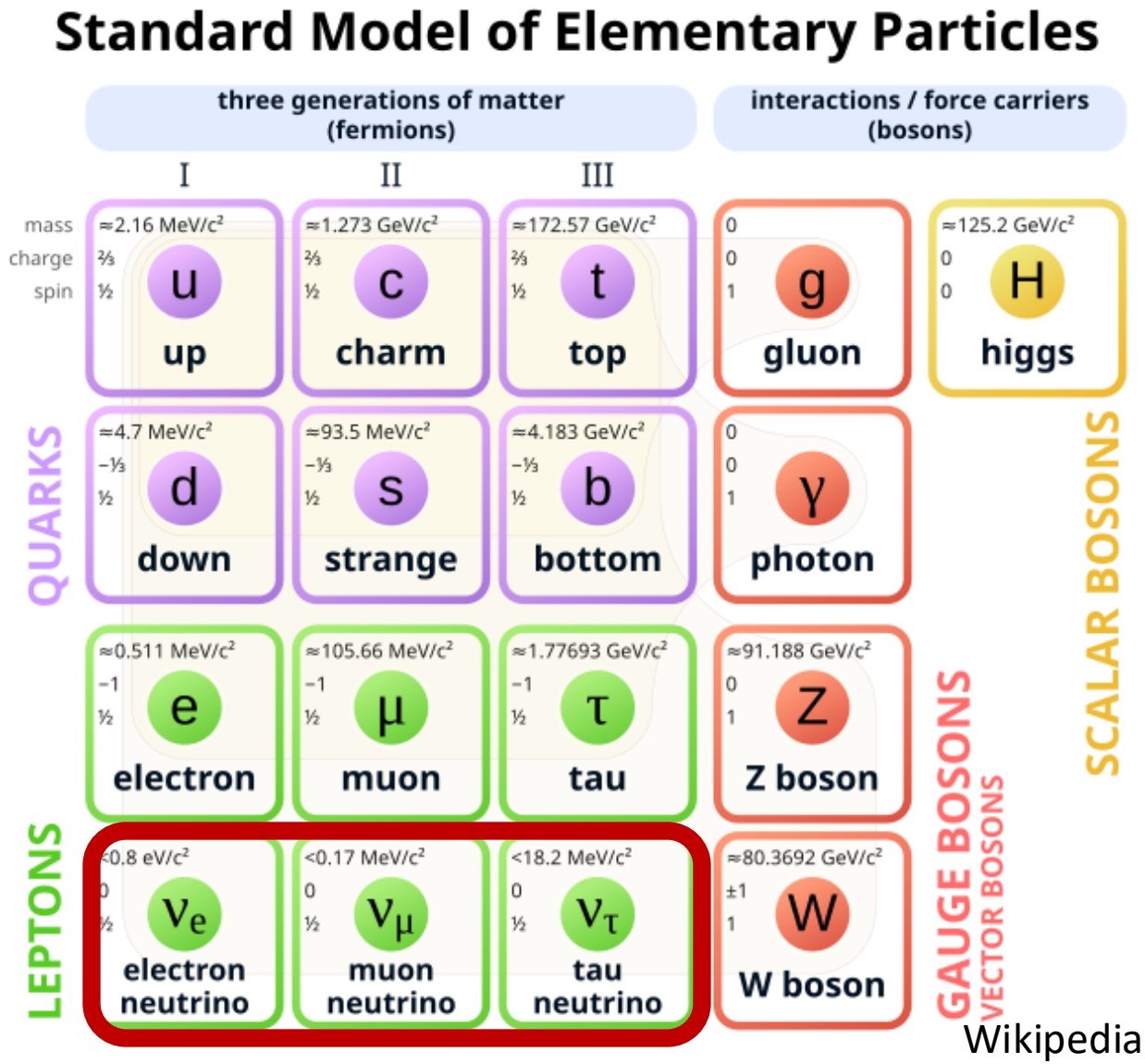
Neutrinos are elementary particles with zero charge, tiny mass, and weak interaction.

$$m_\nu << m_e$$

(<1 eV) (511 keV)

Three flavors corresponding to three generations of leptons



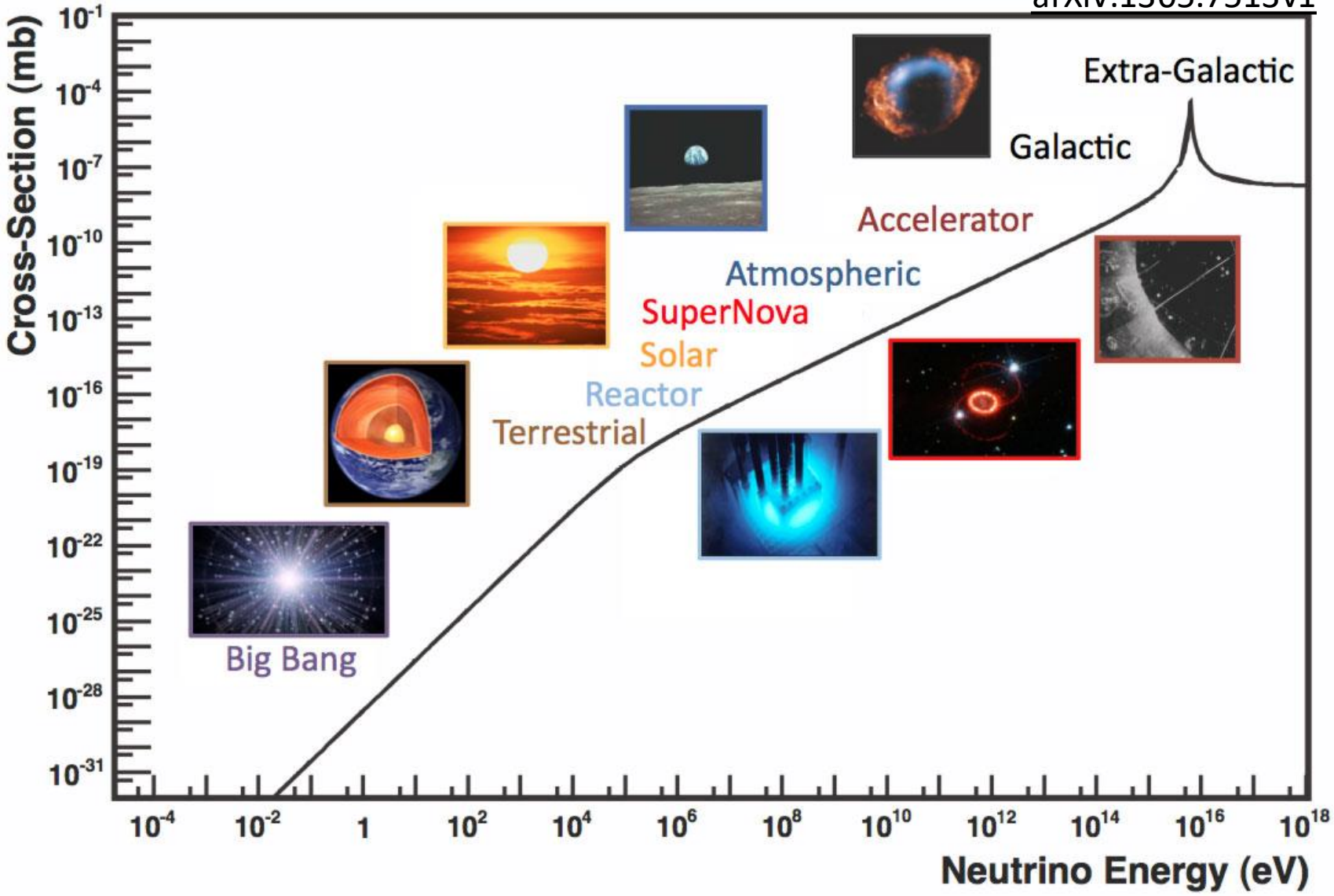
Wikipedia

Neutrinos are produced both naturally and from artificial sources.

Comes with a wide range of energies

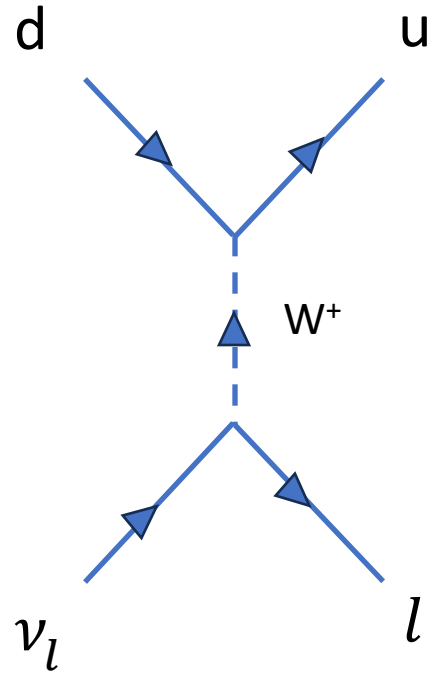
Highest Energy Observed 220 PeV

arXiv:1305.7513v1



Neutrino interacts with quarks and leptons via the weak nuclear force mediated by $W^{\pm}$ and Z^0 bosons.

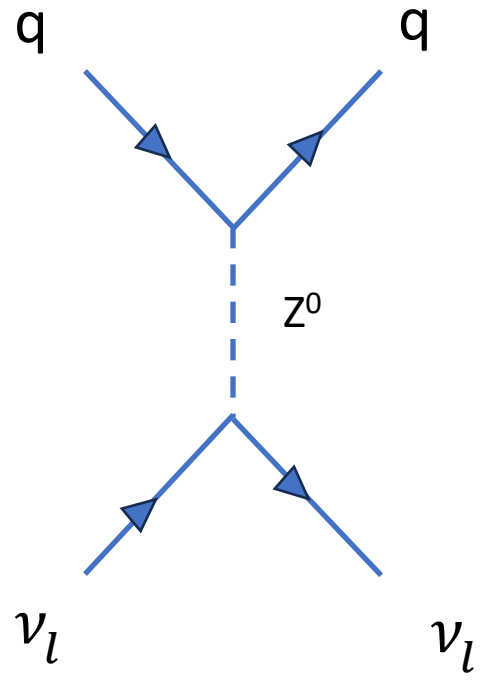
Charged current



q : quark

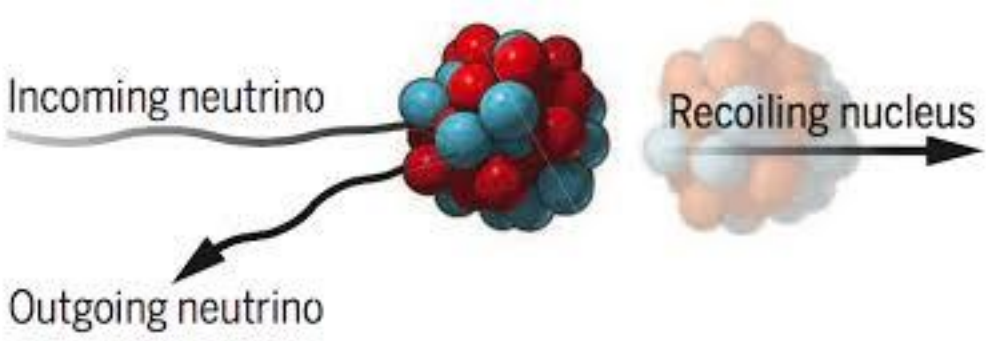
l: e^-, μ^-, τ^-

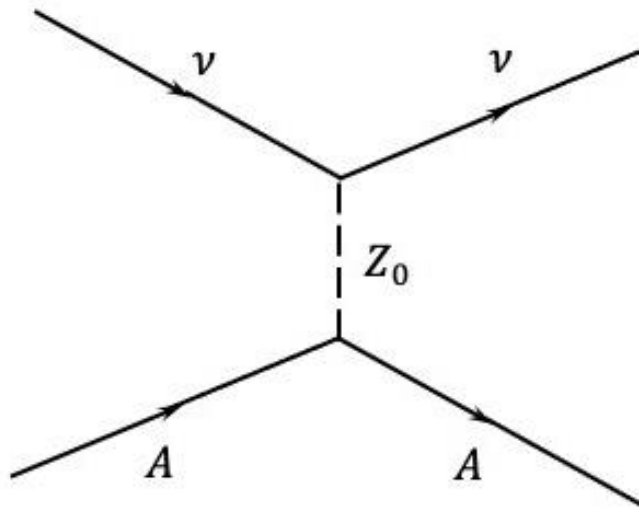
Neutral current



$$\nu_l + q \rightarrow l^{\pm} + q'$$

Coherent Elastic neutrino-Nucleus Scattering (CEvNS)





Neutrino interacts with
the entire nucleus instead
of individual nucleons

$$\nu + A \rightarrow \nu + A$$

CEvNS was first predicted in 1973 and is well known theoretically within the Standard Model.

CEvNS Interaction cross section

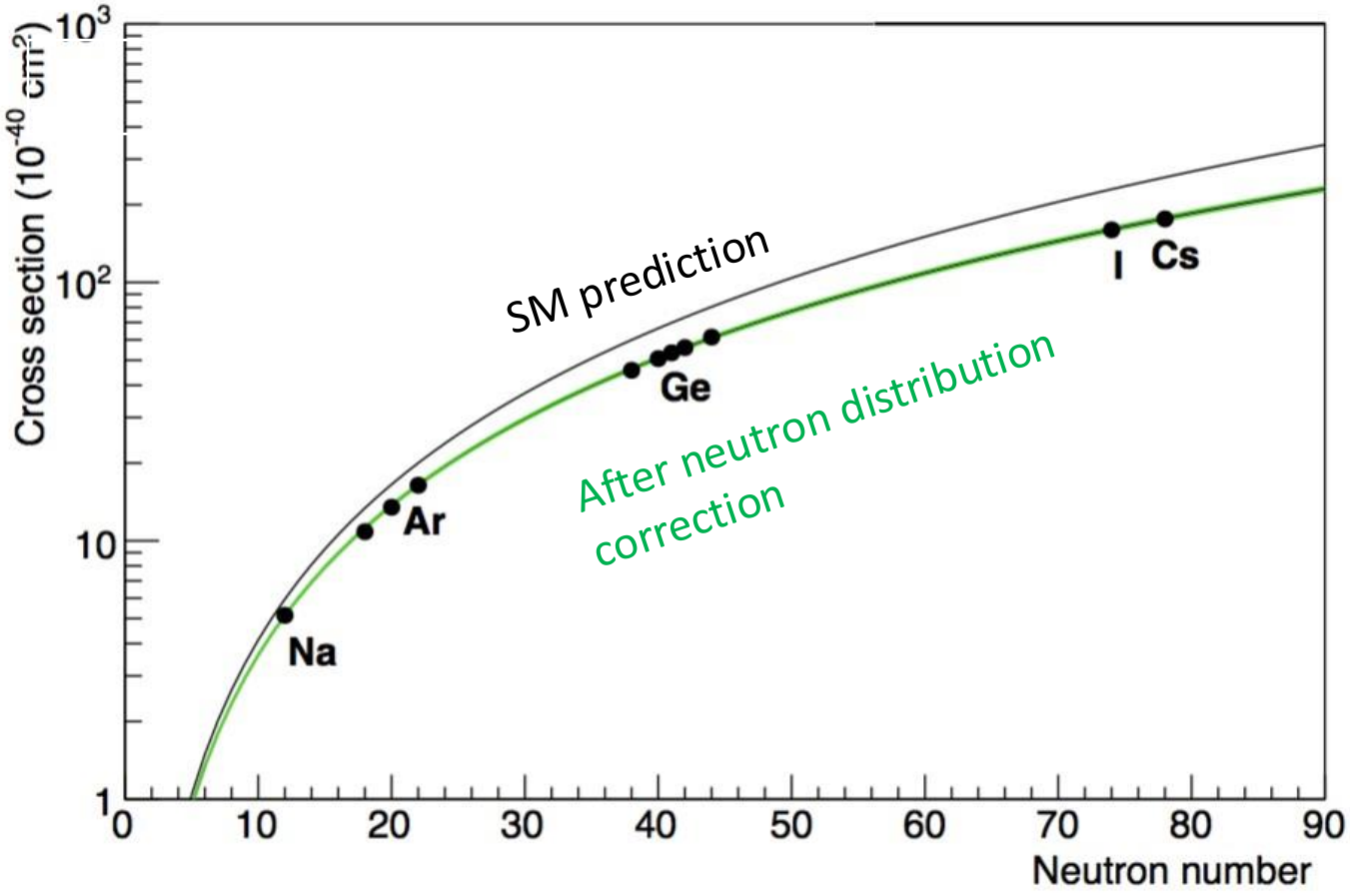
$$\frac{d\sigma}{dT} = \frac{G_F^2 M}{2\pi}\frac{Q_W^2}{4} F^2(Q)\left(2 - \frac{MT}{E_v^2}\right)$$

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

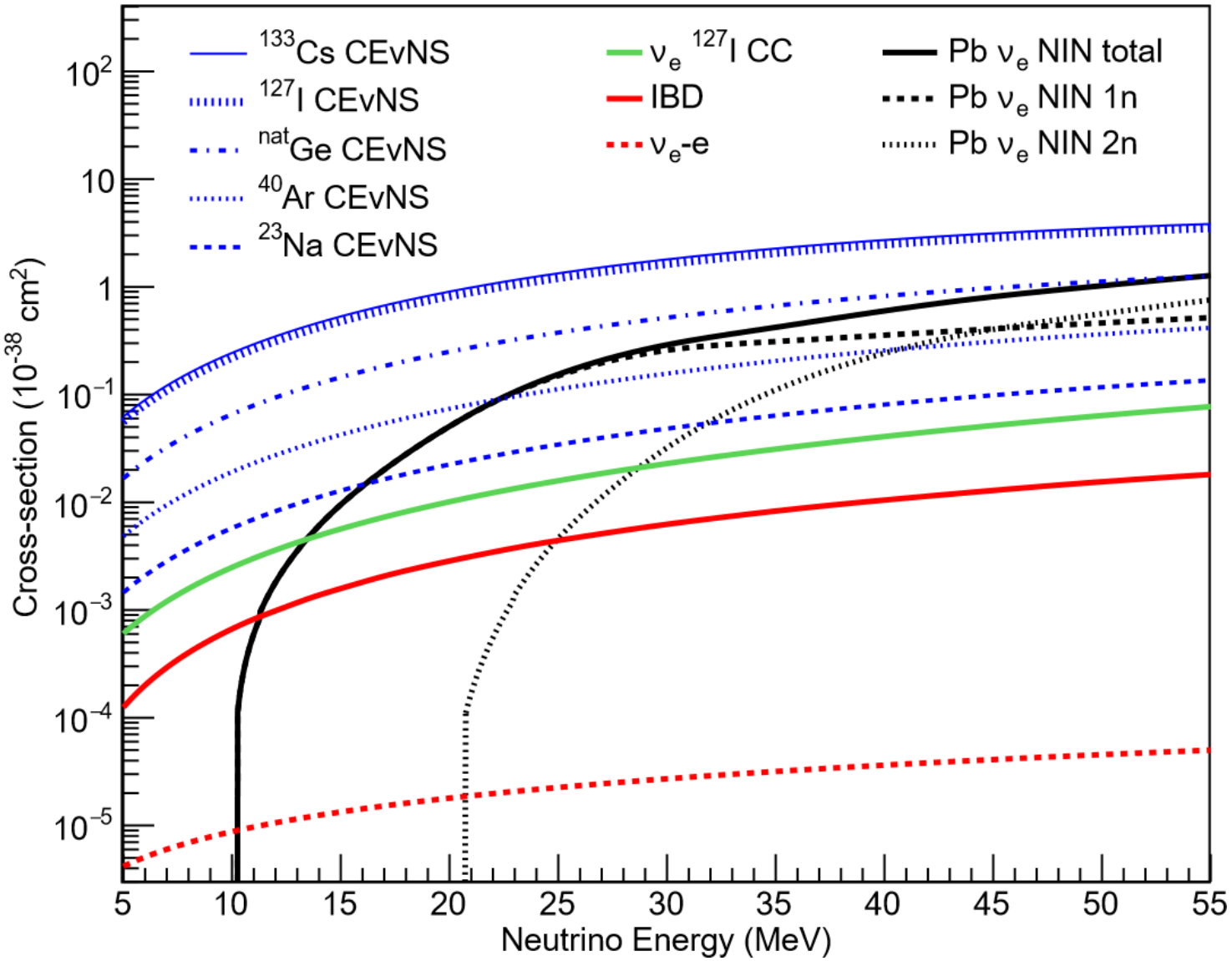
$$\sin^2\theta_W = 0.231$$

$$Q_W \propto N$$

$$\boldsymbol{\frac{d\sigma}{dT} \propto N^2}$$



Interaction probability of CEvNS is higher at lower energies

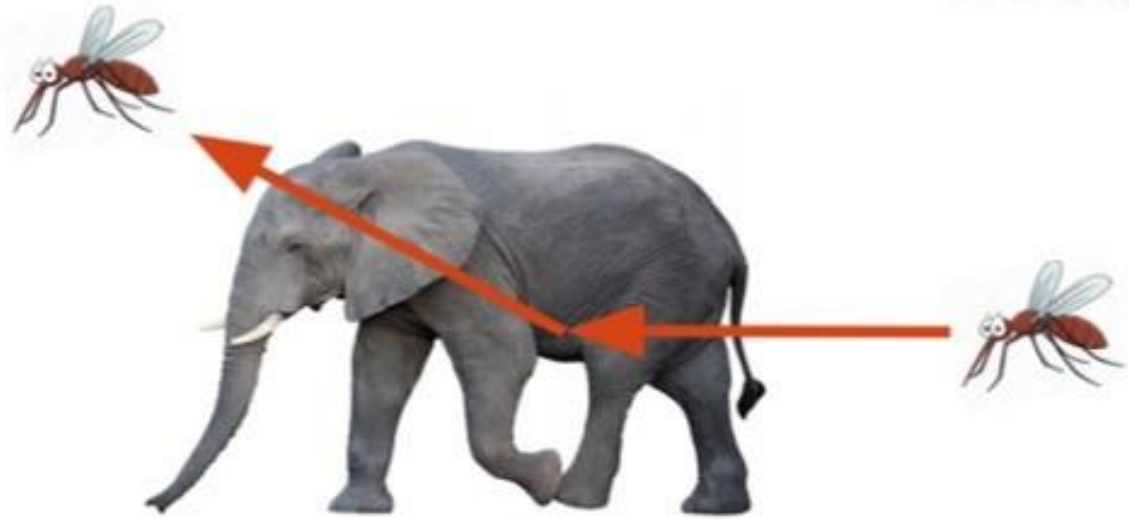


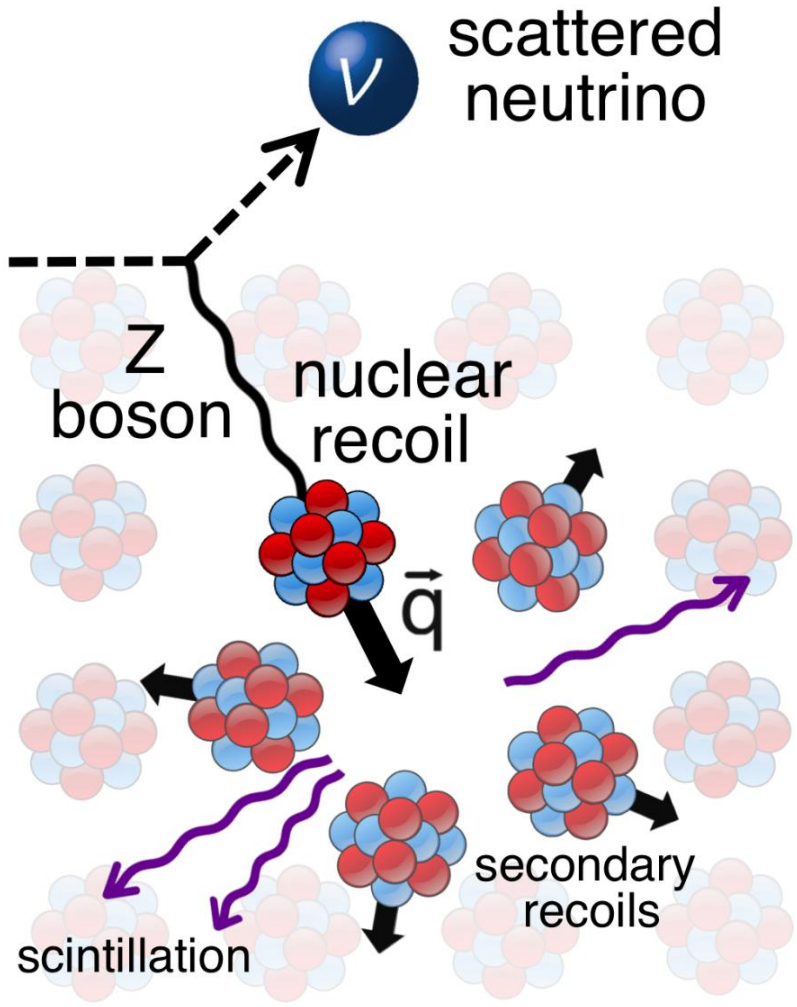
IBD : Inverse Beta Decay

ν_e-e : neutrino electron elastic scattering

NIN : Neutrino-Induced Neutron background

Although CEvNS cross-section is large, it is difficult to observe due to tiny nuclear recoil energies.



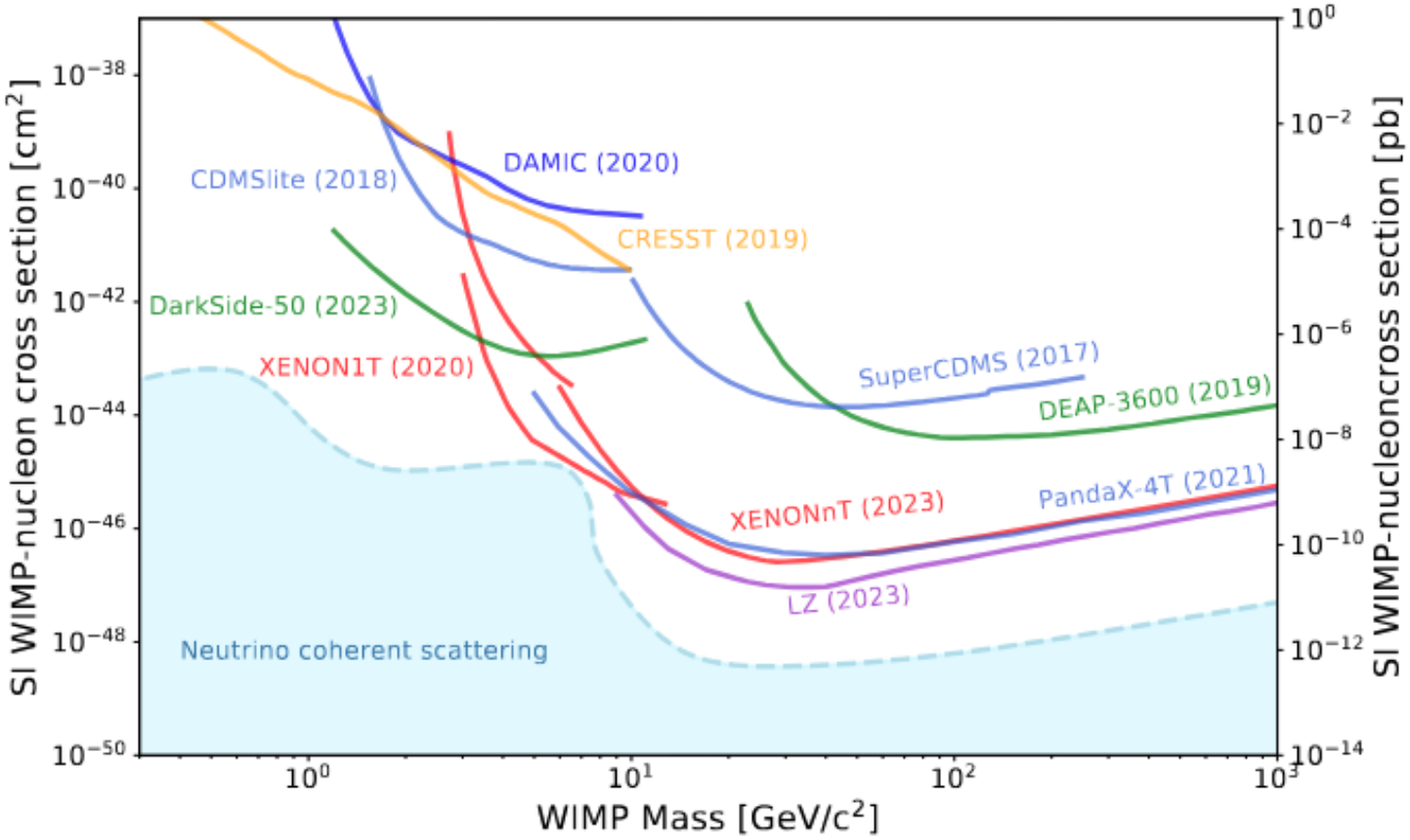


What would be helpful

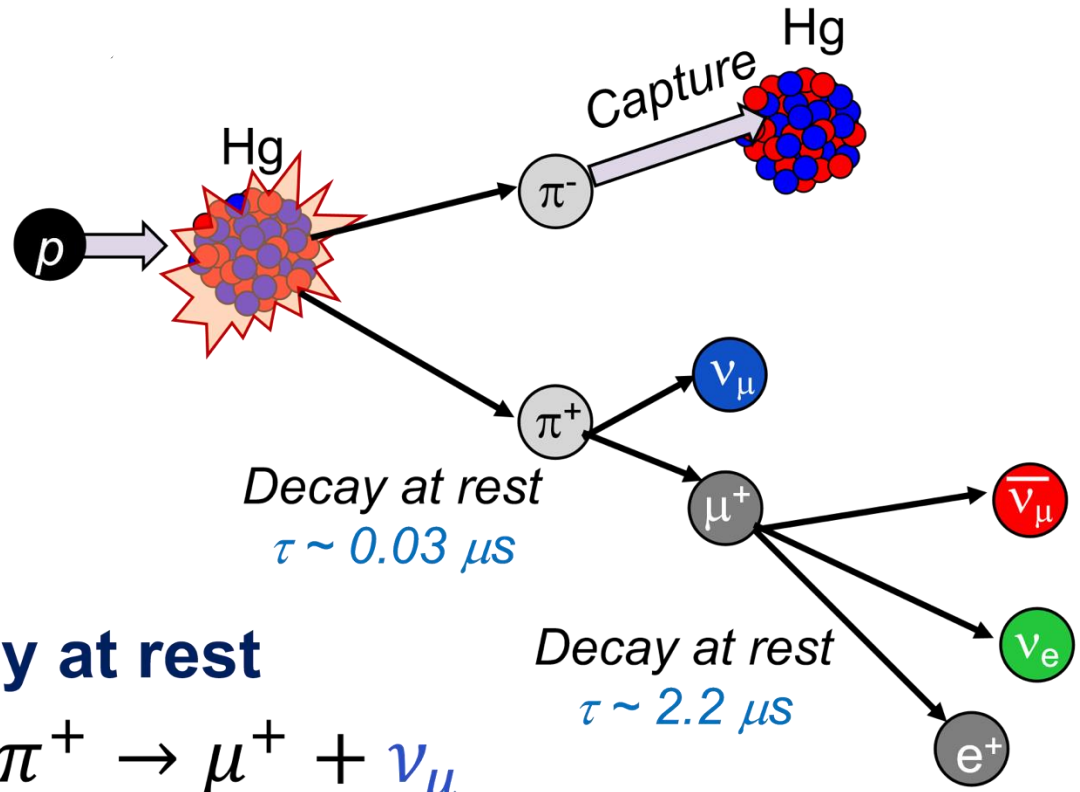
- High flux neutrino source
- Background rejection
- Deploy close to the source

Measuring CEvNS has applications that ranges from testing the Standard Model to applications.

- Dark matter detection background
- Search physics beyond the Standard Model
- Astrophysical signals
- Supernova processes
- Understanding nucleus
- Applications



The Spallation Neutron Source at ORNL produces neutrinos through pion decay at rest.



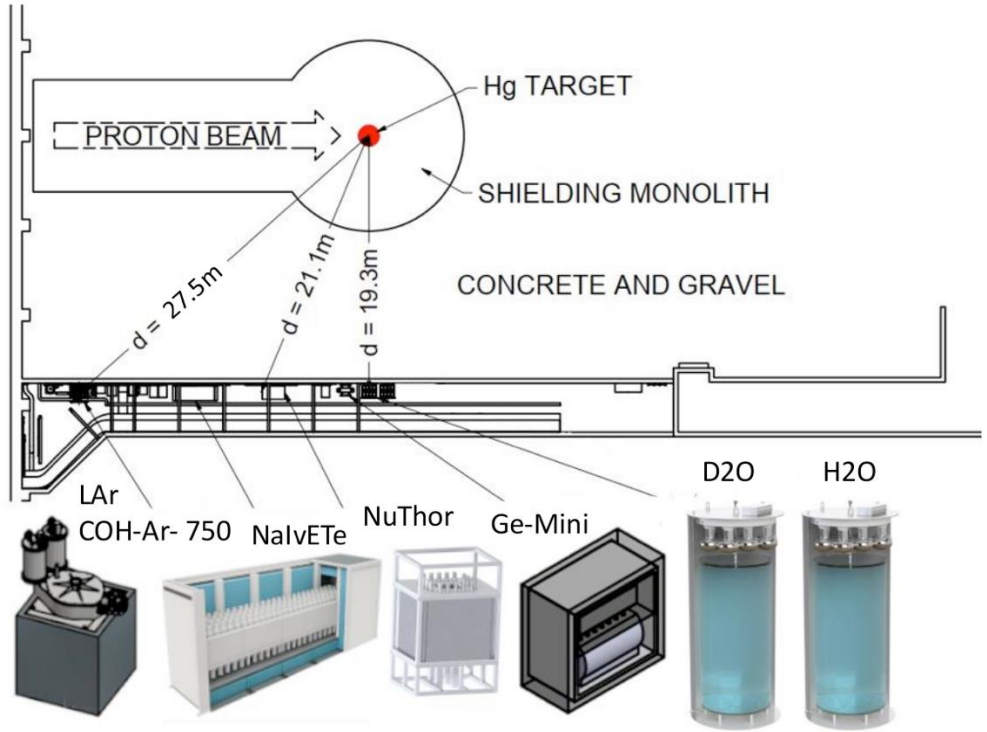
1.3 GeV proton linac
1.8 MW beam power
60 Hz pulsed source

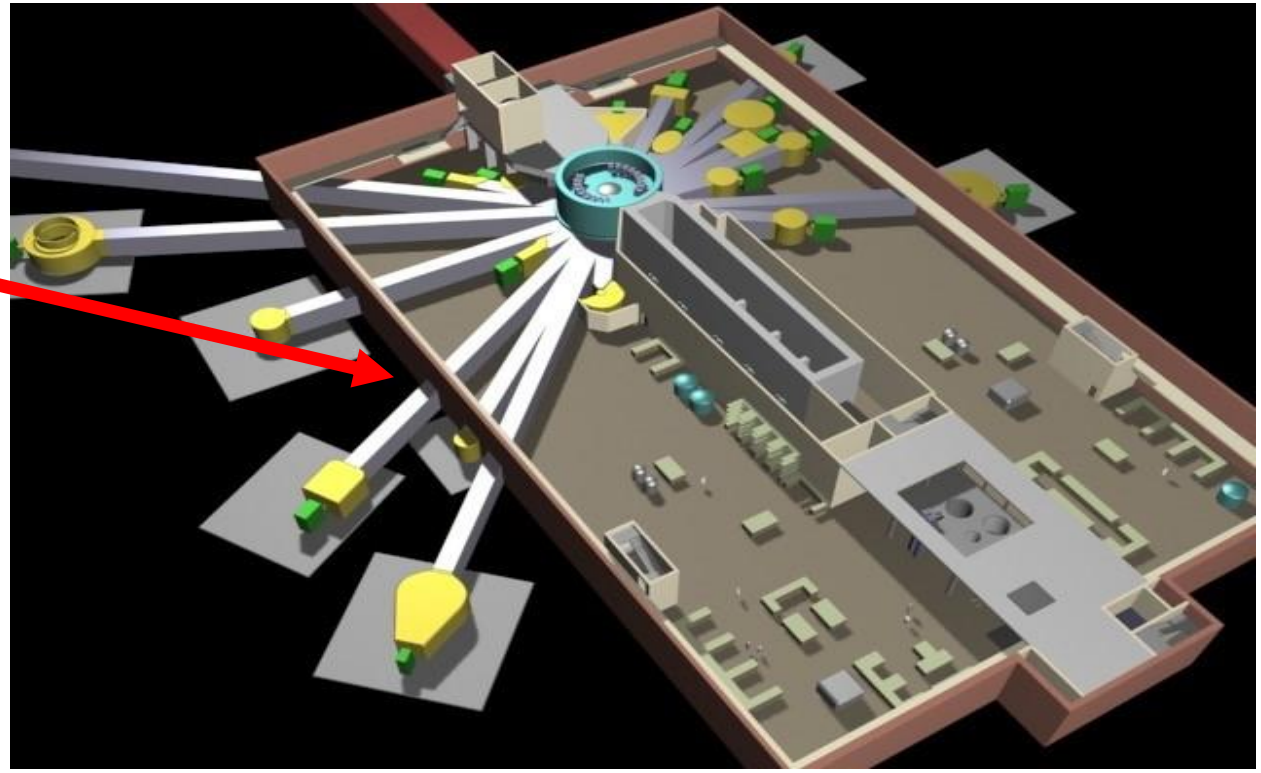
Pion decay at rest

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

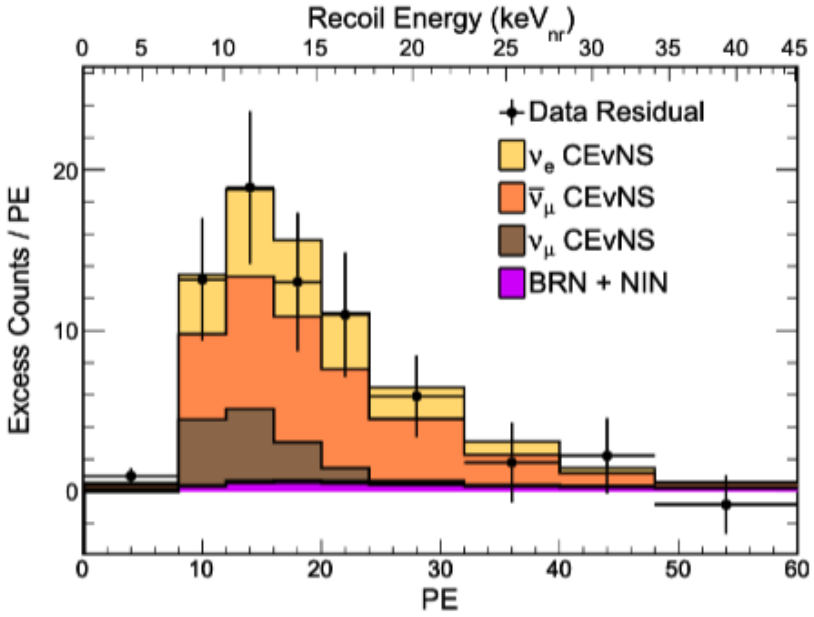
Neutrino Alley at the SNS is a perfect location for CEvNS measurements.



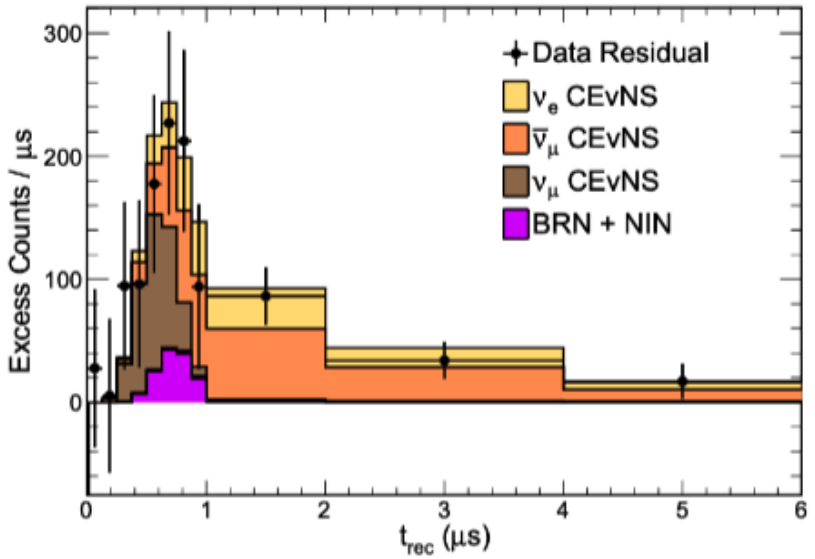


SNS Basement → Neutrino Alley
Good shielding
20-30 m from the target

COHERENT first detected CEvNS in 2017 using a CsI[Na] detector deployed at the Neutrino Alley.



PRL 129 081801 (2022)

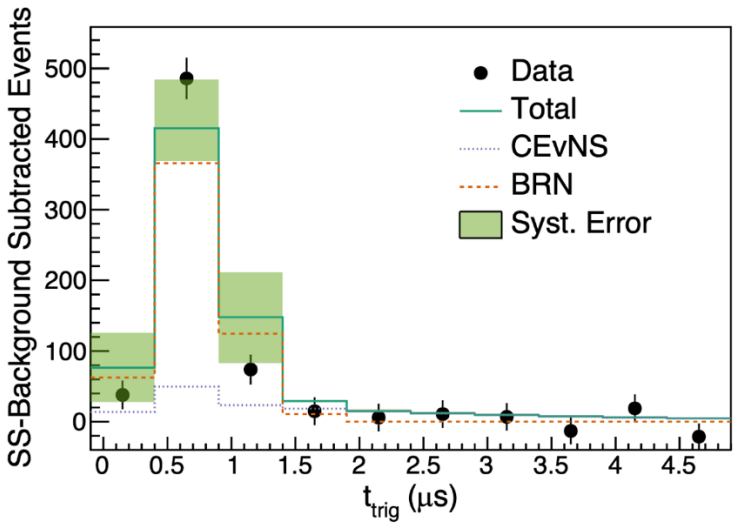


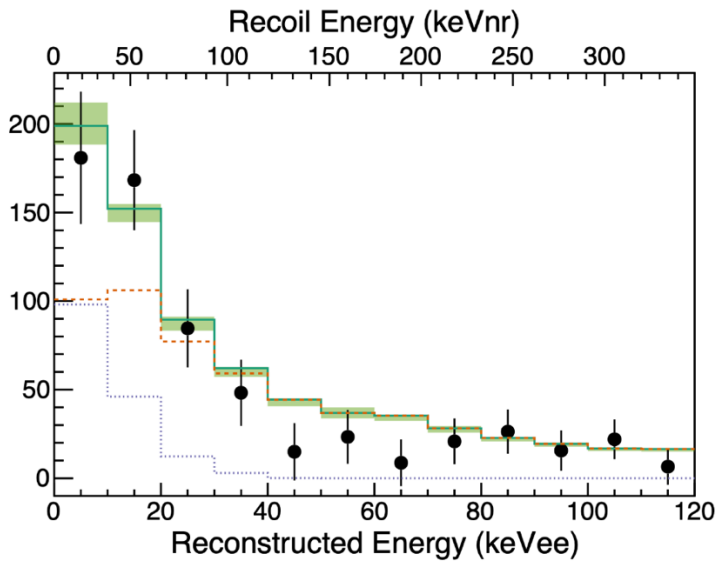
11.6 σ with full dataset

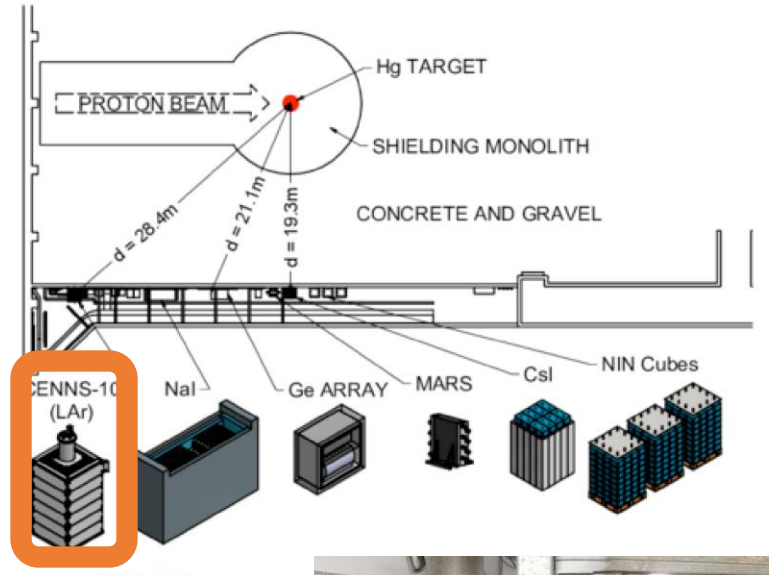
14.6 kg CsI[Na] scintillation detector

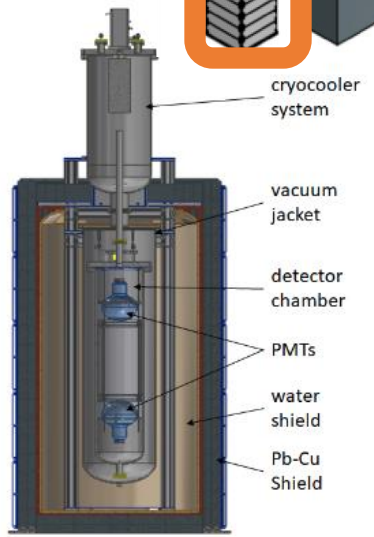
In 2020, COHERENT measured CEvNS in Ar using the CENNS-10 (LAr) detector

PRL 126, 012002 (2021)



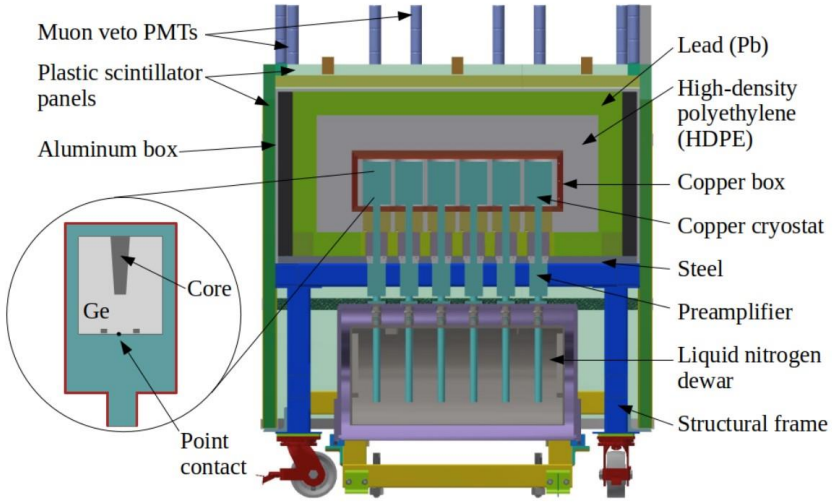






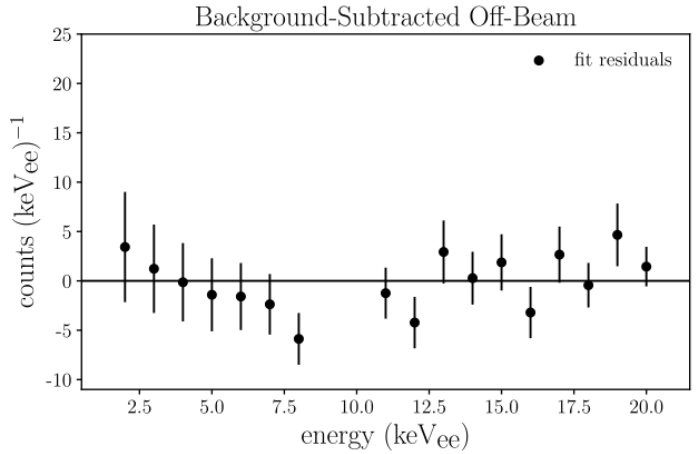
- 24 kg Single-phase liquid argon
- 2×8” PMTs
- H_2O/Cu/Pb shielding

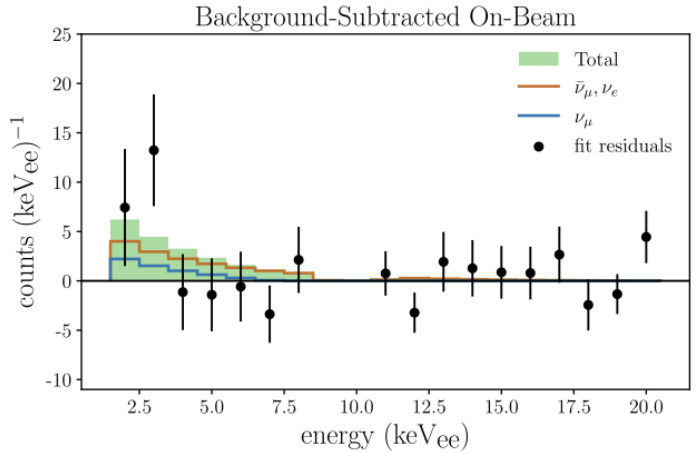
In 2024, COHERENT detected CEvNS on Ge with the Ge-Mini detector.

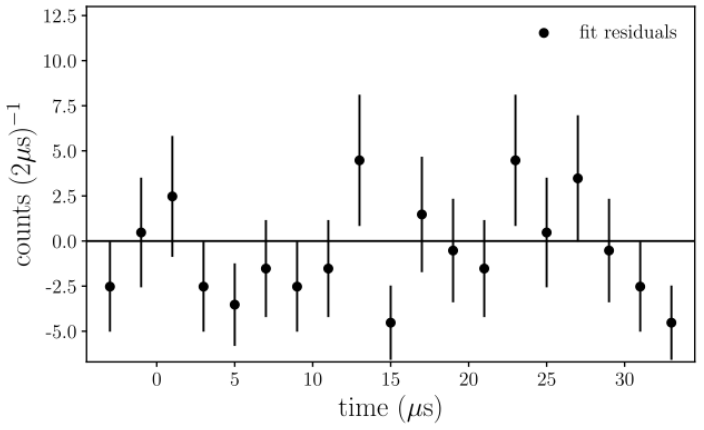


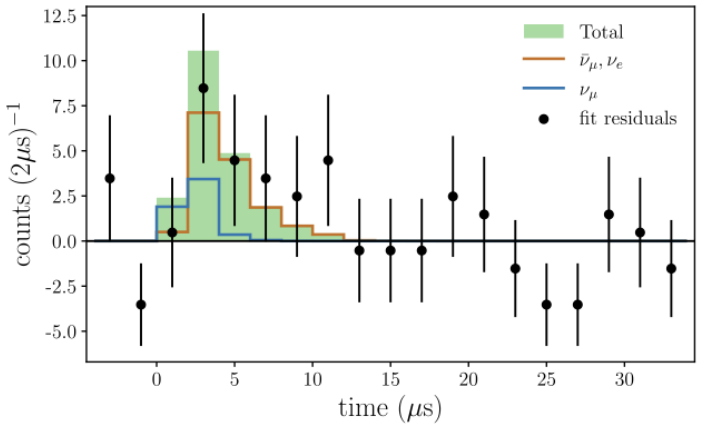
- 18 kg High-Purity Germanium detector
- Shielding: Cu, HDPE, Pb, muon veto

PRL 134, 231801 (2025)

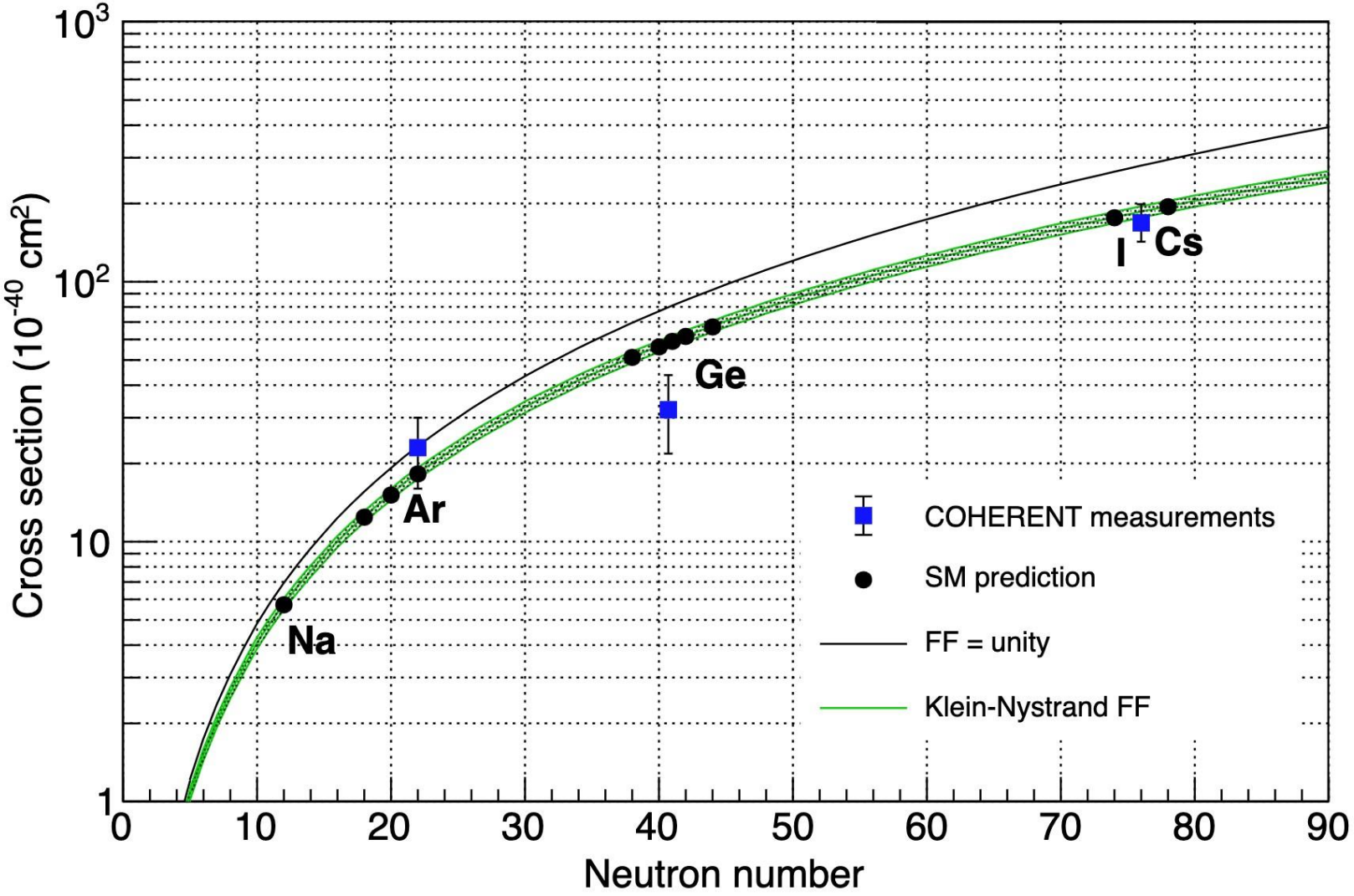








The COHERENT measurements are in agreement with the Standard Model within one sigma.



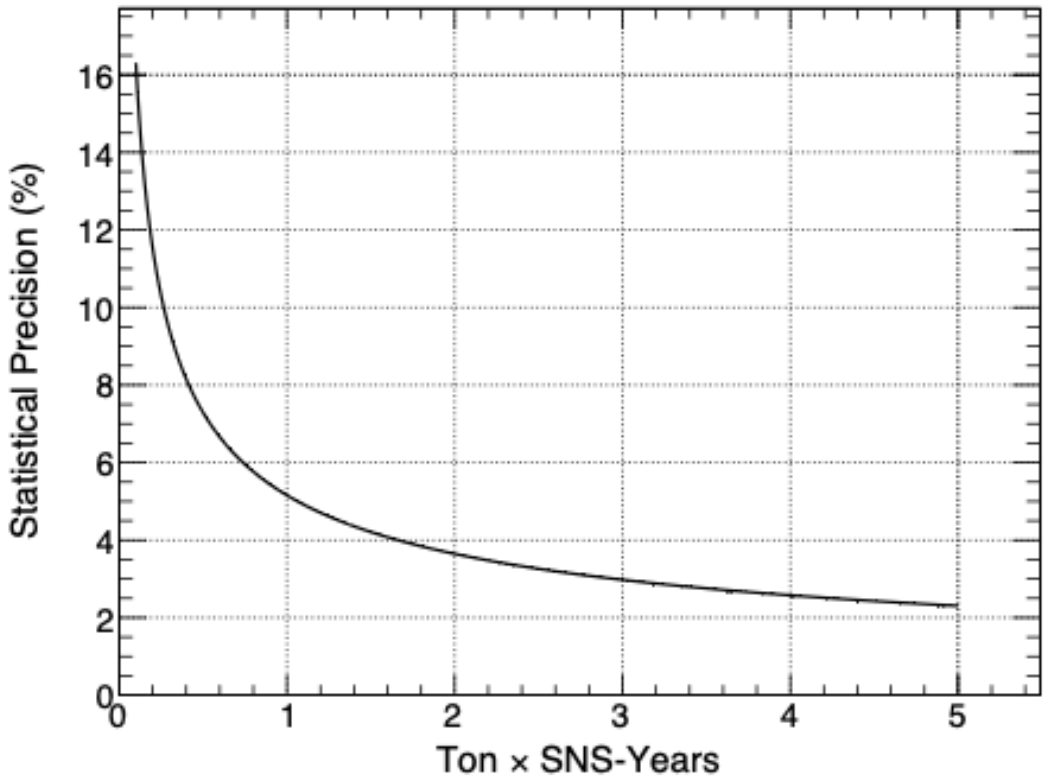
Proves the N^2 dependence

However, accuracy is limited so far

Dominant source of uncertainty is neutrino flux uncertainty

Heavy water detector has been deployed to reduce systematic uncertainty of the SNS neutrino flux.

JINST 16 P08048 (2021)

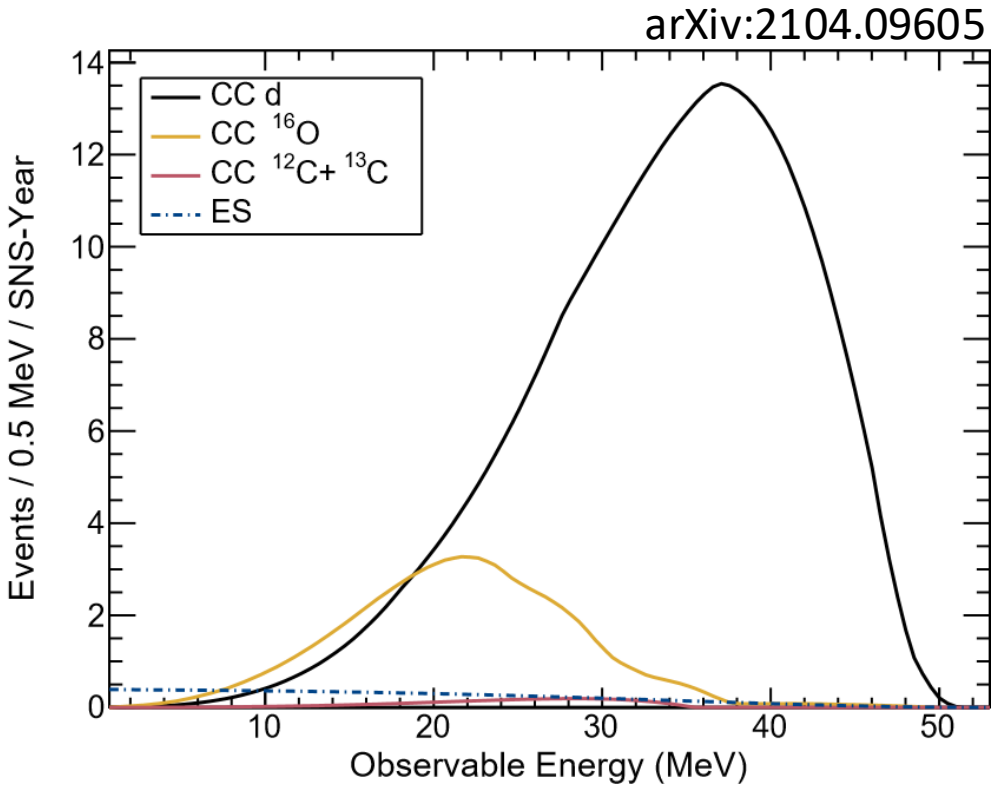


$\nu_e + d \rightarrow p + p + e^-$

Reduce uncertainty from 10% to 2-3%

D_2O volume with H_2O tail catcher, Pb shielding, and muon veto

The second module for measuring charged-current interaction in oxygen is being commissioned.



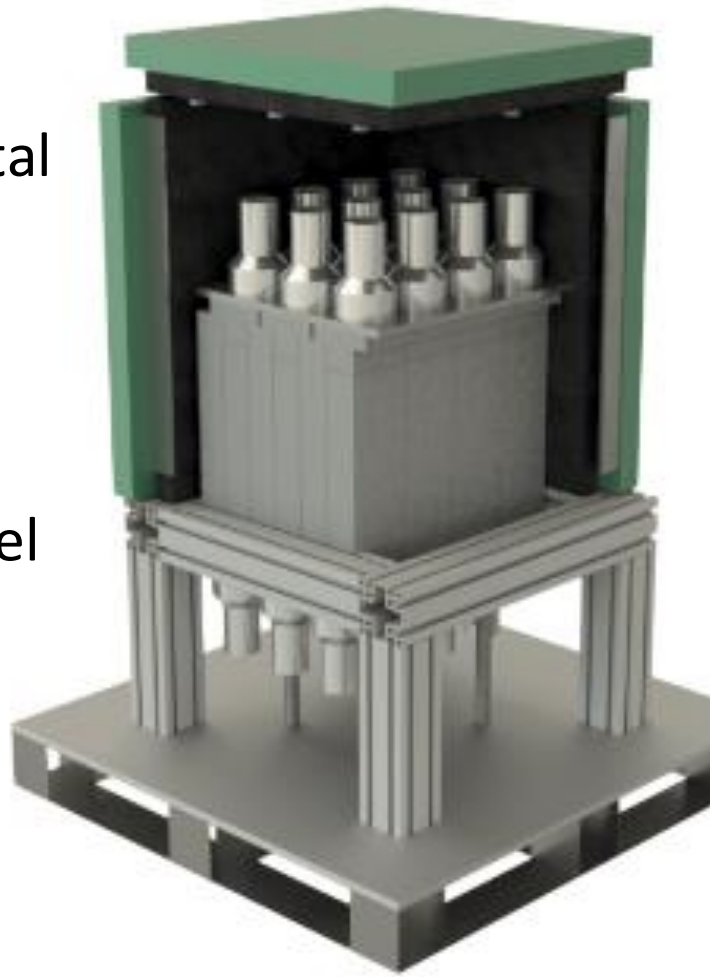
- Measure charged-current ν_e+^{16}O cross-section at SN energies
- Study background events

$\nu_e + {}^{16}O \rightarrow e^- + {}^{16}F^*$

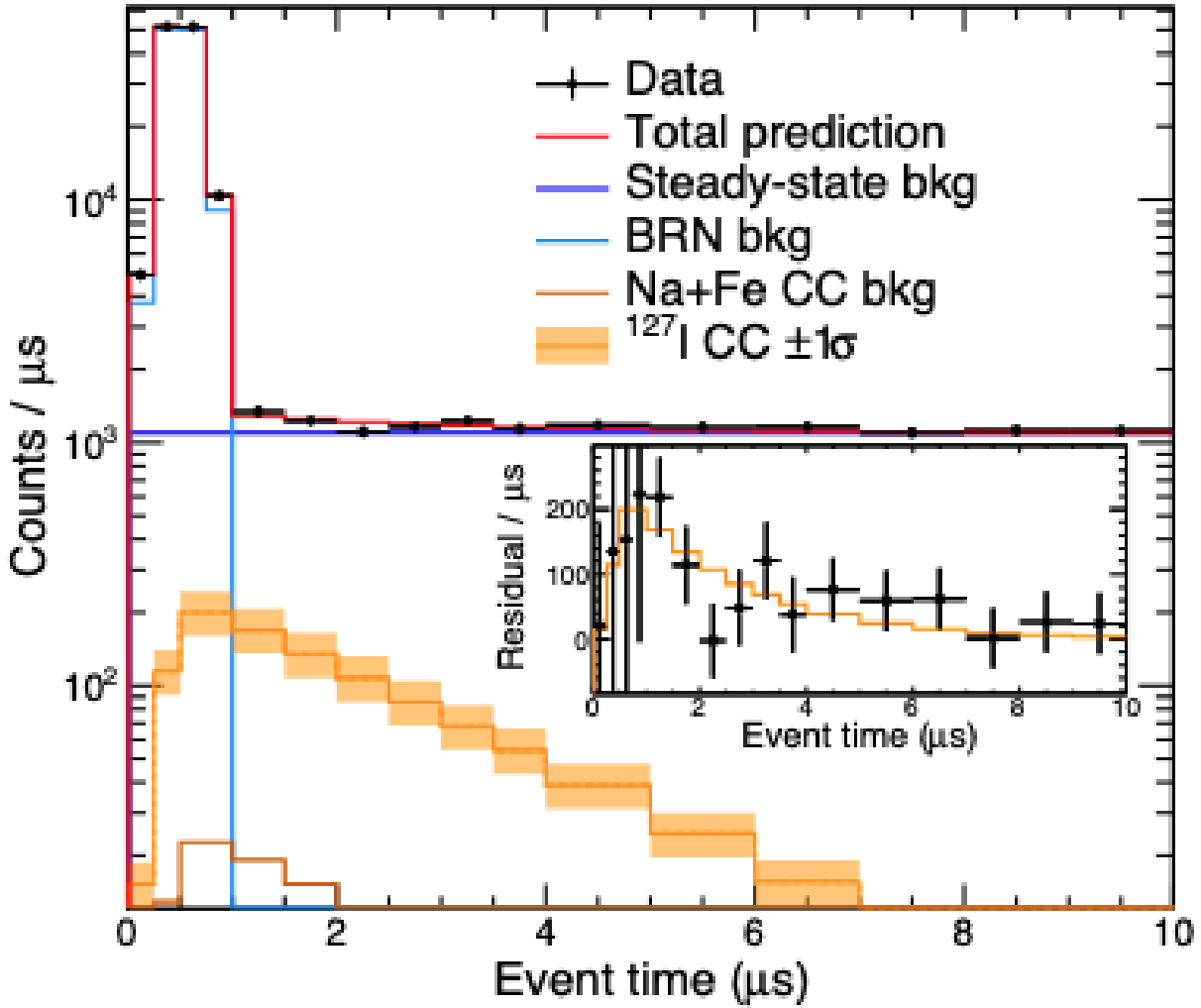
H_2O volume with H_2O tail catcher, Pb shielding, and muon veto

The COHERENT NaIvE detector measured the electron-neutrino charged-current cross section on ^{127}I.

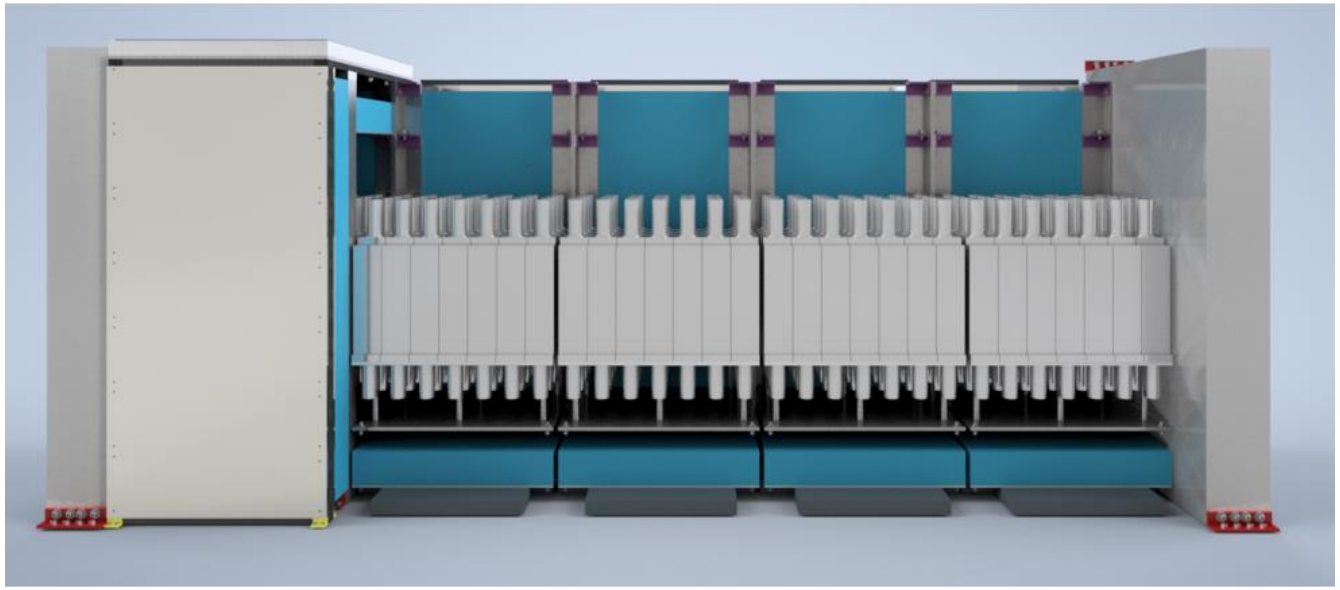
- 24 NaI[Tl] scintillator crystal 185 kg
- Steel shielding
- Muon veto panel



PRL 131 221801 (2023)



A tonne-scale sodium iodide detector is being installed to measure CEvNS on sodium.

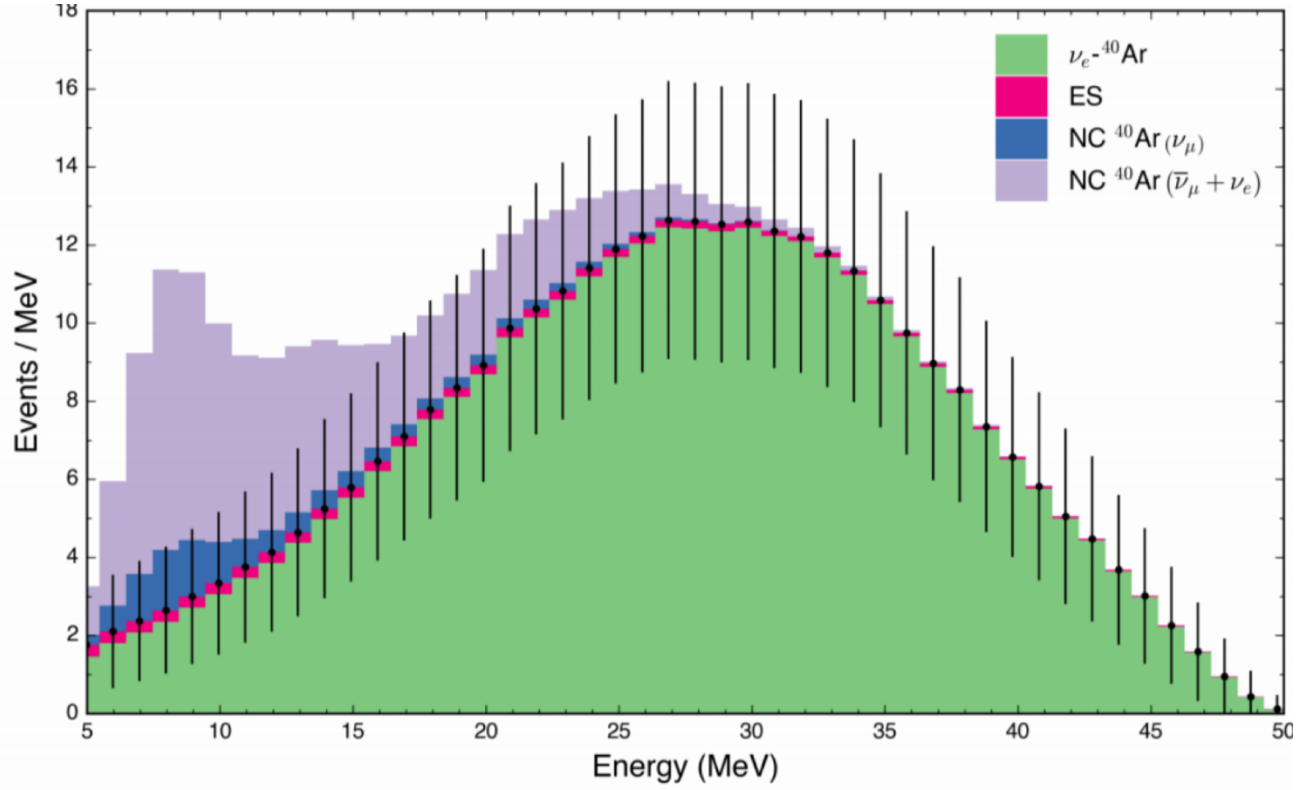


Measure CEvNS on ^{23}Na and CC on ^{127}I
Three modules installed and taking data
Analysis underway

NaIvETe (2.4 t NaI)
Two more modules will be deployed soon

COH-Ar-750 with 480 kg fiducial volume will replace CENNS-10 (24 kg) detector for precision measurements.

arXiv:2204.04575



~5000 CEvNS per SNS-year

~500 inelastics per SNS-year

Commissioning at ORNL

Cryogenic CsI detector will significantly improve the CEvNS measurement in CsI.

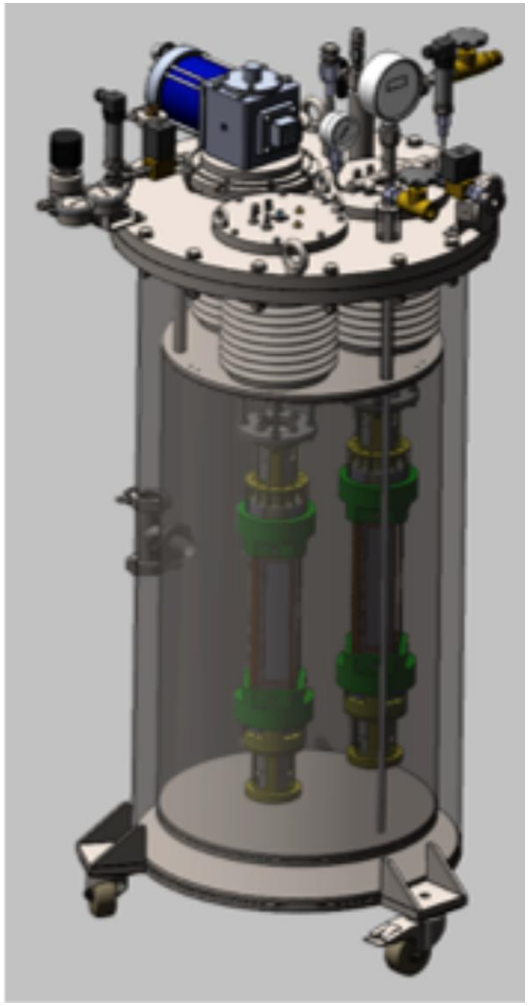
- Lower threshold
- High light yield
- Good timing resolution

Shielding

- 10cm HDPE
- 5cm Lead
- Steel frame

Will also study

- Neutrino nonstandard interaction
- Accelerator produced dark matter



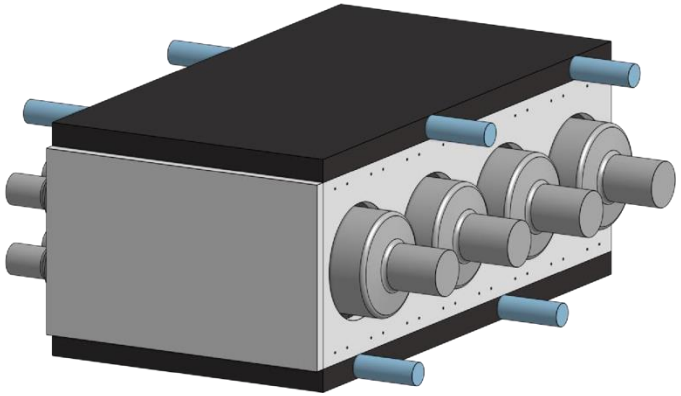
6.6 kg Cryo-CsI

Detectors have been deployed and are being developed to study inelastic interactions.

NuThor

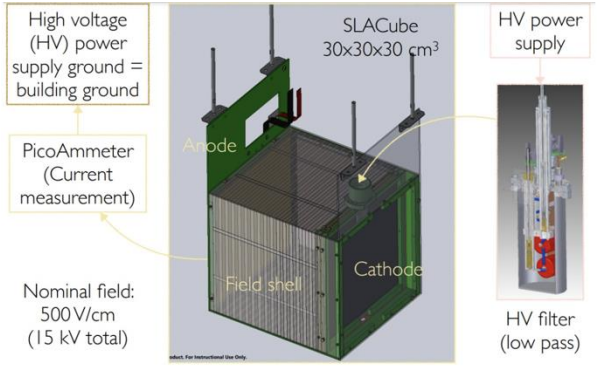
Study neutrino-induced fission of Th (52 kg)
Analysis in progress

Lead Glass



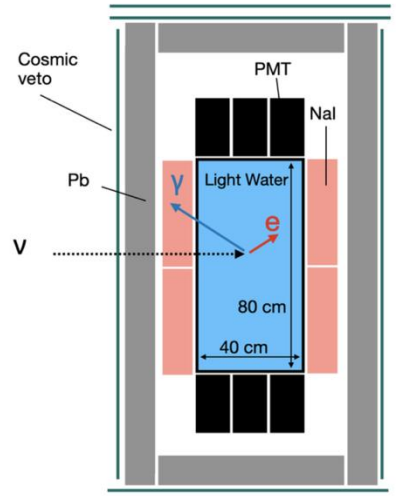
Study neutrino interaction on lead

Lar TPC



Proposal:
250 kg LAr TPC for DUNE like CC detection

H_2O



100 L water to measure ν_e-O CC

Summary

- **CEvNS:**
  - Neutrino interaction with the entire nucleus, predicted in 1973
  - Higher interaction probability at low energies but difficult to detect due to tiny nuclear recoil.
- **COHERENT Experimental Milestones:**
  - First CEvNS detection in 2017 (CsI[Na]), followed by Ar (2020) and Ge (2024) using beam neutrinos at SNS.
  - All measurements are in agreement with the Standard Model.
  - Inelastic cross-section measurement on ^{127}I.
- **Advancements & Future Prospects:**
  - COHERENT expanding detector network and collecting more data at SNS for higher precision CEvNS and inelastic measurements
  - Neutrino nonstandard interaction and dark matter searches

Thank you