COHERENT At The Spallation Neutron Source

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Coherent elastic neutrino-nucleus scattering (CEvNS)

\[
\frac{d\sigma}{d\Omega} = \frac{G^2}{4\pi^2} k^2 (1+\cos\theta) \left( N - \left(1 - 4\sin^2\theta_{\omega}\right) Z \right)^2 \frac{F^2(Q^2)}{4}
\]


- Nuclear recoil from Z exchange is coherent for all nucleons
- Well accepted but never directly measured
- Flavor blind
- Enhanced cross section
- Important background for future DM experiments
- Proportional to \(N^2\)
CEvNS by COHERENT

“The COHERENT collaboration aims to measure CEvNS (Coherent Elastic Neutrino-Nucleus Scattering) using the high-quality pion-decay-at-rest neutrino source at the Spallation Neutron Source”

Why look for CEvNS?

• Large $\sigma$ in supernova processes
• Excellent test of Standard Model calculations
• Possible applications in reactor monitoring

Detectors used by COHERENT for background assessment

COHERENT.phy.duke.edu
CEvNS detection

It is very difficult to observe....

- Intense neutrino source of appropriate energy needed
- Detection signal of order 10keV nuclear recoil

\[ E_{\text{MAX}, \text{recoil}} = \frac{2E^2}{M} \]

Recoil energy in Ge for a 30 MeV neutrino

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CEvNS as WIMP background

But....
Dark matter detectors have been developed with order 1keV sensitivity! We can measure CEvNS!
“SNS is a one-of-a-kind research facility that provides the most intense pulsed neutron beams in the world”

neutrons.ornl.gov/sns

CEvNS at the SNS

A stopped pion neutrino source

\[ \pi^+ \rightarrow \mu^+ + \nu_\mu \]
\[ \mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e \]

- Lots of FREE neutrinos
- \(-1\)GeV POT pulse at 60 Hz with 380 ns FWHM
- Spectrum comparable to that of SN

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CEvNS at the SNS

- Timing structure of the SNS is a huge advantage in background rejection
- Neutrino flavors have prompt/delayed time structure

\[ \pi^+ \rightarrow \mu^+ + \nu_\mu \]
\[ \mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e \]

\[ \frac{G^2 N^2}{4\pi} E^2 \]

REMEMBER
Cross section and nuclear recoil energy increase with neutrino energy
Detector siting at the SNS

Reference design siting for deployment in SNS basement (measured neutron backgrounds low)
Other Physics – Neutrino Induced Neutrons (NINs)

- Important in R process nucleosynthesis and SN detection
- Pb and Fe are used extensively in shielding
- A substantial flux of NINs can be contamination (or a chance for measurement) in a CEvNS experiment
- Currently ongoing at the SNS

Model dependence on $\nu$-Fe cross-section

What is COHERENT doing

- Search for NINs in CsI and ν cubes
- Up selection of 3 detector technologies (CsI, Ge, Lxe) and continued development
- Continuing background measurement efforts
- Data is coming in

CsI and ν cubes deployed at the SNS
Summary

- CEvNS has never been measured directly.
- Detector technology has improved to the point that this measurement is now possible.
- The physics is important for many applications.
- Along the way, other new measurements can be made.
- The results will come in on short (few year) time scales.
Neutron background measurements

- Have been ongoing at SNS
- Several potential experiment sites have been identified
- SNS basement has substantial reduction in neutron flux
Comparison of stopped pion neutrino sources