Abstract

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) was detected by the COHERENT experiment at the Spallation Neutron Source.\(^1\)

\[
\frac{d\sigma}{d\cos\theta} = \frac{G_F}{\pi} Q_N^2 E^2 (1 + \cos\theta)
\]

\[Q_N = Z(4 \sin^2 \theta_W - 1) + N\]

We study the possibility of probing new physics at a reactor source. Bolometers at a reactor source probe lower energy portions of the CEvNS spectrum:

![Graph showing Neutrino rate vs time for the Double Chooz experiment.](image)

This enables stronger bounds on:
- Neutrino Magnetic Moment
- Massive Scalar Mediator Model
- Massive Vector Mediator Model
- Non-Standard Interactions

Methods

Current and planned CEvNS Projects:
- MINER: 10 kg Si+Ge at a 1 MW research reactor. Projected threshold 200 eV.
- NUCLEUS: Several grams CaWO\(_4\) + Al2O3, 10 eV energy threshold and strong external background rejection with surrounding vetos.
- Ricochet: Several kg of Zn, Ge, Si, or Os, with a 50 eV threshold.

Double Chooz Reactor:
- Two cores, 8.5 GW power combined
- Two possible sites, 400 m (Near Site) and 80 m (Very Near Site)
- Both cores on 60% of the time, one core 40%

![Graph showing Neutrino rate vs time for the Double Chooz experiment.](image)

Backgrounds:
- Compton: 100 eVts/kg/day in Ge
- Neutrons: 10 times larger at very near site
- Other backgrounds are negligible

![Graph showing Measurement uncertainty vs Target mass.](image)

Neutrino Magnetic Moment

In minimal extensions of the Standard Model, a Dirac neutrino can obtain a magnetic moment as high as \(\mu_N = 10^{-12} \mu_B\), while a Majorana Neutrino could allow \(\mu_N = 10^{-15} \mu_B\) or higher.

A neutrino magnetic moment adds a term to CEvNS:

\[
\frac{d\sigma_{\text{map}}}{d(E_N)} = \frac{\pi \alpha \mu_N^2 Z^2}{m_n^2} \left(1 - \frac{1}{E_N - E_R + 4E_v^*} \right)^2 (E_E)
\]

![Graph showing Measurements and projections for the Double Chooz experiment.](image)

Bounds become competitive with terrestrial bounds after several years runtime

Massive Scalar Mediator

Adds a term to CEvNS:

\[
\frac{d\sigma_{\phi}}{d(E_N)} = \frac{g_N^2 Q_{2\phi}^2 E_N m_{\phi}^2}{4\pi} \left(\frac{E_N}{E_N + m_{\phi}^2}\right)^2 (E_E)
\]

\[Q_{\phi} = (15.1Z + 14N)g_q
\]

![Graph showing Measurements and projections for the Double Chooz experiment.](image)

Massive Vector Mediator

Interferes with SM CEvNS:

\[Q_W \to Q_{SM+NP} = Q_W - \frac{\sqrt{2}}{g_F} Q_Z, Q_{2\phi}
\]

A monolithic target allows for fully destructive interference, giving a stronger bound.

For both the scalar and vector mediator, a low mediator mass strongly deforms the spectrum at low energies, allowing a bolometer at a reactor to place strong bounds on mediator strength.

![Graph showing Measurements and projections for the Double Chooz experiment.](image)

References:

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