Measuring and Understanding Coherent Neutrino Scattering

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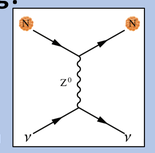
RICOCHET
A Coherent Neutrino Scattering Program

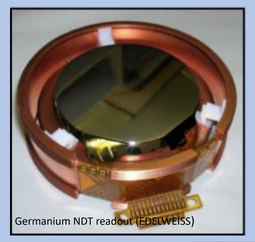
Background

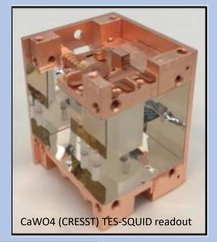
What is coherent neutrino scattering?

- Neutrino enters and collides with a nucleus
- Moderated by the weak force with the Z boson
- Happens for all flavors of neutrinos
- Experiments measure the recoiling nucleus
- Last detected Standard Model interaction: Summer 2017 [1]



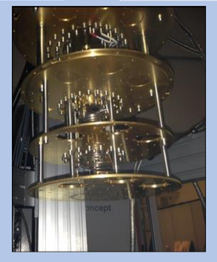
What does the detector look like?


Germanium NDT readout (EDELWEISS)


CaWO4 (CRESST) TES-SQUID readout


Zn TES-SQUID readout

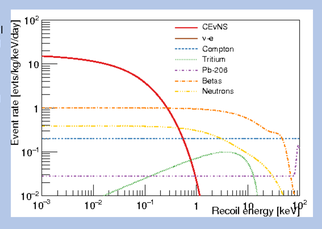

Dilution Refrigerator called Despereaux, commissioned at M.I.T.



- Phonons from scattering detected in cryogenic crystals in dilution refrigerator
- Operate 10 kg, at 15 mK with threshold of 100 eV

- CHOOZ near detector site near 2 reactors
- 8 x 10^10 **ν** /cm^2/s
- No reactor neutron backgrounds
- Infrastructure in place for experiments
- Schedule aims for 2019

The differential signal rate and projected background rates versus detector recoil energy for operation at CHOOZ assuming the EDELWEISS radiative backgrounds [2]



- Next to a nuclear reactor
- Proximity allows a high flux of neutrinos to come through
- Creates early universe like conditions
- Could cause a high neutron background

Importance of Simulations

- Have an understanding of what kind of problems we will run into
- Can work to understand signal before everything is implemented
- Understand background that comes from the reactor
- Try to solve problems before they arise

Abstract

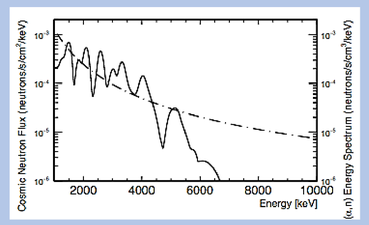
Ricochet is a experiment searching for coherent neutrino scattering through novel detector development. The purpose is to detect and characterize coherent neutrino scattering from a nuclear reactor source. Coherent neutrino scattering has applications for research in many fields, such as supernova physics, sterile neutrinos, nuclear form factors at low energy and nuclear proliferation monitoring. Coherent neutrino scattering has only just been measured for the first time, and continued measurement can bring along a greater understanding of the physics of neutrinos.

Ricochet's Strengths

- Colliaboration on the international level gives experience from a wide range of experiments and specialties
- Reduction of backgrounds (Goal: 1.5 events/kg/day)
- Multiple targets/technologies
- CHOOZ site has overburden and water tank shielding, and no reactor operation correlated neutrons
- Pushing detector technology to low thresholds (<100 eV) nuclear recoil, such low thresholds can help with dark matter detection efforts

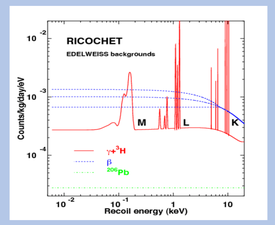
Backgrounds

External



- Primary concern is cosmogenic neutrons
- Normalized to the Double CHOOZ measure of ~3.4 per day
- Upper limit of 1 per day, but with additional borated poly shielding, we expect this to come < .1 per day

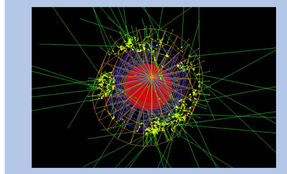
Internal



- EDELWEISS-III backgrounds are applied to Ricochet
- Red: gammas with cosmogenic activation lines, tritium beta decay
- Blue: 210Pb betas (with uncertainty in extrapolation to low energies)
- Green: 206Pb nuclear recoils

What I do

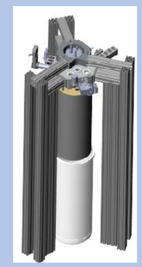
ChoozSimulation

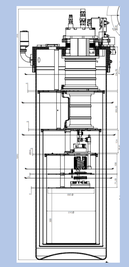


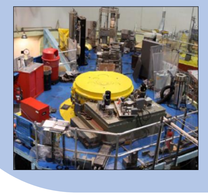
- Detector has yet to be built in its final state
- ChoozSimulation is a program written by Alex Leder (M.I.T. graduate student)
- Simulated the detector with Geant4 particle physics package
- I installed ChoozSimulation on the UW server, including its required dependencies

Refrigerator Geometry

- Changing ADR (Adiabatic Demagnetization Refrigerator) to Dilution Refrigerator "Despereaux"
- Rewriting the geometry, including a visualization tool that we hope to get working on our servers
- Despereaux is currently at M.I.T., undergoing hardware updates and fixes







What is Next?

- Hardware updates
  - Northwestern designing and fabricating TES chips
  - Zn crystals cryogenically tested at M.I.T.
  - Zn crystals cryogenically tested in France
  - Bringing Despereaux into commission
- Testing at M.I.T.
- Moving detector to France and be in operation in 2019

Citations

[1] Akimov, D., et al. "Observation of Coherent Elastic Neutrino-Nucleus Scattering." *Science*, 3 Aug. 2017, doi:10.1126/science.aao0990.

Anderson, A.J., et al. " Coherent Neutrino Scattering with Cryogenic Semiconductor Detectors" 2012, conference: C12-03-03.

[2] Billard, J., et al. "Coherent Neutrino Scattering with Low Temperature Bolometers at Chooz Reactor Complex." *IOPScience,* 21 Aug. 2017, doi: 10.1088/1361-6471/aa83d0.

Leder, A., et al. " Unfolding Neutron Spectrum with Markov Chain Monte Carlo at MIT Research Reactor with He-3 Neutral Current Detectors." *Jinst,* 2 Oct. 2017, doi: FERMILAB-PUB-17-441-AE.