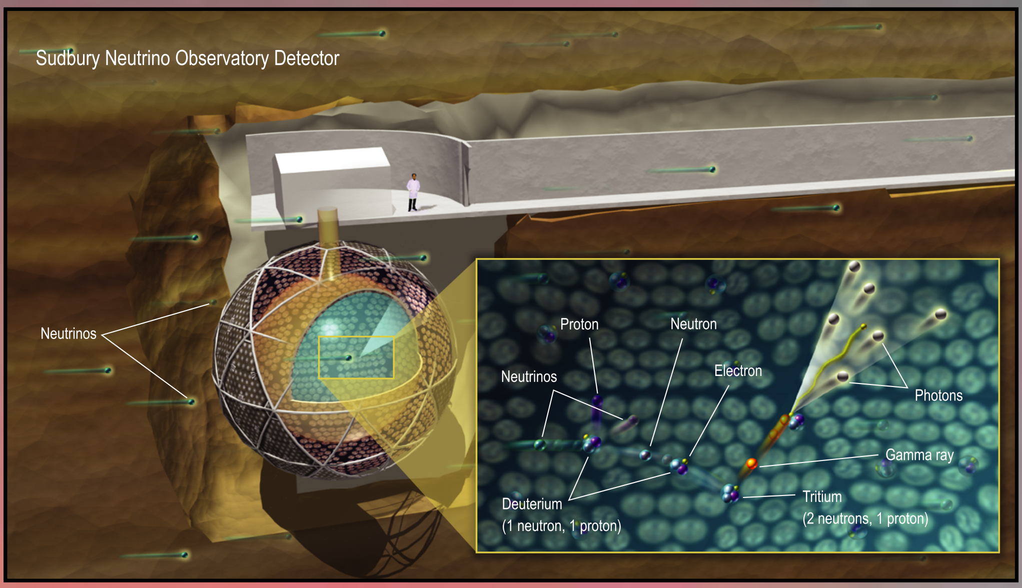
PHYSICS

Sudbury Neutrino Observatory

Taking Physics Beyond the Standard Model

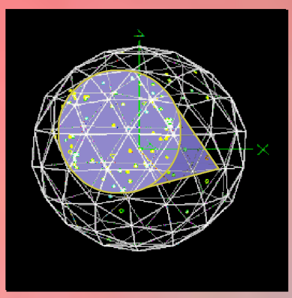
The search for evidence of neutrino mass and the study of neutrino interactions with nuclei have evoked continuous experimental efforts by scientists from Los Alamos for over 50 years. Determining whether neutrinos have mass is an issue of great importance to particle physics, astrophysics, and cosmology. We are playing a leading role in the Sudbury Neutrino Observatory (SNO)—a terrestrial detector located 6,800 ft underground in an active nickel mine in Ontario, Canada—to understand why solar neutrino fluxes measured in terrestrial detectors fall significantly short of standard solar model predictions. Both accelerator- and non-accelerator-driven neutrino experiments provide important tests that may challenge the Standard Model of electro-weak interactions while searching for neutrino oscillations.

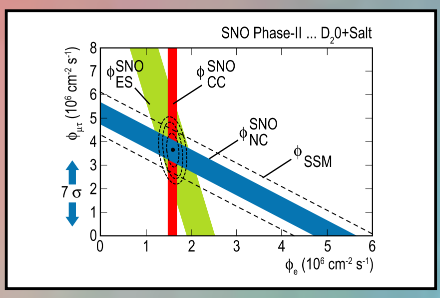


At the heart of SNO is 1,000 metric tons of ultra-pure D_2O contained in a 12-m-diameter acrylic vessel. In a neutral current interaction (in the inset), a neutrino entering the detector interacts with a deuterium nucleus, breaking up the deuterium into a proton and a neutron. The neutron is captured by another deuterium nucleus, producing a tritium atom that decays, releasing a gamma ray, which then collides with an electron. Cerenkov light is emitted and detected by the 9,438 eight-inch photomultiplier tubes (PMTs) that line the SNO vessel.

Recent Results and Implications

SNO is capable of measuring three interactions that have different sensitivities to electron and muon/tau neutrinos (SNO cannot distinguish between muon and tau neutrinos). This allows us to search for the oscillation of electron neutrinos from the Sun into muon/tau neutrinos. As is shown, the result of combining the three reactions is that two-thirds of the electron neutrinos from the Sun arrive at Earth as muon or tau neutrinos. The effect observed by SNO is at the 7-σ level and thus provides compelling evidence for neutrino oscillations, which in turns shows that neutrinos have a finite mass. The discovery of neutrino mass is the first firm evidence for new physics beyond the standard electroweak model that is generically predicted by unified field theories.

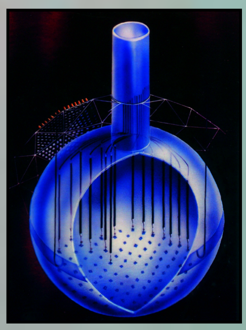


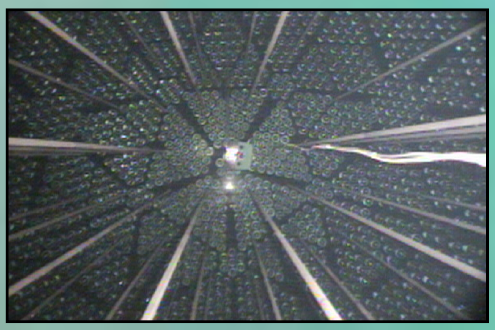


The image on the left is a typical neutrino event as observed in the SNO detector. The Cerenkov ring of light emitted in the neutrino interaction is visible. The image on the right shows the ratio of electron neutrinos and muon/tau neutrinos as plotted for the Neutral Current (NC), Charged Current (CC), and Electron Scattering (ES) reactions. The intersection of the three reactions (shown by the black dot) determines the flux of electron and muon/tau neutrinos. The analysis of NC data has been a focus of the LANL effort.

Installation of Neutral Current Detectors

The next phase of SNO is the installation of ^{3}He proportional counters that directly detect the neutron produced in the NC reaction. These NC Detectors (NCDs) allow a complete separation of the CC and ES Cerenkov events from the NC events. The NCDs will provide a more accurate determination of the flux of electron and muon/tau neutrinos. The separation of NC events with the NCDs will also provide a much better probe for understanding the dynamics of a supernova explosion in our galaxy. The NCDs were conceived and developed at LANL using LDRD funds.





The schematic on the left shows the full array of NCDs installed in the SNO detector. The image on the right shows the actual NCDs being installed in the SNO vessel.

SNO is a collaborative effort involving the following institutes:

Brookhaven National Laboratory
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
University of Pennsylvania
University of Texas
University of Washington
Carleton University, CRPP
Laurentian University
Queen's University
TRIUMF
University of British Columbia
Rutherford-Appleton Laboratory
University of Guelph
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