# Supernova Detection in SNO+

Kevin Labe and Matthew Strait for the SNO+ Collaboration
Dept. of Physics and Enrico Fermi Institute, University of Chicago, Chicago, IL

## SNO+ Detector

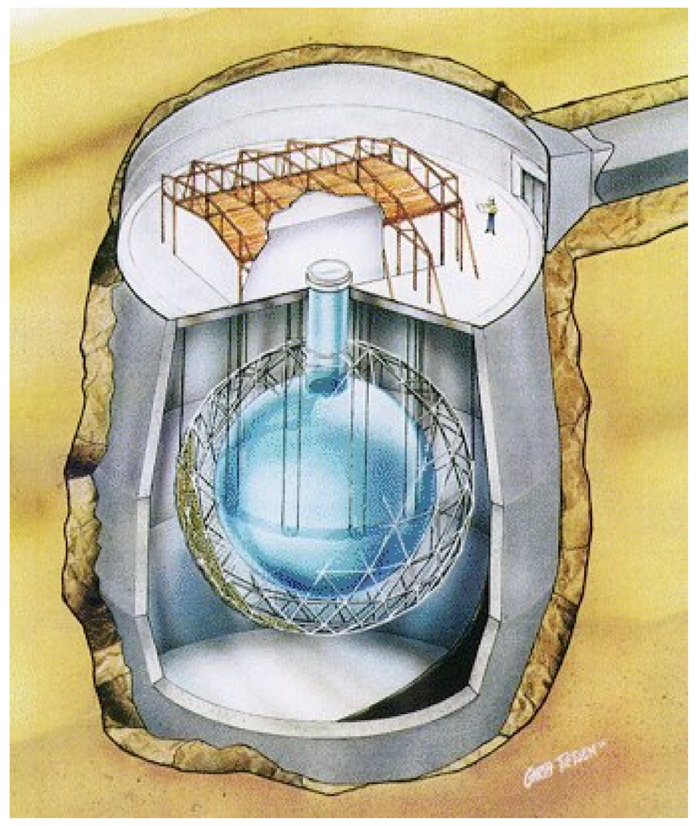
SNO+ is a neutrino experiment located in Vale's Creighton Mine, in Sudbury, Ontario, at a depth of 6000 m.w.e.

The detector consists of a spherical acrylic vessel (AV) of radius 6 m, surrounded by ~ 9500 PMTs on a geodesic sphere of radius 8.3 m. Both AV and PMTs are suspended in a cavern filled with high purity water.

Stages of the experiment:

- Water Fill - measure some external backgrounds; nucleon decay search
- Scintillator Fill - AV filled with linear alkylbenzene (LAB)
- Tellurium Loading - Neutrinoless double beta decay candidate

We are currently filling the detector with water; data taking is expected to begin in Autumn 2014.



Artist's representation of the SNO Detector

The primary physics goal of SNO+ will initially be the search for neutrinoless double beta decay, but we also plan research programs focusing on nucleon decay, supernova detection, and geo-, reactor-, and solar- neutrino physics.

## Supernova Alert, Level 2 Filter, Data Storage

- Raw data arrives from DAQ → Full Data Buffer
- Raw data arrives from DAQ → Event over threshold? → yes → Reduced Data File → Grid Storage
- Reduced Data File → Is there a burst? → yes → Burst File → Instrumental Noise Removal; Signal Analysis; Alarm Sent

Galactic supernovae will create bursts of events in our detector, 10 to 30 seconds in length. Detection of such bursts proceeds in several steps:

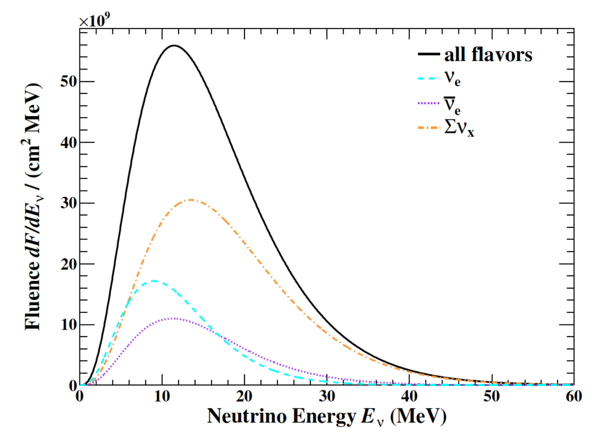
- Burst identification: elevated rate of large events
- Instrumental noise removal
- Analysis for consistency with supernova signal

We will be able to identify bursts within 30 seconds of their start, and expect to achieve latency of a few minutes after detailed analysis.

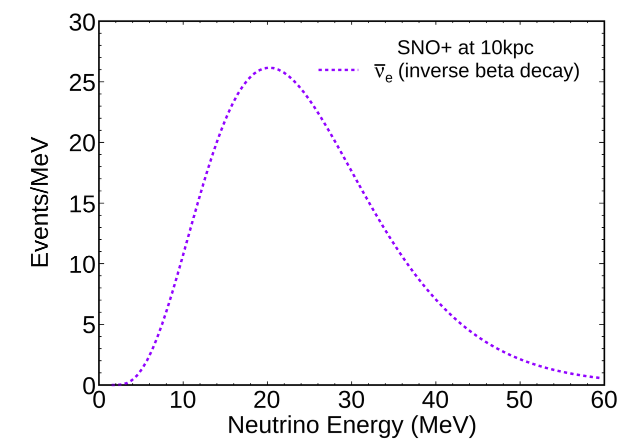
The detector will operate at a low threshold that will capture nearly all supernova events. We retain all these events in a week-long buffer, applying a level-2 software filter to produce a reduced dataset for non-supernova analysis. This same nearline software performs our search for supernova-like event bursts.

We plan to join the SNEWS network once we have demonstrated the efficacy of our system.

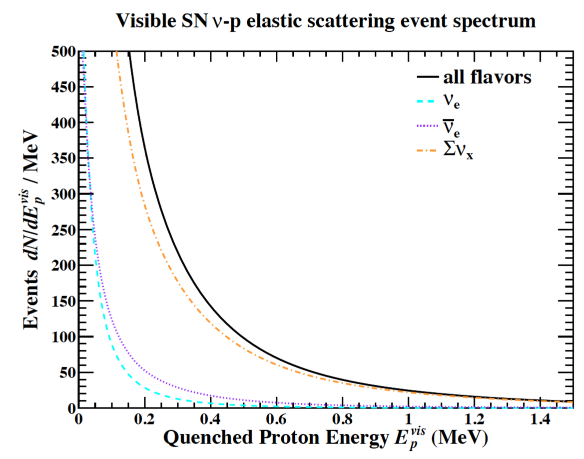
## Supernova Physics



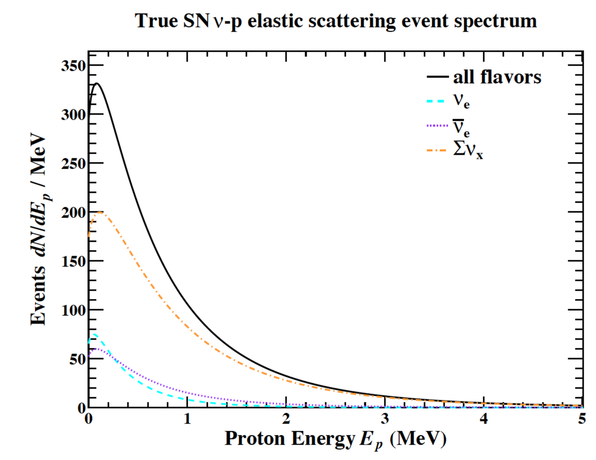

Modeled true neutrino spectrum




Inverse beta decay spectrum in SNO+




Visible proton scattering spectrum




Proton scattering spectrum in SNO+

- **Constraints on Supernova Physics**: Neutrinos provide a unique look into the core of supernovae. Observing supernova neutrinos allows us to distinguish between models of supernova dynamics. The time evolution of the luminosity and energy spectrum provides information about the explosion mechanism. Flavor data answers questions about the equipartition of energy among flavors and the neutrino energy hierarchy.
- **Shock Breakout**: The likelihood of observing this early peak in electromagnetic radiation would be significantly enhanced by an observation in neutrino detectors telling astronomers when and where to look.
- **Black Holes**: A sudden cutoff of the neutrino signal in time would signal the formation of a black hole. This would be a new direct confirmation that black holes exist, as well as providing an example of a star collapsing to one, which can be compared against stellar evolution models.
- **Neutrino Physics**: Observation of supernova neutrinos will provide information on the neutrino mass hierarchy, will probe the existence of sterile neutrinos, and will allow us to place a limit on the neutrino lifetime.

## Our Strengths

Scintillator allows detection of all neutrino flavors

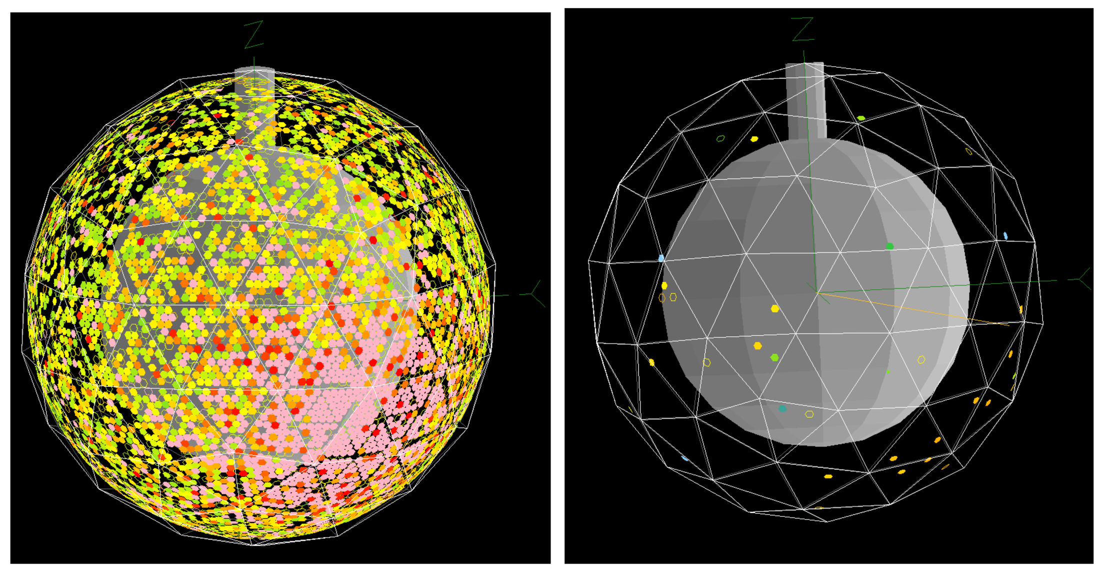
One of few large, deep detectors

## Signal

The SNO+ detector will be sensitive to supernovae once water fill is complete, but the proton recoil channel will become available only once the transition to scintillator phase begins. Because the IBD channel is unqiue to $\bar{\nu}_e$, we can disentangle the contributions to the signals from the electron and $\mu/\tau$ flavors. Expected signal in the detector for a 10 kpc Vogel & Beacom supernova (astro-ph/9811350):

| Event Type | Counts (Water Fill) | Counts (Scintillator Fill) | Flavor Sensitivity | Directional Information |
|---|---|---|---|---|
| Electron Scattering (water) | 45 | 28 | all | yes |
| Electron Scattering (LAB) | 0 | 14 | all | no |
| Proton Scattering | — | 510 | all | no |
| Inverse Beta Decay | 700 | 640 | $\bar{\nu}_e$ | slight |
| Nuclear Excitations | 100 | 87 | all | no |

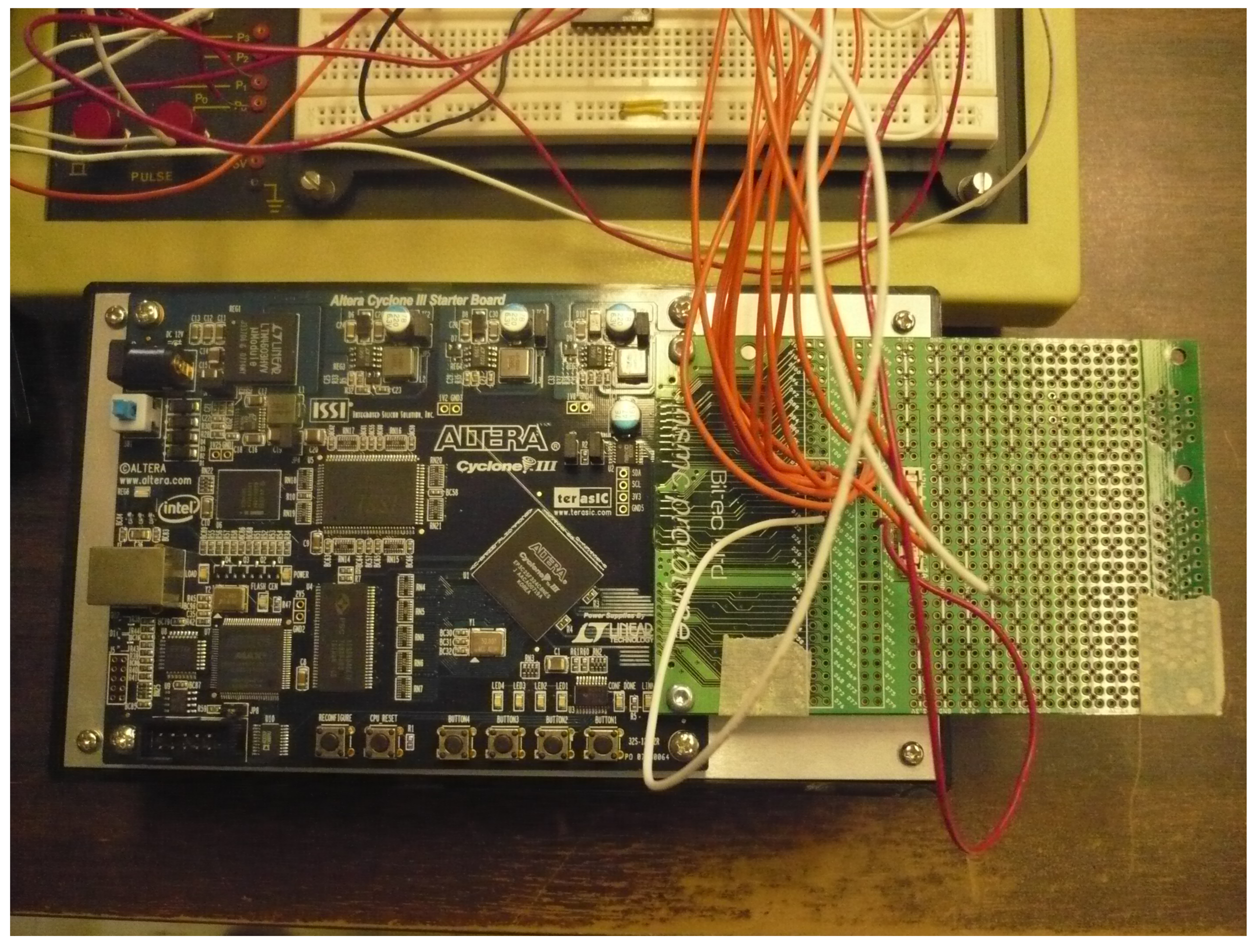
## Simulation



Simulated data in two of the supernova detection channels. Left: 25 MeV inverse beta decay event in the scintillation volume. Right: Proton recoil event at 300 keV. Color indicates PMT charge.

## Supernova Calibration Source

The Supernova Calibration Source is a laser diode. We will deploy it in the detector to produce events with any desired energy and timing spectrum. This will test the response of our detector, data acquisition, and burst identification systems under any model of interest under realistic high-rate conditions.



Work fabricating the supernova calibration source is ongoing.

## Acknowledgements

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