Status update and progress on the HALO supernova detector
Outline

- Philosophy and design
- Motivation
- Personnel
- One year ago
- Progress highlights
- Detailed status
- Future plans
- Outreach
- Conclusions
HALO - a Helium and Lead Observatory


Philosophy - to produce a
- Very low cost
- Low maintenance
- Low impact in terms of lab resources (space)
- Long-term, high livetime
dedicated supernova detector

“Helium” - because of the availability of the $^3$He neutron detectors from SNO +

“Lead” - because of high $\nu$-Pb cross-sections, low n-capture cross-sections, sensitivity to $\nu_e$ (dominantly) and $\nu_x$ complementing water Cerenkov and liquid scintillator detectors

HALO will use an available 76 tonnes of Pb
HALO-I - Design Overview

- **Lead Array**
  - 32 three meter long columns of annular Lead blocks
  - 76 tonnes total lead mass (864 blocks)
- **Neutron detectors**
  - Four 3 meter $^3$He detectors per column
  - 384 meters total length
- **Moderator**
  - HDPE tubing
- **Reflector**
  - 15 cm thick graphite blocks
- **Shielding**
  - 30 cm of water
High Z increases $\nu_e$ CC cross-sections relative to $\bar{\nu}_e$ CC and NC due to Coulomb enhancement of electron wavefunction overlap.

Neutron excess ($N > Z$) Pauli blocks $\bar{\nu}_e + p \rightarrow e^+ + n$ further suppressing the $\bar{\nu}_e$ CC channel.

Results in flavour sensitivity complimentary to water Cerenkov and liquid scintillator detectors.
In 76 tonnes of lead for a SN @ 10kpc\(^{\dagger}\),

- Assuming FD distribution with T=8 MeV for \(\nu_\mu\)'s, \(\nu_\tau\)'s.
- 65 neutrons through \(\nu_e\) charged current channels
  - 29 single neutrons
  - 18 double neutrons (36 total)
- 20 neutrons through \(\nu_x\) neutral current channels
  - 8 single neutrons
  - 6 double neutrons (12 total)

\(\approx 85\) neutrons liberated; ie. \(~1.1\) n/tonne of Pb


Cristina Volpe and Daavid Vaananen are currently investigating HALO and HALO-II sensitivity to \(\nu-\nu\) collective effects in supernovae

Neutron detection efficiencies of 50% have been obtained in MC studies optimizing the detector geometry, the mass and location of neutron moderator, and enveloping the detector in a neutron reflector.
HALO - Collaboration List

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Personnel evolution

- Taylor Shantz defended her MSc thesis on “Design and Construction of the Helium and Lead Observatory for Supernova Neutrinos” at Laurentian in August 2010
- Alicja Kielbik is starting her MSc thesis at Laurentian on a HALO topic in September
- 2010 summer / Co-op students working on HALO were:
  - Kurt Nicholson – Guelph U.
  - Alicja Kielbik – Laurentian U.
  - Axel Boeltzig – TU Dresden
  - Ben Bellis – Duke U.
  - Victor Buza – U. Minnesota Duluth
  - Brian Redden – Armstrong Atlantic State U.
  - “T.J.” – U. North Carolina
And a big thanks to...

- Mike Schumaker
- Stan Yen
- Christine Kraus
- Alicja Kielbik
- Taylor Shantz
- Kurt Nicholson
- Brian Morissette and the SNOLAB construction team

For keeping up the momentum on HALO during my sabbatical!
Painted Pb blocks on surface ready for transport underground

Analysis of creep in lead studies forced decision to reinforce at least the bottom four layers of Pb blocks

Design of iron reinforcement ring in place

Starting measurements in creep test set up with Pb block and reinforcement ring

Gantry crane for lead array assembly delivered

Developing physics analysis ideas

Simulations continue...
Progress highlights

- Creep tests terminated → iron rings in 5 layers
- Seismic study → implications for Pb array
- NSERC grant renewed / doubled
- Fabrication of steel support structure
- Fabrication of iron reinforcing rings
- Pb array construction
- NCD storage rack design and procurement
- Baseline survey defined
- In-situ creep monitoring defined
- Pre-amp / cable testing underway
- Internal website up with DocDB (114 documents and counting), svn and trac for MC development
- Public website up – see halo.snolab.ca
One page status
Detailed status - Lead Array
New end-caps designed at U. Washington
- O-ring seals against corrosive atmosphere
- New gold HV contact scheme (SHV to NCD)
Still trying to locate NCD un-deployment tube cutter
NCDs still stored in old SNO control room

³He proportional counters in storage
Detailed status – Moderator

- Optimization simulations terminated
- Procurement is awaiting review of a final moderator design report
Detailed status – Reflector

- Explicitly not funded by NSERC but they encourage us to find alternative sources of funding
- Preliminary contact made with Kurchatov Institute

graphite blocks
Detailed status – Shielding

- PP shielding installed under steel support structure
- Re-using PICASSO shielding boxes, balance procured
- T2K donated PS beads for filling voids
Have been studying electronic noise as a function of:

- Singly versus doubly shielded signal cable
- Long versus short cables (pre-amps inside or outside of shielding)
- Single $^3$He detector versus two detectors T’d
- Version of shaper cards and pre-amp designs

Studies with all but the final pre-amp design terminated

Report and cabling decisions expected soon

TRIUMF will fabricate the cables reusing where possible existing NCD cabling
New robust “charge” pre-amp design
Have 10 in hand for NCD qualification test stand
U. Washington ready to provide needed number of channels (new production above and beyond existing SNO pre-amps)
Stand for 8 NCDs designed – Stan Yen and Taylor Shantz

Being fabricated at TRIUMF

Expected next week

Configured to test 4 NCDs at a time with a neutron source and then all 8 overnight without a source

Lacks cabling for 8 channels at moment but otherwise have enough channels of new pre-amps and electronics

$^{252}\text{Cf}$ neutron source before SNOLAB source committee
- Rack design complete and approved – Jack Fowler, Duke U.
- 1st rack being assembled in HALO stub
- Cost sharing HALO / SNOLAB
Supported by U. North Carolina
- Using ORCA
- UNC providing new computer and VME single board computer
- HALO members ORCA trained
Detailed status - Electronics

- Supported by U. Washington and DigiPen Institute of Technology
- Presently using SNO NCD phase electronics for “cable” tests (1 channel)
- Will expand to 8 channels for NCD Qualification tests
- Some decisions still to make concerning digitization of the NCD signals and how much of the NCD electronics will be re-used
- Some concerns over corrosion and reliability of electronics that has been underground since ~2003
Detailed status - Calibration System

- Calibration tube system installed into Pb array during assembly
- Have sourced an existing $^{252}$Cf n source of appropriate intensity
- Source being reviewed by SNOLAB source committee
- Source delivery system and interface with front shielding still to be worked out
Pb array is initially certified for a period of 10 years due to creep concerns.

Plans for a baseline survey to establish year 0 state of the Pb array are developed.

Ready to proceed with survey in next weeks.

Idea is to repeat in 10 years time for re-certification.
Detailed status - Long-term creep monitoring

- 16 Pb blocks in various positions will be instrumented to be periodically monitored for creep
- Most hardware has been purchased some machine shop work to do
- To be installed and commissioned before shielding installed
Detailed status - Monte Carlo simulations

- Most work to date has been with GEANT 4.6
- Transition to GEANT 4.9 accomplished
- Acceptance document out for review
- Work done on improving accuracy of geometry
  - Steel support structure
  - Iron reinforcing rings
  - Detailed water box description
  - HALO drift added to world volume
- Integration of SNGEN and GENIE into simulation package
- Jeff Secrest (AASU) coordinating MC development
Summary of contributions to HALO (outside of HALO grant)

- Steel support structure – SNOLAB
- Iron reinforcing rings – SNOLAB
- NCD end-cap design and fabrication – U. Washington
- PICASSO donated ~350 previous water shielding boxes
- T2K donated 740 kg PS beads
- Cable fabrication – TRIUMF
- Pre-amp design and fabrication – U. Washington
- NCD Qualification Test Stand fabrication – TRIUMF
- NCD storage rack design – Duke U.
- NCD storage rack – partially SNOLAB
- DAQ computer and VME SBC – U. North Carolina

25/8/2010
Future Plans

- Shielding installation sequence
  - Baseline survey
  - Installation of long-term creep monitoring
  - Filling water boxes including polystyrene beads in voids
  - Front face is last

- NCD qualification and installation sequence
  - Relocate NCDs to new storage racks
  - Establish NCD qualification test stand
  - Select detectors for installation
  - Build NCDs into moderator tubes
  - Instrument Pb array with populated moderator tubes
  - Progressively cable and commission electronics
Welcome to the Helium and Lead Observatory

The Helium and Lead Observatory (HALO) is a dedicated supernova neutrino detector that is presently under construction underground at SNOLAB in the Creighton Mine in Sudbury Ontario Canada.

It uses 78 tonnes of annular lead blocks instrumented with 128 tubular Helium-3 neutron detectors to detect neutrinos from supernovae within our galaxy. As a part of the worldwide Supernova Early Warning System (SNEWS), it will help detect supernovae by their neutrino burst, before their light reaches Earth, allowing time to notify both professional and amateur astronomers.

News & Events
keep up to date with HALO

March 29, 2010
Construction of the lead array is complete
All 804 lead blocks are now assembled in the HALO array. The supporting superstructure on top of the array has also been included. Altogether the HALO lead assembly took 10 days.

March 10, 2010
Lead array assembly has begun
The steel superstructure has been installed in the HALO shift. The first lead block was placed today.

Gallery
construction and calibration pictures

view all news
Talks

Conclusions

- Much progress in last year
- Design work in most areas well advanced
- Procurement in most areas in good shape
- Expect an installation intensive Fall
- Excellent involvement of offsite collaboration members
- Excellent material / service contributions from offsite collaboration members
- Aiming for installation of shielding (all but front side), NCDs in moderator tubes by year end
- Commissioning followed by closing shielding and calibration in the Spring