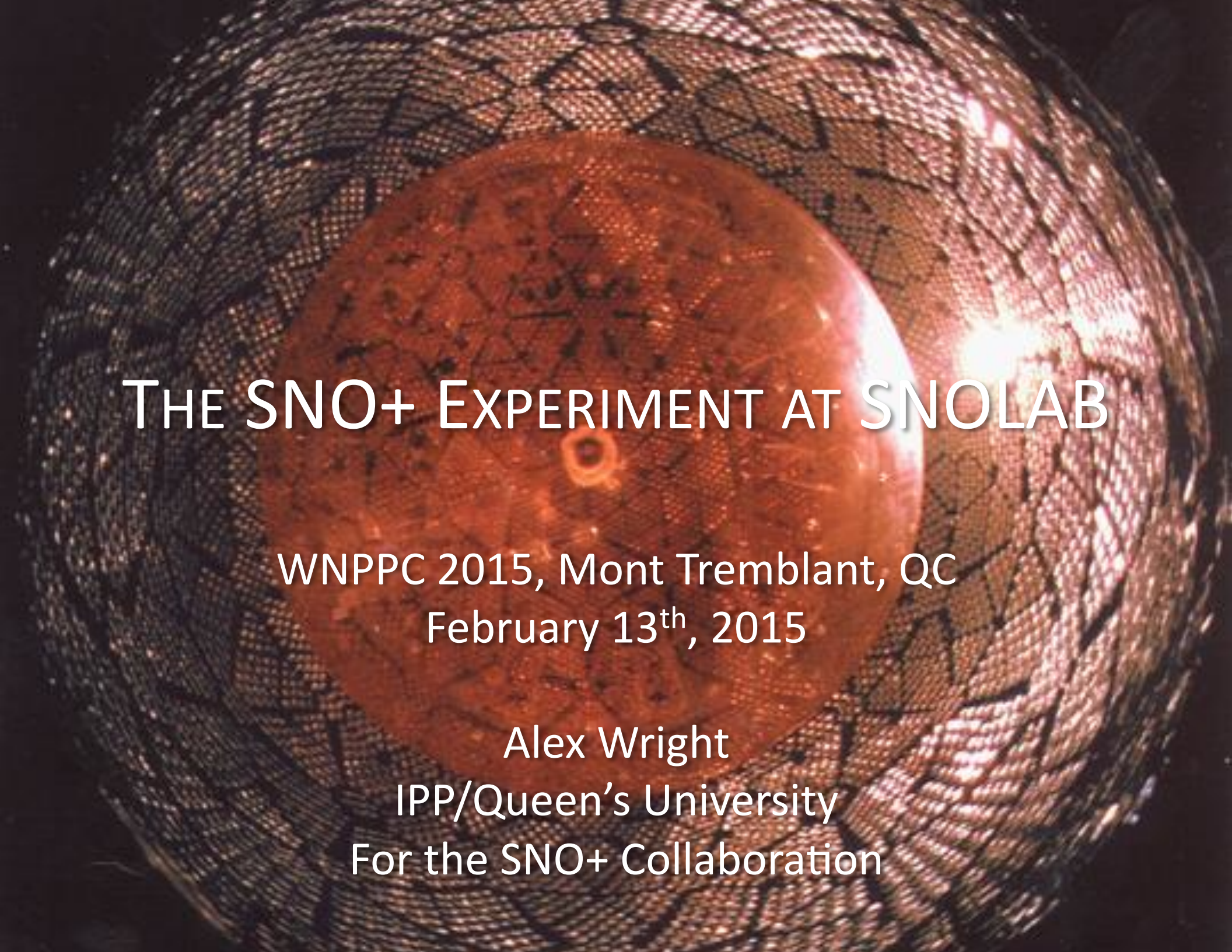


The SNO+ Experiment at SNOLAB

WNPPC 2015, Mont Tremblant, QC
February 13th, 2015

Alex Wright
IPP/Queen's University
For the SNO+ Collaboration

SNO+

- 780 tonnes of liquid scintillator as active volume
  - Can be loaded with double beta decay isotope
- ~9500 PMTs
- 1500 + 5300 tons ultra-pure water shielding
- 6800’ underground in SNOLAB

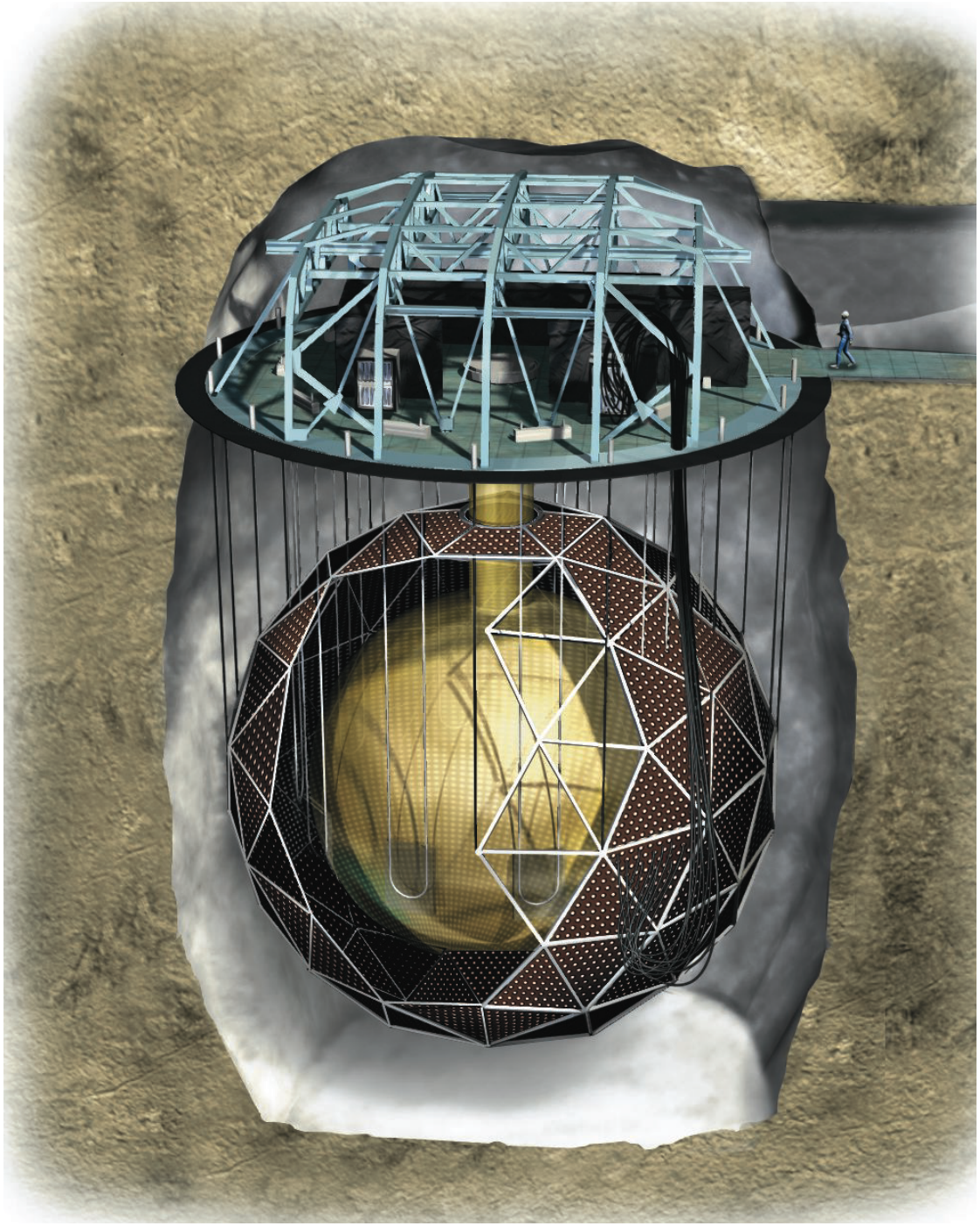
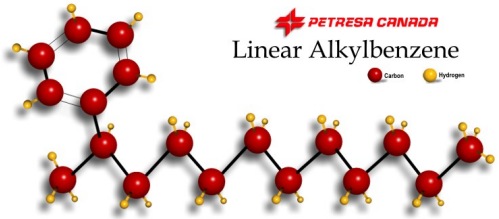


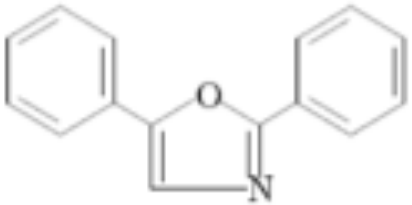
Image courtesy National Geographic

The SNO+ Collaboration

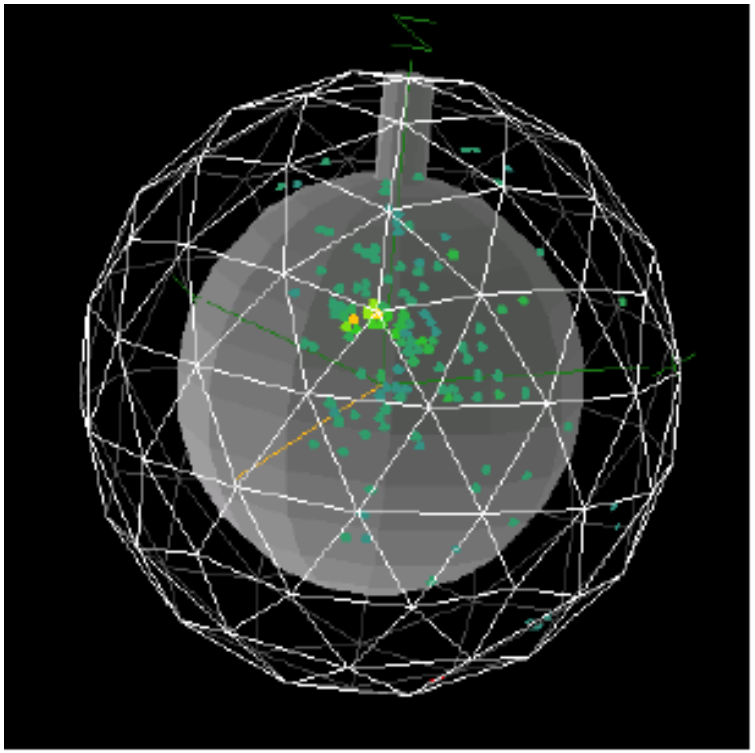
Armstrong Atlantic State University
Brookhaven National Laboratory
Lancaster University
Laurentian University
LIP Coimbra
LIP Lisboa
Oxford University
Queen Mary, University of London
Queen's University
SNOLAB
Technical University of Dresden
TRIUMF
Universidad Nacional Autónoma de México
University of Alberta
University of California – Berkeley
& Lawrence Berkeley National Laboratory
University of California - Davis
University of Chicago
University of Liverpool
University of North Carolina at Chapel Hill
University of Pennsylvania
University of Sussex
University of Washington



Detection Principle

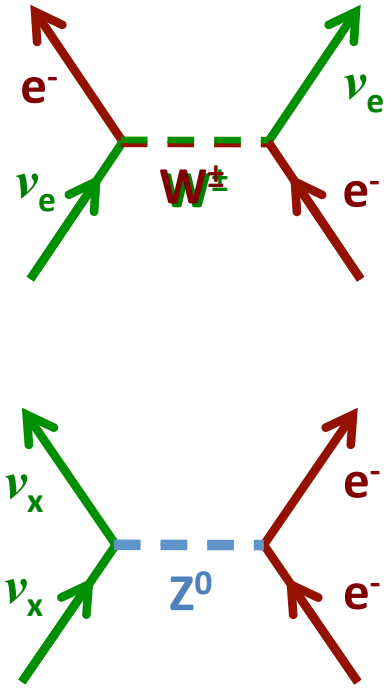


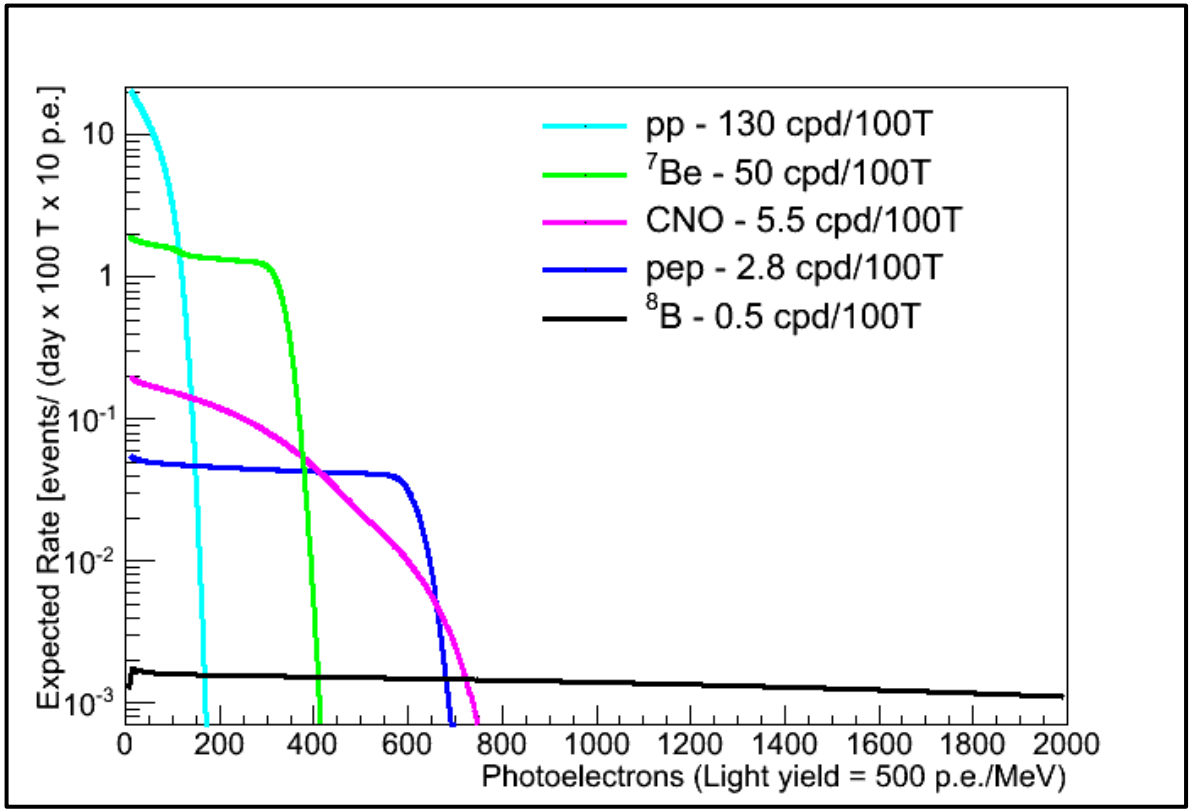
- Organic scintillator (LAB + PPO) produces light when excited by charged particles
- ~10,000 photons/MeV, of which a few hundred photons/MeV are detected by the PMTs
  - Can detect events depositing < 50 keV
- Calorimetric measurement + pulse shape
  - Event energy from number of photons
  - Event position from photon time-of-flight



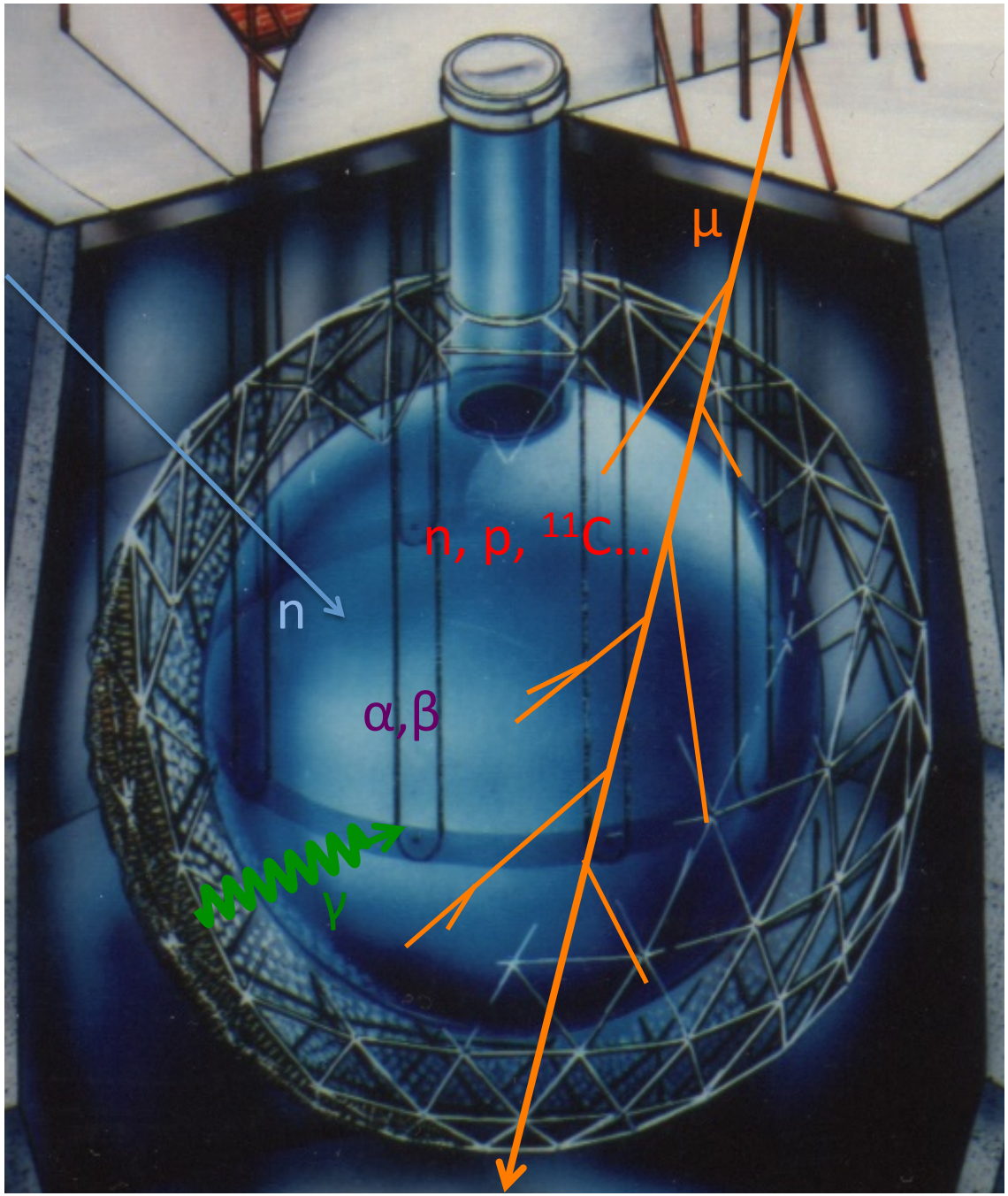
Neutrino Detection

- Neutrinos interact via elastic scattering with electrons
  - Sensitive to all neutrino species, but cross section is 4-7 times larger for ν_e than $\nu_{\mu,\tau}$
  - Detect scintillation from the recoiling electron





Central Challenge: Backgrounds



Internal Radioactivity
traces of radioisotopes (U/Th chain, ^{40}K, etc) in the scintillator.

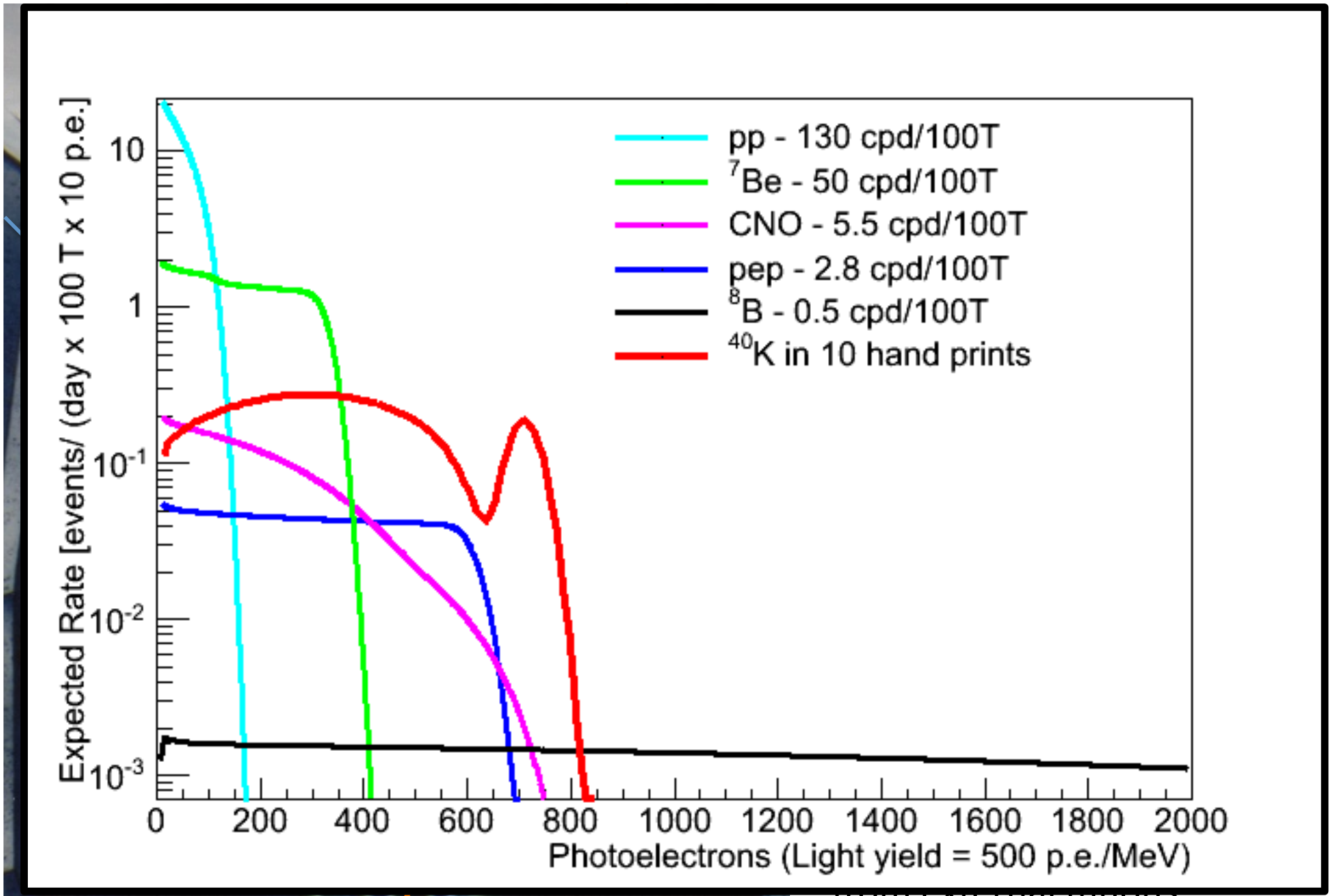
External Gammas
from decays in the acrylic, water, PMTs, etc.

Cosmic Ray Muons

Cosmogenics
Neutrons and radionuclides from spallation and hadronic showers

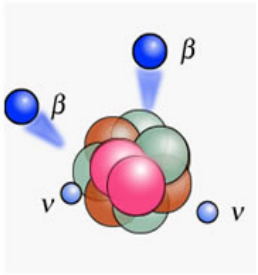
Fast Neutrons
from external muons

Central Challenge: Backgrounds

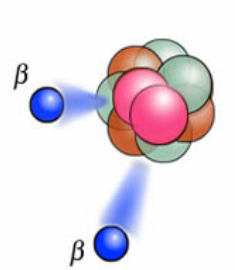


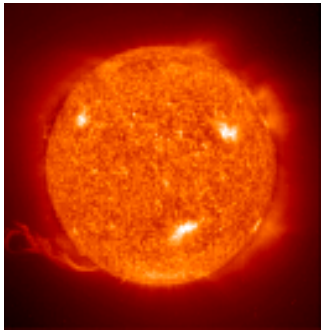
from external muons

SNO+ Physics

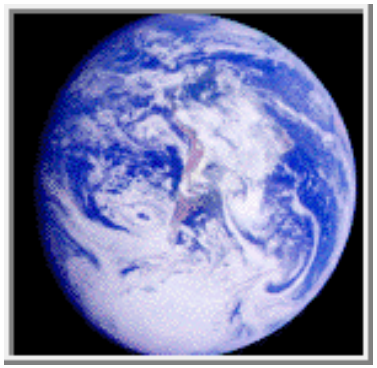


Neutrinoless Double Beta Decay





Low Energy Solar Neutrinos



Reactor Antineutrinos

Geo-Neutrinos

Supernova Neutrinos

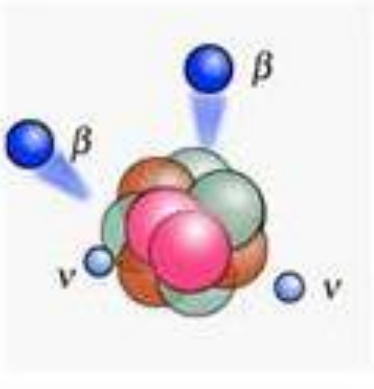
Neutrinoless Double Beta Decay

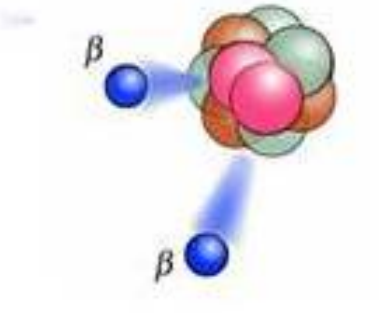
- Are neutrinos Majorana or Dirac particles?
  - Are they their own anti-particles?
- In double beta decay, a nucleus releases two electrons and two antineutrinos:

$$(A, Z) \rightarrow (A, Z + 2) + 2e^- + 2\overline{\nu}_e$$

- If neutrinos are Majorana, sometimes neutrinoless double beta decay occurs:

$$(A, Z) \rightarrow (A, Z + 2) + 2e^-$$





Detection of neutrinoless double beta decay proves that neutrinos are Majorana and provides information about the neutrino mass.

Searching for neutrinoless double beta decay involves looking for a tiny monoenergetic peak at the end of a large double beta decay continuum.

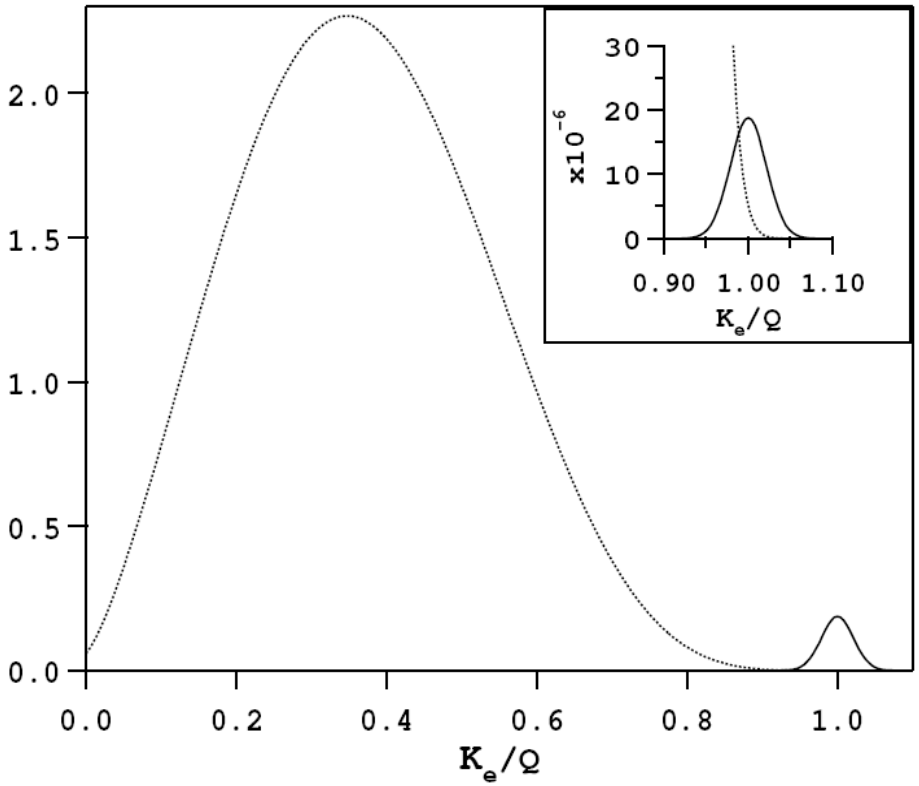


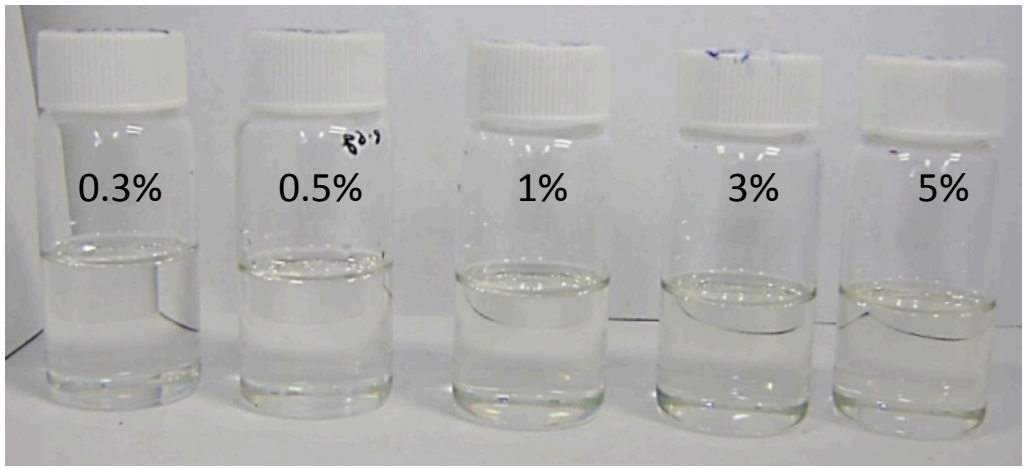
Image from Elliott and Vogel, hep-ph/0202254

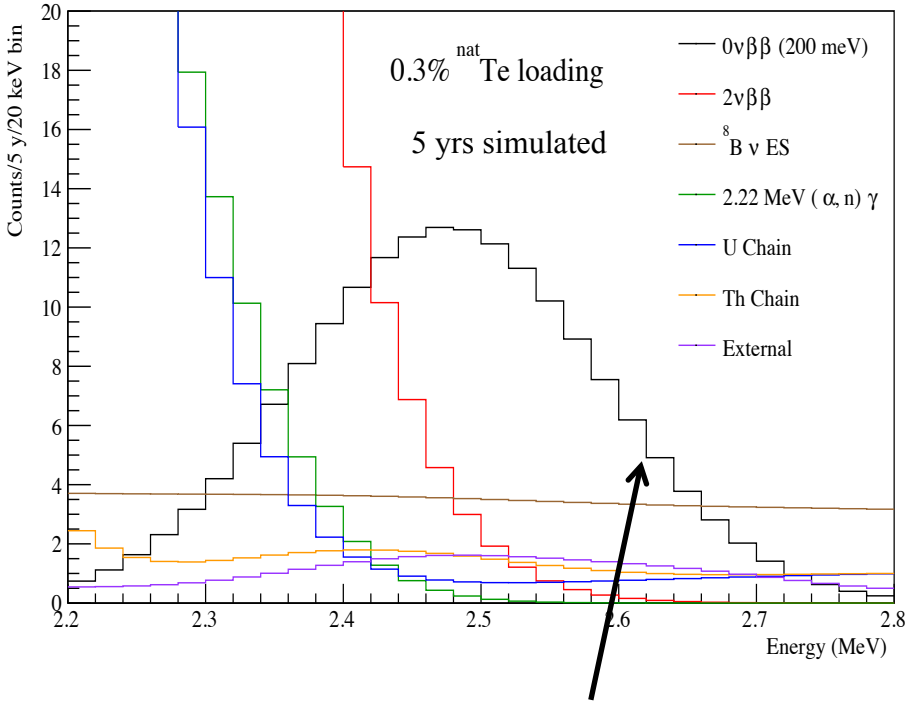
D.B.D. experiments need good energy resolution, low backgrounds, and large amounts of isotope.

Neutrinoless Double Beta Decay in SNO+

Loading tellurium metal into the SNO+ scintillator gives 800 kg of ^{130}Te at 0.3% loading

LAB scintillator with different Te loading levels



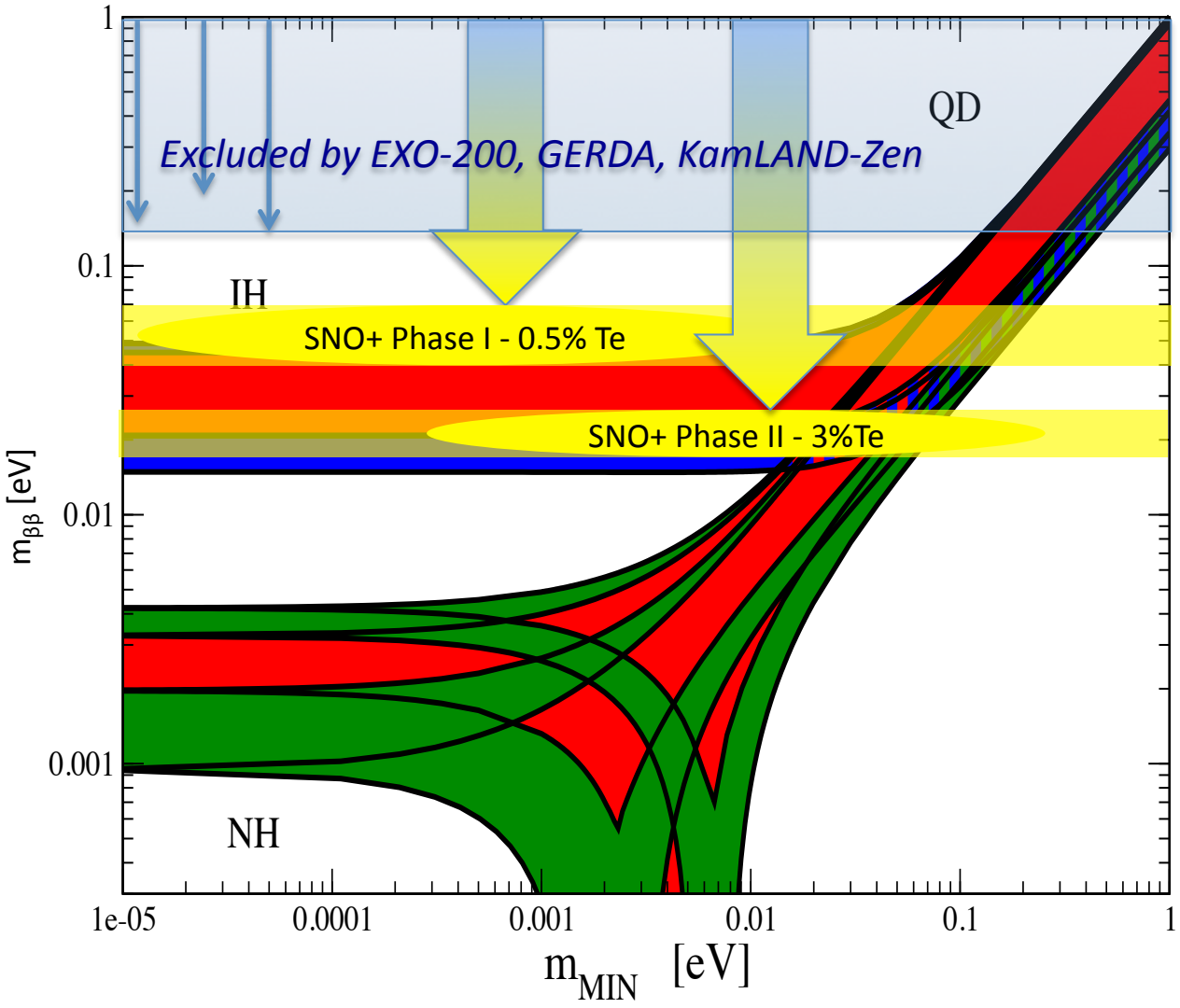


Expected 0νββ signal at roughly the current limit

Extremely low background compensates for modest energy resolution.

If the TeLS is sufficiently radiopure, the dominant background in SNO+ will be ^{8}B solar neutrinos. Then sensitivity scales directly with Te loading!

Neutrinoless Double Beta Decay in SNO+

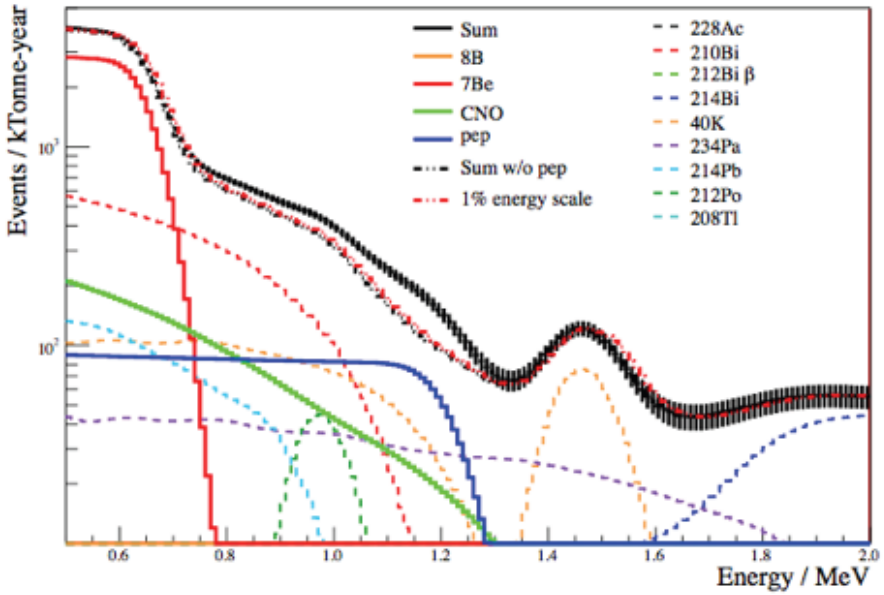


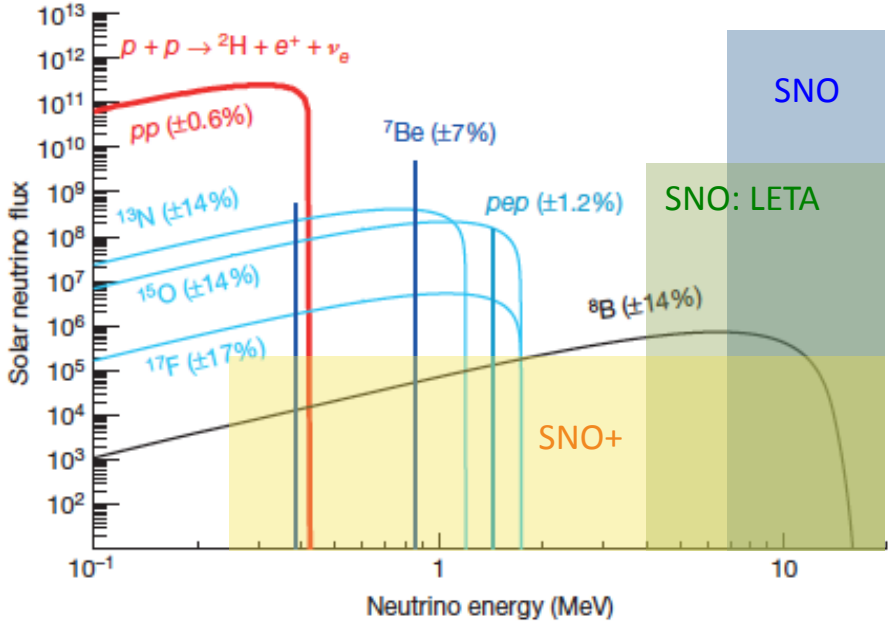
A staged approach will give SNO+ leading sensitivity for years to come.

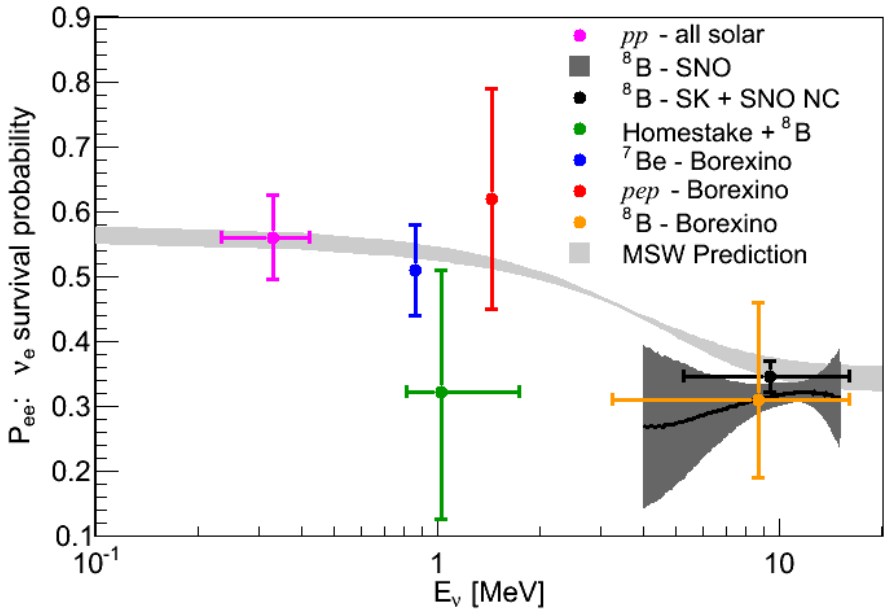
Background plot adapted from PRD 77, 113003 (2008)

Solar Neutrinos

Precise measurements of the low energy solar neutrinos can confirm that we understand the neutrino oscillation mechanism, how neutrinos interact with matter, and what's going on inside the sun.







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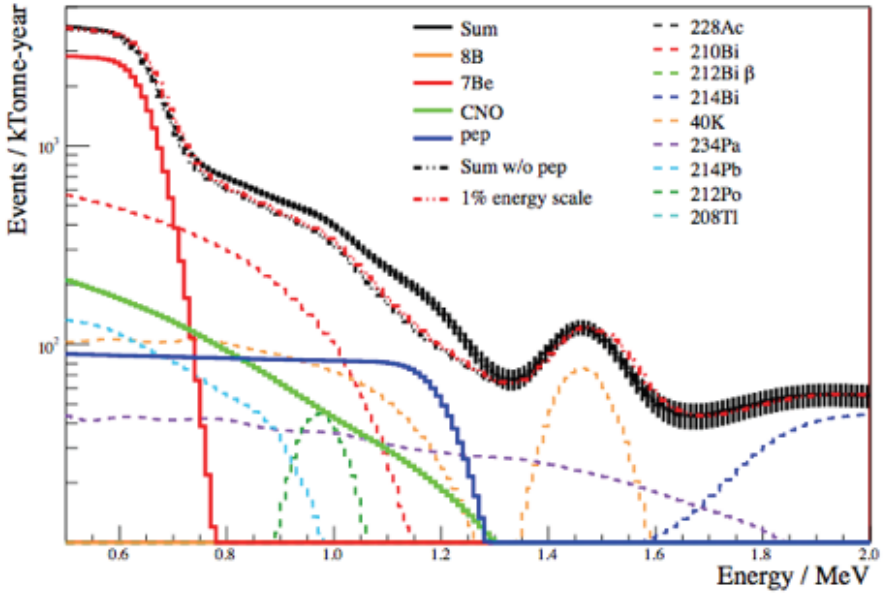
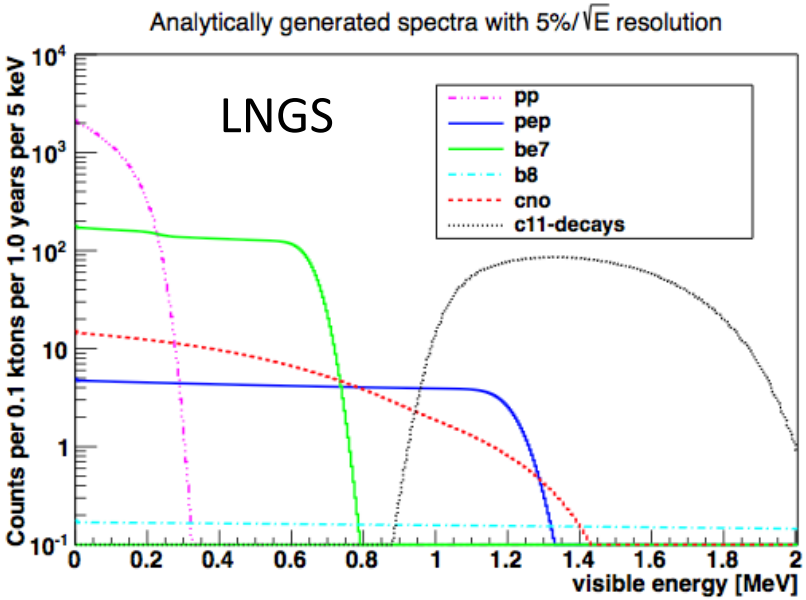
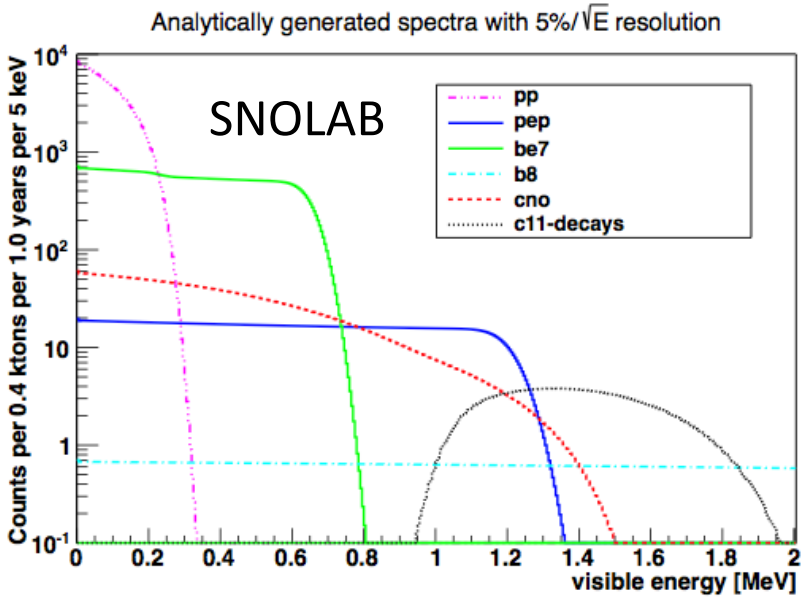






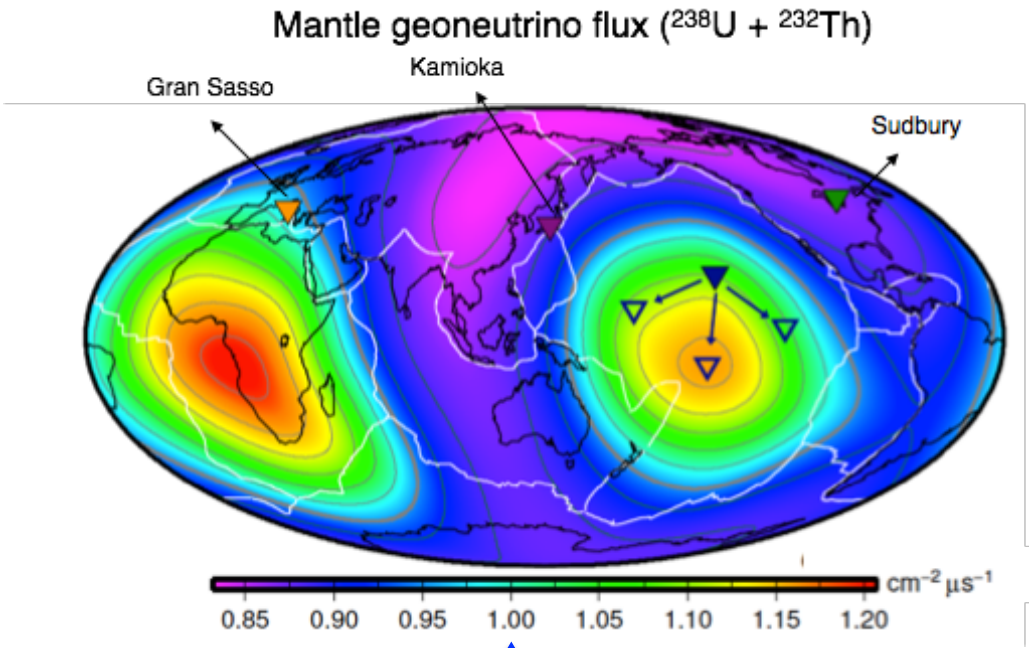
The depth of SNOLAB gives SNO+ a unique opportunity to make a precise measurement.

Geo- and Reactor Antineutrinos

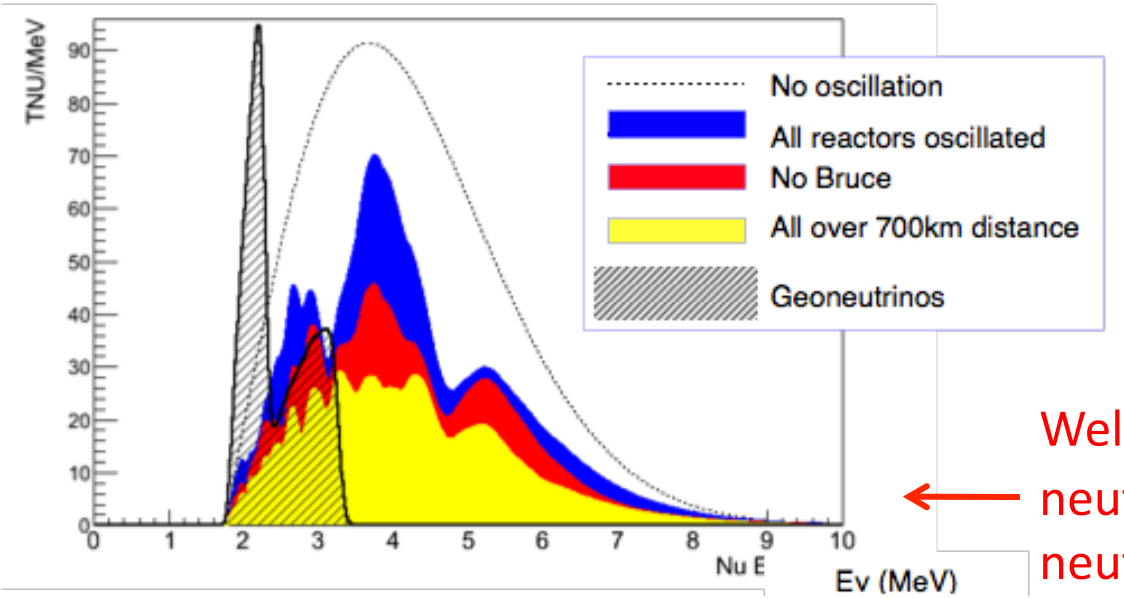
Detect antineutrinos via:

$$\overline{\nu}_e + p \rightarrow e^+ + n$$

Delayed coincidence means very low backgrounds!



Measuring the geo-neutrino flux tells us about the earth's internal chemical composition, and thermal history



Well known fluxes and baselines for reactor neutrinos provides precision probe of neutrino oscillations

Supernova Neutrinos

- Type II supernovae release ~99% of their gravitational binding energy as neutrinos
  - More neutrinos in a few seconds than in the rest of the star's life combined
  - Burst detectable at galactic distances
- Galactic supernovae estimated to happen ~once in 30 years
- Neutrinos provide "early warning" of supernova for optical observations
- Neutrinos provide information on neutrino oscillations, the supernova itself, cosmological parameters, etc.

Expected signal for a 10kPc Supernova

(Anti)Neutrino Interaction	*Expected Number of Events*
$\nu_e + e^- \rightarrow \nu_e + e^-$	8
$\bar{\nu}_e + e^- \rightarrow \bar{\nu}_e + e^-$	3
$\nu_{\mu,\tau} + e^- \rightarrow \nu_{\mu,\tau} + e^-$	4
$\bar{\nu}_{\mu,\tau} + e^- \rightarrow \bar{\nu}_{\mu,\tau} + e^-$	2
$\bar{\nu}_e + p \rightarrow n + e^+$	263
$\nu_e + {}^{12}C \rightarrow {}^{12}N + e^-$	27
$\bar{\nu}_e + {}^{12}C \rightarrow {}^{12}B + e^+$	7
$\nu_x + {}^{12}C \rightarrow {}^{12}C^*(15.11MeV) + \nu_x$	58
$\nu_x + p \rightarrow \nu_x + p$	273**

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- G
  to
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	4
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	27
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	273**

YET ANOTHER PAPER ON SN1987A: LARGE ANGLE OSCILLATIONS, AND THE ELECTRON NEUTRINO MASS

Peter J. Kernan and Lawrence M. Krauss

Department of Physics
Case Western Reserve University
10900 Euclid Ave., Cleveland, OH 44106-7079

The SNO+ Story

- Past
  - Identify acrylic compatible scintillator
  - Install acrylic vessel hold-down net
  - Upgrade electronics
  - Clean acrylic vessel
- Present
  - Design purification systems for tellurium and surfactant
  - Install scintillator purification plant
  - Fill detector with water
  - Upgrade calibrations and covergas systems
- Future
  - Operate water filled detector to study backgrounds and nucleon decay - 2015
  - Commission scintillator plant and fill detector with scintillator – 2015-2016
  - Install isotope and surfactant purification equipment – 2016
  - Purify and load DBD isotope – 2016-2017

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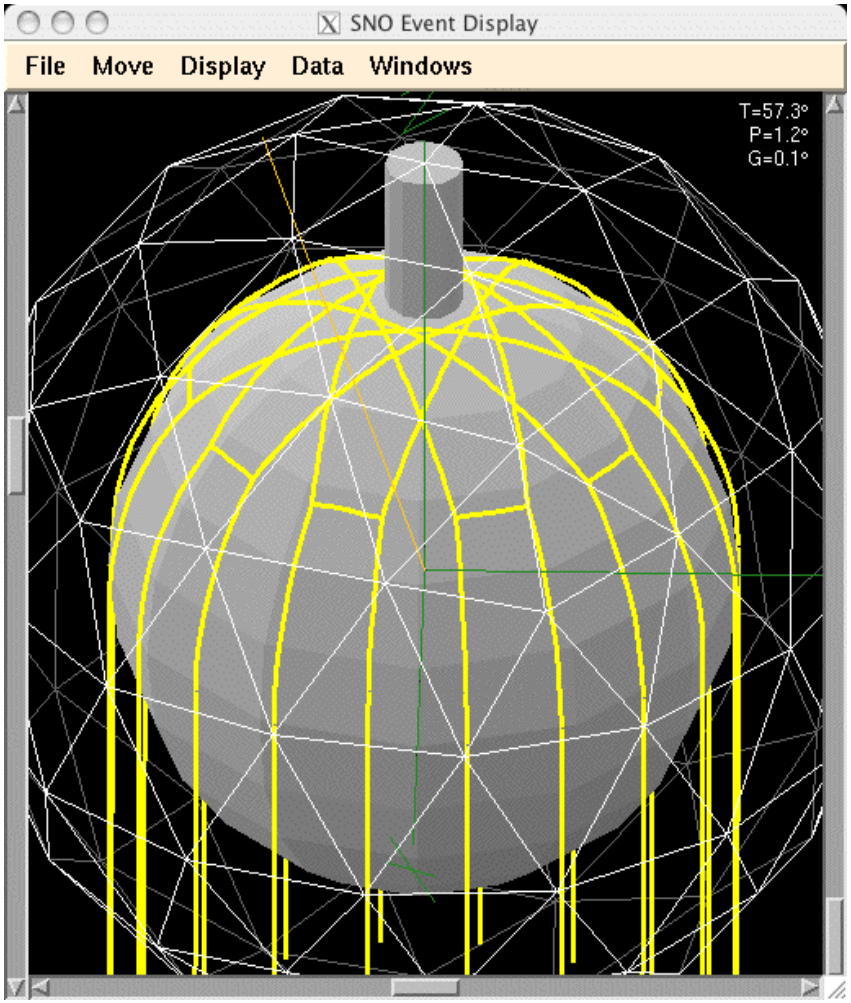
Talk by C. Miller, session 5b

Talk by T. Zhao, session 5a

Talk by I. Lam, session 4a

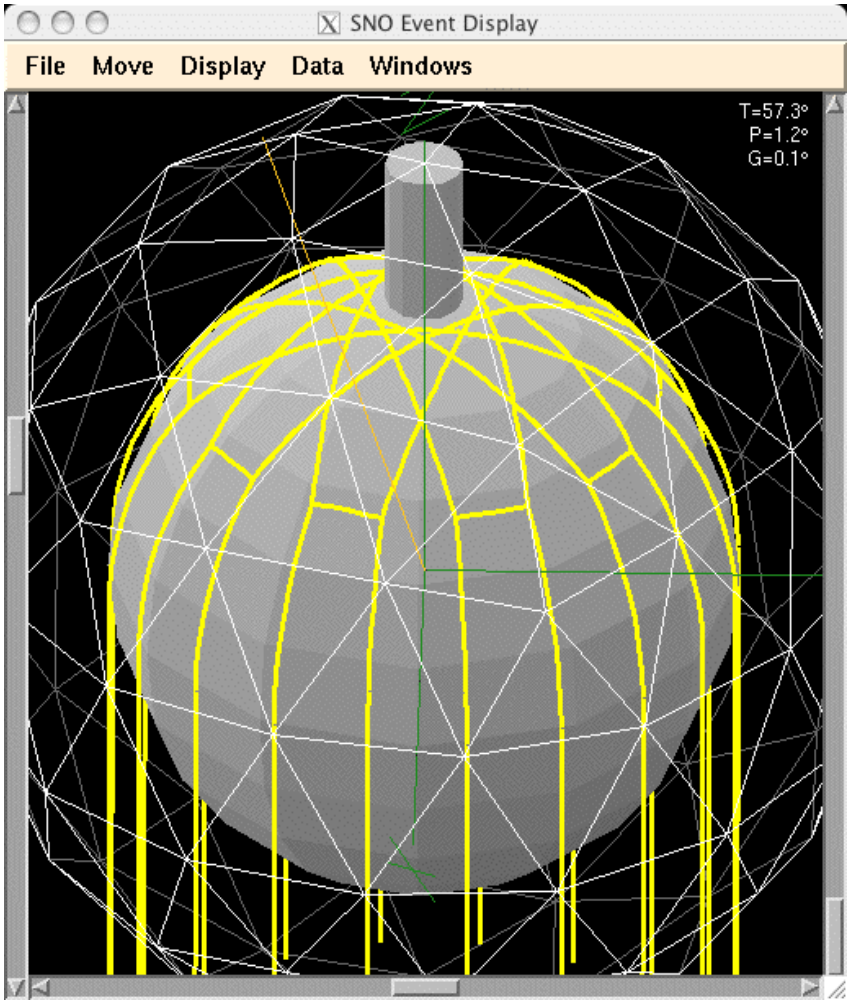
Talk by Y. Liu, session 5b

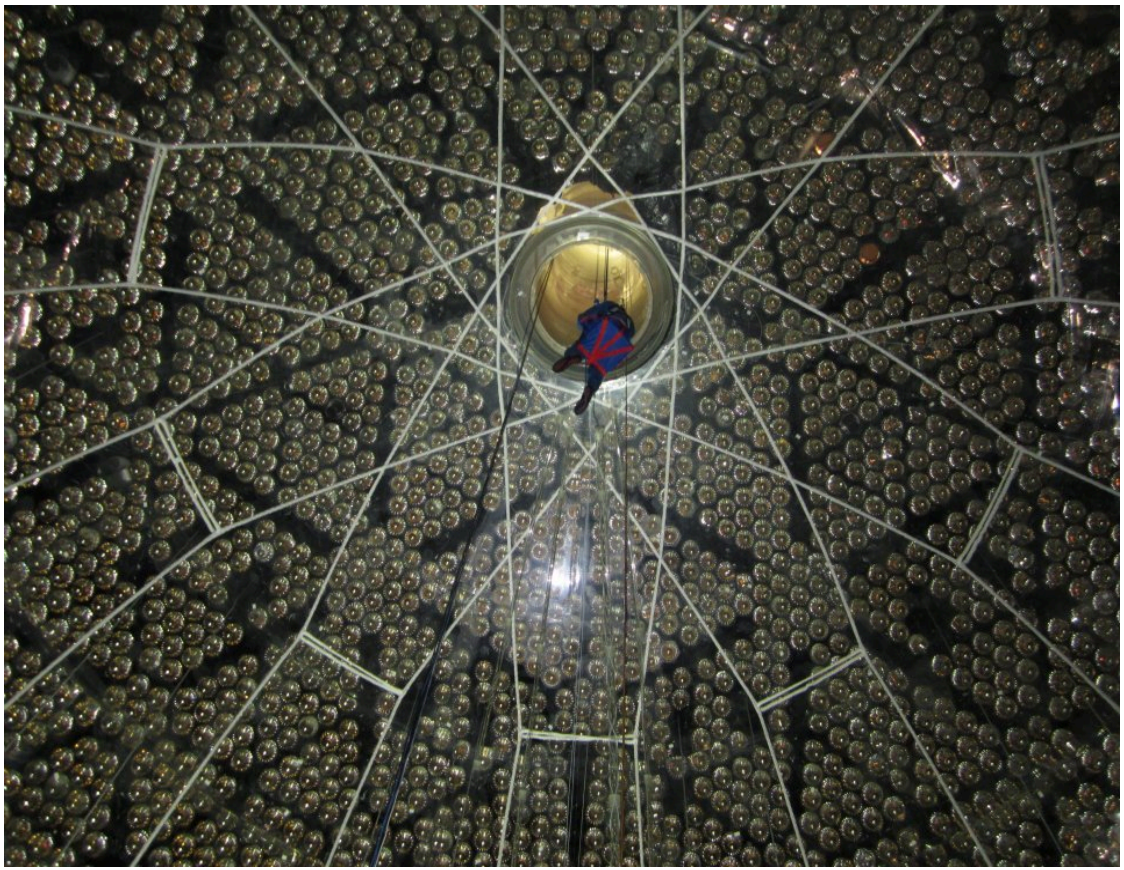
Install AV Hold-Down Net



Hold-down anchors and new floor liner installed

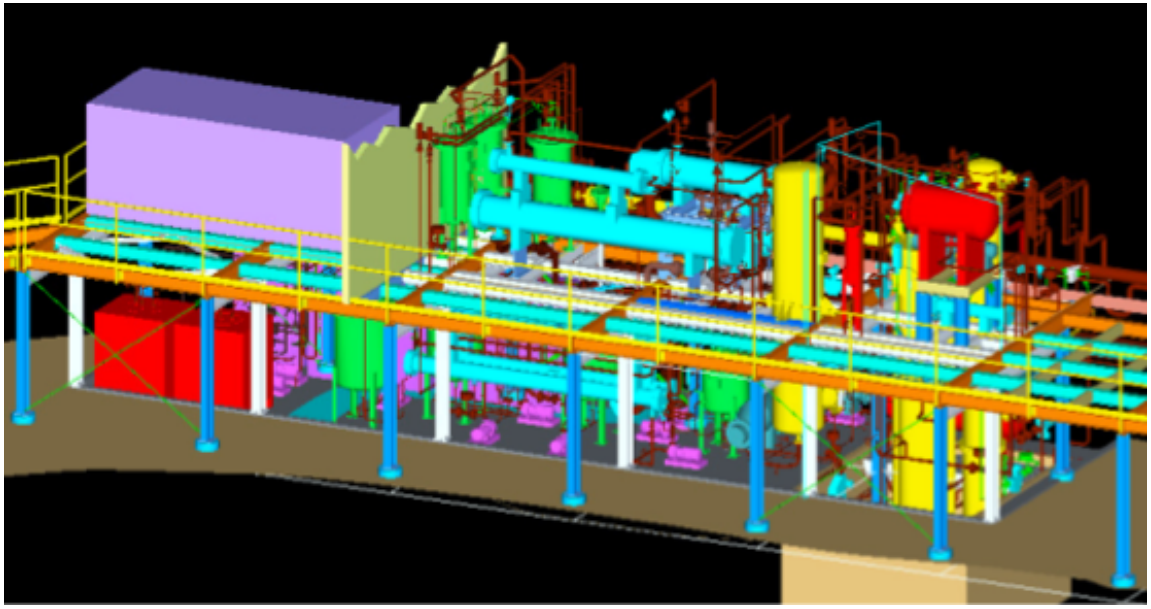
Install AV Hold-Down Net





Hold-down rope net installed, pre-tensioned, and tested by "float the boat" testing.

Scintillator Process System

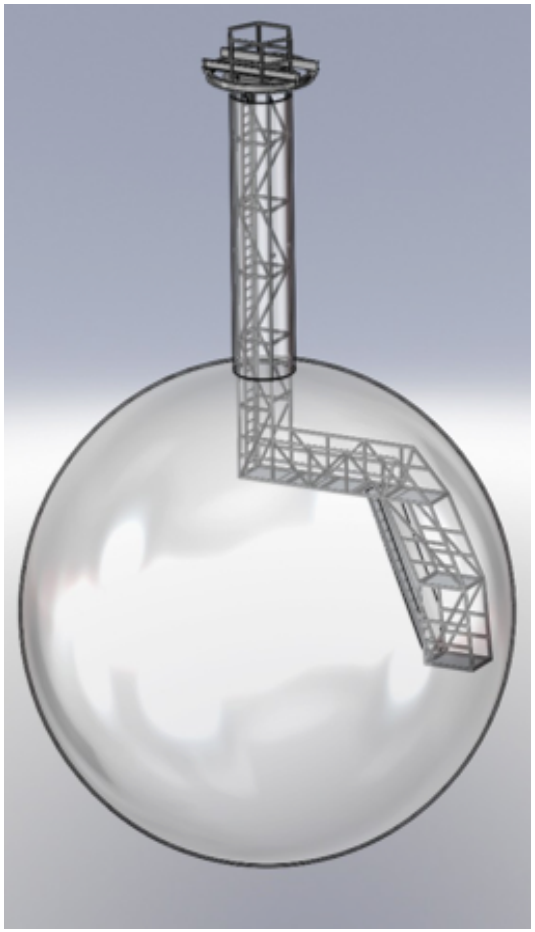


Essentially had to install an industrial petrochemical processing facility underground. Major piping/vessel installation done, working on leak checking, then cleaning & passivation

Scintillator Process System

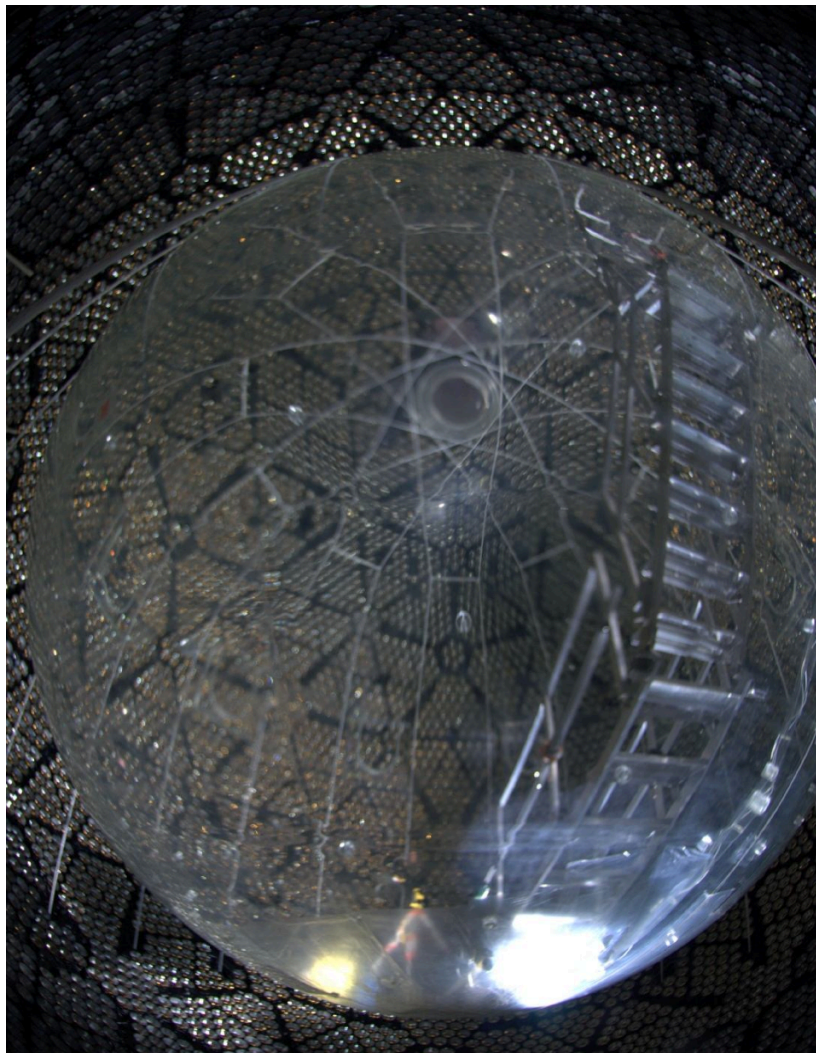
Essentially had to install an industrial petrochemical processing facility underground. Major piping/vessel installation done, working on leak checking, then cleaning & passivation

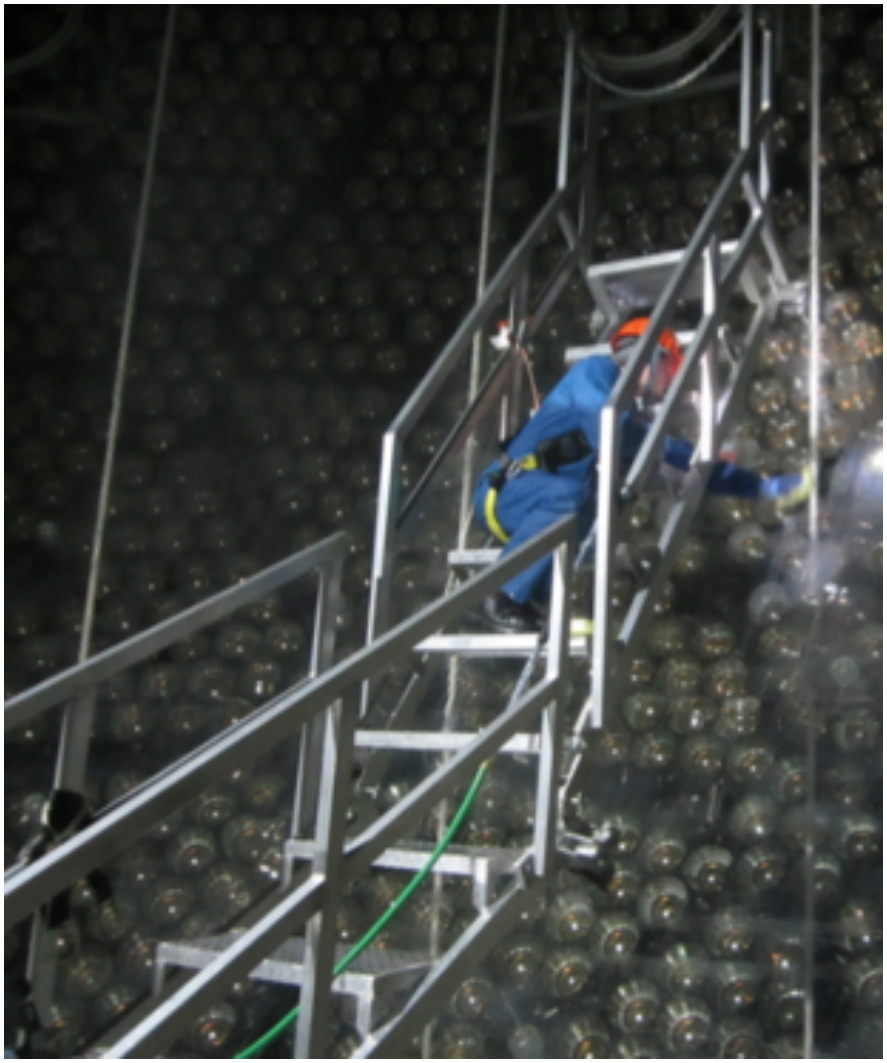
Acrylic Vessel Cleaning



Upper hemisphere – suspended platform

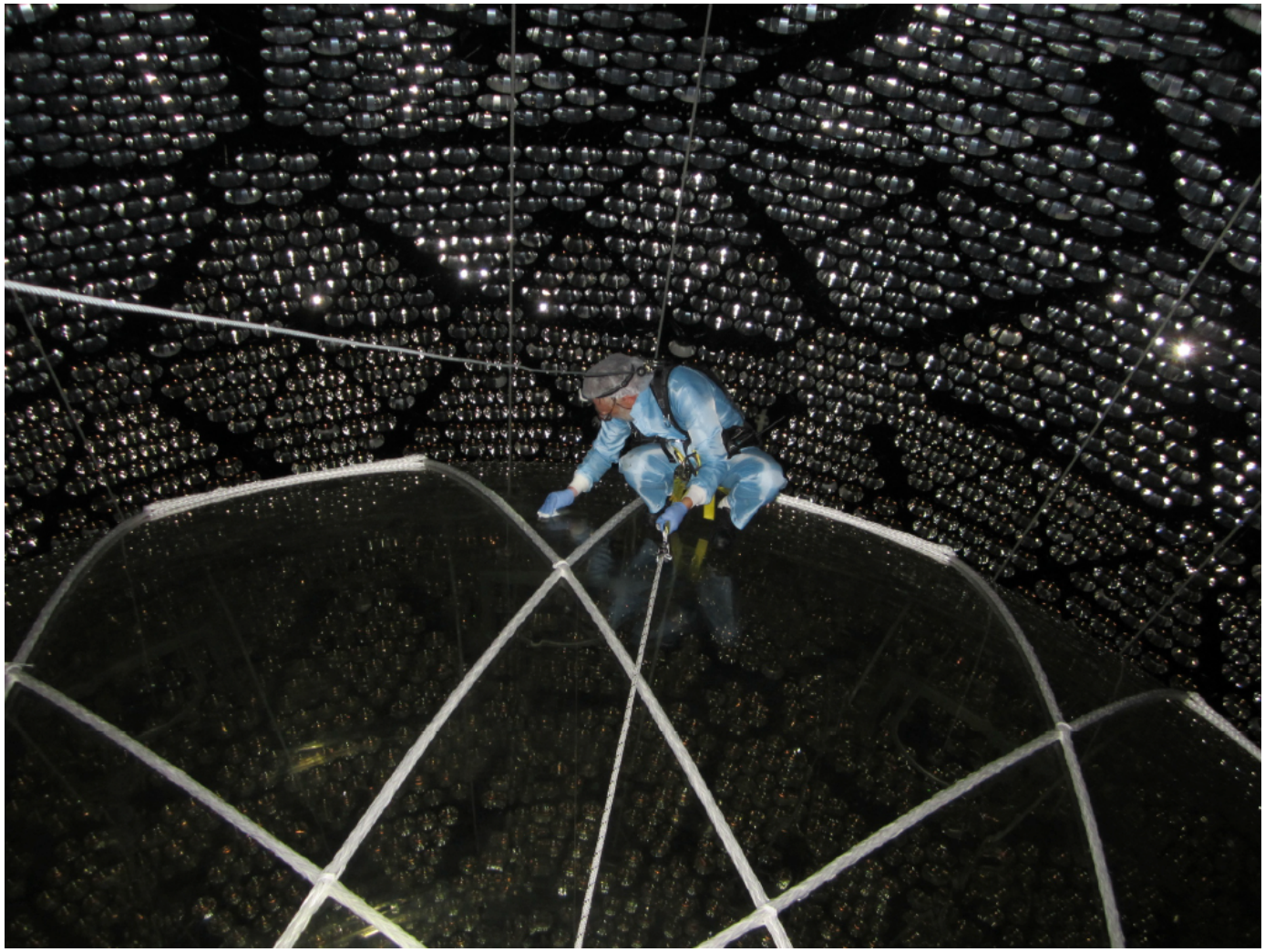
Acrylic Vessel Cleaning





Lower hemisphere - rotating ladder

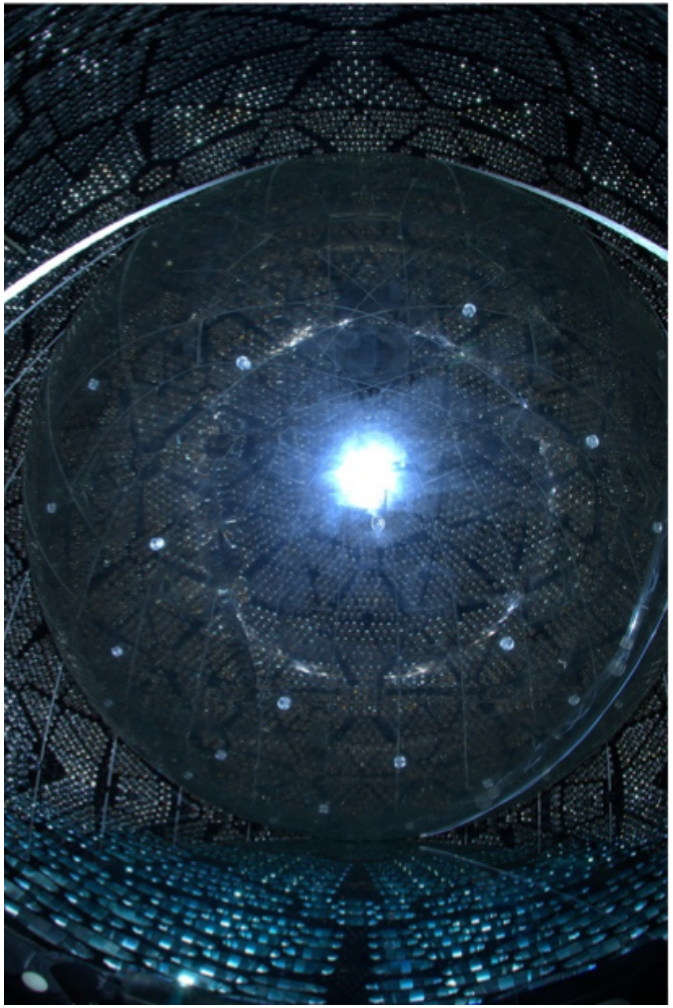
Acrylic Vessel Cleaning



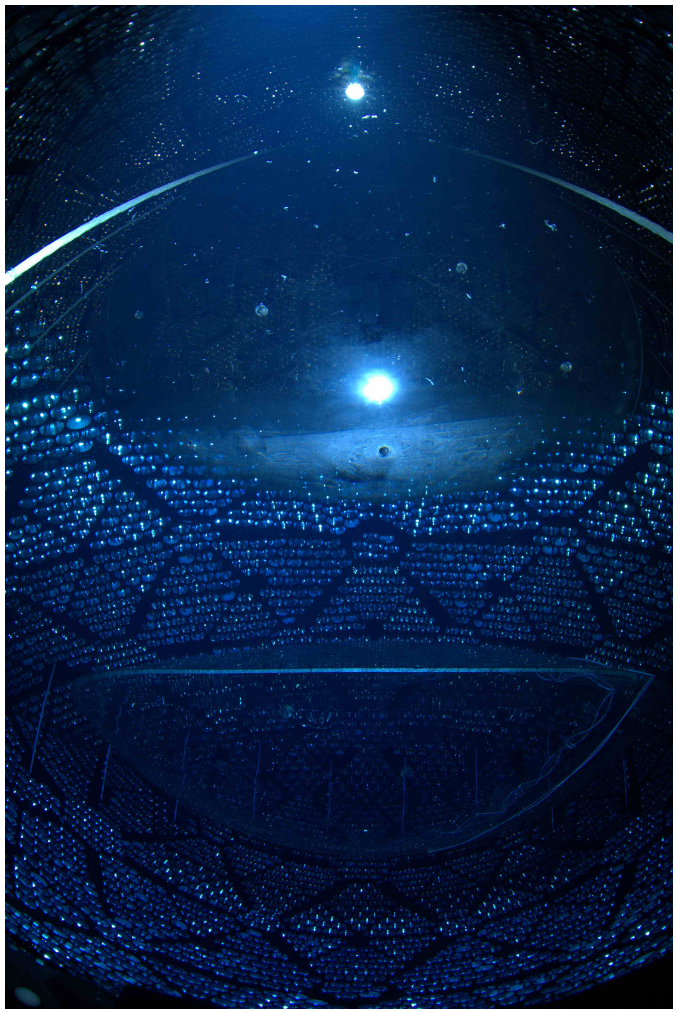
Even the outside!

Water Filling

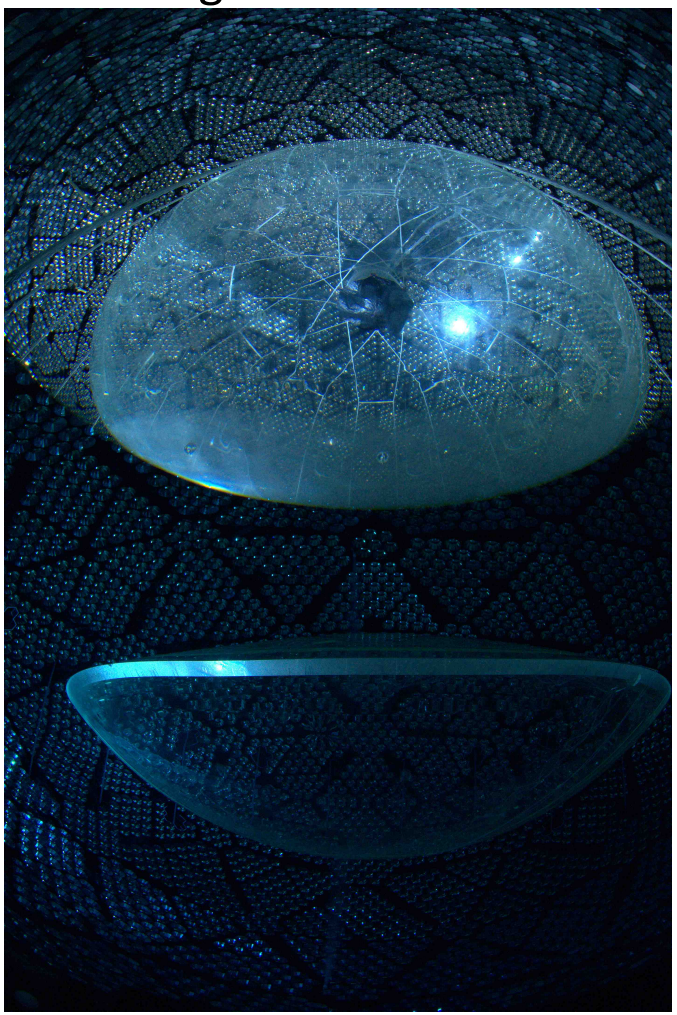
Camera above water



Camera and light underwater



Camera underwater, light above water



The detector and cavity are currently about half filled with water. This leads to interesting optics!

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Talk by C. Miller, session 5b

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Conclusion

- SNO+ is a multipurpose neutrino detector capable of a number of important measurements
  - Priority on neutrinoless double beta decay
  - Also solar neutrinos, reactor and geo antineutrinos, and supernova neutrinos
- Experiment is currently under construction, with water data expected this year. Then, on to scintillator fill and neutrinoless double beta decay!