Status of the SNO+ Experiment

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16th Lomonosov Conference on Elementary Particle Physics

SNO+ Collaboration

SNOLAB
TRIUMF
University of Alberta
Queens University
Laurentian University

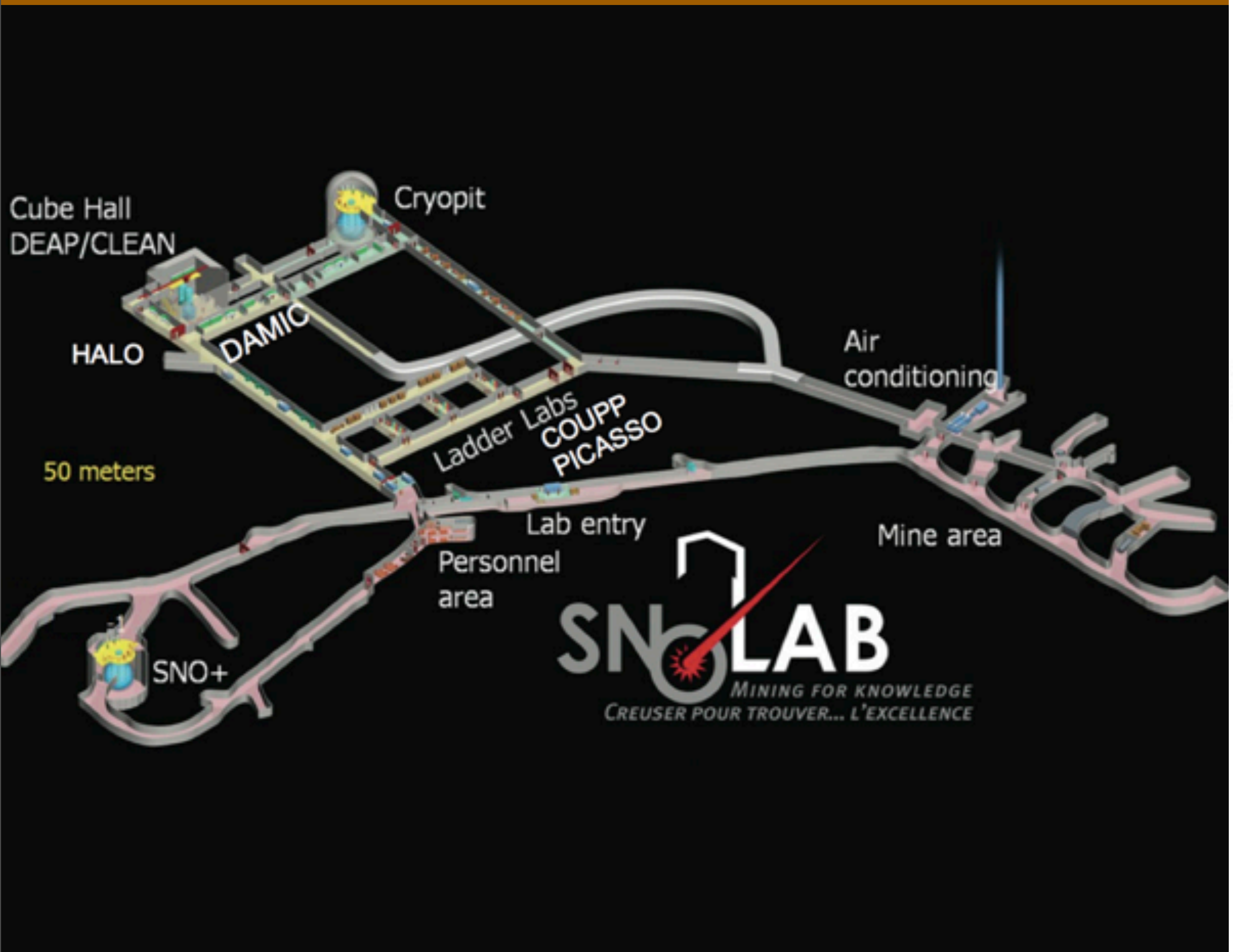
Oxford University
Queen Mary,
University Of London
University of Liverpool
University of Sheffield
University of Sussex

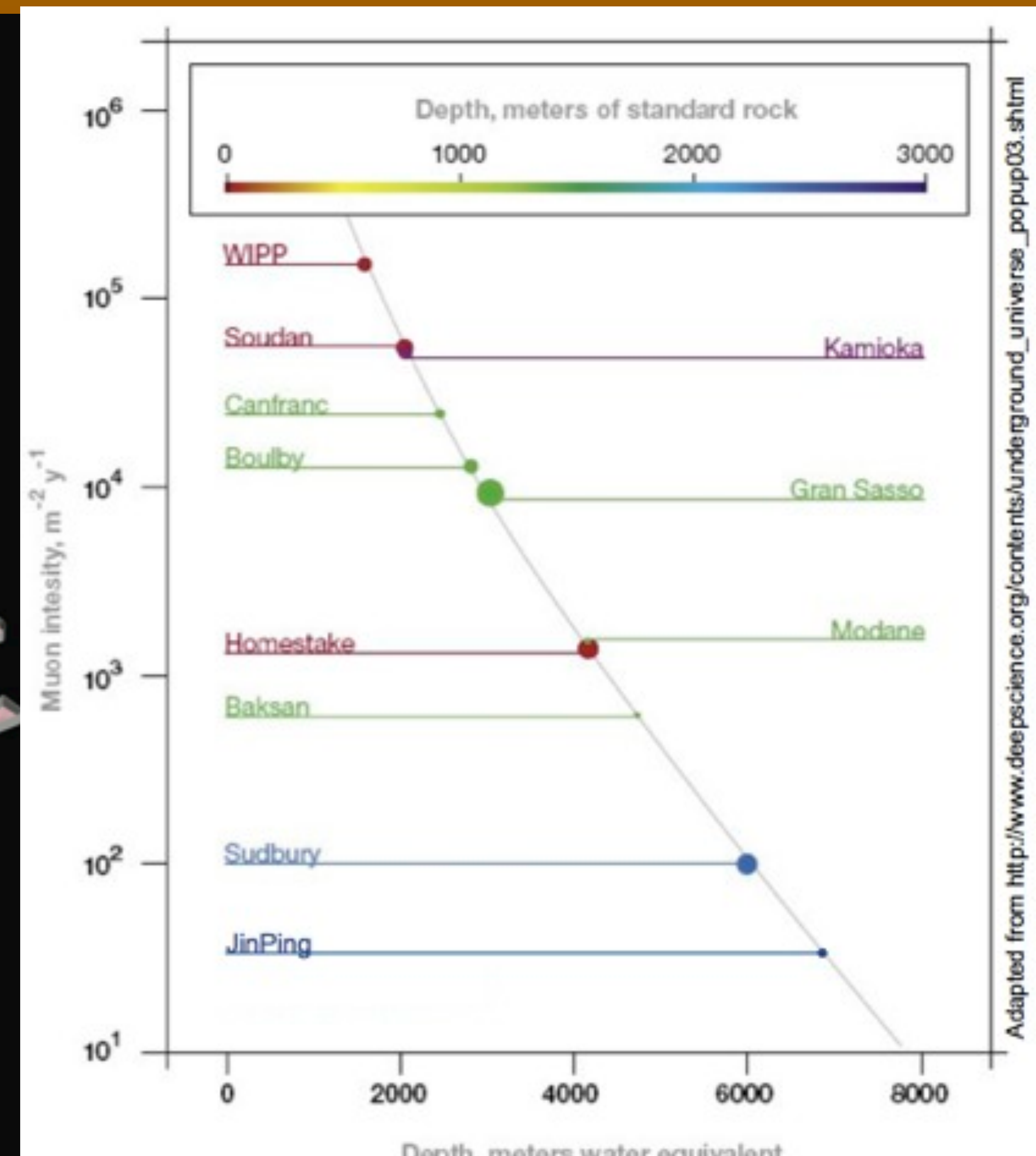
Armstrong State University
Black Hills State
Brookhaven National Lab
University of California
Berkeley
University of Chicago
University of North Carolina
University of Pennsylvania
University of Washington

TU Dresden

LIP Coimbra
LIP Lisboa

SNOLAB





- 6800 ft (2 km) below the surface
- 6000 m.w.e (70 muons/day)
- Class-2000 clean room

SNO+ Detector

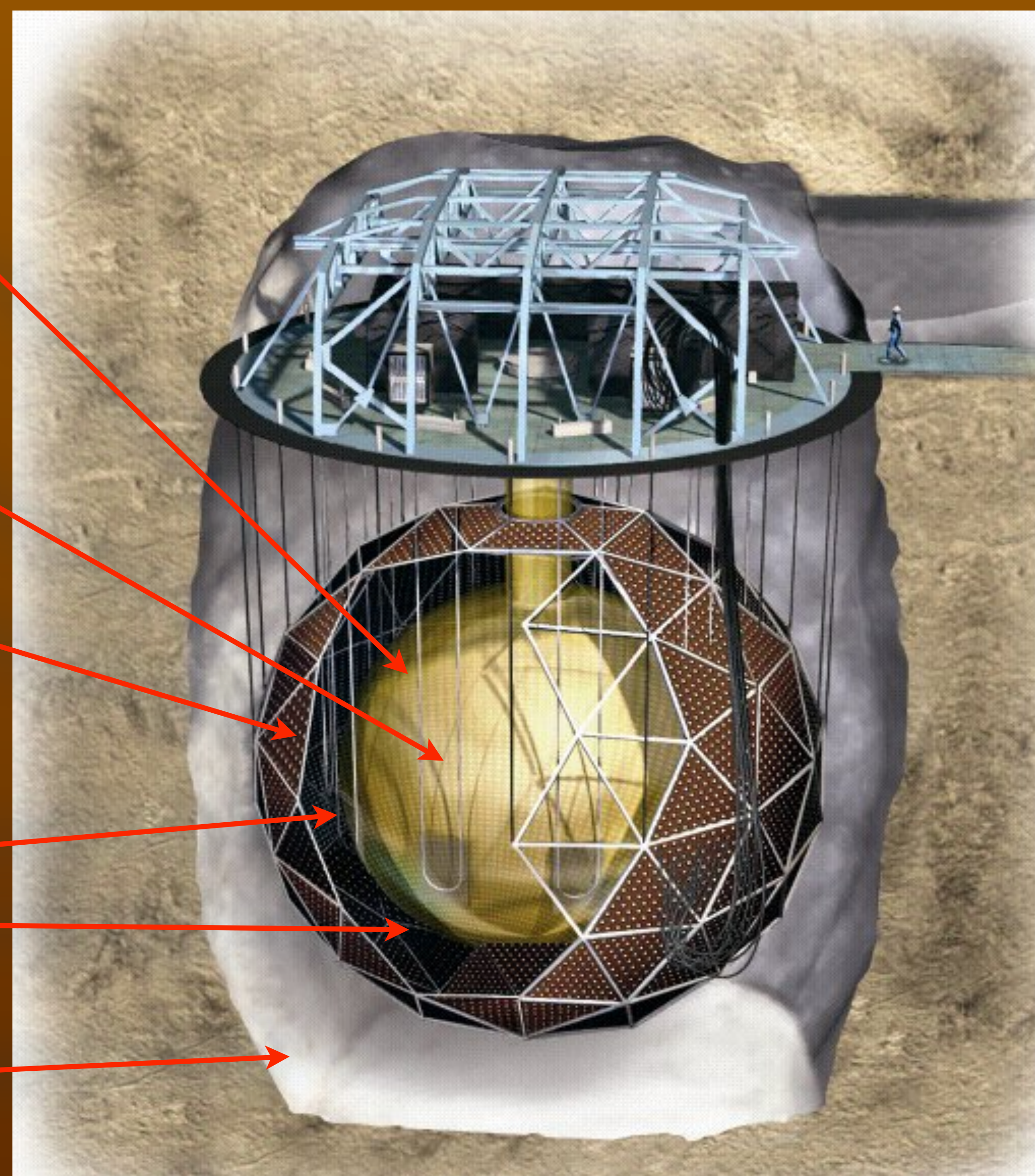
Acrylic Vessel
- 12 m diameter

LAB scintillator
- 780 ton

PMTs
- 9500

Water Shielding
-1700 t inner
- 5300 t outer

Urylon Liner
(Radon Seal)

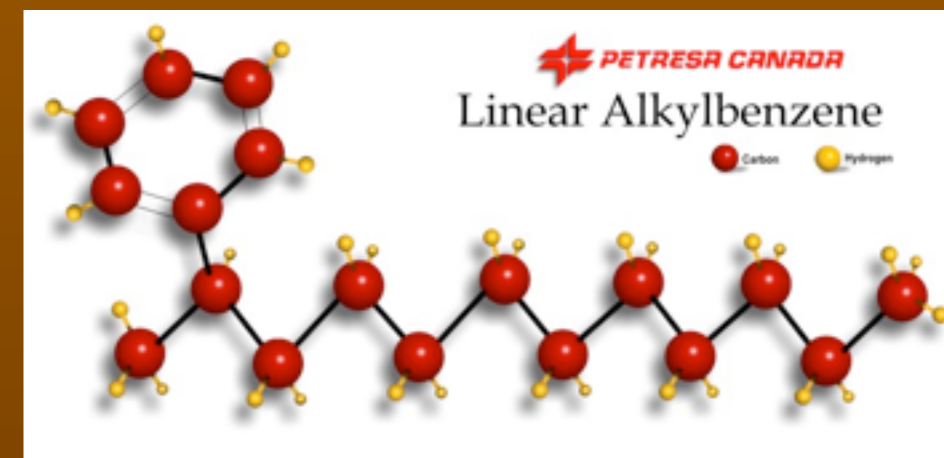


Physics Program

- Low Energy Solar Neutrinos (pep, CNO, pp, ^{7}Be, ^{8}B)
- Geo, Reactor, and Supernova neutrinos
- **Neutrinoless Double Beta Decay with ^{130}Te (Priority)**

SNO+: Liquid Scintillator

- Linear Alkyl Benzene (LAB) is liquid scintillator solvent.
- High light yield (~11,000 pe/MeV)
- High purity
- Low scattering & good optical transparency
- Fast timing
- High flash point (140 C) and high Boiling Point (278-314 C)



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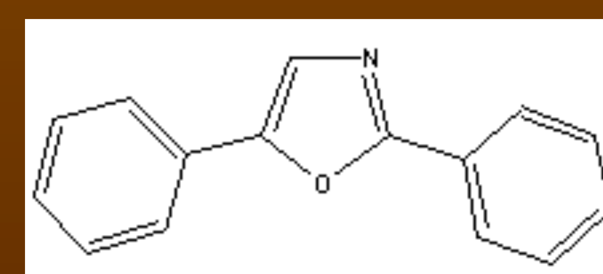
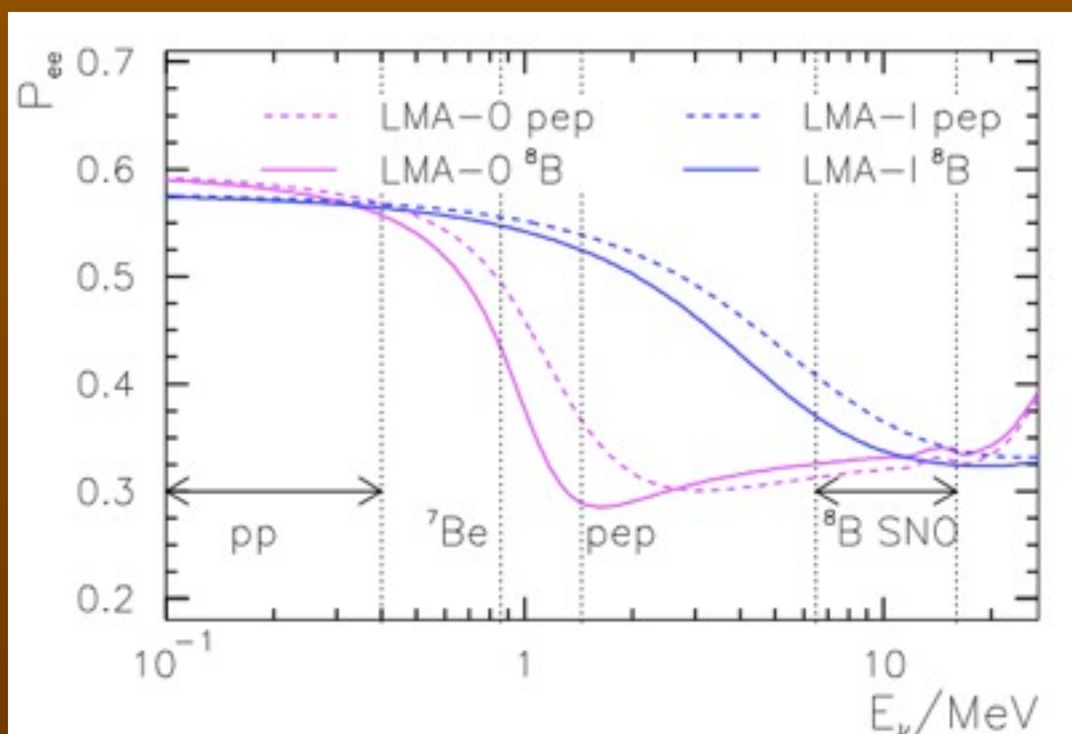


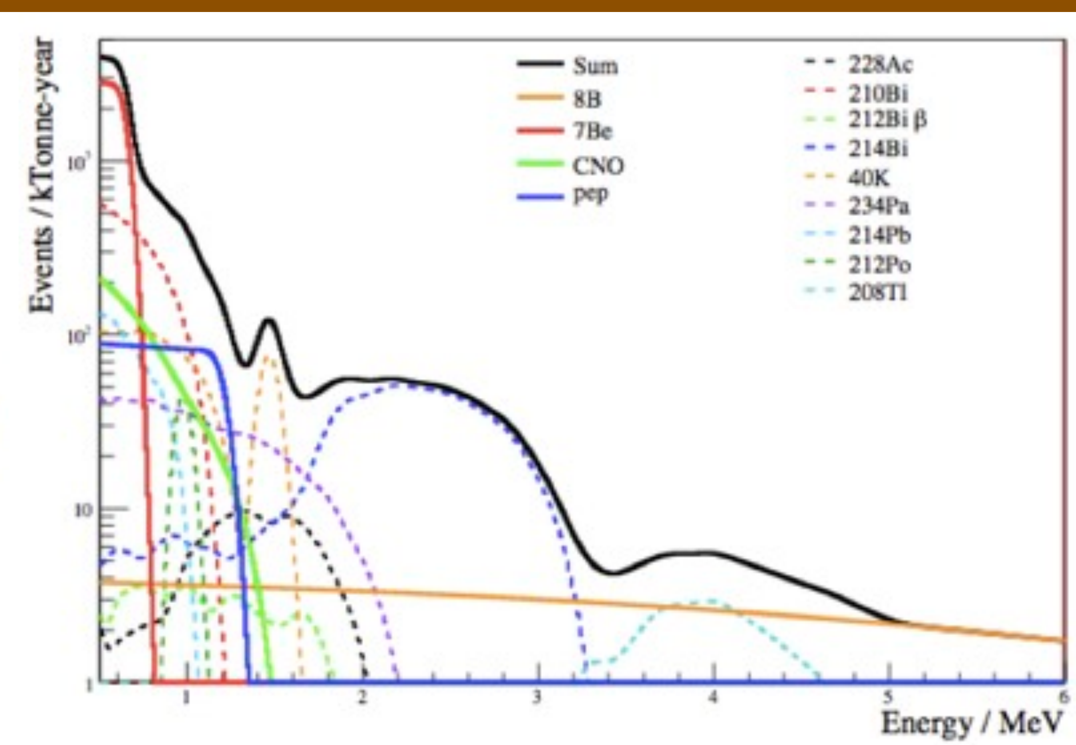
PPO

Solar Neutrinos

- Measurement of pep, CNO, and pp fluxes
- Precision measurement of ^{8}B and ^{7}Be fluxes

Phys. Lett B, 594.347, 2004

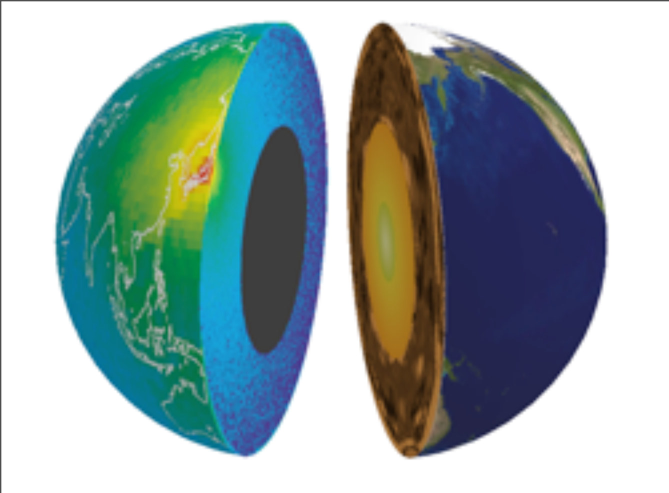




Probe Transition Region from Vacuum to Matter-dominated neutrino oscillations

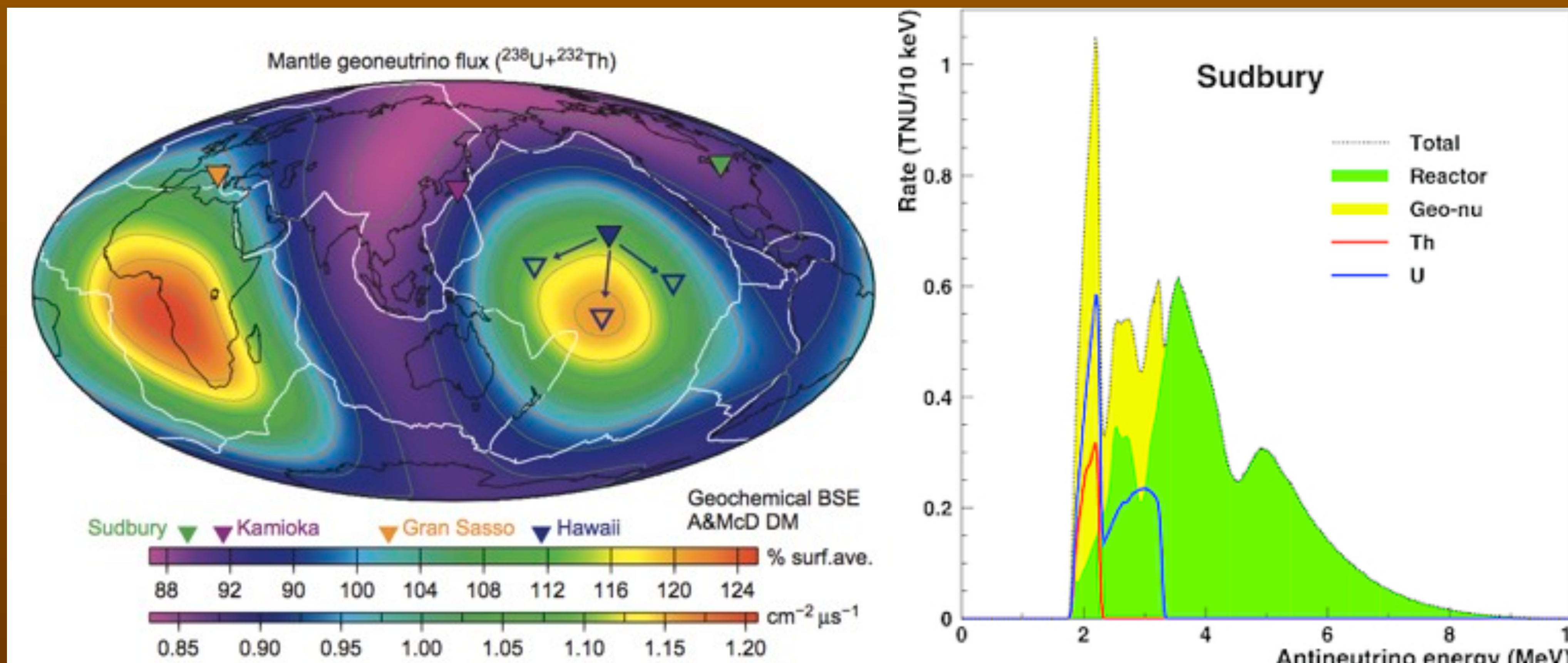
Assuming Borexino level Backgrounds:

	1 year	2 years
pep	9.1%	6.5%
8B	7.5%	5.4%
7Be	4%	2.8%
pp	A few %	
CNO	~15%	



Geo Neutrinos

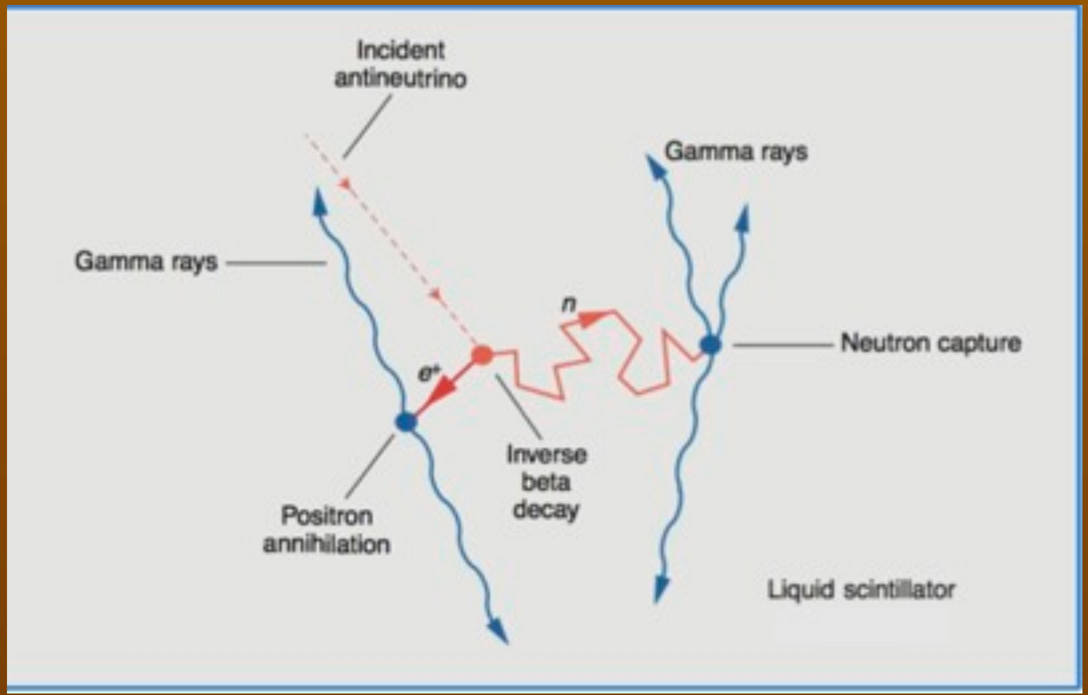
Earth Planet. Sci. Lett 361.356 2013



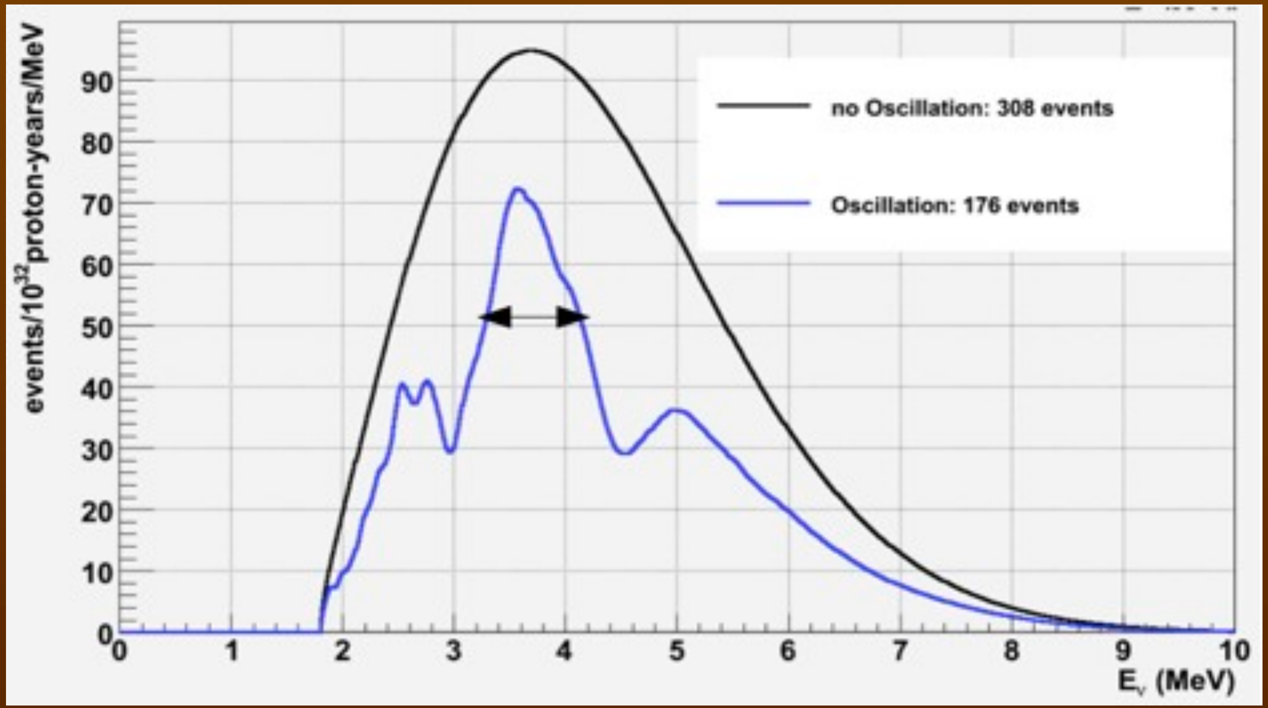
Rev. Geophys. 50:RG3007 2012

- 1/2 of anti-neutrino signal in SNO+
- Well-studied local crust composition

Reactor anti-neutrinos

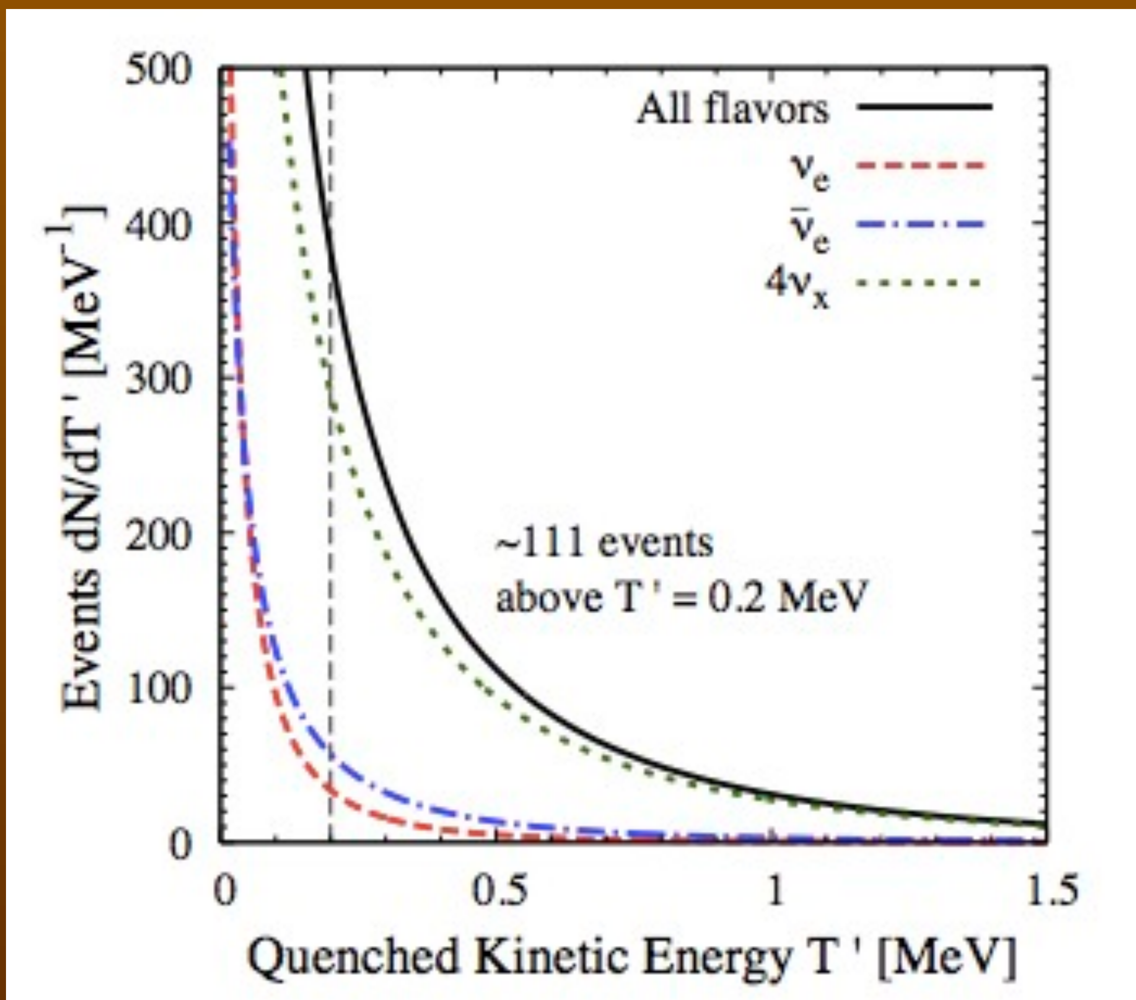


- 90 events / yr
- Two baselines give shape which provides sensitivity to Δm_{21}^2



Friday, August 9, 13

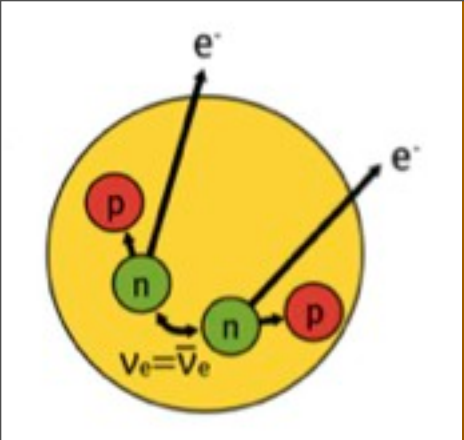
Supernova Neutrinos



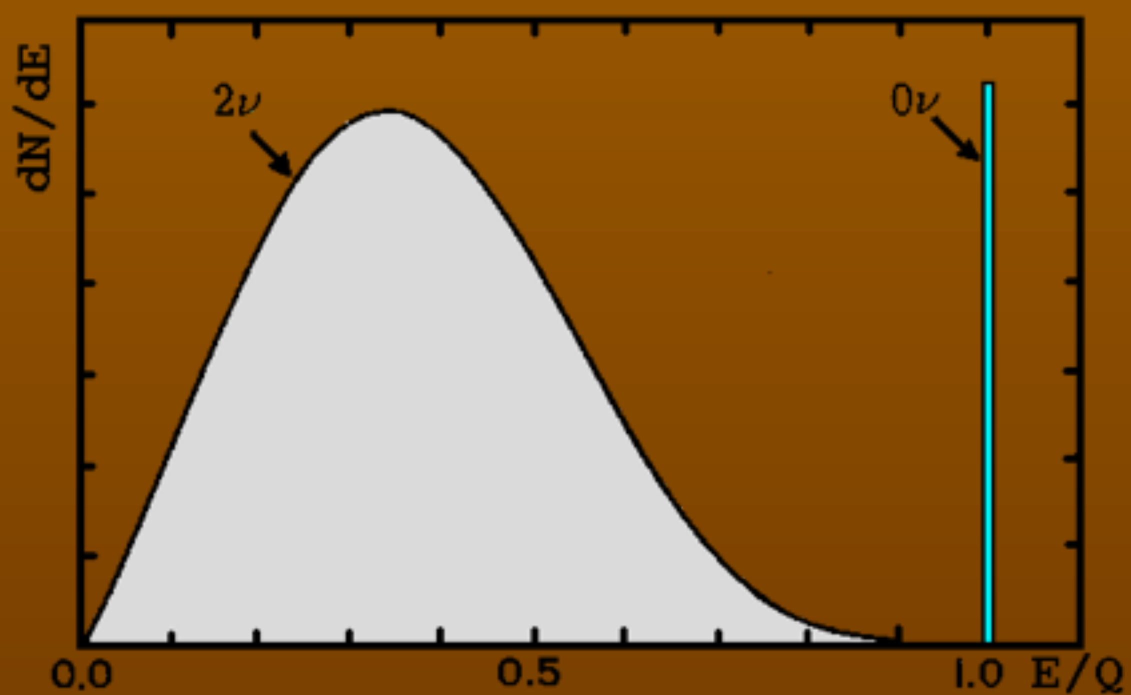
Dasgupta, Beacom Phys.Rev.D83:113006,2011

111 ν-p Events for a 3 x 10^{53} erg supernova at 10 kpc. (ν+C can add a few events

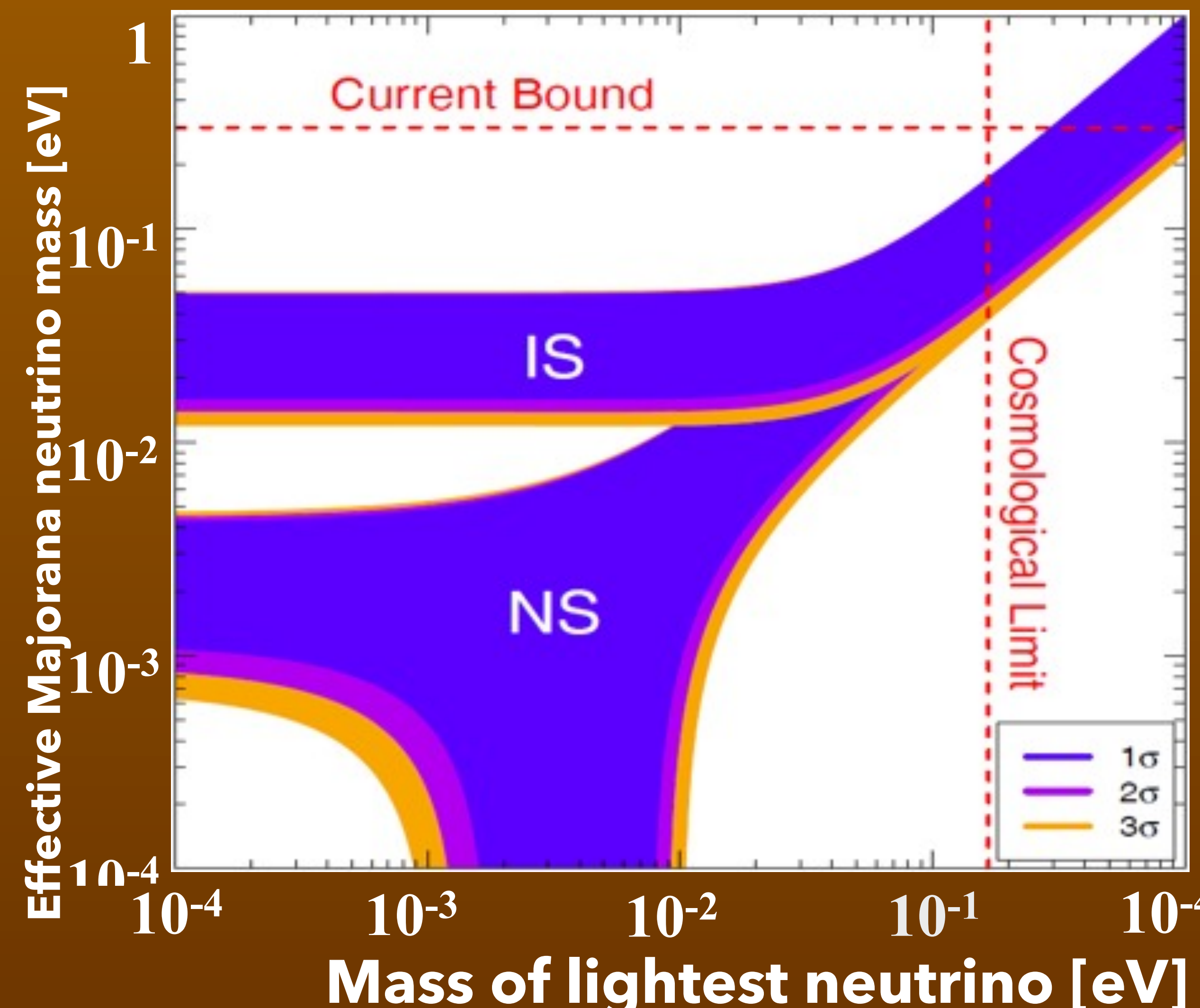
Friday, August 9, 13



Neutrinoless double beta decay

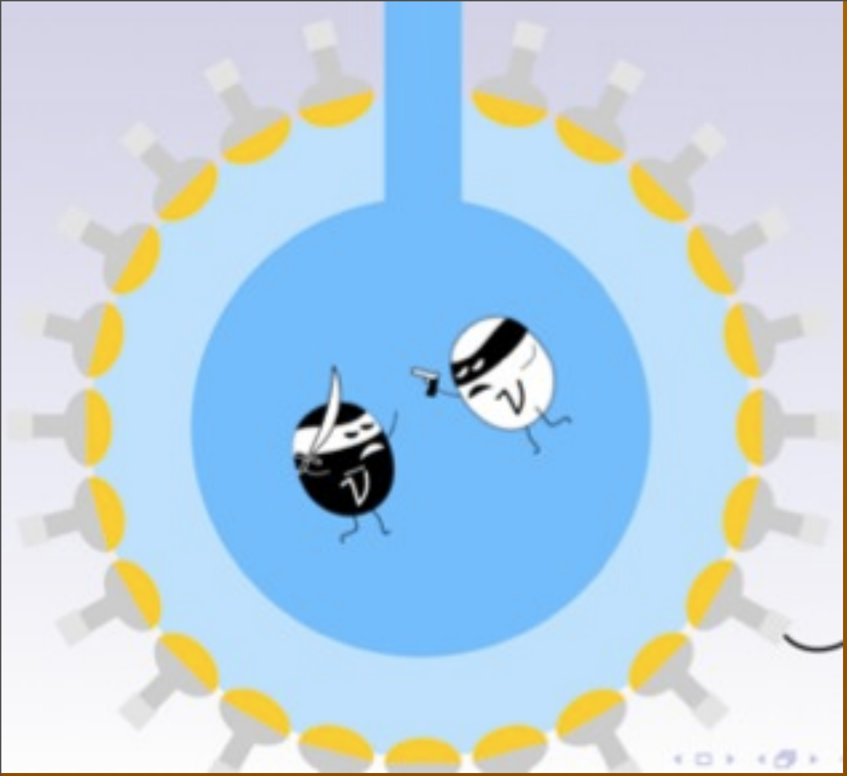


- Neutrinos: Majorana or Dirac?
- Absolute Mass Scale
- CP violating Majorana Phase important for Leptogenesis



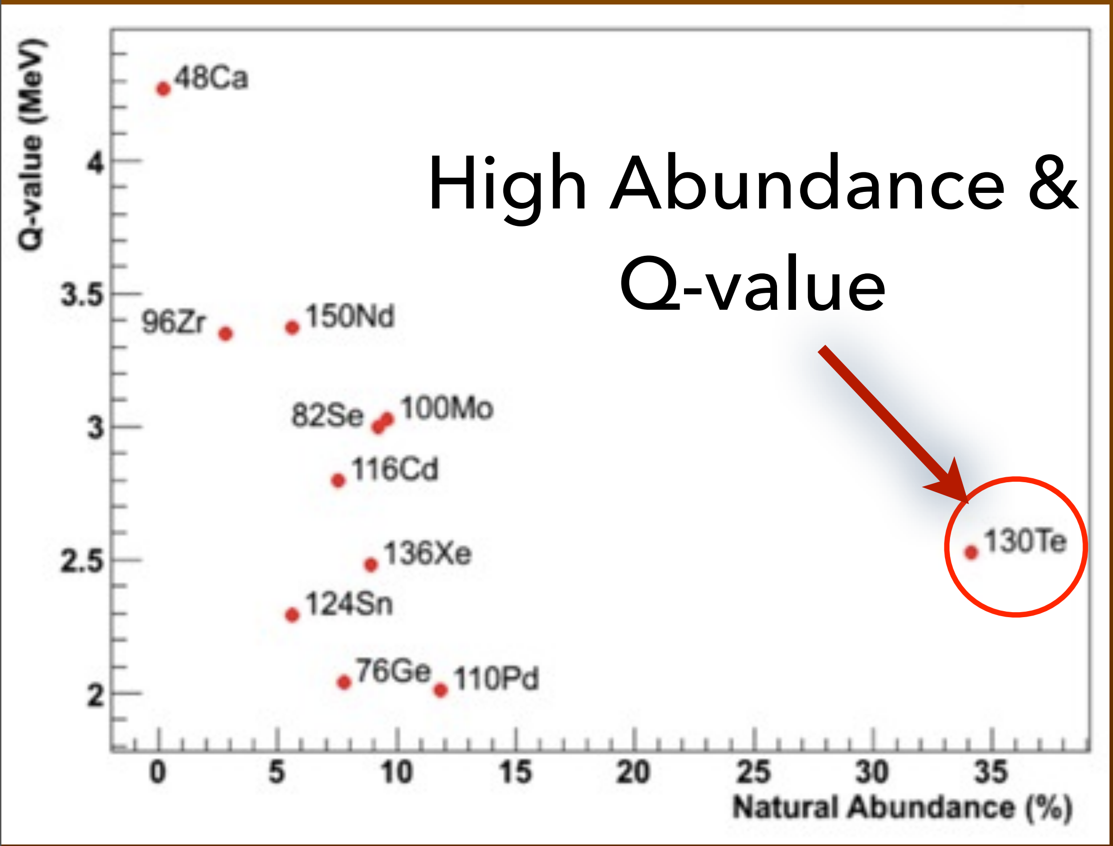
Effective Majorana neutrino mass:

$$< m_{ee} >= \left| \sum_i |U_{ei}|^2 e^{i\beta_i} m_i \right|$$

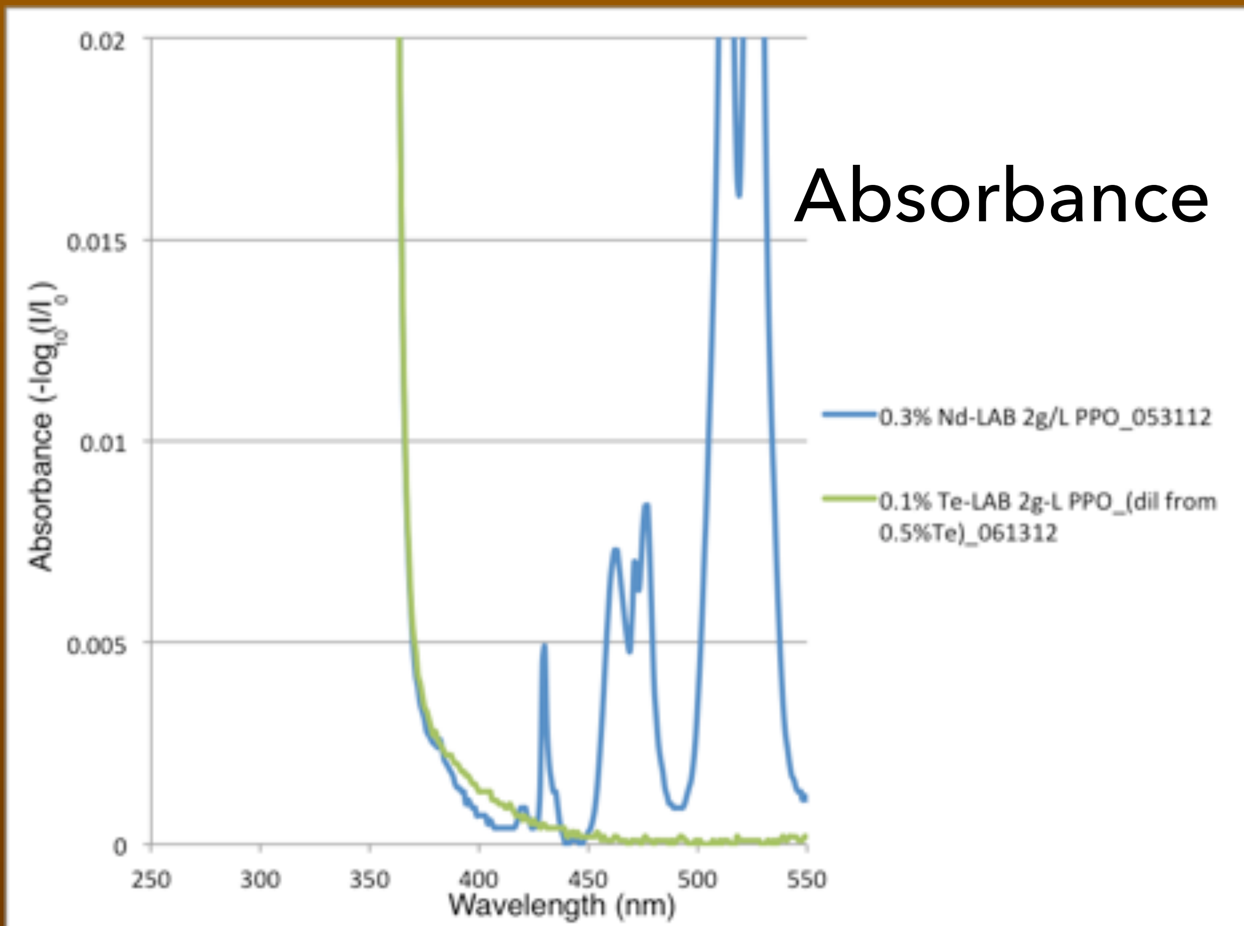


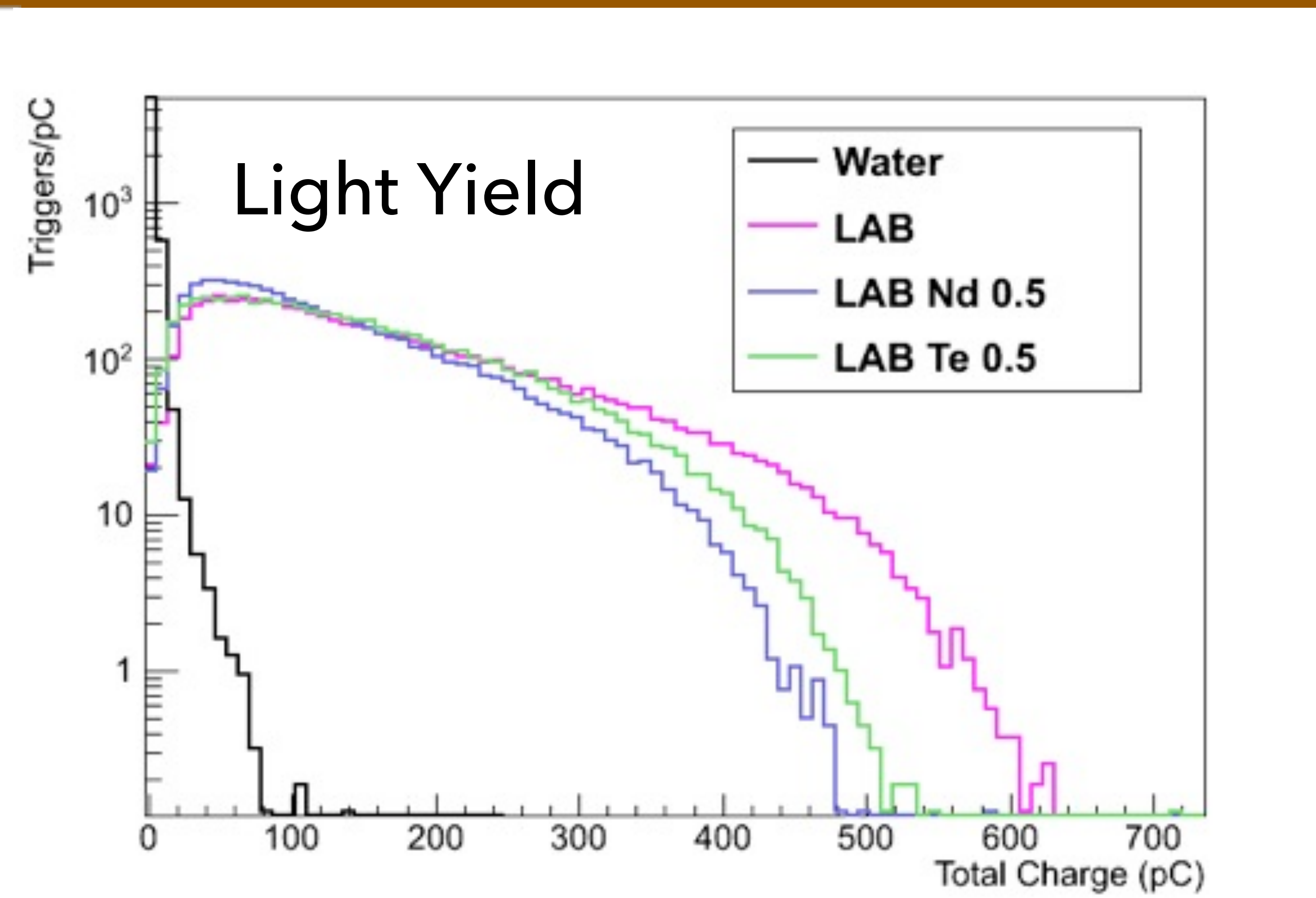
0νββ in SNO+ with ^{130}Te

- Load ~2.3 tons of natural Te in 780 t of LAB liquid scintillator.
- 34.1% ^{130}Te isotopic abundance: no need to enrich
- Large active mass of LAB scintillator allows fiducialization
- Large mass, spectral fitting, low inherent backgrounds, and precise timing compensate for poor energy resolution
- Demonstrated removal of cosmogenic backgrounds
- Can be loaded in scintillator to percent level concentrations



Te-loaded LAB Optical Properties and Backgrounds

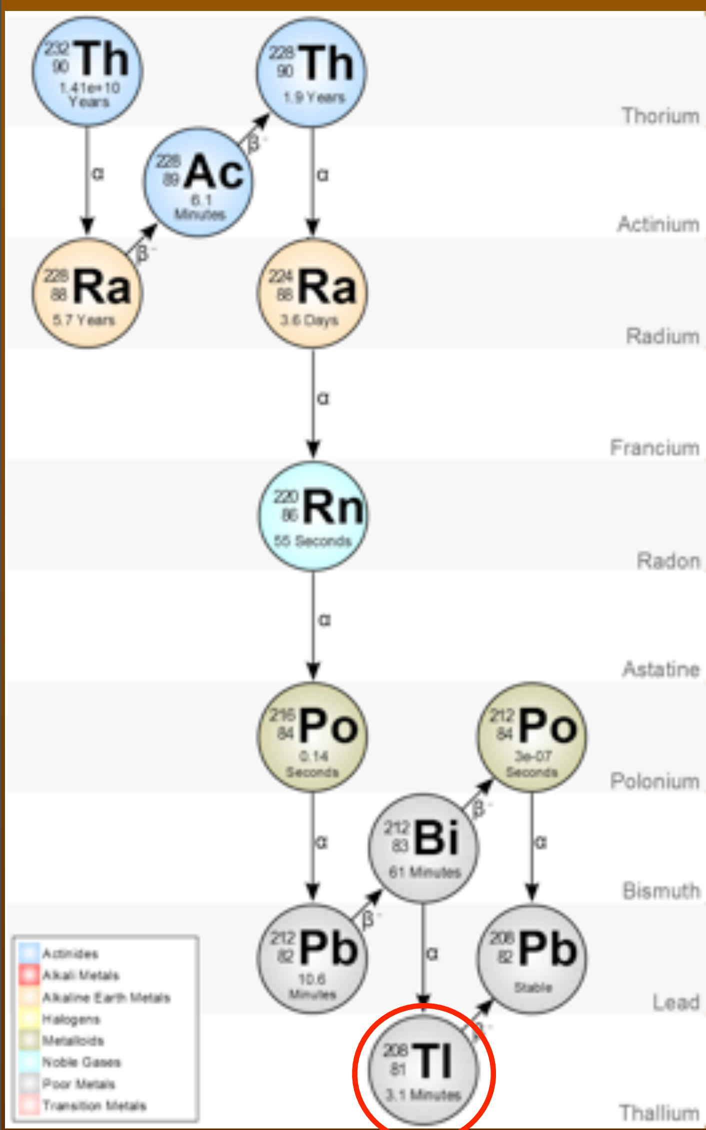




- **2νββ:** Intrinsic Background
- **⁸B Solar:** Irreducible
- **Cosmogenic Backgrounds:** Demonstrated reduction to negligible levels

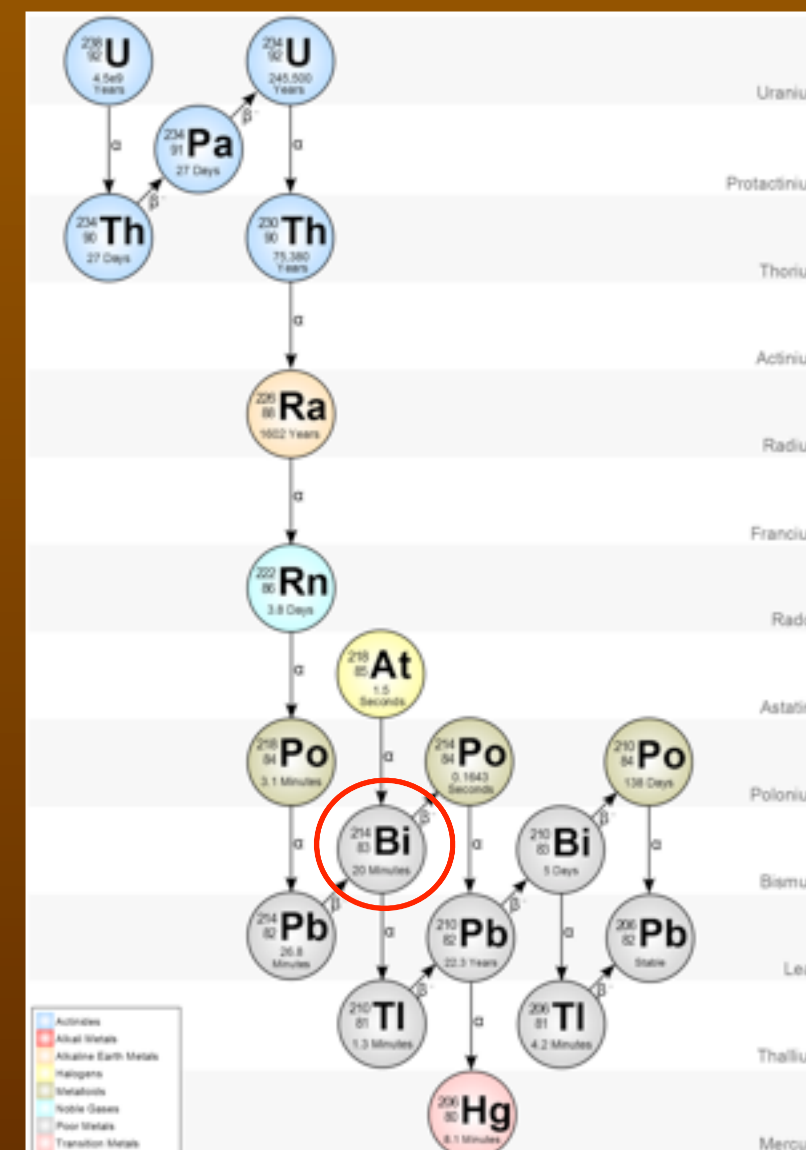
- Te loading stable over time
- High light yield (~9800 photons/MeV)
- Optically clear; less absorption than Nd-loading
- Candidate wavelength shifters under investigation

SNO+ Backgrounds - Cont



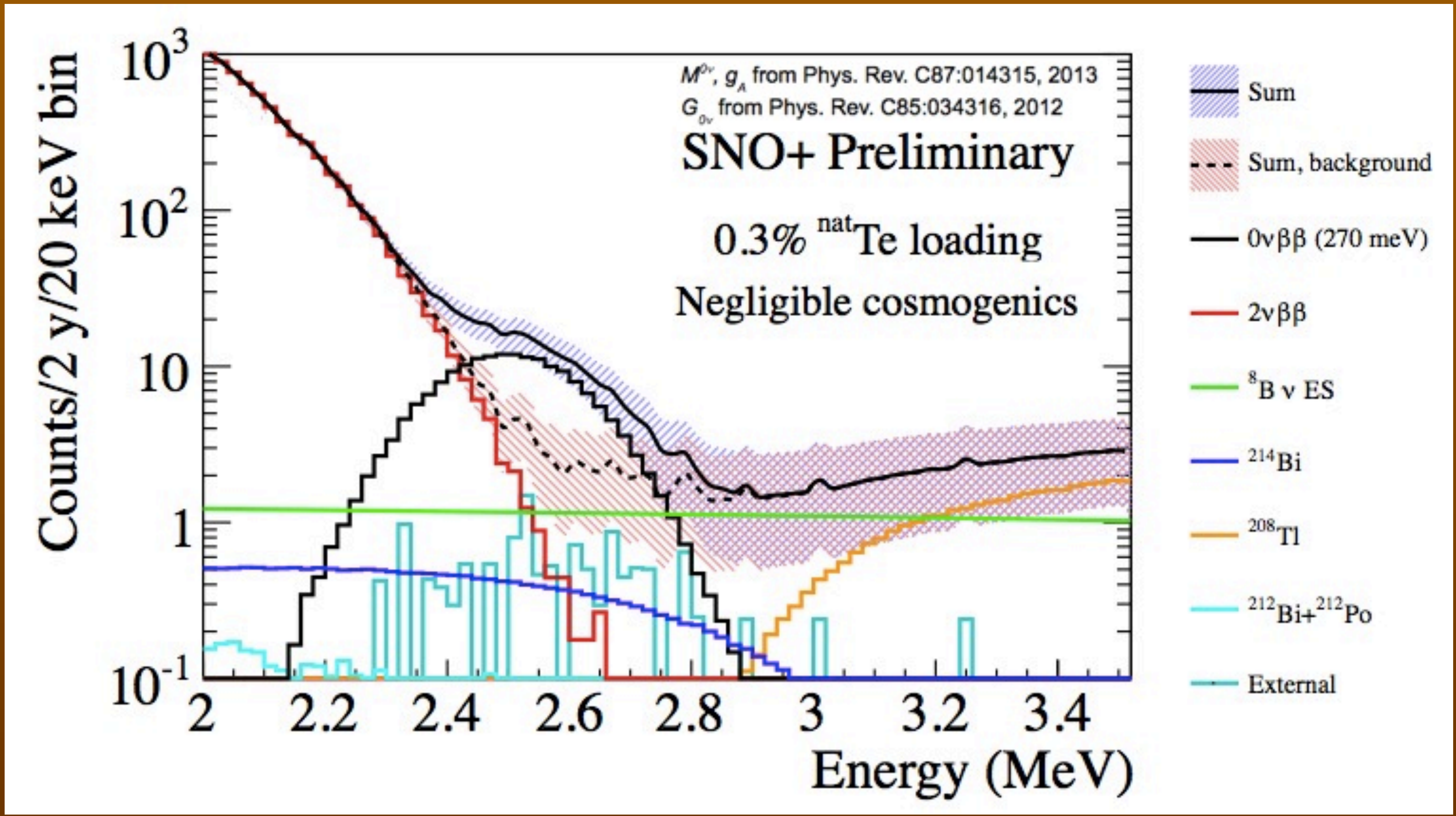
Thorium Chain

- Target Purity of Scintillator: 10^{-14} g_U/g_{Te} and 10^{-15} g_{Th}/g_{Te}
- ^{214}Bi - ^{214}Po β /α coincidence tagging reduces by 99.99%
- ^{212}Bi - ^{208}Tl α/β tagging reduces by 97%.
- Different U/Th concentrations for "External" Backgrounds (U/Th in AV, Water Shielding, PMT glass)
- External Backgrounds minimized by self-shielding of scintillator
- Dominant backgrounds don't scale with Te mass



Uranium Chain

Expected SNO+ Energy Spectrum

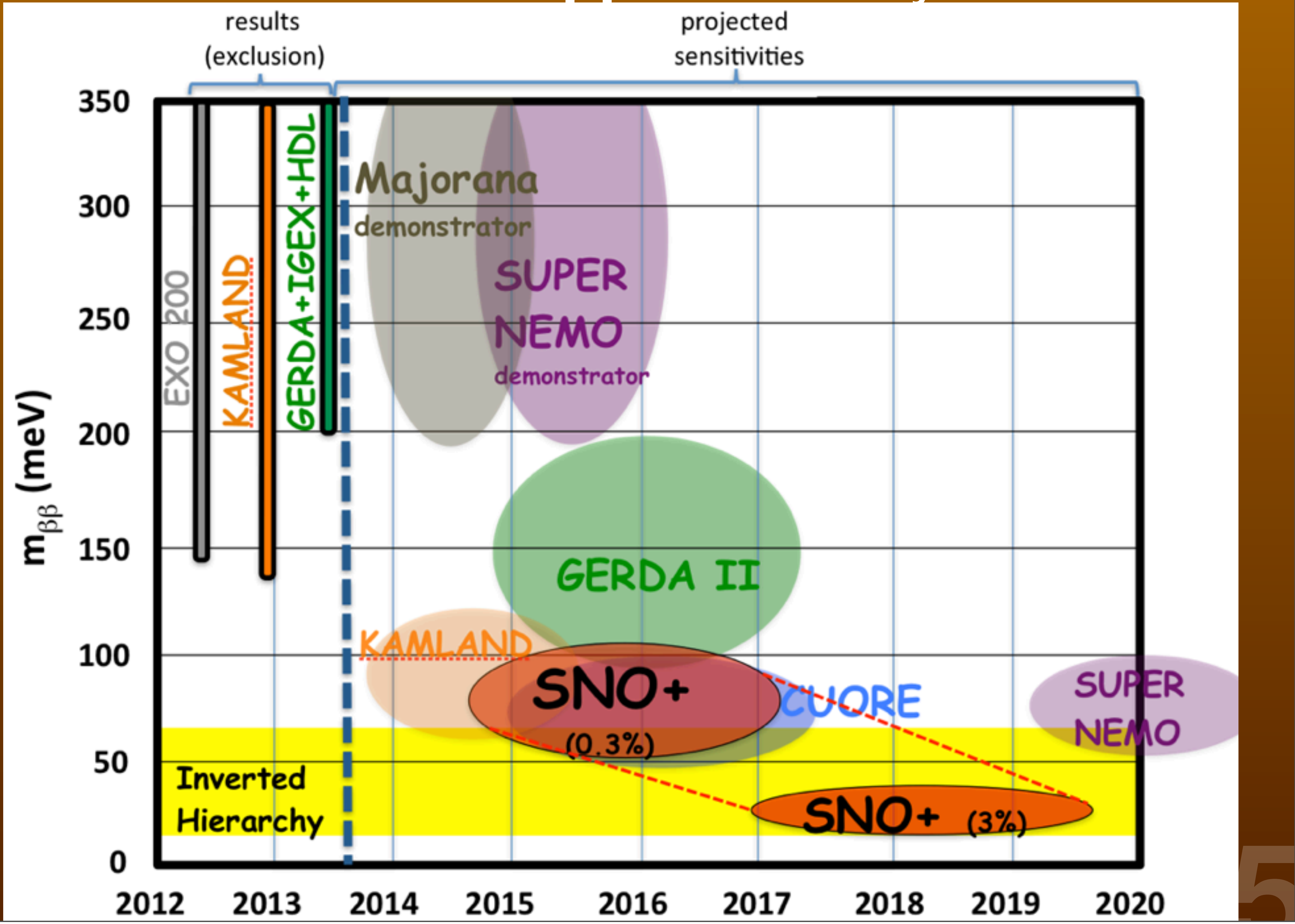


Assumptions:

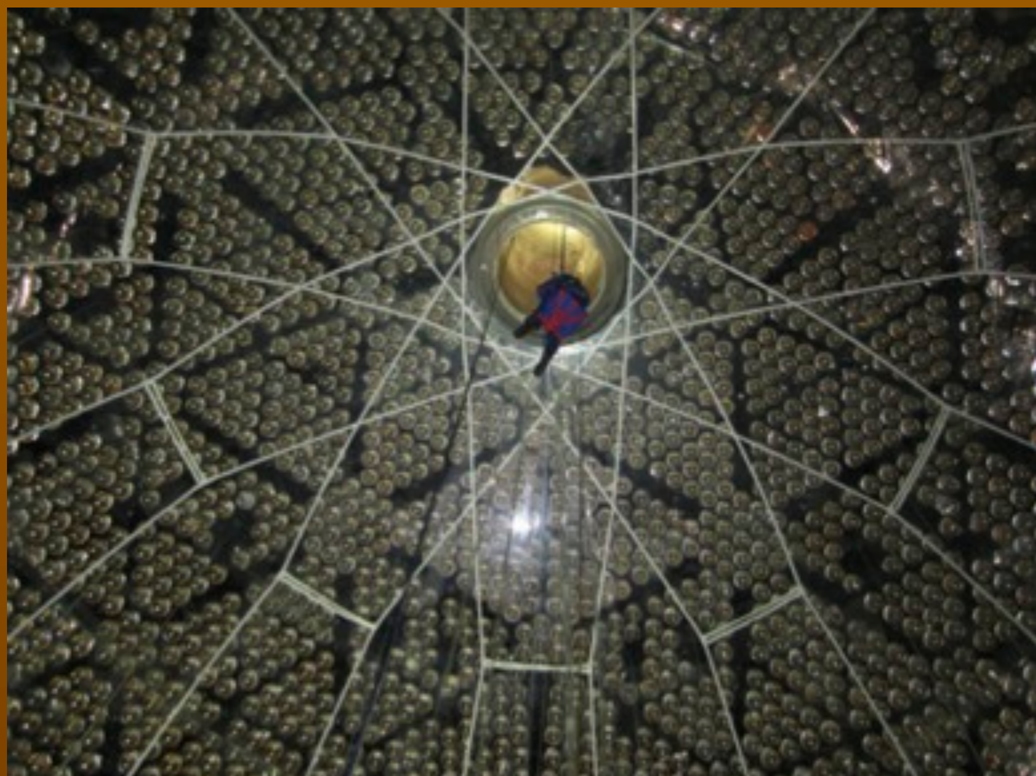
3.5 m (20%) fiducial volume cut
2 year livetime
99.99% efficient ^{214}Bi tag
97% efficient internal ^{208}Tl tag
100% reconstruction efficiency
Factor 200 reduction ^{212} Bi

$m_{\beta\beta}$=270 meV
no systematic uncertainties
Te cocktail radioactivity SNO H_2O levels
Acrylic and PMT radioactivity at SNO levels

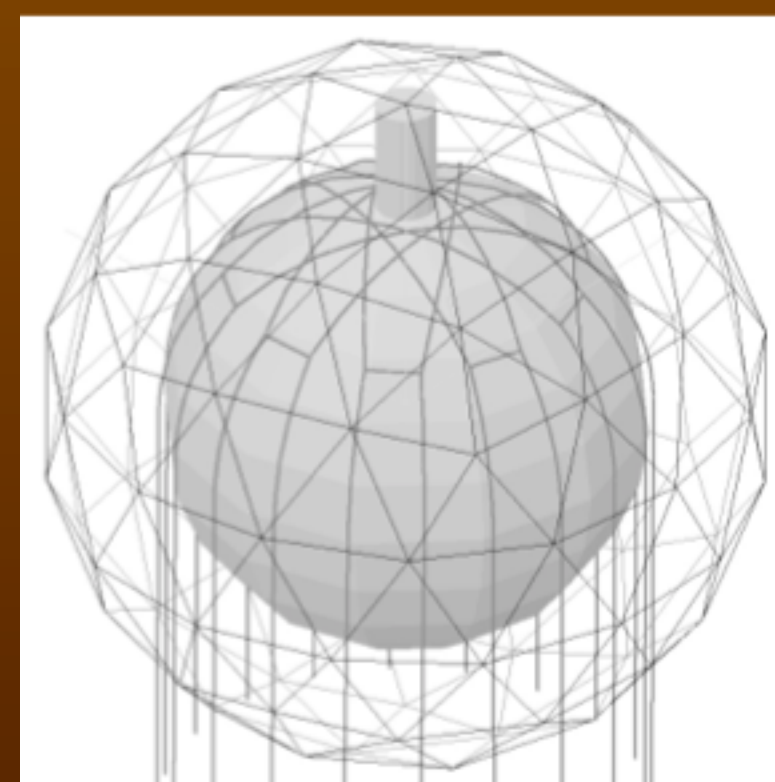
SNO+ 0νββ Sensitivity



Changes in SNO+: Rope Net



- Liquid Scintillator is less dense than Water
- Hold Down Rope system installed to hold AV in place
- Ropes pre-tensioned



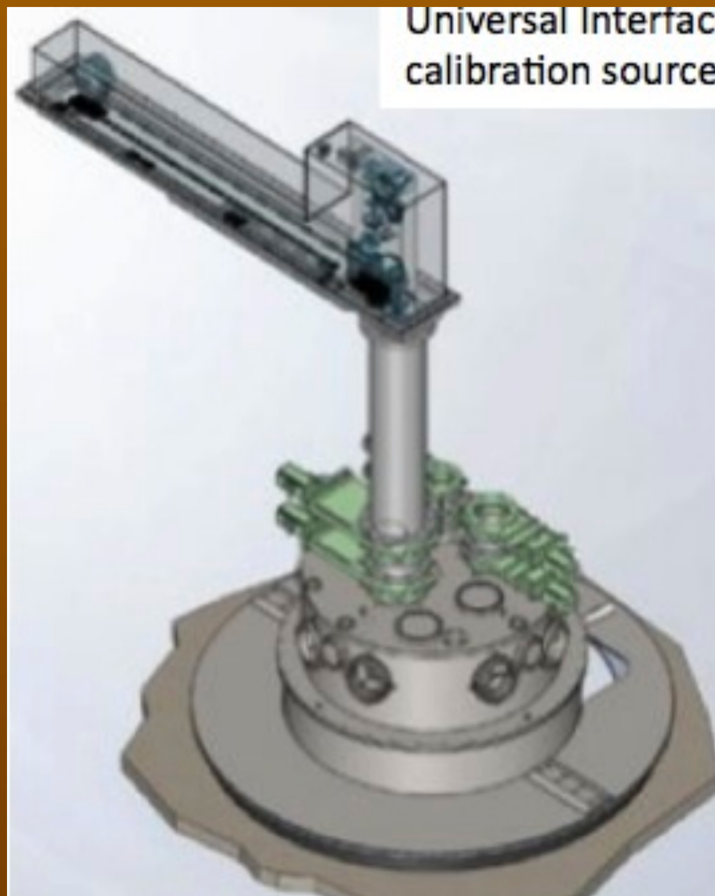
Changes in SNO+: Electronics

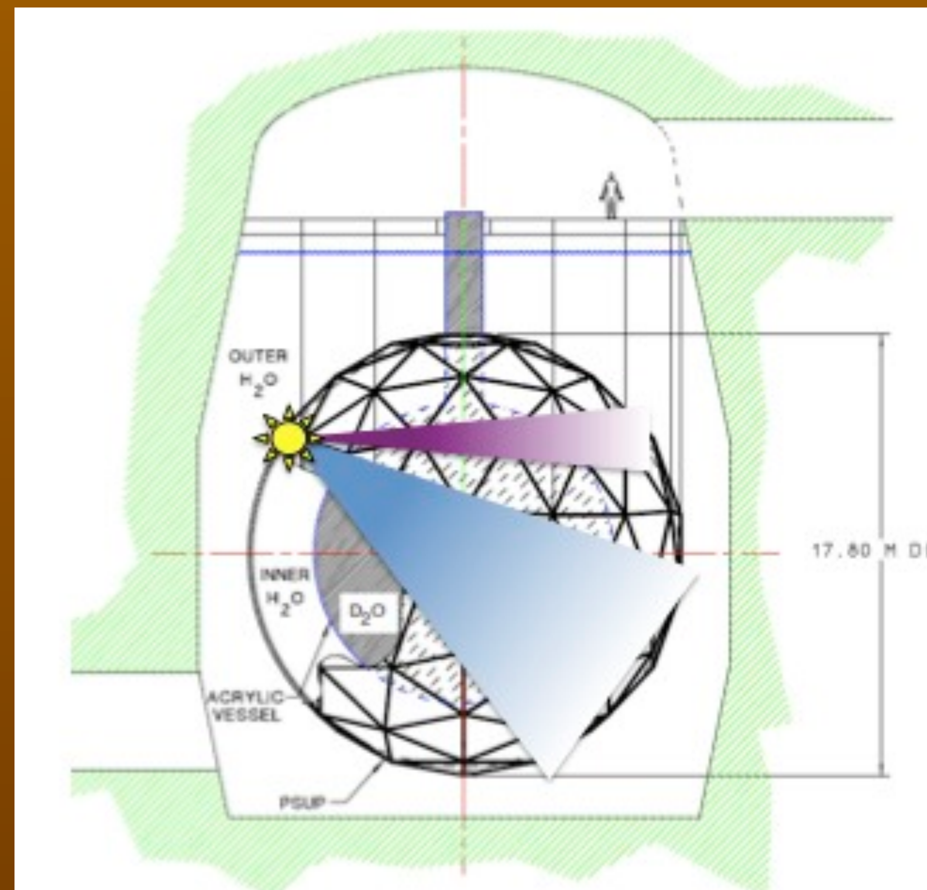
- Trigger rates dramatically increased due to liquid scintillator.
- Upgrades to the trigger, readout electronics, and DAQ have been made to handle the increased rates

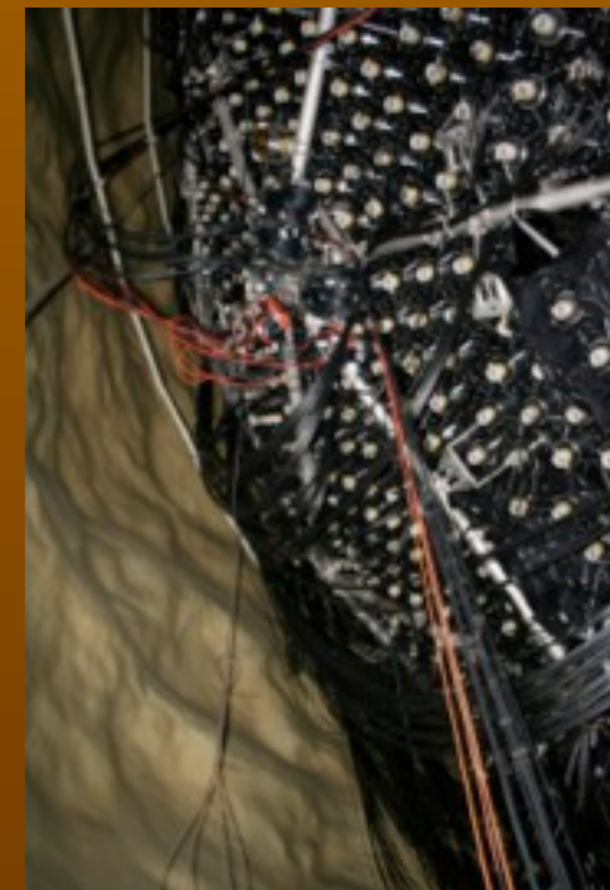
Changes in SNO+: Scintillator Purification

- LAB Liquid Scintillator Replaces Heavy Water
- New Purification systems needed.

Changes in SNO+: Calibration







- New calibration sources being developed.
- Redesigned universal interface and new cover gas system
- New in-situ light source calibration systems

Summary & Outlook

- SNO+ Now searching for 0ν double beta decay through ^{130}Te
- 0ν Sensitivity similar to CUORE and can be improved with likelihood fitting techniques and increased loading. (ongoing)
- Schedule:
    - Fall 2013: First water data, calibrations, nucleon decay
    - Early 2014: Start filling with scintillator
    - Summer 2014: Scintillator data taking
    - Fall 2014: Te isotope deployment

Backup Slides

Solar Neutrinos

- SNO+ has decided to prioritize the search for neutrinoless double beta decay
- Radon daughters have accumulated on the surface of the AV over the last few years in a significant way. If these leach into the scintillator, the purification system has the capability to remove them.
- However, depending on the actual leach rate, that removal might be inefficient and the 210Bi levels in the scintillator too high for a pep/CNO solar neutrino measurement without further mitigation
- Mitigation could include enhancing online scintillator purification, draining the detector and sanding the AV surface to remove the radon daughters, or deploying a bag.
- Neutrinoless double beta decay and the 8B solar neutrino measurements are not affected by these backgrounds.

0ν sensitivity: Counting method

arXiv:1109.0494

Efficiency

$$\hat{T}_{1/2}(n_\sigma) = \frac{\log 2}{n_\sigma} N \cdot \epsilon \sqrt{\frac{M \cdot t}{b \cdot \delta E}} \cdot f(\delta E)$$

Confidence level

Number of ^{130}Te nuclei

Backgrounds

~Energy Resolution

- Two classes of Backgrounds: One that scales with mass of ^{130}Te (b*M) and one class that's independent (c).

- δE Limited by loaded scintillator light yield. **Accurately Measure Intrinsic Scintillator Light Yield**

External Background Sources

External Background sources

	Mass		Activity	Decays/year
Hold-down ropes *1	222.09 kg	Bi 214	0.58 ± 0.40 [Bq/kg] *2	4.06E+06
		Tl 208	0.33 ± 0.15 [Bq/kg] *2	2.30E+06
AV	30 t	Bi 214	1.0E-12 g/g *3	1.29E+07
		Tl 208	1.0E-12 g/g *3	1.38E+06
shielding water	1555 t	Bi 214	2.1E-13 g/g *3	9.80E+07
		Tl 208	5.2E-14 g/g *3	2.87E+06
AV dust	0.1μg/cm2	Bi214	1.1E-6 g/g *4	1.20E+05
		Tl 208	5.6E-6 g/g *5	2.03E+05
PMT	9456 PMTs	238 U	100 μg / PMT *6	3.70E+11
		232 Th	100 μg / PMT *6	1.20E+11

internal backgrounds

Source	Isotope	Activity	Decays/Year
LAB Scintillator	Bi 214	1.6×10^{-17} g/g	4896
	Tl 208	6.8×10^{-18} g/g	245
Nd	Bi 214	1×10^{-15} g/g	918
	Tl 208	1×10^{-14} g/g	1078
Te	Bi 214	1×10^{-15} g/g	918
	Tl 208	1×10^{-14} g/g	245

2νββ Nd: $T_{1/2} \sim 10^{19}$ y ($\sim 10^{7}$ events/year)
Te: $T_{1/2} \sim 10^{21}$ y ($\sim 10^{6}$ events/year)
Irreducible

^{8}B ν Cosmogenic Activation of Isotope