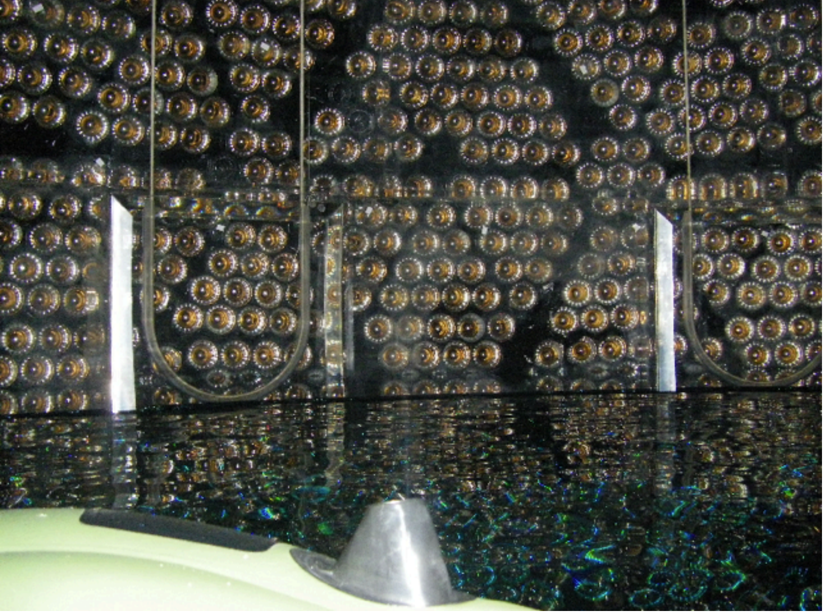


SNO+ and Future Solar Neutrino Experiments

Mark Chen

Queen's University

PHYSUN, Gran Sasso, October 5, 2010

Outline of this Talk

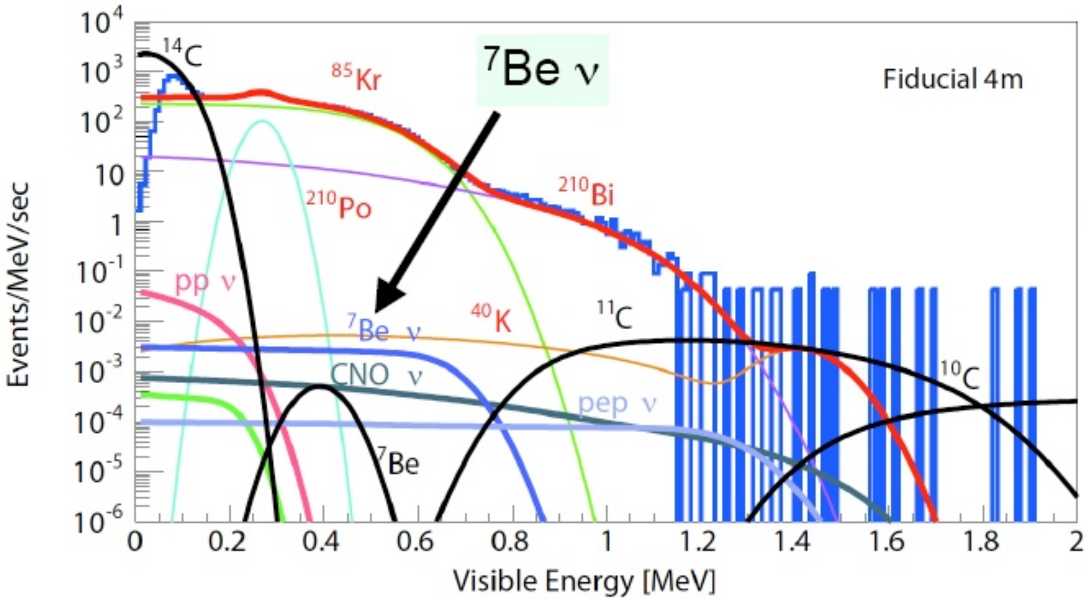
- a brief look at future solar neutrino experiments
  - and what new physics they will explore
- SNO+ status

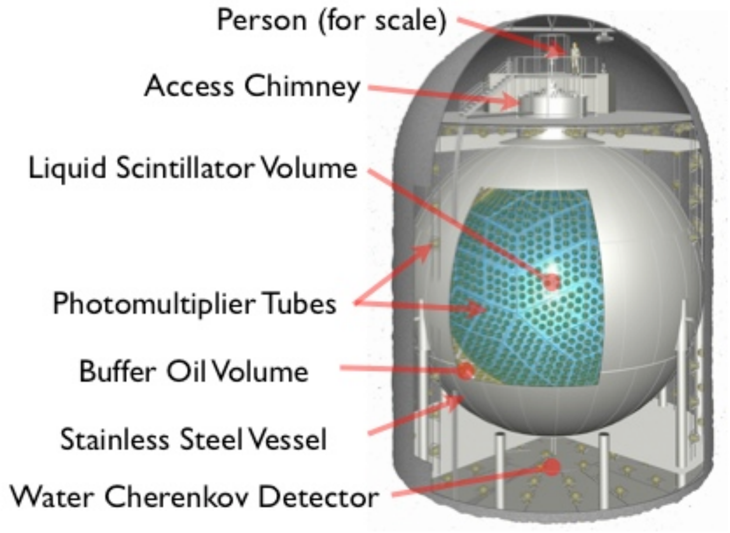
- ...to discuss future prospects, I will start with an examination of recent results and activities

- Note: I have borrowed figures and material from many experiments and many people. Thanks to all of them!

KamLAND

- 1000 tons (80% dodecane, 20% pseudocumene)
- 1880 PMTs (17" and 20")
  - 34% photocathode coverage
- singles spectrum shows ^{210}Pb and ^{85}Kr and also ^{40}K contamination





must purify liquid scintillator to achieve solar ν sensitivity

goal: 10^5 to 10^6 reduction

KamLAND information from LRT Workshop presentation in Sudbury, August 29, 2010

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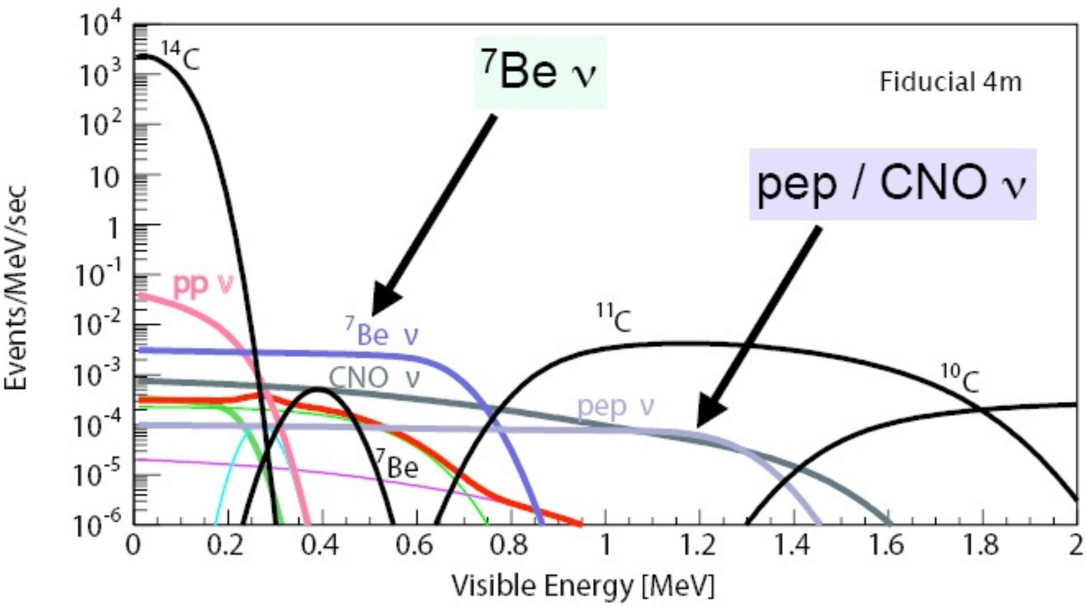

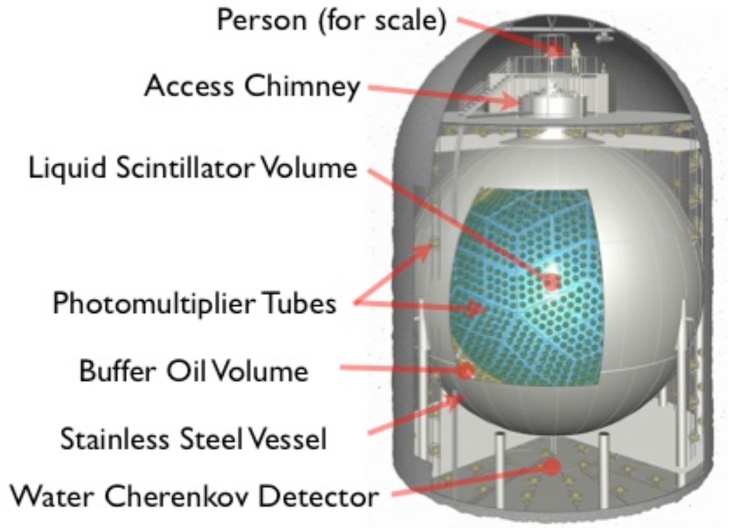

must purify liquid scintillator to achieve solar ν sensitivity

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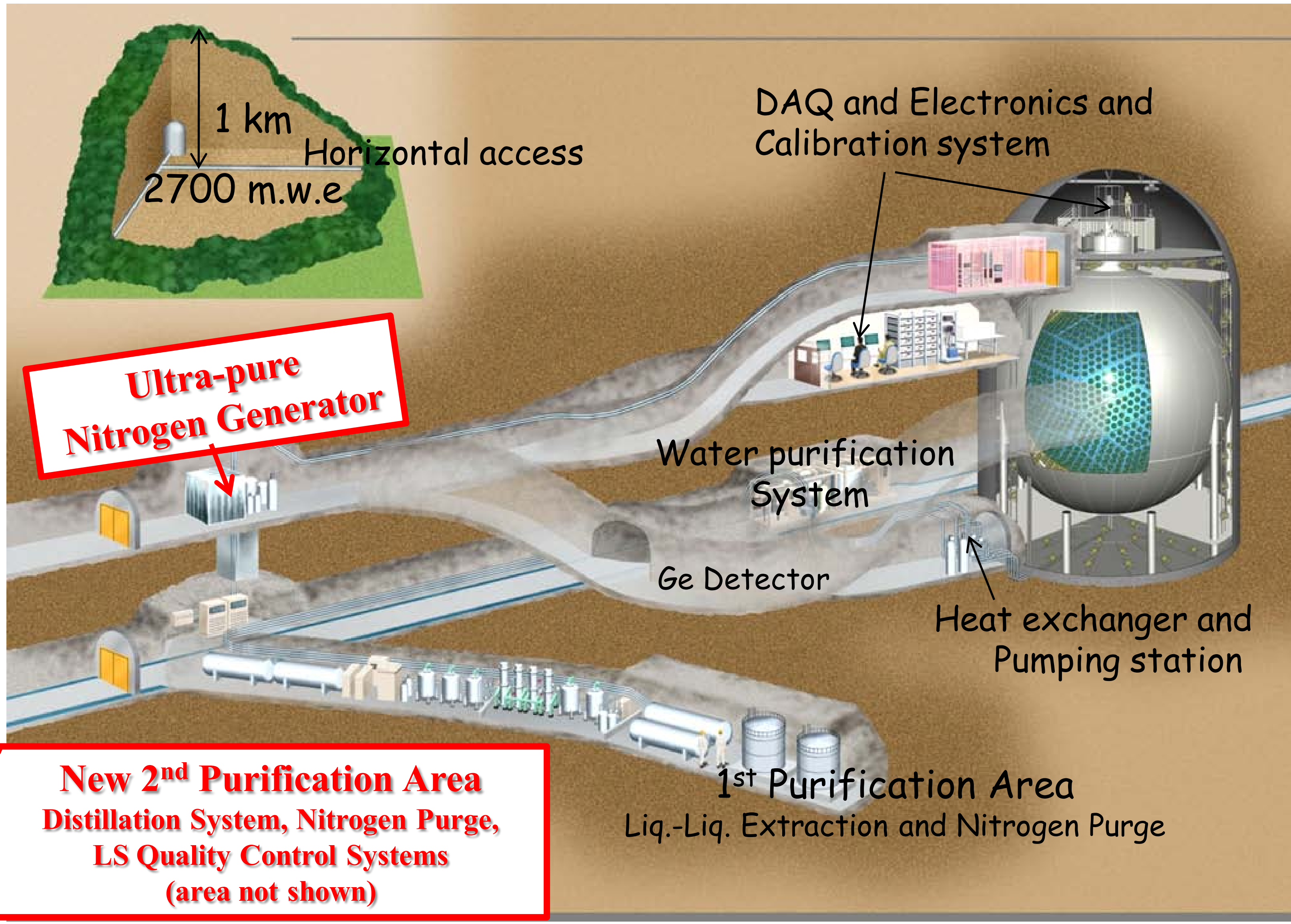
KamLAND Purification Layout

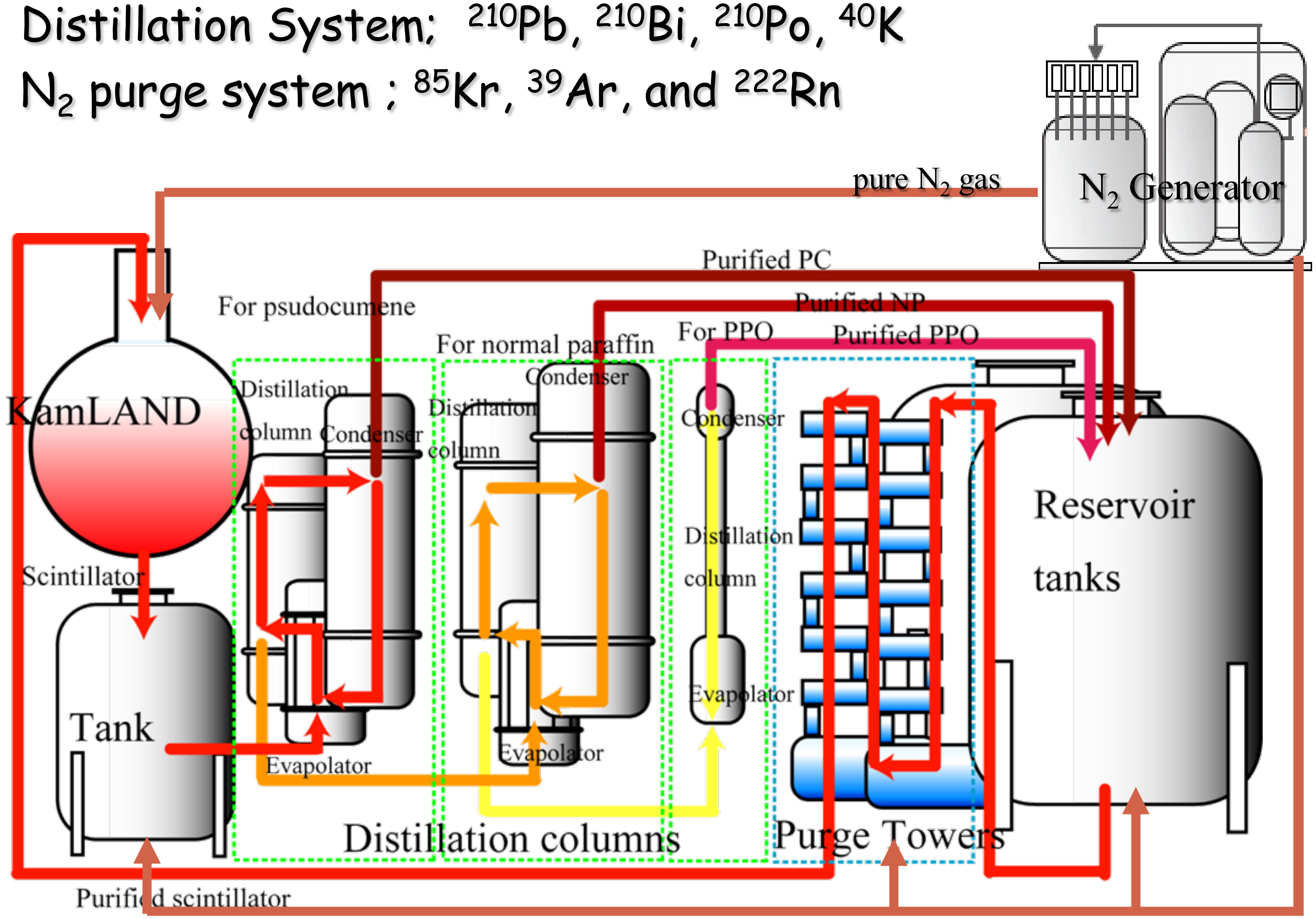


New 2nd Purification Area
Distillation System, Nitrogen Purge, LS Quality Control Systems (area not shown)

KamLAND Purification Schematic

Concept of New Purification System

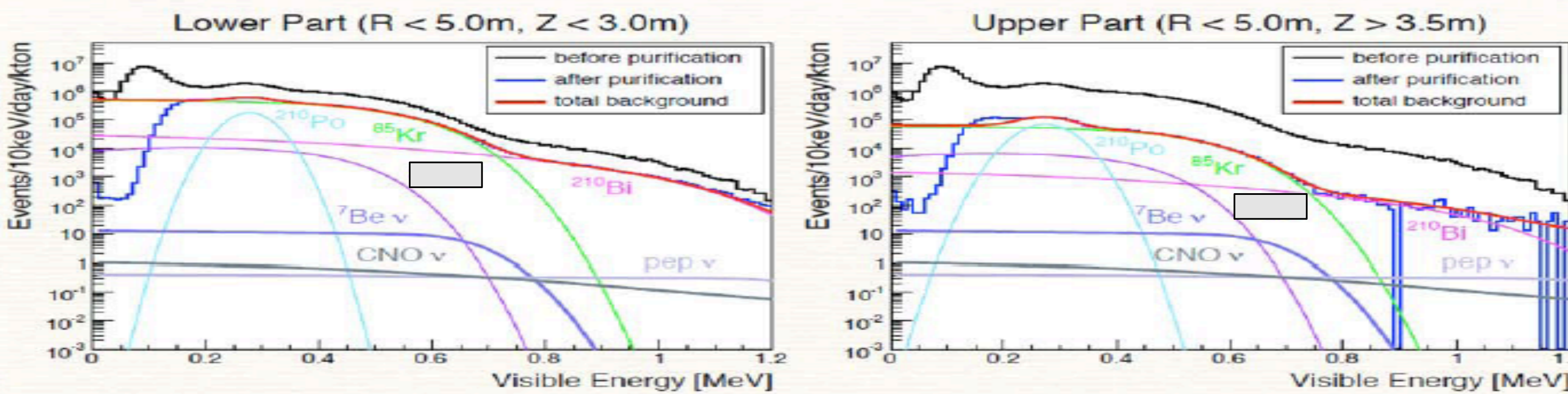
- **Online purification** with the flow rate ~ 1 m^3/h.
- Distillation System; ^{210}Pb, ^{210}Bi, ^{210}Po, ^{40}K
- N_2 purge system ; ^{85}Kr, ^{39}Ar, and ^{222}Rn



KamLAND Purification Status

- 1st purification campaign: 2007-05-12 to 2007-08-01
  - purified 1500 m^3, some reduction seen

	^{210}Bi	^{85}Kr	^{39}Ar	^{210}Po	^{40}K
Before	42^{+8}_{-6}	508^{+19}_{-34}	18^{+38}_{-18}	43^{+1}_{-2}	44±4μBq/m^3
After (top) (low)	0.2±0.1 10±1	14^{+1}_{-4} 185^{+1}_{-2}	0^{+5}_{-0} 0^{+2}_{-0}	9±1 14±1	- 13±1μBq/m^3
Reduction (top) (low)	$(4.8\pm2.6)\times10^{-3}$ 0.24±0.05	$(2.8\pm0.8)\times10^{-2}$ 0.36±0.02	- -	0.21±0.03 0.33±0.03	- 0.29±0.03



- 2nd purification campaign: 2008-06-16 to 2009-02-06
  - three full volumes purified, 10^4 to 10^5 reduction seen

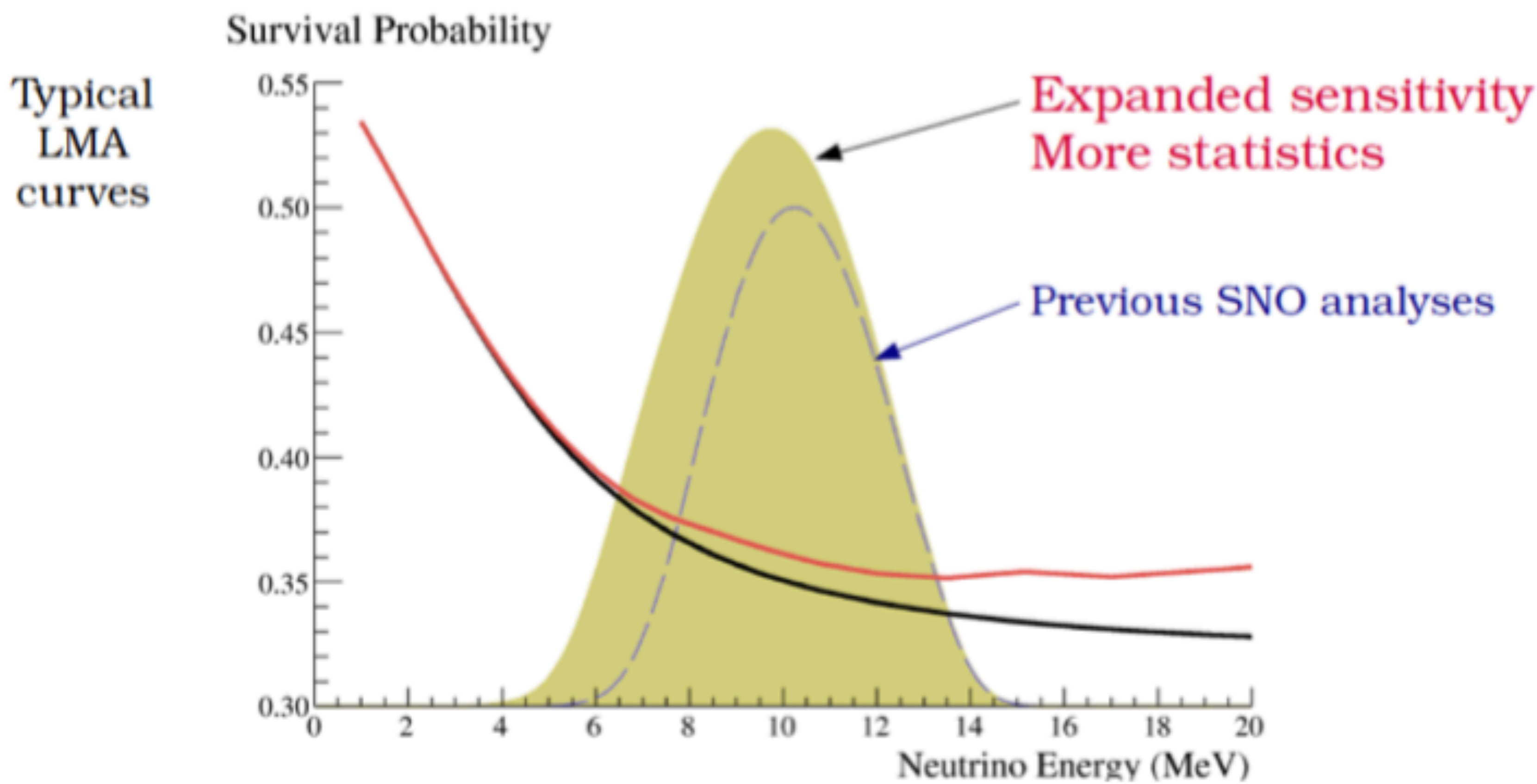
Latest SNO Results

Physical Review C **81**, 055504 (2010)

- lower energy threshold analysis (LETA)
- combined Phase I+II joint fit
  - signal extraction in each phase helps constrain the other
  - improvement is better than just simple statistical combination
- improved simulations and analysis (e.g. energy resolution is slightly better helping suppress steep background tails)
- reduced systematic uncertainties
- two different (one novel) signal extraction techniques
- 3-ν oscillation analysis

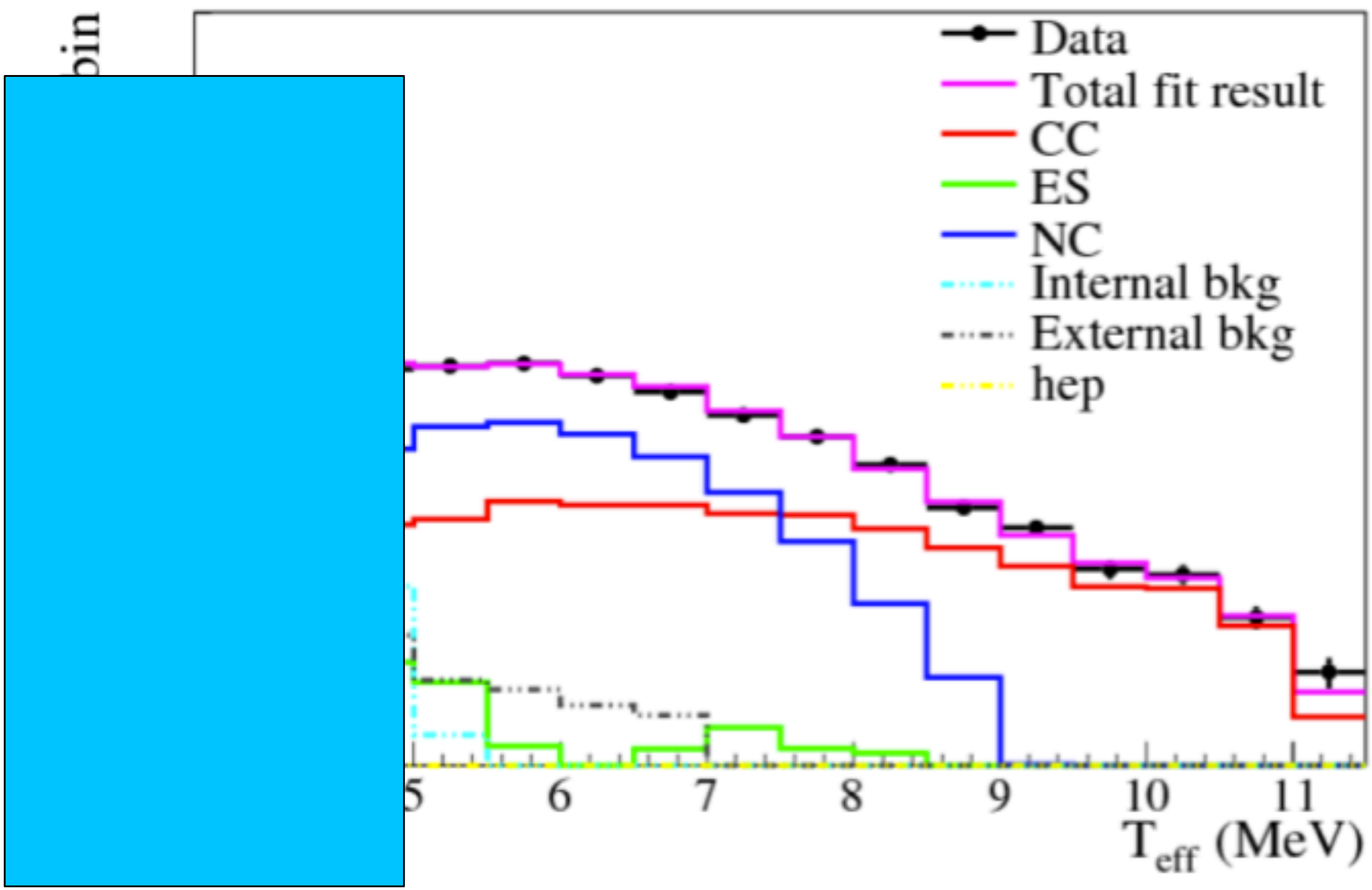
From 5 → 3.5 MeV Analysis Threshold

CC statistics



Extracted Spectrum (Signals and Background)

$\chi^2 = 13.6 / 16$ Fit Result



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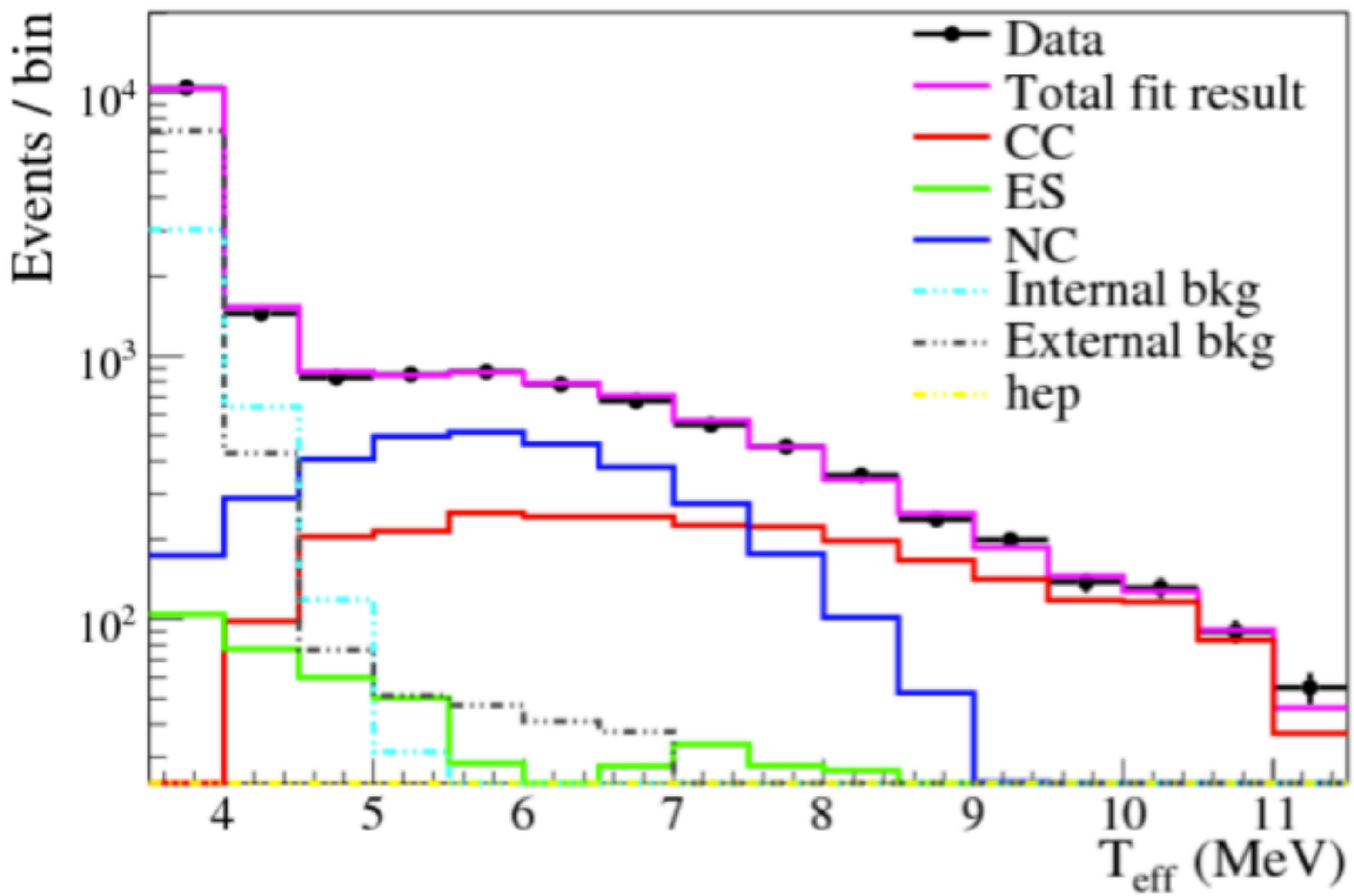

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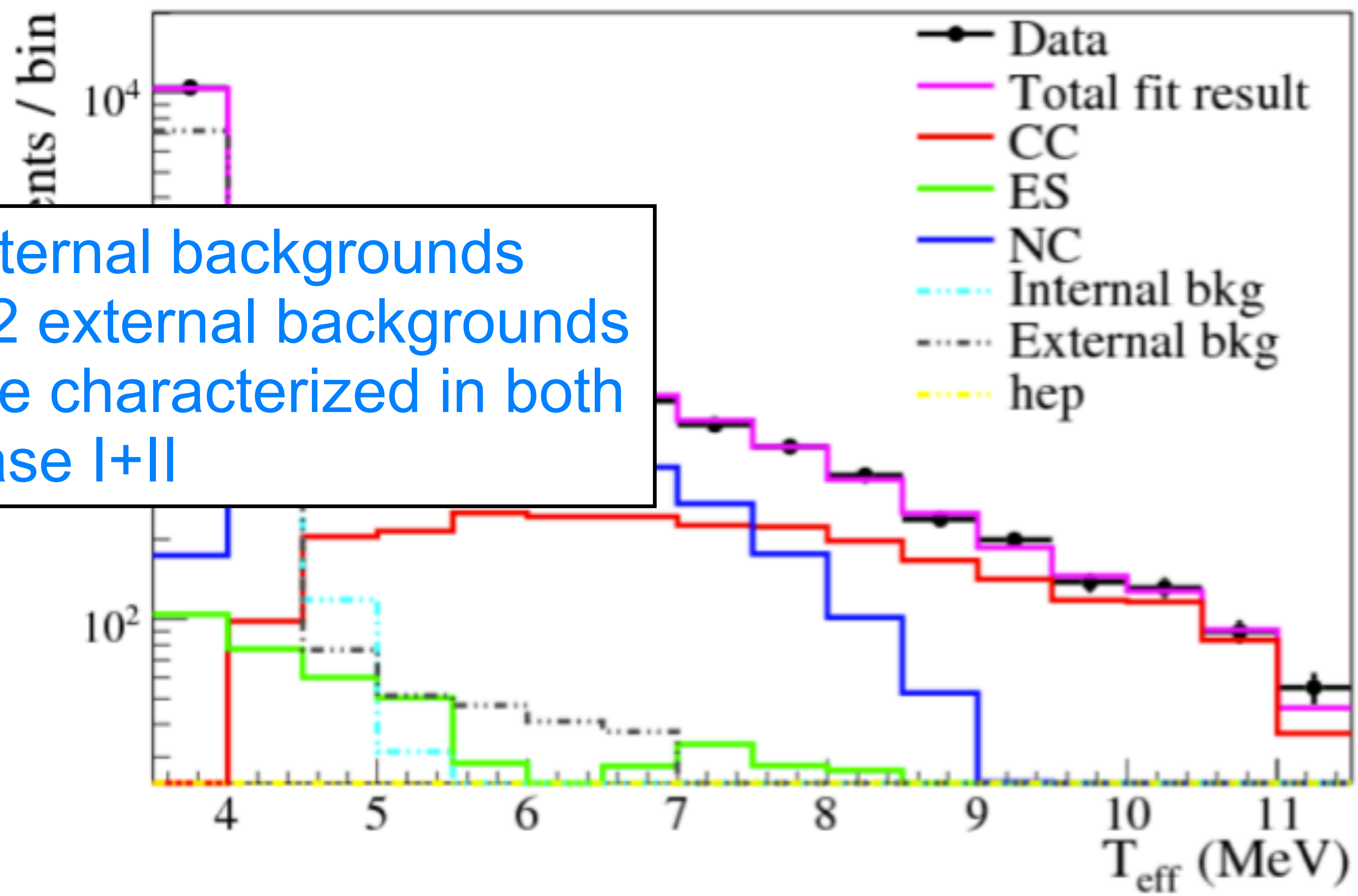
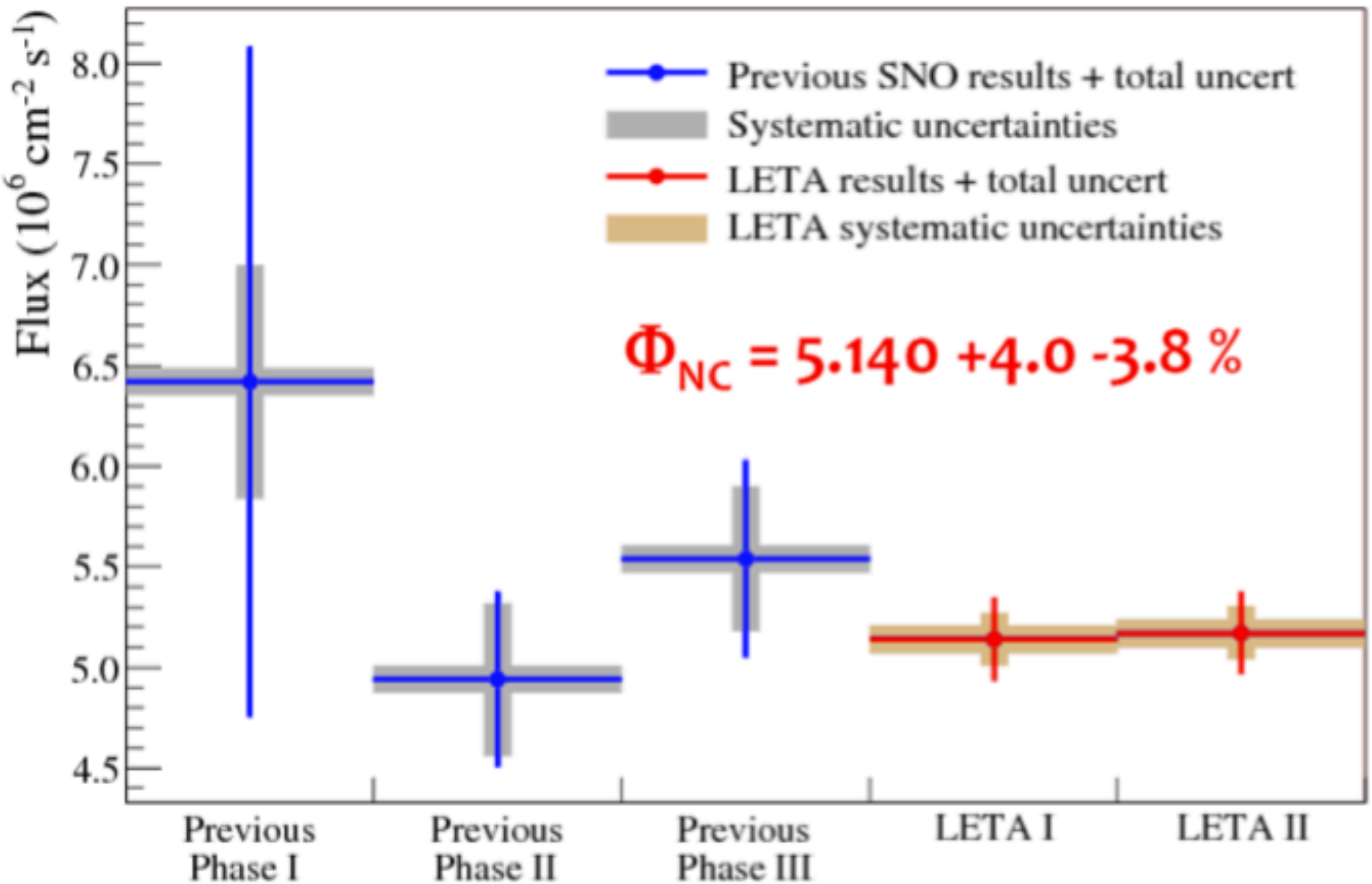


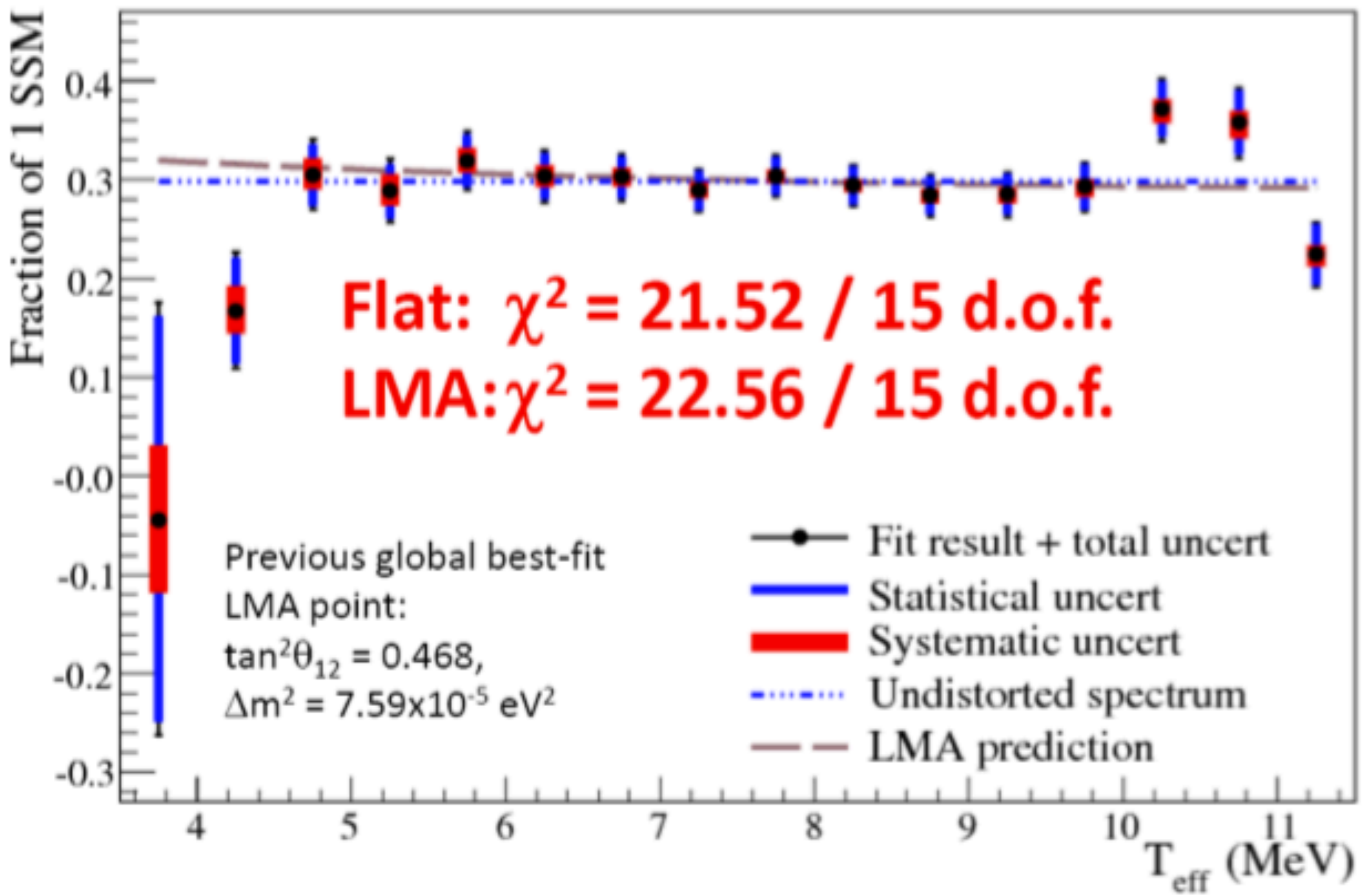
5 internal backgrounds
+ 12 external backgrounds
were characterized in both
Phase I+II

New SNO Low Energy Threshold Analysis
^{8}B Solar Neutrino Flux Measurements



Spectrum from CC Events

CC Recoil-Electron Spectrum



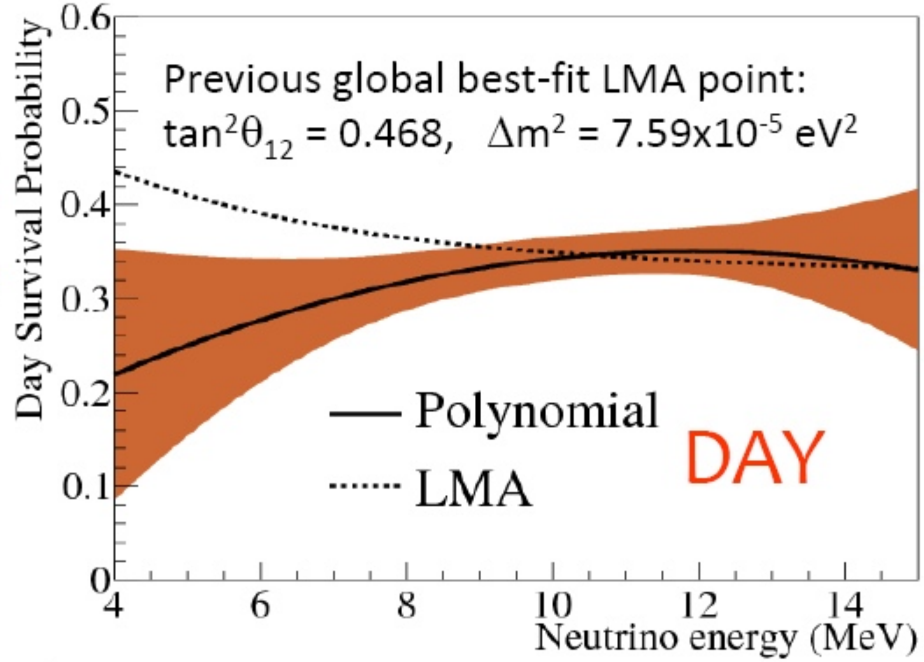
Direct Fit for Energy-Dependent Survival Probability

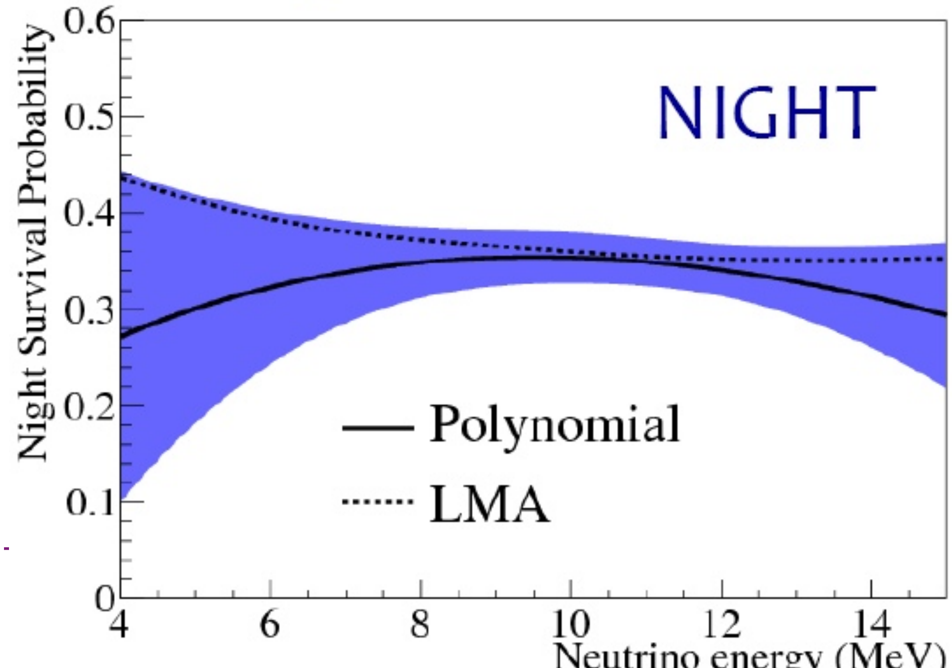
No distortion, no a/s:

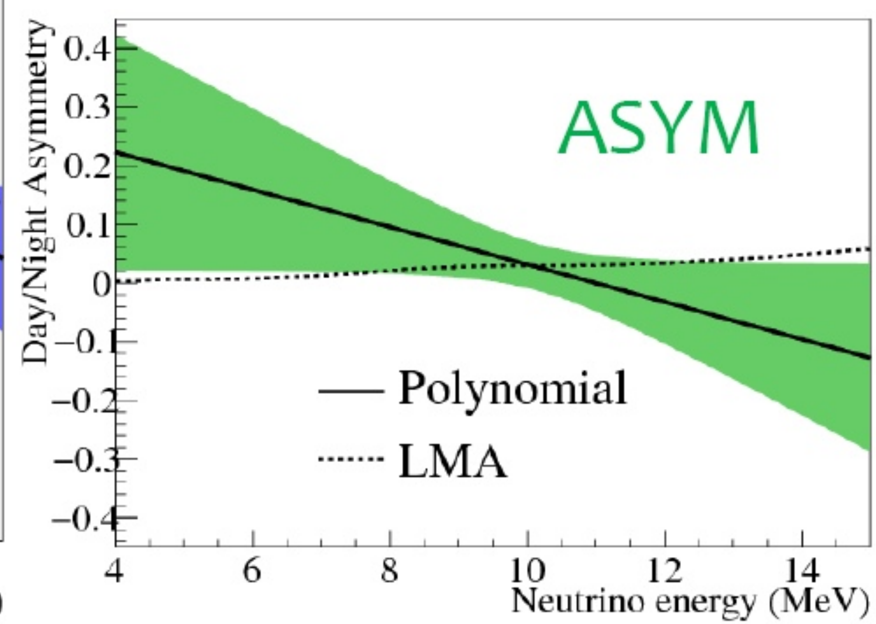
$\Delta\chi^2 = 1.94 / 4$ **d.o.f.**

LMA-prediction:

$\Delta\chi^2 = 3.90 / 4$ **d.o.f.**

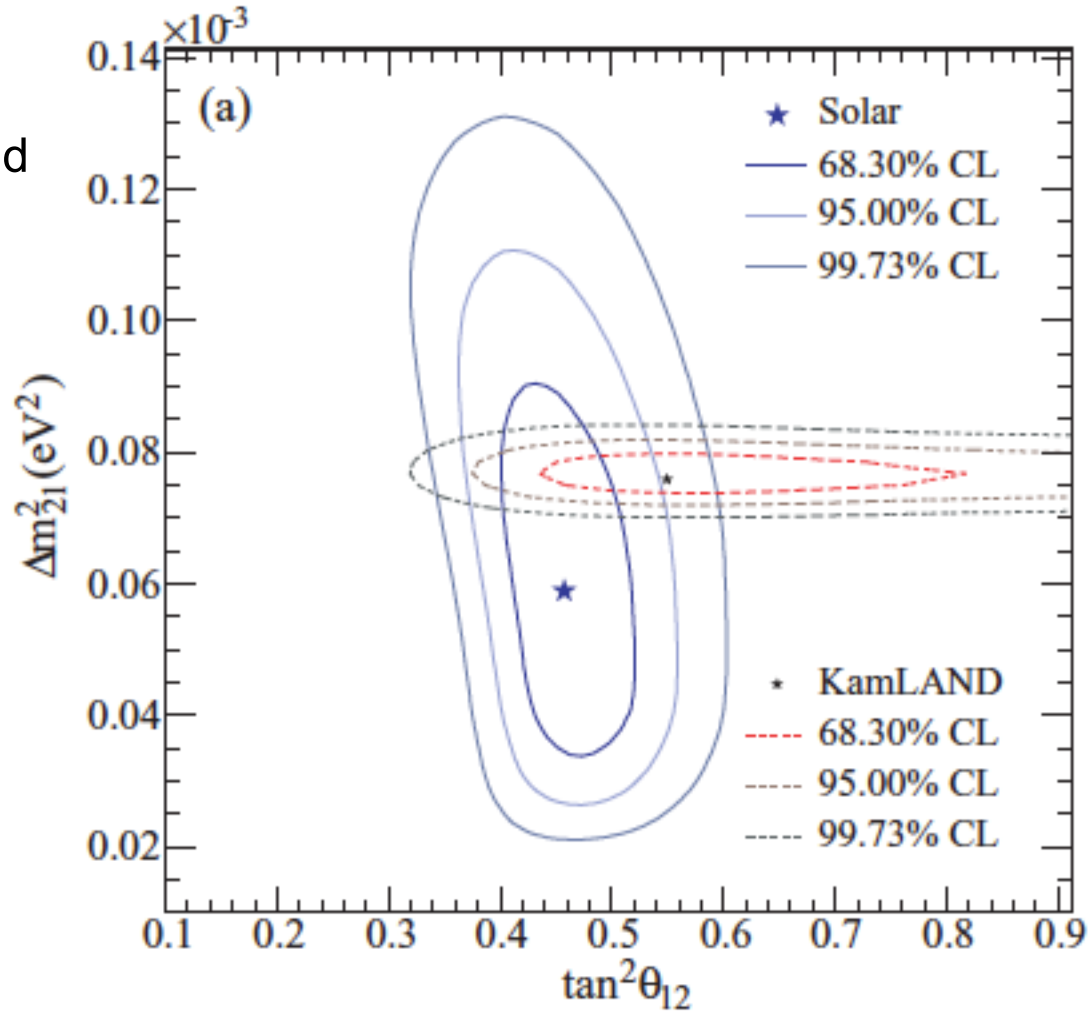






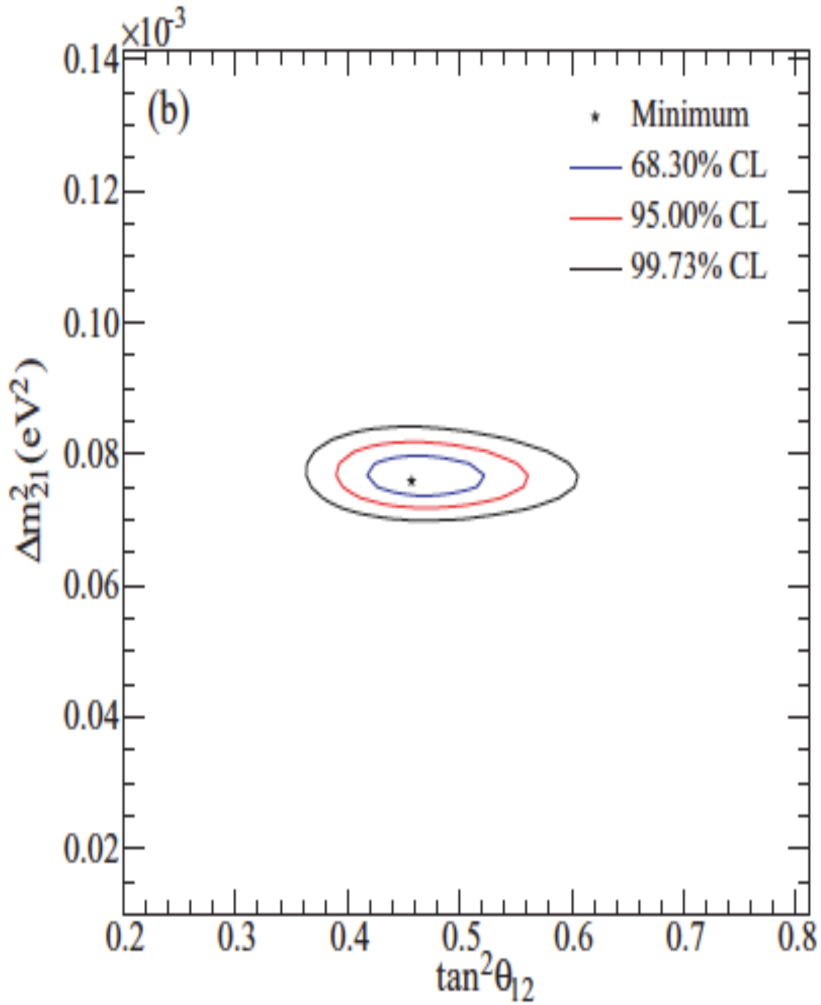
SNO LETA has a 3-ν Oscillation Analysis

global solar and KamLAND separately



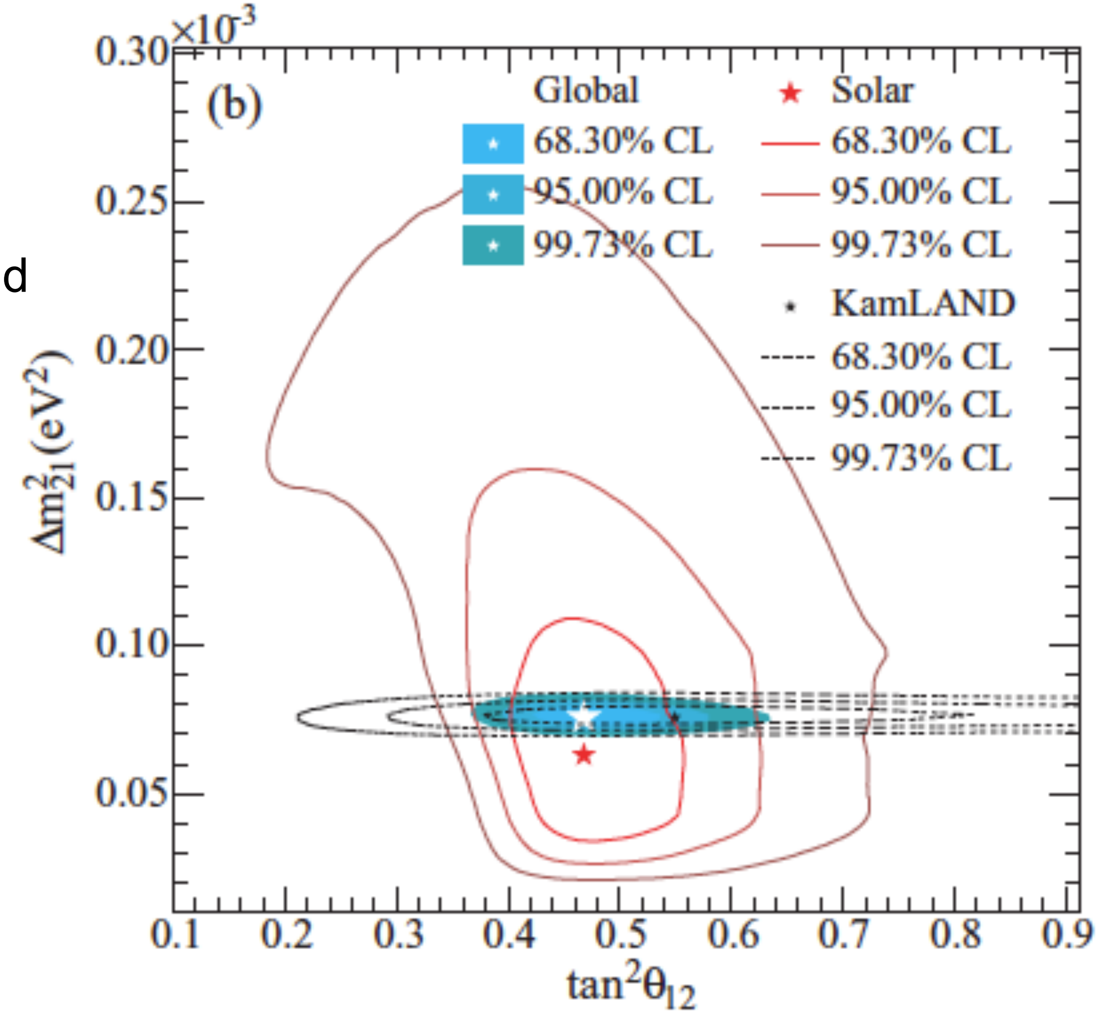
SNO LETA has a 3-ν Oscillation Analysis

global solar plus
KamLAND



Solar + KamLAND 3-Neutrino Overlay

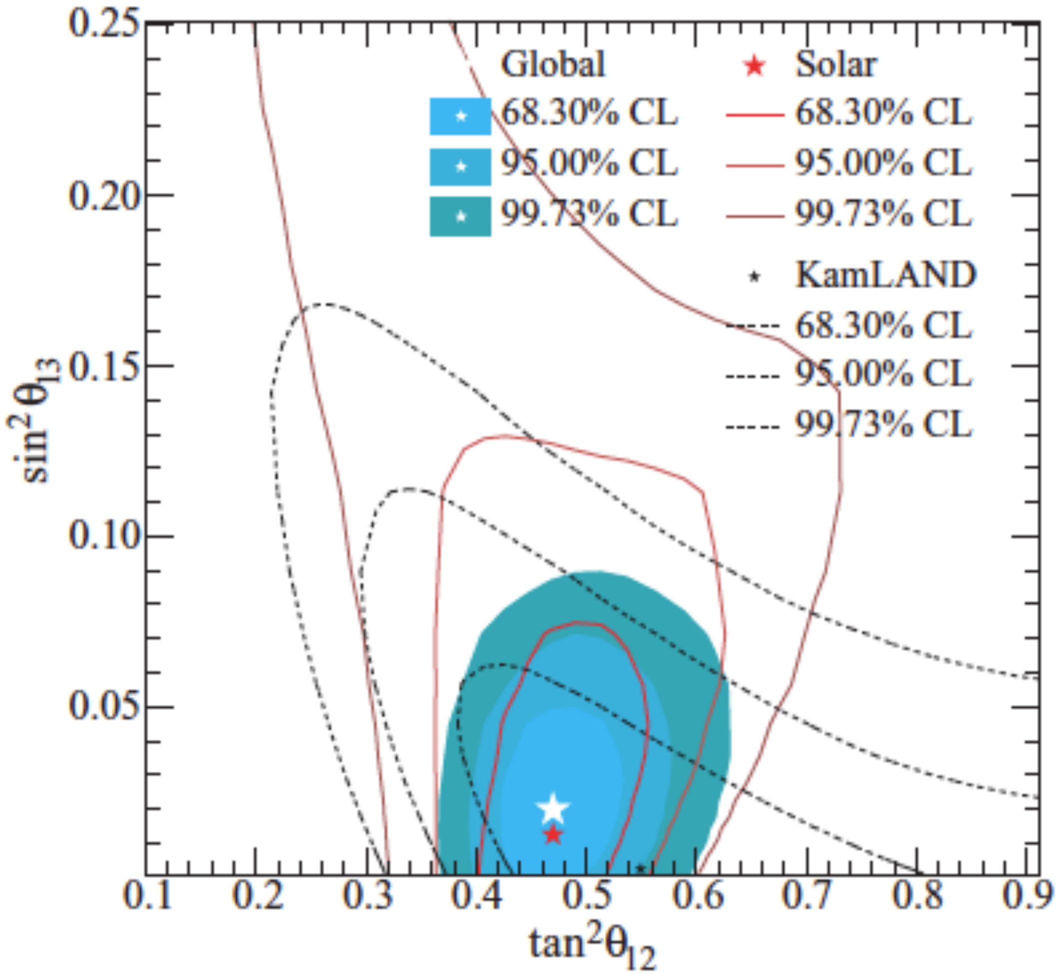
global solar and KamLAND separately



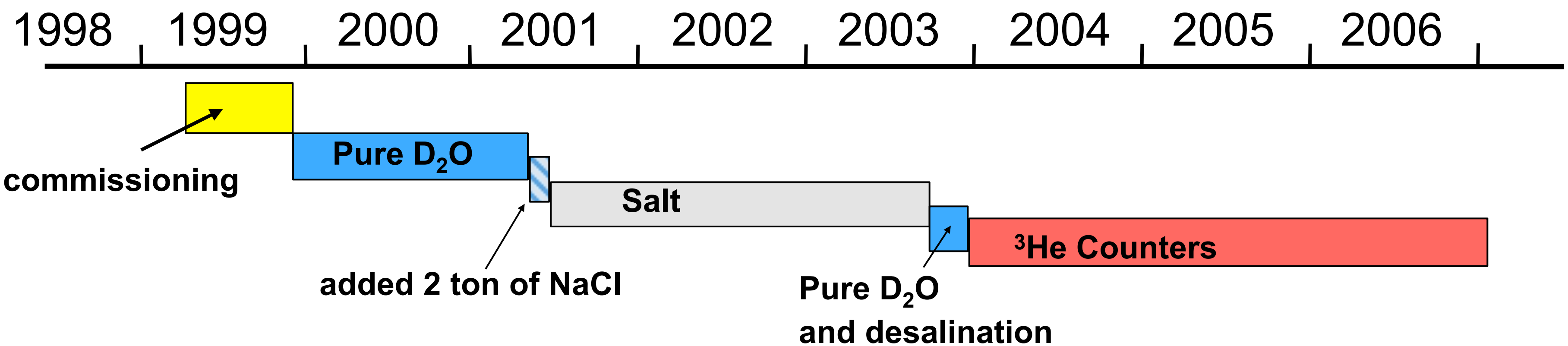
Solar + KamLAND 3-Neutrino Overlay

$$\sin^2\theta_{13} = 2.00^{+2.09}_{-1.63} \times 10^{-2}$$

$$\sin^2\theta_{13} < 0.057\,(95\%\ \mathrm{CL})$$



SNO Timeline Summary

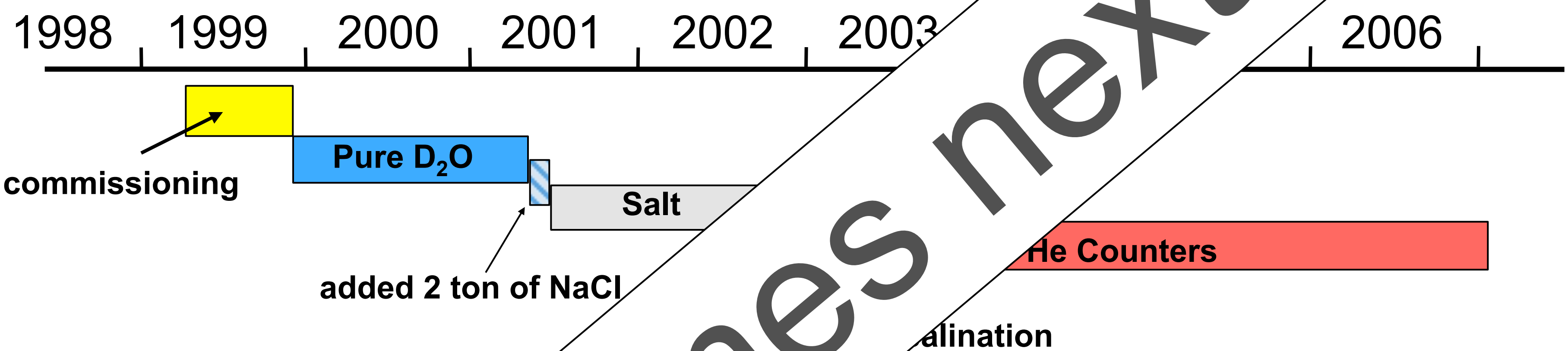


- pure D_2O phase discovered active solar neutrino flavors that are not ν_e

- salt phase moved on to precision determination of oscillation parameters; flux determination had no spectral constraint (thus could use it rigorously for more than just the null hypothesis test) – day/night effect and spectral shape were studied as well as the total active ^{8}B solar neutrino flux

- Phase III configuration offered CC and NC event-by-event separation, for improved precision and cleaner spectral shape examination; analyses combining all three phases are in progress

SNO Timeline Summary



what comes next?

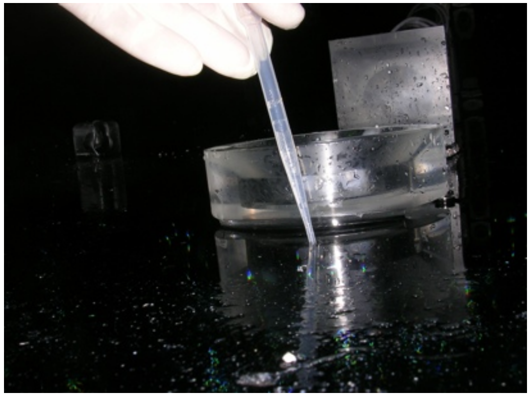
• pure D_2O phase discovere … trino flavors that are not ν_e

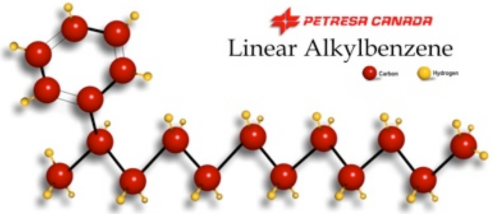
• salt phase moved … ermination of oscillation parameters; flux determination had … traint (thus could use it rigorously for more than just the n…) – day/night effect and spectral shape were studied as … tive ^8B solar neutrino flux

• Pha… n offered CC and NC event-by-event separation, for imp… and cleaner spectral shape examination; analyses combining all thr… are in progress

SNO+

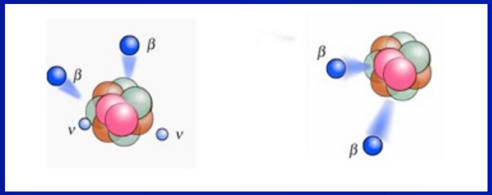
- $300M of heavy water removed and returned to Atomic Energy of Canada Limited (every last drop)
- SNO detector to be filled with liquid scintillator
  - 50-100 times more light than Čerenkov
- linear alkylbenzene (LAB)
  - compatible with acrylic, undiluted
  - high light yield, long attenuation length
  - safe: high flash point, low toxicity
  - cheaper than other scintillators
- physics goals: *pep* and *CNO* solar neutrinos, geo neutrinos, reactor neutrino oscillations, supernova neutrinos, double beta decay with Nd



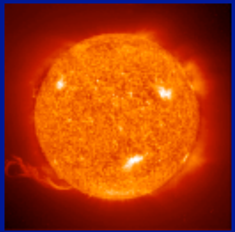


SNO+ Physics Program

- search for neutrinoless double beta decay



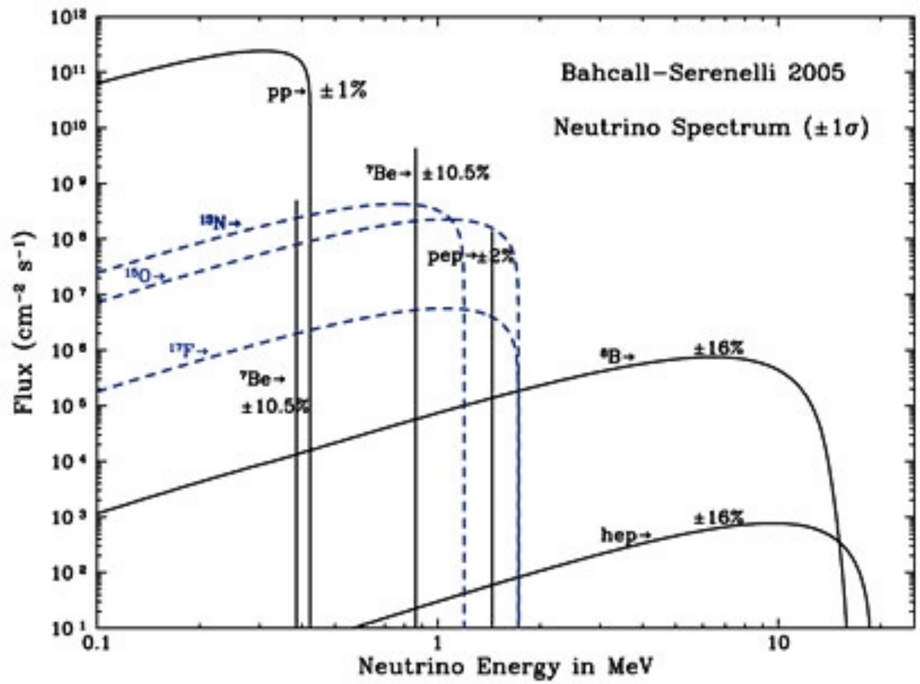
- neutrino physics
  - solar neutrinos
  - geo antineutrinos
  - reactor antineutrinos
  - supernova neutrinos



SNO+ Physics Goals

Solar Neutrinos: What's Known
Putting It All Together

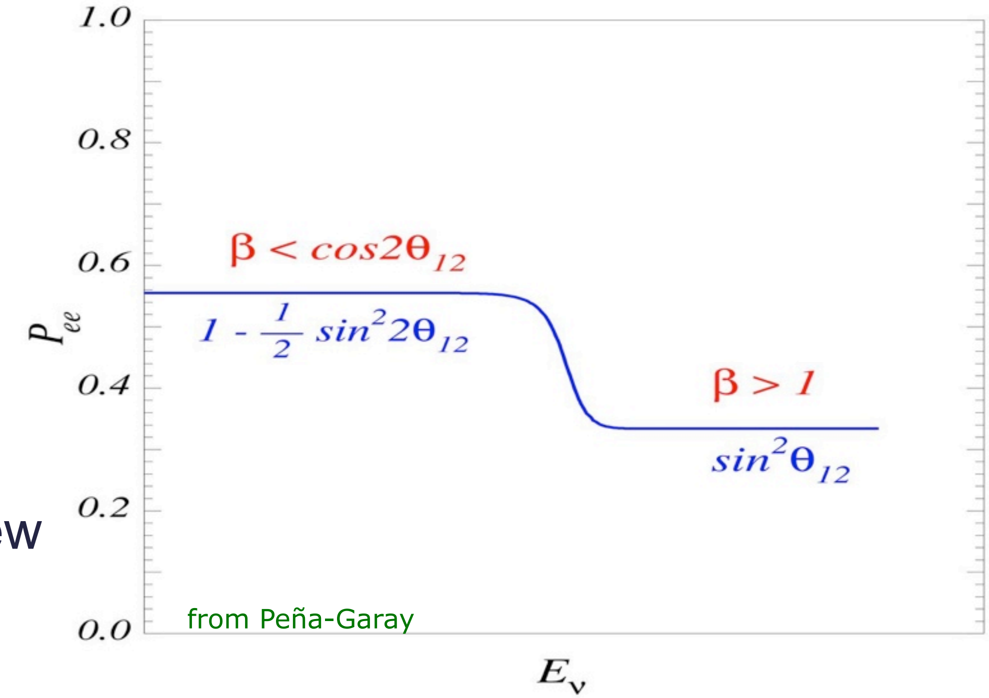
- ^{8}B solar ν well studied
  - by Super-K and SNO
- there are good data on *pp* solar ν's from the Ga experiments
  - must determine contribution of ^{8}B and ^{7}Be, subtract, and you get *pp* from the Ga experiments
- Borexino has measured the ^{7}Be flux



***pep* and *CNO* solar neutrinos are the next targets and SNO+ aims to detect these**

Non-Standard Interactions

- exploring the vacuum-matter transition is sensitive to new physics
- new neutrino-matter couplings (either FCNC or lepton universality violating) can be parameterized by a new “MSW” term ε
- where is the relative effect of new physics the largest?
  - at resonance!



$$\begin{pmatrix} -\frac{\Delta m^2}{4E}\cos 2\theta + \sqrt{2}G_F N_e & \frac{\Delta m^2}{4E}\sin 2\theta \\ \frac{\Delta m^2}{4E}\sin 2\theta & \frac{\Delta m^2}{4E}\cos 2\theta \end{pmatrix}$$

Hamiltonian for neutrino propagation in the Sun

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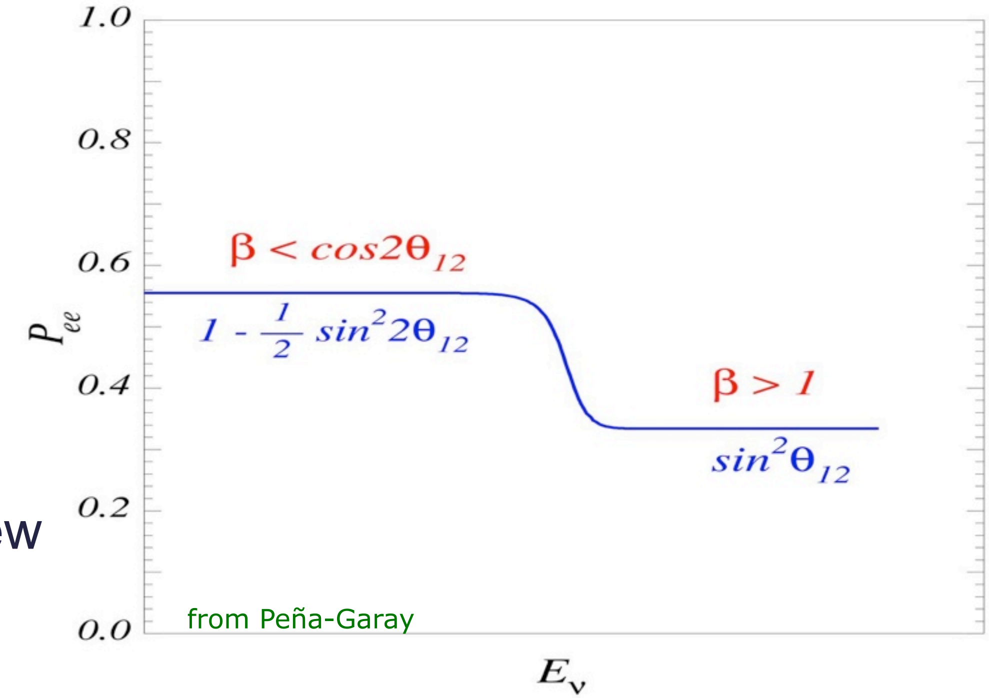
- for $\Delta m^2 = 8 \times 10^{-5}$ eV^2, $\theta = 34°$ N_e at the centre of the Sun → E is 1-2 MeV

***pep* solar neutrinos → good place to look for new physics**



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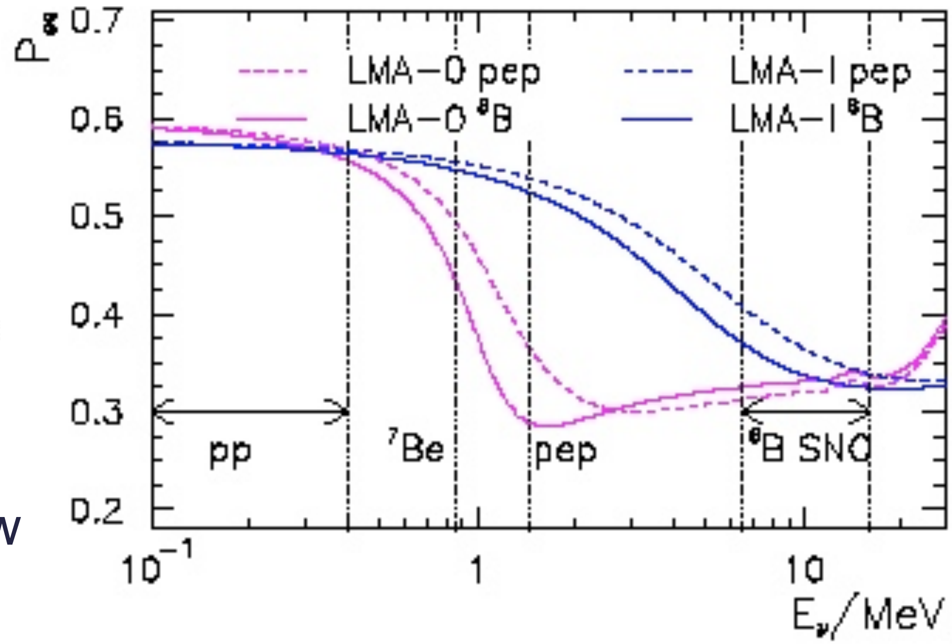
P_{ee} curve with non-standard interactions

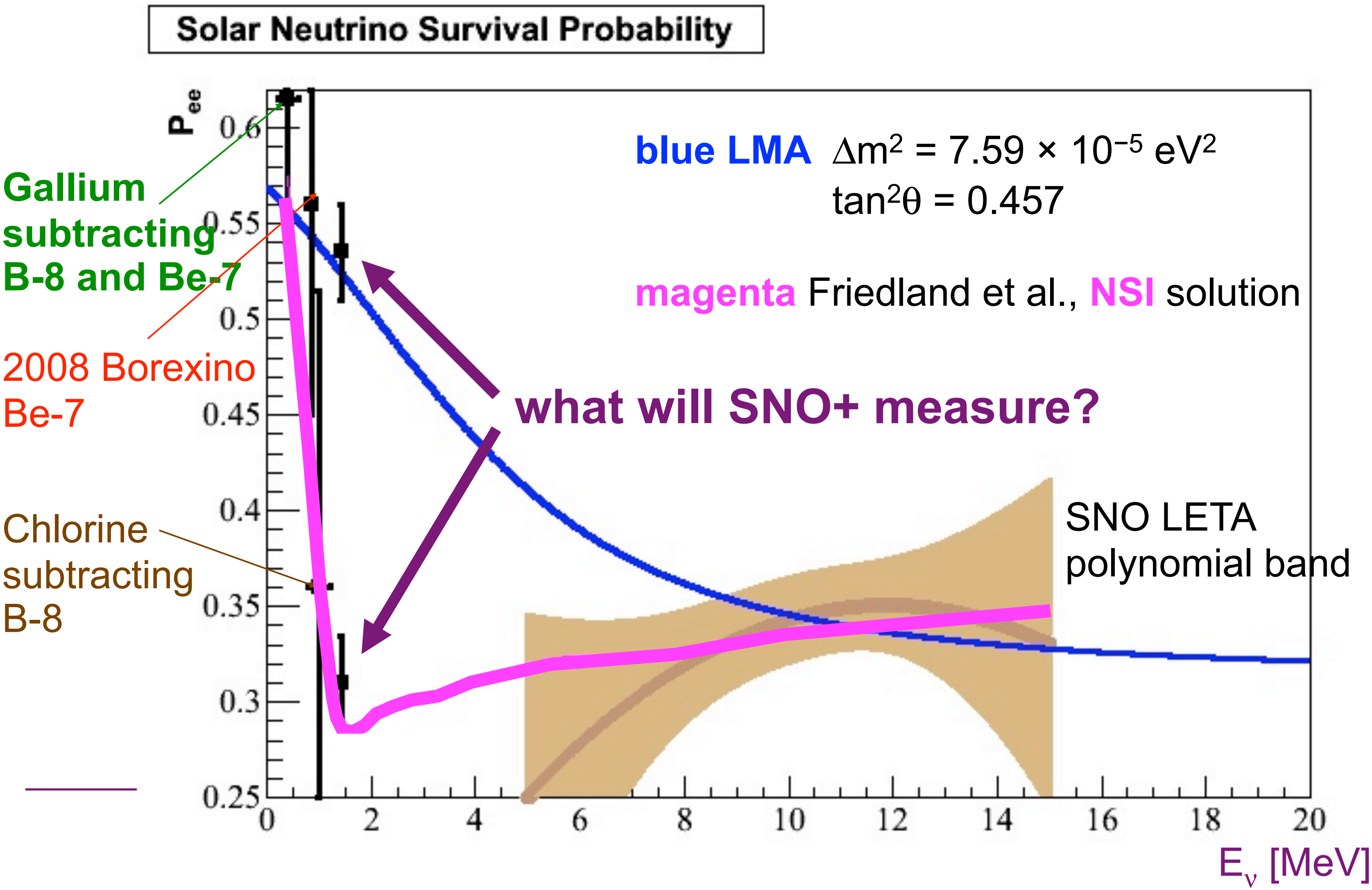


from Friedland, Lunardini, Peña-Garay, hep-ph/0402266

$$\begin{pmatrix} -\frac{\Delta m^2}{4E}\cos 2\theta + \sqrt{2}\, G_F N_e & \frac{\Delta m^2}{4E}\sin 2\theta \\ \frac{\Delta m^2}{4E}\sin 2\theta & \frac{\Delta m^2}{4E}\cos 2\theta \end{pmatrix}$$

Hamiltonian for neutrino propagation in the Sun

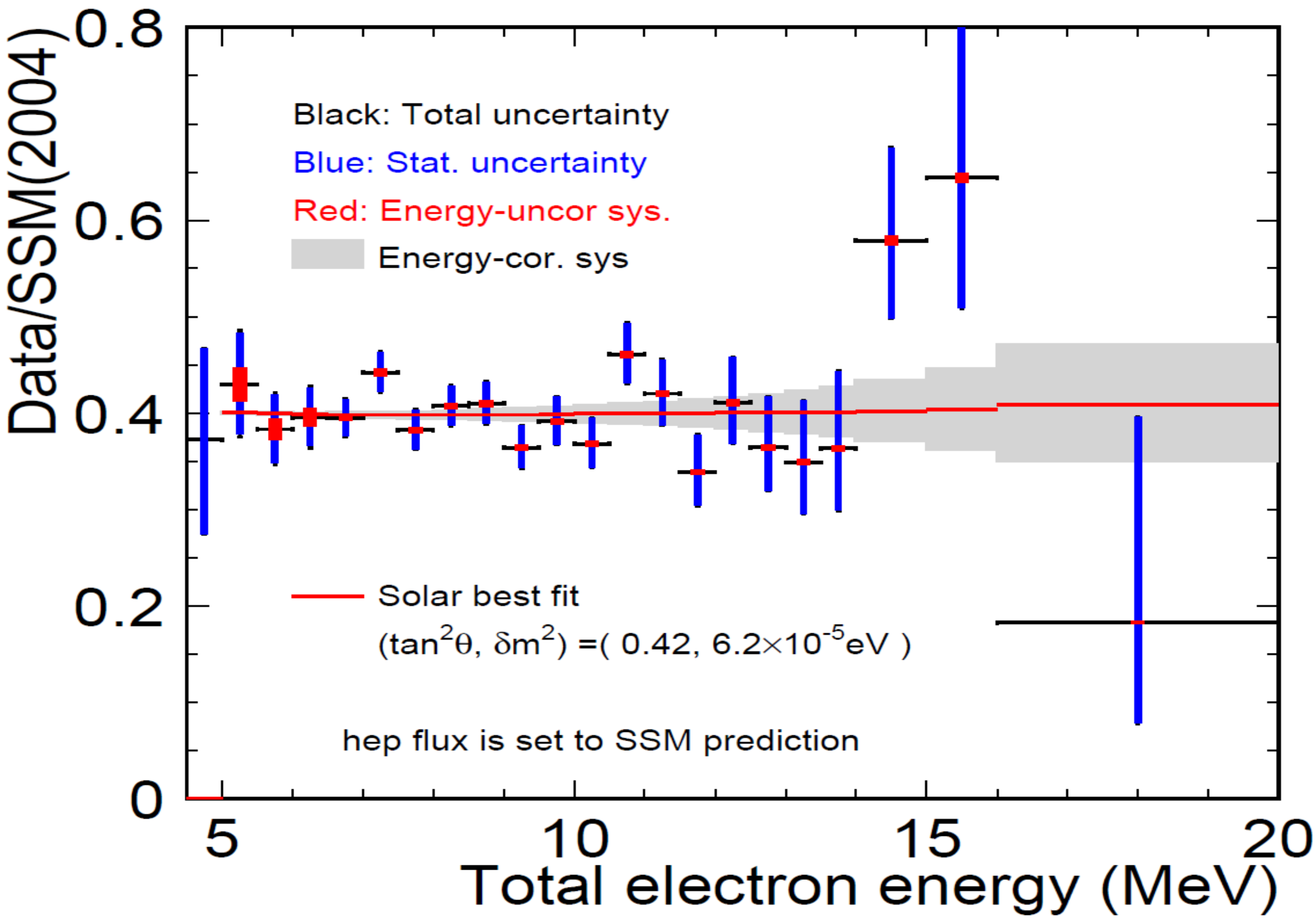
Survival Probability for Solar Neutrinos: All Experimental Data Distilled



as seen in S. Yamada's talk at this workshop

SK-III ^{8}B Spectrum is Flat

DATA/SSM



Borexino ^8B Solar Neutrinos

arXiv:0808.2868v3

- lowest energy bin does not exhibit rise either

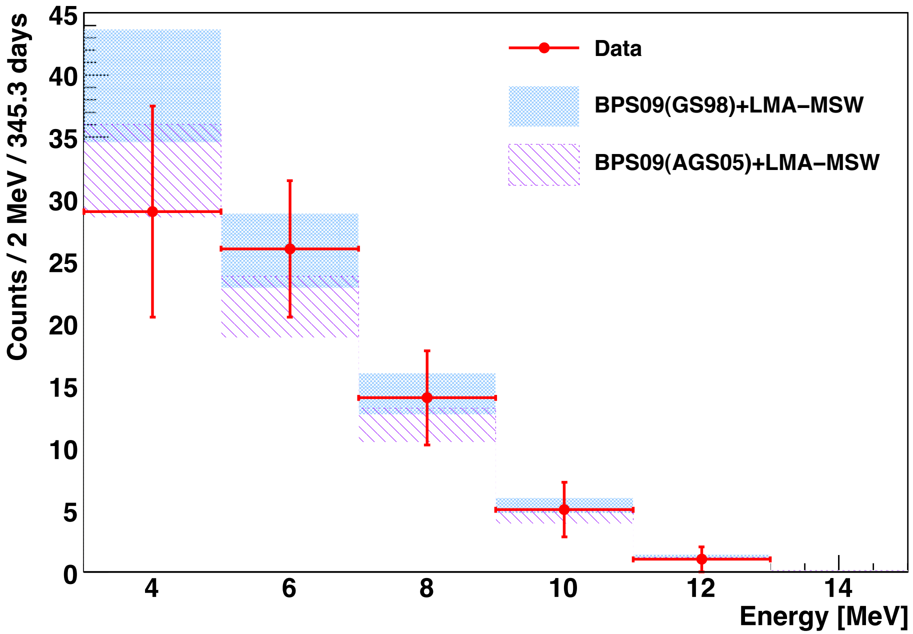
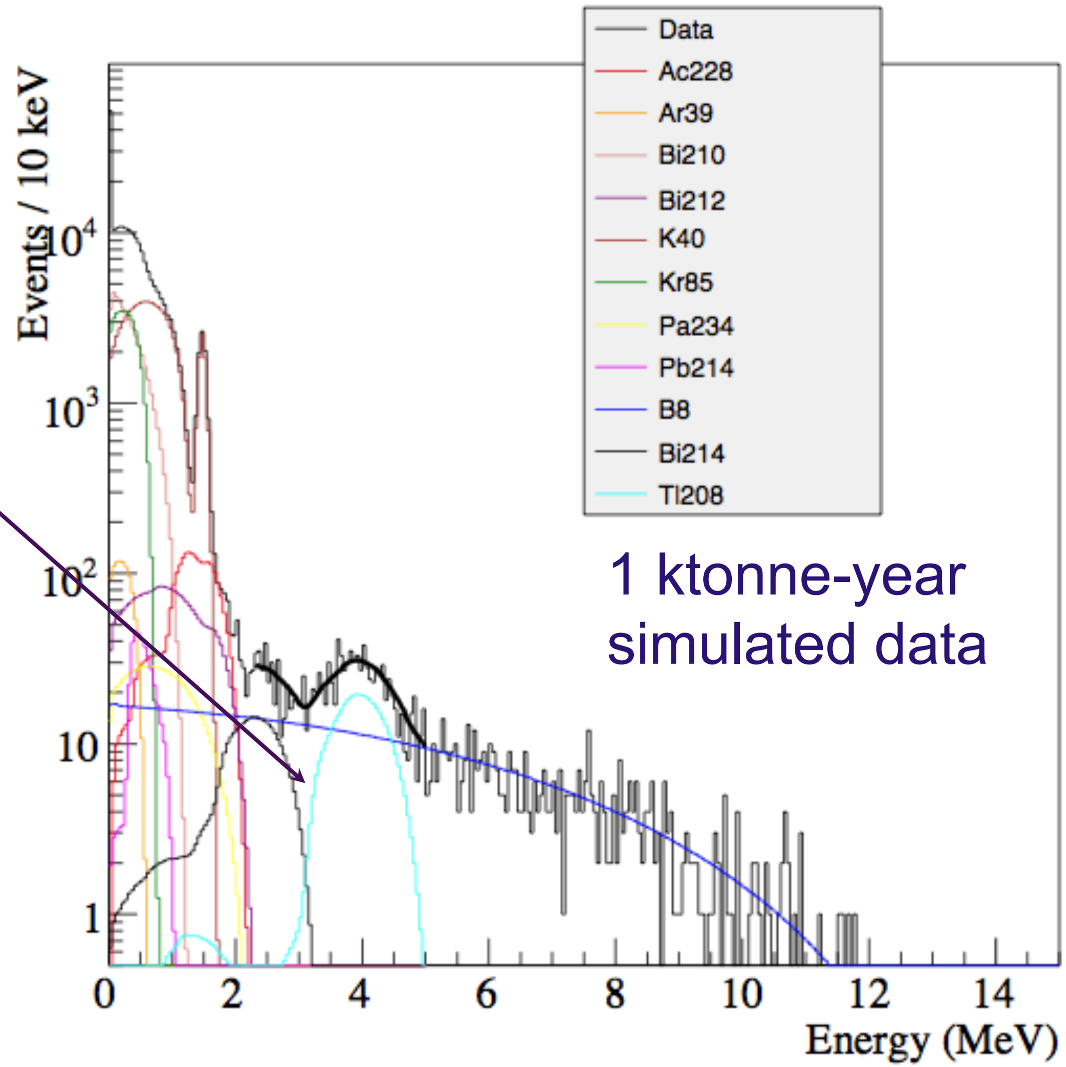


Figure 7: Comparison of the final spectrum after data selection and background subtraction (red dots) to Monte Carlo simulations (blue) of oscillated ^8B ν interactions, with amplitude from the Standard Solar Models BPS09(GS98) (high metallicity) and BPS09(AGS05) (low metallicity), and from the MSW-LMA neutrino oscillation model.

see also G. Testera's talk at this workshop

SNO+ Lower Energy ^{8}B Solar Neutrinos

- SNO+ can also detect lower energy ^{8}B solar neutrinos
- cosmogenic backgrounds are lowest in SNO+
  - compared to KamLAND and Borexino
- low background pocket between ^{214}Bi (radon in the U chain) and ^{208}Tl (internal Th chain contamination)
  - will give a data point with smaller uncertainties
  - ^{214}Bi backgrounds can be tagged, cut by delayed coincidence (haven't included in this plot, so real data will be better)
  - ^{208}Tl backgrounds harder to tag; but, if can't tag, still use to constrain via ^{212}Bi-^{212}Po coincidence



Solar Neutrinos and Metallicity

Source	Hi-Z BPS08(GS)	Lo-Z BPS08(AGS)	Difference
pp	$5.97(1 \pm 0.006)$	$6.04(1 \pm 0.005)$	1.2%
pep	$1.41(1 \pm 0.011)$	$1.45(1 \pm 0.010)$	2.8%
hep	$7.90(1 \pm 0.15)$	$8.22(1 \pm 0.15)$	4.1%
^{7}Be	$5.07(1 \pm 0.06)$	$4.55(1 \pm 0.06)$	10%
^{8}B	$5.94((1 \pm 0.11)$	$4.72(1 \pm 0.11)$	21%
^{13}N	$2.88(1 \pm 0.15)$	$1.89(1 \ ^{+0.14}_{-0.13})$	34%
^{15}O	$2.15(1 \ ^{+0.17}_{-0.16})$	$1.34(1 \ ^{+0.16}_{-0.15})$	31%
^{17}F	$5.82(1 \ ^{+0.19}_{-0.17})$	$3.25(1 \ ^{+0.16}_{-0.15})$	44%
Cl	$8.46^{+0.87}_{-0.88}$	$6.86^{+0.69}_{-0.70}$	
Ga	$127.9^{+8.1}_{-8.2}$	$120.5^{+6.9}_{-7.1}$	

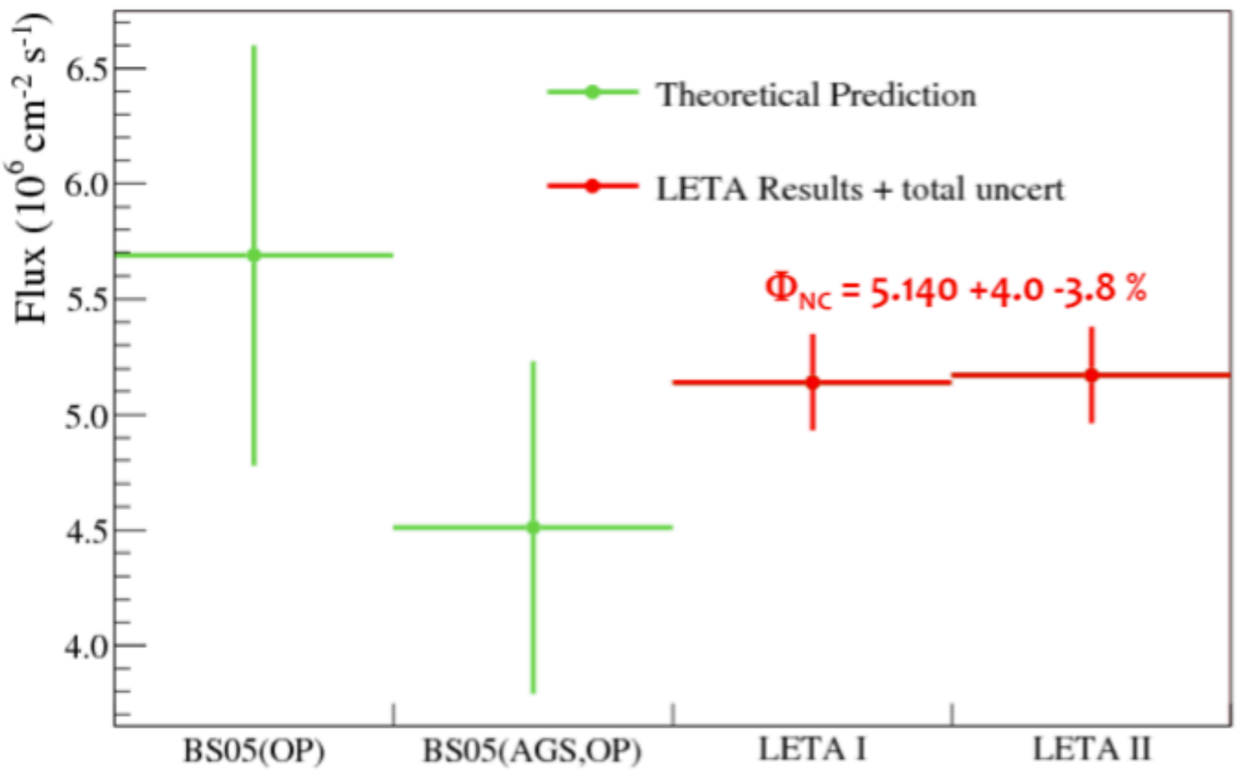
low Z changes core T

directly related to core C, N, O content

BPS08 solar model: Peña-Garay and Serenelli, arXiv:0811.2424

Solar Metallicity and ^{8}B Flux

^{8}B Flux Result

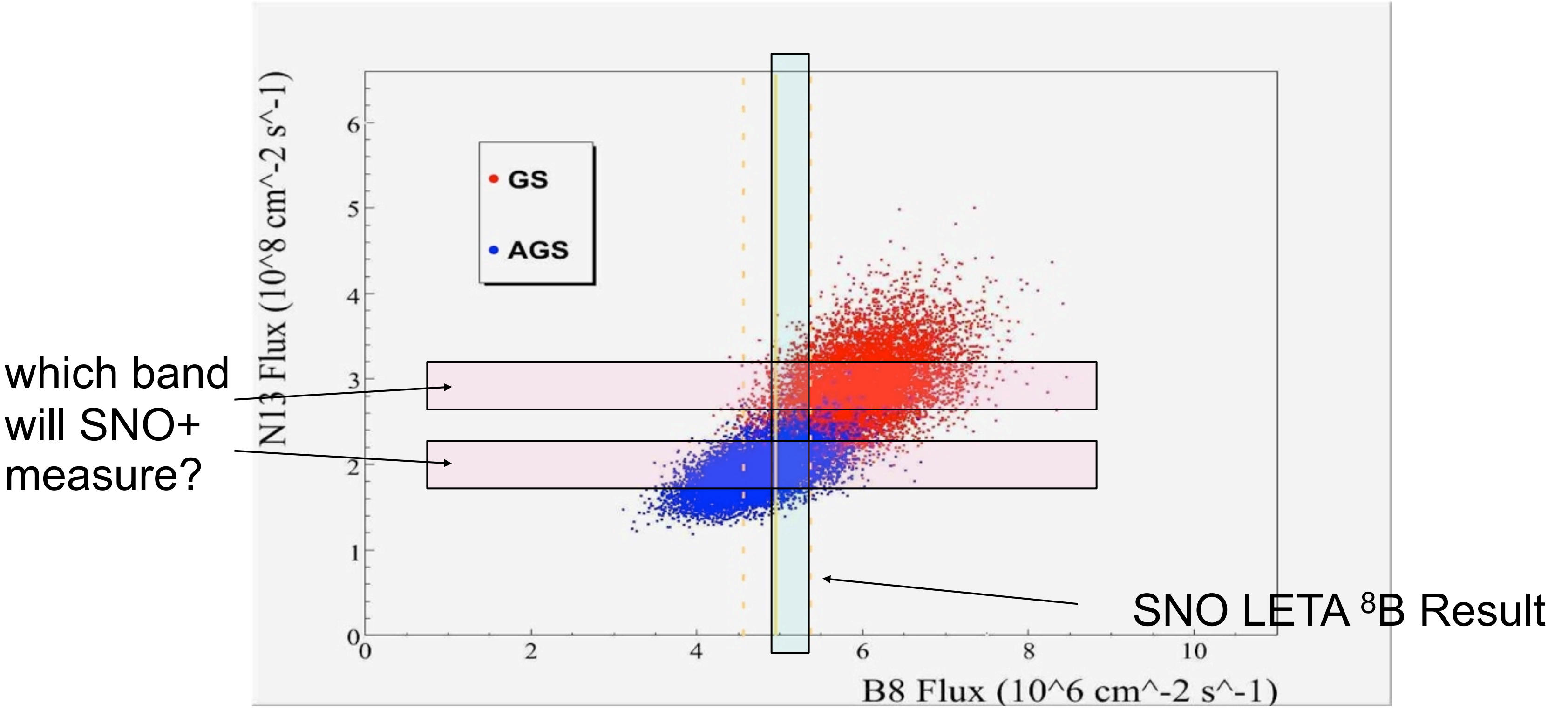


J. N. Bahcall, A. M. Serenelli, and S. Basu, AstroPhys. J. **621**, L85 (2005)

SNO+ CNO and SNO ^{8}B

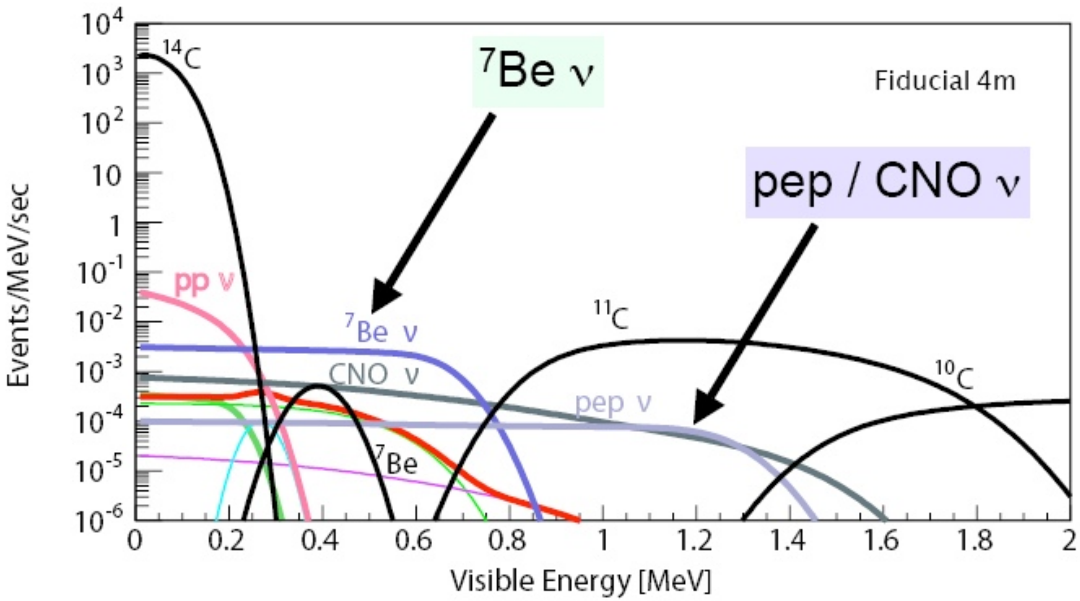
à la Haxton and Serenelli

- use the SNO ^{8}B measurement to constrain "environmental variables" in the solar core which also affects CNO ν
- measure CNO flux (to ±10%) and compare with solar models to differentiate high-Z / low-Z core metallicity



Measuring the *pep* and *CNO* Neutrino Flux

- underground cosmogenic background from ^{11}C is eliminated at SNOLAB depths of 6000 mwe
  - muon flux is ~700 times lower than Kamioka, ~100 times lower than Gran Sasso

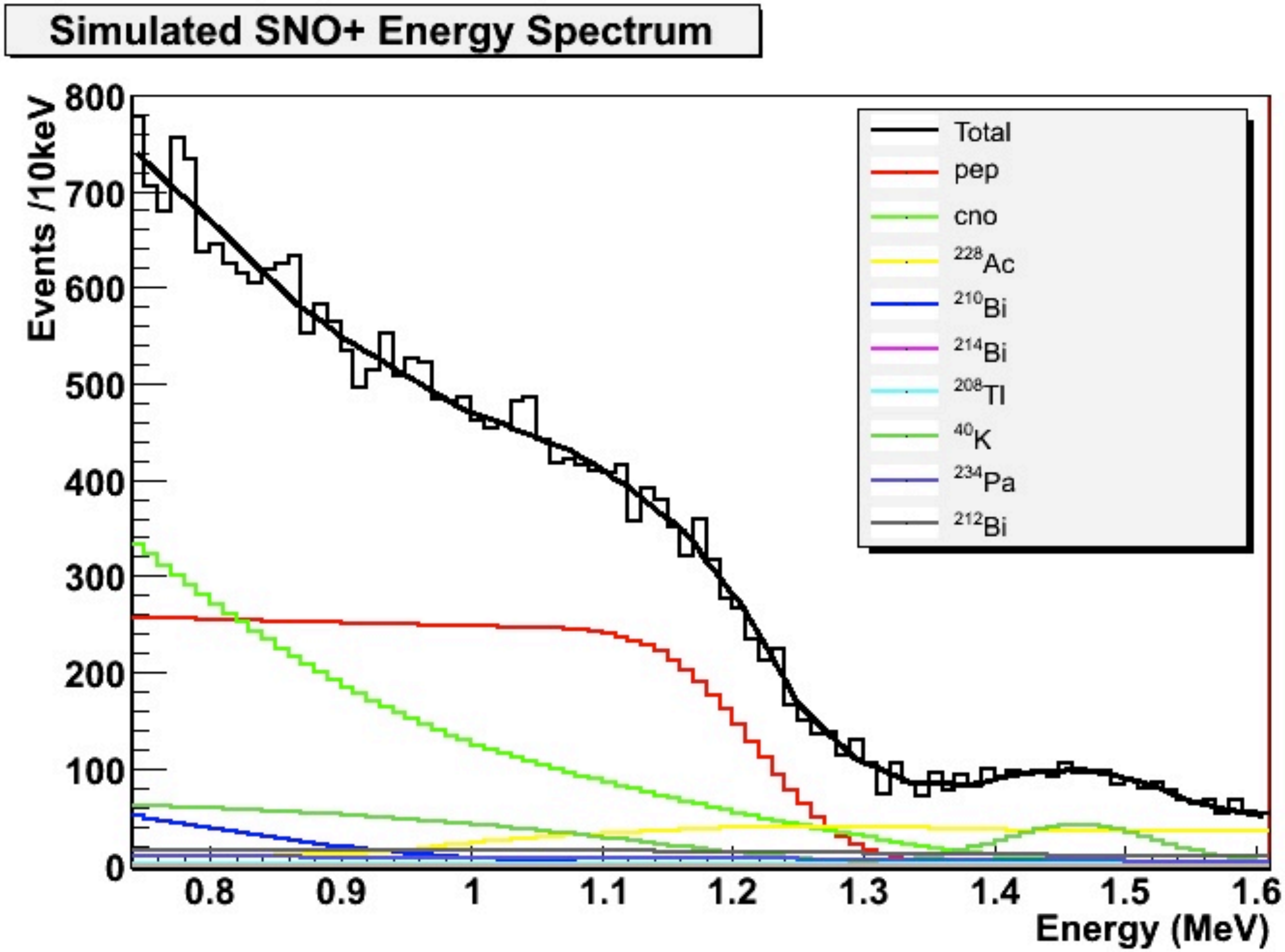


^{11}C has a 20 min half-life – challenging to veto or tag this background for ~10,000 muons/day

SNO+ will have ~70 muons/ day

figure from KamLAND: solar neutrinos in KamLAND (after purification) and cosmogenic carbon backgrounds

SNO+ pep and CNO Solar Neutrino Signals



an accurate measurement of the rate of pep solar neutrino interactions:
$R = \Phi\, P_{ee}\, \sigma$
flux is calculated in SSM to ±1.5%; cross section is known (ν-e scattering)
➔ yields an accurate measure of the survival probability

CNO measurement uncertainty: ±7% statistical after 3 years

3600 *pep* events/(kton·year), for electron recoils >0.8 MeV
<u>±5% total uncertainty</u> after 3 years (including systematic and SSM)

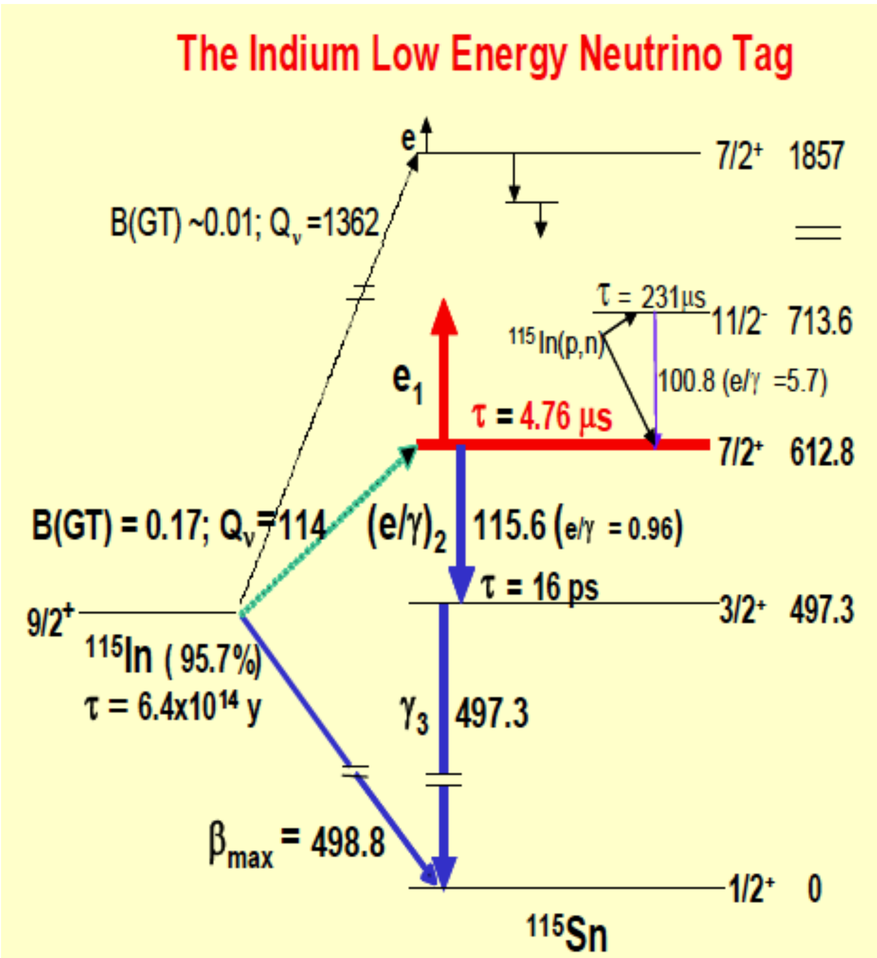
Future Experiments

- charged-current reactions — principal focus
  - LENS (In) [R&D and prototype] — *pp*
  - MOON (Mo) [small-scale R&D] — *pp*
- neutrino-electron scattering
  - KamLAND [purified, analyzing data] — ^{7}Be
  - SNO+ [under construction] — *pep+CNO*
  - CLEAN [building DM prototype] — *pp*
  - XMASS [building DM prototype] — *pp*
  - LENA [R&D] — *pep+CNO+hep*

LENS – Low Energy Neutrino Spectroscopy

$$\nu_e + {}^{115}In \rightarrow \underbrace{e^-}_{\text{solar signal}} + \underbrace{\gamma + (\gamma / e^-)}_{\text{delayed tag } (\tau = 4.76\,\mu s)} + {}^{115}Sn$$

40 *pp* events/(year·ton of In) includes event tag efficiency



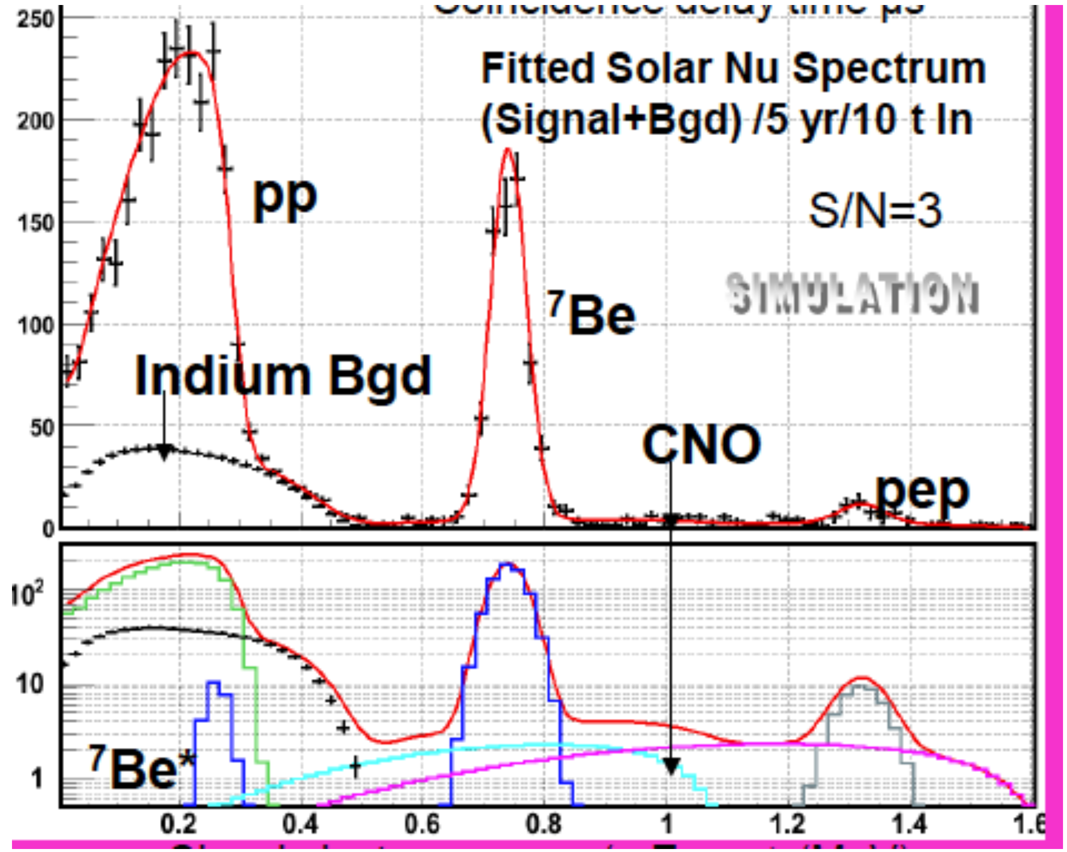
- CC measurement of *pp* flux using an 8% In-loaded scintillator
- suppress ^{115}In β^- background
  - 79×10^{11} backgrounds/(yr·ton of In)
  - use spatial event topology
  - use coincidence time
  - β^- energy <500 keV
  - tagged sum = 613 keV
- requires neutrino source calibration of CC cross section*
- Mini-LENS being built: 125 L of scintillator (1/1000 of LENS)

*propose to use Borexino ^{7}*Be* ν-e to calibrate CC cross section on indium

Tagged Signal → No Backgrounds

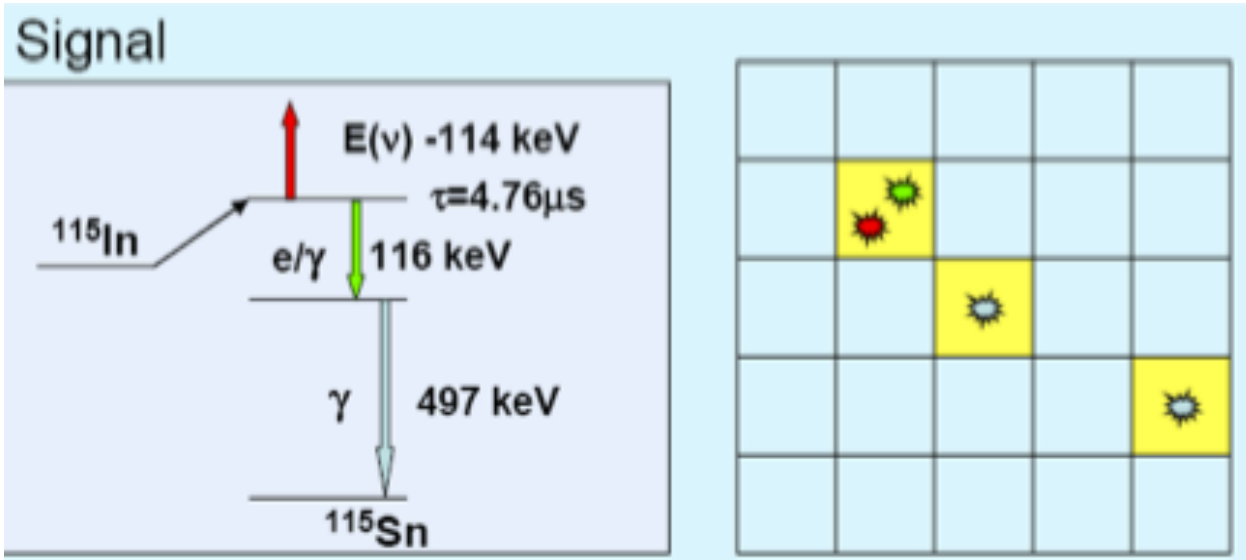
only *pp* suffers from the indium beta background

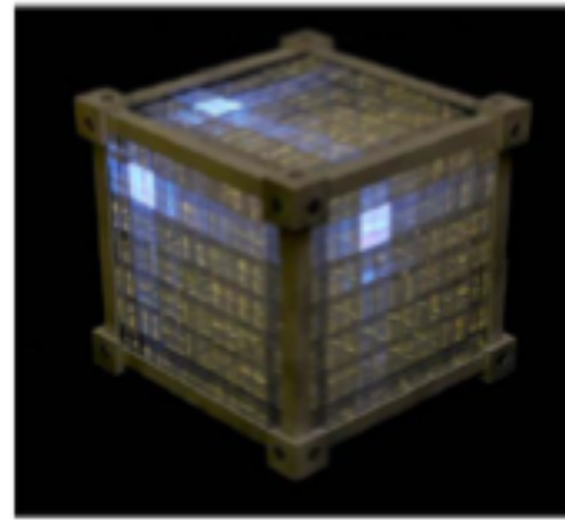
- clean spectroscopy of low energy solar neutrinos
- for 5 yr and 10 ton of In, the *pp* and ^{7}Be neutrinos are clearly measured
- ~2000 *pp* events
- ~750 ^{7}Be
- ~150 *CNO* events



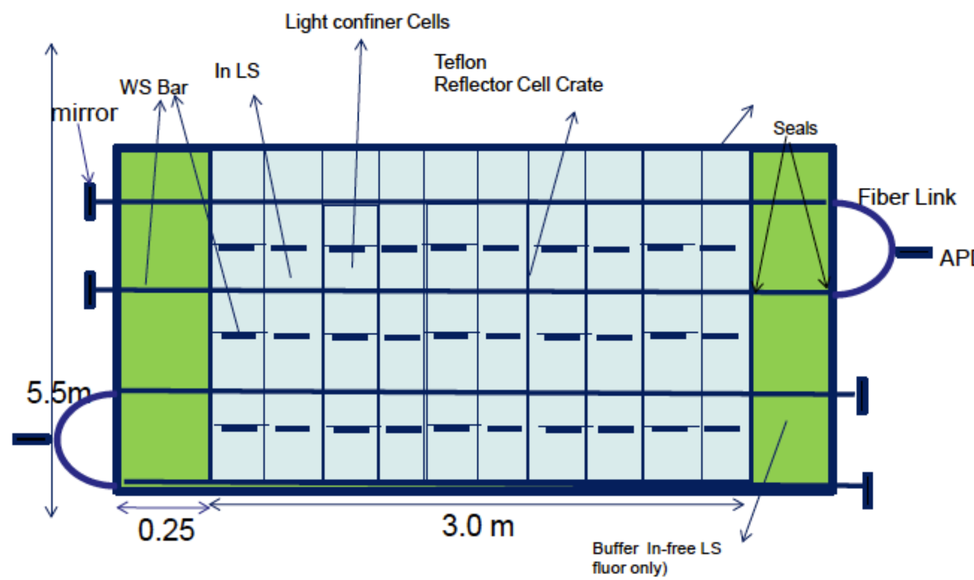
signal electron energy [MeV]

LENS Novel Lattice Readout





Lens NUFlu Chamber—3.5m3.5mx5.5m (including side buffer--~10 ton Indium



even newer readout idea under R&D

Kimballton Mine

Mini-LENS will be installed in Kimballton Mine

LENS may be in Kimballton or DUSEL

status: by Raju...

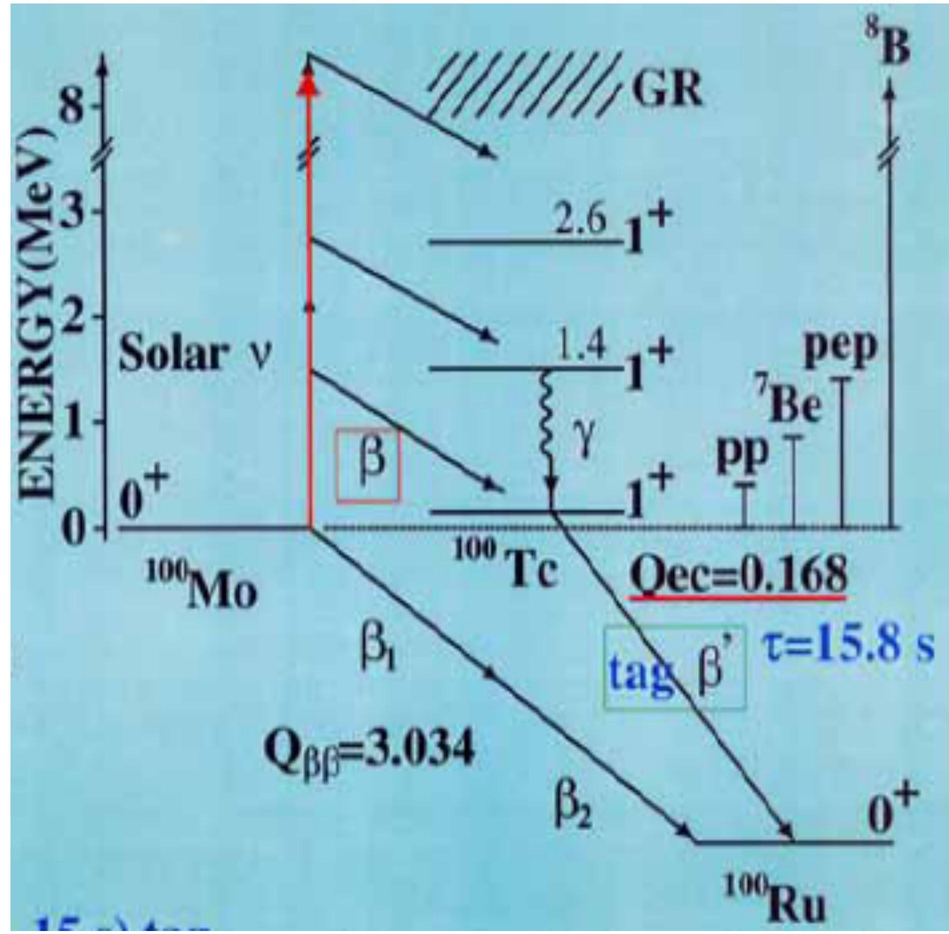
^{100}Mo as a Solar Neutrino Target

$$\nu_e + {}^{100}\text{Mo} \rightarrow {}^{100}\text{Tc} + e^-$$
$${}^{100}\text{Tc} \rightarrow {}^{100}\text{Ru} + e^- + \bar{\nu}_e$$

just like ^{176}Yb, this is another instance of a double beta isotope serving as a solar neutrino target

0.168 MeV threshold for CC ν_e
^{100}Tc beta decay: 15.8 s lifetime

tagged solar neutrino sensitive to *pp*



MOON – Molybdenum Observatory Of Neutrinos

- CC measurement of *pp* flux using Mo target foils
  - $\nu_e + {}^{100}Mo \rightarrow {}^{100}Tc + e^-$ (threshold 168 keV)
  - ${}^{100}Tc$ β decays with 16 s half-life, Q = 3.0 MeV
- has background from 2νββ of ${}^{100}Mo$

Reaction	Rate/yr/ton ${}^{100}Mo$
pp	120
${}^{7}Be$	40
pep	2.5
${}^{8}B$	5.1
${}^{13}N$	4.2
${}^{15}O$	6.1

9.6% natural isotopic abundance

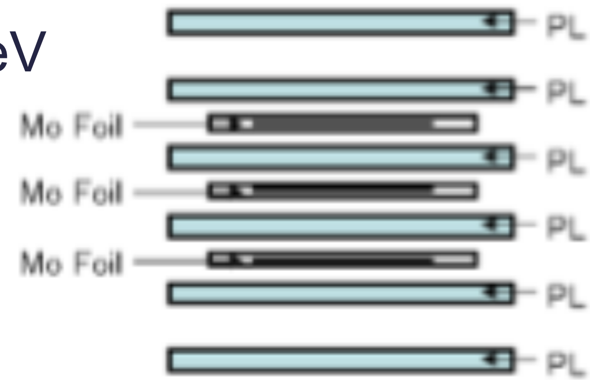
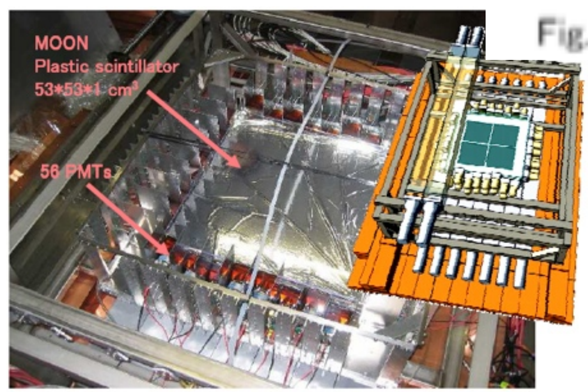


Fig. Cross section view of MOON-1



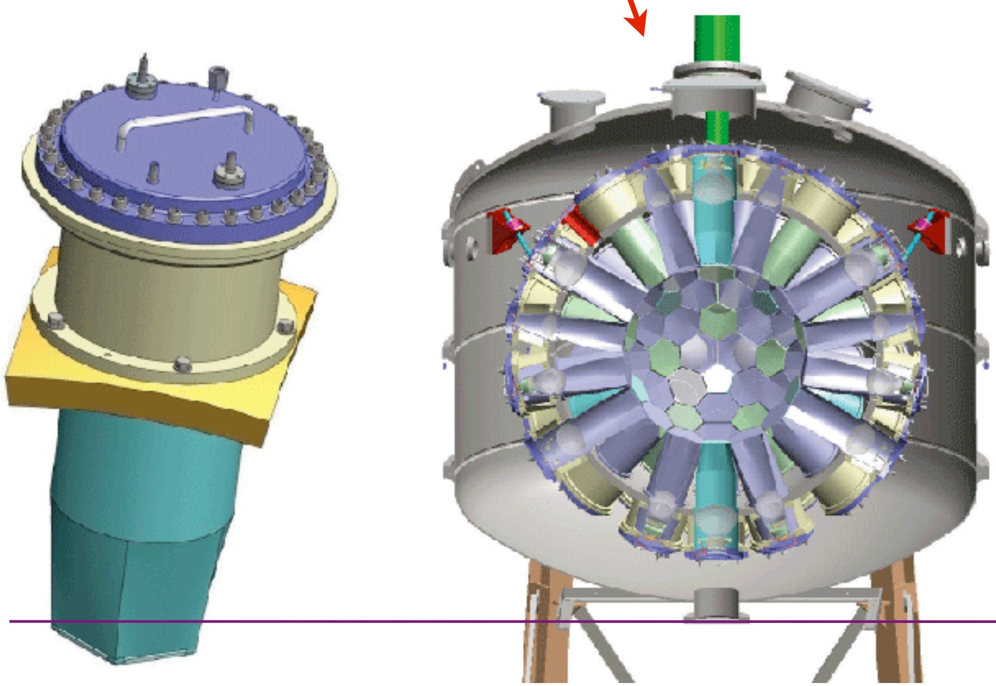
MOON-1 prototype
142 g of ${}^{100}Mo$ foil
40 mg/cm^2

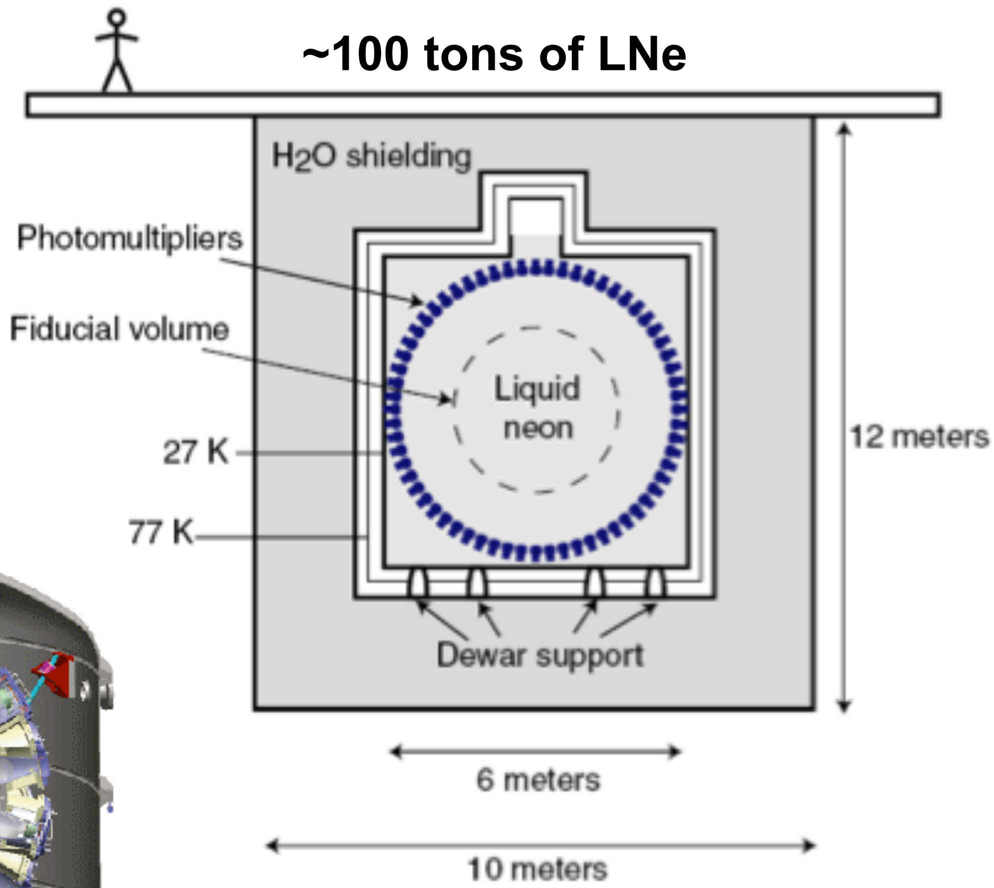
Elastic Scattering Experiments: CLEAN and XMASS

- ν-e scattering in noble liquid (scintillation) to detect *pp* solar neutrinos
- these are dual purpose detectors: dark matter and solar ν
  - XMASS also double beta decay of ^{136}Xe
- oscillated event rate: ~1 *pp* ν event/(day·ton) for 50 keV threshold
- main detector concept behind each experiment
  - CLEAN: liquid neon has no radioactive contamination
  - XMASS: liquid xenon has very effective self-shielding

CLEAN – Cryogenic Low Energy Astrophysics with Neon

- building MiniCLEAN a 360 kg prototype dark matter detector with LNe/ LAr in SNOLAB





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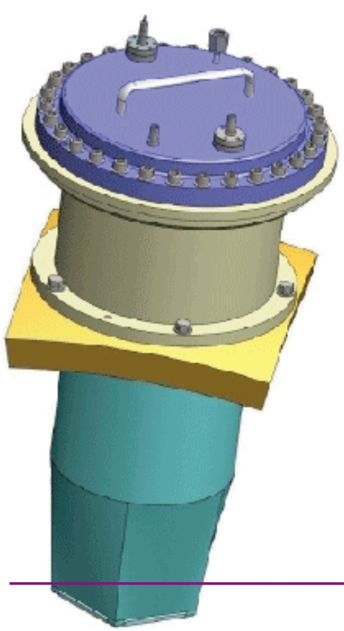
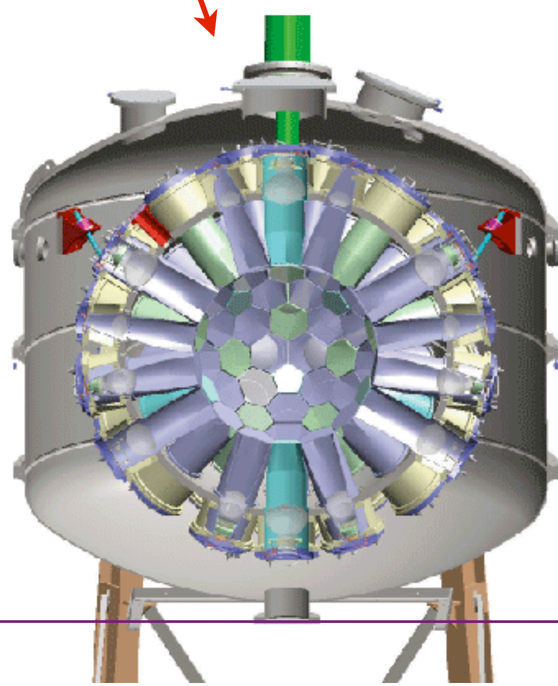
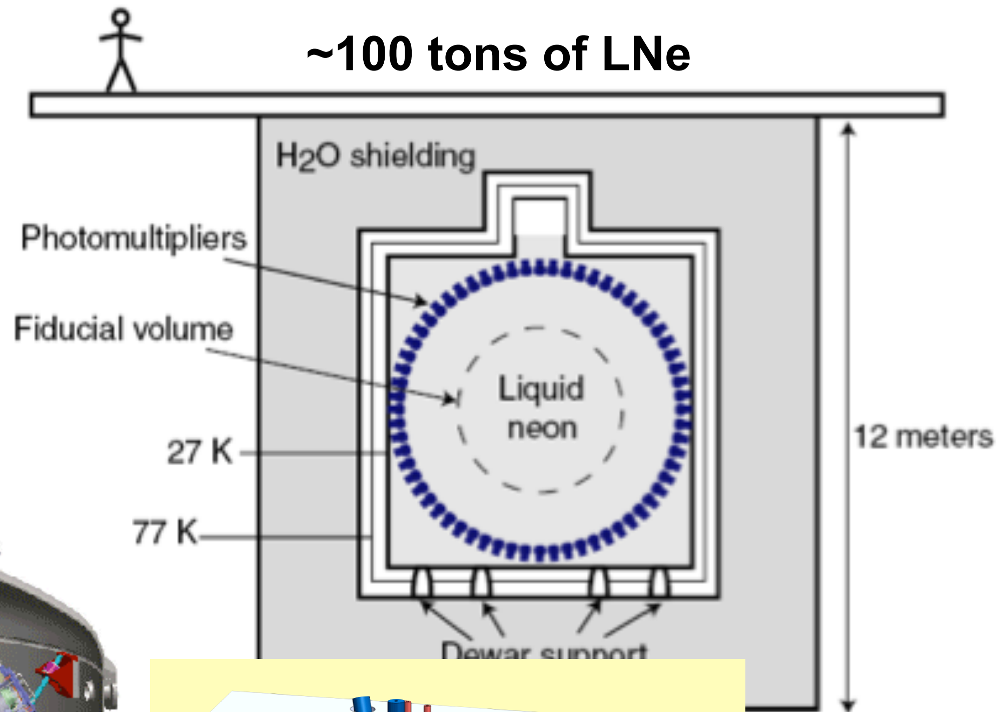
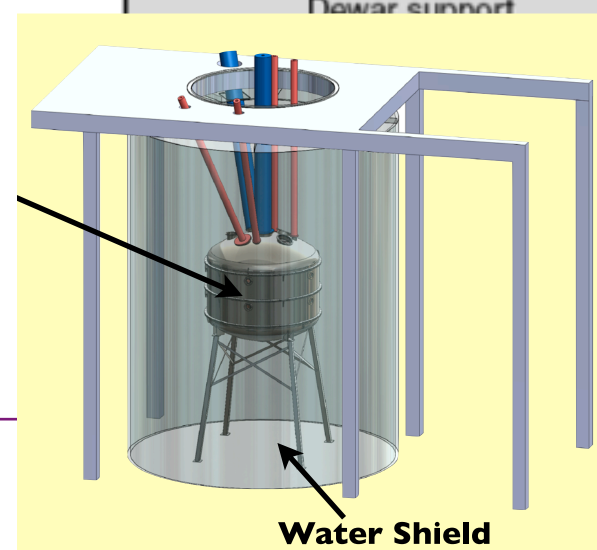






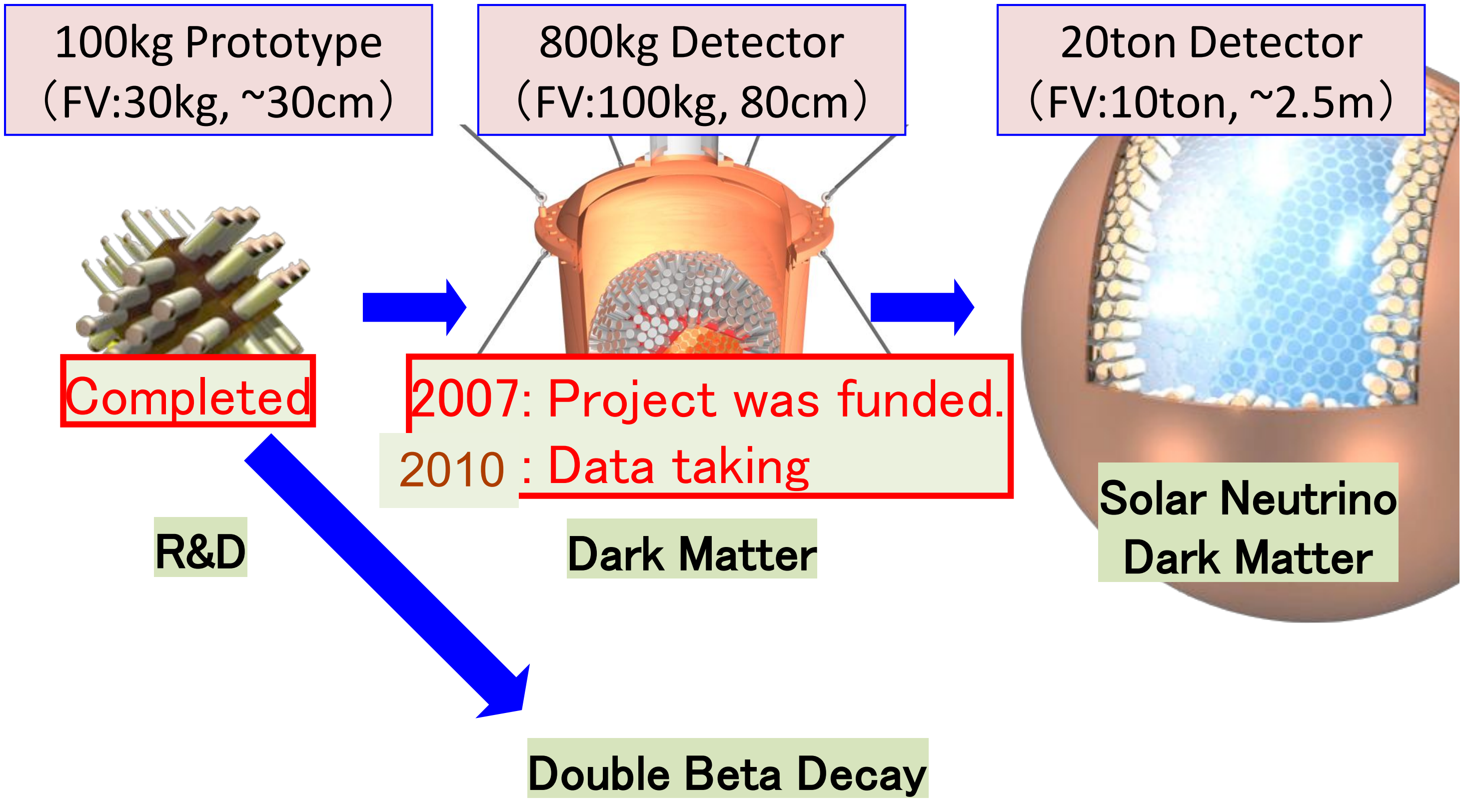


SNOLAB Cube Hall Preparing for MiniCLEAN

XMASS – Xenon MASSive Detector

- 100 kg prototype built, operated, studied
- soon (this week!) turning on ~850 kg detector for dark matter
- *pp* solar neutrinos require 10 ton fiducial volume and even larger size for self-shielding

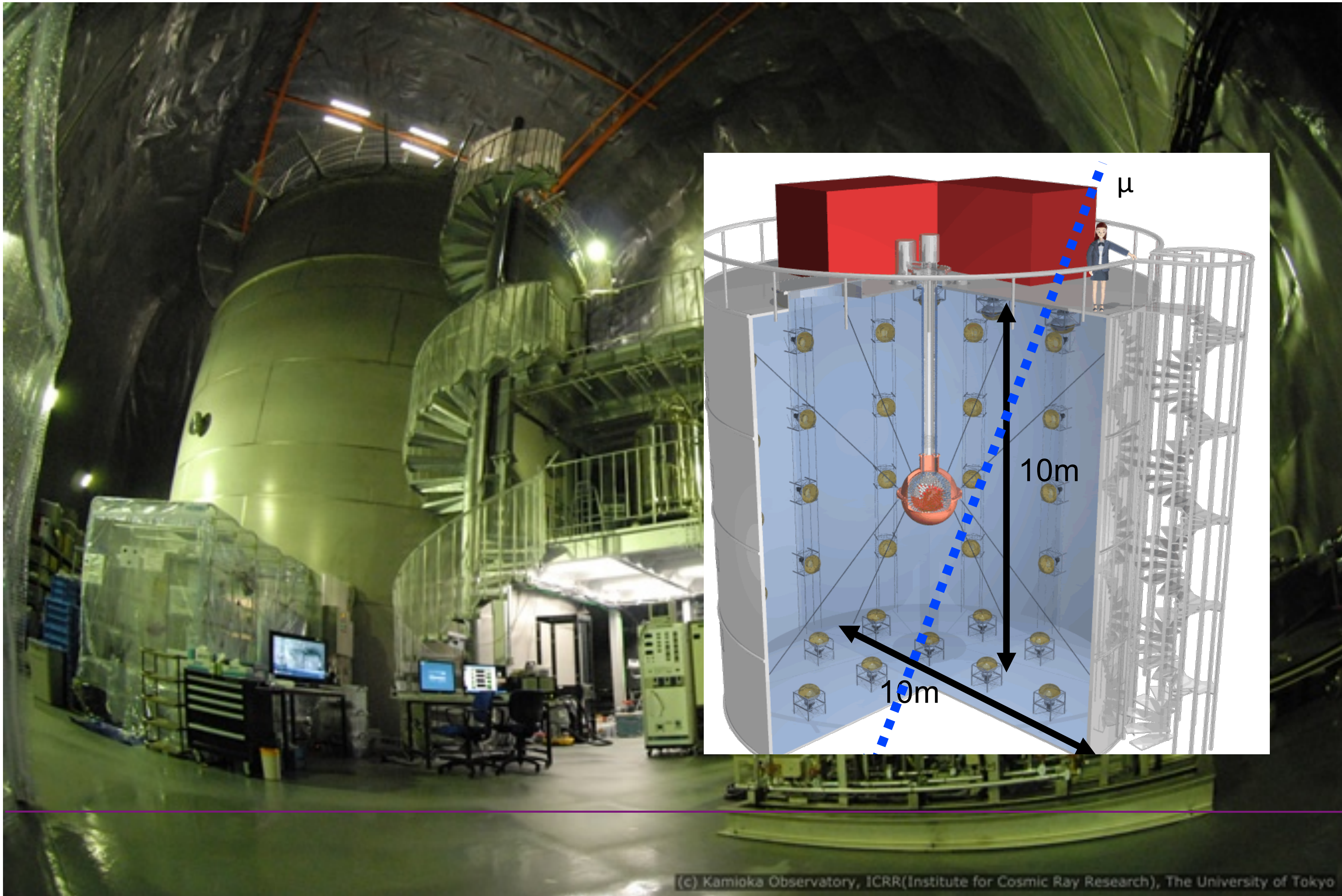
Three phases of XMASS experiment



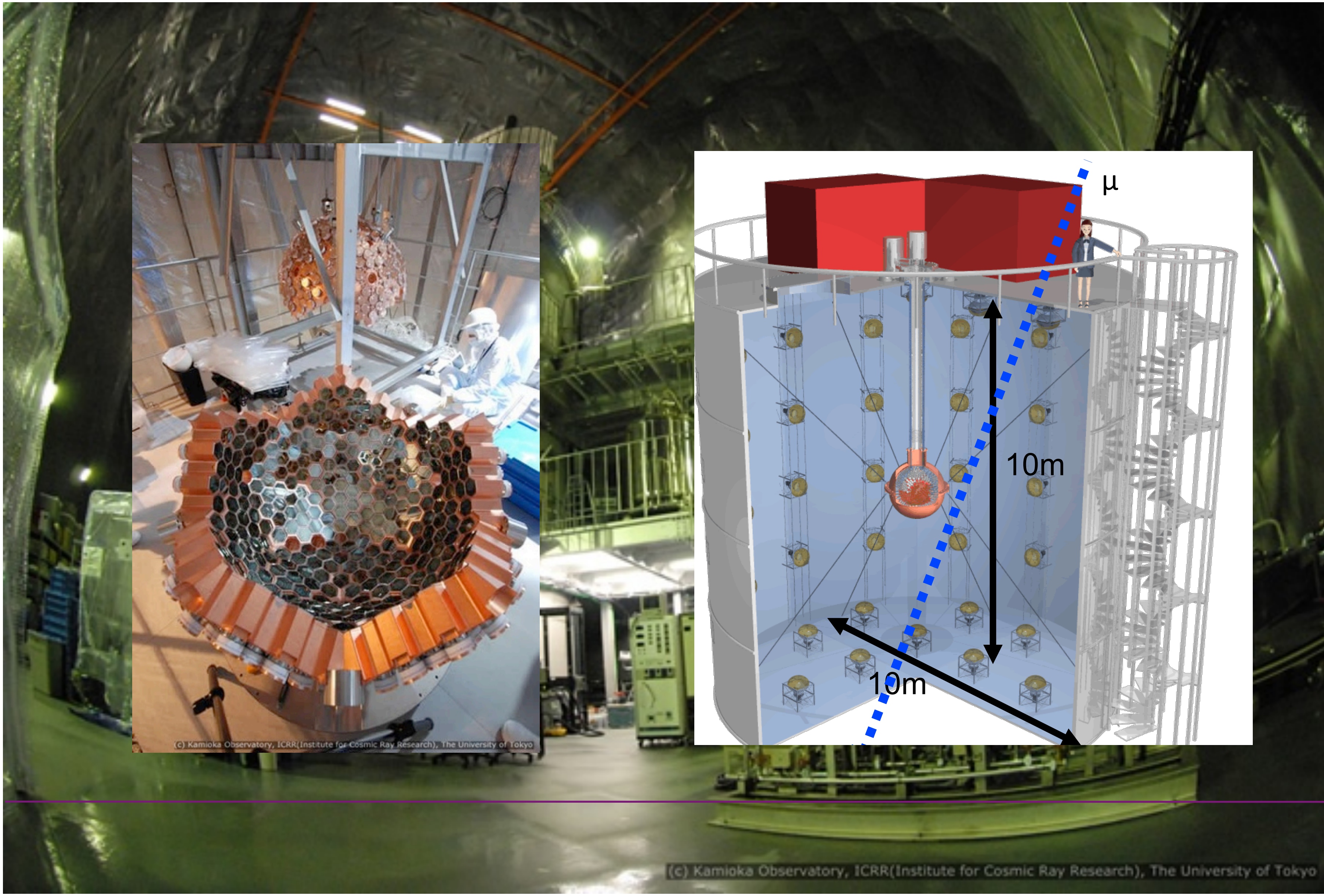
from K. Kobayashi's talk at IWDD'09

XMASS Detector in Kamioka

XMASS Detector in Kamioka



XMASS Detector in Kamioka



XMASS Low Background Developments

- were necessary for dark matter but also necessary for *pp* solar neutrinos
  - purification of Xe
  - distillation tower to remove Kr
  - PMT base selected for low radioactivity
  - no leaching of PMT material into liquid xenon
  - OFHC copper for inner and outer vacuum chambers and filler
- if XMASS has low enough backgrounds between 50-200 keV in 100 kg fiducial volume, then will see ~36 *pp* ν after first year

LENA

Liquid Scintillator
50 kt PXE / 43kt LAB
contained in an
Inner Nylon Vessel
R = 13m, 150mm thick

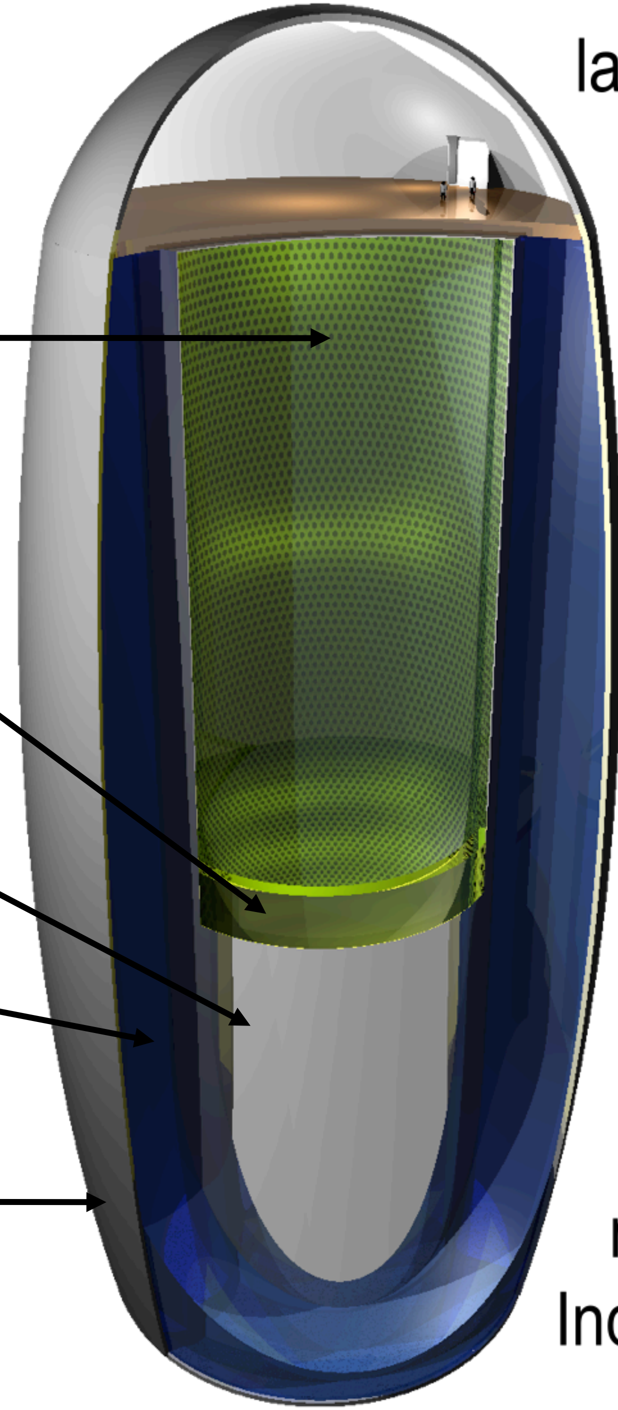
Buffer Region
Quenched scintillation, 2m thick

Steel Tank,
48,000 Pms (8")
R = 15m, h = 100m

Water Čerenkov Veto
1500 PMs, at least 2m

Egg-Shaped Cavern
about 10^8 m^3

Overburden:
> 4000 mwe

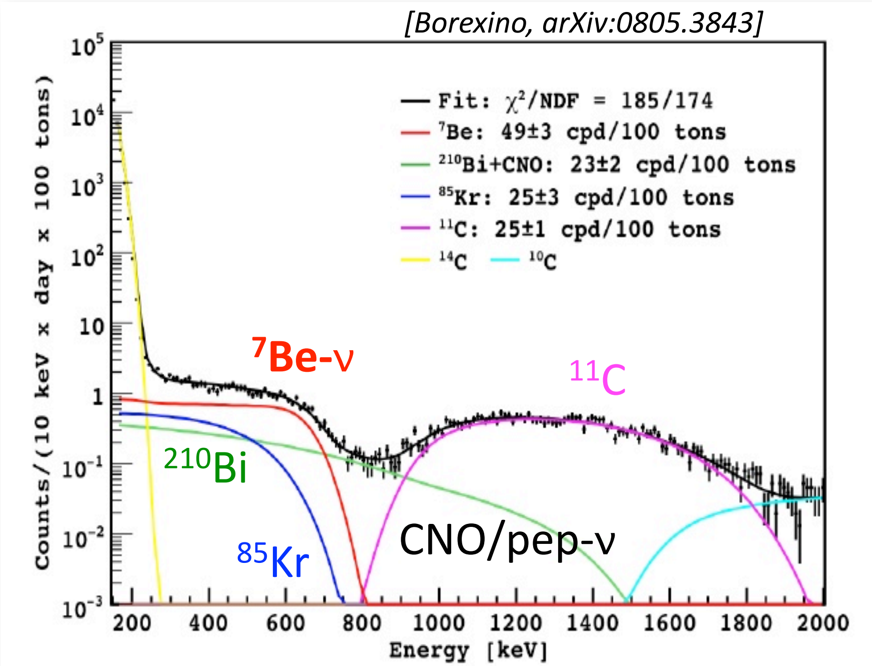


large-volume multi-
purpose observatory
For Low-Energy
Neutrino Astrophysics

SCIENTIFIC GOALS

Nucleon Decay
Supernova neutrinos
Diffuse SN neutrinos
Geoneutrinos
Solar neutrinos
Atmospheric neutrinos
Neutrino properties by
reactors/accelerators
Indirect dark matter search

Solar Neutrinos in LENA



Channel	Source	Neutrino Rate $[d^{-1}]$ BPS08(GS)	Neutrino Rate $[d^{-1}]$ BPS08(AGS)
νe	pp	24.92±0.15	25.21±0.13
	pep	365±4	375±4
	hep	0.16±0.02	0.17±0.03
	^{7}Be	4984±297	4460±268
	^{8}B	82±9	65±7
	CNO	545±87	350±52
^{13}C	^{8}B	1.74±0.16	1.56±0.14

Rates above threshold, assuming a conservative fiducial mass of 18kt

Detection Channel

elastic ν-e scattering, $E_{th,e}$ > 0.2MeV

Background Requirements

- U/Th concentration of 10^{-18} g/g (achieved in Borexino)
- shielding of >4000 mwe for CNO/pep-ν meas.

Scientific Motivation

- determination of solar parameters
  - hep-ν contribution
  - total ν-luminosity via pep-ν meas.
  - CNO contribution → discrimination of high/low metallicity solar models
- search for temporal modulations in ^{7}Be-ν flux (sensitivity on sub-percent level, g-modes?)
- probe the MSW effect in the vacuum transition region (^{8}B-, pep-ν)

  → new osc. physics
- search for $\nu_e \rightarrow \bar{\nu}_e$ conversion

SNO+ is Under Construction

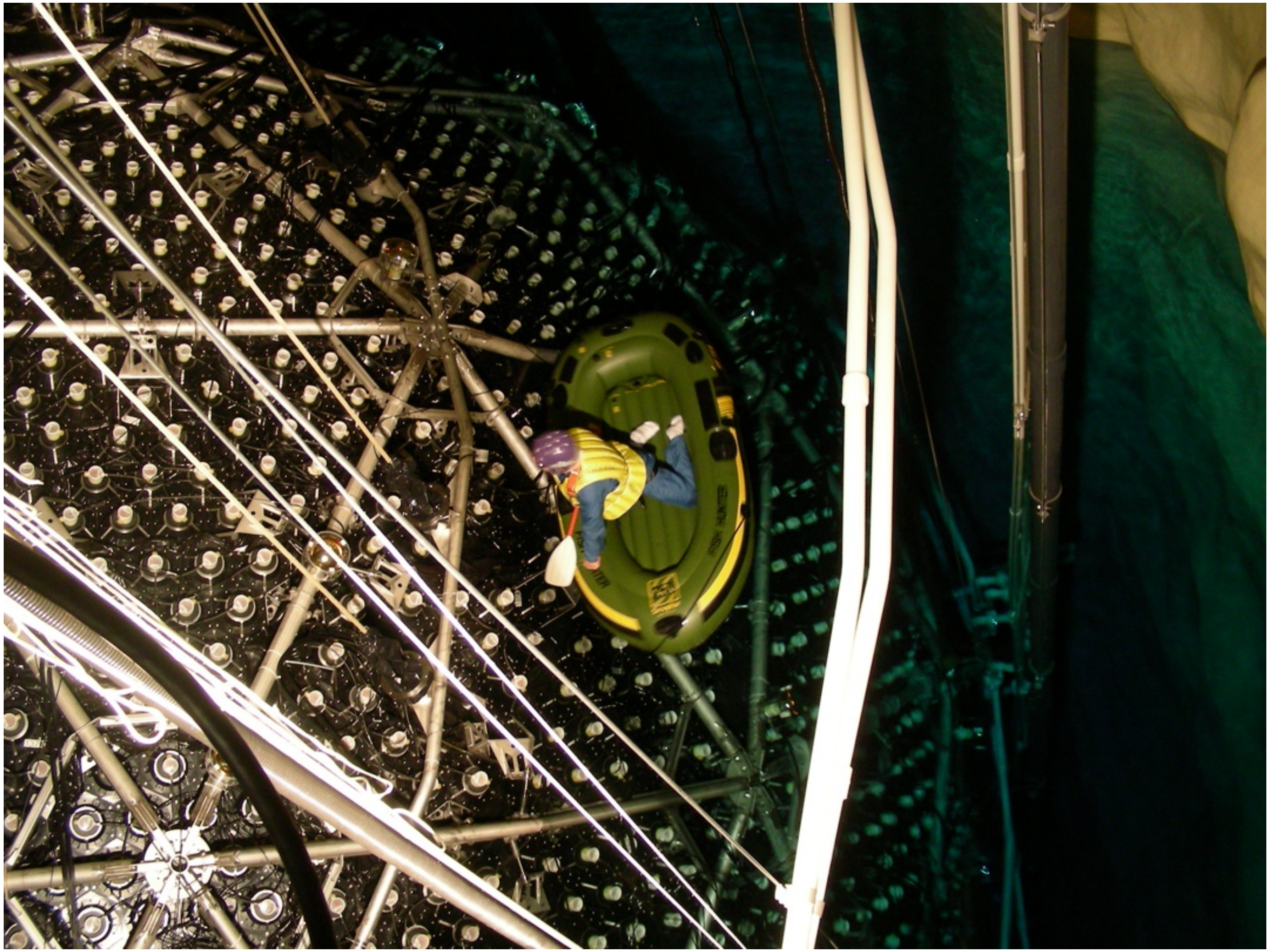
- in my remaining time, I will show photos and describe the status of SNO+ construction

Turning SNO into SNO+

- to do this we need to:
  - buy the liquid scintillator
  - install hold down ropes for the acrylic vessel
  - build a liquid scintillator purification system
  - make a few small repairs
  - minor upgrades to the cover gas
  - minor upgrades to the DAQ/electronics
  - change the calibration system and sources

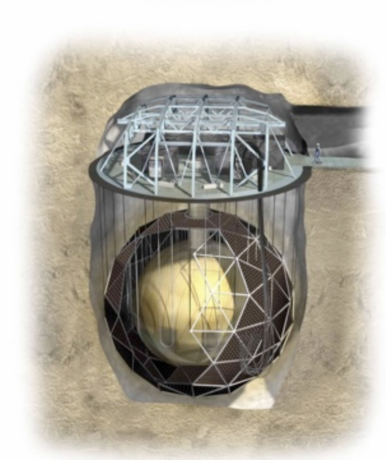
we are building a new experiment with new and diverse science goals, for modest cost

Draining SNO and Boating Inspections



Inside AV Boating

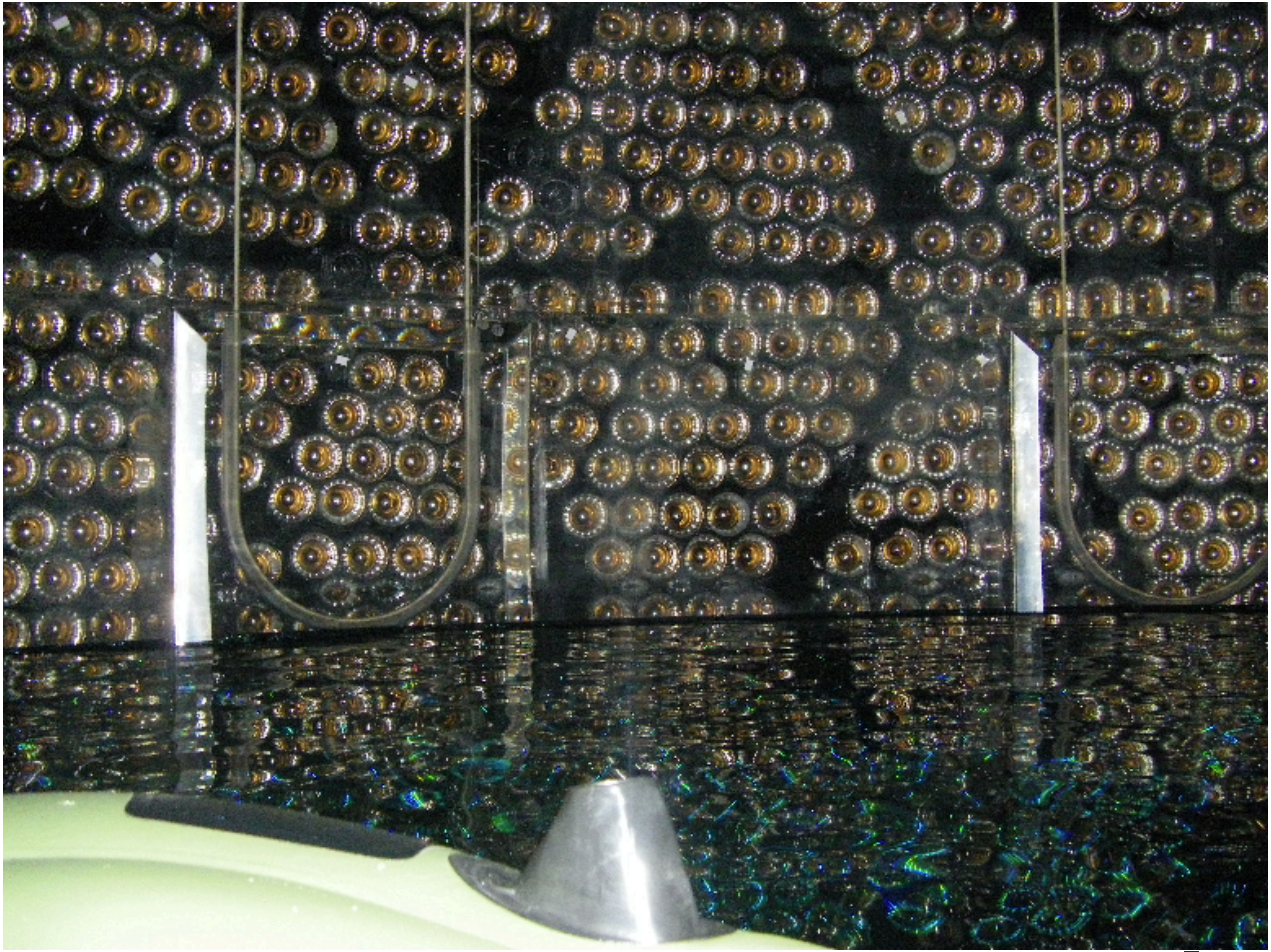
no crazing or deterioration of acrylic seen



- boating has taken place *inside* the acrylic vessel
  - to attach survey targets
  - inspection for engineering re-certification
- many inspections in the outer detector and cavity

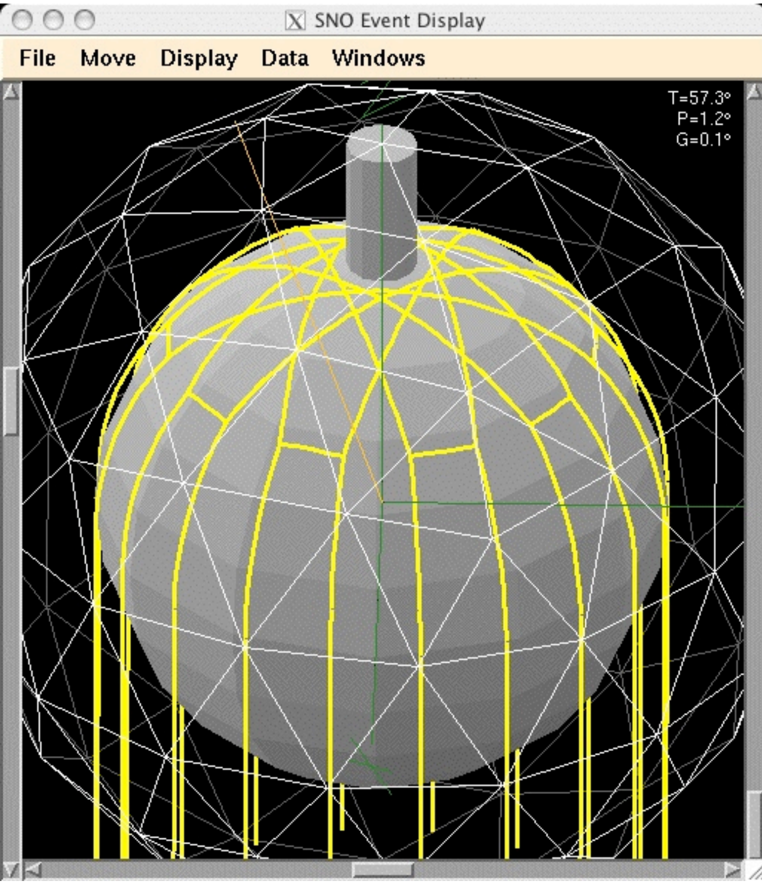
outside PSUP boating

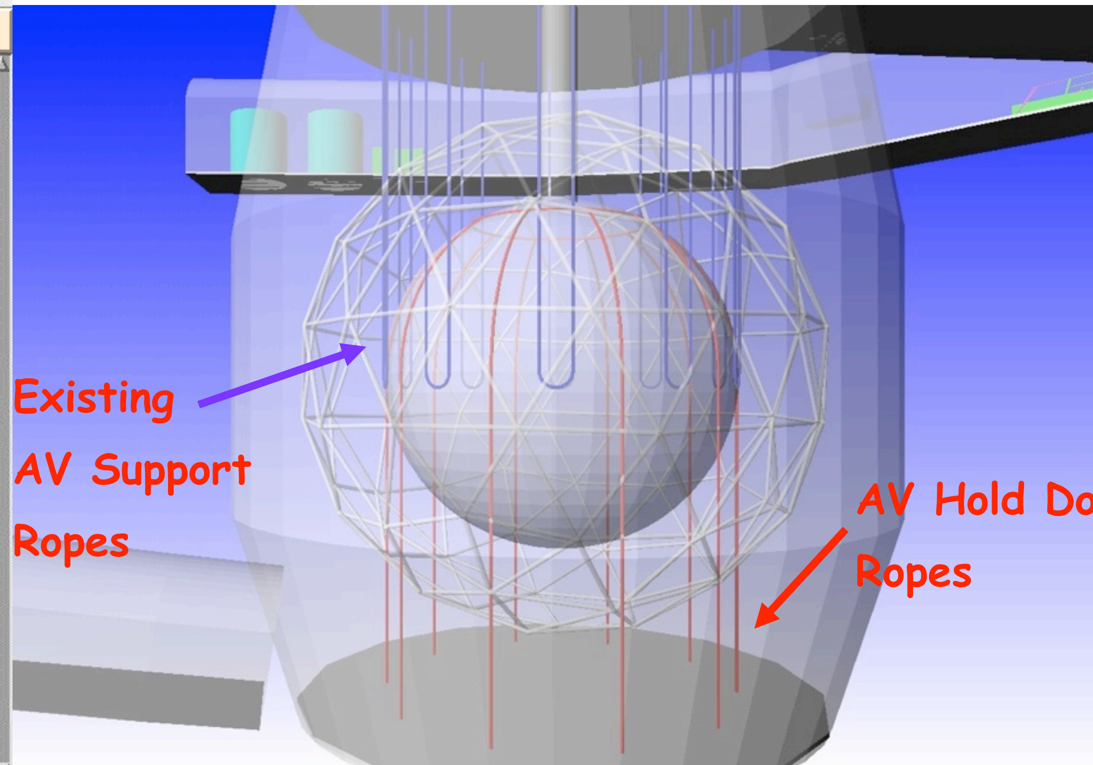
not heavy water!



SNO+ Rope Hold Down Net

sketch of hold down net

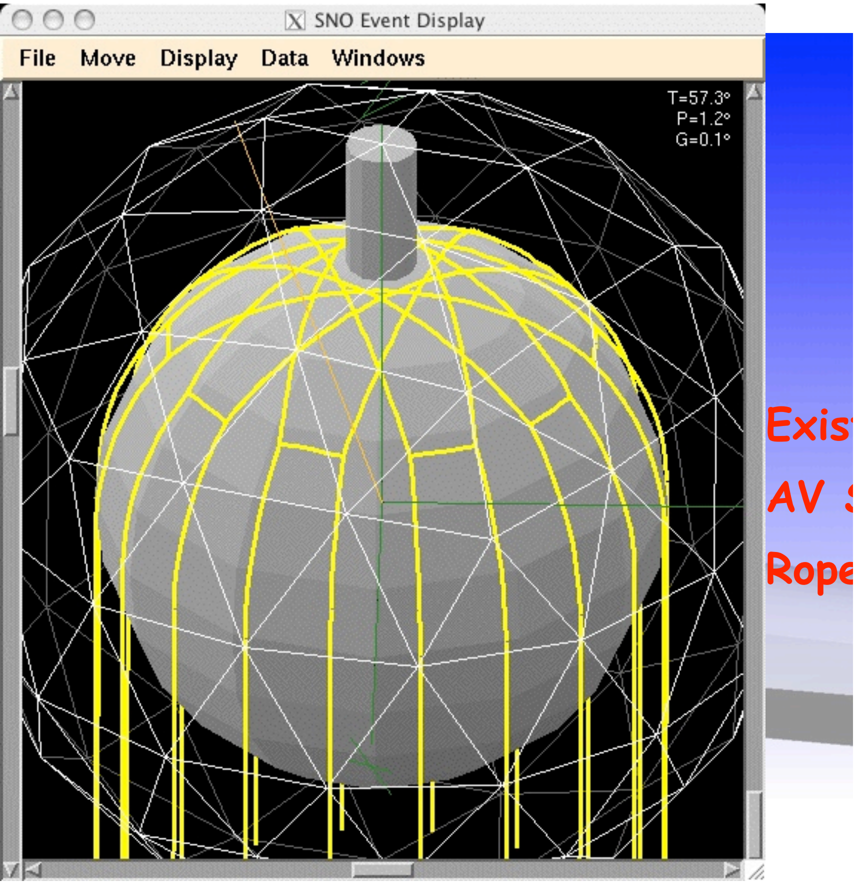




rope tension calculation and
visualization of net-PSUP geometry

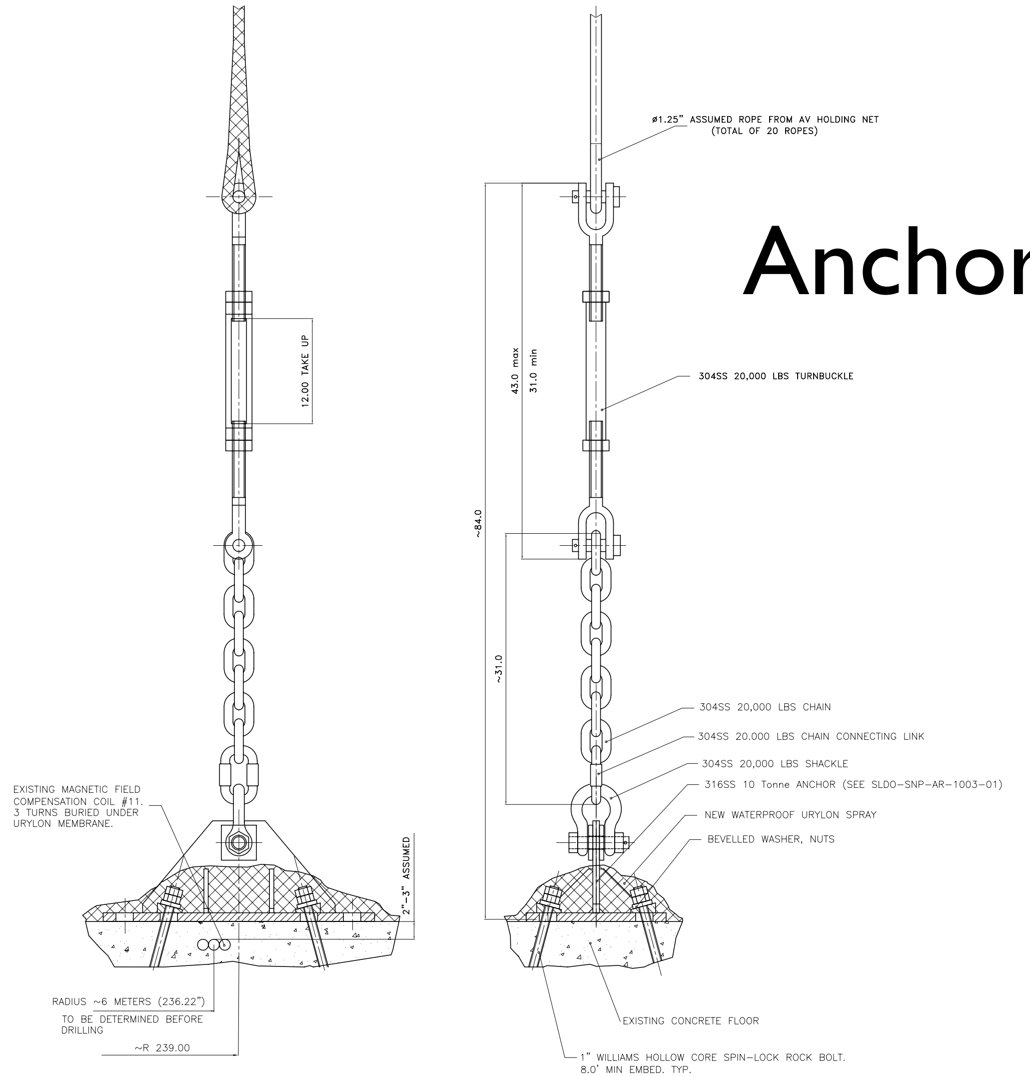
SNO+ ropes will be Tensylon: low U, Th, K ultra-high molecular weight polyethylene

SNO+ Rope Hold Down Net



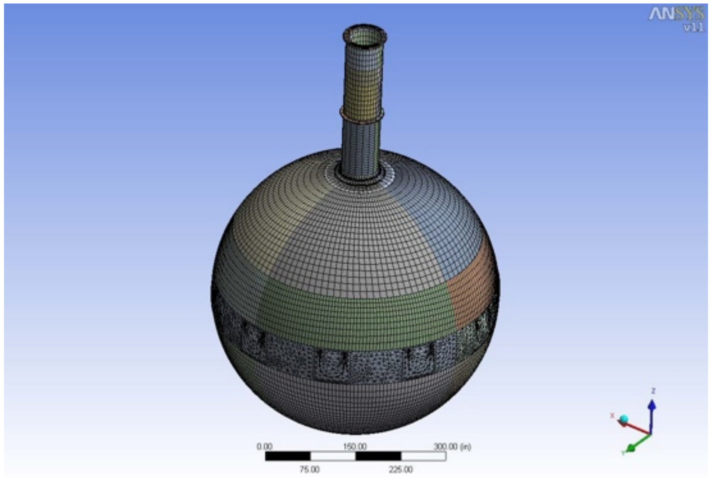
rope tension calculation and
visualization of net-PSUP geometry

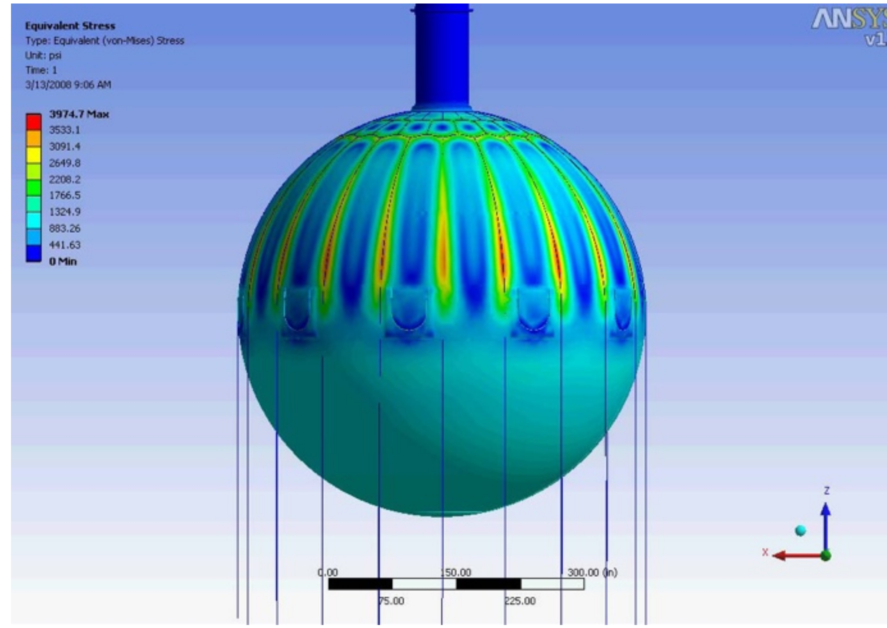
Anchor

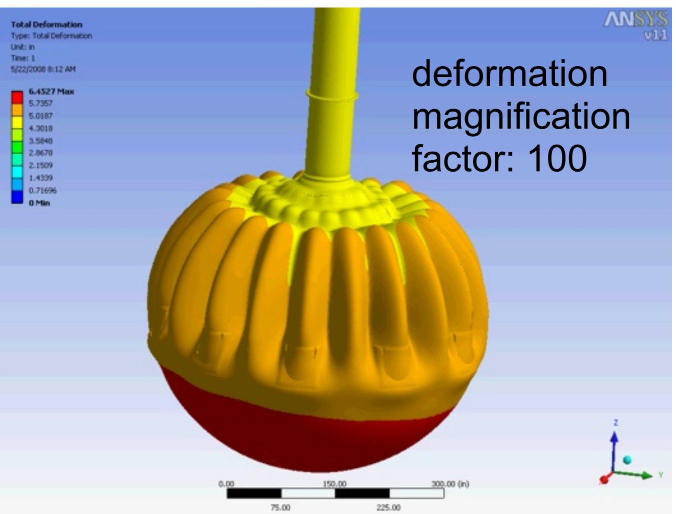


SNO+ ropes will be Tensylon: low U, Th, K ultra-high molecular weight polyethylene

Buckling and Finite Element Analysis



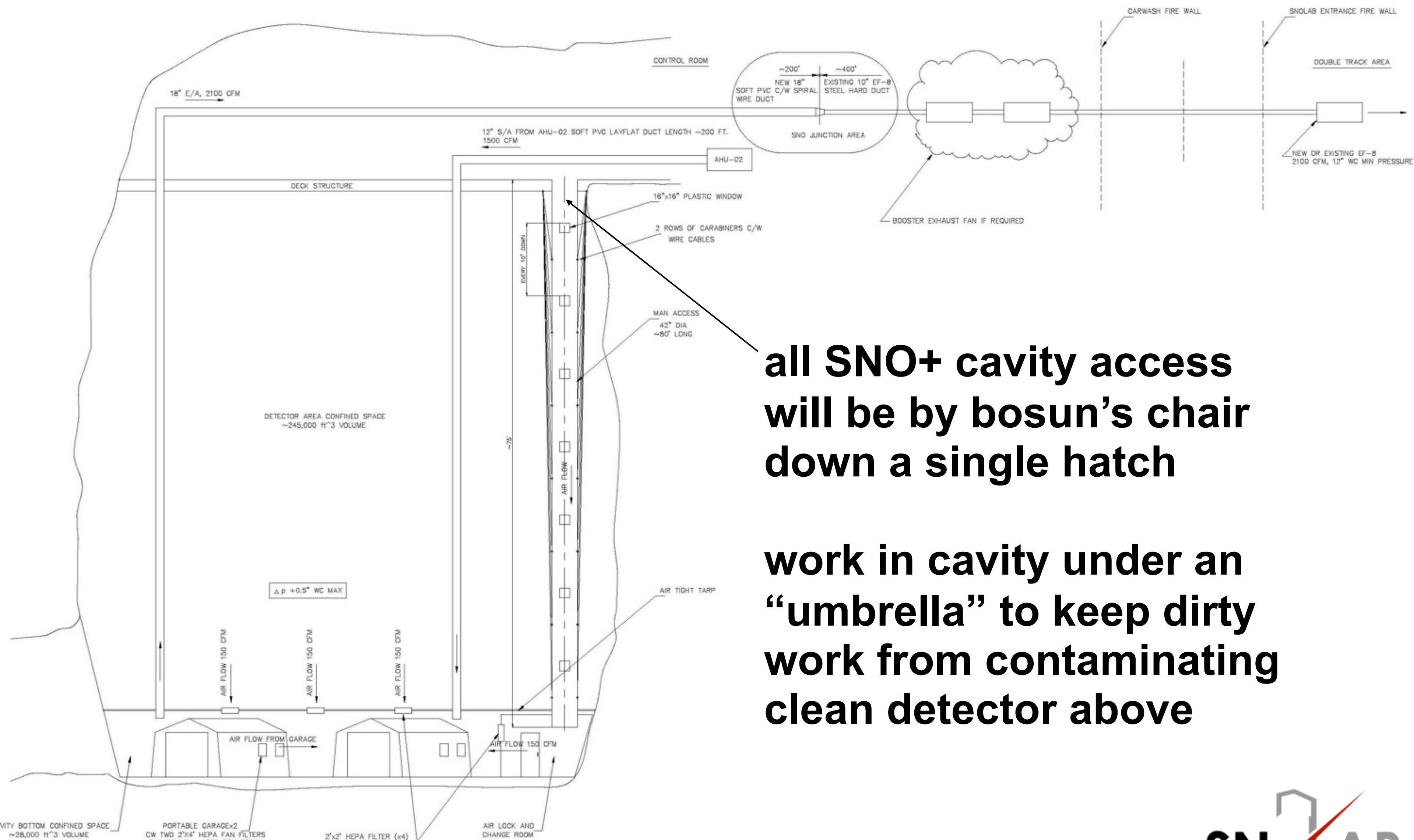




- stresses below SNO limit of 600 psi
- considered extreme case with **empty AV** surrounded by water outside: **does not buckle**

AIR HANDLING FLOWSHEET

(see drawing # SLDO-SNP-FL-2001-01)



all SNO+ cavity access will be by bosun's chair down a single hatch

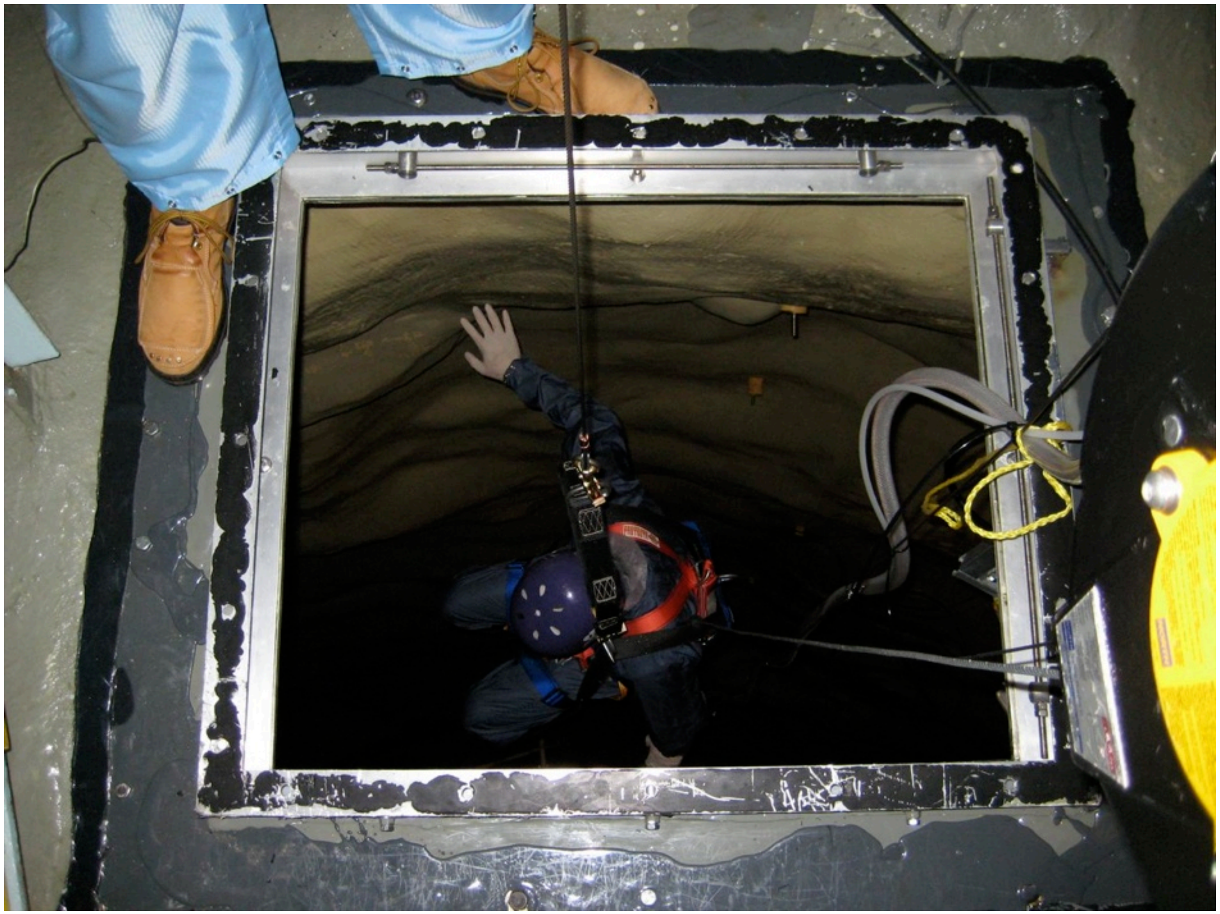
work in cavity under an "umbrella" to keep dirty work from contaminating clean detector above

SNOLAB

Entering the SNO Cavity – Inspections

Entering the SNO Cavity – Inspections

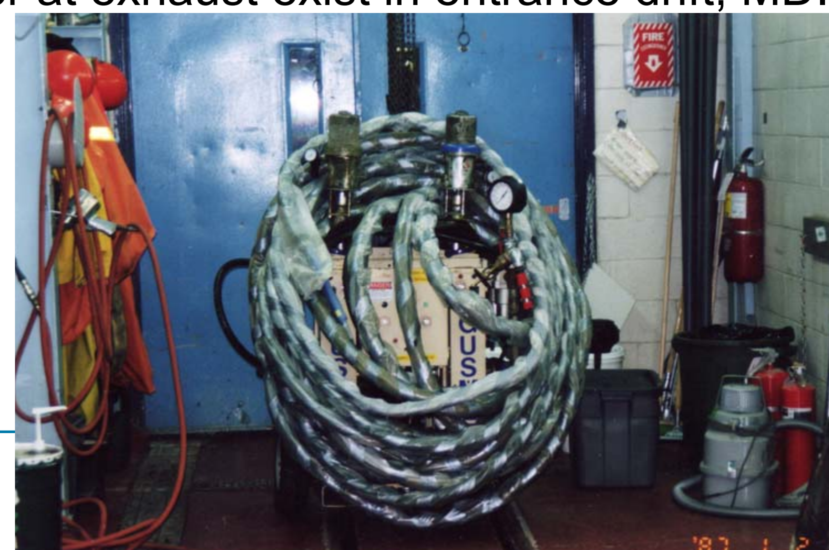
Entering the SNO Cavity – Inspections



Entering the SNO Cavity – Inspections

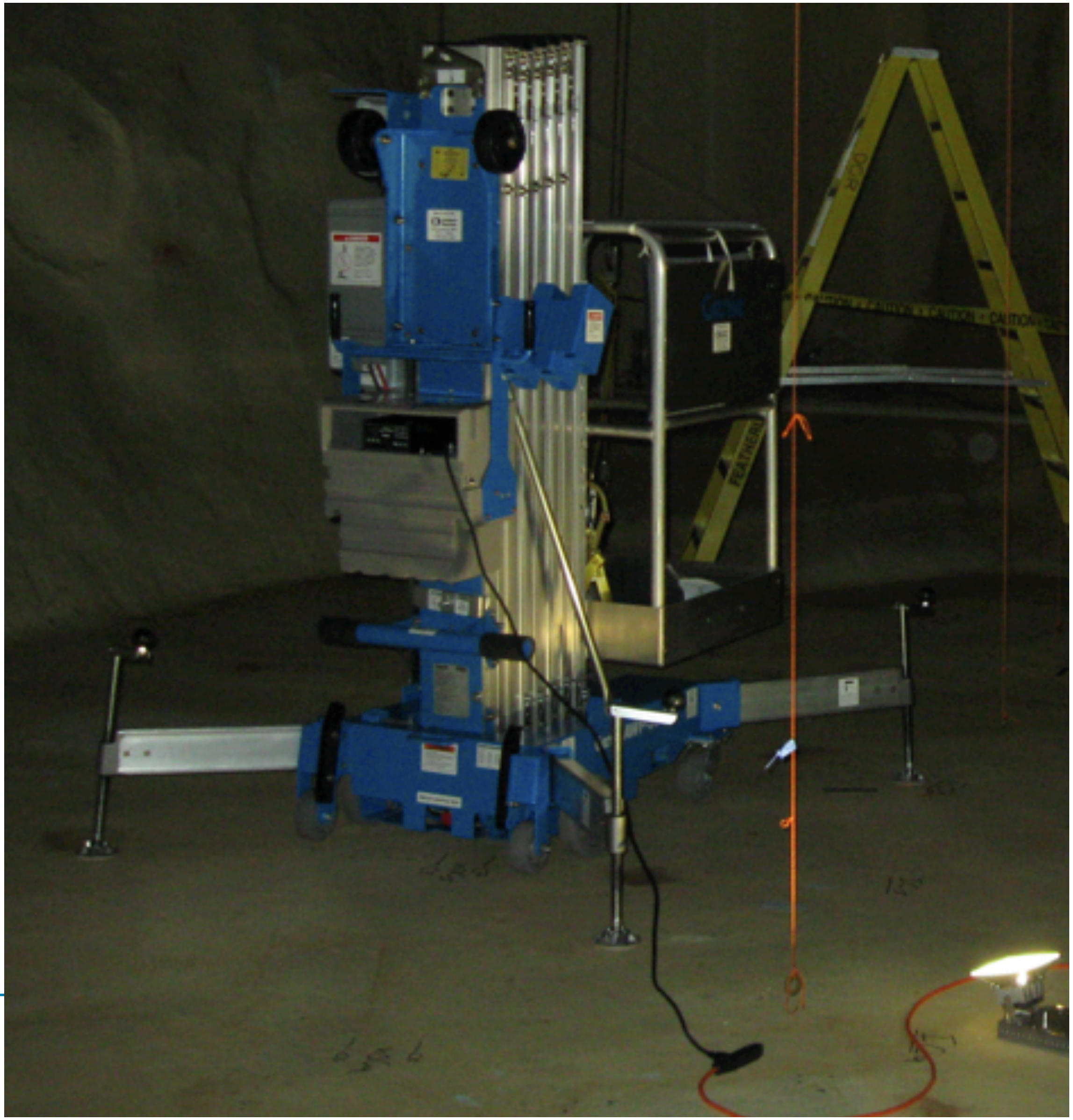
Spray New Cavity Liner

- 0.30” thick *Five Star Polyurea* floor – 6 layers of 0.050” each (made up of two spray passes in perpendicular directions) alternating gray & white colour – takes 4-5 days.
- Air supply full face respirators used.
- Spray pump unit – 4 ft x 4 ft footprint plus room for 4 polyurea component barrels – 10 ft x 15 ft area near hatch.
- Material delivery – double wall container - holds two 55 gal drums.
- Storage of extra drums (9 sets of A+B) near SNOLAB entrance.
- Heated hose (210 ft long) – from deck to all points on floor – deck hatch, route to floor, penetration through umbrella.
- Ventilation system – designed, 3 jet scrubber at exhaust exist in entrance drift, MDI monitoring in spray area and upper cavity.



PMT Repair using Genie Lift in the Cavity

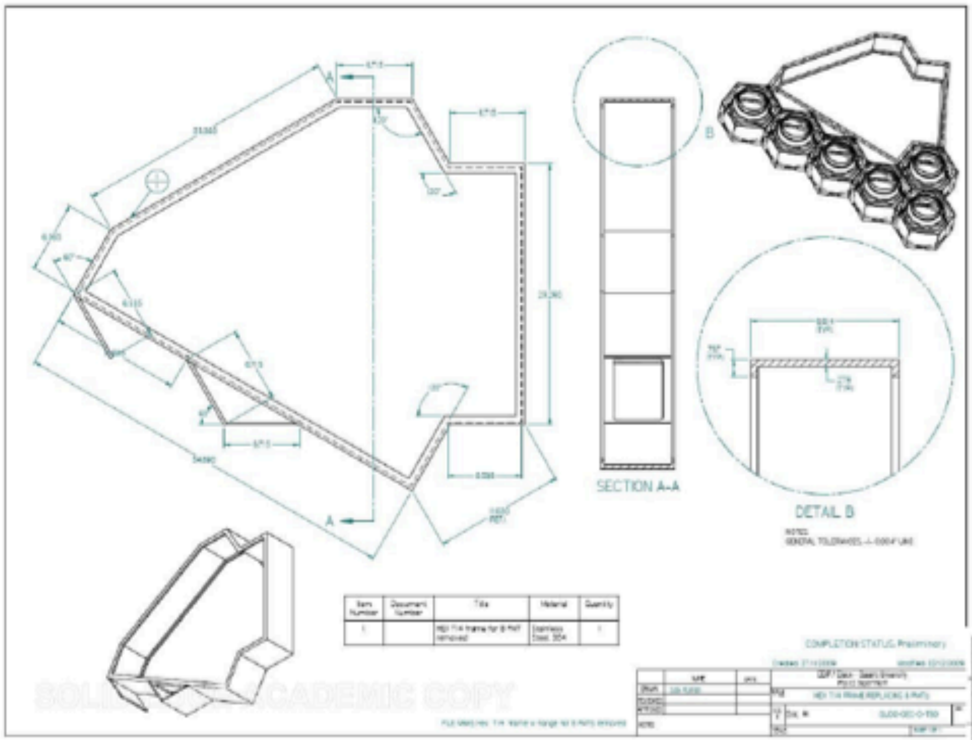
- for accessing PMTs, modifications of the PMT support structure, and repairing PMTs (bonus!)
- about 200-250 easily accessible “dead“ PMTs
- replace damaged bases, re-seal and pot, and replace
- only 2 out of first 60 were not repairable (e.g. one PMT lost photocathode)
- since not on critical path, in spare moments can work on this

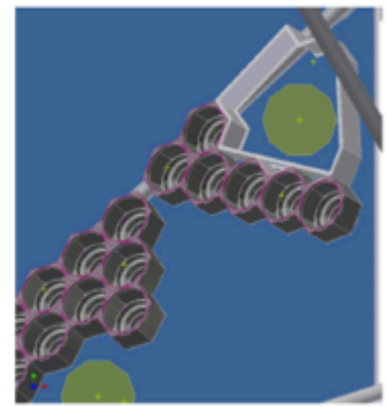


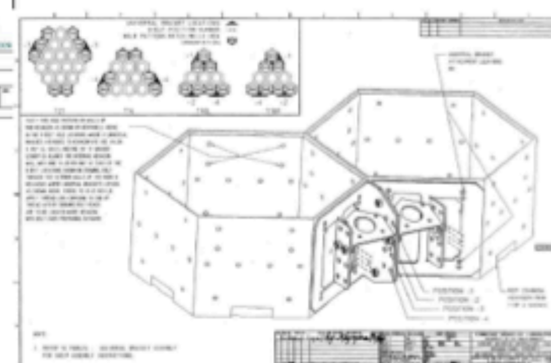

HANDLE WITH CARE
8204 116 50924

PMTs Removed – Replacement Frames

Typical Hex Panels – frames for PMTs removed







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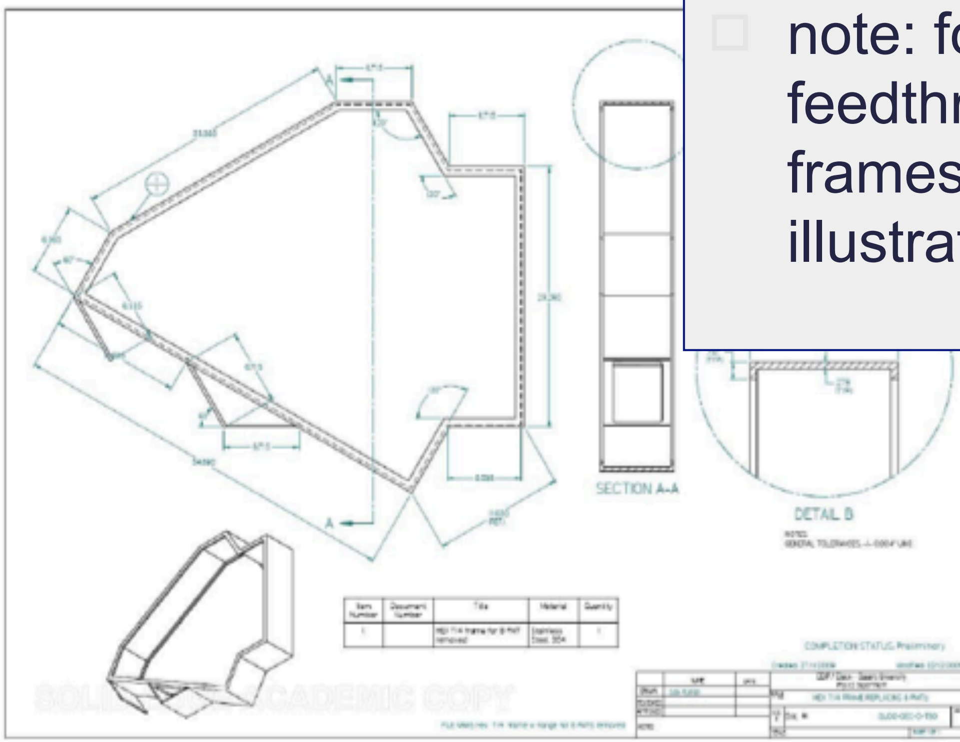
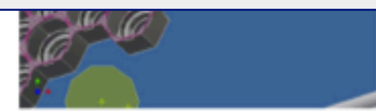
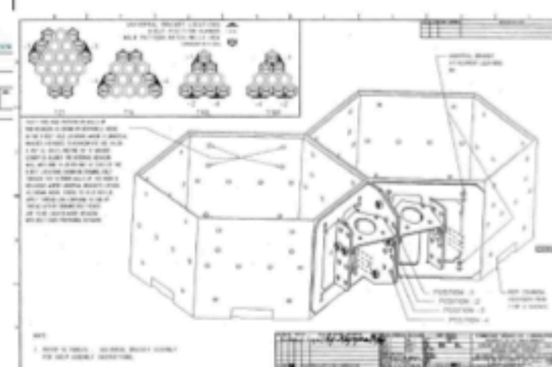
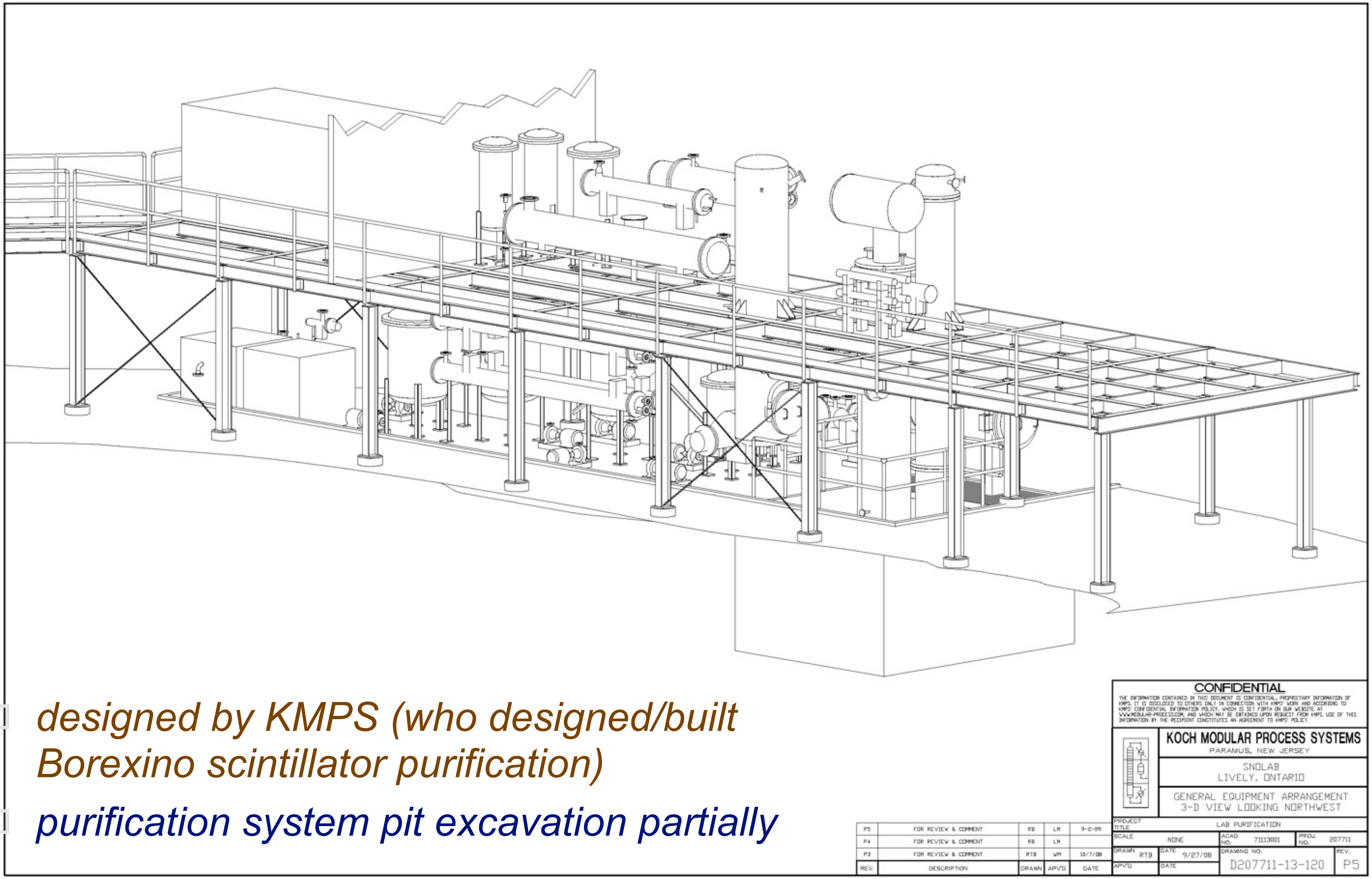


- note: for 8” diameter feedthroughs, displaced PMT frames will be smaller than illustrated in these drawings



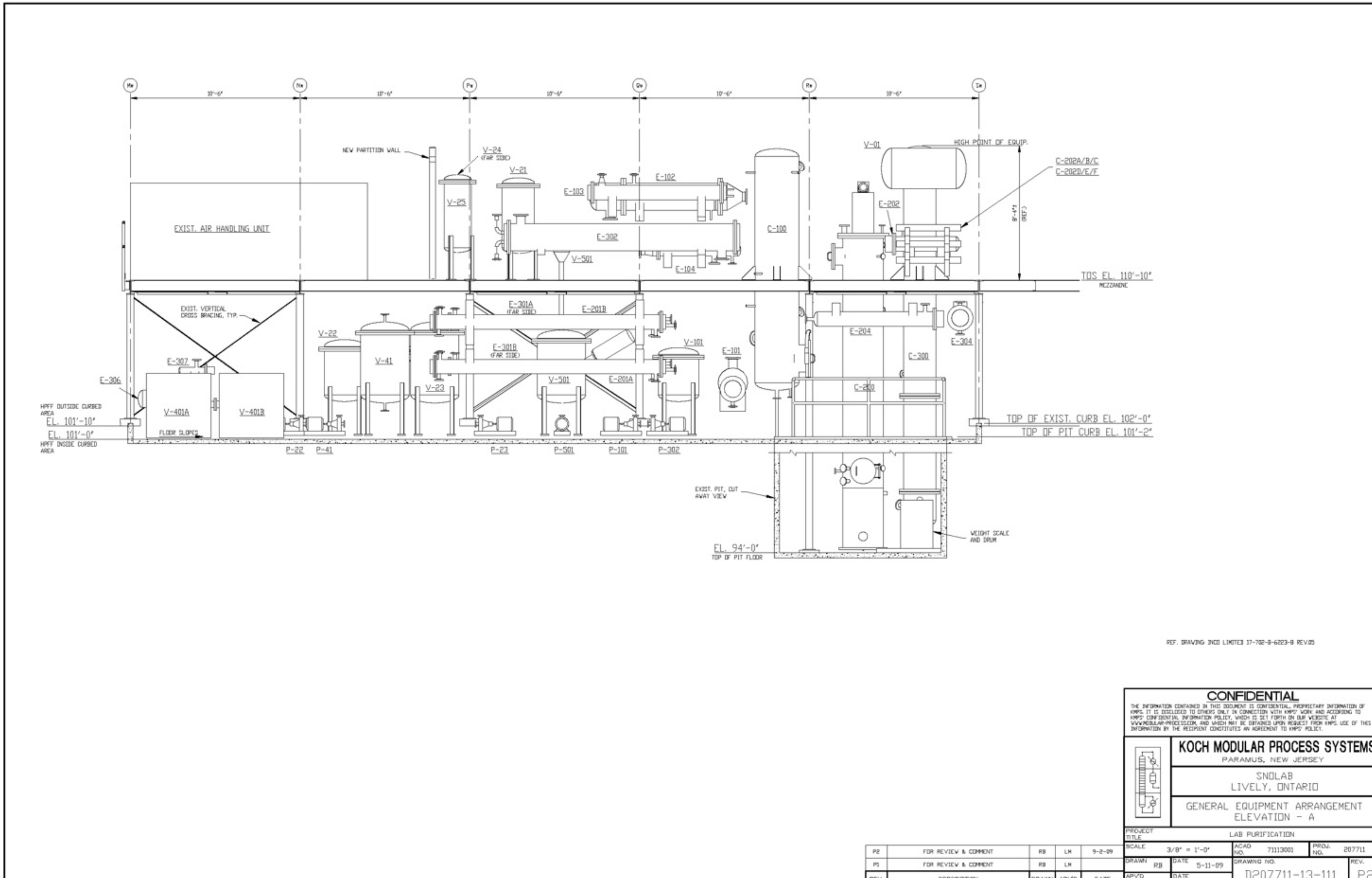


Scintillator Purification System



- *designed by KMPS (who designed/built Borexino scintillator purification)*
- *purification system pit excavation partially*

Scintillator Purification System



SNO+ Pit – Mining in a Clean Room

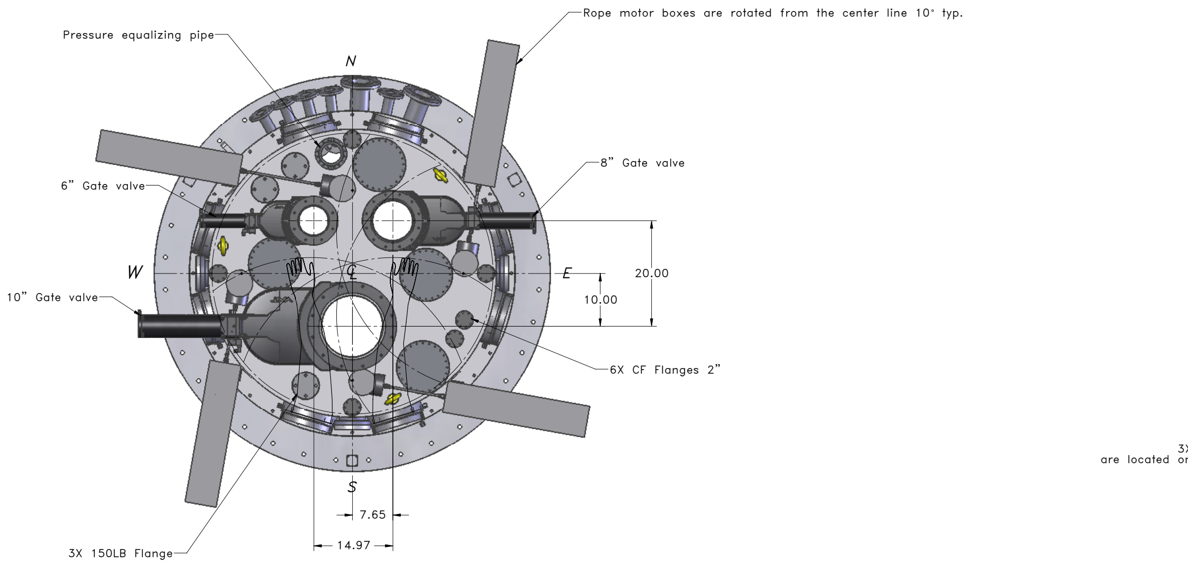
SNO+ Pit – Mining in a Clean Room

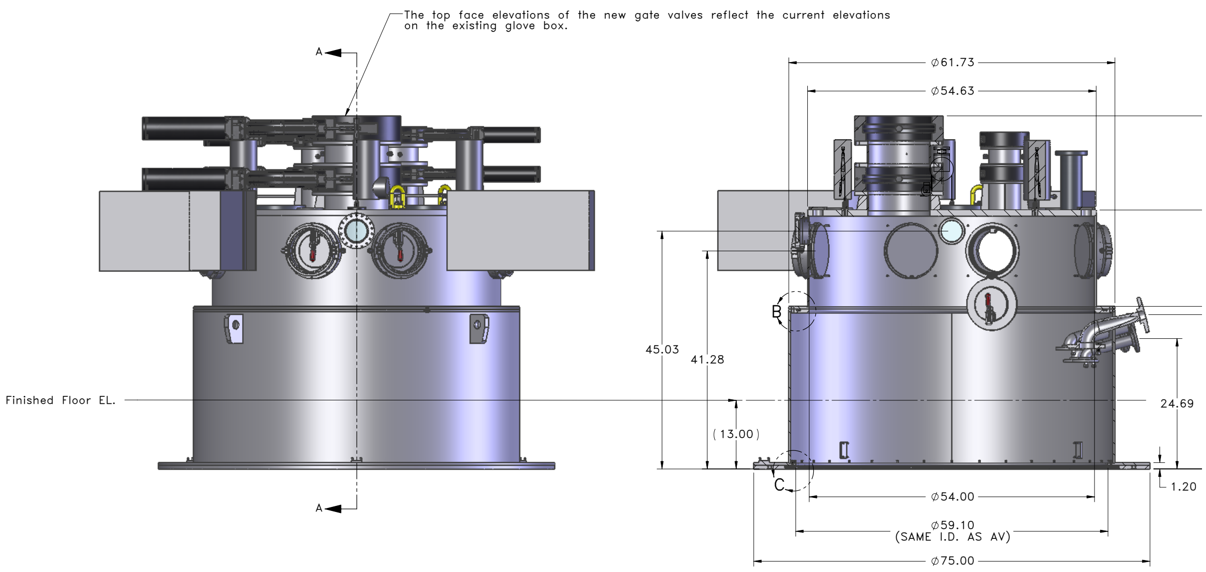
SNO+ Pit

SNO+ Pit

SNO+ Pit

Universal Interface





- being fabricated at TRIUMF

Status of SNO+ Construction

- SNO+ is fully funded and under construction
- major construction work in the cavity is beginning now
- scintillator purification system ordered, designed and being built; installation in Fall 2011
- some “dead” SNO PMTs are being removed, repaired, and replaced
  - it’s not planned to repair all dead SNO PMTs; rather, while we have time, we have found many PMTS are easy to repair and easily accessed
- schedule: scintillator filling to start in Spring 2012

HANG ON, FOR MORE SOLAR NEUTRINOS IN THE NEAR FUTURE!