TECHNISCHE UNIVERSITÄT DRESDEN

Mathematik und Naturwissenschaften Institut für Kern- und Teilchen Physik

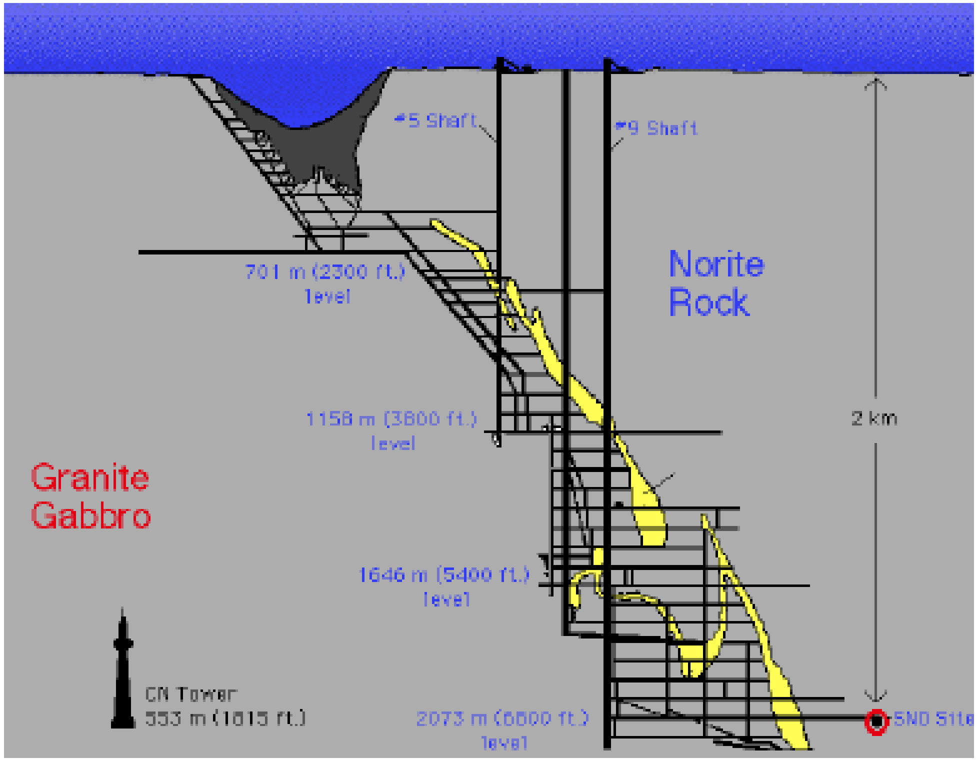
The SNO+ experiment: current status and future prospects

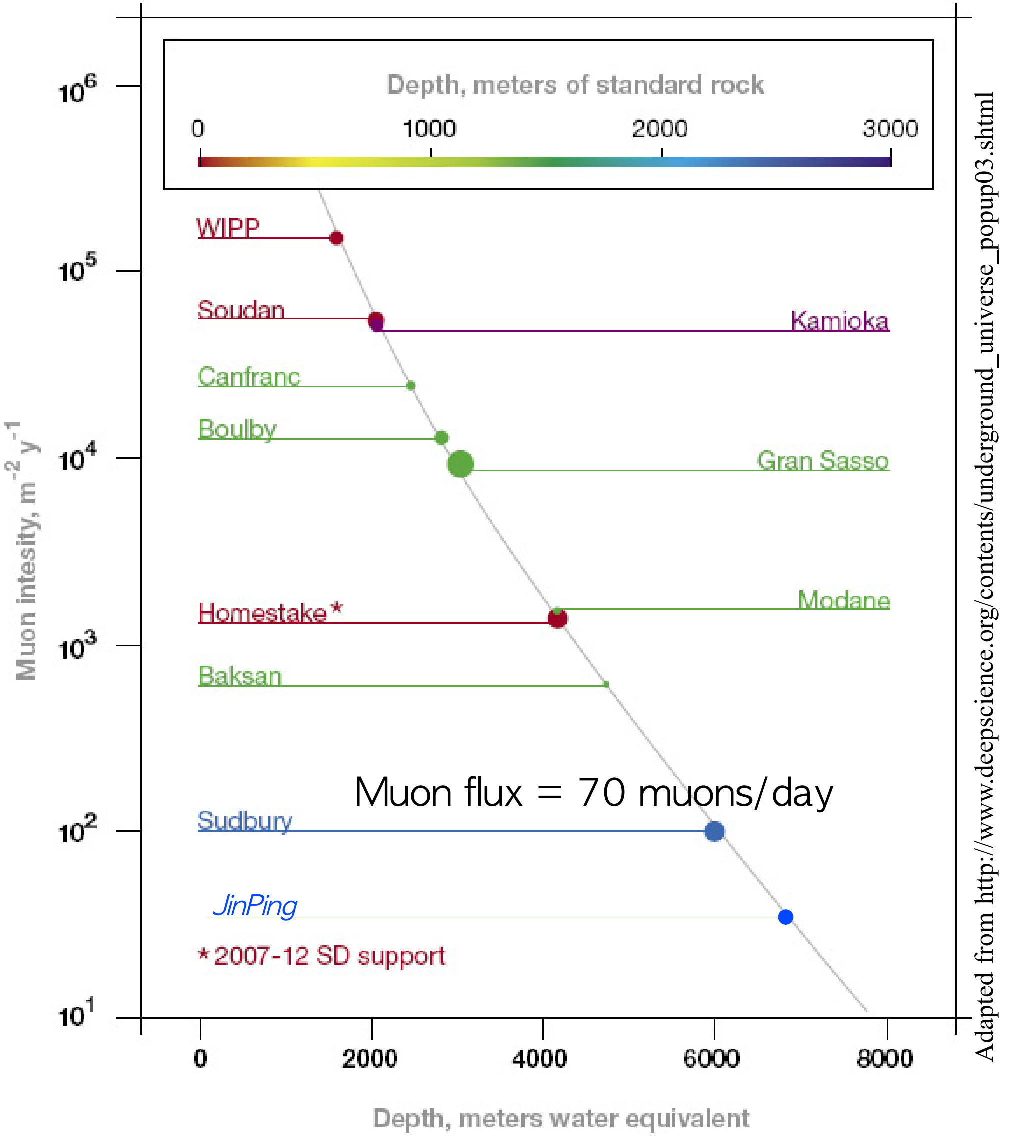
Valentina Lozza for the SNO+ collaboration

TU Dresden, Germany

Magellan Workshop, Hamburg 18/03/2016

LOCATION: ~6000 M.W.E





Muon flux = 70 muons/day

DETECTOR

780t of liquid scintillator
Active medium

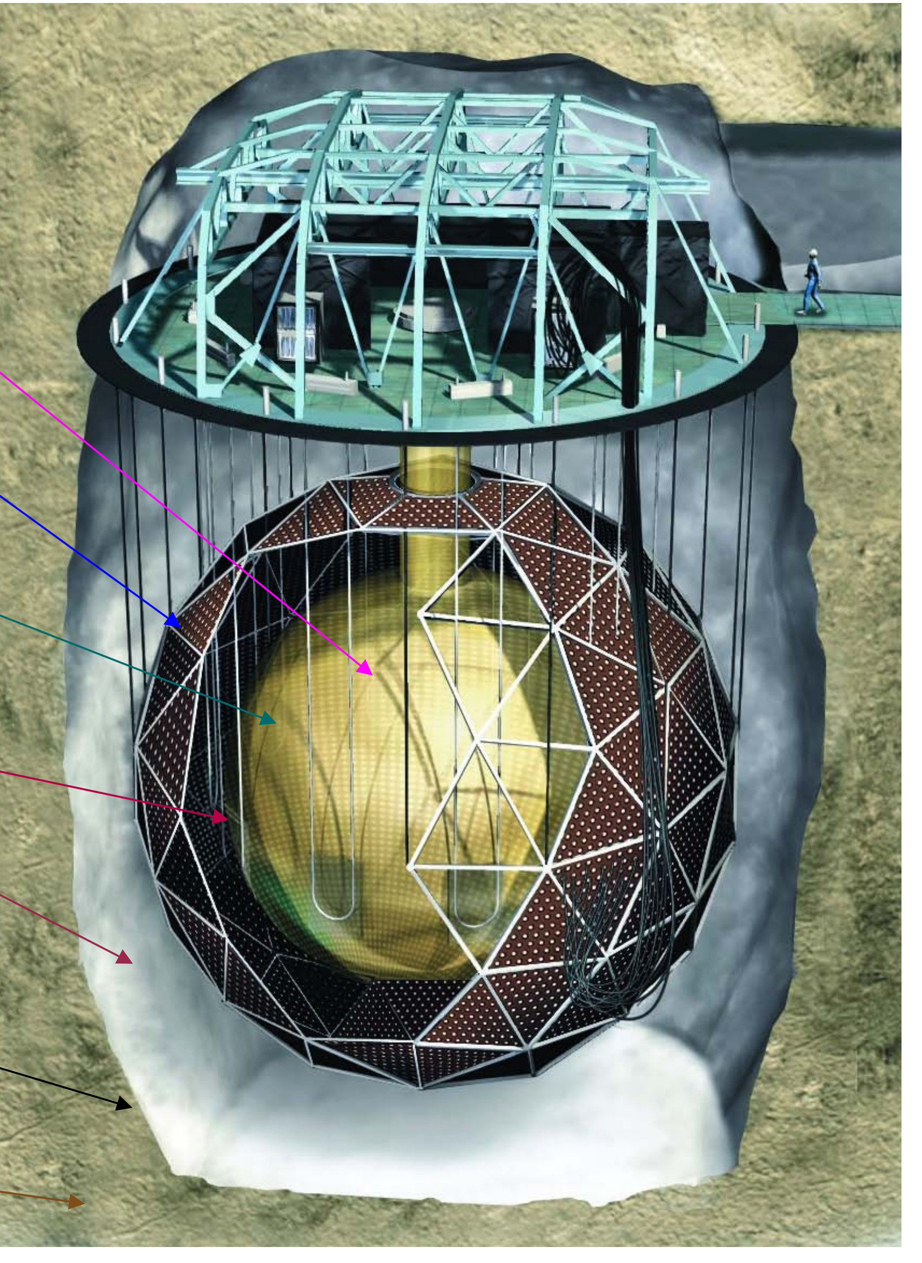
PSUP = PMT Support Structure
~9400 PMT
54% Coverage

Acrylic Vessel (AV)
ϕ=12 m, thickness = 5 cm

Light water (H_2O) shielding
- 1700t internal
- 5300t external

Urylon Liner/Radon Seal

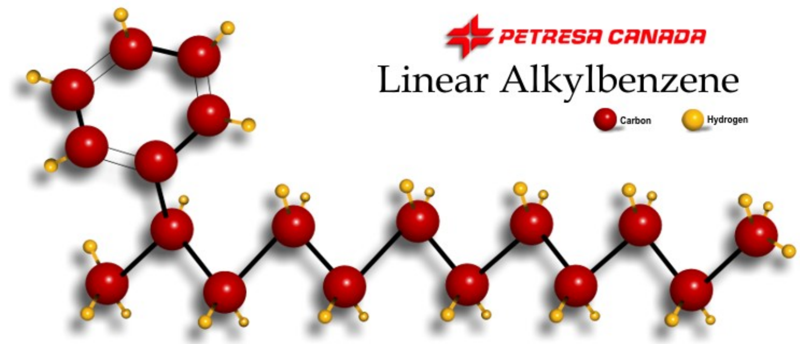
Norite Rock



Liquid scintillator: LAB

Linear alkylbenzene (LAB) + 2g/L fluor 2,5-diphenyloxazole (PPO)

- Chemical compatibility with acrylic
- High light yield (~10,000 optical photons/MeV)
- High purity available
- Low scattering
- Good optical transparency
- Fast decay (different for betas and alphas)



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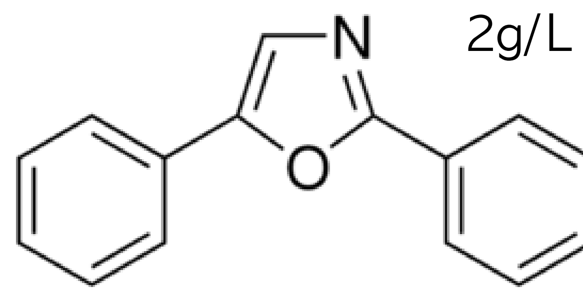


2g/L PPO

Petresa Plant – Quebec

Purification: LAB

- Target radiopurity levels

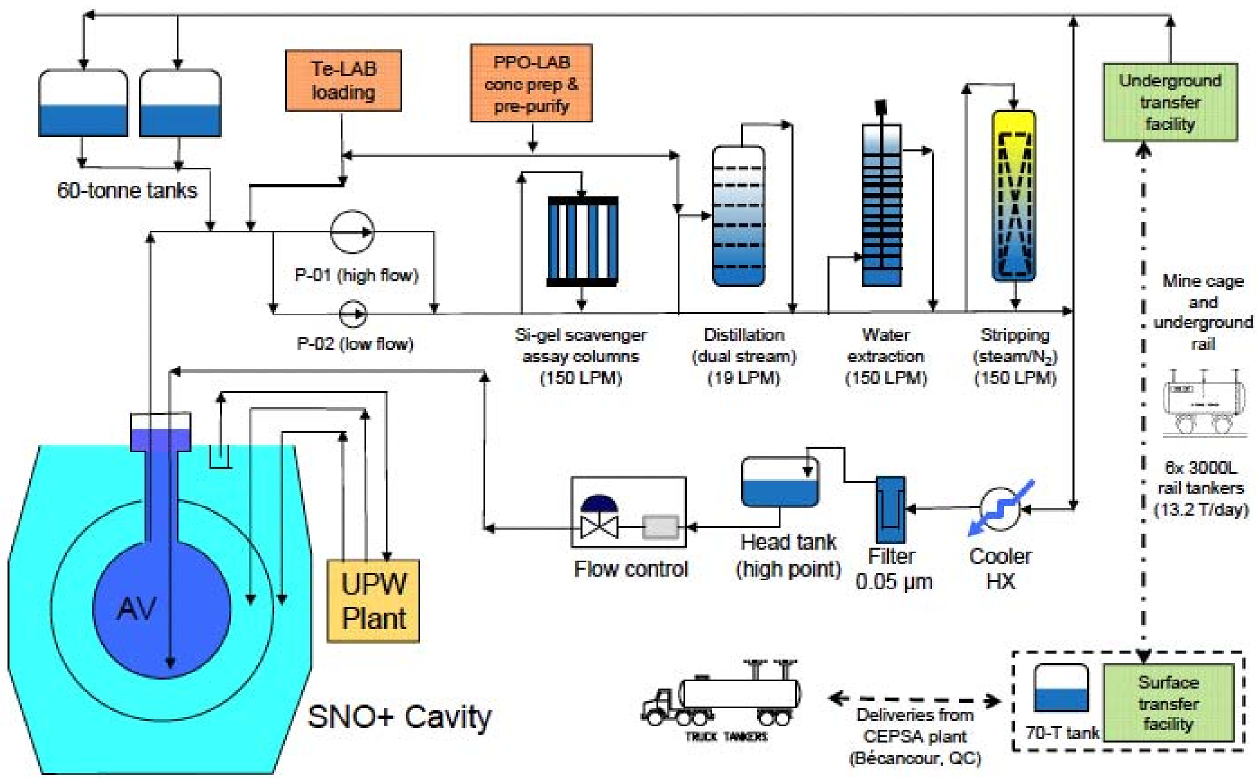
  $^{85}Kr < 10^{-25}$ g/g

  $^{40}K < 10^{-18}$ g/g

  $^{39}Ar: 10^{-24}$ g/g

  ^{238}U-chain: 10^{-17} g/g

  ^{232}Th-chain: 10^{-18} g/g



Industrial petrochemical plant built underground

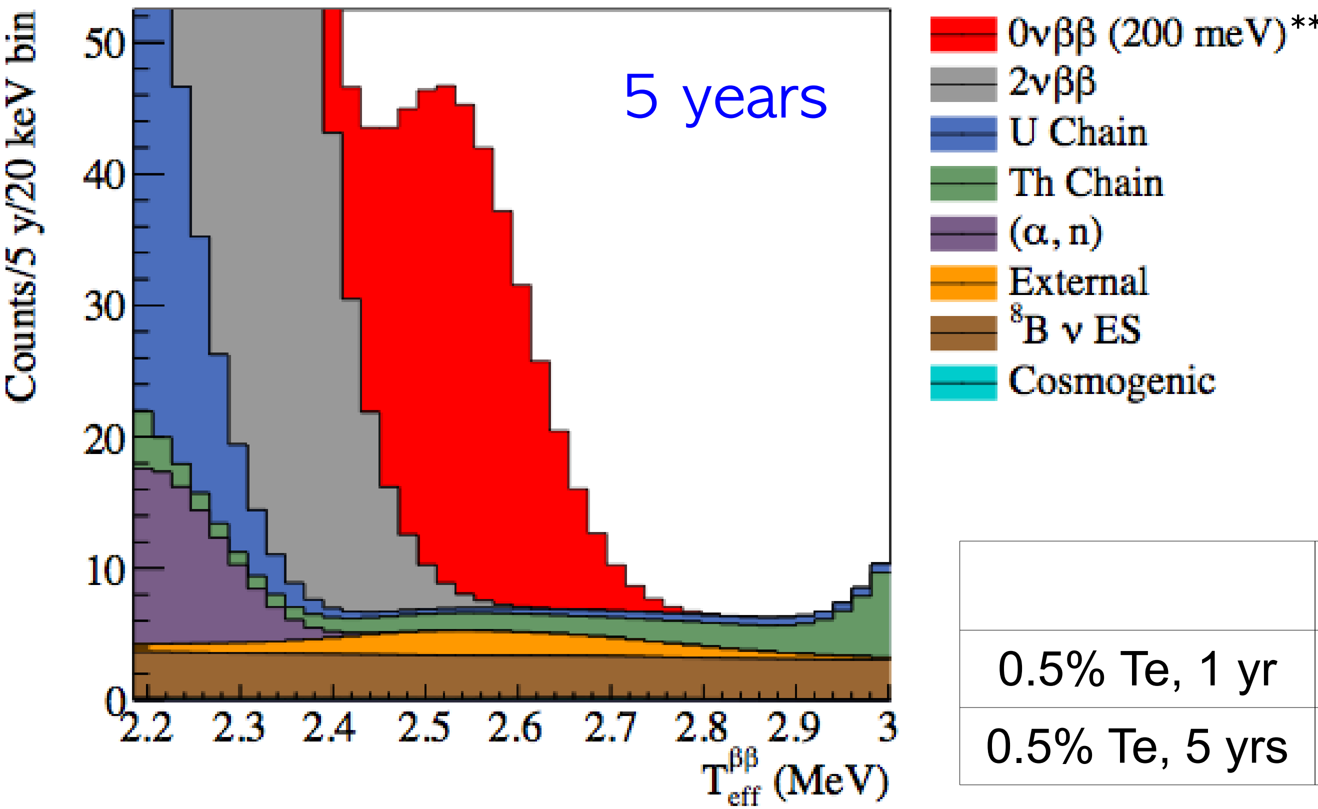
- ≻ Multi-stage distillation
- ≻ Pre-purification of PPO concentrated solution
- ≻ Steam/N_2 stripping under vacuum
- ≻ Water extraction
- ≻ Metal scavengers
- ≻ Microfiltration

Physics program

Goal	Water phase	Pure liquid scintillator Phase	Te-loaded phase
$0\nu\beta\beta$-decay			X
^{8}B solar neutrinos		X	X
Low-energy solar neutrinos		X	
Supernova neutrinos	X	X	X
Reactor Antineutrinos		X	X
Geo Antineutrinos		X	X
Exotic searches (i.e.nucleon decay)	X	X	X

DBD WITH TE

- The candidate isotope is ^{130}Te (nat. ab. 34.08%, Q-value = 2.53 MeV)
- 3.9 tonnes of ^{nat}Te are loaded into liquid scintillator



Assumptions:

- 0.5% ^{nat}Te loading
- R 〈 3.5 m (FV= 20%)
- 〉 99.99% (98%) rejection of ^{214}BiPo (^{212}BiPo)
- light yield 390 Nhits/MeV

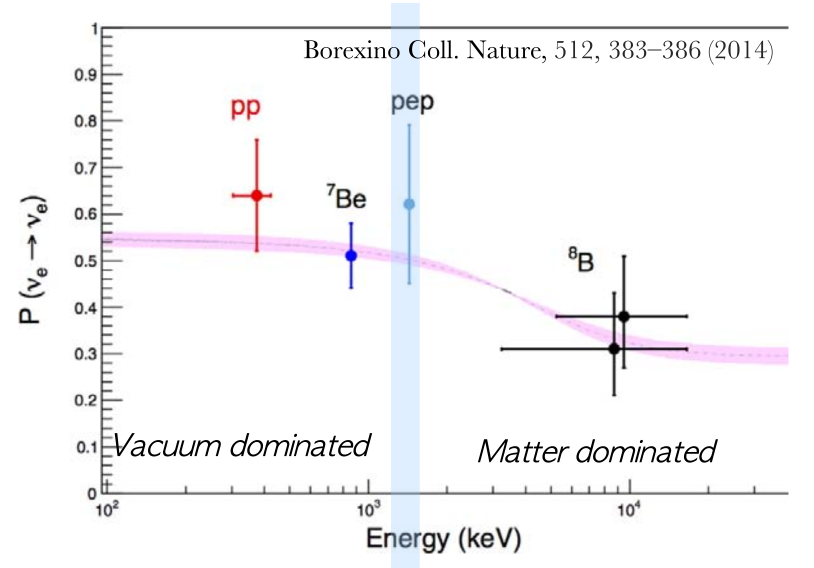
	$T_{1/2}$ [yr]	$m_{0\nu\beta\beta}$ [meV]
0.5% Te, 1 yr	8×10^{25}	75.2
0.5% Te, 5 yrs	1.96×10^{26}	38 – 92

**J. Barea et al. Phys. Rev. C87 (2013) 014315
J. Kotila, F.Iachello. Phys. Rev. C 85 (2012) 034316

Solar neutrinos

- Precision measurement of pep solar neutrino and low energy ^8B neutrinos
  ⇨ Probe the interactions of neutrinos with matter to search for new physics

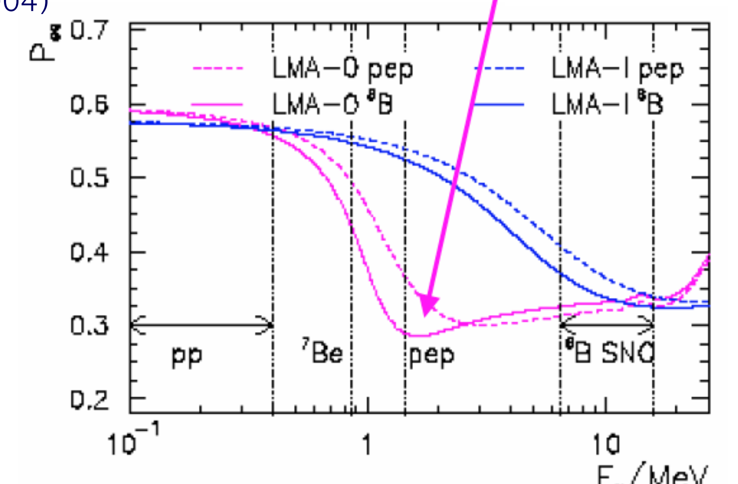
- Pep component is favorable due to:
  - single energy (1.44 MeV)
  - very well predicted flux (1.2 % uncertainty)



- ^8B neutrinos are favorable due to:
  - the production region closer to solar interior (new physics effects enhanced)

Friedland, Lunardini, Peña-Garay, PLB 594 (2004)

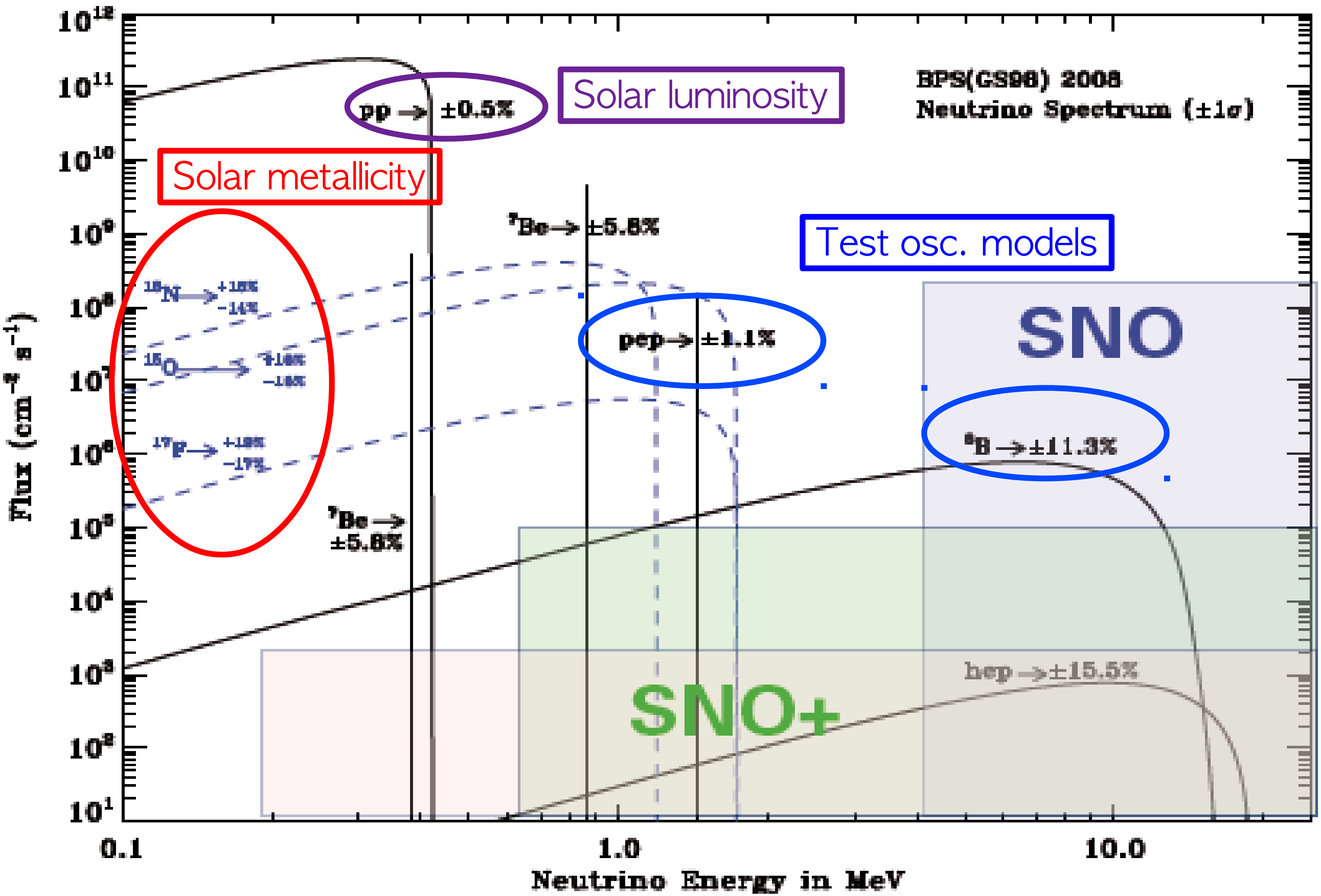
Good probe for NSI



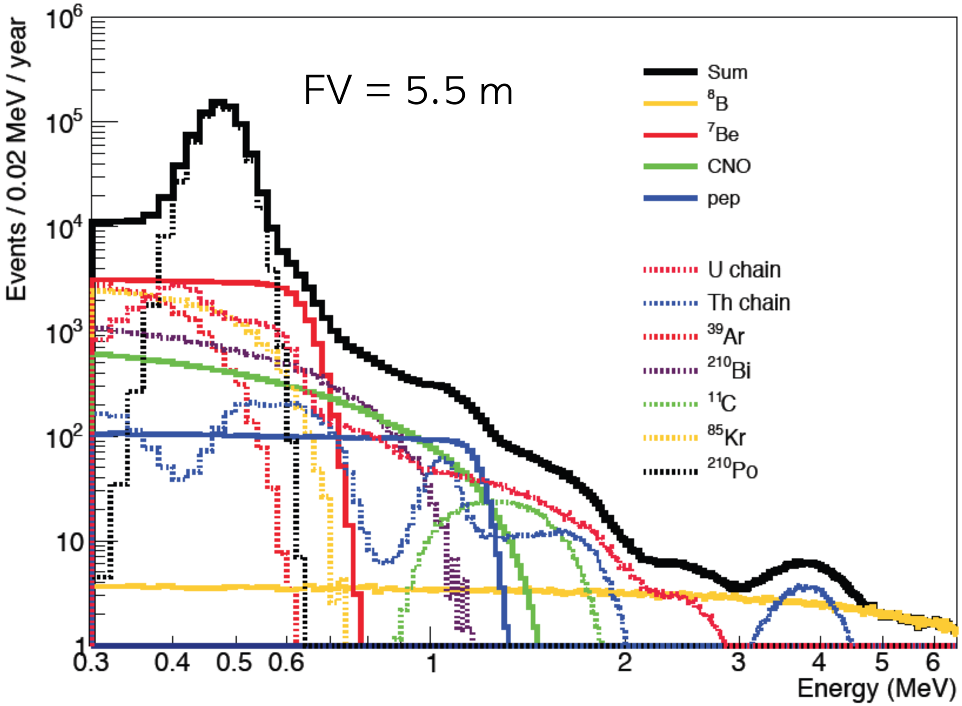
- CNO neutrinos: depends linearly on the core metallicity
  ⇨ Constrain metallicity of the solar interior and resolve the metallicity problem

- pp neutrinos depend on the ^{14}C and ^{85}Kr levels in pure scintillator

Solar neutrinos



Full spectrum – LAB

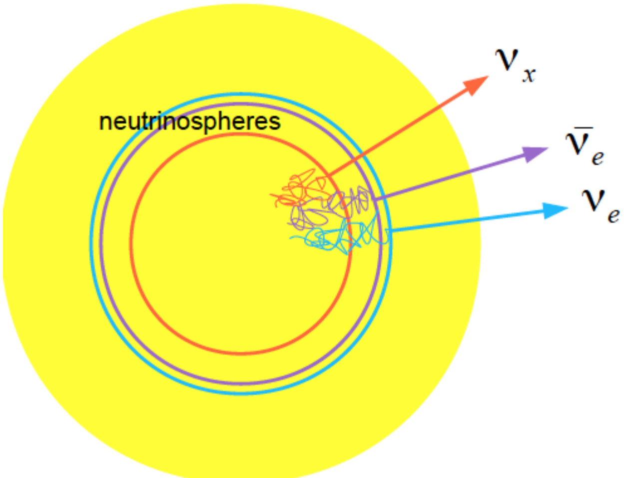


Assumptions:

- 400 Nhits/MeV light yield
- FV = 50%
- 95% reduction of ^{214}Bi via delayed coincidence
- 95% reduction of ^{210}Po and ^{214}Po via alpha tagging
- 50% constraint on ^{85}Kr
- 25% on ^{232}Th-chain
- 7% on ^{238}U chain

	6 months	12 months
^{8}B	10%	7.1%
^{7}Be	5.1%	3.3%
pep	13%	8.9%
CNO + ^{210}Bi	6.5%	4.4%

SN – SIGNAL

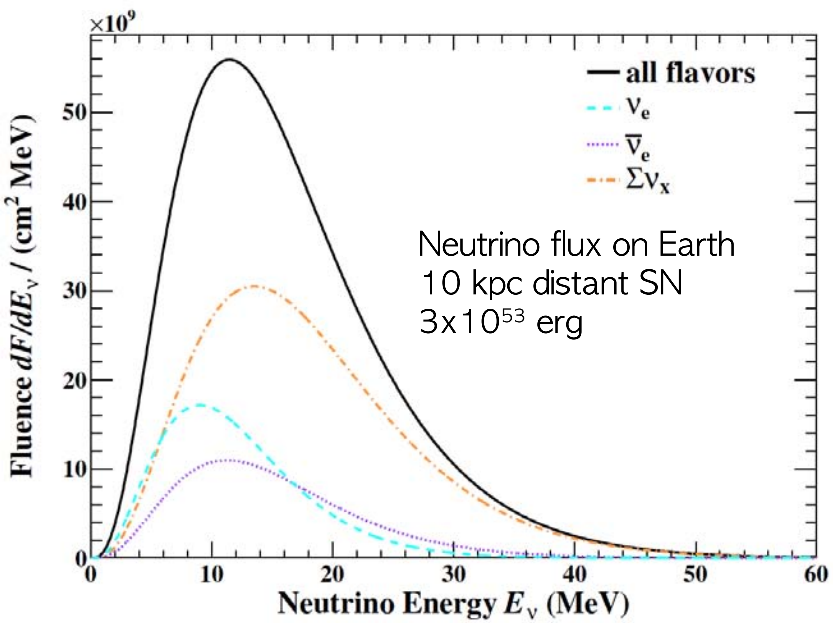


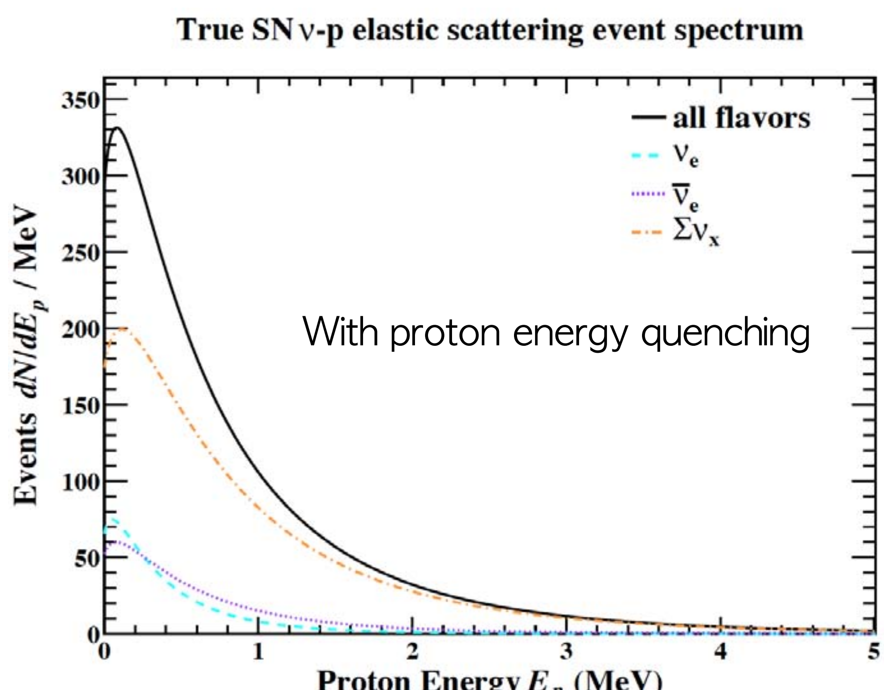
Core-collapse supernovae: 99% of their gravitational binding energy released in the form of neutrinos (several 10^{53} erg)

$$\langle E_{\nu_x} \rangle > \langle E_{\bar{\nu}_e} \rangle > \langle E_{\nu_e} \rangle$$

Common assumption (with large uncertainty) = equal partitioning of total energy ε

SNO+ sensitivity to $\langle E_\nu \rangle$ and total energy ε_ν





SN – Detection

Detection ways & expected signal (5.5 m FV):

Reaction	Number of Events
NC: $\nu + p \rightarrow \nu + p$	429.1 ± 12.0 [a]
CC: $\bar{\nu}_e + p \rightarrow n + e^+$	194.7 ± 1.0
CC: $\bar{\nu}_e + {}^{12}C \rightarrow {}^{12}B_{g.s.} + e^+$	7.0 ± 0.7
CC: $\nu_e + {}^{12}C \rightarrow {}^{12}N_{g.s.} + e^-$	2.7 ± 0.3
NC: $\nu + {}^{12}C \rightarrow {}^{12}C^*(15.1\,\mathrm{MeV}) + \nu'$	43.8 ± 8.7
CC/NC: $\nu + {}^{12}C \rightarrow {}^{11}C$ or ${}^{11}B + X$	2.4 ± 0.5
ν–electron elastic scattering	13.1 [b]

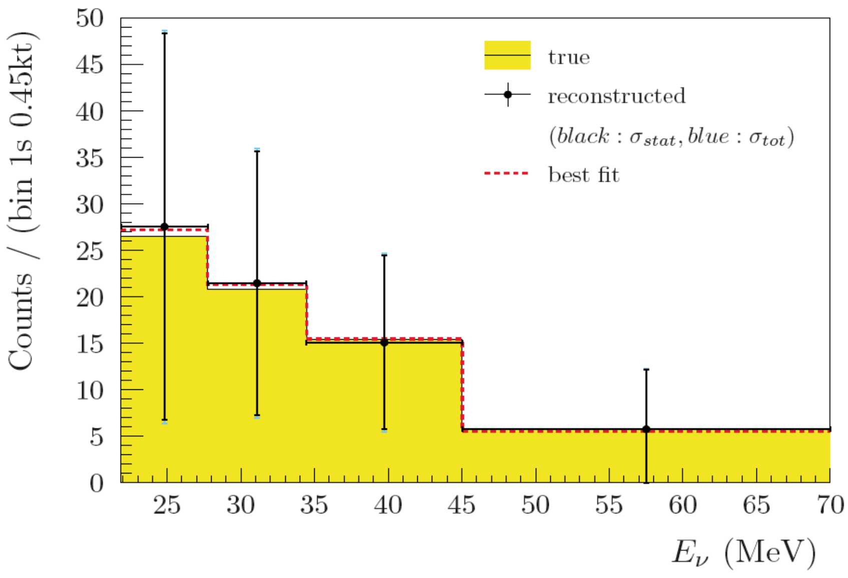
[a] 118.9 ± 3.4 above a trigger threshold of 0.2 MeV visible energy.
[b] The Standard Model cross section uncertainty is $< 1\%$.

Best fit values:

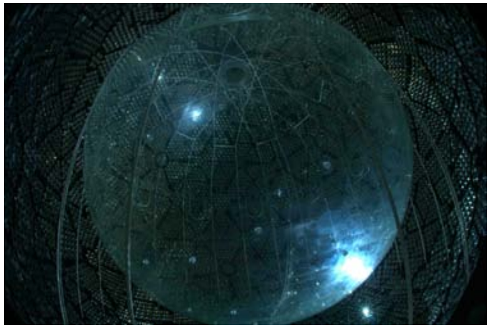
$E_{\nu x} = 17.8^{+3.5}_{-3.0}(\mathrm{stat})^{+0.2}_{-0.8}(\mathrm{syst})$ MeV

$\varepsilon_{\nu x} = (102.5^{+82.3}_{-42.2}(\mathrm{stat})^{+16.2}_{-13.0}(\mathrm{syst})) \times 10^{51}$ erg

Expectation = 18 MeV and 100×10^{51} erg



Upgrades and Status/1



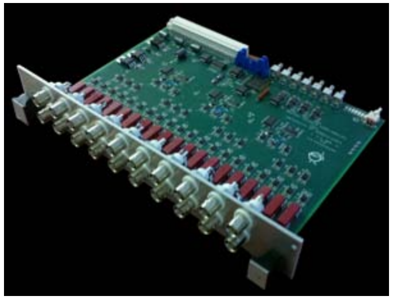
- New hold-down rope system on the top of the AV anchored to the cavity floor.
  High purity Tensylon ropes

- New hold-up rope system material (Tensylon)

- DAQ and trigger system upgraded to cope with the high light yield of scintillator

- ~ 500 defective PMT bases have been repaired
  Expected ~9400 working PMT at the start of data taking

- New calibration system
  Optical sources (LED and lasers coupled to fibers)
  Radioactive sources (gamma, alpha, neutron, beta)

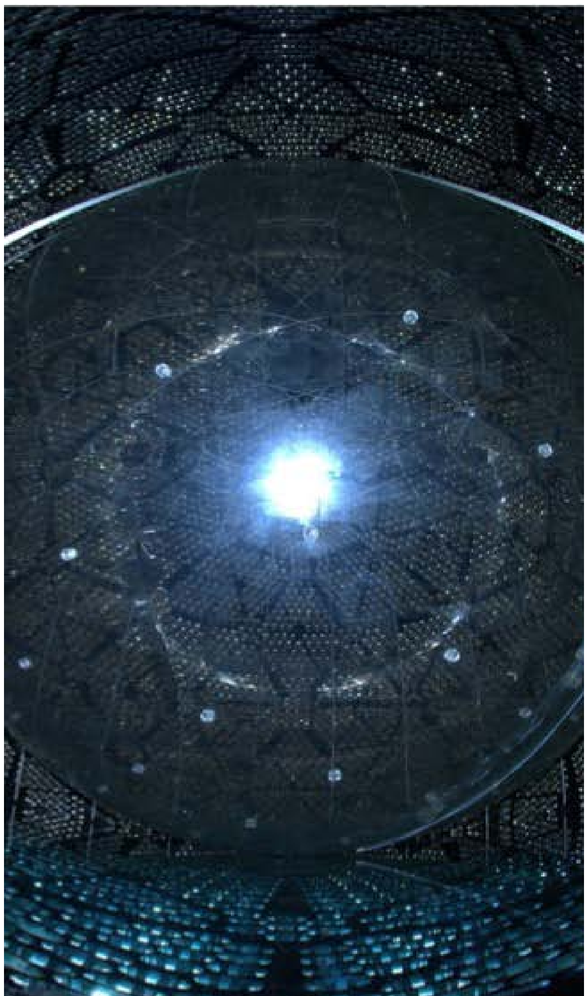


- New cover gas system to limit Rn ingress into the detector

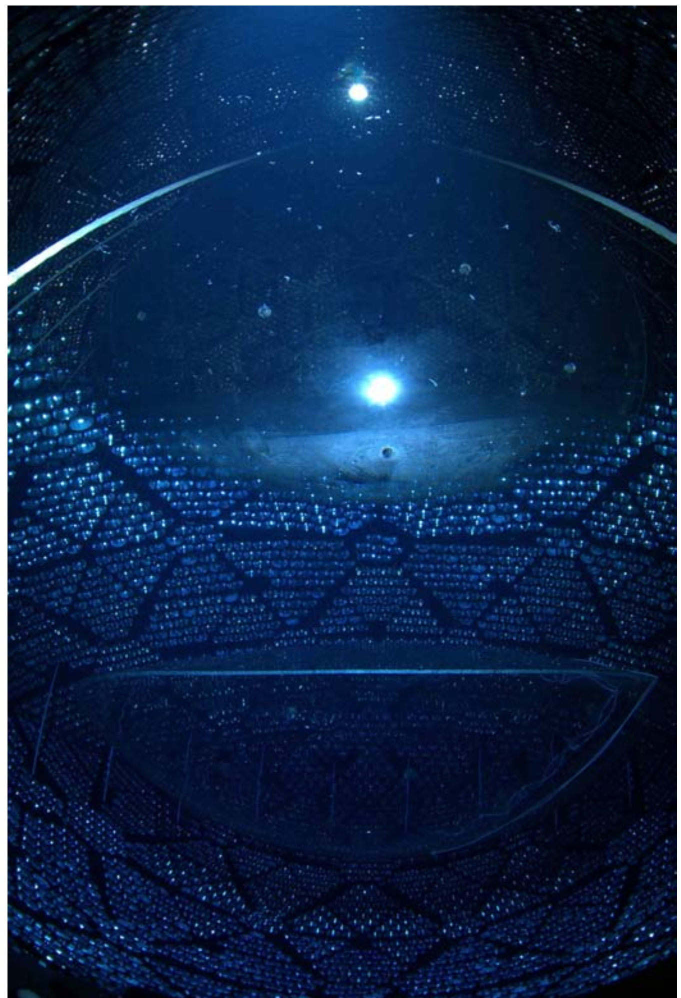
Upgrades and Status/2

Cavity and AV filling is ongoing

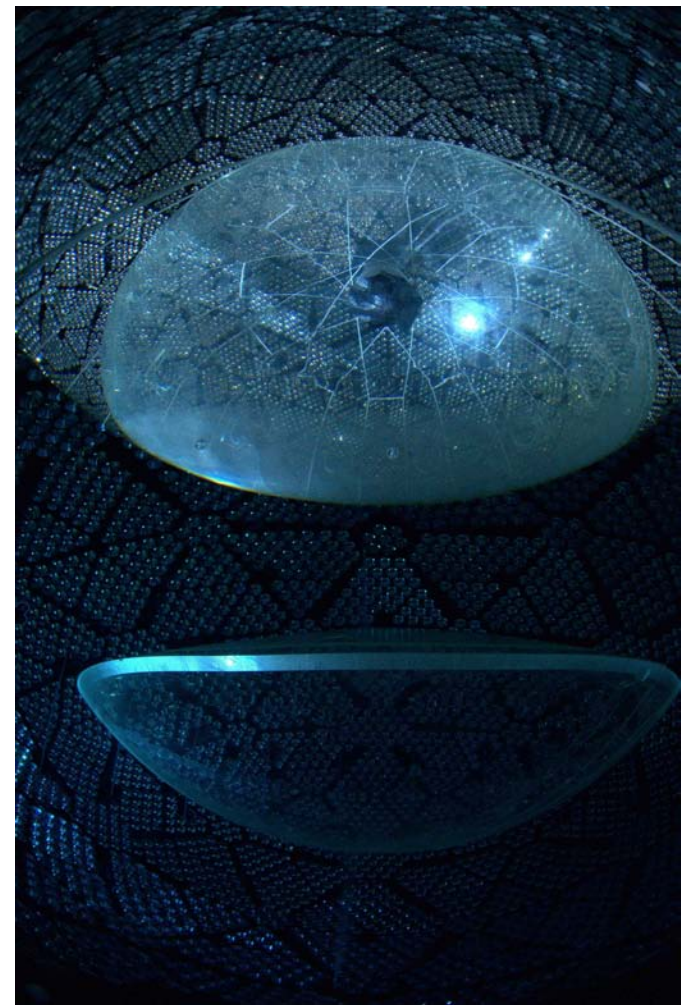
Camera above water



Camera and light underwater



Camera underwater,
light above water



Time scale

- June 2016: water fill and water data
  - Nucleon decay physics
  - Backgrounds analysis
  - Supernovae neutrinos
- End 2016: start liquid scintillator fill
  - Background analysis
  - Reactor- and geo- antineutrinos
  - Supernovae neutrinos
  - Low energy solar neutrinos
- 2017: 0.3 – 0.5% Te loading
  - Neutrinoless double-beta decay
  - Reactor- and geo- antineutrinos
  - Supernovae neutrinos
  - ^{8}B neutrinos

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SNO+

Thank you for your attention

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Queen Mary, University Of London
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University of Sussex
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