SNO+ Experiment Status

EPSHEP 2013

Matthew Mottram
University of Sussex
On behalf of the SNO+ Collaboration

SNOLAB
TRIUMF
University of Alberta
Queens University
Laurentian University

TU Dresden

LIP Coimbra
LIP Lisboa

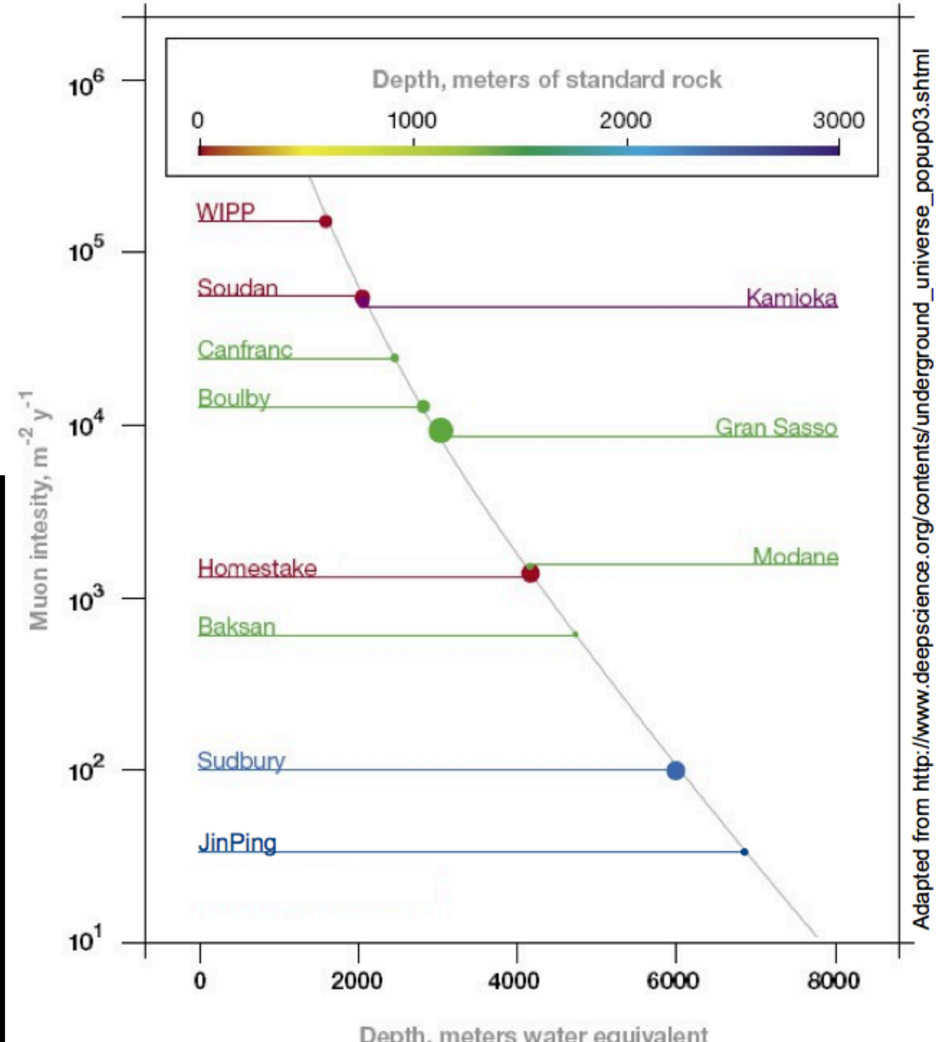
Armstrong Atlantic State
Black Hills State
Brookhaven National Lab
UC Berkeley & LBNL
University of Chicago
University of North Carolina
University of Pennsylvania
University of Washington

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

SNO+ Collaboration

SNOLAB overview

- **Large**: 5000 m^2 of underground clean space
- **Deep**: 6800 ft (2km) below surface
  - 6000 m.w.e.
  - ~70 muons/day
- **Clean**: Class-2000 clean-room in a working mine



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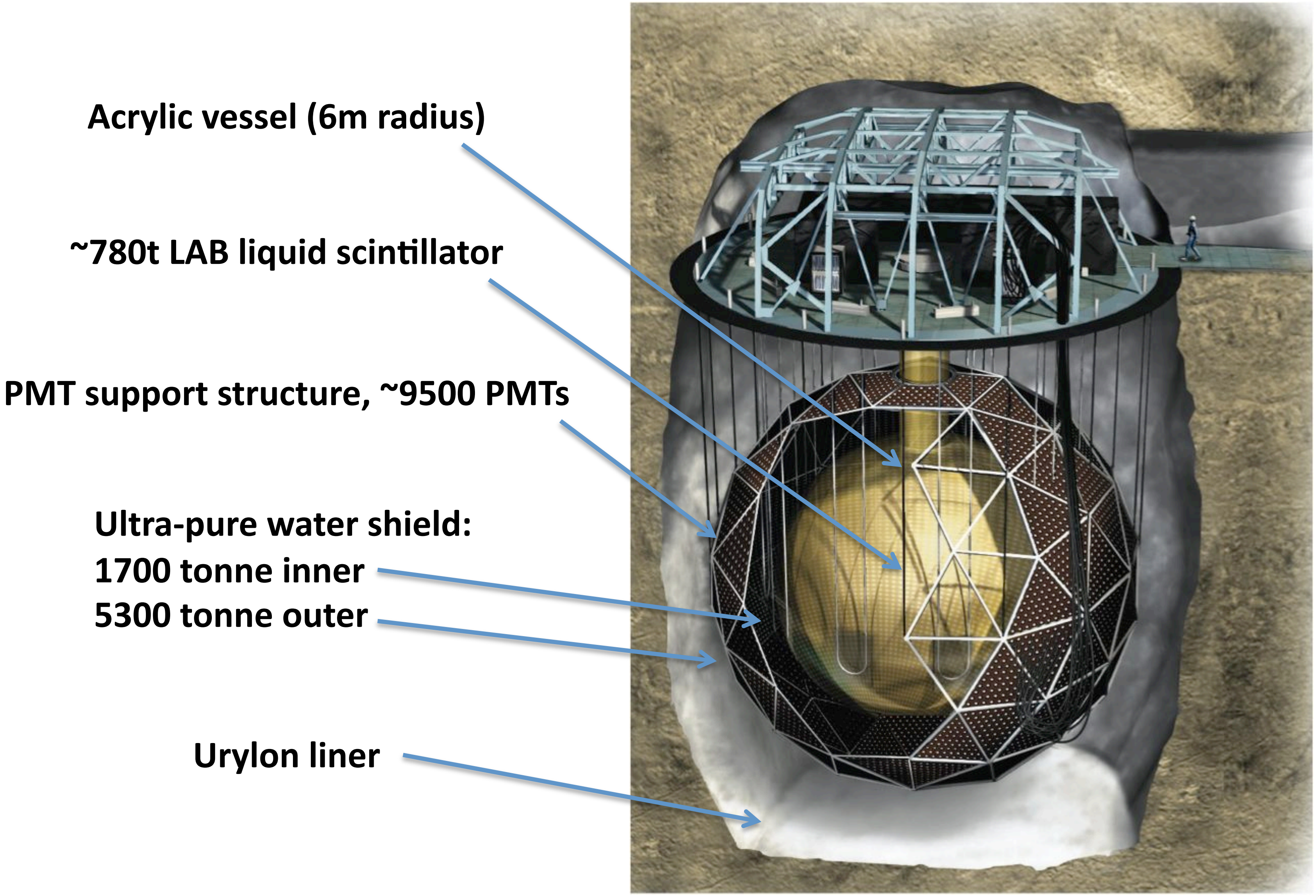
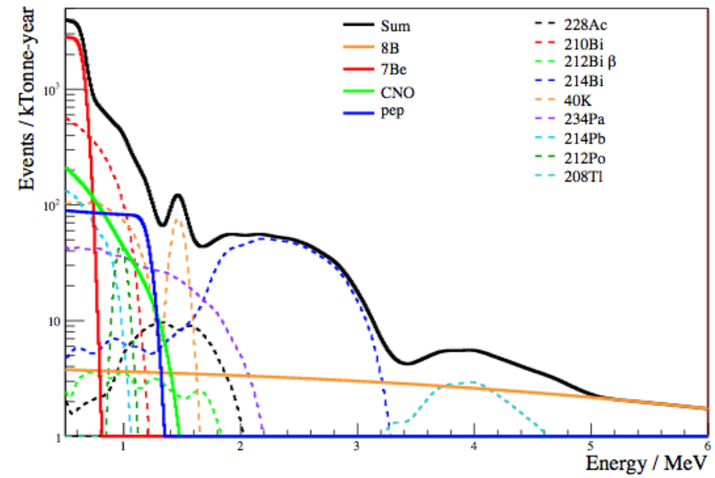
SNO+ overview



Physics goals

- SNO+ has decided to prioritise **double beta-decay**
- However, other physics goals remain:
  - Solar neutrinos
    - pep & CNO neutrinos
    - Matter/vacuum dominated oscillations
  - Geo-neutrinos
    - Well understood local crust composition
    - U/Th distributions
  - Reactor neutrinos
    - Nearby reactors
    - Different spectral features to KamLAND
  - Sensitive to neutrinos from potential supernova
    - Expect 100s of events for Galactic supernova



* Assuming Borexino-level backgrounds are reached

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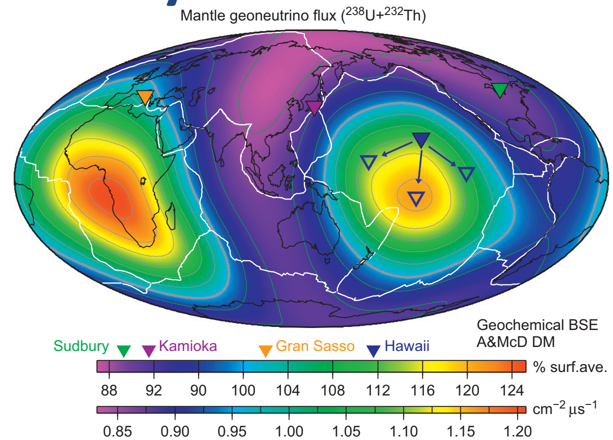
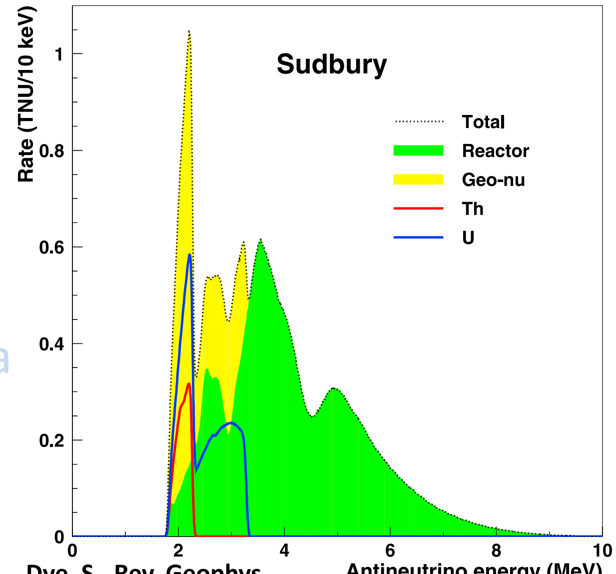
Sramek, O et al., Earth & Planet Sci. Lett., 361, 356 (2011)





Dye, S., Rev. Geophys., 50, RG3007 (2012)

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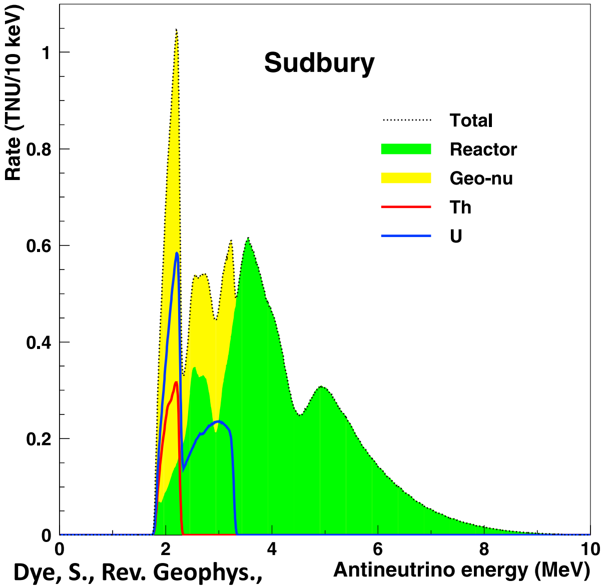

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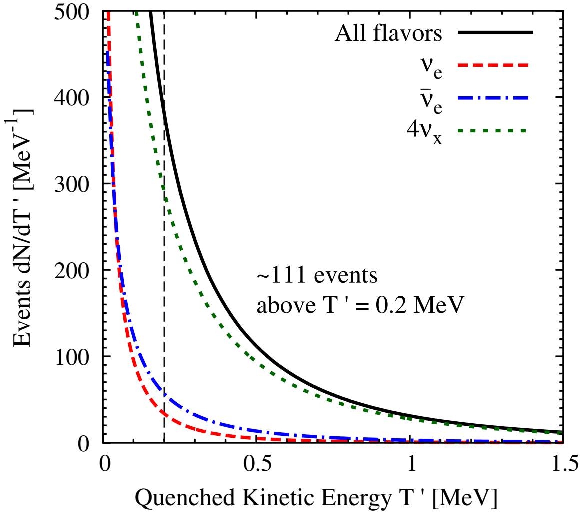

FIG. 3 (color online). Galactic SN neutrino-proton elastic scattering event spectrum at SNO+ .

Dasgupta, B. & Beacom, J., PRD 83 113006 (2011)

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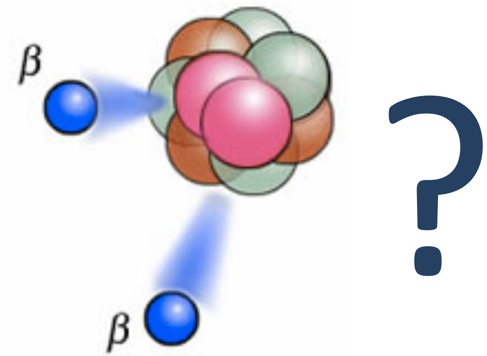
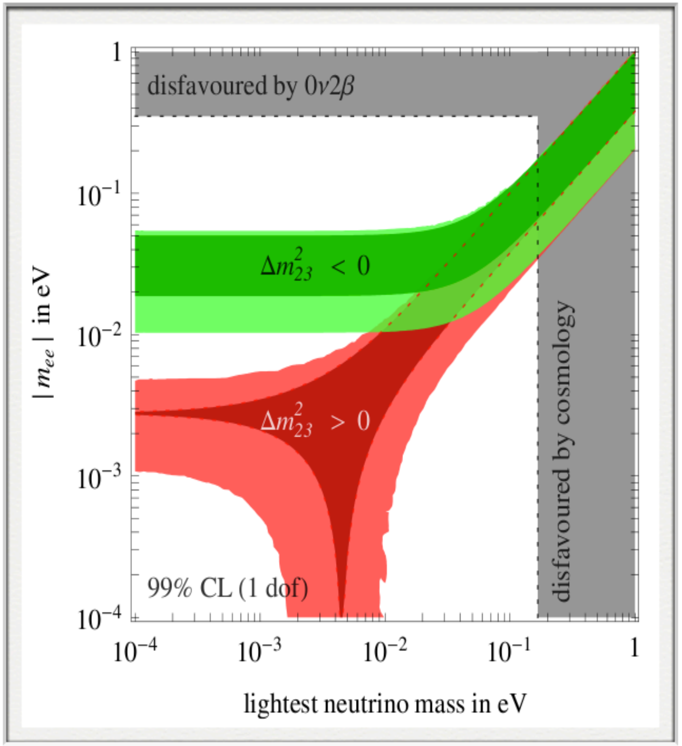
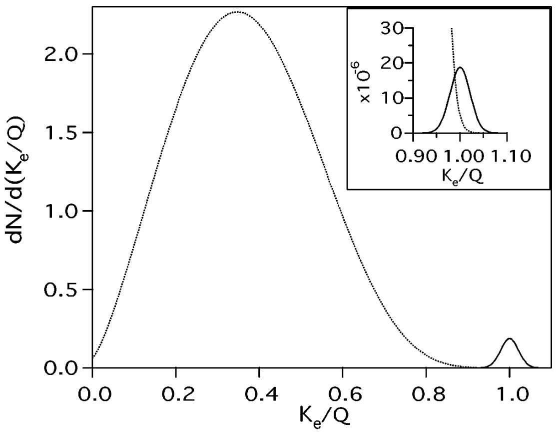
Neutrinoless double beta-decay search

- **Motivation:**
  - Is the neutrino Majorana or Dirac?
  - If Majorana, what is the effective neutrino mass?
- **Liquid scint / SNO+ DBD experiment:**
  - Large isotope mass for small % loading
  - Low backgrounds (self shielding, fiducialisation, SNO+ overburden)
  - Spectral fitting in place of energy bin counting







Elliot, R. & Vogl, P., Annu. Rev. Nucl. Part. Sci., 52, 115 (2002)

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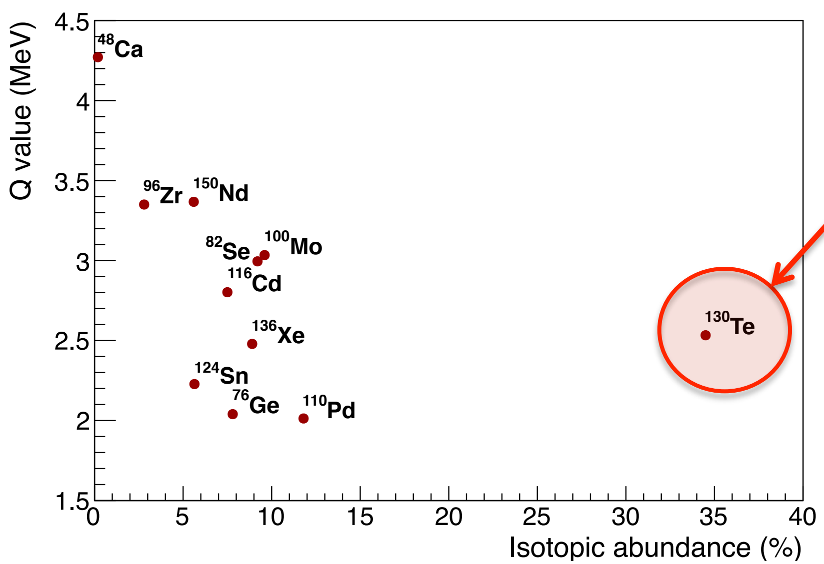
Double beta-decay search

- **SNO+ DBD concept**: deploy element containing DBD isotope in LAB liquid scintillator
- **SNO+ isotope**: deploy 0.3% loading (~2.3 tonne) of **Te**
  - 800 kg of **^{130}Te** (160 kg in 3.5m fiducial volume)
  - Intention to increase loading once technique is demonstrated



^{130}Te:

- Highest natural abundance
- $2\nu\beta\beta$ background 100 times lower than for ^{150}Nd
- Large $0\nu\beta\beta$ matrix element
- Proven ability to load in LAB LS

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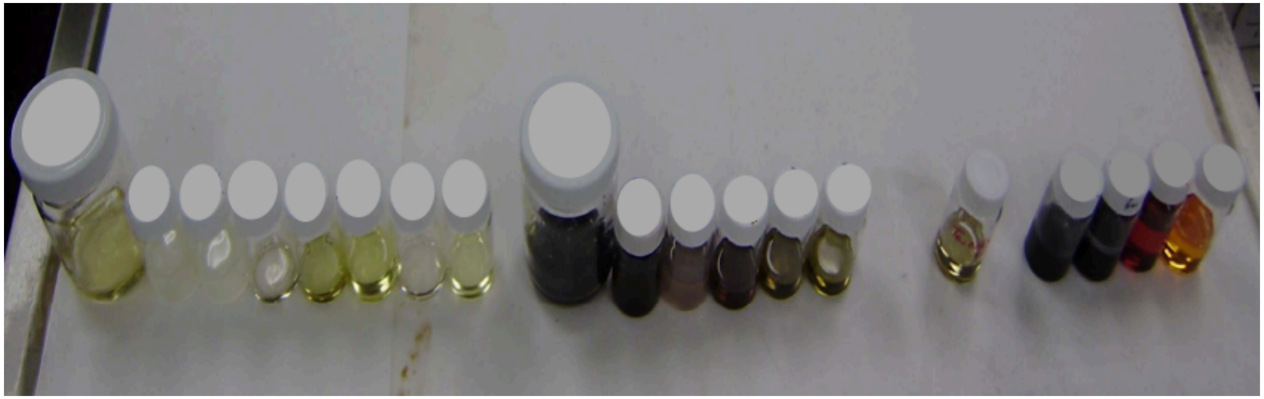
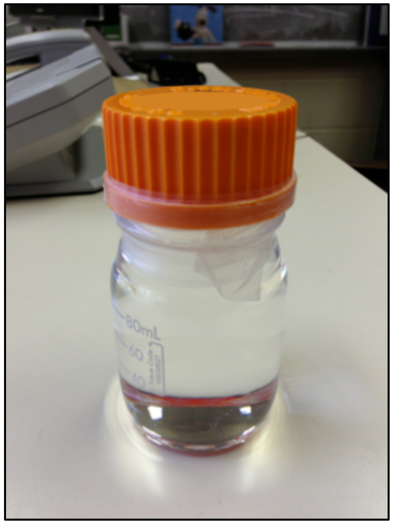
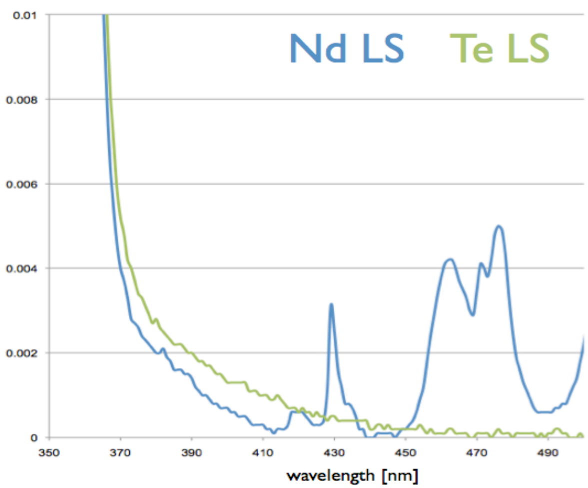
Tellurium-130





Optically transparent Te-loaded scintillator

- SNO+ collaborators have demonstrated that ^{130}Te can be deployed and purified to a high level in LAB scintillator
- Intrinsic light yield higher than for ^{150}Nd
- No absorption lines in SNO+ wavelength range: **potential for increased deployment concentration**



Absorption vs wavelength for LAB+PPO+0.1% loading

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SNO+ 0νββ backgrounds

- **2νββ**: Intrinsic to deployment of isotope
- **^{8}B solar ν**: Irreducible background
- **Cosmogenic**: Reduction to negligible level demonstrated, minimise isotope time at surface
- **^{214}Bi & ^{208}Tl**: reduced by delayed coincidence α/β tagging (expect 99.99% and 97% respectively)
- **Dominant backgrounds do not scale with Te mass**

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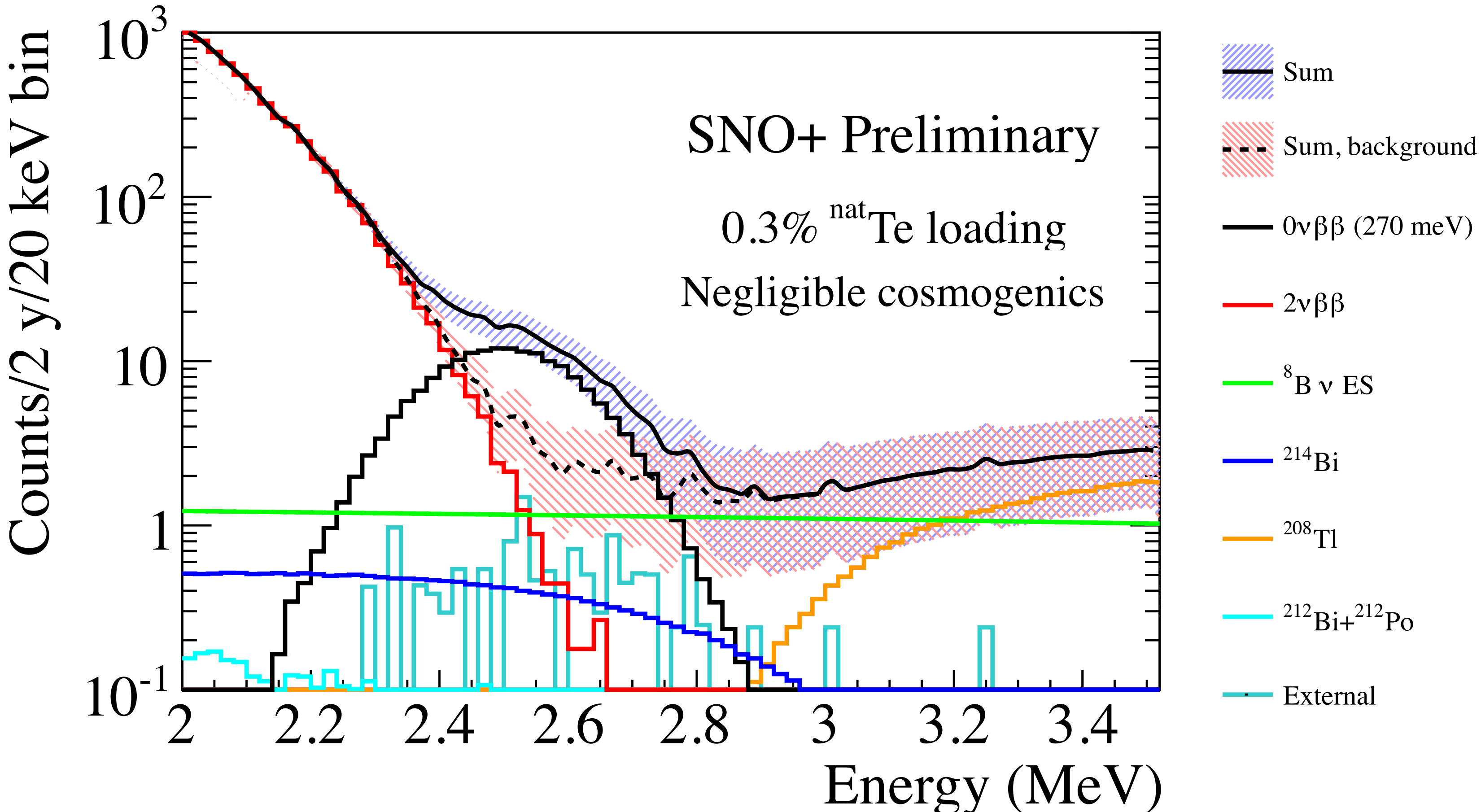
0νββ expectation



$M^{0\nu}$,g_A from Phys. Rev. C, 87, 014315(2013)

$G_{0\nu}$ from Phys. Rev. C, 85, 034316 (2012)

Assumes:

- $m_{\beta\beta}$=270meV
- 2 year livetime
- 3.5m fiducial volume
- 100% efficiency of detection & analysis
- 99.99% and 97% efficient internal ^{214}Bi and ^{208}Tl α tag respectively
- Factor 200 rejection ^{212}Bi

- Negligible systematics
- Negligible cosmogenics
- Material used to load Te has radioactivity between SNO H_2O and D_2O levels
- Acrylic and PMT radioactivity at SNO proposal levels

Light yield and detector optics based on UPenn and BNL measurements

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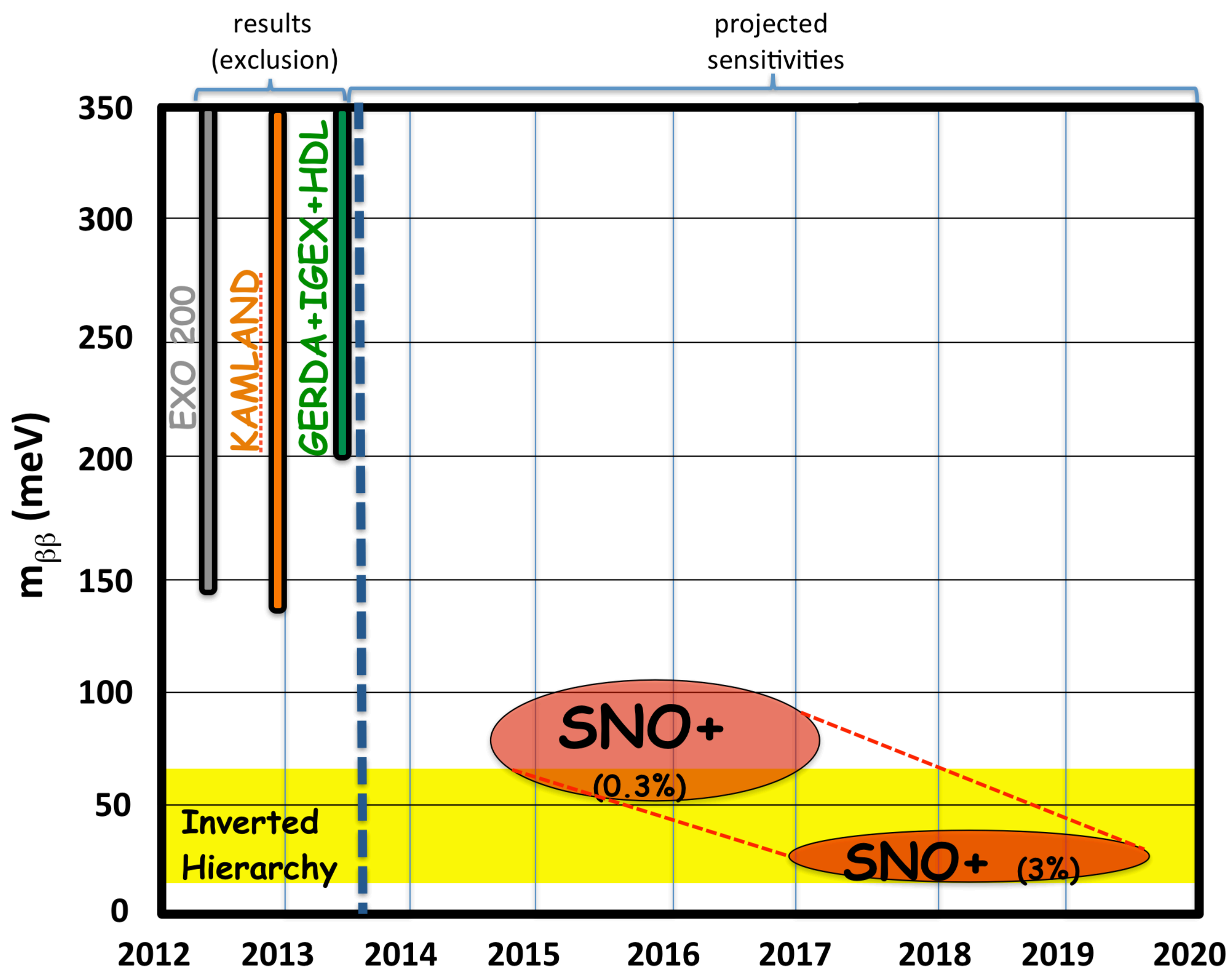
SNO+ 0νββ sensitivity

- SNO+ expected to be very competitive, with scope for increased ^{130}Te loading in the future



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D_2O -> LAB (SNO+ preparation)

- **Buoyancy**: installed "hold down" rope net

Above: rope net partially deployed
Below: view of upper AV with rope net

D_2O -> LAB (SNO+ preparation)

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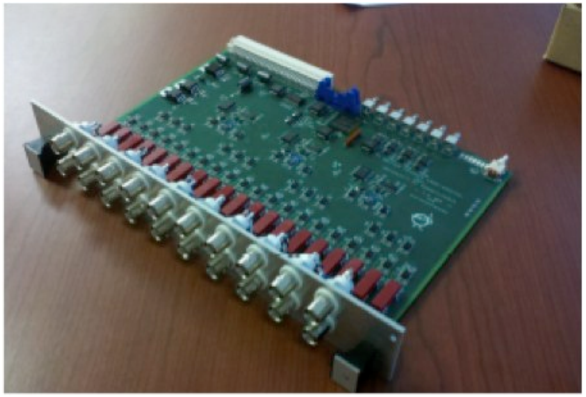
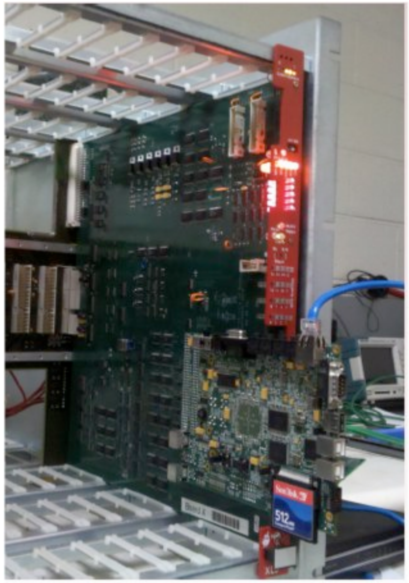
- **Light yield**: upgrades to trigger & readout electronics and DAQ





New trigger and readout electronics

D_2O -> LAB (SNO+ preparation)

- **Buoyancy**: installed “hold down” rope net
- **Light yield**: upgrades to trigger & readout electronics and DAQ
- **Purification**: new LAB purification systems

Parts of LAB processing system arriving on site

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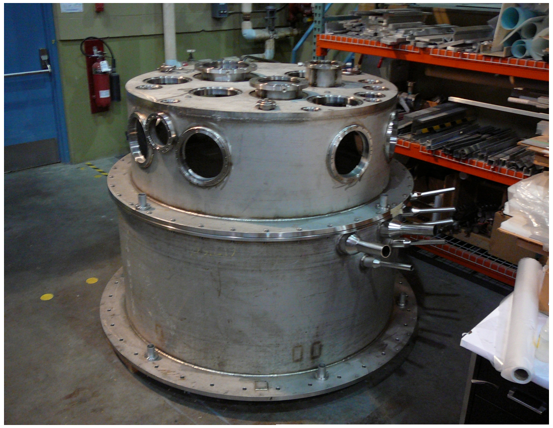
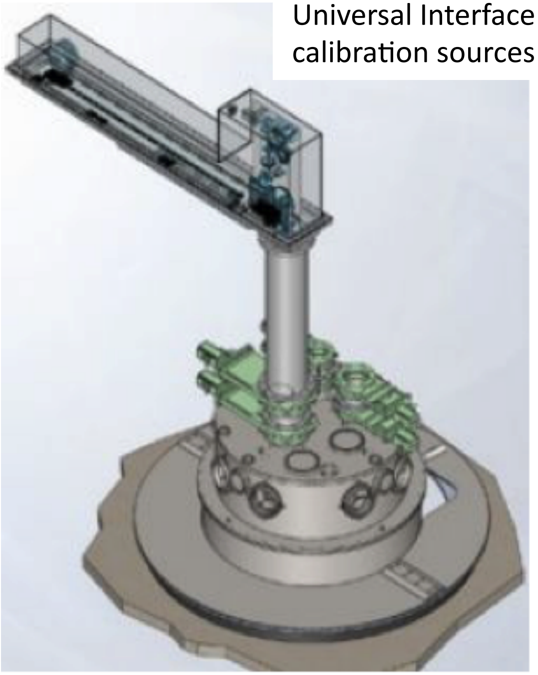
D_2O -> LAB (SNO+ preparation)

- **Buoyancy**: installed "hold down" rope net
- **Light yield**: upgrades to trigger & readout electronics and DAQ
- **Purification**: new LAB purification systems
- **Deployed calibrations**: new cover-gas & calibration source deployment system





Universal Interface for calibration sources

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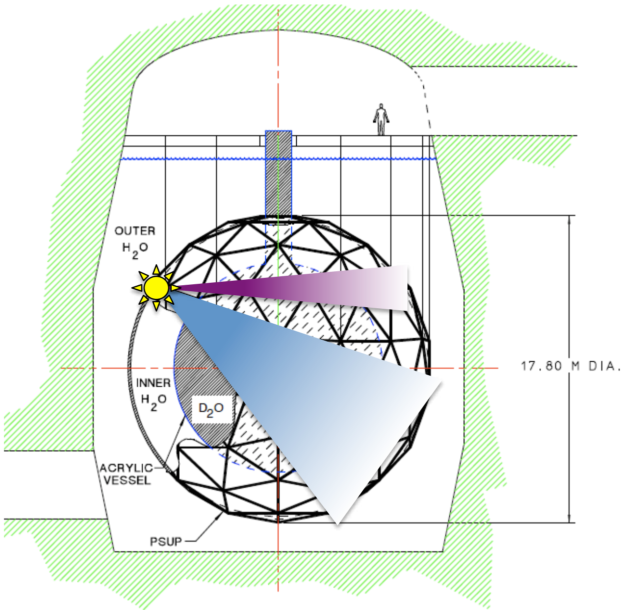
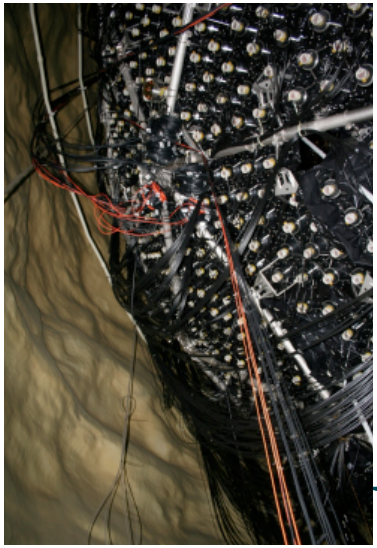
- **Purification**: new LAB purification systems
- **Deployed calibrations**: new cover-gas & calibration source deployment system
- **Optical calibrations:** new in-situ light source calibration systems



ELLIE (in-situ) calibration concept



ELLIE fibres in the SNO+ cavity

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D_2O -> LAB (SNO+ preparation)

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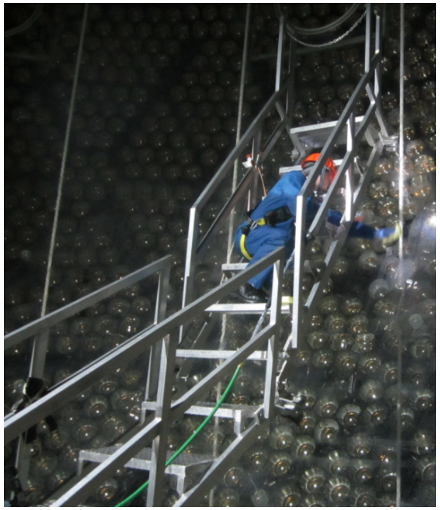
- **Purification**: new LAB purification systems
- **Deployed calibrations**: new cover-gas & calibration source deployment system
- **Optical calibrations:** new in-situ light source calibration systems
- **Cleanliness**: clean inside of AV



AV cleaning ladder

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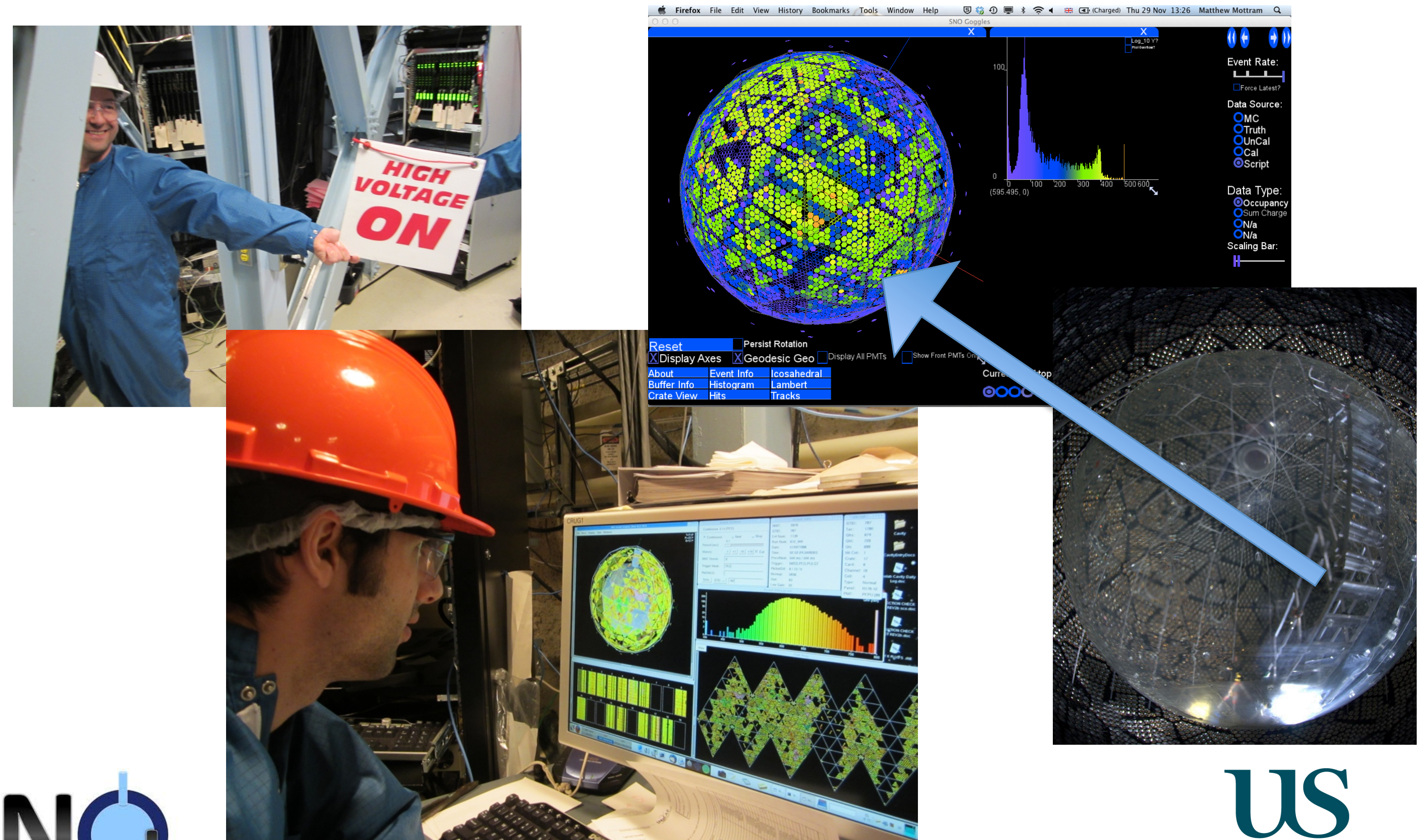
SNO+ commissioning

New electronics, DAQ and in-situ light injection systems have been commissioned over several periods of dry ("air-fill") running



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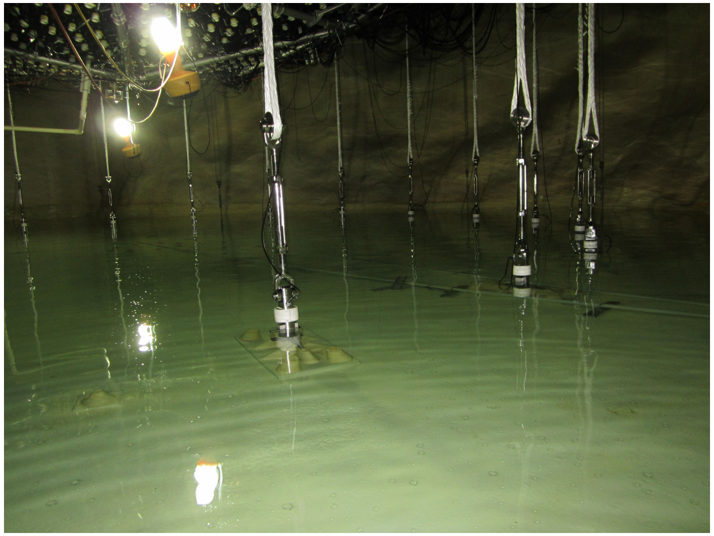
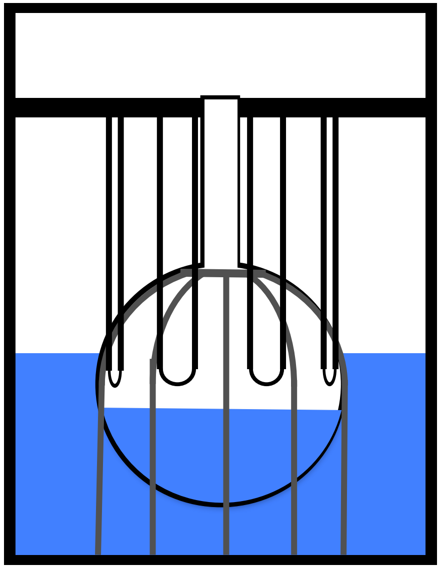
SNO+ status & schedule

- Current status:
  - Approx 2.5m water in cavity
  - Testing water purity & new floor liner
- Schedule:
  - **Summer 2013:** Continue water fill, test AV buoyancy & rope net tension
  - **Autumn 2013**: Water data – calibrations and nucleon decay search
  - **Early 2014**: Begin scintillator fill
  - **Summer/Autumn 2014**: Deploy double beta isotope



Water in cavity!



Buoyancy and rope net test schematic

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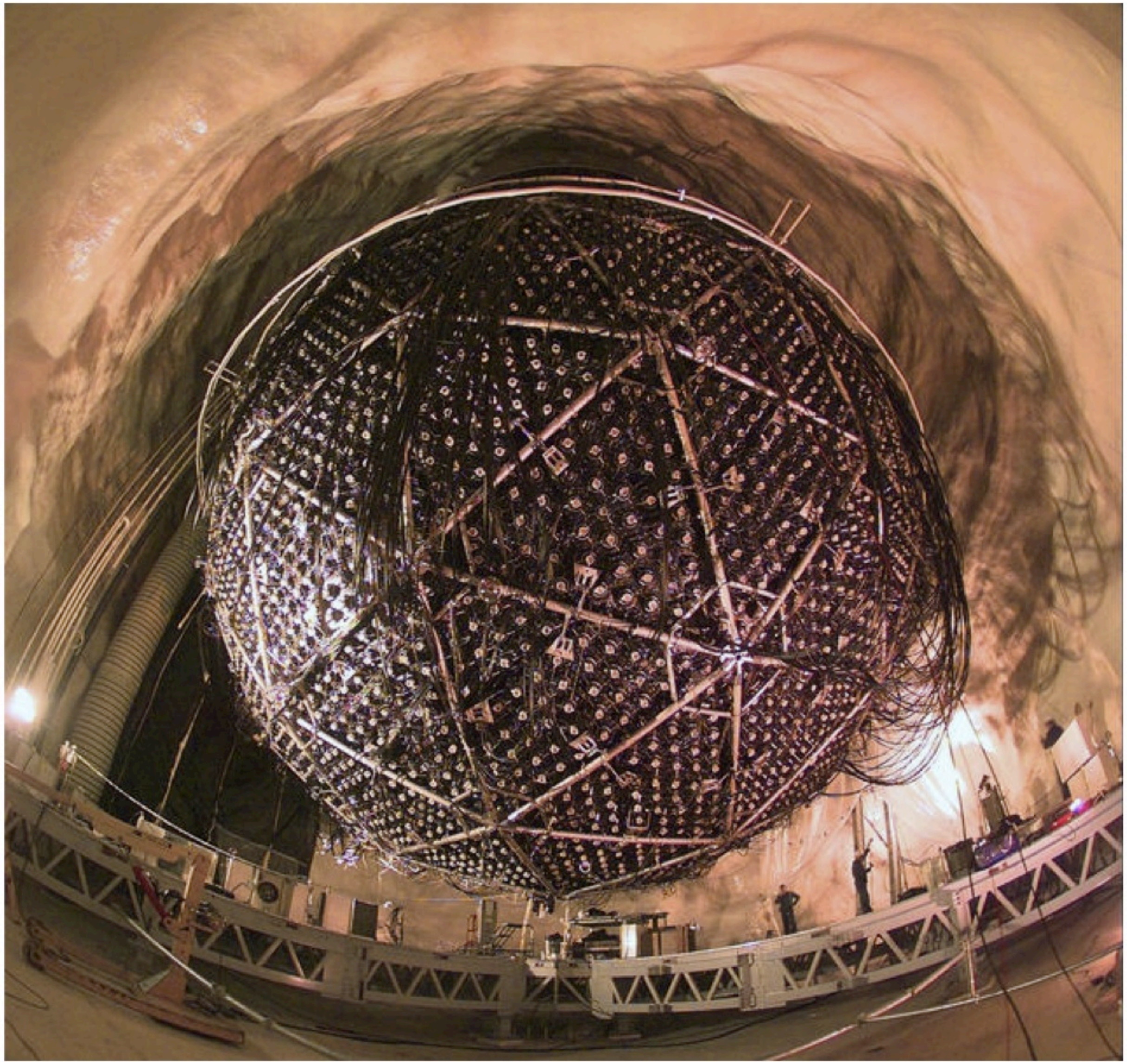
Thanks for listening!



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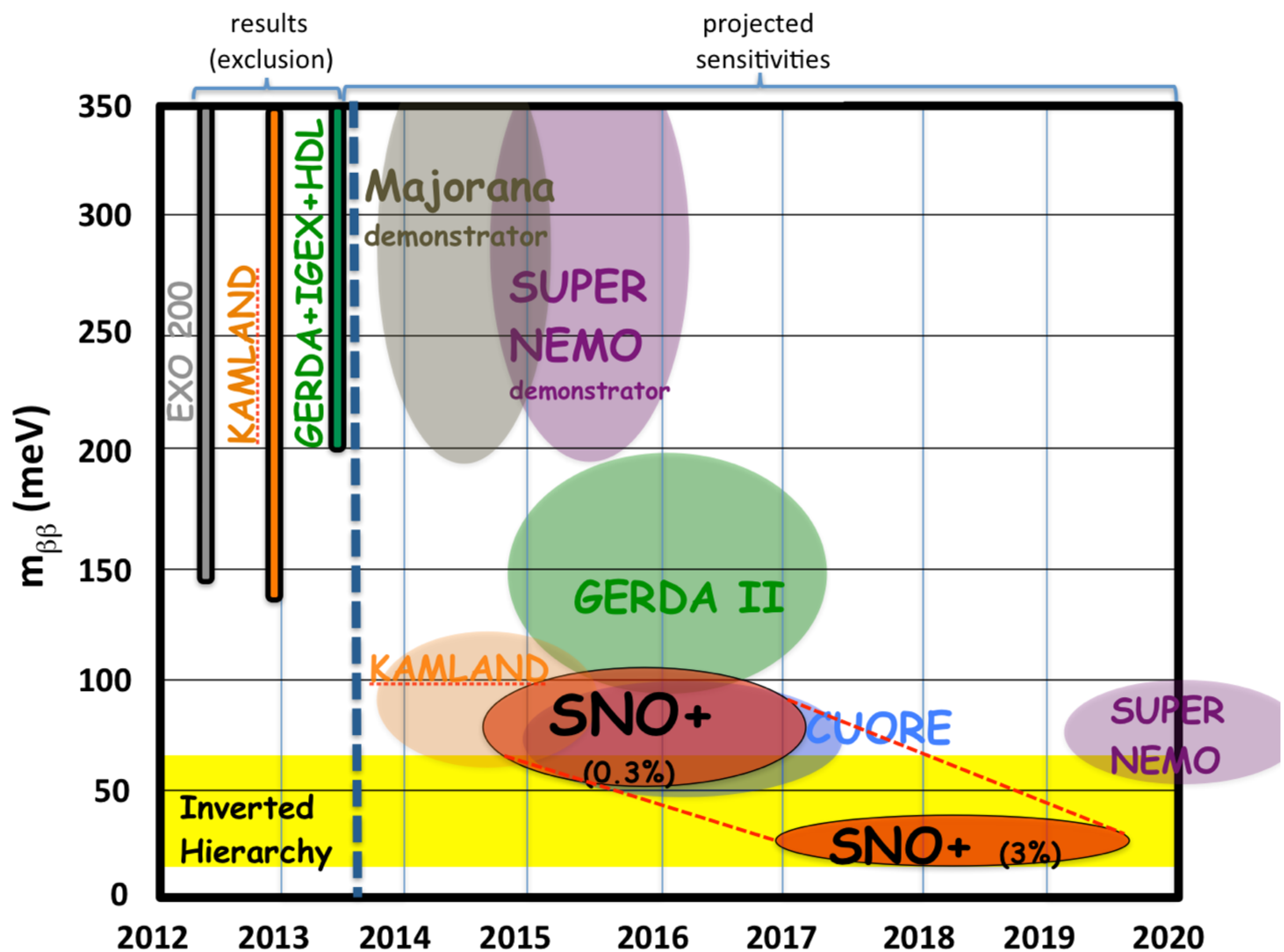
BACKUP SLIDES

Sensitivity comparison



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Double beta backgrounds

- Dominant $0\nu\beta\beta$ backgrounds do not scale with isotope mass:
  - b: backgrounds that scale with mass
  - C: backgrounds to do not scale with mass
  - δE: energy resolution
  - n_σ: confidence level

$$T_{1/2}^{0\nu\beta\beta} = \frac{N_{isotope} \ln 2}{n_\sigma} \sqrt{\frac{t}{(bM + C)\delta E}} f(\delta E)$$

Solar neutrinos

- SNO+ has decided to prioritise $0\nu\beta\beta$
- 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 radon daughters, or deploying a bag.
- $0\nu\beta\beta$ and low-energy 8B solar neutrino measurements are not affected by these backgrounds