Status of SNO+

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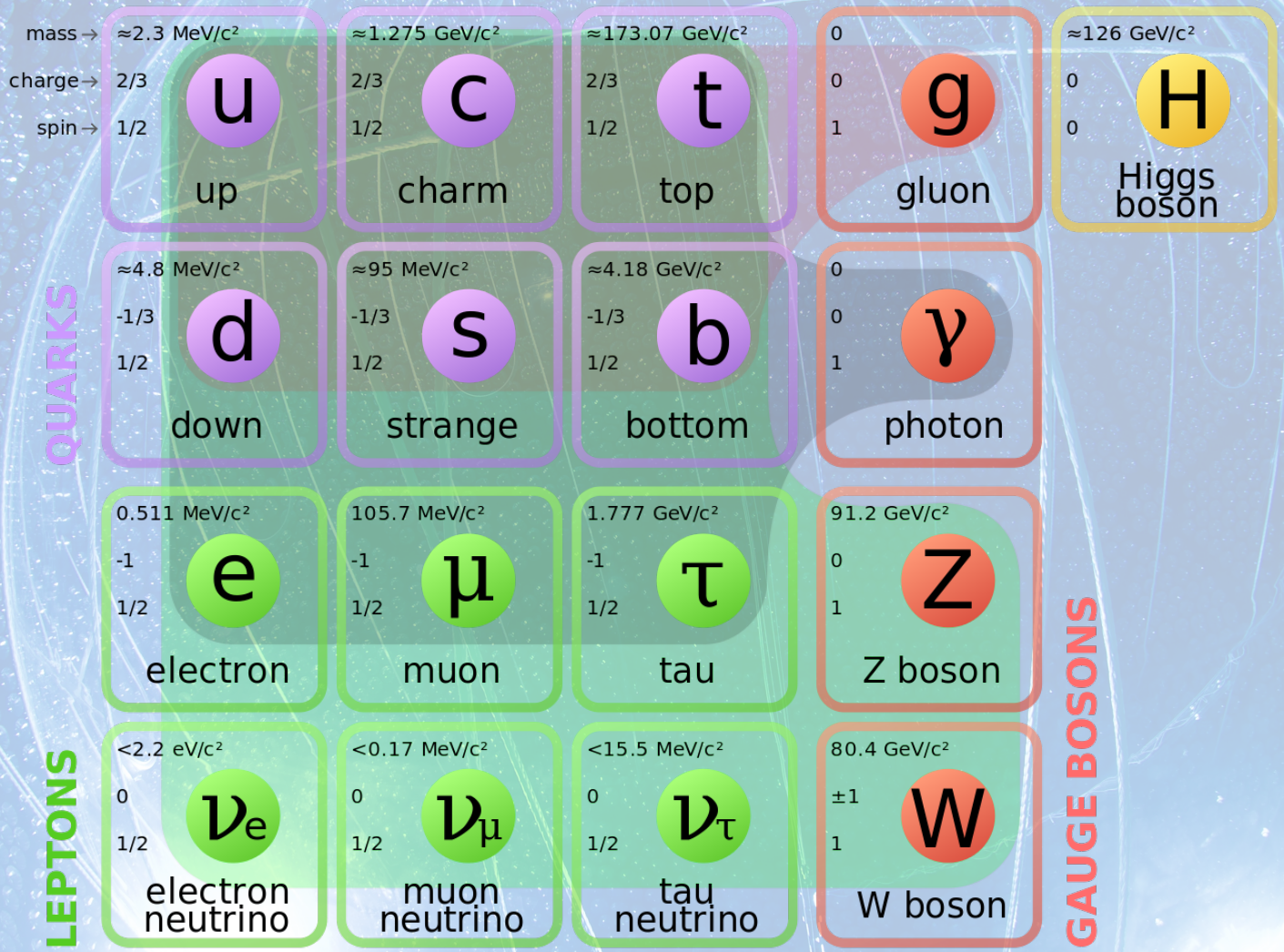
On Behalf of the SNO+ Collaboration

Laurentian University

2021 CAP Congress
June 8, 2021

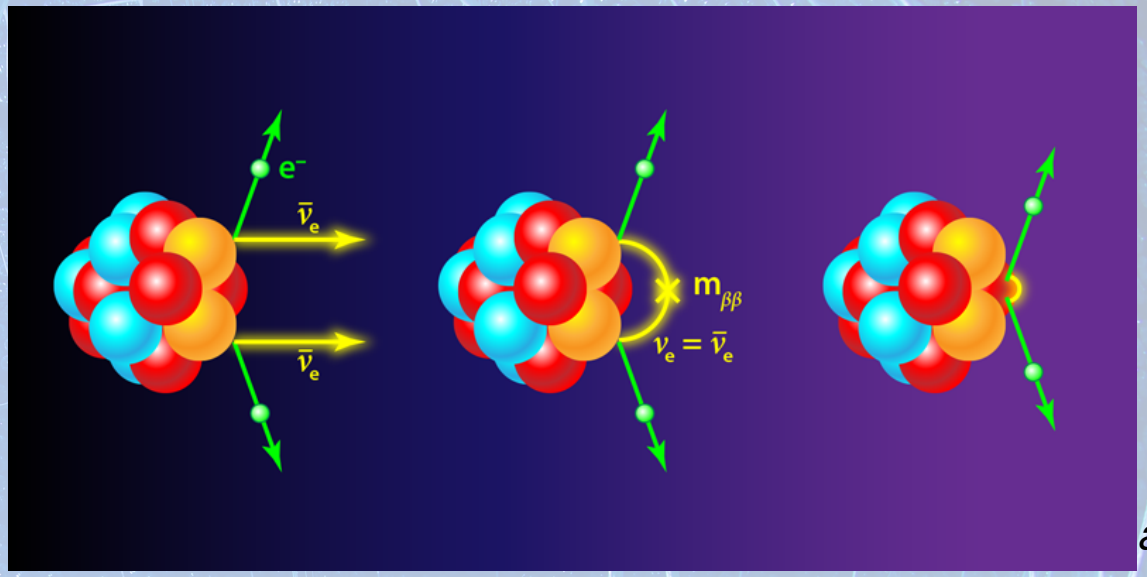
Neutrinos in the Standard Model



- Neutrinos explicitly assumed to be mass-less
- Measurements from SNO and Kamiokande show they are not

Neutrino Mass and Neutrino-less Double Beta Decay

- One path to ν mass is a Majorana mass term
- Allows for a violation of lepton number



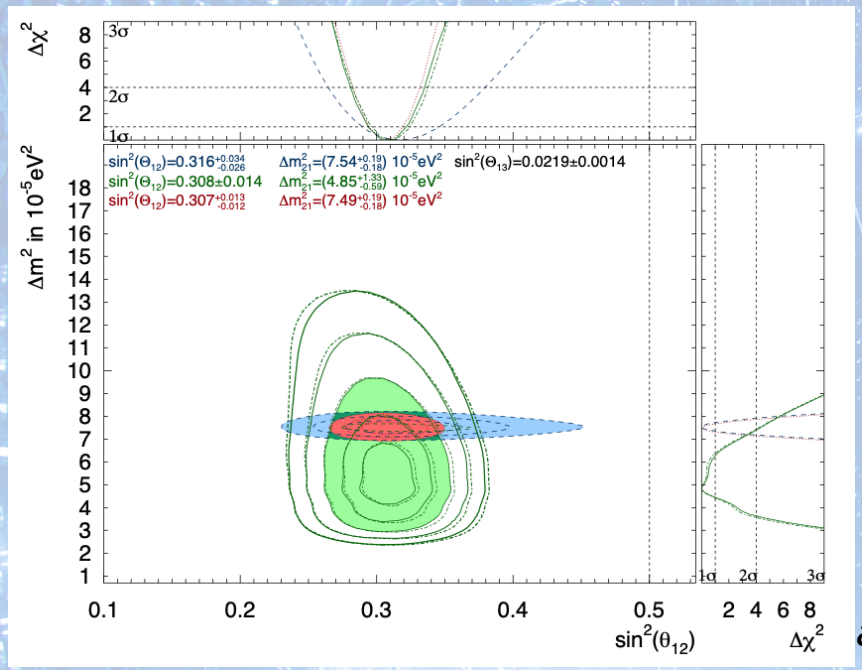
[a]

[a] J. Engel, P. Vogel, Physics 11, 30 (2018)

- 2 neutrino β decays are preferred in some isotopes
- If lepton number violation is allowed then $0\nu\beta\beta$ decays allowed
- Rate of the process is proportional to the neutrino mass
- The chance of discovery scales with $\beta\beta$ isotope mass in an active volume

Solar Oscillation Tension

- Neutrinos oscillations appear in solar and reactor experiments



[a]

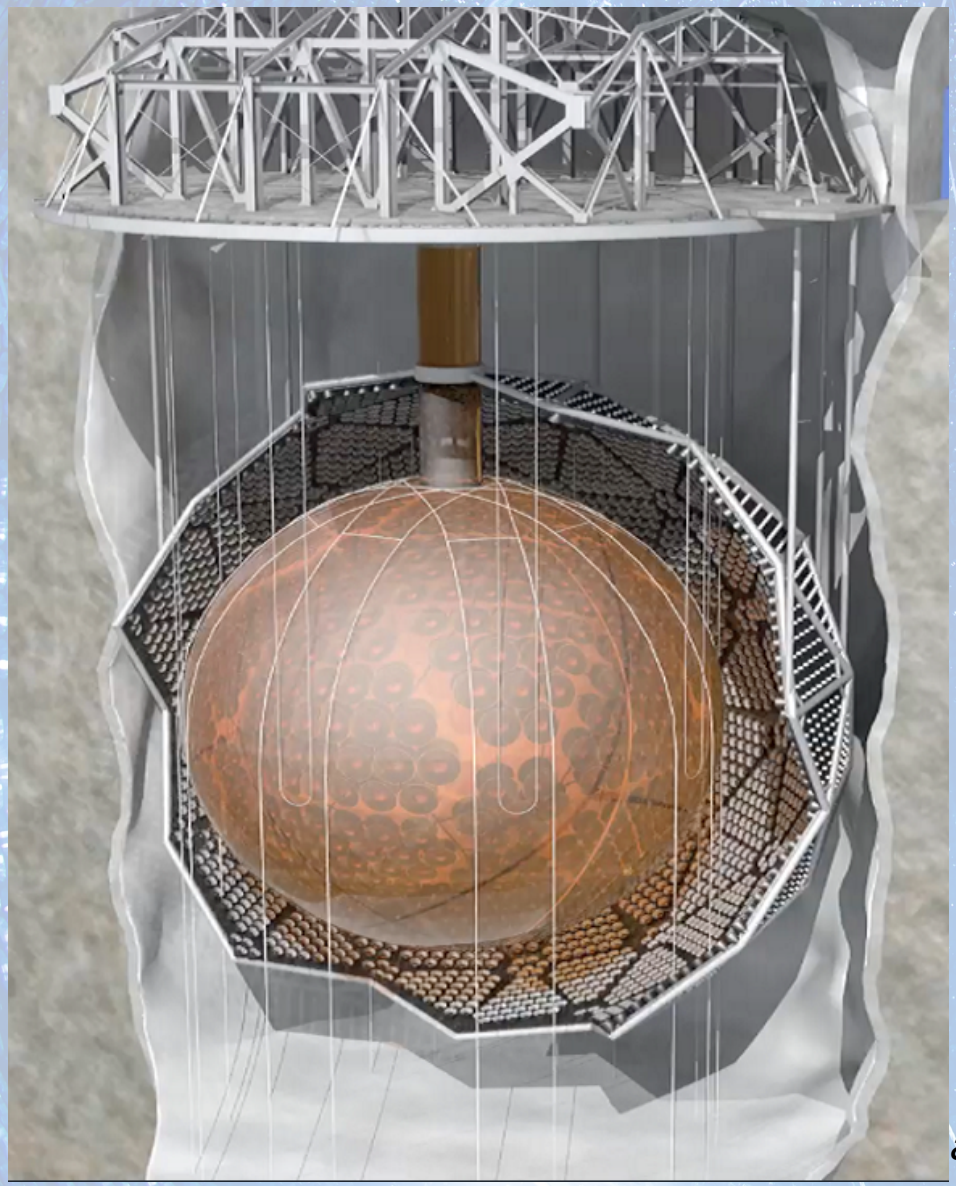
$$P_{ee} = 1 - \sin^2 2\theta_{12} \sin^2 \frac{1.267 \Delta m^2 L}{E}$$

- Solar neutrino oscillations measured in SNO and Super Kamiokande
  - $\Delta m^2 = (4.8^{+1.3}_{-0.6}) \times 10^{-5}$ eV^2
- Adding Reactor measurements from KAMLAND
  - $\Delta m^2 = (7.53 \pm 0.18) \times 10^{-5}$ eV^2

- Simultaneous solar and reactor neutrino experiment can address this tension

[a] Phys. Rev. D. 94, 052010 (2016)

The SNO+ Detector



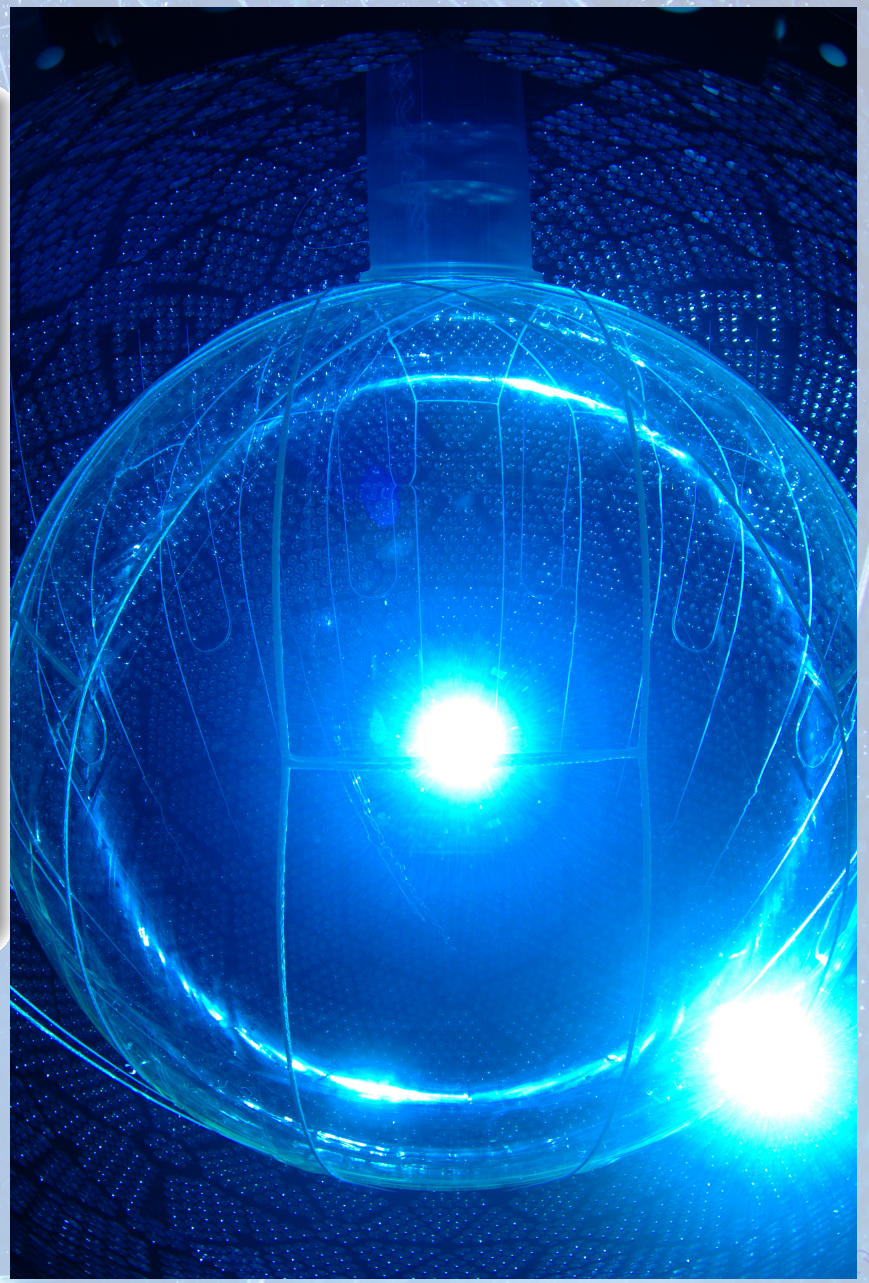
[a]

- Located at SNOLAB 2 km (≈6000 m.w.e.) underground
- Urylon lined cavern 30 m height, 24 m radius
  - filled with water shielding
- Consists of 12 m diameter acrylic vessel
  - Filled with 780 T linear alkylbenzene
  - Doped with PPO wavelength shifter
- Surrounded by ≈9400 PMTs
  - Supported by ≈17 m geodesic structure

[a] arXiv:2104.11687

LAB Filling History

- Nov 2018 - June 2019 Commissioning/Early fill
- June 2019 - Nov. 2019 Pause to check backgrounds (43.4 T)
- Dec 2019 - March 2020 Fill Resumed
- March 2020 - November 2020 Pause for Covid (364 T)
- Dec 2020 - March 2021 Fill Resumed
- April 2021 Last water removed, AV prepared for recirculation



- Now undergoing a program of recirculation and PPO addition
- Scintillator Paper — JINST16 P05009 (2021)

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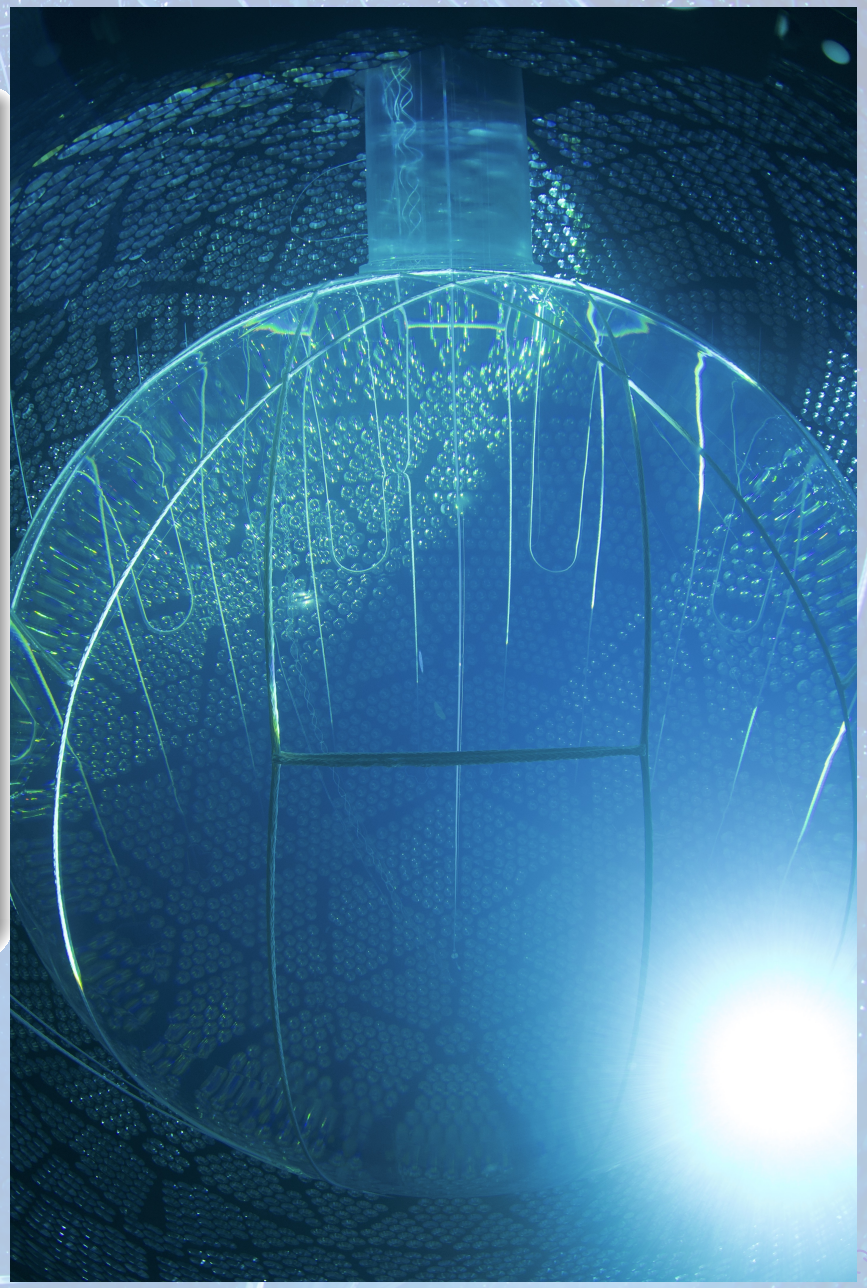

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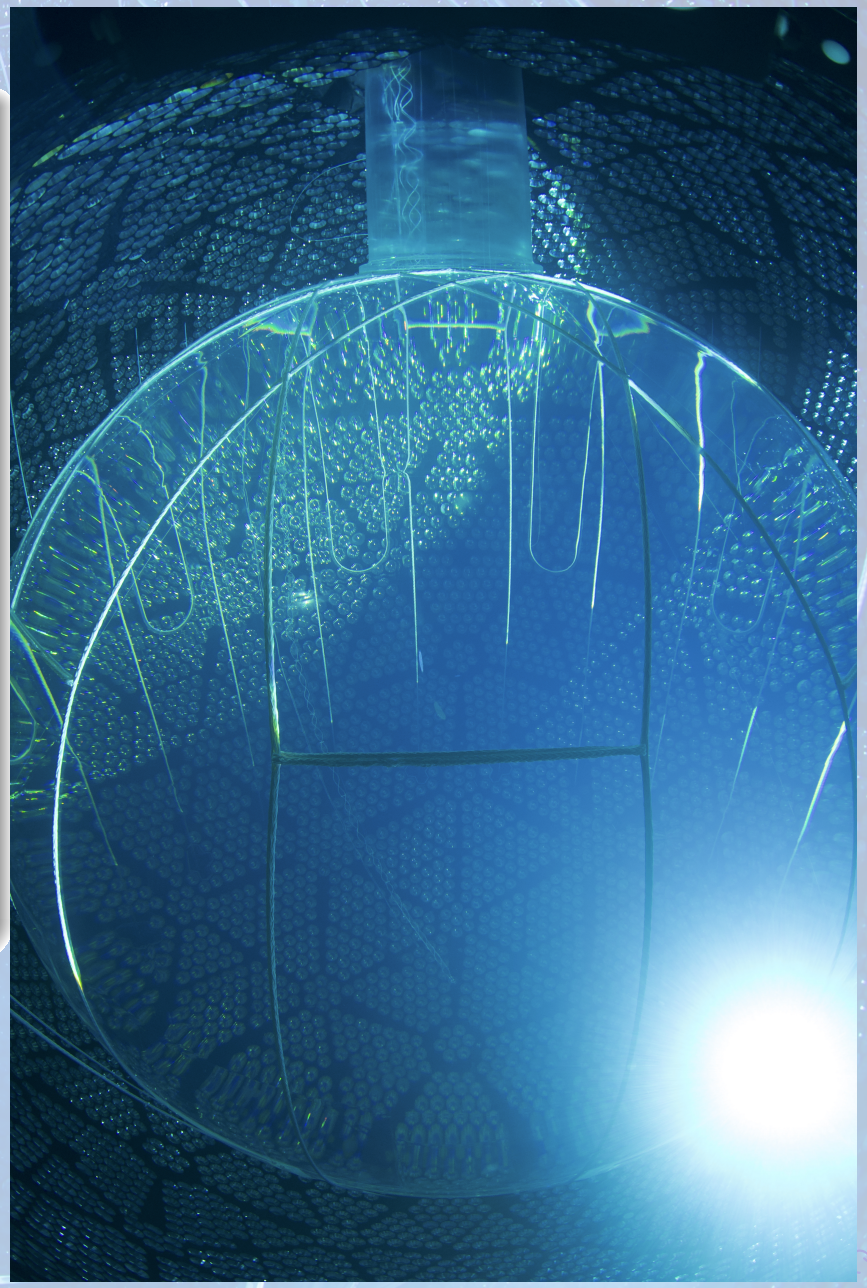

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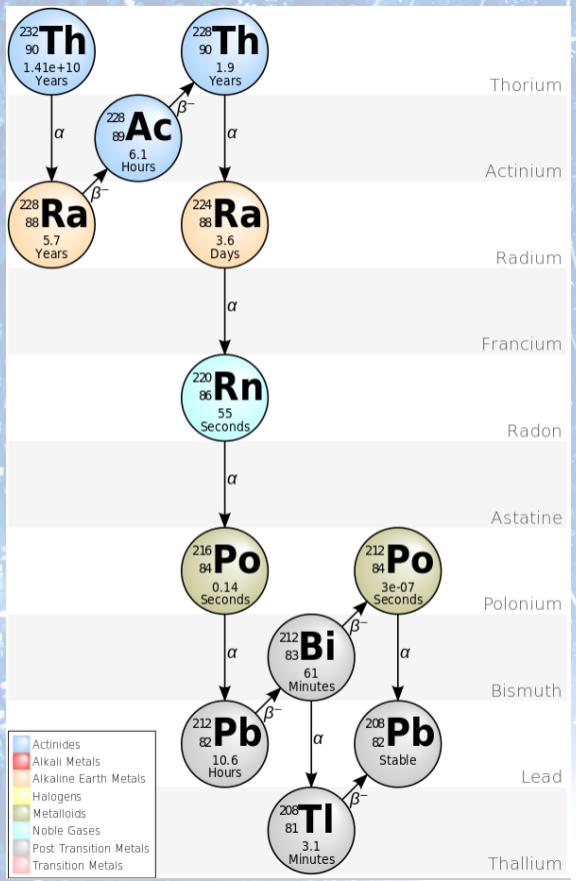
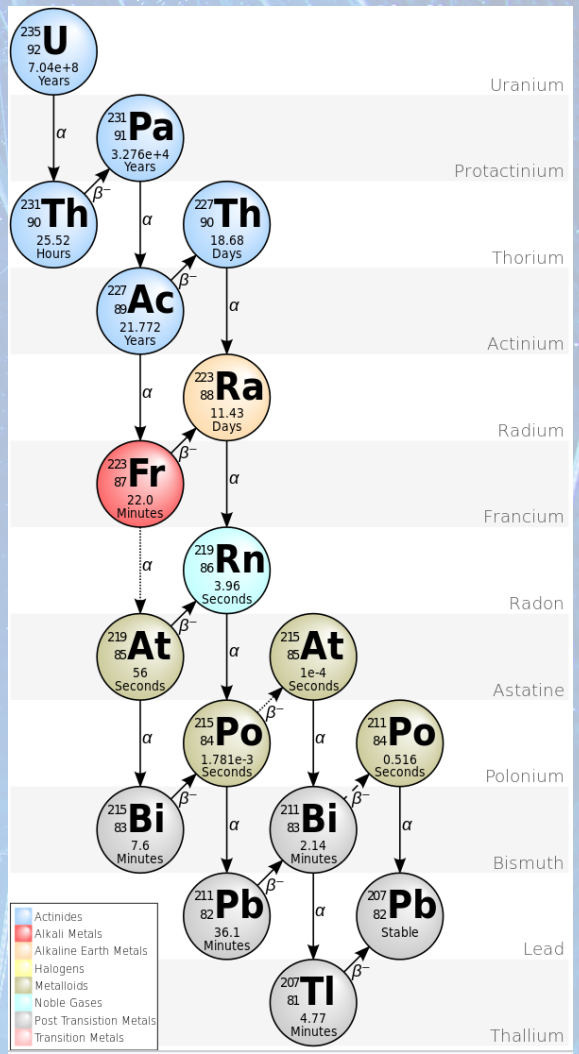
Sources of Backgrounds

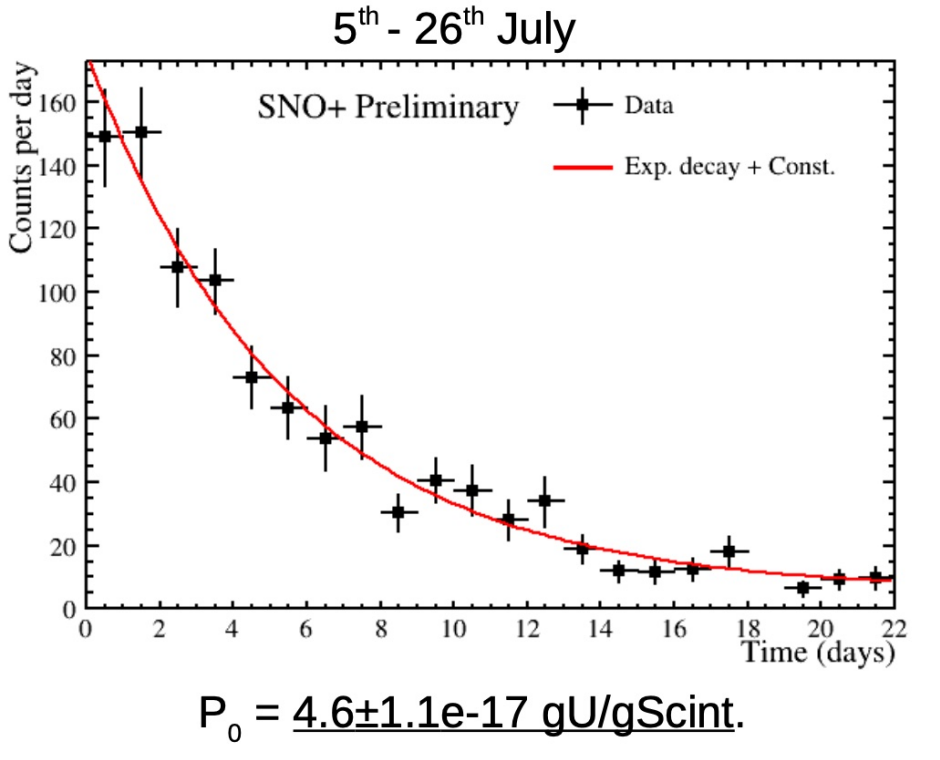


- Backgrounds from natural U and Th decay chains
- Monitor Radon ingress
  - Reduced by maintaining N_2 cover over detector volume
  - Rn content of cover gas monitored at all times
- Presence of these isotopes limit measurement sensitivities



Measured Background Rates

- 2020 data are being analyzed for background rates

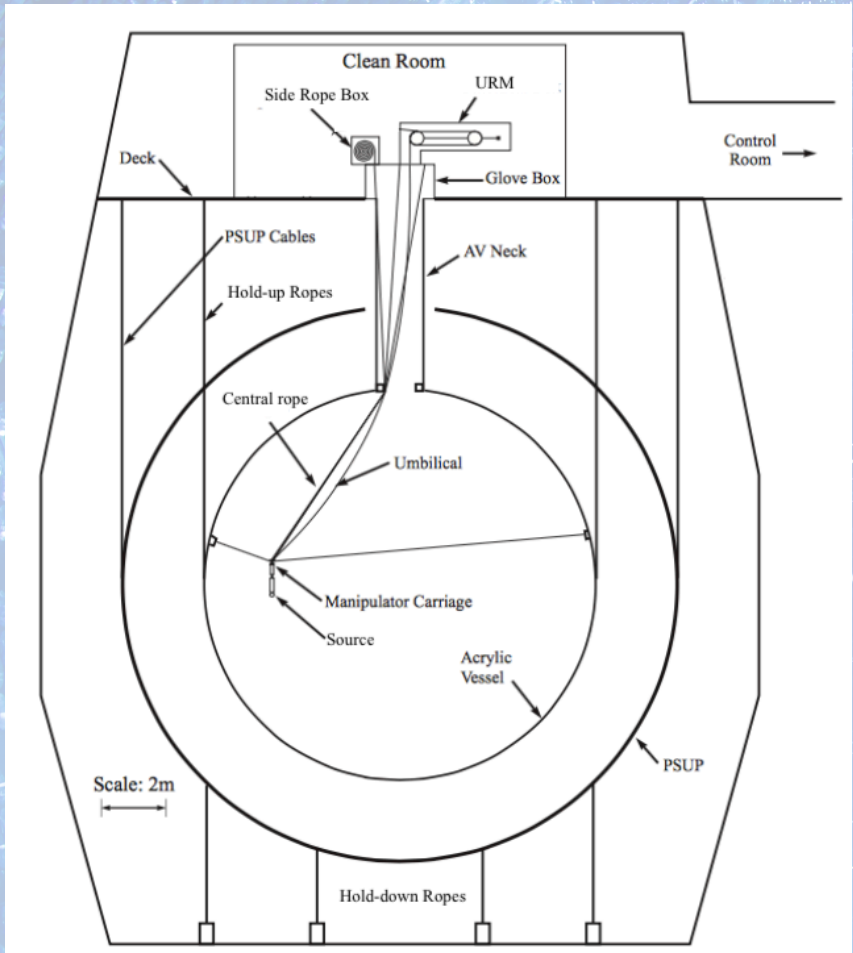


P_0 = 4.6±1.1e-17 gU/gScint.

- Focus on ^{214}Bi-^{214}Po rates
- Rates fluctuated during filling process
- Decreased through steady state period

- Analysis continues to track and mitigate new sources of radon
- See posters by Syed M Adil Hussain (J85) and Parmesh Ravi (J86)

SNO+ Calibration Systems

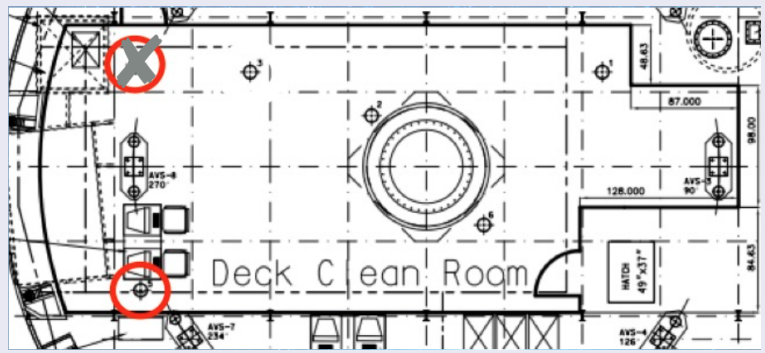


- Umbilical/central rope stored in URM
- Four rope boxes control side ropes
- URM and rope boxes connected to AV through Universal Interface (UI)

- Sources deployed via system of ropes
- Source steered in two dimensions
- Services carried via polyurethane (tygothane) "umbilical"
- Complemented with fixed fibre light injection system

External Deployment

- Guide tubes pass outside AV
- Complementary source deployment



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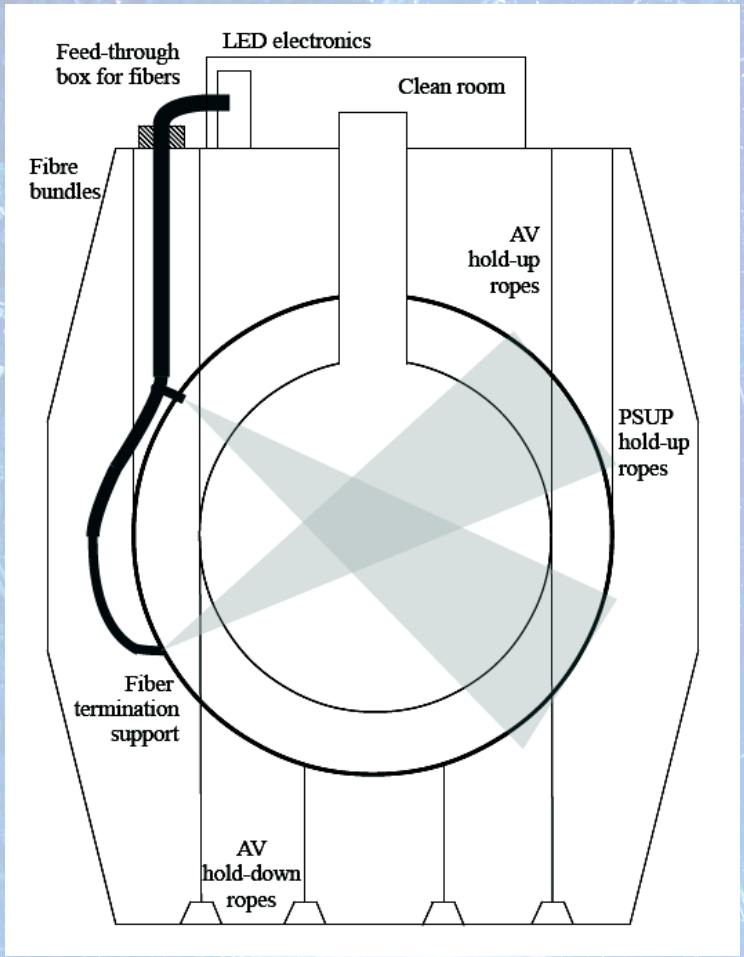

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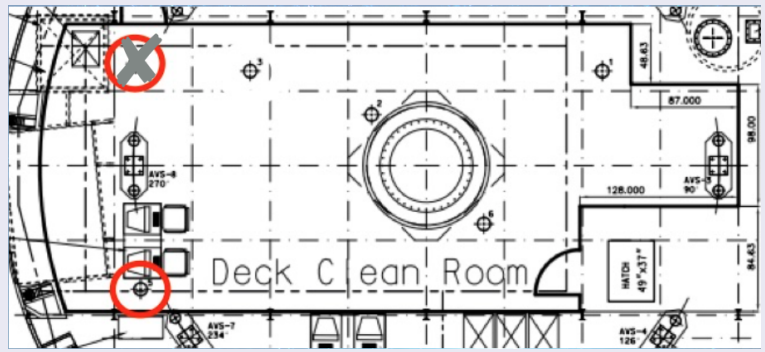
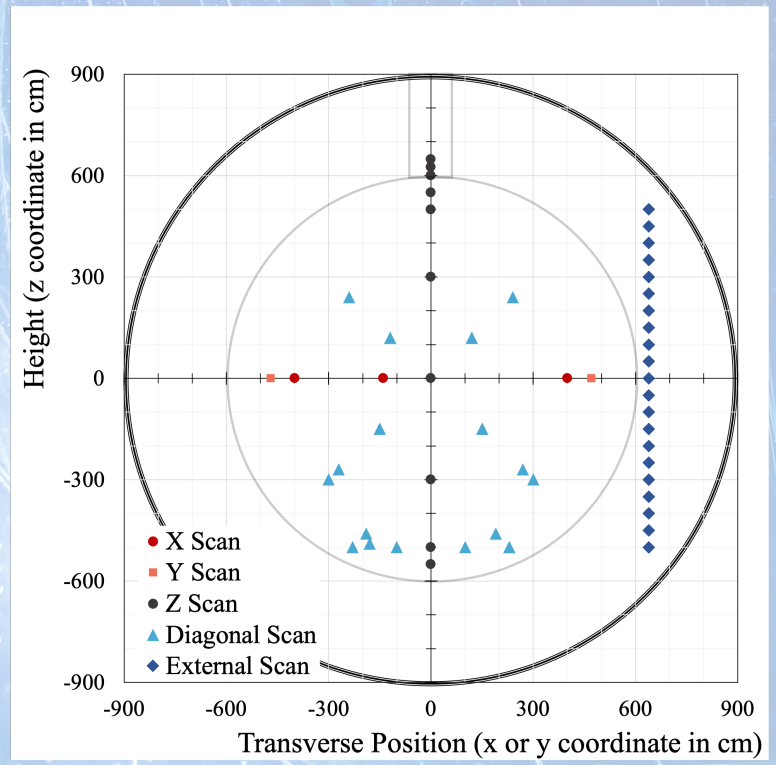
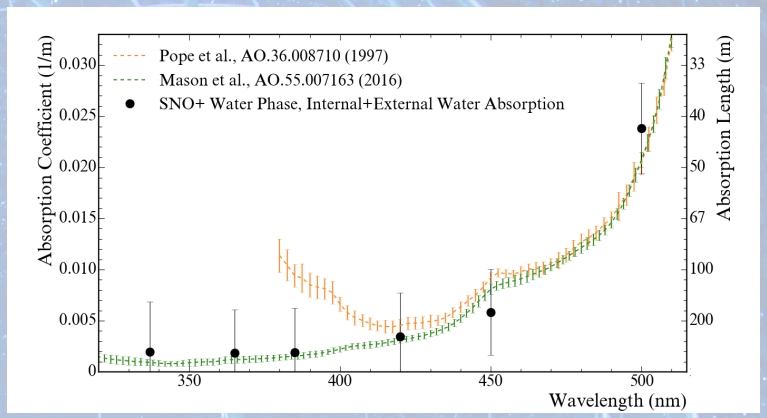
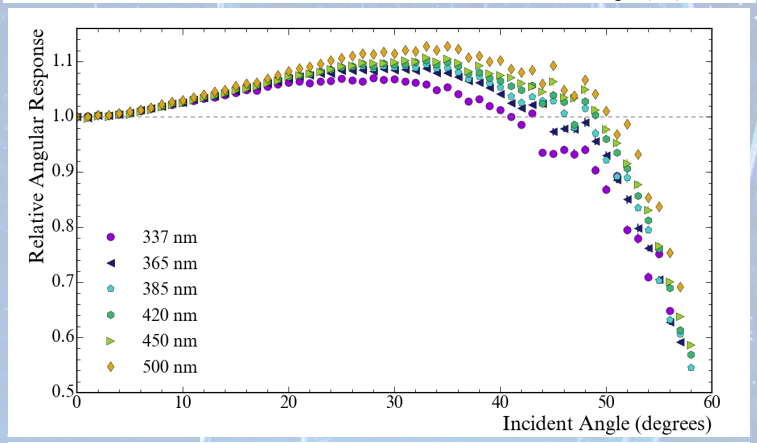


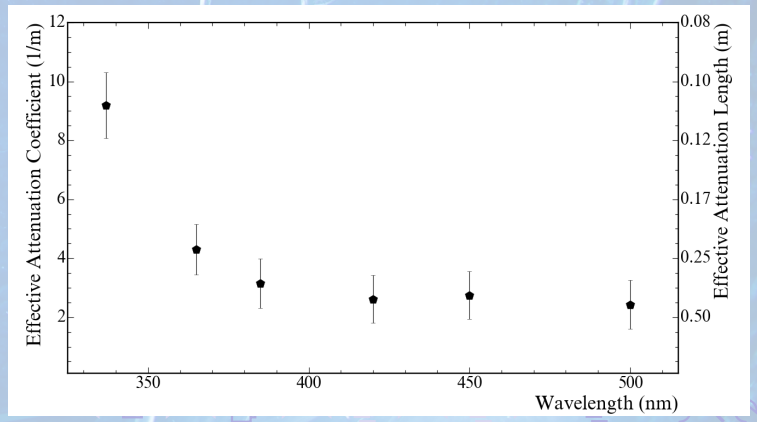
Detector Calibrations in Water

- Extensive campaigns conducted in water phase
- Determined the response of PMTs and optical properties of detector
- optical and radioactive sources
- deployed inside AV and outside AV
- Detailed paper in preparation





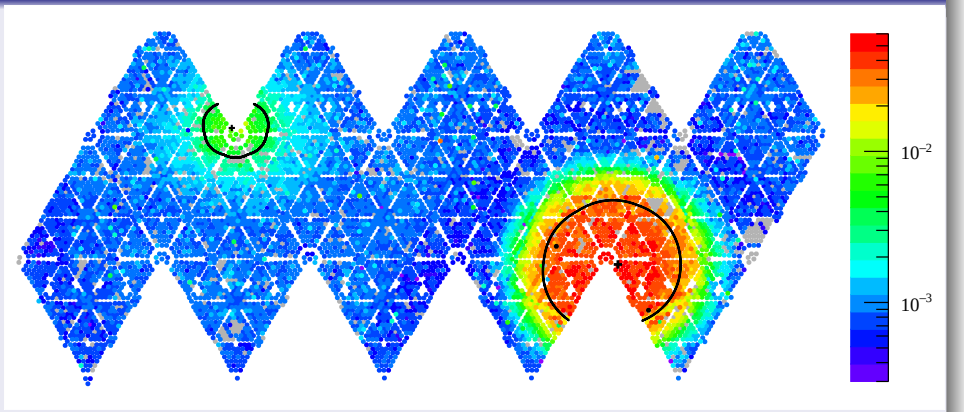




Calibrations in Scintillator

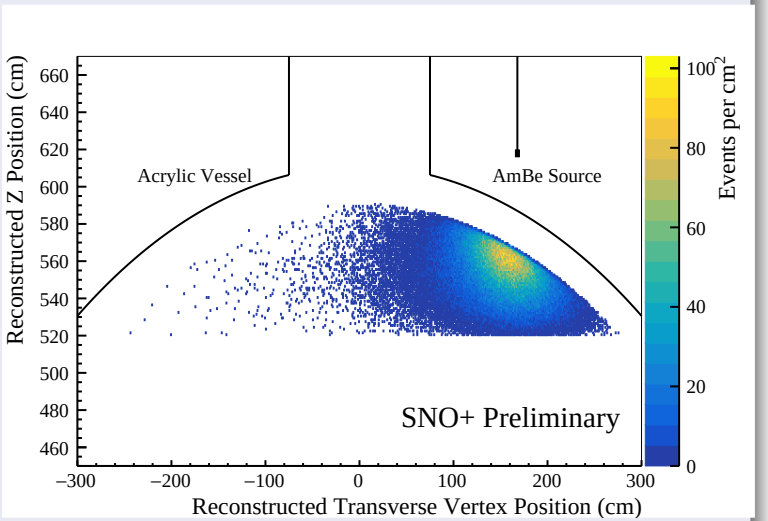
Fixed Optical Fibre System

- Fibres embedded in PSUP
- Shine LED or laser light across AV
- Measures PMT timing and light scattering, absorption



External Source Deployments

- Deployed γ and N sources in Cavity
- Translate the results from the edge to the centre of AV
- Compare neutron capture in water[a] to scintillator
- See talk by Jamie Grove (R2-9)



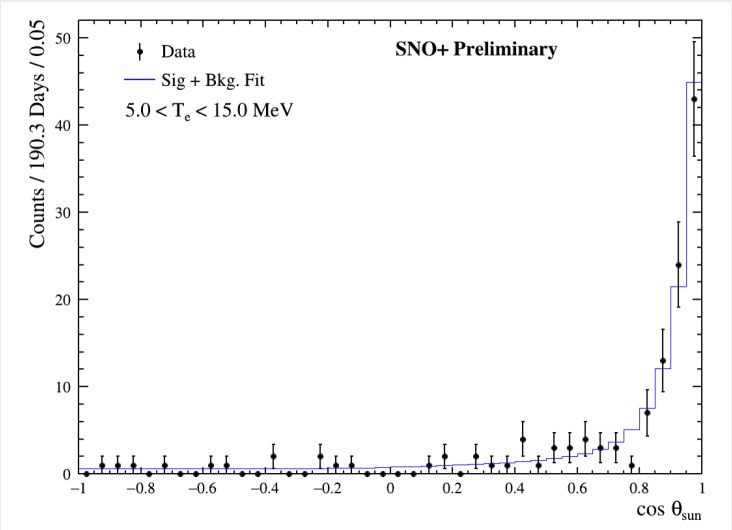
[a] Phys. Rev. C 102, 014002 (2020)

Highlights of Water Phase

Solar

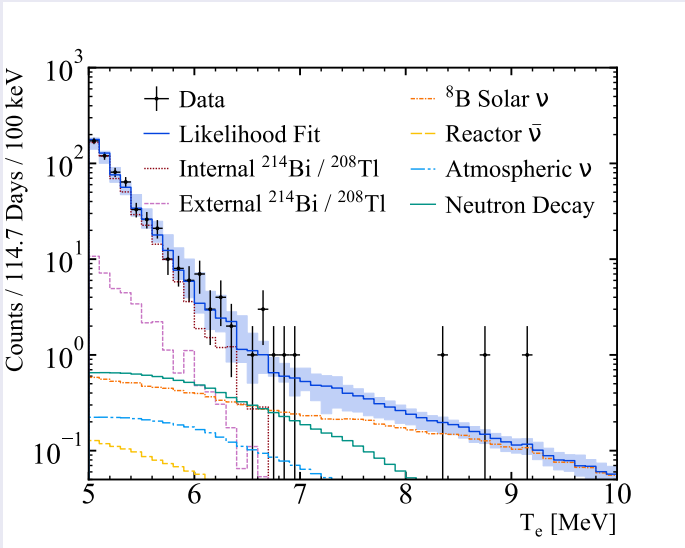
- Verification of solar neutrino flux conducted with water filled detector
- Published [a]

$$\phi_{ES}(^8B) = 2.53^{+0.31}_{-0.28} {}^{+0.13}_{\cdot -0.10}$$



[a] Phys. Rev. D 99 012012 (2018).

Nucleon Decay Measurements



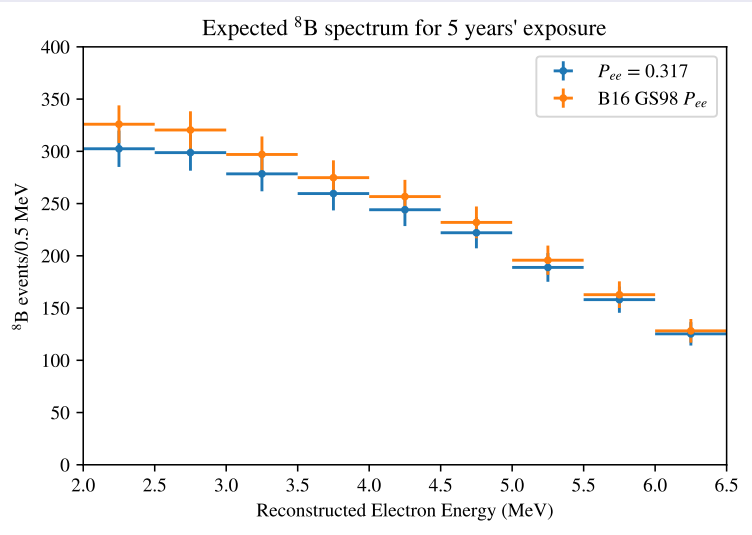
- Sought excitations from p, n decays
- Set 90% C.L. limits[a]
  - $\tau(p \to invis) > 3 \times 10^{29}$ y
  - $\tau(n \to invis) > 2.5 \times 10^{29}$ y

[a] Phys. Rev. D 99, 032008 (2019)

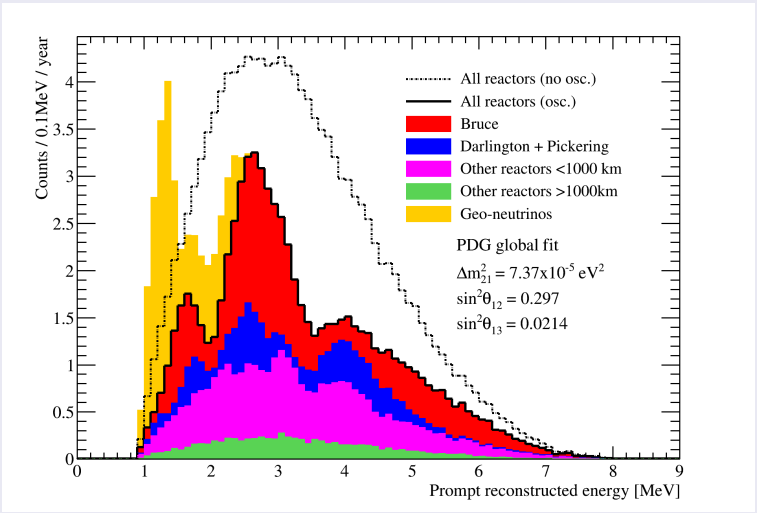
- Improved measurements with additional existing data in progress

Solar and Reactor Predictions in SNO+ Scintillator

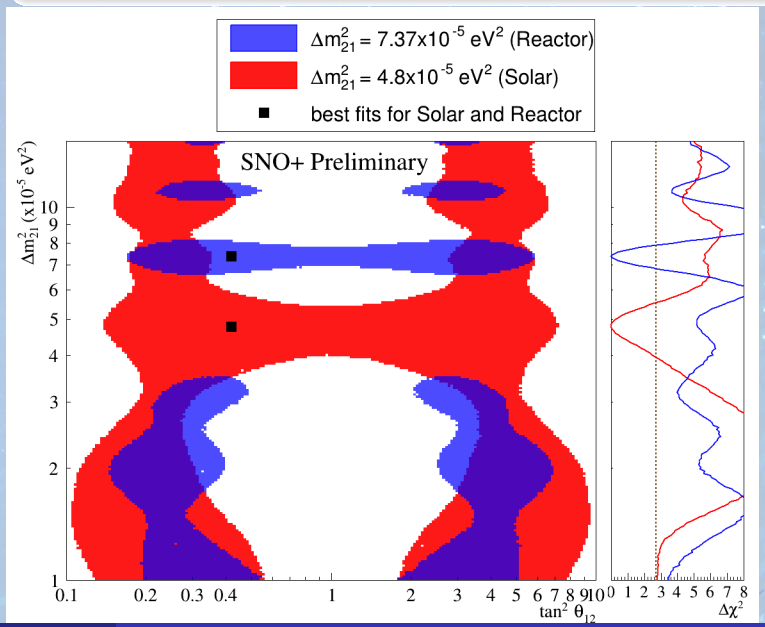
Solar Rates



Reactor Rates

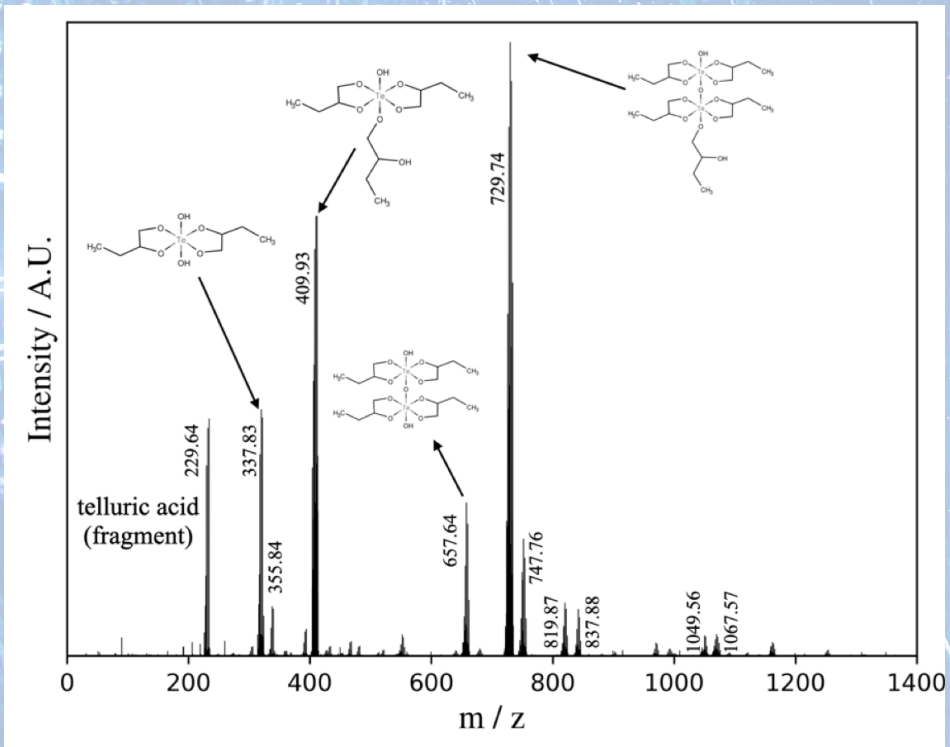


- Prediction of rates from solar and reactor events ongoing
- An analysis of reactor events from last stable period is in progress
- Can project limits for 12 months of data



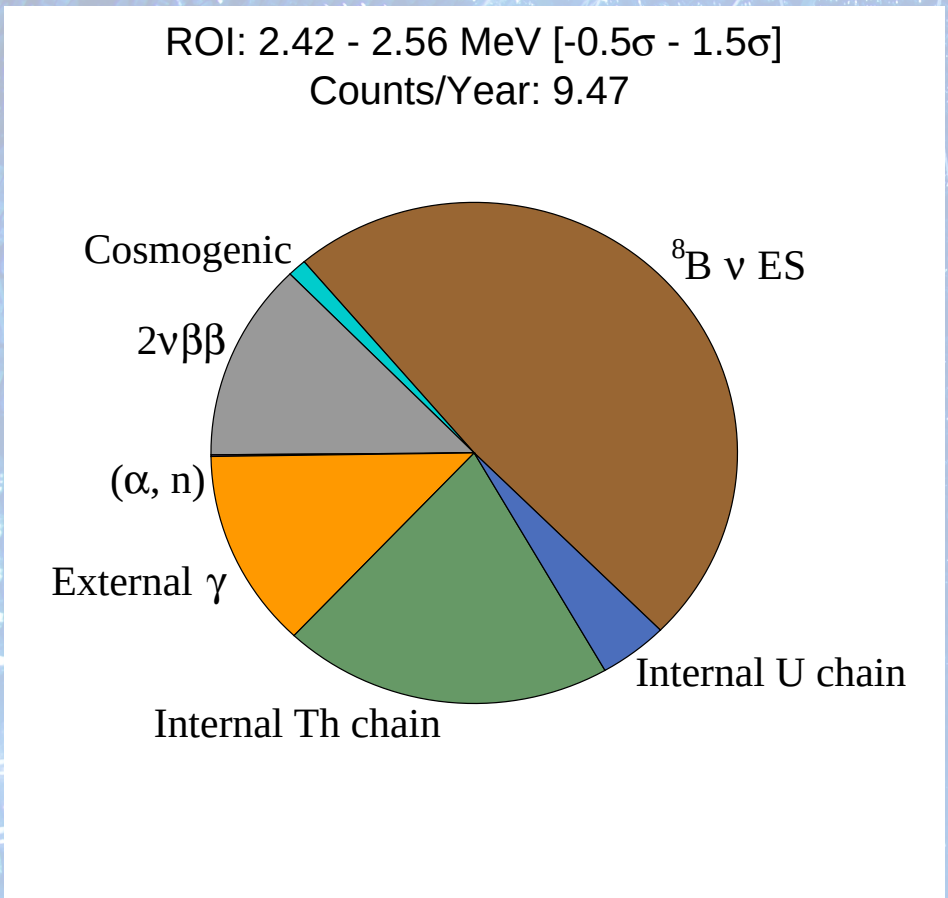
Adding Double Beta Decays to SNO+ (^{130}Te)

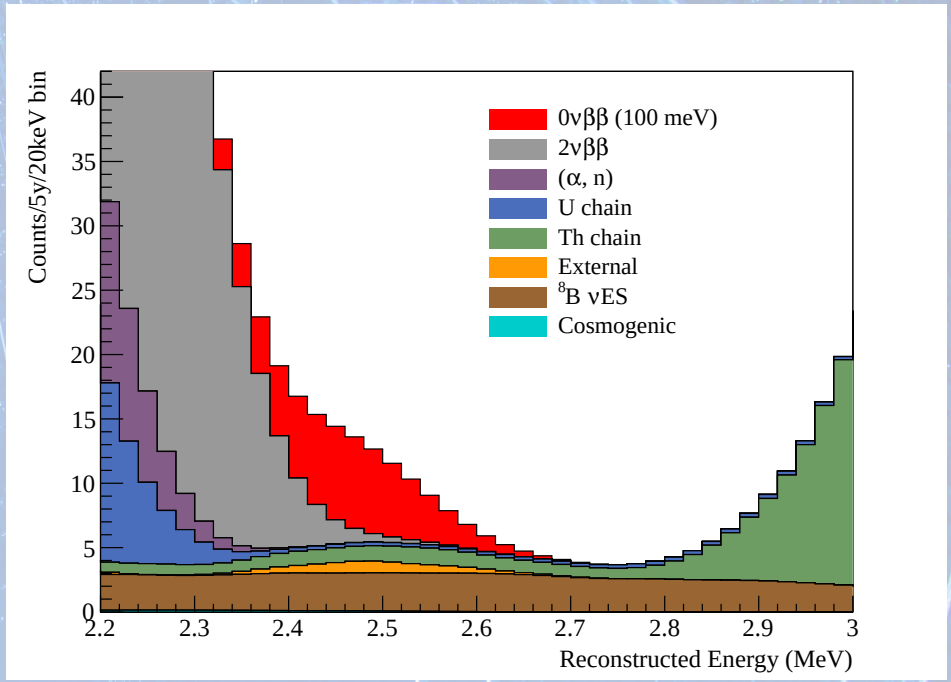
- ^{130}Te occurs with 34% natural abundance
  - No enrichment required
- Chemistry for suspending ^{130}Te in LAB has been developed



- Plants for processing and adding ^{130}Te are being commissioned underground

Projected $0\nu\beta\beta$ Measurments





- Example simulations used a cocktail LAB, PPO, 0.5%Te, Diol, DDA

- Projected limits
  - half life $T_{1/2} > 2.1 \times 10^{26} years$
  - $m_{\beta\beta}$ range for 5 years: 37 - 89 meV
- Larger Te loading proposed for later stages in the experiment

Summary

- SNO+ has completed the fill of the detector acrylic vessel
  - Recirculation and further addition of PPO ongoing
  - Quantifying and assessing backgrounds source
- Have calibrated the detector based on data from water phase
  - Calibration of scintillator properties now underway
- Physics program is being pursued
  - $0\nu\beta\beta$ measurement planned
  - Solar and Reactor neutrino measurements underway
  - Analysis of Partial fill data in preparation
  - Other programs also ongoing (Supernova, Geoneutrinos)