

# In Situ Calibration of Liquid Scintillator in SNO+

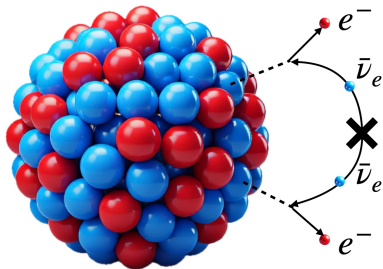
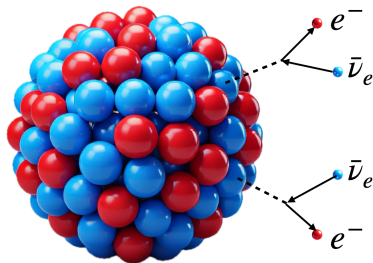
Ryan Bayes

CAP Congress, June 25, 2026



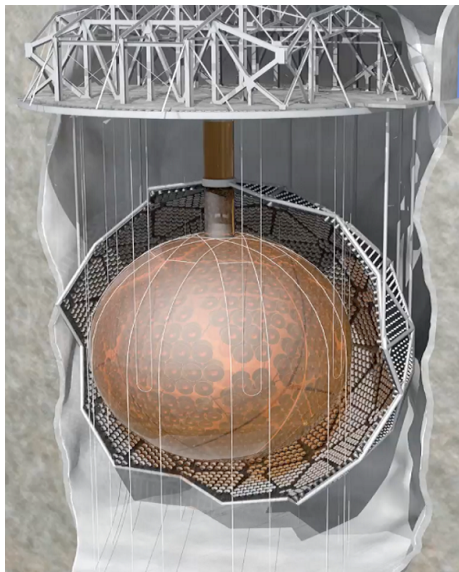
# Neutrino Mass

- Neutrino mass mechanism not fully understood
  - ▶ Dirac versus Majorana neutrinos
  - ▶ Is the neutrino its own antiparticle?
- Tested explicitly in double beta decay
  - ▶ Neutrinoless process a closed neutrino interaction
  - ▶ Violates lepton number by 2
  - ▶ Observation informs absolute neutrino mass
  - ▶ Extremely rare process
- Low background experiment required



# SNO+ Detector

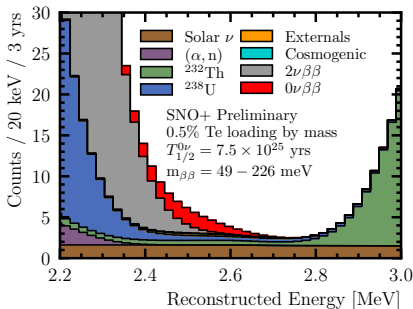
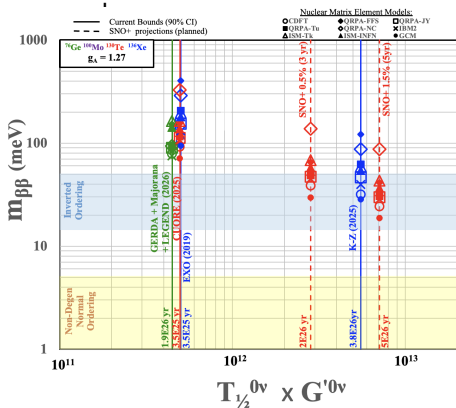
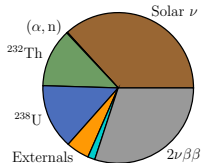
- JINST 16 P08059
- 2 km underground
  - ▶ suppress atmospheric muon flux by  $2 \times 10^8$
- 12 m diameter acrylic vessel
  - ▶ 780 tonnes liquid scintillator
- 9362 inward facing PMTs
- $\approx 17$  m diameter geodesic support structure
- UPW shielding fills surrounding cavity (external veto)



# SNO+ $0\nu\beta\beta$ Physics

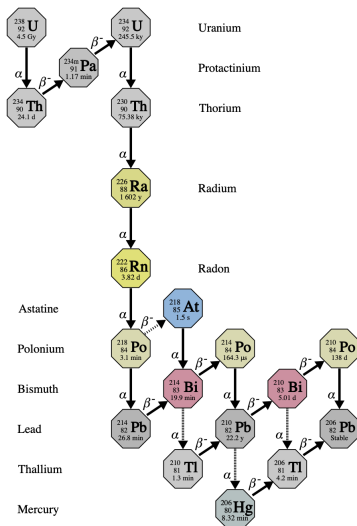
- Will deploy  $^{130}\text{Te}$  in scintillator
  - ▶ Natural abundance of  $^{130}\text{Te}$  is 34%
  - ▶ Enrichment not required
  - ▶ 1.3 tonnes  $^{130}\text{Te}$  to be deployed
- Studies of background and light yield

ROI: 2.42 - 2.62 MeV  $[-0.5\sigma - 1.5\sigma]$   
Counts/year = 15



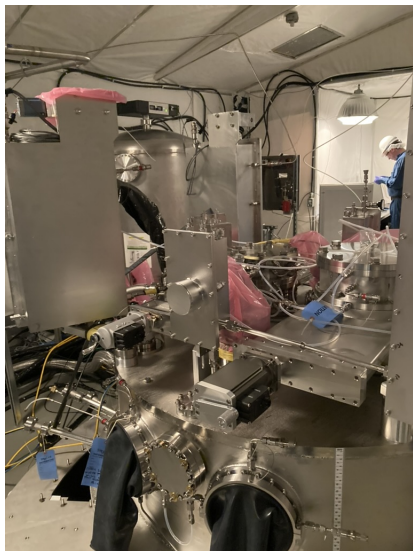
# Backgrounds

- Enter the detector as gas (Rn) or dust (Th)
- Detector hermetically sealed
  - ▶ N<sub>2</sub> blanket above scintillator
  - ▶ 3 bags allow N<sub>2</sub> volume to react to pressure changes
- <sup>222</sup>Rn level monitored in N<sub>2</sub> volume
- Background suppression efforts;
  - ▶ All parts cleaned
  - ▶ Steel parts electropolished or passivated
  - ▶ Use vacuum rated fittings
- <sup>238</sup>U background level of  $6.2 \pm 0.1 \times 10^{-17}$  g(U)/g(LAB)
- <sup>232</sup>Th background level of  $7.5 \pm 0.7 \times 10^{-17}$  g(U)/g(LAB)



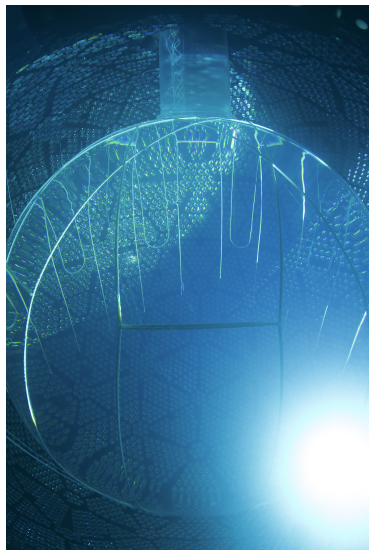
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# Systematics and Calibrations

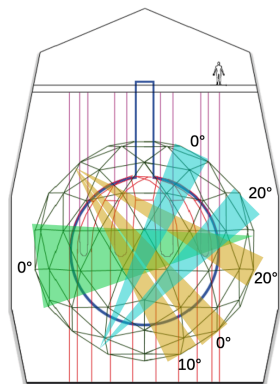
- Optical properties
  - ▶ Wavespeed in scintillator
  - ▶ Attenuation
  - ▶ Light yield
- Photomultiplier response
  - ▶ Occupancy
  - ▶ Timing properties
- Reconstruction Validation
  - ▶ PID
  - ▶ Position
  - ▶ Energy



- Have used backgrounds for calibrations to date

# SNO+ Internal Calibration Systems

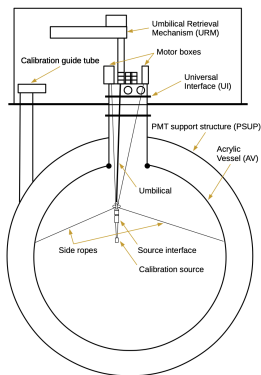
- Embedded light injection system
- Operated regularly



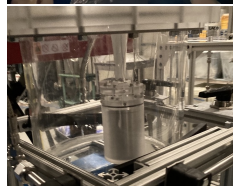
TELLIE

AMELLIE

SMELLIE

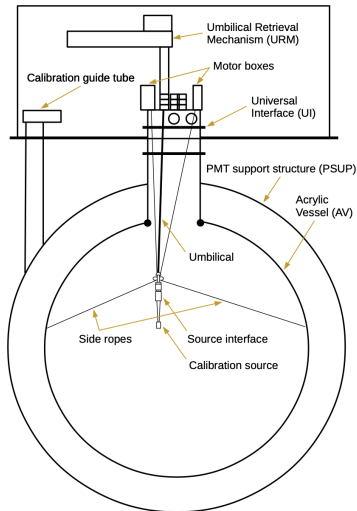


- Deploy sources
- Radioactive (AmBe) and Optical (laser driven)
- Mobile in xz or yz plane

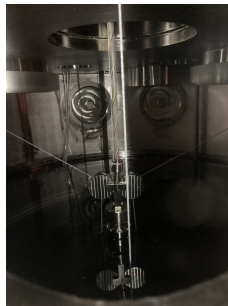


# In Situ Calibration Development and Commissioning

- Construction completed July 2025



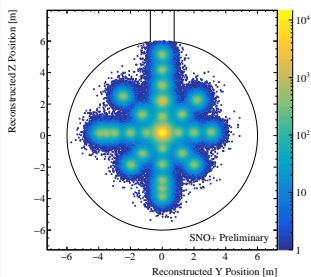
- Redesign of calibration equipment required
- New materials and methods needed to be tested



- System Operational Oct 2025
- Collected data throughout commissioning

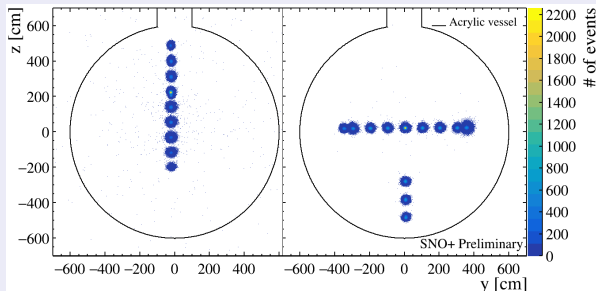
# Source Position Reconstruction

## AmBe Source



- First source
- Neutron interactions and scattering
- Tested limits of system

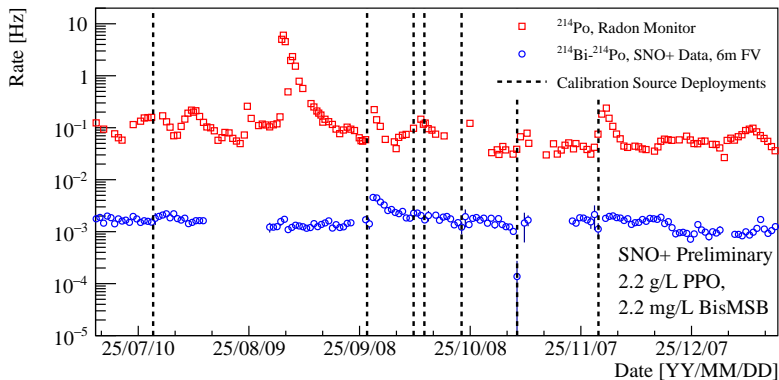
## Optical Source



- Multiple wavelengths per position
- Necessary feedback for commissioning
- Ability to position source with cm level precision

# Background Suppression

- Procedures and hardware developed to suppress Radon ingress
  - ▶ Deployment systems kept in  $N_2$  environment
  - ▶ Double vacuum seals
  - ▶ Pump-purge interstitial volumes
- No significant ingress into detector from deployments
  - ▶ Single incidental ingress sets suppression factor



# Conclusions and Future Studies

- SNO+ is a low background neutrino experiment with the goal of observing  $0\nu\beta\beta$
- Needs excellent calibration to separate  $0\nu\beta\beta$  from  $2\nu\beta\beta$
- Calibration system for SNO+ now complete;
  - ▶ data analysis in progress
  - ▶ Refinements planned for Te phase
- Calibration system does not affect the detector background load
  - ▶ Radon ingress strictly controlled and suppressed

Thank you

