The SNO+ Tellurium Deployment Programme

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on behalf of the SNO+ Collaboration
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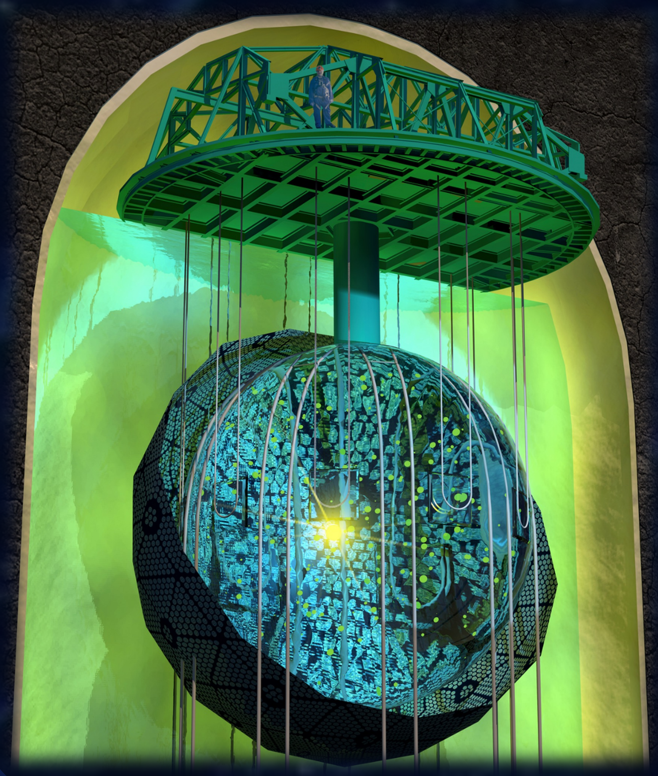
The SNO+ Experiment



Multi-purpose liquid scintillator detector [1]

- Located 2070 m underground at SNOLAB
- 7000 m^3 ultrapure water shielding
- 904 m^3 acrylic vessel (main detector body)
- Events observed with 9362 PMTs
- Extensive physics programme

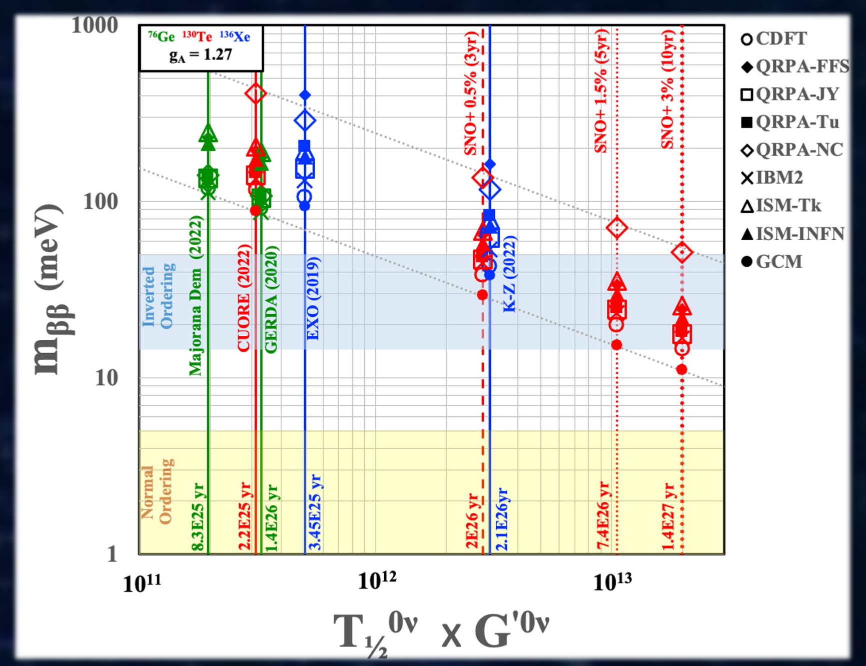
SNO+ Liquid Scintillator [2]

- 792 tonnes Linear Alkylbenzene (LAB)
- 2.2 g/L 2,5-Diphenyloxazole (PPO)
- 2.2 mg/L 1,4-Bis(2-methylxtyryl) benzene (bis-MSB)
- 6.5 mg/L Butylated Hydroxytoluene (BHT)

0νββ Programme

Primary SNO+ Science Objective: Searching for 0νββ in ^{130}Te

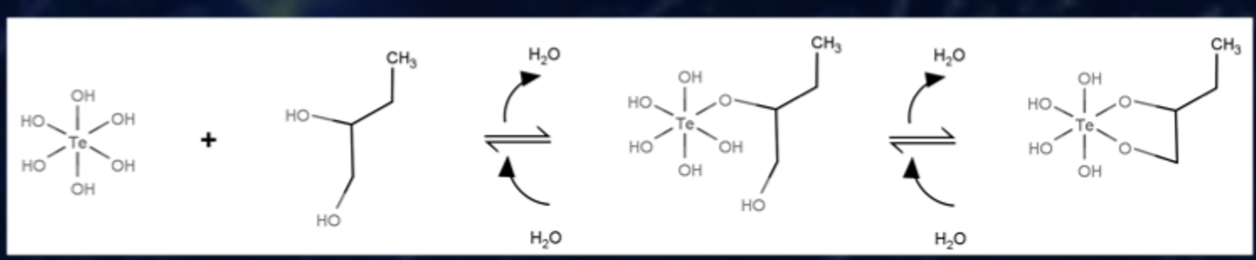
- Initial Deployment of 3.9 tonnes ^{nat}Te (0.5% by mass), corresponding to 1.3 tonnes ^{130}Te
- Only planned future ^{130}Te 0νββ experiment
- All detector and scintillator backgrounds are measured prior to isotope deployment
- Projected initial sensitivity (90% C.L) of $S^{0\nu}_{1/2} = 9.20\times10^{25}$ years after 1 year live time
- High scalability due to relatively low cost, as no isotope enrichment is necessary (34% natural abundance)
- Further loading of up to 23.4 tonnes ^{nat}Te (3% by mass) feasible



Tellurium Loading Methodology

Tellurium Loading Technique [3]

- New novel method developed to evenly and stably dissolve Te into the SNO+ liquid scintillator
- Based on a condensation reaction between Telluric Acid (TeA) and 1,2-butanediol (BD) to create oil-soluble tellurium butanediol (TeBD)
- Solubilisation in LAB accomplished through a mixture of heating and amine neutralisation using N,N-dimethyldodecylamine (DDA).
- All reagents required are distillable and can be safely handled underground, allowing for low background radioactivity

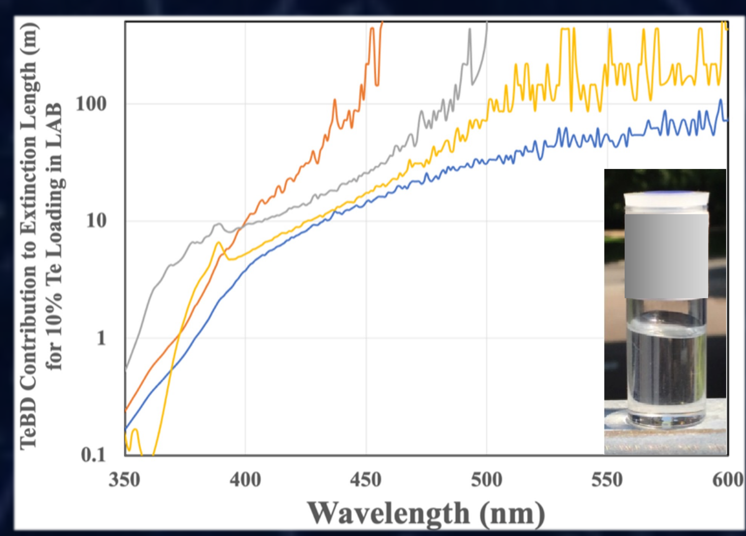


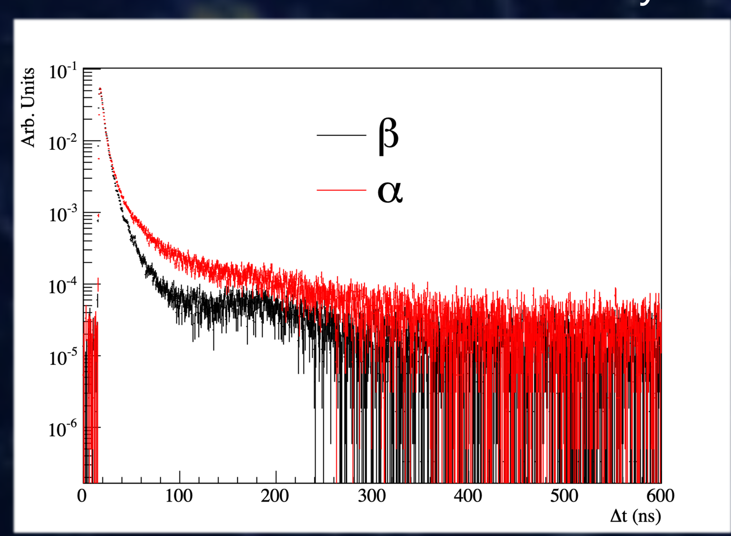
Chemical Stability

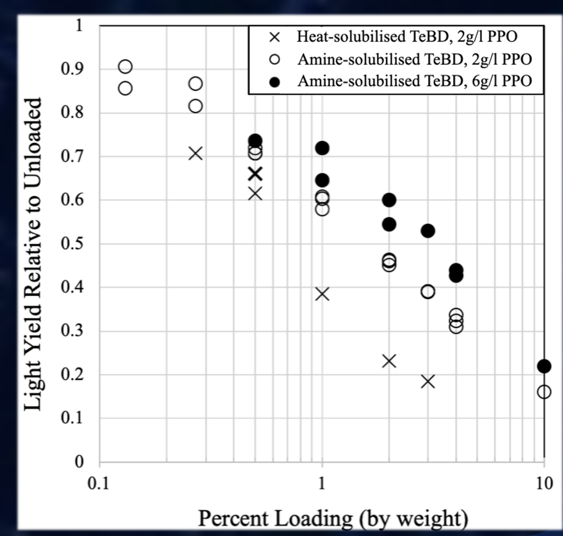
- The DDA also prevents a reverse hydration reaction from occurring, improving chemical stability.
- Added at molar ratio of 0.25:1 DDA:Te
- TeBD (with DDA) has been explicitly demonstrated to be stable in time scales of over 8 years
- The optical clarity of the liquid scintillator is unchanged following the loading of TeBD (0.5% by mass) over 5 years.

Optical Characteristics

- Excellent transparency achieved at loading concentrations of up to 10% by mass
- Emission time profiles of 0.5% Te-loaded scintillator under α and β excitation show reasonable pulse shape discrimination
- High scintillator light yields are maintained following Te-loading at percent-level concentrations, which can be offset by further addition of PPO.





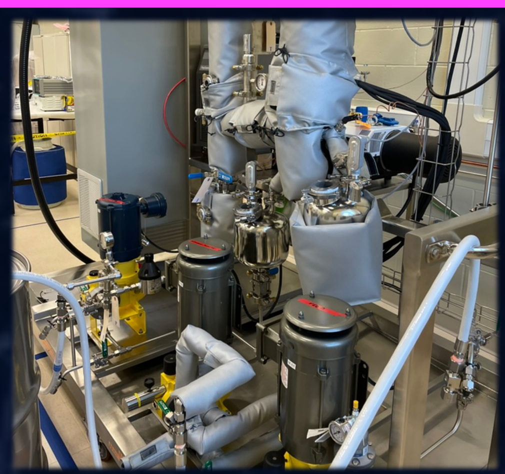


Tellurium Deployment Strategy

DDA Purification

- Purified using a thin-film distillation technique
- Distilled with a plant in the SNOLAB surface facility
- Distilled DDA brought underground immediately to minimize potential for cosmogenic activation

Status: Constructed, commissioning



TeBD Synthesis

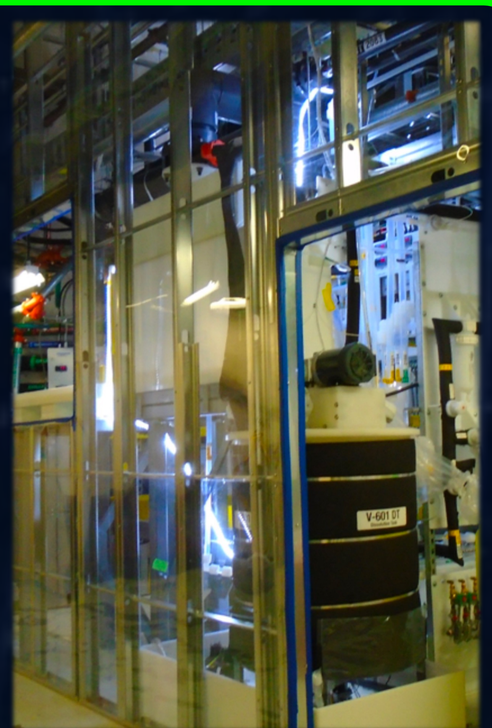
- TeBD is synthesized at a 3:1 TeA:BD ratio
- Water is driven off using partial vacuum, heating, agitation, and nitrogen sparging to promote condensation reaction
- Solubilisation in LAB performed using a mixture of heating and amine neutralisation with DDA

Status: Constructed, commissioning

Telluric Acid Purification

- Raw TeA powder stored underground since 2015 to "cool off" cosmogenic activation
- TeA purified by pH and thermal recrystallisation in an underground purification plant
- The TeA purification plant has been demonstrated to achieve expected yields and purification targets.
- Safe handling and logistics of the full process has been explicitly demonstrated underground

Status: Constructed, commissioned



Addition to the Detector

- TeBD is diluted to desired concentration using the scintillator deployment systems
- System is regularly used to recirculate liquid scintillator
- Recirculation through this system for additional Te loading is planned and possible

Status: Constructed, commissioned, well-tested

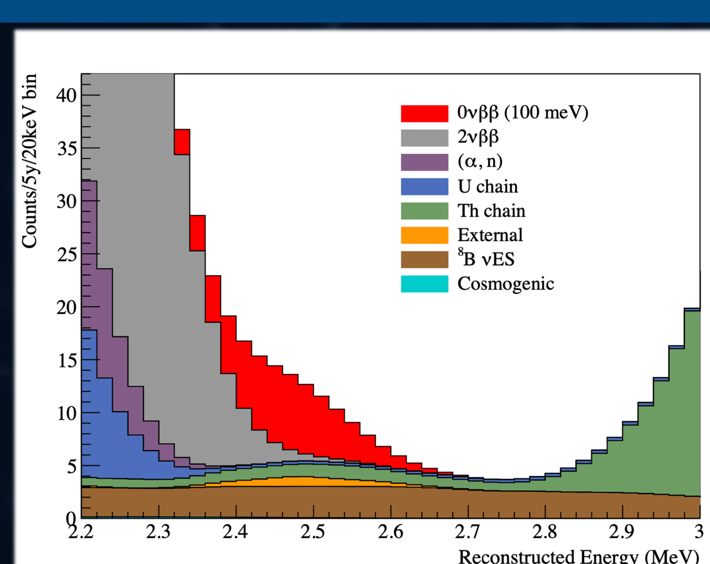
Butanediol Purification

- BD will be purified underground using multi-stage distillation
- Purification will utilize the same plant that successfully purified and deployed the SNO+ liquid scintillator

Status: Constructed, commissioned, well-tested

Conclusions and Prospects

- Novel tellurium loading methodology has been developed, tested, and well-understood
- All major Te deployment infrastructure and hardware built and in late stages of commissioning
- Purification of tellurium has been tested, with yield and purification targets achieved
- Ongoing measurement of scintillator backgrounds underway prior to addition of Te
- Initial deployment of 1.3 tonnes ^{130}Te (0.5% by mass) planned next year
  - Projected 0νββ sensitivity of $S^{0\nu}_{1/2} = 9.20\times10^{25}$ years after 1 year live time
  - Final sensitivity depends on purity achieved during Te loading
- Further loading up to 3% by mass feasible



Acknowledgements

[1] SNO+ Collaboration (2021) JINST **16** P08059
[2] SNO+ Collaboration (2021) JINST **16** P05009
[3] D. Auty, S. Manecki, B. Tam et al (2023) NIM.A **1051** 167204

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