# TeA-TeDiol-DDA system for SNO+

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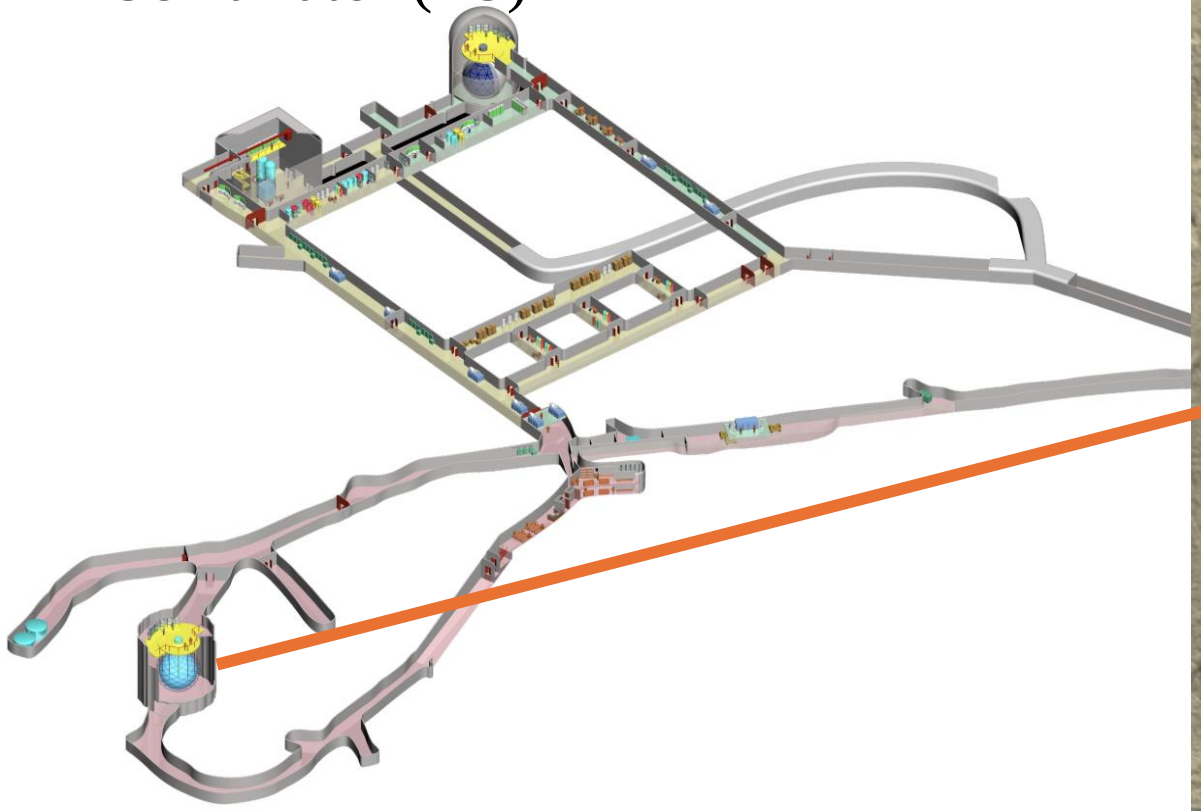
SNOLAB User Meeting 2024, June 26

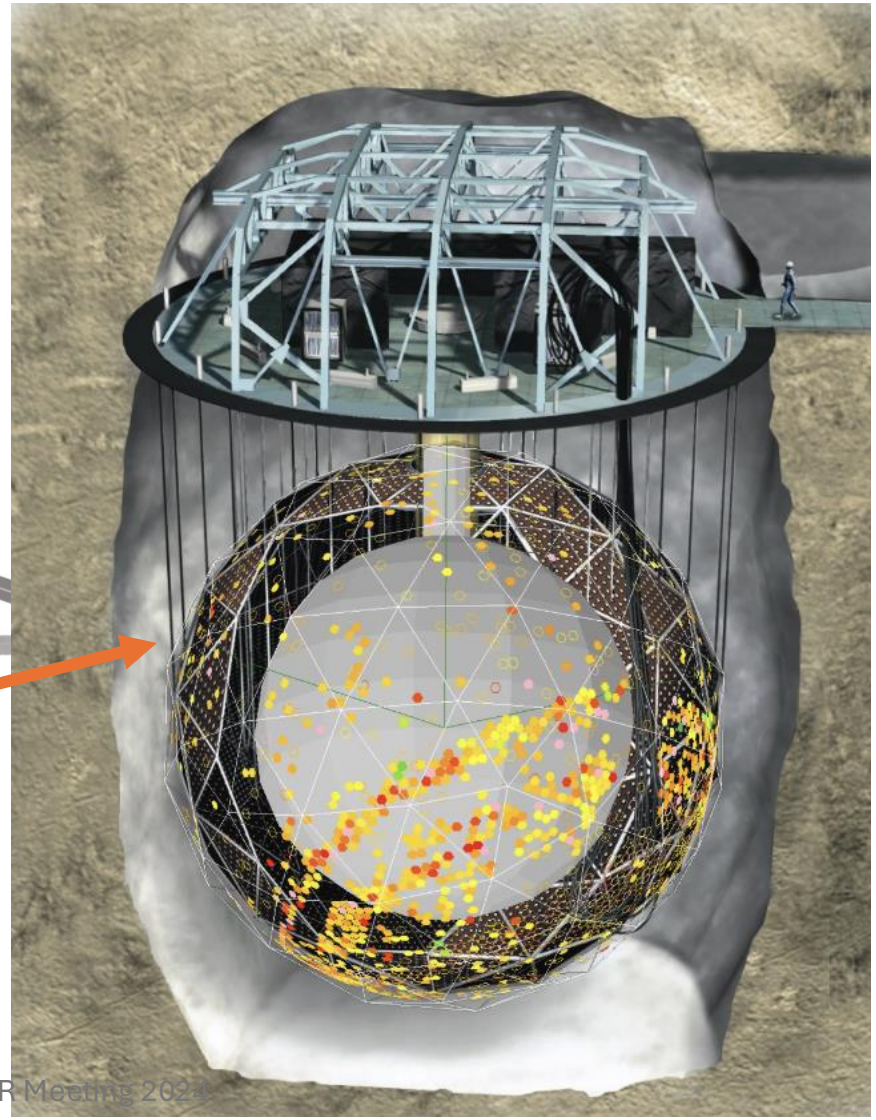


# SNO+ and its primary goal

The main goal is to look for $0\nu\beta\beta$

using 780 tonnes of Liquid Scintillator (LS)

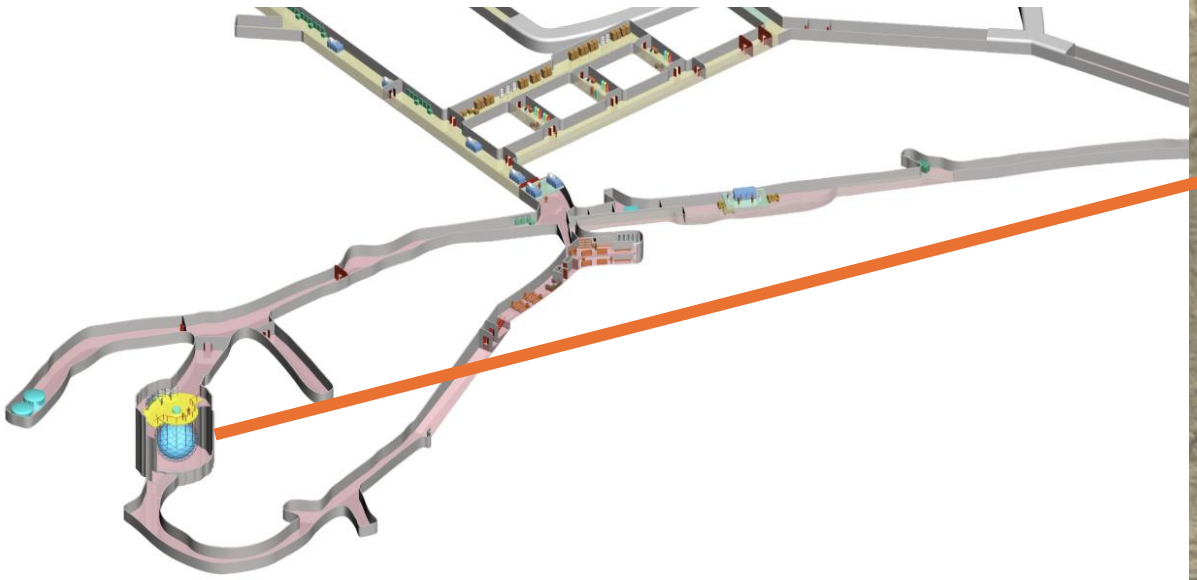


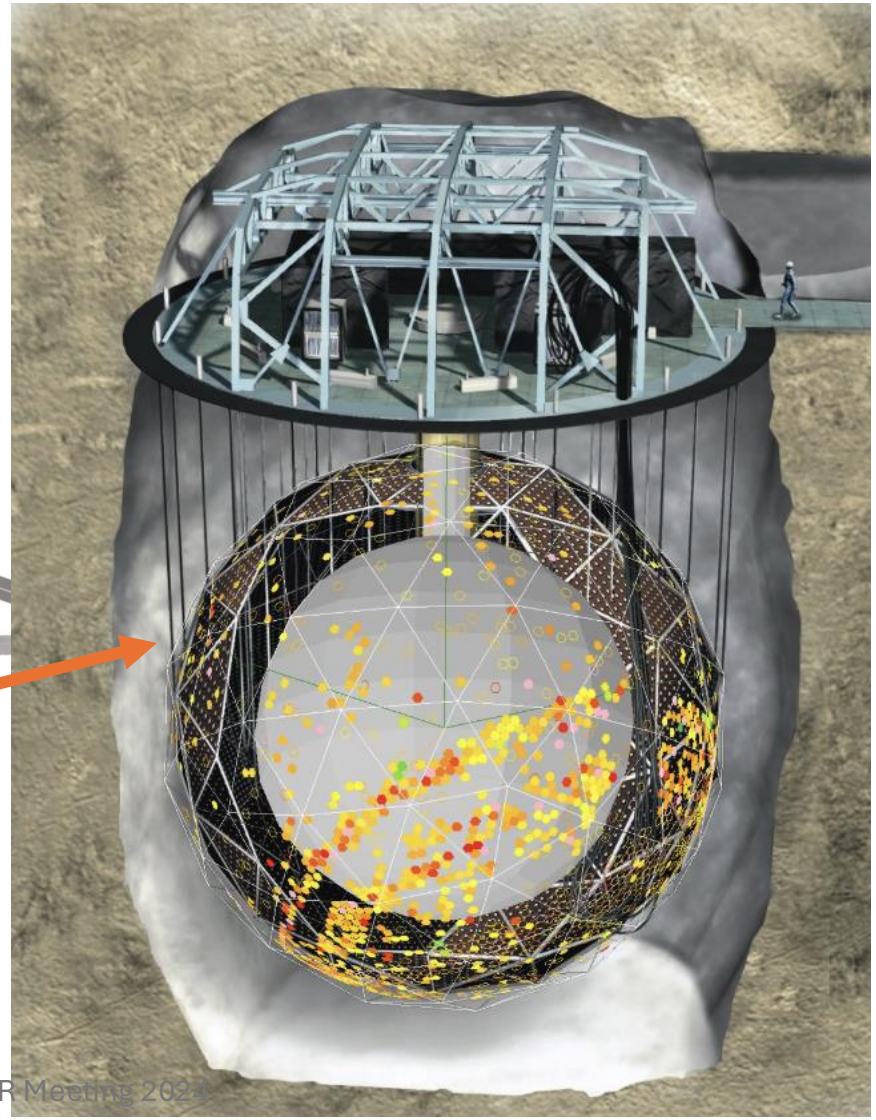


# SNO+ and its primary goal

Search requirements for $0\nu\beta\beta$

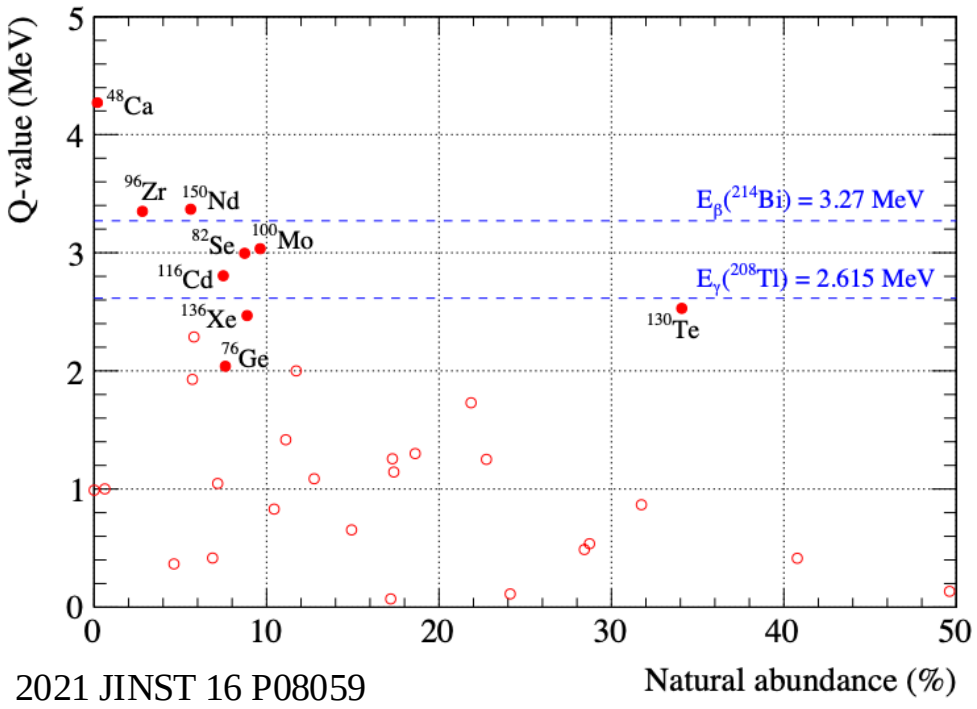
- Low Backgrounds
- Good Energy Resolution
- Large amount of isotopes





# SNO+ and Tellurium

- $^{130}$Te has 34% natural abundance = does not require costly or logistically difficult procurement of enriched isotope
- Q-value > 2 MeV helps to avoid natural Radioactive Backgrounds.
- Further loading of up to 23.4 tonnes $^{nat}$Te (3% by mass) feasible.
- SNO+ : only experiment will use $^{130}$Te
  - provide best half-life of $^{130}$Te.




2021 JINST 16 P08059

# SNO+ Liquid Scintillator (LS): now

## What is in the detector?

- 780 tonnes Linear Alkylbenzene (LAB)
- 2.2 g/L 2,5-Diphenyloxazole (PPO) [Primary Fluor]
- 2.2 mg/L 1,4-Bis(2-methylxtyryl) benzene (bis-MSB) [Wavelength Shifter]
- 6.5 mg/L Butylated Hydroxytoluene (BHT) [Stabilizer]

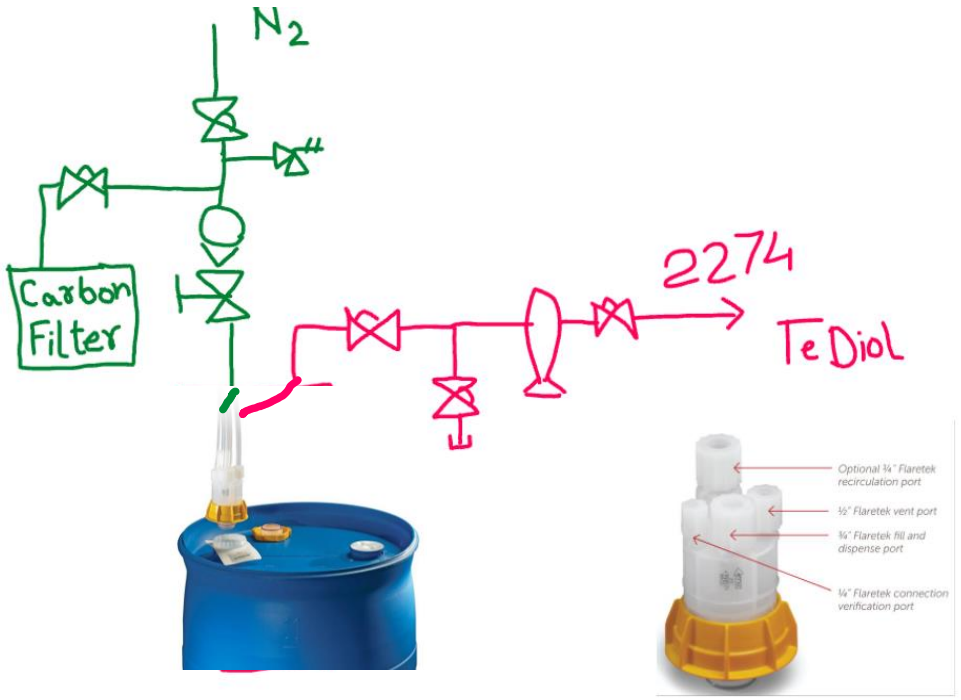
# SNO+ Liquid Scintillator: future - LS+TeBD+DDA

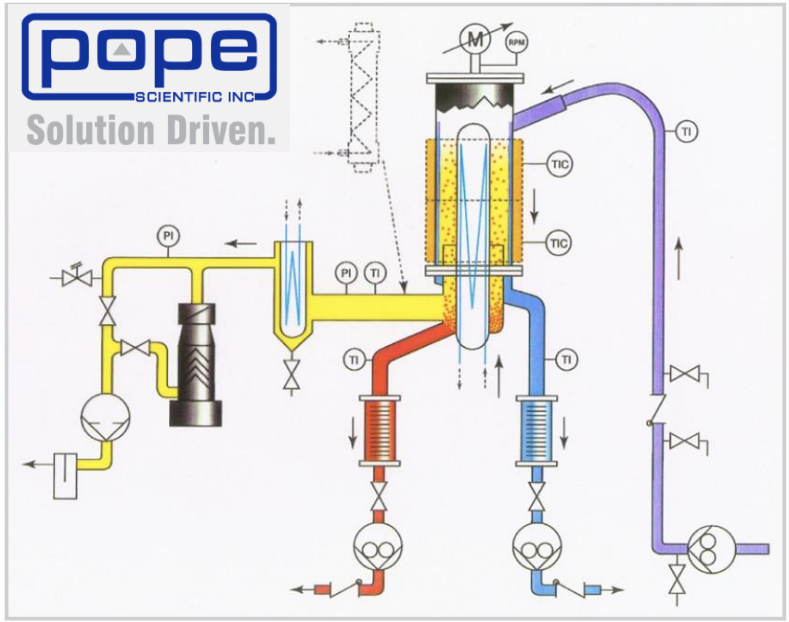
## What is yet to be added into the detector?

- 3.9 tonnes $^{nat}$Te (0.5% by mass), corresponding to 1.3 tonnes $^{130}$Te.
- Based on a condensation reaction between Telluric Acid (TeA) and 1,2-butanediol (BD) to create oil-soluble tellurium butanediol (TeBD).
- Solubilization in LAB is accomplished through a mixture of heating and amine neutralization using N,N-dimethyldodecylamine (DDA). [Stabilizing Amine]
  - DDA prevents reverse hydration reaction: improves chemical stability
- TeBD has been explicitly demonstrated to be stable in time scales of over 8 years.
- The optical clarity of LS is unchanged following the loading of TeBD over 5 years.

# Tellurium Deployment: DDA purification

- Purify DDA using a thin-film distillation system installed on surface lab at SNOLAB
- Distilled DDA is placed in an ultra-pure PFA drum and taken underground rapidly to avoid cosmogenic exposure
- DDA is transferred to the TeDiol plant using a transfer station at UG

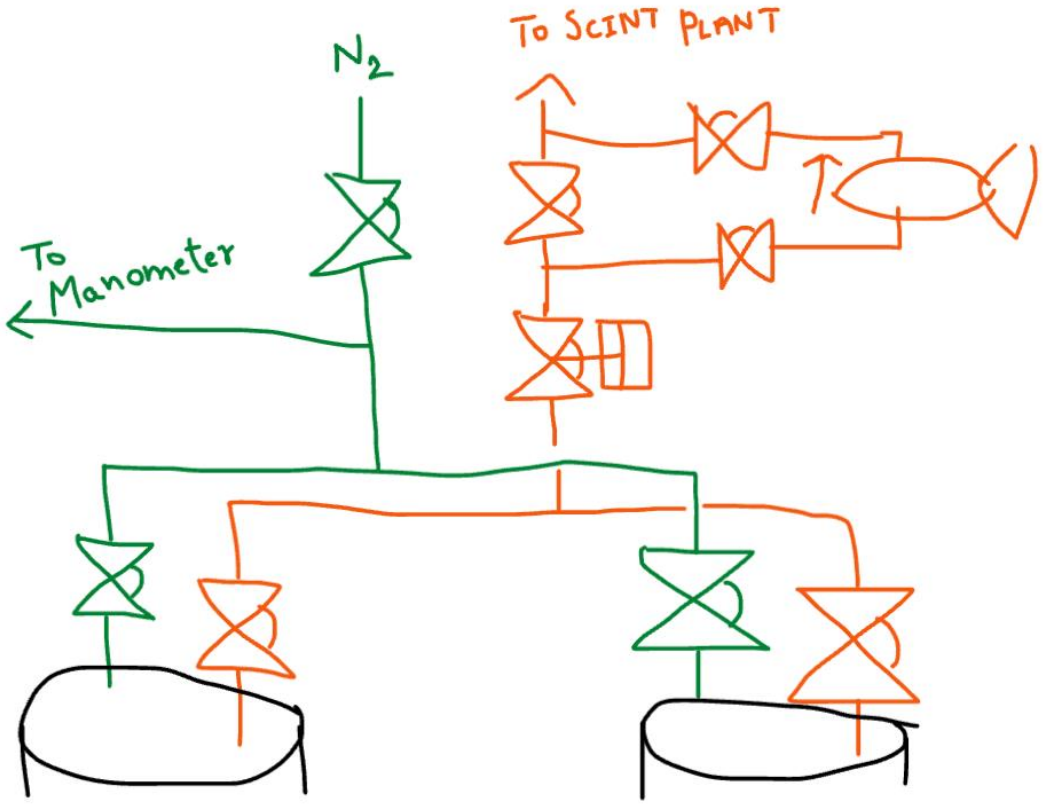



Wiped-Film Distillation Process

# Tellurium Deployment: BD purification

- BD will be transferred to the Scint-Plant Distillation column using a 'Transfer Station'
- BD will be purified using multi-stage distillation in the UG plant (like LAB) and send to the TeDiol plant

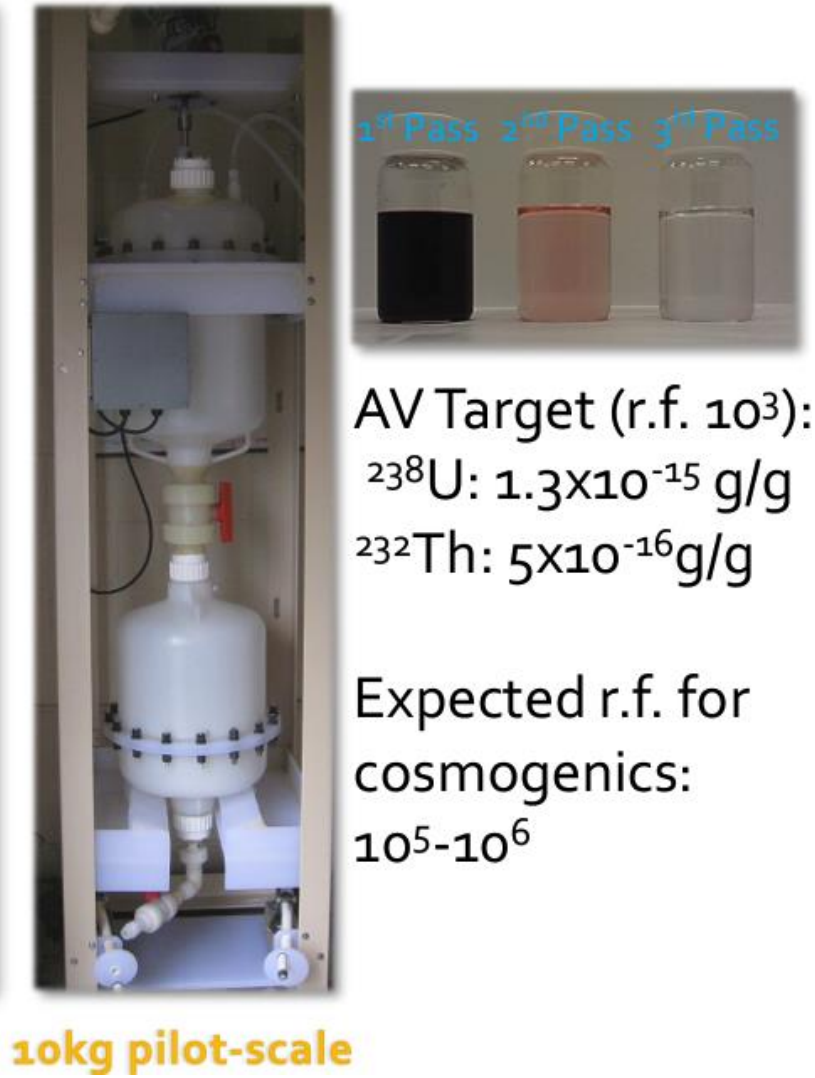


# Tellurium Deployment: TeA purification

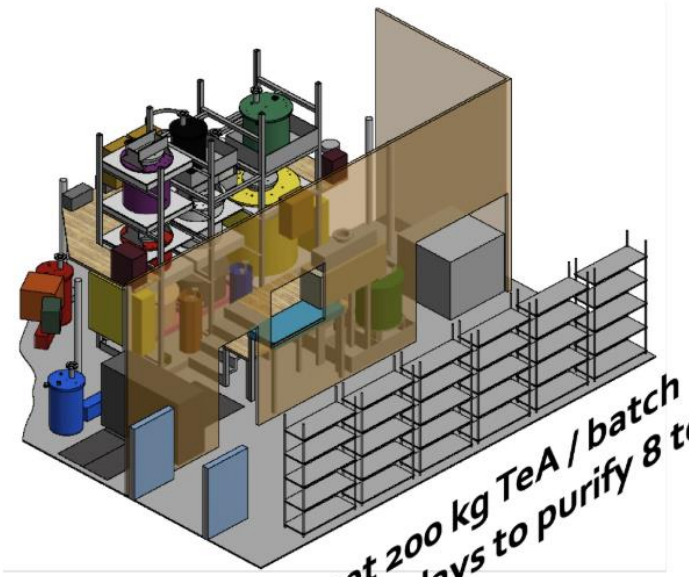
- Raw TeA crystal stored UG since 2015 to 'cool off' cosmogenic activation
- TeA purified by pH and thermal recrystallization in an UG purification plant.
  - The purification technique relies on solubility of TeA in water based on pH

$$\underset{\text{in-soluble}}{Te(OH)_6} \leftrightarrows \underset{\text{soluble}}{Te(OH)_5O^-} + H^+$$

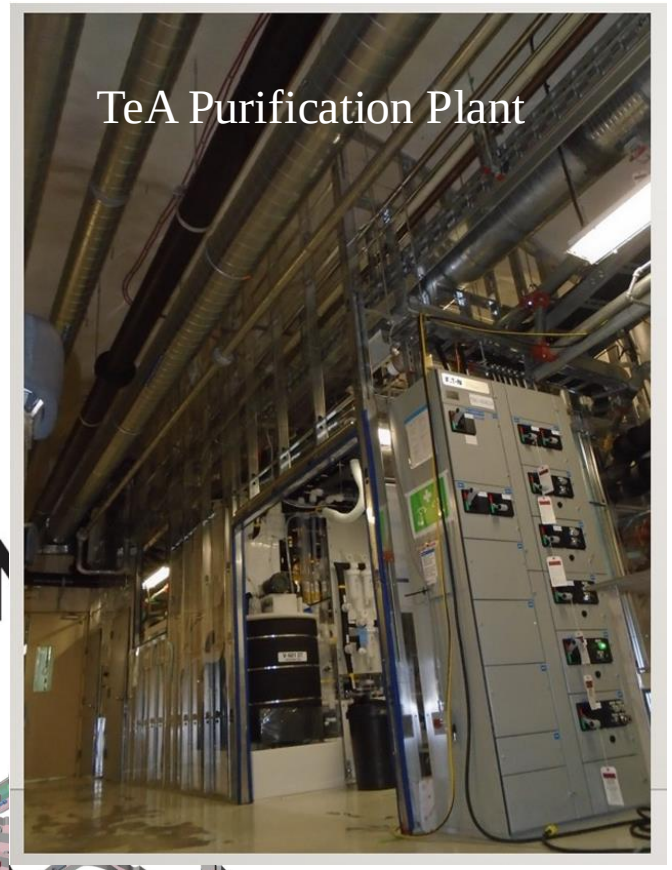
  - Insoluble contamination: Dissolve in water, and filter
  - Soluble contamination: Force TeA to recrystallize by adding Nitric Acid, let it precipitate out, and drain the "dirty" liquid
- A full scale 200 kg of Te test batch to verify yield purification factors is currently underway.
- Safe handling and logistics of the full process has been explicitly demonstrated UG.

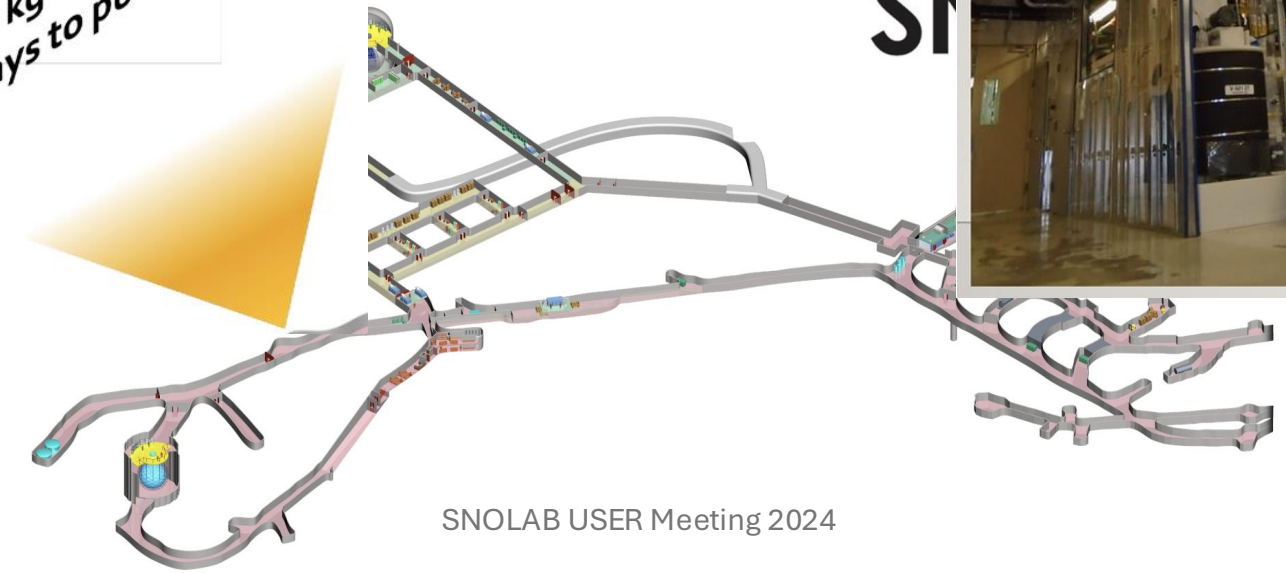


# Tellurium Deployment: TeA purification plant

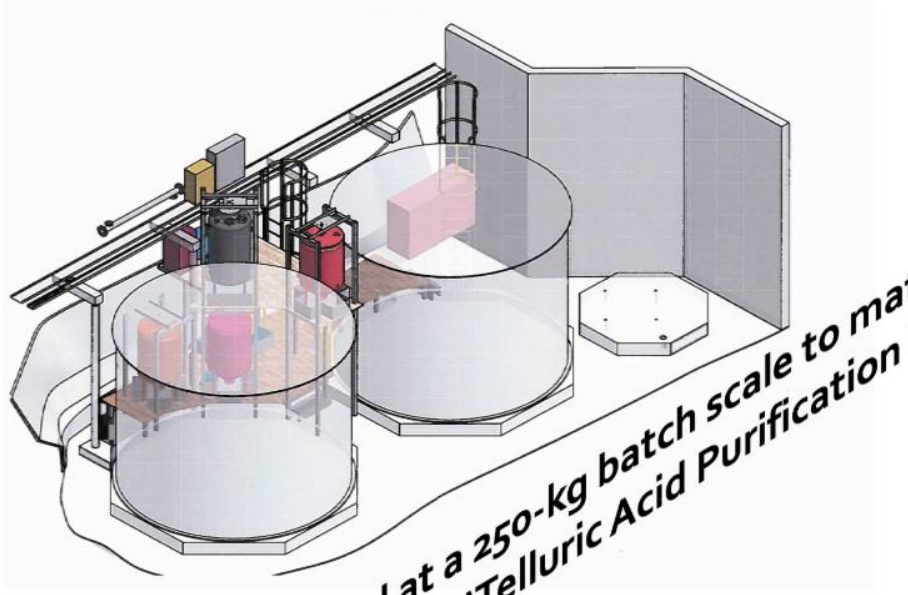


Target 200 kg TeA / batch
~50 "working" days to purify 8 tonnes

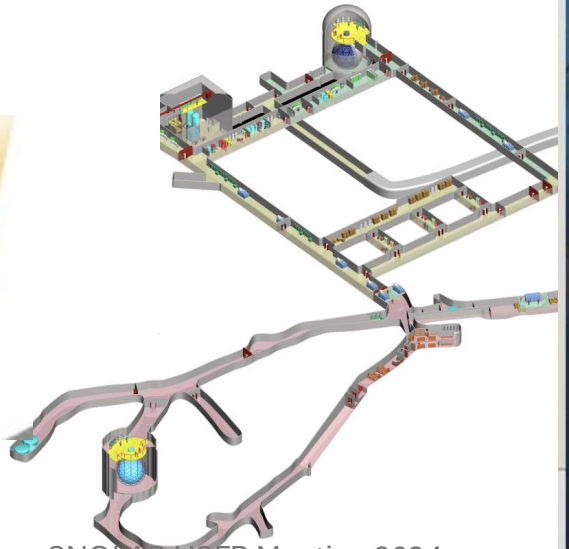


# Tellurium Deployment: TeDiol plant



Produce TeDiol at a 250-kg batch scale to match the throughput of the 'Telluric Acid Purification Plant'



Te-Diol Synthesis Plant

# Tellurium Deployment: TeBD synthesis at the TeDiol plant

A Method to Load Tellurium in Liquid Scintillator for the Study of Neutrinoless Double Beta Decay

*(NIM A, Volume 1051, 2023, 168204 )*

- 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 is performed using a mixture of heating and amine neutralization with DDA
- TeBD is diluted to desired concentration using the LAB deployment system
- LAB recirculation system helps for additional Te loading in future.

# Conclusions and prospects

- Novel Te loading methodology has been developed for the 1st time at a large scale, tested, and well-understood.
  - Post Testbatch plan:
    - improve some leaks
    - Test batch of TeDiol plant
    - Analyze QA samples through ICPMS
- Initial deployment of 1.3 tonnes of $^{130}$Te planned next year
  - Projected sensitivity for $0\nu\beta\beta$: $9.2 \times 10^{25}$ years after 1 year live time

# SNO+ Liquid Scintillator: future - LS+TeBD+DDA

## Optical Characteristics

- Excellent transparency is 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.