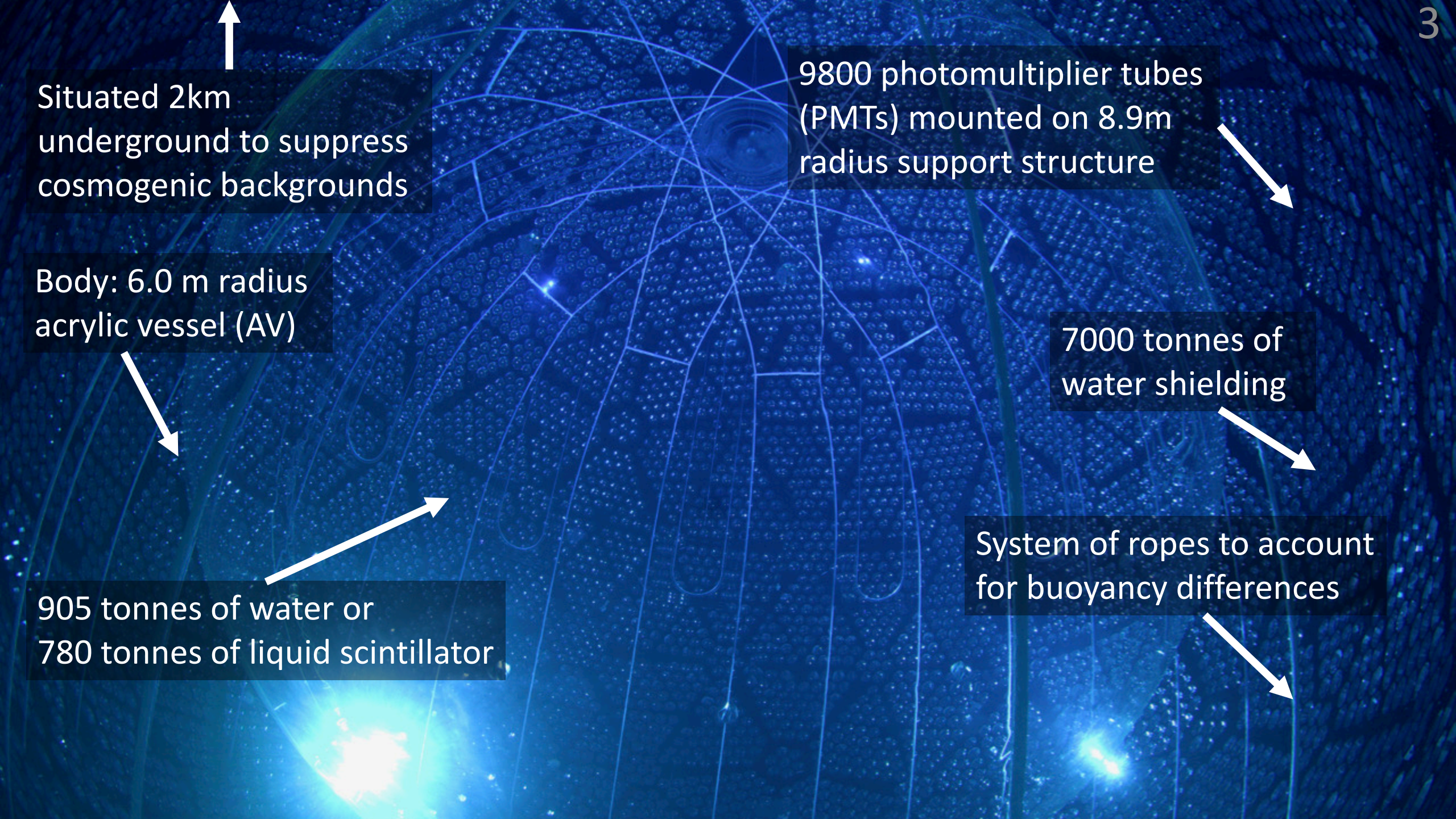
The SNO+ Scintillator Fill

Benjamin Tam (for the SNO+ Collaboration)
2022 CAP Congress
June 8, 2022


Situated 2km underground to suppress cosmogenic backgrounds
9800 photomultiplier tubes (PMTs) mounted on 8.9m radius support structure
Body: 6.0 m radius acrylic vessel (AV)
7000 tonnes of water shielding
905 tonnes of water or 780 tonnes of liquid scintillator
System of ropes to account for buoyancy differences

Three Operational Phases based on AV medium:

Phase	Medium	Physics Goals	Dates
1	Ultrapure Water	• Invisible Nucleon Decay search • Solar Neutrino Measurements • Supernova neutrinos • Axion-like particle search	Operated May 2017 – July 2019
Scintillator Fill: Replace ultrapure water with liquid scintillator			
2	Liquid Scintillator	• Solar neutrino measurements • Reactor anti-neutrino measurements • Geo-neutrino measurements • Supernova neutrinos	Operation started April 2022
Tellurium Loading: Dope liquid scintillator with tellurium isotope			
3	Tellurium-loaded Liquid Scintillator	• Neutrinoless double beta decay search in ^{130}Te* *Primary Physics Goal	Planned initial deployment 2024

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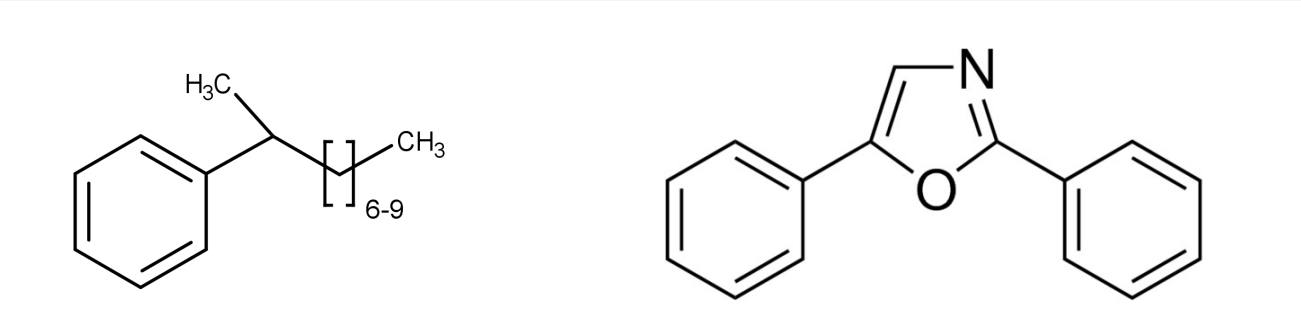
Liquid Scintillator

- Linear Alkylbenzene (LAB) + Diphenyloxazole (PPO)



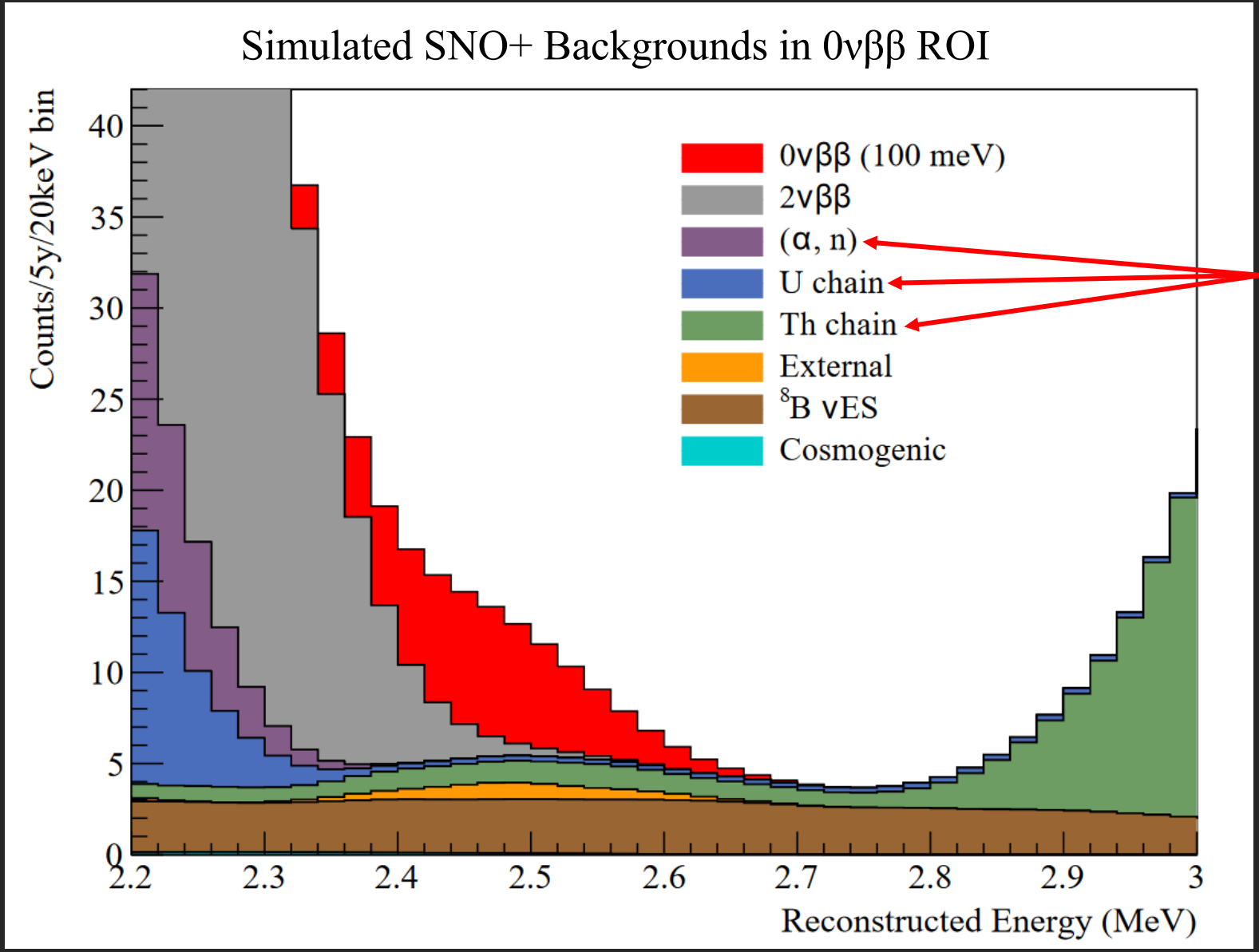
- Developed by SNO+, successfully used in Daya Bay and RENO
- LAB more compatible with acrylic and safer than other widespread liquid scintillators

Pseudocumene (PC) (Borexino, KamLAND)

Phenyl-o-xylylethane (PXE) (Double CHOOZ)

- PPO acts as a fluor emitting in the ~420nm range
- >50x higher light yield than water

Scintillator Purity



Chief experimental challenge for all physics goals

Controlled by ensuring extreme scintillator purity during the scintillator fill

Purpose-built scintillator purification plant build underground

Purification Strategy

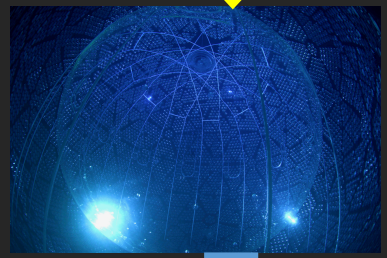
Stage 1: Bulk Fill of the AV

A. High quality LAB shipments arrive in 20T tanker trucks

B. Shipped underground in passivated 2T steel railcars while under N_2 cover gas

C. Purified in scintillator purification plant primary processes

D. Purified LAB sent to the top of the detector



Water removed from the bottom of the detector

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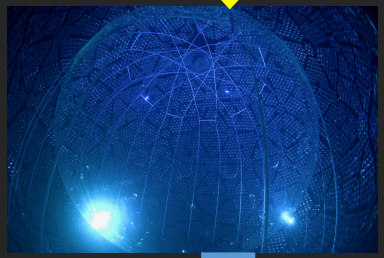
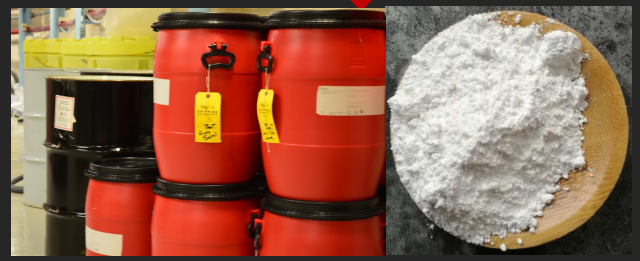
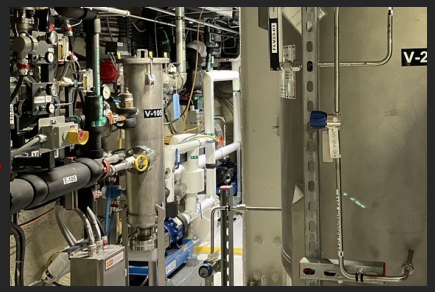


Water removed from the bottom of the detector

E. Purified LAB diverted



F. “Neutrino-grade” high quality PPO added to LAB



G. Purified in scintillator purification plant secondary processes

H. Purified PPO added

Purification Strategy

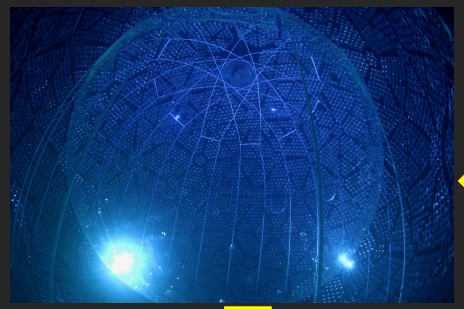
Stage 2: Recirculation

A. Continuously recirculated in scintillator plant to remove water

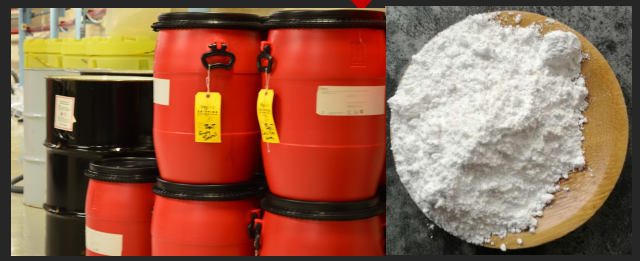
Purification Strategy

Stage 2: Recirculation

A. Continuously recirculated to remove water in scintillator plant



B. Scintillator diverted



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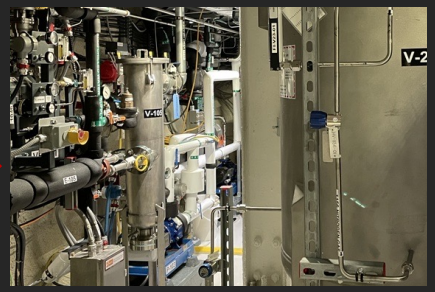


D. Purified in scintillator purification plant secondary processes

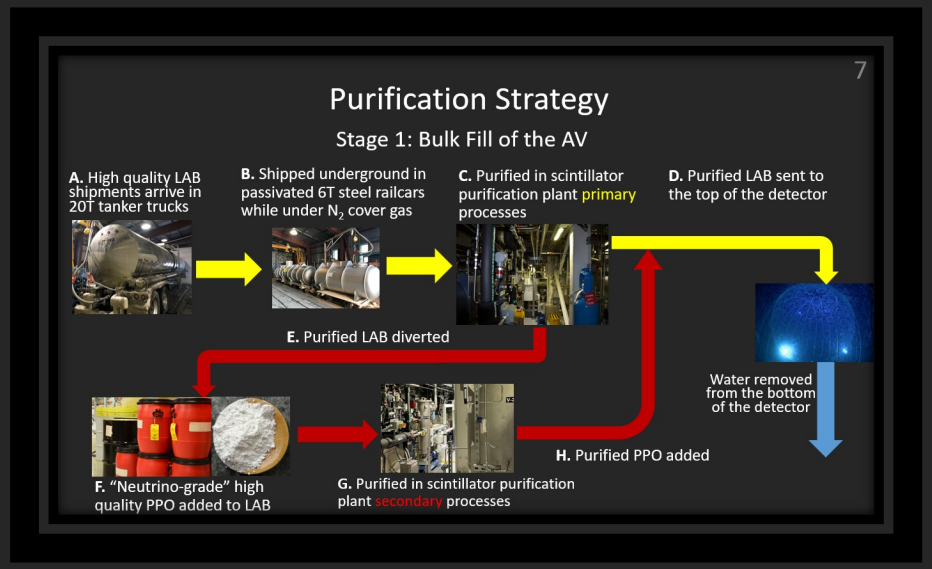
Scintillator Purification Plant

Primary Processes (For LAB)

- Multistage distillation
  Removes lower volatility impurities including heavy metals and oxidized organics
- N_2 and steam stripping
  Removes dissolved gases and volatile liquids including water
  Used during recirculation to remove residual water

Secondary Processes (For PPO)

- N_2 stripping
  Removes dissolved gases and volatile liquids
- Water extractions
  Removes ionic impurities
- High temperature “flash” distillation
  Removes heavy metals and oxidized organics



Scintillator Quality Assurance

Scintillator tested and assessed for quality hourly during all purification plant operation and detector filling

- **Nephelometry**: Assesses solid particulate contamination
- **Densiometry**: Assesses liquid and dissolved contaminants
- **UV-Vis Spectroscopy:** Assesses optical clarity (proxy for radiopurity), verified PPO concentration

Further tests also regularly performed

- **Infrared Spectroscopy:** Accesses absorption for contaminants at wavelengths beyond UV-Vis
- **Neutron Activation:** Additional elemental concentration analysis
- **Light yield:** Verified through a 6L 4-PMT detector
- **Karl-Fischer Titration**: Measures water concentration

Quality assurance team underground 24 hours/day…

Scintillator Fill Complete!

Completed April 29, 2022

- 792.4 tonnes LAB purified and added
- 2.01 tonnes PPO purified and added
- 4376.9 tonnes recirculated
- 4925 scintillator samples tested through the quality campaign

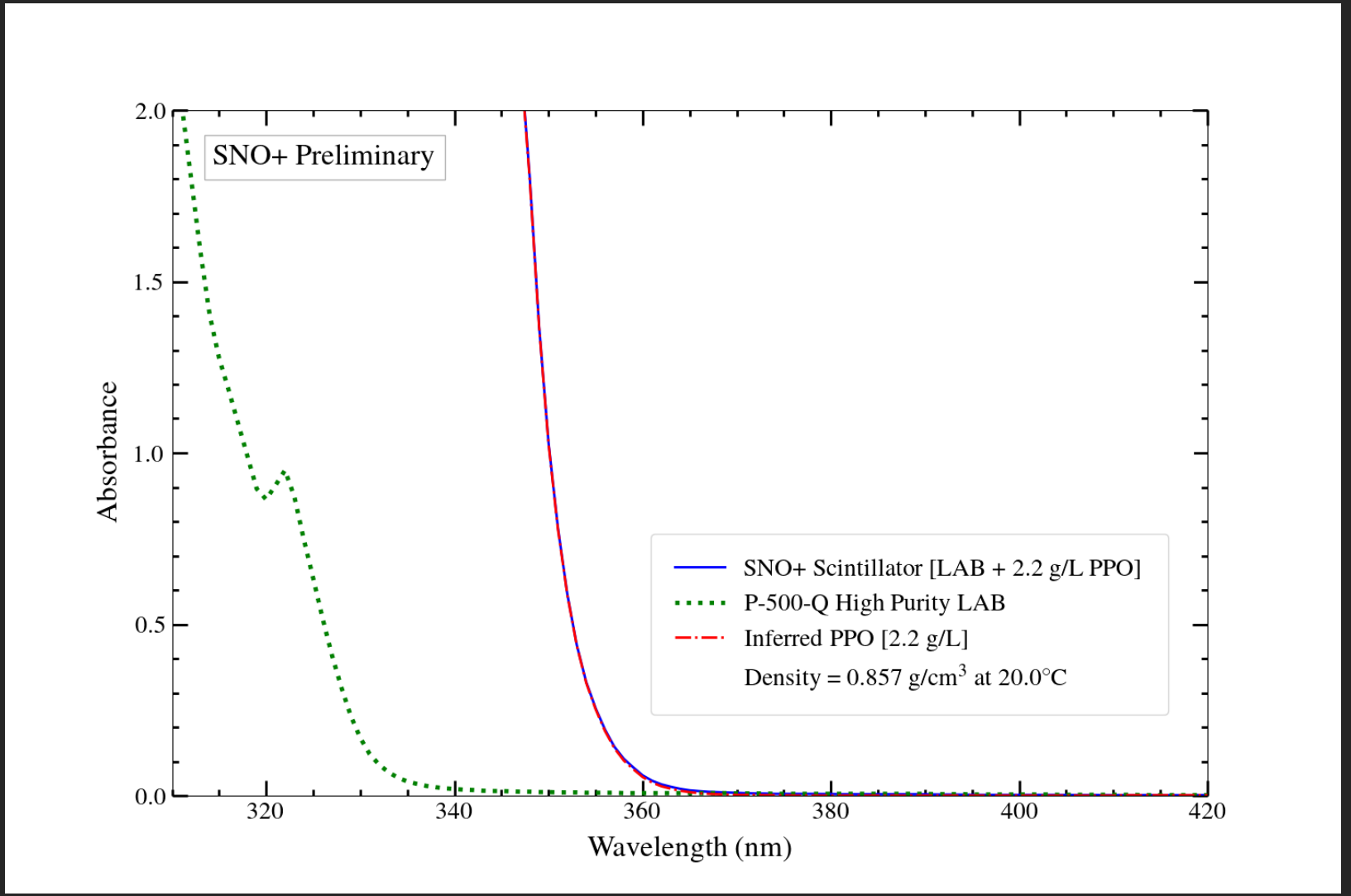
Final SNO+ Scintillator

LAB + 2.2 g/L PPO

“The Last Sample”

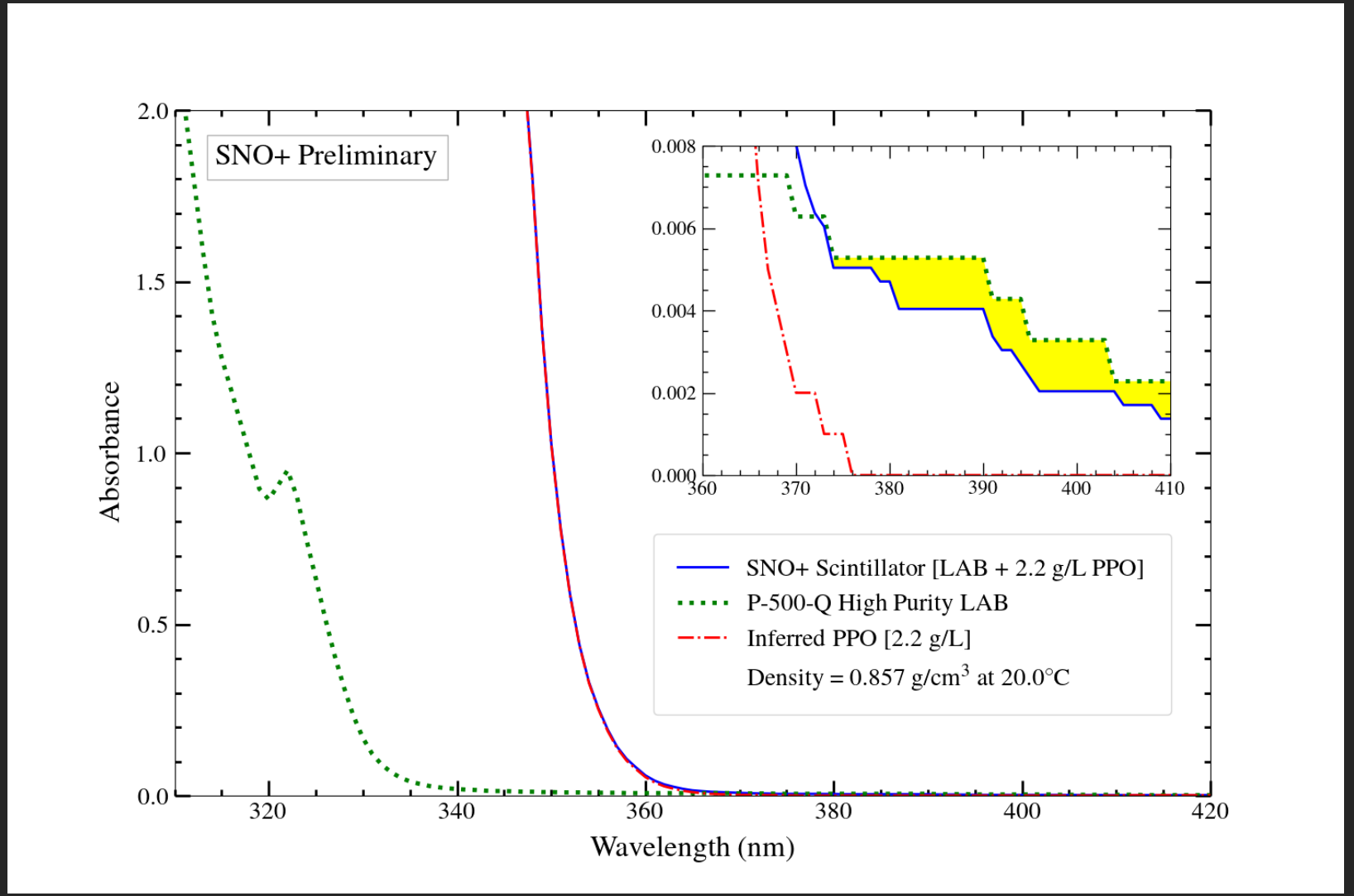
How did we do?

UV-Vis Absorption Spectrum



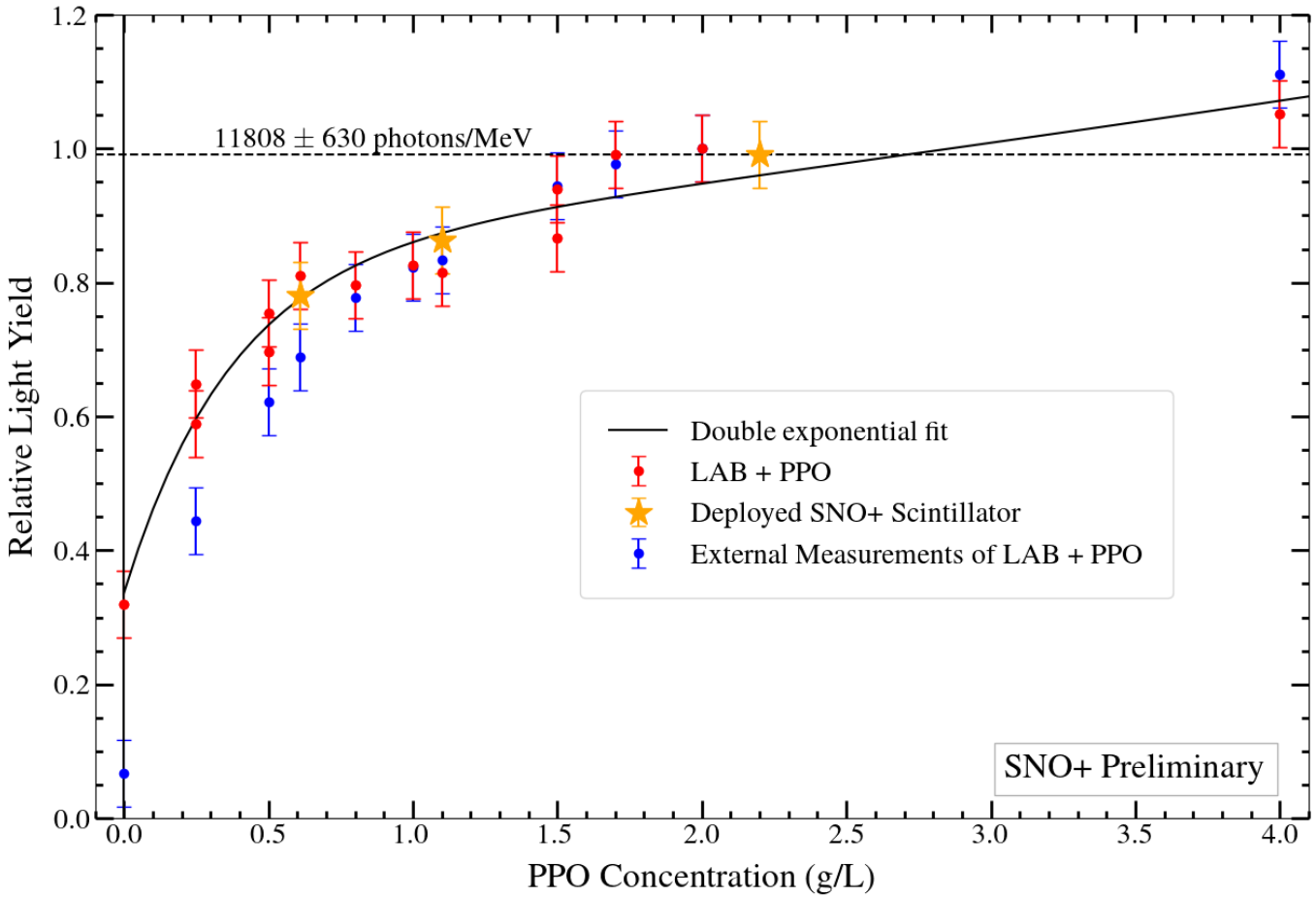
UV-Vis Absorption Spectrum

Optical clarity is superior to the best possible manufacturer standard at all wavelengths above PPO absorption!



Light Yield

Measured Light yield aligned with existing measurements and models!

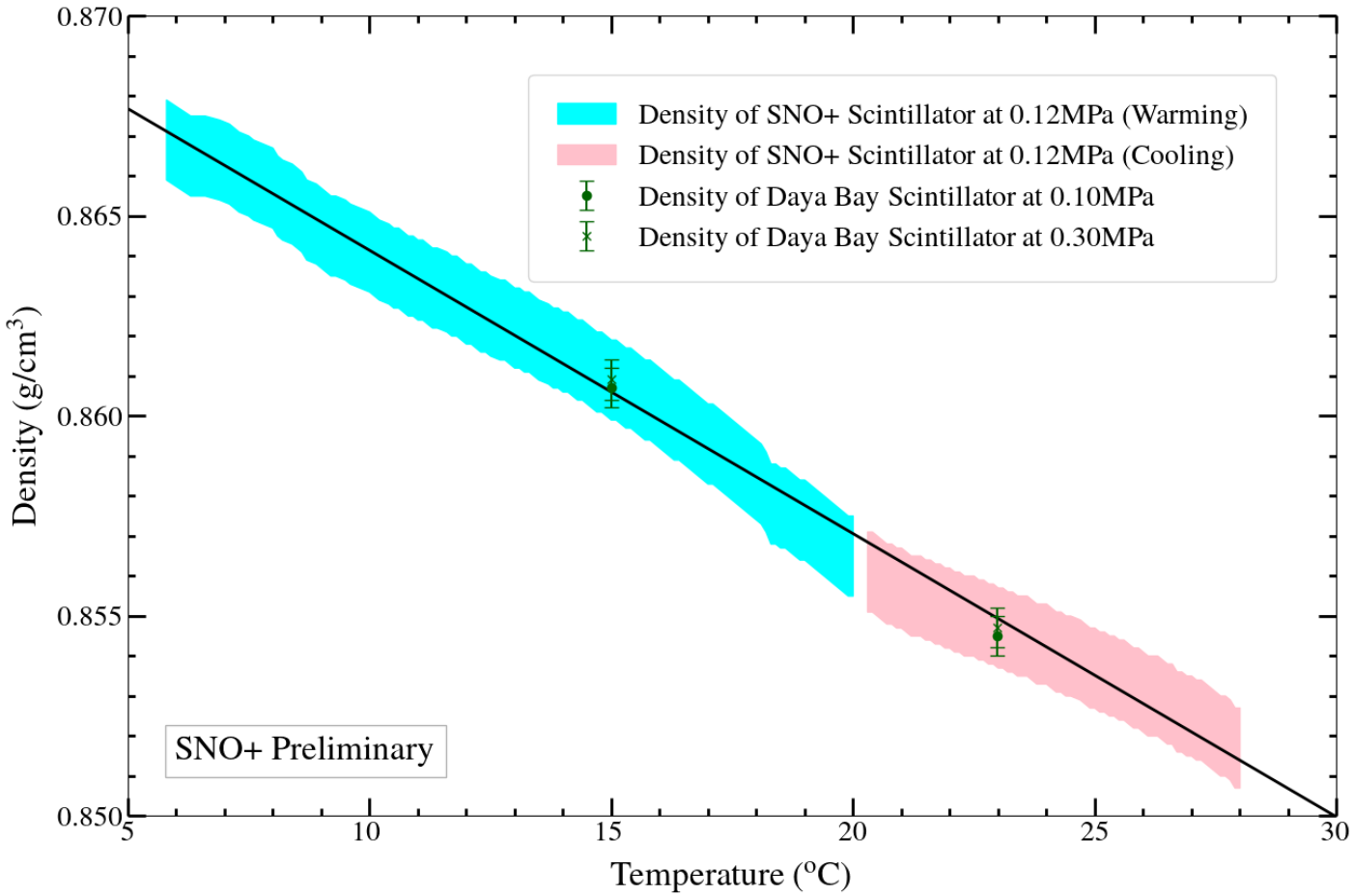


Other Measurements

Density
0.857 ± 0.001 @ 20°C
Follows expected linear relationship at all near-operational temperatures!

Index of refraction
1.483 ± 0.001 @ 20°C

Water Content
< 5ppm
(method detection limit of Karl Fischer titration)



SNO+ Scintillator Phase officially underway!

New physics results coming soon…

University of Alberta
U.C. Berkeley
LBNL
Boston University
Brookhaven
University of Chicago
U.C. Davis
T.U. Dresden
Lancaster University
Laurentian University
LIP Lisbon






LIP Coimbra
Kings College London
University of Liverpool
UNAM
University of Oxford
University of Pennsylvania
Queen's University
Queen Mary University
SNOLAB
University of Sussex
TRIUMF

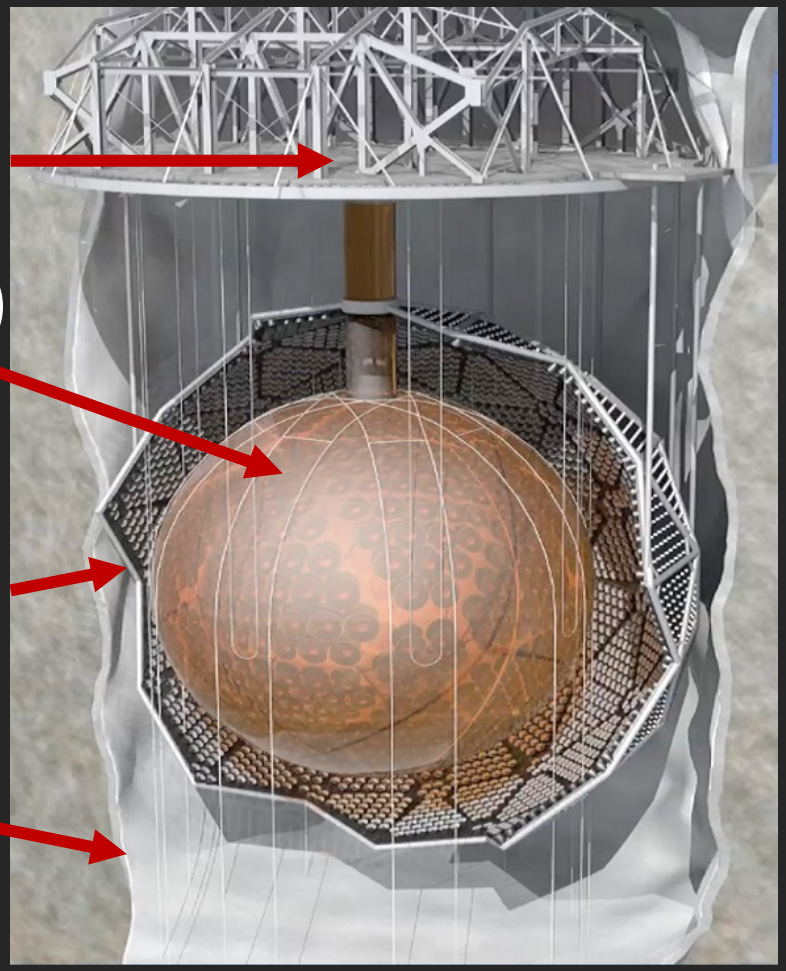
Backup Slides

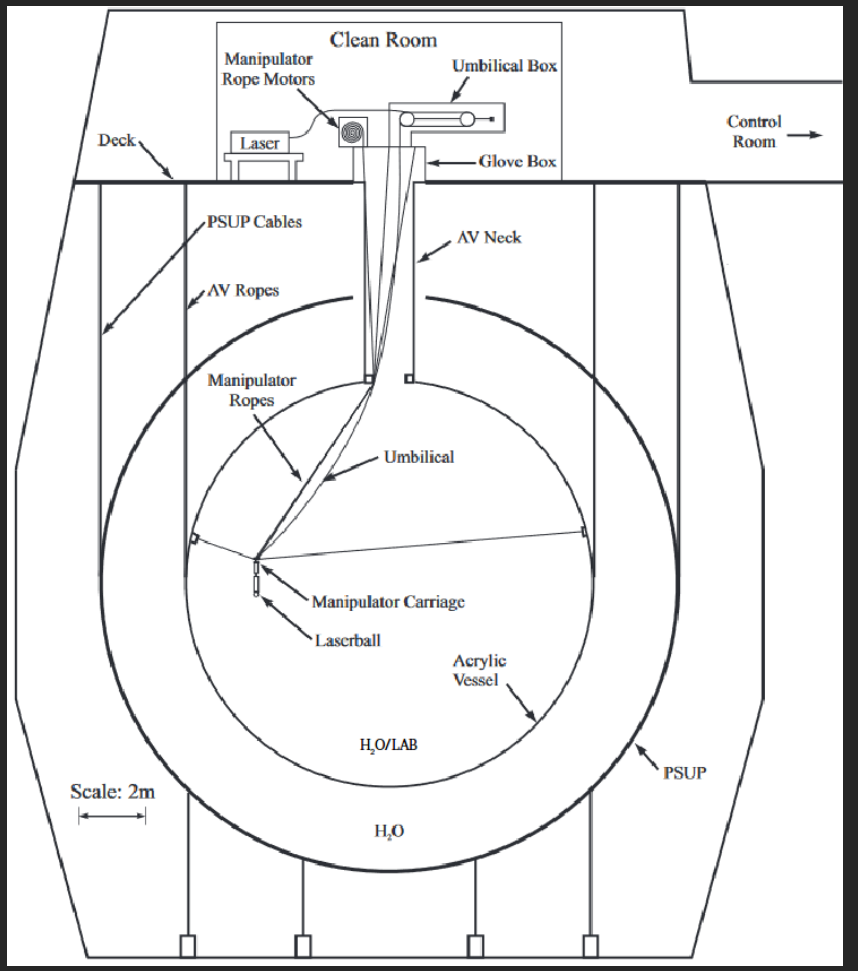
Deck Clean Room

Acrylic Vessel (AV)

PMT Support Structure (PSUP)

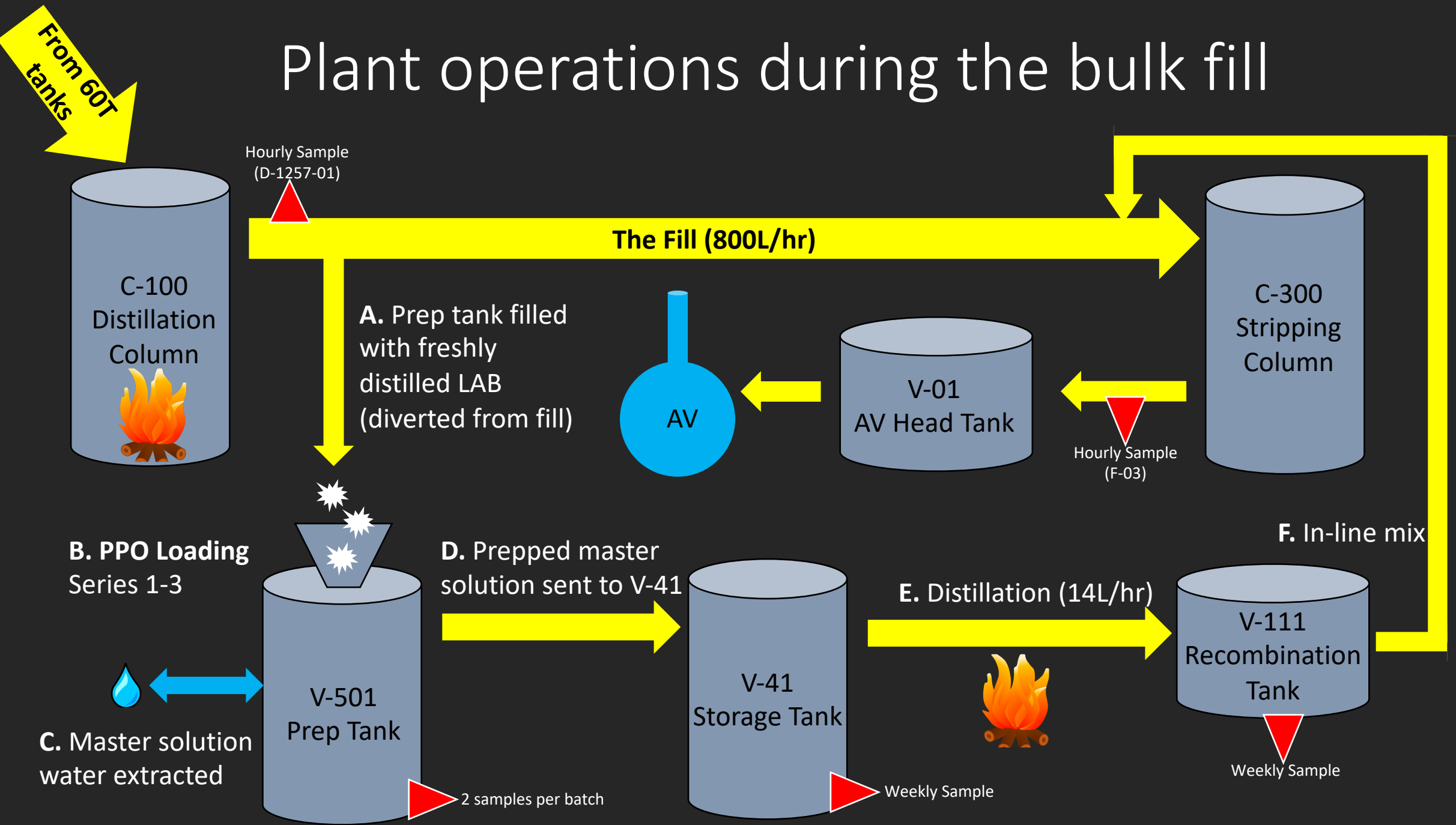
Cavity





Contaminant Type	Distillation 220°C @40 Torr	N2/Steam Stripping 100°C	Water Extraction
Heavy Metals (radioactive)	Bi, K, Pb, Po, Ra, Th		U, Th, Ra, K, Pb
Dissolved Gases (radioactive)		Ar, Kr, O_2, Rn	
Oxidised Organics (Optical clarity)	Carboxyl groups, 1,4-benzoquinone		
Volatile Liquids (Optical clarity)		Residual water	

Plant operations during the bulk fill



Plant Operations during recirculation