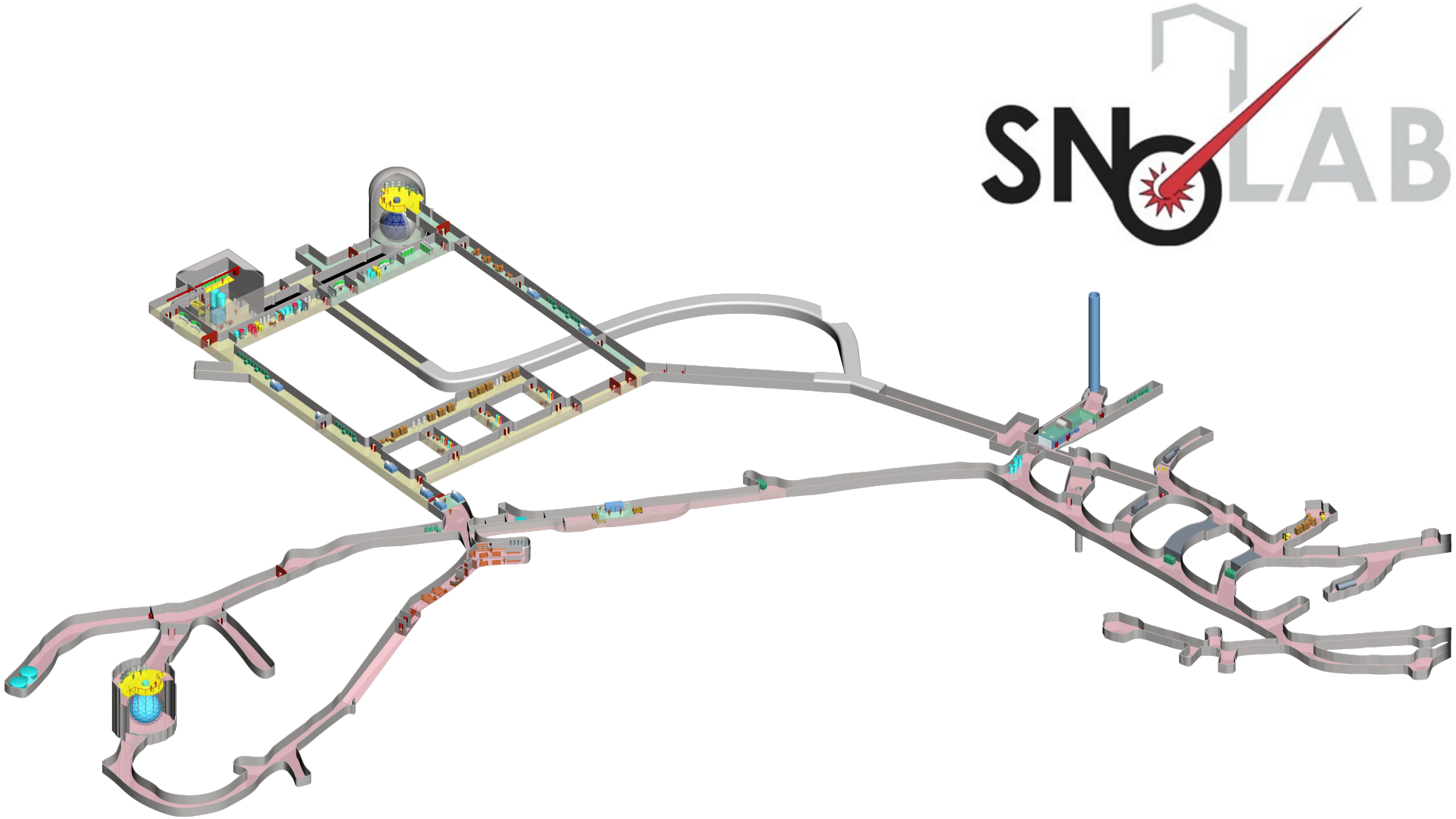
Tellurium Purification and Deployment in SNO+

Szymon Manecki, SNOLAB Research Scientist,
LRT, May 20th, 2019

Introduction



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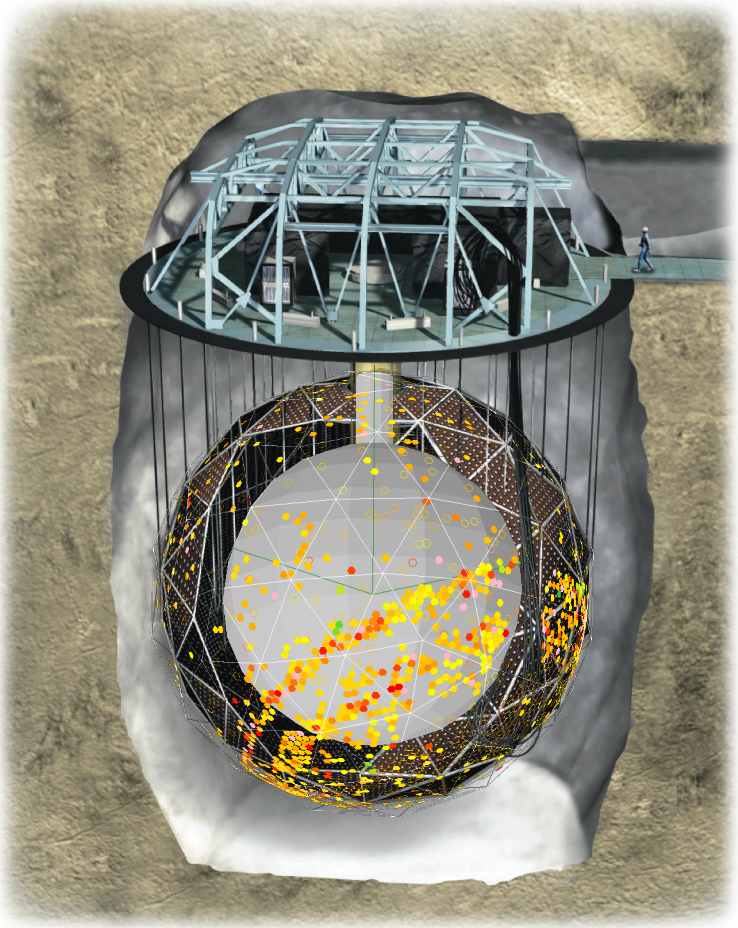
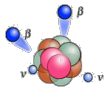
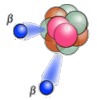


SNO+
Physics Goals

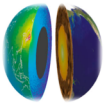
- Neutrinoless Double Beta Decay

- Low Energy Solar Neutrinos

- Reactor Antineutrinos

- Geo-Neutrinos



- Supernova-ν

SNO+ Collaboration, Phys. Rev. D 99, 012012 (2019)
SNO+ Collaboration, Phys. Rev. D 99, 032008 (2019)

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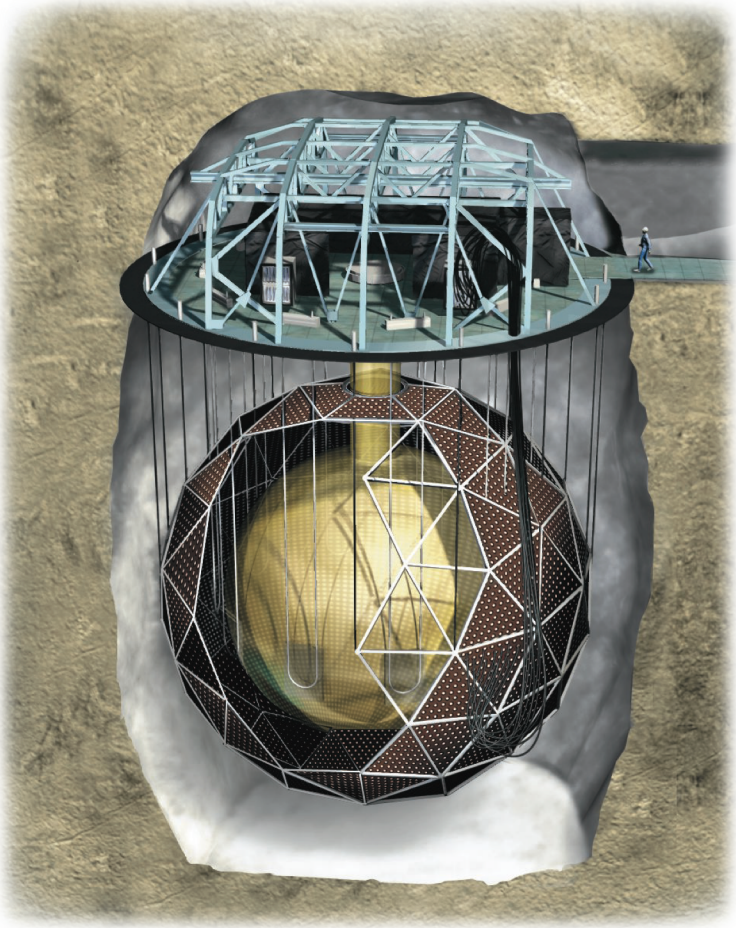
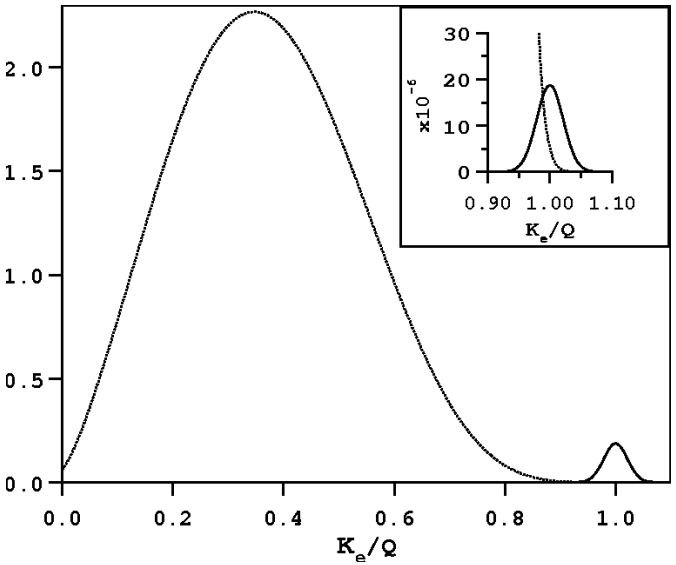


ovββ Search Requirements

- Low backgrounds
- Good energy resolution
- Large amounts of isotope



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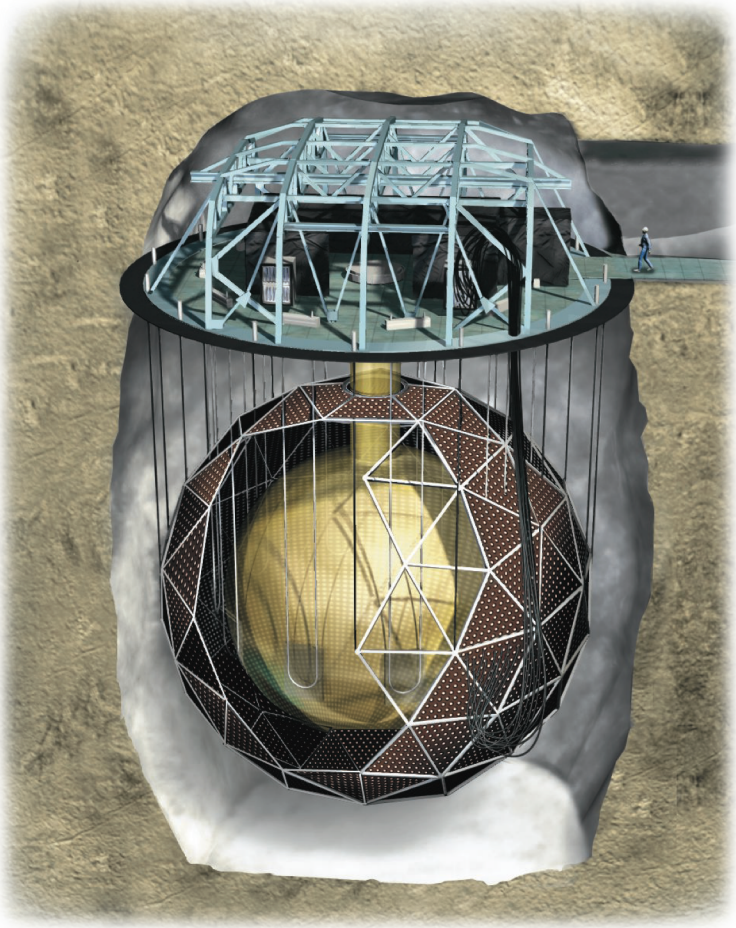

0νββ Search Requirements

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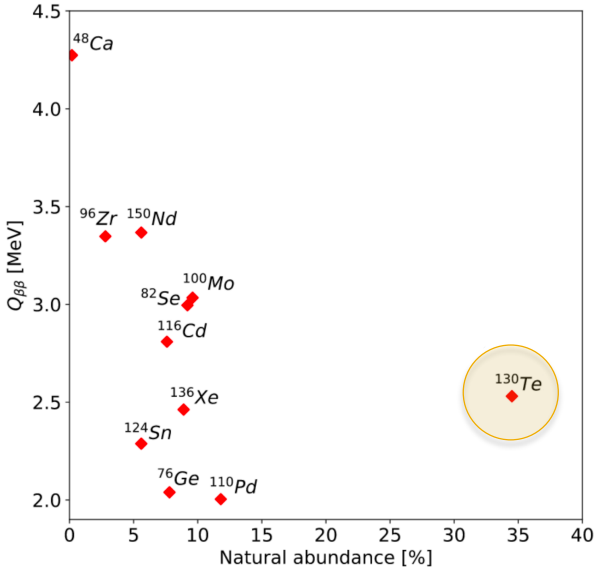
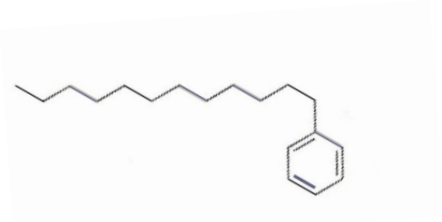
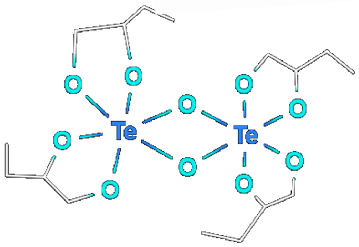
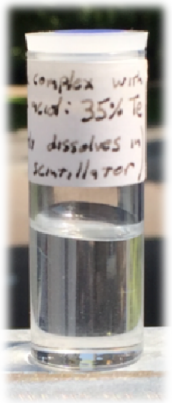


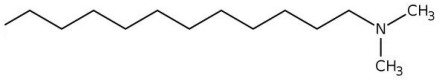
Te Scintillator

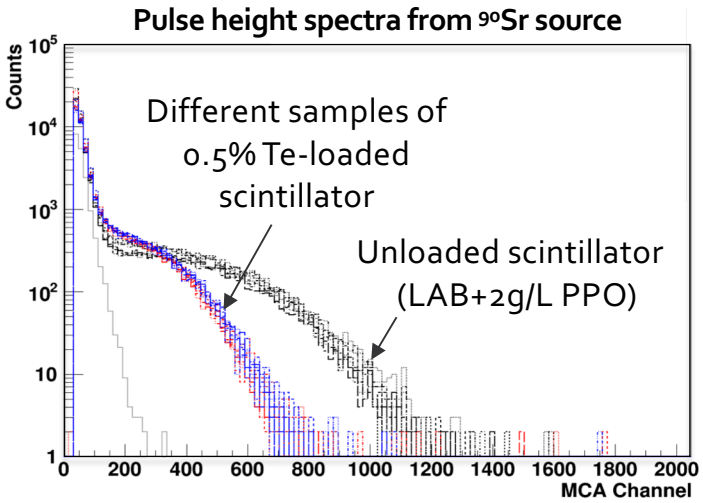
- 780 T Linear Alkylbenzene (LAB)
  + 2 g/L PPO (Primary Fluor)
  + 15 mg/L bisMSB (WS)
- Tellurium Butanediol (TeDiol)
  0.5% Te in LAB
- DDA (stabilizing amine)
  0.4% in LAB

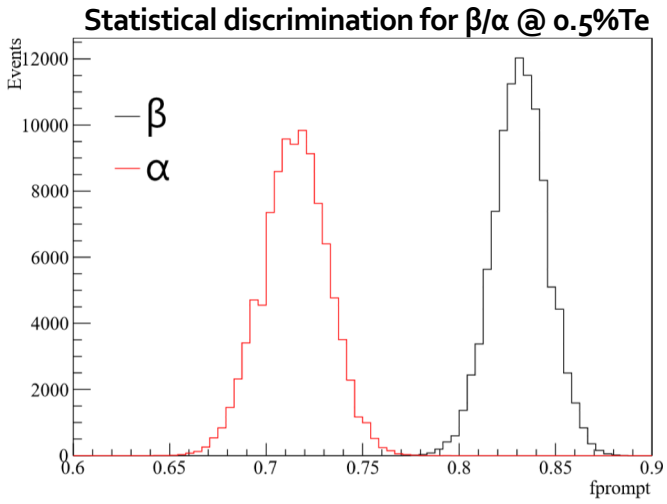






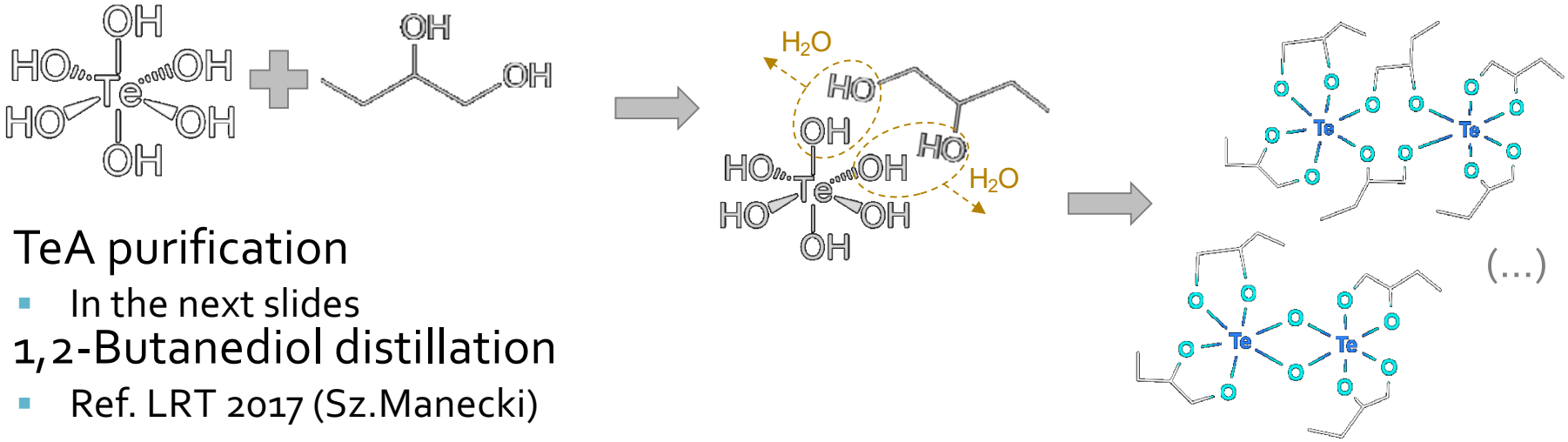






Te Scintillator

- LAB-soluble TeDiol complexes are formed in condensation and further oligomerization reactions of Telluric Acid with 1,2-Butanediol



- TeA purification
  - In the next slides
- 1,2-Butanediol distillation
  - Ref. LRT 2017 (Sz.Manecki)

- DDA purification
  - U/Th target at ~10^{-15}g/g (expected reduction factor of 1000 from the assayed level has been easily reached with spiked distillation)
  - Expected reduction factors for Co/Na have been achieved, but clean handling post-distillation is going to be important

Te Scintillator

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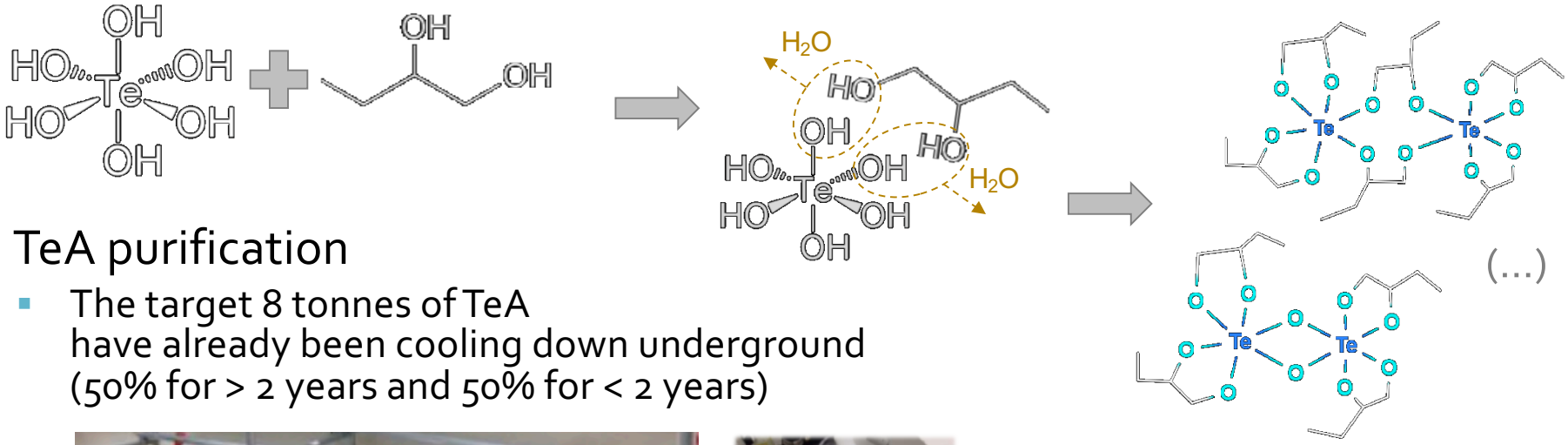


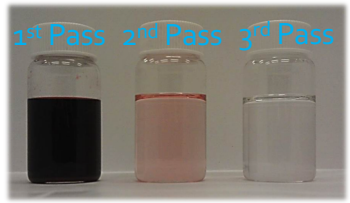
- TeA purification
  - The target 8 tonnes of TeA have already been cooling down underground (50% for > 2 years and 50% for < 2 years)

TeA Purification

- The purification technique relies on solubility of TeA in water based on pH
  - $Te(OH)_6 \leftrightarrow Te(OH)_5O^- + H^+$
    in-soluble soluble
- 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

Isotope	t_{exp}=1 yr
^{22}Na	15309
^{26}Al	0.048
^{42}K	565
^{44}Sc	102
^{46}Sc	43568
^{56}Co	2629
^{58}Co	25194
^{60}Co	6906
^{68}Ga	37343
^{82}Rb	18047
^{84}Rb	11850
^{88}Y	390620
^{90}Y	823
^{102}Rh	276189
^{102m}Rh	133848
^{106}Rh	1534
^{110m}Ag	69643
^{110}Ag	939
^{124}Sb	3101138
^{126m}Sb	240
^{126}Sb	358996

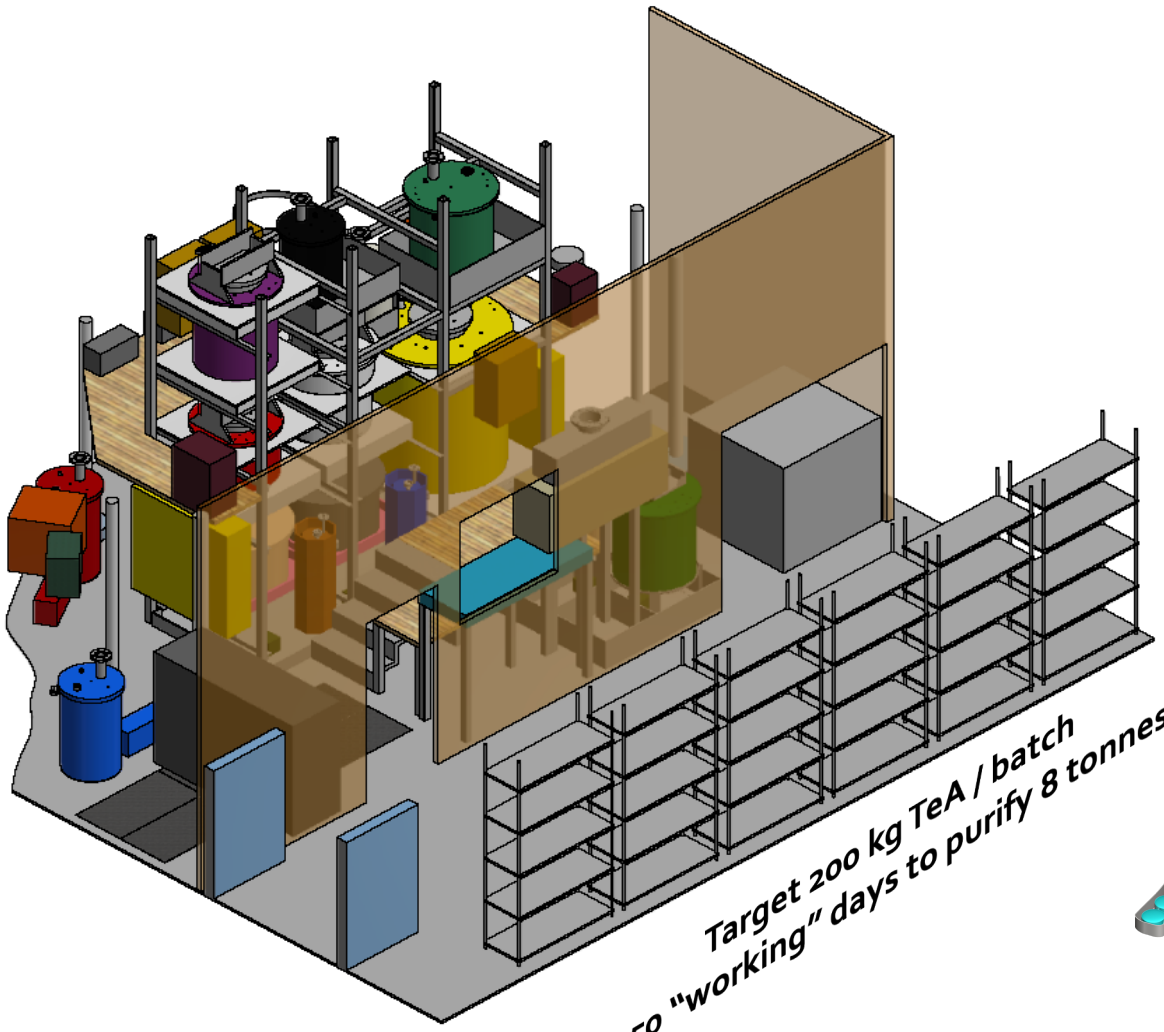
10kg pilot-scale



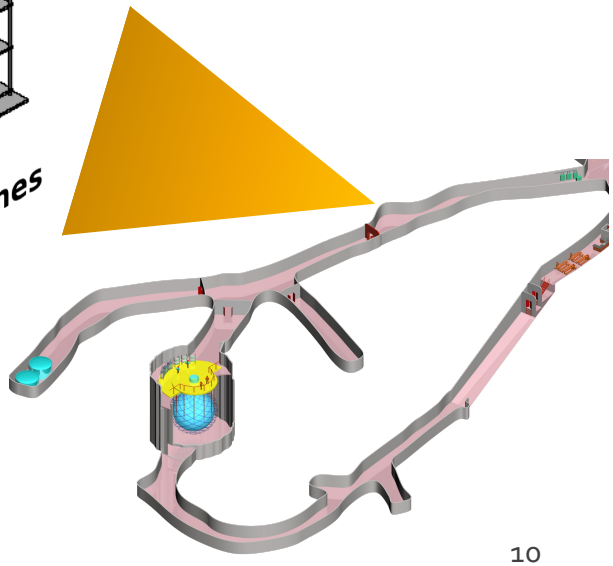
Target (r.f. 10^3):
^{238}U: 1.3×10^{-15} g/g
^{232}Th: 5×10^{-16} g/g

Needed reduction for cosmogenics by: 10^5-10^6

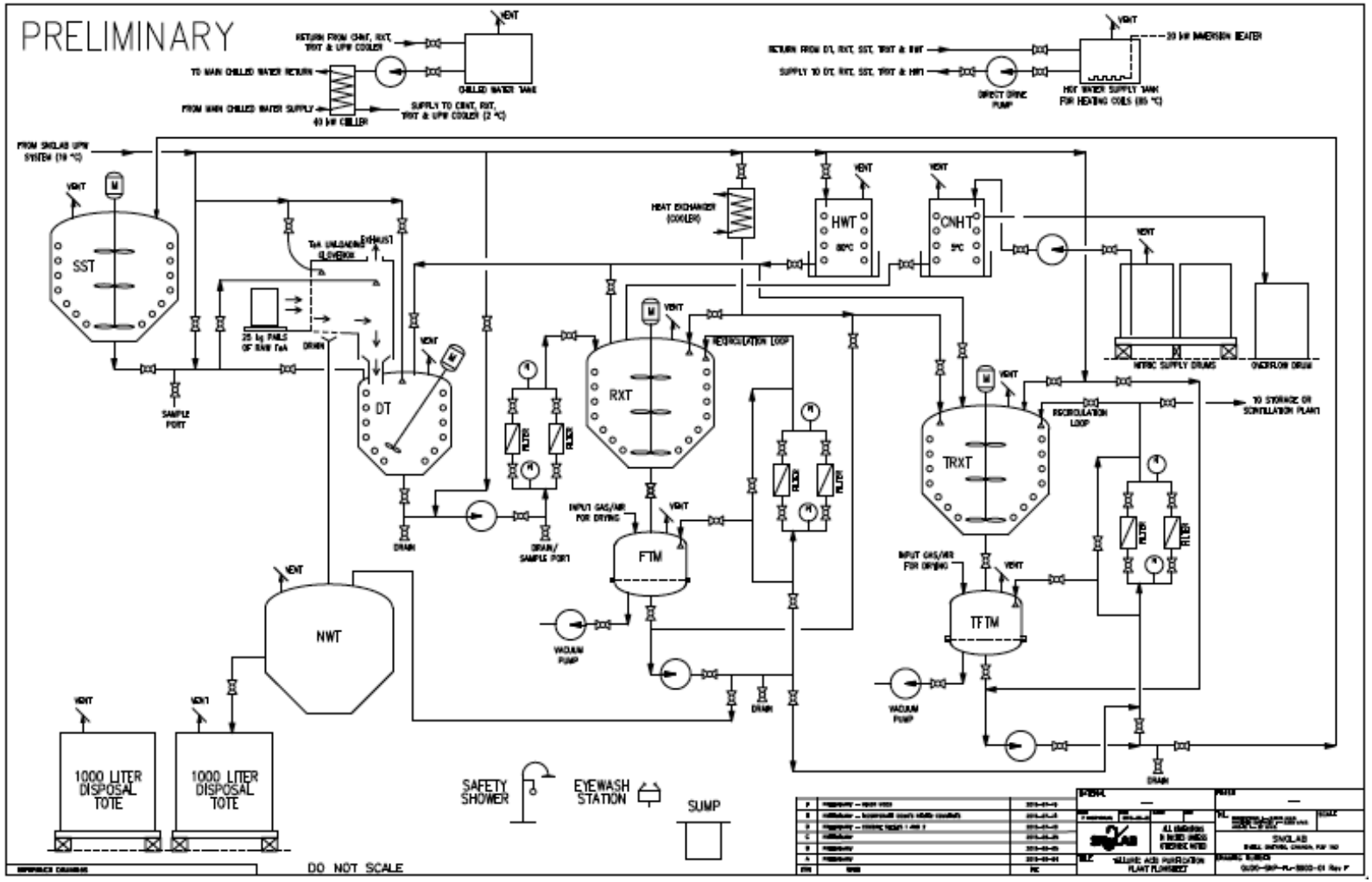
TeA Plant Isometric Layout



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

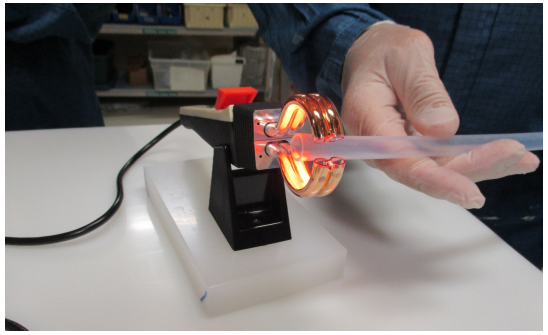


TeA Plant Flow Diagram



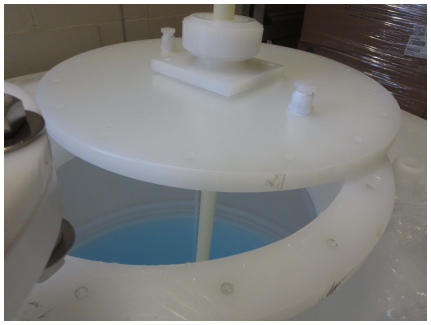
TeA Fabrication & Cleaning

- All wet process lines and vessels constructed with plastic to suppress metals leaching
  - Polypropylene vessels designed and delivered by SeaStar
  - On-site contractors trained in clean PFA piping installation



TeA Fabrication & Cleaning

- SeaStar process vessel leaching (with warm acid solution)



Results from ICP-MS assay of leachate (ppt)

	Soak 1 (2 days)		Soak 2 (4 days)		Soak 3 (4 days)	
	RXT	TRXT	RXT	TRXT	RXT	TRXT
U	1	0.2	<0.05	<0.05	<0.05	<0.05
Th	5	1	1.1	<0.1	<0.1	<0.1
Ca	2700	2000	380	180	<20	<20
Fe	5600	5000	220	170	17	37

Compare: goal of 0.1 ppt U and <0.05ppt Th in purified TeA.
Other measured metals (relevant for cosmogenics) lower than Ca and Fe, <0.1 ppb goal.

Vessels meet our purity requirements!

Further cleaning/leaching with nitric acid after installation will provide additional safety factor.

TeA Plant Construction

Dec-2016

2017

2018

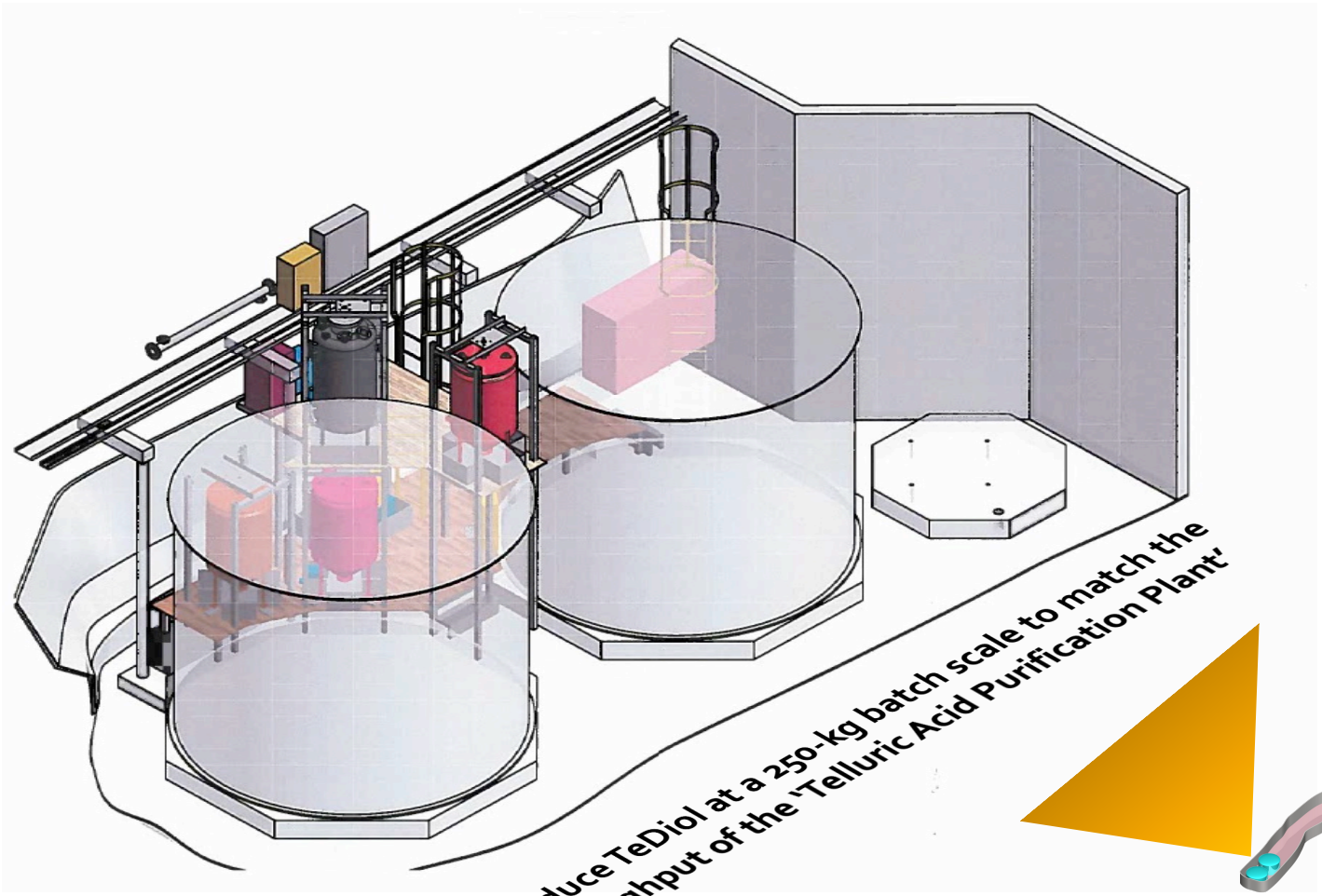
Jan-2019

COMPLETED

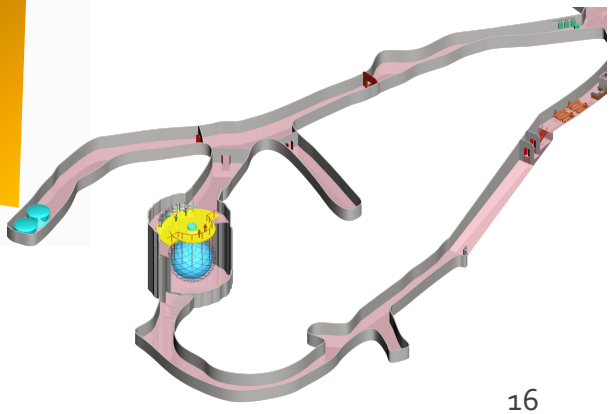
TeA Plant Outlook & Schedule

- The most critical components of the plant have been commissioned
  - Vacuum and process pumps, blowers, fans agitators and instrumentation
  - Process controls and operations programming is in an advanced stage
- Commissioning/cleaning with Nitric Acid
  - Summer, 2019
- Plant ready for Operation
  - Fall, 2019

TeDiol Plant Isometric Layout



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



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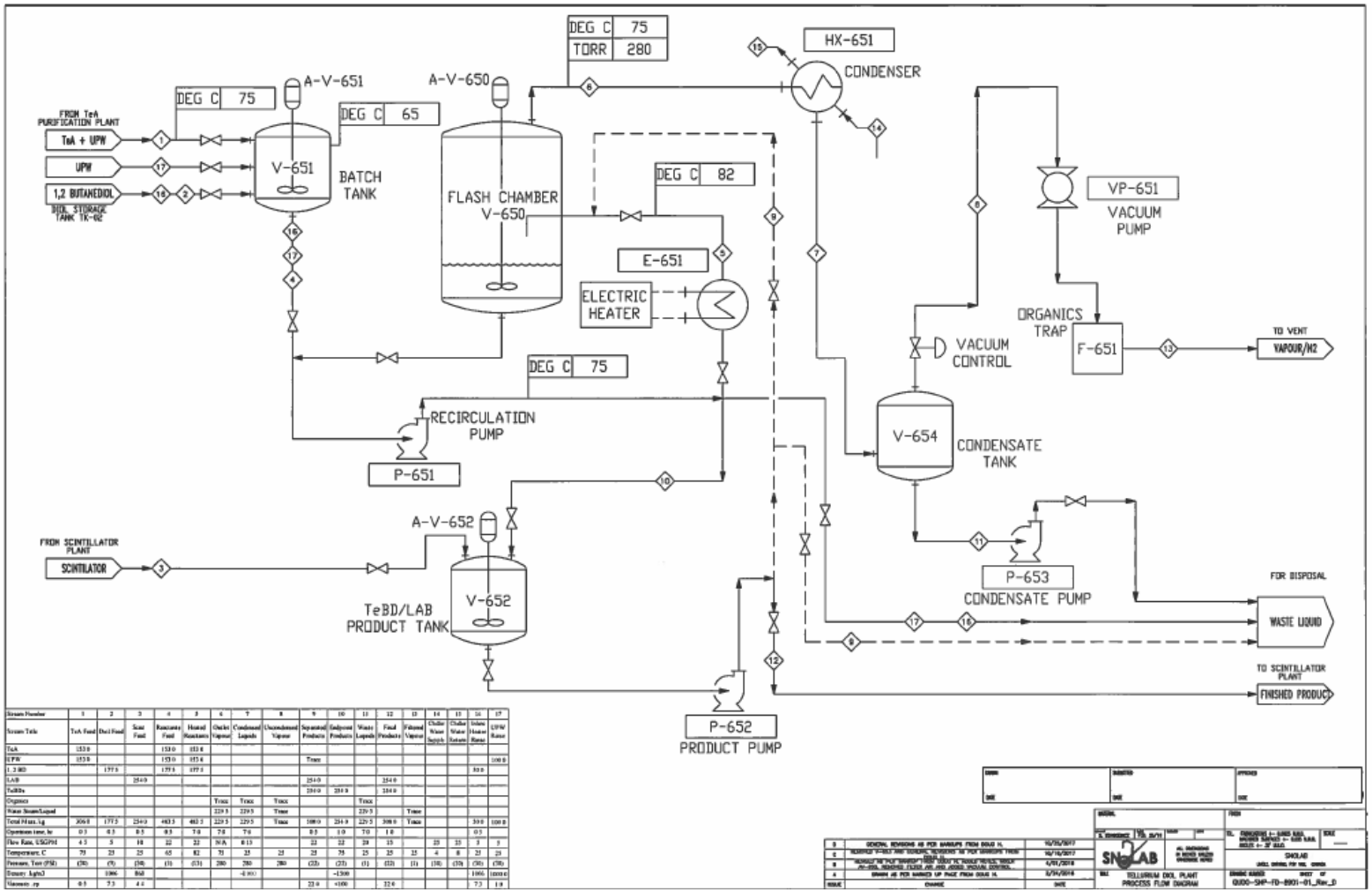
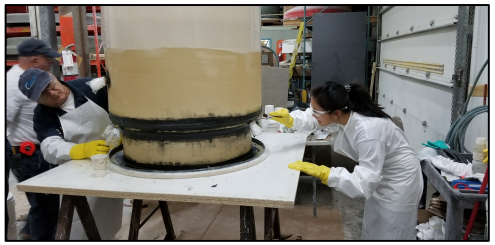
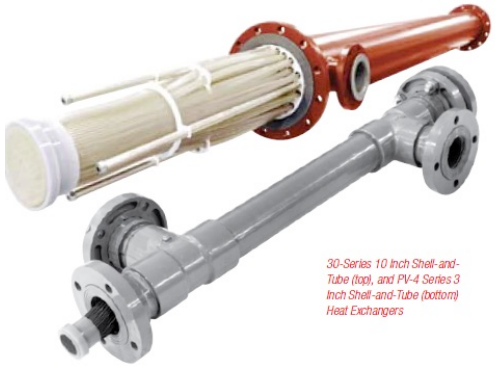


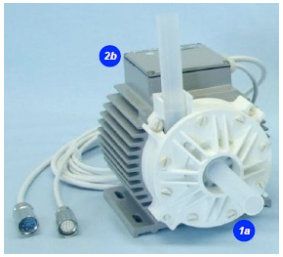
TeDiol Fabrication & Cleaning

- PFA (PerFluoroAlkoxy) lined FRP (fiberglass-reinforced polymer) tanks for main process vessels
  - Flash chamber, batch tank & product tank
- PFA in-line heater
- PFA condenser
- PFA Centrifugal Pumps
- Nitrogen sparging system
- Stainless steel condensate tank





30-Series 10 Inch Shell-and-Tube (top), and PV-4 Series 3 Inch Shell-and-Tube (bottom) Heat Exchangers



TeDiol Plant Construction

Feb-2018

May-2019

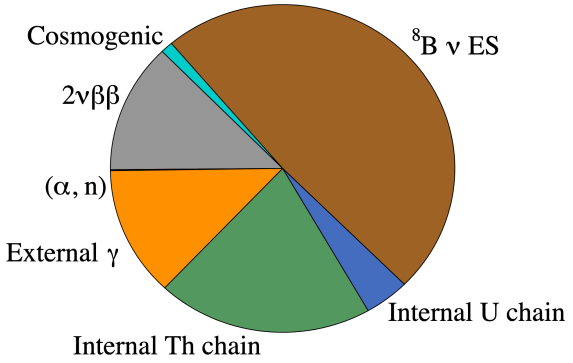
COMPLETED

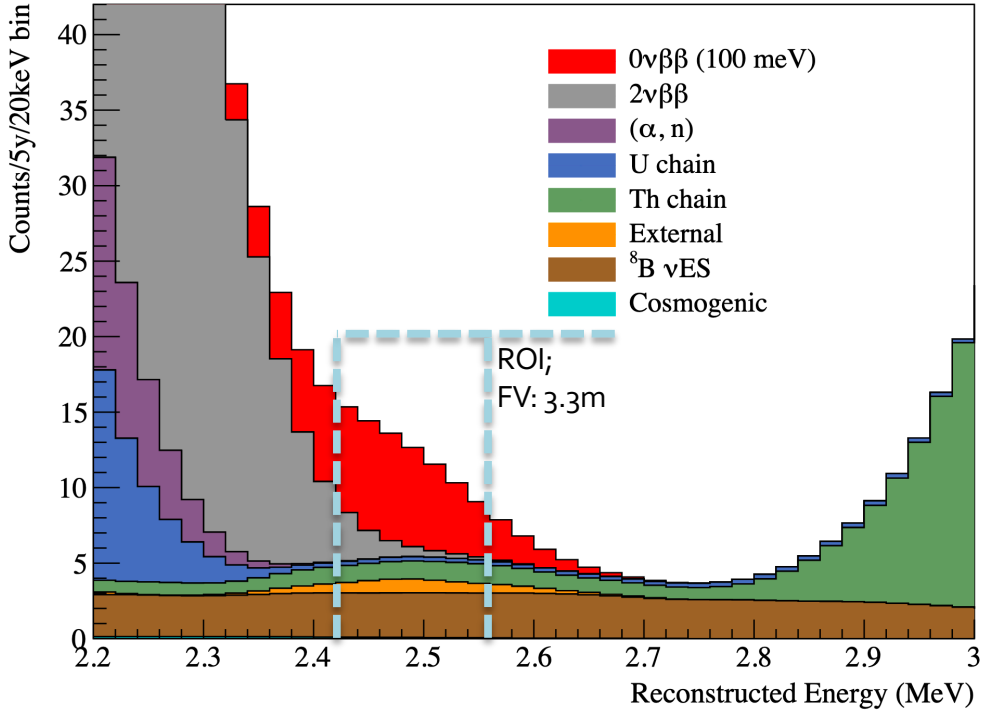
TeDiol Outlook & Schedule

- The construction of the plant has been completed
  - Only minor tasks remain (heat insulation, labeling, filters etc)
  - Commissioning of the equipment has been initiated
- Acid cleaning & commissioning
  - Summer, 2019
- Plant ready for Operation
  - Fall, 2019

SNO+ Te Phase

- With 0.5% Te loading
  - $T^{0\nu}_{1/2} > 2.1 \times 10^{26}$ yrs
  - $m_{\beta\beta} > 45$ meV$_{(IBM\text{-}2)}$





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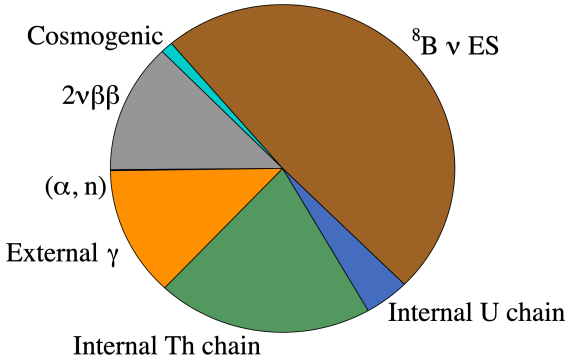

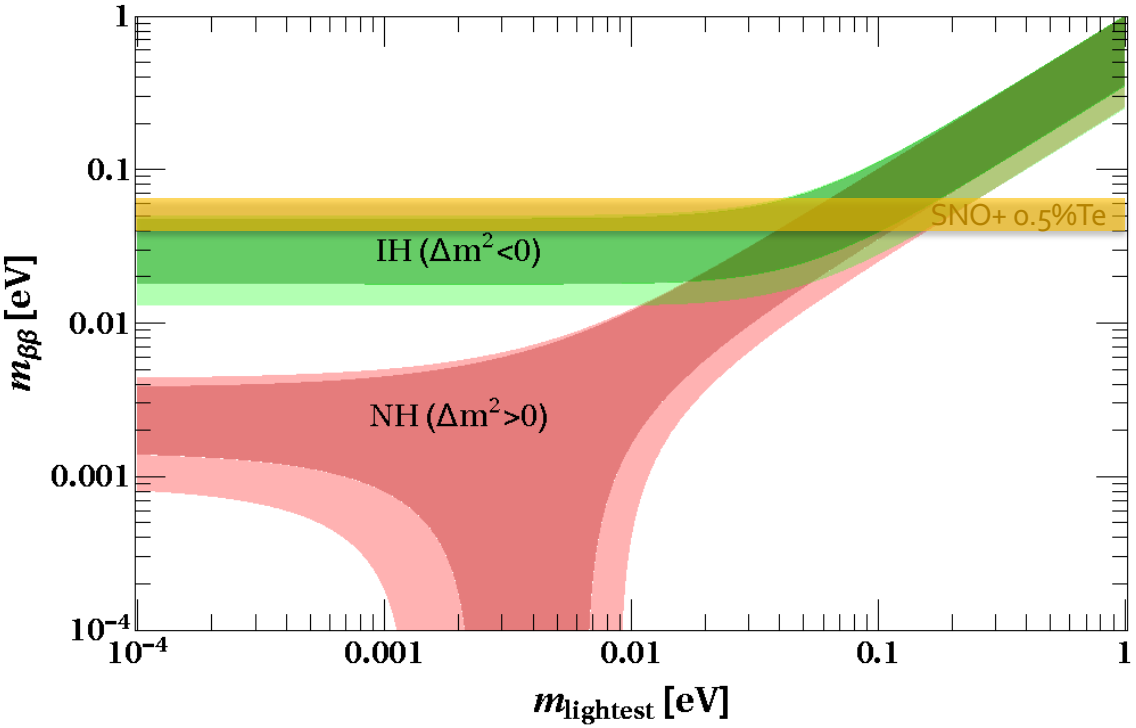

Thank You