Water Assay Using Hydrous Titanium Oxide Technique for the SNO+ Experiment

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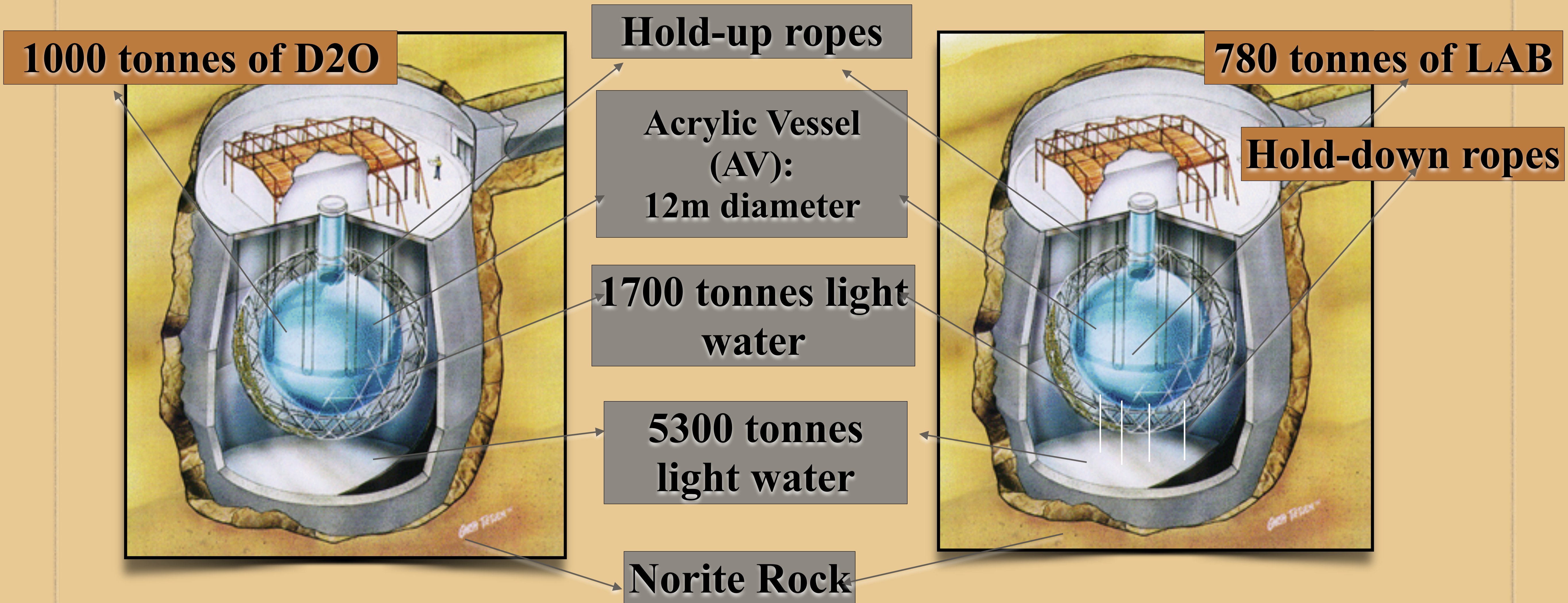
INTRODUCTION

- SNO+ is a multi-purpose neutrino detector.

SNOLAB Surface Building

SNO → SNO+



1. Replace 1000 tonnes of D_2O by 780 tonnes of Linear Alkyl Benzene (liquid organic scintillator).

2. New hold-down rope system to counter AV buoyancy has been installed.

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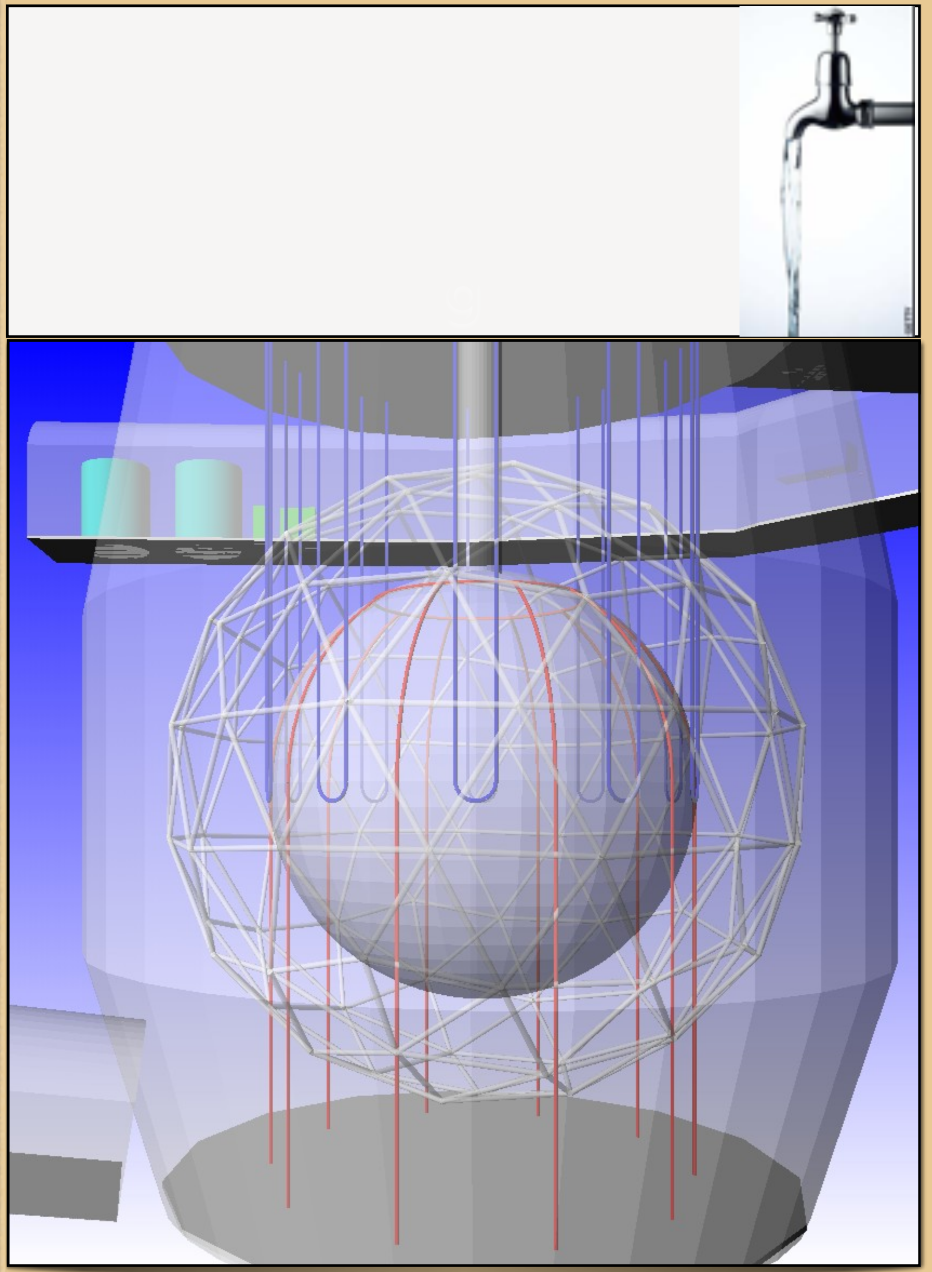
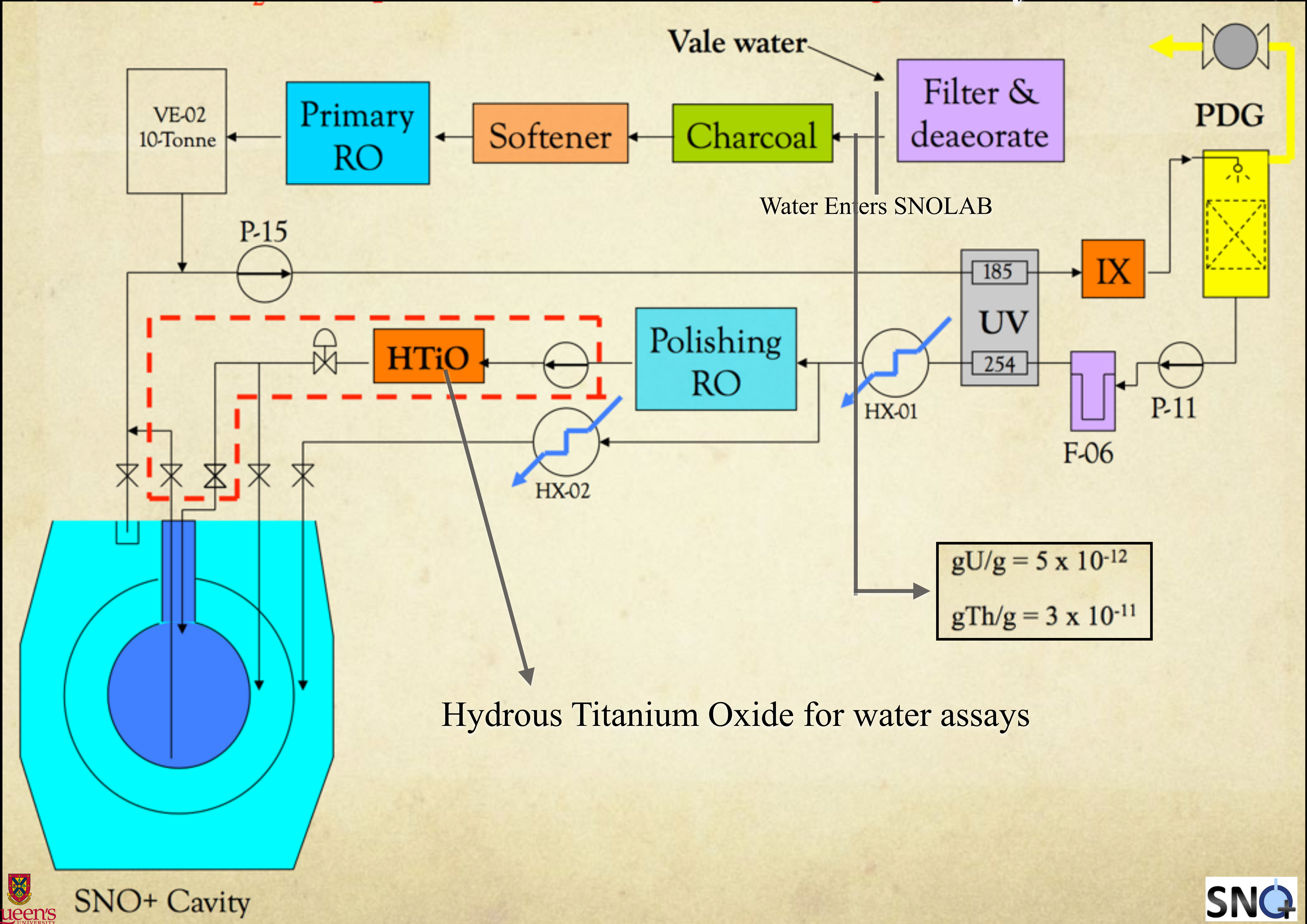
Initial Water Fill Phase: 2014



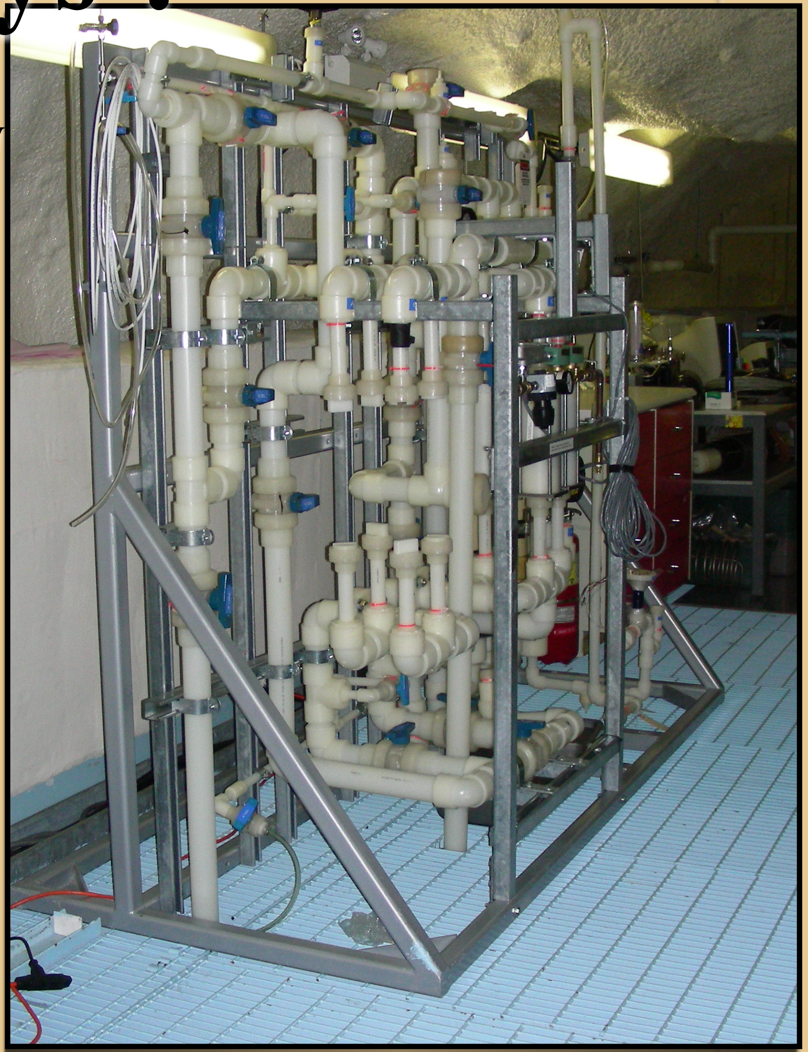
- Fill AV with water from Top.
- Currently filling cavity with water: 18 feet.

Motivation : important to understand the radioactivity levels in water.

Water Before It Goes In The SNO+ Cavity/AV



Why Do We Need Water Assays ?



Main backgrounds: Due to naturally occurring radioactivity (U and Th decay chains) .

↓

Water as a radioactive shield.

↓

Extremely low radioactivity levels needs to be achieved

↓

Radioactivity levels present in the water needs to be continuously monitored and water purified on a regular basis.

⇓

HTiO technique was developed for SNO to measure activity of ^{232}Th and ^{238}U chains by extracting ^{228}Th, ^{224}Ra, ^{226}Ra, and ^{212}Pb from the water.

The target levels for water purity are:

Outside the AV: 5.2×10^{-14} gTh/g and 2.06×10^{-13} gU/g

Inside the AV: 3.5×10^{-15} gTh/g and 3.5×10^{-14} gU/g

Hydrous Titanium Oxide (HTiO) Technique

- HTiO is an inorganic ion-exchanger that has the ability to remove heavy ions like Ra, Th from water.

- It's hydroxide structure allows anionic exchange at low pH and cationic exchange at high pH.

For SNO+ water, pH = ~7.

$$\text{M-OH} + \text{OH}^- + \text{N}^+ \longrightarrow \text{M-O}^-\text{N}^+ + \text{H}_2\text{O}$$

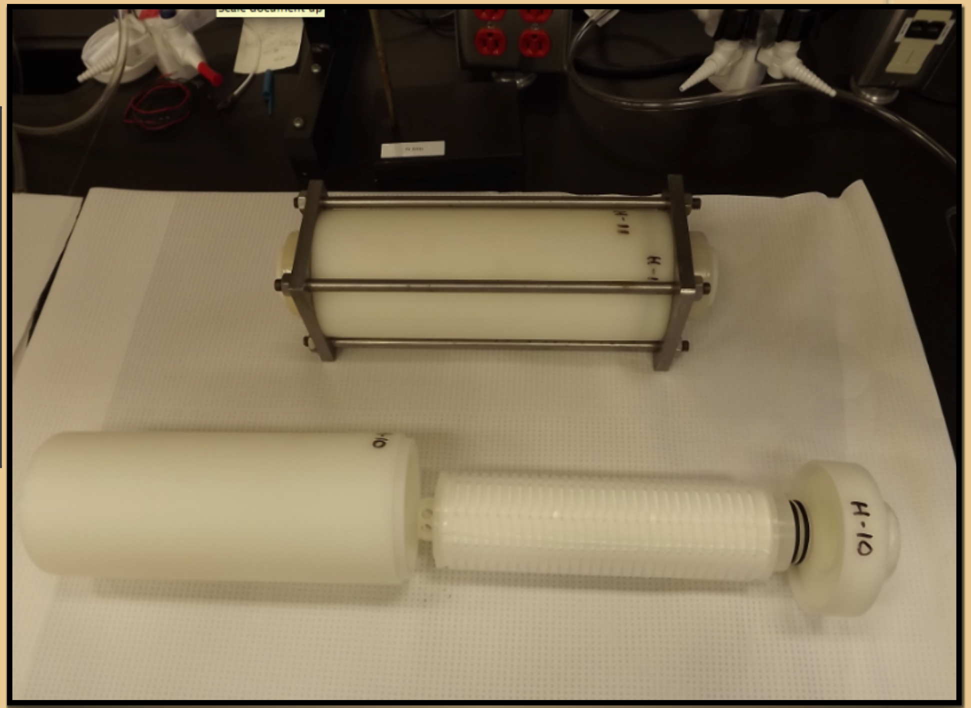
M-OH = hydrous oxide
N+ = heavy ion

- HTiO Technique is a six stage process.

- Both Ra and Rn are present in the water. But Ra is picked up by HTiO during an assay and Rn (gas) is not.

(See Janet Rumleskie's poster: LAB Radon Assay Board for the SNO+ Experiment, June 18, 19:04)

Stages of HTiO Technique



1. HTiO Preparation	• 1M NaOH added to Ti(SO4)2 until pH 12 • Sol. centrifuged, rinsed with UPW and stored in HTiO bottles

2. HTiO Deposition	Deposited onto a pair of memtrex filter (2.5g/m

The columns are then sealed and transported UG.

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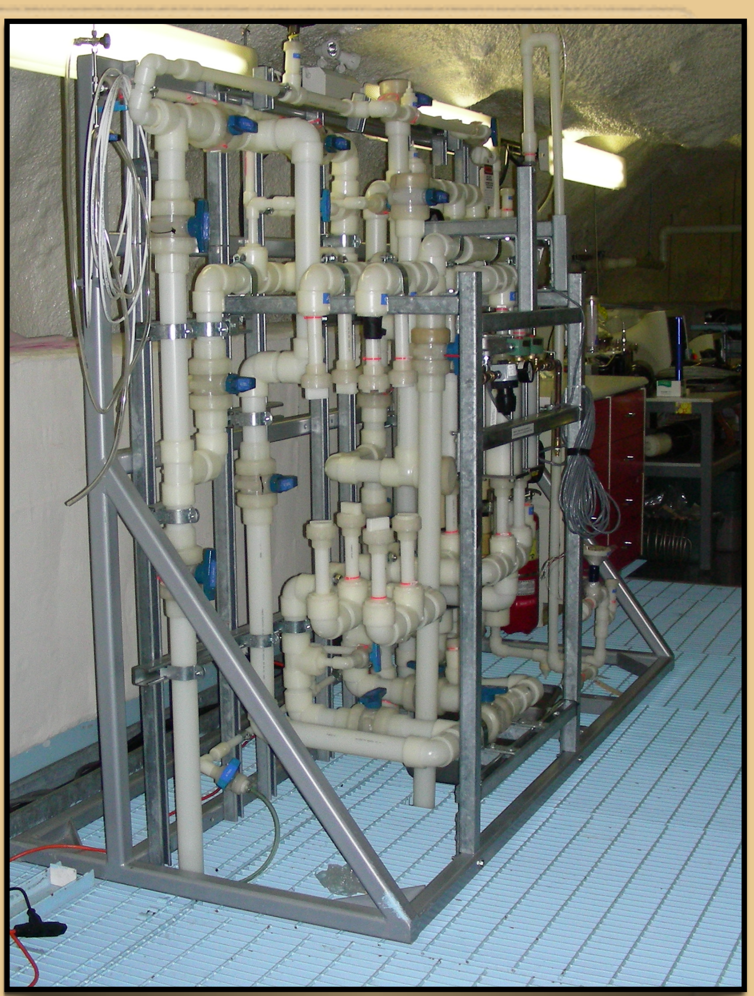
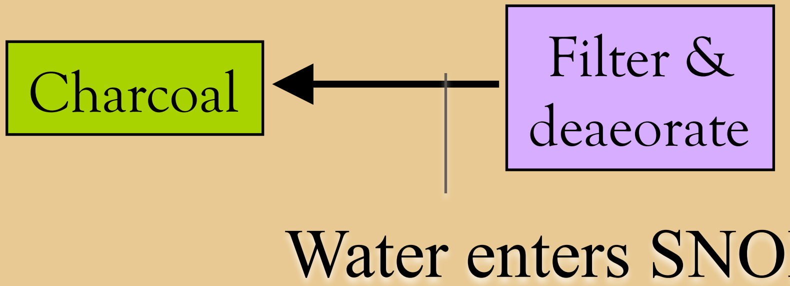
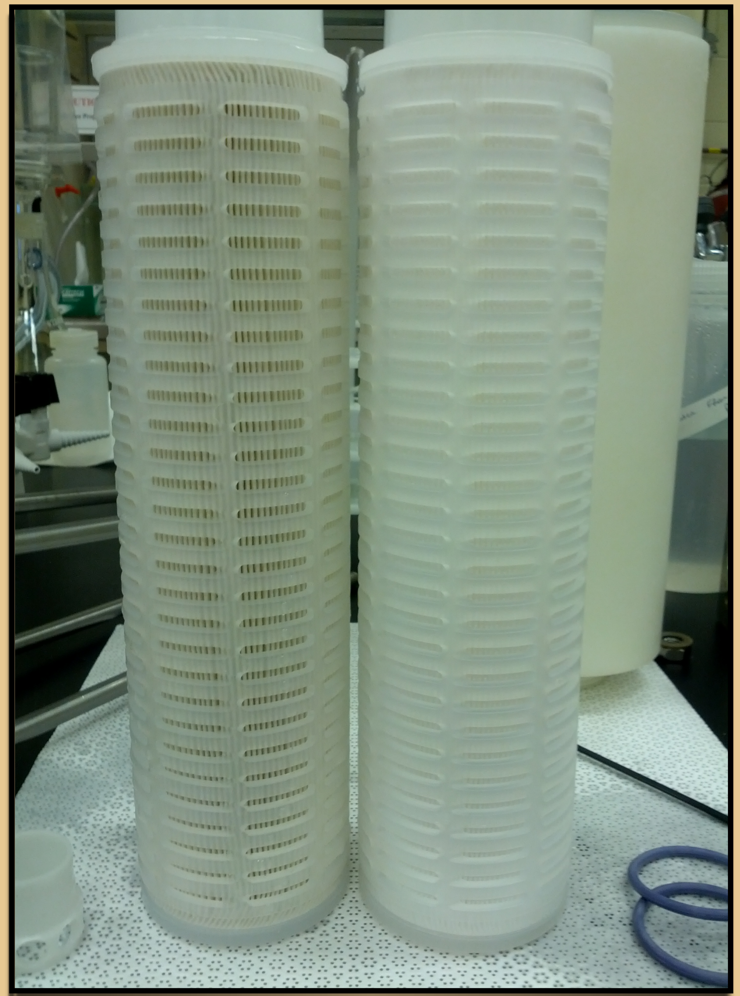
Stages of HTiO Technique

3. Ra Extraction (from water onto HTiO loaded filters)	• Columns mounted on water system. • Water extracted from different regions. • Start assay (for pre-determined period of time) • Ra trapped on cols., stop assay



Water Assay when it enters SNOLAB



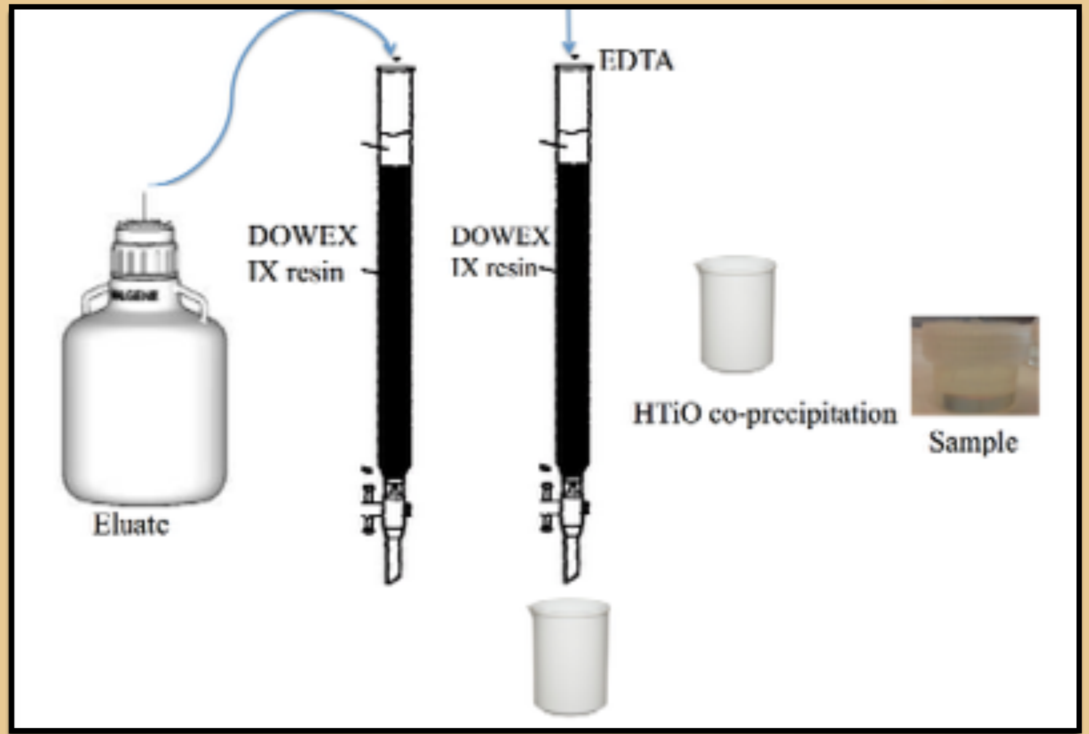


The columns sealed and taken back to surface clean lab

Stages of HTiO Technique

4. Elution (Removing Ra from HTiO loaded filters)	• Columns mounted on elution rig. • Elute the columns using HCl. • Collect eluate (~ 15L)

Secondary Concentration Step:



5. Secondary Concentration (Separating Ra from acid using IX method)	• IX extraction • IX elution • EDTA decomposition • HTiO co-precipitation • Sample preparation

6. Counting	• Count sample (~ 2 weeks) to get Ra activity

Blank/ Background Assays

- In addition to sample runs, blank runs are also performed.
- Blank assays are done to determine contribution of equipments, chemicals to the radioactive signals for an assay.
- Involves same steps for HTiO technique (except for extraction).

True Activity = Sample activity - Blank activity

- 3-4 x 10^-16 g/g U and Th sensitivities achieved in SNO with HTiO technique (275 tonnes D2O assay).
- We want extremely low level of radioactivity in water

⇒ It is very important to know the efficiency of the HTiO technique

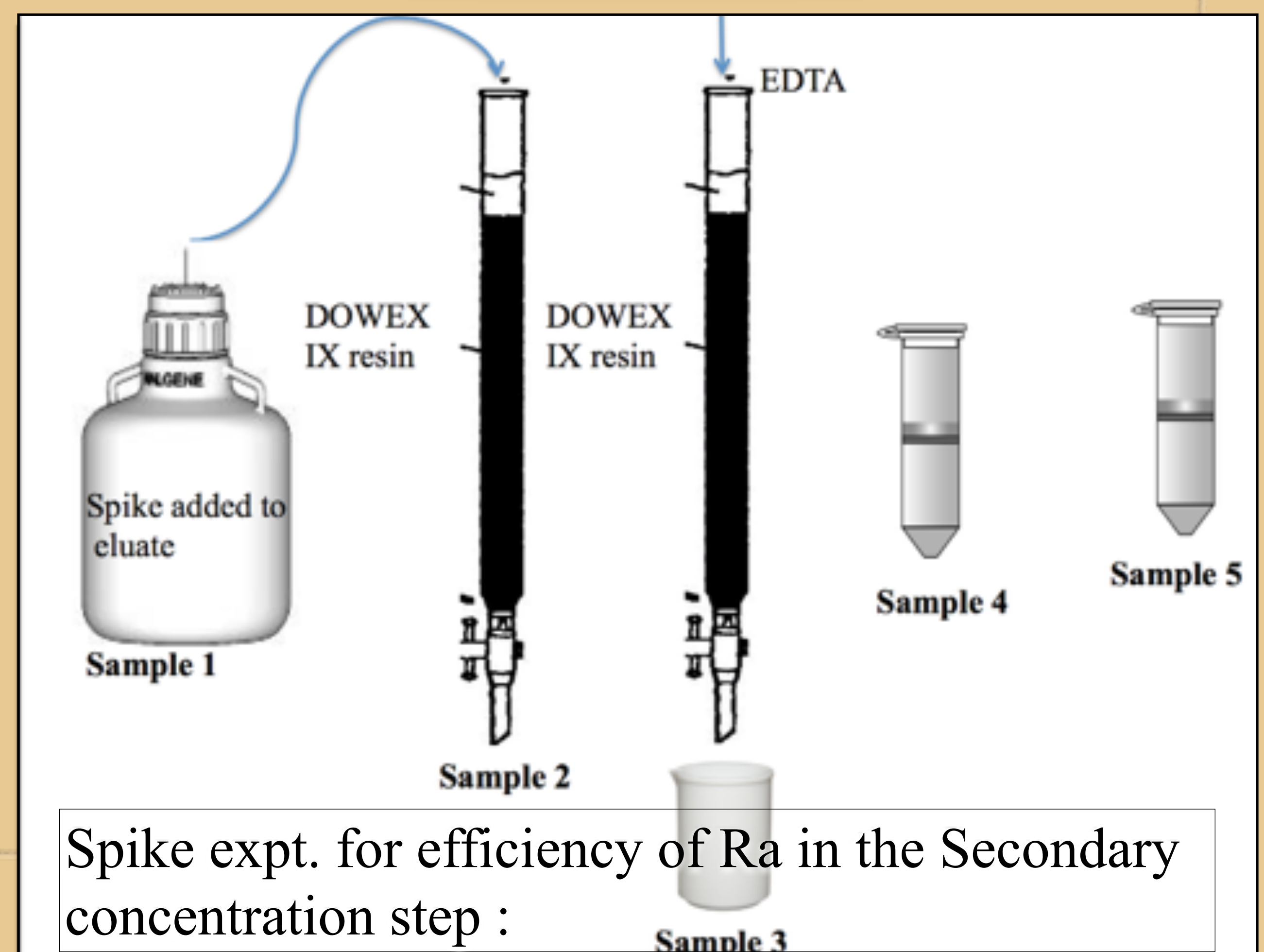
Efficiency At Each Stage of HTiO Technique

- HTiO is multi stage process, so need to understand the efficiency at each step.
- We do set of independent measurements to see how effective is our technique
- The ability of the HTiO technique to remove Ra from water can be measured at each step of an assay using spike tests.
- Measurements have been done on SNO and some have been repeated for SNO+ (secondary concentration).

*B.Aharmim et al. / Nuclear Instruments and Methods in Physics Research A 604 (2009) 531-535

How efficient is HTiO Technique

Steps	Efficiency 226Ra(%)	Efficiency 224Ra(%)
HTiO Preparation:		
HTiO Deposition:		
Extraction:	*95 ± 5	*95 ± 5
Elution:	*90 ± 10	*90 ± 10
Secondary Concentration:	*58 ± 6	37 ± 10
Total Chemical * (ε_{ext} . ε_{elu} . ε_{conc})	*50 ± 8	33 ± 8
Counting:	*60 ± 10	*45 ± 5
Total* (ε_{ext} . ε_{elu} . ε_{conc} . ε_{count})	*30 ± 7	15 ± 4

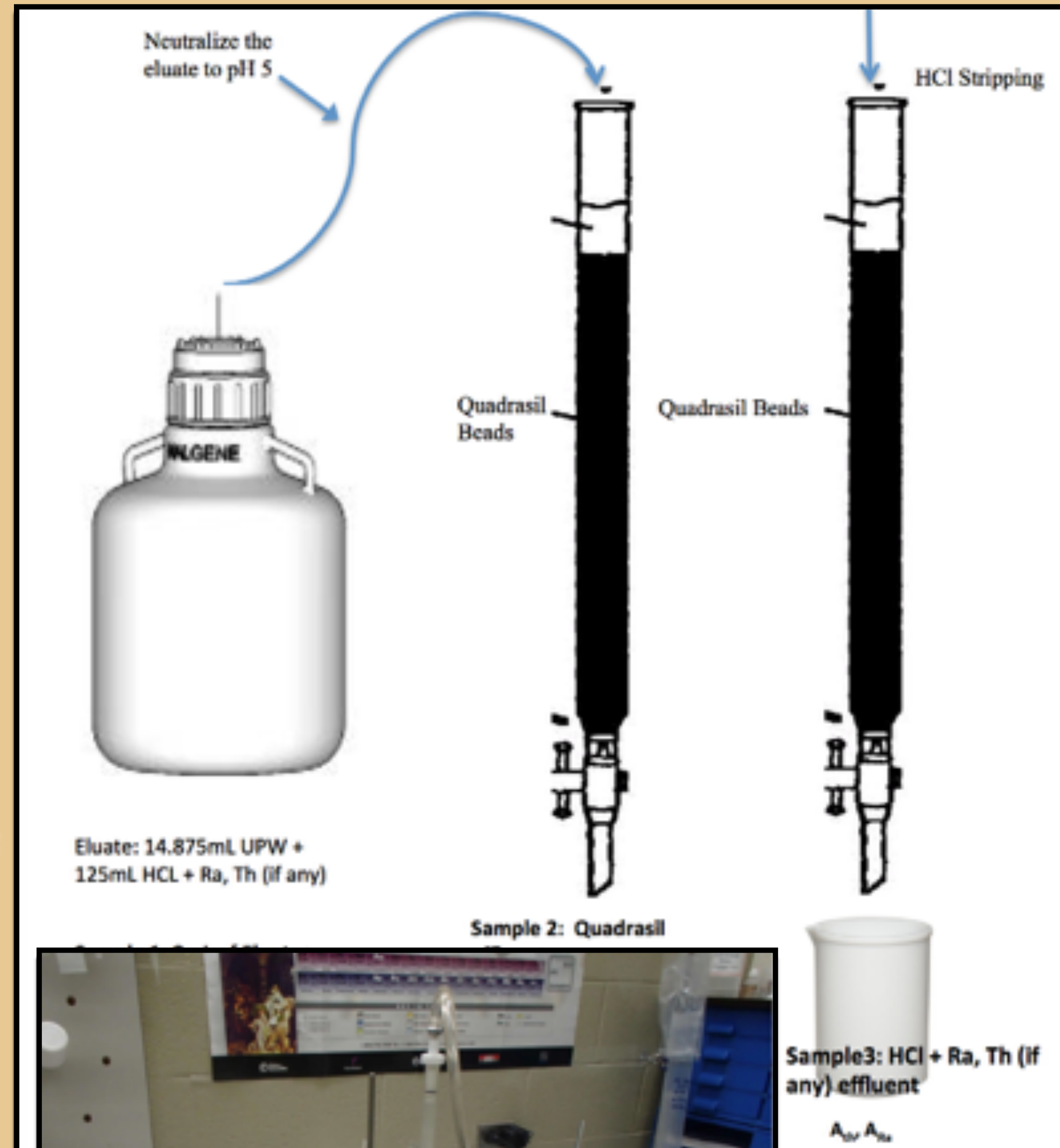


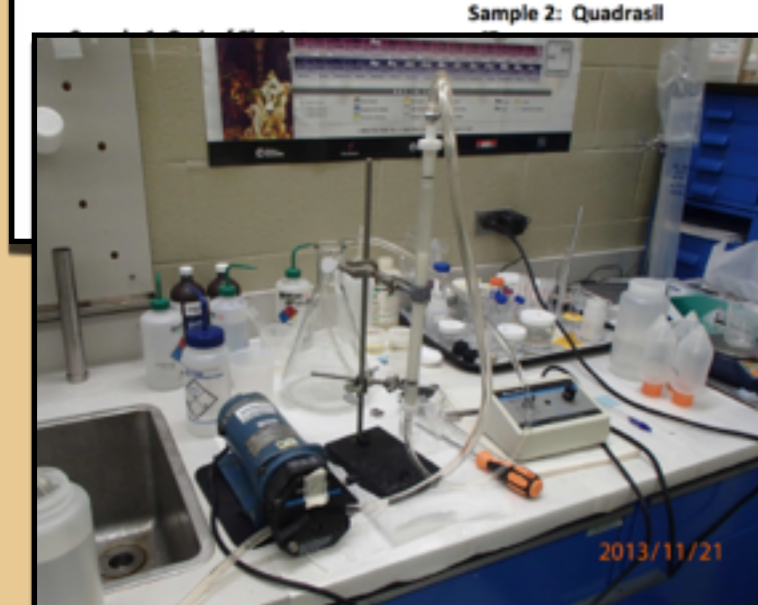
Spike expt. for efficiency of Ra in the Secondary concentration step :

Alternative Approach to Secondary Concentration Step

Secondary Concentration step using Quadrasil Beads

1. For LAB, new assay technique has been developed by SNO+ *
2. It looks promising as a simple and better way to do this with water.
3. Involves Quadrasil AP beads (as for LAB) instead of DOWEX resin in the secondary concentration step.
4. Having two parallel technique will tell us which method is better and the results can be compared as well.
5. Many spike tests being performed to explore this option. R&D will be ongoing for several months and is being done at LU.





* R. Ford, M. Chen, O. Chkvorets, D. Hallman, E. Vazquez-Jauregui, "SNO+ Scintillator Purification and Assay". (http://dx.doi.org/10.1063/1.3579580)

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Conclusions

- Sensitivity of water assay comparable to those from SNO experiment have been achieved.
- Improved/alternative approach in secondary concentration technique in progress.
- Keeping track of radioactivity levels in water is very crucial for our experiment and hence water assays.

SNO+ Collaboration

Queen's
Alberta
Laurentian
SNOLAB
TRIUMF

BNL, AASU
U Penn, UNC
U Washington
UC Berkeley/LBNL
Chicago, UC Davis

Oxford
Sussex
QMUL
Liverpool
Lancaster

LIP Lisboa
LIP Coimbra

TU Dresden

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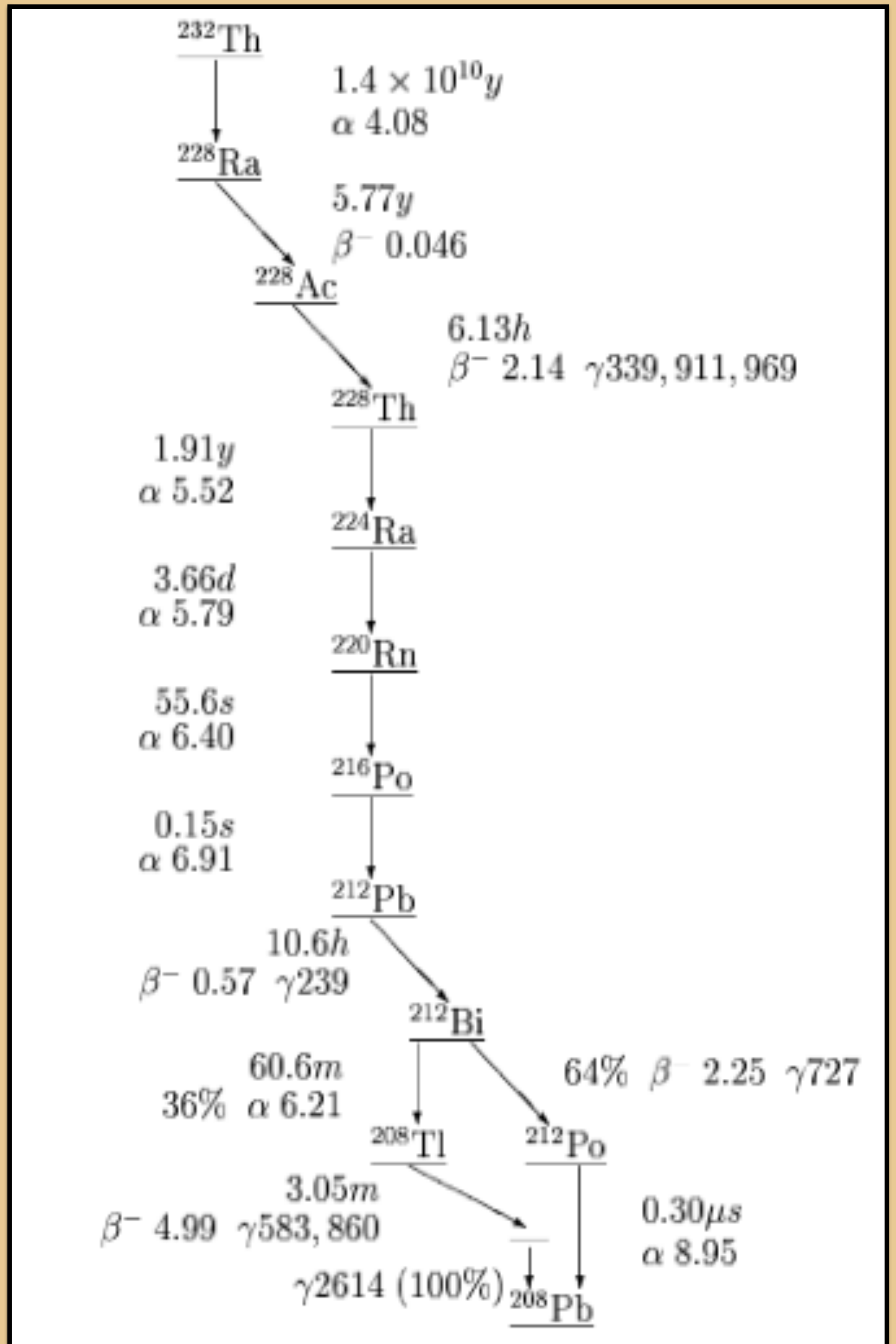
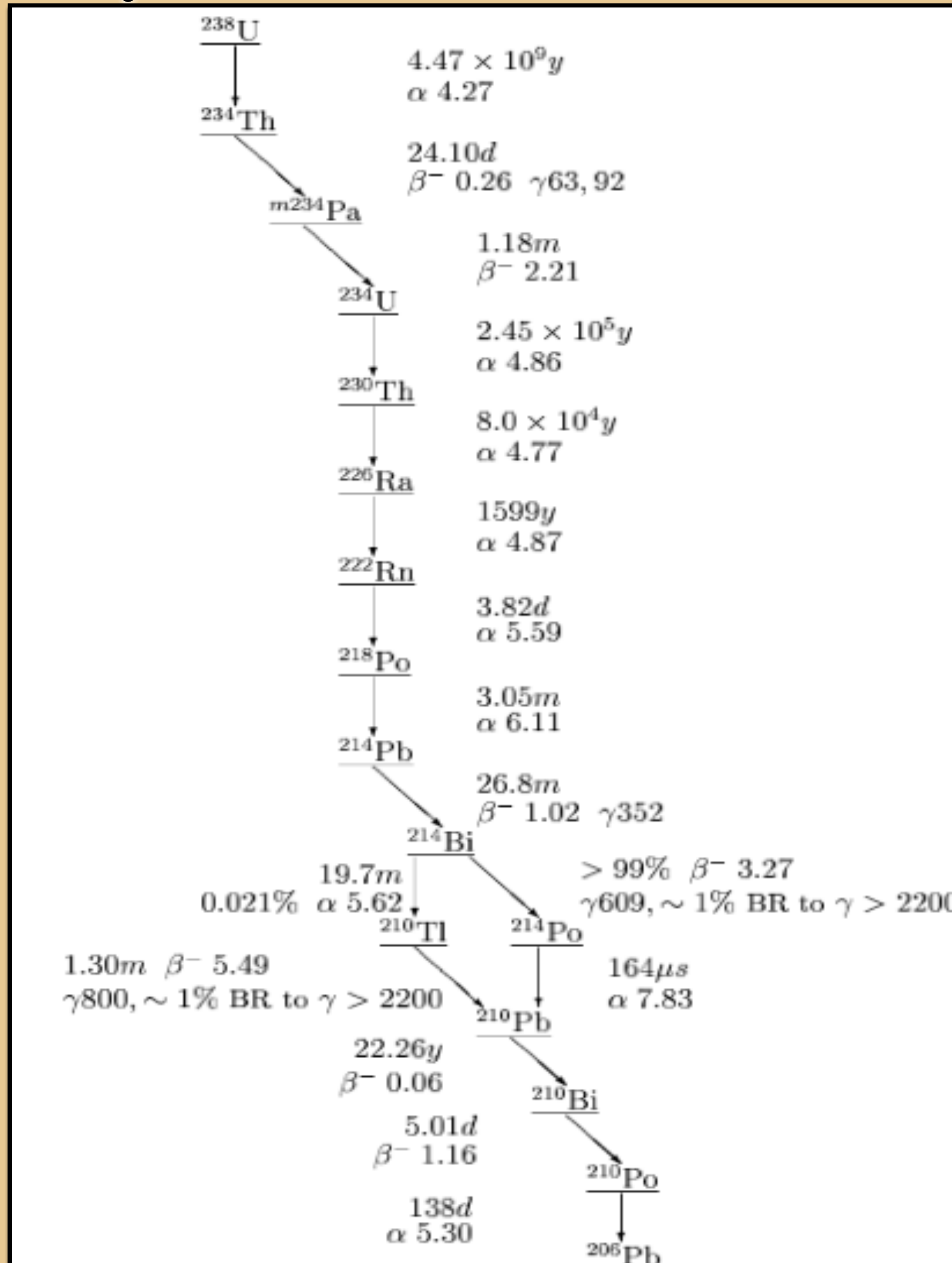
Backup Slides

Th and U decay chain





Why LAB?

1. High light yield (~10000 optical photons/MeV).
2. Long attenuation length.
3. Chemical compatibility with acrylic.
4. High purity available.
5. Low scattering
6. Good optical transparency.
7. Low toxicity.
8. Environmentally safe.
9. Inexpensive.
10. Low solubility in water

Advantages of Te

1. 34% natural abundance.
2. $2\nu\beta\beta$ rate is low.
3. Internal U/Th backgrounds can be actively suppressed by identifying 214Bi-214Po alphas.

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SNO+ Physics Goals:

1.Search for neutrino less double beta decay:

- This will be achieved by loading 130Te in LAB.
- If we see neutrino less double beta decay, it would mean that neutrinos are their own anti-particles (neutrinos are Majorana particles).

2.Detection of low energy solar neutrinos:

- *pep neutrinos:*

• The pep reaction produces mono energetic neutrino (1.442 MeV) and has well predicted flux (1.5% uncertainty).

• Detecting the pep neutrinos and measuring their survival probability can improve the precision on neutrino oscillation parameters and sensitivity to alternative models of neutrino mixing.

• pep neutrino measurement requirements:

i.Depth: C-11 produced by muons interacting with carbon atoms of LAB. C-11 is a background for pep neutrinos. So deeper location is effective in reducing the cosmogenic backgrounds.

ii.Radiopurity: should be at the level of 10^(-17) g/g of U and Th. Bi-210 mimics the pep signal events.

- *CNO neutrinos:*

• CNO neutrinos can be sued to test the Sun's metallicity. i.e. if the elements are homogeneously distributed in the Sun.

• Main source of background for CNO signal is Bi-210.

SNO+ Physics Goals:

3.Detection of geo- and reactor neutrinos:

- *Geo-neutrinos:*
- SNO+ located in a thick crust, well studied geology and a lower reactor neutrino background.
- Emitted by natural radioactivity in the earth (U, Th decays). With this study, we can assay the earth (radiogenic heat production).
- The U/Th composition in the earth's crust and mantle are unknown. With large liquid scintillator neutrino detector, we can directly measure crust and mantle U/Th composition by detecting the emitted anti-neutrinos through IBD.
- *Reactor Neutrinos:*
- Study of reactor neutrinos would demonstrate oscillation phenomenon and result in sensitivity to neutrino oscillation parameters similar to KamLAND after ~3yrs data taking even though the expected flux is ~5 times smaller. Lower no. of reactors give rise to clear oscillation patter

4.**Supernova neutrinos:**

- If a supernova occurs in our galaxy, SNO+ will see 100 of neutrinos.
- Observing these neutrinos would tell us about neutrino-matter interactions and about the core collapse supernova mechanism

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Experimental and Manpower Hours

Step	Time
HTiO Preparation	8-9 days
Cleaning of elution rig	2 hrs
HTiO Deposition (2 columns)	4 hrs
Ra Extraction	3 days
Elution	3hrs
Secondary concentration	7 hrs
Counting	~ 2weeks
Total time	26-27 days for one assay (UG) or ~18 days (not including HTiO prep)