SNOLAB water purification and radon and radium assay techniques

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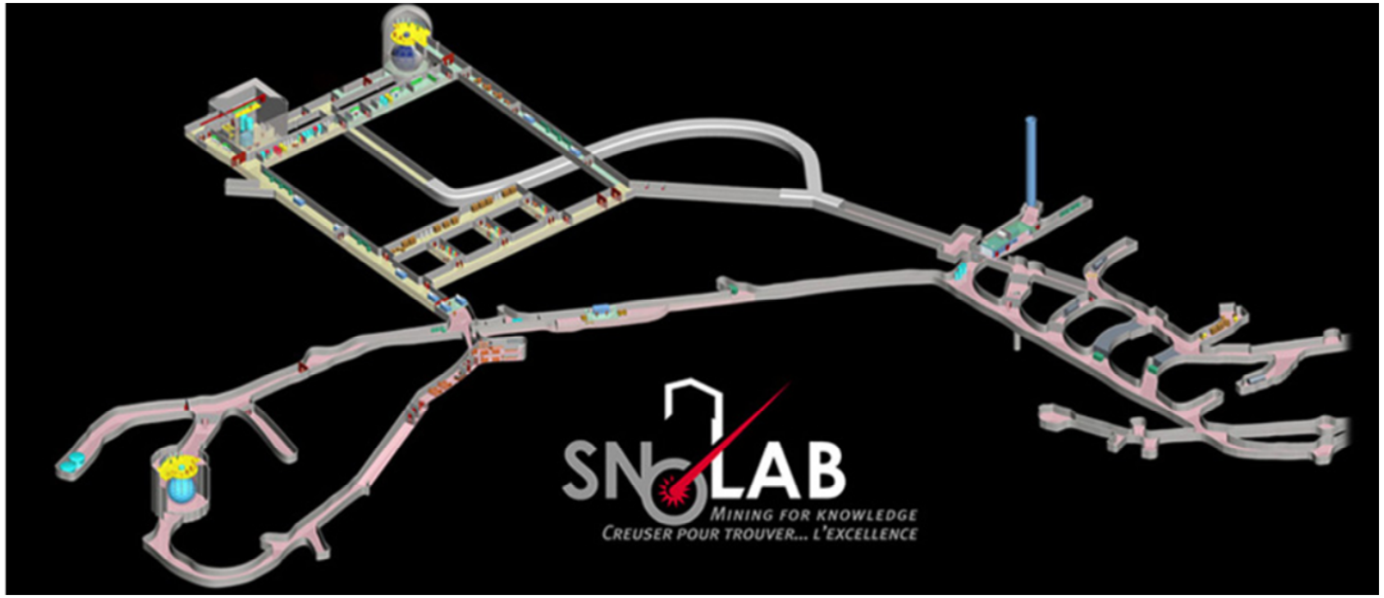
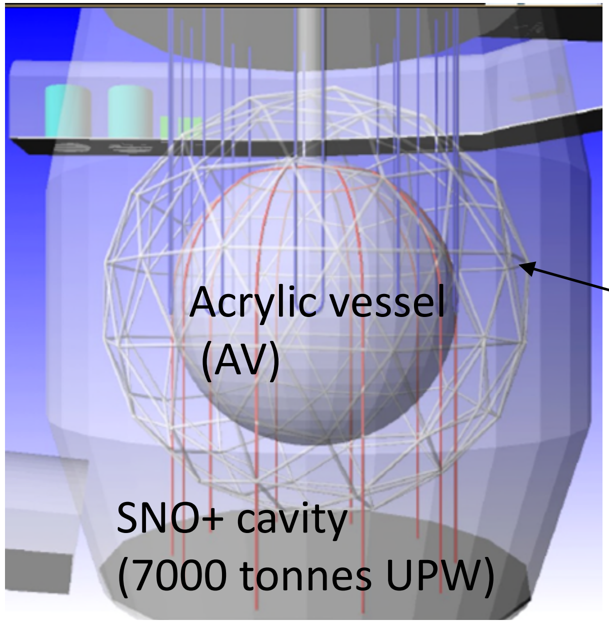
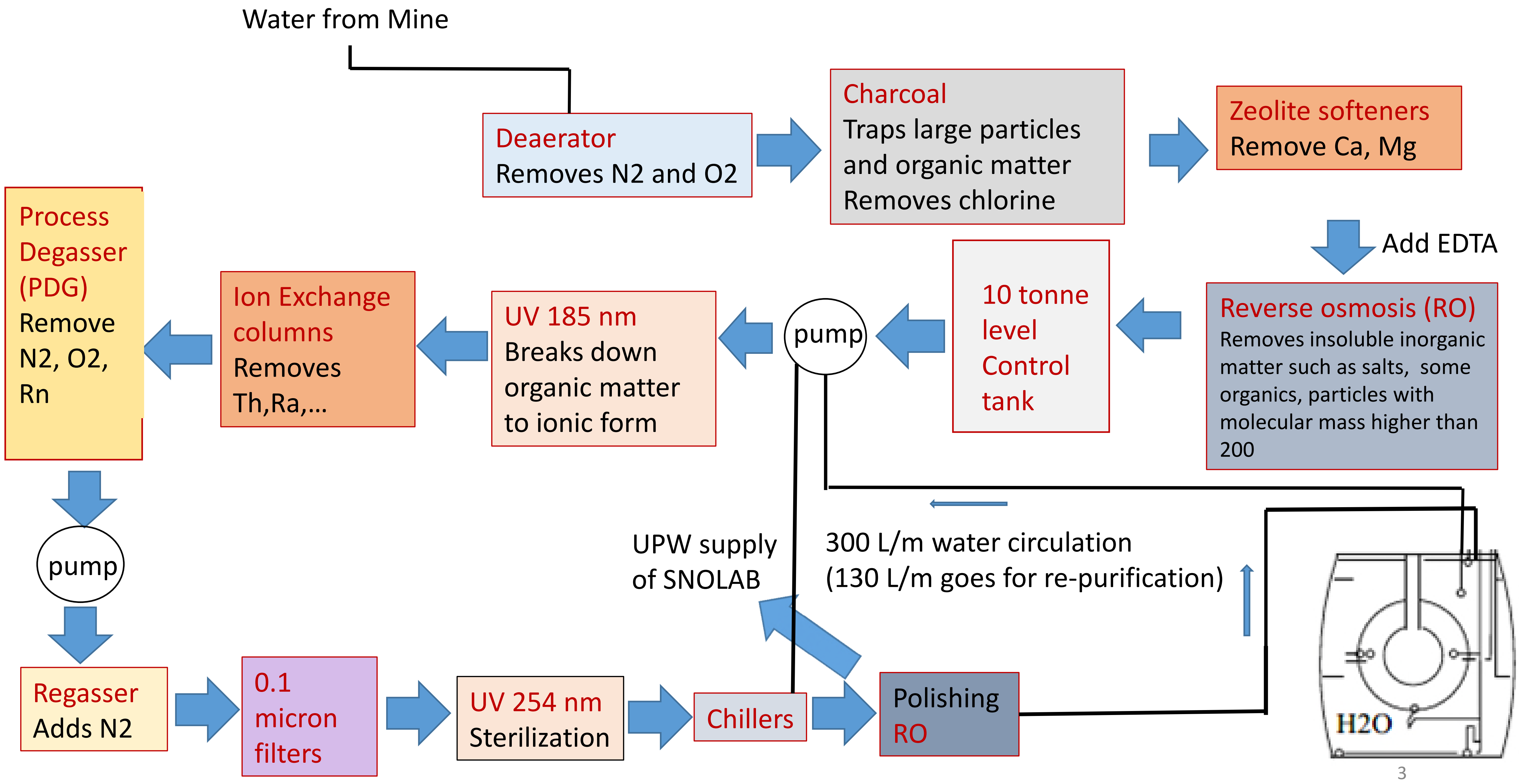
Overview of water purification plant

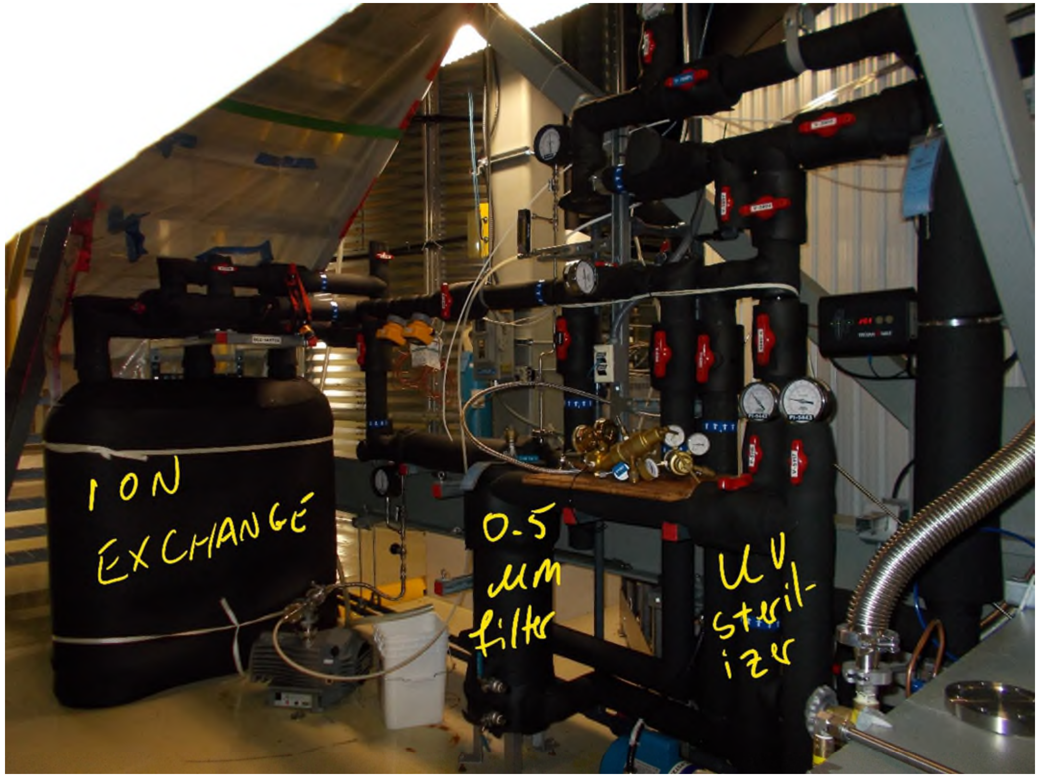
- Ultra pure water (UPW) provides shielding for SNOLAB experiments
- Potable water from Vale is treated and purified to remove radioactivity, organic and inorganic impurities
- SNO+ uses large majority of SNOLAB UPW (focus of this talk)
- Other experiments such as DEAP-3600 post treating SNOLAB UPW






Water from Mine
Deaerator
Removes N2 and O2
Charcoal
Traps large particles
and organic matter
Removes chlorine
Zeolite softeners
Remove Ca, Mg
Add EDTA
Reverse osmosis (RO)
Removes insoluble inorganic matter such as salts, some organics, particles with molecular mass higher than 200
10 tonne level Control tank
pump
UV 185 nm
Breaks down organic matter to ionic form
Ion Exchange columns
Removes Th,Ra,…
Process Degasser (PDG)
Remove N2, O2, Rn
pump
Regasser
Adds N2
0.1 micron filters
UV 254 nm
Sterilization
Chillers
Polishing RO
UPW supply of SNOLAB
300 L/m water circulation
(130 L/m goes for re-purification)
H2O

- Other experiments, such as DEAP-3600, are further away from SNOLAB water plant and performing further treatment



UPW background measurement using ex-situ techniques for SNO+

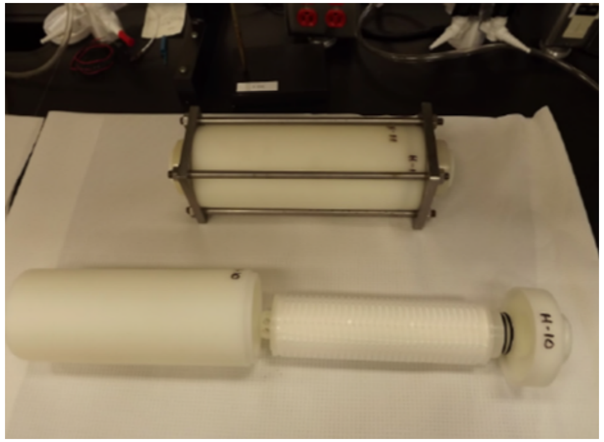
- ^{232}Th and ^{238}U content in UPW needs to be monitored regularly
- ^{224}Ra and ^{226}Ra can be measured using **Hydrous titanium oxide technique (HTiO)**

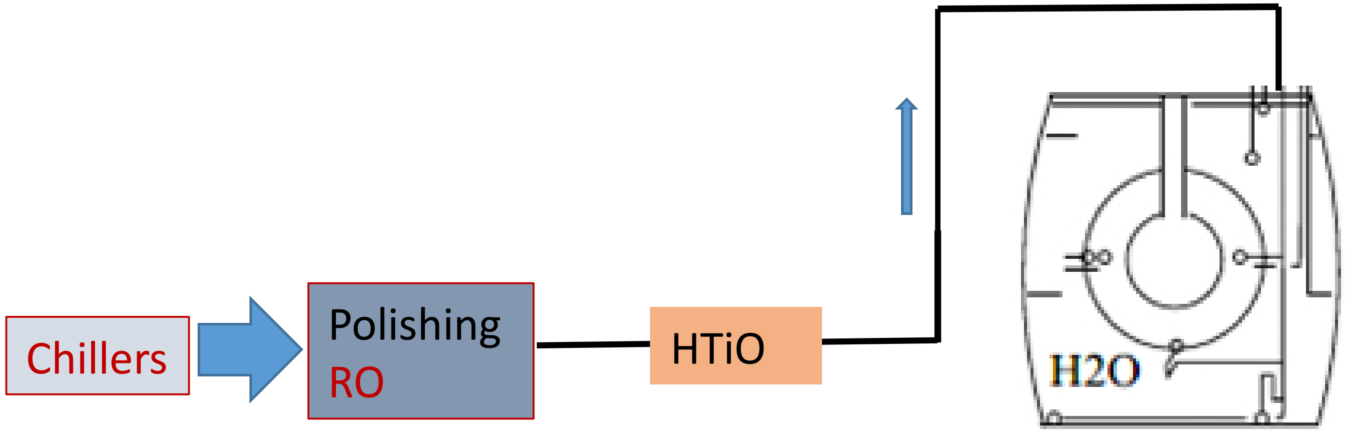
  Sufficient to measure Th-chain backgrounds but not U-chain
- ^{222}Rn ingress from the PMT cables and rock surrounding the cavity causes disequilibrium in ^{238}U chain
- ^{222}Rn is measured by using **degassing and trapping radon technique**
- ^{232}Th and ^{238}U target levels for SNO+ PSUP are (10.1103/PhysRevC.72.055502):

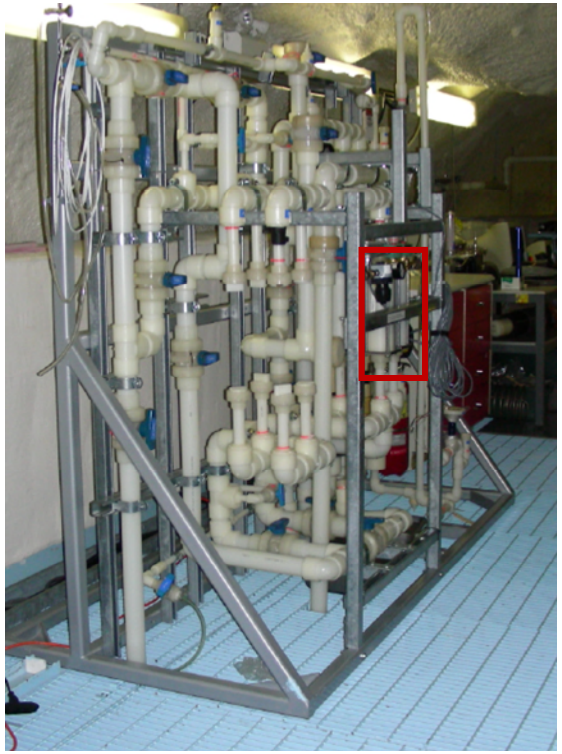
^{238}U	**2.06 E-13 g/g**
^{232}Th	**5.2 E-14 g/g**

HTiO technique

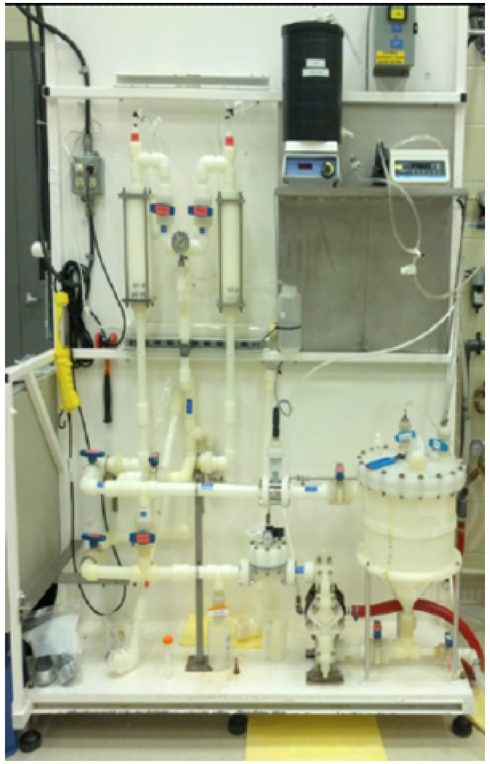
- The method is described in NIMA 604:531, 2009
- HTiO is an inorganic ion-exchanger, can remove heavy ions (^{224}Ra, ^{226}Ra) from water
- Deposited on to a pair of memtrex filters with Ti coverage of 2.5 g/m^2 on surface
- Typically 30 tonnes of UPW passes through HTiO per assay

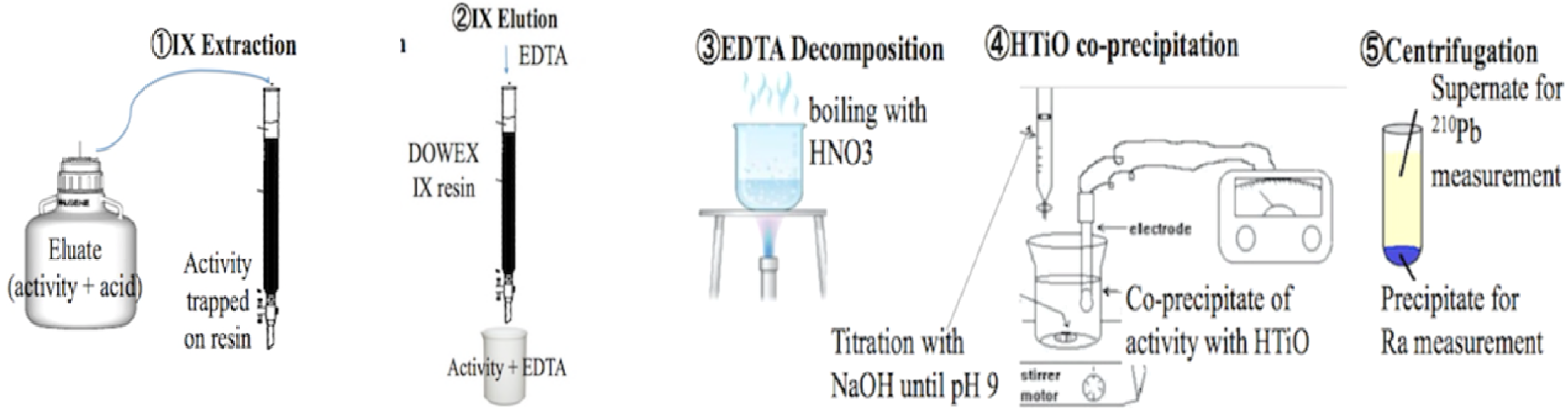




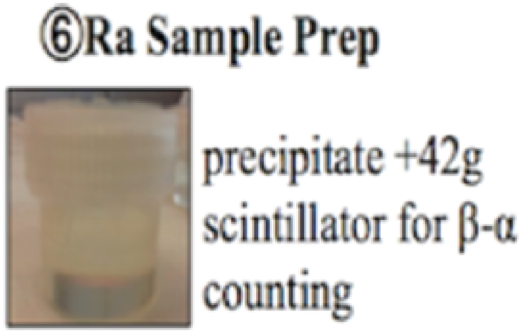


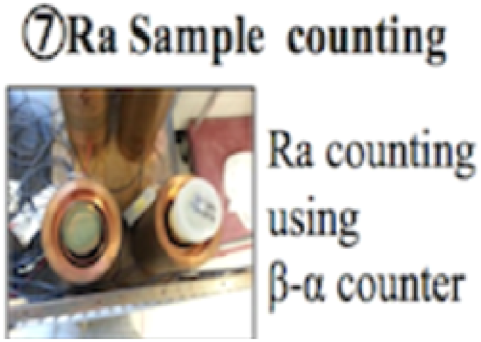
- In elution stage 15L of 0.1 mol/L HCl passes through the columns
- The elute is then concentrated in preparation for counting





- This final sample was added to Optiphase HiSafe 3 liquid scintillator
- Used beta-alpha coincidence counting system





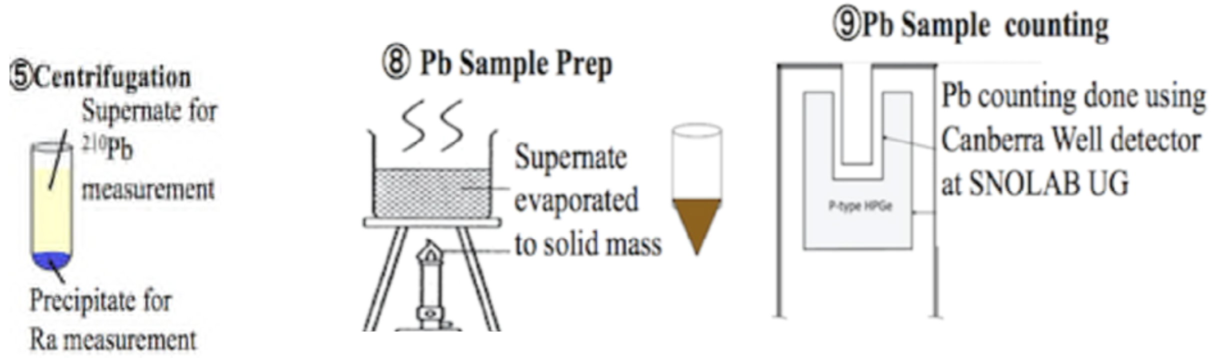
- Working on finalising the uncertainty on efficiency of the concentration stage
- The minimum detectable concentration during SNO was 4 E-16 $g^{232}Th/g$ H_2O

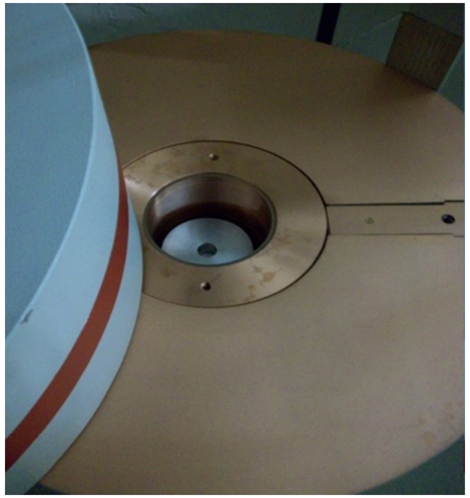
SNO efficiencies

Efficiency	^{226}Ra (%)		^{224}Ra (%)
Extraction ε_{ext}		95 ± 5	
Elution ε_{elu}		90 ± 10	
Secondary concentration ε_{conc}		58 ± 6	
Total chemical ($\varepsilon_{ext} \cdot \varepsilon_{elu} \cdot \varepsilon_{conc}$)		50 ± 8	
Counting ε_{count}	60 ± 10		45 ± 5
Total ($\varepsilon_{ext} \cdot \varepsilon_{elu} \cdot \varepsilon_{conc} \cdot \varepsilon_{count}$)	30 ± 7		22 ± 4

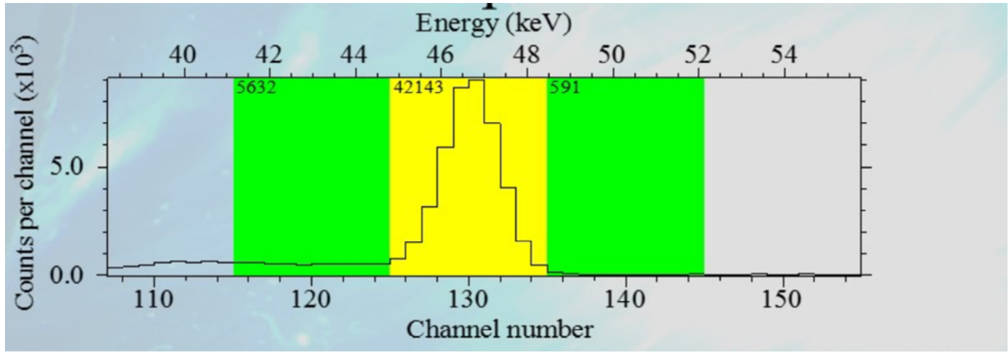
^{210}Pb capability

- SNOLAB Canberra Well detector can measure ^{210}Pb with high precision



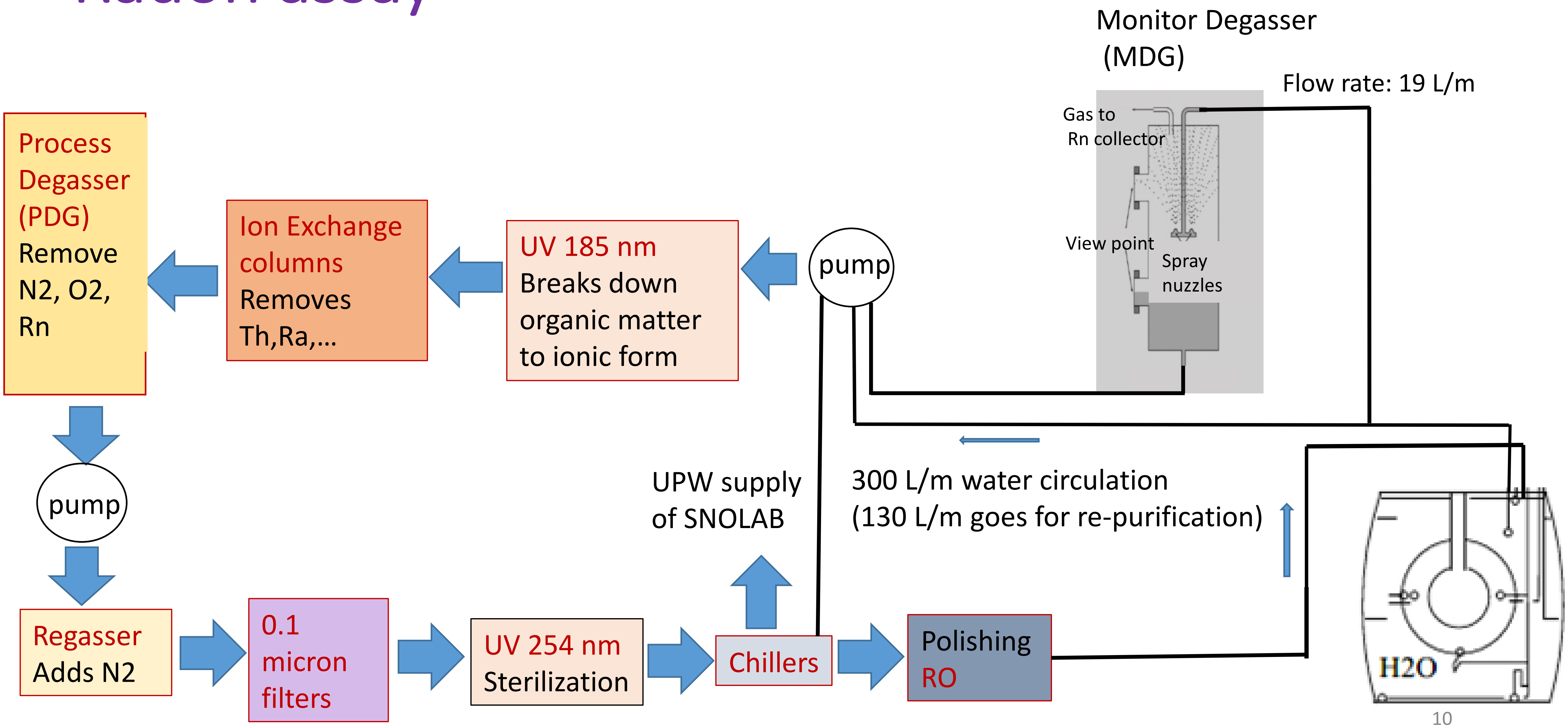


- Preliminary work:
  - 66% ^{210}Pb total measurement efficiency
  - Sensitivity of Pb-210 assay technique:
  - 0.4 $\pm$0.13 mBq/m^3



Prefill commissioning water sample
(D. Chauhan et al, TAUP 2017 poster)

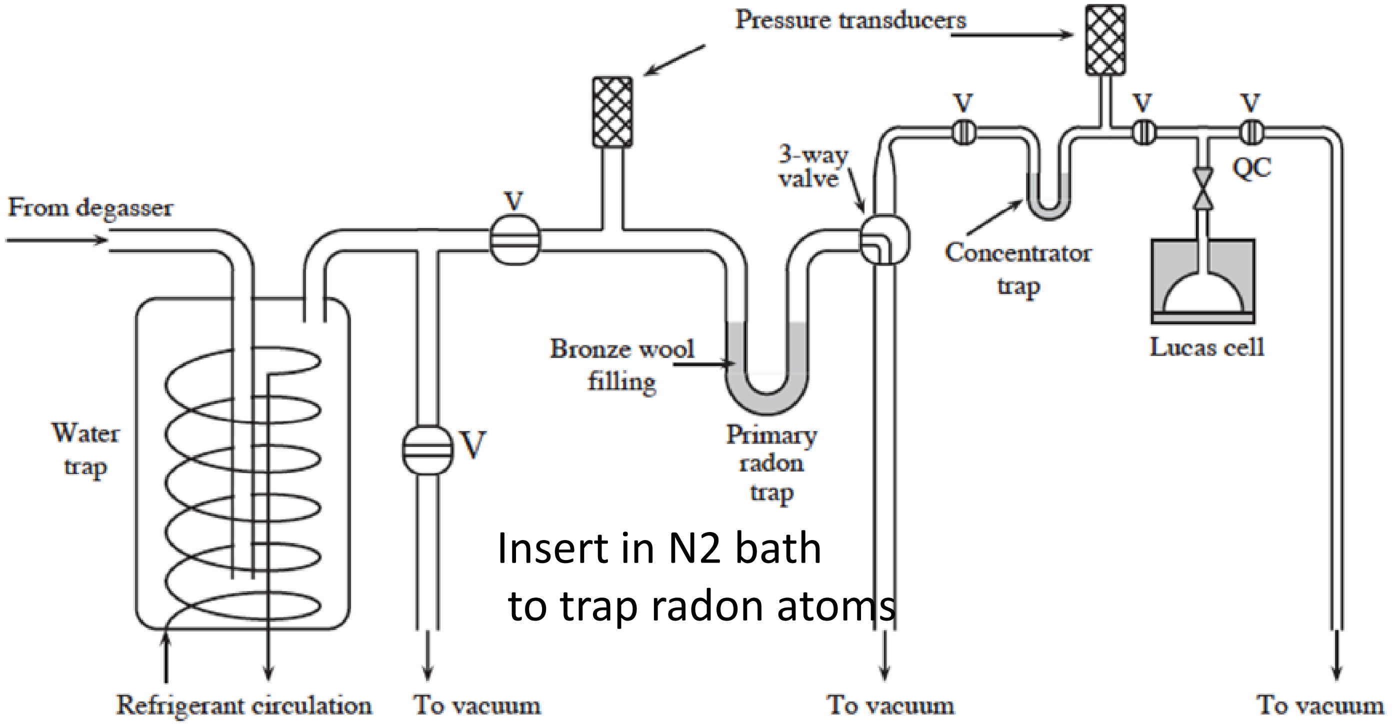
Radon assay



Monitor Degasser
(MDG)
Flow rate: 19 L/m
Gas to
Rn collector
View point
Spray
nuzzles
Process
Degasser
(PDG)
Remove
N2, O2,
Rn
Ion Exchange
columns
Removes
Th,Ra,…
UV 185 nm
Breaks down
organic matter
to ionic form
pump
pump
Regasser
Adds N2
0.1
micron
filters
UV 254 nm
Sterilization
Chillers
UPW supply
of SNOLAB
300 L/m water circulation
(130 L/m goes for re-purification)
Polishing
RO
H2O

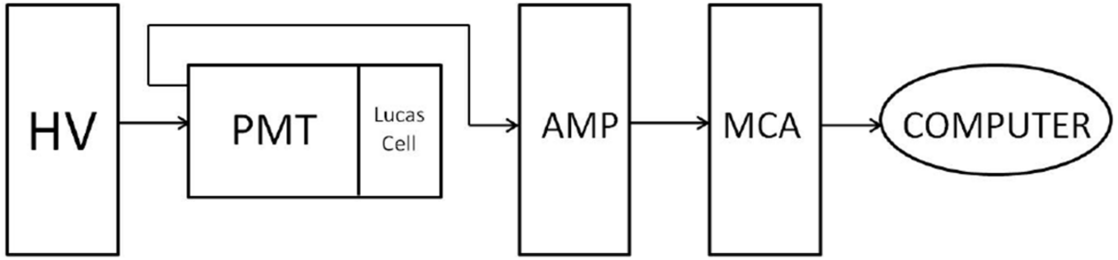
Radon assay

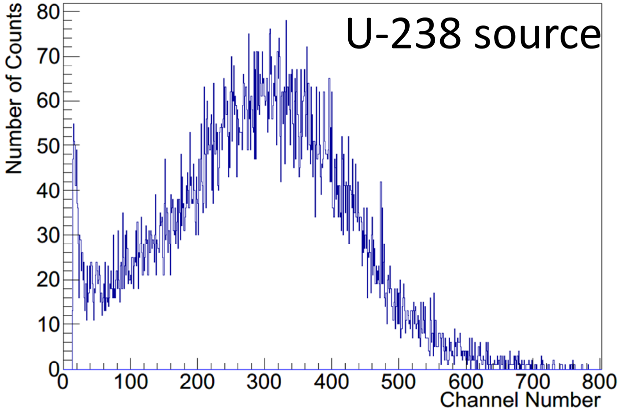
- The system is described in: NIMA 517:139, 2004
- Rn is extracted by vacuum stripping, then concentrated using a series of cold traps, before being transferred to a Lucas cell
- Typical assays are half an hour (570 L)
- Total radon collection efficiency =77%



Radon counting system

- Using ZnS coated Lucas cells to count decayed alphas

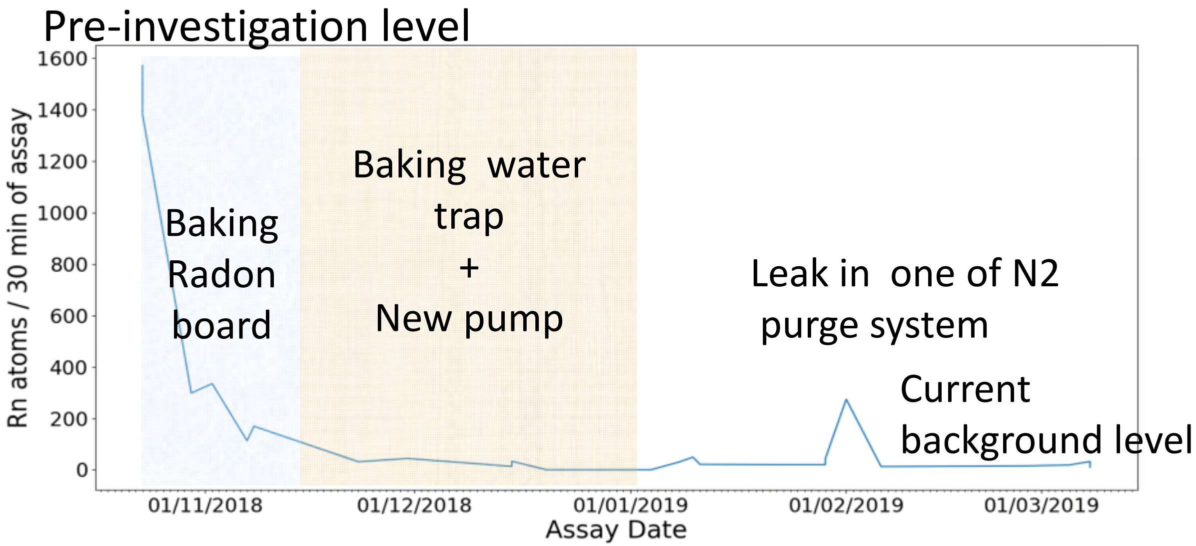




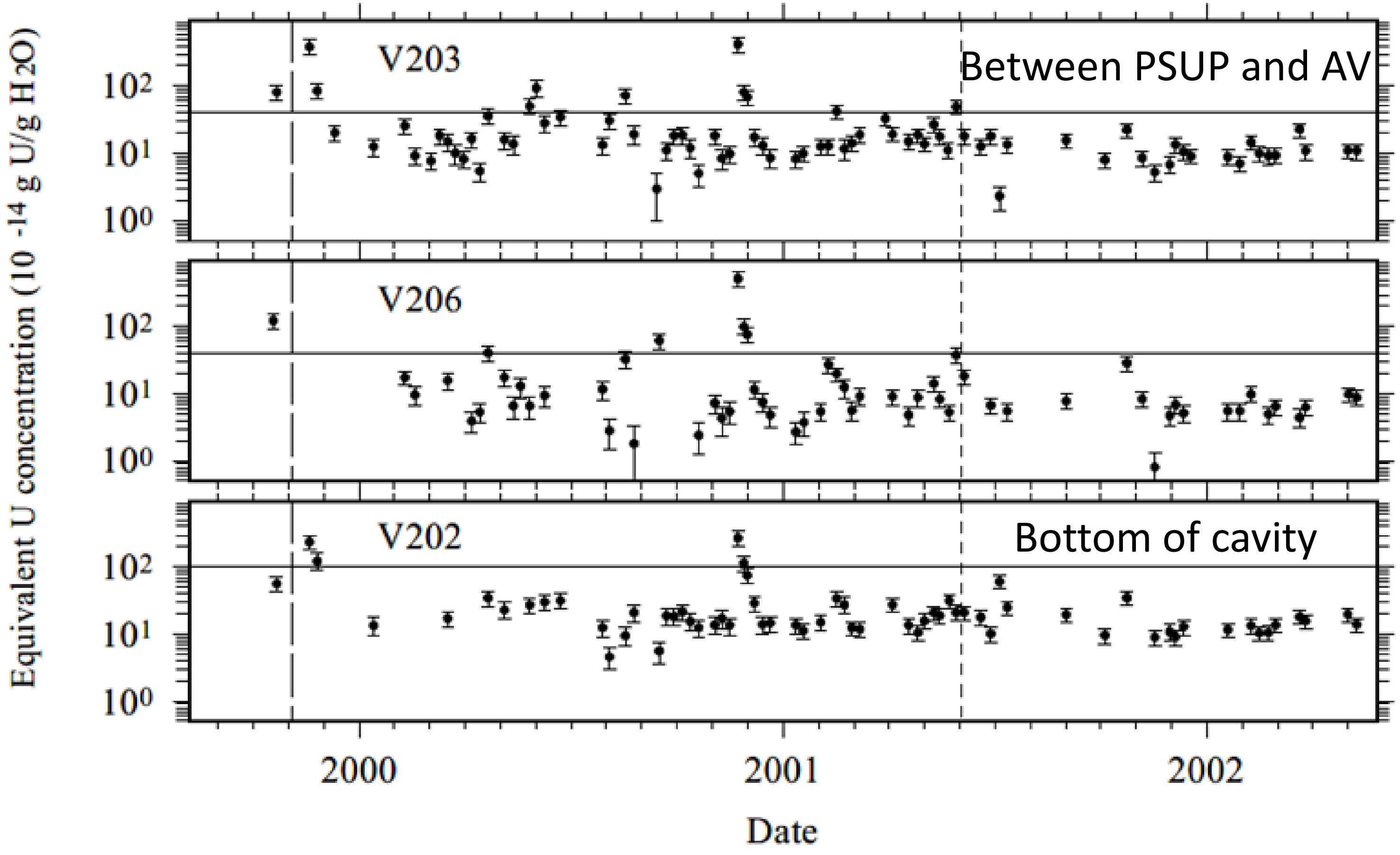
This year SNOLAB purchased 8 new channels with CAEN electronics used for both SNO+ radon assays and SNOLAB radon emanation counting

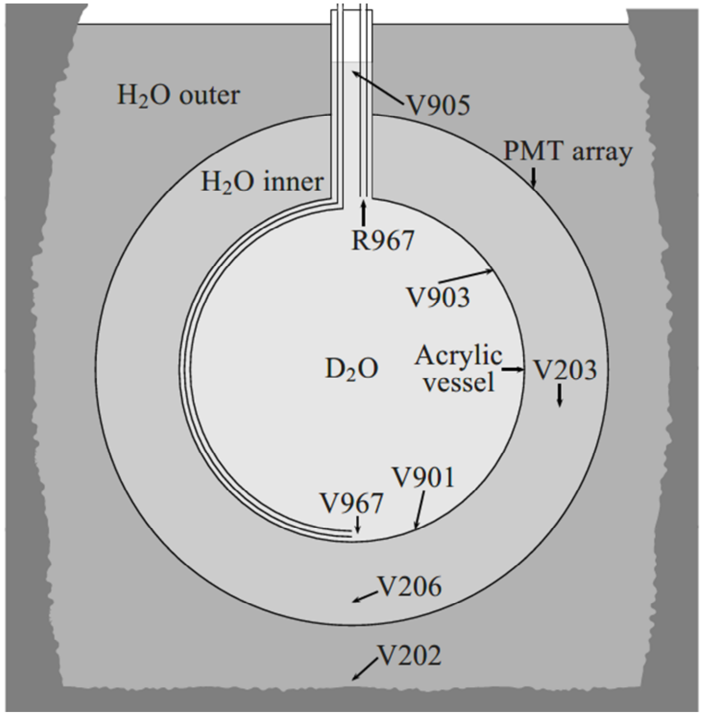
Rn-assay system's background

- The background of the system during SNO times was 20^{+9}_{-6} Rn atoms/h
- The background level was seen to be higher during recommissioning for SNO+
- Mixture of baking the traps and locating leaks in N2 purge system reduced the background
- The oil vacuum pump was replaced with dry pump
- Leak discovered in one of the purge lines
- The current background level is 45±13.5 Rn atoms/h

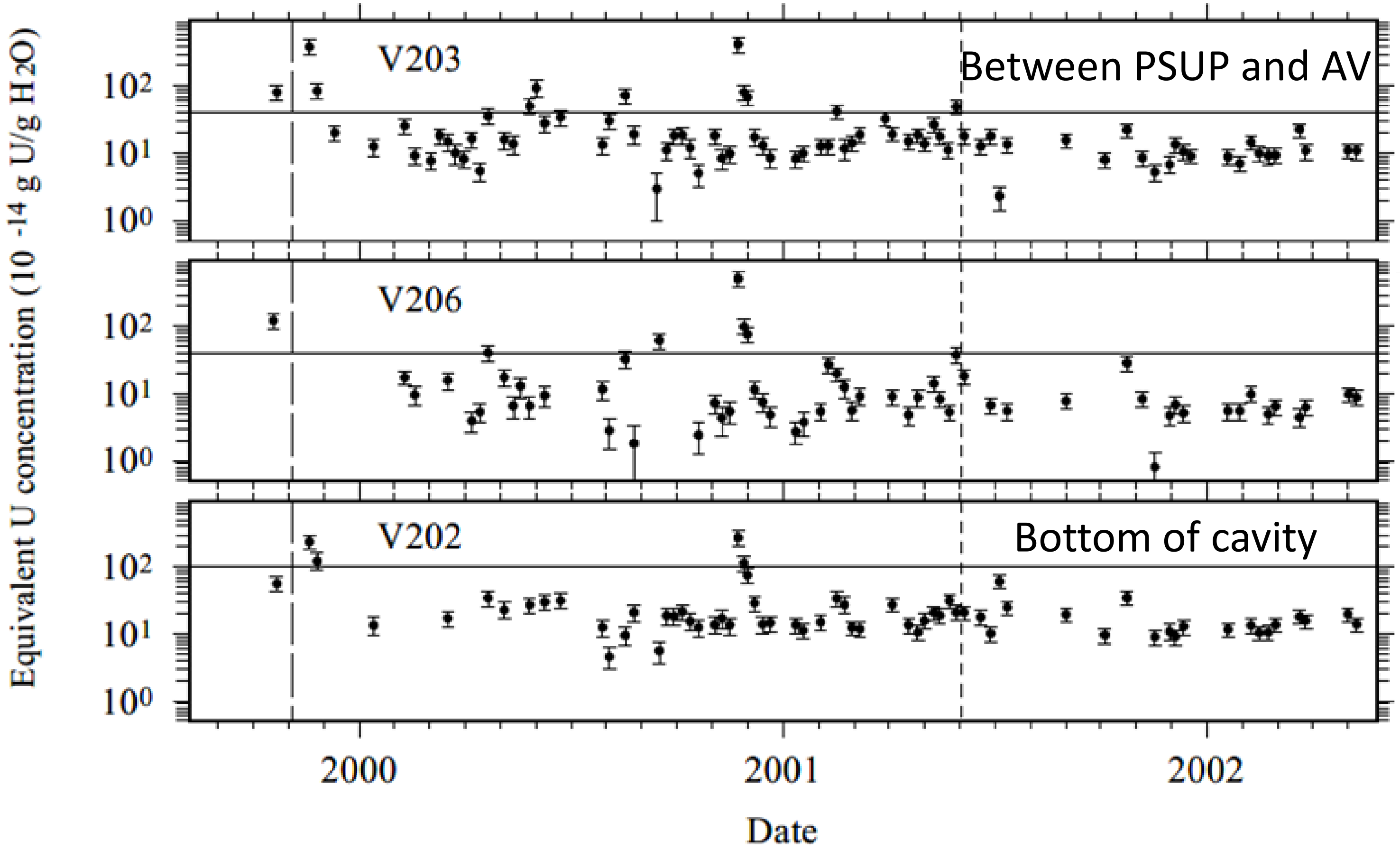


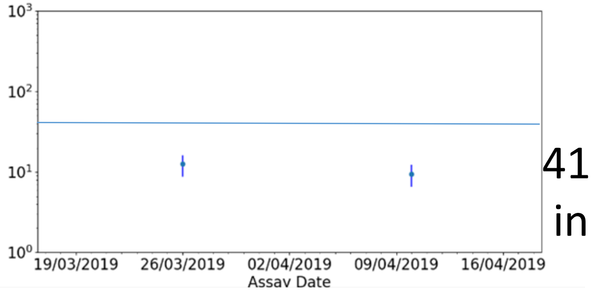
Historical assays



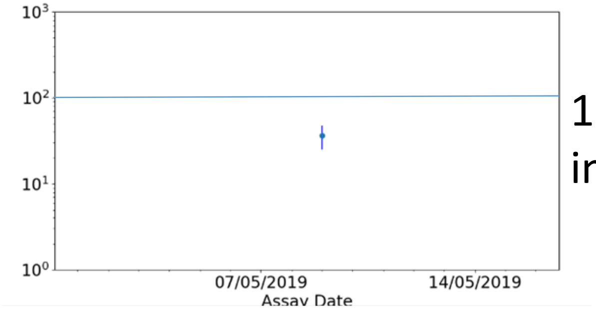


Recent assays





413±123.9 Rn atoms
in 600 L of UPW



1185±355 Rn atoms
in 640 L of UPW

Summary and outlook

- Water purification developed by SNO is performing well for SNOLAB experiments and the quality of the water is similar to SNO times
- HTiO system for SNO+ is being recommissioned and final tests are ongoing
- Radon assay system for SNO+ is commissioned and regular assays are resumed

Backup

Water purification (details of components)

- Softeners: two 0.14m3 bottles containing strong base Purolite C100-E cation exchange resin
- Reverse osmosis: Tweleve spiral-wound thin film composite (polyamide on polysulfone) membranes
- Ion Exchange: two sets of six bottles containing 0.1m3 of purolite nuclear grate NWR-37 mixed (cation and anion) bed resins