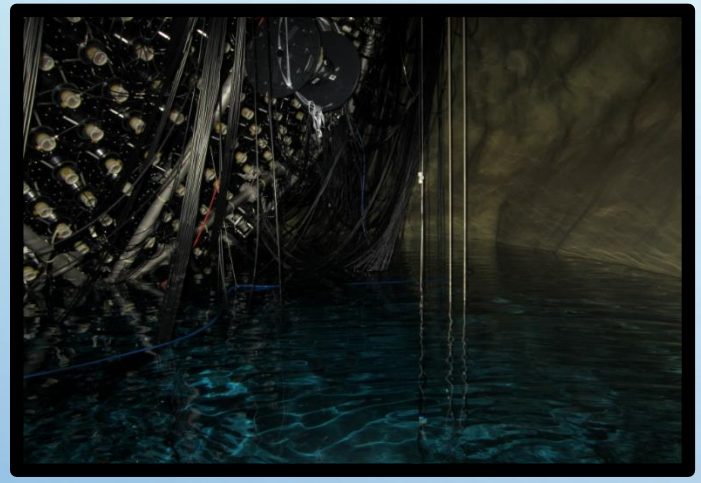


# SNO+ STATUS

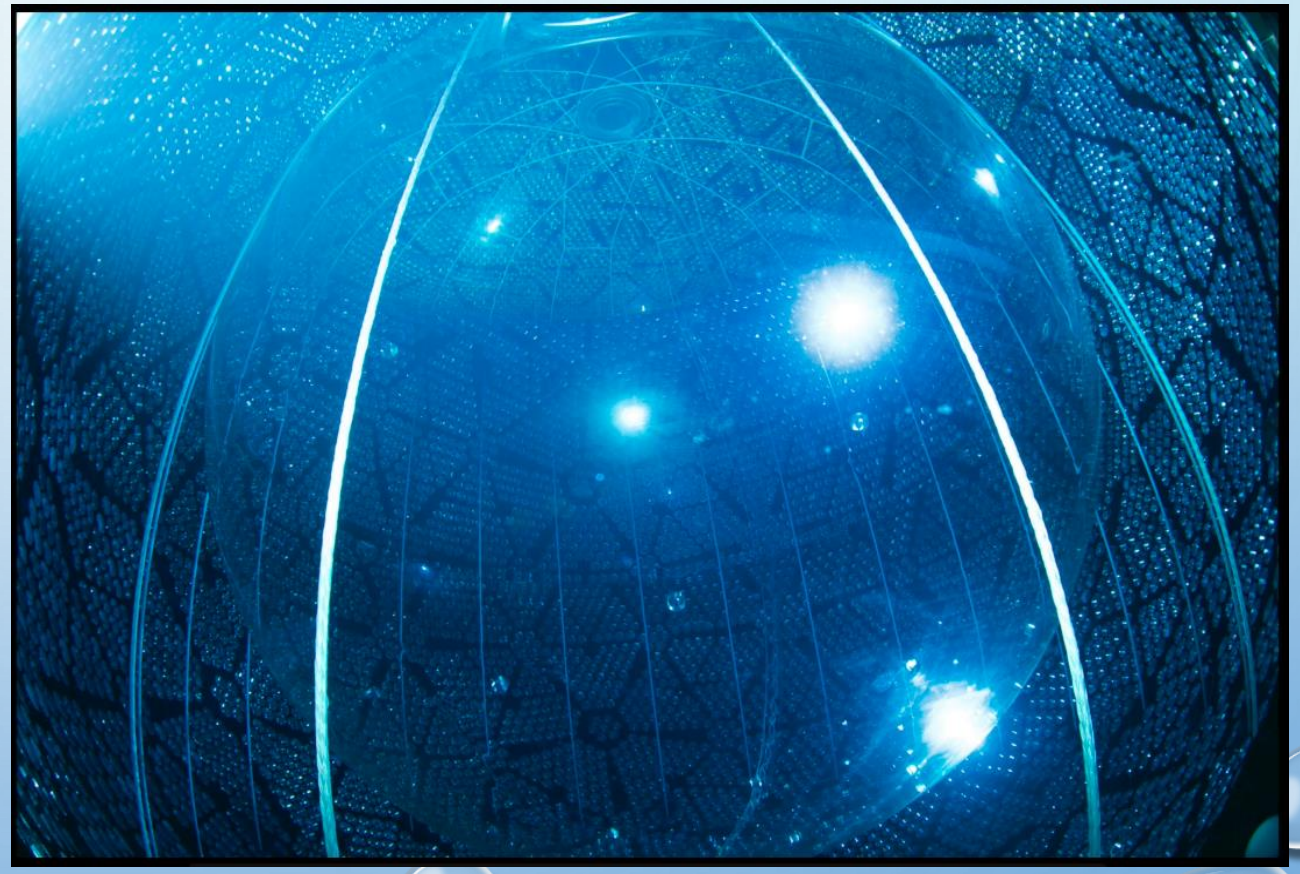
CHRISTINE KRAUS FOR THE SNO+ COLLABORATION

LAURENTIAN UNIVERSITY

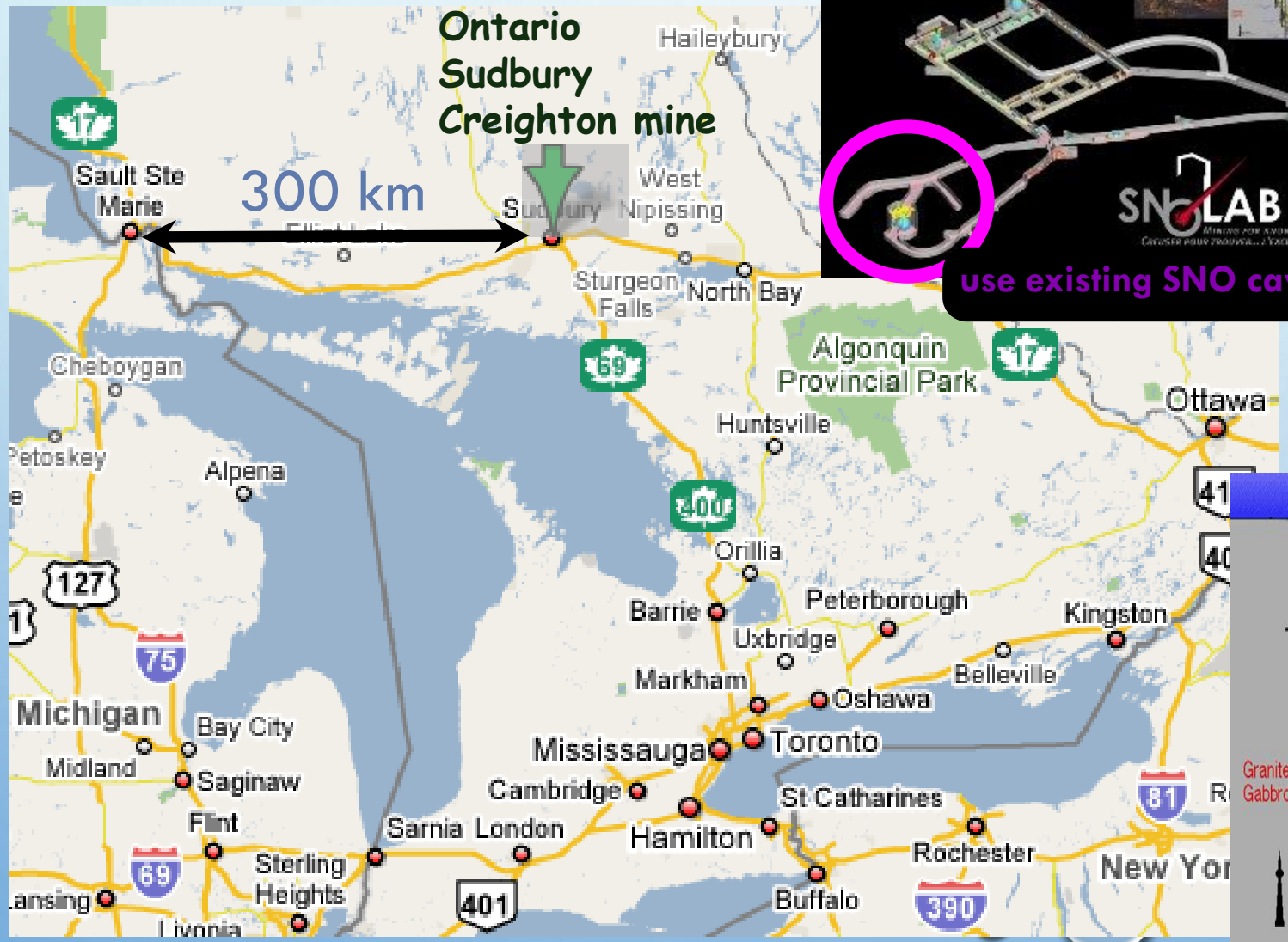
CAP 2016 OTTAWA, JUNE 13TH 2016

# OUTLINE

- SNO+ INTRODUCTION
- SNO+ DOUBLE BETA DECAY PHASE
- ACCOMPLISHMENTS LAST YEAR
- OUTLOOK
- SUMMARY

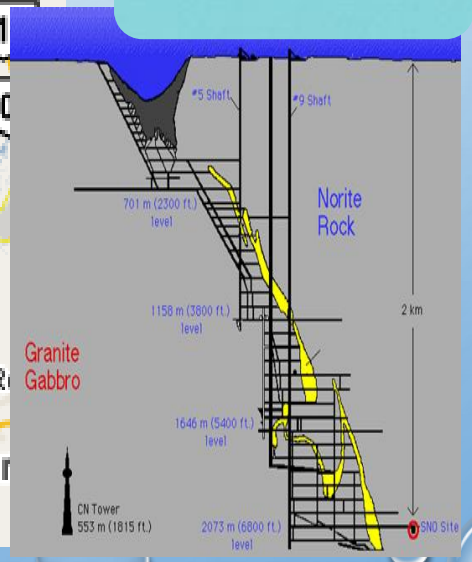


# SNO+ IS LOCATED AT SNOLAB

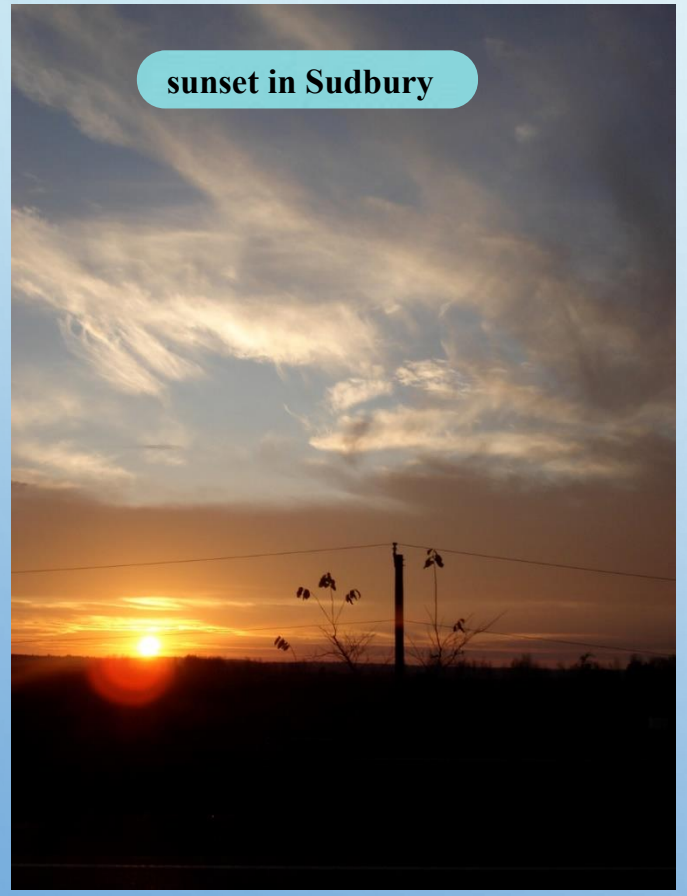


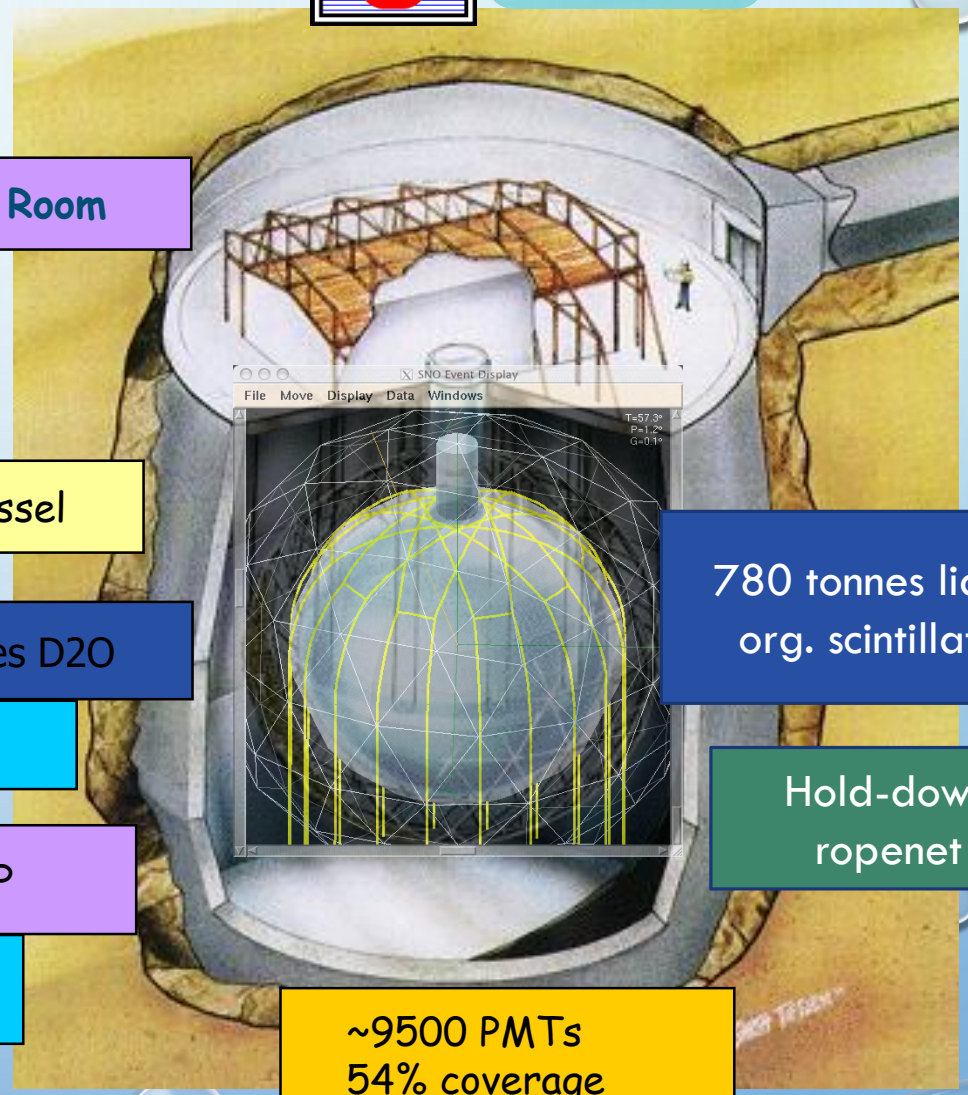


2 km or
6000 m.w.e.



# SNO DETECTOR (INHERITED)




DCR = Deck Clean Room

12 m acrylic vessel

1000 tonnes D2O

1700 t H2O (inner)

18 m PSUP

5300 t H2O (outer)

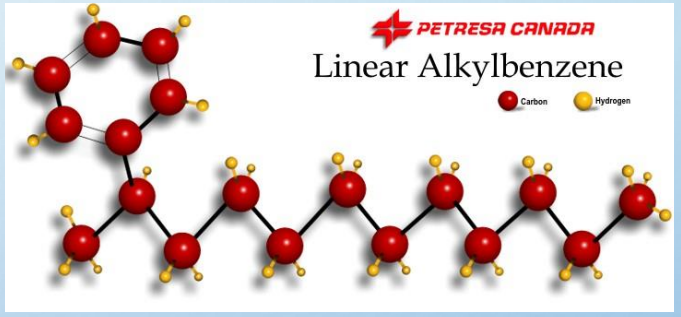
780 tonnes liquid org. scintillator

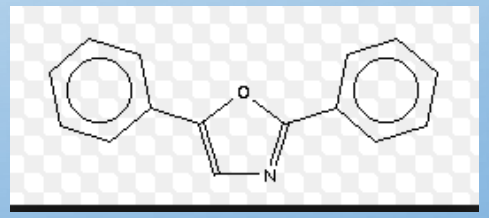
Hold-down ropenet

~9500 PMTs
54% coverage

# LIQUID SCINTILLATOR

- DETECTOR TO BE FILLED WITH 780 TONNES OF ORGANIC LIQUID SCINTILLATOR (LS)
- MORE LIGHT YIELD THAN ČERENKOV , AROUND 400 P.E./MEV, ENABLING LOWER ENERGY THRESHOLD
- LINEAR ALKYLBENZENE (LAB)
  - HIGH LIGHT YIELD
  - LONG ATTENUATION LENGTH
  - SAFE: HIGH FLASH POINT AND LOW TOXICITY
  - MORE AFFORDABLE THAN OTHER SCINTILLATORS
- ADD WAVELENGTH SHIFTER
  - INITIAL PLAN: 2G/L PPO FLUOR



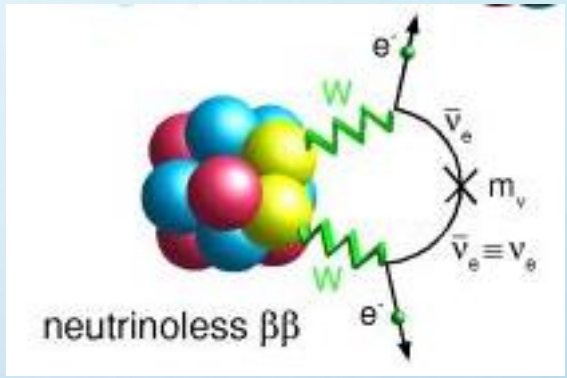



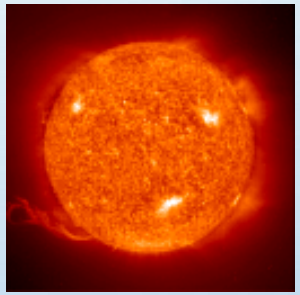
# SNO+ BROAD PHYSICS PROGRAM

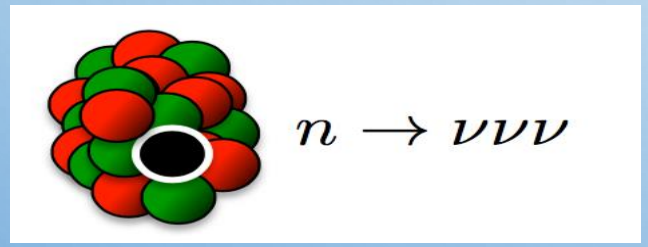
- **NEUTRINOLESS DOUBLE BETA DECAY – SCINTILLATOR LOADED WITH $^{130}$TE**

  (0.5% LOADING ~ 1300 KG OF $^{130}$TE)
- GEO- AND REACTOR NEUTRINOS
- SUPERNOVA NEUTRINOS
- SOLAR NEUTRINOS (PEP, CNO, LOW $^{8}$B)
- NUCLEON DECAY (WATER PHASE 2016)

**Multi-purpose detector**




- Review paper released this year (S. Andringa, E. Arushanova, S. Asahi, et al., "Current Status and Future Prospects of the SNO+ Experiment," *Advances in High Energy Physics*, vol. 2016, Article ID 6194250, 21 pages, 2016. doi:10.1155/2016/6194250)

# TOWARDS TE LOADED DETECTOR

- NOW – WATERFILL – EXPECT COMPLETED BY END OF SUMMER

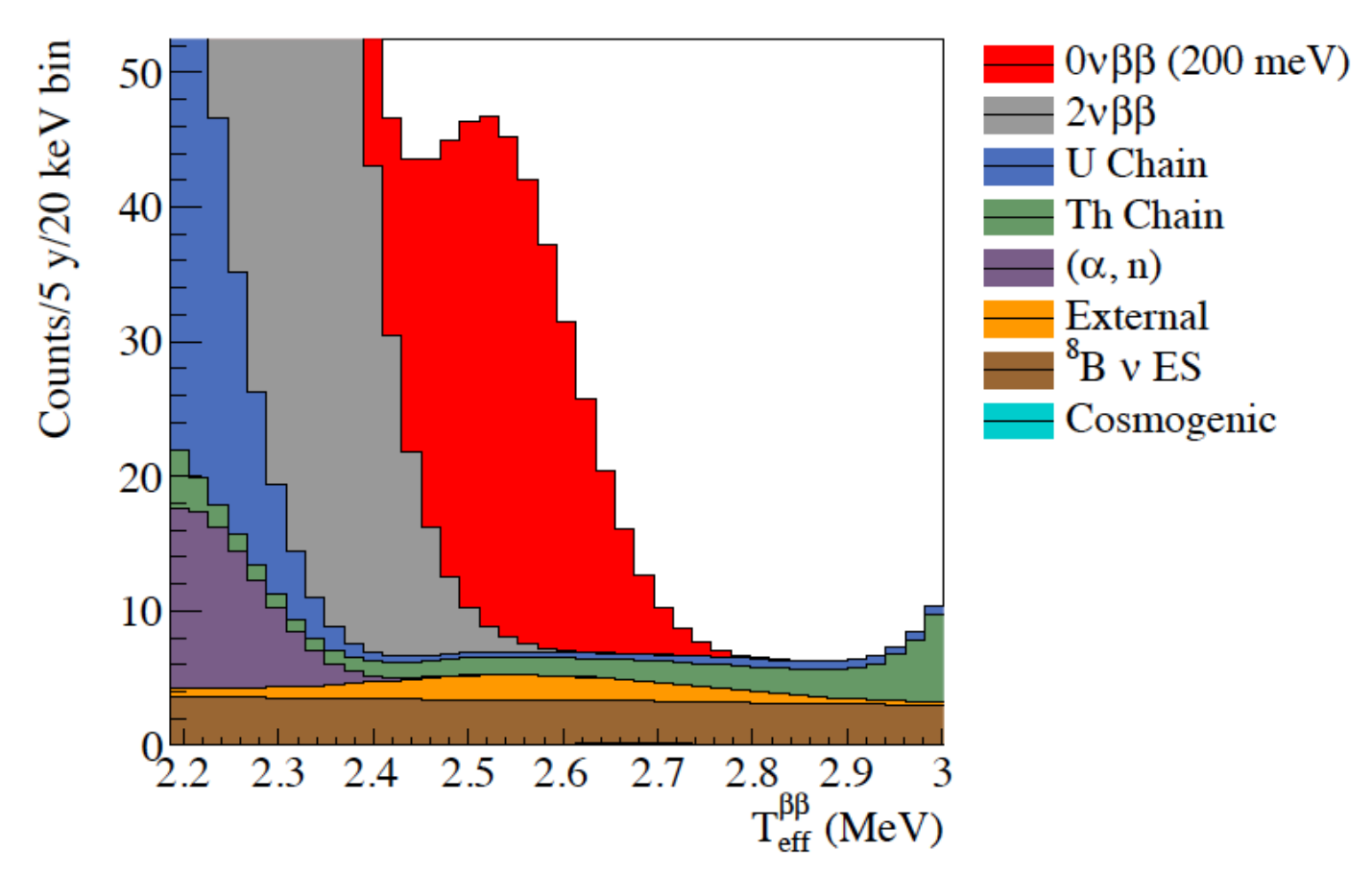
- EXTERNAL BACKGROUNDS AND INVISIBLE NUCLEON DECAY MEASUREMENT WITH WATER FILLED DETECTOR
- INTERNAL BACKGROUND WITH PURE SCINTILLATOR FILLED DETECTOR (2017)
- TE LOADING IN 2017 – DOUBLE BETA PHASE STARTS LATE 2017/EARLY 2018

Scintillator Cocktail:
LAB + PPO
Telluric Acid (TeA)
1,2 butanediol
Ultrapure water (during synthesis)

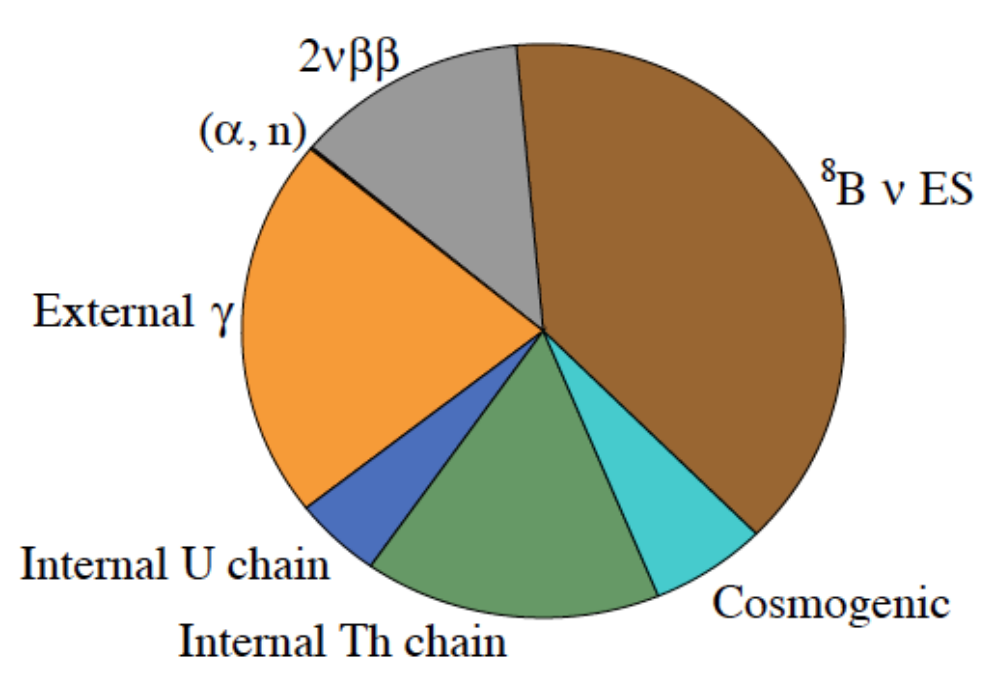
# SNO+ WITH TE LOADED SCINTILLATOR

- VERY LOW BACKGROUNDS ARE ACHIEVABLE IN LARGE LIQUID SCINTILLATOR DETECTORS
  - DOMINANT BACKGROUND FROM SOLAR NEUTRINOS!
  - SENSITIVITY SCALES DIRECTLY WITH LOADING
- TWO MAIN CLASSES OF TE INTRINSIC BACKGROUND:
  - DECAY CHAINS OF LONG-LIVED RADIOISOTOPES
    - NEED $10^{-14}$-$10^{-15}$G/G $^{238}$U, $^{232}$TH, "RAW" TELLURIUM HAS ~$10^{-12}$G/G
  - SOME TE COSMOGENICS HAVE LONGISH HALF-LIVES AND DECAYS THAT OVERLAP THE 0$\nu$BB ENERGY REGION (E.G. $^{60}$CO, $^{22}$NA, $^{102}$RH, $^{110M}$AG)
  - V. LOZZA AND J. PETZOLDT, "*COSMOGENIC ACTIVATION OF A NATURAL TELLURIUM TARGET*", ASTROPARTICLE PHYSICS 61 (2015) 62-71
- NEED A PURIFICATION TECHNIQUE THAT SEPARATES OTHER METALS FROM TELLURIUM AT THE $10^4$-$10^6$ LEVEL
  - ADDITIONAL SAFETY FACTOR FROM UNDERGROUND TEA STORAGE AND PURIFICATION

Estimated spectrum after 5 years of running




Background budget – 13.4 counts per year




ROI, fiducial volume cut at 3.5 m radius, background coincidence rejection, modest light yield 200 NHIT per MeV

$T_{1/2}$ > 1.96e26 yr (90% CL)

$m_{\beta\beta}$ < 36-90 meV

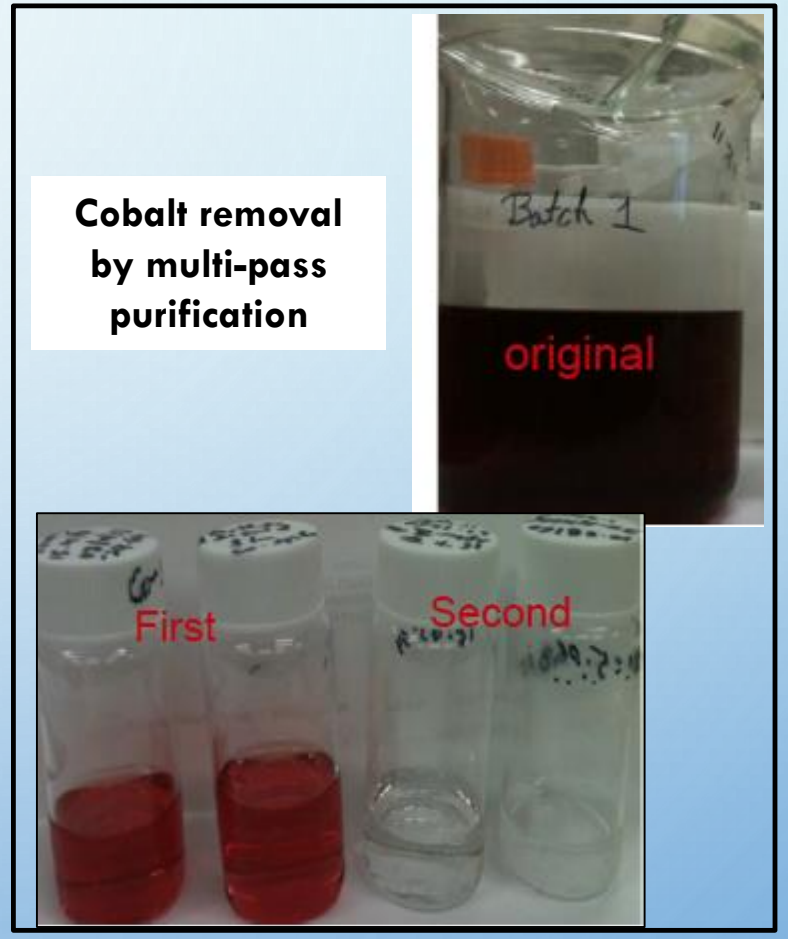
# PH SELECTIVE TELLURIC ACID RE-CRYSTALLIZATION

- TELLURIC ACID OBEYS THE FOLLOWING EQUILIBRIUM:

$$Te(OH)_6 \leftrightarrow Te(OH)_5O^- + H^+$$

Insoluble — Soluble

  - PH DETERMINES THE EQUILIBRIUM STATE
- PURIFICATION BASICS:
  1. DISSOLVE TELLURIC ACID IN WATER AND FILTER IT
     - REMOVES WATER INSOLUBLE IMPURITIES
  2. ADD NITRIC ACID TO FORCE THE TELLURIC ACID TO RECRYSTALLIZE/PRECIPITATE, PUMP AWAY THE LIQUID, RINSE
     - REMOVES ACID SOLUBLE IMPURITIES
- BY "TUNING" THE PROCESS PH'S, THIS CAN BE QUITE SPECIFIC TO TELLURIC ACID – MOST OTHER CHEMICALS ARE REMOVED WITH HIGH EFFICIENCY



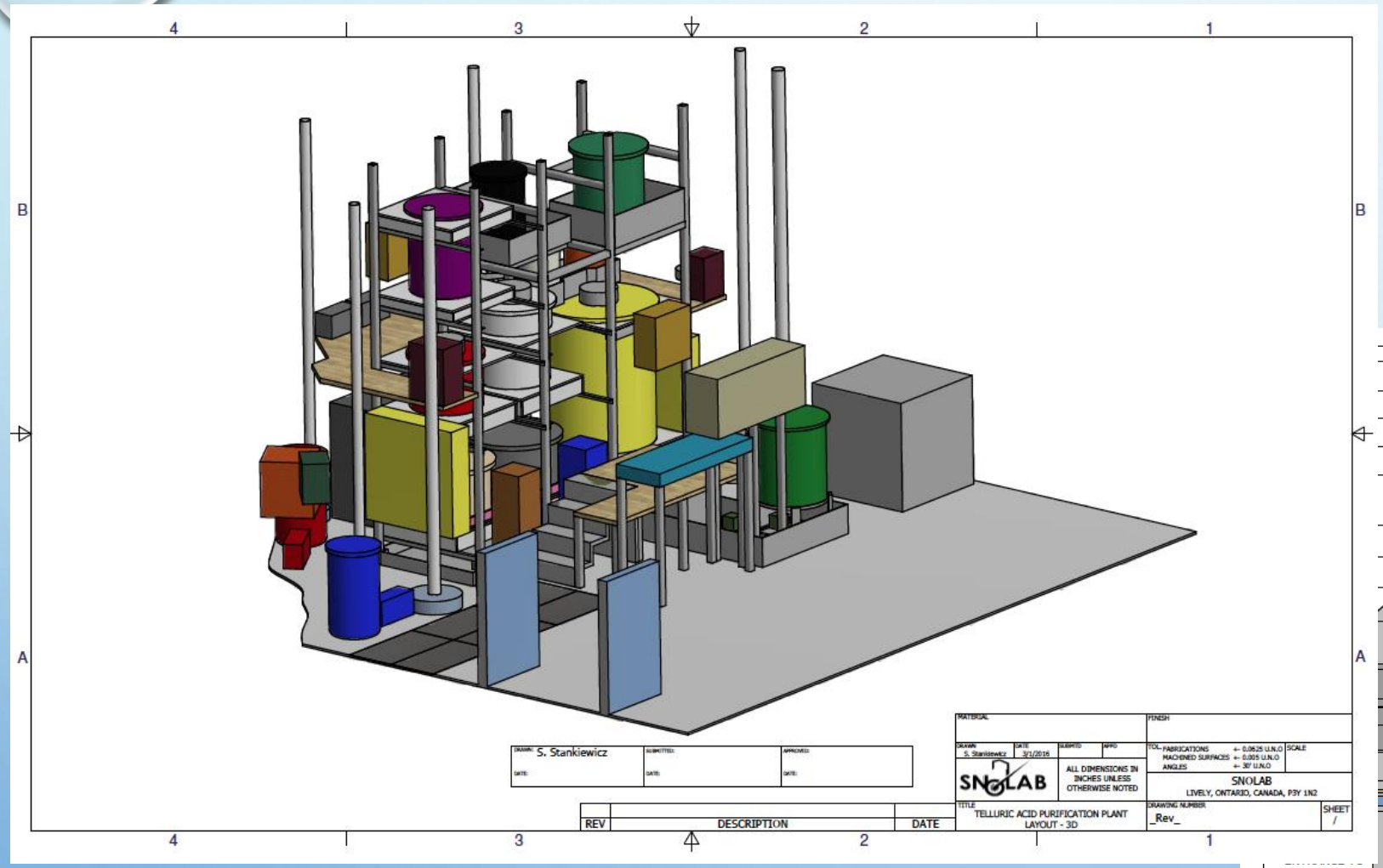

See S. Hans et. al. NIM A **795**:132-139 (2015).

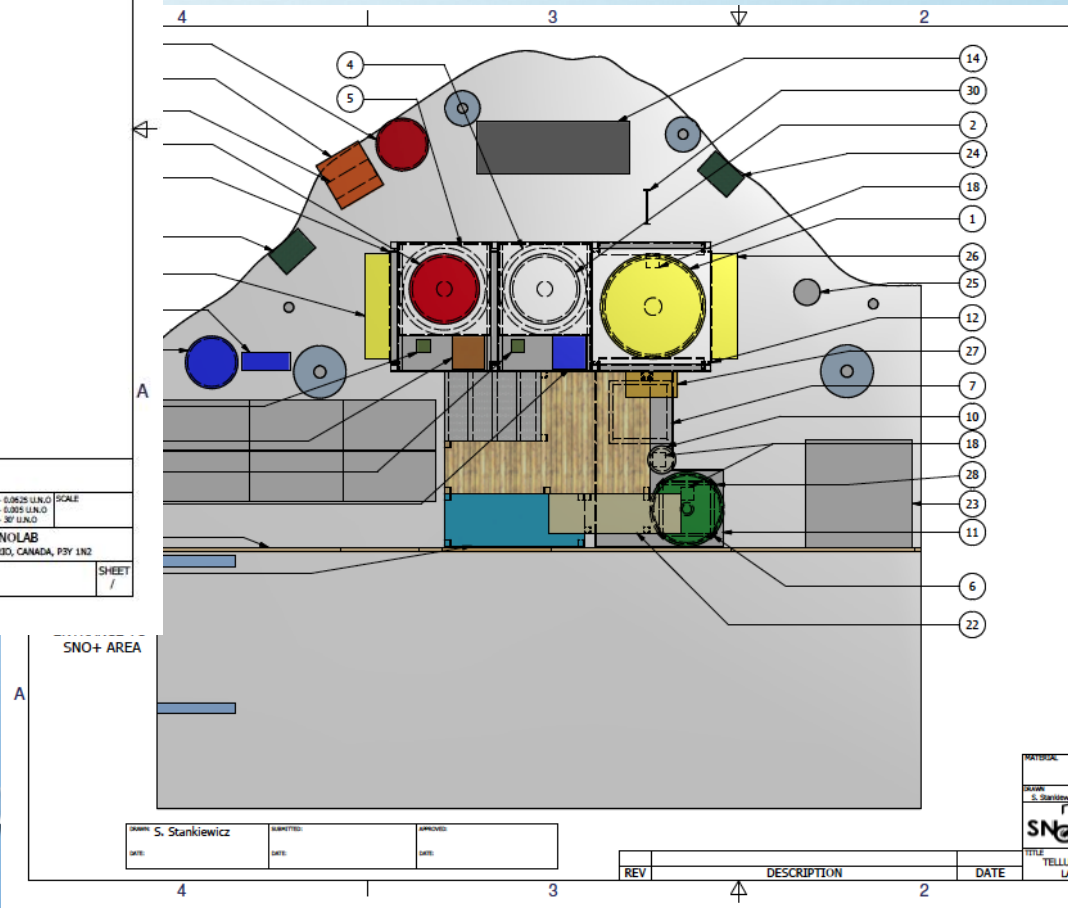
# MEASURED SINGLE PASS PURIFICATION FACTORS

| Element | Reduction Factors From Spike Tests | Non-spiked, before purification (ppb) | Non-spiked, after purification (ppb) |
|---|---|---|---|
| Sn | $>1.67\times10^2$ | 20 | <20 |
| Zr | $>2.78\times10^2$ | 70 | <10 |
| Ti | | 40 | <10 |
| Co | $(1.62\pm0.34)\times10^3$ | <10 | <10 |
| Mn | | 150 | <5 |
| Fe | | 40 | <30 |
| Ag | $>2.78\times10^2$ | <10 | <10 |
| Y | $>2.78\times10^2$ | <10 | <10 |
| Sc | $>1.65\times10^2$ | <10 | <10 |
| Sb | $>2.43\times10^2$ | 20 | <20 |
| Th | $(3.90\pm0.19)\times10^2$ | <0.02 | <0.02 |
| Ra | $(3.97\pm0.20)\times10^2$ | | |
| Ba | | 1400 | <5 |
| Pb | $(2.99\pm0.22)\times10^2$ | 440 | <3 |
| Bi | $(3.48\pm0.81)\times10^2$ | 300 | <10 |
| U | $(3.90\pm0.19)\times10^2$ | <0.02 | <0.02 |

***Two-pass purification (with a thermal recrystallization step to remove nitric acid) is expected to meet our purity goals.***

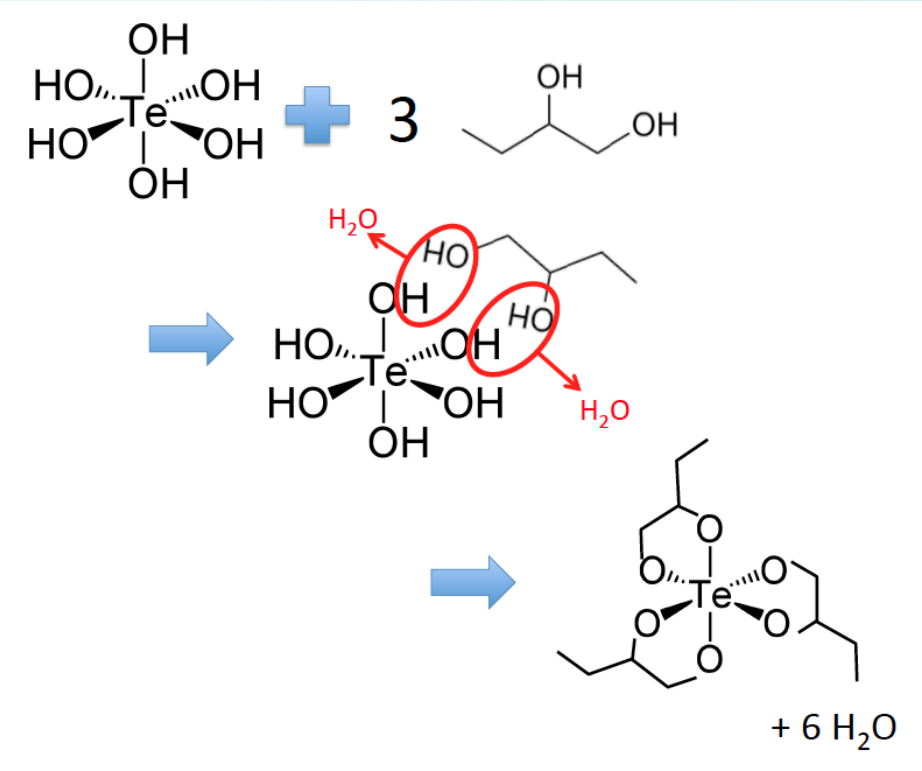
# PLANT LAYOUT – LOWER LEVEL



# TELLURIUM LOADING – NEW APPROACH

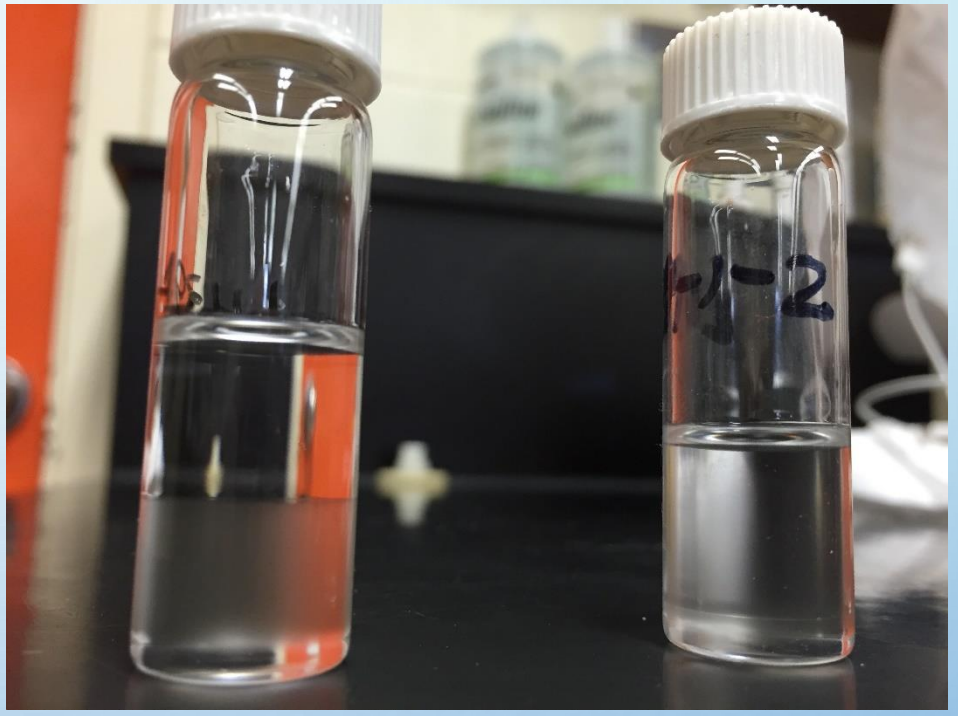
- LATE 2014:
  - NEED A "NEW" METHOD OF SUSPENDING TELLURIUM IN THE LIQUID SCINTILLATOR THAT IS CLEAN, STABLE, AND GIVES GOOD OPTICS
  - SET TARGET OF DEFINING LOADING METHOD BY END 2015
- JANUARY 2016: TELLURIUM-BUTANEDIOL TECHNIQUE SELECTED




*"Condensation reaction" produces organometallic compound miscible in LAB.*

# PILOT PLANT AT LAURENTIAN

Setup past week – Queen's and LU team

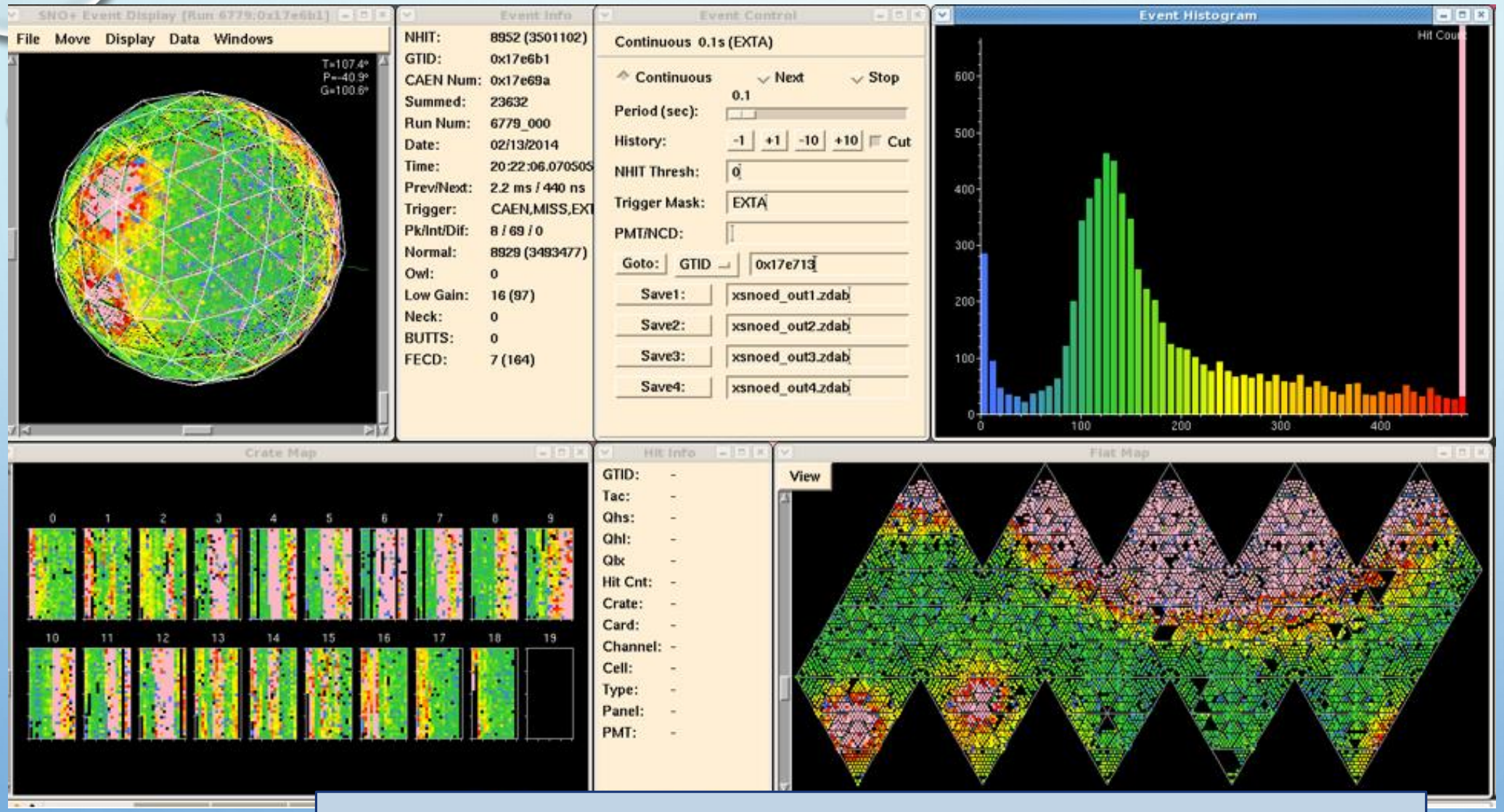


Successfully produced a 150g batch

# ACCOMPLISHMENTS LAST YEAR

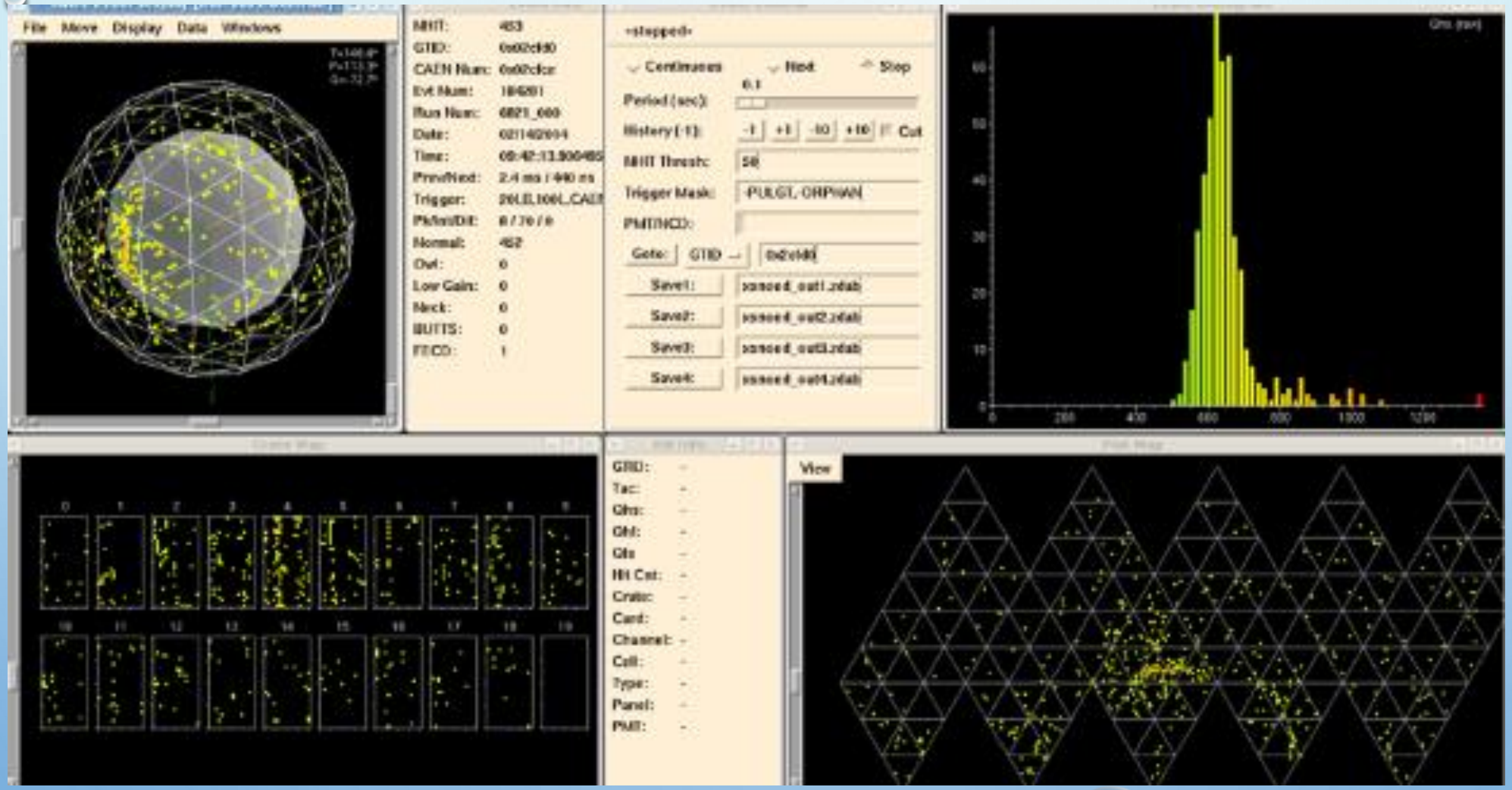
- DETECTOR – DAQ DEVELOPMENT AND TESTING — ERICA CADEN (TUESDAY MORNING)
- SCINTILLATOR PLANT – WATER COMMISSIONING — RICHARD FORD (TUESDAY MORNING)
- ASSAY SYSTEMS DEVELOPMENT — JANET RUMLESKIE (THIS SESSION)
- CALIBRATION – GAS BOARD FOR UI — ZACK BARNARD (POSTER)
- COMPLETE TEST OF HOLD-DOWN ROPE SYSTEM TO FULL LOAD
- LOCATE AND FIX CAVITY LEAKS
- INSTALL CALIBRATION HARDWARE COMPONENTS (UI, SLIDING FLOOR, ETC.)

# FIBER DATA



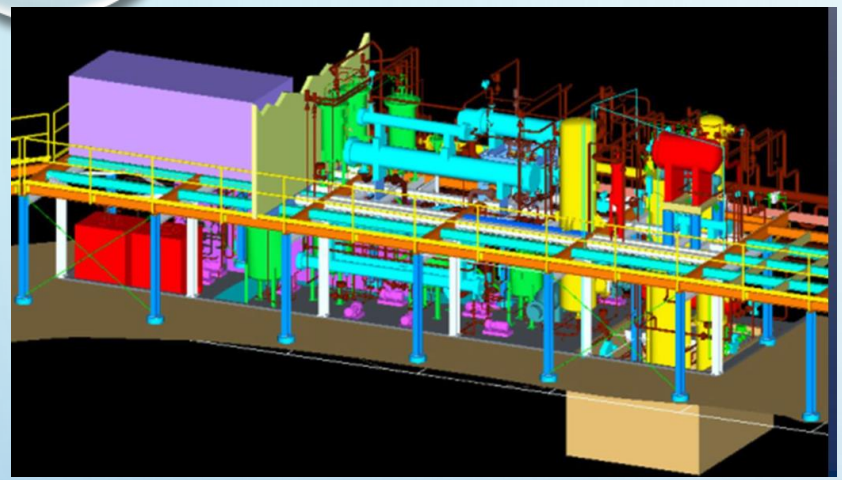

**11.2 million events total for timing calibration**

# MUON




See: Commissioning SNO+ detector by Erica Caden (Detector Manager) – Tuesday T1-5

# SCINTILLATOR PLANT



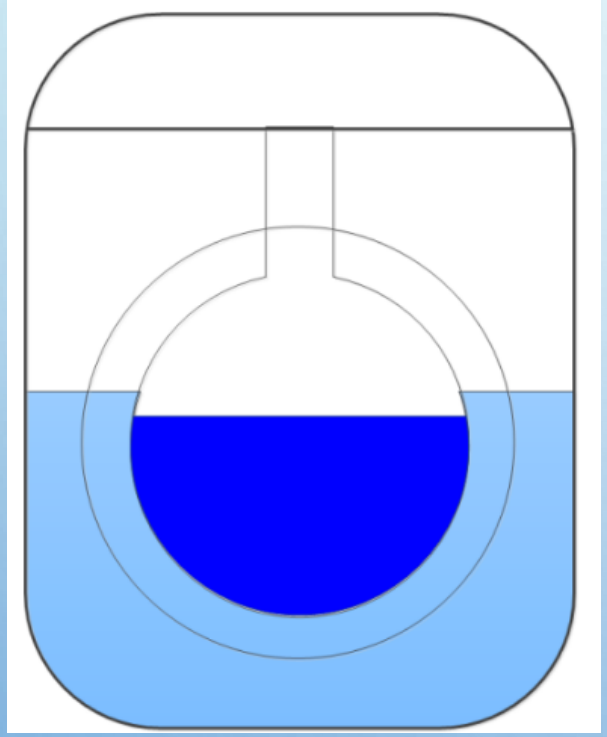
He leak checking
And cleaning/passivation
Completed

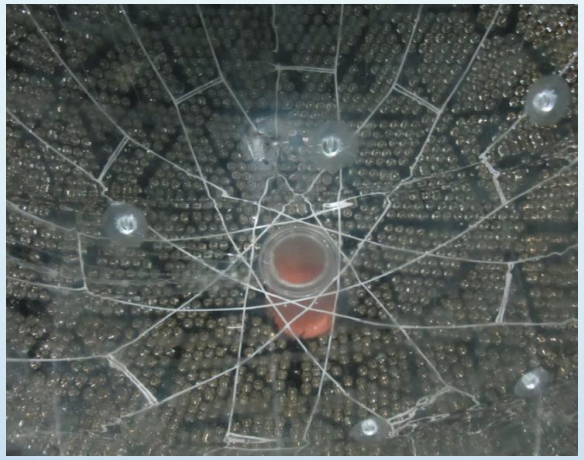
1 mille of pipes

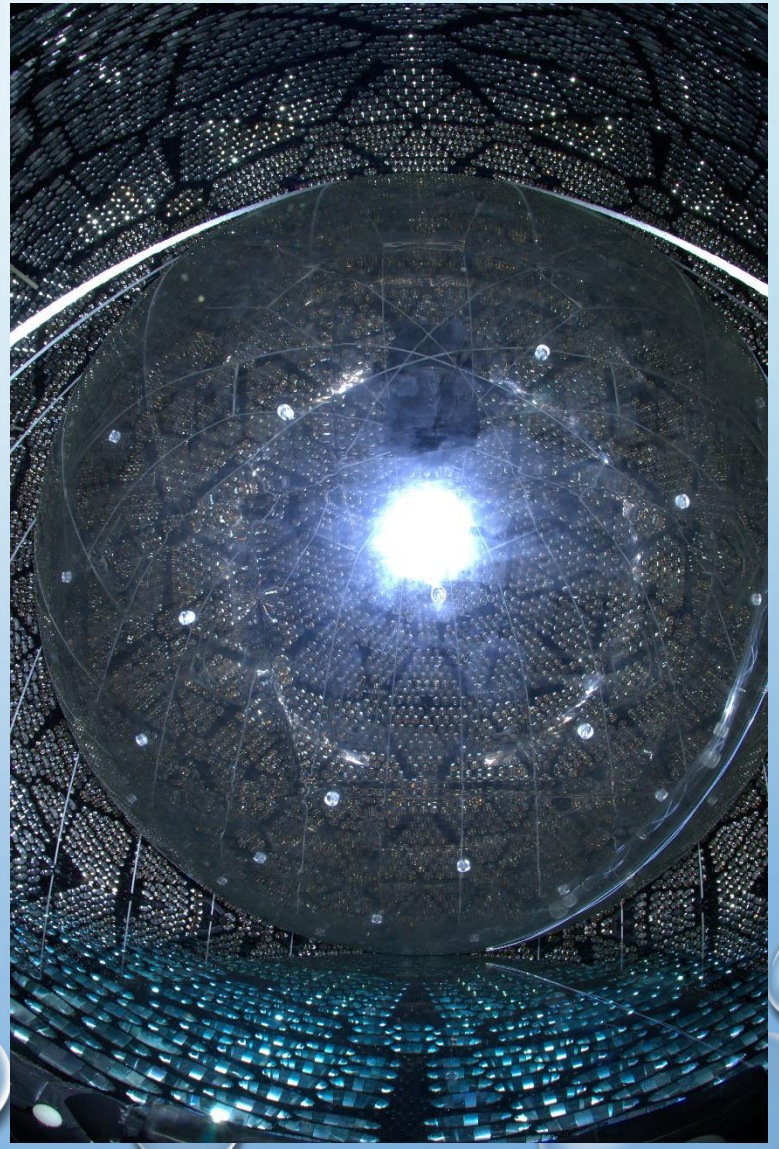


See: A Scintillator Purification Plant and Fluid Handling System for SNO+ by Richard Ford – Tuesday T1-5

# ROPENET FULL LOAD TEST (FTB)

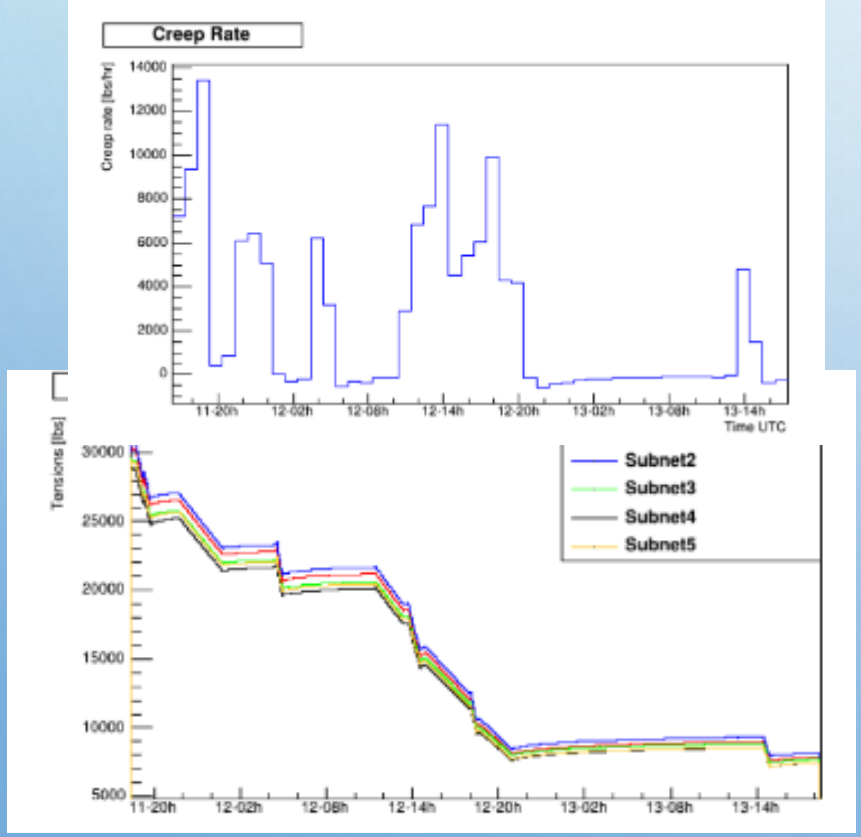


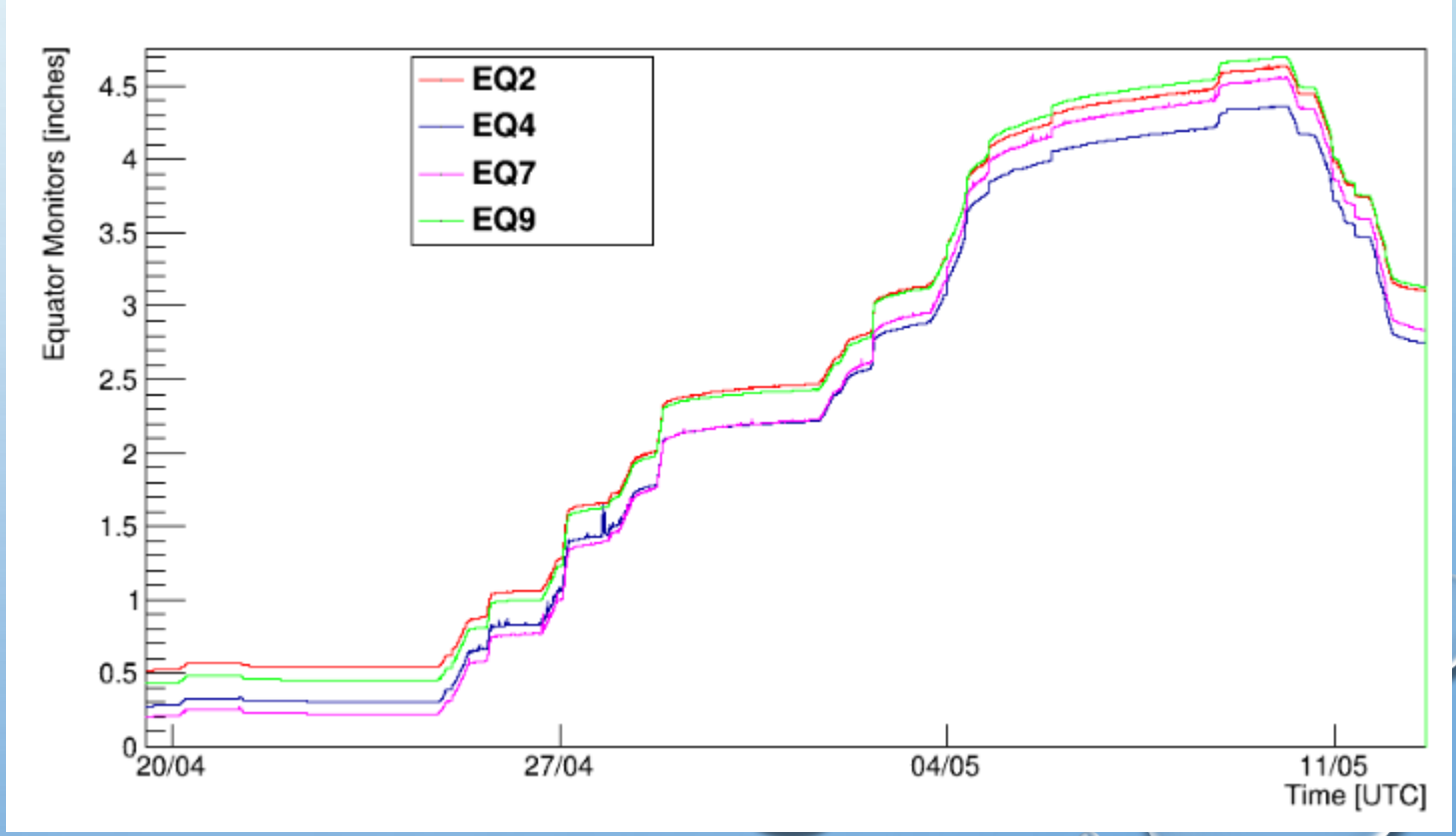




# APRIL 25TH TO MAY 13TH 2016

- RAISE CAVITY WATER LEVEL FROM 36 TO 40 FEET, WHILE AV WATER LEVEL STAYS CONSTANT
- RAISE IN 5 STEPS TO FULL LOAD OF 284 000 LBS
- ROPE NET BEHAVES AS EXPECTED – SUCCESSFUL TEST



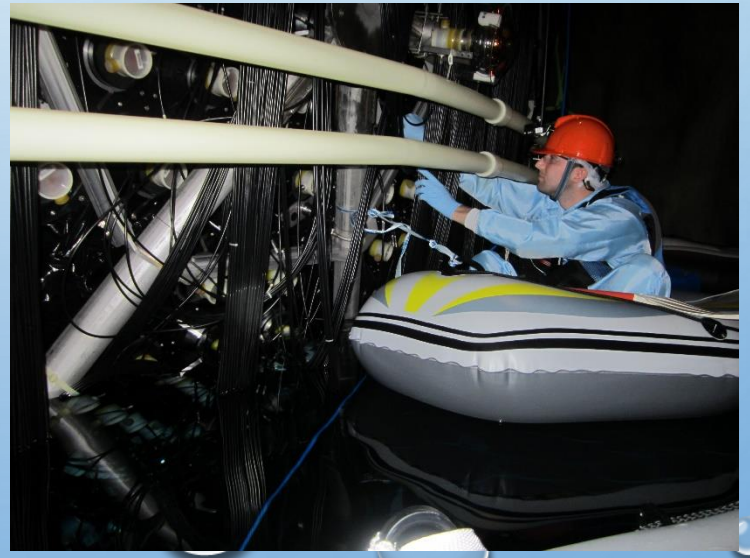



# FIBER INSTALLATION

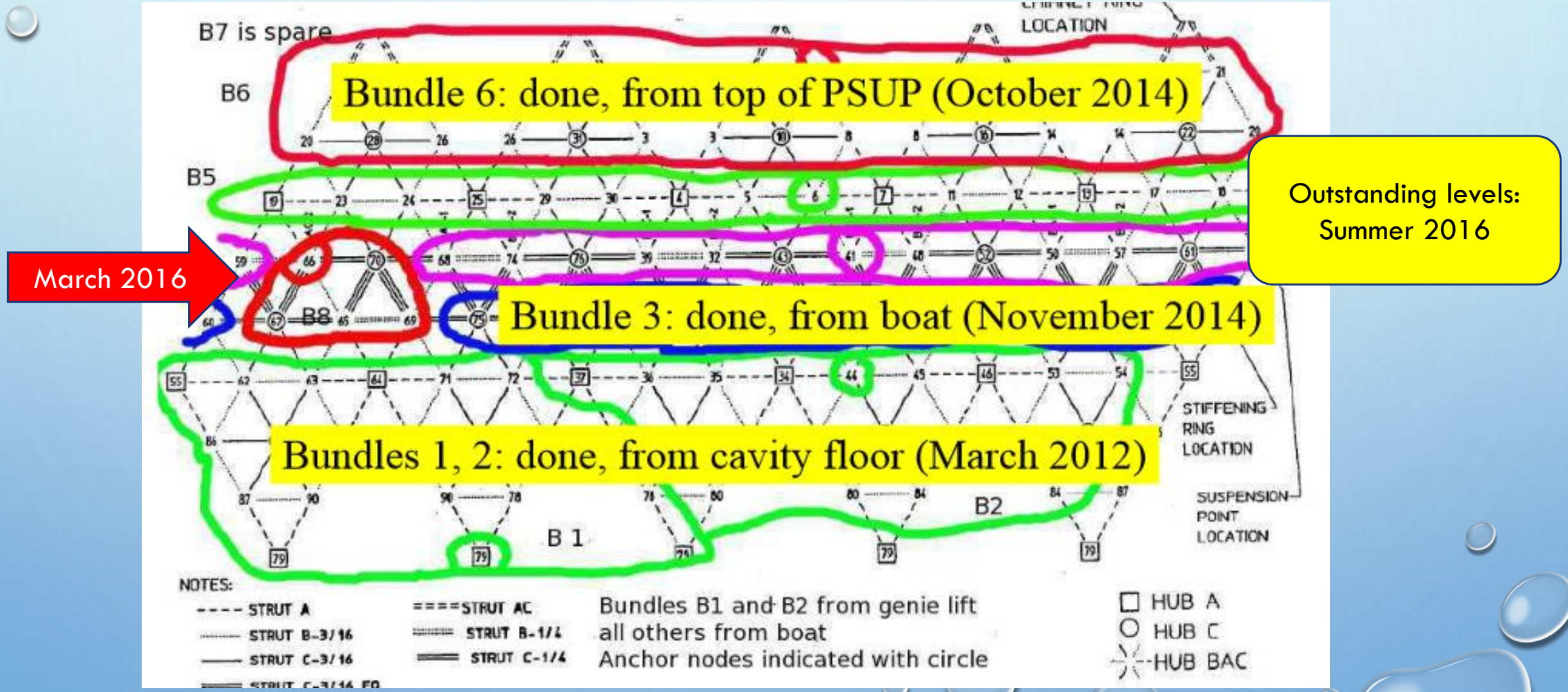
Upper PSUP

From a boat

- UPPER PSUP COMPLETE
- LEVEL BELOW EQUATOR COMPLETE
  - **> 2/3 COMPLETE**
  - COMPLETED LAYER BELOW EQUATOR
  - REMAINING LAYERS ABOVE EQUATOR (2)



# NEXT STEPS – FIBER INSTALLATION



# PMT REPAIRS

- DEVELOPED AT QUEEN'S (BELOW EQUATOR) --- 220 PMTS **DONE**
- ACTIVE FACILITY AT LAURENTIAN (UPPER PSUP) --- 150 PMTS **DONE**
- PHILOSOPHY: DO WHAT WE CAN WITHOUT HOLDING UP WATER FILL
- **480** PMTS REMAINING DURING BOATING (WORKING ON 50 NOW)

Resources:

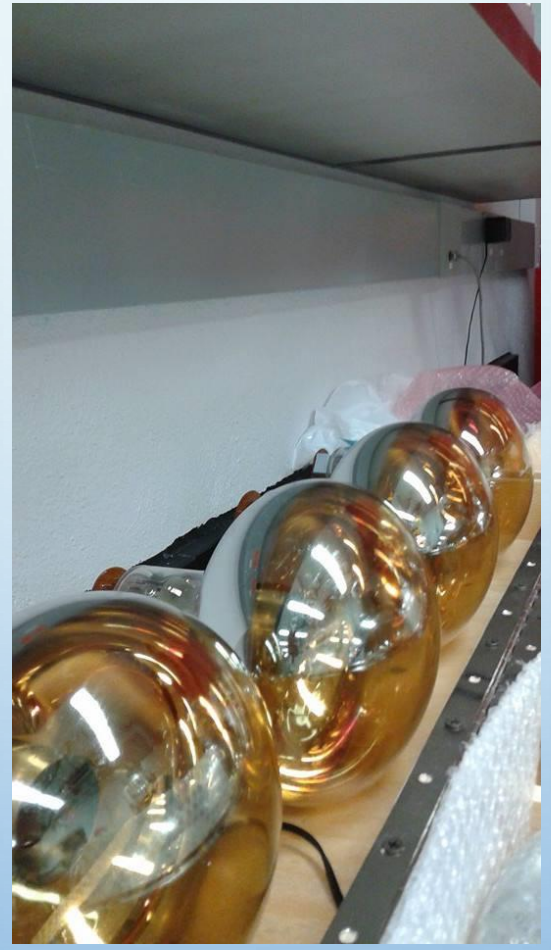
Boating team

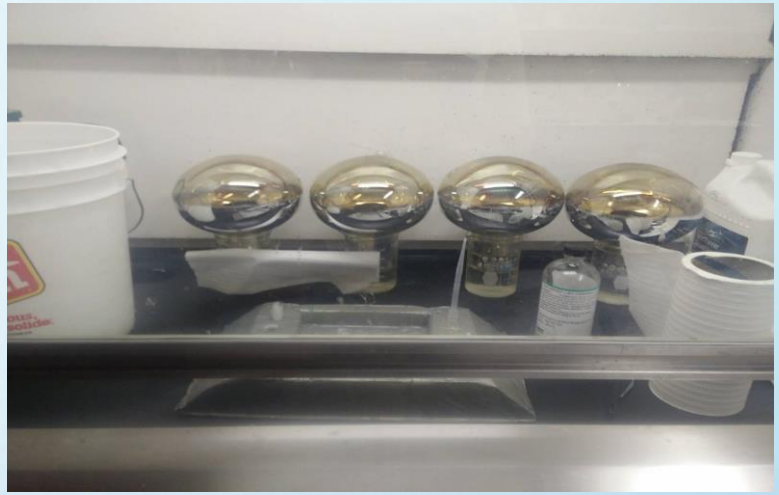
2 people repair team for 1 week per batch (10)

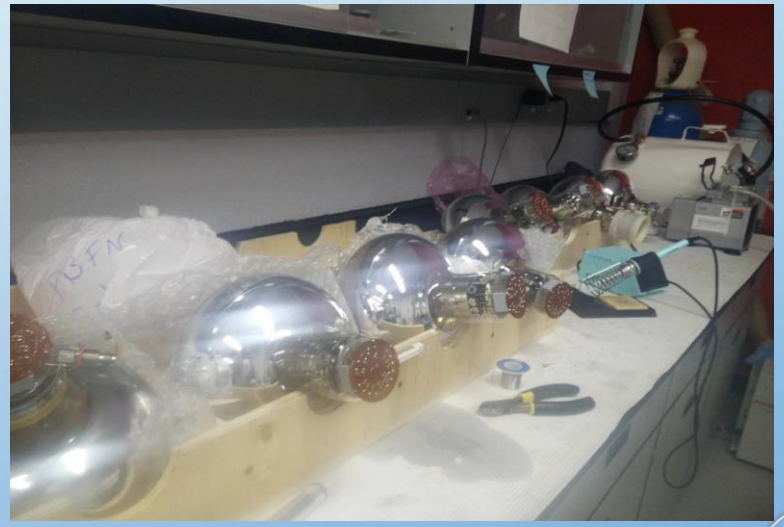
Testing high efficiency PMTs

# PMT REPAIRS

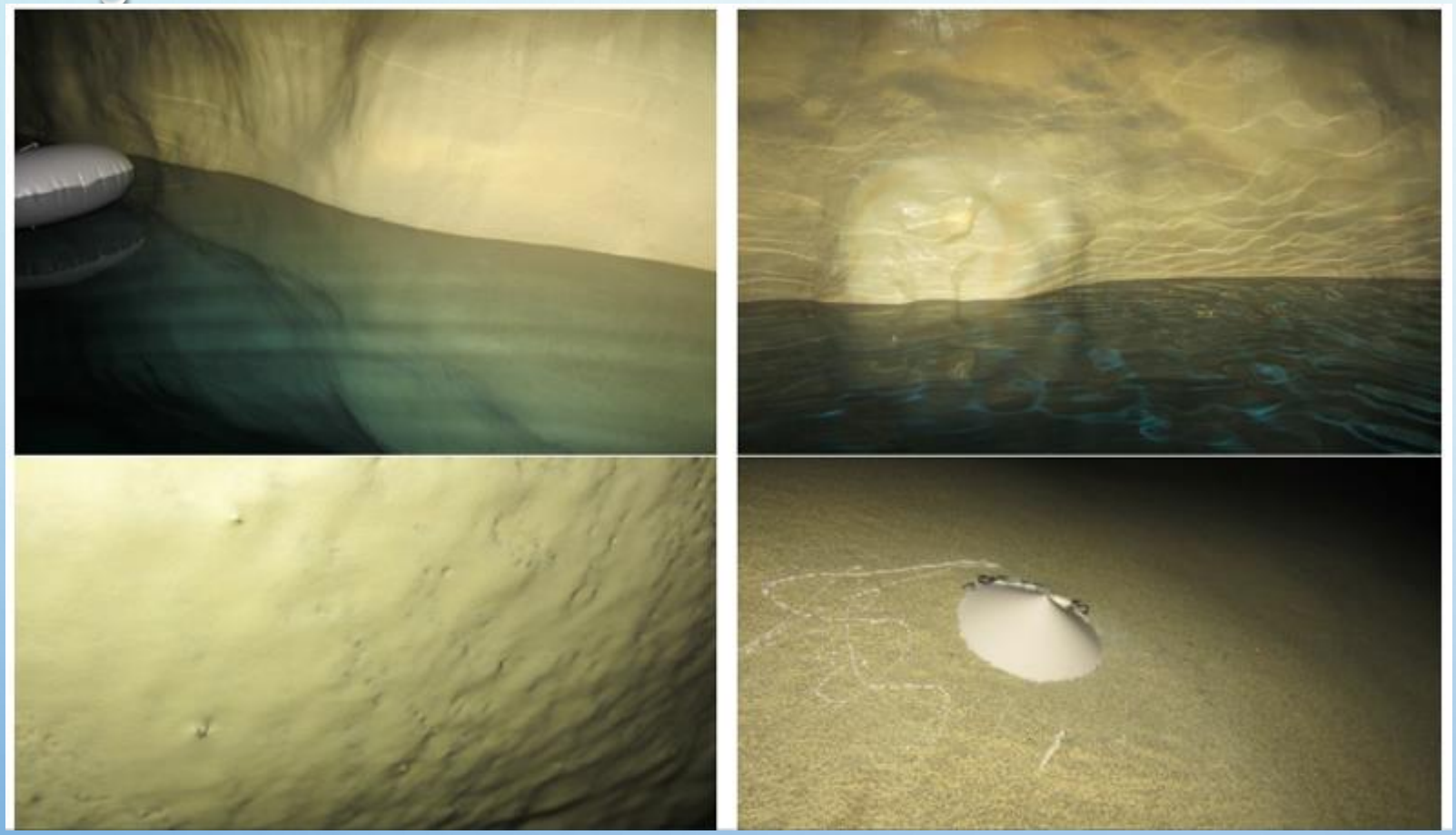
- Take “advantage” of the leak
- Resumed PMT repairs
- ~400 PMT's swapped so far.







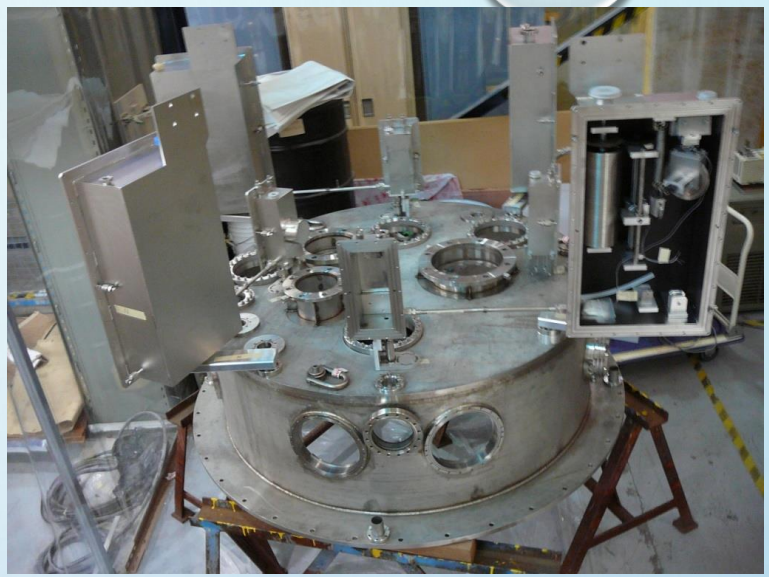
# CAVITY LINER INSPECTIONS



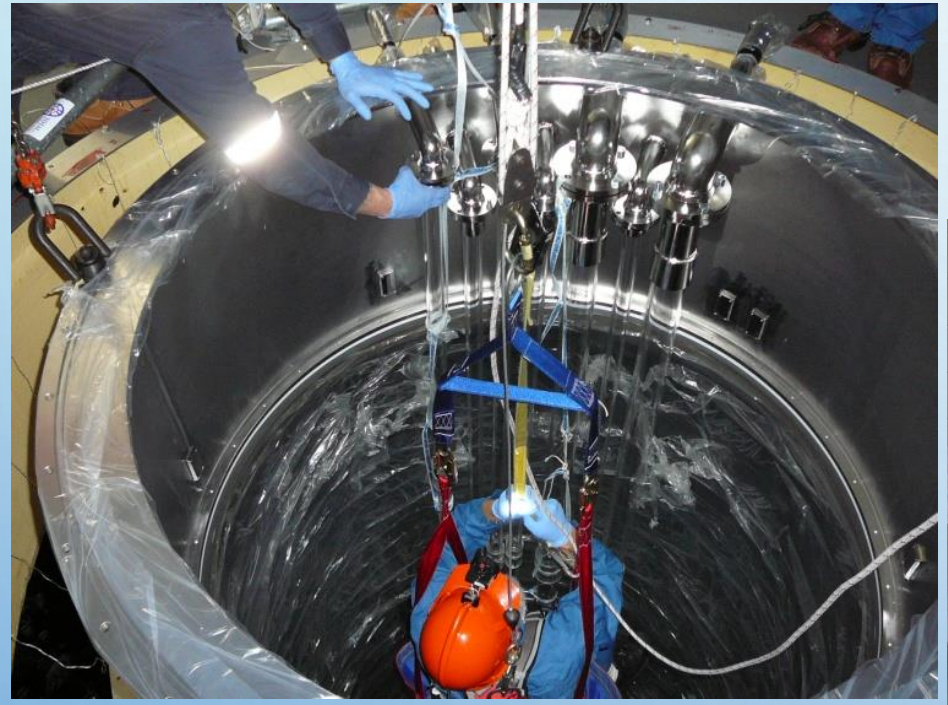
**Located and fixed several leaks in the cavity liner**
**Well developed methods and monitoring**

# CLOSING AV

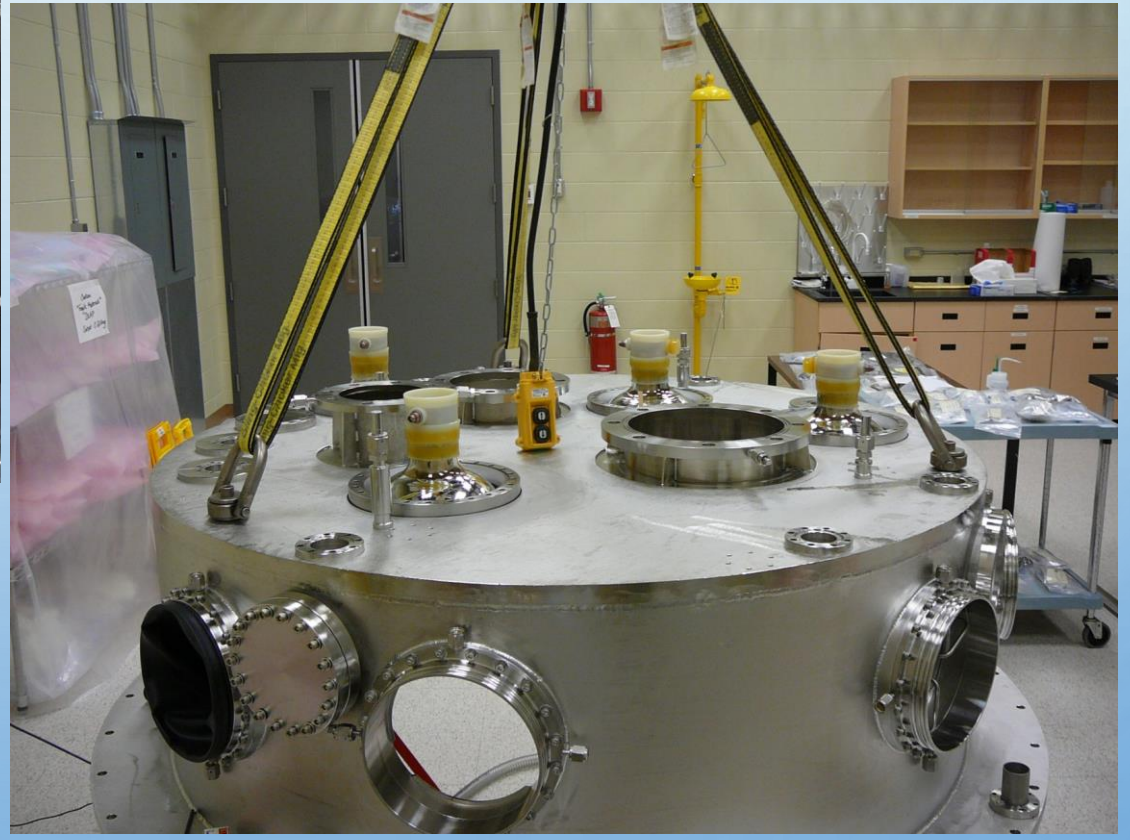
Upper half at Triumf



Lowe half – installed 2014



Upper half at SNOLAB



Upper half shipped UG
Ready to install

# SNO+ DATA TAKING

- COMPLETE WATERFILL AND DETECTOR COMMISSIONING THIS SUMMER
- WATER FILLED DATA – FALL 2016
- SCINTILLATOR PLANT LAB COMMISSIONING – FALL 2016
- SCINTILLATOR FILL AND PURE SCINTILLATOR DATA IN 2017
- TE PURIFICATION AND LOADING PROCESS – FALL 2017
- TE FILLED SCINTILLATOR DATA LATE 2017/EARLY 2018

Queen's University
Laurentian University
University of Alberta
TRIUMF
SNOLAB

University of Pennsylvania
University of Chicago
University of Washington
Armstrong Atlantic University
University of North Carolina
UC Berkeley and LBNL
UC Davis

Oxford University
Sussex University
Liverpool University
Queen Mary University
Lancaster University

LIP Lisboa and Coimbra

Dresden TU

UNAM


# Thank you