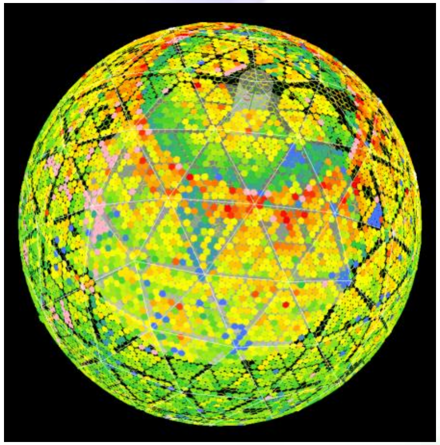
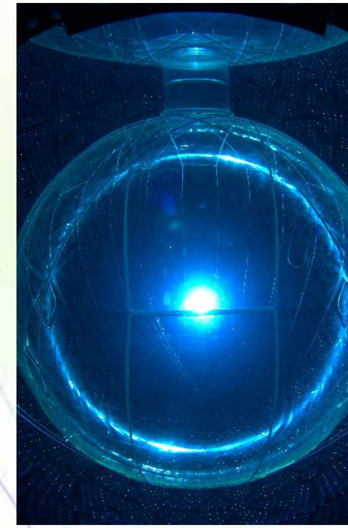


SNO+ experiment



IPP townhouse meeting during 2017 CAP
Sunday, May 28th 2017
Christine Kraus

Canada
Canada Research Chairs

LaurentianUniversity
UniversitéLaurentienne

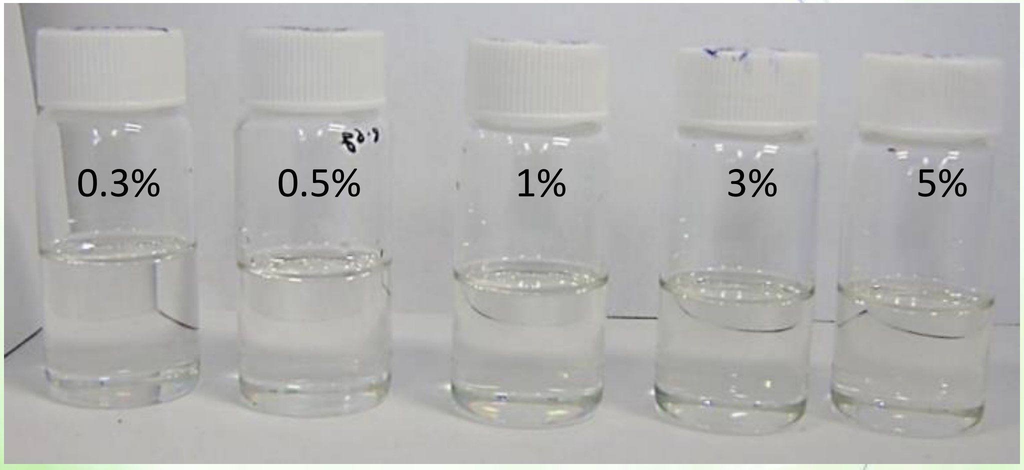
SNO+

Outline

- SNO+
- Highlights last year
- Water phase data taking
- Te loading

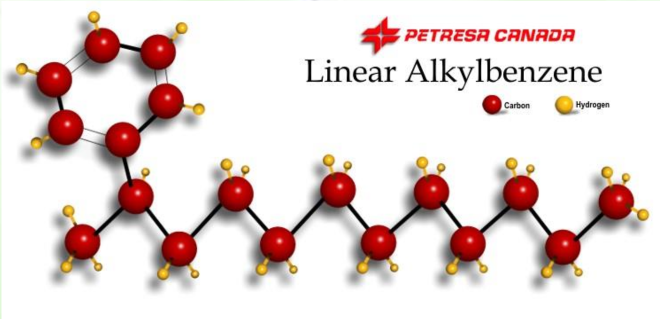
Several SNO+ talks/posters during CAP – Tu, We

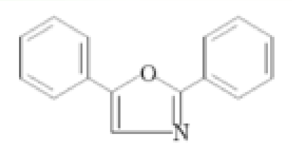
LAB scintillator with different Te loading levels

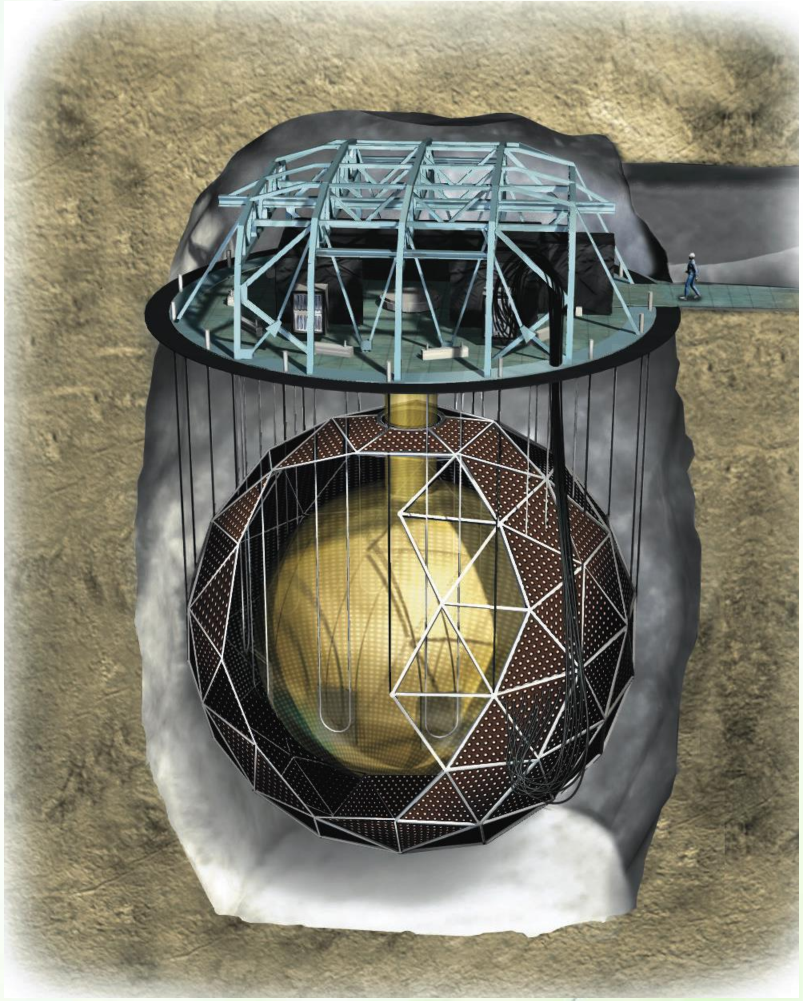


SNO+ experiment

- 780 tonnes of liquid scintillator as active volume
  - Can be loaded with double beta decay isotope
- ~9500 PMTs
- 1500 + 5300 tons ultra-pure water shielding
- 6800’ underground in SNOLAB

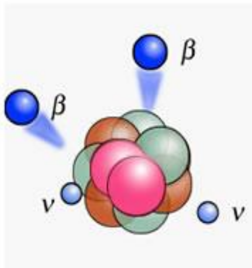


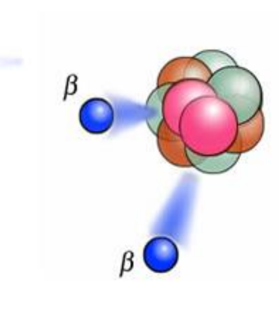




Organic scintillator Linear Alcyl Benzene (LAB) and PPO
Add 130Te and as loading for double beta phase

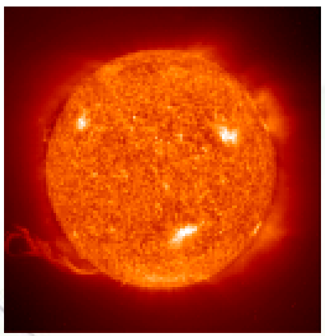
Physics goals - scintillator





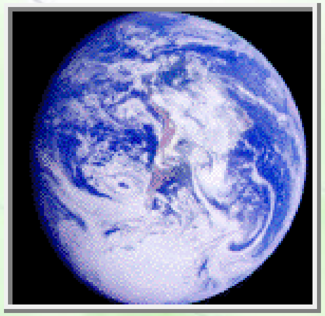
Neutrinoless Double Beta Decay

Low Energy Solar Neutrinos



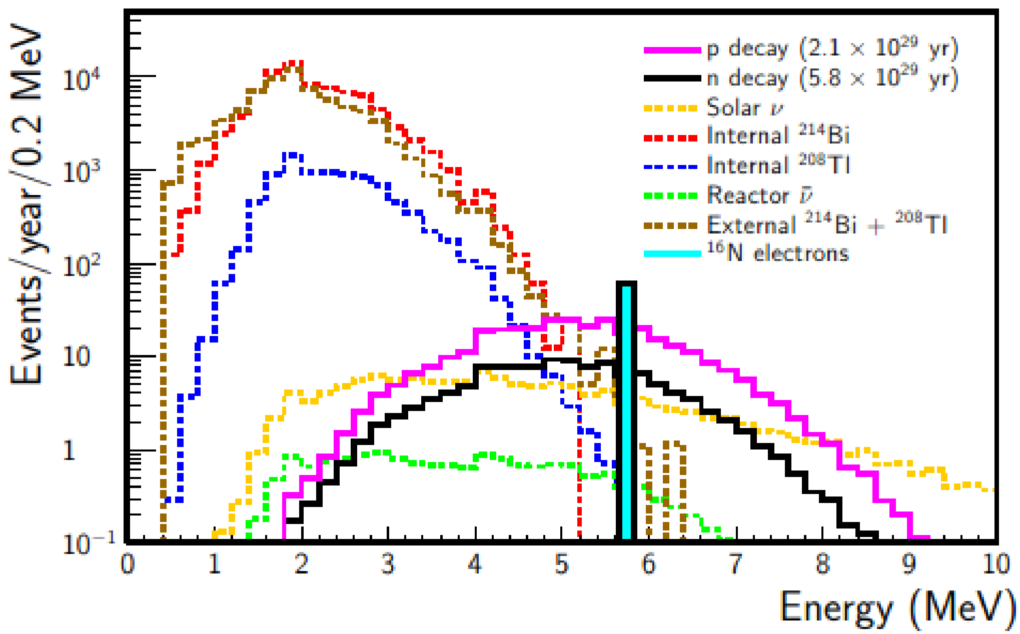
Reactor Antineutrinos

Geo-Neutrinos



Supernova Neutrinos

Water phase – started May 04th 2017



Understand Energy Scale with ^{16}N Calibration Source
[1]I. Coulter, SNO+ Collaboration

5.5 m fiducial volume cut
Sun directional cut
Several month of data needed

Nucleon decay:
- Many visible channels ruled out
- SNO+ sensitive to invisible channels

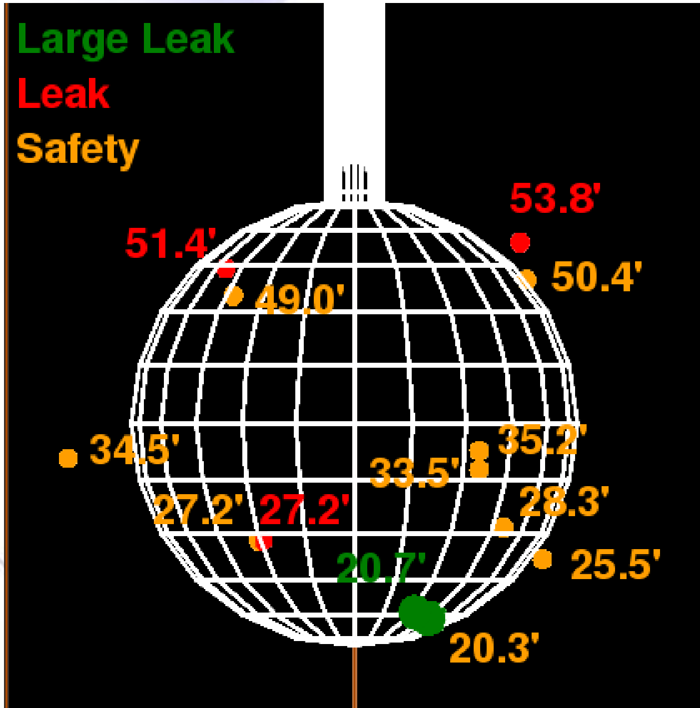
$$n \rightarrow \nu\bar{\nu}\bar{\nu}, \quad p \rightarrow \nu\bar{\nu}\bar{\nu}$$

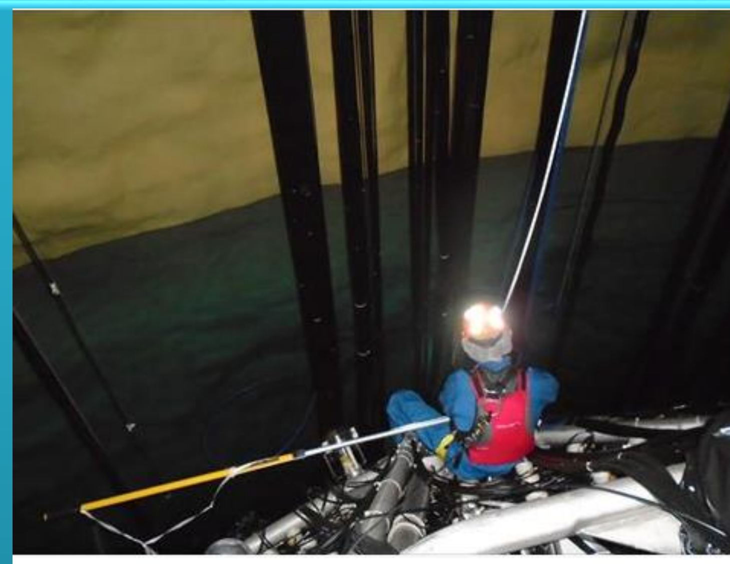
- $^{16}O \rightarrow {}^{15}N^* \rightarrow \gamma$
- $^{16}O \rightarrow {}^{15}O^* \rightarrow \gamma$
- Predicted by many standard model extensions , eg. GUT, SUSY

In addition – external background analysis
Use time to circulate, clean and cool …

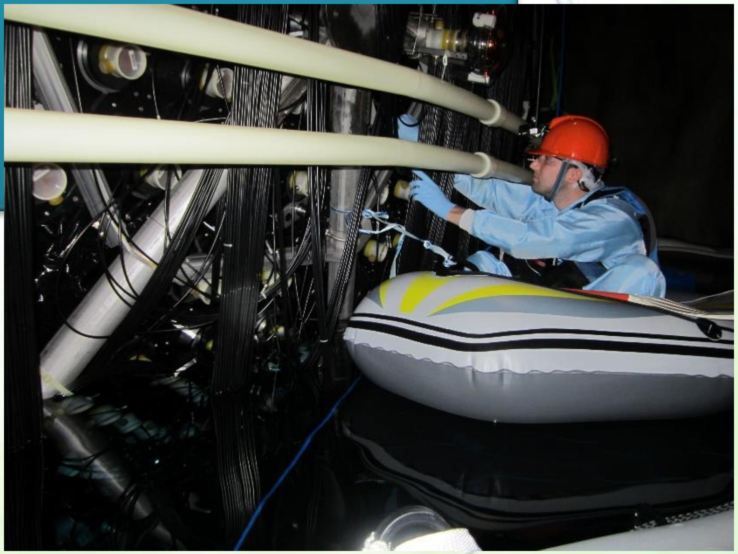
Also looking at anti-neutrino analysis and
Detector is supernova life …

Cavity installation and fill complete !!!





Complete boating, upper PSUP work



Below 10’ – **2 leaks** - significant
[10’ to 20’ – area with 3 safety patches]
20.7’ – most significant leak

20’ to 30’ – **1 leak**, 4 holes (safety patches)
30’ to 40’ – 3 holes (safety patches)
40’ to 56’ – **2 leaks**, 2 safety patches

Cavity → Detector

- Aug 2016 - workshop
- Oct 2016 - UI
- Nov 2016 – neck fill
- Nov 28th - shifts
- Feb 2017 – DCR
- May 04th – water phase
- Apr/May – central axis
- May – assay prep

Universal interface

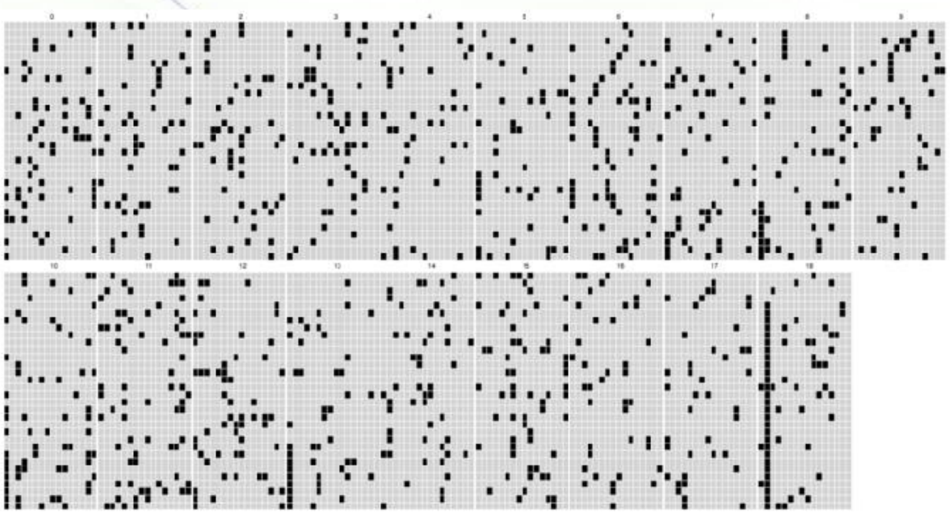
Water phase calibration hardware new DCR

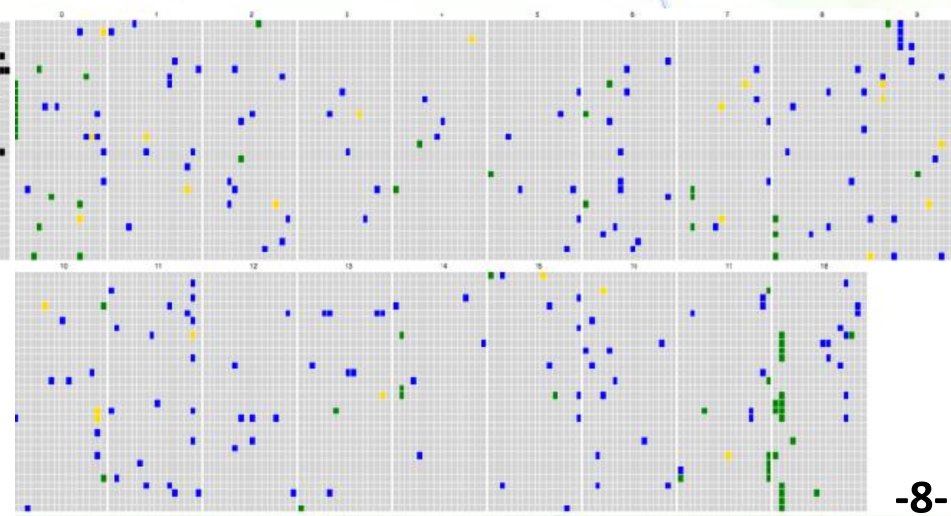
Detector commissioning

Start November 28th 2016 – exactly 10 years after last day of SNO data taking

- Preparation – complete work on deck (resistor replacement from PMT repairs)
- November 2016 – installed 370 feed resistors
- 924 PMTs not usable at the end of SNO, this number is now 348

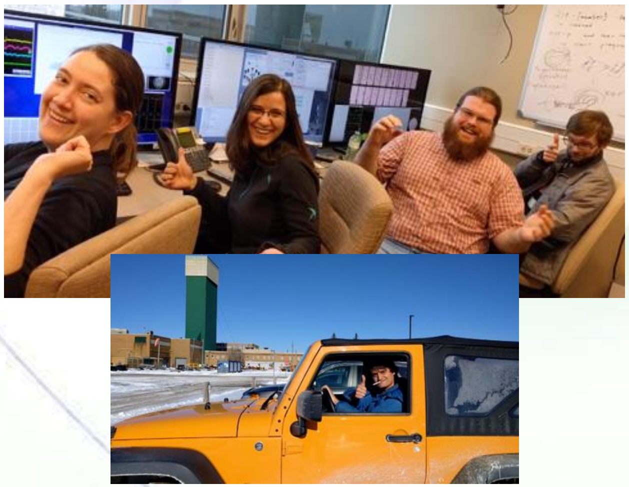
SNO → SNO+



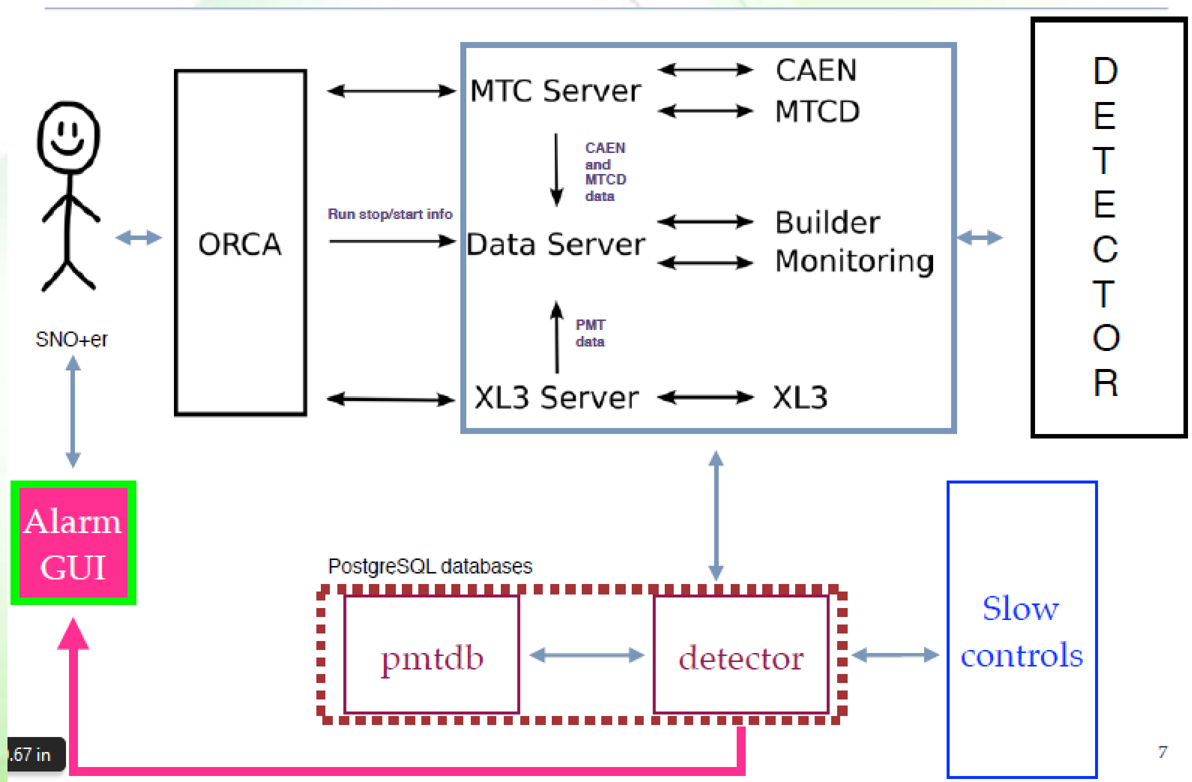


DAQ commissioning

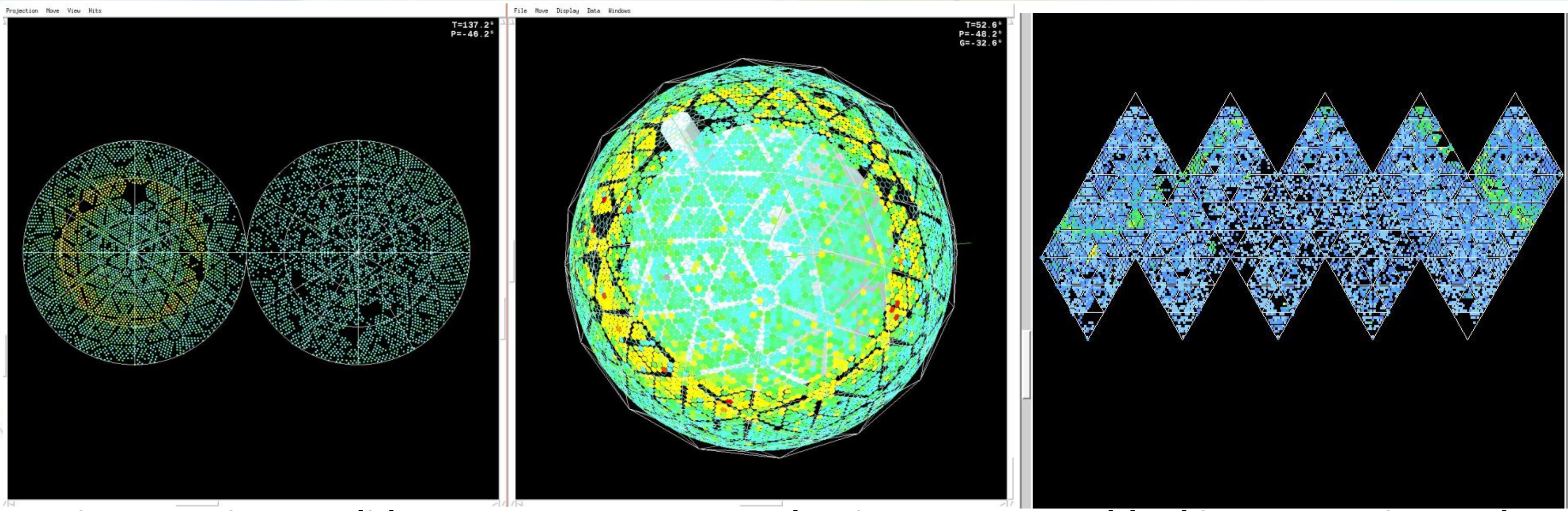
- December 2016 to mid February



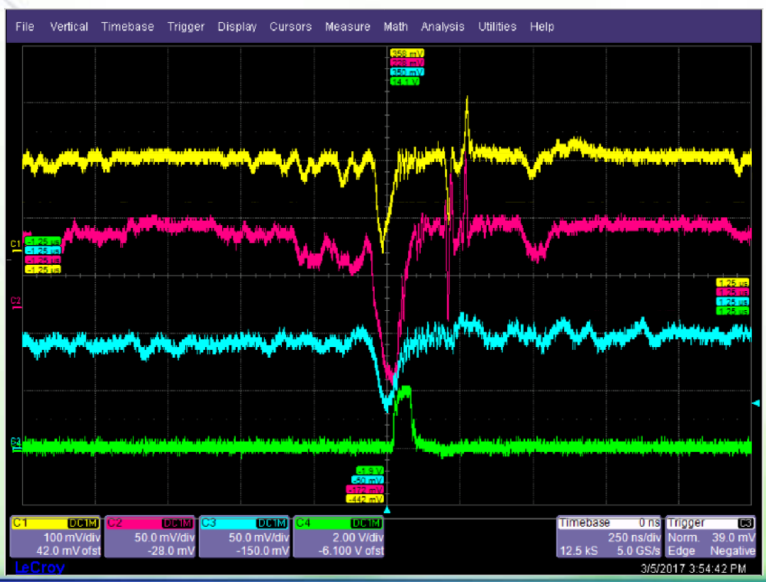
Trained 45 detector operators

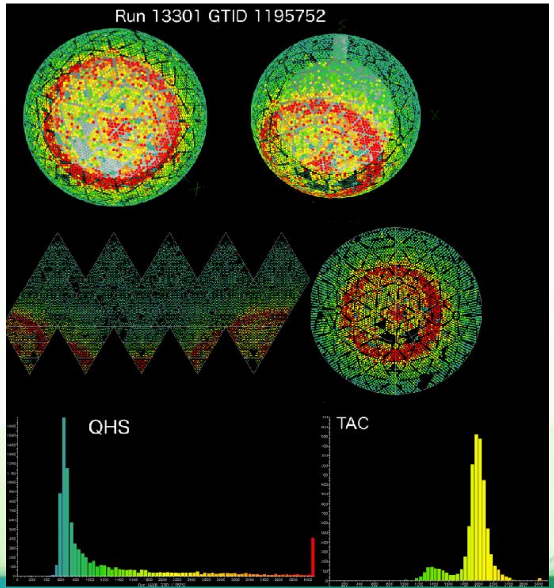


Currently Taking Data (~24/7 shifts)



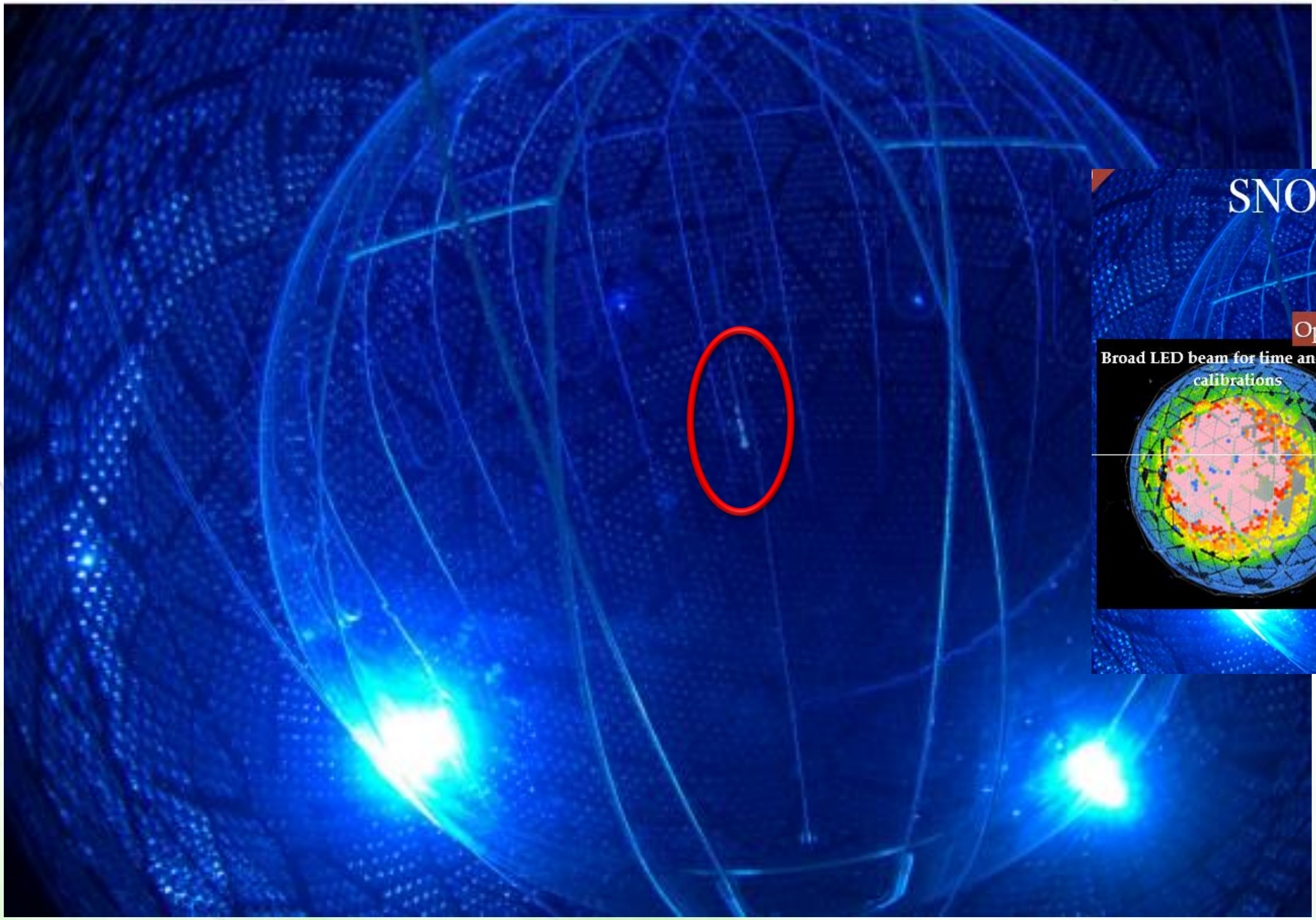
First neutrino candidate: 2017-02-05, upward-going, no outward-looking PMTs triggered

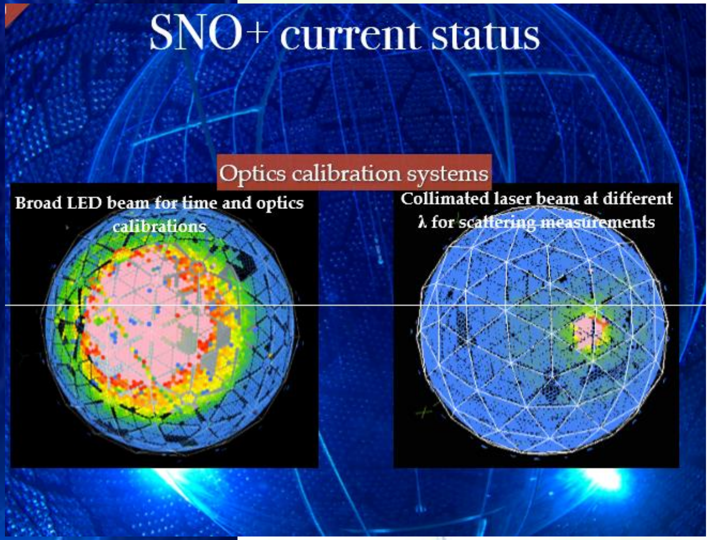




Electronics working well

Calibrations





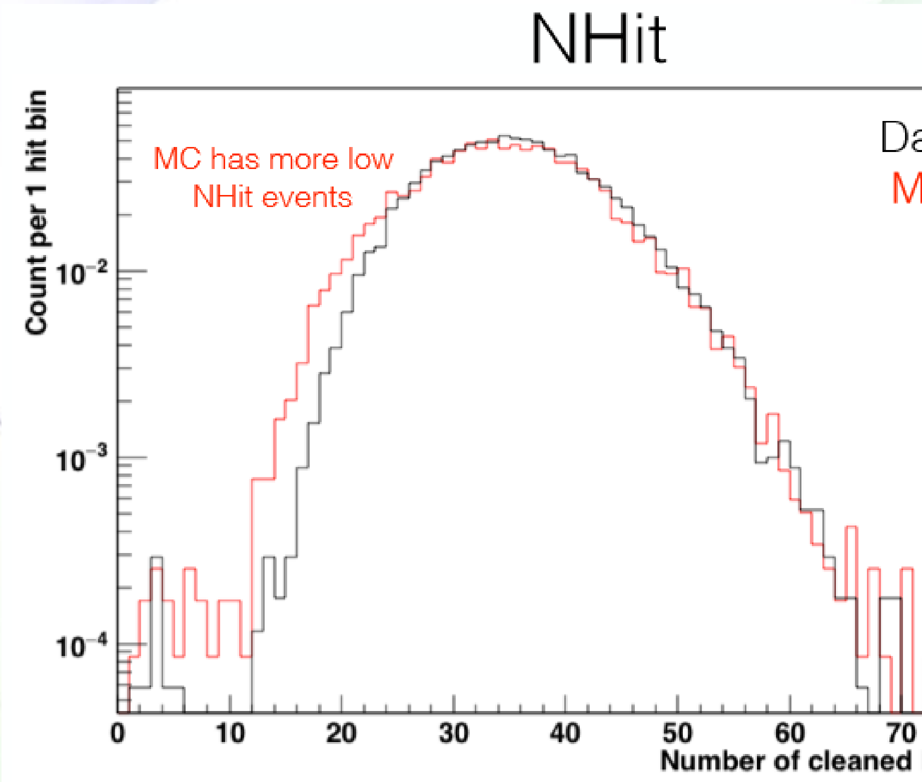
Timing

Also fibers mounted on PSUP

Drive tests laser ball – April 2017 – PSUP mounted camera system

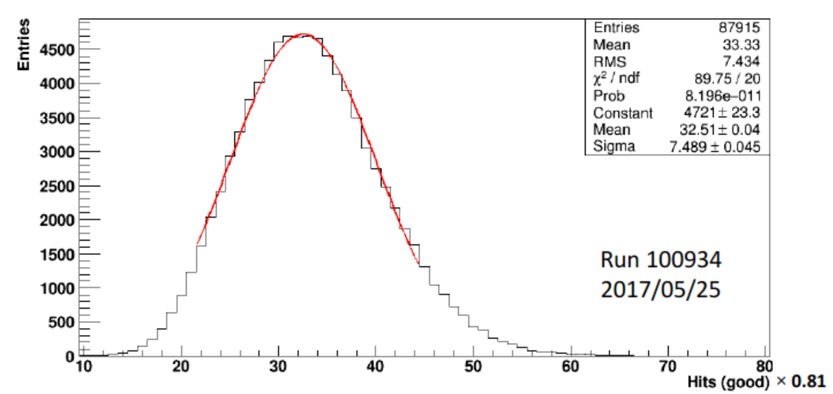
N16 data - preliminary

- Data taken last Wednesday, less than 24 h later:

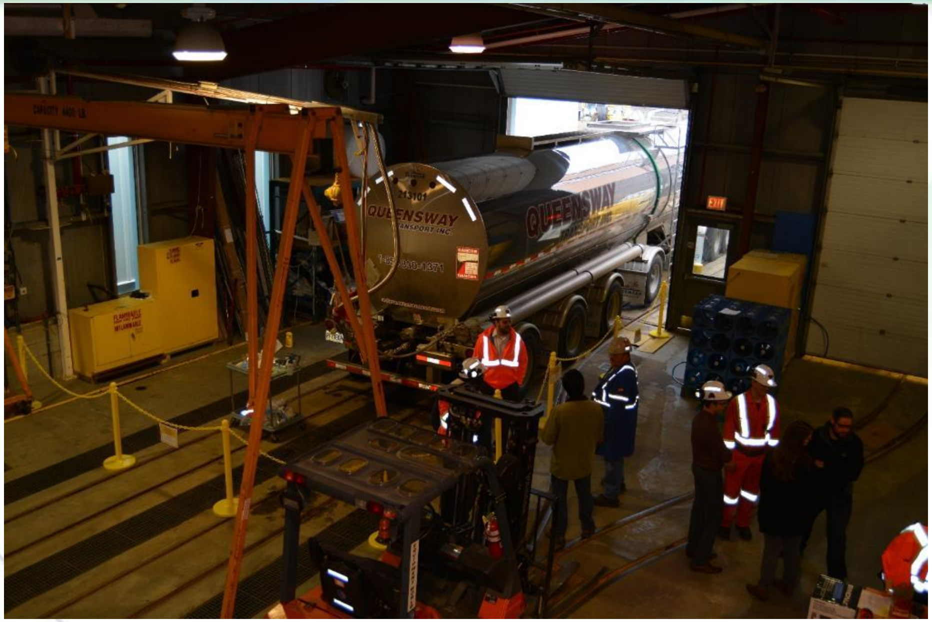


Looks quite good

Measured in SNO+ water at center.

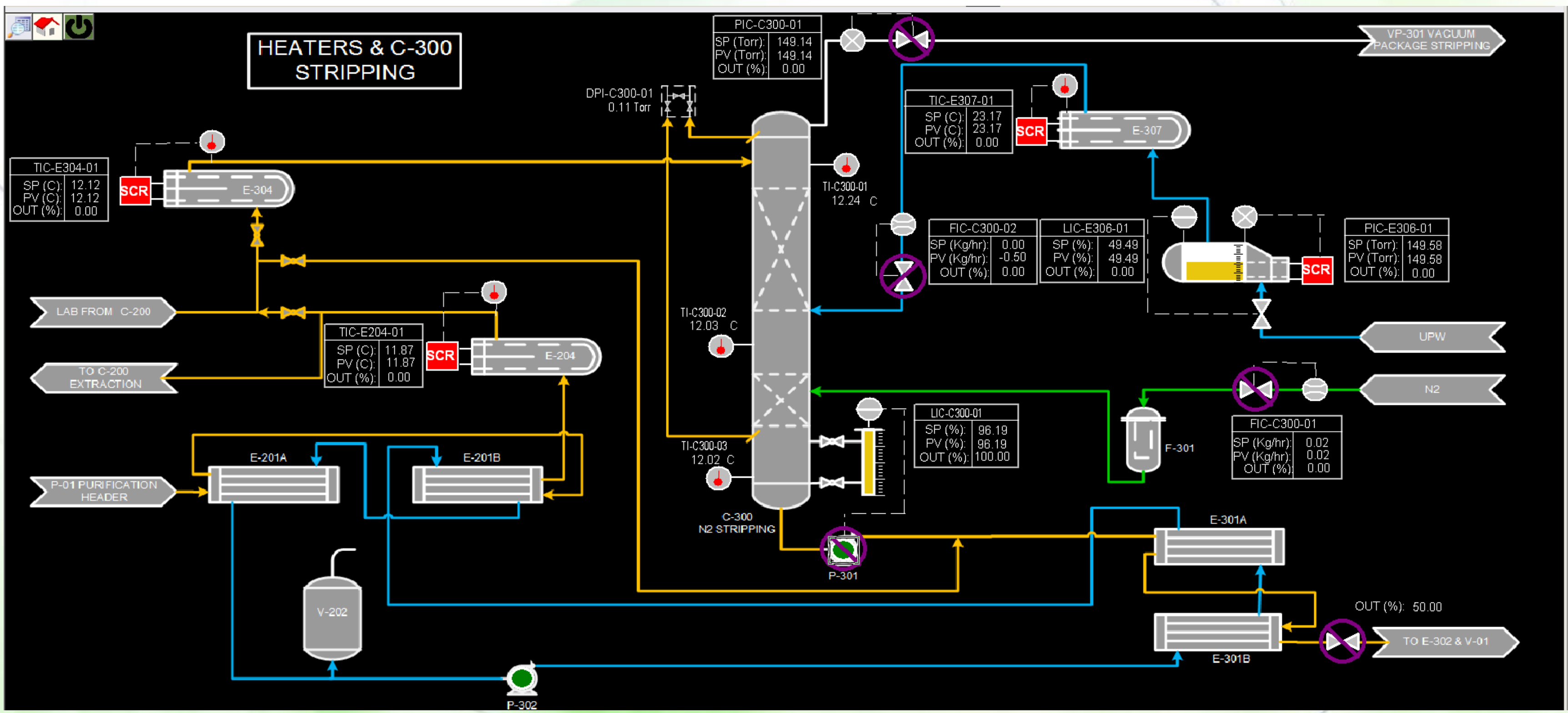


40 mT LAB arriving on site – Nov 2016



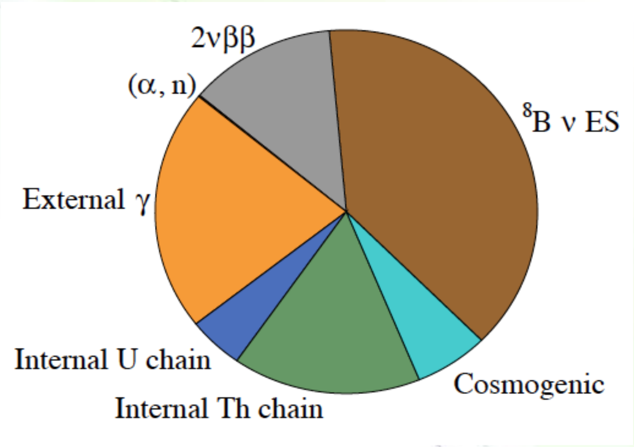
Scintillator Plant LAB Commissioning

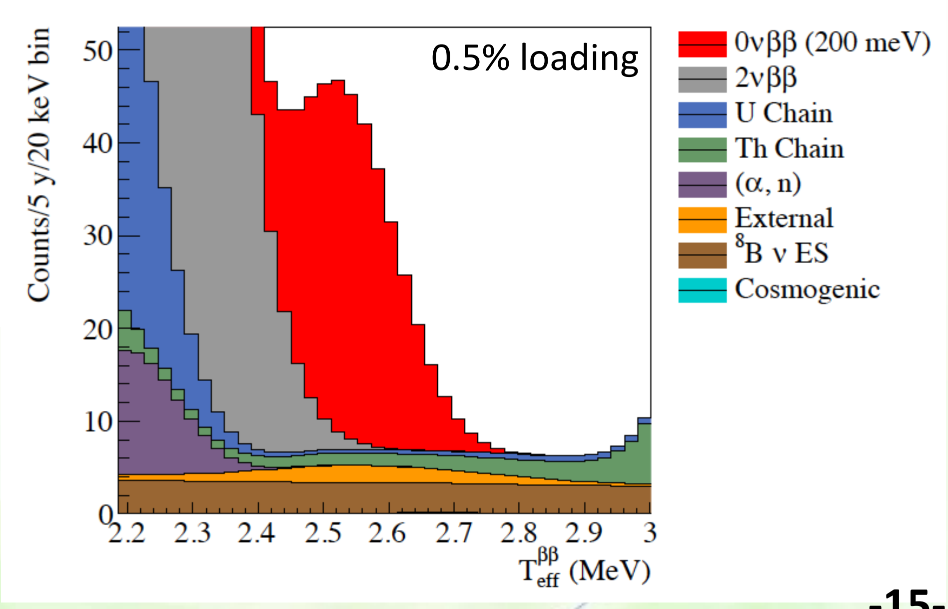
- SNOLAB Gateway 3A.2 Review in January 2017
  - recommended actions being closed out
  - successfully completed plant commissioning using water last year



Tellurium Purification for SNO+

- 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:
  - “Standard” 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 $0\nu\beta\beta$ energy region (e.g. ^{60}Co, ^{22}Na, ^{102}Rh, ^{110m}Ag)
    - Expected rates carefully estimated: V. Lozza and J. Petzoldt *Cosmogenic activation of a natural tellurium target*. Astropart. Phys. 61:62 (2014)
- 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



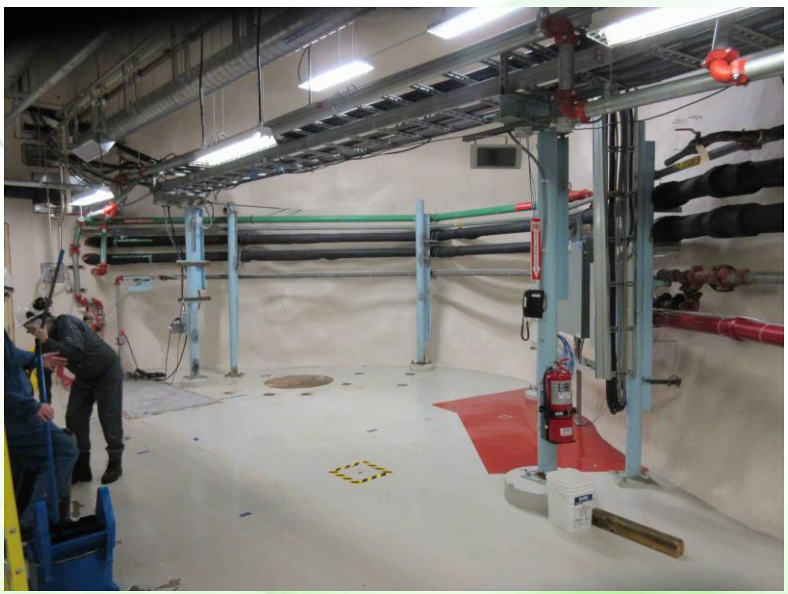


Te acid purification

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

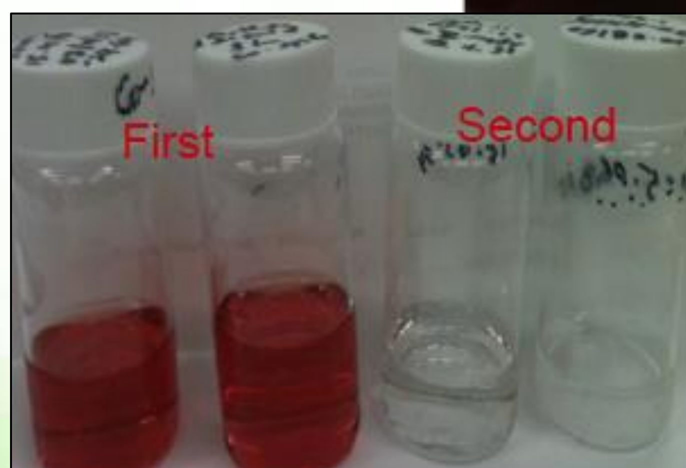
Insoluble *soluble*

- 2016 Review
- Jan 2017 start of plant construction



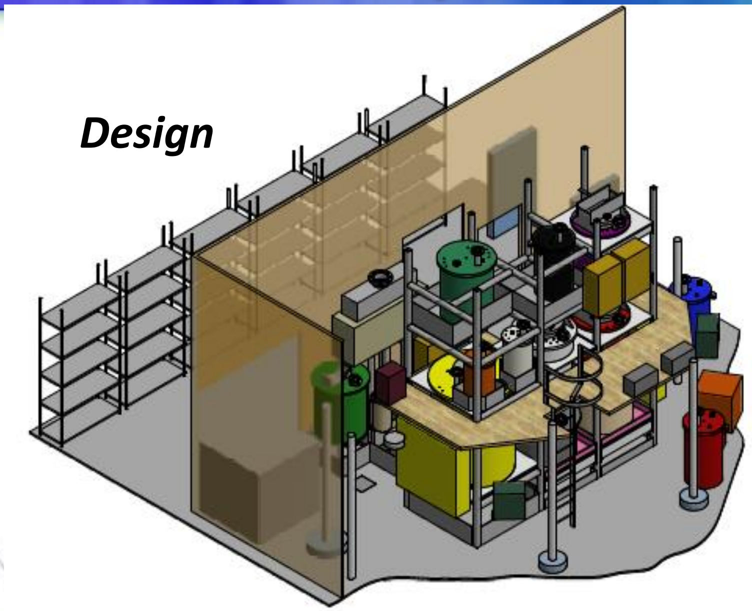
Dec 2016 – pre-treatment area cleared

Cobalt removal by multi-pass purification



Te acid purification plant - status

Design



Feb 2017 – steel structure

Vessels

May 2017 – all trays, many vessels

May 2017

Leaching – cleaning warm acid solution

Results from ICP-MS assay of leach-rate (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.

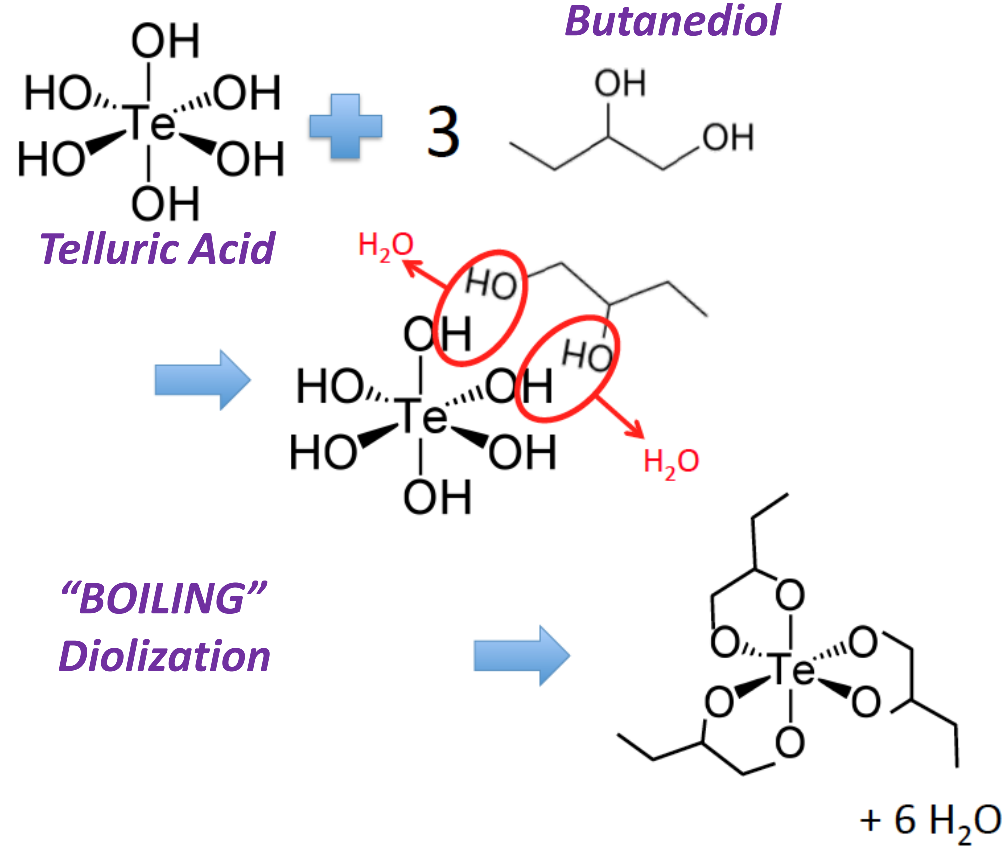
Vessels meet our purity requirements!

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

TeDB synthesis

- large natural isotopic abundance 34% for ^{130}Te
  - 0.3% Te (by weight) in SNO+ is 2.34 tonnes of Te or **800 kg** of ^{130}Te ***isotope***
  - *SNO+ phase I will be **0.5% Te loading** corresponding to **1,300 kg of isotope***

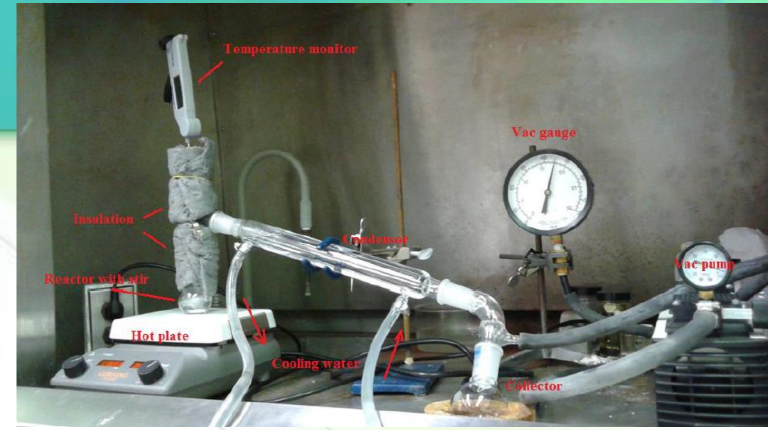
3.8 tonnes of $Te(OH)_6$ or 2.1 tonnes Te Corresponding to ~0.26% loading are stored UG (cooling)

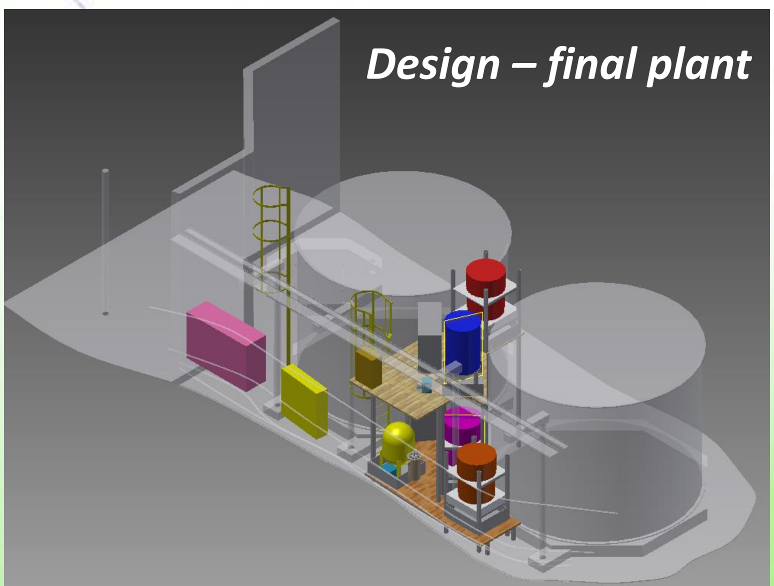


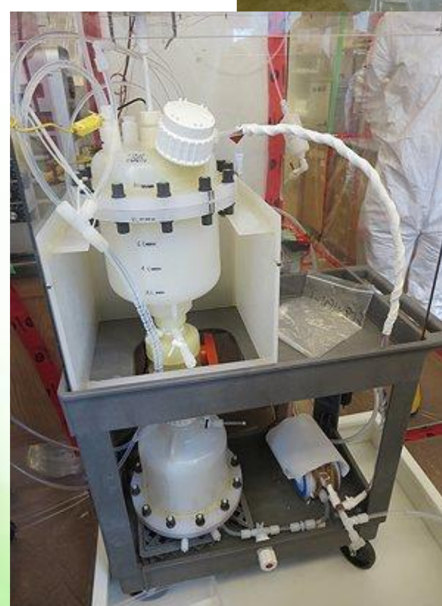
“Condensation reaction” produces organometallic compound miscible in LAB.

Scale-up path

- 8 g – principle
- 160 g – systematic study
- kg order batches
- Final plant 250 kg batch







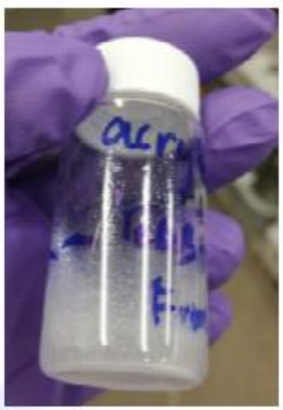
R&D program
Purification
Stability
Acrylic compatibility
Extraction
Improvements

Amine

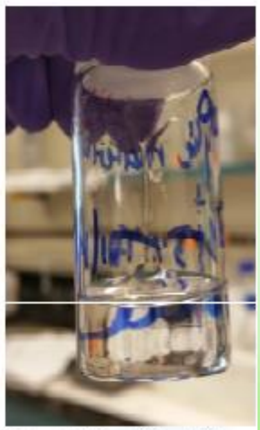
- Improve stability and light yield

Water exposed.

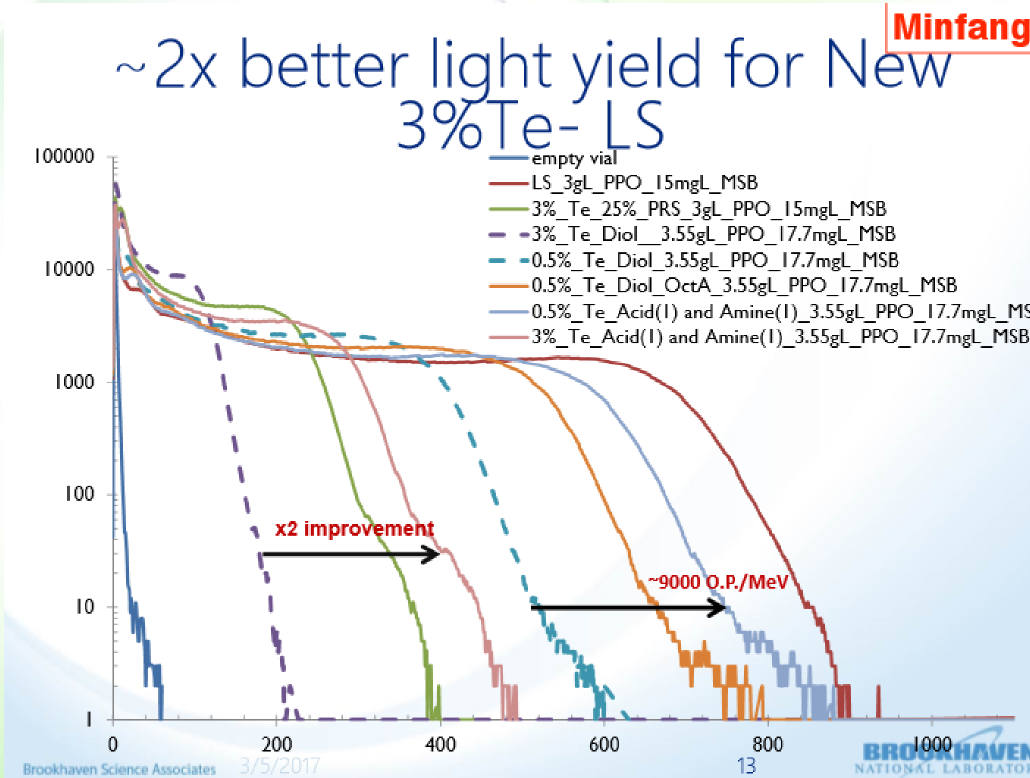
Water exposed.



3% Te-diol in LAB
(prepared in Fall 2015)



Crahed 3% Te-diol in LAB
after addition of ~4% OctA
on 06-20-16



Collaboration Demographics

SNO+ Collaboration: Canada, US, UK, Portugal, Germany and Mexico

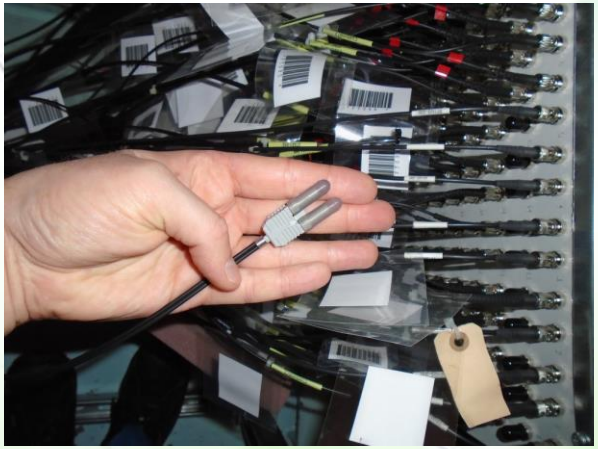
Canada	43
US	37
UK	30
Portugal	5
Germany	4
Mexico	1

Alberta, Laurentian, Queen's, SNOLAB, TRIUMF
AASU, BNL, UC Berkeley/LBNL, UC Davis, Chicago, Penn, UNC
Sussex, Oxford, QMUL, Liverpool, Lancaster
LIP Lisboa and Coimbra
TU Dresden
UNAM

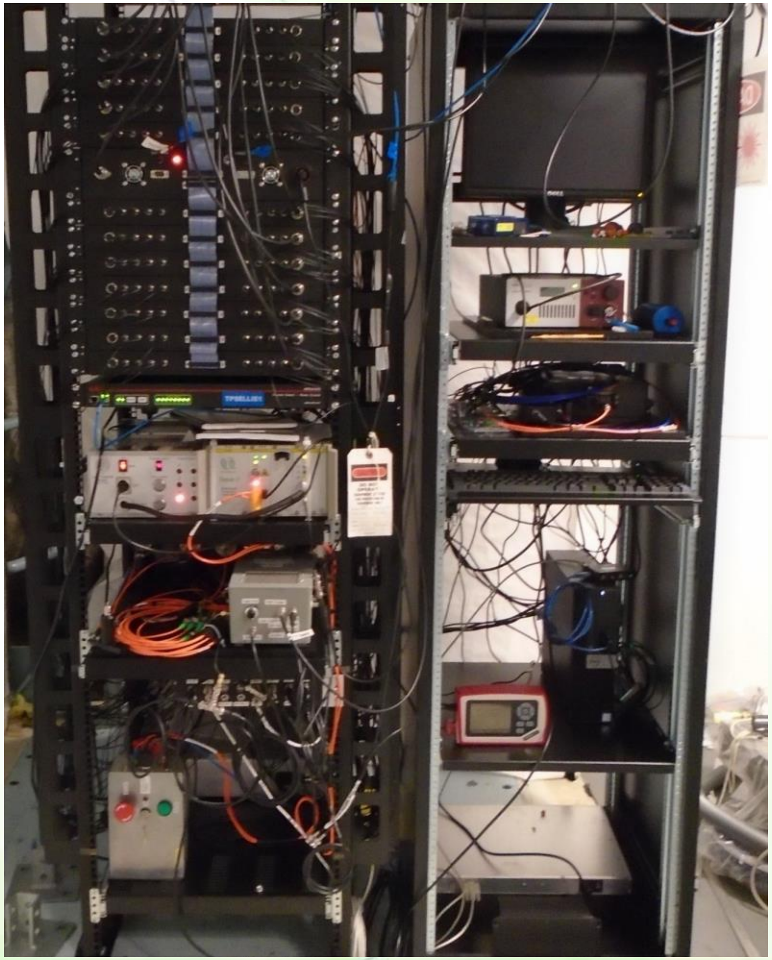
Additional slides …

Fiber system

- Scattering module – 2 lasers and monitoring
- Recently completed hardware tuning – ready to go
- Located in DCR



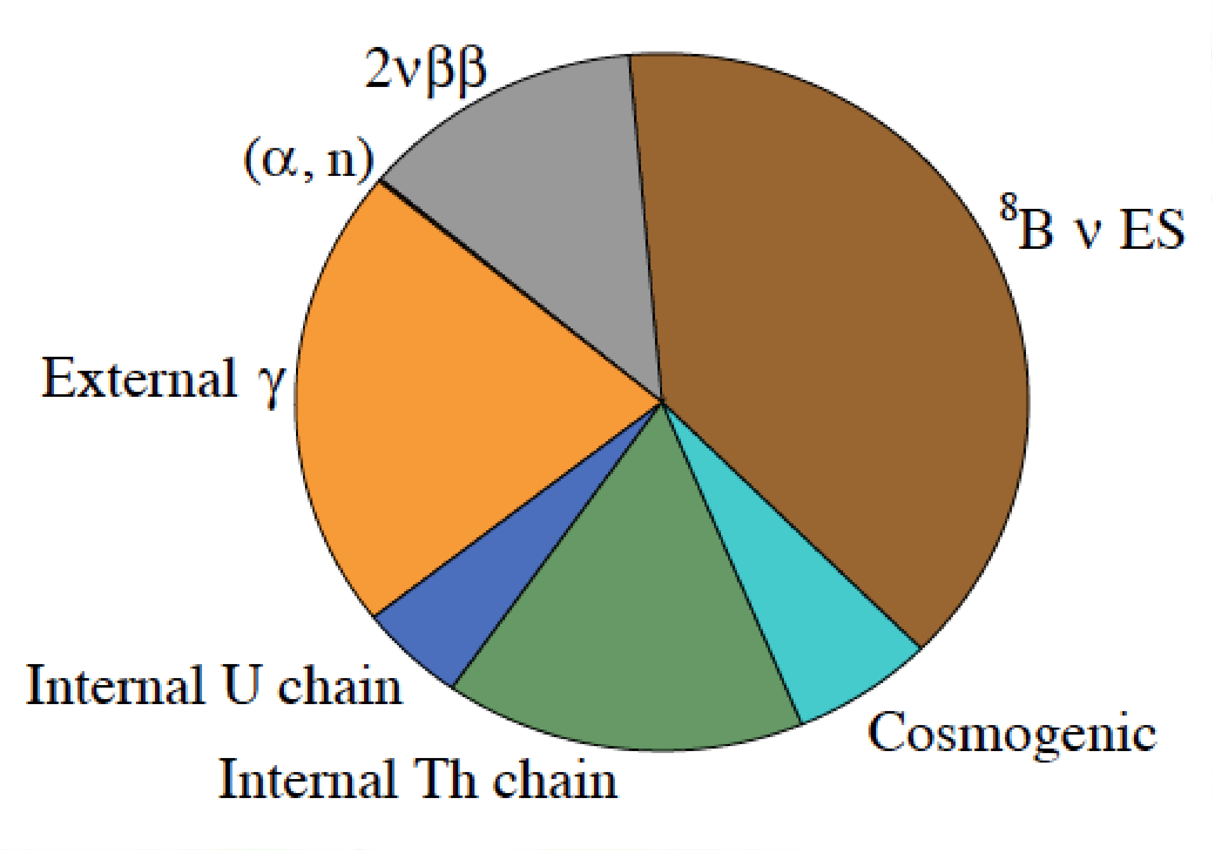
- Timing module
- 92 fiber positions
- Test performed
- Located in DCR



New SNO+ Source Manipulator (URM)

- build by LIP (Portugal)
- delivered and unpacked at SNOLAB on 2017-02-02

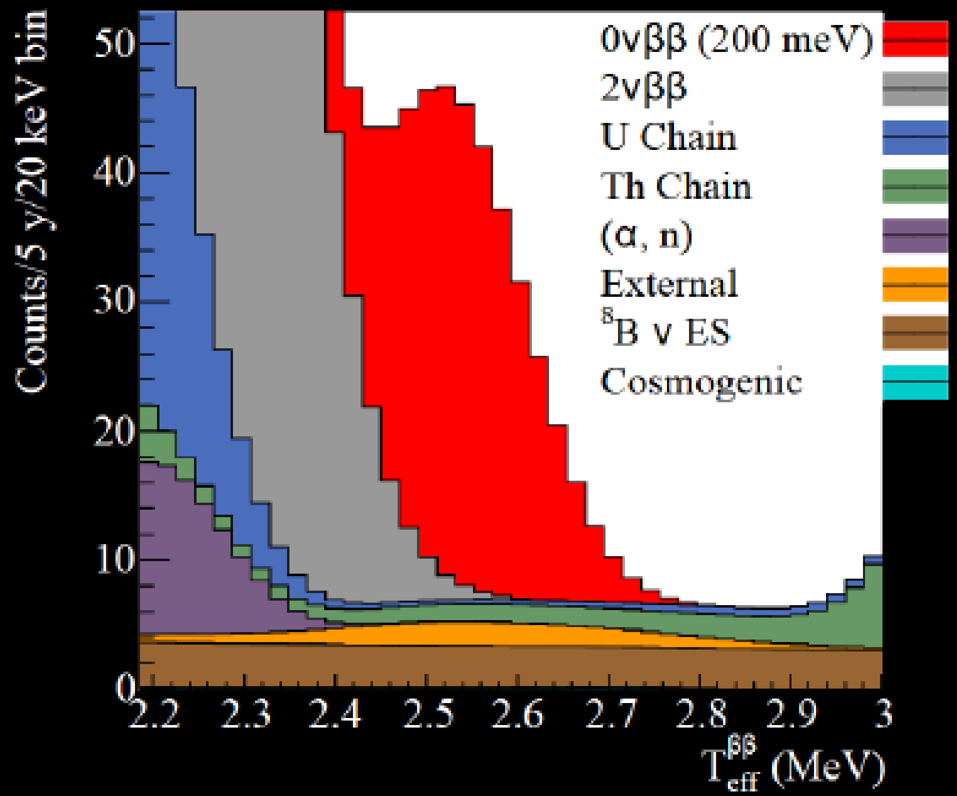
NLDBD Background budget



Total 13.4 counts/year in ROI (Year 1)

Sensitivity 0νββ

- 1.3 tonnes of ^{130}Te in LAB (at 0.5% ^{nat}-Te)



- [-0.5; +1.5] σ around $Q_{\beta\beta}$
- 400 NHits/MeV (~4% ΔE)
- Fiducial Volume: 20% total

	$T_{1/2}$ [yr]	$m_{0\nu\beta\beta}$ [meV]
1 yr	8×10^{25}	75.2
5 yrs	1.96×10^{26}	38 – 92

Block Diagram