Status & Commissioning of the SNO+ experiment

Gersende Prior
(for the SNO+ collaboration)

Lake Louise Winter Institute – 19-24 February 2018

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

OUTLINE

- Physics goals
- $0\nu\beta\beta$ sensitivity reach
- Detector status and commissioning
- Calibration systems and data
- Water phase data
- Outlook

SNO+ PHYSICS GOALS

Multipurpose detector with different physics & phases:

Water phase | Pure scintillator phase | Te-loaded phase

Supernova neutrinos

Nucleon decay

8B solar neutrinos

Reactor and geo-neutrinos

$0\nu\beta\beta$

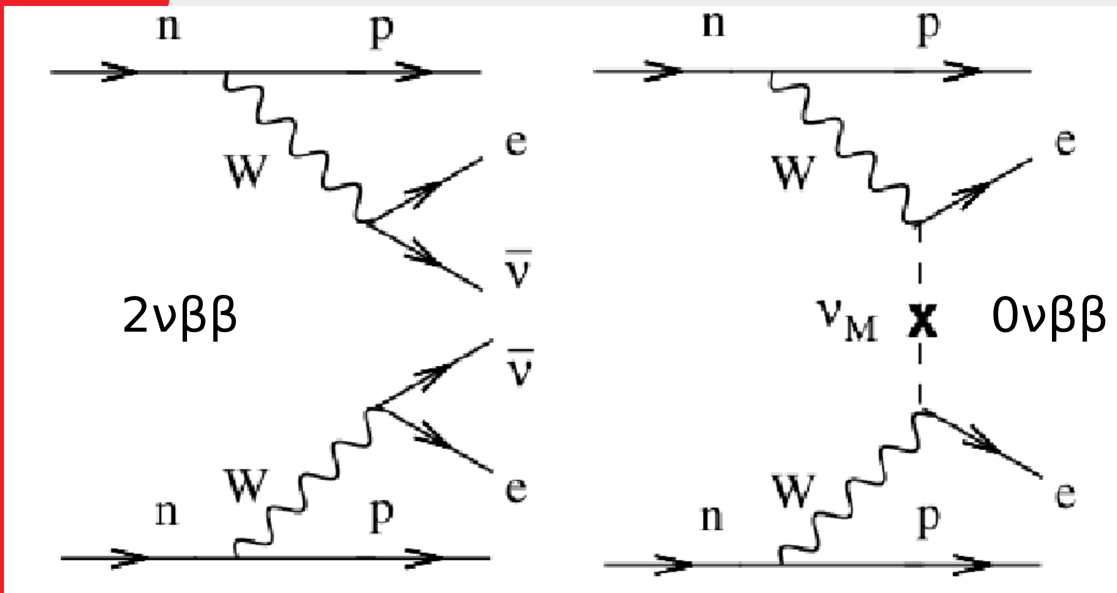
Low energy solar neutrinos

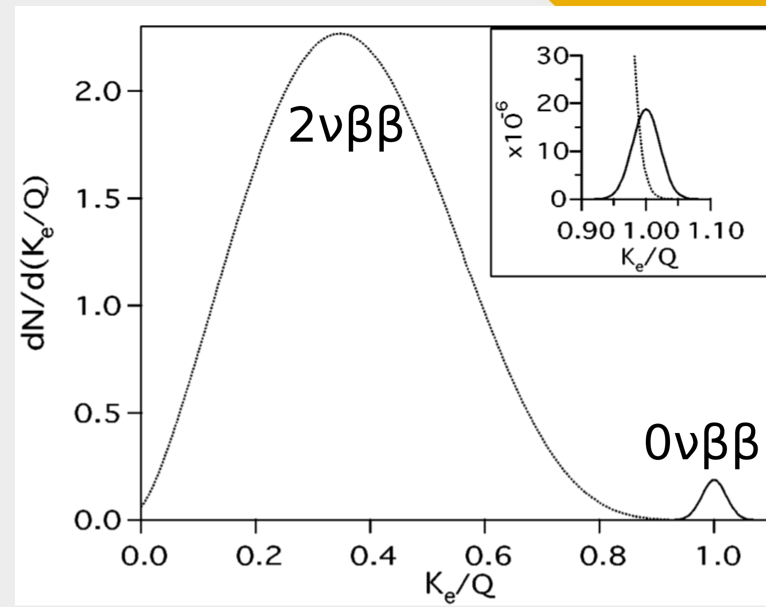
Exotics search: e.g. solar axions

+ Background measurements across all phases

+ Calibrations (optics,energy...) across all phases

0νββ SENSITIVITY REACH (1/)





S.R. Elliott & P. Vogel, Annu. Rev. Nucl. Part. Sci., 52:115-51 (2002)

$$\Gamma^{0\nu\beta\beta} = \ln(2).(T_{1/2}^{0\nu\beta\beta})^{-1}$$
$$= \ln(2).G_{0\nu}(Q_{\beta\beta},Z).|M_{0\nu}|^2.<m_{\beta\beta}>^2/m_e^2$$

$$<m_{\beta\beta}>=|\Sigma m_i.U_{ei}^2|, i=1,..,3$$

Two neutrino double beta decay(2νββ):

- allowed by the Standard Model (conserves lepton number)
- occurs in nuclei where single beta-decay is energetically forbidden
- already observed for 11 nuclei – $T_{1/2} \sim 10^{18} - 10^{24}$ years

Neutrinoless double beta decay (0νββ):

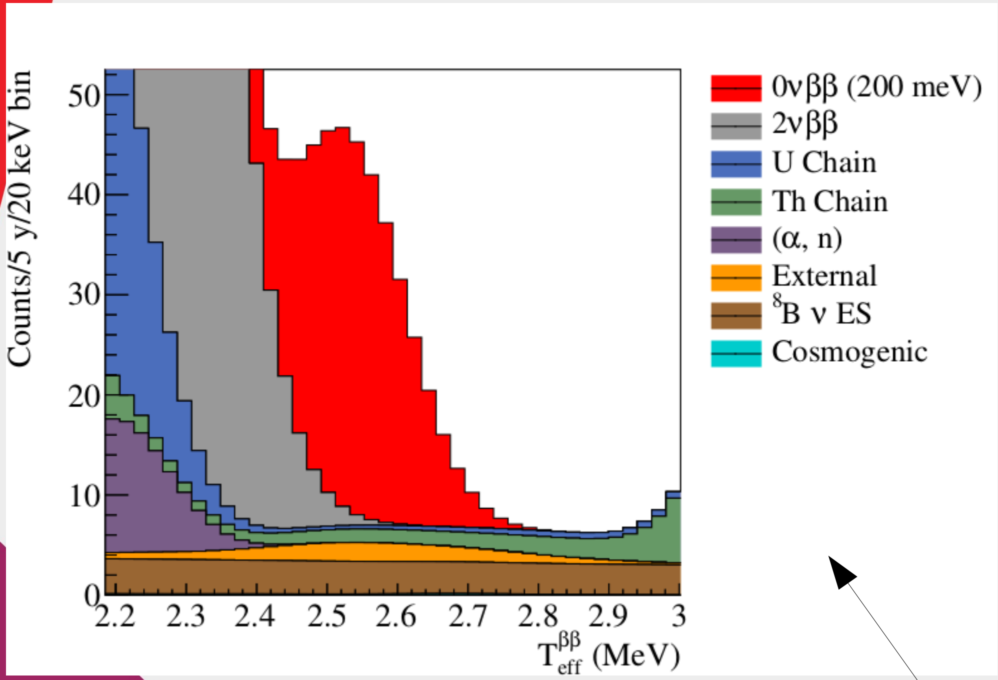
- can occur if neutrinos are Majorana (i.e. their own anti-particles)
- violates the lepton number conservation
- never been observed

0νββ SENSITIVITY REACH (2/)

^{130}Te as 0νββ candidate:

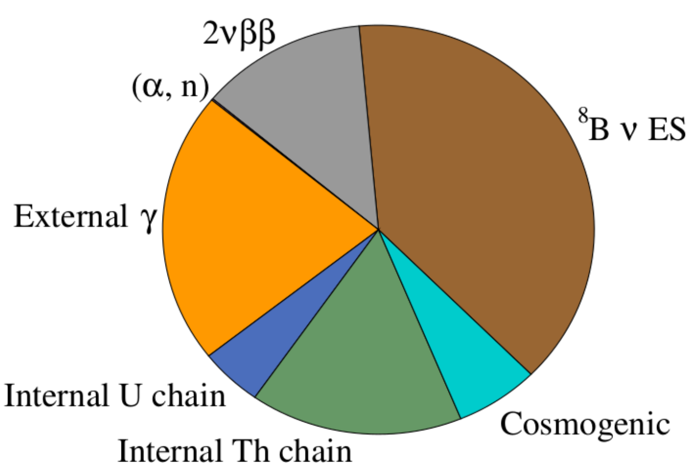
- high natural abundance (34%) → loading of several tonnes, no enrichment
- long measured 2νββ half-life (8x10^{20} yr) → reduced background contribution
- TeLS with good light yield, good optical transparency and stable over years
- end-point Q=2.53 MeV

The backgrounds are well understood and can be experimentally constrained



Expected spectrum after 5 years of data-taking with 0.5% ^{nat}Te loading and FV cut R= 3.5 m.

Backgrounds budget for year one



~13 counts / year in the first year

0νββ SENSITIVITY REACH (3/)

Expected sensitivity with:

- light yield ~ 390 hits/MeV (LAB+PPO) using Te-Diol loading technique
- 0.5 % ^{nat}Te loading
- phase space factor $G_{0\nu}$ = 3.69x10^{-14} yr^{-1}
- Nuclear Matrix Elements $M_{0\nu}$ = 4.03 (IBM-2)
- FV cut R = 3.5 m

Phase I:

1 year of data-taking:

$T^{0\nu\beta\beta}_{1/2}$ > 0.8 x 10^{26} yr

$m_{\beta\beta}$ ~ 59-144 meV

5 years of data-taking:

$T^{0\nu\beta\beta}_{1/2}$ > 1.96 x 10^{26} yr

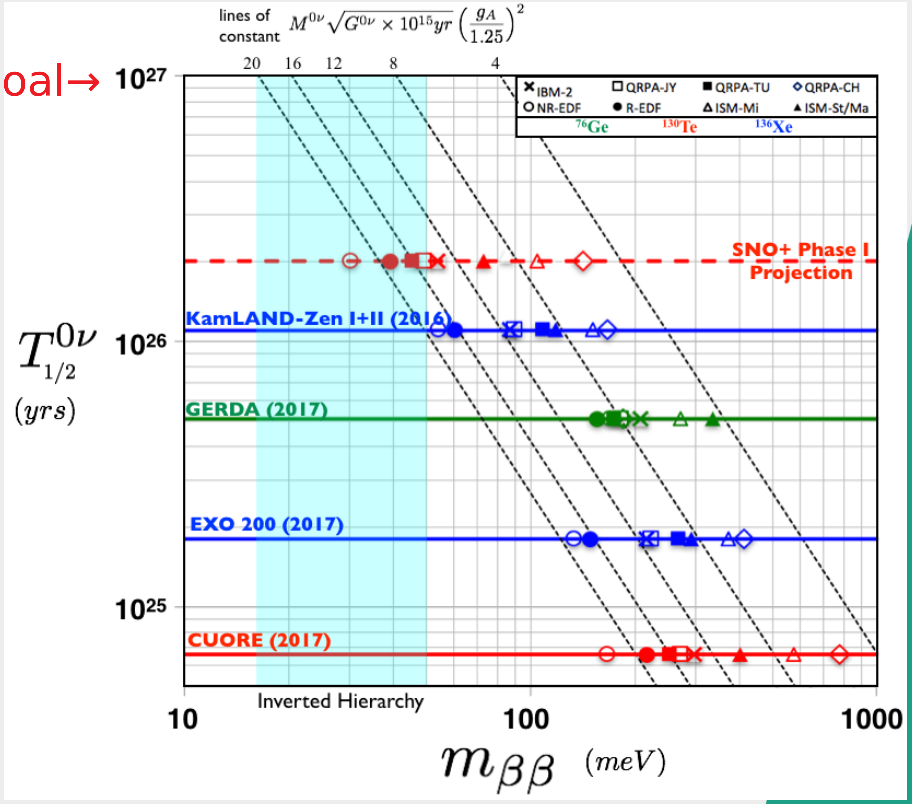
$m_{\beta\beta}$ ~ 38-92 meV

Phase II:

Increased loading

HQE PMTs

Phase II goal→



SNO+ location on the 0νββ "map"

THE SNO+ DETECTOR (1/)

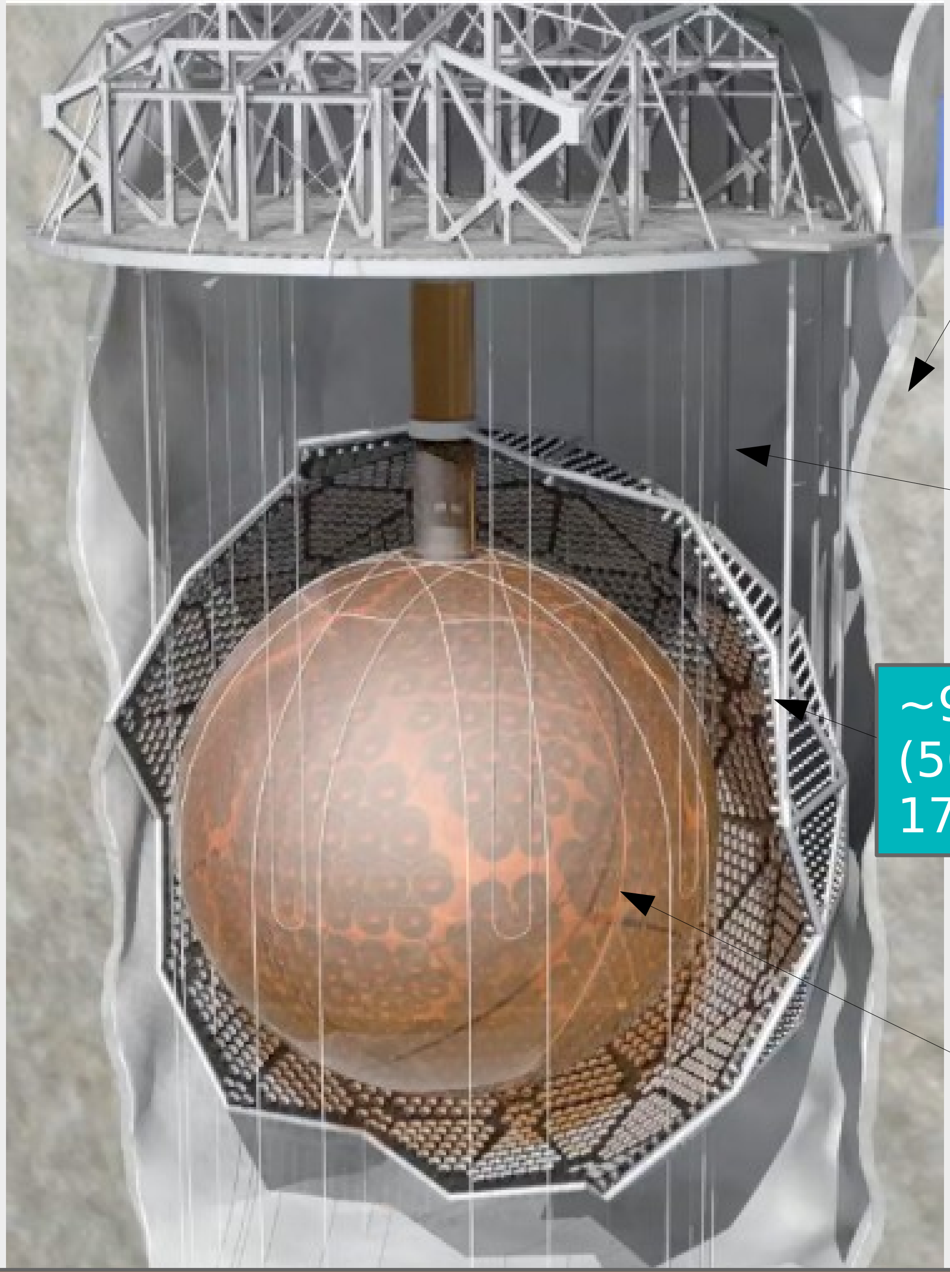
SNO+ heavy water replaced by 780 tons of liquid scintillator

Liquid scintillator will be loaded with different amounts of Te (~1330 kg ^{130}Te in phase I)

New hold down rope system

New DAQ system and readout cards

New calibration systems



Norite + granite/gabbro

7kt ultra-pure water shield

~9400 PMTs
(50% coverage)
17 m diameter structure

12 m diameter
5 cm thickness
acrylic vessel

Creighton mine, Sudbury, ON (Canada), 2 km (6000 m.w.e) depth

DETECTOR STATUS (1/)

Repaired leaks in cavity and replaced/repaired PMTs

LEDs/laser calibration system installed

Hold-down rope system installed and fully tested for buoyancy/tensioning as water level was raised

Upgraded electronics and DAQ tested a high data flow and high trigger rate

Original source deployment hardware refurbished and installed for the water phase

New clean room above detector hatch construction achieved

Scintillator source deployment system construction achieved (shipped on-site)

Scintillator plant installed, commissioning on-going

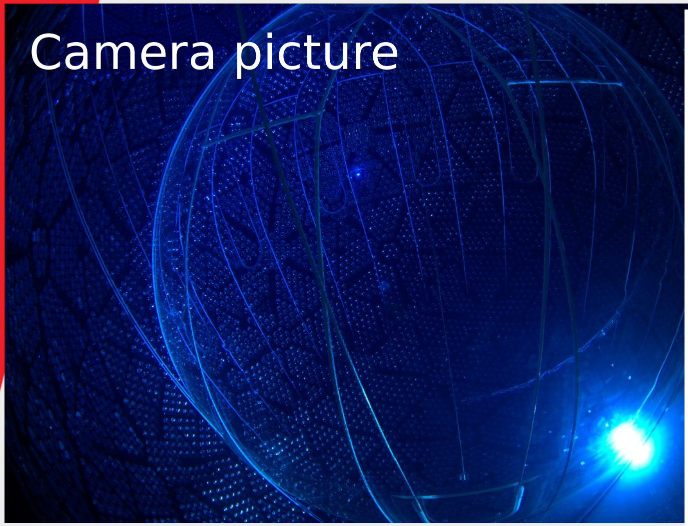
First shipment of scintillator received

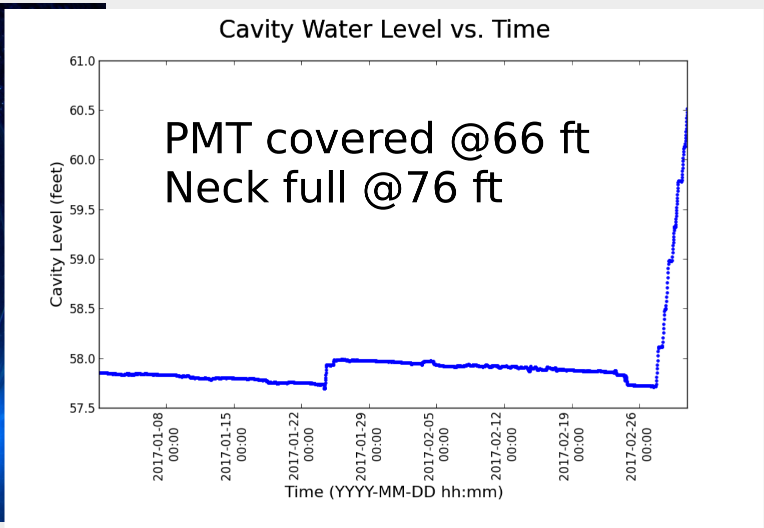
Tellurium purification plant under construction underground

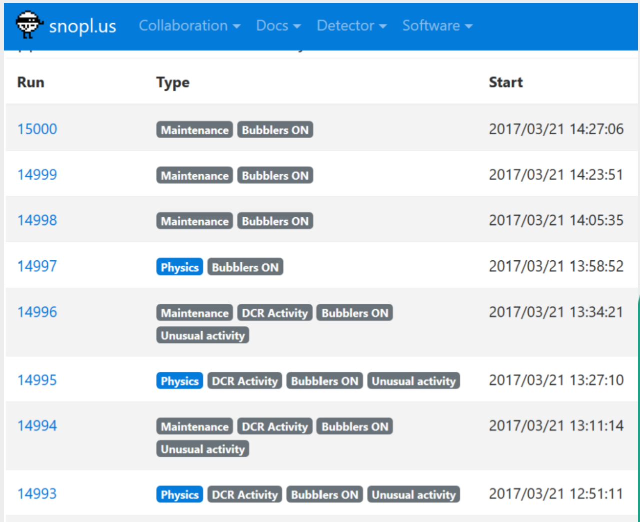
Telluric acid underground and “cooling” since 2015

DETECTOR COMMISSIONING (1/)

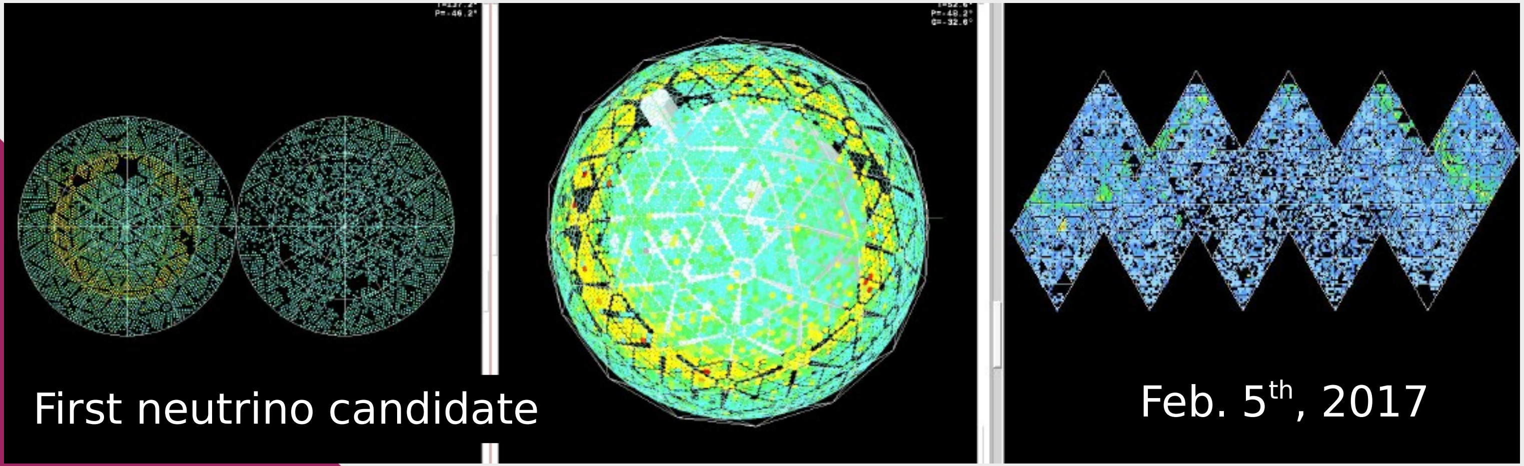
Detector commissioning between Dec. 2016 and April 2017:
Full commissioning of the electronics/DAQ/trigger systems
Commissioning and DAQ implementation of the calibration systems
Detector status/data-quality databases and nearline software commissioned
Completion of detector water fill

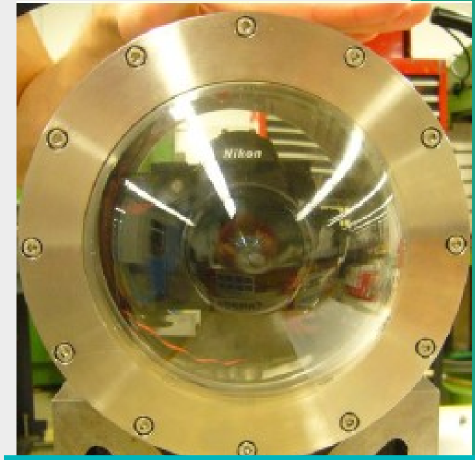






Run	Type	Start
15000	Maintenance Bubblers ON	2017/03/21 14:27:06
14999	Maintenance Bubblers ON	2017/03/21 14:23:51
14998	Maintenance Bubblers ON	2017/03/21 14:05:35
14997	Physics Bubblers ON	2017/03/21 13:58:52
14996	Maintenance DCR Activity Bubblers ON Unusual activity	2017/03/21 13:34:21
14995	Physics DCR Activity Bubblers ON Unusual activity	2017/03/21 13:27:10
14994	Maintenance DCR Activity Bubblers ON Unusual activity	2017/03/21 13:11:14
14993	Physics DCR Activity Bubblers ON Unusual activity	2017/03/21 12:51:11

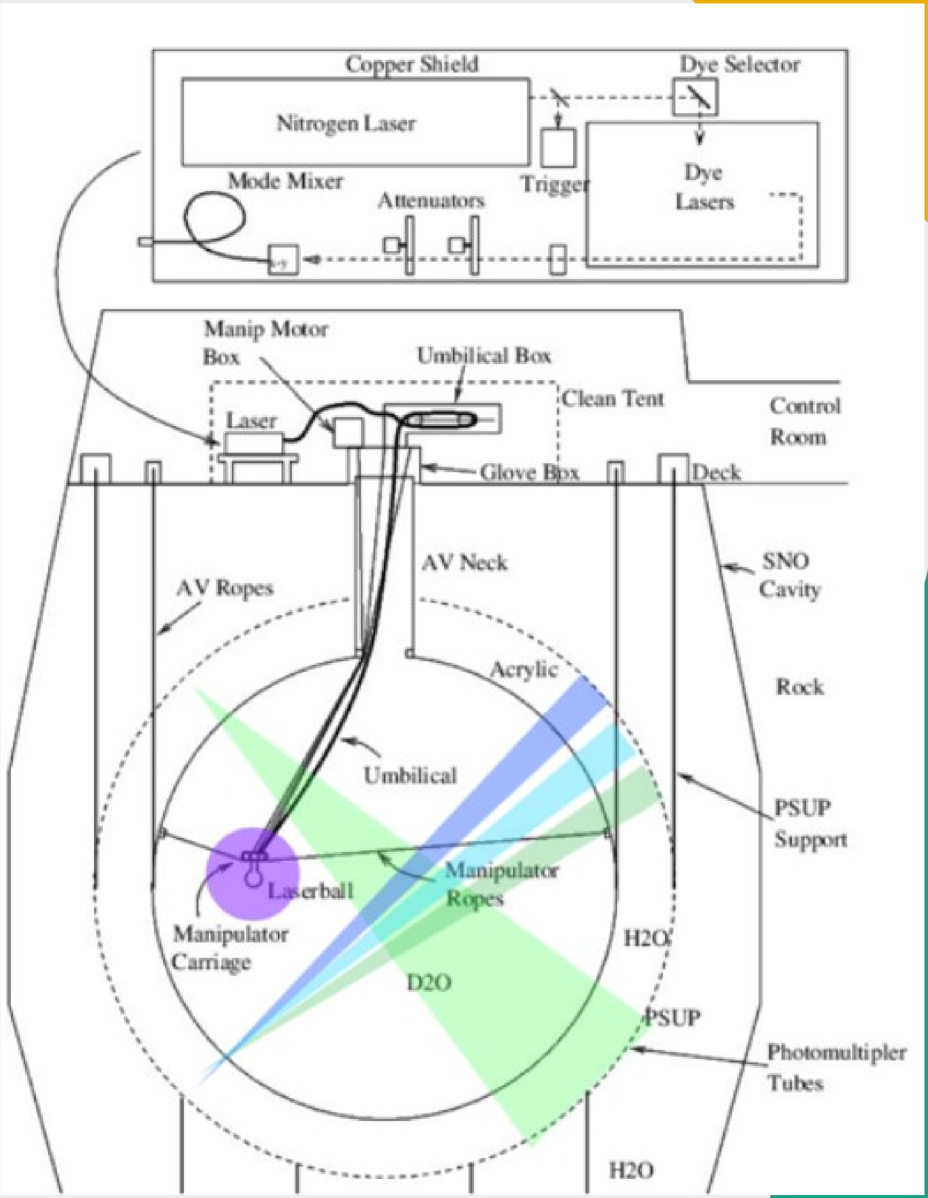




CALIBRATION SYSTEMS (1/)

Optical calibration:
- measure the PMTs response (angular, timing,gain)
- measure in-situ the optical properties of the media (attenuation,scattering)
- monitoring of the media transparency
- PMTs relative efficiency

Optical systems:
- fixed fiber-based system using LEDs/laser light injection placed on the PMTs array
  - different wavelengths
  - different fibres angles
  - 106 different location points
- deployed light (laser with dyes) diffusing sphere (laserball)
  - different wavelengths
  - 40 different location points
- deployed Cherenkov light source
- underwater cameras
  - improve deployed system position

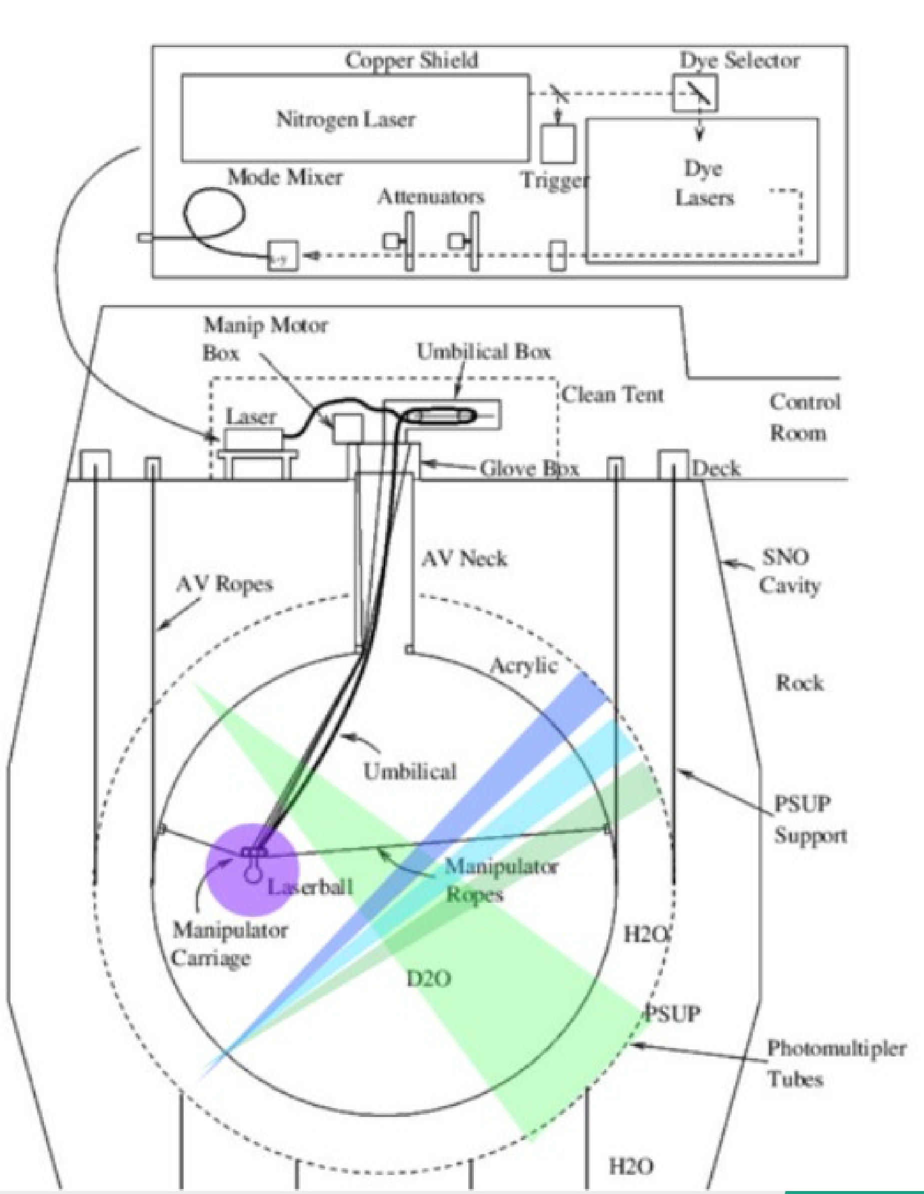


Successful deployed light calibration and fibers data campaigns in water phase

CALIBRATION SYSTEMS (2/)

Radioactive sources:
Measure efficiency and systematic uncertainties of event reconstruction such as energy, position, particle id

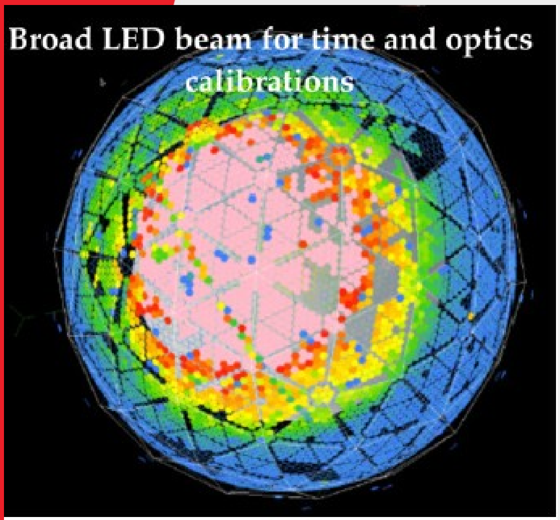
Source	Radiation	Energy [MeV]
AmBe	n, γ	2.2, 4.4 (γ)
^{60}Co	γ	2.5 (sum)
^{57}Co	γ	0.122
^{24}Na	γ	4.1 (sum)
^{48}Sc	γ	3.3 (sum)
^{16}N	γ	6.1
^{220}Rn/^{222}Rn	α, β, γ	various

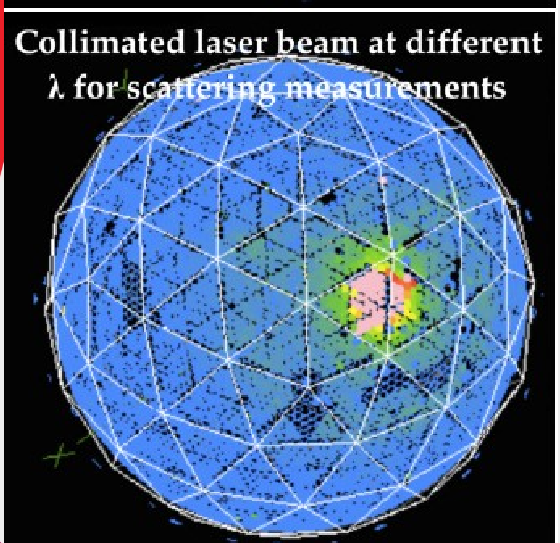


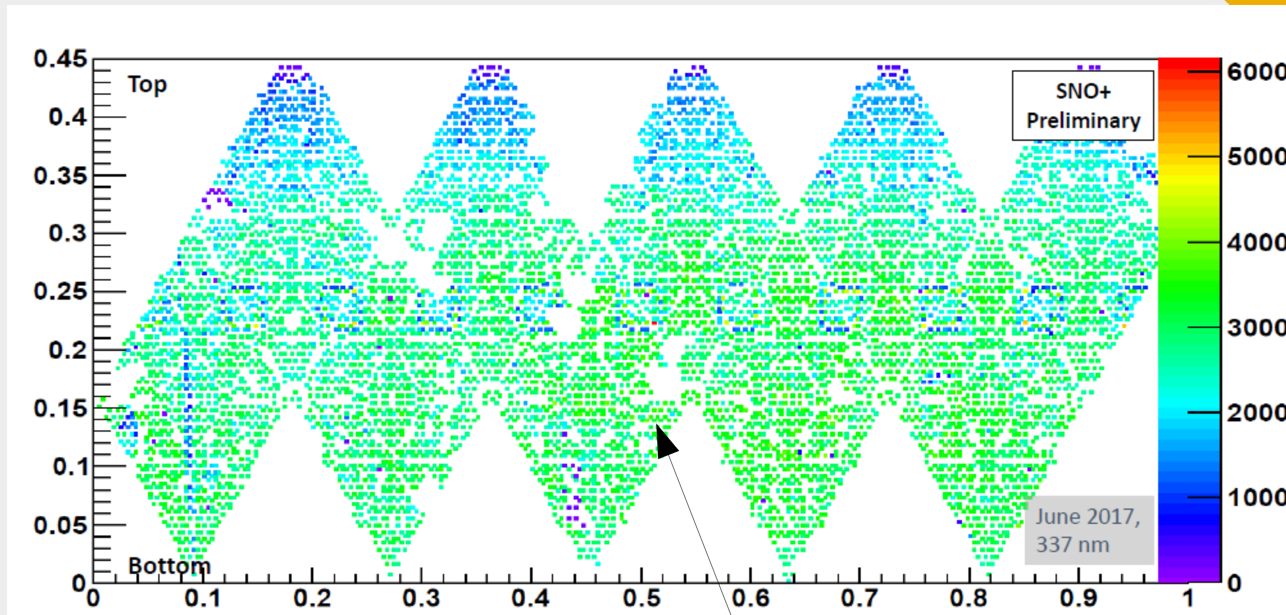
AmBe and ^{16}N sources deployed successfully in the water phase

Sources and source encapsulations for the scintillator phase, preparation work on-going.

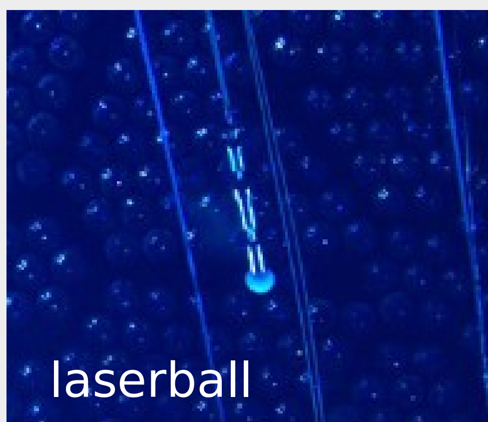
CALIBRATION SYSTEMS (3/)







PMTs occupancy map: central laserball run



Calibration campaigns in water with:
- two radioactive sources
- light diffusing sphere
- fixed fibers system

WATER PHASE DATA (1/)

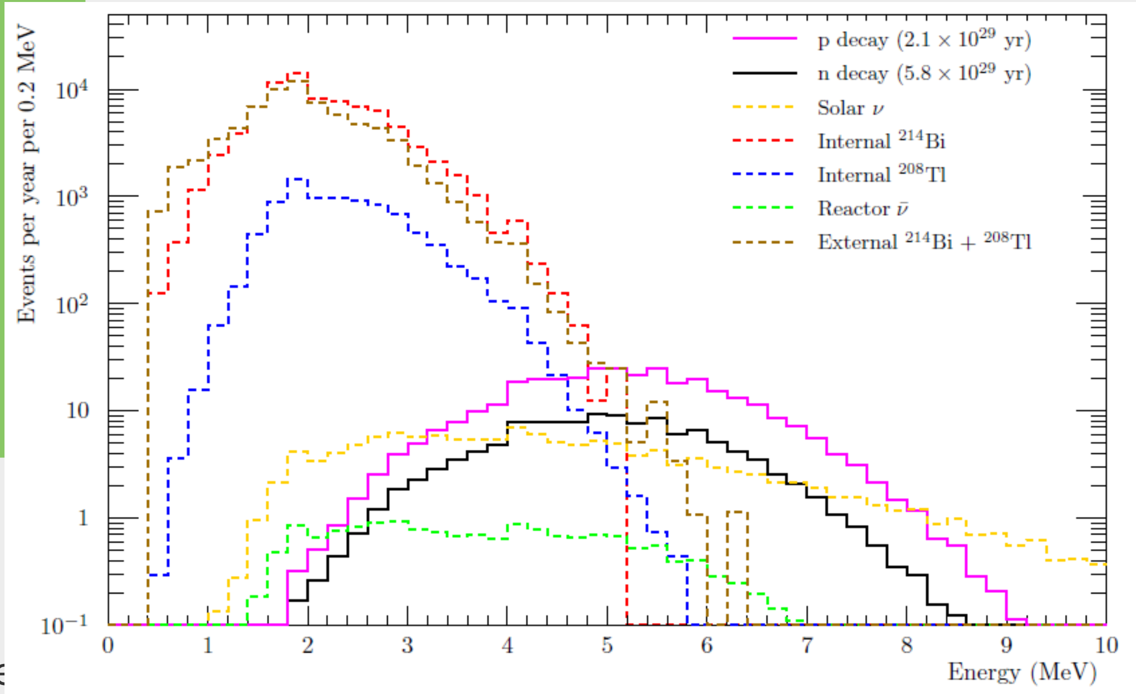
Nucleon Decay search:

- Invisible decay modes, e.g. n→ ννν
- $^{16}O \rightarrow {}^{15}O^*$ or $^{15}N^*$ ~ 5 MeV visible energy
- 6 months of data → 30 background counts in ROI
- 90% C.L:
  - τ_n = 1.2 x 10^{30} years (current limit from KamLAND 5.8 x 10^{29} yr)
  - τ_p = 1.4 x 10^{30} years (current limit from SNO 2.1 x 10^{29} yr)

Run Selection (May 2017–Jan. 2018):
215 days 31 h 0 min 16 s detector up

210 days 9 h 43 min 16 s in PHYSICS
(83% of detector up time)

139 days 12 h 23 min 24 s GOLDEN
(66% of PHYSICS):
- ~ 5 days open data-set
- ~ 4 months blind data-set



OUTLOOK

SNO+ is currently filled with water and taking data since May 2017

- 6 months of data taking will provide the most stringent limit on invisible nucleon decay

The scintillator plant is being commissioned

The Tellurium plant is under construction

- Tellurium already underground for cool-down

Scintillator fill and first data expected in 2018

STAY TUNED !

THANKS !

The SNO+ Collaboration:
University of Alberta - University of California, Berkeley - LBNL - Boston University - Brookhaven National Laboratory - University of Chicago - University of California, Davis - Technical University of Dresden - Lancaster University - Laurentian University – LIP Lisbon and Coimbra - University of Liverpool - Universidad National Autonoma de Mexico - University of North Carolina at Chapel Hill - Norwich University - University of Oxford - University of Pennsylvania - Queen's University - Queen Mary University of London – SNOLAB - University of Sussex – TRIUMF

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BACKUP SLIDES

Background mitigation

$2\nu\beta\beta$
- irreducible but constrained using an asymetric [μ-0.5σ,μ+1.5σ] ROI
- limited in energy resolution

(α,n)
- coincidence cuts with efficiency 99.6% for the prompt signal
- coincidence cuts with efficiency 90.0% for the delayed signal

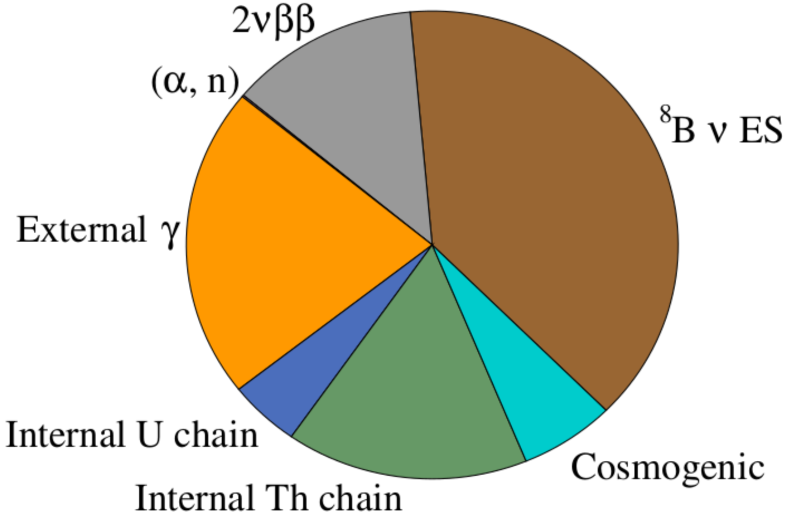
External γ
- Fiducial volume and PMTs time distribution cuts

214BiPo and 212BiPo from U/Th chains
- coincidence cuts with 100% rejection power in separate windows

Cosmogenics
- purification techniques
- long term underground storage

8B elastic-scattering interactions
- irreducible but continuous background
- published data will be used for normalization

Backgrounds budget for year one



~13 counts / year in the first year