-- Design and Calibration --

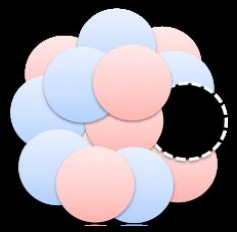
5th Hyper-Kamiokande Workshop

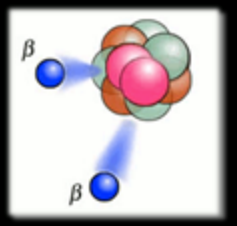
Szymon M Manecki

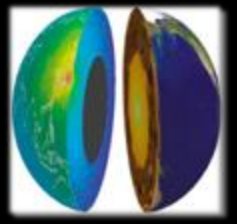
SNO+ Physics Goals

In All Phases

- <u>Neutrino-less double beta decay</u>
- Nucleon decay
- Solar neutrinos
- Geo-neutrinos
- Reactor neutrinos
- Supernova neutrinos



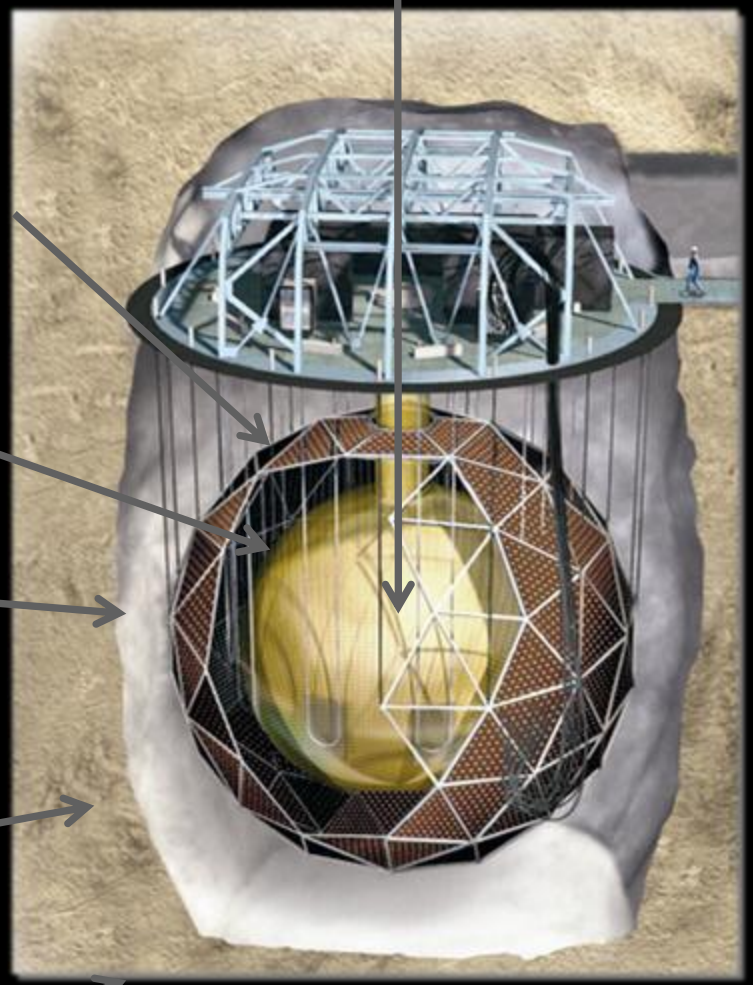




SNO+ Design

780t of liquid scintillator
(LAB+PPO)

Replaced Heavy water with LAB
(x50 Light Yield)



PSUP = PMT Support Structure
~9500 PMT, 54% Coverage

Lower Energy Threshold
(^{14}C's β is now the limit)

Acrylic Vessel (AV)
Φ=12m, thickness=5cm

Hold Down Ropes Installed
(LAB lighter than water)

Light water (H2O) shielding
- 1700t internal
- 5300t external

New Electronics,
Repaired PMTs,
Cleaned AV

Urylon Liner/Radon Seal

New purification plant

Norite Rock

New Physics

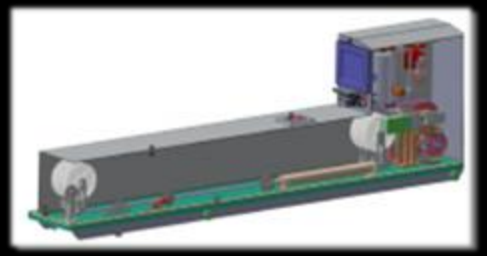
SNO+ Calibration
NEW Challanges

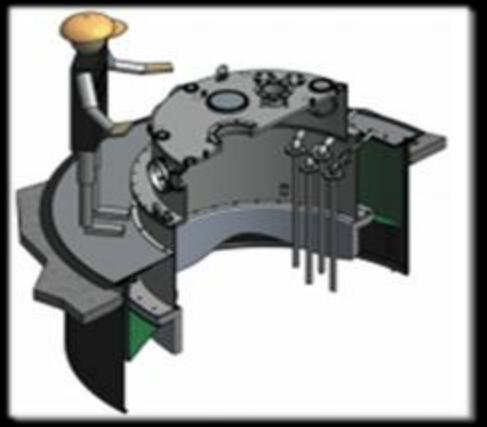
- Extreme purity of the liquid scintillator places serious concerns on the frequency of calibrations;
- SNO/Super-K/Hyper-K could insert almost anything;
- SNO+ perhaps as late, and rarely as only possible:
  - Internal Sources need to be ultra-clean;
  - Emphasis on External Sources will be important (external LED/Optical calibration, but also Ext. Bkg.)
  - Use of the Internal Backgrounds is being investigated (^{14}C, ^{210}Po, $^{214}BiPo$, $^{212}BiPo$ - fast coincidences studied)

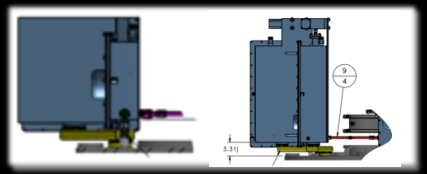
SNO+ Calibration

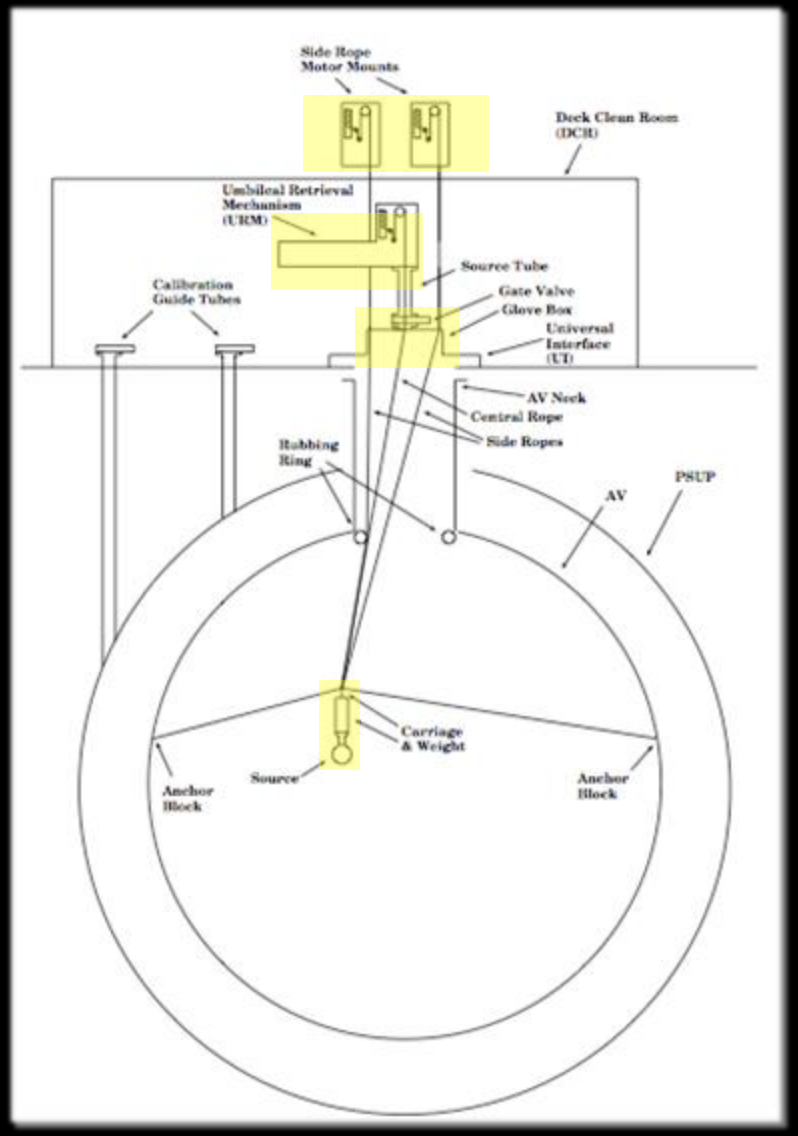
Hardware

New (Re)Design

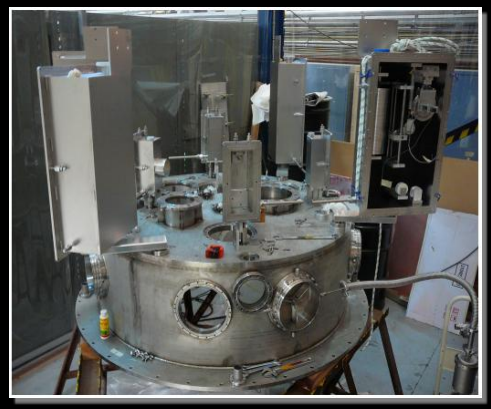






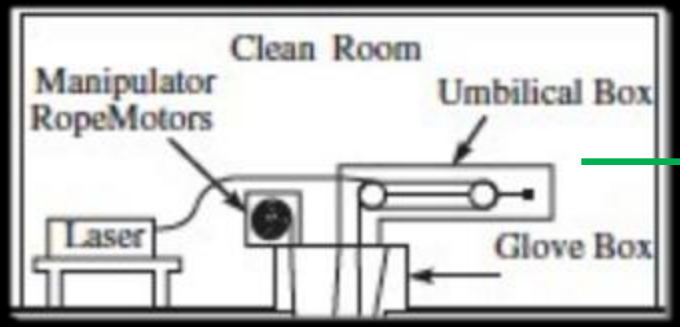


New Technology

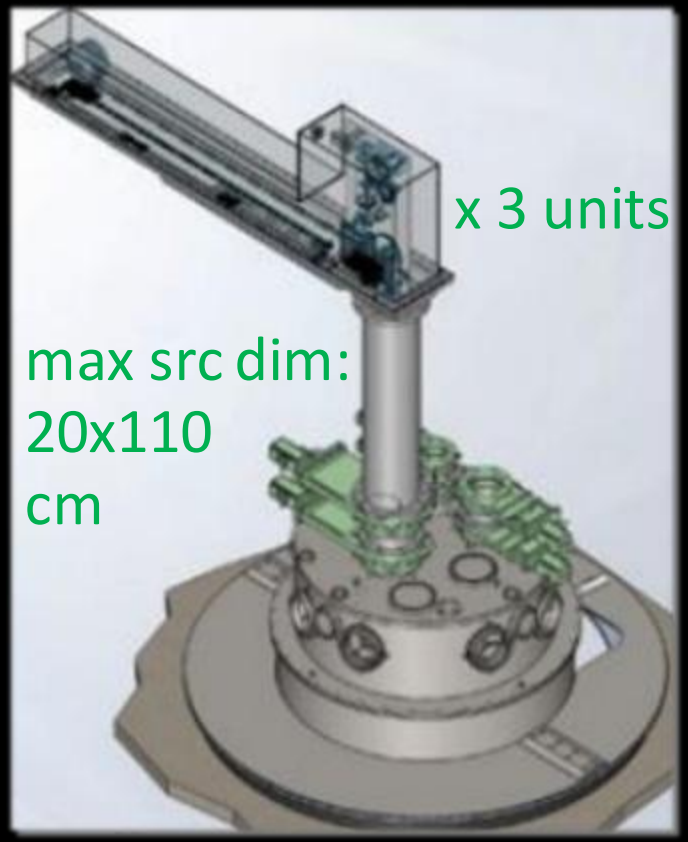


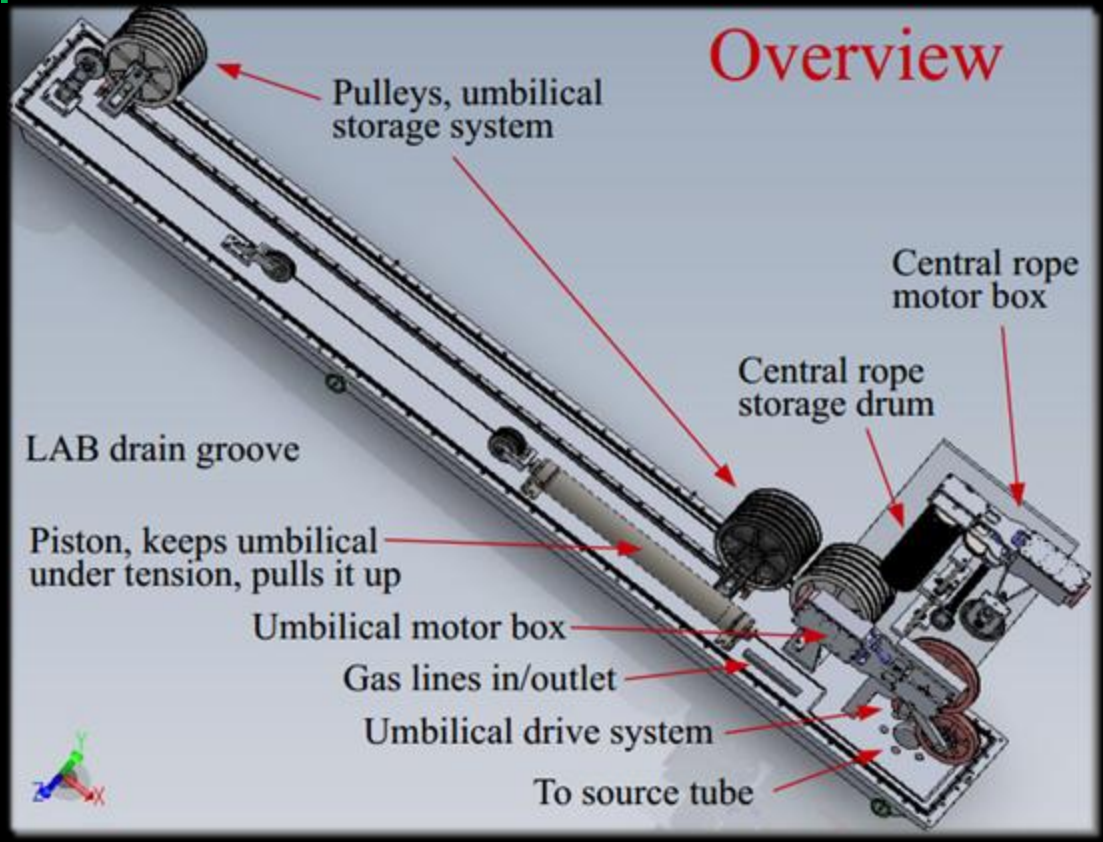
SNO+ Calibration

Umbilical Retrieval Mechanism



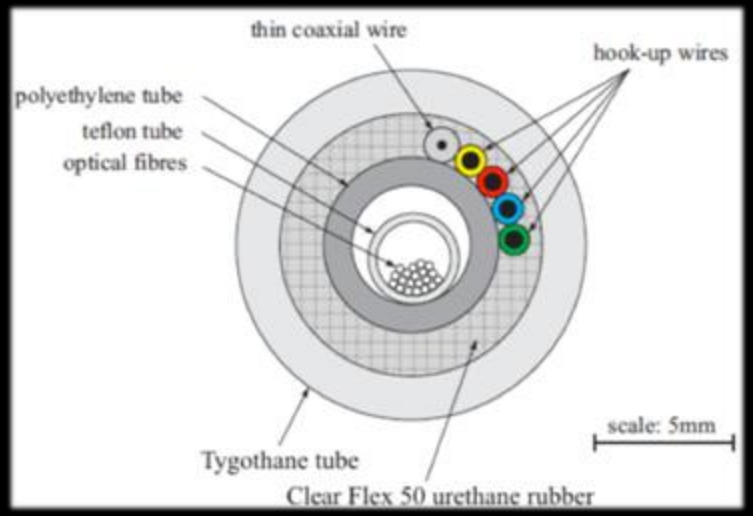
- Successfully used in Water
- Now upgraded for LAB





SNO+ Calibration

Umbilical Tubes



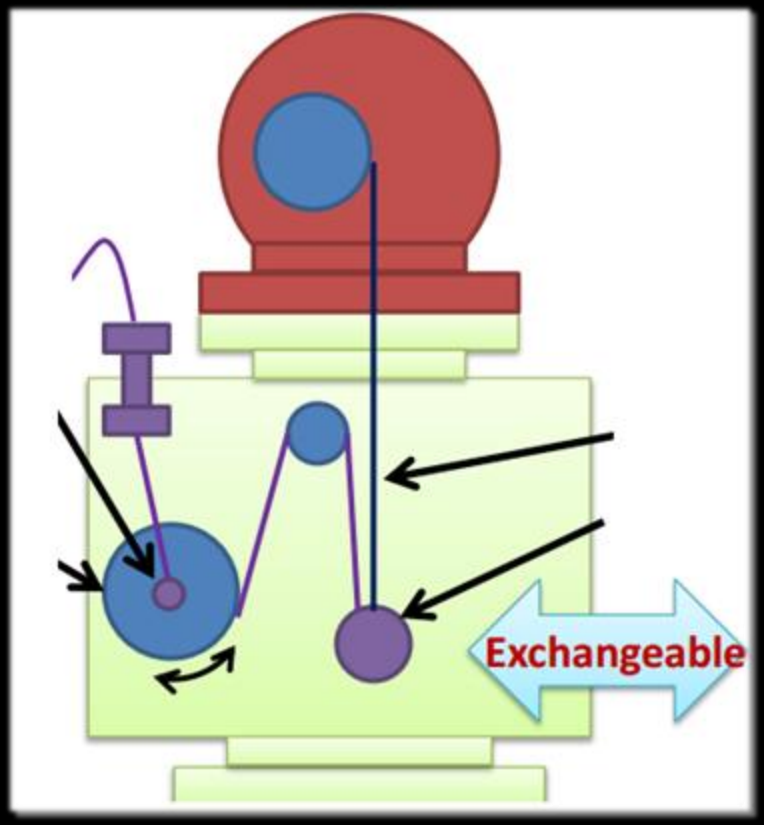
- Elastic, volume filled with gel;
- 1/2” OD, 100’ long (at its MAX);
- Deliver hook-up and coax wires;
- As well as optical fibers and gas.

SNO+ Calibration

Off-Axis Ropes

4th HK Meeting; Atsumu Suzuki

Development of the new Super-K Insertion System

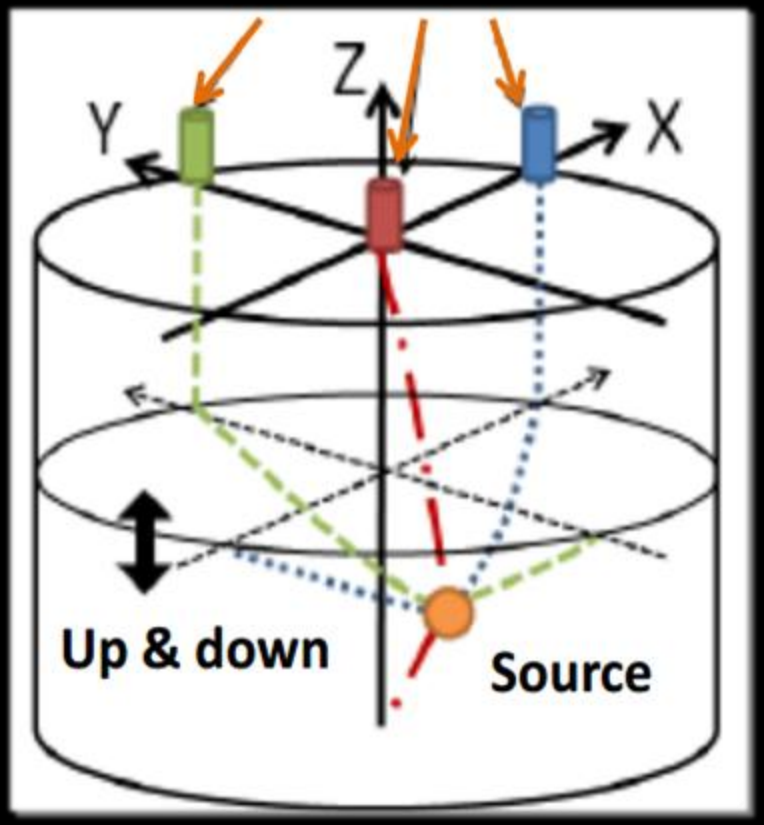


In Hyper-K

3D

Is a

MUST

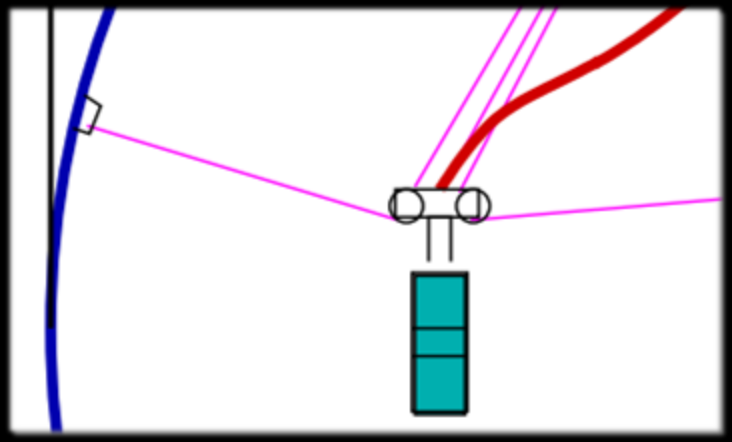


SNO+ Calibration

Off-Axis Ropes

1 central rope

Anchor on AV

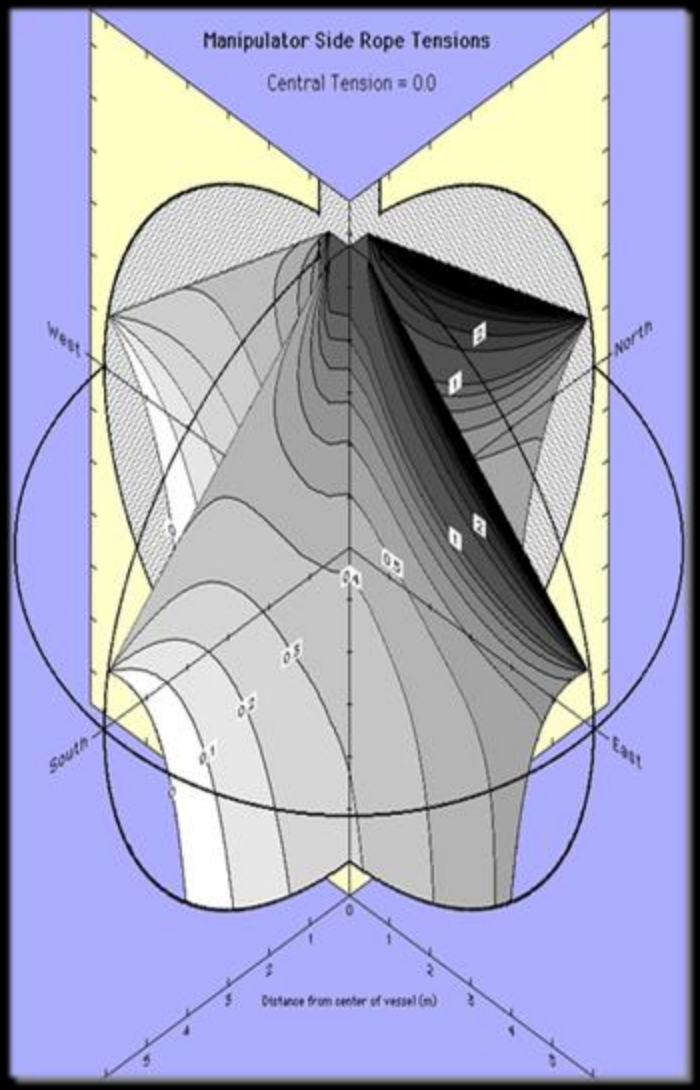


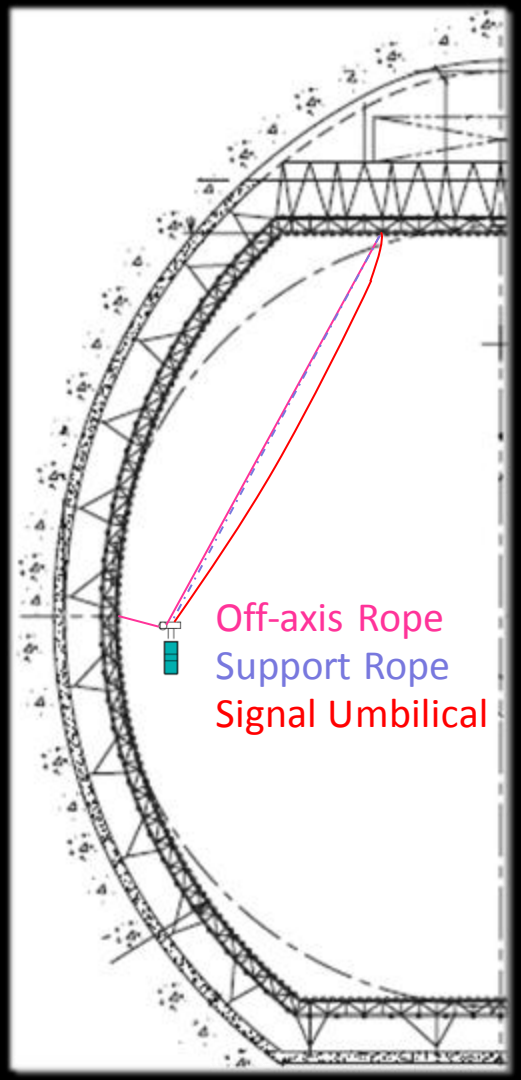
4 side ropes

- 4 side ropes, permanently submerged in Water or LAB;
- Tensylon material selected: low stretch, low creep;
- Allow positioning of the source in 2D (2-planes);
- CCD's will be also used for position recon.

SNO+ Calibration

Off-Axis Ropes





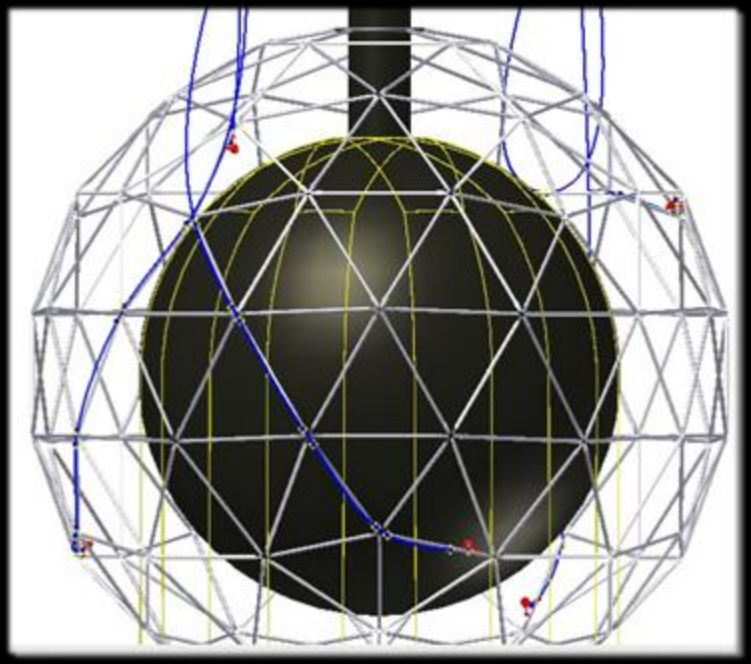
In Hyper-K:

- With the vertical calibration system add off-axis ropes, only to side ports.
- That is where the asymmetry of the detector exists.

SNO+ Calibration

Source Location

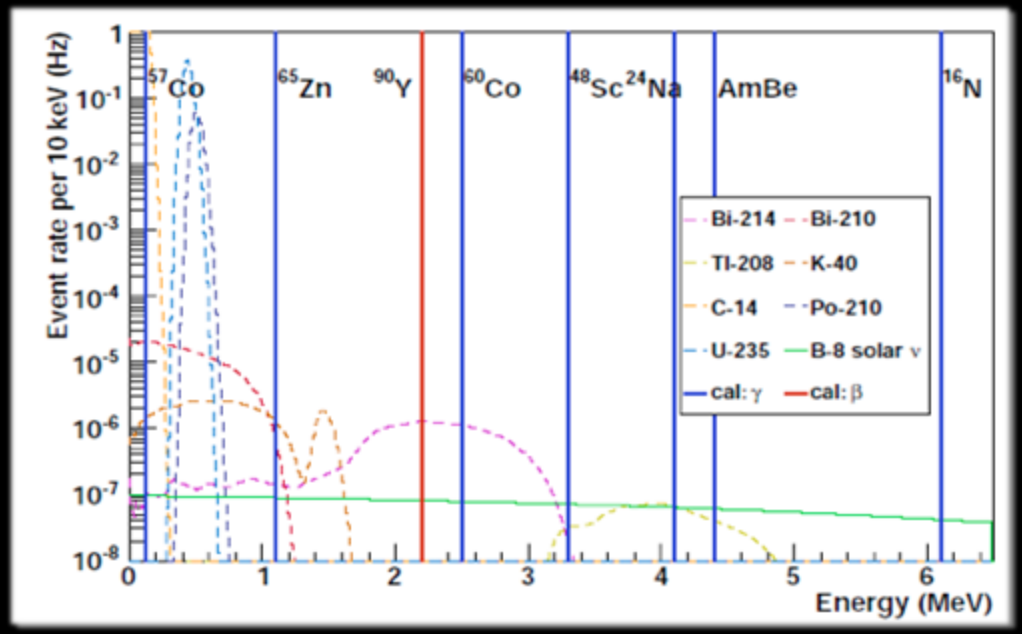
- 6 CCD cameras will be installed on the PSUP 3 top, 3 bot;
- Cameras calibrated using known positions of the PMTs;
- Goal: Positioning of the calibration sources, monitoring of the ropes status and potential issues with the net;

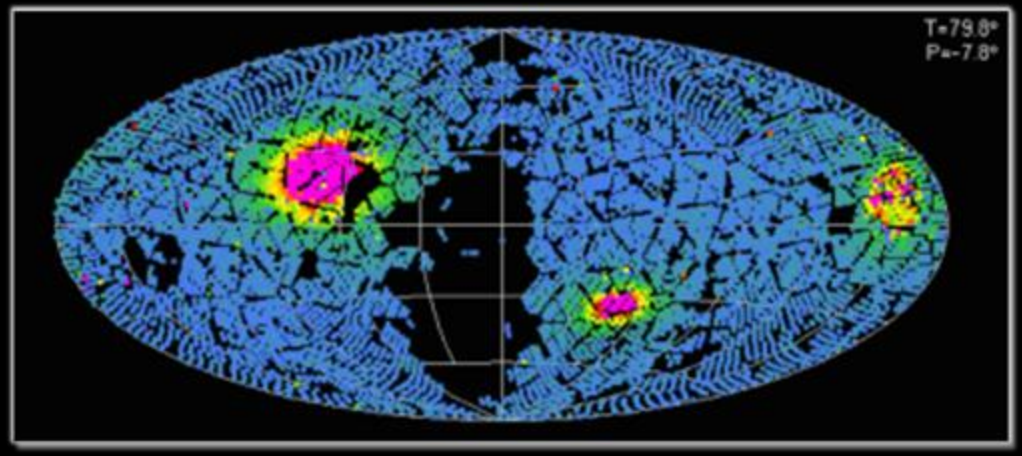


SNO+ Calibration

Sources

- Radioactive and optical sources, α, β, γ, n, with laser injection, laserball and Cherenkov;
- In three phases of SNO+
  - Air run
  - Water fill
  - Scintillator fill
  - Scintillator + Te load





SNO+ Calibration

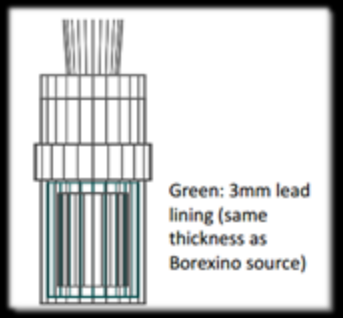
Internal Sources

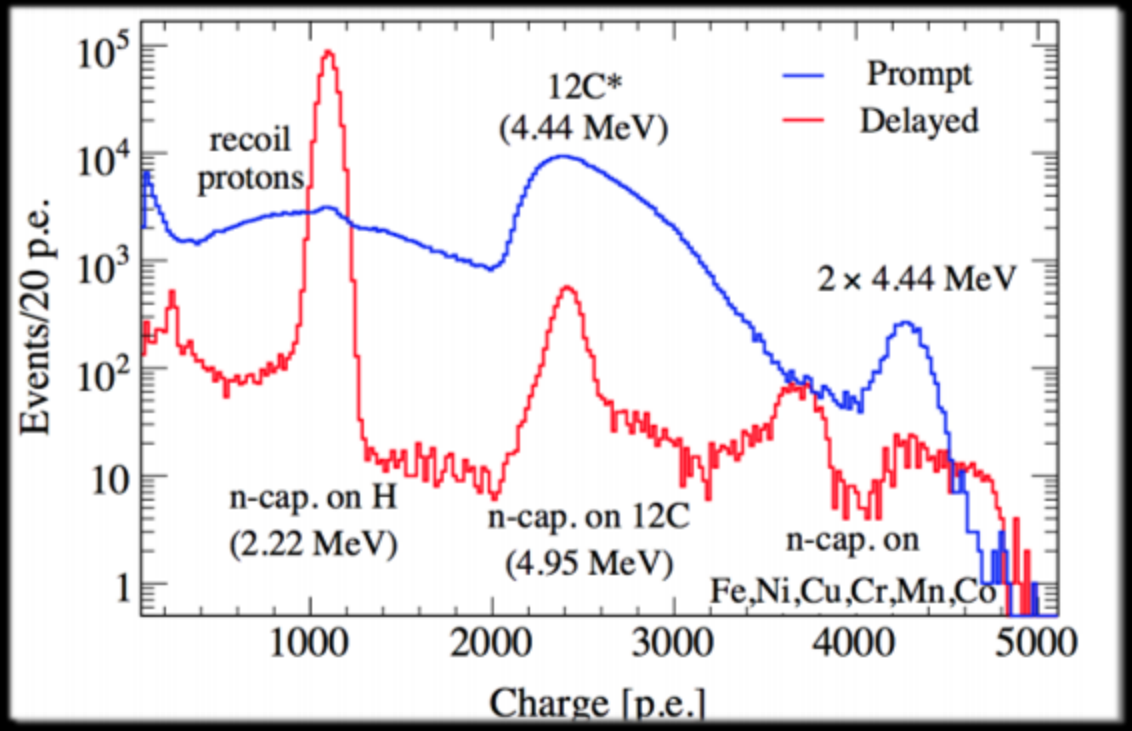
$^{241}Am^{9}Be$ source: :gamma/neutron

- ^{241}Am releases an α, inducing $^{9}Be(\alpha, n)^{12}C$ -> 4.4 MeV γ;
- α release gives off many low energy (~keV) gammas
- Shielding required

Borexino
3mm Pb

Similar in SNO+





arXiv:1207.4816

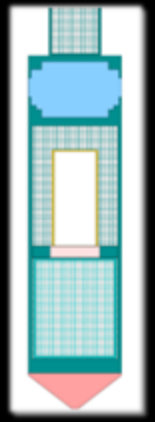
SNO+ Calibration

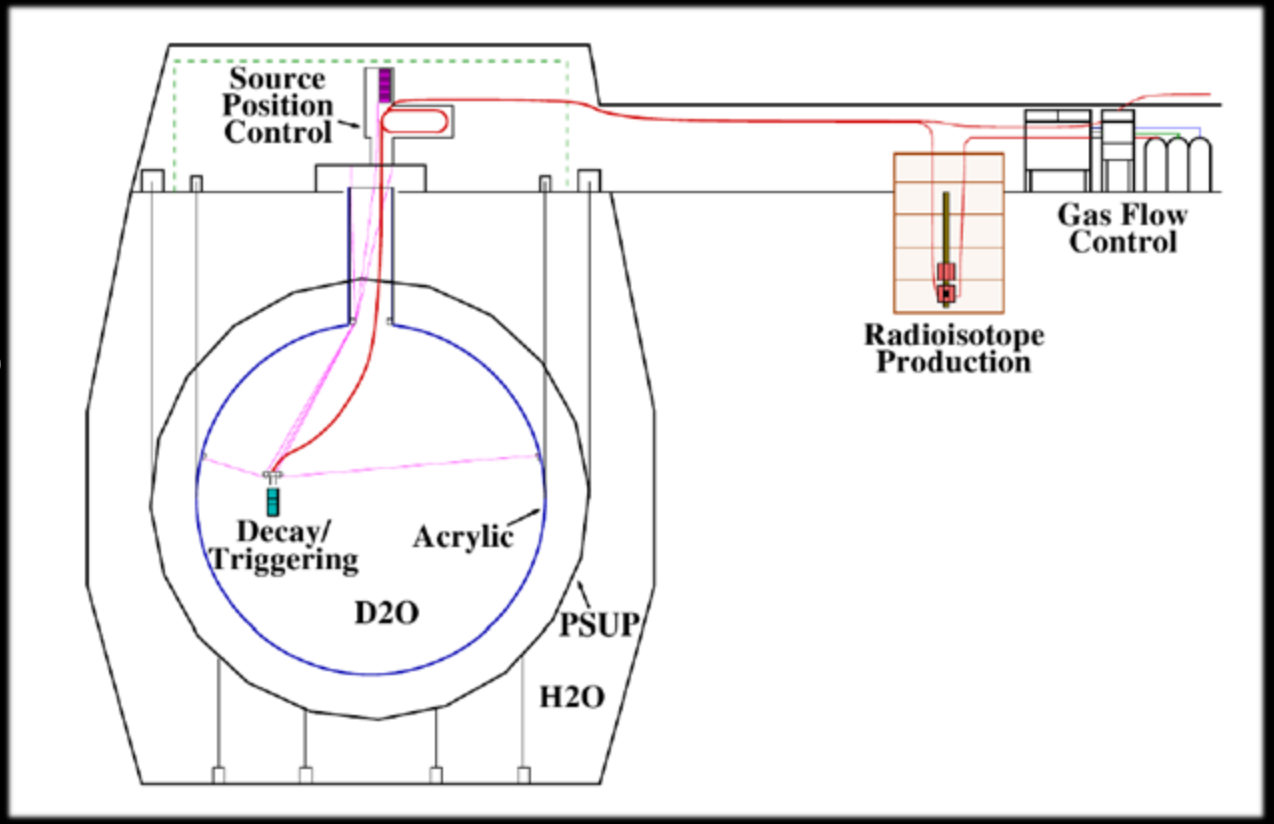
Internal Sources

^{16}N source: :tagged gamma

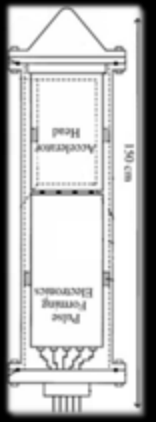
Transfer ~7.12 s CO_2 Gas

Decay Chamb





DT Generator



arXiv:nucl-ex/0109011

SNO+ Calibration

Internal Sources

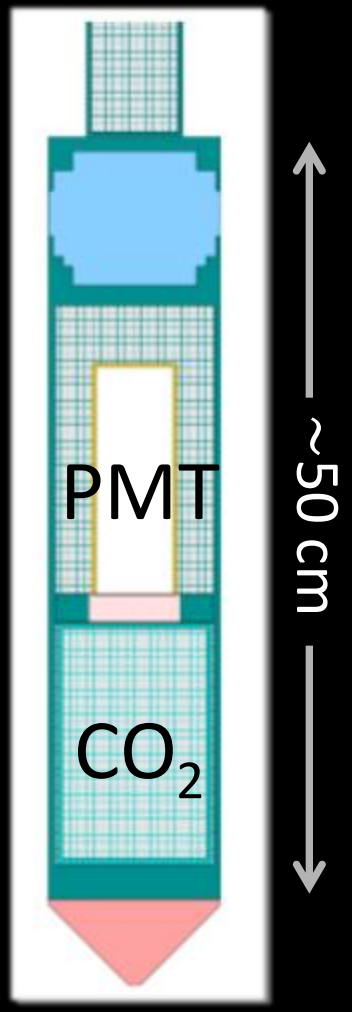
^{16}N source:

Advantages:

- DT Generator in fixed location;
- Shared coupler and hardware;
- Good position recon + tag.

Disadvantages:

- Half-life of ^{16}N is short, ~7.12s;
- Currently max length ~30m.



SNO+ Calibration

Optical, LED

In-Situ:

Standard optical sources designed: laserball (optics, angular response), Cherenkov (PMT efficiency).

Ex-Situ:

ELLIE (Embedded LED/Laser light injection entity)

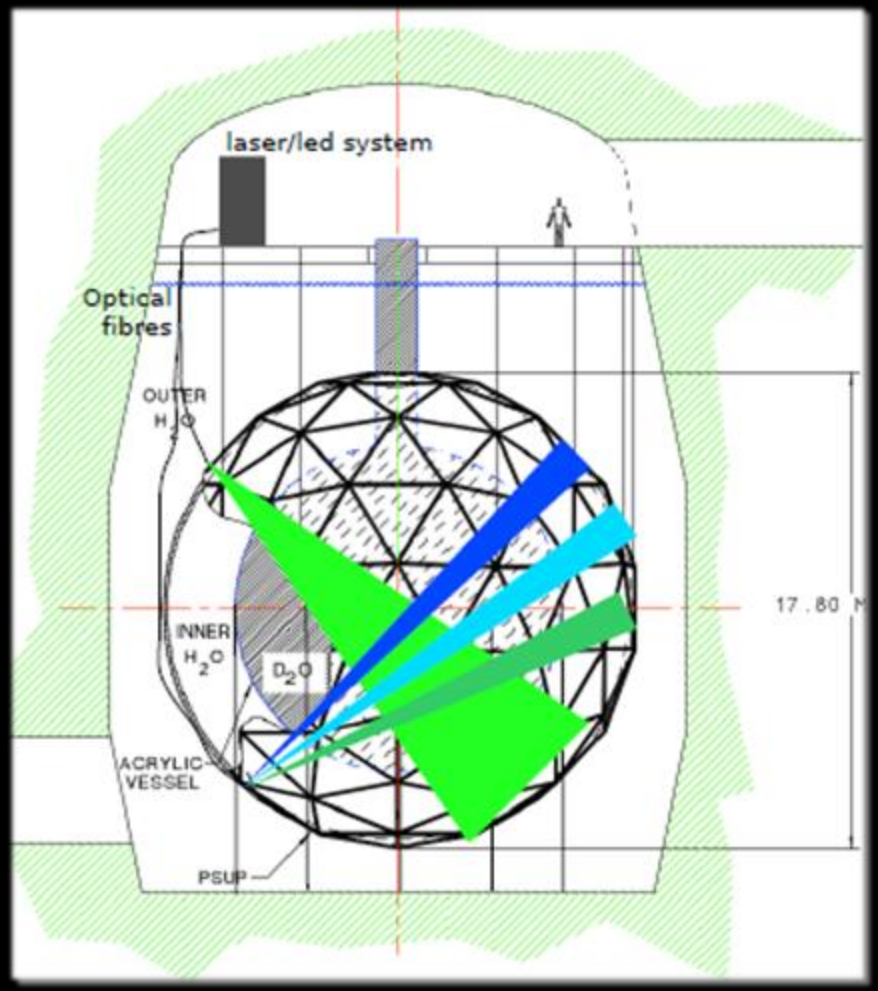
TELLIE (timing, gain of PMTs, and optics of LS)

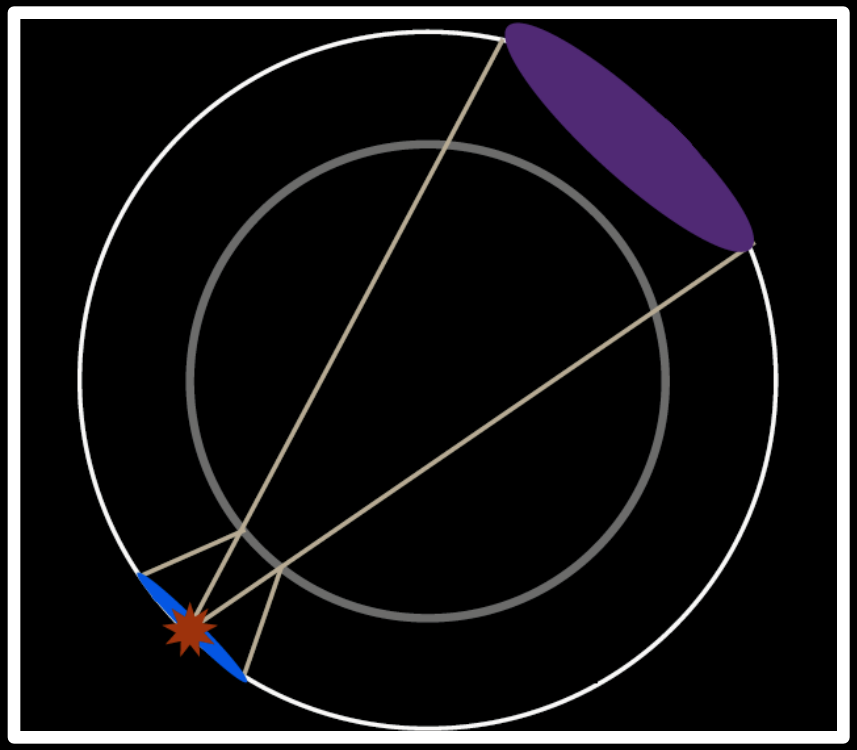
SMELLIE (scattering properties)

AMELLIE (attenuation length)

SNO+ Calibration

Optical, LED

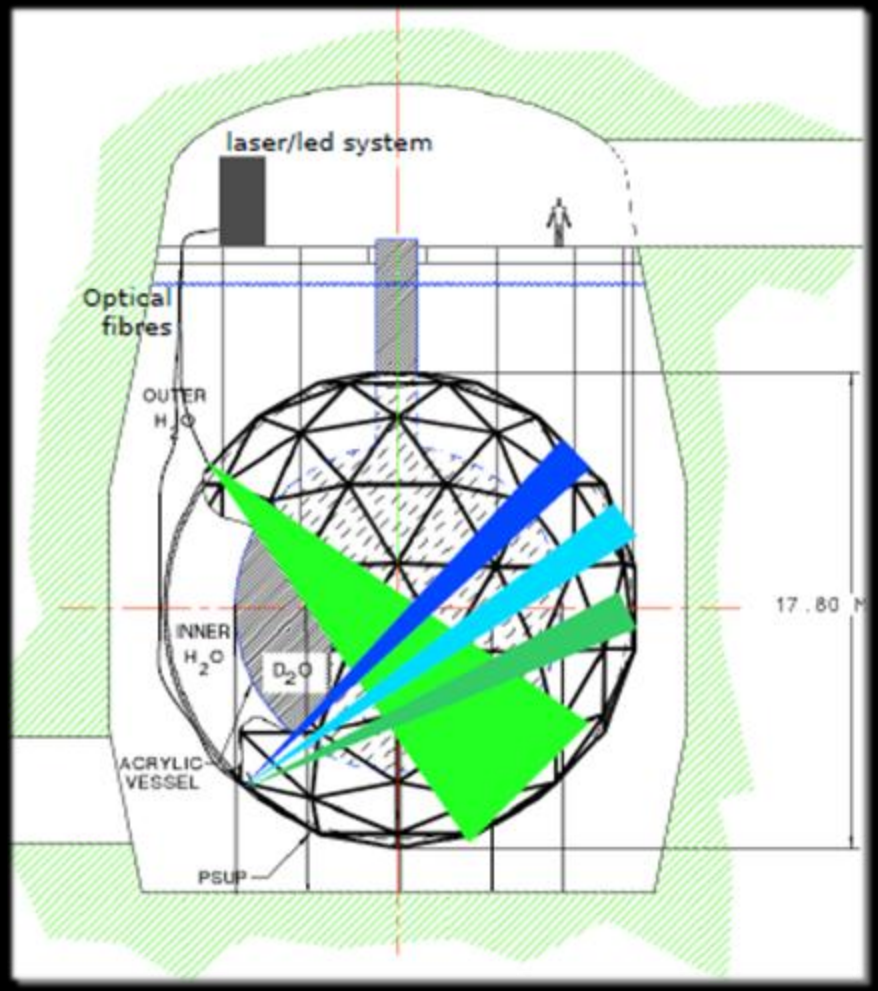


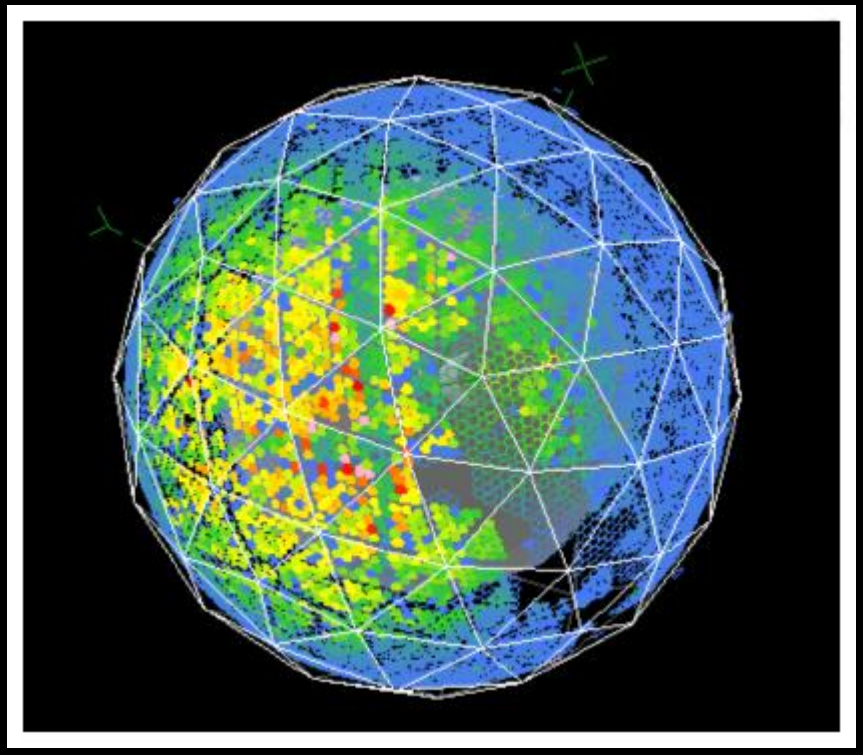


Light emitted from the support structure from 92 fibres installed between PMTs. Each gives 10E3-10E5 photons/pulse.

SNO+ Calibration

Optical, LED





Hit map of the PMT array of an TELLIE commissioning run; Only air in the cavity and the detector. The system is able to verify the position of the hold-down ropes.

Time Line

2014: water fill and water commissioning
- Nucleon decay physics
- Backgrounds analysis
- Supernovae neutrinos

2015: start liquid scintillator fill
- Background analysis
- Reactor- and geo- antineutrinos
- Supernovae neutrinos
- Low energy solar neutrinos

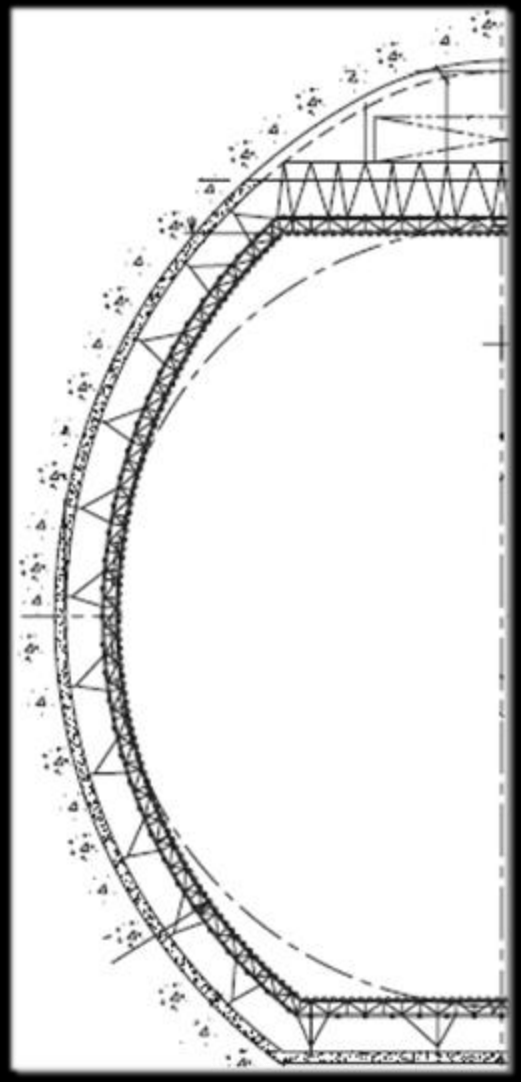
2016: 0.3% Te loading
- Neutrinoless double beta decay
- Reactor- and geo- antineutrinos
- Supernovae neutrinos


Chief Awaiting Data

Thanks!

Ending Remark

Symmetric HK



Egg-shaped HK affects:

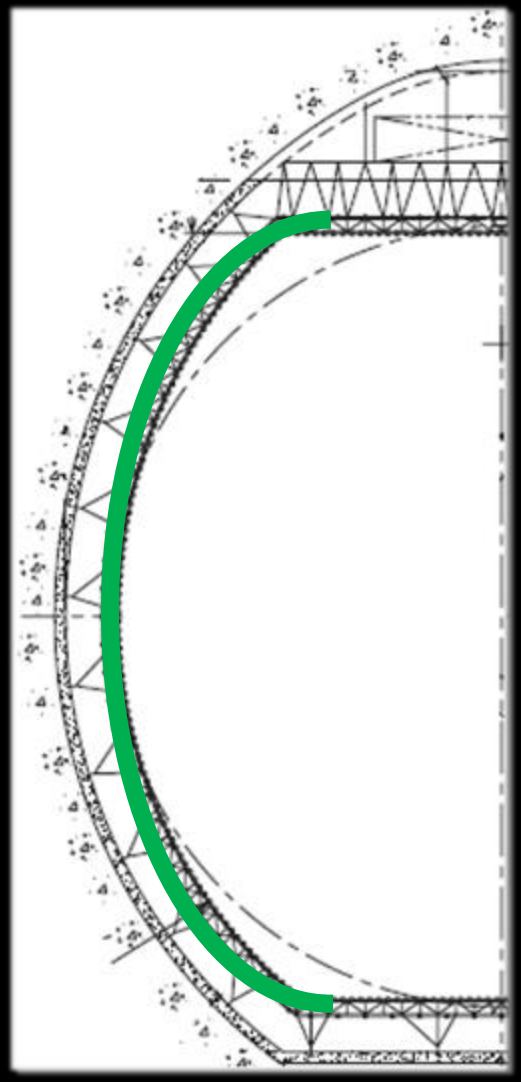
- Limited access of the calibration sources, even w/ the off-axis ropes;
- Uniformly distributed standard PMTs as in the Super-K case.

We ‘cannot’ redesign the tank or cavity.

Can we redesign the PMT support frame to spherical geometry, while preserving the same cavity shape ?

Ending Remark

Symmetric HK



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Thanks, again.