

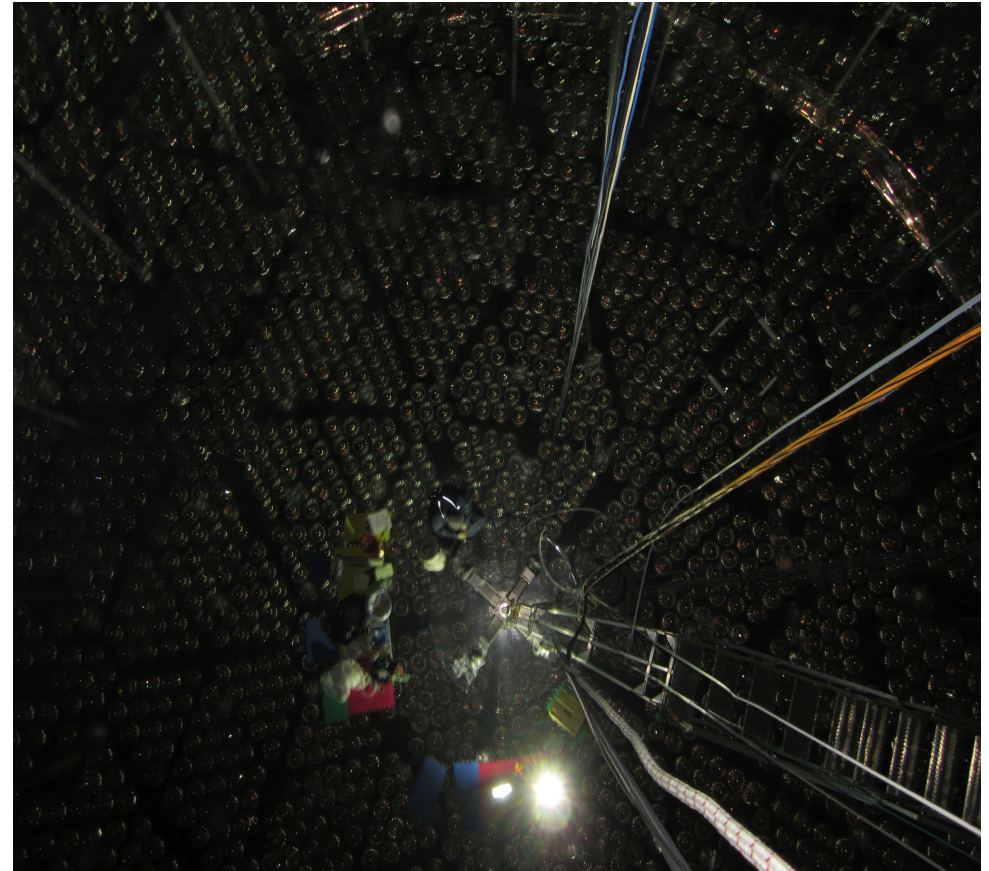
Optical calibration of SNO+

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Content:



- The SNO experiment
 - Optical calibration motivation and techniques
 - Detector asymmetry
- SNO+ upgrade
 - Deployed optical sources
 - In-situ optical sources
 - Status



The SNO detector:



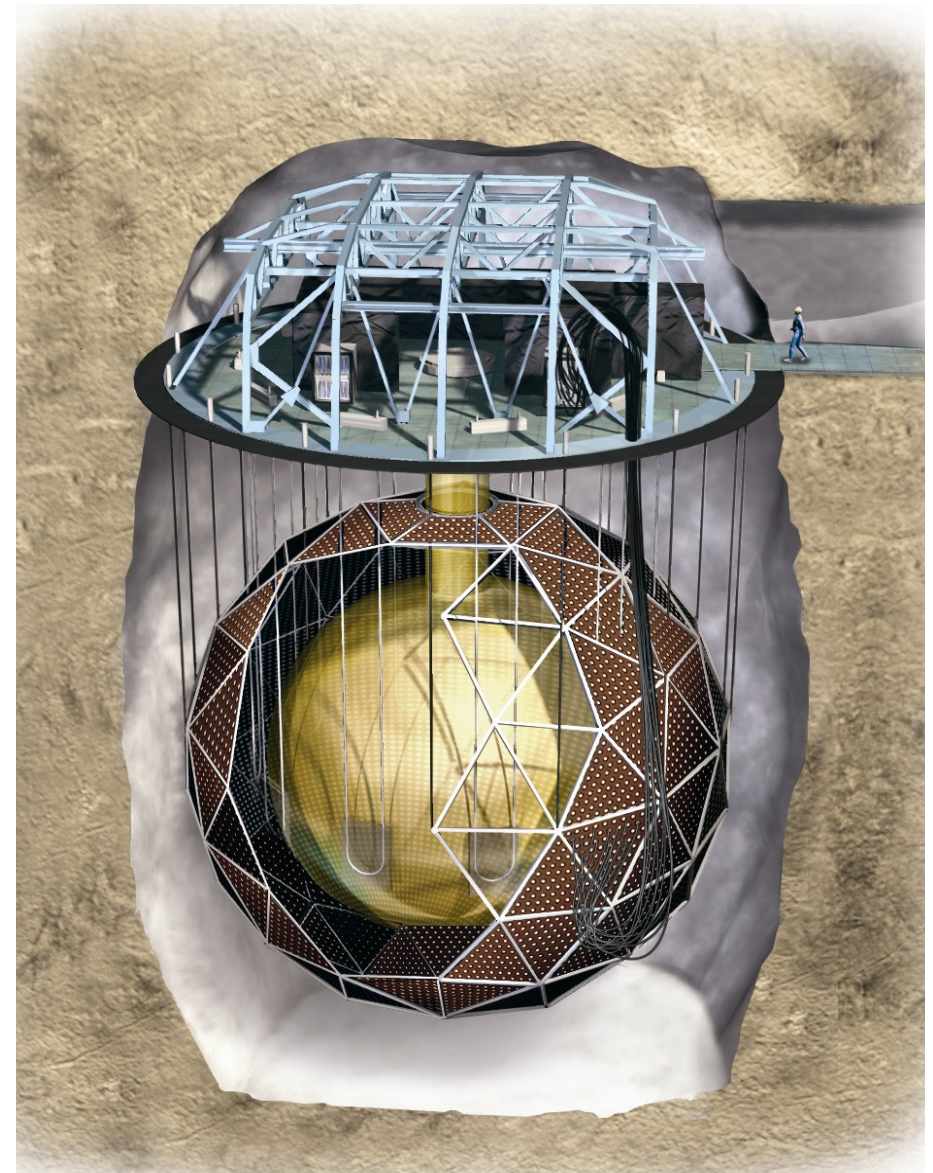
12 m diameter acrylic vessel (AV)
surrounded by ~ 9500 PMTs.

2.07 km Underground:
3 muons per hour

Solar neutrino detector phases:

- Heavy water
- Heavy water + salt (NaCl)
- Heavy water + ^3He prop. counters

...Neutrino flavour change.



Optical calibration in SNO



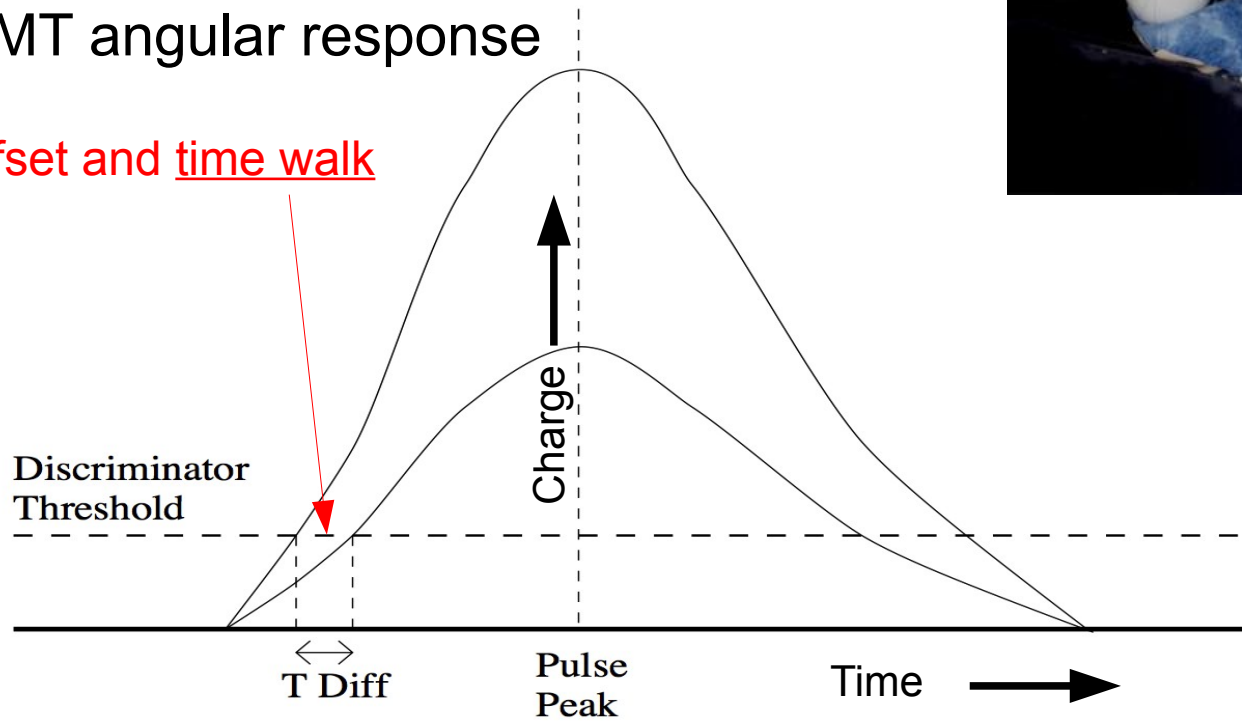
The Laserball - N₂-dye laser with 6 central wavelengths: 337, 365, 386, 421, 500, 620 nm. Coupled to a light diffusing sphere deployed within AV.

Calibrating:

- PMT Timing and Gain
- Transmission as function of wavelength
- Relative PMT angular response



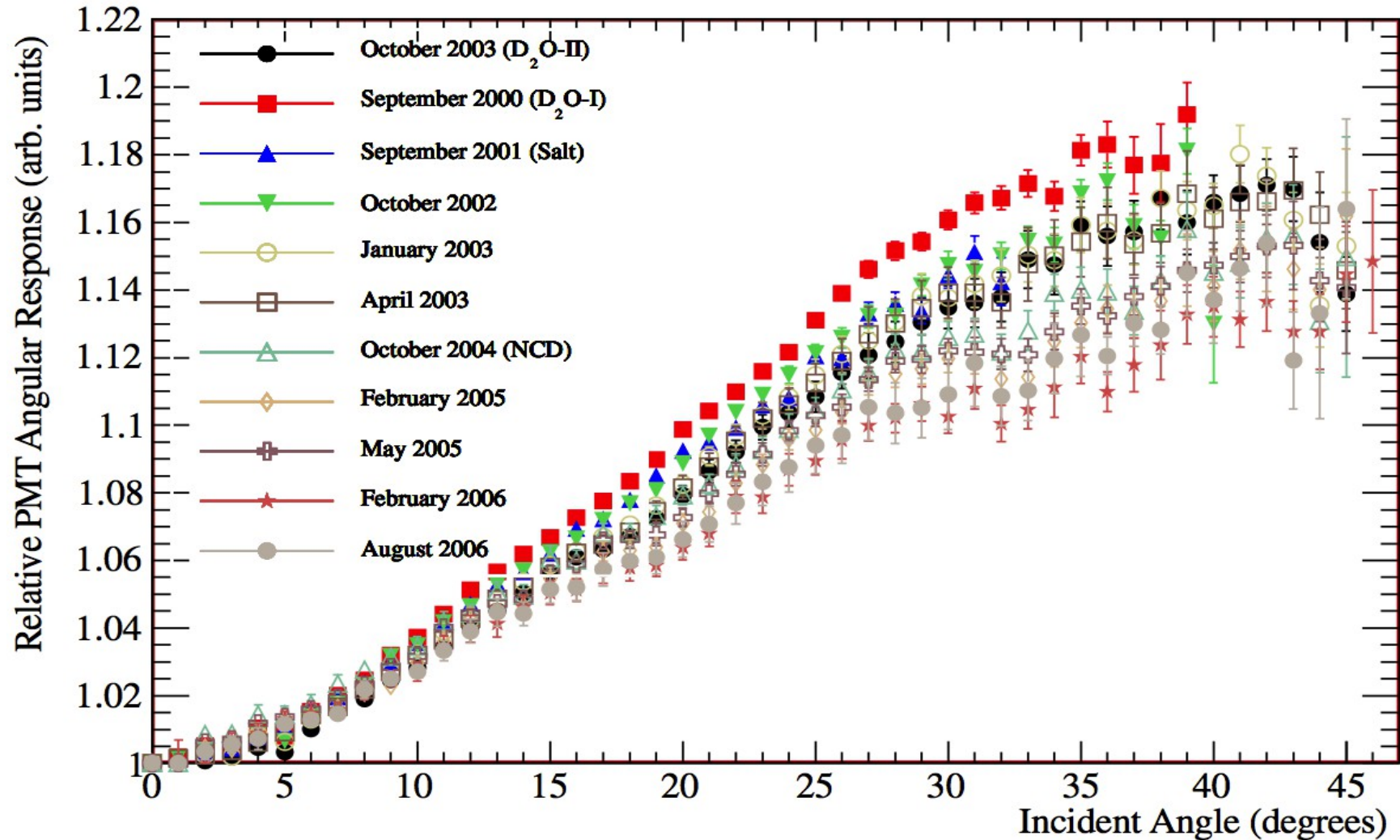
Time offset and time walk



Optical calibration in SNO



Relative PMT Angular Response at 500 nm vs Incident Angle

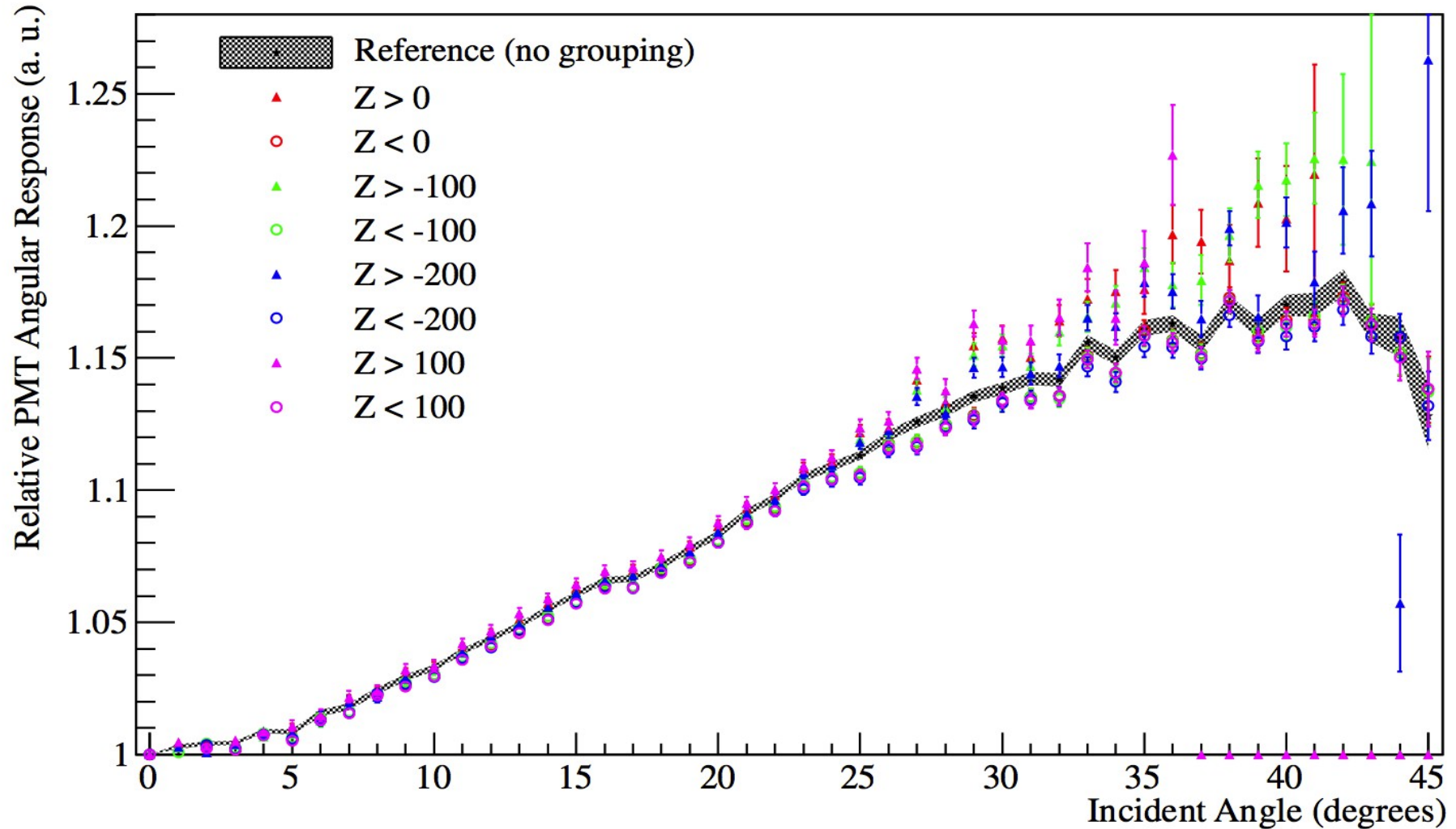


PMT angular response as function of angle from 2000 - 2006

Optical calibration in SNO



Relative Angular Response at 500nm (oct03)



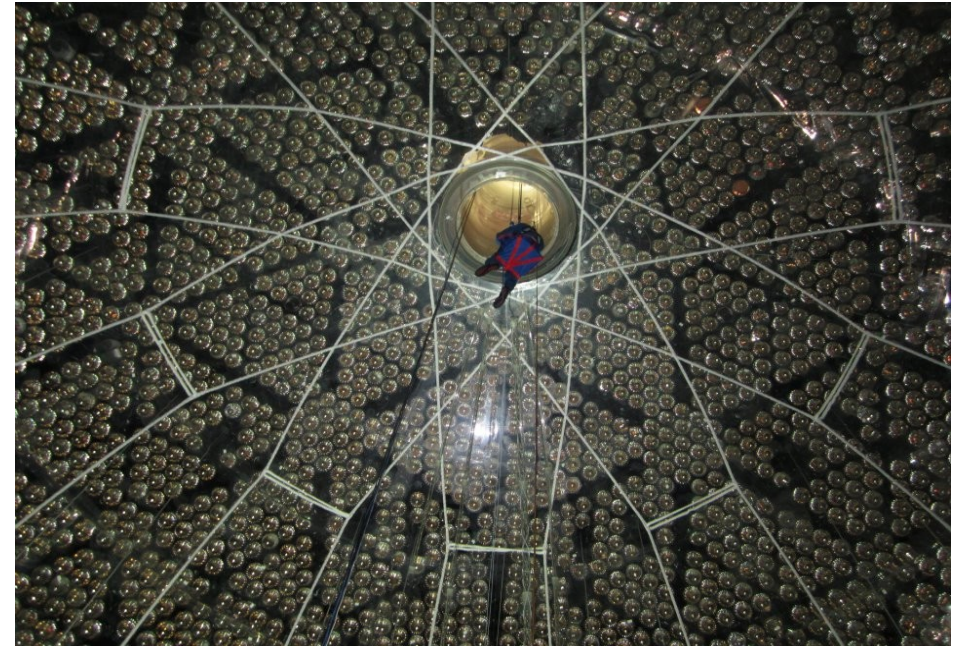
PMT angular response obtained by grouping PMTs in different horizontal slices of the detector

The SNO+ upgrade



Physics goals:

- **Neutrinoless double-beta decay**
- Solar, geo, reactor and supernova neutrinos
- Nucleon decay



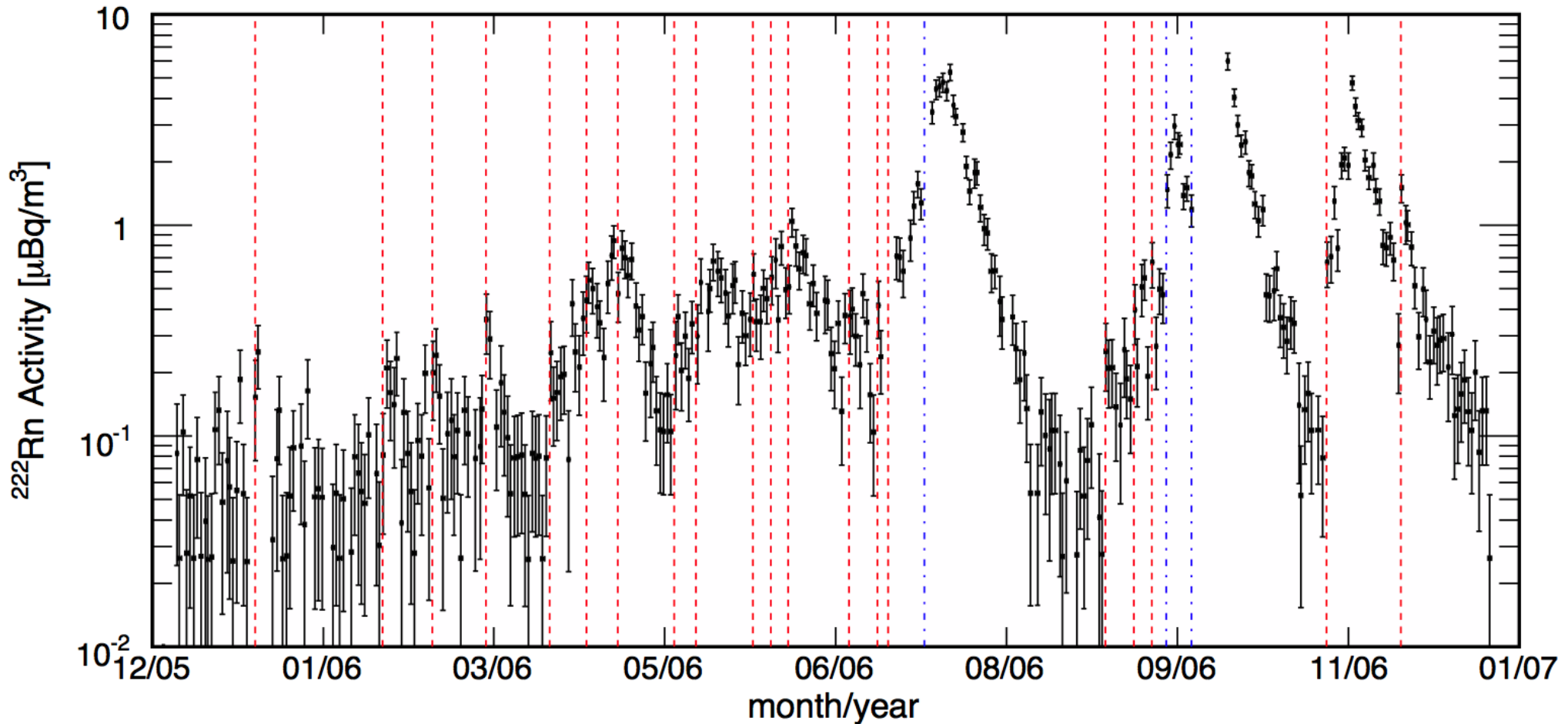
Upgrades:

- ^{130}Te loaded LAB scintillator
- Scintillator purification system
- Hold down rope net for AV
- New calibration systems
- Higher throughput electronics/DAQ

Radiopurity requirements



Lower energy threshold – risk of background affect from deployed sources:



^{222}Rn activity in Kamland (JINST 4 P04017, 2009). Red/blue lines: start of calibration.

Laser ball upgrade

Fully synthetic quartz

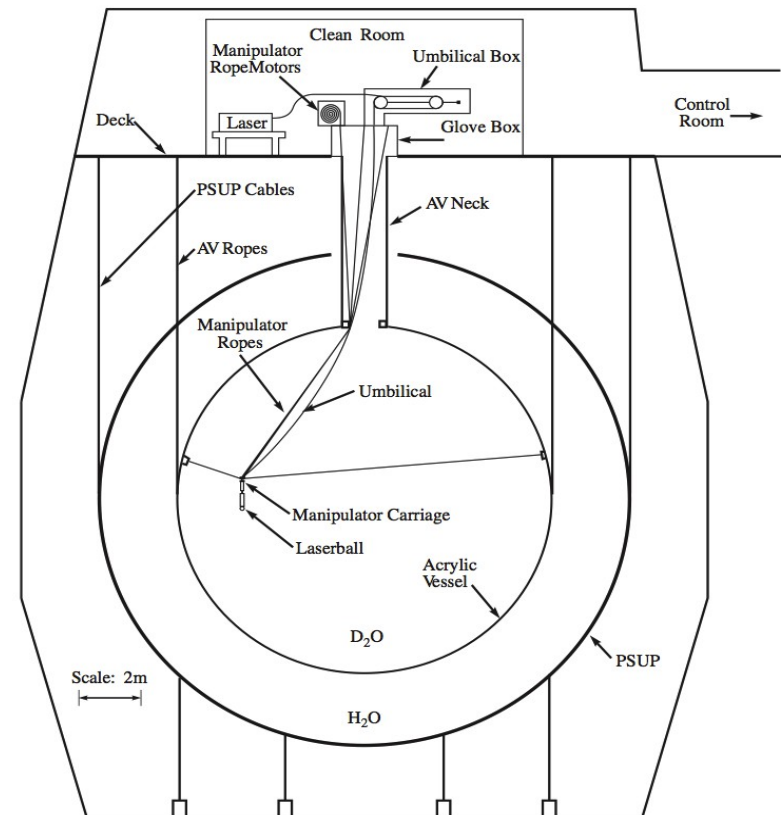
- Radioactively pure
- Meets limit of 13 counts per day of ^{222}Rn

Reduced neck diameter (38 to 19 mm):
Minimise shadow to upper hemisphere

Optimized laser dyes

Stringent storage and deployment techniques

Deployed sources discussed in
M. Mottram's parallel talk

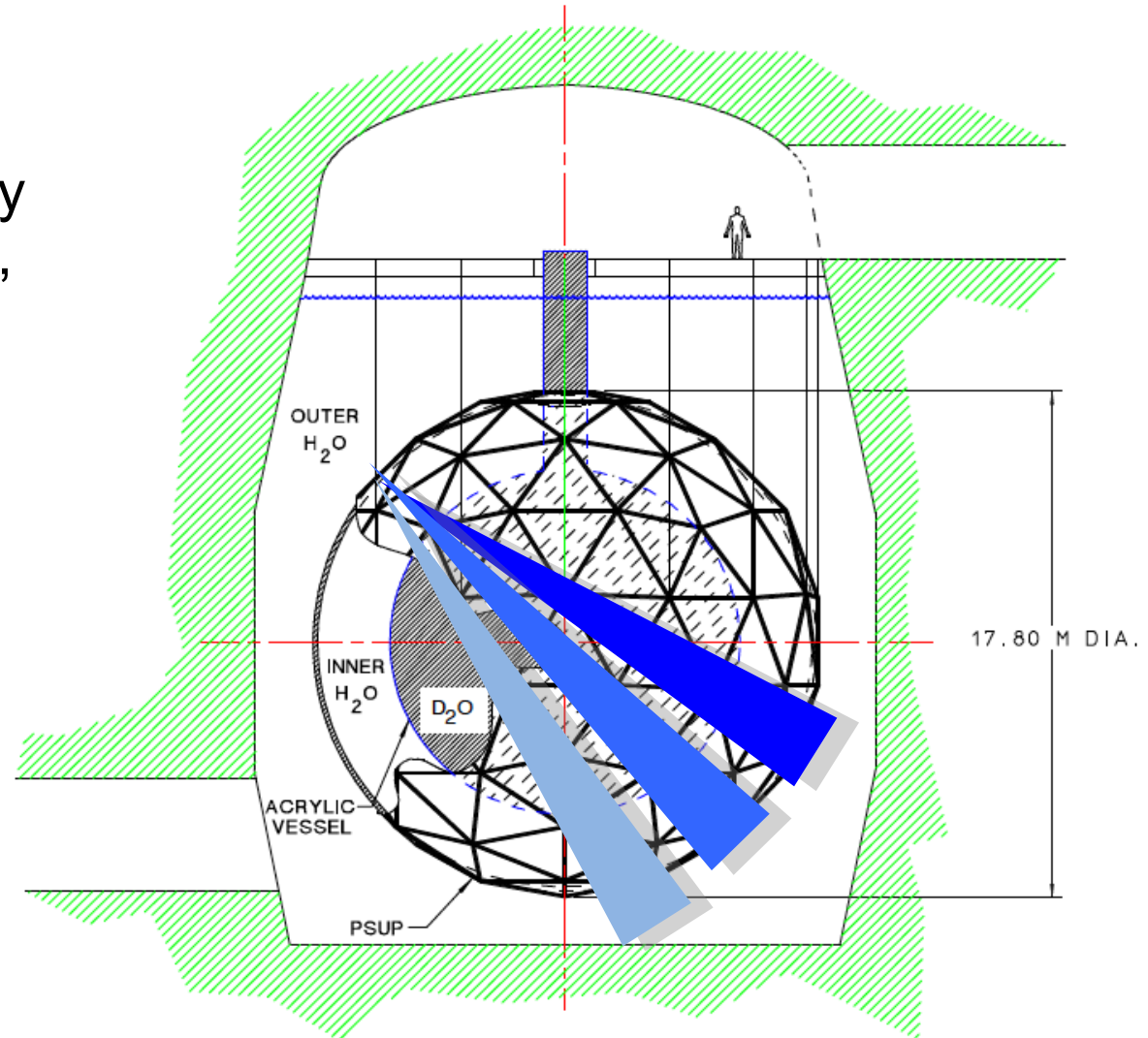


In-situ optics

Embedded LED/Laser light injection entity (ELLIE).

LED/Laser pulses generated by externally mounted electronics, injected via optical fibres terminating at PMT support structure.

Providing continuous optical calibration, minimising risk of contamination.



Timing (T)ELLIE

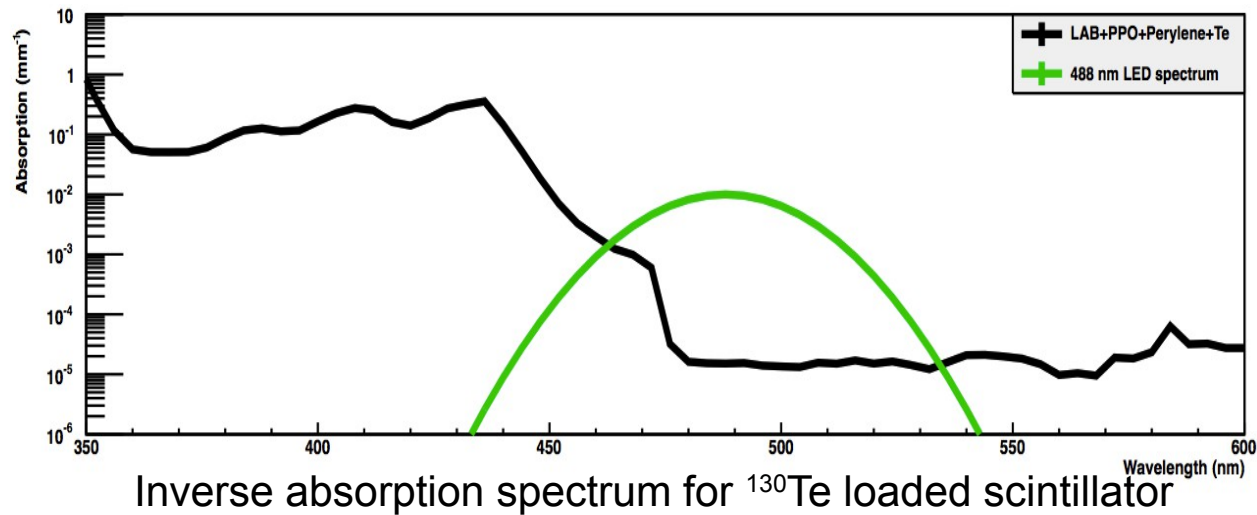
Measure time offset, time walk and gain calibration of the PMTs.

Monitor transmission.

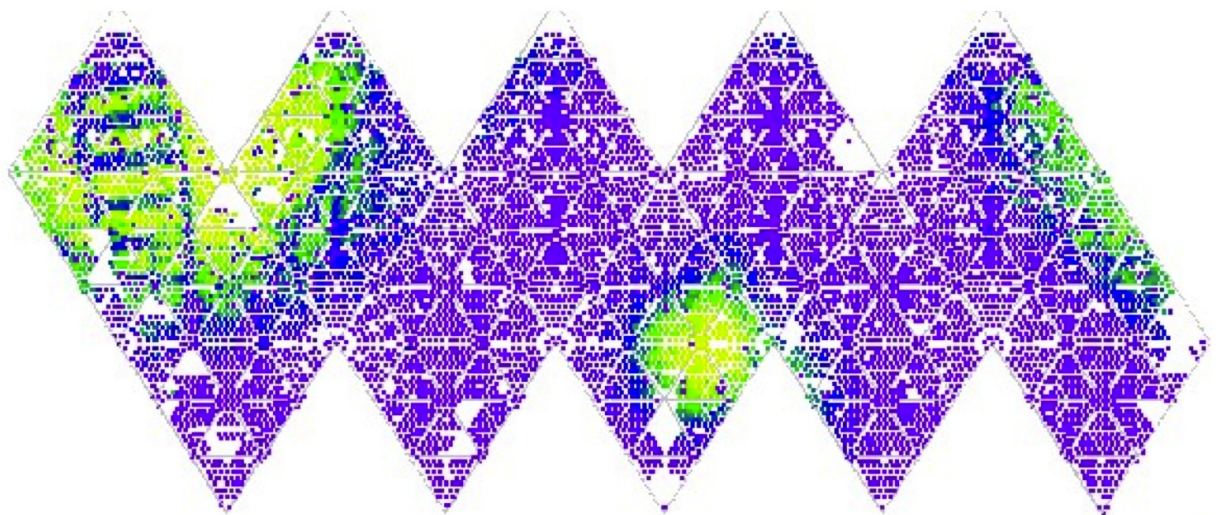
Pulses from LEDs selected to match target mass absorption spectrum.

92 PMMA fibres, cover redundantly all PMTs.

Range 10^5 to 10^3 photons, pulse width <5 ns.



Inverse absorption spectrum for ¹³⁰Te loaded scintillator



Oct 2012 Air-fill TELLIE event, showing temporary access ladder

Timing (T)ELLIE

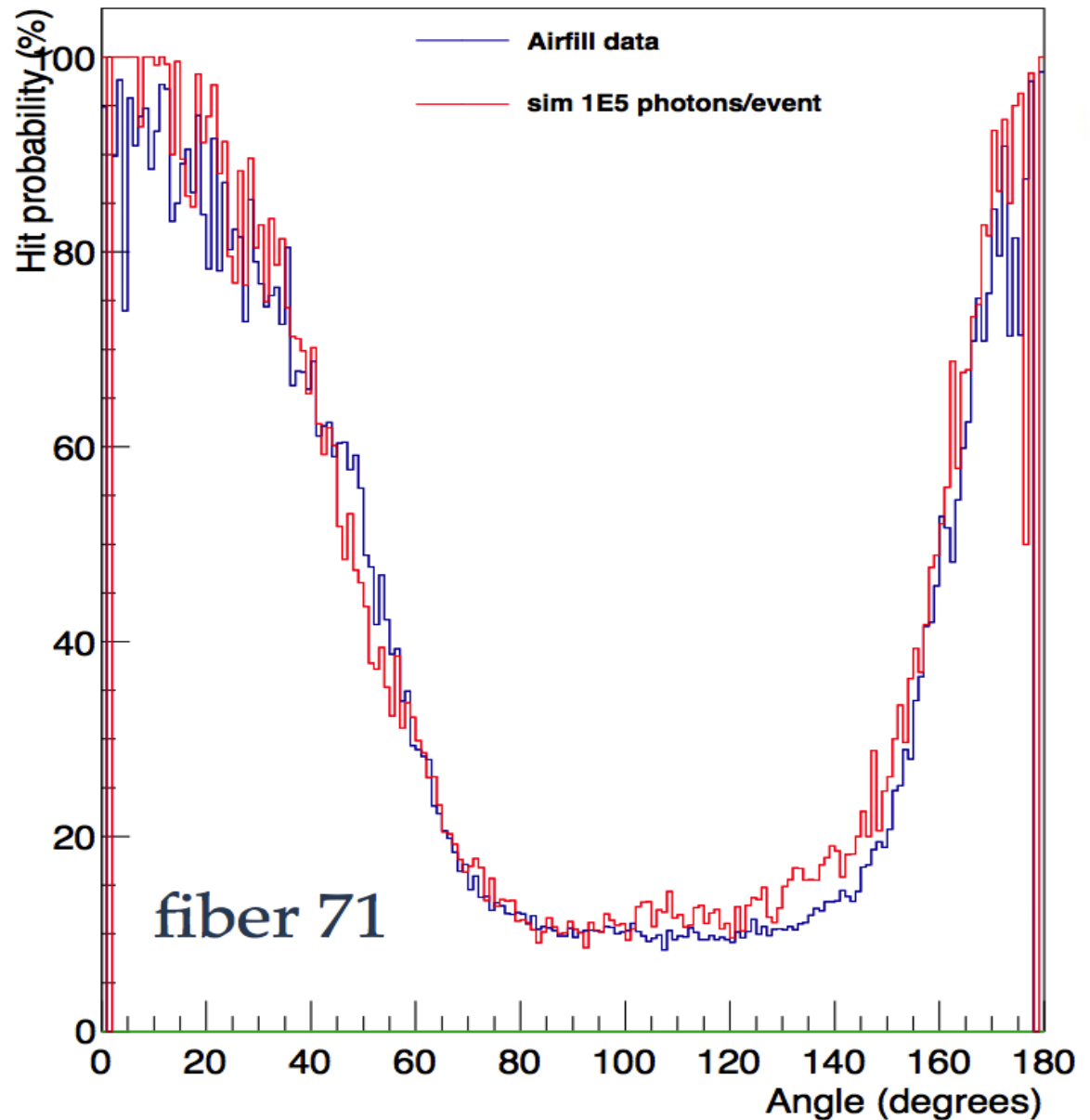
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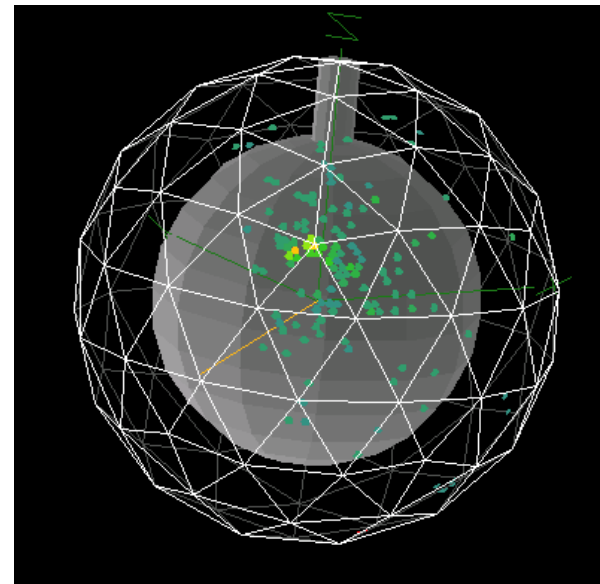
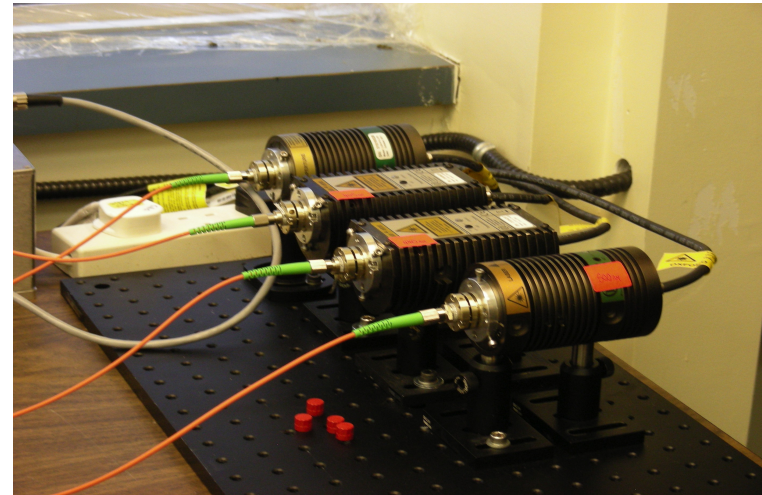
PMT hit probability as function of injection angle

Scattering measurement

Comparison of scattering within central beam spot and outside. Only practical in-situ.

375, 405, 440 and 500 nm lasers coupled to quartz fibres.

12 collimated beams of different wavelengths, pointing in 3 different directions from 4 locations.



Mar 2013 Air-fill SMELLIE event

Schedule



April 2013: Start filling with water

- ELLIE installation to be completed by boat

Fall 2013: ELLIE and laserball commissioning

July 2013: First water data

January 2014: Begin scintillator fill

May-June 2014: First scintillator data

Summary

The upgrades to SNO+ are nearing completion.

The ELLIE systems have been shown to work during air-fill, providing useful demonstration of DAQ and data flow readiness. Installation will continue during water fill.

Deployed laserball has been developed to meet radiopurity requirements at lower energy threshold.

