Calibration of the SNO+ Detector

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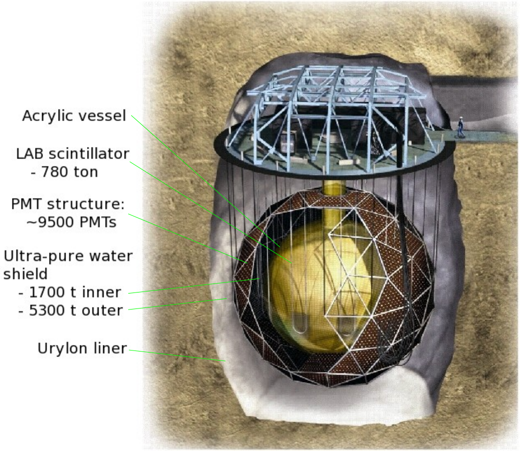
University of Sussex, 03/04/2012

SNO+ Overview



Physics outlook:

- Double beta decay
- Solar pep neutrinos
- Geo-neutrinos
- Supernova neutrinos
- Reactor neutrinos
- Nucleon decay (water phase)

UK involvement

UK collaboration members *(indicates convener roles)*:

- Leeds: S. Bradbury, J. Rose
- Liverpool: N. McCauley *(data processing)*
- Oxford: S. Biller *(reconstruction, nucleon decay, anti-neutrinos)*, I. Coulter, N. Jelley, K. Majumdar, A. Reichold, M. Schwendener
- QMUL: F. Di Lodovico, P. Jones, J. Wilson *(analysis)*
- Sheffield: J. McMillan
- Sussex: E. Falk, J. Hartnell *(data processing)*, G. Lefeuvre, M. Mottram, S. Peeters *(calibration)*, J. Sinclair, R. White

UNIVERSITY OF LEEDS

UNIVERSITY OF LIVERPOOL

UNIVERSITY OF OXFORD

Queen Mary University of London

The University Of Sheffield.

US University of Sussex

What to calibrate?

Calibration requirements determined by physics goals (and there are lots of physics goals!):

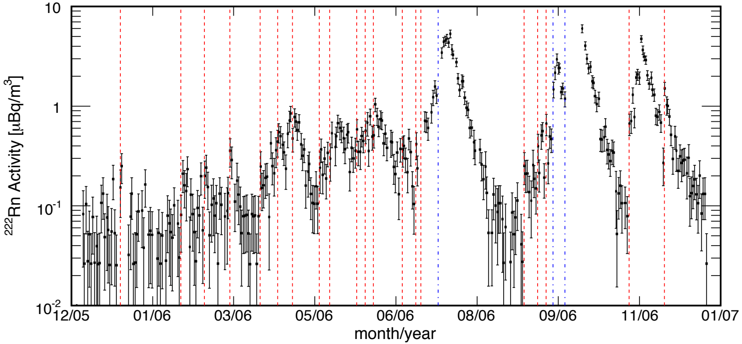
- Good understanding of: energy response (and uniformity) over 0.1–10 MeV, thresholds (0.1–0.2 MeV), energy resolution, energy distribution tails, position reconstruction, particle identification ... etc

No one device/technique can tackle all of these:

- Deployable light source (laserball)
- Deployable radioactive sources
- Deployable sealed radon source ball
- Permanent optical calibration system (ELLIE)

The UK is responsible for a number of essential calibration sources.

Kamland Rn activity & calibrations



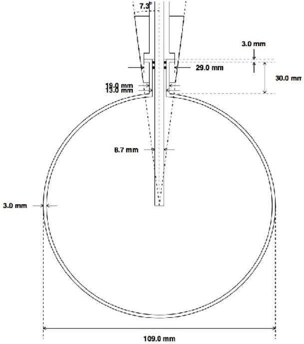
^{222}Rn activity vs time in Kamland (JINST 4 P04017, 2009). Red/blue lines: start of calibration period.

Laserball (Sussex)

Laser light injected via fibre into quartz diffusing flask:

- Creates quasi-isotropic light
- Used for full optical calibration of the detector (PMT relative angular response, optical attenuation for different detector media)
- Workhorse for SNO
- Improved laserball for SNO+
- Can be used as supernova calibration source

Problem: SNO+ purity requirements more stringent that SNO - need to minimise deployment of laserball (and other sources) ...



… ELLIE (Embedded LED/laser Light Injection Entity) (Sussex, Leeds, Oxford, QMUL (+ LIP Lisbon/Coimbra))

Timing ELLIE:

- 91 injection points
- Monochromatic (435 nm) from LEDs
- Light coverage of entire in-facing detector

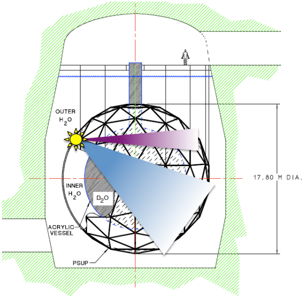
Scattering Module for ELLIE:

- 12 injection points (three at each of four locations)
- Multiple wavelengths from lasers

Attenuation Monitoring for ELLIE:

- Eight injection points (two at each of four locations)
- Two wavelengths (385 nm & 500 nm)

Will provide continuous calibrations throughout SNO+ operation

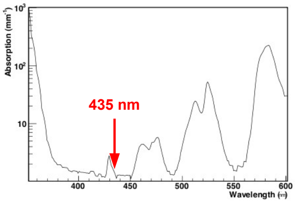


ELLIE electronics (drivers & LEDs/lasers) will housed on the deck above the experiment (along with DAQ electronics). Light will pass through optical fibres, with emission points located on the PMT support structure.

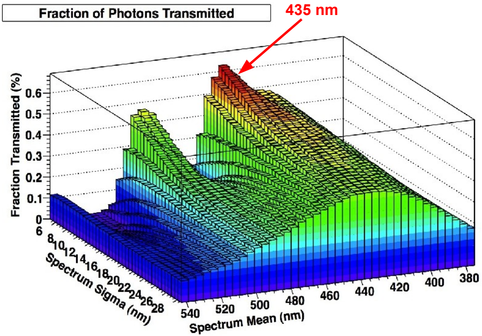
ELLIE: LED selection

Timing calibration, for best measurement:

- minimise photon loss



Absorption of photons in LAB+PPO+Nd.

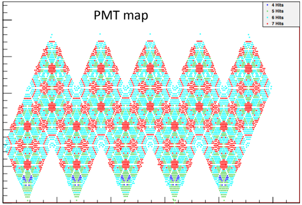


Simulation of fraction of transmitted photons as a function of LED wavelength (mean and sigma), includes PMT response & effect of all media in detector.

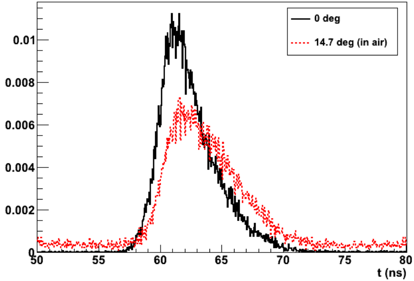
ELLIE: timing and coverage

Timing calibration, for best measurement:

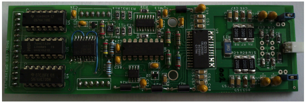
- minimise photon loss
- fast rise/fall time profile
- ensure all PMTs calibrated (with redundancy)



All PMTs will see photons from at least two TELLIE fibres (two (blue) up to five (red))



After 45 m of 1 mm optical fibre, 2 ns risetime, 5.6 ns falltime.



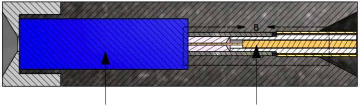
TELLIE LED driver developed for *very* fast light pulses (Leeds, Sussex)

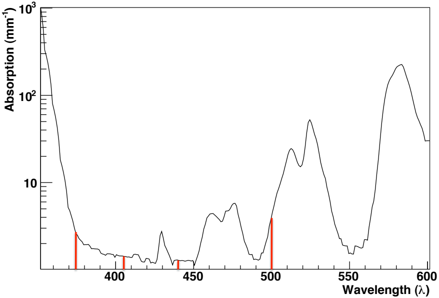
ELLIE: hardware development

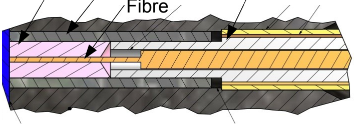
Laser and collimator hardware for scattering module and attenuation monitoring developed at Oxford.

- Collimator to narrow opening of light beam
- Four laser heads, 375, 405, 440, 500 nm

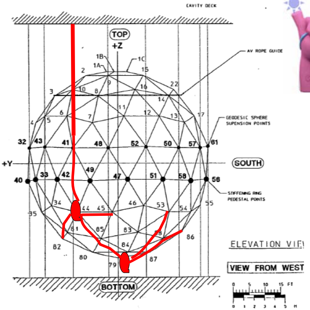
Collimator



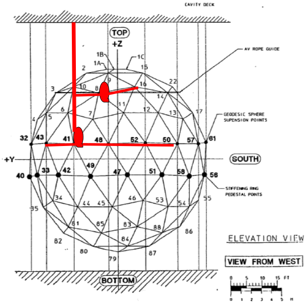




ELLIE Installation

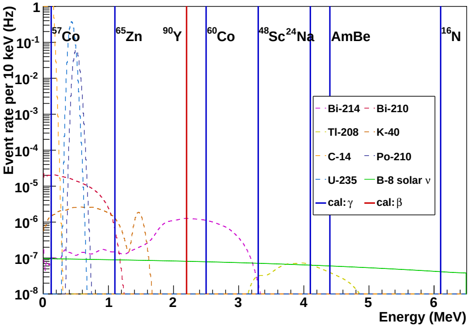


Installation: empty cavity (completed)



Installation: water-fill (from a boat)

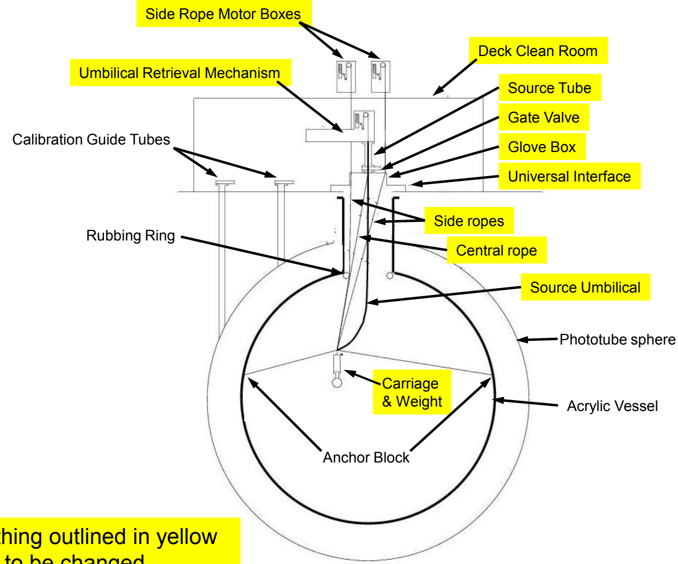
Calibration point-like sources



A number of challenges to overcome in calibration with in-situ sources:

- ^{222}Rn leaking into detector
  - minimise number of deployments of calibration sources
  - maintain low radon cover gas system
- Sources contaminating experiment / encased too well
  - develop secure containers that still allow radiation to escape and scintillate

Source deployment



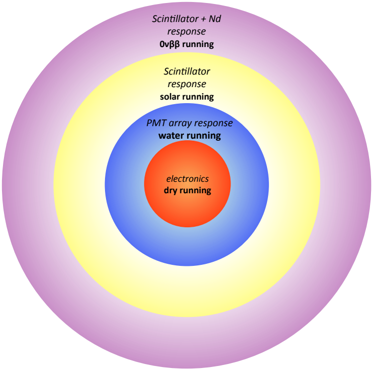
Everything outlined in yellow needs to be changed.

Calibration requirements

Calibration tools	Absolute optical response	Relative optical response	Energy scale, particles	Recon-struction	Electronics
Cherenkov source	✔				
Laserball, ELLIE		✔		✔	
Pointlike sources	✔		✔	✔	
Source ball			✔	✔	
Distributed source			✔	✔	
Internal test pulse					✔

Calibration & SNO+ data taking

Phased approach to commissioning and operating SNO+ $\rightarrow$ phased approach to calibration:



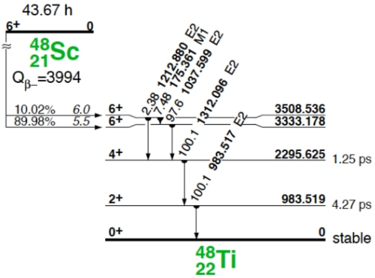
- **Dry running (aka air fill)**:
  - Single fibre and LED for testing
  - First dry run **complete**, ran for $\sim$10 days, saw ELLIE signals!
- **Water fill**:
  - ELLIE commissioning
  - laserball
  - ^{16}N source
  - Cherenkov source
- **Scintillator fill**:
  - ELLIE & laserball operational
  - All sources deployable

Conclusion

- Much experience (and some technology) inherited from SNO
- A variety of systems will ensure redundancy in the calibration of SNO+
- In-situ point-like source developement is underway (and near completion for a number of sources)
- Optical calibration is also progressing well:
  - ELLIE calibration fibres installed in March, electronics production underway
  - Triggered on light from the ELLIE system during dry-running in Feb/March
- UK is leading the SNO+ calibration effort and is directly responsible of delivering a number of major calibration sources

Backup slides

Example source: ^{48}Sc TU Dresden (not UK)

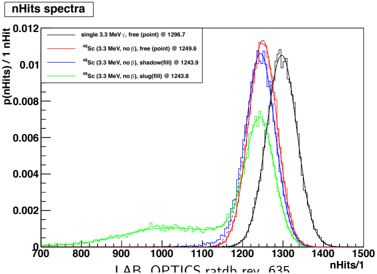


Decay scheme of ^{48}Sc, γ energy:

- $\sim$90% 3.33 MeV
- $\sim$10% 3.51 MeV

Simulations and initial designs for two sources (^{48}Sc and ^{60}Co) completed.

^{48}Sc source casing prototype



Preliminary simulation example: number PMT hits from ^{48}Sc source