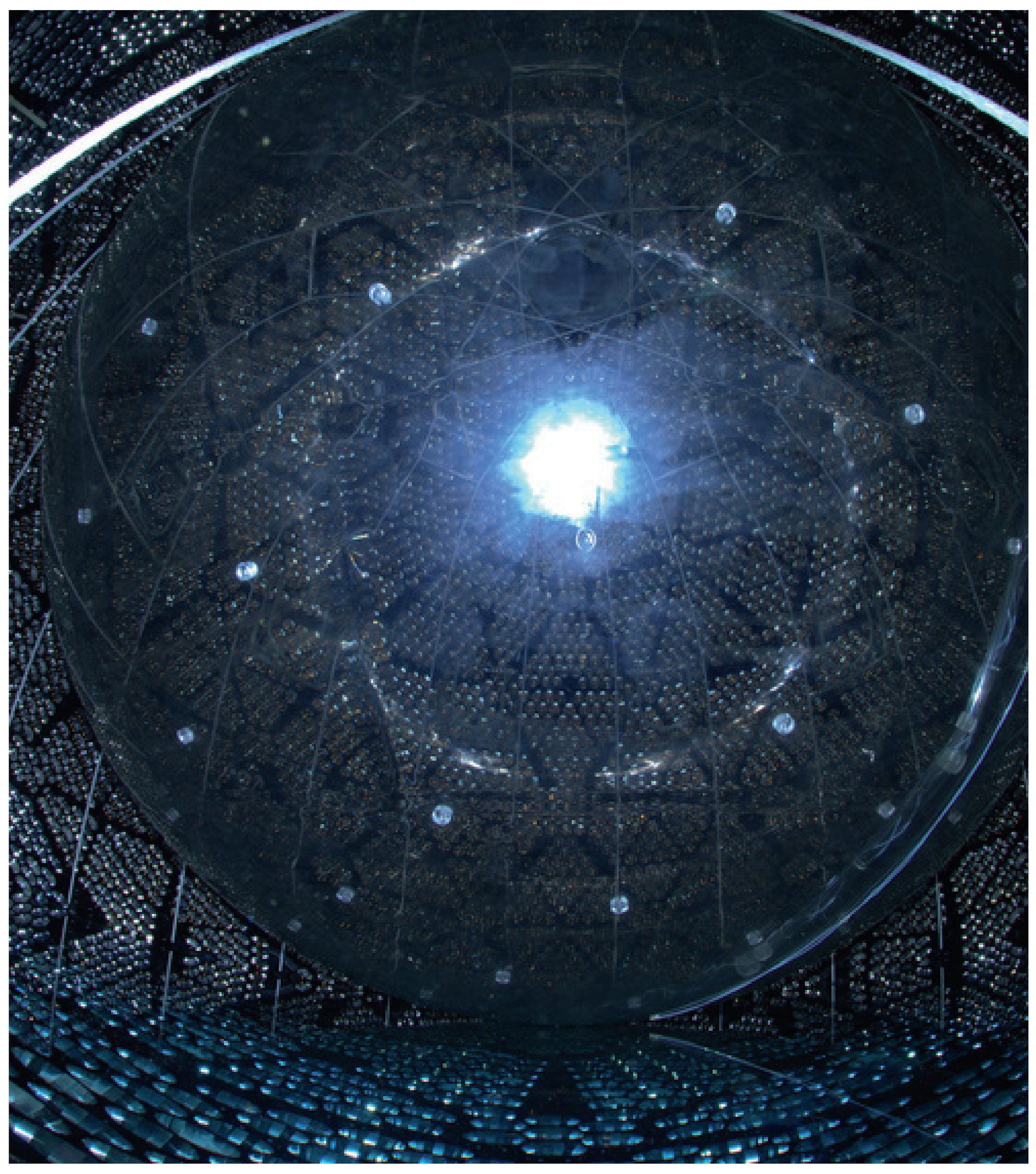
SNO+: readiness for data taking and neutrinoless double beta decay phenomenology

Ashley Back, for the SNO+ Collaboration
Queen Mary, University of London and University of Sussex

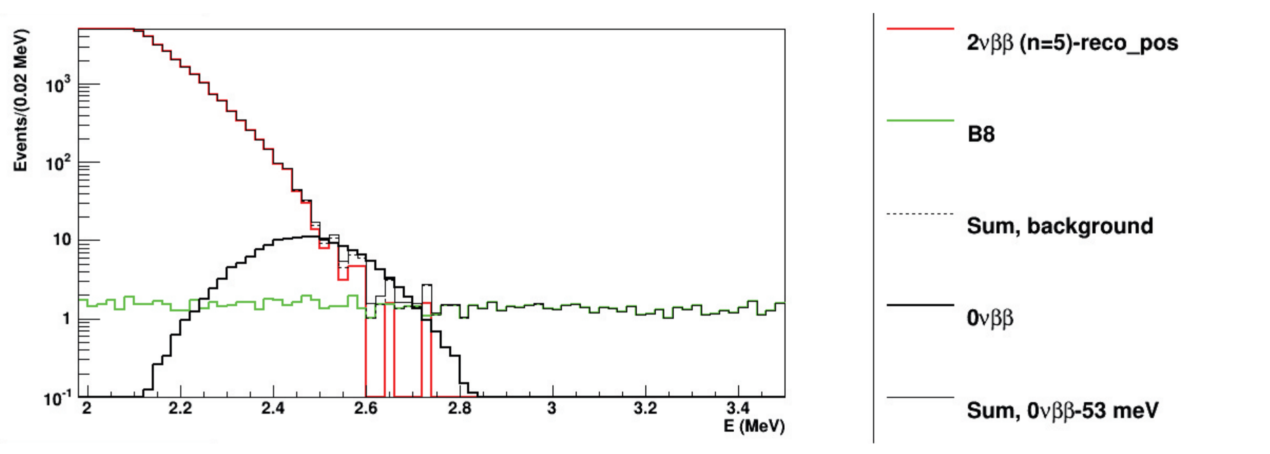
Introduction

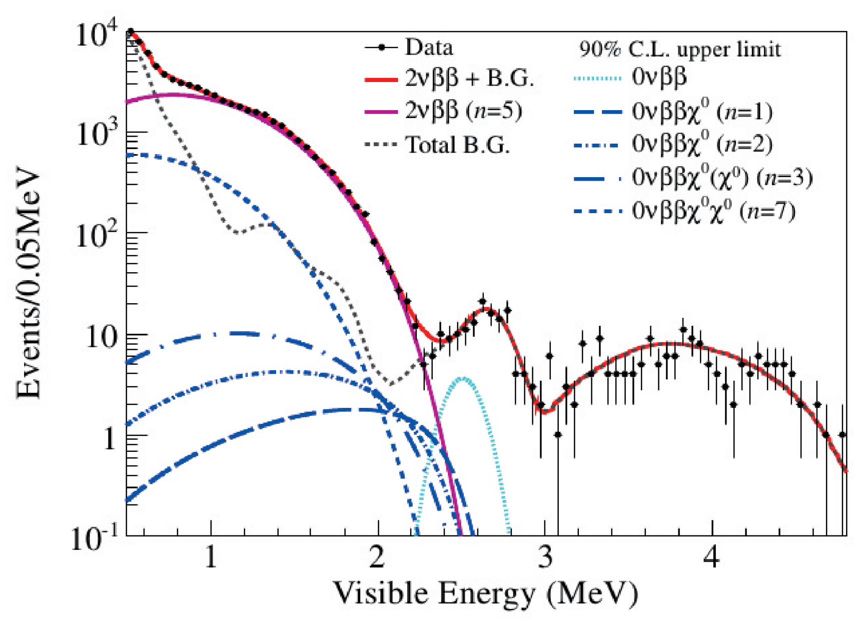
SNO+ is a multipurpose neutrino detector, located near Sudbury, Ontario, Canada. Its varied physics program ranges from solar neutrinos, to supernovae and reactor neutrinos, but its primary focus is neutrinoless double beta decay ($0\nu\beta\beta$) in ^{130}Te. Much of the necessary hardware was inherited from predecessor SNO, making SNO+ a cost effective yet competitive $0\nu\beta\beta$ experiment. The detector, located over two kilometres underground, in SNOLAB, holds nearly a kilotonne of liquid scintillator, loaded (initially) with 0.3% natural Te. First scintillator data is expected autumn, 2015.

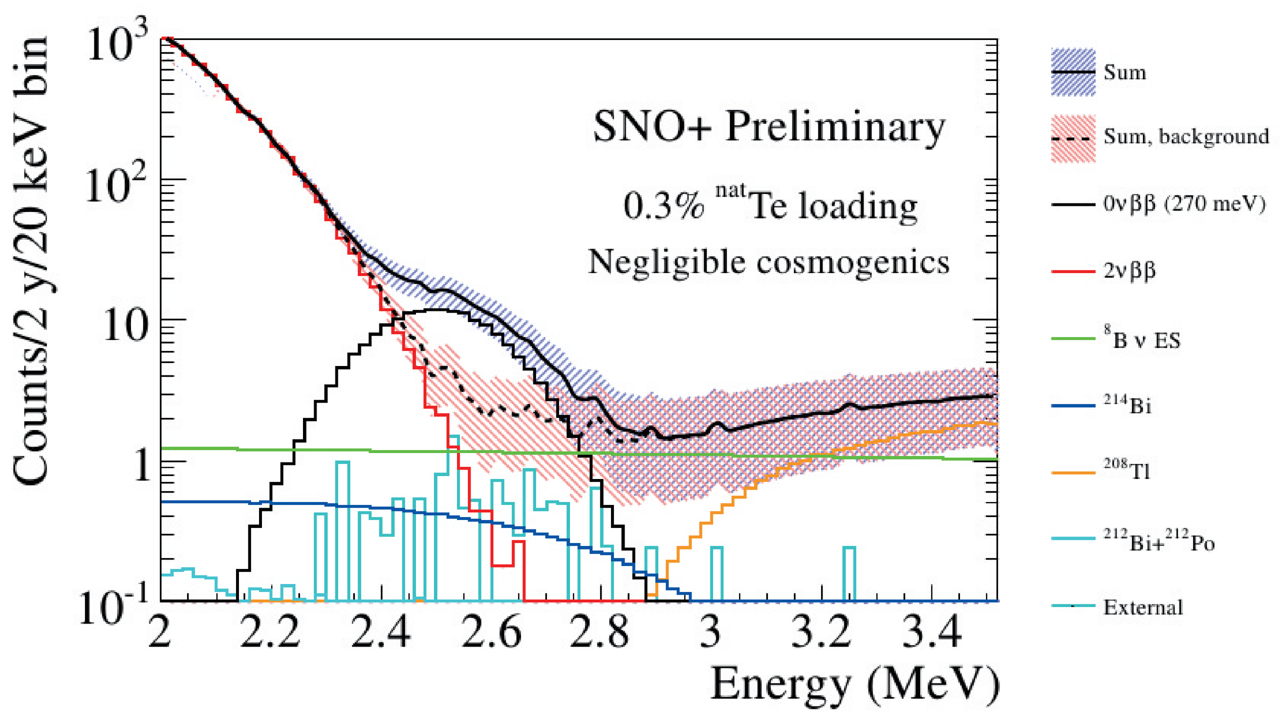
Most $0\nu\beta\beta$ searches - including the main SNO+ analysis - are based on the exchange of a light Majorana neutrino. This poster presents the first stages in an investigation to determine the potential sensitivity of SNO+ to alternative models for $0\nu\beta\beta$. An example, which has already been studied by KamLAND-Zen [1], is $0\nu\beta\beta$ via the production of Majorons. To study these alternative models, and indeed to achieve any of its physics goals, SNO+ requires quality data. SNO+ Data Quality (DQ) performed well during tests on recent comissioning data. Development and testing will continue, to ensure data readiness when the first phase of continuous data taking begins towards the end of this year.

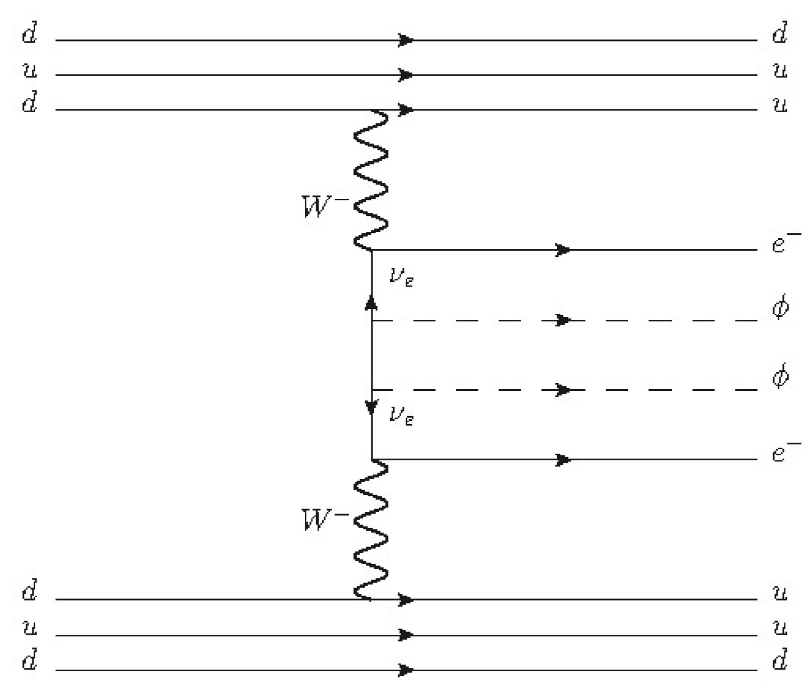


Top-right: view of the SNO+ acrylic vessel, taken from inside the detector
Below-right: KamLAND-Zen spectrum including Majoron-emitting decay modes [1]
Below: 90% confidence limit $0\nu\beta\beta$ signal, with two main backgrounds, using log-likelihood fitting
Bottom-left: SNO+ spectral plot
Bottom-right: feynman diagram for $0\nu\beta\beta$ with two Majorons





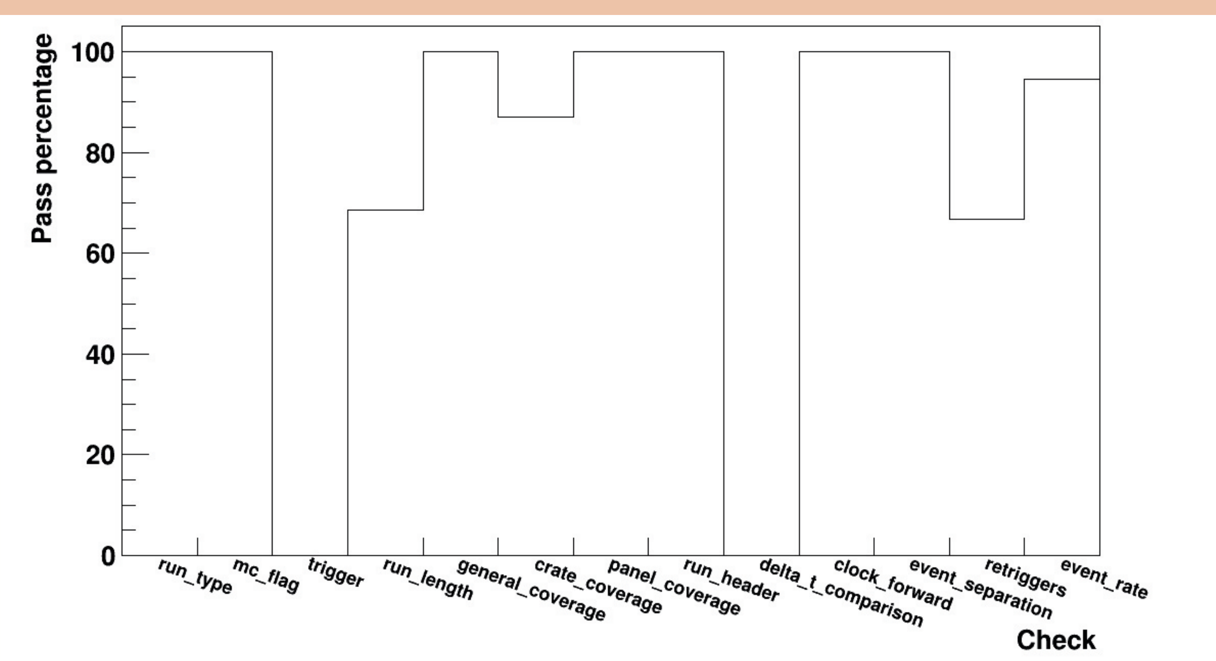




SNO+ Data Quality

- DQ is performed offline → investigate non-physical effects across entire run/detector
- Primary input for run selection → suitable for publication analysis

The software was developed using SNO run selection [5] as a guide. Three groups of checks have been implemented and tested so far.

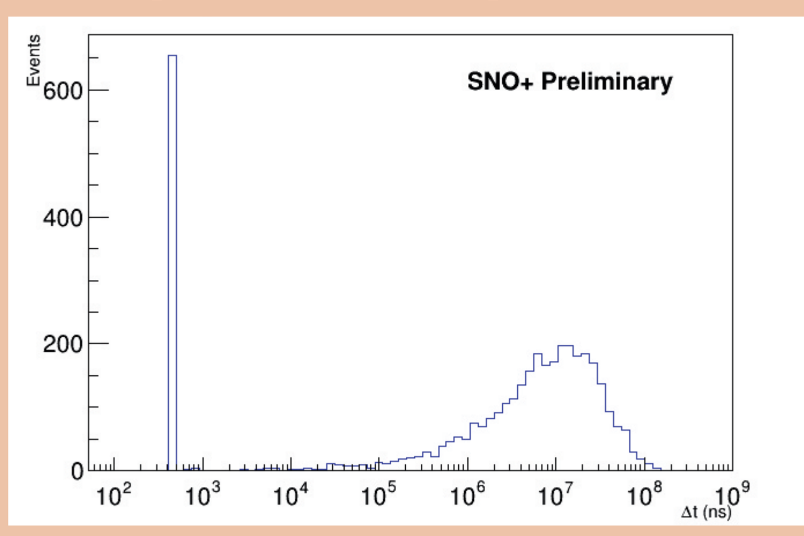


Results of testing

Results from testing on 42 runs of comissioning data from February 2014.

- All except for two tests had a 60% average pass rate, or greater
- Remaining two tests had a 100% failure rate → known issues → event builder write out
- Offline monitoring plots e.g. event separation profile

Below-left: performance of the DQ checks during recent testing
Below: profile of event separation times



$0\nu\beta\beta$ phenomenology

The eventual aim of this work is to perform a SNO+ sensitivity study for Majoron-emitting and other exotic $0\nu\beta\beta$ modes. The results presented here are intended for verifying the methodology ahead of the main sensitivity study.

Majoron-emmiting modes

- Introduced by Gelmini & Roncadelli [2] → massless Goldstone boson
- Charged Majorons [3] → conservation of lepton number
- Various scenarios:
  - One or two Majorons (see Feynman diagram)
  - Charged or uncharged
  - Categorised by spectral index [4]

Methods

- Assume a $0\nu\beta\beta$ effective mass ($m_{\beta\beta}$)
- Fit summed signal ($0\nu\beta\beta$) + background → summed background (two neutrino double beta decay ($2\nu\beta\beta$) + solar neutrinos)
  - Calculate summed log-likelihood → range of $m_{\beta\beta}$
- Obtain 90% confidence limit (C.L.) on $m_{\beta\beta}$, by minimising χ^2 (log-likelihood)

Results

Reproduced SNO+ spectral plot in for the two dominant backgrounds. The 54 meV $m_{\beta\beta}$ limit set using log-likelihood analysis approaches the SNO+ 90% C.L. 80 meV.

References

[1] Gando A et al. 2012 Phys. Rev. C 81 021601.
[2] Gelmini G B and Roncadelli M 1981 Phys. Lett. B 99 411.
[3] Burgess C P and Cline J M 1994 Phys. Rev. D 49 5925.
[4] Bamert P et al. 1995 Nucl. Phys. B 449 25.
[5] Wilson J 2004 PhD thesis University of Oxford.

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