The SNO+ Neutrinoless Double Beta Decay programme: Demonstration of a Scalable and Cost-effective Approach

The SNO+ Collaboration

The SNO+ experiment builds on the success of the Sudbury Neutrino Observatory, replacing the heavy water with liquid scintillator. The principal scientific goal of the SNO+ experiment is the development of an economical and scalable approach to $0\nu\beta\beta$ searches through the loading of ^{130}Te in liquid scintillator, and the application of this technology to achieve world-leading sensitivity in the Majorana mass range corresponding to the inverted neutrino mass hierarchy for the light neutrino exchange mechanism. We also believe that this project has important implications for the long-term future of the field as it is one of the very few approaches that has the potential to eventually reach the sensitivity range of the non-degenerate normal mass hierarchy in a practical way, and the multipurpose nature of the experiment provides mechanisms for collaborative funding across many subfields. The use of both germanium and xenon will be very challenging in the normal hierarchy regime simply based on economic grounds, with the next generation of such instruments already pushing the boundaries of affordability. SNO+ has pioneered a significantly more affordable approach, promising high sensitivity that can continue to be extended beyond that of the currently planned next generation of instruments. As such, we feel it is crucial to not only achieve the results projected for the current 0.5% ^{nat}Te (0.18% ^{130}Te) loading phase, but to demonstrate the scalability by subsequently increasing the loading levels to several percent and, in so doing, to rival the sensitivity of other contemporaneous experiments at a fraction of the cost.

Notable progress has been made in the development of tellurium loading in scintillator, achieved through forming a soluble compound from telluric acid, $Te(OH)_6$, and organic 1,2-butanediol. This compound is miscible with linear alkylbenzene at all concentrations, though increased fluorescence quenching limits practical loading levels to several percent Te by weight. Modifications to the synthesis process have been found to reduce this quenching to allow higher light yield at increased loading levels.

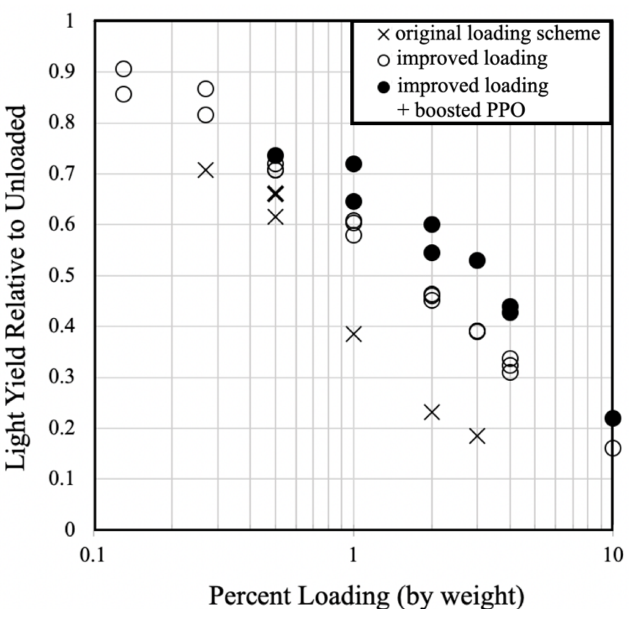

Fig 1: Relative light yield as a function of natural Te loading

We anticipate that the current system could be employed for an increased loading with little or no modification. Doubling the loading should therefore be very straight-forward and is projected to take about 5 months after reagents etc. are secured and prepared. If one were to continue at that rate, we could, in principle, reach a 3% loading of ^{nat}Te (1% ^{130}Te) in a little over 2 years following the start of a campaign to increase the Te loading. Alternatively, a phased loading scenario, such as the one indicated below, could be implemented. Studies indicate that this would be sufficient to achieve a half-life sensitivity of >10^{27}yrs.

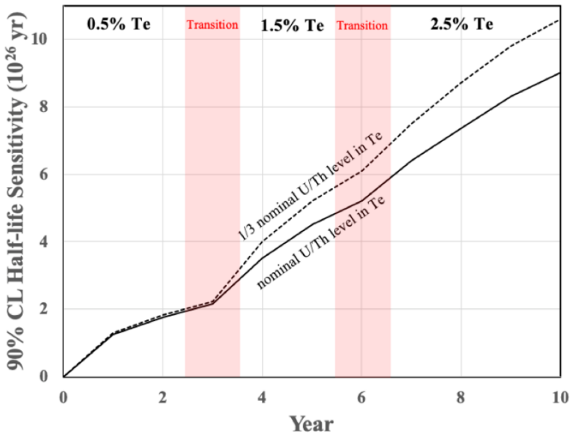

Fig 2: Phased loading scenario for SNO+

For SNO+, a 3% loading of ^{nat}Te by weight would cost roughly \$15M. This loading level would correspond to nearly 24 tonnes of tellurium, or about 8 tonnes of ^{130}Te isotope in the full volume. Hence, the inherent incremental loading cost of the technique corresponds to less than \$2M per tonne of ^{130}Te isotope. Rather than the use of an additional inner containment bag, the SNO+ fiducial volume effectively uses only 1/4 of this, but costs are low enough for this to be economical viable. In future larger scale detectors, a much larger fraction of tellurium could be made available by optimising the detector geometry and/or through the use of a containment bag. Thus, in addition to achieving good sensitivity in the inverted hierarchy range, such an increased loading would be an important demonstration of loading on a scale of interest to push beyond this range in a future generation of instruments. Such future detectors could also take advantage of improved light detection technologies and new methods of Cherenkov separation (such as slow fluors) for rejection of solar backgrounds in order to push sensitivities even further.