$0\nu\beta\beta$ and Other Neutrino Physics with SNO+

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SNO+ is a multi-purpose neutrino experiment that will leverage the large US- and other countries' capital investment in SNO, re-using the detector and replacing the heavy water target with liquid scintillator (LS) to allow lower operating threshold and improved energy resolution.

A primary physics goal of SNO+ is to use the existing Sudbury Observatory (SNO) detector to search for the neutrinoless double beta decay by loading the liquid scintillator with a neutrinoless double beta decay isotope such as ^{150}Nd. Isotope loading in LS is a fine balance between event rate and light yield. Nd dissolved in LS absorbs scintillation light, requiring a careful optimization: too little Nd and the source is too weak; too much Nd and the energy resolution of the detector becomes too broad to separate the signal from background. At a natural Nd concentration of 0.3% we anticipate a sensitivity to the effective neutrino mass $\langle m_{\beta\beta} \rangle$ of 120 meV at 90% C.L. in a three year run, beginning mid-2014.

There is an additional physics program possible with SNO+ that goes beyond neutrinoless double beta decay. In particular, SNO+ will detect low-energy solar neutrinos allowing it to probe the vacuum/matter transition wregion which is sensitive to new physics. Observations of neutrinos from the CNO cycle may help to resolve questions associated with the metal content of the solar interior. SNO+ can make sensitive measurements of geoneutrinos, reactor antineutrinos, and supernova neutrinos should one occur during the experiment's lifetime.

A future program for SNO+ would firstly include the deployment of either enriched isotope or an entirely different isotope. Nd enriched in ^{150}Nd could provide up to a factor of twenty improvement in lifetime sensitivity with no change to the detector at all. An improvement of that size would, depending on nuclear matrix elements, place the SNO+ sensitivity to $m_{\beta\beta}$ at the bottom of the inverted hierarchy region. Estimates for the cost of enrichment of 500 kg are roughly around $20M, and would probably be available around 2018. Should another clean isotope be able to be loaded with optical clarity as good or better than Nd-loaded scintillator, it could easily be exchanged with Nd. Further upgrades to SNO+ might include the replacement of the twenty-year-old PMT array with modern, high-quantum efficiency PMTs, and the reflective light-concentrators with an upgraded design, leading to perhaps a doubling of overall light yield. With the additional light yield from such changes, backgrounds from the 2ν decay would be reduced leading to a factor of two or more in lifetime sensitivity.