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HALO - the helium and lead observatory for supernova neutrinos

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Abstract. The Helium and Lead Observatory (HALO) is a supernova neutrino detector under development for construction at SNOLAB. It is intended to fulfill a niche as a long term, low cost, high livetime, and low maintenance, dedicated supernova detector. It will be constructed from 80 tonnes of lead, from the decommissioning of the Deep River Cosmic Ray Station, and instrumented with approximately 384 meters of ^{3}He neutron detectors from the final phase of the SNO experiment. Charged- and Neutral-Current neutrino interactions in lead expel neutrons from the lead nuclei making a burst of detected neutrons the signature for the detection of a supernova. Existing neutrino detectors are mostly of the water Cerenkov and liquid scintillator types, which are primarily sensitive to electron anti-neutrinos via charged-current interactions on the hydrogen nuclei in these materials. By contrast, the large neutron excess of a heavy nucleus like Pb acts to Pauli-block p→n transitions induced by electron anti-neutrinos, making HALO primarily sensitive to electron neutrinos. While any supernova neutrino data would provide an invaluable window into supernova dynamics, the electron neutrino CC channel has interesting sensitivity to particle physics through flavour-swapping and spectral splitting due to MSW-like collective neutrino-neutrino interactions in the core of the supernova, the only place in the universe where there is a sufficient density of neutrinos for this to occur. Such data could provide a test for $\theta_{13} \neq 0$ and an inverted neutrino mass hierarchy. In addition, the ratio of 1-neutron to 2-neutron events would be a measure of the temperature of the cooling neutron star. For the 80 tonne detector, a supernova at 10 kpc is estimated to produce 43 detected neutrons in the absence of collective ν-ν interactions, and many more in their presence. The high neutrino cross-section and low neutron absorption cross-section of lead, along with the modest cost of lead, makes this technology scalable and a future upgrade, to of order 1 kilotonne, is under active consideration.