HUNTER (Heavy Unseen Neutrinos from Total Energy-momentum Reconstruction)

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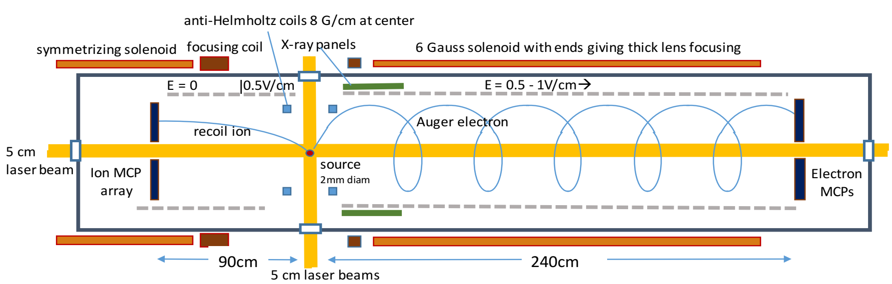
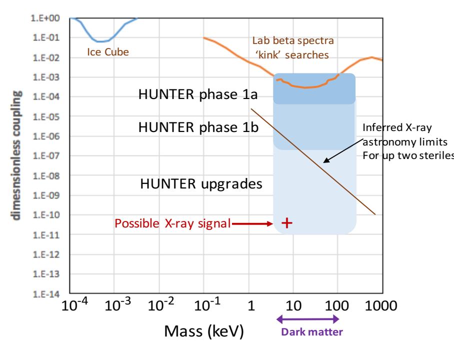
The aim of this experiment is to make a first detection of sterile neutrinos – particles needed to complete the existing neutrino family and which could also provide a solution to the galactic dark matter problem. The no-zero masses of the three known neutrinos, strongly indicates that right handed states should also exist in each lepton generation (one option referred to as the nuMSM model (see Bezrukov arXiv 0710.2501 2007) but these are as yet unseen because their interaction strength is orders of magnitude less than the known neutrinos. Theoretical studies (eg Xi and Fuller, PRL 82 (1999) 2832) also show that keV mass sterile neutrinos could have been produced in the early universe in sufficient numbers to account for the galactic dark matter density, and yet with a sufficiently small coupling that the decay time would exceed the life of the universe.

Current dark matter detectors would be insensitive to these, but we propose to demonstrate their existence in a laboratory scale experiment using the K-capture isotope ^{131}Cs. This decay releases a neutrino, the nucleus recoiling to conserve momentum, followed by an atomic X-ray and one or two Auger electrons. By precision measurement of the momenta of all the visible particles the momentum and mass of the unseen neutrino can be calculated for each observed event. The proposed system is shown in the figure. The radioactive atoms are suspended in high vacuum in a magneto-optical trap. The emitted X-ray, used as a trigger for the decay process is detected by position sensitive scintillator and silicon photomultipliers. The recoil ion and Auger electrons are directed by electric fields onto micro-channel plate TOF detectors. The majority of events will kinematically reconstruct to a neutrino mass close to zero, but with a sufficient number of events any keV range sterile neutrinos will form separate peaks up to the Q-value of the ^{131}Cs - ^{131}Xe decay (350 keV).



The limit plot shows the potential of the experiment. Existing limits in the keV mass range, from the absence of distortions in beta spectra, reach only ~ 10^{-3} in relative coupling. The blue area shows the potential of HUNTER in reaching the ~ 10^{-5} – 10^{-10} range expected for sterile neutrinos. Phase 1 (proposed to the Keck Foundation) would demonstrate the mass reconstruction precision at an initial cost-limited range of coupling sensitivity. Major future improvements are possible with upgrades to trapped atom number, and detector solid angle.



Future DOE funding would enable the full discovery potential of this technique to be achieved, revealing any sterile neutrinos in the 5 – 350 keV mass range, which have also been shown to provide a viable solution to the galactic dark matter problem. It could also reach the sensitivity level corresponding to an unexlained X-ray signal from galactic clusters and our galactic center, which has been proposed as resulting from the decay of 7 keV sterile neutrino dark matter.