CSU PHYSICS COLLOQUIUM

“Counting atoms one by one for a decade: discovering the possible identity of neutrino and antineutrino”

Bill Fairbank

Colorado State University

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Abstract

In the standard model of elementary particles, the fundamental particles in nature from which matter is made consist of three quarks, three electron-like particles, and three neutrinos. Each of these has an antiparticle of opposite charge and opposite quantum numbers. The chargeless neutrinos are intriguing because the charge quantum number alone cannot distinguish a neutrino from an antineutrino: 0=0. A yet undiscovered possibility exists that in fact, each neutrino may be the same particle as the corresponding antineutrino. The only known realistic way to resolve this question is to discover an extremely rare decay called neutrinoless double beta (0nbb) decay. Current limits on 0nbb decay with 10’s to 100’s of kg of a special isotope (in our EXO-200 experiment 136Xe) are on the order of 1026 years. Next generation 0nbb decay experiments nEXO, LEGEND and CUPID will search with tons of isotope up to the 1028 year half-life level. Next generation may have kilotons of isotope and 1030 year half-life sensitivity. In 1991 double beta decay pioneer Mike Moe proposed that in a transparent Xe liquid detector, in addition to detecting the two fast electrons emitted in 0nbb decay, the Ba+ daughter could be detected at the decay site by laser spectroscopy. Background events could be separated from bb decay events by this “barium tagging”, leading to higher sensitivity for detecting 0nbb decay. The larger the detector, the more this technique may be needed. Our group is currently working on capturing the Ba daughter from liquid xenon by trapping it in a cryogenic solid xenon layer and then scanning the layer with a laser for 1 Ba atom/ion or 0 Ba atom/ion. We can now image single Ba atoms in a solid xenon layer. With the laser parked on one atom, we see the single Ba atom fluorescence suddenly turn off and even blink. Ours is the first work where the properties of single atoms in noble gas matrices are finally being probed. I will present these results and our parallel work to date towards grabbing and detecting Ba+ ions from a liquid xenon cell. I also plan to touch on efforts by other groups in Ba tagging and the growing international interest in using atoms and ions in noble gas matrix for fundamental physics and quantum sensing.

Biography

Prof. Fairbank received a bachelor’s degree from Pomona College and a Ph. D. from Stanford University, under the direction of Arthur Schawlow and Ted Hänsch. He is a long-time member of the EXO-200 and nEXO neutrinoless double beta decay collaborations and has been working on Ba tagging since 1997. His research interests include ultrasensitive experiments and precision measurements with lasers for fundamental physics.