Research into the implementation of a Supernova neutrino detector for DUNE

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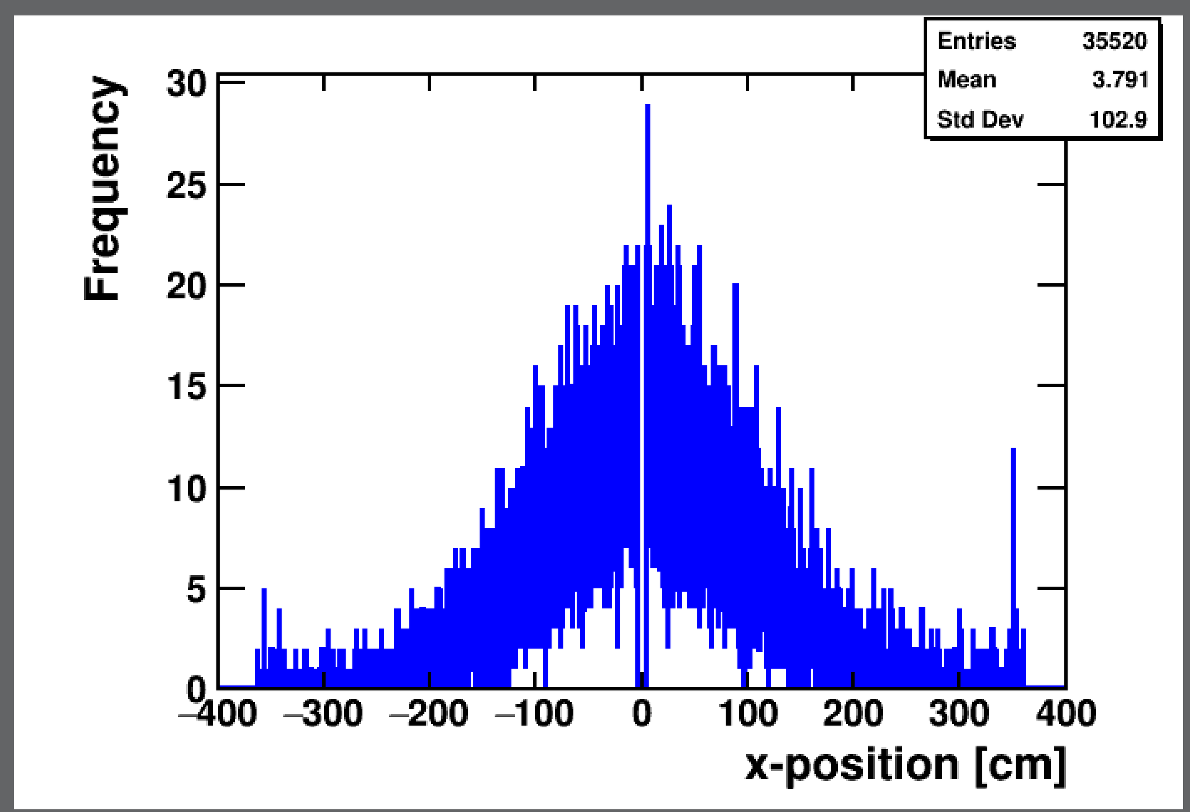
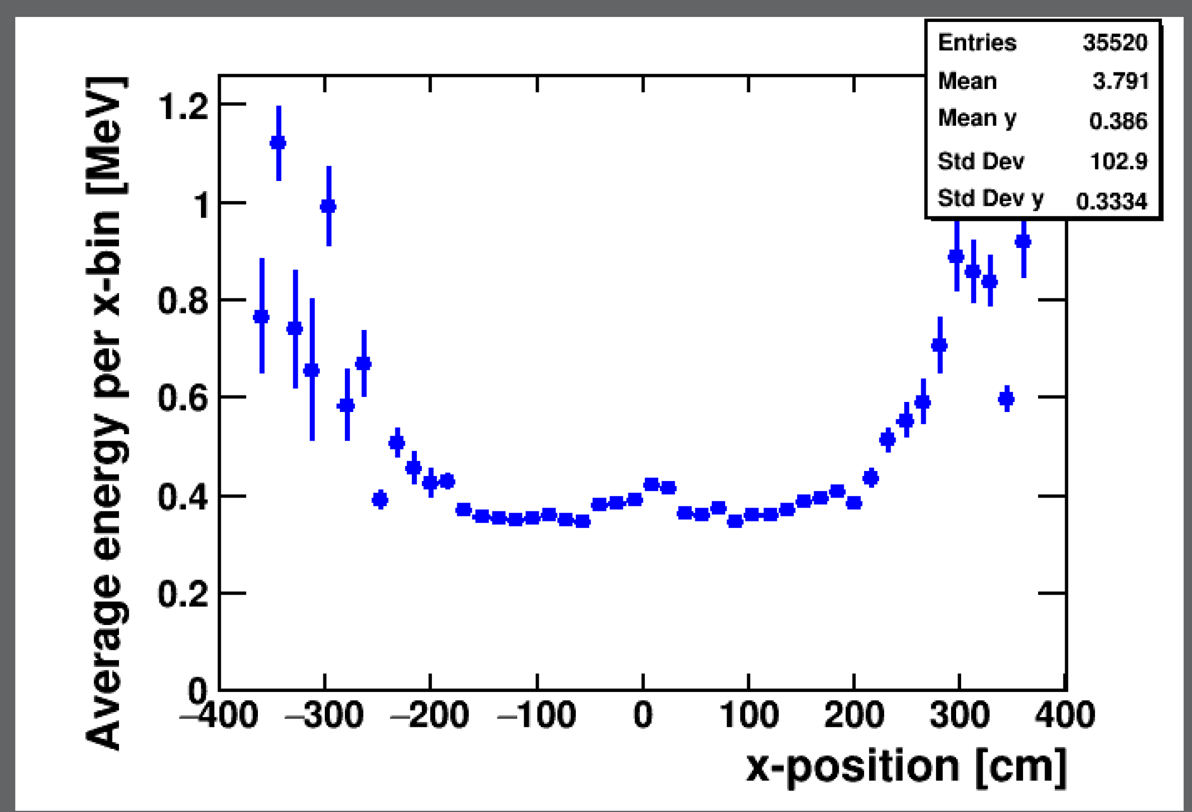
DUNE is due to be part of the next generation of neutrino detectors, which is to be based in Northern America and finished construction within the next decade. DUNE will search for CP-violation in neutrino oscillations, determine the ordering of the neutrino masses, test the three-neutrino paradigm, search from proton decay if it exits and will provide new information on how supernovae explode and what new physics can be learnt from a supernova neutrino burst - there has only been one recorded supernova neutrino event.

Supernovae occur when a white dwarf is prevented from collapsing by electron degeneracy pressure, accretes enough matter from another nearby star that the star becomes massive enough to undergo core-collapse (type I), or at the end of a massive star's lifetime as the energy released from fusion is no longer great enough to balance the gravitational forces pulling matter inwards, causing the star to collapse (type II). In both types of Supernovae it is more energetically favourable for electrons to be captured by protons than it is to fill electron states and so neutrinos and neutrons are produced by inverse beta-decay/electron capture.

Neutrinos are electrically neutral elementary particles with very small masses (neutrino means, literally, small neutral one). They come in three known flavors – electron, muon and tau as well as having corresponding antiparticles (there is some debate as to whether the neutrino is its own antiparticle. Neutrinos can be created in several ways, including in beta decay of atomic nuclei or hadrons, nuclear reactions such as those that take place in the core of a star, and supernova, and in other high energy collisions such as cosmic rays or in particle detectors. DUNE produce a beam of muon neutrinos by accelerating protons and firing them at nuclei to produce particles such as kaons and pions (with a momentum along the beam direction) which will decay mostly to muon neutrinos after travelling a distance of the order of 100 metres. These will be detected in the near detector as well as 800 miles away in the far detector.

My project investigated the characteristics of a supernova event that the far detector will measure, such as the distributions of neutrino energy, momentum, number of neutrinos per event (an event is the shortest time that the detector can record) and the positions of hits within the detector. This required a good understanding of the detector geometry and interactions within the detector as well as software to model these events.





A plot of the x-position of reconstructed hits showed a non-uniform distribution due electrons further away from the APA plane not reaching it if they fully re-ionize. The plot of the average energies of electrons in a bin confirms this theory.