High Energy Resolution in High-Pressure Xe Gas TPCs

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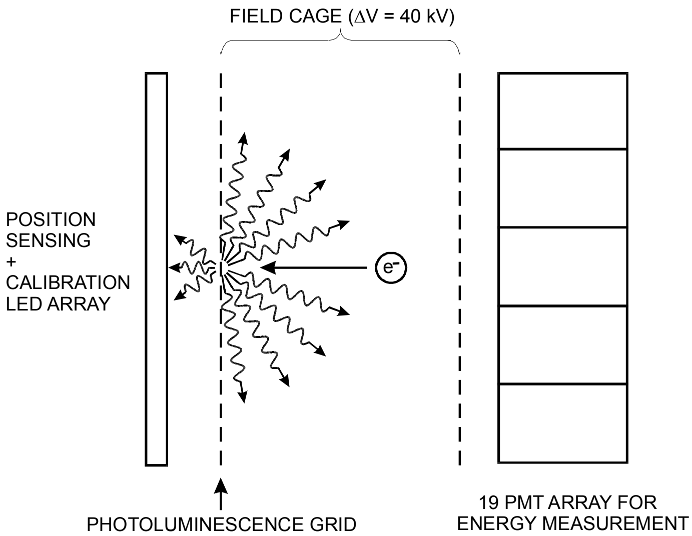
Searches for rare events such as neutrinoless double beta decay require discrimination between backgrounds and desired events. In part this can be achieved by energy resolution, but the ability to record the event topology is extremely useful. Existing data indicate that high-pressure Xe gas can provide excellent energy resolution in addition to sufficient position resolution in a TPC to reconstruct the event topology.

The intrinsic energy resolution $\sigma^2 = FEE_i$, where E is the absorbed energy, E_i the energy required to form a signal charge pair, and F is the Fano factor. In Xe gas up to a density of 0.55 g/cm^3 the Fano factor $F = 0.15$, which increases rapidly at higher densities. In Xe the ionization energy $E_i \approx 25$ eV. Neutrinoless double-beta decay would produce a single peak at 2480 keV, so the relative energy resolution

$$\frac{\Delta E}{Q} = 2.35 \cdot \sqrt{\frac{FE_i}{Q}} \approx 3 \cdot 10^{-3} \text{ FWHM}.$$

For comparison, at this energy Ge diodes yield $\Delta E/E \approx 1-2 \cdot 10^{-3}$ FWHM and in liquid Xe $\Delta E/E \approx 35 \cdot 10^{-3}$ FWHM, i.e. an order of magnitude worse than in gas. Existing measurements have been at lower energies, so it is important to verify the predicted resolution. The fluctuation in the number of signal charges $\sigma_N^2 = F(E/E_i)$, which for 2.5 MeV is about 125 electrons. This is very small, so internal gain is required to override readout fluctuations and noise. However, fluctuations in internal gain must be much smaller than σ_N. This can be achieved through photoluminescent gain, where a signal electron is accelerated sufficiently to excite optical states without displacing secondary electrons. Sequential excitations are independent of one another, so fluctuations are small, unlike avalanche gain. A photoluminescent gain of about 300 is sufficient and appears to be practical.

Ultimately a chamber of roughly 1 m size operating at a pressure of 20 bars (0.1 g/cm^3) will be required for detection of 2.5 MeV, so our initial tests of energy scaling are in a small chamber with an active volume of about 14 cm diameter and 8 cm length. The figure to the right shows the simplified configuration. This will allow tests up to about 700 keV.



Critical design aspects are tied to the requirement that systematic uncertainties in the energy measurement must be no greater than 0.1%. The presentation will describe the current design and discuss how this will be achieved and ultimately applied to a full-scale chamber. This work is in connection with related efforts at Texas A&M, LLNL, and in the NEXT collaboration.