# Making Electron Lifetime Measurements with the CRT

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# Electron Lifetime Measurements Previously

History of the Measurement in ProtoDUNE

- Purity monitors measure the lifetime to be somewhere around 8 ms, this can be extrapolated at higher electric field to roughly 30 ms.
- In January, Ajib, Tianle and Lisa measured at approximately 35 ms using cathode-anode crossing tracks.

They both have issues with measurements. Tingjun and I are using the CRT to investigate.

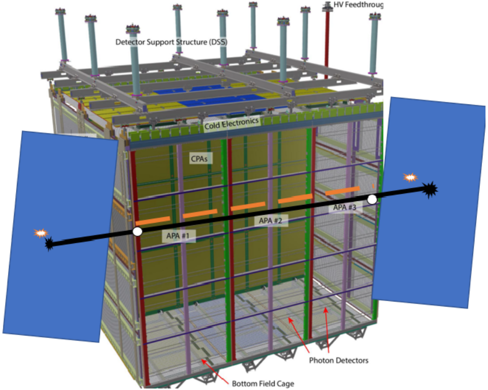
# Advantages to using a CRT

- Get a T0 and a track. We can do SCE tracking calibrations on-the-fly with the CRT track.
- dQ/dx can vary a lot with positions in X, but cathode-anode crossers only really move in X. The CRT avoids this as we can select tracks that travel nearly parallel to the z-coordinate.
- This means that dQ/ds calibrations can be stable per track and ds can be measured from the CRT using the wire pitch and CRT track's direction.

Simply, we can avoid a lot of the calibration issues associated with a track moving mostly in x.

# Matching Methodology

- Match using US AND DS (two CRT).
- Minimize $\Delta x$ and $\Delta y$ between TPC's predicted CRT hit and the reco CRT hit.



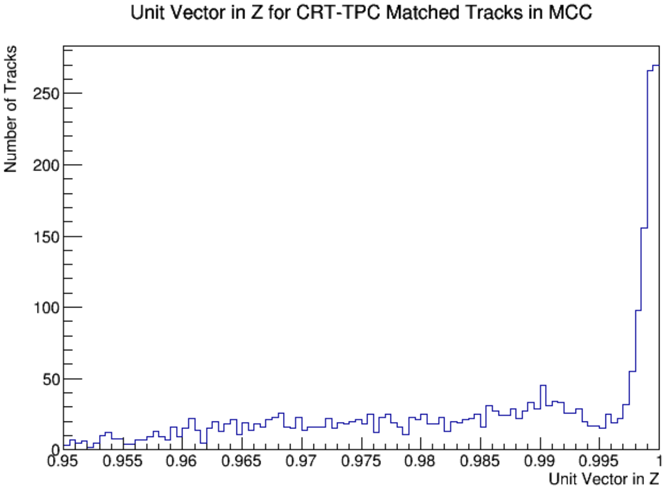

Example of CRT (black) and TPC (orange) track analysis. The white "hits" represent predictions we could make comparing the two tracks.

# Measuring lifetime using the CRT

1. Match a track between TPC and CRT. Check to see how parallel to the wire plan it is in z and t0-correct the track hit time.
2. We need areas well-known in z to do the CRT tracking calibration; therefore, we select areas, stolen from Ajib, Lisa, and Tianle, of 230<z<460 cm and 200<y<400 cm. We then use the straight line from the CRT as a truth track for positions in x and y as a function of z.
3. Calculate Q from the integral of a hit on the collection plane. dQ/dx is calculated from the wire pitch and track direction:
    - $dQ/dx = \frac{Q}{\frac{4.867\ mm}{dir_z}}$
4. Calibrate dQ/dx based on electric field by multiplying a correction coefficient of nom/meas dQ/dx using recombination. Find the electric field using CRT trackpoints.
5. Fit slices in 100 us to a Landau-Gauss and then make a MPV vs. track time plot to measure the lifetime.

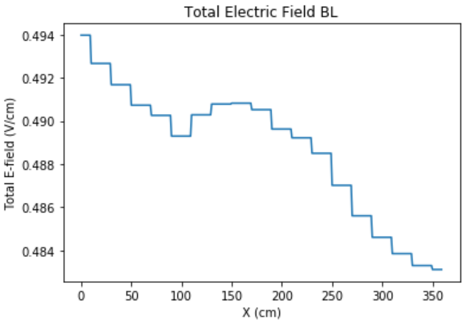
# Selection Criteria

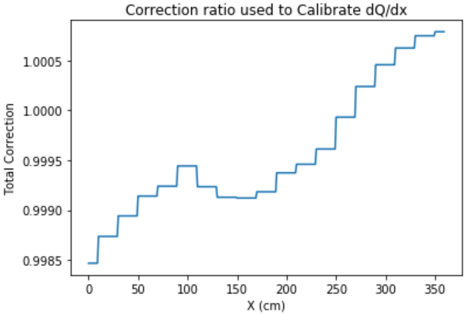
Measuring the directionality of a CRT track in z.




Direction in Z for CRT matched tracks in MCC with SCE (zoomed in near 1)

# Calibration Calculations

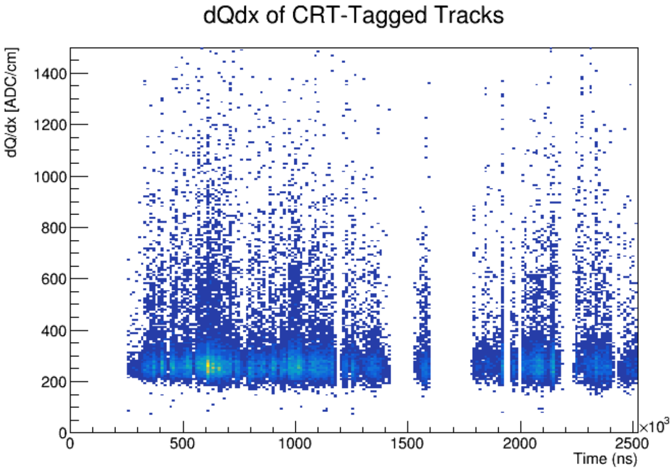



Total Efield BL (left) and dQ/dx calibration as a function of distance (right).

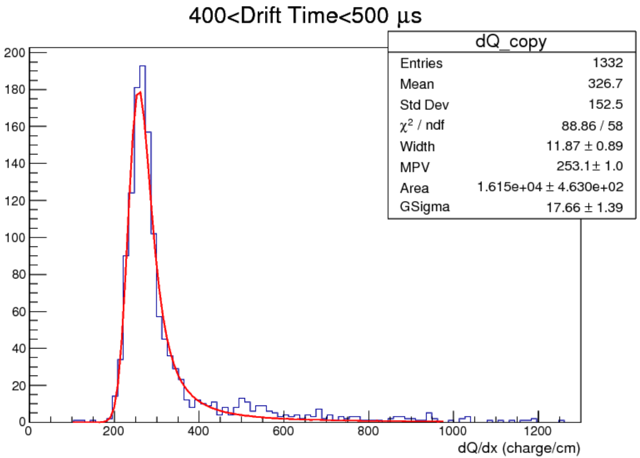
# Measuring dQ/dx using the CRT

Each slice contains a Landau-Gauss distribution that needs fitting.




Uncalibrated dq/dx using CRT matched tracks with SCE in MCC.

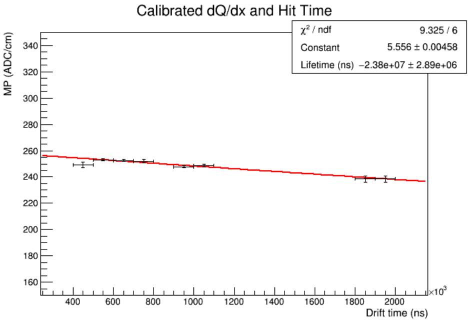
# Landau-Gaussian Fits

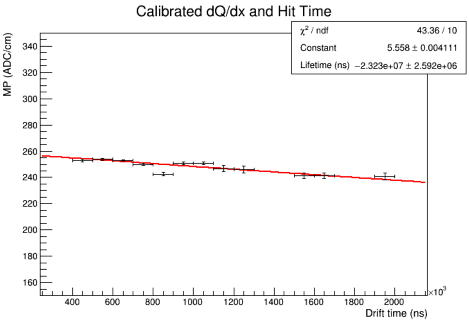



Land-Gauss fit for MCC with SCE

# MCC Electron Lifetime Measurements

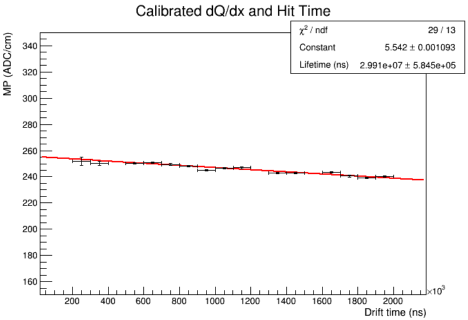
Fit: dQ/dx=exp([0]+t/[1])
All MCC samples has 35 ms as the input lifetime.

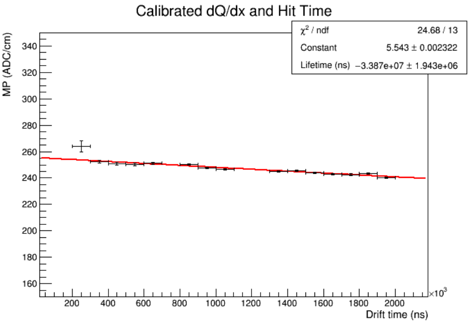



Lifetime in with MCC with no SCE (left) and MCC with SCE (right)

# MCC Electron Lifetime Measurements

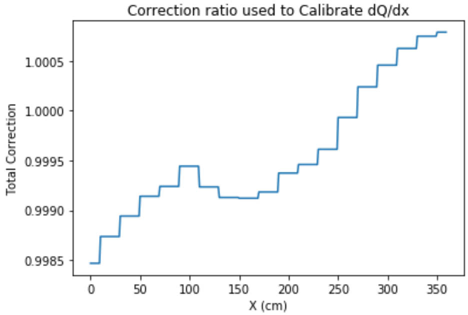



Lifetime with with no SCE with no transverse diffusion but with longitudinal diffusion (left) and no SCE with no diffusion (right)

# Explaining the Fits (or: Excuses for the Fits)

- It is hard to measure an exponential for a flat trend.
- Diffusion makes a definite impact on the lifetimes, so we don't expect to get 35 ms out immediately.
- Because dQ/dx is flat, this means that SCE effects are non-negligible. They are never negligible, but they make a bigger impact with a flat trend.




dQ/dx calibration as a function of distance (right).

# Moving Forward

- Measuring the electron lifetime using the CRT has numerous benefits other methods cannot provide. The CRT can measure with real tracks and they can measure parallel to z.
- Lifetimes in MCC measured as expected given how diffusion impacts such a measurement at high lifetime.
- Need to understand how to calibrate in data specifically, currently we see approx. 50 ms lifetime (not shown in these slides).
- Lifetime in LongBo also sees a flat trend. (See LongBo paper 1504.00398). LongBo fit at 30 ms included below.