Supernova T0 Updates

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August 28, 2019

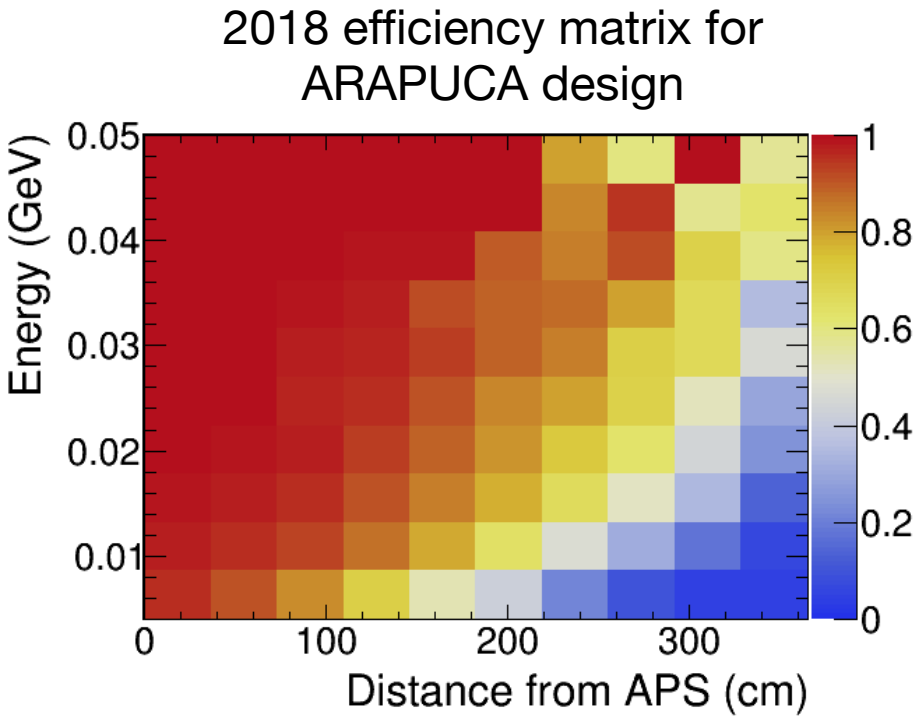
SNB/LE Working Group Meeting

Outline

- Updates from the last talk:
  - Updated efficiency matrix
  - Studied alternate drift correction method
  - Studied different figures of merit from fractional difference from neutrino energy:
    - Fraction of events contained in largest peak
    - ”Intrinsic” resolution of largest peak
- Figures of merit vs energy
- Takeaways

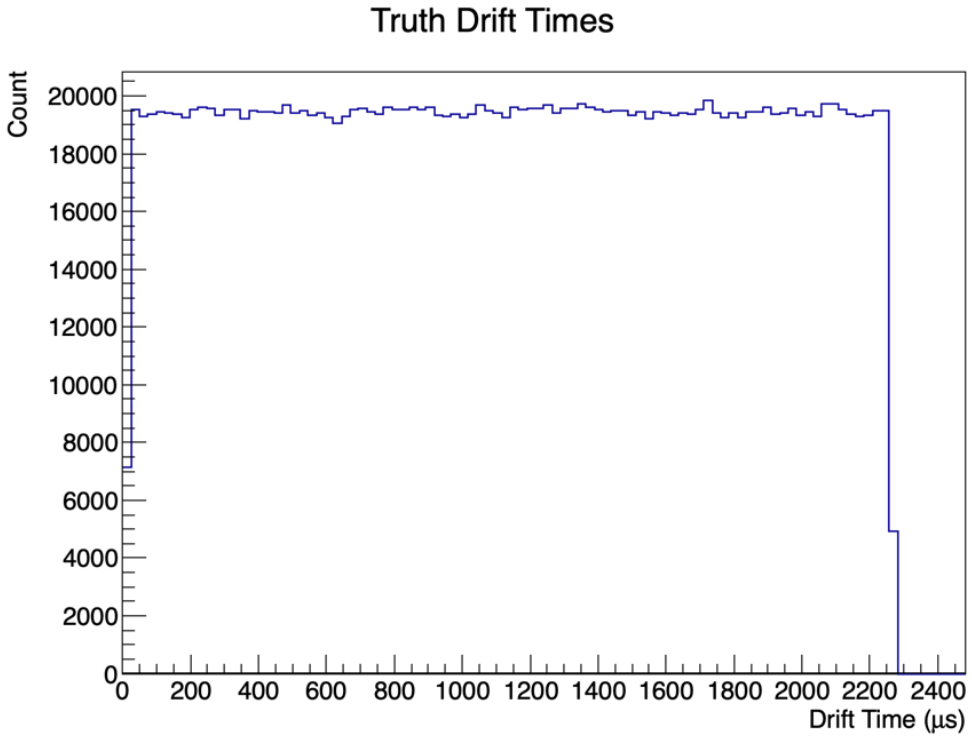
Studying PD Effects: Reminder

- In 2018, developed toy drift correction scheme to understand effects of PD system on supernova events
  - Use efficiency matrices corresponding to different PD performances
- Using MCC11 MARLEY events and updated PD performance types, study effects of PD systems for supernova event energy reconstruction



Reminder: “Random T0” Method

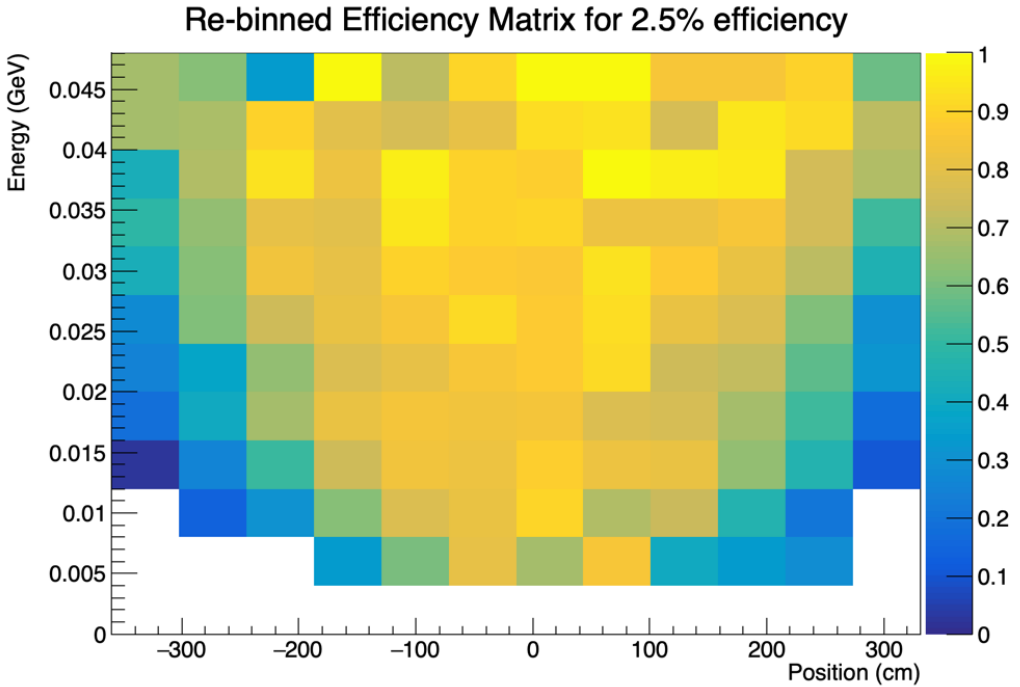
- Given MARLEY neutrino energy and distance from APA, find probability in efficiency matrix (different PD performances)
- Throw a random number [0.0, 1.0] to determine what correction will take place:
  - If less than efficiency, drift correct with MC truth T0
  - If greater than efficiency, correct with a random T0



Distribution used for random correction

Updated Efficiency Matrices

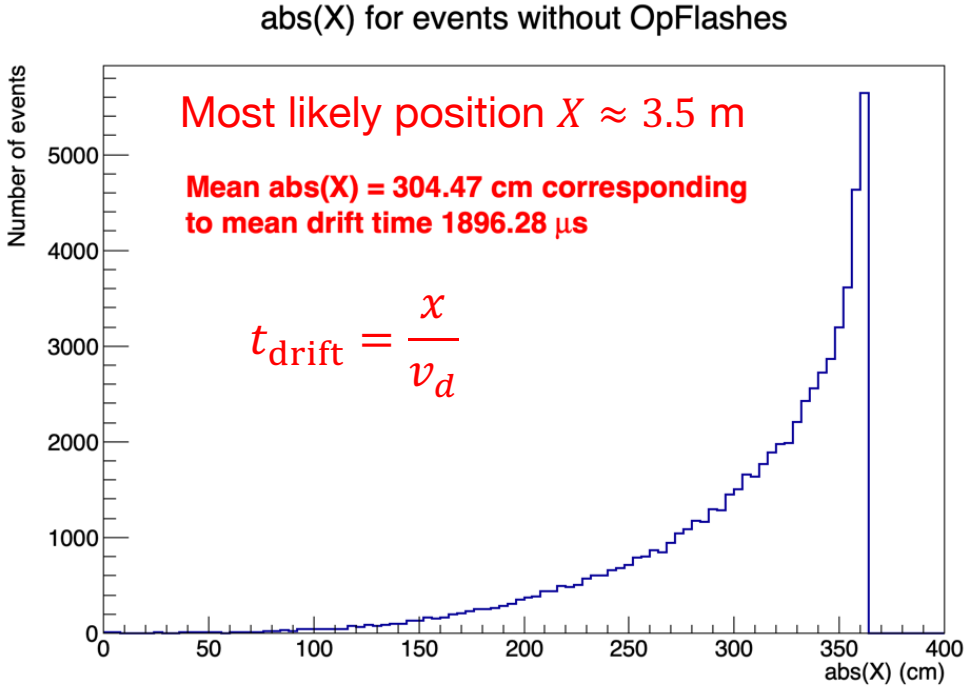
- Probability of successful flash matching as a function of energy and distance from APS
  - Re-binned; see backup
- Stringent efficiency definition (finding largest flash with distance cut associated with event)
  - Example matrix shown here; events farther from APA less likely to find photon flash



Example efficiency matrix

Other Toy Correction Schemes

- For events that don't find flash in toy method, drift correct with specific MC truth T0
  - Use mean, most likely position of events that don't have OpFlash's
  - Essentially making the assumption that we can identify bad flash matches



Fractional Energy from Truth

- See effects of toy drift correction by looking at fractional energy from truth: $(E_{\text{reco}} - E_{\text{true}})/E_{\text{true}}$
- Right: fractional energy distributions for MARLEY MCC11 clean events (weighted by GVKM supernova energy spectrum)

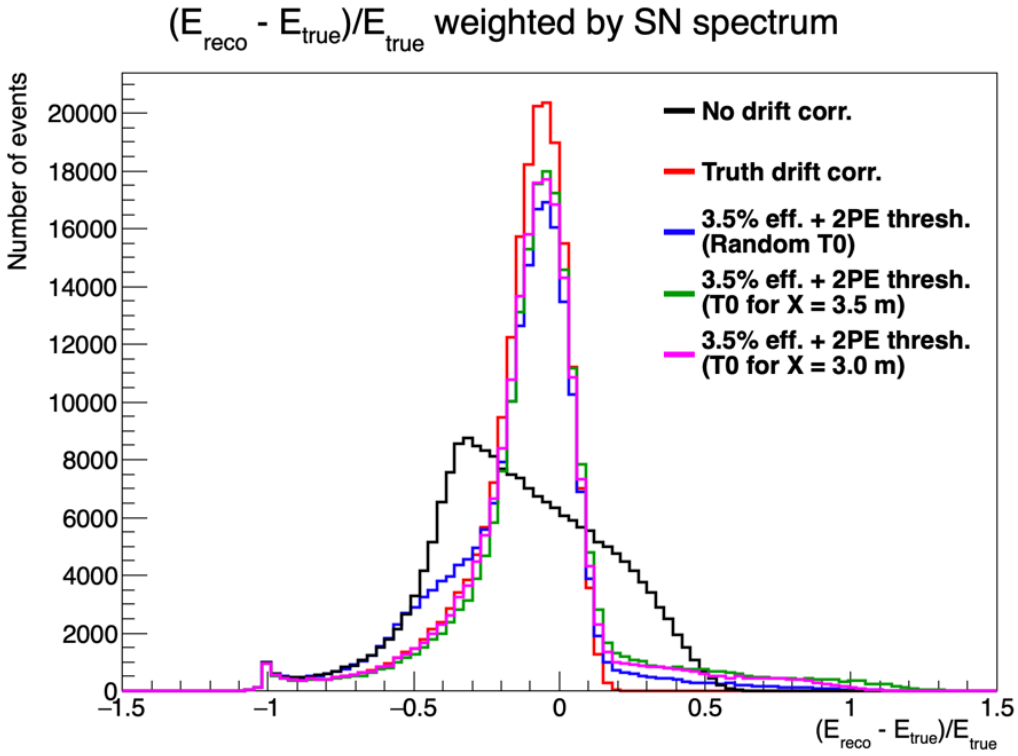
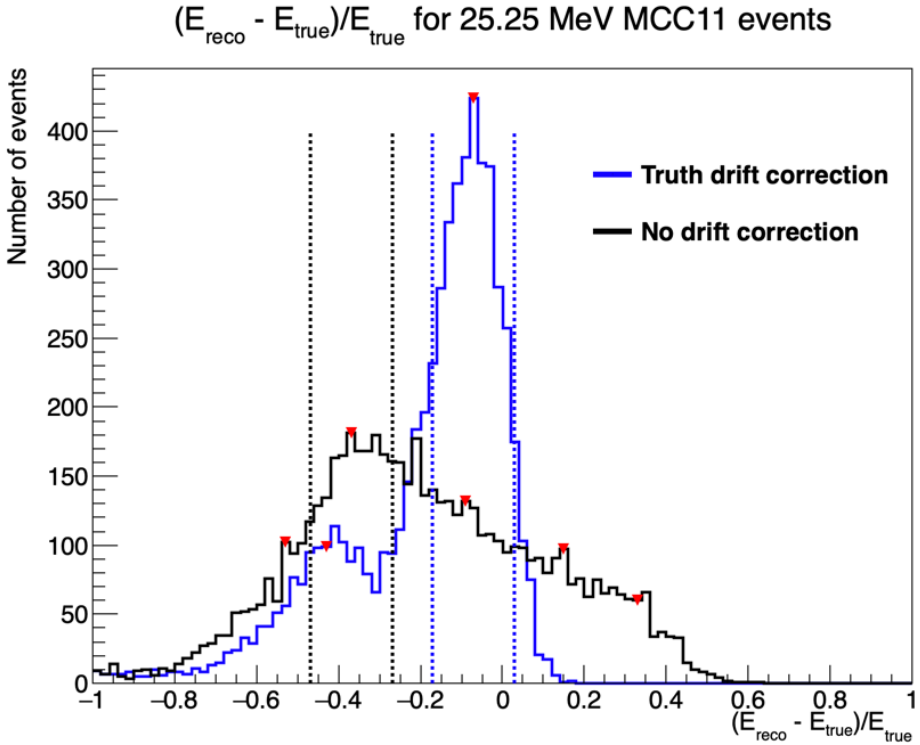


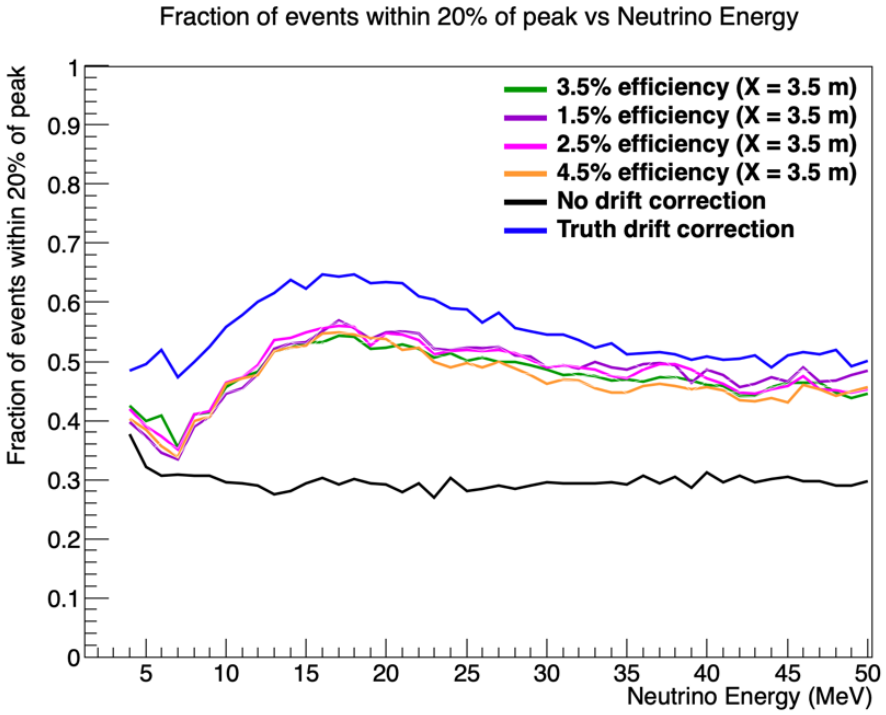
Figure of Merit for MARLEY Events

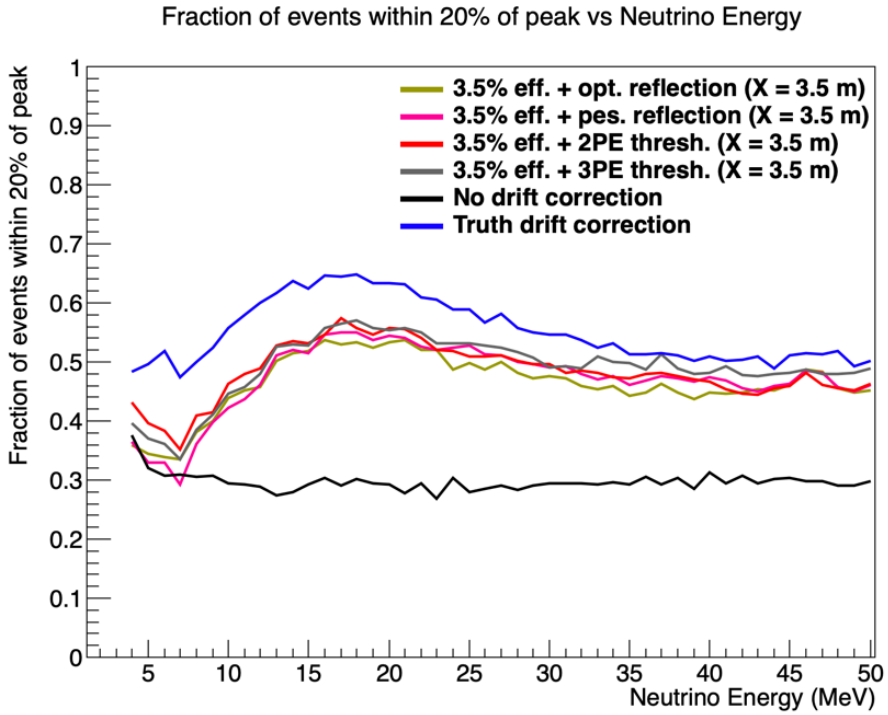
- Previous metric (σ of fractional differences) not suitable for this study; see backup
- New metric considered events close to peak
  - Found largest peak using ROOT peak-finding tools
  - Found number of events in region $(\text{peak} - 0.1, \text{peak} + 0.1)$
  - Metric:

$$\frac{\#\text{ of events in region}}{\text{Total }\#\text{ events}}$$



Metric vs Energy: X = 3.5 m correction

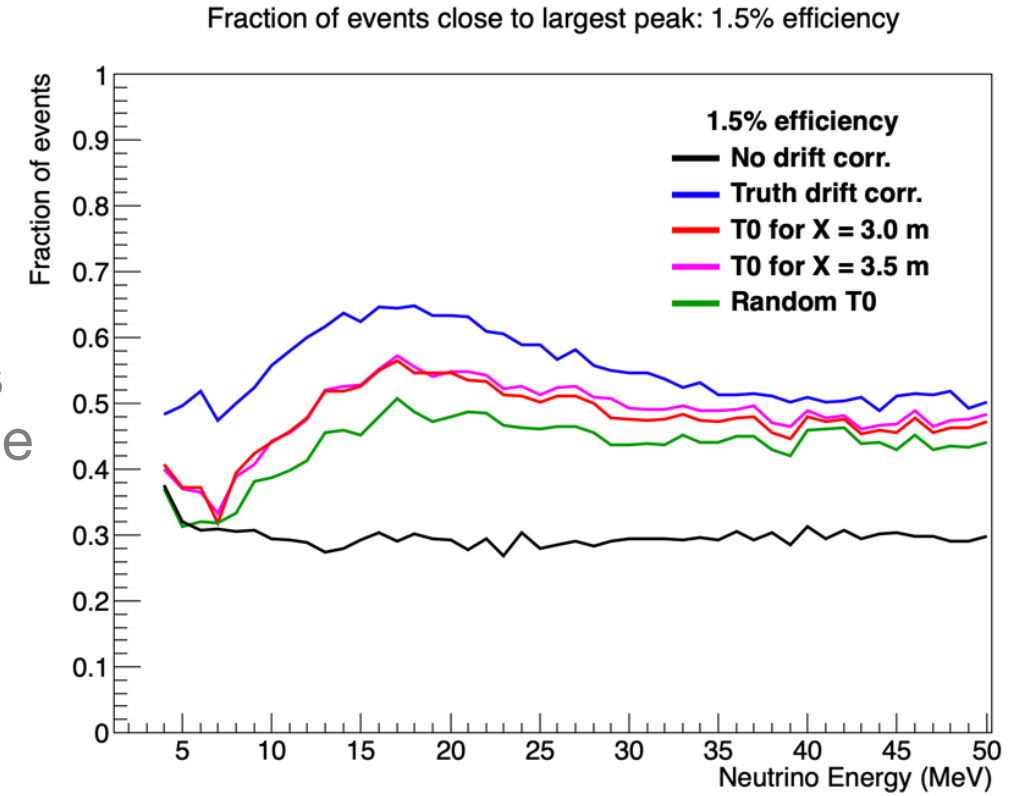




Re-binned 2 MCC11 energy levels → 1 bin to reduce the noisy behavior

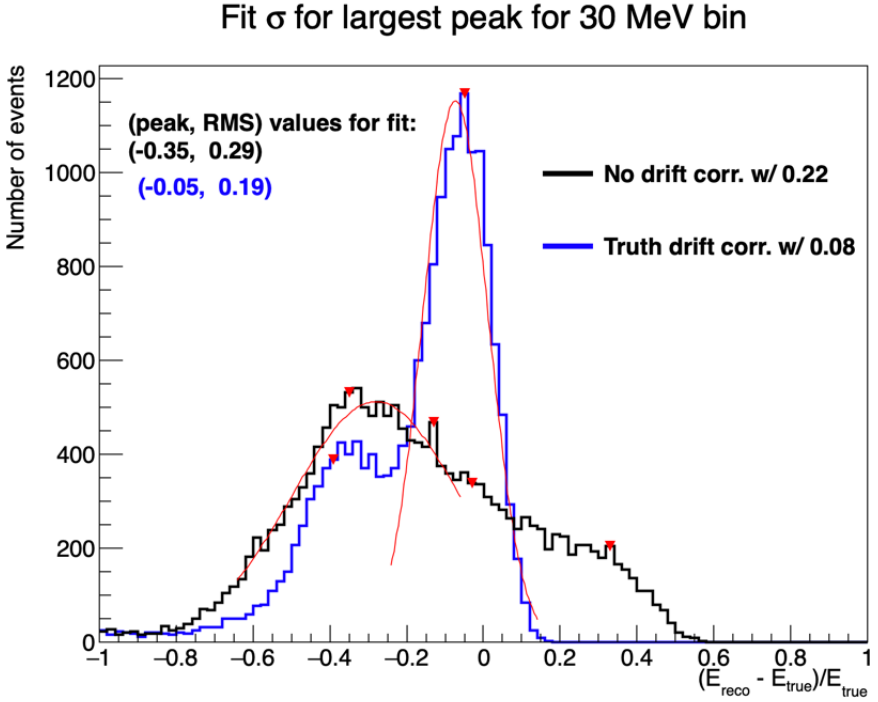
Comparing Drift Correction Methods

- Toy method performances (different ways of correcting events w/o flash matches) between no drift correction and truth correction
- Random T0 method performs the worst – makes sense since the correction was random
  - Correction using X = 3.5 m tends to perform the best – makes sense since it's the largest correction



Alternate Figure of Merit: “Intrinsic” Resolution

- Try to find metric that captures “true” resolution (resolution of events without nucleon emission)
- From histogram of fractional differences, find largest peak
  - Then fit the distribution from $(\text{largestPeak} - \text{RMS}, \text{largestPeak} + \text{RMS})$
  - The σ from that Gaussian fit is the metric



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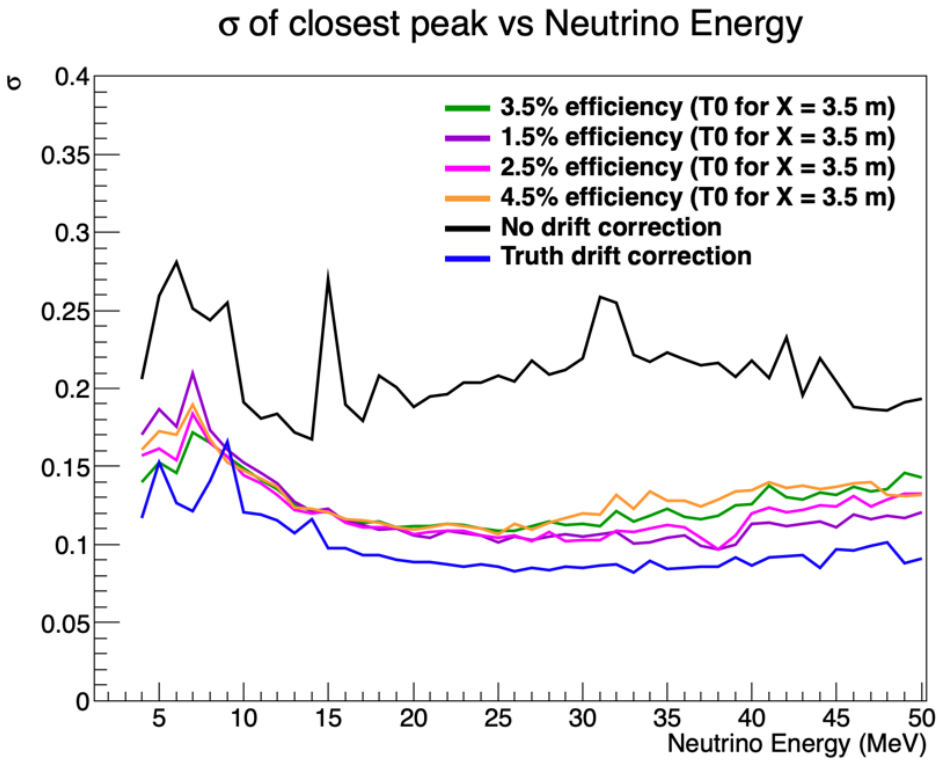
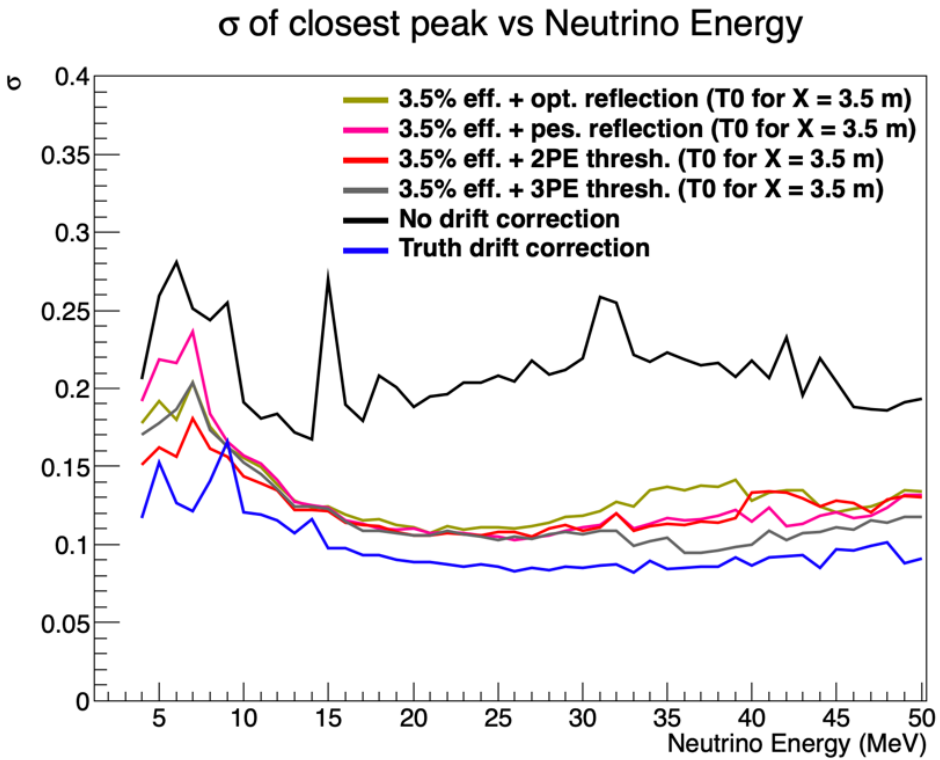




Takeaways

- PDs improve energy reconstruction, but resolution not strongly tied to detector performance
  - Both metrics capture quality of energy reconstruction, but do not distinguish different PD performance types
- Note: these results might only be true for MCC11 MARLEY sample

Backup Slides

Drift Correction Reminder

True drift correction

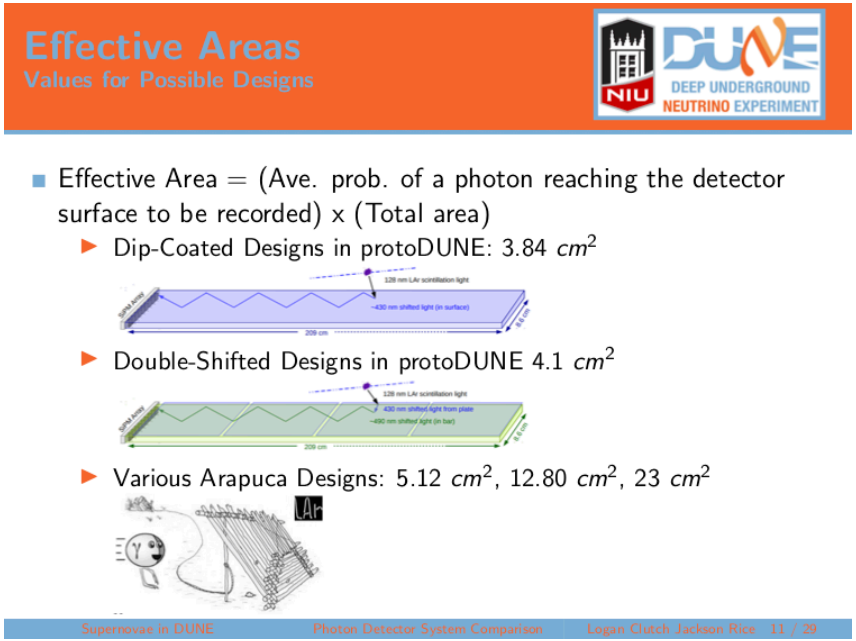
- $Q = Q_0 \exp\left(\frac{x}{v_d \tau_e}\right)$
  - Q: Truth charge
  - Q_0: Observed charge
  - x: Distance from electron vertex to APA (MC Truth)
  - v_d: Electron drift velocity
  - τ_e: Electron lifetime

Reco drift correction

- $Q = Q_0 \exp\left(\frac{t_0}{\tau_e}\right)$
  - Q: Truth charge
  - Q_0: Observed charge
  - τ_e: Electron lifetime
  - t_0: Reco interaction start time
- Find t_0 using photon flash, reco hit information (used longest track as reco electron track)

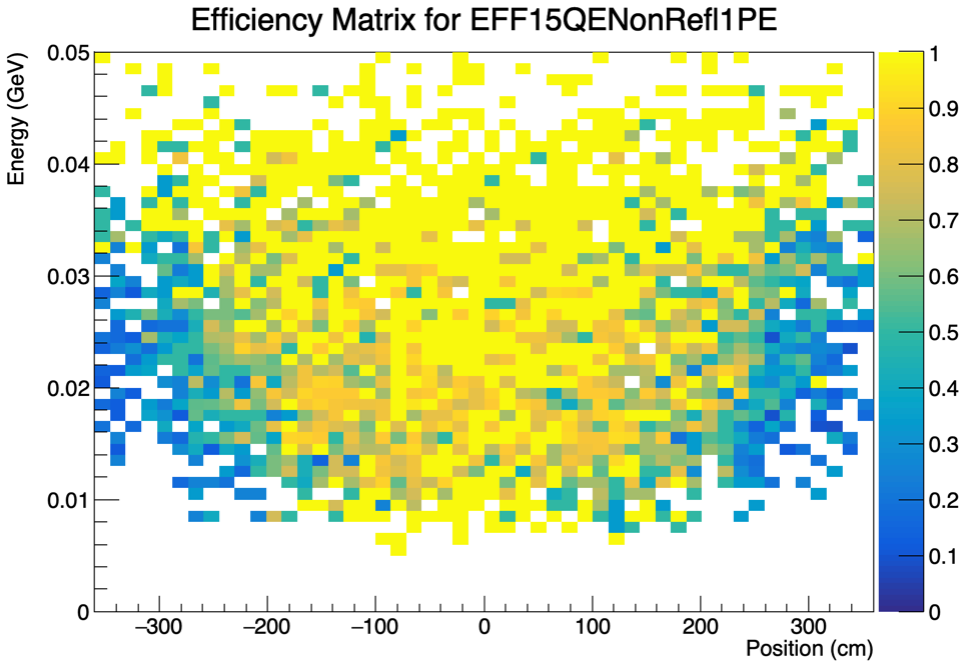
PD Performance Types: Reminder

- Motivation: evaluate photon detector requirements for SN physics; coupling physics to PD performance
- Distinguish photon detector performance variations based on “effective area”
  - Right: slide from a talk by Logan Rice



Un-binned Efficiency Matrices

- Efficiency matrix: Probability of successful flash matching given true neutrino energy, distance from APA
- Less statistics compared to previous efficiency matrices; re-binned to reduce number of “holes”
  - Merged 4 bins into 1 for both axes



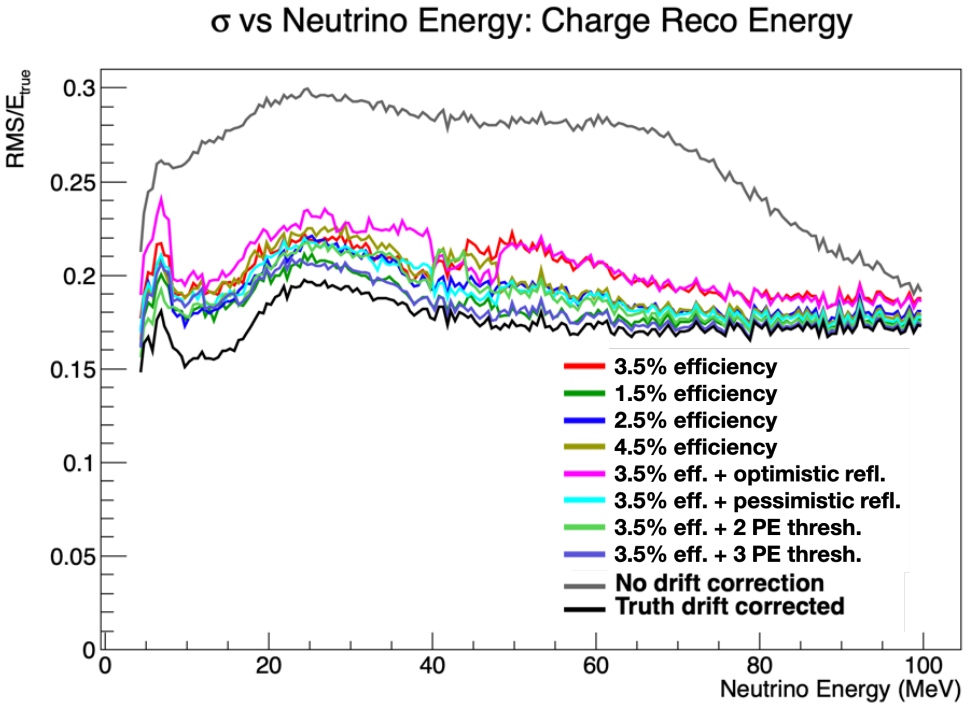
1.5% QE (before re-binning)

Resolution Plots: Random T0 Method

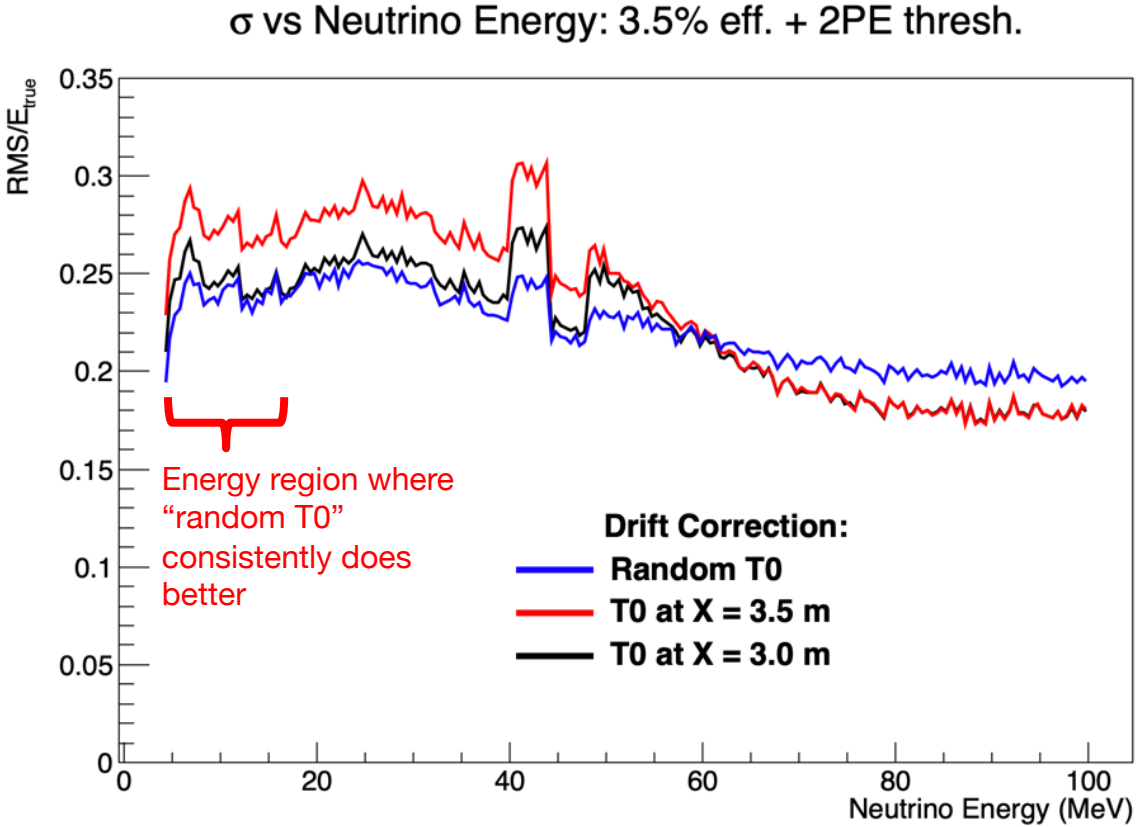
- Using fractional energy values, calculate standard deviation:

$$\sigma_{\text{frac}} = \sqrt{\frac{\sum_{i=1}^{N}\left(E_{\text{frac,i}} - \bar{E}_{\text{frac}}\right)^2}{N-1}}$$

- Comparable to truth drift correction!
- This metric failed to capture differences in drift correction methods for each PD performance type



Comparing Drift Correction Methods



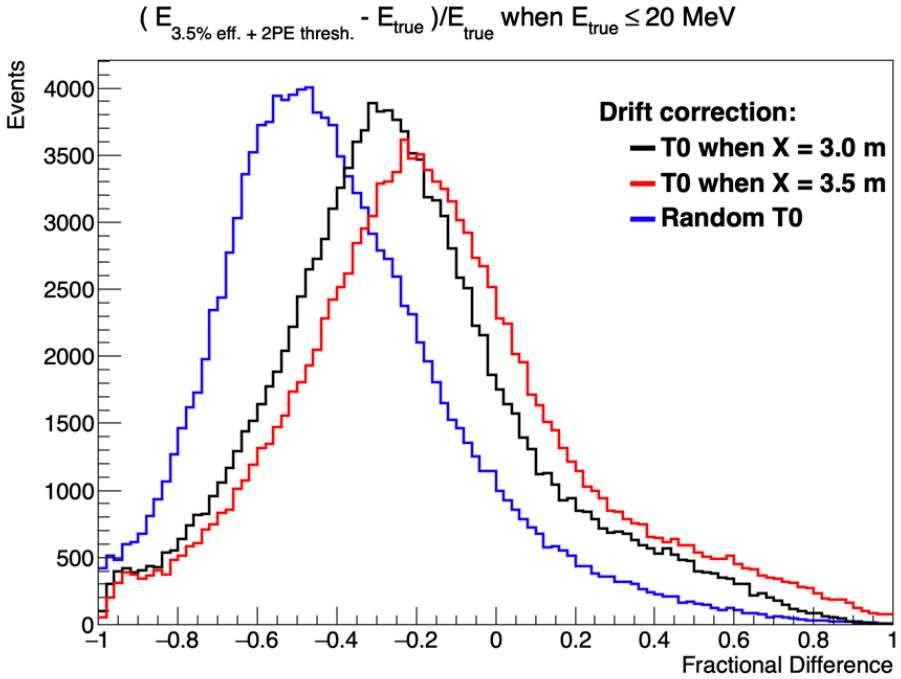
Using fractional energy values, calculate standard deviation:

$$\sigma_{\text{frac}} = \sqrt{\frac{\sum_{i=1}^{N}\left(E_{\text{frac,i}} - \bar{E}_{\text{frac}}\right)^2}{N-1}}$$

However, this figure of merit implies that the "random T0" method is better for events under 50 MeV, which doesn't make sense…

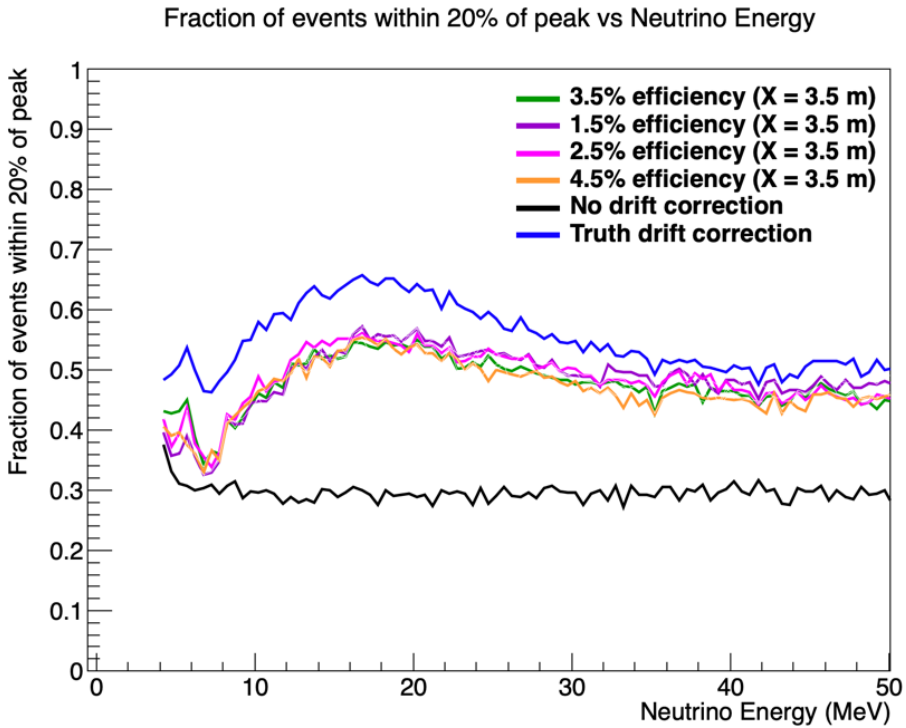
Comparing Drift Correction Methods

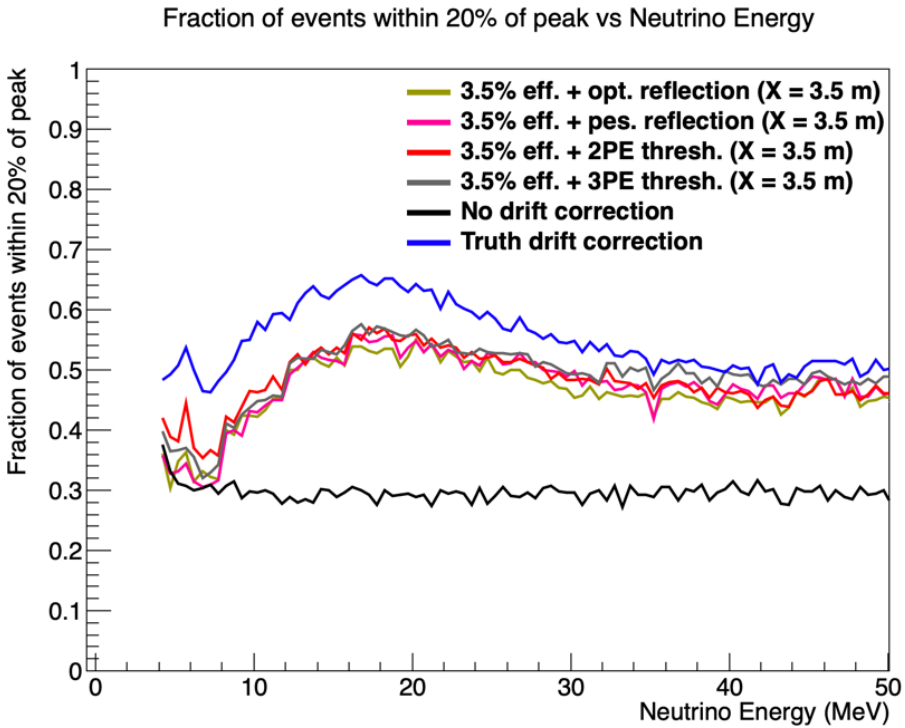
- Consider histograms of fractional difference, $(E_{\text{reco}} - E_{\text{true}})/E_{\text{true}}$
- Random T0 method reconstructs less energy on average, but σ/width looks smaller by eye
  - Motivated search for new figure of merit



Fractional difference histograms for events without flash and energy cut

Updated Metric vs Un-binned Energy





Metric vs Energy: X = 3.0 m correction