Geometric Efficiency Correction Discussion

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Detector Acceptance

• We reject events with hadronic energy in outer ~30 cm
  – …to guarantee that we’ve contained all of the energy
• This means that events near the edge of the detector have worse efficiency
  – Ciaran has shown that the ND efficiency correction (if performed via a traditional based method) is a large source of systematic uncertainty in the DUNE-PRISM Linear Combination analysis
• The geometric efficiency correction overcomes this issue by calculating the efficiency directly from the measured events themselves (rather than relying on MC)
Data-driven efficiency reminder

- Use symmetries of neutrino interactions in ArgonCube:
  - Symmetric with respect to translations in the LAr volume.
  - Symmetric with respect to rotations around beam axis.

- Algorithm:
  - For a given selected ND event, rotate and translate 3D hadronic energy deposits and reconstructed muon position and momentum vectors N times.
  - For the hadronic side:
    - Count how many of the trials would have passed the hadronic containment cut.
    - Take the ratio to the total number of trials get the “geometric” hadronic containment efficiency for that event.
  - For the muon side:
    - Use a neural network trained on particle gun MC to estimate the muon selection efficiency for a given translation/rotation.
  - Combine both to get event-level efficiency.

\[
\eta = \frac{0 \times 0.8 + 1 \times 0.3 + 0 \times 0.7 + 1 \times 0.4 + 1 \times 0.95}{5} = 33\%
\]
Hadronic efficiency

- A perfect correction to the "generated" level is impossible because some event topologies will never be selected at the ND.
- But some of these events might be selected at the FD!
ND Efficiency of FD Events

• After calculating the geometric efficiency of a ND event, we apply a threshold (e.g. eff = 1%)
  • Events below this threshold are declared “undetectable at the ND”
  • Such events are more likely to occur near the FV boundaries

• We must also calculate the ND efficiency of each FD event
  • Again, events below this threshold are declared “undetectable at the ND”
  • Such events are set aside in the standard analysis and must be treated differently (if at all)

• However, where do we calculate the ND efficiency?
  • We will get different answers for:
    • Different detector locations
    • Different event locations within a given detector location
FD Detection Threshold

• It appears feasible to map out the ND efficiency of each FD event as a function of $x_{\text{det}}$ (small effect) & $x_{\text{vtx}}$ (large effect)

• For FD events that have eff > threshold for all values of $x_d$ & $x_v$, the linear combination analysis proceeds as usual

• For FD events that have eff < threshold for all values of $x_d$ & $x_v$, the FD event should be excluded from the linear combination analysis

• What about FD events where eff < threshold for some values of $x_d$ & $x_v$ and eff > threshold for other values of $x_d$ & $x_v$?
The FD event above is below threshold for certain off-axis slices. This means the equivalent ND events will be absent in certain ranges of off-axis position. An (overly) simplistic solution would be to add the FD event to the ND off-axis samples where its ND equivalent events are missing (with appropriate weights). 

- For this solution, properly treating the statistical uncertainty would get messy in a hurry.
- Instead, we might try weighting the FD event in the FD histogram to account for its missing strength in its $E_{\text{rec}}$ bin in the ND prediction.
- Finally, you could make a FD efficiency histogram for each ND off-axis slice, and apply it prior to the ND linear combination.
FD Correction for ND Efficiency

- For each FD event, calculate the geometric efficiency as a function of $x_{cavern}$
  - $x_{cavern}$ depends on $x_d$, $x_v$, and the detector position run plan (POT at each chosen $x_d$ and $x_v$)

- For each ND off-axis slice, add an entry in a histogram of your observable variable(s) (e.g. Erec) if the ND geometric efficiency of this FD event is above the threshold in that off-axis slice
  - If the geometric efficiency is only above threshold for a portion of a given off-axis bin, add a weighted entry

- Divide each of these histograms by the full FD histogram (weight = 1 for each FD event) to derive the efficiency for each off-axis slice