TPC GAIN STUDIES

Low Energy Reconstruction Efficiency

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Goal

Study effect of TPC gain **decrease** in **low-energy event reconstruction**.

Methodology

- Use **standard** low energy **production** fcls for HD.
- Use **Wirecell** and change **gain setting and noise file (provided by TPC electronics group)** in configuration files. **Evaluate waveforms**.
- Use SolarNuAna analyzer to evaluate detection efficiency:
  - Use **recob:hit** (gaushit).
  - **Cluster hits** according to time & channel number (max 25 tick & 3 ch).
  - **Match col + induction** (at least 1) planes for y-z cluster reconstruction.
  - **Group clusters** into “primary” and “adjacent” (R adj cl. < 1m & charge adj. < charge primary).
  - **Compute efficiency:** probability of finding at least one cluster per event.

FHICL Settings: dune10kt_1x2x6

- All modification in custom branch (dunereco/tree/gain_dunereco)
- Found gain setting in params.jsonnet file (see figure).
- Gets called from wcls-sim-drift-simchannel-nf-sp.jsonnet.
- Finally configuring standard_detsim_dune10kt_1x2x6.fcl

```
// Take BNL cold electronics on ProtoDUNE as reference here
elec: super.elec {

    type: "ColdElecResponse",

    // copied from pdsp
    gain: 140*wc.mV/wc.fC,
    shaping: 2.2 * wc.us,
    postgain: 1.1365,
    start: 0,
},
```

- Generated new set of *_gain*.jsonnet/fcl files for new workflow (see branch).

Productions

Using dune10kt_1x2x6, vary **gain** setting 14 (default) and 7.8 [mV/fC].

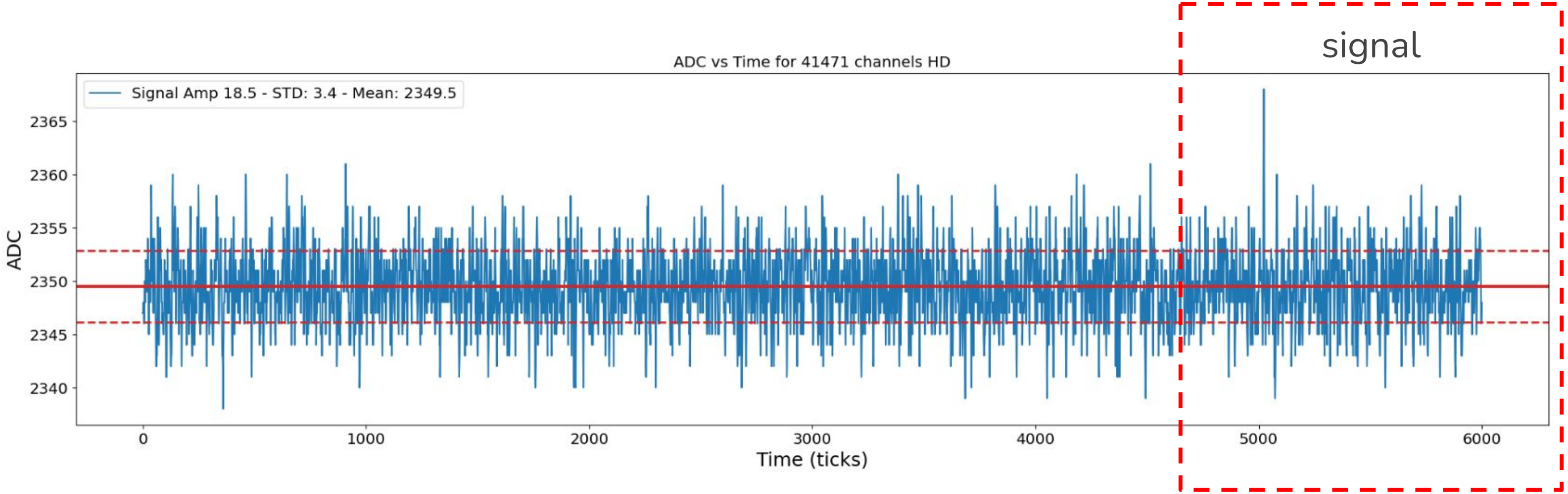
- **Production**: Flat **elastic scattering neutrino interactions** 0-5 MeV homogeneous across detector producing **electron tracks** (see backup slide).

  → Use alternative detsim config (wcls-sim-drift-simchannel.jsonnet) to export raw waveforms.

  → Follow standard workflow. Reco efficiency from events with reconstructed clusters (see slide)

Raw Waveform Comparison

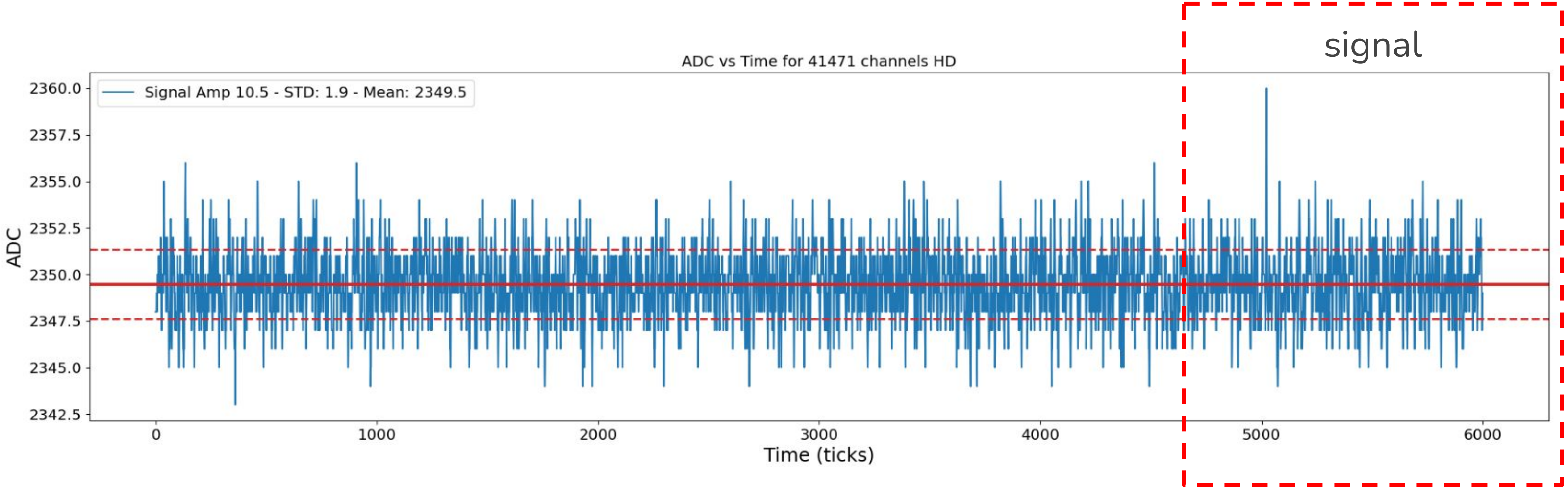
- Waveform (~**5 MeV electron**) for gain 14.0 [mV/fC].
- No zoom, y-scale set to waveform amp.



Selected wvf with maximum signal in full sample

Raw Waveform Comparison

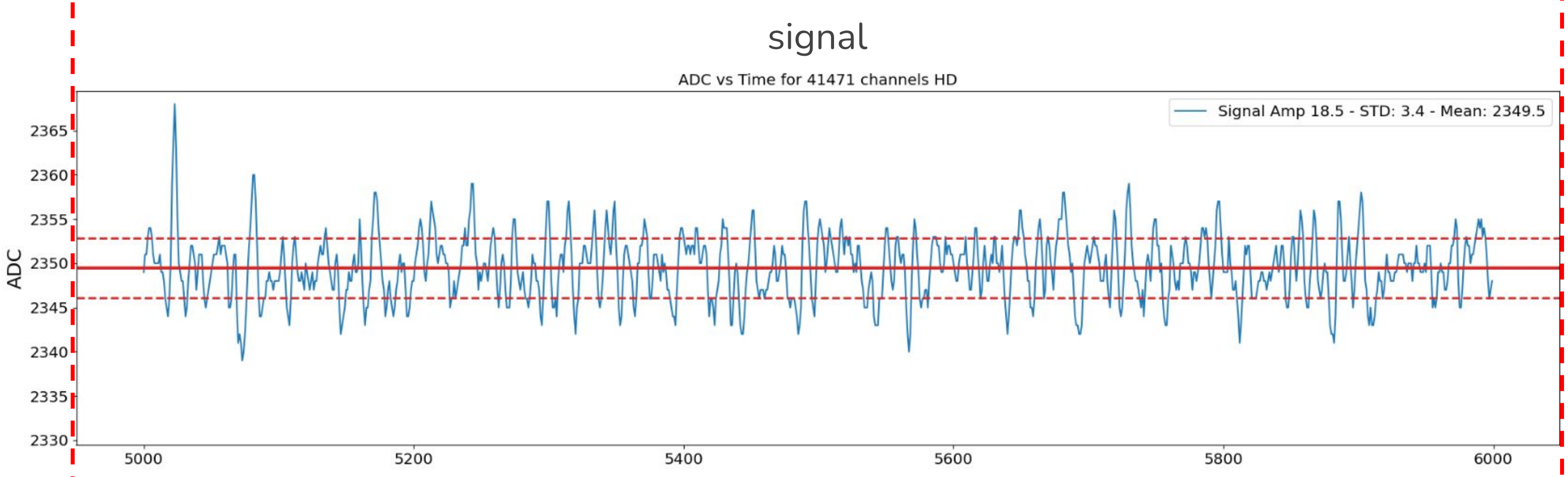
- Waveform (~**5 MeV electron**) for gain 7.8 [mV/fC].
- No zoom, y-scale set to waveform amp.



- **Gain changes with 14/7.8 = 1.8** & as expected: **Signal amp. 18.5/10.5 = 1.8** and **STD 3.4/1.9 = 1.8**.
- Because of this, no changes are expected in overall results.

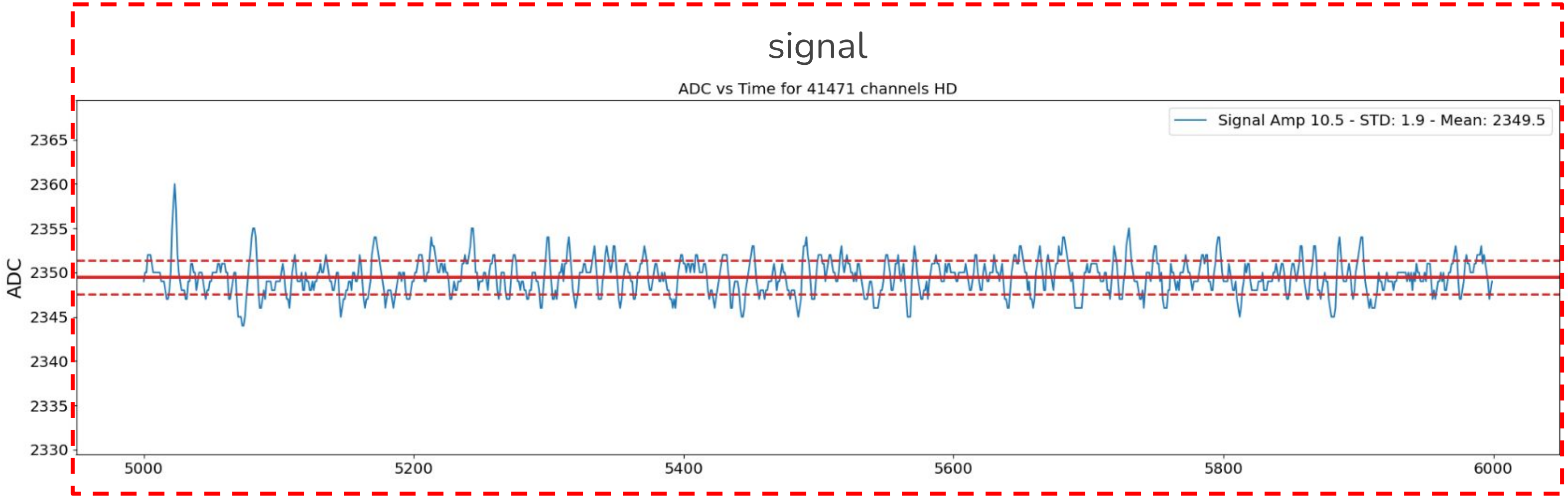
Raw Waveform Comparison

- Waveform (~**5 MeV electron**) gain 14.0 [mV/fC].
- Zoomed, y-scale set to 40 ADC.



Raw Waveform Comparison

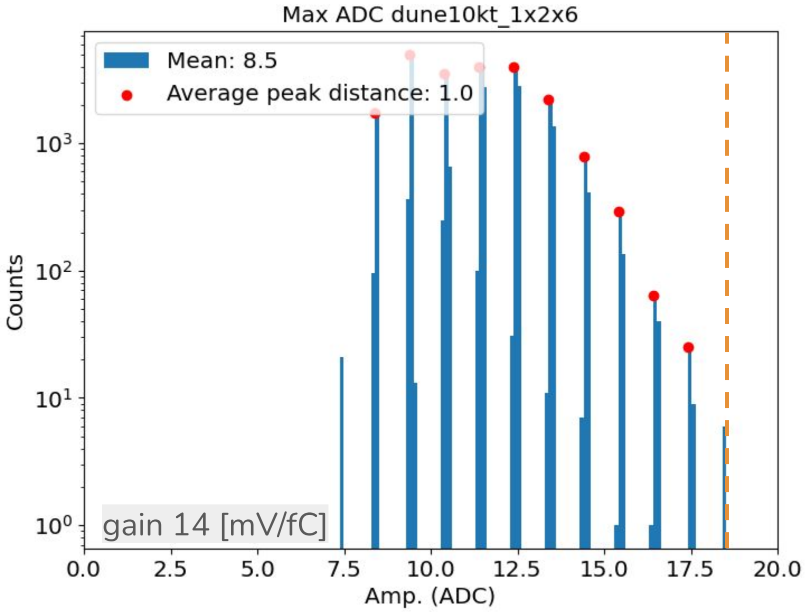
- Waveform (~**5 MeV electron**) gain 7.8 [mV/fC].
- Zoomed, y-scale set to 40 ADC.

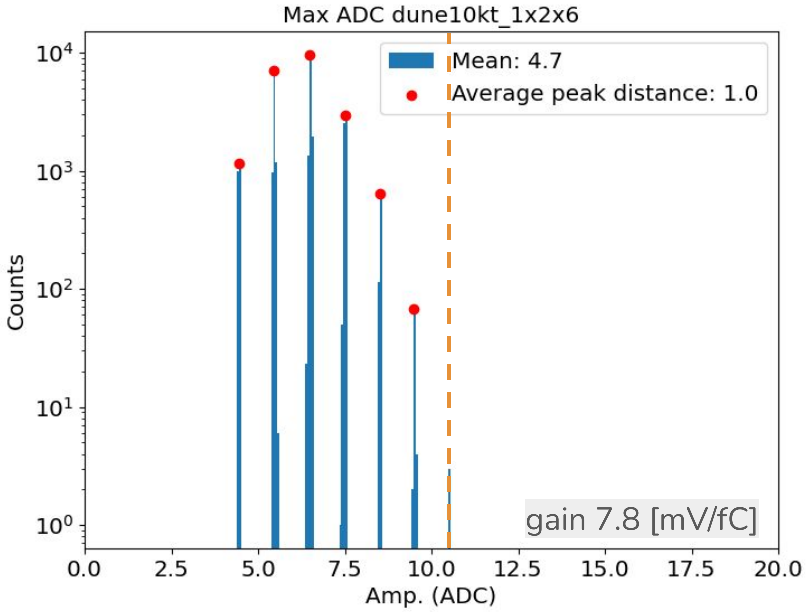


- **Results** are effectively a **noise and signal scaling** with the same factor 1.8.

Waveform Max. Amplitude Distributions

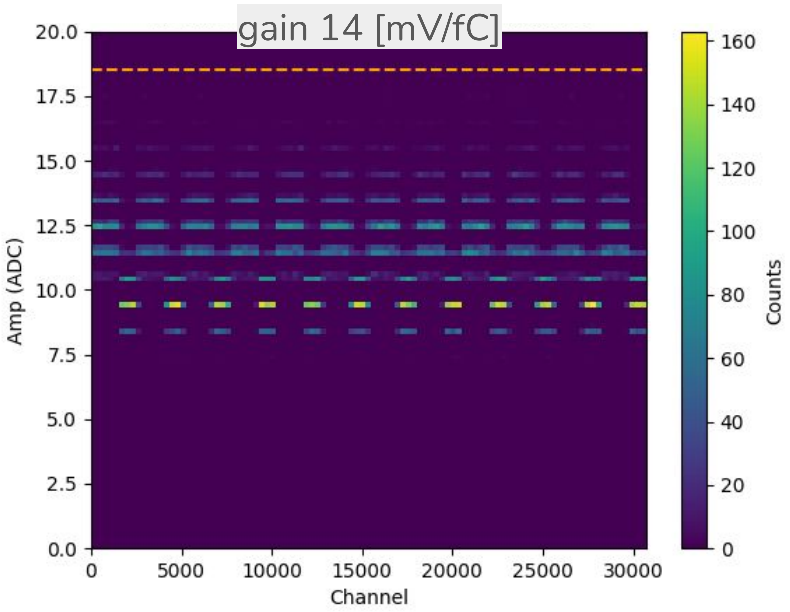
- Showing noise wvf. max amp distributions.
- Waveform digitization checks to 1 ADC increments.

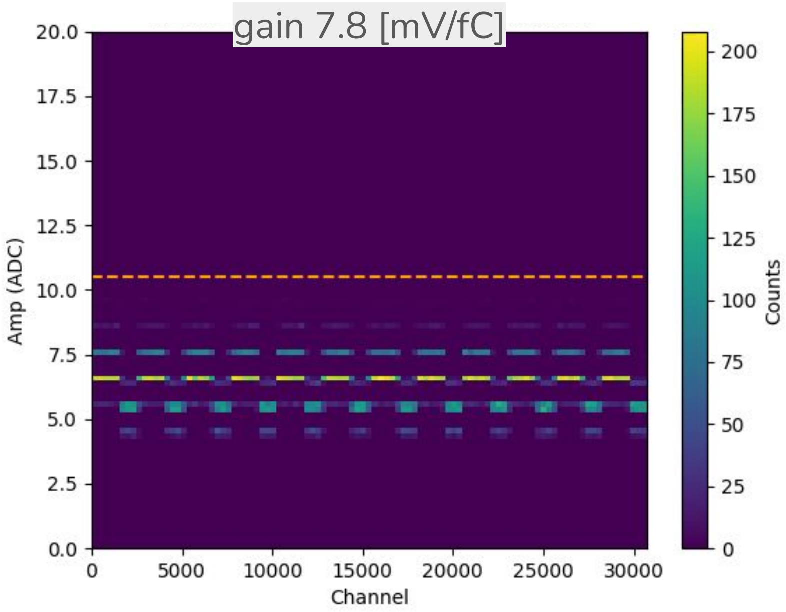




Waveform Max. Amplitude Per Channel

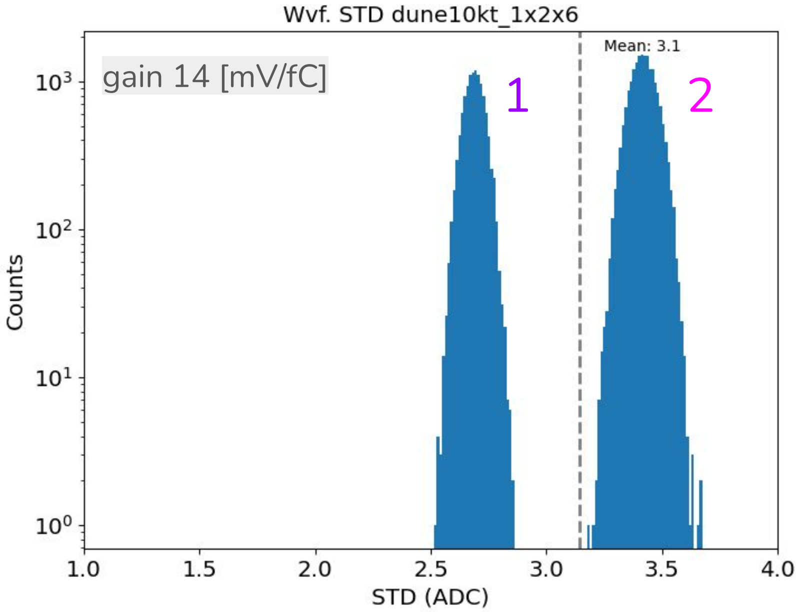
- Noise vs channel reveals a certain pattern. Ref. line showing max value.
- What is the reason for this **channel grouping**?

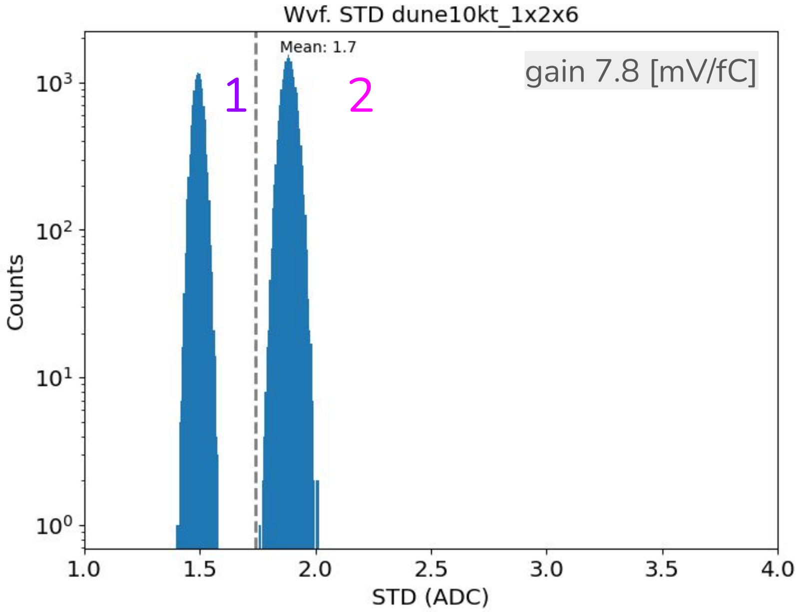




Waveform STD Distributions

- STD distributions replicates noise amplitude results in terms of scaling.
- For 1 MeV electron → amp. of *3.7 - 2.1 & S/N of ~1.4 or ~1.1.

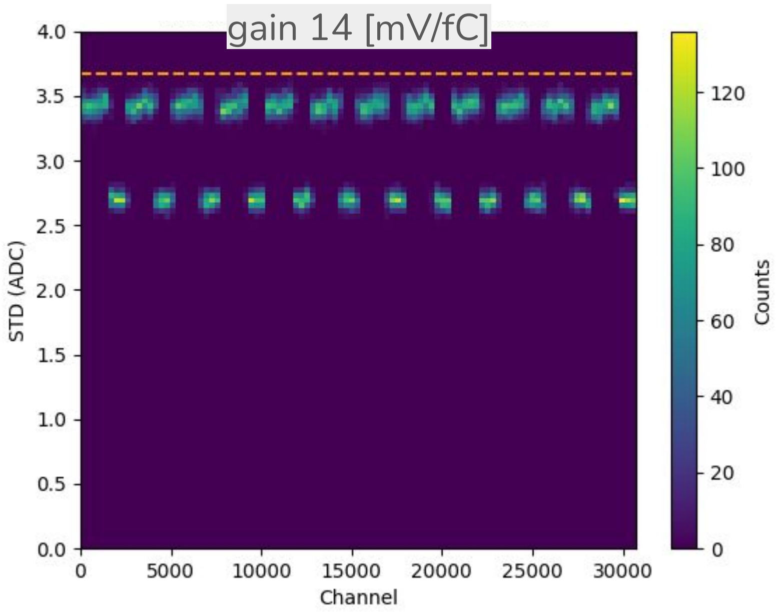


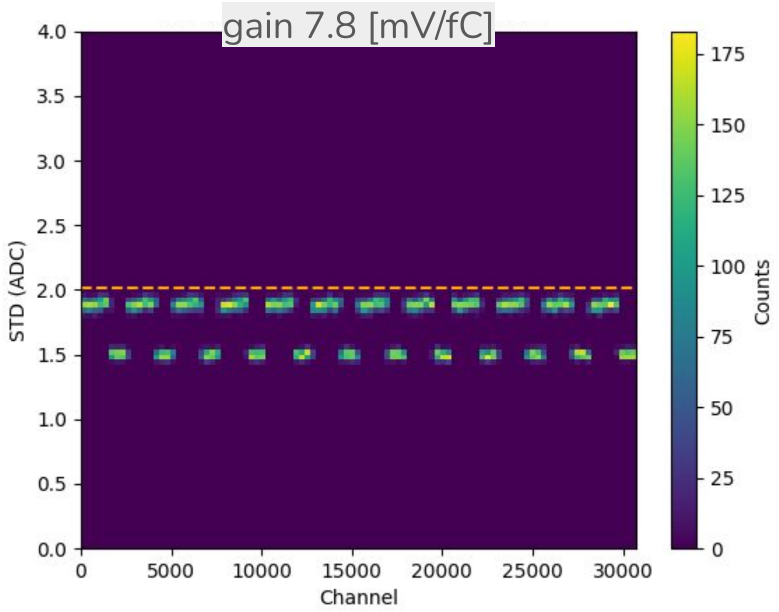


*Scaled down from wvfs. in slides 5, 6.

Waveform STD Distributions

- Clear **channel grouping** conserved in updated noise model. Same distribution in both productions but different scaling.

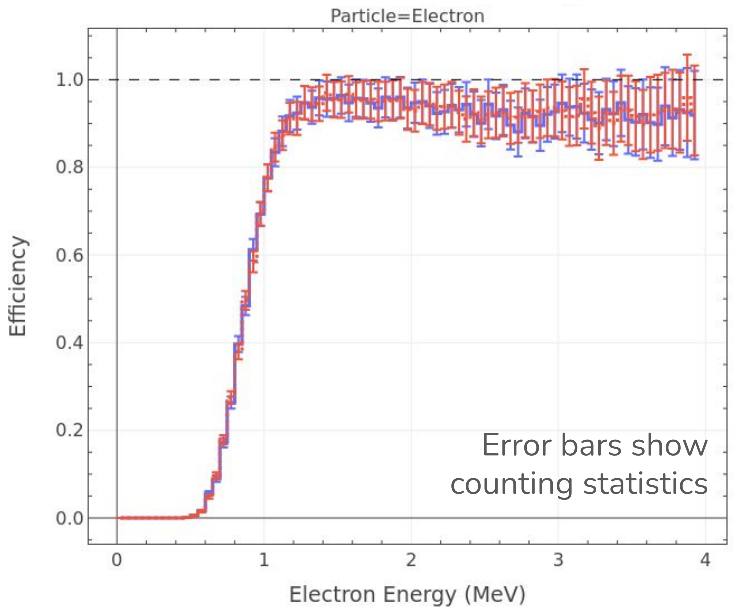


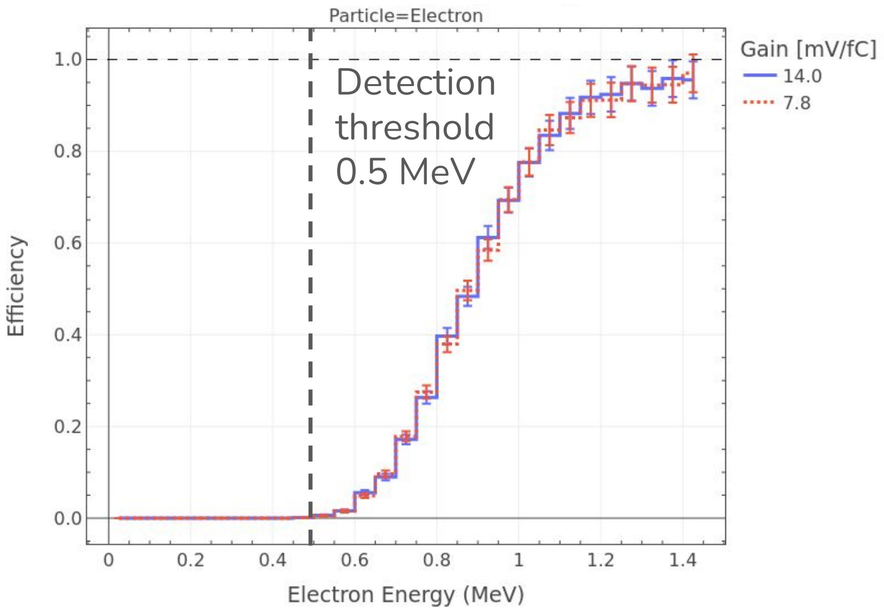


Ref. line showing max value.

Detection Efficiency

- **Wirecell correctly adapts** to the changes in waveform.
- Both gain configurations present **identical detection efficiency**.

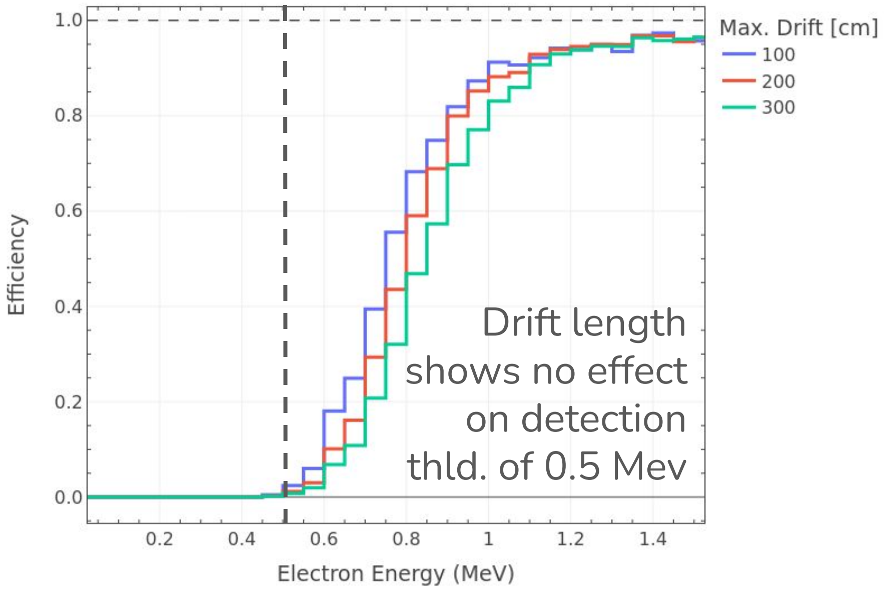




Gain Comparison

- **Waveforms look identically scaled** (by factor 1.8) in terms of signal amplitude and noise.
- New gain configuration leads to expected changes in signal and **reconstruction adapts accordingly**.
- Nevertheless, at low energies 1 MeV electron S/N is quite low: 1.4 - 1.1.
- Is this scaling **realistic for full scale detector**?
- Do we understand **noise distributions per channel**?

Detection Efficiency



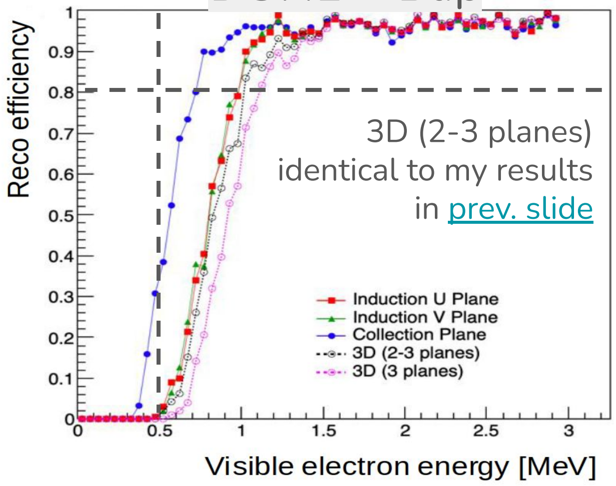
*Electrons are distributed homogeneously across detector

- Showing change in detection eff. with different **fiduzializations in drift coordinate**.
- **No effect on threshold**.
- **No effect on max. efficiency**.
- Only **small effect on "slope"**.
- Possibility to compare against other LArTPC experiment.

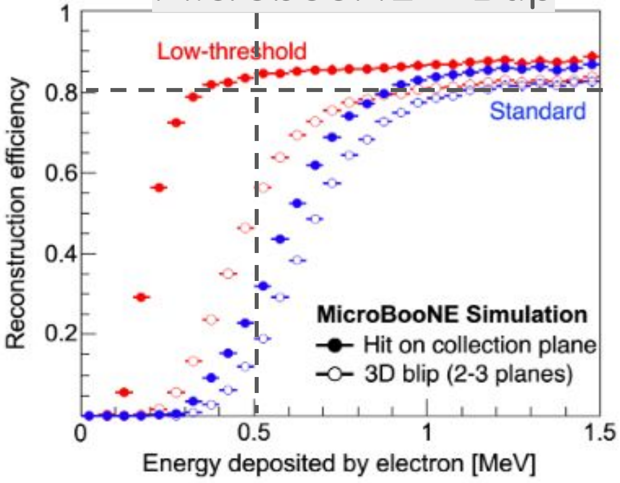
Detection Efficiency: MicrobooNE Comparison

- Presented in LowE meeting Blip Reconstruction in DUNE.

DUNE + Blip



MicrobooNE + Blip

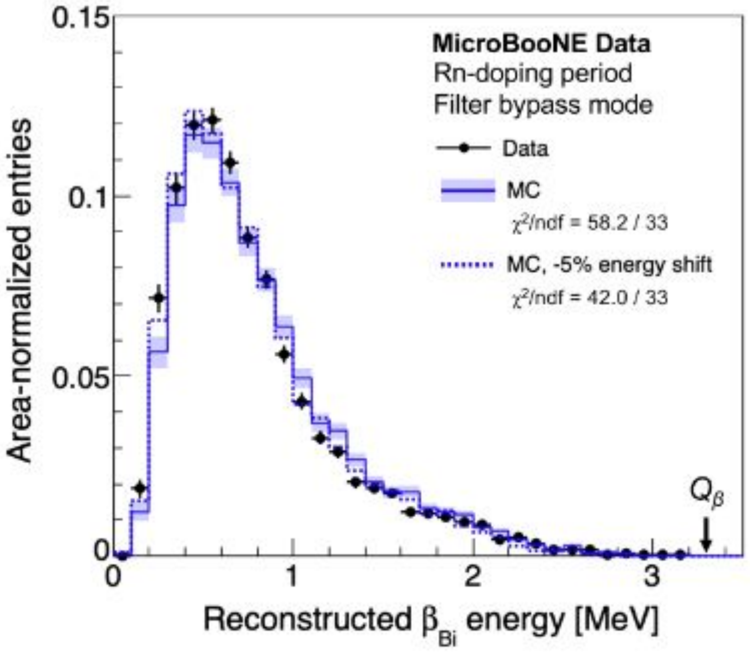


MicroBooNE Ambient Radon

- With same reco. algo. **MicrobooNE simulation delivers better efficiency**.
- With **tuned wirecell Low-threshold** config **even better** results!

MicrobooNE Comparison

MicroBooNE Ambient Radon

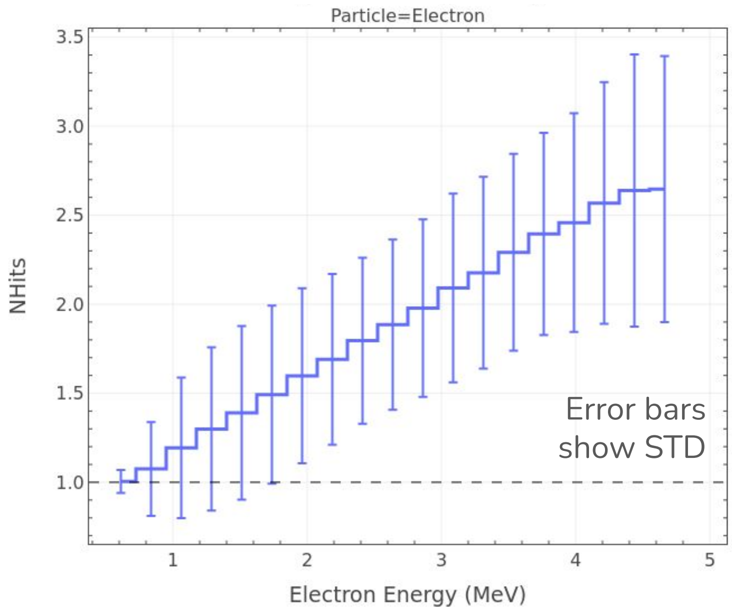


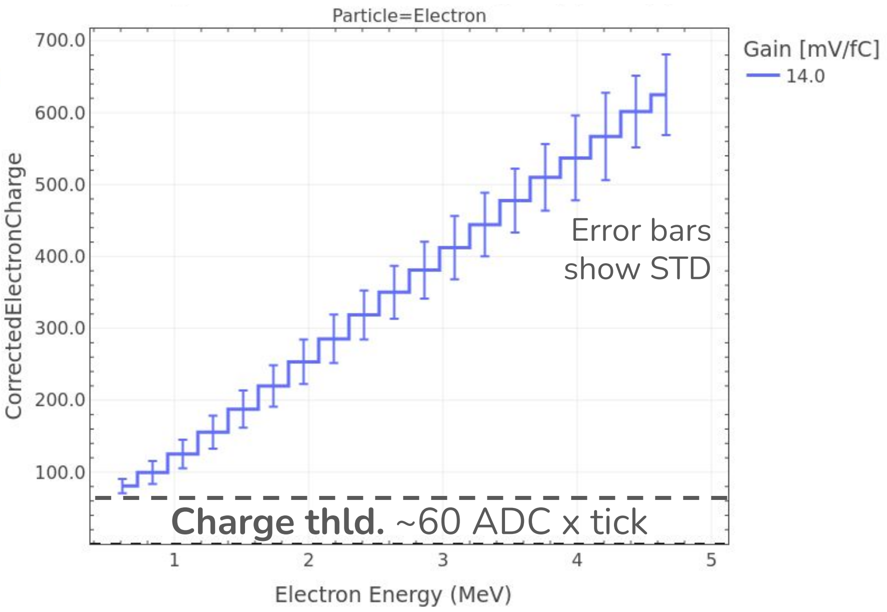
- Showing nice low energy result from MicrobooNE. **Is this possible in DUNE?**

	MicrobooNE Low-Thld	MicrobooNE Standard	DUNE
Detection Threshold	0.2 MeV	0.3 MeV	0.5 MeV
Threshold 80% eff.	0.8 MeV	1 MeV	1 MeV
Energy Resolution	8%	—	10%

Cluster Statistics

- Average number of **hits below 3 for e⁻ < 5 MeV**.
- Charge behaves linearly with slope ~140 ADC x tick / MeV and 60 ADC x tick thld.



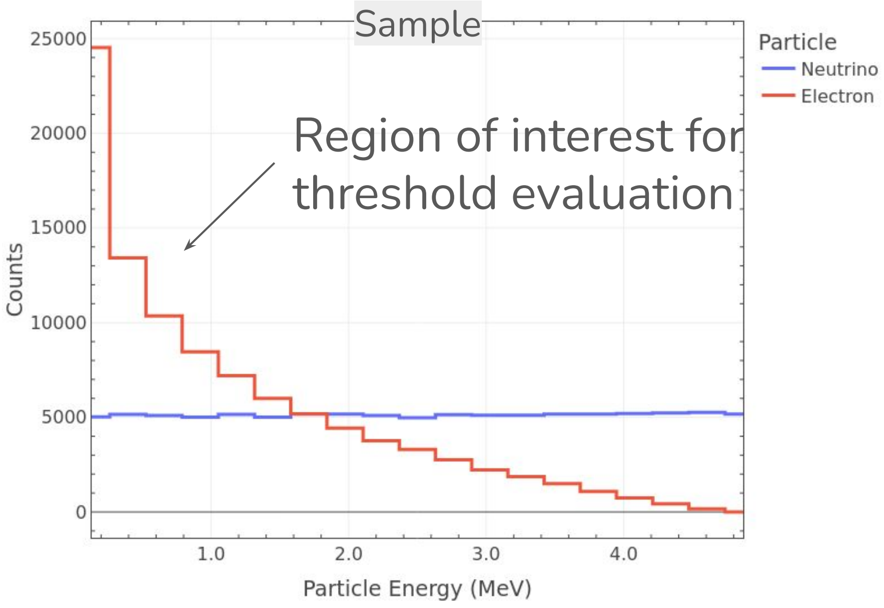


Questions

- **Limiting factor** for low energy reco.? **S/N not enough below 1 MeV**?
- How does wirecell calculate the **hit threshold**?
- Can we **review/improve wirecell** reco./deconvolution for **low energy** studies?
- Ready to **implement gain change** into standard workflow?

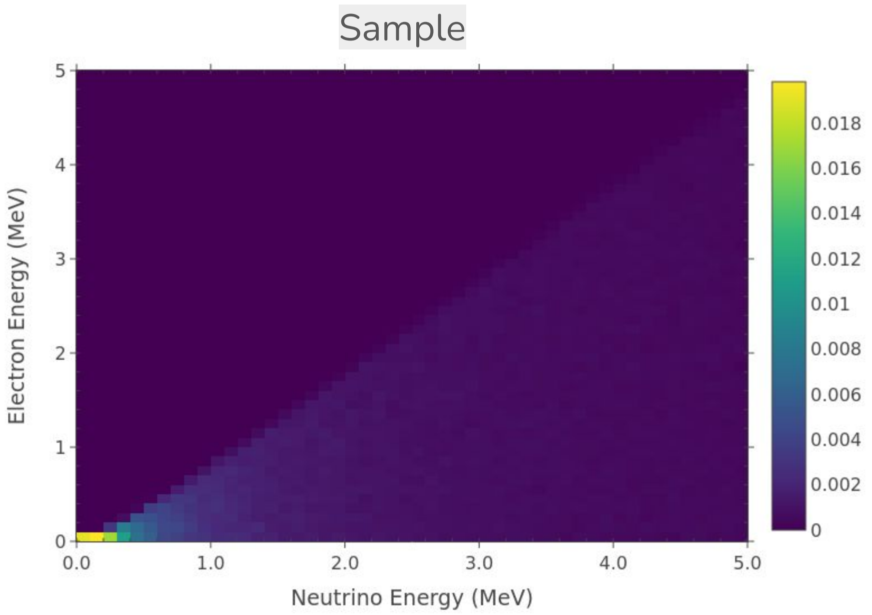
Backup

True Electron Spectrum



- Due to the process of elastic scattering, the flat neutrino spectrum leads to an **exponential electron sample** in energy.
- Distribution **favours threshold statistics**.
- All **values are calculated per bin** avoiding spectral bias.
- Errors will be statistical or STD depending on convenience.

True Electron Spectrum



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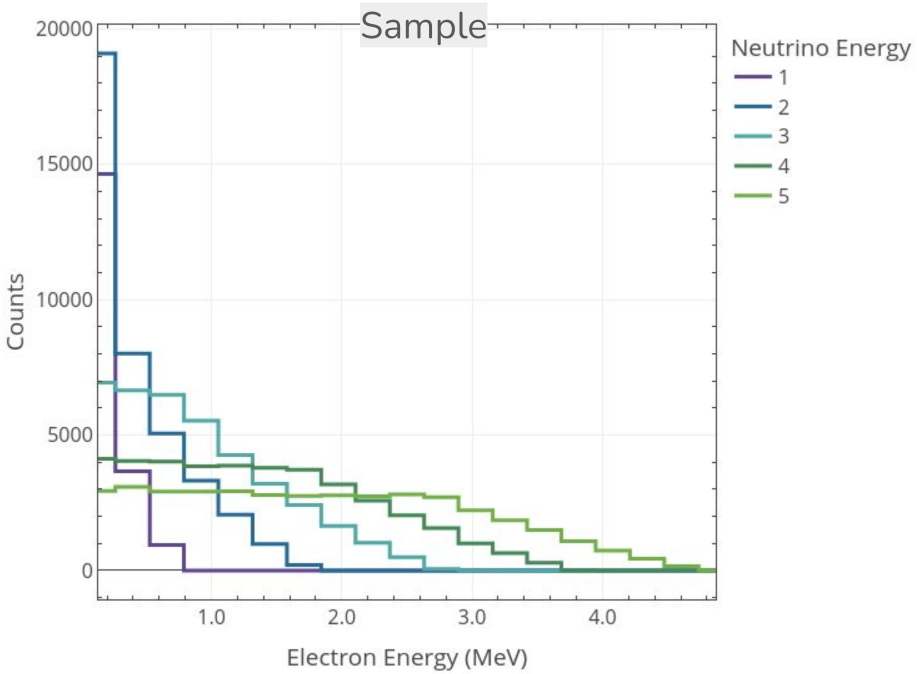

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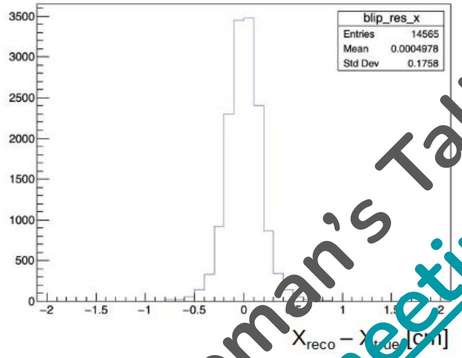
Energy Reconstruction: Microboone Comparison

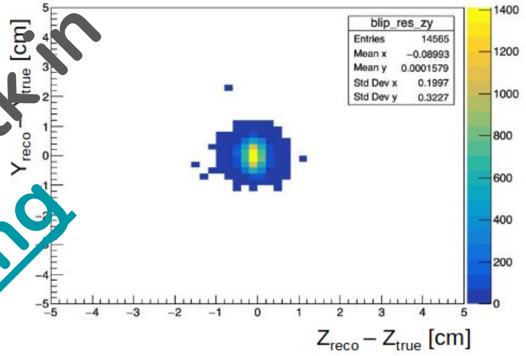
Position resolution
$\sigma_x \sim 0.18$ cm
$\sigma_y \sim 0.32$ cm
$\sigma_z \sim 0.20$ cm

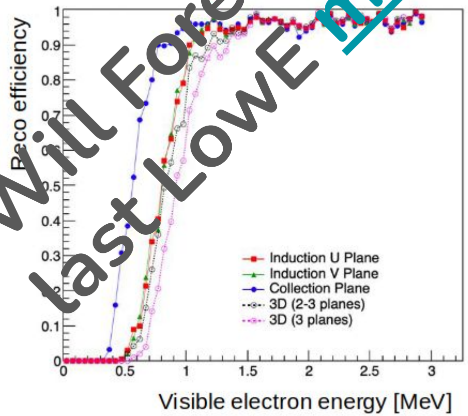
Energy resolution
$\sigma_E \sim 10\%$ for > 1.8 MeV
$\sigma_E \sim$20-30% at 1MeV
(need more stats)

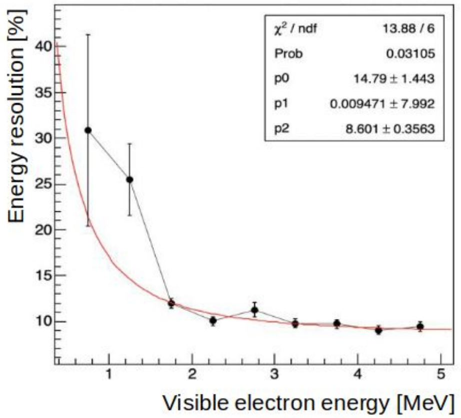
Energy threshold
> 95% above 1.3 MeV
>50% above 0.8 MeV
(0.6 MeV for 2D hits on collection plane)

See Will Foreman's Talk in last LowE meeting



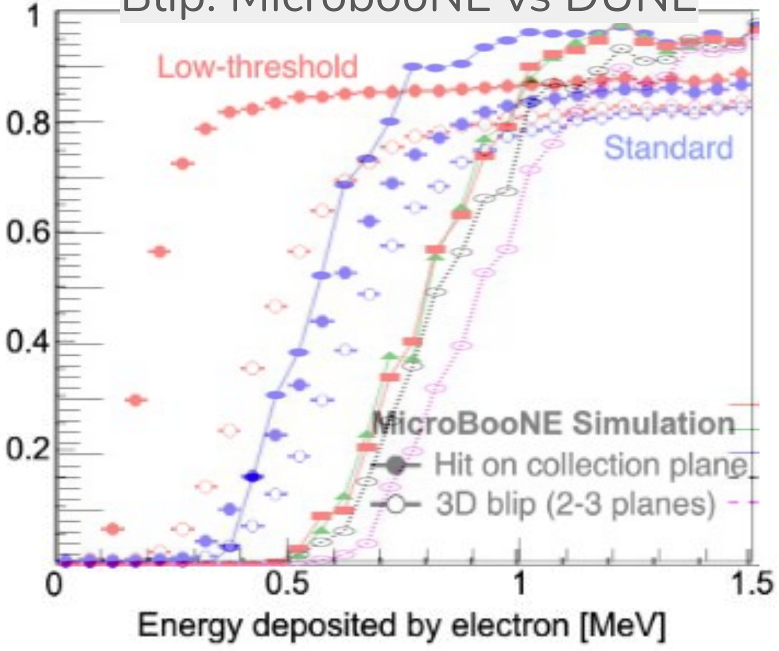




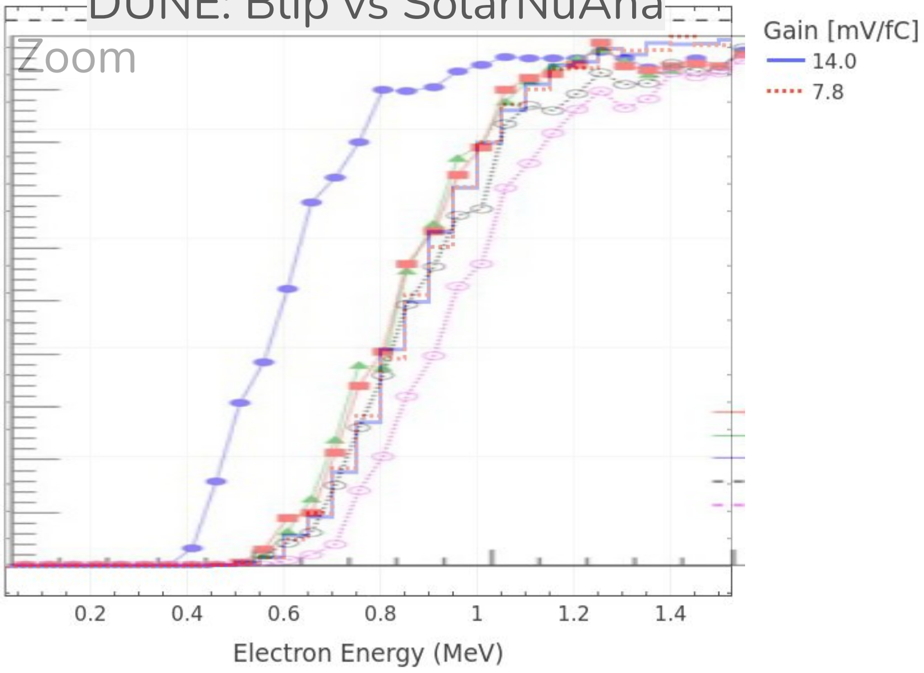


Electron Threshold: Experiment Comparison

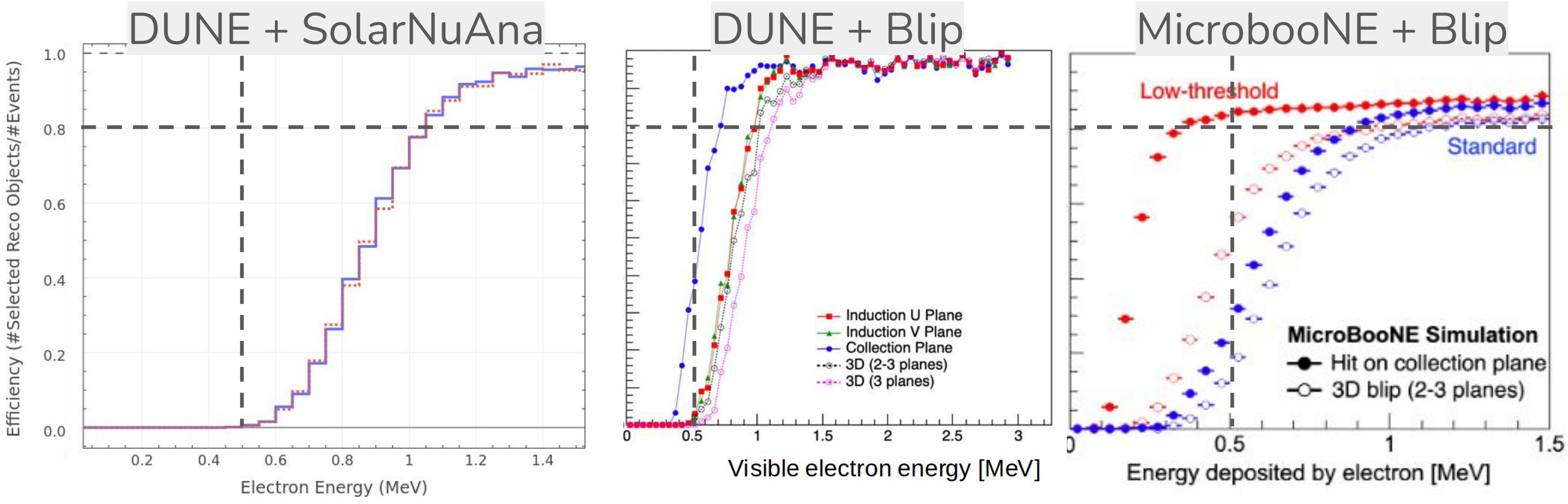
Blip: MicrobooNE vs DUNE



DUNE: Blip vs SolarNuAna



Energy Threshold: MicrobooNE Comparison

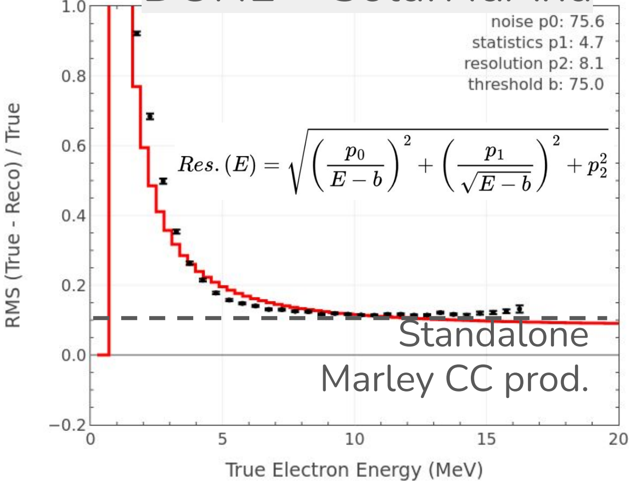


MicroBooNE Ambient Radon

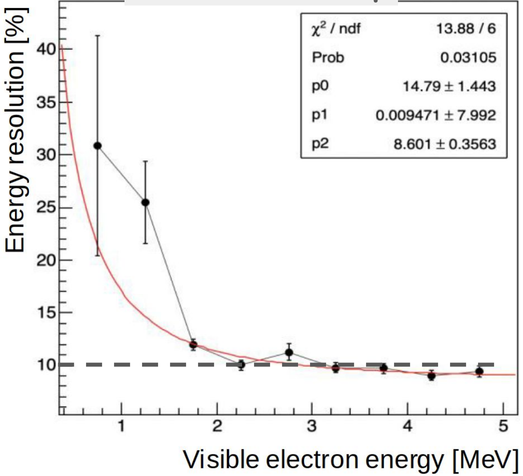
- Blip: **MicrobooNE low energy reconstruction ported to DUNE**.
- MicrobooNE simulation delivers better efficiency.

Energy Resolution: MicrobooNE Comparison

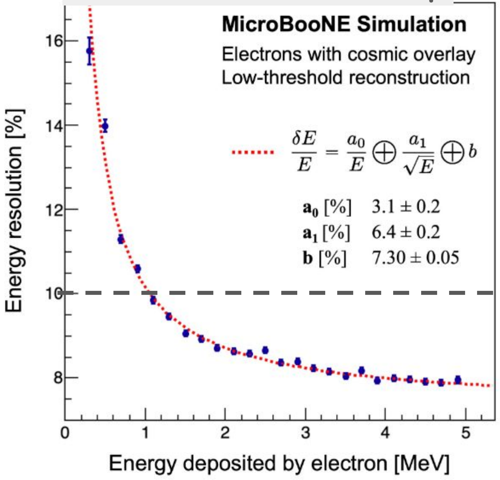
DUNE + SolarNuAna



DUNE + Blip



Microboone + Blip



MicroBooNE Ambient Radon

- MicrobooNE implemented lowe changes in wirecell allowing better energy resolution and threshold.