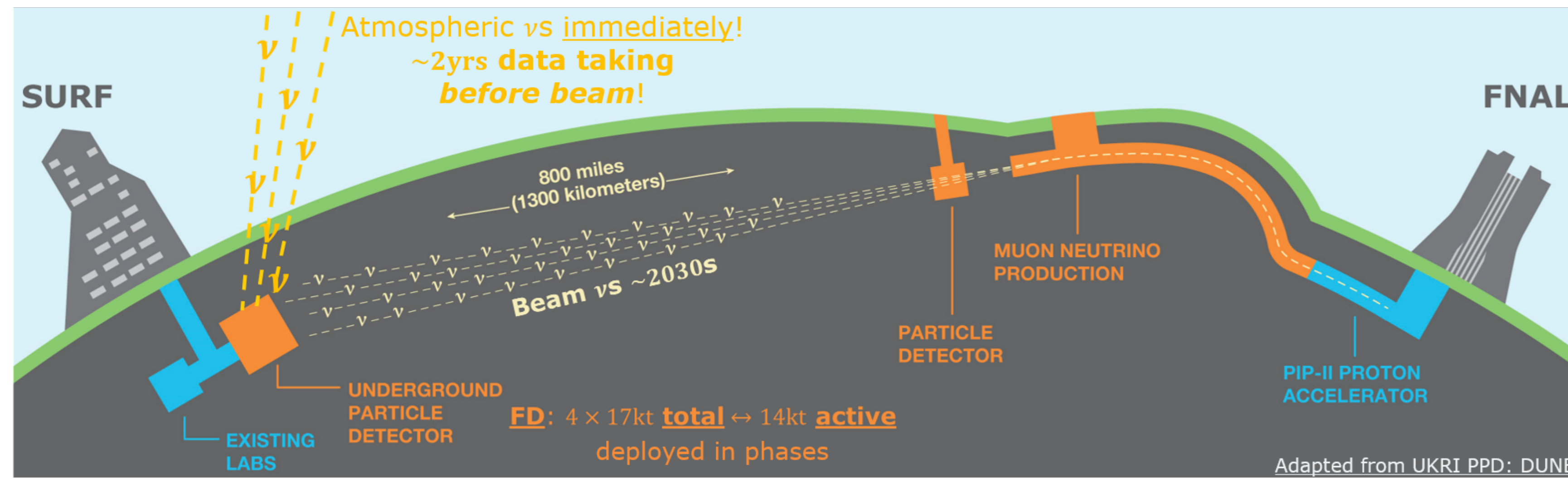


Detector Related Systematic Uncertainties for DUNE Oscillation Analysis with Atmospheric Neutrinos

The Deep Underground Neutrino Experiment



DUNE will study neutrino oscillations with atmospheric neutrinos before the Fermilab beam is ON. Will get first sensitivity to Mass Ordering with the atmospheric analysis.

Typical source of uncertainty in LArTPC:
Electron attenuation (attachement to impurities) during drift.

Charge collected after attenuation, Q_{att} :

$$Q_{att} = Q_0 \cdot e^{-t_{drift}/\tau}$$
 with Q_0 the initial charge, t_{drift} the drift time,
 τ the electron lifetime.

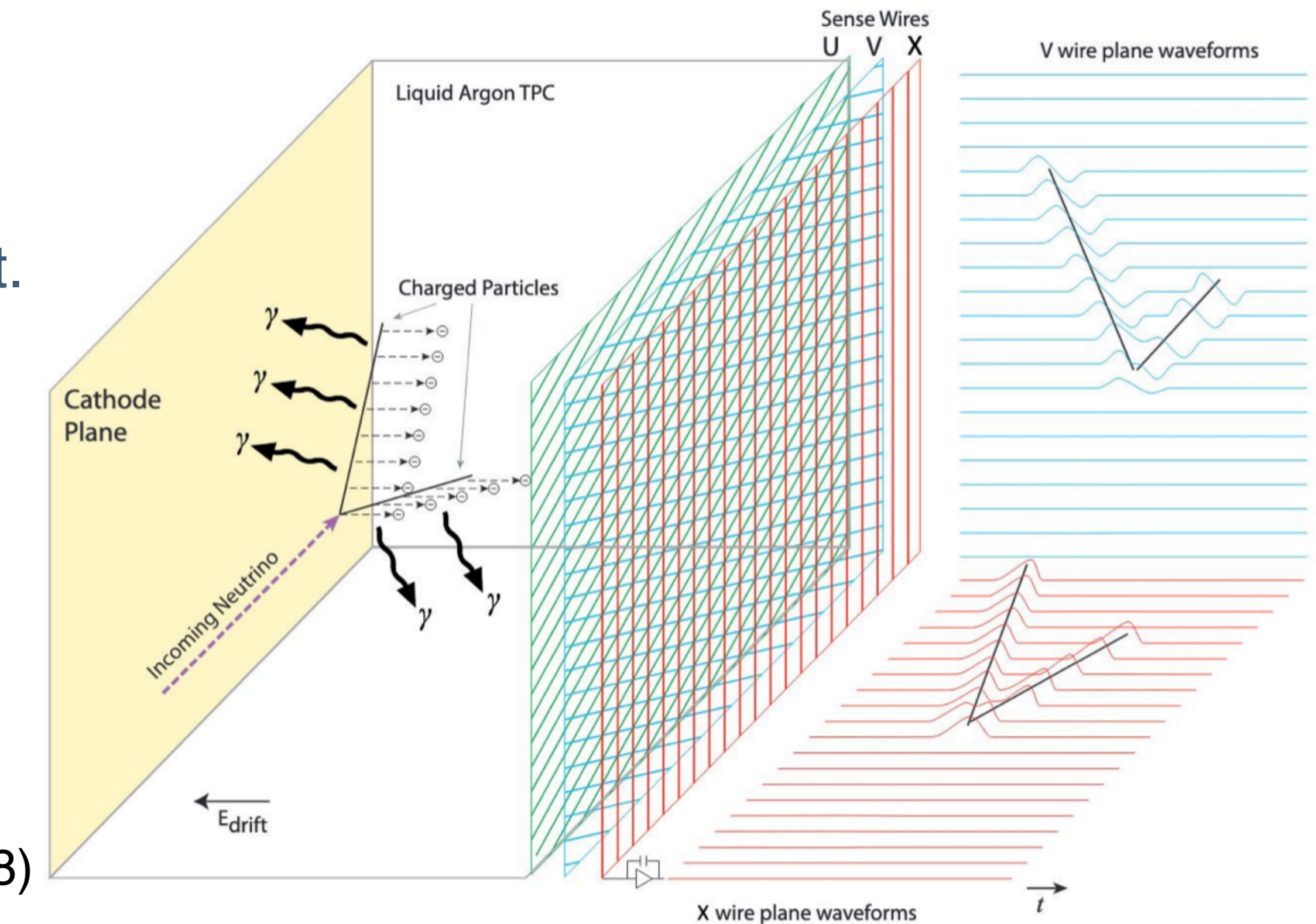


Figure 1: Schematic representation of one DUNE Far Detector: the Horizontal Drift LArTPC (JINST 15 T08008)

Detector Related Systematic Uncertainties Estimation

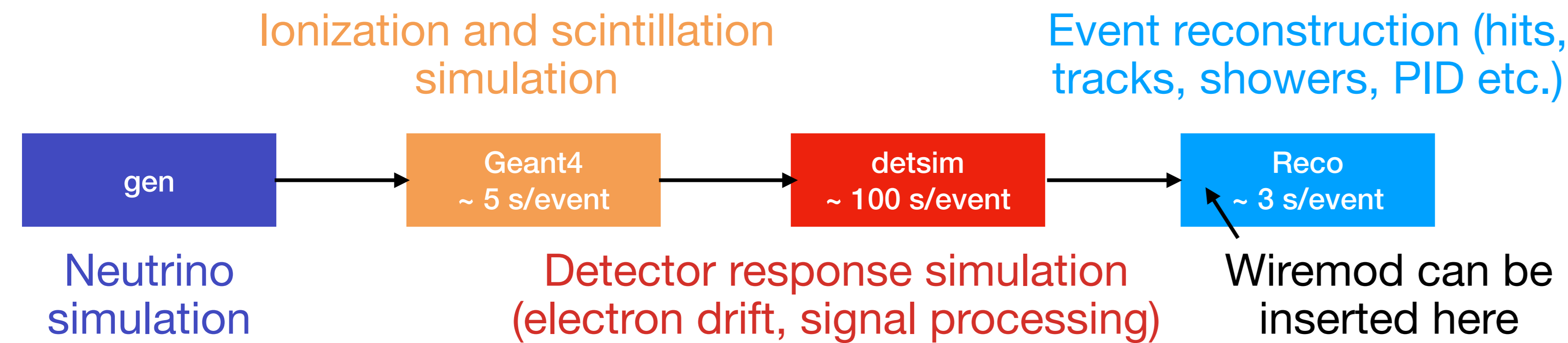


Figure 2: Neutrino event simulation and reconstruction chain in DUNE

Methods for estimating detector systematic uncertainties

- **Detector variation:** re-run simulation from detsim with varied value of parameter
- **Wiremod*** (< 1 s/event): rescale the waveform at reco stage to mimic the variation

$$c^{ij} = \frac{1}{N_{samples}} \sum_{s \in samples} (N_s^i - N_{nom}^i) \times (N_s^j - N_{nom}^j)$$

* Eur. Phys. J. C 82, 454 (2022)

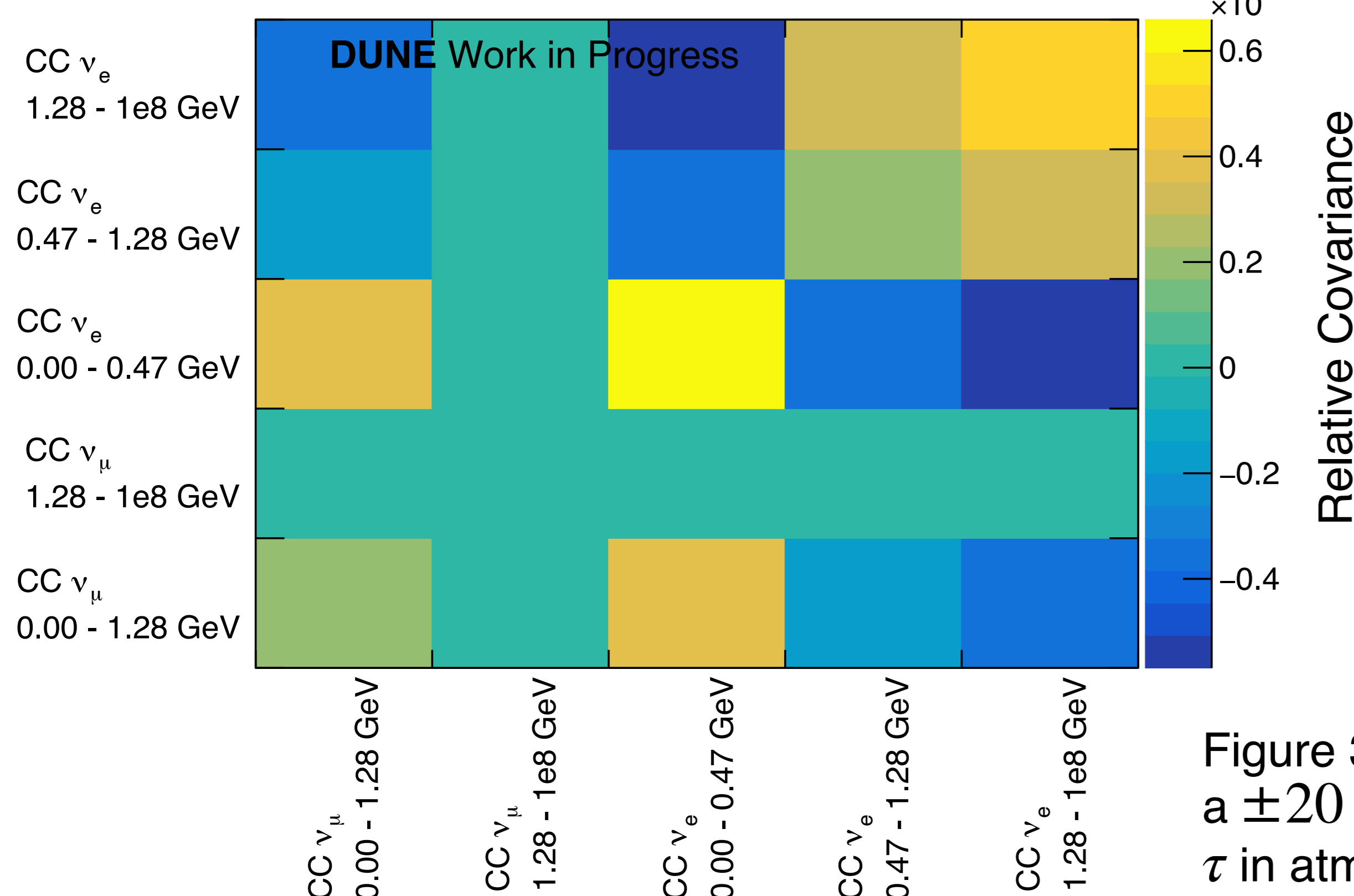


Figure 3: Covariance matrix obtained for a $\pm 20\%$ variation of the electron lifetime τ in atmospheric neutrinos simulation

- $N_{samples}$ 1σ variation samples
- i, j : bin indices
- N_s^i : number of events
- nom : nominal sample

Wiremod Performance

Wiremod takes as input the simulated waveforms from detsim:

- Estimation of true property of waveform from simulated energy deposits (e.g., true drift distance)
- Analytical rescaling of waveform based on true properties

Wiremod 13 times faster on average!

Very encouraging first results!

Investigating little discrepancies wrt detector variation

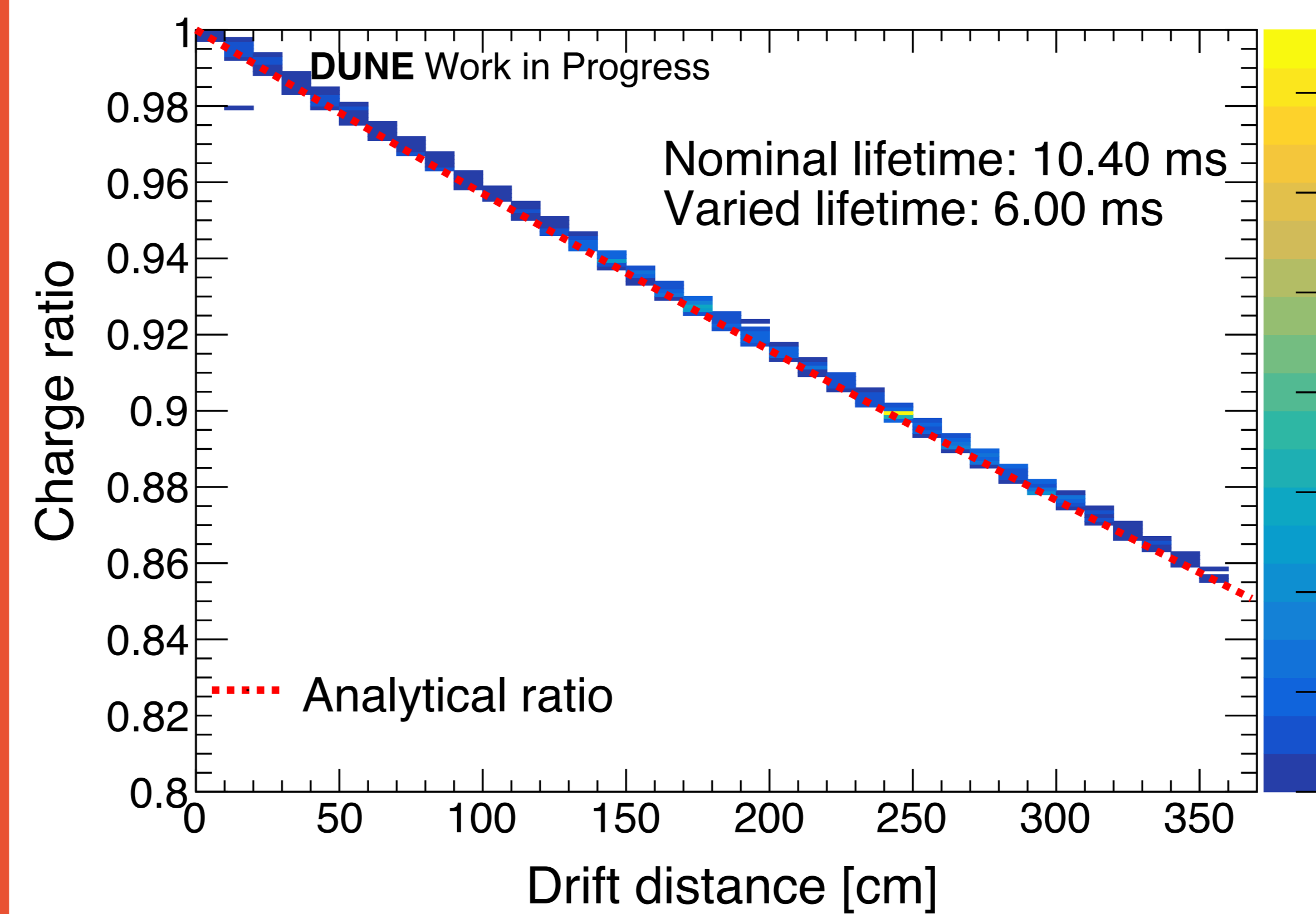


Figure 4: Ratio of waveform charge after divided by before the rescaling with wiremod compared to analytical expectation.

DUNE Work In Progress Stage	Detector variation	Wiremod
Detsim	101.4 s	-
Reco1	0.1 s	4.8 s
Reco2	3.0 s	3.2 s
Sum	104.5 s	8.0 s

Figure 5: Average CPU-Time per event of each stage

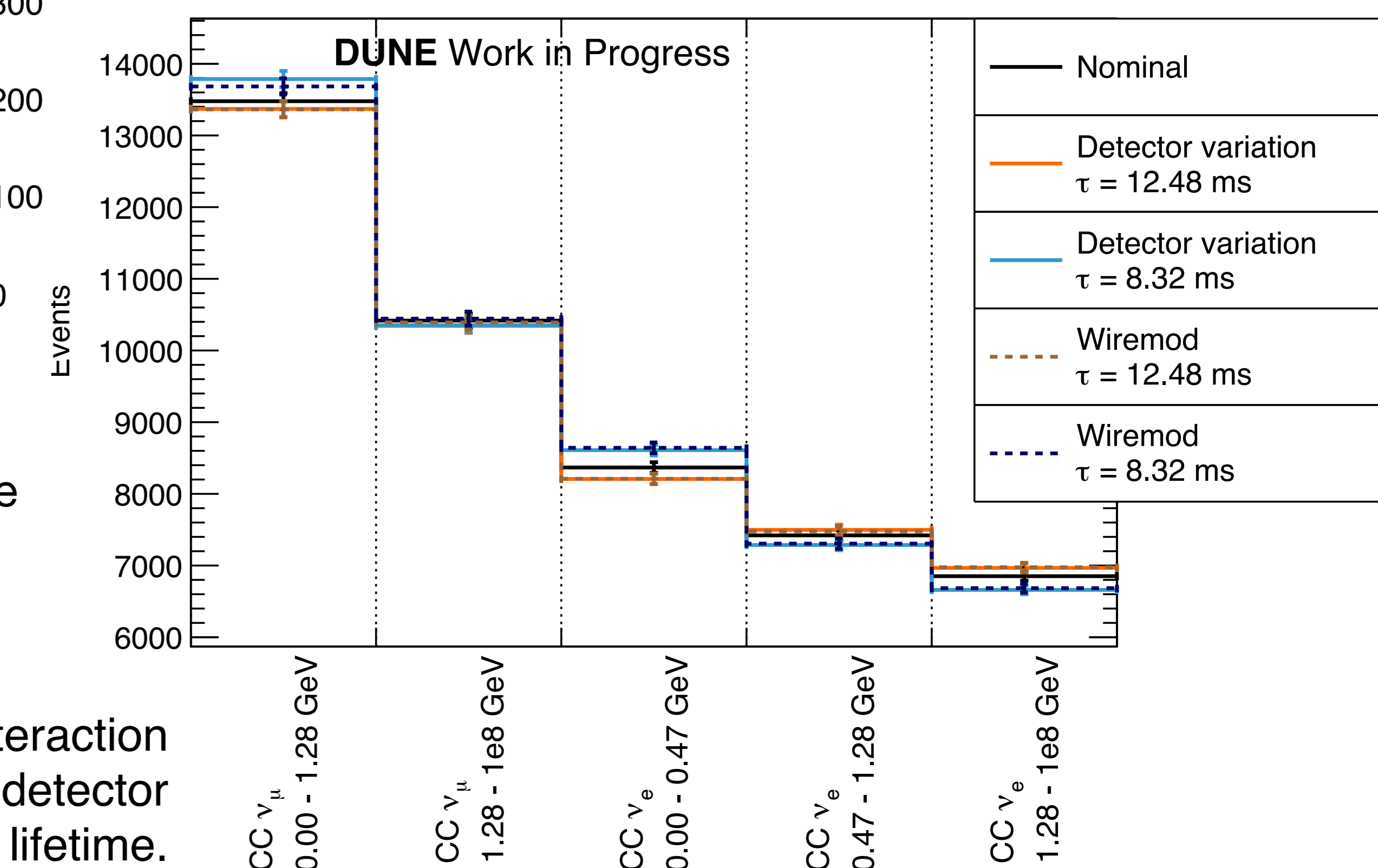


Figure 6: Comparison of the number of events per tagged interaction type and reconstructed neutrino energy bin obtained for a detector variation or a wiremod variation of $\pm 20\%$ of electron lifetime.