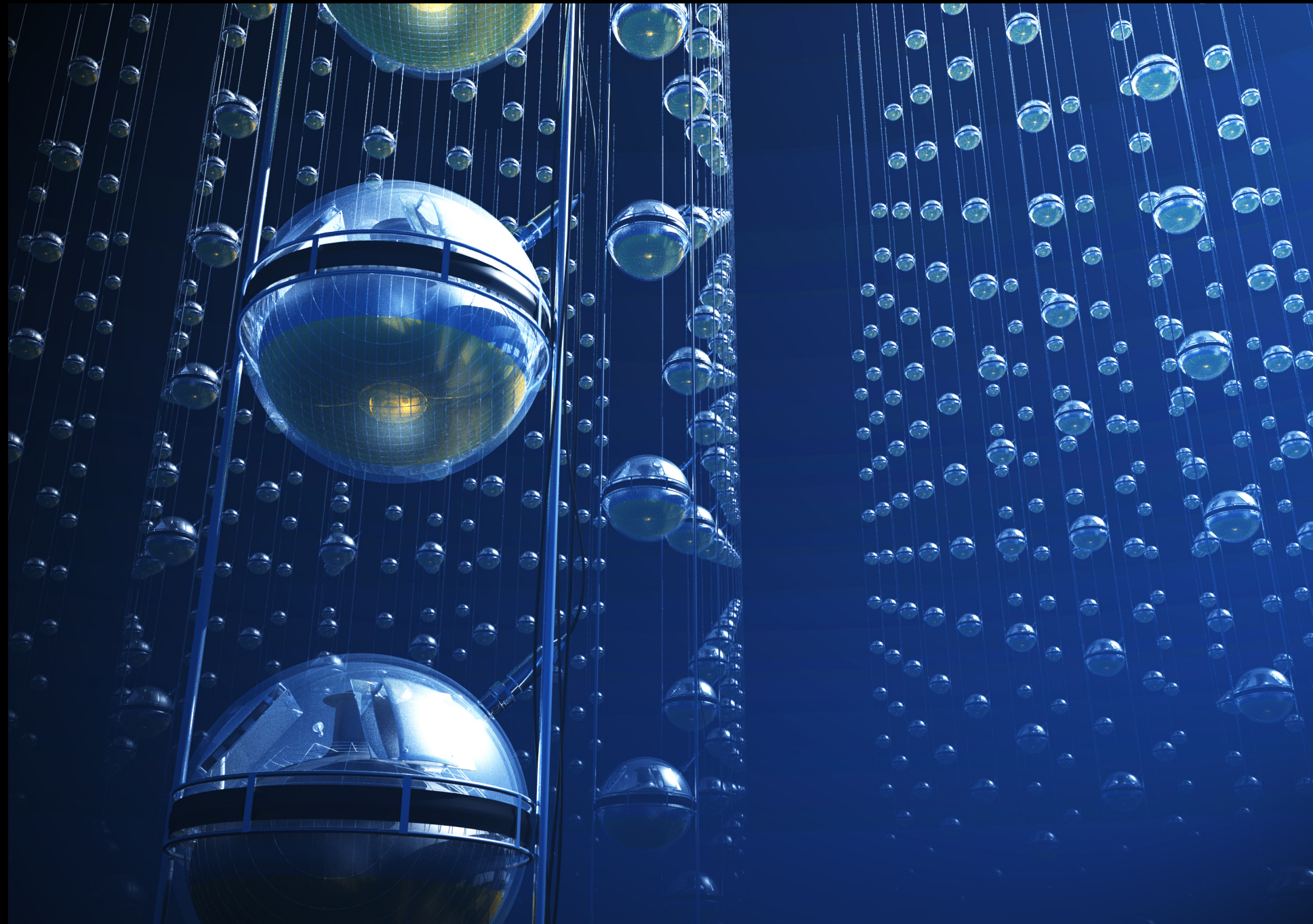


Machine Learning for HUNT

Simulation & Reconstruction

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1. **AI Fast Simulation:**

- End-to-end generation of PMT responses
- Fast simulation for large-scale event samples

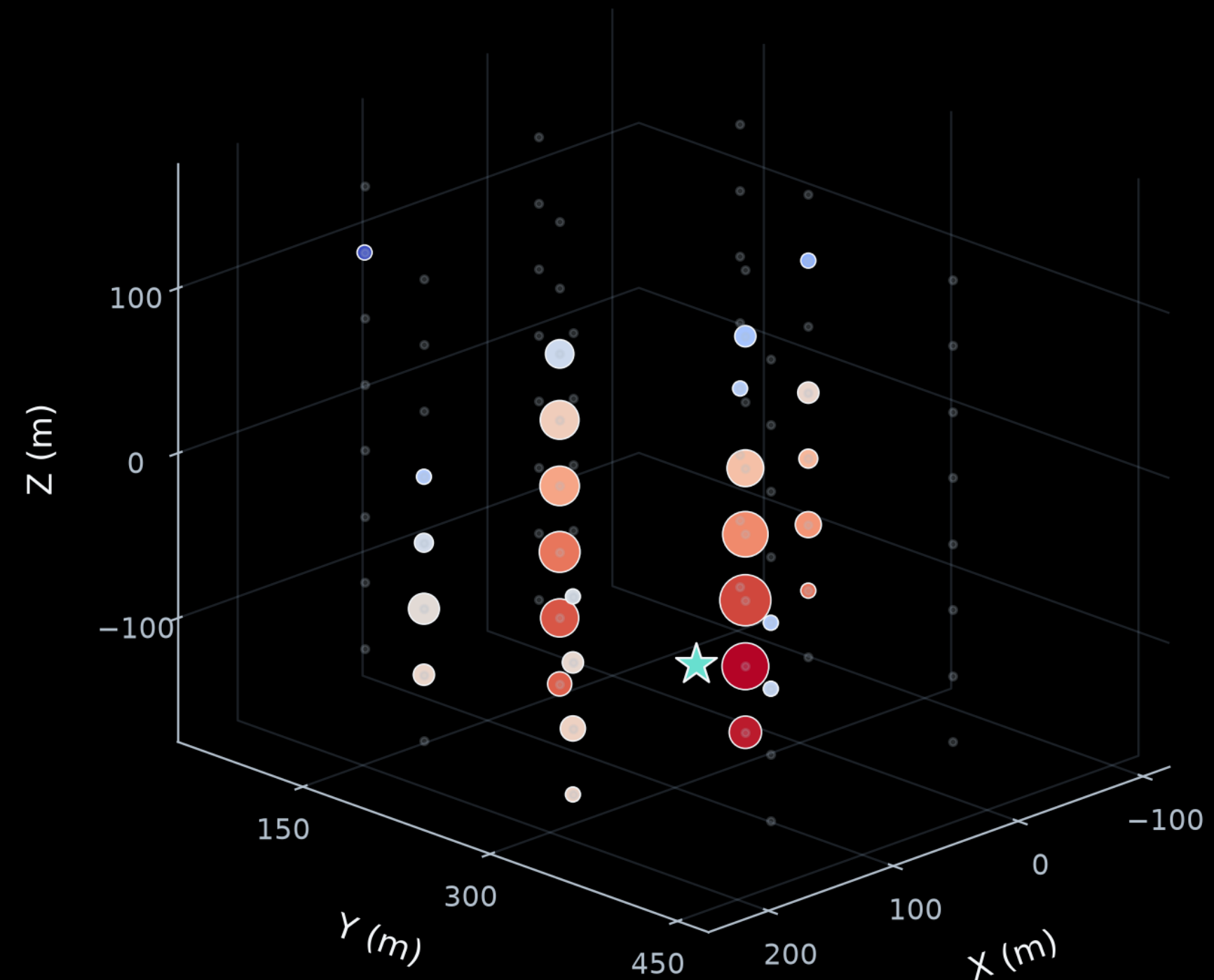
2. **Denoising & Reconstruction:**

- Machine-learning-based signal–noise separation
- Event direction and energy reconstruction

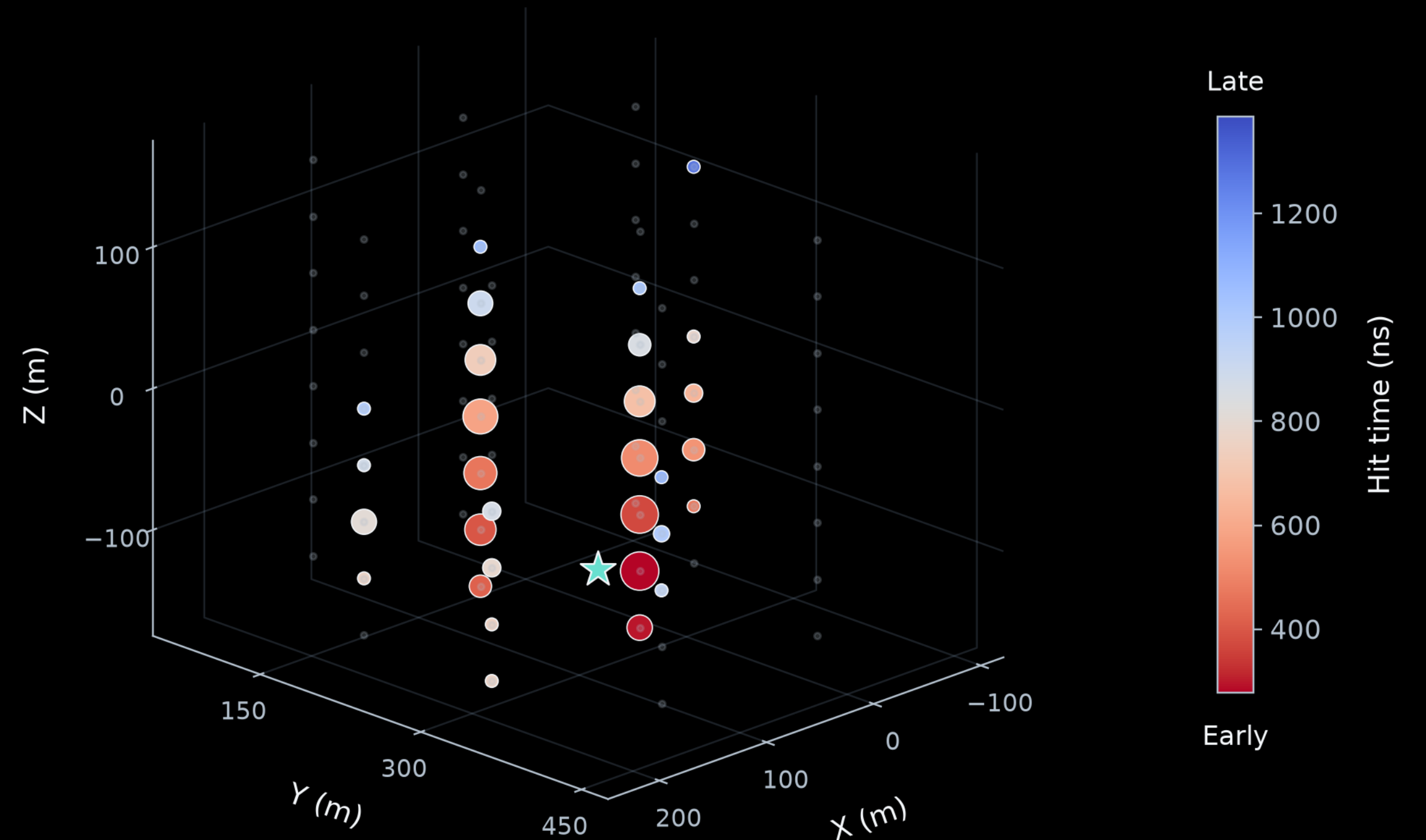
Fast Simulation: From Event Conditions to PMT Responses

Cascade | $E = 730.6 \text{ TeV}$ | Same energy, vertex and direction

Reference MC | 29 hit PMTs



HUNT-SIM S8.2 (calibrated) | 30 hit PMTs



★ Interaction vertex • Detector PMT

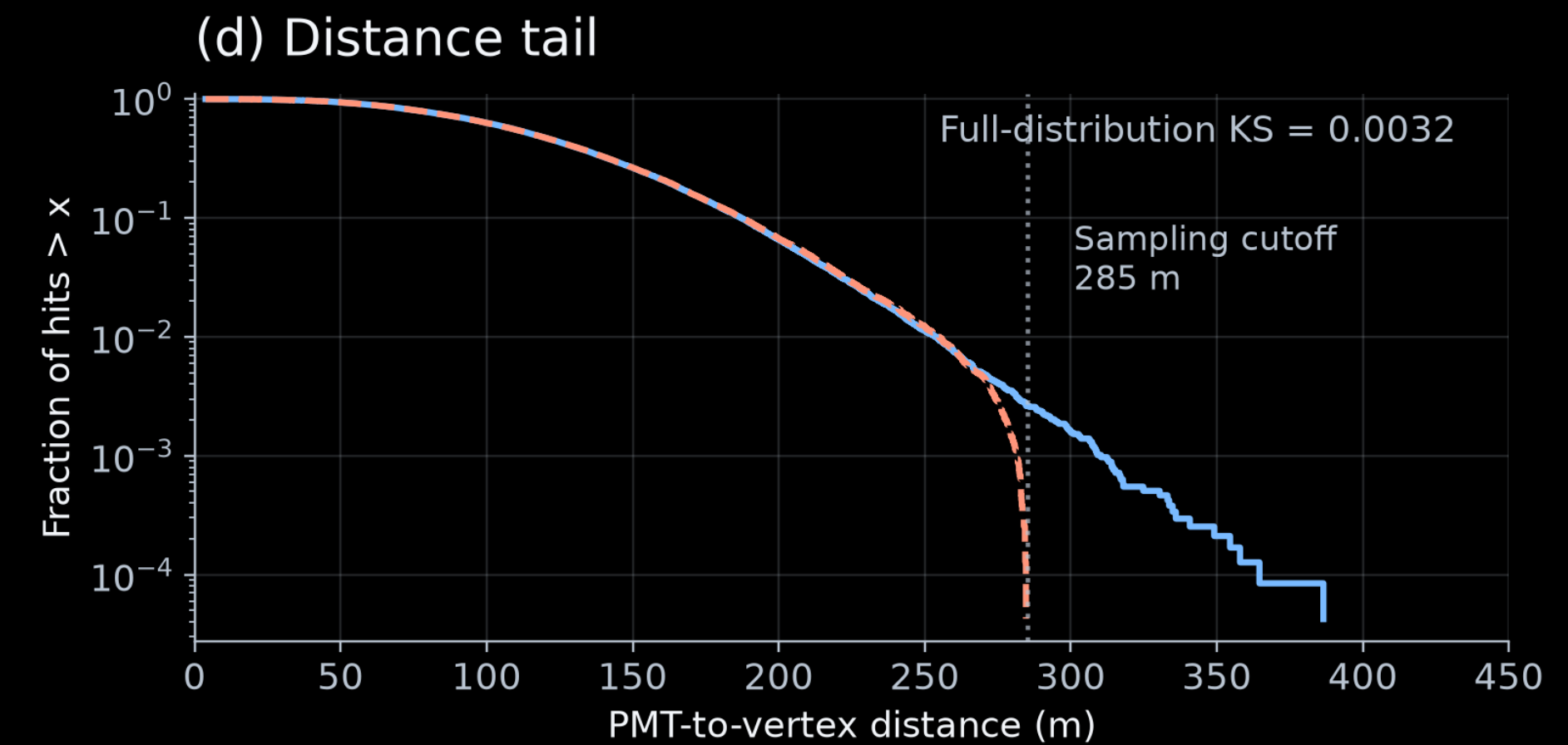
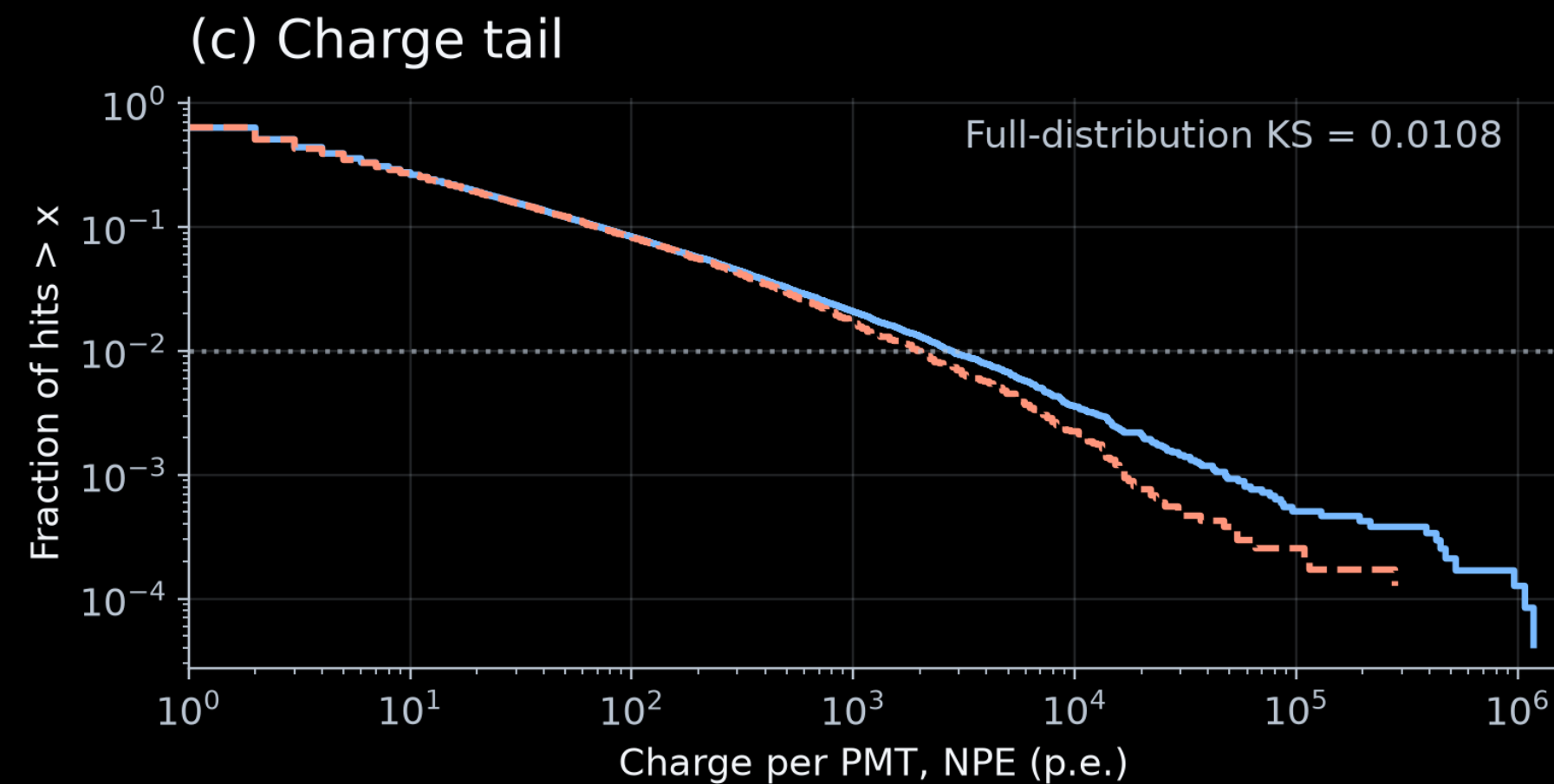
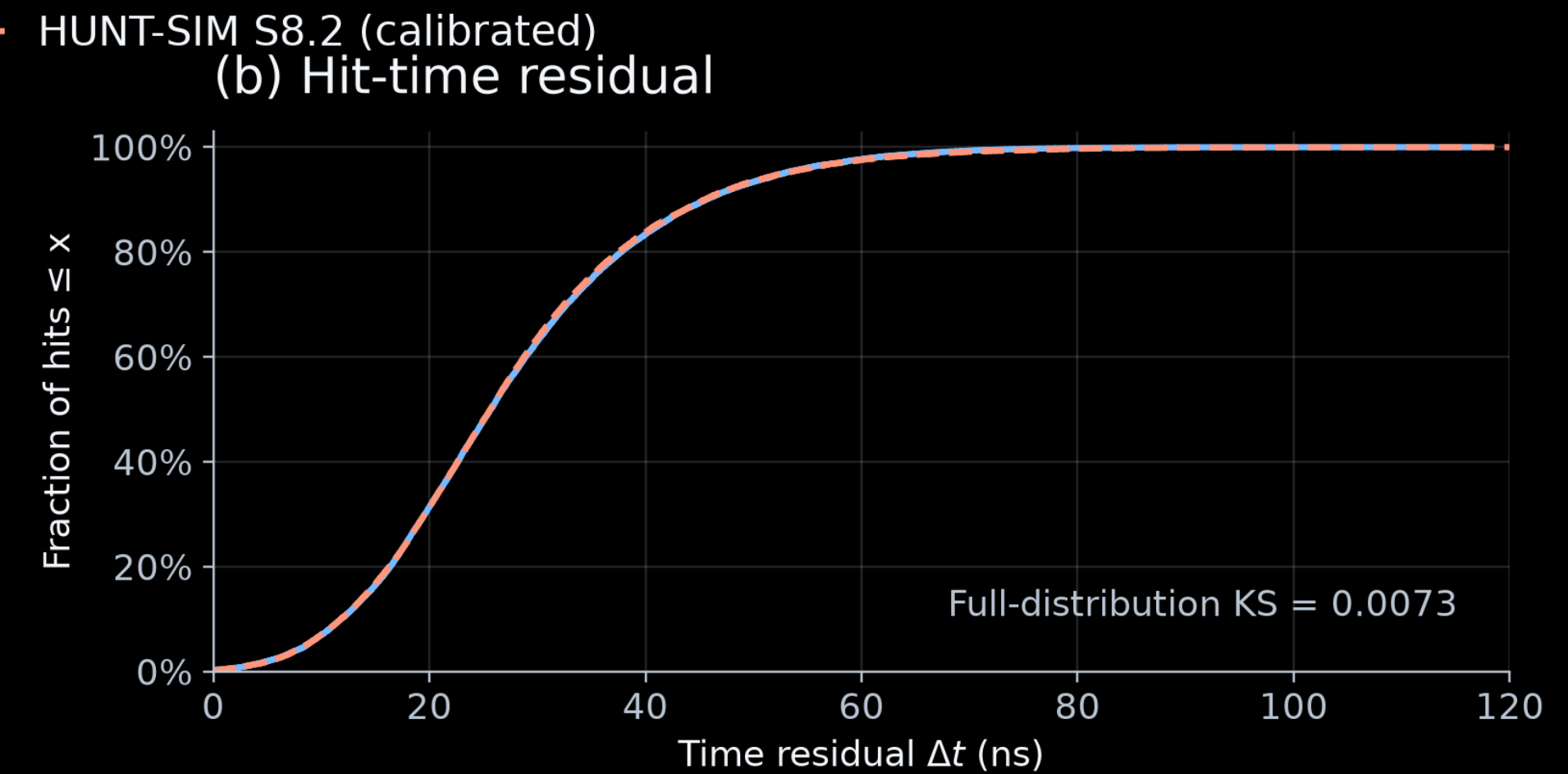
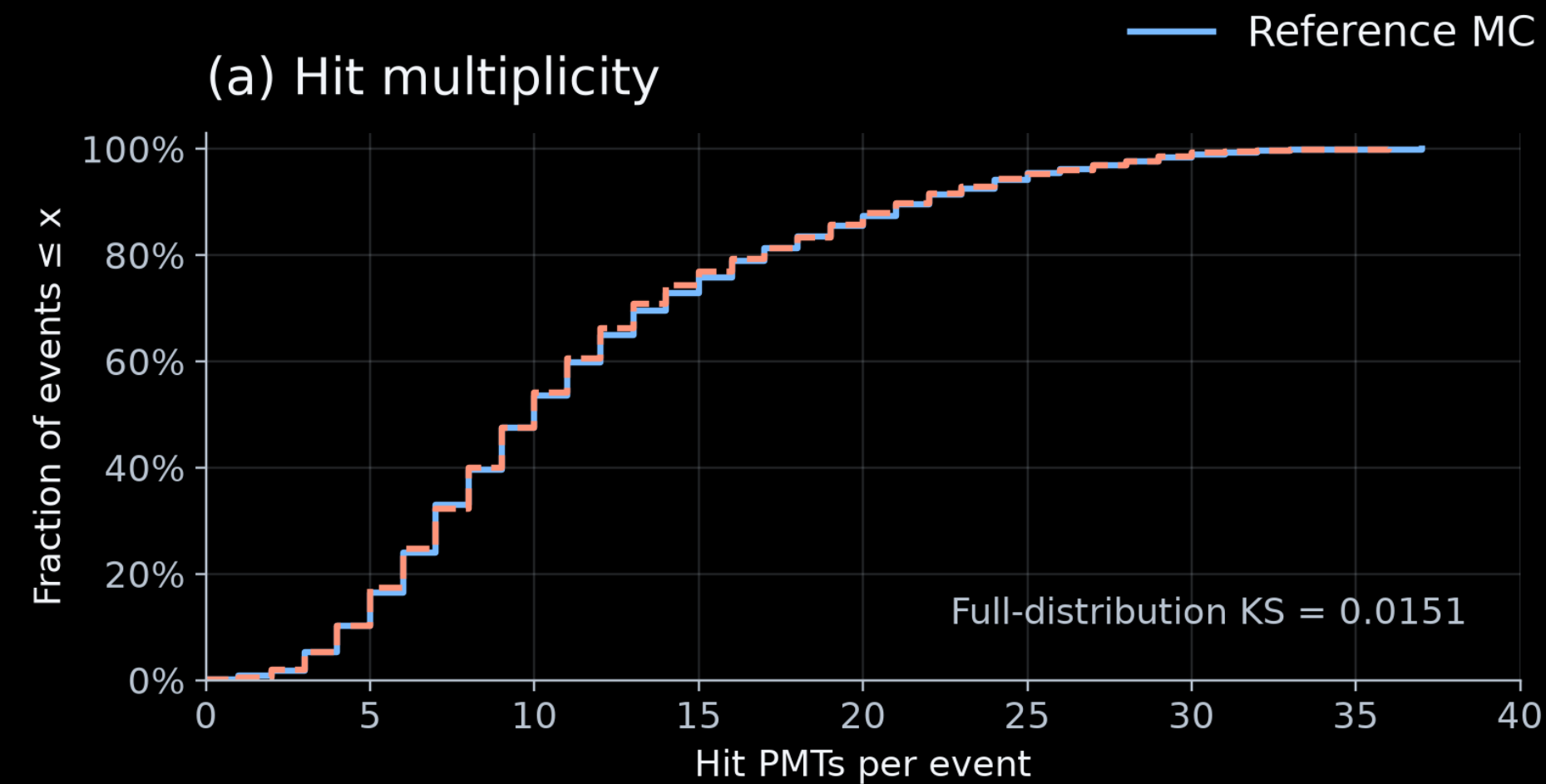
Marker area $\propto \log(1 + \text{NPE})$ | Red: early; blue: late | Shared axes and scales

One generated response under the same event conditions.

On an RTX 5090, generating one complete event response takes about 2 milliseconds.

Generation Quality: Bulk Distributions and Rare Tails

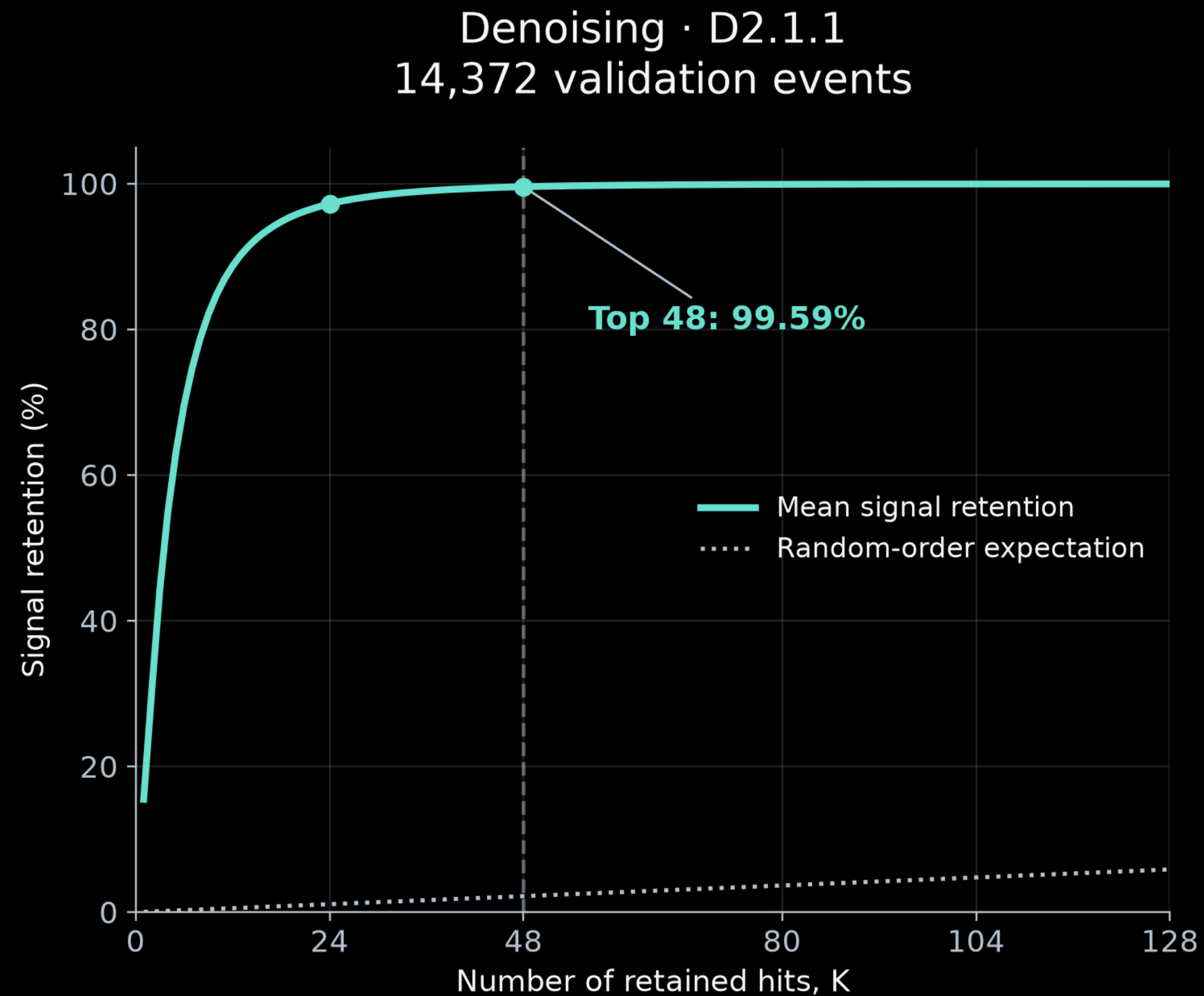
Calibrated model | 2,048 paired development-set conditions | Cascade, 10-1000 TeV



$\Delta t = t_{\text{hit}} - d/v_{\text{water}}$ | Top: cumulative distributions. Bottom: logarithmic tail probabilities.

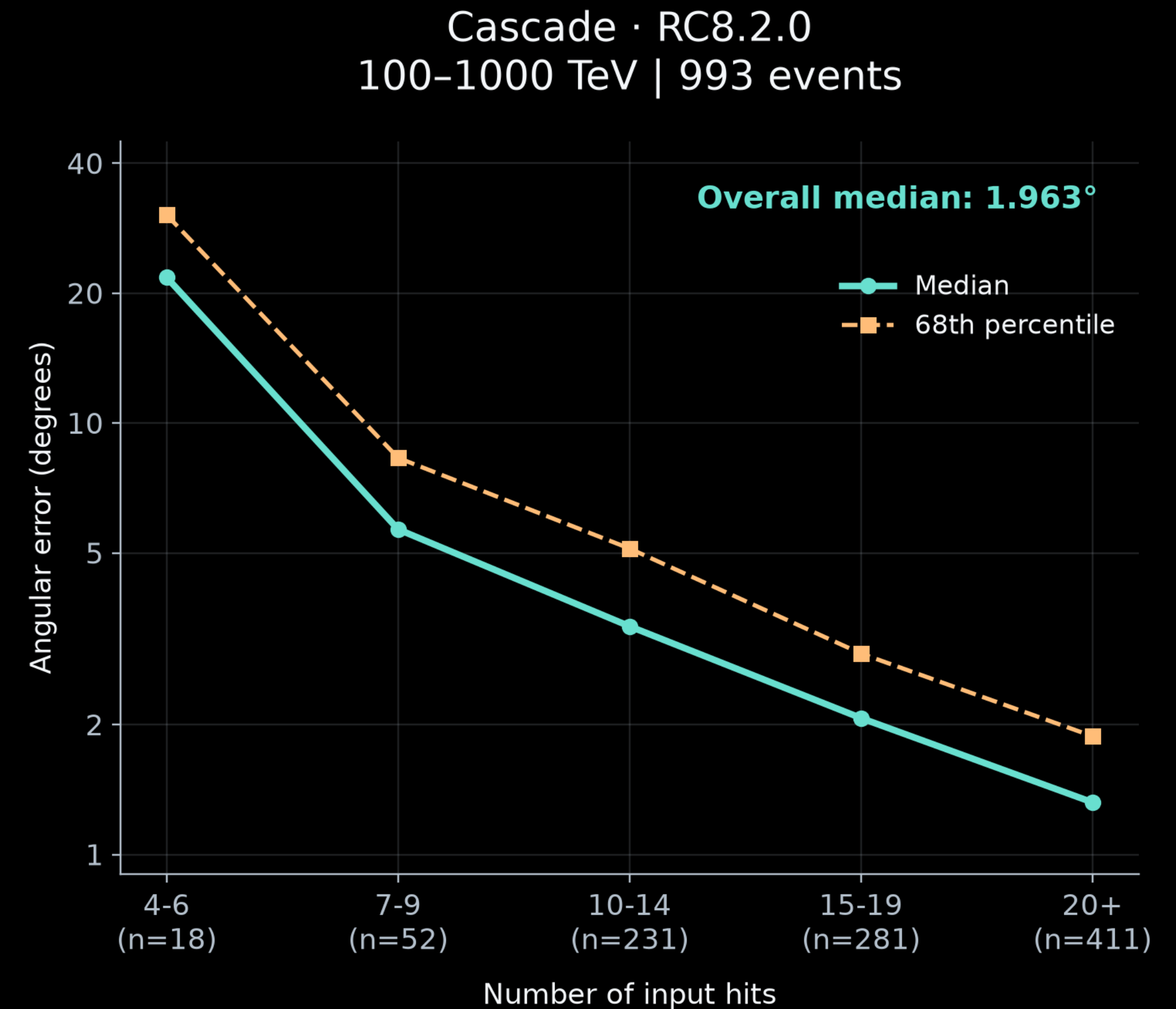
Hit count is event-weighted; other distributions pool all hits. Panel (b) shows 0-120 ns; KS uses all values.

Denoising & Reconstruction: Signal Retention and Angular Precision



Top 48: 99.59% mean signal retention

Mean signal purity: 20.39%



Median angular error: 1.96°

Dashed curve: 68th-percentile event errors

Separate historical validation results; not a chained DEN→REC benchmark.