



Electronics Saturation Correction

Xiang Li

University of Science and Technology of China

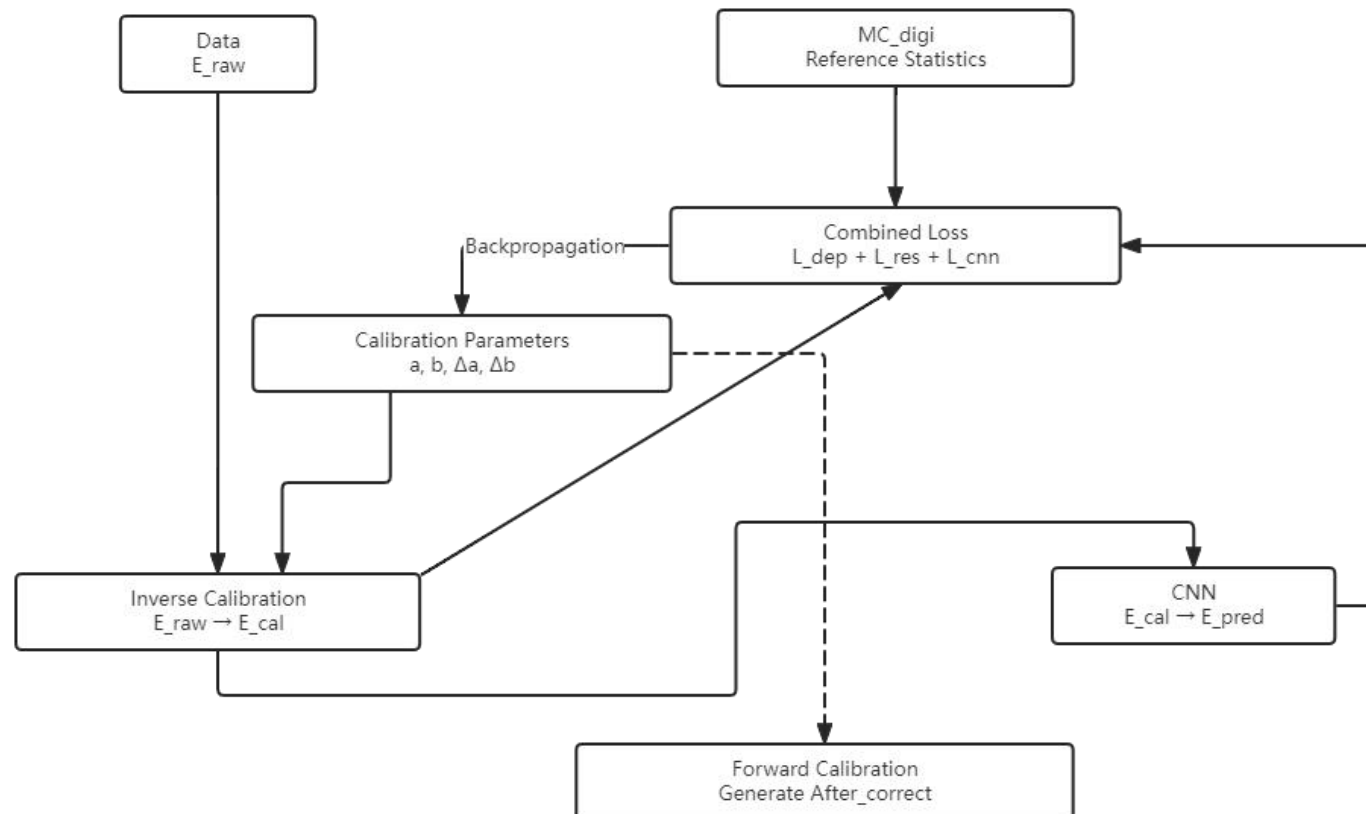
2026.9.18

Calib cell level parameter a,b

Step 2: Using Inverse function to make data approach MC_digi.

$$f^{-1}(x) = \frac{x}{\left[1 - \left(\frac{x}{a}\right)^b\right]^{1/b}}$$

SPS e- data 80,100,120 GeV MC_digi 80,100,120 GeV



Total Loss:

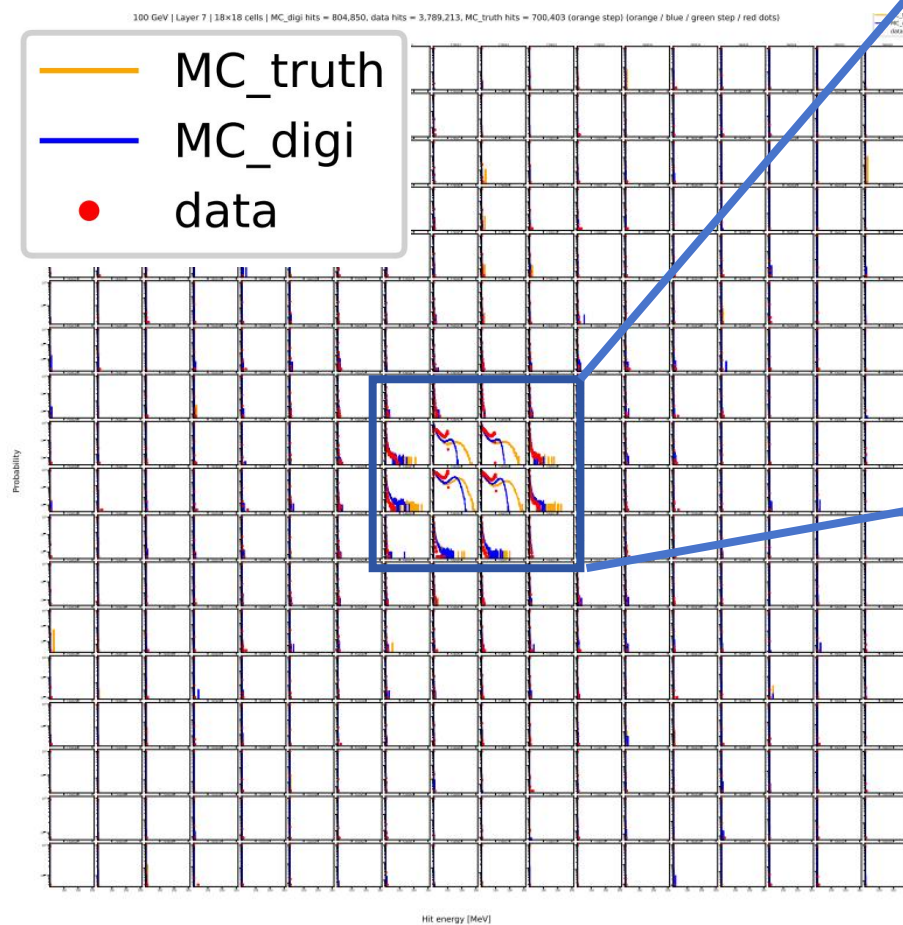
$$L = L_{ref} + \lambda_{cnn} L_{cnn} + \lambda_{dep} L_{dep}$$

- Reference Loss: L_{ref}
- Minimize the discrepancy with the **MC_digi distribution**.
- CNN Energy Prediction Loss L_{cnn}
- Evaluates the accuracy of the **network's macroscopic physical prediction**.
- Cell-level Deposition Loss: L_{dep}
- Constrains the **energy deposition distribution** at the microscopic (per-cell) level.

Cell level difference

➤ Difference of MC_truth MC_digi Data

100 GeV | Layer 7 | 18×18 cells



Electron

➤ MC_truth

- Raw MC simulation

➤ MC_digi

- After SiPM non-linearity

➤ Data

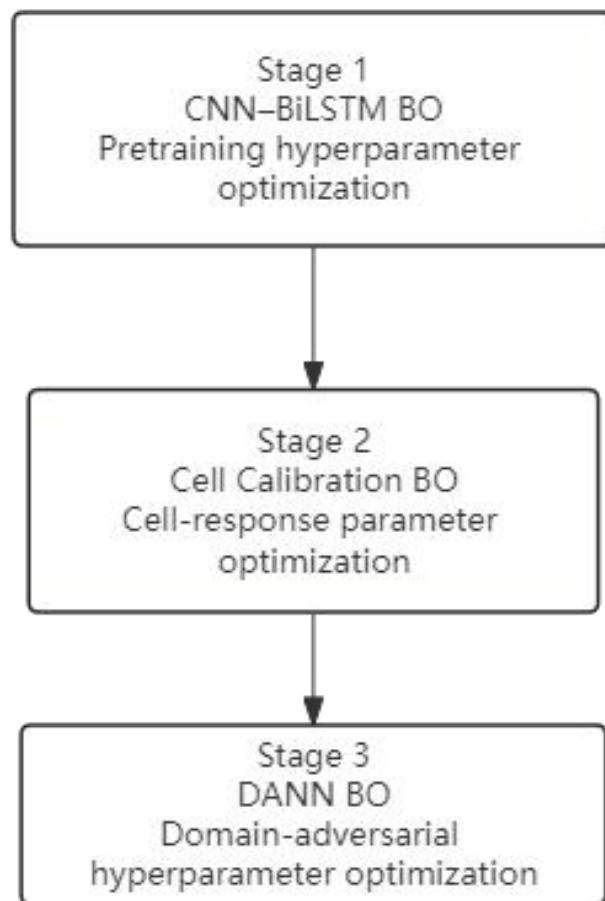
- Beamtest data (SPS)

◆ Possible reason of difference

➤ Saturation effect and Cell nonuniformity

- Electronic Saturation effect

➤ Beam center and Beam size



Stage 1 — CNN-BiLSTM BO

- Goal: optimize the energy-reconstruction backbone
- Objective: $S_{\text{pre}} = \left\langle \frac{|E_{\text{pred}} - E|}{E} \right\rangle_{\text{val}}$
- Key idea: minimize the validation relative energy error

Stage 2 — Cell Calibration BO

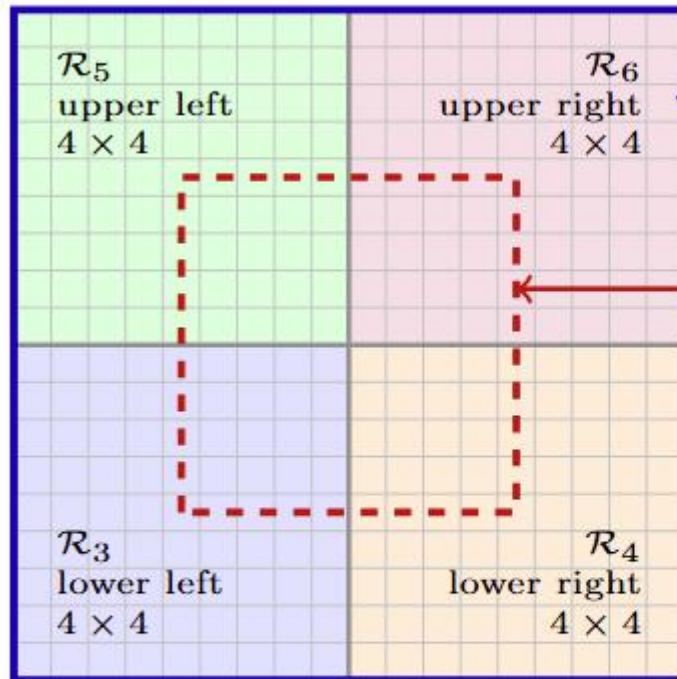
- Goal: optimize hierarchical cell-response parameters a,b
- Objective: $S_{\text{cell}} = 0.4L_{\text{reg}} + 0.3L_{\mu} + 0.3L_{\sigma}$ $L_{\mu} = \frac{|\mu_{\text{data}} - \mu_{\text{MC}}|}{\mu_{\text{MC}}}$, $L_{\sigma} = \frac{|\sigma_{\text{data}} - \sigma_{\text{MC}}|}{\sigma_{\text{MC}}}$
- Key idea: simultaneously preserve energy regression and improve MC-Data response closure

Stage 3 — DANN BO

- Goal: optimize domain-adversarial fine-tuning
- Objective: $S_{\text{DANN}} = 0.2 L_{\text{digi}} - I_{\text{res}}^{\text{data}} + L_{\text{mean}}^{\text{data}}$
- Key idea: improve data resolution while preserving energy scale and MC regression performance

Region-Of-Intere

AHCAL layer: 18×18 cells



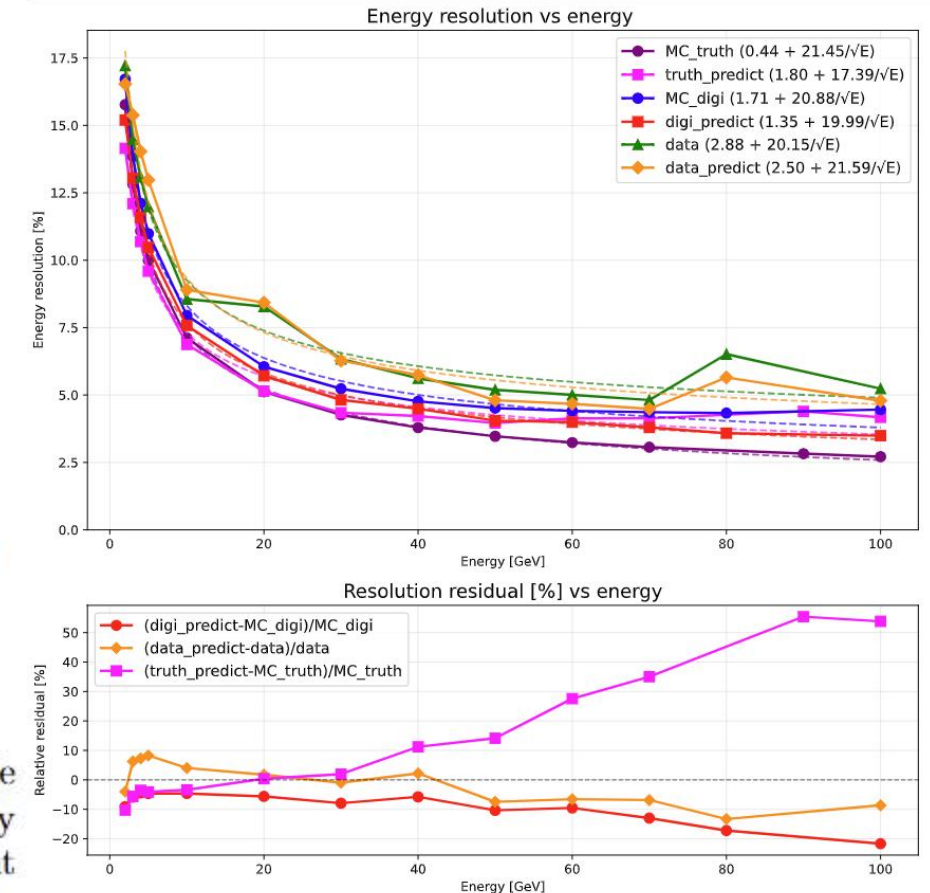
$\mathcal{R}_1$: full layer
pooling output: 1×1

$\mathcal{R}_2$: central 50%
pooling output: 9×9

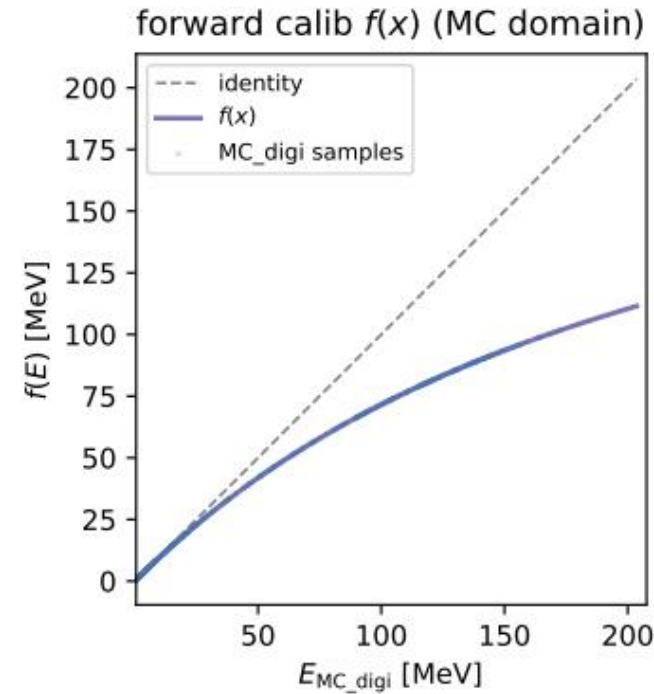
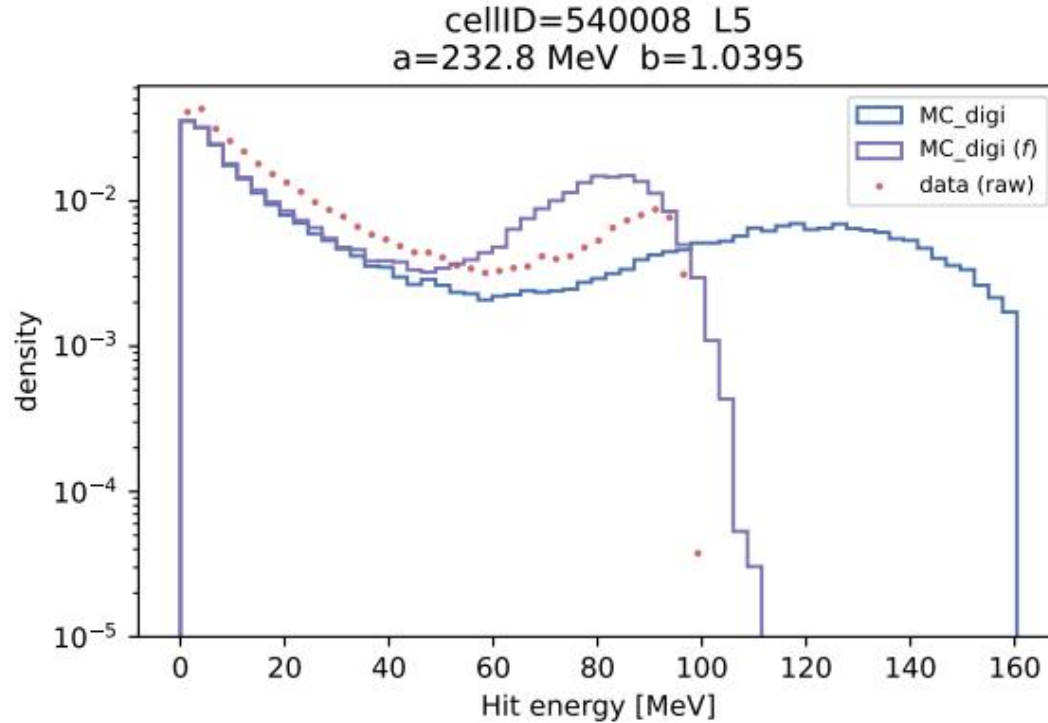
$\mathcal{R}_3$ – $\mathcal{R}_6$: quadrants
pooling output: 4×4 each

Figure 10: Spatial definitions and adaptive-pooling output sizes of the six multi-scale ROIs. The blue outer boundary denotes the full-layer region $\mathcal{R}_1$, the red dashed boundary denotes the central region $\mathcal{R}_2$, and the four lightly shaded areas denote the quadrant regions $\mathcal{R}_3$ – $\mathcal{R}_6$.

Why getting worse?



Singel Cell Performance



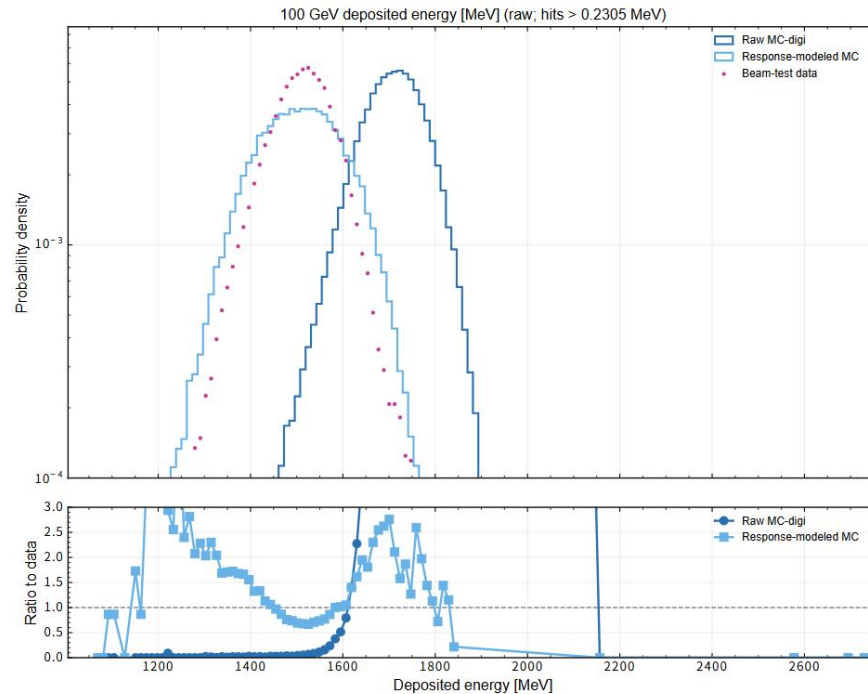
$$y = f(x; a, b) = \frac{x}{\left[1 + (x/a)^b\right]^{1/b}}$$

- Edep<40 MeV: Data >> MC-digi, likely dominated by residual beam-size and beam-center mismatches.
- Edep>40 MeV: Data << MC-digi due to strong saturation-induced response suppression.
- After calibration: The optimization balances these opposite effects to match the overall deposited-energy response, so a residual MC–Data discrepancy can remain in the saturation-dominated high-energy region.

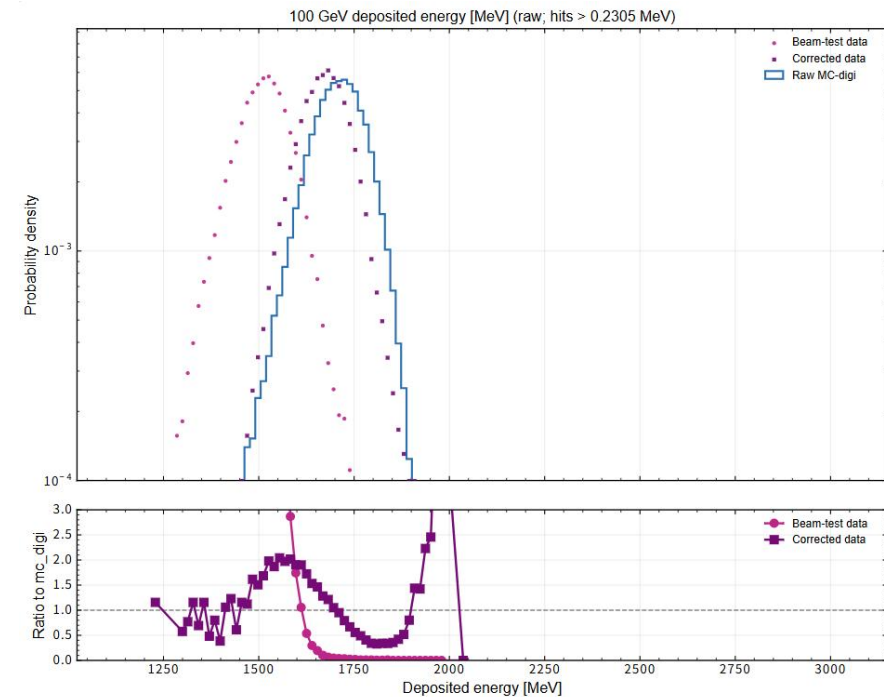
Singel Energy Point Performance



Response-modeled MC_digi



Corrected Data



Mean response: Response-modeled MC-digi agrees well with data.

Distribution width: The modeled MC-digi still shows a larger sigma.

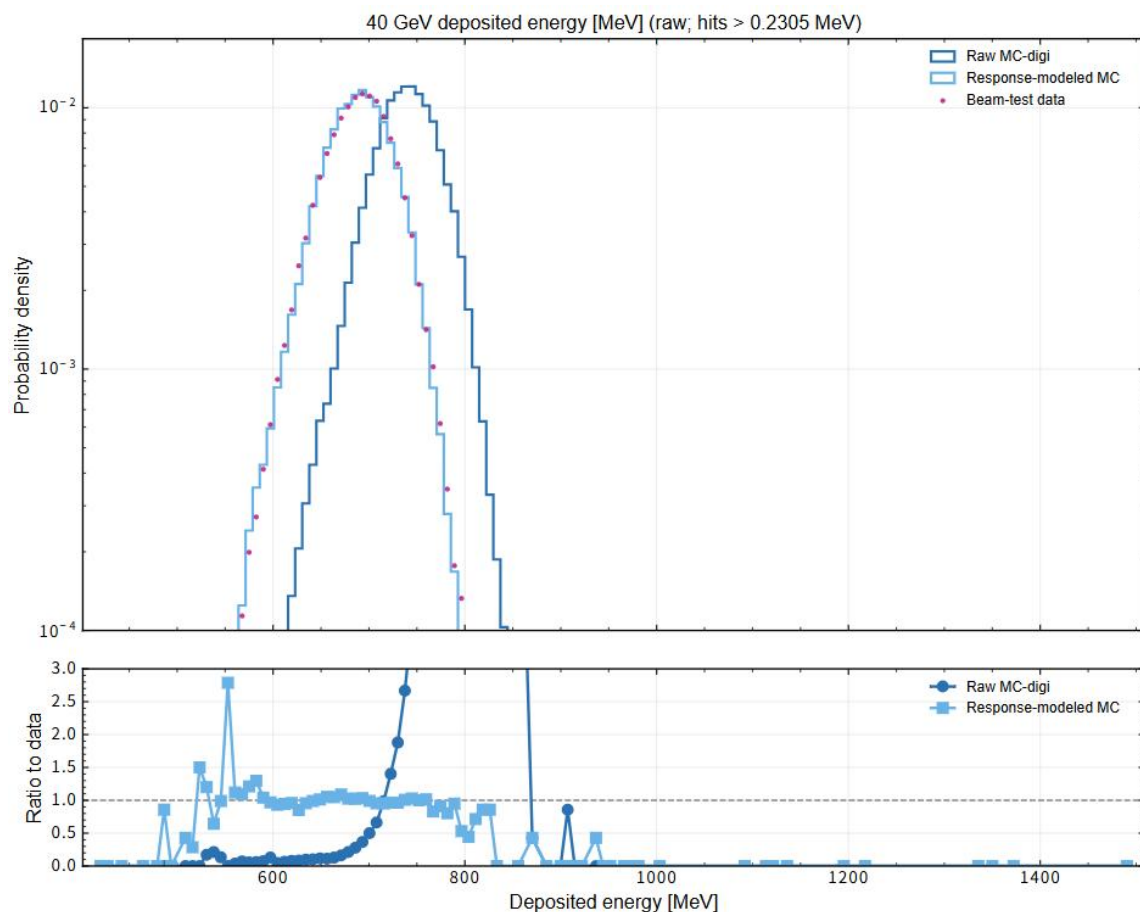
Residual mismatch: Corrected data are not fully aligned with raw MC-digi.

Interpretation: The high-energy saturation loss is partially compensated by the low-energy excess, leading to agreement in the overall response but not in the full distribution shape

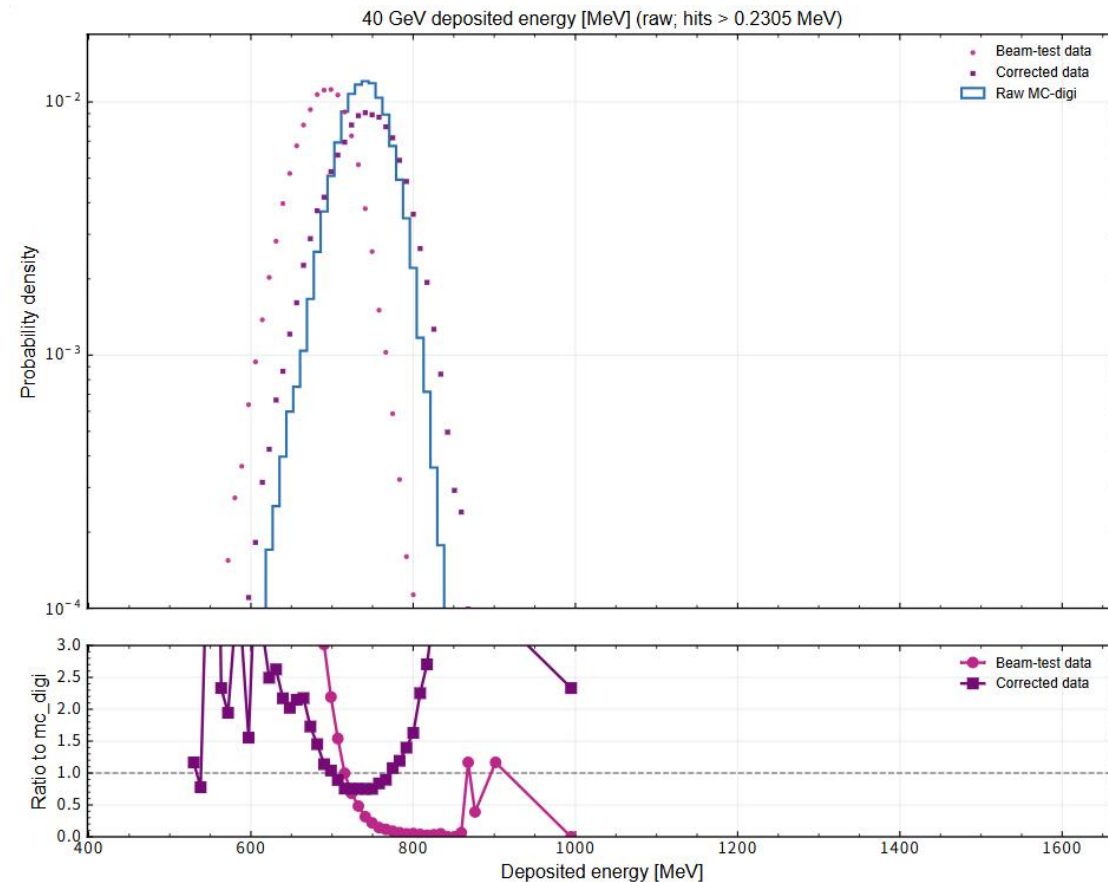
Other Energy point



Response-modeled MC_digi



Corrected Data



The learned response function and its inverse can be directly applied to other beam-energy points.

Remaining Question: Can the cell-response model fully describe the saturation effect when the high-energy

2026-9-20 response loss is partially compensated by the low-energy excess?

ECAL Update



The SiPMs in one ECAL layer have been replaced with a new type. As a first step, we are testing this layer to check for any electronics-related issues introduced by the replacement.

