ePIC Barrel HCAL energy calibration using Machine Learning

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Neutron and Cluster selection

Truth Particle

pdgPar == 2112

1.0 <= ePar < 10.0 GeV

abs(etaPar) < 1.0

BHCal cluster quality

abs(etaBHCalCluster) < 1.0

nClustBHCal >= 1

nHitsBHCalCluster >= 2

eBHCalCone03 >= 0.1 GeV,

eScFiCone03>=0.1 GeV
eImageCone03>=0.1 GeV

Image)Cone03 >= 0.1 GeV

Truth-to-cluster matching:

DeltaR(truth neutron, BHCal cluster) < 0.10

Truth-association purity:

hcalAssocTargetIsLeading == 1
hcalAssocLeadingPDG == 2112
hcalAssocNParticles <= 2

Fixed-energy single neutron evaluation selection

1.0 <= Etrue <= 10.10 GeV

abs(etaTrue) < 1.0

abs(etaBHCalCluster) < 1.0

nClustBHCal >= 1

nHitsBHCalCluster >= 2

eBHCalCone03 >= 0.1 GeV

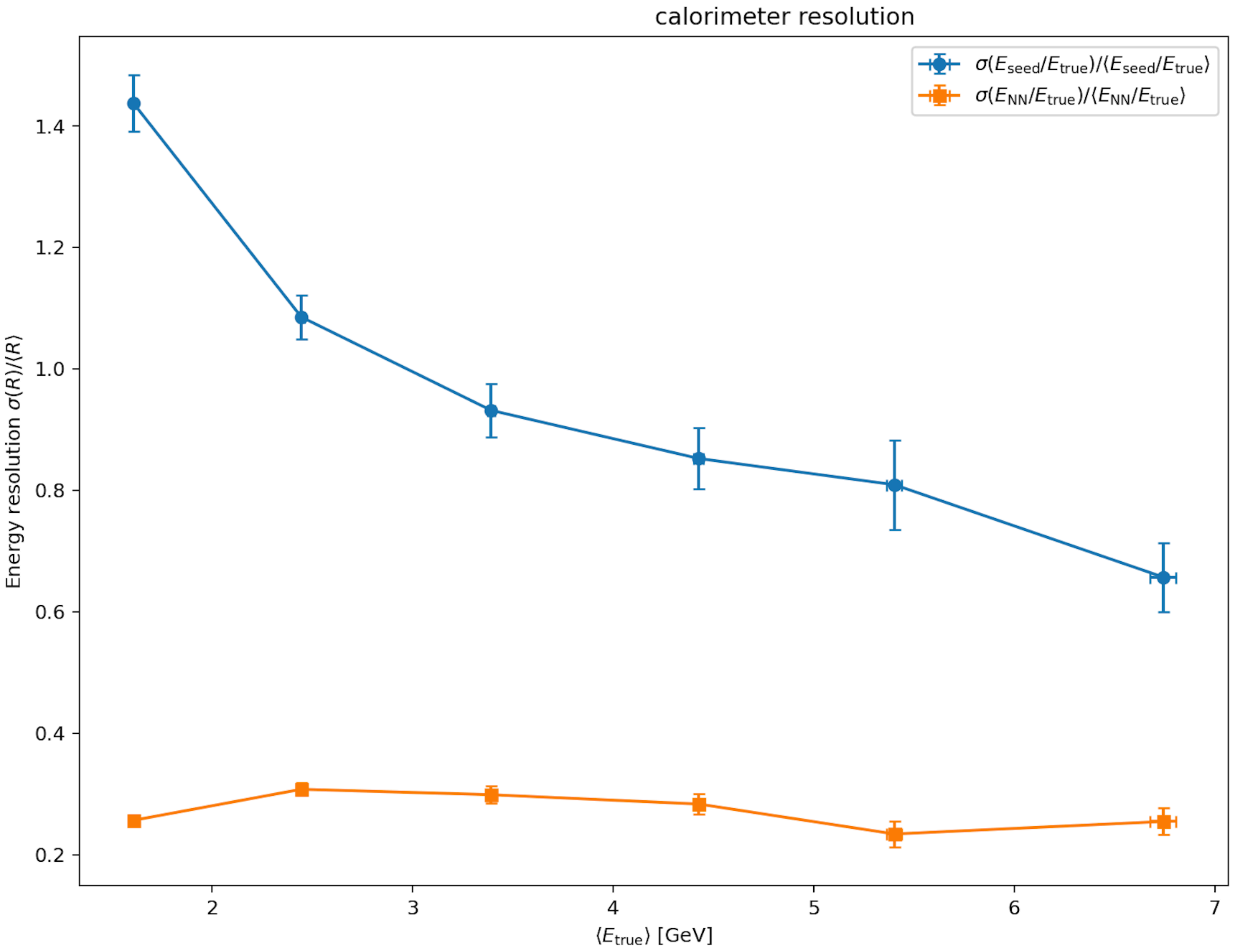
eScFiCone03 >= 0.1 GeV

eImageCone03>=0.1 GeV

DeltaR(truth neutron, BHCal cluster) < 0.10

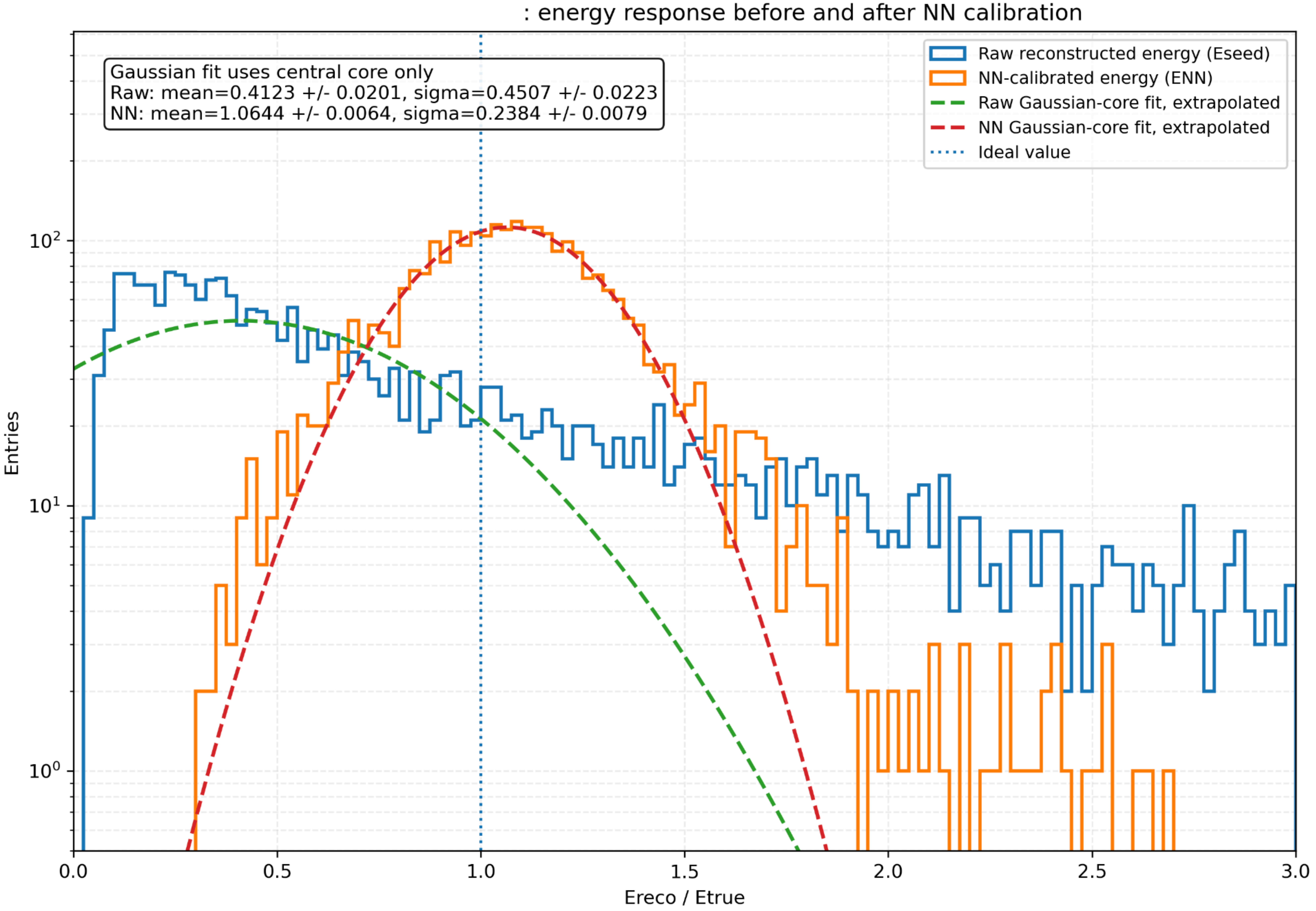
Energy Resolution

- The uncalibrated energy has a broad resolution, especially at low energy, while the MLP-corrected prediction reduces the relative resolution to approximately 25 to 30 percent across the studied energy range. This shows that the network learns an event-by-event missing-energy correction and provides a more stable neutron-energy estimate.



Energy response before and after NN calibration

- Raw calorimeter response is strongly underestimated, with a mean of 0.41 compared with the ideal value of 1.
- After NN calibration, the mean response improves to 1.06, corresponding to about 6% overestimation.
- The core width decreases from 0.45 to 0.24, showing a substantial improvement in energy resolution.
- Non-Gaussian tails remain and require further investigation.

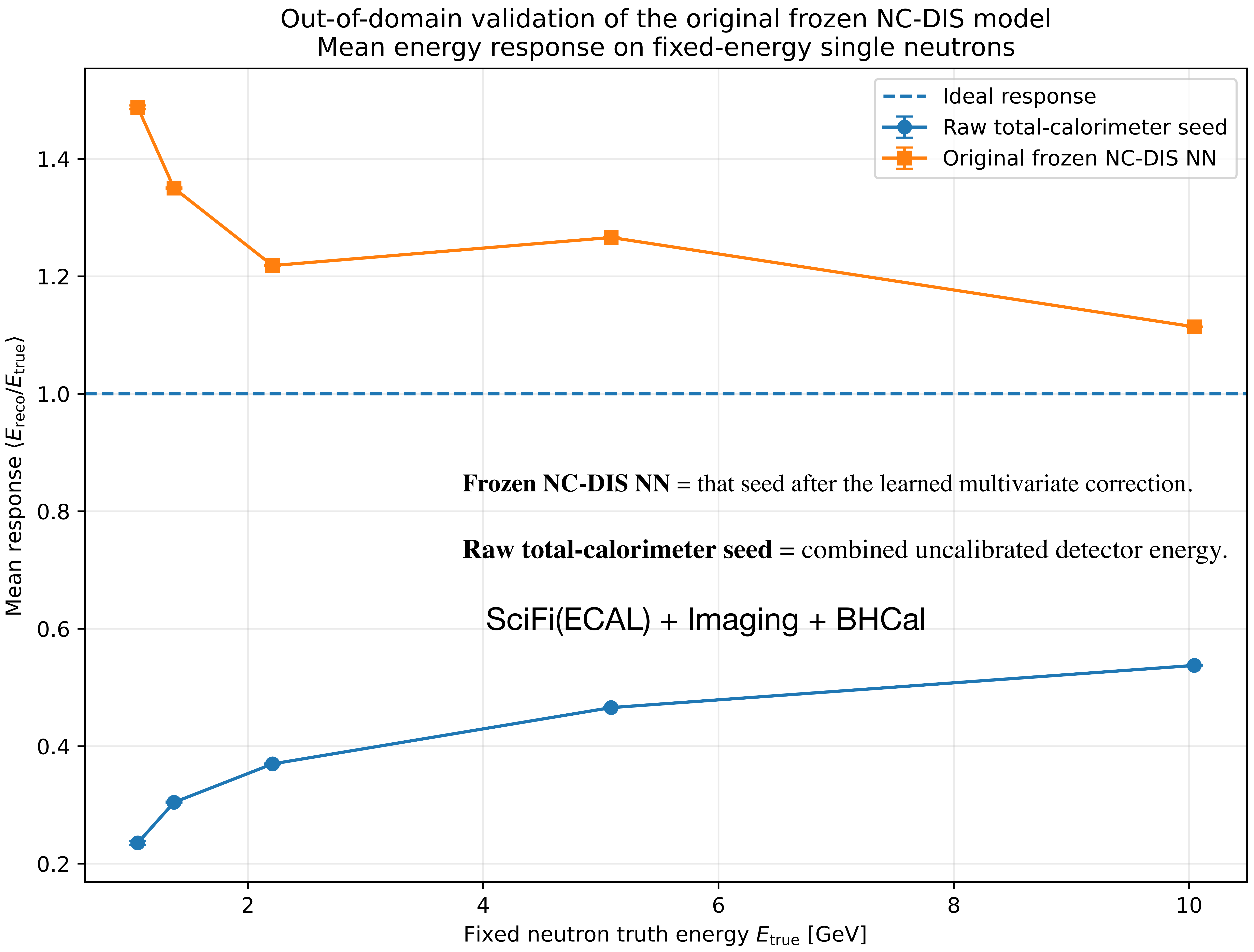


Out of domain test

- An **out-of-domain test** means applying a trained model to data that differ from the type of data used during the training. (In this case, I trained NC-DIS first and applied to single energy neutron data (monoenergetic sample)
- Model was trained first on NC-DIS sample where there could be,
  - Other particles and calorimeter deposits;
  - Overlapping activity and contamination;
  - Event-topology correlations;
- Froze that model and applied it to **isolated fixed-energy single neutrons**. These events use the same detector and the same input variables, but their event environment and energy distribution differ from the NC-DIS training sample to isolated fixed energy.

Frozen NC-DIS model on fixed-energy single neutrons: response linearity

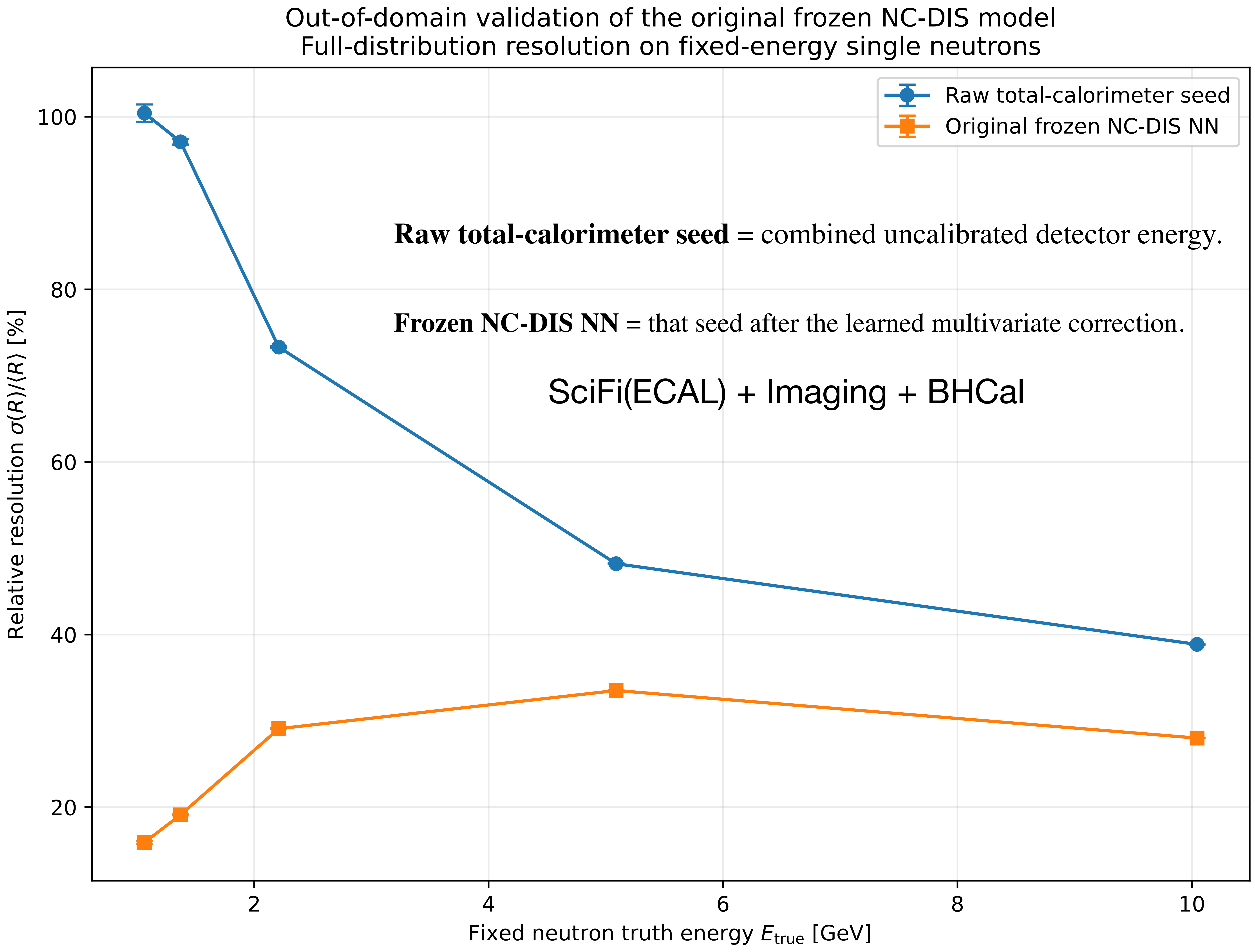
- The original NC-DIS model is applied **without retraining** to five independent fixed-energy single-neutron samples.
- The mean NN response remains above unity and changes from approximately **1.49 at 1.06 GeV to 1.11 at 10 GeV**.
- Therefore, the model does not transfer linearly to isolated single neutrons; this is an **out-of-domain stress test**, not a single-neutron calibration.



Frozen NC-DIS model on fixed-energy single neutrons: energy-dependent resolution

- The NN substantially reduces the width relative to the raw total-calorimeter seed.
- However, the NN resolution remains clearly energy dependent: approximately 16%, 19%, 29%, 34%, 28%

- Therefore, the NN does **not** eliminate the underlying energy-dependent calorimeter fluctuations.



Summary

- NN calibration strongly improves the NC-DIS neutron response.
- The calibrated NC-DIS resolution is approximately 25–30%.
- The NC-DIS model does not transfer directly to isolated single neutrons.
- Next step: train or fine-tune using mixed NC-DIS and single-neutron samples.