Tracking with ML

19th February 2025

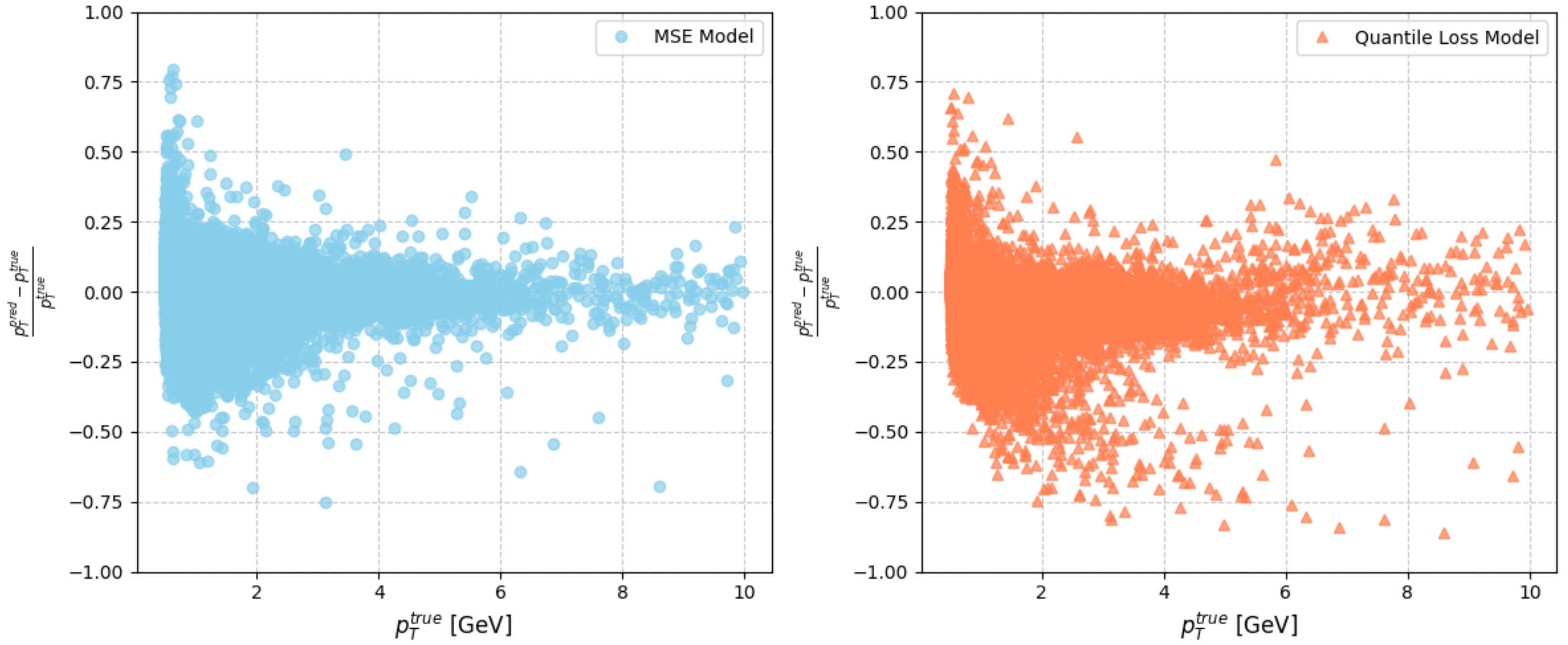
Jeremy Couthures

More results

x y z

TrackML Zenodo

Relative error resolution for p_T ((tx, ty, tz) → (p_T, p_z))



More results

x y z

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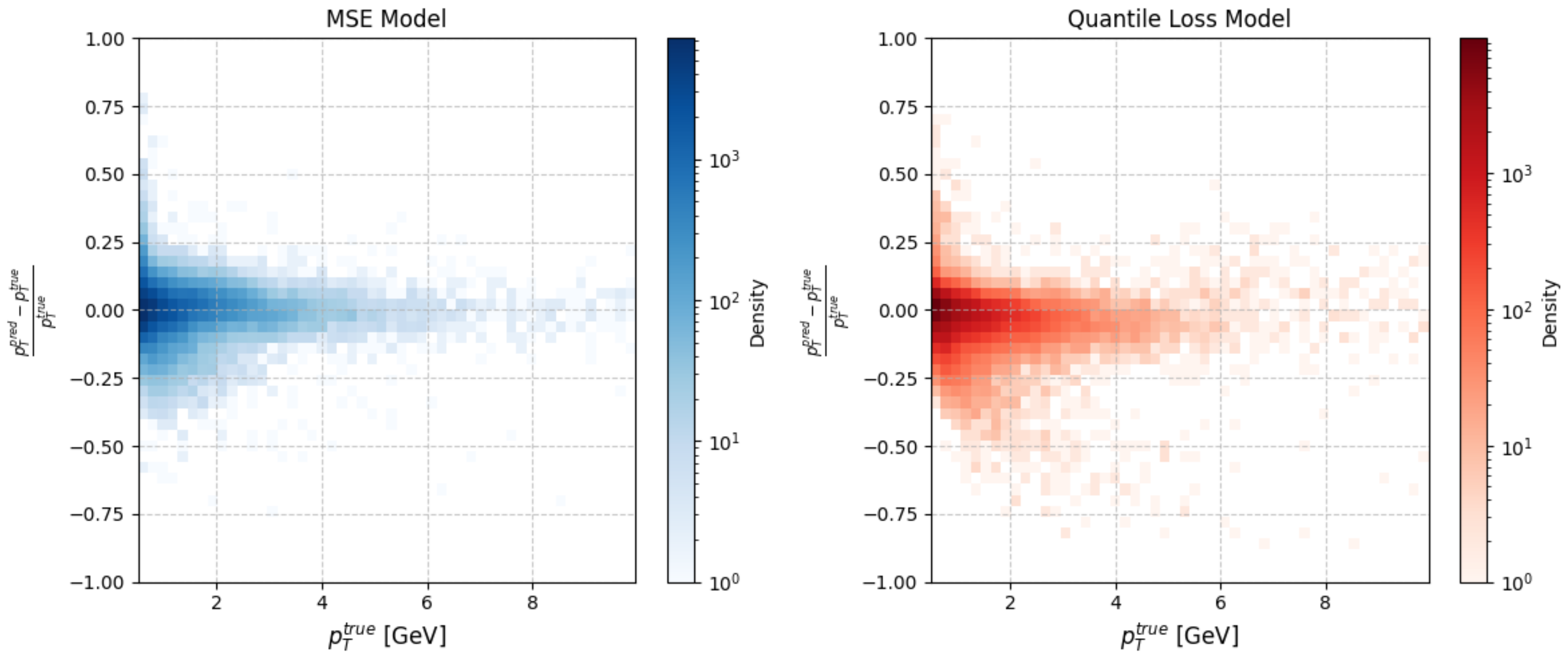
Relative error resolution for p_T $((tx, ty, tz) \to (p_T, p_z))$



Computing resolution

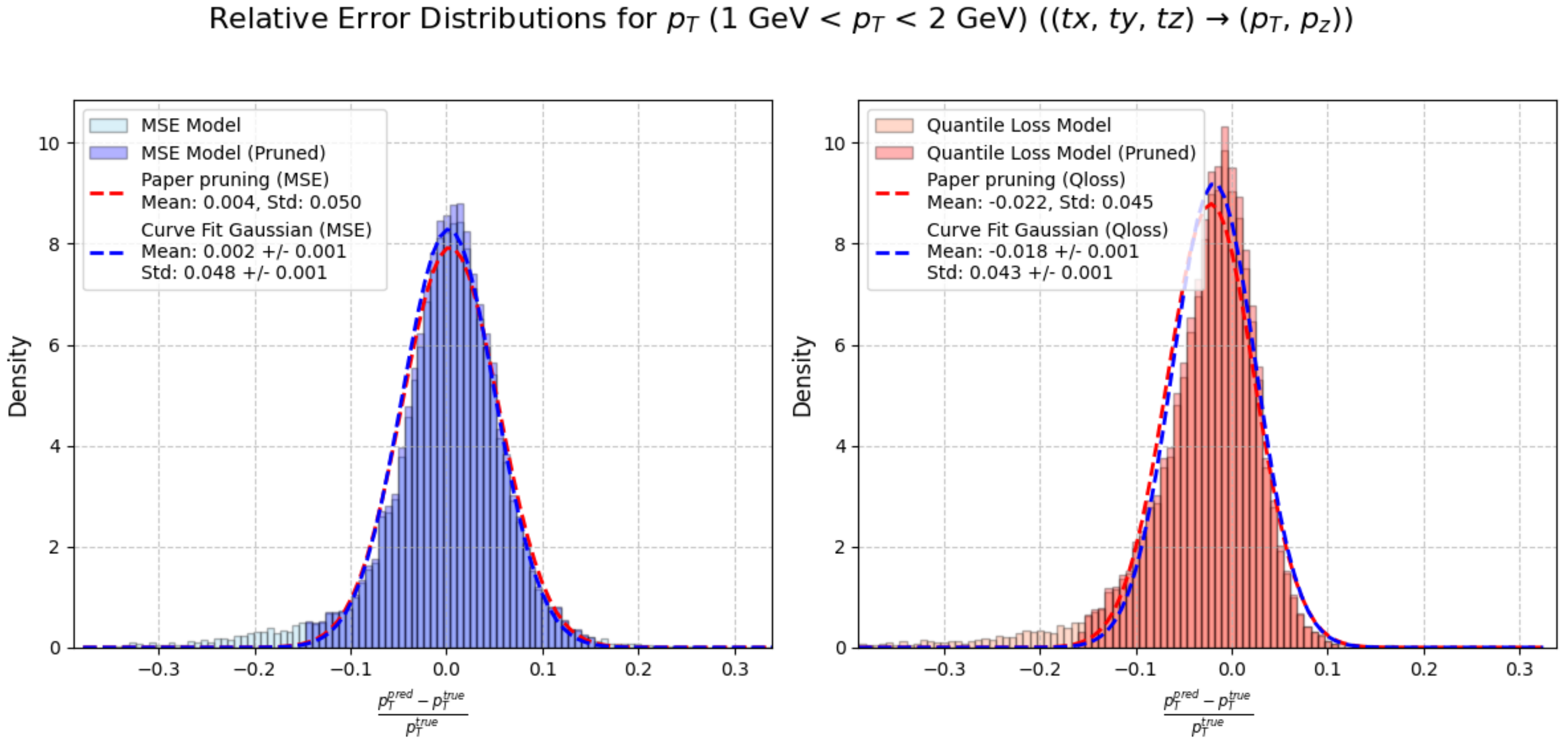
3 approaches:

- **Paper approach:**
  - Iterative pruning of distribution pred-truth from points away from the mean by more than 3 rms
- **Quantile approaches:**
  - Take quantiles equivalent to 5 sigma (of a normal distribution) from the median:
    99.99994266968912% quantile
    5.733031088084317e-05% quantile
  - Estimate mean and std with MLE (scipy norm.fit)
  - Use curve_fit or ROOT to fit a gaussian

Resolution

x y z

TrackML Zenodo



Resolution

x y z

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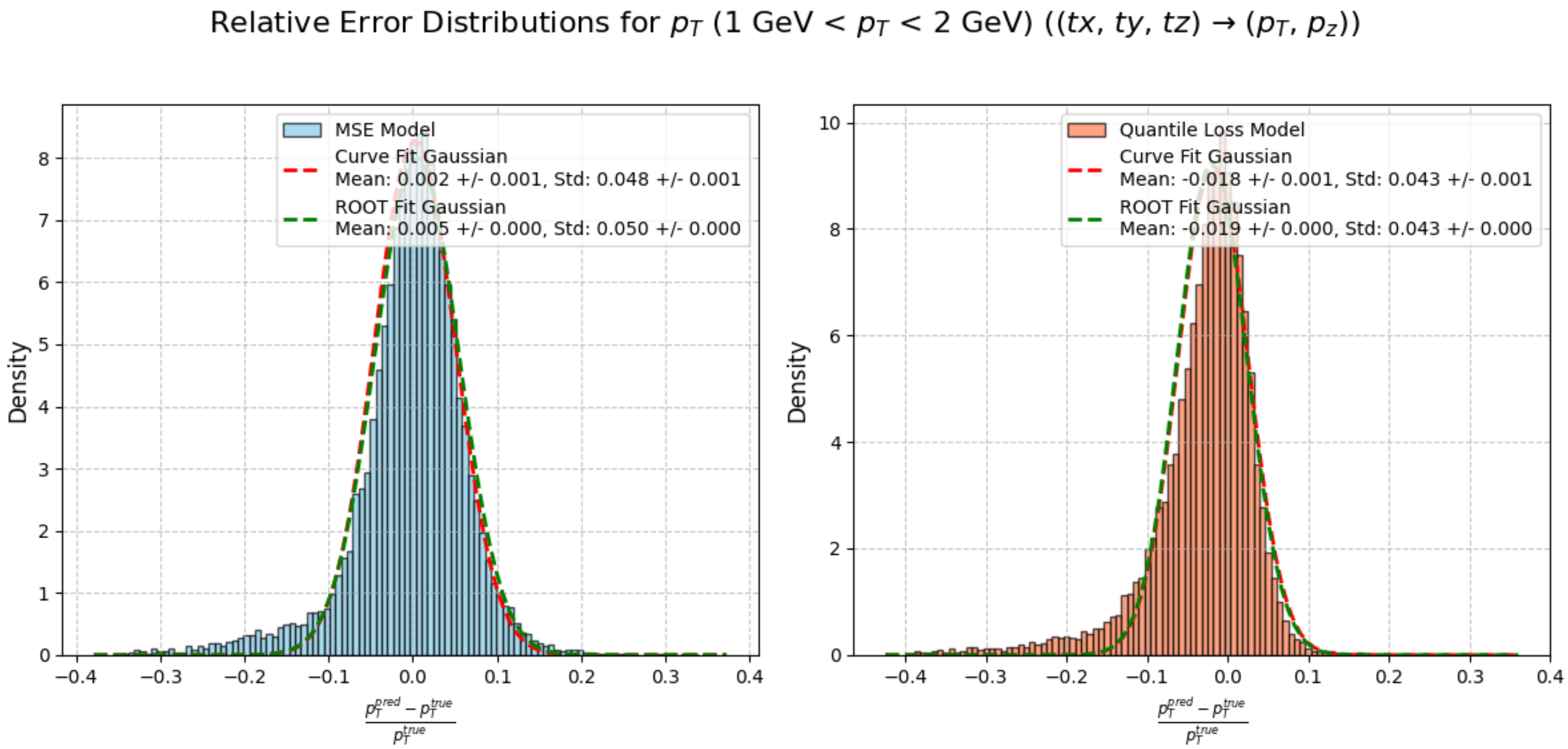

Resolution

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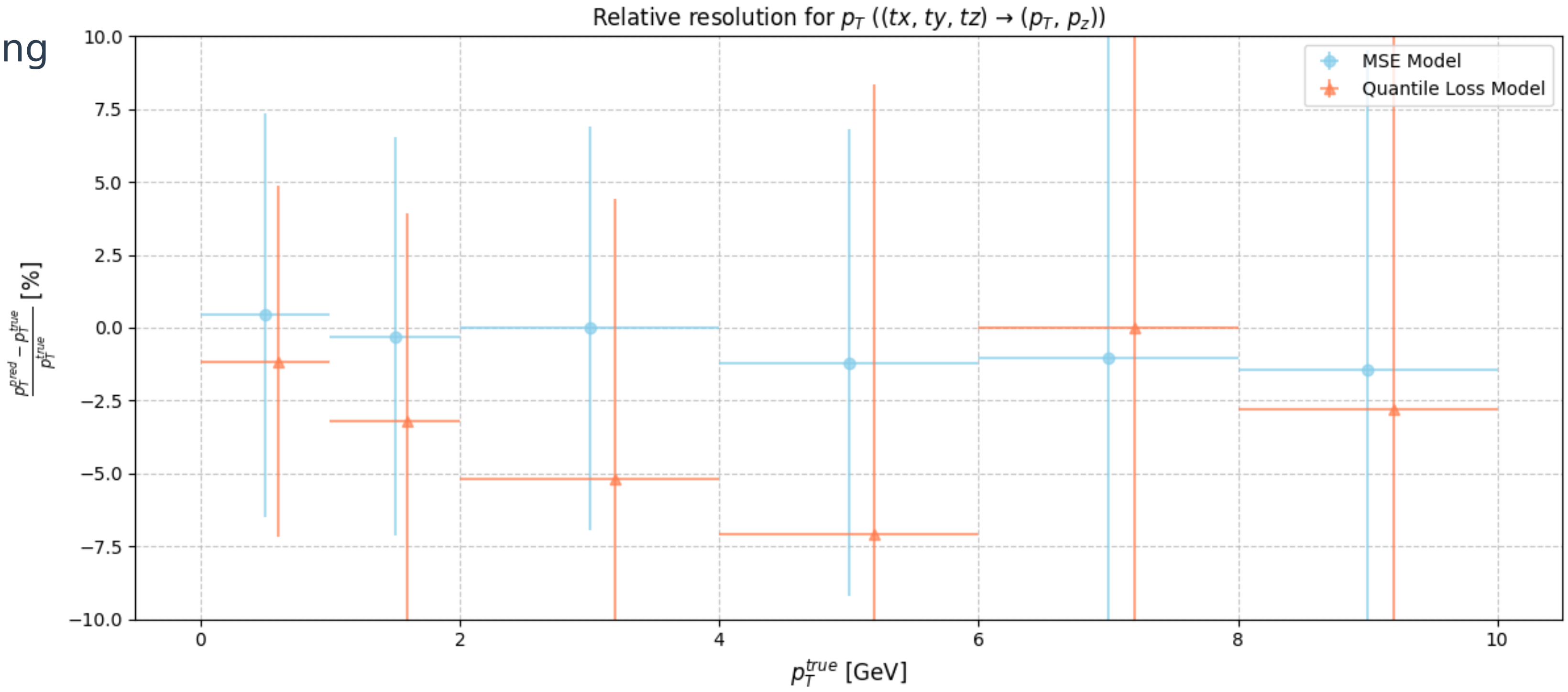
No pruning



Quantile loss is worst

Resolution

x y z

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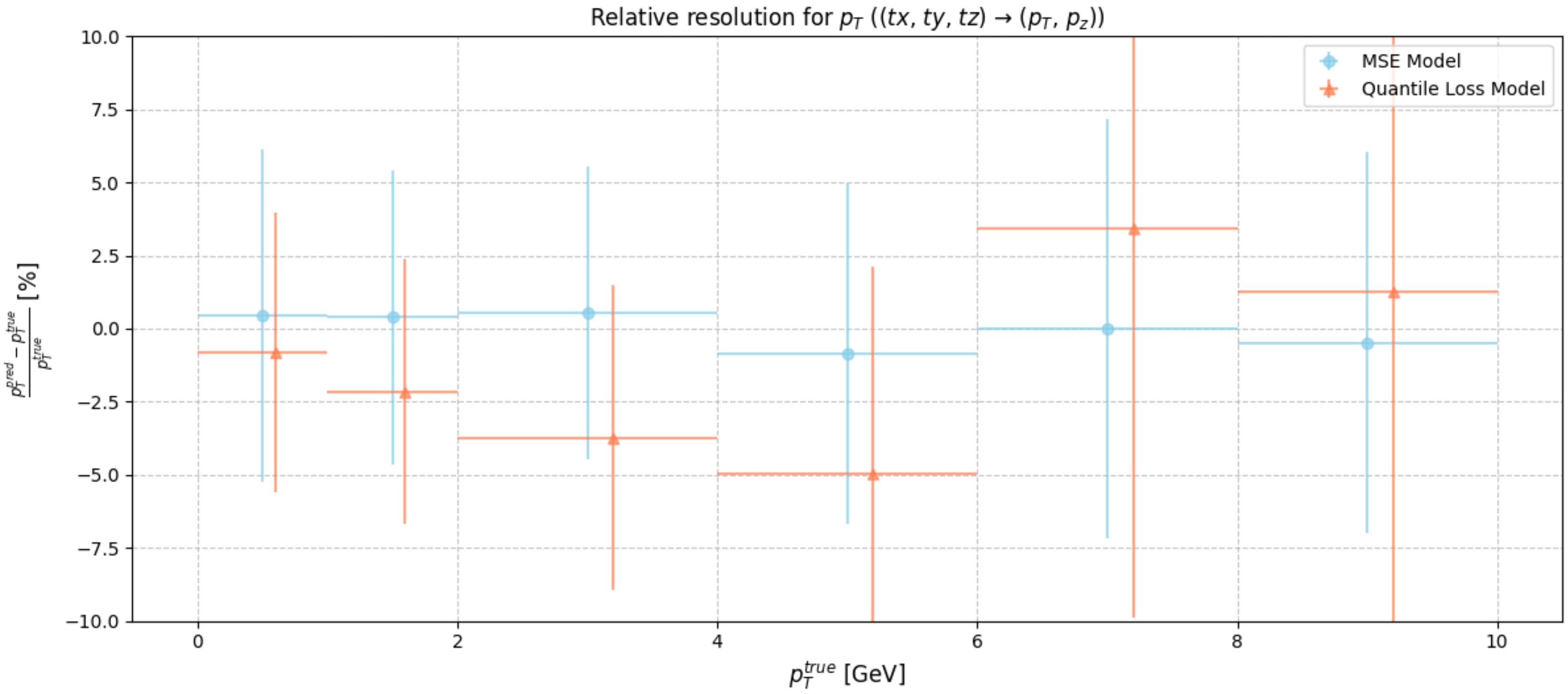
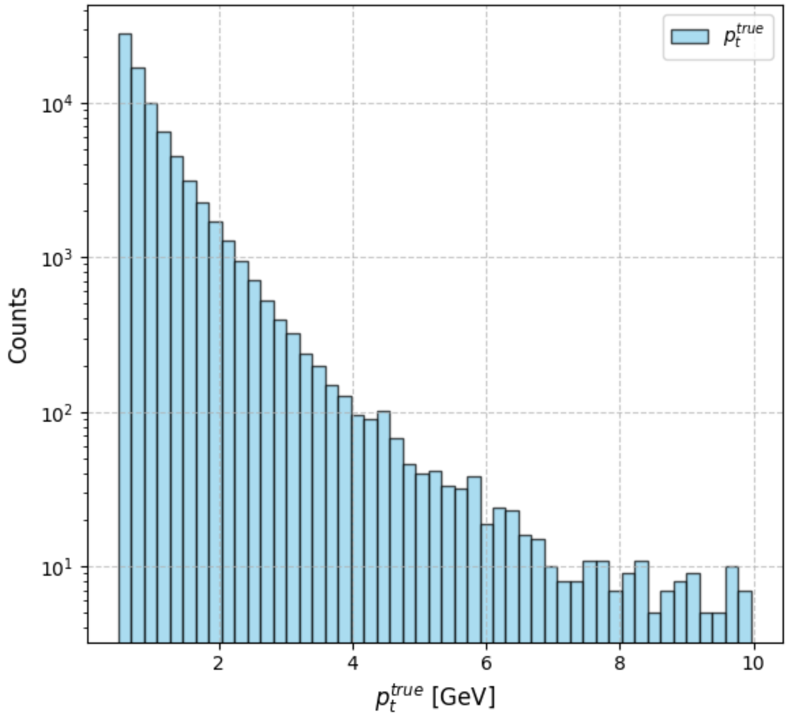
Pruning

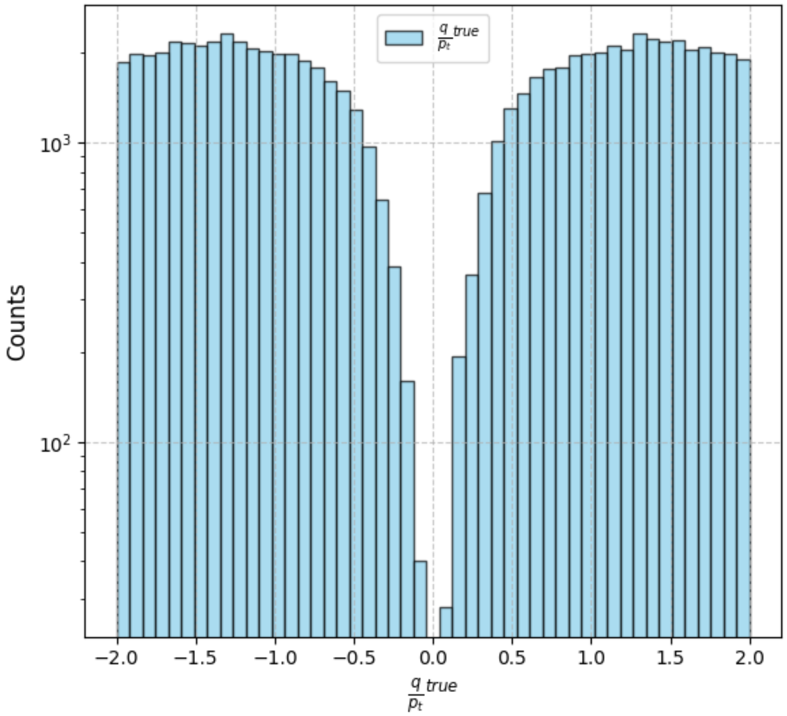


Pruning improves results

q/pT

Target variable:



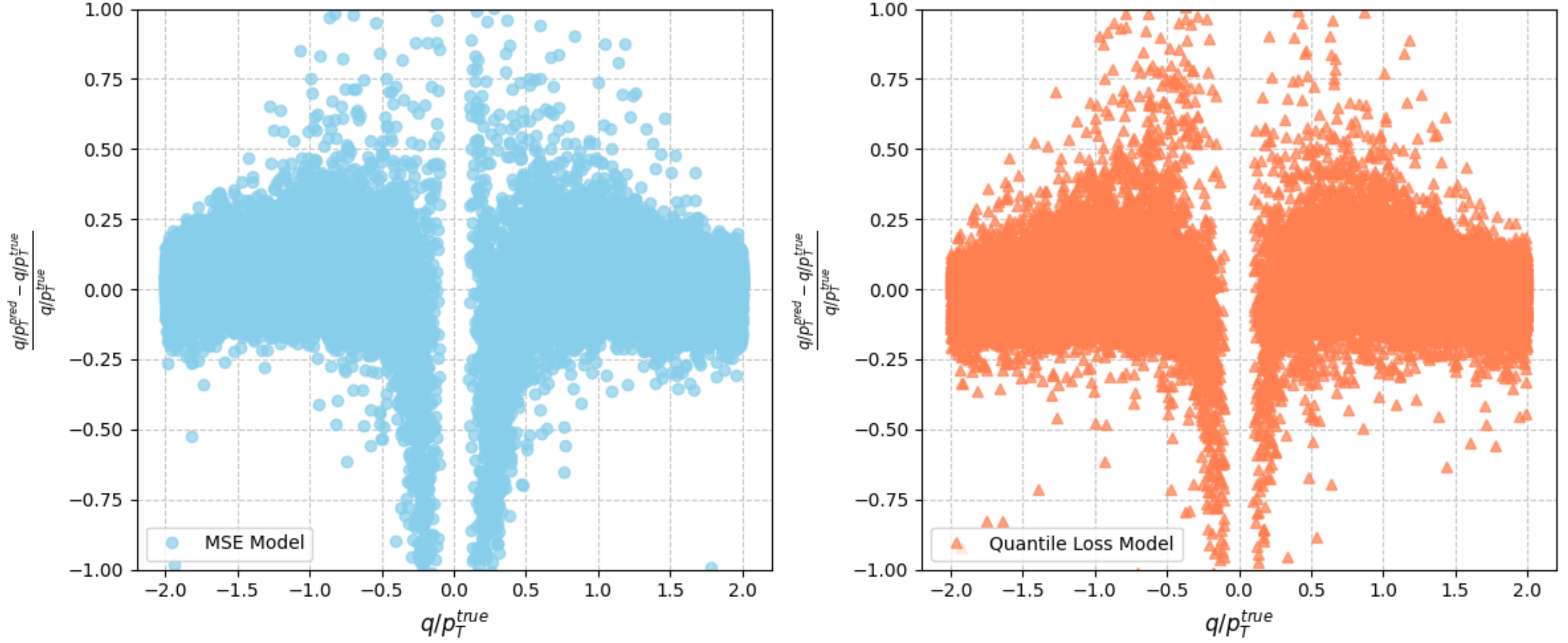


More results

x y z

TrackML Zenodo

Relative error resolution for q/p_T $((tx, ty, tz) \rightarrow (q/p_T, p_z))$

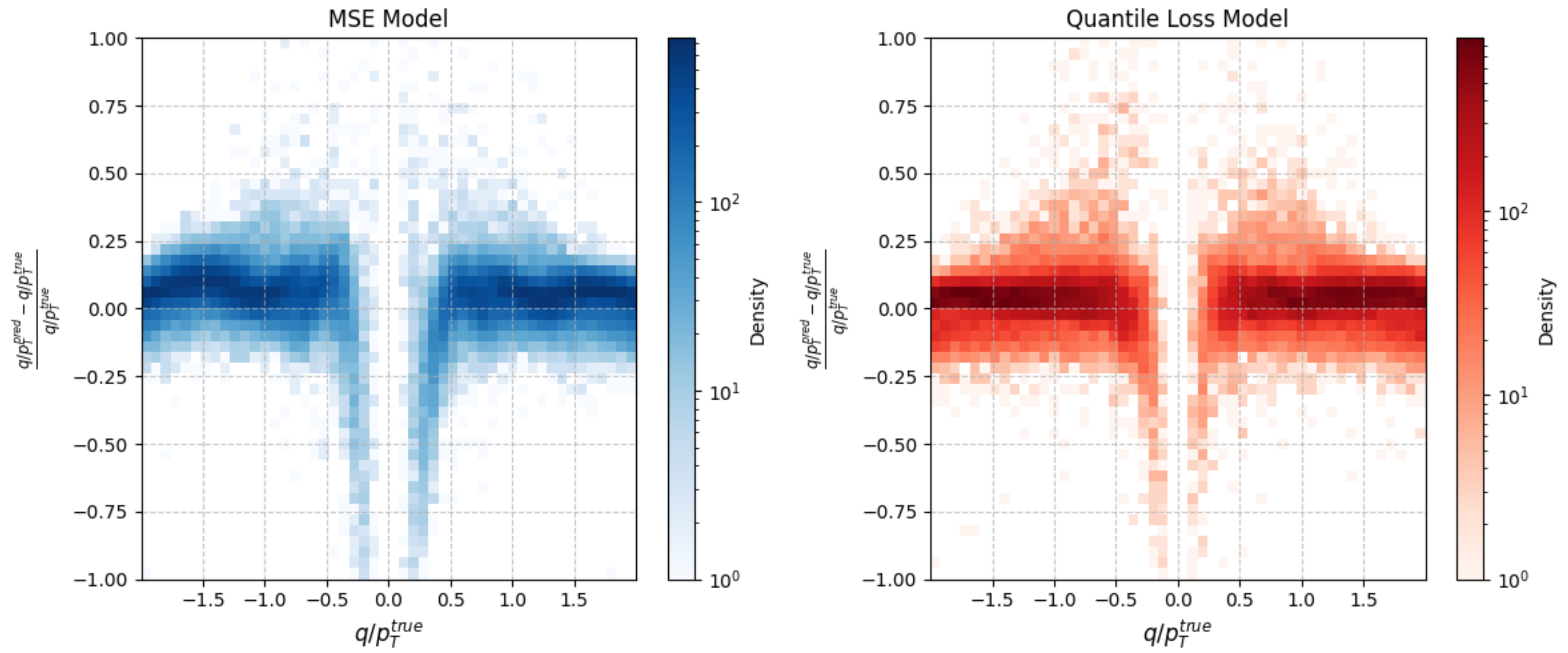


Resolution

x y z

TrackML Zenodo

Relative error resolution for q/p_T $((tx, ty, tz) \rightarrow (q/p_T, p_z))$

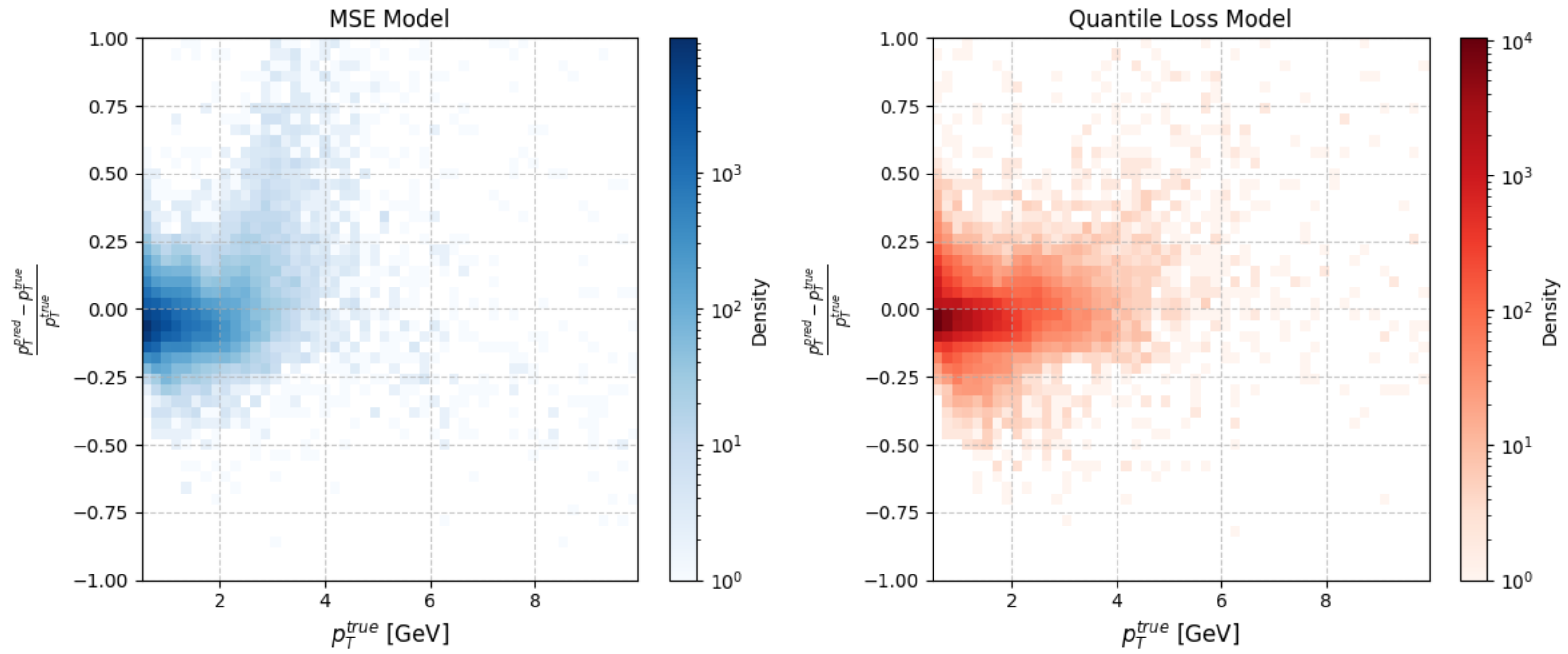


Resolution

x y z

TrackML Zenodo

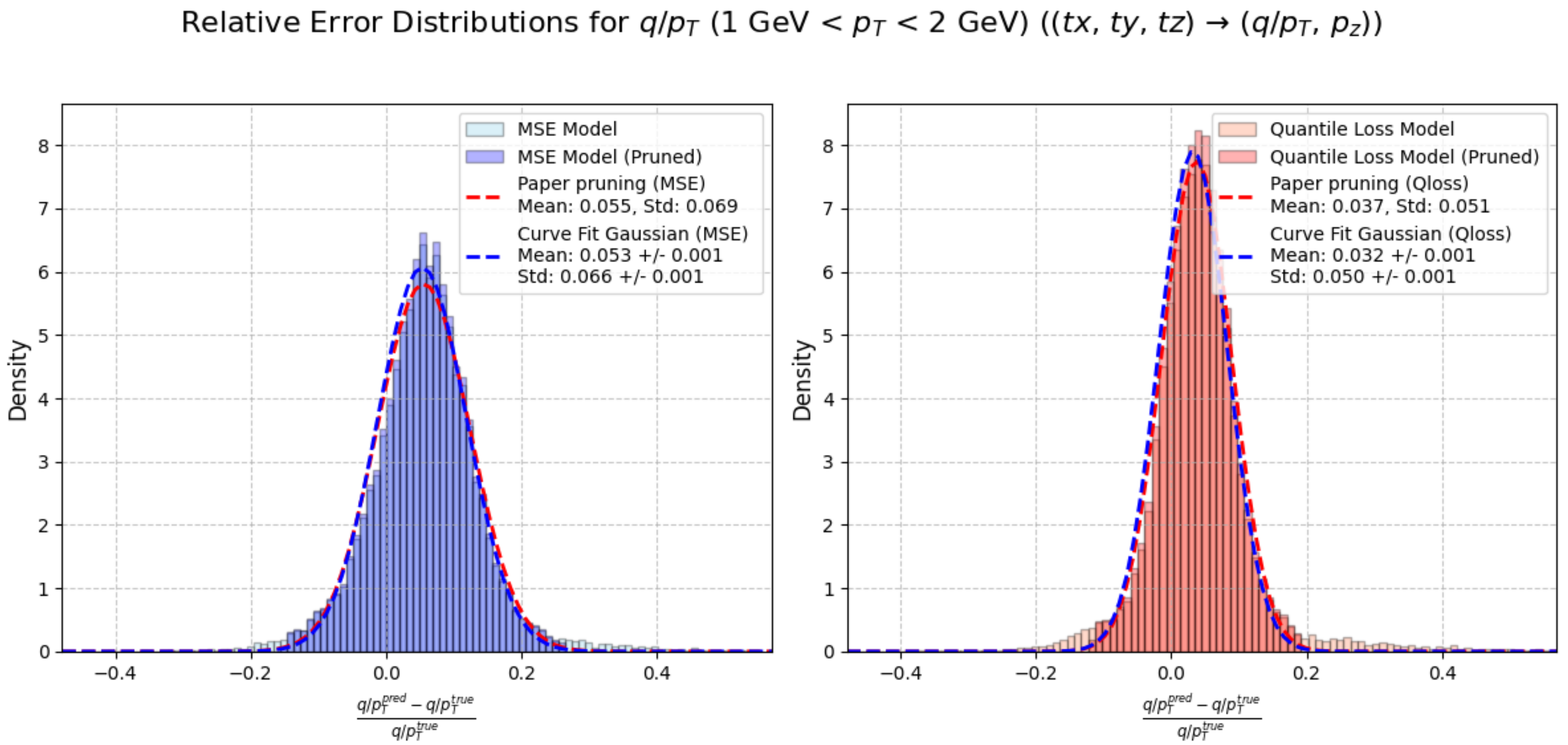
Relative error resolution for p_T $((tx, ty, tz) \rightarrow (q/p_T, p_z))$



Resolution

x y z

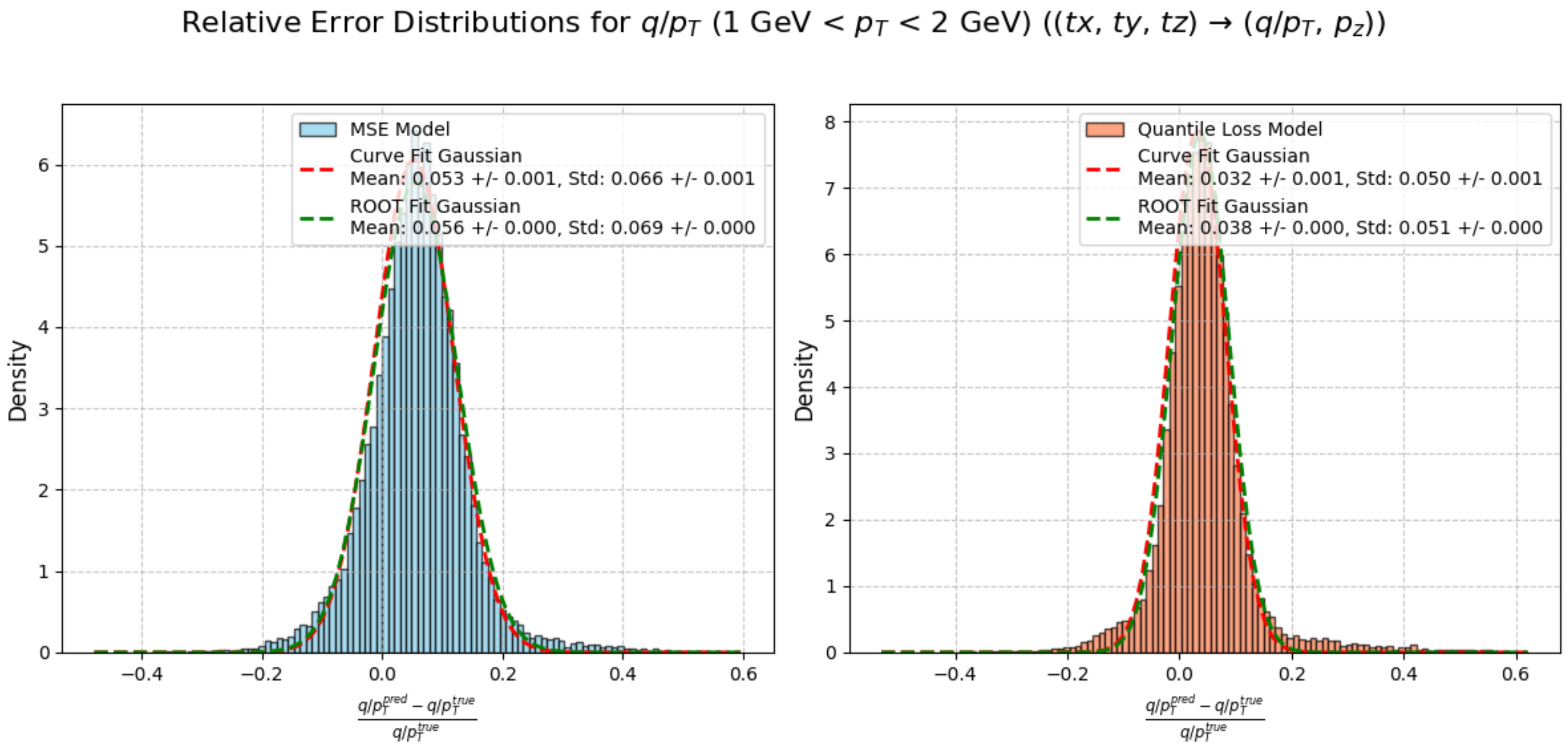
TrackML Zenodo



Resolution

x y z

TrackML Zenodo

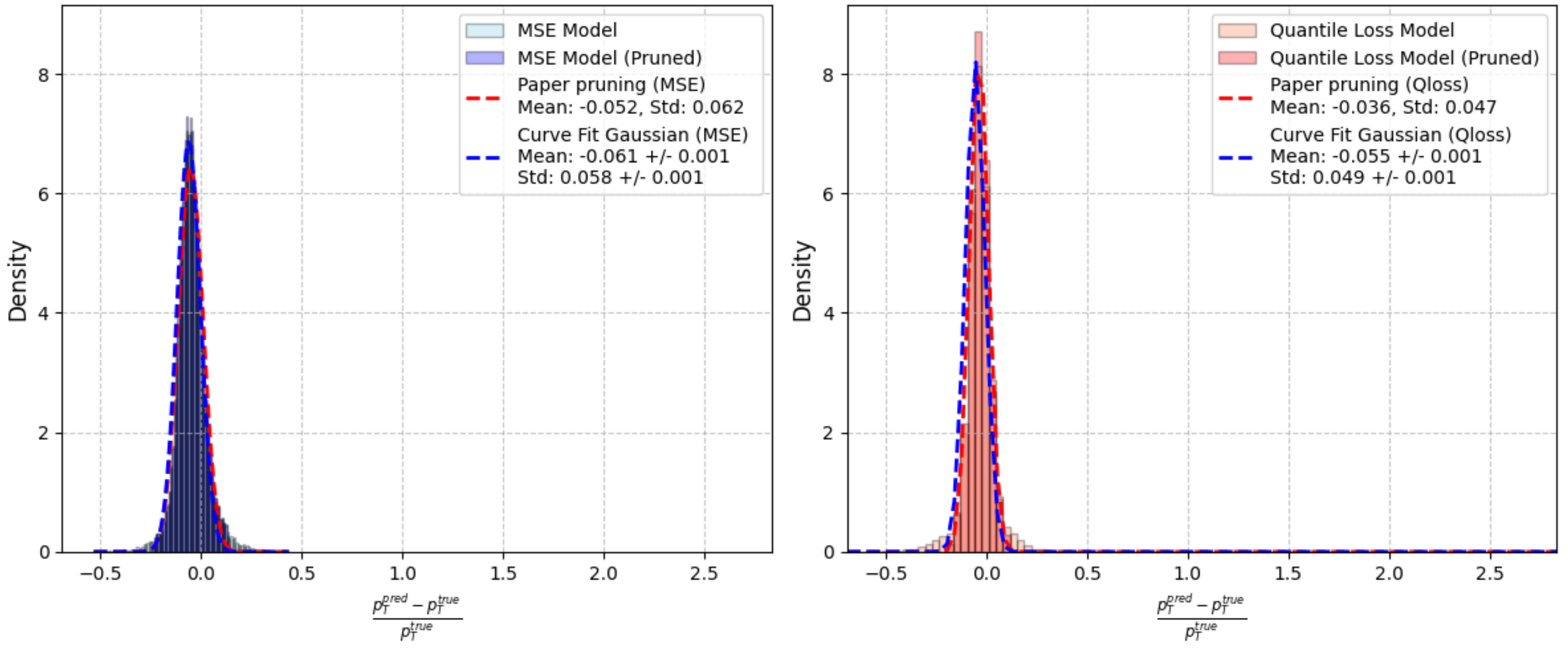


Resolution

x y z

TrackML Zenodo

Relative Error Distributions for p_T (1 GeV < p_T < 2 GeV) ((tx, ty, tz) → (q/p_T, p_z))

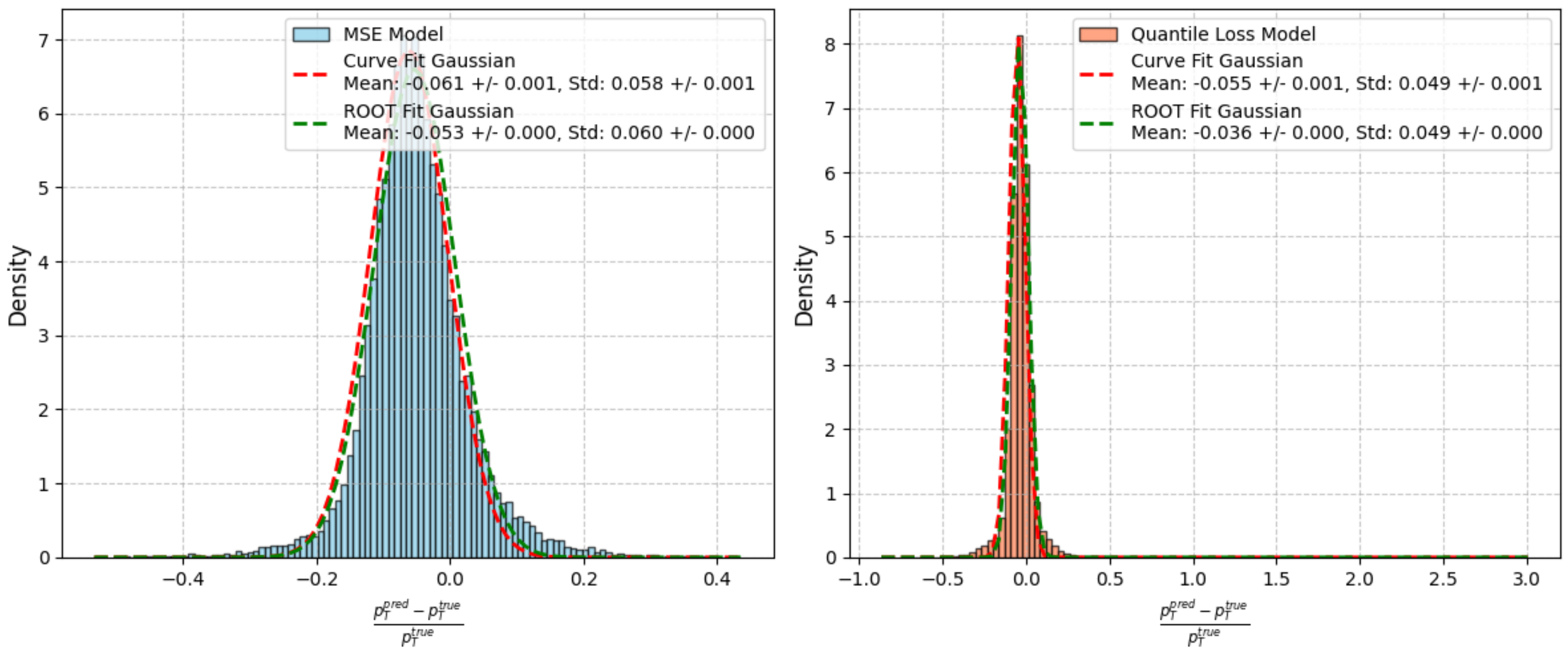


Resolution

x y z

TrackML Zenodo

Relative Error Distributions for p_T (1 GeV < p_T < 2 GeV) ((tx, ty, tz) → (q/p_T, p_z))

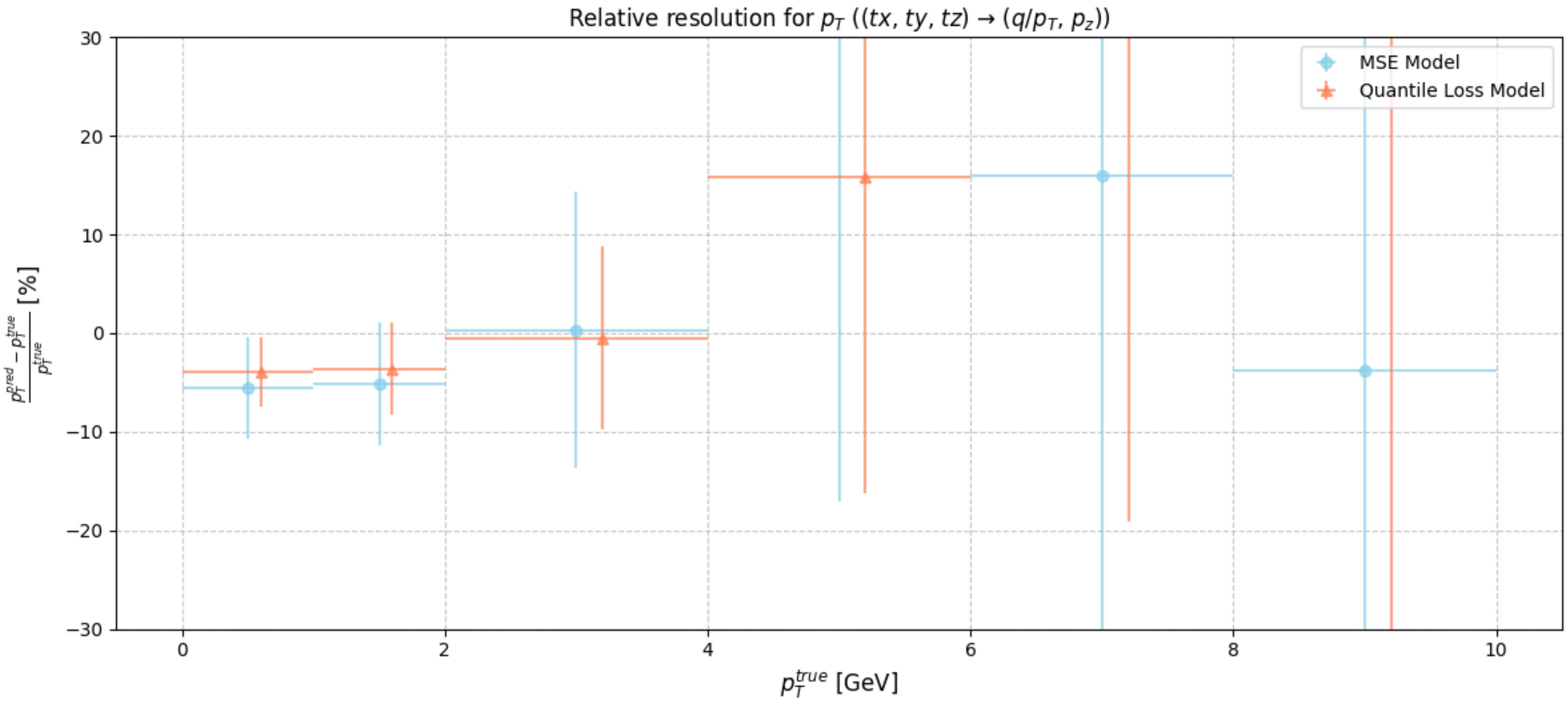


Resolution

x y z

TrackML Zenodo

Pruning



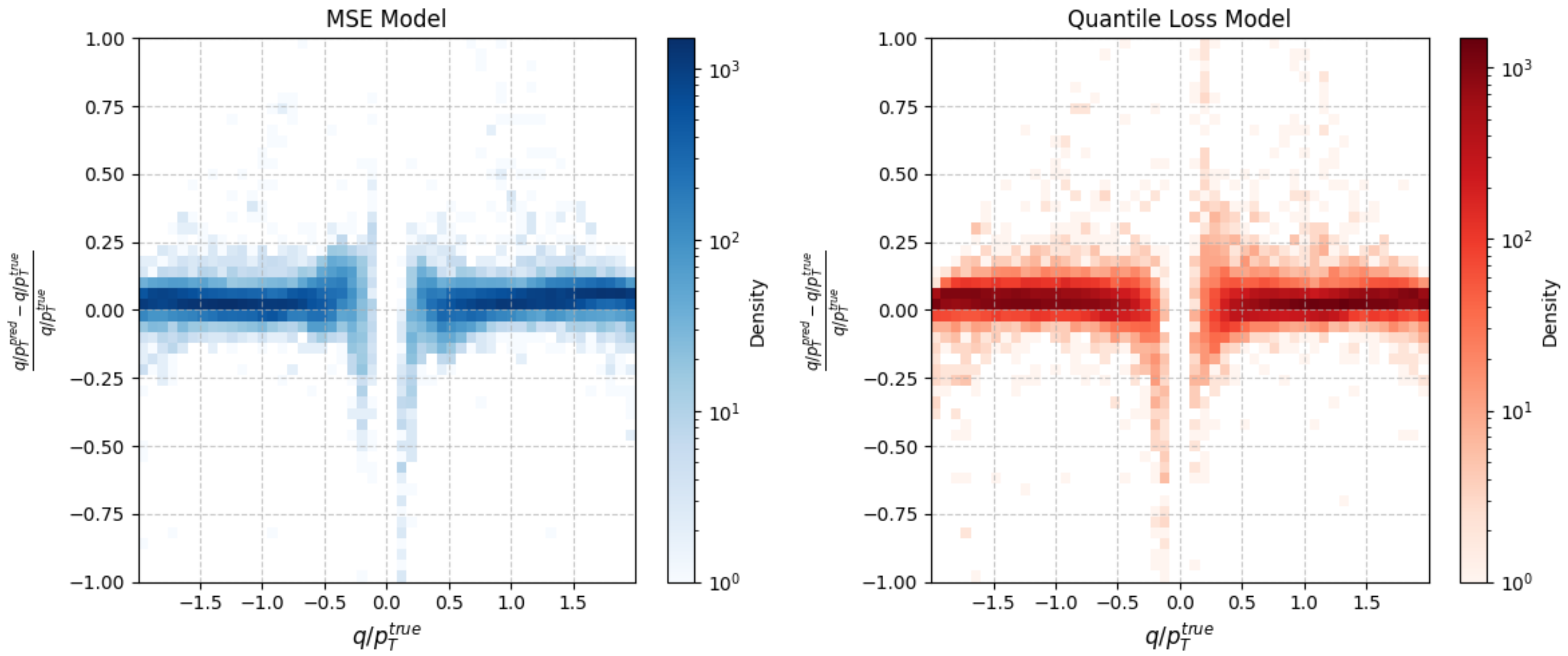
r, dphi, z → q/pT, pz

Resolution

r dphi z

TrackML Zenodo

Relative error resolution for q/p_T $((tr, d\varphi, tz) \rightarrow (q/p_T, p_z))$

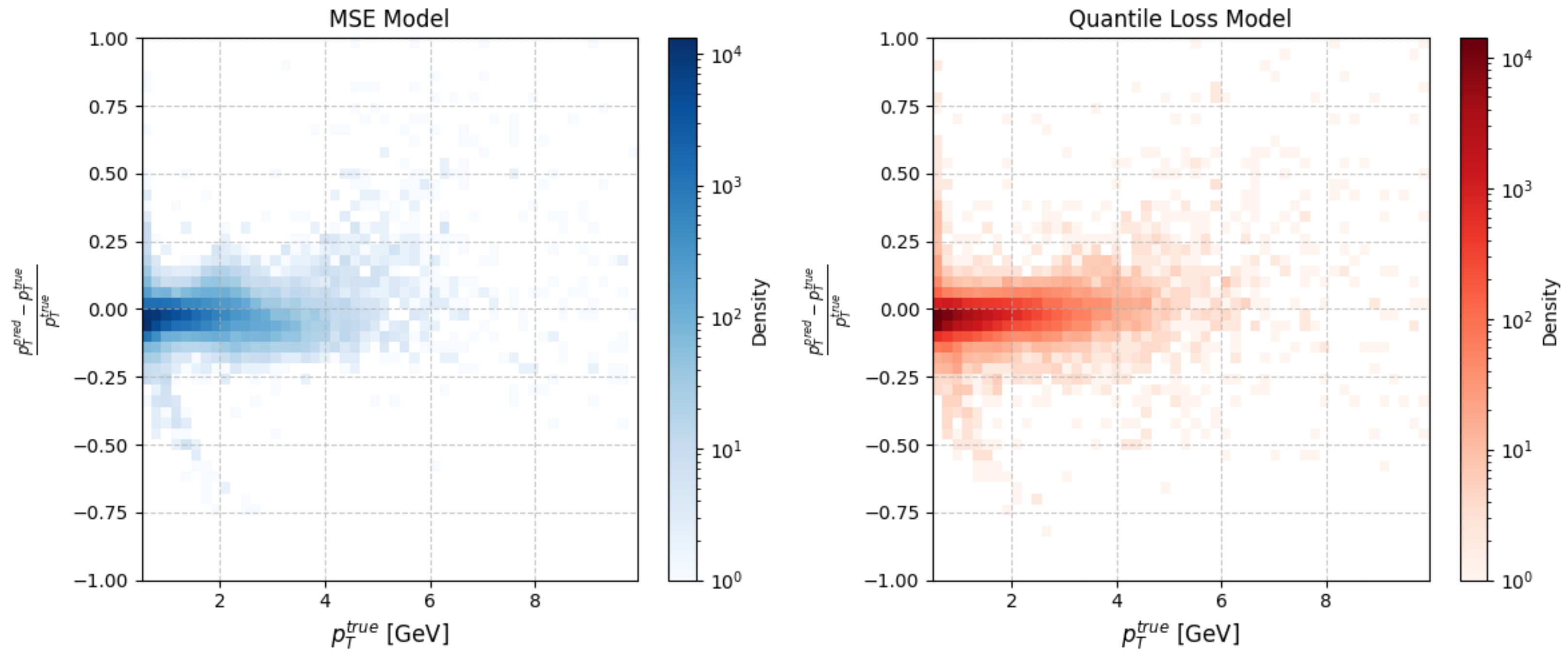


Resolution

r dphi z

TrackML Zenodo

Relative error resolution for p_T ((tr, $d\varphi$, tz) → (q/p_T, p_z))

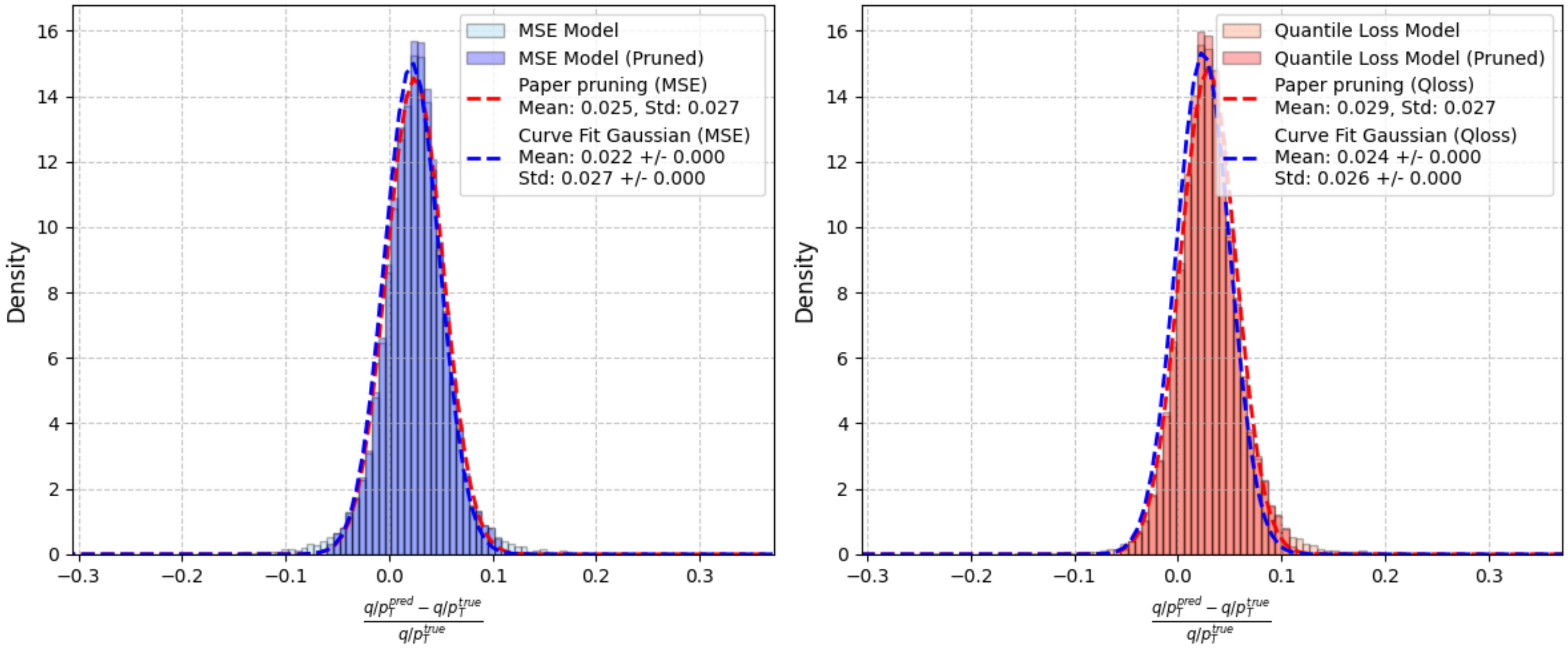


Resolution

r dphi z

TrackML Zenodo

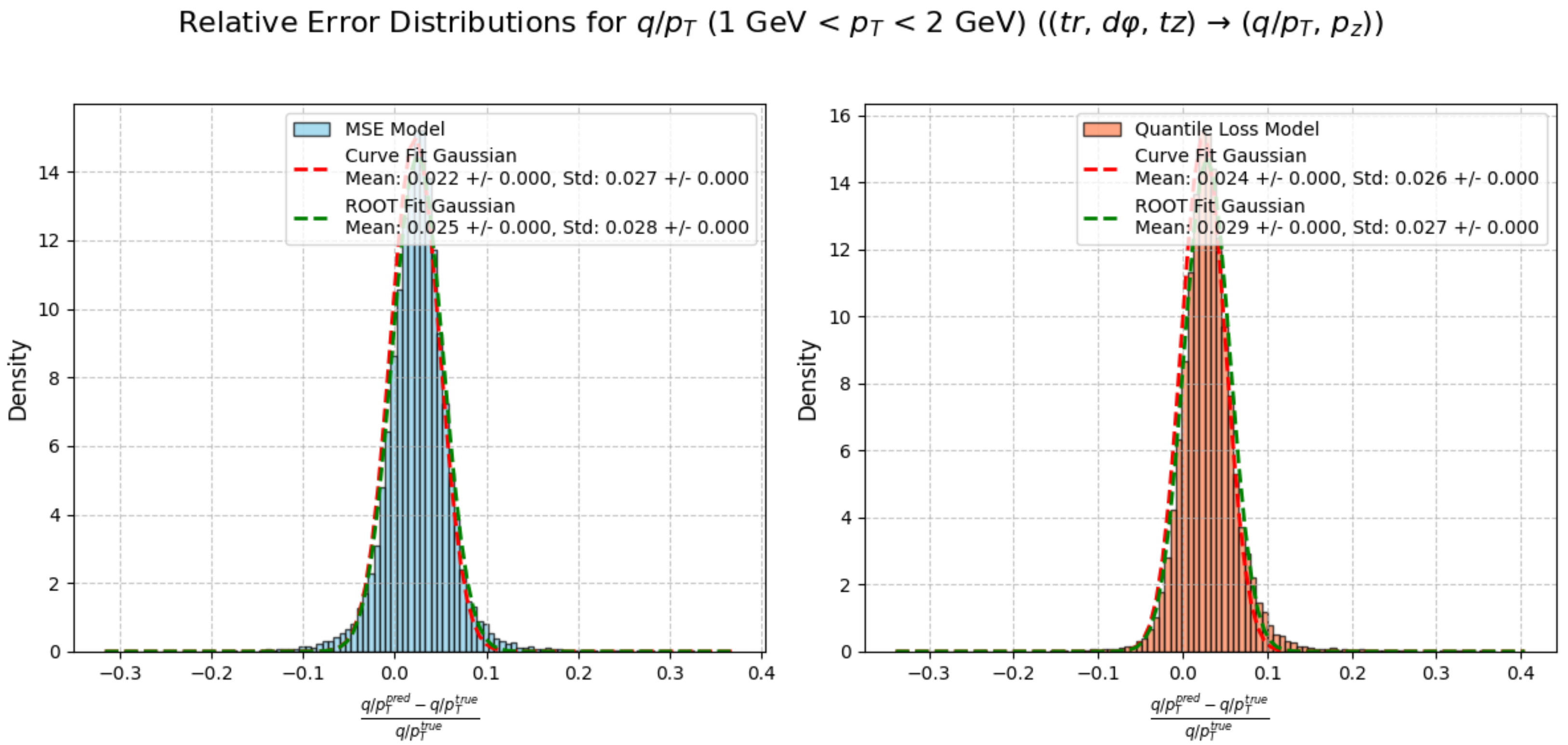
Relative Error Distributions for q/p_T (1 GeV < p_T < 2 GeV) ((tr, $d\varphi$, tz) → (q/p_T, p_z))



Resolution

r dphi z

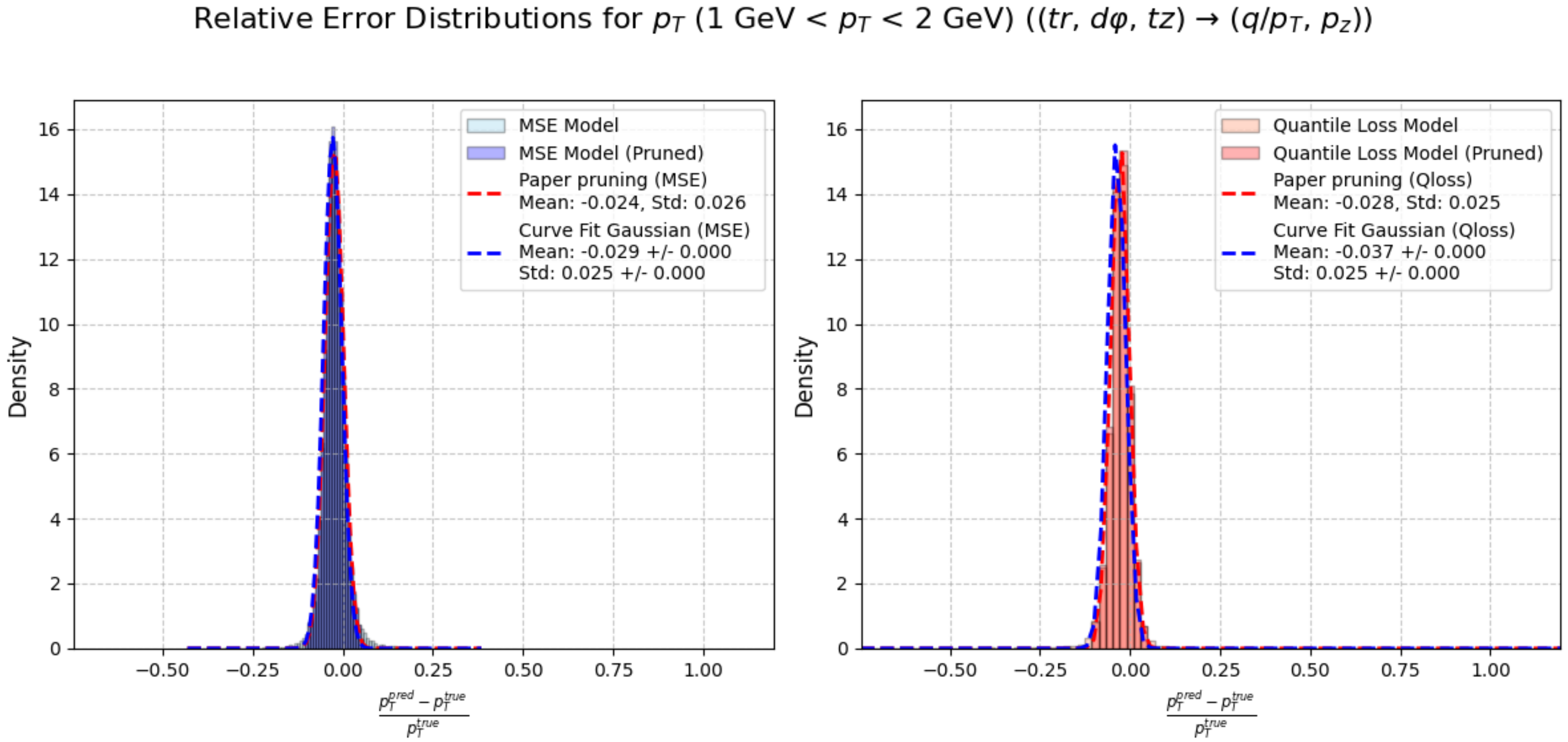
TrackML Zenodo



Resolution

r dphi z

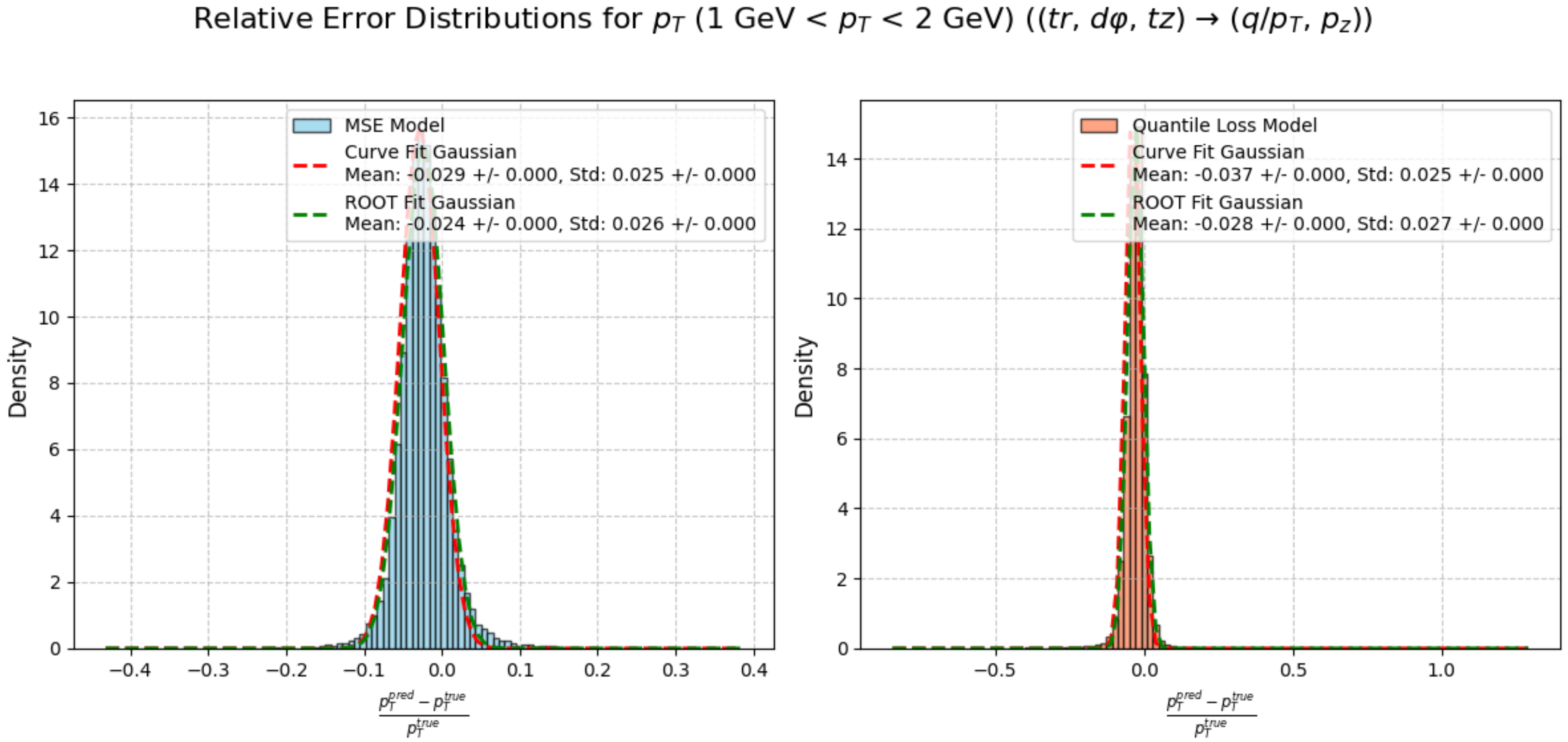
TrackML Zenodo



Resolution

r dphi z

TrackML Zenodo

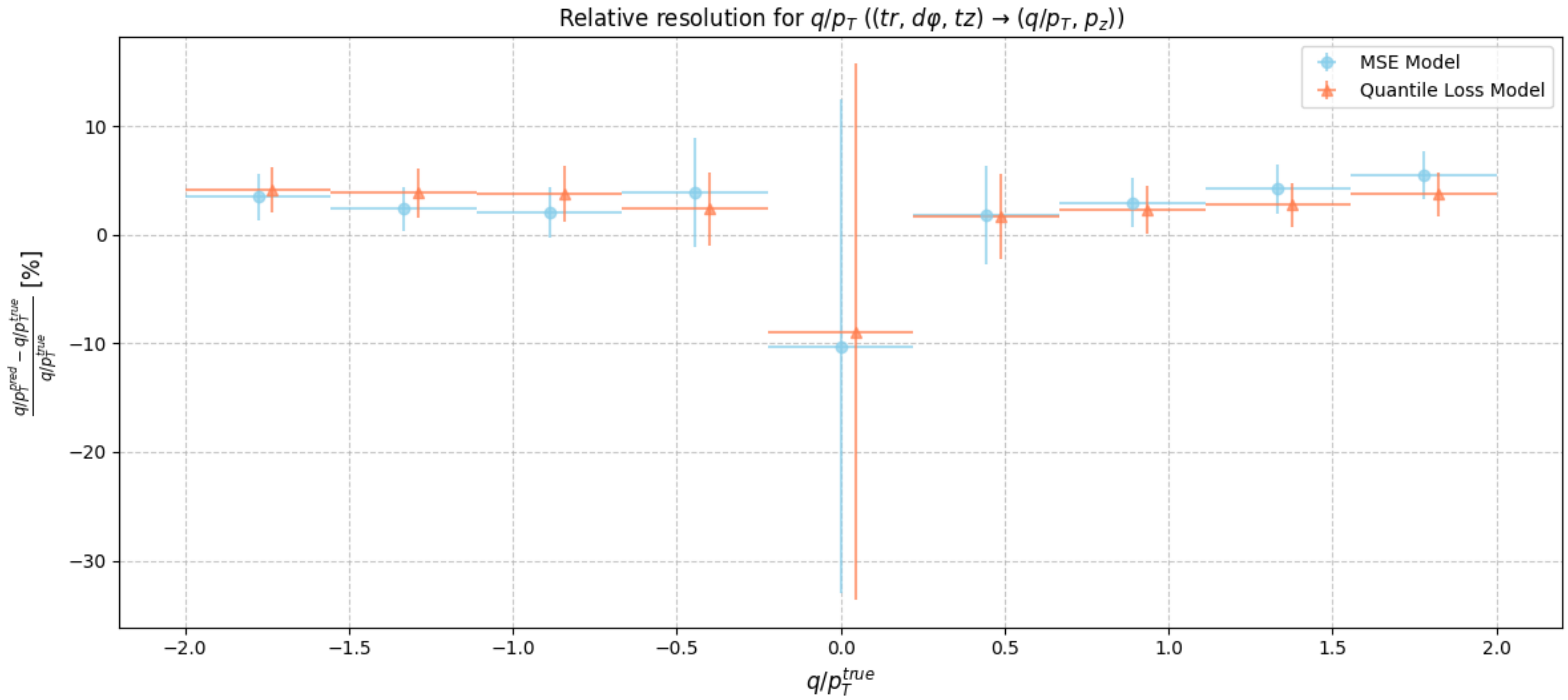


Resolution

r dphi z

TrackML Zenodo

Pruning

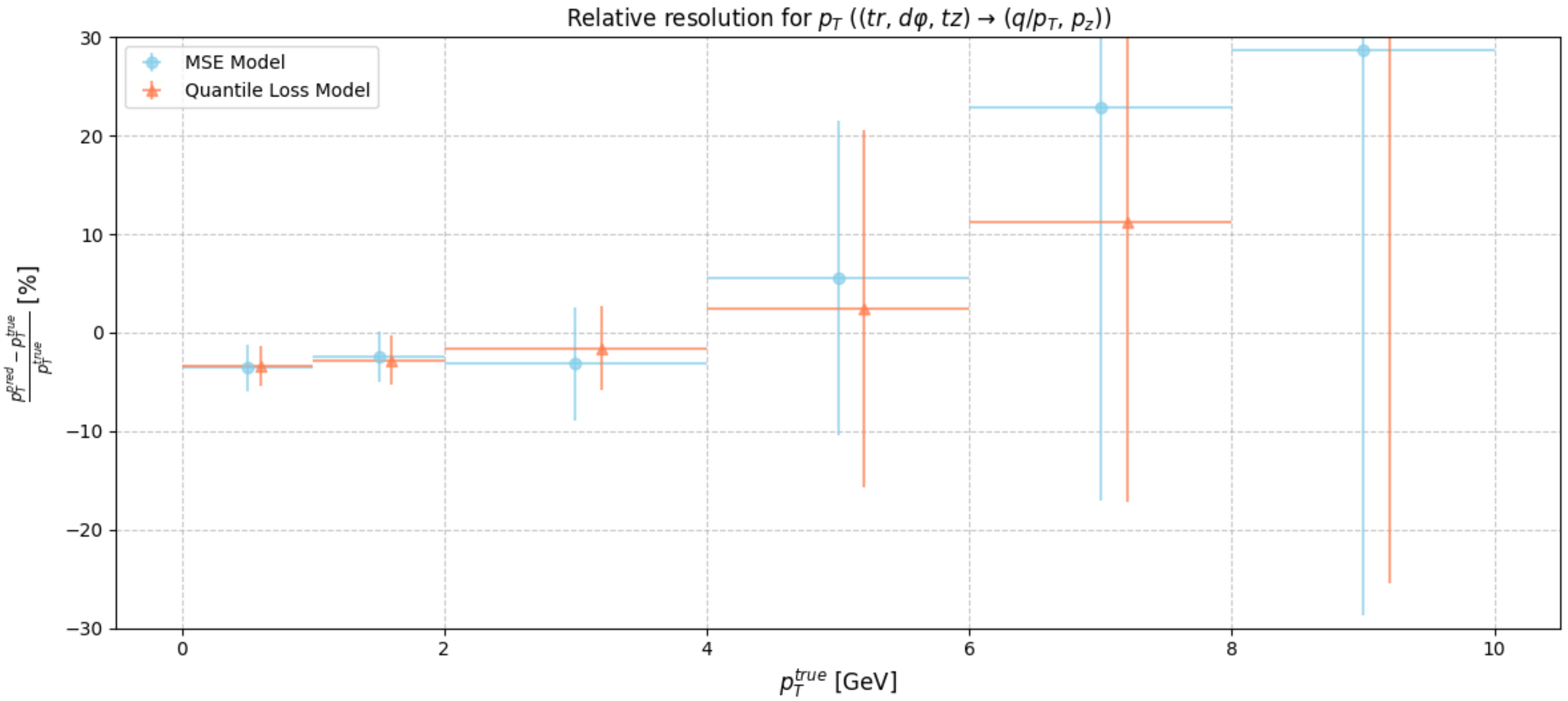


Resolution

r dphi z

TrackML Zenodo

Pruning



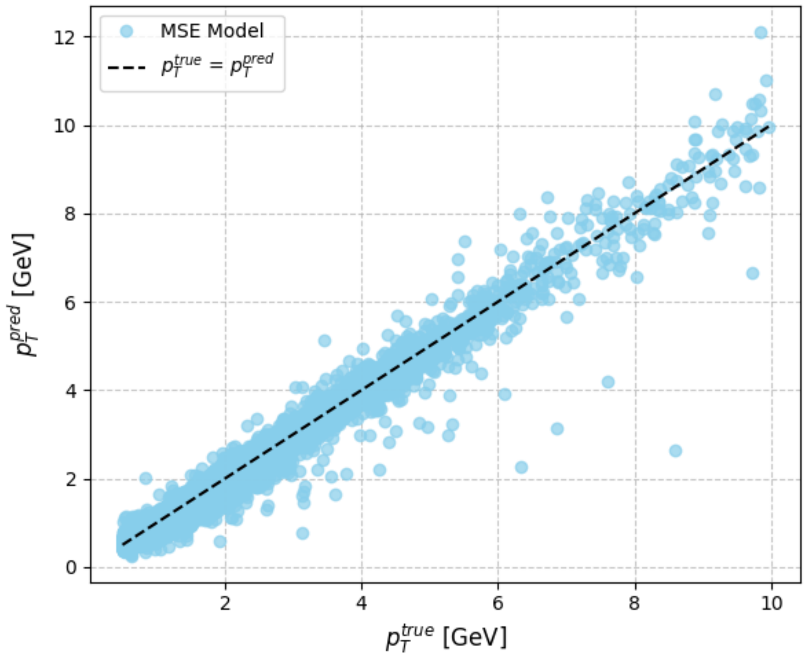
BACKUP

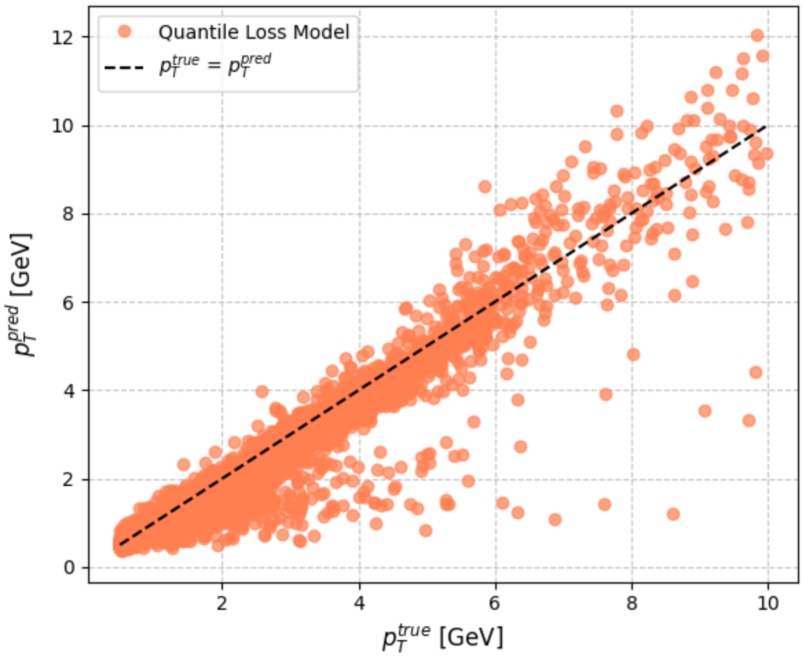
More results

x y z

TrackML Zenodo

p_T^{true} vs p_T^{pred} $((tx, ty, tz) \rightarrow (p_T, p_z))$



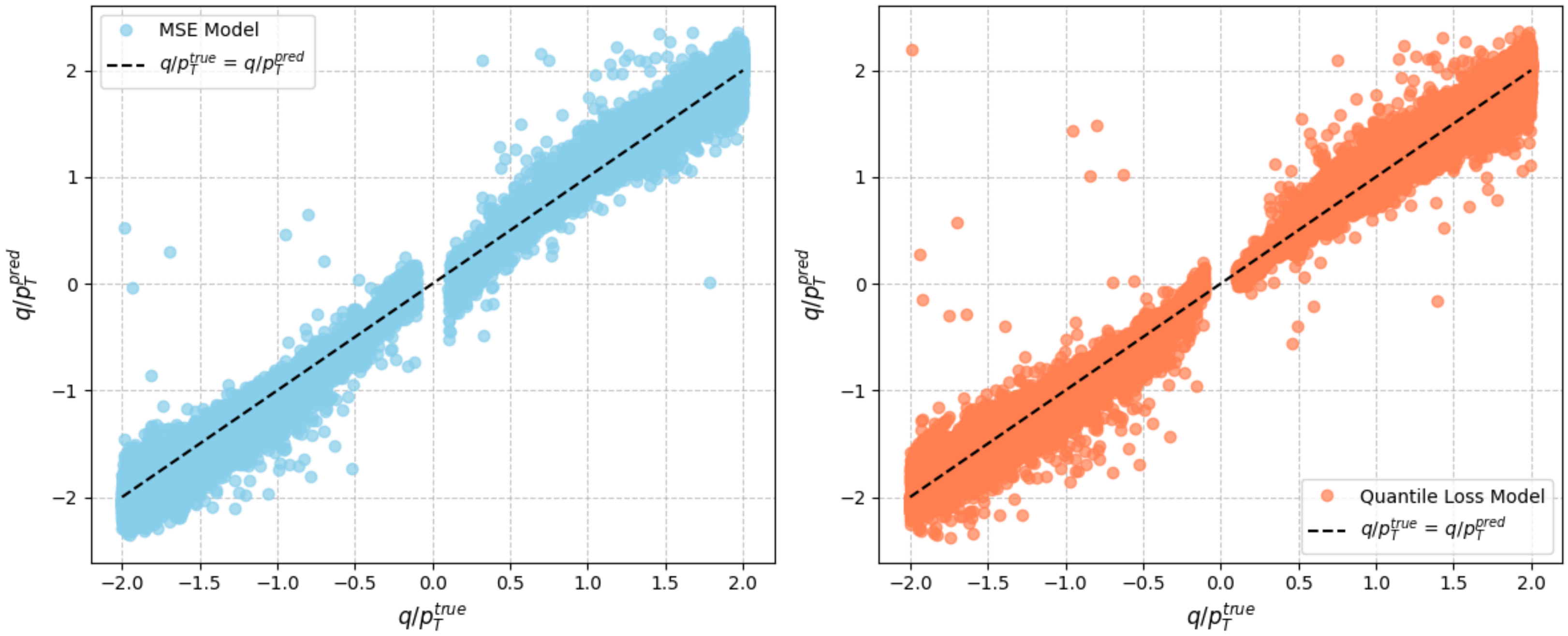


More results

x y z

TrackML Zenodo

q/p_T^{true} vs q/p_T^{pred} $((tx, ty, tz) \rightarrow (q/p_T, p_z))$

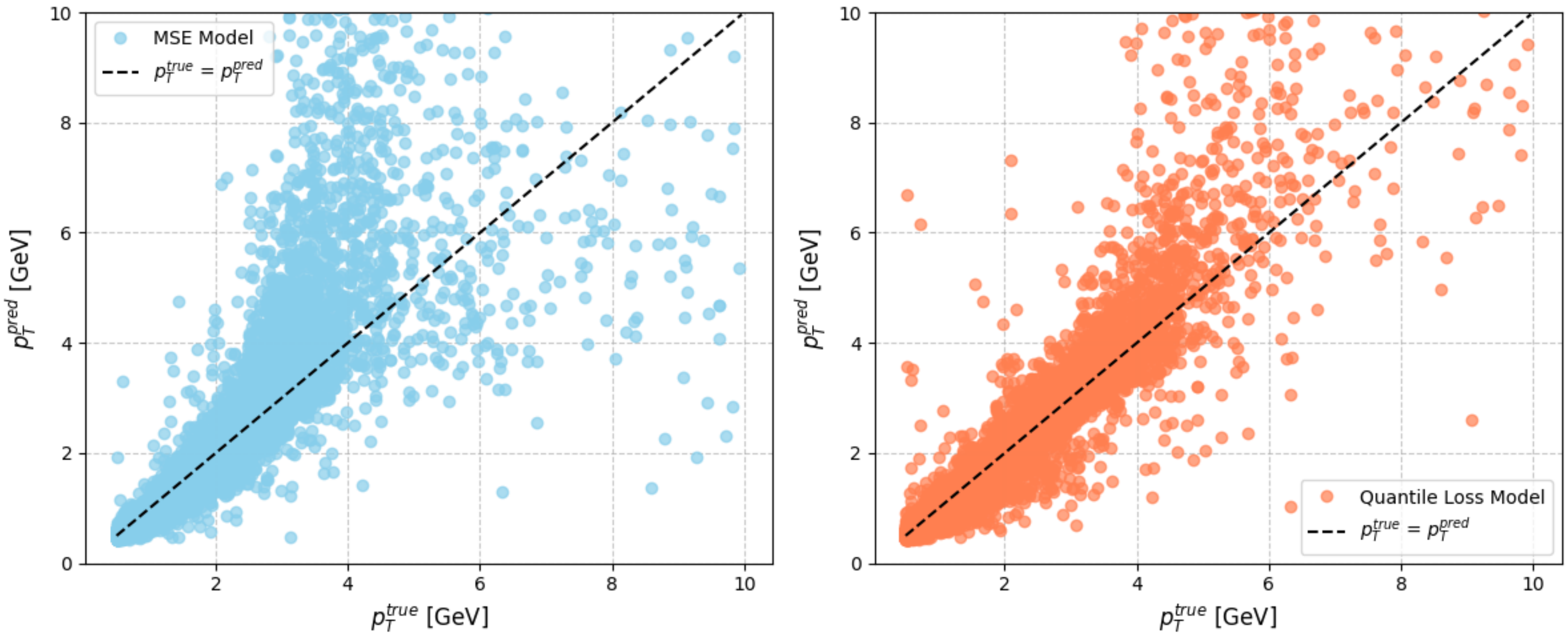


More results

x y z

TrackML Zenodo

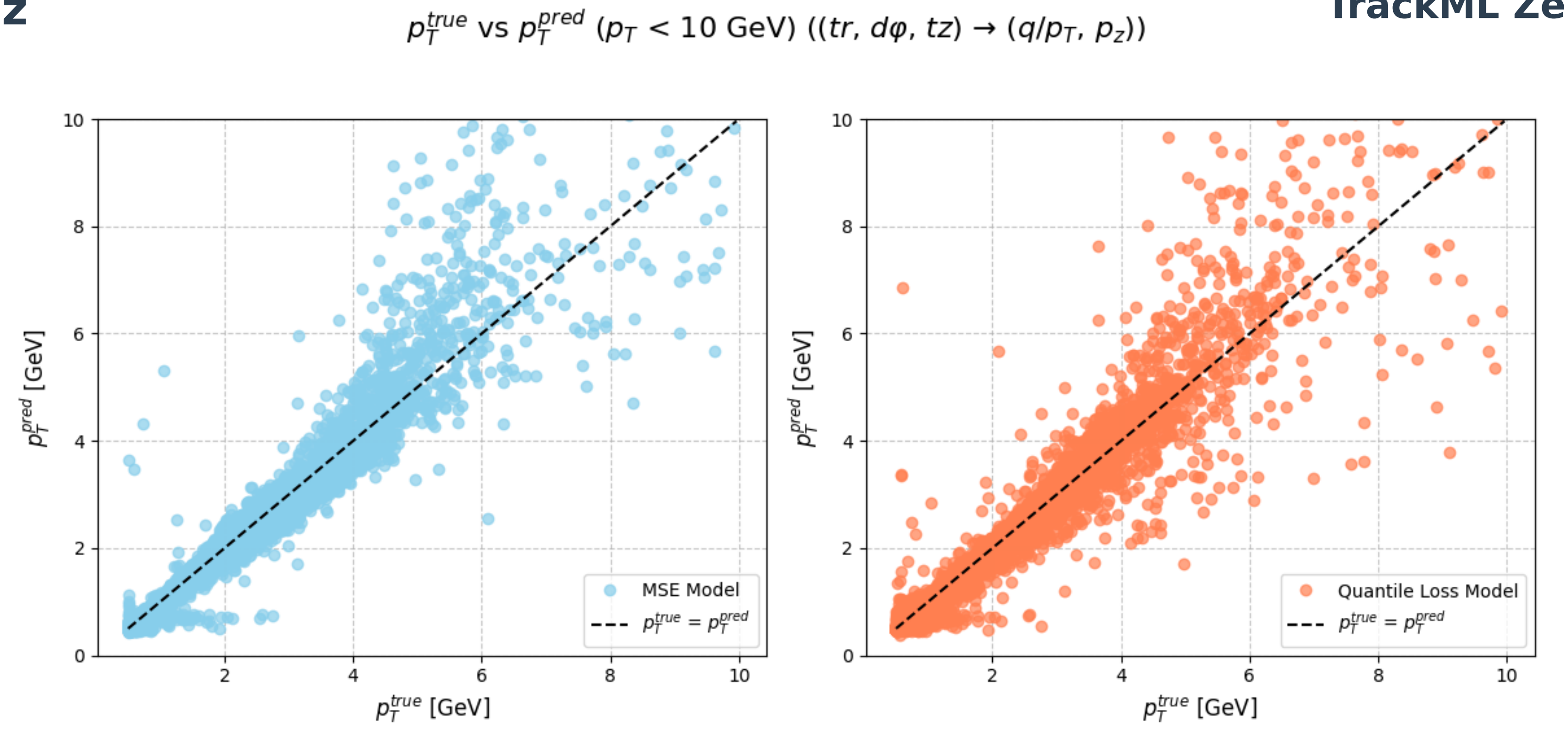
p_T^{true} vs p_T^{pred} $((tx, ty, tz) \rightarrow (q/p_T, p_z))$



More results

r dphi z

TrackML Zenodo

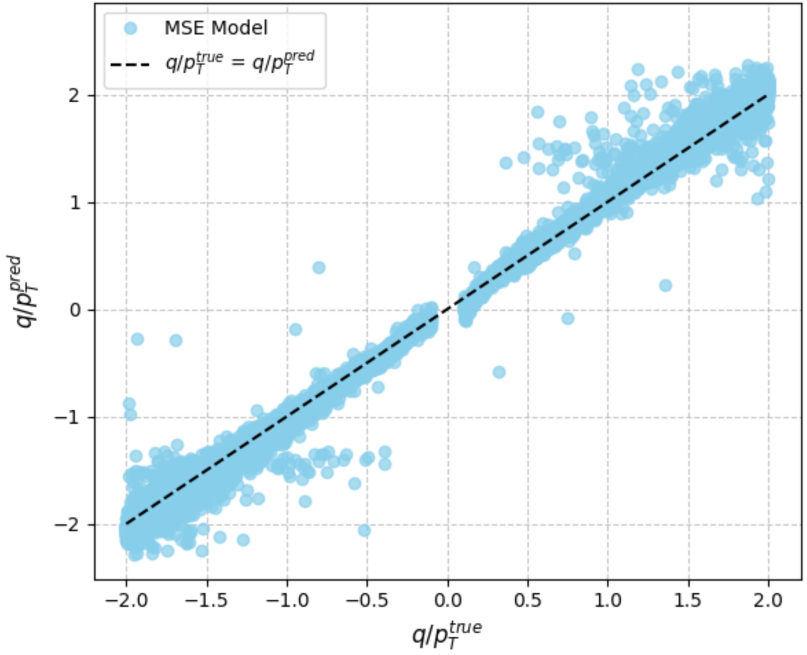


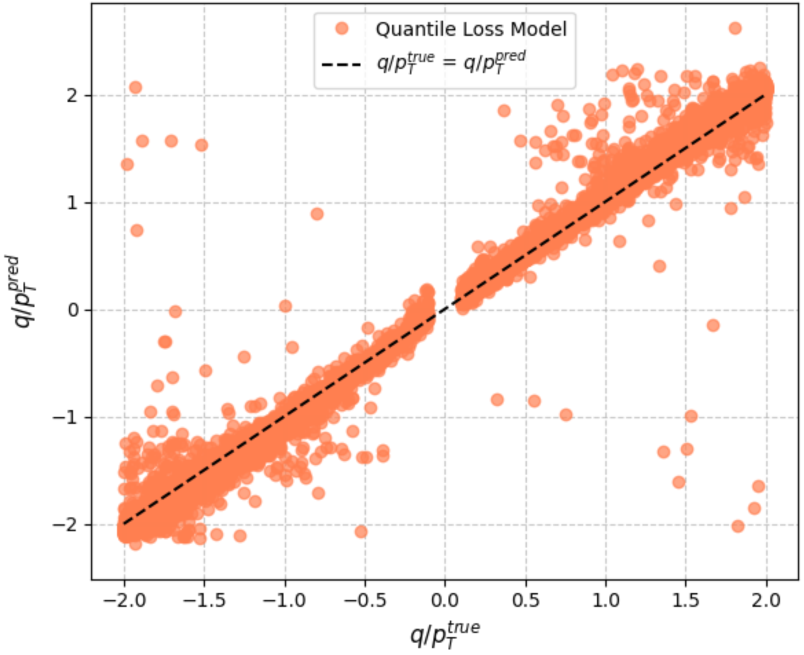
More results

r dphi z

TrackML Zenodo

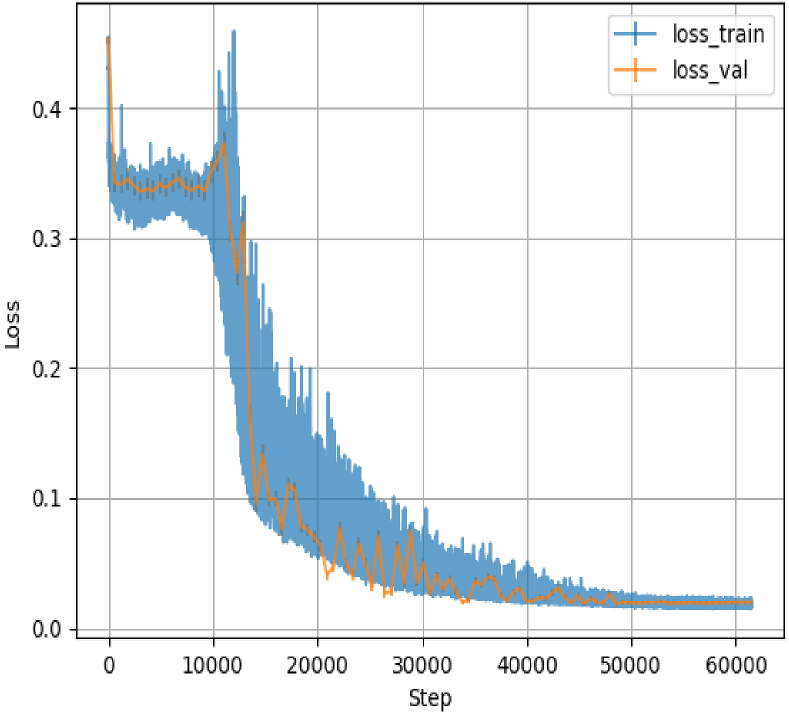
q/p_T^{true} vs q/p_T^{pred} $((tr, d\varphi, tz) \rightarrow (q/p_T, p_z))$



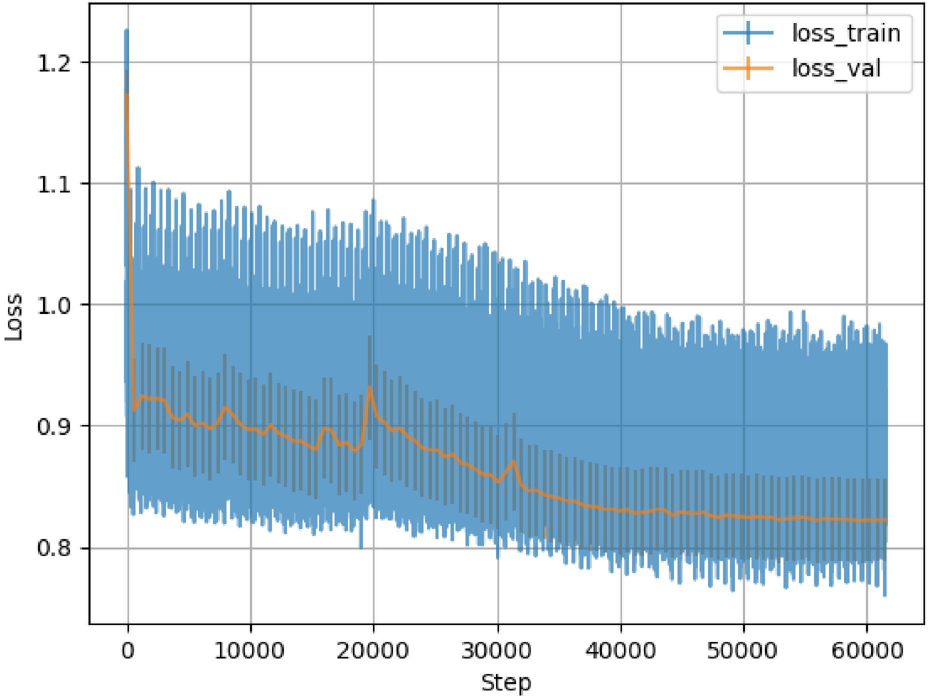


Loss

r dphi z Target: q/pT



r phi z **TrackML Zenodo**



Dataset update

Selections:
- nhits >= 3
- 0.5 <= pT <= 10   [GeV]
- |v_x| < 1 && |v_y|< 1   [mm]
- |eta| <= 1

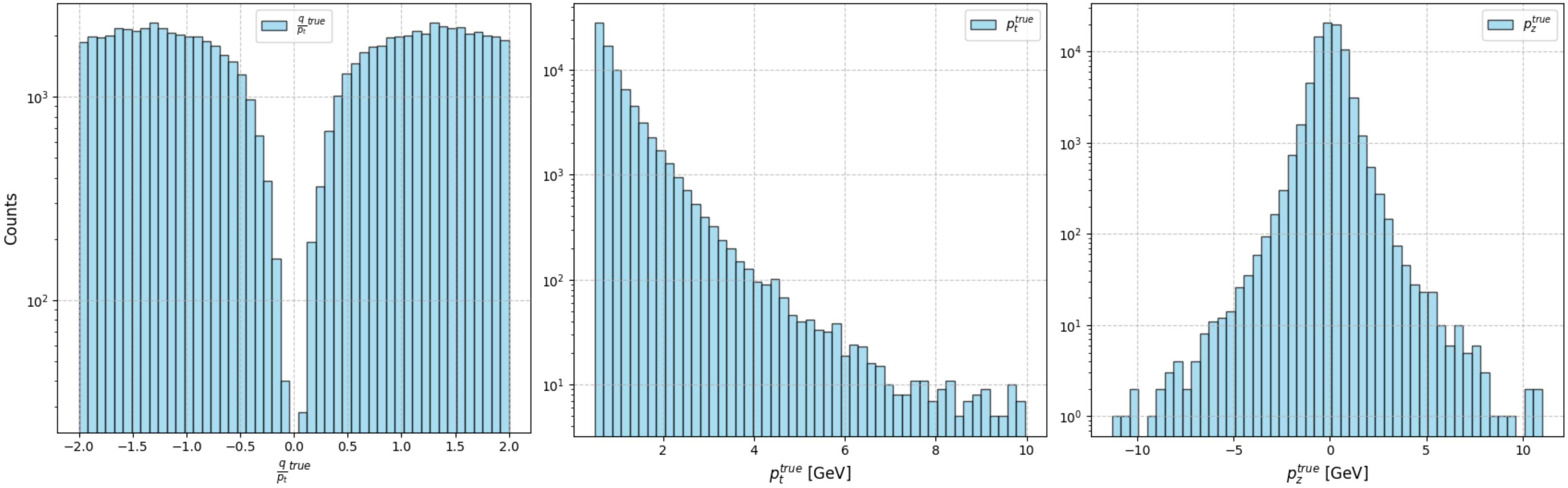
TrackML Kaggle:

Training: 1 232 896 particles
Validation: 154 082 particles
Testing: 153 788 particles

TrackML Zenodo:
(first file)

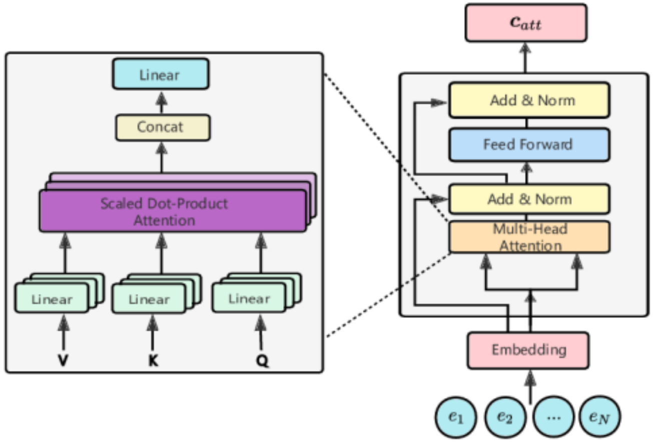
Training: 629 265 particles
Validation: 78 107 particles
Testing: ~78 656 particles

Target variables



TrackFormer

- **Transformer for track parameter regression**
- **Tested on several dataset: ToyTracks, Acts, TrackML**
- **Regression in pt and pz**
- **Shown promising results**

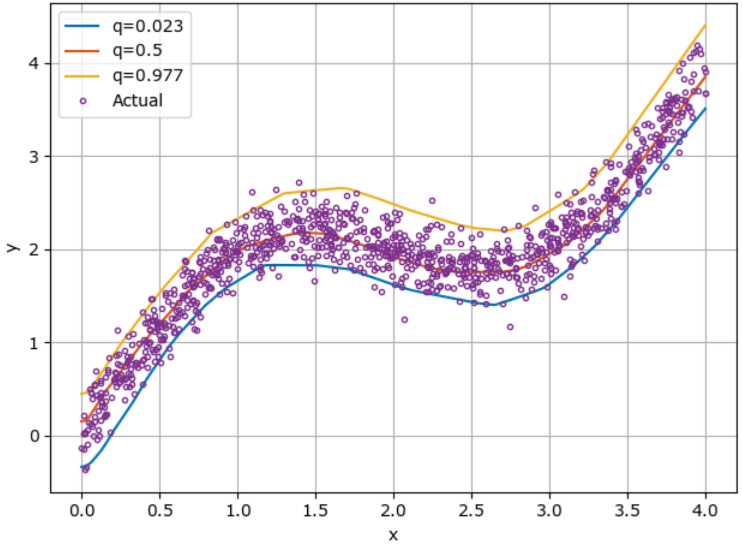


Sequences were padded to a fixed length

TrackFormer loss functions

Mean squared error:

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$



Quantile loss:

$$\mathrm{QL} = \frac{1}{n}\sum_{i=1}^{n}\left(\max(q(y_i - \hat{y}_i), (q-1)(y_i - \hat{y}_i))\right)$$

Dataset selection details

Selections:

- nhits >= 3
- 0.5 <= pT <= 10   [GeV]
- |v_x| < 1 && |v_y|< 1   [mm]
- |eta| <= 1

Test dataset:

Total: 1643787 particles

621539 particles, min_pt=0.5, max_pt=10

599332 particles, min_hits=3, min_pt=0.5, max_pt=10, keep_secondaries=True

553606 particles, min_hits=3, min_pt=0.5, max_pt=10, keep_secondaries=False ("|vx| < 1 && |vy| < 1" cut)

153788 particles, min_hits=3, min_pt=0.5, max_pt=10, keep_secondaries=False, max_abs_eta=1

Training

Architecture:
- input_dim: 3
- model_dim: 128
- num_classes: 2
- num_heads: 4
- num_layers: 2

Training:
- warmup: 100
- lr: 0.0005
- dropout: 0.1
- input_dropout: 0.1
- batch_size: 1024
- max_epochs: 100

Saving:
- monitor: val_loss
- mode: min

Variables:
- input:
  - tx, ty, tz
- input:
  - tr, tphi, tz
- input:
  - tr, dphi, tz
- target:
  - pt, pz
- target:
  - qopt, pz