The state-of-the-art quantum technology

The Transformer & its Applications to High Energy Physics Problems

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Workshop on Tensor Networks

☐ Performance of quantum circuit simulations using tensor network and state-vector techniques.

☐ The discussion about Quantum Machine learning:

　　○ Variational quantum algorithms

　　○ Quantum Generative Adversarial Networks

　　○ Quantum Anomaly Detection

☐ Most of the questions asked:

　　○ Where does classical machine learning fail?

　　○ What's hard to do using classical machine learning?

　　○ How do we be more specific and try to solve the problem that's hard to do classically?

　　○ How do we consider the performance to be better?

☐ A standard benchmark dataset for machine learning is used to understand the performance of different models and why we shouldn't make a benchmark for HEP data.

$$\mathcal{H}(\ell, k) = \mathcal{H}_{\mathrm{CAS}}(\ell) \bigoplus \mathcal{H}_{\mathrm{RAS}}(L - \ell, k)$$
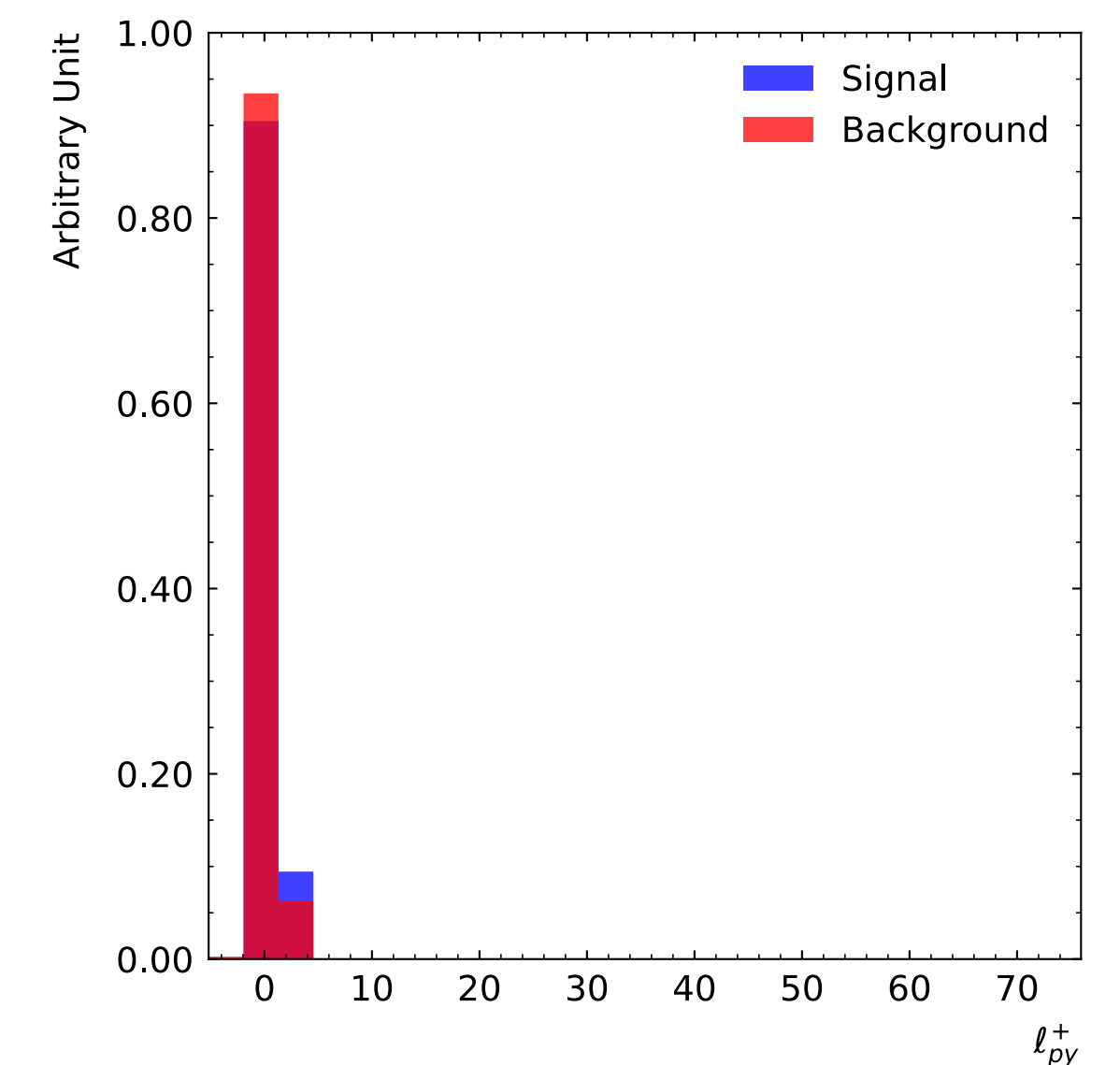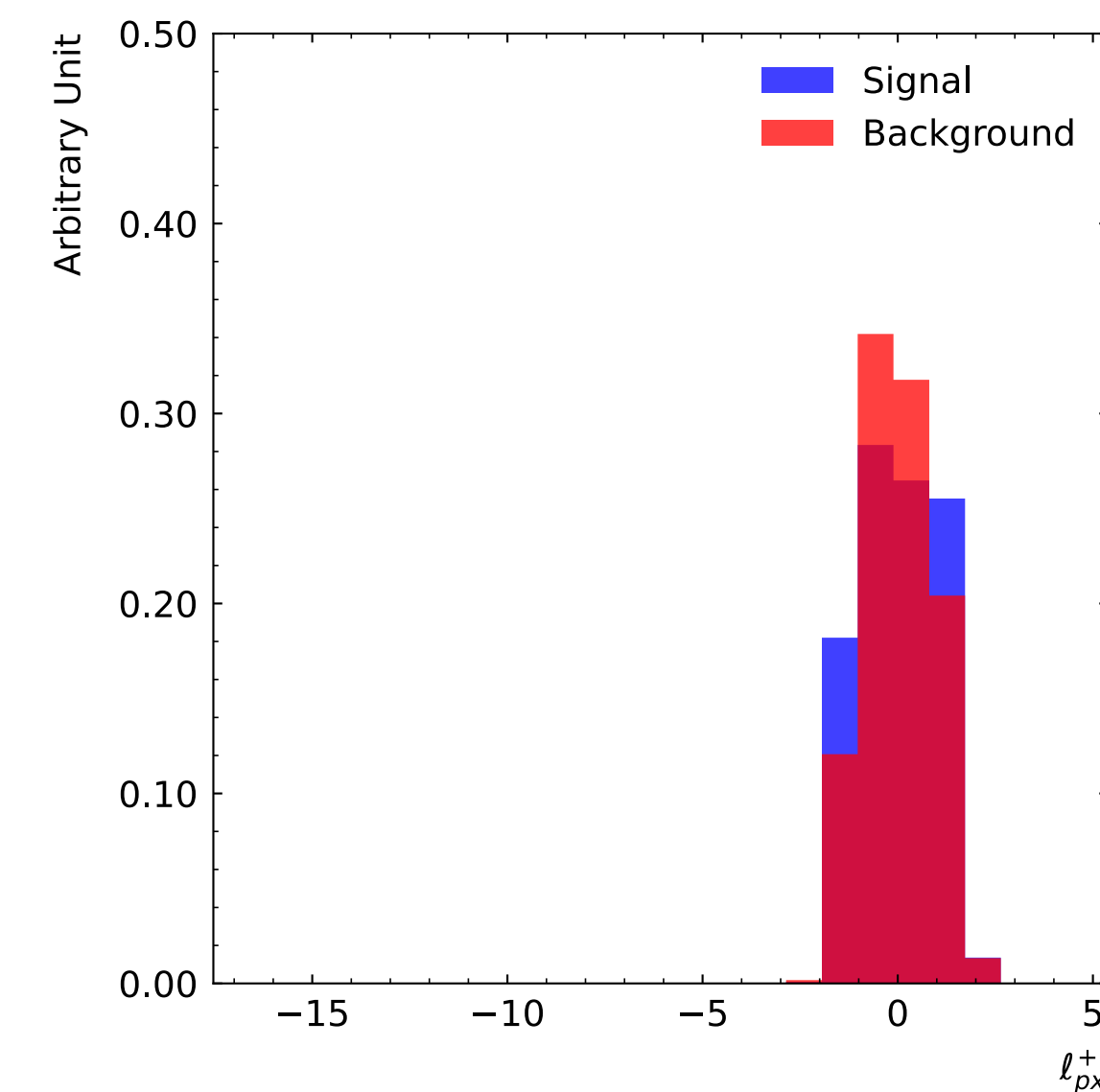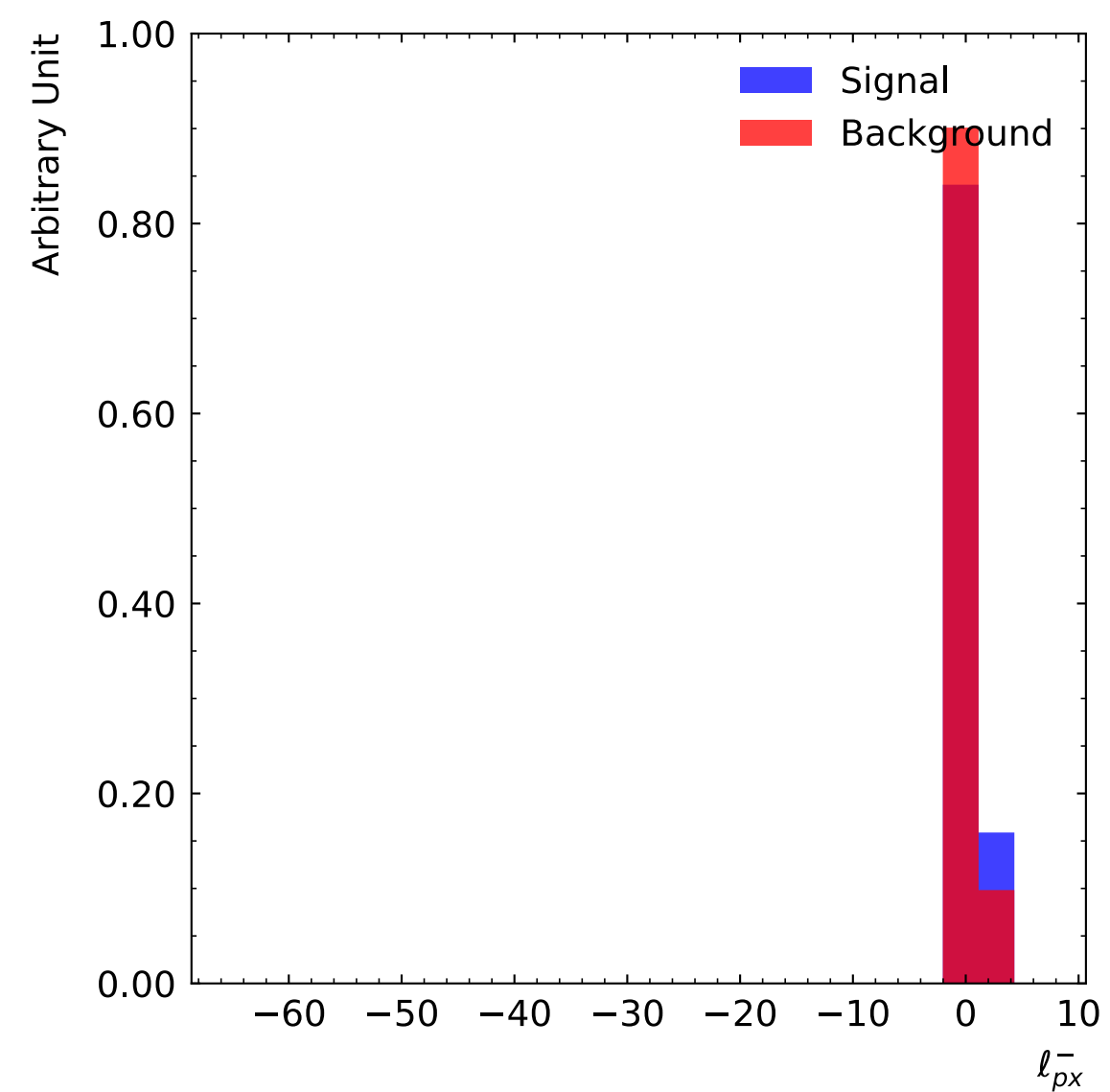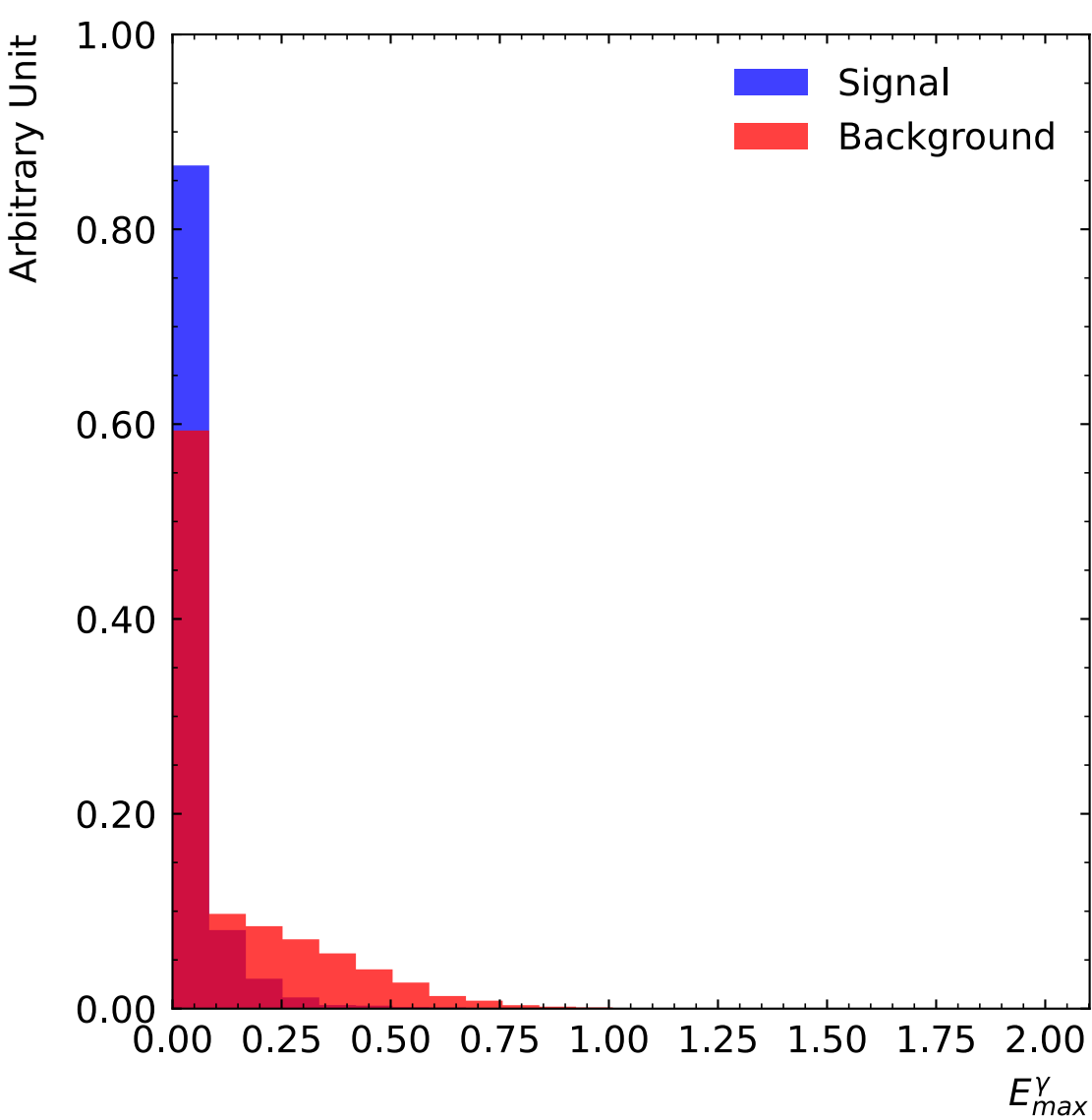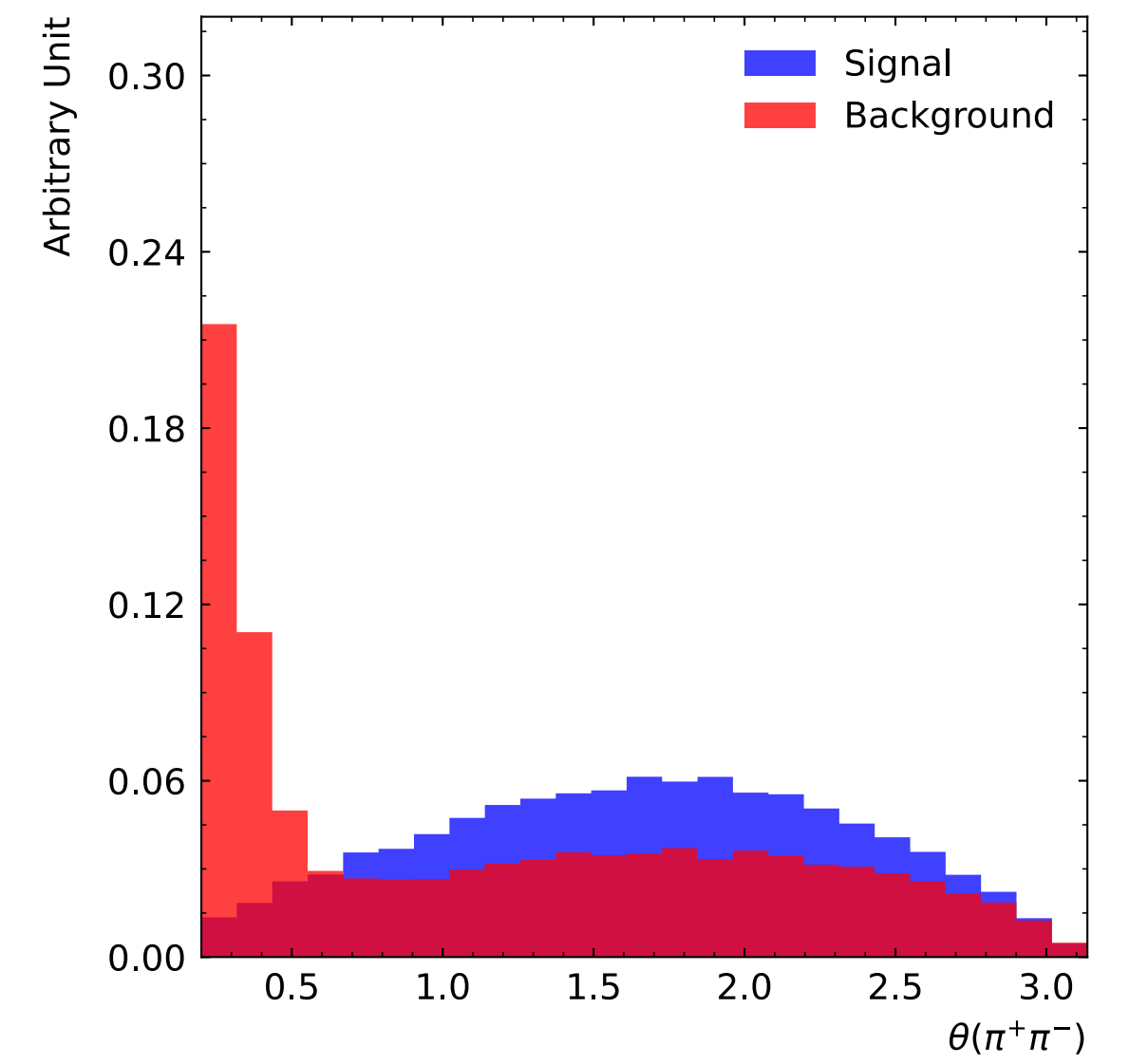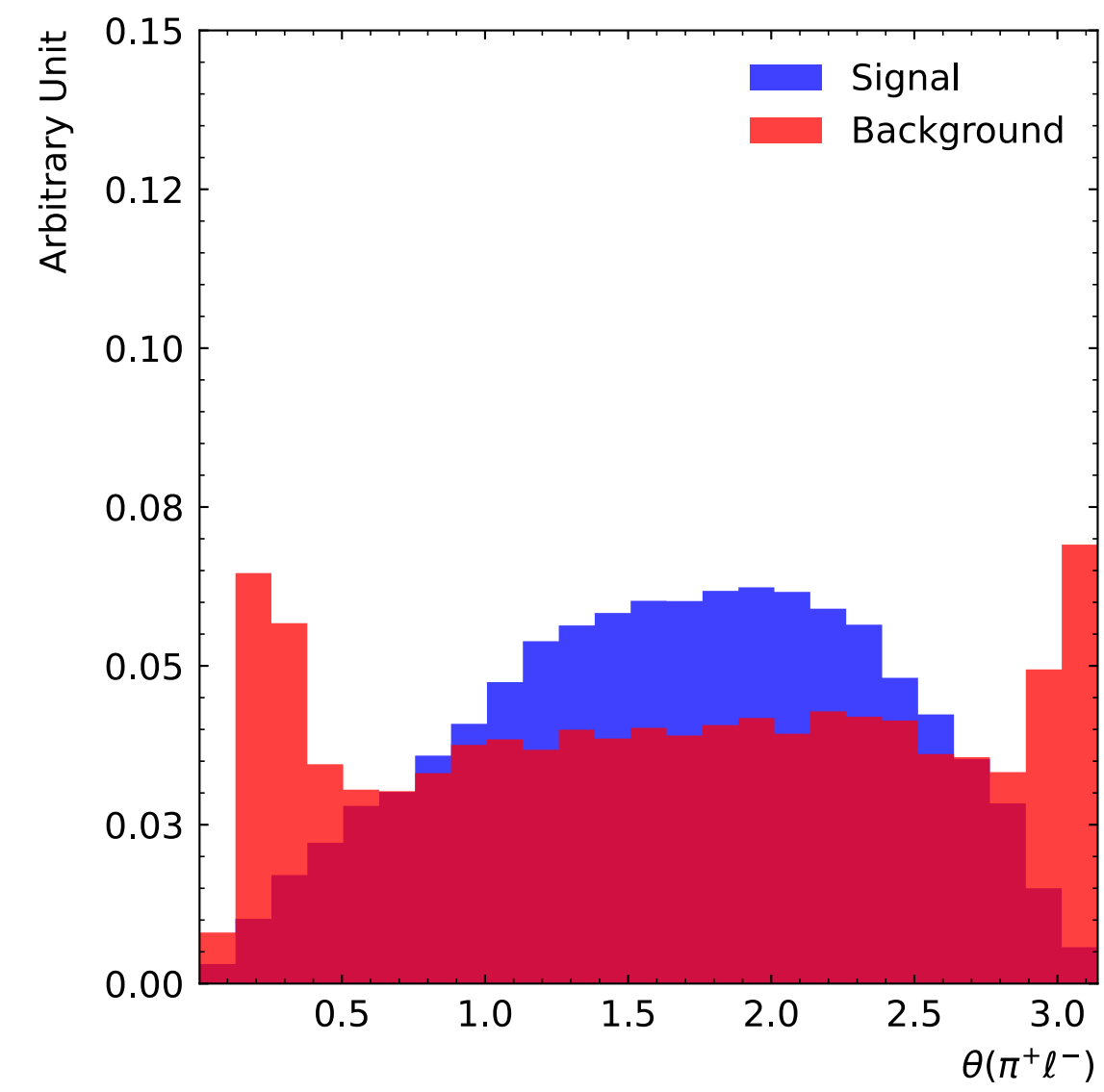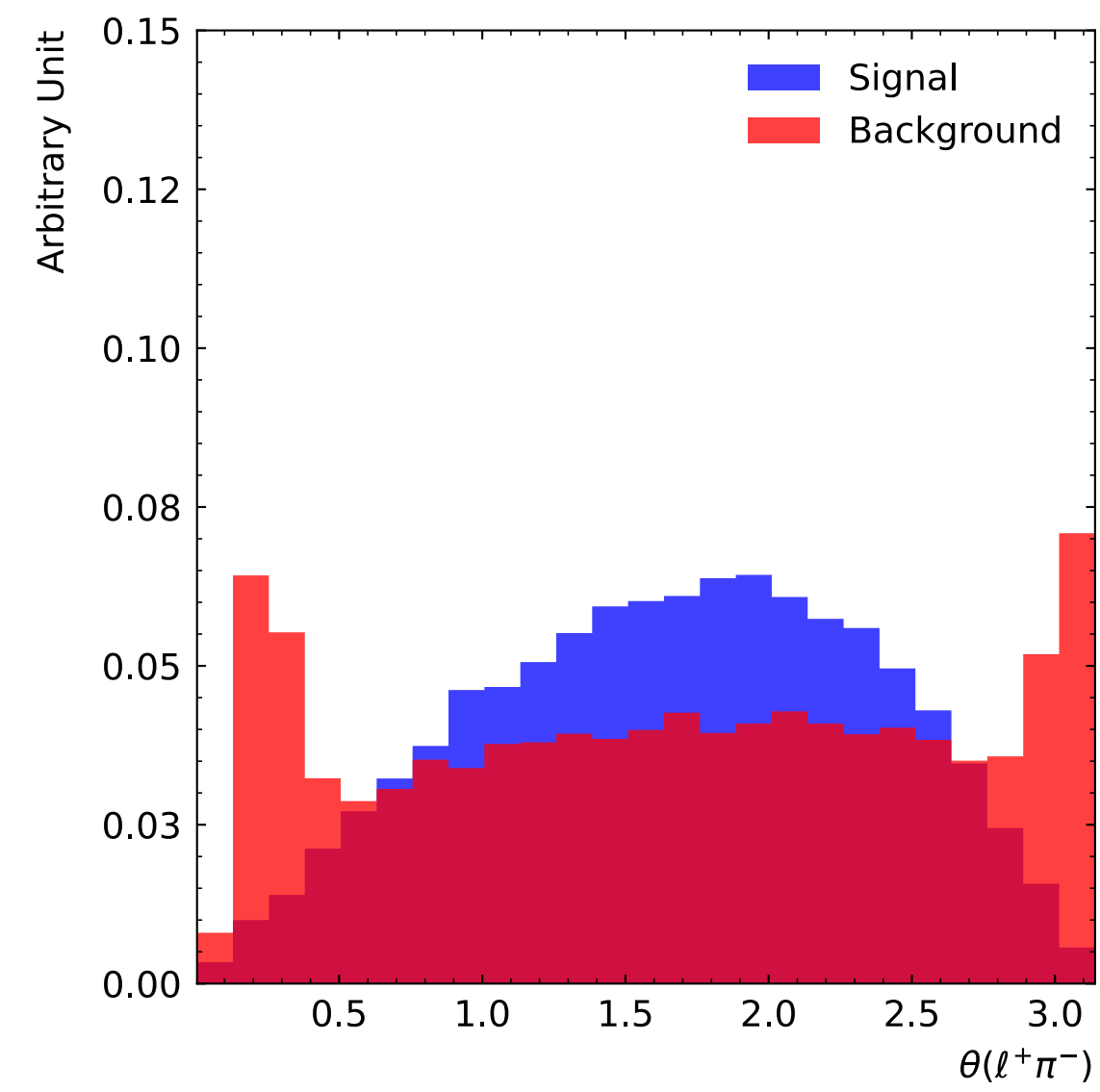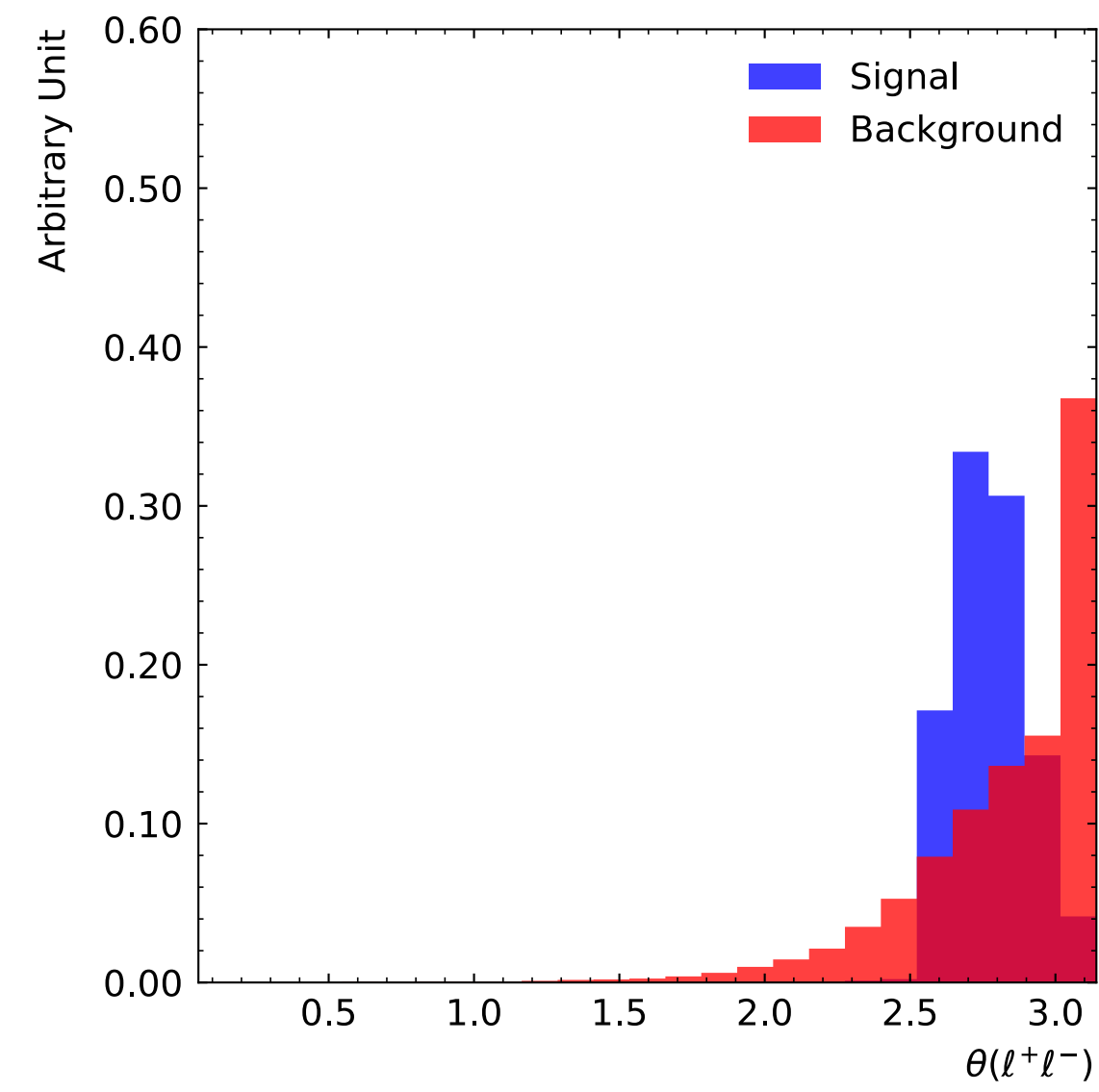
$$U(\alpha_1, \ldots, \alpha_d) = \sum_{m_1=1}^{r_1} \cdots \sum_{m_{d-1}=1}^{r_{d-1}} A_1(\alpha_1, m_1) A_2(m_1, \alpha_2, m_2) \cdots A_d(m_{d-1}, \alpha_d).$$
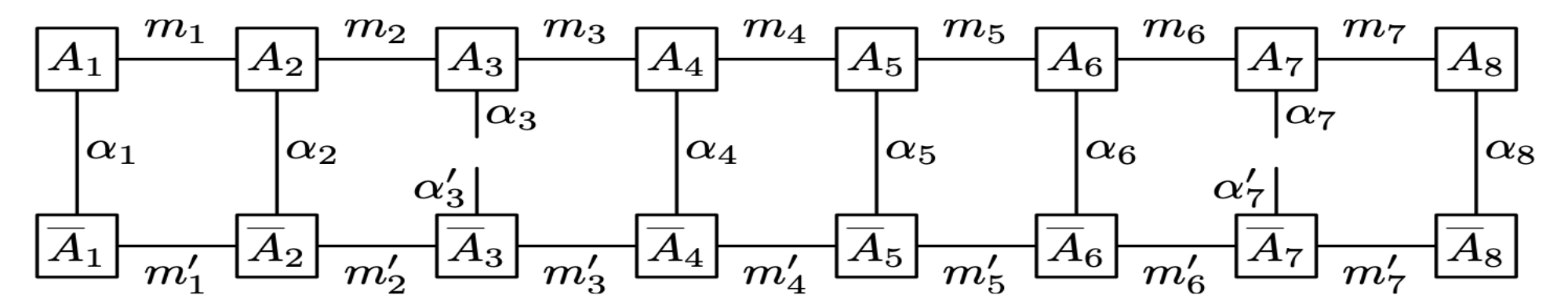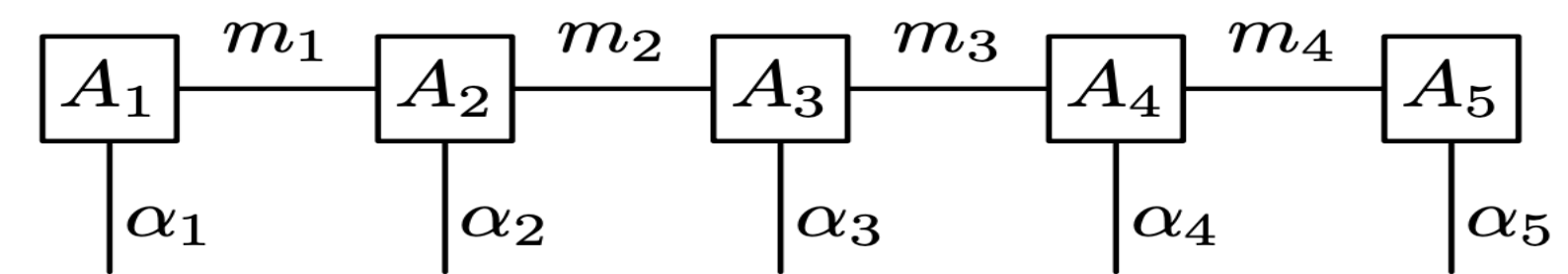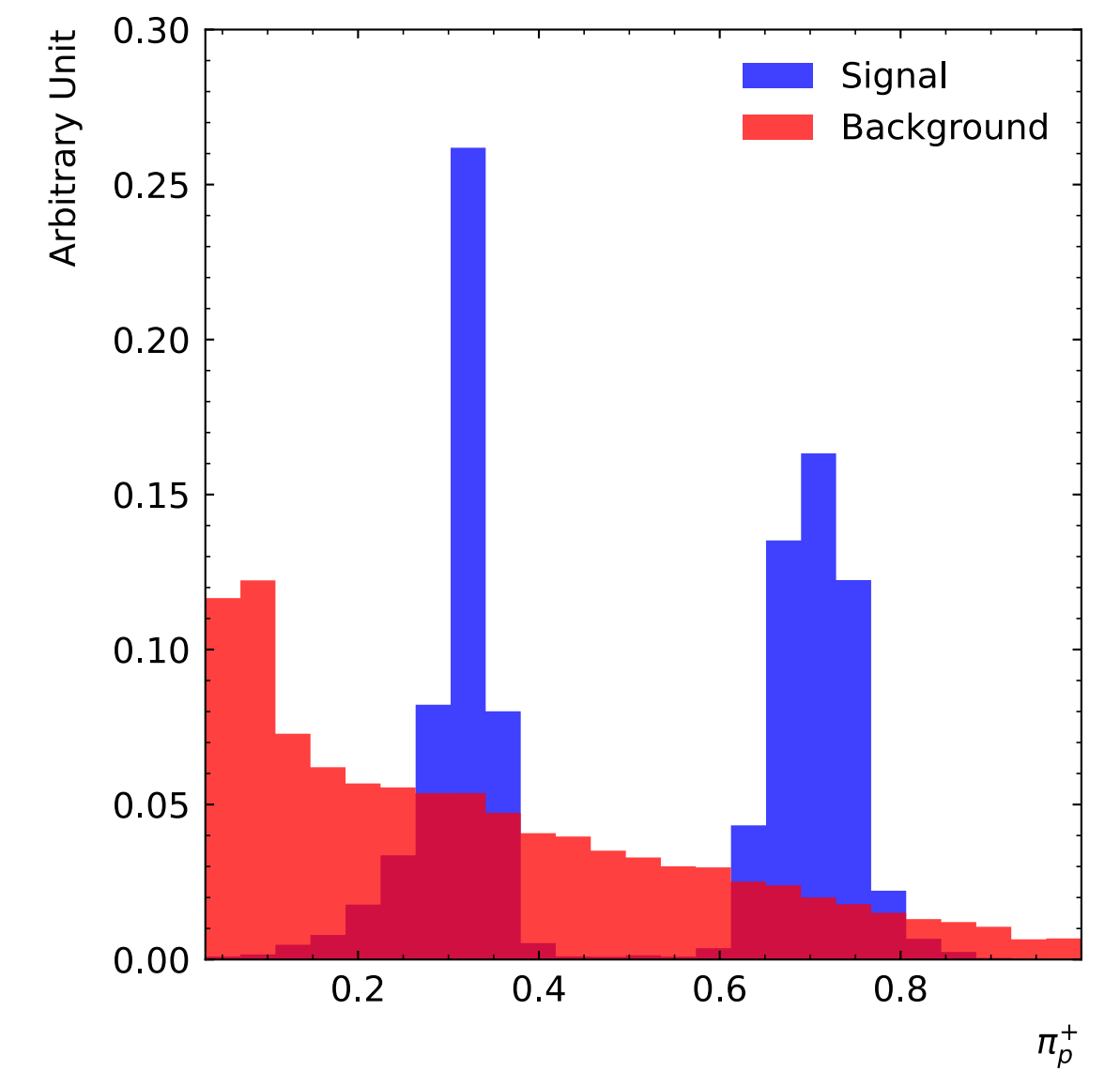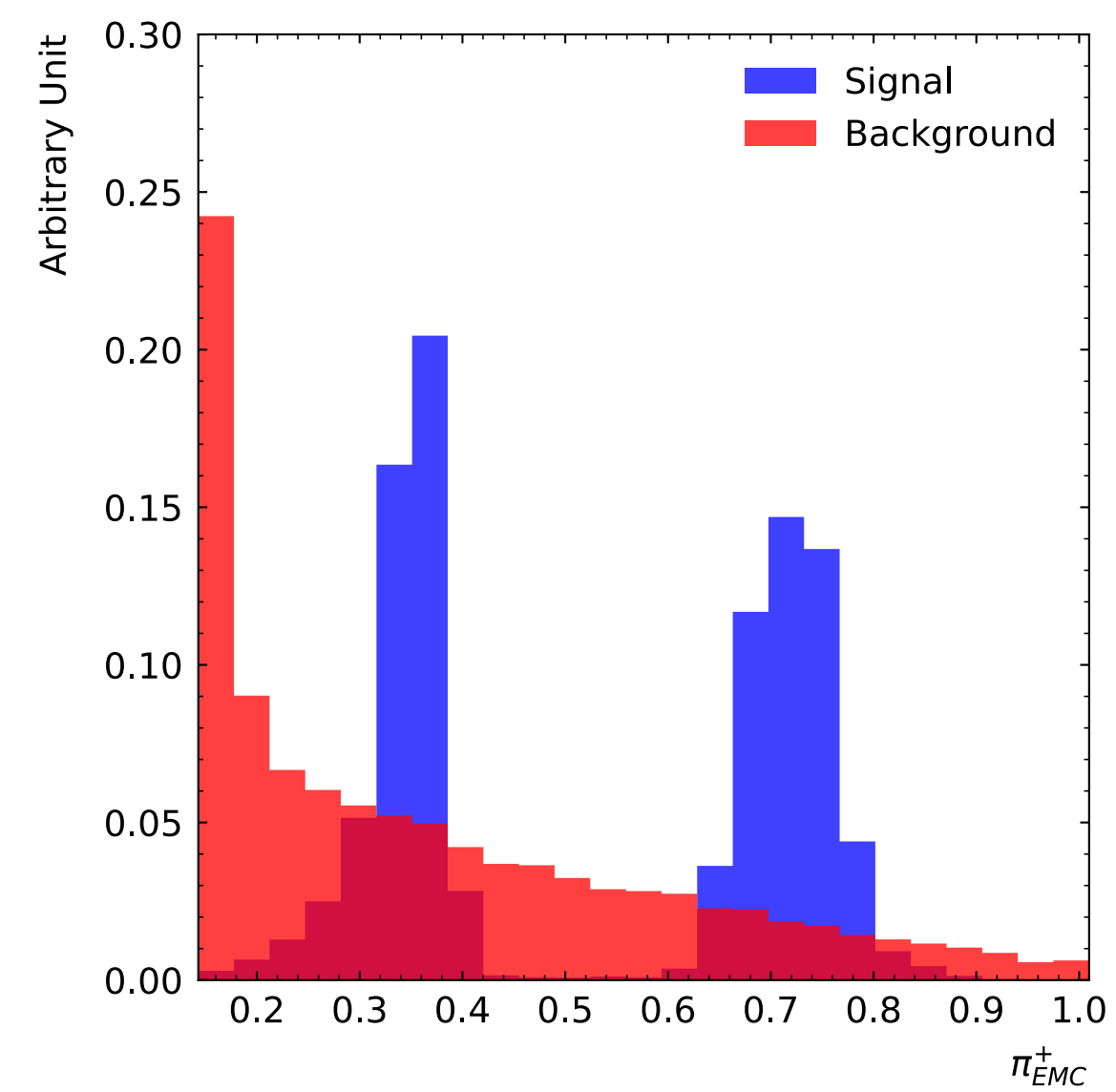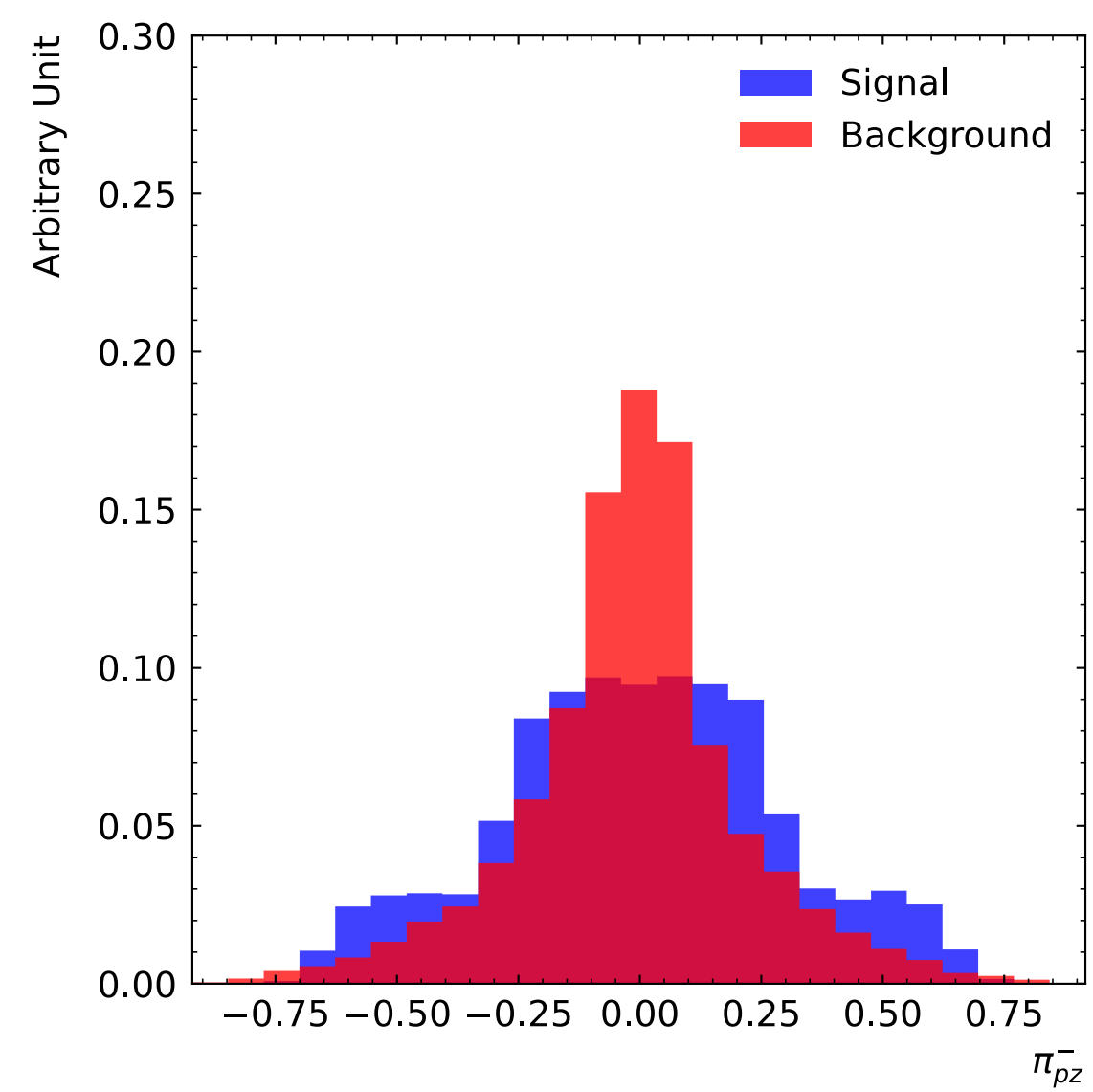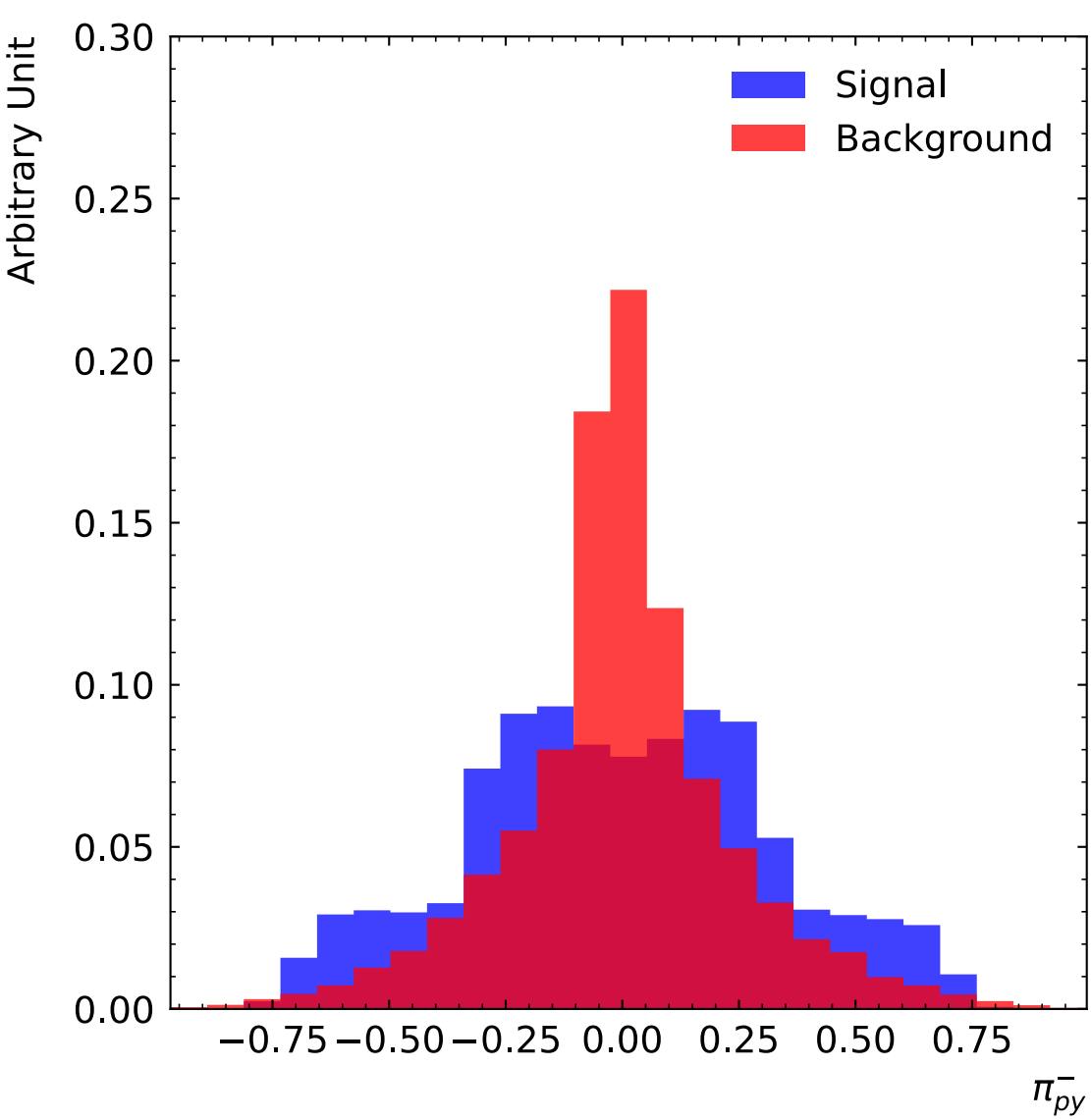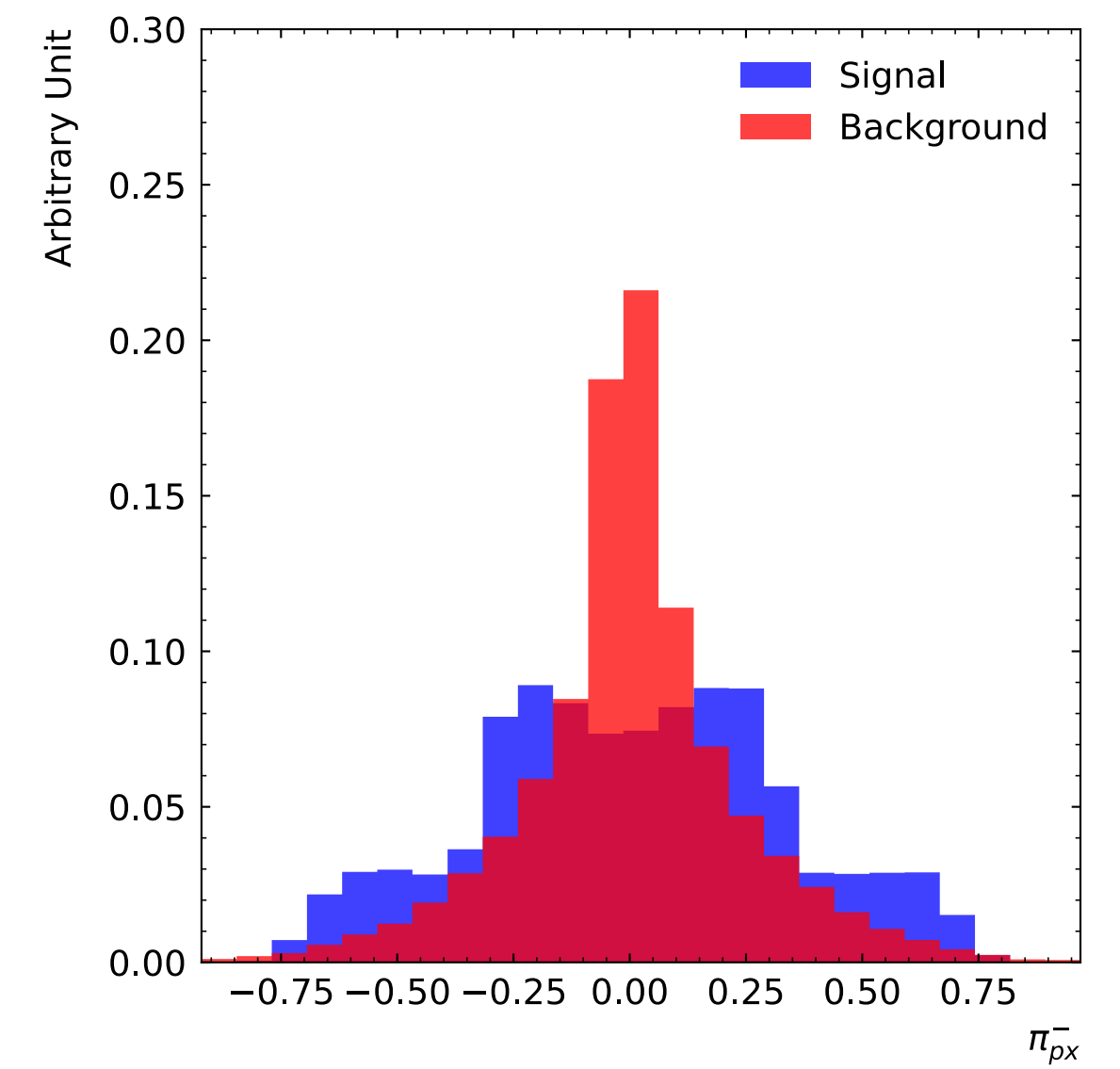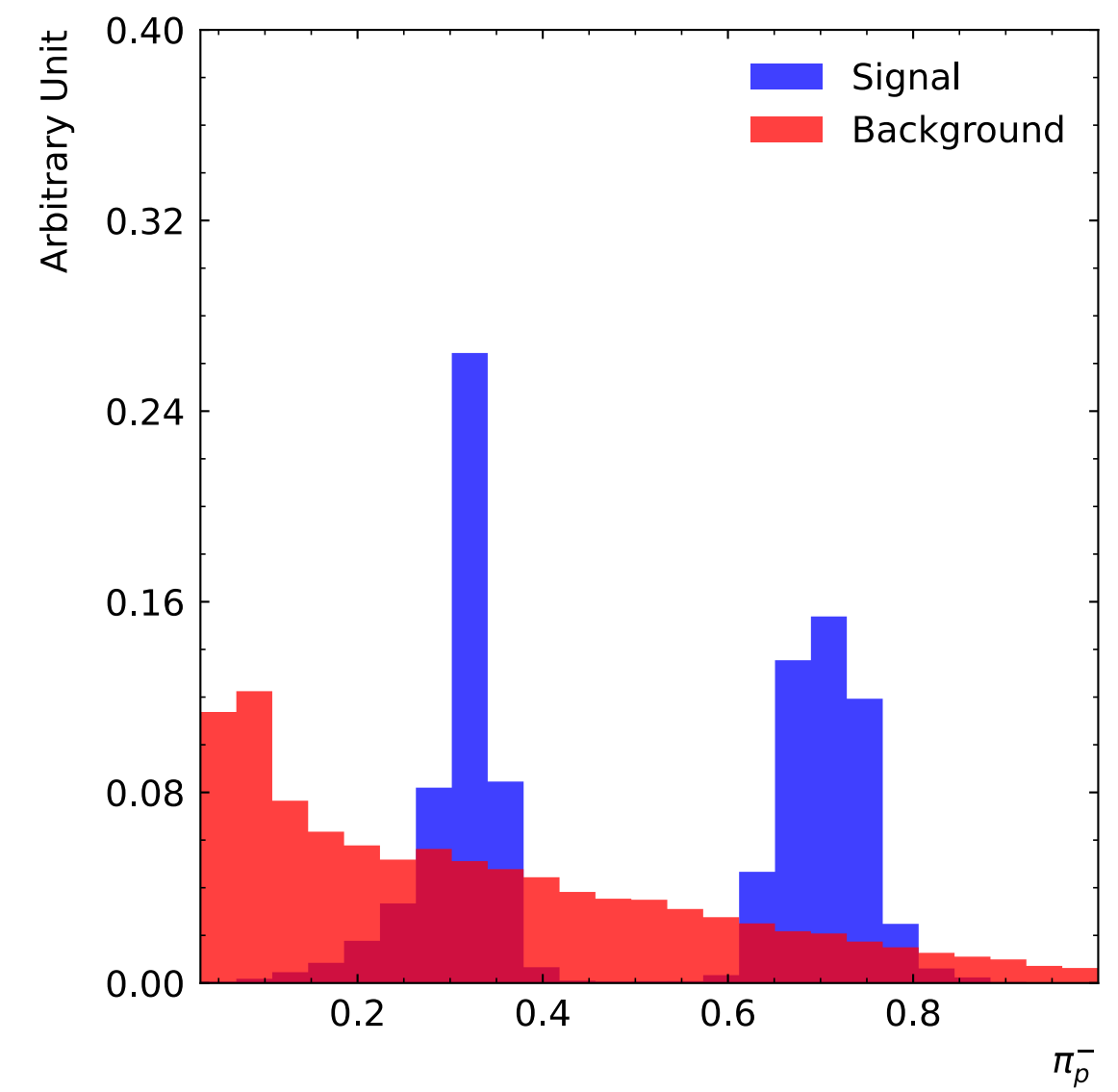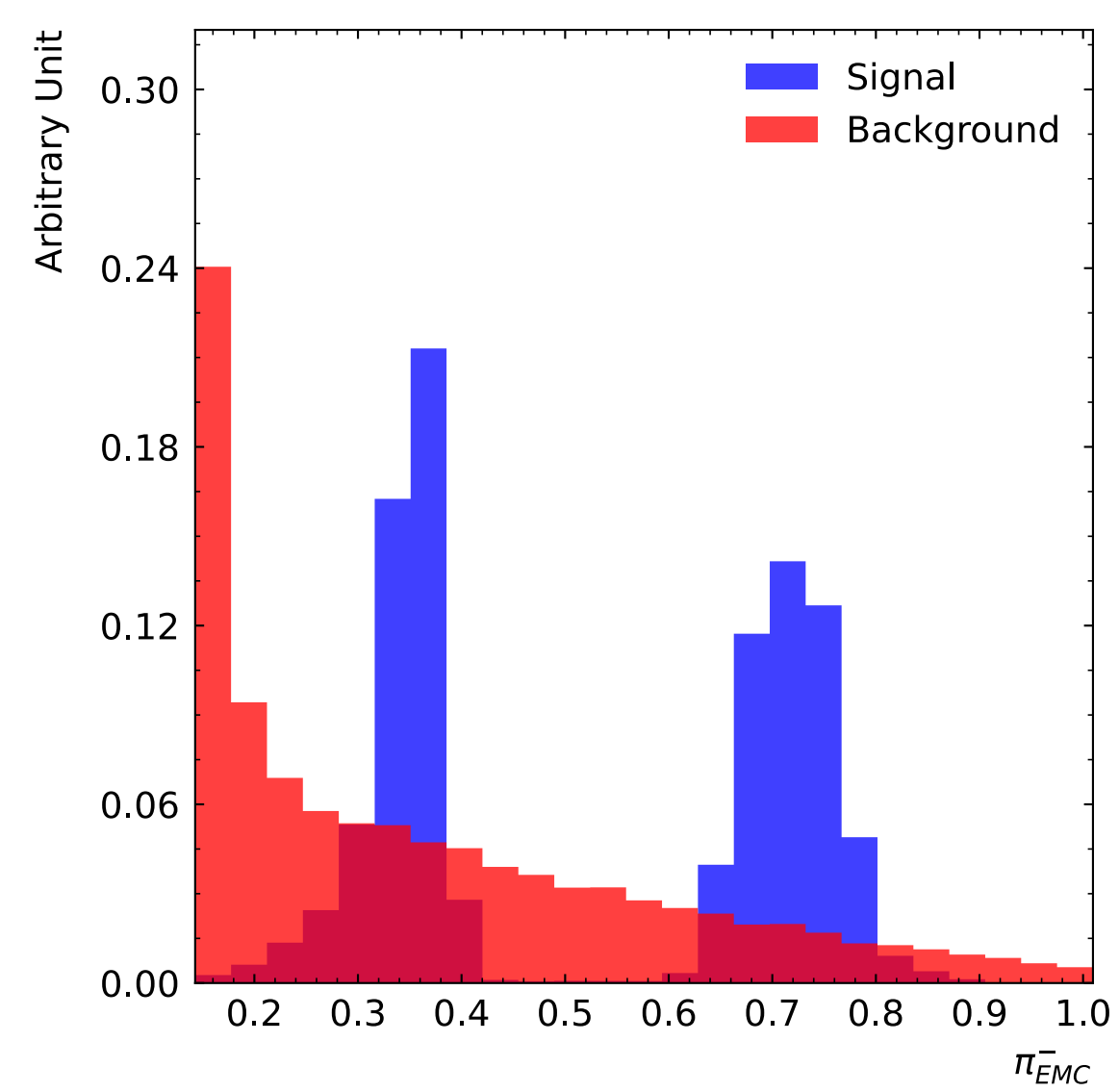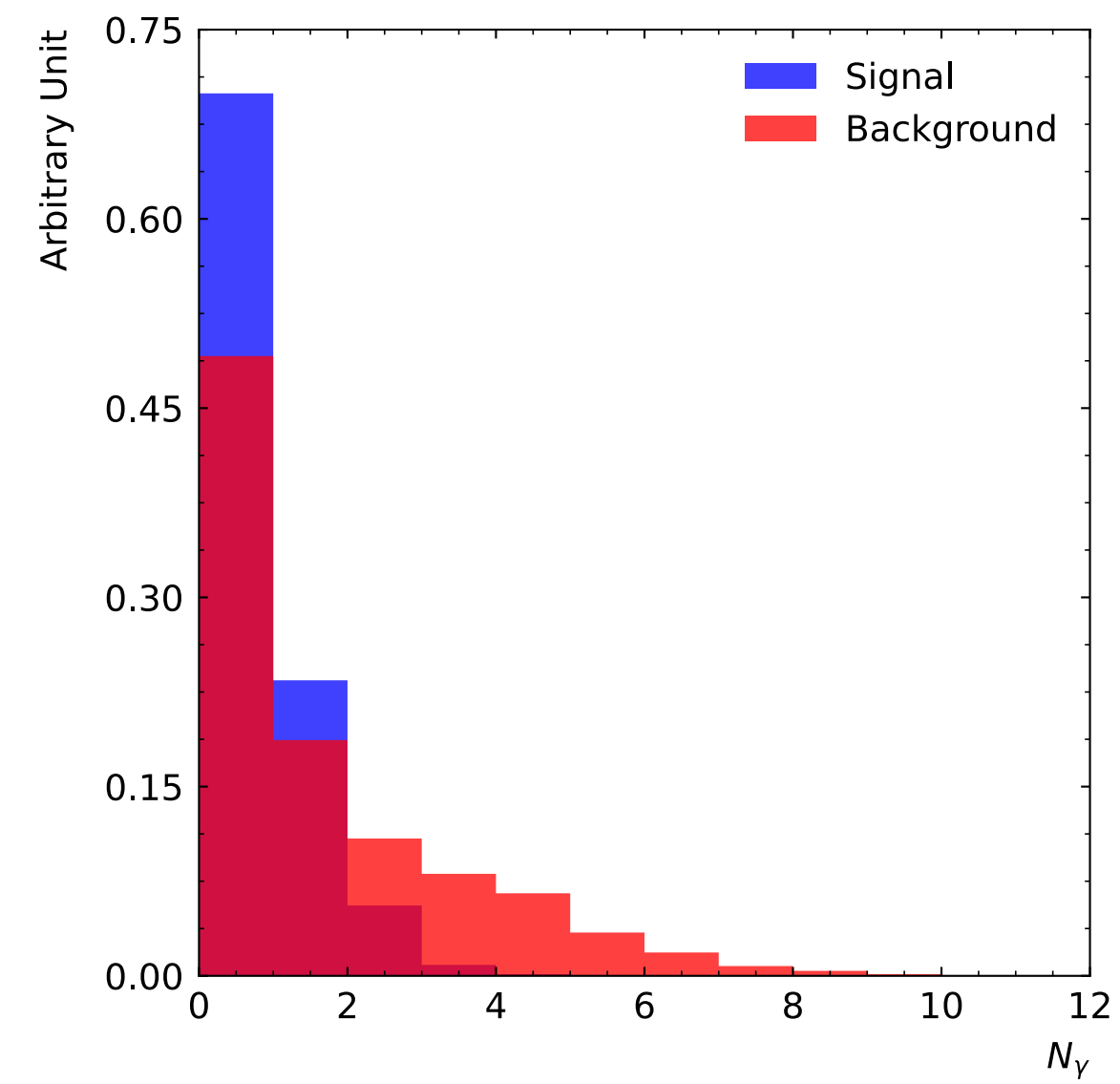
Search for Zc(3900) at BESIII

☐ I'm going to cross-check what Pan's did.

☐ Using 26 variables and 20k events for training, validation, and testing the Q/Transformer.

☐ I'll also look at the distributions of different variables to ensure things are all right.
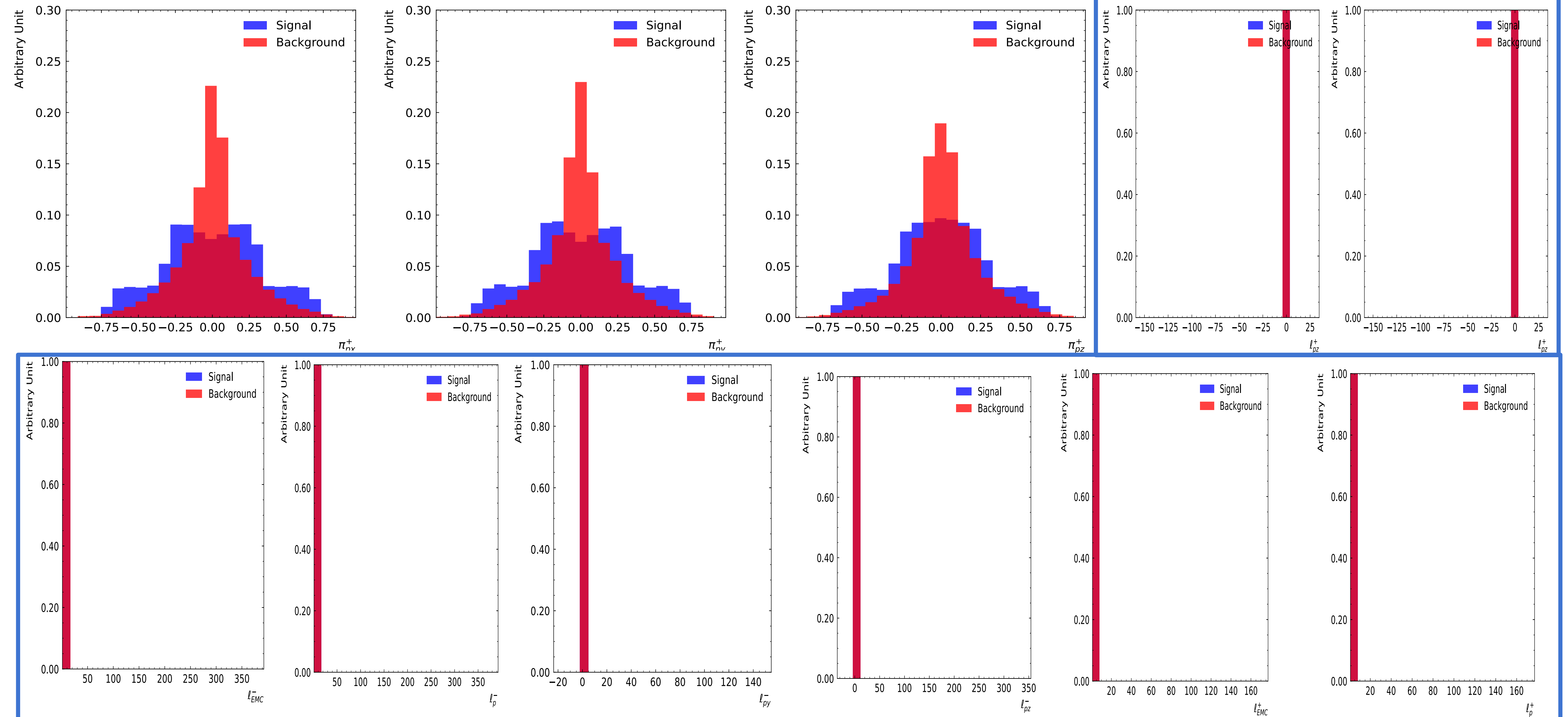
☐ Thanks to Pan for providing the samples.

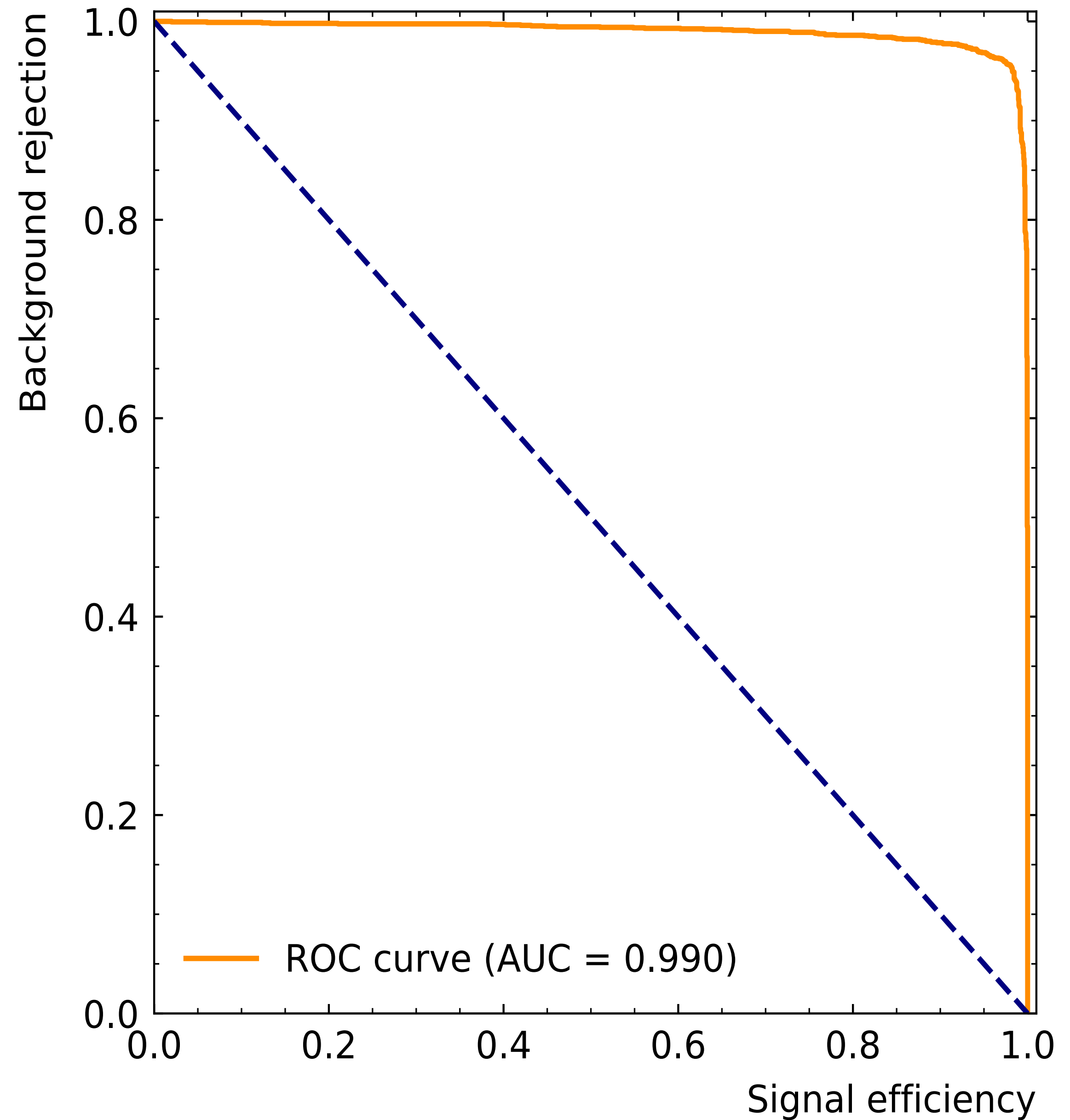# Kinematic distributions

Kinematic distributions
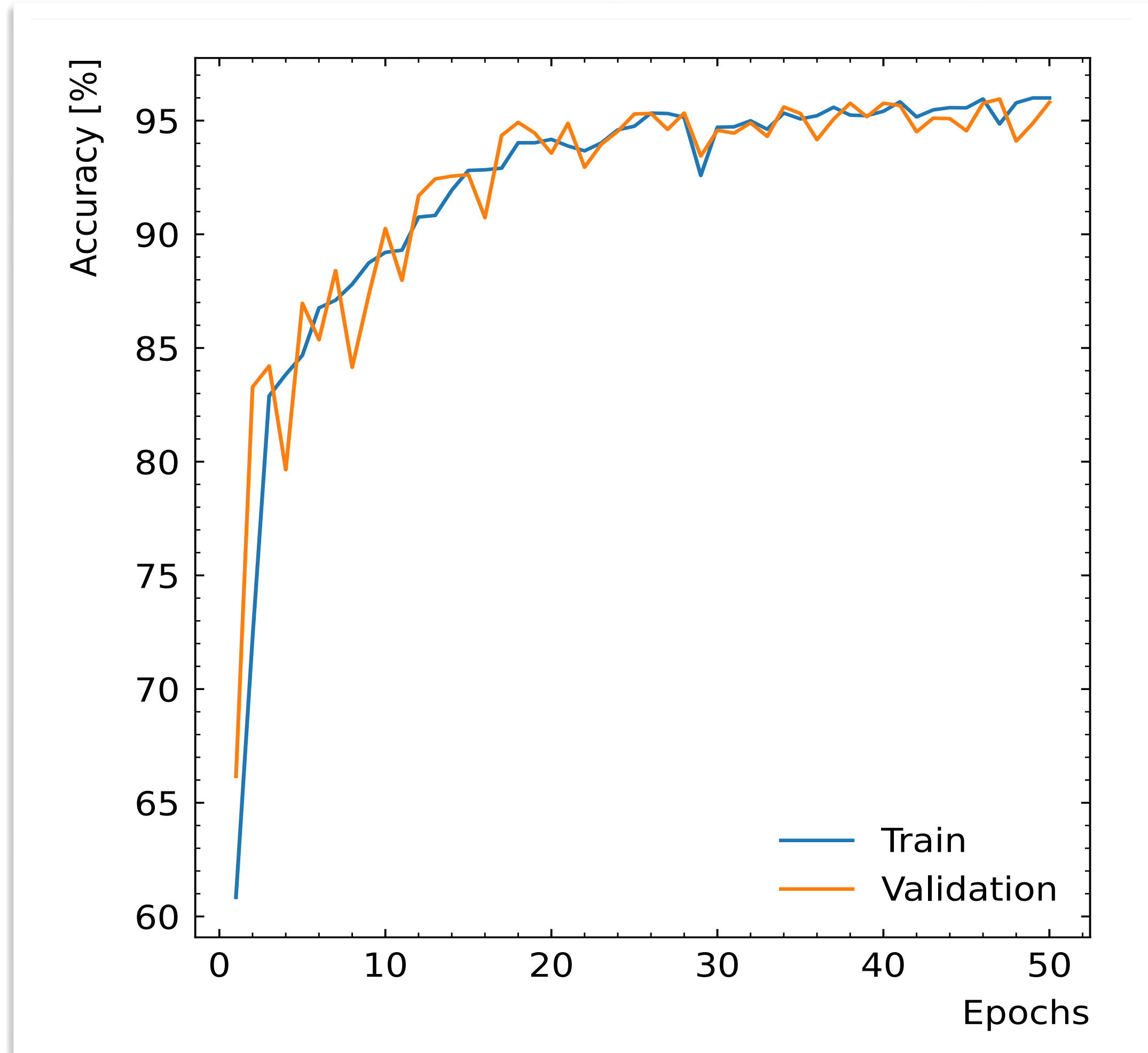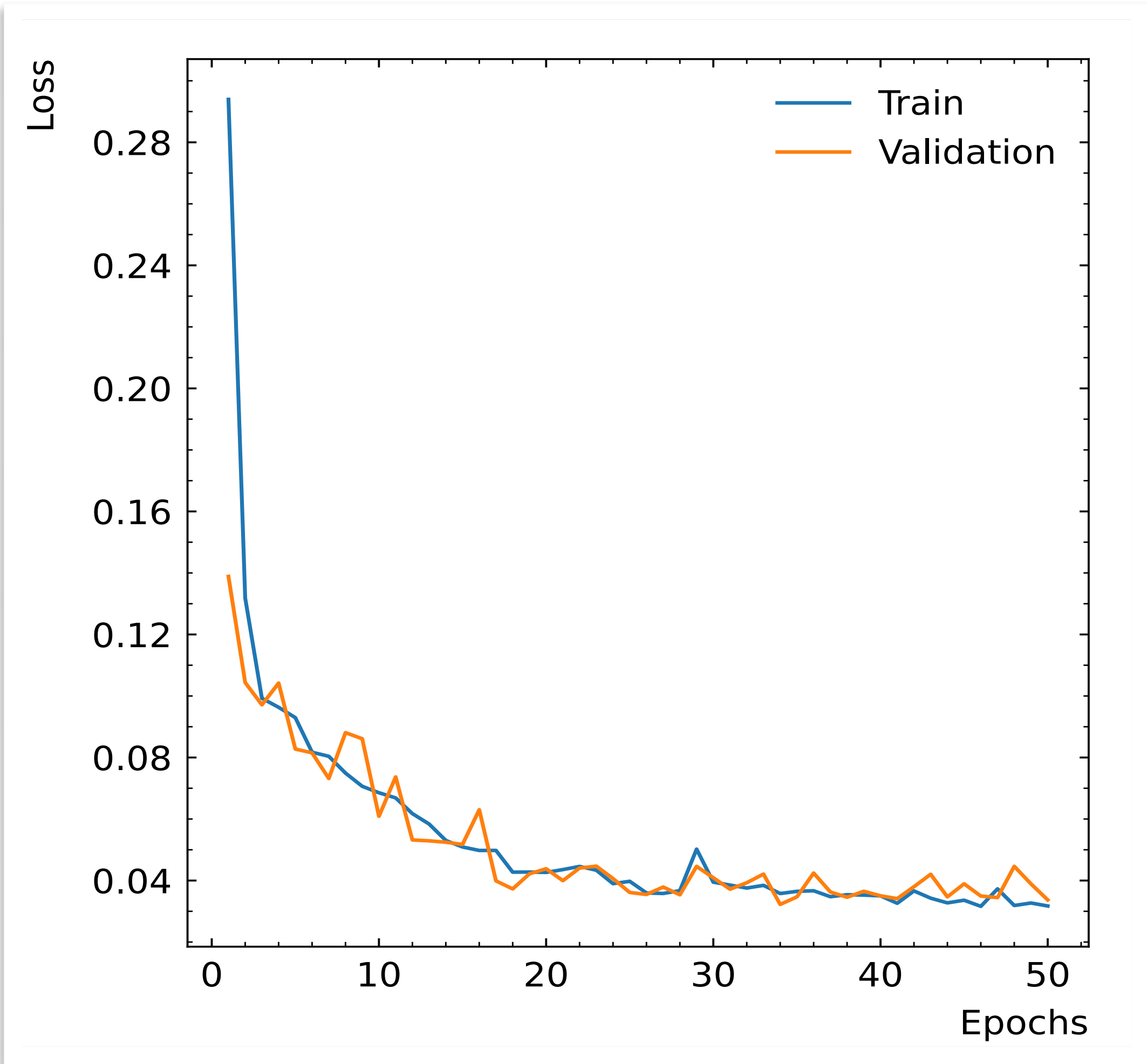
Kinematic distributions

Transformer for the Zc(3900)

☐ Total number of events: 20k.

☐ Training, validation, and testing: 11.2k, 4.8k, and 4k

☐ Number of variables: 26

☐ L rate & batch: 0.0036 & 128

☐ **Architecture:**

   ○ $d_{FF} = 500$

   ○ Dropout = 0.0066

   ○ $iL = 6$

   ○ $h = 4$

   ○ Embedded dimension: 64

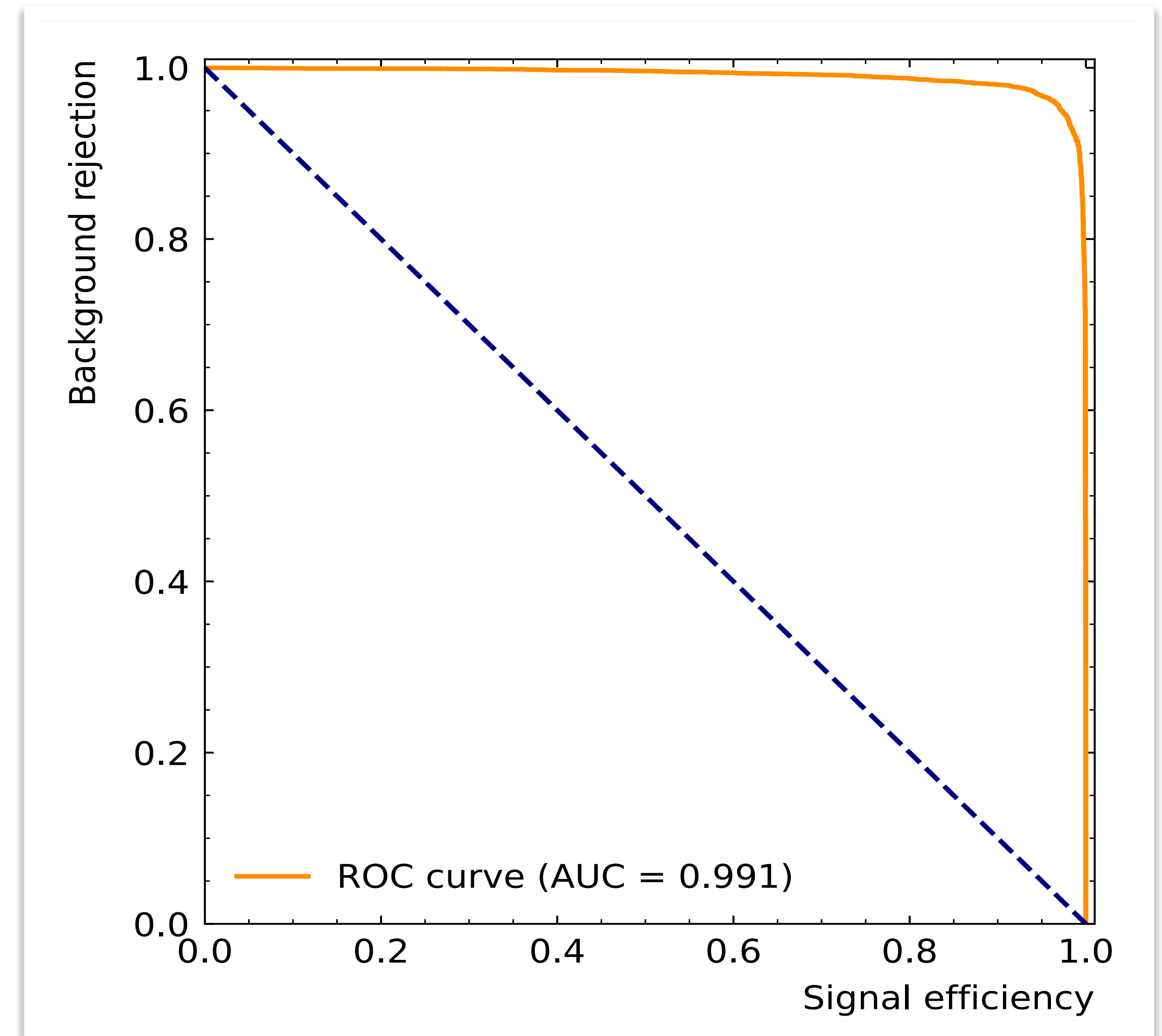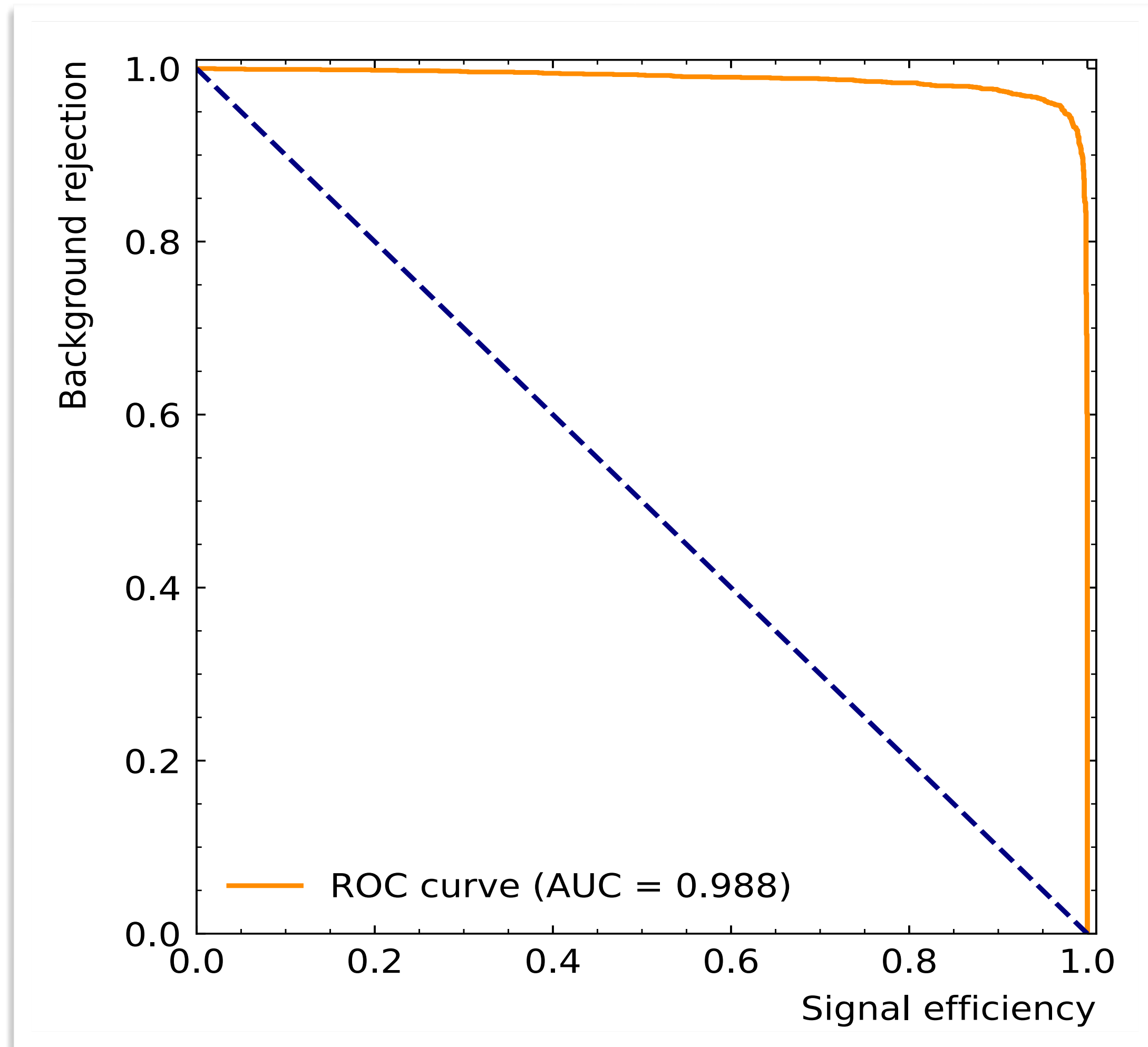☐ Total time for the training and validation: 0h:3m:32s

Transformer for the Zc(3900)

☐ Total number of events: 20k for 26 variables.

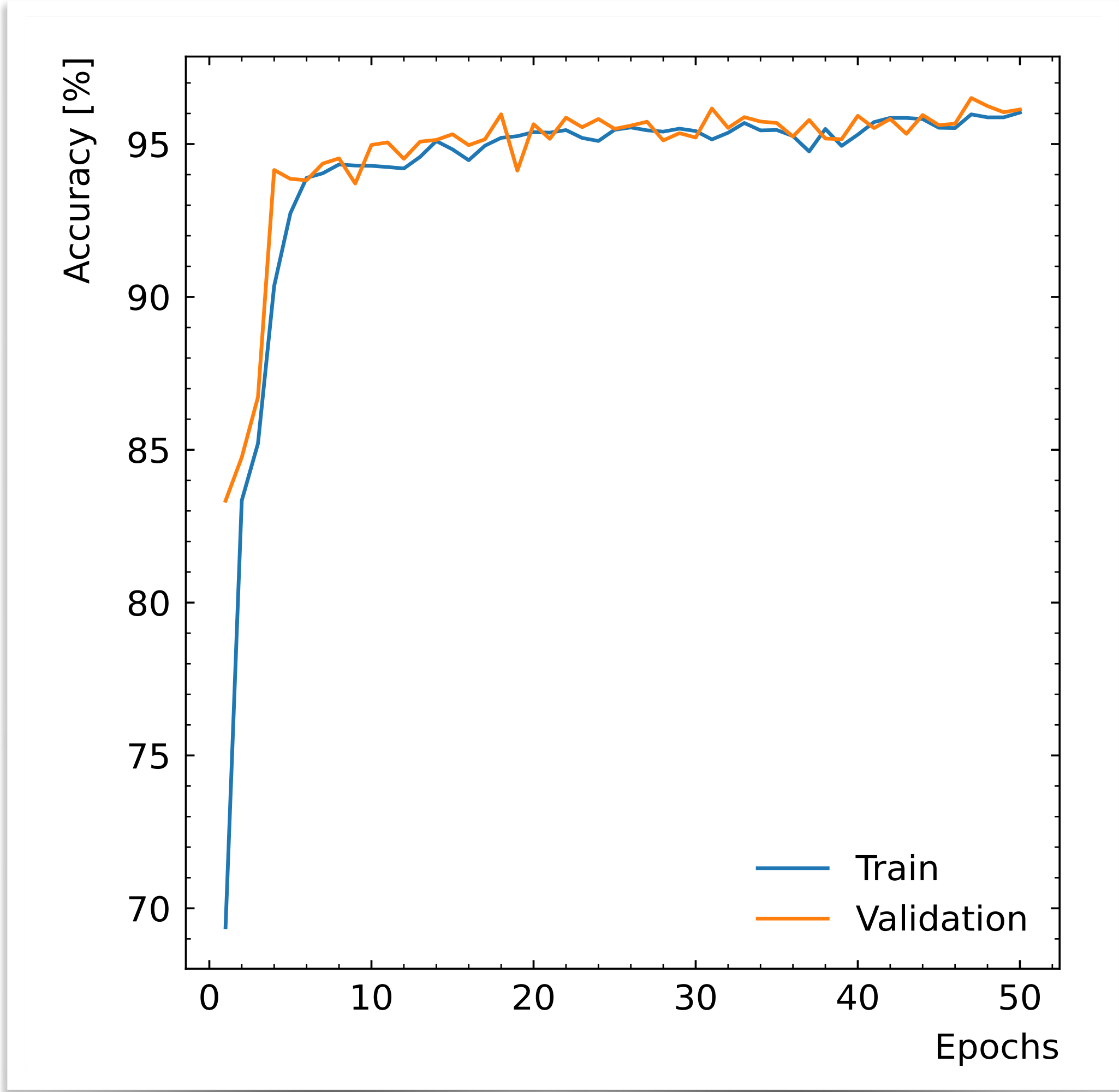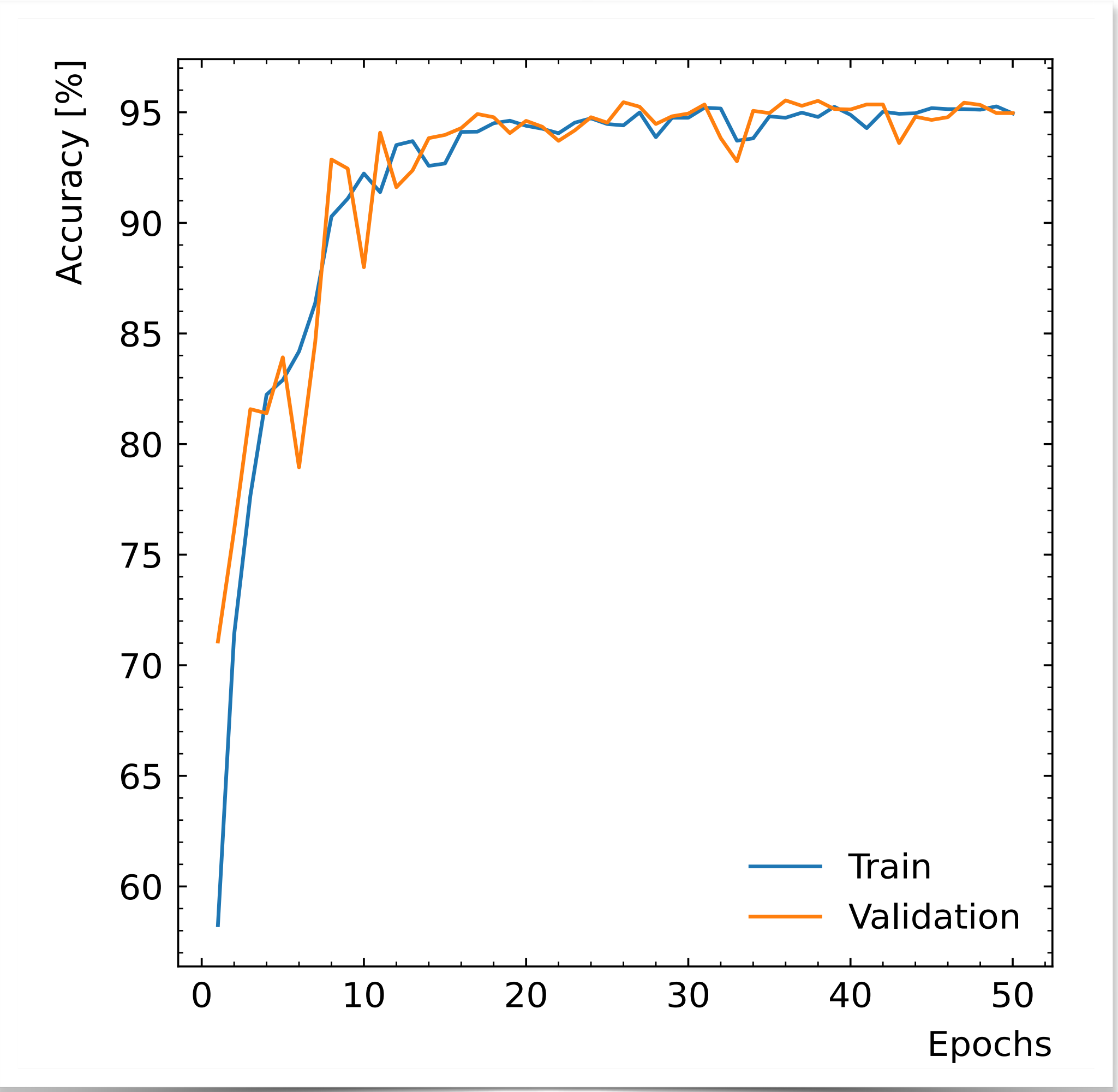☐ Training, validation, and testing: 11.2k, 4.8k, and 4k

Transformer for the Zc(3900)

□ Total events: 20k (left) and 50k (right) for 19 variables.

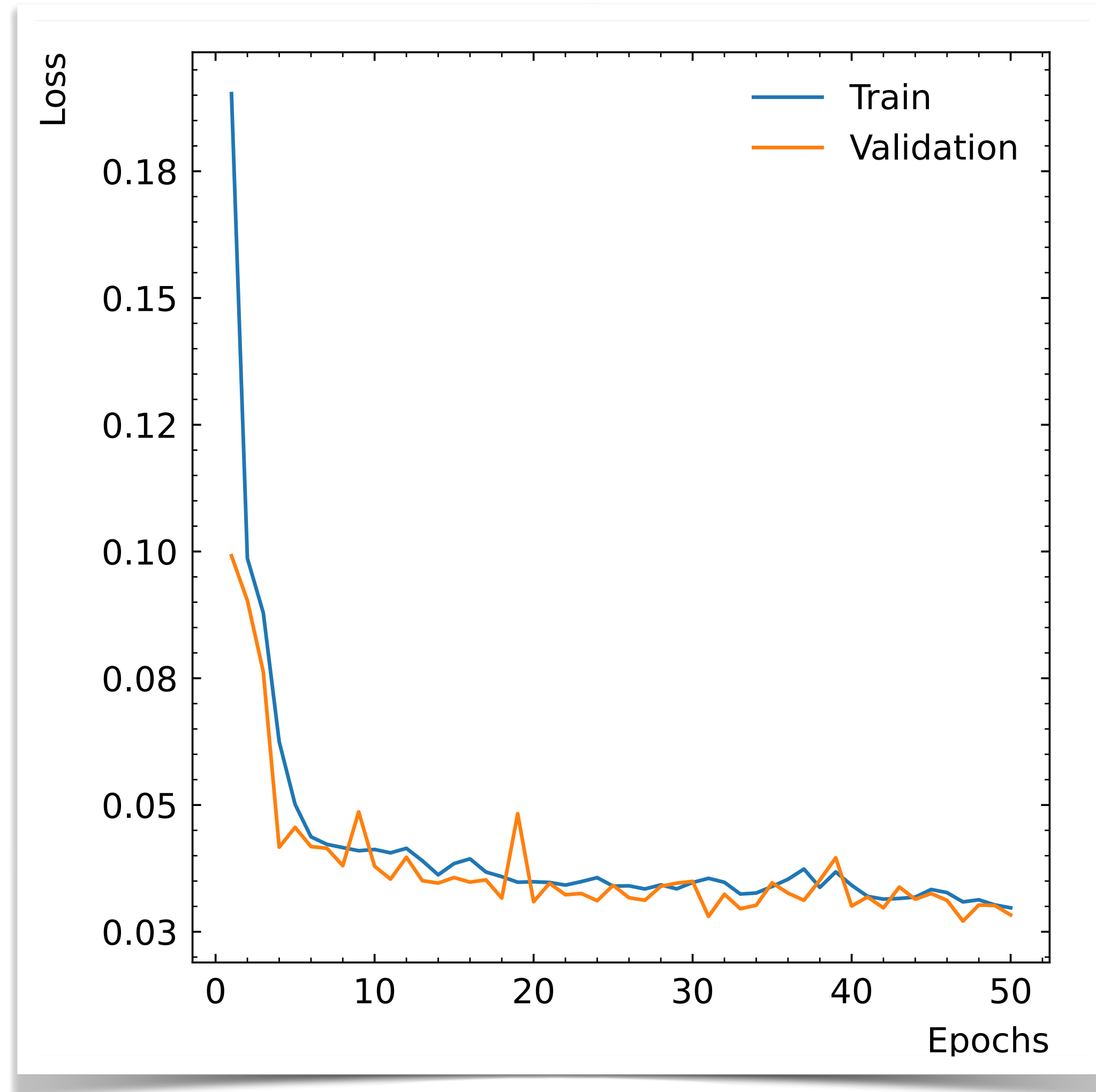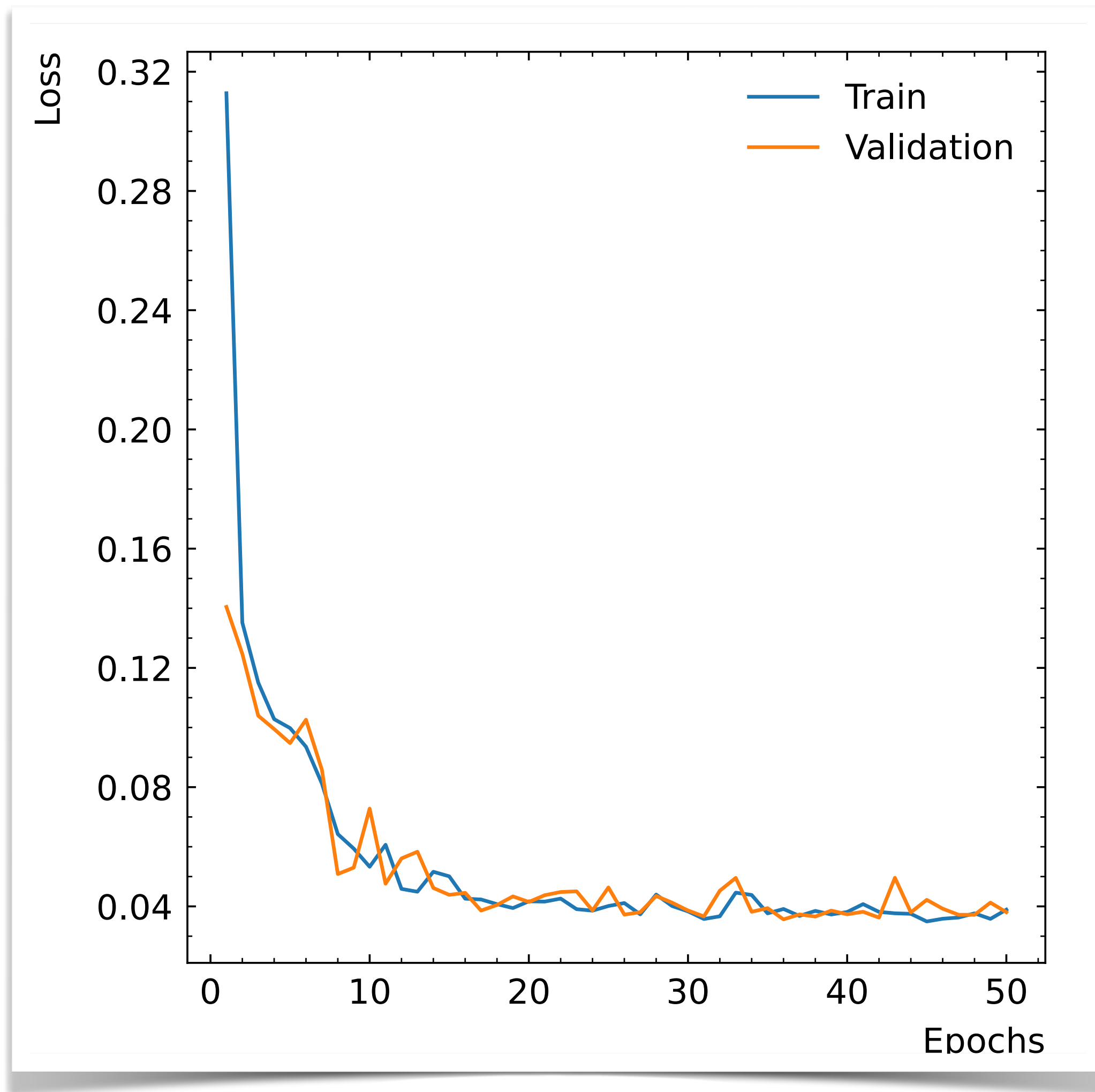□ Validation and testing: 30% and 20%

Transformer for the Zc(3900)


☐ Total events: 20k (left) and 50k (right) for 19 variables.

☐ Validation and testing: 30% and 20%

Transformer for the Zc(3900)

☐ Total events: 20k (left) and 50k (right) for 19 variables.

☐ Validation and testing: 30% and 20%

Hybrid-Quantum Transformer

☐ Total number of events: 20k.

☐ Training, validation, and testing: 11.2k, 4.8k, and 4k

☐ Number of variables: 18

☐ L rate & batch: 0.0036 & 128

☐ Epochs: 6

☐ **Architecture:**

    ○ $d_{FF} = 10$

    ○ Dropout = 0.0066

    ○ $iL = 3$

    ○ $h = 8$

    ○ Embedded dimension: 64

☐ Total time for the training and validation: 3h:34m:14s
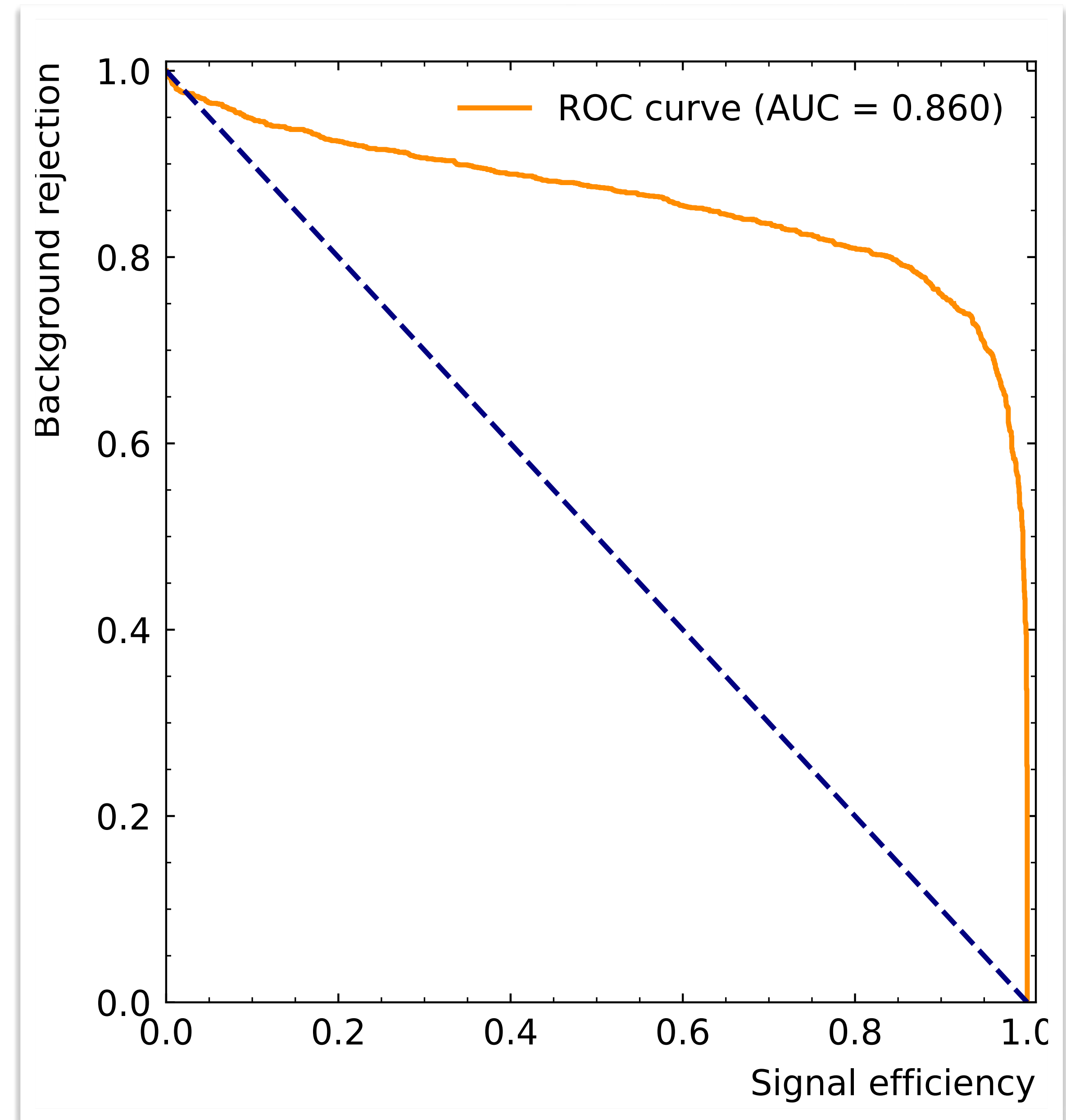
Summary

☐ **The Transformer results look OK with 0.99 AUC.**

☐ **The variables can be optimised a bit.**