Masked particle modelling

Foundation models for HEP

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Foundation models

Why build them?

- Goal is to learn generic and robust representations
  - Allows models to be efficiently trained on **small datasets**
  - **Same** model can be reused for **many** downstream tasks
  - Save on resources

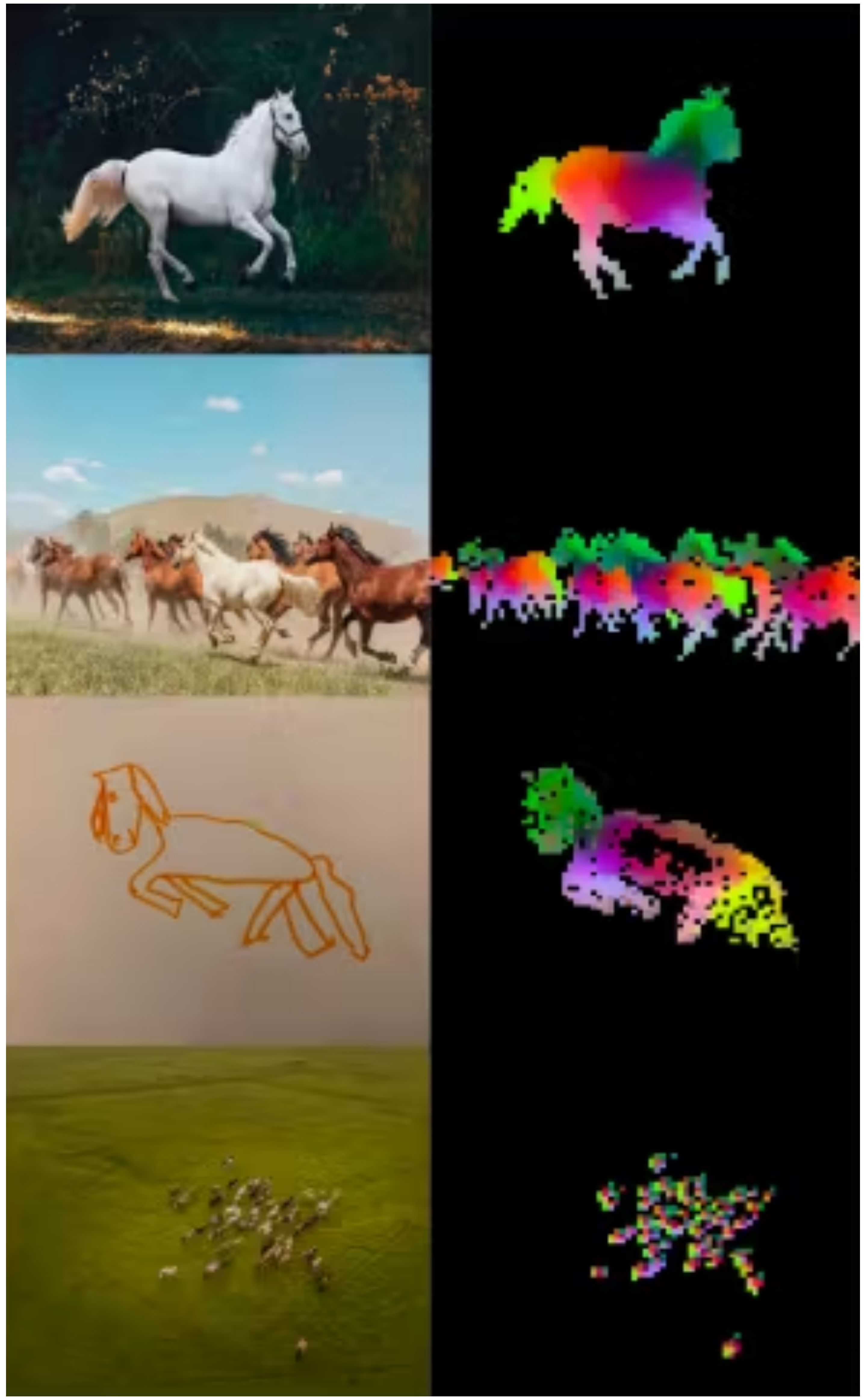
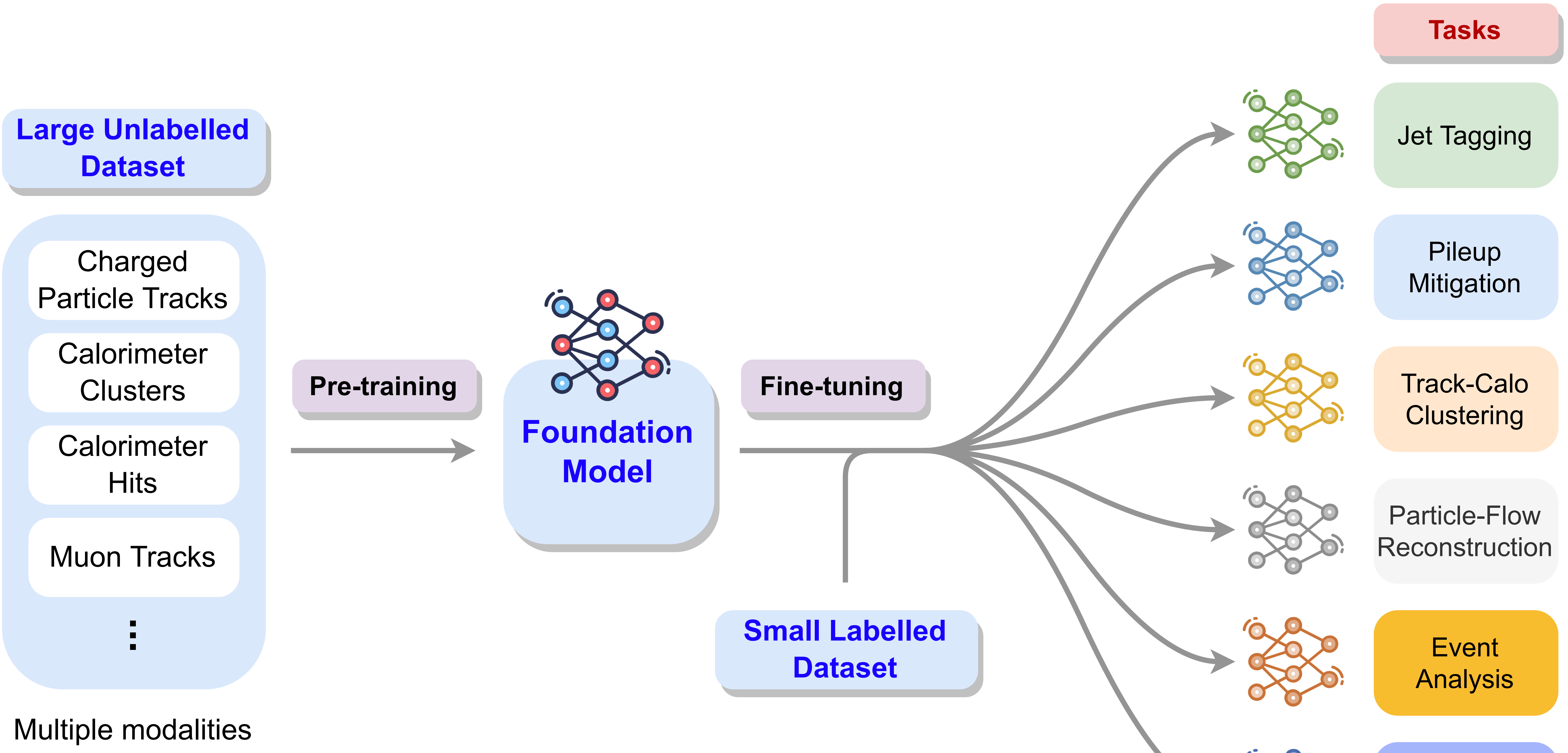


Image from DINOv2

Foundation models

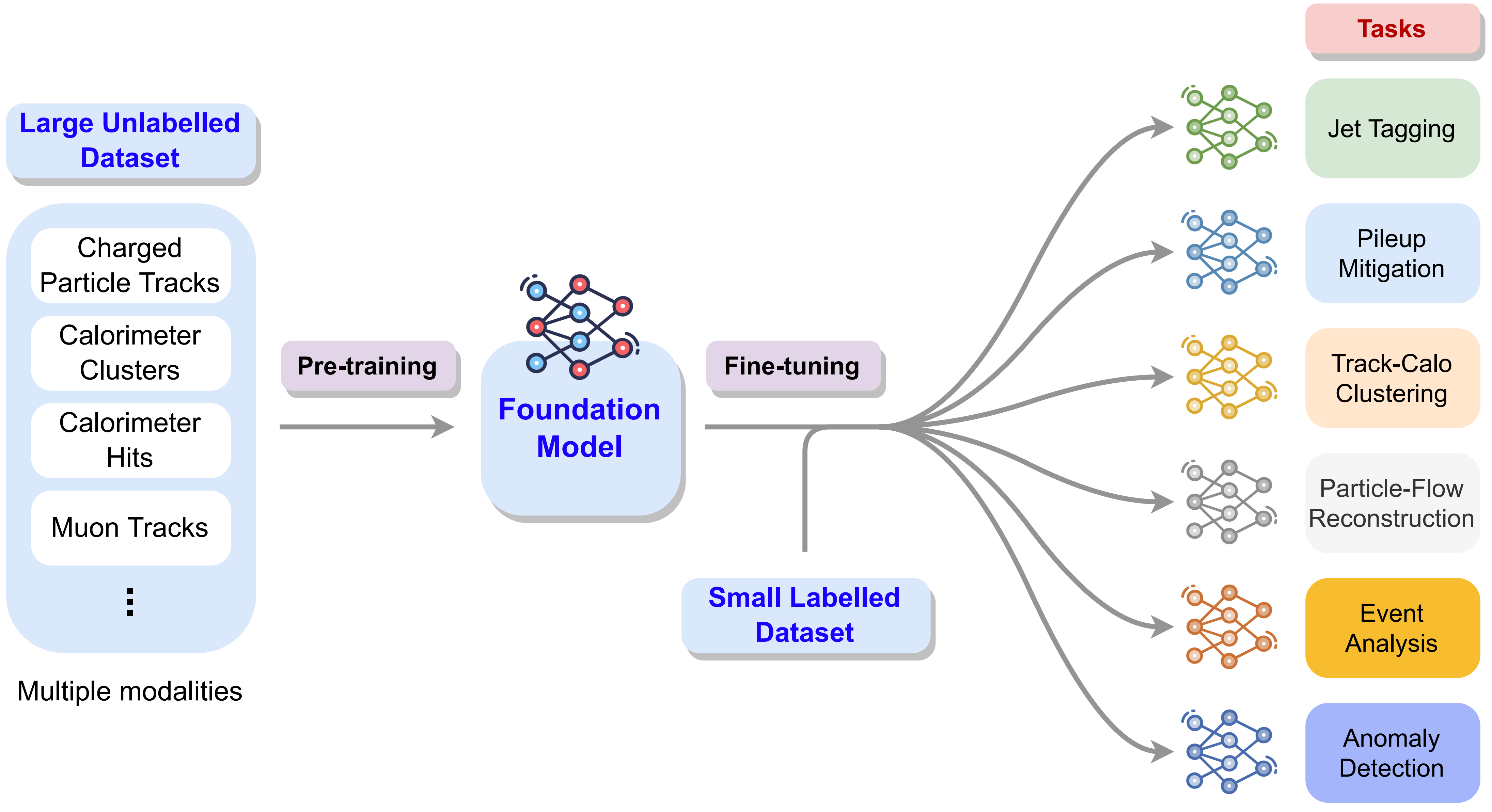
In HEP?



Foundation models

In HEP?

- Reduce dependence on large simulated datasets for supervised learning
- Help mitigate uncertainties related to domain shift?
- The problem: existing SSL strategies are **data type specific**, so we need new methods!



Masked modelling

Images and words

- The BERT pretraining strategy has been very successful for NLP
- So has BEiT for images
- Both based on recovering masked input sequences

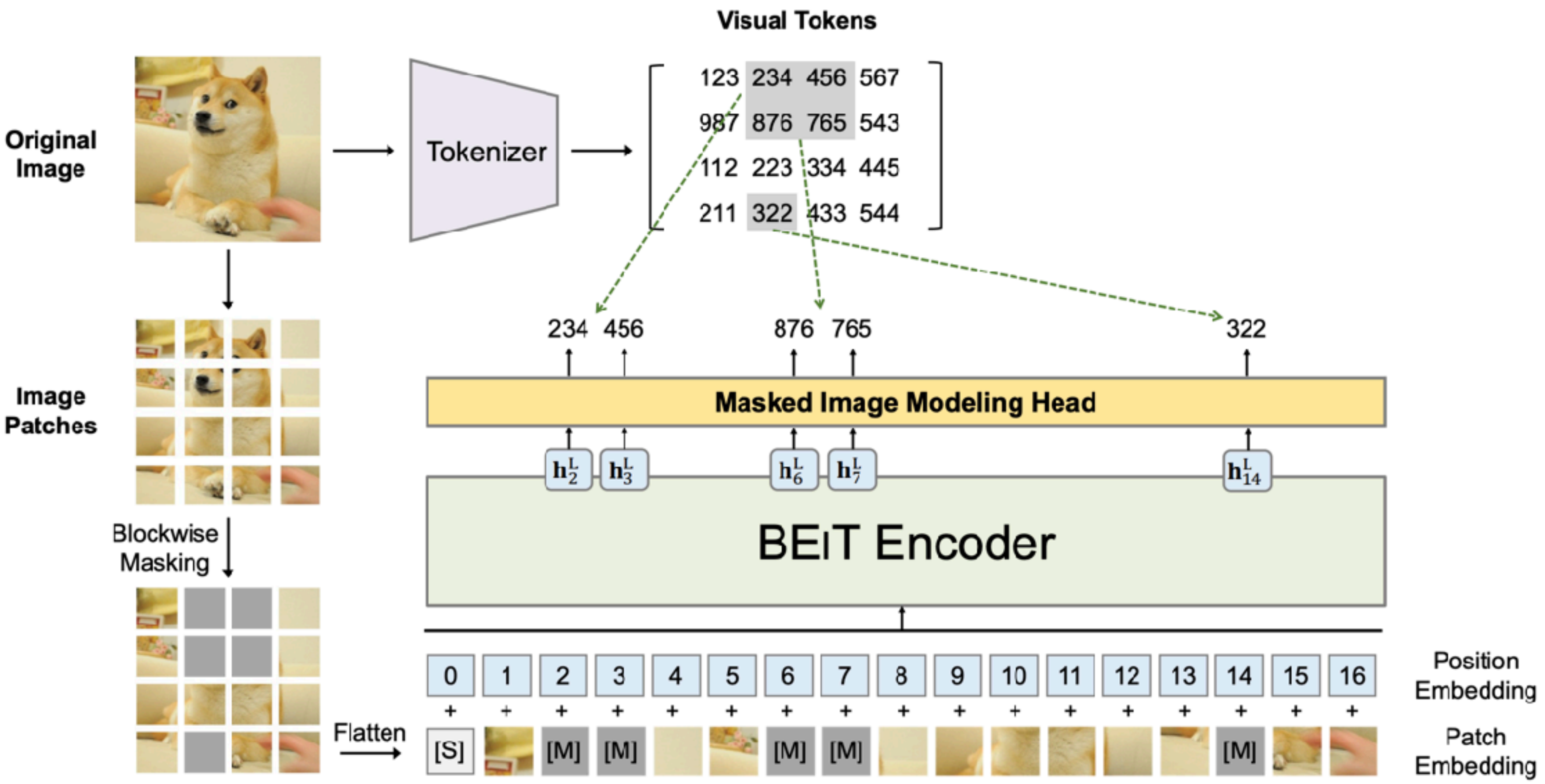
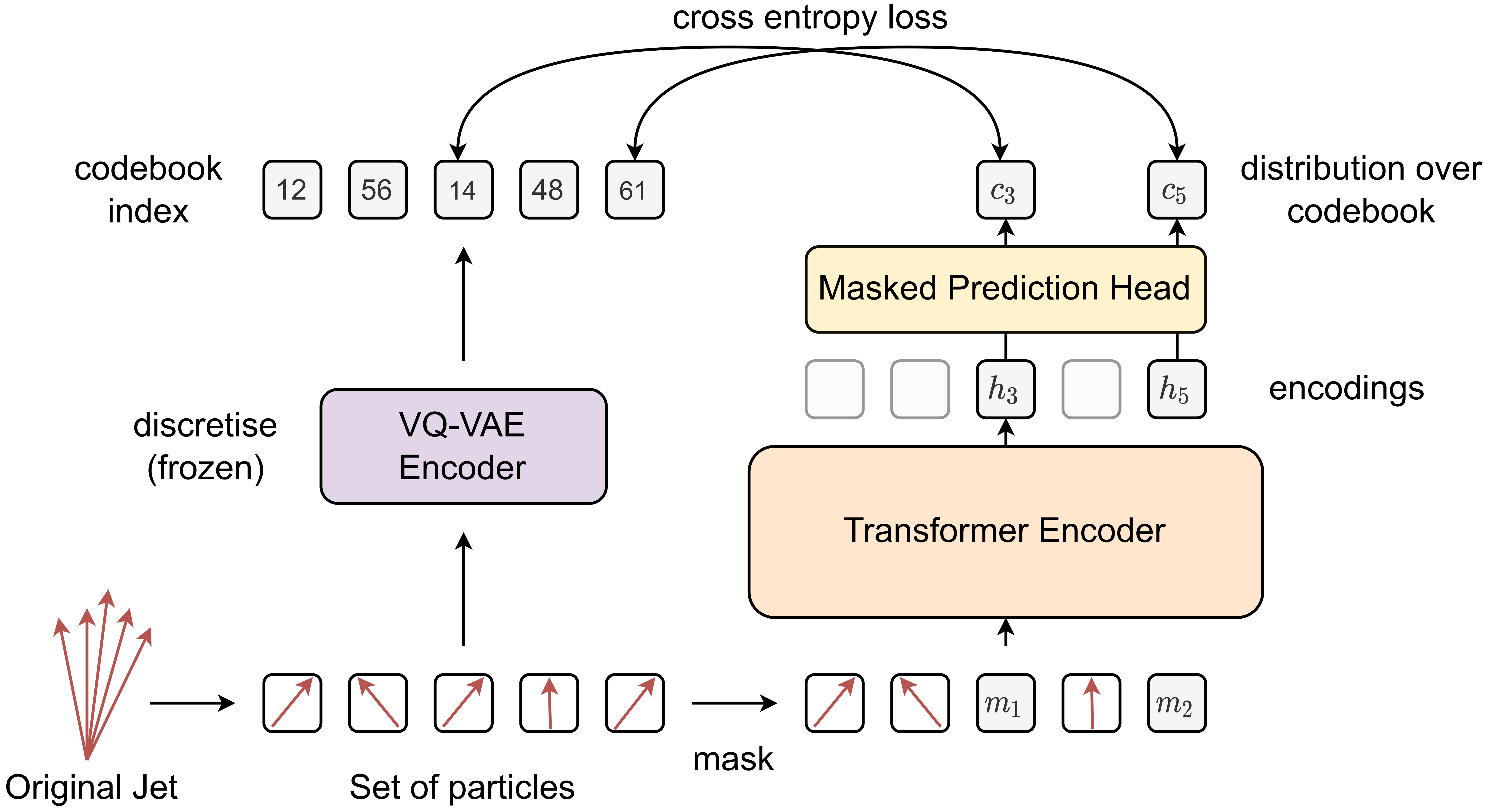


Image from 2106.08254

Masked modelling

Does this work for HEP: Jets

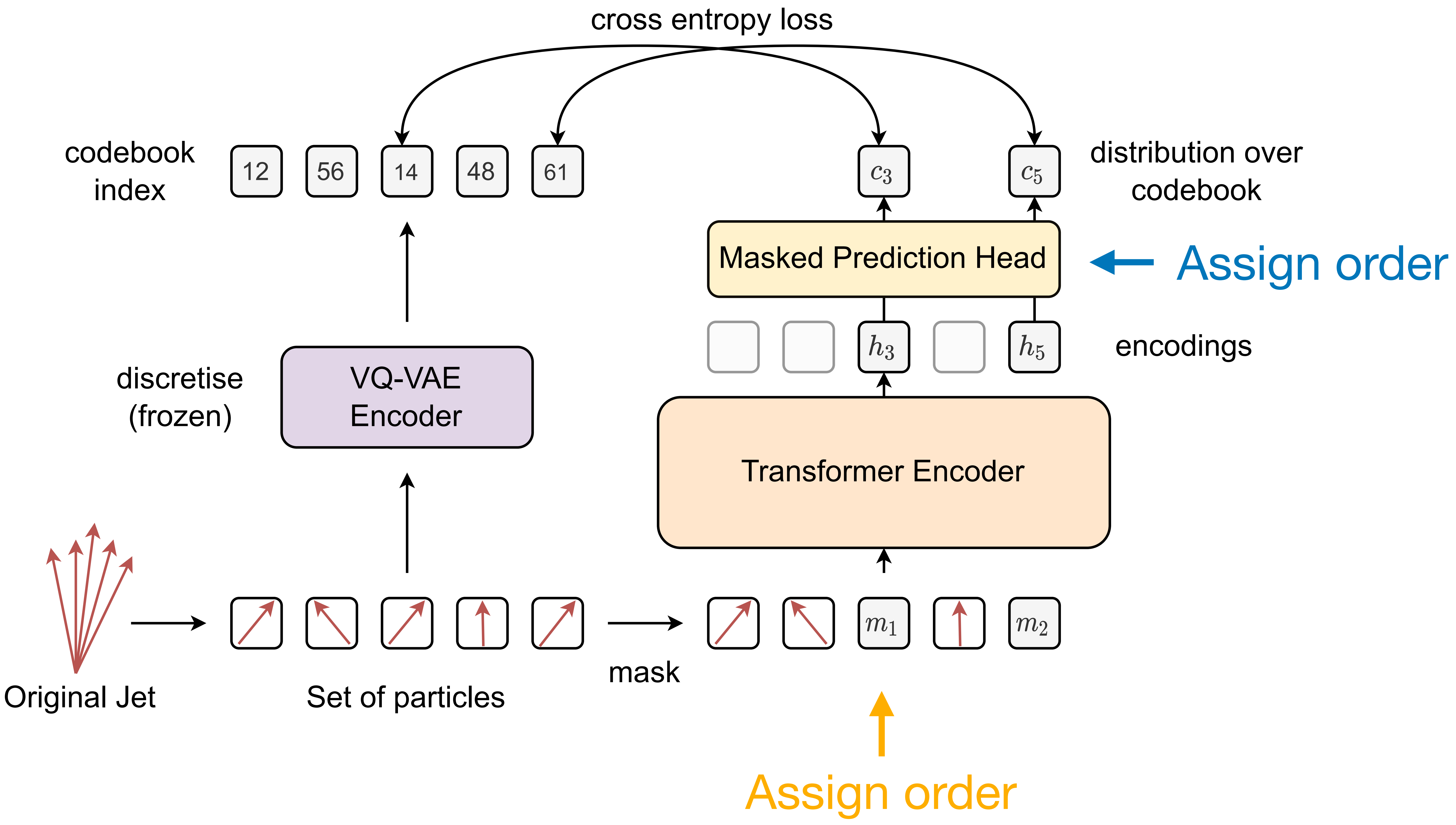
- Like images: continuous inputs
- Like language: ‘meaningful’ constituents
- Unlike both: no positional information
- No public massive dataset
    - Use jetClass 100M



Masked modelling

Permutation invariance

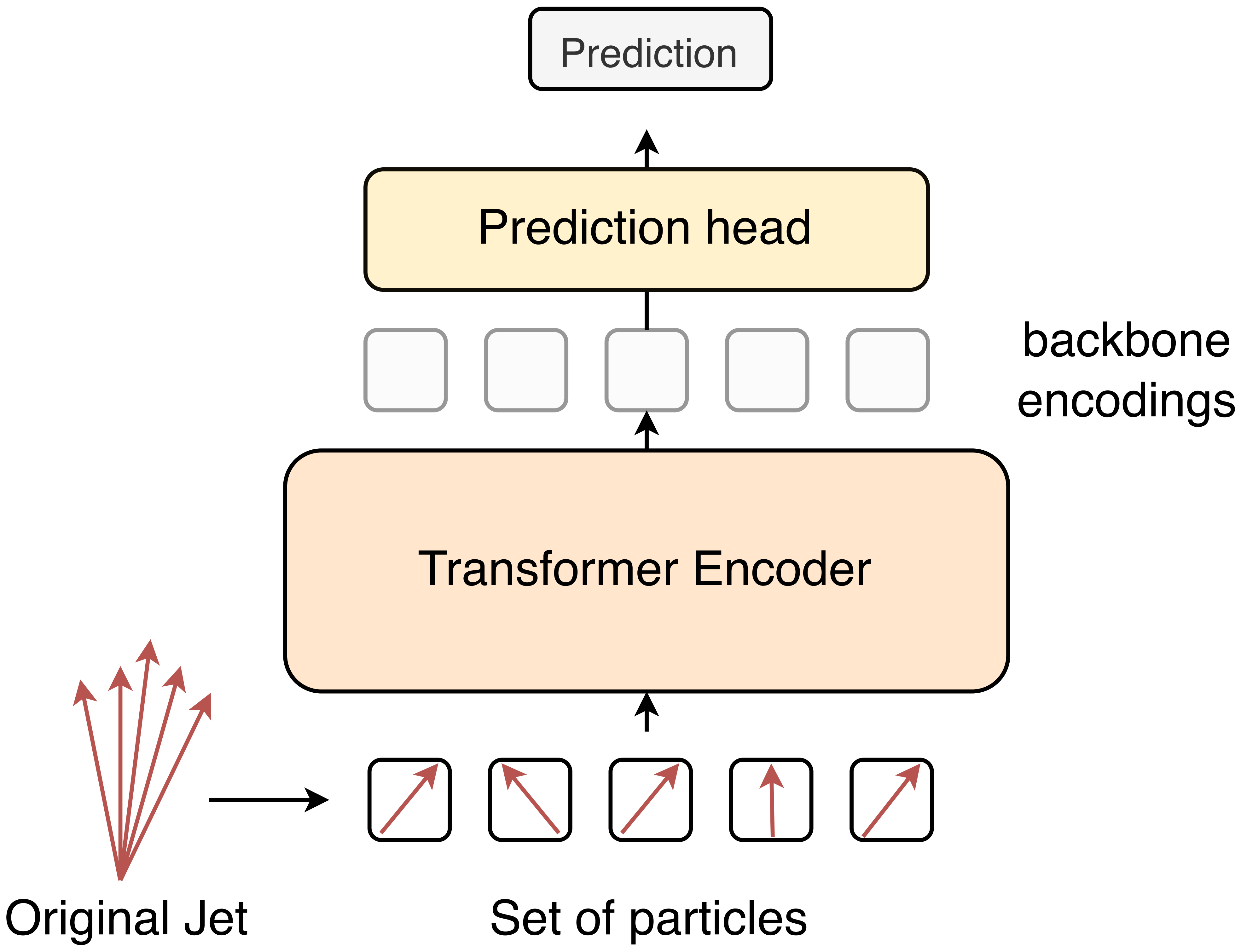
- Three approaches to permutation invariance
  - Don’t worry about it
  - Input to backbone
  - Input to masked prediction head



Masked modelling

Permutation invariance

- Three approaches to permutation invariance
- Which one to pick?
- JetClass has 10 classes
- Use linear separation



Masked modelling

Permutation invariance

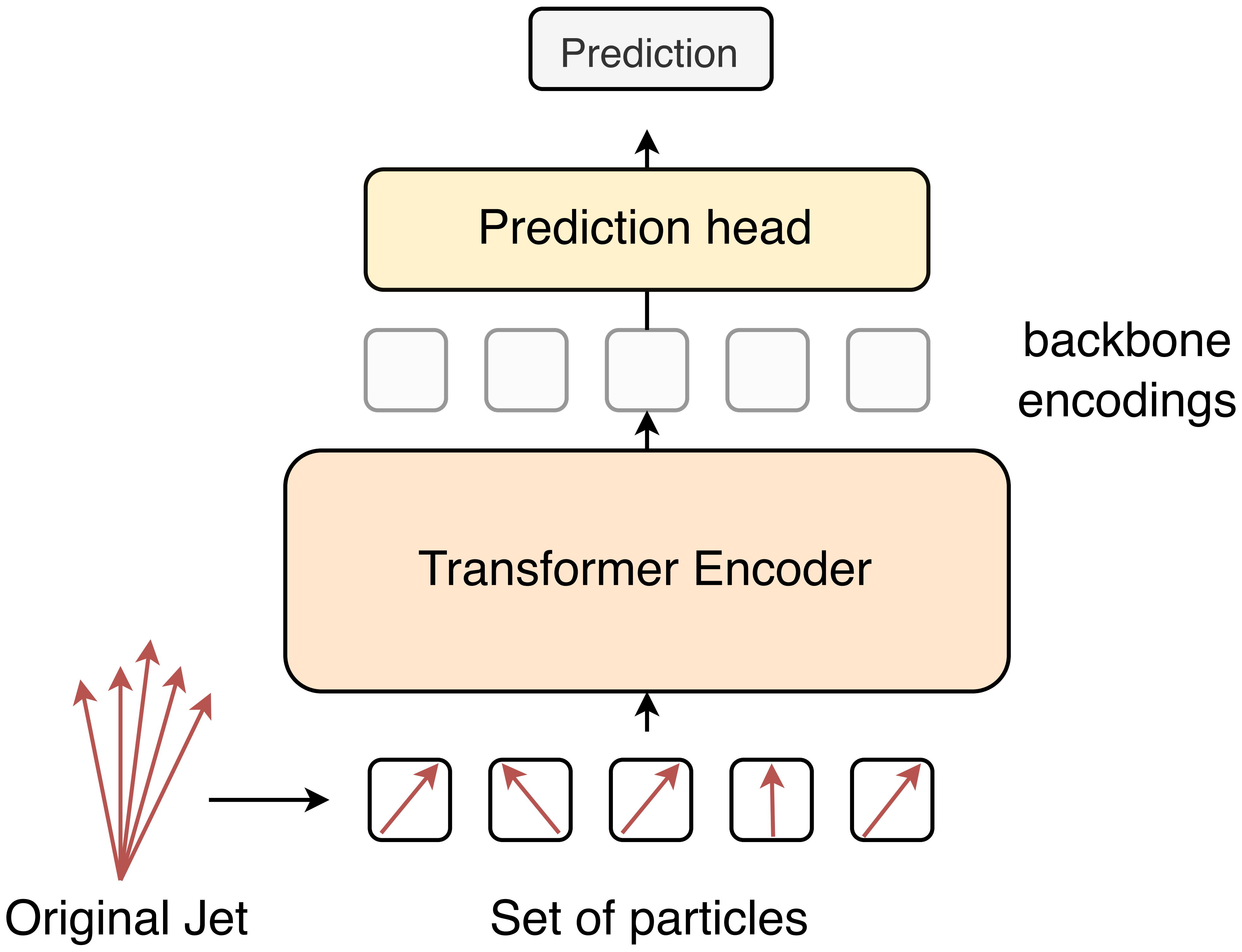
- Ordering at the pretraining head does the best
- Ordering at the input leads to overfitting

	No order	Order input	Order head
Linear Accuracy	54.1%	53.4%	**56.8%**

Masked modelling

Performance

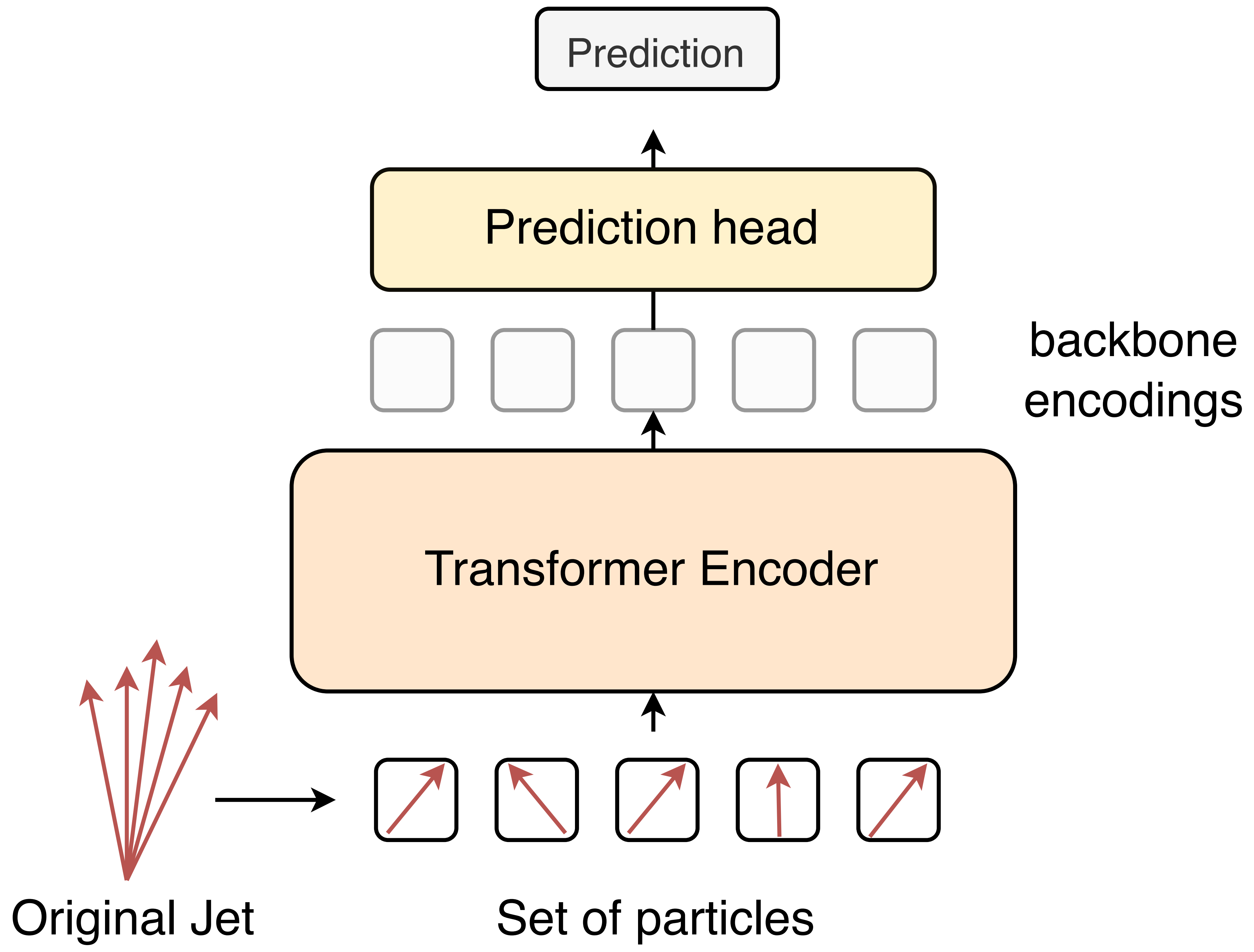
- How to quantify the performance of a pretrained model?
  - Array of downstream tasks — fine tuning
- Pretraining on 100M Jets from JetClass
- Fine tuning on array of different jet level tasks



Masked modelling

Training strategies

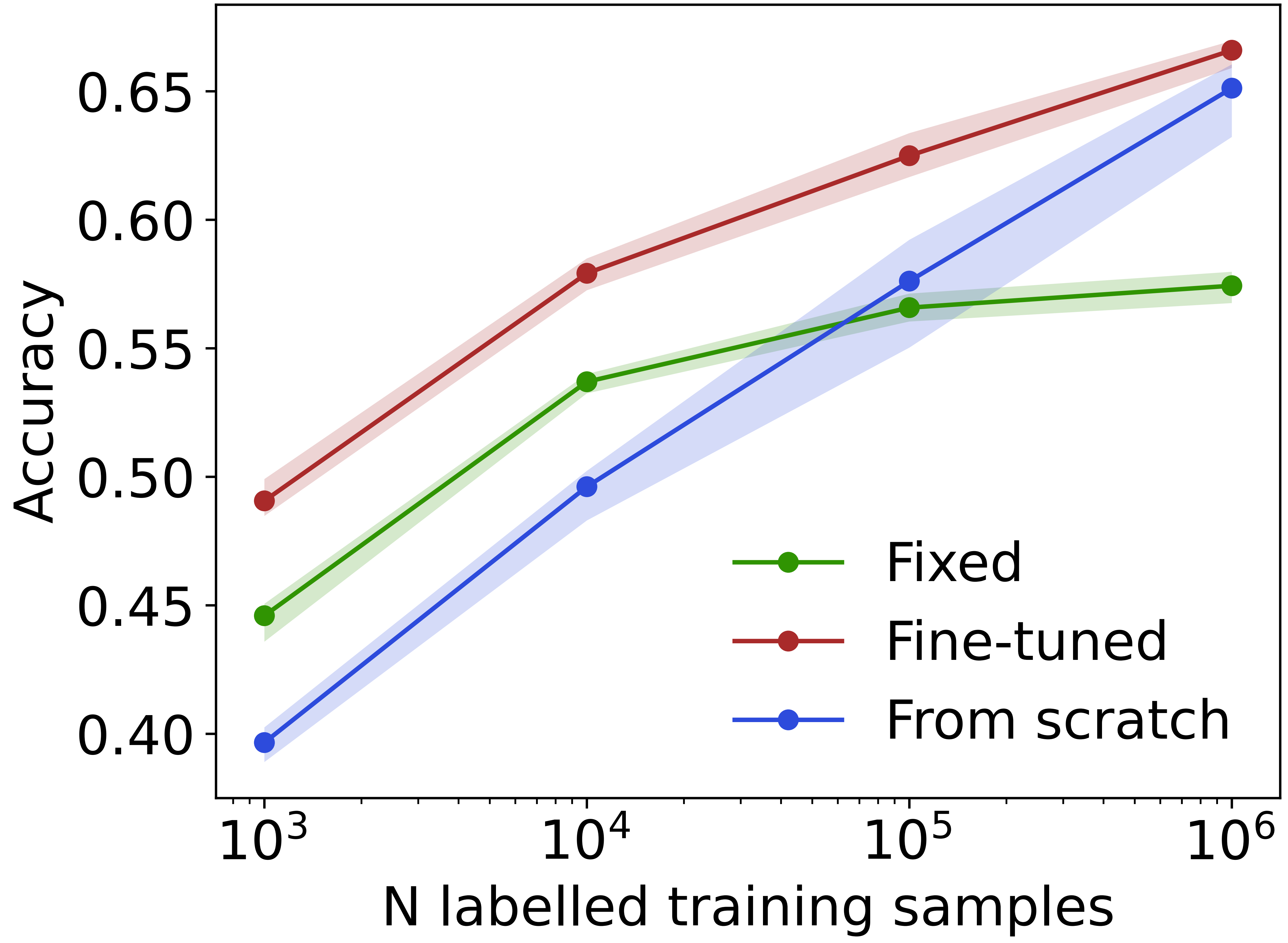
- **fixed backbone:**
  Freeze the encoder
- **fine-tune backbone**:
  Train the prediction head and the backbone
- **from scratch:**
  Reinitialise model from scratch



Masked modelling

Fine tune on pretraining set

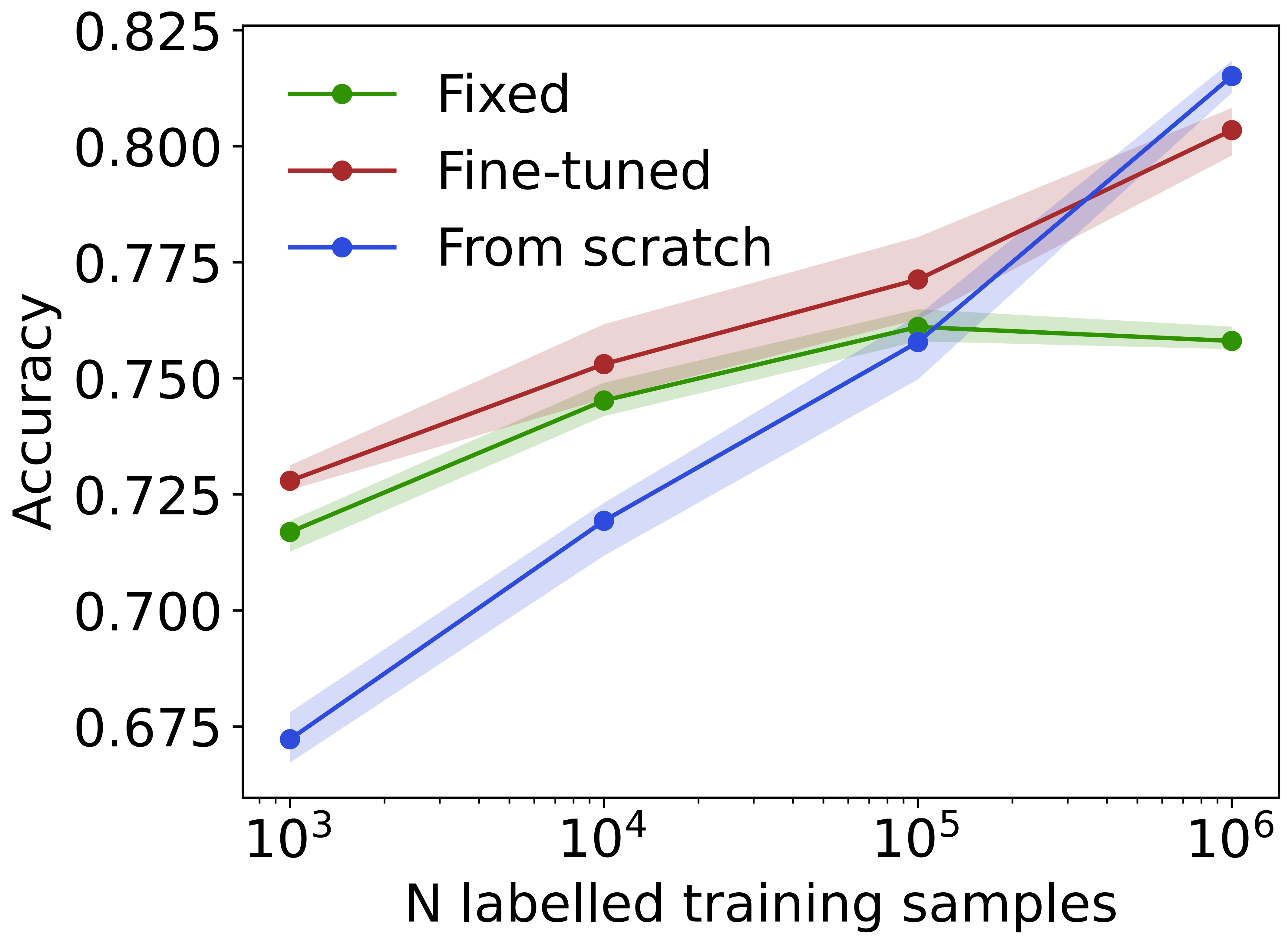
- JetClass contains 10 classes
- Select N events and fine tune
- The backbone model outperforms from scratch



Masked modelling

Fine tune on new dataset

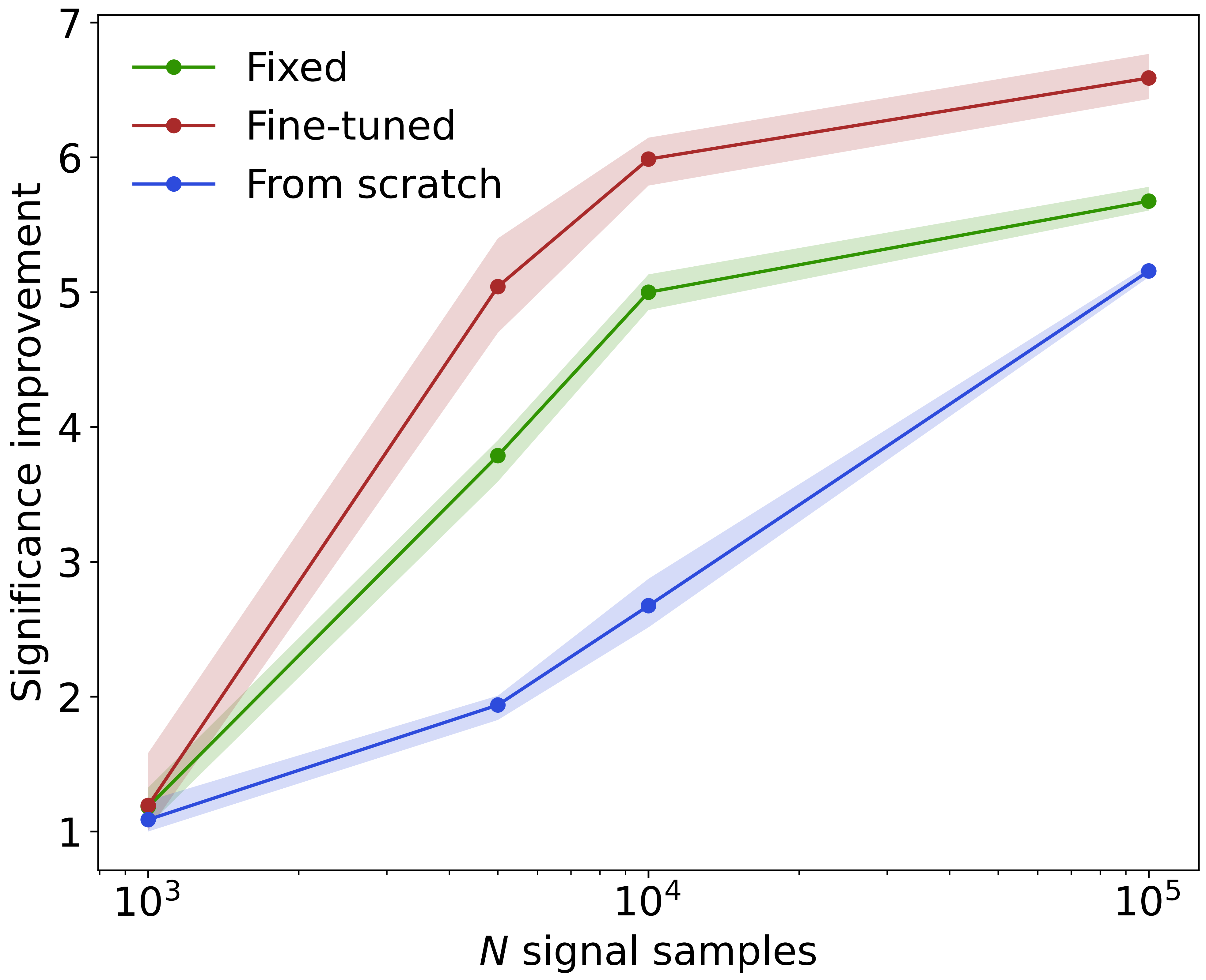
- The learned features are generically useful
- The performance gain applies to data generated with a different simulator
  - Change card to Atlas and fine-tune (JetClass is CMS)



Masked modelling

Fine tune on weak supervision

- Take two QCD samples
- Add x top jets to one sample and label ‘signal’
- Fine-tune model on noisy labels
- Pretraining helps!



Summary

Masked particle modelling

- Masked particle modelling is a useful pretraining task for HEP
- Simple and easy to set up (when using a kNN)
  - Can be applied to low level data cheaply
- Foundation models can and should be built for HEP
- Permutation invariant issue not tackled in other domains
  - Plays important role in HEP