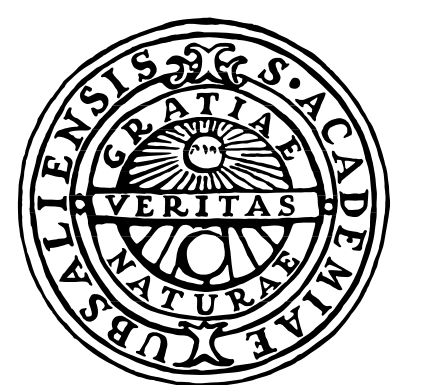


# Generating Lagrangians for Particle Theories

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When AI Starts To Learn Particle Theory!

If Lagrangians are Particle Physicists' Language, can LLMs learn it? **YES!**

How?

- Transformers + seq-to-seq : Works!
- Lagrangian Sampling : Important!
- Math Tokenization : Important!

Large LLM = Lagrangian Model

Why?

Foundational Model for Particle Theory Understanding

- Auto Lagrangian Completion
- Model Extraction from Literature
- Symbolic Manipulation
- Direct Theory Inference from Data
- ...

In Language :

Mary Had A Little Lamb, ...  
P(Had | Mary) P(A | Mary Had) P(Little | Mary Had A) P(Lamb | Mary Had A Little)

In Lagrangians :

$$D_\mu \Phi^\dagger D^\mu \Phi + m^2 \Phi^\dagger \Phi + \lambda \Phi^\dagger \Phi \Phi^\dagger \Phi + \dots$$

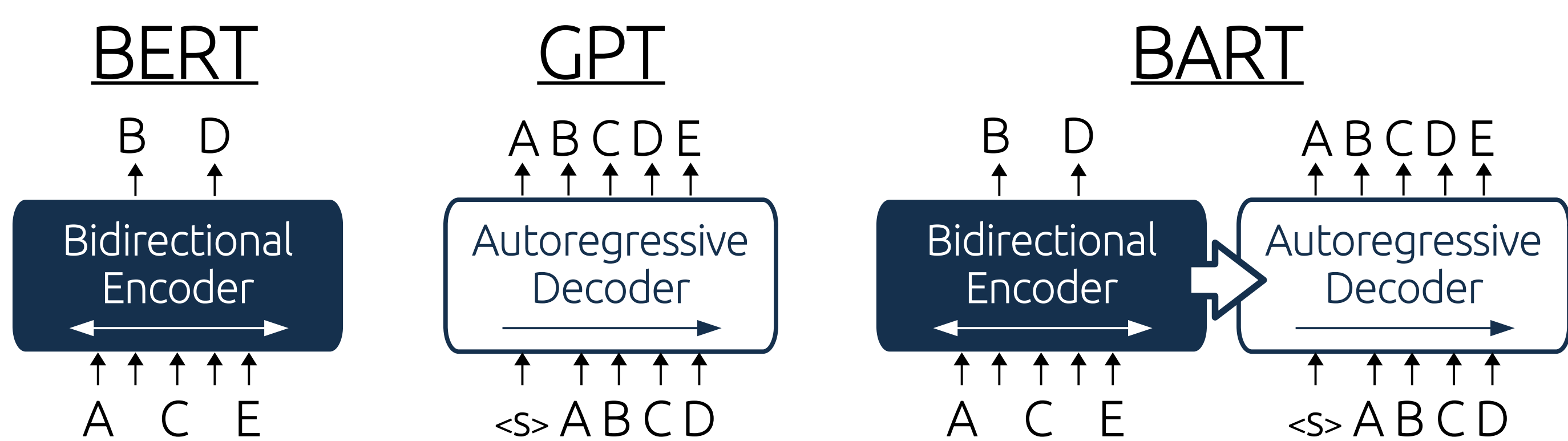
P(m<sup>2</sup>Φ<sup>†</sup>Φ | D<sub>μ</sub>Φ<sup>†</sup>D<sup>μ</sup>Φ) P(λΦ<sup>†</sup>ΦΦ<sup>†</sup>Φ | D<sub>μ</sub>Φ<sup>†</sup>D<sup>μ</sup>Φ + m<sup>2</sup>Φ<sup>†</sup>Φ)

Model Task :

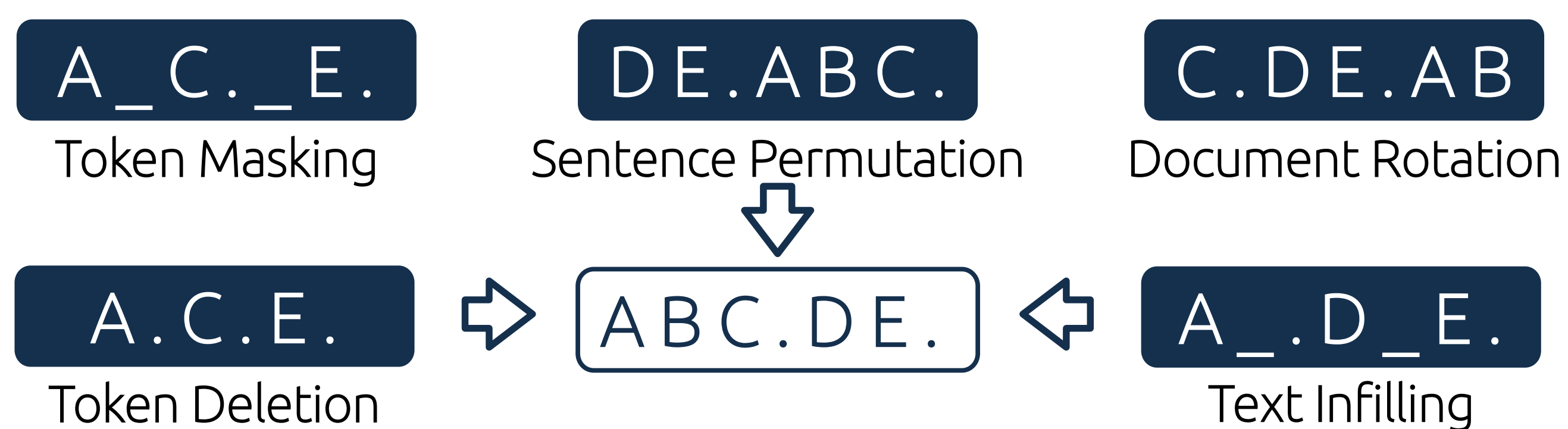
$$\Phi_{(3,3,1)}, \Phi'_{(1,2,1/6)} \rightarrow \dots + \lambda \Phi^\dagger \Phi \Phi'^\dagger \Phi' + \dots$$

## BART

Bidirectional and Auto-Regressive Transformers



### Noise Transformation



## Dataset

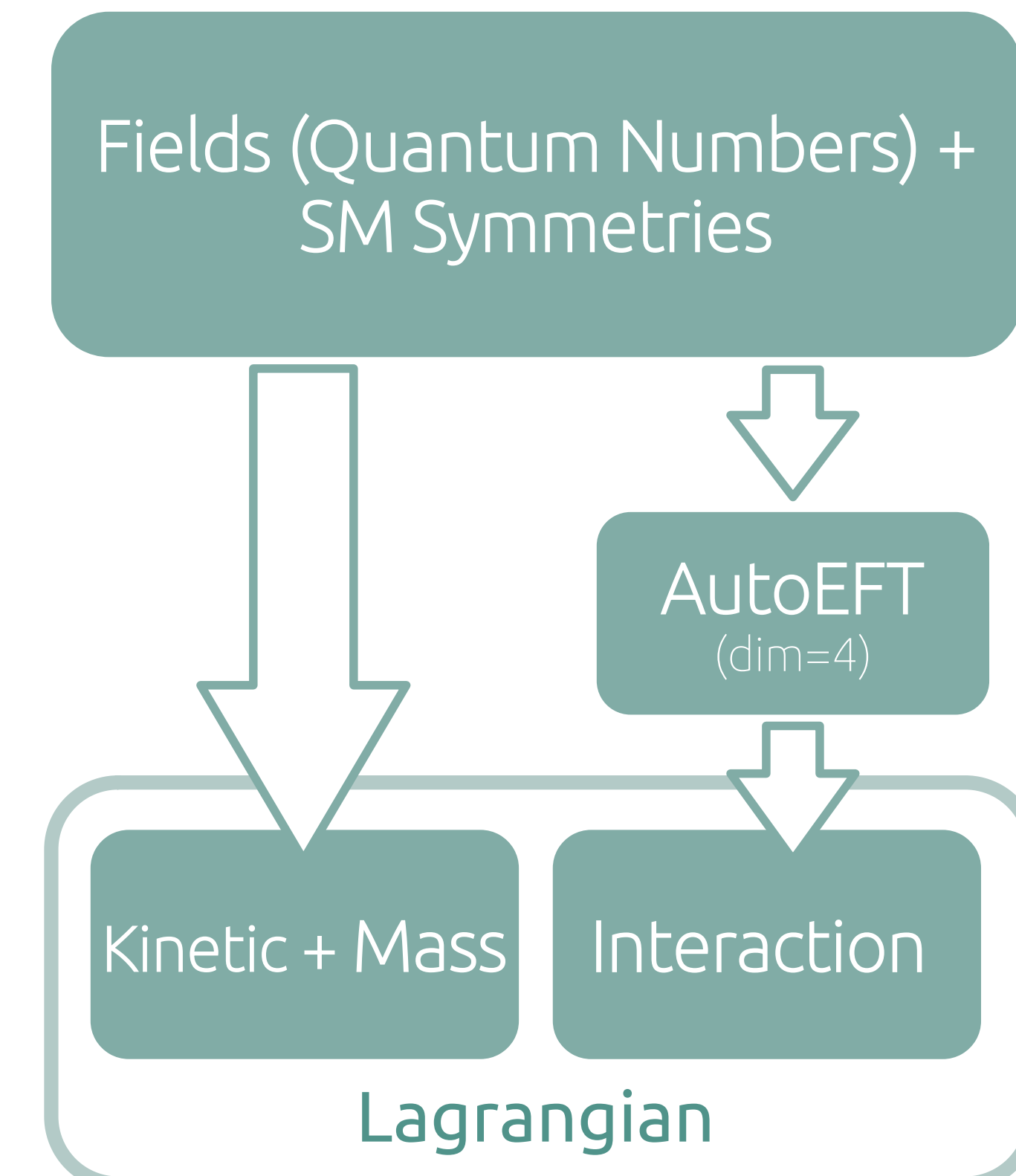
What and How to teach AI Particle Theory

Lagrangians	Data size
With Fermions	23 K
With Scalars	14 K
Total	37 K

Quality over Quantity!

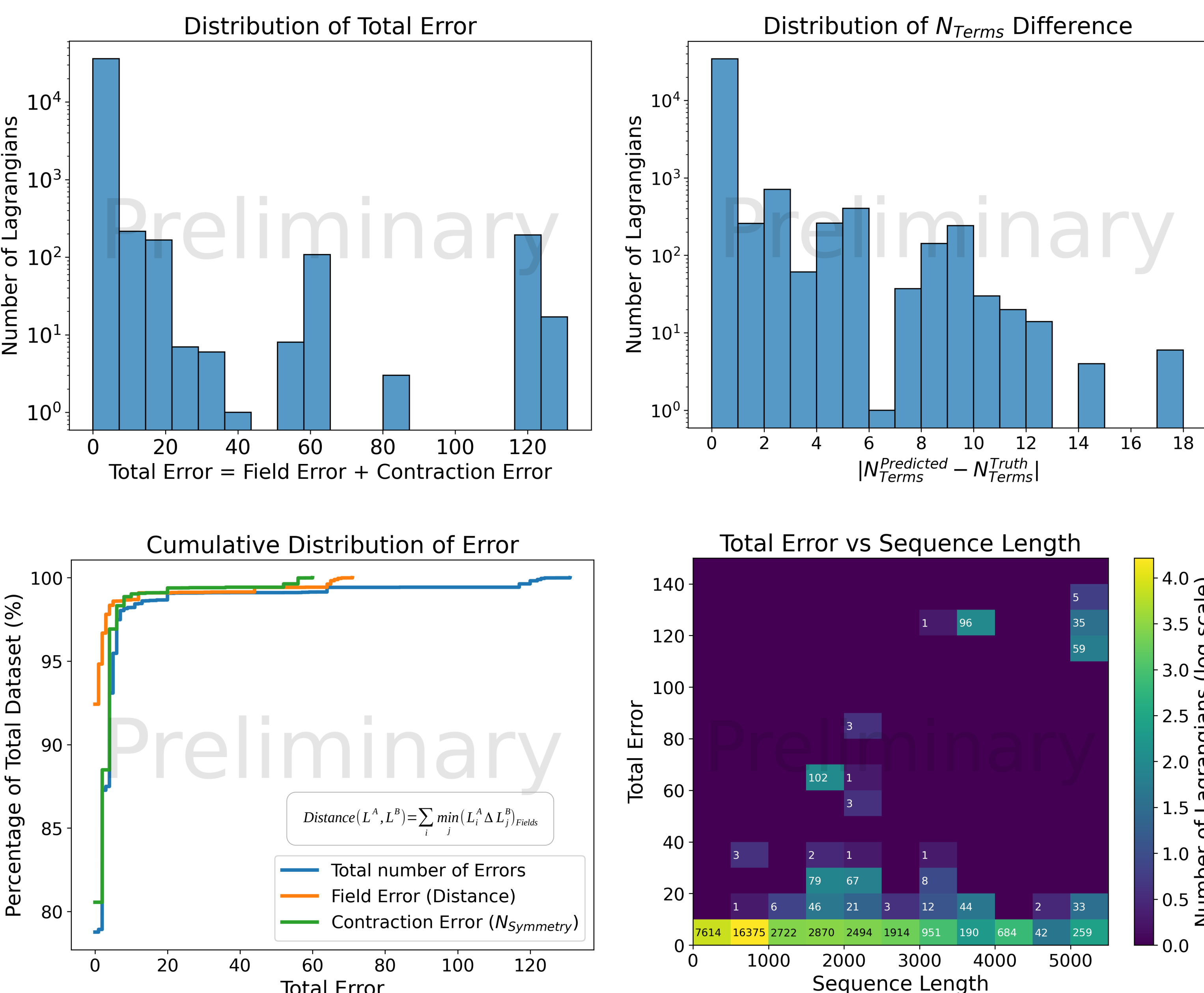
	Baseline	Enriched
% with trilinear	~ 2%	~ 9%
% with singlets	~ 1%	~ 5%

Important-Feature-Based Sampling Approach is Needed!



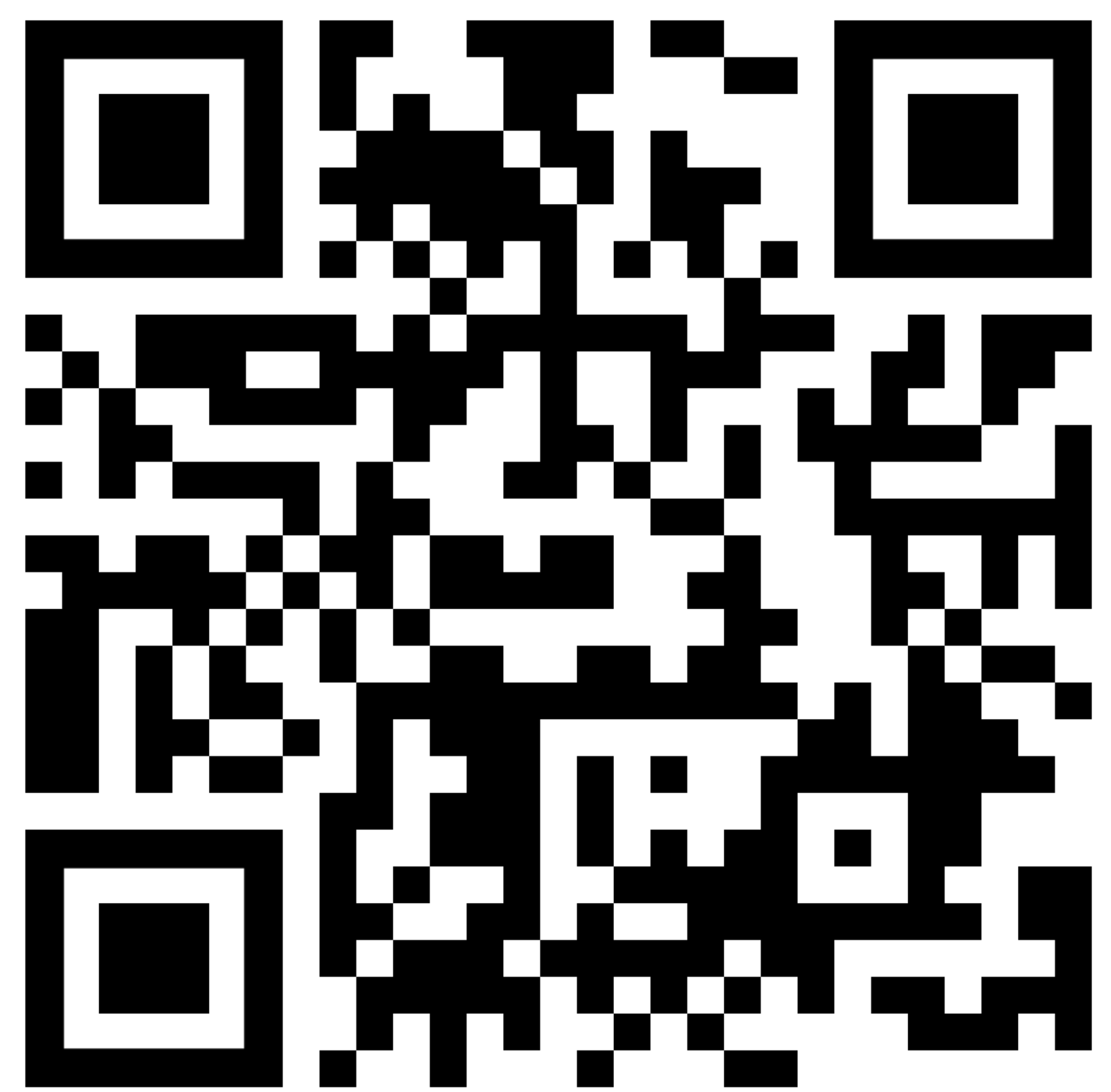
## Performance

Number of Parameters : 357 M  
Context Length : 2048  
Attention Heads : 16  
Embedding Dimension : 1024



## TRY IT OUT YOURSELF!

Number of Parameters : 110 M



Ask an AI to write a Lagrangian of your choosing!

## Acknowledgment

The computations and data handling were enabled by resources provided by the National Academic Infrastructure for Supercomputing in Sweden (NAISS), (partially funded by the Swedish Research Council through grant agreement no. 2022-06725). This material is based upon work supported by the Google Cloud Research Credits program with the award GCP19980904.