

Towards an End-to-End approach to muon tracking with Machine Learning and Differentiable Programming techniques

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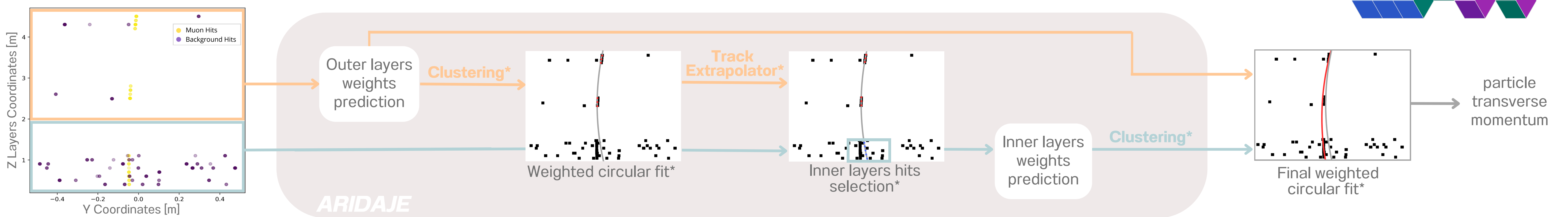
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Introduction

Differentiable Programming (DP) is becoming a valuable tool for incorporating physics principles into Machine Learning algorithms, and the judicious integration of relevant physical information could play a crucial role in model training. In this context, we present ARIDAJE, an innovative method for muon tracking that utilizes advanced libraries enabling differentiable programming techniques.

ARIDAJE : AuxiliaRy use of physics Information in Differentiable Layers training Approach with Jax-based Environment



Toy model based on GEANT4 inspired by the ATLAS Muon Spectrometer (MS) geometry: 9 + 8 detector layers.

*Defined through differentiable functions

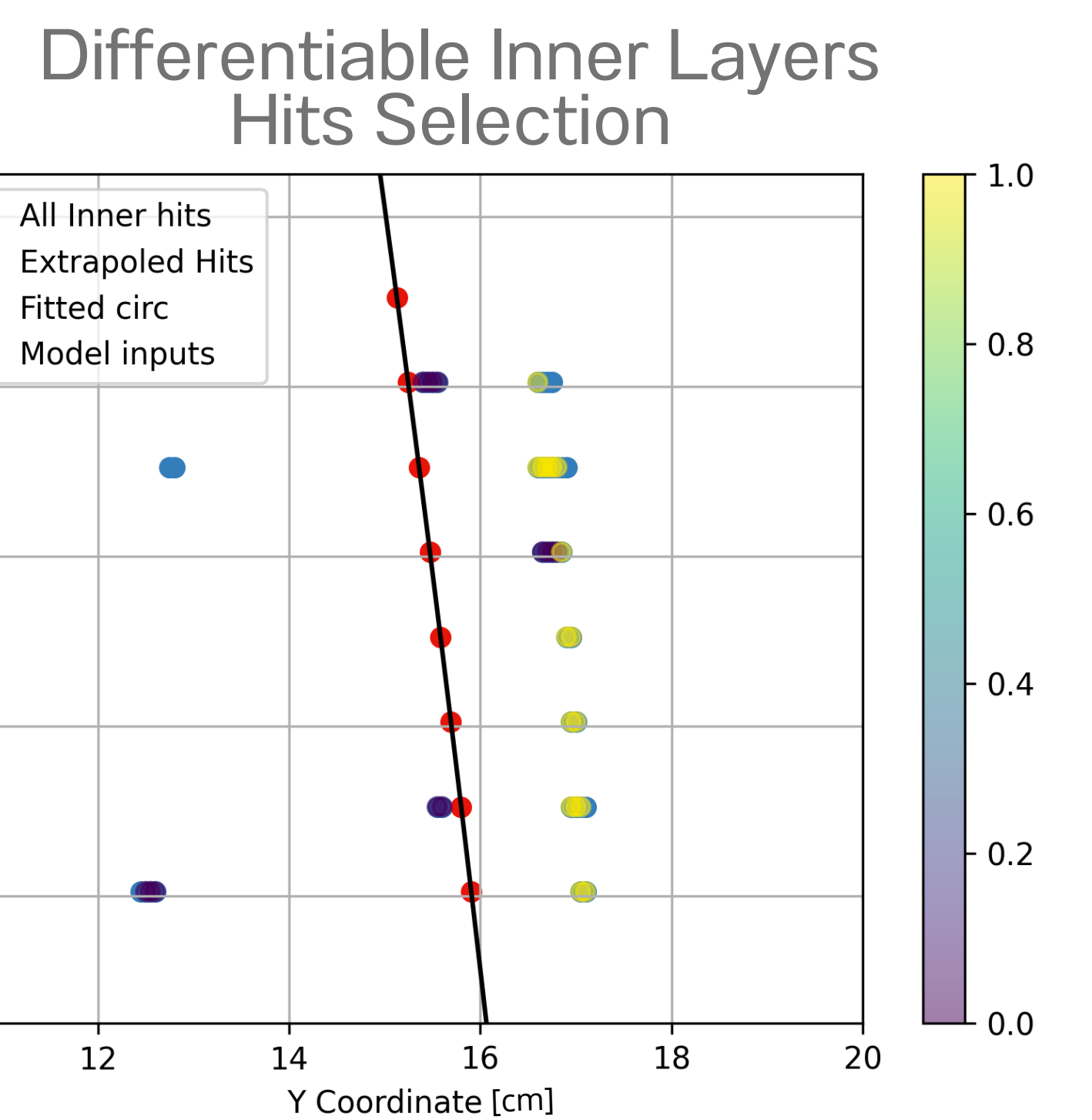
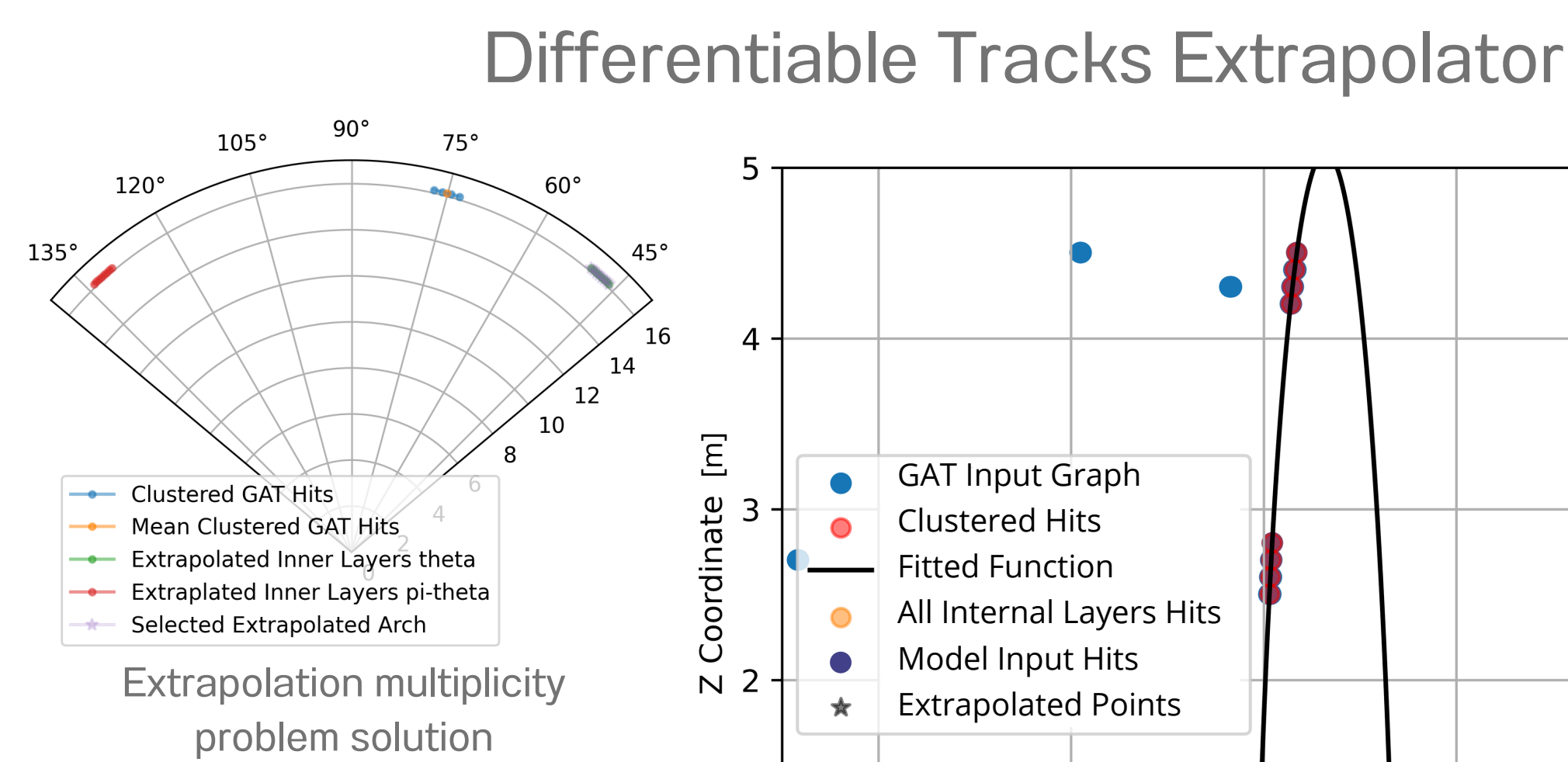
Differentiable Steps

Differentiable Clustering and weighted chi-square with implicit differentiation

$$S = \sum_{i=1}^{N_{layers}} \frac{q_i(y_i|z_i) - C_i(y_{c,i}|\vec{h}_i, \vec{w}_i)}{\sigma_{C_i}^2}$$

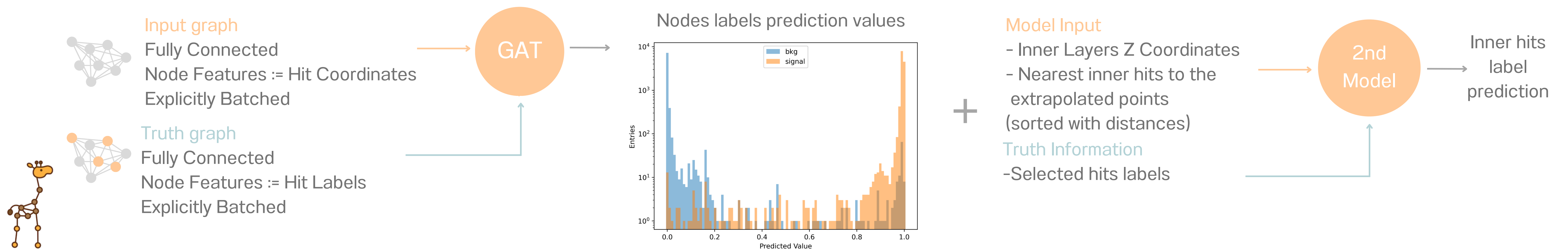
$$C_i = \frac{\sum_{j=1}^{N_{hits}} w_j \cdot h_j(y_j, z_j)}{\sum_{j=1}^{N_{hits}} w_j} \quad \forall i \in N_{layers}$$

h_j = Hits,
 w_j = GAT Predictions,
 $y_{c,i}$ = Clustered Hits

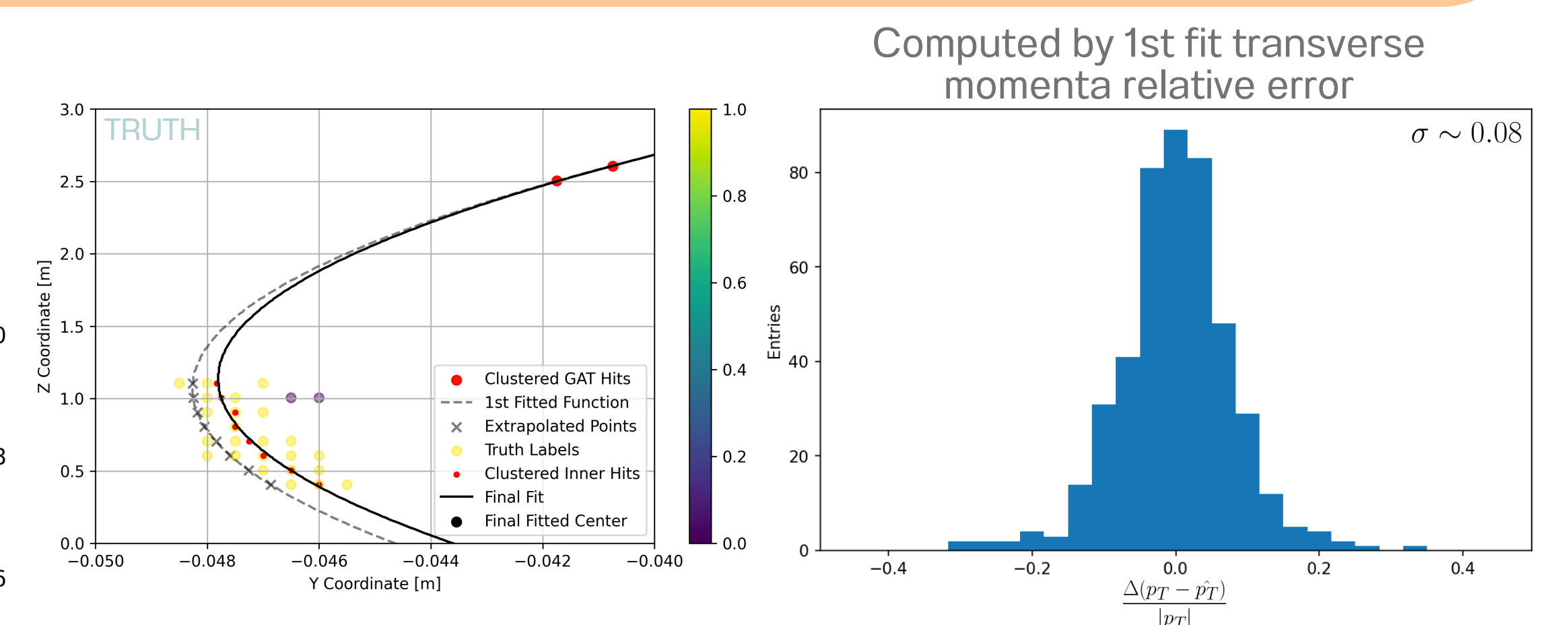
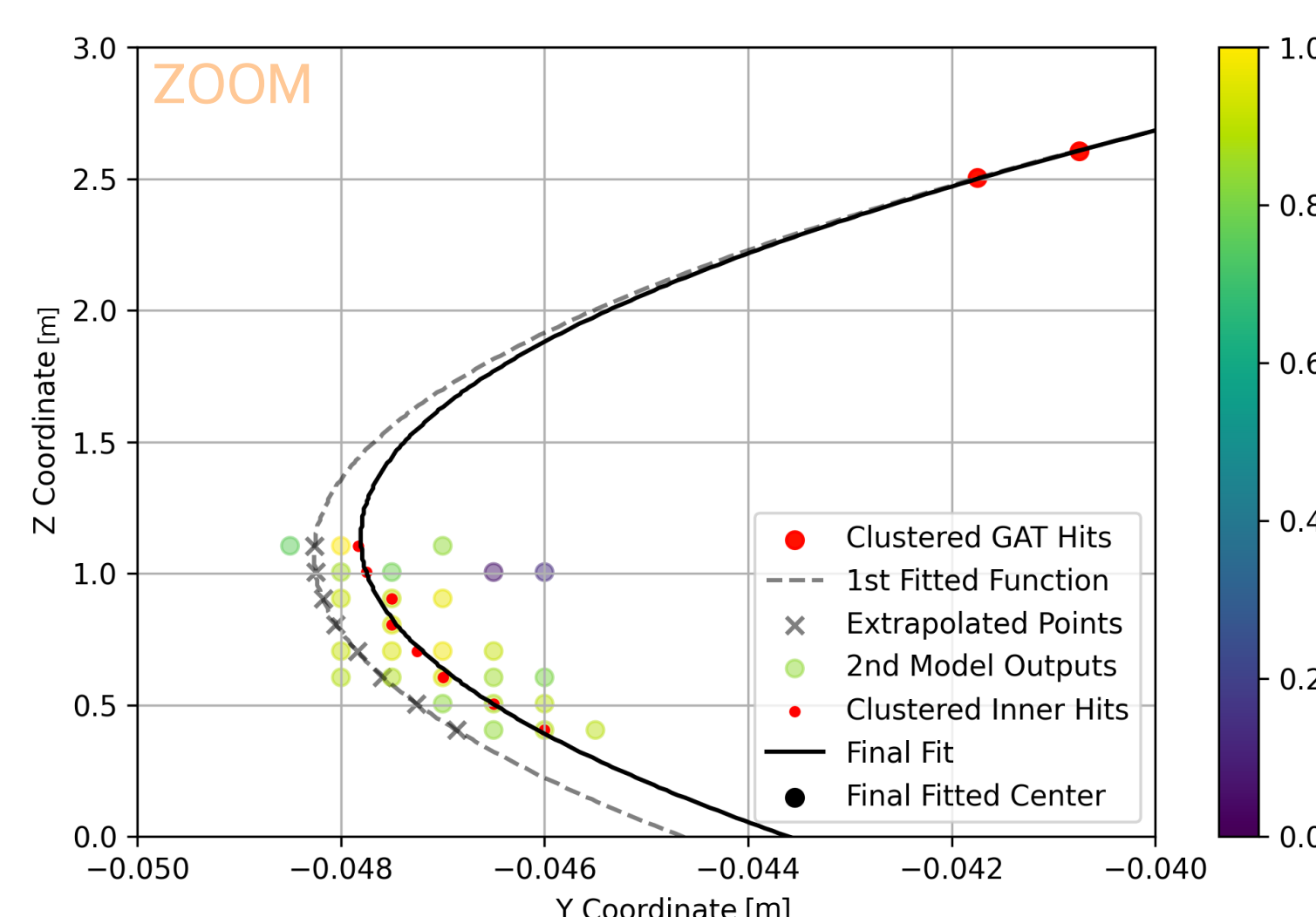
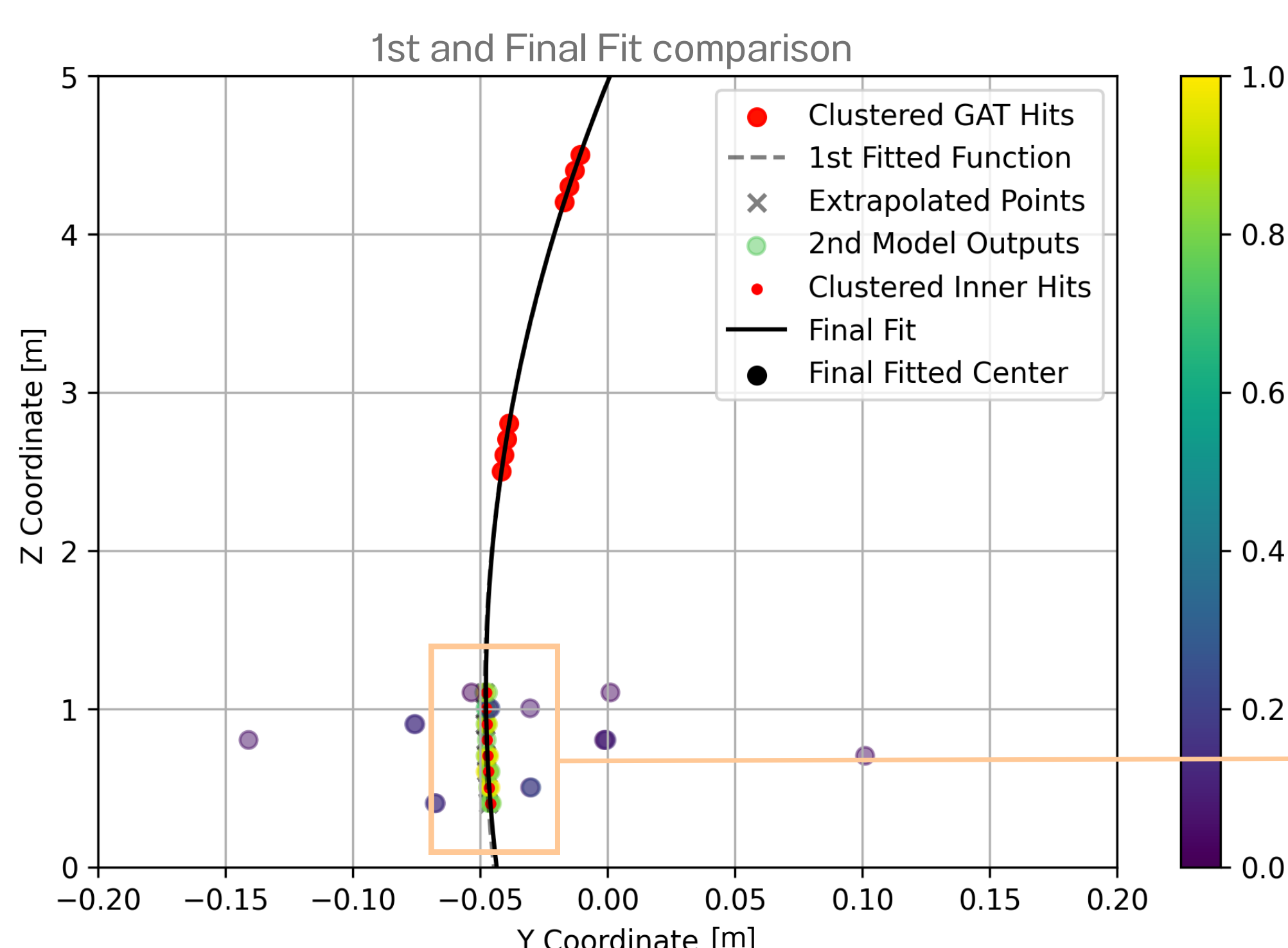


Models

For the outer layers pattern recognition a Graph Attention Network (GAT) is used



Results and Conclusions



References and Related Works:

Fast Differentiable Sorting and Ranking
Mathieu Blondel and Olivier Teboul and Quentin Berthet and Josip Djolonga, 2020
Differentiable Vertex Fitting for Jet Flavour Tagging
Rachel E. C. Smith, Inès Ochoa, Rúben Inácio, Jonathan Shoemaker, Michael Hagan, 2023