Enhancing Detector Alignment with ML

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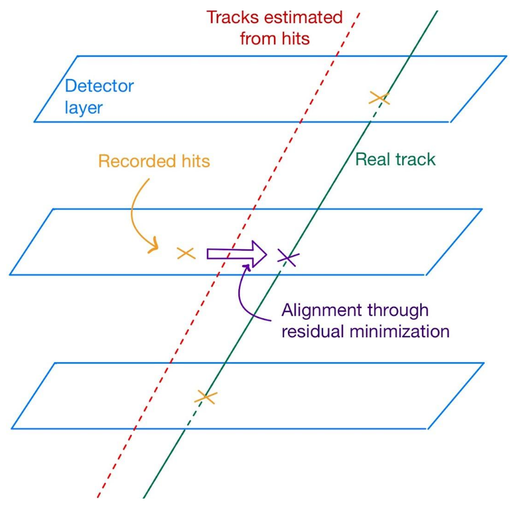
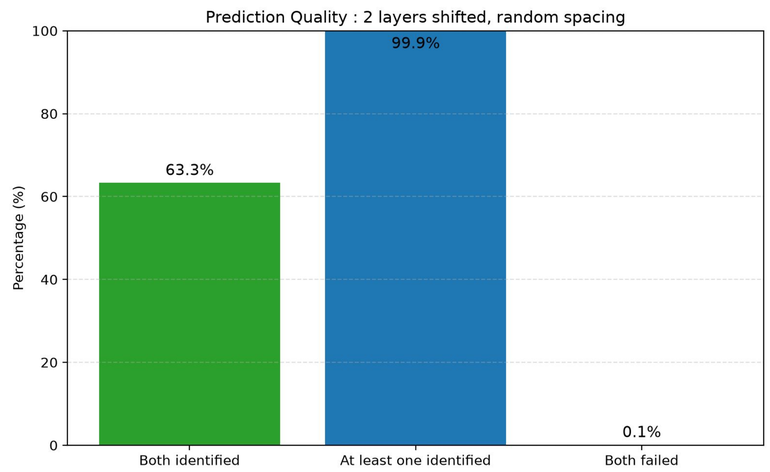
Motivation

Current alignment techniques:
- Fit real tracks to reconstructed tracks by reducing residuals
- Classical fitting algorithms can be computationally heavy (100s of thousands of parameters)

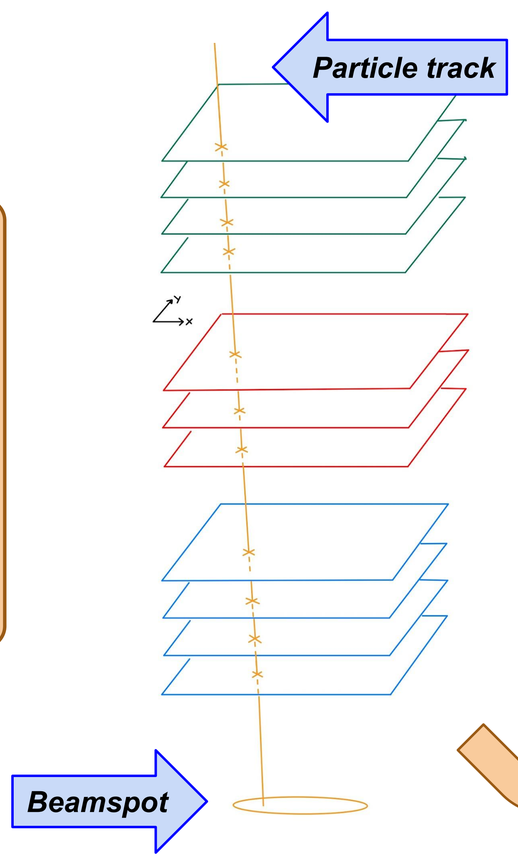
Our goal: use GNNs to reduce the areas for which classical alignment algorithms are used.



Proof-of-concept test:
- Telescope detector with 10 parallel layers
- Trained on one or two neighbouring misaligned layers
- Tested on two random misaligned layers
- Promising results

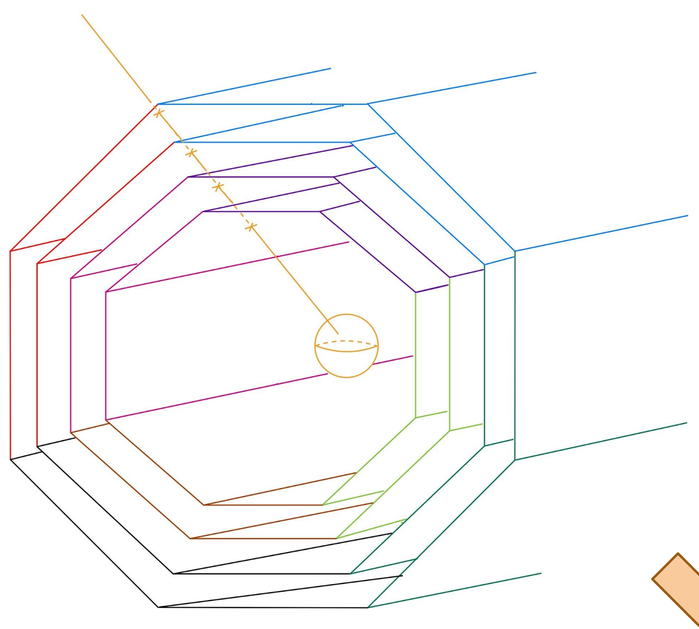


Detectors



[x, y]
[x, y]
[x, y]
[x, y]

Note! To create training datasets with misalignments, some readings are artificially shifted after calculating the correct intercept values.



[ID_z, ID_φ, X, Y]
[ID_z, ID_φ, X, Y]
[ID_z, ID_φ, X, Y]

Networks

[graphs]

GCN
A. Two SAGEConv hidden layers
   a. 32 hidden nodes
   b. ReLu activation
B. Final Linear layer
   a. 4 out features
   b. No activation function

$$\begin{bmatrix} 0.97 \\ 4.32 \\ -1.15 \\ 0.01 \end{bmatrix}$$

Loss
CrossEntropyLoss for multiclass classification.

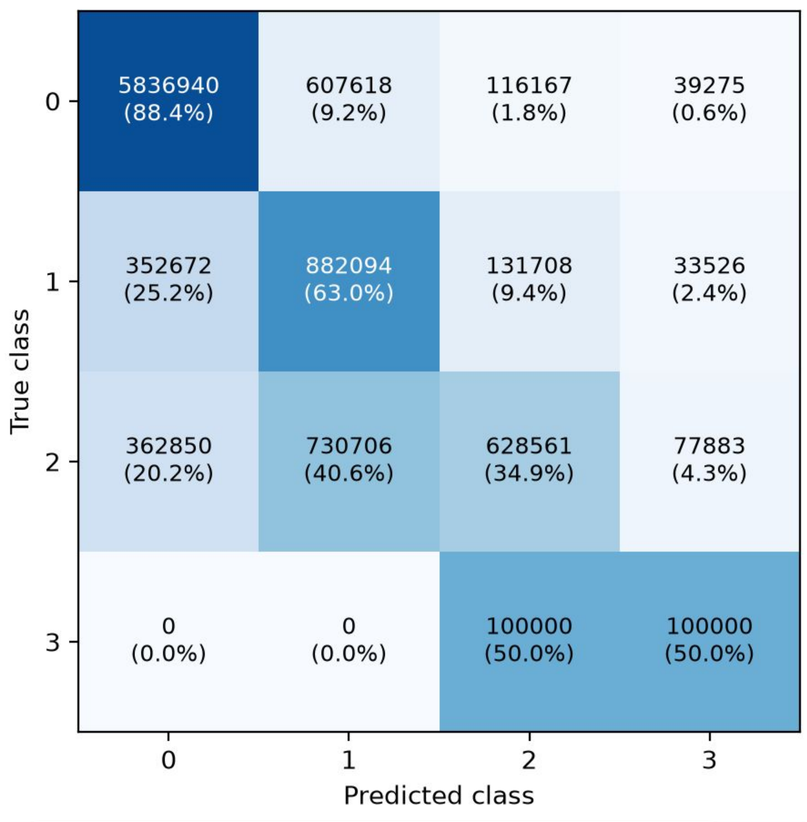
Weights based on the occurrence rate of each class.

Note! Undergoing testing of hypernodes/hyperlinks in the architecture.

There were observed problems during the training that make the current implementation unpredictable.

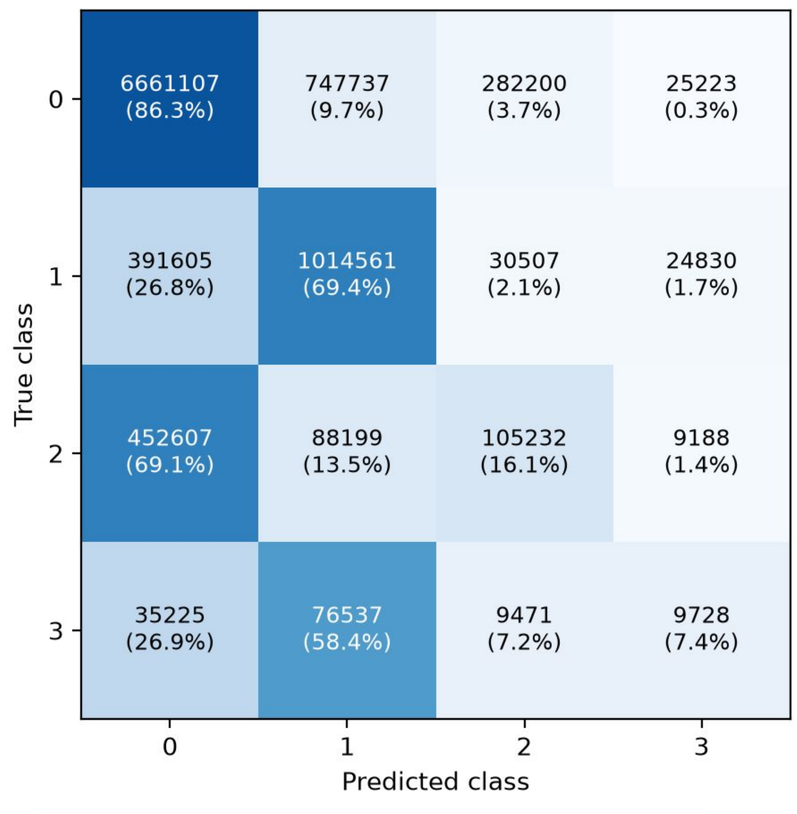
Note! Matching the 4 possible node types:
(0) no shift, (1) shifted with the block, (2) shifted alone, (3) shifted alone and with the block.

Results



Telescope detector:
- 30 runs training, 100k particles/run
- Adam optimizer, 1e-3 learning rate;
- Convergence in around 10 epochs
- 99% accuracy on validation set
- Second evaluation on 10 runs with different shift types
- Inaccuracy in very defective setups (more than 50% of layers shifted)

Cylindrical detector:
- 10 runs training, 100k particles per run
- Adam optimizer, 1e-3 learning rate
- Convergence not achieved in 50 epochs
- 80% accuracy for training validation
- Second evaluation on 10 runs with similar errors
- Decent at finding block errors



Prospects

Hyperstructures:
- More complex architectures require better defined hyperstructures for understanding the geometry
- Working idea: hyperlinks between nodes in the same block
- Future idea: hypernodes for block evaluation

Geometry:
- Current geometries still similar to “proofs-of-concept”
- Working idea: train using data from standard tracking software e.g. ACTS
- Future idea: creating a “reasonable enough” model that is easily adaptable for a large range of geometries

Pipeline integration:
- This work should not fully replace global fittings, just help narrow down areas simulated
- Working idea: making the frameworks compatible with popular data types and formats
- Future idea: potentially use it as a “real-time” misalignment monitoring tool