Particle tracking with graph neural networks

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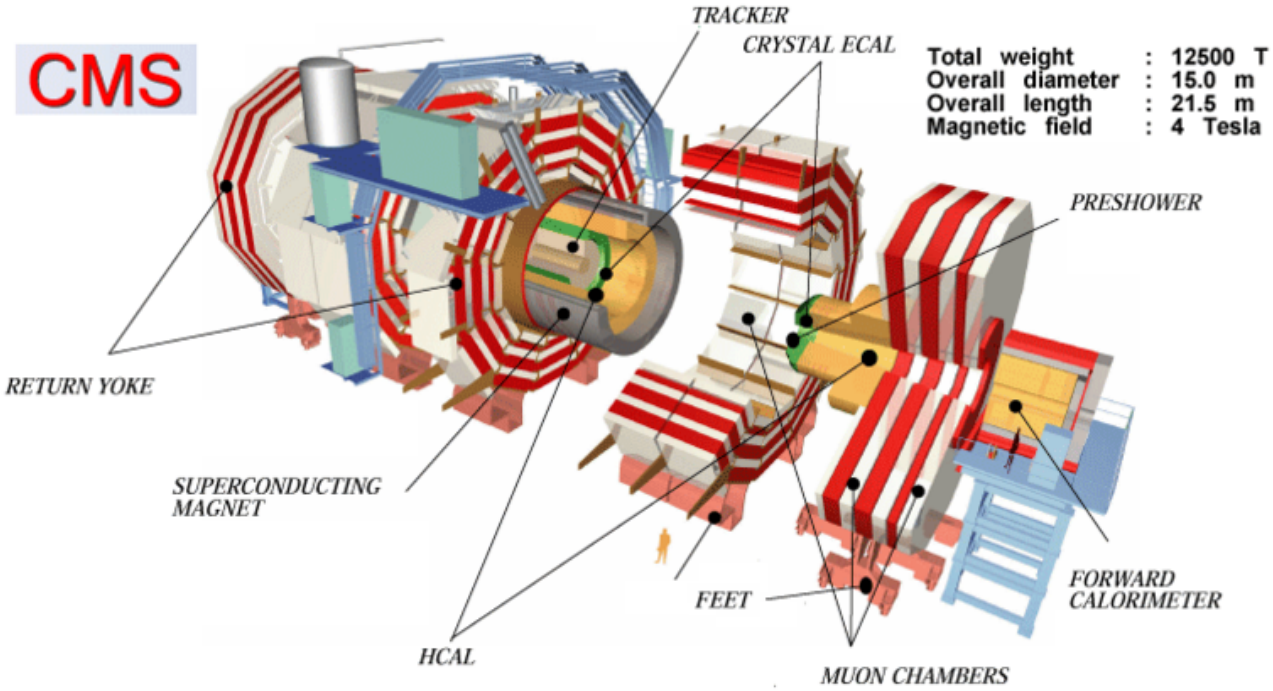
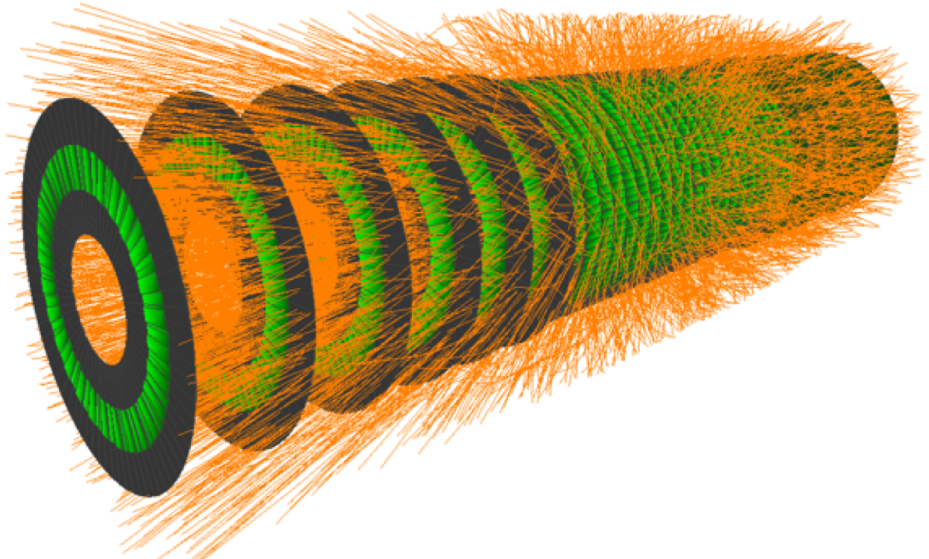
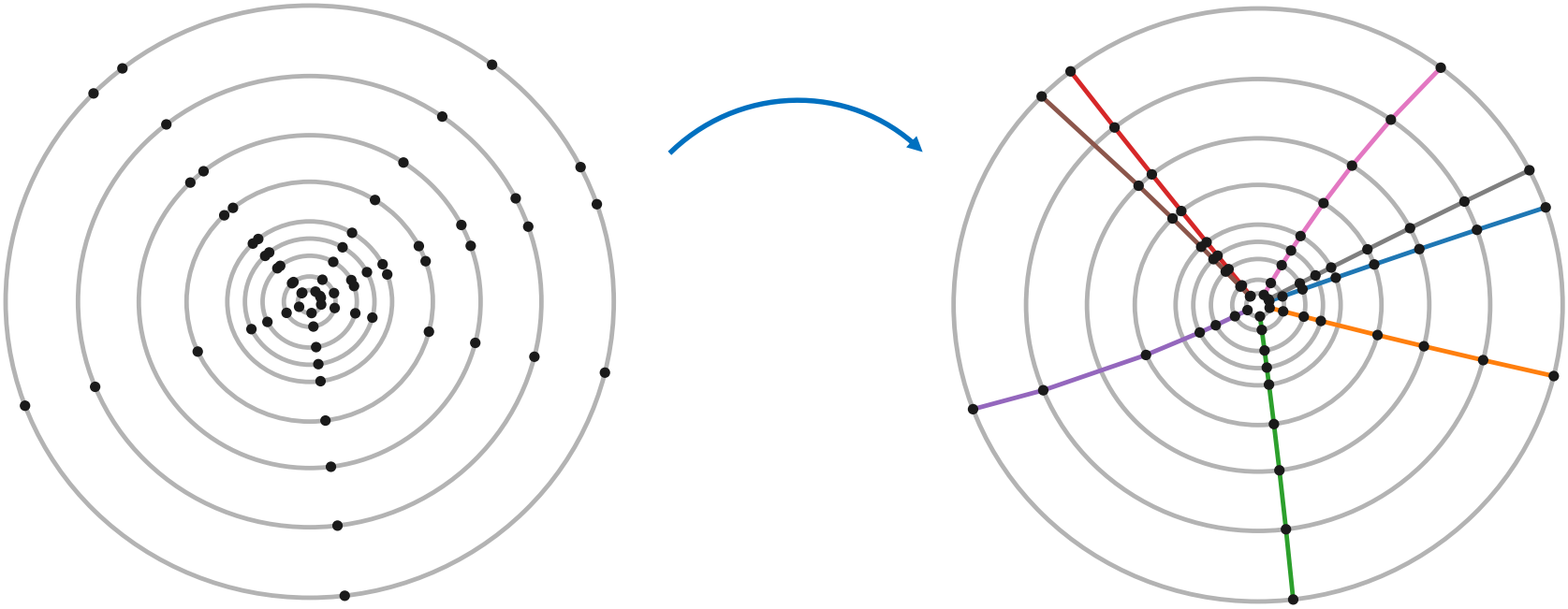
Introduction to the problem





Particle tracking problem



Machine learning approach proposal

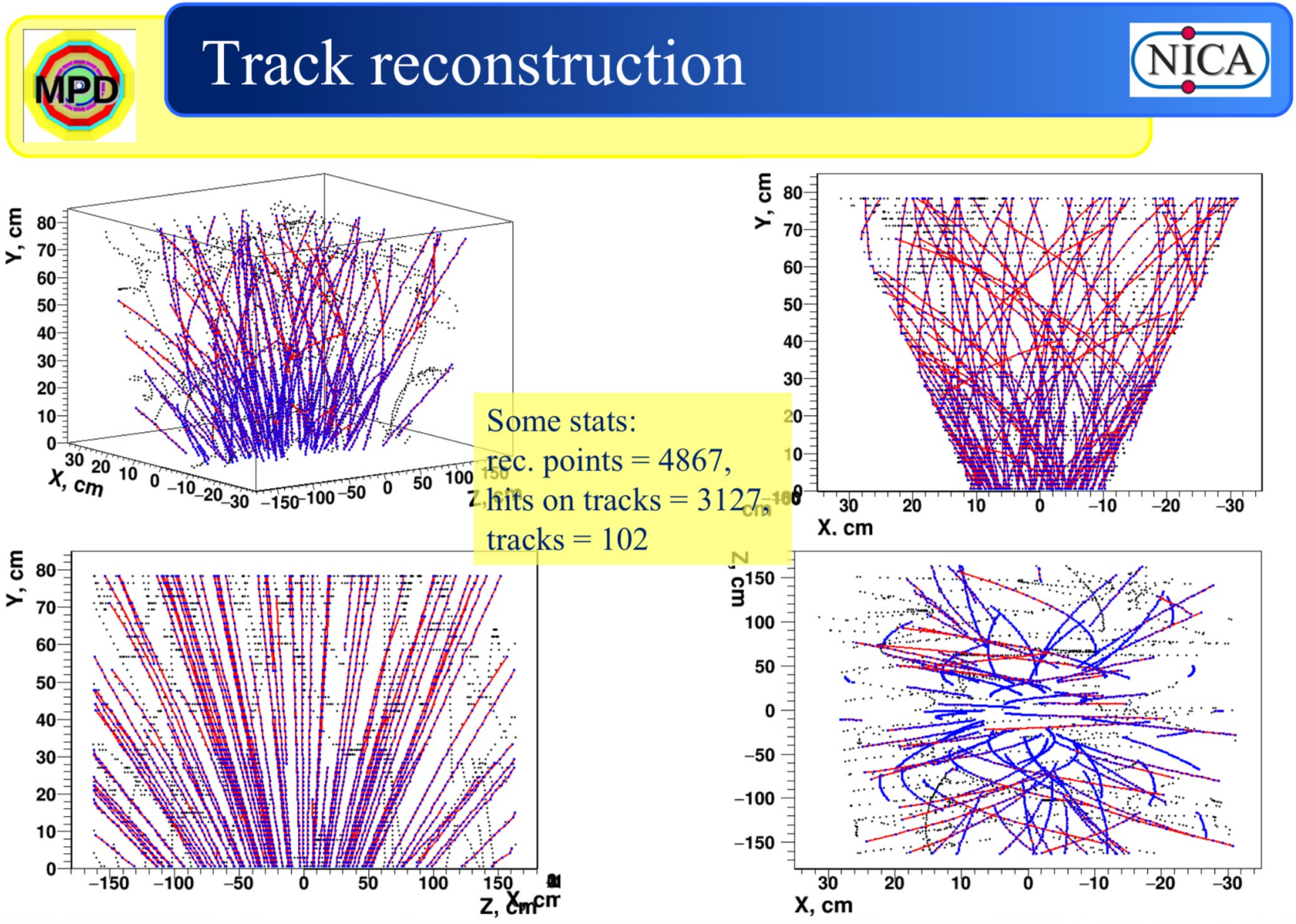
Treat this problem as a clusterization task.

Object space: hits $\{x_1, \ldots, x_n\} \in X \subset \mathbb{R}^3$

Clusters: tracks labels $Y \subset \mathbb{N}$

Required: reconstruct mapping $f : X \to Y$

Real data example



Synthetic data

$$
\begin{cases}
t \sim \exp(\lambda) & & \\
x = x_0 + r \cdot \cos(a \cdot t + \phi_0) & + & \mathcal{N}(\mu_x, \sigma_x^2) \\
y = y_0 + r \cdot \sin(a \cdot t + \phi_0) & + & \mathcal{N}(\mu_y, \sigma_y^2) \\
z = z_0 + b \cdot t & + & \mathcal{N}(\mu_z, \sigma_z^2)
\end{cases}
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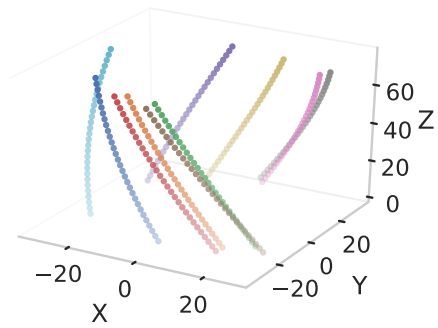
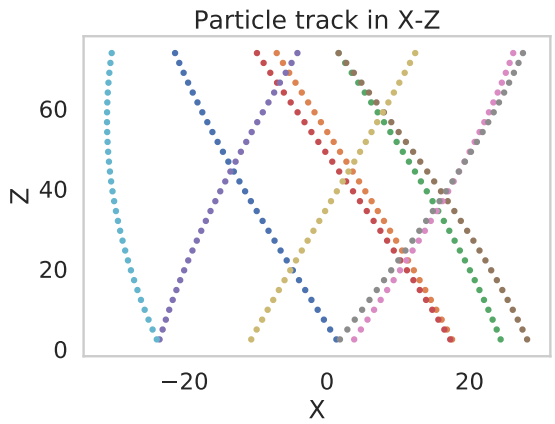
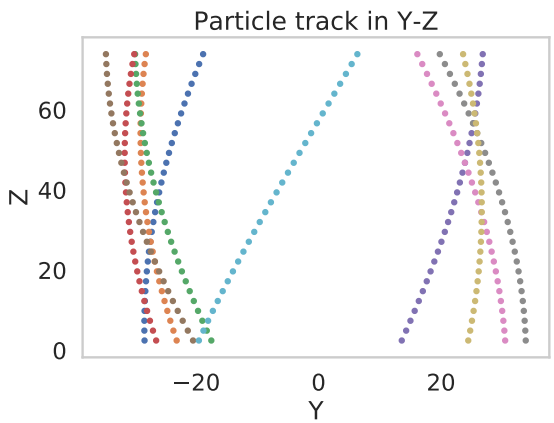
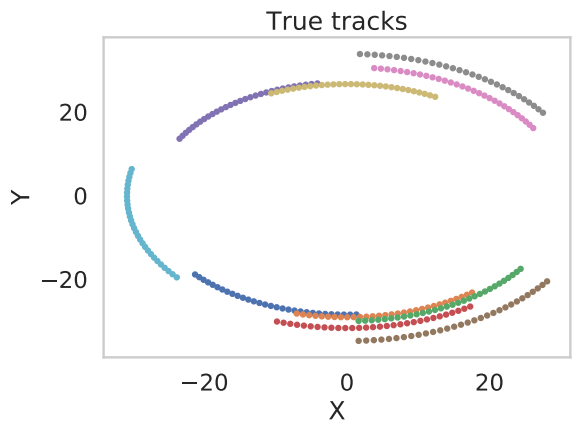






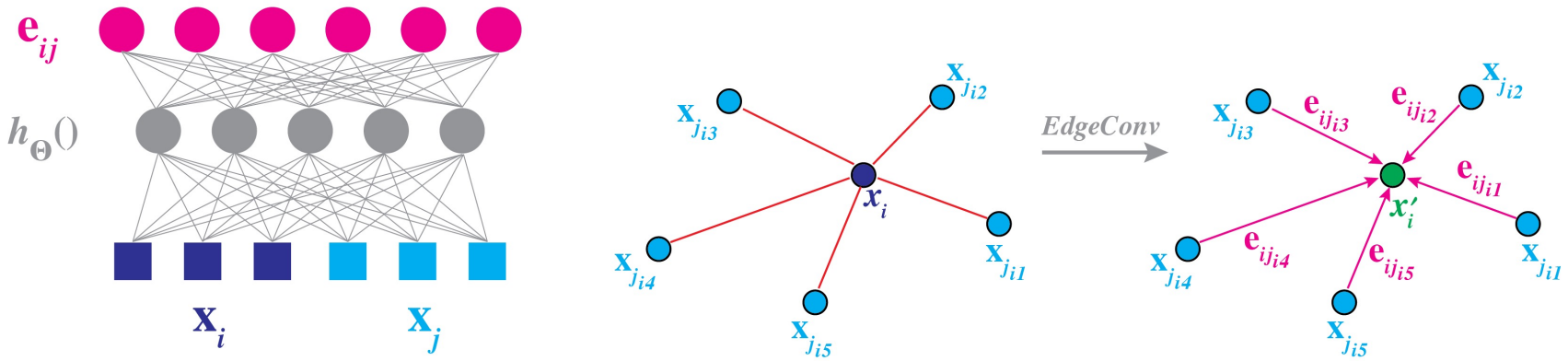


TrackML metric

Very short description:

It is the intersection between the reconstructed tracks and the ground truth particles, normalized to one for each event, and averaged on the events of the test set.

Edge Convolution



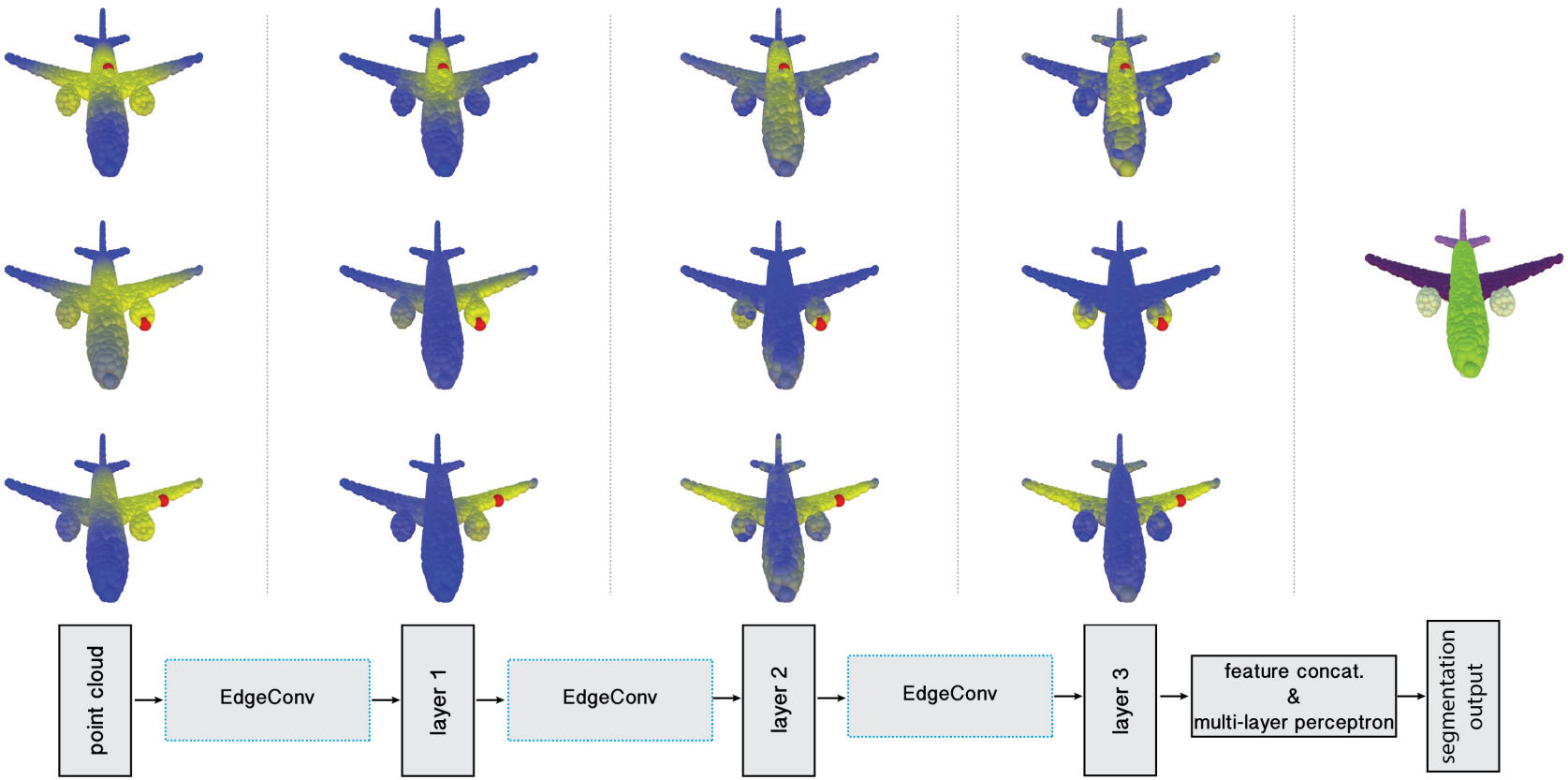
Point cloud: $X = \{x_1, \ldots, x_n\} \subset \mathbb{R}^F$
F represents the feature dimensionality of a given layer.

Edge features: $e_{ij} = h_\Theta(x_i, x_j)$, where
$h_\Theta : \mathbb{R}^F \times \mathbb{R}^F \to \mathbb{R}^{F'}$ – nonlinear function with a set of learnable parameters Θ. The output of **EdgeConv** at the i-th vertex:

$$x'_i = \square_{j:(i,j)\in\mathcal{E}} h_\Theta(x_i, x_j)$$

$\mathcal{E}$ – edges of the k-nearest neighbor (k-NN) graph of X in $\mathbb{R}^F$

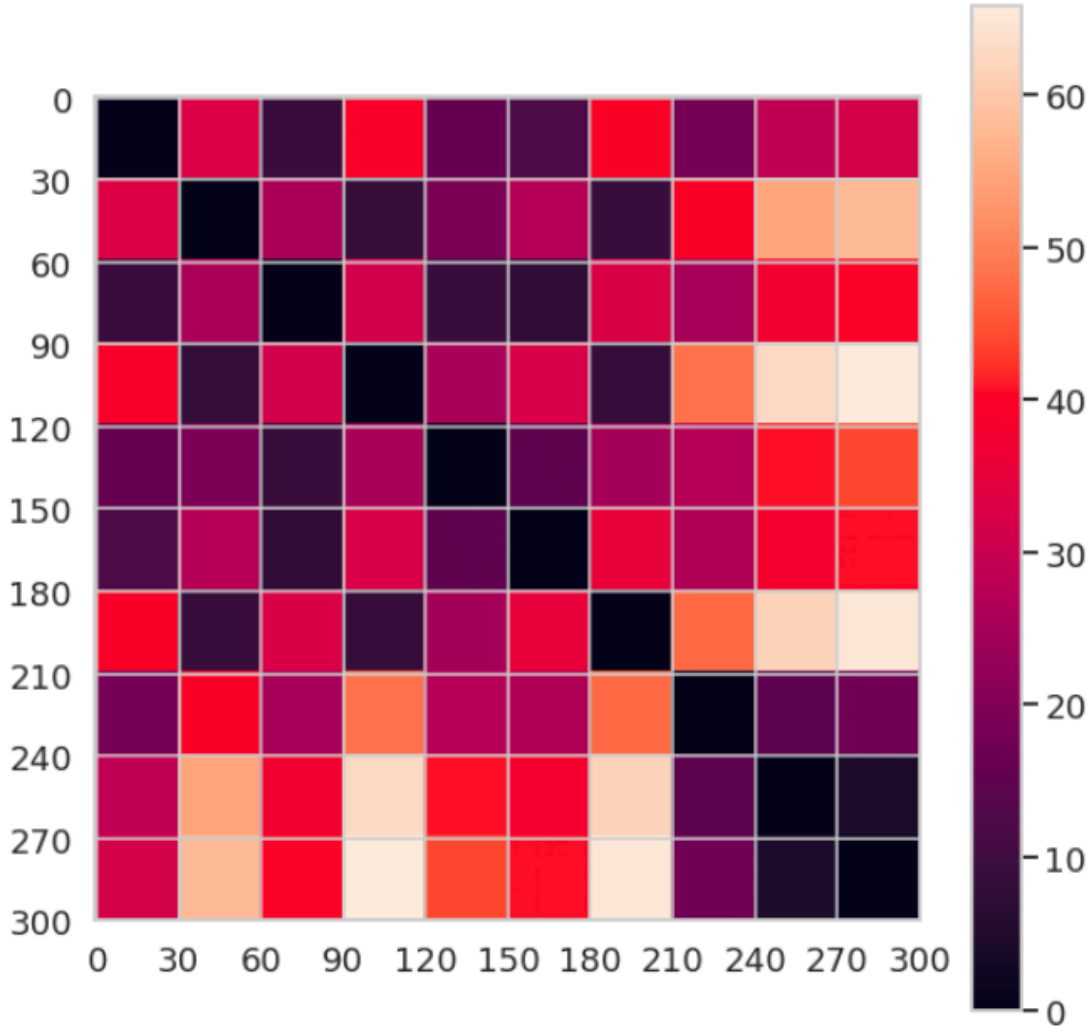
Dynamic Graph CNN[1]



[1]Wang et al. Dynamic Graph CNN for Learning on Point Clouds, 2019

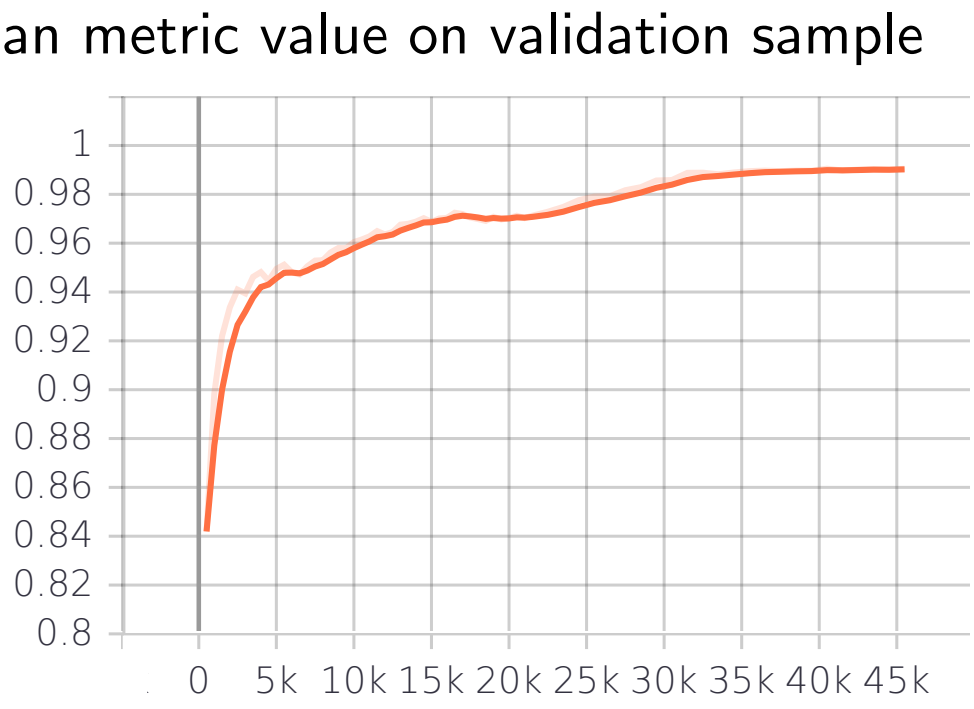
Proposed approach for tracking

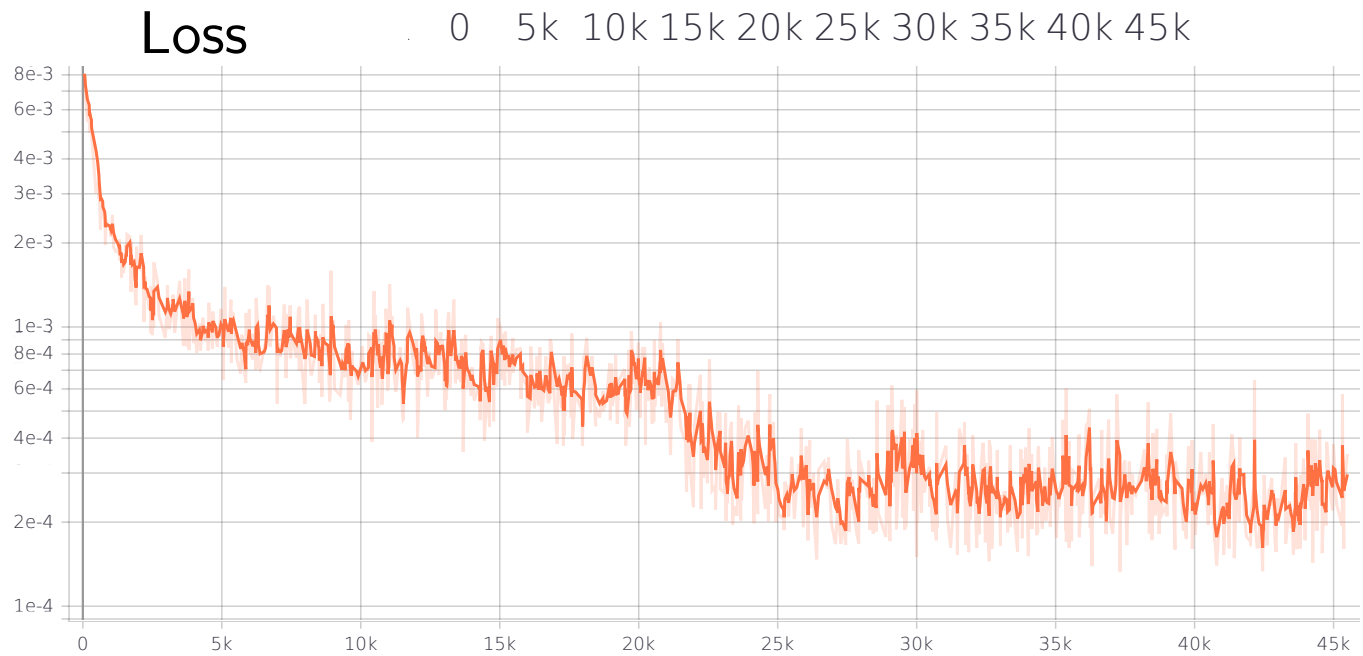
- DGCNN
- Calculation of the matrix of pairwise distances



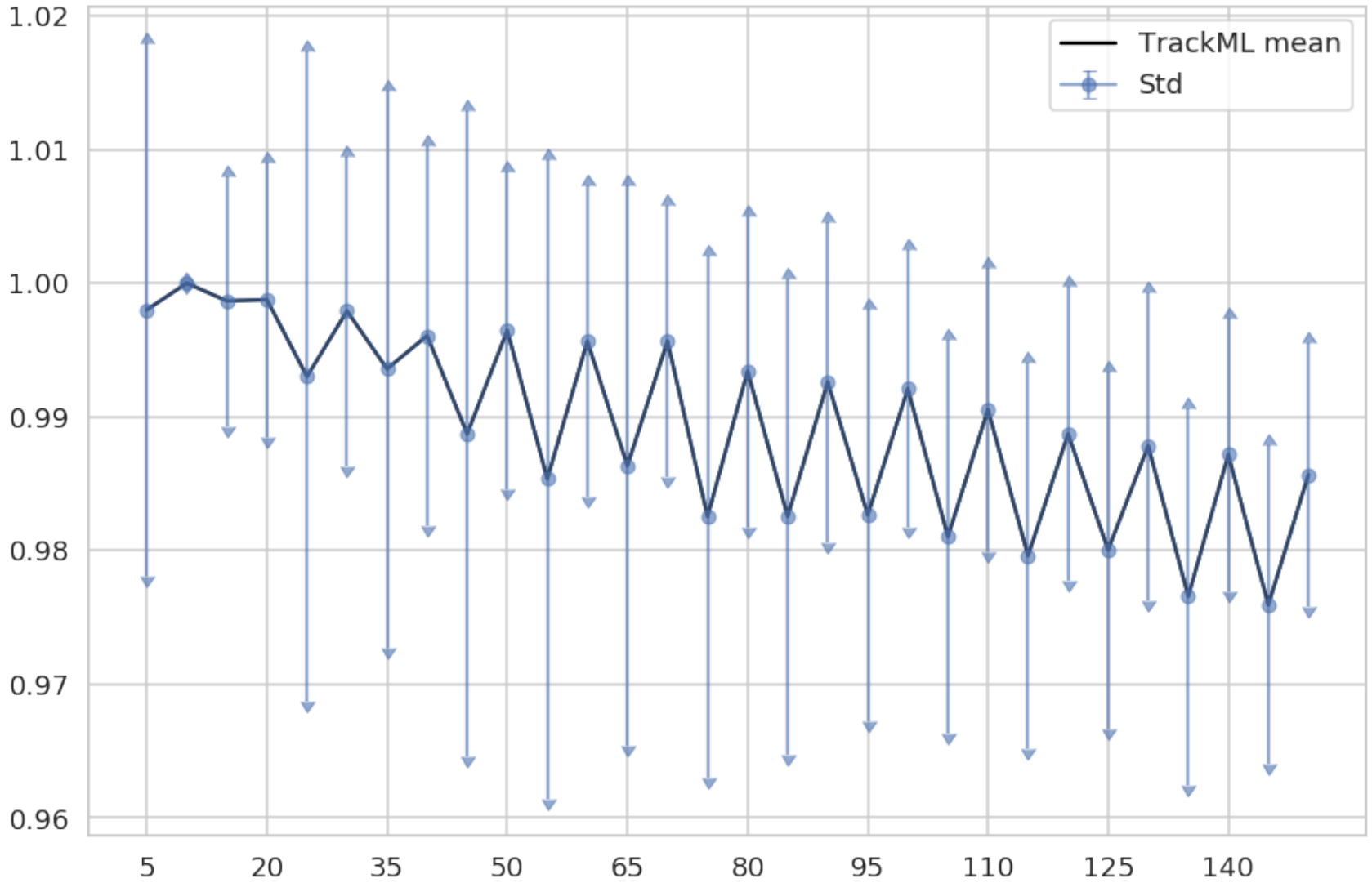
- Hierarchical agglomerative clustering

Model training





Metric value dependence on the number of tracks



Thank you for your attention.

Any questions?