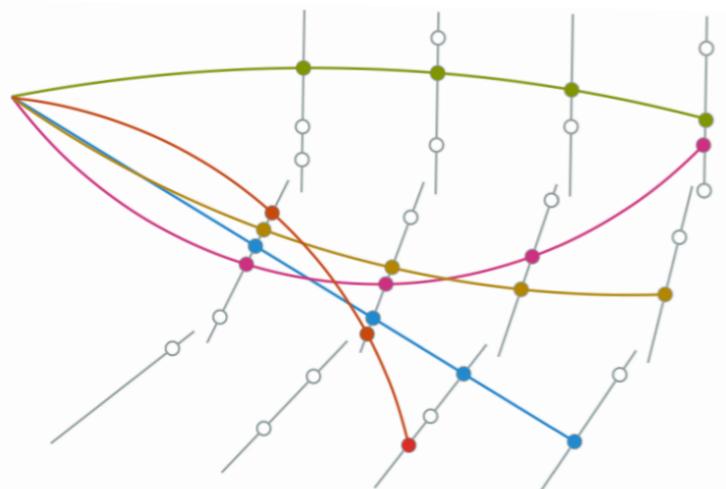
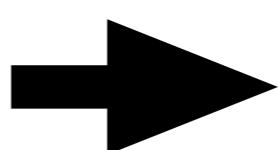


TrackFormers: Transformer-Based Models for High-Energy Physics Track Reconstruction

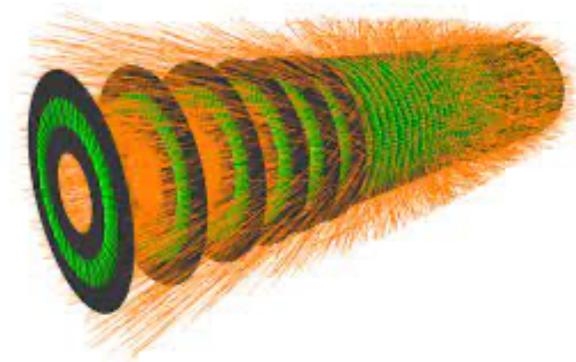
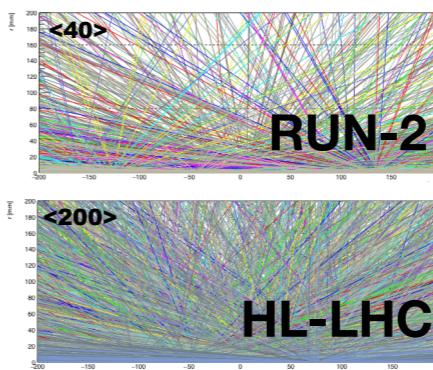


The task of **connecting detector hits into charged particle trajectories**

Introduction

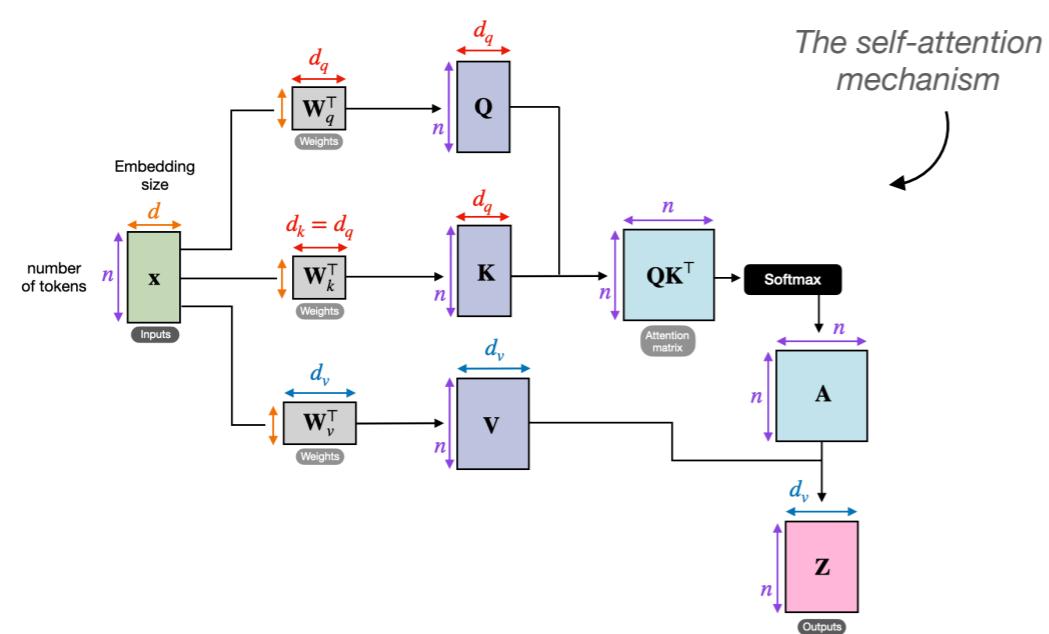


Why is this a challenge?



The HL-LHC will experience ~ 200 simultaneous interactions per bunch crossing, creating highly complex tracking environments.

Transformers

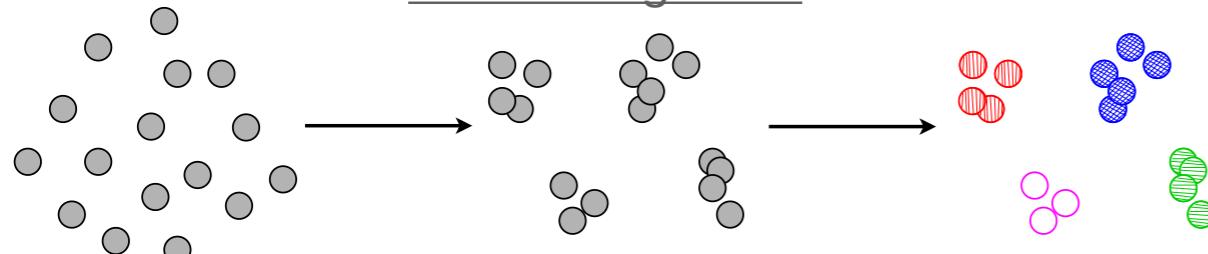


Transformers capture **long-distance relationships** in inputs by using the self attention mechanism, originally proposed for natural language processing

Motivation: **long-distance relationships also important for tracking!**

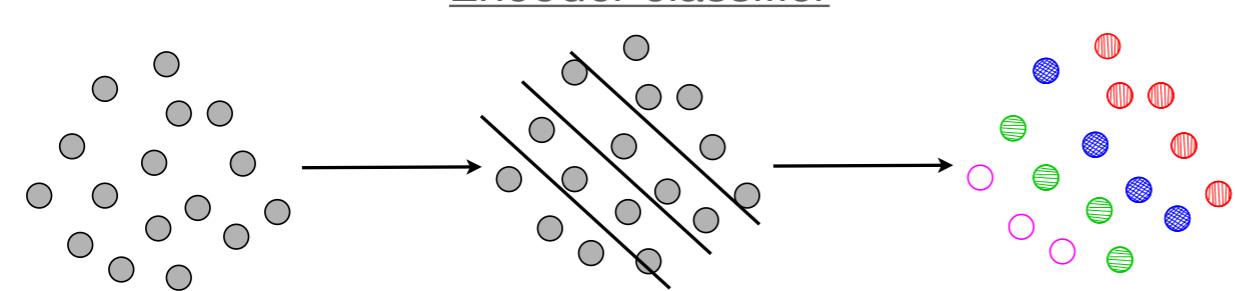
This is similar to the motivation for using Graph Neural Networks (GNN) for charged particle tracking, which has recently also gained significant traction

Encoder regressor



- Inputs are full set of hit coordinates
- Regresses track parameters per hit
- track parameters can subsequently be clustered to construct tracks

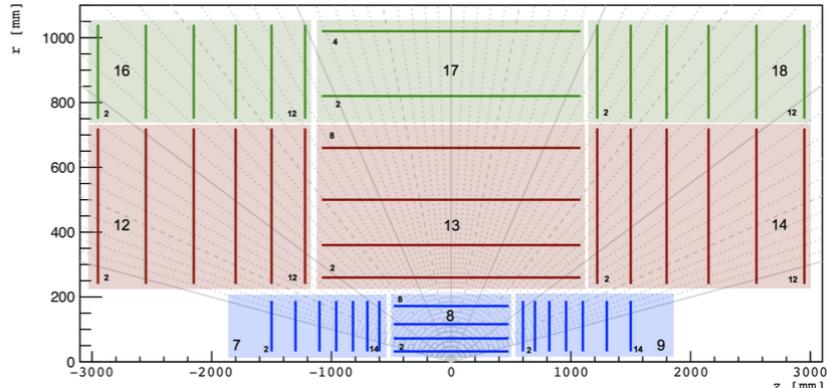
Encoder classifier



- Inputs are full set of hit coordinates
- Defines multiple track classes in track parameter space, classifies hits in those classes

Both models classify the whole event in a single inference step. This is the main advantage compared to hit-by-hit (autoregressive) models, such as Kaman Filter

Dataset



Using the **TrackML dataset**, originally made for a Kaggle competition, remains the benchmark dataset in literature

Generalised representation of LHC tracker

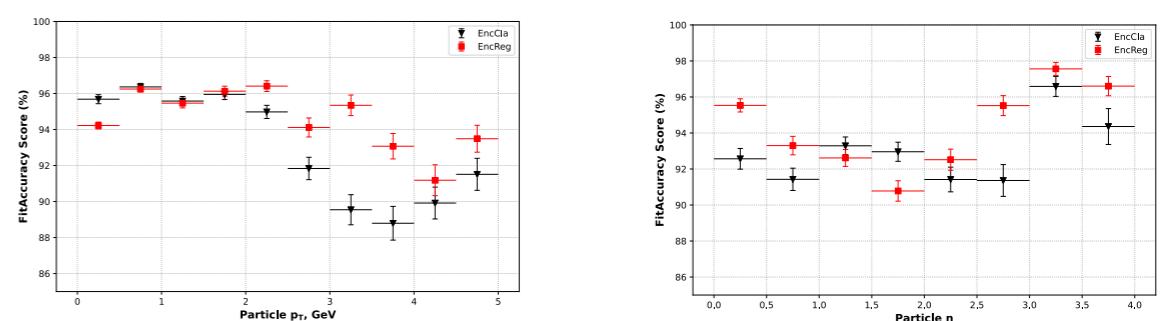
Reduce dataset to multiple complexities for proof-of-concept approach

results

Inference times and TrackML scores on 200-500 tracks dataset

Model	CPU Inference (ms)	GPU Inference (ms)	FitAccuracy (%)
EncCla	0.1	7.0	78%
EncReg	70.5	31.9	70%

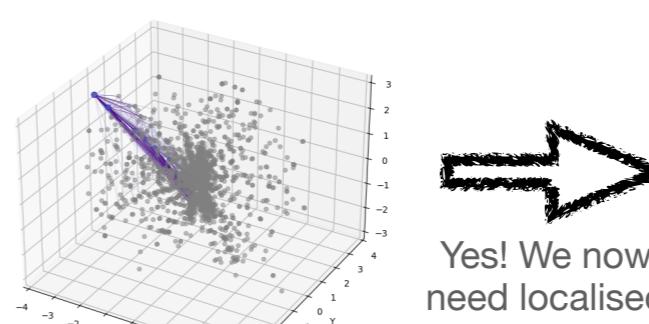
TrackML scores on 10-50 tracks dataset



Ongoing work

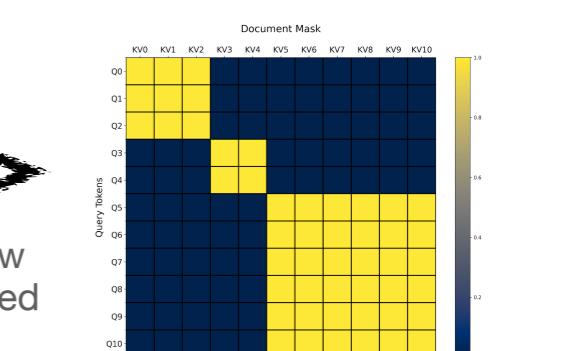
Problem: attention matrix grows significantly with more hits (n by n)

Idea: Maybe we do not need to use all relationships. Can we use localised attention mechanism?



Trained attention scores

Yes! We now need localised attention



Masked attention matrix (FlexAttention)

Strategy: Define appropriate “locality” for FlexAttention mechanism, and implement it in model for full TrackML dataset



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