Connecting the Dots: Machine Learning for Tracking at the LHC

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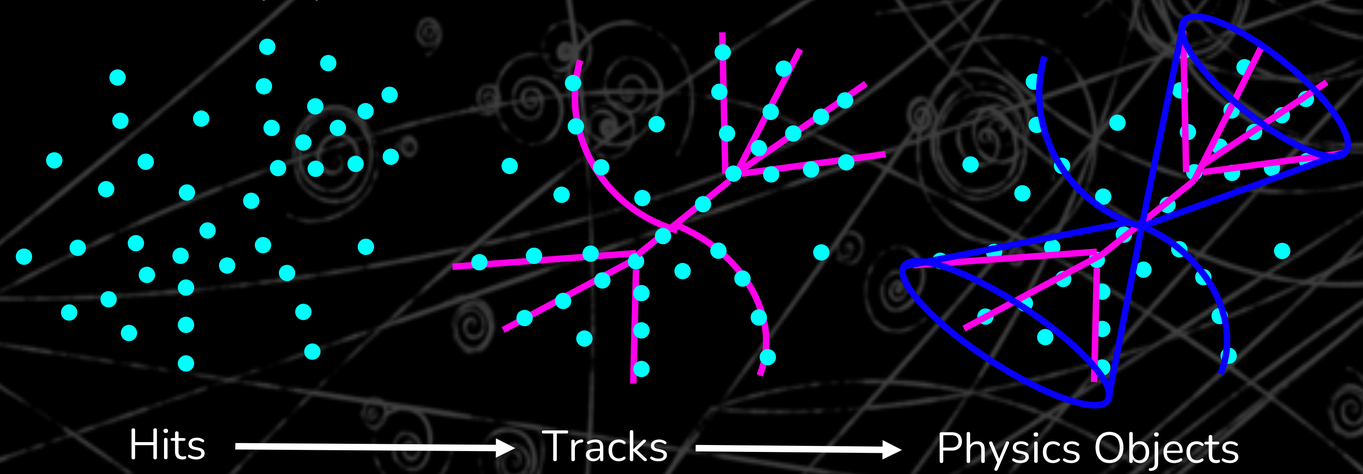
What is tracking?

- Reconstructing the tracks of charged particles from the hits they leave as they traverse the detector
- Tracks make up particles or jets of particles, and are fundamental to the all physics we do at ATLAS and the LHC

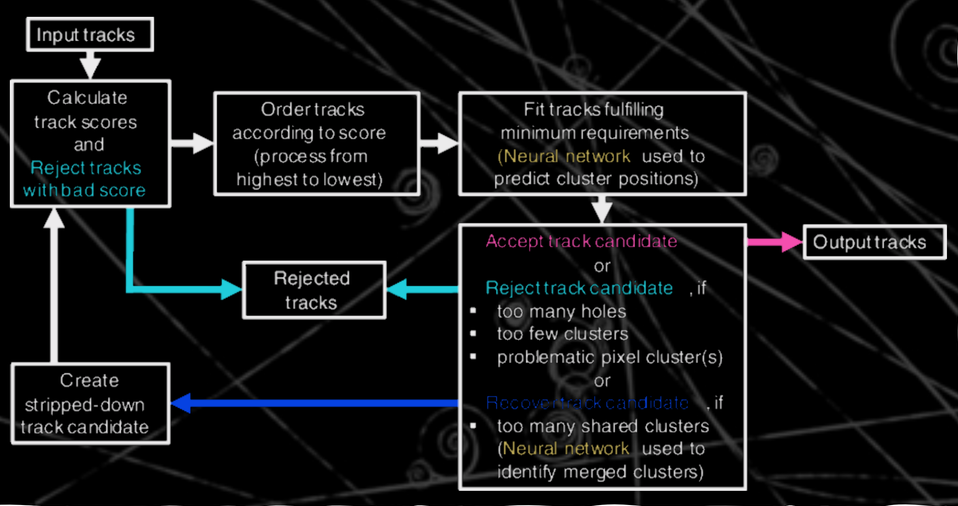


Challenges & Benefits

- In each event are around 100,000 hits and 1,000 tracks, increasing to 750,000 and 8,000 respectively after the hi-luminosity upgrade
- Poor tracking → can miss or hallucinate particles → can miss interesting physics that actually happened
- For example, a 2x improvement in b-tagging efficiency resulting from better tracking → 8x sensitivity in HH→4b analyses

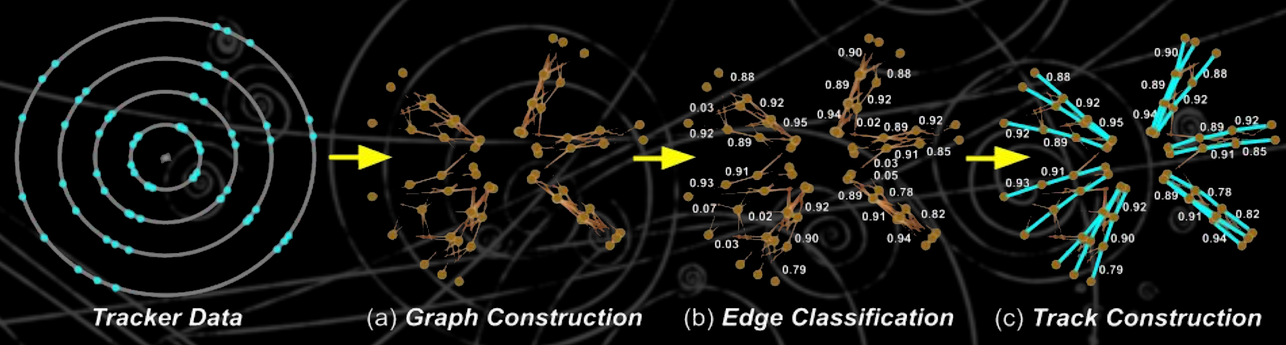
Tracking in ATLAS

- The conventional tracking approach is to use a Kalman filter which iteratively finds potential tracks
- Inevitably will end up with some spurious tracks that are not actually there
- Then try and weed these tracks out using an ambiguity solver



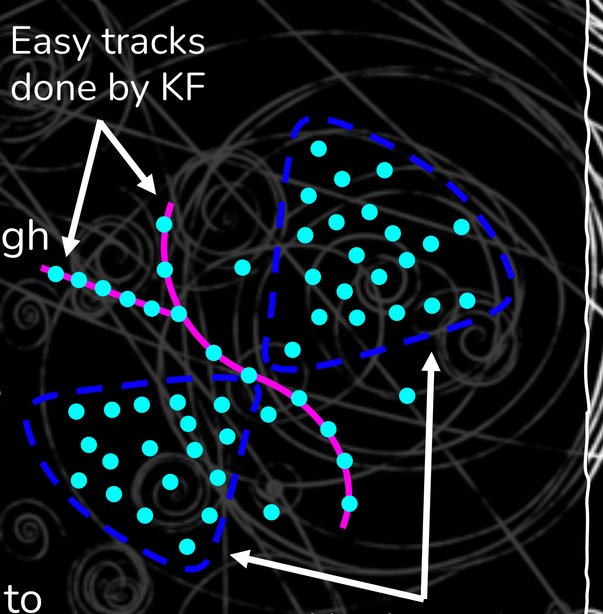
Machine Learning & Tracking

- Already efforts to use graph neural networks for tracking
- Connect nearby hits/nodes with edges, classify these edges to exist or not - connected strings of nodes are then tracks
- Focus on the full event → need preprocessing steps to keep the number of edges manageable
- Information travels along the edges → distant hits can't communicate well with each other



Our proposal

- Traditional tracking is already pretty good, just suffers where tracks are very dense & close
  - But these cases are important for interesting high momentum Higgs physics!
- Idea: use ML for just the ambiguity solver / dense regions of hits that are more difficult to resolve. With this we can:
  - Use a more powerful ML model (transformers) to connect every hit to every other hit, via attention
  - Incorporate lower-level information (i.e., pixels)



Takeaway

Using ML in the ambiguity solver allows us to test the benefits of using more powerful transformer models and lower-level information. It is also more feasible to incorporate into the existing ATLAS pipeline and so can deliver improvements in time for the next phase of the LHC.

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