Graph Neural Network based Track Finding in the Central Drift Chamber at Belle II

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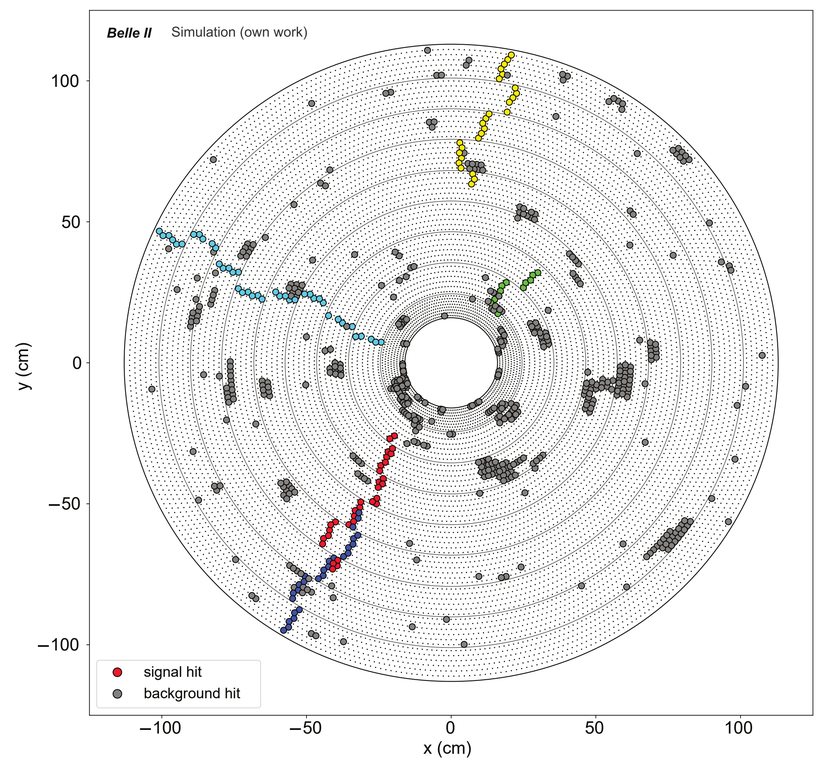
Motivation

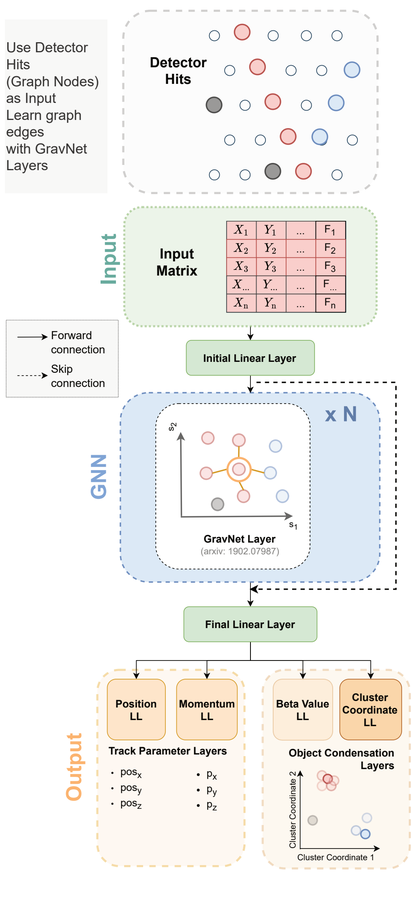


- Decay products of long-lived particles are an **important signature** in dark sector searches in collider experiments.
  → current Belle II tracking algorithm is optimized for tracks originating from the interaction point

Develop New Tracking Algorithm that can:

- Find **unkown** number of tracks
  → Object Condensation [1]
- Fit with computing **resource** and **time** constraint
  → Graph Neural Networks

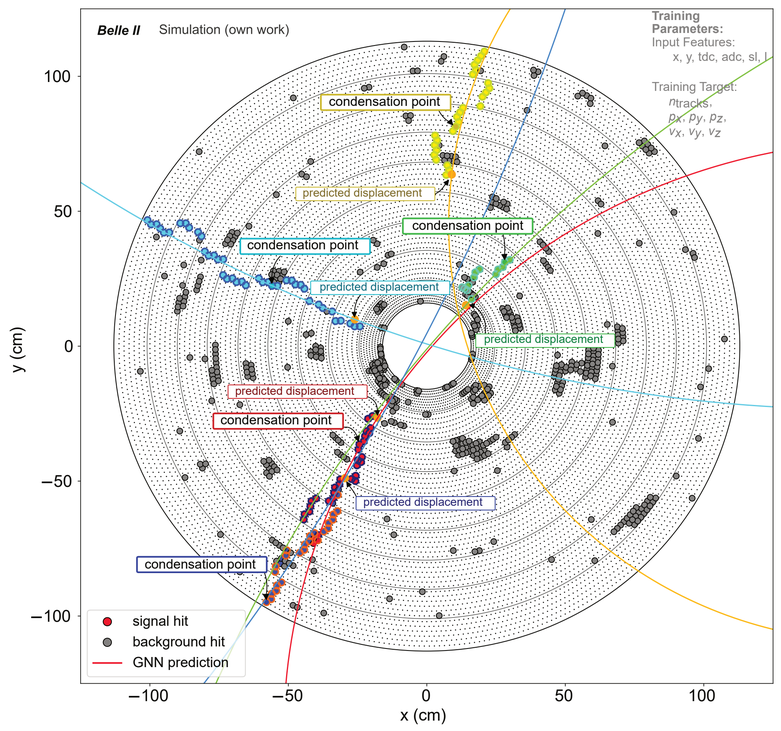
Model Overview



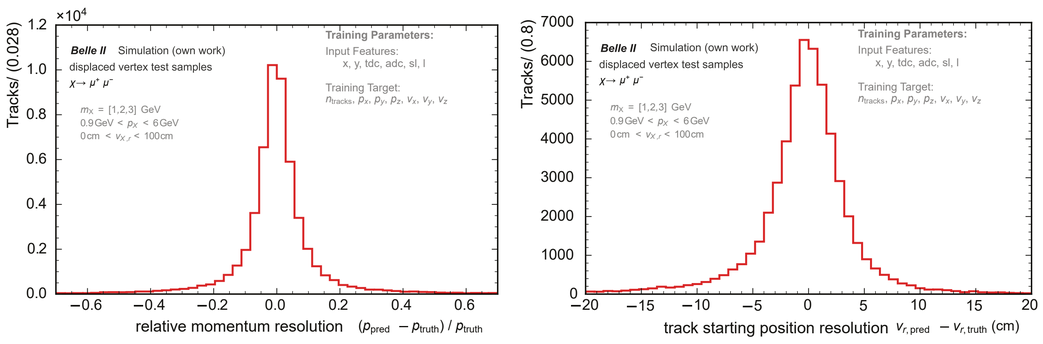
Watch how our network learns to find tracks!

Training Samples and Track Parameters

- **Belle II simulated training samples generated with basf2** [2], uniform mix of displaced vertex, 1-5 tracks from the interaction point, and 1-5 displaced tracks
- Input features are wire information: position of a hit wire, signal height, and signal time
- Predict number of tracks and the respective track parameters: momentum and track starting position

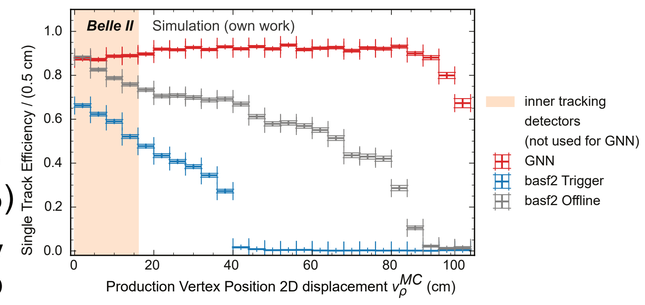


Model Track Parameter Prediction Resolution



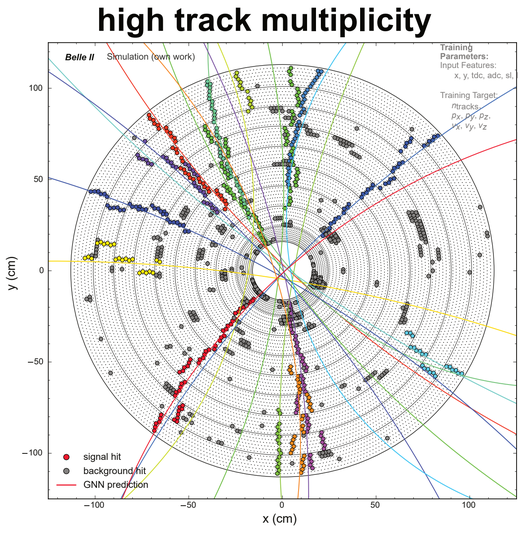
Track Finding Efficiency

- **GNN** (basf2 Offline) achieves **96.8%** (65.6%) track finding **efficiency** on displaced vertex test samples at the cost of
  - fake rate of 2.3% (8.6%)
  - clone rate of 0.7% (0.4%)
- GNN track finding efficiency constant and **independent** up to 80cm radial displacement



Conclusion and Outlook

high track multiplicity

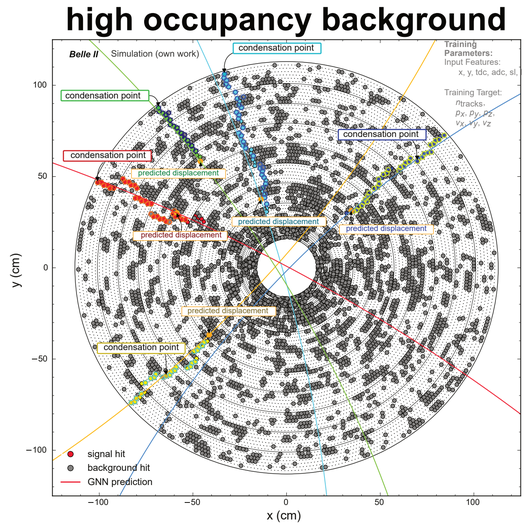


- Implemented Object Condensation for Drift Chamber Track Finding
  → **Full Track Finding and Fitting GNN model working!**
- Object Condensation good at **generalizing** (can be applied to high occupancy background and higher multiplicity track events)
- **New** tracking methods can tackle also high occupancy due to increased backgrounds expected in the upcoming data taking of Belle II
  → GNN based track finding approach shows promising results with high occupancy

Next Steps

- Implementation of GNN Track Finding in basf2 tracking software
- Investigation for real-time application in the level 1 trigger system

high occupancy background



[1] Object condensation: one-stage grid-free multi-object reconstruction in physics detectors, graph and image data. Kiesler, J. In *Eur.Phys.J.C,* vol. 80 no. 9 (2020).
[2] The Belle II Core Software. Kuhr, T., Pulvermacher, C., Ritter, M., Hauth, T. and Braun, N. In *Computing and Software for Big Science*, vol. 3 no. 1 (2019), https://github.com/belle2/basf2

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