Advances in developing deep neural networks for finding primary vertices in proton-proton collisions at the LHC

New approach based on Graph Neural Network

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S. Akar
University of Cincinnati

PV-finder motivations & context

- Over the next years, LHC detectors will face **significantly increased luminosities**
- One of the main challenges in this **high pile-up environment** will be the ability to perform **efficient vertexing**

- **The PV-finder project:**
  - train **DNN algorithms** to **find PVs** with **high efficiency** and **low false positives rates**
  - understand **how the results depend on underlying model architectures** and input features

- **PV-finder originally developed** targeting the **LHCb** geometry and conditions
  - Several studies and developments based on a Hybrid ***Fully connected*** **(FC)** + ***Convolutional Neural Networks*** **(CNN)** model over the past years: [CtD20 ; CHEP21 ; ACAT22 ; CHEP23; CERN IML24]
  - ***CNN****-based* approach recently adapted to the **ATLAS** experiment with extremely promising results [ATL-PHYS-PUB-2023-011]

PV-finder motivations

- Over the next years, the LHC detectors will face ***significantly increased luminosities***
- One of the main challenges in this ***high pile-up environment*** will be the ability to

Disclaimer

I will focus on *3 takeaway messages*, and will skip all details…
…for these see you tomorrow during the poster session!

- Several studies and developments based on a **hybrid *Fully connected* (FC) + *Convolutional Neural Networks* (CNN)** model over the past years allowing for continuous improvements [CtD20 ; CHEP21 ; ACAT22 ; CHEP23; CERN IML24]
- ***CNN-based*** approach recently adapted to the **ATLAS** experiment with extremely promising results [ATL-PHYS-PUB-2023-011]

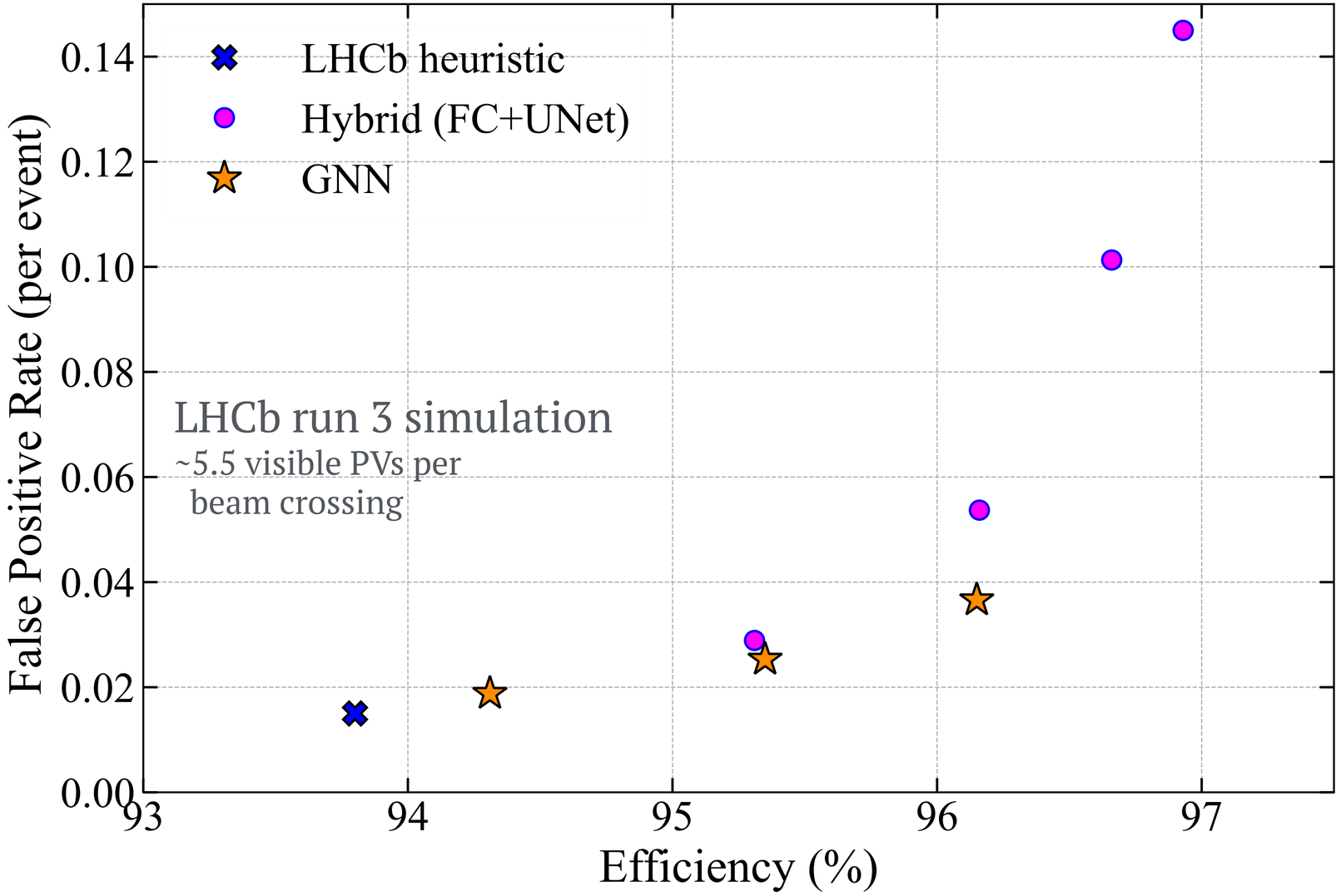
GNN approach: motivation

- **Graph Neural Network (GNN)** approach has been demonstrated to outperform heuristic algorithm in terms of physics performances:
  - GNN-based pipeline for track finding from hits in the Velo at LHCb [talk@CTD23]

- **GNN** models appear to be quite **versatile**:
  - With **minimal adaptation, similar models allow to perform very different tasks:**
    - edge classification for track reconstruction
    - node feature prediction for PV finding

Hybrid vs GNN: model performances

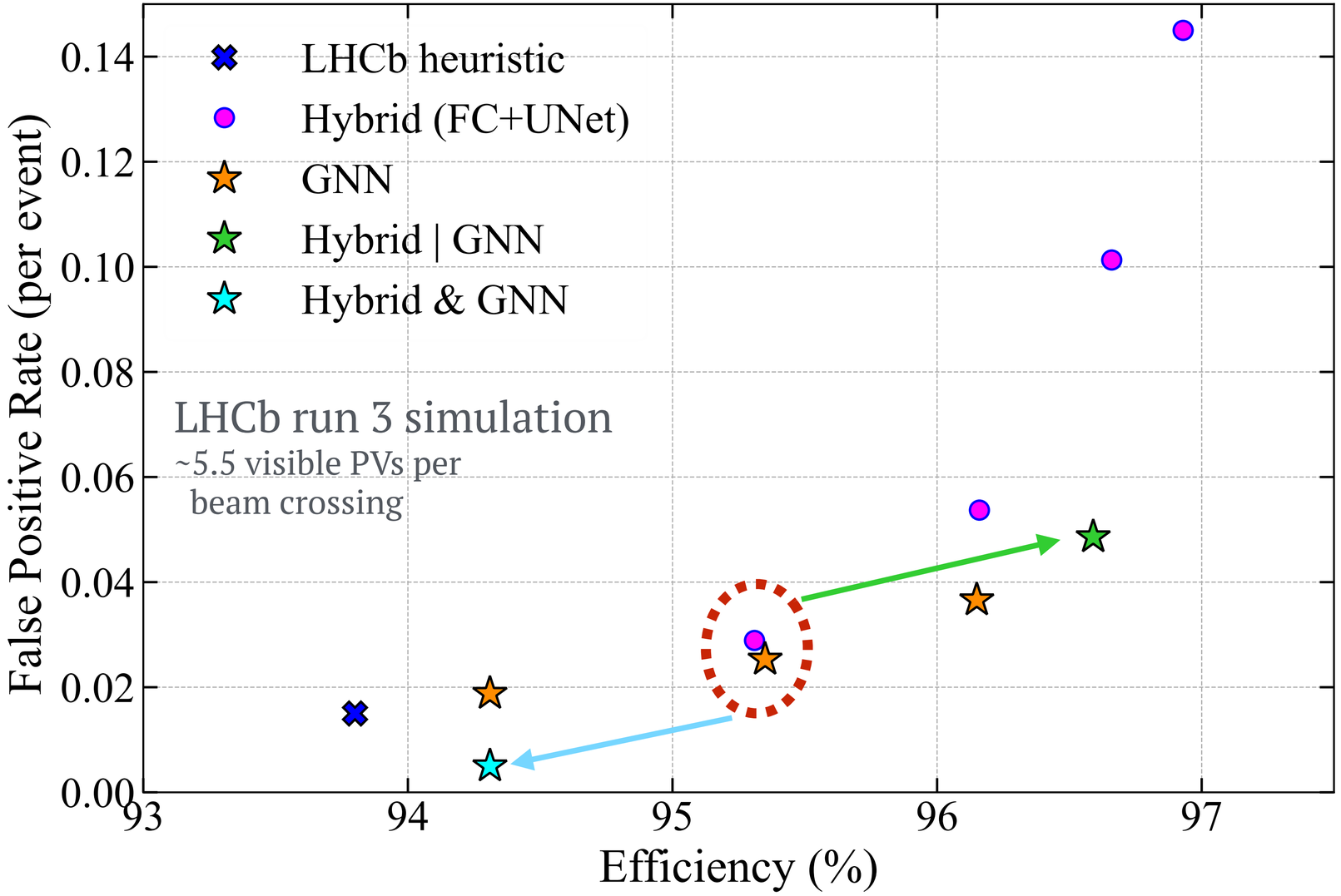
- ☑ **Hybrid best model results** from developments over the past years with refined models
- ☑ **GNN model achieve slightly better physics performance** than hybrid model
- **Conceptually different ML approach yields similar performances!**



Hybrid vs GNN: model performances

- ☑ **Compare GNN and hybrid models outputs with similar intrinsic performances**

- **Combination of output from models allows to either significantly increase efficiency or decrease false positive rate**



PV-finder GNN approach: Summary

Takeaway messages:

1. **GNN** models appear quite **versatile**
   similar model achieve good performances for different tasks (tracking vs PV finding)

2. **GNN** and **Hybrid** **models** achieve **similar intrinsic physics performances…**

3. **…**but only partial overlap meaning **GNN** and **Hybrid** **models** did **not learn exactly the same relations from identical input data!**

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All of the machine learning training described here was done in PyTorch using nvidia GPUs