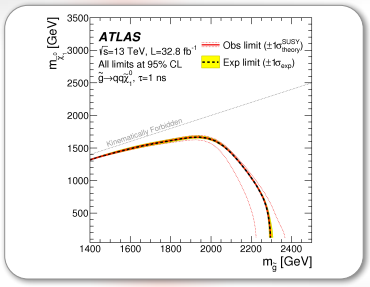
Towards Fast Displaced Vertex Finding

Kim Albertsson Brännn, kim.albertsson@cern.ch, Luleå University of Technology (LTU)
Federico Meloni, federico.meloni@cern.ch, DESY



Goal

- Is there a displaced vertex in this event? Where?
- Improve sensitivity for long lived particle searches with small momentum imbalance by triggering on displaced vertices

This Work

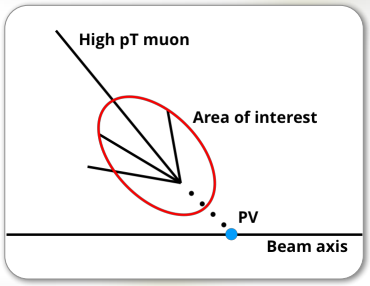
- Study regression of primary interaction location
- Start simple and scale up
- Dense networks in ideal conditions

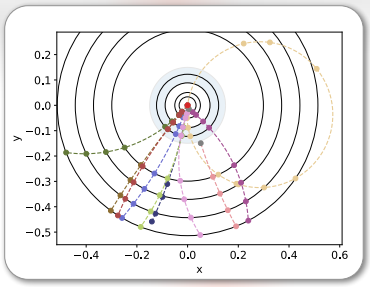
Strategy

- Estimate position of primary interaction
- Define area of interest from primary interaction and trigger object
- Process constrained search space in ~10 ms

Challenges

- Arbitrary data ordering of detector hits
- Events are rotationally invariant
- Detector has non-grid topology





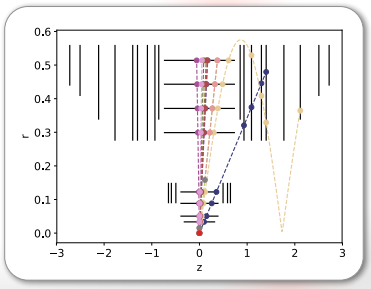
Data and Generation

- Using idealised geometry (based on ATLAS detector)
- Ideal helical propagation in homogenous magnetic field
- Simulation includes primary interaction, soft interactions and displaced decays

- Pythia 8.2 + MadGraph5_aMC@NLO 2.6.4 for event generation
- Delphes 3.4.1 with custom module for particle propagation

Currently studying two collision environments

- **electron-positron:** clean events to study efficiency and biases
- **proton-proton:** large track multiplicity (especially at low-pT) to study noise robustness

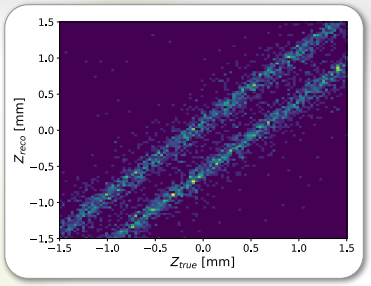


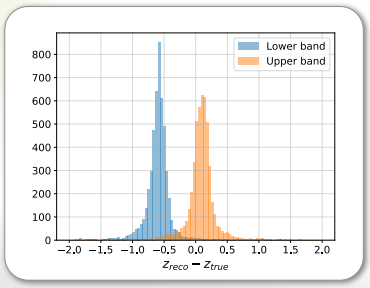
Input pre-processing

- Fixed number of tracks with fixed number of hits for each (discard/pad if mismatch)
- Input variables: hit position in cylindrical coordinates
- Order tracks according to phi
- Order hits within a track according to layer
- Idealised setup!

Problem: Rotational Invariance

- At one point double peak in loss due to track order
- Remedied by fixing track order
- Can be approximated by track roads for high-pt tracks





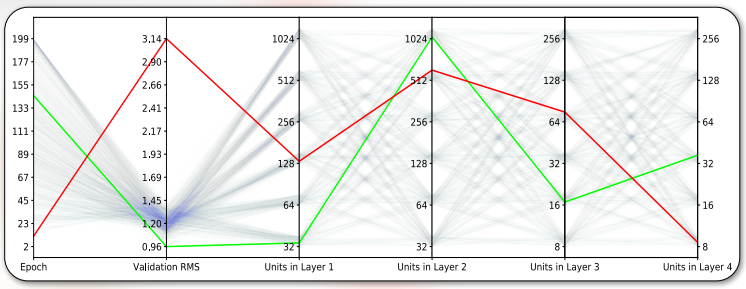


Figure: Hyperparameter optimisation
- Hyperparameter optimisation on four layer dense network using electron-positron dataset
- Input: First 2 tracks (20 hits)
- Output: Z position of primary interaction
- Showing best score for each training
- Excluding runs with validation RMS error larger than 5 mm (unfortunate initialisation)
- Green line: Best scoring network
- Red line: Worst scoring network

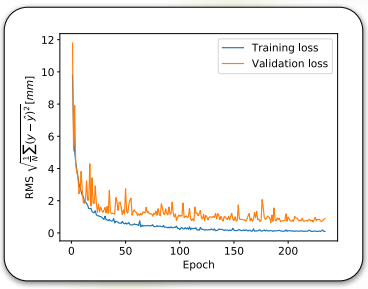


Figure: Typical loss curve
- Training on electron-positron dataset
- Rapid decline for first 10 epochs

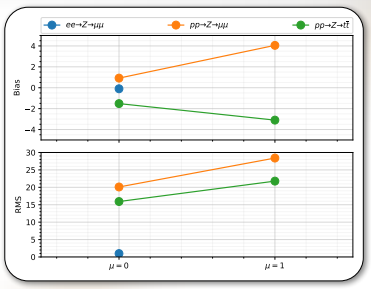


Figure: Bias and RMS vs pileup
- Four layer dense network
- Input: First 200 tracks (2000 hits)
- Output: Z position of primary interaction
- Layer widths: 512, 512, 256, 256
- Two settings: With and without pileup interactions

Discussion

- Expected results: Error bias and RMS close to 0 when no pileup
  - electron-positron: Bias ~0.1 mm, RMS ~0.9 mm
  - proton-proton: Bias ~4 mm, RMS ~20 mm (due to track order?)
- Good scores evenly distributed; Missing modelling capacity?
- Bias present, indicates training can be refined (restart with lower learning rate)
- Results process dependent
- Time for evaluating single event ~0.10 ms

Future work

- Full problem setup: Definition of area of interest and regression of displaced vertex
- Approximate idealised input pre-processing
- Investigate different approaches e.g. graph networks and techniques for natural language processing
- Add detector imperfections e.g. binned detector elements
- Investigate synergies with hardware-level track reconstruction in HEP experiments

References

[1] *Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in √s=13 TeV pp collisions with the ATLAS detector*, The ATLAS Collaboration, **Phys.Rev. D97 (2018) no.5, 052012**
[2] *DELPHES 3: a modular framework for fast simulation of a generic collider experiment*, The DELPHES 3 collaboration, de Favereau, J., Delaere, C. et al. **J. High Energ. Phys. (2014) 2014: 57**
[3] *An Introduction to PYTHIA 8.2*, Sjöstrand, T. et al. **Comput.Phys.Commun. 191 (2015) 159-177**
[4] *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations*, Alwall J. et al. **JHEP 1407 (2014) 079**