LULEÅ TEKNISKA UNIVERSITET

Displaced Event Classification

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Displaced Event Classification

Objective

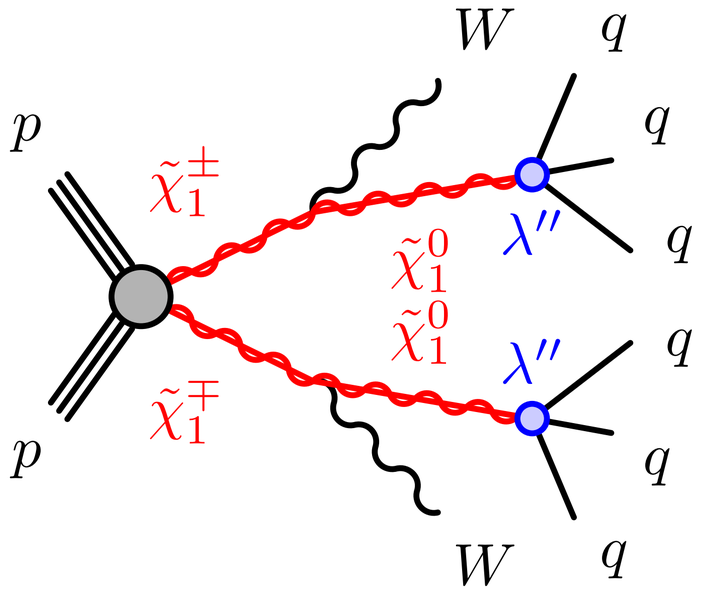
Use classification to identify events with high-mass displaced vertices based on raw detector hits, skipping track and vertex reconstruction

What

Investigate GNN performance in ATLAS-like Inner Detector for a SUSY process at increasing levels of pileup

Why

BSM searches limited by trigger level filtering favouring prompt events; Dedicated displaced vertex algorithms can be expensive



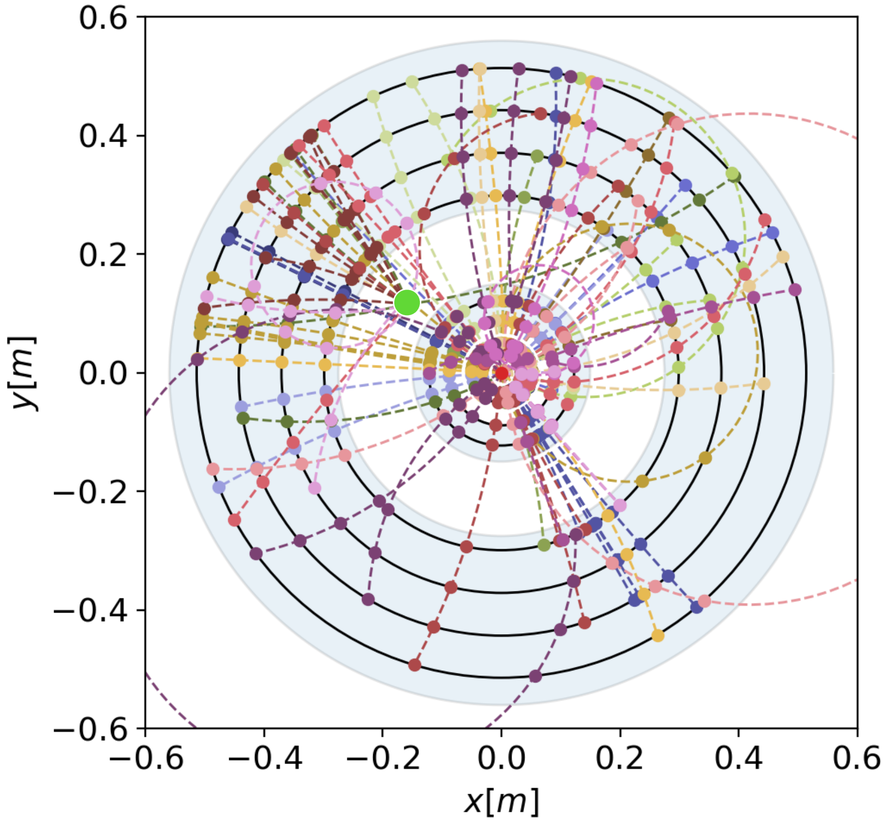
Scope

Heavy SM particles (e.g. W, Z, top quarks…) decay close to the *pp* interaction point

However, there several other sources of displaced vertices, such as:

- Long-lived mesons (e.g. K_S^0, …)
- Hadronic interactions

New heavy LLPs could decay with **high-mass** displaced vertices.

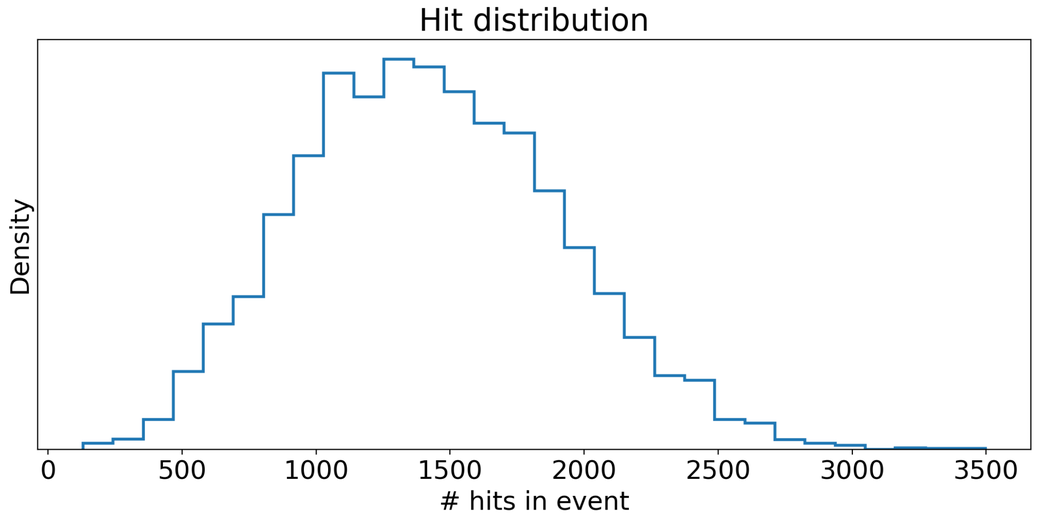


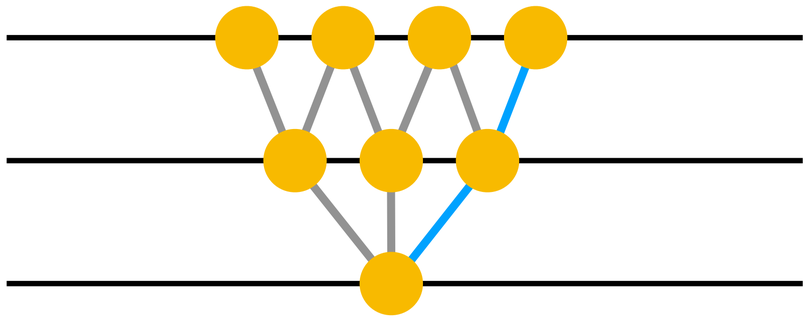
The problem

Number of input features (hits) per event highly variable

Absolute position of hits carries little information, relative position important

Event contains strong structure (tracks) with variable connectivity (cmp. image grid)





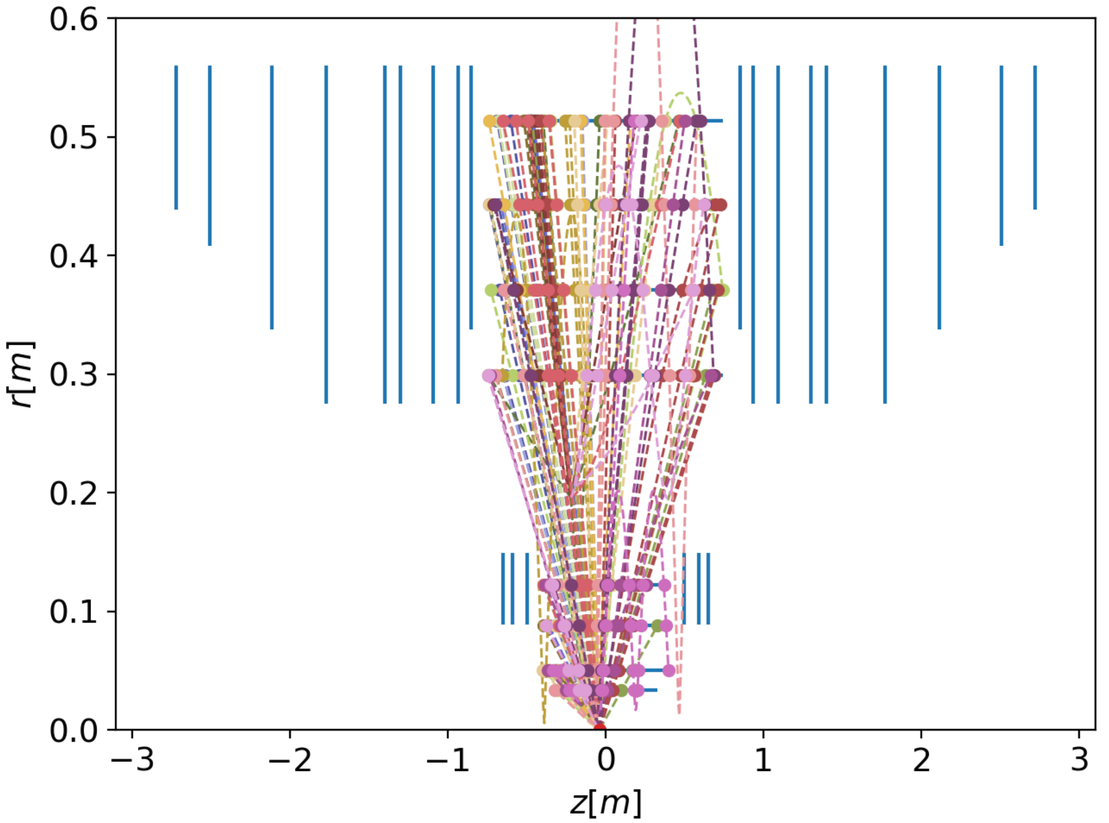
Simulation Environment

Custom event simulation

- MadGraph5_aMC@NLO 2.7.2 and Pythia8: event generation and showering
- Delphes: for detector simulation with custom modules for particle propagation and detector geometry

Detector geometry

- Inspired by ATLAS inner detector
- Detector surfaces modelled as ideal shapes
- Intersections between charged particle tracks and active detector surfaces stored as detector hits
- No multiple scattering, no detector element inefficiencies



Our Model

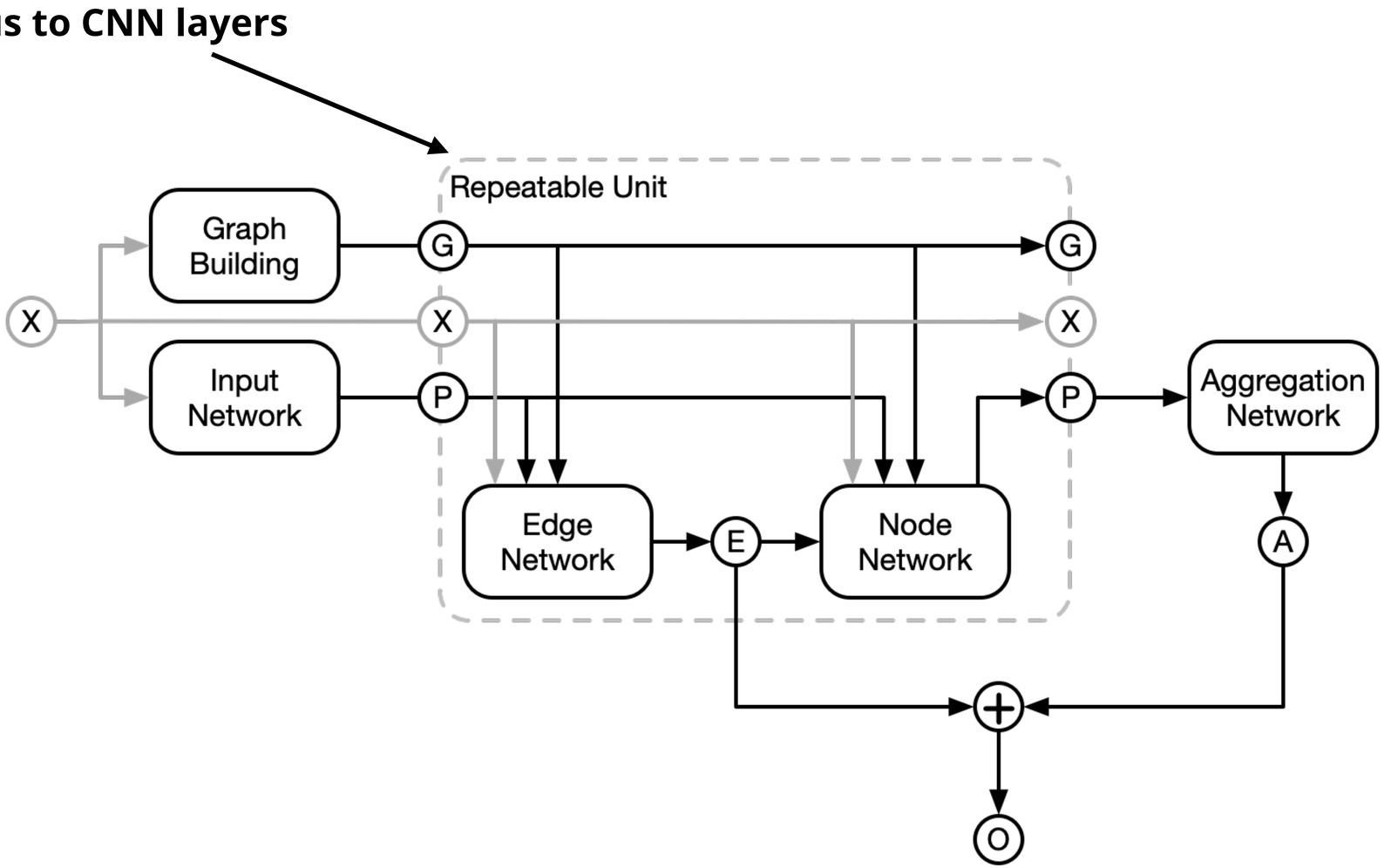
Similar to CNN

- Dynamically build graph per event
- Convolution replaced by *message passing*. Neighbouring nodes can exchange information

Our network

Based on interaction networks

- Per-event scalar output
- Internal representation of segments, only used in training.



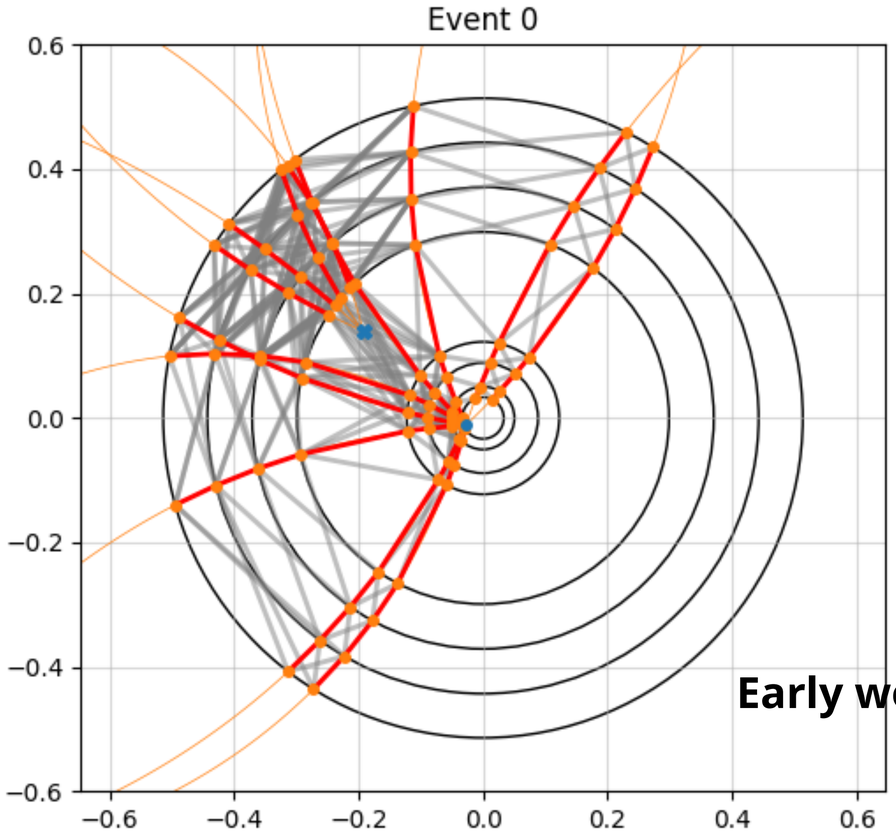
Processing pipeline

Hits (orange dots) used to construct graph (track *segments* in gray)

Criterion based on angle and extrapolated intersection with beam spot

Model takes hits and segments as input

Outputs 1 scalar per event



Early work (in 2D)

Processing pipeline

Hits (orange dots) used to construct graph (track *segments* in gray)

Criterion based on angle and extrapolated intersection with beam spot

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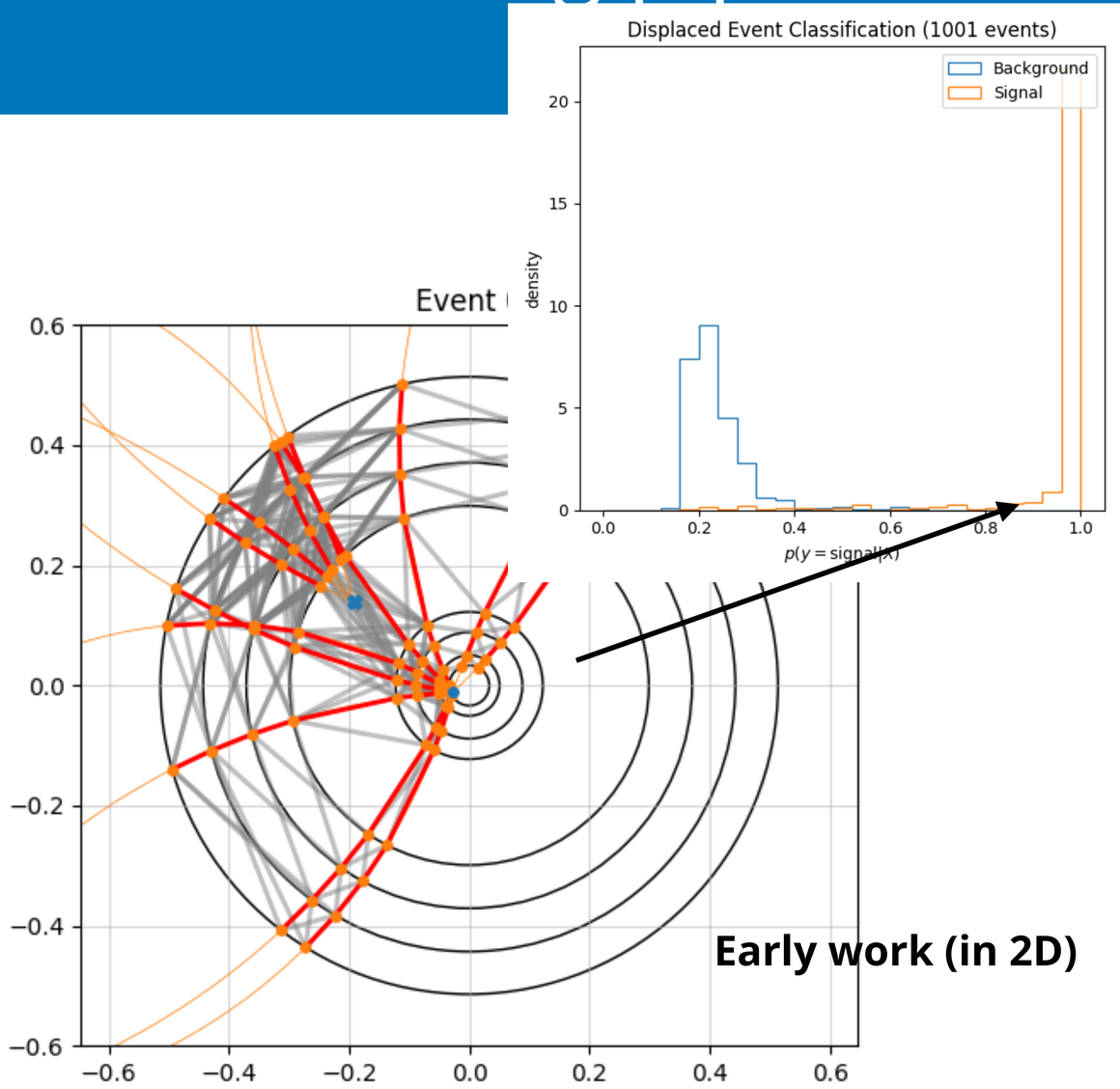


Experiment Setup

Data

Signal: $pp \rightarrow C_1^+ C_1^- \rightarrow W^{\pm} C_1^0$

Background: $pp \rightarrow jj$

Preprocessing

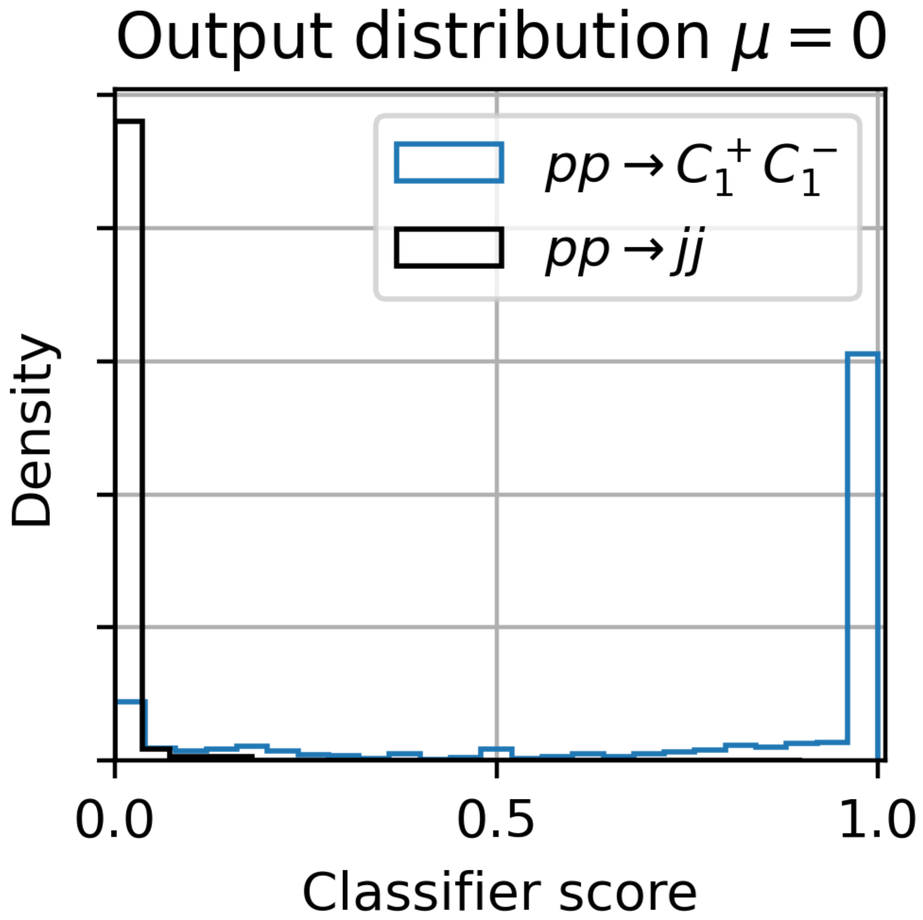
Barrel hits only; Select only tracks with fewer than 200 hits.

Training

Done in *no-pileup* environment

Evaluation

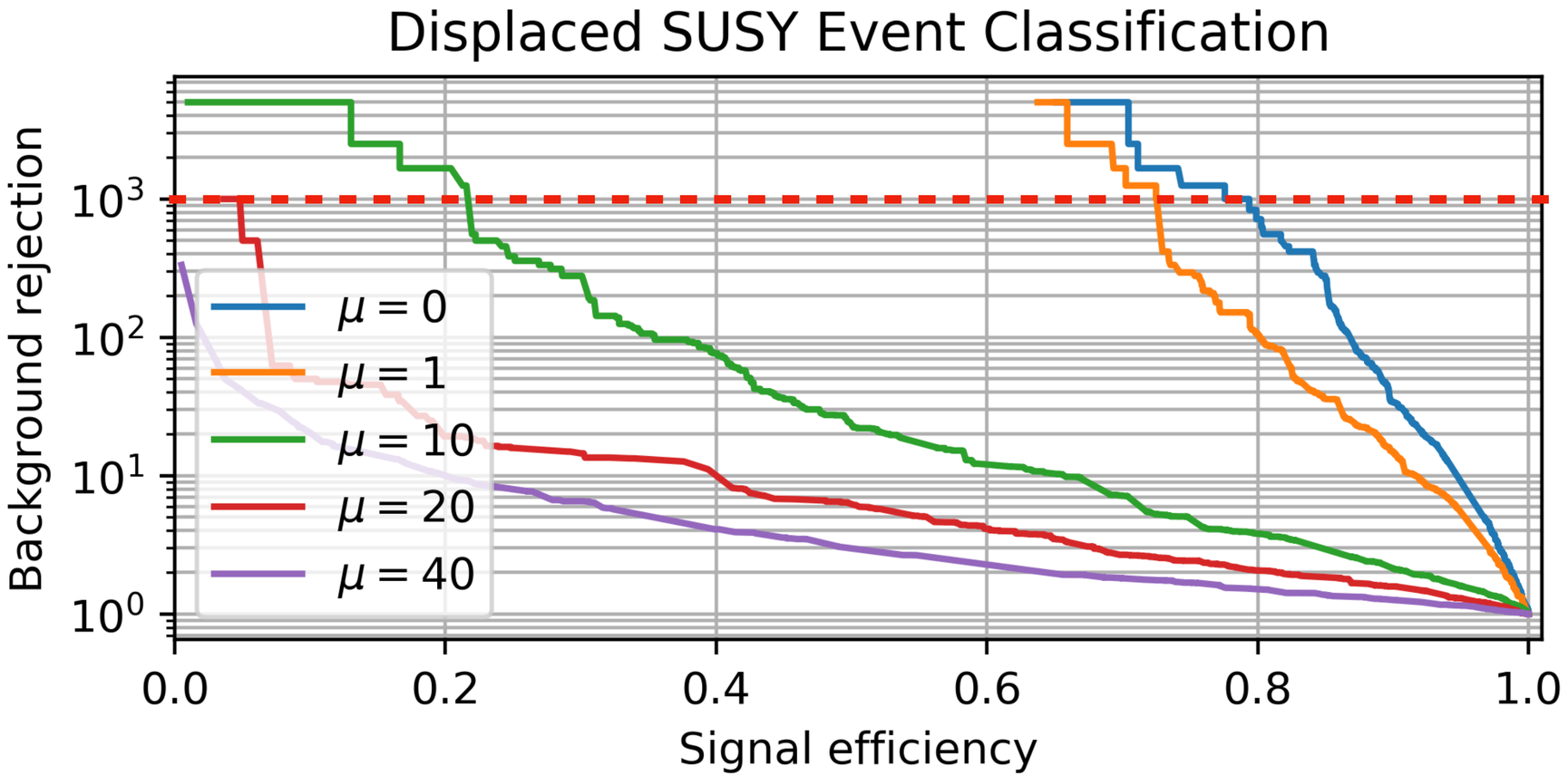
Done with pileup levels of [0, 1, 10, 20, 40]



Results

Background rejection
Factor by which background rate is reduced

Performance
Strong signal efficiency in training region



Conclusion

Investigation of GNN physics performance for displaced vertex *detection*. Current training in no-pileup environment.

Promising results

- 80% signal efficiency in no-pileup environment with high background rejection, decreasing signal efficiency for higher levels of pileup
- Dedicated training at higher pileup is expected to recover efficiency
- Stay tuned for the next update!

Thanks

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