LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Generation of PXD background using Generative Adversarial Networks

Fabio Novissimo, Nikolai Hartmann, Thomas Kuhr

LMU Munich

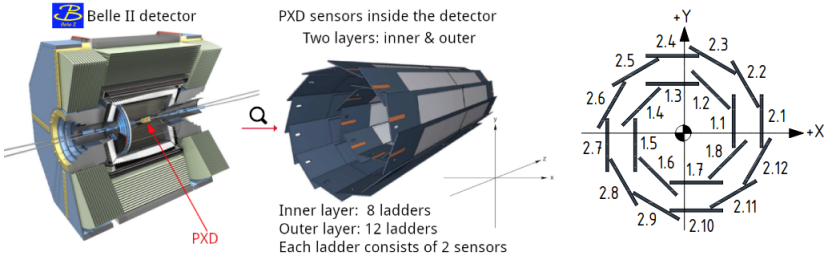
DPG-Frühjahrstagung, March 8th 2024

KISS

Bundesministerium für Bildung und Forschung

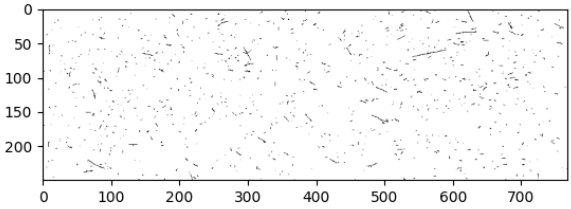
Introduction

- The **Pixel Vertex Detector (PXD)** is the innermost semi-conductor sub-detector of Belle II, at 1.4 cm from the collision point.
- The sensitive area of the PXD is made up by 40 modules. Each module consists of a 250×758 pixel matrix.
- **Inner layer**: 16 modules implemented into 8 ladders.
- **Outer layer**: 24 modules implemented into 12 ladders.

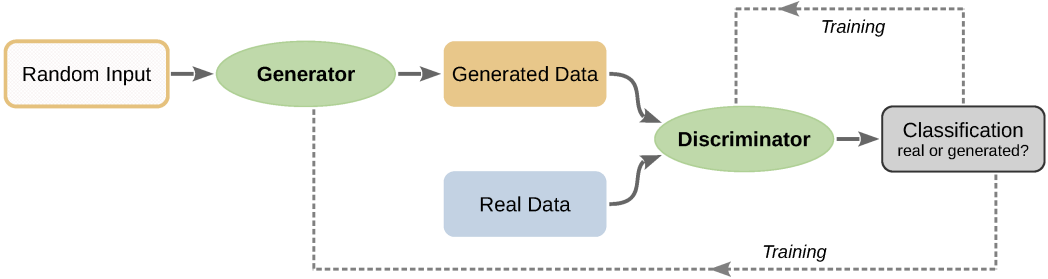


Background

- PXD hits come mainly from background processes.
- Two ways to include background processes:
  - Monte Carlo generation $\longrightarrow$ shows sizeable discrepancies with measurements.
  - Taking random trigger events.
- **Problem: large amount of resources required for storage and distribution of the background data.**
- Solution: generate background hits on the fly for each sensor.



Generative Adversarial Network



Generating pixels with GAN

Previous approach:

- GAN conditioned on sensor number with a transformer-based relational reasoning module to reproduce the correlations between sensors(IEA-GAN).

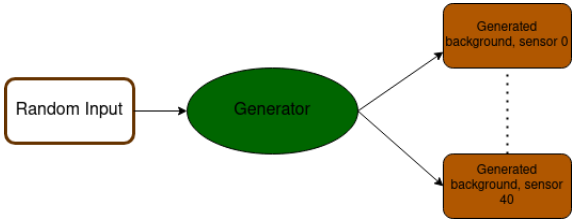
Generating pixels with GAN

Previous approach:

- GAN conditioned on sensor number with a transformer-based relational reasoning module to reproduce the correlations between sensors(IEA-GAN).

New approach: generate the background using a GAN without conditioning on the sensor number.

- Generate instances of background for all sensors at once.
- Wasserstein GAN with CNN layers used in the Generator and Discriminator.



Generating pixels with GAN

Previous approach:

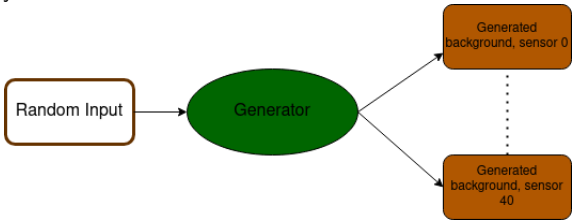
- GAN conditioned on sensor number with a transformer-based relational reasoning module to reproduce the correlations between sensors(IEA-GAN).

New approach: generate the background using a GAN without conditioning on the sensor number.

- Generate instances of background for all sensors at once.
- Wasserstein GAN with CNN layers used in the Generator and Discriminator.

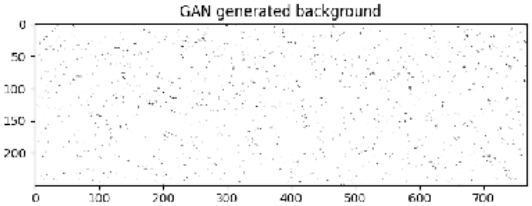
Main goals:

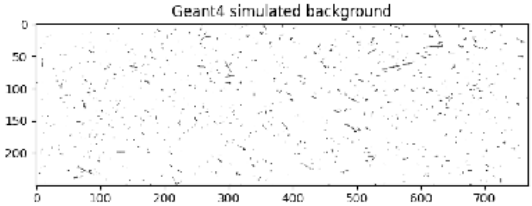
- Check if it is feasible to train the GAN without conditioning.
- Reproduce correctly the correlations between the sensors.



Generated background

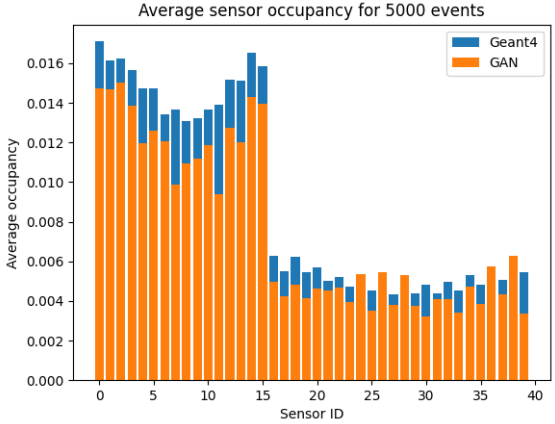
The generated images are visually very similar, but with some subtle differences.

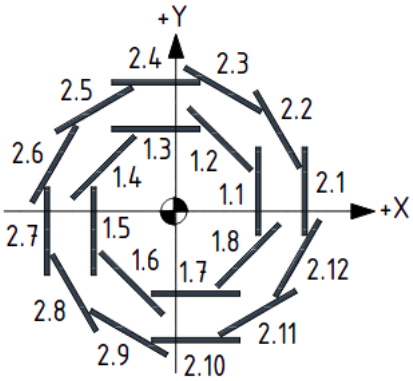




Evaluation - Occupancy per sensor

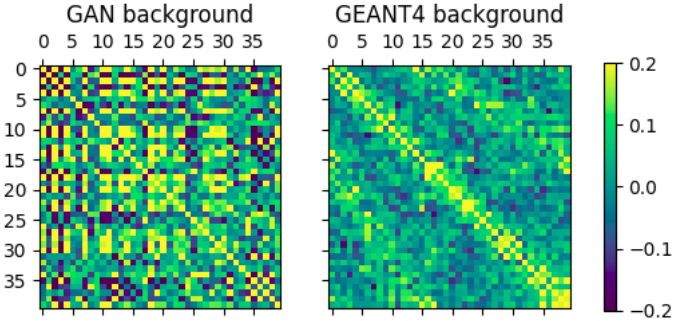
The model seems to reproduce quite well the sensor occupancy, aside from some minor details probably due to some fluctuations in the weights of the model.





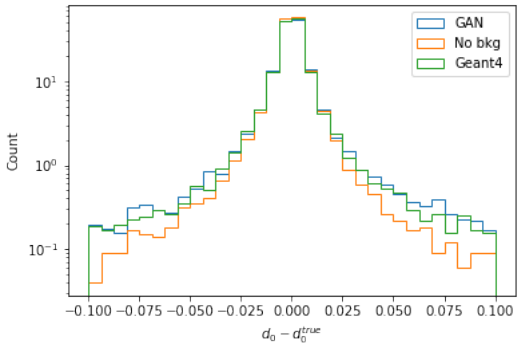
Evaluation - Correlation

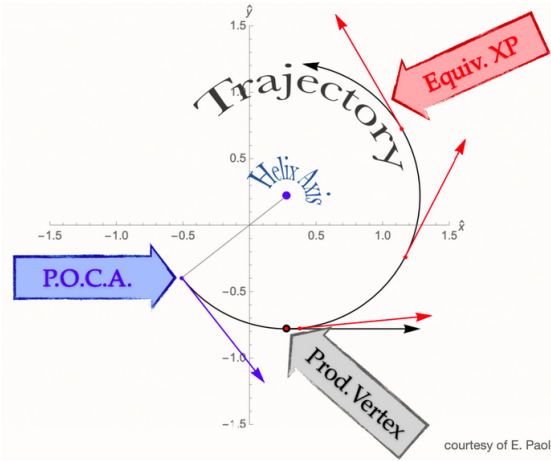
The model does not reproduce correctly the correlation between the sensor occupancy.



Evaluation - helix parameters resolution

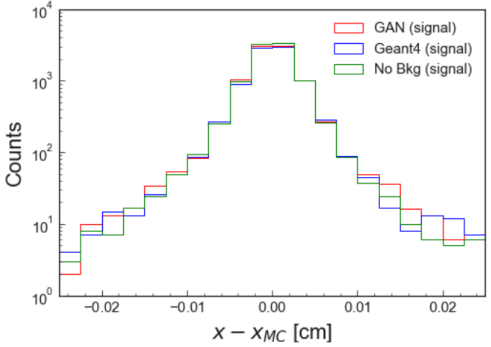
GAN background can be used to reproduce resolution of the helix parameters.

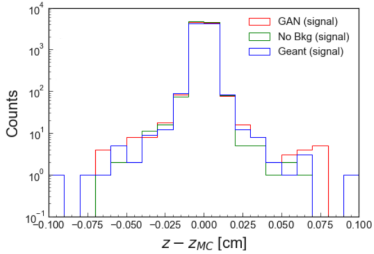


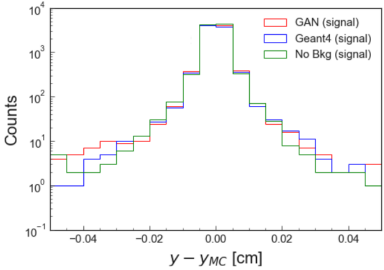


Vertex reconstruction

- Vertex resolution of D^0 in the decay $D^0 \to K^- \pi^+$
- Results suggests that there is no difference when including the background.

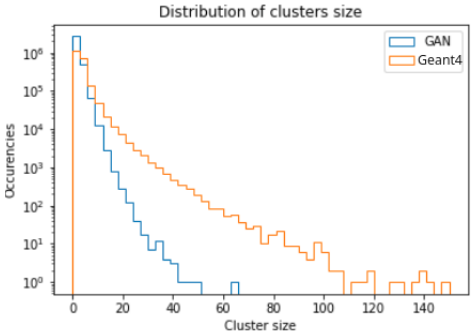


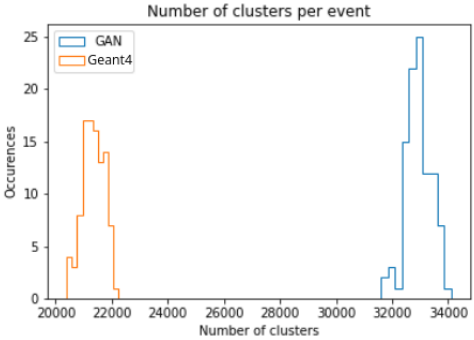




Evaluation: Clusters

The generated background images have different clusters distributions.





Cluster generation with GAN

- Train GAN to directly generate clusters instead of full sensor pixels.
- Trained using clusters of sizes from 1 to 30.
- Training dataset uniform in cluster size.

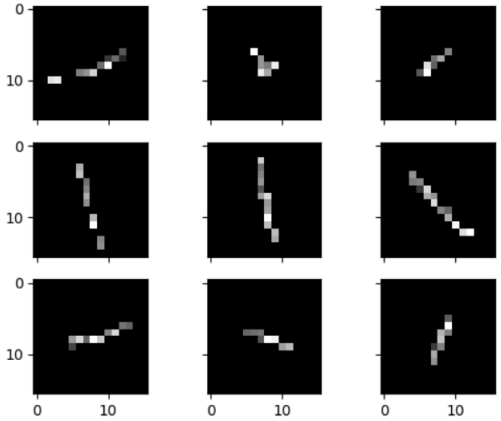
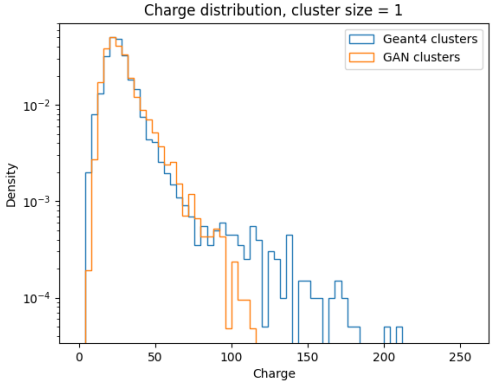
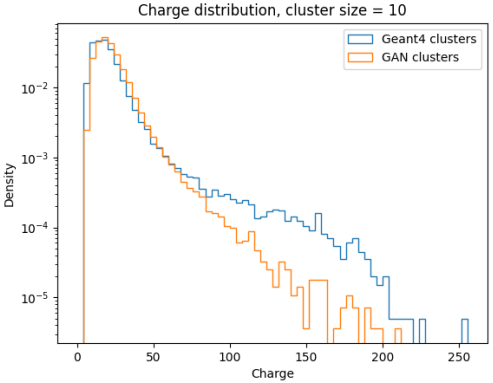


Figure: Example of generated clusters

Evaluation: charge distribution

Distribution well reproduced in the peak, but some differences arise for higher values of the pixel charge.





Conclusions and next steps

- Successfully trained a GAN to generate PXD hitmaps.
- Differences between simulated and generated images, especially regarding sensor occupancy correlation and clusters.
- Generated background reproduces helix parameters resolution well and does not have any effect on the vertex resolution for the decay $D^0 \to K^- \pi^+$.
- Successfully trained a GAN to generate clusters.

Next steps:

- Produce whole sensor background data from clusters.
- Investigate possible correlations between cluster's shape and sensor position.

Thank you for your attention!

Backup - Generator

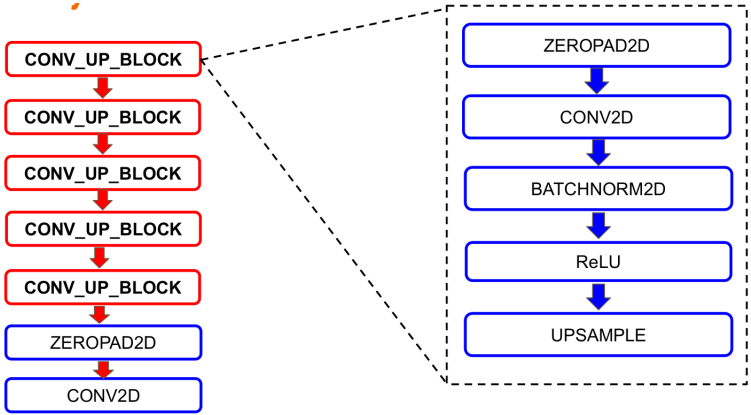


Figure: Generator architecture

Backup - Discriminator

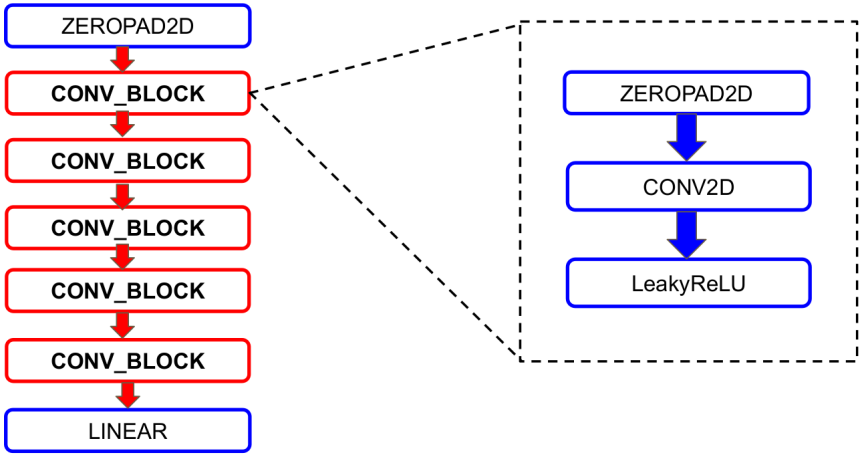


Figure: Discriminator architecture

Evaluation: cluster size