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Using Graph Neural Networks for hadronic clustering and to reduce beam background in the Belle˜II electromagnetic calorimeter

The Belle˜II electromagnetic calorimeter (ECL) is not only used for measuring electromagnetic particles but also for identifying and determining the position of hadrons, particularly neutral hadrons.
Recent data-taking periods have presented two challenges for the current clustering method:
Firstly, the record-breaking luminosities achieved by the SuperKEKB accelerator have increased background rates, leading to a higher number of crystals with energy depositions, and an overall increase in the total energy measured in the ECL.
This resulted in poorer photon energy resolution and the introduction of more fake photon clusters.
Secondly, challenges arise from the nature of hadronic interactions.
In contrast to γ and $e^{\pm}$, hadrons interacting in the ECL result in irregular, sometimes even multiple clusters.
These clusters can be misinterpreted as photon clusters, thereby reducing the position resolution of neutral hadrons or causing a complete misidentification of the hadron.
Graph neural networks (GNNs) offer a promising solution to both challenges.
By representing crystals with an energy measurement as nodes, graphs capture the sparsity of the input.
Using message-passing layers that learn the graph edges also helps to address the asymmetry of Belle˜II's ECL.
In this talk, I will present a novel approach to clustering in Belle˜II's ECL that relies on GNNs to reduce the number of fake photons and to cluster both electromagnetic and hadronic interactions.
I will show that the approach reduces the number of fake photons, enhances the identification of hadrons, and improves the position resolution for neutral hadrons.

Significance

This work aims to be the first application of Graph Neural Networks to cluster hadrons in Belle II's ECL and simultaneously reduce the impact of high backgrounds on energy and position resolution.

References

https://arxiv.org/pdf/2306.04179
https://arxiv.org/abs/1902.07987

Experiment context, if any

Belle II

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