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Progress towards an improved particle flow algorithm at CMS with machine learning

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The particle-flow (PF) algorithm is of central importance to event reconstruction at the CMS detector, and has been a focus of developments in light of planned Phase-2 running conditions with an increased pileup and detector granularity. Current rule-based implementations rely on extrapolating tracks to the calorimeters, correlating them with calorimeter clusters, subtracting charged energy and creating neutral particles from significant energy deposits. Such rule-based algorithms can be difficult to extend and may be computationally inefficient under high detector occupancy, while also being challenging to port to heterogeneous architectures in full detail.

In recent years, end-to-end machine learning approaches for event reconstruction have been proposed, including for PF at CMS, with the possible advantage of directly optimising for the physical quantities of interest, being highly reconfigurable to new conditions, while also being a natural fit for deployment on heterogeneous accelerators.

One of the proposed approaches for machine-learned particle-flow (MLPF) reconstruction relies on graph neural networks to infer the full particle content of an event from the tracks and calorimeter clusters based on a training on simulated samples, and has been recently implemented in CMS as a possible future reconstruction R&D direction to fully map out the characteristics of such an approach in a realistic setting.

We discuss progress in CMS towards an improved implementation of the MLPF reconstruction, now optimised on generator-level particle information for the first time to our knowledge, thus paving the way to potentially improving the detector response in terms of physical quantities of interest. We show detailed physics validation with respect to the current PF algorithm in terms of high-level physical quantities such as jet and MET resolution. Furthermore, we discuss progress towards deploying the MLPF algorithm in the CMS software framework on heterogeneous platforms, performing large-scale hyperparameter optimization using HPC systems, as well as the possibilities of making use of explainable artificial intelligence (XAI) to interpret the output.

Significance

References

Experiment context, if any

CMS Collaboration

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