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Transfer learning for FCC detector optimization

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We demonstrate transfer learning capabilities in a machine-learned algorithm trained for particle-flow reconstruction in high energy particle colliders. This paper presents a cross-detector fine-tuning study, where we initially pre-train the model on a large full simulation dataset from one detector design, and subsequently fine-tune the model on a sample with a different collider and detector design. Specifically, we use the Compact Linear Collider detector (CLICdet) model for the initial training set, and demonstrate successful knowledge transfer to the CLIC-like detector (CLD) proposed for the Future Circular Collider in electron-positron mode (FCC-ee). We show that with an order of magnitude less samples from the second dataset, we can achieve the same performance as a costly training from scratch, across particle-level and event-level performance metrics, including jet and missing transverse momentum resolution. Furthermore, we find that the fine-tuned model achieves comparable performance to the traditional rule-based particle-flow approach on event-level metrics after training on 100,000 CLD events, whereas a model trained from scratch requires at least 1 million CLD events to achieve similar reconstruction performance. To our knowledge, this represents the first full-simulation cross-detector transfer learning study for particle-flow reconstruction. These findings offer valuable insights towards building large foundation models that can be fine-tuned across different detector designs and geometries, helping to accelerate the development cycle for new detectors and opening the door to rapid detector design and optimization using machine learning.

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