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Heavy Flavor machine learning algorithms for Fast Data Processing in sPHENIX

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Major high-energy nuclear and particle experiments are challenged by the processing of large volumes of high precision data generated by sophisticated detectors in high-rate collisions, e.g., experiments at RHIC and LHC. To address this challenge, state-of-the-art real-time AI technology is being developed using modern deep neural networks and AI-centric hardware innovations. Supported by the DOE Office of Science Nuclear Physics AI-Machine Learning initiative program, this project aims to process extremely high-rate data streams from the tracking detectors of the upcoming sPHENIX experiment at RHIC by integrating real-time readouts and the intelligent control system that accelerates AI inference with FPGA hardware. This design allows us to collect rare heavy-flavor events with high efficiency in the high rate p+p collisions of O(10) MHz with much limited DAQ bandwidth at 15kHz. The developed approach includes high efficiency heavy-flavor trigger algorithms in the Graph Neural Network framework trained by full sPHENIX p+p collision simulation data, the optimized conversion of AI models into Firmware using the hls4ml package developed by the HEP community, and the deployment of real-time AI technologies on the powerful FELIX-711(712) boards with the Xilinx Kintex Ultrascale FPGA. The successful deployment of AI-based real-time data streaming and reduction at sPHENIX will have significant and immediate impacts: minimizing the computation resources and accelerating the end-to-end pipeline from experiments to physics discovery. Our project delivers a demonstrator that brings essential benefits to a key science driver of the sPHENIX experiment and enables comprehensive studies of heavy-flavor production in p+p and p+Au collisions. Furthermore, this technique and experience can be applied in other fields where high throughput data streams and real-time detector control are required, including the future EIC experiments. This talk presents the progress of the design and implementation of the AI-intelligent heavy-flavor triggering system for sPHENIX, showcasing the potential of AI and FPGA technologies in revolutionizing real-time data processing pipelines for high-energy nuclear and particle experiments.

Category

Experiment

Collaboration (if applicable)

sPHENIX

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