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A reconfigurable neural network ASIC for detector front-end data compression at the HL-LHC

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Despite advances in the programmable logic capabilities of modern trigger systems, a significant bottleneck remains in the amount of data to be transported from the detector to off-detector logic where trigger decisions are made. We demonstrate that a neural network autoencoder model can be implemented in a radiation tolerant ASIC to perform lossy data compression alleviating the data transmission problem while preserving critical information of the detector energy profile. For our application, we consider the high-granularity calorimeter from the CMS experiment at the CERN Large Hadron Collider. The advantage of the machine learning approach is in the flexibility and configurability of the algorithm. By changing the neural network weights, a unique data compression algorithm can be deployed for sensors in different detector regions or for changing detector or collider conditions. To meet area, performance, and power constraints, we perform a quantization-aware training to create an optimized neural network hardware implementation. The design is achieved through the use of high-level synthesis tools and the hls4ml framework, and has been implemented in an LP CMOS 65 nm process. It occupies a total area of 3.6 mm^2, consumes 95 mW of power, and is optimized to withstand approximately 200 Mrad ionizing radiation. The simulated energy consumption per inference is 2.4 nJ. This is the first radiation tolerant on-detector ASIC implementation of a neural network that has been designed for particle physics applications.

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