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A simulation system for signal readout of CMOS pixel sensors in high energy physics experiments

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Since the successful application in STAR experiment, CMOS pixel sensors (CPSs) are preferred to be used in some other high energy physics experiments such as ALICE, CEPC and so on for particle tracking due to the low cost and potentially high performance. In order to achieve extreme high readout speed and low power consumption, many researches are focused on data sparsification and data compression during the signal readout. For example, the pixel signals in the Orthopix chips are projected in four directions for reducing the signal readout times. In the ALPIDE chips, the pixel signals are only read out when it is true. Different with the traditional CPS chips, in which each pixel signal is indistinguishably processed, the signal processing in such chip may be different between frames due to the random input particle images induced by the impinging particles. The signal reconstruction in the Orthopix design and the readout data volume in the ALPIDE design are related with the input particle images. A simulation system with proper input particle images will be helpful for designing, optimizing and verifying the readout strategies and evaluating the design performances like the efficiency of the image reconstruction and the readout speed. In this paper, we present an efficient simulation system for CPS and its applications on simulating the Orthopix design and the ALPIDE design. The proposed simulation system generates amounts of input particle images according the imaging characteristics in high energy physics experiments and evaluates the signal readout times and the data reconstruction efficiency. The detection efficiency of the Orthopix design is simulated with various images of different signal cluster sizes, signal distribution and signal occupancy for obtaining the proper projection directions and the signal threshold that adjusting the cluster size. The detection efficiency from the simulation results is consistent with that from the beam test. The readout times of the ALPIDE design are simulated with various images and the readout speed can be derived by considering the maximal readout times. In one word, the proposed system demonstrates good efficiency on simulating the readout procedures of CPS. The simulation systems can also be utilized to study and design other readout strategies of CPS for particle tracking.

Author: Dr WEI, Xiaomin (Northwestern Polytechnical University)

Co-authors: Mr LI, Bo; Mr HE, Yingjie; Mr NIU, Wei; Dr ZHENG, Ran; Dr WANG, Jia; Prof. WEI, Tingcun; Dr HU, Yongcai

Presenter: Mr LI, Bo

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