Detector development for ePIC experiment in US electron-ion collider

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Building and electron-ion collider (EIC) is the highest priority future project in nuclear physics in the United States. This EIC will be the world's first collider of polarized electrons and nuclei including polarized protons and is being constructed at Brookhaven National Laboratory (BNL). The EIC will search for parton structures of nucleons and nuclei in the unexplored small-x region, particularly new high-density gluon-saturated states, utilizing their high beam luminosity and three-dimensional analysis. It will also be used to investigate the origin of nucleon mass and spin and perform detailed studies on quantum chromodynamics. The ePIC collaboration is an international collaboration established in 2022, currently involving 171 institutions from 24 countries worldwide. The ePIC collaboration will construct and install a collider-experiment detector covering all directions at the first collision point of the EIC. From Japan, ten universities and research institutes (Hiroshima University, Kobe University, Nara Women's University, Nihon University, RIKEN, Shinshu University, University of Tokyo, University of Tsukuba, Tsukuba University of Technology, Yamagata University) are participating and leading the research in the ePIC experiment. Gunji (University of Tokyo) is serving as a member of the Executive Board, Goto (RIKEN) is the technical contact of the zero-degree calorimeter (ZDC) detector, and Yano (Hiroshima University) is the deputy detector subsystem lead of the time-of-flight (TOF) detector. The Japan group is currently working on the detector design and development to contribute to the following three subsystems within the ePIC experiment.

1) For the ZDC detector, we are optimizing the design by evaluating the performance required from the aspect of physics by performing detector simulation calculations. Considering budgetary limitations, the electromagnetic calorimeter part combines a tungsten + silicon detector behind a crystal scintillator. The latter adopts the technology of the ALICE-FoCal-E calorimeter, which is being promoted mainly by the University of Tsukuba group. The hadron calorimeter part uses a sandwich of iron and plastic scintillator tiles with embedded silicon photomultiplier detectors. Test beam evaluations of the prototype detector of the electromagnetic calorimeter section were performed at the CERN and Tohoku University ELPH facilities, and neutron irradiation tests of the silicon detector and electronic circuit components were performed at the RIKEN RANS neutron facility.

2) We are promoting the development of the barrel section of the TOF detector using an AC-coupled low-gain avalanche detector, which has excellent temporal and spatial resolution, as a core institute. In FY2023, we obtained a test board containing a sensor fabricated at the BNL and a readout application-specific integrated circuit (ASIC) fabricated in France. A test bench was set up at Hiroshima University with high-performance measurement devices. We plan to evaluate the performance of various combinations of sensors and ASICs, along with new sensor development with Hamamatsu Photonics K.K., toward the final design of the detector. We have also begun evaluating the overall design, including its effect on momentum measurement, in collaboration with institutes in Taiwan. We also aim to obtain a construction budget and take the lead as the Japanese group in building the detector prototype and real detector.

3) The collision rate at the EIC is expected to be 500 kHz. To take all collision events, the ePIC experiment will deploy a triggerless streaming data acquisition system. Under continuous readout, the total amount of data from the frontend of the ePIC experiment will be 100 Tbps. Similar to the ALICE experiment, online data reconstruction using field programmable gate arrays and graphics processing units is required. In cooperation with SPADI-Alliance, CNS-Tokyo will develop an online data processing using hardware-accelerators, apply artificial intelligence and machine learning technologies, and perform benchmarking to estimate the required computing resources and design the workflows for the data processing.

We have continued to hold monthly EIC-Asia meetings since late 2022 to deepen our collaboration in the Asian region, particularly with the groups in South Korea and Taiwan. RIKEN and University of Tokyo co-hosted an EIC-Asia workshop at RIKEN in March 2023.[1)] It was followed by a workshop at National Cheng Kung University in Taiwan in January 2024, and the next one will be in Shanghai, China in July 2024.

In addition to the three subsystems mentioned above, we will further deepen regional and international collaboration. Collaboration between the nuclear and high-energy physics communities will also be developed and expanded.

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Reference

1) https://indico2.riken.jp/event/4389/.

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