Expression of interest for EIC-Japan

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The Electron-Ion Collider (EIC) is a great research opportunity for Japan, and we are working to form a Japanese group (EIC-Japan). We will form a high-energy accelerator-based experimental group in the field of both nuclear and particle physics. In response to the "Call for Expressions of Interest (EOIs) for Potential Cooperation on the EIC Experimental Program" by BNL and JLab, we submitted an EOI by the EIC-Japan group in November, 2020. The EOI is non-binding, and its purpose is to guide expectations and better understand the potential EIC experimental equipment scope.

In Japan, the Science Council of Japan (SCJ) developed a master plan for large-scale research programs in academia (Master Plan 2020) in 2019–2020. The EIC was recognized as an important international collaborative research project with a long-term research plan by the Future Planning Committee of the Committee on Nuclear Physics, and it was proposed to the Master Plan. Consequently, the EIC was selected as an academic major research project although it was not yet selected as a priority project in the Master Plan 2020.

The EIC-Japan group plans to design and construct forward detectors of the EIC detector, especially calorimeters, to lead the study on forward and very forward physics. Forward detectors are one of the most important detectors for precisely reconstructing certain events of the deep inelastic scattering (DIS) process, which is the basis of all research at the EIC. We can precisely determine the spin and internal orbital motion of partons in the nucleon, which is still poorly understood, by measuring the forward and most forward jets, hadrons, photons, and electrons and by studying their correlations. In particular, the contribution of gluons, sea quarks, and orbital angular momentum to the proton spin remains a mystery. In addition, our understanding of the most forward events is expected to greatly enhance the development of QCD-based event generators. Further, this will greatly contribute to eliminating uncertainties in other high-energy particle experiments and cosmic ray observations.

We participated in the development of the forward hadron calorimeter,[1)] which is essential for forward jet reconstruction and hadron energy measurements, as well as triggering. Designing and developing the calorimeter is a joint project with the EIC generic detector R&D group eRD1 and the STAR upgrade project. A prototype calorimeter developed as the STAR forward calorimeter comprises 38 layers of iron absorbers and plastic scintillator plates. A wavelength-shifting (WLS) plate provides uniform and efficient light collection from all scintillation tiles along the depth of the tower. The light from the WLS plate is measured with SiPMs. Since the energy resolution of this detector is $70\%/\sqrt{E(\mathrm{GeV})}$ with an additional constant term, the one for the EIC requires higher energy resolution.

We proposed the development of a zero-degree apparatus in the EIC experiment,[2)] and it has been approved as eRD27 this year. Zero degree detectors serve critical roles for a number of important physics topics at the EIC. We study the requirements and technologies of zero-degree detectors, and we develop a position-sensitive zero-degree calorimeter (ZDC). In this program, we will conduct 1) a photon detector study at a low energy <300 MeV, cooperating with eRD1 for crystal and glass scintillators; 2) a prototype study of ZDC with position sensitivity, with the ALICE-FoCal technology and the LHC-ZDC technology with fused silica; and 3) a radiation hardness study of scintillators.

Subsequently, in addition to the proposals in the master plan, we have expanded our activities as a Japanese group to include a group interested in building a silicon tracking detector. The team is open to new collaborators. Heavy flavor quarks are highlighted at the EIC as the ideal probe to study open questions in QCD, such as mass and flavor dependence of energy loss, fragmentation and hadronization modification in a nuclear medium, nuclear parton distributions, and so on. Silicon sensor detectors are the key technology employed for heavy flavor detection by observing their decay vertex precisely. The performance of silicon sensors thus plays a crucial role in pursuing the research in heavy flavor physics at a satisfactory level. We propose to apply a silicon sensor based on silicon-on-insulator monolithic pixel (SOIPIX) detector technology[3)] that has been developed by the KEK group. SOIPIX has demonstrated the world's best tracking resolution of 0.680 ± 0.006 μm in a silicon detector using 120 GeV FNAL's test beam. Further SOIPIX is employed as the inner vertex detector of 4π silicon hybrid detector proposed by ANL and BNL collaborators.

References

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3) Y. Arai *et al.*, Nucl. Instrum. Methods Phys. Res. A **636**, S31–S36 (2011).

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