Zero degree calorimeter for the ePIC experiment

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The Electron Ion Collider (EIC) is the next collider scheduled to be built at the Brookhaven National Laboratory in US. It collides electrons and protons or nuclei and will provide a powerful measure to examine the structure of protons and nuclei. In 2022, a new collaboration was formed, named ePIC, as an experiment at the interaction point IP6. The ePIC detector will be a multi-purpose detector, with suites of detectors in the far-forward and far-backward regions of the ion-beam direction.

The Zero Degree Calorimeter (ZDC) is one of the far-forward detector systems. It is used to detect photons and neutrons coming from the interaction point. The ZDC enables measurements for several key EIC physics programs[1)] such as exclusive vector meson production in $e + A$ collisions or spectator-neutron-tagged $e + d$ deep inelastic scattering. Its first design was considered for EIC in the previous report.[2)] It comprises a crystal calorimeter and three types of sampling calorimeters.

The same ZDC design was adopted to the ePIC detector as a baseline ePIC ZDC design. In the ePIC collaboration, a new software framework was developed and the ZDC design was migrated there. Figure 1 shows a schematic of the ePIC detector including the ZDC.

A few details of the ZDC design are examined and discussed: material of the crystal calorimeter, radiation resistance of photon detectors, and placement of the ZDC.

The material of the crystal calorimeter was studied by simulation. Two materials were compared: LYSO and $PbWO_4$, where the former has a >100 times higher light yield but is more expensive with respect to the latter. Considering the photon counting effect, the comparison showed no large difference in the cluster finding efficiency. Worse energy resolution was observed for $PbWO_4$, but it is still acceptable for the physics requirement of 20%. As far as the performance of the calorimeter system is sustained as designed, $PbWO_4$ can be used for the ZDC crystal calorimeter.

The crystal calorimeter requires photon detectors to detect light in the crystal, and avalanche photodiodes (APDs) are the first candidate for the ZDC. Hamamatsu APDs S8664-55 were irradiated at RANS, RIKEN Accelerator-driven compact Neutron Sources, to test their radiation resistance. Following two days of irradiation, the estimated dose on the APDs is 10^{12}–10^{13} neutrons/cm^2.[a)] All the irradiated APDs seem to lose their function. With the EIC operation for a third of a year, the EIC ZDC is expected to be exposed to 8×10^{12} n_{eq}/cm^2 per year.[3)] The APDs do not have sufficient radiation resistance for the EIC ZDC and another technology is needed.

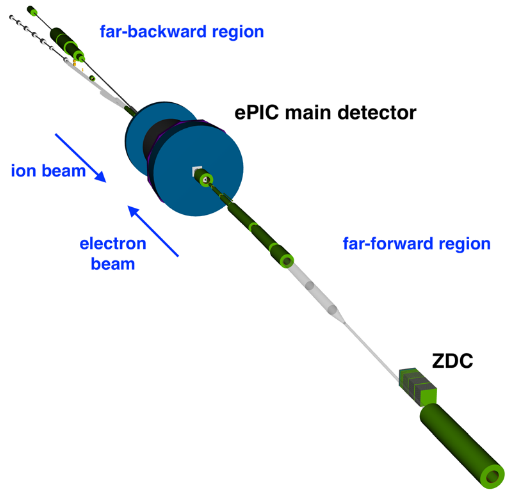

Fig. 1. A schematic of the ePIC detector, observed from the downstream of the ion beam line, as implemented in the ePIC software framework. The ion beam goes from the left side top to the right side bottom as indicated by the arrow. The large disks are calorimeter endcaps of the ePIC main detector. The ZDC is the set of rectangular solids at the bottom right. In the far-forward region, only the ion beam line is shown.

The ePIC ZDC will be situated between the electron and ion beam lines. Its placement was revised following consultations with experts in US. The ZDC has a limited space to place the front-end system close to the ZDC. Discussion on the readout system has started and is ongoing.

In summary, the previously reported ZDC design is adopted to the ePIC detector and discussions on several aspects is ongoing for realization of the design. The ZDC effort is also in close contact with the ALICE FoCal development,[4)] which had several test-beam experiments conducted in 2022, as the same technique will be used in ZDC sampling calorimeters.

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a) The dose estimation is based on the measurement using radioactivation of indium foils.

References
1) R. A. Khalek *et al.*, EIC Yellow Report, arXiv:2103.05419.
2) S. Shimizu *et al.*, RIKEN Accel. Prog. Rep. **55**, 47 (2022).
3) V. Baturin, internal document.
4) ALICE collaboration, ALICE-PUBLIC-2019-005, https://cds.cern.ch/record/2696471 .