Converging on the design for the ePIC Zero Degree Calorimeter
A proposal for US-Japan Hadron Physics Exchange

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I. INTRODUCTION

The Zero Degree Calorimeter (ZDC) at the future EIC is a small but impactful detector that will support a wide variety of physics programs. It must measure the energy and, critically, the angle of photons and neutrons over a wide range of energy. Its dynamic range include $O(10)$ MeV photons for measuring nuclear de-excitation in eA events up to $O(100)$ GeV photons for u-channel DVCS and π^0 production; a wide range of neutron and $\Lambda \to n\pi^0$ with energies from about 10 GeV to 275 GeV, e.g., for Sullivan reactions; as well as to measure multiple neutrons in eA collisions, each up to 110 GeV (for a total energy of about 5000 GeV). Though outlined in the EIC Yellow Report, the ZDC's physics requirements are actively debated within ePIC as technical limitations and achievable performance with advanced reconstruction software are refined.

The ePIC ZDC baseline is still under discussion and optimization. It currently consists of a crystal calorimeter and a high-granularity iron-scintillator section, which is enabled through SiPM-on-tile technology. Options for the crystal part are either LYSO or $PbWO_4$, with SiPM or APD readout. The ePIC collaboration, through its Technical Integration Council (TIC), has established the culmination of the baseline design of the ZDC as a high priority, and several TIC meetings have been dedicated to the topic [1]. Current open questions include the length of the crystal portion and the combined performance of the crystal and iron-scintillator portions. Additionally, complex final states like $\Lambda \to n\pi^0$ pose challenges to realistic reconstructions, particularly due to its displaced vertex of $O(10)$ cm.

Converging on an optimized design, backed by quantitative comparisons of realistic performance estimates for various options, is thus badly needed. This is especially true since the final-design review for far-forward detectors is currently slated for early next year.

The ePIC collaboration co-Detector-Subsystem Leaders are Dr. Yuji Goto and myself. My group has recently published several studies on high-granularity calorimetry relevant to the ZDC SiPM-on-tile design, including simulations, AI/ML applications on regression and generative models, as well as prototyping, benchtop testing, and test beam results [2–9].

In this proposal, we seek support for a 12-day trip for myself and a UCR student to visit RIKEN, hosted by Dr. Yuji Goto. The trip will also include visits to the University of Tsukuba and Kobe University, as detailed below. Goals of this trip include:

- Converge on full simulations of LYSO and $PbWO_4$ calorimeters combined with an iron-scintillator calorimeter for neutron and $\Lambda \to n\pi^0$ final states. This will require developing software reconstruction to be included in the official ePIC software, EICRECON.
- Facilitate knowledge exchange on AI/ML approaches for high-granularity calorimetry between Japanese institutions and UC Riverside.
- Visit HEP group experts in SiPM-on-tile technology to exchange information on corresponding designs. Seek to establish new collaborations.

The 12-day trip will be primarily based at RIKEN, hosted by Dr. Yuji Goto. It will also include the following visits, which Dr. Goto has kindly agreed to help arrange:

- A 2-day visit to the University of Tsukuba to meet with Prof. Chujo, who leads FoCal-E in Japan.
- A 2-day visit to Kobe University to meet with Prof. Yamazaki or Prof. Kawade (Shinshu Univ.).

The trip is planned for Fall 2024, with exact date to be determined depending on availability of hosts, to coincide with a quarter sabbatical leave that I am going to be taking. The trip will originate from LAX, with a round-trip flight to Tokyo estimated at around $800 in late September. Uber from Riverside to LAX is about 100 USD each way.

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[1] ePIC Collaboration, TIC meetings (selection of ZDC discussions)
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03/18/24 https://indico.bnl.gov/event/22508/ 03/04/24: https://indico.bnl.gov/event/22321/
12/28/23 https://indico.bnl.gov/event/21107/ 11/20/23: https://indico.bnl.gov/event/20940/
10/09/23 https://indico.bnl.gov/event/20648/.

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[4] M. Arratia, B. Bagby, P. Carney, J. Huang, R. Milton, S. J. Paul, S. Preins, M. Rodriguez, and W. Zhang, Beam Test of the First Prototype of SiPM-on-Tile Calorimeter Insert for the EIC Using 4 GeV Positrons at Jefferson Laboratory, Instruments **7**, 43 (2023), arXiv:2309.00818 [physics.ins-det].

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