

# Expression of Interest for high resolution Zero Degree Calorimeters

Michael Murray (contact)<sup>1</sup>, Quan Wang<sup>1</sup>, Christoph Royon<sup>1</sup>,  
John Arrington<sup>2</sup>, Mateusz Ploskon<sup>2</sup>, Charles Hyde<sup>3</sup>, Constantin  
Loizides<sup>4</sup>, Matthias Perderkamp<sup>5</sup>, and Ricardo Longo<sup>5</sup>

<sup>1</sup>*University of Kansas*

<sup>2</sup>*Nuclear Science Division, LBNL*

<sup>3</sup>*Old Dominion University*

<sup>4</sup>*Physics Division, ORNL*

<sup>5</sup>*University of Illinois Urbana-Champaign*

November 1, 2020

## Abstract

We propose to design a high-resolution position-sensitive Zero Degree Calorimeter, ZDC, to measure photons and neutrons at the EIC [3]. At the Electron Ion Collider the ZDCs will serve critical roles for a number of important physics topics, such as distinguishing between coherent diffractive scattering in which the nucleus remains intact and incoherent scattering in which the nucleus breaks up; measuring the geometry of  $e + A$  collisions, spectator tagging in  $e + d/{}^3\text{He}$ , asymmetries of leading baryons, and spectroscopy. These physics goals require that the ZDCs have high efficiency for neutrons and for especially low-energy photons, excellent energy,  $p_T$  and position resolution, large acceptance, sufficient radiation hardness and fast timing to reject background. We will build ZDCs that along with the B0 tracker, Roman Pots, and the Off Energy Detectors, form an integrated forward system for characterizing electron ion collisions and satisfying the physics goals described in the EIC Yellow report [2].

# 1 Contact

Michael Murray, [mjmurray@ku.edu](mailto:mjmurray@ku.edu), +1 785 550 8835

# 2 Institutions

- University of Kansas
- University of Illinois, Urbana-Champaign
- Oak Ridge National Laboratory
- Lawrence Berkeley National Laboratory
- Old Dominion University

# 3 Potential Equipment Cooperation

This EOI is for the design of a ZDC, including simulation and detector testing, with excellent multi-photon and neutron reconstruction with precision timing for background rejection. We seek synergies between the Cerenkov calorimetry work done by ATLAS and CMS for neutron detection and high granularity FOCaL silicon tungsten calorimeter being developed for ALICE. At least one silicon layer will be dedicated to a fast timing measurement. The group will also exploit the developments in electronics coming out of the LHC. These ZDCs would be appropriate for both interaction regions, although they may not be identical.

Several Japanese institutions (Yamagata Univ., RIKEN, Kobe Univ., Shinshu Univ., Univ. of Tsukuba, Tsukuba Univ. of Technology, Japan Atomic Energy Agency (JAEA) and Nihon Univ.) are involved in eRD27, and are detailing planned efforts on the ZDC in their own EOI (contact Y. Goto). These institutes are interested in making both intellectual and hardware contributions to the ZDC project

## **4 Potential contributions are for each item of interest**

At this preliminary stage we will focus on design and test beam studies. Well developed simulations from (KU/UIUC) are available for both the ATLAS/CMS ZDC upgrade and the ALICE FOCaL (LBNL, ORNL) and these will be integrated with the EIC simulation framework. ODU will bring there experience to bear on background studies. Given their expertise on FOCaL, the ORNL and LBNL groups are well placed to drive the design of the electromagnetic part while Urbana and Kansas will exploit their ZDC experience to facilitate the design of hadronic section. Joint beam tests will use both FOCaL and ZDC components.

## **5 Assumptions about items from EIC Project**

The group has sufficient design and engineering expertise to develop the ZDCs but will need to work closely with the EIC project on integration with the beam matrix in the far forward region.

## **6 Labor Contributions**

We anticipate the duration of this collaborative effort to cooperate on the EIC Project to start in the design phase and to be for a period of five years. In addition to the effort listed in Table 1, a small amount of additional effort is supported, mainly in simulations, from the eRD27 consortium proposal.

From 2021 thru 2025 the average time commitment of members of the group in the EIC efforts described in this EoI is shown in Table 1. After 2025 most groups should be finished with their LHC construction work and would expect to increase their effort significantly for the construction phase. The collaboration would anticipate taking significant roles in construction and commissioning of the ZDC and to provide management for ZDC construction.

## **7 Timing Constraints**

We are assuming that most groups will be ramping down their work on LHC upgrades by 2025.

INSTITUTION	Professor	Research Professor	Staff Scientist	Postdoc	Graduate Student	Undergraduate Student	Engineer	Designer	Technician	Total Sum
KANSAS	.1	0	0	0.25	0.25	0.5	0	0.2	0.2	1.5
UIUC	.05	0	0	0.25	0.6	0.4	0	0.1	0.1	1.5
ORNL	0	0	1.0	0	0	0	0.8	0	0.6	2.4
LBNL	0	0	0.4	0.3	0	0.3	0	0	0	1.0
ODU	0.05	0	0	0.25	0.5	0	0	0	0	0.8

Table 1: Summary of estimated annual time commitments in FTE for this effort, estimated to continue through 2025. After this time all groups should be largely finished with their LHC or JLab construction work and would expect to increase their effort significantly.

## 8 Other Information

The Kansas group has worked on ZDCs for RHIC and LHC (CMS). Kansas is the lead institution on the eRD27 project [1] to design ZDCs for the EIC and works closely with UIUC on developing ZDCs with excellent energy and timing resolution for ATLAS & CMS in Run 4 of the LHC. The KU group has an excellent machine shop as well as electronic design facilities and significant expertise in fast timing for the CMS proton spectrometer within Roman Pots and the effort to add timing to the main detector.

UIUC has built the electromagnetic calorimeters, EMCs, for E821 at BNL, a pair of forward EMCs for PHENIX (the MPC). Currently the group is working on the construction of the sPHENIX EMC as well as R&D for the High Luminosity LHC ZDCs. The UIUC Nuclear Physics Laboratory has its own machine shop and significant instrumentation capabilities for detector R&D. Illinois leads the joint CMS-ATLAS R&D project for developing radiation hard ZDCs and reaction plane detector for LHC run 4. Illinois will contribute general knowledge of calorimetry to the EIC ZDC and new

radiation hard technology developed for the operations of ZDC during HL LHC operations. Illinois will also contribute to project management.

LBNL has a proven track record in design and construction of major instrumentation for particle collider experiments - featuring Time Projection Chamber, and more recently, the Heavy-Flavor Tracker for the STAR Experiment at RHIC. Moreover, LBNL served as the lead lab for the construction project of the ALICE EMCal and leads the US-based construction scope of the ALICE MAPS-based Inner Tracker System featuring elements of carbon fiber mechanical support structure, sensor readout, the power distribution system, integration and testing of major detector elements. LBNL scientists support the LoI of the FOCaL project (recently endorsed by the LHC Committee) and plan for a significant contribution to the potential construction project.

ORNL has decades of experience developing advanced detector and readout systems for major experiments in the field (multiple STAR and PHENIX subsystems, ALICE EMCal, TPC and ITS, sPHENIX MVTX), and is leading the FOCaL ALICE project. For EIC, ORNL focuses on the overall integration of EIC detector subsystems including all mechanical support structures, cooling and power, as well as integrated continuous readout systems with online data processing.

Old Dominion University has expertise on forward physics and will be a leading group on background simulations for the EIC forward region. The ODU group is collaborating with KU on the ERD 27 effort.

## 9 Other EOIs relevant to the ZDCs

The work of several other groups is relevant to the work proposed in this EOI:

- The expressions of interest from the individual institutions listed in this EOI.
- Expression of Interest in “Precise central silicon tracking and calorimetry with integrated parallel and continuous readout for an EIC detector” (ORNL, Vanderbilt U., Wayne State U.)
- “ECCE, Electron ion Collider Consortium Expression of interest (using selected components of the sPHENIX Experiment)”, submitted by consortium including ORNL, BNL, Catholic Univ. of America, Columbia

Univ., George Washington Univ., Iowa State Univ., Livermore National Lab, Massachusetts Institute of Technology, Rice Univ., Rutgers Univ., Stony Brook Univ., TAU, Univ. Connecticut, Univ. Illinois Urbana-Champaign, UMA, Univ. New Hampshire, Univ. Virginia, Vanderbilt Univ.

- “EOI for Precision Timing Silicon Detectors for a Combined PID and Tracking System”, submitted by consortium including Rice U., ORNL, and U. Kansas.
- EIC-Japan’s EOI (contact: Y. Goto) submitted by a consortium of Yamagata Univ., RIKEN, Kobe Univ., Shinshu Univ., Univ. of Tsukuba, Tsukuba Univ. of Technology, Japan Atomic Energy Agency (JAEA) and Nihon Univ., and KEK

## References

- [1] BNL R&D proposal: Developing a High Resolution ZDC for the EIC. [https://wiki.bnl.gov/conferences/images/9/98/EIC\\_LOI\\_For\\_ZDC.pdf](https://wiki.bnl.gov/conferences/images/9/98/EIC_LOI_For_ZDC.pdf), Jun 2020.
- [2] EIC Users Group. EIC Yellow Report. to be submitted, 2020.
- [3] Brookhaven National Laboratory. An Electron-ion Study. 2020.