EOI for a KLM subdetector component of an EIC Detector

Will Jacobs[1], Pawel Nadel-Turonski[2], Gary Varner[3], and Anselm Vossen[4]

[1]Center for the Exploration of Energy and Matter, Indiana University
[2]Department of Physics and Astronomy, Stony Brook University
[3]Department of Physics and Astronomy, University of Hawaii
[4]Department of Physics, Duke University

October 2020

1 The name of the contact person for this submission:

- Primary contact: Pawel Nadel-Turonski (turonski@gmail.com)
- Technical contact: Gary Varner (varner@phys.hawaii.edu)

2 The institutions collectively involved in this submission of interest:

- Center for the Exploration of Energy and Matter, Indiana University

  The nuclear physics group at IU has over the years been involved in the construction and oversight of many large-scale pieces of experimental apparatus. CEEM (the Center for Exploration of Energy and Matter) is still housed in the former IU Cyclotron Facility building, retaining some essential infrastructure and expertise, and allowing IU to take on major project roles. Jacobs is a long-standing member of the local IU group, has considerable project experience and actively contributes to Belle/Belle II and STAR collaboration upgrades, operations and physics efforts.

  One focus of recent such activities has been in electronics support. Our electronics group with two senior EEs (Gerard Visser, Brandon Kunkler), has extensive experience in developing detector readout electronics and associated firmware for numerous high energy and nuclear experiments. Besides contributing to the original Belle II KLM and iTOP upgrades, they have been significantly engaged in projects for STAR/BNL, ATLAS/CERN, HELIX, NOvA and others. A current big effort for the STAR forward upgrade is the FEE readout of SiPMs for the Electromagnetic and Hadronic calorimeters. Relevant to the present EOI, they will play essential roles in the new electronics readout systems for the anticipated next Belle II Barrel KLM upgrade to an all scintillator strip readout from the present RPC modules.

- University of Hawaii

  The UH group and particularly its Instrumentation Development Laboratory have a long and established successful track record in fielding world-class, discovery experiments in particle and astroparticle physics. Most relevant to the KLM endeavor is that UH provided the ASICs and readout system for the Belle II KLM scintillator upgrade. In particular UH has been responsible for the design, fabrication, installation and support of the 20,000 channels of KLM scintillator readout. Two postdoctoral fellows that were key to the success of fielding the UH-developed ASICs for the iTOP and KLM subsystems, are the principles that subsequently formed Nalu Scientific. Nalu staff have a long history of working with UH and also developing next generation commercially available waveform digitizing ASICs. Dr. Kevin Flood, UH Affiliated Graduate Faculty member and Nalu Senior Scientist, convened the Babar PID group for several years, is a PID algorithms/software expert and has experience leading the salvage of another major Babar subdetector (EM Calorimeter). Close collaboration allows for the utilization of fungible engineering resources, which are simply no longer viable at a university level, in the era of projectization and a rather limited number of very large projects. In addition to excellent facilities for electronics design, evaluation and verification, university-subsidized CNC machine shop capabilities are available in support of detector components, in particular in support of the readout electronics.

- Duke University The Duke University group is relatively young and was started in 2018 when Vossen moved from Indiana University to Duke. While at IU, Vossen and Jacobs led the IU group to join Belle II and then led the development of the Barrel KLM RPC front-end-electronics. Vossen coordinated the IU contributions to the KLM commissioning and continues to support the detector at Duke as well. The Duke group is very active in the ongoing Yellow Report process and has gained extensive experience in fast simulations for the EIC in the process. At Duke University the group has access to significant technical resources of the University and the Triangle Universities Nuclear Laboratory located on the Duke University campus. In particular this extends to laboratory space and mechanical and electrical technicians.

3 The items of interest for potential equipment cooperation:

We are interested in exploring the use of a KLM (K-long and muon detector) subdetector system at the EIC, either as a major component of a reduced size (compact) EIC detector, or as an option for other EIC detector configurations (e.g., those that possibly would not reuse the sPHENIX barrel Hcal).

Our experience is with the Belle II KLM detector, both its construction and use for physics in its current form, as well as in a proposed upgrade currently under CDR and proposal discussion. We believe it is a relatively low-cost device that can be adapted and optimized for EIC physics requirements.

The KLM as implemented at Belle II, for both the barrel and endcap components, comprises active detector layers sandwiched between the separated iron plates of the detector solenoidal magnet return yoke. For the EIC, compared to a full Hcal, the KLM would be more cost effective and likely focus on spatial resolution in separating e.g., K_L from other tracks in a jet (a HCAL measurement of the K_L deposition would not significantly reduce the jet energy uncertainty). The actual requirements for a KLM subdetector in various EIC detector configurations would have to be studied, most efficiently starting from performance parameters based on experience with the Belle II KLM.

4 The level of potential contributions are for each item of interest:

The institutional members of this EOI are currently engaged in writing a CDR and preliminary proposals for a Belle II barrel KLM upgrade. This will involve a switch to an all scintillator strip detector with upgraded readout electronics utilizing SiPMs and next level technology.

One focus of efforts needed for a KLM application beyond that in Belle II, is to perform simulations to demonstrate the performance of a KLM-like detector in different detector configurations for a selection of high impact channels. For this, the participating institutions plan to commit multiple PD/student FTE, though obviously cannot do so at this time. For the further detailed design of the detector, support structure and electronics, as well as eventual construction, additional resources from new collaborators and/or dedicated funding would be needed. As a point of reference, the Belle KLM involved three primary institutions and of order 10 FTE (composite engineer, technician, PD, student, faculty) for the 3 years of construction and commissioning.

5 Assumptions made as coming from the EIC Project or the labs for your items of interest:

If KLM is adopted as an EIC subdetector, significant outside support and additional collaborators would be needed to further design and construct such a device. Some additional experience will of course be gained with the Belle II barrel KLM upgrade project, expected in the upcoming years (see also section 7).

6 The labor contribution for the EIC experimental equipment activities:

Details of any implementation of a KLM subdetector at the EIC are well beyond the scope of this EOI. One can, however begin to estimate the amount of effort that would need to go into the Belle II Barrel KLM upgrade. For the electronics part, despite re-using infrastructure and firmware from the existing BKLM as much as possible, and leveraging DOE supported SBIR funded ASICs development, we envisage roughly 2.6-2.7 FTE engineering, 3.0 FTE postdoc and 3.0 FTE graduate level student support will be needed (in addition to faculty and scientific effort) to build and commission the $\sim$ 20k channels for the updated Belle II Barrel KLM. Some fraction of this effort will likely be of benefit to a EIC KLM detector in terms of technological advances. But more broadly, this gives only a very rough scale in terms of just a particular part of a more inclusive construction effort, and even for that aspect, already omits many items (notably no new crates, and engineering of other needed items if one was to consider starting to build from scratch and integrate into a completely different environment).

7 Indicate if there are timing constraints to your submission:

The possibility of upgrading the Belle II barrel KLM detector and its timescale is relevant to this EOI because of the expected leveraging of Belle II technical developments for a EIC detector implementation. While it is uncertain exactly how the Belle II project will proceed, work on a CDR will begin in the next months, followed by efforts (and time) needed to review, put together a construction plan, write funding proposals as required, etc. Once this is all in hand, a preliminary estimate for the electronics upgrade part indicates a pre-production plus production timescale of approximately 2 years, with 6-9 months for installation and commissioning around a 2026 window. The timing of this installation window is driven by other major SuperKEKB machine upgrades now under discussion.

8 Indicate any other information you feel will be helpful:

Relevant to this section, please see the information included in the various "institutional introductions" in section 2 (above) for a description of capabilities, accomplishments and relevant infrastructure. Some physics motivation is provided in the following section.

9 Physics impact and implementation in an EIC detector:

The muon identification and neutral hadron detection capabilities of the KLM are important for several key aspects of the EIC physic program. Exclusive production of charmonium, which decays to di-leptons, gives access to the transverse spatial structure of hadrons (gluon GPD) and nuclei. The tomography of hadrons also heavily relies on Compton scattering, where the timelike equivalent to (spacelike) DVCS produces a lepton pair with large invariant mass in the final state. The comparison between the two, and at low x also with double-DVCS, would be important for demonstrating the universally of GPDs and for understanding

NLO contributions at low x. Muon detection is crucial as it provides an unambiguous way to distinguish the scattered electron from the decay lepton (muon).

At EIC energies, mid rapidity jets are best reconstructed though tracking, EM calorimetry, and PID of individual particles, as the jet energy obtained from a Hcal does not provide a comparable resolution. A fraction of the jets do, however, contain a K_L (baryons are rare at central rapidities), and not having a detector able to tag them leads to a deterioration in the reconstructed jet energy. The KLM provides a cost-effective solution for tagging neutral hadrons with good angular resolution.

The KLM can be used in any EIC detector in lieu of a barrel Hcal, and would offer a natural complementarity to a detector re-using the sPHENIX solenoid and Hcal. The KLM can be integrated with the flux return of a new solenoid, reducing cost and improving performance (since sensitive elements could be distributed throughout the volume rather than only being present "outside" as would be the case in an add-on scenario). In combination with an all-Si central tracker and an ultra-compact DIRC inside a new, small volume solenoid, the KLM is the baseline choice for the general-purpose Compact EIC Detector concept, which aims at reducing the overall cost by making the subsystems smaller, without compromising the detector performance.