Expression of Interest (EOI)
Questionnaire

1) Contact person for this submission:

G. Kalicy (CUA)

2) All institutions collectively involved in this submission of interest:

CUA (contact: Greg Kalicy)

GSI (contact: Jochen Schwiening)

BNL (contact: C.Woody)

W&M (contact: Justin Stevens)

USC (contact: Yordanka Ilieva)

SBU (contact: Klaus Dehmelt)

UH (contact: Gary Varner)

JLAB (contact: Carl Zorn, J. McKisson)

ODU (contact: Charles Hyde)

3) Items of interest for potential equipment cooperation:

Software development

- cost/performance optimization of hpDIRC – for Detector 1 or Detector 2, study PID/physics performance, impact of backgrounds (CUA, GSI, W&M, ODU)
- explore DIRC design options for Detector 2, optimize reconstruction/PID algorithms, optimize e/pi separation (CUA, GSI)

Component R&D

- development of readout electronics for commercial MCP-PMTs or LAPPDs (SBU, UH)
- validation of sensors – commercial MCP-PMT, SiPM, and LAPPDs; pixel size, B-field (USC, JLab)
- validation of optics design – spherical vs aspherical lenses, prism shape, bar width/thickness, sensor coverage, timing precision (CUA, GSI)
- reuse of BaBar DIRC bars – transport, disassembly, polishing, reassembly (CUA, SBU)

Prototype program

- near-term Detector 1 design validation in cosmic ray telescope and/or Fermilab test beam (CUA, GSI, W&M, SBU, UH, ODU)
- mid-term evaluation of Detector 2 design in cosmic ray telescope and/or Fermilab test beam (CUA, GSI, W&M, SBU, UH, ODU)

Component fabrication

- explore funding solutions for Detector 1 and Detector 2 components (CUA)

Construction/assembly

- mechanical design, integration, facilities for construction and assembly (SBU)

Photosensor studies

- Investigation of readout using SiPMs (BNL – C.Woody, JLab)
- SiPM radiation damage studies (BNL – C.Woody)
- Investigation of readout using LAPPDs (BNL C.Woody & A.Kiselev, JLab)

4) Level of potential contributions are for each item of interest:

In-kind labor

- Optics (radiator bars, prism expansion volumes)
  - Reuse BaBar DIRC bars or fabrication of new bars (CUA and GSI will coordinate)
- Focusing lenses
  - Validation on test benches (CUA, ODU)
- Sensors
  - Validation in Magnetic field (USC, JLab, ODU)
  - Characterization of sensor candidate prototypes (USC, JLab)
  - Radiation hardness of SiPM
    - These readout devices will be studied as part of BNL's interest and involvement with EIC detector R&D, including calorimetry, tracking and PID. Additional contribution from JLab detector group.
  - Quality assurance of series production sensors (USC)
- Support structure
- Electronics (UH)
- DAQ/slow controls/online software (UH)

- Prototype construction/commissioning and testing (CUA, GSI, ODU, and SBU)
    - CUA will coordinate and contribute labor for construction, commissioning and operating of the prototype
    - CUA will contribute lens
    - GSI will contribute optics (bars, plate, prism, lenses), mechanical elements, initial electronics, initial MCP-PMT units
    - SBU will provide space for the prototype and CRT and workshop support
    - ODU will contribute to CRT (Gas Cherenkov for muon velocity selection)
    - UH will contribute to pre-production electronics prototyping
- hpDIRC assembly (CUA, GSI advising)
- Monte Carlo simulation studies (CUA, GSI, W&M)
- Reconstruction/PID algorithm development (GSI)

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

EIC Project:

- labor on the BaBar DIRC bar reuse (should be assigned to one of the labs)
- labor for sensor validation and characterization studies
- support to establish a sensor testing setup at USC for characterization and quality assurance of series production photosensors

Existing capabilities needed at the Labs:

- JLab:
    - Transportation and space for BaBar DIRC bar boxes
    - Test space for photo sensors
    - Equipment base established from eRD14 MCP-PMT tests in a high magnetic field
    - Design and construction of custom readout electronics for candidate sensors

- BNL: test space for photo sensors
- BNL:We expect that BNL will support all forms of detector R&D for EIC as it is the host institution for the project and that many members from its various research groups will participate.

6) Labor contribution for the EIC experimental equipment activities:

The time commitment of members of the interested institutions in the EIC efforts described in this EoI is anticipated to be as follows:

Institution Name	Professor	Research Professor	Scientist	Postdoc	Graduate Student	Undergrad Student	Engineer	Designer	Technician	Total Sum
CUA	0.25			0.5	0.2	0.2			0.5	1.65
										1.65
GSI			0.1				0.1			0.2
			0.2							0.1
			0.1							0.1
										0.4
W&M	0.1			0.25	0.2	0.2				**0.75**
USC	0.15				0.2	0.8			0.05	**1.2**
SBU		0.2		0.5	0.2	0.2				**1.1**
UH	0.1			1.0			0.2			**1.3**
JLab			0.1				0.1			**0.2**
ODU	0.25			0.5	0.3				0.5	**1.55**

CUA: It is anticipated that the collaborative effort of CUA to cooperate on the EIC Project is to include (at an annual basis) 0.25 full-time equivalent FTEs of a professor, 0.5 FTE of a postdoctoral researcher, and 0.2 FTEs of Ph.D. students, and 0.2 FTEs of undergraduate students. The technical collaborative effort contributed is to include up to 0.5 FTE of a technician. The CUA group is responsible for hardware evaluation and development supported by the detector R&D program. That includes special focussing lens development and coordinating hpDIRC prototype realization. We are also performing in collaboration with GSI group software studies. We plan to coordinate and actively participate in further R&D activities as well as later construction and operation of the hpDIRC detector.

GSI: The GSI group will contribute the expertise of three staff scientists and one engineer on DIRC detectors, based on our experience with the DIRC counters in BaBar, GlueX, PANDA, and the EIC. We anticipate our contribution to be primarily in the areas of software development for the design, simulation, and reconstruction/PID algorithms and the performance validation with system prototypes. In the near future we plan to send many of the PANDA Barrel DIRC prototype components to SBU as long-term loans. This effort will happen in close cooperation with CUA and SBU. We plan to participate in the prototype evaluation, the setup of the

components at SBU and bringing the system into operation. We also plan to work on the analysis of the data from the future cosmic ray facility at SBU and possible beam tests at Fermilab. Our work on the system design and the software development for the reconstruction and PID with hpDIRC will continue for the foreseeable future. Last but not least we plan to work to the preparation of the reuse of the BaBar DIRC bars for the hpDIRC by contributing our expertise with bar fabrication and bar box assembly.
The primary responsibility of the GSI group is to the PANDA experiment at FAIR, in particular the PANDA Barrel DIRC system. We are also responsible for work packages on the GlueX DIRC system. We have been involved in the R&D for the DIRC at EIC since the start, in 2011, and believe that we can maintain the contribution to the hpDIRC at the level indicated in the table above, until the completion of the construction phase.

BNL: This information was presumably submitted by the various BNL groups directly to NPP and EIC Project Management.

W&M: The William & Mary group anticipates contributing experienced personnel with an average total of 0.7 FTE each year, with experience in DIRC assembly, installation, commissioning and analysis from the GlueX experiment. In the near term, the group plans to participate in simulation of detector performance for different physics processes and evaluation of the prototype in beam tests at Fermilab.

USC: The USC group plans to contribute to the validation and characterization of photosensor candidate prototypes, as well as take responsibility for the quality assurance of series production sensors. The magnetic field validation and the characterization of sensor prototypes has been/will be done in collaboration with JLab, following our established collaborative framework from the EIC R&D program. We envision to adapt our locally existing laboratory space for the needs of the quality assurance of series production photosensors to allow the possibility for continuous work throughout the academic year. In terms of manpower, we expect to contribute up to 1.2 FTE annually, which includes 0.15 FTE of a regular faculty, 0.05 FTE of a technician (as needed), 0.2 FTE of a graduate researcher, and up to 0.8 FTE of undergraduate student labor. The latter includes 4 undergraduates working on average two months each per year. There is a room to further increase the contribution of undergraduate students if needed.

SBU: The Stony Brook group will participate in the efforts of the hpDIRC project with providing labor contributions toward the prototype program. Furthermore, it is anticipated that SBU will participate in the LAPPD project which might be also used toward the hpDIRC readout options. Eventually, we anticipate to contribute to mechanical design, integration, facilities for construction and assembly. It is anticipated that SBU will have two research faculty members contributing with a total of 0.2 FTE, one postdoc contributing 0.5 FTE, a graduate as well as an undergraduate student, contributing each with 0.2 FTE to the project.

UH: The University of Hawaii group will work with commercial partner Nalu Scientific to develop and deploy readout electronics for the hpDIRC, both in support of test campaigns, as well as for the production installation. This task includes integration into the DAQ and slow control systems. Board design provided 0.2 FTE engineer and testing/operations support from an Instrumentation-focused 1.0 FTE postdoc. Nalu will provide ASICs and firmware support for these devices.

JLAB: Personnel from the JLAB Radiation Detector and Imaging Group are expected to continue support for the photodetector tests that have been performed at Jefferson Lab, originally as part of the eRD14 consortium, and will continue as needed for hpDIRC. An established equipment base has been setup for these tests including a superconducting magnet for high B-field tests, cryogenic containers to supply the liquid nitrogen and helium for the superconducting magnet, a picosecond pulsed laser, numerous pulsed LED-based light sources, a photodetector test chamber, and a complete CODA-based DAQ system. In addition, the Radiation Detector and Imaging Group will continue to design and build custom readout electronics for candidate sensors as needed.

ODU: The effort described above is current, and is expected to be sustained throughout the EIC project. Current hpDIRC work includes design of a threshold Cherenkov for a Cosmic Ray telescope, optical characterization of prototype DIRC lenses, and general detector design and integration. The ODU team is also engaged in detailed background studies from beam gas interactions and synchrotron radiation, which will impact estimates of event multiplicities and photo-sensor dose. ODU contributed a picosecond pulsed laser to the magnetic field tests of candidate photo-sensors, and there is also an Atomic Physics collaboration at ODU with Nalu Scientific.

7) Timing constraints to submission:

Test of components with the prototype at CRT and test beam planned for 2021-2023

- CUA: Currently 50% of research time is devoted to the GlueX experiment.
- BNL: The BNL sPHENIX Group is currently heavily involved and committed to building and subsequently running the sPHENIX experiment. As such, the availability of manpower and resources from the sPHENIX group to work on EIC will be limited for the next several years.
- SBU: A part of the SBU group is, similar to the BNL group heavily occupied with the sPEHNIX experiment. This will allow only a limited amount of in-kind labor to be contributed to the project within the next few years.
- UH: In partnership with Nalu Scientific, support test beams with pre-production prototype electronics. Given current constraints, this implies a second beam test.
- JLAB: expects to support the onsite sensor tests according to the schedule constraints of the hpDIRC sensor test group (PI: Y. Ilieva, USC)
- The full ODU group has commitments to Jefferson Lab experiments for the next 5 years. Nonetheless, we expect within the one year, and for the duration of the EIC project at least 50% of the research time of two faculty members and two postdocs to be dedicated to EIC projects. Currently 50% of the research time of one faculty member, 100% FTE postdoc, 100% of one graduate student, and 25% of our technician are dedicated to EIC projects.

8) Other helpful information:

Specific skills/expertise/etc.:

- CUA:
    - DIRC experience at GSI, ODU, and CUA since 2010:

      → PANDA Barrel DIRC (2010-2014), hpDIRC (since 2013), GlueX DIRC (since 2015)
    - Optical tests of DIRC components, Geant and ray-tracing simulation, prototype beam tests at GSI and CERN, radiation hardness tests, high-B tests, GLueX DIRC installation and commissioning.
- GSI team:
    - RICH/DIRC expertise from work on BaBar DIRC (1995-2008), SLD CRID (1997-2008), SuperB fDIRC (2001-2008), PANDA Barrel DIRC (since 2007), EIC DIRC (since 2011), GlueX DIRC (since 2015).
    - Experience with all aspects of DIRC design, construction, and operation; software development for reconstruction, simulation, and particle ID; optical design software, ray-tracing software, Geant, CAD and FEE software; evaluation of DIRC prototypes in cosmic ray facility and in particle beams; optical lab for measuring properties of DIRC bars and plates; electronics lab for evaluation of readout electronics for PMTs and MCP-PMTs; mechanical lab for the development of mechanical elements; PANDA Barrel DIRC prototype, available for transfer to US.

- BNL: The sPHENIX Group has a great deal of expertise in all areas of detector development, including both hardware and software. In relation to the DIRC project, the expertise on the use of SiPMs for the sPHENIX calorimeters may be most useful. This includes studying the sensors themselves, their readout and associated electronics, calibration, and extensive radiation damage studies. The group has also been extensively involved in developing tracking detectors using MPGD readouts, which also includes investigating MPGD readouts for LAPPDs. This research is currently being carried out in collaboration with ANL and Incom which manufactures LAPPDs.

- W&M: The W&M group's DIRC experience comes from the GlueX experiment where it had roles in project management, MAPMT and electronics characterization, installation and commissioning. The group is presently active in GlueX and the EIC Yellow Report effort as a convener of the Semi-inclusive Physics Working Group

- USC: The USC group has experience in characterization of MCP PMTs through the EIC R&D program. In addition, the group has expertise in the design and construction of

scintillator detectors having delivered the FTOF for CLAS12 and the SPS, beam monitor, and veto detectors for the MUSE experiment. Of the latter, the ability to manage large scale detector projects and to mobilize substantial student participation in support of these activities is relevant for the EIC DIRC. Another relevant aspect of our past detector work that is available for this project is local infrastructure, including laboratory space and equipment.

- The SBU group and its members have a long history in contributions to all kinds of experimental apparatuses, providing expertise in all possible detector technologies. The group has not only a long history but also was the key player in many efforts. The detector technologies span over gaseous and solid state tracking detectors, particle identification systems, calorimetry, polarimetry, readout electronics, and software contributions. The group is presently actively participating in a variety of EIC detector R&D groups.

- 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 hpDIRC endeavor is that UH provided the intellectual input into what became the Belle II imaging Time Of Propagation (iTOP) detector, which shares many similarities in PID function with the hpDIRC. In particular UH has been responsible for the design, fabrication, installation and support of the iTOP system. Prof. Varner currently serves as iTOP detector coordinator. 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.

- JLAB:
    - Extensive experience with photodetectors, specifically, standard vacuum photomultipliers, position-sensitive PMTs, microchannel plate PMTs, and silicon photomultipliers

    - Original and continuing support group for the high B-field tests of photodetectors for EIC R&D

- ODU: The ODU group has worked extensively on EIC topics, including the original JLEIC detector concept, DIRC PID simulations and test beam campaigns (S.L. Allison, PhD 2017), magnetic field tests of DIRC photo-sensors, and beam-gas background studies (eRD21). We are currently measuring the optical properties of DIRC lenses at ODU in collaboration with CUA.