**Expression of Interest (EOI) for the EIC Collider Detector (“ECCE”) Consortium**

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**Institutions collectively involved in this submission of interest:**

AANL/Armenia, Boulder, CUA, Charles U./Prague, Columbia, FIU, GWU, GSU, ISU, Kentucky, LLNL, Lehigh, MIT, ODU, ORNL, Rice, Rutgers, SUNY, TAU/Israel, UConn, UIUC, UNH, UVA, Vanderbilt, and IJCLab-Orsay/France.

**Items of interest for potential equipment cooperation:**

The EIC enables an exciting research program which will advance our understanding of the structure of hadronic matter. A state-of-the-art collider detector for the EIC, which is needed to realize its physics program, will be extremely complex. It will require extensive infrastructure, and will need to be integrated into the operation of the accelerator to a very high degree. The technically driven reference schedule for the EIC project is aggressive and presents a significant challenge for an EIC detector to be designed, built, commissioned, and ready to start delivering science when the machine begins to deliver collisions. The substantial resources needed to construct a state-of-the-art detector for the EIC present an additional challenge. Time-tested strategies for addressing such challenges include the reuse of existing infrastructure where suitable and leveraging the hard-won expertise gained through previous successful projects.

The EIC Collider dEtector (ECCE) consortium comprises more than 25 institutions assembled around the idea of building on the foundation of existing infrastructure available at RHIC IP8 and experimental equipment available there and elsewhere at JLab and RHIC. The consortium includes institutions with wide-ranging world-class detector expertise, strong familiarity with the EIC-suitable characteristics of IP8, and an understanding of the approach to DOE project management. Appropriate use of existing infrastructure will help mitigate several technical and schedule risks of an EIC detector project. The technical expertise in the consortium can build on and extend upon the base provided by existing equipment to provide a complete detector with capabilities mandated by the EIC science requirements as defined by the recent EIC Yellow-Report community effort. The substantial project management experience of the involved institutions provides credible “out of the box” know-how for realizing such a complicated detector.

Our working principles in developing this consortium have been:

* To follow the guidance provided by the Yellow Report detector design study.
* Explore utilization and/or upgrades of existing detectors and infrastructure that would enable EIC science by meeting the Yellow Report performance requirements.
* To assemble the talent and expertise to develop and build new equipment when required.

Our collective experience spans a wide range of activities including detector development and construction, mechanical support and infrastructure, readout electronics and computing, algorithm development, etc. for RHIC (sPHENIX, STAR, etc.), JLab (Hall C, CLAS12, GlueX, etc.), the LHC experiments, and more. The discussions below are informed in part by a prior design study[[1]](#footnote-1).

**Please indicate what the level of potential contributions are for each item of interest:**

*(e.g. indicate if contributions are for full in-kind experimental equipment components – we have provided a rough direct cost estimate for many components in an appendix (see slide 10 & 11 at*

*https://indico.bnl.gov/event/7449/contributions/35863/attachments/27277/41597/EIC.Comp.Det.032020.eca.pptx, if contributions are for partial in-kind experimental equipment components, if contributions are for in-kind labor contributions, etc.).*

Here we need each group to send us a paragraph (or few) detailing what contributions they can make for the items they want to work on. Example text for several groups are given below.

Below we detail the specific equipment we would like to help realize and the relevant experience members of our consortia have in realizing such/similar equipment. We note that individual EOIs were submitted by several consortia groups and/or for various equipment elements. These EOIs contain additional details that go beyond the scope of the current consortia EOI and are cross-referenced herein.

* **Central Barrel Detector:**
	+ Hadronic Calorimetry (Rutgers, ISU)
		- We would like to realize an hadronic calorimeter, possibly based on the existing sPHENIX magnet flux return. The Rutgers and ISU groups had a leading role in the R&D, test beams, design and construction of the hadronic calorimeters for the sPHENIX detector.
	+ Electromagnetic Calorimetry (UIUC)
		- The UIUC group is manufacturing the W-fiber EMCal towers for the sPHENIX central barrel and have a wealth of experience and significant factory capabilities. While the existing sPHENIX EMCal will not be adequate for an EIC detector, their expertise will be key in realizing a barrel ECAL for “ECCE”.
	+ Central Tracker
		- Silicon timing detectors for tracking (MIT, Rice)
		- Vertex (ORNL)
		- GEMs (UVA, GWU, MIT-BATES)
			* The UVA group is currently running a world-class GEM development and construction laboratory. They recently successfully built GEMS for the PRAD and SBS experiments at JLab and will build GEMs for MOLLER, SOLID and others. The GWU group is currently working with MIT-BATES to realize a sister lab to UVA in order to enhance manufacturing capabilities. This will be put to use for GEM trackers for “ECCE”.
		- TPC (SBU, ORNL, Vanderbilt)
			* The Stony Brook is manufacturing the TPC for the sPHENIX experiment and has a wealth of expertise with GEMs and gaseous detectors. Vanderbilt is the site of one of the GEM factories for the sPHENIX TPC. The groups intend to use their expertise and existing lab infrastructure towards realizing a TPC for “ECCE”.
	+ Pre-shower (Taiwan)
* **Hadron Endcap**
	+ Forward HCal (ISU)
	+ Forward Electromagnetic Calorimeter (ISU)
		- ISU participated in design studies for forward instrumentation in sPHENIX and R&D for different EMCal designs. In particular, a hadronic calorimeter similar to the UCLA design for the STAR forward upgrade has been considered, as has repurposing the PHENIX EMCal or E864 calorimeter blocks[[2]](#footnote-2). ISU will use its experience with calorimetry in sPHENIX to develop a solution for forward calorimetry in “ECCE”.
	+ Particle ID:
		- Cherenkov (XX)
		- RICH (XX)
		- DIRC (ODU)
		- TOF (MIT)
		- TRD (XX)
	+ Forward Tracking:
* **Lepton Endcap:**
	+ Hadronic Calorimeter
	+ Electromagnetic Calorimetry (MIT, CUA, Lehigh, FIU, Kentucky, AANL/Armenia, Charles U./Prague, IJCLab-Orsay/France)
		- We would like to collaborate with the project to help realize scattered electron detection in the electron-going direction covering pseudorapidity -3.5 to -1 with an electromagnetic calorimeter. The team has a long-standing track record with the construction of homogeneous EM calorimeters based on high-resolution crystals and glass. Our collective experience spans a wide range of activities including detector design and construction, technical support and infrastructure, readout electronics, crystal/glass fabrication and characterization, etc.
	+ Particle ID:
		- Cherenkov (XX)
		- RICH (XX)
	+ TOF (MIT, TAU)

The MIT and TAU groups have vast experience building fast TOF detectors and multichannel laser calibration and monitoring systems that are being used at Jefferson-Lab. For the ECCE is it unlikely that traditional scintillator detectors will reach the desired resolutions. The groups will thus work towards realizing a Si or mRPC based detector. Based on past experience we anticipate that the TAU group will be able to provide a large part of such a detector as an in kind contribution to the project.

* + TRD (XX)
* **Far Forward Detectors:**
	+ ZDC (MIT, UIUC)
	+ Roman pots (XX)
	+ Off-momentum tracking (GEMs: UVA, GWU, MIT-BATES)
* **Far backward (low-Q2):**
* **Polarization:**
	+ Polarized Beam (MIT, UNH)
	+ Detector polarimetry (UNH)
* **Electronics:**
	+ Electronics (Columbia)
	+ DAQ / Trigger (ISU)
		- The ISU group designed and built the Global Level-1 trigger for the PHENIX experiment as well as multiple Level-1 trigger systems. ISU has access to electronics design and testing facilities though the EE Department, and has collaborated with EE on electronics design as well as wafer-probing and sensor testing.
	+ Streaming Readout (SBU)
* **Computing:** (LLNL, ORNL)
* **Project Management**
	+ Many of the institutions in the ECCE consortium have significant experience working on large DOE/NSF projects and would bring that experience to the ECCE project. This experience varies from the upper level of project management to experience at L2/3 in detector projects.

**Please indicate what, if any, assumptions you made as coming from the EIC Project or the labs for your items of interest:**

For this EOI we assume the availability of the IP8 interaction point at RHIC, along with the corresponding mechanical, electrical, safety and cryogenic infrastructure, as well as the availability of certain components of the sPHENIX detector.

The IP8 hall is 17.4m in length and 18.6m in width and includes an overhead crane with a 12 ton capacity. The width of the assembly hall to the exterior of the RHIC ring could be expanded without substantial civil construction as it is a standard metal building that extends out of the RHIC berm. The opening to the interaction hall from the assembly area is 9.3m x 10.2m. The height of the beamline above the floor is 5.2m. The IP8 area is already equipped with a safety system that includes radiation monitoring, ODH monitors and smoke alarms.

In support of new RHIC experiments, the DOE has recently invested a total project cost (TPC) of $33.4M in IP8 infrastructure, including:

* Superconducting solenoid magnet
* Cryogenic support for solenoid
* Detector carriage and structural components, including the magnet flux return
* Electronics racks with power, cooling and safety systems

By using the existing solenoid, barrel flux return and detector carriage we expect substantial removal and recovery savings for transitioning from sPHENIX to the ECCE.

The existing superconducting solenoid, inherited from the BaBar experiment at SLAC, is 3.5m long with a 1.4m inner bore diameter, and generates a 1.4T inner field in the sPHENIX configuration. A higher inner field (up to ~1.5T) is possible with appropriate modifications to the flux return design. The magnet and power supply have been transported to BNL and refurbished, including a new valve box and cryogenic interface. It has successfully undergone both low-current and high-current testing in preparation for RHIC running and plans are underway to fully map the magnet with the current flux return in 2022. Operational procedures and limits have been established by the BNL Superconducting Magnet Division to safely operate the solenoid. By the time the ECCE is realized, the solenoid will have three or more years of operational experience at RHIC. Last, it should be noted that the solenoid cryostat and chimney will fit through the existing opening between the interaction and assembly halls.

We believe that leveraging the existing solenoid enables the possibility to free up resources for detectors and instrumentation. We do, however, recognize that using an existing solenoid carries its own set of risks and the solenoid may require additional refurbishment before use in ECCE to ensure reliable operations during the EIC era.

The detector carriage and structural components support part of the solenoid flux return and solenoid both in IP8 and in its assembly hall. Currently the barrel solenoid flux return is instrumented to provide an outer layer of hadronic calorimetry; this could be upgraded or replaced to provide the same functionality for the ECCE. Additional investments have also been made in IP8 to reinforce the rails used to move the detector between IP8 and the assembly hall.

The sPHENIX detector will require electronics racks that include power, cooling, fire suppression and safety interlock systems. When sPHENIX is decommissioned these racks will be available for reuse.

The institutions of the consortium will also contribute their world-class project management experience toward the challenge of realizing a fully capable EIC detector, ready to start the EIC science program when the accelerator first delivers collisions. The successful experiences of the sPHENIX MIE, MVTX, inner HCal, and IP8 infrastructure upgrade projects, and the ALICE EMCal upgrade have resulted in an extremely capable project management team. This is a workforce that is experienced with current DOE management practices and expectations and will be indispensable in realizing a complex EIC detector project.

The use of the existing supporting infrastructure at IP8 will reduce the technical and schedule risk of an EIC detector project substantially. We emphasize that the “ECCE” detector concept is not *driven* by the reuse of equipment. Our focus is on delivering an EIC detector that is fully capable of realizing the EIC scientific program, but this approach has broader implications for the EIC program as a whole. We support a complementary approach to the physics program enabled by two detectors. The savings and risk reduction realized through the appropriate reuse of IP8 infrastructure could be used to invest in a second EIC detector in IP6.

**Please indicate the labor contribution for the EIC experimental equipment activities:**

The time commitment of members of the ECCE groups in the EIC efforts described in this EoI is anticipated to be as follows. As this EOI cross-references a large number of EOIs, we count the time commitment in the table below as “total (dedicated)”, where total counts the commitment listed in the other EIOs and dedicated counts the commitment that is only counted in this EIO. See appendix for details and examples. The entries in the table below are in annual fractional full time equivalent (FTE).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Institution Name | Prof. | Res. Prof. | Staff Scientist | Postdoc | Grad. | Ugrad. | Engineer | Designer | Tech | Total Sum |
| AANL/Armenia(from EEEMCal EOI) | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 0.2 |  | 0.3 | 2.0\* |
| Boulder |  |  |  |  |  |  |  |  |  |  |
| CUA(from EEEMCal EOI) | 0.2 |  |  | 0.5 | 0.2 | 0.2 |  |  | 0.5 | 1.6\* |
| Charles U./Prague(from EEEMCal EOI) |  0.1 |   | 0.4  |  0.2 | 0.1  |   | 0.4 | 0.1  | 0.2  | 1.5\*  |
| Columbia |  |  |  |  |  |  |  |  |  |  |
| FIU(from EEEMCal EOI) | 0.35 |  |  | 0.5 | 0.4 | 0.8 |  |  | 0.1 | 2.15\* |
| GWU |  |  |  |  |  |  |  |  |  |  |
| GSU |  |  |  |  |  |  |  |  |  |  |
| ISU | 0.4 | 0.4 |  | 1.5 | 1 | 0.4 |  |  |  | 2.8 |
| Kentucky(from EEEMCal EOI) | 0.1 |  |  | 0.4 | 0.3 | 0.2 |  |  |  | 1.0\* |
| LLNL |  |  |  |  |  |  |  |  |  |  |
| Lehigh(from EEMCal EOI) | 0.2 |  |  |  | 1.0 | 0.2 |  |  |  | 1.4\* |
| MIT |  |  |  |  |  |  |  |  |  |  |
| ODU |  |  |  |  |  |  |  |  |  |  |
| ORNL |  |  |  |  |  |  |  |  |  |  |
| Rice |  |  |  |  |  |  |  |  |  |  |
| Rutgers |  |  |  |  |  |  |  |  |  |  |
| SUNY |  |  |  |  |  |  |  |  |  |  |
| TAU/Israel |  |  |  |  |  |  |  |  |  |  |
| UConn |  |  |  |  |  |  |  |  |  |  |
| UIUC |  |  |  |  |  |  |  |  |  |  |
| UNH |  |  |  |  |  |  |  |  |  |  |
| UVA |  |  |  |  |  |  |  |  |  |  |
| Vanderbilt |  |  |  |  |  |  |  |  |  |  |
| IJCLab-Orsay/France(from EEEMCal EOI) | 0.2 | 0.2 | 0.8 |  | 0.1 | 0.2 |  |  |  | 1.5\* |
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NOTE: for a professor, full-time equivalent research time may be limited to 25% max, for a research professor (or a sabbatical) or a staff scientist limited to 50% max, for a postdoc maybe 100%, and for a grad. student perhaps 50% (on average). For an undergraduate student research time (on average) is limited to 20% max.

It is intended that the collaborative effort of the “ECCE” consortium will start at the detector design phase and continue for a period of five years or more (through the detector construction period).

**Please indicate if there are timing constraints to your submission:**

*(e.g., indicate any known or anticipated timing profile assumed in your EOI. This can include anticipated time frames folding in constraints due to ongoing commitments, due to ongoing R&D and its anticipated completion date, etc.)*

**Please indicate any other information you feel will be helpful:**

*(e.g., this could be things like assembly and storage space at your institute, clean rooms and class, special skills or machine shops, or perhaps some pointers to past accomplishments – you can expand on those in an appendix. If you could make existing engineering, design or technician labor available to the EIC experimental equipment but would rely on funds coming from the EIC Project you can also list those here).*

Appendix A: Related Expressions of Interest

* Electron Endcap Electromagnetic Calorimeter (EEEMCal), Tanja Horn (contact).
1. https://indico.bnl.gov/event/5283/attachments/20546/27556/eic-sphenix-dds-final-2018-10-30.pdf [↑](#footnote-ref-1)
2. https://indico.bnl.gov/event/3867/attachments/10442/12745/sPH-cQCD-2017-001\_draft\_2017\_06\_02.pdf [↑](#footnote-ref-2)