**Expression of Interest (EOI)**

**Questionnaire**

**Please indicate the name of the contact person for this submission:**

Leo Greiner (LBNL) - (primary)

Laura Gonella (University of Birmingham), Iain Sedgwick (RAL) - (for the UK groups, please refer to UK EOI for details)

Grzegorz Deptuch (BNL)

Xiangming Sun (CCNU Wuhan)

Latifa Elouadrhiri (JLAB)

Kenneth Read (ORNL)

**Please indicate all institutions collectively involved in this submission of interest:**

Currently the consortium consists of LBNL, University of Birmingham, Rutherford Appleton Laboratory, BNL Instrumentation Division, CCNU (Wuhan), JLAB, ORNL, Institute of Modern Physics (IMP, China). We have been contacted by members of INFN, IN2P3 and additional UK grpups expressing interest in working together but as yet EIC Silicon Consortium membership has not been formalized.

**Please indicate the items of interest for potential equipment cooperation:**

The goal of this consortium is to develop a MAPS sensor and associated powering, support structures, control and ancillary parts as necessary to produce a detector solution for silicon tracking for the central tracking parts of an EIC detector. This will include significant design, testing, prototyping and the groundwork/R&D to lead to a funded construction project. Much of this work would be included in a MIE project and the work done by the consortium would offset some of the funding that would be needed to complete this work inside of a construction project. The potential benefits would be prototype designs for the range of components listed that would provide the input for generating a WBS based estimate for the construction of a silicon based tracking central detector system for EIC.

The product of this effort can be used at either or both interaction points. It is intended as a full silicon based inner tracking solution. The overall designs (number of layers, spacing, etc.) may be different for each region, but the need for high precision inner tracking is likely to be present at both detectors.

The members of this consortium believe that the most successful path to achieve this goal is to join the ongoing effort at CERN to develop a new MAPS sensor based on the Towe-Jazz 65 nm process for use in the upcoming ALICE ITS3 upgrade. The requirements for the ITS3 and what is needed for an EIC tracking sensor have very broad overlap and the synergies of joining an already funded effort strongly increase the probabilities of success. A more detailed description of the current path that leads to an EIC optimized sensor and associated infrastructure can be found in the ERD-25 proposal, <https://wiki.bnl.gov/conferences/images/6/6d/ERD25-Report-FY21Proposal-Jun20.pdf>

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

The size of a potential contribution is difficult to assign a cost value. This would be able to be assessed as the EIC develops detector collaborations and detailed project documents for separate detectors go through costing exercises. Based on previous experience, the costed design and prototype phases (exclusive of R&D) can reach up to 40% of the actual construction costs based on US accounting practices where the costs of engineers and technicians is counted on project. In the ALICE ITS, the cost of the construction project in European accounting was ~14M Euro for a detector of similar size in m^2. Typically this amount is doubled or more to reach the US accounting equivalent. This should give the scale of the possible contribution.

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

We will be using existing capabilities at the consortium member laboratories. The breadth of the consortium capabilities includes the necessary experience and skills to address the work as laid out. Support would be needed from the EIC project to continue the ERD type efforts over time as the technology matures. Support will be required from DOE and other funding agencies to support these EIC related activities in the base grants as well as separate funding agency equipment grants to support the effort at the participating institutions. At this point there is not a complete work plan laid out as a WBS structure, so actual cost estimates are not available. We hope and expect that these efforts will be supported in the manner described.

Each consortium member will provide information on their individual capabilities and available equipment in their institutional proposals as well as information on the roles that they expect to play in the consortium.

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

The time commitment of members of the <INSTITUTION NAME> group in the EIC efforts described in this EoI is anticipated to be as follows:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Institution Name | Professor | Research Professor | Staff Scientist | Postdoc | Graduate Student | Undergrad. student | Engineer | Designer | Technician | Total Sum |
| LBNL |  |  | 1.5 | 1.0 | 0.9 |  |  |  |  | 3.4 |
| UK groups total (please refer to UK EOI for details) | 0.9 |  | 0.65 | 4.0 | 3.0 | 1.0 | 3.9 |  | 2.0 | 15.45 |
| BNL |  |  | 1 | 0.7 |  |  | 1 | 0.4 | 0.4 | 3.5 |
| CCNU |  |  | 2 |  | 2 |  |  |  |  | 4 |
| JLAB |  |  | 1.5 |  |  |  | 0.5 | 1 | 0.5 | 3.5 |
| ORNL |  |  | 3.7 | 2.0 | 0.7 |  | 1.5 | 0.6 | 0.6 | 9.1 |
| IMP |  |  | 2 |  | 2 |  |  |  |  | 4 |

NOTE: FTE in the above table represents the annual fractional full time equivalent (FTE).

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.

As a guide to illustrate the scope and interests on the consortium members, the table below indicates the capabilities and area of contribution for consortium members:

|  |  |  |
| --- | --- | --- |
| **Institute** | **Capabilities** | **Area of Contribution** |
| UK groups total (please refer to UK EOI for details) | * Extensive CMOS imaging sensors/MAPS design expertise for HEP and other scientific and commercial applications
* Lab and clean rooms fully equipped for silicon detectors R&D and large-scale trackers production at multiple sites;
* Experience with silicon detector characterization during R&D, and quality control (QC) and quality assurance (QA) during production
* Irradiation facilities (protons, x-rays);
* Engineering resources for full system DAQ development;
* Engineering resources and expertise for the development of ultralight support structures.
 | * During the design/R&D phase:
* Collaboration with the ITS3 project for the development of an EIC MAPS sensor at the 65 nm node;
* Design and build of a readout system for characterisation and testing of the CMOS MAPS sensors;
* Characterisation and testing of the CMOS MAPS sensors, including bench and beam tests, data analysis, device simulations etc
* Irradiation studies of sensor and electronics performance;
* R&D on ultralight support structure prototypes;
* Physics performance studies for detector layout optimization
* During the construction phase
* Detector assembly, QC/QA at multiple sites.
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| ORNL | * -electronics engineers experienced in design of high speed digital and analog readout systems; development of associated ASICs, multilayer and rigid-flex PCBs for complex circuits (including associated simulations and analysis), firmware, and delivery of fully integrated systems
* -electronics laboratories with advanced measurement equipment
* -irradiation test facility
* -mechanical engineers experienced in design and analysis of all aspects of detector mechanical systems including mechanical support structures
* -large scale carbon fiber mechanical design and fabrication facilities
* -laboratory space with clean rooms (will let you know classifications)
* -professional project management, project control, and ES&H teams with experience in coordinating very large projects
* -computer engineers with experience in on-the-fly data processing of very high data volumes
* -advanced high performance computing facilities
 | * -participation in ITS3 MAPS sensor design, development, and characterization
* -design, development, production, and test of continuous parallel readout system with the on-the-fly data processing
* -power system design and development
* -cooling system design and development
* -mechanical support structure design and development
* -detector assembly
* -professional project management and project controls
* -production and analysis of detector performance simulations
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| LBNL | * Silicon design
* Sensor prototype testing and characterization with HI and proton beams
* Carbon fiber composite structures design and fabrication
* Full spectrum electronics design and fabrication.
* Full spectrum mechanical design and fabrication
* Project management and leadership
 | * Collaborating on the silicon design with the CERN based ITS3 team and other members of the EIC Silicon consortium with a particular focus on low power pixel circuitry, design for high yield in the stitching process and serial powering options.
* Work on the particular mechanical and electrical design of discs based on ITS3 type sensors.
* Work on the particular mechanical and electrical design of staves based on ITS3 type sensors.
* Targeted R&D on the reduction of the mass of the services needed for the sensors.
* Cooling of the staves and discs.
* Mechanical adaptation of the ALICE ITS3 stitched vertex detector design for the EIC beam pipe configuration.
* Mechanical support stability and deflection studies.
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| BNL Instrumentation Division | he BNL Instrumentation Division (<https://www.bnl.gov/instrumentation/>) has a number of facilities suited for the consortium work, including:* The Integrated Electronics Laboratory with focus on the development (design) and testing of Application Specific Integrated Circuits (ASICs), signal processing and electronics, DAQ and controls, Printed Circuits Boards (PCBs).
	+ Extensive expertise in low-noise front-end, spectroscopic circuit design for radiation detectors, using process node down to 65 nm,
	+ Wide record of multichannel integrated circuits with sparsified readouts with data acquisition, including pixel detectors
	+ Recent extension on digital back-ends and digital on top design methodologies for higher data throughput and streamlined readouts and processing,
	+ State-of-the-art software ECAD design and verification tools,
	+ Assembly, testing and high-density interconnect infrastructure.
* The Silicon Detector Laboratory as a part of a series of laboratories and cleanrooms dedicated to the development of semiconductor detectors (Semiconductor Detector Laboratory) with the focus of this facility on the development and production of silicon detectors
	+ Cleanrooms and lab space dedicated to different parts of sensor processing, including post-processing, testing, calibration, metrology, and integration,
	+ Software, design, and verification tools for semiconductor detectors.
* The High-Density Interconnect and Electronics Assembly Laboratory
	+ A large cleanroom space with a multitude of tools for designing, fabricating interconnections and performing metrology and inspections – including computer-aided design software and high-tech interconnect equipment – for large international experiments.
* The Solid State Irradiation Facility (SSIF), with an 1150 Ci 60Co source that can provide 1.17 and 1.33 MeV photons from 3 Gy/hr to 800 Gy/hr in addition to other irradiation possibilities existing at BNL, such as Tandem and NSRL (with focus on single event effect testing)
 | * Design and testing of the EIC targeted sensor.
* Providing infrastructure and expertise for all collaborative efforts with the consortium upon availability of laboratory spaces, personnel and equipment.
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| JLAB | **Silicon Tracker Experience**: The JLab team gained experience from the CLAS12 SVT and Heavy Photon Search SVT projects can be extended to the current pixel tracker technology. JLab silicon groups were actively involved in all aspects of silicon tracker work including management plans, risk evaluation, general tracker simulation and design, R&D on silicon sensors and detector modules, readout and DAQ, mechanical support, tracker services (cooling, purging, power supplies), tracker safety and monitoring systems, data logging. The JLAB silicon teams have a successful experience of collaboration with silicon labs at FNAL and SLAC on these projects, following development, quality assurance and deliverables of critical detector components with different vendors. JLAB has essential expertise in silicon tracker integration, commissioning, and operation at high luminosity, track reconstruction, data validation and analysis.**Infrastructure:** JLab’s clean rooms were used for testing and assembling the silicon tracker. JLab has probe stations, wire-bonding stations, and test stations for the silicon project R&D. **Beam Test:** CEBAF provides a unique opportunity to satisfy various needs of the silicon tracker R&D in testing the functionality of the tracker modules, readout, DAQ, trigger etc. | **Design**SensorCabling**Mechanical Support Structur**eFE AnalysisExtensive experience with Carbon Fiber Module assemblyAssembly and Integration**Trigger**Level 1 triggerLevel 3 trigger improving efficiency and purity**DAQ**DesignReadout DesignStreaming Readout design and testing**Simulations**Full Geant simulation interfacing between engineering design CAD Model and software developersBackground simulations of synchrotron radiation, beam gas interactions and other backgrounds to determine rates, radiation doses and occupancies**Prototyping/Testing in clean room****Beam test:** Design the setup and carry on the test experiment and data analysis |
| CCNU Wuhan | Silicon sensor design, clean room assembly, wire bonding, etc. | silicon sensor design |
| IMP | sensor testing | sensor testing |
|  |  |  |

**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.)*

This information is difficult to coordinate between the participating institutions in advance as the institutions have different schedules for filling out their individual EOIs. We will respond individually in the institutional EOIs and provide information on the individual institutional commitments and timeframes where effort could be ramped up or down based on those commitments. This information can then be transferred to this table from all participating institutions.

**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).*

Many of the institutions that are part of the consortium are national laboratories with extensive experience in silicon and detector design and construction. As such they are well provisioned with local shops, engineering groups, clean rooms, laboratories, and test beam facilities. Each individual EOI should contain ample description of the institutional capabilities and resources.

As additional material on the Silicon Consortium plans, we reference the following presentations:

Initial proposal at EICUG YR meeting at MIT:

<https://www.jlab.org/indico/event/348/session/5/material/0/0.pdf>

Description of ITS3 R&D project at EICUG YR meeting at Temple:

<https://indico.bnl.gov/event/7449/contributions/35955/attachments/27131/41358/2020_03_18_EIC_ITS3_tech.pdf>

ERD-25 proposal talk:

<https://wiki.bnl.gov/conferences/images/1/1c/ERD25-proposal-Jul20.pdf>

Full ERD-25 proposal and progress report

<https://wiki.bnl.gov/conferences/images/6/6d/ERD25-Report-FY21Proposal-Jun20.pdf>

EOI “Precise central silicon tracking and calorimetry with integrated parallel and continuous readout for an EIC detector” submitted by ORNL with collaborating institutes (in alphabetical order) Florida State Univ., Univ. Tennessee, Vanderbilt Univ., Wayne State Univ. This document provides further details (FTEs, timing, funding) concerning the ORNL contributions relevant for this Silicon Consortium EOI.