**Argonne National Laboratory Expression of Interest:**

***Ultrafast silicon sensors, hybrid SOI/LGAD tracker for the central region, pixelized MCP-PMTs and a gas RICH for the forward region, superconducting nanowire particle detectors, and computing for the EIC experiments.***

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

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

Argonne National Laboratory

*Our collaborating partners:*

* BNL (*contact persons: A. Kiselev, R. Nouicer, A. Tricoli*)
* IJCLab (*contact person: R. Dupré*)
* KEK (*contact person: Y. Arai*)
* Los Alamos National Laboratory (*contact person: X. Li*)
* New Mexico State University (*contact person: M. Paolone*)
* RIKEN (*contact person: I. Nagakawa*)
* Temple University (*contact person: N. Sparveris*)
* UC Santa Cruz (*contact person: A. Seiden*)
* UIC (*contact person: Z. Ye*)

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

Argonne National Laboratory has interest for potential equipment cooperation in four broad areas of an EIC experiment. We are interested in taking the lead of a full detector subsystem and ancillary components.

1. **Ultrafast Silicon in the central detector**
	1. R&D towards the development of LGAD TOF tracker with a timing resolution < 10ps. We recently demonstrated <15ps timing resolution in a beamline experiment, and the pathway to 10ps is straightforward.
	2. Design and construct a hybrid SOI/LGAD vertexing/tracking/TOF system for the central detector (in barrel and endcaps), in line with our TOPSiDE detector concept.
	3. Development of readout ASICs for ultrafast silicon sensors.
	4. R&D towards a timing distribution and synchronization system.
	5. Experience and ability from ATLAS (CERN) to design and construct the necessary carbon fiber structures (local and global mechanics), and the required cooling system.
	6. Module assembly and loading.
	7. Development of on-detector services
	8. CMOS development.
2. **Pixelized MCP-PMT technology and RICH**
	1. R&D towards 10x10cm MCP-PMTs pixelized through capacitively coupled readout boards. We already successfully prototyped this technology through our Argonne 6x6cm MCP-PMTs, which have precise time resolution and have been demonstrated to be highly resilient in high magnetic fields. We are currently constructing our 10x10cm fabrication facility on-site and have a pathway towards commercialization through SBIR with our industrial partners.
	2. Development and validation of pixel readout electronics compatible to Argonne 10x10cm MCP-PMT. We designed pad pixel readout scheme and will soon test its performance with our MCP-PMT.
	3. Design and construction of a gas RICH for high-momentum particle identification in the forward region. A gas RICH would complement a TOF-based approach for lower-energy particles. Our group has extensive experience with Cherenkov (including RICH) R&D and construction.
3. **Superconducting nanowire detector technology**
	1. R&D to develop superconducting nanowire particle detectors, leveraging superconducting nanowire single-photon sensors (SNSPDs) designed for quantum optics. We have found these sensors to be highly efficient, insensitive to magnetic fields up to at least 5 T, very fast (20ps timing resolution), and very resilient to high levels of radiation.
	2. Development of high channel count readout electronics for cold environments in collaboration with industry partners.
	3. Development and eventual construction of detector systems utilizing superconducting nanowire detectors include
		1. Roman pot detector in the forward region.
		2. Detector integration inside superconducting accelerator magnets for very forward ion detection. Integration of the sensor within the cold bore of the superconducting magnet.
		3. Development of a nanowire-based detector in front of the ZDC and around the forward ion spectrometer section, filling in the detection gaps where radiation-hard sensors with excellent position and timing resolution are needed.
		4. Use of the detector in a high-rate electron detector for a Compton Polarimeter to measure the azimuthal asymmetries needed to extract the beam polarization.
4. **Computing for the EIC experiments**
	1. Long history at Argonne with high-performance computing (HPC). Can leverage exascale computing at Argonne for data processing and simulations. Furthermore, we can use peripheral services to facilitate distributed data storage and sharing, similar to the Petrel storage already deployed for the EICUG YR effort.
	2. Software R&D towards a state-of-the-art software ecosystem for end-to-end simulation, reconstruction, and monitoring in future heterogeneous computing environments.
	3. R&D towards AI techniques to accelerate the processing of the globally sparse/locally dense data unique to particle physics. Draw on broad expertise with AI at Argonne.

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

* Argonne is actively investing through LDRD and Program Development funds towards the EIC. In the short-term (FY2021-FY2022) we have funding from Argonne to support the majority of our R&D efforts toward EIC.
* Our MCP-PMT R&D is partially funded through eRD14 and our superconducting nanowire detector R&D is partially funded through eRD28.
* Managerial experience leading large projects.
* We can leverage the extensive infrastructure and investments already made at Argonne:
	1. Argonne Micro Assembly Facility (AMAF) with probe-station, wire bonders, metrology equipment, etc. The facility is for module assembly and loading.
	2. Permanent pixel telescope at the Fermilab Test Beam Facility (FTBF).
	3. Extensive data-acquisition experience in both PHY and HEP.
	4. 6x6cm and 10x10cm MCP-PMT fabrication and testing facility.
	5. Existing relations through SBIR with industry partners on MCP-PMT fabrication and readout ASIC development.
	6. Argonne 4 Tesla Solenoid Facility for high-magnetic field testing of large detector prototypes.
	7. In-beam tests possible onsite at the Argonne Wakefield Accelerator (AWA), Low-Energy Accelerator Facility (LEAF), Advanced Photon Source (APS), and Argonne Tandem Linac Accelerator System (ATLAS).
	8. Electronics Support Group for construction of electronic readout boards.
	9. Center for Nanoscale Materials (CNM) and the Material Sciences Division (MSD) for manufacturing and testing of superconducting nanowire sensors.
	10. Extensive expertise with engineering and construction of large detector systems.
	11. World-class HPC facilities and expertise at ALCF and LCRC.

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

As a national lab, the majority of engineering support and M&S comes from project funding. For FY2021-FY2022, the R&D effort at Argonne is supported through Argonne LDRD and Program Development funding. After this we assume project funding to cover M&S and mechanical engineering labor for R&D and/or construction.

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

The time commitment of members of the Argonne National Laboratory group in the EIC efforts described in this EoI is show in the table below. The first row shows the existing efforts throughout FY2021 and FY2022. The bottom row illustrates that we expect an increasing FTE profile as we move forward towards EIC.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Institution Name | Professor | Research Professor | Staff Scientist | Postdoc | Graduate Student | Undergrad. student | Engineer | Designer | Technician | Total Sum |
| **Argonne FY21-22(funded LDRD)Argonne FY23+** |  |  | **2.4** | **3.9** |  |  | **0.5** | **0.5** |  | **7.3** |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  | **4+** | **5+** |  |  | **1+** | **1+** |  | **11+** |
|  |  |  |  |  |  |  |  |  |  |

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.

It is anticipated that the collaborative effort of Argonne National Laboratory to cooperate on the EIC Project is to include (at an annual basis) at least 2.4 FTEs of staff scientists and 3.9 FTEs of postdoctoral researchers. The technical collaborative effort contributed is to include up to 0.7 FTE of a (mechanical or electronics) engineers and 0.5 FTE of a designer. These numbers are for FY2021 and FY2022, where the majority of our funding comes from Argonne LDRD, Program Development Funds and programmatic funding. As our commitments in other projects wind down, we will be able to allocate more staff and postdoc FTEs towards EIC. The available FTEs for the mid-to-long-term could be significantly larger contingent on appropriate project funding. Our staff has managerial and engineering experience leading large projects.

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

We are already funded through Argonne LDRD and Program Development Funds to work on EIC and anticipate an increasing labor profile when we move towards construction.

**Cross-reference to other EoIs with involvement of collaborators**

* Expression of Interest for Lepton Polarimetry(*contact persons E.-C. Aschenauer and D. Gaskell*)
* Fast timing silicon detectors for EIC (*contact person W. Li*)
* General Software Expression of Interest (*contact person M. Diefenthaler*)
* Japanese Group’s Expression of Interest (*contact person Y. Goto*)
* Los-Alamos National Laboratory’s EoI (*contact person X. Li*)