EIC simulation infrastructure BNL LDRD-A 2023

Description of project

This proposal addresses the topic area from the LDRD call: *Research and Development towards the Second Detector and Computing at the Electron-Ion Collider*

The EIC detector development process to date has in its software and computing aspects advanced very rapidly to establish the basis for a modern software stack and infrastructure directed at effectively meeting near term needs and providing a smooth development path towards EIC datataking. The needs of the ePIC detector's development program naturally prescribe priorities, design choices and work plans for software development. Detector 2 software and computing is expected to leverage ePIC's, reflecting a universal emphasis on common software in the EIC community. The longer Detector 2 timeline presents opportunities to advance EIC S&C computing R&D in the near term without conflicting with the detector development timeline. For example in the crucial simulation domain much research and development is still needed to effectively leverage both new capabilities in our simulation tools and the rapidly evolving ecosystem in common scientific software.

We propose a three year R&D program on EIC detector simulation tools and infrastructure targeting initially the Detector 2 development program and timeline, with deliverables defined in collaboration with ePIC for eventual adoption there as well. The work would be a collaborative effort with JLab where in recent years a strong capability in the most advanced detector simulation tools and techniques has been established. This project would closely couple BNL and JLab efforts in a combined program with BNL taking leadership roles in topics supported by this proposal. Without the resources this project would provide, BNL is unable to fully draw on our simulation expertise and EIC software leadership roles towards advancing EIC simulation.

This proposal builds on an existing collaborative BNL-JLab EIC simulation project, eAST (e-A Simulation Toolkit). Led by Makoto Asai at JLab, one of Geant4's principal architects and experts, eAST is being used as a development testbed for new tools and technologies that are important to EIC simulation, but are on a longer developmental timescale than the tight timeline of ePIC (ePIC is selectively integrating eAST components such as a new EIC physics list). Neither BNL nor JLab currently has the effort to turn eAST's planned development program into an active one. This project would establish active efforts in eAST's highest priority areas as follows.

Integrated fast and full simulation: Detailed simulation of detector subsystems, interaction region, and support structures are time consuming, both in terms of people- and CPU-hours. The latter can be eased by leveraging new and rapidly evolving computing technologies for fast simulations; speed-ups by a factor of 400 have already been demonstrated. To address the former, we plan to implement a common and integrated approach for fast and full simulations in Geant4 with a plug and play modular approach, leveraging and building on Geant4's fast simulation capabilities.

Python interface to Geant4 and its extensions (eAST): We propose to develop a Python interface to major components of the EIC simulation software stack, including the ePIC framework, and open for integration into the future Detector 2 software. The motivation is to provide a flexible, user-friendly access to the rich and complex functionality of the simulation software, while incorporating new features and capabilities of Geant4 and eAST. In addition, Machine Learning is a cornerstone of modern fast simulation, and a Python layer will facilitate detector surrogate models which can complement Geant4's built-in capabilities. This Python interface will be implemented as a package, and will be usable by the EIC researchers as well as the wider Geant4 community.

Sub-event level parallelism: *We could add a third topic to the project, to incorporate Geant4.11's new support for sub-event level parallelism as an enabler for high concurrency and use of accelerators, beneficial e.g. for Cerenkov detectors (ePIC alone has two) with their high processing demands for optical photon simulation, well suited to leveraging GPUs. But this would increase the needed postdoc count to 2, and thereby the cost, so we leave it out. The single-postdoc requested budget below includes only the above two topics.*

Expected results

Production level fast/full simulation for EIC, drawing on and demonstrating G4's fast/full simulation capability, integrated in the Detector 2 stack and ready to be used by others.

Geant4/eAST python interface providing access to major components of the EIC simulation software stack and framework, integrated in the Detector 2 stack and ready to be used by others.

Funding opportunities & programmatic benefits

BNL's EIC S&C effort is under-resourced relative to BNL's EIC role and the well-resourced efforts elsewhere, particularly JLab. This project would contribute to redressing this imbalance to the benefit of the scale and scope of BNL's EIC S&C program in the future, and to the benefit of BNL's detector development program now (highly dependent on simulation) and EIC physics program later (highly dependent on S&C).

Personnel

All personnel have backgrounds in simulation leadership: Wenaus (BaBar), Kauder (ePIC), Potekhin (STAR, PHENIX). Wenaus at BNL and Diefenthaler & Asai at JLab founded the eAST project.

PI:
Torre Wenaus, ePIC Deputy Software and Computing Coordinator

Key personnel:
Kolja Kauder, ePIC Simulation Convener
Maxim Potekhin, BNL lead on EIC software infrastructure

Requested budget

1 postdoc + 30% of existing staff member for 3 years.
(2 postdocs if we include sub-event level parallelism)