



<https://eic.ai/>

C. Fanelli, T. Horn

**Report from
Artificial Intelligence WG**



EICUG Annual Meeting, 23-31/July/2023

What is “AI4EIC”?

EIC has the unique opportunity to start incorporating AI from the very beginning and to systematically leverage on it during all phases of the project.

AI will be an integral part of the EIC software (ePIC and beyond) and we will take advantage of intelligent decisions in all aspects of data processing from detector readout and control to analysis.

The AI4EIC initiative originated as a consortium, which was integrated, as a sector, into the SWG of the EICUG in December 2021. Within the EICUG, the AI WG serves as an accessible entry point for AI applications, orchestrating workshops, tutorials, hackathons and Kaggle-like challenges.

The AI4EIC initiative continues evolving to date following two successful workshops (each with 200+ participants), an international hackathon, with a forthcoming workshop and hackathon in 2023, the publication of ten proceedings, and a community paper.

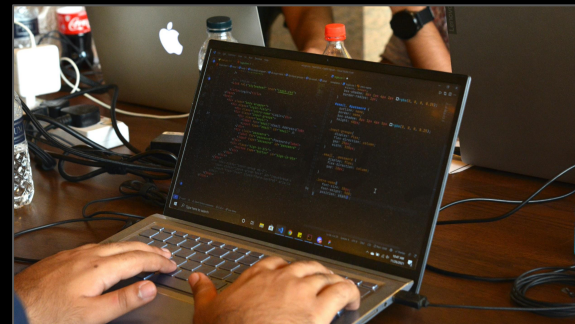
AI4EIC 2nd Workshop: Oct 10-14 2022, William & Mary



- We had a total of 220 registered participants with a very good attendance in person
- Workshop: 6 sessions (15 [conveners](#), 40+ [speakers](#))
 - Design
 - Intersection Theory/Experiment (morning + afternoon sessions)
 - Reconstruction & PID
 - Infrastructure and Frontiers** (+ Panel Discussion)
 - Streaming Readout

<https://indico.bnl.gov/e/AI4EIC>

- Community:
 - 4 Tutorials
 - Hackathon (10 teams from North, South America, Asia, Europe)



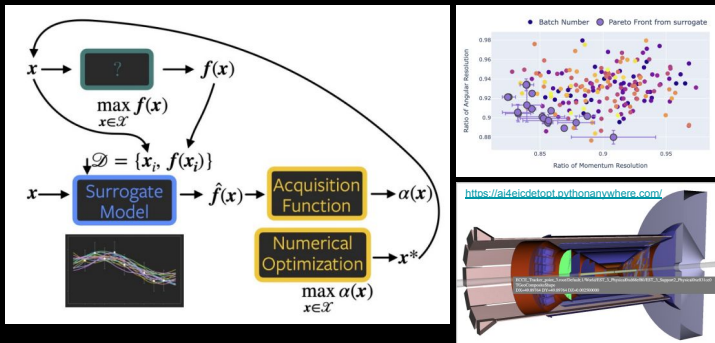
300+ users in ai4eic slack
sign-up [here](#)

<https://eic.ai/workshops>

Provided by experts from industry and national labs and research centers



M. Balandat, Meta AI



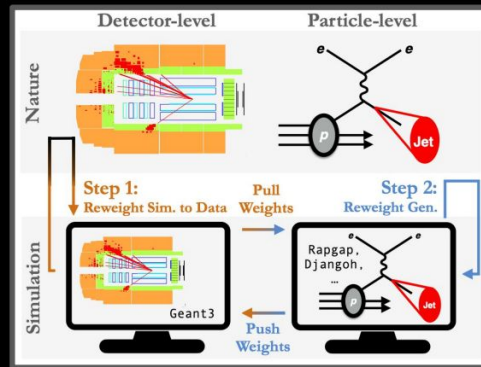
Multi-objective Optimization



F. Torales Acosta (LBNL)



V. Mikuni (NERSC)



OmniFold

Unfolding



K. Rajput, JLab/DS

flow

Tracking

Record and query experiments: code, data, config, results

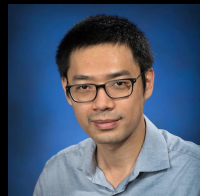
Projects

Packaging format for reproducible runs on any platform

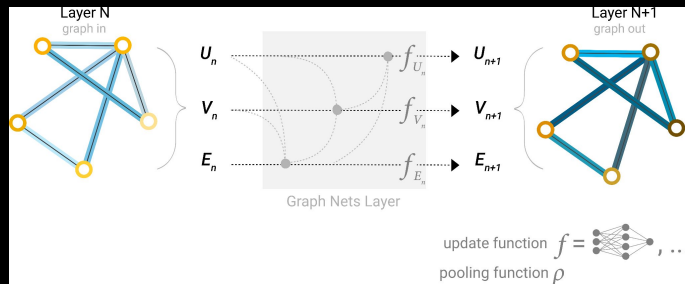
Models

General format for sending models to diverse deploy tools

MLflow — ML lifecycle

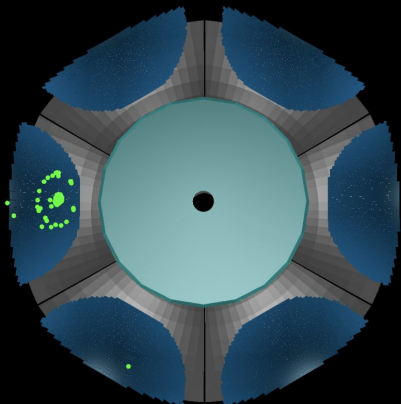


Y. (Ray) Ren (BNL)



Graph Neural Network

Hackathon



π , K datasets

Organizers: Cris Fanelli (William & Mary/JLab), Diana McSpadden (JLab/Data Science), Kishan Rajput (JLab/Data Science)

Advisory and problem definition: Evaristo Cisbani (INFN), Wouter Deconinck (U. Manitoba)

Computing resources: Eric Walter (William & Mary, IT)

Data generation, Documentation, Validation: James Giroux (U. Regina), Karthik Suresh (U. Regina)

Technical Assistance: Eric Walter (William & Mary, IT), James Giroux (U. Regina), Karthik Suresh (U. Regina)



CF, DMcS, KR, EC, WD, EW, KS, JG

<https://zenodo.org/record/7197023>



AI4EIC Hackathon

Congrats Team JINR!!!!!!! (submission on 10-14-2022)

Hackathon Leaderboard

RANK	TEAM	SCORE	QUESTIONS ATTEMPTED
1	Jets	295.502	Q 1, Q 3, Q 2
2	JINR	294.508	Q 1, Q 3, Q 2
3	JB and EC	262.313	Q 1, Q 3, Q 2

Problem Number	Threshold Accuracy
Problem 1	94%
Problem 2	86%
Problem 3	80%

Training Events	1.5 Million Events	With Magnetic Field ($\sim 1.5T$)
Momentum	15 GeV/c	at Interaction Point (0, 0, 0)
Theta θ	20°	at Interaction Point (0, 0, 0)
Phi ϕ	0°	at Interaction Point (0, 0, 0)

Problem 1

Solutions:

- JINR: CatBoost, <https://catboost.ai>
- Jets: 2D CNN

Training Events	3 Million Events	With Magnetic Field ($\sim 1.5T$)
Momentum	15 – 20 GeV/c	at Interaction Point (0, 0, 0)
Theta θ	15 – 16°	at Interaction Point (0, 0, 0)
Phi ϕ	0 – 5°	at Interaction Point (0, 0, 0)

Problem 2,3*

*Problem 3: addition of noisy hits

The best solutions were all Machine Learning/Deep Learning-based, they were quite original, and they outperformed solutions based on classical approaches (followed by some teams). While this is only a first step towards deeply learning the identification of particles reconstructed with the dual-RICH, these exploratory studies clearly indicates the potential of ML/DL approaches for reconstruction and PID.

<https://eic.ai/hackathons>

AI4EIC Paper

[Submitted on 17 Jul 2023]

Artificial Intelligence for the Electron Ion Collider (AI4EIC)

C. Allaire, R. Ammendola, E.-C. Aschenauer, M. Balandat, M. Battaglieri, J. Bernauer, M. Bondi, N. Branson, T. Britton, A. Butter, I. Chahrouh, P. Chatagnon, E. Cisbani, E. W. Cline, S. Dash, C. Dean, W. Deconinck, A. Deshpande, M. Diefenthaler, R. Ent, C. Fanelli, M. Finger, M. Finger Jr., E. Fol, S. Furlotov, Y. Gao, J. Giroux, N. C. Gunawardhana Waduge, R. Harish, O. Hassan, P. L. Hegde, R. J. Hernández-Pinto, A. Hiller Blin, T. Horn, J. Huang, D. Jayakodige, B. Joo, M. Junaid, P. Karande, B. Kriesten, R. Kunnawalkam Elayavalli, M. Lin, F. Liu, S. Liuti, G. Matousek, M. McEaney, D. McSpadden, T. Menzo, T. Miceli, V. Mikuni, R. Montgomery, B. Nachman, R. R. Nair, J. Niestroy, S. A. Ochoa Oregon, J. Oleniacz, J. D. Osborn, C. Paudel, C. Pecar, C. Peng, G. N. Perdue, W. Phelps, M. L. Purschke, K. Rajput, Y. Ren, D. F. Renteria-Estrada, D. Richford, B. J. Roy, D. Roy, N. Sato, T. Satogata, G. Sborlini, M. Schram, D. Shih, J. Singh, R. Singh, A. Siodmok, P. Stone, J. Stevens, L. Suarez, K. Suresh, A.-N. Tawfik, F. Torales Acosta, N. Tran, R. Trotta, F. J. Twagirayezu, R. Tyson, S. Volkova, A. Vossen, E. Walter, D. Whiteson, M. Williams, S. Wu, N. Zachariou, P. Zurita

The Electron-Ion Collider (EIC), a state-of-the-art facility for studying the strong force, is expected to begin commissioning its first experiments in 2028. This is an opportune time for artificial intelligence (AI) to be included from the start at this facility and in all phases that lead up to the experiments. The second annual workshop organized by the AI4EIC working group, which recently took place, centered on exploring all current and prospective application areas of AI for the EIC. This workshop is not only beneficial for the EIC, but also provides valuable insights for the newly established ePIC collaboration at EIC. This paper summarizes the different activities and R&D projects covered across the sessions of the workshop and provides an overview of the goals, approaches and strategies regarding AI/ML in the EIC community, as well as cutting-edge techniques currently studied in other experiments.

Artificial Intelligence for the Electron Ion Collider (AI4EIC)

Abstract

The Electron-Ion Collider (EIC), a state-of-the-art facility for studying the strong force, is expected to begin commissioning its first experiments in 2028. This is an opportune time for artificial intelligence (AI) to be included from the start at this facility and in all phases that lead up to the experiments. The second annual workshop organized by the AI4EIC working group, which recently took place, centered on exploring all current and prospective application areas of AI for the EIC. This workshop is not only beneficial for the EIC, but also provides valuable insights for the newly established ePIC collaboration at EIC. This paper summarizes the different activities and R&D projects covered across the sessions of the workshop and provides an overview of the goals, approaches and strategies regarding AI/ML in the EIC community, as well as cutting-edge techniques currently studied in other experiments.

Keywords: Artificial Intelligence, Deep Learning, EIC, ePIC, Machine Learning, QCD, Physics

1 Introduction

In October 2022, the second workshop on Artificial Intelligence for the Electron-Ion-Collider (AI4EIC) has been held at William & Mary. The workshop delved into a range of active and potential application areas of AI/ML¹ for the EIC, and it was also an opportunity to showcase some of the ongoing research activities in these areas for the recently formed ePIC Collaboration.

The event also had a strong outreach and educational component with different tutorials given by experts in AI and ML from national labs, universities, and industry as well as a hackathon satellite event during the last day of the workshop.

In Table 1 at the end of this document, we list many of the methods encountered in this work, with their respective acronyms.

As discussed in the EIC Yellow Report [1] and as further deepened during the AI4EIC workshops, AI/ML will permeate all phases of the EIC schedule (shown in Fig. 2), and will involve accelerator and detector activities.

The second AI4EIC workshop broadened the scope of its predecessor. While the initial workshop was centered on experimental applications for accelerators and detectors, the subsequent meeting pivoted towards the EIC detectors program, emphasizing applications and fostering linkages between theoretical and experimental aspects.

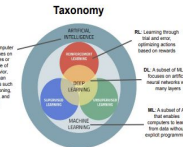


Fig. 1 Taxonomy: A diagrammatic representation of artificial intelligence, machine learning, and deep learning is provided to familiarize readers with the corresponding acronyms utilized in the text.

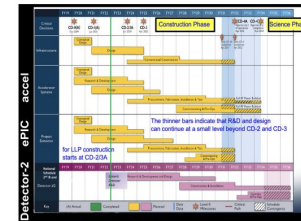


Fig. 2 EIC schedule: the Gantt chart represents different phases (design, construction, science) for accelerator, the ePIC experiment, and a potential detector-2 at EIC. Image taken from [2] and presented in October 2022.

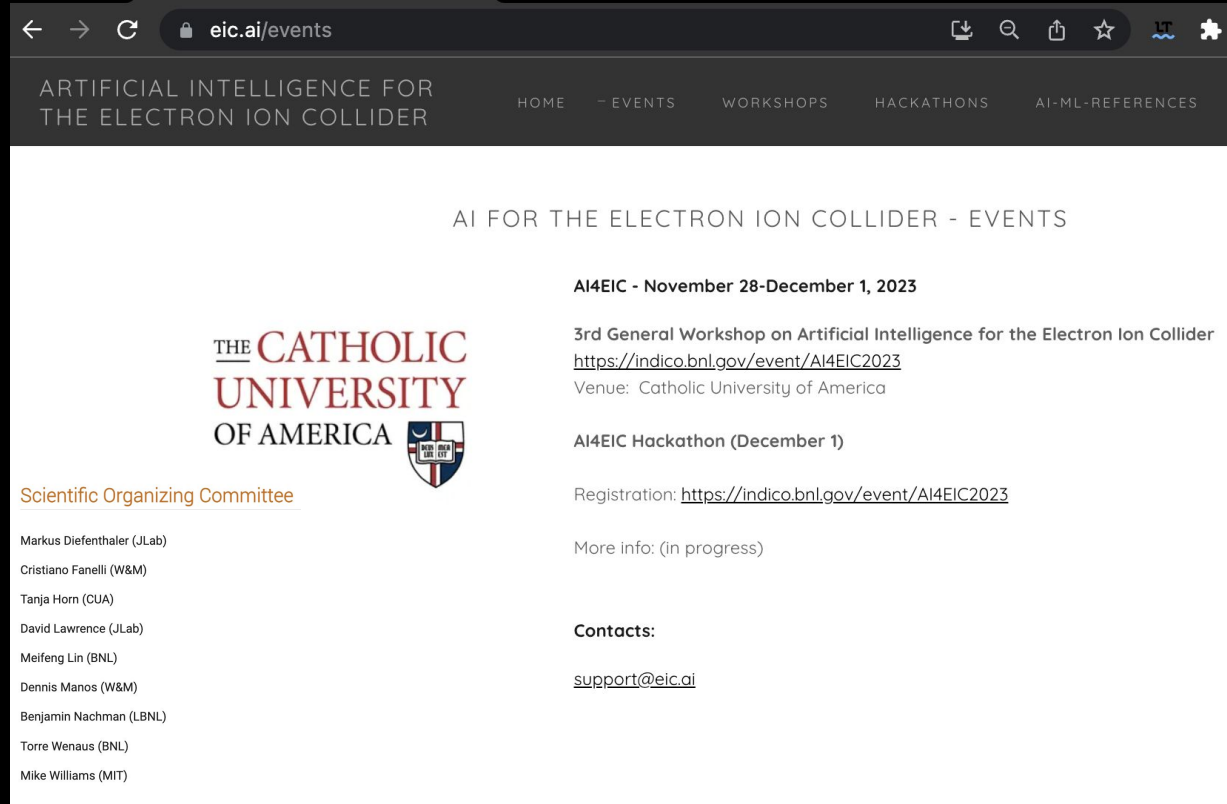
- Design
- Intersection theory/experiment
- Reconstruction and PID
- Infrastructure and Frontiers
- Streaming
- Community efforts:
 - Tutorials
 - Hackathon

<https://arxiv.org/abs/2307.08593>

(July 17 - submitted to Computing and Software for Big Science)

Upcoming Events

- Forthcoming workshop +hackathon at CUA in Washington D.C. November 28 - 30, 2023
- Hackathon (Dec 1, 2023)
- Hybrid format (in-person + virtual)
- Contributions
 - Abstract submission
 - By invitation
 - JINST Proceedings



The screenshot shows a web browser at the URL eic.ai/events. The page title is "ARTIFICIAL INTELLIGENCE FOR THE ELECTRON ION COLLIDER". The navigation menu includes "HOME", "EVENTS", "WORKSHOPS", "HACKATHONS", and "AI-ML-REFERENCES". The main content area is titled "AI FOR THE ELECTRON ION COLLIDER - EVENTS".

AI4EIC - November 28-December 1, 2023

3rd General Workshop on Artificial Intelligence for the Electron Ion Collider
<https://indico.bnl.gov/event/AI4EIC2023>
Venue: Catholic University of America


AI4EIC Hackathon (December 1)

Registration: <https://indico.bnl.gov/event/AI4EIC2023>

More info: (in progress)

Contacts:

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THE CATHOLIC UNIVERSITY OF AMERICA 

Scientific Organizing Committee

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Meifeng Lin (BNL)
Dennis Manos (W&M)
Benjamin Nachman (LBNL)
Torre Wenaus (BNL)
Mike Williams (MIT)

<https://indico.bnl.gov/event/AI4EIC2023>

A Pathway to Collaboration & Funding Opportunities

- During the recent AI4EIC workshop, we explored the concept of a multi-university AI/ML Center for the EIC Science. This platform aims to serve as a collaborative venue, bringing together diverse minds to exchange ideas, knowledge, and resources, while fostering partnerships among various universities.
- Challenges / motivating factors:
 - The current landscape of AI/ML activities tends to be fragmented, leading to unnecessary duplication of similar efforts despite their sparsity.
 - To implement AI/ML applications at scale and in production (particularly for streaming readout), the EIC requires significant collaborative action. Development of novel approaches/solutions may sometimes be necessary.
 - Current funding mechanisms for AI/ML can pose a challenge especially for universities with more limited resources.
 - Multidisciplinary efforts: the aim is to foster synergies among physics, data science, and computer science.
- The timing of AI4EIC is apt, considering the ongoing expansion and focus on data science. A significant educational component is entailed, necessary for nurturing the next generation of scientists active in EIC.

AI4EIC at W&M: Fostering AI/ML Research for the EIC

This is what AI4EIC looks like at the university of William & Mary



- A dedicated physical space
- Strategically positioned near Jefferson Lab
- A dynamic hub for Data Science

space in Applied Science at W&M and plan to migrate in newly built ISC3/4 building in the next years

- University students
- Postdocs
- Visiting Researchers
- Fellows

The center will address the challenges of scattered efforts, amplify collaborative AI/ML initiatives for the EIC, assist in securing funding, and encourage cross-disciplinary collaboration.

Outlook

We will have the third annual workshop and hackathon on Nov 28-Dec 1, 2023 in Washington DC — <https://indico.bnl.gov/event/AI4EIC2023>

People interested in the AI4EIC activities and/or in proposing new ideas can email support@eic.ai

More info on <https://eic.ai>