



<https://eic.ai/>

*C. Fanelli, T. Horn*

**AI4EIC**  
**Collaboration with Data Science Community**

ePIC AI Town Hall Meeting

# 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 and for a range of applications, from optimizing accelerator and detector performance to advancing phenomenological studies and theoretical physics.*

*AI will increasingly be an integral part of the EIC software (ePIC and beyond (Detector-2)) and we will take advantage of intelligent decisions in all aspects of data processing from detector readout and control to analysis.*

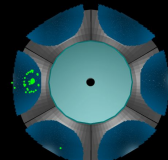
*The AI4EIC initiative originated as a consortium. An AI WG was integrated as a sector of the SWG in the EICUG, at the end of 2021. Within the EICUG, the AI WG serves as an accessible entry point for AI applications, orchestrating workshops, tutorials, hackathons and Kaggle-like challenges.*

*The AI4EIC initiative continues evolving 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.*

<https://eic.ai>

# Activities (in 1-slide)

## Hackathon



**AI4EIC Hackathon**  
 Organized by: Chris Fanelli (William & Mary/Lab), Diana McSpadden (Lab/Data Science), Kishan Rajput (Lab/Data Science)  
 Advisory and problem definition: Evaristo Cibani (INFN), Wouter Deconinck (U. Marche)  
 Computing resources: Eric Wather (William & Mary IT)  
 Data generation, Documentation, Validation: James Gross (U. Regina), Karthik Suresh (U. Regina)  
 Technical Assistance: Eric Wather (William & Mary IT), James Gross (U. Regina), Karthik Suresh (U. Regina)



**Hackathon Leaderboard**

RANK	TEAM	SCORE	QUESTIONS ATTEMPTED
1	Jets	295/302	Q1 Q3 Q4
2	JET	284/288	Q1 Q3 Q4
3	ab and EC	262/313	Q1 Q3 Q4

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

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

$\pi$ , K datasets

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

Problem 1

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

Problem 2,3\*

\*Problem 3: addition of noisy hits

Solutions:

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

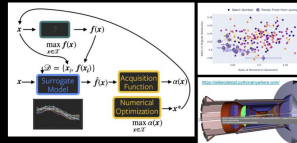
The best solutions were all Machine Learning/Deep Learning-based, they were quite original, and they outperformed solutions based on classical approaches followed by some teams. While this is only a first step towards deeply learning the identification of particles reconstructed with the dual-RICH, these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

## AI4EIC Tutorials

Provided by experts from industry and national labs and research centers



M. Balandat, Meia AI



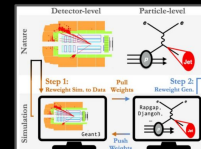
Multi-objective Optimization



F. Torales Acosta (LBNL)



V. Mikuni (NERSC)



OmniFold Unfolding



K. Rajput JLab/DS

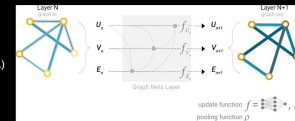
flow



MLflow — ML lifecycle



Y. (Ray) Ren (BNL)



Graph Neural Network

<https://eic.ai/hackathons>

<https://eic.ai/community>



- 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)



(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. Chahrouf, 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. Furletov, Y. Gao, J. Giroux, N. C. Gurawardhana Waduge, R. Harish, O. Hassas, P. L. Hegde, R. J. Hernandez-Renta, A. Hiller Blin, T. Horn, J. Huang, D. Jayakodige, B. Joo, M. Junaid, P. Karande, B. Kriesten, R. Kunnawallam Elayavalli, M. Lin, F. Liu, S. Liuti, G. Matousek, M. McEneaney, D. McSpadden, T. Menzo, T. Miceli, V. Mikuni, R. Montgomery, B. Nachman, R. Nair, J. Nestroy, S. A. Ochoa Oregon, J. Oleniacz, J. D. Osborn, C. Paudel, C. Pecar, C. Peng, C. Peng, G. N. Perdue, W. Phelps, M. L. Purschke, K. Rajput, Y. Ren, D. F. Renteria-Estrada, D. Richford, S. J. Roy, D. Roy, N. Sato, T. Satogata, G. Sborini, 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. Twagiriayezu, R. Tyson, S. Volkov, 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 EIC 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 EIC 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, EIC, 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 cutting-edge and potential application areas of AI/ML for the EIC, and it was also an opportunity to discuss some of the ongoing research activities in those areas for the recently formed EIC 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 workshop event during the last day of the workshop.

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

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. 1), 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 reconstruction and detection, the subsequent meeting pivoted towards the EIC detection programs, emphasizing applications and fostering linkages between theoretical and experimental aspects.



Fig. 1: Timeline of a representative approximation of artificial intelligence, machine learning, and deep learning a needed to facilitate interactions with the computing resources utilized in the text.



Fig. 2: EIC schedule: the EIC schedule represents the phase (Design, construction, start-up, acceleration, the EIC operation, and a potential detector at EIC. Image taken from [2] and presented in October 2022.

<https://eic.ai/workshops>

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

(submitted to Computing and Software for Big Science)

# AI4EIC for ePIC

- AI4EIC will serve as a specialized conduit for amplifying the involvement of data scientists, computer scientists and physicists, facilitating the integration of interdisciplinary teams with expertise in AI/ML into the EIC's science.
- In synergy with ePIC, AI4EIC will contribute developing robust algorithms and computational solutions that address mutual research challenges. These solutions will be rigorously tested and subsequently deployed at scale into the EIC's production environment.
- AI4EIC embraces a substantial educational and outreach agenda. Collaborating synergistically with ePIC, AI4EIC will contribute additional workforce dedicated to crafting comprehensive documentation for AI/ML techniques pertinent to ePIC's research applications. AI4EIC will play an instrumental role in curating educational content, including tutorials and specialized training programs, to facilitate capacity building and knowledge transfer within the broader EIC community.

# Creation of an AI4EIC Network



- A multi-university AI/ML Network for the EIC Science. This platform has been created based on the inputs of the community in the last AI4EIC workshop: the network will serve as a collaborative venue, bringing together diverse minds to exchange ideas, knowledge, and resources, while fostering partnerships among various universities.
- Challenges / motivating factors (from last workshop):
  - *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 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.

- *Educational/Outreach*
- *Increase AI/ML literacy in EIC*
- *Funding Opportunities*

# AI4EIC Network: fostering AI/ML for EIC

The AI4EIC Network will address the challenges of scattered efforts, amplify collaborative AI/ML initiatives for the EIC, assist in securing funding, and encourage cross-disciplinary collaboration.

The AI4EIC events, which include both research-related activities and education/outreach initiatives, (e.g., workshops, schools, hackathons, and data challenges, etc), will rotate among participating universities to foster community building and create diverse opportunities.

The AI4EIC Network will be headquartered at W&M, serving as a central hub for administrative matters, and a base for students and visiting researchers



- A dedicated space for students and postdocs, visiting researchers, fellows
- Strategically positioned near Jefferson Lab
- Area becoming a dynamic hub for Data Science

Currently situated in the Applied Science building, with provisions in place for expansion to the under-construction ISC4 building in the coming years to accommodate future growth.

# How to connect/join?

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 network activities and/or in proposing new ideas can email [support@aic.ai](mailto:support@aic.ai) — to join mailing list, specify in the subject line of your email (subject: [subscribe your Full Name](#))

More info can be found on <https://aic.ai> (being updated)