AI4EIC Activities

https://ai4eic.org/

Cristiano Fanelli, Tanja Horn

Summer 2026 Joint EICUG/ePIC Collaboration Meeting

NP community recognized AI as a Grand Challenge

❖ Harness the physics program of the Electron Ion Collider (EIC)

➢ AI/ML will help guarantee maximum science output from the EIC

Next generation QCD experiments like EIC can integrate AI from the start

❖ Realize the science potential of FRIB

➢ A variety of AI/ML tools will be developed to address specific needs including beam generation, event characterization, detector response, experiment optimization, and data analysis

❖ Event Reconstruction in Nuclear Physics

➢ AI techniques for reconstruction of tracks in time projection chambers at FRIB, and for heavy ion collisions

❖ Improve Tracking Algorithms

➢ AI/ML to significantly improve tracking at all NP accelerator facilities

❖ Particle Identification

➢ AI/ML to complement existing Monte Carlo methods for PID

➢ Gamma-Ray Energy Tracking Array (GRETA): AI/ML to reconstruct the pat of multiple gamma rays from measured interaction positions and deposited energies

Community activities / perspectives related to EIC

- ☐ 2020 ASCAC Subcommittee on AI for Science
- ☐ EIC Yellow Report (Nucl. Phys. A **1026** (2022) 12247)
- ☐ 2023 NSAC Long-Range Plan
- ☐ AI4EIC (C. Allaire, C. Fanelli, ..., T. Horn, et al., Comp. & Softw. For Big Science **8** (2024) 1, 5)

*From Town Hall Meetings 2019/2020

From Community Vision to National Priority

U.S. DEPARTMENT of ENERGY

Home

The Genesis Mission

A national initiative to build the world's most powerful scientific platform.

The Genesis Mission unites DOE National Labs, industry, academia, and more to harness AI for breakthroughs in energy dominance, discovery science, and national security.

U.S. DEPARTMENT of ENERGY | Office of Science

Advanced Scientific Computing Research (ASCR)

THE AMERICAN SCIENCE CLOUD (AmSC)

DOE National Laboratory Program Announcement Number:
LAB 25-3555

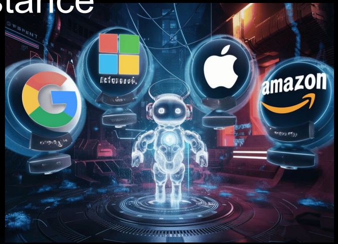
Announcement Type: Initial

AmSC: "Cornerstone of the Genesis Mission's Platform infrastructure, hosting and distributing AI models and scientific data to the broader research community."
https://www.energy.gov/articles/energy-department-advances-investments-ai-science

The question is no longer whether AI will transform nuclear physics, but how the community can best harness it.

AI/ML is Ubiquitous

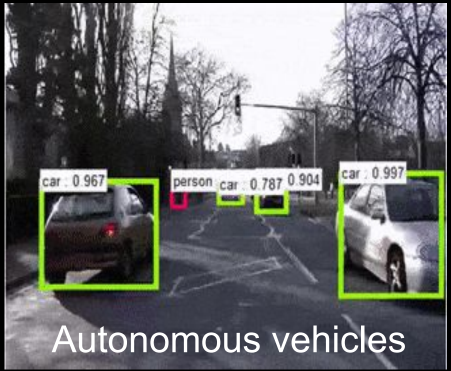
Assistance



AI-Powered POS

Entertainment

Health



Autonomous vehicles

Home automation

Security

Generative AI

Gen AI is revolutionizing how we work, communicate, and innovate across nearly every field. Can create new content—text, images, code, or even data

The AI4EIC WG

- AI/ML is becoming ubiquitous also in NP. AI is playing a key role in empowering data processing, analysis and enabling autonomous experimentation and control.

Artificial Intelligence

https://www.eicug.org/content/wg.html

The mission of the Artificial Intelligence (AI) Working Group is to develop and maintain connections to the data science community, and engaging with the rapidly evolving AI/ML (Machine Learning) toolset that may impact the realization of the EIC science mission. The AI will organize events to educate and assist the EIC community in utilizing AI/ML techniques in the area of detector design and controls, simulations, data readout and analysis, and theory and phenomenology. The AI will also serve as an entry point to AI applications.

- The entry point, ai4eic.org, is structured in such a way to track all AI4EIC events (workshops, hackathons, tutorials, meetings). Projects and AI/ML software repositories are included in a resource-hub webpage. The website contains also a living review of AI-related papers for the EIC science and also features spotlights on impactful works.

- AI is a rapidly evolving field. AI4EIC acts as both a catalyst and an incubator for ideas, demonstrating how cutting-edge AI techniques can be applied to advance EIC science. E.g.,
  - How can generative AI contribute to the EIC science?
  - How can foundation models enable scalable AI solutions across EIC science workflows?
  - etc

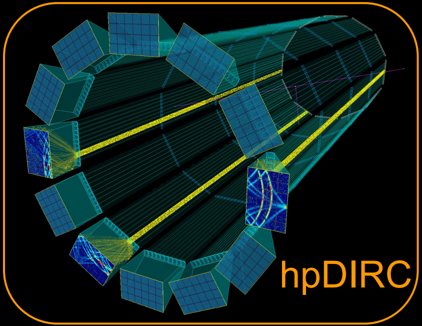
Generative AI for EIC: Cherenkov

Ongoing collaboration with the ePIC DIRC WG

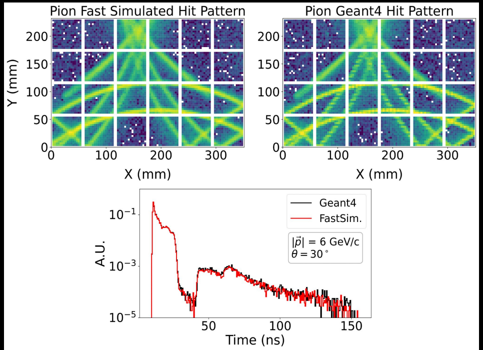
1. High-Fidelity Fast Simulation:

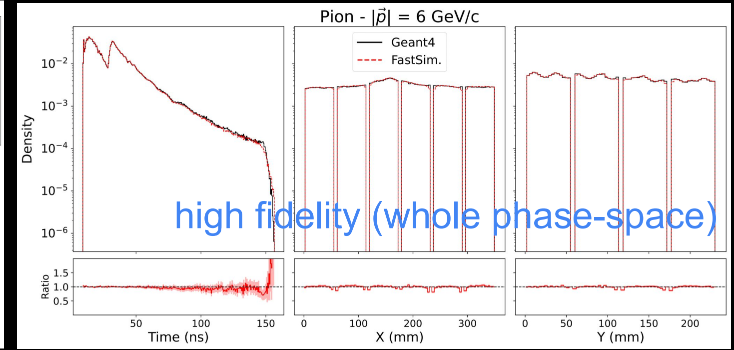
Developed generative models capable of producing photon hit distributions with fidelity comparable to Geant4, but at a fraction of the computational cost—critical given the expense of tracking optical photons through complex geometries.

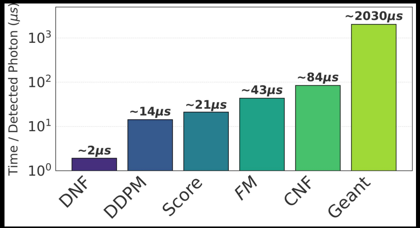
J. Giroux, M. Martinez, CF "Generative Models for Fast Simulation of Cherenkov Detectors at the Electron-Ion Collider." arXiv:2504.19042 (2025). — submitted Machine Learning: Science and Technology [link]



Flow-based







2. Enhanced Particle Identification:

Achieved competitive PID performance across the full detector phase space, with significantly reduced computational time—O(10us/track)—compared to traditional methods

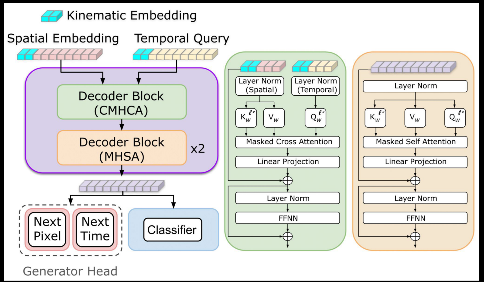
CF, J. Giroux, and J. Stevens. "Deep (er) reconstruction of imaging Cherenkov detectors with swin transformers and normalizing flow models." Machine Learning: Science and Technology 6.1 (2025): 015028. [link]

3. Towards Foundation Models for Cherenkov Detectors:

Transformer-based

Unified model architecture capable of performing reconstruction, fast simulation and noise filtering, enabling simultaneous achievement of (1) and (2) within a single framework.

J. Giroux, CF, "Towards Foundation Models for Experimental Readout Systems Combining Discrete and Continuous Data." 2026 Mach. Learn.: Sci. Technol. 7 015031. [link]



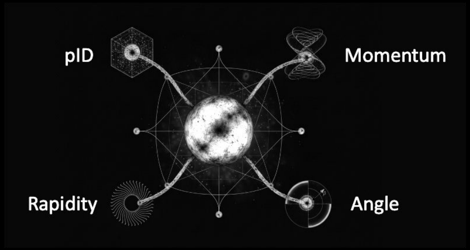
data as sequences of tokens

https://github.com/orgs/ai4eic/repositories

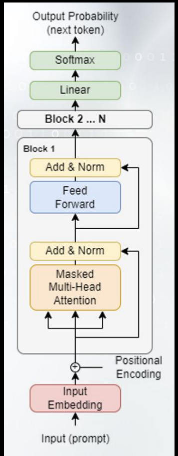
From Event Generation to Foundation Models

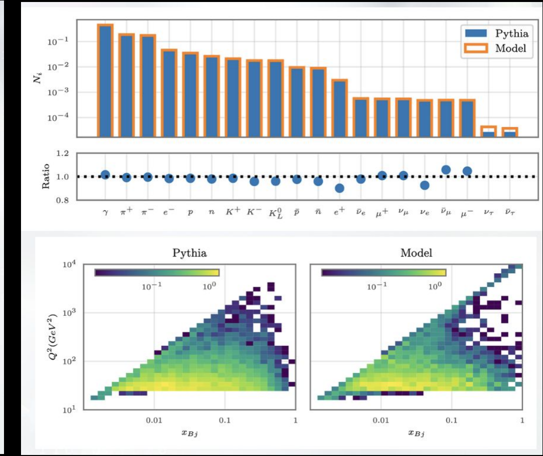
S. Goldenberg, Electron-Proton Scattering Event Generation using Structured Tokenization

- Utilize tokenized data for sequence prediction using transformer architecture for generative results



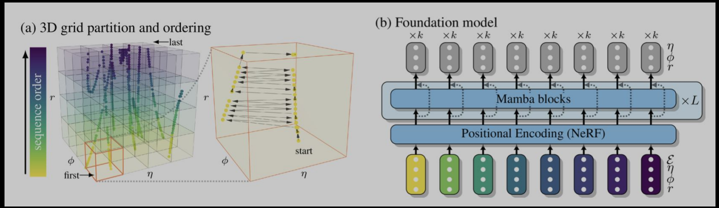
$$(\mathtt{e\_start}, \mathtt{p\_start}, \mathrm{pID}_i, p_{t_i}, \eta_i, \phi_i, \mathtt{p\_start}, \cdots, \phi_n, \mathtt{e\_end})$$

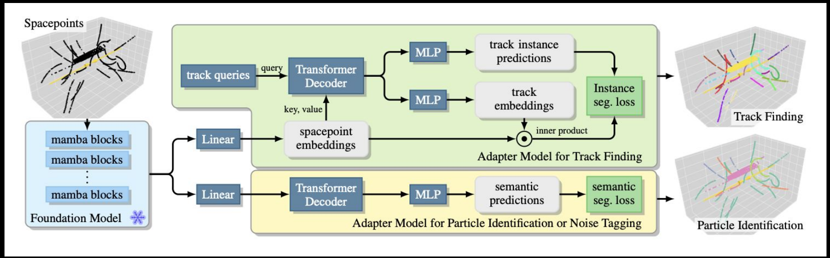


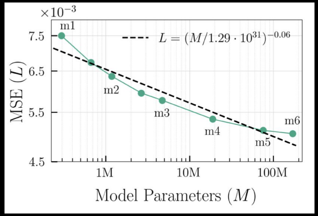


S. Li, FM4NPP: A Scaling Foundation Model for Nuclear and Particle Physics

- Use TPC data from sPHENIX (*each detector spacepoint treated as an input "token")
- Mamba backbone: learns global event representations from ordered detector points with linear sequence scaling





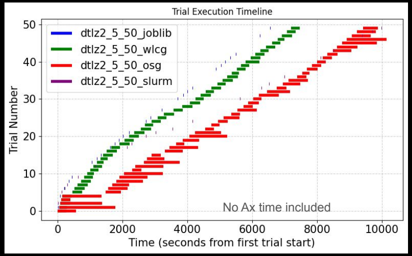


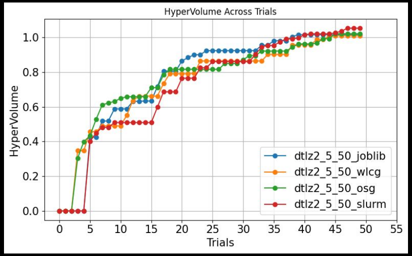
- Reusable FM: lightweight task-specific adapters enable track finding, particle identification, and noise tagging.
- Scaling to bigger models

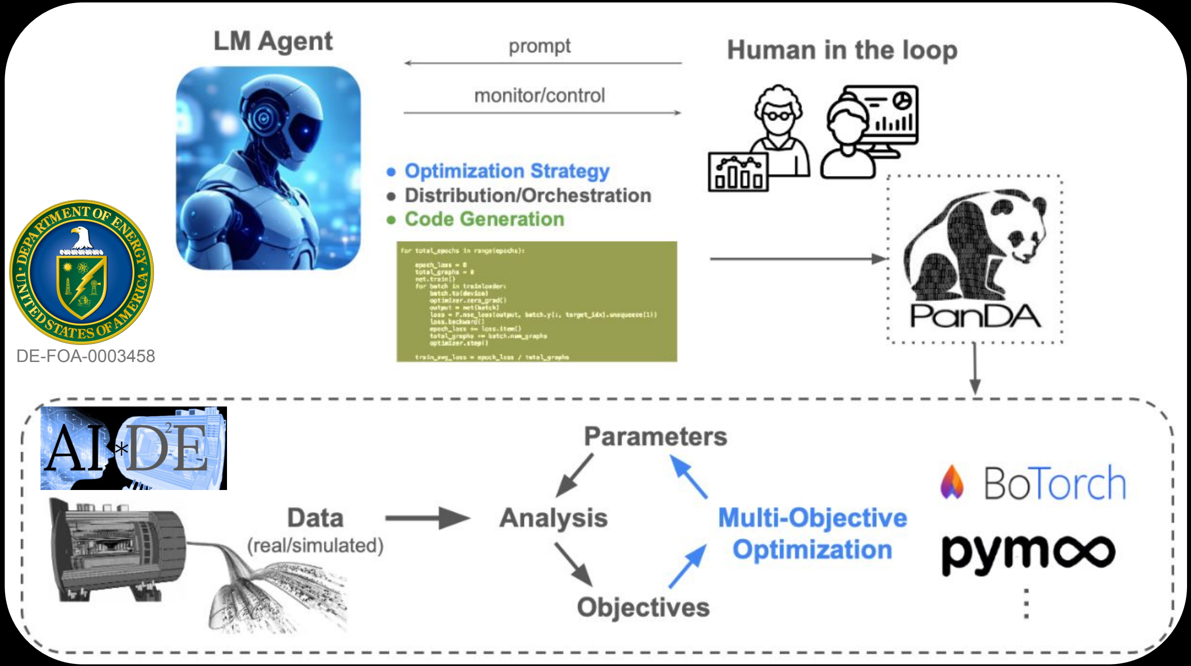
https://arxiv.org/abs/2508.14087

LLM-enhanced Design & Optimization of Experiments

- Augment AID2E's PanDA-orchestrated MOO workflows with LLM agents for workflow assistance, run monitoring, and human-in-the-loop control.
- AID2E supports Joblib, Slurm, PanDA (OSG and WLC) — plots showing studies with DTLZ benchmark







LM automates the workflow: optimization pipelines, tasks distribution, code generation

Human-in-the-loop control: experts monitor, validate, and guide the process

Multi-objective optimization: with tools such as BoTorch and pymoo

Distributed workflow management: enabled through PanDA

W. Guan, Scalable AI-assisted Workflow Management for EIC Detector Design Across Distributed Heterogeneous Resources with PanDA-iDDS

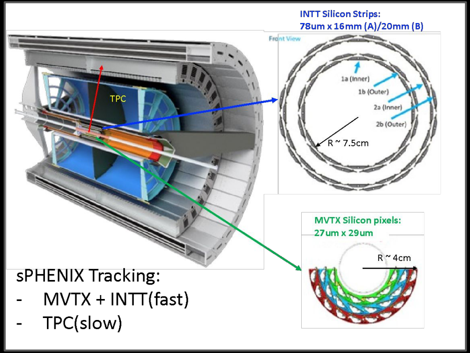
P. Nilsson, MCP Agents in PanDA

AI applications for real time event processing

M. Liu, Intelligent Experiments through real time AI

ML on FPGA

- Fast Data Processing and Autonomous Detector Control for sPHENIX and Future EIC Detectors



Identify D/B hadrons with real-time ML

- Topology of D/B decays
- Monitor collision vertex
- Feedback for improvement

The challenges:

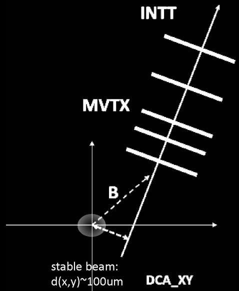
Very high p+p collision rate: ~3MHz

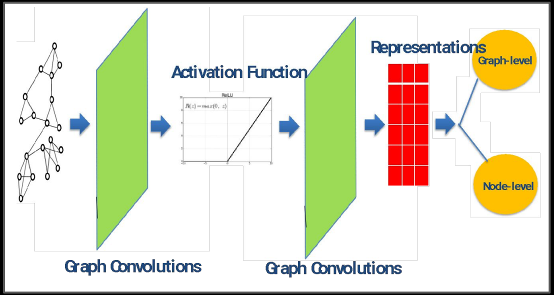
Low rate of rare signals: ~150Hz (beauty for eg)

Limited DAQ trigger bandwidth: ~15 kHz

(or 0.5% of p+p collisions)

No effective conventional triggers available





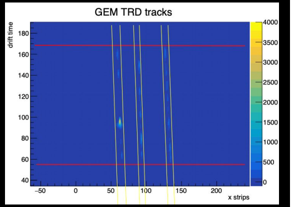
J. Kvapil et al, JINST 19.02 (2024): C02066.

- Machine learning on FPGA for event selection at JLab

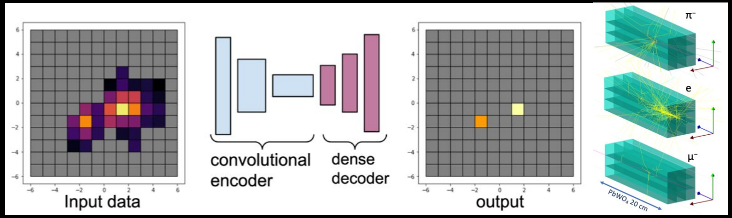
AI algorithms on FPGA:

- GNN for pattern recognition
- DNN/LSTM track fitting
- DNN for PID
- VAE for calorimetry

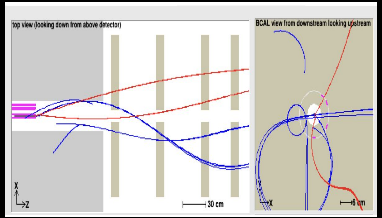
F. Barbosa et al, IEEE Trans. Nucl. Sci. 70 (2023) 6, 960-965
S. Furletov, JINST 17 (2022) 06, C06009 (AI4EIC proceeding)



GEM TRD



Calo reconstruction



Tracking in GlueX

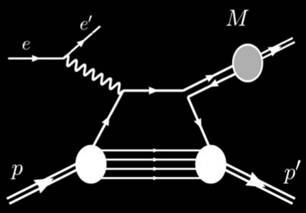
D. Furletov, ML on FPGA for PID and Tracking

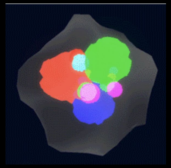
See other contributions at the 'ePIC and beyond' and 'ML in production' sessions of AI4EIC-2025 http://indico.bnl.gov/e/AI4EIC2025

Advancing EIC Theory and Phenomenology with AI

Z. Panjsheeri, NNGPD: Neural Network Generalized Parton Distribution

AI/ML tools (Deep Learning + Symbolic Regression) for “seeing” inside the nucleon





GPD Feynman diagram at tree level

Selection criteria	Predictions over full phase space	Symbolic Forms	Fitness metrics WMSE MSE	Complexity
H^1_{BF}		$\frac{3.3(1-0.8\,x^2)^{5.2}}{x+\ 2\,\boldsymbol{t}+(1.52\,\boldsymbol{t}^{\boldsymbol{t}})^{\boldsymbol{t}}}$	3.3×10^{-3} 2.1×10^{-6}	21
H^2_{BF}		$\frac{(0.034\,x^{-4.52})^{x}}{1.89\boldsymbol{t}+0.9451x+0.94\{[(0.86(\boldsymbol{t}+1)-x)^{\boldsymbol{t}}]^{\boldsymbol{t}}\}^{\boldsymbol{t}}}-0.031$	2.5×10^{-3} 2.3×10^{-6}	31
H^3_{BF}		$\frac{1.02\{0.0047[[x+(\boldsymbol{t}-0.82)(\boldsymbol{t}-0.29)]^{\boldsymbol{t}}]^{x}\}^{x}-0.018}{1.77^{\boldsymbol{t}}-0.64}$	1.9×10^{-3} 2.1×10^{-6}	29
H^1_{FF}		$1.55\left(-0.483+\frac{1}{(0.42+\boldsymbol{t})^{0.75}}\right)\left(\frac{-0.0019+0.0043^{x}}{x}\right)^{x}$	6.6×10^{-2} 4.4×10^{-5}	23
H^2_{FF}		$\frac{-0.01+1.45(323^{x}x^{x})^{-x}}{0.56+\boldsymbol{t}^{1.14}}$	4.3×10^{-2} 5.5×10^{-5}	19
H^3_{FF}		$\frac{1.19\{-0.048+2.34[(0.063^{x})^{x}]^{1.85}\}}{(0.913+\boldsymbol{t}^{\boldsymbol{t}})^{\boldsymbol{t}}+\boldsymbol{t}}$	7.1×10^{-3} 2.0×10^{-5}	29
H_{Regge}		$2.74\ e^{[-\boldsymbol{t}-0.67\ \ln^2(1-x)]}x^{0.087}(1-x)^{1.57}$	1.5×10^{-2} 1.9×10^{-4}	26

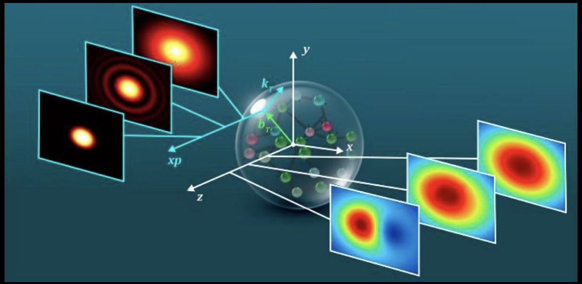
TABLE I: SR functional forms for all three models: Best-Fit (BF), Forced-Factorized Fit (FF), and Semi-Reggeized (Regge). For BF and FF, the functional forms corresponding to the three different clusters determined in this analysis are displayed and numbered, with $K = 1, 3$. The fitness metric and complexity values associated with each determination are discussed in the text. The boldface $\boldsymbol{t} = -t/\Lambda^2$, with $\Lambda^2 = 1$ GeV^2, is used to ensure that all numerical coefficients in the symbolic expressions are dimensionless.

EXCLAIM project —
EXCLusives ($ep\to e'p'\gamma(M)$) with AI and ML
https://arxiv.org/pdf/2408.00163
https://arxiv.org/pdf/2504.13289

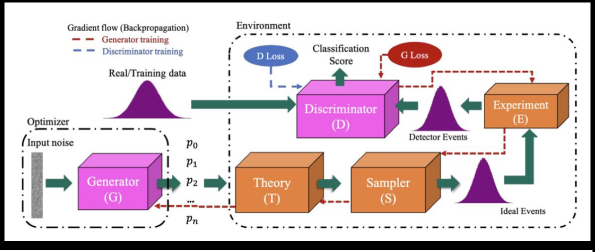
“Why jump to AI/ML? To get a proper resolution of the x dependence, a large number of moments is required. But the SOTA lattice calculations only go up to ~ 5 or 6 moments!”

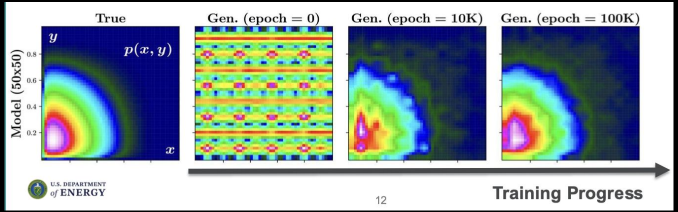
D. Lersch, SAGIPS: A Scalable Framework for SCIDAC QuantOm

Extract Quantum Correlation Functions (QCFs) from DIS experiments.
3D imaging of nuclei



GAN workflow — All components need to be differentiable





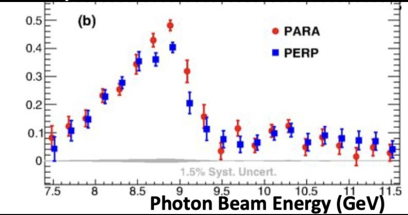
See also I. Fernando and D. Keller, DNN for extracting the 3D Structure of Nucleon at EIC

AI for Experimental Control & Monitoring

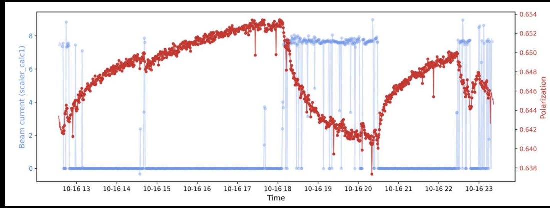
P. Moran, Optimal Control of Polarized Sources and Targets

- Polarized Photon Beam
- Polarized Cryogenic Target - Dynamic Nuclear Polarization

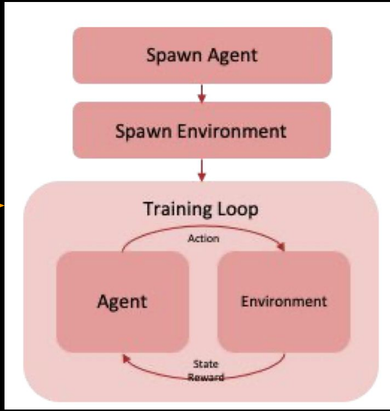
GlueX beam polarization changes as the e-beam conditions, diamond-radiator alignment, and coherent-bremsstrahlung spectrum drift or are deliberately re-tuned over time.



Target polarization increases when beam is off because target cools down, and degrades when beam is on due to beam heating and increased concentration of free radicals (e-, atomic H) in the sample

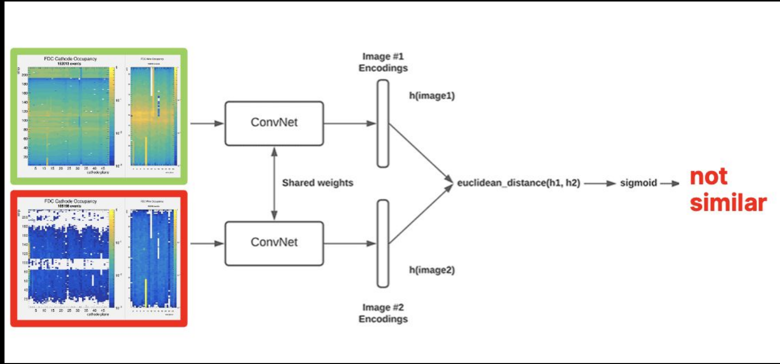


RL solutions to maintain high and stable polarization

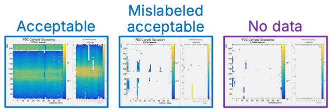


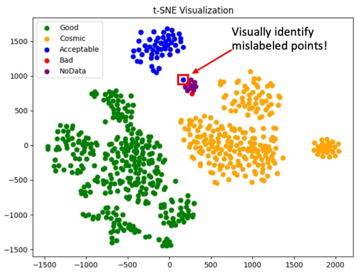
T. Britton, AI-Enabled Data Quality Monitoring with Hydra

- Hydra is a scalable framework for training and managing AI models for data quality monitoring and visualization
- Supports Classification and Siamese models



Clustering on the embeddings from the siamese model can be used to identify mislabeled images that are used in training





AI/ML for Accelerators

A strong and growing focus within AI4EIC

https://indico.bnl.gov/event/28082/timetable/#20251027.detailed

10:00	**Explainable and Differential Reinforcement Learning for Multi Objective Optimization in Particle Accelerators**	*Kishansingh Rajput*	
	Differentiable beam dynamics codes, their use in AI-ML for accelerators and potential applications to the EIC	*Chenran Xu*	
	Symplectic machine learning model for fast simulation of space-charge effects	*Jinyu Wan*	10:50 - 11:15
11:00	**Coffee Break**		11:15 - 11:30
	Use of AI/ML for higher brightness and higher polarization of hadron beams	*Eiad Hamwi*	11:30 - 11:55
12:00	**Framework for the Development of Virtual Accelerator Models for Machine Learning Applications**	*Adwaith Ravichandran*	
	Machine-Learning–Accelerated Bayesian Uncertainty Quantification for Digital Twin Modeling and Control of the AGS B	*Christopher Kelly*	
	Machine Learning Approaches to Improved Ion Profile Monitor Measurements	*Christopher Hall*	12:35 - 12:55
13:00	**Use of Generative AI and LLMs for Accelerator Design**	*Onur Gilanliogullari*	12:55 - 13:15

Key themes

- Differentiable accelerator modeling
- Fast surrogate simulations, digital twins, UQ
- RL for optimization and control
- Beam diagnostics, brightness, and polarization
- Generative AI for accelerator design

Building on this momentum, AI4EIC established a dedicated sub-working group on AI/ML for accelerators. I will expand on this in the next slides.

DOE Recognition of AI4EIC

- The AI Working Group within the EICUG has gained notable recognition in recent DOE Funding Opportunity Announcements, underscoring the growing impact of our efforts on supporting the future of EIC science with AI/ML
- Highlighted in two consecutive FOAs DE-FOA-0002875 (2023) and DE-FOA-0003845 (2025) both reference the AI4EIC workshops, emphasizing our role in addressing how AI/ML might contribute to advance the research, design, and operation of the future EIC.
- Recognition reflects the DOE's alignment with EICUG's vision to integrate AI/ML with experimental data analysis and high-performance computing in nuclear physics.

DE-FOA-0002875 (deadline: Jan 11, 2023; award ceiling $2M/year)
Artificial Intelligence and Machine Learning For Autonomous Optimization and Control of Accelerators and Detectors

NP held a one-day roundtable on "Machine Learning and Artificial Intelligence for NP Accelerator Facilities" on January 30, 2020, with focus on discussing opportunities in AI/ML for improving efficiencies of accelerator operations of NP facilities. Additional information on the workshop and copies of presentations can be found at: https://science.osti.gov/np/Research/ai. An NP community workshop at TJNAF in March of 2020 considered priority research opportunities in AI/ML. Also, an NP community computational science workshop in September 2022 was held to identify future directions in computational nuclear physics by a combination of high-performance computing combined with AI/ML and experimental data. And in October of 2022, an AI for EIC workshop was held to address how AI might contribute to advance research, design and operation of the future EIC. More information on these workshops and meetings can be found in the Reference section below.

DE-FOA-0003845 (deadline: Jan 14, 2025; lab award ceiling $3.5M/year)
Artificial Intelligence and Machine Learning Applied to Nuclear Science and Technology

2022 identified future directions in computational nuclear physics by a combination of high-performance computing combined with AI/ML and experimental data. And in October 2022 and October 2023, AI for EIC workshops were held to address how AI might contribute to advance research, design and operation of the future EIC. More information on these workshops and meetings can be found in the Reference section below.

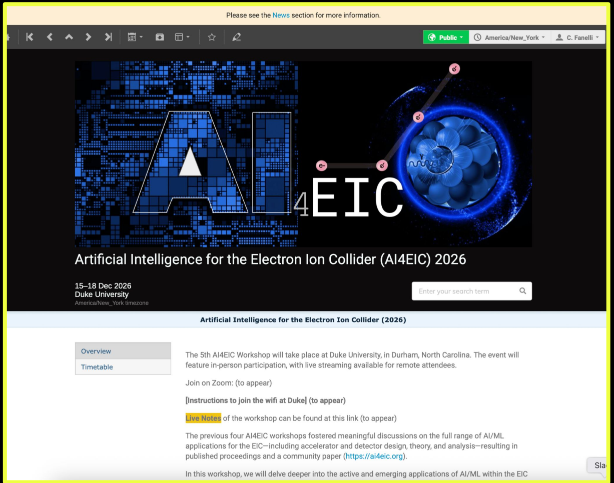
These mentions affirm our trajectory and provide momentum for continued cross-disciplinary collaboration and future funding opportunities.

AI4EIC Workshops

https://ai4eic.org/workshops

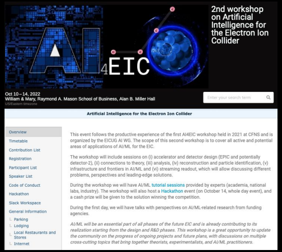
Duke (Dec 15-18, 2026)

http://indico.bnl.gov/e/AI4EIC2026

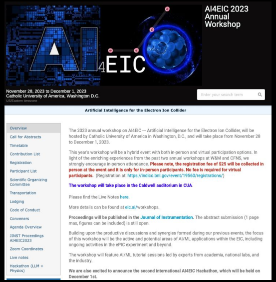


- 6 workshops organized or co-organized by the AI4EIC WG. In 2025 we contributed to organize the 4th AI4EIC workshop at MIT supported by the Institute for Artificial Intelligence and Fundamental Interactions (IAIFI).

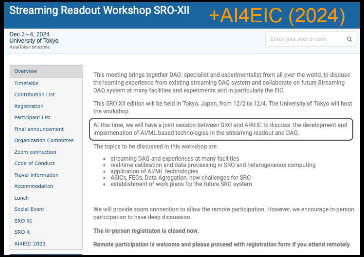
CFNS (2021)



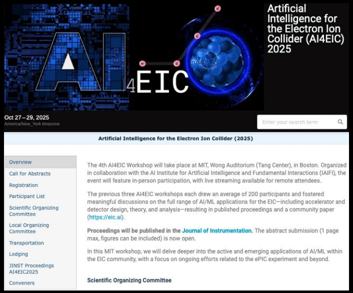
W&M (2022)



CUA (2023)



Joint SRO+AI4EIC, Tokyo (2024)



MIT (2025)

~50 speakers

Past Editions

average ~200 participants

2026 AI4EIC Workshop @Duke

AI4EIC

Duke UNIVERSITY

EIC User Group

Scientific Organizing Committee

Abhay Deshpande, Stony Brook, BNL

Anselm Vossen, Duke

Ben Nachman, Stanford

Cris Fanelli, W&M

Daniel Lersch, JLab

David Lawrence, JLab

Laura Biven, JLab

Lin Meifeng, BNL

Marco Battaglieri, INFN

Mike Williams, MIT

Tanja Horn, CUA

Torre Wenaus, BNL

December 15-18, 2026

- 2 sessions per day - AI4EIC 2026 will feature invited talks and selected abstract contributions.
- Abstract submission (1 page max, figures can be included) is now open.
- Workfest/Tutorials: organized by the AI4EIC working group.

Sessions (Past Editions)

AI/ML for Accelerators

AI/ML for Calibration, Monitoring, and Experimental Control with Data Streams

AI/ML for ePIC and Beyond

AI/ML for Data Analysis and Theory

Trends in Data Science

AI/ML in Production and Distributed ML

indico.bnl.gov/event/AI4EIC2026

AI4EIC Publications

2022*

Using machine learning for particle identification in ALICE
Łukasz Kamil Graczykowski *et al* 2022 *JINST* **17** C07016
Open abstract | View article | PDF

Artificial Intelligence for imaging Cherenkov detectors at the EIC
C. Fanelli and A. Mahmood 2022 *JINST* **17** C07011
Open abstract | View article | PDF

High performance FPGA embedded system for machine learning based tracking
T. Xuan *et al* 2022 *JINST* **17** C07003
Open abstract | View article | PDF

Machine learning on FPGA for event selection
S. Furletov *et al* 2022 *JINST* **17** C06009
Open abstract | View article | PDF

Design of detectors at the electron ion collider with artificial intelligence
C. Fanelli 2022 *JINST* **17** C04038
Open abstract | View article | PDF

AI for Experimental Controls at Jefferson Lab
T. Jeske *et al* 2022 *JINST* **17** C03043
Open abstract | View article | PDF

Frontiers in computing for artificial intelligence
T.S. Humble *et al* 2022 *JINST* **17** C03037
Open abstract | View article | PDF

Machine learning for track reconstruction at the LHC
L.-G. Gagnon 2022 *JINST* **17** C02026
Open abstract | View article | PDF

Accelerator and detector control for the EIC with machine learning
T. Britton and B. Nachman 2022 *JINST* **17** C02022
Open abstract | View article | PDF

EIC detector overview
D.W. Higinbotham 2022 *JINST* **17** C02018
Open abstract | View article | PDF

2024*

R. Kelleher, A. Vossen
Normalizing flows for domain adaptation when identifying Λ hyperon events (AI4EIC proceeding, *JINST* **19** C06020)

G. Matousek, A. Vossen
Photon classification with Gradient Boosted Trees at CLAS12 (AI4EIC proceeding, JINST 19 C06006)

S. Gardner, R. Tyson, D. Glazier and K. Livingston
Object condensation for track building in a backward electron tagger at the EIC (AI4EIC proceeding, *JINST* **19** C05052)

G. Gavalian on behalf of the CLAS12 Collaboration
Real-time charged track reconstruction for CLAS12 (AI4EIC proceeding, *JINST* **19** C05050)

J. Craft et al
Performance optimization for a scintillating glass electromagnetic calorimeter at the EIC (AI4EIC proceeding, *JINST* **19** C05049)

K. Suresh et al
Towards a RAG-based Summarization Agent for the Electron-Ion Collider (AI4EIC proceeding, *JINST* **19** C07006)

C. Fanelli et al
Physics Event Classification Using Large Language Models (AI4EIC proceeding, *JINST* **19** C07011)

M. Diefenthaler et al
AI-Assisted Detector Design for the EIC (AID(2)E) (AI4EIC proceeding, *JINST* **19** C07001, 2024)

T. Jeske et al.
Hydra: Computer Vision for Data Quality Monitoring (AI4EIC proceeding, *JINST* **19** C12005, 2024)

D. Lawrence et al.
ML-based Calibration and Control of the GlueX Central Drift Chamber (AI4EIC proceeding, *JINST* **19** C11012, 2024)

M. Karwowska et al.
Particle identification with machine learning from incomplete data in the ALICE experiment (AI4EIC proceeding, *JINST* **19** C07013, 2024)

2024

Home > Computing and Software for Big Science > Article

Artificial Intelligence for the Electron Ion Collider (AI4EIC)

Review | Open access | Published: 15 February 2024

Volume 8, article number 5, (2024) Cite this article

Download PDF | You have full access to this open access article

C. Allaire, R. Ammendola, E.-C. Aschenauer, M. Balandat, M. Battaglieri, J. Bernauer, M. Bondì, N. Branson, T. Britton, A. Butter, I. Chahrour, 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, ... P. Zurita Show authors

28 citations (INSPIRE-HEP)

*(not full list; 20+)

https://ai4eic.org/living-review

AI4EIC-2025 Proceedings (JINST)

(Ready for publication)

R. Kelleher et al, ML for the hKLM at the 2nd Detector

Z. Xia et al, ScatterPrism: convergence for generative simulation and inverse problems in particle and nuclear physics

P. Nilsson, MCP Agents in PanDA

L. Nguyen et al, "A Unified Vision of AI/ML at the Electron-Ion Collider: Infrastructure and Capabilities"

T. Gosh et al., Retrieval-Augmented Question Answering over Scientific Literature for the Electron-Ion Collider

D. Samuel et al., LLMs in particle physics analysis: Results from a toy model

Z. Panjsheeri et al., "Neural Network Generalized Parton Distributions (NNGPD)"

S. Pandey et al., “Markov chain Monte Carlo (MCMC) based Likelihood Extraction of Chiral-Odd Compton Form Factors from Deeply Virtual Exclusive Experiments.”

W. Guan et al. (AID2E Collaboration) “Scalable AI-assisted Workflow Management for EIC Detector Design Across Distributed Heterogeneous Resources with PanDA-iDDS”

C. Rossi et al., “Multi-FPGA distributed MLP NN model for data reduction in ePIC dRICH readout system”

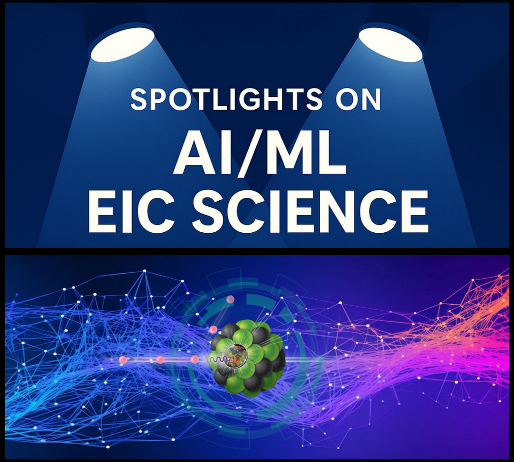
Journal of Instrumentation
an IOP and SISSA journal

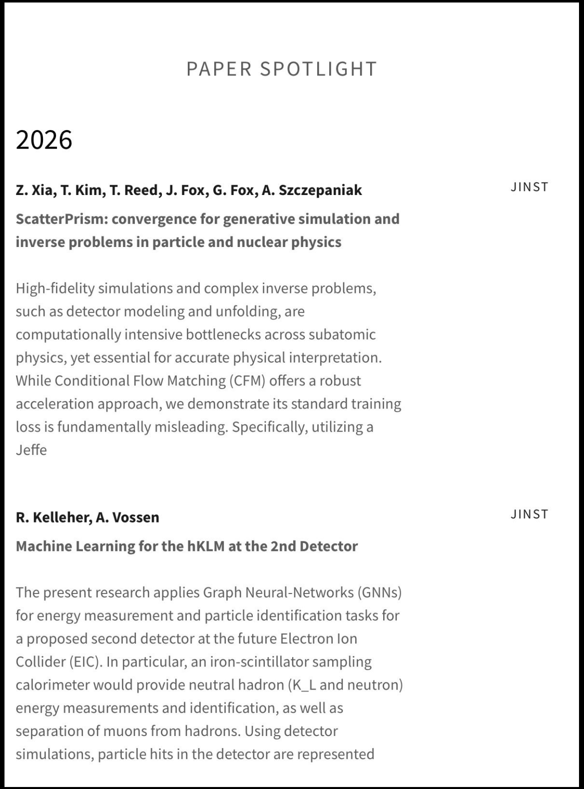
20th
2006-2026

AI4EIC

Spotlight on AI/ML for EIC Science

- This spotlight features a curated selection of the most influential papers per year that showcase cutting-edge applications of AI and ML to EIC science.
- These works represent milestones in the integration of modern computational techniques into experimental and theoretical efforts within the EIC community. We highlight these papers for their innovation, impact, and potential to guide future research in EIC.
- A sub-committee within AI4EIC is appointed to select the spotlights





PAPER SPOTLIGHT

2026

Z. Xia, T. Kim, T. Reed, J. Fox, G. Fox, A. Szczepaniak JINST

ScatterPrism: convergence for generative simulation and inverse problems in particle and nuclear physics

High-fidelity simulations and complex inverse problems, such as detector modeling and unfolding, are computationally intensive bottlenecks across subatomic physics, yet essential for accurate physical interpretation. While Conditional Flow Matching (CFM) offers a robust acceleration approach, we demonstrate its standard training loss is fundamentally misleading. Specifically, utilizing a Jeffe

R. Kelleher, A. Vossen JINST

Machine Learning for the hKLM at the 2nd Detector

The present research applies Graph Neural-Networks (GNNs) for energy measurement and particle identification tasks for a proposed second detector at the future Electron Ion Collider (EIC). In particular, an iron-scintillator sampling calorimeter would provide neutral hadron (K_L and neutron) energy measurements and identification, as well as separation of muons from hadrons. Using detector simulations, particle hits in the detector are represented

Full list can be found here:
https://ai4eic.org/spotlight

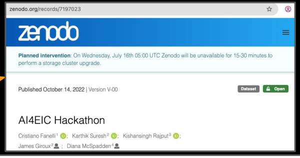
Impact of AI4EIC Initiatives: Examples

The seeds planted through AI4EIC initiatives continue to bear fruit over the years, giving rise to follow-up research and publications

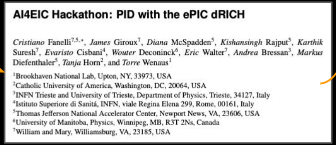
AI4EIC hackathon (ML for Cherenkov detectors)

(2022)

dataset



CHEP proceeding



AI4EIC Hackathon: PID with the ePIC dRICH

Cristiano Fanelli[7,5,*], *James* Giroux[7], *Diana* McSpadden[5], *Kishansingh* Rajput[5], *Karthik* Suresh[7], *Evaristo* Cisbani[4], *Wouter* Deconinck[6], *Eric* Walter[7], *Andrea* Bressan[3], *Markus* Diefenthaler[5], *Tanja* Horn[2], and *Torre* Wenaus[1]

[1]Brookhaven National Lab, Upton, NY, 33973, USA
[2]Catholic University of America, Washington, DC, 20064, USA
[3]INFN Trieste and University of Trieste, Department of Physics, Trieste, 34127, Italy
[4]Istituto Superiore di Sanitá, INFN, viale Regina Elena 299, Rome, 00161, Italy
[5]Thomas Jefferson National Accelerator Center, Newport News, VA, 23606, USA
[6]University of Manitoba, Physics, Winnipeg, MB, R3T 2Ns, Canada
[7]William and Mary, Williamsburg, VA, 23185, USA

(2024)

Inspired development of ML algorithms for Cherenkov detectors

Mach. Learn.: Sci. Technol. 6 015028

(2025)

Foundation Models

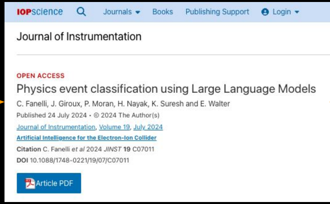
Mach. Learn.: Sci. Technol. 7.1: 015031

(2026)

AI4EIC hackathon (LLM for EIC Science)

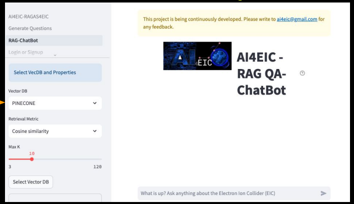
(2023)

JINST proceeding



(2024)

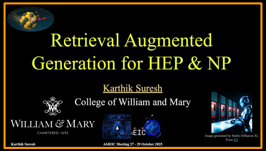
RAG4EIC Project



JINST 19.07 (2024): C07006.
https://github.com/ai4eic/EIC-RAG-Project

(2025)

Workfest

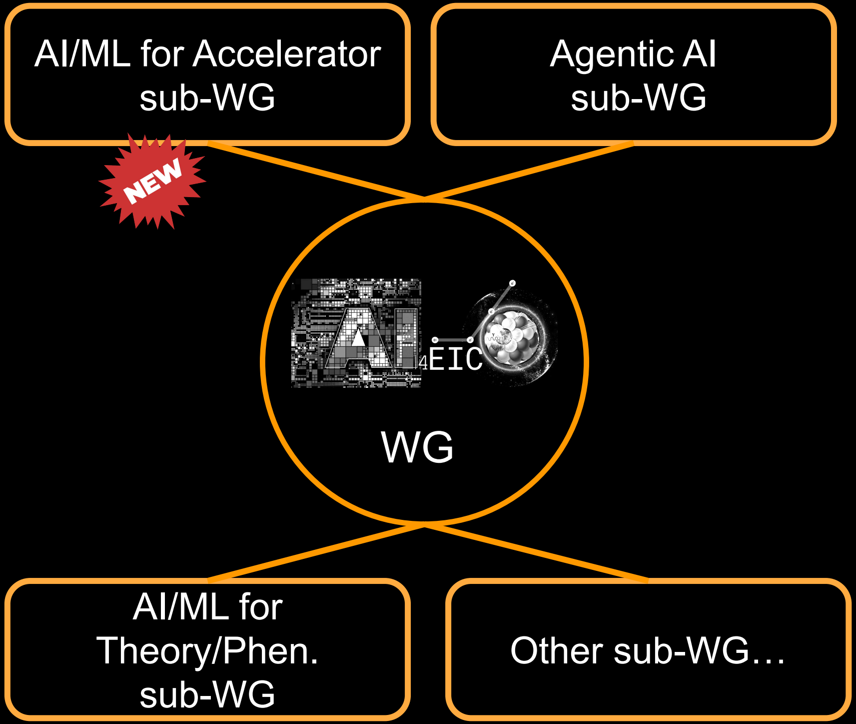


+ JINST Proceeding (2026)

Building AI4EIC Sub-Working Groups

- Establish focused sub-working groups aligned with the main themes of the AI4EIC workshop.
- Provide a sustained forum for collaboration, networking, and project updates across AI initiatives in nuclear and particle physics, including efforts supported by GENESIS and AmSC.
- New in 2026: AI/ML for Accelerators sub-working group.
- In development: AI/ML for Theory and Phenomenology sub-working group.
- Maintain momentum in emerging areas, including agentic workflows and community projects such as RAG4EIC.

https://github.com/ai4eic/EIC-RAG-Project



To get involved: support@ai4eic.org

AI/ML Accelerator sub-WG

co-conveners

Kevin Brown (BNL)

Todd Satogata (JLab)

Georg Hoffstaetter de Torquat (Cornell)

- Organization of joint meetings with the EIC-BeamAI working group of the international Accelerator Collaboration
- Kickoff meeting on Tuesday, June 30, 2026

https://indico.global/category/1612/

In this meeting we will review activities of the working group over the past few months. The meeting will be broken up into five parts.

- Summary of the 6th Workshop on Machine Learning for Particle Accelerators of the AI4EIC workshops
- Summary of International Particle Accelerator Conference activities
- Overview of the Multi-Office Accelerator Team (MOAT) collaboration activities
- Overview of the NP AI Ready Accelerator Data (NARAD) project
- Overview of the EIC-BeamAI collaboration

Great turnout ~ 50 people

Agentic AI sub-WG

A workfest organized during the AI4EIC workshop by the Agentic sub-WG (slides)


Karthik Suresh (W&M) Tapasi Gosh (Ramaiah)

(source code) https://github.com/ai4eic/EIC-RAG-Project

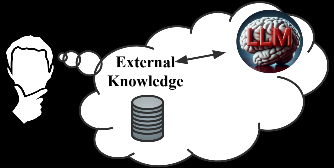
(agent) https://rag4eic.ds.wm.edu/

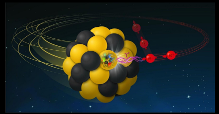
What is Retrieval Augmented Generation (RAG)?

- Access up to date information without explicitly training of LLM.
- Reduce “Hallucination” of LLM.
- Grounding LLM to truth to increase reliability by providing citations.

Why need RAG for Large Scale Physics Experiments?

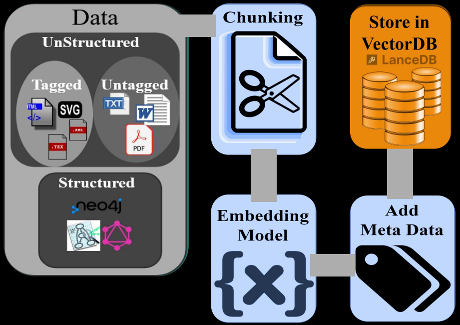
- EIC large scale experiment (e.g., EICUG ~1,500 users, ePIC 180 institutions)
- Regular updates to documents, Wiki etc; Tot document size ~ scale of experiment
- Newbies may take months to get to know the full experimental details





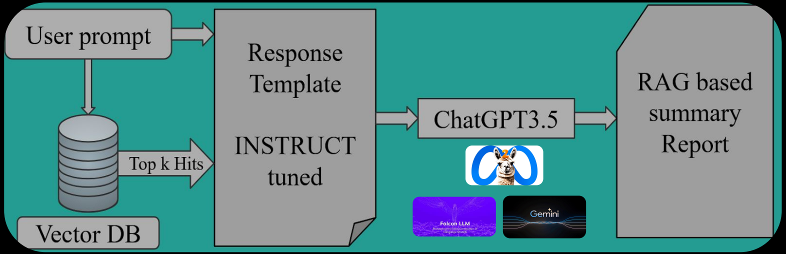
“Ingestion” of data

- Creation of vectorized knowledge base
- Every node below influence RAG performance
- 200+ recent arXiv papers on EIC (since 2021)



“Inference”

- Given a prompt compute similarity index to most similar vectors in VectorDB
- Use LLM to further narrow down and summarize the finding



K. Suresh, et al "Towards a RAG-based summarization for the Electron Ion Collider." JINST 19.07 (2024): C07006.
ATLAS (LHC) also working in this direction. See ChATLAS, D. Murnane et al, presented at AI4EIC,

Agentic AI sub-WG

Community Effort

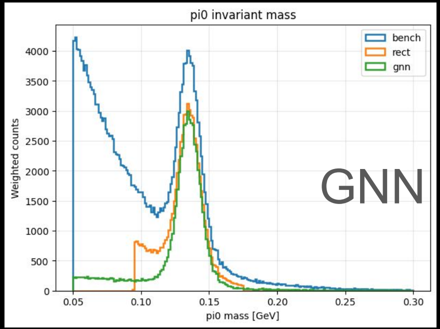
- AI4EIC Collaboration with Ramaiah University, Data Science (India)
  - B.Sc. thesis by Tina J Jat (supervised by Tapasi Ghosh) – This project advances prior OpenAI-based work by developing a fully open-source RAG pipeline for the EIC, using LLaMA 3.2/3.3 and mxbai-embed-large. With a local vector database, it ensures data privacy, avoids external sharing, and remains cost-effective.
  - A proceeding published on JINST (2026)
- Now EIC RAG works with open source models within olamma. Working towards agentic workflows (ongoing)
- Topical Meeting: a topical meeting took place in July 30, 2025 (https://indico.bnl.gov/event/28948/)
- Workfest@AI4EIC2025: A workfest on AI agents for EIC took place during the AI4EIC workshop at MIT, October 27-30, 2025

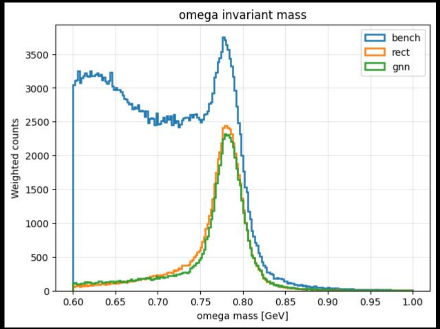
(source code) https://github.com/ai4eic/EIC-RAG-Project

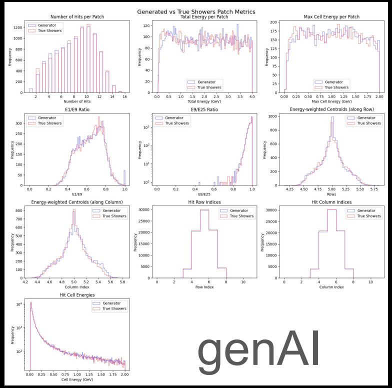
(agent) https://rag4eic.ds.wm.edu/

Educational Activities - APS

- AI4EIC helped organizing two short courses:
  - "*Data Science for Physicists*" at the APS-Global Physics Summit 2026 in Denver
    - https://ai4eic.github.io/APS2026_GPS_tutorials/landing_page.html
  - "*Deep Learning Tutorials for Experimental Nuclear Physics*" offered at APS-DNP, 2025 in Chicago
    - https://ai4eic.github.io/DNP2025-tutorials/landing_page.html
- These tutorials are part of AI4EIC's broader effort to bring modern machine-learning methods to the physics community
- Topics included CNN, GNN for classification and regression, as well as generative AI for fast simulations.
- The tutorials used data from the GlueX Collaboration at JLab.







AI4EIC–ePIC Synergies

- AI4EIC brings established expertise in AI education and community building, including tutorials, workshops, hackathons, benchmark datasets, and industry engagement. — https://ai4eic.org/ai4eic-resource-hub
  - In response to community requests, AI4EIC and ePIC are exploring the launch of a joint EIC/ePIC-specific AI training in early 2027.
  - AI4EIC can connect ePIC with the broader AI community, facilitating continuous knowledge transfer, exchanges on emerging methods, tools, and applications relevant to the collaboration.

    ⇒ Establish quarterly meetings and provide a forum for sharing relevant advances and identifying opportunities for collaboration, complementing the annual AI4EIC workshop and other activities.

Summary

https://ai4eic.org/

- **Active Engagement and Events**
  - Overall organized five AI4EIC workshop (+tutorials and hackathons), plus a joint event with Streaming Readout in December 2024; and also contributing to joint workshops with APS GPS and DNP
  - AI4EIC workshops have become a pivotal venue in the NP community, recognized by federal agencies in their Funding Opportunity Announcements.
  - A workshop at Duke is upcoming (December 15-18, 2026) http://indico.bnl.gov/event/AI4EIC2026
- **Successful Events**
  - AI4EIC Hackathons and Workfest have achieved remarkable success, fostering innovation and collaboration and new research papers. (Software infrastructure developed by AI4EIC utilized by ePIC hackathon.)
- **Promoting AI/ML Literacy**
  - Continued efforts to enhance AI/ML literacy within the EIC community, resulting in:
    - Editor of 30+ JINST proceedings for the AI4EIC workshops.
    - 2 hackathons documented in peer-reviewed papers.
    - 1 community paper on Computing and Software for Big Science published in 2024 with 14 citations.
    - Other AI4EIC contributions: APS GPS and DNP workshops; lecture series for summer school students (HUGS)
- **Topical Meetings, Innovative Projects and Synergies**
  - Covering cutting-edge topics and projects actively involving the AI4EIC community.
    - See, e.g., the repository on RAG-based summarization and workfest at MIT
  - Established a new sub-WG on AI/ML for Accelerator in partnership with the EIC-BeamAI
  - Collaborating with ePIC on tutorials and topical meetings on AI/ML for the EIC community