



<https://eic.ai/>

C. Fanelli, T. Horn

AI4EIC Activities

Summer 2024 Joint EICUG/ePIC Collaboration Meeting

Outline

- AI4EIC paper based on 2022 workshop
- Workshop 2023
 - Proceedings
- Hackathon
 - Paper
- Meetings
 - EIC summarization agent
 - Repository, A Web-Application, Sub-working group
 - Other Topical seminars
- Next Events
 - Streaming Readout Workshop with AI4EIC Collaboration (Tokyo, Dec 2024)
 - Organizing 2025 workshop

Artificial Intelligence for the Electron Ion Collider (AI4EIC)

- What is AI4EIC?
 - Community Paper published in 2024 on Computing and Software for big Science
- Areas:
 - Design of EIC
 - Intersection between Theory and Experiment
 - Reconstruction and PID
 - Infrastructure and Frontiers
 - Streaming Readout
 - Community Efforts (Tutorials, Hackathons and Outreach in general)

Computing and Software for Big Science (2024) 8:5

<https://doi.org/10.1007/s41781-024-00113-4>

REVIEW



Artificial Intelligence for the Electron Ion Collider (AI4EIC)

C. Allaire⁶⁰ · R. Ammendola²² · E.-C. Aschenauer³ · M. Balandat³³ · M. Battaglieri³⁶ · J. Bernauer^{6,46} · M. Bondi³⁵ · N. Branson^{14,32} · T. Britton²⁷ · A. Butte²⁶ · I. Chahrouh⁵⁵ · P. Chatagnon²⁷ · E. Cisbani³⁷ · E. W. Cline⁴⁶ · S. Dash²³ · C. Dean³¹ · W. Deconinck³⁴ · A. Deshpande^{3,6} · M. Diefenthaler²⁷ · R. Ent²⁷ · C. Fanelli^{27,64} · M. Finger¹⁰ · M. Finger Jr.¹⁰ · E. Fol⁵ · S. Furlotov²⁷ · Y. Gao³ · J. Giroux^{56,64} · N. C. Gunawardhana Waduge⁵⁸ · O. Hassan^{54,57} · P. L. Hegde⁹ · R. J. Hernández-Pinto¹⁶ · A. Hiller Blin²⁵ · T. Horn⁴⁷ · J. Huang³ · A. Jalotra⁵³ · D. Jayakodige^{21,27} · B. Joo³⁹ · M. Junaid⁵⁶ · N. Kalantarians⁶² · P. Karande³⁰ · B. Kriesten⁹ · R. Kunnavalkam Elayavalli⁶¹ · Y. Li⁴¹ · M. Lin³ · F. Liu³⁹ · S. Liuti⁵⁸ · G. Matousek¹⁵ · M. McEneaney¹⁵ · D. McSpadden²⁷ · T. Menzo⁵¹ · T. Miceli¹⁷ · V. Mikunj⁶⁵ · R. Montgomery⁵² · B. Nachman¹ · R. R. Nair³⁴ · J. Niestroy⁶⁴ · S. A. Ochoa Oregon¹⁶ · J. Oleniacz⁶³ · J. D. Osborn³ · C. Paudel¹⁸ · C. Peca¹⁵ · C. Peng¹ · G. N. Perdue¹⁷ · W. Phelps^{11,27} · M. L. Purschke³ · H. Rajendran⁹ · K. Rajput²⁷ · Y. Ren²⁹ · D. F. Renteria-Estrada¹⁶ · D. Richford² · B. J. Roy³⁸ · D. Roy⁴⁵ · A. Saini¹⁷ · N. Sato²⁷ · T. Satogata^{27,40} · G. Sborlinj^{12,20} · M. Schram²⁷ · D. Shih⁴⁴ · J. Singh⁴³ · R. Singh⁴⁷ · A. Siodmok²⁶ · J. Stevens⁶⁴ · P. Stone⁶⁴ · L. Suarez⁶⁴ · K. Suresh^{56,64} · A.-N. Tawfik¹⁹ · F. Torales Acosta²⁹ · N. Tran¹⁷ · R. Trotta⁴⁷ · F. J. Twagirayezu⁵⁰ · R. Tyson⁵² · S. Volkova⁴² · A. Vossen^{15,27} · E. Walter⁶⁴ · D. Whiteson³¹ · M. Williams³¹ · S. Wu⁵⁴ · N. Zachariou⁵⁹ · P. Zurita^{13,24}

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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

<https://eic.ai>

AI4EIC Workshop Dec 2023, CUA

- More than 40 contributors, great talks! Thanks a lot to all the speakers!

Sessions:

- AI/ML for ePIC and Beyond
- Calibration, Monitoring, and Experimental Control in Streaming Environments
- AI/ML for Accelerators
- AI/ML for Data Analysis and Theory
- Foundation Models and Trends in Data Science
- AI/ML in Production, Distributed ML

Tutorials: Continual Learning, Reinforcement Learning

- ~150 registered participants. Average attendance of 50+, with 30+ in person in the first 2 days and in the morning session
- Thanks also to the advisory committee, conveners and speakers. Many talks presented novel methodologies and were extremely engaging!



<https://eic.ai/workshops>
<https://eic.ai/community>

Some key points

- Important opportunities for AI in the new EIC (AI/ML for accelerator applications, new capabilities offered by **Foundation Models**, **Language Models**, etc.),
- In the discussions identified the need to have common requirements for data feature extraction, testing — **Benchmarks**
 - This could be a session in the next workshop
 - As well as on **Uncertainty Quantification**
- There are many interesting projects currently supported by DOE. Presence of DOE PMs during AI4EIC.
- During the workshop, participants from universities, national labs, and industry: diverse community strongly interested in AI for the EIC science
- There is a large span of technical areas and AI is a common foundation for it

<https://eic.ai>

Outlook

- There is interest in organizing the next AI4EIC event in Europe (targeting spring/summer 2025). This would be the first time outside the US
- It has been highlighted the uniqueness of EIC, as it is likely the only new collider in the US for many decades
- Many ideas have been proposed in the second AI4EIC workshop at W&M in 2022. Since then, we now have DOE-funded projects on AI/ML for EIC and NP in general!
- Now we are at the stage where we review/look at all these efforts together and start identifying commonalities and where the different projects can benefit from each other and enhance each other. AI4EIC is of course the important forum for that too.
- Next workshop might further explore synergies and work towards quantifying common requirements/needs — AI4EIC brings diverse backgrounds together, fostering new ideas and opportunities

Proceedings of 2nd AI4EIC Workshops

- AI4EIC published a total of 13 proceedings this year
 - Performance optimization for a scintillating glass electromagnetic calorimeter at the EIC, J. Crafts *et al* 2024 JINST 19 C05049
 - Real-time charged track reconstruction for CLAS12, Gagik Gavalian (on behalf of the CLAS12 Collaboration) 2024 JINST 19 C05050
 - Object condensation for track building in a backward electron tagger at the EIC, S. Gardner *et al* 2024 JINST 19 C05052
 - Photon classification with Gradient Boosted Trees at CLAS12, G. Matousek and A. Vossen 2024 JINST 19 C06006
 - Normalizing flows for domain adaptation when identifying Λ hyperon events, R. Kelleher and A. Vossen 2024 JINST 19 C06020
 - AI-assisted detector design for the EIC (AID(2)E), M. Diefenthaler *et al* (on behalf of the AID2E Collaboration) 2024 JINST 19 C07001
 - Towards a RAG-based summarization for the Electron Ion Collider, K. Suresh *et al* 2024 JINST 19 C07006
 - Bayesian Neural Network Variational Autoencoder Inverse Mapper (BNN-VAIM) and its Application in Compton Form Factors Extraction (accepted for publication), Y. Li *et al* (on behalf of the EXCLAIM Collaboration)
 - Beam Condition Forecasting with Non-destructive Measurements at FACET-II (accepted for publication), M. Kilpatrick *et al*.
 - Particle identification with machine learning from incomplete data in the ALICE experiment (accepted for publication), M. Karwowska *et al*. (on behalf of the ALICE Collaboration)
 - ML-based Calibration and Control of the GlueX Central Drift Chamber (accepted for publication), T. Britton *et al*.
 - Hydra: Computer Vision for Data Quality Monitoring (accepted for publication), T. Jeske *et al*.
 - Physics Event Classification Using Large Language Models (accepted for publication), C. Fanelli *et al*.

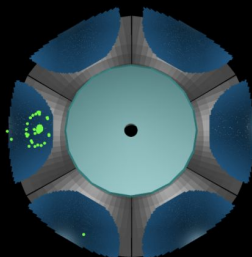
<https://eic.ai/ai-ml-references>



2022 Hackathon: CHEP Proceeding published

- Already presented in the past EICUG Meeting
- News:
 - Talk on this experience accepted at CHEP23 (Collaboration, Reinterpretation, Outreach and Education)
 - Proceeding published

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, DM:SKR, EC, WD, EW, KS, JG

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

Training Events	1.5 Million Events	With Magnetic Field (~ 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

Training Events	3 Million Events	With Magnetic Field (~ 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



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

Hackathon Leaderboard

RANK	TEAM	SCORE	QUESTIONS ATTEMPTED
1	Jets	295.502	0 1, Q 3, Q 2
2	JINR	294.508	0 1, Q 3, Q 2
3	JB and EC	262.313	0 1, Q 3, Q 2

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

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.

Open Access

EPJ Web of Conferences

Issue EPJ Web of Conf.
Volume 295, 2024
26th International Conference on Computing in High Energy and Nuclear Physics (CHEP 2023)

Article Number 08004

Number of page(s) 8

Section Collaboration, Reinterpretation, Outreach and Education

DOI <https://doi.org/10.1051/epjconf/202429508004>

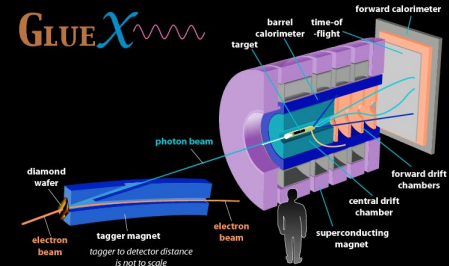
Published online 06 May 2024

<https://doi.org/10.1051/epjconf/202429508004>

2023 Hackathon: Problem

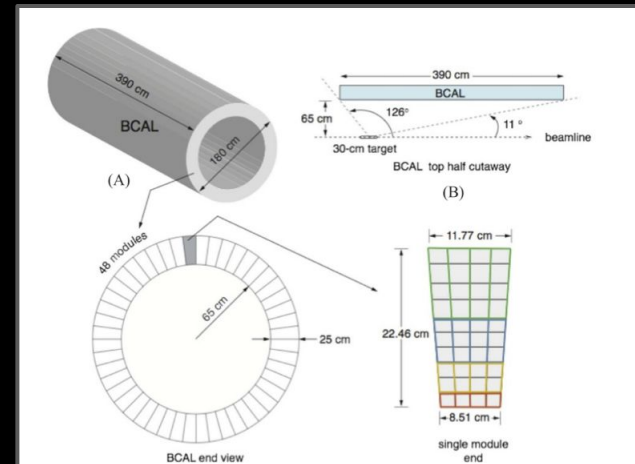
The LLM problem: Participants are tasked with developing a machine learning (ML) model for a classification problem of experimental physics using only an LLM (ChatGPT) interface. The scope of the hackathon is to evaluate the following.

1. *LLM for Code Assist:* Creating the scripts necessary to build a machine learning model for binary classification with limited dataset information by using a Language Model (LLM) and making use of its responses.
2. *Few-Shot Prompting:* Constructing the best-performing ML model for binary classification task while minimizing the number of total number of prompts used.



- Simulated data from GlueX/Hall D
- Photon/neutron identification in the barrel calorimeter (BCAL)
- Goal is increase distinguishing power, based on shower profile features

- Problem 1 - Full phase space coverage. High degree of separability.
- Problem 2 - Reduced phase space coverage. Lower degree of separability.



2023 Hackathon: Rules

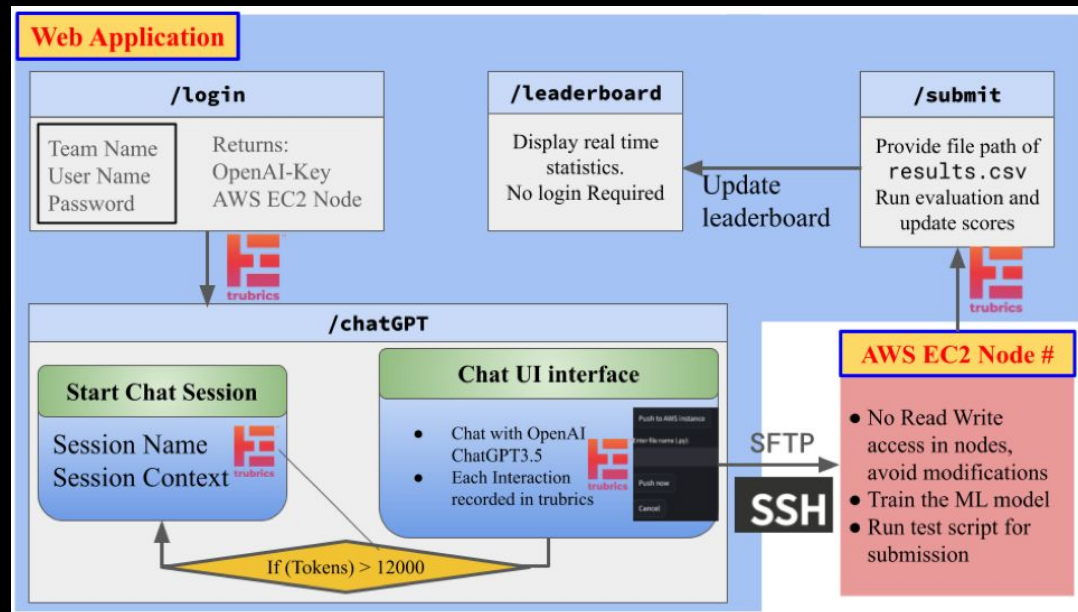
- Participants could only use the provided custom Chat interface built for this hackathon to interact with ChatGPT3.5. This interface served as the primary platform for participants to formulate queries and receive responses from ChatGPT, allowing seamless interaction with LLM throughout the hackathon.
- Furthermore, participants did not have direct access to the datasets; this restricted participants to train the network elsewhere other than the provided infrastructure and could assess submissions on equal footings.
- Participants did not have access to any editors or could edit the code snippets provided by ChatGPT3.5. Participants were even forced to use ChatGPT to install libraries to run code snippets.
- Finally, to minimize the total number of prompts needed to build the model, all chat interactions were broken down into sessions. Each chat session had a fixed conversational history beyond which the chat session would restart.
- It has been shown that “in-context learning” improves LLM performance [2]. To facilitate this feature, participants were provided with the option to set the ‘session context’ at the start of each chat session.

2023 Hackathon: Infrastructure

Compute resources:

[Supported by Dept. Data Science and HPC Research Computing at W&M]

- Users were instructed to form teams of up to four participants, in which each team member received their own AWS g5.2xlarge instance with a single Nvidia A10G GPU, 8 cores, 32 GB of RAM and 450 GB of disk
- The user interface was built using the [Streamlit](#) platform, specifically built for LLM interfaces. The application was hosted on an AWS c5.24xlarge, where users could access the website using the provided URL



2023 Hackathon: Outcome

Results: Participants Exceeding Expectations The participants and their AI-assisted coding strategies greatly exceeded our expectations in the second problem. Internal tests prior to the hackathon indicated an expected accuracy of around 92%, under the same constraints as the participants, but with prior knowledge of the data set. We requested ChatGPT to provide us with a syntactically correct program, deploying an under-sampling technique to combat imbalanced data, a basic XGBoost [9] decision tree, and a performance analysis as a function of decision boundary placement in the validation set to find the optimal threshold of the model. Remarkably, all teams and participants managed to greatly exceed this score with unique solutions. In fact, all teams submitted scores approaching $\geq 99\%$ and are within statistical error. The final decision came down to the combination of the minimum number of prompts to obtain their result and the time submitted in which the “Jets’ team emerged victorious. Their strategy involved a CatBoostClassifier [10] coupled with a hyperparameter optimization technique, all of which were directly accessed via concise commands to ChatGPT.

AI4EIC Hackathon 2023

Welcome to the AI4EIC Hackathon 2023. Navigate to the different pages of the hackathon.

Rank	Team Name	Team Members	Q1 Score	Q2 Score	Total Score
1	Jets3	<ul style="list-style-type: none">• Dhruvi Kulkarni• Derek Anderson• Charles Hughes	99.935	99.777	199.712
2	Small Language Models	<ul style="list-style-type: none">• Maitav Ezer• Vincenzo Mikami• Francesco Testa	99.928	99.77	199.698
3	SPIN 2023 Local Organization Committee	<ul style="list-style-type: none">• Matthew McEneaney• Connor Pecir• Gregory Matuszek• Simon Schneider	99.932	99.773	199.706
4	404 Brain Not Found	<ul style="list-style-type: none">• Alex Smith• Simon Gierber• Roberto Prohensia	99.919	99.756	199.675
5	Messed Ups	<ul style="list-style-type: none">• Shivam Raj• Bharat Singh• M. Iqbal Hussain• Ansh Singh	99.918	99.614	199.532
6	EPSCI	<ul style="list-style-type: none">• David Lawrence• Gogh Corvicio	99.917	99.613	199.531

- The hackathon included educational outreach for Nuclear and Particle Physics researchers, scientists, and practitioners, raising awareness of LLM capabilities.
- LLM tools like ChatGPT are often key contributors to completing ML tasks, providing detailed code explanations and increasing productivity.
- Saved metadata amounted to a total of 752 prompts between 19 unique users during the 8-hour period of the hackathon and will be subject to study

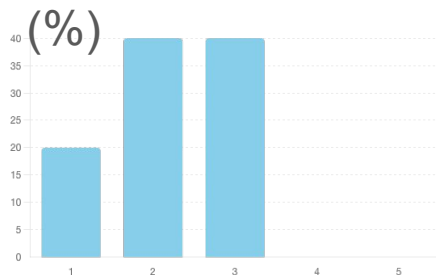
2023 Hackathon: Survey

1 (no/min) to 5 (yes/max)

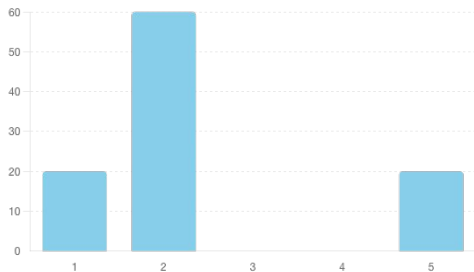
Survey: 5

Total hackathon participants: 20+

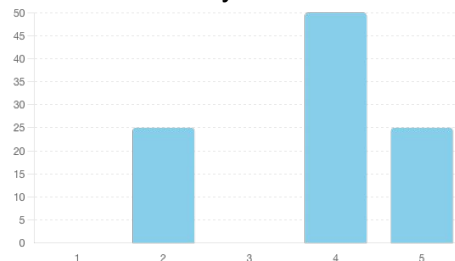
1. Have you used ChatGPT before?



2. How relevant and helpful is ChatGPT for your everyday work?



3. If you haven't used ChatGPT as a coding assistant in the past, how likely are you to use it after your Hackathon experience?



4. What is your main takeaway from this hackathon?

ChatGPT can be a very powerful tool for coding. Brief but precise prompts tended to produce the best results. I am shocked that ChatGPT did such a good job at picking ML algorithms for classification problems without a-priori knowledge of the data those algorithms would be using.

ChatGPT generates valid programs with much higher rate than I expected

Inspiration

Having never used ChatGPT before, honestly my biggest takeaway was just learning how to use ChatGPT to get reference code snippets!

How much chatGPT can do when it comes to suggesting ideas for how to solve problems with AI and how to implement that solution. Since the hackathon I have used chatGPT to help in my own work and will continue to do so.

2023 Hackathon: Survey

1 (no/min) to 5 (yes/max)
Survey participants: 7
Total hackathon participants: 20+

- Any overall feedback for the event?

Thanks again to organizers. Please keep arranging these hackathons at conferences.

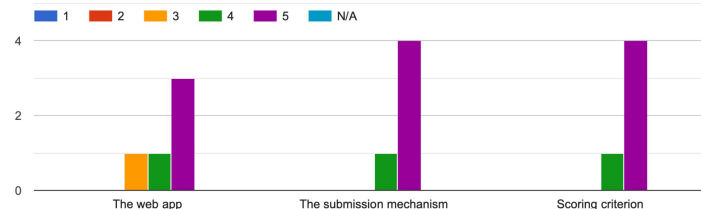
Was a great event! Many thanks to the organizers.

will be happy to host the same hackaton in my institute soon

This was great!! I had a blast and learned a lot!

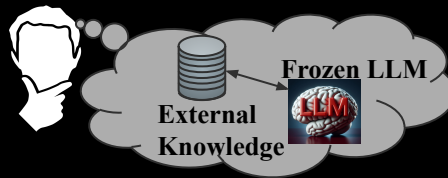
If possible I would like access to the training data sets and test data set with answers - my supervisor teaches machine learning to undergraduate students and was very interest in taking a look at this and potentially setting something similar for his students.

How satisfied were you with the hackathon?



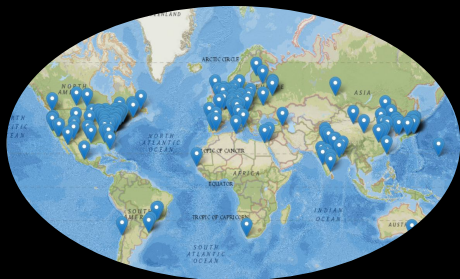
Satisfaction for
the built infrastructure

Topical Meeting: RAG-based Summarization



Why a summarization tool?

- Ease of retrieving up to date information on topics.
- Extremely useful for new collaborators and especially students.
- Large Scale Experiments \propto Size of document database.



EICUG > 1400 physicists, 240 institutions and 38 countries....

Why LLM based summarization?

- Increased contextual understanding posed by LLM
- Enhanced information retrieval and faster decision making.

The requirements?

- Should be free of hallucinations.
- Should unfold all contexts using short prompts
- Provide up to date information without “being” constantly trained

Indico: <https://indico.bnl.gov/event/24262/>
Paper: Suresh et al., DOI 10.1088/1748-0221/19/07/C07006
Repository: <https://github.com/oi4eic/EIC-RAG-Project>

Also an Ongoing HEP Effort

chATLAS

An AI Assistant for the
ATLAS Collaboration

DANIEL MURNANE, GABRIEL FACINI,
RUNZE LI & CARY RANDAZZO

AI4EIC WORKSHOP
NOVEMBER 30, 2023



BERKELEY LAB



LOUISIANA TECH
UNIVERSITY

What is the ATLAS paper publication process? 4 results

The ATLAS paper publication process involves the ATLAS Publication Committee receiving papers intended to be published as scientific notes. The Publication Committee will provide ATLAS referees to evaluate each paper, judge its suitability for publication, and interact with the authors regarding possible revisions. The Publication Committee will then make a final recommendation to the spokesperson. Journals publishing scientific notes will independently referee them. If major issues are identified during ATLAS circulation or journal review, the analysis team will inform the conveners of the Working Group and relevant sub-Working Group about major changes in the analysis or major changes in the paper.

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Ask me something!

OPEN QUESTIONS & CONCLUSION

- How to avoid hallucinations? Probably "GPT-5/Q*/AGI" will make this hurdle irrelevant
- How to best "censor" politically incorrect responses (e.g. which analysis team is the best?)
- How to measure the quality of responses – LangSmith AI-assisted evaluators?
- What is the best dataset to gather for fine-tuning?
- How to anonymize email threads and discussion forums?



We are having a lot of fun building this thing from scratch, but if there was an open-source scientific community framework for AI Assistants, it would be even more fun!

Talk at AI4EIC-2023

An AI Assistant for the ATLAS Collaboration

The ongoing AI4EIC Project: Retrieval Augmented Generation using LLM pipeline

Ingestion

- Load data (**semantic**) both structured and unstructured from sources
- Split data in small repetitive chunks – **text corpus**
- **Embed** these chunks into a vector space using an embedding model
- Store these vectors in a database for retrieval later.

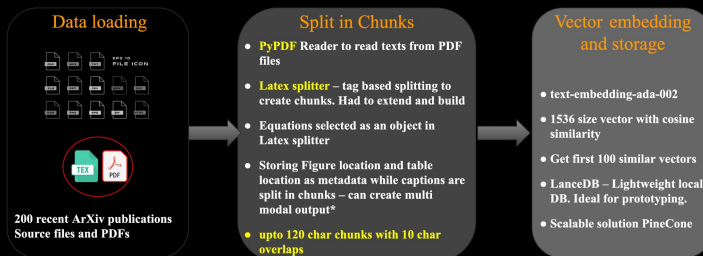


Inference

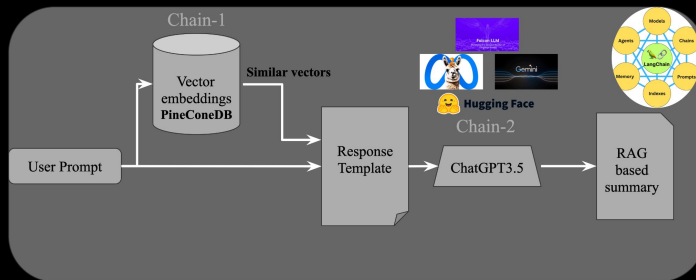
- Given a prompt, compute similarity index. Select the most closest vectors
- Choose a response template. Embed the vectors along with input prompt and feed into LLM
- Evaluate the response
 - Model fine-tuning
 - Build metrics for context tuning
- Multi Modal Output

A pilot study – Ingestion

- The Objective – Summarization tool with “relevant citations” for within EIC.
- Framework built has to be scalable and fairly automated



The Generic Workflow of building Traditional RAG



Talk at AI4EIC-2023

A Large Language Model-based Assistant for the Electron Ion Collider

The ongoing AI4EIC Project:

RAG application and evaluation

Repository: <https://github.com/ai4eic/EIC-RAG-Project>
Web-Application: <https://rags4eic-ai4eic.streamlit.app/>

AI4EIC - RAG QA-ChatBot

What are the polarization parameters used to study J/ψ polarization in SIDIS at large PT?

Gathering info from Knowledge Bank for this query...

Hello! Here are the polarization parameters used to study J/ψ polarization in SIDIS at large PT:

- The study of J/ψ polarization in large-PT semi-inclusive deep-inelastic scattering (SIDIS) at the Electron Ion Collider (EIC) can help in getting information on the J/ψ formation mechanism, both at large z (high- and low-energy set-ups) and as a function of PT (at large energy)|[1].
- Future measurements of transversely polarized $\Lambda/\bar{\Lambda}$ in SIDIS will potentially allow us to gain further insights and to distinguish between different scenarios, contributing to the understanding of the J/ψ polarization in SIDIS at large PT[2].

I hope this helps to answer your question.

- <http://arxiv.org/abs/2301.11987v1>
- <http://arxiv.org/abs/2301.11987v1>

[View the trace](#)

What is up? Ask anything about the Electron Ion Collider (EIC)

[Check out the full trace of the pipeline in langsmith](#)

Classic Metrics

Metric Name	Definition	Score
Output Renderer Frequency	Frequency of correctly rendered output response in the markdown format	78.0% \pm 5.8%
Claim Recognition Rate	$CRR = \frac{\text{Number of answered claims}}{\text{Total number of claims in question}}$	96.4% \pm 3.4%
Claim Accuracy Rate	$CAR = \frac{\text{Number of correctly answered claims for a question}}{\text{Total number of recognized claims in question}}$	88.9% \pm 8.3%
Source Citation Frequency	$SCF = \frac{\text{Number of time question's source cited}}{\text{Total queries}}$	85.3% \pm 5.0%
Hallucination Frequency	$HF = \frac{\text{Number of hallucinations}}{\text{Total queries}}$	2% \pm 2%

RAGAS – LLM based evaluation

Metric Name	Definition	Score
Faithfulness	Fraction of correctly rendered output response in the markdown format	87.4% \pm 5.5%
Context Relevancy	Relevancy of the retrieved context to the question and generated answer	61.4% \pm 4.3%
Context Entity Recall	$CER = \frac{\text{claims in context} \times \text{claims in ground truth}}{\text{claims in ground truth}}$	98.7% \pm 1.2%
Answer Relevance	Measures relevancy of the generated answer to the retrieved context and the question	77.2% \pm 2.3%
Answer Correctness	Measures correctness of the generated answer to the idea response	72.3% \pm 2.4%

Talk at AI4EIC-2023

A Large Language Model-based Assistant for the Electron Ion Collider

Next Events: Streaming Readout & AI4EIC

- Streaming Readout Workshop + AI4EIC - Tokyo, December 2 - 4, 2024

This meeting brings together DAQ specialist and experimentalist from all over the world, to discuss the learning experience from existing streaming DAQ system and collaborate on future Streaming DAQ system in particularly the EIC.

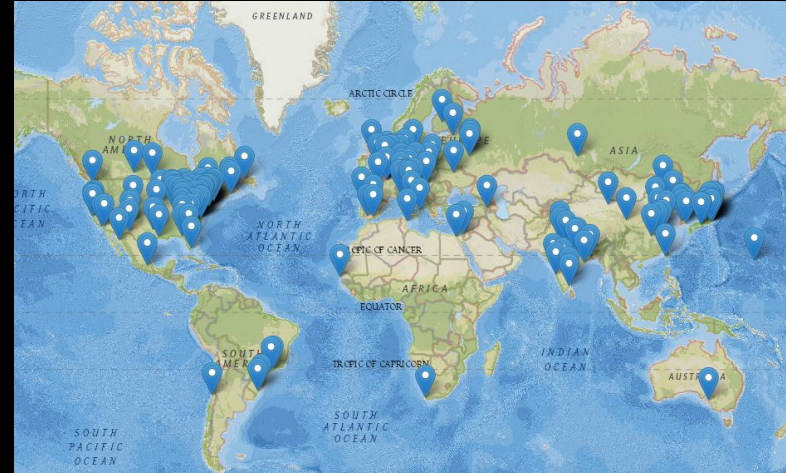
This SRO XII edition will be held in Tokyo, Japan, from 12/2 to 12/4. The University of Tokyo will host the workshop.

At this time, we will have a joint session between SRO and AI4EIC to discuss the development and implementation of AI/ML based technologies in the streaming readout and DAQ.



Next Workshop (abroad) 2025

- There is growing interest in organizing the next AI4EIC workshop abroad, with discussions already underway with international institutions.
- This reflects our commitment to fostering global collaboration and sharing cutting-edge developments in AI and EIC research with a broader audience.
- We believe that holding the workshop in a vibrant international venue will not only enhance the diversity of perspectives but also provide unique opportunities for networking and partnership building.
- The venue details are currently being finalized, and we look forward to announcing the location soon. Stay tuned for updates on this exciting development.



<https://www.eicug.org/content/map.html>

Conclusions

DE-FOA-0002875

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.

- **Active Engagement and Events**

- Organized the third successful workshop (+tutorials and hackathon) in December 2023 and planning a joint event with Streaming Readout in December 2024.
- AI4EIC workshops have become a pivotal venue in the NP community, recognized by federal agencies in their Funding Opportunity Announcements.

- **Successful Hackathon Events**

- AI4EIC Hackathons have achieved remarkable success, fostering innovation and collaboration.

- **Promoting AI/ML Literacy**

- Continued efforts to enhance AI/ML literacy within the EIC community, resulting in:
 - 13 proceedings published this year.
 - 2 hackathons documented in peer-reviewed papers.
 - 1 community paper on Computing and Software for Big Science.

- **Topical Meetings and Innovative Projects**

- Initiated topical meetings on cutting-edge topics and projects, actively involving the AI4EIC community.
- For more details, see the repository on RAG-based summarization project.
- Other meeting announced soon (topic UQ)

- **Future Plans**

- Planning a new workshop and hackathon outside of the US, in collaboration with international partners.