AI in ePIC: Toward an Integrated Scientific Workflow

The presentation builds on the AI Town Hall and AI Workfest held during the ePIC Collaboration Meeting in Glasgow.

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AI Is Changing How Science Is Done

Capabilities

Coding • Scientific Agents • Mathematical Reasoning

AI is taking on increasingly complex tasks across the scientific workflow.

Cost

Large-scale AI investment is reshaping the computing landscape

Major technology companies are driving demand and pushing hardware costs upward.

Opportunity

Accelerate science • Maximize scientific reach

Use AI to make scientific workflows faster and more capable while improving accuracy and fidelity.

The ePIC Computing Model Enables Closed-Loop Scientific Workflows

Streaming readout, AI, and distributed computing provide the foundation for this transition.

1. ## Streaming Readout
   Maximizes scientific reach through unbiased event selection and continuous measurement of backgrounds and detector noise.

2. ## AI
   Accelerates science through autonomous alignment, calibration, and validation, shortening the path to physics results and publications.

3. ## Distributed Computing
   Enables flexible access to dedicated and opportunistic computing resources where they are needed.

Toward a Closed-Loop Workflow

Data taking

↓

Data processing

↓

Physics analysis

↓

Feedback and optimization

The opportunity is not just to use AI, but to rethink the scientific workflow.

"The AI revolution in science is a workflow revolution."

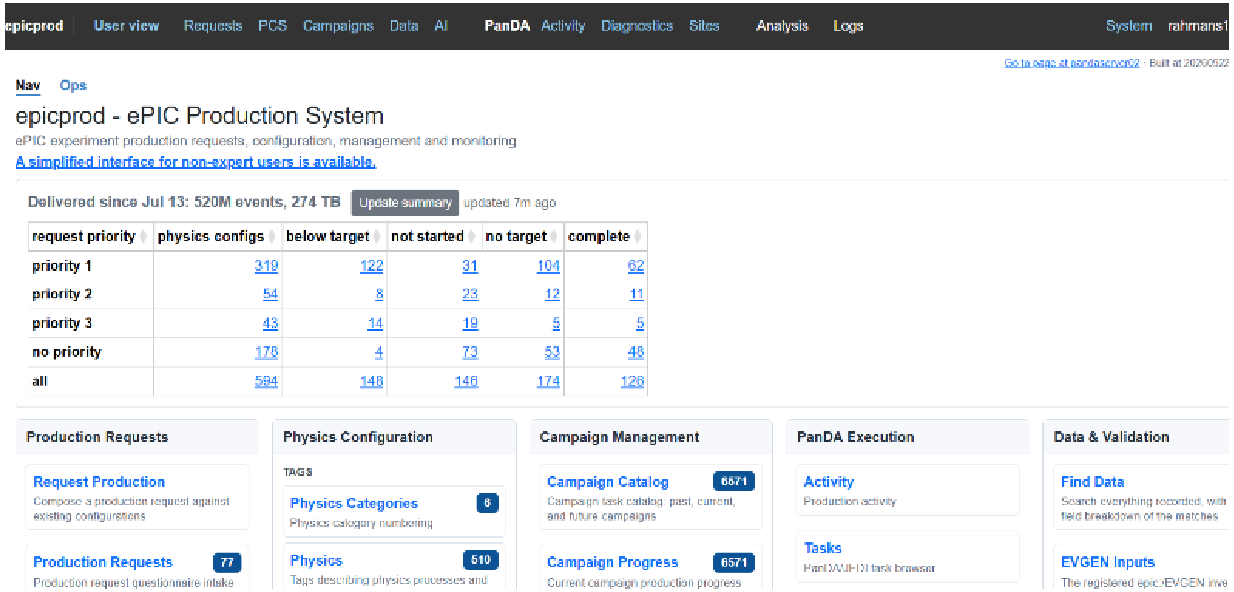
David Lawrence, EICUG-ePIC meeting

AI Is Already Part of the ePIC Workflow

epicprod

Autonomous system for simulation production in ePIC, based on PanDA and agentic workflows.

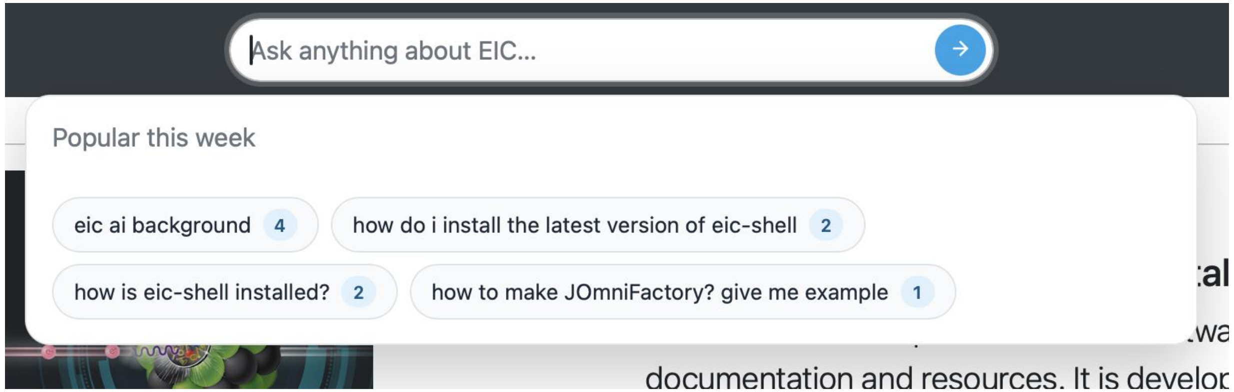
https://epic-devcloud.org/prod/



AI-enabled search

Supports onboarding and user learning in ePIC through AI-assisted search across documentation and tutorials.

https://eic.github.io



AI Town Hall: Mapping AI Across ePIC

Purpose: Showcase the breadth of AI, machine learning, data science, and related computational activities across ePIC.

For each project, we asked

- What problem and part of the ePIC workflow does it address?
- What data, software, and infrastructure does it use?
- What would help move it toward integration and broader use?

Broader Goal

- Connect projects.
- Share tools, data, expertise, and infrastructure.
- Integrate AI into ePIC workflows.

15 Talks: Topics span the full ePIC workflow, from **detector design and streaming data processing to reconstruction, analysis, data, dissemination and validation.**
Talks and materials: AI Town Hall, July 16, 2026

AI Town Hall: Detector Design

- **AID(2)E: AI-Assisted Detector Design for the EIC**
  Derek Anderson (JLab)
  Uses multi-objective Bayesian optimization to explore detector-design trade-offs and develop a reusable optimization framework for ePIC.
- **Geometry Optimization of the B0 Tracking System**
  Baptiste Fraïsse (Catholic University of America)
  Uses AID(2)E to optimize B0 tracking-disk positions and active areas for improved reconstructed-angle resolution.

AI Town Hall: Streaming Data Processing

- **AI-Based Multi-FPGA Data Reduction for DCR Noise Filtering and Bandwidth Control in the dRICH DAQ Stream**
  Cristian Rossi (INFN Rome)
  Uses FPGA-based ML to distinguish noise-only from signal-plus-noise events in the dRICH data stream, reducing the data rate before downstream processing.
- **Intelligent Experiments through Real-time AI for EIC: Fast Data Processing and Autonomous Detector Control for High-Energy Nuclear Experiments (Fast-ML)**
  Ming Liu (LANL)
  Develops real-time AI/ML at the hit level for beam-background rejection, tagging rare and calibration events, and fast data filtering, building on FPGA demonstrators for sPHENIX.
- **GNN applied to streaming readout in EICrecon**
  Oliver Partridge (Tokyo City University)
  Uses a graph neural network to pre-filter streaming readout in EICrecon and distinguish physics activity from detector-background noise.

AI Town Hall: Reconstruction

- **CNN and Vision Transformers for DRICH-PID**
  *Deepak Samuel (*Central University of Karnataka*)*
  Explores CNN and Vision Transformer approaches for dRICH particle identification, including performance under noisy conditions and the use of timing information.
- **AI/ML for Imaging Cherenkov Reconstruction and Simulation**
  James Giroux (William & Mary)
  Develops generative and foundation-model approaches for Cherenkov detectors, targeting **fast simulation**, reconstruction, particle identification, and noise filtering.
- **Foundation Models for Nuclear and Particle Physics (FM4NPP)**
  Joe Osborn (BNL)
  Pretrains a foundation model on unlabeled detector data and adapts it to reconstruction tasks including track finding, particle identification, and noise tagging.
- **Jet Energy Reconstruction using Bayesian Deep Learning with UQ**
  Hemalata Nayak (William & Mary)
  Uses Bayesian deep learning to improve reconstructed jet energy while providing epistemic and aleatoric uncertainty estimates for precision measurements.
- **GNN + Attention-Based Cluster Finding in Live Experiment in Hall C, JLab**
  Chi-Kin Tam (Catholic University of America)
  Combines waveform information, detector geometry, graph networks, and attention to identify and assign detector signals to clusters.

AI Town Hall: Analysis

- **AGENT-ASSISTED DATA ANALYSIS**
  Henry Klest (ANL)
  Uses AI agents to carry out and coordinate major parts of physics analyses, including simulation, unfolding, uncertainties, plotting, and documentation, with human supervision.

- **Deconvolution of Momentum Transfer Distributions Through Deep Learning**
  Maci Kesler (Kent State University)
  Explores deep-learning deconvolution of momentum-transfer distributions in exclusive vector-meson production to recover diffractive structure needed for gluon imaging.

AI Town Hall: Data, Dissemination and Validation

- **AI-READY DATA FOR BIC**
  Zhiwan Xu (ANL)
  Develops low-level, pre-reconstruction BIC datasets with measurements, labels, uncertainties, and metadata structured specifically for AI training and downstream reconstruction.
- **AI Smart Search**
  Alexandr Prozorov (Czech Technical University in Prague)
  Addresses fragmented collaboration knowledge by combining lexical and vector search with LLM-generated answers and citations across documentation, tutorials, publications, and meeting material.
- **HYDRA**
  Thomas Britton (JLab)
  Provides AI-based data-quality monitoring by organizing and visualizing monitoring images and using supervised and unsupervised learning for automated validation of simulation campaigns and CI artifacts

Selected Examples of Major AI-for-Science Initiatives

U.S.: Genesis Mission

Integrated platform connecting **compute, data, AI, and experimental facilities**.

ePIC connection: closed-loop approaches and integrated scientific workflows. Several selected Genesis Mission projects directly overlap with ePIC's AI and computing priorities (see slide 16).

Japan: ARiSE

National strategy linking **AI, advanced computing, data, and autonomous experimentation.**

ePIC connection: ARiSE includes an EIC-focused proposal for an **autonomous scientific experimentation platform** and builds on the **U.S.-Japan partnership through the Genesis Mission.**

Source Taku Gunji, AI Workfest

Italy: AI / HPC Ecosystem

National ecosystem linking **AI research, HPC, data infrastructure, and AI applications**.

ePIC connection: The Italian AI/HPC ecosystem offers opportunities for **digital twins, AI reconstruction, workflow automation, and data interoperability**.

Source M. Battaglieri & D. Elia, AI Workfest

Common direction: integrating AI, data, computing, and experiments to accelerate science.

From AI Projects to Integrated ePIC Capabilities

Next Steps from Software & Computing Planning

2026 Build Shared Infrastructure and Define Integration Requirements

Computing Infrastructure Start consolidating a common computing platform for streaming testbeds and production, with collaboration-wide access and stable interfaces to AI services.

Initial Scope: epicprod • Hydra • AI-enabled search • Firebird

Success metric: Joint infrastructure plan, coordinated with ECSJI, and initial implementation underway.

Reconstruction Use existing examples and high-impact demonstrators to define requirements for integrating AI/ML algorithms into EICrecon.

Success metric: Document requirements for integrating AI/ML algorithms into EICrecon.

2027 Closed-Loop Workflows

Autonomous Calibration Implement representative alignment and calibration workflows, including autonomous change detection to trigger workflows, and start integration with Streaming Orchestration.

Success metric: Autonomous triggering demonstrated; integration with Streaming Orchestration initiated; workflow requirements finalized.

AI Policy for ePIC: Beyond Coding

AI use spans the scientific workflow:

- **Software development:** AI-assisted coding, testing, and review.
- **Scientific work:** AI-assisted analysis, agentic workflows, and interpretation.
- **Scientific communication:** technical documents, papers, and presentations.
- **Data:** appropriate use of ePIC data and information
- **Collaboration culture:** equitable access to AI tools and capabilities

Direction from the Collaboration Meeting

Develop a **lightweight policy**, rather than strict restrictions, that provides collaboration-wide guidance on:

transparency • responsibility • accountability • data use • equitable access

The goal is to enable responsible use of AI across ePIC, not to prescribe individual tools.
Next step: Form a committee with SPs and CC input and present a draft at the next collaboration meeting.

Toward an Integrated Scientific Workflow

AI is already part of ePIC

AI is being used across **production, reconstruction, scientific workflows, and collaboration tools**, with activity spanning the full data lifecycle.

The opportunity is integration

Move from individual AI projects toward **shared infrastructure, closed-loop workflows, and reusable capabilities** across ePIC.

Integration requires more than technology

Common infrastructure needs to be accompanied by a **lightweight AI policy** addressing responsible use, data, transparency, accountability, and equitable access.

Use AI to accelerate science and maximize the scientific reach of ePIC.

Backup

Genesis Mission

The first round of Genesis Mission projects was announced on July 22. Projects relevant to ePIC are listed below.

- **Agentic AI for Real-time Expedited Discovery from High-Complexity EIC Data Streams** (Purdue, FNAL, LANL, MIT, NJIT)
- **A.I. Era Spin Physics of Quantum Systems: Real-Time Feedback and Neural Network Optimization of Polarized Targets** (UNH, JLab, NMSU, UTK, UVA)
- **AI-Driven Expedited Discovery and Background Separation for Petabyte-Scale Streaming Readout** (CUA, JLab)
- **Foundation Models for Transferable Particle Tracking in Nuclear Physics** (Stony Brook, ANL, BNL)
- **Mixture-of-Experts Foundation Models for Scalable Holistic Reconstruction, Modeling, and Interpretation of Particle Interactions** (William and Mary, BNL, JLab, SLAC)
- **Multi-modal and Multi-facility Application of the FM4NPP Foundation Model: Silicon Trackers and Electron Colliders** (MIT, BNL, Iowa)
- **Multimodal Enhancements to the Foundation Model for Nuclear and Particle Physics (FM4NPP)** (LLNL, BNL, Boulder, Columbia)
- **Principles of Foundation Models for Particle and Nuclear Physics** (Wisconsin, ANL, CMU, Kentucky)
- **Transforming Computing Cyber Infrastructure for Collider Experiments to AI-Based Computing and AI-Ready Data** (BNL, JLab, UPitt, UTA)