# AI for HEP Experimental Operations

Blueprint Workshop: Towards a National-Scale AI Collaboration in HEP

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Genesis Mission

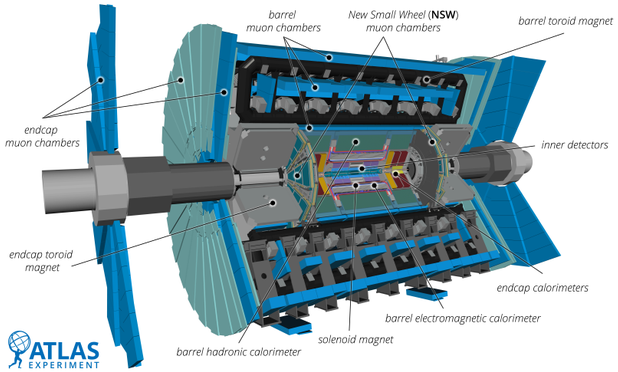
U.S. DEPARTMENT of ENERGY

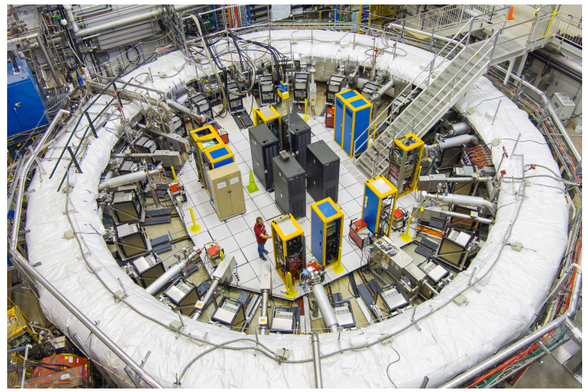
# MOTIVATION: BETTER FAULT DETECTION, LESS HUMAN EFFORT

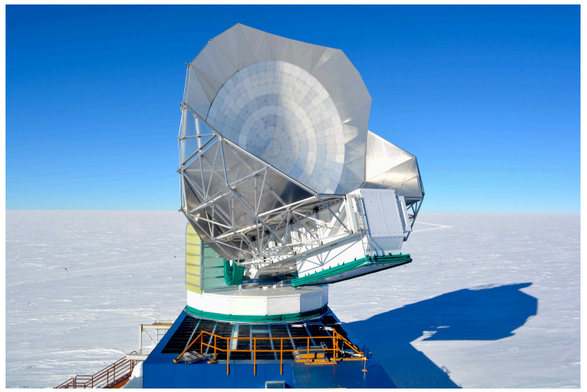
- Modern experiments produce enormous amounts of monitoring data
- Current monitoring systems include automation but require significant human effort
- Recent relevant AI/ML advances
  - Anomaly detection: we have lots of good data and don't know how future faults will look
  - Transformers: have long-term context awareness (i.e., they take past data into account)
  - Large-Language Models (LLMs): can process large bodies of documentation and logs

**Opportunity to combine different fault detection models and LLMs to find subtle patterns in high-dimensional data and to suggest corrective actions**

# OPERATIONS ACROSS HEP EXPERIMENTS



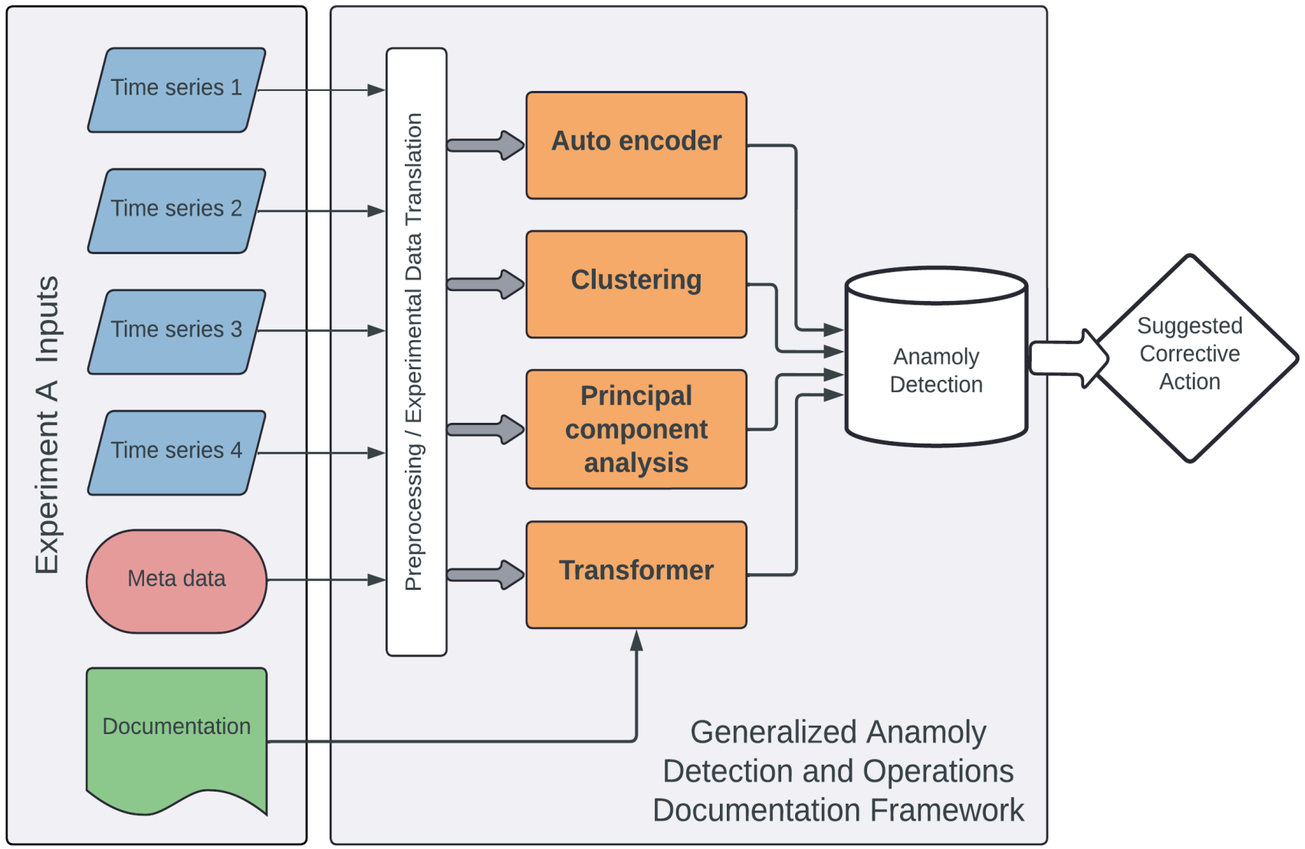





- Many HEP experiments have similar monitoring needs
- Similar data types (time series, histograms/heat maps, logs)
- Similar workflows:
  - Detect fault
  - Find and follow troubleshooting documentation
  - Log problem
  - Potentially notify and summarize problem to expert

**Develop AI methods applicable across experiments that leverages commonalities to reduce development effort and increase robustness**

# AI OPERATIONS FRAMEWORK




- Modular AI/ML models for different tasks
  - Dimensionality reduction
  - Autoencoders
  - Transformer models
- Orchestration layer to combine model outputs
- LLM integration for documentation and log parsing

**Building knowledge base of how to apply and combine AI/ML models to HEP operations**

# CURRENT STATUS AND HIGH LEVEL PLANS/TIMELINE

Recently started: fall of 2025

Current status: early-stage development

- Testing time-series transformer-based anomaly detection on data from multiple experiments
  - ATLAS, SPT-3G, CMS, Muon g-2
- Initial LLM for CMS DQM implementation

Next steps:

- Apply to more varied data from different experiments and subsystems
- Develop orchestration layer to combine model outputs (prototype agent-based system already exists)
- Work with operations experts on data delivery
- LLMs for application log parsing

# COLLABORATION BEYOND THE FUNDED PROJECT

Already have shared experiences with several groups beyond the core team

- CERN WP9.1 which focuses on AI (and specifically LLM) for operations
- chATLAS developers at UCL for LLM for operations
- ARCHI developers
- Mu2e experimentalist at Argonne and University of Virginia
- Brookhaven for ITk (initial discussions)
- Some discussions with accelerator physicists (mainly at Argonne)
- Nebraska for histogram anomaly detection
- Buffalo for similar applications

We aim to avoid duplicate effort by sharing lessons, code, and results across experiments, and our meetings are open to anyone interested in AI for HEP operations

# PLANS FOR AN EVENTUAL GENESIS PHASE 2 OR OTHER PROPOSAL

- Potentially expand with a Genesis Phase 2 in the future, beyond the expected December 2026 call
- Likely will focus on infrastructure and deployment of methods

# HOW IS THE PROJECT LEVERAGED BY THE EXPERIMENTS?

- Discussions with experiment teams are ongoing to understand their needs and integrate the developed methods
- Experts for specific experiments or subsystems are already involved in the development
  - And they are the ones implementing the models/framework for their applications