ALLEN4EIC: A Real-Time Data Processing Framework for the ePIC Detector

Town Meeting, Hadron Physics in Horizon Europe

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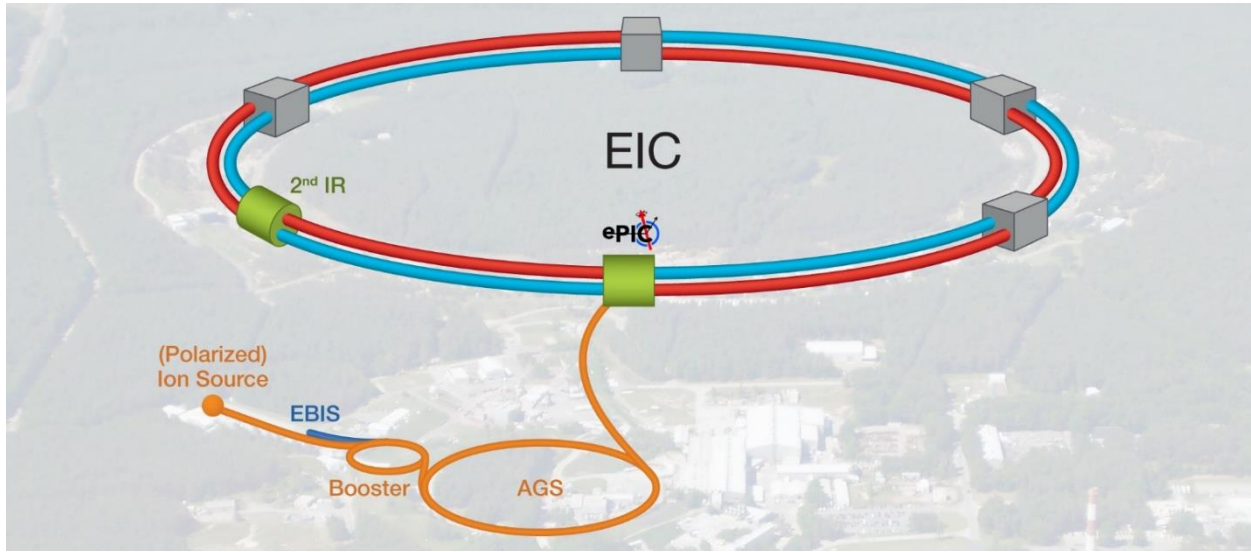
The EIC facility at BNL (NY, U.S.A.)

- Highly polarized electron / Highly polarized proton and light ions /Unpolarized heavy ions
- CME: ~ 20–140 GeV
- Luminosity: ~ $10^{33\text{-}34}$ $cm^{-2}s^{-1}$

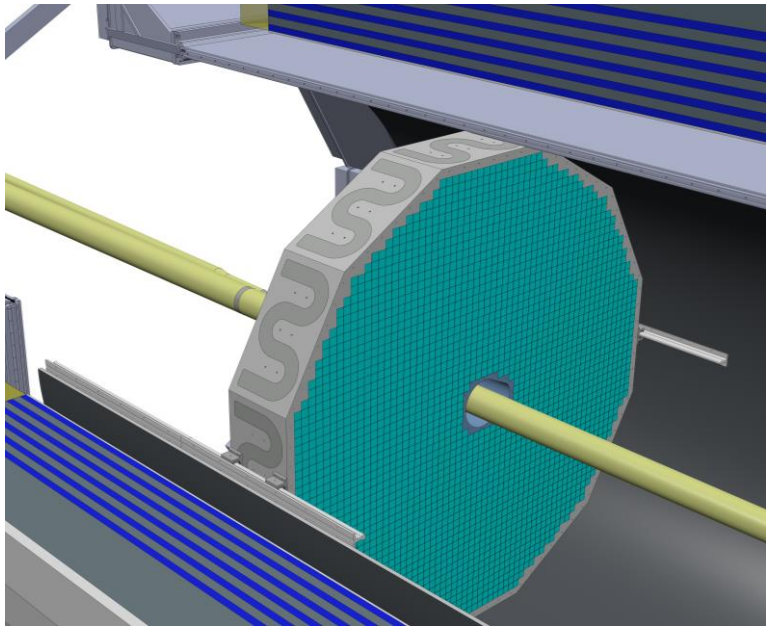


EIC detector milestones

- **Dec 2021:** Detector design
- *Currently: Detector R&D*
- End 2025: TDR completed (CD-3), start of construction
- 2030: Detector commissioning
- 2031: Pre-ops
- 2034: Start of physics program (CD-4)

- ❑ Polarized proton beams and ion beams based on existing RHIC facility
- ❑ 2 detector interaction points capability in the design

Backward Ecal in ePIC (EIC detector)

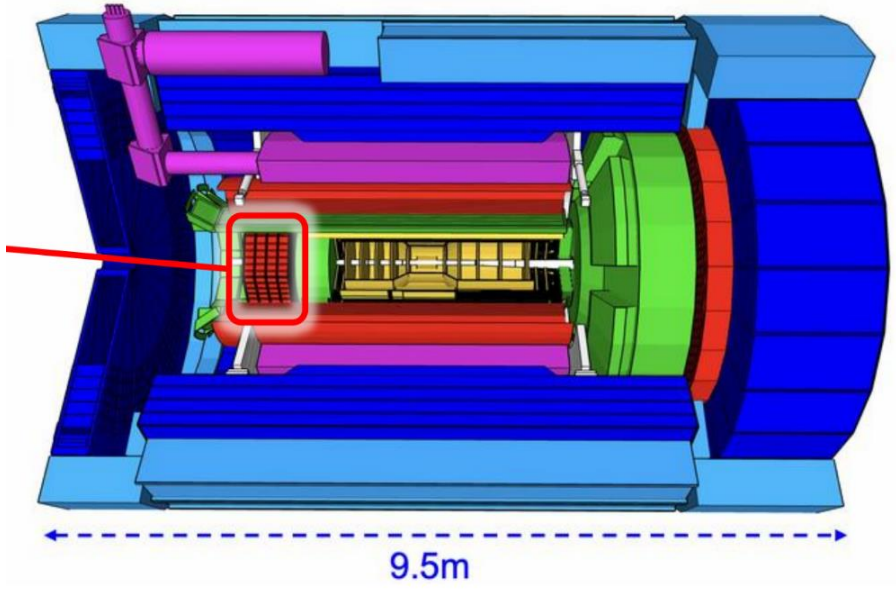


- ~3000 PWO crystals
- SiPM readout
- Cooling
- LED monitoring

Requirements:

- Energy resolution: $2\%/\sqrt{E} + (1\text{-}3)\%$
- Pion suppression: $1{:}10^4$
- Minimum detection energy: > 50 MeV

High resolution only achieved with homogeneous materials, such as crystals

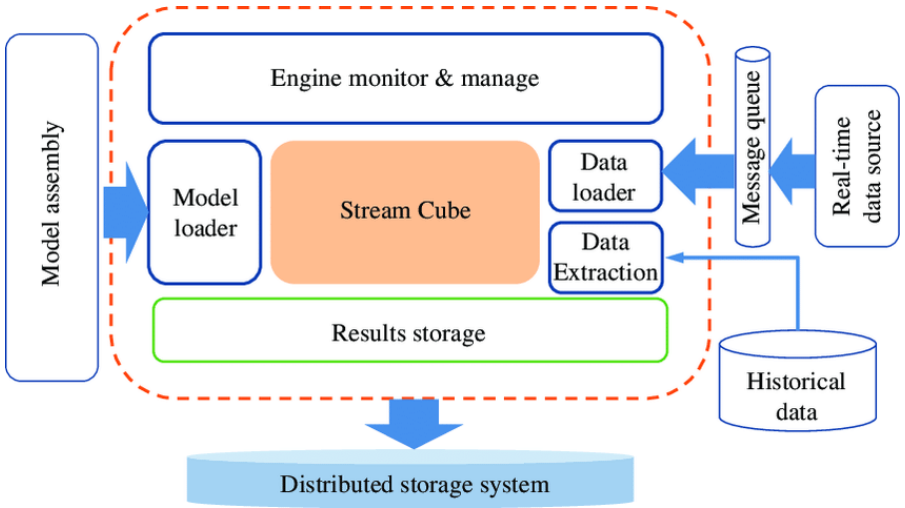


In situ calibration:

- $\pi^0 \rightarrow \gamma\,\gamma$
- Single electrons (& tracker info)
- MIPs

Why Real-Time Processing at the EIC?

- ePIC uses streaming readout, no hardware trigger.
- Enables autonomous calibration, fast alignment, low-latency reconstruction.
- Requires scalable GPU-based processing for real-time physics workflows

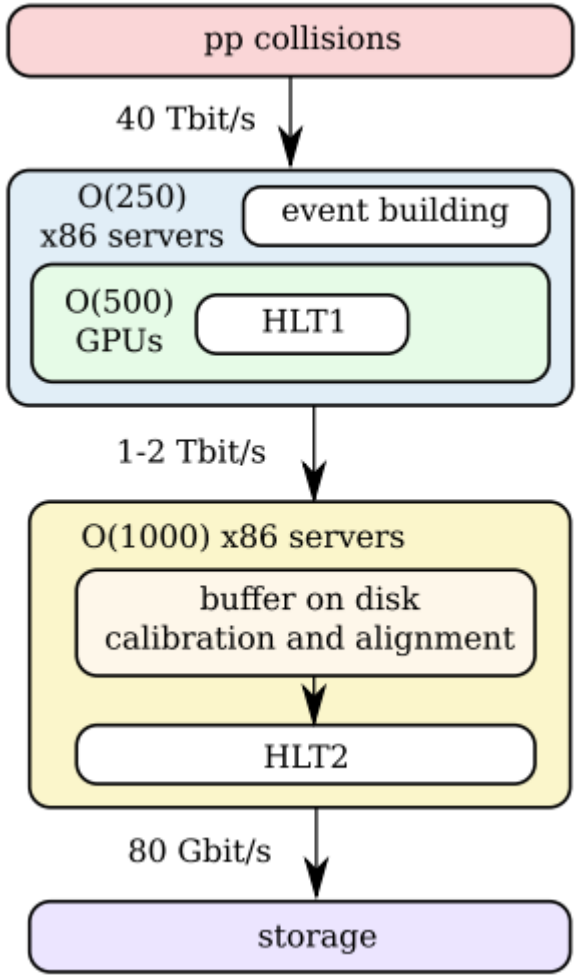


The ePIC detector's streaming architecture opens new possibilities for fast analysis, but demands a shift in how we process data. We're moving from post-processing to real-time processing, integrating AI and calibration algorithms on-the-fly.

Allen Framework: Proven at the LHCb Experiment

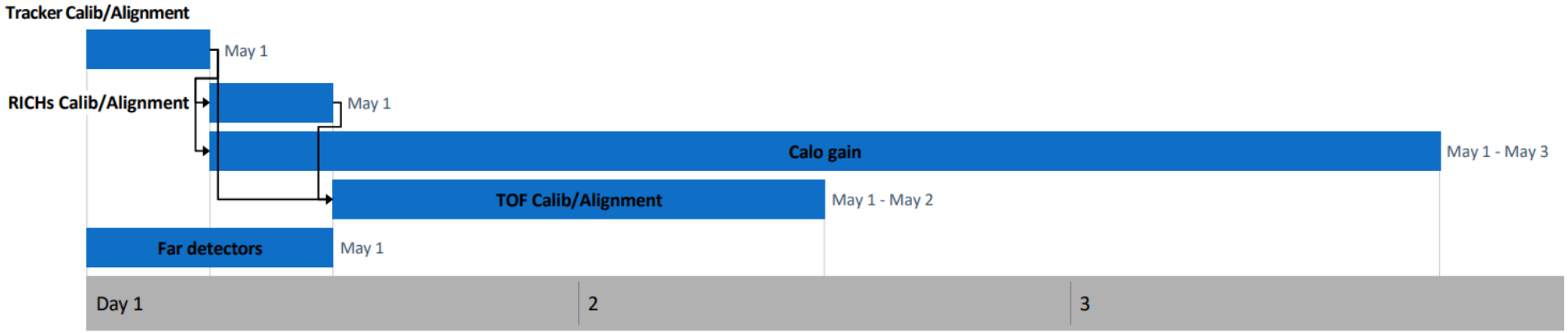
- Developed for GPU-based high-level triggering at LHCb.
- Processes 30 million events/sec using commodity GPUs.
- Cross-platform (x86, CUDA, ARM); Python + C++/CUDA.
- Includes monitoring, high energy-efficiency.

Allen replaces hardware triggers using GPUs and high-performance software. It's portable, open-source, and energy-efficient. Perfect candidate for EIC-style real-time computing.



Adapting Allen for the ePIC Detector

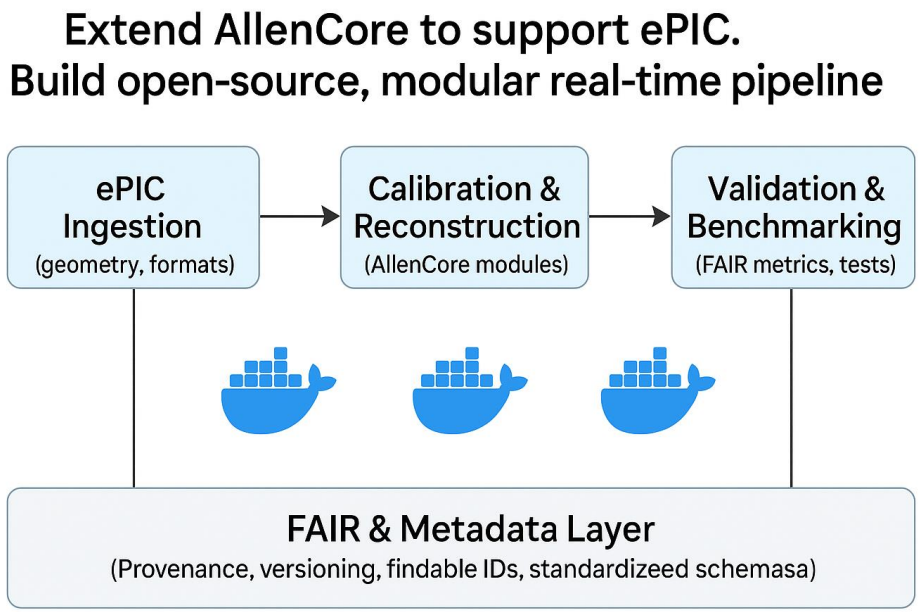
- At ePIC: Allen shifts from trigger filter to real-time reconstruction tool.
- First use: calibration for the backward EM calorimeter.
- Will support ePIC data model, geometry, streaming architecture.
- Built on AllenCore (modular version, expected Q1 2026).



At ePIC, Allen will operate downstream, not just filtering but reconstructing and calibrating in real time, a new mode of use, but one Allen is well-suited for.

ALLEN4EIC: Key Objectives

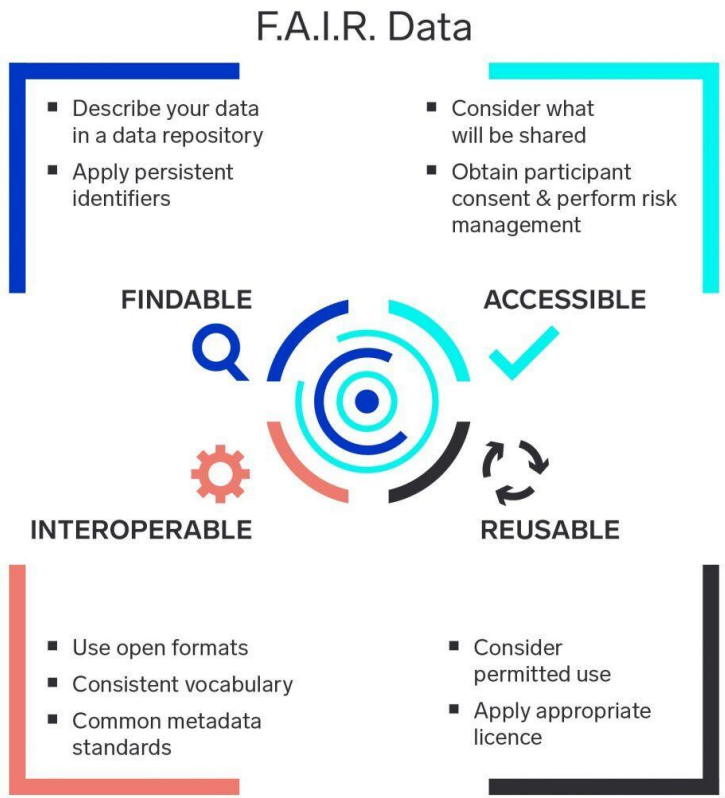
- Extend AllenCore to support ePIC.
- Build open-source, modular real-time pipeline:
- - ePIC integration (geometry, formats)
- - Calibration and reconstruction
- - Validation and benchmarking tools
- Containerized and FAIR-compliant.



The idea is not just a one-off application but a reusable software service that can be deployed on any compatible infrastructure.

Scientific and Infrastructure Impact

- Open Virtual Access model with reusable tools.
- Training: in-person and online workshops.
- Integrated with EOSC and FAIR data practices.
- Enables wide adoption in hadron physics community.



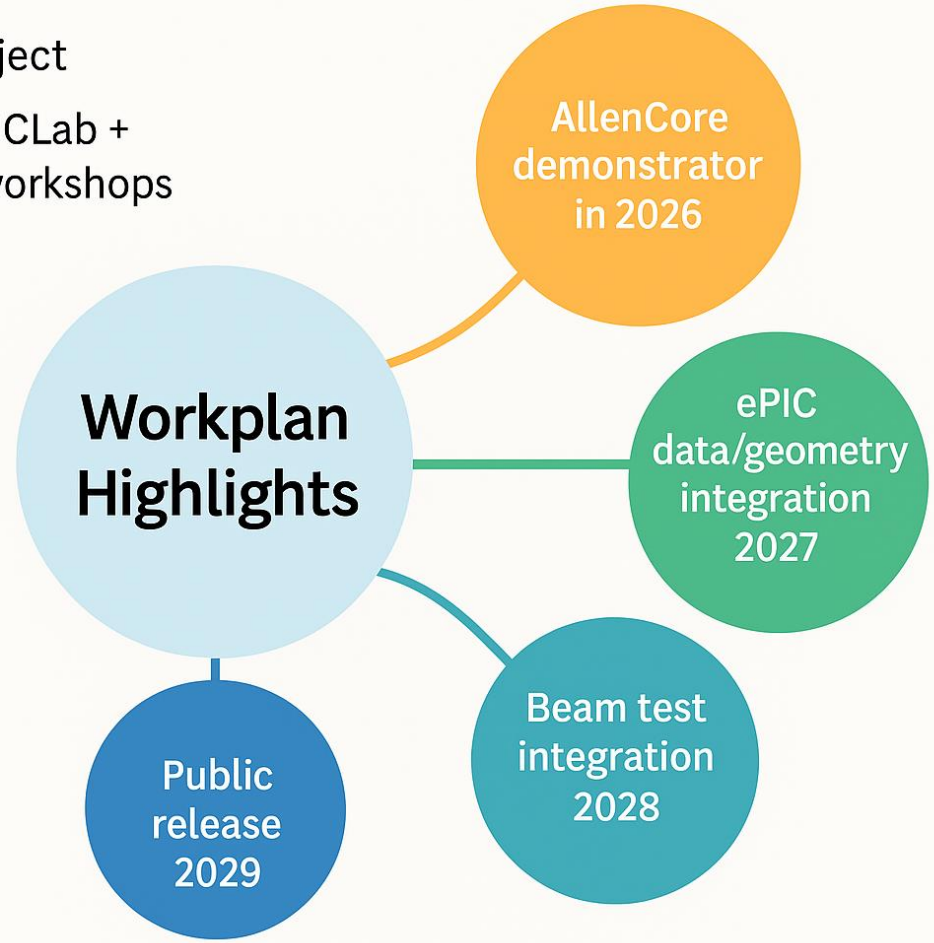
The project promotes reproducibility, collaboration, and skills development, aligned with Horizon Europe and the European Open Science Cloud (EOSC) goals.

A Strong, Cross-Institutional Consortium

- IJCLab – ePIC adaptation & calorimetry
- LPNHE & CPPM – Allen developers (LHCb)
- INFN Genova – Streaming readout expertise
- CERN – AllenCore support
- Jefferson Lab – Integration and test at EIC

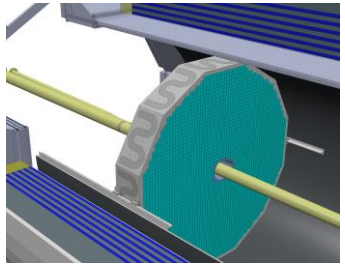
Work Plan Highlights

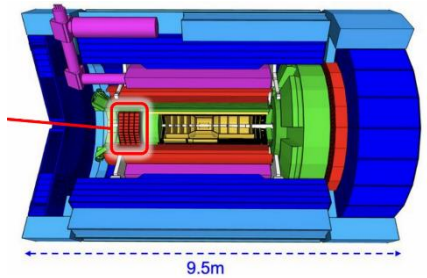
- 36-month project
- 1 postdoc at IJCLab + €60k travel/workshops

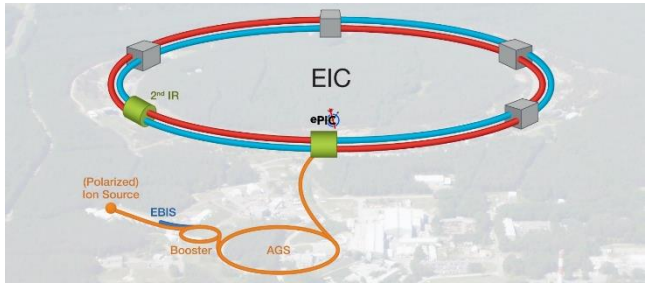


Back up

ALLEN4EIC: Virtual Access to Real-Time Data Processing for the EIC







Objective:

Adapt the Allen real-time processing framework (from LHCb) to the ePIC experiment at the Electron-Ion Collider (EIC) — creating open, high-throughput processing tools for the nuclear physics community.

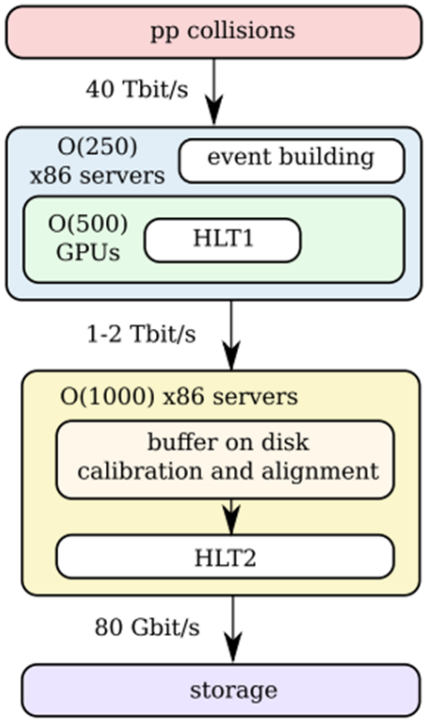
Key Features:

- GPU-based, heterogeneous computing for scalable, low-latency workflows
- Autonomous calibration and reconstruction for ePIC's streaming architecture
- Emphasis on Virtual Access (VA): remote, reusable software services for real-time analysis
- First use case: calibration of ePIC's backward electromagnetic calorimeter

Core Deliverable:

A modular, containerized, open-source platform providing Virtual Access to real-time pipelines and validation tools — advancing FAIR and reproducible research in hadron physics.

ALLEN4EIC: Virtual Access Impact, Infrastructure & Team



Virtual Access Impact:

- Publicly released pipelines, tools, and documentation via community repositories
- Accessible training resources (online + in-person) for high-throughput computing
- Integrated with the **European Open Science Cloud (EOSC)** for long-term sustainability
- Researchers across Europe can **run, adapt, and validate workflows remotely**

Broader Impact:

- Enhances EIC computing infrastructure at Brookhaven (BNL)
- Reduces data volumes and accelerates time to physics
- Demonstrates Allen's value beyond LHCb in a new domain

Partners:

- **CNRS/IN2P3:** IJCLab (C. Muñoz), LPNHE (V. Gligorov), CPPM (D. vom Bruch)
- **INFN-Genova** (streaming DAQ integration)
- **Jefferson Lab** (ePIC SRO/testing)
- **CERN/LHCb** (AllenCore adaptation)

Budget Request:

- 1 Postdoc (36 months @ IJCLab)
- €60,000 for international collaboration, training workshops, and CERN coordination

Title