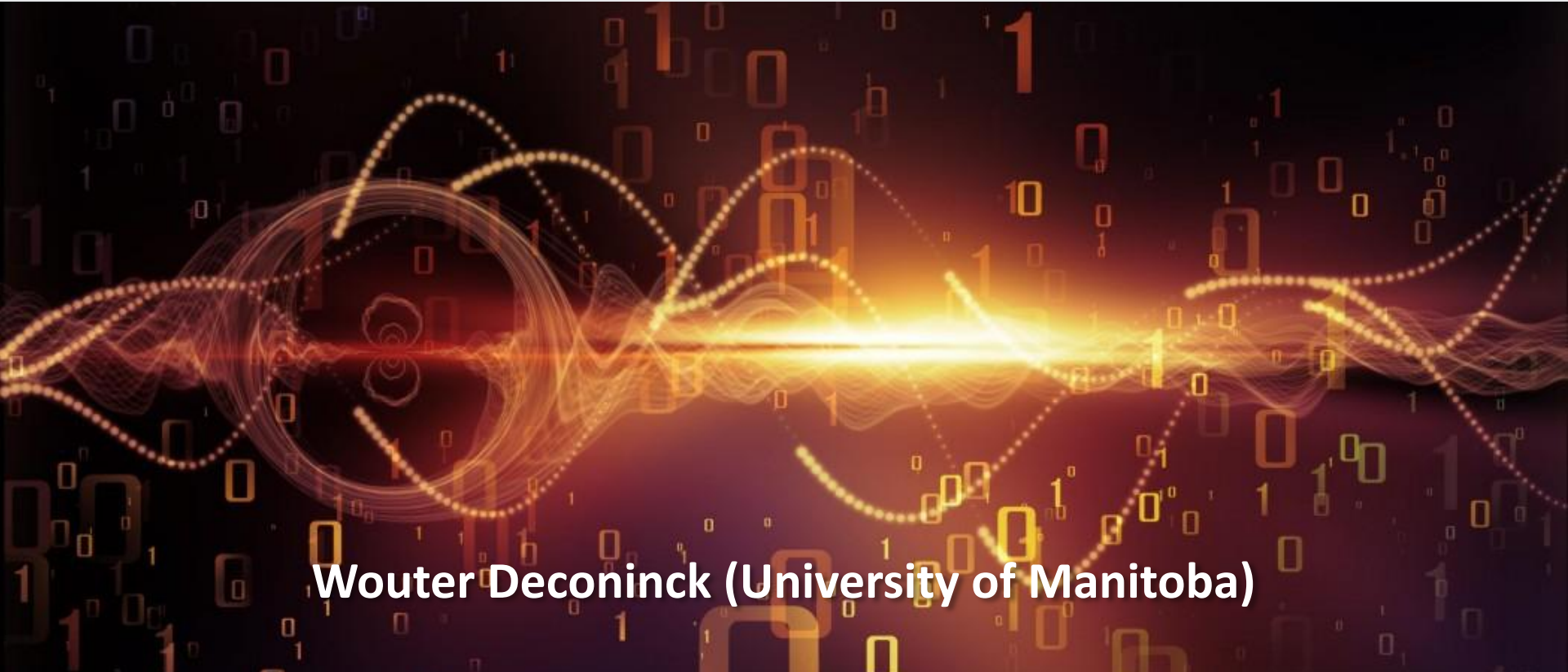
Working with the Broader Community



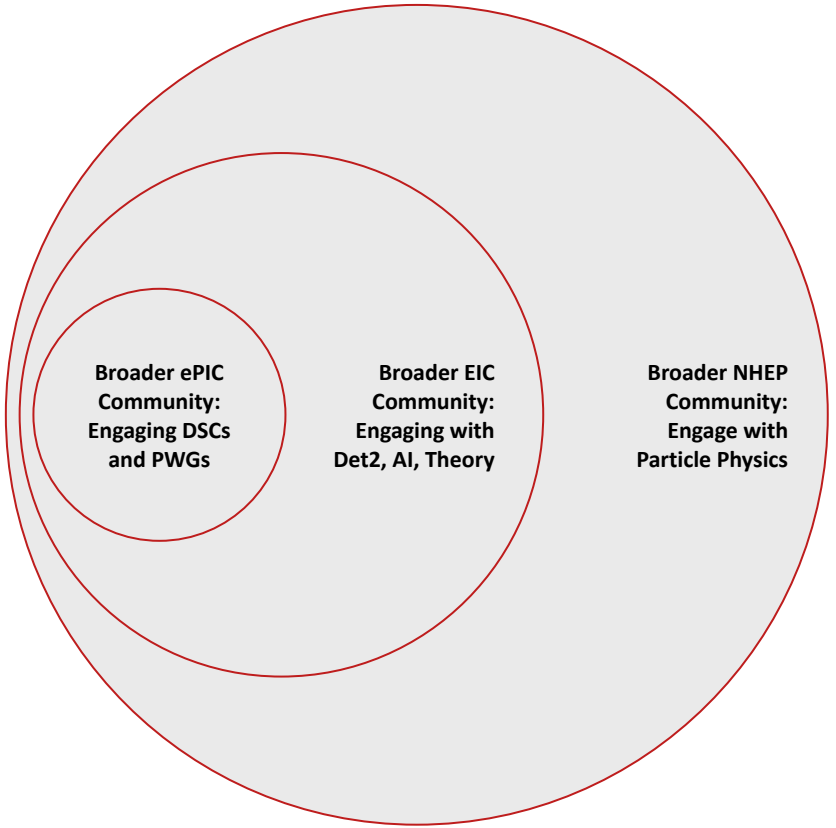
Wouter Deconinck (University of Manitoba)

Summary Upfront

Charge:

4. Broader Community

Assess as appropriate engagements with aligned Software and Computing organizations across nuclear physics and particle physics communities and other relevant communities.



Summary Upfront

Broader ePIC Community: Engaging DSCs and PWGs

ePIC Software & Computing is engaging the full collaboration in development

- Successful **landing page** for onboarding new collaboration members.
- **Tutorials inside the collaboration** built to onboard detector experts and analyzers into the software framework, organized by User Learning working group.
- **Continuous integration** and **deployment** of software efforts to reduce time from contributions by experts to output in nightly environment and monthly campaigns.

Broader EIC Community: Engaging with Det2, AI, Theory

ePIC Software & Computing is engaging with other EIC communities

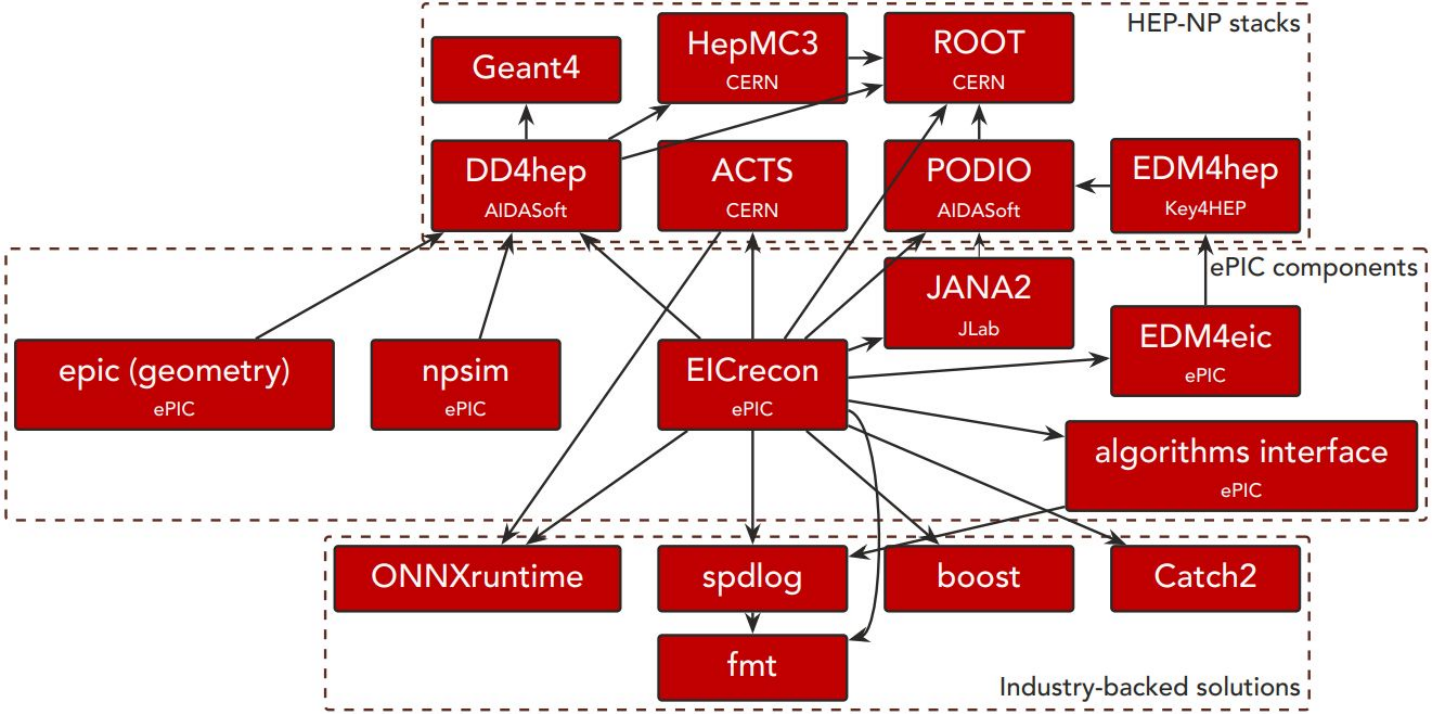
- **Tutorials on general applicability of EIC software** at CFNS/EIC/CTEQ summer schools
- **Community expansion** through workshops, including recent **HSF-India/ePIC meeting**.
- Engagement with AI4EIC workshops series, with bidirectional exchange of expertise.

Broader NHEP Community: Engage with Particle Physics

ePIC Software & Computing is engaging external software projects and compute providers

- **Active engagement in community software dependencies:** ACTS, Key4HEP, etc.
- **Active engagement in compute providers in the US and abroad:** OSG, Italy, Canada, etc.
- **Participation and leadership in global NHEP software ecosystem:** HEP Software Foundation; representation at CHEP and other computing conferences and workshops.

The ePIC Software Stack and Key Dependencies: Modular Components



A **modular software stack** with interdependent components with well-defined interfaces **avoids lock-in** but requires **full-stack testing**, validation, benchmarking.

Working With Broader Communities

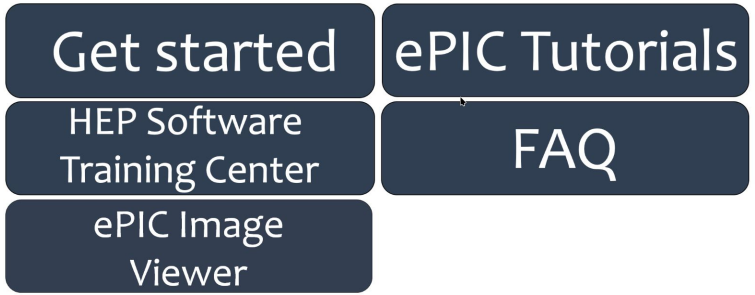
Broader ePIC Community: Engaging DSCs and PWGs

Broader EIC Community: Engaging with Det2, AI, Theory

Broader NHEP Community: Engage with Particle Physics

Documentation/tutorials for beginner/advanced

- Main page on EIC software: eic.github.io,
- Main page on ePIC collaboration: epic-eic.org
- Landing page with starting sources of info: eic.github.io/documentation/landingpage.html
- Tutorials: formatted based on the swcarpentry format (old version)

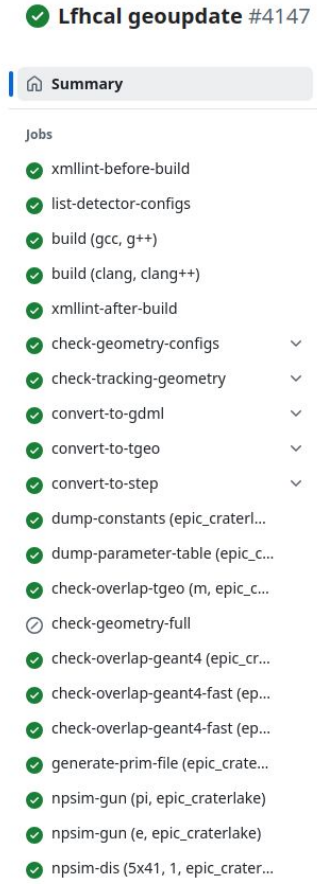


Current tutorials are summarised in the table below -

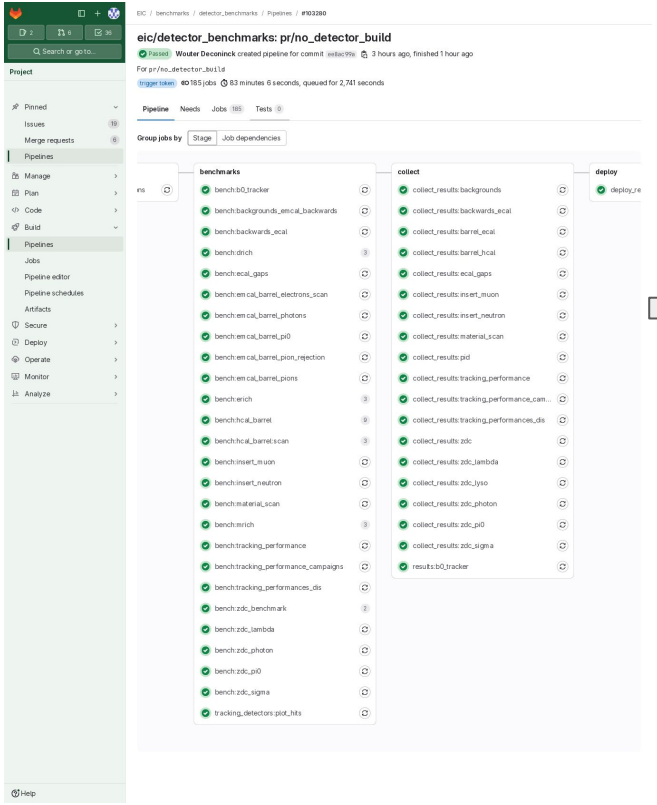
Tutorial	Difficulty	Tags
Setting up an environment	Beginner	[Setup] [Environment]
Analysis and simulation output	Beginner/Advanced	[Analysis] [Data]
Simulating detectors	Expert	[Simulation] [Detector] [DD4hep]
Modifying geometry and digitization	Advanced	[Geometry] [Digitization]
Understanding simulation output	Advanced	[Simulation] [Data]
Getting started with physics analysis	Advanced	[Physics] [Analysis]
Inclusive kinematics reconstruction	Advanced	[Reconstruction] [Kinematics]
Reconstruction algorithms	Expert	[Algorithms] [Reconstruction]
Developing benchmarks	Expert	[Benchmarking] [Performance]
Simulations with npsim and geant4	Advanced	[Simulation] [Geant4] [npsim]
Reconstruction framework	Expert	[Framework] [JANA2] [Reconstruction]
Analysis bootcamp	Advanced	[Python] [Analysis] [Bootcamp]

Full-Stack Testing, Validation, Benchmarking Workflow

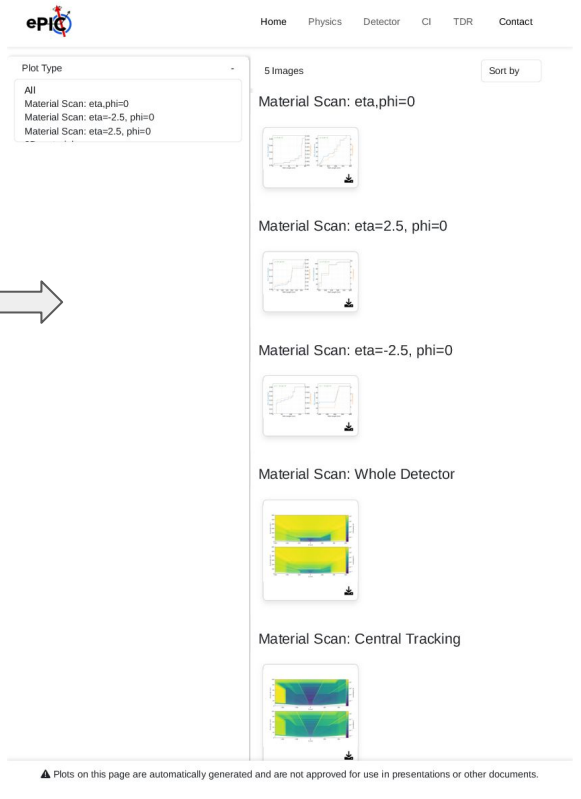
Code change on GitHub



Benchmarking on Gitlab



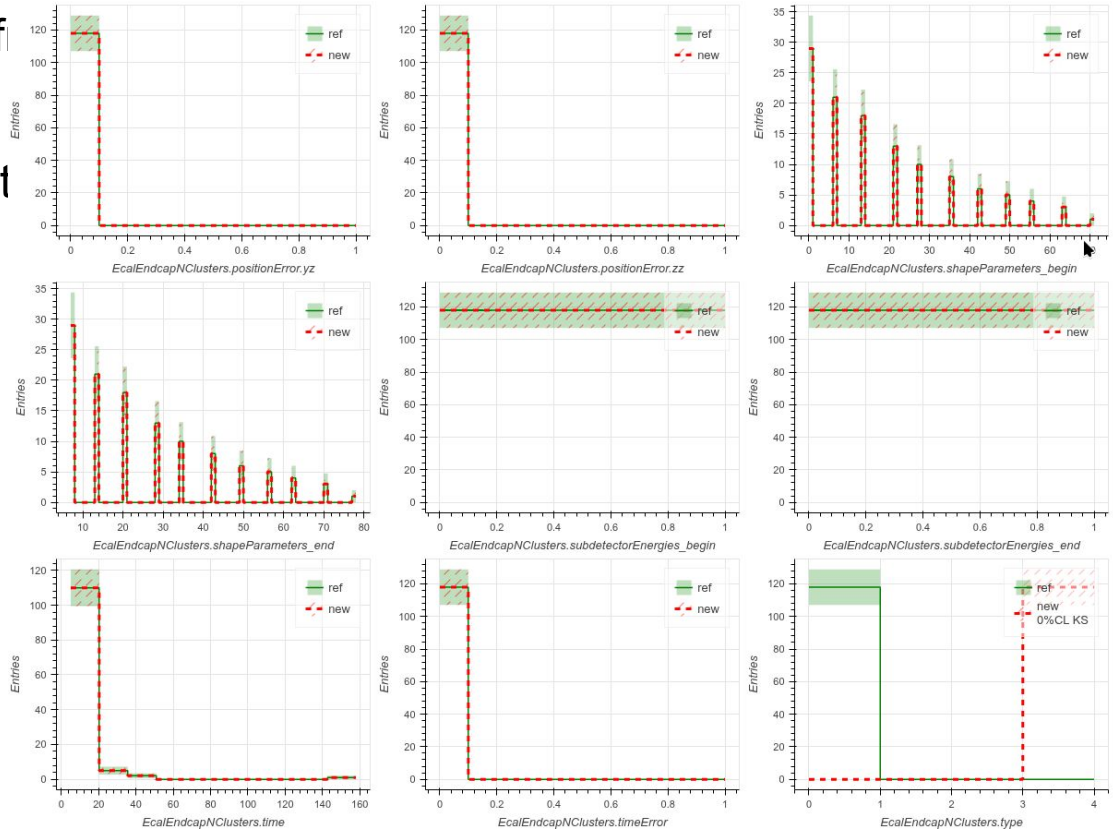
Presentation Interface



Capybara: Artifact Comparisons for Pull Requests

Automatic comparison of artifacts f
target branch

Ranked by confidence level on stat



User Learning

Successful Landing Page for Onboarding

- Many new collaborators successfully onboarded themselves using only the landing page.
- Regarded as a *"game changer"* by Physics Analysis Coordinators:
  - Significantly improved engagement and progress in the Physics WGs.

Any member of the collaboration can **directly contribute by submitting change requests**.

Tutorial Series Continues

- **Understanding the Simulation Output** (Shujie Li): How is the information in the simulation output generated (algorithms, data model)?
- **Analysis and Working with the Simulation Output** (Stephen Kay 🇬🇧): How to work with the simulation output for detector and physics studies?
- **Getting Started with a Physics Analysis** (Alex Jentsch): How does one get started with a physics analysis based on the simulation output?
- **Inclusive Kinematics Reconstruction** (Stephen Maple 🇬🇧): How can one obtain the most accurate information about inclusive DIS kinematics?

Community Building

Regular meetings to drive forward priority targets and provide an avenue for new collaboration members to engage.

Summary: Status and plans for software and simulations; preparations for first ePIC Software & Computing review.

Summary: Status and plans for software and simulations, including TDR priorities, tutorials; streaming computing; software projects with HEP.

Working With Broader Communities

Broader ePIC Community: Engaging DSCs and PWGs

Broader EIC Community: Engaging with Det2, AI, Theory

Broader NHEP Community: Engage with Particle Physics

Open Formats and Discoverability: Reaching Broader Communities

EIC Statement of Software Principles (based on user-centered design)

> "5. Our data formats are **open**, **simple** and **self-descriptive**"

Goal:

- Interoperability with broader communities without imposing barriers to data access

Implementation:

- Flat data structures, self-descriptive names, metadata included along with data
  - Flat TTree data structures readable by `uproot` and ROOT alike
  - ONNX for model interchange, generated by all major ML platforms
- Immediately accessible from common AI/ML toolkits, from variety of ecosystems
  - PyHEP and `scikit-hep` toolkits used extensively within ePIC
  - Usable (and used) in ML with jax, tensorflow, torch, xgboost, and TMVA, Sofie
- Public access to environments and monthly simulation production campaigns
  - Singularity/docker/podman container, XRootD data storage with anonymous access

Outcomes:

- Hackathons/tutorials with **very low barrier to entry** (no pre-installation needed)

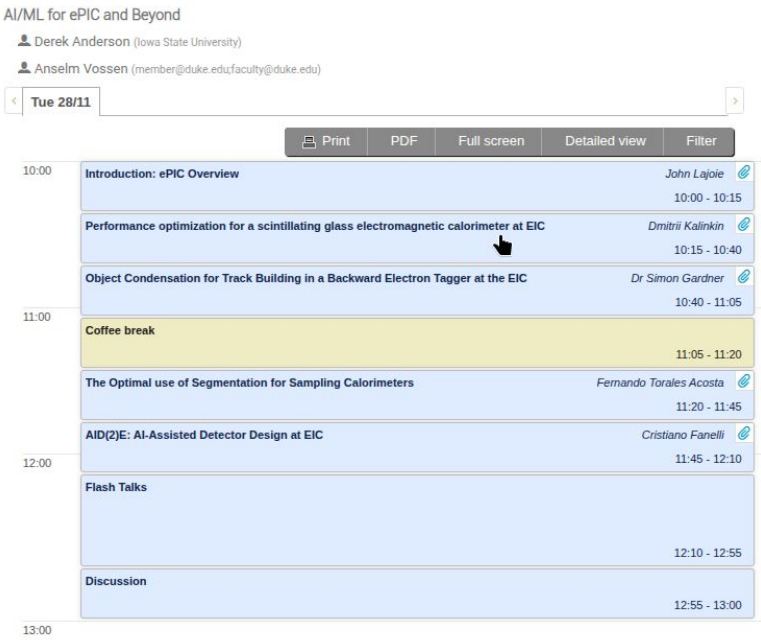
ePIC AI Town Halls, ePIC AI Hackathons, and AI4EIC 2021–Present

ePIC AI Town Halls and Hackathon: semi-annual showcase of the use of AI/ML within ePIC, open to outside attendees

- January 2025 (WAITH): Barrel Imaging Calorimetry; data reduction with AI; GNNs for hadronic calorimetry
  - Hackathon: Low-Q2 momentum regression, PID classification in the DIRC
- September 2025 (FAITH): AI strategy within ePIC; AI-assisted software development

AI4EIC: annual workshop on the use of AI in EIC science (accelerator, theory, ePIC experiment, etc)

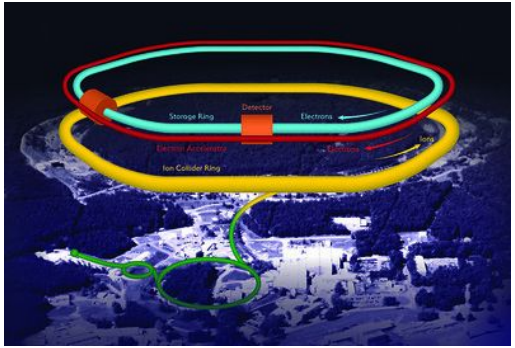
- Focus on combining AI/ML model developers with knowledge domain experts
- Contributions from cross section of AI activities within ePIC working groups



CFNS-CTEQ Summer School and MC4EIC Workshops

Annual **CFNS-CTEQ summer school** targeted at EIC experimentalists (ePIC, Detector-2, and polarimeters), theorists, and accelerator scientists.

- Inclusion of multi-day tutorials series on the ePIC software ecosystem as the *de facto* EIC software environment, with use cases for all EIC scientists including theory



Annual **MC4EIC workshops**:

- Status of Monte Carlo event generators for the Electron-Ion Collider and their related experimental needs
- Inclusion of Rivet tutorial and analysis session
- Inclusion of Rivet hackathon for new analyses on ep and ed data

Working With Broader Communities

Broader ePIC Community: Engaging DSCs and PWGs

Broader EIC Community: Engaging with Det2, AI, Theory

Broader NHEP Community: Engage with Particle Physics

HEP Software Foundation: Participation in the NHEP Software Community

HEP Software Foundation (HSF) facilitates cooperation and common efforts in High Energy Physics software and computing internationally.

The EIC has been an active and equal partner to the HEP projects in the HSF activities.

Joint activities:

- HSF-India/ePIC workshops
- Software & Computing Round Table meetings (EIC-wide)
- Future Trends in Nuclear Physics Computing workshops (EIC-wide)

HSF roles held by ePIC collaborators:

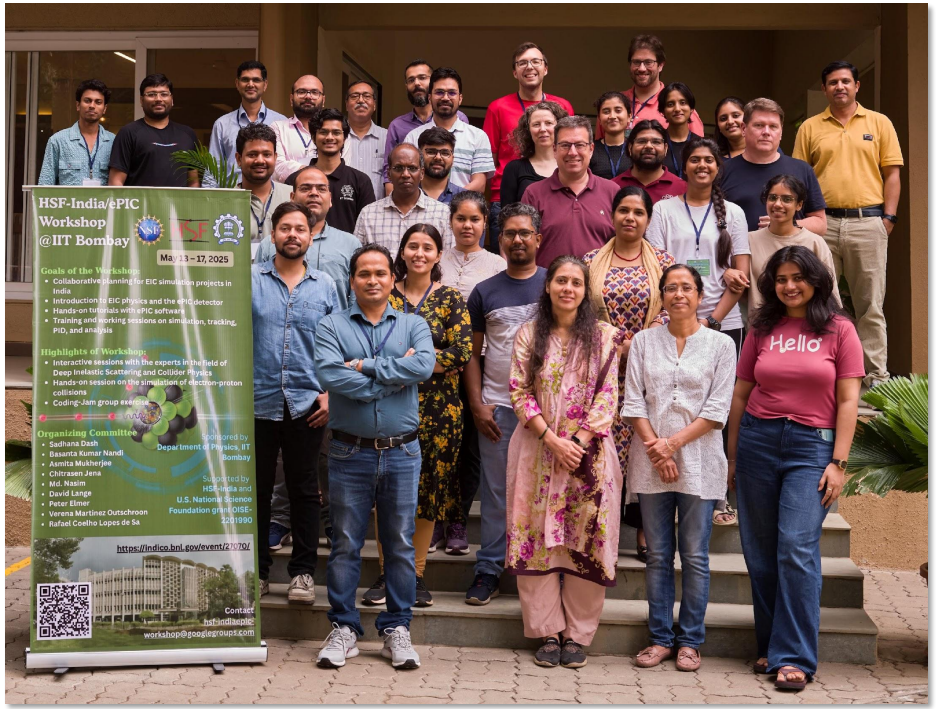
- Training WG: conveners, instructors, mentors, and facilitators
- Physics Generators WG: conveners
- Detector Simulation WG: conveners
- Reconstruction and Software Triggers WG: conveners
- Software Developer Tools and Packaging WG: conveners
- Google Summer of Code: mentors, program coordinators
- Affiliated Projects and Software: reviewers

Community Building in India

The HSF-India project aims to join networks in India to networks in the U.S. and Europe in order to build international research software collaborations.

HSF-India/ePIC Meeting

- **Five introductory talks covering** the EIC and the science it will enable, a theory perspective on spin physics, EIC/ePIC in India, research software collaborations, and contributing to ePIC.
- Several long-format tutorials by:
  - Chandradoy Chatterjee (INFN Trieste)
  - Stephen Kay (University of York)
  - Charlotte Van Hulse (University of Alcalá)
- **Meeting Survey**: Students found the workshop content very useful and appropriately paced.
- Planning a hackathon-style follow-up end of October 2025 to encourage students to initiate their own projects.



44 registered participants, including 33 master's and doctoral students
Students from: Central University of Karnataka, Central University of Tamil Nadu, IIT Bombay, IIT Indore, IIT Madras, IIT Mandi, Malaviya National Institute of Technology, Ramaiah University of Applied Sciences

Key4HEP: Turnkey Software for Future Colliders

The Key4hep project focuses on providing the necessary infrastructure and central components that allow the different communities to develop their reconstruction and analysis algorithms and workflows.

Contributions:

- Frequent contributions to podio, EDM4hep, DD4hep, k4-spack, k4fwcore, k4actstracking

Coordination

- Monthly North America-friendly Key4HEP meetings
- Active in discussions in key4hep mattermost

Milestones

- Multithreaded `ddsim` running (taking advantage of multithreading in Geant4)
  - https://github.com/AIDASoft/DD4hep/pull/1240
  - Technically still in progress since running modes outside of ePIC require some work
- Integration of Celeritas and DD4hep: development of DD4hep plugin
  - https://github.com/celeritas-project/celeritas/pull/1756
  - (more on this later)

ePIC

ROOT: Our Data Storage Layer

We aim for integration both with the AI/ML ecosystem outside of ROOT, as well as with the tools that ROOT provides. Our output storage uses POD collections (podio) stored in ROOT TTrees and/or RNTuples.

Contributions:

- Bugfixes addressed and upstreamed (e.g. TGeoTessellated facet determination, k630ForwardCompatibility, nullptr in TTreePlayer::Restart, qemu emulation)

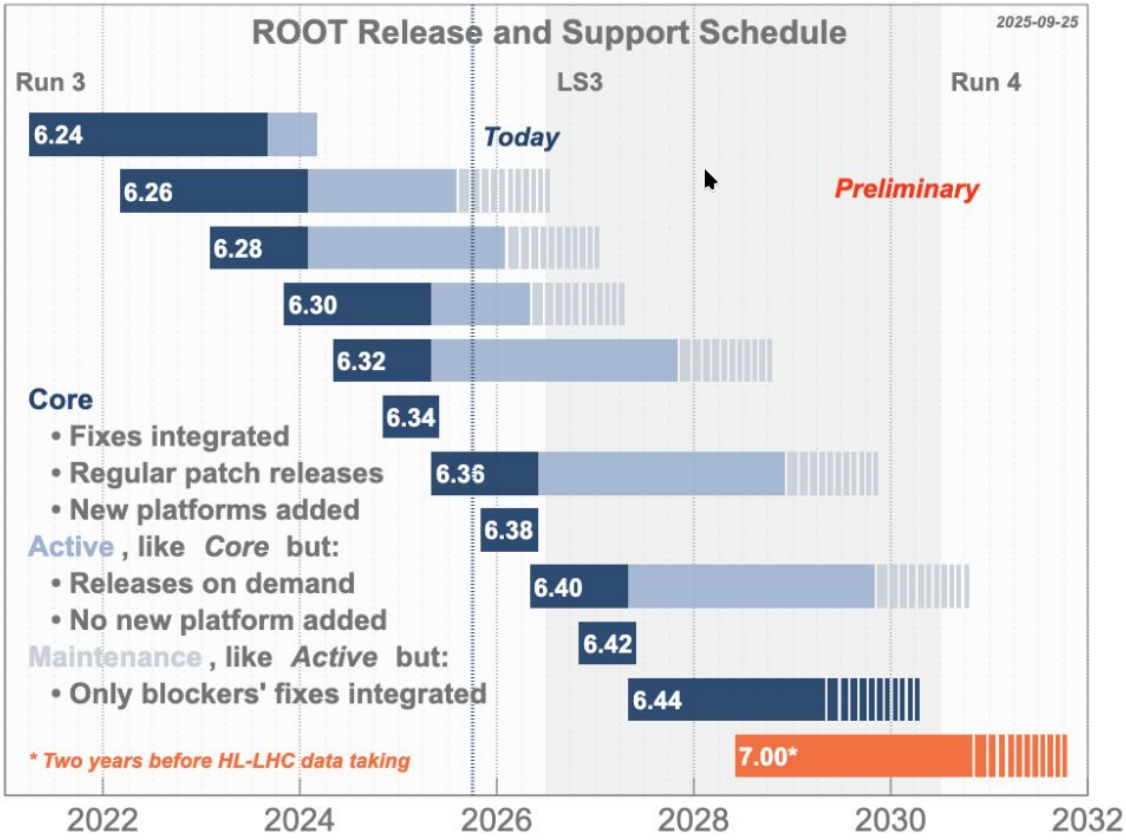
Coordination:

- Active in discussions in ROOT mattermost
- Feedback on Quarterly Planning Meetings as large experimental user:
  - Intentional support window strategy discussed at ROOT Q2 2025
    “A release and support plan is proposed until the start of Run 4”
    “Thanks to ePIC for proposing the idea of providing one”
- Attendance with invited talk at ROOT Users Workshop 2025

Milestones:

- Evaluated anticipated benefits from RNTuple support in Key4HEP (podio) and DD4hep: approximately 50% smaller output files in a direct TTree to RNTuple conversion

ROOT: Our Data Storage Layer



Geant4: Simulation of the Passage of Particles Through Matter

Geant4 is currently and is projected to remain the workhorse for ePIC simulations. We benefit from global development on Geant4, from extensive physics validation, and from increasing accuracy. We also intend to benefit from ongoing efforts to increase sub-event level parallelism.

Synergistic opportunities:

- Looking forward to sub-event level parallelism in Geant4, and contributing to this through efforts of the JLab group

Coordination:

- Attendance at Geant4 collaboration meetings and representation in user forum
- Area of active research and engagement by JLab group (M. Asai)
- Submission of bug reports on bugzilla

Milestones:

- Upgraded to Geant4 11.3.2 (after some bug fixes contributed and applied)

Spack: Package Management for HPC and HTC Systems

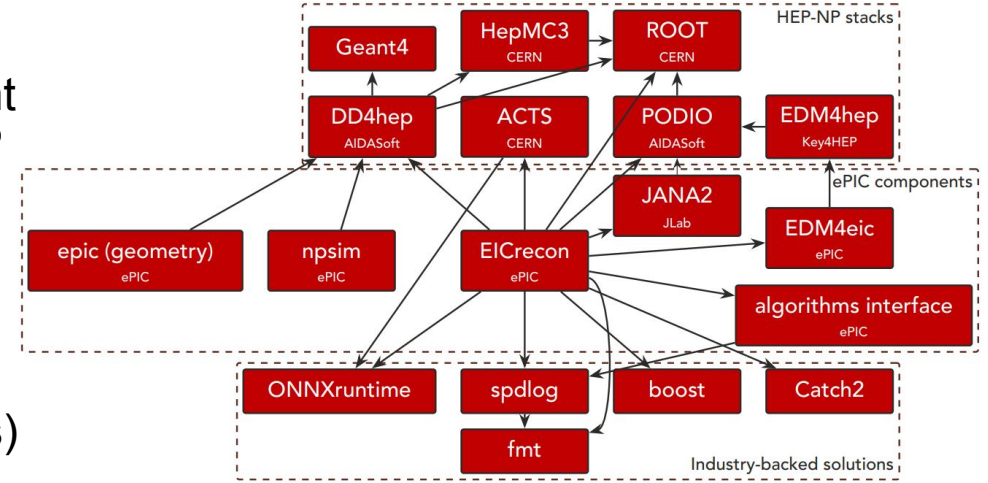
Spack is a package management tool designed to support multiple versions and configurations of software on a wide variety of platforms and environments.

Synergistic opportunities:

- Melding of packaging and deployment approaches in HPC, HTC, and NHEP

Coordination:

- Active in discussions in Slack spack, with dedicated #hep channel
- Membership in Technical Steering Committee (monthly project meetings)



Milestones:

- Built active NHEP community within Spack, incl. representation from Key4HEP
- EIC represents NP workflows on Spack TSC (others at FNAL also represent HEP)
- Spack CI pipeline for large NHEP environments on matrix of CPU, CUDA archs

Opticks : GPU Accelerated Optical Photon Simulation using NVIDIA OptiX

Opticks is a framework for tracking of optical photons using NVIDIA OptiX on RT cores, or on CUDA cores. It allows significant speedup of optical photon simulations and integrates with Geant4. Originally developed for JUNO.

Synergistic opportunities:

- Optical photons in DIRC bars are secondary sink of compute resources, in particular for generation of large lookup tables
- Also useful for RICH simulation and reconstruction

Coordination:

- Frequent mailing list exchanges with opticks developer
- Area of active research and engagement by BNL NPPS group

Milestones:

- EIC-Opticks, https://github.com/BNLNPPS/eic-opticks, fork of opticks https://github.com/simoncblyth/opticks for EIC applications (pfRICH)
- Available as spack package for integration in other environments

ePIC

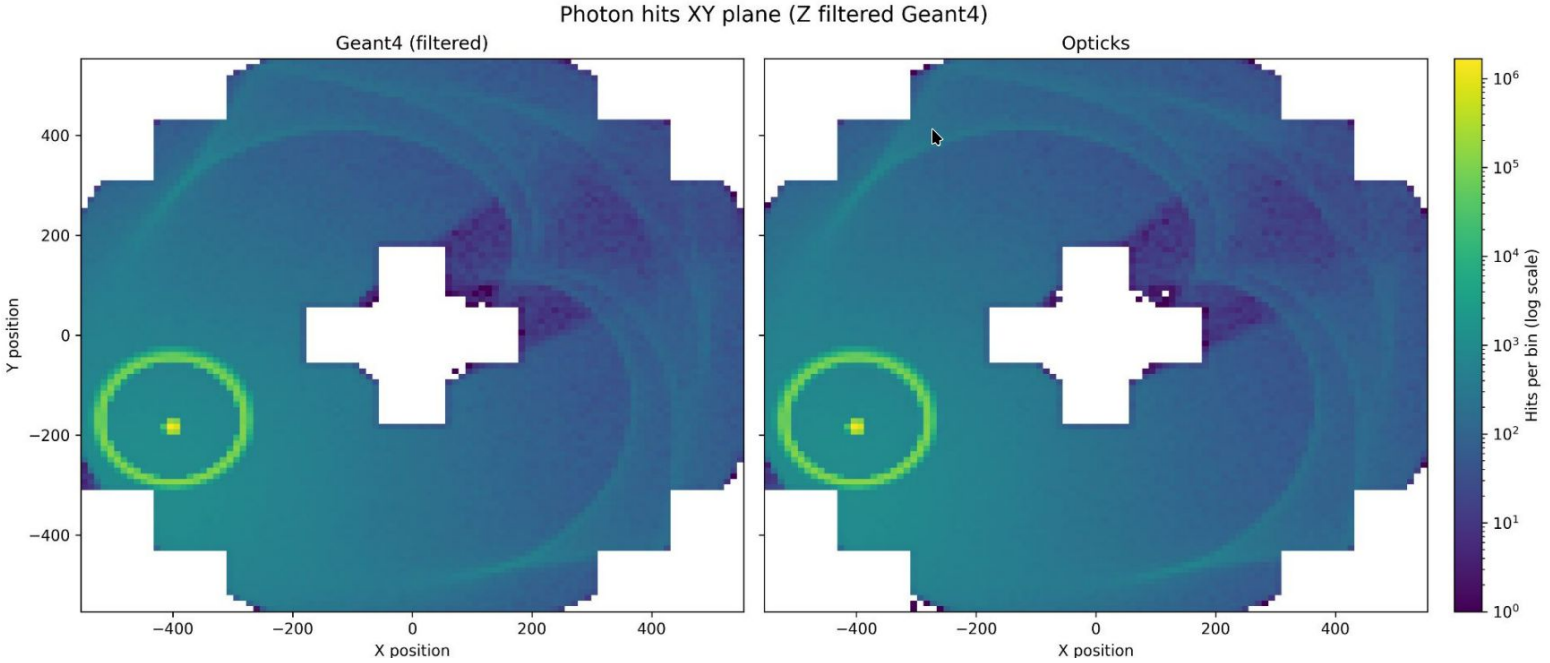
Opticks : GPU Accelerated Optical Photon Simulation using NVIDIA OptiX

Milestones:

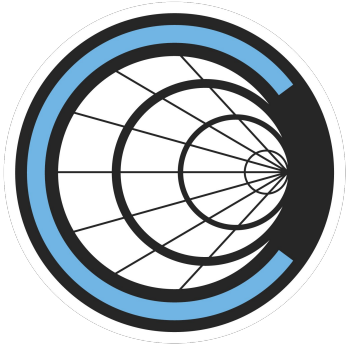
- demonstrated 137x speed increase over single-threaded optical photon running

Geant4 generated

EIC-Opticks (GPU) generated



Celeritas: GPU-accelerated High Energy Physics Monte Carlo simulation



Celeritas is a new Monte Carlo transport code designed to accelerate scientific discovery in high energy physics by improving detector simulation throughput and energy efficiency using GPUs

Synergistic opportunities:

- Electromagnetic showers are main sink of simulation compute resources; offloading on GPU is a promising approach
- Optical photons in DIRC bars are secondary sink of compute resources, in particular for generation of large lookup tables; also for RICH reconstruction

Coordination:

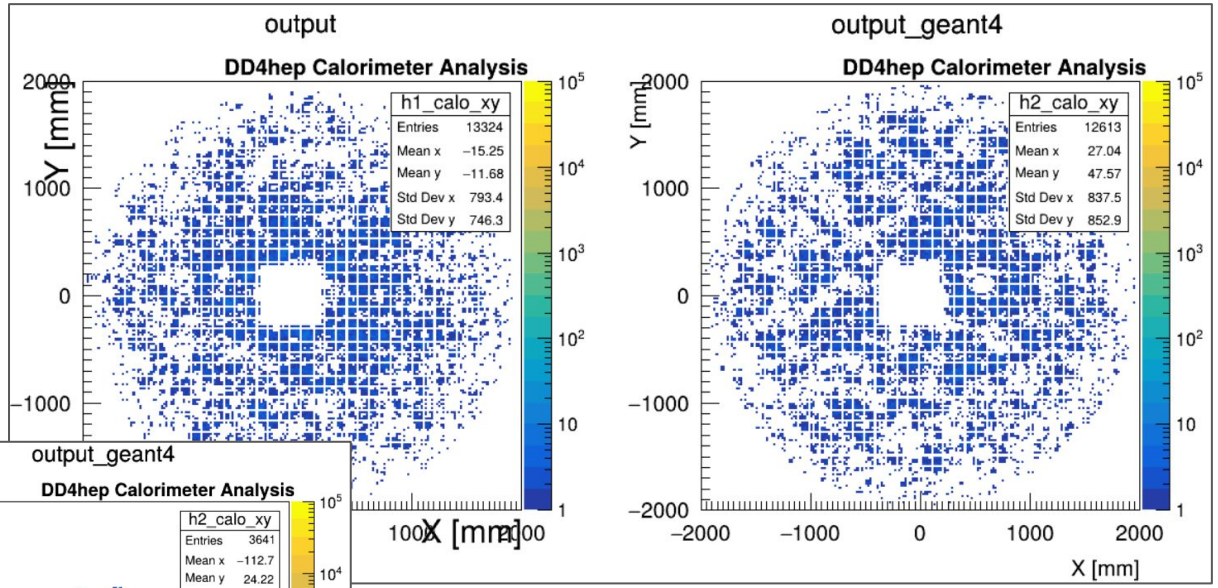
- Bi-weekly open meeting with Celeritas developers team
- Active discussion in Celeritas slack, with dedicated #epic channel
- Area of active research and engagement by BNL NPPS group

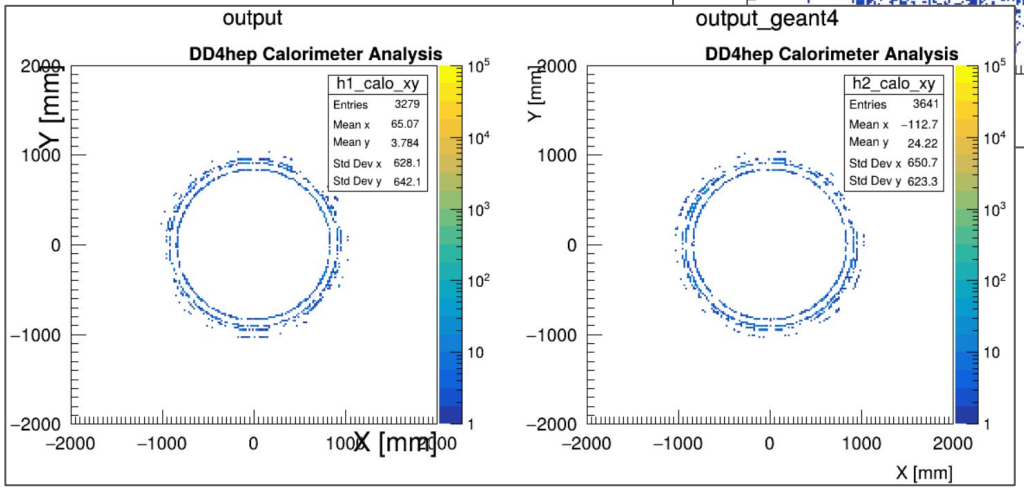
Milestones:

- Integration of Celeritas and DD4hep: development of DD4hep plugin
  - https://github.com/celeritas-project/celeritas/pull/1756

Celeritas: GPU-accelerated High Energy Physics Monte Carlo simulation

Forward EM calorimeter →





← Barrel imaging calorimeter

ACTS: A Common Tracking Software

ACTS is an experiment-independent toolkit for (charged) particle track reconstruction in (high energy) physics experiments implemented in modern C++.

Synergistic opportunities:

- Used for the track finding, tracking fitting, and primary/secondary vertex finding
- Unique challenges:
  - Large crossing angle (25 mrad) breaks assumptions about detector cylindricity
  - MPGD detectors with significant charge sharing require treatment beyond what is included in ACTS (based on ATLAS tracker)
  - Far forward and far backward detectors (telescope detectors working group in ACTS)

Coordination:

- Attendance (somewhat irregular) at weekly ACTS developer meetings
- Active in discussions in ACTS mattermost, with dedicated #ePIC-ACTS channel
- ACTS4NP workshop (see later slide)

Milestones:

- Integration of ePIC reconstruction build as downstream ACTS CI check

ePIC

ACTS: A Common Tracking Software

Summary

Jobs

- linux_ubuntu
- linux_ubuntu_extra (ubuntu2404_...
- macos
- external_eic-shell
- linux_examples_test
- linux_physmon
- linux_physmon_perf_report

Run details

- Usage
- Workflow file

external_eic-shell
succeeded 1 hour ago in 30m 9s

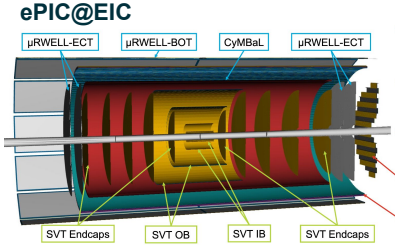
Search logs

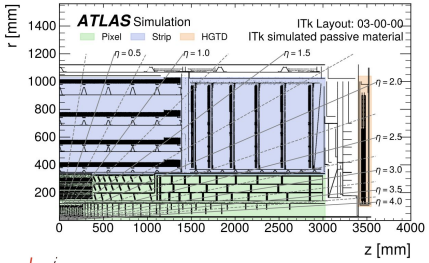
Build 29m 19s

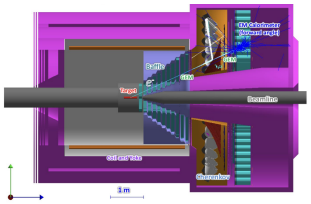
```
296  ▶ Acts configure phase
432  ▶ Acts build phase
934  ▶ Acts install phase
1819 /work
1820 /work/EICrecon /work
1821 ▶ EICrecon configure phase
1944 ▼ EICrecon build phase
1945   [0/2] Re-checking globbed directories...
1946   [1/204] Create datamodel glue headers
1947   Generating datamodel_glue.h ...
1948   [2/204] Building CXX object
     src/utilities/eicrecon/CMakeFiles/eicrecon.dir/eicrecon.cc.o
1949   [3/204] Building CXX object
     src/services/particle/CMakeFiles/particle_service_library.dir/ParticleSvc.cc.o
1950   [4/204] Linking CXX shared library
     src/services/particle/libparticle_service.so
1951   [5/204] Building CXX object
     src/utilities/eicrecon/CMakeFiles/eicrecon.dir/eicrecon_cli.cpp.o
1952   [6/204] Building CXX object
     src/algorithms/tracking/CMakeFiles/algorithms_tracking_library.dir/ActsGeometryP
     rovider.cc.o
1953   FAILED:
     src/algorithms/tracking/CMakeFiles/algorithms_tracking_library.dir/ActsGeometryP
     rovider.cc.o
```

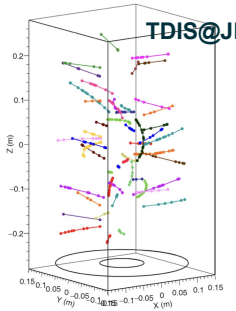
ACTS: A Common Tracking Software

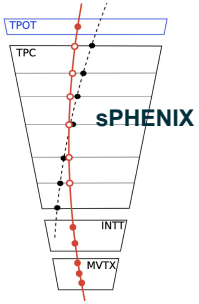
Joint organization of ACTS4NP workshop, May 12-16, 2025

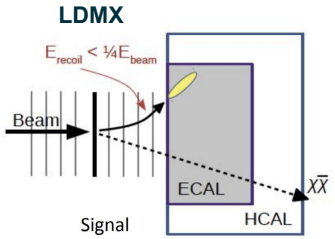


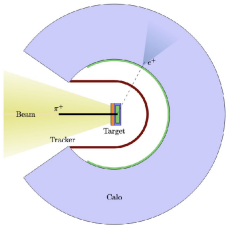




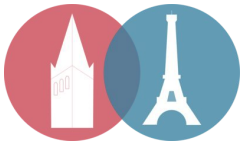


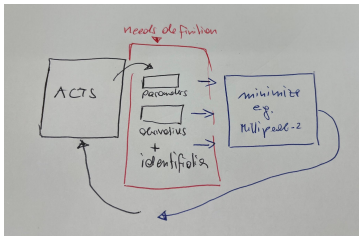


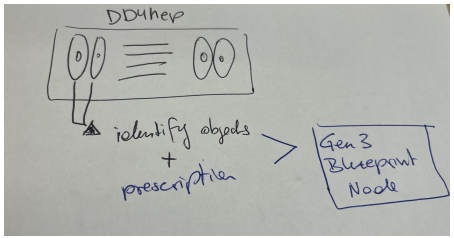




Supported by the
France-Berkeley Fund







Phoenix Event Display

Phoenix is an experiment independent web-based event display for High Energy Physics.

Synergistic opportunities:

- Integration of Phoenix with DD4hep geometries and EDM4hep events
- Development of both in-browser and command line interfaces, with access to server-side and client-side event collections

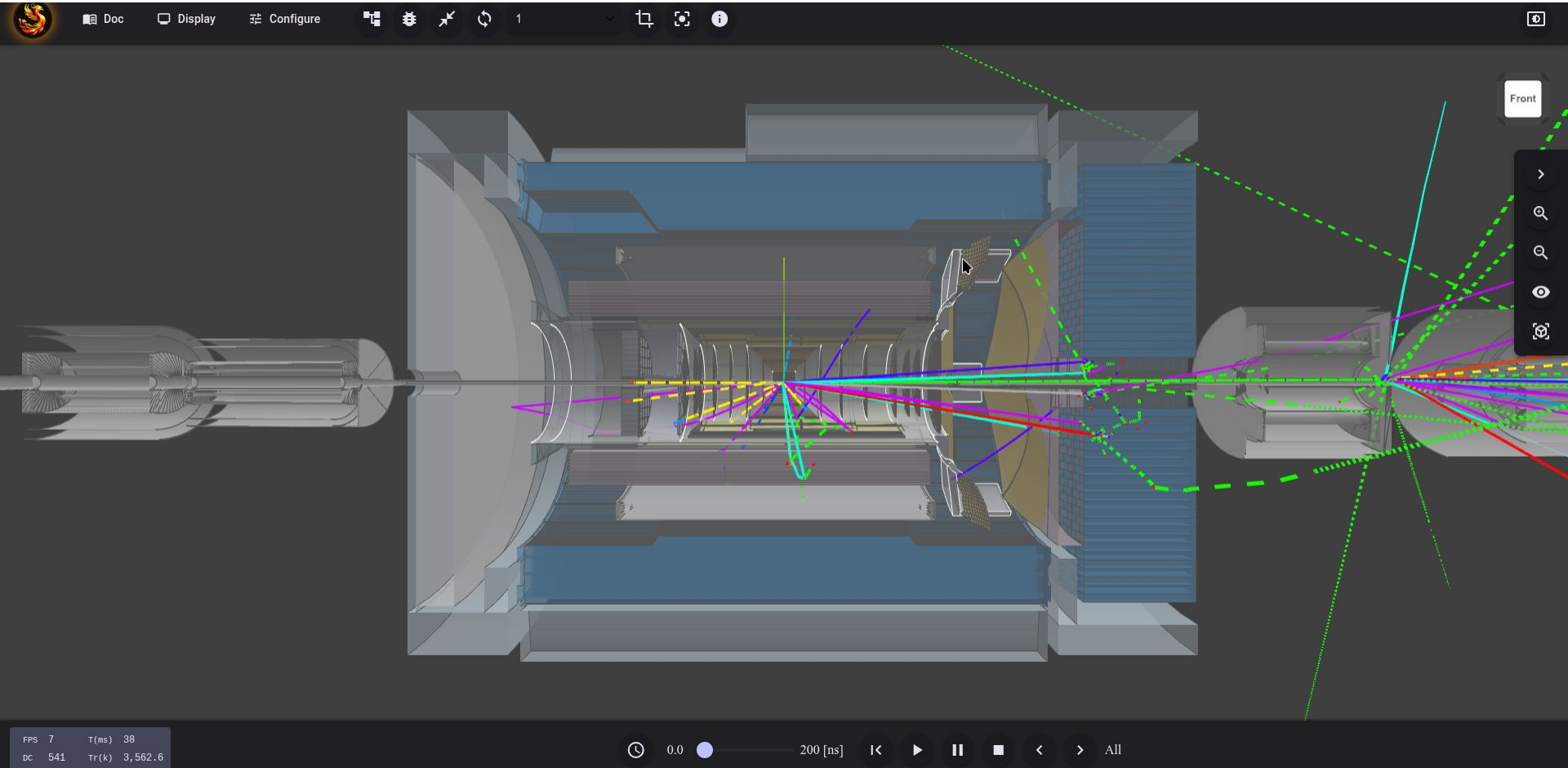
Coordination:

- Interaction via Phoenix GitHub repository
- Direct interaction with main Phoenix developers at UMass
- Area of active research and engagement by JLab EIC group

Milestones:

- New HSF project to integrate DD4hep geometries into Phoenix, https://github.com/HSF/phoenix-dd4hep
- Rollout of ePIC event display to the collaboration

Phoenix Event Display



Rucio: Scalable Distributed Data Management

Rucio is an open-source scientific data management system created at CERN to handle the exa-scale data needs of modern scientific communities. It grew out of the ATLAS collaboration, and now also serves other communities.

Synergistic opportunities:

- We are actively evaluating (in our simulation production campaigns) the use of Rucio for our distributed data storage. Rucio storage elements have been stood up at JLab, BNL, and Canada, and are being stood up elsewhere.
- Geographically co-located writes of analysis outputs with third-party copy equalization in off-peak times presents a way to load balance on a global scale.

Coordination:

- Area of active research and engagement by JLab Physics Division (incl. MOLLER)
- Active leadership in core Rucio development activities (e.g. json/jsonb metadata storage with schema validation, OIDC authentication development)

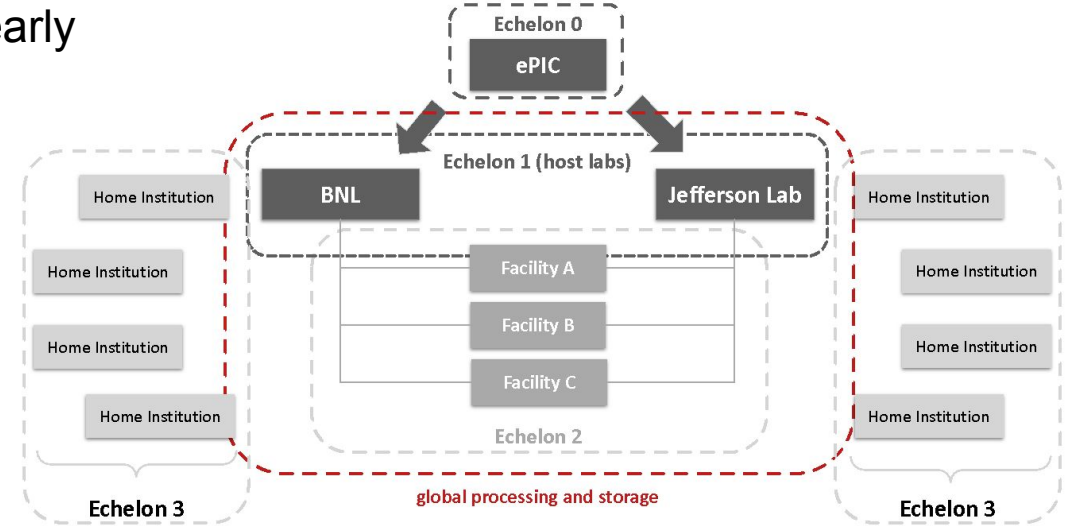
Milestones:

- All ePIC simulation production campaign written to Rucio (since January 2025)
- Close to rolling out of metadata storage in Rucio database (json/jsonb format)

Distributed Computing Model Resource Providers

Building Echelon 2 capacity through early integration in simulation campaigns

- Central infrastructure at **JLab**:
  - HTCondor submit node
  - Rucio main server
  - Rucio storage element
- Central infrastructure at **BNL**:
  - HTCondor submit node
- Active integration of **Canada** and **Italy** as compute providers integrated through OSG
- Commissioning of **Canada** as Rucio storage element provider
- Planning in progress for **Japan** and **Taiwan** as storage providers



Charter for **EICO** (EIC International Computing Organization) being reviewed by RRB:

- Coordination of pledges and Echelon 2 development by Canada, France, Italy, Japan, Taiwan, and United Kingdom with ECSJI and host labs

Summary

Broader ePIC Community: Engaging DSCs and PWGs

ePIC Software & Computing is engaging the full collaboration in development

- Successful **landing page** for onboarding new collaboration members.
- **Tutorials inside the collaboration** built to onboard detector experts and analyzers into the software framework, organized by User Learning working group.
- **Continuous integration** and **deployment** of software efforts to reduce time from contributions by experts to output in nightly environment and monthly campaigns.

Broader EIC Community: Engaging with Det2, AI, Theory

ePIC Software & Computing is engaging with other EIC communities

- **Tutorials on general applicability of EIC software** at CFNS/EIC/CTEQ summer schools
- **Community expansion** through workshops, including recent **HSF-India/ePIC meeting**.
- Engagement with AI4EIC workshops series, with bidirectional exchange of expertise.

Broader NHEP Community: Engage with Particle Physics

ePIC Software & Computing is engaging external software projects and compute providers

- **Active engagement in community software dependencies:** ACTS, Key4HEP, etc.
- **Active engagement in compute providers in the US and abroad:** OSG, Italy, Canada, etc.
- **Participation and leadership in global NHEP software ecosystem:** HEP Software Foundation; representation at CHEP and other computing conferences and workshops.