Fermilab – Laboratory support for FCC

V. Daniel Elvira for the Fermilab PED team

USFCC 2026, SLAC

Outline

- The Fermilab collider physics team
- Laboratory priorities
- Fermilab in USFCC-PED
  - LDRD and in-kind contributions
- Status and next steps

The Fermilab collider physics group

FUTURE CIRCULAR COLLIDER

Fermilab's Collider Physics, Theory, Computational Science organizations have unique capabilities in all areas relevant to the FCC-ee

Built up over 40 years of being at the forefront of collider experiments

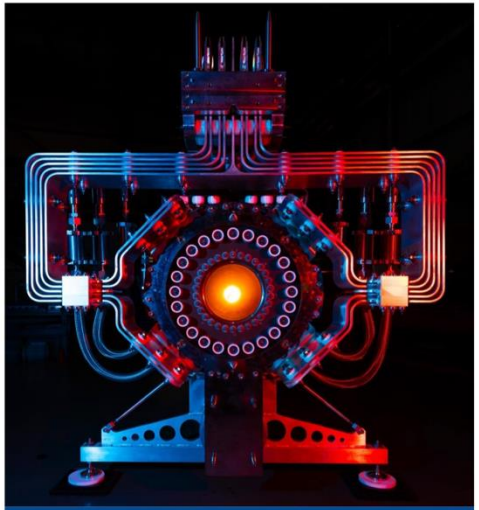
- Detector design, construction, commissioning experts
- Software infrastructure, including event processing framework developers
- Event generator developers
- The largest Geant4 team in the United States
- Algorithm developers in the context of modern computing systems
- Artificial intelligence applications to all areas of particle physics
- Physics teams with expertise reconstructing and calibrating physics objects
- Analysis teams with interest and experience in SM & Higgs measurements, and BSM searches

Unique set of facilities

- Silicon Detector laboratory (SiDet), the Helen Edwards Engineering Research Center (HEERC)
- High-rate testing and irradiation facilities

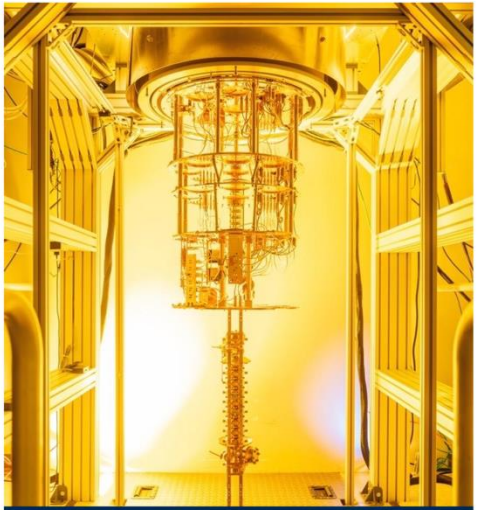
CMS group > 200 active members (~100 FTEs): research, operations, upgrade

Fermilab's top priorities



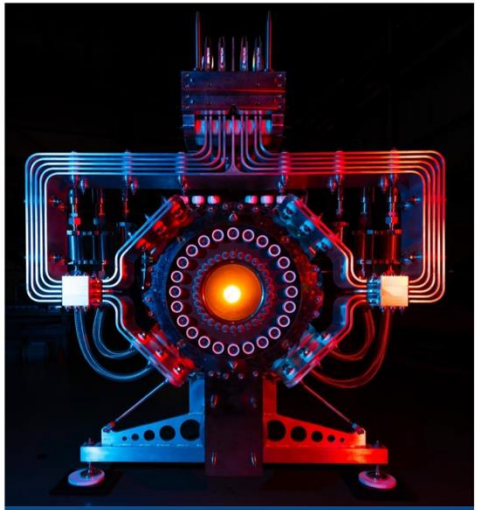
Beam to LBNF/DUNE-US by 2031

HL-LHC



Driving Innovation

Fermilab's top priorities



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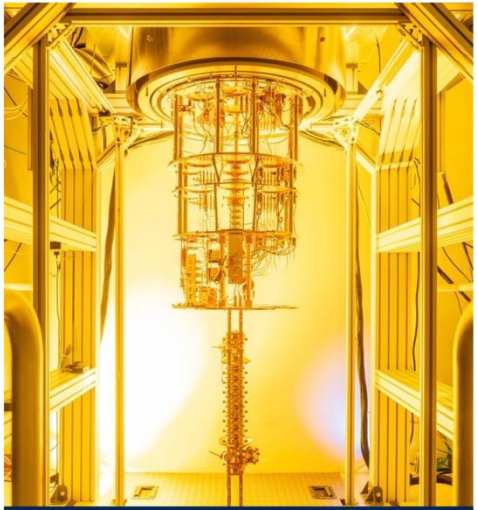


Driving Innovation

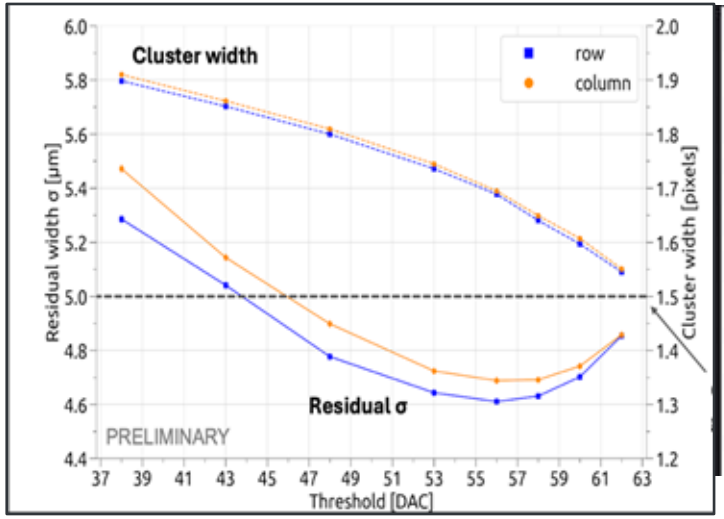
Norbert Holtkamp (first all-hands meeting): "The CERN program should be a big part of our future not only for the exploitation of the LHC but also the involvement in collider physics".

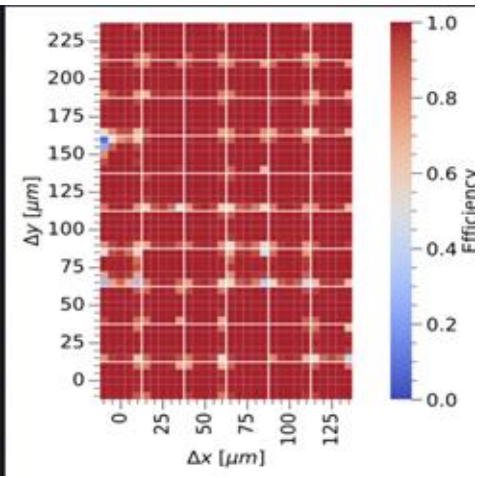
Silicon Detectors

MAPS R&D for next generation HEP experiments

- Sensors monolithically integrated into std CMOS using a US-based foundry
- Different detector and MAPS designs for the SkyWater 90nm bulk CMOS process

- In-depth characterization of ARCADIA sensors
  - Uniform efficiency measured with IR-Laser
  - Position resolution ~4.5 μm measured in FTBF





USFCC supported

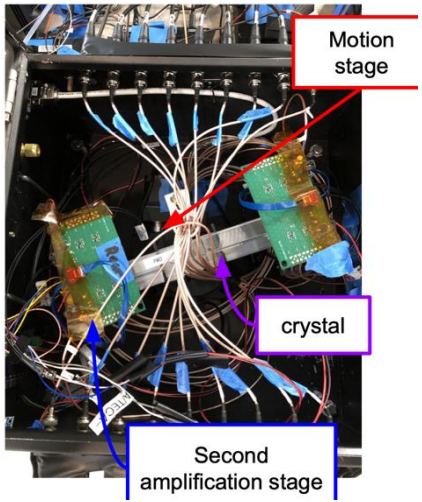
+ LDRD, funded (FY25-27) – D. Berry PI

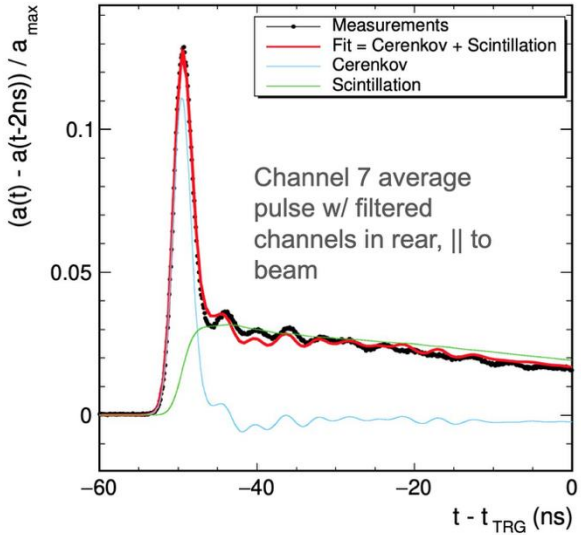
(+?) LDRD under review (FY27-29) – A. Apresyan PI

Calorimeters

FCC-ee R&D for both EM and HAD calorimeters **USFCC supported**

- Core member of CalVision with focus on properties of signal timing in candidate crystals, fast/low-power ASICs for scintillation/Cherenkov signal separation, test beams, detector prototyping
- CMOS MAPS-based high granular electromagnetic calorimeter
- Sampling dual-readout calorimetry using innovative, in house-developed, approaches based on optical thin film interference filters





Software and Computing **LDRD, funded (FY26-27, maybe 28)** – L. Gray co-PI for FCC

FUTURE CIRCULAR COLLIDER

R&D on modern software frameworks that optimally serve event generators and simulations, along with fast columnar data analysis in future collider experiments

- **Extend Key4hep** by integrating two common software tools developed at Fermilab:
  - **Stitched**, a highly-concurrent experiment software framework
  - **Coffea**, a columnar-based end-user analysis framework
- **Addendum to MOU:** Accelerator Protocol III for Participation by the U.S. Department of Energy in the Future Circular Collider (FCC) Feasibility Study
  - Title: “Enhancements to the FCC software infrastructure”
- Do not miss **Lindsey Gray’s presentation** later today:
  - *“Integrating stitched and coffea into the key4hep ecosystem”*

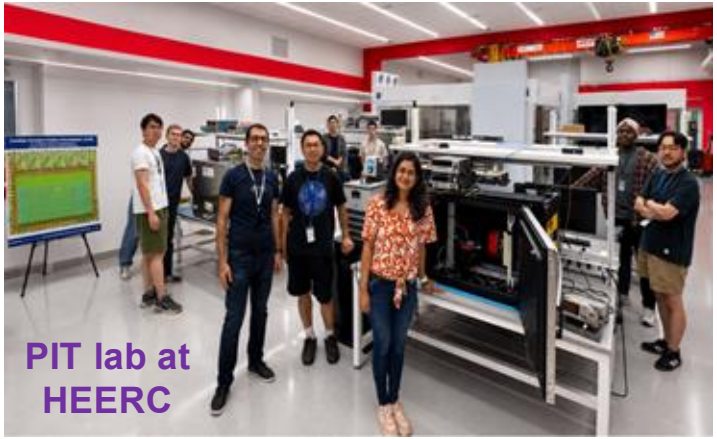
Experiment Design (?) LDRD, under review (FY27-29) – D. Elvira PI

Title: *"Detector concept optimization with simulation and AI"*

- If funded, this LDRD would enable Fermilab to contribute to experiment design for physics performance optimization in the context of the Detector Subsystems and Concepts work package

In-kind contributions to FCC

- World-class **Precision Instrumentation & Timing (PIT) laboratory**
  - **Sensor design:** in-house design, fabrication with industry
  - **Integration**: electronics and readout for precision timing and tracking
  - **Characterization**: in-depth characterization of sensors, ASICs and full systems
  - **Collaborations** with Universities and National Labs

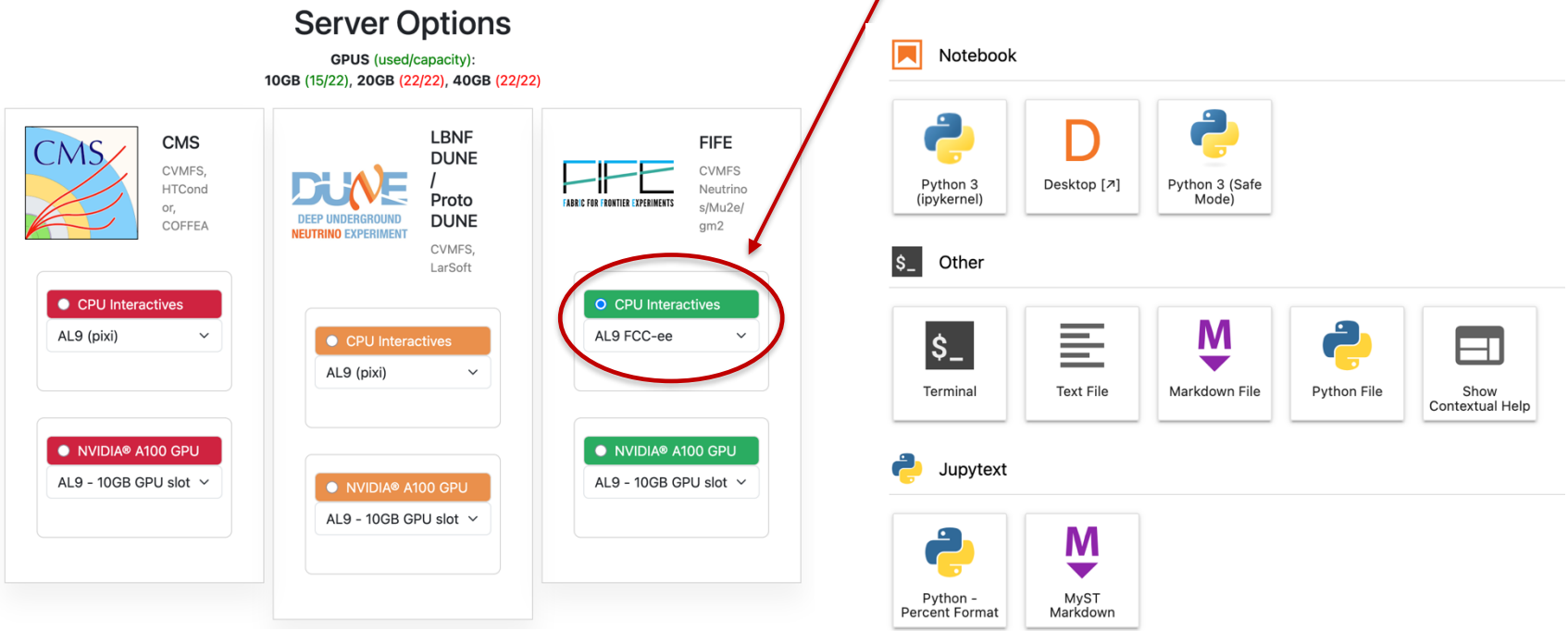


- **The Fermilab Elastic Analysis Facility (EAF)**

  Web-based, container-driven data platform for particle physics and machine learning workflows
  - **JupyterHub Interface** (access to interactive environments: terminals, code editors, notebooks)
  - **Integrated to Dash and HTCondor**, enable users to run large-scale parallel Python tasks
  - **Access to high-performance resources**, including GPU instances (such as NVIDIA A100s) for heavy machine learning and data processing tasks

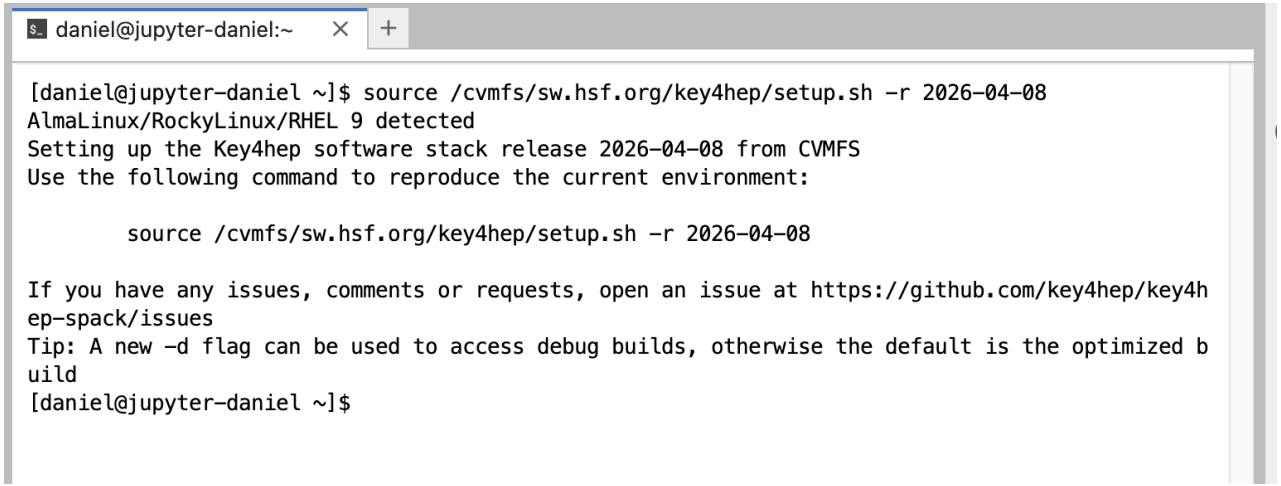
In-kind contributions to FCC

Dedicated “experiment-specific” environment for FCC-ee



In-kind contributions to FCC

The **key4hep software stack** is accessible within the Fermilab EAF



To use these resources, you only need a **Fermilab computer account**

[Fermilab user with a "Future Collider Physics and Detectors" affiliation]

In-kind contributions to FCC

The **key4hep software stack** is accessible within the Fermilab EAF

```
daniel@jupyter-daniel:~
[daniel@jupyter-daniel ~]$ source /cvmfs/sw.hsf.org/key4hep/setup.sh -r 2026-04-08
AlmaLinux/RockyLinux/RHEL 9 detected
Setting up the Key4hep software stack release 2026-04-08 from CVMFS
Use the following command to reproduce the current environment:

        source /cvmfs/sw.hsf.org/key4hep/setup.sh -r 2026-04-08

If you have any issues, comments or requests, open an issue at https://github.com/key4hep/key4hep-spack/issues
Tip: A new -d flag can be used to access debug builds, otherwise the default is the optimized build
[daniel@jupyter-daniel ~]$
```

Member of the Fermilab FCC-ee user community

To use these resources, you only need a **Fermilab computer account**

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Status summary and next steps

- The three top priorities at Fermilab are:
  - Beam to LBNF/DUNE by 2031, the HL-LHC program, driving innovations (critical technologies)
- The CERN program is a big part of Fermilab's future
  - Not only for the exploitation of the LHC but also the involvement in collider physics
- Fermilab is granting "strategic" LDRDs for FY27
  - FCC-ee is not a strategic priority thus competes in the general call
- The Fermilab PED team is making substantial contributions
  - USFCC leadership **[see backup slide]**
  - Detector and S&C R&D
  - In-kind contributions: instrumentation facilities and computing resources for staff and users
- Fermilab signed an MOU for PED work in April 2026
  - Listed as an FCC collaborating institute in the CERN Grey Book

Ongoing discussions with lab management on support for FCC in the context of the administration policies, Fermilab's priorities, and FCC-ee schedule

Backup slides

Fermilab in USFCC leadership

- L1 Software/Computing Co-coordinator: Lothar Bauerdick
- L2 AI, Integration and Microelectronics: Jim Hirschauer
- L3 Calorimetry: Grace Cummings