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Fermilab Test Beam Facilities Status and Plans

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U.S. DEPARTMENT
of **ENERGY**

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Introduction

- User-oriented facility with a 20 year history driving innovation and advancement as a proving ground for essential technologies used by the US HEP(&NP) program across all major projects and frontiers
- Fermilab Test Beam Facility (FTBF)
 - Uniquely capable in the US
 - No beam since July 2024
 - Next opportunity ~2031 after the long shutdown (requires funding)
- Irradiation Test Area (ITA)
 - Active through 2027 before permanent shutdown of LINAC operations.
 - Future irradiations would require new extraction and enclosure from PIP-II



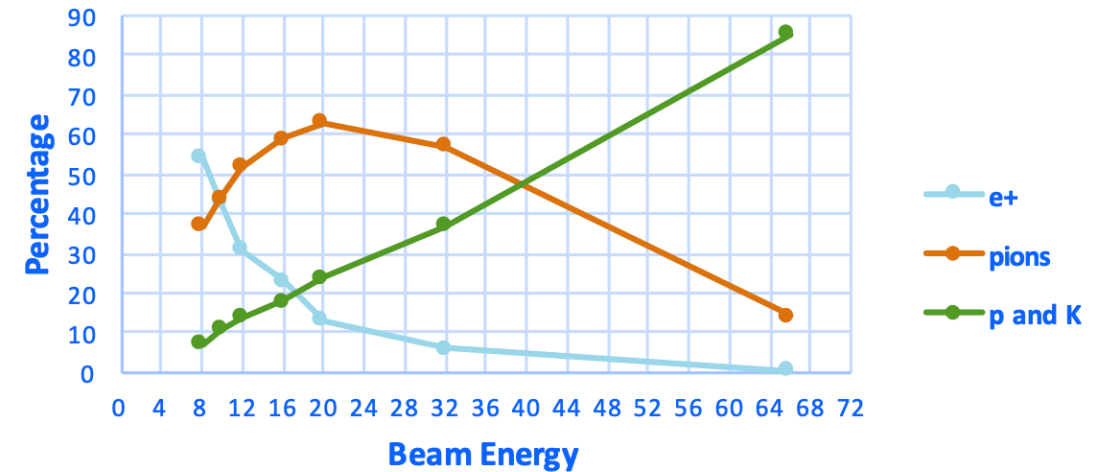
FTBF –
Meson
Detector
Building

ITA –
Irradiation
Test Area

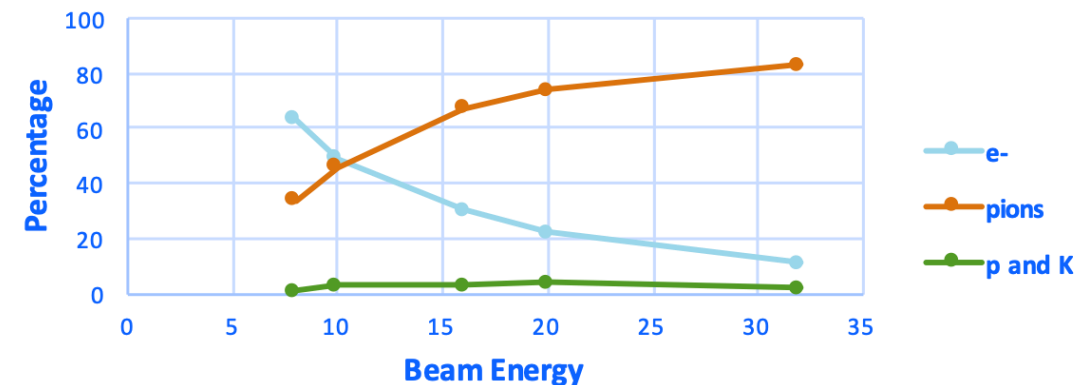
FTBF Beam Details

- 4.2 second slow extraction beam spill every super cycle (~ once per minute) from Main Injector
- ~1000 to 900,000 particles per spill
- MTest
 - 120 GeV protons
 - 1-66 GeV mixed secondary beam
 - ~2cm spot size
 - typically 1-4 week experiments
- MCenter
 - Secondary beam, 8-90 GeV pions
 - Two tertiary beam stations down to 200 MeV
 - Longer term experiments (Primarily has supported the neutrino community and DUNE)
- Only high energy hadron test beam facility in the US.

Positive Beams Composition, Open Collimators 2016



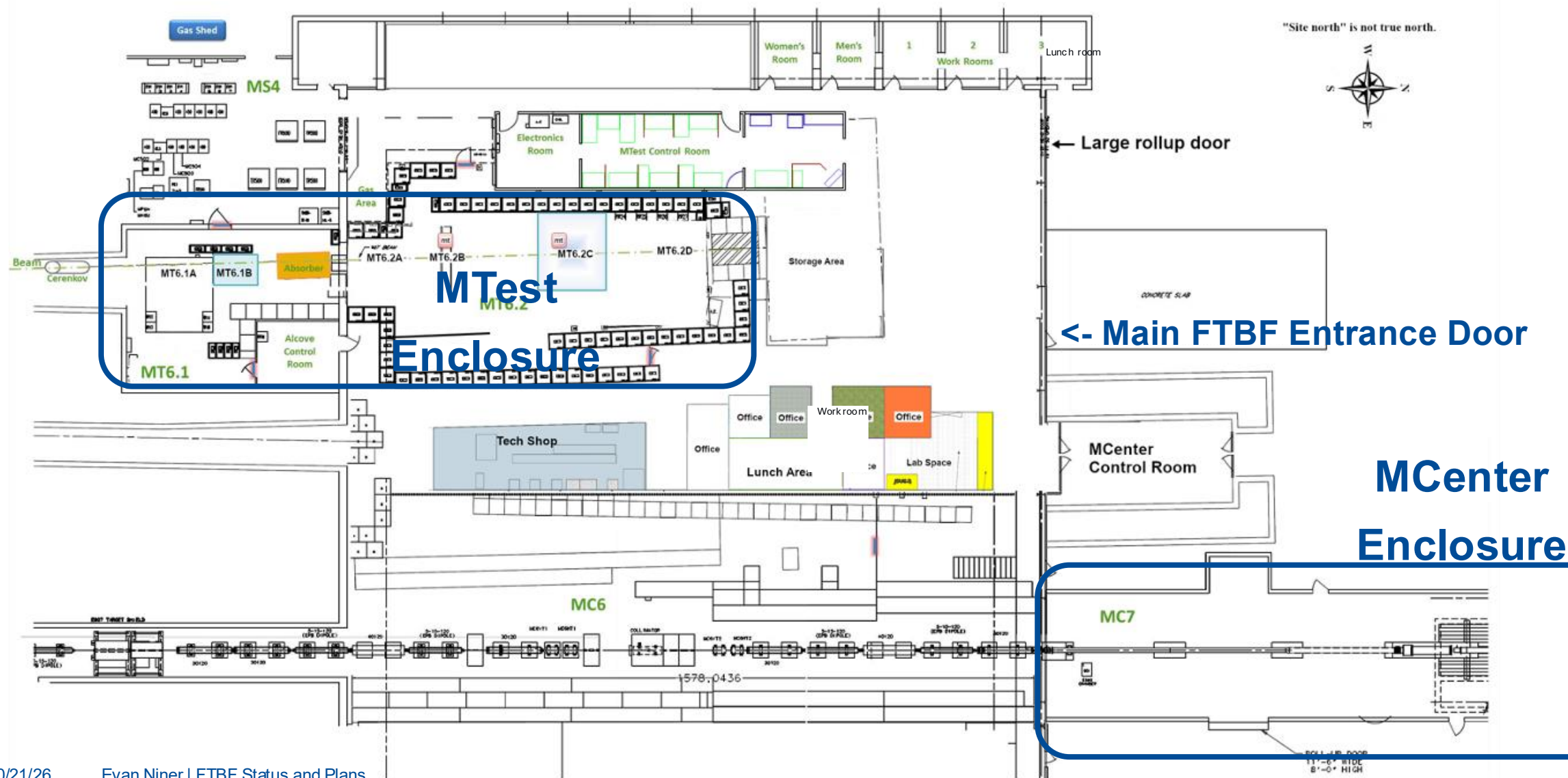
Negative Beams Composition, Open Collimators 2016



<https://ftbf.fnal.gov/beam-overview/>

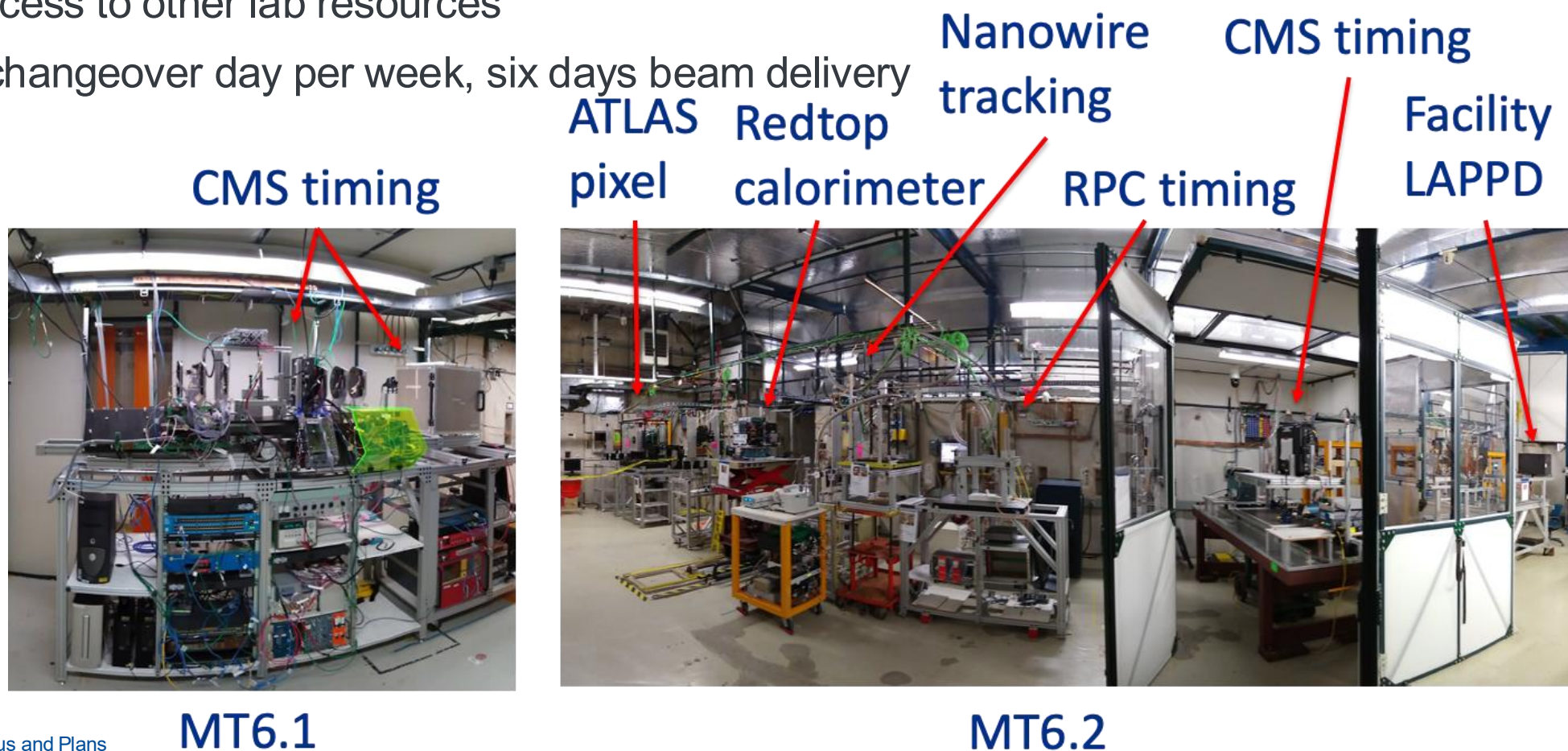
FTBF Layout

Onsite technical and scientific staff coordinate experiments from planning through execution safely and efficiently.



FTBF Layout - MTest

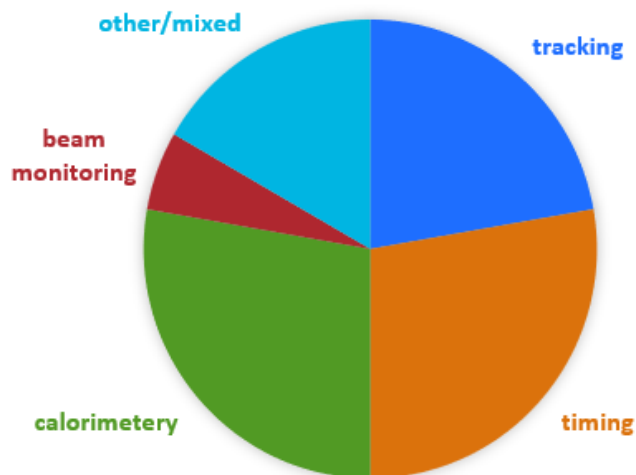
- Maintain plug-and-play infrastructure to minimize installation overhead and maximize beam efficiency
- FTBF provides beamline instrumentation and DAQ, tools, cabling and patch panels, motion tables, common equipment pools, gas delivery systems, control room and computing, beam physicists and operators, and access to other lab resources
- One experiment changeover day per week, six days beam delivery



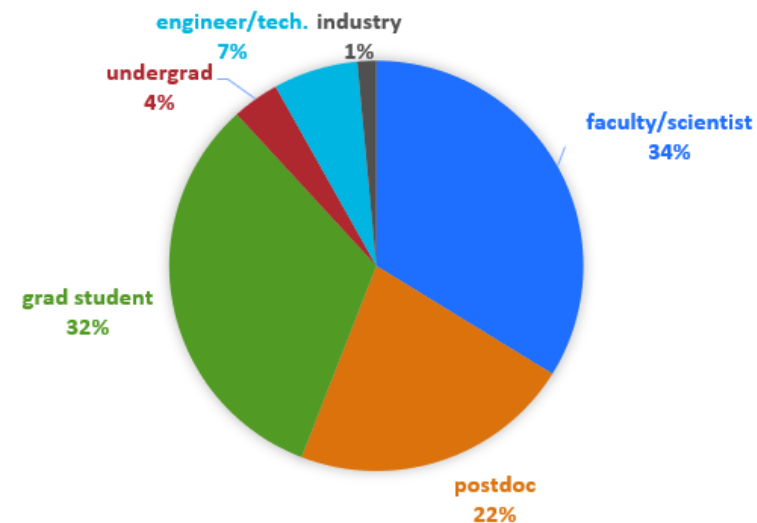
Who Uses FTBF?

- 223 users in FY23
- Users from 53 Universities/Labs (18 international)
- 20 Experimental efforts, 4 new efforts
- 20 weeks delivered

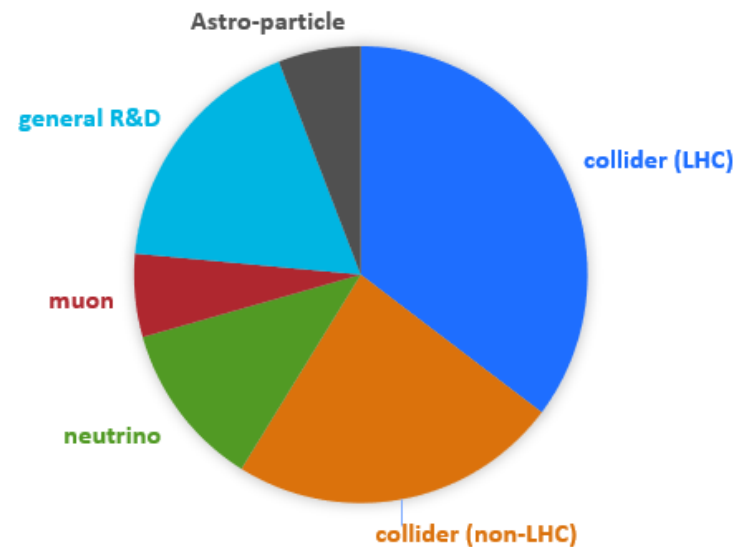
Experiment by detector



Users by professional category

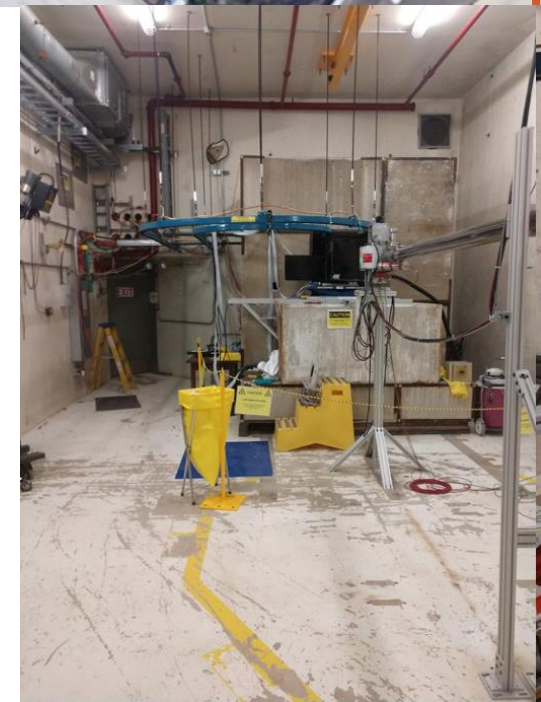


Experiment by research focus



Irradiation Facility

- Operating since 2021
- Beam line is approved for a maximum intensity of 2.7×10^{15} particles per hour per the current shielding.
- Delivers both passive irradiations to high fluence and active SEU/SEE electronics studies
 - HL-LHC, LBNF, and materials studies
- Operations continue through 2027 as long as linac runs. No facility after 2027 when linac permanently shuts down unless a new one is built from PIP-II.
- Taking requests for 2026/2027 beam time, contact ftbf_co@fnal.gov





Future Test Beam Facilities at Fermilab



Test Beam Planning

- We have been engaging the facility user community, laboratory management, advisory committees, and the DOE for several years on future facility planning.
- [Snowmass white paper](#) in 2022 based on community survey addressed future facility plans and community needs
- 2025 Fermilab task force re-examined the future community test beam facility needs and developed prioritized list of required maintenance and refurbishment activities to enable continued use of the existing facility.
- Fermilab Physics Advisory Committee (PAC) [April 2026 Meeting report](#): “The PAC recommends the laboratory works with the DOE to develop a sustainable funding model for preserving unique capabilities of ITA and FTBF in support of instrumentation R&D after the long shutdown.” [FTBF Presentation](#)
 - In association with this meeting many experiments and R&D communities provided statements identifying future test beam requirements for their efforts and expressing significant concern if FTBF is not brought back to operation as soon as possible. See backup material for excerpts.



Community Survey 2025

- **29 survey responses representing diverse interests across all frontiers and future major projects.**
 - Majority of work focused on intensity frontier (DUNE phase II/LBNF, Mu2e-II) and energy frontier (FCC) with additional work in EIC, quantum, cosmic, and general detector R&D
- **Proposed work requests indicated 100% occupancy of the facility in both beamlines in the 2030s.**
- Survey respondents expressed needing all facility capabilities and beam energies currently offered
 - 120 GeV protons being most heavily requested followed by mixed secondary beams with broad energy range, then Mcenter.
- **Groups overwhelmingly expressed that FTBF is the only high energy hadron beam in the US with no viable alternative to meet their needs. Moving work to CERN has limited time and is prohibitively expensive for sustained R&D. Necessary US detector R&D would be significantly impacted without this facility at Fermilab.**
- **Surveyors noted that the fluences required for next generation collider experiments are difficult/impossible to reach at any existing irradiation facilities. PIP-II would have the capability to deliver the required beam if a facility was constructed.**

Global Perspective

- Test beam facilities globally are fully subscribed and seeing rising demand. FTBF, CERN and DESY have been three pillar facilities.
- FTBF and CERN are the sources of the highest energy hadron beams available in the world
- FTBF is unique with no viable substitute in the US
 - For many detector development activities including calorimetry and precision studies of highly pixelated sensors there is no substitute for a high energy hadron beam
 - Infrastructure and capacity to support rapid testing cycles of emerging technologies

Facility	# of Beams	Particles	Energy Range	Availability
CERN/PS	2	e,h, μ (sec.)	0.5-10 GeV/c	9 mos/yr
CERN/SPS	4	p(prim.); e,h, μ (sec.); e,h(tert.); Pb(prim); other ion species	20-400 GeV/c proton equivalent	9 mos/yr
CERN/CLEAR	1	e^-	50-250 MeV/c	8-9 mos/yr
DAFNE Frascati	1	e^+/e^- (prim. and sec.); photons	25-750 MeV/c	25-35 wks/yr
DESY (Hamburg, GE)	3	e^+/e^- (sec.); e^- (prim., planned)	1-6 GeV/c; 6.3 GeV/c	11 mos/yr
ELPH (Sendai, JP)	2	photons (tagged); e^+,e^- (conversion)	0.7-1.2 GeV/c; 0.1-1 GeV/c	2 mos/yr
ELSA (Bonn, GE)	1	e^-	1.2-3.2 GeV/c	~ 30 days/yr
FTBF (Fermilab, US)	2	p (prim.); e,h, μ (sec.); h (ter.)	120 GeV/c; 1-66 GeV/c; 200-500 MeV/c	8 mos/yr
IHEP (Beijing, CN)	2	e (prim.); e,p, π (sec.)	1.1-2.5 GeV/c; 0.1-1.2 GeV/c	3 mos/yr
IHEP (Protvino, RU)	5	p,C-12 (prim.); p,K, π,μ,e (sec.)	70 (6-300) GeV/c; 1-45 GeV/c	2 mos/yr
MAMI (Mainz, GE)	3	e^- ,photons	< 1.6 GeV/c	~ 30 days/yr
NSRL (Brookhaven, US)	1	p, heavy ions	0-1 GeV/n	10 mos/yr
piEI,ppiMI,etc. (PSI, CH)	2-4	π,μ,e,p	50-450 MeV/c	6-8 mos/yr
PIF (PSI, CH)	1	p	5-230 MeV/c	11 mos/yr
RCNP (Osaka, JP)	7	p,heavy ions,n, μ^+	24-400 MeV/c	7-8 mos/yr
SLAC (Stanford, US)	0	e (prim.); e (sec.)	8 GeV/c; 2-8 GeV/c	Returning 2027
SPRING-8 (Compton Facility, JP)	2	photons (tagged), e^+,e^- (conv.)	0.4-2.9 GeV/c	>60 days/yr



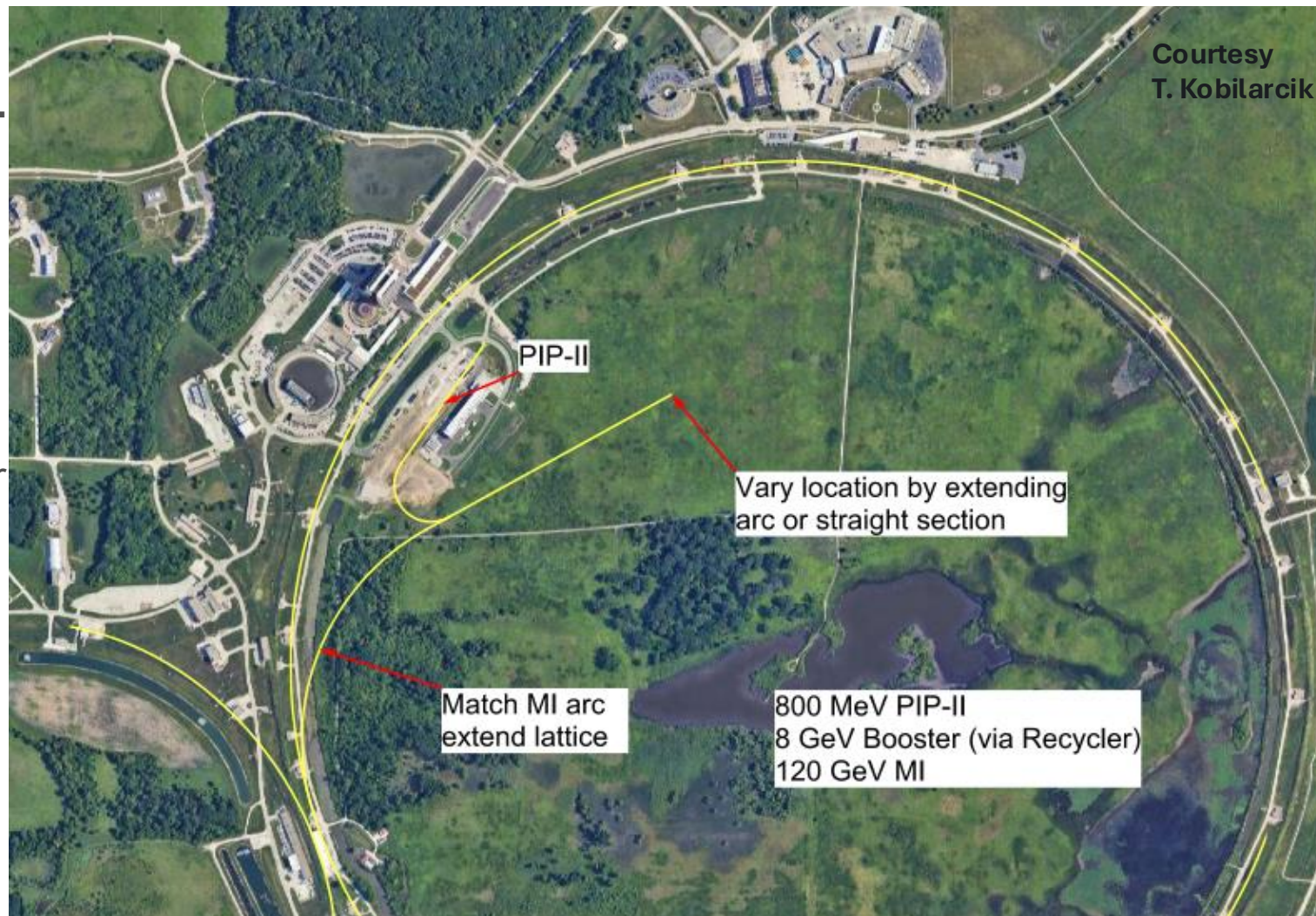
Near Future

- Fermilab is doing its best to preserve the FTBF experimental facilities and Switchyard beamline in a state where they can be recovered after an extended shutdown.
 - This still requires investment both in infrastructure upkeep and refurbishment of aged beamline components (power supplies, water systems, cables). This is not currently budgeted.
- We are working together with the DOE to engage the HENP user and facility communities to identify future test beam and irradiation needs
 - Identify the most essential R&D activities requiring test beams for the next decade in the community and the necessary facility features.
 - Match those facility features onto existing spaces in the HENP complex and identify the gaps where refurbishment, upgrades or new facilities are required.
 - Based on the outcome of this community exercise, work together with DOE to develop plans for Test Beam and Irradiation facilities at Fermilab best matched to HENP needs.



New Irradiation Facility and Possible Test Beam

- PIP-II satisfies the beam requirements for a next generation irradiation facility. An extraction line and facility could be built in the Tevatron infield
- On a longer timescale a test beam facility could be added to the same location.
 - New location within the main accelerator complex security footprint
 - Substantially shorter beam path and new components to reduce maintenance
 - Reviving FTBF would still be required in 2031 to bridge gaps to any new construction.





Summary

- FTBF is a user-oriented facility with a 20 year history driving innovation and advancement as a proving ground for essential technologies used by the US HEP program.
- ITA is still available for use through 2027, If you have needs please reach out.
- **FTBF plays an essential role in the Office of Science. No other US test beam facility has the combination of beam energies, capacity, infrastructure, and synergies with other co-located world-class capabilities needed for the next generation of detector development across all major experiments and initiatives in the HENP community in the 2030s.**
- **We are ready to work with the DOE and the HENP user and facility community to develop a coordinated plan for the essential beam facilities needed across the complex to meet future R&D needs.**

Backup



Recent Publications

- Optimization of LYSO crystals and SiPM parameters for the CMS MIP timing detector (<https://arxiv.org/abs/2410.08738>)
- Results for pixel and strip centimeter-scale AC-LGAD sensors with a 120 GeV proton beam (<https://arxiv.org/abs/2407.09928>)
- High Energy Particle Detection with Large Area Superconducting Microwire Array (<https://arxiv.org/abs/2410.00251>)
- First Observation of Antiproton Annihilation At Rest on Argon in the LArIAT Experiment (<https://arxiv.org/abs/2409.13596>)
- Dual-readout calorimetry with homogeneous crystals (<https://arxiv.org/abs/2408.11973>)
- Novel indium phosphide charged particle detector characterization with a 120 GeV proton beam (<https://arxiv.org/pdf/2404.12497>)
- Beam Test Results of the RADiCAL -- a Radiation Hard Innovative EM Calorimeter (<https://arxiv.org/pdf/2303.05580>)
- First survey of centimeter-scale AC-LGAD strip sensors with a 120 GeV proton beam ([arXiv:2211.09698](https://arxiv.org/abs/2211.09698))
- Argonne Pixel Tracking Telescope at the Fermilab Test Beam Facility (<https://arxiv.org/pdf/2202.05316>)
- Characterization of BNL and HPK AC-LGAD sensors with a 120 GeV proton beam (<https://arxiv.org/abs/2201.07772>)
- Test beam characterization of sensor prototypes for the CMS Barrel MIP Timing Detector (<https://arxiv.org/abs/2104.07786>)
- Test Beam Study of SiPM-on-Tile Configurations (<https://arxiv.org/abs/2102.08499>)
- Resistive AC-Coupled Silicon Detectors: principles of operation and first results from a combined analysis of beam test and laser data (<https://arxiv.org/pdf/2007.09528>)



FTBF Impact

- Support general R&D in developing new technologies across all research thrusts
- Projects
 - HL-LHC (CMS/ATLAS), Mu2e have had critical tests that depended on FTBF to make design decisions.
 - Muon g-2 and sPHENIX/ePIC/EIC have also used the Test Beam when designing components for projects.
 - LBNF/DUNE work on beam monitors and detector development
- LArIAT provided [physics results](#) and LArTPC R&D
- NOvA and [MINERvA](#) successful test beam campaigns have led to reduced systematics in the primary experiment analyses.
- About 5 publications per year from experiments
- Projects end, users remain: Heavy HL-LHC users transitioning to apply detector expertise to EIC, NASA, FCC, quantum, and general R&D innovation applications while continuing to use FTBF

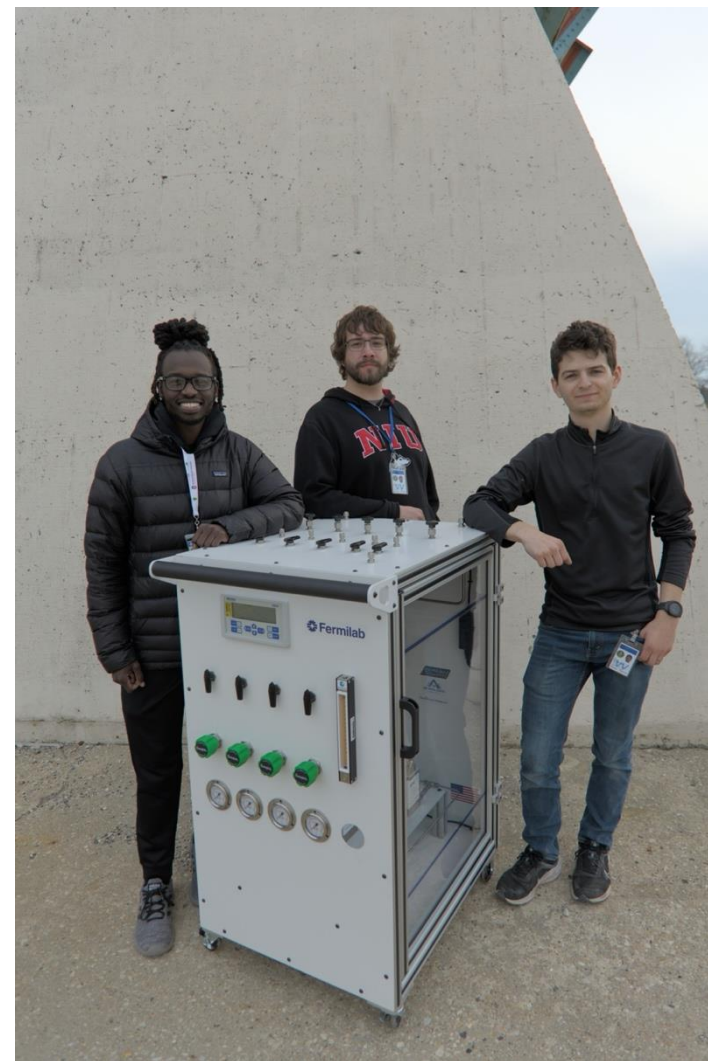
FTBF Workforce Development

- Students use the Test Beam to develop critical skills
 - FTBF allows students to experience a full lifecycle of an experiment, writing their theses using detectors they built and tested.
 - 1-2 theses per year
 - FTBF supports 2-5 student interns every year.
 - FTBF is an essential part when FNAL hosts the EDIT school
- Early Career
 - FTBF is a vital component for several successful early career (EMPHATIC), LDRD (ArCS), and New Initiative KA25 (CalVision) proposals
 - Students and postdocs have returned to FTBF as PIs



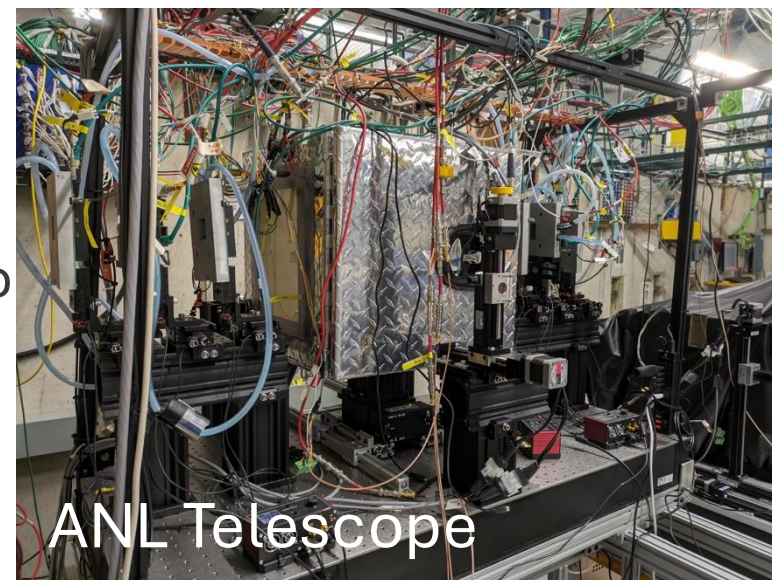
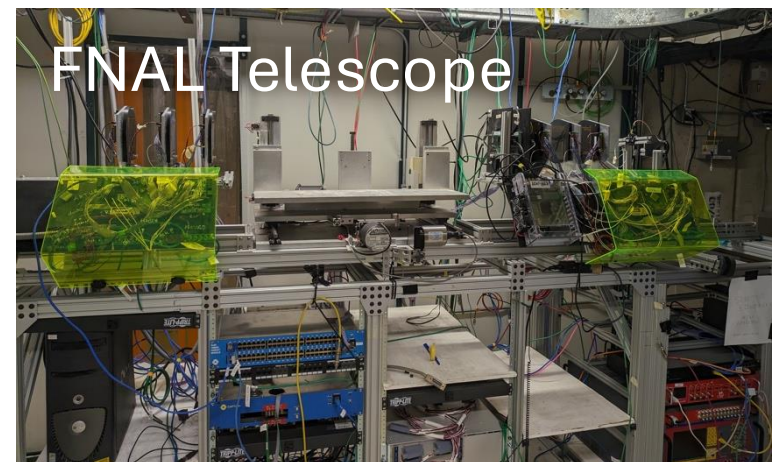
Instrumentation upgrades – Gas mixer system

- Over the 2023-24 school year we had a group of senior engineering students from Northern Illinois University design and built a gas mixing system which will be used in MTest
- Allows mixing of up to 4 different gasses in precise ratios
- Reduces need for users to bring their own mixers which require significant cost and lead time in engineering and safety approval
- Mixer complete and ready for use



Tracking Telescopes

- 2 silicon telescopes are in the MTest beam line
 - One built and operated by FNAL
 - One built and operated by ANL
- Allow precision tracking of particles to $\sim 5\mu\text{m}$
- Motion tables allow scanning location of devices under test
- Used largely for CMS and ATLAS tracker tests, but available to all users
- Crucial infrastructure for a test beam facility

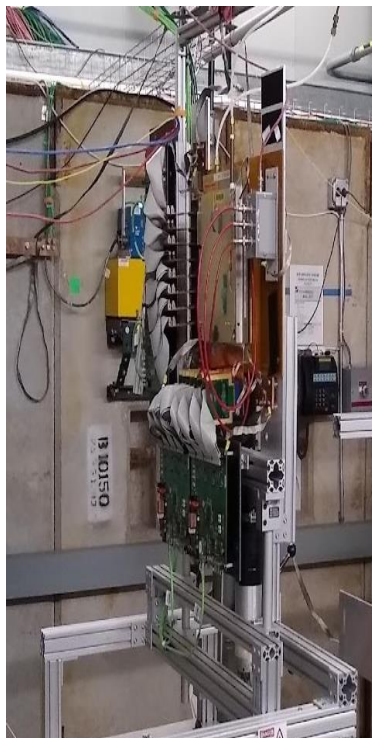




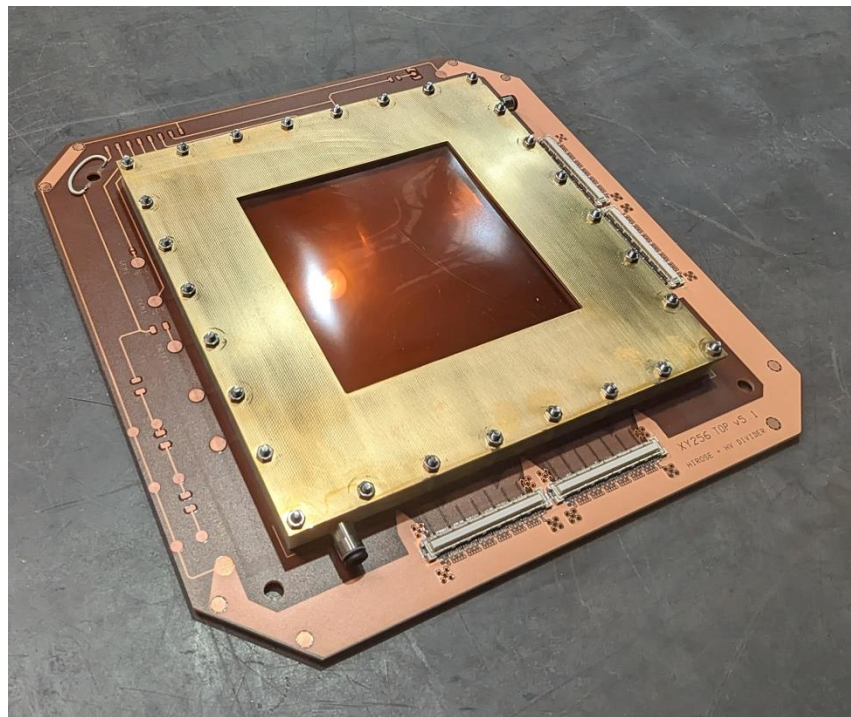
Instrumentation upgrades – Particle tracking

- Replacing Fenker chambers for particle tracking in MT6.2 with CERN GEM chambers
- GEM chambers have arrived at FNAL in March
- Scalable Readout System DAQ solution, developed by RD52 collaboration, has arrived and system is in process of being deployed

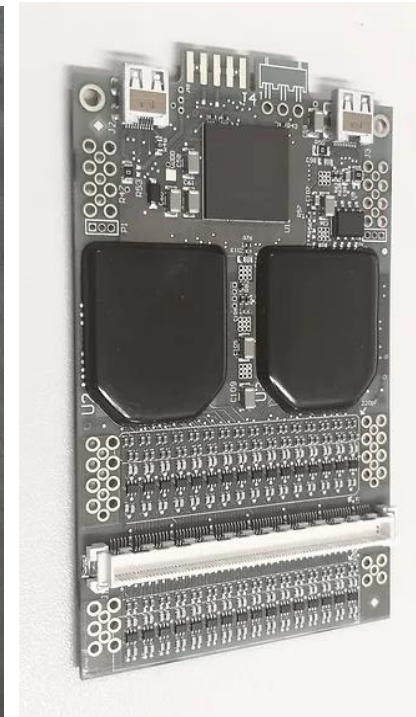
Fenker Chamber

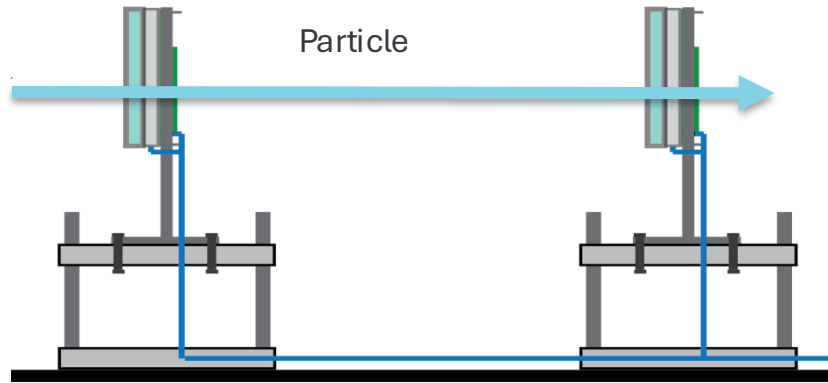


GEM Chamber



SRS VMM3a card

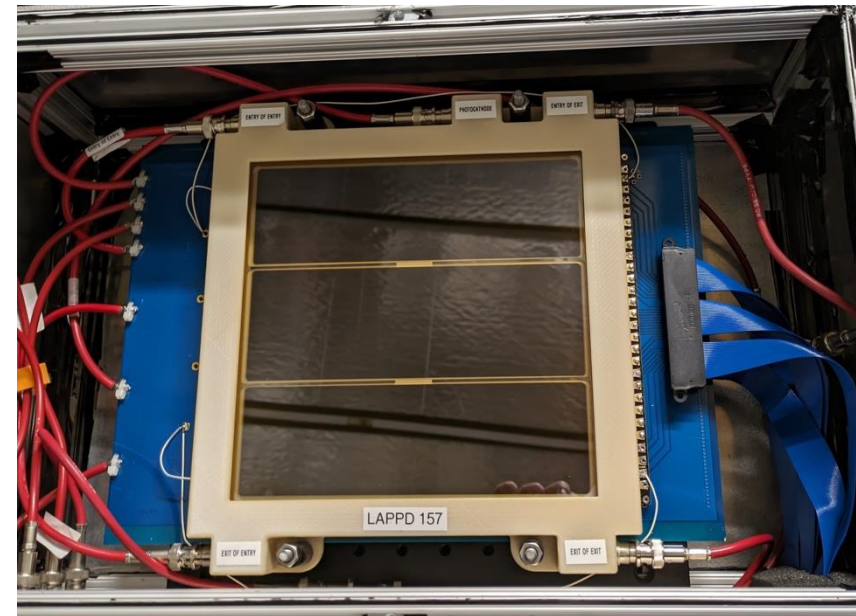




E. Angelico

- With 50 m distance allows
 - e/ π separation to 7 GeV
 - π /K separation to 25 GeV
- Hope to install system in FY25
- Initial work piloted by U. Chicago

- Use pairs of Large Area Picosecond PhotoDetectors (LAPPD) to measure time of flight (TOF) of particles at FTBF. Allows for particle ID



Angelico, Evan. doi:10.2172/1637600	$\sigma_L / \sqrt{N_{pe}}$	σ_{pulse}	σ_{WR}	σ_{tof}	Maximum π/K momentum at 5 m / 45 m
Use of fused silica window	55 ps / $\sqrt{200}$	7 ps	5 ps	14 ps	8.2 / 25 GeV/c

Irradiation Facility

- Counting house in service building next to beam enclosure.
 - Set of ~50' penetrations connect the two spaces for cabling.
- Beam line is approved for a maximum intensity of $2.7e15$ particles per hour per the current shielding.
 - Typical rates are around $2.2e15$ particles per hour
- Unique in the US to have an irradiation facility and test beam onsite together
 - Ongoing work with radiation safety on process to bring potentially contaminated sensors at ITA to FTBF.



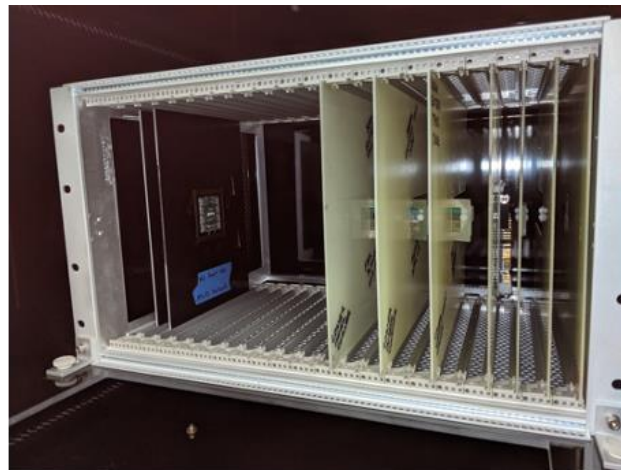
Experimental Hall



Irradiation Infrastructure



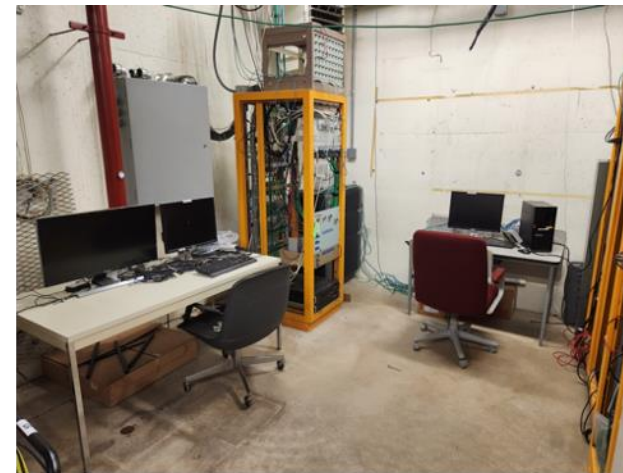
Photo courtesy Abhishek Bakshi



Very first samples from CMS and ATLAS ready for irradiation. Photo courtesy Corrinne Mills



Photo courtesy Todd Nebel



Electronics Testing for TID and NIEL

- For 400 MeV proton beam:
 - Achieve 1 Grad total ionizing dose (TID) in silicon $\sim 2.6 \times 10^{16}$ protons/cm²
 - Achieve 2×10^{16} neq/cm² displacement damage from non-ionizing energy loss (NIEL) $\sim 2.4 \times 10^{16}$ protons/cm²
- Able to reach TID and NIEL levels expected at the HL-LHC inner trackers simultaneously.
- Reach these doses in ~ 2 -3 days of continuous beam depending on Linac conditions.

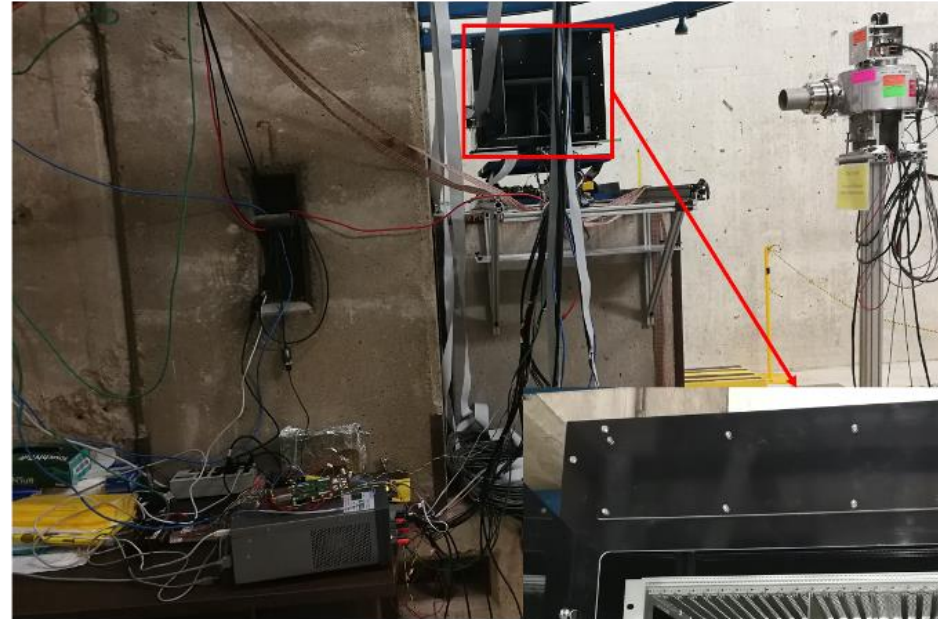


Photo by Jennet Dickinson

Single Event Upset/Effect (SEU/SEE) Electronics Testing



CMS ECON-T ASIC irradiation. Photo courtesy D. Noonan (FNAL).



ATLAS GBCR2 ASIC irradiation. Photo courtesy T. Liu (SMU).



- Linac beam is fixed intensity, leaving an intense beam for electronics testing.
- Some success has been had locating samples off-axis and with shielding.



Community Input and Letters, April 2026

- Fermilab SAC: “Without FTBF, Fermilab scientists—and the broader U.S. community—will have limited access to CERN test beams and will be lower priority, except when working with collaborators from CERN member states. **This will limit our ability to maintain leadership in detector technology, as we have over the past five decades.**”
- ePIC: “The ePIC collaboration welcomes a resumption of FTBF operations in 2030, by which time we will be able to beam test individual final production components in a hadron beam right before installation into the full ePIC experiment. **Having such a facility available in the US greatly reduces complexity, cost and overall project risk to the EIC project.**”
- DESY & CERN: “**With the shutdown of Fermilab for the foreseeable future, we lose a major pillar for providing test beam both for the community in the US and globally.** As you’ve written yourself, global scientific leadership depends on the ability to build and deliver the world’s most advanced scientific research capabilities, which includes world-class test facilities like a test beam. **Without the possibility to test new detectors and new concepts, the whole development chain for new experiments breaks down.**”
- DUNE Spokespersons: “As the only US facility offering unique, high-energy test beam capabilities, FTBF plays an important role in supporting detector R&D and measurement programs for various experiments including DUNE. Through programs such as EMPHATIC, ArCS and testing of Muon Monitors, DUNE continues to greatly benefit from FTBF. We support reinstatement of this facility in the future as we anticipate an enduring need for test-beam-based activities in view of future phases of the program.”



Community Input and Letters, April 2026

- CalVision: “FTBF, one of the two publicly available sources of high energy hadrons in the world, is integral to the success of the CalVision program. **Without the ability to experimentally confirm our technology with hadrons, this potentially revolutionary technology could be lost to physics.**”
- USHFCC Calorimetry: “Combined with the instrumentation for tracking, particle identification, and timing, FTBF is ideal for the characterization of the modern maximal information calorimeters demanded by future colliders...**With the shutdown of FTBF, we have lost our home team advantage.** While we acknowledge that the decision to cancel the FY26 and FY27 operation of the facility was not taken lightly, **we cannot stress enough how deeply this decision threatens American leadership in calorimetry**...Please prioritize reviving the facility after the LBNF-DUNE shutdown. **The future of instrumentation innovation in the US and at Fermilab is at stake.**”
- DRD Calo: “**It would be a major loss for the community if the FTBF would shut down indefinitely – one could even classify it as a catastrophe for the field.** As a major player in particle physics, Fermilab should make every effort to keep this facility open. We would like to urge the Physics Advisory Committee to consider this aspect and we are available for further communication on the matter.”