



Fermilab Test Beam Facility

Joe Pastika

55th Annual Users Meeting

Introduction

- Fermilab Test Beam Facility (FTBF) – Supports a wide program of research and detector R&D
- 2 Beamlines (MTest and MCenter) – can provide particles from 120 GeV protons to secondaries of ~ 200 MeV
- Irradiation Test Area (ITA) – provides up to 2.7×10^{15} 400 MeV protons / hour
- Beam is available ~ 9 months a year



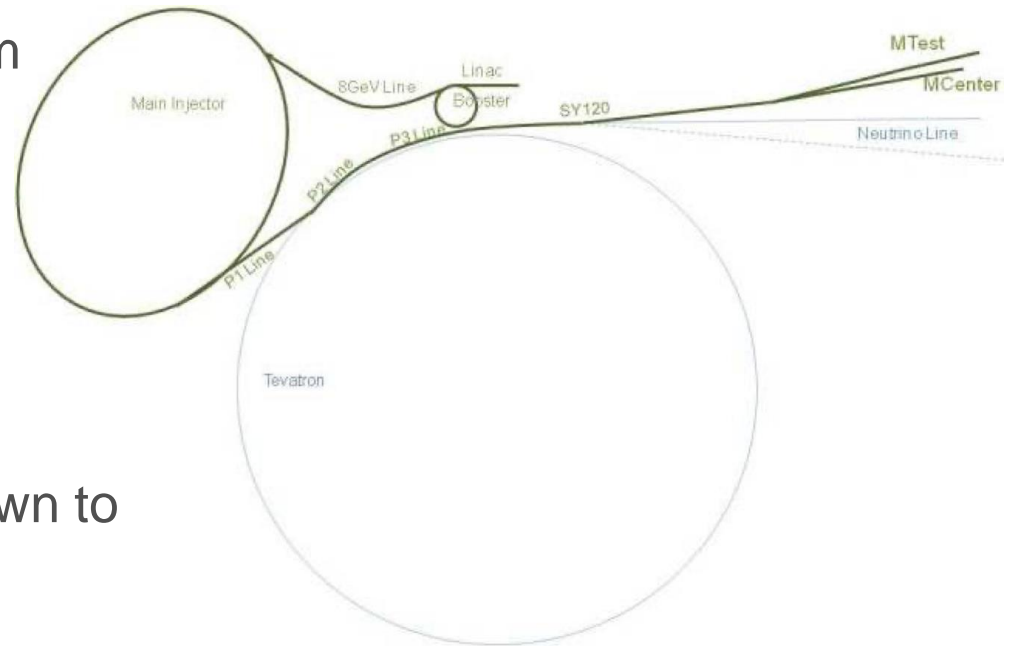
Where are FTBF and ITA?



Meson detector Building – west

Beamline Details

- 4 second beam spill every 60 seconds, available 24/7
- ~1000 to 900,000 particles per spill
- MTest
 - 120 GeV primary protons
 - 1-66 GeV secondary beam
 - ~2cm spot size
 - 1-4 week runs
- MCenter
 - Secondary beam
 - Two tertiary beamlines down to 200 MeV
 - longer term experiments



Beam Performance – MTest

Positive Beams Composition, Open Collimators 2016

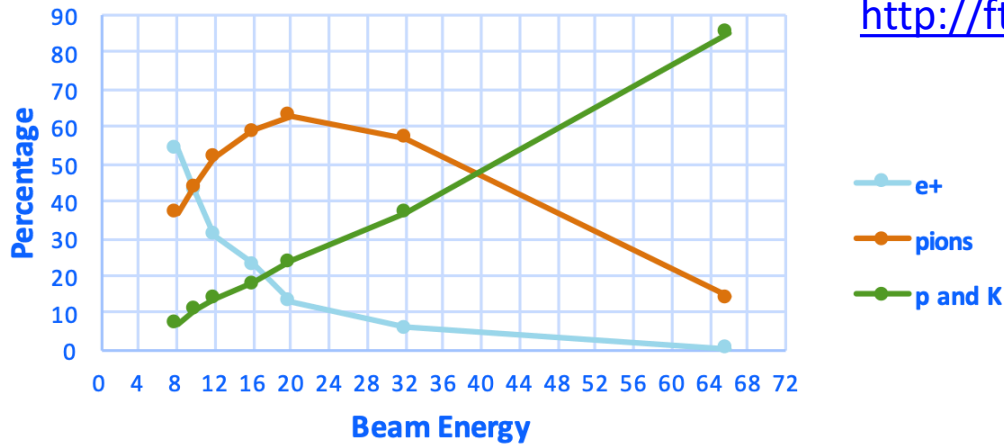
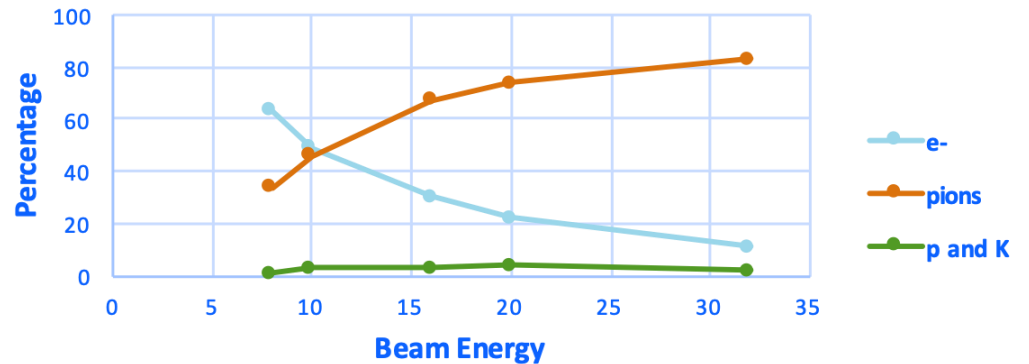


Table with energies, beam spread, percentages:
<http://ftbf.fnal.gov/mtest-beam-details-2/>

e+
pions
p and K

Negative Beams Composition, Open Collimators 2016



Studies by E. Skup and D. Jensen

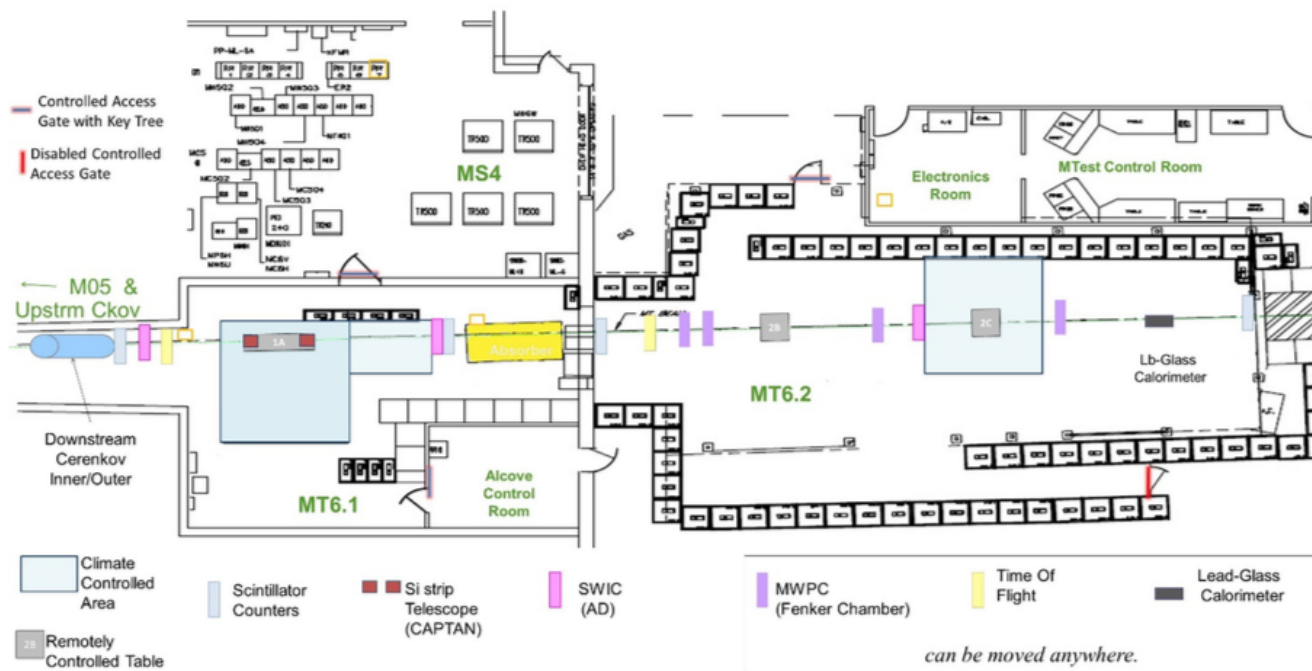
Facility Layout

- MTest and MCenter beamline enclosures



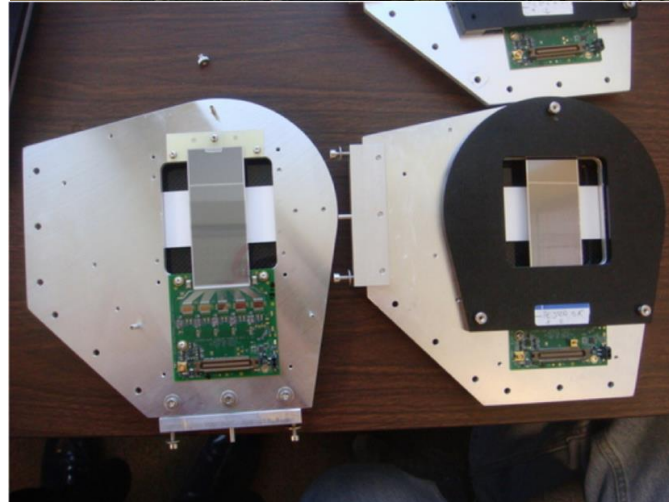
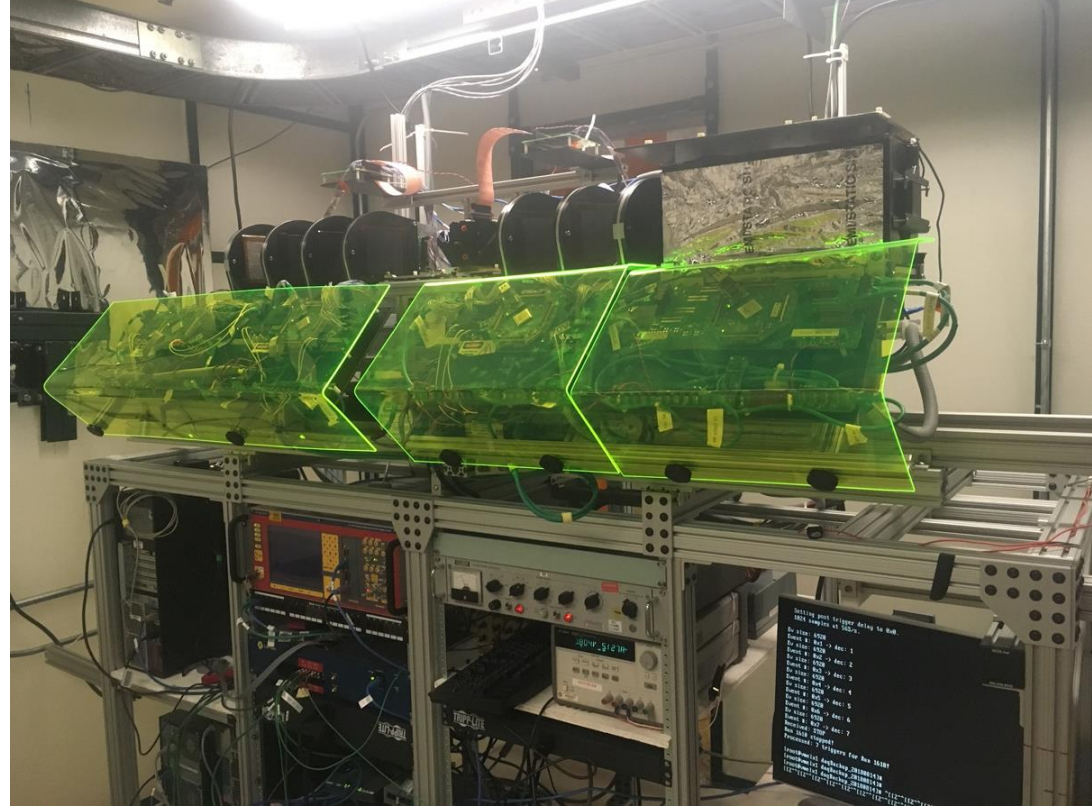
- Beam Areas
- Work Areas
- Control Rooms

Instrumentation Layout - MTest



Silicon Telescope

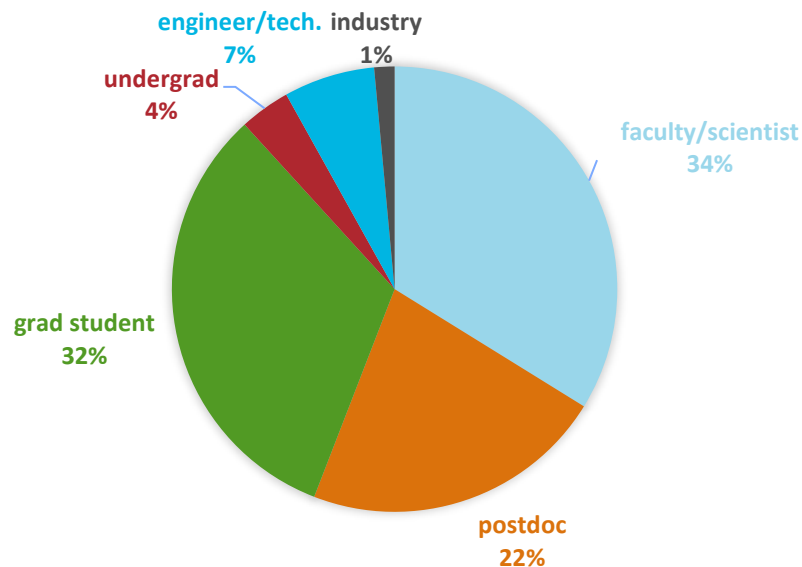
- Tracking telescope based on silicon strips and pixel planes
 - <http://www.sciencedirect.com/science/article/pii/S0168900215015521>
- 5 μm resolution on DUT
- 3.8 x 3.8 cm coverage of silicon strips
- Moveable arms and motion table for sample positioning
- Pixel sensors upgraded



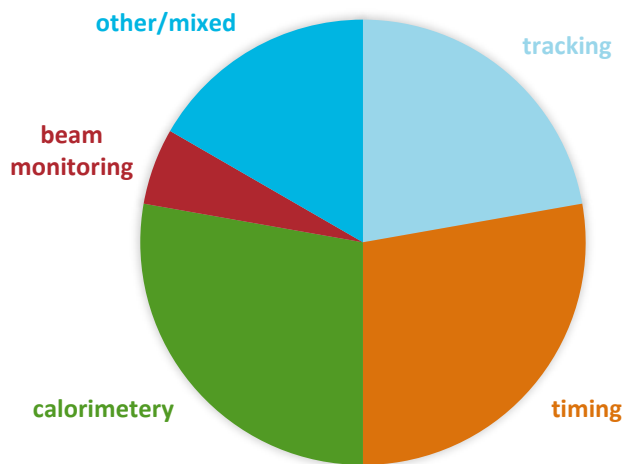
Who uses FTBF?

- 160 users from 18 different experimental efforts in FY22
- 18 Experimental efforts, 4 new efforts

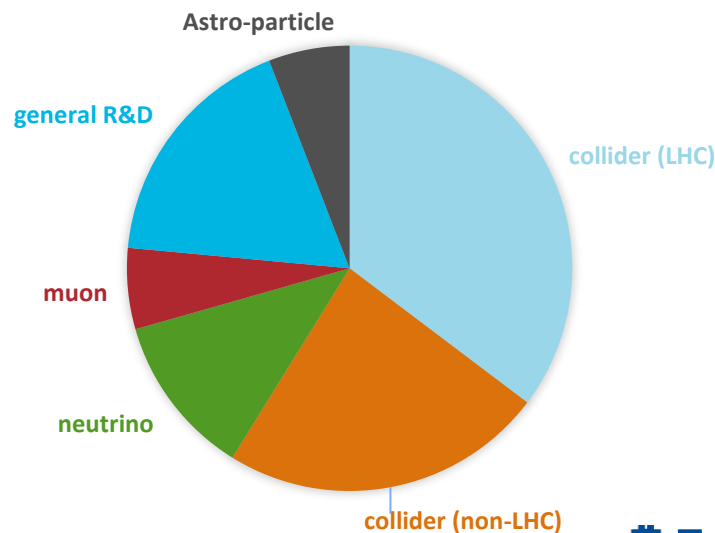
Users by professional category



Experiment by detector

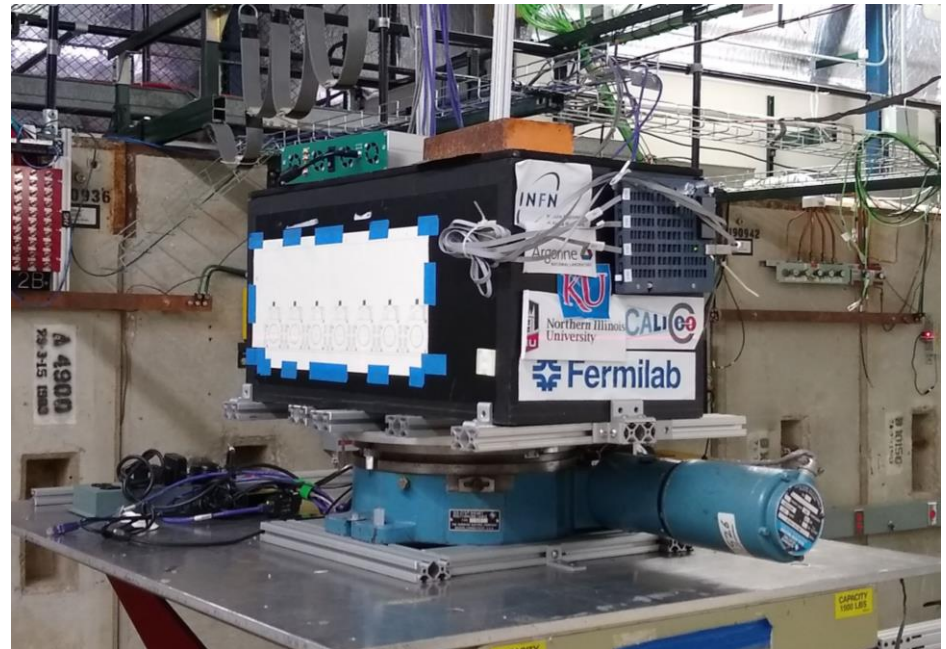


Experiment by research focus



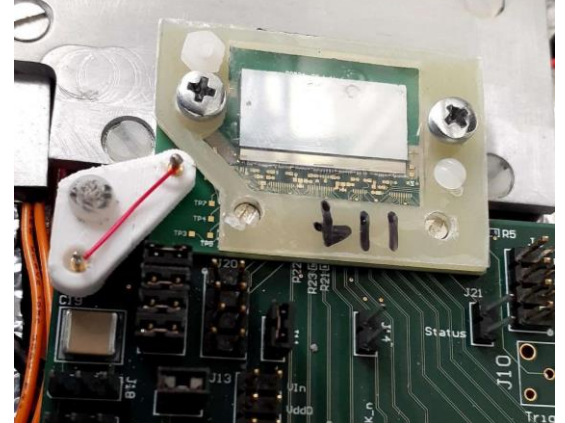
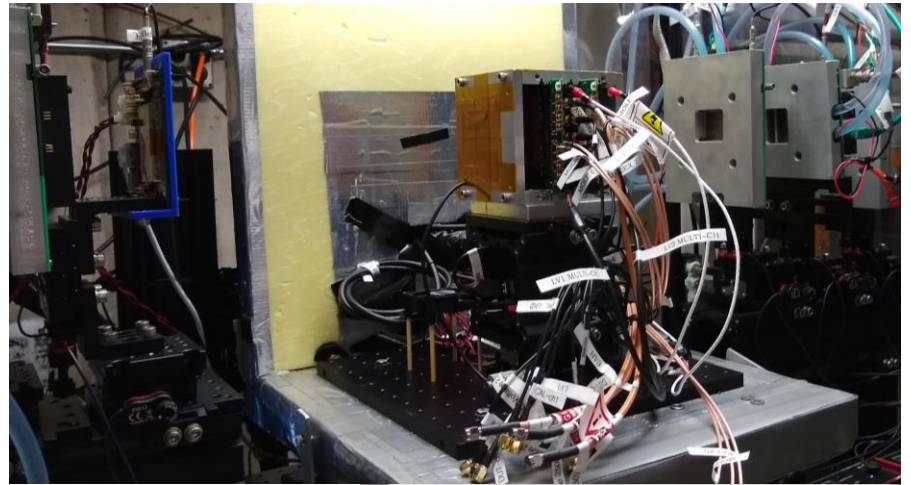
Calorimeter Studies

- Electron Ion Collider (EIC) and sPHENIX detector R&D
- General R&D for future detectors
- Advanced Particle-astrophysics Telescope prototype



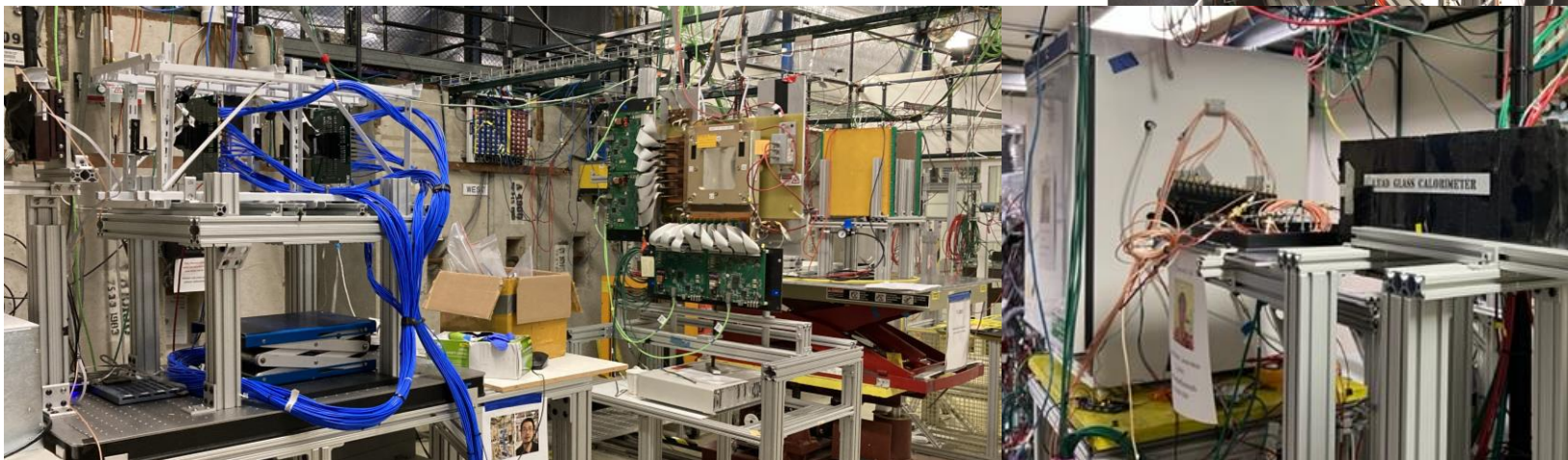
Tracking studies

- CMS/ATLAS HL-LHC pixel tracking upgrades
- GEM R&D
- Mu2e Muon veto tests



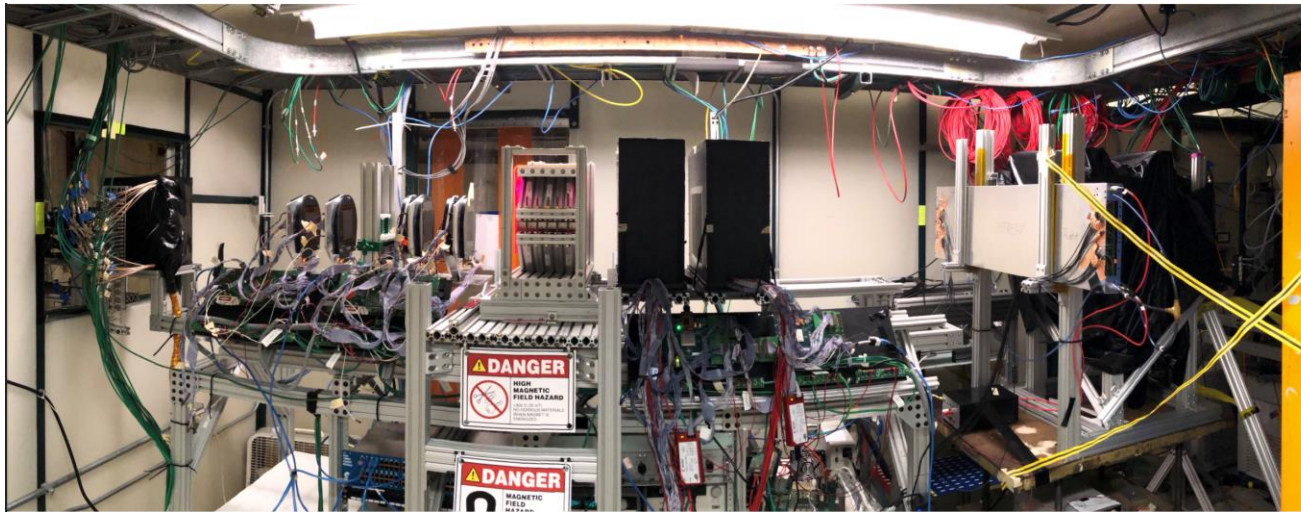
Timing studies

- Rad hard precision timing detectors for LHC: LGAD, SiPM+LYSO
- LGAD sensors tested in “high rate” area – matches rates predicted at CMS
- Precision timing at EIC: LGAD, MCP-PMT, RPC



Other Efforts

- EMPHATIC: Measure hadron production to constrain flux for neutrino experiments
- Test of “switchilator” sensitivity to charged particle beams
- Tests of new beam monitoring equipment



MCenter activities

- NOvA test beam detector
 - Designed to reduce NOvA systematics
 - Set to uninstall at the end of this beam year
- Two new detectors to be installed in MCenter
 - LArIAT liquid argon TPC will be operated in the Jolly Green Giant magnet
 - High pressure gas TPC with MCPs will be tested



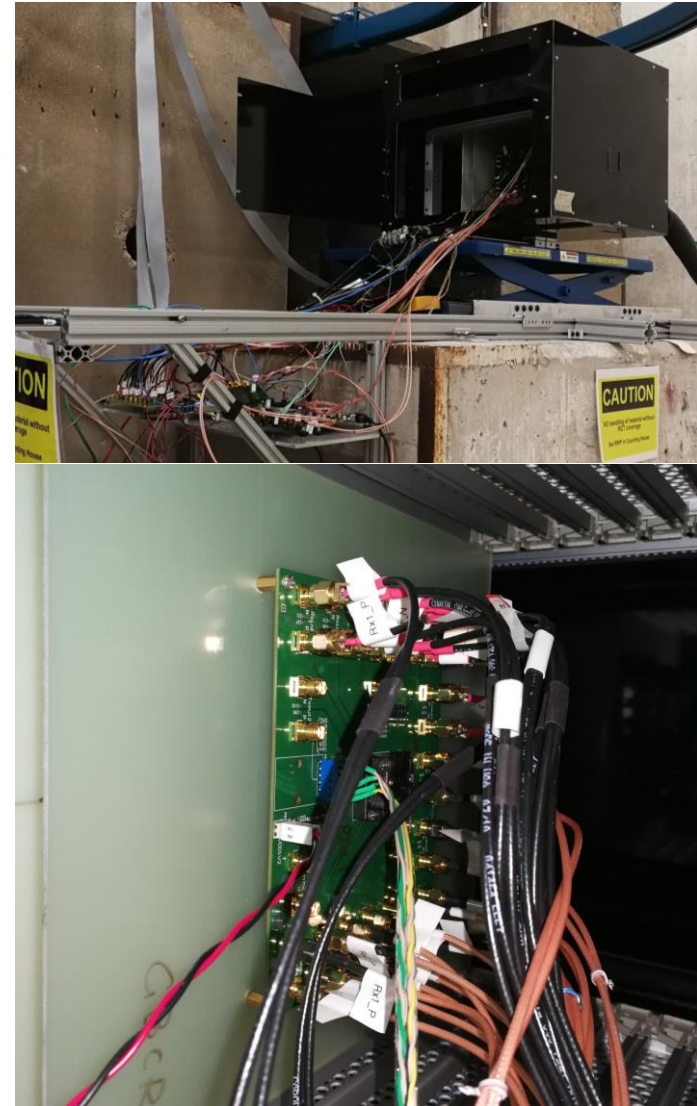
Irradiation Test Area

- Proton irradiation facility targeting HL-LHC dose rates
- Using 400 MeV protons from the LINAC
 - Beam comes for 4 seconds every minute
 - Can request 1-15 pulses per 4 second window
 - Pulse length adjustable from $\sim 6\text{-}40\ \mu\text{s}$
 - Can deliver $\sim 2.7 \times 10^{15}$ protons per hour (administrative limit of 1.3×10^{18} per year)
- Most samples placed in VME crate on a motion table on the “front porch”
- Heavy samples can be placed inside the shielding cave



ITA users

- Several irradiations from CMS and ATLAS
 - Passive high rate irradiation of tracker modules
 - Active readout single event upset testing of on-detector ASICs
- Measurements of interaction length in liquid argon
- Interest from more users in and outside HEP
- Operational startup difficulties
 - Initially limited to one pulse per minute (issue solved)
 - Removable contamination found on some samples receiving large doses (mitigation in place)
 - Difficulty clearing samples after irradiation

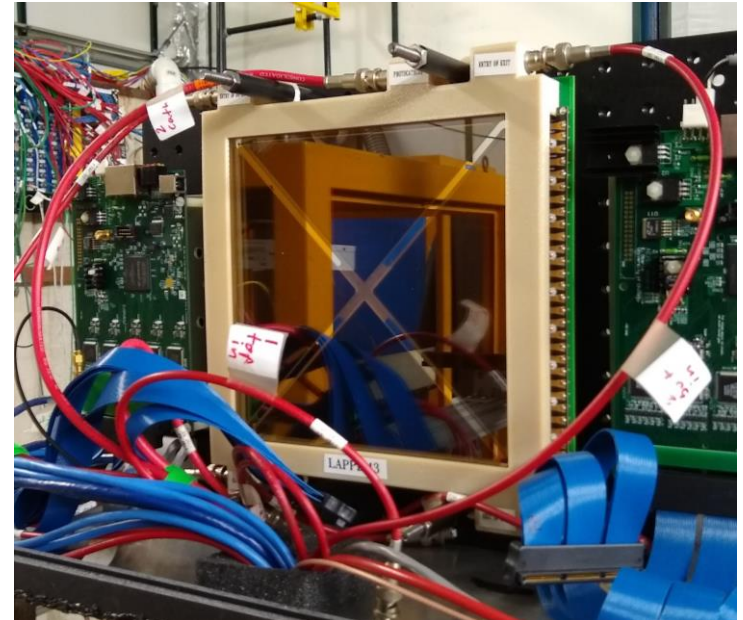


Becoming an FTBF/ITA user

- Talk to the facility about a [proposed experiment](#) and fill out a Technical Scope of Work
 - Agreement between test beam collaboration and the lab over what resources are used
 - Do you need significant engineering or tech support? Computing support? Will you have enough users to cover your shifts?
 - Document can be broad and cover multiple years and uses
- TSW information can be found here: http://programplanning.fnal.gov/tsw_orc/
 - Email us: rominsky@fnal.gov (Mandy), edniner@fnal.gov (Evan), pastika@fnal.gov (Joe)
 - Approvals typically take 4-6 weeks, depends on needs
- Scheduling for FY23 beam run (~Nov 2022 - June/July 2023) will start soon, but reach out anytime!
 - MTest requests for typically 1-4 week periods with 12 hours of primary beam use, many groups can be accommodated at once
 - MCenter requests at lower energies, often longer periods, single user

Upcoming plans at FTBF

- LAPPD based time of flight system
 - Concept tested in 2019
Angelico, Evan. doi:10.2172/1637600.
 - Making use of ANNIE readout electronics, modified for use at FTBF
 - Measured time uncertainty of 19 ps
- Jolly Green Giant (JGG) refurbishment
 - The large bore JGG magnet is needed by the LArIAT tests planed for next year
 - The magnet will be refurbished over the summer shutdown
 - 0.7 T large bore magnet



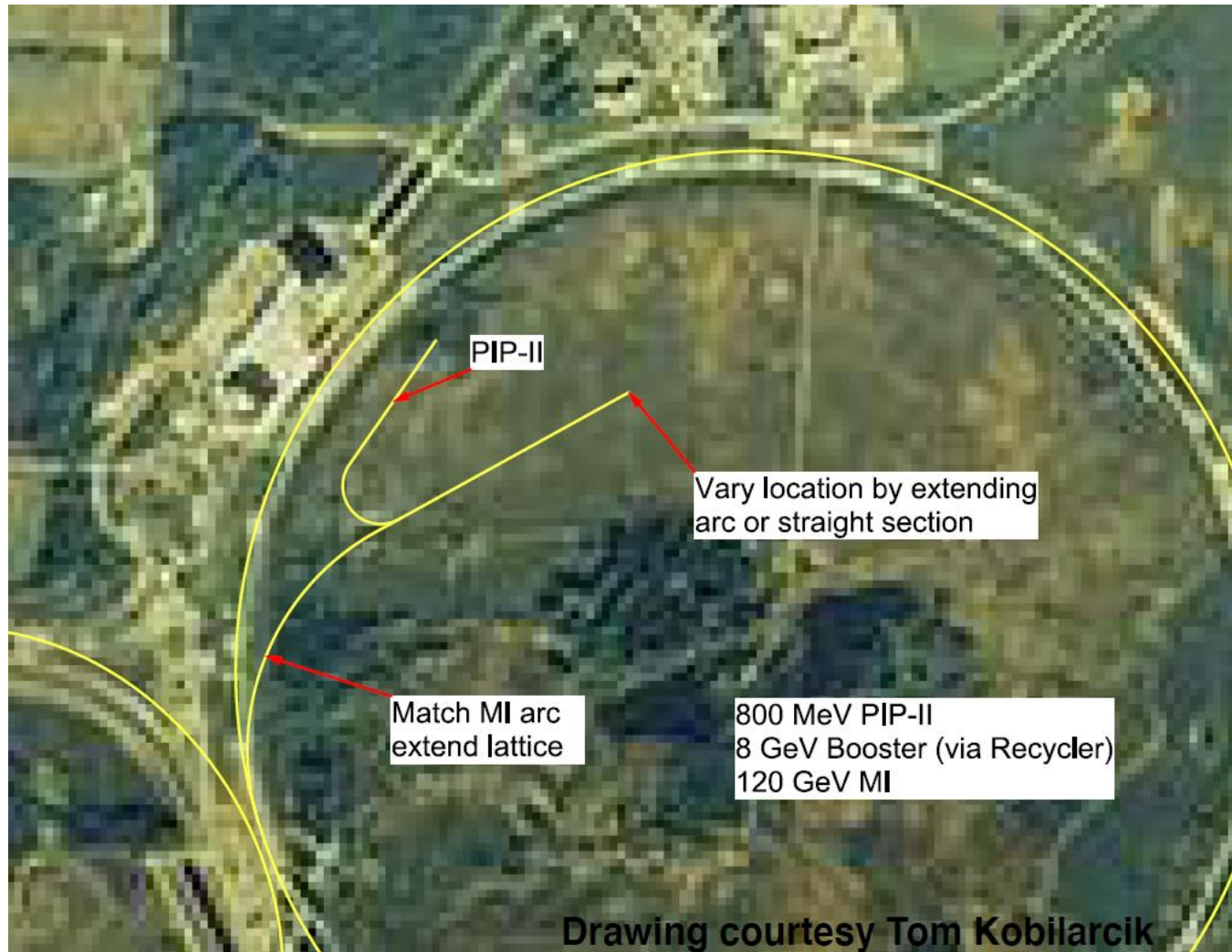
Evolving FTBF/ITA demands

- FTBF is in high demand with usage near capacity each year
 - High demand for 120 GeV beam and tracking to support collider needs
 - Increased interest in high purity electron/muon beams from muon, dark matter, neutrino communities
 - Emerging interest from APRA-E and NASA
- ITA is new facility, but has seen many users with continued interest
 - Beamline commissioned with some initial growing pains
 - Many groups have done both successful passive and active irradiation
 - Difficulties with radiation control and clearance procedures
 - Facility good for HL-LHC level radiation, but insufficient for FCC
- Potential space for months to year long small experiments
- MCenter provides secondary/tertiary beams, but with a large configuration overhead

Future test beam facility proposal

- Ongoing accelerator upgrades to PIP-II and booster provide a great opportunity for a new test beam facility
 - New location closer to accelerators makes facility more convenient and have less beamline to maintain
 - PIP-II accelerator could reach levels predicted at FCC ($\sim 10^{18}$ 1-MeV $n_{\text{eq}} / \text{cm}^2$)
 - 4-6 beamlines
 - 120 GeV from MI
 - 8 GeV from booster
 - 800 MeV from PIP-II
 - Clean secondary lines for electrons, muons, and pions
 - Collocate test beam and irradiation facilities
 - Dedicated infrastructure for control rooms, experimental staging, facility infrastructure, irradiated material handling and storage

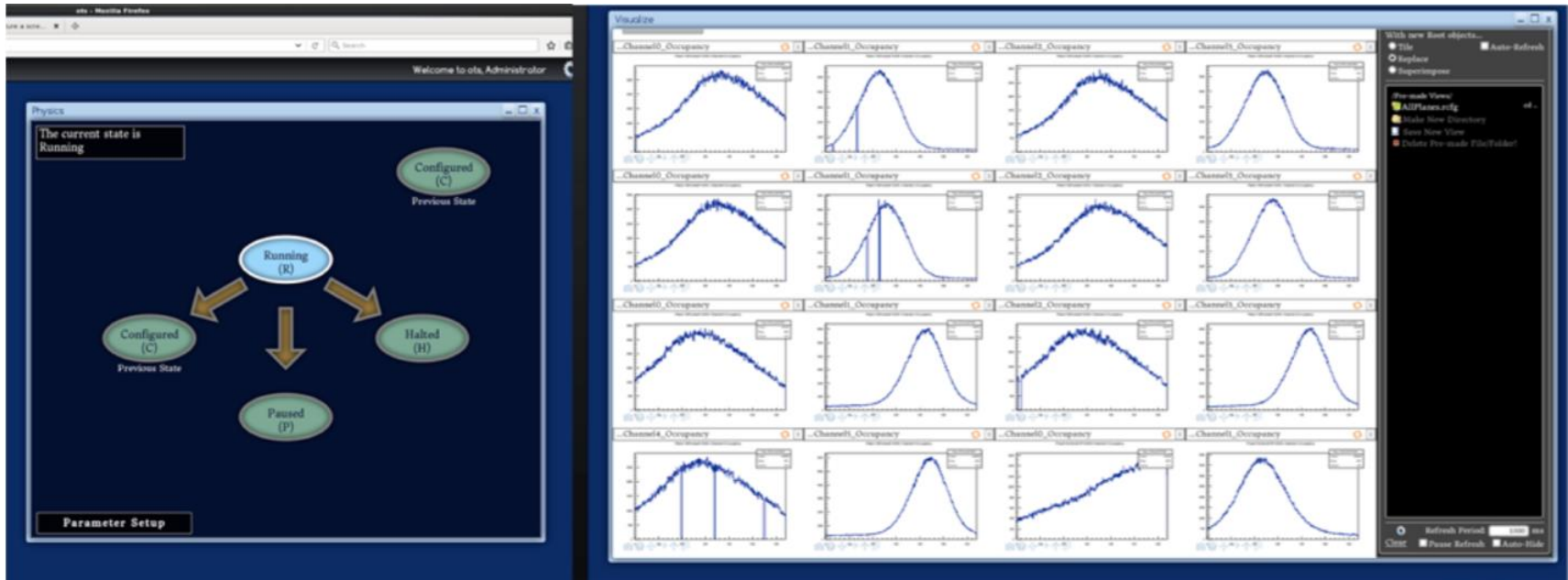
Potential location for new facility



Summary

- The Fermilab Test Beam Facility is a user-oriented facility aimed at providing high energy particle beams for applications particle, nuclear, and beyond
- ITA has had its first full year of running, many groups ran successfully despite challenges
- We are always working to improve the facility and our user's experience, suggestions are welcome!
- A big part of our mission is outreach, we encourage students to come and we support interns over the summer (restarted in person as of this summer)
- We look forward to seeing you at Fermilab! To learn more:
 - Slack Team: [fnal-testbeam](#)
 - Webpage: ftbf.fnal.gov
 - Listserv: test_beam@fnal.gov

Off-The-Shelf Data Acquisition (OTSDAQ)



- FNAL computing division developed, flexible and scalable system allowing integration with other devices
 - Based on XDAQ (CMS) and ArtDAQ (Fermilab)
- Tied into facility MWPCs, Cherenkov detectors, silicon strip telescope.
- Several groups (CMS outer tracking, CMS Timing, RD53 chip, LHCb) have integrated and taken fully synchronized data with the telescope

NIM+

- Fermilab built a board (NIM+) that accept NIM/TTL signals and it can be plugged in any FPGA board that has a standard FMC connector
- Firmware written to allow sync with a 40Mhz clock (LHC)
- Already used by multiple experiments
- Ethernet controlled can stay in enclosures
- Streams trigger data allowing multiple users to run at the same time with different trigger rates

