Fermilab Test Beam Facility

Vallary Bhopatkar
On behalf of FTBF

54th Fermilab Users Meeting
Aug 2, 2021
Fermilab Test Beam Facility (FTBF)

• In operations since 2005, more than 1000 users from around 30 countries
• Accommodate broad spectrum of experiments
• Two beamlines
  • MTest: 120 Gev protons, 2-80 GeV mix
  • MCenter: 200 MeV to 80 GeV mix
• One of the high energy test beam facility in the world
Beam Overview

- Beam is available 24/7 from Nov-May with 4 second beam spill every 60 seconds
- Tunable rate from 100 to 300,000 Hz
- 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
- Further details can be found [http://ftbf.fnal.gov/beam-overview/](http://ftbf.fnal.gov/beam-overview/)
FTBF Layout

- Beam Areas
- Work Areas
- Control Rooms
Facility Infrastructure

- ACNET controlled motion tables
- Laser alignment
- Helium tubes
- Web based cameras
- Crane coverage (30 ton)
- Climate controlled huts
- Gas patch panels
- Signal, network, HV panels
- Two control rooms
- Counting house
- Tech shop
- Technical staff to help turn any plan into reality
MTest Instrumentation Layout
Facility Instruments

- Facility has number of different instrumentation systems. Details can be found here: https://ftbf.fnal.gov/instrumentation-overview/
  - Cherenkov detectors¹
  - Multi-Wire Proportional² Chambers
  - Lead glass calorimeter³
  - Assorted scintillator paddles⁴
  - Silicon Strip and Pixel detectors⁵
Beam Monitoring

• Users can monitor live beam status using https://www-bd.fnal.gov/synoptic/display/MTest/FTBF_Status

FTBF Status
Mtest Energy: 120 GeV
MTest Mode: Proton

MT6SC1 0 Cnts
MT6SC2 0 Cnts
MT6SC3 0 Cnts
MT6SC4 0 Cnts

SC1+SC2+SC3+Spill (F:MTSCL5) 2237015 Cnts
MWPC Triggers 2239959 Cnts
Experiment Triggers 2761279 Cnts
Next Spill 1445661 Sec
Various Users Experiments at FTBF

- strips
- felix
- telescope
- fast-timing
- LHC
- CMS
- pixel
- ATLAS
Various Users Experiments at FTBF

Collider Experiments

- GEMs
- TPCS
- EIC
- Micromegas
- LGADs
- Micromegas
- sPHENIX
- DAQ Testing
Various Users Experiments at FTBF

Neutrinos & Muons

Detector R & D

EMPHATIC

Nova

Mu2E

LAPPD

Crayfis
FTBF Control Room During Covid 19

- Maximum occupancy: 6 people only for 15 mins
- Extended occupancy: Max 2 people in workstation and 1 in conference room

Mask and alcohol wipes available for users

Screens and partitions between different workstations

North entrance to the M-Test control room

North end looking south
**Users during Covid-19**

- **MTest:**
  - 54 User weeks (27 week provided beam)
  - 16 Experimental groups (some groups came multiple times)
  - Most of the group locally based
  - Some travel domestically
  - Several experiments were cancelled due to COVID restrictions

- **Experiments:**
  - Neutrino: 1 (NOvA)
  - Collider: 4 (sPHENIX, Solid)
  - CMS/ATLAS: 9
  - General R&D: 2 (ADRIANO, LGADs)

- **MCeter:**
  - NOvA was using MCcenter whole time
User Experience: T1224
Argonne Pixel Tracking Telescope
Argonne Pixel Tracking Telescope

In MT6.1B Enclosure

Up-stream 3 pixel quad modules
DUT cold box
Down-stream 3 pixel quad modules

120 GeV proton beam

DUT Cold Box

Chiller
DCS Computer
Telescope DAQ
DUT DAQ Computer

Up-stream 3 pixel quad modules
T0 T1 T2

Down-stream 3 pixel quad modules
T3 T4 T5

Beam direction
Telescope Plane

Second and fourth plane rotated by 90°

Planar Pixel Quad Module

Flexibility to switch between chips for changing master chip by adding jumpers

For easy mounting for alignment
Monitoring plots: Occupancy and Correlation

Narrow Beam

Wide Beam

Occupancy

Correlations

Beam spot

Correlation between first plane’s rows and second plane’s planes column
Tracking Analysis: Tel0

\[ \sigma_{\text{expected}} = \frac{\text{Pitch}}{\sqrt{12}} \]

\[ \sigma_X = \frac{250 \, \mu m}{\sqrt{12}} \]

\[ \sigma_Y = \frac{50 \, \mu m}{\sqrt{12}} \]

\[ \sigma_X \approx 72 \, \mu m \]

\[ \sigma_Y \approx 14.43 \, \mu m \]

FTB data 2020
Proton 120 GeV
Tel0

Mean = 12.93 \, \mu m
RMS = 71.83 \, \mu m

Mean = 2.23 \, \mu m
RMS = 12.78 \, \mu m

\[ \sigma = 71.83 \, \mu m \]

\[ \sigma = 12.78 \, \mu m \]
Argonne has successfully installed the pixel telescope in enclosure MT6 1B

Efficiency of the telescope is about 99%

Currently used to test RD53A pixel detectors developed for ATLAS LH-LHC upgrade

Also supports DAQ testing
  • Felix DAQ upgrade for LH-LHC

Now implementing synchronization with LGADs for fast timing results
As a FTBF User

• To become a user, contact facility with a proposed experiment and submit the Technical Scope of Work (TSW)

• Possibility of converting a proposal into running experiment for couple months. Facility has a dedicated technical staff and experts to assist

• As a user one can gain following experiences:
  • Design and assemble experiment in the beam line
  • Lean to operate DAQ system
  • Working with Main Control Room (MCR) to optimize the beam, control access
  • Performed data analysis

• Develop relationships with experts across the laboratory in accelerators, computing, detector technologies, safety, and the broader FTBF user community
Fermilab Irradiation Facility
Fermilab Irradiation Facility

• In 2020, started operation of a new Irradiation Test Area at (ITA) the end of a refurbished 400 MeV beamline

• Shielding cave and associate infrastructure is installed

3’x3’x9’ cave with an additional 3’ depth on “front porch”
ITa Infrastructure

- Card cage is available at the facility to install samples
- Patch panel in the ITA allows possibility for cooling and cabling
- Rare of the box supports the PIN diode array for real-time dosimetry and position information
- Addition mounting request can be accommodated

- Experiment monitoring and data taking can be performed remotely from counting house
- Remote camera is available for surveillance

- Freezer storage is available for storing samples

- RG-58 BNC, RG-58 SHV, and cat6 cable patch panels connect to enclosure
- Additional cabling can be pulled upon request
FY2021 ITA Campaigns

• During challenging covid times, successfully started operation and ran first four campaigns with CMS and ATLAS experiments
• One of the ATLAS campaign used the powered readout tests
• During one of the CMS campaign, facility reached its full design intensity
• Thanks to beam physicist Jason St. John and RSO Sue McGimpsey and the wider support from AD and ESH for the efforts to get the new facility commissioned in time
• Large scale operations are planed for next year
• Currently accepting the proposals for FY2022
Becoming User and Scheduling

• First step is to contact the facility staff for time and write the TSW (Technical Scope of Work)
  • Evan Niner: edniner@fnal.gov, Mandy Kiburg: rominsky@fnal.gov
  • Agreement between user and the lab over what resources are used; in particular the materials being irradiated and final destination.

• Support campaigns with remote or physical presence at FNAL
  • We can irradiate and ship passive samples to/from a user remotely
  • Possible to travel to FNAL, install an advanced setup in the beam enclosure and actively monitor from the counting house.

• Users can schedule ITA time concurrently with the Fermilab Test Beam Facility to test devices before/after irradiation.

• Anticipate changing over samples ~weekly once full intensity is established.
• Radionuclide Analysis Facility (RAF) available onsite to provide dosimetry.
Summary

- FTBF is one of the world class facility with high energy beam for detector R & D
- At Fermilab, new radiation facility is started in 2021. CMS and ATLAS were the first user to irradiate samples early this year
- At full capacity ITA will deliver 2.7e15 protons per hour @ 400 MeV
- Continuously improving facility resources and user experience
- Scheduling for FY22 is now open for FTBF and ITA
- Look forward to seeing you at Fermilab! To learn more:
  - Slack Team: fnal-testbeam
  - Webpage: ftbf.fnal.gov, ita.fnal.gov
  - Listserv: test_beam@fnal.gov
Support Across the Lab
Backup
Beam Performance: MTest

Positive Beams Composition, Open Collimators 2016

Negative Beams Composition, Open Collimators 2016

Studies by E. Skup and D. Jensen

Table with energies, beam spread, percentages:
MTest Instrumentation: Silicon Telescope

- Tracking telescope based on silicon strips and pixel planes
- 5 µm resolution on Device-Under-Test (DUT)
- 3.8 x 3.8 cm coverage of silicon strips
- Moveable arms and motion table for sample positioning
MTest Instrumentation:

Beam Direction

Coincidence Trigger  Tracking

MWPC1  MWPC2  MWPC3  MWPC4

Lead Glass

Ckv U  Ckv D  SC1  Silicon telescopes  SC2
MTest Instrumentation:

Beam Direction

Particle Identification

Fig. 9. 32 GeV/C Density Curve after Mirror Alignment
User Experiments: LHC groups

• High Luminosity LHC upgrade R&D by ATLAS and CMS
• Variety of sensor and readout chip (RD53a) testing.
  • Both before and after irradiation
• Radiation hard timing detectors with 30-40 picosecond resolution
• Argonne Pixel Telescope development and testing
User Experiments: Other Collider Experiments

- Electron Ion Collider (EIC) and sPHENIX detector R&D
- Calorimeters, trackers, vertex detectors, TPCs, GEM and Micromegas
- Ongoing program testing options. Component integration and DAQ testing
User Experiments: Neutrinos and Muons

- Mu2E scintillator testing
- EMPHATIC, Measure hadron production to constrain flux for neutrino experiments
- NOvA Test Beam program, constraining systematic uncertainties
User Experiments: General Detector R & D

• Projects as small as one student, come develop your idea!

• Crayfis: Cosmic ray detection with cell phone cameras

• Characterizing properties of Large-area Picosecond Photo Detectors (LAPPD™) for use in a time-of-flight system
  • Evan Angelico, University of Chicago 2020 thesis: Development of Large-Area MCP-PMT photo-detectors for a Precision Time-of-Flight System at the Fermilab Test Beam Facility
MTest Instrumentation: Off-The-Shelf Data Acquisition (OTSDAQ)

- SCD developed, flexible and scalable system allowing integration with other devices
- Tied into facility MWPCs, Cherenkov detectors, silicon strip telescope.
- Working to integrate with facility, enhance user experience, document
- Several groups (CMS outer tracking, CMS Timing, RD53 chip) have integrated and taken fully synchronized data with the telescope

L. Uplegger, R. Rivera, E. Flumerfelt

https://otsdaq.fnal.gov/
MTest Infrastructure: NIM+

- SCD 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
Facility Background

- Beam line and enclosure originally constructed in 2003-2007
- MuCool Test Area to explore ionization based beam cooling components for the Muon accelerator program
- Hosted a range of radio frequency experiments
- Program ended in 2016, providing a suitable beam line and enclosure for irradiations
2019-2020 Refurbishment

• Cleaned out the MuCool infrastructure
• Added moveable stripping foil at final bend in beamline to produce 400 MeV protons but retain the ability for H- beam (electrons still stripped at final vacuum window but on same trajectory as protons)
• Adjust location of final focusing triplet
• Update beamline instrumentation and add shielding cave and experiment infrastructure
• Improve facility shielding and update assessment

Photos courtesy Jason St. John