Fermilab Test Beam Facility

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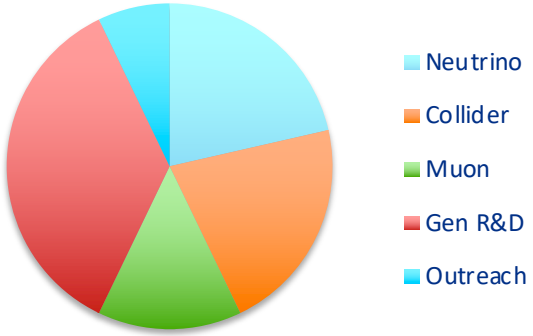
On behalf of FTBF

54th Fermilab Users Meeting

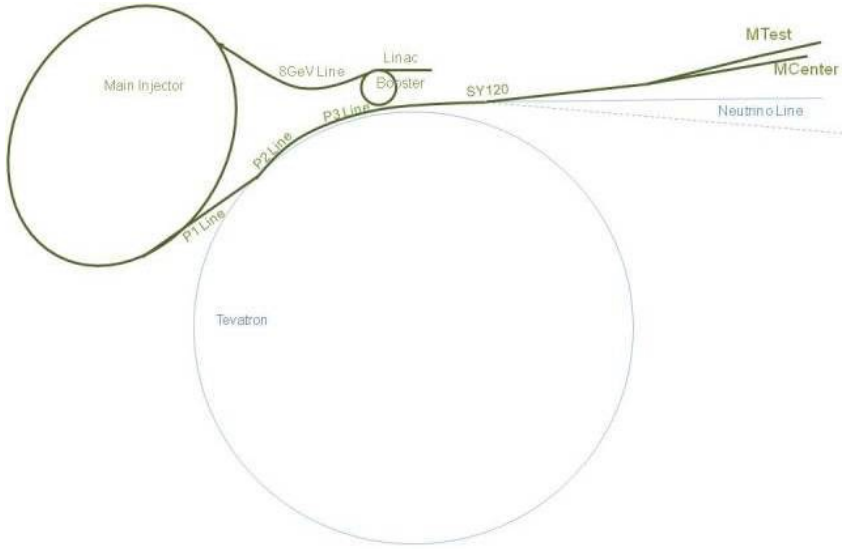
Aug 2, 2021

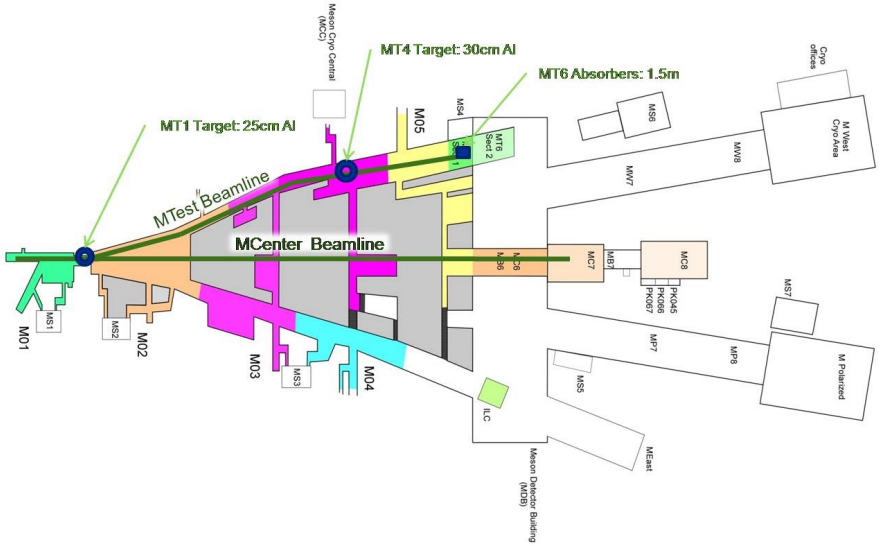
Fermilab Test Beam Facility (FTBF)

- 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



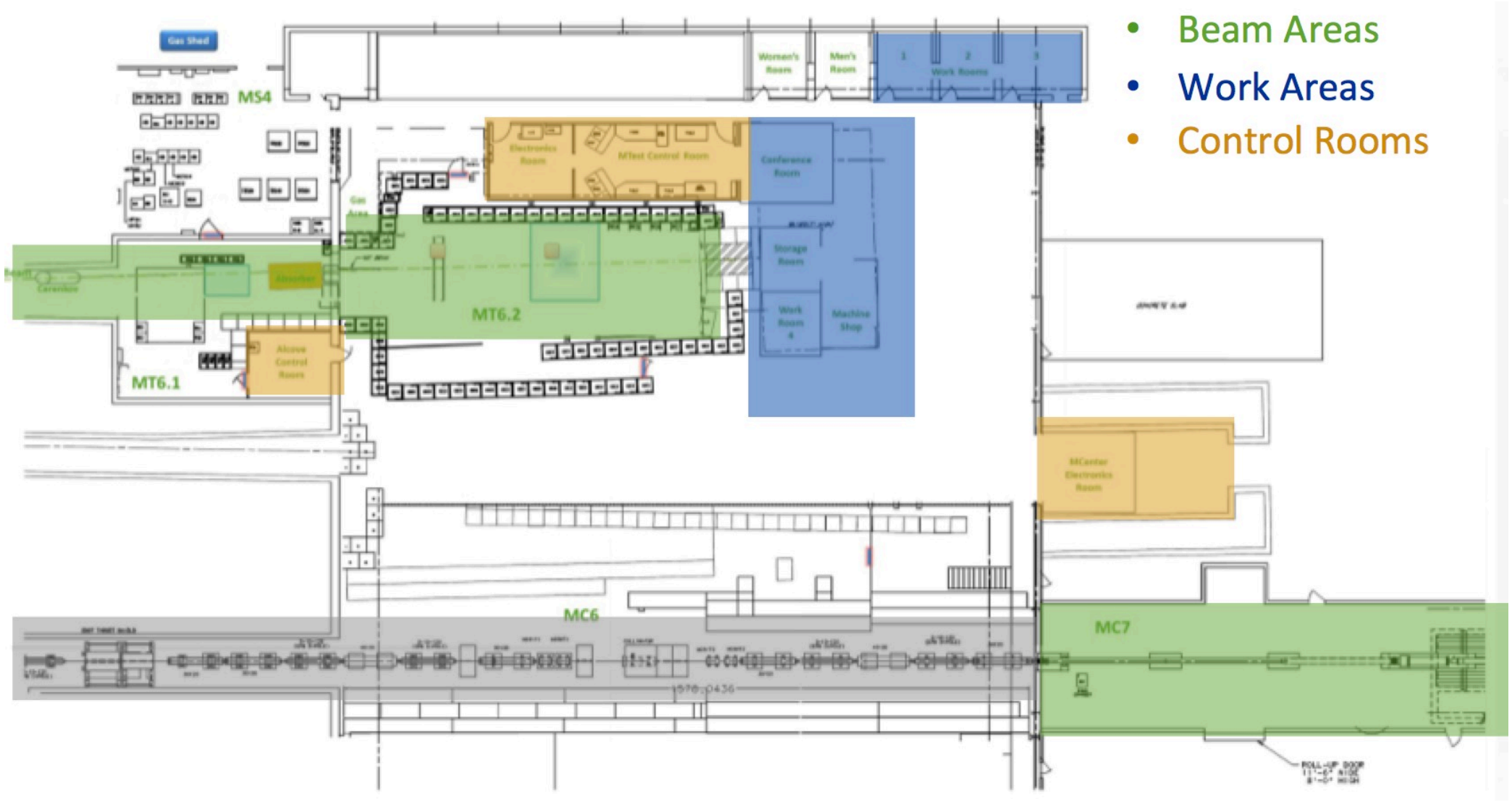
Beam Overview





- 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/

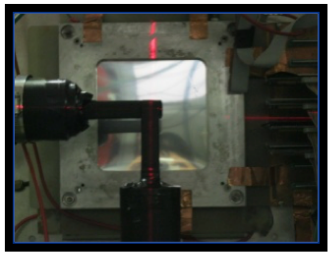
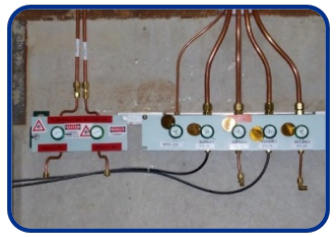
FTBF Layout



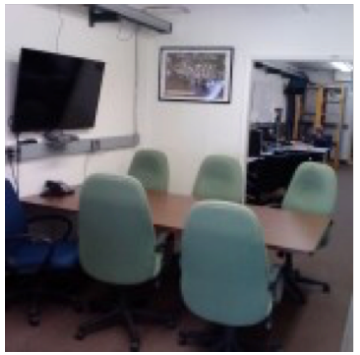
Facility Infrastructure

- 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

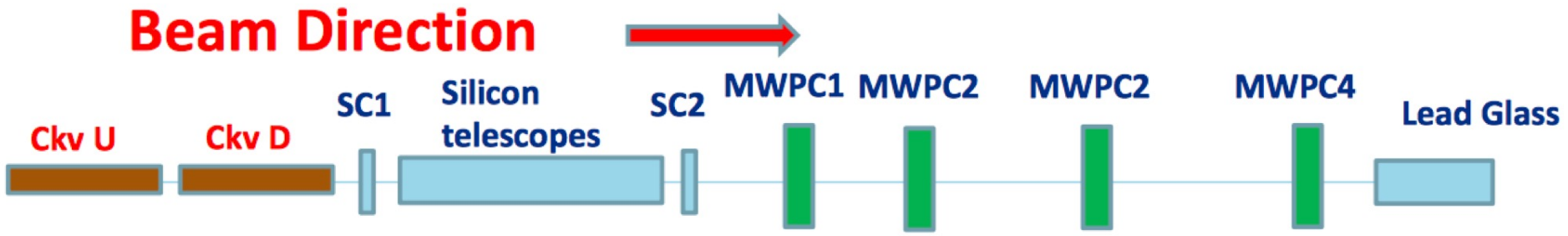


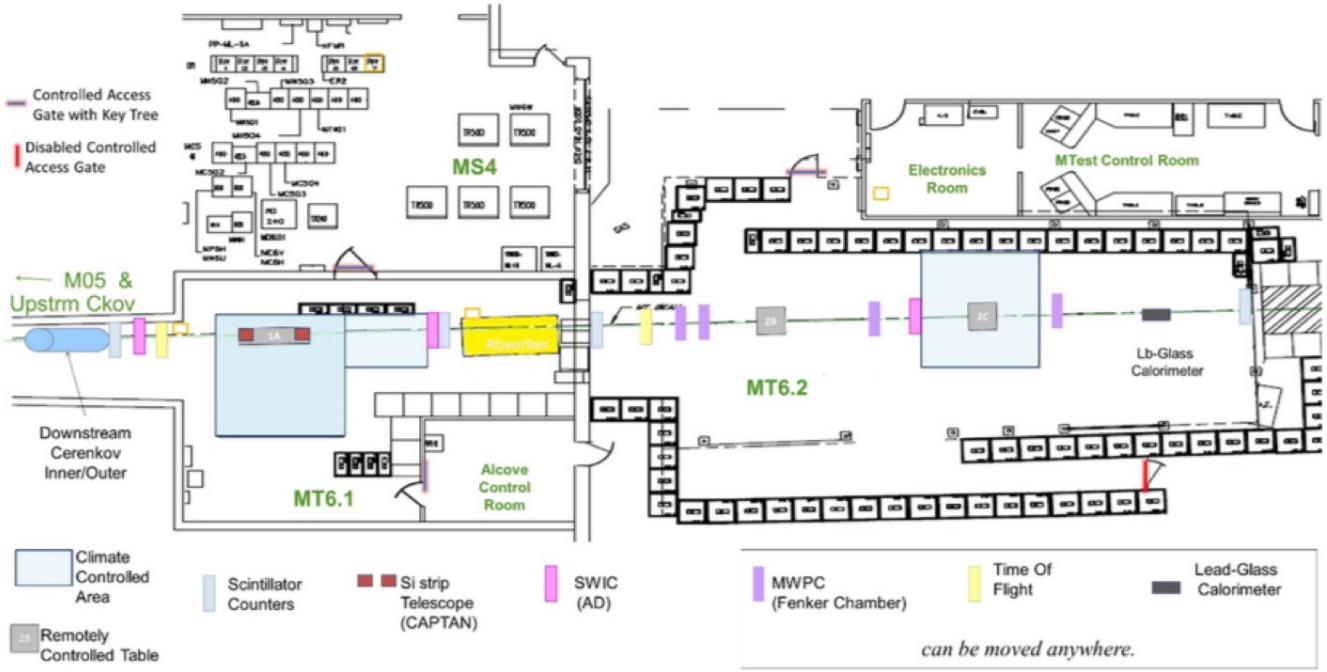








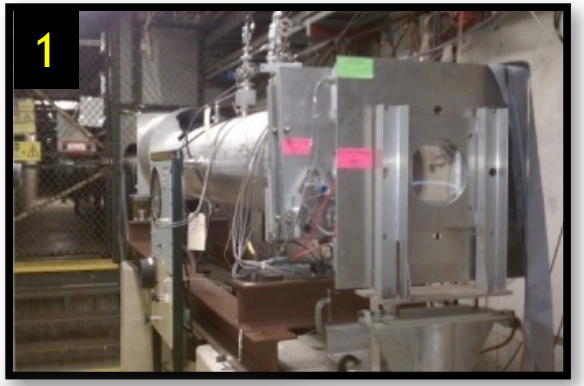
MTest Instrumentation Layout

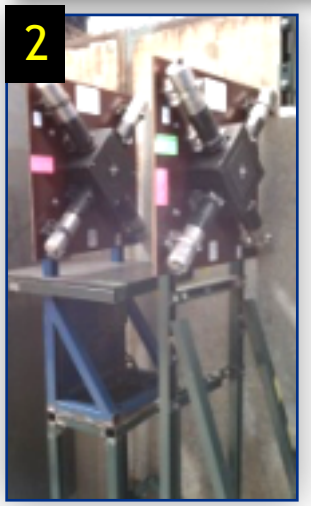


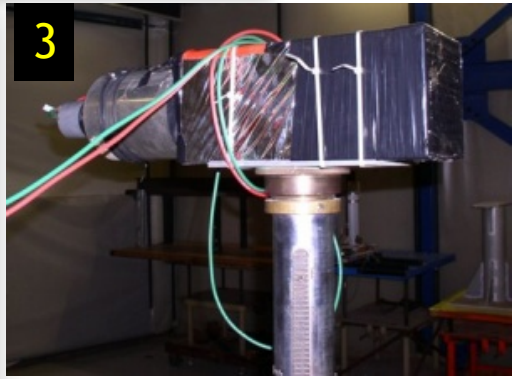


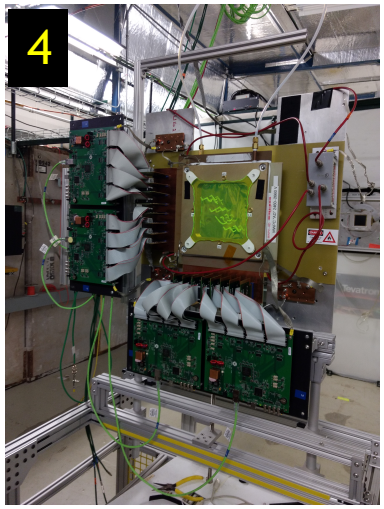
Facility Instruments

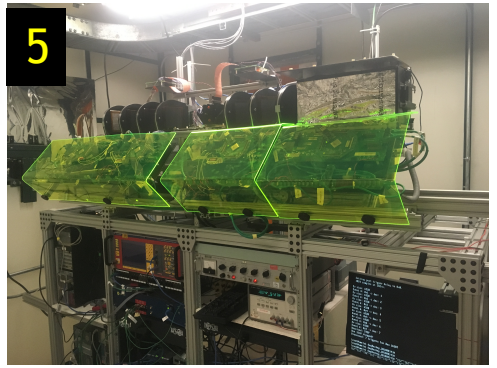
- Facility has number of different instrumentation systems. Details can be found here: https://ftbf.fnal.gov/instrumentation-overview/
  - Cherenkov detectors[1]
  - Multi-Wire Proportional[2] Chambers
  - Lead glass calorimeter[3]
  - Assorted scintillator paddles[4]
  - Silicon Strip and Pixel detectors[5]



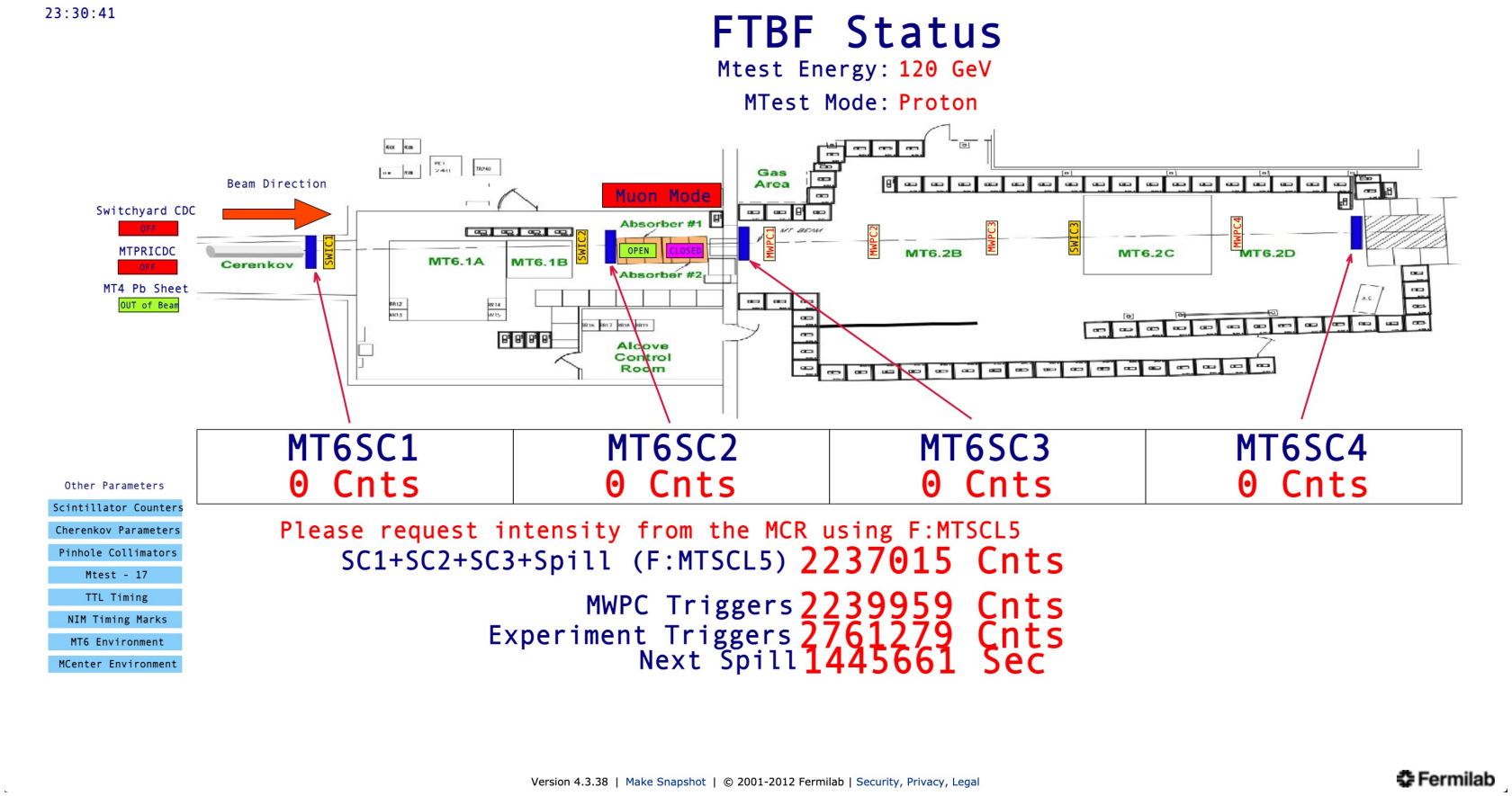








Beam Monitoring

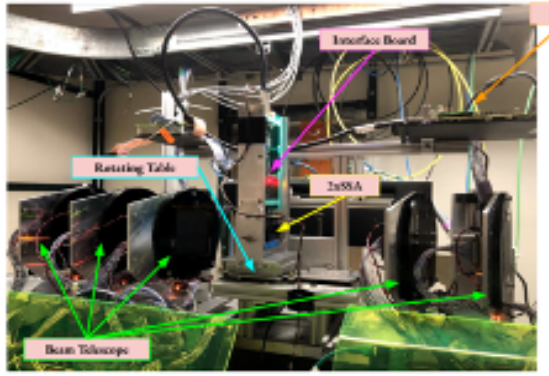


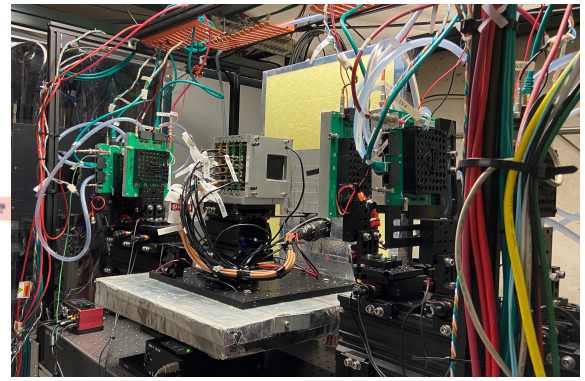
- Users can monitor live beam status using

https://www-bd.fnal.gov/synoptic/display/MTest/FTBF_Status

Various Users Experiments at FTBF

strips

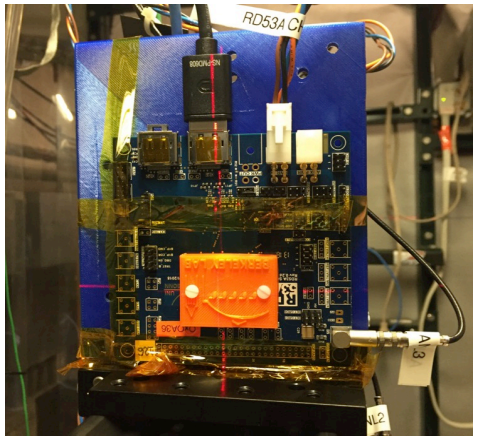




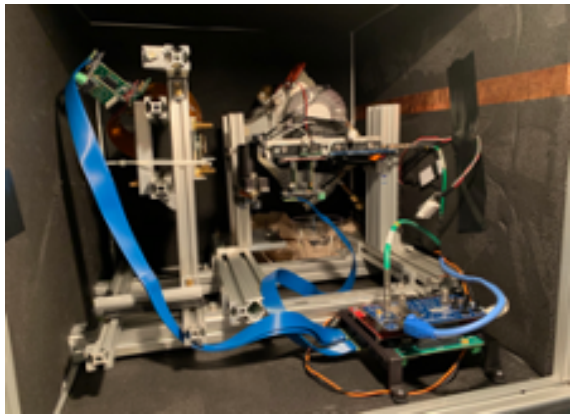
LHC

telescope

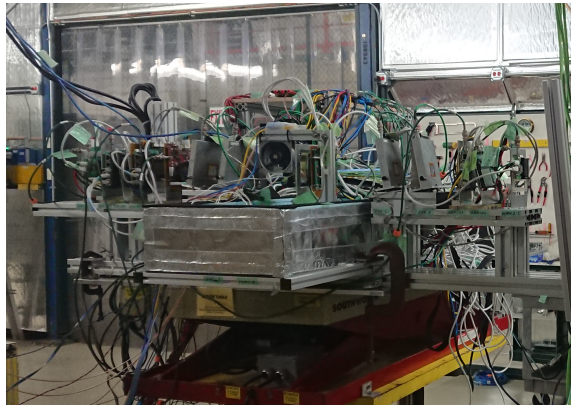
felix



CMS



fast-timing

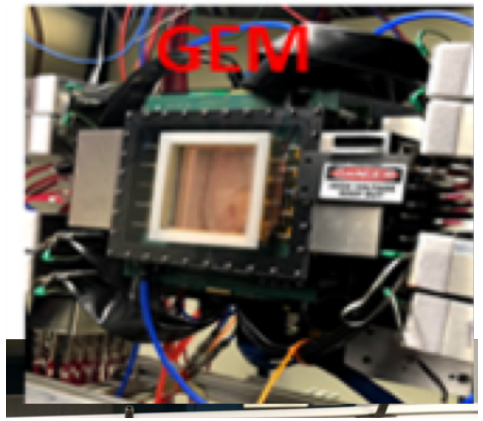


ATLAS

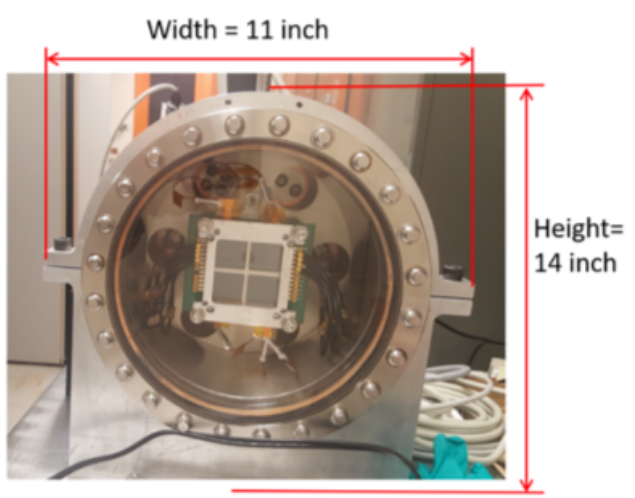
pixel

Various Users Experiments at FTBF

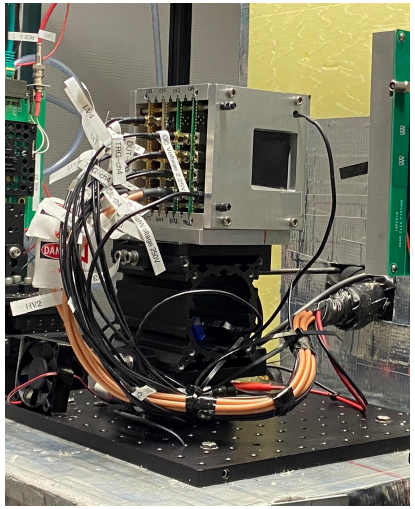
GEMs



TPCs



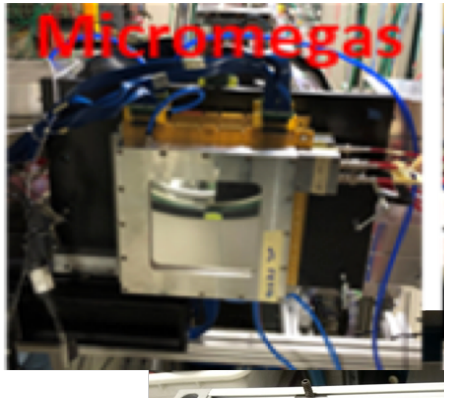
LGADs



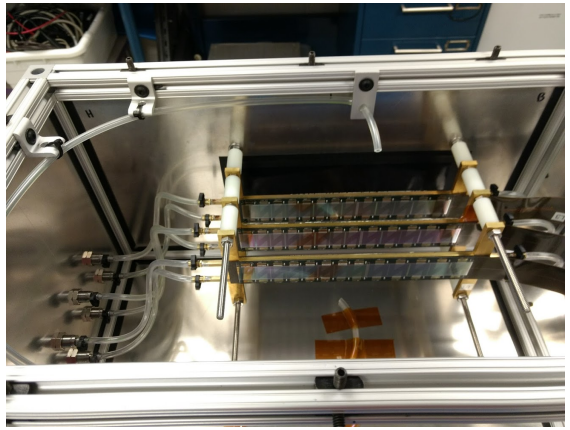
Collider Experiments

sPHENIX

EIC



Micromegas



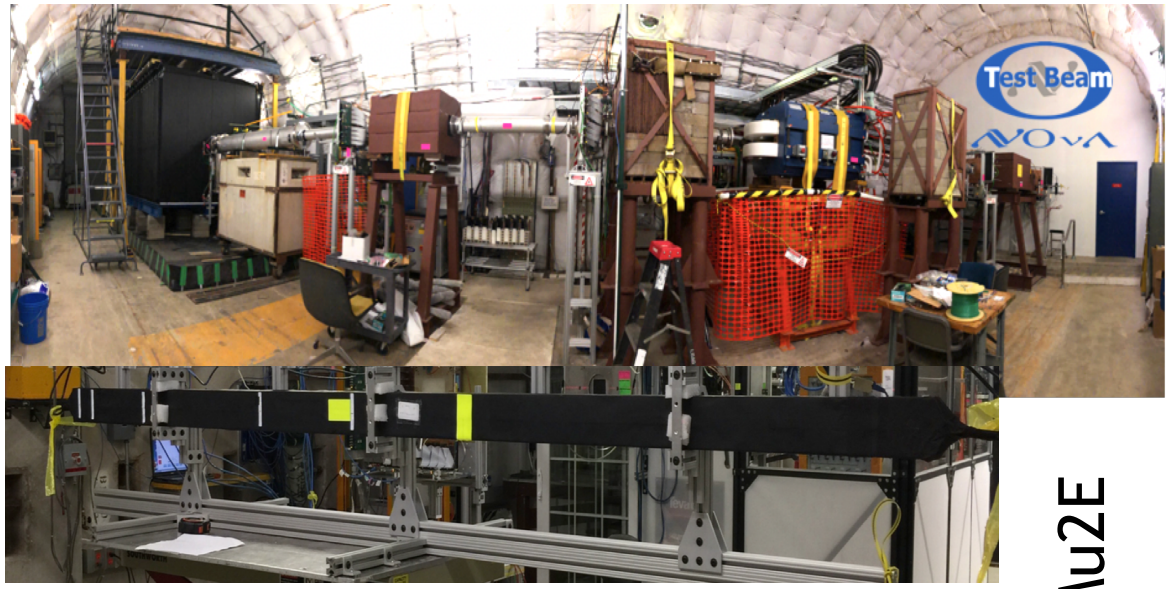
DAQ Testing

Various Users Experiments at FTBF

Neutrinos & Muons

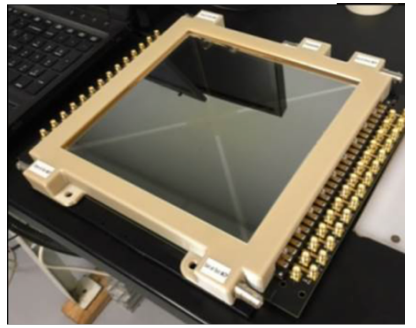
EMPHATIC

Nova



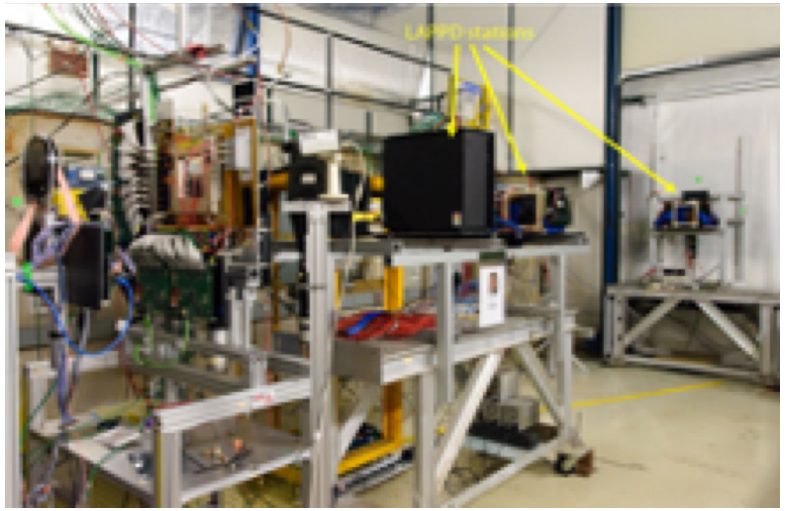
Mu2E

Crayfis

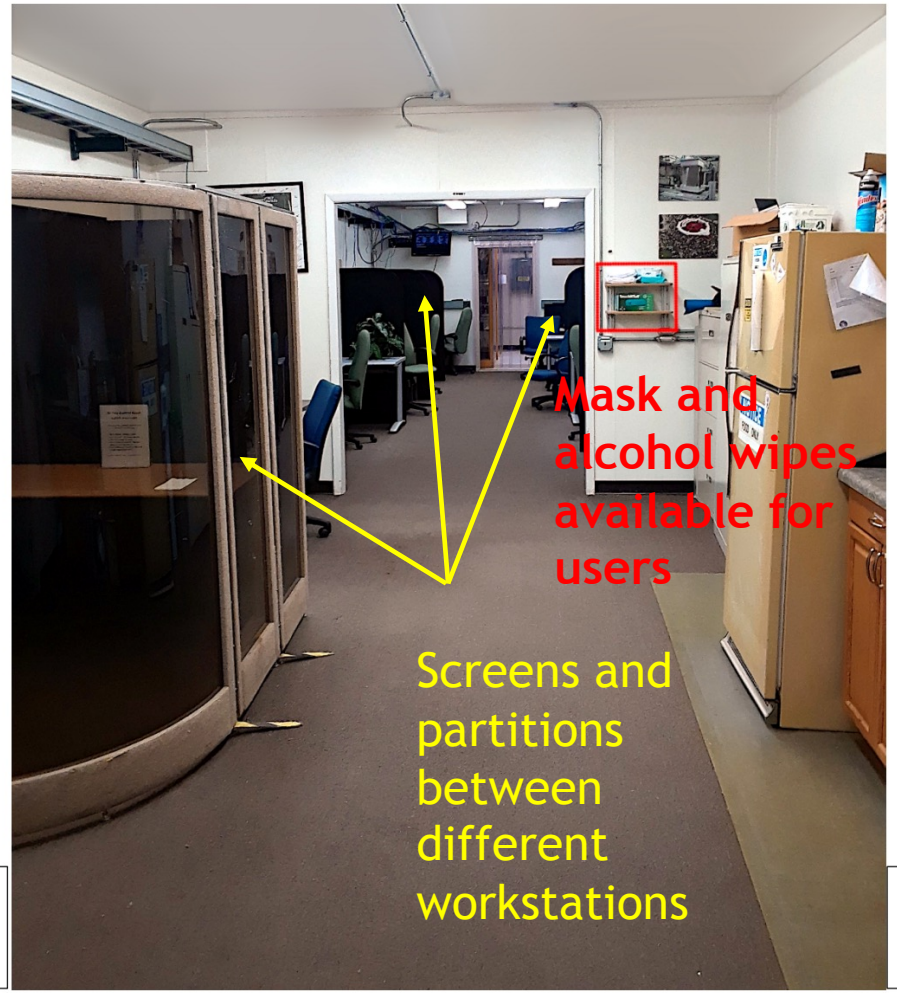


Detector R & D

LAPPD



FTBF Control Room During Covid 19

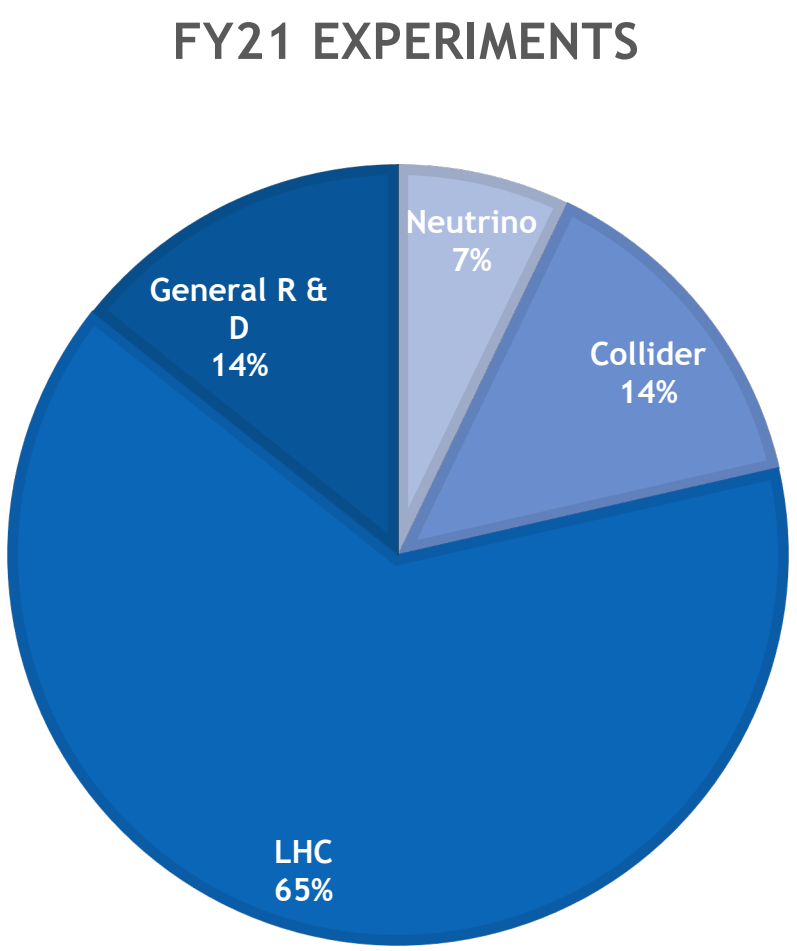


North entrance to the M-Test control room

North end looking south

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

Users during Covid-19

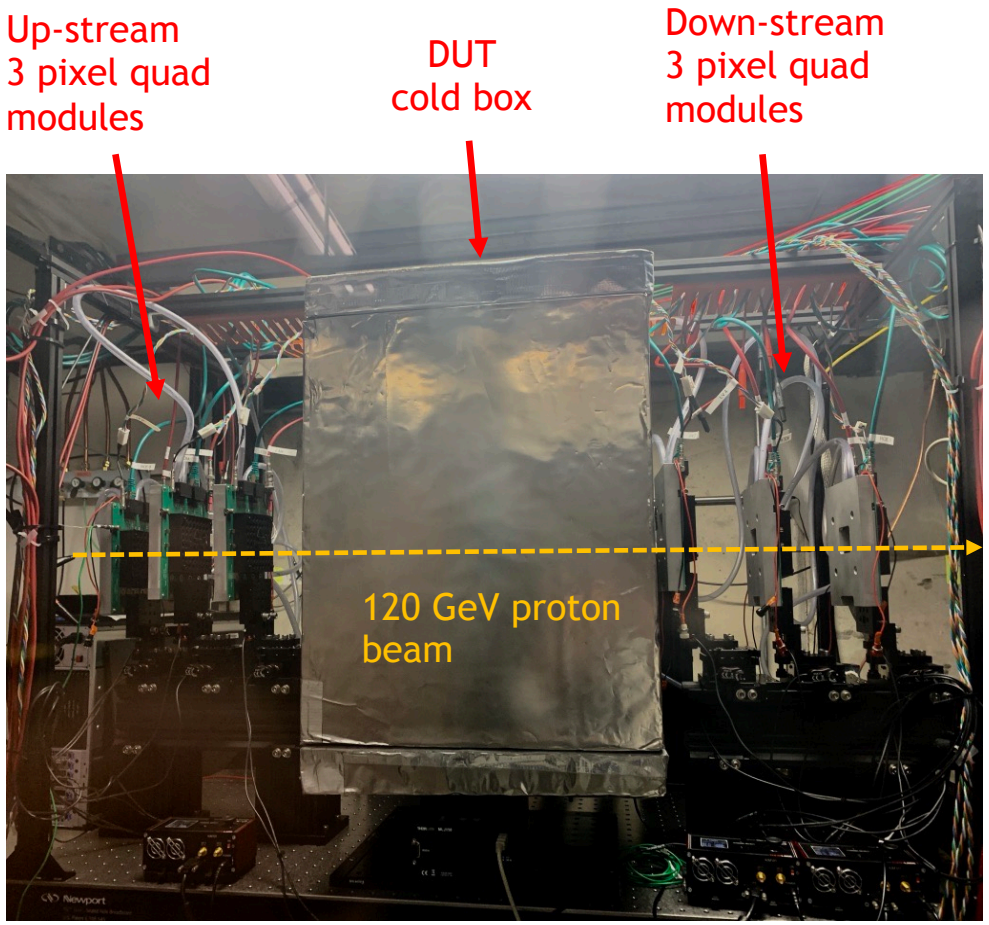


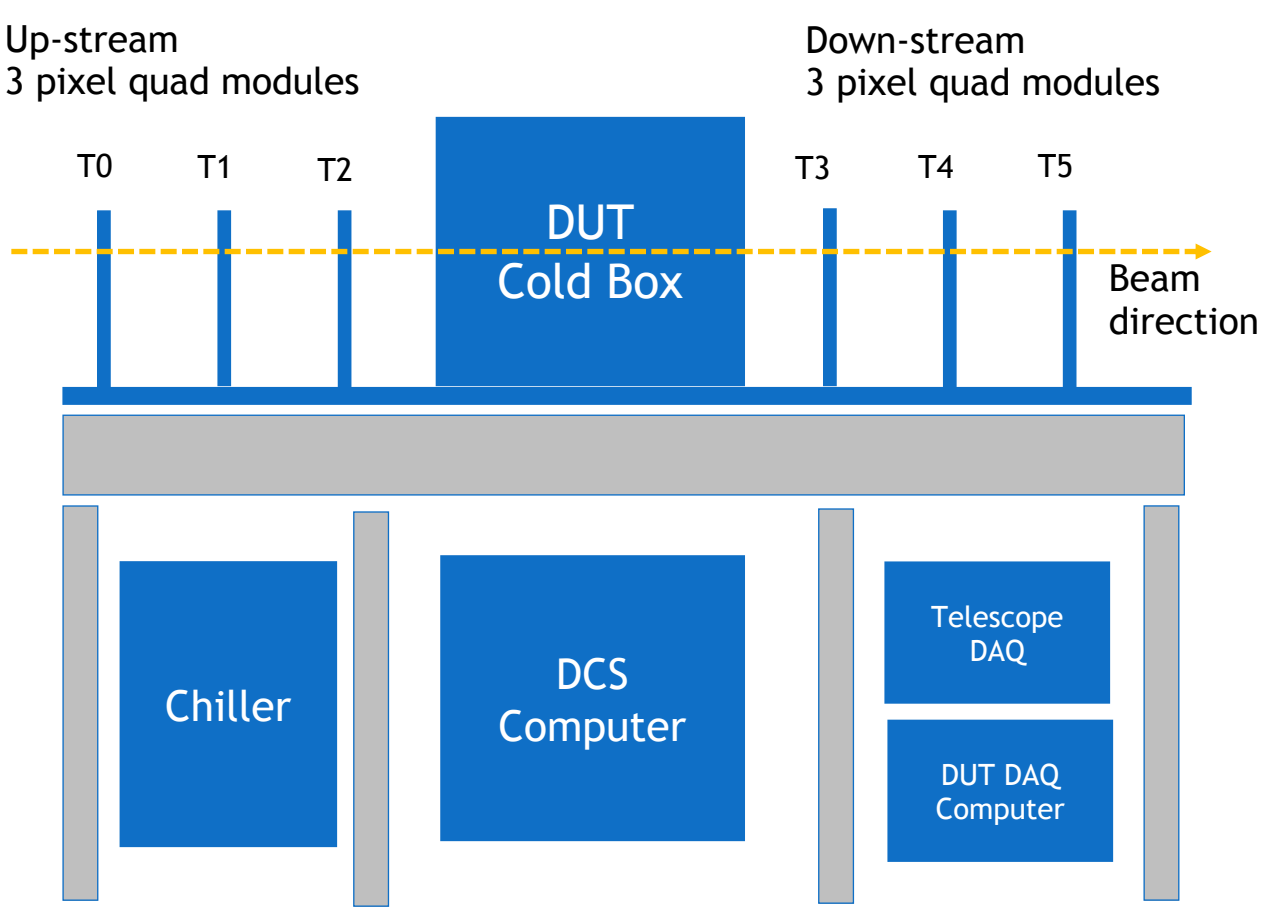
- MTest:
  - 54 User weeks (27 week provided beam)
  - 16 Experimental groups (some groups came multiple times)
  - Most of the group locally based
  - Some travel domestically
  - Several experiments were cancelled due to COVID restrictions
  - Experiments:
    - Neutrino: 1 (NOvA)
    - Collider: 4 (sPHENIX, Solid)
    - CMS/ATLAS: 9
    - General R&D: 2 (ADRIANO, LGADs)
- MCeter:
  - NOvA was using MCenter whole time

User Experience: T1224
Argonne Pixel Tracking Telescope

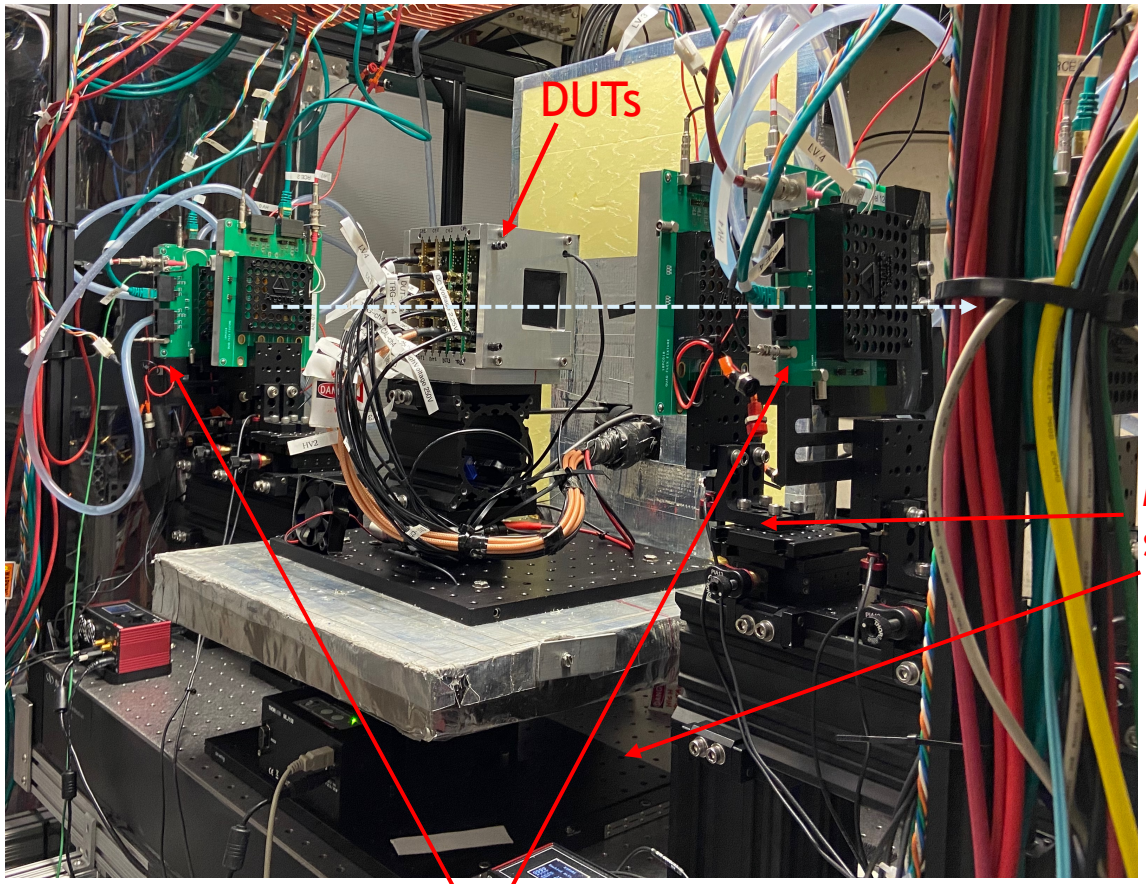
Argonne Pixel Tracking Telescope

In MT6.1B Enclosure



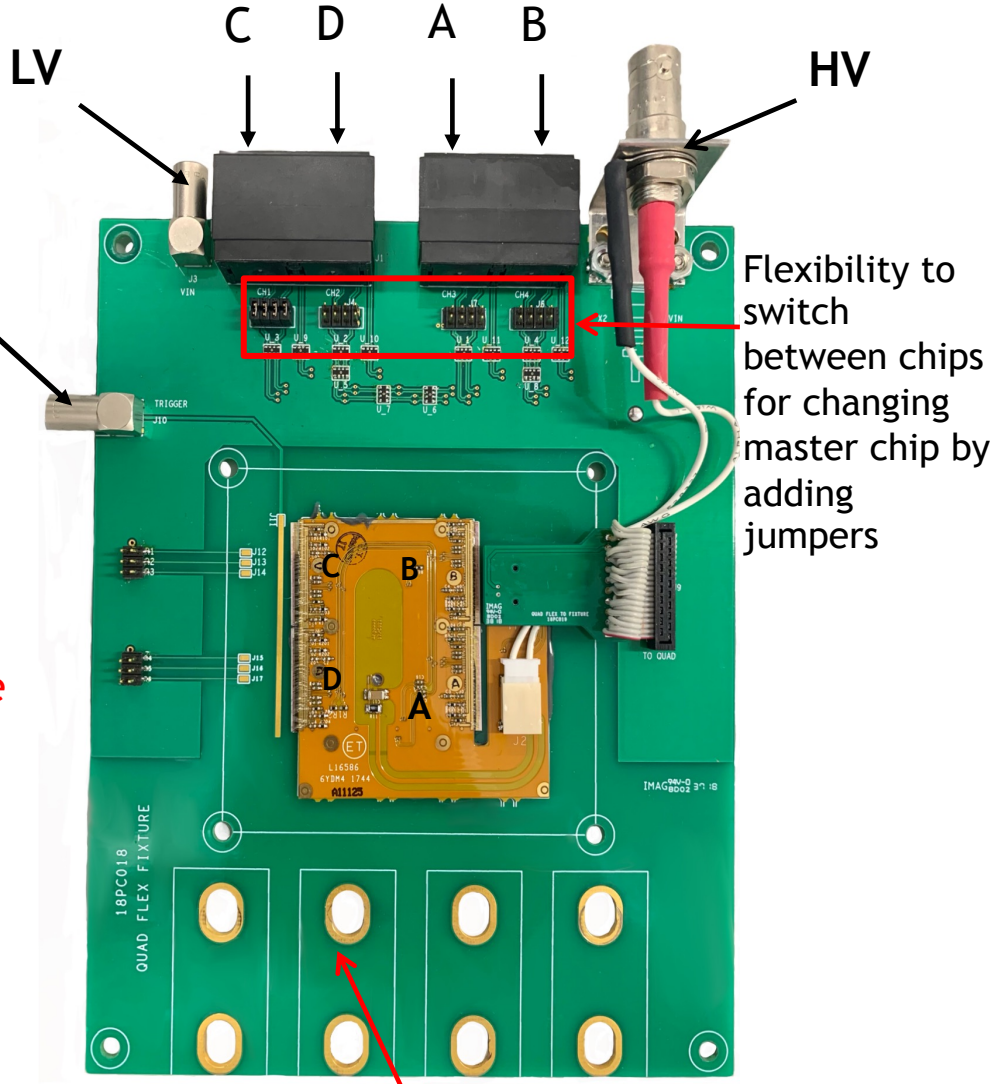


Telescope Plane



Second and fourth plane rotated by 90°

Planar Pixel Quad Module

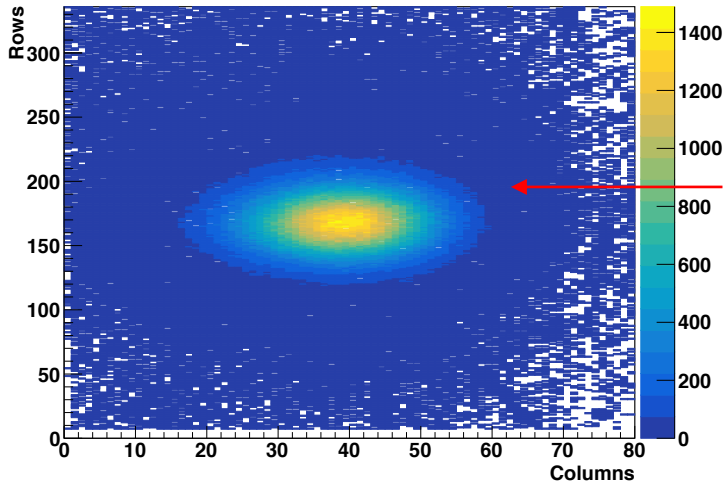


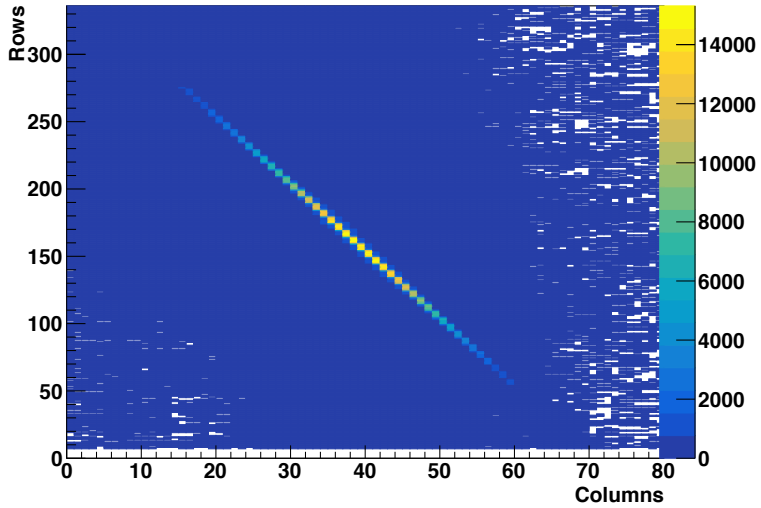
Monitoring plots: Occupancy and Correlation

Occupancy

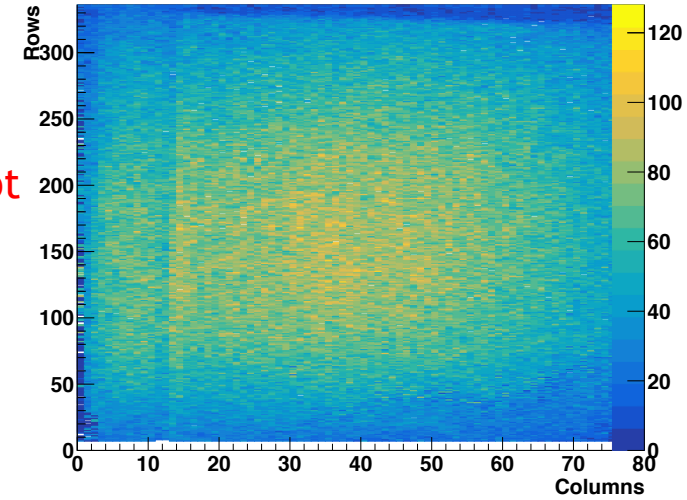
Correlations

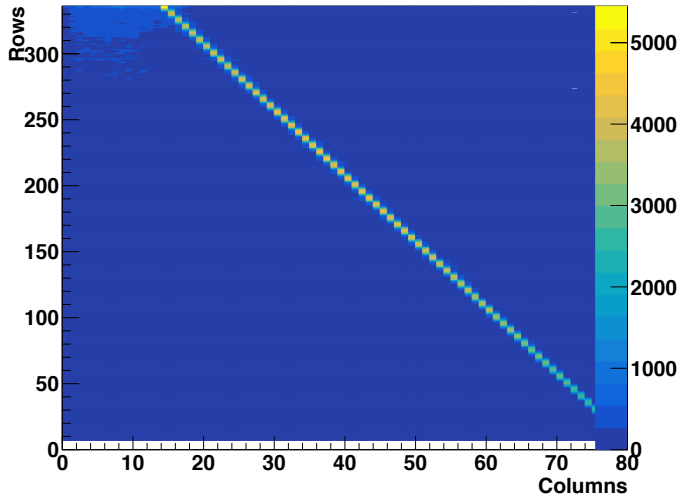
Narrow Beam





Wide Beam

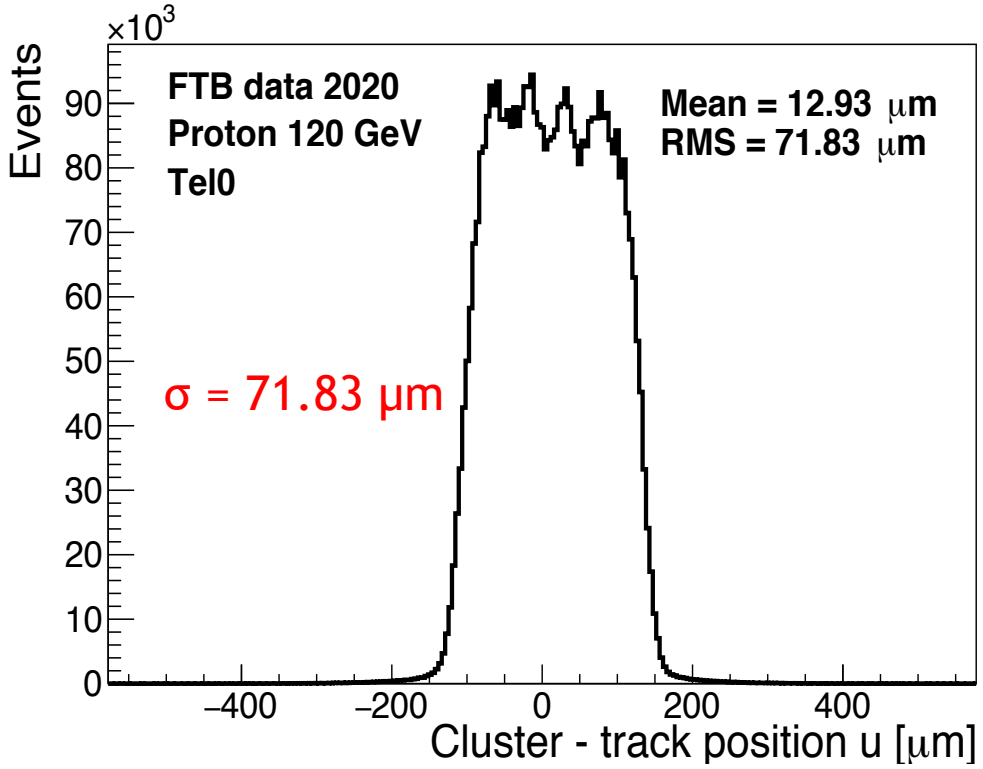




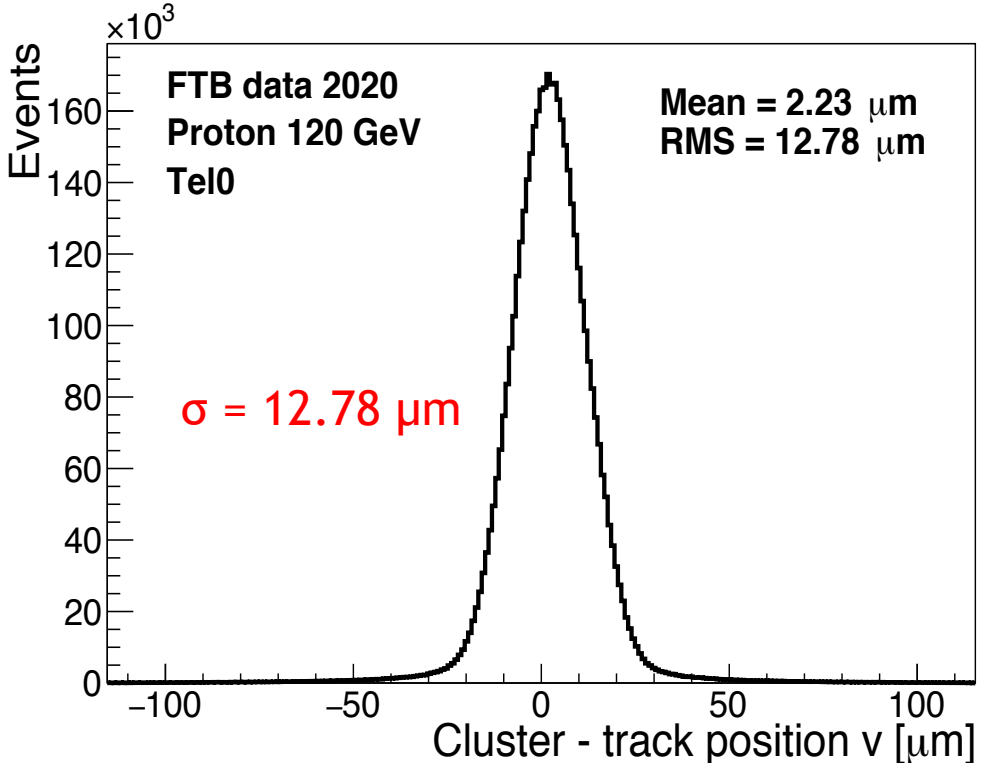
Correlation between first plane's rows and second plane's planes column

Tracking Analysis: Tel0

X residual



Y residual



$$\sigma_X = \frac{250\ \mu m}{\sqrt{12}}$$

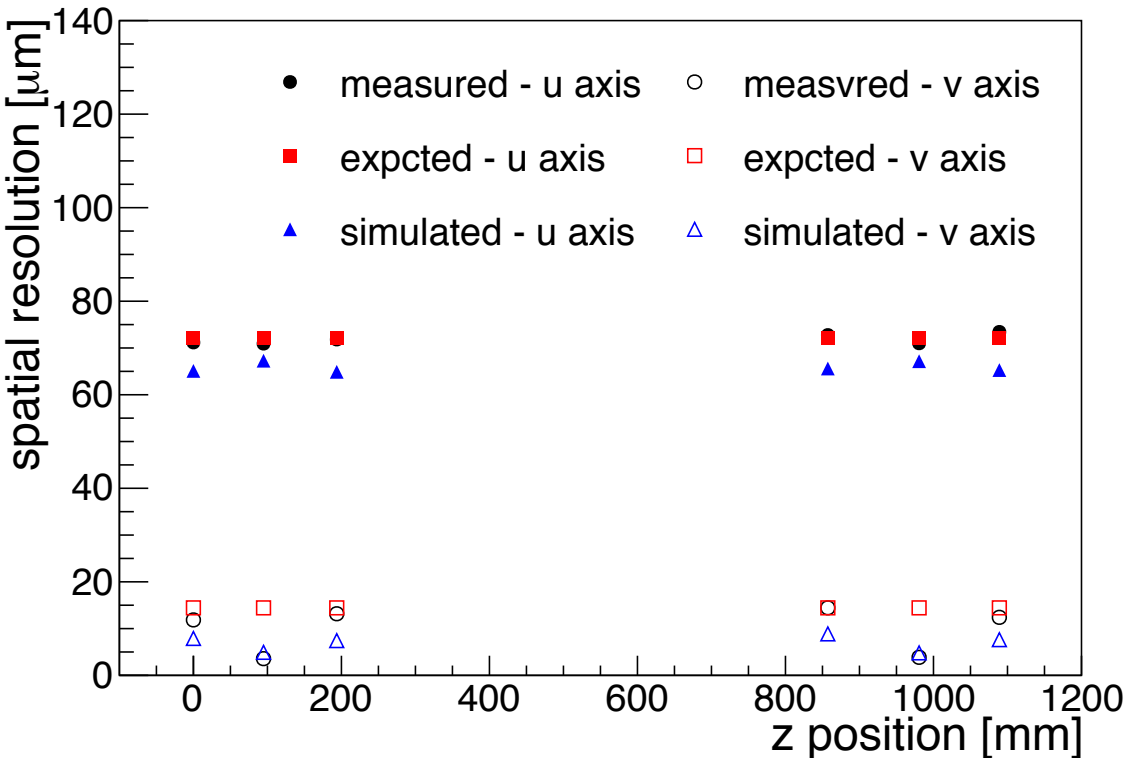
$$\sigma_X \approx 72\ \mu m$$

$$\sigma_{expected} = \frac{Pitch}{\sqrt{12}}$$

$$\sigma_Y = \frac{50\ \mu m}{\sqrt{12}}$$

$$\sigma_Y \approx 14.43\ \mu m$$

Argonne Pixel Tracking Telescope



- 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

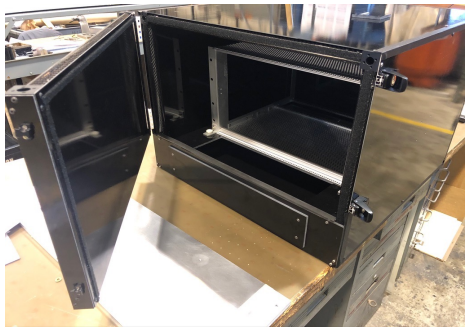
Fermilab Irradiation Facility

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

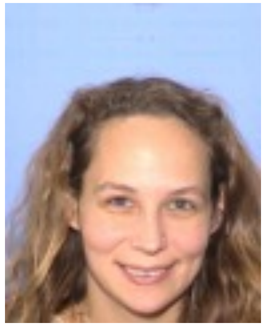
- FTBF is one of the world class facility with high energy beam for detector R & D
- At Fermilab, new radiation facility is started in 2021. CMS and ATLAS were the first user to irradiate samples early this year
- At full capacity ITA will deliver 2.7e15 protons per hour @ 400 MeV
- Continuously improving 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

















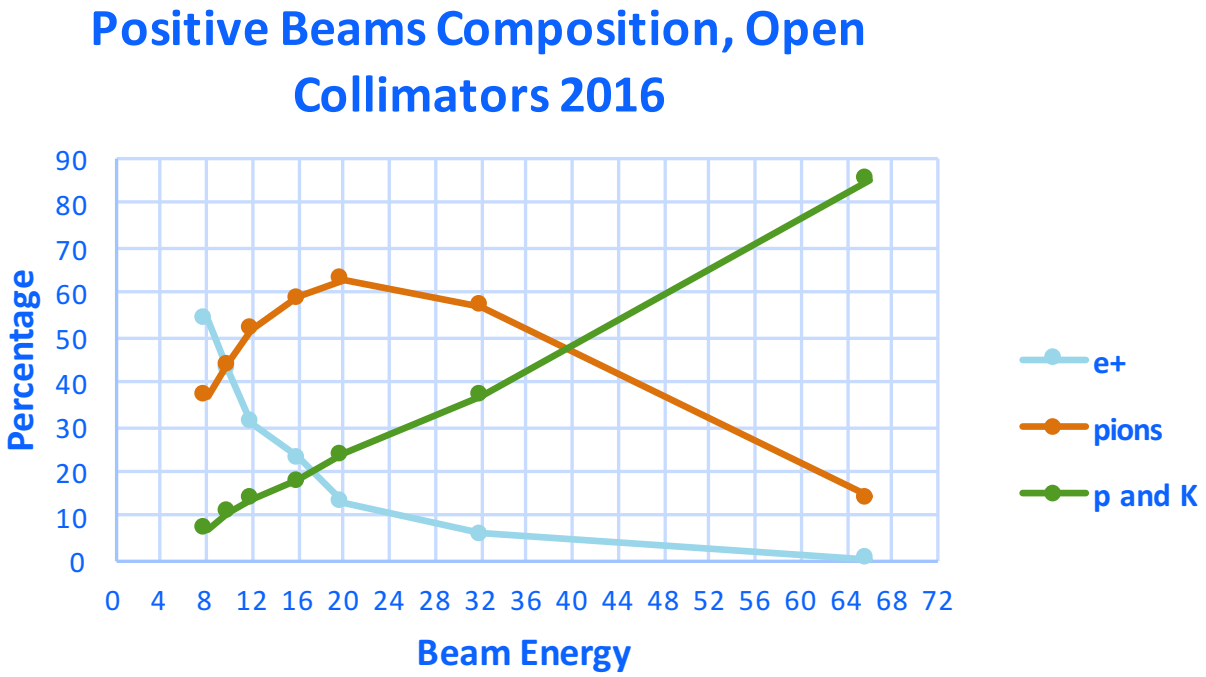


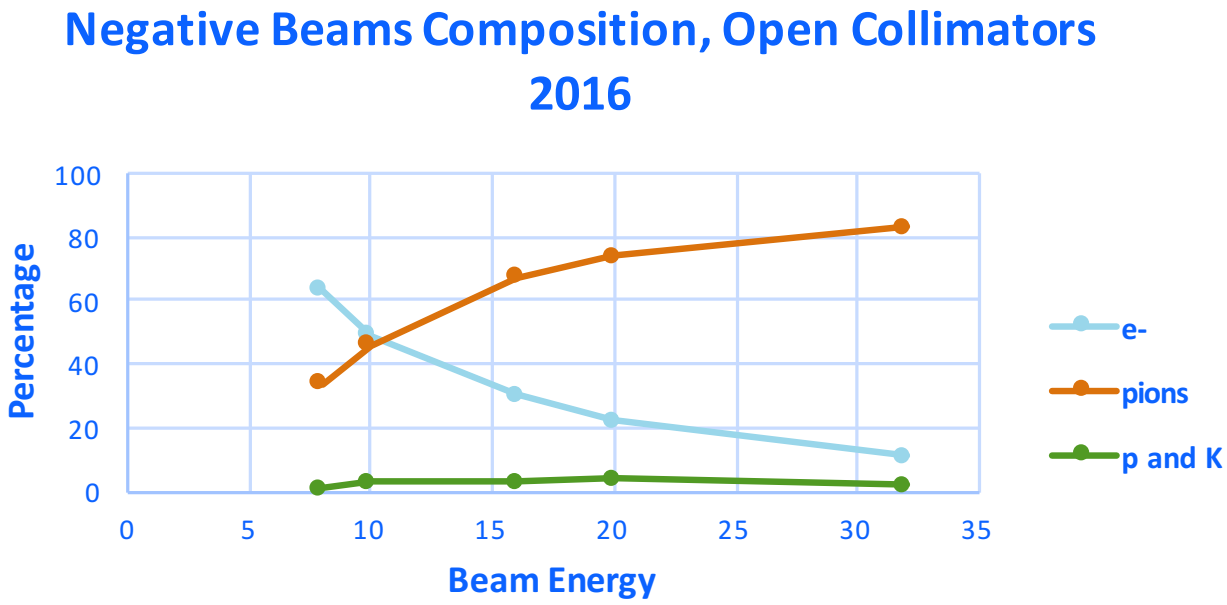




Backup

Beam Performance: MTest



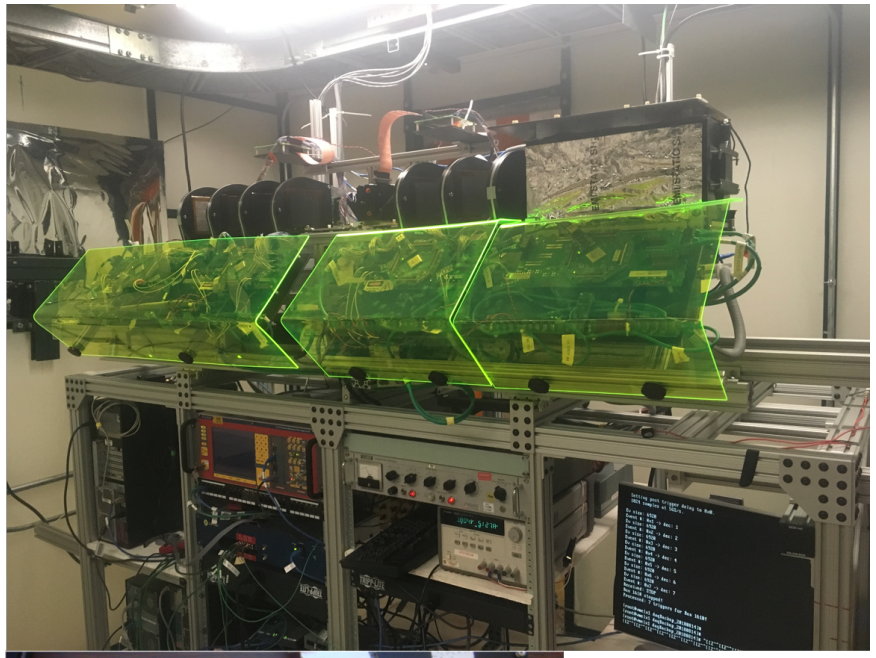


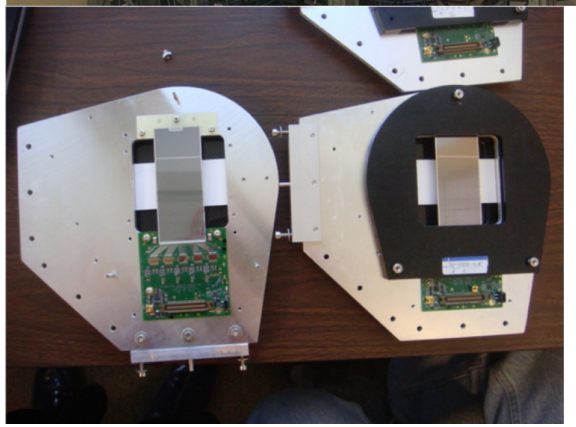
Studies by E. Skup and D. Jensen

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

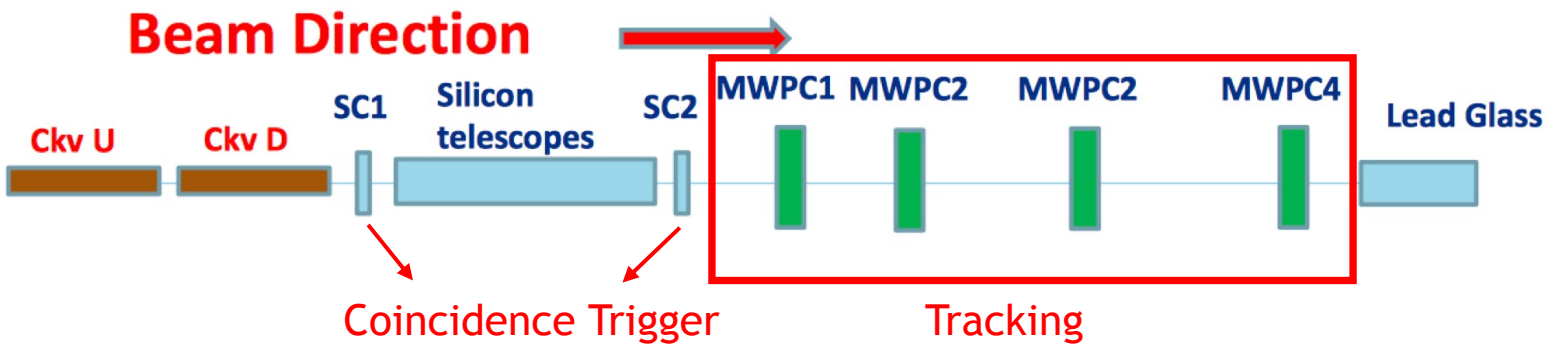
MTest Instrumentation: Silicon Telescope

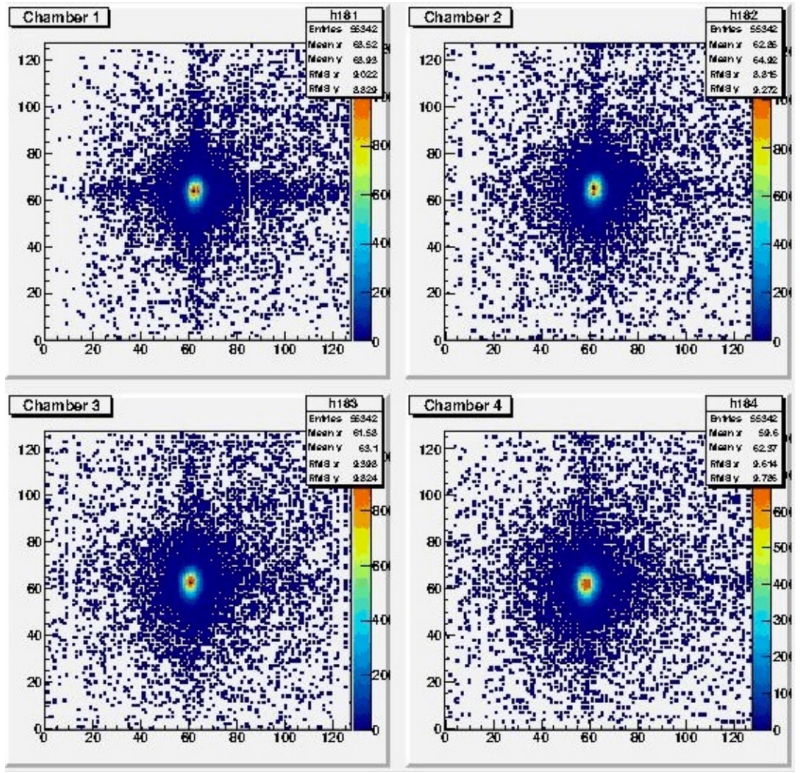
- Tracking telescope based on silicon strips and pixel planes
  - http://www.sciencedirect.com/science/article/pii/S0168900215015521
- 5 μm resolution on Device-Under-Test (DUT)
- 3.8 x 3.8 cm coverage of silicon strips
- Moveable arms and motion table for sample positioning





MTest Instrumentation:





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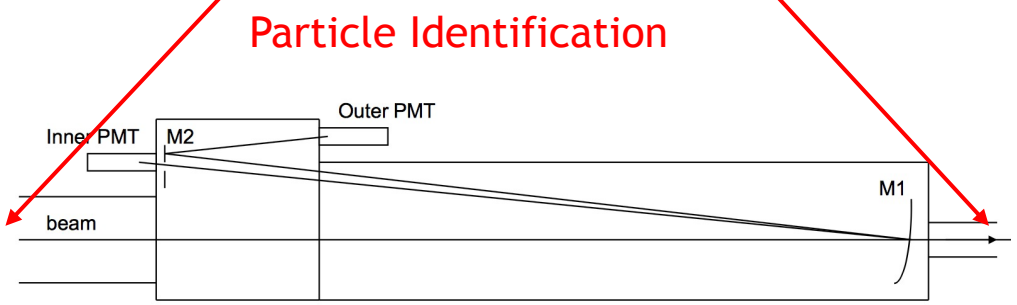
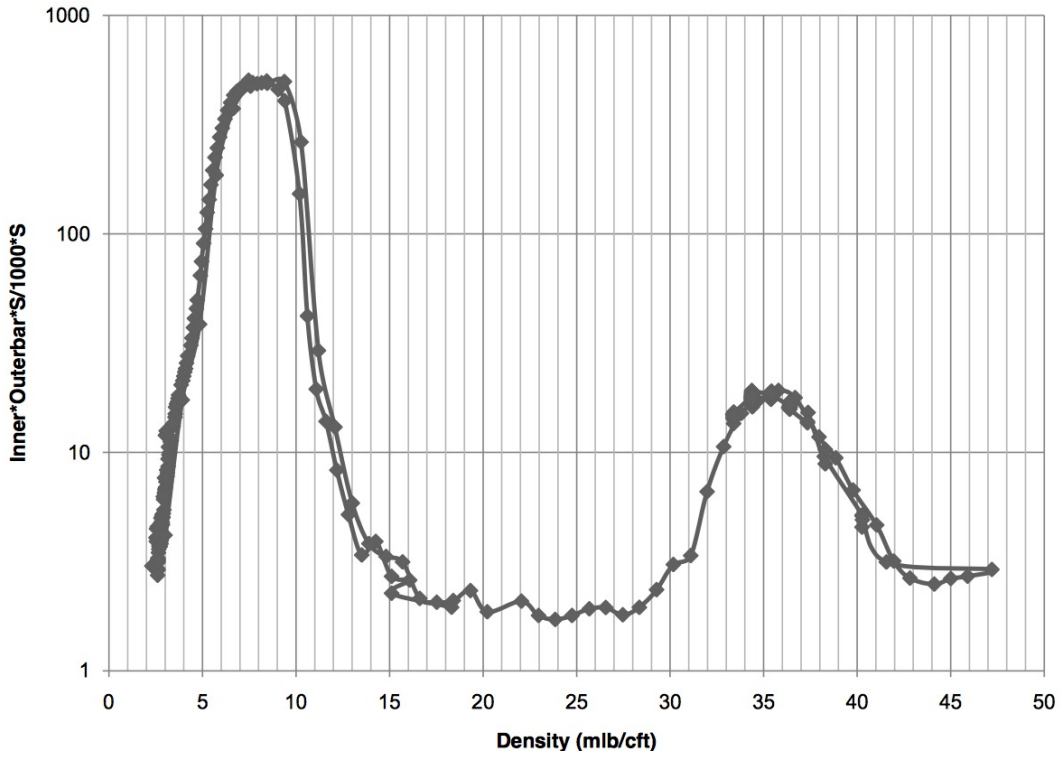
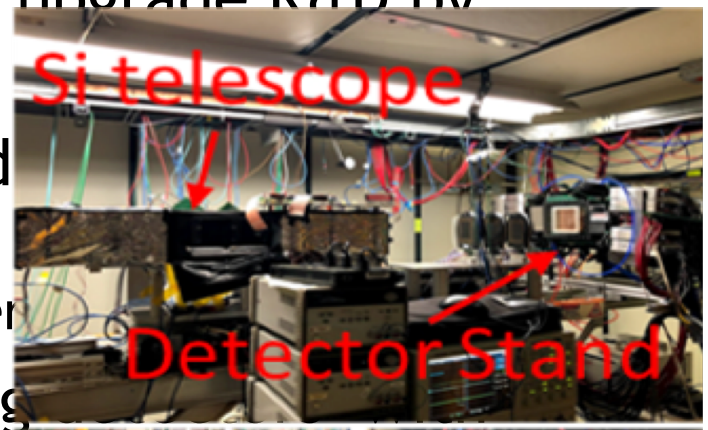


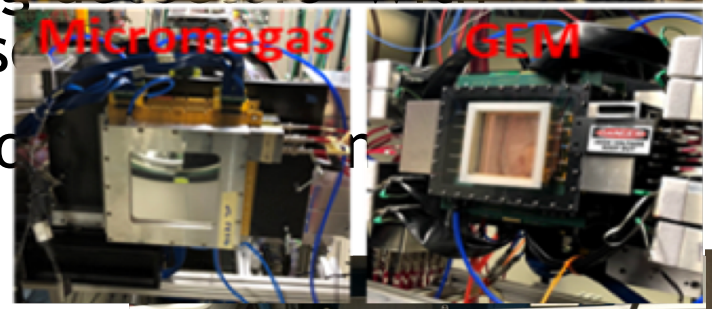
Fig. 9. 32 GeV/C Density Curve after Mirror Alignment

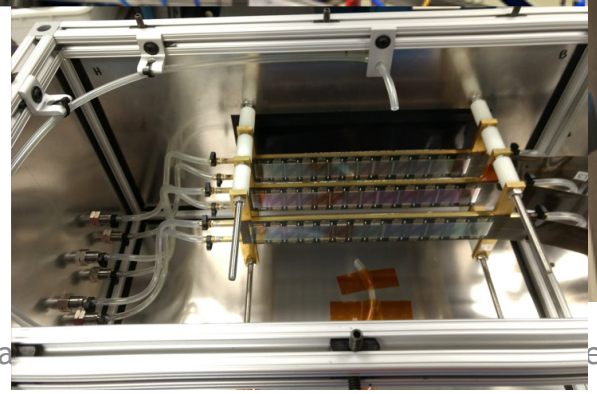


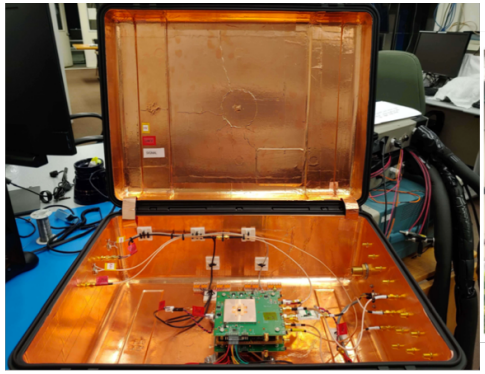
User Experiments: LHC groups

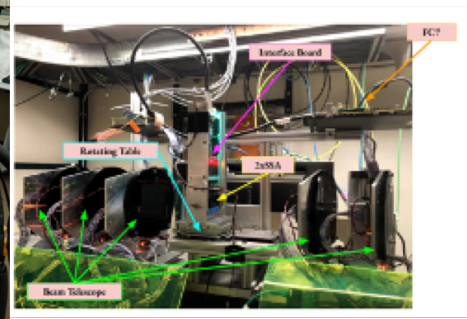
- High Luminosity LHC upgrade R&D by ATLAS and CMS
- Variety of sensor and (RD53a) testing.
  - Both before and after
- Radiation hard timing 30-40 picosecond res
- Argonne Pixel Telesco and testing

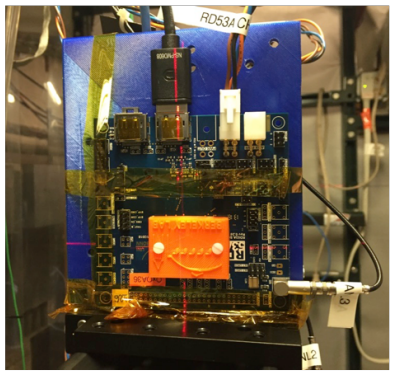


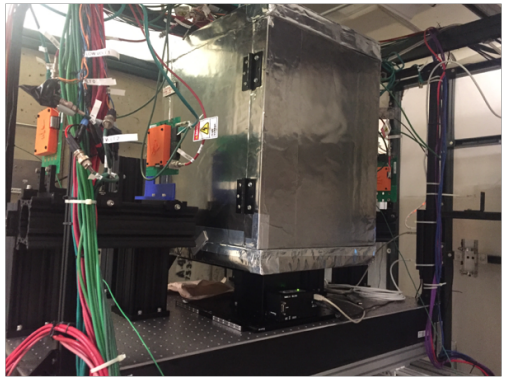


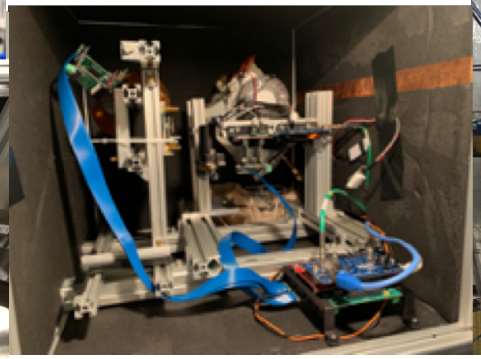


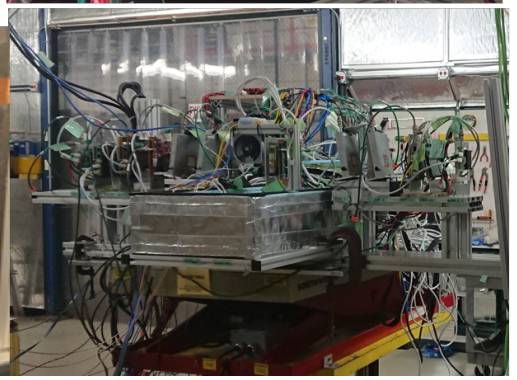






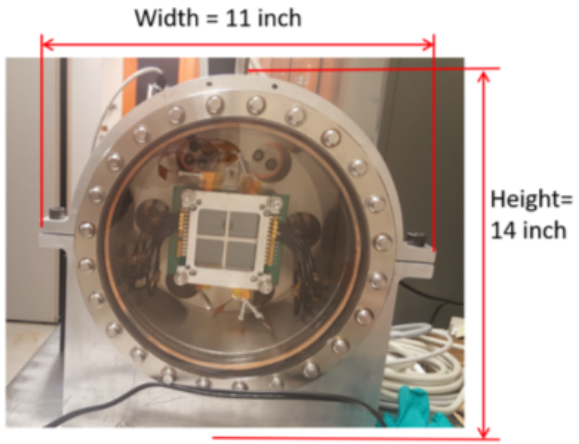


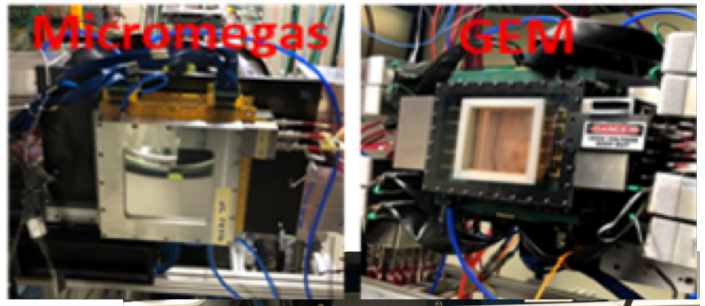


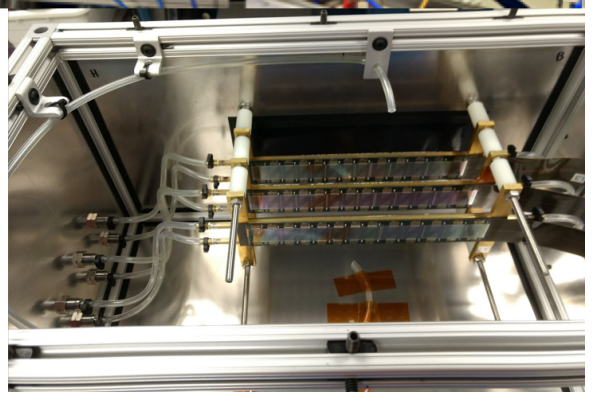


User Experiments: Other Collider Experiments

- 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

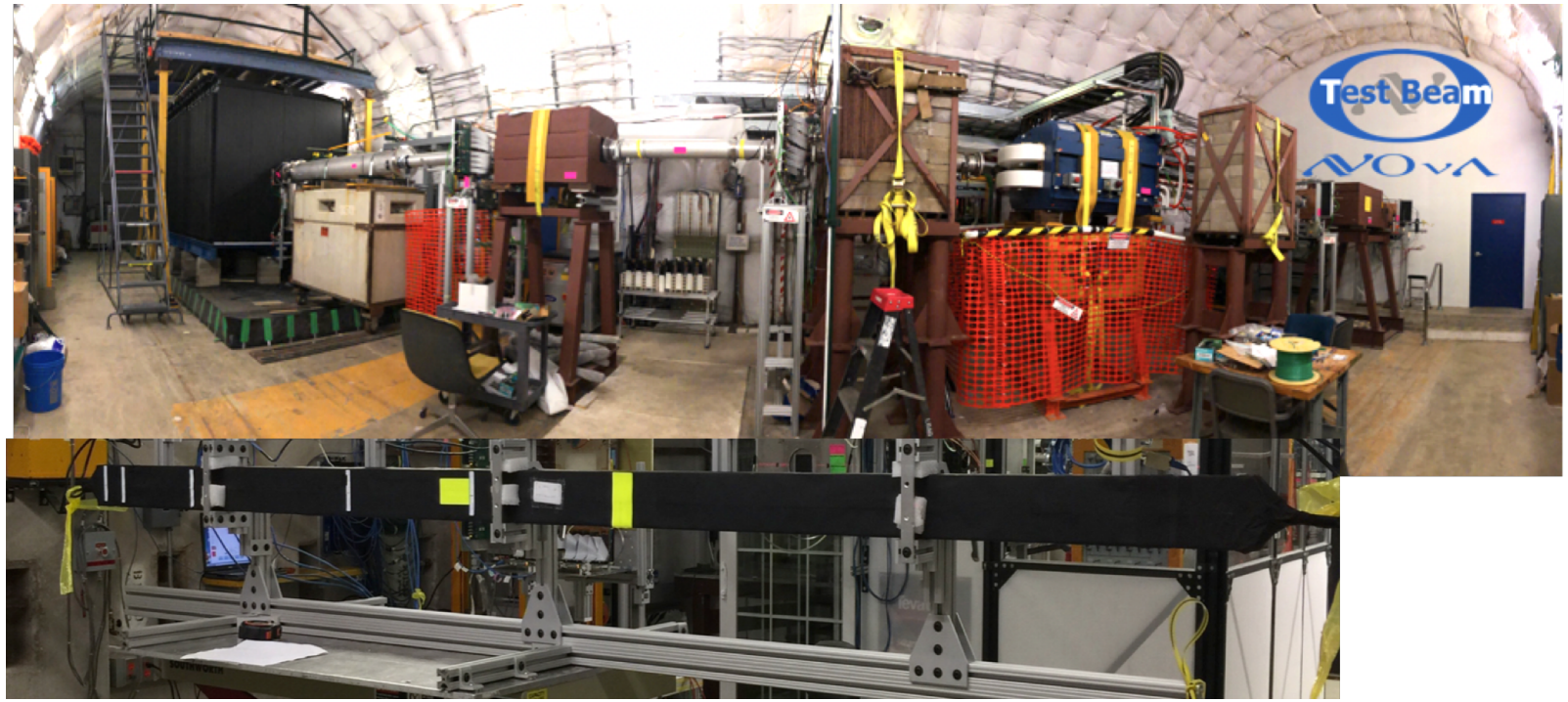






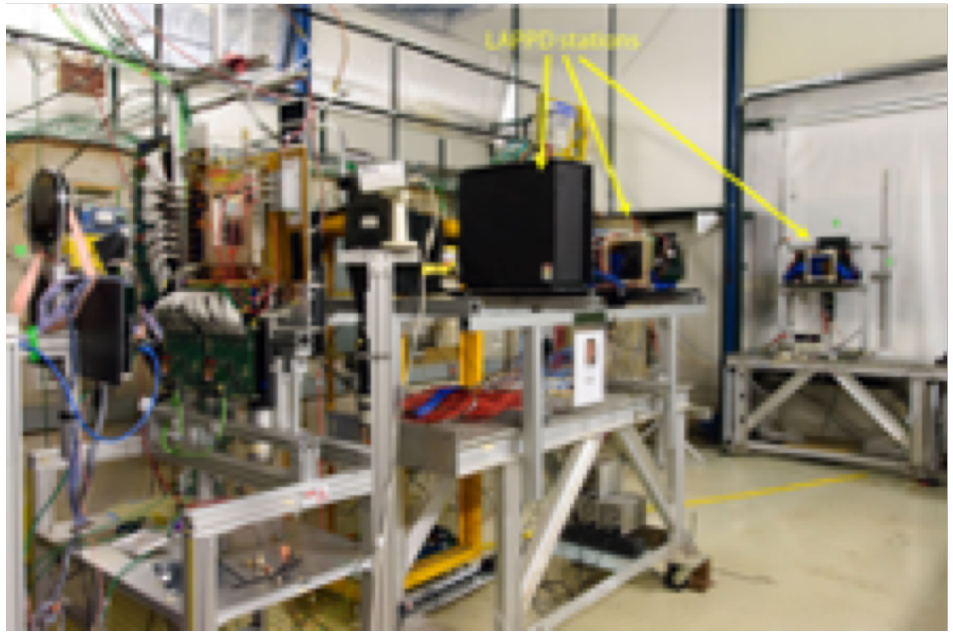
User Experiments: Neutrinos and Muons

- Mu2E scintillator testing
- EMPHATIC, Measure hadron production to constrain flux for neutrino experiments
- NOvA Test Beam program, constraining systematic uncertainties

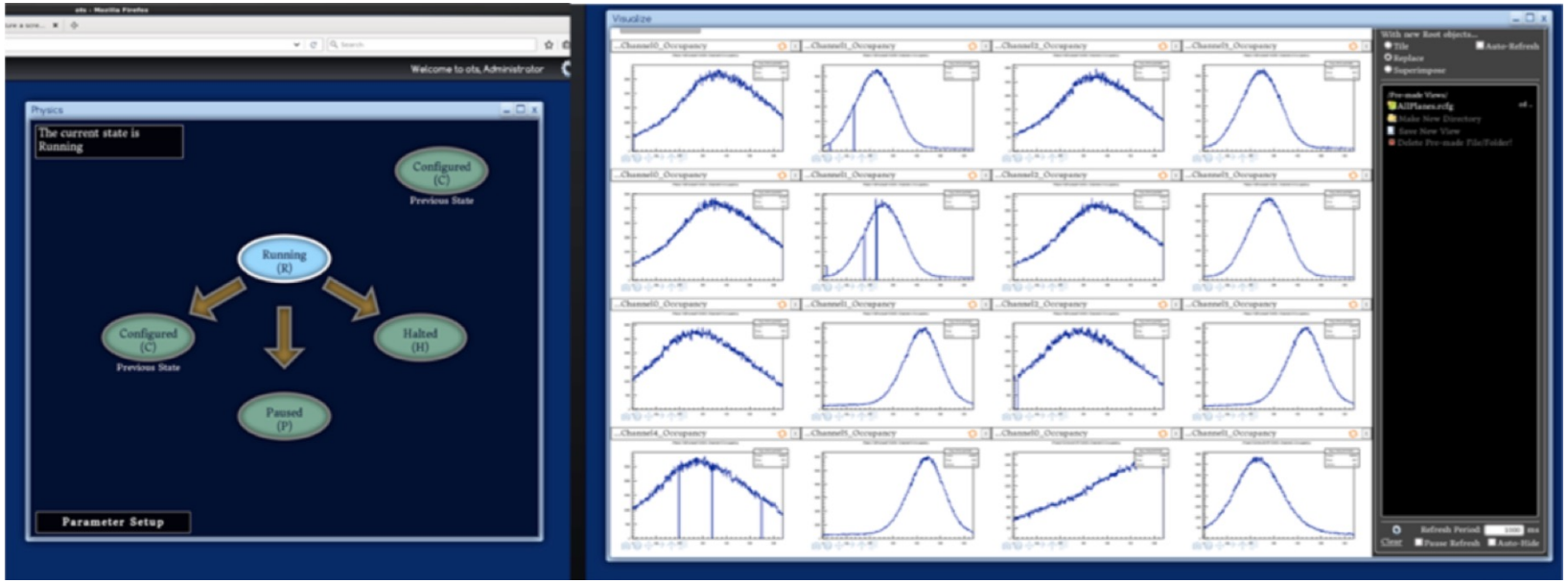


User Experiments: General Detector R & D

- 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)



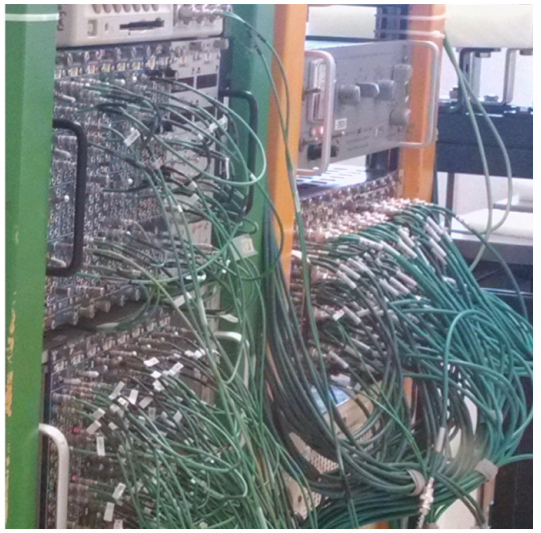
L. Uplegger, R. Rivera, E. Flumerfelt

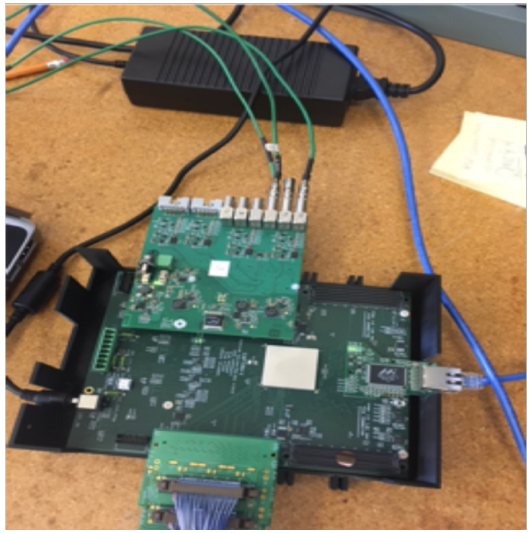
https://otsdaq.fnal.gov/

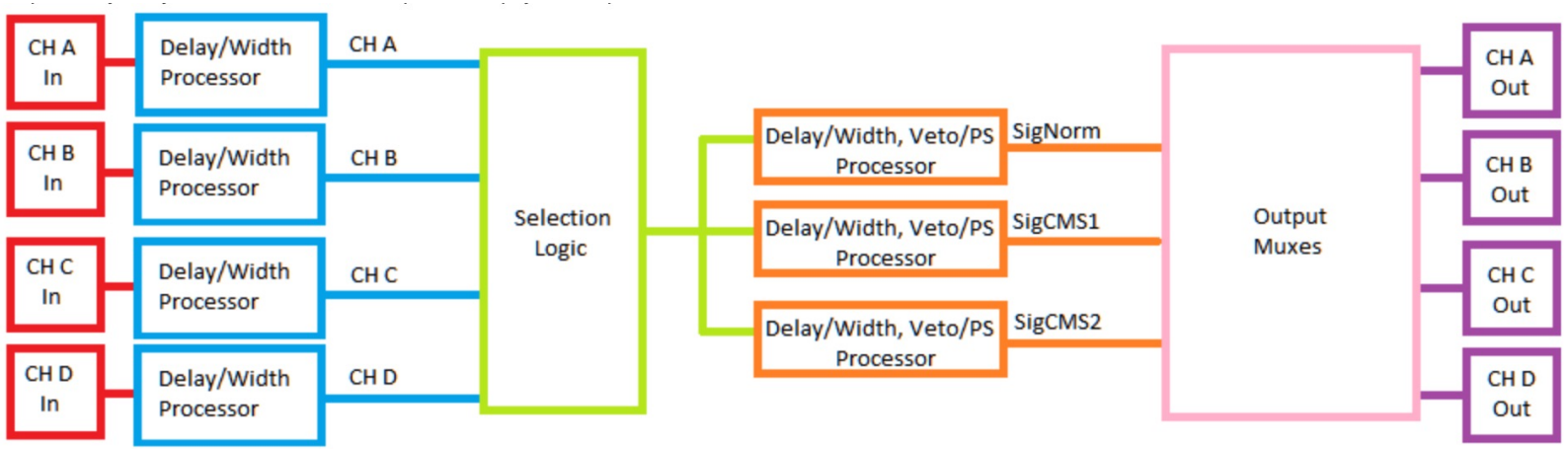
- SCD developed, flexible and scalable system allowing integration with other devices
- Tied into facility MWPCs, Cherenkov detectors, silicon strip telescope.
- Working to integrate with facility, enhance user experience, document
- Several groups (CMS outer tracking, CMS Timing, RD53 chip) have integrated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

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 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

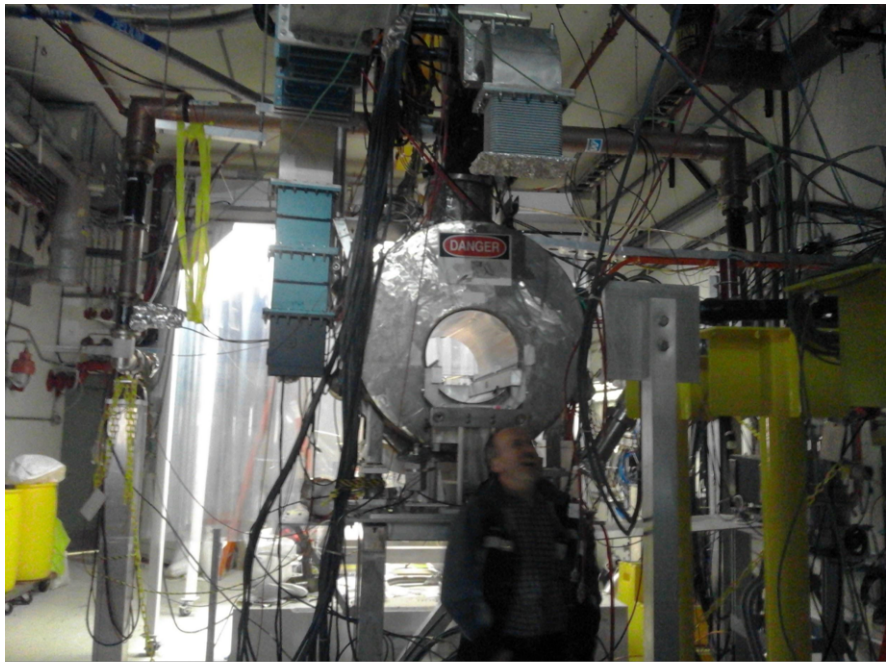






Facility Background

- 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



Photos courtesy Jason St. John

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