



Fermilab Test Beam Facility

Evan Niner

53rd Annual Fermilab Users Meeting

10 August 2020

What is the Test Beam Facility?

- Operating since 2005, served over 1000 users from 30 countries.
- Broad program spanning collider, muon, neutrino, and general R&D
 - CMS, ATLAS, LHCb, sPHENIX, EIC, Mu2E, g-2, LArIAT, IceCube, SBN, DUNE, MINERvA, NOvA, EMPHATIC, and more.
- Two beam lines and many experimental spaces with energies from 120 GeV primary protons down to ~200 MeV in the tertiary line.
- Flexible infrastructure and experimental spaces to cover a wide range of detector sizes, technologies, and timescales of operation.
- During the CERN LS2 shutdown FTBF is the only high energy test beam facility in the world.

Where?

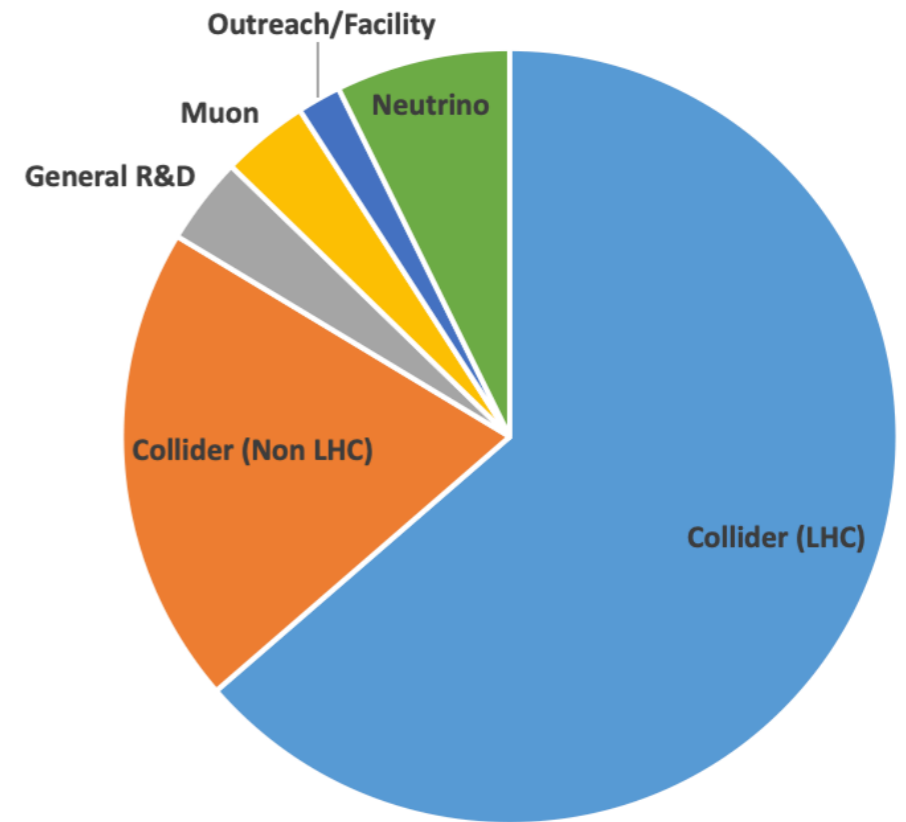


Meson Detector Building - West

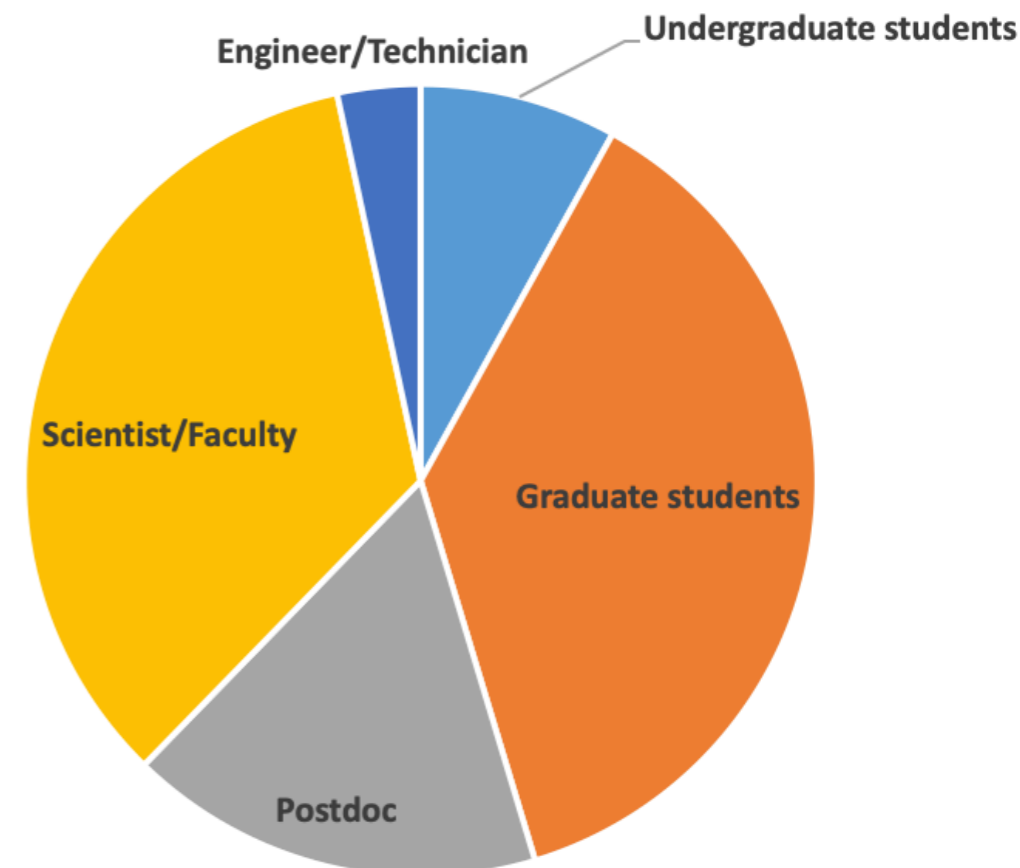
Who?

- 230+ users from 21 experimental efforts in FY19
- In short FY20 run saw 14 groups use 49 equivalent weeks during 15 weeks of beam
- New experiments every year plus repeat customers
- We welcome student and intern participation at all levels. Its a great place to get hands-on experience!

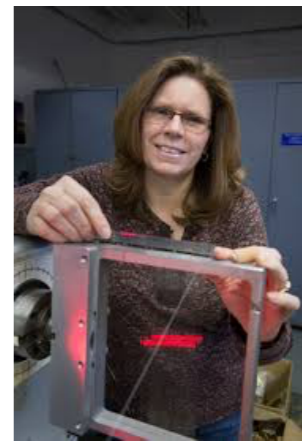
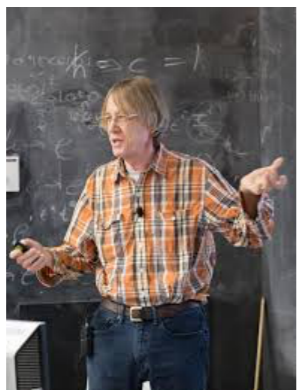
FY19 User Groups by Research Focus



FY19 Users by Job Type



Support across the lab



Beam Details

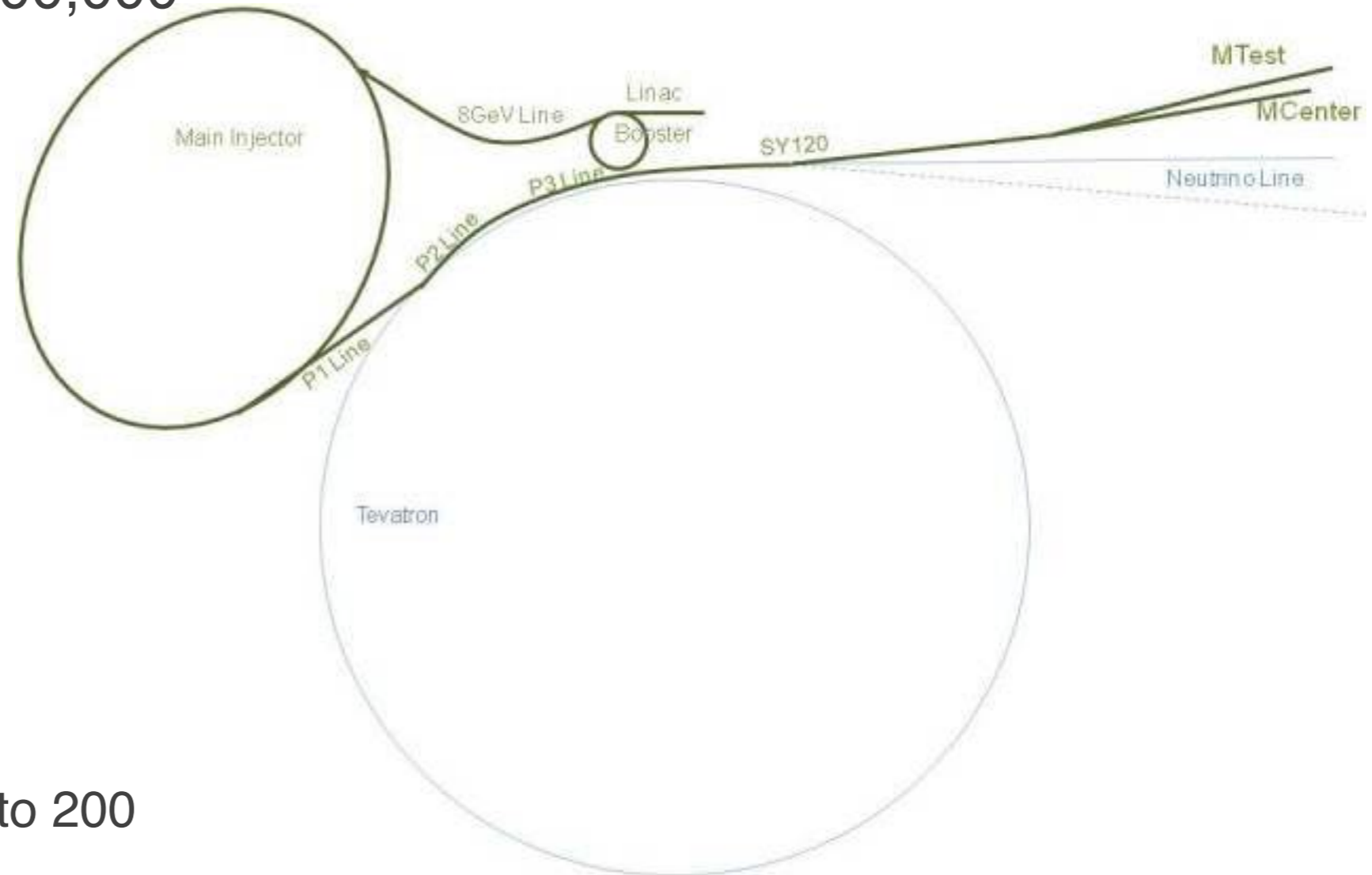
- 4 second beam spill every 60 seconds, available 24/7
- Tunable rate from 100 to 100,000 Hz

- 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



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

Beam Performance - MTest

Positive Beams Composition, Open Collimators 2016

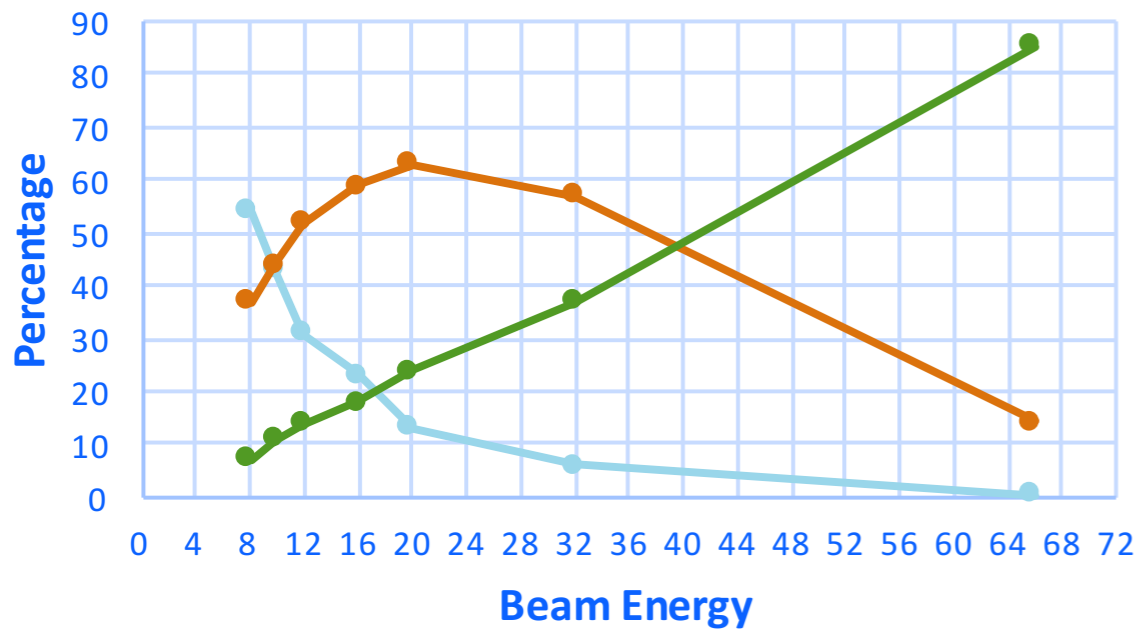
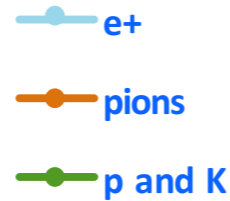
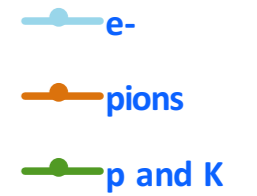
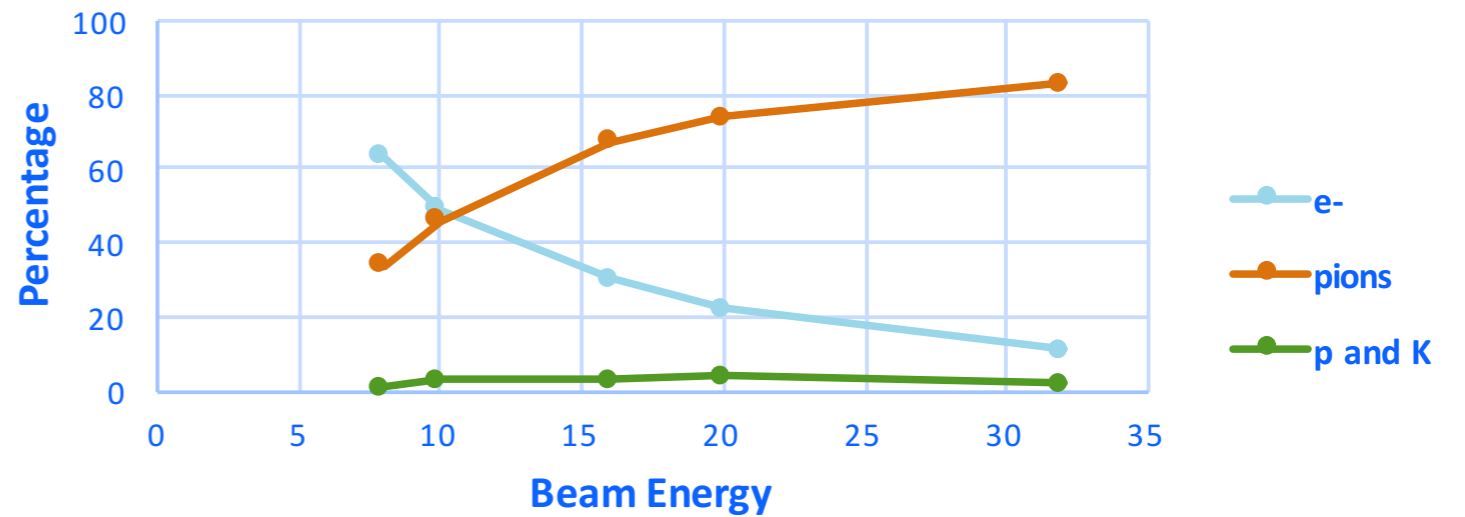


Table with energies, beam spread, percentages:
<http://ftbf.fnal.gov/mtest-beam-details-2/>



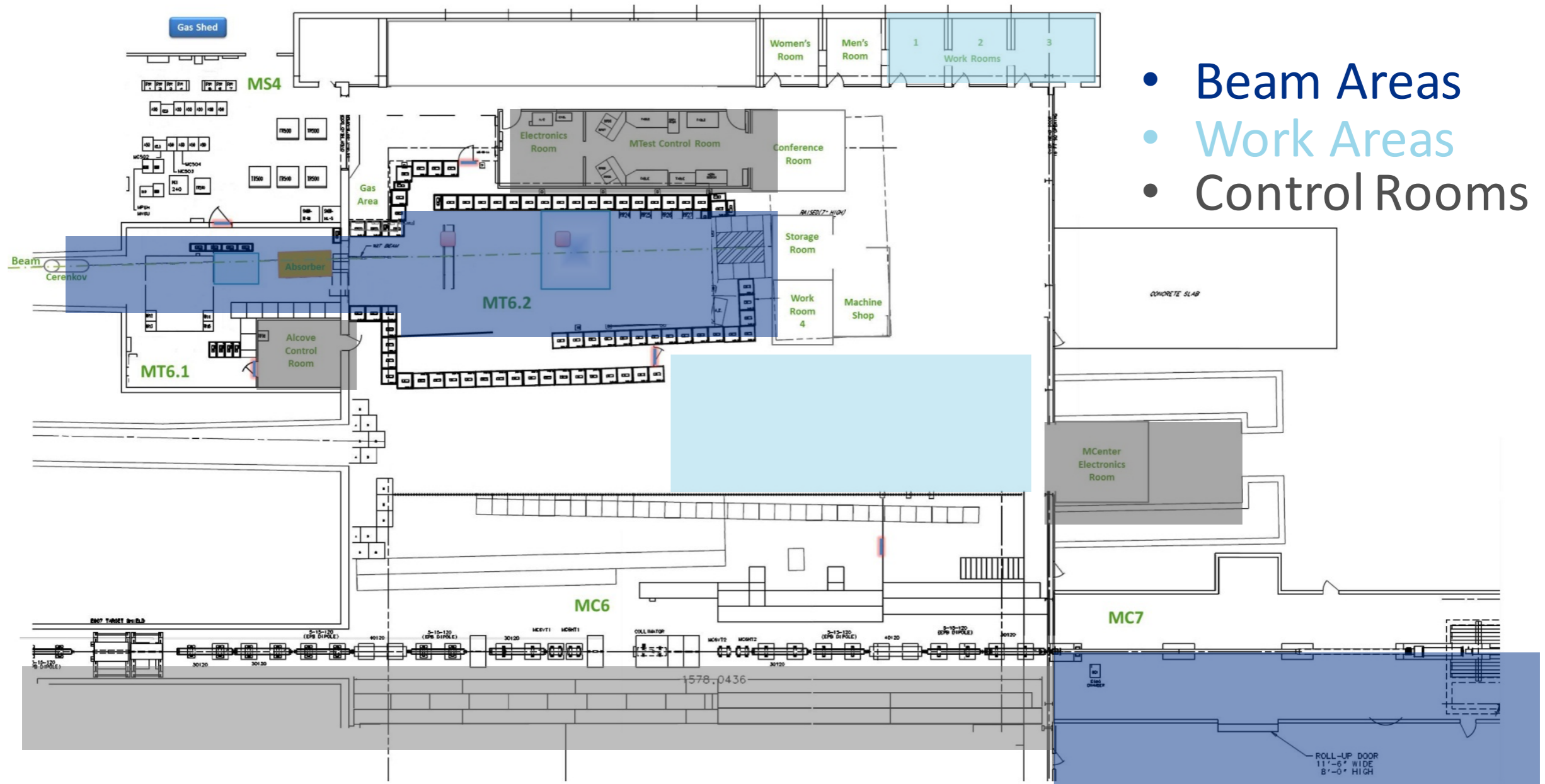
Negative Beams Composition, Open Collimators 2016



Studies by E. Skup and D. Jensen

FTBF Layout

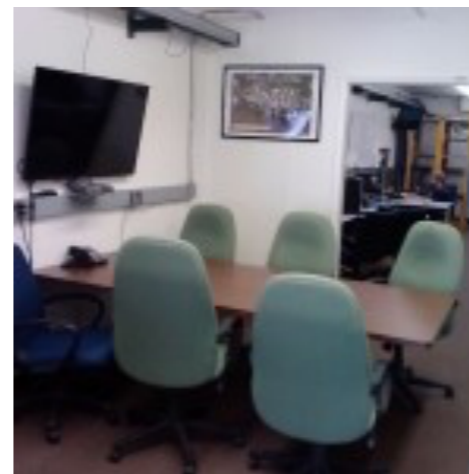
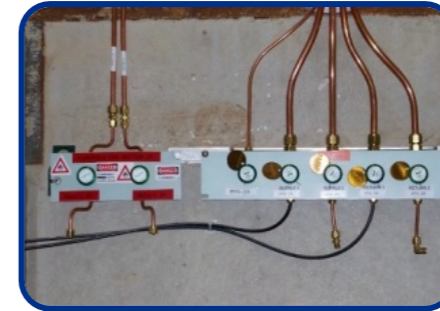
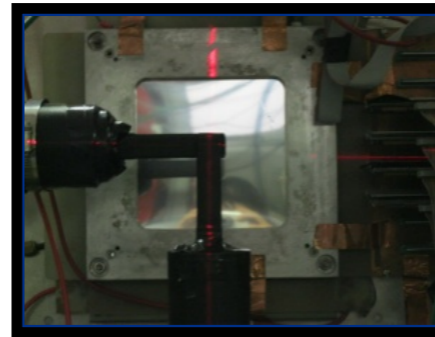
MTest Beamline



MCenter Beamline

Facility Infrastructure

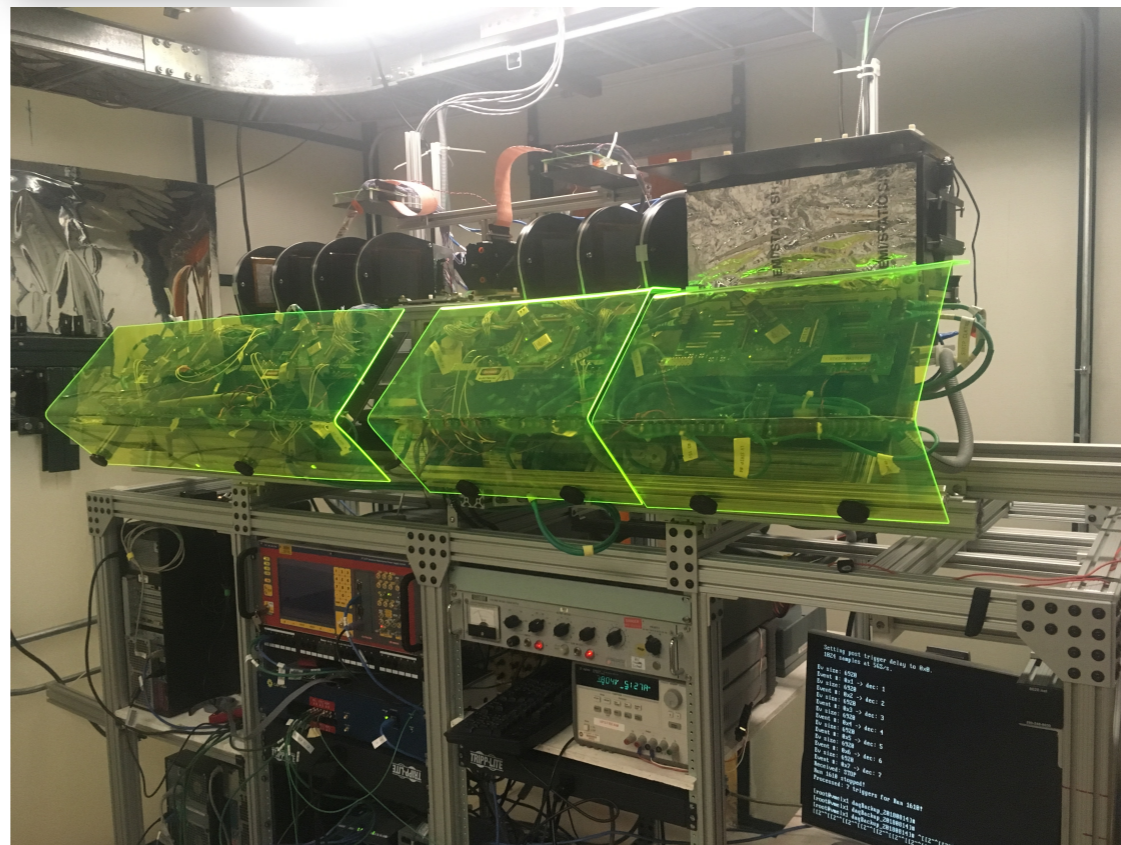
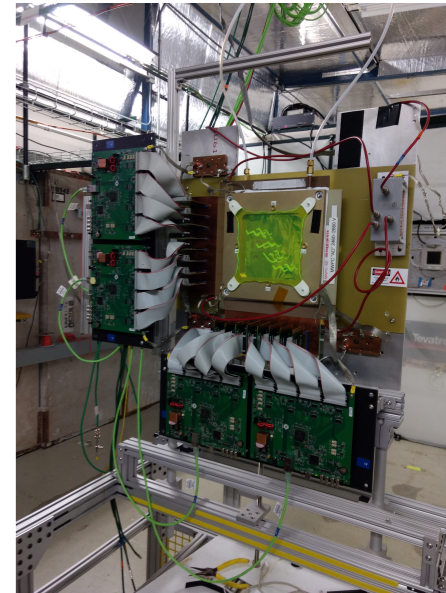
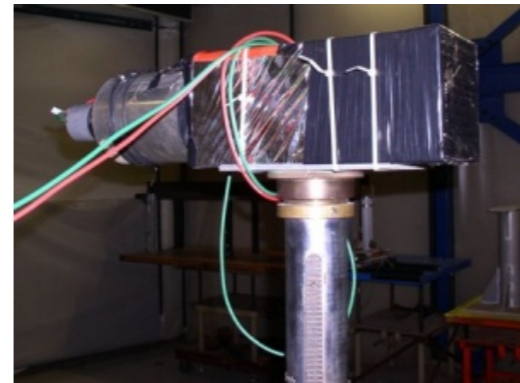
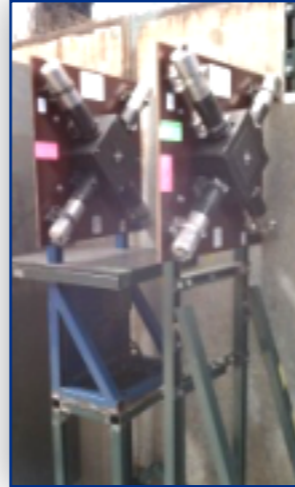
- ACNET controlled motion tables
- Laser alignment
- Helium tubes
- Web based cameras
- Crane coverage (30 ton)
- climate controlled huts
- Gas patch panels
- Signal, network, HV panels
- Two control rooms
- Counting house
- Tech shop
- Technical staff to help turn any plan into reality



Facility Instrumentation

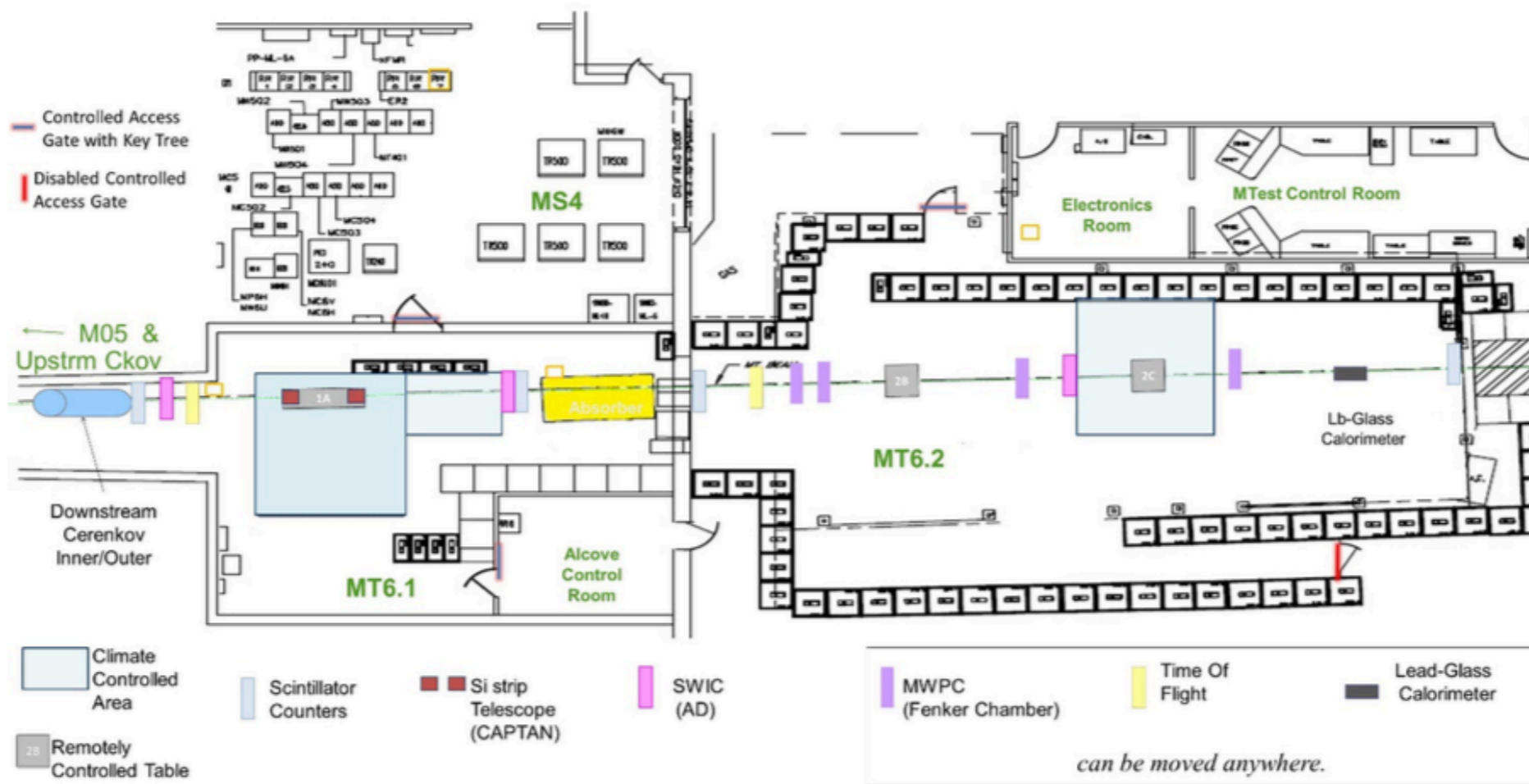
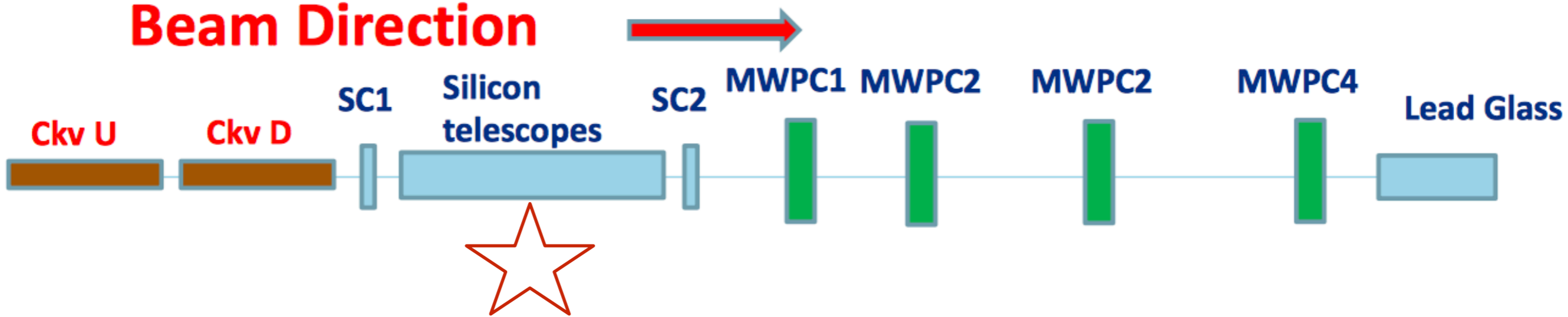
- Cherenkov detectors
- Multi Wire Proportional Chambers
- Lead glass calorimeter
- Assorted scintillator paddles
- Silicon strip and pixel telescope

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



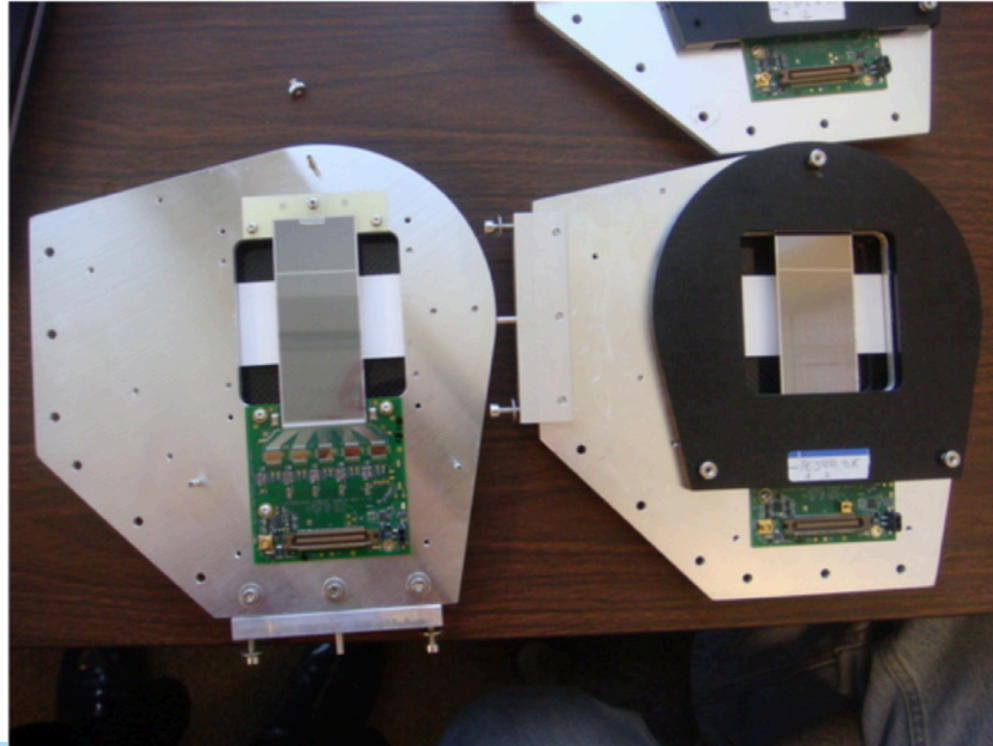
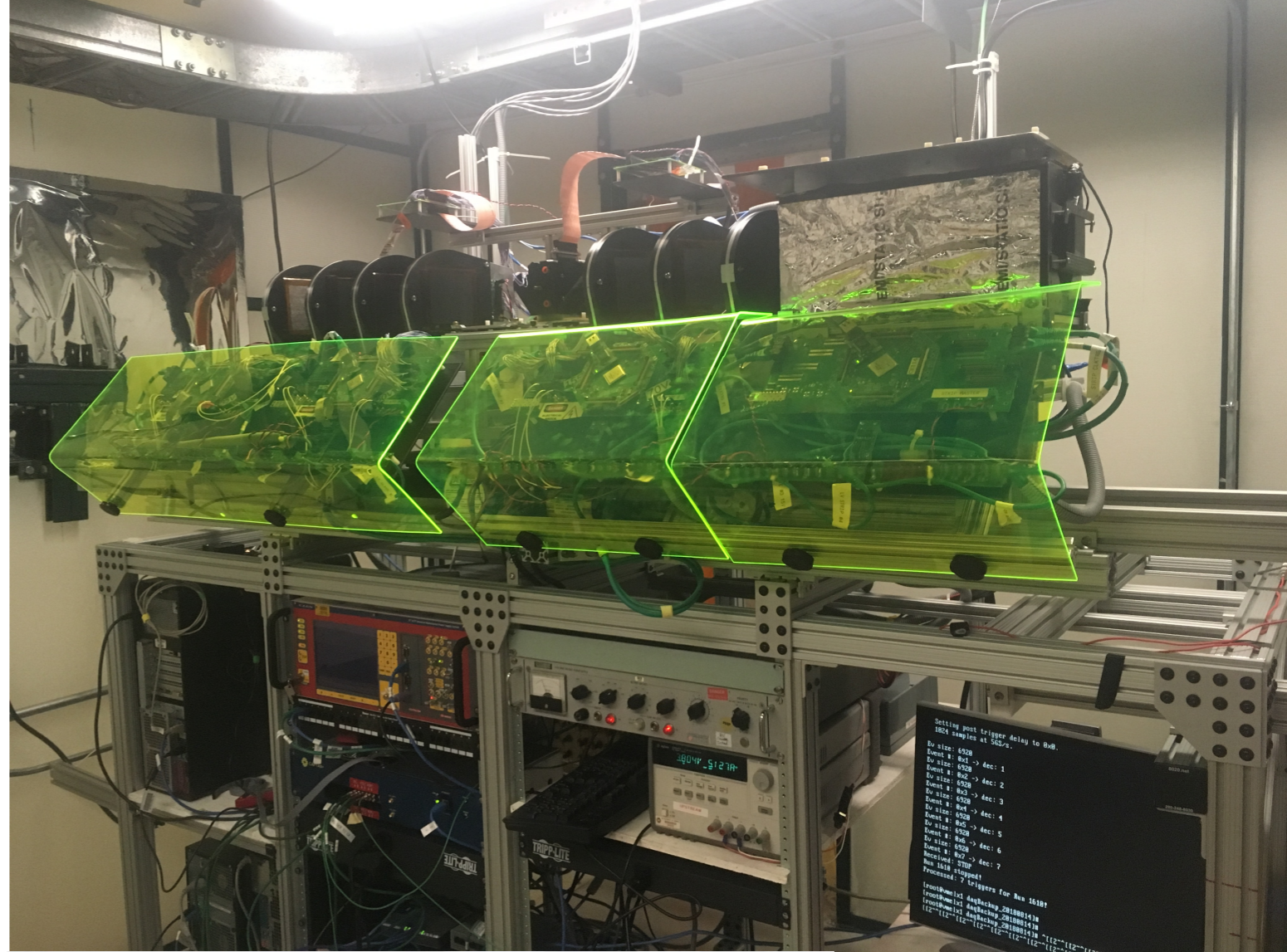
MTest Instrumentation Layout

Beam Direction

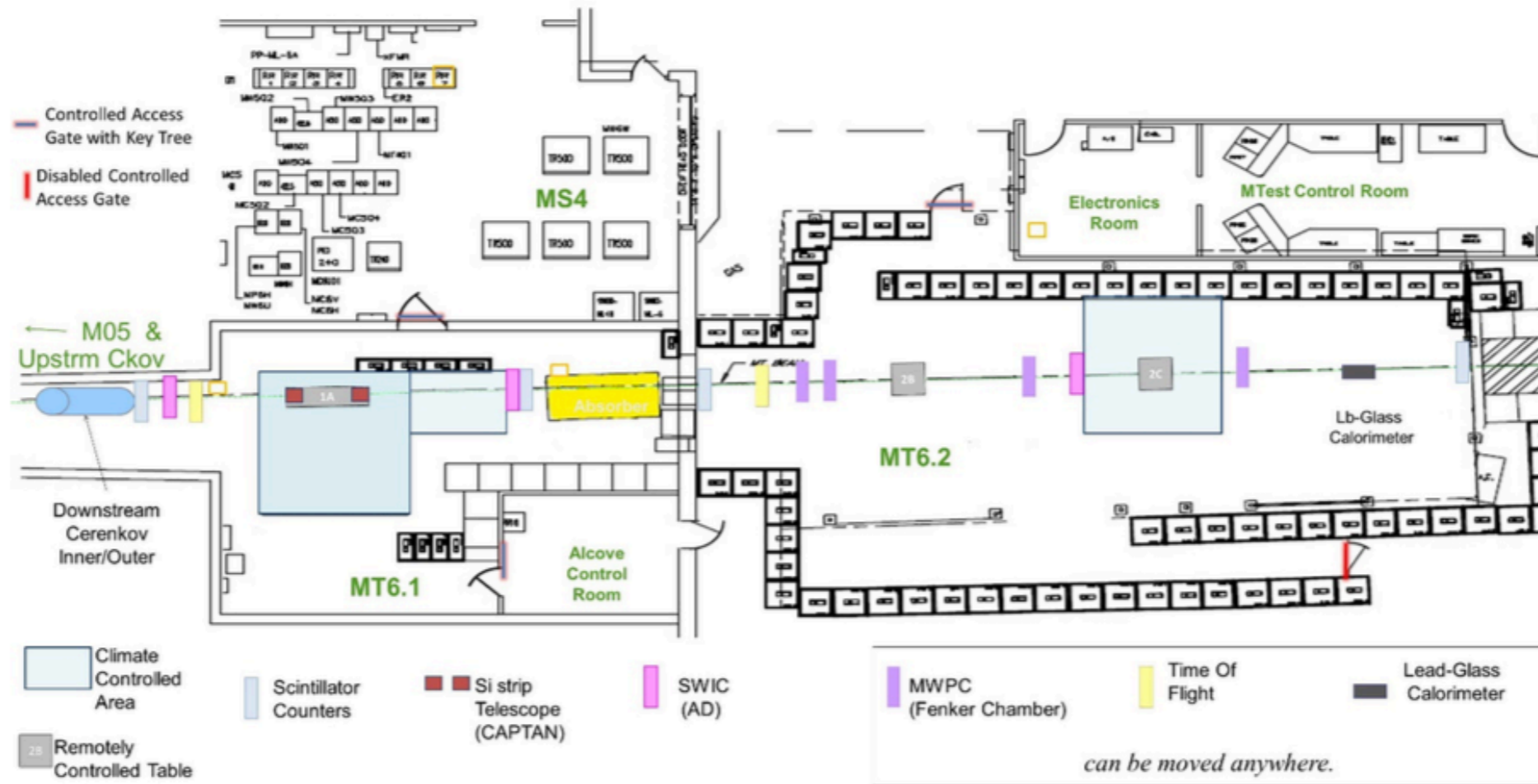
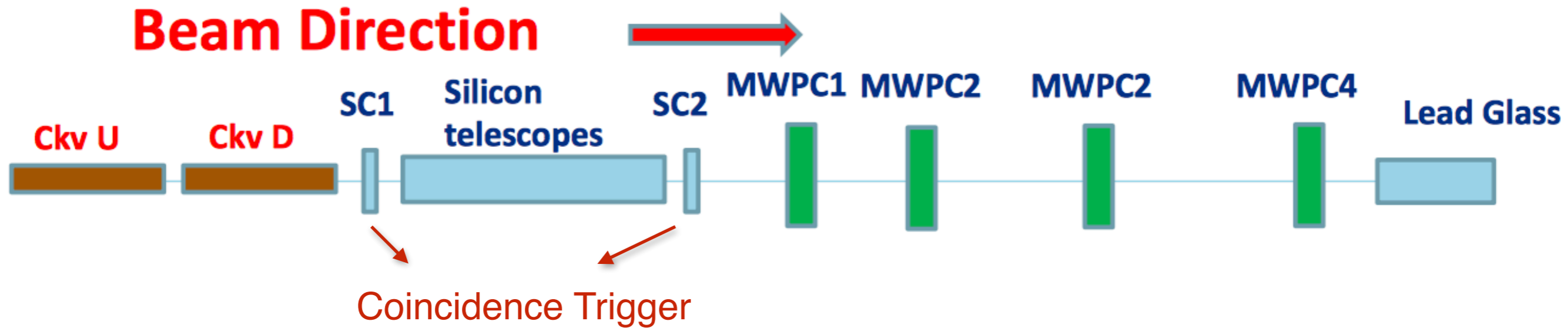


Silicon Telescope

- 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

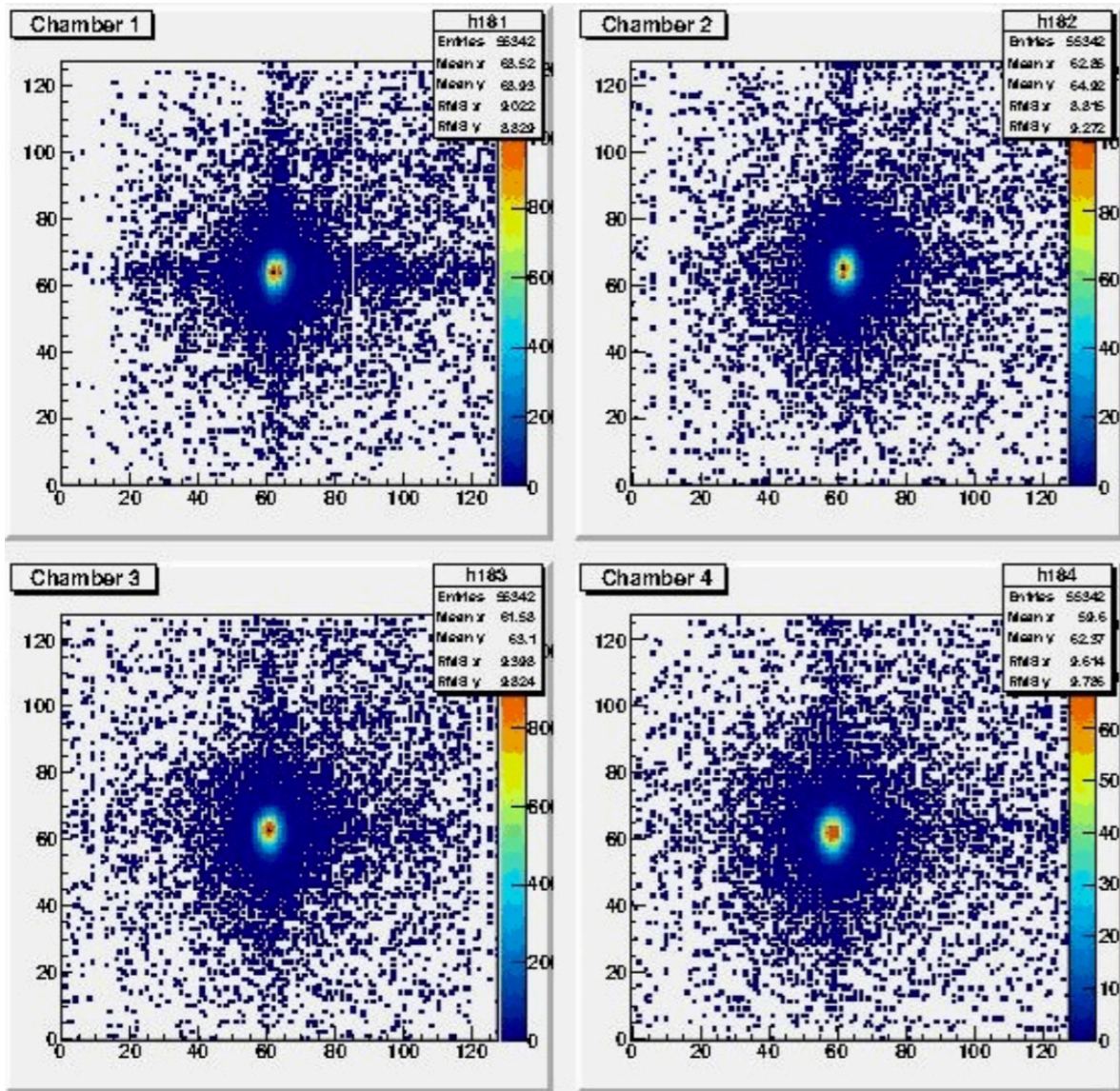


MTest Instrumentation Layout

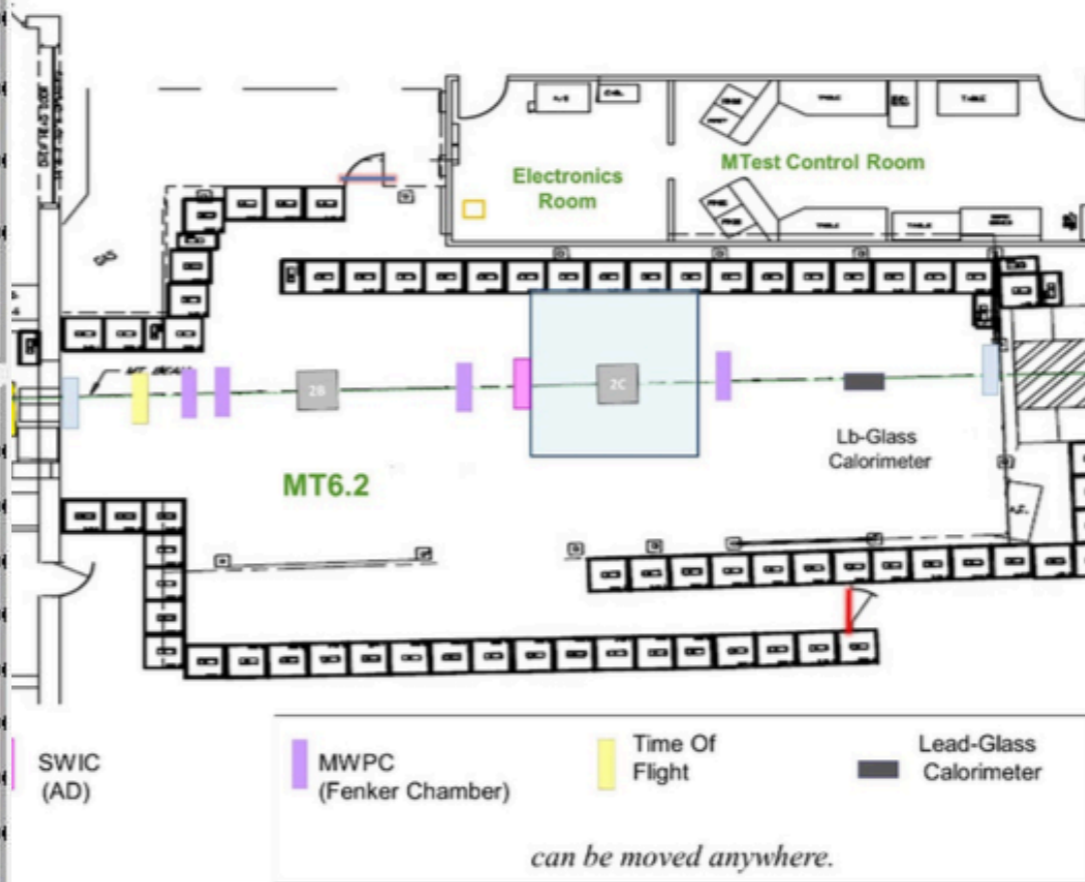


MTest Instrumentation Layout

Beam Direction 

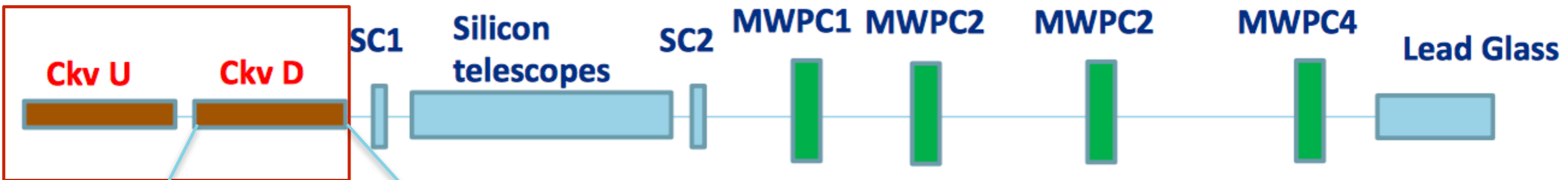


Tracking



MTest Instrumentation Layout

Beam Direction



Particle Identification

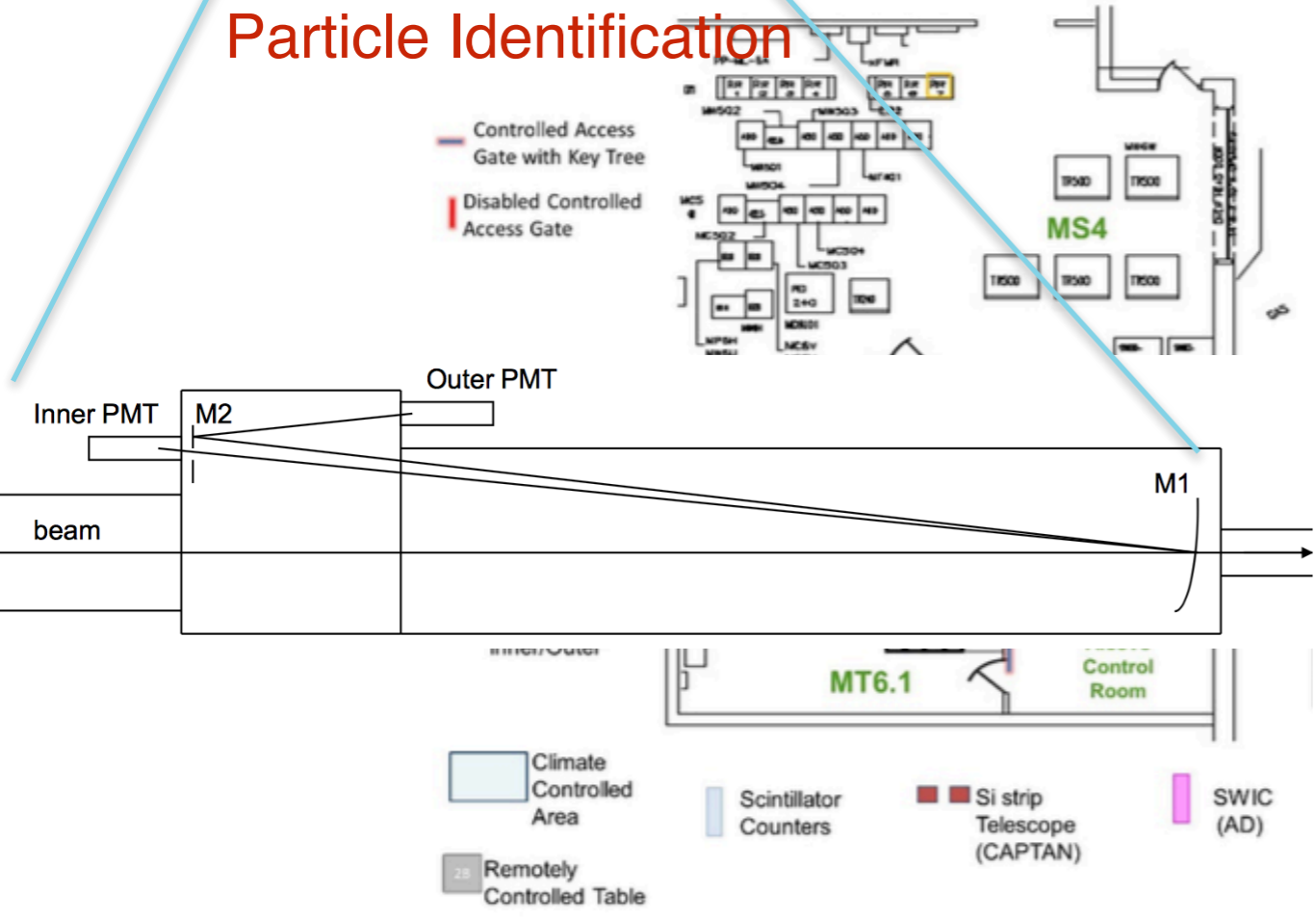
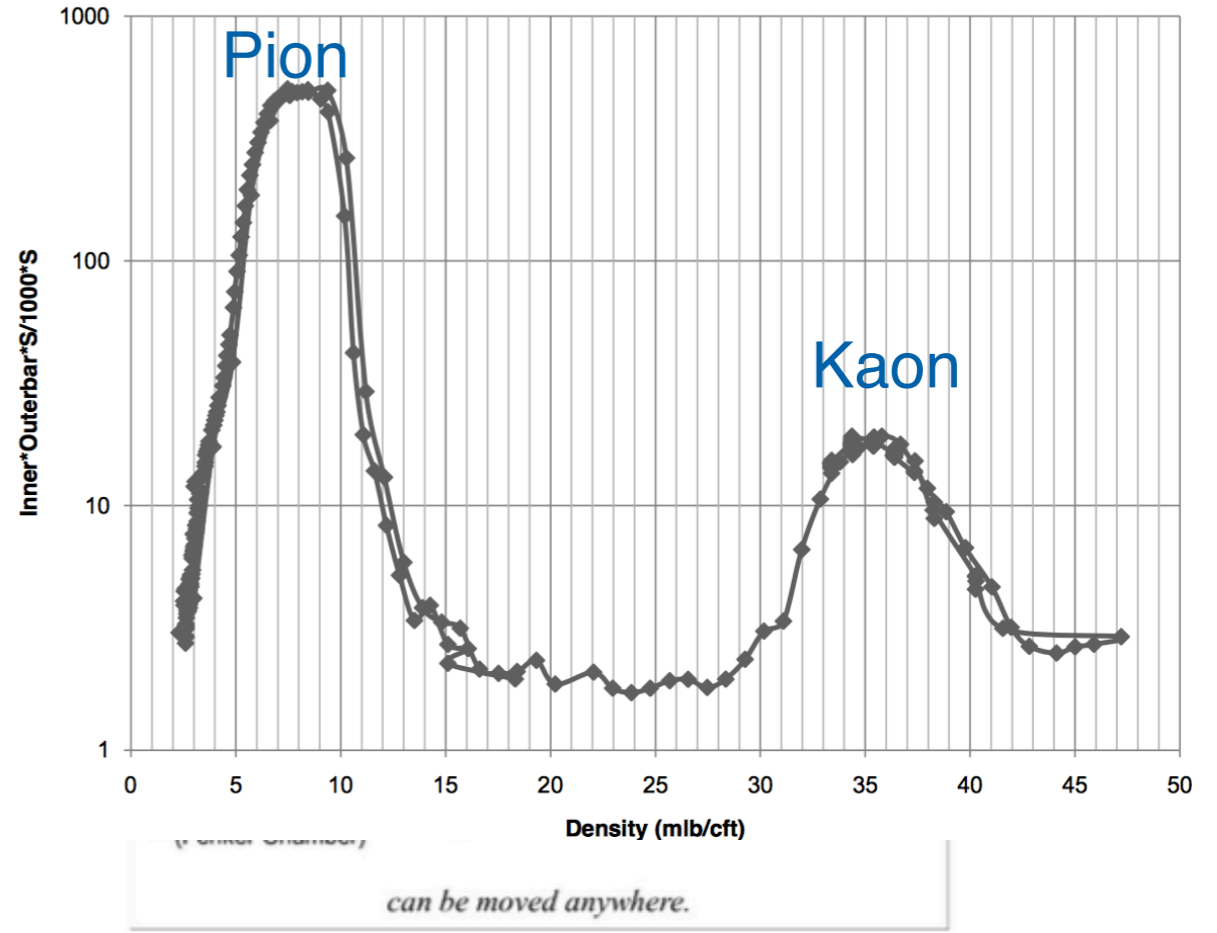
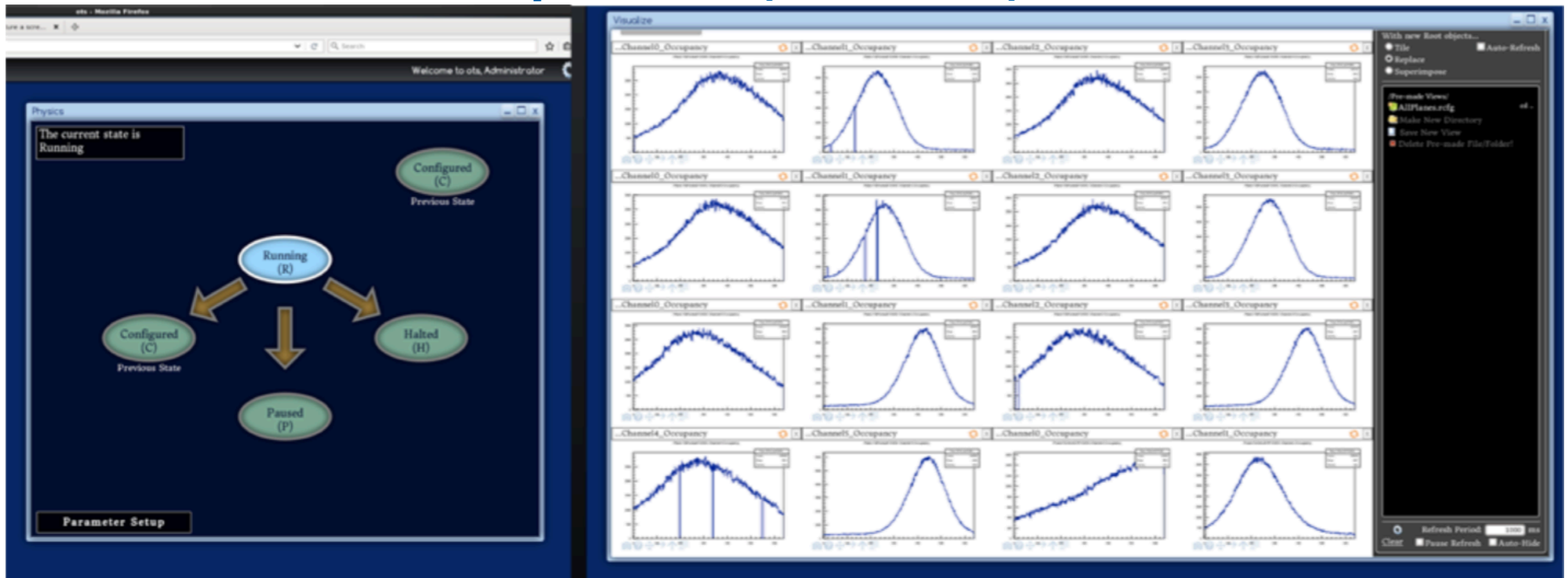


Fig. 9. 32 GeV/c Density Curve after Mirror Alignment



Off-The-Shelf Data Acquisition (OTSDAQ)



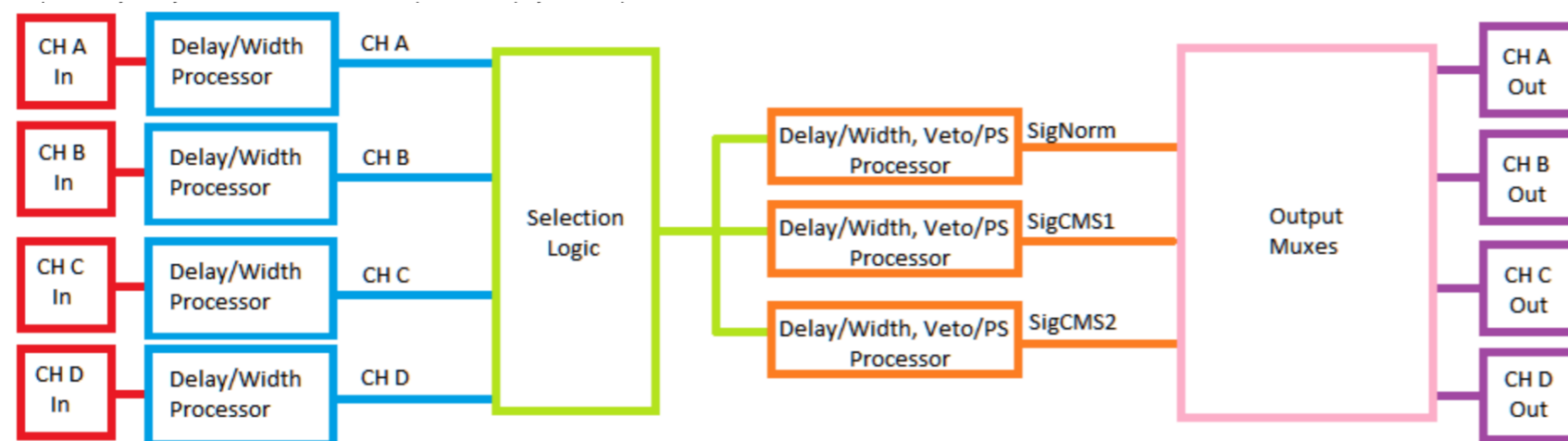
- SCD developed, flexible and scalable system allowing integration with other devices
- Tied into facility MWPCs, Cherenkov detectors, silicon strip telescope.
- Working to integrate with facility, enhance user experience, document
- Several groups (CMS outer tracking, CMS Timing, RD53 chip) have integrated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

L. Uplegger, R. Rivera, E. Flumerfelt

<http://otsdaq.fnal.gov/>

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

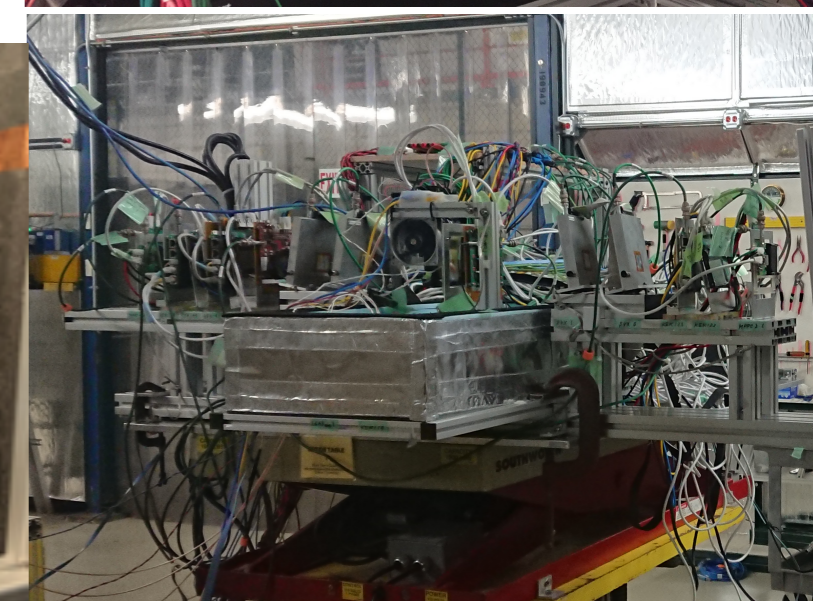
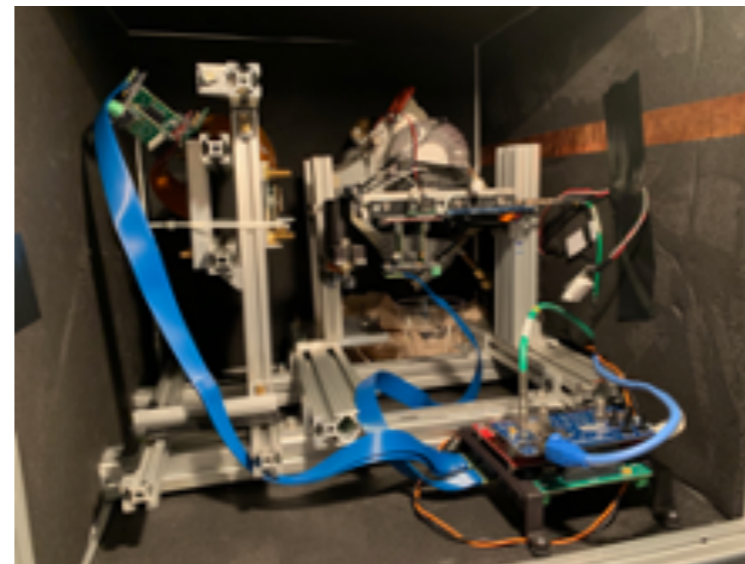
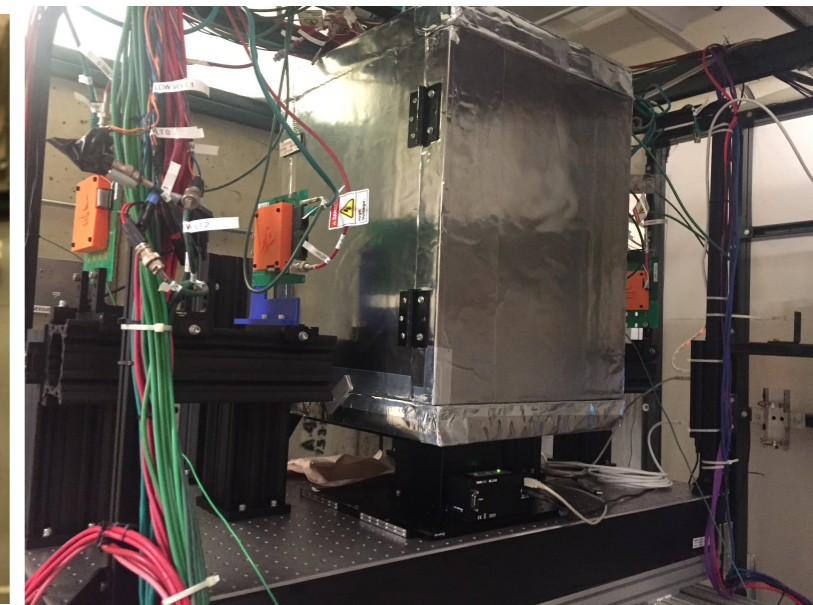
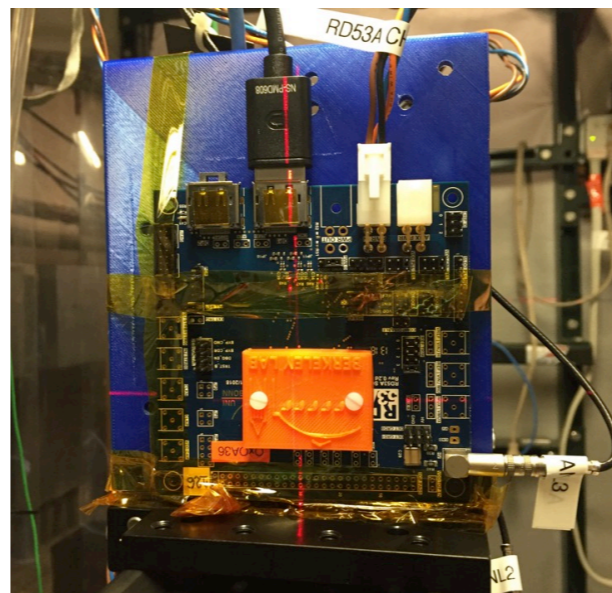
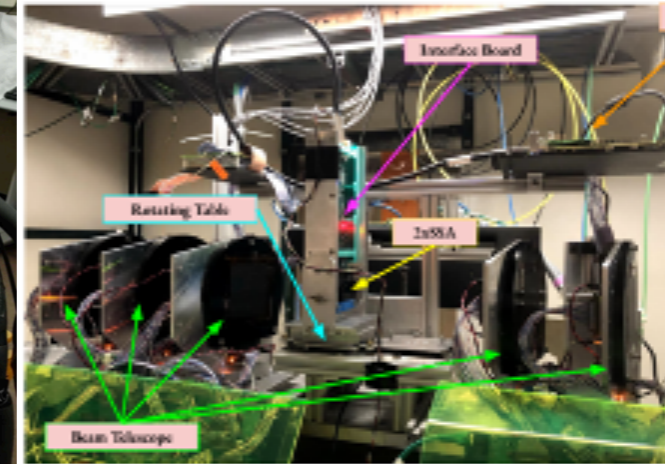
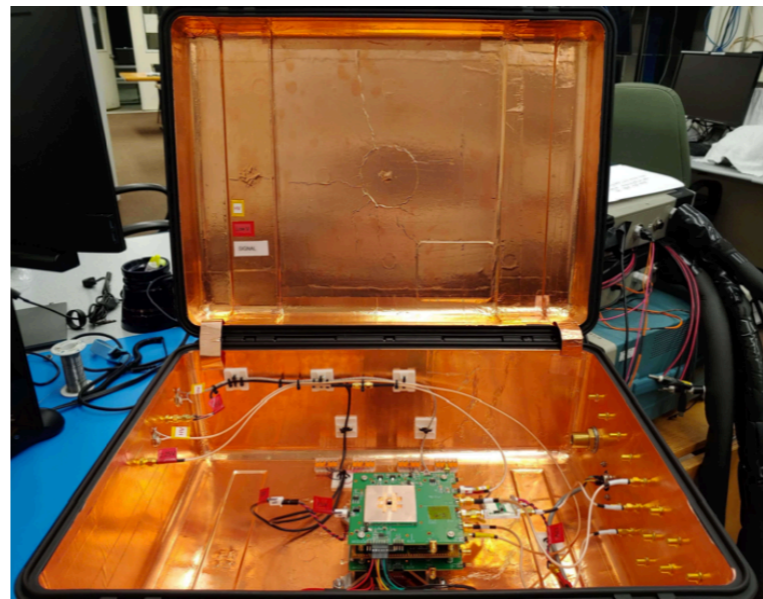


Life as an FTBF User

- Talk to the facility about a proposed experiment and fill out a Technical Scope of Work
- Possible to convert a proposal into running experiment in a couple months. Facility has a dedicated technical staff and experts to assist.
- Full experience designing and assembling experiment, operating DAQ, working with MCR to optimize beam, controlled accesses to make adjustments, data analysis.
- Develop relationships with experts from across the laboratory in accelerators, computing, detector technologies, safety, and the broader FTBF user community.

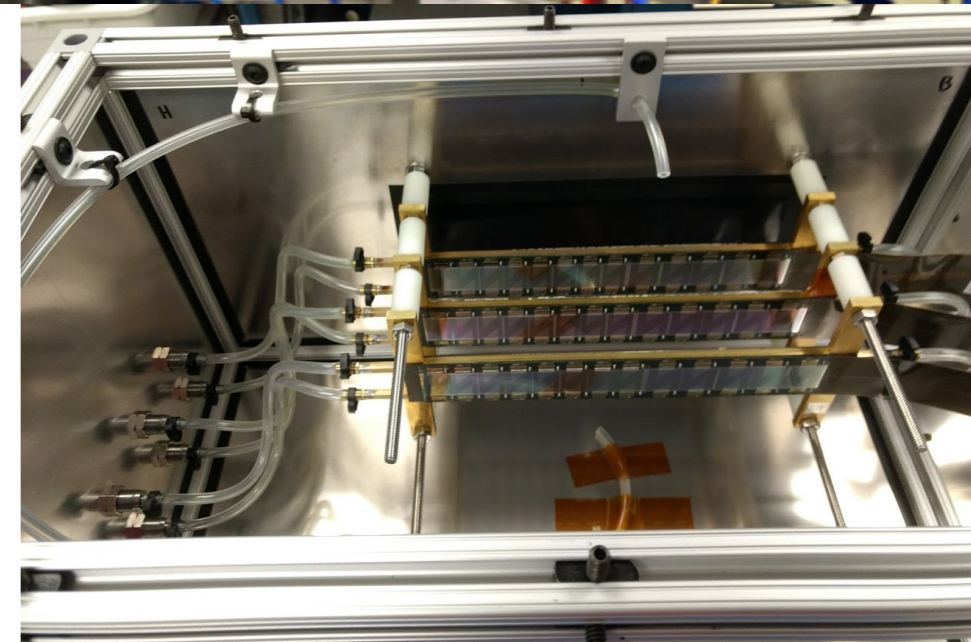
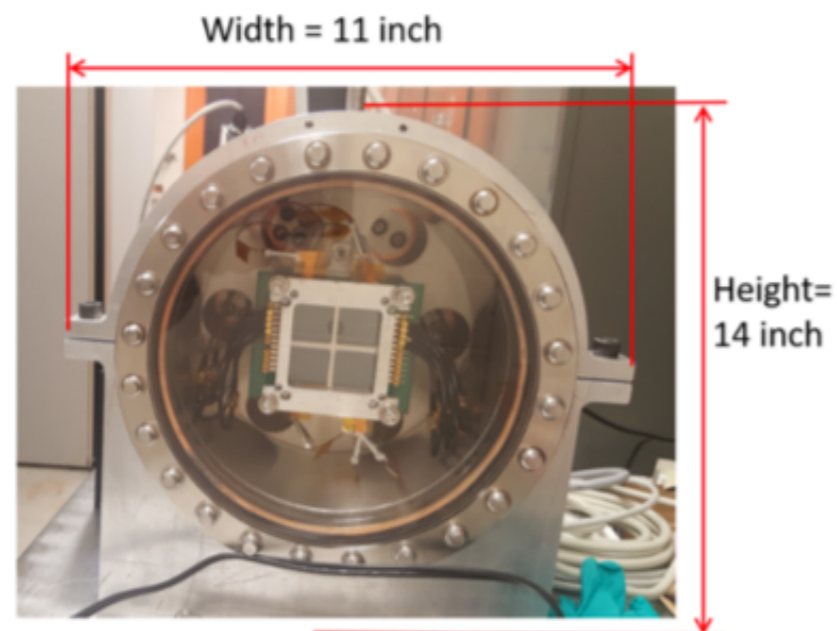
LHC Groups

- High Luminosity LHC upgrade R&D
- Variety of sensor and readout chip (RD53a) testing.
 - Both before and after irradiation
- Radiation hard timing detectors with 30-40 picosecond resolution
- Telescope development and testing



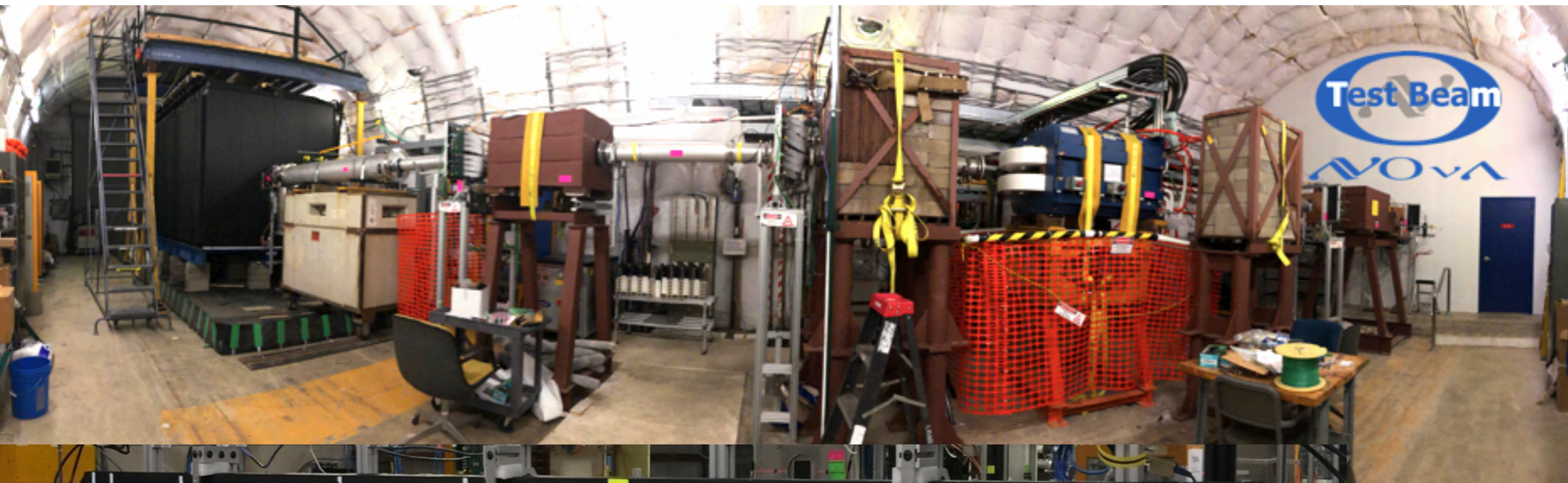
Other Collider Efforts

- 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



Neutrinos and Muons

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

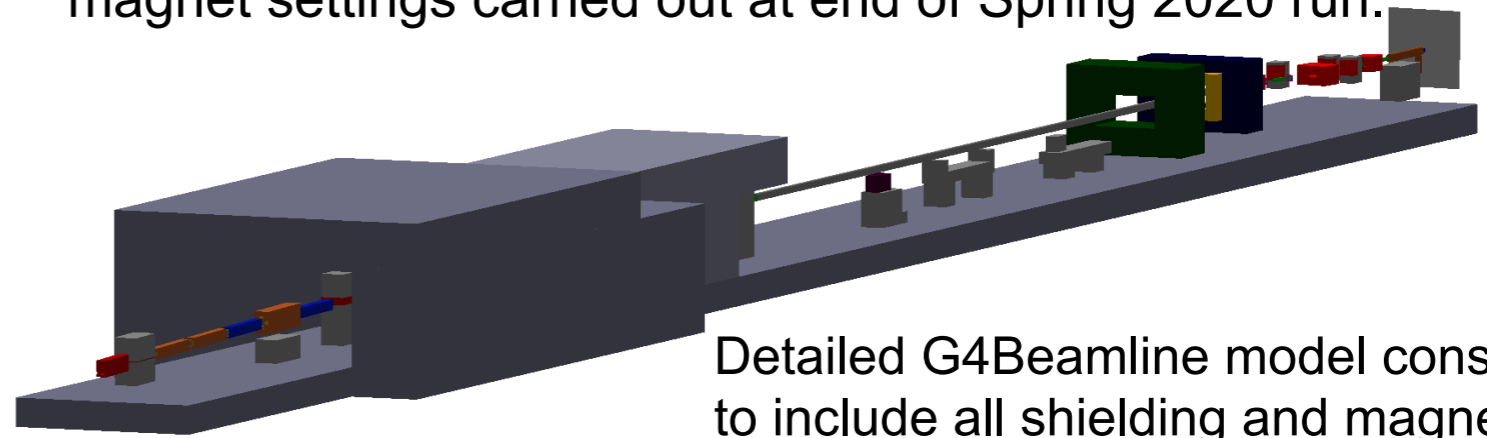
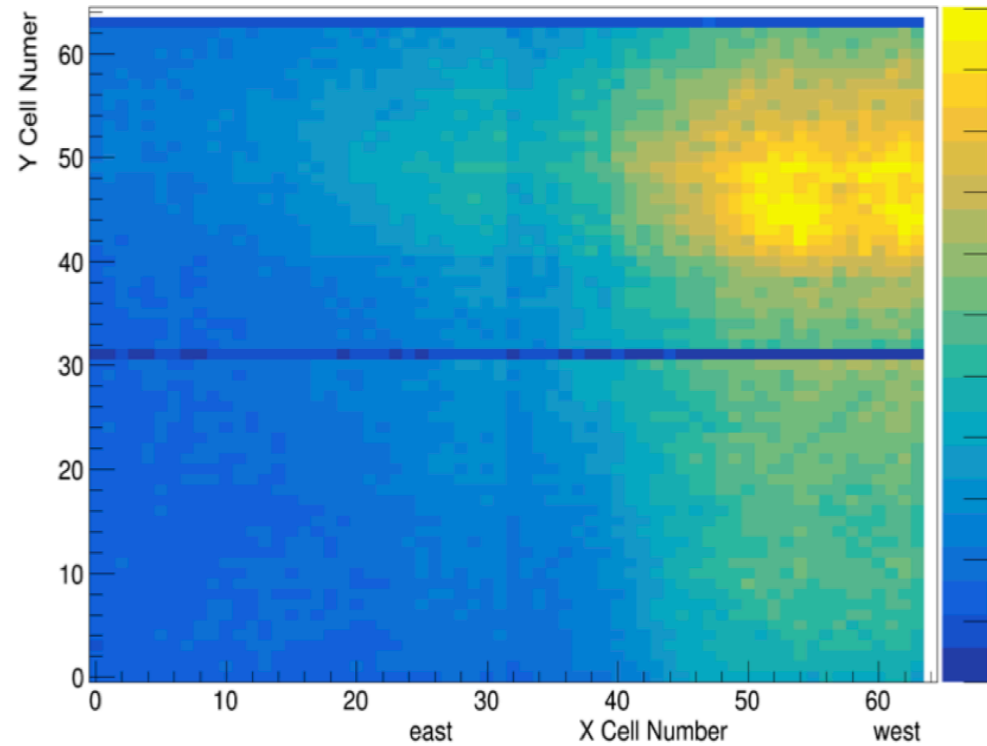


Working Together: MCenter Beam Improvements

Beam profile measured using the first two planes of the NOvA detector.

Concerted effort by the External Beams Group (AD), the NOvA Test Beam group, and the Test Beam Facility to improve understanding of beam and guide deployment of mitigating measures.

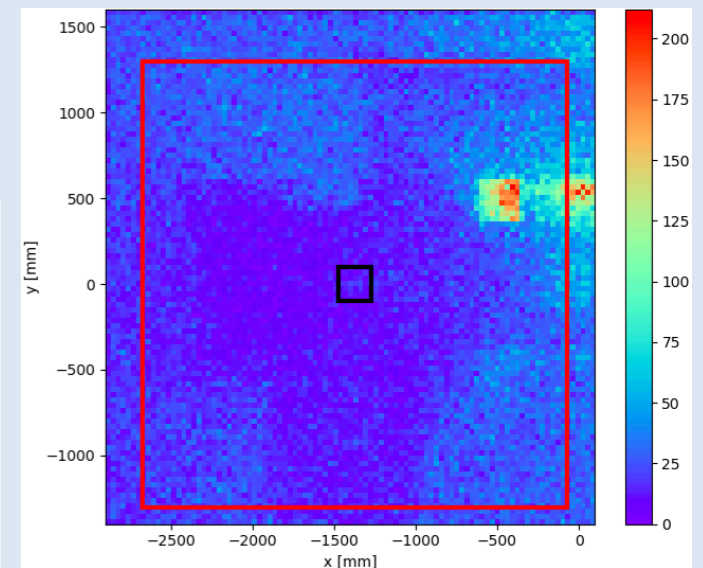
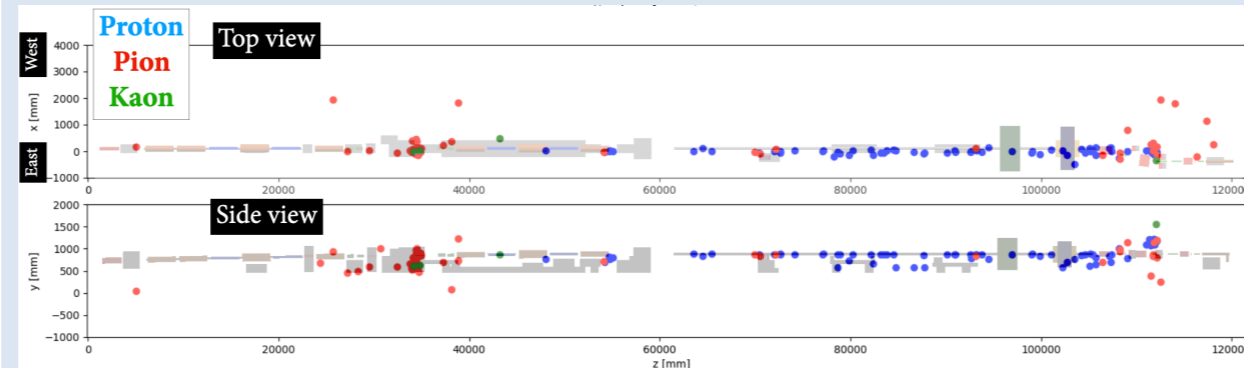
Simulated results qualitatively match observations from comprehensive beam studies varying beam line collimator and magnet settings carried out at end of Spring 2020 run.



Detailed G4Beamline model constructed to include all shielding and magnet yoke field simulations.

Observed highly localized intense particle 'plume' limiting data-taking with the NOvA detector.

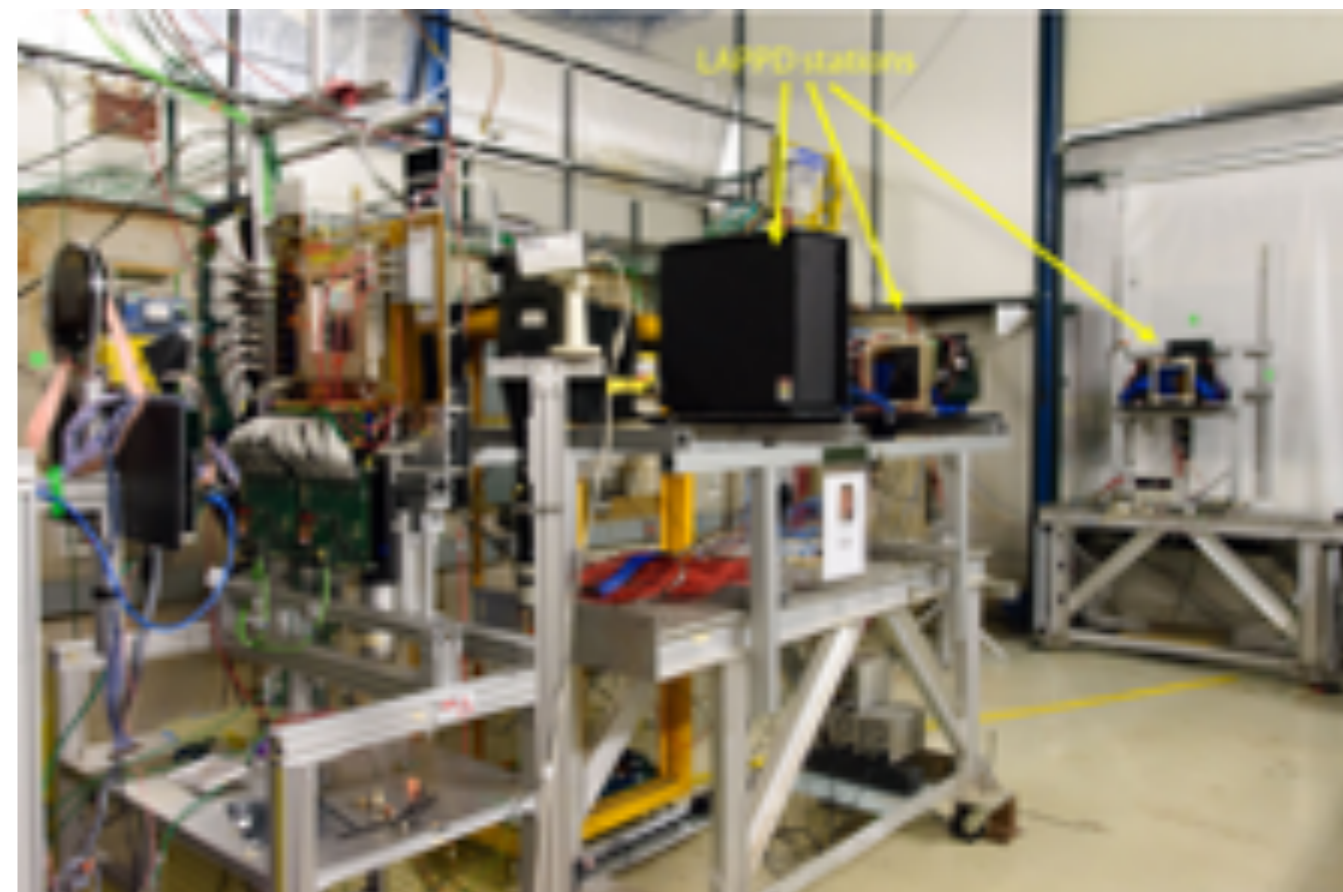
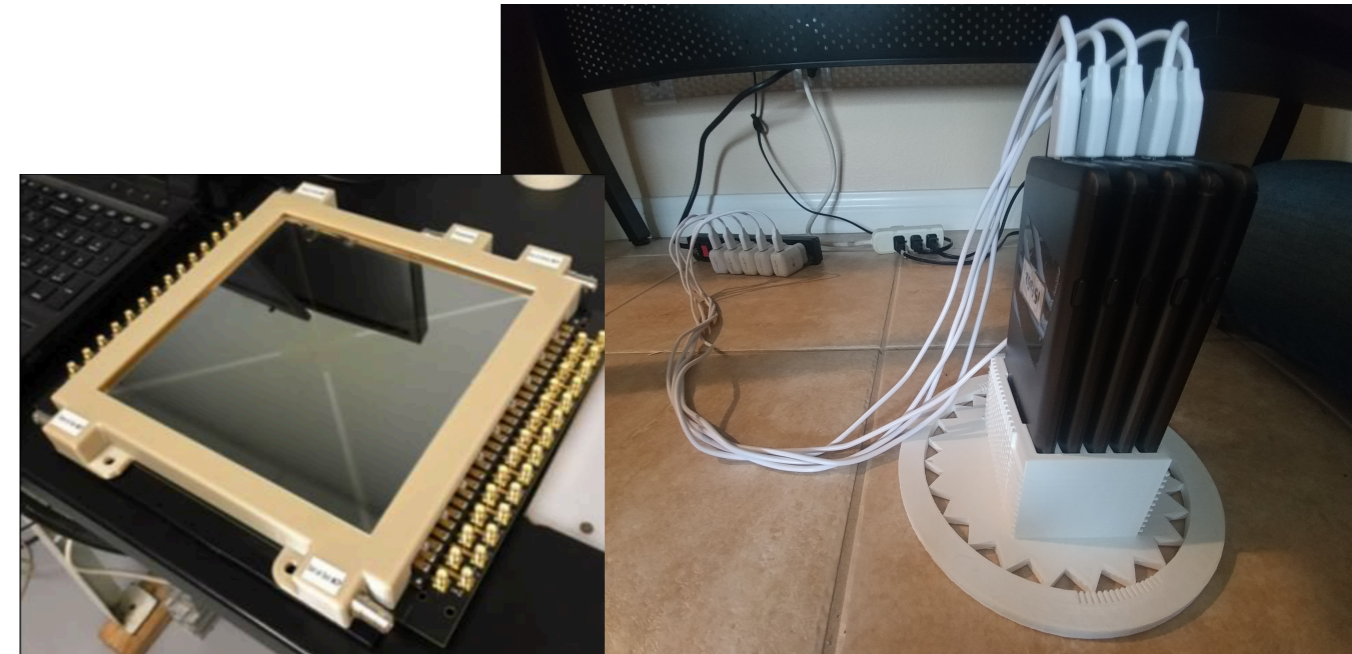
Able to reproduce the plume in improved simulation and identify the origin of the particles in the beam. Additional shielding needs identified and being readied for deployment.



Provided by M. Wallbank and A. Watts

General 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*



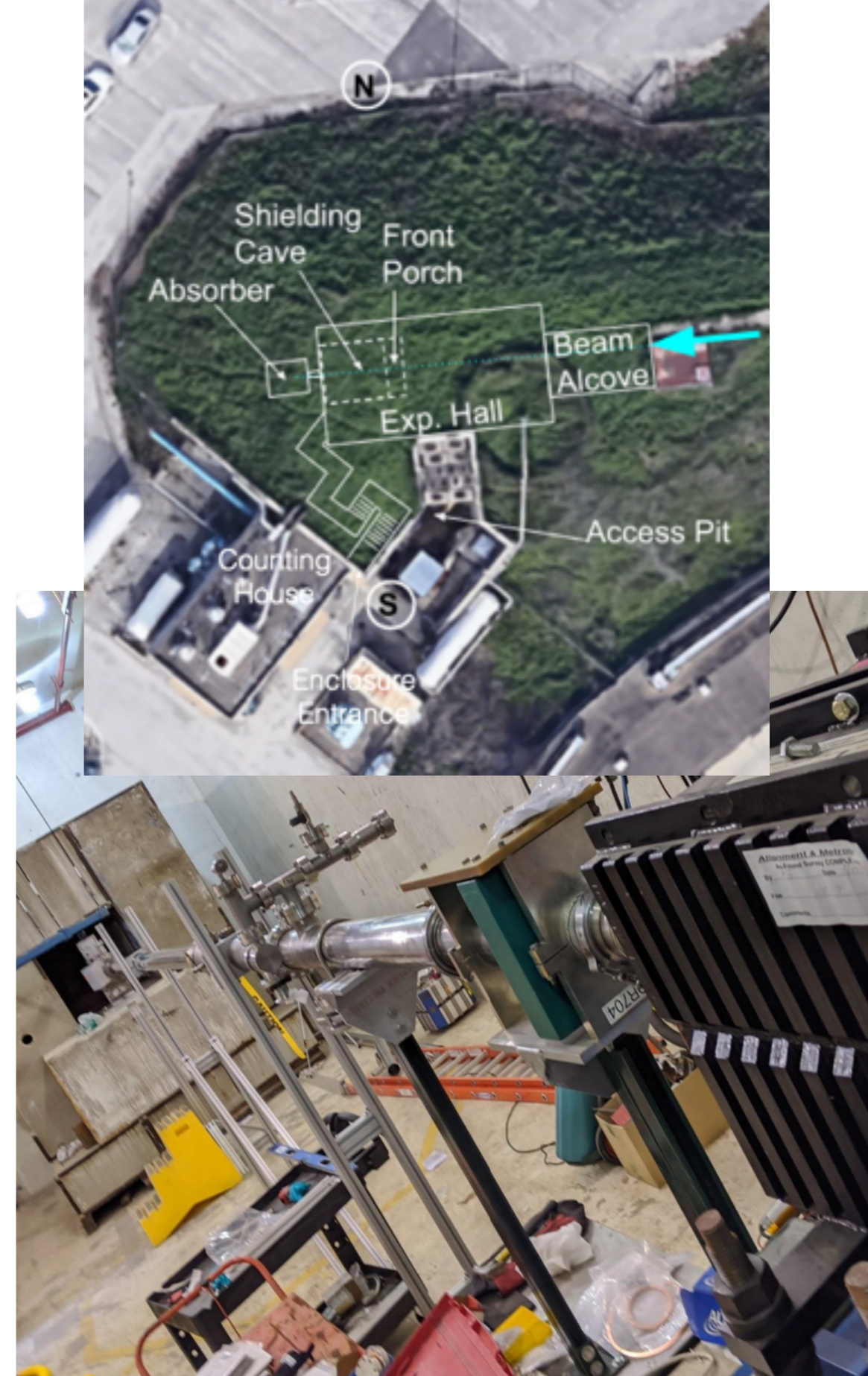
On the Horizon

Irradiation Test Area

- Significant demand from community to have an on-site facility to study the effects of radiation and radiation damage on detector components.
- CMS, ATLAS, Mu2e-II, DUNE, LHC-B, sPHENIX, TOTEM, RD50, RD53, CubeSats, and more have expressed interest.
- Yearlong effort to clean out and refurbish the MuCool Test Area at the end of the Linac for this purpose.
- 400 MeV proton beam, designed to reach fluences of $1 \times 10^{16}/\text{cm}^2$ in a few hours.
- Synergistic with FTBF to allow rapid cyclings of irradiation and beam test all onsite

Irradiation Test Area

- Flexible infrastructure to mount samples in shielding cave, motion table, power and cooling, small counting house for monitoring.
- Ready for commissioning and operations this Fall after accelerator shutdown.
- Operating 12 hours of beam per week during the beam year.
- Starting to schedule initial users. Contact us for details!



Facility Improvements

- Resurrecting the Jolly Green Giant large aperture magnet in MCenter.
- Updates to the facility beam line instrumentation, slow controls, and DAQ.
- 120 GeV beam in MCenter.
- Exploring opportunities with PIP-II and the Booster replacement for a high intensity irradiation area and expanded test beam capabilities.
- User input is very valuable to our future planning. We strive to meet the needs of our community.
- If you have ideas for a test beam experiment that is not possible with the present facility, come and talk to us. Tell us about your beam needs for the next decade.

Summary

- FTBF is a world class facility for detector R&D.
- We look forward to seeing first beam at the ITA this year.
- Continually improving facility resources and the user experience.
- Great training ground for students.
- Scheduling FY21 beam time soon. If you have a project in mind we are dedicated to making it happen!
- Learn more
 - FTBF [elog](#)
 - Slack Team: [fnal-testbeam](#)
 - Webpage: ftbf.fnal.gov
 - Listserv: test_beam@fnal.gov