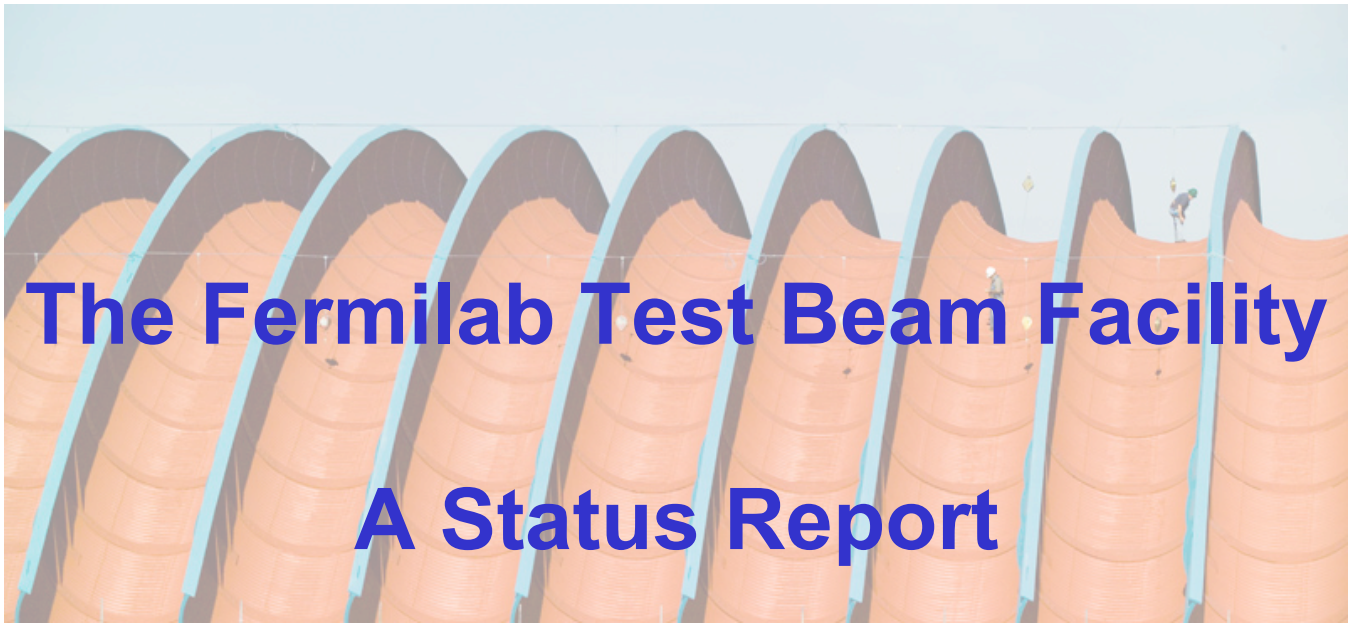

The Fermilab Test Beam Facility

A Status Report

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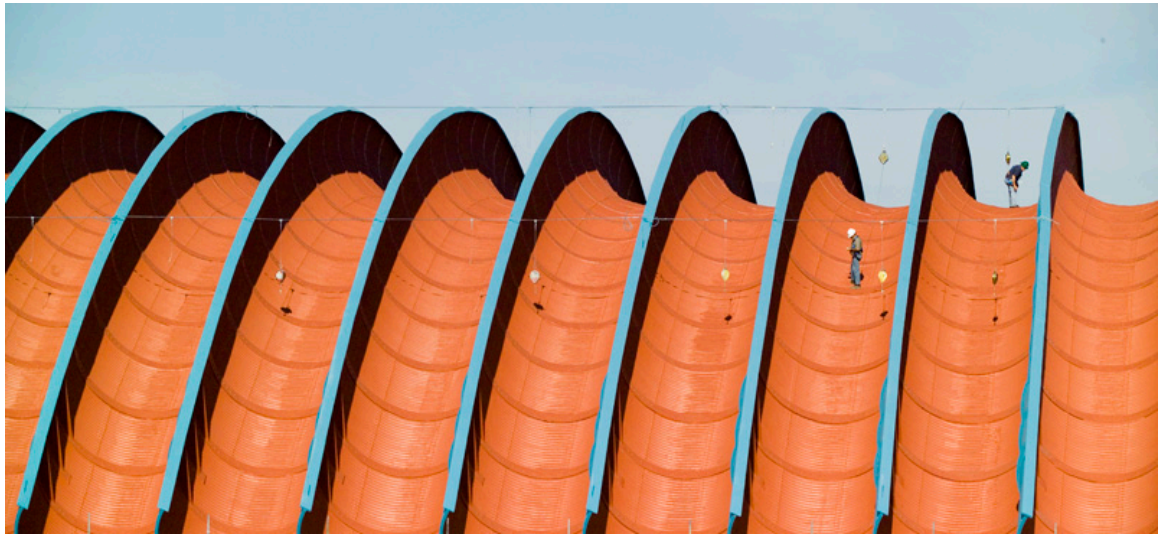
Erik Ramberg, Marcel Demarteau*

Fermilab

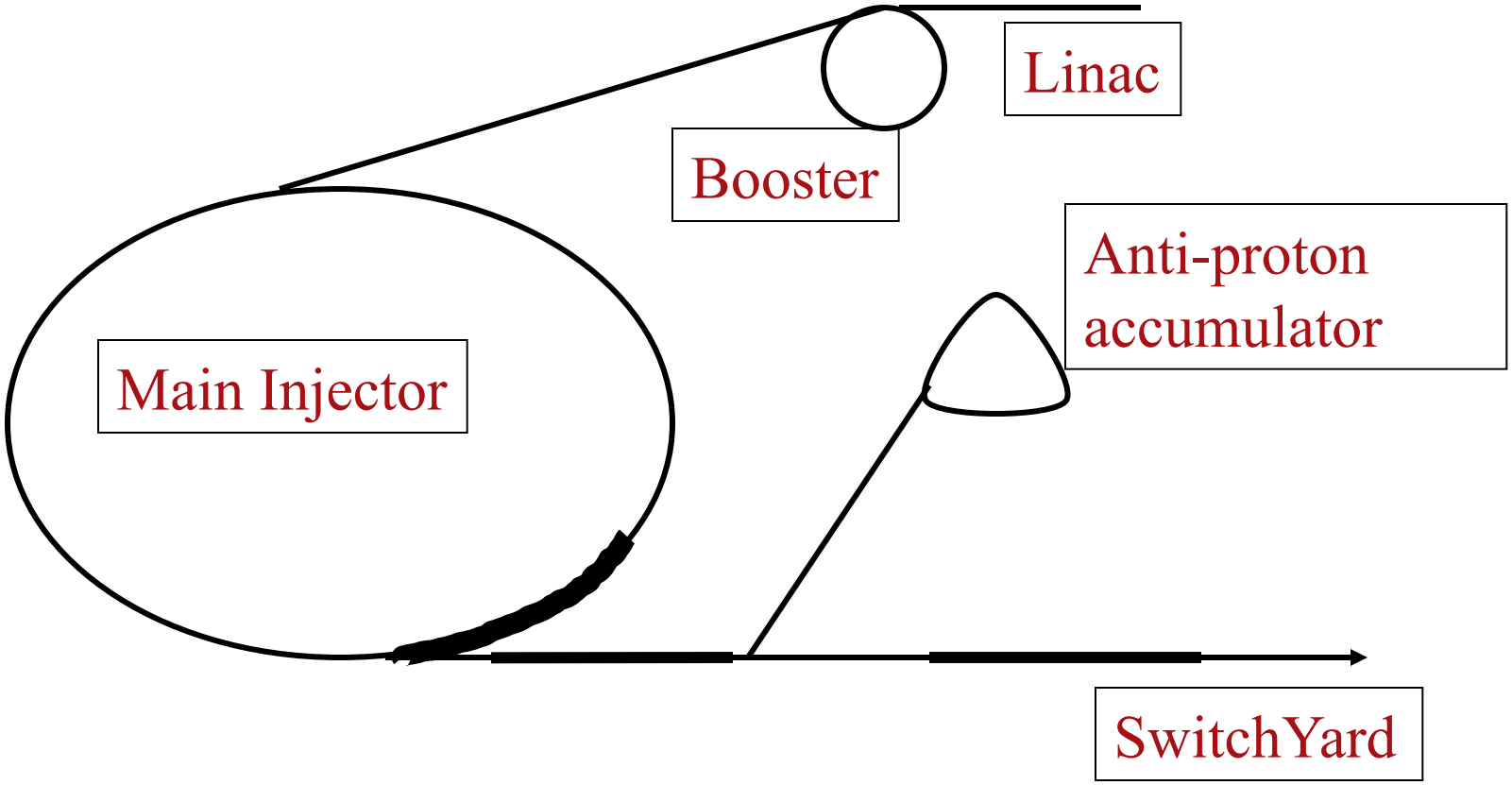
29 March, 2010
LCWS 2010
Beijing

* = presenting

BEAM DELIVERY



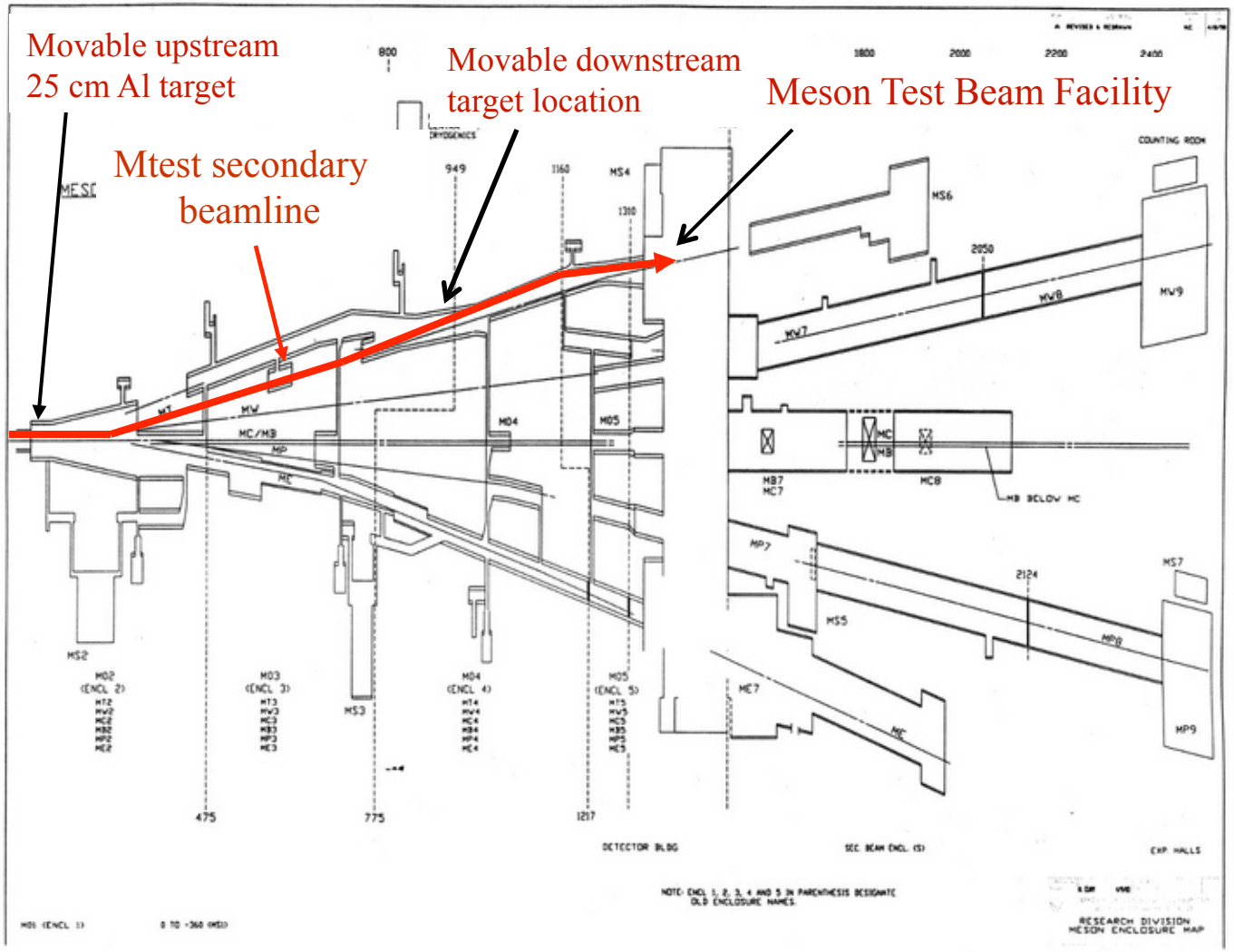
Accelerator Complex and Extraction



Extraction of beam from Main Injector:

- Load 1 batch from Booster to the Main Injector
- The batch length ranges from 0.2 to 1.6 μsec in length – Full batch equals 2E11 protons
- A fraction of the beam is resonantly extracted in a slow spill for each Main Injector rotation

Beam Delivery to MTest User Facility



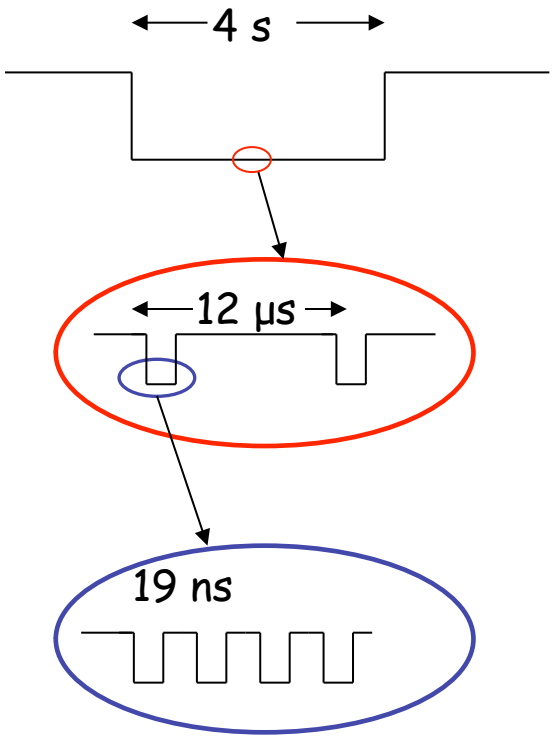
Proton Mode: 120 GeV protons transmitted through upstream target

Pion Mode: 8-66 GeV beam tuned for secondaries from upstream target

Low Energy Pion Mode: 1-32 GeV beam tuned for secondaries from downstream target

Tertiary Mode: Energies below 1 GeV

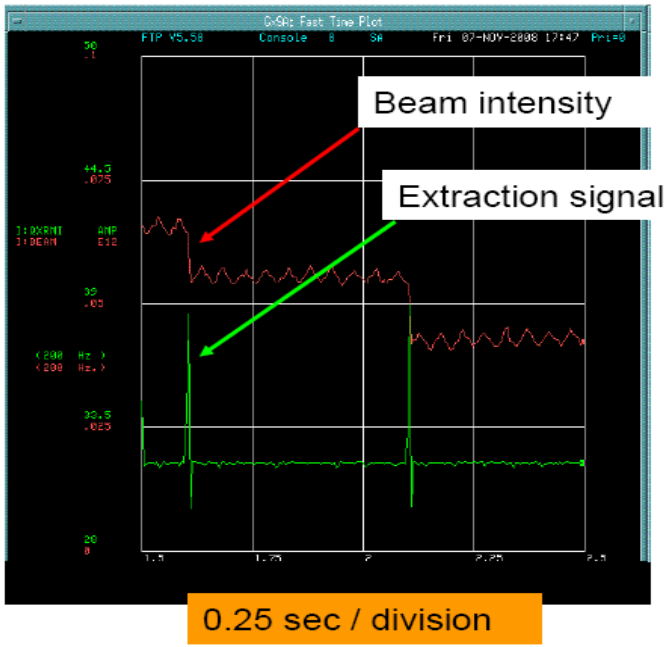
Spill options available at MTest

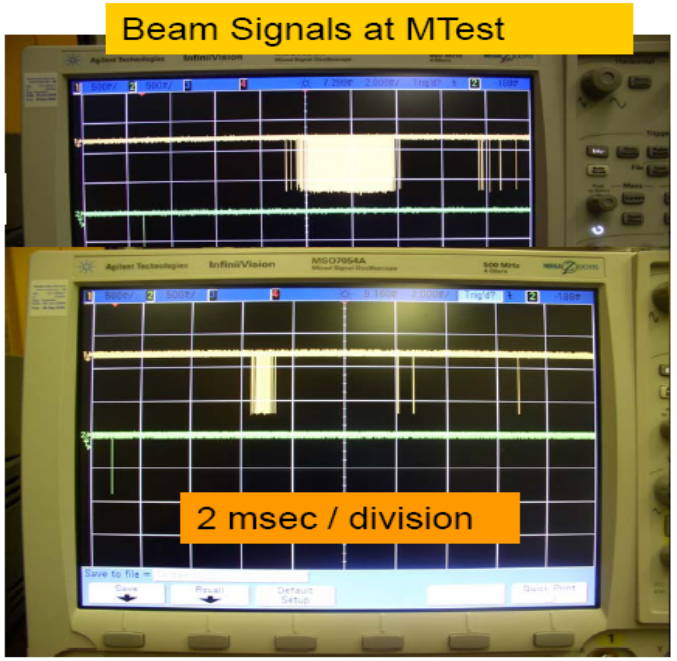


- Daily hours: 04:00 to 18:00
- Spills per min: One 4 second spill/minute, or
  Two 1 second spills/minute
- # Pulse trains: ~80,000 'batch rotations'/second
  (1 microsecond train, followed by
  11 microsecond void)
- # Pulses: from 5-60 'bunches' per 'batch'
  (each bunch is 19 nsec long)

ILC-like 'Train' Structure

- The ILC is a 5 Hz machine: 1 ms train with a 199 ms inter-train quiet period
- The Accelerator Division has installed pulsed quadrupole extraction hardware that can deliver beam within 1 to 5 ms short spills, or 'pings' (=train)

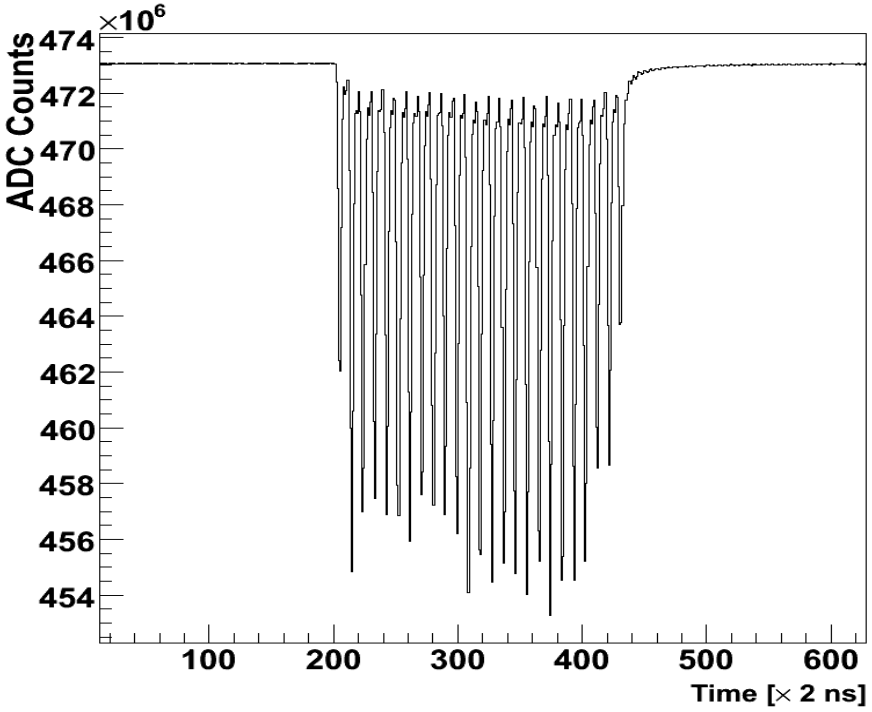




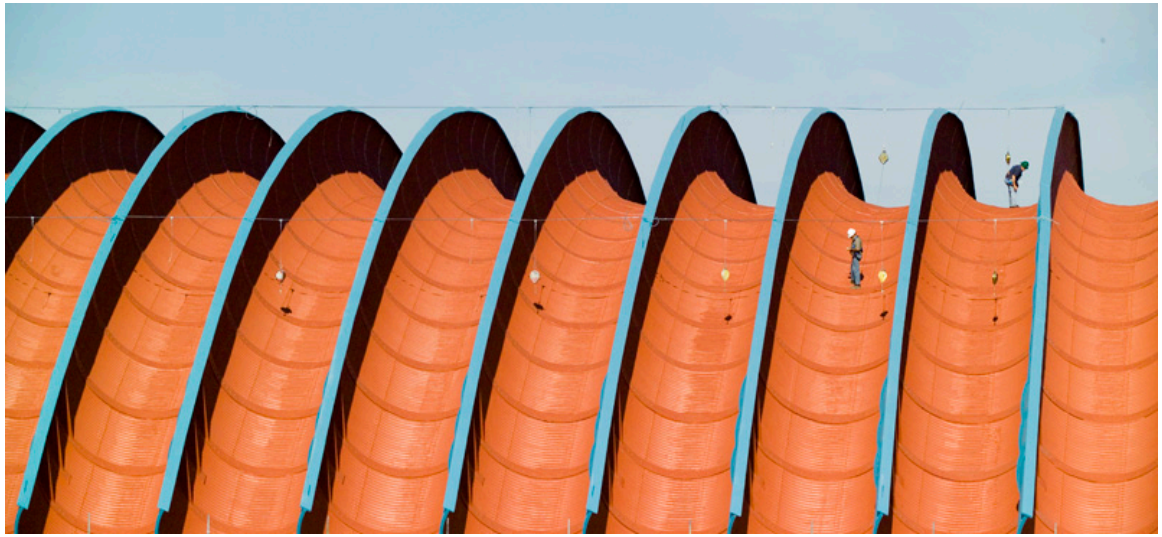
- Several of these pings can be delivered within the assigned 1 second spill time
- Two or more groups of protons (3-7 bunches each) can be coalesced with 400 ns spacing

Uniformity of Beam Delivery

- The Airfly collaboration (T988) has built a DAQ system that can resolve the bunch spacing of beam arrival (19 ns) within the entire macroscopic 4 second spill
- The population distribution is relatively uniform in each batch, as shown

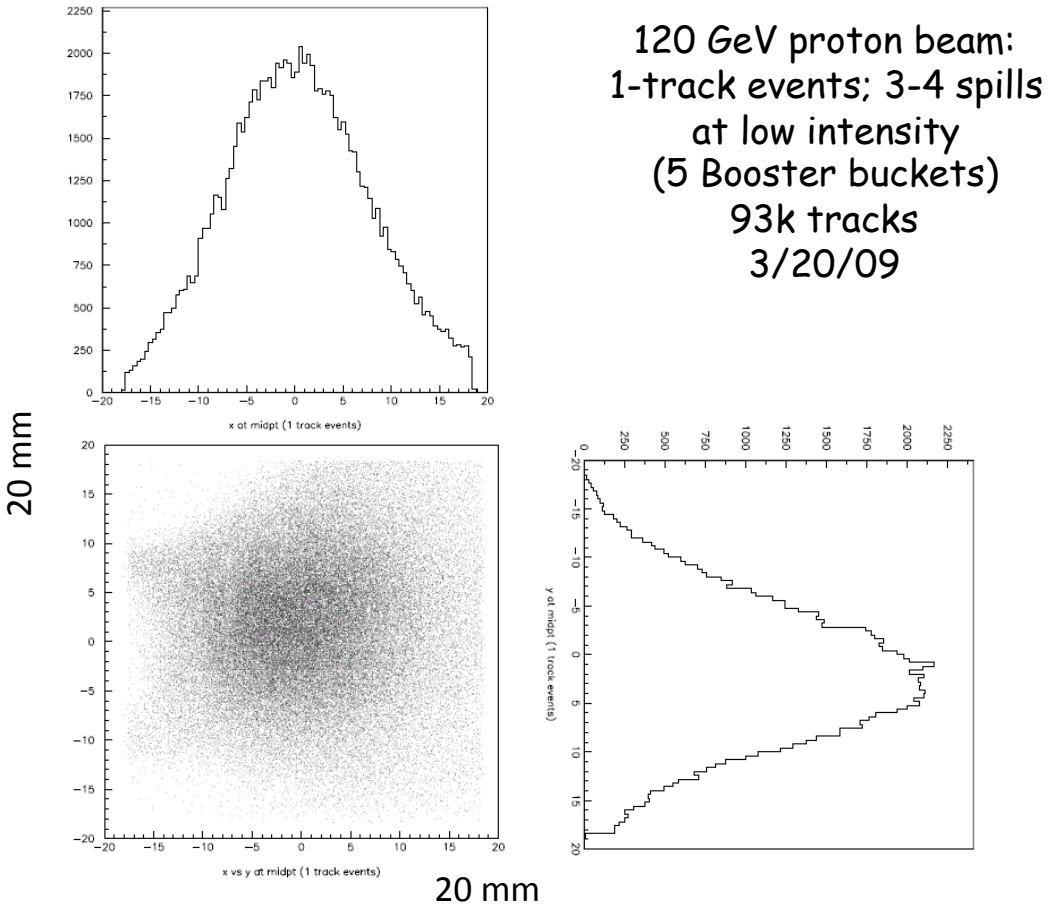


BEAM CHARACTERISTICS



Beam Position Profile (last quads off)

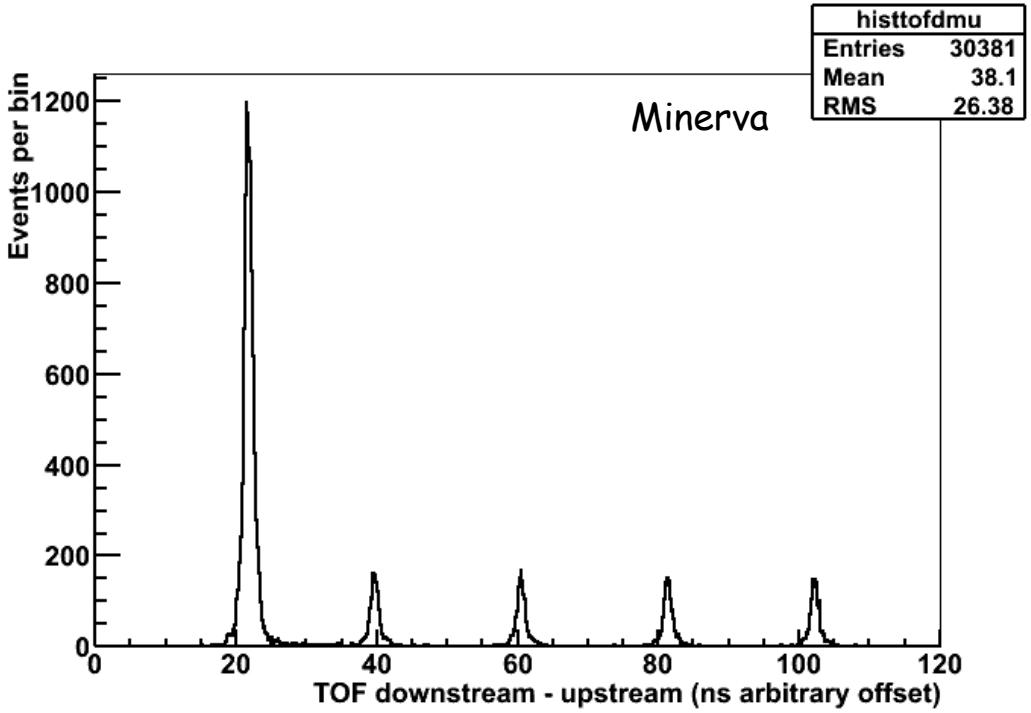
- Beam position profile as measured with one of the pixel telescopes (see later)



120 GeV proton beam:
1-track events; 3-4 spills
at low intensity
(5 Booster buckets)
93k tracks
3/20/09

Double Occupancy

- Because of the batch structure, where less than 1/6 of the Main Injector is filled with beam, there is a higher probability of encountering a second beam particle within 20 ns of a triggered particle.
- This ‘double occupancy’ is on the order of 5-10%, as shown by MINERVA.
- Integrating the pulse height in a trigger signal can reduce this substantially.



Beam Rates and Electron Content

- Rates measured without lead scatterer

Beam Energy (GeV)	Rate at Entrance to Facility (per spill)	Rate at Exit of Facility (per spill)	%Pions, Muons**	% Electrons**
16	132,000	95,000	87%	13%
8	89,000	65,000	55%	45%
4	56,000	31,000	31%	67%
2	68,000	28,000	<30%	>70%
1	69,000	21,000	<30%	>70%

- Rates with ¼" lead scatterer

Beam Energy (GeV)	Rate at Entrance to Facility (per spill)	Rate at Exit of Facility (per spill)	%Pions, Muons**	% Electrons**
16	86,000	59,000	100%	0%
8	31,000	18,000	98%	2%
4	5,400	1,300	74%	15%
2	4,100	250	<30%	>70%
1	4,900	120	<30%	>70%

*Rates here are normalized to 1E11 at MW1SEM

Beam Delivery for CALICE

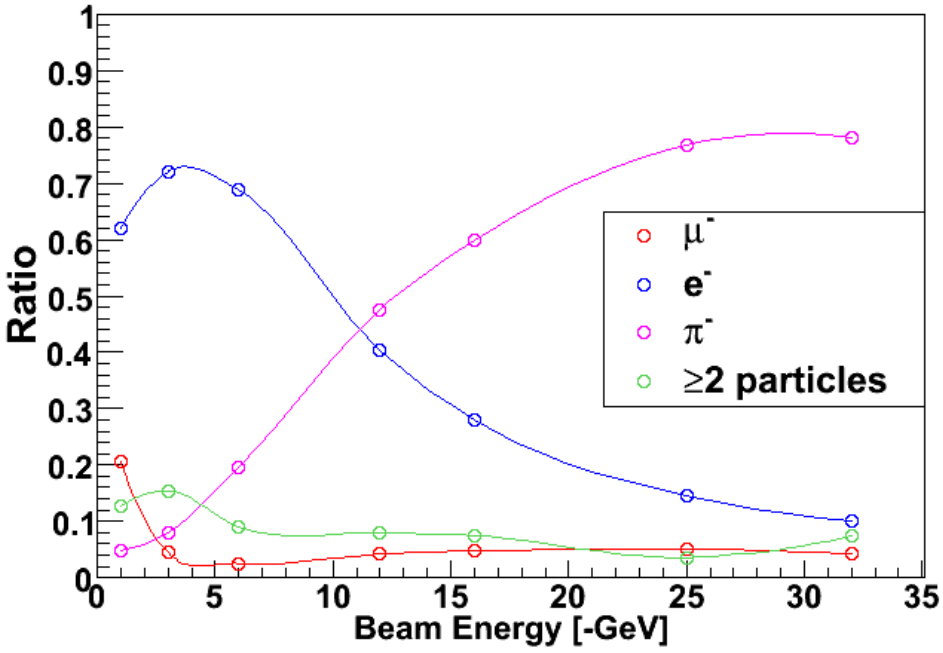
- The CALICE experiment (T978) has been the most comprehensive detector system to be installed at MTest and has summarized their results for beam composition.
- The Fermilab Accelerator Division has created beam tunes for CALICE as follows:

  Negative

  1,2,3,4,6,8,10,12,15,20,30 GeV

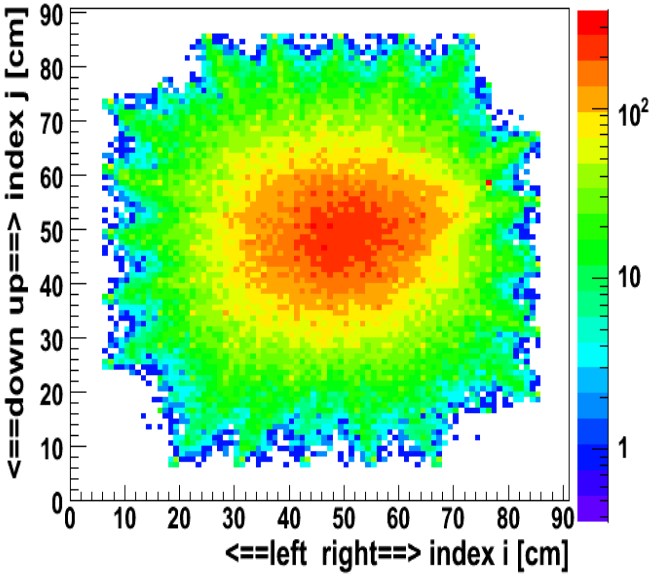
  Positive

  32 GeV (high rate muon mode), 120 GeV (proton mode)

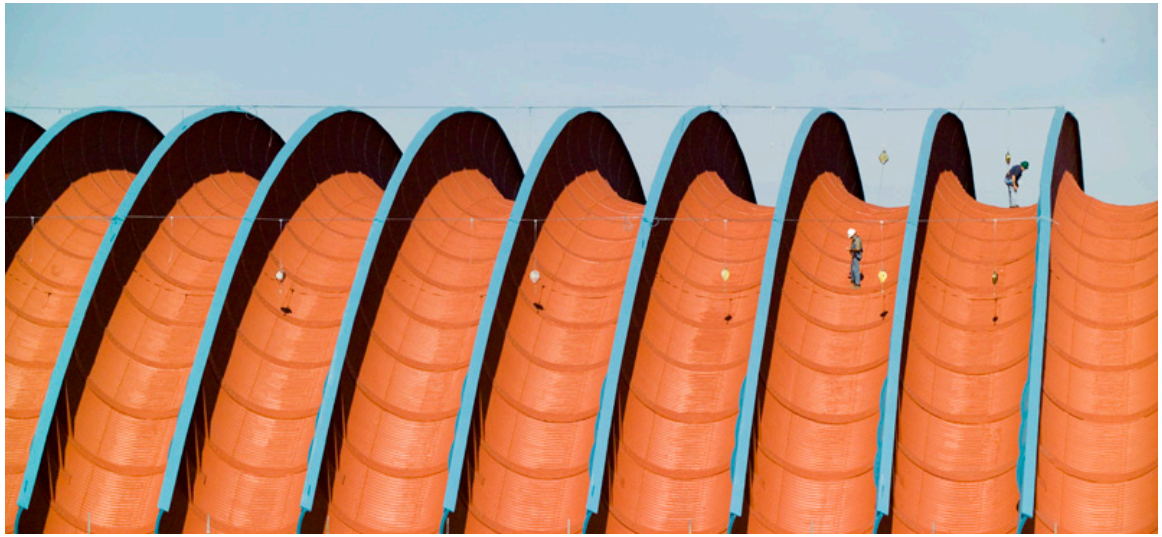


Muon beam at MTest

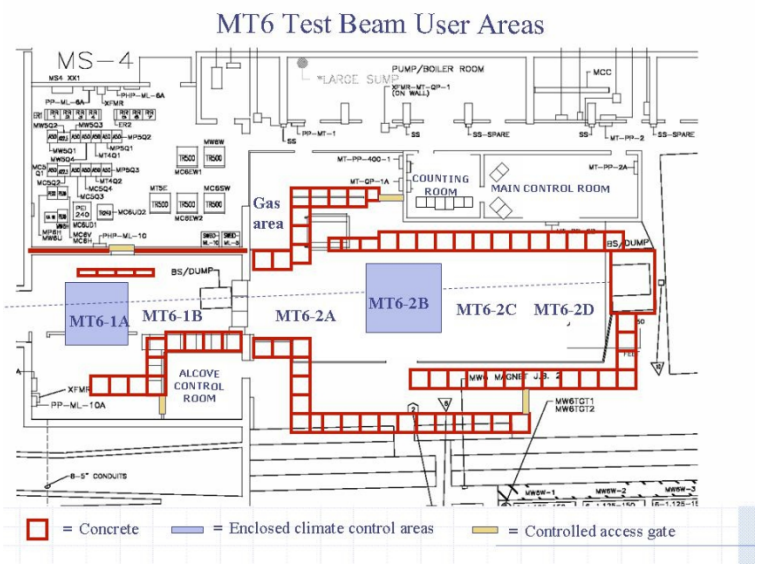
- Can maximize muon flux by running high intensity at 32 GeV, and inserting 2.5 meter beamstop just before the user area.
- Broad-band muon flux can be delivered at several kHz over a square meter, as shown by CALICE

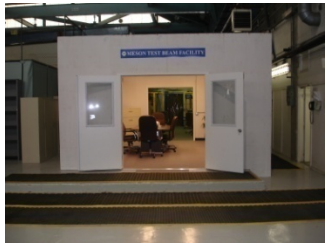


USER FACILITIES

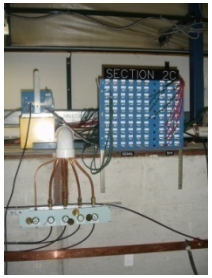


User Facility





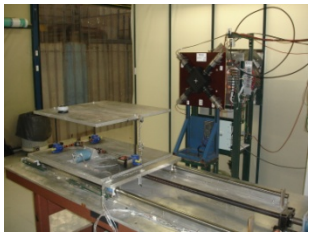
Spacious control room



Signal and HV cables

Gas delivery to 6 locations

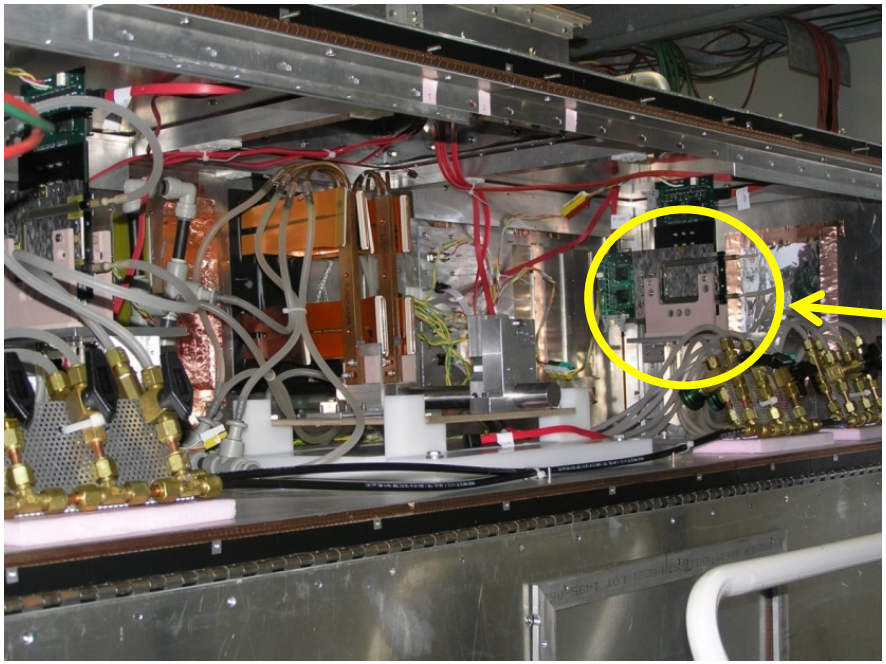
4 station MWPC spectrometer

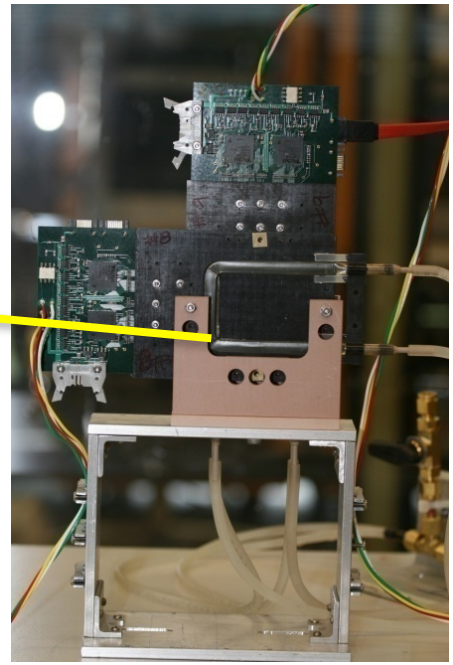


Two motion tables

Two Pixel Tracker Telescopes in MTest

- PHENIX Pixel Telescope

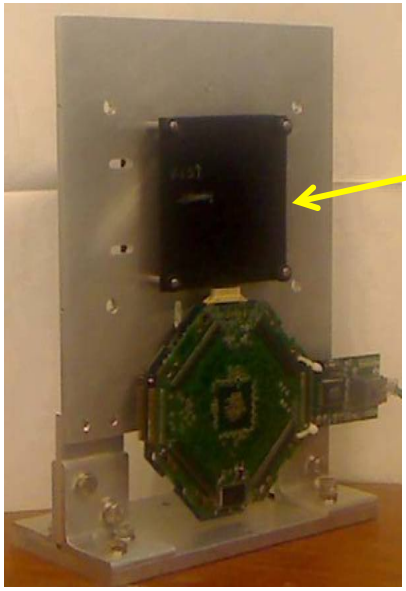


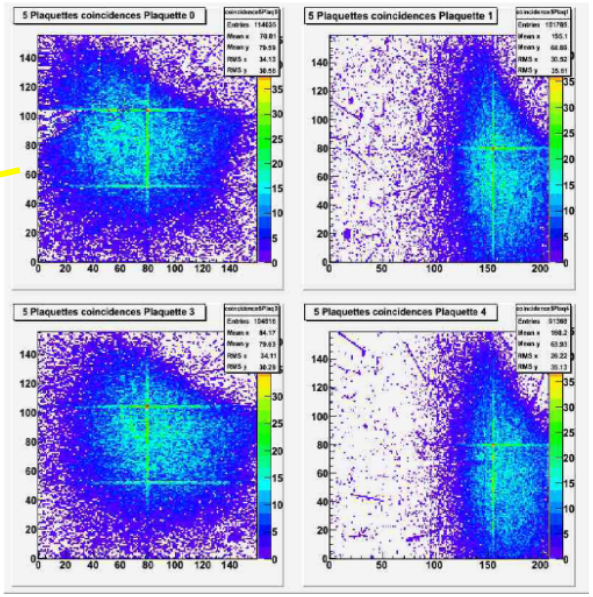


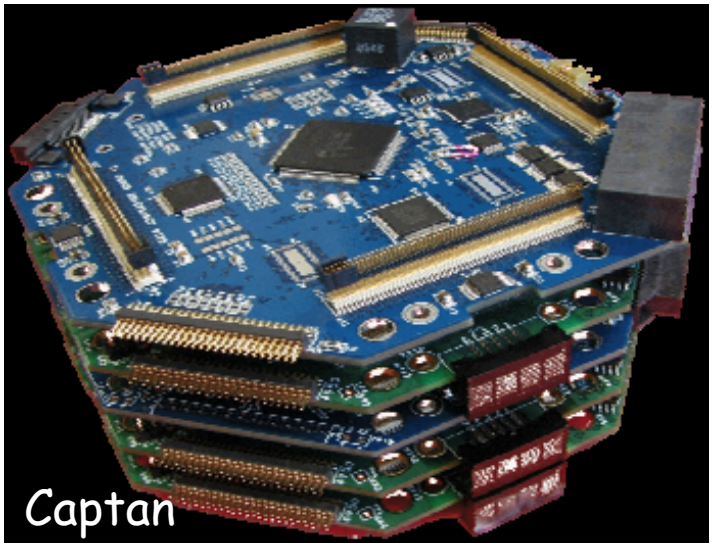
- Sensors are spares from PHENIX
- Read out with FPIX chip from bTeV
- Pixel size is 50 x 400 μm2
- Pointing resolution for DUT is <10 μm
- Total active area per X-Y station is 6x6 cm2
- Currently two stations

CMS Sensor Pixel Telescope

- Employs B-grade CMS pixel sensors
  - Fully functional at low intensity.
- Overlap area is 2x2 cm^2
- 4 stations of 100x150 μm^2 pixels gives <6 μm resolution



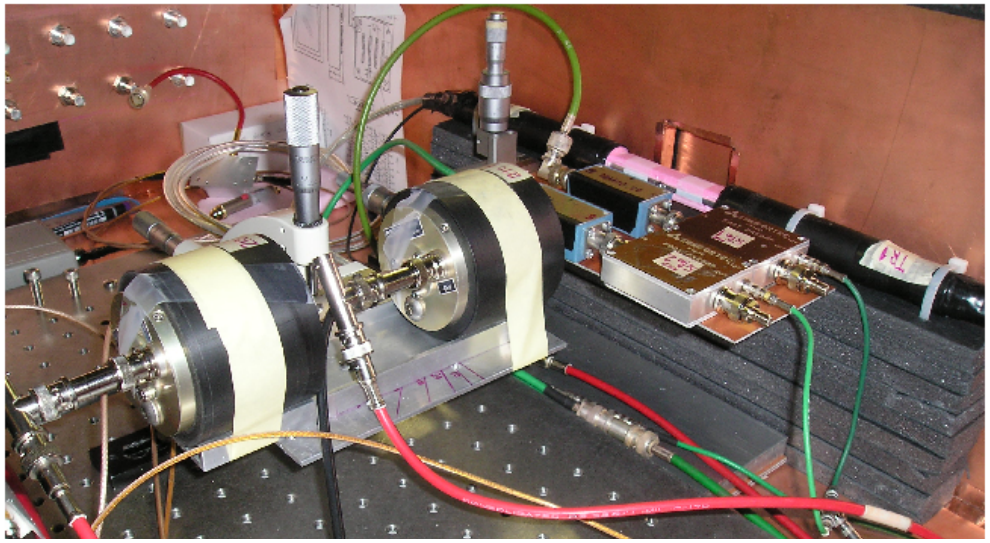




- Vertically integrated DAQ system ("CAPTAN")
- Node processing boards and data conversion boards.
- Daisy chain connectivity for output
- Multi-threaded application software running on Windows

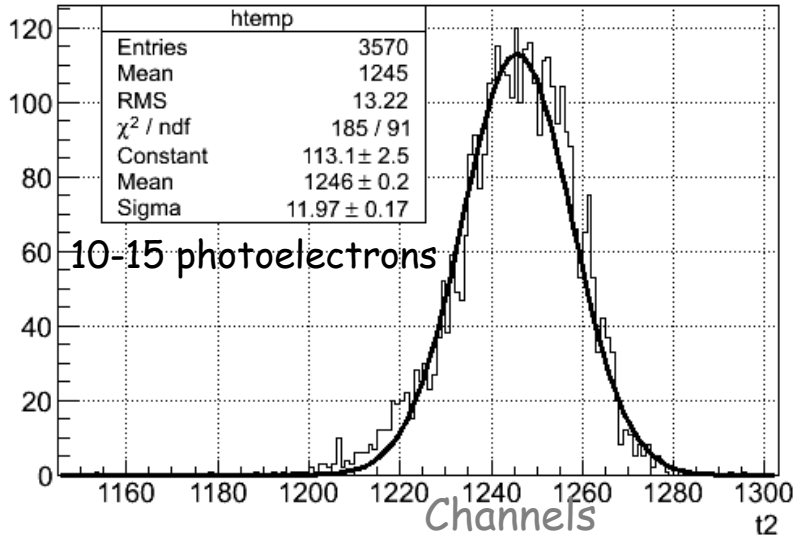
Fast Timing Detectors at MTest

- Use Photek 210 MCP (10 mm area) and Photek 240 MCP (40 mm)
- Several different configurations tested in last run
- In-line configuration gives 6 ps resolution with the Photek 240 device
- Configuration with quartz bars at Cerenkov angle minimizes material at first measurement position

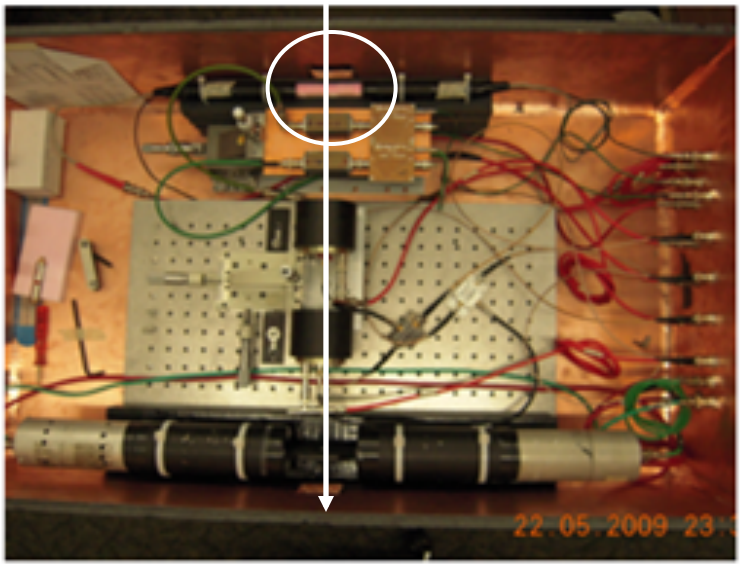


Silicon Photomultiplier Tests

- Determination of timing resolution with Silicon Photomultipliers (SiPM) and quartz bars
  - Eight Hamamatsu SiPMs, 3mm x 3mm
  - In beam with quartz Cherenkov radiators
    - several thicknesses (4 – 12mm), mirrored and not mirrored.
- Under best conditions: σ(t) ~ 33 – 37 ps

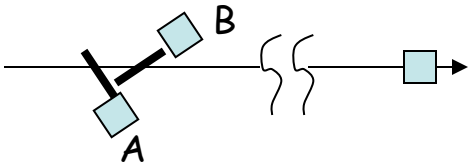


Pulse height slewing correction applied



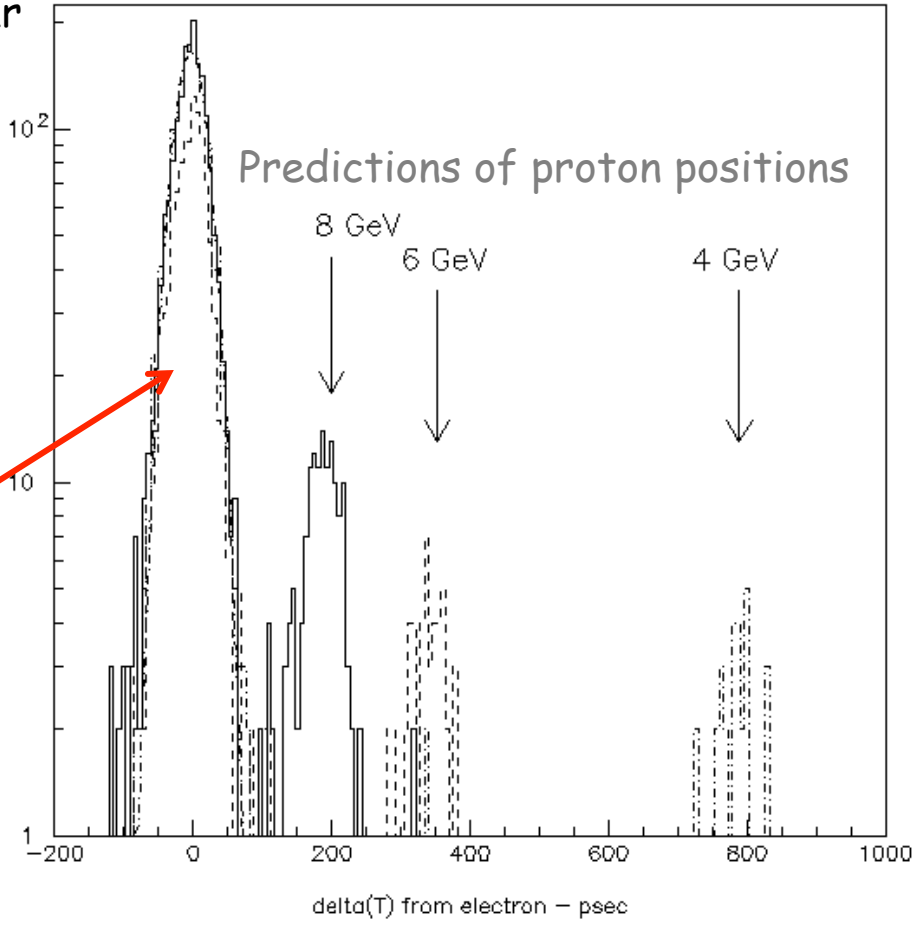
Extreme Time-of-Flight System

- Deployment of Time-Of-Flight (TOF) system
  - Start signal = double quartz bar
  - Stop signal = Photek 240
  - Start-stop distance = 8.7 m

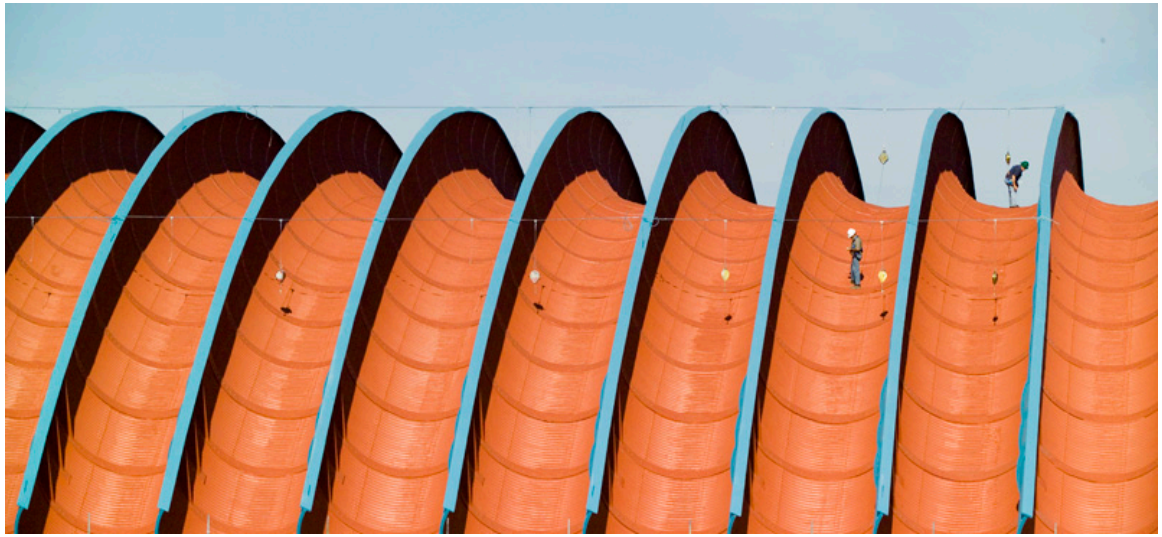


- Using the average times of A and B, a 24 ps resolution obtained for positrons

- System allows for tagging and momentum measurement of protons up to energies of ~10 GeV



USER SCHEDULE



A World-Class Program

- The Fermilab Mtest facility is a heavily used user facility
  - Strong demand for this infrastructure

Meson Test Beam Facility

List of Test Beam Memoranda of Understanding (MOU):

(In Meson Test Beam Facility, unless noted otherwise)

T994: JASMINE Radiation Measurements Under review

T992: Radiation hard sensors for the SLHC Under review

T991: Chameleon Afterglow Search Under review (Magnet Test Facility)

T988: AIRFLY - Air fluorescence measurements Taking data

T987: DARK MATTER IN CCD's Taking data (MINOS tunnel)

T984: PHENIX VTX Taking data

T979: Ultra-fast timing Taking data

T978: CALICE Experiment Taking data

T977: MINERVA Experiment Installing

T976: CsI Timing Experiment Experiment completed

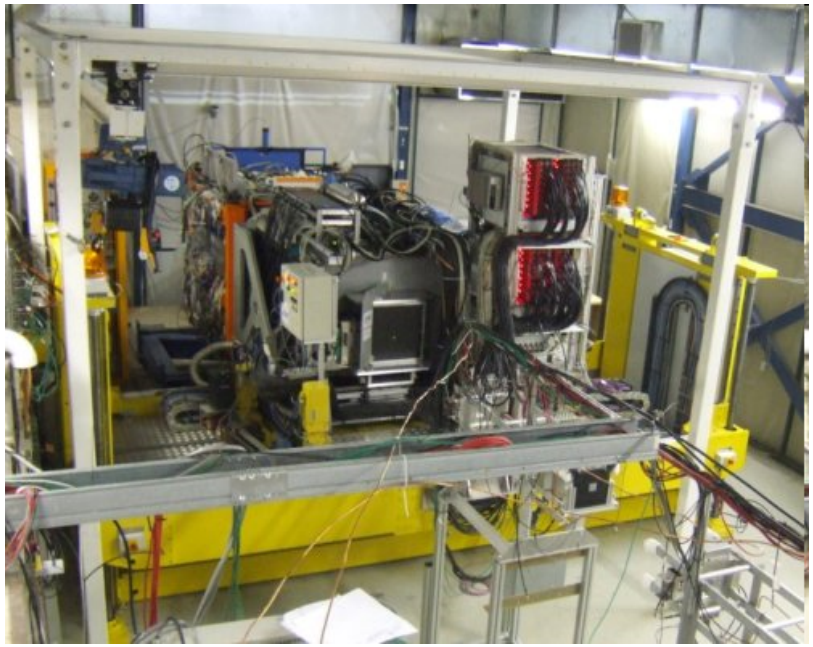
Affiliations of Test Beam Users, According to their MOU

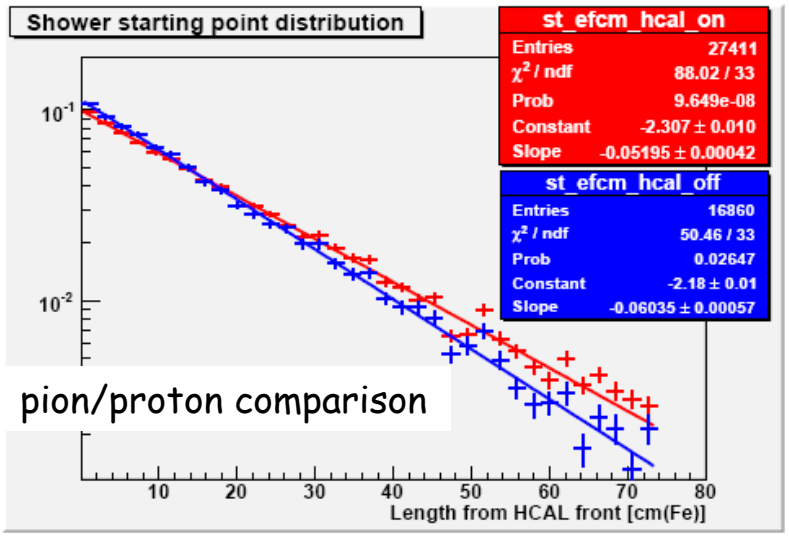
Year	Experiments	Institutions	People	Countries
2009	7	49	147	14
2008	5	42	112	13
2007	10	28	102	8
2006	5	18	65	6

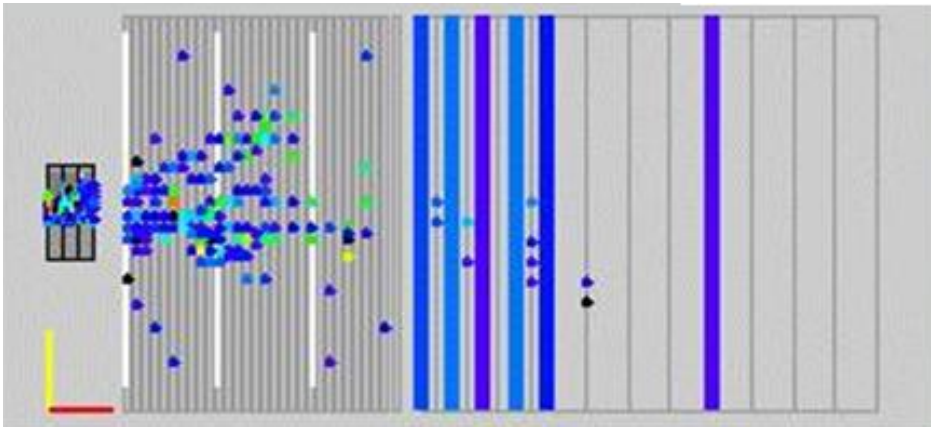
http://www-ppd.fnal.gov/mtbf-w/

CALICE User

- The CALICE experiment (T978) has been the most comprehensive detector system installed at MTest to date
- Results of their tests are being published (archiv: 1003.2662)



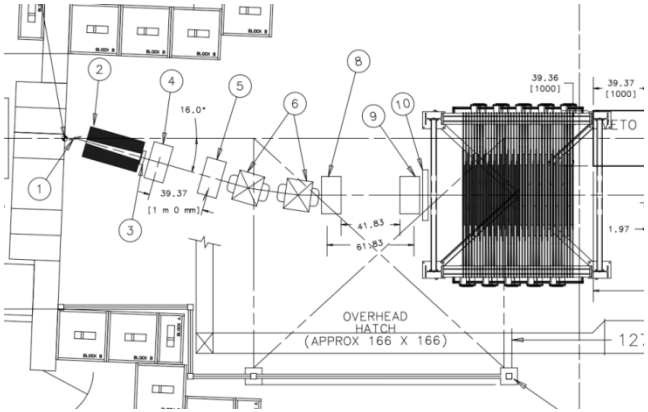


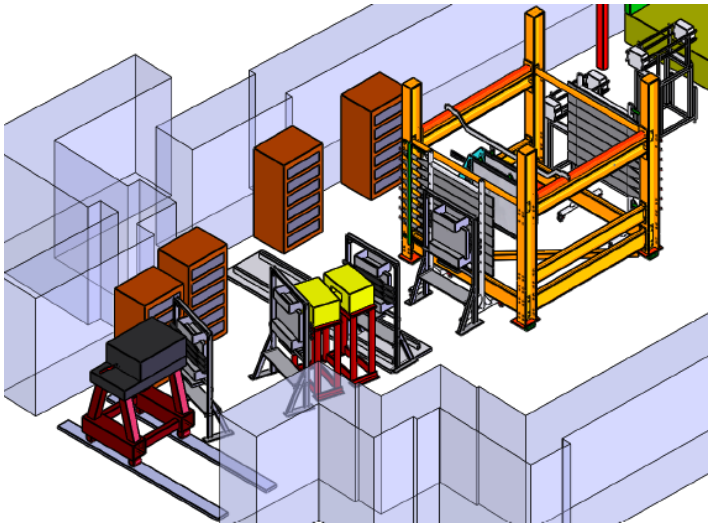


- We always welcome feedback on how to improve our facilities

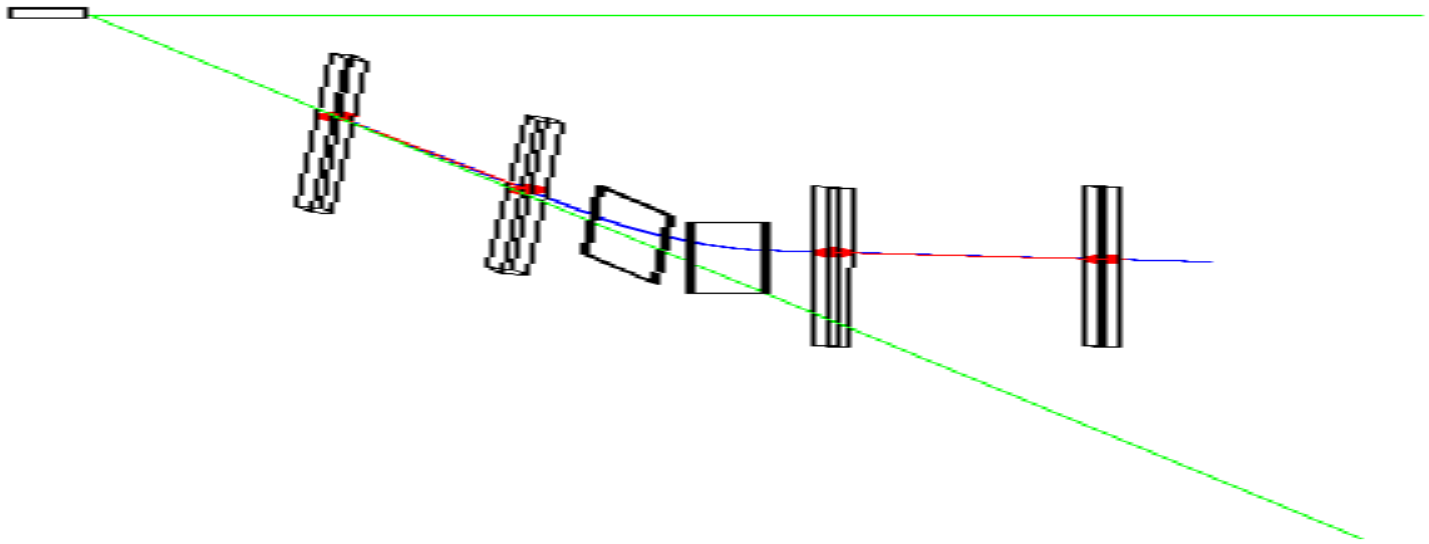
Tertiary 300 MeV/c Beamline

- The MINERVA experiment requested space to create a new tertiary beamline that could deliver pions down to 300 MeV/c momentum
- Full tracking and TOF will allow for momentum measurement and particle i.d.
- Target station rolls away for other users.
- The full spectrometer has been tested in November, 2009 and full detector test in April, 2010



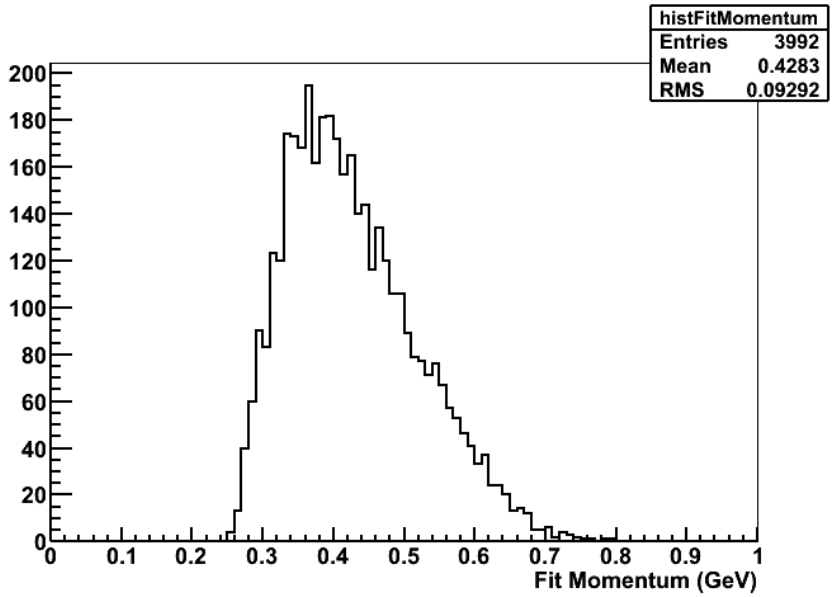


Event Display from Tertiary Beamline

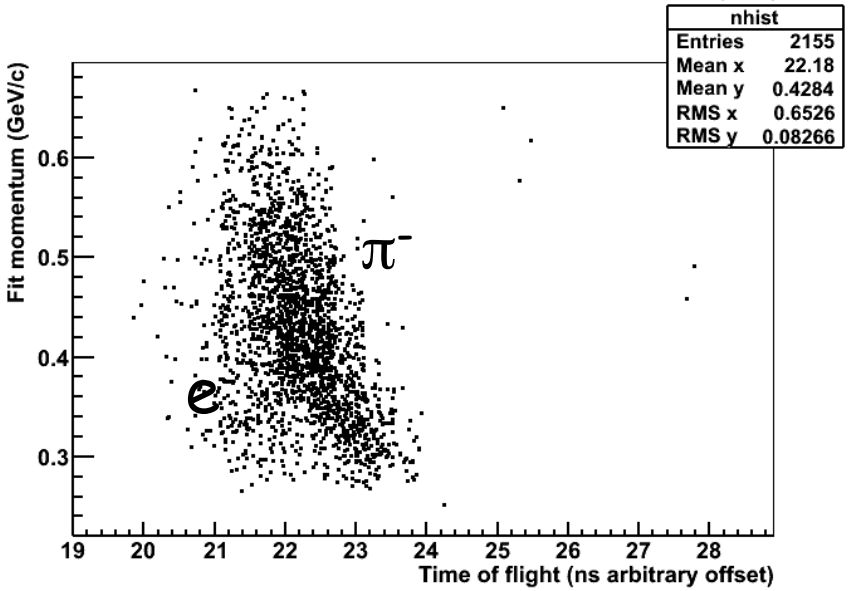


Preliminary Results From Tertiary Beamline

- Very preliminary results from engineering runs in November indicate that the momentum spectrum is as expected.



- The resolution of the TOF system to be improved, but discrimination between pions and electrons already apparent at low momenta



Schedule

- Currently, the schedule calls for the whole complex to be down most of 2012

Draft 2010-13 Fermilab Accelerator Experiments' Run Schedule

Typically Revised Annually - This Version from October, 2009

Calendar Year		2010	2011	2012	2013
Tevatron Collider		CDF & DZero	CDF & DZero	OPEN	OPEN
Neutrino Program	B	MiniBooNE	MiniBooNE		OPEN
		OPEN	OPEN		MicroBooNE
	MI	MINOS	MINOS		OPEN
		MINERvA	MINERvA		MINERvA
		ArgoNeuT			
			NOvA		NOvA
SY 120	MT	Test Beam	Test Beam		Test Beam
	MC	OPEN	OPEN		OPEN
	NM4	E-906/Drell-Yan	E-906/Drell-Yan		E-906/Drell-Yan

This draft schedule is meant to show the general outline of the Fermilab accelerator experiments schedule, including unscheduled periods.

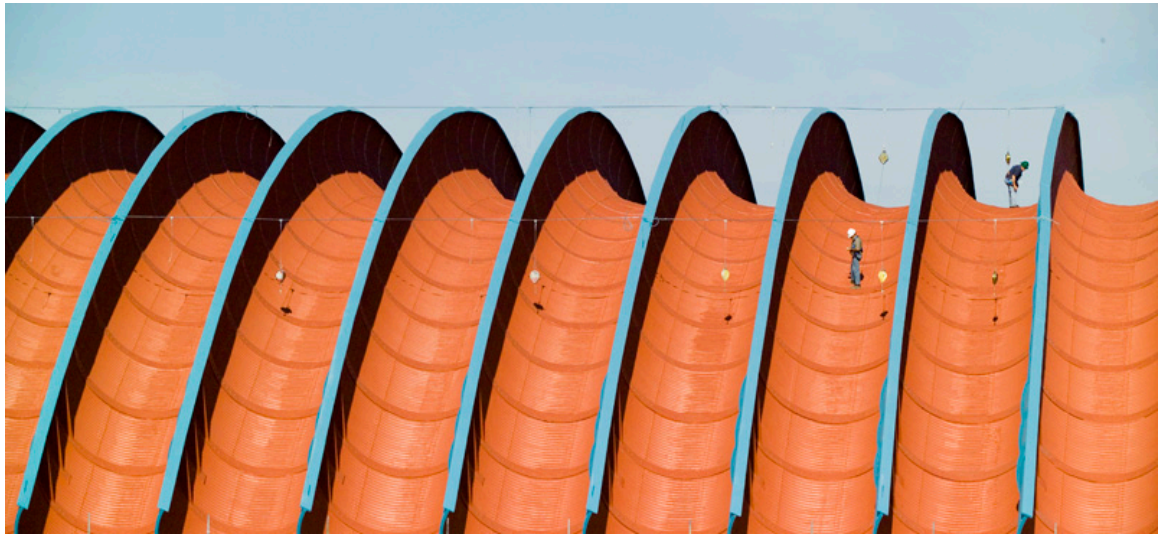
Major components of the schedule include shutdowns:
In Calendar 2010, a 4-6 week shutdown for maintenance is shown.
In Calendar 2011, no shutdown for maintenance is shown.
A 2012-3 11-month shutdown is shown to upgrade the proton source and change the NuMI beam to the Medium Energy (ME) config.

RUN/DATA
STARTUP/COMMISSIONING
INSTALLATION
M&D (SHUTDOWN)

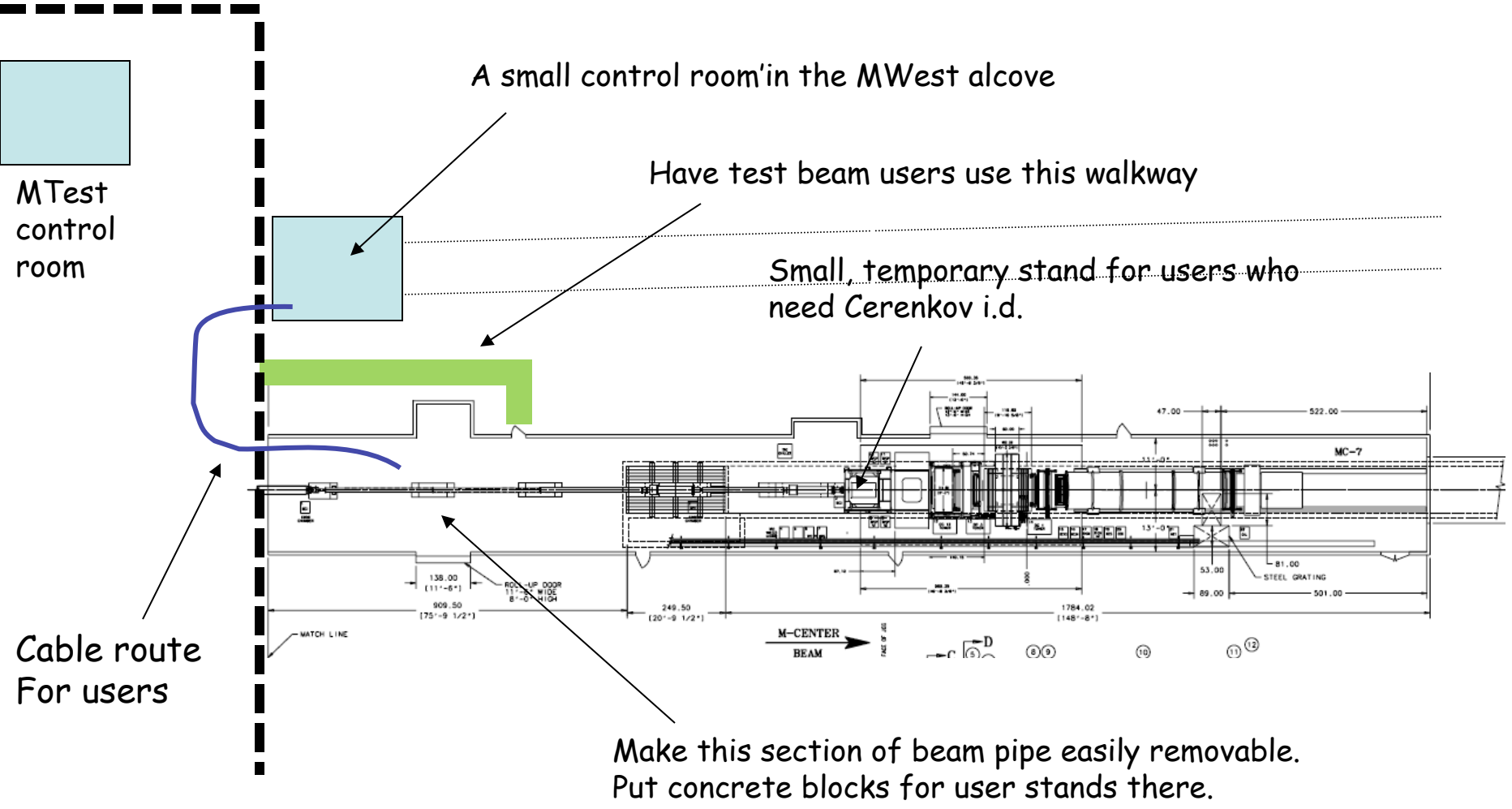
19-Oct-09

- 11 month "NOvA" shutdown beginning March 1, 2012, for the installation of equipment to allow to get to 700 KW in the NuMIbeam line.

UGRADES PROPOSED



Proposal for a Small Test Beam Area in MCenter



An Irradiation Facility

- The JASMIN experiment (T993) has irradiated thin foils as part of their shielding and neutron production program.
- They used the M01 area, where the split between MCenter and MTest takes place.
- A small area, with SEM measurement of beam flux, can support future irradiation experiments for thin detectors
- Full intensity is 2 x 10^{11} protons per minute, in about 1 cm^2

Summary

- The MTest facility continues to support a large variety of advanced detector tests
- The beamline is quite versatile, delivering secondary beams from 1 to 64 GeV, and a primary beam of 120 GeV protons. Electrons are dominant at low energies. Wide-band muons can be selected with a beam stop.
- A new tertiary beam has been developed, which delivers tagged pions down to 300 MeV/c.
- Two new pixel telescope systems have been created for the facility, with resolutions of 5-10 microns.
- A new TOF system has been tested, with a resolution of 24 psec. Individual measurements on a 4 cm MCP/PMT show 6 psec resolution
- A proposal has been approved at Fermilab to support test beam activities in the MCenter beamline.
- Can support irradiation tests for thin detectors
- We welcome user feedback