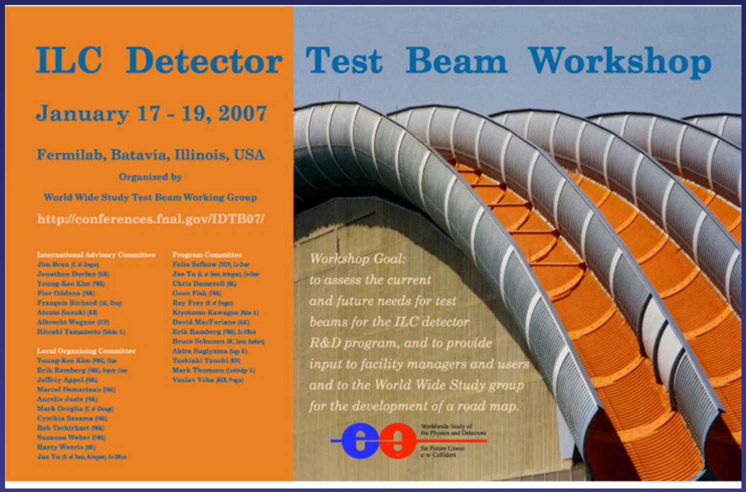
Review
of
World Wide Test Beam Facilities

Erik Ramberg

Fermilab

October 23, 2007

ILC Detector Test Beam Workshop - January 17-19, 2007 at Fermilab



- A list of the speakers who discussed their test beam facilities.
  - Fermilab: Erik Ramberg
  - SLAC: Carsten Hast
  - KEK: Osamu Tajima
  - LBL: Devis Contarato
  - IHEP, Beijing: Li Jia-Cai
  - IHEP, Protvino: Alexander Kozelov
  - DESY: Ingrid-Maria Gregor
  - CERN: Christoph Rembser
  - EUDET: Felix Sefkow
- Marcel Demarteau (Fermilab) gave an excellent summary of these talks, upon which this talk is based.

Roadmap document for ILC test beams

KEK Report 2007 – 3
FERMILAB-TM-2392-AD-DO-E

Roadmap for ILC Detector R&D Test Beams

World Wide ILC Detector R&D Community

October 18, 2007

Abstract

This document provides a roadmap for ILC Detector test beam needs in the next 3 – 5 years. In this period, detector Letters of Intent are expected by fall 2008, the ILC Engineering Design Report to be submitted in early 2010 (with detector Technical Design Reports soon thereafter) and funding approval to construct the ILC and its detectors in 2012. ILC Detectors are required to have unprecedented precision to be able to elucidate new physics discoveries at TeV energies from the LHC and ILC machines, and to fully exploit experimental investigation at the electroweak unification energy scale. Achieving this requires significant investment for detector test beam activities to complete the R&D needed, to test prototypes and (later) to qualify final detector system designs, including integrated system tests. This roadmap document describes the need for a significant increase in resources for ILC test beam activities. It should be used by test beam facility managers and the worldwide ILC leadership to assure that the necessary resources and facilities are made available to meet the needs in time.

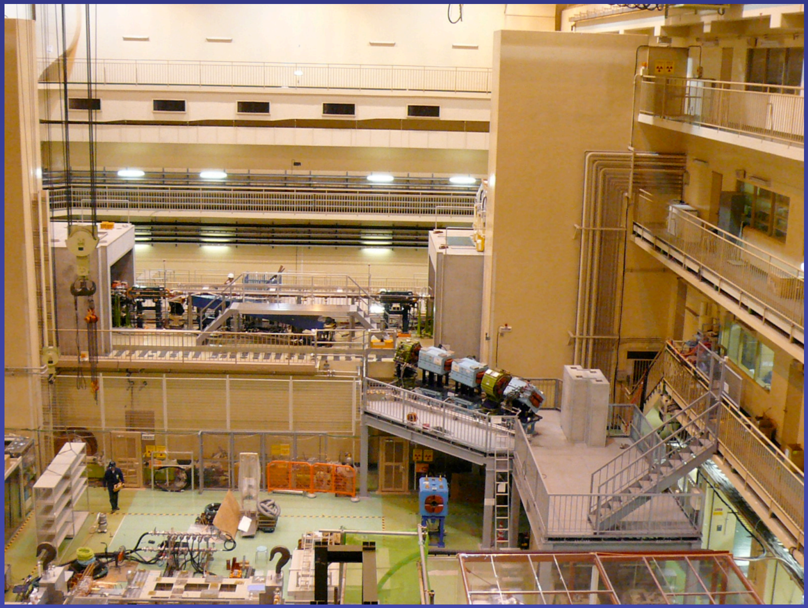
ILC Challenges

- Many detector technologies not established
  - Vertex detector technologies: SOI, MAPS, 3D, CPCCD, FPCCD, DEPFET, …
  - EM Calorimetry: Silicon-Tungsten based fine pixels
  - HAD Calorimetry: analogue/digital with RPC, GEM, MicroMegas, Scintillator readout
  - Forward Calorimetry: BeamCal and LumCal
  - TPC: Gas amplification systems, GEM, Micromegas and readout
  - Muon Detection: MPPC readout
- Simulation
  - Development of PFA algorithms and modeling of shower simulations in Monte Carlos and validation of Particle Flow algorithms
- ILC Parameters
  - Magnetic fields up to 5 Tesla
  - Power consumption requirements / Power pulsing techniques
  - EMI, Material Budget, Integrated Tracking

- Many of these issues can only be addressed through beam tests
- This is a compilation of test beam facilities with a look towards requests from the user community for further enhancements

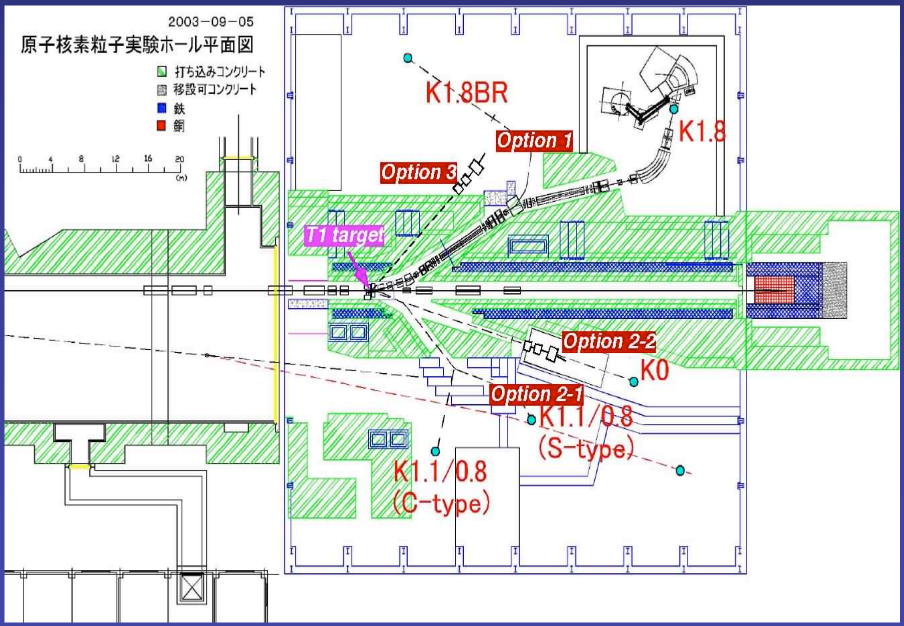
KEK Test Beam Facility

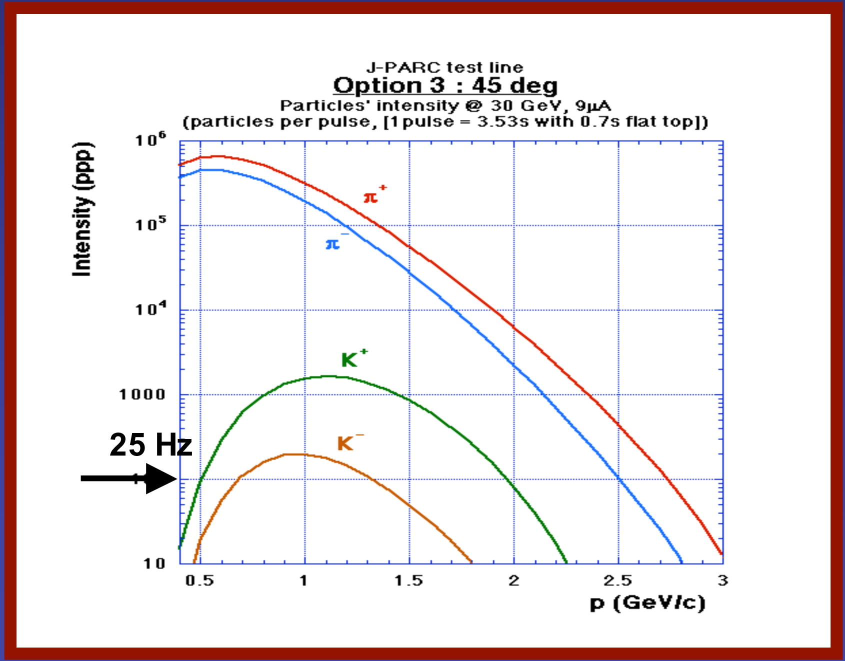
- Osamu Tajimi reports that “Fuji Test Beam Line” has just become operational - Oct. 12, 2007!
  - Bremsstrahlung photons from 8 GeV e- beam scattering on residual-gas: ~1.6×10^5 photons/sec
  - Photons are converted in Tungsten converter, 3mm thick, ~$1X_0$
  - Converted particles are extracted to experimental area outside of KEKB tunnel
- Expected performance
  - ~ 100 electrons/sec (continuously)
  - momentum range: 0.5 - 3.4 GeV/c
  - Momentum resolution ~ 0.4%
  - Spot size +/- 1cm
- Already booked through 2007
  - Web site: http://fujibeam.kek.jp
  - Contact: kawasaki@hep.sc.niigata-u.ac.jp



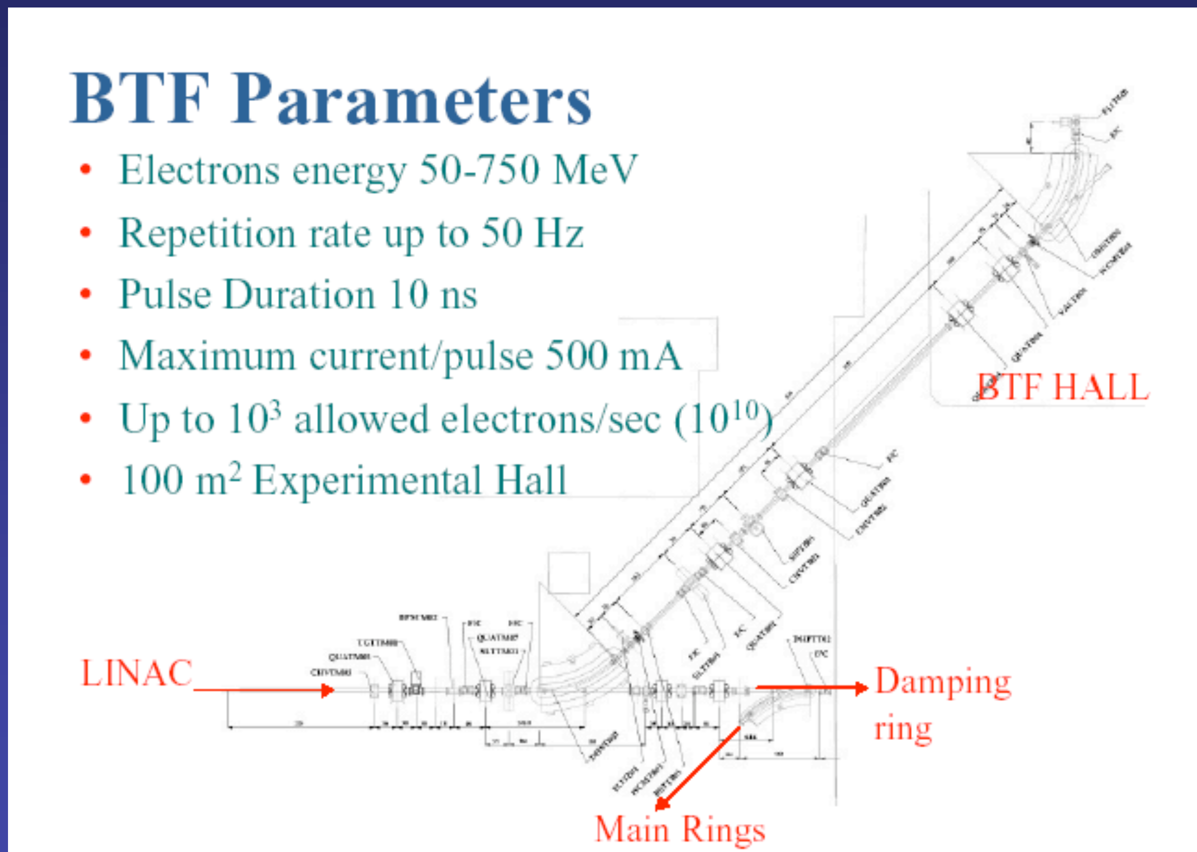
J-PARC Test Beam Facility

- “Option 3” aimed at providing a test beam facility at the 50 GeV PS at J-PARC
- Currently no concrete plans
- Earliest possible availability is 2010

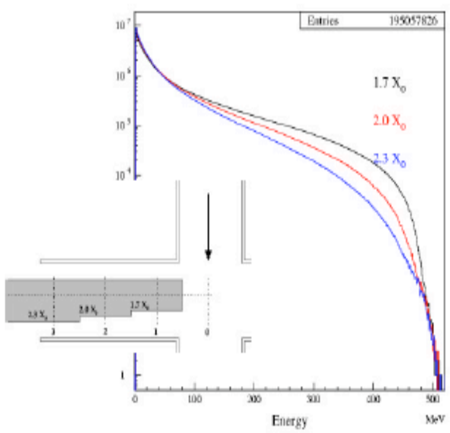




Frascati Test Beam Facility

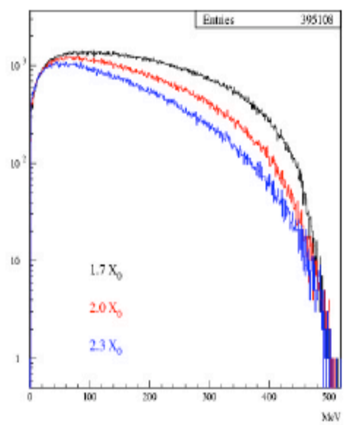


Frascati - Energy and Multiplicity



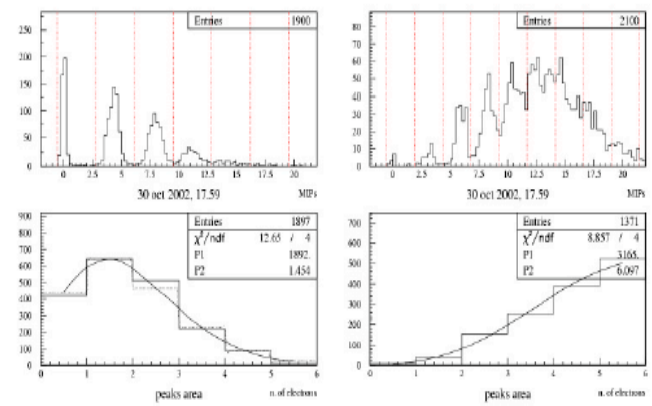
Electron energy distribution
Outgoing TGMTT001

Electron energy distribution in the chamber acceptance before the bend DHSTB001



Energy selector system and transport optics can be modulated in order to obtain the desired electron number distribution at different energies

The efficiency depends on energy and on the transport optics (the quadrupoles)

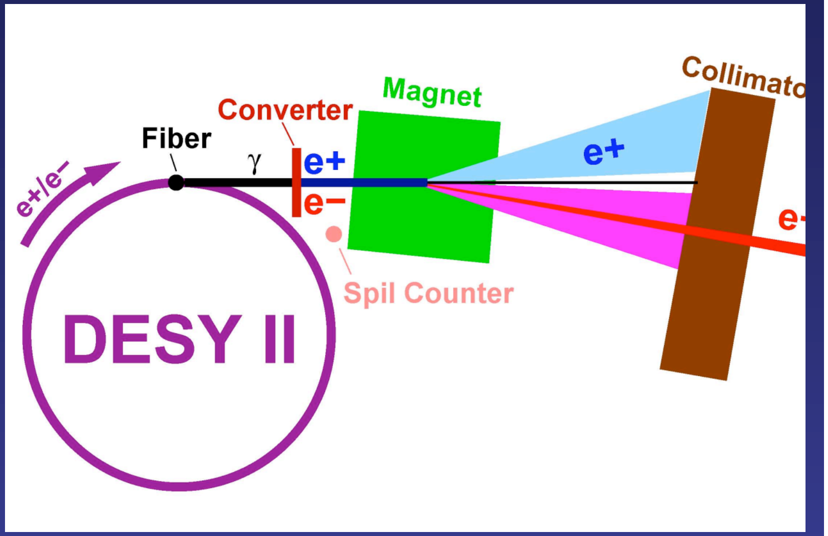


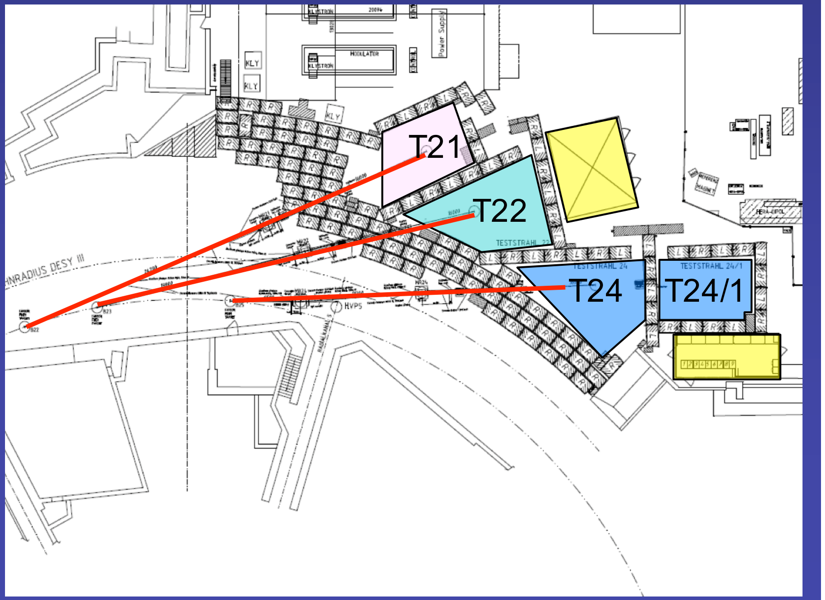
DESY Test Beam Facility

- DESY provides three test beam lines
  - No beam optics
    - Only momentum selection via magnet
  - 1-6 GeV/c electrons
  - Repetition rate 12.5 Hz
  - Bunch length 30 ps
  - Two conversion targets (Cu, Al)

Rates	Target	
Energy	3mm Cu	1mm Cu
1 GeV	~330 Hz	~ 220Hz
2 GeV	~500 Hz	~330 Hz
3 GeV	~1000 Hz	~660 Hz
5 GeV	~500 Hz	~330 Hz
6 GeV	~250 Hz	~160 Hz

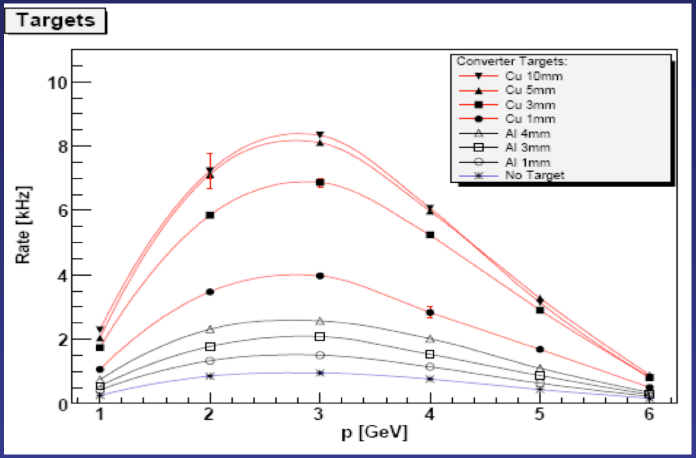
- Availability: down for 1st half of 2008
- User brings own DAQ
- External beam diagnostics: none



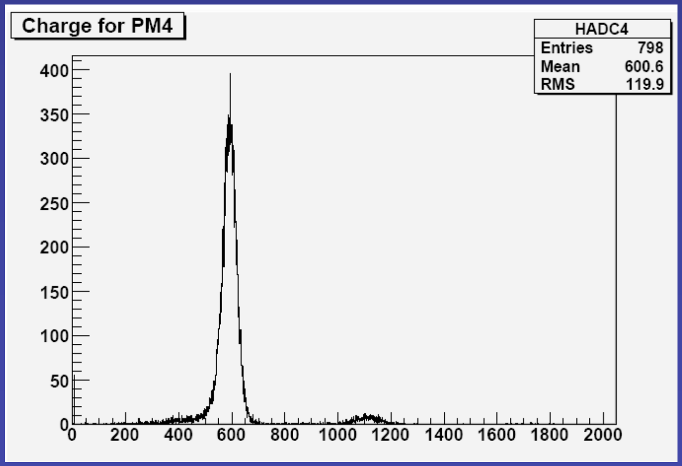


DESY - Rates and energies

- The rates are influenced by many parameters.
- Ideally, the maximum rate around 2 kHz (3 GeV, 3mm Cu convert, Collimator ca.
  5mm x 5mm, DESY II maximum energy at 7 GeV, no beam extraction, no DESY III ramp).
- Few hundred Hz are realistic

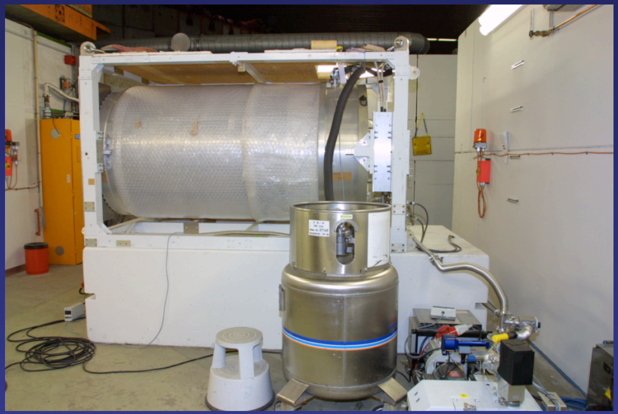


Rate vs. momentum measured at TB22



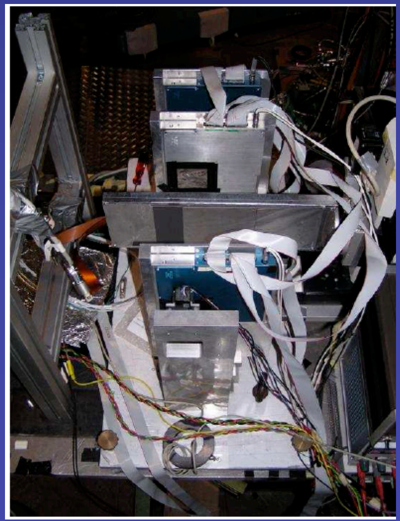
Energy distribution of 3GeV electrons in beam line 22. DESY primary energy set to 7GeV. Second small peak reflects events with two hits.

DESY - Plans



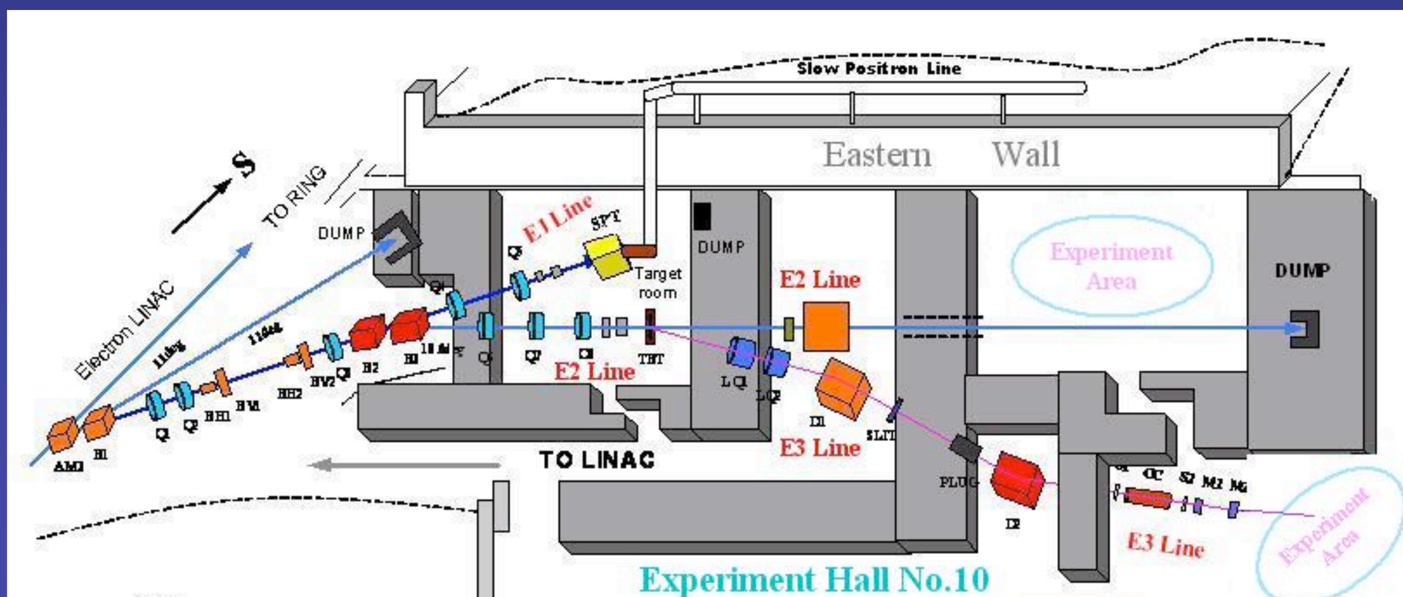
- Area T24 will be dedicated to EUDET facility
- Improvements to facility:
  - First half of 2008: long shutdown
    - New Vacuum System
    - New Control System
- Availability of test beam area
  - Available on continuous basis to users
  - Currently no conflicts between users foreseen
  - Impact of PETRA3 on test beam under evaluation

ZEUS silicon strip telescope available for users



IHEP Beijing Test Beam Facility

- IHEP-Beijing provides three test beam lines
  - Two primary beam lines E1 and E2
    - 1.1-1.5 GeV electrons/positrons
    - Repetition rate 25 Hz
    - Bunch length 1.2 ns
  - Secondary beam line E3
    - 0.4-1.2 GeV/c, $e^{\pm}$, $p^{\pm}$, p
    - Repetition rate 1.5 Hz (single particle)
  - External beam diagnostics
    - TOF system
    - Threshold Č-counter
    - MWPC with 50% dE/dx resolution



IHEP Beijing - Plans

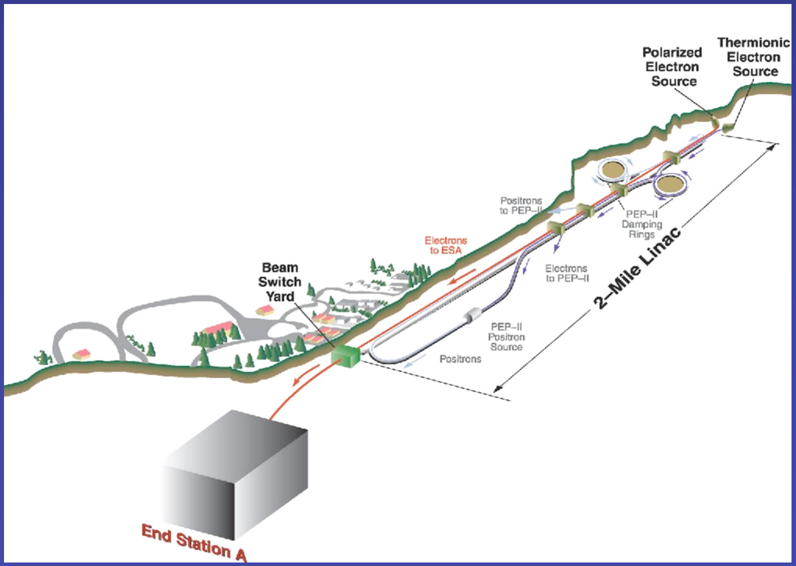
- Alteration of the E2 Line to extend vacuum pipe to reduce particle multiplicity
- A New E3 Line in Hall 10
  - Enhancement of pion's intensity by shortening the decay length from 23m to 15m long
  - New optics for the new beam lines
    - Two dipole and two quadrupole magnets
  - New hodoscopes H1-H3, three triggers S1-S3 and a new Cherenkov counter
    - Improved particle track reconstruction
    - Improved momentum resolution
    - Better particle id.
- Availability of test beam area
  - In 2007 dedicated to calibration of Yangbajing Airshower Core detectors and an experiment of the Electron Scattering.
  - A six month shut down period follows for upgrade
  - Available on continuous basis to users starting March '08

SLAC Test Beam Facility

- SLAC provides one beam line to End Station A (ESA)
  - 28.5 GeV primary electron beam, 3.5 x 10^{10} e^-/pulse at 10 Hz
  - Secondary beam accepted into A-line at 0.5 deg production angle
    - 1.0 - 20 GeV
    - Momentum analyzed to <1%
    - PID through time-of-flight and threshold Cherenkov counters
      - At 13 GeV: 50% p^+, 50% e^+, 0.4% protons, <1% K^+

- Many machine and MDI related tests being carried out at ESA
  - Collimator design, wakefields
  - Energy spectrometer, BPM's
  - Bunch length diagnostics, …

- Mike Woods talk at ALCPG meeting



SLAC - Schedule of tests

2006 Runs:

i. January 5-9 commissioning run
ii. April 24 – May 8, Run 1
iii. July 7-19, Run 2

2007 Runs:

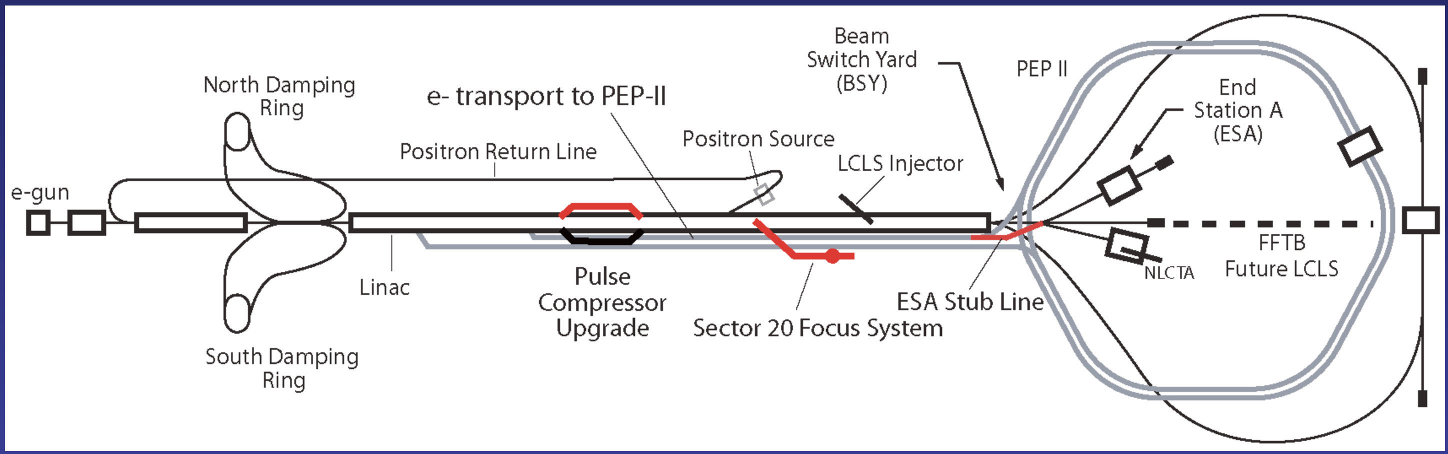
i. March 7-26, Run 3
ii. July 5-8, T490 w/ LCLS beam
iii. July 9-25, Run 4

2008: planning for two runs in late April and August

Beyond 2008: FACET proposal to DOE now being considered. Primary beams for IP Beam Instrumentation and MDI, + secondary beams for Detector Tests. Facility for 2010-2015 time frame.

SLAC - Test Beams beyond FY08

SABER proposal has been revised, renamed to FACET and submitted to DOE:
***F**acilities for **AC**celerator Science and **E**xperimental **T**est Beams at SLAC*

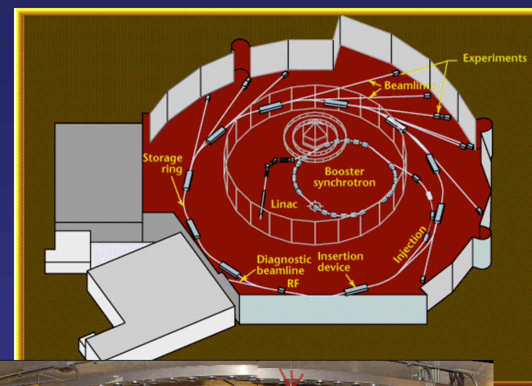


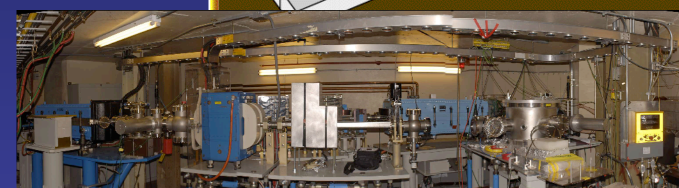
2 Experimental Regions:

1. 24 GeV beam to new Sector 20 Experimental Region for advanced accelerator physics: plasma and dielectric wakefield acceleration + other experiments requiring high energy densities
2. General purpose test beam facility in ESA: primary beams for accelerator research, secondary beams for detector R&D, beam dump experiments for radiation physics studies. Initially limited to 12-GeV electron beam, with later upgrade to 24 GeV. Secondary hadron beam would have 60 Hz pulses, with ~10 pions/pulse

LBNL Test Beam Facility

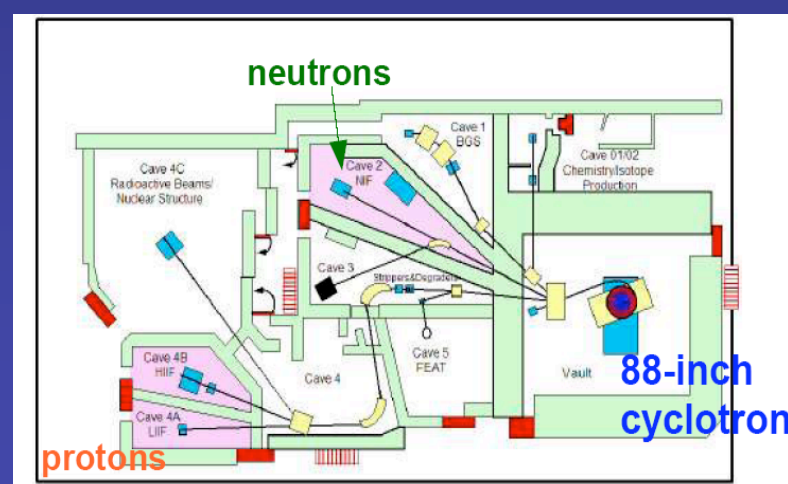
- Advanced Light source (ALS)
  - Beam test line (BTS) extracted from injection booster
  - e^- at 1.5 GeV at 1 Hz rep rate and variable intensity
  - 4 plane pixel telescope w/ 10 m resolution





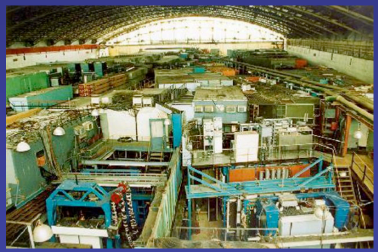
- Laser Optics and Accelerator Systems Integrated Studies (LOASIS)
  - 1 GeV e^-, with possibility for tuning beam energy from ~50 MeV to 1 GeV
  - Plans for upgrade to 10 GeV

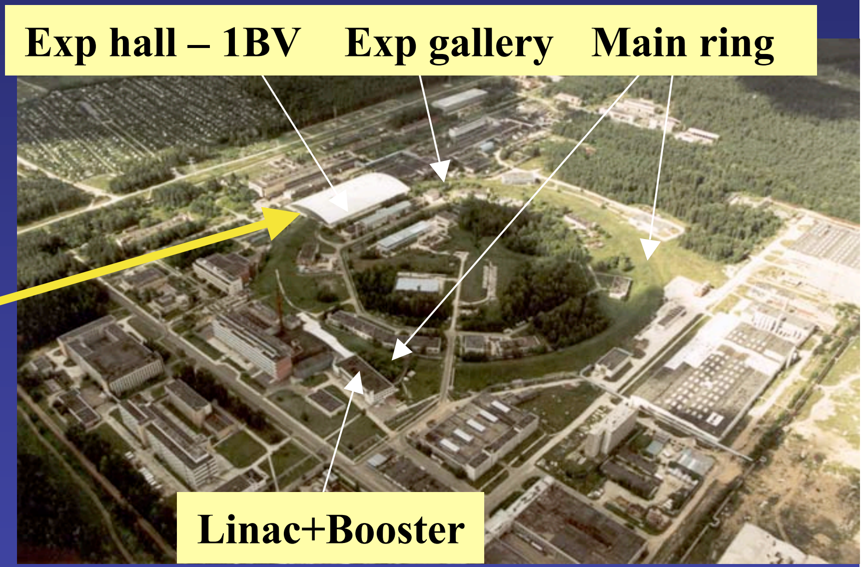
- 88-inch cyclotron
  - Dedicated beam-lines for proton (heavy ion) and neutron irradiations
  - E_p up to 55 MeV, E_n < 30 MeV
  - Tunable flux
    - typical ~$1\times10^8/cm^2/s$



IHEP Protvino Test Beam Facility

- At least four beam lines available
- Beam parameters:
  - cycle time: 10 s
  - spill time: 1.8 s
  - intensity: ~ 10^7 particles/spill
  - number of bunches: 30
  - bunch length: 40 ns, spacing 160 ns
- High intensity and low intensity beams available





Beamlines	N2B	N4V	Soft Hadron	N22
Momentum Range	e: 1 - 45 GeV m 33 - 55 GeV h: 33 - 55 GeV	e: 3 - 15 GeV m 20 - 40 GeV h: 20 - 40 GeV	h: < 4 GeV	e: 7 - 40 GeV h: 1 - 70 GeV

IHEP Protvino - N2B Beam Line

Electron Beam				
Energy, GeV	Intensity in spill on 10^{12} pot	Content		
		e (%)	μ (%)	h (%)
1	$4\cdot10^2$	82	10	5
2	$1\cdot10^3$	77	15	8
5	$2\cdot10^3$	50	32	18
10	$5\cdot10^3$	34	35	30
27	$4\cdot10^4$	77	9	13
45	$2\cdot10^4$	91	4	5

Hadron Beam (33-55 GeV)	
Particle Type	Content
π^-	96.4 %
μ^-	1.0 %
k^-	2.3 %
p^-	0.3 %

- 70 GeV proton beam also available
- Wide array of beam diagnostics
- DAQ available

IHEP Protvino – N4V beamline for soft hadrons

Negative hadron - beam

Intensity for $\Delta p/p = \pm 3\%$

Scattering angle 25^0

$\Delta\phi = \pm 100$ mrad

$\Delta\theta = \pm 10$ mrad

Same place as for beam line N 4V

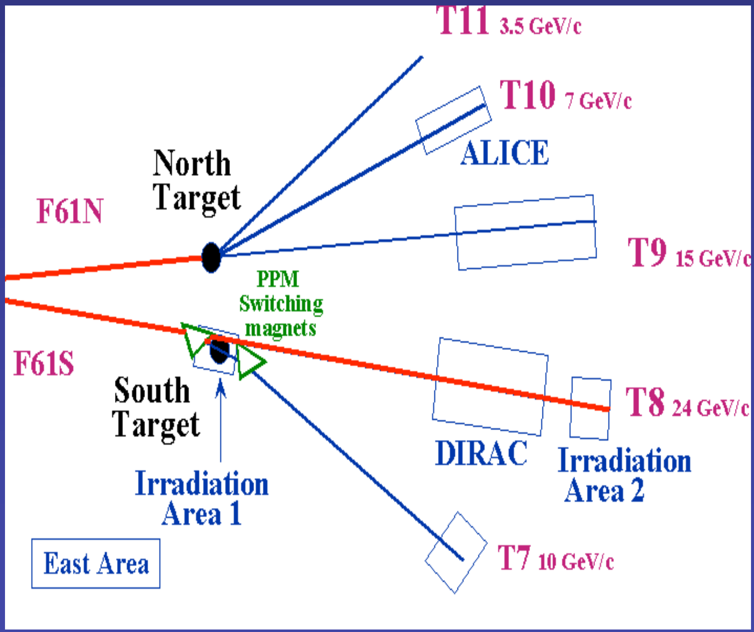
Energy, GeV	Intensity in spill at 10^{12} pot
1	$1.5 \cdot 10^6$
2	$2.4 \cdot 10^5$
3	$5.4 \cdot 10^4$
4	$1.2 \cdot 10^4$

CERN Test Beam Facilities

- Two areas at two machines, with four beam lines each: North area at the SPS and East area at the PS

- PS Area:

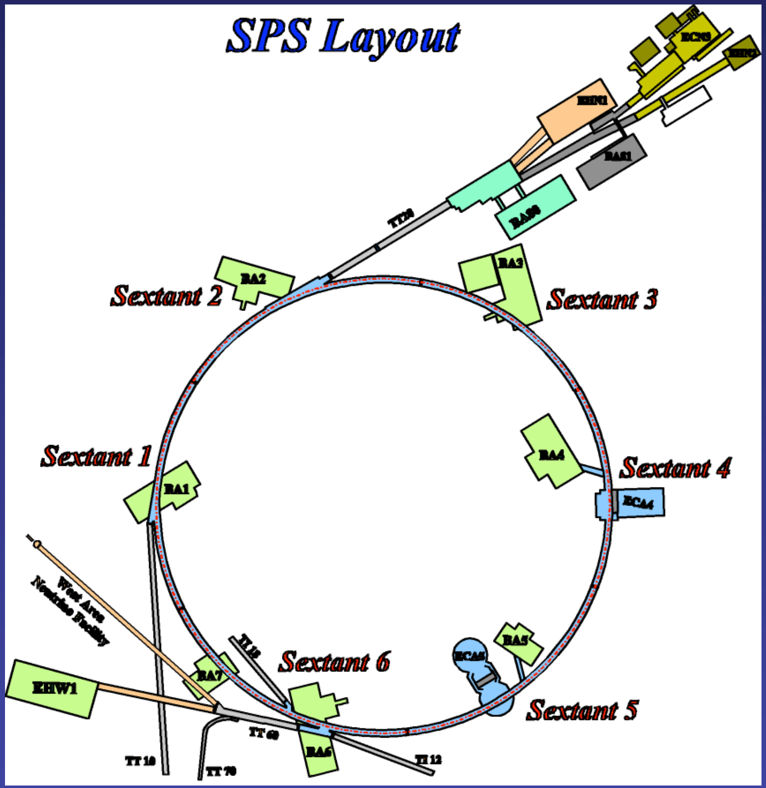
PS Beamlines	
Momentum Range	1 - 3.6 GeV (T11) 1 - 7 GeV (T10) 1 - 10 GeV (T7) 1 - 15 GeV (T9)
Spill Duration	400 ms
Duty Cycle	2 spills / 16.8 s
Particle Type	electrons hadrons muons
Intensity	1 - 2 10^6 part. /spill



CERN - SPS Facility

- SPS Area:

SPS Beamlines	
Momentum Range	10 - 400 GeV (H2) 10 - 400 GeV (H4) 10 - 400 GeV (H8) 10 - 205 GeV (H6)
Spill Duration	4.8 – 9.8 s
Duty Cycle	1 spill / 14 – 40 s
Particle Type	electrons hadrons muons
Intensity	~ 10^8 part./spill



- Beamline configurations
  - Beamlines share targets (H2/H4, H6/H8) and are thus coupled
  - Up to three user areas per beamline
  - H4 can be set up for very clean electron beam up to 300 GeV
  - H2 and H8 have low energy (2 - 10 GeV) tertiary beams

CERN - Plans

- What has happened in 2007:
  - PS test beams: May 2 - Nov 12 (28 weeks)
  - requested beam time (T7,T9-T11)
    - ~43% LHC & LHC upgrade
    - ~12% external users
  - SPS test beams: May 25 - Nov 12 (23.5 weeks)
  - requested beam time (H2-H8):
    - ~52% LHC & LHC upgrade
    - ~35% external users
- 2008:
  - Heavily dependent on LHC status and LHC beam request
  - Second highest priority is CNGS
  - 25 weeks is planned for (June – November)

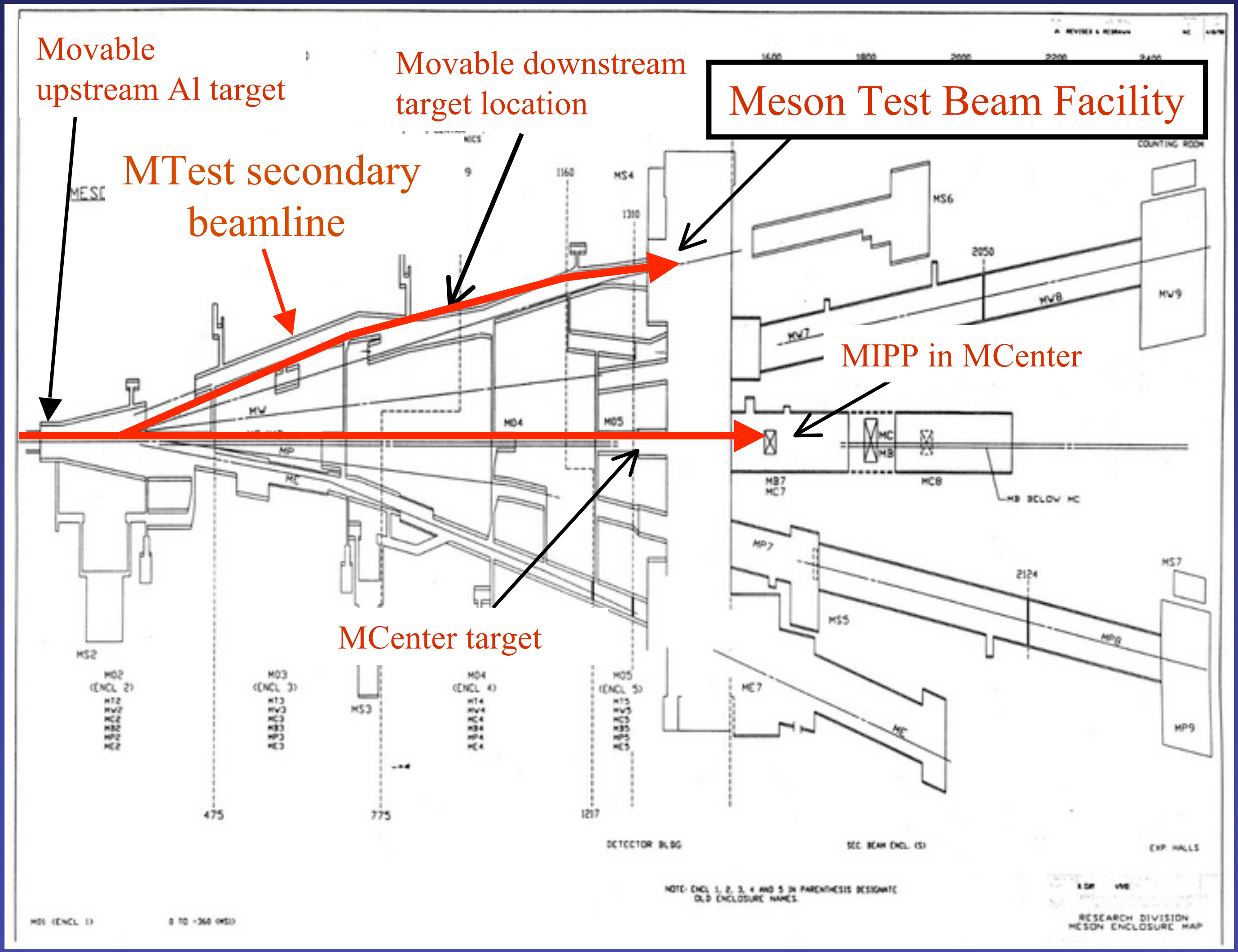
Fermilab Test Beam Facility

- Last year the Fermilab Meson Test Beam
  - Could not deliver a pion beam lower than 4 GeV
  - Electrons had a low flux because of significant material in the beam
- Motivated by the ILC community, the laboratory designed a new beamline that was completed early this year:
  - Moved entire beamline transversely
  - 13 magnets moved
  - 11 new beamline elements installed
  - Scattering material minimized
  - 2 target movers installed

Meson Test
Beam Facility

- Also motivated by the ILC community, revised the spill structure and restated the program impact
  - SY120 beam can impact the program at the 5% level following a flexible algorithm
  - Spill structures:
    - One 4 second spill every minute, for 12 hours a day
    - Two 1 second spills every minute, for 12 hours a day
- Accelerator Division is working now to investigate whether pulsed extraction can work with the Main Injector, with the possibility of simulating ILC beam structure.

Fermilab - Beam Delivery



Proton Mode: 120 GeV protons transmitted through upstream target

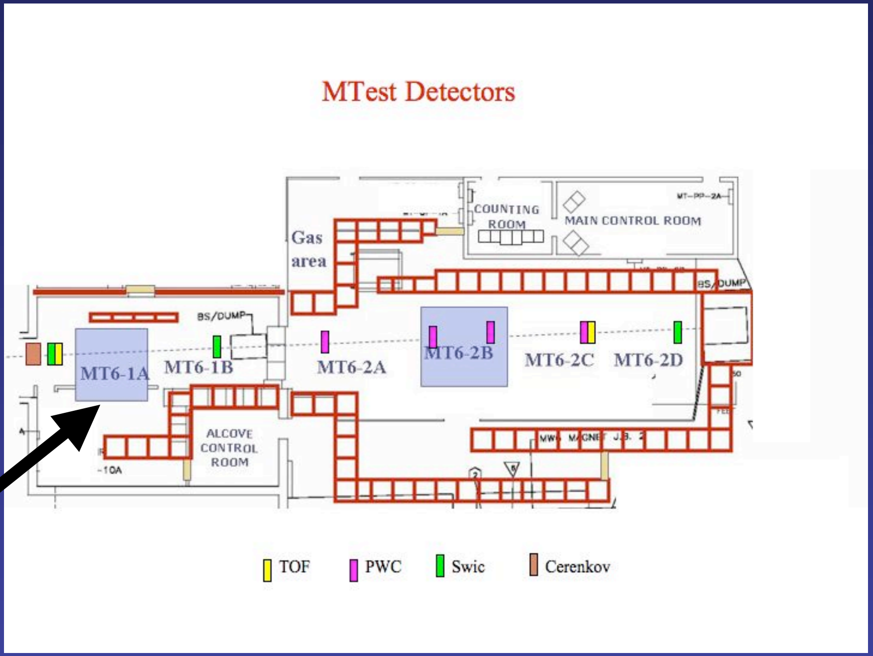
Pion Mode: 8-66 GeV beam tuned for secondaries from upstream target

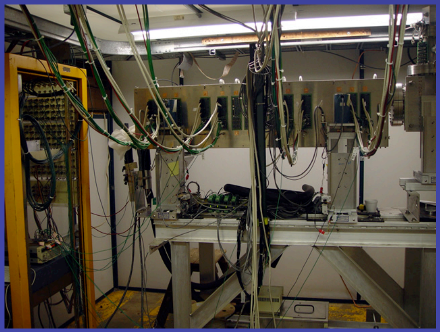
Low Energy Pion Mode: 1-32 GeV beam tuned for secondaries from downstream target

Fermilab - Beam Monitoring

An array of beam monitoring, including:

- Time-of-flight
- Differential and threshold Cerenkov
- 4 station MWPC
- Lead glass calorimeter:





Now working on production of pixel telescope in the upstream area of Mtest.

Sensors are from PHENIX and infrastructure is from BTeV/CMS. Resolution better than 20 μ

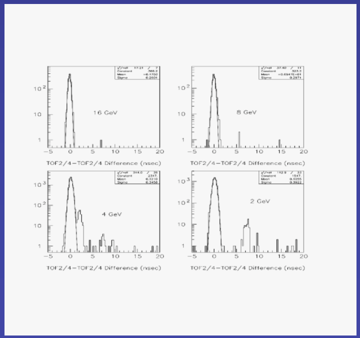
Complete by February, 2008

Fermilab - Rates and Content

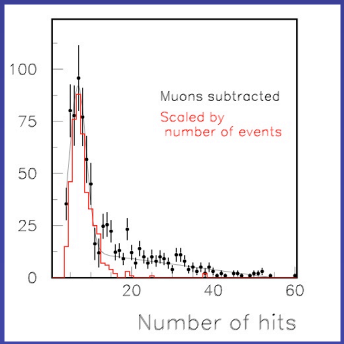
Nominal Rates* without lead converter

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	82%	18%
8	89,000	65,000	42%	58%
4	56,000	31,000	26%	72%
2	68,000	28,000	34%	65%
1	69,000	21,000	<50%	>50%

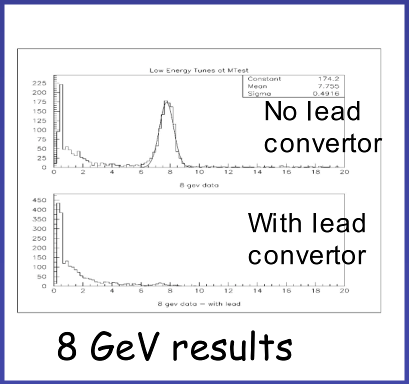
*Rates here are normalized to 1E11 at MW1SEM
**Measured at exit of facility with PbG calorimeter



TOF results showing proton (and deuteron) peaks

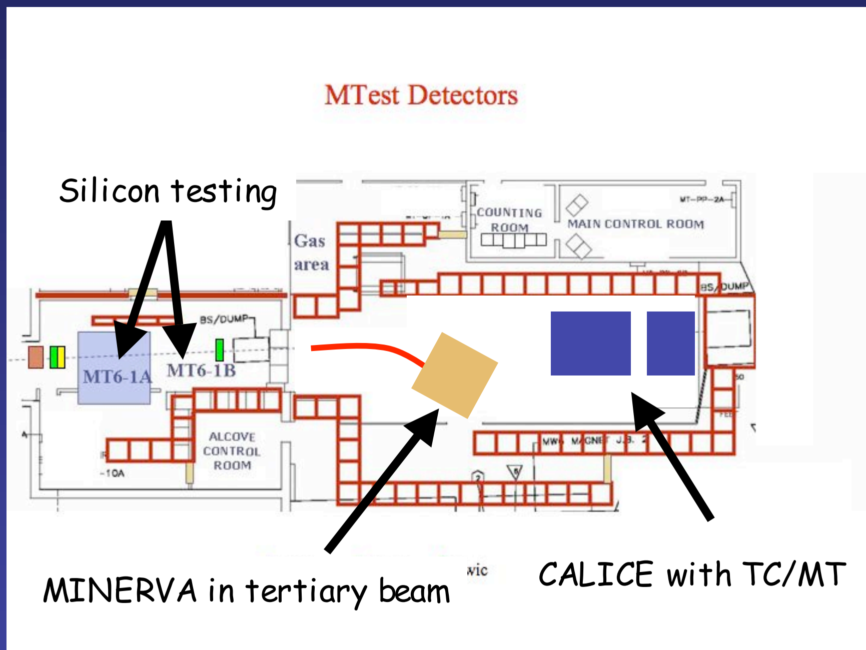


T970 results showing both muon tracks and pion showers at 2 GeV



Lead coverter at focal point reduces electron content of beam

Fermilab - future spatial conflicts



Where do we put this?
(magnet for TPC studies)

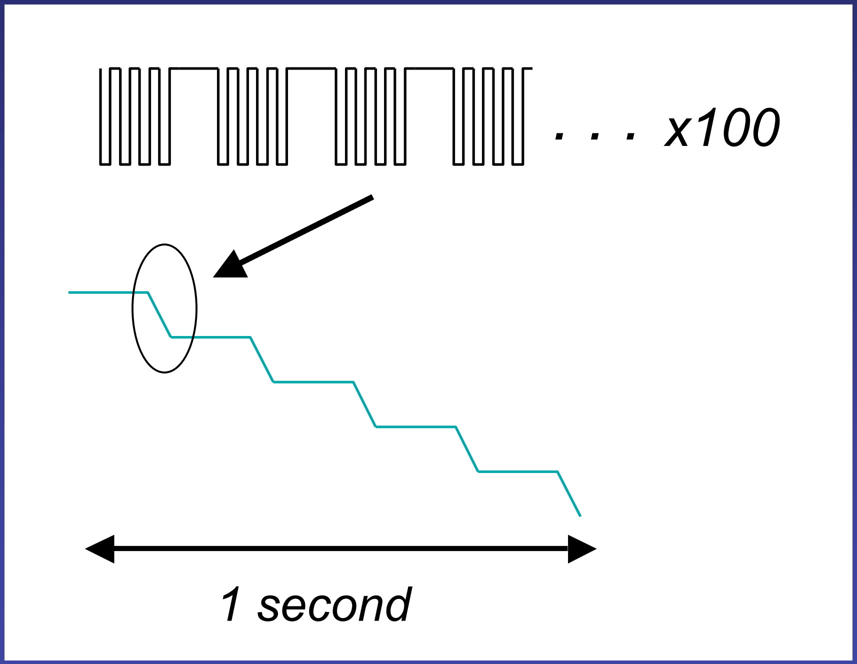
When MIPP has completed its program, Meson Center area could provide a place for several ILC tests:

- **Jet simulation and large scale calorimetry**
- **Slice test with vertex, tracker, ECAL/HCAL, TC**
- **Space for a large magnet for TPC work**

Fermilab - Simulating ILC Beam Structure

Possible path to ILC beam structure:

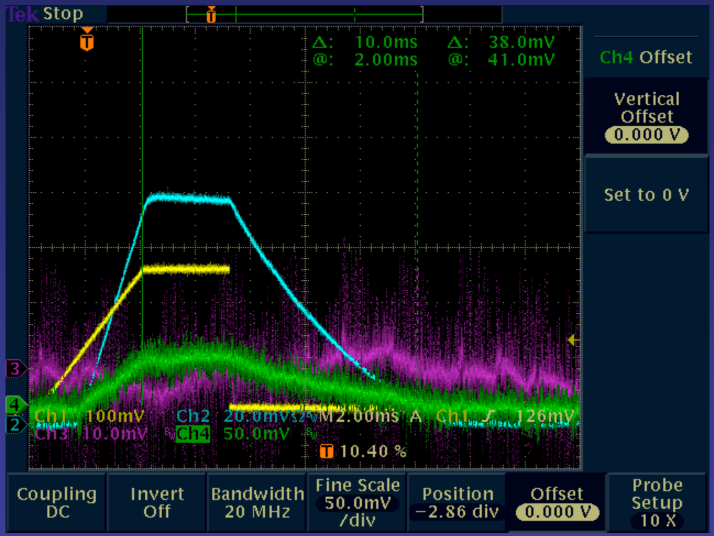
- Fill Main Injector with 4 Booster batches, with 19 nsec RF structure.
- Turn on already existing 2.5 MHz coalescing cavities. This results in a 400 nsec particle bunch spacing, with gap after 4 buckets.
- Implement a shorter - 1msec? - partial extraction cycle ('ping') using current quadrupole resonance magnet.
- Fit 5 of these pings in a 1 second spill



Fermilab - Simulating ILC Beam Structure

Peter Prieto in front of pulsing circuit for QXR

QXR quadrupole in Main Injector

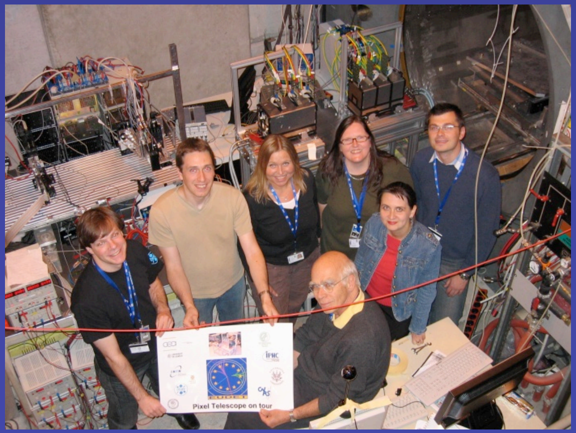


Pulsing the QXR supply with ~3 ms / 45 Volts

Accelerator Division will continue to work on this exciting possibility if ILC R&D groups show an interest.

EUDET Test Beam Infrastructure

- EUDET not a beam test facility per sé; it provides infrastructure for test beam facilities and large ILC prototypes anywhere in the world
- Construction and initial tests at DESY with possibility to move it elsewhere
- Activity organized in ~5 tasks
  - Detector R&D Network
  - Transnational Access
  - Joint Research Activities
    - Test beam infrastructure
    - Calorimetry
    - Tracking detectors
- Many experiments being supported:
  - Large bore solenoid magnet obtained from KEK
  - TPC: field cage, end plate interface, readout, Timepix chip
  - Calorimetry and readout
  - Pixel telescope development
- Budget is large by American standard:
  - 7M Euros contribution
  - Supports 21M in European contribution
  - 17 FTE fully funded
  - 4 year duration



Test beam facility summary

Laboratory	Energy Range	# Beamlines	Particle Types	Diagnostics	Availability
CERN PS	1 - 15 GeV	4	e, h, μ	Ckov,TOF,MWPC	6 months in 2008, as LHC commissioning permits
CERN SPS	10 - 400 GeV	4	e, h, μ	Ckov,TOF,MWPC	6 months in 2008, as LHC commissioning permits
DESY	1-6.5 GeV	3	e	Pixel telescope	After mid-2008
Fermilab	1-120 GeV	1	e, h,p, μ	Diff. Ckov,TOF,MWPC Pixel telescope	~ 9 months per year
Frascati	25-750 MeV	1	e		~ 6 months per year
IHEP Beijing	0.4-1.5 GeV	3	e, h, μ	Ckov,TOF,MWPC	After mid-2008
IHEP Protvino	1-45 GeV	4	e, h, μ	Differential Ckov TOF,MWPC, DAQ	One month, twice a year
J-PARC			e, h, μ		Possibly open in 2010
KEK Fuji	0.5-3.4 GeV	1	e, h, μ		Available in 2008
LBNL	1.5 GeV	1	e, h, μ	Pixel telescope	Continuous
SLAC	1-20 GeV	1	e, h, μ		Parasitic to Pep II, non-concurrent with LCLS

Summary

- Detector R&D for the ILC is critical to extract the physics from the machine and test beams are crucial in proving detector technologies.
- Many laboratories have demonstrated themselves to be very supportive of the requests of the test beam user community, even when budgets are being stretched and competition exists from other parts of the program.
- To be most effective, the user community should formulate clearly its needs and provide feedback to the available facilities.
- Likewise, regular updates of the status of the facilities (like this talk) should be made available.