FERMILAB TEST BEAM
& THE ILC

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presented by Marcel Demarteau

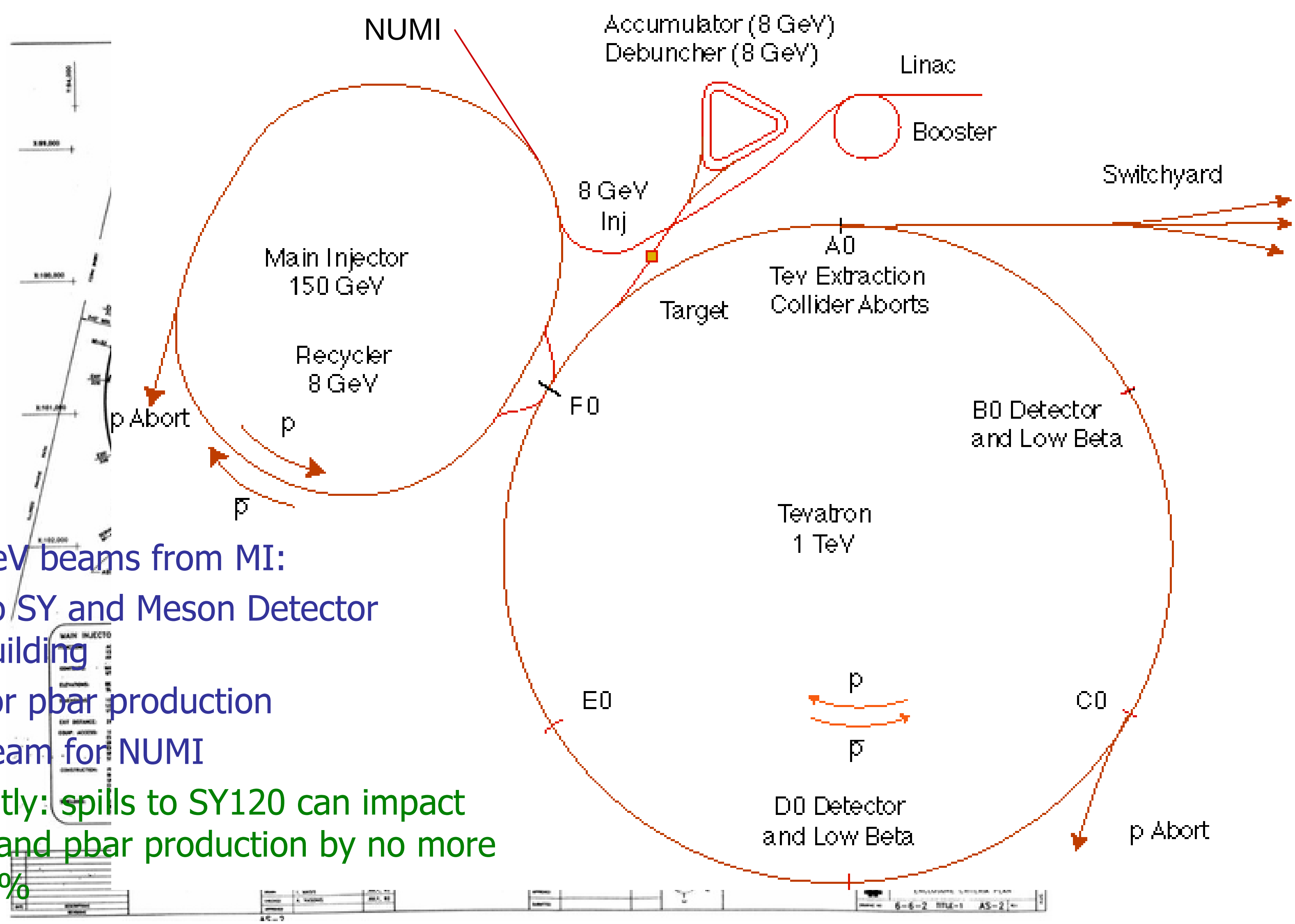
OUTLINE

1. **Introduction to the Fermilab facilities and their beam structure**
2. **Fermilab Test Beam Facility**
3. **Present Test Beam Capabilities**
4. **Approved and Planned Experiments**
5. **Possible Improvements to facilities currently under review**
   - ✓ **Gain from Reducing Material in the MTest Beamline**
   - ✓ **Further Gain from Reduced Length of the MTest Beamline**
   - ✓ **(Re-) commissioning other beamlines**
6. **Summary & Conclusion**

- url for Test Beam at Fermilab: http://www-ppd.fnal.gov/MTBF-w
- Test Beam Coordinator: Erik Ramberg - ramberg@fnal.gov
- MTest Beamline Physicist : Brajesh Choudhary - brajesh@fnal.gov
- ILC Detector R&D coordinator: Marcel Demarteau - demarteau@fnal.gov

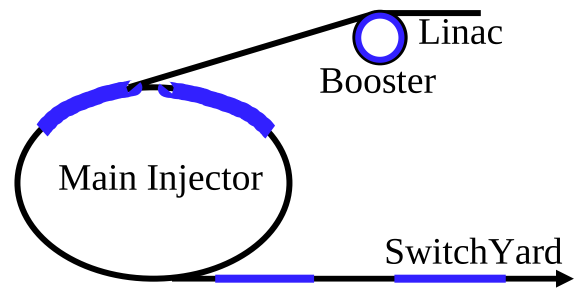
THE FERMILAB ACCELERATORS

NUM

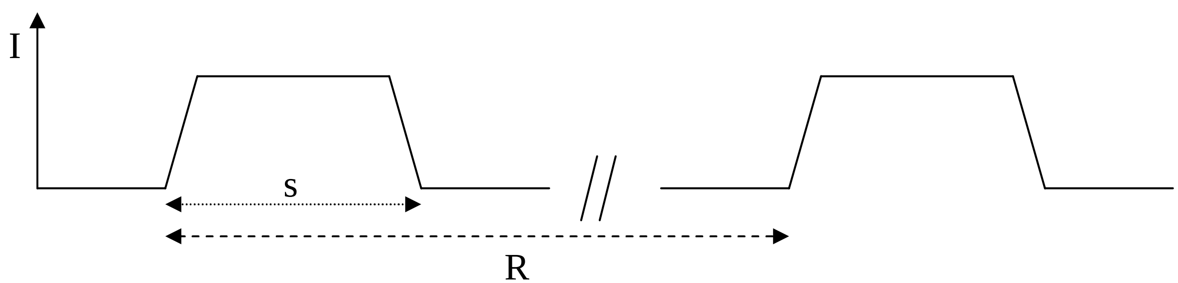


- 120 GeV beams from MI:
  - To SY and Meson Detector Building
  - For pbar production
  - Beam for NUMI
- Currently: spills to SY120 can impact NUMI and pbar production by no more than 5%

TIME STRUCTURE OF THE BEAM



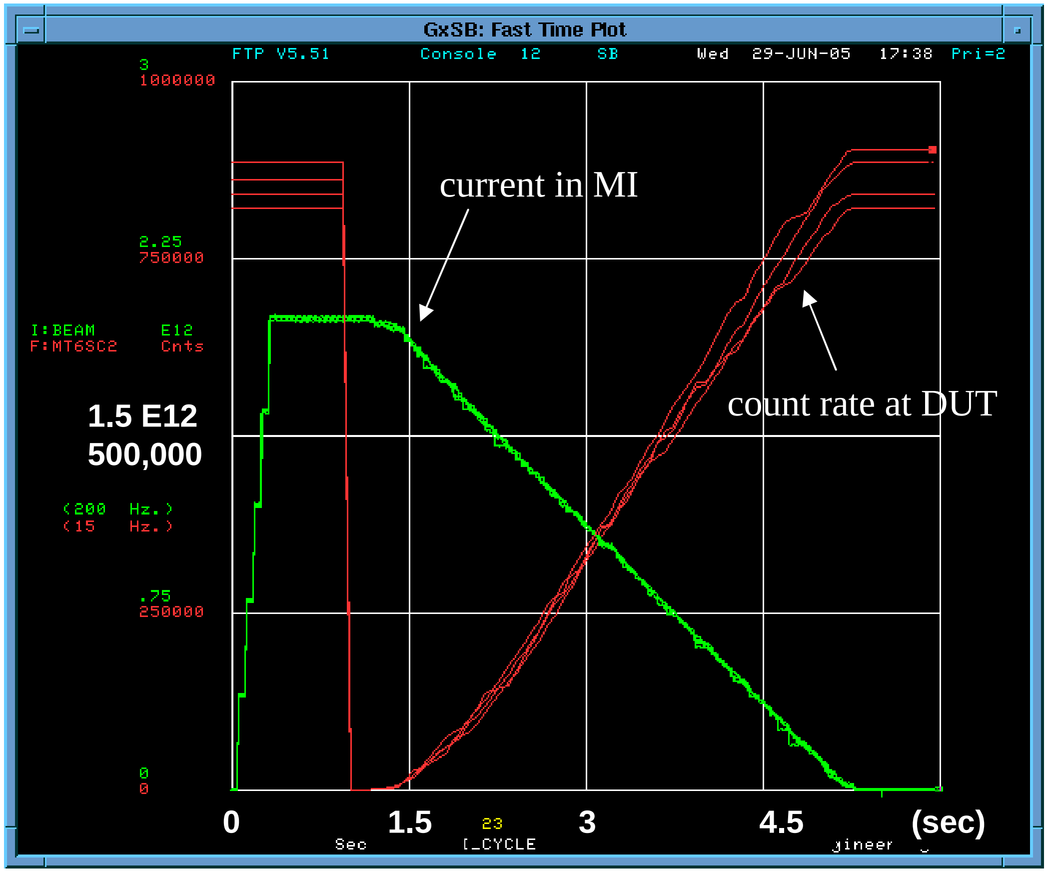
- Injection
  - At 8 GeV Booster RF is 52.81 MHz (18.9ns)
  - Full circumference of booster holds 84 buckets
    - Normally only 30 to 60 buckets are filled; beam train is 0.6 μs to 1.2 μs long.
  - Main Injector circumference: 588 = 7*84 buckets
    - Total of n_b=7 booster batches could be injected into MI; $n_b < 7$ for abort gaps, etc.
  - Same MI buckets can be filled multiple times: number of turns
- Ramp
  - acceleration of beams, plus rampdown each takes ~ 1 s.
- Beam Delivery: resonant extraction
  - Gradual depletion of beam from MI



s = length of spill
R = repetition rate
Duty cycle = s/R

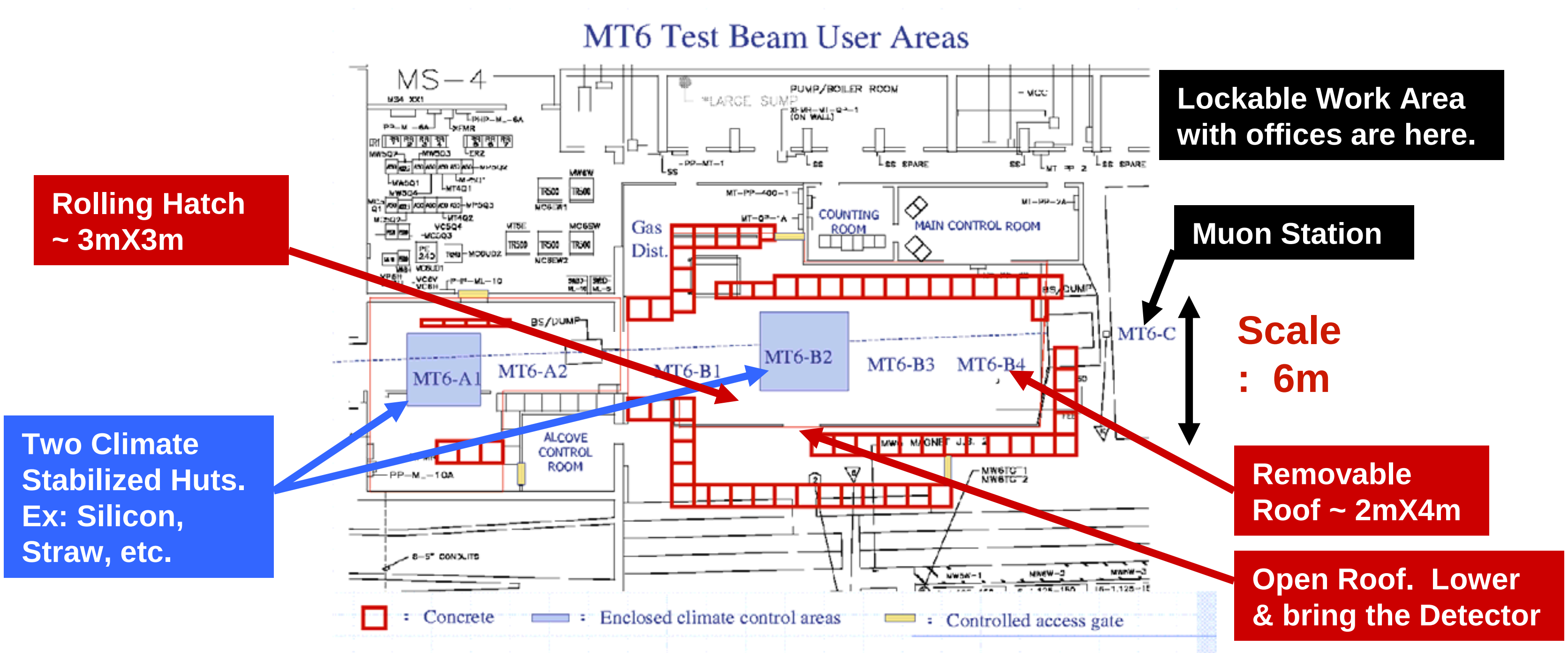
  - Within the flattop there is an 18.8 ns time structure, reflects the fill configuration of the MI

SY120 TIME STRUCTURE & RATE – 120 GeV



- Configuration:
  - 5 booster batches
    - 84 bunches/batch
  - One turn
    - $I_{beam} = 1.9\ 10^{12}$
  - Resonant extraction
  - 4s spill

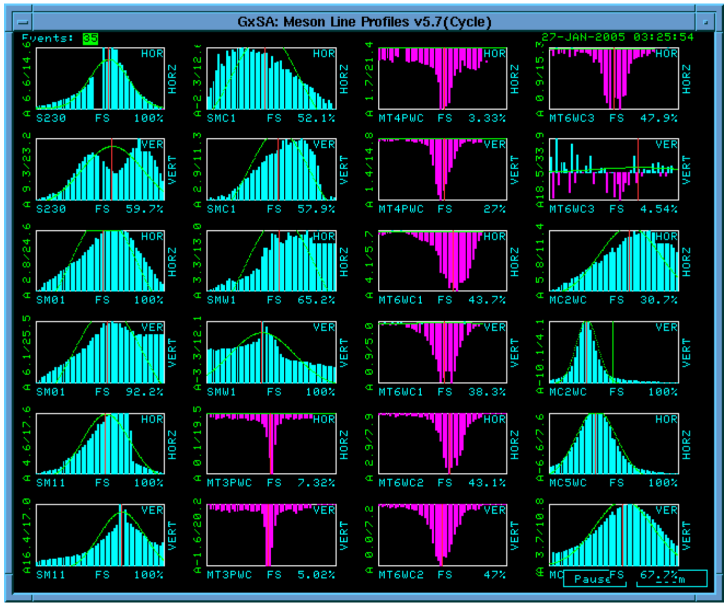
- Current operation: single slow spill of 6 sec with a 4 sec flat top every 2 min.
  - Dutry cycle set by Fermilab management
  - 4 s flattop limit due to cooling of MI magnets
  - If MI completely dedicated to SY, to 20, 3sec cycles/minute (0.6s flattop)



- ✓ **2 beam enclosures, but currently operated as single one (more shielding needed)**
- ✓ **6 user stations, with a 7th downstream of the beam dump. Can be easily used for muon data.**
- ✓ **An experiment can take up more than one station.**
- ✓ **2 climate stabilized huts with air conditioning.**
- ✓ **2 separate control rooms.**
- ✓ **Outside gas shed + inside gas delivery system brings 2 generic gas lines, 1 nitrogen line and 2 exhaust lines to each of the user areas**
- ✓ **Lockable work area with 3 offices for small scale staging or repairs, plus 2 open work areas.**

OPERATIONAL CHARACTERISTICS OF MTEST LINE

- 120 GeV protons impact on 40 cm long block of Aluminum as a production target.
- There are two operational modes of the test beamline:
  - Proton Mode: Tune beamline for 120 GeV protons that get transmitted through the target
  - Secondary Mode: Vary the tune of the beamline according to the momentum desired. Maximum secondary momentum is 66 GeV while minimum momentum achieved so far is 3 GeV. Lower momenta under study
- Spot sizes can be made as small as 2-5 mm rms and as large as 5 cm rms with 120 GeV protons
- Momentum spread – From Calorimeteric studies – 1-2% peak in the electron data.



Typical SWIC profiles while delivering 120 GeV beam (1 mm wire spacing: ~ 7 mm RMS)

PRESENT RATE IN THE MTEST BEAMLINE

Particle Energy (GeV)	Protons/spill from the Main Injector	Rate measured @MT6SC2	Beam Condition (Batches, Bunches, Turns)	MT6SC2 rate normalized to 1E12 protons/spill from MI	Electron Fraction
120	2E12	850-900K	5, 84, 1	~400-450K	---
66	2.1E12	205K	2, 84, 3	~100K	---
33	2.1E12	61K	2, 84, 3	~30K	~0.7%
16	2.1E12	42K	2, 84, 3	~20K	~10%
8	2.1E12	11K	2, 84, 3	~5K	~30%
4	1.5E12	1050	2, 84, 2	~700	~60%
3	1.5E12	250	2, 84, 2	~160	Mostly Electrons

Shielding limits in various sections of MTEST are:

2E12 protons/2.9sec from M02 to M03 pinhole collimator

2E7 particles/2.9sec from M03 pinhole collimator and downstream

7E5 particles/2.9sec in the MT6 experimental area.

FINISHED, APPROVED & PLANNED EXPERIMENTS

T926: RICE

T927: BTeV Pixel

T930: BTeV Straw

T931: BTeV Muon

T932: Diamond Detector Research– Signed – Will Take Data

T933: BTeV ECAL

T935: BTeV RICH

T936: US-CMS Forward Pixel – Need More Data

T941: U. Iowa PPAC Test

T943: U. Hawaii – Monolithic Active Pixel Detector

T950: Straw Tracker – Need More Data

T951: ALICE EMCAL Prototype Test

T953: U. Iowa - Cerenkov Light Tests

T955: RPC Detector for ILC – Need More Data

T956: ILC Muon Detector Test – Indiana U., UCD, Notre Dame, Wayne State & Fermilab/ILC – Need More Data.

T957: NIU Tail Catcher/Muon Tracker for ILC

Jim Russ – CMU - Silicon Tracker for the LHC Upgrade

John Hauptman – Iowa U. - Dual Readout Calorimetry for the ILC

Wojtek Dulinski - Strasbourg - Irradiation Tests for the CMOS Chip

Victor Rykalin - NIU - Extruded Scintillator Light Yield – ILC

Mike Albrow – FNAL - FP420 Silicon Tracking & Timing counters

Jae Yu – UTA - ILC Calorimetry - CALICE

POSSIBLE IMPROVEMENTS TO THE CURRENT BEAM

- Improvements to rate:
  - Duty Cycle:
    - Currently: SY runs with a 5% duty cycle: 1 spill every 2 minutes.
    - The laboratory is currently re-evaluating the duty cycle and its allocation per 24 hours, and a 10% duty cycle may be possible: gain by factor 2
  - Spill Structure
    - Currently: 6 sec cycle with 4 sec flat top
    - The laboratory is currently re-evaluating the possibility to go to two 3s long spill every minute. Gain by a factor of 2 if not limited due to DAQ rate.
  - Beam Intensity
    - Quoted rates are for 1E12 ppp in the MI. One can easily go to 2.0-2.5 E12 ppp. Gain by a factor of 2.0 to 2.5.
- Reduction of the amount of material in the beamline
    - Gain varies with beam configuration
- Move of target further downstream by ~700'

GAIN FROM REDUCING MATERIAL IN THE PRESENT MTEST BEAMLINE

The transmission of secondary beam in the present MT beamline gets degraded due to large air gaps, several windows and various redundant instrumentation. It is possible to reduce the total material that the secondary beam encounters.
A GEANT model was used to study the hadron and electron yields at the standard beamline energies.

Type of Material	Radiation Length (X_0)	Interaction Lengths (λ)
Air	0.055	0.022
17 Windows	0.049	0.007
Scintillators	0.038	0.020
PWCs	0.036	0.008
Total	0.18	0.057

Materials up to MT6SC1

The exact thickness of windows are not known, so we have used a typical 4mils of Titanium.

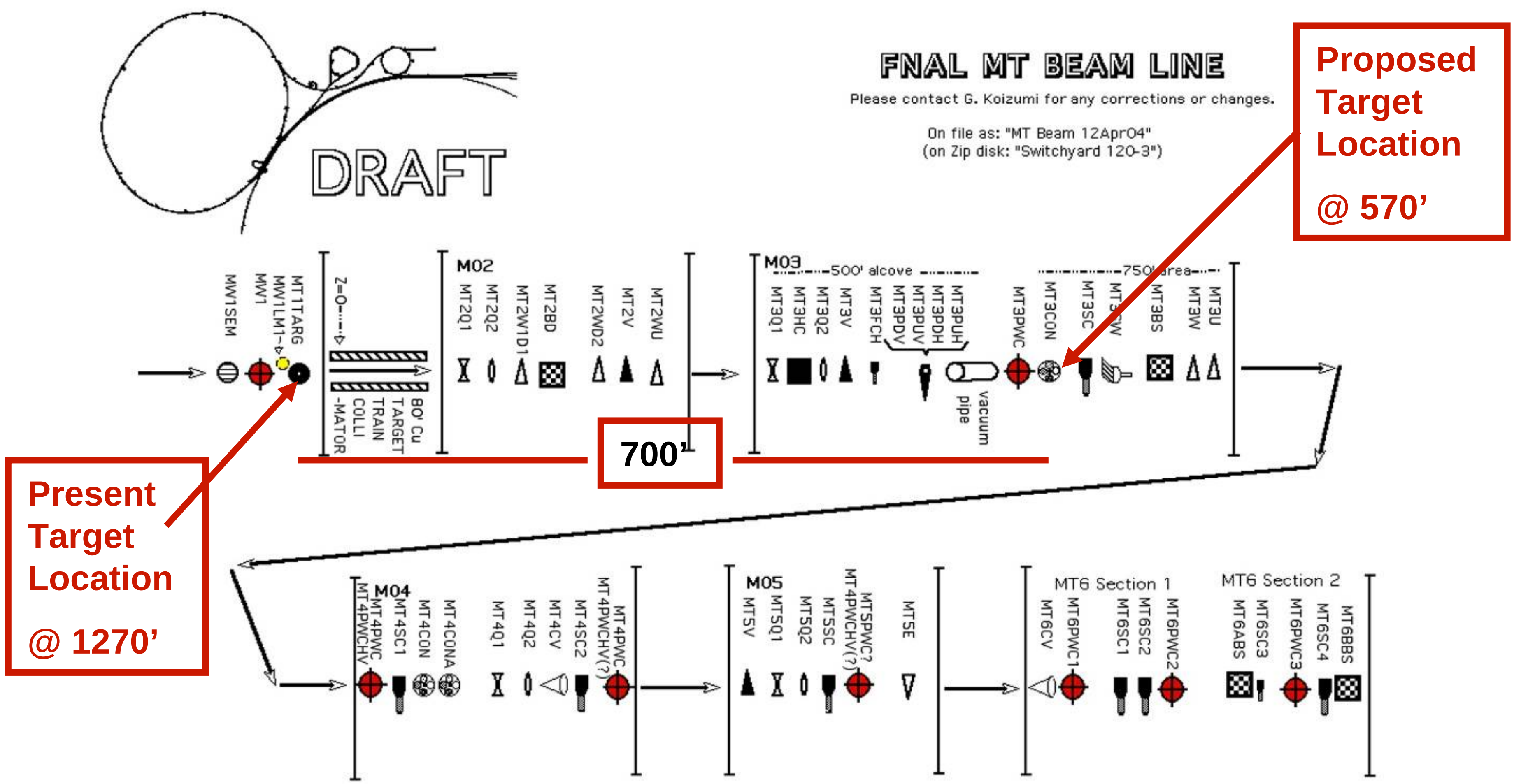
Energy (GeV)	Hadron Reduction due to Presence of Material in Beam	Electron Reduction due to Presence of Material in Beam
4	25	~90
8	6.4	14
16	2.5	6.3
33	1.4	4.2
66	1.2	1.9

Conservatively assumed that only 50% of the material can be removed.

POSSIBLE GAIN

Energy (GeV)	Present MT6SC2 Rate for 1E12 PPS from MI	What can be done with the Present Long MTEST Beamline?	Gain due to Reduction by 50% of material in the Beamline	Possible Overall Gain	Expected New Rate
1	---	Possible Gain by a Factor of 8 - 10 due to Increased Beam Current 2.0-2.5x Rep Rate 2x Spill Structure 2x	----	----	
2	---		----	----	
3	~150		10	~100	10K+
4	~700		10	~100	50K+
8	~5K		3.0	~30	100K+
16	~20K		1.5	~15	200K+
33	~30K		1.2	~12	300K+
66	~100K		1.0	~10	~1000K

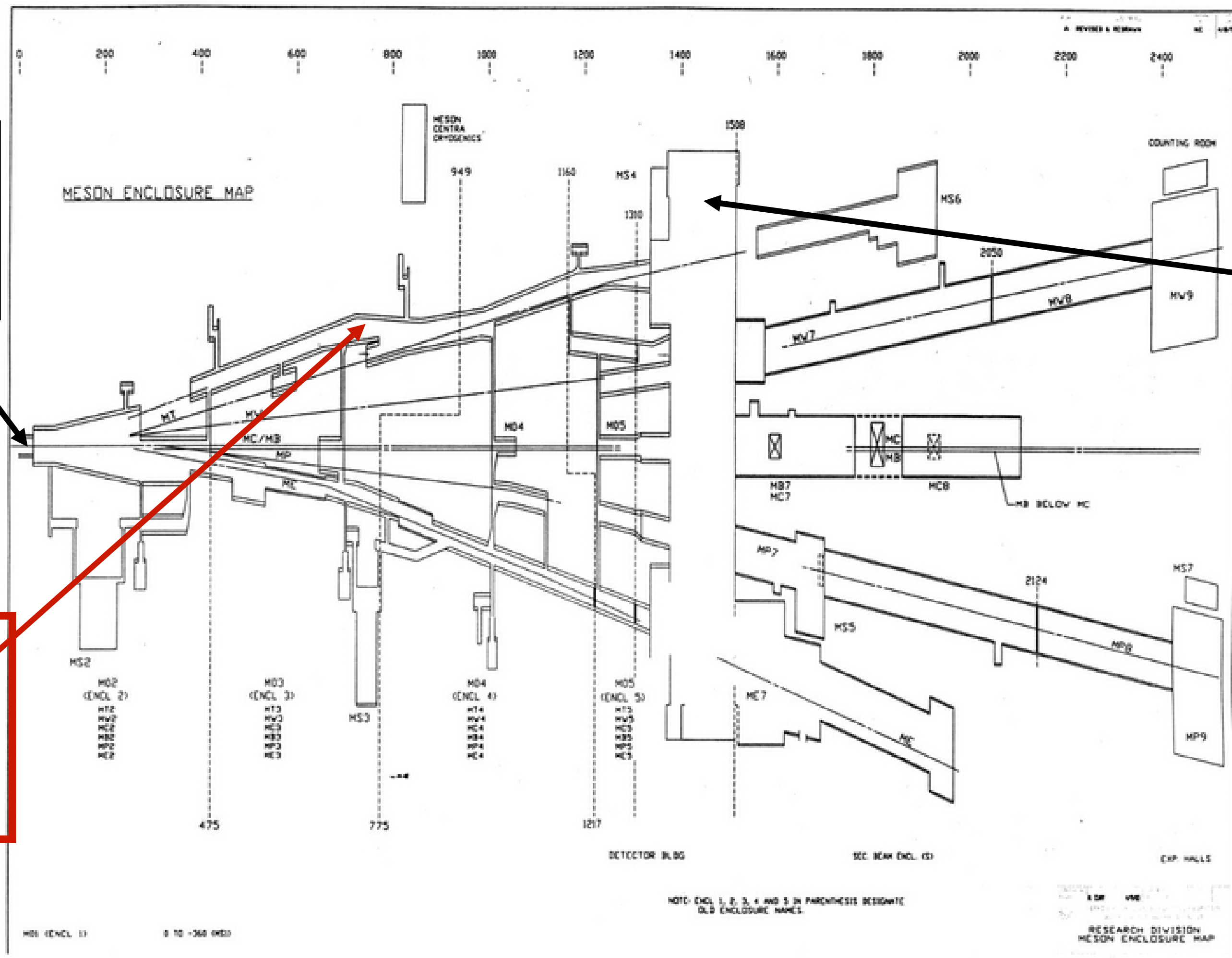
TARGET MOVE



FNAL MT BEAM LINE
Please contact G. Koizumi for any corrections or changes.
On file as: "MT Beam 12Apr04"
(on Zip disk: "Switchyard 120-3")
DRAFT
Proposed Target Location
@ 570'
Present Target Location
@ 1270'
700'
M02
M03
M04
M05
MT6 Section 1
MT6 Section 2

THE MTEST BEAMLINE

40 cm Aluminum Target



Meson Detector Building

Proposed Target Location ~700' down

GAIN FROM MOVING PRIMARY TARGET DOWNSTREAM TO MT3CON

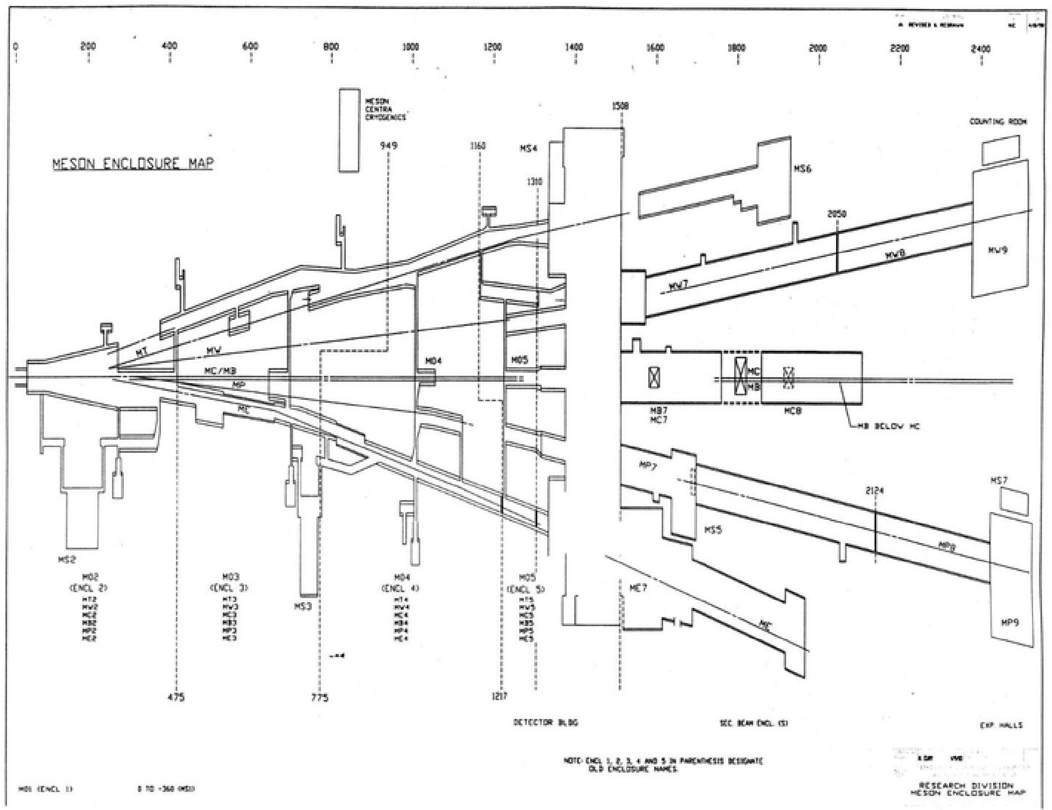
- Moving the target 700' downstream to MT3CON will
  - Reduced amount of the material in the secondary beamline
  - Reduced the loss due to decays at lower momentum
  - Increased the fraction of pions at lower momentum compared to present rate

Energy (GeV)	Present MT6SC2 Rate for 1E12 PPS from MI	Rate Improvements	Gain due to Pion Decay factor	Gain due to reduced material in the shorter Beamline	Available gain due to momentum bite and phase space	Possible Gain due to Shorter Beamline	Possible Overall Gain
1	---	Possible Gain by a factor of 8 to10 due to I_{beam}: 2.0-2.5x Rep rate 2x Spill struct. 2x	45	---	Approximately 4 to 20: Momentum bite increase by 1 - 5x And phase space increases by 4x		
2	---		6.8	---			
3	~150		3.6	4.0		50 - 250	> 400 - 2000
4	~700		2.6	3.5		35 - 170	> 250 – 1200
8	~5K		1.6	2.0		12 - 60	> 100 – 500
16	~20K		1.3	1.5		7 - 30	> 50 – 250
33	~30K		1.1	1.0		4 - 20	> 35 – 200
66	~100K		1.0	1.0		4 - 20	> 30 – 150

MESON CENTER

- MCenter currently houses the MIPP (Main Injecter Particle Production) experiment
  - Measures the particle production in various targets for different particles within a range of momenta
  - Data could be useful for the understanding of hadronic shower development and, as such, for the development of PFA

- The MCenter beamline is currently unscheduled. Lab management is entertaining the possibility of the use of the MCenter as an additional test beam area
- MCenter:
  - high flux
  - Low momenta



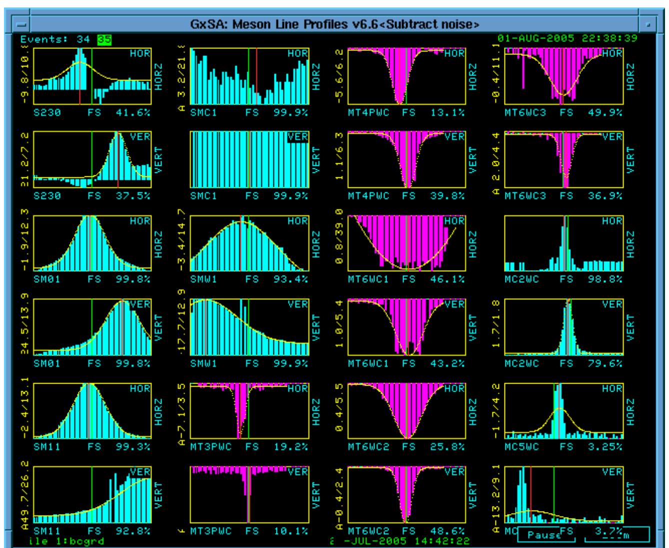
SUMMARY

- MTest has successfully delivered and continues to deliver beams of various momentum to the user community
  - U of Hawaii MAPS detector, CMS pixel, ALICE, PHENIX EMCAL ILC tailcatcher, ILC RPC, …
  - Useful feedback obtained from the user community
- The current MTest configuration is being re-evaluated
  - Improvements in rate
  - Improvements in beam instrumentation
  - Moving target downstream
  - Possibility to increase yield at very low momenta by a factor of ~1000
  - Revamped DAQ system
- Meson Center beamline will become available latest at the end of next year
  - It is being re-evaluated if MCenter could be used as user test area
    - At MCenter higher flux, lower momenta

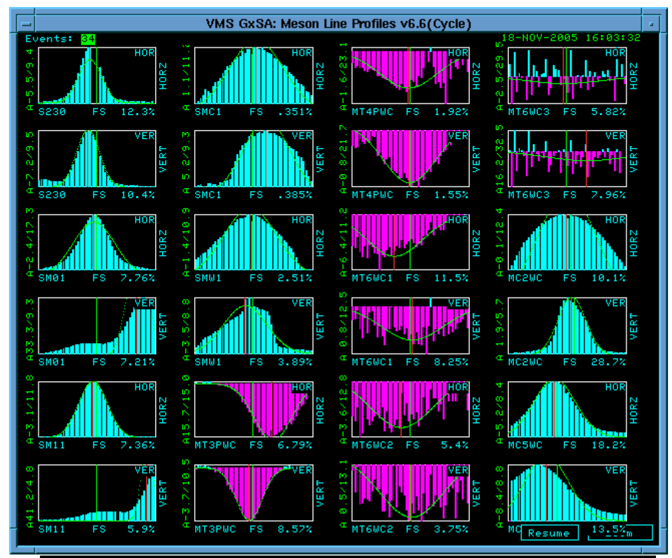
- We are open to any suggestion from the user community. We would appreciate feedback on requirement and specifications from the user community.

OPERATIONAL CHARACTERISTICS OF MTEST LINE

- **120 GeV protons from MI impact on a 40 cm long block of Aluminum as a production target.**
- **There are two operational modes of the Meson test beamline:**
  - **Proton Mode:** Tune the beamline for 120 GeV protons that get transmitted to the target
  - **Secondary Mode:** Vary the tune of the beamline according to the requested momentum. Maximum secondary momentum is 66 GeV, while the minimum momentum achieved so far is 3GeV. Lower than 3GeV momentum beam is possible, but in the present setup pion rate will be quite low and electron scattering will probably be quite high. But if the target is moved downstream then higher pion and electron rate could be achieved simultaneously.
- Spot sizes can be made as small as 2-5 mm RMS and as large as 5 cm RMS with 120 GeV protons.
- Momentum spread – From Calorimeteric studies – 1-2% peak in the electron data.

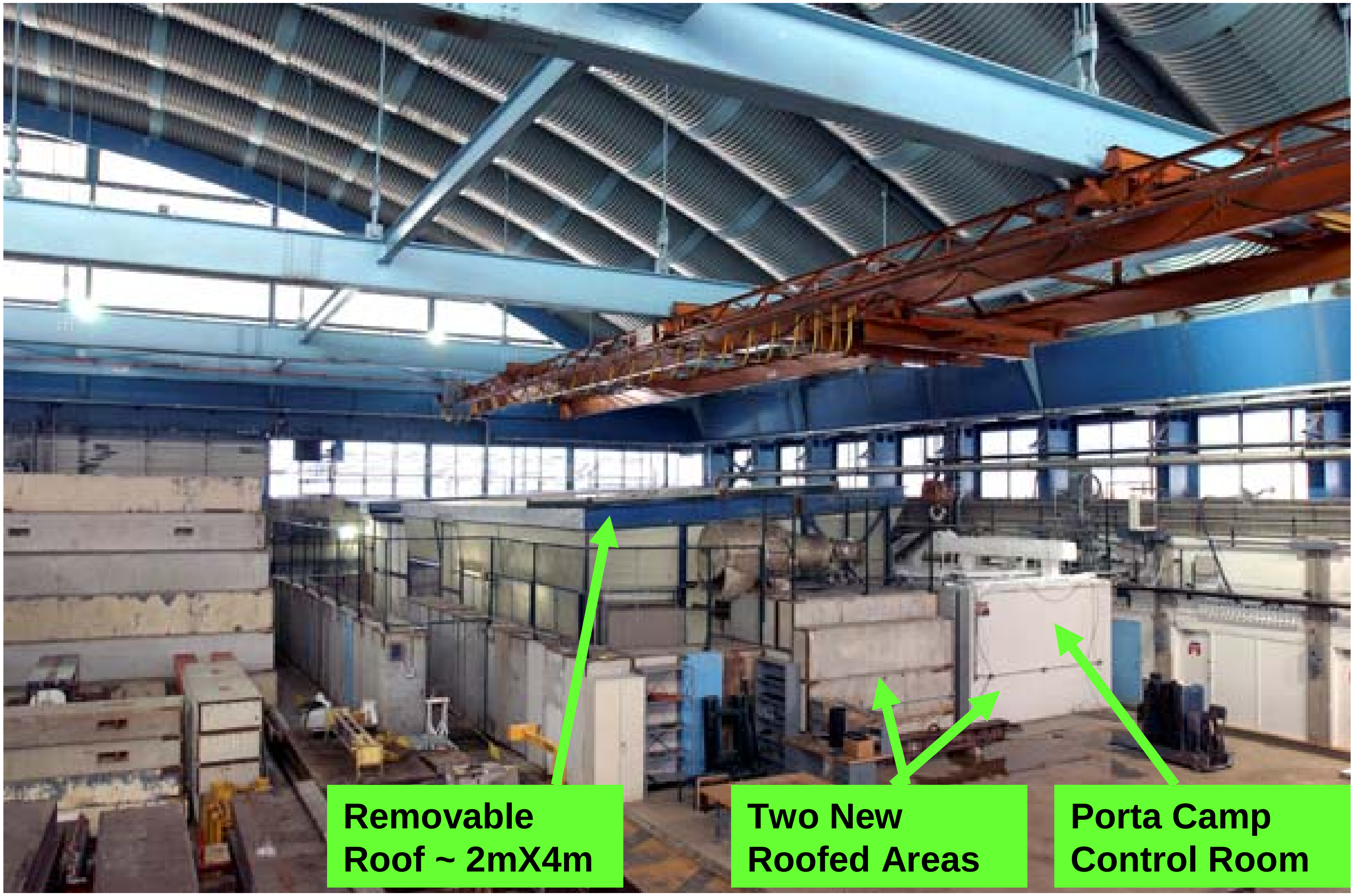


1st August 2005 – 120 GeV Beam - 1mm wire spacing – 2-5mm RMS in vertical & horizontal @MT6SC2

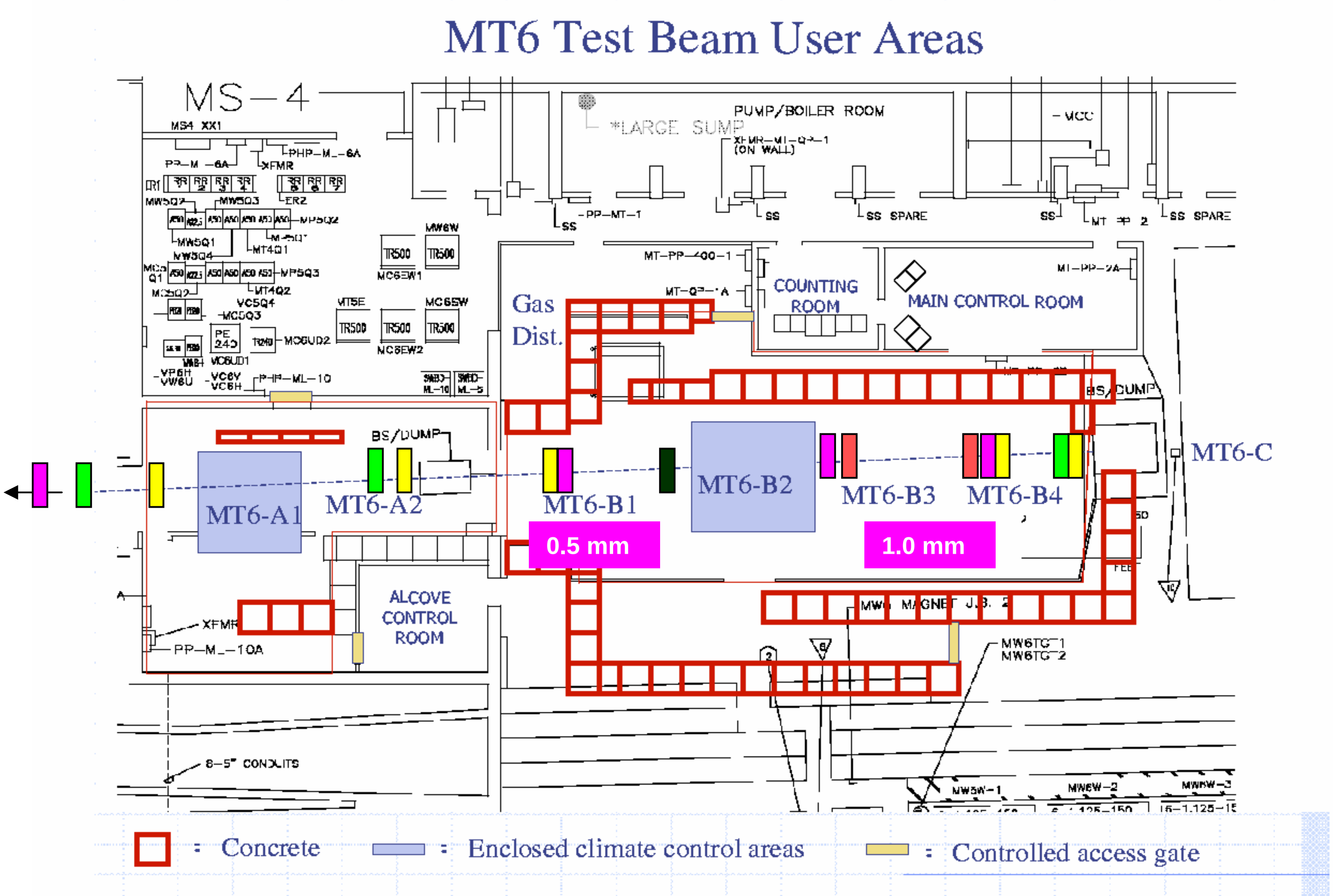


18th November 2005 – 8 GeV Beam - 1mm wire spacing – ~12mm RMS in both planes @MT6SC2

MESON LINE – THE BLUE & RED BUILDING – INSIDE VIEW



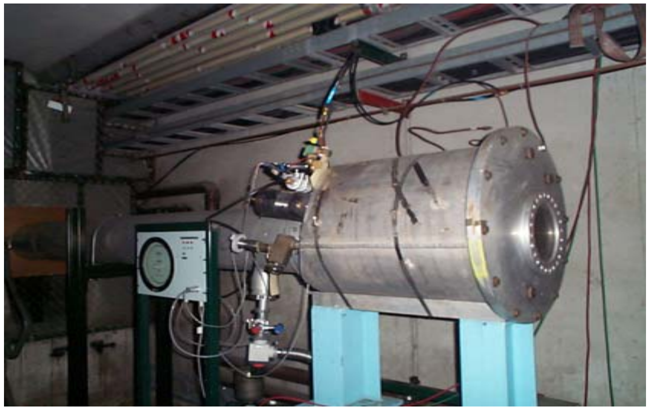
MTEST BEAM FACILITY DETECTORS

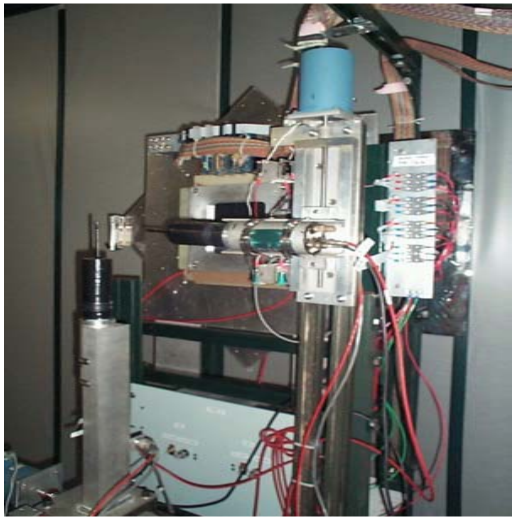


Scintillator **PWC** **Finger counters** **SWIC** **SSD**

DETECTOR PHOTOGRAPHS

One of the Cerenkov Counters





Remote Controlled Scintillator Finger Counter

One of the Three PWC Stations

Silicon Tracker