



Directorate

**MEMORANDUM OF UNDERSTANDING
FOR THE 2010 MESON TEST BEAM PROGRAM**

T-995

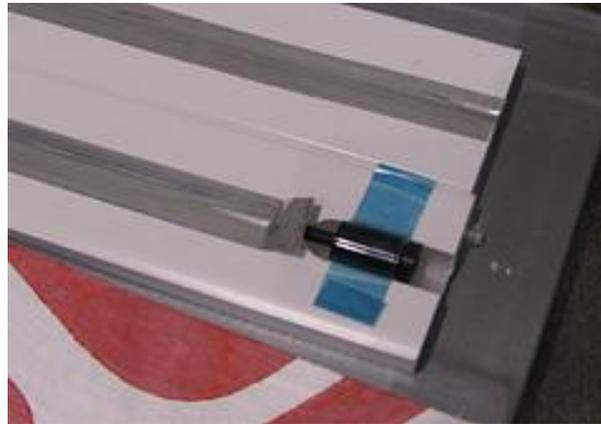
Muon Detector / Tail Catcher R&D

January 18, 2010



INTRODUCTION

I.	PERSONNEL AND INSTITUTIONS	5
II.	EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS	6
III.	RESPONSIBILITIES BY INSTITUTION - NON FERMILAB	10
IV.	RESPONSIBILITIES BY INSTITUTION - FERMILAB	11
	4.1 Fermilab Accelerator Division	11
	4.2 Fermilab Particle Physics Division	11
	4.3 Fermilab Computing Physics Division	12
	4.4 Fermilab ES&H Section	12
V.	SUMMARY OF COSTS	12
VI.	SPECIAL CONSIDERATIONS	13
	SIGNATURES	14
	APPENDIX I - MT6 TEST BEAM AREA LAYOUT	15
	APPENDIX II - EQUIPMENT NEEDS	16
	APPENDIX III - HAZARD IDENTIFICATION CHECKLIST	17
	BIBLIOGRAPHY	18



INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory and experimenters from Fermilab, Indiana University, Northern Illinois University, University of Notre Dame, Wayne State University, INFN (Trieste / Udine, Roma I, Padova, Ferrara) who have committed to participate in beam tests to be carried out during the 2010 MTBF program.

The memorandum is intended solely for the purpose of providing a budget estimate and a work allocation for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties. However, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to negotiate amendments to this memorandum which will reflect such required adjustments.

The test objectives are to continue the development of extruded scintillator-based muon counters begun in T-956 with emphasis on the use of Si Pixelated Photon Detectors (PPDs). The R&D program outlined here continues the T-956 studies using particle beams to test long strip counters, up to 6m, and new prototype TB4 electronics developed at Fermilab¹ which the experimenters expect will lead to the assembly of future large-scale integrated systems that may be the subject for a future proposal. For the purpose of this work, T-995 will require limited space and resources which may be compatible with other users' equipment in the testing area. The T-995 experimenters may not always require control of the beam.

The T-995 experimenters will use some of the same apparatus that is to be used by the experimenters who will study total absorption dual readout calorimetry at MTest (experiment T-1004). The T-995 and T-1004 experimenters both use newly designed Fermilab electronics to digitize the shape of the PPD pulse corresponding to the scintillator output. Both projects will share most of the data acquisition software and typically they will share the same beam instrumentation (beam defining counters and coincidence circuits). Both sets of experimenters will share some of the same counting house logic and analysis software for on-line data analysis. Some of the T-995 and T-1004 manpower available to the two projects will work on both projects although many of the studies will not run concurrently.

Muon Detectors

The muon counter tests will focus on:

- Setup and testing of Fermilab-based TB4 front-end (FE) electronics at MTest. The electronics per channel consist of a chain of integrated circuit board modules: shaper-amplifier, threshold trigger pulse, 12-bit 210MSPS ADC, fast memory and high speed LVDS link to a VME module or 100baseT Ethernet capability for fast data block transfers. This electronics is designed to sample the input signals at 5ns intervals and knowledge of how the total charge is distributed in time will lead to a better under-

standing of the PPD output and allow optimization for fast timing charge integration and background rejection.

- Measurement of the number of photo-electrons (p.e.) for short (1m) and long (6m) strips equipped with 1.2mm dia. wave-length shifting fiber (KurarayY-11 double clad) with several different varieties of PPDs (HPK, FBK-IRST, SensL, Zecotek) with various pixel sizes, fill-factors, and planar shapes. The scintillating strips will be equipped with PPDs at either one or both ends of the strips for comparison of single and dual readout. Previous measurements of 1.8m strips with multi-anode photomultiplier detectors indicated about 50% greater integrated charge was obtained with dual readout.² Single readout from fibers with mirrored ends will also be evaluated.
- Evaluation of the position of the impact point along the strip from the timing difference between signals read out from both ends or between direct and reflected (from the mirrored end) signals read out from the same end.
- Optimization of pulse shaping and charge integration for charge resolution so as to be able to identify single photoelectron peaks for self calibration
- Optimization of optical couplings between WLS fibres and PPDs
- Measurement of signal attenuation as a function of position of the beam along the length of the strips and the inefficiency across the strips due to the ~1mm thick coating of white TiO₂ that ensures good light pulse reflection along the scintillating strip. This measurement will require upstream tracking to project the charged particle to the scintillator. This measurement will involve the use of MTest upstream tracking detectors.
- The standard photo-detectors to be used initially will be 1.2mm diameter FBK-IRST PPDs with either epoxy (“glob-top”) or quartz window protection of the photocathode. A measurement of photons that escape detection because of angular divergence at the photo-detector/WLS fiber interface will be attempted by making measurements of integrated charge with a larger area pixilated photon detector that is 3mm X 3mm. The charge collected from light pulses as a function of distance between the photo-cathode on the PPD and the polished end of the WLS fiber will also be measured in a bench test with a light pulser. This will be cross-checked using light created by charged particles in the scintillator.
- Because the PPDs exhibit dark current (noise) the individual counter efficiencies will be measured vs. PPD gain with threshold cuts at 0.5, 1.5, 2.5, ... photo-electrons . This should correlate well with the calibration that is established with noise pulses; i.e. the pulse height spectra obtained without beam. The gain can be varied by changing the PPD’s bias voltage and/or by changing the FE-amplifier gain.
- One of the test objectives is the optimization of extrusion type , e.g. measurement of photo-electron yield for scintillator with an extruded hole instead of a groove for holding the WLS fiber. A variation on this theme is to test two fibers in two extruded holes (e.g. NIU strips and strips being developed for INFN Padova/Ferrara).
- If a significant fraction of the expected photo-electrons is not detected because of fiber/photo-detector optical phase-space mismatch, that problem will be worked on. Preliminary calculations indicate that a focusing fix may be possible. This will first require bench testing before the test beam comes into play.
- One important application of the pulse – shape digitization is that it will allow evaluation of the relative contributions of WLS and scintillator relaxation times to the overall time distribution of the signals. The relaxation time of the WLS is reported to be 12

ns.³ This may take a bit of effort to get right. The scintillator is supposed to be fast, but this will be confirmed by measurements for which the MTest beam data will be important.

Appendix I shows the anticipated location of the scintillator testing setup. Set-up and tests will begin with single extrusions used in T-956 with PPDs and the TB4 FE electronics currently being developed at FNAL. With this configuration, tests will continue in early 2010 with a preliminary version of the FE electronics. A preliminary version of the TB4 FE electronics was tested in 2008; the 2010 tests will constitute running under typical operating conditions.

These tests will require a movable stand which can be operated remotely to limit the number of accesses needed to vary the position of incident particles and enough space, transverse to the beam, to accommodate extrusions up to 6m in length. Measurements are most easily made by moving the counters across the beam and defining the incident beam spot with appropriate trigger counters. The incorporation of a tracking system should further improve the procedure and a tracking system will, at some point, be needed for tests of crystal and glass elements for T-1004.

I. PERSONNEL AND INSTITUTIONS:

Spokespersons and physicists in charge of beam tests: Gene Fisk/Giovanni Pauletta
Fermilab liaisons: Aria Meyhoefer, Erik Ramberg

The group members at present and others interested in the test beam are:

1.1 Fermilab: Gene Fisk , Adam Para , Erik Ramberg, Paul Rubinov
Other commitments: D0(GF), MINOS(AP), MINERvA(PR)

1.2 University of Notre Dame: Mitchell Wayne
Other Commitments: D0, CMS

1.3 Wayne State University: Paul Karchin, Alfredo Gutierrez
Other Commitments: CMS, CDF

1.4 NIU: David Hedin, A. Dychkant, V. Zutshi
Other Commitments: D0

1.5 Indiana University: Rick Van Kooten
Other Comittments: D0

1.6 INFN Trieste/Udine: Walter Bonvicini, Diego Cauz, Anna Driutti, Giovanni Pauletta, Aldo Penzo

Other commitments: PAMELA(WB), CDF(DC and GP), CMS(AP)

1.7 INFN Roma I: Maurizio Iori

Other commitments: CDF

1.8 INFN Padova: Mario Posocco

Other commitments: Super B

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

The T-995 tests will be moved ~ 6m downstream of the previous T-956 test area (MT6 section 2A) to MT6 section 2C where the space transverse to the beam direction is sufficient to accommodate both the 3.65m long extrusions and passage of the MTest beam between the vertical supports of the MINERvA test detector and its plates. The T-995 tests will thus take place upstream of the CALICE detectors as shown in Fig. 1 below.

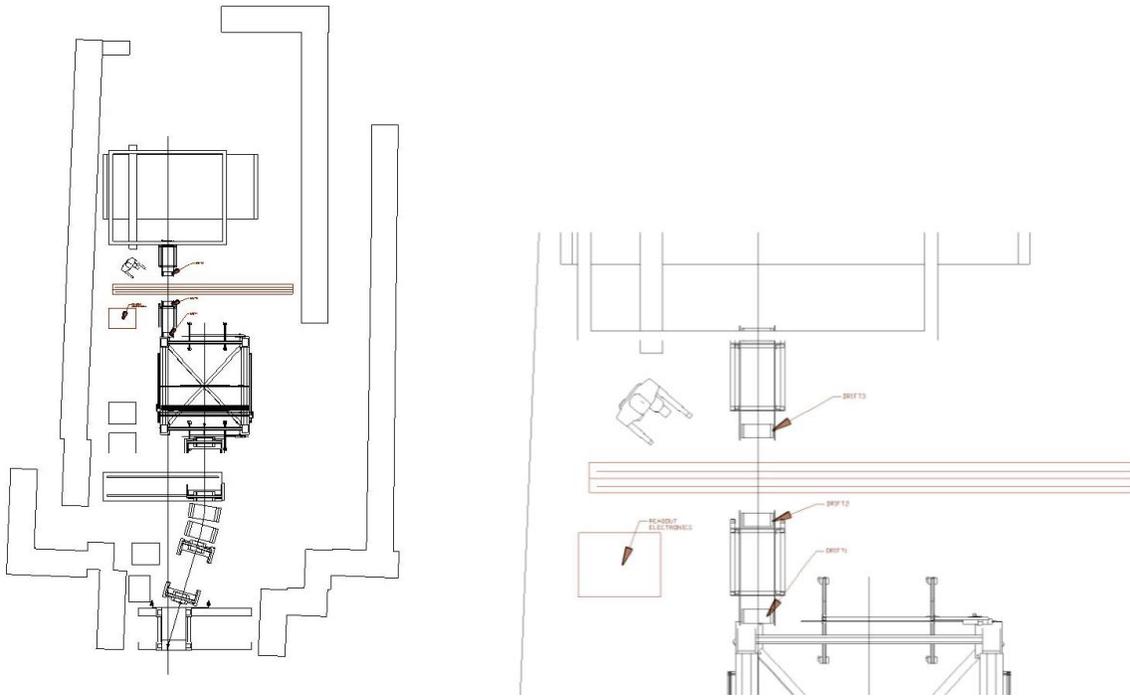


Figure 1 MTest locations of MINERvA, T-995 and CALICE (left). Expanded plan view T-995 (right).

2.2 BEAM

2.2.1 BEAM TYPES AND INTENSITY

Type of beam needed:

Operation with a variety of beam types is possible insofar as they constitute minimum ionizing particles (MIPs). The first choice for best rate and spot size is the 120 GeV positive beam, although running with lower energy beams is possible. Muons may be desired on occasion.

No exceptional requirements regarding momentum resolution are foreseen at this time.

Intensity Needed: 1-10 KHz

Size of Beam needed:

In the absence of tracking, a small spot size is preferred, so as to maximize the intensity intercepted by small (~2cm x 2cm x 6mm thick) trigger counters. When tracking becomes available, a larger spot size may be preferable so as to simultaneously illuminate as large an area as possible. The cross-sectional areas to be illuminated are typically $< 10 \times 10 \text{ cm}^2$.

2.2.2 BEAM SHARING

Given the nature of the T-995 tests, which will require frequent changes of physical configuration of the elements being tested, and because of limited manpower and other commitments, T-995 can alternate beam time with other users to the degree that such running is mutually compatible. T-995 notes that frequent access to their detectors may be incompatible with efficient sharing of scheduled beam time.

The amount of material in the beam would be approximately 2 cm of polystyrene scintillator.

2.3 EXPERIMENTAL CONDITIONS

2.3.1 AREA INFRASTRUCTURE

All components of the remotely moveable support used for T-956 should still be available at MT6 for T-995 running (or comparable remotely movable mounts). This is necessary to remotely move extruded scintillator strips a distance of ~ 1.5 m across the beam thereby reducing the number of accesses required to reposition the apparatus. A typical set of measurements for a scintillator strip will comprise horizontal and/or vertical scans of the strip.

An important goal of the T-995 tests is the determination of efficiency for the strip scintillator system. Such a measurement is to be based on extrapolation of beam particle trajectories to the vertical interface between adjacent strips where there is about a 1mm distance between the active scintillators due to the co-extruded TiO₂ casing that encloses the scintillator as a reflective coating. The vertical (and possibly horizontal) trajectories of individual particles will be determined by a tracking system composed of existing MT facility PWCs and associated CAMAC electronics which presents PWC data to the LINUX host computer. See <http://www->

ppd.fnal.gov/MTBF-w/ for more information. The system will be readout with the same DAQ currently in use at MTest. These chambers, commonly referred to as the “Fenker PWCs”, offer 2 X and 2 Y planes with 1mm spacing which results in approximately 0.5mm resolution in X and Y. With these chambers positioned in front of the T-995 experimental apparatus, the particle trajectory can be determined with better than the needed precision. Since the T-995 experimental apparatus uses a separate DAQ(PC), some care will be required to match the data from the two systems. The plan is to use a simple and robust scheme that requires an event sequence-number that is matched for the two data streams. The schematic diagram is shown in Figs. 2 and 3 below. T-995 requests that Erik Ramberg lead the effort to locate the chamber next to the T-995 apparatus and to commission the PWCs and associated readout electronics. T-995 also expects to use the existing trigger infrastructure, to be composed of two small scintillator paddles placed close to the T-995 apparatus, one small and one large area scintillator placed close to the upstream end of the MT6B enclosure. The purpose of these counters would be to provide triggers to T-995 as well as the PWCs CAMAC system and to estimate beam rates through and around the T-995 detector. This would involve only the existing MTest NIM electronics and HV infrastructure.

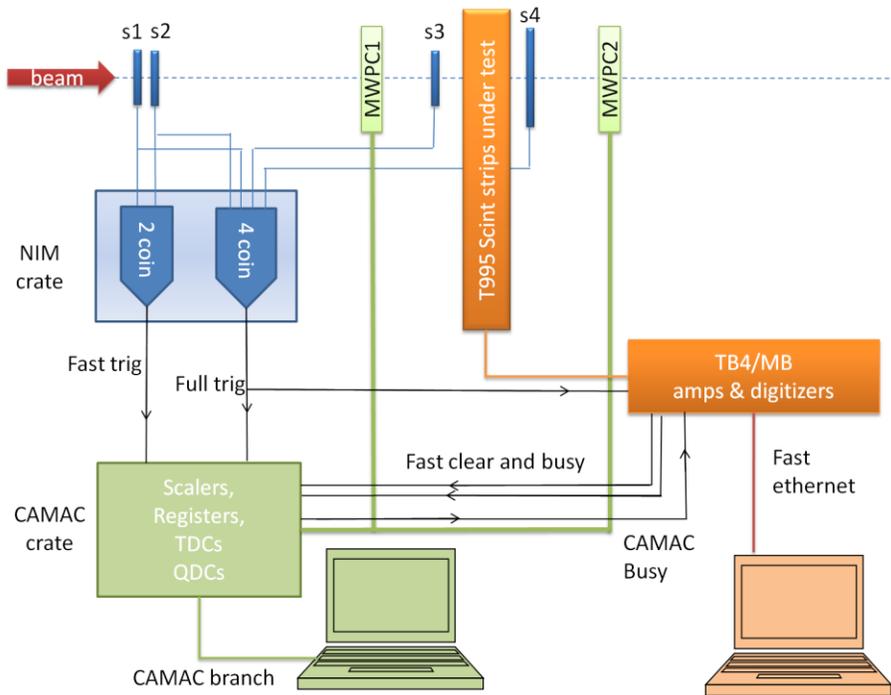


Figure 2 NIM and CAMAC logic diagram for T-995 trigger and DAQ operation.

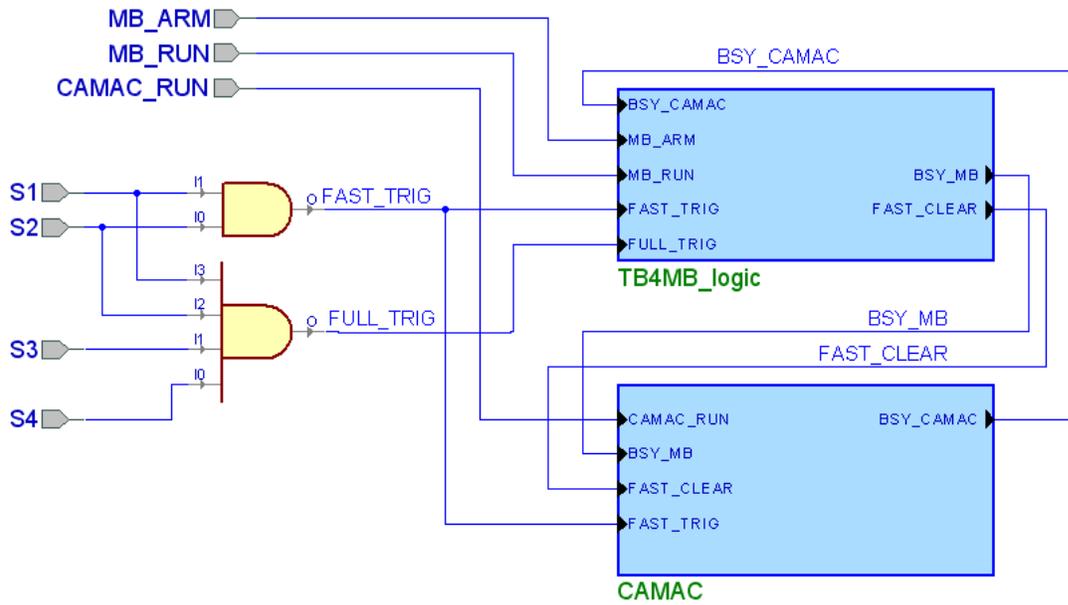


Figure 3. Logic diagram that will be implemented to simultaneously readout both the TB4 electronics and the Fenker beam PWCs.

Rack space, patch panels and cable tray space for 12 RG58 signal and 12 RG58 HV cables will be required from the “to be tested elements” into the counting room patch panels. Additional space may be required for the tracking system described above.

In addition, it is planned to try and incorporate the ‘CAPTAN’ pixel tracker readout simultaneously with the experiment and Fenker chamber readout. This will provide redundancy for tracking.

2.3.2 ELECTRONICS NEEDS

The number of channels for the scintillator tests is small: 2 channels corresponding to the two ends of each strip which would amount to fewer than 12 channels total.

When read out by the new in-house TB4 electronics, each channel carries both bias voltage and signal on a single RG58 signal cable. T-995 will therefore need cable tray space for 12 RG8 cables. Assuming that alternate conventional photomultipliers will be used occasionally for PPDs, 12 RG58 HV cables should be added to this number. Four RG58 signal cables and 4 RG58 HV cables will be needed for trigger counters. The maximum voltage on the RG58 HV cables will be 1000V (not including trigger counter PMT voltages).

Assuming each channel will be read out by in-house TB4 electronics which have 4 channels per card, 3 such cards will be needed that can be accommodated on a single VME mother board. Therefore at least 2 VME slots (one as a spare) will be needed in the counting room.

In-house TB4 electronics have on-board signal digitization, but ADCs will be required for instances in which MAPMTs will be used with readout electronics for comparison. A limited number (12 channels each) of ADCs and TDCs, as well as the corresponding CAMAC crate space should be sufficient for this purpose. The same CAMAC crate can accommodate scaler units which will be used to monitor rates and live times.

NIM crates with a complement of discriminators, coincidence units, gate generators and fast x10 PMT amplifiers will be needed for the beam trigger logic and for the conventional PMT readout of our test elements. A list of NIM and CAMAC units the experimenters expect to use is included in Appendix II.

2.4 DESCRIPTION OF TEST SETUP

After the apparatus to be tested (extruded scintillator strips) is mounted and aligned with support from FNAL, then T-995 will:

2.4.1 PERFORM TRIGGER SETUP

Set up and time-in trigger scintillators and Cerenkov detectors and configure the DAQ trigger.

2.4.2 DETERMINE OPERATING VOLTAGES FOR PIXELATED PHOTON DETECTORS

Determine bias voltage for the PPD detectors and optimize electronic parameters, e.g. discriminator thresholds, ADC gates for DAQ, etc.

2.4.3 SETUP TRACKING SYSTEM

Set-up and test the tracking system (Fenker MWPCs).

2.4.4 SETUP DUAL STREAM DAQ

Implement the dual stream data acquisition system that is indicated in Figure 3.

2.5 SCHEDULE

Based on previous experience, preliminaries will require ~10 shifts of 12 hours with access and beam control. After these preliminaries have been completed and a few data runs have been taken over a few days it should be possible to yield control of the beam and area to other experimenters and resume further measurements at short notice.

Typical runs will include:

- (a) Horizontal scans along scintillator extrusions;
- (b) Vertical scans at various horizontal positions of the extrusions.

Assuming horizontal tracking information step sizes for scans will be typically ~ 10 cm and

MOU for Scintillator-based muon detector / Tail catcher R&D at MTEST

remote position control of ~ 1.5 mm , an average trigger rate of 1 kHz and 300 K events per point, running for ~ 1 shift between accesses to move the apparatus, and on occasion to vary counter position and other configuration conditions. Ideal circumstances at this stage would see T-995 running for one 12 hour shift/day.

It is proposed that installation begin in January 2010 including both the equipment and electronics setups. After setup, T-995 may take beam as secondary users whenever it is available and there is sufficient manpower.

Measuring several short strips and the two long strips that we presently have available will probably take two calendar-weeks of shifts. Thus the total measurement process will likely take **three weeks with a fourth week as contingency**. This should probably be divided into two distinct periods with at least two weeks between the running periods to look at data and respond to possible needs.

III. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

([] denotes operating cost for the institution.)

- | | |
|---|-----------|
| 3.1 Indiana U.: MTest setup, shifts and testbeam analysis | [\$5K] |
| 3.2 No. Illinois Univ.: SiPM tests, Testbeam shifts, data analysis | [\$5K] |
| 3.3 U. of Notre Dame: strips assembly/optical coupling, testbeam shifts and testbeam data analysis. | [\$5 K] |
| 3.4 Wayne State U: Testbeam setup, shifts and data analysis; | [\$5K] |
| 3.5 INFN Trieste/Udine SiPMs/mech. support/optical couplings, MTest setup, shifts and analysis. | [\$15K] |
| 3.6 INFN Roma I MTest setup, shifts, analysis, SiPM tests. | [\$5K] |
| 3.7 INFN Padova/Ferrara MTest setup, shifts, analysis. | [\$5K] |

Total: \$45K

IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 Fermilab Accelerator Divisions:

- 4.1.1 Use of the MTest beam.
- 4.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.
- 4.1.3 Set up and maintenance of beam line MWPC's.
- 4.1.4 Scalers and beam counter signals should be made available in the counting house.

- 4.1.5 Connection to beams control console and remote logging (ACNET) should be made available in the counting house.
- 4.1.6 Experimenters access to T-995 equipment in the test beam should be assured.
- 4.1.7 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR).
- 4.1.8 Position and focus of the beam on the experimental devices under test will be under control of MCR. Control of secondary devices that provide these functions may be delegated to the experimenters as long as it does not violate the Shielding Assessment or provide potential for significant equipment damage.
- 4.1.9 The integrated effect of running this and other SY120 beams will not reduce the antiproton stacking rate or neutrino-beam flux by more than 5% globally, with the details of scheduling to be worked out between the experimenters and the Office of Program Planning.

4.2 Fermilab Particle Physics Division

- 4.2.1 The test-beam efforts in this MOU will make use of the Meson Test Beam Facility. Requirements for the beam and user facilities are given in Section 2. The Fermilab Particle Physics Division will be responsible for coordinating overall activities in the MTest beam-line, including use of the user beam-line controls, readout of the beam-line detectors, and MTest gateway computer. [0.5 person weeks]
- 4.2.2 Continuing development of the TB4 electronics/firmware by Paul Rubinov and Tom Fitzpatrick. This work is expected to be dove-tailed with similar development for MTest measurements by MINERvA.
- 4.2.3 LINUX box computing support as needed (J. Ormes).[0.5 person weeks if no significant problems are encountered.]
- 4.2.4 Implementation of the CAMAC/TB4 readout hardware and software. This effort is to be led by Erik Ramberg with help from Paul Rubinov. Their involvement will result in re-commissioning the “Fenker PWCs” with the logic displayed in Figure 3.
- 4.2.5 T-995 and MTest facility physicists will attempt to incorporate the CAPTAN pixel tracking system into the experiment DAQ. This effort should bring it into a status where it is routinely available at MTest. A concrete plan is to be developed and implemented in the next several months.

4.3 Fermilab Computing Division

- 4.3.1 Internet access should be continuously available in the counting house.
- 4.3.2 See Appendix II for summary of PREP equipment pool needs.
- 4.3.3 The CAPTAN pixel telescope will be available as a resource for use by members of the T995 collaboration. Engineers of CD/ESE will work with T995 collaborators to integrate the telescope into the timing and trigger architecture for the experiment prior to the beginning of data collection with the test beam. It is expected that a total of about 1 person-week would be needed prior to the data collection period.
- 4.3.4 A short training session on the use of the user interface for the telescope will also be provided by an ESE engineer.

4.3.5 The CAPTAN pixel telescope will be supported with a "best reasonable effort". This means that ESE personnel will make an honest attempt to resolve any difficulties that may arise during the operation of the telescope. ESE personnel will not be expected to be resident at the Meson Test facility during this time. However, if T995 members encounter difficulties with the telescope system, they may contact ESE personnel and ESE engineers will evaluate the problem. Depending on the nature of the specific problem, ESE engineers will work to resolve the issue.

4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.

4.4.2 Loan of radioactive source (preferably 1 mCi Cs¹³⁷) for the duration of the test beam.

V. SUMMARY of COSTS

Source of Funds [\$K]	Equipment	Operating	Personnel (person-weeks)
Particle Physics Division	\$15K	\$10 K	10.0
Beams Division	0	0	0
Computing Division	0	0	1.
Totals Fermilab	\$15.0 K	\$10K	11.
Totals Non-Fermilab		[\$45K]	

VI. SPECIAL CONSIDERATIONS

- 6.1 The responsibilities of the Spokespersons and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters": (<http://www.fnal.gov/directorate/documents/index.html>). The Spokespersons agree to those responsibilities and to follow the described procedures.
- 6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The Spokespersons will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer.
- 6.3 The Spokespersons of the collaboration will ensure that at least one person is present at the Meson Test Beam Facility whenever beam is delivered and that this person is knowledgeable about the experiment's hazards.
- 6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.
- 6.5 All items in the Fermilab Policy on Computing will be followed by the experimenters. (<http://computing.fnal.gov/cd/policy/cpolicy.pdf>).
- 6.6 The Spokespersons will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.
- 6.7 The experimenters will be responsible for maintaining both the electronics and the computing hardware supplied by them for the experiment. Fermilab will be responsible for repair and maintenance of the Fermilab-supplied electronics listed in Appendix II. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.
- 6.8 At the completion of the experiment:
 - 6.8.1 The Spokespersons are responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the Spokespersons will be required to furnish, in writing, an explanation for any non-return.
 - 6.8.2 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters unless removal requires facilities and personnel not able to be supplied by them, such a rigging, crane operation, etc.
 - 6.8.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied.
- 6.9 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters' Meeting.

SIGNATURES:

_____/ / 2010
Gene Fisk/Giovanni Pauletta, Spokespersons

_____/ / 2010
Michael Lindgren, Particle Physics Division

_____/ / 2010
Roger Dixon, Accelerator Division

_____/ / 2010
Peter Cooper, Computing Division

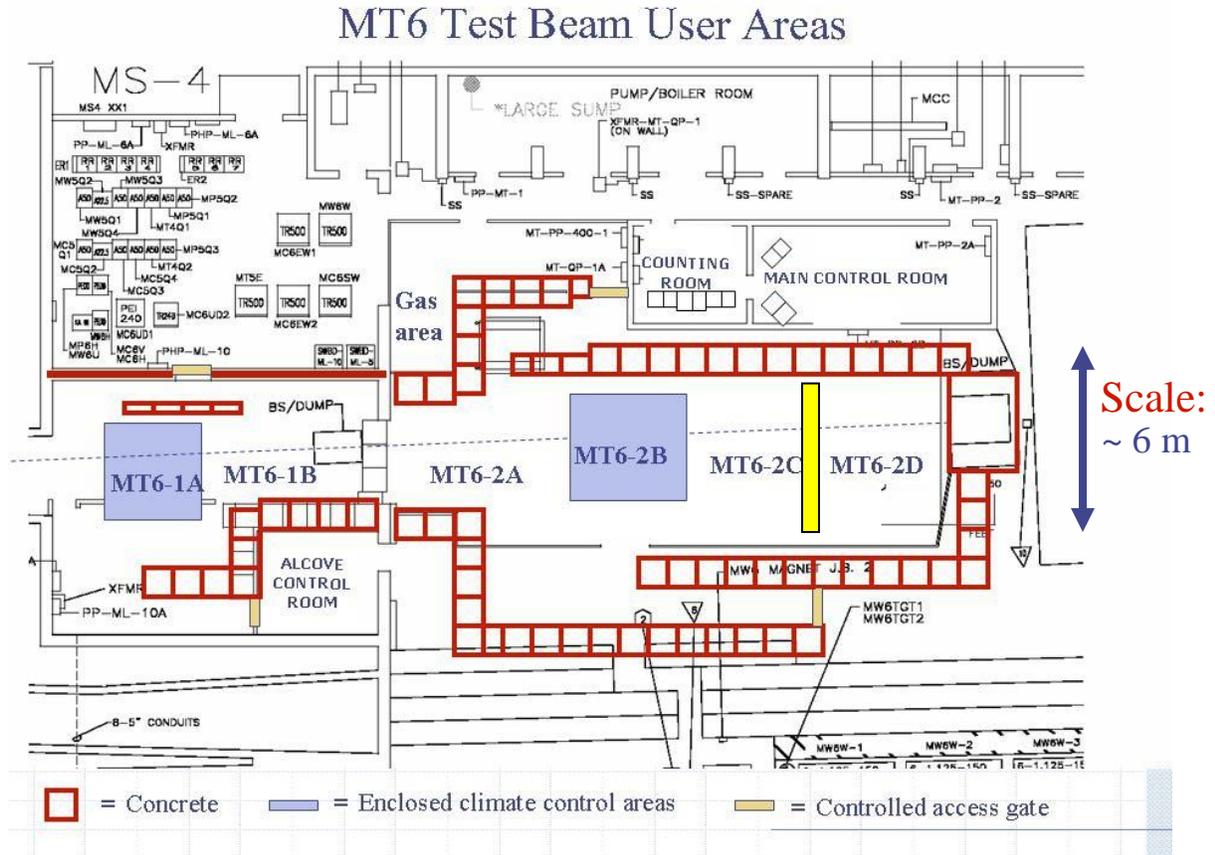
_____/ / 2010
Nancy Grossman, ES&H Section

_____/ / 2010
Greg Bock, Associate Director, Fermilab

_____/ / 2010
Steven Holmes, Associate Director, Fermilab

APPENDIX I MT6 TEST BEAM AREA LAYOUT

The T-995 apparatus will be located downstream of the MT6-2B area, bounded by the yellow rectangle.



MOU for Scintillator-based muon detector / Tail catcher R&D at MTEST

APPENDIX II: – EQUIPMENT NEEDS

Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup. Numbers in brackets [] are the numbers of units that the experimenters could move to MTEST.

Quantity Description

Equipment Pool Items:

3	NIM crates, with cooling fans [3]
1	CAMAC crate, powered [1]
3	CAMAC LeCroy 2249 ADC for 36 signals
8	NIM Octal discriminators LeCroy 623B [8]
4	NIM logic fan out LeCroy 429 [4]
6	Visual scaler channels with presets [6]
1	NIM 12-signal X-10 amplifiers LeCroy 612 or similar [1]
5	NIM quad-coin. 2-fold logic LeCroy 621/622 or similar [4]

Particle Physics Division Items:

12	TB4 FE electronics board and 3 mother boards
1	analogue oscilloscope Tektronix 485
10	SHV cables from detector to patch panel in MTEST [6]
10	SHV cables from MTEST patch panel to counting house
52	RG58 / BNC cables from scintillation counters to MTEST patch panel [have 64 32ns cables]
52	RG158 cables from MTEST patch panel to counting house
100	Lemo cables, various lengths [have ~50]

APPENDIX III - Hazard Identification Checklist

Items for which there is anticipated need have been checked

Cryogenics		Electrical Equipment		Hazardous/Toxic Materials	
	Beam line magnets		Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target	X	high voltage		
	Bubble chamber		exposed equipment over 50 V		
Pressure Vessels		Flammable Gases or Liquids			
	inside diameter	Type:			
	operating pressure	Flow rate:			
	window material	Capacity:			
	window thickness	Radioactive Sources			
Vacuum Vessels			permanent installation	Target Materials	
	inside diameter	X	temporary use		Beryllium (Be)
	operating pressure	Type:	CS137		Lithium (Li)
	window material	Strength:	3 mCi		Mercury (Hg)
	window thickness	Hazardous Chemicals			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
X	Permanent installation		Scintillation Oil		Uranium (U)
	Temporary installation		PCBs		Other
	Calibration		Methane	Mechanical Structures	
X	Alignment		TMAE		Lifting devices
type:			TEA	X	Motion controllers - remote
Wattage:			photographic developers		scaffolding/elevated platforms
class:			Other:		Others

Bibliography

-
- ¹ P. Rubinov, (2009, October 2). *2009 Linear Collider Workshop of the Americas*.
<http://ilcagenda.linearcollider.org/getFile.py/access?contribId=333&sessionId=22&resId=1&materialId=slides&confId=3461> This Fermilab-developed circuitry is referred to as TB4 electronics.
- ² R. Abrams et al. LC Scintillator-based muon detector tail-catcher R&D, FERMILAB-CONF-07-589-E, LCWS-2007-CAL14, Nov 2007. 5pp. Presented at 2007 International Collider Workshop (LCWS07 and ILC07), Hamburg, Germany, 30 May – 3 Jun 2007. *In the Proceedings of 2007 International Linear Collider Workshop (LCWS07 and ILC07), Hamburg, Germany, 30 May - 3 Jun 2007, pp CAL14*. Also in *Hamburg 2007, LCWS/ILC 2007* 590-594
- ³ K. Andert et al. *Como 2005 Proceedings, Astroparticle, particle and space physics, detectors and medical physics applications* p 389-394. URL-str(9) Villa Erba, Como, Italy, 17-21 Oct 2005.