FERMILAB-PROPOSAL-1004

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Fermilab

Directorate

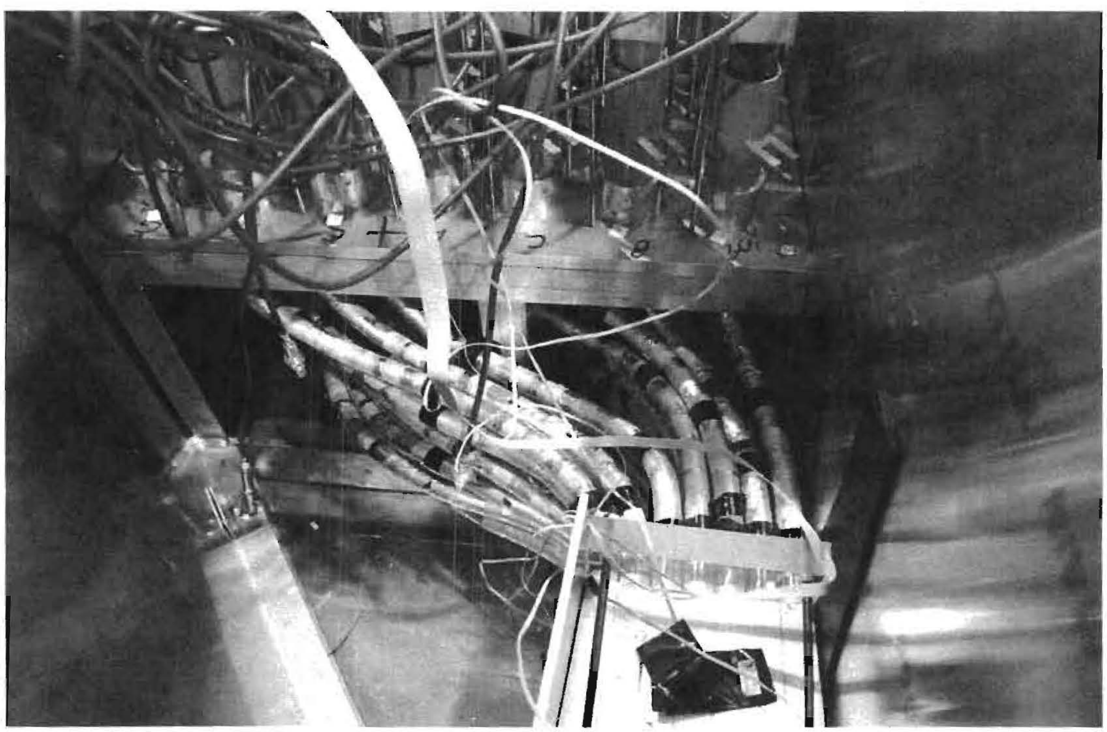
MEMORANDUM OF UNDERSTANDING

FOR THE 2010 MESON TEST BEAM PROGRAM

T-1004

Total Absorption Dual Readout Calorimetry R&D

10 March, 2010



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INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory and experimenters from Fermilab, Caltech, University of Iowa, Argonne National Laboratory, Fairfield University, CERN, INFN Trieste/Udine, INFN Roma I, Shinshu University and the University of Cyprus who have committed to participate in beam tests to be carried out during the 2009/2010 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 tests have the objective to continue the development of elements and techniques related to total absorption dual readout calorimetry.

Until this time, the R&D program has focused on simulations and tests using cosmic rays. The purpose of the program outlined here is to continue this work using particle beams to accelerate the process and to subject the counters and readout electronics to operating intensities and backgrounds with well-defined beam conditions and/or tracking of incident particles. The work will use new prototype electronics developed at Fermilab[1] which will lead to the assembly of future large-scale integrated systems, which may be the subject for a future proposal. For the purpose of this work, the T-1004 experimenters will require limited space and resources and need not always have control of the beam.

Dual Readout Calorimetry

The calorimetry R&D will focus on establishing a proof of concept for totally active hadron calorimetry[2,3]. The initial studies will involve single (or, at most, a few) crystal or glass samples as a continuation and acceleration of on-going work using cosmic-ray muons. The purpose of these studies is to evaluate the performance of the different crystal and glass samples in combination with different light collection and readout alternatives to optimize simultaneous collection of Cerenkov and scintillation light components for application of the Dual Readout technique to total absorption calorimetry. To determine the correlation of the light collection efficiency with the parent particle trajectory a tracking system will be required to determine the path of particles through the crystal/glass sample. Crystals will be equipped with various optical filters to study the separation of Cherenkov and scintillation light capability via the wavelength separation. Several photo-detectors will be placed in different positions on the crystal sides to investigate the angular and position dependence of the collected light. The typical experimental setup is shown in Fig. 1.

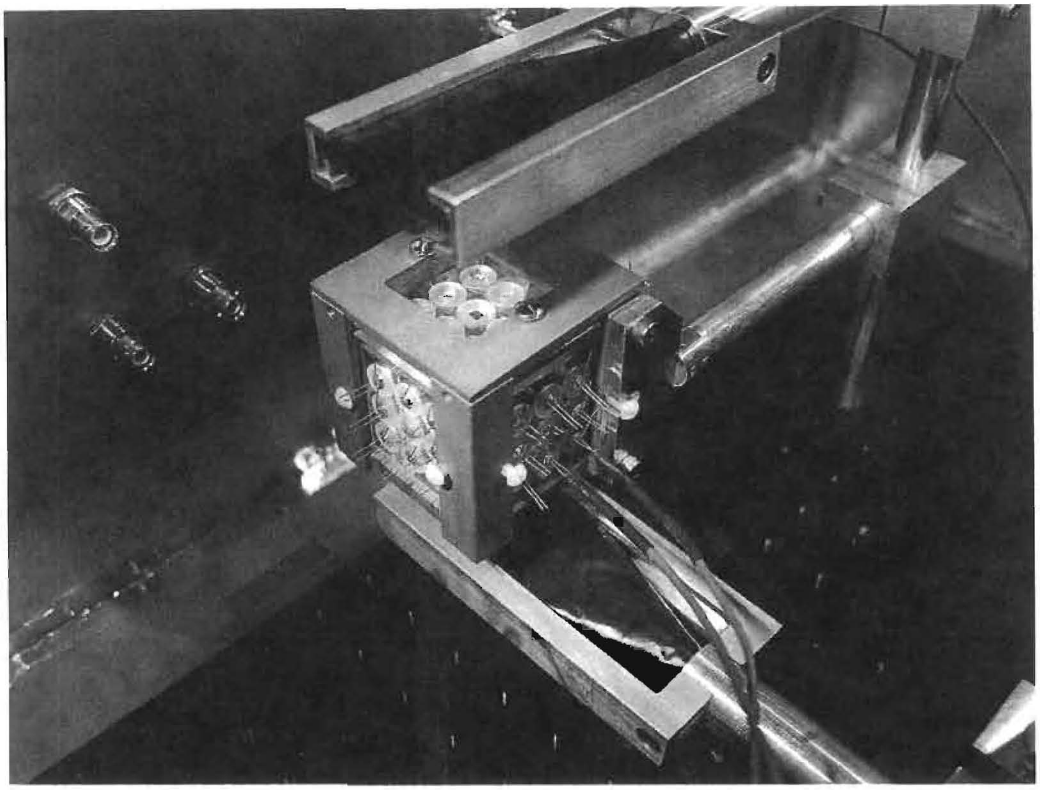

Fig. 1 Scintillating crystal equipped with optical filters and several photo-detectors

The experiment plans to investigate several possible photo-detectors:

- Hamamatsu 1 x 1 mm^2 devices with 100μ, 50μ and 25 μ pixels sizes
- Hamamatsu 3 x 3 mm^2 devices with 50μ pixel size
- IRST 1 x 1 mm^2 devices with 40μ pixel size
- IRST 4 x 4 mm^2 devices with 40μ pixel size

The optical couplers are designed to allow an arbitrary choice of the photo-detectors and any mix of them.

The photo-detectors will be read out using the latest generation of the Fermilab TB4 boards designed explicitly for calorimetry applications. Four motherboards with four daughter cards each, see Fig. 2, will provide 64 channels of waveform digitizers. In addition to the overall response of various detectors, the experiment will study the timing characteristics of the produced signal, in particular to investigate the Cherenkov and scintillation light separation using the temporal characteristics. These studies will be carried out using a high rate segmented memory digital oscilloscope, Agilent 7054, with the data readout out over the Ethernet link.

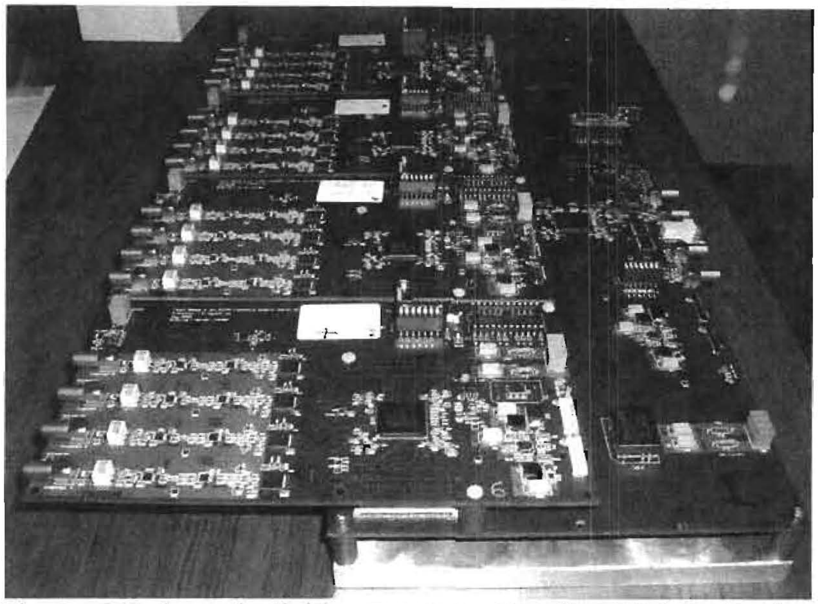

Fig. 2 32-channels digitizers system using four TB4 readout boards

The optimal location of the crystal and the associated electronics is the housing of the silicon pixel hodoscope in the MT6-1A or 1B area. One of the pixel telescopes would be used to provide the information about the beam particle position. It would be highly desirable to have a remotely controlled translation and rotation stage inside the housing. The desired travel range is of the order of 5 cm translation and 45 degrees rotation. An important requirement for this test would be a light-tightness of the entire housing. It is envisaged that various samples of crystals and photo-detectors will be studied, as the R&D process advances.

Hadron and electrons beams, in addition to muons, will be used to investigate the characteristics of scintillation and Cherenkov light produced by various particles.

The angular distribution of Cherenkov light produced in the hadronic shower is one of the very important questions that need to be addressed. The studies will be conducted by placing a crystal equipped with photo-detectors on all sides enclosed in a steel block of varying thickness. The resulting assembly is unlikely to fit into the pixel hodoscope housing and will be carried out in the MT6-2B or MT6-2C area (see Fig in Appendix I).

In addition to single crystal studies the experiment plans an exposure of several electromagnetic crystal calorimeters to investigate the issues associated with larger systems, to establish and check the calibration procedures and to evaluate various potential crystal samples. These will be larger and heavier assemblies that will be carried out in the MT6-2B or 2C area.

The initial set of studies will involve detailed studies of the electromagnetic calorimeter consisting of $PbWO_4$ crystals constructed by the University of Iowa for the CMS test beams exposure. The experiment plans several steps of these studies:

1. Re-assemble the calorimeter in a 7 x 7 crystal matrix, using the PMT's as photodetectors and verify that the performance is consistent with that obtained in CMS studies.

This test will be performed with the narrow momentum bite electron beam directed along the crystal axis. The electromagnetic shower will be contained in a very few crystals and the relative calibration of crystals can be derived from the data itself.

2. Relative calibration of crystals is a serious issue in a longitudinally segmented crystal calorimeter. T-1004 experimenters will try to cross-calibrate various crystals using cosmic ray muons. A very sensitive test of the calibration procedure will be performed by exposing the crystal matrix rotated by 90 degrees, hence spreading the shower energy depositions over a large number of crystals.
3. Photomultipliers provide a baseline performance, but they are not viable photo-detectors for a segmented hadron calorimeter. T-1004 experimenters will investigate the performance of the calorimeter equipped with silicon photo-detectors by adding a SiPM to every crystal. This will allow for a direct comparison of a device equipped with different photo-detectors and will allow studies of various systematic effects inherent with the silicon photo-detectors (e.g. signal saturation).

Electromagnetic calorimeters are expected to provide spatial information and two-photon separation information in addition to the energy measurement. The experiment will investigate the potential of the segmented crystal calorimeter by constructing a matrix of crossed (X-Y) crystals and by placing several layers of silicon detectors (provided by INFN Trieste) at several depths of the calorimeter.

The second phase of the studies will involve construction and operation of segmented electromagnetic calorimeters constructed from different crystals: $PbWO_4$, BGO and PbF_2 to test/demonstrate the energy resolution and the response uniformity. In particular, the results of the initial phase of the studies will be used to design the final method of separation of Cherenkov and scintillation light and to establish an adequate calibration procedure for both readout channels. Comparison of the response and the energy resolution obtained with dual readout crystals, like BGO, with those obtained with a pure Cherenkov radiator, like PbF_2, will provide a test of the quality of the separation of the components of light.

The first part of the program involving the PMT photodetectors will require 49 channels of HV and the corresponding number of CAMAC ADC channels. Measurements involving the SiPMs will be carried out using four motherboards with the total of 13 TB4 cards.

It is expected these tests will lead up to assembly of a full size (~ 1 m^3) calorimetry module, complemented by a muon detector/tail catcher, for an unambiguous test of the dual readout technique in total absorption calorimetry which will be the subject of a future proposal.

I. Personnel and Institutions:

Spokesperson and physicist in charge of beam tests:	Adam Para
Fermilab liaison:	Aria Meyhoefer

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

Institutions	Collaborators	Other commitments
1.1 Fermilab	Mike Crisler	COUPP
	Gene Fisk	D0
	Adam Para	
	Erik Ramberg	COUPP
	Paul Rubinov	MINERvA
	Hans Wenzel	
1.2 Caltech	Rihua Mao	CMS
	Liyuan Zhang	CMS
	Ren-yuan Zhu	CMS
1.3 University of Iowa	Yasar Onel	CMS
	Ed Norbeck	CMS
1.4 Argonne National Laboratory	Steve Magill	ATLAS
1.5 Fairfield University	Dave Winn	
1.6 CERN	Paul Lecoq	CMS
	Etiennette Auffray	CMS
	Georgios Mavromanolakis	CMS
1.7 INFN Triese/Udine	Walter Bonvicini	PAMELA, FACTOR
	Diego Cauz	CDF
	Anna Driutti	
	Giovanni Pauletta	CDF, FACTOR
	Aldo Penzo	CMS, FACTOR
1.8 INFN (Roma I)	Maurizio Iori	CDF
1.9 Shinshu-University	Tohru Takeshita	CALICE
1.10 University of Cyprus	Photios Ptochos	CDF

II. Experimental Area, Beams and Schedule Considerations

2.1 Location

2.1.1 Investigations of single crystals involve a very small setup which can be located at any location. The principal requirement is that of the knowledge of the incoming beam position with the accuracy better than 1 mm. If a silicon pixel telescope is available for the experiment then the MT6-1A or 1B is the preferred location, but the studies can be also carried out in the MT6-2B or 2C area with an MWPC tracker.

Studies of the electromagnetic calorimeter involve somewhat larger and heavier object. The approximate volume is about 1 m^3 and the total weight is about 100 kg. The requirements of the knowledge of the incoming beam particle position are the same as in the case of the single studies. These studies can be carried out at in the MT6-2B or 2C area.

2.2 Beam

2.2.1 Beam Types and Intensity

Type of beam needed:

Studies of the single crystals will require beams of hadrons, electrons, and muons over the available energy range. No particular requirements regarding momentum resolution are necessary.

Intensity Needed: 1-10 KHz

Investigations of the electromagnetic calorimeters modules will be carried out with electrons or positrons at a few different energies over the available range. The beam energy and its spread should be kept ~~below 1%.~~ as low as possible

Intensity Needed: 1-10 KHz

Size of Beam needed: A small spot size of the order of few cm^2 is preferred.

2.2.3 Beam Sharing

On one hand, the detectors studied are very simple and it is expected that the setup time should not exceed a couple of hours in the worst case. On the other hand, the exploratory nature of the studies may require significant analysis effort to develop or optimize the data taking strategy. Given the limited manpower and other commitments, it is preferred to alternate beam time with other users or, to the degree that it is compatible with other users requirements, to share the beam.

The material in the beam is dominated by the crystals under study would vary between a minimum of 5 cm and a maximum 30 cm of crystal. This represents from ¼ to about 1 interaction length. The number of radiation lengths presented by crystals is too large to make an electron beam usable downstream of the T-1004 setup. When this amount of material is not compatible with other users, the test setup could be moved out of the beam on a short notice.

2.3 Experimental Conditions

2.3.1 Area infrastructure

The test setup will be enclosed in a light-tight box with the approximate dimensions of 30 x 30 x 60 cm^3 and a total weight of 10 kg for a single crystal and 100 x 100 x 60 cm^3 and a total weight of 150 kg for a electromagnetic calorimeter. The experimental setup should be supported on a remotely controlled moveable table with the overall travel distance of the order of 20 cm. In addition it is desired that the support table can be rotated in a horizontal plane by $\pm 90^{\circ}$.

Trajectories of individual beam particles should be determined by a tracking system with the precision of the order of 1 mm or better. It is envisioned that small scale crystals can be tested in conjunction with the pixel detector system in section 1. Larger scale efforts will reside on one of the motion tables in section 2, with tracking provided by the MWPC system.

The beam Cherenkov will be required to tag particle species.

Rack space, patch panels and cable tray space for 63 RG58 signal and 63 RG58 HV cables will be required in the proximity of the test elements.

An Ethernet connection in the experimental enclosure for the digital oscilloscope used to acquire the waveforms and for the data acquisition computer will be necessary.

Corresponding patch panel space will be needed in the counting room

2.3.2 Electronics needs

The single crystals will be read out by silicon photodetectors, up to 9 photodetectors per side, thus making a total number of channels up to 54. The bias voltage and the signals will be carried on a single RG58 signal cable per channel.

The initial crystal array will be read out by 49 phototubes, thus requiring 49 RG58 HV cables and 49 RG58 signal cables. The same signal cables can be used for both the single crystal and the crystal array if both setups are placed in the same enclosure. At the later stages the crystal array will be reconfigured to 7 x 9 configuration, thus making the number of cables required, signal and HV, to be 63 each.

The signals from the silicon photodetectors will be digitized in the experimental enclosure using the TB4 boards and transmitted over the Ethernet link. In a similar manner the wave-forms digitized with the Agilent digital scope will be transmitted over the Ethernet link.

The HV required for the PMT's will not exceed 1700V.

A total of 63 channels of ADCs plus spares, as well as the corresponding CAMAC crate space, will be necessary to digitize the PMT signals. 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 required by the experiment is included in Appendix II

2.3.3 Description of Tests

The crystal setups and the corresponding readout electronics will be thoroughly tested and commissioned using the cosmic-ray muons. The primary effort in the commissioning phase is expected to be that of the alignment, set-up of the beam trigger scintillators, Cherenkov counters and the tracking system. This initial period may take up to ~5 days.

The experimental studies will typically include position and angular scans with a selected beam conditions with a typical acquired data from of the order of 100,000 beam particles per point, 5 positions and angles of incidence at given beam conditions. It is expected that no access to the detector will be necessary between the different runs, once the commissioning phase is successfully finished except possibly for angle changes if this is not automated for remote control.

2.4 Schedule

The experimental setups are nearing completion. It is expected that a thorough debugging and commissioning can be completed by the end of January, and that the test beam studies of the initial crystals configuration can start in February. As more crystals, of different dimensions and compositions will be acquired, the beam tests will continue accordingly.

Total requested beam time is 2 weeks in FY2010.

III. Responsibilities by Institution - Non Fermilab

([ ] denotes operating cost for the institution.)

3.1 Iowa U.:

Lead tungstate crystals, PMT's and support structure, shifts and data analysis [$50 K]

3.2 Argonne:

photomultipliers and bases, shifts, data analysis [$15K]

3.3 INFN Trieste/Udine

silicon photodetectors, shifts and data analysis [$10K]

Total: $75K

IV. Responsibilities by Institution – Fermilab

4.1 Fermilab Accelerator Division:

4.1.1 Use of 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 Scalers and beam counter signals should be made available in the counting house.

4.1.4 Reasonable access to the equipment in the MTest beamline.

4.1.5 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR).

4.1.6 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.

4.1.7 The integrated effect of running this and other SY120 beams will not reduce the antiproton stacking rate and the neutrino 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:

4.1.8 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]

4.1.9 Set up and maintenance of tracking MWPC's and provide help to incorporate them into the experiments DAQ and trigger system. [0.5 person weeks]

4.1.10 Provide assistance in incorporating the BTeV pixel telescope into the experiments DAQ and trigger architecture, if needed. [0.5 person weeks]

4.3 Fermilab Computing Division

4.3.1 Internet access should be continuously available in the counting house.

4.3.2 Assistance in incorporating the CAPTAN pixel detector readout system into the experimental architecture, if needed. [0.5 person-weeks]

4.3.3 DAQ LINUX box computing support as needed (mtbf.fnal.gov computer). [0.5 person weeks]

4.3.4 See Appendix II for summary of PREP equipment pool needs.

4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.

4.4.2 Loan of radioactive source (preferably 1 mCi Cs^{137}) 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	1.5
Beams Division	0	0	0
Computing Division	0	0	1
Totals Fermilab	$15.0 K	$10K	2.5
Totals Non-Fermilab		[$75K]	

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 will ensure 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.

VII. Bibliography

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2. High Resolution Jet Calorimetry:Total Absorption Homogeneous Calorimeter With Dual Readout, Adam Para, TILC09, http://ilcagenda.linearcollider.org/getFile.py/access?contribId=104&sessionId=24&resId=1&materialId=slides&confId=3154

3. Physics Principles Of High Resolution Jet Calorimetry, Adam Para, Krzysztof Genser, Hans Wenzel, http://ilcagenda.linearcollider.org/materialDisplay.py?contribId=296&sessionId=12&materialId=slides&confId=3461

SIGNATURES:

3 / 17 / 2010
Adam Para, Spokesperson

3 / 17 / 2010
Michael Lindgren, Particle Physics Division

3 / 19 / 2010
Roger Dixon, Accelerator Division

3 / 17 / 2010
Peter Cooper, Computing Division

3 / 18 / 2010
Nancy Grossman, ES&H Section

3 / 19 / 2010
Greg Bock, Associate Director, Fermilab

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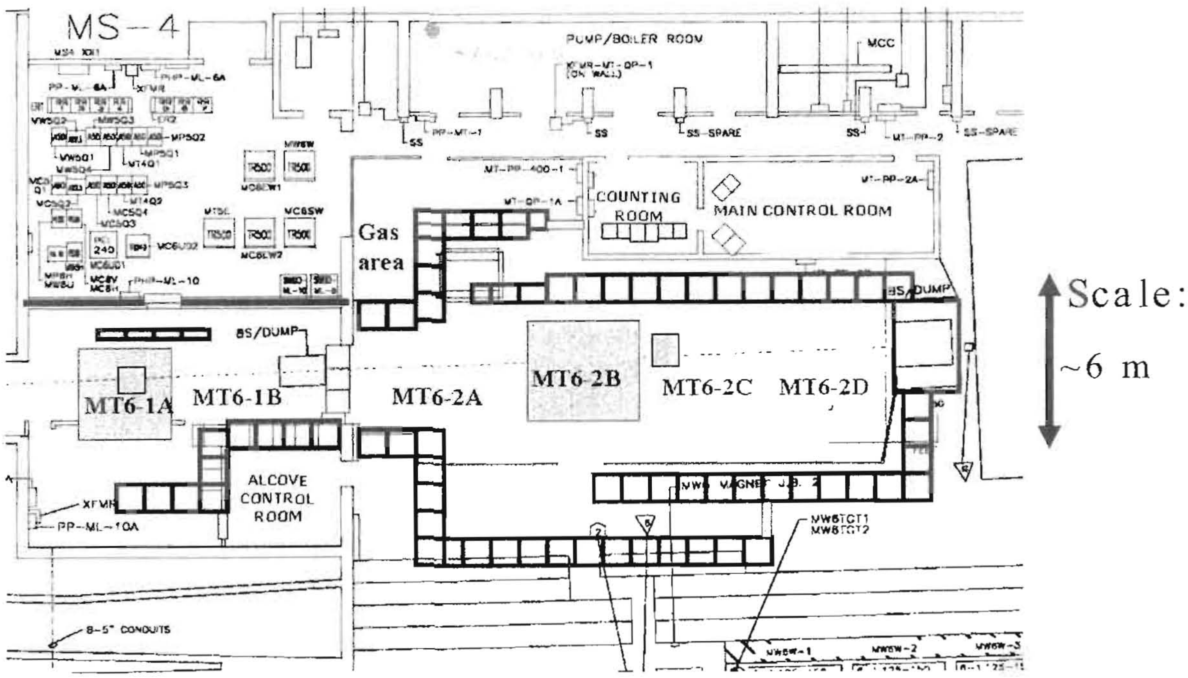
Steven Holmes, Associate Director, Fermilab

APPENDIX I: MT6 AREA LAYOUT

The T-1004 apparatus will be located in either the MT6 Section 1A area, or downstream of the MT6 Section 2-B area, bounded by the yellow rectangle.

MT6 Test Beam User Areas



= Concrete = Enclosed climate control areas = Controlled access gate

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 currently in Lab 6, and could move to MTEST.

Quantity	Description
T-1004	
12	TB4 FE electronics board and 3 mother boards
PREP	
6	NIM crates, with cooling fans [3]
1	CAMAC crate, powered [1]
4 6	Camac LeCroy 2249 ADC for 63 phototube signals (or 3 LeCroy 4300 FERA) [2249s with several dead channels]
3	16-channel LeCroy 4616 or equivalent 16-channel NIM-ECL translator/adapter [1]
12	NIM Octal discriminators LeCroy 623B [1]
15	NIM logic fan out LeCroy 428/429 [2]
6	Visual scaler channels with presets [4]
2	NIM gate generators Philips 794 or similar [2]
4	NIM 12-signal amplifiers LeCroy 612 or similar [1]
12	NIM quad-coin. 2-fold logic LeCroy 621/622 or similar [4]
2	NIM quad discriminators, LeCroy 821 or equivalent [5]
24	NIM dual delay modules to delay the 48 SiPM signals to the ADCs [2]
2	HV supplies for Scintillation counters utilizing PMTs and dividers (up to 2500V)
1	1 digital oscilloscope [1 each]
PPD	
63	SHV cables from detector to patch panel in MTEST [6]
63	SHV cables from MTEST patch panel to counting house
63	RG58 / BNC cables from scintillation counters to MTEST patch panel [have 64 32ns cables]
63	RG158 cables from MTEST patch panel to counting house
100	Lemo cables, various lengths

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	X	Lifting devices
type:			TEA	X	Motion controllers - manual
Wattage:			photographic developers		scaffolding/elevated platforms
class:			Other: Activated Water?		Others