Fermilab

Directorate

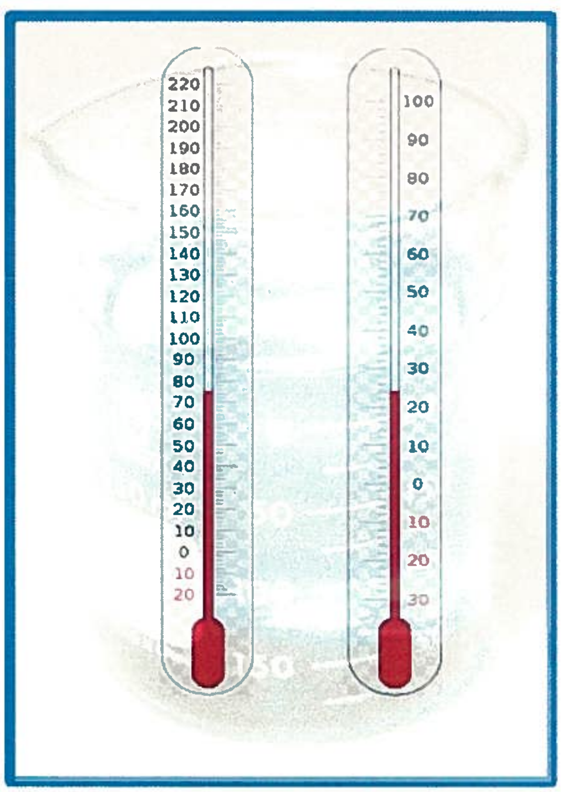
# MEMORANDUM OF UNDERSTANDING

# FOR THE 2011 – 2012 FERMILAB TEST BEAM FACILITY PROGRAM

## T-1015

## Dual Readout Calorimetry with Glasses

**June 23, 2011**



# TABLE OF CONTENTS

## INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters from Fermilab, INFN Trieste/Udine, and INFN Lecce, who have committed to participate in beam tests to be carried out during the 2011 – 2012 Fermilab Test Beam Facility program.

The memorandum is intended solely for the purpose of recording expectations for budget estimates and work allocations 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 modify this memorandum to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

### *Research Program: Long Term Objectives*

The ultimate objective of the research outlined in this document is that of testing the potential of Dual Readout (DR) hadron calorimetry ([1], [2]) when applied to calorimeters with totally active absorbing media [3]. As such, it overlaps with that of experiment T-1004. However, the program outlined below focuses on the use of glasses, and, because a supply of potentially suitable scintillating glasses is already present at the laboratory [4], it could be possible to perform a "proof of principle" test of Total Absorption Dual Readout (TADR) calorimetry in a relatively short time and at reduced cost. New scintillating glasses, are also being developed and could eventually be substituted for the currently available ones.

At the same time, a new technique (ADRIANO – see below) has been proposed which employs glasses designed to act as a totally active absorbing medium for the Cerenkov component, and as the passive (sampling) medium for the scintillation component of a DR calorimeter. These glasses are presently being developed, with the support of the INFN, at the University of LECCE.

The development and application of Silicon Photomultipliers (SiPM) [5] for light collection and amplification, and of the associated frontend electronics [6] is an important element of the program which was initiated in the course of T-956, T-995 and T-1004 and which will be continued here. Other potentially suitable photodetectors and frontend electronics will also be investigated.

The use of plastic scintillator, to detect and/or correct for leakage from the calorimeter components will be an integral part of the strategy and this will afford an occasion to continue the tests of scintillator strips, extruded at FNAL for the construction of tail-catcher/muon detector/veto counter components initiated in T-956 and T-995.

Given the resources available, the time until the shutdown in 2012 will barely be sufficient to verify the properties of the existing glass, to begin testing those of the new glasses and to develop the associated readout and tail-catcher elements. If the results obtained support them, future plans for the assembly of prototype calorimeter module will benefit from the shutdown period and be the subject of a future MOU.

*Calorimetry with SGC1-C scintillating glass*

The SGC1-C scintillating glass developed for Exp. 705 has properties which appear to be suitable for our purpose:

| | |
|---|---|
| Ratio of Cherenkov to scintillation signal C/S | 40/60 |
| Scintillation decay time | 70 ns |
| Refraction index | 1,61 |
| Radiation length | 4,25 cm |
| Interaction length | 45,6 cm |
| Density | 3,36 g/cm³ |

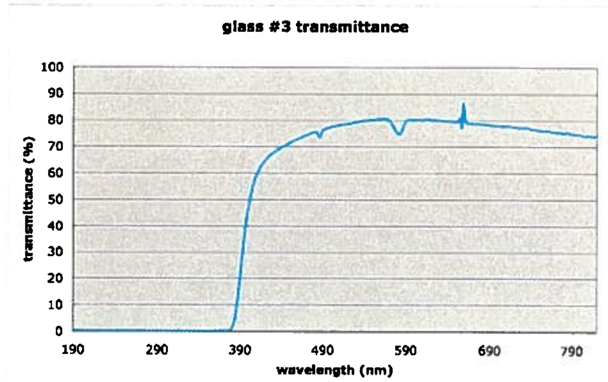



Figure 1: Measured transmittance (%) vs. wavelength in nm.

The decay time of the scintillation signal, whose properties are due to the Cerous oxide ($Ce_2O_3$) dopant, is adequately fast for background and pile-up rejection and long enough for the scintillation component to be separable from the Cerenkov component with state – of – the art electronics, while the ratio of scintillation to Cherenkov light is by far inferior to that of BGO crystals, where it is so large as to be overwhelming. The obvious drawback of this glass, as opposed to the heavier crystals is the smaller density and longer interaction length, which renders it unsuitable for use in compact collider detectors, where interaction lengths of ~ 20 cm are barely sufficient for adequate containment. However, this drawback does not prevent it from being used for a test of the TADR concept in test beam conditions where such space limitations do not exist, providing enough glass is available to ensure adequate containment.

On the basis of the E705 inventory, there should be 74 "large" (15 x 15 x 89 $cm^3$) and 212 "small" glasses (92 of dimensions 7.5x7.5x89 $cm^3$ plus 120 of dimensions 7.5x7.5x97.5 $cm^3$). A survey in the storage location found all of the 74 large glasses but only 161 of the smaller ones. Some of the glasses may be damaged. All of them need to be cleaned and refurbished.

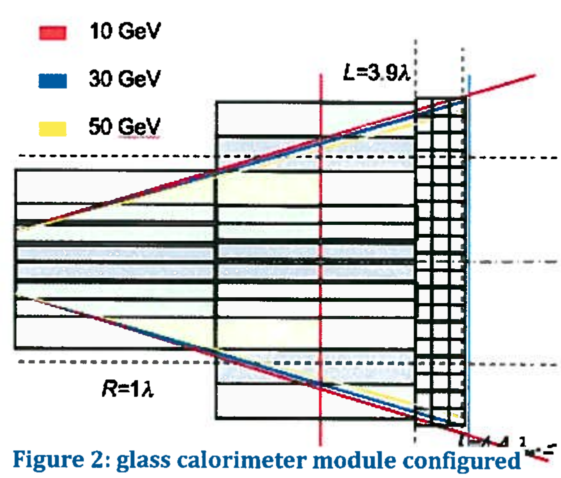



Figure 2: glass calorimeter module configured to contain 95% of the hadron shower, both laterally and longitudinally, up to 30 GeV

Assuming 90% (5% lateral leakage and 5% longitudinal) to be an acceptable level of containment and published containment evaluation methods to be reliable, this "glass budget" could be used, as illustrated in fig. 2, to construct a test module capable of containing hadronic showers, at an acceptable level, up to ~ 30 GeV. The colored lines represent 95% containment limits at different energies: for 95% lateral (inclined blue lines) and 95% longitudinal (blue vertical line) containment at 30 GeV, a volume corresponding to the blue truncated cone, whose base coincides with the limit of our array, is required. 72 of the larger glass elements (out of a total of 74) and 144 of the smaller ones (out of a total of the 161 identified) are required for this configuration. One could obtain better lateral containment by cutting some glasses. For further detail regarding the SGC1 – C glasses and how they might be assembled to constitute a prototype calorimeter module, see ref [7].

The characteristics of some of these glasses have been verified using cosmics as illustrated in figure 3 where the response of two photomultiplers, to the passage of cosmic muons is summarized (for further details, please refer to [8]). The signal from the (black) Hamamatsu PMT, viewing the right-hand extremity of the glass, at an angle relative to the center of the track which corresponds to the Cherenkov angle, shows clear evidence of the Cerenkov component whereas the signal from the (blue) EMI PMT, at the other end, is dominated, as expected, by the slower scintillation component. These measurements are consistent with the properties listed in table 1 and give an indication of the Cherenkov (C) and Scintillation (S) light intensities generated by a minimally ioninizing particle (mip). Exposure to particle beams is necessary to establish their relative intensities for electrons and hadrons. Given that, judging from our light transmission measurements illustrated in figure 1, the wavelength spectrum of detectable Cerenkov light overlaps that of the scintillation component, the difference in timing characteristics of these two signals will be the only means of differentiating between them.

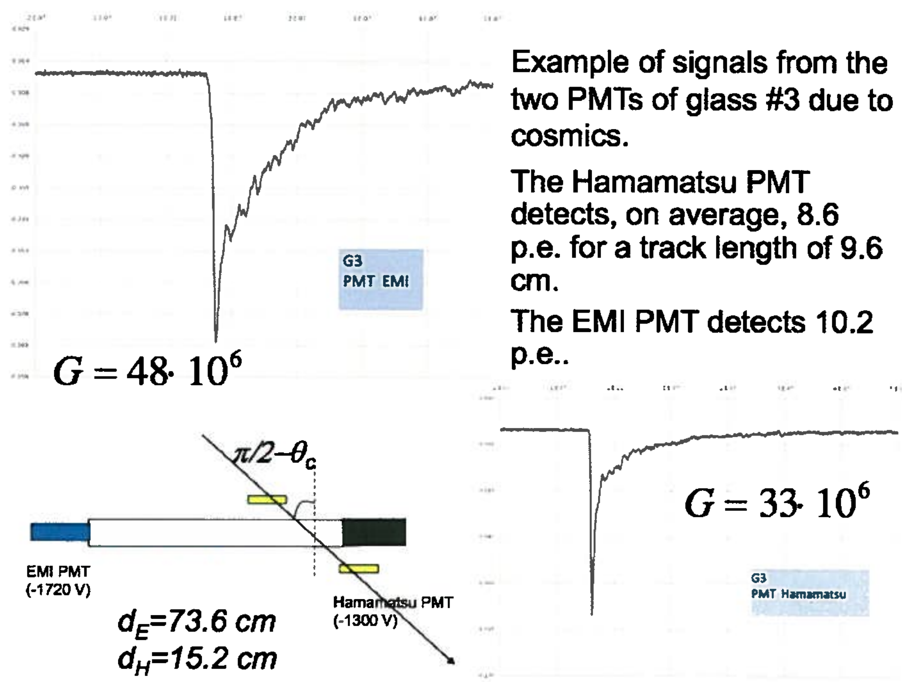



**Figure 3: The response of EMI (on the left) and Hamamatsu (on the right) PMTs to cosmic muons as measured by a CRT (time scale: 20 ns/div). Measured PMT Gains (G) are indicated.**

On these premises, the experimenters propose the test beam activity for the forthcoming year to be dedicated to the exposure of single glass elements to electrons, pions (and, possibly, muons) with the purpose of measuring the C/S ratios for electrons and pions, optimizing light collection (photodetection and optical coupling) and DAQ (frontend electronics) and establishing algorithms for separating the C and S signal components.

At the same time, one would develop detectors (plastic extrusions) for leakage correction.

If these preliminary objectives are achieved, one could then envisage assembly of a calorimeter module during the shutdown and its test when beam returns. This would be the subject of a new MOU.

Assembly of a calorimeter module would involve a substantial amount of work to refurbish the glass samples presently in storage and, given expected non – uniformities in the response of the SGC1 glasses, this would have to include a glass-by-glass measurement of response using cosmic muons.

*ADRIANO*

ADRIANO methodology has been extensively studied with Monte Carlo simulations using ILCroot framework with Geant4 and Fluka as transport back-end. The details implemented in the simulation will be described in an article soon to appear: they intend to make the results as realistic as possible, include such effects as the mechanisms of light production, propagation and collection in the various media, electronic signal generation and readout.

A list of the most relevant effects taken into account in ILCroot simulation is listed below:

1) Shower production in a medium of known A, Z and density by a relativistic particle;
2) Cerenkov light production by radiation in a medium with highly dispersive refractive index. The Sellmeier dispersive equation is adopted in this case.
3) Cerenkov light propagation in ADRIANO cells with glasses with highly wavelength dependent attenuation length;
4) Collection of Cerenkov light by WLS fibers contained in grooves, with optical coupling via optical glue;
5) Light production and propagation in scintillating fibers of known numerical aperture and attenuation length;
6) Saturation effects of scintillating fibers via Birks mechanism;
7) Effects of coupling of scintillating and WLS fibers to SiPM;
8) SiPM QE as a function of photon wavelength
9) ENF of SiPM's
10) Constant electronic noise
11) Limited resolution of a 10 bit ADC
12) Effect of a 3pe threshold for the front end electronics.

The effects listed above are mostly known by measurement by other experimenters. Their results have been used either AS IS or extrapolated to the conditions of ADRIANO. They are implemented as multiplicative constants in the ILCroot simulations. A total of twelve such constants appear in the simulation, the most critical being those related to the propagation of the Cerenkov light in the glass, the collection, absorption and emission efficiency of the WLS fibers and the optical coupling of the fibers to a SiPM. Infact, although their values have been measured several times by other experimental groups in their respective setups, such constants are highly dependent on the specific ADRIANO layout, the finishing of the glass surfaces and the optical coupling of the various components. Furthermore, a thermal cycle at high temperature applied to the glass during the fabrication of some ADRIANO cells is known to change some of the morphological and optical parameter of the glass (i.e. the refractive index and the light attenuation length) in a way that might be very dependent on the cycle itself.

Therefore, the purpose of the proposed test beam is that of measuring a set of the above listed constants in a specific ADRIANO layout. The test beam setup is being accurately replicated in ILCroot. Four different fibers layouts and two different fiber diameters will be tested in order to disentangle some of the constants used in the simulation of the WLS collection mechanism. Finally five different beam energies will be exploited to reduce the energy dependence of the Monte Carlo simulation packages and the effects of shower leakage.

**PERSONNEL AND INSTITUTIONS:**

Spokespersons and physicists in charge of beam tests: Giovanni Pauletta (scintillating glass), Corrado Gatto (ADRIANO)

Fermilab liaison: Aria Soha

The group members at present are:

| | Institution | Collaborator | Rank/Position | Other Commitments |
|---|---|---|---|---|
| 1.1 | INFN Trieste/Udine and University of Udine | Diego Cauz | Researcher | CDF, TWICE |
| | | Anna Driutti | Graduate Student | TWICE |
| | | Giovanni Pauletta | Professor | CDF, TWICE |
| | | Lorenzo Santi | Associate Professor | CDF, TWICE |
| | | Walter Bonvicini | Researcher | PAMELA, TWICE |
| 1.2 | Fermilab | Aldo Penzo | | |
| | | Erik Ramberg | Scientist | |
| | | Paul Rubinov | Engineering Physicist | |
| | | Adam Para | Scientist | |
| | | Hans Wenzel | Scientist | |
| | | Gene Fisk | Scientist | |
| | | Aria Soha | Engineering Physicist | g-2 |
| 1.3 | INFN Lecce | Anna Mazzacane | Fellow | CDF |
| | | Benedetto Di Ruzza | Fellow | CDF |
| | | Corrado Gatto | Scientist | Muon Collider |
| | | Vito di Benedetto | Graduate Student | |
| | | Antonio Licciulli | Professor | |
| | | Massimo Di Giulio | Professor | |
| | | Daniela Manno | Professor | |
| | | Antonio Serra | Professor | |
| 1.4 | INFN and University Roma I | Maurizio Iori | Researcher | |
| 1.5 | University of Salerno | Michele Guida | Professor | |
| | | Heinrich R. Neitzert | Professor | |
| | | Antonio Scaglione | Professor | |
| | | Francesco Chiadini | Professor | |
| 1.6 | University of Modena | Cristina Siligardi | Professor | |
| | | Monia Montorosi | | |
| | | Consuelo Mugoni | Graduate Student | |
| | | Giuglia Broglia | Graduate Student | |
| | | Luca Pasquali | Professor | |
| 1.7 | University of Cyprus | Photios Ptochos | Professor | CDF |
| 1.8 | University of Iowa | Burak Bilki | | |
| | | Yasar Onel | Professor | |

# II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

## 2.1 LOCATION

2.1.1 The beam tests will take place on the remotely controlled motion tables in MT6.2B and 2C.

## 2.2 BEAM

### 2.2.1 BEAM TYPES AND INTENSITIES

Types of Beam:

- 1 – 30 GeV electrons/pions and muons
- 120 GeV protons

Intensity: 10k – 100k particles/ 4 sec spill

Beam spot size: smallest possible at all energies – the experiment will trigger on particles confined to a 5mm$^2$ spot around the most intense part of the beam. This requirement will reduce the useful intensity considerably.

### 2.2.2 BEAM SHARING

When testing glass samples, we will be inserting them in the beam at location MT6.2B. They will vary in thickness between roughly 0.2 and 2 interaction lengths (7.5 – 90 cm of glass). This will make it difficult for downstream users to be compatible with us. On the other hand, the experiment could be compatible with upstream users. Tests of extrusion – based muon/leakage/veto counters might involve their location at MT6.2C and could be compatible with other upstream users up to MT6.2B. Given that these tests require a relatively modest number of readout channels, they are most likely to be adaptable to conditions dictated by other primary users.

## 2.3 EXPERIMENTAL CONDITIONS

### 2.3.1 APPARATUS AND AREA INFRASTRUCTURE

***SGC1-C Test Beam Configuration***

The SGC1-C glasses to be tested are 7.5 (15) x 7.5(15) x 89.5 cm$^3$ in size and weigh 17(70)kg. They will be viewed at their extremities by an array of four 4x4 mm$^2$ ( or 2,8 x 2,8 mm$^2$) SiPMs and a 1 cm – diameter (UV – extended) PMT mounted in light-tight housings fitted to the end of the glasses. The total number of readout channels for each glass will therefore be 10.

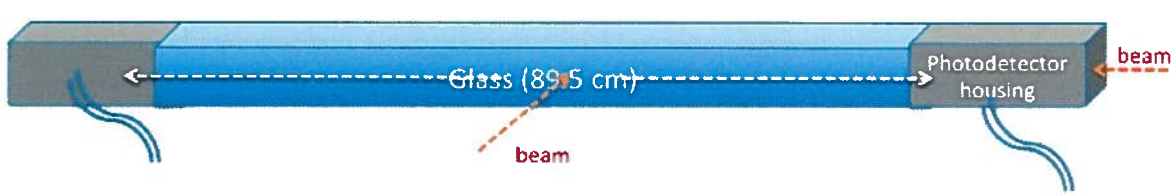



**Figure 4.1: SGC1-C glass**

No light tight enclosure is required and the glasses can rest on the remotely movable table in the MT6.2B area in any position compatible with the ADRIANO apparatus with the beam parallel or perpendicular to the length of the glass, as shown below in figure 4.2.

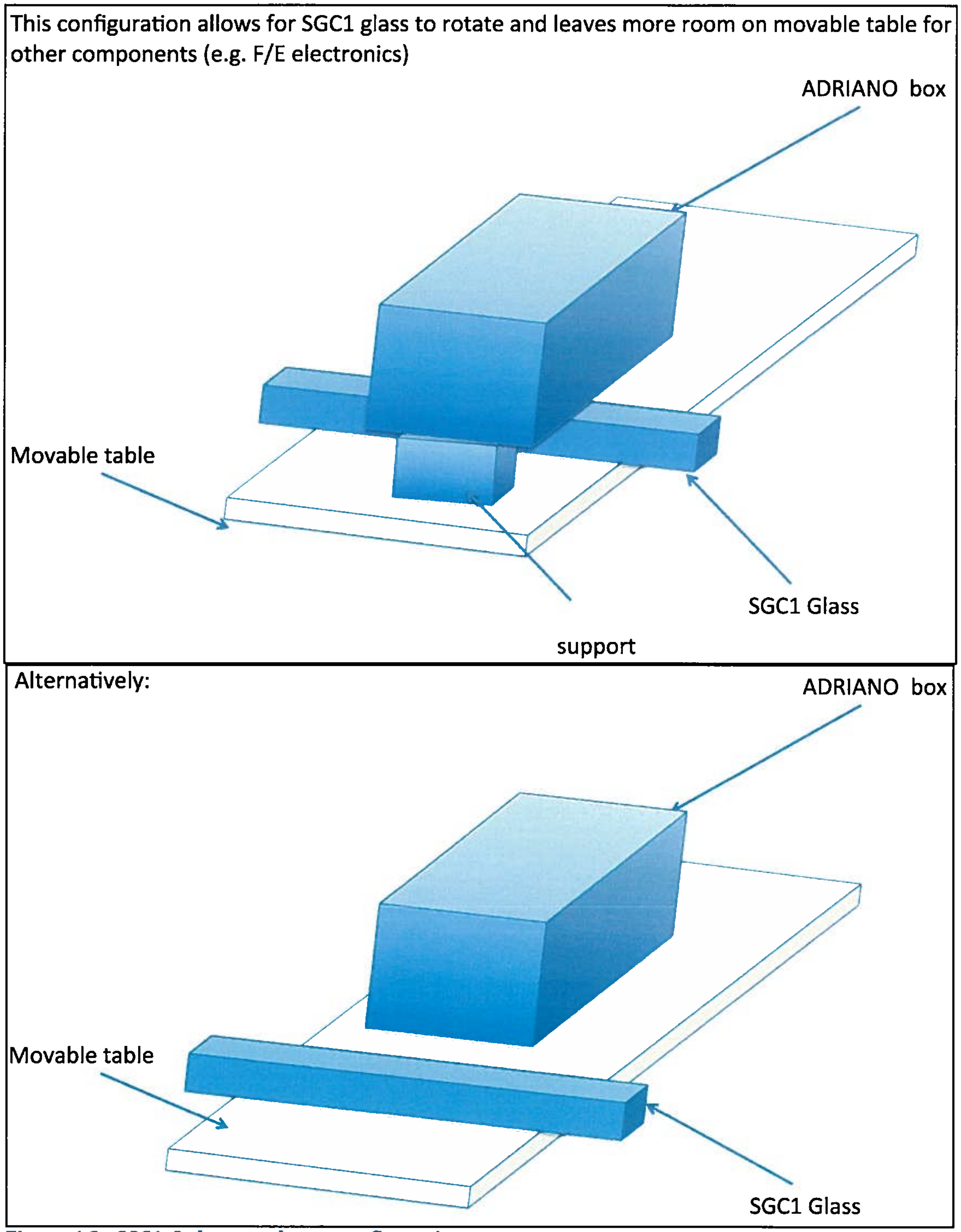



**Figure 4.2: SGC1-C glass test beam configuration**

## *ADRIANO Test Beam Configuration*

The ADRIANO samples will be located in a light tight box as illustrated in figure 5.

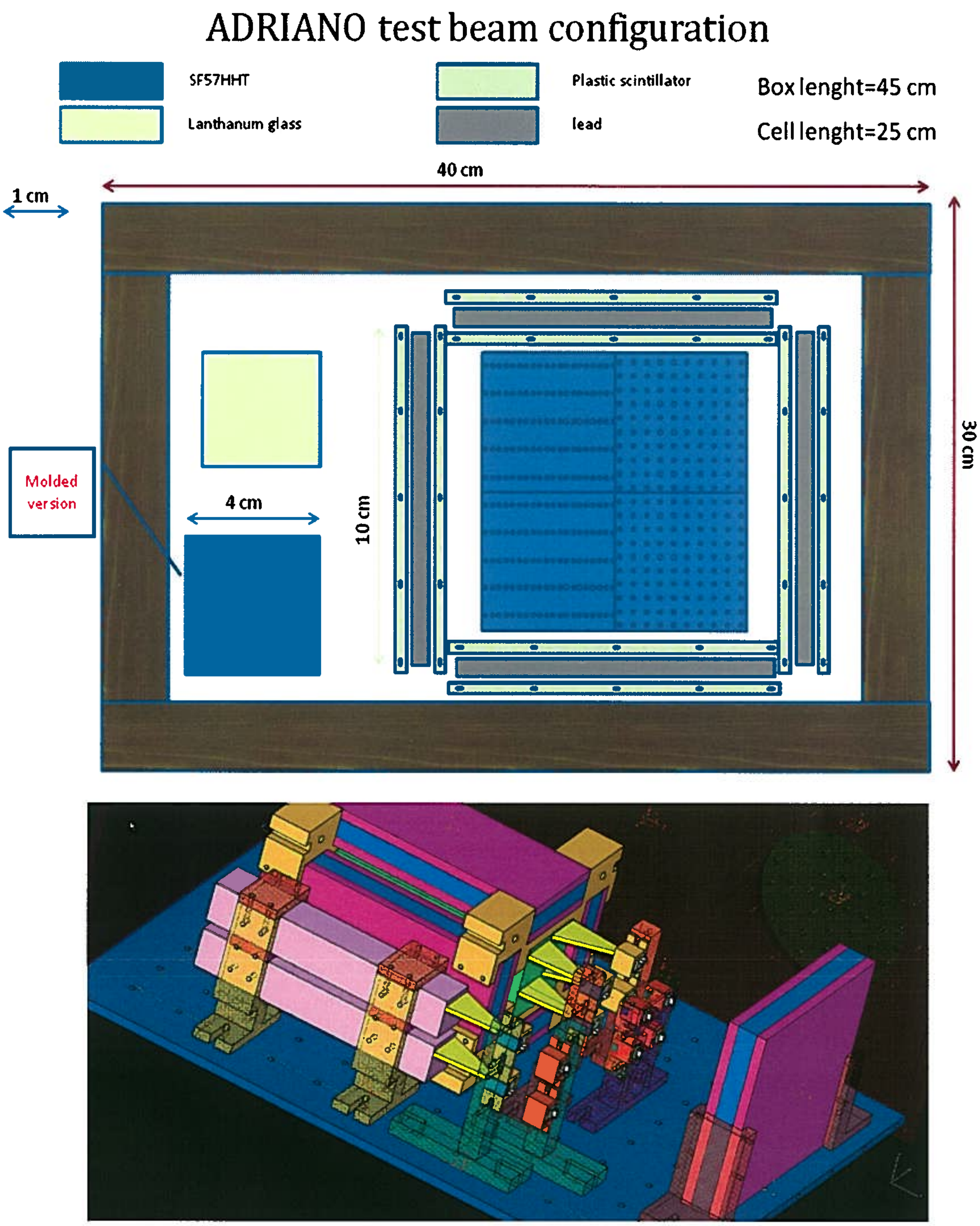



**Figure 5: Layout and support structure for testing ADRIANO glass samples**

All glass samples will be contained in a light-tight box. Four of the ADRIANO prototype samples, each with different fiber configurations, will be surrounded by four "leakage counters" parallel to the beam and one downstream counter normal to the beam direction. The leakage counters will consist of extruded scintillator, separated by lead plates. A molded version of an

ADRIANO prototype and a Lanthanum – doped scintillating glass sample will be included as soon as they become available.

The 80 – 100 scifi fibers from each ADRIANO sample will be concentrated on each of two (upstream and downstream) 4 x 4 $mm^2$ SiPMs by means of Winston Cones. Another 4 x 4 $mm^2$ SiPM will accommodate the 12 – 16 wls fibers for Cerenkov readout while a fourth SiPM will investigate Cerenkov readout by via direct optical contact with the downstream face of the glass, for a total of 4 readout channels per sample. This corresponds to 20 readout channels for 5 samples. Another four channels are reserved for readout of the scintillating glass sample.

Wls fibers from each leakage counter will be concentrated on two SiPMs (one per scintillator) for a total of 10 channels. The SiPM channel count for the ADRIANO box is therefore 34.

Upstream 2 x 2 $cm^2$ and 5 x 5 $mm^2$ scintillators will be used as needed to define the beam spot at trigger level while a downstream (~10 x 10 $cm^2$) trigger counter will be used to tag mips which do not shower in the glass samples. An additional 2mm x 2 mm upstream finger scintillator can be used to restrict triggers to particles incident at the sample's center when necessary. A 2.8 $mm^2$ thin scintillator, faced up to a SiPM will be used upstream of the samples to tag particles incident at the center of the samples. These counters will be read out for a total of 4 additional DAQ channels.

Initial measurements will rely on the trigger/tagging counters and remote table position adjustment to define the beam spot on the test samples. At a later stage it may turn out to be necessary to employ the tracking system (MWPCs and, possibly, Si microstrips) for improved efficiency.

Alignment lasers will be needed for aligning apparatus and monitoring its position when moved remotely

The gas Cerenkov in the beam, upstream of MT6.1A will be required to distinguish between pions and electrons. Tracking detectors (microstrips in MT6.1 and/or MWPCs) may be required at a later stage.

### 2.3.2 Electronics Needs

The in-house DAQ system developed by Paul Rubinov will be the only one used for DAQ in the early stages of the experiment. Each "mother board" contains 4 "daughter boards (see fig. 6) with 4 channels each, for a total of 16 channels. Four motherboards will be mounted in an ad – hoc "TB4 crate" for a total of 48 channels which will be located on the MT6.2B movable table, together with the SGC1 glasses and the ADRIANO box, as was done for T-1004. In the initial stages of the test program, all signals will be read out and transmitted from the experimental enclosure via Ethernet link by the TB4 DAQ system. Four RG 58 signal cables and the corresponding patches will be required to transmit HV ( < 2000 V) from the electronics room to the four trigger counters. The same number of RG58 signal cables and patches will be needed to form the trigger in the electronics room. Two more RG 58 HV cables and patches will be needed to power (<2000V) the two PMTS viewing the SGC1 glass sample.

Figure 6: A TB4 Motherboard with a full complement (4) of daughter board for a total of 16 DAQ channels

NIM bin space in the electronics room, equivalent to about 1 bin, and a complement of discriminators, gate generators, coincidences and logic fan-outs for the trigger logic will be needed, together with a few (< 4) patches to the experimental enclosure for the exchange of trigger-related control signals with the electronics in the experimental enclosure. A NIM bin will also be needed in the enclosure for logic needed to relay trigger – related signals between the TB4 frontend electronics and the electronics room.

At some point, the experiment may upgrade to faster frontend electronics. These will be a CAEN 6742 digitizer, located in a NIM bin, in the MT6.2B enclosure. A rack containing a NIM crate will be required in this location. Data transfer from this unit will be via single USB cable or optical link.

### 2.3.3 Description of Tests

The experiment will run tests with pions and electrons, at 1, 2, 4, 8, 10 GeV, as time will permit for ADRIANO, whereas 4 and 20 GeV will suffice for SGC1. However SGC1 will also want to run with 120 GeV protons and some runs with muons will also be useful to clearly define the response to mips.

| Energy | sample | # of samples | # of positions | # of runs |
|---|---|---|---|---|
| 1 GeV π/e | ADRIANO | 5 | 5 | 25 |
| | La - Glass | 1 | 5 | 5 |
| 2 GeV π/e | ADRIANO | 5 | 5 | 25 |
| | La - Glass | 1 | 5 | 5 |
| 4 GeV π/e | ADRIANO | 5 | 5 | 25 |
| | La - Glass | 1 | 5 | 5 |
| | SGC1 | 2 | 7 | 14 |
| 8 GeV π/e | ADRIANO | 5 | 5 | 25 |
| | La - Glass | 1 | 5 | 5 |
| 10 GeV π/e | ADRIANO | 5 | 5 | 25 |
| | La-Glass | 1 | 5 | 5 |

| | | | | |
|---|---|---|---|---|
| 20 GeV π/e | SGC1 | 2 | 7 | 14 |
| 120 GeV *p* | SGC1 | 2 | 7 | 14 |
| 30 GeV μ | SGC1 | 2 | 3 | 6 |

**Table 2: Glass tests**

At each energy, 5 positions/ sample x 6 samples = 30 runs are required by ADRIANO and the La - Glass, whereas 5 runs/sample x 2 samples = 10 runs are required by SGC1, with glasses positioned normal to the beam direction. Another 2 runs, at each energy, will be required by SGC1, with glasses aligned longitudinally with the beam. Accesses will be necessary to rotate SGC1 glasses and swap samples. The experimenters estimate 1 access/day.

Event rates will be limited by data acquisition; from previous experience, this is 200 events/spill. Assuming running at the DAQ limit and accumulating 10 k events/run, each run will take 50 minutes. Allowing 10 minutes for adjustments between runs, run-times are estimated to be 1 hour.

According to the scheme outlined above, the number of ADRIANO and La – glass runs will be 150, corresponding to 150 hours. Assuming 60% efficiency, this corresponds to 250 hours (~ 10 days).

The number of SGC1 runs is 48, corresponding to 48 hours at the standard rate. Since muon rates will probably be lower, the total is rounded off to 50 hours. Assuming 60% efficiency and more than one entry/day, a total of 4 days is estimated.

1 - 2 days will probably be needed for set up and safety review.

Tests of leakage detectors/tail-catchers/veto-counters will be performed with 120 GeV protons and 30 GeV muons. The muon runs can take place at the same time as the SGC1 tests. The proton runs will require the glasses to be out of the beam. These tests are more likely to be compatible with other primary users working upstream of MT6.2C. 20 positions at 1 hour/position/counter for a total of 20 hours/counter, corresponds to approximately 2 days/counter at 60% efficiency as a typical requirement.

## 2.4 SCHEDULE

Given the exploratory nature of this work and the limitations on scheduling imposed by other commitments, running time needs to be distributed over more than one period.

The Lecce group is relatively free of commitments as of now and they estimate they will be ready to start testing ADRIANO samples towards the end June 2011. The Udine group is tied up with teaching commitments until the beginning of July and they count on using the summer months to prepare for running in the, as yet to be scheduled, fall period when they are relatively free of teaching commitments. Given these circumstances a running period scheduled towards the end of June, followed by at least one other running period in the fall. If the results of these tests warrant it, the experimenters would then ask for more time before the 2012 shut down.

The June – July run would be dedicated principally to the test of ADRIANO modules. Should it turn out to be possible, the experimenters would devote a fraction of the time to the SGC1 glasses, but it is unlikely. The following runs could accommodate tests of both glasses and leakage counters and an eventual later run would probably involve the test of an assembly of SG1 glasses.

Based on the running times evaluated in section 2.3.3, a 10 – 14 day period would be required to perform the listed ADRIANO runs. A two week period at the end of June would therefore suffice.

Subsequent runs should include approximately 4 days for SGC1 glasses and 2 days for leakage counter tests in addition to ADRIANO requirements which will be better defined after the June-July run. One can anticipate requiring another 10 – 14 day period in the fall.

## III. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

3.1 INFN TS/UD :

- Develop, test and furnish SiPMs, optical couplings
- Technical support for Glass and leakage counter assembly and for beam – defining trigger counters
- Supply wls and Scifi fiber and PMTs for leakage counter development
- Prepare beam – defining trigger counters
- Furnish CAEN 6742 and fast amplifiers digitizer
- Shifts and data analysis (~ 50 k$)

3.2 LECCE :

- Develop and assemble ADRIANO and La – glass samples
- Construct light – tight housing for ADRIANO and La – glass samples at test beam
- Assemble ADRIANO leakage counters
- Shifts and data analysis (30k$)

## IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

### 4.1 FERMILAB ACCELERATOR DIVISION:

4.1.1 Use of MTest beam as outlined in Section II.
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 Connection to beams control console and remote logging (ACNET) should be made available.
4.1.6 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR). [0.5 person-weeks/week]
4.1.7 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.
4.1.8 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:

4.2.1 The test-beam efforts in this MOU will make use of the Fermilab Test Beam Facility. Requirements for the beam and user facilities are given in Section II. 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 computers. [0.5 person weeks/week]
4.2.2 Set up tracking system when needed. MWPC resolution would suffice if there are sufficient planes for both horizontal and vertical tracking [0.2 person weeks/week]
4.2.3 Set up and maintenance of the Cherenkov particle ID system needed to tag particle species ($\pi$, e, $\mu$ ) at DAQ level, or to select them at trigger level. [0.2 person weeks/week]
4.2.4 Support for the FTBF DAQ system as needed[0.2 person weeks/week]
4.2.5 Supply and maintain TB4 DAQ as needed
4.2.6 Set up and maintenance of two trigger scintillation counters[0.1 person weeks/week]
4.2.7 Supply and assembly of scintillator and lead for ADRIANO leakage counters [$600]
4.2.8 Purchase refractometer for ADRIANO glass sample measurements [$550]
4.2.9 Supply, cut and lap wls fiber for ADRIANO [$550 for fibers and 0.5 person-weeks]
4.2.10 Support of chemistry laboratory in Lab6
4.2.11 Support of ultrasonic cleaner in Lab6
4.2.12 Support of DarkBox station in Lab7 for UV-light testing of fibers

### 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.

### 4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.
4.4.2 Provide necessary training for experimenters.

## V. Summary of Costs

| **Source of Funds [$K]** | **Materials & Services** | **Labor** (person-weeks) |
|---|---|---|
| Particle Physics Division | 1700 | 5.3 |
| Accelerator Division | 0 | 0.5 |
| Computing Division | 0 | 0 |
| | | |
| Totals Fermilab | $1.7K | 5.8 |
| Totals Non-Fermilab | $80k | [400] |

## 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 Researchers": (http://www.fnal.gov/directorate/PFX/PFX.pdf). 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 Fermilab 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. The Spokespersons also undertake to ensure no modifications of PREP equipment take place without the knowledge and written 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.

*At the completion of the experiment:*

6.8 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.

6.9 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.

6.10 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied.

6.11 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters' Meeting.

## VII. BIBLIOGRAPHY

[1] P. Mockett, "A review of the physics and technology of high-energy calorimeter devices," Proc. 11th SLAC Summer Inst. Part. Phy., July 1983, SLAC Report No. 267 (July 1983), p. 42,

[2] Akchuring N., Wigmans R., et al.,

*Hadron and Jet Detection with a Dual- Readout Calorimeter,* 2005,

**Nucl. Instr. and Meth., A537 537.**

[3] A.Para, "High Resolution Jet calorimetry: Total Absorption Homogenous Calorimeter With Dual Readout", TILC09 , Tsukuba, Japan April 2009.

http://ilcagenda.linearcollider.org/materialDisplay.py?contribId=104&sessionId=24&materialId=slides&confId=3154

[4]L. Antoniazzi et al., " The Experiment 705 Electromagnetic Shower Calorimeter" Fermilab-Pub-93-001 Jan 1993, Published in Nucl Instr. Meth. A223: 57-77, 1993

[5] *G Pauletta et al.,* **IRST SiPM characterizations and application studies,**

Published in **PoS PD07:014,2008.**,

*W. Bonvicini et al.,* **First results on SiPM characterization within the FACTOR experiment** Published in **Nuovo Cim.30C:515-527,2007**.

[6] H.E. Fisk and P. Rubinov , CALOR 2010, Beijing, China, May 2010.

http://indico.ihep.ac.cn/materialDisplay.py?contribId=203&sessionId=3&materialId=slides&confId=910

[7] http://www-cdf.fnal.gov/~pauletta/T1015/glass-calorimeter-3.pdf

[8] http://www-cdf.fnal.gov/~pauletta/T1015/DRM-14-12-10-1.pdf

**SIGNATURES:**

________________________________ / / 2011
Giovanni Pauletta, Experiment Spokesperson, Scintillating Glass

________________________________ / / 2011
Corrado Gatto, Experiment Spokesperson, ADRIANO

K. M. Kephart for M. Lindgren 06 / 23 / 2011
Michael Lindgren, Particle Physics Division, Fermilab

Paul C Czarapata for Roger L. Dixon 6 / 23 / 2011
Roger Dixon, Accelerator Division, Fermilab

Peter Cooper 6 / 23 / 2011
Peter Cooper, Computing Division, Fermilab

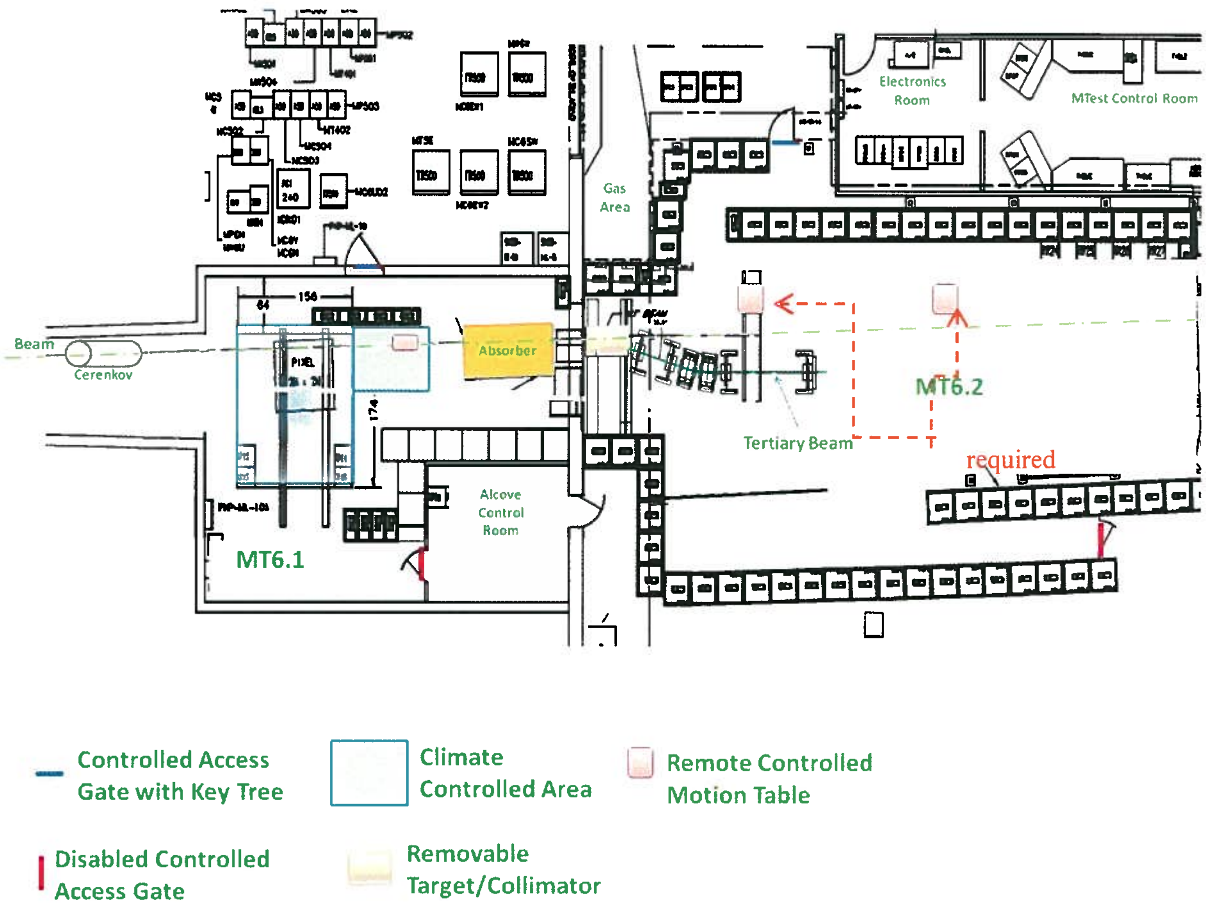
Martha E. Michels for 6 / 23 / 2011
Nancy Grossman, ES&H Section, Fermilab

________________________________ 6 / 22 / 2011
Greg Bock, Associate Director for Research, Fermilab

Roger L. Dixon For 6 / 27 / 2011
Stuart Henderson, Associate Director for Accelerators, Fermilab

## APPENDIX I: MT6 AREA LAYOUT

### MTEST AREAS




Glass Samples will be set up on moveable table at MT6.2B

SGC1 leakage/tail-catcher/veto counters will be set up on moveable table at MT6.2C

## Appendix II: Equipment Needs

Provided by experimenters:

<u>INFN Trieste</u>

SiPMs and Optical couplings for SGC1 glasses ADRIANO samples an La-Glass

Scifi fiber for ADRIANO

Fast amplifiers for CAEN 6742 –based DAQ

<u>INFN and University of Udine</u>

wls fiber for leakage/muon/tail-catcher detectors

PMTs for SGC1 tests

Beam–defining trigger counters

CAEN 6742 digitizer

<u>INFN Lecce</u>

ADRIANO and La – glass samples

light – tight housing for ADRIANO and La – glass samples at test beam

<u>FNAL</u>

TB4 electronics: 4 motherboards with complement of 16 daughter boards, power supplies and associated cabling. (P. Rubinov)

Refractometer (A. Pla)

Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup.

PREP EQUIPMENT POOL:

| Quantity | Description |
|---|---|
| 1 | NIM crate with cooling fan |
| 1 | CAMAC crate, powered |
| 1 | 16-channel LeCroy 4616 or equivalent 16-channel NIM-ECL translator/adapter |
| 2 | NIM octal discriminator (Lecroy 623B or similar) |
| 2 | Quad discriminators (LeCroy 821 or similar) |
| 2 | NIM 12-signal amplifiers LeCroy 612 or similar |
| 2 | NIM quad-coin 2-fold logic LeCroy 621/622 or similar |
| 2 | NIM Fan IN/Out units (Le Croy 438/429 or similar) |
| 2 | NIM gate generators (Philips 694 or similar) |
| 2 | HV (< 2500V) supply for PMTs |
| 1 | digital oscilloscope |

PPD FTBF:

| Quantity | Description |
|---|---|
| 2 | Trigger counter paddles |
| 2 | MWPC tracking statins |
| 2 | beam Cherenkov counters |
| | Cables as needed |
| | DAQ system |

## APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is an anticipated need have been checked.

| **Flammable Gases or Liquids** | | **Other Gas Emissions** | | **Hazardous Chemicals** | | **Other Hazardous /Toxic Materials** |
|---|---|---|---|---|---|---|
| Type: | | Type: | | | Cyanide plating materials | List hazardous/toxic materials planned for use in a beam line or an experimental enclosure: |
| Flow rate: | | Flow rate: | | | Hydrofluoric Acid | |
| Capacity: | | Capacity: | | | Methane | |
| **Radioactive Sources** | | **Target Materials** | | | photographic developers | **Lead (Pb)** for veto |
| | Permanent Installation | | Beryllium (Be) | | PolyChlorinatedBiphenyls | |
| X | Temporary Use | | Lithium (Li) | | Scintillation Oil | |
| Type: | | | Mercury (Hg) | | TEA | |
| Strength: | | | Lead (Pb) | | TMAE | |
| **Lasers** | | | Tungsten (W) | | Other: Activated Water? | |
| | Permanent installation | | Uranium (U) | | | |
| | Temporary installation | | Other: | **Nuclear Materials** | | |
| | Calibration | **Electrical Equipment** | | Name: | | |
| | Alignment | | Cryo/Electrical devices | Weight: | | |
| Type: | | | Capacitor Banks | **Mechanical Structures** | | |
| Wattage: | | X | High Voltage (50V) | | Lifting Devices | |
| Class: | | | Exposed Equipment over 50 V | | Motion Controllers | |
| | | | Non-commercial/Non-PREP | | Scaffolding/ Elevated Platforms | |
| | | | Modified Commercial/PREP | | Other: | |
| **Vacuum Vessels** | | **Pressure Vessels** | | **Cryogenics** | | |
| Inside Diameter: | | Inside Diameter: | | | Beam line magnets | |
| Operating Pressure: | | Operating Pressure: | | | Analysis magnets | |
| Window Material: | | Window Material: | | | Target | |
| Window Thickness: | | Window Thickness: | | | Bubble chamber | |

## NUCLEAR MATERIALS

### REPORTABLE ELEMENTS AND ISOTOPES / WEIGHT UNITS / ROUNDING

| Name of Material | MT Code | Reporting Weight Unit Report to Nearest Whole Unit | Element Weight | Isotope Weight | Isotope Weight % |
|---|---|---|---|---|---|
| Depleted Uranium | 10 | Whole Kg | Total U | U-235 | U-235 |
| Enriched Uranium | 20 | Whole Gm | Total U | U-235 | U-235 |
| Plutonium-242[1] | 40 | Whole Gm | Total Pu | Pu-242 | Pu-242 |
| Americium-241[2] | 44 | Whole Gm | Total Am | Am-241 | – |
| Americium-243[2] | 45 | Whole Gm | Total Am | Am-243 | – |
| Curium | 46 | Whole Gm | Total Cm | Cm-246 | – |
| Californium | 48 | Whole Microgram | – | Cf-252 | – |
| Plutonium | 50 | Whole Gm | Total Pu | Pu-239+Pu-241 | Pu-240 |
| Enriched Lithium | 60 | Whole Kg | Total Li | Li-6 | Li-6 |
| Uranium-233 | 70 | Whole Gm | Total U | U-233 | U-232 (ppm) |
| Normal Uranium | 81 | Whole Kg | Total U | – | – |
| Neptunium-237 | 82 | Whole Gm | Total Np | – | – |
| Plutonium-238[3] | 83 | Gm to tenth | Total Pu | Pu-238 | Pu-238 |
| Deuterium[4] | 86 | Kg to tenth | $D_2O$ | $D_2$ | |
| Tritium[5] | 87 | Gm to hundredth | Total H-3 | – | – |
| Thorium | 88 | Whole Kg | Total Th | – | – |
| Uranium in Cascades[6] | 89 | Whole Gm | Total U | U-235 | U-235 |

[1] Report as Pu-242 if the contained Pu-242 is 20 percent or greater of total plutonium by weight; otherwise, report as Pu 239-241.

[2] Americium and Neptunium-237 contained in plutonium as part of the natural in-growth process are not required to be accounted for or reported until separated from the plutonium.

[3] Report as Pu-238 if the contained Pu-238 is 10 percent or greater of total plutonium by weight; otherwise, report as plutonium Pu 239-241.

[4] For deuterium in the form of heavy water, both the element and isotope weight fields should be used; otherwise, report isotope weight only.

[5] Tritium contained in water (H2O or D2O) used as a moderator in a nuclear reactor is not an accountable material.

[6] Uranium in cascades is treated as enriched uranium and should be reported as material type 89.

## OTHER GAS EMISSION

### GREENHOUSE GASSES (NEED TO BE TRACKED AND REPORTED TO DOE)

- ❑ Carbon Dioxide, including $CO_2$ mixes such as $Ar/CO_2$
- ❑ Methane
- ❑ Nitrous Oxide
- ❑ Sulfur Hexafluoride
- ❑ Florinaded Gases (eg; Hydrofluorocarbons, perfluorocarbons)
- ❑ Nitrogen Trifluoride