

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

T-1005

Muon $g-2$ Calorimeter Prototypes

May 3, 2010

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INTRODUCTION

This is a Memorandum of Understanding (MOU) between the Fermi National Accelerator Laboratory and experimenters of the muon g-2 experiment who have committed to participate in beam tests to be carried out during the 2010 Test Beam Facility 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.

Description of Detector and Tests:

The muon g-2 experiment at Brookhaven Nation Laboratory has measured the muon anomalous magnetic moment to 0.54 ppm [1]. A proposed upgrade [2] to the experiment would increase the precision of the measurement to 0.16 ppm. In order to achieve this, a factor of 5 increase in the rate of muon beam is necessary along with a reduction of systematic errors. One of the primary systematic errors in the experiment is due to pileup. Using the current g-2 lead-scintillating fiber calorimeters, a factor of 5 increase in the muon rate will result in a proportional increase in the pileup systematic error which is unacceptable. In order to overcome this problem a new, segmented calorimeter design has been developed.

The proposed design is a tungsten-scintillating fiber calorimeter with 35 segments, each read out by a separate PMT. Tungsten, which is significantly denser than lead, produces compact showers. This is necessary, in order to improve shower separation in analysis and to fully contain the showers within a calorimeter that satisfies the strict space constraints of the experiment. A single calorimeter segment ($4 \times 6 \times 15 \text{ cm}^3$) has been constructed in order establish the feasibility of the new design and study its properties. Initial tests of the detector segment at the Paul Scherrer Institute were conducted with a low energy $<400 \text{ MeV}/c$ electron beam. A higher-energy test with electrons up to a few GeV/c was performed at the Test Beam Facility under the experimental number T-967. All data from that test have been analyzed and published [3] and the tungsten-scintillating fiber calorimeter still appears to be a viable candidate. For this test beam run, a larger calorimeter ($15 \times 15 \times 11 \text{ cm}^3$) has been constructed and an emphasis will be placed on understanding shower leakage and the ability to separate pileup events with a more granular readout.

The experimenters propose to use 0.5 – 4 GeV electrons from the Fermilab Test Beam Facility to measure the energy resolution, linearity, and shower size of the calorimeter segment. This will provide important information for finalizing decisions on the angle of the fibers relative to the incoming electrons and the optimal granularity of the readout.

I. PERSONNEL AND INSTITUTIONS:

Spokesman and physicist in charge of beam tests: Chris Polly
 Fermilab liaison: Aria Meyhoefer

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

	<u>Institution</u>	<u>Collaborator</u>
1.1	University of Illinois at Urbana-Champaign(UIUC)	David Hertzog
		Noah Schroeder
		Jason Crnkovic
		GregDamhorst
1.2	Univeristy of Kentucky	Vladimir Tishchenko
1.3	University of Virginia	Emil Frlez
1.4	Fermi National Accelerator Laboratory	Chris Polly
		Mike Syphers
		Aria Meyhoefer
		Brenden Casey

II. EXPERIMENTAL AREA, BEAMS, AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

2.1.1 The beam tests will be carried out in the MTest beamline, in MT6 section 2B.

2.2 BEAM

2.2.1 BEAM TYPE AND INTENSITY

Energy: 0.5 GeV – 4 GeV
Particles: Electrons
Intensity: 0.1-1 KHz
Beam spot size: 1-10 cm² (as small as achievable)

The experimenters would like an electron beam that can be tuned between 0.5 GeV/c and 4 GeV/c. The calorimeters are expected to have an energy resolution of $10\%/\sqrt{E}(\text{GeV})$ and the momentum spread of the beam should be small relative to this benchmark. Ideally the momentum spread would be less than 1/3 of the energy resolution of the calorimeter at any energy. The Accelerator Division will make a best effort at attempting to deliver a beam with better resolution, down to 2%. The experimenters and Fermilab will collaborate in determining the momentum dispersion as a function of position in the beam. Pions will likely be a major background in the beam. A Cerenkov detector should allow tagging such that electrons will be the dominant component of the analyzed data. It is important to have beam impact position information recorded to a precision of approximately 1 mm in the horizontal and vertical directions (2 mm is acceptable, but not ideal).

2.2.2 BEAM SHARING

The small size of the calorimeters and other detectors used for the test should make moving the apparatus out of the way relatively easy if necessary.

2.3 EXPERIMENTAL CONDITIONS

2.3.1 DESCRIPTION OF TESTS

The apparatus will consist of a tungsten-scintillating fiber calorimeter which is the focus of the test. The new prototype has 25 readout channels, which are independent. Each covers a 3 x 3 cm³ area on the downstream face of the detector. Two lead-scintillating fiber calorimeters will be used on occasion as reference detectors since

their performance is well documented. A Cerenkov detector, provided by Fermilab, will be used to tag electrons. One MWPC station and pixel telescope will be provided by the Test Beam Facility to accurately (to within 1 mm) measure position of beam on the calorimeter. Operation and understanding of the beam Cerenkov detector is the responsibility of the experimenters after introduction to the device by Facility scientists.

The major steps in the test are as follows:

- (a) Set up trigger devices and Cerenkov detectors and time in with calorimeter signals.
- (b) Perform HV scan to determine proper HV settings for individual PMTs.
- (c) With beam centered on tungsten calorimeter record ADC spectra for beam energies between 1 and 4 GeV in 0.5 GeV steps. Scan across boundaries, and near edges of block.
- (d) With beam centered on the calorimeter tilt the detector at 0, 5, and 10 degree angles to check for changes in detector response due to channeling effects in fibers. This is very important for g-2 as electrons enter from 0 to 30 degrees.

2.4 SCHEDULE

The experimenters propose to perform multiple tests on the same detector before the long shutdown scheduled for March 2012. Each test will last several days, with a few days for equipment setup prior to running.

III. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

3.1 UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAGNE (UIUC)

- Scintillator detectors for triggering
- CAMAC and NIM crates
- NIM and CAMAC logic/ADC/TDC modules
- CAMAC readout and DAQ
- Prototype calorimeter with tubes and cabling.

IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 FERMILAB ACCELERATOR DIVISION:

- 4.1.1 Use of MTest beam line 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 beam line.
- 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 Access to beams control console and remote logging (ACNET) will be made available.
- 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 Use of the Test Beam Facility, as outlined 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 gateway computer.
- 4.2.2 A Cerenkov counter provided by facility for trigger and start time.
- 4.2.3 One of the MWPC stations will be moved into place in front of the calorimeter.
- 4.2.4 Assistance will be provided in integrating this chamber and the trigger devices into a CAMAC DAQ system provided by the facility.
- 4.2.5 The test beam facility shall provide a table upon which the counter assembly is mounted, with a total weight of 125 lbs. The table will to provide vertical and horizontal motion to a precision of 1mm. The value of the position will be available.
- 4.2.6 Provide a HV power supply system for 30 channels and associated signal and HV cables.

4.3 FERMILAB COMPUTING DIVISION

- 4.3.1 Internet access should be continuously available in the counting house.
- 4.3.2 Best effort 8 hours a day, 5 days a week, support of DAQ computing.
- 4.3.3 The CAPTAN pixel telescope will be available as a resource for use by members of the T-1005 collaboration. Engineers of CD/ESE will work with T-1005 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. [1 person-week]

- 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 Test Beam Facility during this time. However, if T-1005 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.
- 4.3.6 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 A low level radioactive beta source will be made available to the experimenters to diagnose and calibrate their equipment before running beam.

V. SUMMARY OF COSTS

Source of Funds [\$K]	Equipment	Operating	Personnel (person-weeks)
Particle Physics Division	\$0 K	\$0 K	1
Accelerator Division	0	0	0.5
Computing Division	0	0	1
Totals Fermilab	0 K	0	2.5
Totals Non-Fermilab			

VI. SPECIAL CONSIDERATIONS

- 6.1 The responsibilities of the Spokesperson 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 Spokesperson agrees 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 Spokesperson 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 spokesperson will ensure at least one person is present at the 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 Spokesperson 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 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. Any items for which the experiment requests Fermilab performs maintenance and repair should appear explicitly in this agreement.
- At the completion of the experiment:*
- 6.8 The Spokesperson is 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 Spokesperson 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.

MOU for Muon g-2 Calorimeter Prototypes

SIGNATURES:

_____/ / 2010
C.C. Polly, Muon g-2 Calorimeter Spokesperson

_____/ / 2010
Michael Lindgren, Particle Physics Division

_____/ / 2010
Roger Dixon, Accelerator Division

_____/ / 2010
Robert Tschirhart, Computing Division

_____/ / 2010
Nancy Grossman, ES&H Section

_____/ / 2010
Greg Bock, Associate Director, Fermilab

_____/ / 2010
Steven Holmes, Associate Director, Fermilab

APPENDIX I - REFERENCES

1. G.W. Bennett *et al.*, *Final Report of the Muon E821 Anomalous Magnetic Moment Measurement at BNL*, Phys. Rev. D**73**, 072003 (2006).
2. R.M. Carey *et al.*, *The New ($g-2$) Experiment: A proposal to measure the muon anomalous magnetic moment to ± 0.14 ppm precision.*, FERMILAB-PROPOSAL-0989, Feb 2009. 129pp.
3. R. McNabb, *et al.*, *A Tungsten / Scintillating Fiber Electromagnetic Calorimeter Prototype for a High-Rate Muon $g-2$ Experiment*, Nucl. Instrum. Meth. A**602**:396-402 (2009)

APPENDIX II: EQUIPMENT NEEDS

Provided by experimenters:

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

PREP EQUIPMENT POOL:

<u>Quantity</u>	<u>Description</u>
3	Lacroy2249A ADC modules

APPENDIX III - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked

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

