Fermilab

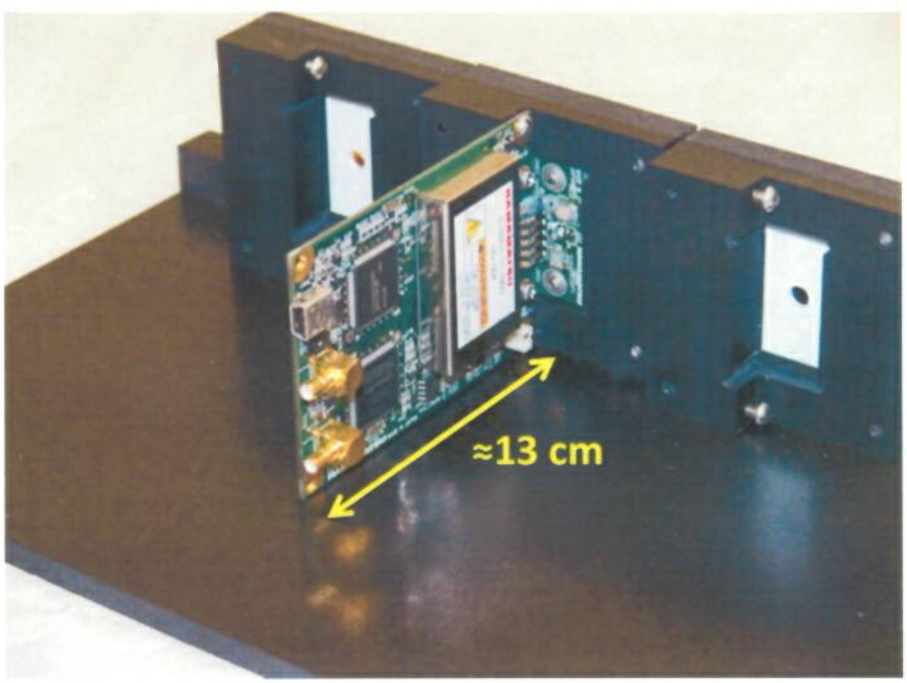
Directorate

TECHNICAL SCOPE OF WORK
FOR THE 2013 FERMILAB TEST BEAM FACILITY PROGRAM

T-1045

Mu2E Fast Extinction Monitor Tests Using Cherenkov Light from Quartz Cells

August 8, 2013



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INTRODUCTION

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of Northern Illinois University (NIU) and Lewis University who have committed to participate in beam tests to be carried out during the 2013 – 2014 Fermilab Test Beam Facility program.

The TSW is intended primarily 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 scope of work to reflect such required adjustments. Actual contractual obligations will be set forth in separate documents.

This TSW fulfills Article 1 (facilities and scope of work) of the User Agreements signed (or still to be signed) by an authorized representative of each institution collaborating on this experiment.

Description of Detector and Tests:

The detector consists of quartz cells (cherenkov radiators) coupled to Hamamatsu multi-pixel photon counters (MPPC).

The goal of the tests is to characterize the Cerenkov quartz detector and to understand its performance and limitations in an environment as similar as possible to the expected mu2e beam.

The experimenters will first do some noise measurements with the device outside the beamline, and will then study the detector response to one particle per bucket and further to multiple particles and in different angles with respect to the beam. These test beam studies need to be completed in order to demonstrate that this detector technology is viable before the Mu2e CD2 review.

1. PERSONNEL AND INSTITUTIONS:

Spokesperson: Robert Bernstein, Fermilab

Physicist in charge of beam tests: Shulamit Sher

Fermilab liaison: Aria Soha

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	Northern Illinois University	USA	Sasha Dyshkant Dave Hedin Eric Johnson Steven Boi	Research Scientist Professor Technician Student	pCT DØ,
1.2	Lewis University	USA	Ryan Hooper Andrew Trovato Brandon Schabell	Assistant Professor Student Student	DO
1.3	Fermilab	USA	Bob Bernstein Eric Prebys Paul Rubinov Shulamit Sher	Physicist Accel. Physics Center PPD/EED/Front E.E. PPD/Intens. Front	Mu2e Minos

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

2.1 LOCATION

2.1.1 The beam test(s) will take place in the MT6.2 enclosure, on the 2C motion table. Space for a 6U VME crate and power supply will be needed inside the enclosure. Space for a USB hub PC may also be needed.

2.1.2 In addition, space in the MTest control room will be needed for a data acquisition computer and limited work space for 2-5 people.

2.2 BEAM

2.2.1 BEAM TYPES AND INTENSITIES

Energy of beam: 8 GeV (however anything above Cherenkov threshold for quartz ($\beta \approx 0.66$) will work), i.e. the expected 120 GeV beam will suffice.
Particles: Protons
Intensity: Single particles up to as high as possible (in 11 buckets)
Beam spot size: about 10cm^2 (ideally 3cmX3cm approximately)

The experimenters request a 200ns bunch length – a beam time structure that mimics the expected mu2e beam structure. With the current beam configuration coming from the MI, a single Booster batch of 11 buckets per rotation would give the desired time window.

Experimenters will ask to increase intensity in order to increase the multiple occupancy up to the capability of the detector readout.

2.2.2 BEAM SHARING

These tests can run parasitically upstream of other tests as the amount of material added to the beamline will be small, typically 1.5 cm of quartz. One configuration may introduce up to 10 cm of quartz (see configuration diagrams below). A possibility of a thin (~1mm thick steel) scattering plate may be placed in the beamline to generate scattered particles and such running would be coordinated with other users.

The radiation length of quartz is about 12.3cm. The experiment will have 0.5cm or 3.0cm of quartz per cell in the beam, depending on whether it is positioned across or along the beam. The experiment will have at maximum three quartz cells at a time in beam. Therefore, in any case, less than one radiation length.

The experiment can also run downstream of other thin detectors such as the Mu2e Scintillation Detectors.

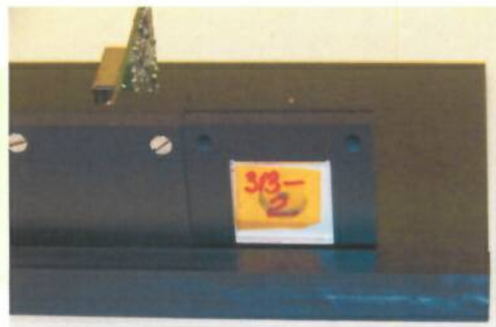
2.2.3 RUNNING TIME

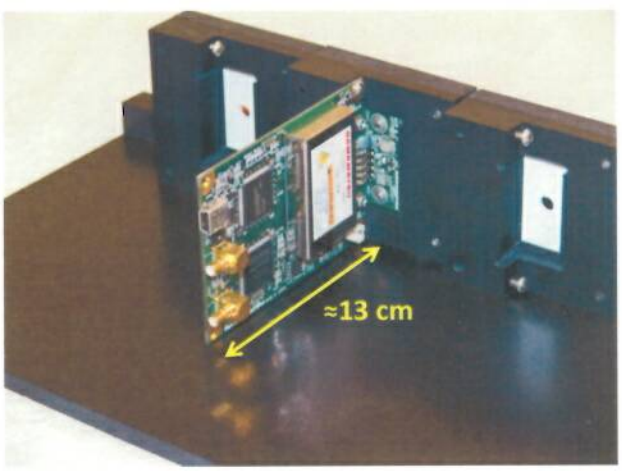
The experiment expects to run for 12 hours a day during day-time hours, (1000-2200). See section 2.3.3 for total run time and long-term schedule.

2.3 EXPERIMENTAL CONDITIONS

2.3.1 AREA INFRASTRUCTURE

The detector will consist of up to three 3cm x 3cm x 0.5cm thick quartz tiles directly coupled to MPPCs. The module will be mounted on one of the FTBF's translation tables allowing for the device's automated translation. See figures below.





2.3.2 ELECTRONICS NEEDS

The readout of the Hamamatsu MPPCs will be done with USB cables. The USB cables will need to reach computers located inside the control room. Another option would be to place a computer to act as the USB hub in the enclosure region (i.e. ~ a few meters from the actual detector) then interact with it via the already in place Ethernet lines.

One TB4 electronics board with low or no gain (and also no bias voltages for MPPC) will be needed. TB4 needs low voltage power supply. The experimenters are in contact with Paul Rubinov for the acquisition of the TB4 board. FTBF will provide an external triggering pulse (NIM format) to indicate the start of spill.

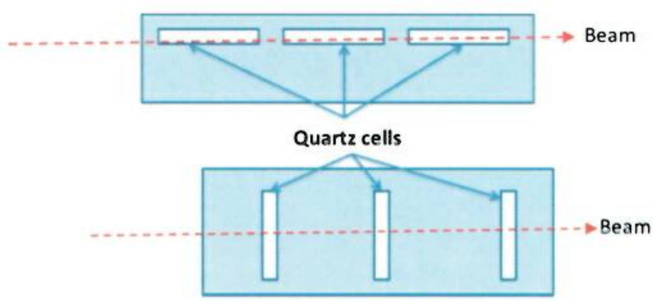
See Appendix II for summary of PREP equipment pool needs.

2.3.3 Description of Tests

The first tests will be with the detector placed directly in the beam to see its response to the beam generated Cerenkov radiation.

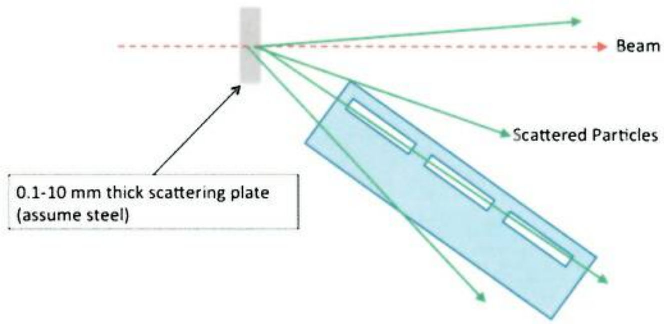
In this setup the experimenters will study the number of photoelectrons (p.e.) per proton or 8 GeV particle(s) using single p.e. spectrum as calibration.

The experimenters then will look at signal from bunched beam at about 200ns bunch length. Using the integrated digitized shape of signal from MPPC and background measured with out-of- time beam, the experimenters hope to create a background subtracted signal.

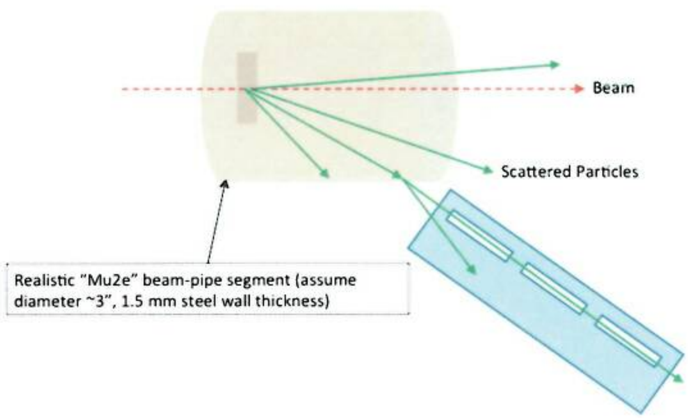


Once the experimenters have firmly established that the system is properly responsive to above threshold particles, the setup will be reconfigured. The detector system will be rotated/translated out of the beam itself (initially by some small angle ~0.1 radians). Then the thin steel scattering plate will be placed in the beamline to produce a measurable amount of scattered particles. The experimenters would like to take data at several different scattering angles relative to the beam direction (see table and figure below).

θ (radians)
0.10
0.30
0.50
0.80
1.00
1.20
1.40



The final configuration would add a segment of realistic "Mu2e" beam-pipe around the scattering plate to better reflect the actual material the scattered particles must traverse in the actual experiment's running configuration (see figure below). The experimenters would then like to repeat the previous set of experiments.



It should take approximately 4 hours for initial setup inside the enclosure.

Overall access to the beam area will be needed rarely. An access would be needed for installation of the steel target, which should not take more than 1 hour. An additional access would be needed to install the "realistic" beam-pipe segment, again this should not take more than 1 hour. While rotation of the device would be ideal, pure x-y translation via the remote controlled table will suffice.

2.4 SCHEDULE

The experimenters request two weeks in Fall of 2013. This should allow more than enough time to complete the setup and data taking.

ˇII. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

3.1 NORTHERN ILLINOIS UNIVERSITY (NIU):

- Primary hardware components (quartz, readout modules) [8K]
- Primary USB DAQ computer [2K]
- TB4 card [1K]
- 6U VME crate with controller [15K]
- Primary low voltage supplies [3K]
- Cables [1K]
- Research scientist and professor

3.2 LEWIS UNIVERSITY:

- Backup low voltage supplies [1K]
- USB power + connector hub [0.1K]
- Undergraduate student(s) and professor

'V. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 FERMILAB ACCELERATOR DIVISION:

4.1.1 Use of MTest beamline 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 readouts will be made available via ACNET in the MTest control room.

4.1.4 Reasonable access to the equipment in the MTest beamline.

4.1.5 Connection to beams 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). [1.0 person-weeks]

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 neutrino flux by more than an amount set by the office of Program Planning, 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 TSW 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 FTBF computers. [2.0 person weeks]

4.2.2 Use of the 2C motion table.

4.2.3 Conduct a NEPA review of the experiment.

4.2.4 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.

4.2.5 Provide safety training as necessary, with assistance from the ESH&Q Section.

4.2.6 Update/create ITNA's for users on the experiment.

4.2.7 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews. [0.2 person-weeks]

4.3 Fermilab Scientific Computing Division

4.3.1 Internet access should be continuously available in the MTest control room.

4.3.2 See Appendix II for PREP needs.

4.4 Fermilab ESH&Q Section

4.4.1 Assistance with safety reviews.

4.4.2 Provide safety training, with assistance from PPD, as necessary for experimenters. [0.2 person weeks]

V. Summary of Costs

Source of Funds [$K]	**Materials & Services**	**Labor** (person-weeks)
Particle Physics Division	0.0	2.2
Accelerator Division	0	1
Scientific Computing Division	0	0
ESH&Q Section	0	0.2
Totals Fermilab	$0.0K	3.2
Totals Non-Fermilab	$32K	4

I. General Considerations

6.1 The responsibilities of the Spokesperson 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 Spokesperson agrees to those responsibilities and to ensure that the experimenters all follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ESH&Q) 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 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 ESH&Q 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 Scientific Computing Division management. The Spokesperson also undertakes to ensure no modifications of PREP equipment take place without the knowledge and written consent of the Computing Sector 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 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 ESH&Q 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 Fermilab 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.

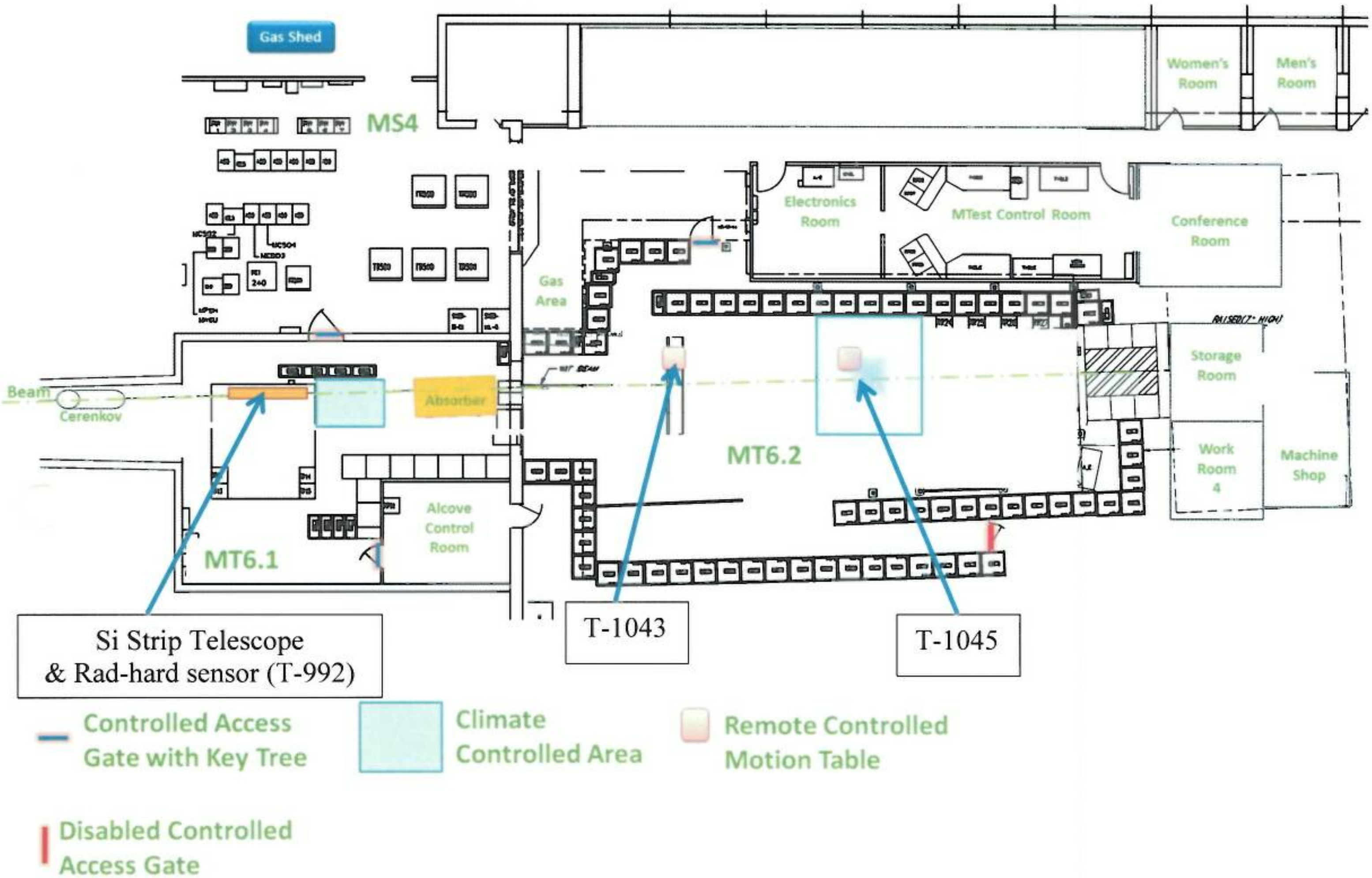
SIGNATURES:

Robert Bernstein, Experiment Spokesperson 8 /20 / 2013

Appendix I: MT6 Area Layout

Due to the overall size of the apparatus (~30cm×30cm×30cm) the experiment is flexible about placement. However, the ability to remotely translate/rotate the setup would be preferred. Some schematics of possible configurations are given in section 2.3.3.

MTest Areas



APPENDIX II: EQUIPMENT NEEDS

Provided by experimenters:

- Quartz cells coupled to Hamamatsu MPPC+readout
- USB cables for readout
- USB power bus+hub (at least 3 USB connections)
- Readout PC and monitor (DAQ system)
- TB4 card
- 6U VME crate with controller
- Low voltage supplies

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

PREP EQUIPMENT POOL:

Quantity	Description
1	Fast Discriminator (at least 3 input channels)
1	Scalars (at least 7 input channels)
1	Coincidence Unit capable of using 3 inputs and checking 4 different combinations
1	Positive to negative signal inverter (at least 3 channels)
1	NIM Crate with Power supply to house modules
1	~~Windows XP PC~~ Not sure we have this RR

PPD FTBF:

Quantity	Description
1	Translation Table
1	Alignment laser system
3	BNC splitters
	Assorted BNC cables

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked. See next page for detailed descriptions of categories.

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	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
	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	X	Other: Stainless Steel plate (~1 mm thick)	**Nuclear Materials**		
	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:			Capacitor Banks	**Mechanical Structures**		
Wattage:		X	High Voltage (50V)		Lifting Devices	
MFR Class:			Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP		Scaffolding/ Elevated Platforms	
			Modified Commercial/PREP	X	Other: S.Steel plate holder	A chuck of standard 4" diameter stainless steel beam-pipe.
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	

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
- ❑ Hydro fluorocarbons
- ❑ Per fluorocarbons
- ❑ Nitrogen Trifluoride

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.

The following people have read this TSW:

8 / 2 / 2013

Michael Lindgren, Particle Physics Division, Fermilab

8 / 12 / 2013

Roger Dixon, Accelerator Division, Fermilab

/ / 2013

Robert Roser, Scientific Computing Division, Fermilab

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8 / 12 / 2013

Martha Michels, ESH&Q Section, Fermilab

8 / 20 / 2013

Greg Bock, Associate Director for Research, Fermilab

8 / 24 / 2013

Stuart Henderson, Associate Director for Accelerators, Fermilab