Fermilab

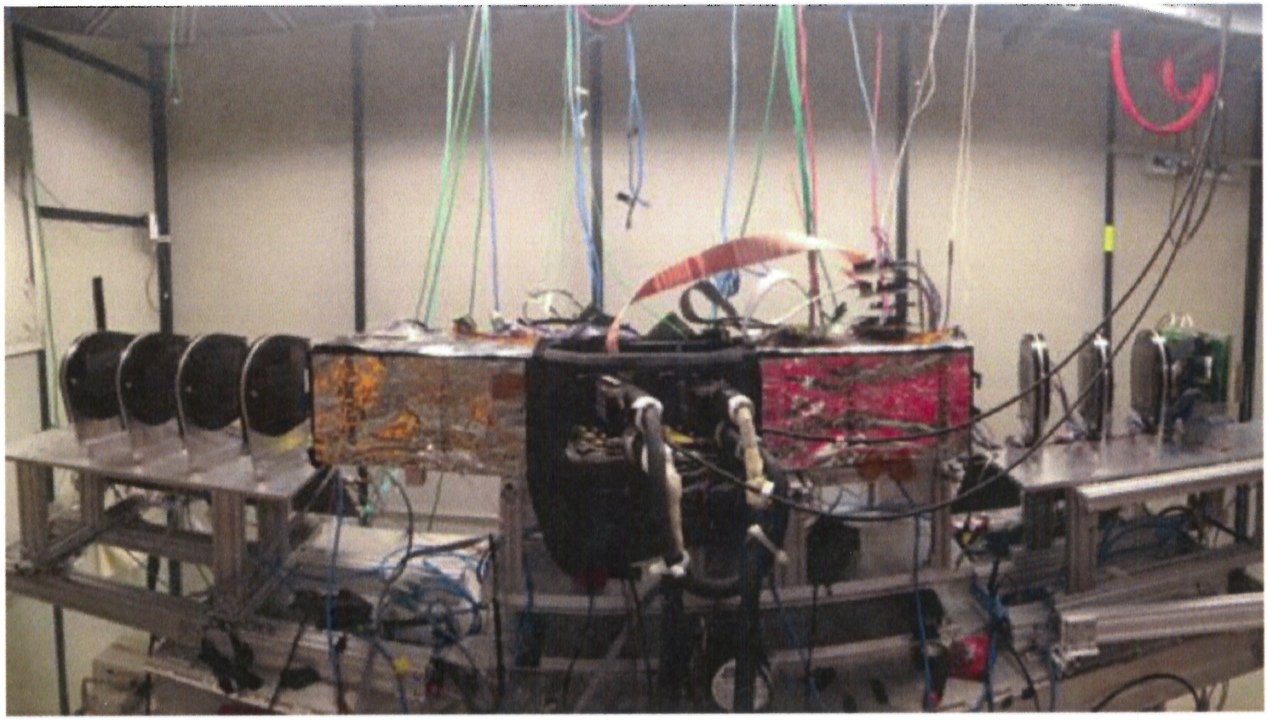
Directorate

TECHNICAL SCOPE OF WORK
FOR THE 2015-2016 FERMILAB TEST BEAM FACILITY PROGRAM

T-992

Test of Radiation Hard Sensors for the HL-LHC

October 16, 2015



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INTRODUCTION

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of Fermilab, Colorado, Purdue, Tennessee, Rutgers, SUNY, Milano and Torino Universities who have committed to participate in beam tests to be carried out during the 2015-2016 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:

At the HL-LHC, after 1500 pb-1 of data, the expected maximum fluence for the pixel region (<20 cm) will be 2.5 x 10^{16} cm^{-2}. To cope with this unprecedented radiation environment, there have been quite a few collaborations being formed at CERN to find possible solutions for vertex and tracking detectors at the HL-LHC. These include the RD42, RD49, and RD50 collaborations. A variety of solutions have been pursued. These include diamond sensors, 3D sensors, MCZ planar silicon detectors made from MCZ wafers, epitaxial, p-type silicon wafers and thin silicon detectors.
The experimenters wish to compare the performance of this wide variety of detectors in a test beam before and after irradiation. To do so, the experimenters plan to use the CMS pixel-based and the strip-based telescope constructed for the MTest facility. In particular, the experimenters are planning to study the charge collection efficiency of the irradiated and unirradiated devices and the spatial resolution as a function of the track incident angle. The experimenters will change the incident angle of the beam by moving the sensors, to investigate how the resolution varies with angle. Many physicists participating in this beam test are members of the RD42 and/or RD50 collaborations.

٦. PERSONNEL AND INSTITUTIONS:

Spokesperson and Lead Experimenter in charge of beam tests: Lorenzo Uplegger (FERMILAB)

Fermilab Experiment Liaison Officer: Mandy Rominsky

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	FERMILAB	USA	Lorenzo Uplegger	Researcher	CMS
			Ryan Rivera	Engineer	CMS
			Alan Prosser	Engineer	CMS
			Gino Bolla	Senior Researcher	CMS
			Petra Merkel	Senior Researcher	CMS
1.2	Purdue University	USA	Matthew Jones	Professor	CMS
			Mayur Bubna	Graduate student	CMS
			Nick Hinton	Technician	CMS
1.3	Colorado University	USA	Steve Wagner	Professor	CMS
			John Cumalat	Professor	CMS
			Ben Bentele	Graduate Student	CMS
1.4	SUNY University	USA	Avto Kharchilava	Professor	CMS
			Ashish Kumar	Postdoctoral Researcher	CMS
1.5	Rutgers University	USA	Yuri Gershtein	Professor	CMS
1.6	Tennessee University	USA	Stefan Spanier	Professor	CMS
1.7	Milano University	Italy	Luigi Moroni	Professor	CMS
			Dario Menasce	Professor	CMS
			Mauro Dinardo	Professor	CMS
1.8	Torino University	Italy	Ada Solano	Professor	CMS
			Margherita Obertino	Professor	CMS
			Fabio Ravera	Postdoctoral student	CMS

I. Experimental Area, Beams and Schedule Considerations:

2.1 Location

2.1.1 The beam test(s) will take place in MT6.1A where the pixel and strip telescopes are located, as shown in Appendix I.

2.1.2 Lab space within MTest shall be provided for pre-testing the detectors and making repairs as necessary. This shall include a few ~ 30"x72" work surfaces in a low dust environment equipped with ESD-safe surfaces and grounding.

2.1.3 Office space including three or more desks and network connectivity will be provided for the duration of this test experiment.

2.2 Beam

2.2.1 Beam Types and Intensities

Energy of beam: 120 GeV
Particles: protons
Intensity: 10k – 400k particles/ 4 sec spill
Beam spot size: about 2 cm^2

2.2.2 Beam Sharing

The experiment can share beam with any other experiment because it is the most upstream one.

The radiation length of the pixel telescope is 9.44% while the radiation length of the strip telescope is 9.54%.

2.3 Experimental Conditions

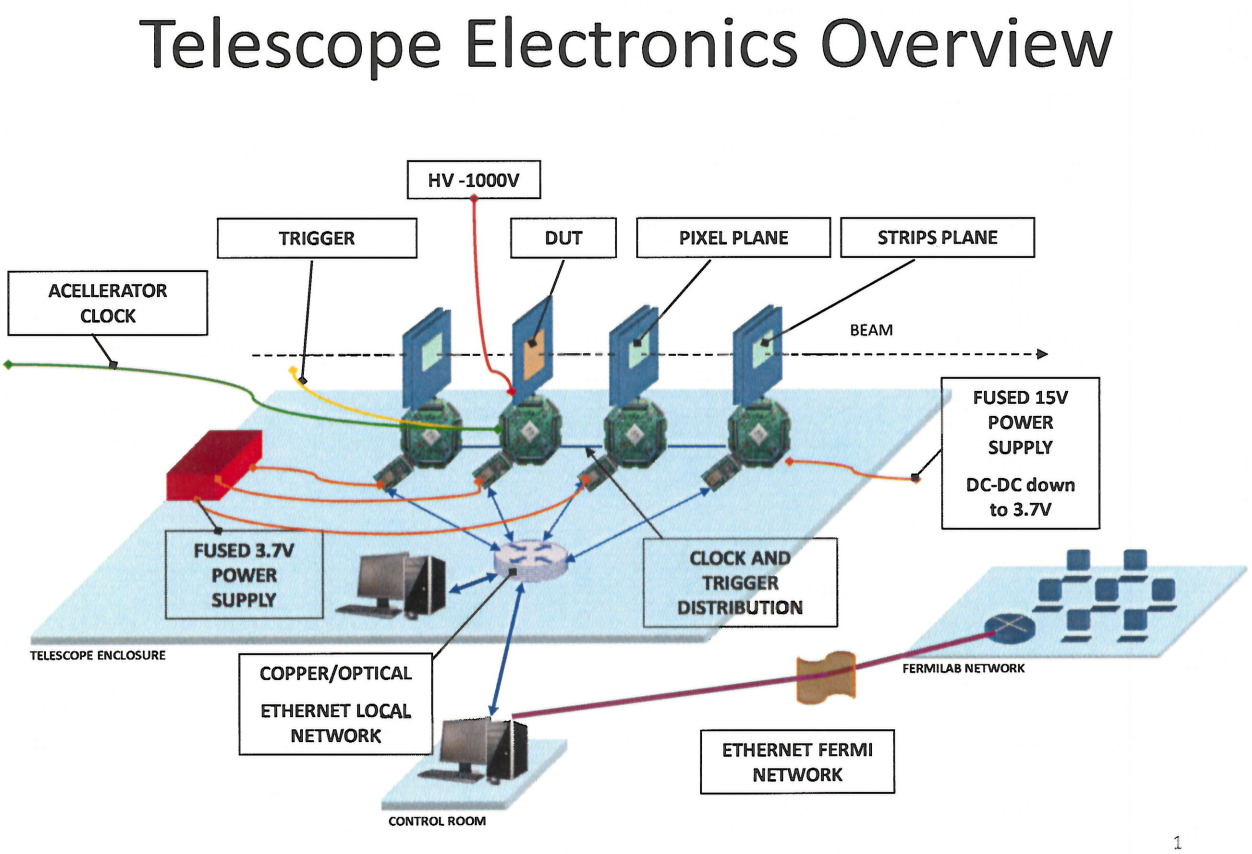
2.3.1 Area Infrastructure

- The Detectors Under Test (DUTs) will be placed in the middle of the pixel telescope and they can vary in size from 1x1 cm^2 to 2x8 cm^2 and they need to be rotated with respect to the beam direction.
- A pixel telescope for the test beam line is required. Fermilab will provide this telescope and appropriate DAQ support including computer, while the experimenters will offer the manpower to operate the telescope.
- The test environment shall be humidity-controlled, preferably with the test devices in a dry nitrogen atmosphere. The experiment will be designed to be an ODH class 0 environment.
- There shall be refrigeration capability so that the detectors under test can be operated at -10o C, the expected operating temperature of vertex detectors for the HL-LHC experiments. Given the power consumption of the pixel readout chips, a cooling capacity of ~ 10W at -30C (temperature of the cooling interface) should be foreseen.

- Fermilab will provide the DAQ and slow control computers for the telescope, trigger counters and associated readout electronics.
- Fermilab will provide a motion table to provide vertical and horizontal motion to align the DUTs with respect to the beam. The expected range should be of the order of 2 cm in both directions. The pixel telescope with a weight of about 20 lbs will sit on the motion table.

2.3.2 Electronics and Computing Needs

The pixel telescope will be read out through a custom DAQ system. A gigabit Ethernet board will be used to route the data to an online computer which will be connected to a Fermilab server via internet. The readout boards will be located close to the detector in the hut. The detectors themselves may be operated up to ~1000 V. No exposed HV parts will be present.
Since the experimenters will be testing different sensors (material, strips, pixels etc), while they will try to have as much as possible common readout electronics and DAQ system, it is possible that there will be a separate trigger, readout, and DAQ system for a particular set of tests. The participating institutes will provide this.



See Appendix II for summary of PREP equipment pool needs.

The experimenters will not bring any computer or other devices (besides personal laptops) that requires to be connected to the network.

2.3.3 Description of Tests

The experimenters have many different detectors to test. At the beginning of the shift we are going to change detectors to test accessing the enclosure. After some checks to make sure that the newly installed detectors are working the experimenters will requests beam typically asking for 60k protons per spill. If the detectors are working in the beam we will take few hours, typically of the order of 12 hours, to characterize the installed DUTs. At the end of the shift, when the DUTs have been fully characterized the experimenters will calibrate them without using the beam.

When the DUTs are considered to be in working conditions the experimenters don't need to access the enclosure until a full characterization is performed. The angle of the DUTs with respect to the beam can be changed remotely from the control room.

2.4 Schedule

The time schedule is primarily dictated by the availability of the pixel-strip telescopes in the test beam and the DUTs. Since the plan is to test the DUTs before and after irradiation and different types of detectors will be tested for the HL-LHC, the test program will last five years. The experimenters request beam time during the next five years. Each year, the experimenters will request up to four slots of beam time, each of two weeks duration.

Experimental Planning Milestones

The experimenters would like to install their detectors on June 3rd 2015 and start the data taking as soon as possible. All the equipment is ready and the experimenters don't need to build any extra piece of equipment.

II. Responsibilities by Institution – Non Fermilab

The personnel from the participating institutes will provide and set-up equipment on the beam line under the Fermilab Particle Physics Division guidance and supervision, provide the DAQ and slow control systems if needed, provide run coordination and funding for its personnel for the beam test.

V. Responsibilities by Institution – Fermilab

4.1 Fermilab Accelerator Division:

4.1.1 Use of MTest beamline as outlined in Section II. [0.25 FTE/week]
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 ACNET console and remote logging 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). [0.25 FTE/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 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. [6.5 FTE/week]
4.2.2 Maintain the FTBF pixel and strip telescopes and assist in coordinating it with the experimenters DAQ.
4.2.3 Personnel will assist in modifying the DUTs housing if needed.
4.2.4 Conduct a NEPA review of the experiment.
4.2.5 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.
4.2.6 Provide safety training as necessary, with assistance from the ESH&Q Section.
4.2.7 Update/create ITNA's for users on the experiment.
4.2.8 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews.

4.3 Fermilab Scientific Computing Division

4.3.1 Internet access should be continuously available in the MTest control room.
4.3.2 The experimenters might require the loan of a radioactive source available at FTBF. A Beta Gun is the source used for calibration purposes.
4.3.3 Set up and maintenance of Si tracking system and assist in supporting it.

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 FTE]

4.5 FERMILAB COLLABORATORS

4.5.1 Lorenzo Uplegger and Ryan Rivera will set up and maintain the Si telescope and will take shifts and provide technical assistance during operations.

4.5.2 Alan Prosser, Gino Bolla, Petra Merkel will take shifts and help the experimenters with technical assistance during operations.

V. SUMMARY OF COSTS

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Accelerator Division	0	0.5
Particle Physics Division	0	6.5
Scientific Computing Division	0	0
ESH&Q Section	0	0.2
Fermilab Collaborators	0	8
Totals Fermilab	$0.0K	15.7
Totals Non-Fermilab	0	8

VI. 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.

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

6.9 The spokesperson, or designee, will generate a one-page summary of the experiment's use of the Test Beam facility during the fiscal year, to be included in the annual Test Beam Report Fermilab submits to the DOE.

At the completion of the experiment:

6.10 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.

6.11 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.

SIGNATURES:

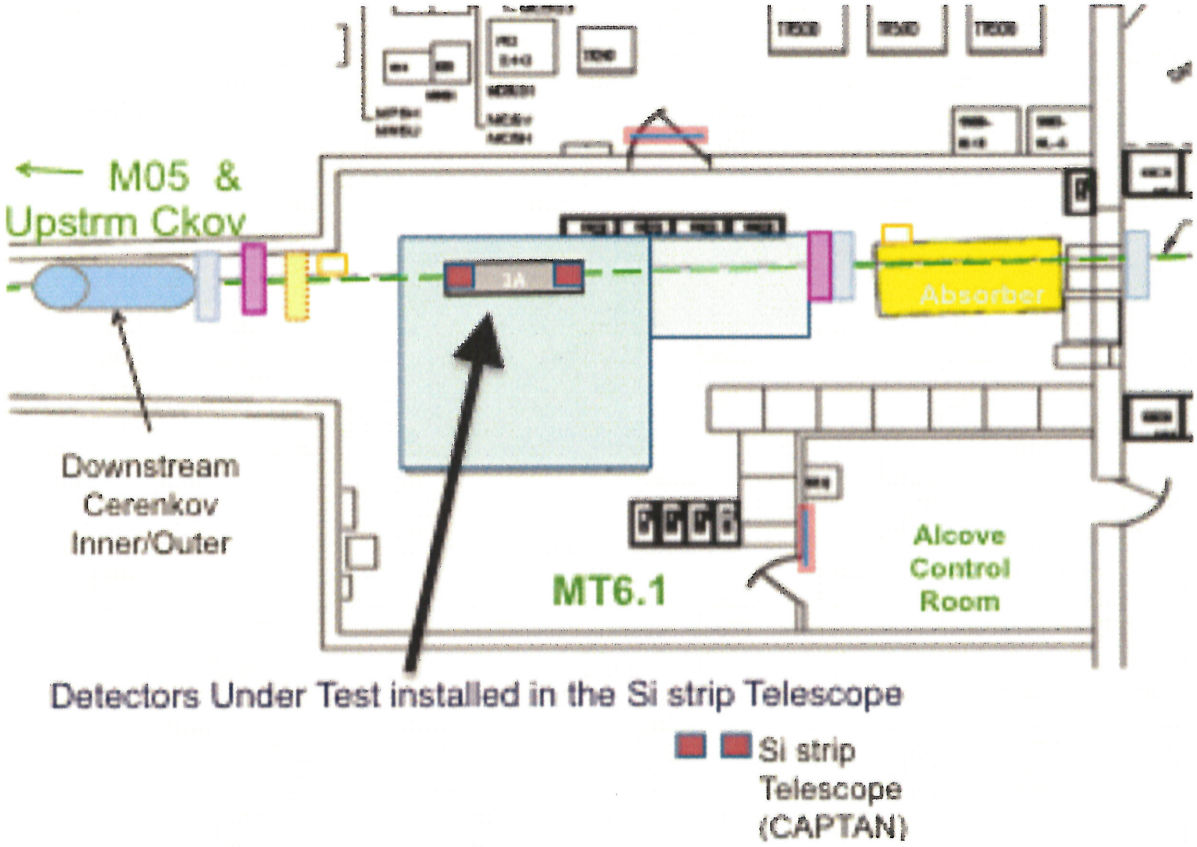
The spokesperson is the official contact and is responsible for forwarding all pertinent information to the rest of the group, arranging for their training, and requesting ORC or any other necessary approvals for the experiment to run.
The spokesperson should also make sure the appropriate people (which might be everyone on the experiment) sign up for the test beam emailing list.

Lorenzo Uplegger 10 / 28 / 2015

Lorenzo Uplegger, Experiment Spokesperson

APPENDIX I: MT6 AREA LAYOUT

MTEST AREAS



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:

Quantity	Description
1	NIM crate
1	LRS 364
1	LRS 621A

PPD FTBF:

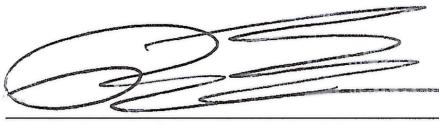
Quantity	Description
1	Si pixel-strip tracking stations

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

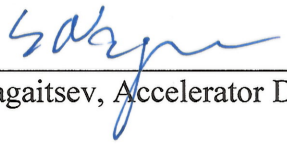
Items for which there is anticipated need should be checked.
See ORC Guidelines for detailed descriptions of categories.
There is NO need to list existing Facility infrastructure you might be using.
(Do Not list FTBF Lasers or Motion Tables, unless you are bringing them)

Flammables (Gases or Liquids)		**Gasses**		**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	
x	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:	Beta Gun		Mercury (Hg)		TEA	
Strength:	Any		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:			High Voltage (50V)		Lifting Devices	
MFR Class:			Exposed Equipment over 50 V	x	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	

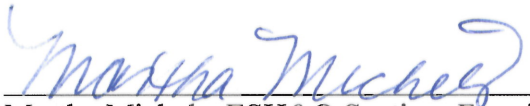
The following people have read this TSW:



Patty McBride, Particle Physics Division, Fermilab — 11 / 18 / 2015



Sergei Nagaitsev, Accelerator Division, Fermilab — 11 / 19 / 2015



Martha Michels, ESH&Q Section, Fermilab — 11 / 18 / 2015

Robert Roser, Chief Information Officer, Fermilab — 11 / 19 / 2015

Joe Lykken, Chief Research Officer, Fermilab — 11 / 23 / 2015