Fermilab

Directorate

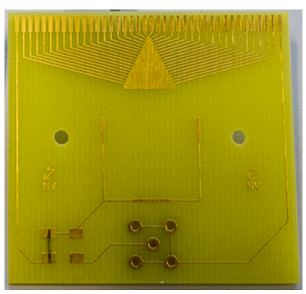
TECHNICAL SCOPE OF WORK
FOR THE 2014 FERMILAB MTA DETECTOR IRRADIATION PROGRAM

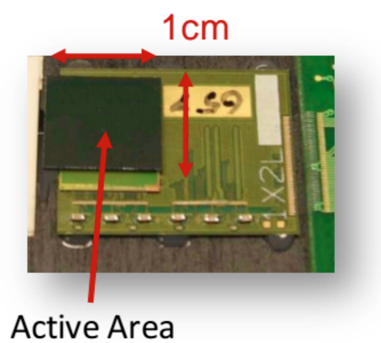
T-992: Appendix I

MTA Irradiation of Radiation-Hard Sensors for the SLHC

5 March, 2014

Last Revised: 9 June, 2014





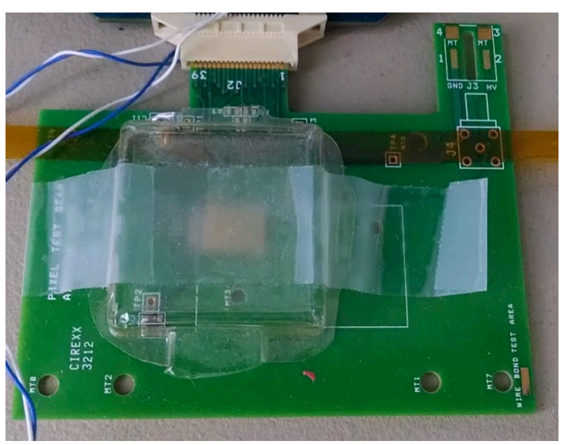


TABLE OF CONTENTS

I. Introduction 4

II. Personnel and Institutions: 5

III. Experimental Area, Beams and Schedule Considerations: 6

3.1 Location 6

3.2 Beam 6

3.2.1 Beam Types and Intensities 6

3.2.2 Beam Sharing 6

3.2.3 Running Time 6

3.3 Experimental Conditions 7

3.3.1 Area Infrastructure 7

3.3.2 Electronics Needs 7

3.3.3 Description of Tests 7

3.4 Schedule 7

IV. Responsibilities by Institution – Non Fermilab 8

V. Responsibilities by Institution – Fermilab 8

5.1 Fermilab Accelerator Division: 8

5.2 Fermilab Particle Physics Division: 8

5.3 Fermilab Scientific Computing Division 9

5.4 Fermilab ESH&Q Section 9

VI. Summary of Costs 10

VII. General Considerations 11

Reportable Elements and Isotopes / Weight Units / Rounding 16

I. INTRODUCTION

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the T-992 experimenters of Fermilab, Purdue University, INFN (Milano and Torino), and University of Colorado to develop and test radiation hard pixel sensors for the SLHC (also known as the HL-LHC).

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:

This TSW describes a test of irradiation of components for pixel sensors for the SLHC. The experimenters plan to conduct radiation tolerance testing on several different types of sensors. All components are small with surface densities less than 1 gm/cm^2. The sensor material and printed circuit board carriers expected in the beamline at any one time amount to approximately 12% of a radiation length and 4.3% of a nuclear interaction length. The experimenters plan on measuring the effect of total ionizing dose (TID) with hadrons at fluences of approximately ranging from 1e14 to 2e15 neutron equivalent/cm^2. Tests are done with unpowered devices. The devices will be mounted on small printed circuit boards so that their performance can be tested after irradiation in another location (e.g. the Fermi Test Beam Facility).

The experimenters plan a two phased test approach. The first phase, not requiring thermal cooling after irradiation, would include irradiation of low interest sensors up to 1e14 neutron equivalent/cm^2 to establish expectations for the process and activation levels. The purpose of Phase 1 is to convince the parties involved that Phase 2 is worth pursuing (considering safety, lab strategy, and the effect on other beamline users).

The second phase would involve irradiating high interest sensors to fluences in the range of 1e14 to 2e15 neutron equivalent/cm^2 and would require immediate (within roughly an hour) thermal cooling (< 4 Celsius) after exposure to prevent annealing. In situ cooling might also be possible although the experimenters, as yet, do not have a viable solution.

It is understood that if Phase 1 does not give the parties involved confidence that Phase 2 can be successfully carried out, then the experimenters will not pursue Phase 2 at Fermilab.

II. Personnel and Institutions:

Spokesperson: Lorenzo Uplegger (uplegger@fnal.gov 630.840.2627)

In charge of beam tests: Lorenzo Uplegger (uplegger@fnal.gov 630.840.2627)

Fermilab liaison: Erik Ramberg

The group members at present include: *(Please use full names)*

Institution	Country	Collaborator	Rank/Position	Other Commitments
Fermilab	USA	Lorenzo Uplegger	App. Physicist	CMS
Fermilab	USA	Ryan Rivera	Engineer	CMS
Fermilab	USA	Alan Prosser	Engineer	CMS
INFN Milano	Italy	Luigi Moroni	Scientist	CMS
INFN Milano	Italy	Mauro Dinardo	Scientist	CMS
INFN Torino	Italy	Maria Obertino	Scientist	
INFN Torino	Italy	Ada Solano	Scientist	
Colorado	USA	John Cumalat	Professor	
Colorado	USA	Steve Wagner	Professor	
Purdue	USA	Daniela Bortoletto	Scientist	CMS
Purdue	USA	Gino Bolla	Scientist	CMS
Purdue	USA	Kirk Arndt	Engineer	CMS
Purdue	USA	Mayur Bubna	Scientist	CMS

III. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

3.1 LOCATION

3.1.1 The beam test(s) will take place in the experimental hall of the MTA.

3.2 BEAM

3.2.1 BEAM TYPES AND INTENSITIES

Energy of beam: 400 MeV
Particles: protons
Required Fluences: 1e14 to 2e15 particles/cm^2
Beam spot size: σ ~ 1 cm diameter

The experimenters request feedback as to the beam position on the devices under test.

The purpose of this test is to uniformly irradiate sensor components to evaluate their use in a high radiation environment such as the SLHC. The flux of particles needs to be known with a precision of 5%.

3.2.2 BEAM SHARING

Beam sharing is feasible as long as it does not interfere with our goal which is to uniformly irradiate our stack of sensors.

3.2.3 RUNNING TIME

We assume for purposes of calculation that 5e12 protons can be delivered per pulse, with one pulse to the hall per minute. Then 20 pulses over 20 minutes would be required to achieve 1e14 protons. And to reach 2e15 protons, it would require 400 pulses, or approximately 8 hours. It is anticipated that the first phase will consist of approximately 20 pulses. If successful, the second phase would approach the 400 pulses which the experimenters understand to be pushing the limits of the facility.

The experimenters want to install all of the sensors at once. It is expected that 10-20 sensors would be available for irradiation. The first phase would involve approximately 5 low interest sensors. The second phase would involve approximately 10 high interest sensors. Access will be required to insert and extract sensors from the beam line. See also section 3.4.

3.3 Experimental Conditions

3.3.1 Area Infrastructure

The experimenters will need radiation monitoring and a location for post-irradiation storage (small refrigerator which could be provided by experimenters) of radioactive material as it cools down.

The experimenters will also need beam flux and position measurements possibly by material activation methods.

3.3.2 Electronics Needs

No electronics are needed.

3.3.3 Description of Tests

No in-situ tests are needed. The irradiated sensors will be evaluated at the Fermi Test Beam Facility and a later date after sensors have cooled enough to be handled.

3.4 Schedule

The experimenters will be ready to begin tests in June 2014 when beam is available. The exact timetable will be determined by the availability of beam time. It is expected that 10-20 sensors would be available for irradiation. As described above, the total time required for irradiation would be about 20 minutes for Phase 1 and 8 hours for Phase 2, assuming 5e12 per pulse. If Phase 2 were successful, the experimenters would want to repeat Phase 2 annually until the CMS Phase II upgrades are completed.

It should be noted that if the beam spot size is larger than 1 cm, then longer irradiation times will be needed to ensure the target dose is achieved at the sensors.

IV. Responsibilities by Institution – Non Fermilab

This is a collaboration of several institutions who are working to study the performance of various sensors that are radiation hard and viable candidates for use in the innermost vertex detector for the HL-LHC environment. Each institution will bring their own items for testing and remove them as soon as handling and transportation is permitted. They will each be responsible for the individual components for testing and the data collection and storage.

V. Responsibilities by Institution – Fermilab

5.1 Fermilab Accelerator Division:

5.1.1 Use of MTA beamline as outlined in Section II.

5.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.

5.1.3 Beam flux, size and position will be made available via ACNET

5.1.4 Reasonable access to the equipment in the MTA beamline will be granted to the experimenters as needed, assuming they are trained for access.

5.1.5 Connection to beams console and remote logging (ACNET) should be made available.

5.1.6 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]

5.1.7 Position and focus of the beam on the experimental devices under test will be under control of the MTA group within the APS section.

5.2 Fermilab Particle Physics Division:

5.2.1 Conduct a NEPA review of the experiment.

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

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

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

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

5.3 Fermilab Scientific Computing Division

5.3.1 Internet access should be continuously available in the MTA control room.

5.4 Fermilab ESH&Q Section

5.4.1 Assistance with safety reviews.

5.4.2 No sources are required for these tests.

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

5.4.4 The ESH&Q section will cooperate with the Accelerator Division radiation safety group to monitor activity of irradiated samples and will be responsible for allowing irradiated samples off site.

VI. SUMMARY OF COSTS

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Particle Physics Division	0.0	0.25
Accelerator Division	0	0.5
APS Section	0	1.0
Scientific Computing Division	0	0
ESH&Q Section	0	0.5
Totals Fermilab	$0.0K	1.7
Totals T-992	0	0

VII. 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 from the experiment is present during all irradiation and cool-off periods 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.

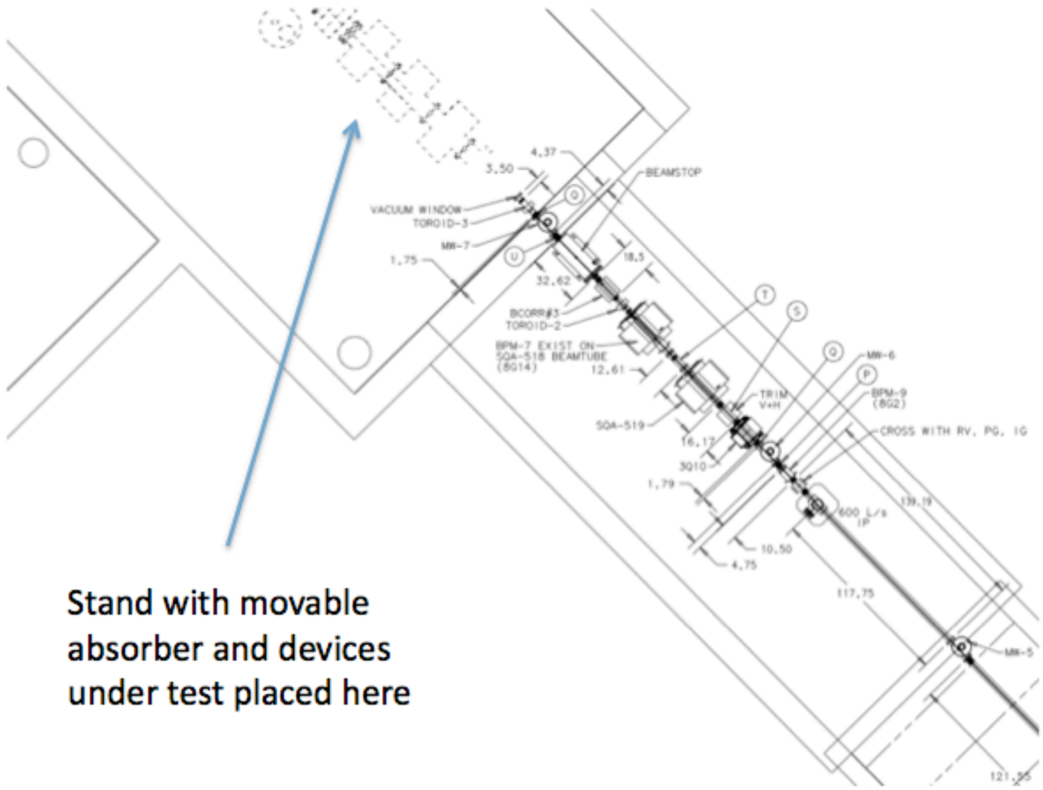
6.11 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters' Meeting.

SIGNATURES:

____ / /2014

Lorenzo Uplegger, spokesman of T992-A1

Appendix 1: Location of Apparatus in MTA



APPENDIX II: EQUIPMENT NEEDS

All sensor components to be tested are provided by the experiment.

The experiment is anticipating providing a small holder that can hold all the sensors aligned with each other. The experiment is requesting of the facility a method of placing and aligning the aforementioned sensor holder in the beam.

A test stand to hold the movable beamstop and devices to be tested is being requested from PPD.

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need *should be* checked. See next page for detailed descriptions of categories. (*There is NO need to list existing Facility infrastructure you might be using*)

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		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		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	

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:

____ / / 2014
Michael Lindgren, Particle Physics Division, Fermilab

____ / / 2014
Sergei Nagaitsev, Accelerator Division, Fermilab

____ / /2014
Mark Palmer, Muon Accelerator Project

____ / / 2014
Robert Roser, Scientific Computing Division, Fermilab

____ / / 2014
Martha Michels, ESH&Q Section, Fermilab

____ / /2014
Greg Bock, Associate Director for Research, Fermilab

____ / /2014
Stuart Henderson, Associate Director for Accelerators, Fermilab