Fermilab

Directorate

TECHNICAL SCOPE OF WORK

FOR THE 2013 – 2014 FERMILAB TEST BEAM FACILITY PROGRAM

T-1036

Tests of a high rate pixel detector for CMS Upgrade

July 10, 2013

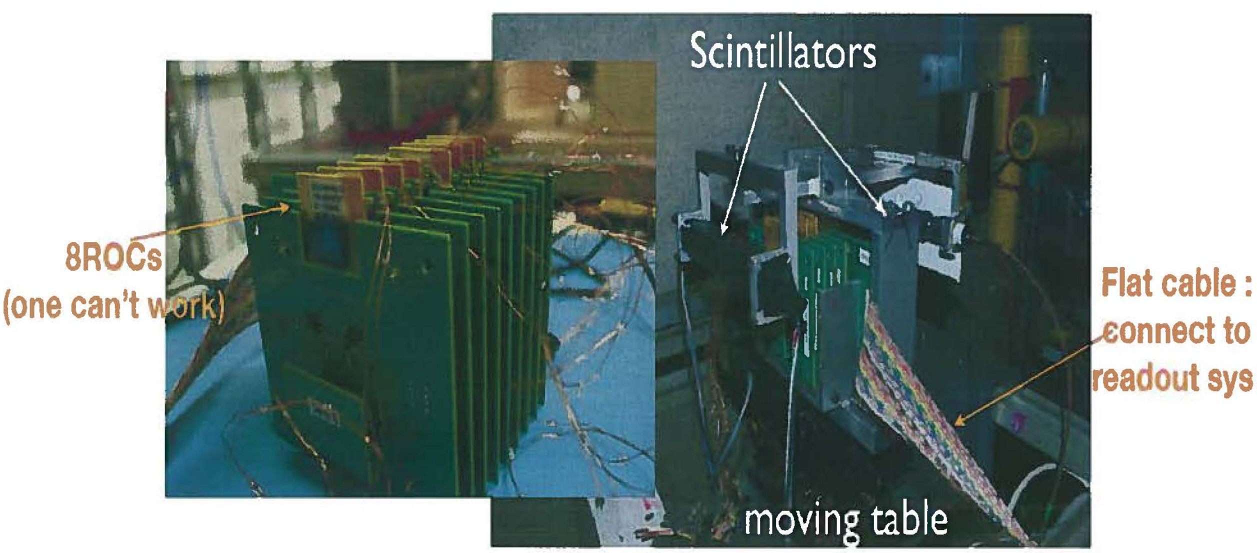


TABLE OF CONTENTS

INTRODUCTION

This is a Technical Scope of Work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of the CMS Pixel group, which consists of individuals from the Bristol University, CERN, Fermilab, Rutherford Laboratory (UK), and National Taiwan 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 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 TSW 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:

Motivation:

Many modern particle detectors require very high rate tracking capability. One example of this is the CMS tracker, and particularly its silicon pixel detector. The existing detector performs well, but will not continue to perform well as the LHC luminosity is increased. For this reason, the pixel detector will be replaced at least twice. Each new detector will be designed to operate in a higher particle fluence than the one it replaces. Both radiation tolerance and the ability to operate efficiently at high, continuous instantaneous rate are required. It is important to verify the rate capability of the new detectors and readout electronics before they are installed in CMS. The first replacement will happen around end of 2016. A new pixel readout chip was recently produced at the Paul Scherer Institute (Switzerland) to handle the foreseen high luminosity running of the LHC towards the end of the decade. High rate test beam areas are possible both at CERN and at PSI, but the beam at CERN will not be available during the upcoming LHC long shutdown and it is not possible to make precise measurements of pixel detector readout performance in the low energy pion beam at PSI. The experimenters therefore propose to test the high rate tracking capability of the new pixel detectors using the new pixel readout chip in the fall of 2013 at the MT3 High Rate tracking area that is currently being developed at Fermilab. The setup will be composed of two telescopes, each containing 8 single pixel readout-chips. One telescope has the sensors planes perpendicular to the beam and in the second the planes are inclined by 20° and 30° with respect to the beam. The drift angle of the charge carriers in the magnetic field in CMS will be simulated by the 20° angle and the 30° angle corresponds to the inclination of the CMS barrel pixel. The result of these inclinations in the two directions is spreading of the charge across more than one pixel unit and thus obtaining a better position resolution.

The two telescopes will serve to test two different features of the digital chip. In case of the zero-angle telescope version, 80% of events will have a single pixel hit and the time stamp buffer will be saturated before the data buffer at high particles rates. In the inclined version the particles will produce hits in 3-5 pixels and the data buffer will saturate before the time stamp buffer. In both cases the experimenters want to measure independently at which fluence each buffer saturates. The two telescopes will be operated in a cold box in order to maintain a consistent operating temperature and to avoid thermal runaway due to an increased leakage current associated with radiation damage.

A variable beam rate of 400 MHz/cm^2 over $\geq$ 1 cm^2 is required as well as the means to measure the rate. The experimenters will provide all the pixel detectors and associated readout electronics and data acquisition system to perform the tests.

I. PERSONNEL AND INSTITUTIONS:

Spokesperson: Anna Elliot-Peisert (CERN)

Experimenters in charge of Beam Tests: Simon Kwan (SCD), Lenny Spiegel (PPD)

Fermilab Liaison: Aria Soha

The group members at present are:

	Institution	Country	Collaborator	Rank/Position
1.1	CERN	Switzerland	Stefano Mersi	physicist
			Anna Elliot-Peisert	physicist
1.2	FNAL	USA	Kevin Burkett	physicist
			David Christian	physicist
			Simon Kwan	physicist
			Lenny Spiegel	physicist
			Lorenzo Uplegger	physicist
			Fan Yang	physicist
			Marco Verzocchi	physicist
1.3	Karlsruhe/CERN	Germany	Andreas Kornmayer	PhD student
1.4	DESY	Germany	Simon Spannagel	physicist
1.5	National Institute of Chemical Physics and Biophysics	Estonia	Imitiaz Ahmed	engineer
1.6	University of Bristol	UK	David Newbold	physicist
			David Cussans	physicist
			Steve Nash	physicist
			Sudeshna Dasgupta	physicist
1.7	Rutherford & Appleton Laboratory	UK	Tim Durkin	physicist
			Kristian Harder	physicist
1.8	National Taiwan U.	Taiwan	Ulysses Grundler	physicist
			Yeng-Ming Tzeng	physicist
			Rong-Shyang Lu	Physicist
1.9	INFN Perugia	Italy	Leonello Servoli	physicist
			Anirban Saha	physicist
			Mauro Menichelli	physicist
			Michele Salvatore	engineer

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

2.1 LOCATION

2.1.1 The beam tests will take place in the MT3 enclosure.
2.1.2 A control room area will be set up for the experimenters in the MS3 service building.

2.2 BEAM

2.2.1 BEAM TYPES AND INTENSITIES

Energy of beam: 120 GeV (or 8-66 GeV secondaries)
Particles: protons (or pion secondaries)
Intensity: Adjustable up to 400 MHz (1.6E9 particles per 4 second spill)
Beam spot size: Slightly larger than 1cm x 1cm with a uniform intensity on the DUT.

Spill Structure: Gaps between beam must be minimized; At least three consecutive Booster batches of at least 80 bunches are required (with no more than 6 empty RF buckets between batches). The length of the spill and repetition rate are not critical parameters.

2.2.2 BEAM SHARING

Users compatible with the above beam conditions could make use of the MT6 areas, as secondary users.

2.3 EXPERIMENTAL CONDITIONS

2.3.1 AREA INFRASTRUCTURE

The Accelerator Division will provide a segmented wire ionization chamber (SWIC) for monitoring the beam profile and assessing the uniformity of the beam on the DUT; a SEM, either in MT3 or nearby enclosure, for monitoring beam intensity. AD will provide clock and RF signals in the MS3 service building. PPD will install cables and other infrastructure for those signals to be available in the MT3 alcove.

A phototube signal digitized by the CMS QIE-10 at the 53 MHz RF frequency will measure the uniformity of the beam in time. This signal will also be used to generate a trigger within the MT3 tunnel for the two beam telescopes.

An XY stage with a step of ~1 mm and remotely controlled is required for aligning the two telescopes with the beam. The telescopes will reside inside a CMS "Vienna" box, which is approximately 40cm wide by 50cm tall by 75cm along the beam direction and should weigh less than 50 kg.

The experimenters will provide the telescopes, data acquisition system, 1-2 scintillators for triggering and monitoring the spill structure, and any required PCs.

There should be sufficient electrical outlets near the setup in the MT3 tunnel and MT3 alcove for the cold box, scintillator power supply, and DAQ. The experiment will adapt all equipment for US 110V/60Hz. If a chiller is needed for the cold box, this will likely require a 220V outlet.

Six pairs of HV/LV RG58 cables (green and red) should run between the enclosure and the control area. Additionally, one RG8 cable should be installed to carry an Accelerator signal from MS3 to MT3. There should also be a fiber optic bundle for Ethernet communication between the enclosure and control area.

2.3.2 Apparatus

The two telescopes will be installed in a box operated at 0° C. The box is cooled by two Peltier elements. The experiment will provide a chiller for removing heat from the Peltier elements. The chiller should sit just outside the MT3 alcove, near the 220V outlet. As an alternative, if a chiller is not available, the Accelerator Divison will provide low conductivity water (T=~30°C) at a pressure of 3 bars for cooling the Peltier elements. It is understood that the LCW line including the cold box will need to be certified by the AD. For the LCW scenario a panel will be needed with IN and OUT valves and a bypass mode. No panel is needed if a chiller is used.

Copper tubing from the gas rack in the MS3 service building will be installed by the FTBF for providing N2 gas (high pressure cylinder) to the cold box. FTBF will also provide a panel in the vicinity of the alcove for regulating the N2 pressure in the cold box and confirming and quantifying the gas flow (which is expected to be less than 10 SCFH).

2.3.3 Electronics Needs

The experiment requires a QIE10-based board for monitoring the spill structure, and this is being prepared by Collaborators at Fermilab. (The same board will be used by the SeaQuest experiment.) FNAL Collaborators will also provide an ET9215B fully transistorized photomultiplier base for monitoring the signal from a single device – probably a scintillation counter – that the beam will pass through. With the exception of some standard PREP equipment (listed in the Appendix) and possibly some low voltage supplies, all other electronics needed for the telescope will be shipped from Europe. This includes the PC used to run the DAQ. The equipment will be controlled from the MS3 area and no offsite access is needed (although would be desirable for backing up data and checking email).

Standard 110V outlets are needed in the MT3 enclosure near the beam telescope. Should a chiller be required for the Peltier units, this would require a 220V outlet. There should be an Ethernet connection between MT3 and MS3.

2.3.4 Description of Tests

After the installation of the apparatus the experimenters might need to access a few times during the first day to troubleshoot the beam telescope. With the remote control of the stage the experimenters should not need any further access for the time of data taking with the straight version of the telescope (a few days). An access will be needed to replace the telescope in the cold box.

The experiment anticipates running from 6am to 6pm but can run during off-hours, especially in the beginning when this might be useful to diagnose the setup without impacting other users.

2.4 Schedule

The next iteration of the CMS pixel readout chip developed for the CMS phase 1 pixel detector upgrade is available now. Since there will not be test beam available at CERN until end of 2014, the experimenters would like to carry out the high rate beam test at Fermilab in the fall of 2013, with a completion before the end of November in order to give timely feedback to the CMS Pixel ROC designers in case weaknesses in the present design are discovered. The experimenters request a total of two weeks, with the first couple of days for setting up and safety inspection. It is important that reliable smooth extraction of three consecutive turns of the MI beam be established early on in the Accelerator startup program, and definitely well before the point where the experimenters would ship the telescopes to FNAL and need to make travel plans.

III. Responsibilities by Institution – CMS

The personnel from the participating institutes will provide and set up equipment in the beamline under the guidance and supervision of the Fermilab Particle Physics Division, provide the pixel detector planes, trigger counters, the DAQ, and all the power supplies. They will provide run plan and coordination. Funding for people participating in the beam test will be provided by their home institutes.

3.1 CMS Pixel Group

3.1.1 CERN will provide all the scintillation counters and associate electronics and power supplies to form a trigger to readout the pixel system. CERN/RAL/Bristol will also provide all the electronics and software for reading out the pixel system and the DAQ system.

3.1.2 PSI will provide 16 single pixel ROCs mounted on carrier boards.

IV. 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 (SWIC, SEM, loss monitors, etc.) instrumentation, controls, clock distribution, and power supplies.
4.1.3 The 53 MHz RF signal should be made available in the MS3 control room.
4.1.4 Reasonable access to the equipment in the MT3 enclosure.
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). [0.5 person-weeks]
4.1.7 Position and focus of the beam on the experimental devices under test will be under control of MCR.
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 FTBF High Rate Tracking Area. 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. [1.0 person weeks]
4.2.2 PPD will transmit the Accelerator 53 MHz RF signal to the MT3 alcove.
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.
4.2.8 Provide support for the moving table, as specified in section 2.3.1.

4.3 Fermilab Scientific Computing Division

4.3.1 Internet access should be continuously available in the MS3 control room. The experimenters will be responsible for backing-up data.
4.3.2 See Appendix II for summary of PREP equipment pool needs.

4.4 Fermilab ESH&Q Section

4.4.1 Assistance with safety reviews.
4.4.2 Provide safety training, with assistance from PPD and Medical Office, as necessary for experimenters. [0.4 person-weeks]

V. SUMMARY OF COSTS

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Particle Physics Division	0	2
Accelerator Division	0	1
Scientific Computing Division	0	0
ESH&Q Section	0	0.4
Totals Fermilab	0	3.4
Totals Non-Fermilab	$40000 (existing eqp)	30**

** 6 people for two weeks for data-taking, 6 person-weeks in preparing the hardware; 12 person-weeks of data analysis.

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 MS3 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 Computing Sector 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:

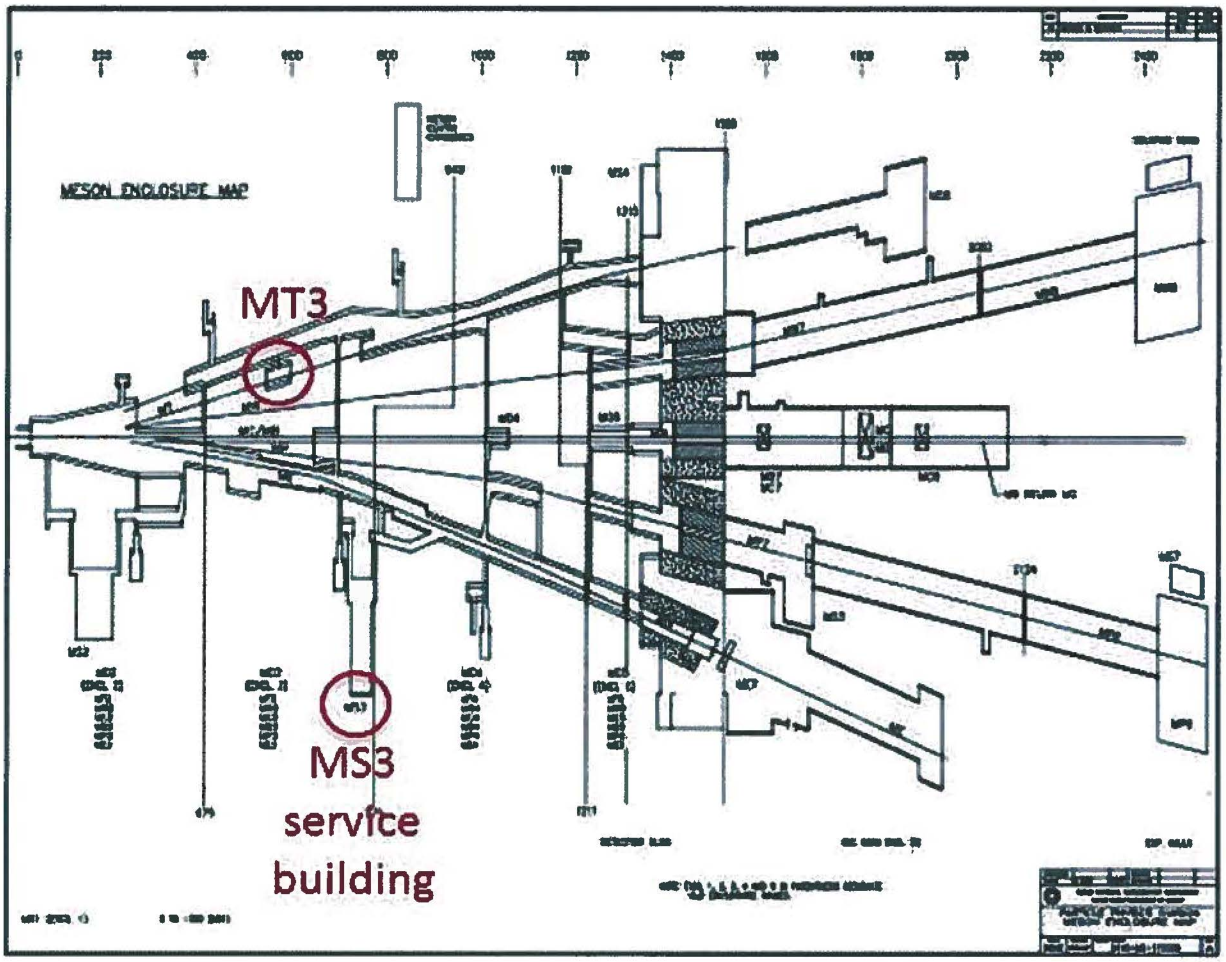
Anna Peisert

Anna Elliot-Peisert, Experiment Spokesperson

12 /July/ 2013

Appendix I: Area Layout

Detector apparatus will be set up in MT3 alcove, within the MT3 enclosure. The apparatus will be monitored from the MS3 service building, in an area set aside for users.



APPENDIX II: EQUIPMENT NEEDS

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

PREP EQUIPMENT POOL:

Quantity	Description
1	NIM Bin with cooling fan
1	Discriminator unit (e.g. LeCroy 621 Quad Discriminator)
1	Coincidence unit (.e.g. LeCroy 465 4-fold coincidence module)
1	Gate generator 9e.g. LeCroy 222 Dual Gate and delay module)

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

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	
X	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:	Strontium		Mercury (Hg)		TEA	
Strength:	low		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	
MFR Class:			Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP		Scaffolding/ Elevated Platforms	
			Modified Commercial/PREP		Other:	
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:		Inside Diameter:		X	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.

TSW for T-1036 Tests of high rate pixel detector for CMS Upgrade

The following people have read this TSW:

________________________________ 7 / 15 / 2013
Michael Lindgren, Particle Physics Division, Fermilab

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Roger Dixon, Accelerator Division, Fermilab

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Robert Roser, Scientific Computing Division, Fermilab

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