Fermilab

Directorate

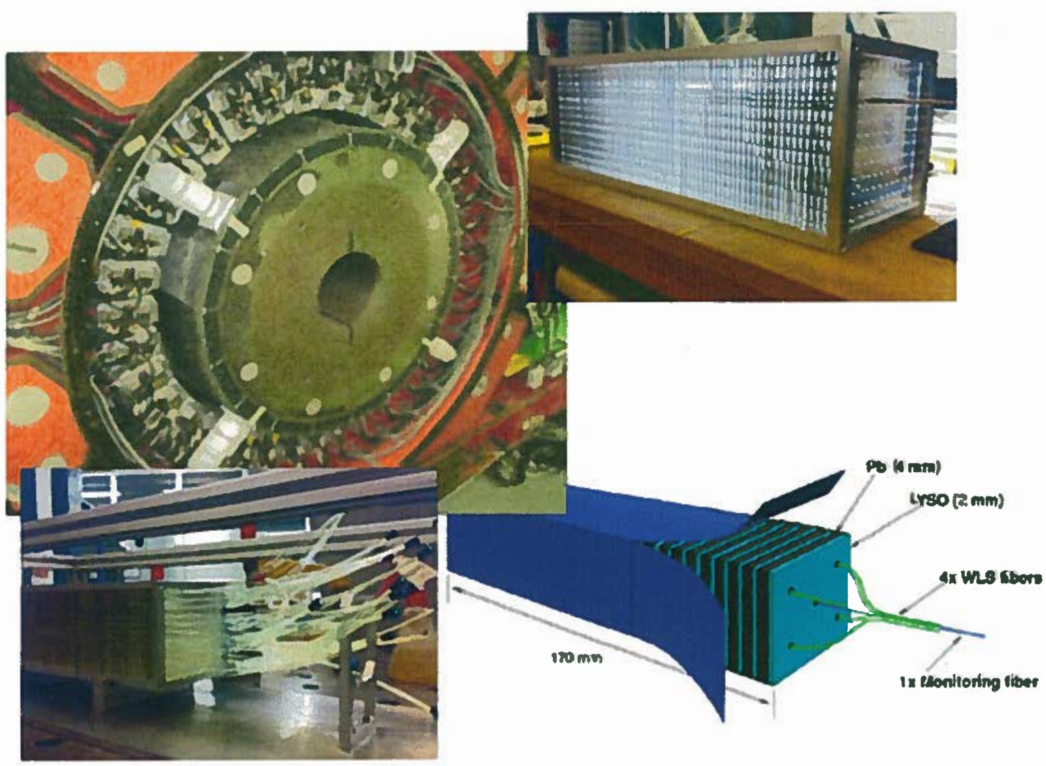
TECHNICAL SCOPE OF WORK

FOR THE 2013 – 2016 FERMILAB TEST BEAM FACILITY PROGRAM

T-1041

CMS Forward Calorimetry R&D

November 11, 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 the CMS Forward Calorimetry Taskforce (FCAL group) who have committed to participate in beam tests to be carried out during the 2013-2016 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:

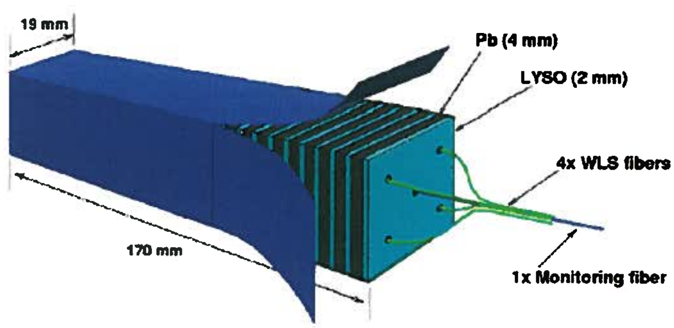
The CMS Forward Calorimetry Taskforce (FCAL group) concentrates on developing new technologies for forward detectors in Phase II Upgrade of the CMS detector. The R&D includes searching for new sensitive materials for forward calorimetry such as radiation hard scintillators/crystals, capillaries and wavelength shifting/quartz fibers as well as novel readout techniques such as precision timing detectors and radiation hard photodetectors. This R&D will have immediate applications related to forward angle calorimeters in CMS.

The R&D program consists of testing several small-large scale prototypes in hadron and electron beams:

1. Strawman design for replacement detectors in the various subsystems. This will be studied for best possible response for e/gamma and hadrons.
2. Shashlik electromagnetic endcap calorimeter tests using scintillating tiles, thick-wall quartz capillaries with WLS core, and GaInP Photosensors. The study involves: Reducing optical paths by about 10 times; scintillation tiles 6 times as rad hard as $PbWO_4$ (LYSO); measurements of energy deposition, optical transport, signal definition; design and interpretation.
3. HE segmentation studies using new sampling media: Quartz plates or scintillators in Quartz capillaries. This study concentrates on improved jet response with more granular transverse segmentation and dual readout; fast timing (Čerenkov for EM component) and scintillation (for EM and hadronic component).
4. RPCs (Resistive Plate Chambers) with high rate capabilities using low resistivity glass.
5. GEMs (Gas Electron Multipliers) for forward calorimetry implementations.

The FCAL group will make the detailed design for the prototypes and optimize the modules for best operability/performance in the forward region. A typical strawman electromagnetic calorimeter prototype is illustrated in Figure 1. The expected size of all the calorimeter prototypes is up to a few cubic feet. Figure 2 shows a shashlik type electromagnetic calorimeter module with W absorbers and scintillating fibers as the active medium. One of the calorimeter prototypes is designed to use Argon gas as part of its active medium. The gas will either be circulated or used in a closed system. The RPC gas is a mixture of three components Tetrafluorethane (R134A): Isobutane : Sulfurhexafluoride (SF_6) with the following ratios 94.5 : 5.0 : 0.5. The mixture is non-flammable. The GEMs will use a mixture of CO_2 and Ar. The readout options are multi-anode PMTs, SiPMs, GaAs and GaInP photodetectors and digital/analog on-board readout. For the case of the secondary emission module tests, the active medium can be considered as the dynodes of the mesh-dynode PMTs. Most of the prototypes will be modular to enable changing the absorber materials, active media and readout devices and associated electronics.

The readout electronics ranges from the standard VME/CAMAC systems to CMS QIE10, Fermilab TB4, Fermilab PADE, APV-SRS and digital readout. Figure 3 shows the electronics readout concept for the high precision shower timing dual readout calorimeter. Figure 4 shows an overview of the APV-SRS readout electronics. All readout options have part of their readout electronics on the detector. One exception is the digital readout, which is entirely on the detector.



Prototype replacement for EE: Absorber plates could be W or Pb; Scintillation plates can be LYSO or other scintillator options. Fiber readout is likely Quartz Capillaries with WLS cores. Photosensors would be GaAs or GaInP Pixelated Geiger Mode APDs.

Simulation model of the Shashlik structure built using Litrani code

Figure 1. Typical shashlik strawman electromagnetic calorimeter prototype.

Figure 2. Pictures depicting a shashlik type electromagnetic calorimeter.

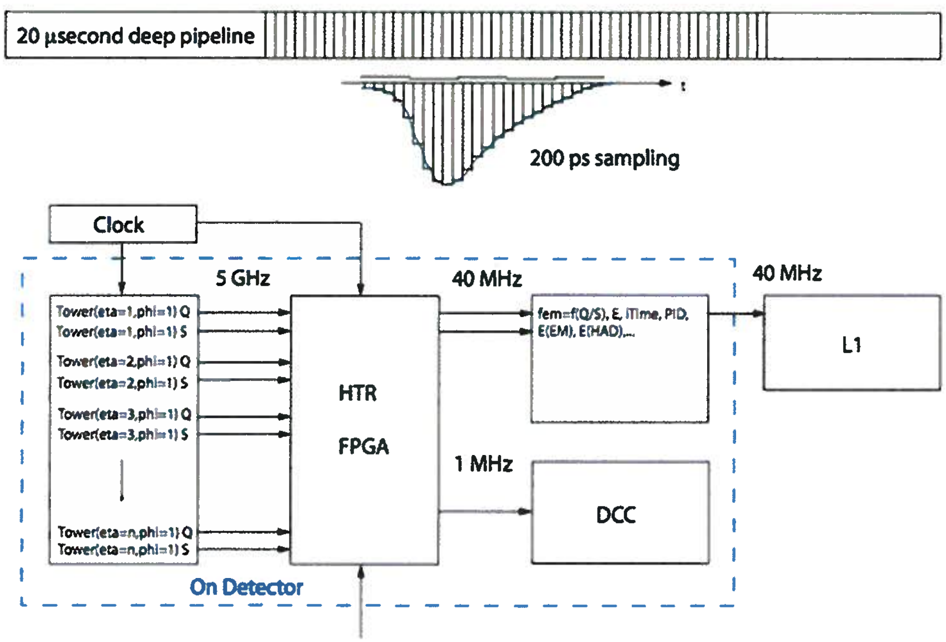


Figure 3. A sketch of the electronics readout concept of the dual readout calorimeter prototype utilizing precision timing of interactions.

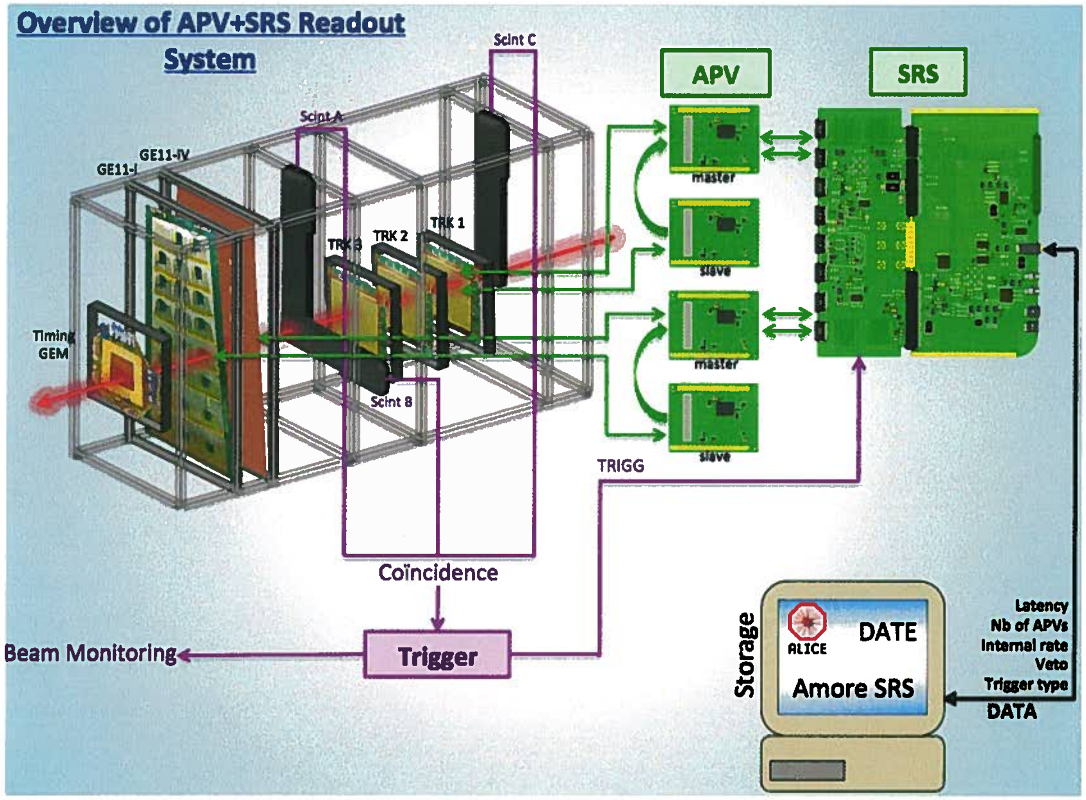


Figure 4. Overview of the APV-SRS readout electronics to be used with the GEM calorimeter prototype (sketch demonstrates a tracking setup).

The initial test beam plans will be based on the following options:

A Shashlik electromagnetic calorimeter composed of W or Pb absorber and LYSO crystal plates. The readout fiber configuration is quartz capillaries with a core of WLS fibers that wavelength shifts the LYSO emissions for the quartz to transmit to the photodetectors (SiPM/GaInP chips).

A hadron calorimeter for the endcap (HE) that has different radiation hard scintillator/quartz plates and a fiber configuration for better transmission but with the same absorber material (brass). Techniques for including dual readout based on wavelength discrimination are under study for this new configuration.

CMS Hadron Forward (HF) calorimeter-like prototypes: The present HF design with QP fibers replaced by QQ fibers. W based detector with hollow quartz capillaries for generation of Čerenkov light and containing in the hollow core with some gas admixture (Argon) for generating scintillation light for a dual readout calorimeter. Alternative fiber materials and geometries will be tested.

Secondary emission module in a sampling calorimeter setup based on the generation of secondary electrons in thin mesh-dynode structure and multiplication of these secondaries in a typical PMT structure.

Quartz plate sampling calorimeter setup with radiation hard photodetectors and/or radiation hard WLS fibers/anthracene or pTp capillaries. The quartz plates are pTp or ZnO –Ga coated to enhance light production and overall calorimeter performance.

A stack of RPCs in a digital readout configuration with at least one layer built with the lower resistivity glass to be tested for high rate capability. The layers can be interleaved with steel/tungsten absorbers to obtain a sampling calorimeter setup. Further R&D might include testing different designs of RPCs (e.g. single-glass RPC, Bakelite RPC, etc.) that could be viable options in the forward calorimetry.

A sampling calorimeter prototype with steel absorbers and GEMs as active layers.

A BaF_2 calorimeter and a quartz fiber calorimeter will be used as tail catcher calorimeters.

These various configurations can all be simulated to some degree, but it is essential that the simulations be accompanied by laboratory tests. To test these various modules, the experimenters will need electron beams of 2-32 GeV, secondary hadron (pion) beams of 2 – 60 GeV, the broadband muon beam and the primary 120 GeV proton beam.

The overall project will consist of a number of short, simple experiments, each lasting from one to three weeks. The FTBF is an excellent facility for such tests.

The data collected by each experiment subgroup is required to be copied to the CMS data storage areas (/castor/cern.ch/cms/testbeam/...) to make it available to the entire CMS collaboration. The experimenters will also be required to use the dedicated CMS elog " http://cmsonline.cern.ch/portal/page/portal/CMS%20online%20system/Elog", "Subsystems/HCAL/Forward Calorimetry TB" to record their activities. The details of the elog and the data storage areas will be provided/reminded by the spokespersons during and after run time.

The experiment subgroups can make publications provided that they use appropriate citations for the T-1041 and CMS experiments and the FTBF. The groups are encouraged to write CMS Detector Notes to report significant results.

I. PERSONNEL AND INSTITUTIONS:

Spokespersons and physicists in charge of beam tests: Burak Bilki and Yasar Onel,

Fermilab Experiment Liaison Officer: Aria Soha

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	University of Iowa	USA	Burak Bilki[1]	Postdoctoral Research Associate	CMS, ILC
			Yasar Onel	Professor	CMS, ILC
			Jose Repond[1]	Physicist	CMS, ILC
			Lei Xia[1]	Physicist	CMS, ILC
			Edwin Norbeck[2]	Professor	CMS, ILC
			Ianos Schmidt	Engineer	CMS
			Paul Debbins	Engineer	CMS
			David Northacker	Engineer	CMS, ILC
			Kai Yi	Postdoctoral Research Associate	CMS
			Viktor Khristenko	Graduate Student	CMS, ILC
			Kamuran Dilsiz	Graduate Student	CMS
			Hasan Ogul	Graduate Student	CMS
			Emrah Tiras	Graduate Student	CMS
			David Southwick	Graduate Student	CMS
1.2	Fermilab	USA	Jim Freeman	Physicist	CMS
			Juliana Whitmore	Physicist	CMS
			Paul Rubinov	Engineer	Minerva
			Michael Albrow	Physicist	CMS
			Sergey Los	Engineer	CMS
1.3	Caltech	USA	Harvey Newman	Professor	CMS
			Ren-Yuan Zhu	Professor	CMS
			Maria Spiropulu	Professor	CMS
1.4	CERN	Switzerland	Etiennette Auffray Hillemanns	Physicist	CMS
			Paul Lecoq	Physicist	CMS
			Kristof Pauwels	Postdoctoral Researcher	CMS

[1] Also at Argonne National Laboratory
[2] Deceased

			Andrea Benaglia	Postdoctoral Researcher	CMS
			Marco Lucchini	Doctoral Student	CMS
1.5	ETH	Switzerland	Francesca Nessi-Tedaldi	Physicist	CMS
1.6	University of Notre Dame	USA	Randal Ruchti	Professor	CMS
1.7	University of Maryland	USA	Sarah Eno	Professor	CMS
			Alberto Belloni	Professor	CMS
1.8	Texas Tech University	USA	Nural Akchurin	Professor	CMS
1.9	University of Virginia	USA	Bradley Cox	Professor	CMS
			Robert Hirosky	Professor	CMS
1.10	University of Minnesota	USA	Roger Rusack	Professor	CMS
			Jeremiah Mans	Professor	CMS
1.11	Carnegie-Mellon University	USA	Manfred Paulini	Professor	CMS
			Ben Carlson	Graduate Student	CMS
			Menglei Sun	Graduate Student	CMS
1.12	Florida State University	USA	Todd Adams	Professor	CMS
			Andrew Askew	Professor	CMS
			Silvia Tentindo	Physicist	CMS
			Marc Weinberg	Postdoctoral Researcher	CMS
			Kenji Ackert	Graduate Student	CMS
1.13	INFN Trieste	Italy	Aldo Penzo	Professor	CMS
1.14	Fairfield University	USA	David Winn	Professor	CMS
1.15	INFN Rome I	Italy	Francesca Cavallari	Physicist	CMS
1.16	INFN Milano Bicocca	Italy	Tommaso Tabarelli De Fatis	Physicist	CMS
1.17	Kansas State University	USA	Yurii Maravin	Professor	CMS
			Lovedeep Kaur Saini	Postdoctoral Research Associate	CMS
			Sachiko Toda	Graduate Student	CMS
1.18	Florida Institute of Technology	USA	Marcus Hohlmann	Professor	CMS
1.19	UCLA	USA	Jay Hauser	Professor	CMS
1.20	University of Rochester	USA	Pawel de Barbaro	Physicist	CMS
1.21	Princeton University	USA	Christopher Tully	Professor	CMS

Experimental Area, Beams and Schedule Considerations:

1.1 Location

1.1.1 The beam test(s) will take place in MT6.2 B-D, as shown in Appendix I

1.1.2 The MTest control room and electronics room will be used to house electronics (NIM/CAMAC/VME crates, DAQ computer, scopes, cables, connectors and other peripherals), and provide a small amount of work space (for several people).

1.2 Beam

1.2.1 Beam Types and Intensities

Energy of beam: 2-60 GeV / 2 – 32 GeV / 32 GeV / 120 GeV
Particles: secondary hadrons (pions) / secondary electrons / muons / primary protons
Intensity: 1k – 100k particles/ 4 sec spill
Beam spot size: about 5 cm^2

1.2.2 Beam Sharing

The experiment can share the beam with any experiment that has a downstream setup, and thin upstream detectors whenever possible.

The material budget of the test equipment will vary from 0 (single active layer) to 70 (calorimeter stack under test and a downstream tail catcher calorimeter) radiation lengths.

1.2.3 Running Time

Assembly of the setup can take several hours before beam time. Modifications to the setup can be made in the controlled accesses. Multiple setups can be placed on the motion table to minimize the number of accesses.

Once the test setup is in working order, an hour or two of beam will provide ample data for a single configuration. A typical run will consist of a series of data-taking runs followed by short controlled accesses to modify the configuration. The experiment intends to run 24 hours a day, as manpower is available. The controlled access frequency will be every 1 – 4 hours. See section 2.3.3 for total run time and long-term schedule.

1.3 EXPERIMENTAL CONDITIONS

1.3.1 AREA INFRASTRUCTURE

For part of the tests, the setup will be on the motion table in the MT6.2 test area. The size of the test equipment will be up to a few cubic feet, weighing 50 – 500 lbs. The experiment will need high voltage and data cables running from the test area to the control room via patch panels.

The experiment will require two wire chambers with 1 mm resolution for beam tracking to be provided by the facility.

One of the calorimeter prototypes is designed to use Argon gas as part of its active medium. The gas will either be circulated or used in a closed system. The RPC gas is a mixture of three components Tetrafluorethane (R134A): Isobutane : Sulfurhexafluoride (SF_6) with the following ratios 94.5 : 5.0 : 0.5. The mixture is non-flammable. The GEMs will use a mixture of CO_2 and Ar.

1.3.2 ELECTRONICS AND COMPUTING NEEDS

The experiment will need several NIM/CAMAC/VME crates and modules. In case some part of this equipment needs to be requested from PREP or Fermilab Test Beam Facility, the experimenters will make this request several days before the test beam start date. The experiment plans to use the existing data and high voltage cables and connectors in the test beam area.

The Phase I Upgrade electronics, namely QIE 10 are custom made. This is the upgrade electronics to the current CMS HCAL electronics. It consists of QIE crates and boards instead of e.g. VME ones. This will be tested in line with the upgrade calorimeters. The experimenters will provide electrical diagrams upon request before the ORC inspection.

Other custom electronics include the Fermilab TB4 board, Fermilab PADE, APR-SRS and digital readout. All of the mentioned electronics have been used in Fermilab experiments previously. The electrical diagrams can be provided upon request.

The experimenters will bring computers for data acquisition, slow control and data analysis purposes. These computers will need to be connected to the general Fermilab network. Some of these computers may need ethernet connections in the control room. For some tests, the data acquisition and slow control computers will need a private wired network. In this case, the experimenters will provide the associated network equipment (cables, switches, etc.).

1.3.3 DESCRIPTION OF TESTS

A typical run plan will consist of a series of data-taking runs followed by short controlled accesses to modify the configuration. The controlled access frequency will be every 1 – 4 hours. The change in the beam energy/type will be requested every 2 – 10 hours.

1.4 SCHEDULE

The experiment will request beam time of 2-3 weeks approximately four times a year. Two are expected to be in the fall and two in the spring. The experiment is expected to be completed by 2016.

II. Responsibilities by Institution – Non Fermilab

2.1 The CMS FCAL Collaboration:

The FCAL collaboration will bring and install the test equipment on a timely basis. The experimenters will bring most of the required NIM/CAMAC/VME data acquisition (DAQ) hardware, the DAQ computer and software. The FCAL collaboration will make requests for additional DAQ hardware from Fermilab PPD or PREP on a timely basis. The replacement cost of the DAQ hardware and the test equipment is $10K-$200K depending on the individual prototype.

III. Responsibilities by Institution – Fermilab

3.1 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 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). [0.25 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.

3.2 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 Set up and maintenance of 2 MWPC tracking stations. [1 FTE/week]
4.2.3 Remotely controlled motion table, as specified in section 2.3.1
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. [0.2 FTE]

3.3 Fermilab Scientific Computing Division

4.3.1 Internet access should be continuously available in the MTest control room.
4.3.2 Computing support for network needs as specified in section 2.3.2
4.3.3 See Appendix II for summary of PREP equipment pool needs.

3.4 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]

IV. Summary of Costs

Source of Funds [$K]	Materials & Services	Labor
Accelerator Division	0	0.5 FTE/week
Particle Physics Division	0.0	7.7 FTE/week
Scientific Computing Division	0	0
ESH&Q Section	0	0.2 FTE
Totals Fermilab	$0.0K	8.4
Totals Non-Fermilab	$10K-$200K	5

V. General Considerations

6.1 The responsibilities of the Spokespersons 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 Spokespersons agree 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 Spokespersons 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 Spokespersons 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 Spokespersons 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 Spokespersons also undertake 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 Spokespersons are 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 Spokespersons 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:

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.

11/13/2013

Burak Bilki, Experiment Spokesperson

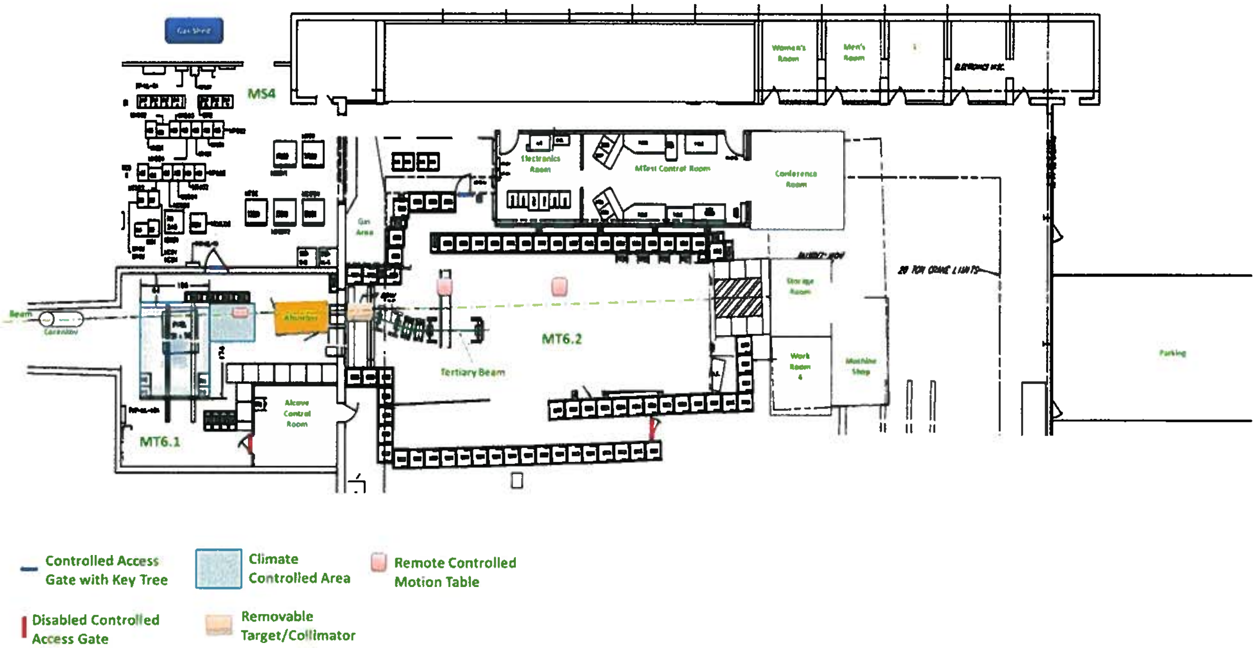
11/13/2013

Yasar Onel, Experiment Spokesperson

Appendix I: MT6 Area Layout

The test equipment will be setup in the MT6.2A-D area. Motion table will be utilized whenever necessary and possible.

MTest Areas



APPENDIX II: EQUIPMENT NEEDS

Provided by experimenters:

The University of Iowa will provide the following DAQ hardware for the experiment/FCAL group:

- 1/2 VME crate(s)
- VME Modules: Wiener VM-USB controller, Wiener MDGG8 delay and gate generator, 2xCAEN V792 QDC
- NIM Modules: Discriminator and coincidence modules

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

PREP EQUIPMENT POOL:

Quantity	Description
1	NIM crate
2	NIM discriminator and coincidence modules

PPD FTBF:

Quantity	Description
Multiple	High voltage and data cables and connectors
2	MWPC Tracking Stations
1	Motion table

APPENDIX III: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked.

Flammable Gases or Liquids		**Other Gas Emissions**		**Hazardous Chemicals**		**Other Hazardous /Toxic Materials**
Type:		Type:	($R_{134}A/C_4H_{10}/SF_6$) (Ar/CO_2)		Cyanide plating materials	List hazardous/toxic materials planned for use in a beam line or an experimental enclosure:
Flow rate:		Flow rate:	(~ 10^{-3} liter / RPC / hour) (~ 1000 cc / minute)		Hydrofluoric Acid	
Capacity:		Capacity:	(~ 4 RPCs) (10-20 GEMs)		Methane	
Radioactive Sources		**Target Materials**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:			Mercury (Hg)		TEA	
Strength:		X	Lead (Pb)		TMAE	
Lasers		X	Tungsten (W)		Other: Activated Water?	
	Permanent installation		Uranium (U)			
	Temporary installation	X	Other: Iron	**Nuclear Materials**		
	Calibration	**Electrical Equipment**		Name:		
	Alignment		Cryo/Electrical devices	Weight:		
Type:			Capacitor Banks	**Mechanical Structures**		
Wattage:		X	High Voltage (50V) (1500V at 1.0mA max - for PMTs)		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	

The following people have read this TSW:

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