Fermilab

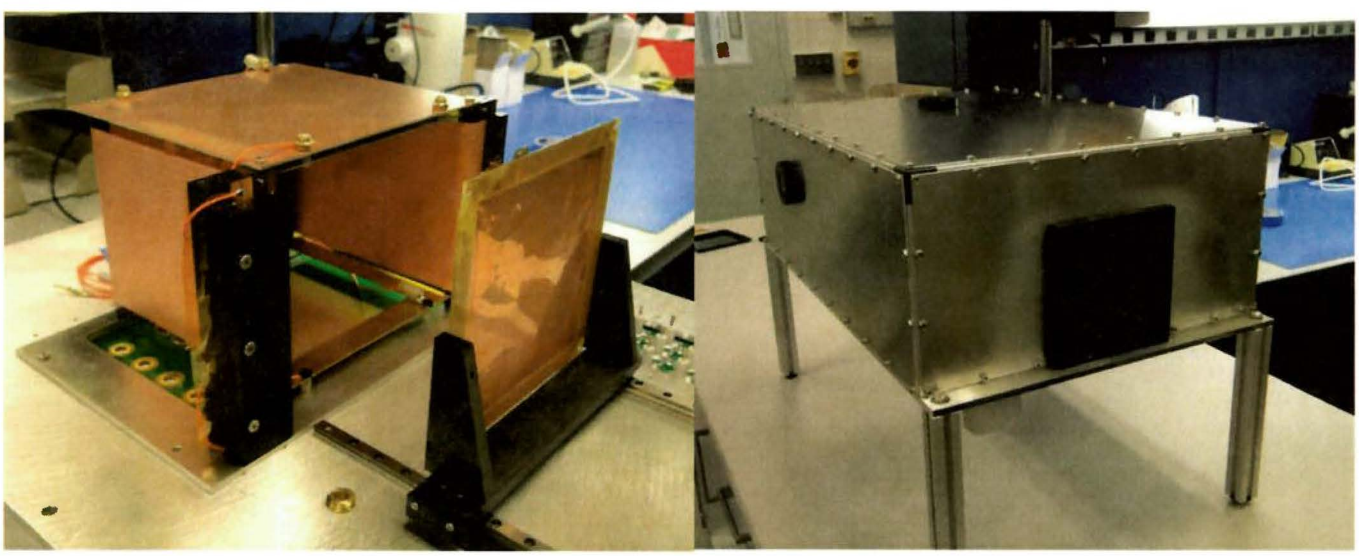
Directorate

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

T-1037

FLYSUB-Consortium Tracking and RICH Performance Evaluation

February 23, 2016



TPC/Cherenkov Detector with Dual GEM Readout

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INTRODUCTION

This is a Technical Scope of Work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of FLYSUB-Consortium who have committed to participate in beam tests to be carried out during the 2016 Fermilab Test Beam Facility program. These tests will be carried out in conjunction with the sPHENIX Calorimeter Test (T1044) that will take place from April 6^{th} through May 3^{rd} 2016. The FLYSUB tests will be carried out parasitically with the sPHENIX test and will not affect their program in any significant way.

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:

FLYSUB is a consortium consisting of BNL, Florida Tech, Stony Brook University (SBU), University of Virginia (UVa), and Yale University. It carried out a series of tests of multiple detectors in October 2013, and followed up with a second test of one its detectors (a Minidrift GEM detector) in February 2014. The follow up test was carried out in conjunction with the first sPHENIX calorimeter test during that time and ran parasitically with that test, and is similar to the arrangement being proposed here.

The detector to be studied in this test is a combination Time Projection Chamber (TPC) and Cherenkov detector. It consists of a small TPC with a 10x10x10 cm^3 drift volume that is read out with a multistage GEM detector, along with a second 10x10 cm^2 photosensitive GEM detector equipped with a CsI photocathode to detect Cherenkov light produced in the TPC gas volume. This detector could be used to provide tracking information and particle id in a single detector and could be used in a variety of applications at a future Electron Ion Collider (EIC). The goal of this test is to study the tracking performance of the TPC portion of the detector and the light detection capabilities of the Cherenkov detector, both individually and in combination with each other. The tracking portion of the detector is similar to the Minidrift GEM detector tested in the 2013 FLYSUB test and the Cherenkov portion is similar to the RICH detector tested in those same tests.

Figure 1 shows a 3D model of the combined TPC/Cherenkov detector. It consists of a 10x10x10 cm^3 drift volume surrounded by a field cage where the ionization from tracks passing through the gas volume is drifted to a multistage GEM detector at the bottom. Cherenkov light produced in the same gas volume passes through a wire field cage plane, which has high optical transparency, and impinges on a photosensitive multistage GEM detector at the exit side of the detector. The photosensitive GEM is mounted on a movable stage that allows adjusting the distance between this GEM and the TPC field cage. Fig 2 shows the actual detector and its various components with the wire field cage plane removed and with a conventional GEM foil in place of the photosensitive GEM. Due to the fact that the CsI photocathode is highly hydroscopic, the detector must be continuously kept under dry gas flow once the actual photocathode is installed.

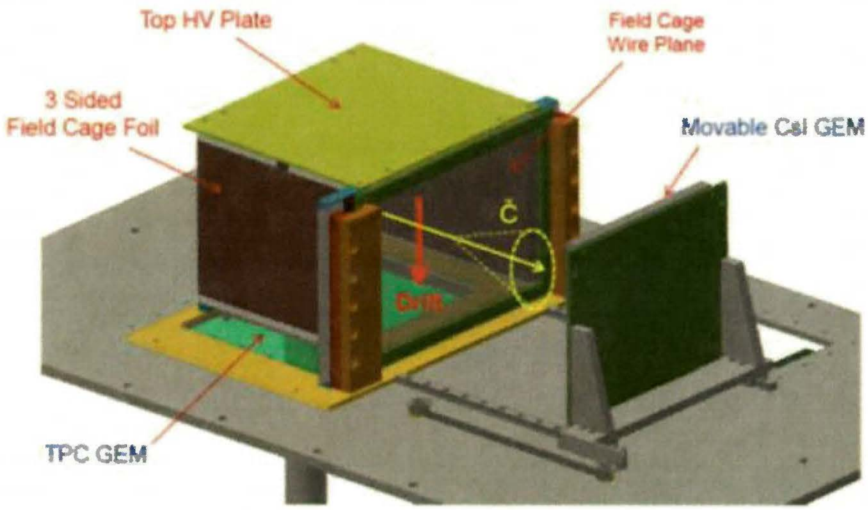


Figure 1. 3D model of the prototype TPC/Cherenkov detector.

Figure 2. Internal components of the actual TPC-Cherenkov prototype detector. The foil on the right is mounted on a movable track where the photosensitive GEM is mounted..

The entire detector is contained within a sealed aluminum box and a baseplate with various feedthroughs, and has two mylar windows at the front and exit sides of the enclosure to minimize material in the beam path. The enclosure is shown in Fig. 3.

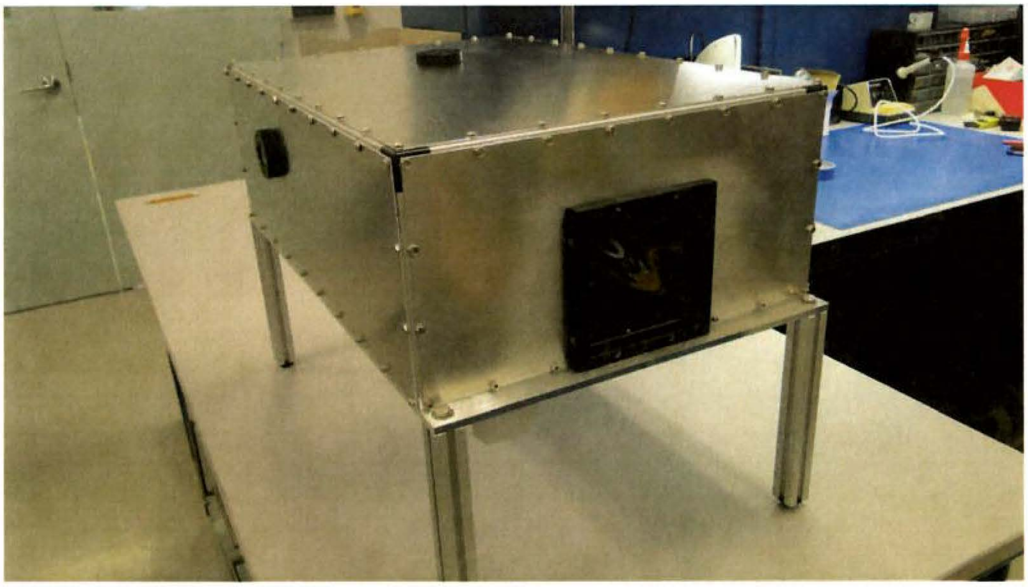


Figure 3. Gas enclosure for the TPC/Cherenkov detector.

The gas used for the drift volume and Cherenkov radiator will be pure CF_4. Gas will be provided by a recirculating gas system, which is the *same* gas system that was used in the October 2013 FLYSUB test of the RICH detector. This system was approved for use in the MT6 test beam area for those tests, and therefore we expect no major problems getting it approved for use again this time.

PERSONNEL AND INSTITUTIONS:

Spokesperson: Thomas Hemmick (Stony Brook University) and Craig Woody (BNL)

Fermilab liaison: Mandy Rominsky

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	Brookhaven National Lab	USA	Bob Azmoun	Research Scientist	sPHENIX
			Craig Woody	Research Scientist	sPHENIX
			Martin Purschke	Research Scientist	sPHENIX
			Takao Sakaguchi	Research Scientist	sPHENIX
			Achim Franz	Research Scientist	sPHENIX
1.2	Florida Tech	USA	Aiwu Zhang	Postdoc	
1.3	Stony Brook University	USA	Thomas Hemmick	Professor	PHENIX
			Klaus Dehmelt	Research Scientist	
			Nils Feege	Postdoc	PHENIX
1.5	University of Illinois	USA	Michael Phipps	Graduate Student	sPHENIX/ATLAS

II. Experimental Area, Beams and Schedule Considerations:

2.1 Location

2.1.1 The detectors will be placed in MT6.1 area just downstream of the silicon telescope (see Appendix I)

2.1.2 Additional space needed:

- Control room for various PCs/monitors and table space
- Electronics Room: one rack
- Storage room: to store shipping boxes for the items
- Meetings in conference room on a daily basis

2.1.3 Access to a class 10 cleanroom (in Lab 3) with a laminar flow hood and glove box in case the photosensitive GEM detectors need servicing.

2.2 Beam

2.2.1 Beam Types and Intensities

Particles: electrons
Energy of beam: 1-4 GeV
Intensity: Single particles (if possible) to few kHz
Beam spot size: as small as possible

Particles: pions
Energy of beam: 1-4 GeV
Intensity: single particles (if possible); variations 1k – 100k particles/ 4 sec spill
Beam spot size: as small as possible; about 1 cm^2

Particles: protons
Energy of beam: 120 GeV (primary beam)
Intensity: single particles (if possible) to few kHz
Beam spot size: as small as possible

2.2.2 Beam Sharing

This experiment will run parasitically with the sPHENIX Calorimeter Test (T1044), and many of the same people are involved in both. This will be a second priority experiment and the overall beam schedule will be determined by the sPHENIX test. We expect that this experiment will run sharing the beam with sPHENIX, or, if special beam conditions are requires, it will run during times when sPHENIX does not need the beam.

The amount of material in the beam presented by the TPC/C detector is listed below, and should a have minimal effect on the beam quality downstream of the detector.

Material in the beam presented by the TPC/C detector:

- Two mylar windows: 2 x .005" (0.1% X_0 total)
- Two plastic (Delrin) light tight covers: 2 x .125" (1.8% X_0)
- Foil field cage: .050 mm kapton + ½ oz copper (0.16% X_0)
- Wire field cage plane: negligible
- Stainless steel mesh for photosensitive GEM: 90% transparency (.02% X_0)
- 4 GEM foils for photosensitive GEM detector: 4 x (.050 mm kapton + ½ oz copper) (0.64 %X_0)
- CsI coating: negligible
- Photosensitive GEM readout board: .125" FR4/Copper (.37% X_0)

Total material in the beam path: 3.1% X_0

The detector will remain in the beam for the duration of the tests unless the sPHENIX group explicitly requires us to remove it.

2.2.3 Running Time

The detector will be set up during the same time frame as the setup for the sPHENIX test, which will be starting on April 5th. This will include the mechanical installation, connection of the recirculating gas system, cabling, HV testing and checkout. We hope that the installation can be completed within two days and that we would be ready for the Experimental Safety Review by Thursday April 7th. Allowing some time to correct any small problems, we would expect to be ready for beam by Friday evening April 8th.

2.3 EXPERIMENTAL CONDITIONS

2.3.1 AREA INFRASTRUCTURE

The TPC/C detector will be located in the MT6.1 area on the same table as the existing silicon telescope. This may require an extension of the table (as was done for our 2013/2014 test of the Minidrift detector) or a separate support stand downstream of the telescope. The total length of the TPC/C is 24", so there should be sufficient room behind the telescope in either configuration. The overall dimensions, including the baseplate and aluminum enclosure are 24" x 15" x 7.5", We will also require the use of the Si telescope and access to its DAQ and output data. This is the same arrangement as was done for the 2013/2014 Minidrift test in which the DAQ for the Si telescope and our detector were run independently and the output events were synchronized offline. This method worked acceptably well and we would do it the same way for this test. We have already contacted the local Si Telescope Group at Fermilab and they told us that the telescope will be available during the time of our test and that they would help us again with the initial setup and synchronization with our DAQ system.

The detector will use pure CF_4 which will be supplied by the recirculating gas system. The CF_4 would be ordered by the experiment to be delivered to Fermilab or ordered through Fermilab directly. The gas system is a pressure regulated closed loop system and long gas lines would pose a risk in the regulating mechanism. Therefore, the recirculating gas system must be located in the MT6.1 beam area.. The gas system also expels a small amount of the recirculating gas and replenishes it with fresh gas. We would therefore also like to have a gas bottle of CF_4 in the beam enclosure as well as the use of one exhaust line. The same gas system was operated remotely in the MT6.2 area for the 2013 RICH test in the same way, so we do not anticipate there being a problem with this

We will also need to locate a NIM crate and another CAEN HV power supply crate to supply high voltage to the detector. This will include the 15V supply for the TPC and several 5KV supplies for the GEMs. All of these power supplies will be controlled remotely via Ethernet from the Control Room.

As long as the experimenters can easily access the apparatus in the enclosure in the case of a power outage there is no need for UPSs.

2.3.2 ELECTRONICS NEEDS

The detector will be read out with CERN APV25 based SRS electronics using our own DAQ system that we will provide. We will require at least one GB-Ethernet connection from the MT6.1 area to the main control room. Some standard cables (BNC, lemo and HV) will be required in addition to the ones we will bring. As mentioned above, we will also require the Si telescope and access to its DAQ system and offline data analysis software.

2.3.3 Description of Tests

The test of the detector will consist of measuring tracks in the TPC and detecting Cherenkov light from those tracks with the photosensitive GEM detector. Measuring tracks in the detector can be done with any charged particles, and would best be done with the primary 120 GeV proton beam, which has the smallest beam spot and is the cleanest in terms of background. This could therefore also be done simultaneously with the sPHENIX calorimeter tests when they use this type of beam. For the Cherenkov tests, we will require electrons with a momentum below 4 GeV/c, which is the pion threshold in CF_4. This test would therefore be best done with 1-3 GeV/c electrons, and could also be combined with some of the sPHENIX EMCAL tests. We also plan to measure tracks in the detector at various incident angles (e.g., 10, 20 and 30 degrees). This will be done by physically moving the detector on its table in order to vary the incident angle.

The detector will be fully constructed and completely tested at Stony Brook before bringing it to Fermilab. It will be transported to Fermilab with dry N_2 gas flowing through the detector in order to preserve the CsI photocathode. It will remain under dry gas flow after its arrival until it is connected to the recirculating gas system, at which point the gas will be switched to CF_4, and it will remain under CF_4 gas flow for the duration of the tests.

2.4 Schedule

The experiment will require approximately one week of setup, debugging and checkout, and one week of actual running time collecting data. However, since the availability of dedicated beam time for the TPC/C detector test depends on the detailed schedule and priorities of the sPHENIX calorimeter test, the amount of calendar time for the anticipated week of actual data taking may be longer, but would not extend beyond the end of the sPHENIX test.

III. RESPONSIBILITIES BY INSTITUTION – NON FERMILAB

3.1 BNL :

BNL will provide the TPC/C detector, its enclosure, HV power supplies for the TPC and GEM detectors, HV cables and various other cables and connectors, and the readout electronics and DAQ system.

3.2 STONY BROOK UNIVERSITY:

Stony Brook University will provide the CsI photocathode for the photosensitive GEM detector, which will be fabricated at Stony Brook and installed in the detector prior to its coming to Fermilab, and the recirculating gas system along with any other auxiliary equipment.

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 (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). [1.5 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. [3.0 person weeks]
4.2.2 Set up and maintenance of Si tracking system, with help from SCD [0.5 person weeks]
4.2.3 Setup and maintenance of trigger scintillators.
4.2.4 Setup and maintenance of lead-glass calorimeter
4.2.5 Setup and maintenance of differential Cherenkov detector
4.2.6 Conduct a NEPA review of the experiment.
4.2.7 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.
4.2.8 Provide safety training as necessary, with assistance from the ESH&Q Section.
4.2.9 Update/create ITNA's for users on the experiment.
4.2.10 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews. [0.2 person-weeks]
4.2.11 Access to Lab 3 clean rooms and glove box, if necessary.
4.2.12 Fork-lift & Crane Operation, if necessary.

4.3 Fermilab Scientific Computing Division

4.3.1 Internet access should be continuously available in the MTest control room.
4.3.2 GB Ethernet connection between beam enclosure and control room.
4.3.3 Set up and maintenance of Si tracking system. [0.5 person weeks]

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]

4.5 Fermilab Collaborators

4.5.1 The Fermilab CMS Silicon Telescope Group (including L. Uplegger, R. Rivera and L. Vigani) have agreed to help us set up and operate the Silicon Telescope in the MT6.1 area. We expect that it will take ~ 1-2 shifts of their time for setup and occasional help during operation.

V. SUMMARY OF COSTS

Source of Funds [$K]	Materials & Services	Labor (person-weeks)
Particle Physics Division	0.0	0.5
Accelerator Division	0	0.5
Scientific Computing Division	0	0
ESH&Q Section	0	0.2
FNAL Si Telescope Group	0	0.5
Totals Fermilab	$0.0K	1.7
Totals Non-Fermilab	[$3k[1]]	[10[2]]

[1] Gas supply

[2] 10 person-weeks in preparing the setup, data-taking, pre-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 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. 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:

Thomas Hemmick

____ 2/15/2016

Thomas Hemmick, Experiment Co-Spokesperson

Craig L. Woody

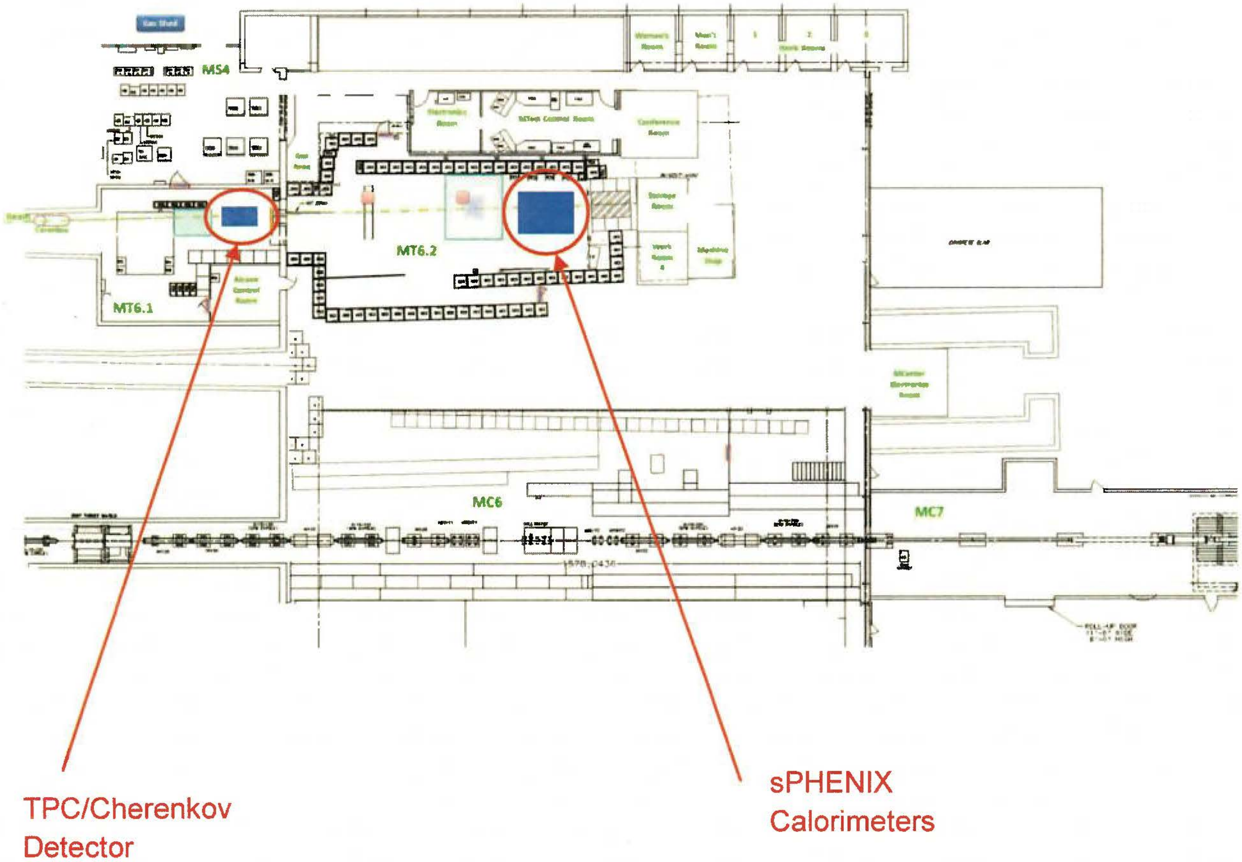
____ 2/15/2016

Craig Woody, Experimental Co-Spokesman

APPENDIX I: MT6 AREA LAYOUT

MT6.1/2 Layout with all detectors along the beam-line (detectors are not to scale).

MTEST AREAS



APPENDIX II: - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need *should be* checked. See next page for detailed descriptions of categories.

Flammable Gases or Liquids		**Other Gas Emissions**		**Hazardous Chemicals**		**Other Hazardous /Toxic Materials**
Type:		Type:	CF_4, 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:	10cc/min up to 400cc/min Ar/CO_2 500cc/min CF_4		Hydrofluoric Acid	
Capacity:		Capacity:	~ 45L		Methane	CF_4 gas
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:		X	High Voltage (50V) **15KV**		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:			Beam line magnets	
Operating Pressure:		Operating Pressure:			Analysis magnets	
Window Material:		Window Material:	Gas bottle		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 (Tetrafluormethane)
- ☐ 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:

____ 3/ 30 / 2015
Patty McBride, Particle Physics Division, Fermilab
Jonathan Lewis, PPD

Paul C Garapati for Sergei Nagaitsev __________________ 3 / 24 / 2015
Sergei Nagaitsev, Accelerator Division, Fermilab

____ 3/ 22 / ~~2015~~ 2014
Martha Michels, ESH&Q Section, Fermilab

____ 4 / 1 / 2016
Robert Roser, Chief Information Officer, Fermilab

____ 3 / 31 / 2015
Joe Lykken, Chief Research Officer, Fermilab

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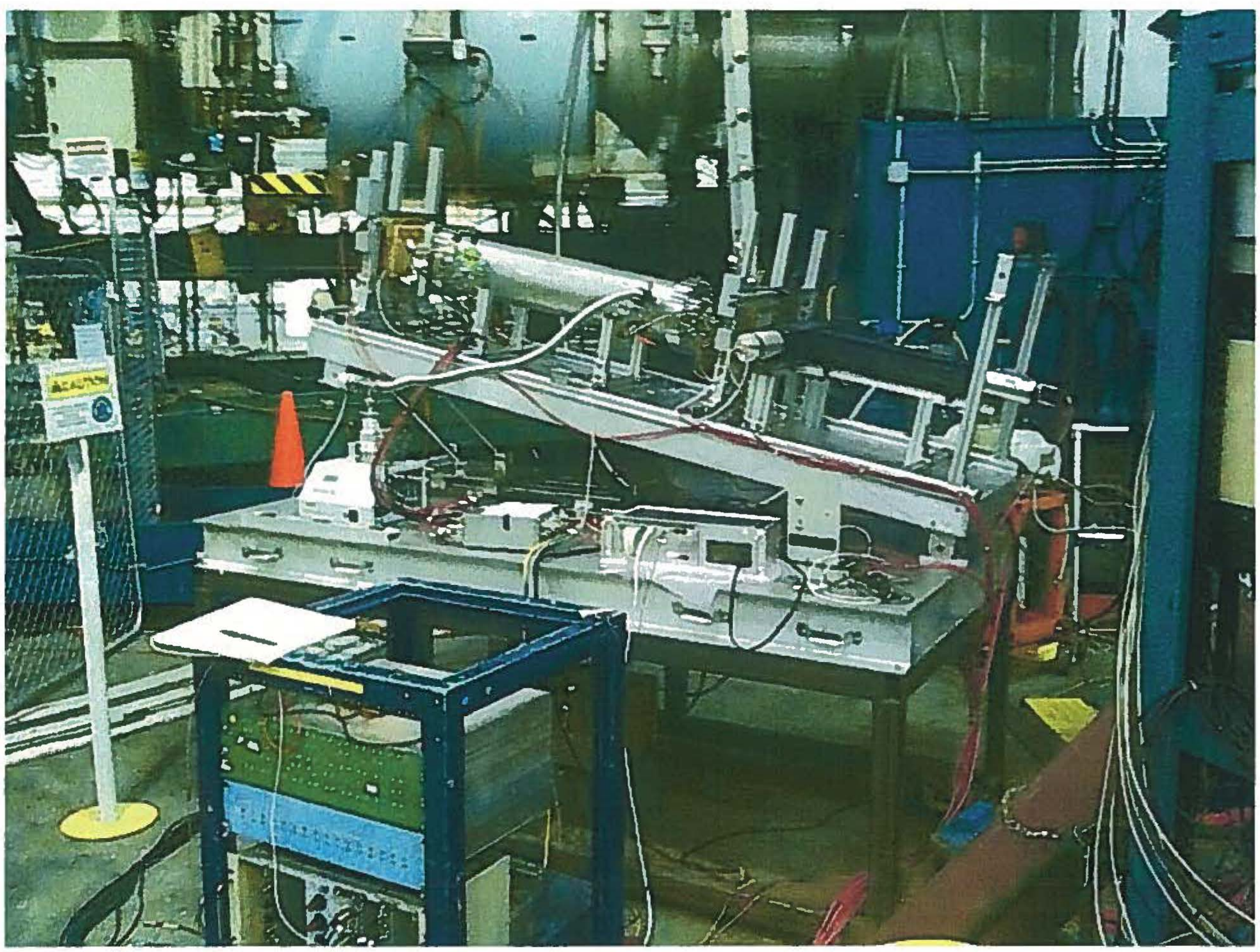

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Description of Detector and Tests:

FLYSUB is a consortium consisting of BNL, Florida Tech, Stony Brook University (SBU), University of Virginia (UVa), and Yale University and is planning to assemble a set of detectors at FTBF which is targeted toward tracking and PID components of an EIC detector. The groups have been working together for about two years and have come up with a common beam-time usage instead of asking for separate test-beam campaigns, with the set-up described in what follows. The ultimate goal of this test-beam effort is to test and verify the performance of the individual components according to their expectation. The detectors are foreseen to share the same beam-line and will be arranged according to their need for particle impact.
The fundamental areas of investigations driving the need of a test-beam campaign are:

- Development of a mini-drift GEM detector for resolving the issue of losing resolution for inclined particle tracks and applying different frontend electronics
- Development of large area planar GEM detectors for endcap tracking
- Development of Cherenkov detectors in the forward direction, with particular emphasis on high momentum hadron ID and development of large area low cost VUV mirrors
- Development of alternative read-out structures for reducing the number of channel counts but conserving the resolution

These areas are split among the institutions and individual contributions are described in the following.

1.) BNL: Test of a mini-drift GEM detector which is made out of standard 10x10cm^2 GEM foils with increased drift gap (> 17 mm). The readout will be performed with SRS-DAQ. Gas to be used is mixed Ar-CO_2 (various mixtures). No special cooling required.

Main goal is to measure position and angular resolution. Desired angular range is 0° to 45°.

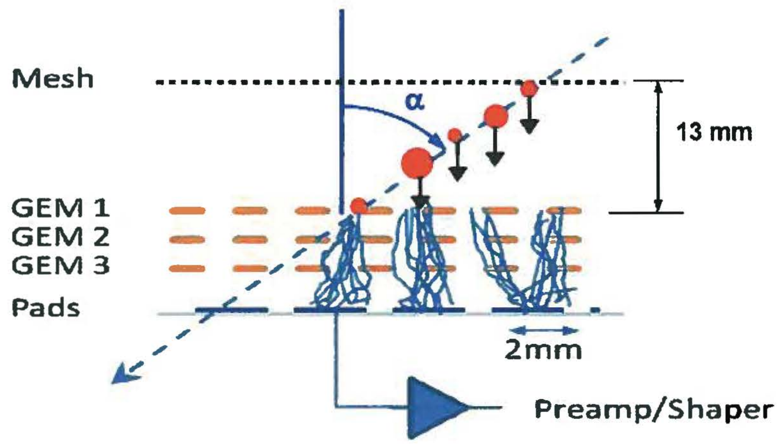


Figure 1 Illustration of mini-drift GEM detector with pad readout.

2.) Florida Tech+UVa: one (possibly two) chambers with 100 cm × (44 – 22) cm trapezoidal prototypes and radial strip readout (24 sectors with 12cm strip length) and one more chamber with zigzag strips would be inserted in the beam line.

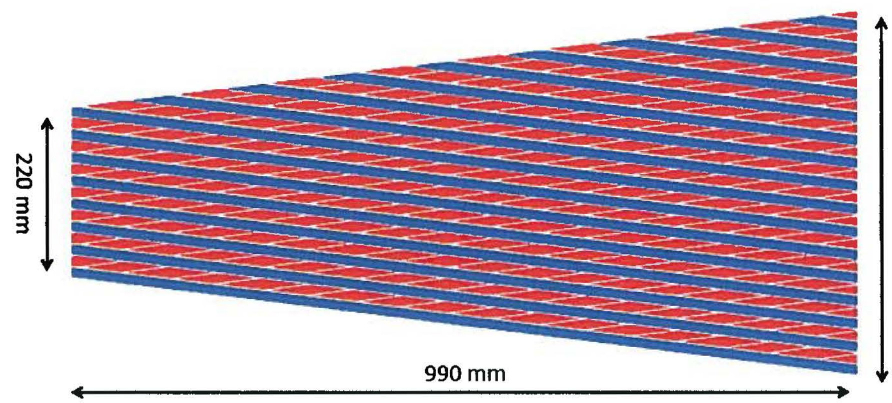


Figure 2 Radial strip readout for a trapezoidal GEM chamber.

Furthermore, a 50 x 50 cm^2 GEM prototype chamber and a 30 x 30 cm^2 self-stretched EIC GEM prototype with zigzag readout strips will be implemented. As a reference tracking system it is planned to provide one 10 × 10 cm^2 Micromegas detector, four 10 × 10 cm^2 Triple-GEM chambers, and one 30 × 30 cm^2 self-stretched Triple-GEM with Cartesian readout (COMPASS style).

The main goal of the studies is to investigate their spatial and timing resolutions for non-standard strip readout geometries (u-v, zigzag) under various conditions:

i. Response under highest available rates
ii. Two-track resolutions
iii. With various gas mixtures of Ar/CO_2

3.) Stony Brook University: The aim of this test is to verify the performance of a Ring-Imaging-Cherenkov (RICH) detector based on Gas-Electron-Multiplier (GEM) detectors and CF_4 as the radiator/counting gas. This technology is foreseen to become part of the Particle Identification (PID) system of an EIC-detector.
The detector consists of a stainless steel tube which is closed at one end with a mirror and at the other end with the GEM-detector in the focal plane of that mirror. The readout plane for a quintuple-GEM detector can be interchanged between two-dimensional strip and single pads readout. The primary goal of the tests is to prove that the ring diameter obtained with both readout-plane structures will suffice particle discrimination up to high momenta.

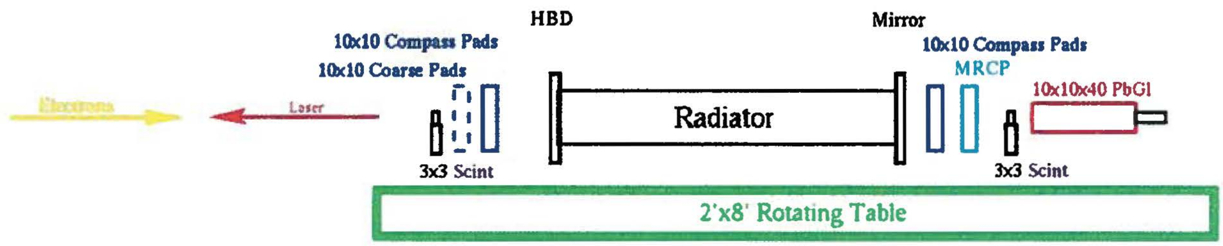


Figure 3: Drawing (not to scale) of the proposed setup for the test in beam of the RICH prototype.

4.) Yale University: Two sets of 4 chambers each, 10 x 10 cm^2 active area, ~1.2% RL each chamber. Each set of 4 chambers will take about 2 feet along the beam line. The readout structure of these detectors is based on a 3-coordinate single readout plane. The goal of the tests is to investigate charge sharing ratio and uniformity of the ratio and ultimately resolution.

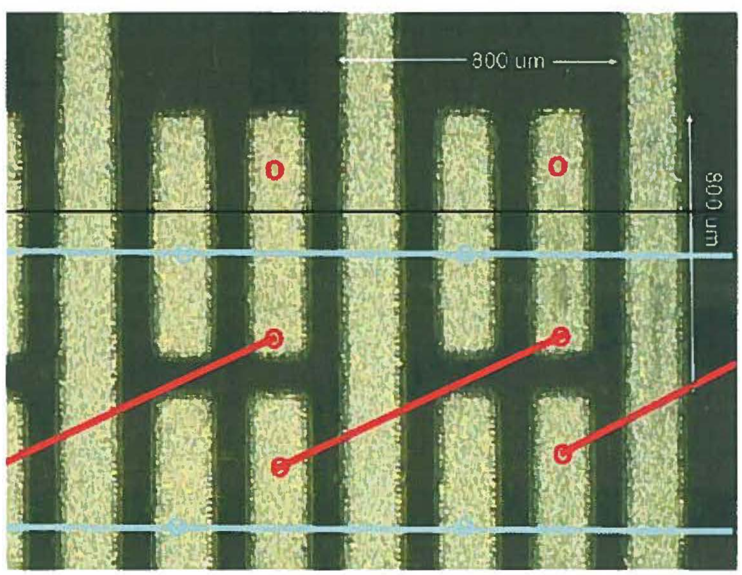


Figure 4: Three-dimensional single readout plane realized by interconnecting different lines of readout strips/pads.

I. PERSONNEL AND INSTITUTIONS:

Spokesperson: Klaus Dehmelt (Stony Brook University)

Fermilab Experiment Liaison Officer: Aria Soha

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	Brookhaven National Lab	USA	Bob Azmoun	Research Scientist	PHENIX
			Marie Blatnik	Undergraduate student	
			Robert Pak	Research Scientist	PHENIX
			Martin Purschke	Research Scientist	PHENIX
			Benedetto Di Ruzza	Research Scientist	STAR
			Craig Woody	Research Scientist	PHENIX
1.2	Florida Tech	USA	Vallary Bhopatkar	Graduate student	
			Marcus Hohlmann	Professor	CMS
			Jessie Twigger	Undergraduate student	
			Aiwu Zhang	Postdoc	
1.3	Stony Brook University	USA	Klaus Dehmelt	Research Scientist	PHENIX
			Abhay Deshpande	Professor	PHENIX
			Nils Feege	Postdoc	PHENIX
			Thomas Hemmick	Professor	PHENIX
1.4	University of Virginia	USA	Xinzhang Bai	Graduate student	
			Kondo Gnanvo	Research Scientist	SOLID
			Chao Gu	Graduate student	
			Nilanga Liyanage	Professor	SOLID
1.5	Yale University	USA	Richard Majka	Research Scientist	STAR
			Nikolai Smirnov	Research Scientist	STAR/ATLAS

II. Experimental Area, Beams and Schedule Considerations:

2.1 Location

2.1.1 The various detectors will be placed in MT6.2 along the beam-line and one detector (mini-drift GEM detector) will be placed in MT6.1 within the CAPTAN Si-telescope (see Appendix I)

2.1.2 Additional space needed:

- Control room for various PCs/monitors and table space
- Electronics Room: four racks
- Storage room: to store shipping boxes for the items
- Meetings in conference room on a daily basis

2.1.3 Access to a class 10 cleanroom (in Lab 3) with laminar flow in case any of the GEM detectors need servicing.

2.2 Beam

2.2.1 Beam Types and Intensities

Particles: electrons
Energy of beam: 10 GeV
Intensity: Single particles (if possible) to few kHz
Beam spot size: as small as possible

Particles: pions
Energy of beam: > 4 GeV (> 20 GeV)
Intensity: single particles (if possible); variations 1k – 100k particles/ 4 sec spill
Beam spot size: as small as possible; about 1 cm^2

Particles: Kaons
Energy of beam: > 13 GeV
Intensity: single particles (if possible) to few kHz
Beam spot size: as small as possible

Particles: protons
Energy of beam: > 27 GeV
Intensity: single particles (if possible) to few kHz
Beam spot size: as small as possible

The experimenters have set up a beam-run-table which includes a detailed plan about running with different particle species at different momenta. See section 2.3.3 for details.

2.2.2 Beam Sharing

Because this experiment consists of multiple detectors in multiple locations beam-sharing with other experiments is unlikely to work out due to physical limitations.

Radiation lengths of the detectors are given in the following table.

Item	Dimension h×w×d (cm×cm×cm)	Weight (kg)	Radiation length/detector ($\%X_0$)	Sum radiation length ($\%X_0$)
16 GEM/MM tracker	10×10×4 each	5 each	1	16
2 GEM tracker	30×30×4	7	0.6	1.2
1 GEM tracker	50×50×4	8	0.6	0.6
Two large, trapezoidal GEM tracker	100×[40-22]×4 each	10	0.6	1.2
RICH detector (on table)	100×65×245	150	5	5

Total: $24.0\%X_0$

2.2.3 Running Time

The first day of requested time will be used for Mechanical Setup, cable and utility hook-up, start of gas flow, and begin electronics check out. Since the test beam will likely have a decent beam trigger, the experiment's part is mainly to set up and incorporate busy signals. The second day will be used to finish electronics checkout, and high voltage check. The third day will be used to obtain ORC and start beam run. In the first week frequent access might be needed for debugging the set-ups. Change and fine-tuning of control parameters that cannot be performed remotely.

Run-time is expected to be 24 hours/day. A beam schedule is shown in Table 2, in section 2.3.3.

See section 2.4 for total run time and long-term schedule.

2.3 Experimental Conditions

2.3.1 Area Infrastructure

All detectors are gaseous detectors and will be read out by APV25-SRS electronics. The detector's dimensions are listed in Table 1.

Table 1 Dimensions and weights for the various detectors used in the set-up.

Item	Dimension h×w×d (cm×cm×cm)	Weight (kg)
16 GEM/MM tracker	10×10×4 each	5 each
2 GEM tracker	30×30×4	7
1 GEM tracker	50×50×4	8
Two large, trapezoidal GEM tracker	100×[40-22]×4 each	10
RICH detector (on table)	100×65×245	300

All detectors except the RICH-detector need mounting structures that can be adjusted such that the detectors can be moved into the beam. The RICH-detector will be coming mounted on a supporting table that can be adjusted such that the RICH detector can be aligned with the beam.

The experiment requests precise tracking detectors (e.g. MWPC, Si telescope) and trigger scintillators, as well as Cherenkov-detectors and lead-glass calorimeter for particle identification, to be provided by FTBF.

The experiment will use Patch-panels (BNC, LEMO) in the counting house leading to the experimental area.

So long as the experimenters can easily access the apparatus in the enclosure in the case of a power outage there is no need for UPSs.

The detectors will need to be supplied with gas. Various gas mixtures will be needed. The RICH detector will need CF_4. Other mixtures are basically Ar-CO_2 mixtures with different ratios. The CF_4 gas would be required to be ordered by the experiment to be delivered to Fermilab or ordered through Fermilab. FTBF has a gas room outside the main hall. Bottles and regulators are there with copper lines running to panels within the enclosure. The experimenters would set gas manifolds (19" rack mount panels) near the detectors to be connected to the patch panels.

The RICH detector needs a rack placed close to the set-up. The gas system is a pressure regulated closed loop system and long gas lines would pose a risk in the regulating mechanism. For this the experimenters would like to have a gas bottle of CF4 in the beam enclosure.

The experiment will need an opportunity to survey the detector's positions with respect to each other and to the beam line, using the laser alignment system provided by FTBF

2.3.2 Electronics Needs

Each detector will be read out with APV25-SRS-electronics. For that each crate needs a GB-Ethernet connection to the control room.

The groups will provide electronics for each individual detector, and diagrams will be provided when requested. Cables might be needed for extending the set-up.

No PREP electronics are requested.

2.3.3 Description of Tests

The detectors will be prepared by the various groups at their home institutes such that the operational status is defined. Once the detectors are operational the parts which are permanently attached to non-movable parts will be disconnected and shipped to Fermilab. This will reduce set-up time at the test-facility. There the detectors will be set up and connected and the systems will be checked for operation and the readout performance will be evaluated during the first week of the 3-week beam request. Once these issues are set the experiment can start with exposing the detectors to the beam.

It is planned to start the tests with conditions that all detector tests will have in common. A general plan can be found in Table 2.

Table 2: General run plan. The run plan starts with the first day of requesting particles traversing the detectors.

Day	Particle species	Energy	Particle count[1]	Spot size (cm^2)
1-3 (Setup, commissioning, and OCR)	Pion	> 20 GeV	few kHz	< 1
4-7	Protons	120 GeV	few kHz	variable
8-10	Pion	> 4 GeV incrementing in 1.) 2 GeV steps up to 10 GeV (4 sets) 2.) 5 GeV steps up to 35 GeV (5 sets)	single to few kHz	< 1
11-13	Kaon	> 16 GeV incrementing in 1.) 2 GeV steps up to 20 GeV (3 sets)	single to few kHz	< 1

[1] In units of particles per 4 sec spill.

		2.) 5 GeV steps up to 45 GeV (5 sets)		
14-16	Proton	> 29 GeV incrementing in 1.) 2 GeV steps up to 35 GeV (3 sets) 2.) 5 GeV steps up to 45 GeV (2 sets)	single to few kHz	< 1
17-18	Identified electrons	1 GeV < E < 10 GeV	1 kHz	1
19	Pions	30 GeV	100 kHz	As small as possible
20-21	TBD			

Detectors will be staying in the beam-line all time, except when experiencing issues with them. Access to the area would be requested when necessary, though it is expected to control the detectors remotely.

2.4 SCHEDULE

The experiment requests a total of two weeks beam-time, plus an additional three to four days of set-up and debugging of which one or two might be with beam particles. The experiment would like to request the first three weeks in October 2013 for the test-beam campaign.

III. Responsibilities by Institution – Non Fermilab

3.1 BNL and Yale University:

will contribute a prototype of a mini-drift TPC (small GEM detector) based on SRS-electronics and two stations of each four small GEM trackers with SRS-readout.

3.2 Florida Tech and University of Virginia:

will contribute two large, trapezoidal GEM trackers, one large sized squared GEM tracker, two medium sized squared GEM tracker, and five small sized reference trackers. All detectors are read out based on SRS-electronics.

3.3 Stony Brook University:

will contribute a RICH detector based on GEMs and SRS-readout. Will also provide a set of two 10 x 10 cm^2 GEM trackers with SRS readout, and two PbGl calorimeter blocks and NIM readout electronics (if needed).

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 (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). [1.5 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. [3.0 person weeks]
4.2.2 Set up and maintenance of Si tracking system, with help from SCD [1.0 person weeks]
4.2.3 Setup and maintenance of trigger scintillators.
4.2.4 Setup and maintenance of lead-glass calorimeter
4.2.5 Setup and maintenance of differential Cherenkov detector
4.2.6 Setup and maintenance of 3 MWPC tracking stations [3.0 person-weeks]
4.2.7 Conduct a NEPA review of the experiment.
4.2.8 Provide day-to-day ESH&Q support/oversight/review of work and documents as necessary.
4.2.9 Provide safety training as necessary, with assistance from the ESH&Q Section.
4.2.10 Update/create ITNA's for users on the experiment.
4.2.11 Initiate the ESH&Q Operational Readiness Clearance Review and any other required safety reviews. [0.2 person-weeks]
4.2.12 Access to Lab 3 clean rooms, if necessary.
4.2.13 Fork-lift & Crane Operation.[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 GB Ethernet connection between beam enclosure and control room.
4.3.3 Set up and maintenance of Si tracking system. [1.0 person weeks]

4.4 Fermilab ESH&Q Section

4.4.1 Assistance with safety reviews.
4.4.2 Loan of the following Radioactive Sources for the duration of the beam run:
Isotope # Source ID # Decayed Microcuries
1.) Sr-90 # 90-0.1-186 # 0.989 uCi
2.) Fe-55 # 55-3.1-11 # 2.785 uCi
3.) Fe-55 # 55-3.1-12 # 2.785 uCi
4.) Fe-55 # 55-2.1-269 # 1.109 uCi
4.4.3 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)
Accelerator Division	0.0	1.5
Particle Physics Division	0	7.4
Scientific Computing Division	0	1
ESH&Q Section	0	0.2
Totals Fermilab	$0.0K	10.1
Totals Non-Fermilab	$5k[2]	30[3]

[2] Gas supply

[3] 15 person-weeks in preparing the setup, data-taking, pre-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 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. 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.

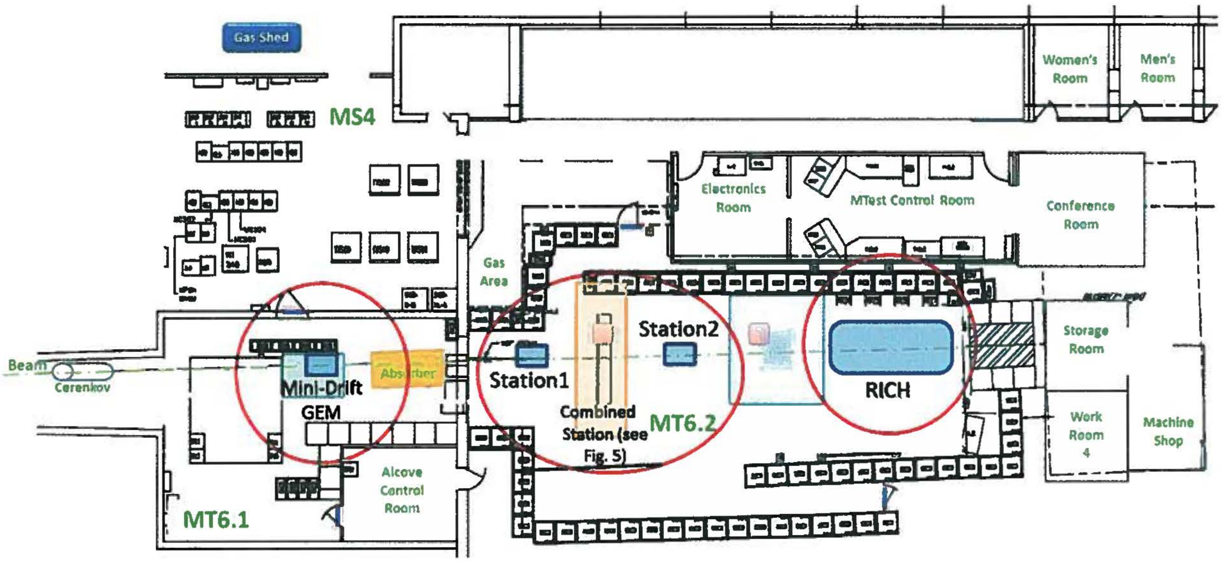
SIGNATURES:

Klaus Dehmelt, Experiment Spokesperson 09/18/ 2013

APPENDIX I: MT6 AREA LAYOUT

MT6.1/2 Layout with all detectors along the beam-line (detectors are not to scale).

MTEST AREAS



Mini-Drift GEM	GEM tracker 10x10cm^2 with larger drift length (17 mm)
Station 1	4 GEM tracker (10x10cm^2 each)
Station 2	4 GEM tracker (10x10cm^2 each)
Medium GEM	1 GEM tracker 30x30cm^2
Trapezoidal GEM	Two large, trapezoidal GEM tracker (100cmx[40-22]cm) (UVa/FIT CMS GEM)
Ref tracker	4 GEM tracker (10x10cm^2 each), 1 MM tracker 10x10cm^2
Large GEM	One GEM tracker 50x50cm^2
RICH	RICH detector on table 4'x8', 2 GEM tracker (10x10cm^2 each), PbGl

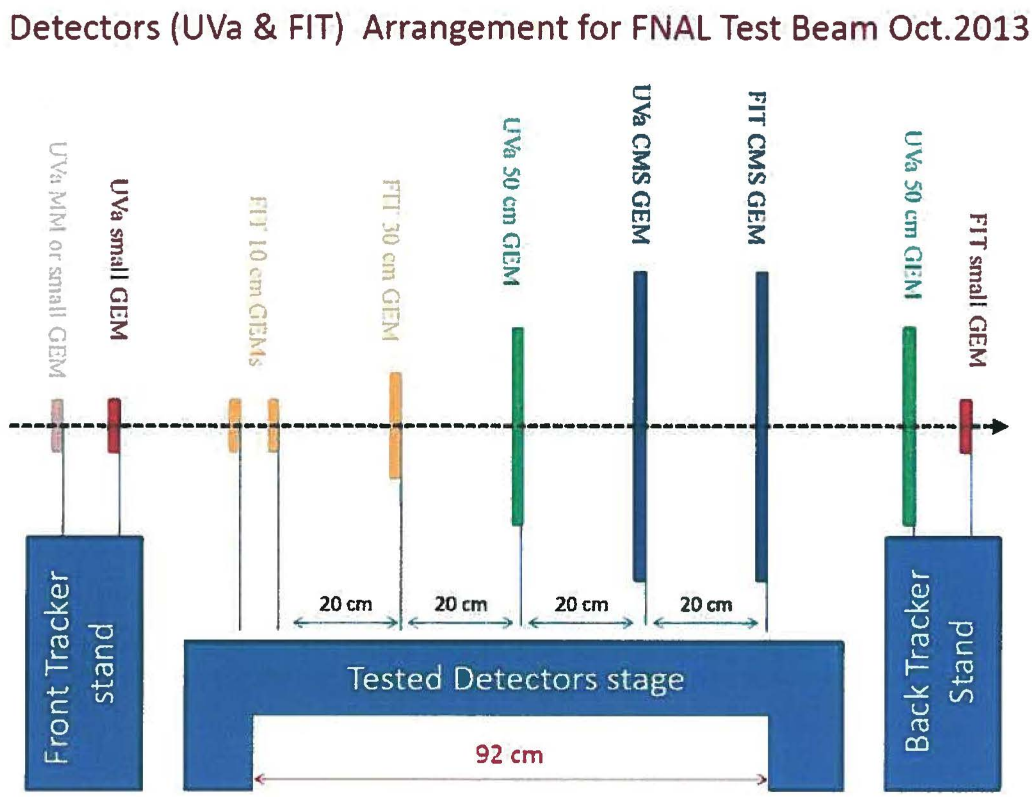


Figure 5 Combined Station

APPENDIX II: - 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:	CF_4 , 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:	10cc/min up to 400cc/min Ar/CO_2 500cc/min CF_4		Hydrofluoric Acid	
Capacity:		Capacity:	CF_4:40L/1200psi $Ar\text{-}CO_2$:40L/2300psi		Methane	CF_4 gas
Radioactive Sources		**Target Materials**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinatedBiphenyls	
X	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:	Cd-109, Sr-90, Fe-55 (2x)		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:		X	High Voltage (50V)		Lifting Devices	
MFR Class:			Exposed Equipment over 50 V		Motion Controllers	
		X	Non-commercial/Non-PREP	X	Scaffolding/ Elevated Platforms	
			Modified Commercial/PREP		Other:	
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:	8-inch	Inside Diameter:			Beam line magnets	
Operating Pressure:	10E-5 / +2 torr	Operating Pressure:			Analysis magnets	
Window Material:	Fused silica, FR4	Window Material:	Gas bottle		Target	
Window Thickness:	4mm, 1/8"	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 (Tetrafluormethane)
- ☐ 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:

______________________________ 9 /23 / 2013
Michael Lindgren, Particle Physics Division, Fermilab

______________________________ 9 /25 / 2013
Roger Dixon, Accelerator Division, Fermilab

Robert Roser / cf
______________________________ 9 /26 / 2013
Robert Roser, Scientific Computing Division, Fermilab

______________________________ 9 /23 / 2013
Martha Michels, ESH&Q Section, Fermilab

______________________________ 9 /27 /2013
Greg Bock, Associate Director for Research, Fermilab

______________________________ 10 / 4 /2013
Stuart Henderson, Associate Director for Accelerators, Fermilab

Fermilab

Directorate

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

T-1037

FLYSUB-Consortium Tracking and RICH Performance Evaluation

March 18, 2013

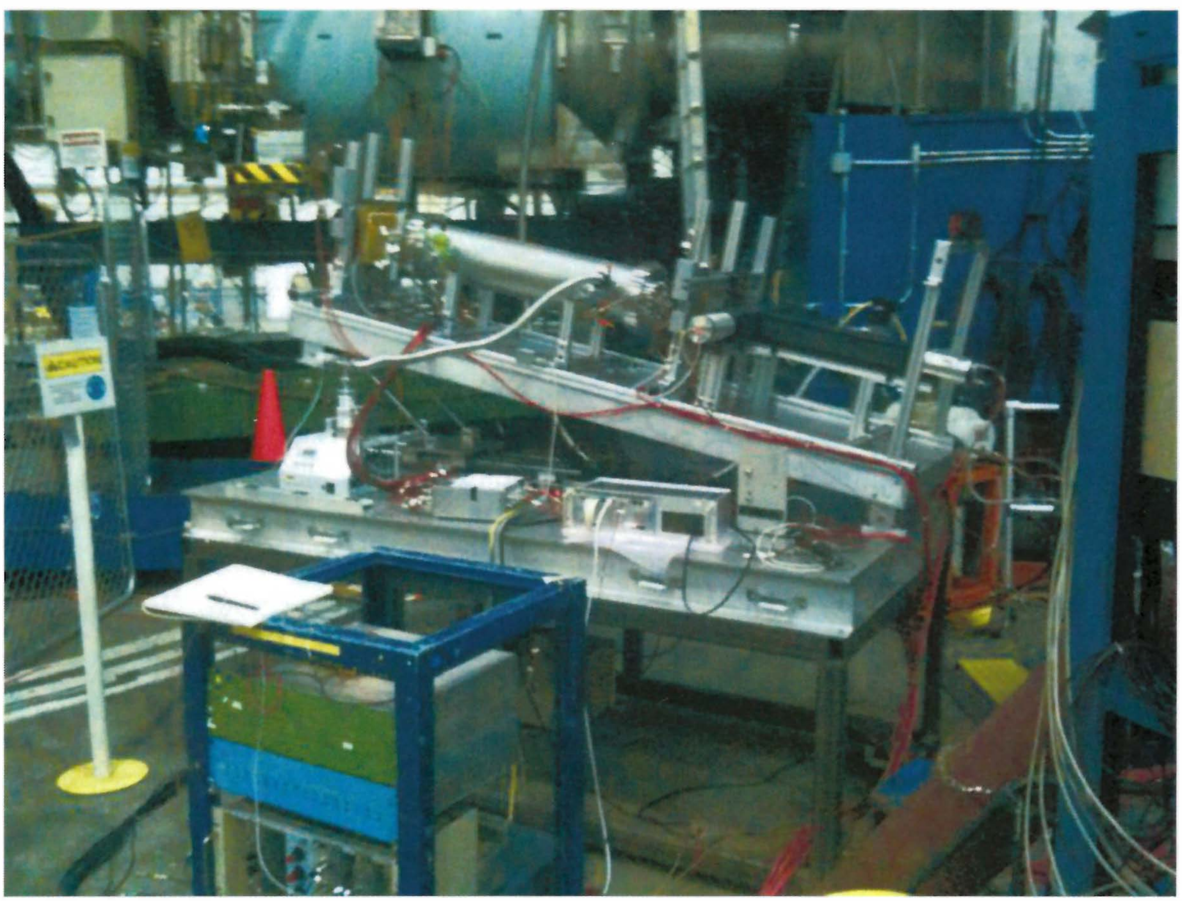


Table of Contents

INTRODUCTION

This is a technical scope of work (TSW) between the Fermi National Accelerator Laboratory (Fermilab) and the experimenters of FLYSUB-Consortium 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:

FLYSUB is a consortium consisting of BNL, Florida Tech, Stony Brook University (SBU), University of Virginia (UVa), and Yale University and is planning to assemble a set of detectors at FTBF which is targeted toward tracking and PID components of an EIC detector. The groups have been working together for about two years and have come up with a common beam-time usage instead of asking for separate test-beam campaigns, with the set-up described in what follows. The ultimate goal of this test-beam effort is to test and verify the performance of the individual components according to their expectation. The detectors are foreseen to share the same beam-line and will be arranged according to their need for particle impact.
The fundamental areas of investigations driving the need of a test-beam campaign are:

- Development of a fast TPC/HBD detector to provide ultra-low mass central tracking, hadron ID via dE/dx, and moderate electron ID via detection of unfocussed Cherenkov blobs
- Development of a mini-drift GEM detector for resolving the issue of losing resolution for inclined particle tracks and applying different frontend electronics
- TRD GEM detectors for electron identification
- Development of large area planar GEM detectors for endcap tracking
- Development of Cherenkov detectors in the forward direction, with particular emphasis on high momentum hadron ID and development of large area low cost VUV mirrors
- Development of alternative read-out structures for reducing the number of channel counts but conserving the resolution

These areas are split among the institutions and individual contributions are described in the following.

1.) BNL: Test of a mini-drift GEM detector which is made out of standard 10x10cm^2 GEM foils with increased drift gap (> 17 mm). The readout will be performed with SRS-DAQ and if available switching to VMM1 readout. Gas to be used is mixed Ar-CO_2 (70/30), Ar-CO_2-CF_4 (95/3/2), or pure CF_4. No special cooling required.

Main goal is to measure position and angular resolution and test the VMM1 readout. Desired angular range is 0° to 45°.

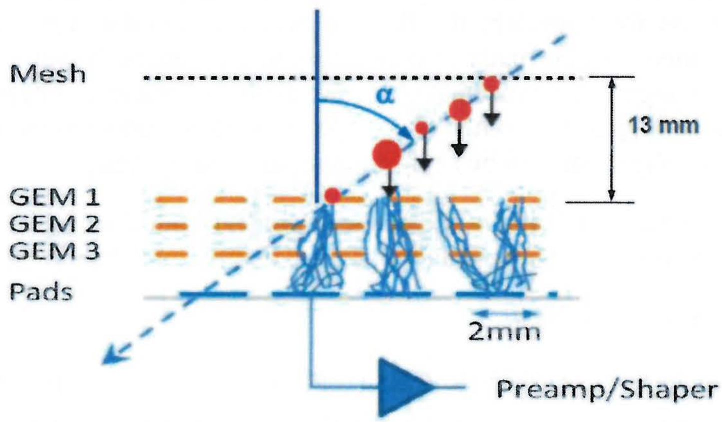


Figure 1 Illustration of micro-drift GEM detector with pad readout.

Test of 10 x 10 cm^2 GEM chambers for measuring the spatial resolution at different incident angles and TR photon yields to identify electrons, HV settings, and gas mixtures.

2.) BNL+Yale: fast compact TPC that can operate with Cherenkov gases. The design would separate the TPC charged particle tracking readout (at the end planes) and Cherenkov photon detection (at the outer barrel surface). The R&D is aimed at finding a single gas mixture that will work as a drift gas, radiator gas and working gas for the GEMs.

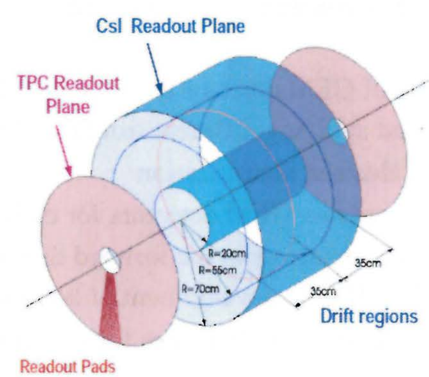


Figure 2 Conceptual design for a combined TPC and Hadron Blind Detector (HBD) proposed for PHENIX ~ 2001. The TPC provided tracking and particle ID by dE/dx. The HBD was a proximity focused Cherenkov detector that identified electrons and had minimal sensitivity

It is foreseen to have a 25 x 27 cm^2 TPC using PHENIX HBD GEM foils and to test the field cage design with one side "open" (likely using wires) for Cherenkov light to reach the photo-detector and adding a CsI GEM detector to the open side and try and operate as a Cherenkov detector in the same gas as the TPC at the same time.

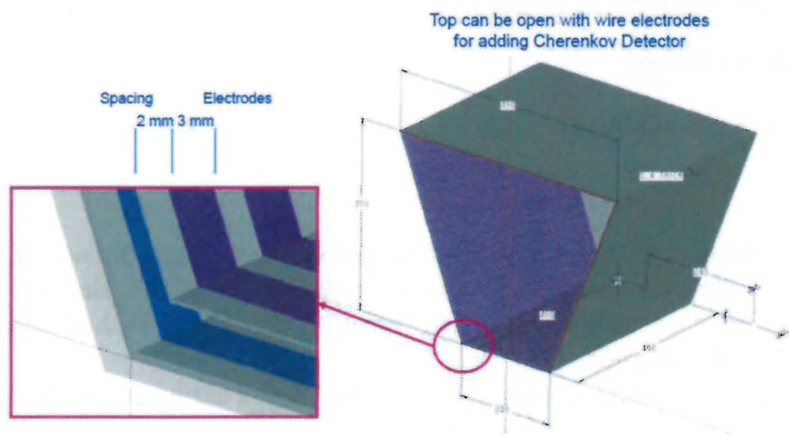


Figure 3 Preliminary design studies for a field cage for a combined compact TPC/RICH as originally proposed for PHENIX.

3.) Florida Tech+UVa: one (possibly two) chambers with 100 cm × (44 – 22) cm trapezoidal prototypes and radial strip readout (24 sectors with 12cm strip length) and one more chamber with zigzag strips would be inserted in the beam line.

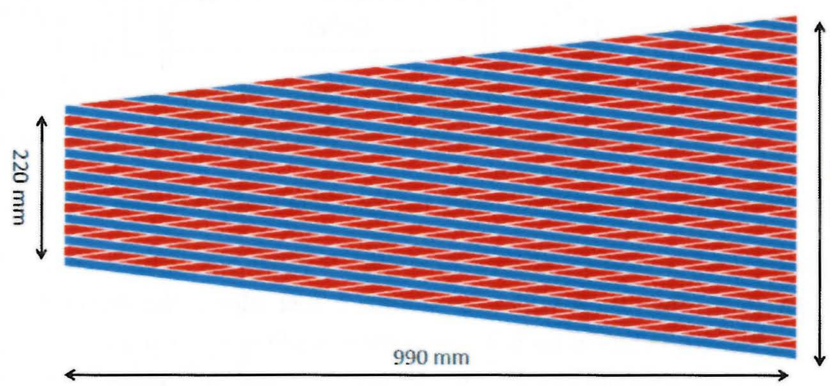


Figure 4 Radial strip readout for a trapezoidal GEM chamber.

Furthermore, a 50 x 50 cm^2 GEM prototype chamber and a 30 x 30 cm^2 self-stretched EIC GEM prototype with zigzag readout strips will be implemented. As a reference tracking system it is planned to provide one 10 × 10 cm^2 Micromegas detector, one or two 10 × 10 cm^2 Triple-GEM chambers, and one 30 × 30 cm^2 self-stretched Triple-GEM with Cartesian readout (COMPASS style).

The main goal of the studies is to investigate their spatial and timing resolutions for non-standard strip readout geometries (u-v, zigzag) under various conditions:

i. Without magnetic field

ii. With magnetic field (at least 0.5 T)

iii. Response under highest available rates

iv. Two-track resolutions

v. With various gas mixtures

4.) Stony Brook University: The aim of this test is to verify the performance of a Ring-Imaging-Cherenkov (RICH) detector based on Gas-Electron-Multiplier (GEM) detectors and CF_4 as the radiator/counting gas. This technology is foreseen to become part of the Particle Identification (PID) system of an EIC-detector.
The detector consists of a stainless steel tube which is closed at one end with a mirror and at the other end with the GEM-detector in the focal plane of that mirror. The readout plane for a quintuple-GEM detector can be interchanged between two-dimensional strip and single pads readout. The primary goal of the tests is to prove that the ring diameter obtained with both readout-plane structures will suffice particle discrimination up to high momenta.

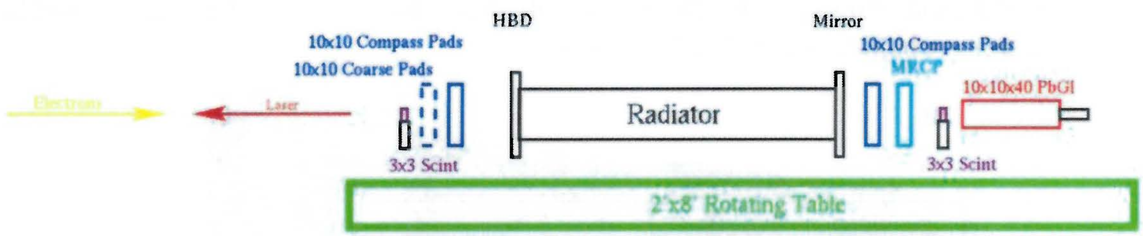


Figure 5 Drawing (not to scale) of the proposed setup for the test in beam of the RICH prototype.

5.) Yale University: Two sets of 4 chambers each, 10 x 10 cm^2 active area, ~1.2% RL each chamber. Each set of 4 chambers will take about 2 feet along the beam line. The readout structure of these detectors is based on a 3-coordinate single readout plane. The goal of the tests is to investigate charge sharing ratio and uniformity of the ratio and ultimately resolution.

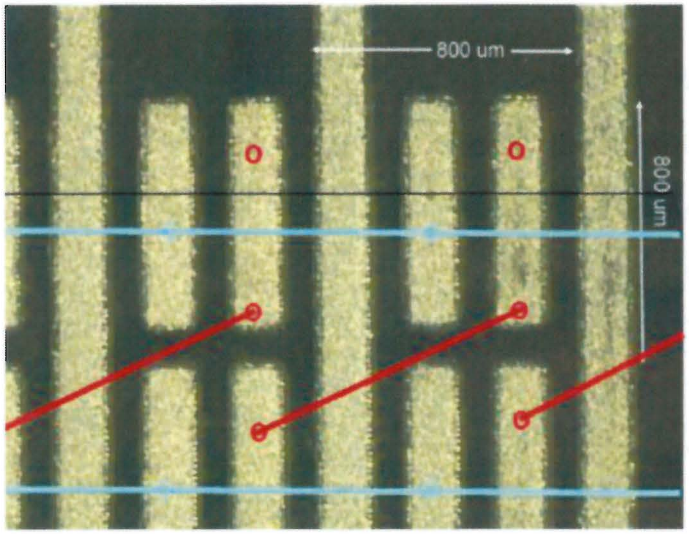


Figure 6 Three-dimensional single readout plane realized by interconnecting different lines of readout strips/pads.

I. PERSONNEL AND INSTITUTIONS:

Spokesperson: Klaus Dehmelt (Stony Brook University)

Fermilab liaison: Aria Soha

The group members at present are:

	Institution	Country	Collaborator	Rank/Position	Other Commitments
1.1	Brookhaven National Lab	USA	Bob Azmoun	Research Scientist	PHENIX
			Robert Pak	Research Scientist	PHENIX
			Benedetto di Ruzza	Research Scientist	
			Craig Woody	Research Scientist	PHENIX
			Zhangbu Xu	Research Scientist	STAR
1.2	Florida Tech	USA	Marcus Hohlmann	Professor	CMS
1.3	Stony Brook University	USA	Marie Blatnik	Undergraduate student	
			Raphael Cervantes	Graduate student	
			Klaus Dehmelt	Research Scientist	PHENIX
			Abhay Deshpande	Professor	PHENIX
			Nils Feege	Postdoc	PHENIX
			Thomas Hemmick	Professor	PHENIX
			Serpil Yalçın	Graduate student	
			Stephanie Zajac	Graduate student	
1.4	University of Virginia	USA	Kondo Gnanvo	Research Scientist	SOLID
			Nilanga Liyanage	Professor	SOLID
1.5	Yale University	USA	Richard Majka	Research Scientist	STAR
			Nikolai Smirnov	Research Scientist	STAR/ATLAS

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS:

2.1 LOCATION

2.1.1 The various detectors will be placed in MT6.2 along the beam-line (see Figure 7 MT6.2 Layout with all detectors along the beam-line (detectors are not to scale).Figure 7):

Station 1	3 GEM tracker (10x10cm^2 each)
Medium GEM	1 GEM tracker 30x30cm^2
Station 2	3 GEM tracker (10x10cm^2 each)
Trapezoidal GEM	Two large, trapezoidal GEM tracker (100cmx[40-22]cm)
Ref tracker	2 GEM tracker (10x10cm^2 each), 1 MM tracker 10x10cm^2
TPC	TPC/HBD prototype 40x27x25cm^3
Large GEM	One GEM tracker 50x50cm^2
TRD station	2 GEM detectors (10x10cm^2 each)
RICH	RICH detector on table 2'x8'

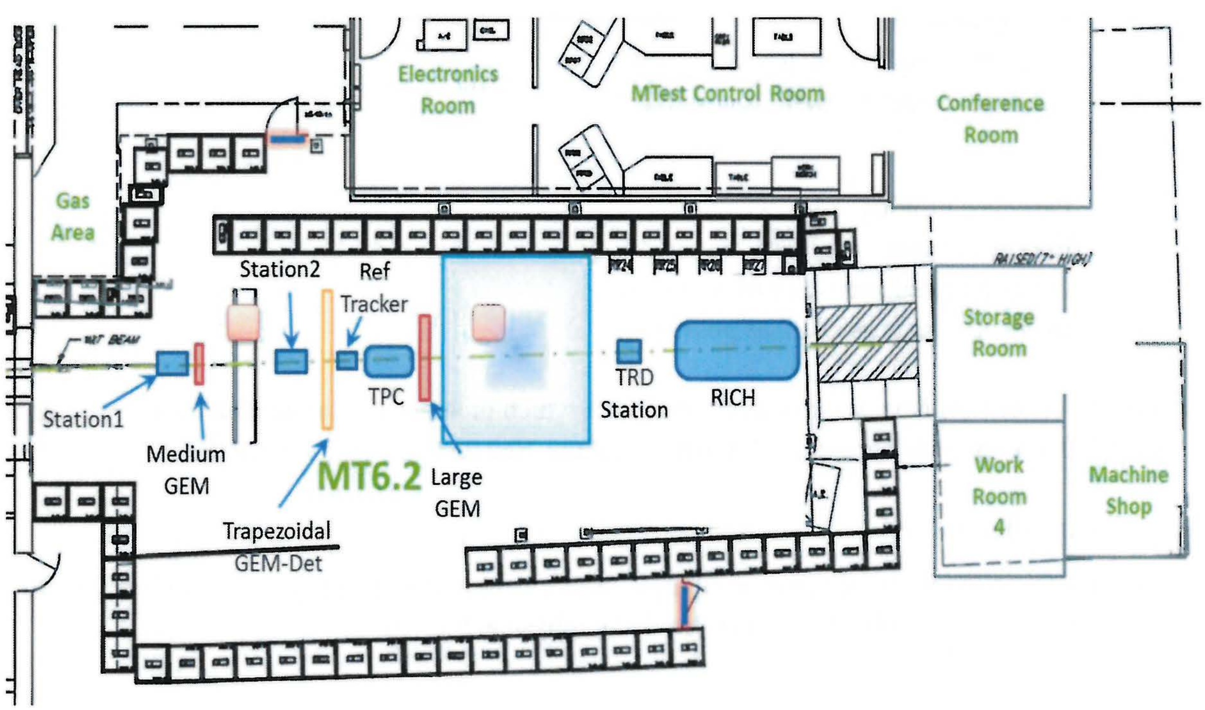


Figure 7 MT6.2 Layout with all detectors along the beam-line (detectors are not to scale).

2.1.2 Additional space needed:

- Control room: various PCs/monitors and table space
- Electronics Room: four racks
- Storage room: to store shipping boxes for the items
- Meetings in conference room on a daily basis

2.2 BEAM

2.2.1 BEAM TYPES AND INTENSITIES

Particles: electrons
Energy of beam: 10 GeV
Intensity: Single particles (if possible)
Beam spot size: as small as possible

Particles: pions
Energy of beam: > 4 GeV, > 20 GeV
Intensity: single particles (if possible); variations 1k – 100k particles/ 4 sec spill
Beam spot size: as small as possible; about 1 cm^2

Particles: Kaons
Energy of beam: > 13 GeV
Intensity: single particles (if possible)
Beam spot size: as small as possible

Particles: protons
Energy of beam: > 27 GeV
Intensity: single particles (if possible)
Beam spot size: as small as possible

The experimenters have set up a beam-run-table which includes a detailed plan about running with different particle species at different momenta. See section 2.3.3 for details.

2.2.2 BEAM SHARING

Because this experiment consists of multiple detectors in multiple locations beam-sharing with other experiments is unlikely to work out due to physical limitations.

2.2.3 Running Time

In the first week frequent access for debugging the set-ups. Change and fine-tuning of control parameters that cannot be performed remotely.

Run-time is expected to be between 1000 and 2200.

See section 2.4 for total run time and long-term schedule.

2.3 Experimental Conditions

2.3.1 Area Infrastructure

All detectors are gaseous detectors and will be read out by SRS electronics except of those which might be switched over to experimental electronics. The latter is basically the mini-drift GEM chamber as described above.

The detector's dimensions are listed in Table 1.

Table 1 Dimensions and weights for the various detectors used in the set-up.

Item	Dimension h×w×d (cm×cm×cm)	Weight (kg)
14 GEM/MM tracker	10×10×2 each	5 each
1 GEM tracker	30×30×2	7
1 GEM tracker	50×50×2	8
Two large, trapezoidal GEM tracker	100×[40-22]×4 each	10
TPC/HBD prototype	27×25×40	20
RICH detector (on table)	100×65×245	120

All detectors except the RICH-detector need mounting structures that can be adjusted such that the detectors can be moved into the beam. The RICH-detector table needs a supporting table that can be adjusted such that the RICH detector can be aligned with the beam.

Each detector will be read out with SRS-electronics. For that each rack needs a GB-ethernet connection to the control room.

The experiment requests precise tracking detectors (e..g. Si-hodoscope) and trigger scintillators be provided by FTBF.

Gas racks which are provided by some groups need to be placed as close as possible to the detector set-up.

The experiment will use Patch-panels (BNC, LEMO) in the counting house leading to the experimental area.

Uninterrupted power supplies would be desirable.

The detectors will need to be supplied with gas. Various gas mixtures would be needed. Many detectors will also need CF_4 either in mixtures or pure gases. Other mixtures are basically Ar-CO_2 mixtures with different ratios. The CF_4 gas would be required to be ordered by the experiment to be delivered to Fermilab or ordered through Fermilab.

The experiment will need an opportunity to survey the detector's positions with respect to each other and to the beam line.

2.3.2 ELECTRONICS NEEDS

The groups will provide electronics for each individual detector. Cables might be needed for extending the set-up.

No PREP electronics are requested.

2.3.3 DESCRIPTION OF TESTS

The detectors will be prepared by the various groups at their home institutes such that the operational status is defined. Once the detectors are operational the parts which are permanently attached to non-movable parts will be disconnected and shipped to Fermilab. This will reduce set-up time at the test-facility. There the detectors will be set up and connected. The systems will be checked for operation and the readout performance will be evaluated. Once these issues are set we can start with exposing the detectors in the beam.

It is planned to start the tests with conditions that all detector tests will have in common. A general plan can be found in Table 2.

Table 2 General run plan. The run plan starts with the first day of requesting particles traversing the detectors.

Day	Particle species	Energy	Particle count[1]	Spot size (cm^2)
1-3	Pion	> 20 GeV	1kHz	< 1
4-6	Pion	> 4 GeV incrementing in	single to few	< 1

[1] In units of particles per 4 sec spill.

		1.) 2 GeV steps up to 10 GeV (4 sets) 2.) 5 GeV steps up to 35 GeV (5 sets)		
7-9	Kaon	> 16 GeV incrementing in 1.) 2 GeV steps up to 20 GeV (3 sets) 2.) 5 GeV steps up to 45 GeV (5 sets)	single to few	< 1
10-11	Proton	> 29 GeV incrementing in 1.) 2 GeV steps up to 35 GeV (3 sets) 2.) 5 GeV steps up to 45 GeV (2 sets)	single to few	< 1
Day	Particle species	Energy	Particle count[1]	Spot size (cm^2)
12	Identified electrons	1 GeV < E < 10 GeV	1kHz	1
13	Pions	30 GeV	100kHz	As small as possible
14	TBD			

Detectors will be staying in the beam-line all time, except when experiencing issues with them. Access to the area would be requested when necessary, though it is expected to control the detectors remotely.

2.4 SCHEDULE

The experiment requests a total of two weeks beam-time, plus an additional four to five days of set-up and debugging of which one or two might be with beam particles. The experiment would like to request the first three weeks in October 2013 for our test-beam campaign.

III. Responsibilities by Institution – Non Fermilab

3.1 BNL and Yale University:

will contribute a prototype of a TPC/HBD with SRS-readout, mini-drift TPC (small GEM detector) based on SRS-electronics and probably with VMM electronics, and two stations of each four small GEM trackers with SRS-readout.

3.2 Florida Tech and University of Virginia:

will contribute with two large, trapezoidal GEM trackers, one large sized squared GEM tracker, one medium sized squared GEM tracker, and three small sized reference trackers. All detectors are read out based on SRS-electronics.

3.3 Stony Brook University:

will contribute with a RICH detector based on GEMs and SRS-readout. Will also provide a set of two PbGl calorimeter blocks and NIM readout electronics.

- Manpower will be provided as listed in .

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 (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). [0.5 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. [1.0 person weeks]
4.2.2 Set up and maintenance of Si tracking system.
4.2.3 Setup and maintenance of trigger scintillators.
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 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 GB Ethernet connection between beam enclosure and control room.
4.3.3 See Appendix II for summary of PREP equipment pool needs.

4.4 <u>FERMILAB ESH&Q SECTION</u>

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	1.0
Accelerator Division	0	0.5
Scientific Computing Division	0	0
ESH&Q Section	0	0.2
Totals Fermilab	$0.0K	1.7
Totals Non-Fermilab	[specify from Section III]	[specify]

VI. General Considerations

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.

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.

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.

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.

All items in the Fermilab Policy on Computing will be followed by the experimenters. (http://computing.fnal.gov/cd/policy/cpolicy.pdf).

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.

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:

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.

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.

The experimenters will assist Fermilab with the disposition of any articles left in the offices they occupied.

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

SIGNATURES:

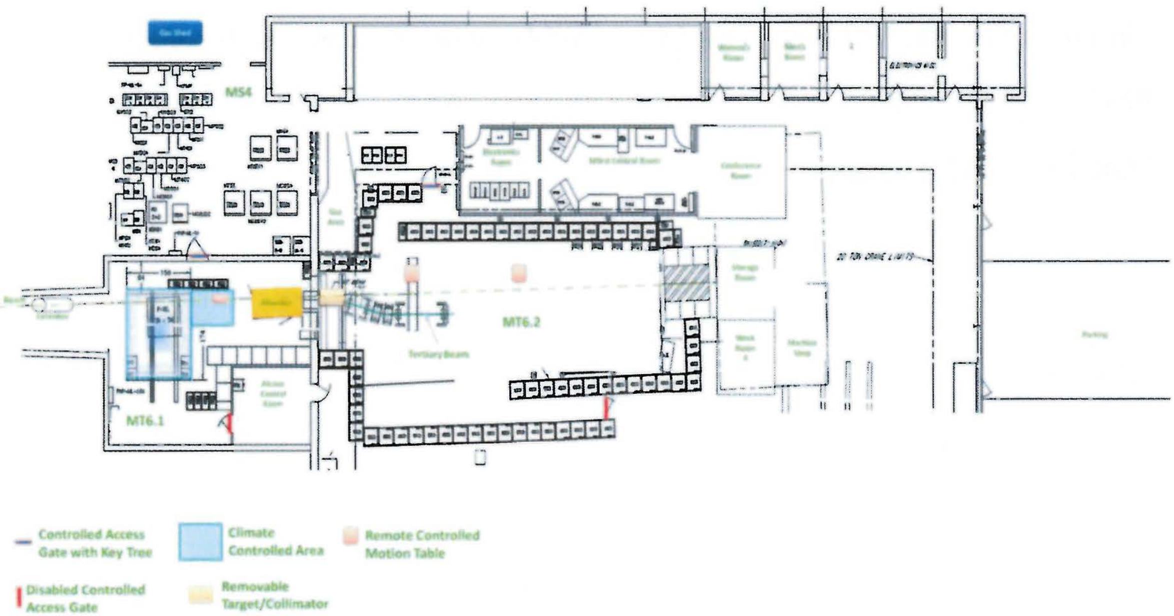
____ / / 2013

Klaus Dehmelt, Experiment Spokesperson

APPENDIX I: MT6 AREA LAYOUT

The detectors are planned to be arranged as described in Figure 7.

MTEST AREAS



APPENDIX II: EQUIPMENT NEEDS

Provided by experimenters:

[If you wish you may include a breakdown of what is being provided by which institution, for your records.]

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

PREP EQUIPMENT POOL:

Quantity	Description
X	Type of item
X	Type of Item

PPD FTBF:

Quantity	Description
X	Type of item
X	Type of Item

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.

TSW for FLYSUB-Consortium

The following people have read this TSW:

____ / / 2013

Michael Lindgren, Particle Physics Division, Fermilab

____ / / 2013

Roger Dixon, Accelerator Division, Fermilab

____ / / 2013

Robert Roser, Scientific Computing Division, Fermilab

____ / / 2013

Nancy Grossman, ESH&Q Section, Fermilab

____ / /2013

Greg Bock, Associate Director for Research, Fermilab

____ / /2013

Stuart Henderson, Associate Director for Accelerators, Fermilab