FERMILAB-TM-2596-DI
January 2015

Fermilab Testbeam Facility Annual Report – FY 2014

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1. INTRODUCTION

This Technical Memorandum (TM) summarizes the Fermilab Test Beam operations for FY 2014. It is one of a series of annual publications intended to gather information in one place. In this case, the information concerns the individual experiments that ran at FTBF – see table TB-1. Each experiment section was prepared by the relevant authors, and was edited for inclusion in this summary.

1.1 The Fermilab Test Beam Facility in Fiscal Year 2014

The Fermilab Test Beam Facility (FTBF) gives users from around the world an opportunity to set up detectors in a variety of particle-beams. A plan view of the facility is shown in Fig. TB-2. The web-site URL for the facility is www-ppd.fnal.gov/FTBF. Since it began operation in 2005, the facility has hosted 58 experiments, serving 835 individual experimenters from 177 institutions, in 30 countries.

The FTBF has two beamlines, Meson Test (MTest) and Meson Center (MCenter), which are part of the Switchyard 120 (SY120) system which is fed by 120 GeV protons resonantly extracted from the Main Injector at moderate intensities and at 1-300 kHz during a 4.2 second spill once per minute. Other configurations of these beamlines with secondary targets allow for a mix of pions, electrons, kaons, or broadband muons with energies from 60 GeV down to 1 GeV or 200 MeV with the tertiary beamline installed in MCenter.

The FTBF was scheduled for beam for 48 weeks of the 52 week period. Beam delivery started on October 7th and continued until September 5th. A total of 7.9×10^{15} protons were delivered. MTest operated for 3232 hours driven by user requests and allowing for partial shift coverage by the users. The reconfiguration and restart of the MCenter beam in FY14 allowed for 309 hours of operation.

1.2 Research Performed at the FTBF in FY 2014

Each test-beam experiment is required to prepare a Technical Scope of Work (TSW) with the Laboratory, in which the beam, infrastructure, and safety requirements are spelled out in detail. Nine new TSWs were approved in FY2014, and 12 new experiments took data during FY 2014. An additional seven experiments returned from previous years to take more data in FY 2014. These 19 experiments are listed in Table TB-1, and represent 321 collaborators from 84 institutions in 20 countries. The chart in Fig. TB-3 shows the growth in these numbers over the last 5 years.

Table TB-1: Test Beam experiments performed in FY 2014.

Test	Description
T0958	FP420 Fast Timing Group
T0979	Fast Timing Counters for PSEC
T0979	Fast Timing Optical Time Projection Chamber
T0987	DAMIC
T0992	SLHC rad hard sensor tests
T0994	JASMIN
T1015	Dual Read out Calorimetry (crystal/glasses)
T1015	Adriano for ORKA
T1015	Adriano for High Energy (ILC)
T1018	Spacordian Tungsten Powder Calorimeter
T1031	ATLAS Tile Calorimeter Electronics Test
T1034	LArIAT Commissioning
T1036	High Rate Pixel Detector for CMS Upgrade
T1037	FLYSUB Consortium
T1041	High Rate RPCs
T1041	Crystal Fibers
T1041	CMS Dedicated Fast Timing
T1041	CMS Precision Timing
T1041	QIE10
T1041	Quartz Plates
T1041	Radiation-Hard Scintillating Fibers
T1041	Radiation-Hard Scintillators
T1041	Secondary Emission Calorimetry
T1041	CMS EE Shashlik array
T1042	Muon g-2 Straw Tracker
T1044	sPHENIX Calorimetry Tests
T1048	PHENIX Fast TOF
T1049	ATLAS large scale Thin Gap Chambers
T1054	sPHENIX PreShower Calorimeter
T1056	ATLAS DBM Module Qualification
T1058	Secondary Emission Calorimeter

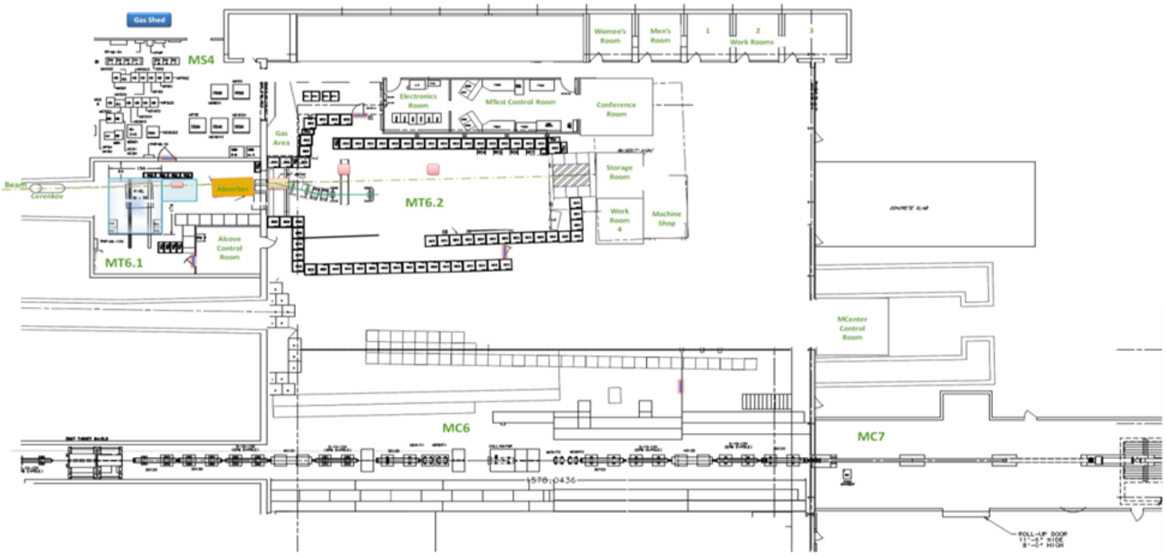


Figure TB-2: View of the Fermilab Test Beam Facility.

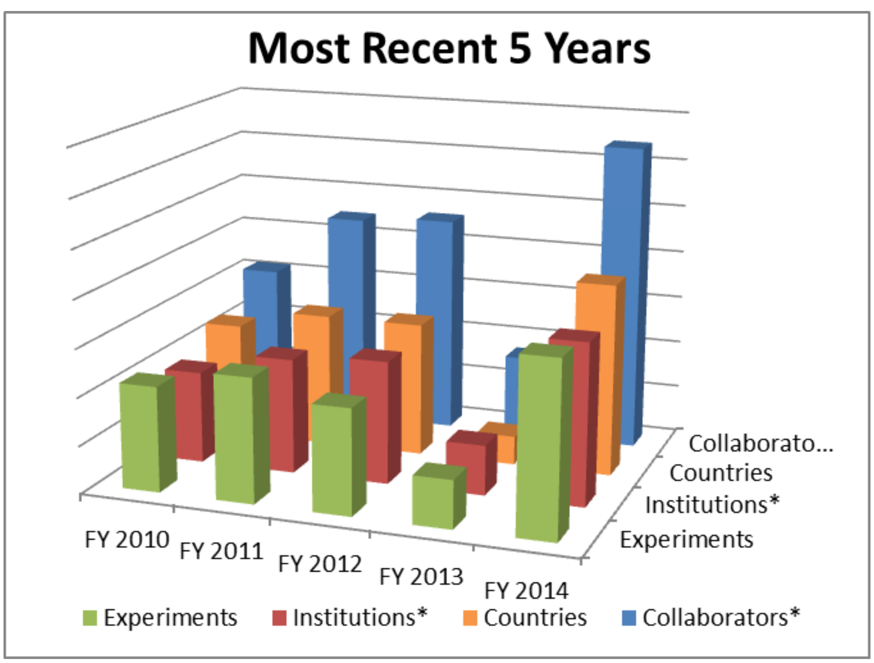
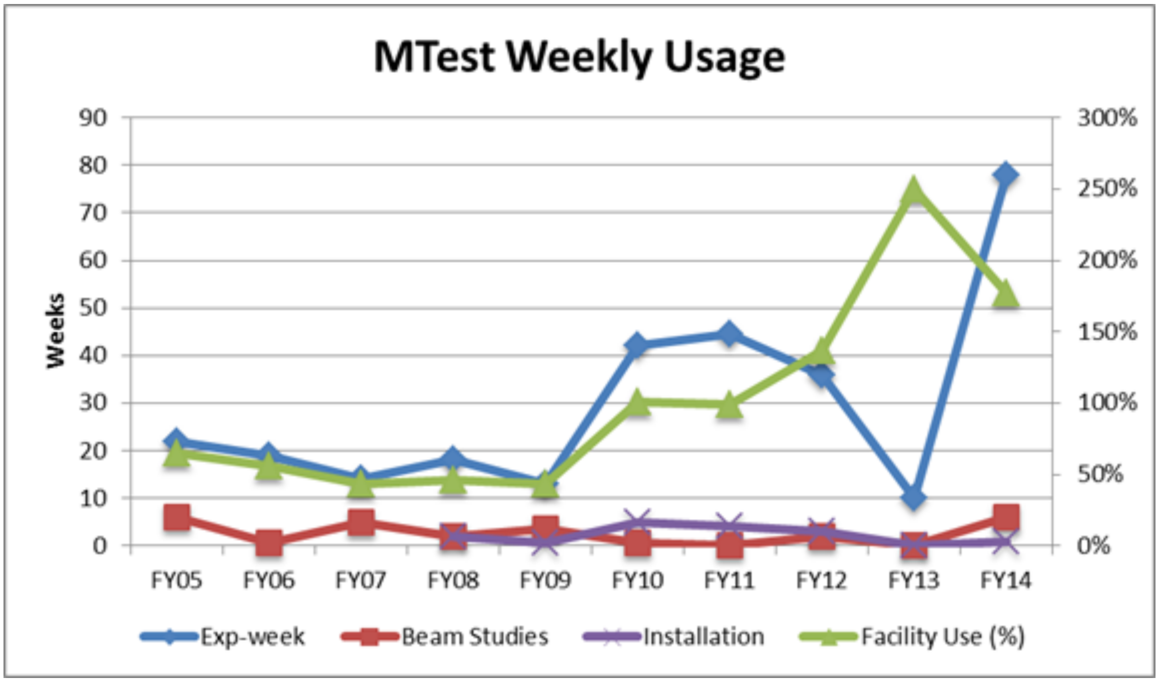


Figure TB-3: Growth in number of experiments, collaborators, institutions and countries served by the FTBF over the past 5 years. *Number of *Collaborators* has been scaled to fit on plot. *Number of *Institutions* has been scaled to fit on plot. Note that due to the planned long shutdown FY12 consisted of only 7 months of beam and FY13 consisted of only 1 month of beam.



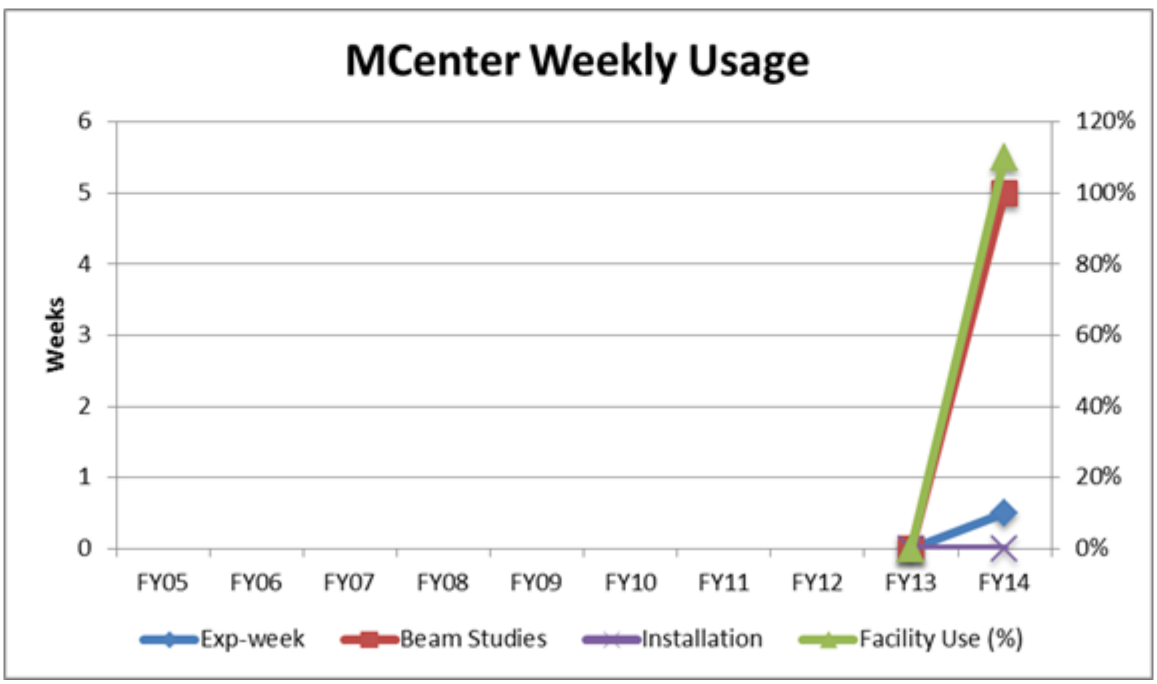


Figure TB-4: Weekly Usage of MTest and MCenter beamlines, nominalized to number of beam-weeks available.

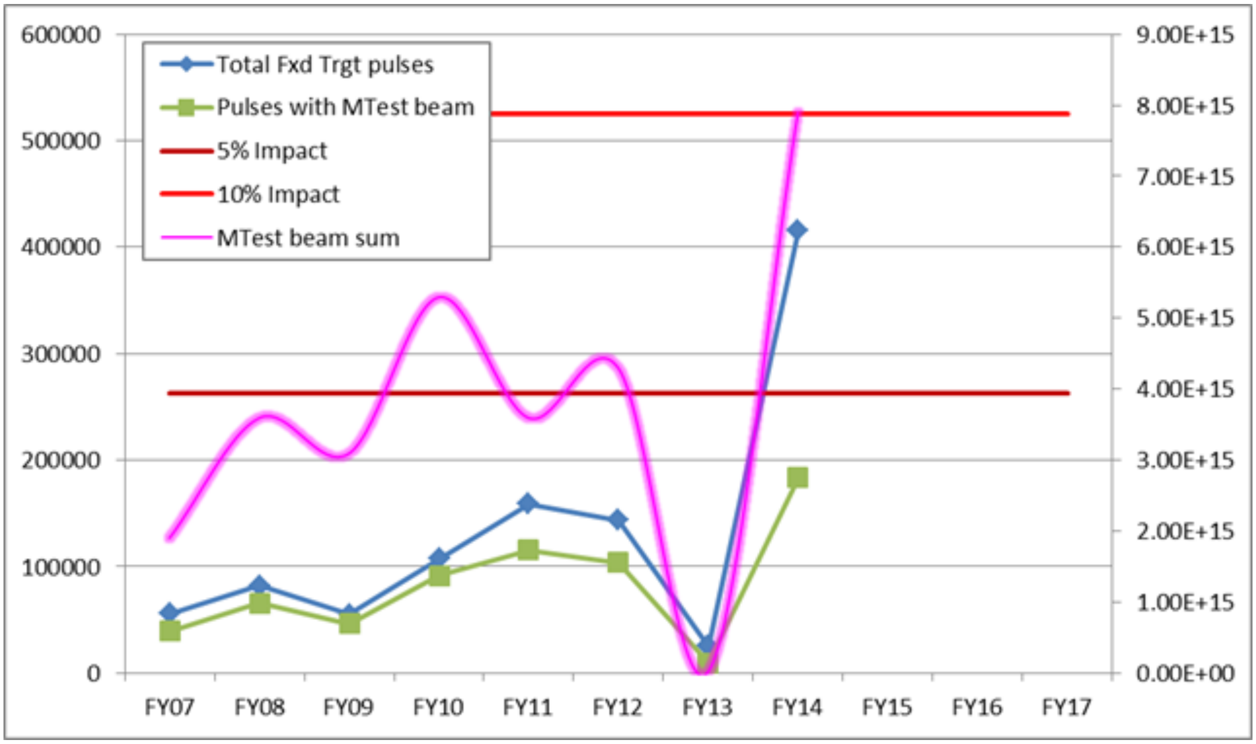


Figure TB-5: Fixed target pulses, to FTBF with and without.

The experiments used the MTest beamline for data taking purposes for a total of 78 experiment-weeks, out of the 48 weeks with beam available during the year. Weekly facility usage since 2005 (when the facility started taking beam) is shown in Fig. TB-4.

In addition, the MCenter beamline was started, and provided beam for 5 weeks, which was used for commissioning the tertiary beamline for the T-1034 LArIAT experiment. This beamline was also used for data taking purposes for half a week by the T-0979: Fast Timing Counters for Psec, experiment.

During the 48 weeks of available beam, a total of 415,178 Fixed Target beam cycles occurred, 183,225 of which had beam for the MTest beamline, for a total beam sum of 7.90×10^{15} protons. The MCenter beamline had 16,496 pulses with beam for a total beam sum of 2.4×10^{16} protons.

Until 2012, the Director's guideline for test beam users' effect on antiproton production and neutrino beams was 5%, this usually results in one 6 second event in the 60 second timeline for 12 hours a day. However, in 2012 the SeaQuest Experiment started running which was allowed a 10% impact on neutrino beam (one 6 second event /60 seconds for 24 hours a day), and test beam user effects became transparent. The chart shown in Fig. TB-5 shows the number of beam cycles per year over the last 7 years. The impact of FTBF operations has been well below the 5% (now 10%) limit set by the Director.

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SECTION 2:
REPORTS FROM THE TEST EXPERIMENTS

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<u>T-958 / Fast Timing @ LHC</u> (A. Brandt[1], M. Rijssenbeek[1])

Beam used: 120 GeV protons
Run dates: Aug20-26/31-Sep2, 2014

Motivation and Goals:
We have successfully designed a time-of-flight system with ~10 ps resolution for a near beam timing detector at the LHC. This precise timing allows precise vertexing, enabling a large rejection factor for multiple interaction events. A change to the accelerator interface (movable beam pipe -> Roman pot) required us to abandon the initial straight bar quartz Cherenkov detector with microchannel plate PMT, for a new design that brings the light out at 90 degrees. In this test beam, we tested a few different configurations for the "LQBAR" which is basically a straight bar at the Cherenkov angle (like a QBAR) but with a 90 degree bend and an elbow cut at 45 degrees and mirrored to maximize the light up the light guide bar to the PMT.

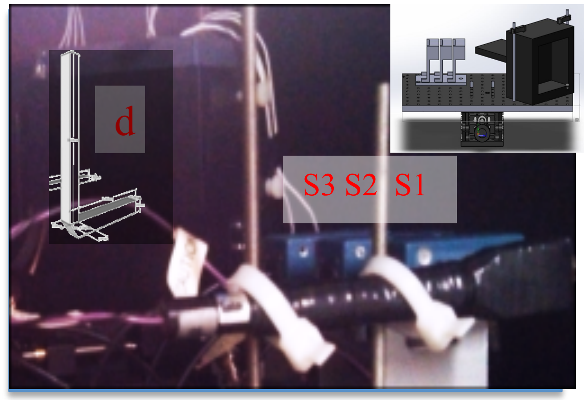

Figure 1: T958 Setup

Setup:
The setup consisted of a light tight box with three 3x3mm SiPM's with a piece of quartz in front (courtesy of M. Albrow and A. Rhonzin) for triggering and reference timing and an LQBAR in a custom holder hooked up to a special new MCP-PMT (provided by Photonis) and readout UTA's 6 GHz 20 Gs/s Teldyne-Lecroy oscilloscope. We varied the LQBAR design and the phototube.

Results and Impact:
Figure 2(a) shows that the SiPM's have excellent resolution: δt=20 ps implies 14 ps each (expect ~11ps from previous test beam after background subtraction); (b) shows the time difference between a SiPM and an LQBAR. The preliminary resolution of the LQBAR is 36 ps, in general agreement with simulations that predicted about 2x less light than the QBAR which was measured at 19 ps in a previous TB). The goal for a two-LQBAR detector was 30 ps, and 36 ps for one bar implies 26 ps for two (36/1.4) and 18 ps for four bars, more than adequate for early use. From simulation, we expect some variations on the geometry to provide futher improvement to less than 20 ps/bar.

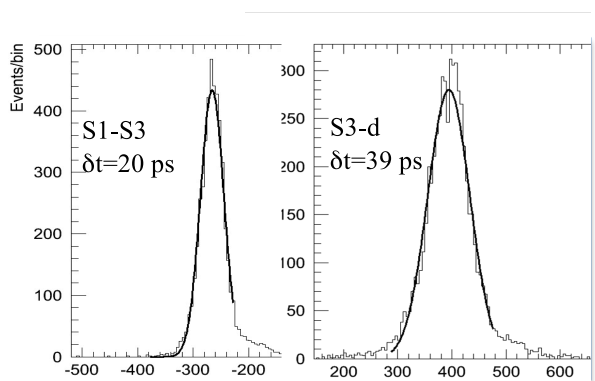

Figure 2: shows time difference between (a) two SiPMS (b) LQBAR and SiPM

[1] University of Texas, Arlington
[2] Stony Brook

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T-979 / Fast timing detectors (M. G. Albrow, S. Los, E. Ramberg, A. Ronzhin et al.)

Beam used: 120 GeV/c protons
Run dates: Nov 27-Dec 3rd 2013 and Jan 8 – 14th 2014 (and previous years)

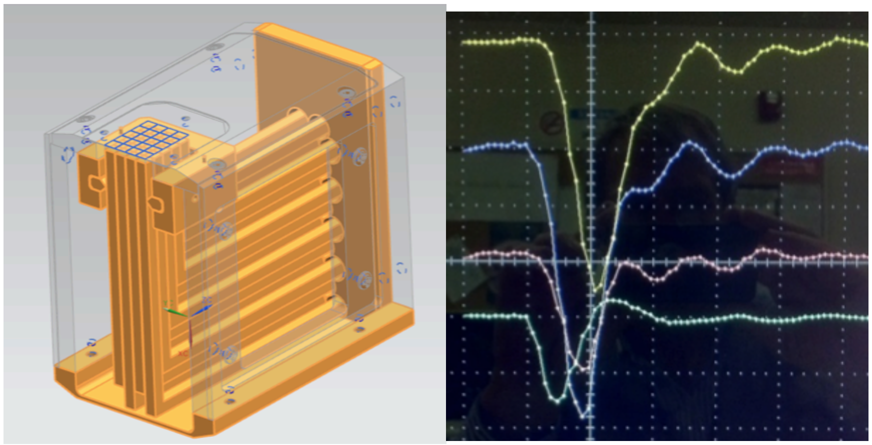

Figure (left) Design of a 20-channel L-bar QUARTIC with 3x3 mm2 bars. (Right) 'Scope traces, 2 ns/div (200 ps samples) and 20 mV/div, of one proton passing through three L-bars with SiPM readout (bottom trace is the reference time signal (50 mV/div) from a MCP-PMT in the beam).

Motivation and Goals:
A proposal was made and approved by the CMS and TOTEM managements to add very forward (210 m downstream) high precision proton detectors to study exclusive processes p + X + p at high luminosity. The project is called CT-PPS. An essential component is proton timing at the level of 10 ps to kill pile-up with protons from different interactions. We are developing a new Cherenkov detector concept, the "L-bar **QUARTIC**", with x-y segmentation (mm^2 level), edgeless on one side, and radiation hard near the beam.

Setup:
In a dark EM-shielded box we have a 2x2 mm^2 trigger scintillator at the front and a shower-veto counter with a small central hole at the back. An MCP-PMT Photek 240 at the back is a reference time counter with 8 ps resolution. The devices to be tested are placed in front of that, and can be changed in short accesses. The assembly is on an x-y scanning table.

Results and Impact:
In a series of studies we tested different Cherenkov counter geometries. An original concept was the "angled-bar **QUARTIC**", with an array of quartz bars inclined at the Cherenkov angle for β = 1 particles, 48°, and butted on to an MCP-PMT. We achieved $\sigma(t)$ = 16 ps for one such counter and 12 ps for a pair in-line. The results are published, together with other tests, in J. Inst 7, 2012, P10027 and in several conference talks. We also developed an alternative, also original Cherenkov design, the L-bar QUARTIC (see Fig.). Radiator bars are parallel to the protons, and at 90° is a light-guide bar (no mirrors, only total internal reflection). An advantage is 2D-segmentation and the use of low-cost SiPMs instead of the MCP-PMT. However the latter have worse single-photon time resolution, and we only obtained $\sigma(t)$ = 31 ps. The L-bar quartic design was adopted by the CT-PPS project as the baseline, while we

continue to improve it. A next step is to use L-bars with MCP-PMTs, and the possible use of sapphire bars instead of quartz. The R&D will continue while we make four baseline modules for installation in Fall 2015 in the LHC. With these we will be able to test, calibrate and use the detectors in real p + X + p events (with X = W+W-, 2-jets etc.).

The CT-PPS project is only possible with fast proton timing, which one of us (MGA) first proposed in 2000 (arXiv:hep-0009336).

<u>T-979 / Optical Time Projection Chamber</u> (E. Oberla[1], H. Frisch[1])

Beam used: T-979 installed at MCenter secondary line: 8, 32, 80 GeV π^+, π^- sitting behind ~2m steel collimator and running parasitic to LArIAT beam requests. Particles/momenta downstream of collimator were not quantified, though expected mostly broadband muons.
Run dates: August 28 – Sept. 4, 2014

Motivation and Goals:
The Optical Time Projection Chamber (OTPC) is a small-scale, prototype water Cherenkov detector using a combination of Micro-Channel Plate (MCP) photo-multipliers and optical mirrors. The goal is to demonstrate the capability of reconstructing 3-D tracks of relativistic particles by sampling the 'drifted' Cherenkov light. (An analog to electrons in a liquid noble TPC, for example.) The MCPs, with fast waveform digitizing readout, allow for the tagging Cherenkov photons with ~30 ps timing and few mm spatial resolution.

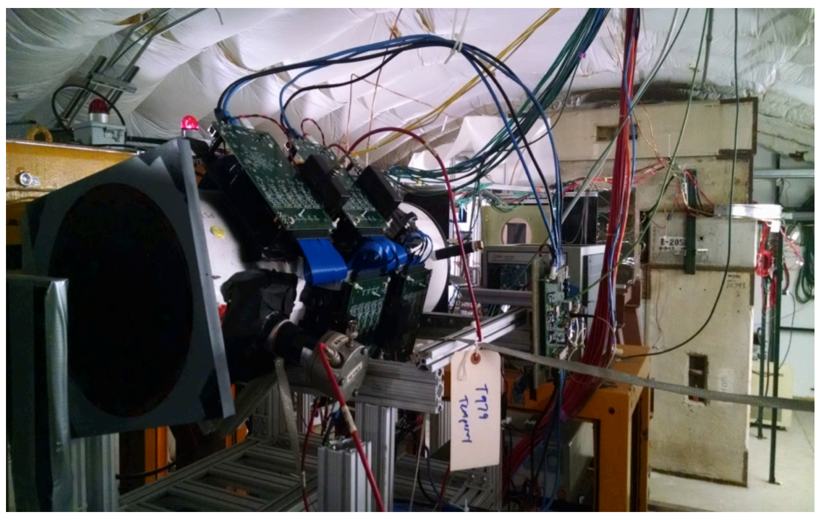

Figure 1: OTPC installed in MCenter secondary line. Image was taken from behind the OTPC, looking towards the incoming beam. The visible PC cards are each mounted behind a MCP photo-detector, and each board has 30 channels of 10 GSPS waveform digitizing readout.

Setup:
The T-979 installation setup is shown in Figure 1. The detector volume is an 11" diameter, 34" long cylinder filled with deionized water (~11 gallons). The center-line of the detector was lined up with the MCenter secondary beam. We set up downstream of a ~2m thick steel collimator. One hundred twenty channels of custom, 10 GSPS waveform sampling readout (PSEC4 ASIC) was used to readout the signal from four 2x2 sq. inch Planacon MCPs. A 1" diameter quartz radiator with MCP was mounted on the front of the detector cylinder, and was used to trigger the DAQ system. A Linux laptop left in the enclosure was used to readout the events over USB 2.0.

[1] University of Chicago, 5620 S. Ellis Ave, Chicago, IL 60637

Results and Impact:
The short beam test was generally unsucessful, with a couple issues that were difficult to solve once installed in the beam enclosure. Issues with the bonding of the Planacon MCPs to the readout board and DAQ firmware both limited the success of this initial OTPC testing. Both issues are actively being solved, and we are working to re-install as soon as possible when the shutdown is over.

We were able to measure particle rates of the secondary line, and our detector did respond to thru-going particles. We gained an enourmous amount of test-beam experience and MCenter was a great place to work. The demonstration of this type of detector has a great potential impact for the deployment of large-area MCPs in the field of HEP neutrino research.

T-0987 / Charge and time characterization of phototube EMI-9954KB with a 0.2 photoelectron threshold

(Leonel Villanueva-Rios[1], M. A. Reyes[1], F. Izraelevitch[2], G. Gutierrez[3], J. Estrada[3])

Beam used: 120 GeV protons
Run dates: December 16-17, 2013

Motivation and Goals:
Due to the searches of very low mass WIMPs as Dark Matter (DM) candidates, the measurement of nuclear recoil quenching factors for energies of about 1-10 KeVs has become very important in the past few years. The DAMIC collaboration is setting up a neutron scattering experiment on a silicon target to measure the nuclear recoil quenching factor. Scintillator bars and PMTs are used to measure the angular distribution of the scattered neutrons. To increase the neutron detection efficiency, the phototubes are operated with a very low threshold (~0.2 p.e.'s). The goal of the experiment carried out at the FTBF was to characterize the charge and time resolution behavior of the PMTs.

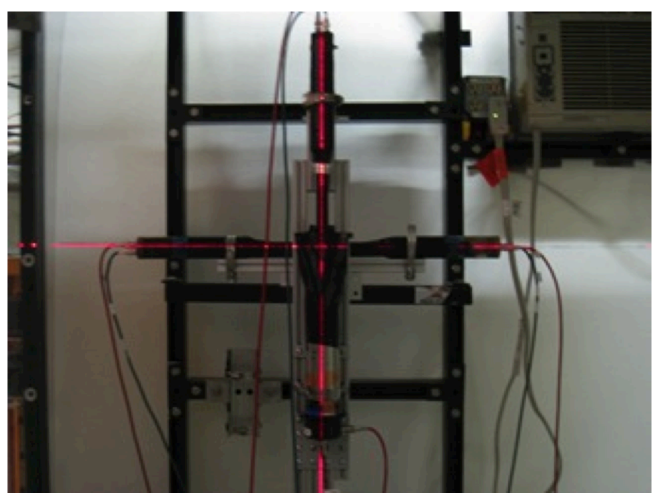

Figure 2

Setup:
The system consisted of two crossed Eljen EJ-200 scintillator bars, with two PMTs attached at the ends of each bar (Figure 1). One bar had two FEU-115M PMTs, and the other had one FEU-115M PMT and one EMI-9954KB PMT. The three FEU-115M PMTs were used as a trigger, and the response of the EMI-9954KB PMT to low light intensity was studied. The

[1] Universidad de Guanajuato, Mexico
[2] Universidad de Bueno Aires, Argentina
[3] Fermi National Accelerator Laboratory

light intensity was controlled by using a series of black paper masks with very small holes of calibrated sizes.

Results and Impact:

The ADC distributions from the EMI PMT were accurately fit by a Poisson distribution with the amplitudes determined by a Landau modulation. This allowed to fit all different ADC distributions of different paper masks with only three parameters. The one p.e. charge distribution was obtained using a tiny hole (0.035mm in radius). Fig. 2 shows the fit to the ADC distribution in this case, the histogram shows the data, the blue curve shows the one p.e. distribution, and the yellow and magenta curves show the two and three p.e. distributions. The red curve is the sum of these distributions. Fig. 3 shows the ADC distribution and the several p.e. fits for a mask with two holes of 1.19mm of radius.

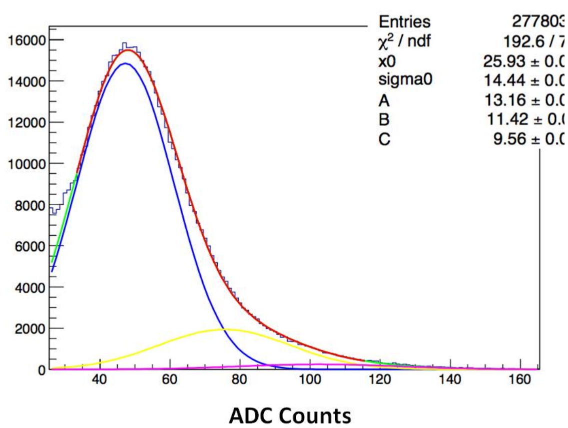

Figure 3

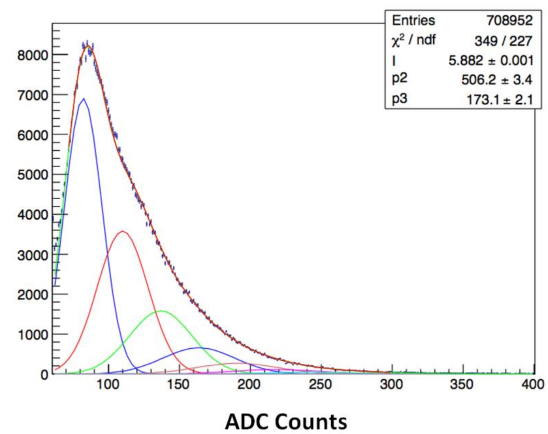

Figure 4

The time resolution was also studied as a function of the number of photoelectrons and found to satisfy the neutron scattering experiment requirements.

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T-992: Tests of radiation-hard sensors for the SLHC (L. Uplegger[1], R. Rivera[1], M. Jones[2])

Beam used: 120 GeV protons
Run dates: Jan 22 – Feb 4, Apr 23 – May 6, Aug 20 – Sep 4, 2014

Motivation and Goals:
At the SLHC, after 2500 pb-1of data, the Expected maximum fluence for the pixel region (<20 cm) will be 2.5 x 10E16 cm-2. To cope with this unprecedented radiation environment, there have been quite a few international collaborations formed to find possible solutions for vertex and tracking detectors at the SLHC.

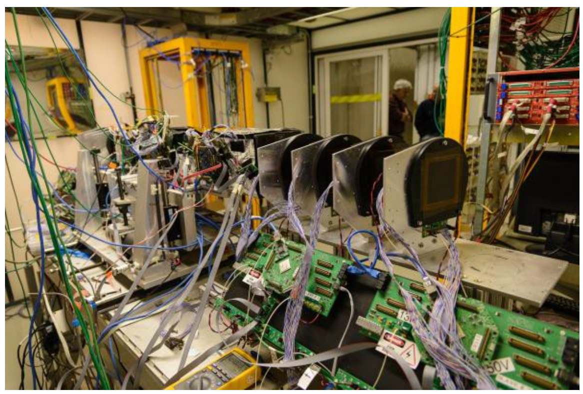


Figure 1 In situ T-992 test beam setup

These include the RD42, RD49, and RD50 collaborations. A variety of solutions have been pursued. These include diamond sensors, 3D sensors, MCZ planar silicon detectors made from MCZ wafers, epitaxial, p-type silicon wafers and thin silicon detectors. The experimenters wish to compare the performance of this wide variety of detectors in a test beam before and after irradiation. To do so, the experimenters use the FTBF pixel and strip tracking telescopes which have < 10 micron resolution at the device under test. In particular, the experimenters are planning to study the charge collection efficiency of irradiated and un-irradiated devices and the spatial resolution as a function of the track incident angle. The experimenters will change the incident angle of the beam by moving the sensors, to investigate how the resolution varies with angle. Many physicists participating in this beam test are members of the RD42 and/or RD50 collaborations.

[1] Fermilab
[2] Purdue

Setup:

The pixel and strip telescopes are read out through a custom DAQ system known as CAPTAN. A gigabit Ethernet board is used to route UDP data to a computer which is connected to a Fermilab server via internet. The readout boards are located close to the detector in the hut, and share a common clock and trigger signal. The detectors themselves may be operated up to ~800 V. No exposed HV parts are present.

Results and Impact:

We have studied both 3D silicon and diamond sensors. 3D tracking detectors are promising radiation-hard candidates to replace planar detectors in the HL-LHC. Radiation damage effects are measured with regards to charge collection, efficiency, and resolution of the particle tracks in beam tests, as well as leakage current and pixel noise. We have studied three varieties of 3D sensors: 1E, 2E and 4E (the number referring to the number of implant pattern per pixel). After irradiation, the 2E showed the least degradation in efficiency and collected charge. Lab and test beam studies are ongoing for more recent batches from FBK, with improved fabrication processes. More work must be done to reach radiation hardness of 10E16 neq/cm2. Using digital ROCs with lower thresholds will improve the charge collection efficiency and the tracking efficiency after irradiation. Technology improvements also need to be made in order to aggressively improve 3D fabrication processes for improved radiation tolerance. For diamond sensors, we have comparatively studied the tracking performance of a single-crystal and polycrystalline diamond. Our measurements demonstrate that the performance of a single-crystal diamond pixel-detector is comparable with that of the best available silicon detectors.

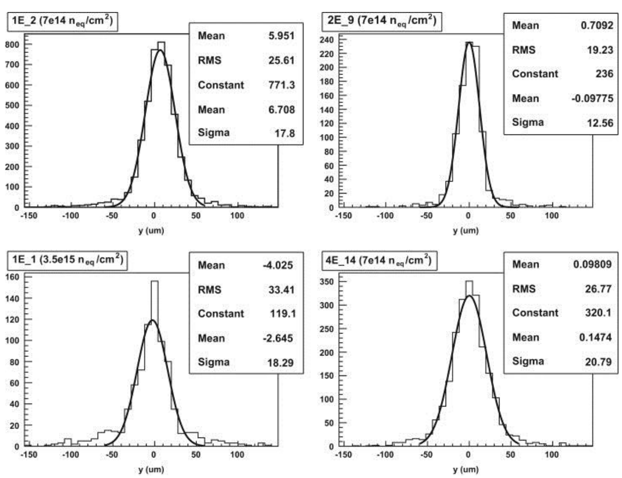


Figure 2 Irradiated sensor residuals for size two clusters, with Gaussian fit. Note that the 1E_1 data provided low statistics.

On the other hand, the study of a medium quality polycrystalline diamond (CCD ~175μm) with the same CMS readout-chip turns out to be challenging but, nonetheless, very instructive. The new digital CMS readout chip, capable of operating at very low threshold is required to understand the sensor's true efficiency.

<u>**T-994 / JASMIN**</u> (S. Sekimoto[1], H. Matsumura[2])

Beam used: 120 GeV p
Run dates: December 11 – 20, 2013

Motivation and Goals:
Production cross sections of long-lived cosmogenic nuclides, such as ^{10}Be and ^{26}Al are indispensable for studying the specific formation mechanisms of these nuclides, where spallation, fission, or fragmentation is a dominant process. Though the fragmentation process is usually studied by production cross sections of light nuclides, few measurements have been made and published for energies >100 MeV. To understand the formation mechanism of nuclides via fragmentation processes, we have measured ^{10}Be and ^{26}Al production cross sections from Y produced by 120 GeV and those from Y and Tb by 400 MeV protons. One of our goals is to discuss the production mechanism of ^{10}Be and ^{26}Al by spallation and fragmentation in two different kinds of high-energy nuclear reactions, whose energy gap is over two orders of magnitude.

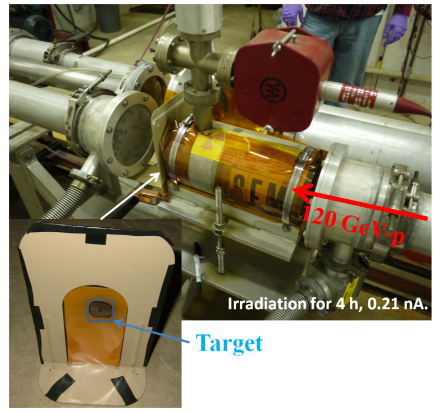


Figure 1: Setup for 120 GeV-p bombardment at M01 in FNAL

Setup and Experiments:
The proton irradiation at 120 GeV and 400 MeV were performed in FNAL Test Beam and the Research Center for Nuclear Physics (RCNP), Osaka University, respectively. The accelerator mass spectrometry for measurements of ^{10}Be and ^{26}Al were performed at Micro Analysis Laboratory, Tandem accelerator, the University of Tokyo.

Results and Impact:
The production cross sections of ^{10}Be from various target mass numbers produced by 50 MeV to 120 GeV protons are shown in Figure 2. From this figure, we observe the following three trends. In case that E_p are several hundreds of MeV and target mass number is less than 60-80; cross section decreases with an increase in the target mass number (E_p-dependent). In case that are higher than a few GeV; cross section increases with an increase in the target mass number (E_p-independent). In case that E_p are several hundreds of MeV and target mass number is higher than 60-80; cross section increases with an increase in the target mass number (E_p-dependent).

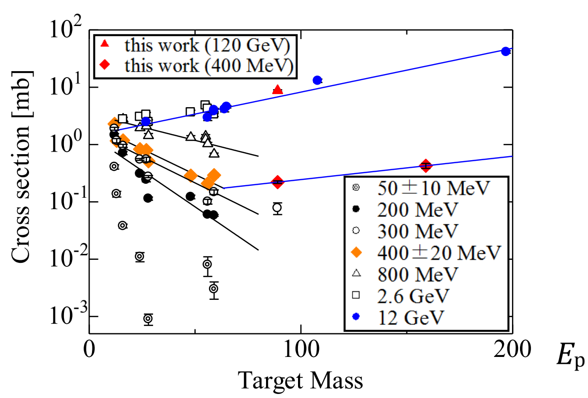


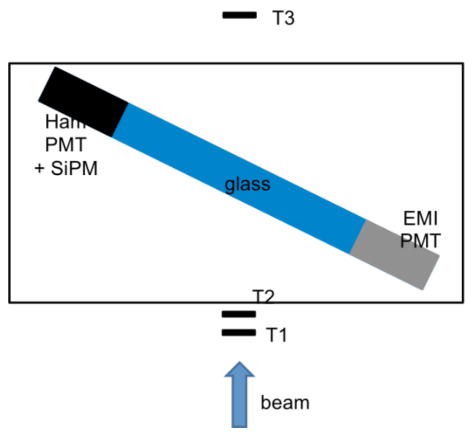
Figure 2: Target mass dependence of the cross sections for the formation of ^{10}Be

[1] Kyoto University Research Reactor Institute,
[2] KEK

<u>T-1015 / sub-experiment 1/ DRC crystal/glasses</u> (G.Pauletta[1])

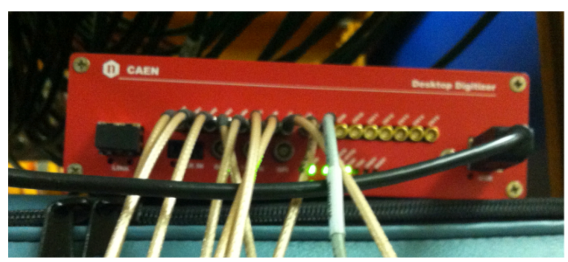
Beam used: 120 GeV p , 12 GeV e^+, 12 GeV π^+, 4 GeV π^-
Run dates: Nov 27th 2013 – Dec. 3rd 2013

Motivation :



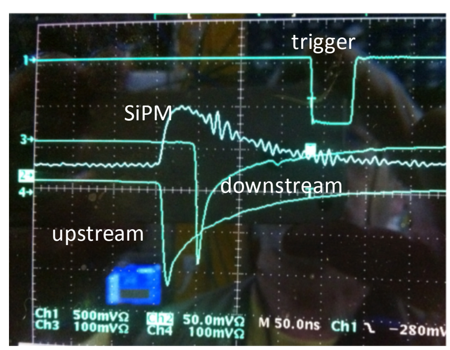
Having established that, for signals generated by the passage of minimally-ionizing particles, the Cherenkov component of signals generated in *SGC1-C* scintillating glass could be separated from the scintillation component, it is essential, for application to hadronic calorimetry, that we establish how well this can be done for hadronic showers. To this end, we needed to expose single glasses to hadronic beam. This was done in the course of previous runs at FNAL and it was shown[2,3] that one could distinguish between Cherenkov and scintillation components in signals corresponding to hadronic showers. It also became evident that, because discrimination depends essentially on the fact that the Cherenkov component develops in a much shorter time interval than the scintillation, the bandwith and sampling rate of the frontend electronics were a critical element. The purpose of this run was to repeat previous measurement with upgraded frontend electronics

Setup:



The setup differs from previous setups only insofar as the previous in-house frontend electronics were substituted with DRS-based CAEN-built electronics[4]

Results and Impact:



The improved bandwidth and sampling rate had the desired effect as illustrated by the "down-stream" (enhanced Cherenkov) and "up-stream" (reduced Cerenkov) PMT signals in the figure. However, we were unable to distinguish a Cherenkov component in the signals generated by the SiPMs . We are investigating this problem using identical glass exposed to cosmics at our home institution before requesting another run.

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[1]INFN Trieste and University of Udine
[2]W. Bonvicini et al., Physics. Proc. 37 (2012) 279-286,
[3] W. Bonvicini et al., Jour. Of Physics: Conference proceedings 404 (2012) 012057

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T-1015 / sub-experiment 2/ ADRIANO prototypes for ILC (C. Gatto[1], A. Mazzacane[2], On behalf of T1015 Collaboration)

Beam used: listed below
Run dates: August 20, 2014 - September 4th, 2014

Motivation:
The ADRIANO technology (A Dual-readout Integrally Active Non-segmented Option) is extensively being developed as part of the research program of T1015 Collaboration for experiments at future lepton colliders or at fixed target with high intensity beam.[1] New construction techniques have been exploited and several detector prototypes have been assembled and tested at FTBF since the inception of T1015 Collaboration to study their performance. The ADRIANO, technology, initially devised to improve the performance of hadron calorimeters through the mechanism of dual-readout compensation, has been extended for applications to electromagnetic calorimeters. The fast response of ADRIANO, along with its intrinsic particle-id features, make this technology particularly well suited for future High Intensity frontier experiments.

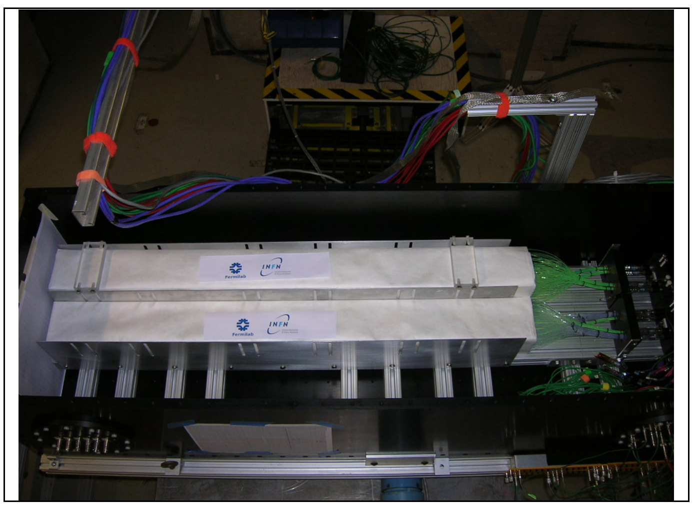

Figure 1: ADRIANO prototypes for an ILC experiment

Setup:
Fermilab's T1015 Collaboration has recently completed in FY2014 the construction of two new ADRIANO detectors about 105 cm long (see Fig. 1) and 10 cm wide. Two different construction techniques and two different layouts have been employed to optimize the light yield and the average density of the detector. ADRIANO 2014A is obtained by

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[1] INFN – Sez. Napoli, Complesso M.S.A., via Cinthia, Napoli, 80125, Italy
[2] Fermilab, Kirk Rd &Pine St, Batavia (IL), 60510, USA

sandwiching 10 layers of thin (thickness=2mm) extruded scintillators and 10 SF57 leadglass plates (thickness=6.5mm). ADRIANO 2014B is obtained by sandwiching 10 layers of scintillating fibers (diameter=mm) and 10 SF57 lead glass plates (thickness=6.5mm). The light capture from the glass and the scintillating plates is implemented via WLS fibers optically coupled to them. The readout is based on Hamamatsu R647 PMT's while a SiPM instrumentation will be tested in a future test beam. DAQ system is Fermilab's TB4 systems developed and maintained by P. Rubinov.

The beam was shared during owl shifts with two more experiments, while, during day shifts, T1015 run parasitically behind experiment T992. The studies we have performed are listed below:

1. Energy scan with secondary beam in pion mode from 1 GeV trough 16 GeV
2. Energy scan with parasitic proton beam with 120 GeV energy
3. Vertical and horizontal position scan with 2 GeV and 4 Gev beams in pion mode
4. Vertical and horizontal position scan with parasitic proton beam with 120 GeV energy
5. Angular scan from 0 trough 90 degrees with secondary beam in pion mode at 4 GeV
6. Angular scan from 0 trough 90 degrees with with parasitic proton beam with 120 GeV energy
7. A total of 13 runs with 32 GeV muons impinging onto the two detectors in various positions.

A total of 183 runs where logged on disk, with an average number of events of about 8500. Beam conditions were, in general, from very good to excellent. Except for few runs in the initial phase of the test, when few problems occurred in the Main Injector, the beam stability was excellent, with few interruption and with beam down time rarely longer than one hour. Ultimately, the program was concluded with half day in advance.

The FTBF facilities used during the experiment are listed:

1. Pick-up for the transportation of the detector to F-Test
2. Crane for the installation of the detector
3. Remotely controlled moving table 2B
4. Remotely controlled rotating table
5. One wire chamber
6. Cherenkov based PID system
7. HV power supply and distribution systems (COW).

All the used facilities worked perfectly and exceeded expectations. One channel of the wire chamber broke during operation; however, that did affect the experiment in a negligible way. The response of the FTBF Management and of the Technical Support Group to any sort of issues (even when generated by the experimenter) was in all cases prompt and of outstanding quality. The overall level of the facility was considered superb.

Results and Impact:

The analysis of the data is still ongoing. Preliminary results will be presented at the LCWS2014 Conference in Belgrade (Sr) – Oct. 6-10, 2014. A preliminary energy scan of ADRIANO 2014A and 2014B are shown in Fig. 2.

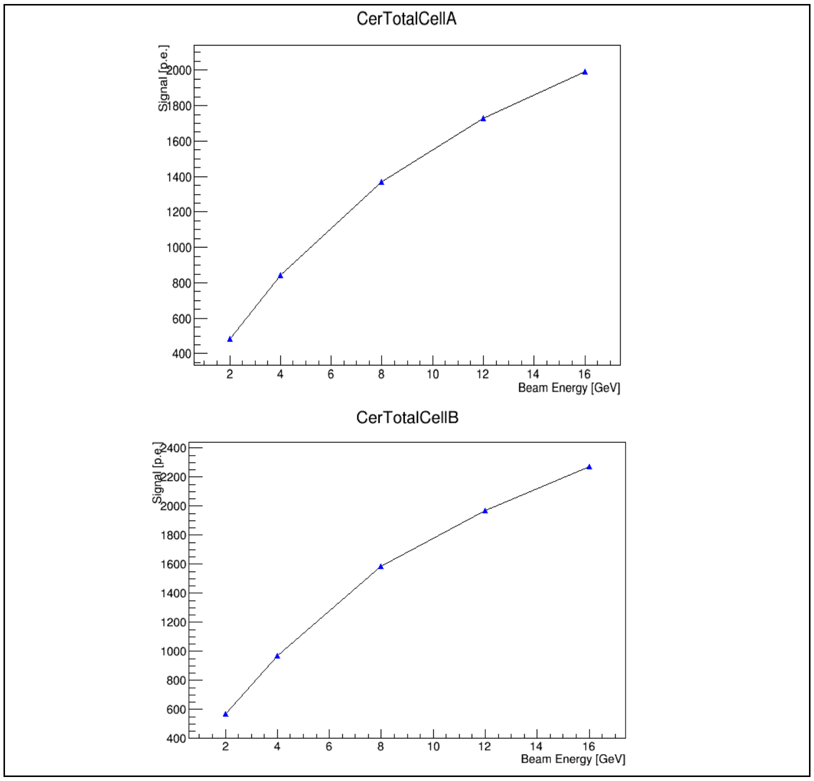

Figure 2: Energy scan of ADRIANO 2014A and 2014B

References

1. http://www-ppd.fnal.gov/FTBF/TSW/PDF/T1015_mou_signed.pdf (2011)
2. C. Gatto et al, Journal of Physics: Conference Series Volume **404** (2012).

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T-1015 / sub-experiment 3/ ADRIANO prototypes for ORKA (C. Gatto[1], A. Mazzacane[2], On behalf of T1015 Collaboration)

Beam used: listed below
Run dates: December 4, 2013 - December 17th, 2013, June 18, 2014 – July 15, 2014

Motivation:
A special version of ADRIANO technology (A Dual-readout Integrally Active Non-segmented Option) has been proposed by T1015 Collaboration for the ORKA experiment. Although not strictly requiring a hadronic calorimeter, the ORKA project would benefit greatly by the particle identification capability and the fast response of an ADRIANO detector. Although the ORKA project has been later cancelled, the R&D originated by it can be applied to other Intensity Frontier experiments necessitating of the same detector capabilities.

Setup:
In order to meet the lower energy threshold required by such experiments, ADRIANO for ORKA has been designed with a considerably higher ratio of scintillating plastic to lead glass and with a larger number of WLS fibers coupled to glass. Fermilab's T1015 Collaboration has completed in FY2014 the construction of two such detectors about each about 38 cm long (see Fig. 1) and 10 cm wide. The detectors are obtained by sandwiching 10 layers of thin (thickness=2mm) extruded scintillators and 10 SF57 lead glass plates (thickness=4.0 mm). The light capture from the glass and the scintillating plates is implemented via WLS fibers optically coupled to them. In the barrel version of ADRIANO for ORKA the fibers are read-out from both sides, while in the endcap version one side is aluminized and the light is read only from the opposite side. The readout is based on Hamamatsu R647 PMT's and SiPM from FBK and STM. DAQ system is Fermilab's TB4 systems developed and maintained by P. Rubinov.

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[1] INFN – Sez. Napoli, Complesso M.S.A., via Cinthia, Napoli, 80125, Italy
[2] Fermilab, Kirk Rd &Pine St, Batavia (IL), 60510, USA

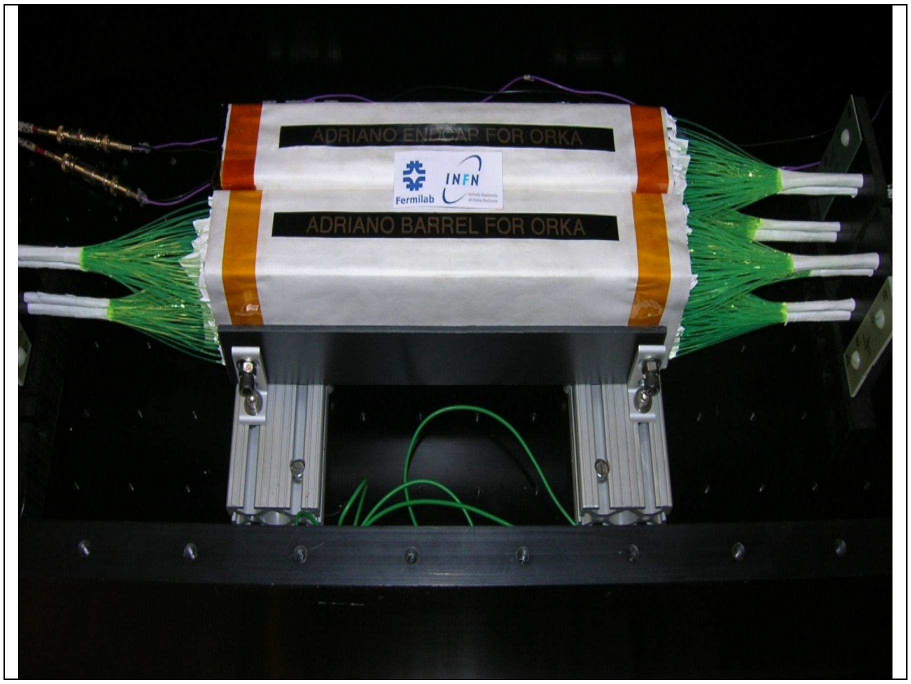

Figure 1: ADRIANO prototypes for an ILC experiment

The two prototypes described above have been tested with beams at FTBF in two separate experiments from December 4th through December 17th 2013 (PMT readout) and from June 18th through July 15th 2014 (SiPM readout). The installation of the detectors on the 2B table of FTBF was entirely taken care of by the above group. That also required the construction of the appropriate fixtures for securing the detector to the table. The entire installation operation required about one day of work.

The beam was used exclusively in both cases, except for the few days where beam studies were carried over by the Accelerator Division. The studies we have performed are listed below:

1. Energy scan with secondary beam in pion mode from 0.5 GeV trough 16 GeV
2. Vertical and horizontal position scan with 1 GeV and 2 Gev beams in pion mode
3. Angular scan from 0 through 90 degrees with secondary beam in pion mode at 2 GeV
4. A total of 31 runs in 2013 and 7 runs in 2014 with 32 GeV muons impinging onto the two detectors in various positions.

A total of 156 runs where logged on disk in 2013 and 140 runs where logged on disk in 2013, with an average number of events of about 4000. Beam conditions were, in general, from very good to excellent. The beam stability was very, with few interruptions and with beam down time rarely longer than one hour. Ultimately, the program was successfully concluded in both test beams.

The FTBF facilities used during the experiment are listed:

1. Remotely controlled moving table 2B
2. Remotely controlled rotating table
3. One wire chamber
4. Cherenkov based PID system
5. HV power supply and distribution systems (COW).

All the used facilities worked perfectly and exceeded expectations. The rotating table was just installed and it was experimental at that time. Nonetheless, it worked flawlessly. One minor problem related to the rotation speed was corrected promptly by the FTBF Technical Support Group. The response of the FTBF Management and of the Technical Support Group to any sort of issues (even when generated by the experimenter) was in all cases prompt and of outstanding quality. The overall level of the facility was considered superb.

Results and Impact:

The analysis of the data is still ongoing although with lower priority compared to the High Energy version of ADRIANO because of the sudden cancellation of the ORKA project. Preliminary results have been presented at the CALOR2014 Conference in Giessen (Germany) Apr. 6-11, 2014 and to the AWLC2014 Conference at Fermilab, May 12-16, 2014. A typical waveform of the Cherenkov component of the detector is shown in Fig. 2.

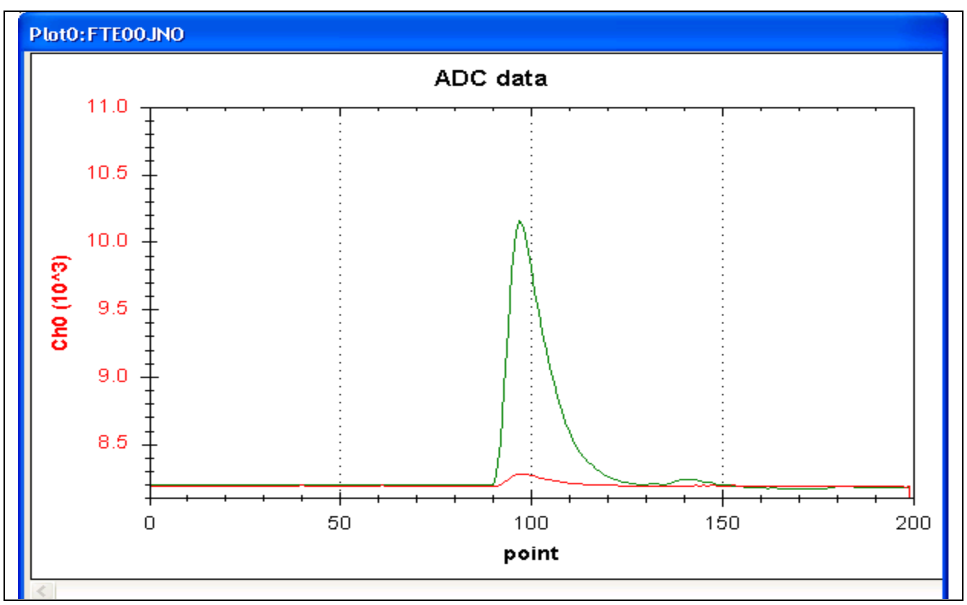

Figure 2: Waveforms from the Cherenkov component of ADRIANO for ORKA for a 1 GeV pion beam.

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T-1018 / UCLA Spacordion Tungsten Powder Calorimeter (S. Trentalange[1])

Beam used: Mixed beams 1-32 GeV, and calibration runs with broad-band muons at 8 GeV
Run dates: Feb.26 – March 18, 2014

Motivation :

During the last three years we have been carrying out an R&D program to develop a new, simple, and cost effective technique to build compact sampling calorimeters utilizing tungsten powder and scintillation fibers. Such calorimeter detectors are under consideration for the planned Electron Ion Collider and upgrades of the STAR and PHENIX experiments at BNL. In the first year of this R&D project we demonstrated a proof-of-principle with the construction of two prototypes of very compact electromagnetic calorimeters, which were tested at FNAL test beam in 2012. We continued development of this technique in subsequent years and tested new electromagnetic and hadronic calorimeter prototypes equipped with compact readout, based on silicon multipliers, in the FNAL test beam in 2014. Figure 1 shows two of the three calorimeter prototypes tested in 2014, along with their compact readout based on MPPCs.

Fig 1. Two recent EM calorimeter prototypes built with our technique: an EIC barrel calorimeter with wedge-type towers and a prototype for the forward upgrade for STAR. Both were read out with silicon photomultipliers, shown on the right side.

Measurements:

Energy resolution for electrons and hadrons, linearity, position resolution, uniformity of response and absolute light yield for different light collection schemes.

2014 Setup:

The EM prototype for the forward region had 16 individual towers, 23 X0 deep, equipped with SiPM readouts upstream of the detector (4 SiPMs/tower). The EM prototype for the central detector consisted of 18 individual wedge-type towers, 18X0 deep, read out with SiPMs downstream of the detector. The HAD calorimeter consisted of 16 towers, each 4 interaction lengths deep, read out with SiPMs (8 SiPM/tower).

[1]UCLA

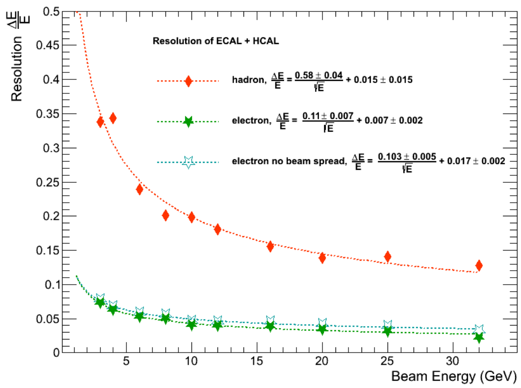

Fig.2. Energy resolution of the binary EM+HAD calorimeter system developed for the STAR forward upgrade.

Figure 2 shows the energy resolution for hadrons and electrons for the binary EM+HAD calorimeter system. These are raw experimental results without any corrections for energy leakage or beam momentum spread.

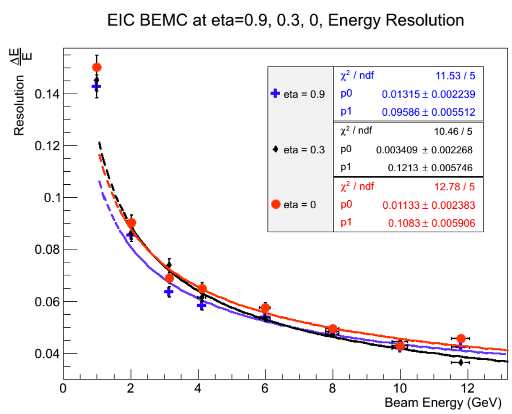

Fig.3. Energy resolution of the central EM prototype for different rapidities.

Figure 3 shows electromagnetic energy resolution of the central EM prototype for EIC for a different rapidity.

Impact:

- sPHENIX collaboration chose this technology for the design of their barrel EM calorimeter.
- EIC chose this technology as the basis for the barrel and forward sampling calorimeters of their dedicated central detector.
- STAR forward upgrade is planning to use this technology for future upgrades.

Future Plans:

In 2015 T1018 plans to perform test runs at FNAL with a high resolution EM sampling calorimeter prototype built with our technology.

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T-1031 / ATLAS Tile Calorimeter Upgrade Electronics Test (M. Oreglia, K. Anderson[1])

Beam used: parasitic mode with any beam
Run dates: November, 2013 - March 2014

Figure 5 Instrument package near pinhole collimator in M03

Motivation and Goals:
FNAL accelerator physicist Igor Rakhno had determined that the environment near the M03 pinhole collimator can be very similar to that of the High-Luminosity LHC cavern environment, particularly when the line is running protons. Our goal was to measure the frequency of Single Event Upsets (SEU) in state-of-the-art electronics being considered for the ATLAS Tile Calorimeter upgrade for LHC Phase 2.

Setup:
The instrument package resided in a rack near the pinhole collimator, and was controlled by a data acquisition system in a radiation-shielded alcove nearby. The electronics under test consisted of an Altera Stratix-V FPGA which sent and received bit patterns via a 10 Gbps Reflex Photonics "snap-12" fiberoptics system. The DAQ system measured the frequency of send/receive mismatches. The setup was also instrumented with two ion gauges and paddle counters to measure the radiation dose.

Results and Impact:
We were successful in getting radiation intensities (as measured by the ion chambers) on par with those expected at HL-LHC, and a total accumulated dose equivalent to several months of HL-LHC running. SEU errors were detected in the electronics, and at roughly the level expected on the basis of our experience with electronics at the present LHC. This was an important vindication of both the state-of-the-art high density FPGAs and the high-speed communications links which are envisioned for use in the upgraded LHC detectors.

The experimenters wish to thank particularly Steve Geer, Aria Soha, Gary Lauten, and JJ Schmidt for their assistance in devising and setting up this very fruitful experiment.

[1] University of Chicago

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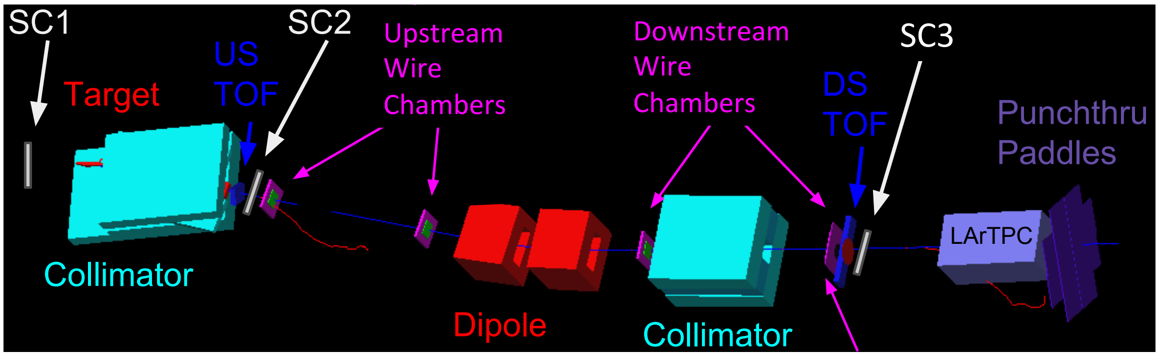
T-1034 / LArIAT Beam Commissioning (J. L. Raaf[1], F. Cavanna[2])

Beam used: 8, 32, 80 GeV $\pi^{+/-}$
Run dates: August 20 – September 5, 2014



Motivation and Goals:
LArIAT (T-1034) will characterize the performance of liquid argon time projection chambers (LArTPCs) in the range of energies relevant to the upcoming MicroBooNE, short-baseline, and long-baseline neutrino (SBN and LBN, respectively) experiments for neutrino physics and for proton decay searches. LArIAT will experimentally measure electron-photon separation, develop criteria for charge-sign determination without a magnetic field, optimize pion and kaon identification capabilities, and study energy resolution improvements that may be achievable by combining information from scintillation light and ionization charge signals.

Setup:
The tertiary beamline in MC7 has recently been set up and commissioned using a set of multiwire proportional chambers (MWPCs) and time-of-flight (TOF) scintillator paddles, indicated in the image above. The incoming secondary beam was operated in both positive and negative polarity for a range of beam energies, which allows us to understand the range of production rates and particle momenta achievable with this beam. These data also gave us the opportunity to commission our full data acquisition system and to test several triggering schemes.

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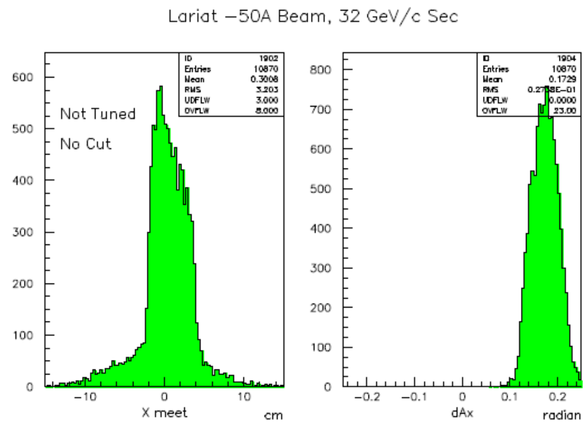
[1] FNAL
[2] Yale

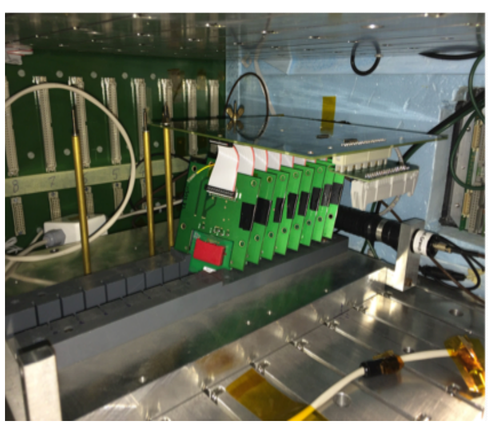
Simple dP/p = dA(vert)/A(hor) = .0038/.17 = 0.022



Results and Impact:
Preliminary analysis of the beam commissioning
data in the MC7 tertiary beam shows a momentum resolution near 2%, as shown in the figure at the right. This analysis is ongoing, and further results characterizing the momentum spectrum, resolution, and particle types will be extracted from these data in preparation for the
first full LArIAT run with all detectors.

<u>T-1036 / CMS High Rate Pixel Detector</u> (A. Elliott-Peisert[1])

Beam used: 120 GeV p (High Rate area)
Run dates: October 9-22, 2013, March 5-18, 2014



[1] CERN, Spokesperson

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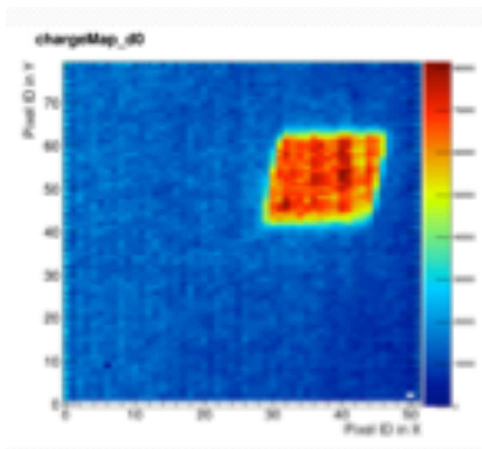
Motivation and Goals:
The main motivation was to test the new, digital readout chip for the CMS pixel system replacement at very high rates (protons/cm^2/s). The goal was to map the saturation of the double column and time-stamp buffers as a function of time into a spill, by comparing efficiency measurements with simulation. At stake was whether the latest version of the ROC (v2.1) would T-1036 Beam Telescopes require a further revision and re-qualification. The high-rate test was envisaged to be the last step in certifying the ROC; none of the usual test beams in Europe (CERN, DESY, PSI) were capable of delivering the required particle rate over the ~1x1 cm^2 area of the ROC.

Setup:
Two beam telescopes in a single cold box enclosure. Each telescope consisted of 8 planes of single PSI46dig Readout Chips on each plane.



ROC Image of Small Scintillator

Results and Impact:
The test results showed that the PSI46dig ROC functioned properly but also indicated some evidence of event mixing at very high occupancy rates. The rate has subsequently been shown to be much higher than the expected rate in the innermost pixel layer, and an order was placed for the production ROCs.

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T-1037 / FLYSUB Consortium (K. Dehmelt[1])

Beam used: 20/25/32 GeV π^+ and K^+, 120 GeV p
Run dates: October 02 – 22, 2013

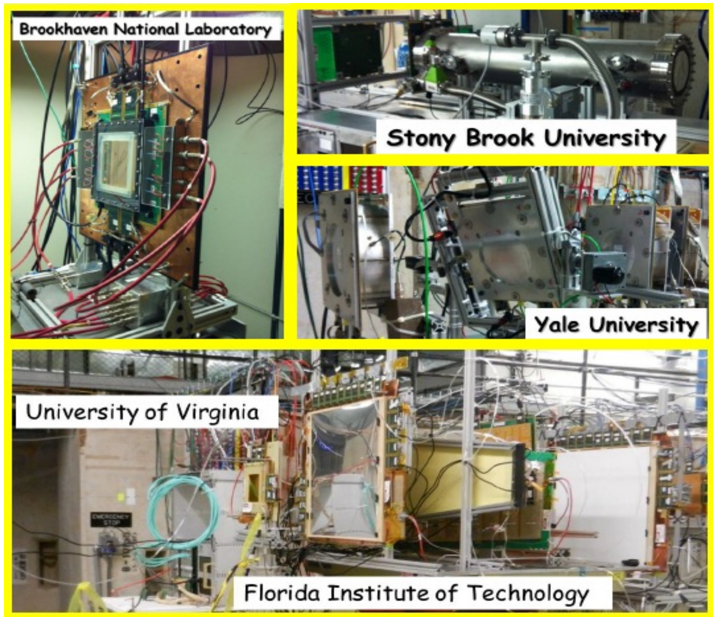


Figure 1 FLYSUB test beam setup.

Motivation and Goals:

The FLYSUB consortium emerged from a collaboration for Electron Ion Collider detector R&D, funded by BNL. Groups from BNL, Florida Institute of Technology, Stony Brook University, University of Virginia, and Yale University were setting up an apparatus using four out of six available stations at FTBF. The ultimate goal of the common beam test was to work toward a sector test of forward tracking and PID prototypes during a single beam period, to test and verify the performance of the individual components according to their expectation:

1) Development of a mini-drift GEM detector for resolving the issue of losing resolution for inclined particle tracks and applying different frontend electronics
2) Development of large area planar GEM detectors for endcap tracking
3) Development of alternative read-out structures for reducing the number of channel counts but conserving the resolution

[1] Department of Physics and Astronomy, Stony Brook University

4) 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.

Setup:

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 was performed with SRS-DAQ. The main goal was to measure position and angular resolution for an angular range is 0° to 45°.

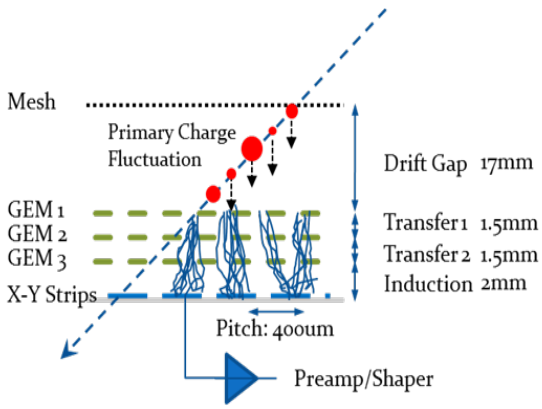


Figure 2 Illustration of mini-drift GEM detector with pad readout.

2) Florida Institute of Technology + University of Virginia: Two trapezoidal (of 100 cm × [43 – 22] cm) Triple-GEM prototypes with different types of readout: One, the UVa-EIC-GEM prototype, with small 2D (stereo angle) u-v strips readout board (Figure 3) and the second FIT-EIC GEM with either radial straight strips or radial zigzag strips were inserted in the beam line. Furthermore, two 50 x 50 cm^2 Triple-GEM prototype chambers and a 30 x 30 cm^2 self-stretched EIC GEM prototype with zigzag readout strips (Figure) had been implemented. As a reference tracking system three 10 × 10 cm^2 Triple-GEM chambers were used.

3) Stony Brook University: The aim of this test was 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 consisted 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 was to prove that the ring diameter obtained with both readout-plane structures will suffice particle discrimination up to high momenta.

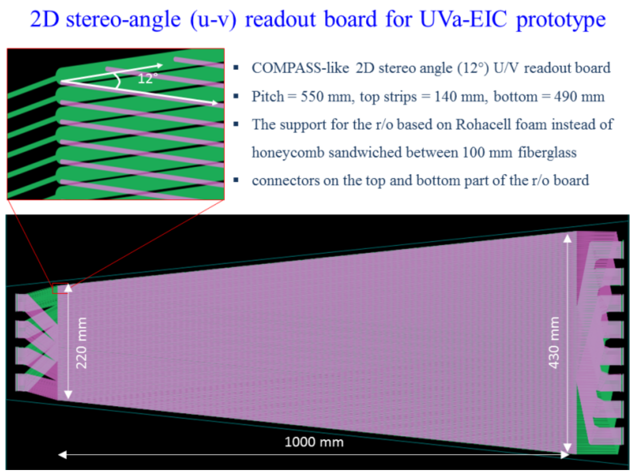


Figure 3 2D (stereo angle) u-v strips readout board for the UVa-EIC GEM chamber.

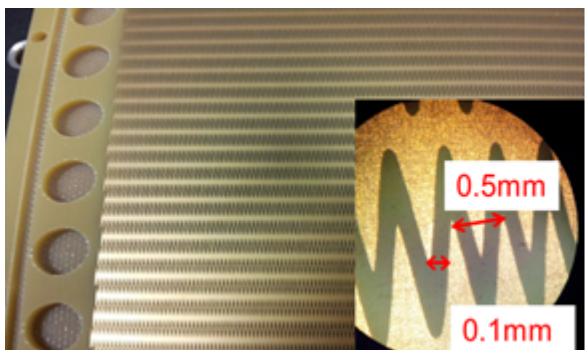


Figure 4 Printed circuit readout board with zigzag strips with a microscope picture of the zigzag structure in the inset.

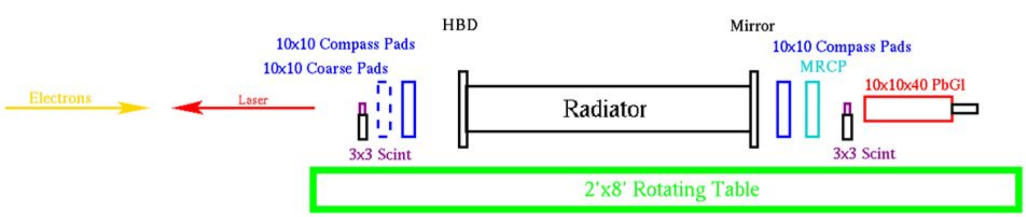


Figure 5: Drawing (not to scale) of the proposed setup for the test in beam of the RICH prototype.

4) Yale University: Two sets of 4 chambers each, 10 x 10 cm^2 active area were arranged such that each set of 4 chambers was taking about 2 feet along the beam line. The readout structure of these detectors was based on a 3-coordinate single readout plane. The goal of

the tests was to investigate charge sharing ratio and uniformity of the ratio and ultimately resolution.

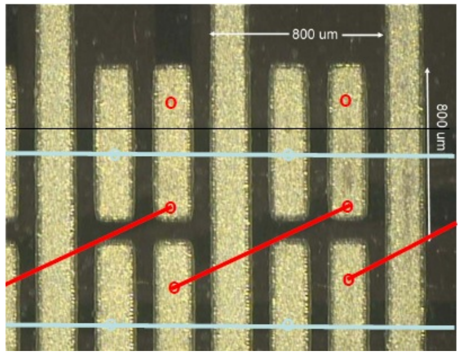


Figure 6: Three-dimensional single readout plane realized by interconnecting different lines of readout strips/pads.

Results and Impact:

The FLYSUB effort is the largest to date at FTBF and was comprised of 19 detector stations all of which worked flawlessly and collected data over a three week period. Many milestones for the EIC Tracking R&D were achieved and described in the following.

1) BNL: The mini-drift GEM detector has returned to FTBF in Feb. 2014 for obtaining more test-beam data since the Oct. 2013 campaign could not be completed toward the goal set forth. Both data sets and a set taken earlier at CERN agree well. CERN and Fermilab campaigns differed mainly in the reference tracking systems. Since GEM tracker position resolution results are always depicted for normal incident of particles on the readout plane, significant degradation occur when the particle's track is not normal incident. This test-beam shows that one can overcome the degradation when raising the drift distance and making use of timing information and measuring a vector, thus using a mini-drift length TPC like detector (see Figure 2 and Figure 7).

2) Florida Institute of Technology + University of Virginia: An extensive setup of trackers was used at station 2B for testing new readout schemes and testing the largest area GEM detectors (Figure 3) built in the U.S. The goals and key features were to investigate the performance of large size detectors to be useful in large experiments. As readout planes different technologies served based on optimization of resolution versus channel count. Large sized GEM detectors with 2D (stereo angle) u-v strips layout as well as zigzag strips were investigated. Scans over the large area were performed (Figure 8) and the spatial resolution in (r, ϕ) at different locations of the chamber were measured (Figure 9).

Radial zigzag strips were used as an alternative readout. This technology results in huge savings in channel count, while providing good spatial resolution, as can be seen in Figure 10.

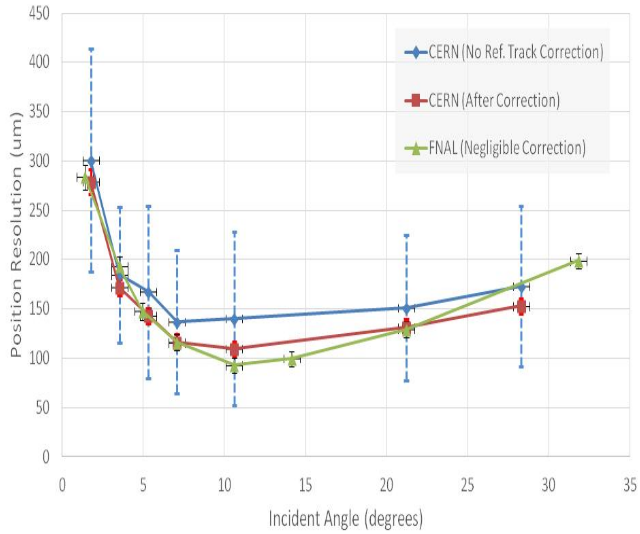


Figure 7 Position resolution of the minidrift detector using the track segment found in the detector as a function of angle for data taken at CERN and Fermilab. Resolutions are shown before and after unfolding the error on the extrapolated track from the two beam tracking systems.

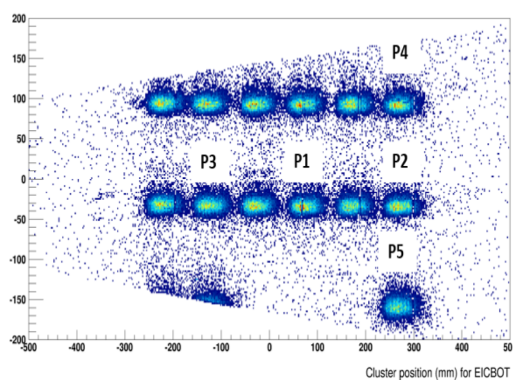


Figure 8 Beam profile reconstructed at 13 locations from position scan run of UVa-EIC Triple-GEM chamber with 32 GeV hadron beam.

3) Stony Brook University: The principal goal was to extend our knowledge of the EIC RICH detector from its performance in an electron beam (wherein all beam particles have saturated their ring radius) to true identification of hadrons. This was possible because FTBF has the ability to deliver various types of hadrons at various momenta and allowed to trigger on the hadrons with the instrumentation provided by FTBF.

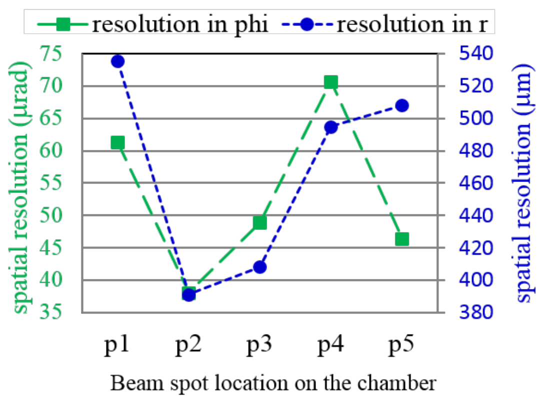


Figure 9 Spatial resolution on different locations on UVa-EIC Triple-GEM chamber using data from 120 GeV proton beam scan.

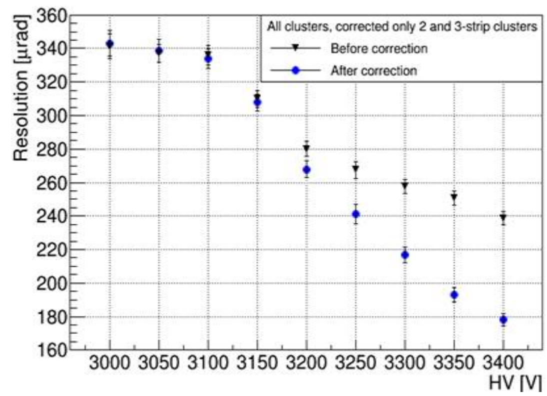
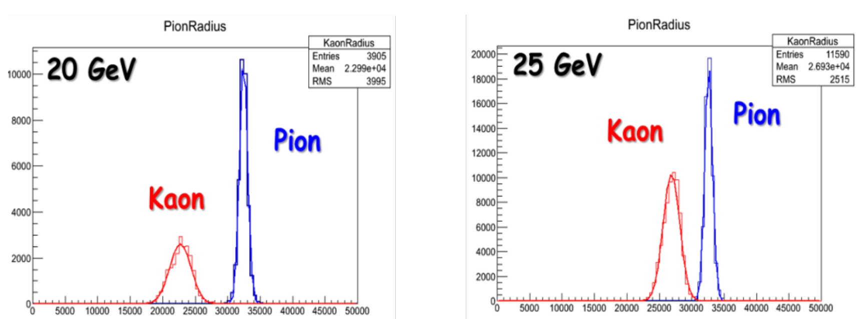


Figure 10 Measured angular resolution for a large-area GEM detector read out with radial zigzag strips before and after strip response correction.



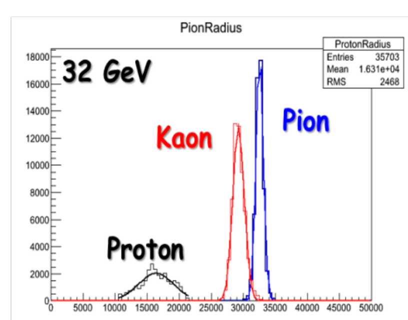


Figure 11 Particle Identification accomplished by the GEM-RICH.

The results obtained from the test-beam campaign can be seen in Figure 11 and the separation of the various hadrons must be considered as superb.

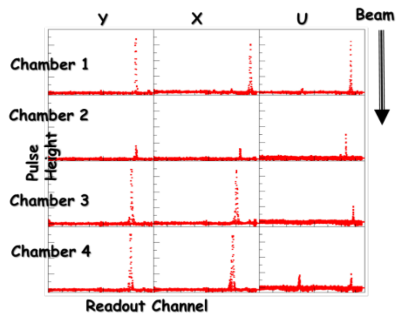


Figure 12 Event display for four single plane 3-coordinate GEM trackers.

4) Yale University: Cartesian readout systems can lead to ambiguities in 2-dim associations in a high multiplicity event environment. To overcome this restriction one can introduce a third coordinate as depicted in Figure 6. This will lead to an increased track density capability per patch and reduces the channel count.

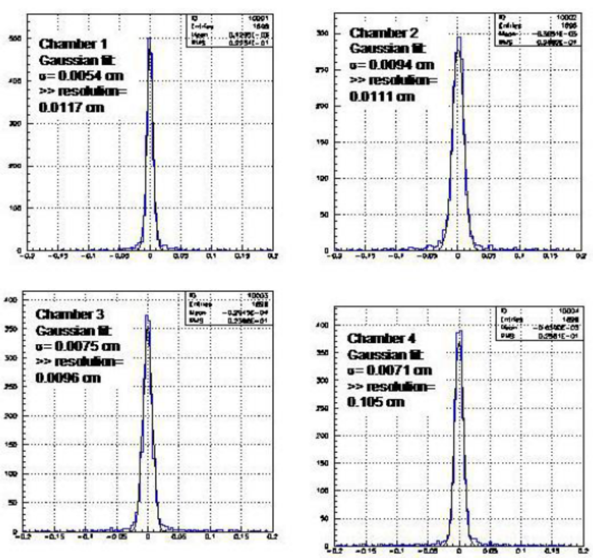


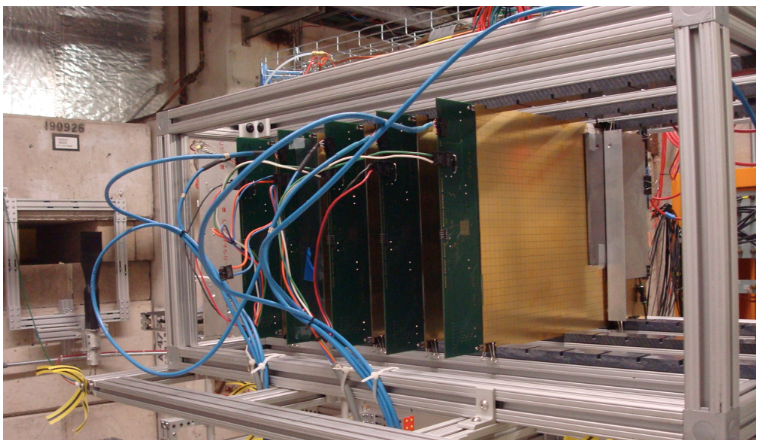
Figure 13 X-residual for the four 3-coordinate GEM trackers.

The test-beam results show again that superb results were achieved: all chambers showed very good response (Figure 12) and resolutions from 97 μm to 117 μm were measured (Figure 13) while having rather coarse readout pitch.

In summary, the FLYSUB consortium, consisting of National Lab and University groups from the U.S. performed a sector test for an EIC detector. Superb results were obtained and main goals for improving detector performance were demonstrated. The FTBF facility provided an excellent environment which made these detector tests possible.

T-1041 High Rate RPCs (J. Repond[1])

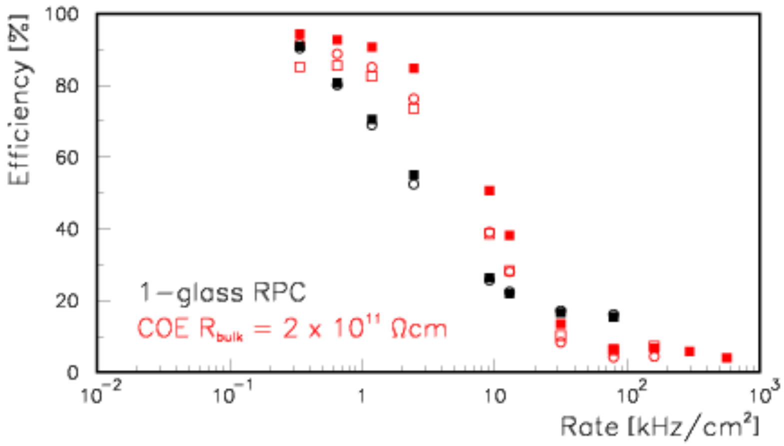
Beam used: Proton
Run dates: April 3-6, June 11-16, 2014



Motivation and Goals:
Develop high-rate RPCs (Resistive Plate Chambers) with low-resistivity glass in order to make possible the use of RPCs in hadron collider detectors.

Setup:
Small-size RPCs with new glass samples in the CALICE Digital Hadron Calorimeter setup.

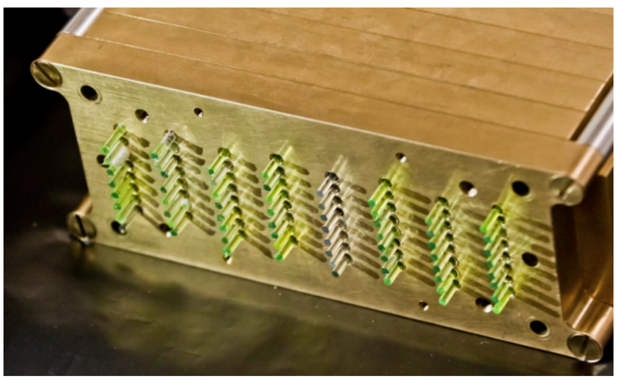
[1] Argonne National Laboratory



Results and Impact:
About an order of magnitude improvement in the rate capabilities of the RPCs is observed.

T-1041 Crystal Fibers (C. Tully[1])

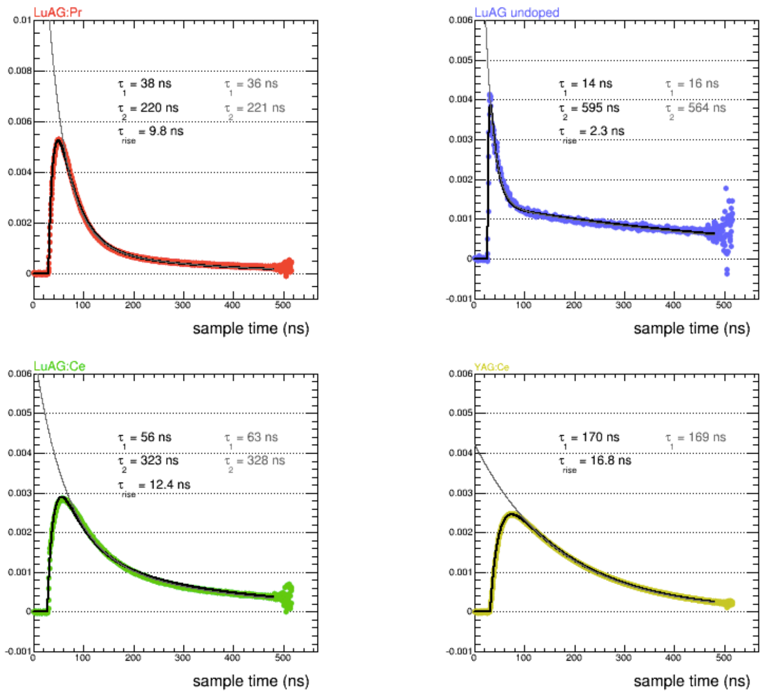
Beam used: Proton; positron with energies 4-32 GeV
Run dates: March 21-25, August 4-9, 2014



Motivation and Goals:
Develop fast and radiation-hard crystal fibers for the Phase II Upgrade of the CMS hadron endcap calorimeters.

Setup:
Various types of crystal fibers placed in a brass absorber.

[1] Princeton University



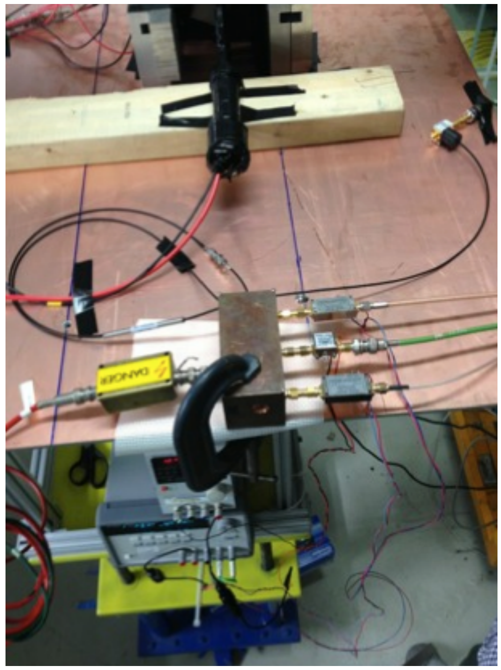
Results and Impact:
We have looked at the time response of a variety of new crystal fiber materials in the real environment of a brass absorber with a 16 GeV electron beam.

The best candidate so far is LuAG:Pr, but we believe that YAG:Pr will be even better.

T-1041 CMS Dedicated Fast Timing (S. White[1])

Beam used: Parasitic (mostly muons) and protons
Run dates: Aug 3-5, 2014

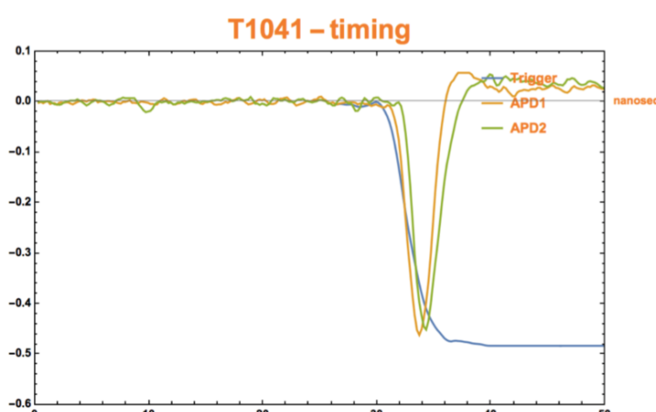
[1] Rockefeller University



Motivation and Goals:
We are developing a single timing layer which measures both charged particle and photon time (a pre-shower layer) for the upgrade to the CMS forward electromagnetic calorimeter (EE). There is concern that the increased pileup in event frames will become so severe that the capabilities of the experiment will be reduced. Resolving in-time pileup will require an order of magnitude improvement in time resolution ~20 psec.

Setup:
The setup utilizes a Silicon telescope in a Copper enclosure, 980 nm VcSel and APDs. The readout was LeCroy 640zi scope.

Results and Impact:
The preliminary results on the ultrafast timing are obtained with the Silicon telescope.



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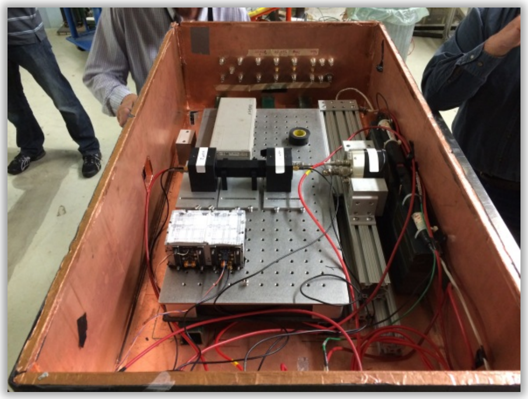
T-1041 CMS Precision Timing (A. Apresyan[1] A. Bornheim[1], S. Xie[1])

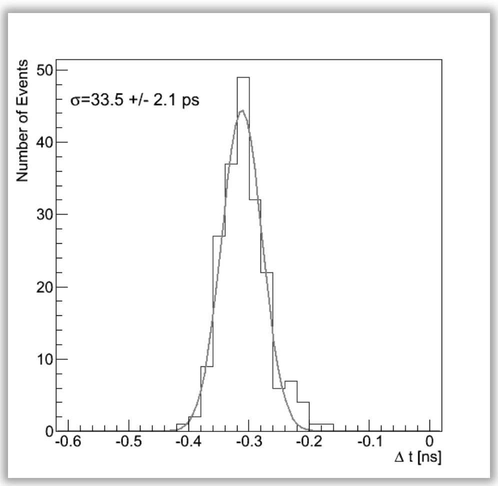
Beam used: Proton; positron beam with energies 4-32 GeV
Run dates: March 19-30, July 29-August 18, 2014



Motivation and Goals:

- Development of calorimeter with picosecond timing capabilities for CMS Phase II
- Purpose: remove neutral energy deposits from pileup interactions
  - Tracker cannot remove neutral particles
- Beam tests to develop techniques to extract time of arrival from showers

Setup:
The setup utilizes a time of flight system with high-resolution photodetectors (PMTs or MCPs) and a dedicated shower timing measurement setup of the shashlik electromagnetic calorimeter module.



Results and Impact:
Precision timing in calorimetry is demonstrated to be possible, achieved 20-30 ps in the test beams.

Single-channel time resolution of a few 10 ps seems achievable for incident particle energies of a few GeVs.

[1] California Institute of Technology

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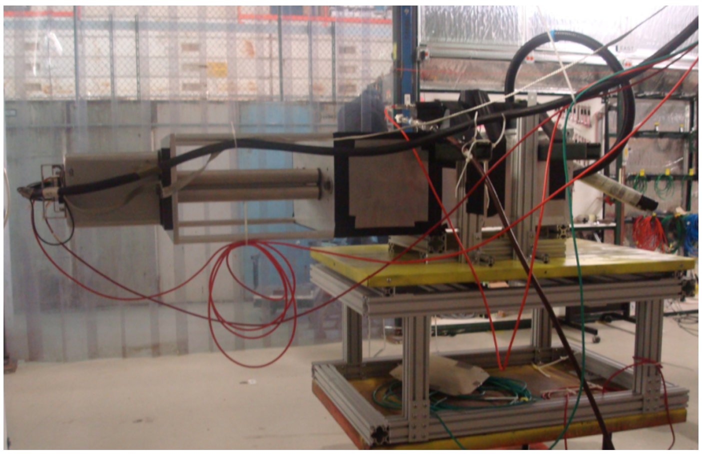
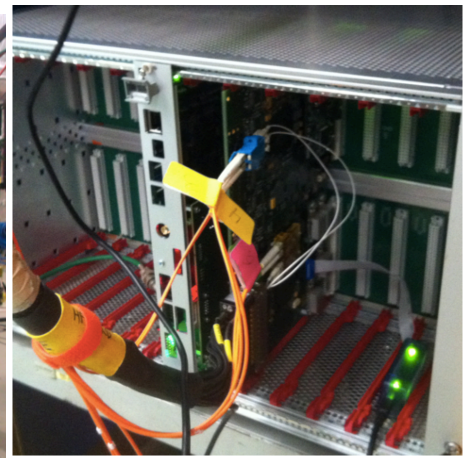
T-1041 QIE10 (A. Whitbeck[1])

Beam used: Muon, proton; positrons at 8 and 16 GeV
Run dates: April 5-15, August 11-20, 2014





Motivation and Goals:
Test the CMS hadron calorimeter upgrade electronics QIE10, Charge Integrator and Encoder, for performance with MIPs and showers.

Setup:
A quartz fiber calorimeter and a long quartz fiber bundle mimicking the CMS Forward Hadron calorimeter with the upgrade readout box.

Results and Impact:
The operations of the QIE10 readout system was validated with simple electronics and physics tests.

[1] Fermilab

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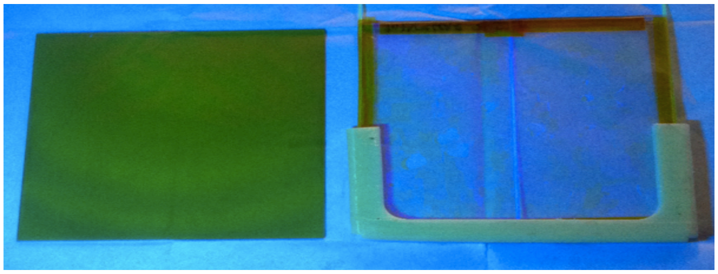
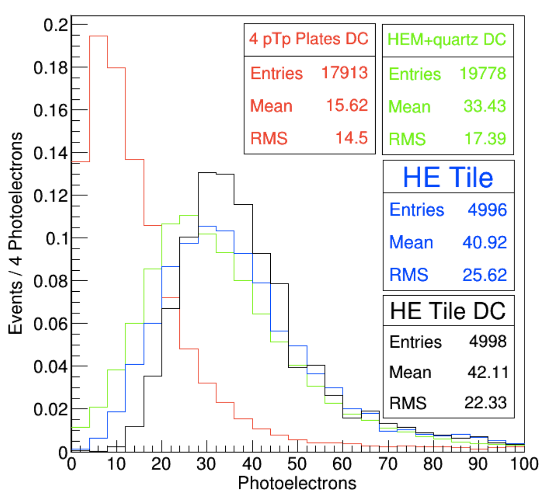
T-1041 Quartz Plates (Y. Onel[1])

Beam used: Muon, proton; positrons at 8 and 16 GeV
Run dates: November 20-26, 2013; August 11-20, 2014



Motivation and Goals:
Develop radiation-hard active media for the CMS hadron endcap calorimeters Phase II upgrade based on the quartz plate technology.

Setup:
Quartz plates with various surface coatings read out with direct coupling or with wavelength-shifting fibers in a light-tight assembly.



Results and Impact:

We identified quartz plate solutions with comparable performance to the current Hadron Endcap (HE) calorimeter performance.

[1] University of Iowa

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<u>T-1041 / Radiation hard scintillating fibers</u> (N. Akchurin[1])

Beam used: 4,8,16GeV π^+; 4,8,16 GeV e^+
Run dates: July 25–29, Aug 4-10 2014

Figure 1: Experimental setup

Motivation and Goals:
The goal of the R&D is to produce radiation-hard optical fibers suitable for use in high radiation environments, such as the CMS endcaps at the HL-LHC. The approach taken to achieve this goal relies on recent advances in the understanding of relevant processes taking place in the radiation-hard inorganic scintillators. Although we concentrate on cerium-doped fused-silica scintillating, variations on the dopant(s) and core/glass/clad structure(s) open myriad possibilities specifically relevant to CMS, such as wavelength shifters for the shashlik and rad-hard scintillators plates for the HE. The goal of this particular beam test is to study the basic characteristic of the light produced in the cerium-doped fused-silica, such as scintillation pulse shape, light yield, attenuation and light propagation speed.

Setup:
On movable table is installed 5x5x200cm calorimeter module. In copper absorbare are longitudinaly inserted 240cm long cerium-dopped fused-silica and clear quartz fibers. Light is collected at the end of each type of fibers and is measured by photo multipliers. The module resembles dual-redout fibe calorimeter. The table rotates horizontaly and allowes to have arbitraty beam incident angle with respect to fibers orientation. System of scintilators provides the triggering signal of the DAQ.

[1] Texas Tech University

Results and Impact:
We have studied the light production in the cerium-doped fused-silica fibers. For the Current prototype from Polymicro (lot ATDJ01A, core/sleeve/clad/buffer = 60/200/230/350 μm) we have measured the following parameters:

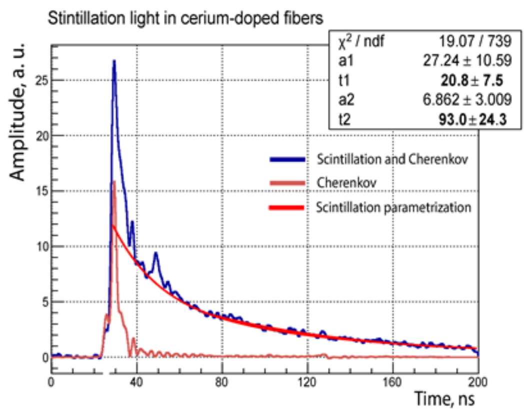


Figure 2: Cerium decay lifetime

- Attenuation length is 7.4 ± 1.1m
- Light propagation speed is 19.4 ± 0.4 cm/ns
- Scintillation light wave form. The tail of the scintillation pulse is best described by two-component exponent with time constants of 21 and 93ns.
- The scintillation light yield is under study, while it is already clear that an increase would be highly desirable.

Measurement of the characteristics of the prototype cerium-doped fused-silica fibers with beam at FTFB in a detector-like configuration are of crutial importance for this R&D project.

T-1041 Radiation-Hard Scintillators (J. Freeman[1])

Beam used: Muon, proton
Run dates: August 12- September 4, 2014

Motivation and Goals:

[1] Fermilab

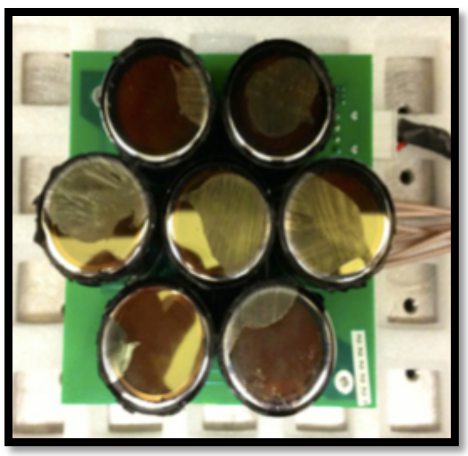
Develop radiation-hard scintillators and wavelength-shifters for the Phase II upgrade of the CMS hadron endcap calorimeters as well as test radiation-hard photo detectors.

Setup:
Various types of scintillators placed in a dark box.

Results and Impact:
Very recent data, analysis underway.

T-1041 Secondary Emission Calorimetry (B. Bilki[1])

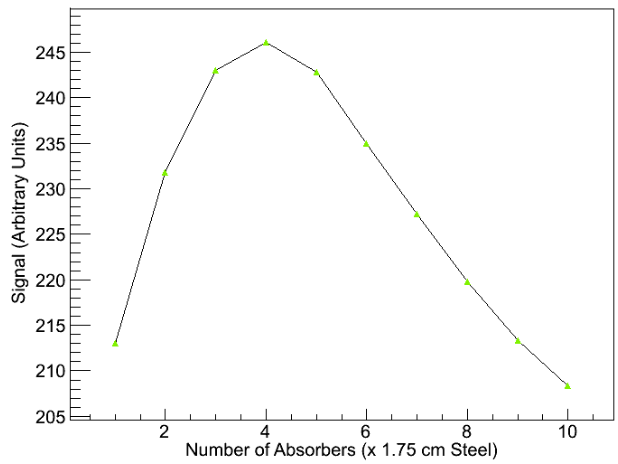
Beam used: Muon, positrons at 4-16 GeV
Run dates: November 20-26, 2013; June 11-16, 2014



Motivation and Goals:
Develop fast and radiation-hard secondary emission calorimetry for hadron collider detectors.

Setup:
For the proof of principle tests, the mesh dynode stack of old PMTs was used as the secondary emitter with the photocathode deactivated. The PMTs were on a custom readout board (pictured above).

[1] University of Iowa, Argonne National Laboratory



Results and Impact:
We have shown that the secondary emission detectors can be used in calorimetry in high energy experiments (shown left is the shower profile of 4 GeV positrons). Further measurements and optimization must be performed for final calorimetric and timing properties.

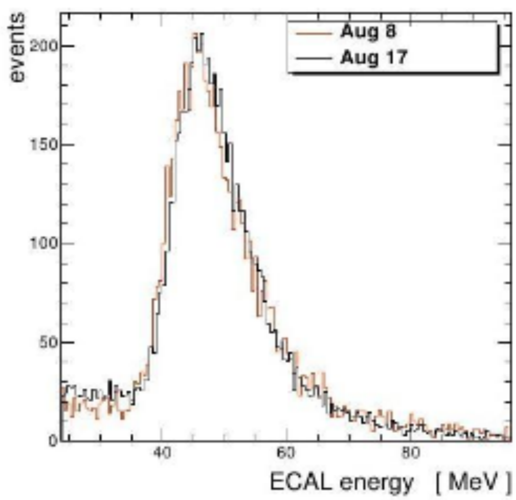
T-1041 CMS EE Shashlik array (M. Arenton[1], B.Hirosky[1], C.Neu[1],B.Francis[1], E.Wolfe[1], D.Sun[1], Y.Wang[1], F. Zia[1],T. Anderson[1],J. Adams[2],S. Bein[2],A. Santra[2],S. Tentindo[2],N. Dev[3],N. Kellums[3],K. Yi[4], P. Debbins[4])

Beam used: Muons, 2,4,8,16,32 GeV e's, 4,8,16,32 GeV pi's
Run dates: April 1-21, July 30-Aug 20, 2014

[1] University of Virginia
[2] Florida State University
[3] University of Notre Dame
[4] University of Iowa

Motivation and Goals:
We are designing an upgrade to the CMS forward electromagnetic calorimeter (EE). It needs very high radiation resistance and fine segmentation. We are using the "shashlik" design with tungsten plates (which have a small Moliere radius allowing fine segmentation) and LYSO scintillating plates which are radiation resistant. This test examines the energy linearity and position uniformity of this design.

Setup:
A 4 by 4 array of 14mm square modules was constructed. Each one is a sandwich of 28 2.5mm thick W plates and 29 1.5mm thick LYSO scintillators. 4 readout fibers penetrate the array and are read out at both ends with SiPM's. A fifth fiber delivers laser pulses into the array for monitoring. Readout used the PADE system.
The beam wire chambers were also read out. The figure above shows the array in the center with the 128 fibers going to the readout SiPM's.



Results and Impact:
The first step in the analysis is to intercalibrate the 128 readout channels and establish the energy calibration of the 16 modules. The figure shows muon energy peaks from two separate runs. The ADC to energy calibration of 46 MeV per muon is calculated with GEANT. Using these calibrations we are starting to look at details of the transverse response of the array and the resolution and linearity of the energy response.

T-1042 / g-2 Straw Tracker (M. Rominsky et. al[1])

Beam used: 120 GeV protons
Run dates: January 22 – February 4, 2014 and April 23- May 6, 2014

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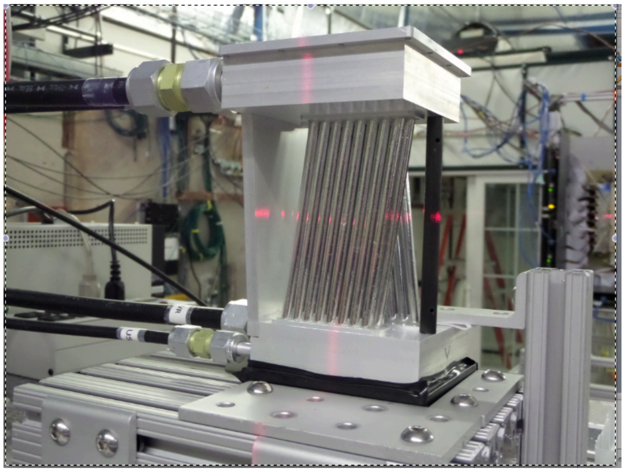
[1] Fermilab, University College London, University of Liverpool, University of Boston, Northern Illinois University, and University of Kentucky all participated in these beam tests.



Motivation and Goals:
The T1042 experiment tested a prototype for the g-2 straw tracker system. We did two test beams, one in atmosphere and one in vacuum. The straws are some of the thinnest walled straws (15 microns) to ever be used in vacuum. We needed to use the test beam to characterize the straws under pressure and in atmosphere. We also needed to understand how good our simulation was, and the test beam was invaluable in helping us with that.

Setup:
We used our straw tracker prototype (pictured above), consisting of 4 planes of straws in a u-v doublet configuration. The electronics were attached to the straws inside the manifold, which was another key point of the design we were testing. In addition, we used the MWPCs at the test beam for both runs as wells a beam monitor for the second run. We were located on the 2B motion table and were able to scan across the whole prototype.

Results and Impact:
Overall, this was a tremendous success. We were able to improve our design and simulation for the g-2 tracker. We have a good handle on what is needed for the next test beam. This was also a great test of the g-2 DAQ. We found that the tracker will meet or exceed all the design specifications need to improve the g-2 experiment at Fermilab.

T-1044 / sPHENIX Calorimeter Test (J. Haggerty[1], E. Mannel[1], S. Boose[1], A. Franz[1], E. Kistenev[1], S. Stoll[1], C. Woody[1])

Beam used: 1,2,4,8,16,30 GeV e/π, 120 GeV p
Run dates: February 5-25, 2014

[1] PHENIX Collaboration and Brookhaven National Laboratory, Upton, N.Y. 11973. Many other members of the PHENIX collaboration contributed to the construction, data taking, and analysis of data from this test.

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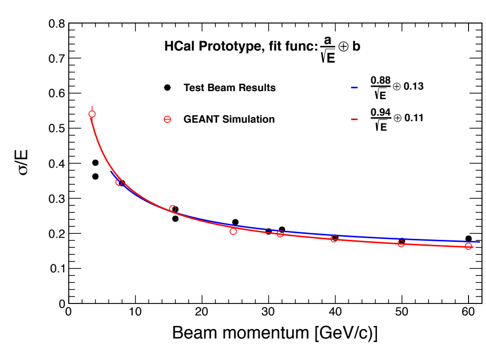
Motivation and Goals:
sPHENIX will measure jets, jet correlations and upsilons to determine the temperature dependence of transport coefficients and the color screening length in the QGP. It will do this with high rate, large acceptance, hadronic and electromagnetic calorimetry and precision tracking. Prototype electromagnetic and hadronic calorimeters proposed for use in this experiment were tested for the first time in the beam.

Setup:
Prototypes of a compact tungsten-scintillator EMCAL and a novel steel-scintillator calorimeter, both read out with solid state silicon photomultipliers with shaper amplifiers and waveform digitizers were tested with a variety of incident particles and energies. A small hodoscope in front of the detectors was used to define the incoming beam, and the FTBF's Cerenkov counter was used to tag electrons. Data were acquired with electronics developed for the PHENIX experiment at RHIC.

Results and Impact:
The test of the calorimeters provided a wealth of important insights into the operation of the calorimeters, from reliable measurements of the light output of the scintillator to calibration methods, uniformity of response, e/h ratio, and energy resolution. Comparison of the data with GEANT4 Monte Carlo has provided an important reality check on our simulation of the proposed detectors.



T-1048 / PHENIX Fast TOF (M. Chiu[1], M. Alfred[2], C. Biggs[1], S. Boose[1], T. Chujo[3], I. Choi[4], M. Hirano[3], M. Inaba[3], J. Lindesay[2], D. Lynch[1], E. Mannel[1], T. Nonaka[3], I. Sakatani[3], W. Sato[3], S. Stoll[1])

Beam used: 120 GeV p
Run dates: February 11 – 25, 2014

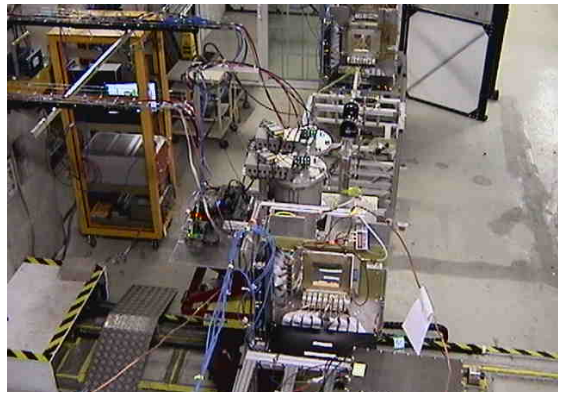


Figure 6: BNL and Tsukuba mRPC Prototypes in FTBF Beamline

Motivation and Goals:
The ability to study the dependency of different observables on particle flavor has been and is expected to be an important part of the physics programs for the RHIC-II and the future eRHIC era at Brookhaven National Lab. Good particle identification beyond current capabilities is an important goal for the sPHENIX/ePHENIX detector upgrades. In addition, fast timing is being pursued as a way to improve port scanner performance dramatically by adding the ability to make a momentum measurement on cosmic muons. Our group is developing an advanced version of multi-gap Resistive Plate Chambers (mRPC), which doubles the number of gas gaps and lowers the gas gap size by 50% to improve mRPC resolutions from the current ~50 ps down to below 20 ps.

Setup:
The goals for this test beam experiment are to verify the timing performance of the two types of time-of-flight detector prototypes under varying conditions of detector design, gas mixture, detector position, detector angle, and differing preamps and readout electronics. There were four prototypes built, using two slightly different designs from BNL and Tsukuba.

Results and Impact:
These were our first prototypes that were ever built by BNL and Tsukuba, so we were particularly interested in the quality of the signal rise-time and the signal-to-noise. The signal rise times were very good, about 500 mV in 500 ps, and the signal to noise was also excellent. Preliminary results indicate about 30 ps resolution. From the beam test we learned we have to improve the preamp performance in order to achieve sub 20-ps resolution.

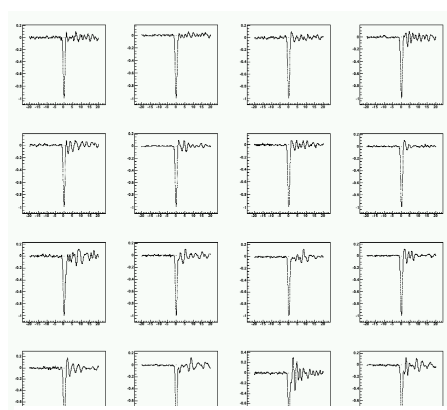


Figure 7: Pulses from mRPC prototypes.

[1] Brookhaven National Laboratory
[2] Howard University
[3] Tsukuba University
[4] University of Illinois at Urbana-Champaign

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T-1049 / ATLAS large scale Thin Gap Chambers A. Bellerive[1], T. Koffas, J. Botte, S. Rettie, S. Weber, M. Batygov, P. Gravelle, M. Bowcock, B. Vachon[2], B. Lefebvre, C. Bélanger-Champagne, A. Robichaud-Véronneau, B. Stelzer[3], H. Torres, D. Mori, N. Lupu[4], A. Vdovin, O. Stelzer-Chilton[5], E. Perez Codina, S. Viel, Y. Benhammou[6], H. Cohen, M. Davies, L. Gauthier[7], G. Mikenberg[8], M. Shoa, V. Smakhtin

Beam used: 32 GeV π^+/π^-
Run dates: May 7 – 20, 2014

Test beam collaboration and FNAL director with a full size sTGC prototype and a pixel telescope.

Motivation and Goals:
The motivation for the luminosity upgrade of the Large Hadron Collider (LHC) is to precisely study the Higgs sector and to extend the sensitivity to new physics to the multi TeV range. In order to achieve these goals the ATLAS experiment has to maintain the capability to trigger on moderate momentum leptons under background conditions much harder than those currently at the LHC. For the Muon Spectrometer, such requirements necessitate the replacement of the forward muon-tracking region with new detectors capable of precision tracking and triggering simultaneously. Thin Gap Chambers (sTGC) have been selected as one of the two technologies that will be used for this upgrade. The requirements on precision for such devices are very hard to achieve. The test-beam at Fermilab allowed for qualifying the assembly procedure before production starts in Canada, China, Chile and Israel.

Setup:
A pixel telescope is used to precisely track the incident point of pions on the sTGC detector and compare it to the measured position in each of the four sTGC detection planes. The residual distribution enables an analysis of the alignment and intrinsic resolution to confirm that the required relative and absolute precision has been achieved. A moveable x-y table is used to expose different regions of the sTGC detector to the particle beam. The setup utilizes newly developed front-end electronics for the sTGC readout. Synchronization logic is used to combine the sTGC data with the data from the pixel telescope based on a scintillator trigger.

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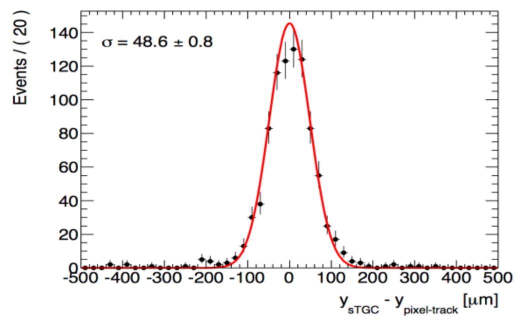
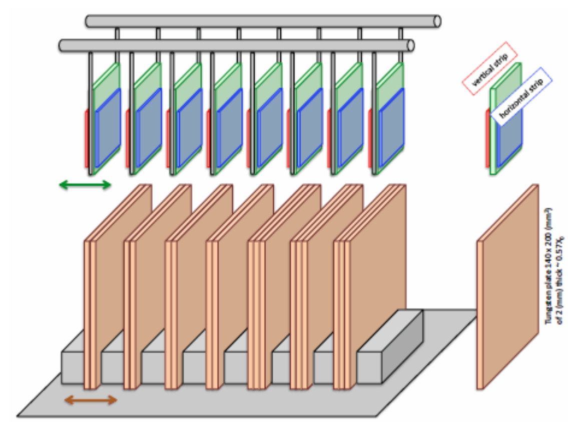
Results and Impact:
Data taking was successfully completed during beam time at Fermilab. The offline analysis of the data is still ongoing. Preliminary results on the calibration of the electronics, tracking and alignment of the pixel telescope allowed extraction of the intrinsic sTGC detector resolution of about 50μm in the best case, as shown in Fig 1. The Fermilab tests provide valuable input for the production phase and further tests are in preparation.



Best intrinsic resolution of the sTGC prototype detector

<u>T-1054 / sPHENIX preshower</u> (BNL[1], Hiroshima[2], Tsukuba[3])



Beam used: 10-60 GeV π^+
Run dates: February 24 – 26, 2014

Motivation and Goals:
The experimenters proposed to install and test in the particle beams at FNAL a small (6x6 cm2 sensitive area) prototype of High resolving power preshower detector for the sPHENIX at BNL. The design of the prototype is based upon recent developments in “no collateral damage” high density and high resolution (position and energy) Si-W calorimetry which has already resulted in approval and construction of preshower detectors for the very forward calorimeters in the PHENIX experiment at RHIC.

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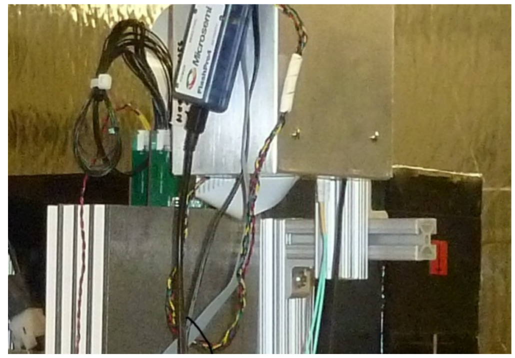
Setup:

The experiment was set to run parasitic to T-1044 with the preshower detector located in front of the T-1044 EMCal≈ on the 2C lift table. No additional support structure except mini-table (frame) to rise the prototype to a common height above the FNAL moving table used to handle the EMC prototype was required.



Results and Impact:

The experiment was competing foor the beam-time with T1044 – both were interested in the data with minimal amount of material in the beam line and as such could run only concurrently. The beam access for T1054 was finally granted on the last date of sPHENIX period (2/25/2014). Available beam time was sufficient to establish detector timing with respect to beam trigger and to accumulate about 100k useful events with different triggers. Online analysis have shown that we were able to establish optimal running conditions for new detector and to see signals of minimum ionizing particles in all exposed silicon strips. Data accumulated at FNAL were further used to tune the software and hardware for the ninipad version of silicon sensors currently used in PHENIX to resolve preshower photons in the very forward directions in asymmertric pA and dA collisions.

T-1056 / ATLAS DBM Module Qualification (Andrej Gorisek[1], Marko Zavrtanik[1], Grygorii Sokhranyi[1], Garrin McGoldrick[2], Matevz Cerv[3])

Beam used: 120 GeV protons
Run dates: July 9–22, 2014

Motivation and Goals:

Qualify modules for use in Atlas Diamond Beam Monitor (DBM) for high precision luminosity measurements at the LHC.

Setup:

Test diamond pixel telescope in beam at FTBF.

Results and Impact:

Tests were successfully completed.

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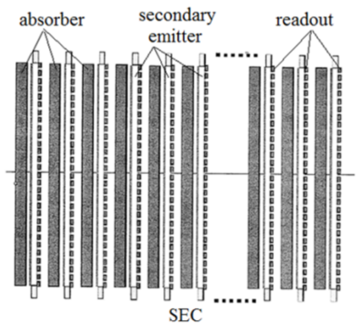
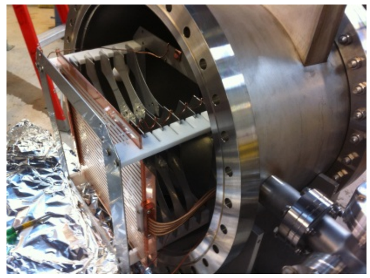
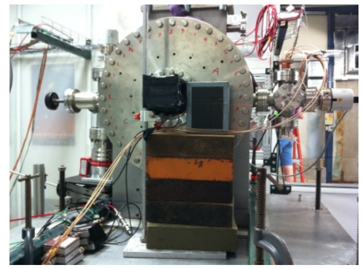
T-1058/Secondary Emission Calorimeter (A. Ronzhin[1], H. Frisch[2], A. Apresyan[3])







Beam used: 16 GeV, 32 GeV
Run dates: September 3-4 night, 2014

Motivation and Goals:
Large-area thin planar economical detectors based on micro-channel plates (MCP) are attractive as the active elements in sampling calorimeters. The properties of such calorimeters are: 1) a 2-dimensional map of energy at each sampling depth, timing information at each depth, and possible separation of electromagnetic and hadron energy based on the differences in timing. We plan to use large-area MCP assembled without photocathodes as the active element in sampling calorimeters. Such LAPPD 20 cm-square modules can be economically assembled in a glove box and then pumped and sealed like PMTs, rather than assembled by a slow and expensive vacuum-transfer process. We present here our plan to test LAPPD MCPs (200x200 mm2) as an active element in a rad-hard ultra-fast calorimeter. The calorimeter works in the following fashion. High energy particles passing through an absorber in a sandwich sampling calorimeter produce secondary particles, positron electron pairs, gammas, etc., which are detected by the MCPs. The response of the MCPs to the shower is proportional to the number of particles in the shower which is dependent on the initial particle energy. We plan to investigate the possibility to produce a full size electromagnetic calorimeter based on W (or Pb) absorber plates sandwiched with LAPPD devices based on MCPs. The LAPPD Collaboration has developed a full digitization and DAQ system to read out tiles. If the results are promising we would like to construct and test a full-size electromagnetic calorimeter module large enough to contain high-energy showers, although this will require investment in additional chips, boards, and person-power.

Setup:
Main part of the setup is based on vacuum vessel, filled with layers of tungsten "sandwiched" by layers of LAPPD MCPs. Anode part of the MCP performed as strip line (SL). The SL hooked up to DRS4 and PSEC digital samplers used to obtain timing and pulse

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height information from the SEC. It is also used scintillation and Cherenkov counters in the setup as part of the FTBF equipment.

Results and Impact:
We had so far just one night for the SEC investigation at the FTBF. The SEC setup was placed at MT6.2C beam line at moving stage. We got the good vacuum inside of the SEC vessel equal 2.5x10-7. The HV recommended for the LAPPD MCP turned out to be stable. The preliminary TB data are under analysis.

3. PLANS AND PROSPECTS FOR FY15 AND BEYOND

The annual maintenance shutdown lasted from September, 2014 into November. In FY15, the major installation of T-977 (Minerva Detector Calibration), together with an associated scheduled running period of several months, reduces the availability of beam time for other experiments. Therefore, run time was not heavily promoted or advertised for the first half of FY15. The FY15 MTEST schedule is booked for all but 6 weeks with several proposals still in the pipeline. Instrumentation and DAQ improvements continue at MTEST and the facility is expected to be fully booked before the fiscal year ends.

MCenter/MC7 has active installation of cryo plan for the liquid argon program. Expectations are that LArIAT (T1034) will take data in the second half of FY15, and T1059 (Optical TPC) will also install and run in MC7. The possibility exists to expand the MCenter program to accommodate other non LAr experiments in FY16.