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

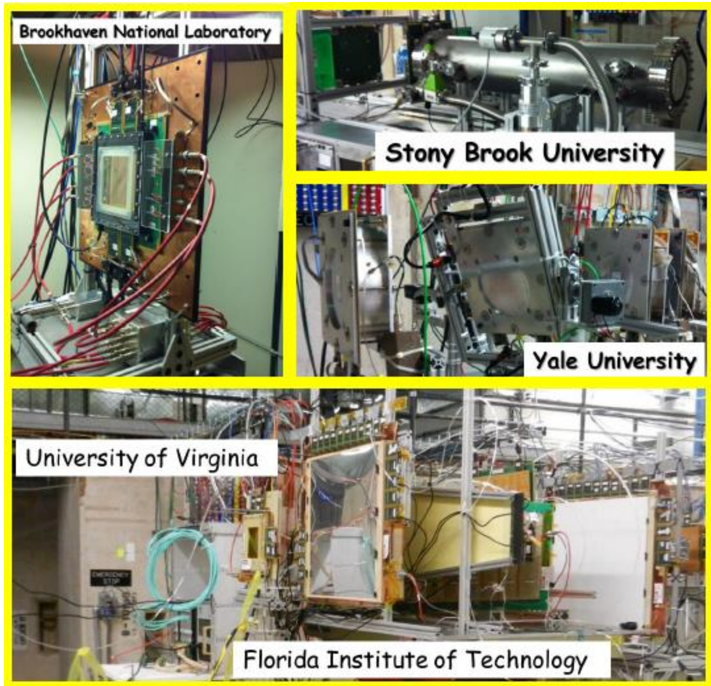

Figure 1 FLYSUB test beam setup.

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

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
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

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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°.

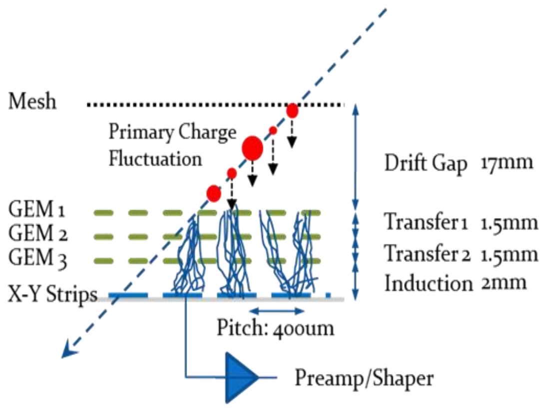

Figure 2 Illustration of mini-drift GEM detector with pad readout.

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 4) had been implemented. As a reference tracking system three 10 × 10 cm^2 Triple-GEM chambers were used.

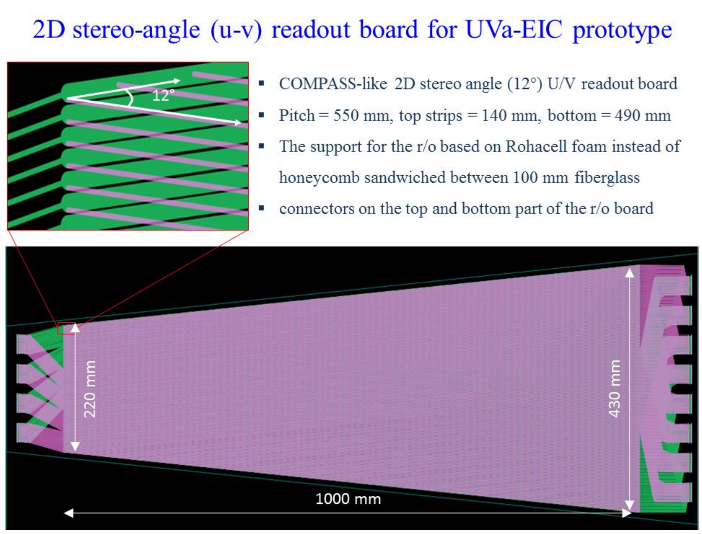

Figure 3 2D (stereo angle) u-v strips readout board for the UVa-EIC GEM chamber.

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.

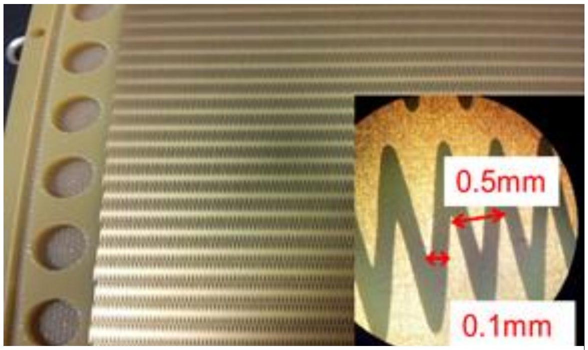

Figure 4 Printed circuit readout board with zigzag strips with a microscope picture of the zigzag structure in the inset.

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.

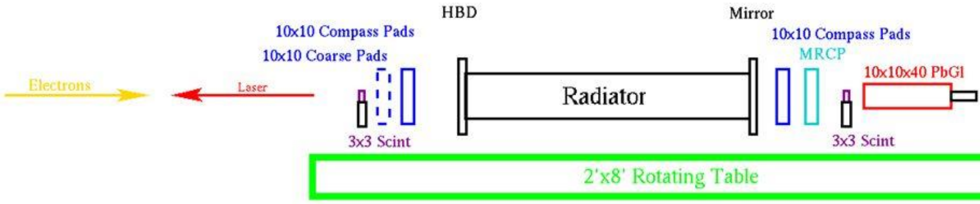

Figure 5: Drawing (not to scale) of the proposed setup for the test in beam of the RICH prototype.

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.

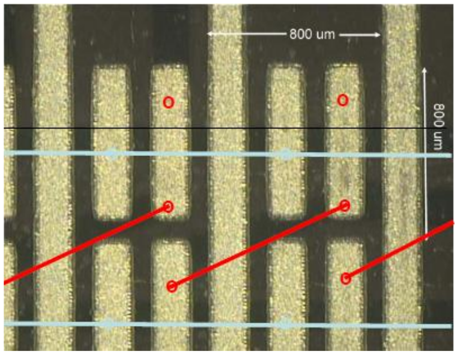

Figure 6: Three-dimensional single readout plane realized by interconnecting different lines of readout strips/pads.

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).

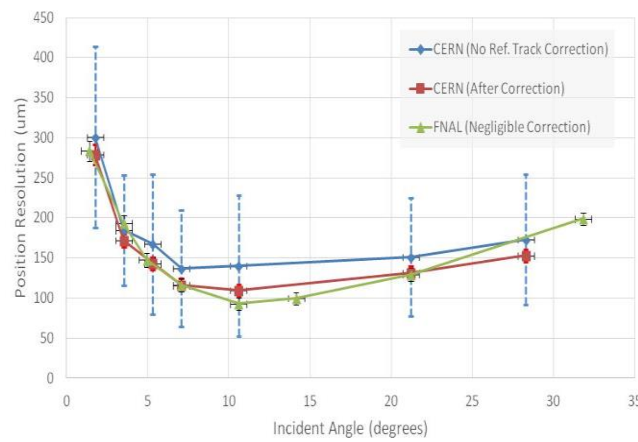

Figure 7 Position resolution of the minidrift detector using the track segment found in the detector as a function of angle for data taken at CERN and Fermilab. Resolutions are shown before and after unfolding the error on the extrapolated track from the two beam tracking systems.

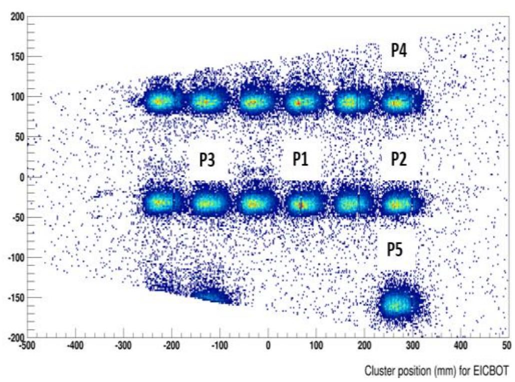

Figure 8 Beam profile reconstructed at 13 locations from position scan run of UVa-EIC Triple-GEM chamber with 32 GeV hadron beam.

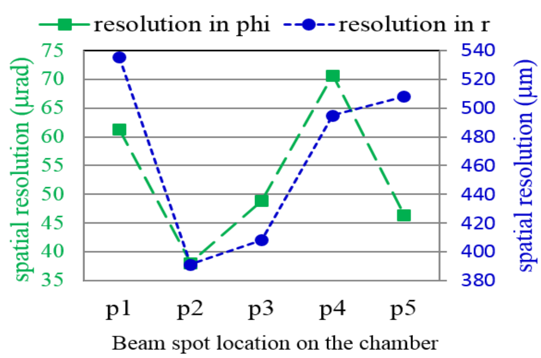

Figure 9 Spatial resolution on different locations on UVa-EIC Triple-GEM chamber using data from 120 GeV proton beam scan.

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.

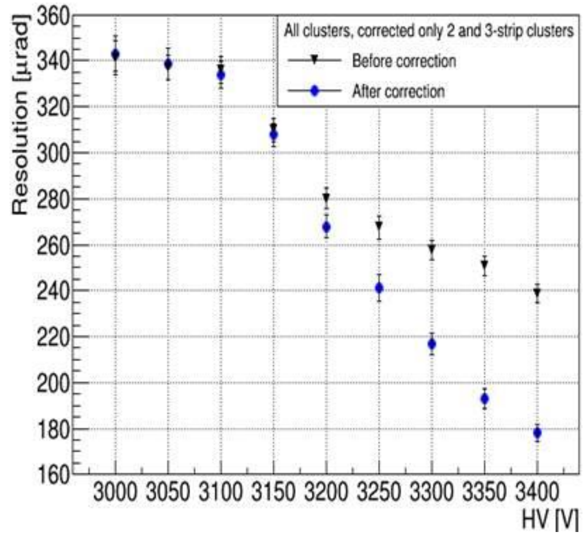

Figure 10 Measured angular resolution for a large-area GEM detector read out with radial zigzag strips before and after strip response correction.

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

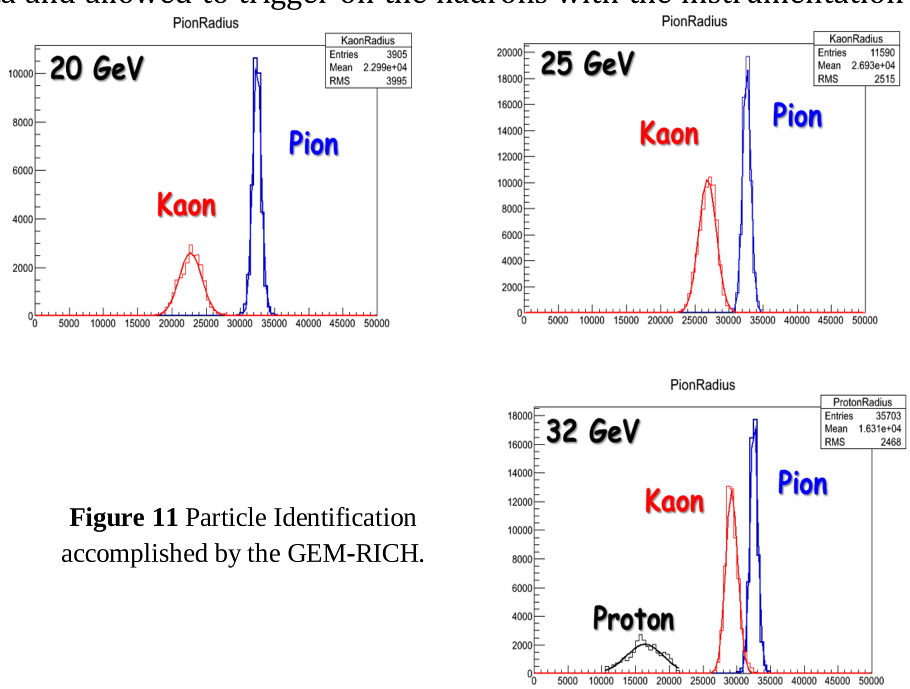

Figure 11 Particle Identification accomplished by the GEM-RICH.

by FTBF. 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.

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.

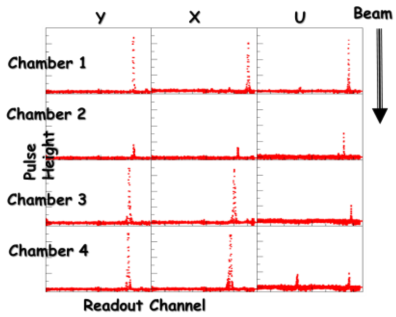

Figure 12 Event display for four single plane 3-coordinate GEM trackers.

The test-beam result 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.

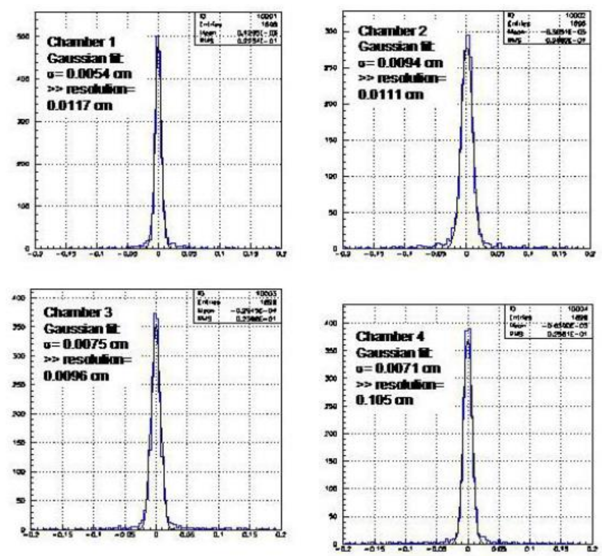

Figure 13 X-residual for the four 3-coordinate GEM trackers.

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.