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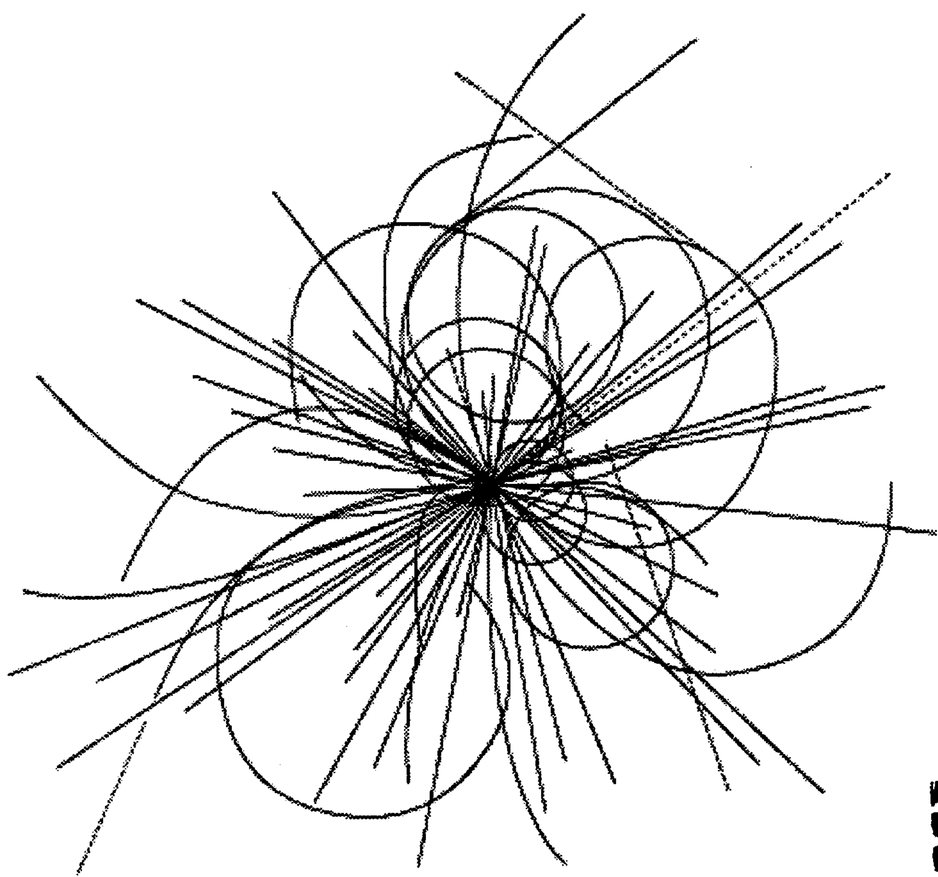

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OVERVIEW OF THE GEM MUON SYSTEM COSMIC RAY TEST PROGRAM AT THE SSCL

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INTRODUCTION

Muon track resolution exceeding 75-μm per plane is one of the main strengths of the GEM detector design, and will be crucial in searches for Higgs Bosons, heavy Z-Bosons, technicolor, and supersymmetry. Achieving this resolution goal requires improved precision in muon chambers and their alignment. A cosmic ray test stand known as the Texas Test Rig (TTR) has been created at the SSCL for studying candidate GEM muon chamber technologies. Test results led to selecting Cathode Strip Chambers[1] (CSC) as the GEM muon system baseline chamber technology.

THE TEXAS TEST RIG (TTR)

The triggerable volume of the TTR is large, with a surface area of 1.2 m $\times$ 5 m and a height of 3 m, allowing studies of as many as six different chambers simultaneously. All chamber types tested to date have shown excellent performance, with resolutions better than the 75-μm GEM design goal. Comprehensive testing has given information on chamber operation, gas mixtures, calibration, mechanical design, data acquisition, and data analysis. The TTR has become the first user facility at the SSCL and a center for GEM muon system R&D, with more than 100 participating physicists from 19 universities and national laboratories in China, Mexico, Russia, and the United States.

The TTR apparatus has several features contributing to its performance as a powerful test instrument. A 1-m thick stack of steel absorbs cosmic rays with less than about 1.3 GeV/c momentum. Removing the "soft" component of the spectrum makes chamber resolution studies less susceptible to the misleading effects of multiple scattering, and also reduces the trigger rate to about 60 Hz. Scintillator hodoscopes with timing resolution of about 300 ps are positioned above and below the steel to provide the fast trigger. The steel

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can be magnetized to 15 kG by energizing coils wound in a solenoidal configuration. With the magnet on, a finer position measurement obtained with four planes of 1-cm pitch Iarocci chambers can be used to select the higher momentum component of the muon spectrum, effectively raising the threshold to 10 GeV/c.

The TTR gas system can provide up to five different gas mixtures simultaneously to chambers under test. Since some chambers operated with flammable gases, a gas leak detector system with 14 sensor heads was deployed. This system was sensitive to hydrocarbon gas concentrations as small as 10% of the lower explosive limit. It provided alarms and signals for turning off the chamber gas and high voltage supplies in the event of a leak. TTR safety systems and procedures appeared to serve as a safety "prototype" for the future GEM experiment. The studies reported here were accomplished without injury.

A data acquisition (DAQ) system developed at the SSCL is used at the TTR. It is modular in design, accommodating a wide variety of electronics and software brought to the lab by visiting groups. VME-based processors running the VxWorks real-time operating system are at the heart of the DAQ. They communicate with muon chamber electronics and trigger units residing in CAMAC crates and other equipment such as high voltage supplies. Digitized data are read by the processors from the crates; then events are built and stored in VME memory. A workstation with a dedicated VME link periodically transfers the events from memory to disk and tape. A graphical user interface controls the DAQ. It features a run configuration editor, various run monitors, and an event display. Any computer running UNIX and x-windows and having network access to the TTR can be used to monitor TTR operation and analyze data.

TTR off-line software[2] is a general framework where users place their analysis code. The software automatically fetches the zero-suppressed data file from disk and stores it on an 8-mm tape robot. It also stores on a database (SYBASE) records describing running conditions, the chambers operating, triggers, and other information. The database can return a list of files satisfying queries. All these operations, including running the analysis program, may be controlled through user-friendly pop-up windows. Thus, the user may access the program from any x-terminal, generate a list of data files from the database, edit the list if needed, and activate the offline analysis program to process data stored on the tape robot. One unique feature is a dynamically loaded subroutine-substitution method that allows specifying replacements for default routines in the standard package.

The offline package processes Iarocci chamber and scintillator data, reconstructing tracks using these data both independently and in a combined fit. These tracks may be compared with tracks measured by the test chambers. In addition, there are routines to process data from the technologies. Histograms may be displayed by PAW; the user may easily define new plots. The standard output is used as input to the event display program.

In addition to the TTR cosmic ray test stand, a laser-based test system has been built for small-scale chamber studies, simulating a particle track using a UV-laser beam. The apparatus includes a laser, optical tools, chambers, and a Macintosh-based data acquisition system. The laser has been used to measure the operational speeds of flammable and non-flammable gas mixtures under consideration for the GEM muon system. Recently a magnet was installed for investigating magnetic field effects on CSC performance.

MUON CHAMBER TEST RESULTS

Four types of detectors have been tested at the TTR. Pressurized drift tubes (PDT), limited-streamer drift tubes (LSDT), and cathode strip chambers (CSC) were candidates for muon position measuring detectors, while resistive plate chambers (RPC) could be used for triggering and bunch tagging.

Separate PDT systems were built at Dubna and Michigan State University. They have staggered layers of tubes 3- to 4-cm in diameter, 4-m long, stacked 32 tubes wide. With a flammable gas mixture, resolution below the 100-μm design goal was measured at one atmospheric, improving to 50 μm at 5 atmospheres (Figure 1).[3] A PDT-based GEM muon system[4] appeared to be competitive with the CSC option that was eventually chosen.

Systematic error correction was an important part of the data analysis. An iterative fit to the data yielded a time-to-distance calibration. Muon tracks were used to determine the wire plane relative shifts and rotations, and individual wire displacements. This procedure was demonstrated for drift chambers, and it should apply also to CSC systems.

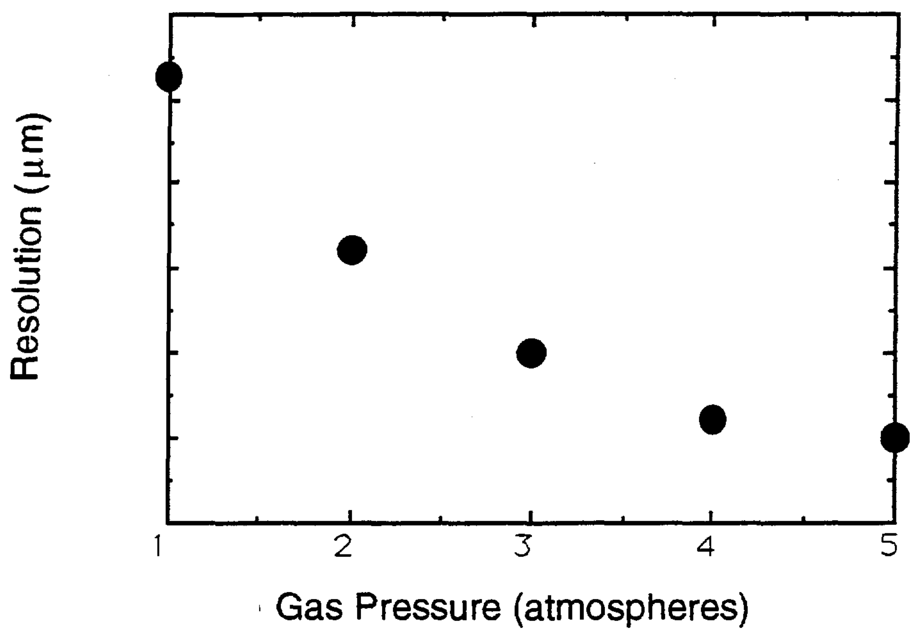

Figure 1. Resolution as a function of gas pressure in the Dubna pressurized drift tube system, measured at the TTR. The gas mixture was Argon:Ethane 50:50.

The MIT-built LSDT system featured precisely machined bridges supporting anode wires inside U-shaped aluminum profiles, and gave resolution below 100 μm A drift tube based trigger concept was tested, suggesting a 94% trigger efficiency.[5]

A 1.2-m × 2.4-m RPC designed and built by an LLNL-MIT group used ABS plastic doped with conducting polymer, and is a low-cost alternative to a scintillator for large area counting. Radioactive source tests indicate rate capability to 1 kHz/cm^2, substantially higher than bakelite RPCs currently in use. PDT and CSC groups were concerned that their chambers would pick up spurious signals from RPCs, but this was not seen in TTR tests.

Three independently developed CSC systems were tested. Designs addressed issues of construction, alignment, and manufacturability. In this type of chamber the cathode is segmented into strips, and the image charge induced on the cathode plane is shared among several adjacent strips. The centroid position is interpolated from the strip charges. All three CSC prototypes have shown spatial resolution better than 70 μm (Figure 2).

The Brookhaven and Dubna CSC designs are proportional chambers with 2.5-mm anode wire pitch. Gas gaps are between paper honeycomb panels with strip boards glued on them. The 4-gap Brookhaven chamber, (0.5-m × 0.5-m), and the Dubna chamber (1.0 m × 1.3 m) were successfully tested at the TTR. A 2-gap trapezoidal chamber, roughly 1.0-m × 2.0-m, with "fanned" strips is currently under test.

The University of Houston CSCs use plastic modules containing eight square tubes enclosing the anode wires. Carbon paint on the wire module interior allows the signals to induce image charges on the cathode strips glued to the wire planes. A chamber with 1-m × 0.5-m sensitive area was tested.

In the baseline CSC design, the strips are made with conventional printed circuit board technology. An alternative being studied is based on package-printing technology. Strip material is made in a subtractive process after the pattern is transferred to a continuous sheet of mylar with a sputtered layer of copper. The strip material appears to be inexpensive and precise. The rms of distribution of measured strip pitches is about 14 μm. Electrical properties were also measured and found to be compatible with CSCs.

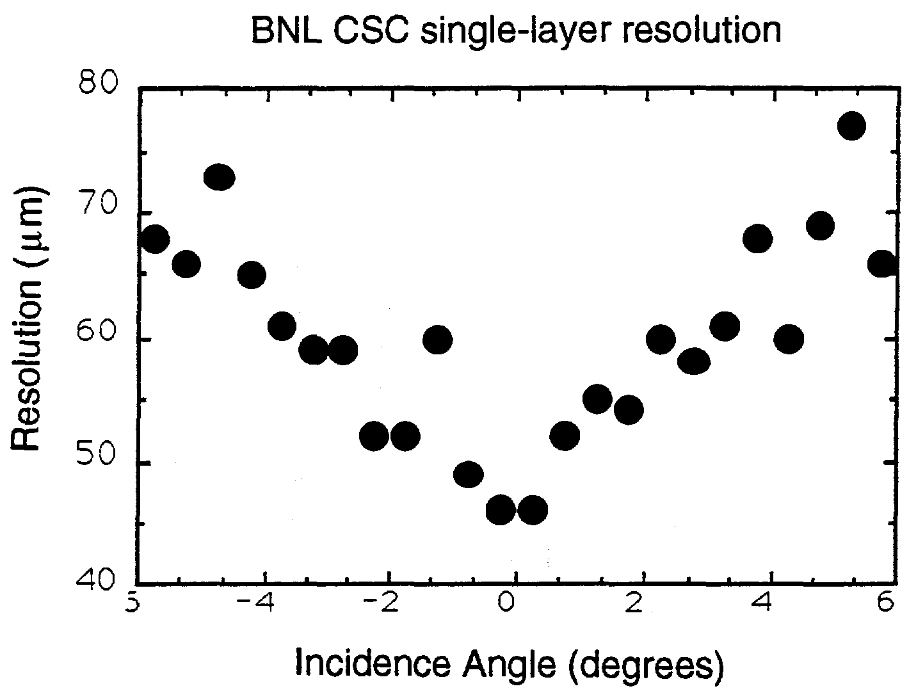

Figure 2. Single-layer resolution of the BNL CSC as a function of incident angle. For the present GEM muon system baseline design, this implies a resolution exceeding 60 μm.

SUMMARY

These results were possible because of advances in chamber design, a sophisticated DAQ system, the size and flexibility of the TTR, and the coherent effort of the GEM muon group. Using cosmic rays at the TTR has been surprisingly fruitful, and the experience has built our confidence in making a high quality muon system for GEM.

REFERENCES

1. "GEM Muon System Based on Cathode Strip Chambers," SSCL TN-92-00199.
2. I. Chow, et al., "Offline Event Reconstruction for TTR (User Guide),"SSCL TN-93-00293.
3. "Muon Technology Choice Performance Comparisons," SSCL TN-93-00282.
4. "The RDT-RPC Technology Option for GEM,"SSCL TN-93-00288.
5. "Muon Trigger Using GEM Drift Tubes,"SSCL TN-92-00161, and SSCL-TN-93-303.