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Proton Radiography: Cross Section Measurements and Detector Development

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Project Goals

The physics goal of this project is to measure forward production of neutrons and photons produced by high-energy proton beams striking a variety of targets. This will provide data essential to proton radiography. This work is being carried out in conjunction with the Fermilab Experiment 907 (MIPP) collaboration including physicists from Lawrence Livermore Laboratory. Our group is responsible for the E907 forward neutron/photon calorimeter.

Progress Report

The general layout of the experiment is shown in Figure 1. The photon and neutron calorimeters are at the end of the beam line to detect forward-going photons and hadrons and to measure their energies.

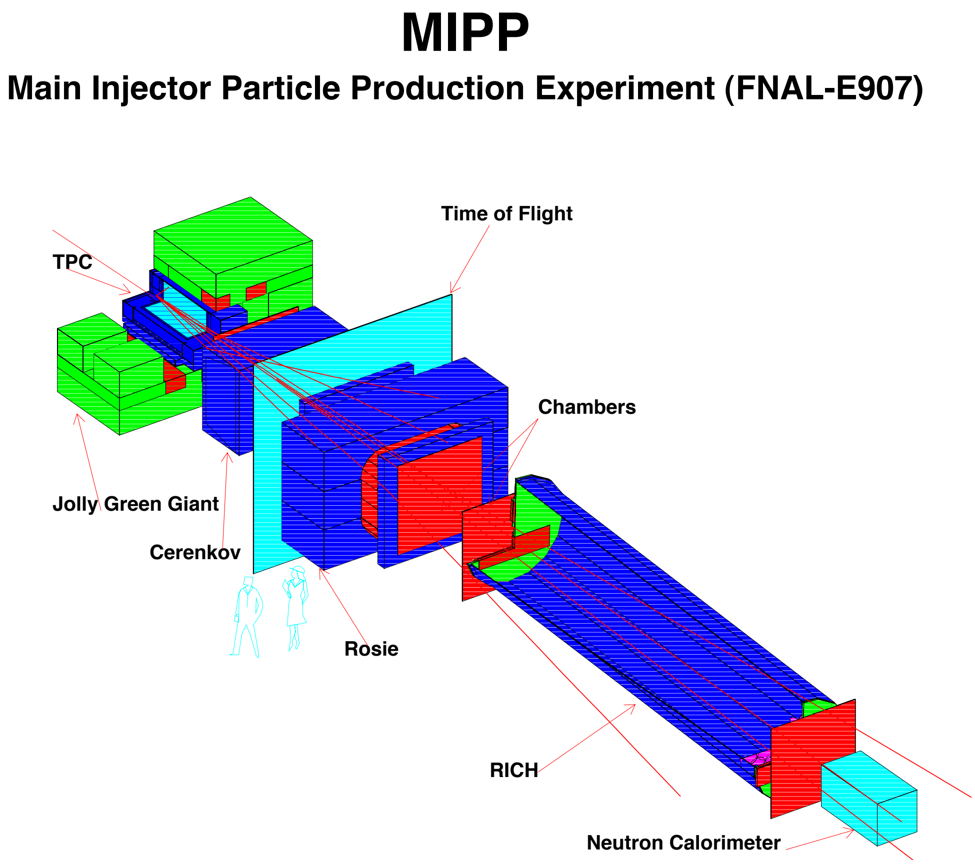

Figure 1: Overall perspective view of the MIPP experiment at Fermilab. The photon and neutron calorimeters are at the end of the beam line.

Neutron Calorimeter

The responsibility for the Neutron Calorimeter is being shared with the University of Virginia group who joined the collaboration in early 2003. The neutron calorimeter is shown schematically in Fig. 2. It is used to detect high-energy neutrons and measure their energy by means of the energy they deposit in the scintillator layers as they interact and shower in the steel plates, eventually losing all their energy.

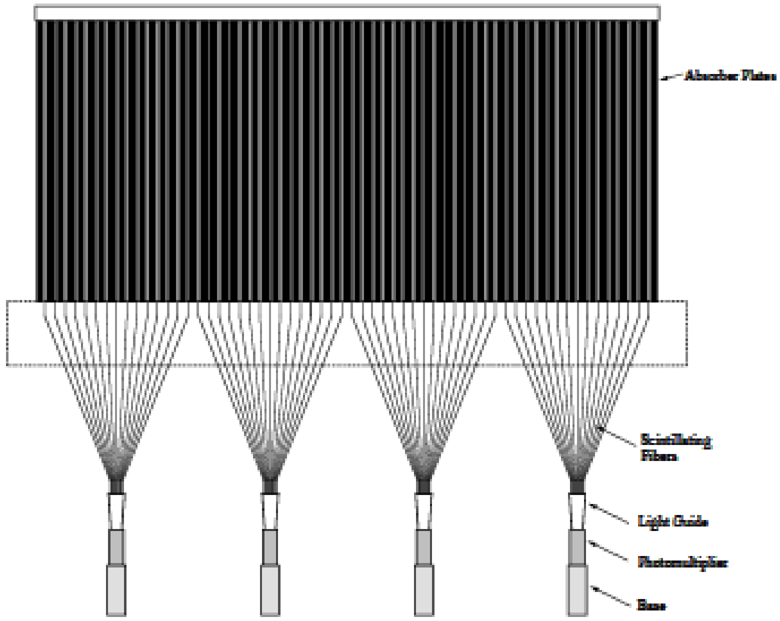

Fig. 2: Schematic top view of the NCAL. The dark lines are steel absorber plates interspersed with plastic scintillator.

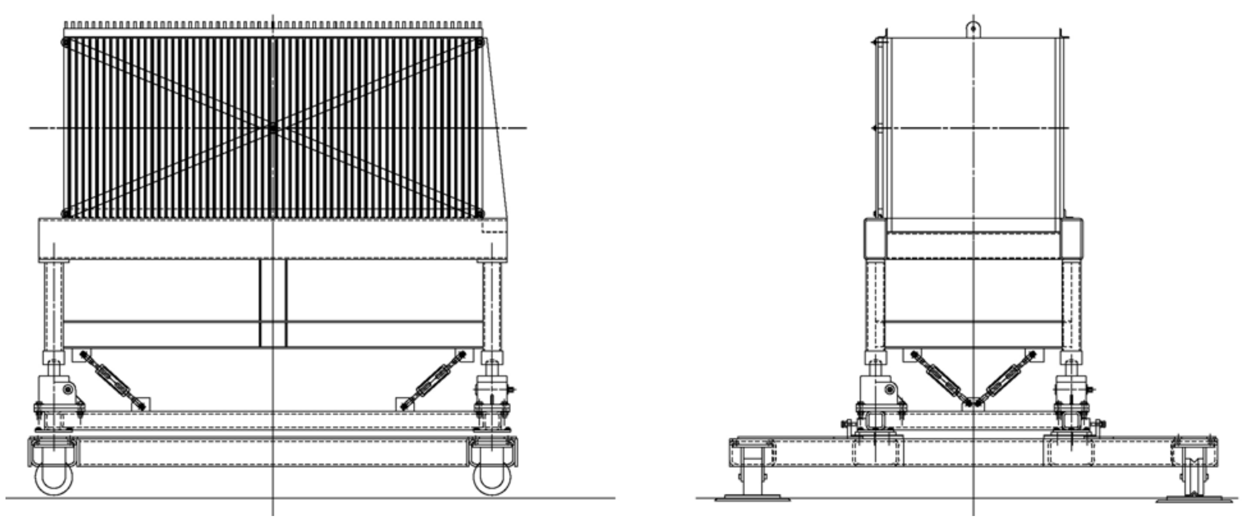

Fig. 3: Side view and front view of the NCAL.

Figure 3 shows the side and front views of the actual calorimeter. This calorimeter was originally built about 10 years ago by the University of Virginia group for Experiment E871 at Fermilab. Considerable refurbishing was required to restore it for use in MIPP. The stand had to be revised. The modifications to the stand were designed and carried out by Fermilab engineers and technicians. New readout electronics had to be designed. This has mostly been completed by the University of Virginia group, and the calorimeter will be ready as soon as there is beam. Early running with muons and with hadron beams will be used to test the calorimeter and to calibrate the energy scale.

Electromagnetic Calorimeter

The electromagnetic calorimeter is used to detect high-energy photons and to measure their positions and energies as they shower in lead plates where they lose most of their energy. The side view of the EMCAL and NCAL is shown in Fig. 4, and the front view of the EMCAL is shown in Fig. 5.

The EMCAL consists of 10 lead-antimony plates, each 5 mm thick. Following each lead plate is a plane of 64 wire proportional chambers with 25.4 mm spacing between wires. Alternate wire chamber planes have wires running horizontally and vertically to get both vertical and horizontal positions of the electromagnetic showers.

For each event, the charge from each wire is digitized with an analog readout system designed by our group. The total charge is a measure of the energy of the photon. The vertical and horizontal location of the beginning of the shower gives the photon angle.

The design, assembly, and testing of the EMCAL has been the responsibility of our group. The lead plates for the EMCAL were ordered in December 2002, soon after the grant was awarded. They were delivered in January 2003. Parts for the frame were also ordered around then.

Stringent safety requirements for working with the lead sheets were necessary. These included covering the working area with polyethylene sheets, wearing respirators when actually working with the sheets, and eventually painting all exposed lead surfaces.

All 10 detector planes were completed by the beginning of May 2003. The assembly of the frame and the mounting of the planes on the frame were completed in early August. Since then we have been assembling and testing the readout and wire chambers. These tests were done using a small test setup and cosmic rays. In the process we tested various gas mixtures for the chambers. We found that a mixture of CF4 with argon and ethane gave much shorter and more uniform pulses than the argon-CO2 mixture used in previous experiments. This should significantly improve the ultimate energy resolution.

The test setup was used to debug the readout on a small scale. The readout electronics for the complete detector is mounted and cabled up. Testing will start in December 2003. We are also integrating the readout into the overall data acquisition for the experiment.

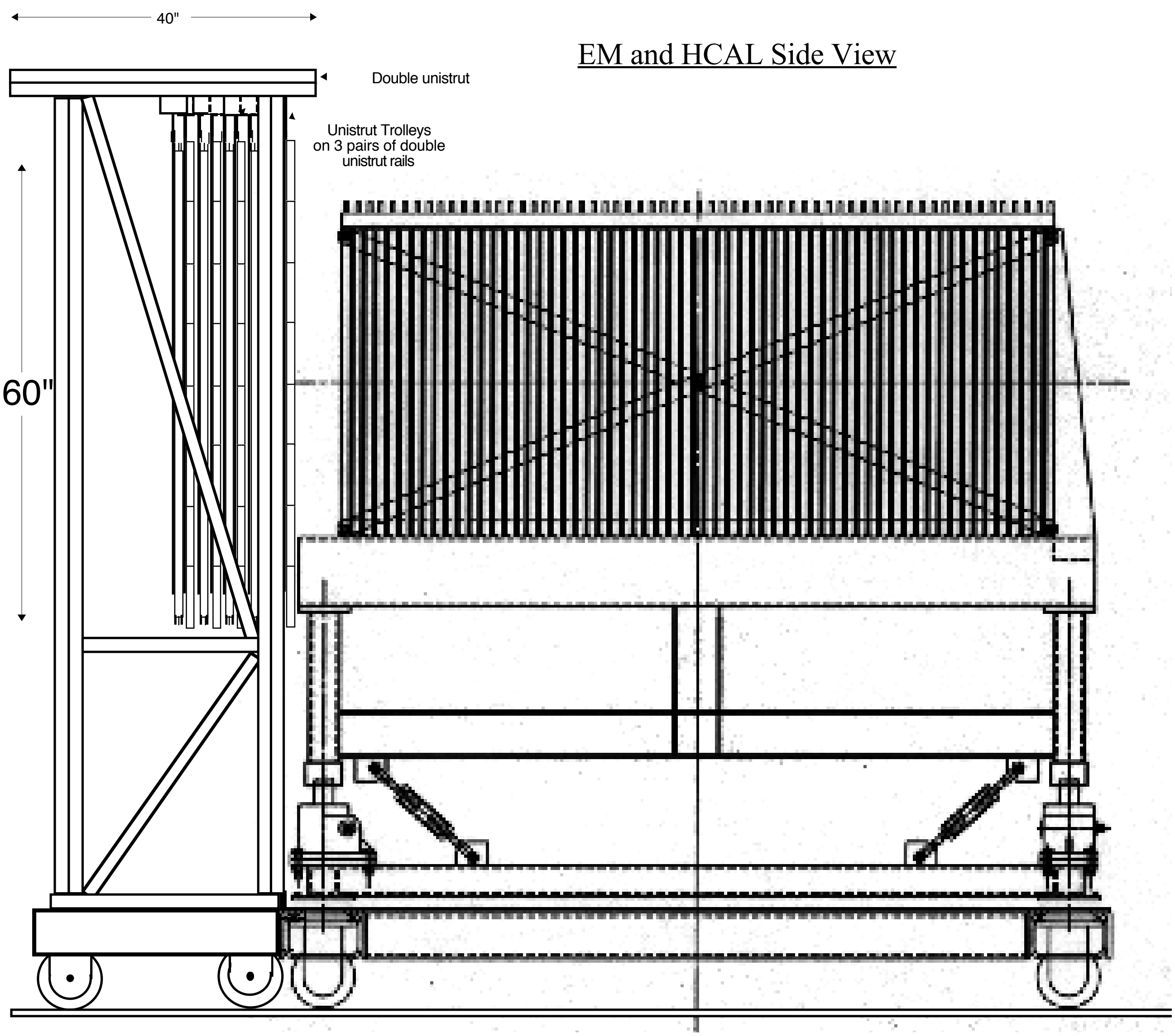

Figure 4: Side view of the EMCAL and NCAL

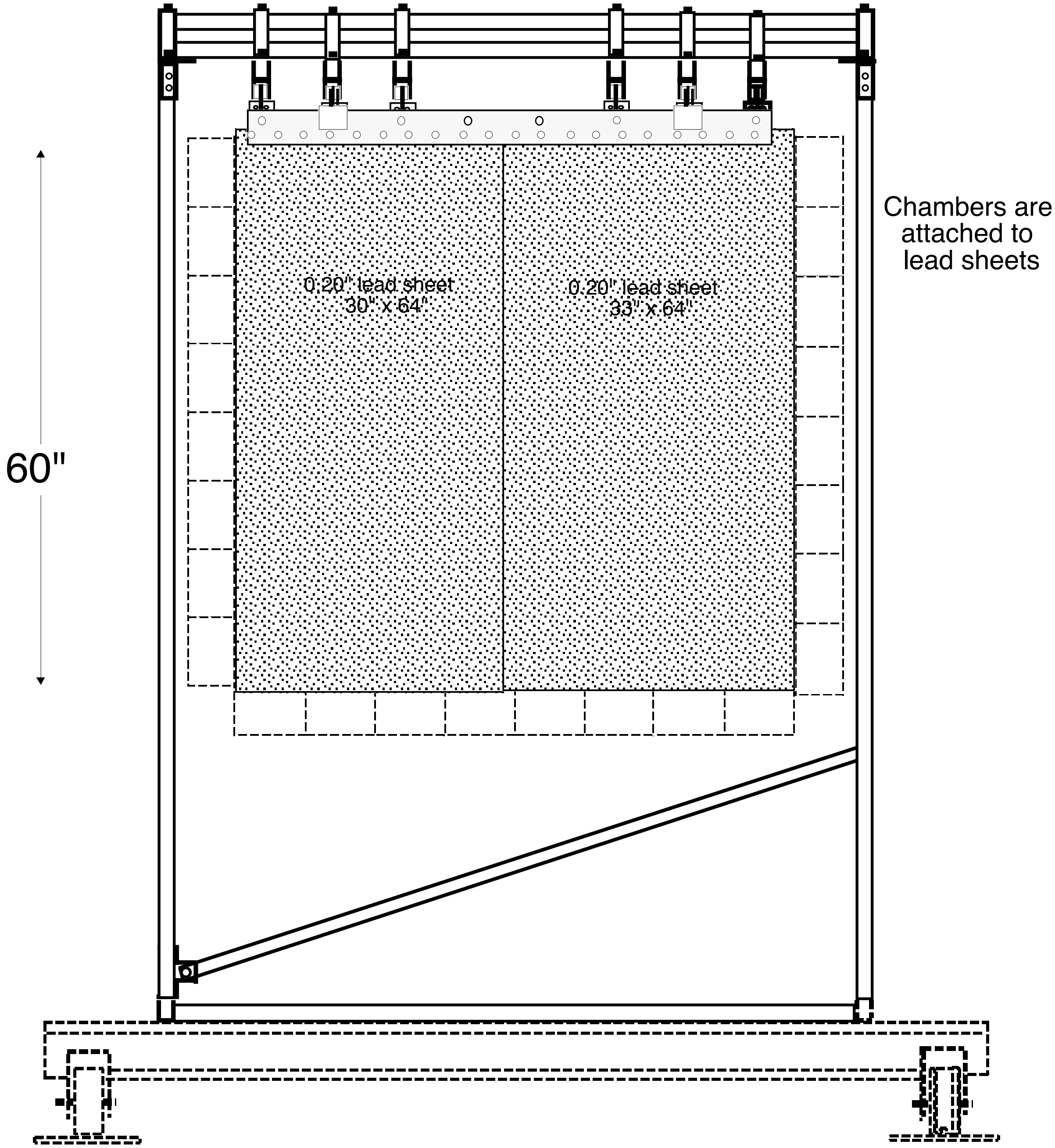

Figure 5: Front view of the EMCAL

Progress Summary

The project is on track to meet its technical milestones, though the overall schedule at Fermilab has slipped. The electromagnetic calorimeter and the hadron calorimeter are both assembled and are undergoing testing. The hadron calorimeter and electromagnetic calorimeter, both ready for testing with beam in December 2003, are shown in Fig. 6.

Figure 6: The hadron calorimeter (left) and electromagnetic calorimeter (right) in the beam line at the Meson Laboratory, ready for final testing with beam.

We have also tested a small version of the detector and readout using cosmic rays. We expect some test beam in December and long periods of test time and data taking during 2004.

Personnel

Michael J. Longo, Professor of Physics at the University of Michigan, is the Principal Investigator. He has overall responsibility for the design, assembly, and testing of the apparatus. He is receiving 2 months summer salary from the grant.

Dr. Richard Gustafson, Senior Research Scientist is responsible for the electronics. He is receiving one month's salary from the grant.

In November 2002, we hired postdoctoral scientist, Durga Rajaram, to work on the project. Dr. Rajaram had recently received his Ph. D. from the Illinois Institute of Technology, and was very familiar with Fermilab since he had done his thesis experiment in the same beam line. Since then he has been working fulltime on the project and is based at Fermilab.

Postdoctoral scientist Dr. Hyangkyu Park, also posted at Fermilab, is working approximately half time on the project.

A University of Michigan senior technician, Helmut Schick, worked on the design of the EMCAL for several weeks.

A part-time technician, George Flanagan, worked several months in 2003 on the project at Fermilab. Undergraduate students Peter Florczak and Thomas Nelson worked on it for 3 months in the summer. We also benefited from summer help from Dr. C. Durandet.

Publications

(None)