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### Abstract

We present results from test beam measurements at SLAC with prototype modules for the MAC detector at PEP. The modules consist of planes of proportional wires interleaved with lead sheets (shower counter) or iron plates (hadron calorimeter).

### Introduction

The use of electromagnetic shower and hadron calorimetry in large  $4\pi$  detectors for storage rings requires sampling energy deposition in many layers of large area. Considerations of economy, ease of construction, and convenience of operation suggest proportional wire chambers for this purpose.<sup>1</sup> This technique will be used in the MAC detector for PEP, and test modules have been constructed and operated in a test beam at SLAC to determine their performance in measuring the energy and position of electromagnetic and hadron showers. The measurements reported here were made with beams of electrons from 0.5 to 15 GeV/c, and negative pions from 1.0 to 15 GeV/c.

### Test Module Construction

Figure 1 shows details of the design and construction of the test modules. Planes of proportional wires

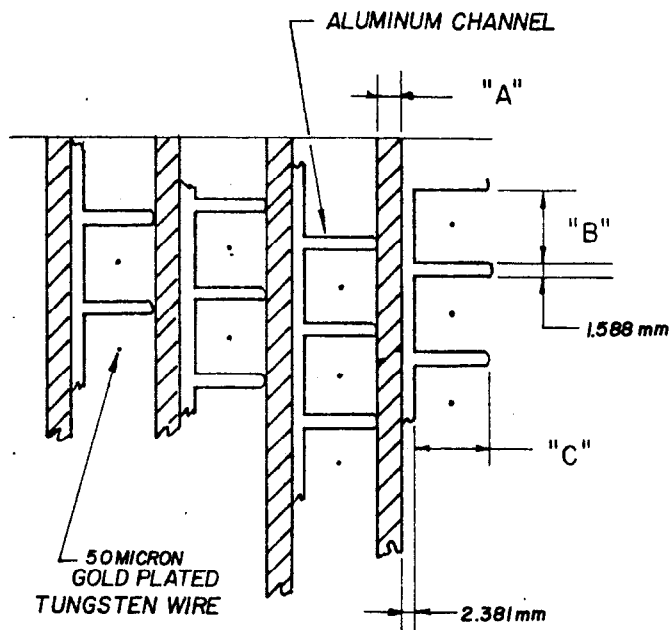


Fig. 1. Cross section showing internal detail of the modules. For the shower chamber, dimension "A" = 2.8 mm of typemetal (83% Pb, 12% Sb, 5% Sn), and "B" = "C" = 9.5 mm. For hadron calorimeter, "A" = 2.7 cm of steel, "B" = 1.75 cm, and "C" = 1.27 cm.

were layered between sheets of appropriate dense material: 0.28-cm-thick lead (type metal) for the shower counter, and 2.7-cm-thick iron for the hadron calorimeter. Each anode wire was strung in the center of an aluminum channel. With a sheet of lead or iron across the top, each channel forms an individual rectangular tube. This technique provides mechanical and electrical isolation between wires, mechanical rigidity, and uniform cathode spacing. Individual planes, each consisting of aluminum channels plus lead or iron top sheet, were isolated from each other by thin sheets of plastic and a resistor-capacitor network to prevent crosstalk of signals induced on the cathodes. For each module, the stack of such planes was enclosed in and electrically insulated from an aluminum box capable of being evacuated and filled with a desired gas mixture. The gas mixture used was 80% Argon + 20% CH<sub>4</sub>. The shower counter consisted of 36 planes, while the hadron calorimeter had 35. The active areas were about 30 x 30 cm<sup>2</sup> and 40 x 40 cm<sup>2</sup> respectively.

With the exception of two planes in the hadron calorimeter, all wires within each plane were ganged and read out together through a single external BNC connector. In the first and twenty-first planes of the hadron calorimeter, each wire was brought out individually to its own external BNC connector, to allow measurement of hadron shower profiles and position in one dimension. To make similar measurements on electron showers, a single separate plane was constructed, in its own gas-tight box. Various numbers of lead sheets could then be stacked in front, with thickness and spacing to match the shower counter. This plane was strung with 20-micron stainless steel wire, to provide high resistance. Each end of each wire was brought out to its own external BNC connector so that position along the wire could be determined from charge division.<sup>2</sup>

### Operation In Test Beam

Beam tests were performed in SLAC Beam Line 6, a secondary particle beam which can be tuned to enhance electrons or pions by varying both the production angle accepted and the amount of lead absorber at one focus. The beam was defined by two small scintillation counters followed by a large helium-filled differential Cerenkov counter to tag the desired particle type. For these tests the beam momentum was varied from 0.5 GeV/c to 15 GeV/c, but a usable fraction of pions was only attainable at 1 GeV/c and above. In addition to beam tests, calibration runs were made with cosmic-ray muons by orienting the modules nearly vertical and triggering on a coincidence of scintillation counters placed on either end.

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All wires in all modules were operated at ground potential, with the surrounding metal at negative high voltage. Signals from the modules travelled over about 23 m of coaxial cable (RG-58) to a set of low-input-impedance integrating charge amplifiers.<sup>3</sup> The amplified integrated signals were digitized by a CAMAC system of ADC's (LeCroy 2248 and 2249 modules). On each event, the CAMAC crate was read by a micro-computer<sup>4</sup> which transferred the data to the SLAC triplex computer system for storage and later analysis. The microcomputer allowed on-line analysis and print-out both during and after a run.

### Results

#### Shower Chamber

Figure 2(a) shows an example of the total response of the shower chamber to electrons. The beam momentum in this case was 4 GeV/c, and the quantity histogrammed is the sum of signals from all 36 individual planes, appropriately corrected for pedestal and gain variations in the ADC's. The measured resolution is  $\sigma = 8.5\%$ . Results for other electron momenta are plotted in Fig. 3. The resolution as a function of momentum is well represented by  $\sigma = 17\%/\sqrt{P_e}$ , as shown on the plot.

Figure 2(b) shows, for comparison, the total shower chamber signal for pions of 4 GeV/c. Clearly if the particle momentum is known, a cut on pulse height alone

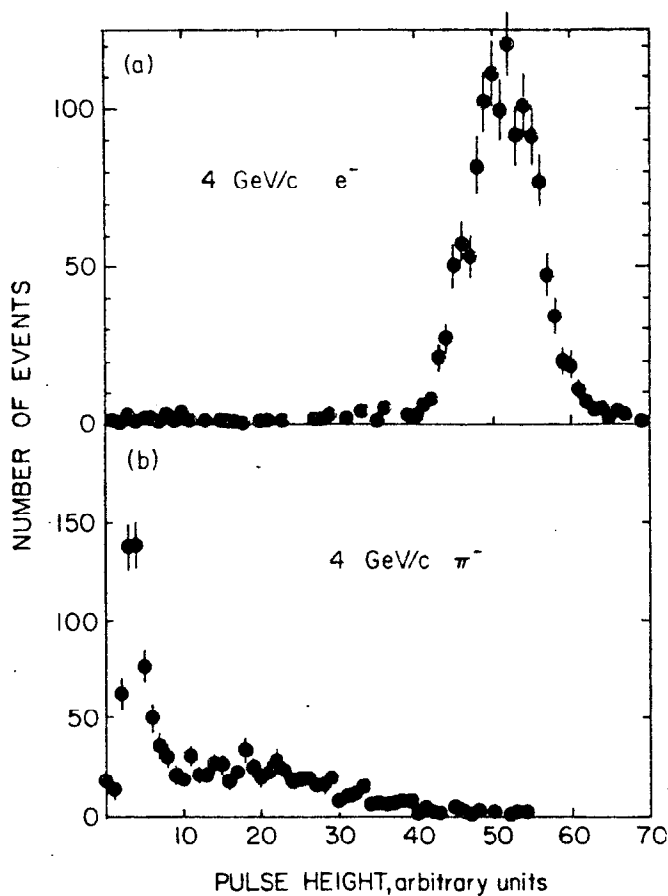


Fig. 2. Shower chamber pulse height spectra for the sum of all 36 planes, with incident 4 GeV/c electrons and pions.

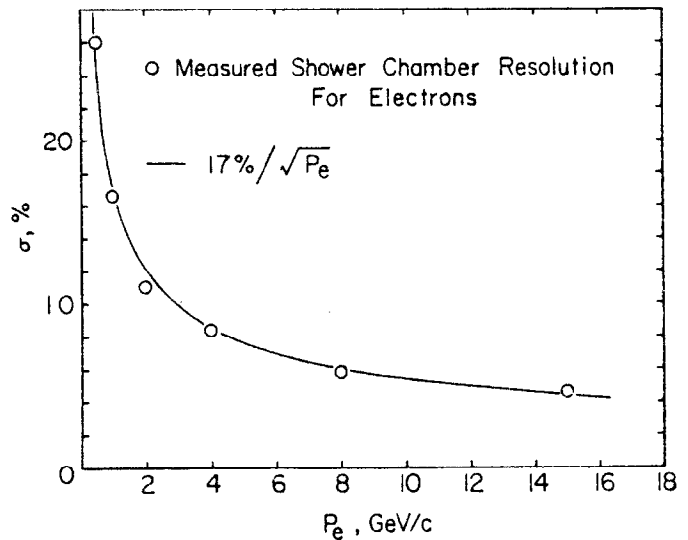


Fig. 3. Measured shower chamber resolution as a function of electron beam momentum.

gives a sizable rejection against hadrons in this device. Further rejection, largely independent of momentum measurement, is possible from the longitudinal shower development information available from this chamber. For example, Fig. 4 shows the average signal per plane as a function of plane number in the stack, starting from the front, for 4 GeV/c electrons and pions.

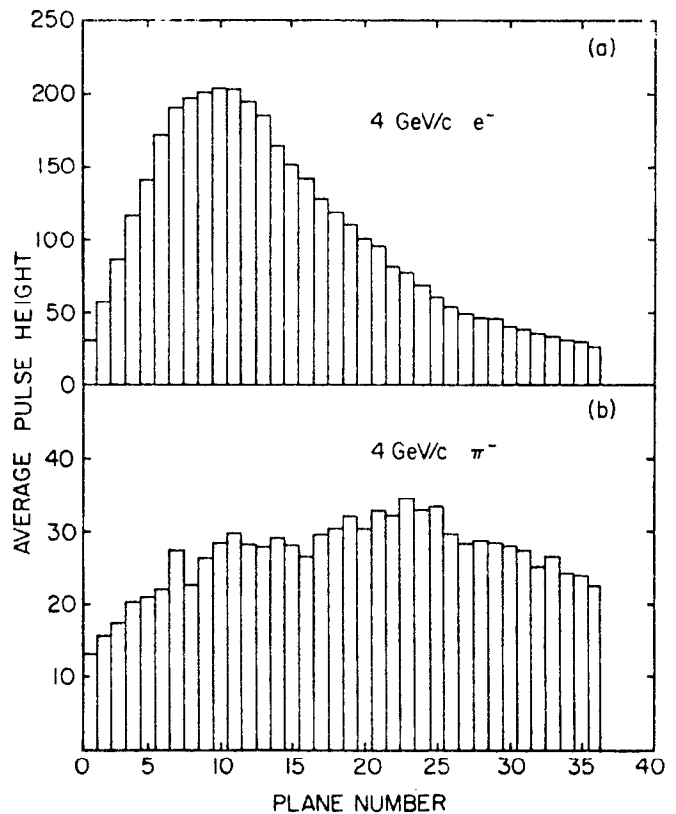


Fig. 4. Average longitudinal distribution of signals from shower chamber planes for 4 GeV/c electrons and pions.

Figure 5 shows information provided by individual wires in a single chamber plane. The data shown were taken with 4 GeV/c electrons incident on a stack of lead sheets followed by the separate single-plane chamber described above in Section II, with wires oriented horizontally. There were a total of 13 lead sheets 2.8 mm thick (0.5 radiation length) spaced about 1.2 cm apart. The wire spacing was 1.11 cm. Figure 5(a) shows the average vertical profile of the observed showers. The FWHM of the distribution is 2.7 cm, and includes a beam width of ~ 1 cm. Figure 5(b) is a histogram of the profile centroid, event-by-event. The full width here is about 2.0 cm, again including beam width. Figure 5(c) shows a histogram of the shower position along the wire direction, determined from the splitting of the signal on each wire between low impedance amplifiers at either end.<sup>2</sup> The resolution is comparable to that obtained in the other dimension. Better position resolution in both dimensions should be possible by sampling more than one plane.

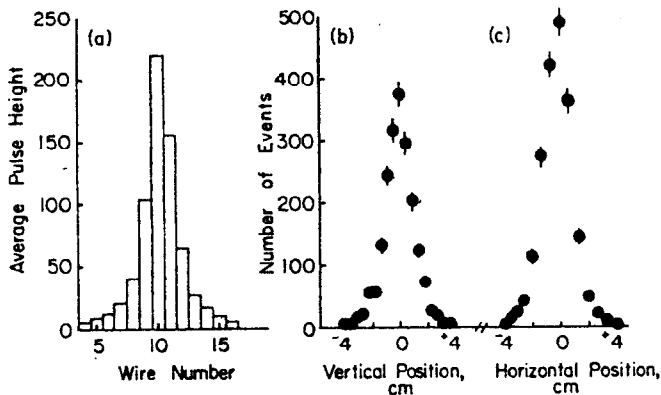


Fig. 5. (a) Average transverse distribution of signals across the wires (1.11 cm spacing) in a single shower chamber plane at a depth of 6.5 radiation lengths, with 4 GeV electrons. (b) Histogram of the vertical position determined for each shower by the centroid of the distribution of signals across the wires. (c) Spectrum of horizontal shower position, determined by the ratio of signals at opposite ends of each wire.

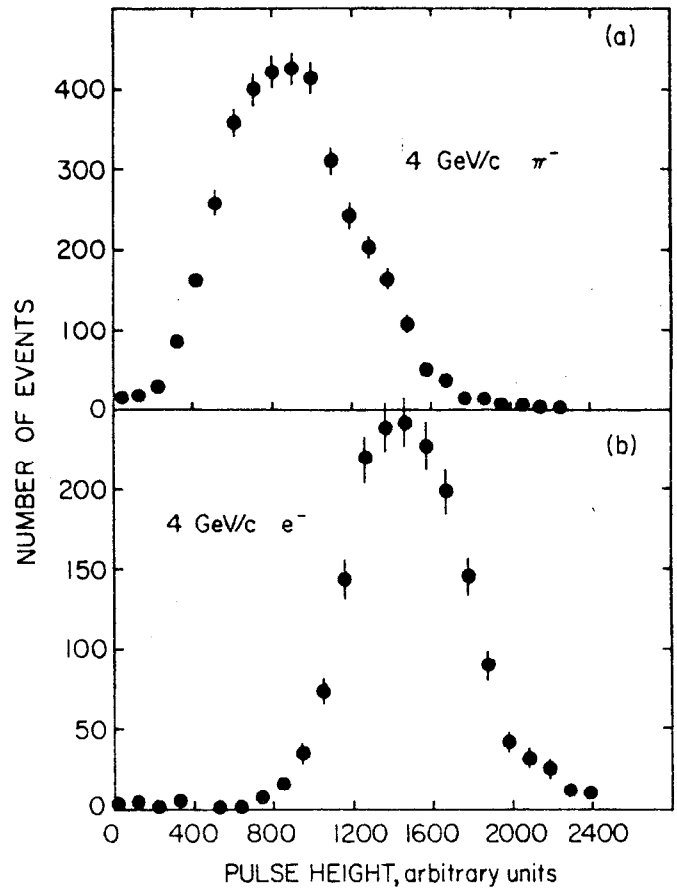


Fig. 6. Hadron calorimeter pulse height spectra for the sum of all 35 planes, with incident 4 GeV/c pions and electrons.

#### Hadron Calorimeter

The response of the hadron calorimeter module is shown in Fig. 6 for incident pions and electrons at 4 GeV/c. All 35 planes have been summed. Due to the greater fluctuations and lower average visible energy inherent in hadron showers, the energy resolution possible for hadrons is considerably poorer than for electrons. Figure 7 shows the resolution for pions obtained at beam momenta of 1, 2, 4, 8 and 15 GeV/c. The results may be represented roughly by  $\sigma = 75\%/\sqrt{P_\pi}$ , plotted for comparison. The energy resolution for electrons is given approximately by  $\sigma = 40\%/\sqrt{P_e}$  for this device.

As with the shower chamber, some discrimination between hadrons and electrons (or photons) is possible by observing shower development. The longitudinal

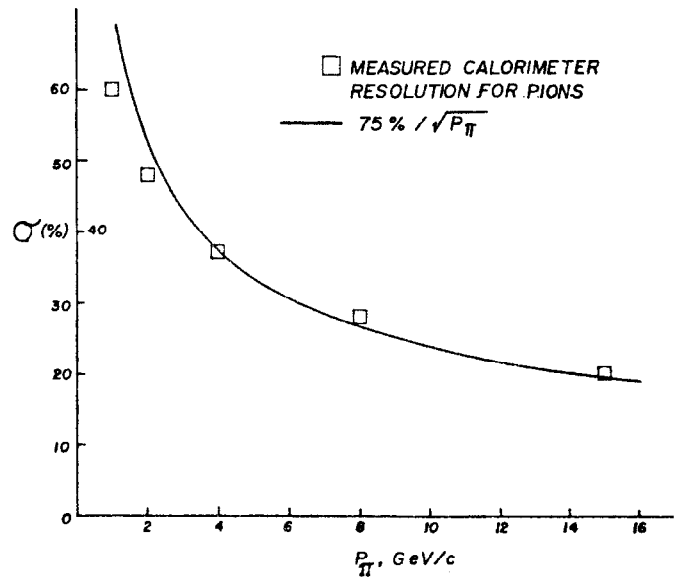


Fig. 7. Measured calorimeter resolution as a function of incident pion momentum.

distributions of energy deposition in the calorimeter for  $\pi^-$  and  $e^-$  at 4 GeV/c are shown in Fig. 8.

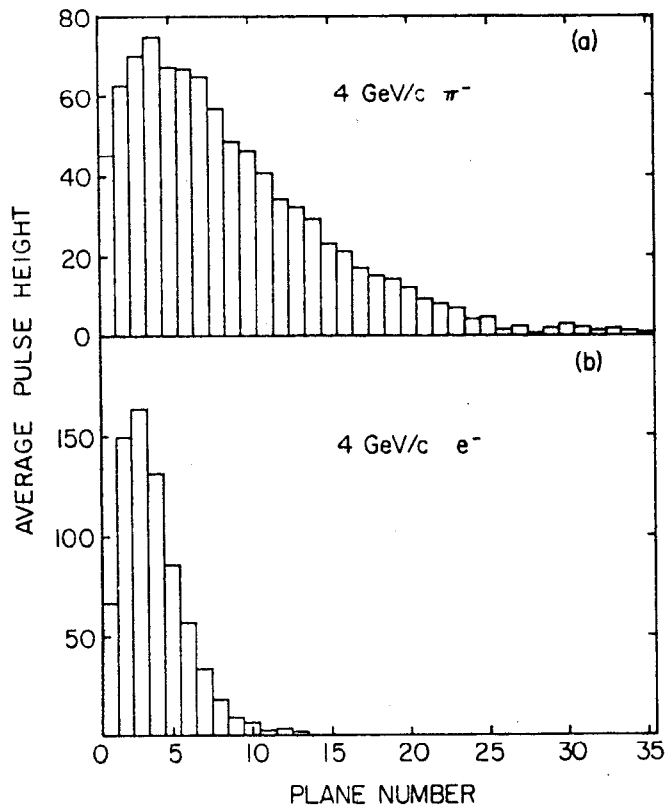


Fig. 8. Average longitudinal distributions of signal from hadron calorimeter planes for 4 GeV/c pions and electrons.

Figure 9 shows hadron shower profile and position measurements using the first calorimeter plane with individual wire readout. The wire spacing was 1.9 cm. For the data shown, 30 cm of iron were stacked in front,

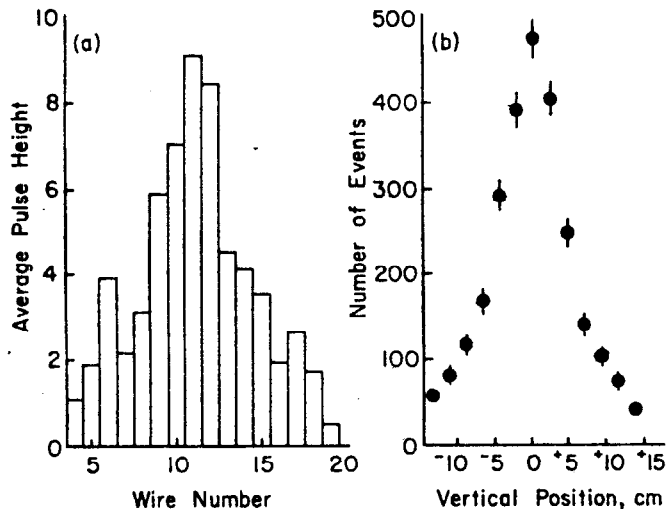


Fig. 9. (a) Average transverse distribution of signals across the wires (1.9 cm spacing) of the first hadron calorimeter plane, with 30 cm of steel in front and incident 4 GeV/c pions. (b) Spectrum of vertical shower position determined from the centroid of the transverse distribution for each event.

and the beam particles were 4 GeV/c  $\pi^-$ . Figure 9(a) shows the average distribution of signal across the wires, and Fig. 9(b) is a histogram of the centroids of such profiles event-by-event. The position resolution so obtained is 9.6 cm (FWHM), compared to a full width for the average profile of about 12 cm.

#### Summary

Construction and operation of shower counter and hadron calorimeter modules using proportional wire chambers have shown this to be a very practical technique. The chambers described here are simple and inexpensive to build, and have proved rugged, reliable and convenient in operation. Considerable readout flexibility is possible in the ganging of wires and planes. The energy resolutions achieved are adequate for a wide range of applications.

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