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Test of a ZEUS BCAL Module Including Presampler and Shower Max Detector in a Low Energy Beam

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Abstract

Two possible upgrades, a shower max detector and a presampler, designed to improve the low energy electron/hadron separation capabilities of the ZEUS barrel calorimeter are described. Testbeam results are reported.

I. Introduction

ZEUS, one of two detectors at the storage ring HERA at DESY in Hamburg, intercepts the products of collision between 27 GeV electrons and 820 GeV protons. A major component of the ZEUS detector is the compensating, uranium/scintillator calorimeter which is divided into three parts, the forward, rear and barrel calorimeters. The barrel calorimeter, or BCAL, is itself composed of 32 modules. Each module is divided into an electromagnetic section (EMC), one interaction length deep (21 Xo), and two hadronic sections (HAC1 and HAC2), each two interaction lengths deep. [1]

Besides providing energy measurements of electrons and jets, the BCAL can also be used for electron/hadron separation. The standard way to do this, is to exploit differences in electron and hadron shower shapes. The electron shower occurs earlier in the calorimeter, is narrower, and is contained in the EMC section of the BCAL, while the hadron shower is later, broader, and deposits most of its energy into the HAC's. This method is not efficient at lower energies where the hadrons also often deposit a sizeable fraction of their energy into the EMC section.

II. Two Possible Solutions

For 2 GeV electrons, their shower maximum occurs after they have traversed about four radiation lengths of matter. Something in the detector sensitive to shower activity, placed after four radiation lengths, would give a second handle on identifying these low energy electrons.

In the EMC section of the BCAL, between the third and fourth layers of uranium, (one layer of uranium is 1 Xo thick) a space was provided for just such a shower max detector. For ZEUS, the shower max detector is called a Barrel Hadron Electron Separator, or BHES for short. The type of shower max detector proposed as an upgrade to the BCAL is a multi-wire proportional chamber, with wire and pad read-out. [2]

The mechanical support for the BHES is a three sided, aluminum, box with rectangular grooves in which the wires are strung. The wires run parallel to the beam axis providing measurement of the phi coordinate. The separation between adjacent wires is 0.68 cm. The pads are on the circuit boards which close the aluminum box. The pads are perpendicular to the wires and so provide information on the theta coordinate. The separation between centers of adjacent pads is 1.74 cm.

Another possible handle on identifying lower energy electrons is provided by a presampler (PRE). Between the ZEUS interaction point and the BCAL modules, there is a superconducting coil that provides the magnetic field for the detector. This coil is about one radiation length thick, and so the low energy electrons are much

more likely to start showering in this coil than are the low energy hadrons. A layer of scintillator tiles between the coil and BCAL would show a multi-mip signal for the showered electrons and a single mip signal for the unshowered hadrons, thus providing discrimination between the two.

III. Testbeam Set-up

Beam tests of the two possible upgrades to the BCAL, the BHES and the presampler, were done at the Brookhaven National Laboratory AGS testbeam using a prototype module that is the same in essential characteristics to the production version. The BHES was inserted into the prototype BCAL module and the presampler was placed between a mock aluminum coil and the module. Data was taken with electrons and pions in the energy range of 1 to 6 GeV. A schematic of the trigger is shown in Figure 1. Scintillator counters S2, S3, Sa and Sb were used to define the beam, and C1 and C2 were Čerenkov counters used to select electrons or pions. The prototype BCAL module was mounted on a stand (the muon stand) that allowed the module to be positioned either in the horizontal or vertical direction with an accuracy of 0.5 mm.

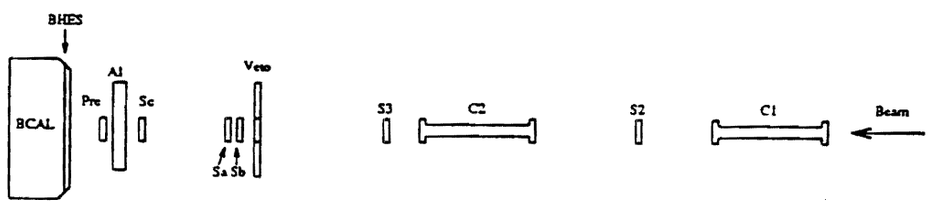

Figure 1 : Schematic layout of the testbeam trigger counters.

IV. Data Analysis

The BHES measures shower activity by means of the ionization produced by the particles in the shower traversing the volume of gas flowing through the BHES. This ionization charge is collected on the wires and pads. To be less sensitive to the noise in the BHES detector coming from the uranium radioactivity, a minimum charge

cut Qmin was used. For a Qmin from 0.01 to 0.1 picocoulombs, the signal from the showering particles was larger than these values.

Two quantities were used in the analysis. The first was the number of wires per event with charge above Qmin. A histogram of this quantity for a central energy of 3 GeV is shown in Figure 2(a) for electrons and in Figure 2(b) for pions. If all events with more than one wire with charge above Qmin are called electrons, then this cut keeps 97.1% electrons for a pion contamination of 26.9%.

The second quantity is the total charge deposited per event. This is shown for both 3GeV electrons and pions in Figure 2(c). If the cut is placed at 0.35 Picocoulombs, then for an electron efficiency of 91.5% there is a pion contamination of 10.0%. The two cuts combined give an electron efficiency of 90.4% for a pion contamination of 8.4%.

The last step in the BHES analysis is to include data from the BCAL itself. To discriminate between electrons and pions using the BCAL, a cut was made on the fraction of the total energy deposited in the EMC sections. The numbers from combining the cuts, as well as the numbers for the BHES and BCAL separately, are shown in Figure 4 for 90% electron efficiency and in Figure 5 for 75% electron efficiency for beam momenta between 1 and 6 GeV. For example, at 3 GeV, combining the two cuts reduces the pion contamination at 90% electron efficiency from 6.2% without the BHES, to 3.2% with the BHES. At 75% electron efficiency, the pion contamination of 3.2% with the BCAL only, is reduced to 0.9% when the BHES is included.

In particular, at 1 GeV for an electron efficiency of 75%, the pion contamination is cut from 15.8% to 6.4% when the BHES is combined with the BCAL.

A similar analysis was done using the presampler data. The presampler signal for 3 GeV electrons and pions is shown in Figure 3. The final numbers for 75% electron efficiency are shown in Figure 6, for PRE alone, BCAL alone, and PRE and BCAL combined. The improvement in electron identification with the presampler over with the BCAL alone is a factor of about two to three.

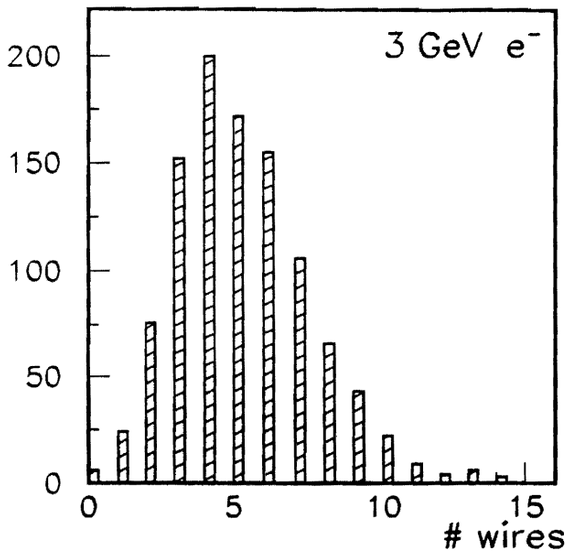

Figure 2a. Number of wires per event with charge above Q_{MIN} for 3 GeV e^-

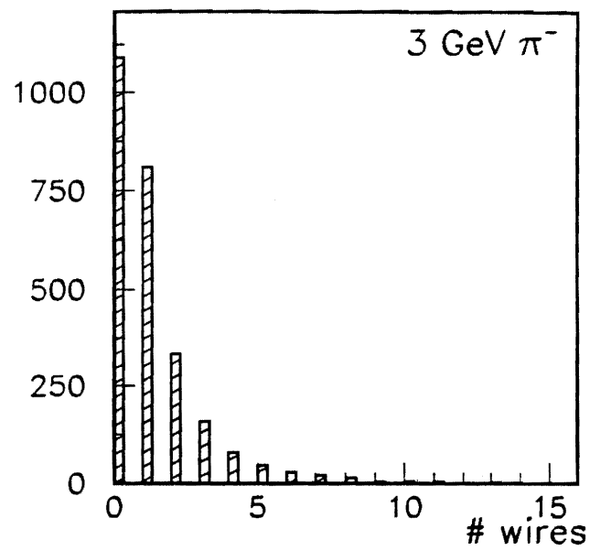

Figure 2b. Number of wires per event with charge above Q_{MIN} for 3 GeV π^-

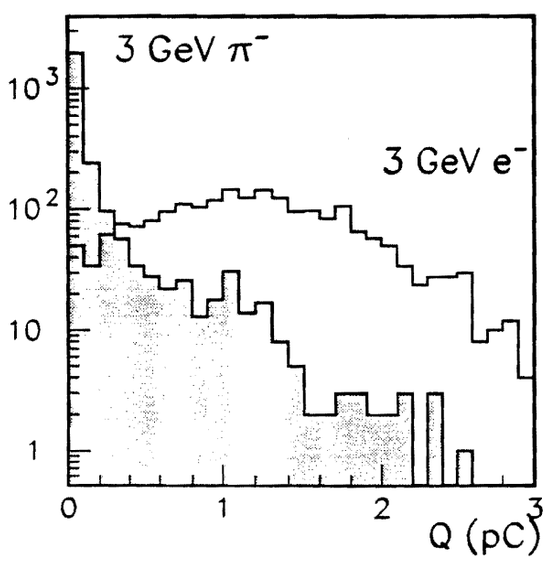

Figure 2c. Total charge deposited on the wires for 3 GeV e^- (open) and 3 GeV π^- (shaded histogram)

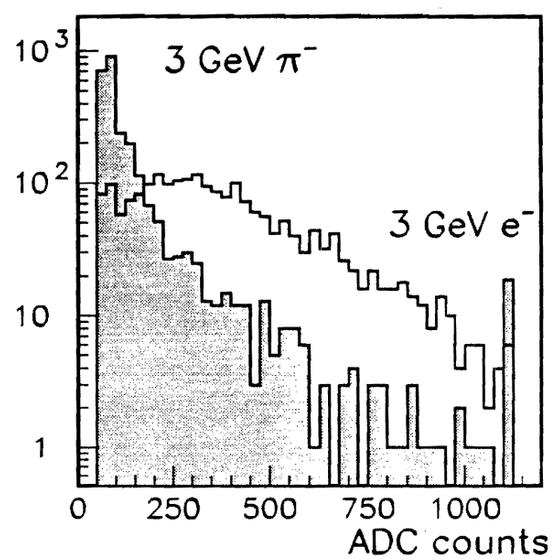

Figure 3. PREsampler pulse height for 3 GeV e^- (open) and 3 GeV π^- (shaded histogram)

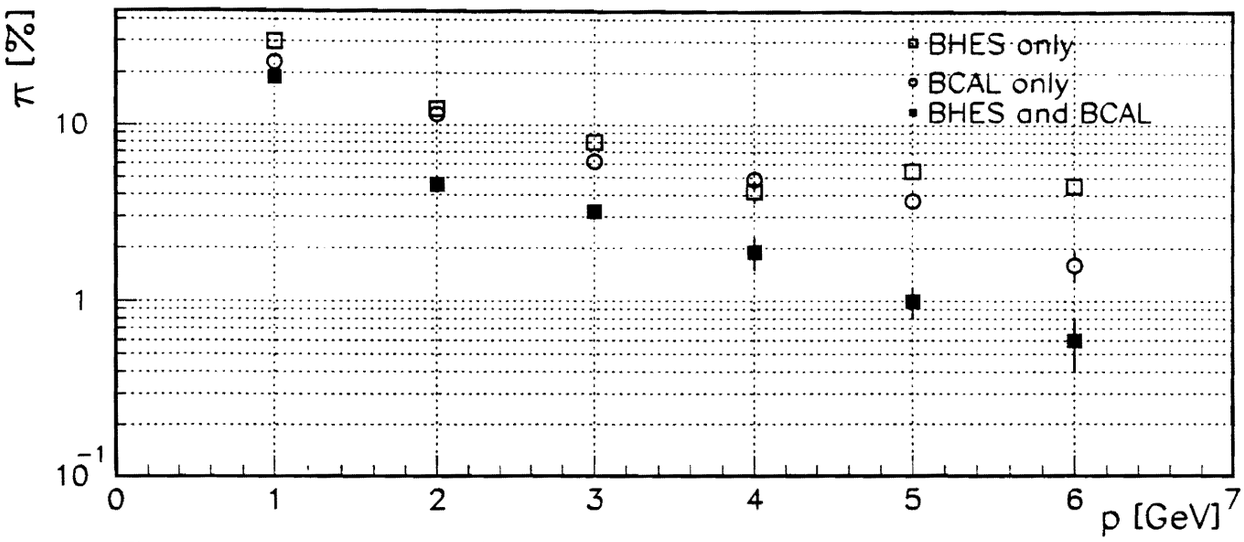

Figure 4. π^- contamination for 90% e^- efficiency for beam momenta between 1 and 6 GeV using the BHES and the BCAL.

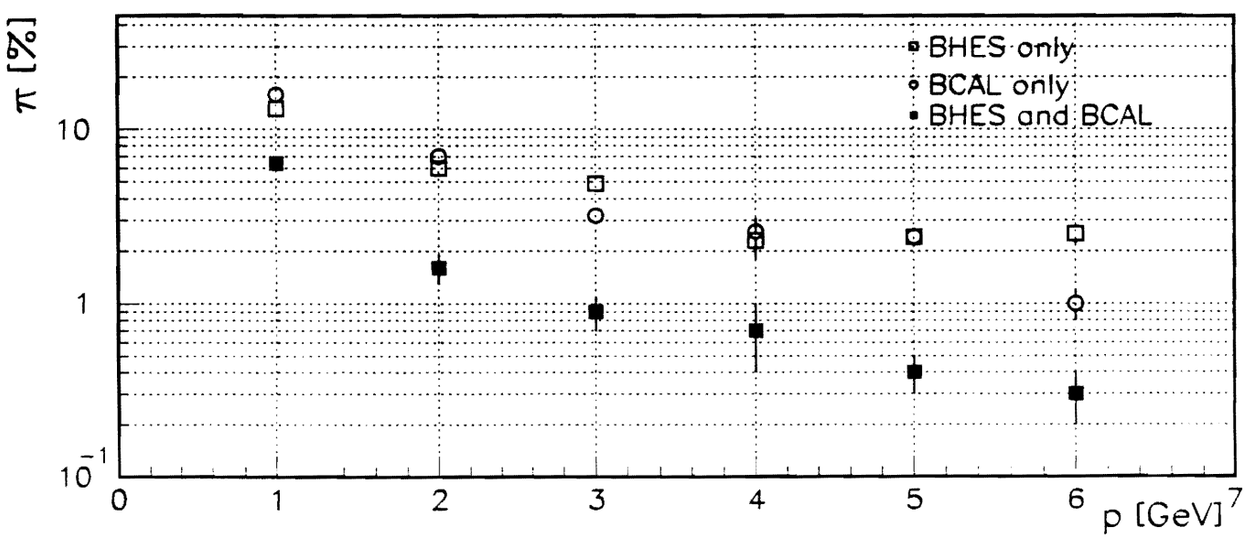

Figure 5. π^- contamination for 75% e^- efficiency for beam momenta between 1 and 6 GeV using the BHES and the BCAL.

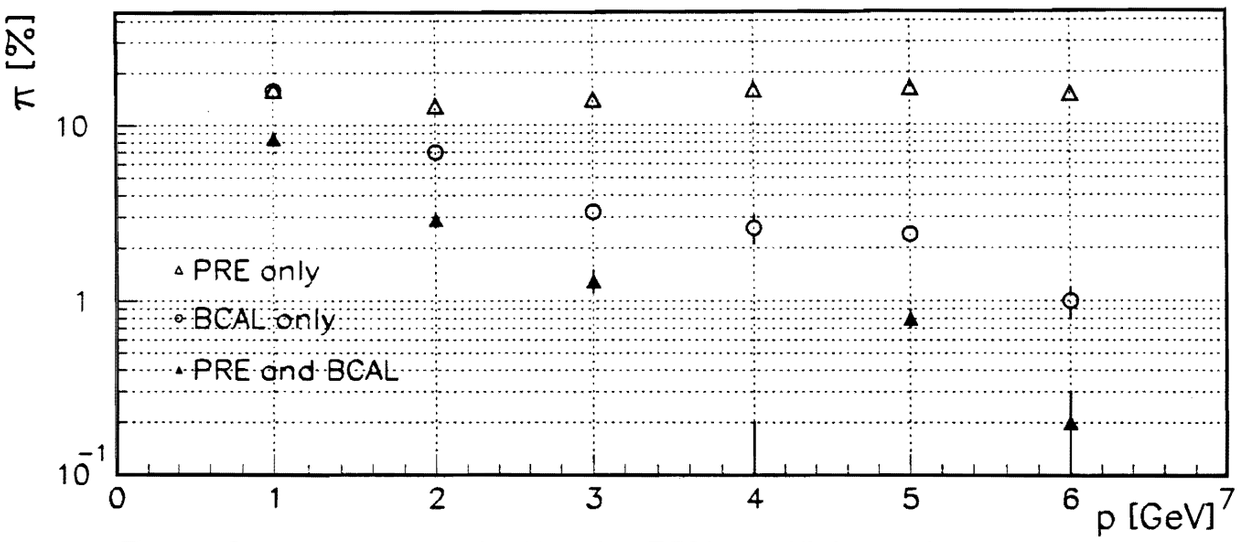

Figure 6. π^- contamination for 75% e^- efficiency for beam momenta between 1 and 6 GeV using the PRE and the BCAL.

V. Position Resolution

The BHES also improves the position resolution of electromagnetic showers in the BCAL. The front face segmentation of the BCAL module is (4.9cm) x (23.3cm). In the 4.9 cm dimension, energy sharing between towers is used to find the position (the theta coordinate), and in the 23.3 cm dimension, the position (the phi coordinate) is estimated from energy sharing between phototubes that read out on opposite sides of the same tower. For the BHES, the position is obtained from the charge weighted average for both the wires and pads. The finer segmentation of the BHES, described in section II, produces a position resolution improved by about a factor of three, as seen in figures 7(a) and 7(b). For 1 and 2 GeV, the electron showers were confined to one tower, and so energy sharing between towers could not be used to find the theta coordinate.

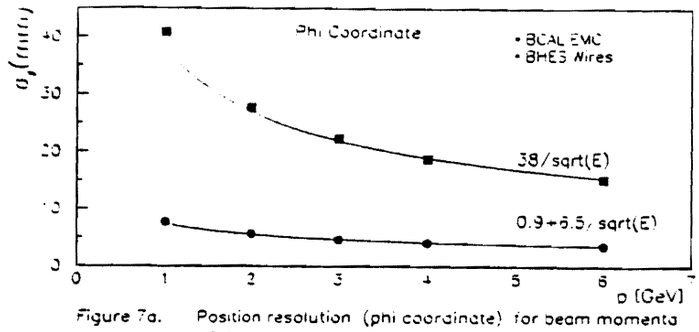

Figure 7a. Position resolution (phi coordinate) for beam momenta between 1 and 6 GeV using the BHES and the BCAL.

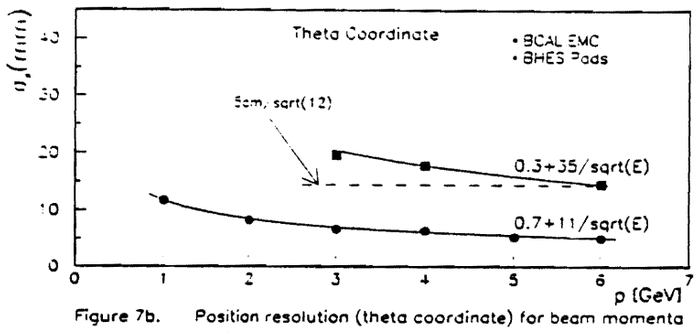

Figure 7b. Position resolution (theta coordinate) for beam momenta between 1 and 6 GeV using the BHES and the BCAL.

VI. Conclusion

The primary purpose of the testbeam was to see how and by how much the electron identification capabilities of the BCAL could be improved. The results are:

****The BHES improves the electron identification capabilities of the BCAL by a factor of 2 to 3, which is especially important at 1 and 2 GeV, where the pion contamination is large.

****If 75% electron efficiency is acceptable, then the PREsampler is also a good tool for separating electrons and hadrons.

****Lastly, the position resolution of electromagnetic showers in the BCAL is significantly improved by the BHES.

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