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USE OF A CATHODE READ-OUT MULTIWIRE PROPORTIONAL CHAMBERFOR SEPARATION OF ELECTROMAGNETIC AND HADRONIC SHOWERS

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ABSTRACT

Data are presented for separation of showers produced by 1 - 4 GeV/c incident electrons and pions after the traversal of ~ 1 radiation-length of aluminium. The use of a cathode strip read-out multiwire proportional chamber and a scintillation counter is shown to improve the rejection obtained with lead-glass counters, giving as much as a factor of 80 at 50% detection efficiency. The parameters of the chamber are : cathode plane to plane gap 1.2 cm, wire spacing .2 cm, width of the cathode strips 1 cm, interstrip .2 cm, sensitive area of the chamber $20 \times 20 \text{ cm}^2$.

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1. Introduction

Previous studies¹⁾ have shown the effectiveness of lead-glass total absorption Čerenkov counters in separating pions from electrons. Further work^{2,3)} indicated that shower sampling with scintillation counters and MWPC's placed after an absorber could enhance this separation. Recently Charpak et al⁴⁾ have shown that a single MWPC with read-out of the cathode strips can achieve a two-dimensional reconstruction of the centroid of the induced charges. The aim of the present work was to use a similar chamber with wider strips, to provide shower localization and improved hadron rejection for the CCOR⁵⁾ experiment at the CERN ISR.

2. Experimental set-up

Figure 1 shows the experimental arrangement in a test beam at the CERN PS. The incident pions and electrons with momenta up to 4 GeV/c were tagged by the two Čerenkov counters $\check{C}_1$ and $\check{C}_2$ and triggered the scintillator coincidence $B_1 S_1 F_1 F_2$ which defined a narrow beam of about 1 cm^2 . The anti-coincidence counter in front of S_1 and the pulse height of S_2 were used to define single incident particles. These particles produced showers in an absorber of one radiation length of aluminium (plus small amounts of vetronite, mylar and steel) which reproduced the material seen by particles traversing the CCOR solenoid coil⁵⁾. The absorber could be removed to study the chamber behaviour with single particles. The shower energy was measured in an array of four $15 \times 15 \text{ cm}^2$ lead-glass counters of length 35 cm, while the multiplicity of the shower was sampled by the S_2 counter. The chamber was placed directly behind S_2 and the pulse heights of all strips and of S_1 , S_2 , $\check{C}_1$, $\check{C}_2$ and the lead-glass were recorded by a small on-line computer via CAMAC.

3. The cathode read-out chamber

The MWPC with cathode strip read-out (STC) was built at the Rutherford Laboratory with the following parameters : total sensitive area $20 \times 20 \text{ cm}^2$, cathode plane to plane gap 1.2 cm, wire spacing 0.2 cm, strip width 1.0 cm, interstrip spacing 0.2 cm. (The tests were done, however, using only $15.2 \times 15.2 \text{ cm}^2$). The gas used was a $\sim 50\% \text{ Ar} - 50\% \text{ CO}_2$ mixture. Each strip was connected to a fast amplifier developed

at CERN⁶⁾, located on the chamber, then to a second stage amplifier (gain ~ 5) and to a commercial 10 bit fast CAMAC ADC. The gate width could be as short as 50 - 100 ns.

The 100% efficiency plateau started at $\sim + 4.3$ KV, and the STC operated safely up to $+ 4.8$ KV before entering the Geiger region. The chamber was found to have a uniform response over its sensitive surface. The mean pulse height from the strips (ADC counts with pedestal subtracted) was constant to within $\pm 6\%$ from strip to strip, including both chamber and electronics variations. The gain on the two planes with cathode strips parallel and perpendicular to the sense wire was equal to within 10%. Figure 2 shows the mean pulse height versus applied high voltage for single ionizing particles of 2 GeV/c on the central strip and its nearest neighbour. The FWHM of the measured ionization distributions were typically $\sim 90\%$. The STC pulse height was consistent with the formula⁷⁾ :

$$PH = \exp 2 \sqrt{a N q r_o} \left(\sqrt{\frac{V_o}{V_s}} - 1 \right)$$

N : Avogadro's constant

a : constant for the gas used

r_o : radius of the sense wire

where : V_o : applied high voltage

V_s : threshold voltage

and $q \propto V_o/2 \ln \frac{\sinh (\pi l/s)}{\sinh (\pi r_o/s)}$ l : cathode to sense wire
s : wire spacing

At $+ 4.5$ KV, the adjacent strip had $\sim 30\%$ of the pulse height of the central strip, most of this being due to the width of the beam as defined by the $B_1 S_1 F_1 F_2$ coincidence. With a narrow beam, the adjacent strip pulse height was $< 10\%$ of the central strip for both horizontal and vertical strips.

4. Basic Shower Information

A shower produced by a pion or an electron was defined as a particle which traversed the S_1 counter giving single ionization, interacted in the absorber and deposited energy in the lead-glass (see 5.). In addition, it was required to have a pulse height of more than 1.8 times the single-ionizing peak (hereafter SIP) in S_2 . Figures 3a and 3b show the pulse height information from the S_2 counter for electrons and pions, respectively.

The raw pulse heights from the STC were required to exceed a minimum pulse height, usually 20 counts above pedestal, to avoid noise and pedestal jitter. For a run at 2 GeV/c, the total pulse height on all strips, the width of the shower (gap between first and last strip in the shower), and the number of strips in the shower are plotted in Figs. 4a, 4b, 4c. There is a clear difference between the electrons and pions both in the analogue (i.e. pulse height) and digital information (spread and number of strips firing) reflecting primarily the lower number of particles in the pion showers.

With the trigger covering $\sim 1 \text{ cm}^2$, the spread of the calculated centre of the induced charges for single particles had a σ of 0.5 cm. The shower centres could be reconstructed with a σ of 1.4 cm for all electrons and 1.2 cm for all pions. These σ 's were 1.5 and 2.2 cm for, respectively, electrons and pions with more than 1.7 SIP in S_2 . Even with this requirement the pion sample includes a significant number of non-interacting particles (see Fig. 3b) which have a narrow distribution of the reconstructed centres, superimposed to the very asymmetric real pion showers which have a broad distribution. The STC was ~ 18 cm from the end of the absorber.

Figure 5 shows the variation of the mean pulse height on the central and adjacent strips as a function of the incident particle momentum for pions and electrons. The ratio of central strip pulse height for electrons as compared to pions is about 2.2 at 1 GeV/c and 2.9 at 4 GeV/c. This difference is due to the increase with momentum of both shower multiplicity and bremsstrahlung losses.

5. Separation of Electron and Pion Showers

The main contribution to pion rejection was expected to come from the requirement that the energy deposited in the lead-glass counter be approximately equal to the momentum of the particle. Additional rejection from the chamber was found to be relatively insensitive to the exact energy requirement from the lead-glass. Hence, analysis was done on runs taken with, in addition to the normal trigger $BS_1F_1F_2$, an extra hardware requirement that the sum of the pulse heights in the four LG blocks exceed a threshold set at 50% of the incident momentum (e.g. 1 GeV/c threshold for 2 GeV/c particles). No further cuts were made on the glass energy. Runs at 2 GeV/c taken without the glass in the trigger showed that this loose requirement on the lead-glass energy cut the pion sample by a factor of ~ 22 with no loss in electron efficiency.

Further rejection could be found from the differences in both the multiplicity and geometry of electron and pion showers. The effectiveness of a multiplicity cut with a given detector was sharply dependent on the resolution and Landau tail of the single-ionizing distribution. (Fig. 3). The good resolution of S_2 made a cut on the pulse height very powerful for rejecting pions although a substantial fraction of the large pulse height pion events still came from the tail of the distribution of single, i.e. non-showering pions. As an example, requiring $S_2 > 1.8$ SIP left 81% of the electrons and 9% of the pions, an additional rejection factor of 9 (where rejection R is defined as the ratio of electron efficiency over pion efficiency).

As is well known, for a given thickness of material traversed, the Landau⁸⁾ tail of the ionization distribution is larger in gases than solids, due to a factor of $\sim 10^3$ in densities. Thus the STC had a broader pulse height distribution compared to the solid scintillator and hence less resolution. For example, at 2 GeV/c a pulse height cut at 2.5 SIP in both planes left 81% of the electrons and 15% of the pions, an additional rejection of ~ 6 . This could, however, be further improved by taking into account geometrical factors such as the width of the shower (Fig. 3b) or the density of particles in the central core³⁾. Figure 6 gives the pulse height profiles on one plane for electron and

pion showers summed over many events. The pion pulse height is normalized by a factor of 2.5 to equal the electron pulse height on the central strip in order to emphasize the difference in the geometry of the showers.

In the sample of all showers ($S_2 > 1.8$ SIP) the pions were dominated by the singles and doubles and their showers look narrow. For $S_2 > 2.7$ SIP shown in Fig. 6b (68% of electrons and 2.2% of pions), it is obvious that the pion showers produced a larger fraction of their pulse height outside the central core (here three strips). This difference could be exploited simply by cutting on the percent of pulse height in core, or by using an algorithm derived from that of ref. 3, to weight the central strip pulse heights preferentially to the other strips.

$$A = M \frac{\sum_i ph_i / \Delta N_i}{\sum_i ph_i}$$

where ph_i = pulse height on strip i
 ΔN_i = number of strips from centre
 (=1 for centre three strips)
 M = multiplicity

The curves in Fig. 7 show the variation of rejection factor with electron efficiency for these various criteria. The associated pion efficiency is given trivially by e_{eff}/R .

It can be seen that for high electron efficiencies $\sim 80\%$, cuts on the STC information alone gave a rejection of 5 - 7 depending on the method used, while S_2 alone gave a factor of 9. This somewhat better rejection from S_2 was due to the better resolution of the solid as compared to a gas counter as explained previously. However, this apparent advantage would be lost under realistic experimental conditions. With large solid angle coverage, the STC could distinguish multiple showers which would be confused in a large scintillator array.

In addition, if lower electron efficiencies could be tolerated in a given experiment, the differences in shower geometries could provide further rejection. For example, at $\sim 50\%$ electron efficiency, the algorithm A was very powerful, giving on its own $R \sim 34$, and as much as 83 for an STC- S_2 combination.

6. Conclusion

The strip chamber prototypes used for this work were easy to construct and operate, giving 2-dimensional information from a single gap using relatively simple electronics. The STC could give an additional electron-hadron separation when used with lead-glass and scintillation counters, a factor ranging from 5 to as much as 83 for electron efficiencies from 80% down to 50% respectively. It also provided good shower localization and would have an important advantage over large scintillators due to the ability to separate multiple showers.

At present, we are building two STC's of $\sim 1.8 \times 2 \text{ m}^2$ sensitive area which will become a part of our present experiment.

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Figure captions

Fig. 1 : Experimental arrangement in a CERN PS test beam.

$\check{C}_1, \check{C}_2$: Čerenkov counters filled with air

$B_1, A, S_1, F_1, F_2, S_2$: scintillation counters

STC : MWPC with cathode read-out.

The coil is made of Al distributed over 16 cm and equivalent to one radiation length of Al (60 cm from the lead glass). The Fe plate is 3mm thick and simulates a magnetic shielding at the ISR.

Fig. 2 : Mean pulse height (ADC counts with pedestals subtracted) of the central and adjacent strips on one plane of the STC where the central strip is illuminated by the beam coincidence.

Fig. 3 : Pulse height of the S_2 counter for pions and electrons.

Fig. 4 : Total pulse height (a), width (b) and multiplicity (c) of hits on one plane of the STC for electron and pion showers.

Fig. 5 : Mean pulse height of pion and electron showers versus incident momentum.

Fig. 6 : STC mean pulse height on each strip for :
a) $S_2 > 1.7$ single ionizing peak (SIP),
b) $S_2 > 3.8$ SIP.

Fig. 7 : Curves of rejection versus electron efficiency for various cuts.

PH is obtained by cutting on the total pulse height of an STC plane, S_2 : cuts on the S_2 pulse height, ALG + PH combined cuts on the algorithm as given in section 5 and the total STC pulse height, $S_2 + ALG$: combined cuts on the algorithm and the S_2 pulse height.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7