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A ČERENKOV TOTAL ABSORPTION SHOWER COUNTER

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Черенковский спектрометр полного поглощения

Описан черенковский спектрометр полного поглощения, использовавшийся для регистрации рассеянных электронов в эксперименте по $\pi^- e$ рассеянию при энергии 50 Гэв.

Сообщение Объединенного института ядерных исследований
Дубна, 1973

Adylov G., Aliev F., Gajewski W., Ion I.,
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A Čerenkov Total Absorption Shower Counter

A Čerenkov total absorption counter is described, which was used for scattered electron detection in the experiment on $\pi^- e$ scattering at 50 GeV.

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Dubna, 1973

1. Introduction

An experiment to measure the electromagnetic size of the π meson was performed at the Serpukhov accelerator in 1970-1971 /1/. One part of the experimental setup was a Čerenkov total absorption counter for selecting scattered electrons. The counter was constructed at the Laboratory of High Energies, JINR. The counter was used in two ways in the experiment. The first method (particle identification) consisted of the detection of the momentum amplitude in each trigger; the second used the detection of a signal above a fixed threshold as a trigger for the setup.

2. Čerenkov Shower Counter

The Čerenkov Shower Counter (ČSC) consisted of two radiators placed side-by-side and separated from each other by a thin aluminium foil. Each radiator was composed of a block of lead glass PEMG2, 20 cm x 24 cm x 40 cm with a density ρ = 3.61 gm/cm^3 viewed by an FEU - 49 photomultiplier. Each photomultiplier also viewed a light diode used for calibration purposes. All radiator surfaces, except the surface covered by the photomultiplier and the light diode, were covered with a reflecting white coating (NE 560) based on MgO. Optical contact between the photomultiplier and the radiator was provided by an optic oil Dow Corning 20 - 075. Each photocathode covered 37% of one 20 cm x 24 cm face. The radiator and the photomultiplier were shielded by type 79NM μ-metal. We denote each part of the counter as ACC1 and ACC2.

Selection of the appropriate photomultiplier divider was made during a series of tests using the light diode and a constant current source that maintained current in the divider equal to (1.000 ± 0.005) ma when the divider resistance was charged from 1 $m\Omega$ to 3 $m\Omega$. Investigation of about 20 photomultipliers showed that the standard divider was near optimum for all tubes, providing the largest amplitude and best resolution. 10 ma dividers cooled by ventilators were used in the experiment in order to extend the region of linearity. Photomultipliers having the best resolution (selected from 20) were used in the counter. The relative resolution with optimum dividers was determined using a light flash from diode comparable to the amount of light emitted by an electron shower in the counter. Diode pulse height resolution was about 10%. The selected photomultipliers and 10 ma dividers saturated when the output pulse amplitude reached ≃ 5v (non-linearity ≃ 10%). Pulse characteristics into a 50 Ω load resistor were

rise time	20-30 nsec
decay time	70-100 nsec

A general view of the Čerenkov Shower Counter is shown in Fig. 1.

3. Circuit Schematic

Figure 2 presents the circuit used for timing and amplitude analysis of the pulses from the Čerenkov Shower Counter. A pulse from the photomultiplier was divided in a resistive splitter; one pulse was used for timing, the other for pulse height analysis.

Pulse Height Circuit

Attenuator I was used to decrease the amplitude of the shower counter pulse so that it fell within the linearity region of a linear gate. An appropriate delay was required to provide the coincidence of the pulse with a gate pulse. The output of the linear gate was a shaped pulse sent to a converter (ADC) that gave a series of pulses whose number was proportional to the input pulse amplitude. These pulses were scaled and sent to a computer by the readout electronics /2/ .

Timing Circuits

Attenuator II served to select (using a constant discriminator threshold of ≃ 100 mV) the minimum energy electron that could trigger the apparatus. Since the presence of an electron was required in at least one of the two parts of the ČSC, signals from the discriminators were fed to an "OR" circuit and then

to the master coincidence circuit. The master coincidence trigger signal was fed through a fanout to a discriminator-shaper circuit which opened the linear gate for ≃ 200 nsec.

A linear gate LG102/N was used in the experiment /3/. Some parameters are as follows:

- output linearity range from 0 to 400 pico coulombs.
- input resistance 50 Ω
- non-linaerity:

integral	1.5%
differential	1.0%.

The resolution of the total circuitry (linear gate, ADC, scalar) gave an integral non-linearity in the range 10 mv to 450 mv of less than 1%.

4. Calibration of the ČSC

The Čerenkov Shower Counter was calibrated in a preliminary fashion in order to set the proper value of electron detection threshold. The value of this threshold was needed both to provide the proper trigger to the spark chambers and to provide the proper event identification. The detection thresholds were estimated by two methods.

1) An approximate estimate of the pulse height of a signal from an electron energy of (for example) 25 GeV was obtained by observing the amplitude spectrum from high energy μ -mesons (Fig. 3). The spectrum shows a peak in the range 30-60 mV. Since a 25 GeV electron shower has ≃ 100 charged particles near shower maximum, the pulse height from electrons of these energies was expected to be in the range 1-5 V as was subsequently observed in the experiment.

2) An independent and much more accurate estimate of the thresholds was obtained by direct calibration of the counters in a variable energy beam at Serpukhov using differential Čerenkov counters to identify electrons.

During calibration runs the connection between the ČSC and the readout electronics was similar to that shown in Fig. 2 except that the timing cables from the photomultiplier to the master coincidence were absent. Electrons were selected by the threshold counters at two beam momenta - 20 GeV/c and 32.5 GeV/c.

Measurements at different beam intensities were carried out in order to check the effect of counter "loading" on the pulse height distribution. When the intensity changed from 75,000 $\pi^-/1$ sec spill to 300,000 $\pi^-/1$ sec spill, the pulse height decreased by 5%. In the $\pi - e$ experiment, the Č SC was not directly in the beam and has an estimated 20,000 $\pi^{-}/1$ sec spill so that loading effects were eligible.

Calibration results are presented in Table I. Satisfactory linearity is observed; however, the resolution is worse than expected.

The performance of these counters was also examined off-line by plotting the pulse height of the electron from pion electron scattering events. Since a spectrum of differing electron momenta impinged on the counter, we divide the observed pulse height of each particle by the corresponding momentum to obtain the normalized pulse height. The resultant width is thus a combination of the width due to resolution and to the nonlinearity of the counter. Figure 4 shows this normalized pulse height for the counter ACC2 (15 to 25 GeV electrons). The resolution of this counter is ± 7% fwhm. A prominent low pulse height tail is seen and is caused by those electrons falling near the counter edge. Figure 5 shows a large reduction in these low pulse height events when the electrons within 2 cm of the counter edge are removed. Some lowpulse height ''tail'' remains, this tail is due both to statistical fluctuations in electron shower development and the fact that some of these particles are in reality pions due to misidentification of events. The corresponding figures for counter ACC1 (25-36 GeV electrons) show a comparable, although slightly better, resolution.

Conclusion

The Č SC worked reliably and well in the experiment. Using it as a trigger requirement reduced unwanted triggers in the experiment by a factor of five. It also proved useful during identification of events during later analyses. The observed resolution ± 7% is worse than might be expected based on shower statistics, nevertheless it was perfectly adequate for this experiment.

References

1. D.Y.Bardin et al. JINR Preprint, E1-4786, Dubna (1969).
2. Z.Guzik et al. JINR Preprint, E1-5818, Dubna (1971).
3. K.B.Keller. Linear gate and Stretcher, By EGG Inc. (1968).

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Table I

Counter	U, kV	P, GeV/c	A	R, %
ACC1	1.8	32.5	278	10
		20	170	13
ACC2	1.6	32.5	340	9
		20	214	12

where: U is the photomultiplier voltage (kV); P is the electron momentum (GeV/c); A is the amplitude in relative units; R is the full width at half maximum in per cent (FWHM).

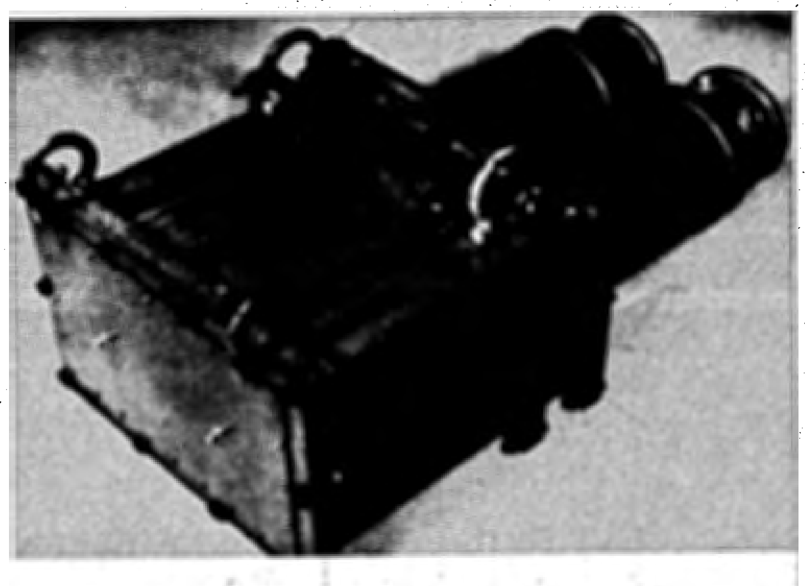


Fig. 1. Čerenkov spectrometer (ČS) used in the Serpukhov pion electron scattering experiment consisting of two lead glass blocks each viewed by a photo tube.

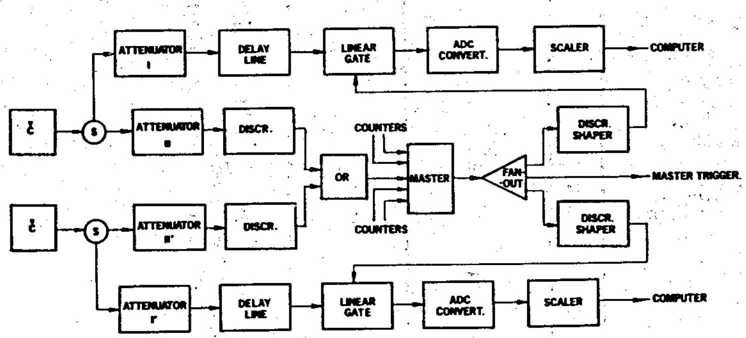
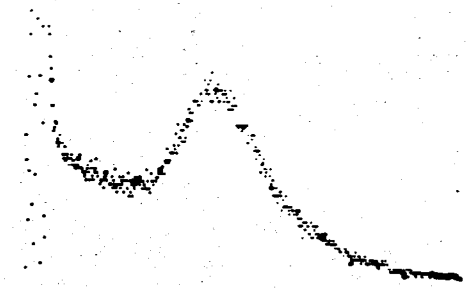


Fig. 2. Block diagram of that part of the electronic logic used by signals from the Čerenkov shower counters.

Fig. 3. Pulse height spectrum for high energy, minimum ionizing muons.



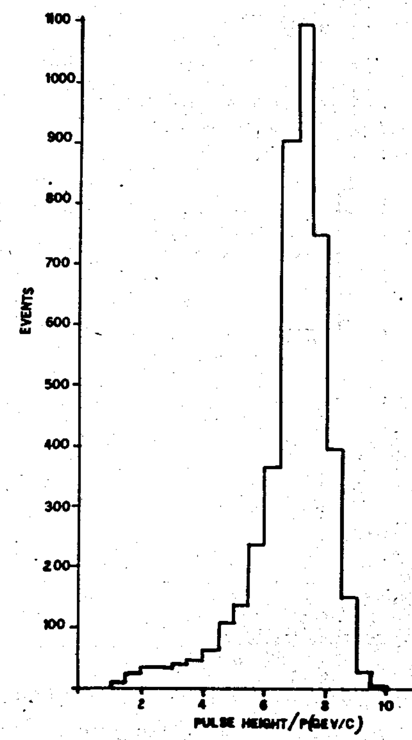


Fig. 4. Normalized pulse height spectrum for ACC2 obtained from all pion electron scattering events. Resolution ± 7%.

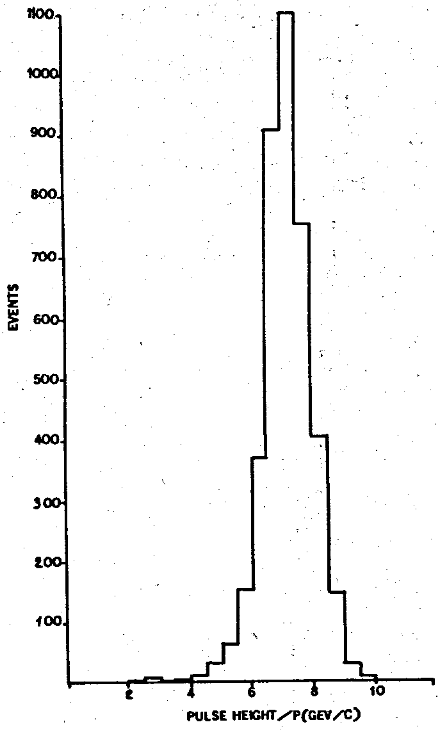


Fig. 5. Normalized pulse height spectrum for ACC2 for all electrons greater than 2 cm from any edge obtained from pion-electron events.