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INVESTIGATION OF ANGULAR DEPENDENCE OF THE CHARGE RESPONSE OF THE DELPHI HADRON CALORIMETER PLASTIC TUBES

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Charge characteristics of the hadron calorimeter plastic tubes operating in streamer mode are presented. The angular dependence of the charge from anode wires is measured in a test setup using cosmic muons.

The investigation has been performed at the Laboratory of High Energies and Laboratory of Nuclear Problems, JINR.

Исследование угловой зависимости отклика пластиковых детекторов адронного калориметра ДЕЛФИ

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Представлены зарядовые характеристики пластиковых детекторов адронного калориметра ДЕЛФИ, работающих в стримерном режиме. Зависимость величины заряда, снимаемого с анодной проволочки, от угла пролетающей через детектор заряженной частицы была измерена с использованием космических мюонов.

Работа выполнена в Лаборатории высоких энергий и Лаборатории ядерных проблем ОИЯИ.

1. Introduction

In order to simulate the DELPHI Hadron Calorimeter (HCAL) data in a reliable way it is necessary to have precise information about the charge distributions of the HCAL plastic tubes.

At present the simulation of the HCAL response [1—4] uses the reference spectrum from a test with cosmic muons [5,6]. In order to take into account any of angular dependences, the reference spectrum is modified by an empirical formula [3]. In this formula the charge depends linearly on $1/\cos^2\theta$ up to 60 degrees, where θ is the angle between the track and normal direction to the plane of anode wires, and is saturated at larger angles. Previous experimental measurements of the reference spectra, however, were performed up to 45 degrees only and the test conditions were quite different from the experimental operation.

In our test the angular dependence of the charge response of plastic tubes to cosmic particles was measured in a wide angular range.

2. Experimental Setup

The study was performed with a plastic tube 80 cm long which was produced in 1987 for the DELPHI HCAL Ecap modules [7]. In our test the tube was operated as in the HCAL running conditions [8]: at 4000 V voltage and with the gas mixture Ar : CO_2 : Isobutane (1:6:3).

To trigger on the cosmic particles we used two scintillating counters with a cross-section 0.8×8.0 cm^2 and 2.0×6.0 cm^2. The distance between counters was 18 cm, see Fig.1 for the details of the layout. The tube was situated in between the counters and its orientation was varied to perform the measurements at different angles.

The angle θ was defined as an angle between the normal direction to the plane of anode wires and the direction chosen by counters. The measurements were performed at six different angles: 0, 30, 45, 50, 60 and 70 degrees. Our geometry allowed actual angles in the range of $\Delta\theta = 4.4$ degrees around the nominal values.

One can see from Fig.1,*b* that in the other projection (angle ϕ) a significant part of particles could cross two tube cells and therefore produce two hits. The contribution of this effect was estimated from the simple Monte Carlo simulation to be about 20%.

The coincidence of the signals from two scintillating counters was used for the trigger. Trigger rate was about 20 per hour. The rate of accidental coincidence was less than 5%.

Analog signal from the anode wires without amplification was sent to the LeCroy 2249W ADCs, the gate was 450 ns. The ADC sensitivity was 0.25 pC/channel [9].

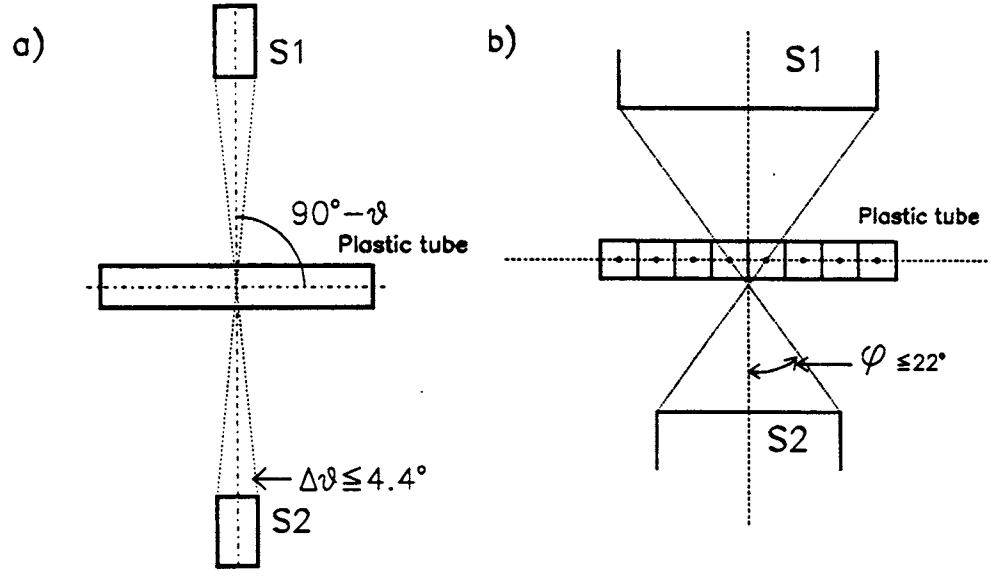

Fig.1. The structural layout of measurements

3. Results

The distributions of the charge from anode wires measured at different θ angles are shown in Fig.2(*a*—*e*).

All the distributions have long tails, which could be explained as an effect of afterpulses.

At θ = 0 degree (Fig.2,*a*) a large peak at 30 pC corresponding to a one-streamer mode is clearly seen. However, even at this angle a significant part of events have larger amplitudes and only half of them can be explained by the contribution from particles passing two tube cells.

At larger angles the part of multi-streamer regime is significantly increased. The dependence of the mean charge on the angle is shown in Fig.3. The behaviour is like $1/\cos^2\theta$ up to 60 degrees with saturation at larger angles. From this point of view our result is in reasonable agreement with the one obtained from the HCAL data [3].

However, one should note a significant change of the shape of distributions with the angle. Starting from being very asymmetric the distribtuions become more gaussian with

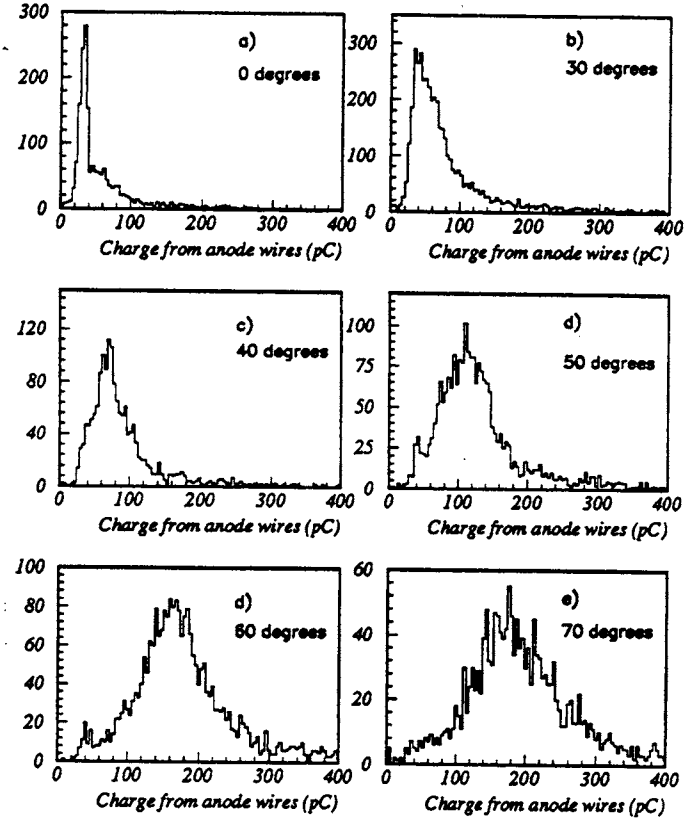

Fig.2(a—e). Charge from wires for various angles

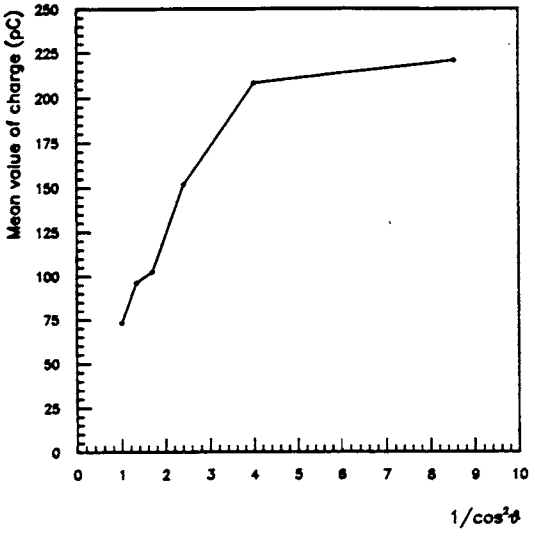

Fig.3. The mean value of charge from anode wire vs angle

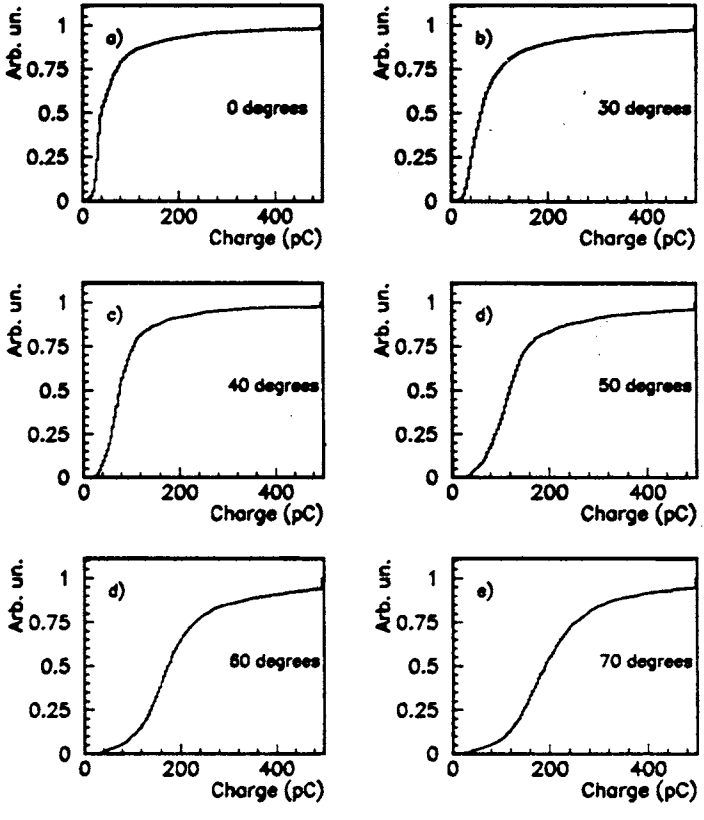

Fig.4(a—e). $F(q)$/square for various angles

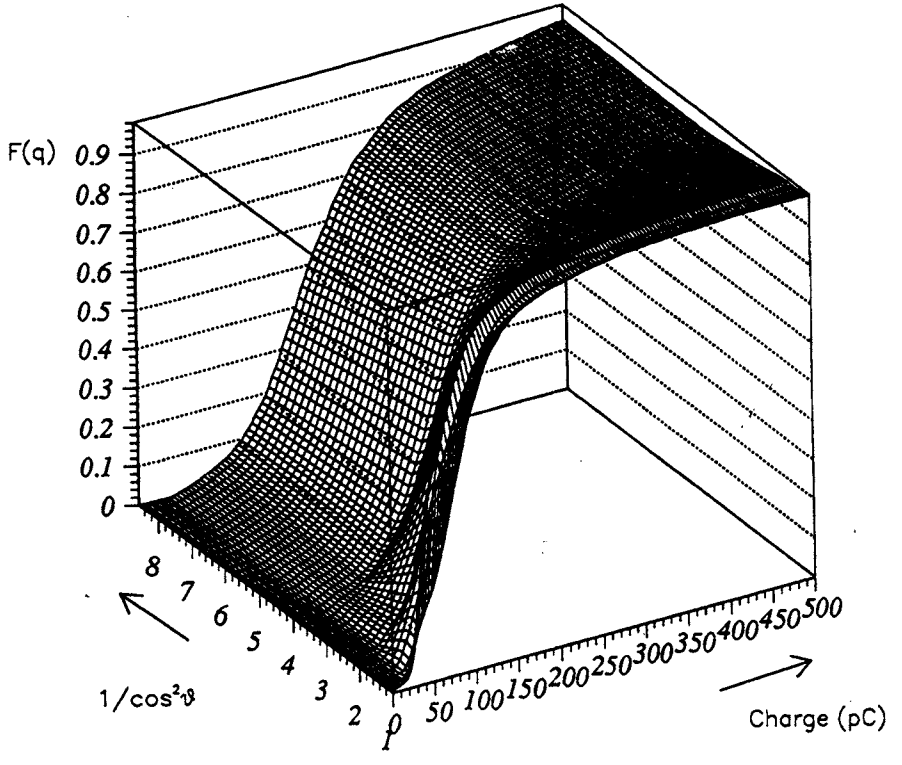

Fig.5. $F(\theta, q)$

the increase of angle. Therefore, the method which uses for simulation only the mean value and r.m.s. of distributions is only a rough approximation.

To simulate the angular response in more detail one can generate charges completely according to the above measurements. Figures 4(*a*—*e*) show the probability distributions $F(q)$ obtained by integrating our measured charged spectra and normalizing the full integral to unity. For the angular dependence an interpolation between the nearest measured angular points can be used. An example of such two-dimensional probability function $F(\theta, q)$ with the linear interpolation of angular dependence is shown in Fig.5.

4. Conclusion

The dependence of the anode response of the plastic tubes on the angle between particle direction and the anode wires was measured in the range from 0 to 70 degrees.

The measurements presented are in reasonable agreement with the results obtained from HCAL data [3].

The measured charge spectra information presented here could be used for the HCAL simulation.

5. Acknowledgements

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