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ЛАБОРАТОРИЯ ВЫСОКИХ ЭНЕРГИЙ

A HIGH RESOLUTION LEAD GLASS CHERENKOV GAMMA - SPECTROMETER

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1. Introduction

In order to study a variety of problems of electromagnetic interactions, a 90-channel Cherenkov mass-spectrometer is being constructed now at the Laboratory of High Energies (JINR, Dubna). Such a mass-spectrometer, first proposed in 1964 /1,2/ and realized in a two-channel variant /3/, made it possible to carry out a series of experiments to prove, in particular, the existence of $\rho \to e^+e^-$ and $\phi \to e^+e^-$ decays and to measure their branching ratio /4,5/.

In this paper we present the results of the calibration experiments using an electron beam for seven improved Pb glass Cherenkov gamma- spectrometers being a part of the 90-channel mass-spectrometer.

2. Description of the Gamma-Spectrometer

A 35 cm counter radiator (14 rad. length) is made of optical Pb glass (type TF-1) having a regular hexagon with a 17.5 cm inscribed circle diameter (7 rad. length) as a basis.

A schematic drawing of the spectrometer C is shown in fig. 1. The main characteristics of Pb glass are given in Table 1.

The counter is viewed by a FEU -49B photomultiplier 17 cm in diameter. The ratio of the "effective" photocathode area to the radiator basis one is equal to 68%.

Optical contact between the glass block and the photomultiplier is accomplished by glue which has a refraction index of 1.50.

For better light collection the radiator was wrapped by reflecting Al foil.

To shield the photomultiplier against the magnetic field, 0.5 mm μ -metal shields were used.

3. Calibration of the Gamma-Spectrometer

The Cherenkov gamma-spectrometer C was calibrated by electrons which comprised a small admixture (about 1%) in a pion beam at 2 and 4 GeV/c. Four 7 cm x 7 cm scintillation counters S defined the beam, and a 160 cm gas Cherenkov counter, filled up with nitrogen, electronically rejected pions and selected electrons.

Figure 2 (a,b,c,d) illustrates the results of calibration at the beam energies of 2 and 4 GeV. The curves in figs. 2a and 2c show the pulse spectra for all particles in the mixed electron-pion beam. The curves in figs. 2b and 2d show the electron spectra when the gas Cherenkov counter is included in triggering to select pulses from electrons with a high efficiency.

The full width values of the electron peaks at half maximum FWHM give the energy resolutions shown in Table 2. The indicated values of the energy resolution were corrected for beam electron scattering, an edge effect because of large sizes of scintillation counters and a finite beam momentum spread $(\Delta p/p = \pm 1\%)$ as well. These corrections amount to 15% and 24% at the electron energy of 2 and 4 GeV, respectively.

Column 3 gives the FWHM resolution corrected for an energy loss out of the sides of the gamma-spectrometer radiator. It was also shown that the seven calibrated spectrometers had the energy resolutions with a rather small spread between the counters (not more than 4%).

The data analysis shows that the spectrometer is linear for the energy values considered.

4. Measurement of the Probability for Imitation of Electrons by Hadrons in the Gamma-Spectrometer

In experiments on rare processes producing electrons with a small frequency in comparison with hadrons, one of the most important parameters of the gamma-spectrometer is a value characterizing the probability for imitation of electrons by hadrons.

It is possible to determine this value by measuring both the electron and hadron spectra at the same beam momentum. It is evident that the latter depends both on the energy resolution and on the energy discrimination level.

The results obtained for the counter C at the electron momentum of 4 GeV/c are presented in Table 3.

The ϵ_e value is the electron detection efficiency at the P_0 momentum; W_0 is the hadron detection probability at the same momentum and the energy discrimination threshold corresponding to the ϵ_e efficiency.

W_0 is defined by the ratio of the number of hadrons, that produced the energy above the threshold to the total number of detected hadrons.

In the second experiment we investigated the possibility to suppress hadrons by means of two Cherenkov gamma-spectrometers C_A and C (see fig. 1)/6/. In front of the main spectrometer C we placed the other one C_A 80 cm long and 8 cm thick (3.2 rad length) along the beam. The output pulse of C and one of the splitted pulses of C_A were linearly added and this signal after gating was connected to a 1024-channel pulse height analyser. The second output of C_A was discriminated and used to gate the pulse height analyser. In this type of triggering it is possible to obtain an additional disctrimination against hadrons, which have not undergone the nuclear interaction in C_A , and, consequently, their contribution to C is excluded.

The results of these experiments are presented in the lower line of Table 3. Here W_A is the probability to imitate electrons by hadrons at the discrimination level at C_A output corresponding to the ϵ_e efficiency, and W_0 is the probability to imitate electrons by hadrons without any discrimination in the hadron channel of C_A at the same ϵ_e efficiency.

The obtained data show that the use of two spectrometers, C and C_A, together with the C_A channel discrimination makes it possible, in comparison with the use of the spectrometer C only, to decrease essentially the probability for imitation of electrons by hadrons at the same values of the electron detection efficiency.

In conclusion we would like to express our gratitude to Prof. A.M.Baldin and Dr. I.A.Savin for their assistance and advices, to Drs. E.Vlasov, V.Arkhipov, A.Kolomychenko and M.Khvastunov for their assistance in the experiments.

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TABLE I

PROPERTIES OF TF-1

PROPERTY	VALUE
RADIATION LENGTH	2.50 cm
DENSITY	3.86 g/cm^3
INDEX OF REFRACTION(n_d)	1.65
CRITICAL ENERGY	~15 MeV

TABLE 2

RESOLUTION AS A FUNCTION OF BEAM ENERGY

ENERGY (GEV)	FWHM (%)	CORRECTED FWHM(%)
2	7.2	6.8
4	5.1	4.7

TABLE 3

HADRON REJECTION POWER AS A FUNCTION OF ELECTRON DETECTION EFFICIENCY AT A BEAM MOMENTUM OF 4 GeV/c

ε_e (%)	30	40	50	60	70	80	90	95
$W_o \times 10^4$	.3	.4	.7	.9	1.2	1.7	2.3	2.8
W_A/W_o	.04	.05	.06	.07	.08	.12	.19	.27

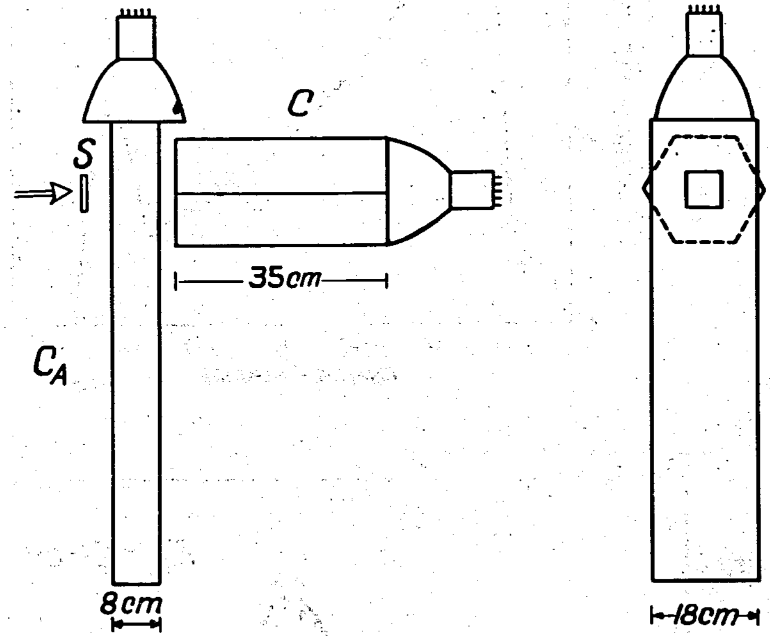
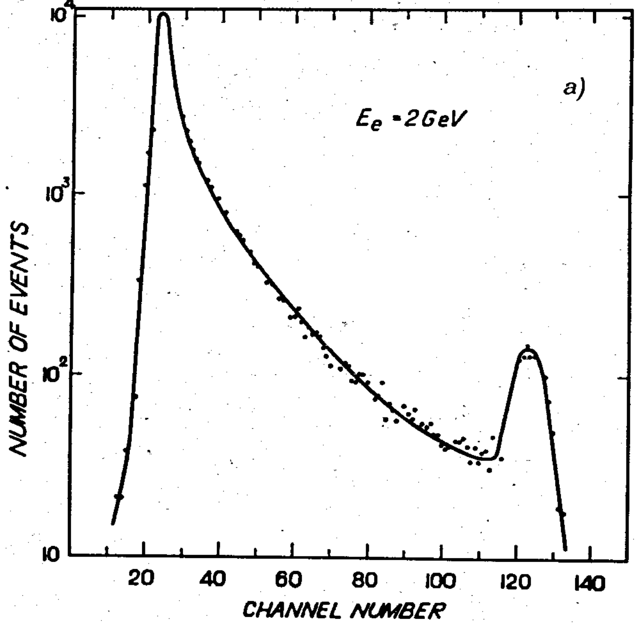
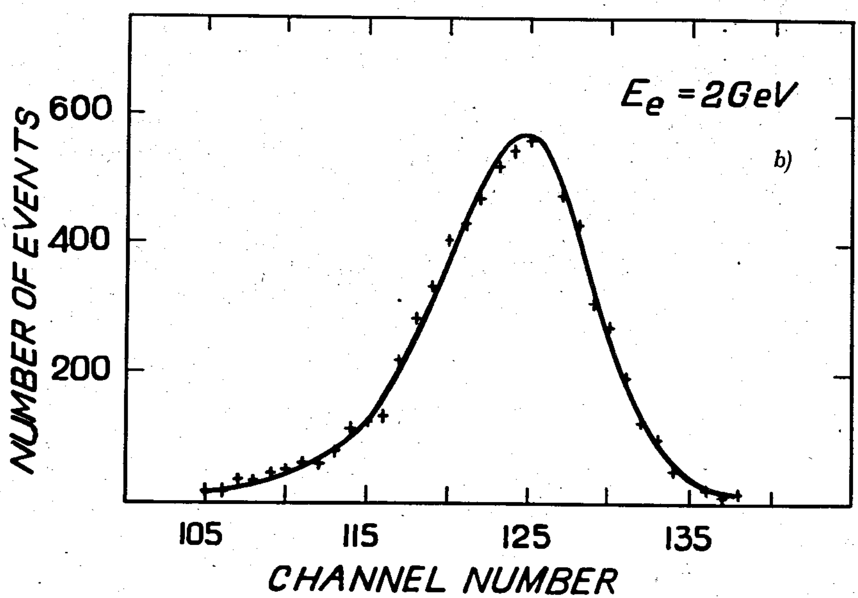
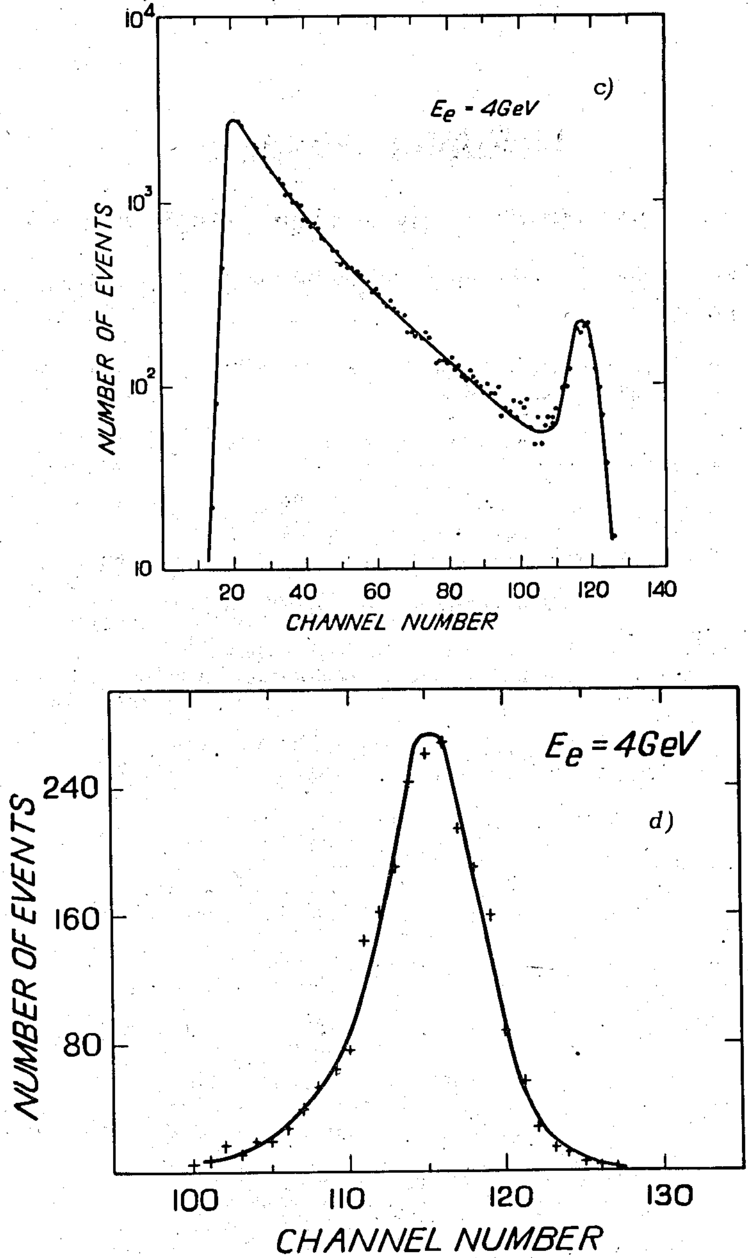


Fig. 1. A sketch of the experimental arrangement.


a)
$E_e = 2 GeV$
NUMBER OF EVENTS
10^4
10^3
10^2
10
20
40
60
80
100
120
140
CHANNEL NUMBER


$E_e = 2 GeV$
b)
NUMBER OF EVENTS
600
400
200
105
115
125
135
CHANNEL NUMBER



2. Pulse height distribution curves for pions and electrons at the beam momentum GeV/c (fig. 2a) and 4 GeV/c (fig. 2c). Pulse height distribution curves for electrons ;eV/c (fig. 2b) and 4 GeV/c (fig. 2d).