

The Spectrum of Hadrons' Energy measured in the Pamir Experiment.

J.Malinowski¹

¹*Department of Experimental Physics, University of Lodz, 90-236 Lodz, Poland, ul. Pomorska 149/153
e-mail: malinow@krysia.uni.lodz.pl*

Abstract

The spectra of the energy of hadrons measured in emulsion chambers in the Pamir experiment (600g/cm²) have been obtained. Experimental spectra of the energy of hadrons above chamber and the energy released by a hadrons interacting with the chamber medium into electromagnetic component have been presented.

The spectra for hadrons' energy $E_h > 70$ TeV registered in five carbon emulsion chambers having the total area of 120 m² are described.

1 Introduction

In the paper experimental data from the Pamir experiment (4370 m a.s.l. - 600 g/cm²) are presented. Detection of hadrons took place in carbon emulsion chambers, the construction, the way of working and all the methodical aspects of which have been described in the paper [1].

The aims of the following paper are:

- presenting the distributions of optical densities of the X-ray film; optical densities derive from the hadrons registered in the particular chambers;
- making the distributions of the energy of hadrons above the chamber E_h and estimation of the values of their parameters;
- making the distributions of the energy $E_h^{(\gamma)}$ transferred into electromagnetic component of a nuclear electromagnetic cascade (NEC) which has been initiated by a hadron interacting with the chamber medium.

2 The distributions of the optical densities

Traces of hadrons on the X-ray film were photometred with a diaphragm having the constant radius r (so called r -const method). The diaphragms with $r= 48, 84$ and $140 \mu\text{m}$ have been used in the measurements. For small diaphragms D grows quickly above $D>2.0$, which causes considerable growth of the photometring errors (so called scattering light effect). The errors are corrected but we wish to minimalize them in the experiment. Therefore, data for $r=140 \mu\text{m}$ have been used for the further analysis.

D distributions (for C141 and C200 chambers) for all used diaphragms have been presented in the paper [3]. The measured D values were standarized and methodically corrected, which has been described in the paper [1] and partly in the papers [2] and [3].

Table 1
Basic information about the experimental data

Chamber	S [m ²]	Year exp.	Time exp. [year]	N hadrons	N measured
C141	24	85/86	0.978	762 for $D>0.2$	2858
C200	24	88/89	1.014	531 for $D>0.2$	3065
C201	14	88/89	0.981	255 for $D>0.2$	1213
C201	10	88/89	0.981	14 for $D>0.7$	20
C169	24	86/87	0.945	23 for $D>0.7$	42
C174	24	87/88	1.000	30 for $D>0.7$	47

Condition $D_{r=140} > 0.2$ corresponds with energy of hadrons $E_h > 18.6$ TeV (i.e. $E_h^{(\gamma)} > 7.7$ TeV).

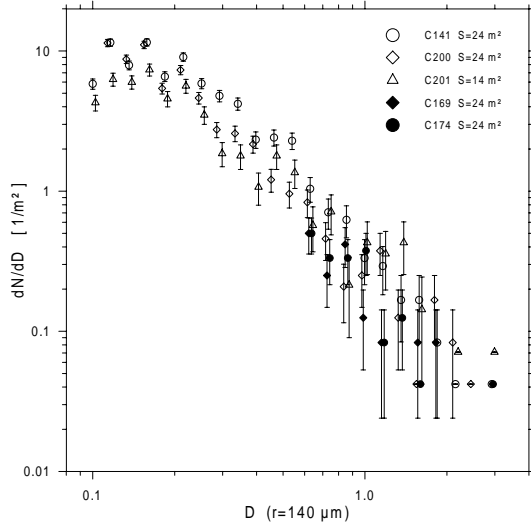


Figure 1: Differential distributions of optical densities of hadrons.

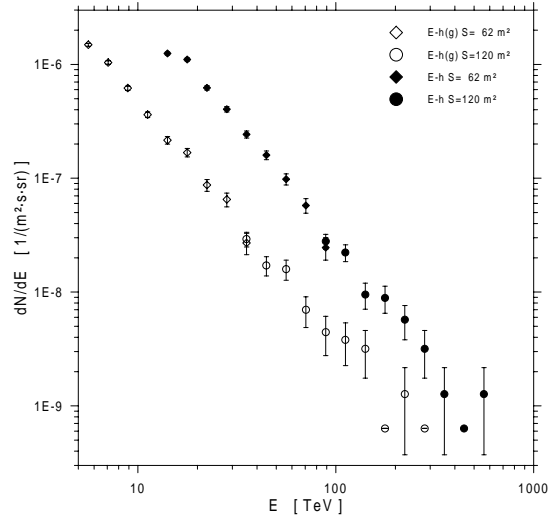


Figure 2: Differential distributions of energy of hadrons.

Experimental data from the five chambers, each having the area of 24 m^2 , have been presented. All registered hadrons were measured in chambers C141, C200 ($2 \times 24 \text{ m}^2$) and C201 (14 m^2). In chambers C169, C174 ($2 \times 24 \text{ m}^2$) and C201 (10 m^2) only the hadrons of high energies ($D > 0.5$) were searched. A part of these data (C141 and C200) has been described in the paper [3]. Multiplicities of hadrons registered in the particular chambers are shown in Table 1.

The distributions of optical densities D shown in Figure 1 were made separately for each chamber. They are normalized to the number of cases for the area unit.

The conclusion can be drawn that the fluctuations of the number of registered hadrons in the particular chambers do not exceed 3 - 4 standard deviation of multiplicity in each D interval.

3 The distributions of the energy

The distributions of the energy of hadrons above the chamber E_h and the energy transferred into electromagnetic component $E_h^{(\gamma)}$ have been made using the functions described in the paper [2]. The way of receiving them is in the papers [2] and [4]. The function used in this paper is following:

$$y = \begin{cases} 1.99853 \exp(0.650457 x) & \text{when } D_{r=140} < 2.38 \\ 1.78675 + 2.03839 x & \text{when } 2.38 < D_{r=140} < 3.59 \\ -2.83366 + 10.3542 x & \text{when } D_{r=140} > 3.59 \end{cases}$$

where

$$y = \log_{10} E_h \\ x = \log_{10} D_{r=140}$$

Differential distributions of the energy of hadrons above the chamber E_h and of the energy transferred into electromagnetic component $E_h^{(\gamma)}$ have been depicted in Figure 2.

Data for $E_h > 17 \text{ TeV}$ have been taken from C141, C200 and partly C201 with total area $S=62 \text{ m}^2$ and mean exposition time $T=0.991$ year. The number of hadrons with $E_h > 17.7 \text{ TeV}$ is 2275, with $E_h^{(\gamma)} > 17.7 \text{ TeV}$ is 345 from 7136 measured.

Energy distributions for $E_h > 70 \text{ TeV}$ (i.e. $E_h^{(\gamma)} > 28 \text{ TeV}$) are from all five chambers with total area $S=120 \text{ m}^2$ and mean exposition time $T=0.984$ year. The number of hadrons with $E_h > 70 \text{ TeV}$ is 201, with $E_h^{(\gamma)} > 70 \text{ TeV}$ is 33 from 7245 measured.

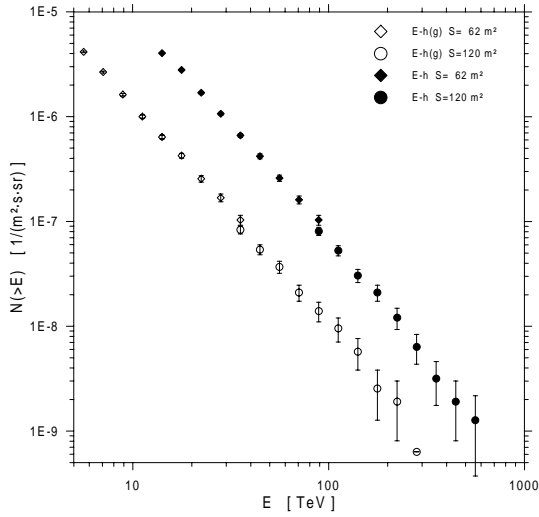


Figure 3: Integral distributions of energy of hadrons.

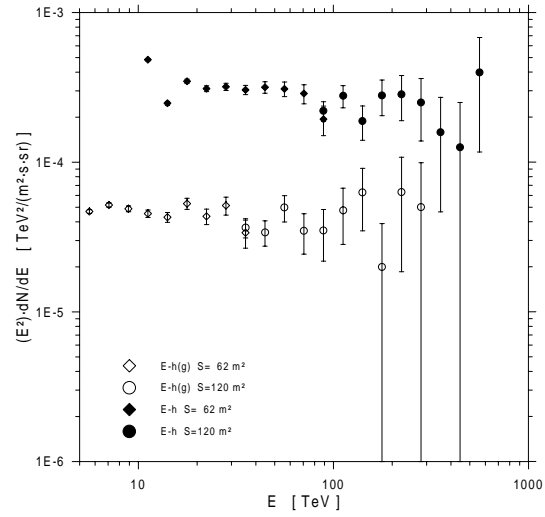


Figure 4: Differential distributions of energy of hadrons.

The presented distributions have been normalized to the unit of area, time, solid angle and with taking into account the efficiency of hadrons' registration:

$$I(> E) = \frac{N(> E)}{S T \Theta_o} \cdot \frac{m + 2}{2\pi(1 - \cos^{m+2} \Theta_o)}$$

where

ω - efficiency of the chamber's registration; $\omega = 0.54$;

m - exponent of the angular differential distribution of hadrons; $m = 6$;

Θ_o - limiting zenithal angle; $\Theta_o = 60$;

The integral distributions of E_h and $E_h^{(\gamma)}$ energies have been presented in Figure 3. The same differential distributions in a different scale have been depicted in Figure 4.

Distributions of energies have been fitted with a power function. For the energies of hadrons above the chamber E_h in the interval 17 - 400 TeV, the following form of a distribution has been received:

$$I(E_h > 17.7TeV) = (2.79 \pm 0.06 \pm 0.85) 10^{-6} \cdot (E_h)^{-2.01 \pm 0.04}$$

For the energies of hadrons above the chamber E_h in the interval 70 - 550 TeV, the following form of a distribution has been received:

$$I(E_h > 70TeV) = (1.28 \pm 0.09 \pm 0.38) 10^{-7} \cdot (E_h)^{-2.07 \pm 0.18}$$

The distribution of hadrons' energies $E_h^{(\gamma)}$ has been estimated in the interval 5.6-200 TeV and has the form:

$$I(E_h^{(\gamma)} > 5.6TeV) = (4.15 \pm 0.07 \pm 1.25) 10^{-6} \cdot (E_h^{(\gamma)})^{-2.04 \pm 0.04}$$

The distribution of hadrons' energies $E_h^{(\gamma)}$ has been estimated in the interval 28-250 TeV and has the form:

$$I(E_h^{(\gamma)} > 28TeV) = (1.68 \pm 0.14 \pm 0.50) 10^{-7} \cdot (E_h^{(\gamma)})^{-1.99 \pm 0.17}$$

In all formulas the intensities have been given in $[m^2 s sr]^{-1}$. The first of the intensity errors is a statistical one, the second is due to a scatter of quantities of hadrons registered in different chambers.

4 Conclusions

The spectrum of the energy of hadrons has been estimated in interval $17 \text{ TeV} < E_h < 550 \text{ TeV}$ registered at the altitude 4370 m a.s.l. (600 g/cm^2) 2275 hadrons have been registered for $E_h > 17.7 \text{ TeV}$; the intensity of the integral spectrum of hadrons' energy is $2.79 \cdot 10^{-6} [\text{m}^2 \text{ s sr}]^{-1}$ and its slope $\beta = -2.01$.

For $E_h > 70 \text{ TeV}$ 131 hadrons have been registered; the intensity of the integral spectrum of hadrons' energy is $1.28 \cdot 10^{-7} [\text{m}^2 \text{ s sr}]^{-1}$ and its slope $\beta = -2.07$.

References

1. Pamir Collaboration, Trudy FIAN, Moscow "Nauka", v.154, (1984)
2. Malinowski J., Bull. Rus. Acad. Sci, Phys. v.63 no.3, (1999) - in press
3. Malinowski J., Nucl. Phys. B (PS) v.75A, (1999) - in press
4. Malinowski J., Tomaszewski A. - 5th Int. Symp. on VHECRI, Lodz 280, (1988)