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ядерных
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B.Słowiński

ELECTROMAGNETIC CASCADES PRODUCED BY GAMMA-QUANTA WITH THE ENERGY E_γ = 100 - 3500 MeV.

I. Method and Experimental Data

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I. INTRODUCTION

In the last few years increasing interest has been expressed again in different characteristics of electromagnetic cascade process (ECP) produced by high energy gamma-quanta (GQ) and electrons in heavy media. Although there are well-known all partial phenomena forming the ECP and the computer programs reconstructing this process are commonly regarded, at least on the whole, to be satisfactory enough, a number of experimental and theoretical works have appeared in this field /1-6/. Most of the experimental works pursue strictly practical objects of obtaining a concrete information on the longitudinal or transversal (lateral) development of cascades inside the concrete material of interest for a given shower detector. Corresponding results are used to determine the energy of photons and electrons in different experimental setups, and at the same time, but rather occasionally they are also compared with appropriate numerical data obtained by means of computer modeling code system /7/. Unfortunately, these results contain merely fragmentary information about showers for lack of detectors registering such a complex process exhaustively to the necessary degree.

In this situation sufficiently big heavy liquid bubble chambers (BC) seem to be still very useful. Xenon BC are of exceptional importance in this regard having a relatively low value of radiation length (RL), L(Xe) = 4.05 +/- 0.17 cm /8/. Therefore a series of experimental works concerning different aspects of electromagnetic cascades (or showers) were performed using the 24 l XeBC of JINR (Dubna)/9/. With the aid of this chamber (12.5*7.5*4RL**3), in particular, a three-dimensional phenomenological description of the average ionization loss in the ECP within the energy interval of primary GQ E_γ = 60-2000 MeV was first obtained. Nevertheless, to miss some shortcomings caused by its limited spatial dimensions (<12.5 RL), for this purpose it was expedient to use pictures of 180 l XeBC of ITEP (Moscow)/10/. This chamber with its large dimensions (25.7*11*10 RL**3) and a clear image of tracks makes it possible to analyse in detail many features of the ECP structure up to the energy values of showers initiating GQ of some GeV. As an illustration, a typical picture of an event of the ECP created by a high energy GQ in the 180 l XeBC is shown in fig. 1.

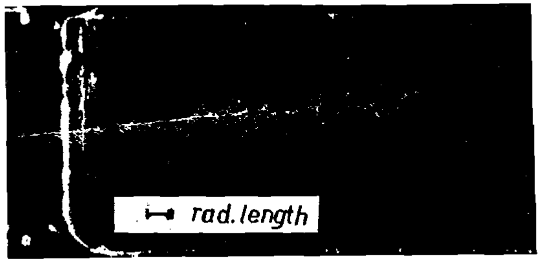

Fig.1.
Typical picture of a shower event produced by a high energy photon in the 180 l XeBC of ITEP (Moscow).

The aim of our investigation is to get comprehensive as far as possible experimental information on the ECP produced in liquid xenon by GQ with the energy E_γ =100-3500 MeV. From the practical point of view of special interest are, first of all, such problems as the longitudinal and transversal development of showers, as well as their appropriate fluctuations and correlations. This program has been carried out using the pictures of the 180 l XeBC of ITEP (Moscow) irradiated in the beam of π^- mesons at the momentum 3.5 GeV/c. Some preliminary results on these topics based on a part of the studied experimental material were published earlier /11 - 13/. This paper is the first in a series devoted to the description of the experimental method employed for the purpose and contains experimental data concerning 6 values of E_γ among 22 investigated in the work.

II. MATERIAL

About 220 thousand pictures of the 180 l XeBC exposed to the beam of π^-mesons at 3.5 GeV/c were scanned twice at least, and 1657 events of showers satisfying the appropriate criteria were selected. In particular, these criteria assume that the shower axis (SA) of each event is in the projection plane of a picture and there are no other disturbing showers or tracks on this picture. For each event chosen during the scanning the energy E_γ of GQ generating the shower was evaluated and the so-called potential length Lpot as well as the maximum shower length t were measured. These lengths were counted out from the conversion point of the photon producing ECP along the SA respectively up to the edge of the registering volume of the XeBC (Lpot) and the remotest visible tracks of shower electrons or positrons (t). Then all selected events were grouped into 22 intervals (bins) of primary photon energy E_γ so that

half the relative width $\Delta E_\gamma / E_\gamma$ of these intervals might be roughly equal to the average accuracy of determining GQ energy in the XeBC, e.g. ~0,1 /14/. To reduce the effect caused by the limited dimensions of the registering volume of the XeBC used in the work (<25.7 RL), the scatter plots (Lpot vs t) for all intervals were examined. Fig.2 shows such plots for three of these intervals. Supposing our samples of events are representative enough, one can expect that the showers satisfying the evident condition

$$\mathrm{Lpot}(E_\gamma) \le \mathrm{Lmin}(E_\gamma) \equiv \mathrm{tmax}(E_\gamma) \qquad (1)$$

are unbiased as far as possible. Here $\mathrm{tmax}(E_\gamma)$ is the maximum value of t in the sample of events belonging to a given bin of primary photon energy centred at E_γ.

The numbers N_γ of selected events of showers falling to each interval of energy E_γ and the average values $\bar{E}_\gamma$ of E_γ in these intervals are quoted in table 1. The values of $\mathrm{Lmin}(E_\gamma)$ and the numbers N_γ of events fulfilling the condition (1) are given there too.

Table 1.
Numbers N_γ of selected events of showers produced by GQ with the energy E_γ. N_γ^* is the number of such events which potential lengths are not lower than $\mathrm{Lmin}(E_\gamma)$. $\bar{E}_\gamma$ is the average value of E_γ within the appropriate interval of energy E_γ +/-ΔE_γ .

E_γ +/- ΔE_γ (MeV)	$\bar{E}_\gamma$ (MeV)	N_γ	$\mathrm{Lmin}(E_\gamma)$ (rad.length)	N_γ^*
3375 +/- 125	3489 +/- 35	46	24.0	15
3125 +/- 125	3139 +/- 18	42	24.0	12
2875 +/- 125	2850 +/- 17	41	24.0	11
2625 +/- 125	2599 +/- 25	53	22.6	12
2375 +/- 125	2372 +/- 16	60	22.6	20
2125 +/- 125	2117 +/- 15	63	21.3	35
1875 +/- 125	1864 +/- 12	80	20.5	33
1625 +/- 125	1615 +/- 9	108	20.0	66
1375 +/- 125	1363 +/- 10	129	20.0	58
1125 +/- 125	1116 +/- 8	158	20.0	80
875 +/- 125	871 +/- 8	204	20.0	86
680 +/- 70	677 +/- 5	138	20.0	60
555 +/- 55	555 +/- 4	108	20.0	58
455 +/- 45	459 +/- 3	103	18.6	59
375 +/- 35	380 +/- 3	65	17.3	61
310 +/- 30	309 +/- 2	58	16.0	53
255 +/- 25	252 +/- 2	55	14.9	55
210 +/- 20	208 +/- 2	49	14.8	47
175 +/- 15	177 +/- 2	29	12.6	29
145 +/- 15	145 +/- 2	24	12.6	24
120 +/- 10	123 +/- 2	21	11.6	20
100 +/- 10	100 +/- 1	23	11.0	14
total		1657		908

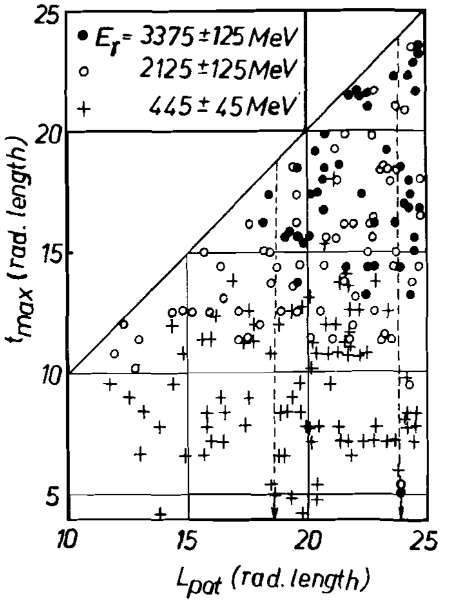

Fig.2.
Scatter plots of potential lengths Lpot vs maximum visible shower lengths t for the selected shower events belonging to the three intervals of the energy E_γ of primary photons producing cascades.

So, among 1657 events of showers selected in the scanning and satisfying the basic criteria only 908 passed the condition (1) and were used for further analysis. It should be also noted that herein we make use of L(Xe) = 4 cm for RL in liquid xenon in accordance with the earlier experiment /8/. But if, for instance L(Xe) is assumed to be 3.8 cm /15/, then all lengths (Lmin and others) ought to be multipied by a factor of 1.05. In particular, the maximum length of the 180 1 XeBC would be equal to 27 RL instead of 25.7 RL taken in the work.

III. METHOD

The energy E_γ of GQ generating showers was determined according to the linear relation between E_γ and the total range ΣR_i of shower electrons and positrons (later: electrons)/16,17/:

$$E_\gamma = \alpha\, \Sigma R_i, \qquad (2)$$

where α = 0.59 +/- 0.02 MeV/mm for liquid xenon /16/.

All 908 events were analysed on the picture plane at an average enlargement of about 0.94 using grid with the dimensions of the elementary square Δt = 0.6 RL along the shower axis and Δp = 0.3 RL in its transversal direction summary plane projection ranges of shower electrons (SER)$\Delta\Sigma re(t,p\,|\,E_\gamma)$ in each square for every event have been measured. Schematic drawing of an event of cascade and the grid used to measure SER is shown in fig.3.

There p = 0 corresponds to the SA and (t=0; p=0) is the conversion point of a primary GQ producing cascade. The smallest plane projection range of shower electrons which can be distinguished explicitly enough on the picture, except the region very close to the SA around the ECP maximum at the energy E_γ greater than about 1000 MeV, is equivalent to the cut-off energy of E_e =0.5-1.5 MeV.

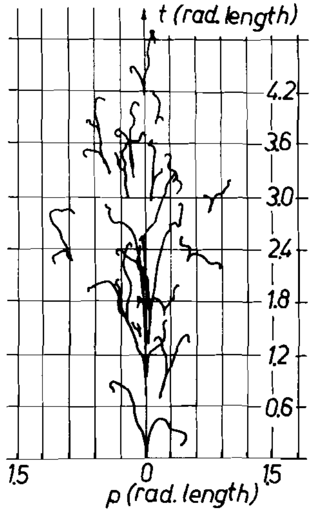

Fig.3.
Schematic drawing of a shower event and the grid used in the work to measure summary plane projection ranges of shower electrons.

By means of the computer modeling of electron ranges in the ECP generated in liquid xenon by GQ with the energy E_γ= 100-3000 MeV it has been shown that the ratio $\eta(t,p|E_\gamma)$ of cascade electron ionization loss (SEI) $\Delta\Sigma Ee(t,p|E_\gamma)$ to relevant SER is constant within a few percent in the central shower region in which, on the average, more than 90% of the total cascade energy is released /18/. So, a more general relation than (2) can be written

$$\frac{\Delta\Sigma E_e(t,p|\,E_\gamma)}{\Delta t\ \Delta p} = \eta(t,p\,|\,E_\gamma)\,\frac{\Delta\Sigma re(t,p|\,E_\gamma)}{\Delta t\ \Delta p}. \qquad (3)$$

At all studied energies E_γ the coefficient turned out to be by about 20% greater than the average one inside a small volume near the conversion point of primary GQ, e.g. at t < 0.5 RL and p <0.1 RL where one observes mostly two straight tracks of a high energy (~E_γ/2) electron/positron only and there is practically no cascading (see, for instance, fig.1). Outside the aforesaid, central shower region η slowly decreases mainly along the SA and essentially at higher energies (E_γ >1000 MeV) by about 10-15%.

Besides, the values averaged over all t and p within each bin of energy E_γ do not depend on E_γ /18/. So, one can admit that η in (3) is a constant value within, on the average, ~3%. The SER were measured with an average accuracy of about 20% but at the end of a cascade it can reach even 50%. In more detail methodical problems are analysed in /19,20/.

IV. EXPERIMENTAL DATA

In table 2 we quote the original experimental data obtained in the work, viz. cascade electron ionization loss (SIL) determined by (3) when η is taken to be constant and equal to 3.63 so that SIL is expressed in MeV/ΔtΔpRL**2, where ΔtΔp = 0.6*0.3 RL*2 is the surface of the elementary grid square.

Table 2.

Average cascade electron ionization loss (ASIL) determined by the relation (3) for shower events belonging to energy bins centred at E_γ.t and p are plane coordinates of elementary square in which ASIL is measured (fig.2). t is expressed in units of 0.6 RL, p - in 0.3 RL, ASIL -in MeV/0.18 RL**2. Statistical errors are given only. The values of ASIL at p and -p at the same value of t (fig.2) are added together.

E_γ = 3375+/-125 MeV

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	p													
1	99.3	1.3												
	6.8	1.2												
2	198.6	10.6	0.3											
	21.7	4.1	0.2											
3	304.2	31.0	3.5											
	35.0	6.5	2.0											
4	395.0	65.7	13.3	3.6	1.4	2.0	2.3							
	35.7	15.4	4.2	2.3	1.4	2.2	2.2							
5	457.3	67.6	21.1	2.5										
	38.0	14.1	8.6	1.5										
6	595.6	88.1	25.9	6.4	3.0	2.5	0.5							
	47.5	15.4	6.0	3.1	1.8	1.7	0.5							
7	611.9	120.4	37.4	10.5	6.8	0.4	0.3							
	35.0	21.2	8.1	4.0	2.4	0.3	0.2							
8	558.7	134.6	49.8	23.6	7.4	2.6	4.4		1.0					
	39.6	15.8	11.9	6.5	5.1	1.8	4.3		0.7					
9	489.5	134.4	58.7	25.8	13.5	3.4	1.9							
	31.2	19.3	13.1	7.6	5.0	1.5	1.8							
10	488.2	145.6	51.9	26.9	9.5	6.1	2.5	0.4	0.4					
	39.0	23.3	13.2	7.4	3.7	2.0	1.4	0.3	0.4					
11	375.6	136.9	48.0	8.4	11.9	6.4	4.4	0.3	0.1					
	39.8	22.9	10.3	2.4	3.9	2.8	2.4	0.2	0.1					

Table 2 (continued)

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	p														
12	283.9	119.7	49.9	28.5	11.4	7.3	1.3	1.8	1.8		1.3	1.9			
	34.2	20.2	12.0	9.3	3.9	3.0	1.2	1.5	1.3		1.2	1.8			
13	295.0	138.3	42.0	14.4	6.4	10.5	8.0	1.1			3.8	0.6	3.1		
	31.3	24.3	7.7	4.1	3.9	4.5	3.9	1.1			3.7	0.6	3.1		
14	243.2	100.6	53.7	8.8	6.4	3.8	7.3	1.8							
	30.5	23.9	12.6	2.8	3.1	2.2	4.0	1.1							
15	217.1	104.1	32.3	15.5	15.0	4.5	3.8	1.6	1.0		0.3	1.0			
	25.2	20.3	6.6	4.9	5.0	2.6	2.2	1.3	1.0		0.2	1.0			
16	216.3	71.8	45.5	20.3	16.6	6.4	4.8	3.1							
	34.2	14.5	11.1	7.4	6.4	3.4	2.7	2.2							
17	174.7	60.6	37.0	18.6	22.0	6.9	5.3	2.5	1.6						
	33.3	11.0	8.5	7.3	7.5	2.9	2.1	1.2	0.9						
18	124.4	50.4	32.2	22.1	14.8	6.3	0.1	1.5			0.6				
	28.9	12.0	9.5	9.8	4.5	3.2	0.1	1.2			0.6				
19	106.6	33.9	32.5	14.5	10.1	8.1	6.3	5.0	2.8	0.9	0.3				
	25.0	7.3	11.6	5.4	4.7	4.2	3.5	3.4	1.9	0.9	0.2				
20	93.6	36.5	21.1	7.8	4.3	5.6	10.1	6.0	1.9						
	22.8	12.3	6.9	2.8	2.3	3.0	5.0	3.8	1.8						
21	62.4	27.5	21.0	20.8	10.6	13.9	7.5	3.3		4.0	0.3	0.6			
	16.9	7.2	6.0	8.4	4.9	5.4	4.5	2.5		3.7	0.2	0.6			
22	38.4	29.8	21.5	8.6	3.5	6.6	3.3	1.9		1.3					
	10.3	8.3	7.4	3.7	2.5	3.4	1.6	1.8		1.2					
23	23.4	8.0	12.6	11.9	7.5	3.6	1.8	3.3	1.9	1.8		0.5			
	7.3	3.1	4.3	5.3	3.9	2.1	1.0	1.8	1.8	1.3		0.5			
24	31.2	6.1	13.0	6.4	3.3	0.4	3.1	3.3		0.6	1.4	0.6			
	13.8	2.7	5.4	3.1	1.7	0.4	2.2	2.3		0.6	1.4	0.6			
25	15.5	5.9	11.8	11.3	4.1	2.5	0.3	5.8	1.0						
	6.8	2.2	6.5	3.9	2.0	1.7	0.2	4.9	1.0						
26	19.6	3.1	7.6	2.8	3.3	2.4	1.8	0.4	1.9	1.5					
	9.6	1.9	4.4	1.4	2.1	2.0	1.2	0.3	1.8	1.5					
27	8.8	10.4	3.0	0.6	1.0	0.8	0.6	0.1		0.3					
	4.0	4.0	2.5	0.4	0.7	0.7	0.4	0.1		0.2					
28	8.8	3.4		2.8	0.9		0.3	1.1	0.5						
	4.1	1.9		2.5	0.7		0.2	0.9	0.5						
29	1.9		3.1	2.8	1.3						1.3	1.3	0.6		
	1.8		1.8	1.5	0.9						1.2	1.2	0.6		
30	2.0	0.6		3.4	5.4		1.3	1.5				1.3			
	1.1	0.4		2.4	2.8		1.2	1.5				0.9			

E_γ = 3125+/-125 MeV

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	p														
1	107.3	0.8													
	6.9	0.8													
2	211.1	2.5													
	16.3	1.6													
3	350.4	21.3	3.6												
	32.7	6.9	2.1												
4	511.5	45.8	7.4	2.7	1.6										
	27.9	12.0	3.3	2.6	1.5										
5	570.9	91.3	22.4	4.2	9.7										
	37.7	16.5	5.6	2.4	6.5										
6	620.9	125.1	36.8	6.9	5.0	1.6									
	45.0	115.0	8.5	2.6	2.9	1.5									
7	620.9	160.9	44.9	16.7	10.0	5.2	0.8								
	38.4	18.2	9.6	5.5	4.5	3.4	0.8								

Table 2 (continued)

E_γ= 1125+/-125 MeV

p t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	107.2	0.8													
	3.8	0.4													
2	164.6	5.0	0.2	0.2											
	7.9	1.2	0.2	0.2											
3	228.5	18.7	3.3	1.0											
	10.6	2.6	1.0	0.6											
4	247.6	31.0	7.7	2.4	0.5										
	10.8	3.1	1.5	0.9	0.4										
5	266.5	52.2	13.7	2.6	0.9	0.1									
	11.4	5.8	2.4	0.8	0.5	0.1									
6	251.0	50.0	19.3	5.8	1.4		0.1	0.5							
	12.6	5.0	2.9	1.3	0.6		0.1	0.3							
7	224.1	53.7	15.8	6.9	2.3	1.5	0.4								
	11.8	5.8	2.2	1.5	0.7	0.7	0.3								
8	184.0	54.2	22.8	5.5	2.9	1.2	0.3	0.2							
	10.1	5.5	3.1	1.1	1.0	0.6	0.3	0.2							
9	148.5	43.5	23.3	10.7	2.1	2.4	0.5	0.7		0.2					
	9.8	4.5	2.7	1.9	0.7	0.8	0.3	0.5		0.2					
10	97.9	29.6	16.7	7.0	5.6	0.5	0.8	0.5	0.6	0.1		0.8			
	8.8	3.6	2.8	1.4	2.0	0.3	0.5	0.5	0.6	0.1		0.8			
11	78.9	29.1	12.9	10.2	2.7	1.0	0.5	0.6	0.2	0.2	0.1				
	7.7	3.9	2.2	2.1	0.8	0.5	0.4	0.5	0.2	0.2	0.1				
12	56.0	28.9	10.8	7.4	5.4	2.0	0.4	0.8	1.1		0.4	0.1			
	6.5	4.1	1.9	1.6	1.4	0.8	0.4	0.4	0.6		0.4	0.1			
13	48.0	25.6	13.0	3.5	3.6	2.0	1.3		0.5	0.3	0.4				
	6.9	3.9	2.7	1.0	1.3	0.7	0.7		0.3	0.2	0.4				
14	40.0	21.9	10.1	3.6	3.4	1.4	0.3	0.5		0.2	0.1		0.4		
	5.5	3.8	1.9	0.9	1.1	0.8	0.2	0.5		0.2	0.1		0.4		
15	31.2	17.6	7.1	4.4	2.7	1.3	1.0								
	3.9	2.9	1.7	1.2	1.1	0.6	0.9								
16	14.9	13.0	7.8	6.3	3.8	1.3	1.2	0.7	0.1						
	2.8	2.3	2.1	2.0	1.2	0.5	0.4	0.6	0.1						
17	13.1	8.1	5.8	5.2	1.7	1.0	0.9	0.4	0.1	0.2	0.8			0.1	
	3.2	1.7	1.4	1.5	0.7	0.6	0.6	0.4	0.1	0.2	0.6			0.1	
18	12.4	8.5	3.3	3.3	2.3	0.7	1.2	0.8	0.5	0.3	0.1				
	2.9	2.3	1.2	1.5	0.8	0.5	0.7	0.5	0.4	0.3	0.1				
19	8.1	4.5	1.1	2.5	1.9	1.6	0.7	0.3	0.1						
	2.3	1.3	0.6	1.0	1.0	0.7	0.4	0.2	0.1						
20	7.8	5.1	2.7	2.1	1.1	1.2	0.5	0.5	0.2		0.1				
	1.9	1.5	1.0	1.3	0.6	0.6	0.4	0.5	0.2		0.1				
21	2.7	2.0	2.5	1.8	0.4	0.6	0.8	0.2							
	1.0	0.9	0.9	0.6	0.3	0.3	0.5	0.1							
22	4.1	1.8	1.5	0.9	0.4	0.7	0.7	0.5	0.6	0.4					
	1.5	1.0	0.7	0.7	0.4	0.5	0.4	0.4	0.6	0.4					
23	4.1	2.1	0.7		0.5	0.3				0.6	0.5				
	1.6	0.9	0.7		0.3	0.2				0.6	0.5				
24	2.5	2.7	0.5	1.0	0.8	1.1	0.1			0.2					
	0.9	1.2	0.3	0.5	0.5	0.6	0.1			0.2					
25	1.6	0.1	0.5	0.6	0.2	0.2	0.4								
	0.8	0.1	0.3	0.5	0.2	0.2	0.4								
26	0.9	0.1	0.2	0.2	0.7	0.5	0.2	0.1							
	0.5	0.1	0.2	0.2	0.5	0.4	0.2	0.1							
27	1.1	0.7	0.8	0.5		0.1				0.1	0.1				
	0.6	0.4	0.6	0.5		0.1				0.1	0.1				
28	0.8	1.1	1.1				0.1	0.1	0.5						
	0.4	0.6	0.6				0.1	0.1	0.5						
29	1.2		0.9		0.5	0.1			0.2	0.3					
	0.8		0.9		0.5	0.1			0.2	0.3					
30		0.2	0.4	0.2											
		0.2	0.3	0.2											

Table 2 (continued)

E_γ= 455+/-45 MeV

p t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	99.9	3.7	1.5	1.6											
	3.5	1.6	0.9	1.3											
2	138.9	7.3	2.5	0.5											
	7.9	2.0	1.1	0.5											
3	152.0	17.2	3.2	0.3											
	10.4	3.4	1.0	0.3											
4	139.1	27.3	9.0	1.6	0.8	0.2	0.1								
	9.7	4.7	2.3	1.0	0.7	0.2	0.1								
5	119.7	29.8	9.2	5.0	0.6	0.6	0.3	0.2		0.5					
	8.7	4.3	2.1	2.0	0.4	0.6	0.2	0.2		0.5					
6	74.1	22.8	10.6	4.9	0.9										
	6.8	3.5	2.6	2.1	0.6										
7	58.1	11.5	9.0	4.8	2.5	0.3	0.3	0.5							
	6.6	2.4	2.6	1.4	1.1	0.2	0.3	0.5							
8	42.6	14.9	4.3	3.4	1.3	0.3	0.2								
	4.9	2.5	1.2	1.2	0.7	0.3	0.2								
9	29.6	16.4	5.9	3.3	0.6		1.1	0.6							
	4.6	3.0	1.6	1.2	0.4		0.9	0.6							
10	25.6	14.3	5.9	4.2	1.5	0.4		0.3							
	4.1	3.6	1.7	1.5	0.7	0.4		0.3							
11	16.2	8.6	4.8	3.1	0.6	1.9	0.4	0.2	0.2			0.5			
	3.2	2.2	1.5	1.1	0.6	1.1	0.4	0.2	0.2			0.5			
12	18.4	6.1	3.0	3.2	0.5	1.3	2.2	0.4							
	3.9	1.5	0.9	1.1	0.3	0.9	1.1	0.3							
13	8.1	5.6	2.9	3.2	0.8	1.1	0.5	0.6			0.3				
	2.2	1.6	1.1	1.3	0.3	0.6	0.3	0.6			0.3				
14	8.9	5.1	3.3	0.6			0.9				0.3				
	2.5	1.8	1.6	0.4			0.6				0.3				
15	4.5	2.1	3.9	1.8	1.2										
	1.6	0.9	1.8	0.8	1.0										
16	0.9	1.5	3.8	0.2	0.5						0.3				
	0.4	0.6	1.4	0.2	0.4						0.3				
17	0.2	0.9	0.6	0.4			0.5	0.3							
	0.2	0.6	0.6	0.3			0.5	0.3							
18	1.3	0.8	0.4	0.6	0.2			0.1	0.2						
	0.5	0.4	0.3	0.4	0.2			0.1	0.2						
19	1.9	0.1	0.4	0.4	0.4				0.2						
	0.9	0.1	0.2	0.4	0.3				0.2						
20	1.1	1.0	1.0	2.1	1.3				0.1						
	0.8	0.8	1.0	1.0	0.9				0.1						
21	0.7	0.3		0.5	0.3										
	0.4	0.2		0.4	0.3										
22		0.3	0.6												
		0.3	0.4												
23		0.3	0.5	0.3				0.3							
		0.3	0.4	0.3				0.3							

Table 2 (continued)

p t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
24	0.3														
	0.3														
25															
26		0.3													
		0.3													
27															
28															
29		0.1													
		0.1													
30		0.3													
		0.3													

E_γ= 175+/-15 MeV

p t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	102.4	1.1													
	6.3	0.6													
2	100.1	11.8	3.0	0.1											
	9.9	3.4	1.5	0.1											
3	54.1	16.1	6.3	0.7											
	6.8	3.7	2.8	0.7											
4	52.8	12.9	2.7	1.6	1.0		0.5	0.6							
	7.7	3.0	1.1	1.0	1.0		0.4	0.6							
5	18.7	10.6	4.7	0.8	0.7	0.8	1.2								
	4.8	3.5	2.9	0.5	0.7	0.5	1.2								
6	17.9	7.8	1.1	1.7											
	5.3	2.5	0.6	1.0											
7	8.3	6.3	1.9	1.4	1.0										
	3.0	2.7	1.0	1.4	1.0										
8	5.2	2.3	3.0		0.8										
	2.0	1.7	1.8		0.8										
9	1.9	3.5	0.2												
	0.9	1.9	0.2												
10	2.6	2.5	1.6												
	2.6	1.2	0.9												
11	1.5	0.5	0.5												
	1.0	0.4	0.4												
12	1.0	1.0	1.0	1.0	1.0										
	0.7	1.0	1.0	1.0	1.0										
13	1.0	0.7	0.6	0.6		0.3									
	0.7	0.5	0.6	0.6		0.3									
14	0.5	3.4	0.1	0.6	0.4	1.0									
	0.4	2.8	0.1	0.6	0.4	1.0									
15		1.3	0.2	1.0											
		0.9	0.2	1.0											
16		0.3				0.6									
		0.3				0.6									
17	0.5								0.5	0.3					
	0.4								0.5	0.3					
18	2.3														
	2.2														

These data contain rich enough original experimental information about electromagnetic showers, and therefore they are very suitable for checking up different theoretical approaches to the ECP problem as well as for several methodical needs.

REFERENCES

1. Lemeilleur F. et al. CERN-EP/89-27.
2. Hirajama H., Ban S., Miura S.-KEK Preprint 86-97.
3. Bianchi F. et al. NIM A279(1989)473.
4. Ferri G. et al. NIM A273(1988)123.
5. Okamoto M., Shibata T. NIM, A257(1987)155.
6. De Angelis A. NIM A271(1988)455.
7. Nelson W.R., Hirayama H., Rogers D.W.O.-The EGS4 Code System, SLAC-265 (December 1985).
8. Niczyporuk B., Słowiński B., Strugalski Z.-JINR, P-2808,Dubna,1966.
9. Kanarek T. et al. Int.Conf. on High Energy Accelerat. and Instr., CERN, Geneva, 1958, p.508.
10. Kuznetsov E.V. et al , PTE 2(1970)56 (in Russian).
11. Słowiński B. et al. JINR P1-86-809, Dubna, 1986.
12. Słowiński B. et al. JINR P1-86-810, Dubna, 1986.
13. Słowiński B. et al. JINR P1-86-811, Dubna, 1986.
14. Ivanovskaya-et al. PTE 2(1968)39 (in Russian).
15. Tsai Y.S. Rev.Mod.Phys. 46(1974)815.
16. Strugalski Z. Materials of the Conf. on the Bubble Chamber Techn., JINR, 796, Dubna, 1961.
17. Kleinknecht K. Detectors for Particle Radiation. Cambridge University Press, 1986, p.150.
18. Słowiński B., Czyżewska D. JINR, P13-88-239, Dubna, 1988.
19. Czaj W.-Thesis. Inst. of Physics. Warsaw University of Technology. Warsaw, 1982.
20. Czyżewska D. Thesis. Inst. of Physics. Warsaw University of Technology. Warsaw, 1989.

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