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ANGULAR DISTRIBUTION OF B AND C PARAMETERS OF NORMALIZED INVARIANT CROSS - SECTION $\rho = C \exp(-BP^2)$ OF $\gamma + A \to P + A'$ REACTION AT MAXIMUM ENERGY OF BREMSSTRAHLUNG γ - QUANTA 4,5 GEV

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ANGULAR DISTRIBUTION OF B AND C PARAMETERS OF NORMALIZED INVARIANT CROSS - SECTION $\rho = C\exp(-BP^2)$ OF $\gamma + A \rightarrow P + A'$ REACTION AT MAXIMUM ENERGY OF BREMSSTRAHLUNG γ - QUANTA 4.5 GEV

Yerevan, 1977

1. It was shown [1,2] that the hypothesis of nuclear scaling for processes induced by strong interacting particles [3,4] is also valid for processes induced by high energy γ- quanta. Analogous data are reported in Ref. [5]. The hypothesis of nuclear scaling is usually considered to be valid for secondaries at emission angles in back hemisphere [4,6] or in kinematically forbidden range of the given particle produced at the interaction of the incident particle with quasi-free nuclear nucleons. It was shown [1,2,4,5] that B and C parameters of exponential representation of normalized invariant cross-section

$$\rho = \frac{1}{\sigma_t}\frac{E}{P}\frac{d^2\sigma}{d\Omega dP} = C \cdot exp(-\frac{T}{T_0}) \equiv C\ exp(-BP^2)$$

change with the variation of the angle of secondary particles. However the angular distribution of these parameters is not yet investigated in detail. Meanwhile our knowledge of the type of these dependences may be very important for the choice of model representations explaining the effect.

In the present work the results on B and C dependences on the emission angle of the proton in process

$$\gamma + A \rightarrow P + A' \qquad (2)$$

on nuclei ^{12}C, ^{63}Cu and ^{208}Pb at maximum energy of bremsstrahlung γ-quanta 4,5 GeV are given.

2. The measurements[7] where conducted at Γ-3 beam of Yerevan synchrotron. Secondary protons in reaction (2) with the kinetic energy T = 80,100,130,180,210,290 MeV were identified by means of the range-telescope [8] for emission angles ranged from 20° to 160°. The errors of angle determination are within ± 15'. The mean -square errors of energy measurement are ± 7,5 MeV for T=80 MeV and ± 3 MeV for T=290 MeV. The intensity of incident γ-quanta was measured by means of Wilson quantameter with ± 2% errors. The results obtained were corrected for nuclear absorption and multiple scattering in the telescope and for the decrease of the effective number of photons due to the pair production in target and for the registration efficiency. For the fixed value of emission angle ϑ and for the given target nucleus the parameters B and C were found by the formula (1).

The dependences of B on the emission angle for ^{12}C (◑), ^{63}Cu (▲) and ^{208}Pb (○) are given in Fig.1. Only the statistical errors are shown. The systematic errors of the determination of B are estimated to be less than 20-25%. From Fig.1 one can see that the parameter B doesn't depend on the target nucleus [1] and decreases smoothly with the emission angle ϑ. In Fig. 1 the experimental points from Ref.[1] and [5] are shown together with our date. As one can see, the ϑ-dependence of B is the same for all the three works, though the values of 3 from Ref.5 exceed systematically those from the Ref [1] and the ones of the present work. It is pointed out in the Ref.[

that the point at $\vartheta = 144^{\circ}$ has large statistical errors($\sim 30\%$) but the points at $\vartheta = 30^{\circ}, 60^{\circ}, 100^{\circ}$ and 120° are statistically well determined. This excess may be possibly due to either the sistematic errors in the measurements or to the fact that the maximum energy of γ-quanta in Ref.[5] was $(E_{\gamma})_{max} = 1{,}2$ GeV. So, according to Fig.1 the B parameter for angles $20^{\circ} < \vartheta < 140^{\circ}$ is the monotone function of $\cos\vartheta$ and tends to saturation at $\vartheta \gtrsim 140^{\circ}$.

4. In Fig.2 the dependences of parameter C on $\cos\vartheta$ for the same nuclei ^{12}C(●), ^{63}Cu (▲) and ^{208}Pb (■) are given. If for ^{12}C nucleus the parameter C increases with the decrease of ϑ angle, it remains constant for ^{63}Cu, while for ^{208}Pb it shows the tendency to decrease. This interesting experimental result confirms the conclusion of Ref.[2] based on preliminary measurements of ϑ-dependence of C that at large angles C depends on the atomic number of the target nucleus and for small angles such a dependence is not observed. Such a behaviour of the parameter C is difficult to explain unambiguously at the present time.

5. Last year there appeared in literature the model estimates for explanation of the cumulative effect and the nuclear scaling. In Ref.[9] an attempt was made to explain the results of available experimental data by calculating the multiple rescattering of secondaries on nucleons of the target nucleus. The author[9] came to the conclusion that the dependence of parameter B has the following form:

$$B = \frac{\vartheta^2}{4mp}\left[d\left(\ln\left(\frac{p\vartheta^2}{2m}+1\right)-\ln\frac{L(\vartheta)}{e\alpha}\right]-\frac{\mathcal{D}}{2p^2} \qquad (3)$$

where ϑ is the emission angle of protons for the angular range $\pi > \vartheta > 1$, m and P are the mass and the momentum of protons, α and D are some constants. The function $L(\vartheta)$ varies over the range 12,5÷(-8) at ϑ changing in the interval ($\pi, \pi/2$). The term $\ln(L/e\alpha)$ is very small with respect to the first term in square bracets. As one can see, B depends not only on ϑ, but on P too. It is necessary to point out that (3) is strictly valid for $P > 2,0$ GeV/c, at $0,4 < P < 1$ GeV/c one can use it for qualitative comparison only[9]. Normalizing the experimental data and the relation (3) e.g. in the point $\vartheta = 90^\circ$, then the quadratic dependence for $60^\circ \leq \vartheta \leq 130^\circ$ agrees well with the results of the present work(Fig.3). Outside this range the discrepancy is considerable.

In Ref. [10] the authors tried to explain the generation of cumulative particles on nuclei by means of the statistical model of the interaction of incident particles with the nucleon of the nucleus. It was supposed first that the cluster (fire-ball) is generated during the collision which could interact with nucleons in the nucleus. The secondary particles are generated owing to the cluster decay at its flight. In this case the invariant cross-section (particles spectrum)

$$f \sim \exp\left(-\frac{E - \vec{V}\cdot\vec{P}}{T_0(1-V^2)^{1/2}}\right) \qquad (4)$$

where V is the critical velocity at which the cluster decay takes place, T_0 is the universal hadron temperature. The present value of T_0 is 160 MeV.

Making use of the uncertainity relation the authors [10] estimated the value of the critical velocity to be V = 0,7.

For T«m (i.e.$T=P^2/2m$) one can find the expression from (4)

$$B=[1-(2mV/p)\cos\vartheta_{VP}]/2mT_o(1-V^2)^{1/2} \quad (5)$$

At high energies, when $E \simeq P (E \gg m)$

$$B=(1-V\cos\vartheta_{VP})/PT_o(1-V^2)^{1/2} . \quad (6)$$

One can see that B depends on both ϑ and P. The ϑ in (5) and (6) is the angle between the direction of cluster motion and the direction of secondaries. Assuming that the direction of cluster motion coincides with the direction of the initial particle, then on the basis of (6) we can find for example $R = B(180^\circ)/B(0^\circ)$.

As the experimental data of the present work are obtained for emission angles from 20° to 160° one can find $B(180^\circ)$ and $B(0^\circ)$ by the extrapolation of data in Fig.1.

It follows from the relation (6), that the calculated value of R_T is 5,7. According to the data of Fig.1, R_{exp} is 4.6±1. Although the relations(4),(5) and (6) are valid for energies of secondaries far in excess of that of secondary protons in the present work, nevertheless the calculated and the experimental values of R turn out to be sufficiently near.

It should be pointed out that the above comparisons have just illustrative character, as the theoretical considerations[9,10] are far from being perfect.

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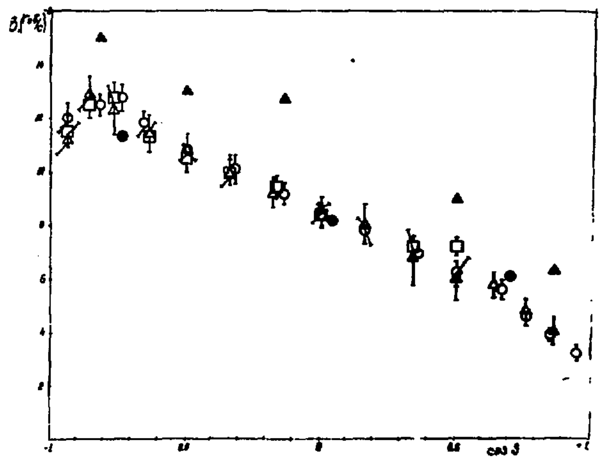

Fig. 1

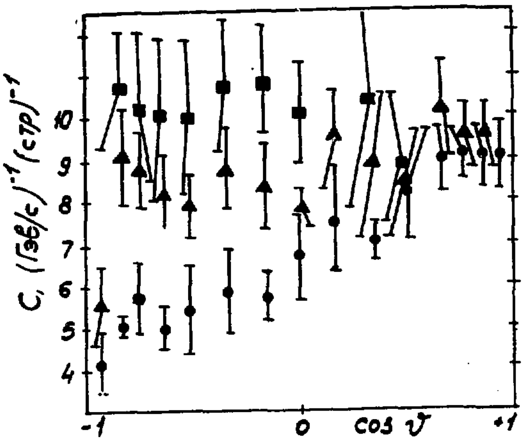
C, (ГэВ/с)^-1 (стр)^-1
4
5
6
7
8
9
10
-1
0
cos ϑ
+1

Fig.2

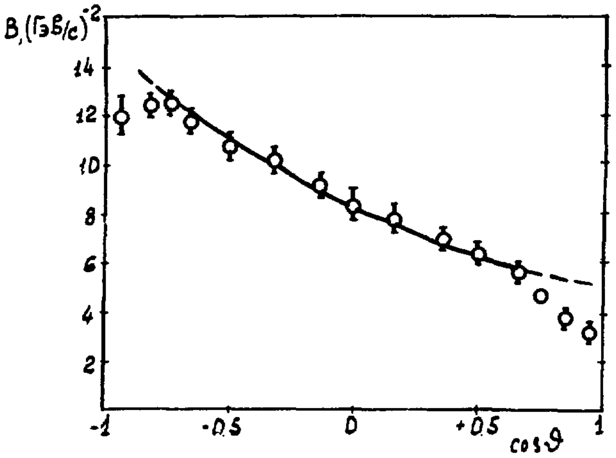
B, (ГэВ/с)^-2
2
4
6
8
10
12
14
-1
-0.5
0
+0.5
1
cos ϑ

Fig.3

Figure Captions

Fig.1. Dependence of parameter B in relation $p = C \cdot \exp(-Bp^2)$ on emission angle of protons in $\gamma + A \rightarrow p + A'$ reaction. The experimental points ○, △, □ correspond to ^{12}C, ^{63}Cu, ^{208}Pb respectively, ● from Ref. [1] △- from Ref. [5].

Fig.2. The same dependence as in Fig. 1 for parameter C. The experimental points ●, ▲, ■ correspond to ^{12}C, ^{63}Cu, ^{208}Pb, respectively.

Fig.3 ϑ-dependence of parameter B for the ^{12}C. The curve correspond to rel.(3) (normalized to the experimental results at $\vartheta = 90^\circ$).

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УГЛОВАЯ ЗАВИСИМОСТЬ ПАРАМЕТРОВ B И C НОРМИРОВАННОГО ИНВАРИАНТНОГО СЕЧЕНИЯ $P = C \cdot exp(-BP^2)$ РЕАКЦИИ $\gamma + A \rightarrow P + A'$ ПРИ МАКСИМАЛЬНОЙ ЭНЕРГИИ ТОРМОЗНЫХ γ -КВАНТОВ 4,5 ГЭВ

(на английском языке)

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