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A b s t r a c t

Cross section of electron-positron pair electroproduction for large angles with the colliding $e^{\pm}e^{-}$ beams is calculated. The result obtained is in good agreement with the experiment.

In experiment with the colliding e^+e^- beams of 2x510 Mev (φ -resonance region) in Novosibirsk /1/ the class of events with non-collinear final particles is found. Preliminary data are given in paper /2/, where electroproduction process $e^+e^- \to e^+e^- + e^+e^-$ is proposed to be a possible source. We consider in present paper the process of electron-positron pair electroproduction for large angles with particles energy of $\varepsilon_\pm \gg \varepsilon_0,\ m \ll \varepsilon_0 \ll \varepsilon$ at $e^\pm e^-$ collision at high energies. The obtained cross section is in good agreement with experimental results (see /1/); so it permits to make an unique identification of observed process.

Let us consider electroproduction process in c.m.system. The main contribution in a total cross section as well as in a cross section we are interested in is given by diagrams on which electron-positron pair is produced by two photons ("two-photons" diagrams). The contribution of these diagrams in a total cross section (without exchange effects) is

$$\sigma = \frac{\alpha^4}{27\pi m^2}\left[28L^3 - 178L^2 + (490 - 82\pi^2)L\right] \qquad (1)$$

where $L = \ln\frac{4\varepsilon^2}{m^2}$, ε is the energy of initial particle. In (1) only the terms with "large" logarithm are remained. The rest diagrams ("one-photon") as well as the account of exchange effects give the contributions containing only the first degree of L. Note, that the dependence $1/m^2$ in the cross section occurs because the contribution gives a region where invariant mass of produced pair is $\Delta^2 = (p_+ + p_-)^2 \sim m^2$ (distribution $d\Delta^2/\Delta^4$), and the origin of logarithms of the main term (1) is the next: L occurs while integrating over square of momentum transfer of virtual photons as well as integrating over energy $(\omega=\varepsilon_+ +\varepsilon_-)$ of produced pair.

In the problem considered another situation takes place if the energy of particles of pair is $\varepsilon_\pm \gtrsim \varepsilon_0$. At large angles $\Delta^2 \gtrsim \varepsilon_0^2$, so that cross section $\sim 1/\varepsilon_0^2$. Because of this the choice of terms which give the main contribution changes essentially. It is clear that the cross section can not contain more than L^2 as for large angles the increasing energy $\varepsilon_\pm$ means the increasing of Δ^2, and for Δ^2 we have power cut off.

Now we pass to calculation of cross section $d\sigma/d\Omega_+ d\Omega_-$ where $\Omega_\pm(\vartheta_\pm,\varphi_\pm)$ are solid angles of particles of produced pair, and $\varepsilon_\pm \gtrsim \varepsilon_\pm^0$, $m \ll \varepsilon_\pm^0 \ll \varepsilon$. We shall carry out an expansion in degrees of $(m/\varepsilon_0)^2$, $\varepsilon_0/\varepsilon$ and remain only the main terms of expansion. Note, that in the considered problem the contribution in cross section of two-photons diagrams when the initial particle deflects on large angles is $\sim 1/\varepsilon^2$. The same estimation is valid also for the contribution of one-photon diagrams as a whole (as well as that of annihilation diagrams) so that the exchange effects are not essential.

The cross section we are interested in may be represented as (with an accuracy to terms $\sim \varepsilon_0/\varepsilon$)

$$\frac{d\sigma}{d\Omega_+ d\Omega_-}=\frac{\alpha^4}{2\pi^4}\frac{q_{1\perp}^m q_{1\perp}^{m'} q_{2\perp}^n q_{2\perp}^{n'} M_{mm'nn'}\,\delta(q_1+q_2-p_+-p_-)}{q_{10}^2 q_{20}^2\left(q_{1\perp}^2+\frac{m^2}{\varepsilon^2}q_{10}^2\right)^2\left(q_{2\perp}^2+\frac{m^2}{\varepsilon^2}q_{20}^2\right)^2}\times$$
$$\times\, p_+ p_-\, d\varepsilon_+ d\varepsilon_-\, dq_{10}\, dq_{20}\, d\vec{q}_{1\perp}\, d\vec{q}_{2\perp} \qquad (2)$$

where q_1, q_2 are momenta of virtual photons; $\vec{q}_{1\perp},\vec{q}_{2\perp}$ are components of $\vec{q}_1,\vec{q}_2$ perpendicular to the direction of initial particles collision; $M_{\sigma\sigma'\varrho\varrho'}$ is Compton tensor of produced pair. In essential region $q_{10},q_{20}\sim\varepsilon_\pm\sim\varepsilon_0$, $\frac{m^2\varepsilon_0^2}{\varepsilon^2}\lesssim q_{1\perp}^2, q_{2\perp}^2\lesssim\varepsilon_0^2$; this determines the choice of the main terms in (2). In our problem $\varepsilon_0 \gg m$, so that in Compton tensor mass m may be omitted. We shall calculate with the accuracy when in $d\sigma/dc_+dc_-$ $(c_\pm=\cos\vartheta_\pm)$ the terms with L remain. These logarithms occur while integrating over $q_{1\perp}^2, q_{2\perp}^2$, so that we must consider the regions in which at least one of these values is small. As a result of calculation we have

$$\frac{d\sigma}{d\Omega_+ d\Omega_-}=\frac{\alpha^4}{16\pi^3}\left\{\frac{1}{(\varepsilon_+^0)^2}\int\limits_{\varepsilon_-^0/\varepsilon_+^0}^{\infty}\frac{dt}{\lambda_1^2\lambda_2^2\left[\delta^2+\frac{m^2}{\varepsilon^2}(\lambda_1^2+\lambda_2^2)\right]}\times\right.$$
$$\times\left(\ln\frac{\delta^2+\frac{m^2}{\varepsilon^2}(\lambda_1^2+\lambda_2^2)}{\frac{m^2}{\varepsilon^2}\lambda_1\lambda_2}-\frac{\delta^2}{\delta^2+\frac{m^2}{\varepsilon^2}(\lambda_1^2+\lambda_2^2)}\right)\left[\left(\frac{1-c_+}{1-c_-}+t^2\left(\frac{1-c_-}{1-c_+}\right)+\right.\right.$$
$$\left.\left.\left.+t\frac{(s_+^2-t^2s_-^2)(c_+-c_-)}{\lambda_1^2(1-c_+)(1-c_-)}\right)+(c_{+,-}\leftrightarrow -c_{+,-})\right]+\begin{pmatrix}\vartheta_+\leftrightarrow\vartheta_-\\ \varepsilon_+^0\leftrightarrow\varepsilon_-^0\end{pmatrix}\right\} \qquad (3)$$

where

$$\delta^2=(ts_- - s_+)^2+2ts_+s_-(1-\cos\varphi),$$
$$\lambda_{1,2}=\frac{1}{2}\left[1\pm c_+ + t(1\pm c_-)\right],\quad t=\frac{\varepsilon_-}{\varepsilon_+},$$
$$\varphi=\varphi_+-\varphi_-,\quad s_\pm=\sin\vartheta_\pm,\quad c_\pm=\cos\vartheta_\pm, \qquad (4)$$

in cross section (3) we put for generality that $\varepsilon_+>\varepsilon_+^0$, $\varepsilon_->\varepsilon_-^0$, polar axis is directed along the initial particle direction.

To clear up qualitative peculiarities of this cross section it is convenient to use an expression which retains only the terms $\sim L^2$ in $d\sigma/dc_+dc_-$ and which is true at $\varphi \gtrsim m/\varepsilon$

$$\frac{d\sigma}{dc_+dc_-d\varphi} = \frac{4\alpha^4}{\pi} \frac{\left[\frac{s_-(1-c_+)}{s_+(1-c_-)} + \frac{s_+(1-c_-)}{s_-(1-c_+)}\right]}{\left[(s_++s_-)^2-(s_+c_-+s_-c_+)^2\right]^2} \times$$

$$\times \frac{\ln\left[\frac{2\varepsilon^2}{m^2}(1-\cos\varphi)\right]}{\sqrt{\frac{m^2}{\varepsilon^2}+2(1-\cos\varphi)}} \left[\theta\left(\frac{\varepsilon_-^0}{\varepsilon_+^0}-\frac{s_+}{s_-}\right)\frac{s_+^2}{(\varepsilon_-^0)^2} + \theta\left(\frac{s_+}{s_-}-\frac{\varepsilon_-^0}{\varepsilon_+^0}\right)\frac{s_-^2}{(\varepsilon_+^0)^2}\right] \quad (5)$$

where θ is θ-function.

Integrating over φ cross section (5) we come to an expression which may be obtained by means of the method of equivalent photons. In this approximation kinematics of the process is the same as at frontal collision of photons with energy q_{10}, q_{20} , i.e. the momenta of final particles are complanar but not collinear. As it follows from (5) the distribution in azimuthal angle (angle of non-complanarity) has logarithmic (i.e. rather wide) peak at small φ , and the cross section of the process with non-complanar events (with $\varphi \sim 1$) is only L time smaller than the cross section integrated over φ . The considered situation is shown in Fig.1 which illustrates the distribution for cross section (3) when ε = 500 Mev, ε_0 = 15 Mev. As to the dependence upon polar angles $\theta_\pm$ it is rather smooth; that is shown in Fig.2 at the same $\varepsilon, \varepsilon_0$.

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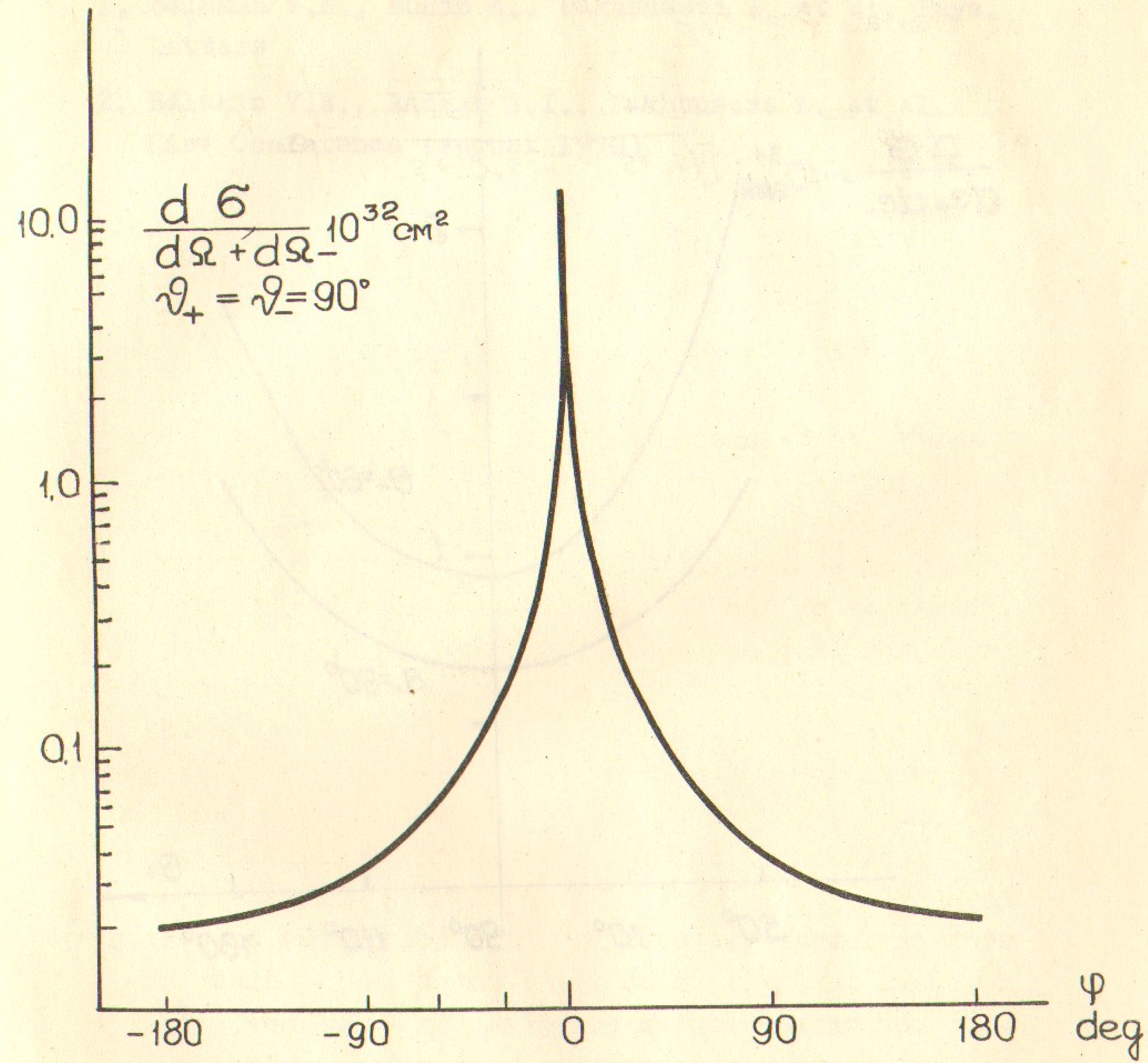

Fig.1

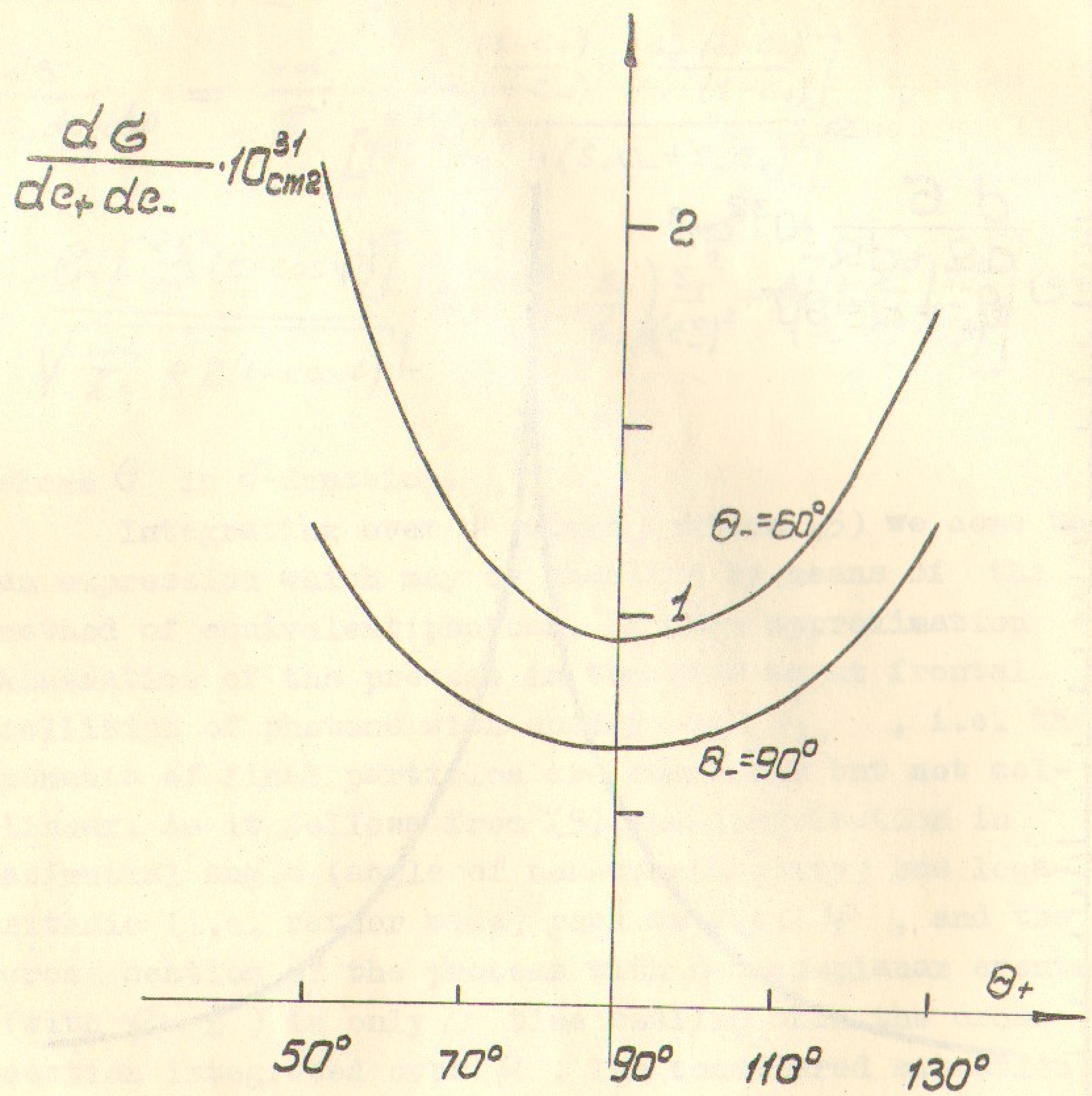

Fig.2

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2. Balakin V.E., Budker G.I., Pakhtusova E. et al. Kiev Conference (august 1970).

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