Experimental observation of type-B coherent photoproduction of e^+e^- pairs in a crystal

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(Submitted 6 March 1990)
Pis'ma Zh. Eksp. Teor. Fiz. **51**, No. 7, 349–351 (10 April 1990)

The energy dependence of the coherent production of e^+e^- pairs in a crystal (diamond, ⟨100⟩) has been measured for the first time at photon energies of 100–1000 MeV. The results confirm the existence of a type-B effect in this process.

Coherent bremsstrahlung and pair production are known[1] to occur at high energies of the initial particles, $\gtrsim 500$ MeV, and at angles of incidence $\theta \neq 0$ with respect to crystallographic axes. These processes were labeled "type-A" processes in Ref. 2. It was shown in Refs. 3 and 4 that coherent effects can also occur in pair production at relatively low photon energies, $E_\gamma = 100$–300 MeV, and at $\theta = 0$. The process predicted in Refs. 3 and 4 is a "type-B" effect, in which planes, rather than rows or points, contribute substantially in reciprocal-lattice space (it is a planar effect). Other type-B effects are coherent bremsstrahlung at low energies[2] and the Okorokov effect[5] and the Primakoff effect[6,7] in crystals at $\theta = 0$.

The occurrence of the coherence effect can be understood on the basis of the following considerations.[1] The minimum longitudinal momentum which can be transferred to a nucleus in the photoproduction of e^+e^- pairs is $q_{\parallel\min} = 2m^2/E_\gamma$, where m is the mass of an electron. Equating $q_{\parallel\min}$ to $2\pi n/d$ at $\theta = 0$, where d is the distance between atoms along an axis, we find $E_\gamma^n = m^2 d/\pi n$, which are the values at which the various planes ($n = 1,2,3,...$) come into the coherence "pancake," leading to the characteristic interference pattern in the cross section. The cross section for the process in a crystal, $\sigma^{\rm cr} = \sigma^{\rm at} + \sigma^{\rm coh}$, was calculated in the Born approximation in Refs. 3 and 4, and it was shown that the ratio $R = (\sigma^{\rm cr} - \sigma^{\rm at})/\sigma^{\rm at}$ reaches values $\sim 20\%$.

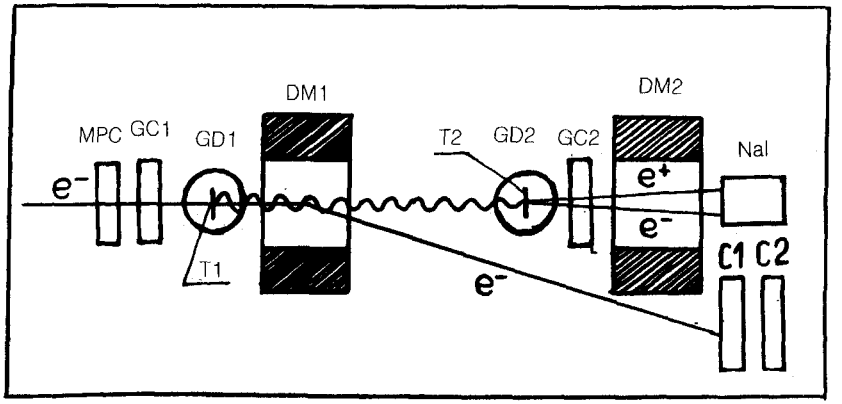

FIG. 1. Experimental layout.

In this letter we are reporting the first experimental results, obtained in the extracted electron beam of the Erevan synchrotron.[8] Figure 1 shows the experimental layout. The 4.5-GeV electron beam, with an angular divergence $\sim 10^{-4}$ rad, enters the vacuum chamber of a goniometer device (GD1), where there is a diamond crystal radiator (T1) with a thickness of 1 mm. The photons which are emitted from electrons channeled in the (110) plane are incident directly on a second diamond crystal (T2), 1 mm thick, in GD2. The radiation emitted during channeling is used here because the photon intensity is more intense (by a factor ~ 50) than the amorphous spectrum in the energy range of interest, $E_\gamma = 100$–300 MeV (Ref. 9). The electrons deflected by magnet DM1 are detected by scintillation counters C1 and C2. The e^+e^-

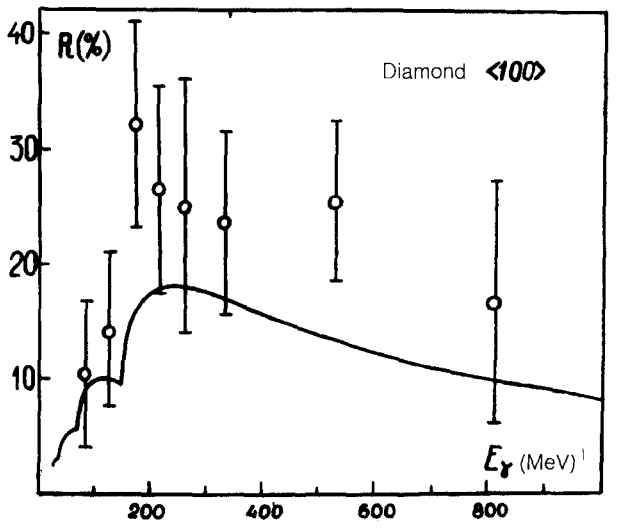

FIG. 2. Experimental and theoretical results on R as a function of E_γ.

pairs produced in T2 are detected by gas-filled proportional counter GC2 and a total-absorption spectrometer using a NaI(T1) crystal. Gas-filled counter GC1 is used to generate a trigger signal, and a multiwire proportional chamber (MPC) provides the coordinates of the primary electrons before incidence on target T1. Magnet DM2 is used to orient crystal T2. In the experiments, at a fixed number of photons incident on T2 we measure the number (N_{or}) of pairs produced in the oriented diamond crystal ($\theta = 0, \langle 100 \rangle$ axis) and the number (N_d) produced in a disoriented diamond crystal ($\theta \approx 100$ mrad). Taking the background measurements for the given E_γ region into account, we calculate $R = (N_{or} - N_d)/N_d$.

Figure 2 shows the results of these measurements (the points) and also a theoretical prediction (solid line) of R as a function of E_γ. Despite the relatively large statistical errors, the experimental and theoretical data show the same energy dependence. There is a tendency for the experimental values to run above the theoretical values. A discussion of this point will be postponed until the planned measurements of the differential cross sections are carried out with the help of a pair spectrometer, as proposed in Ref. 3.

In summary, these results support the prediction[3,4] of type-B coherent effects in the photoproduction of e^+e^- pairs in crystals.

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Translated by Dave Parsons