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THE ELECTROMAGNETIC CHARGE ASYMMETRY IN ANGULAR DISTRIBUTION OF K-MESONS IN PROCESS $e^+e^-\to K^+K^-$ NEAR THE φ-RESONANCE.

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The electromagnetic charge asymmetry in angular distribution of K-mesons created in electron-positron collisions is calculated in the region of φ-resonance. The results are applicable for arbitrary narrow resonance, in particular for the process $e^+e^-\to\mu^+\mu^-$ near ψ-peak.

The electromagnetic charge asymmetry has been discussed previously in the works /1-5/. The effect arises both from the diagrams with emission of real photon (this photon is denoted at the figures by the wavy line) and from the diagrams without radiation of real photon. In the first case asymmetry arises in the interference of graphs in which initial particles radiate (fig.1a) with graphs in which final particles radiate (fig.1b).

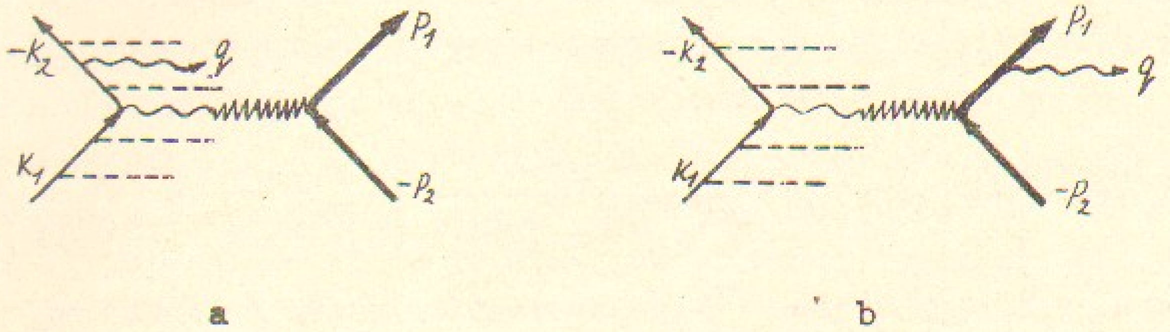

fig.1

In second case the effect arises in the interference of the basis amplitude M_0 (fig.2a) and diagrams with virtual photon(fig.2b).

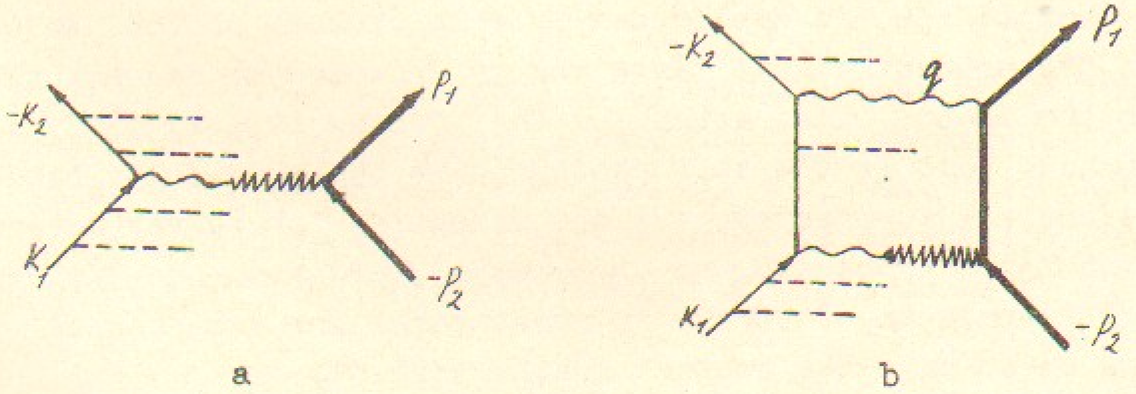

fig.2

In both cases the reason of asymmetry is the interference of the graphs which describe the creation of final particles in states with different charge parity. For narrow resonance doubly logarithmic corrections are also essential. This corrections connected with the emission of the arbitrary number of soft photons by the initial electrons (at the figures this photons are denoted by the dotted lines).

Consider at first the contribution of the diagrams with radiation of real photon. (The asymmetry in process with emission of real photon for unresonance formfactor was calculated previously in paper /6/.) The emission of hard quantum leads the reaction off the resonance, therefore we may use the soft photons approach. C-odd part of the square of amplitude summed over polarizations and integrated over momenta of photon is

$$\frac{\alpha}{\pi^2}|M_0(\varepsilon)|^2 Re\left\{((E-\varepsilon)^2-\mu^2+i\mu\Gamma)\int\frac{d\vec{q}}{\sqrt{\vec{q}^2+\lambda^2}((E-\varepsilon-|\vec{q}|)^2-\mu^2+i\mu\Gamma)}\left[\frac{k_1p_1}{(k_1q)(p_1q)}-\frac{k_1p_2}{(k_1q)(p_2q)}\right]\right\} \quad (1)$$

Here $E=\sqrt{(k_1+k_2)^2}$, μ and Γ are respectively the mass and width of φ-meson. Because of the infrared divergence here as usually we introduce the photon mass λ. ε is the energy carried away by "dotted" quanta. The integration is carried out over the domain $0<|\vec{q}|<\varepsilon_{max}-\varepsilon$, where ε_{max} is the maximal energy which can be carried away by all photons. That is, ε_{max} is the experimental resolution.

Compute now the amplitude M_γ with virtual photon. As well as in the preceding case large energy or momentum can not flow along the photon line, otherwise the process is lead off the resonance, that is the soft photons give the main contribution. Therefore all formfactors are not essential (of course except the resonance propagator of φ-meson), and also one may neglect the momentum of photon in numerators. The same reason allows us to omit the contact graphs (fig.3).

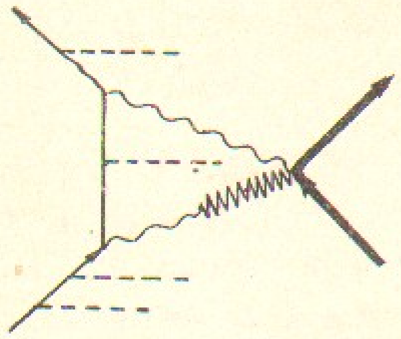

fig.3

Than looks as follows

$$-\frac{i\alpha}{2\pi^3}M_0(\varepsilon)((E-\varepsilon)^2-\mu^2+i\mu\Gamma)\int\frac{d^4q}{(q^2-\lambda^2+i\delta)((E-\varepsilon-q_0)^2-\mu^2+i\mu\Gamma)}\times$$

$$\times\left[\frac{k_1p_1}{(q^2/2-k_1q+i\delta)(q^2/2-p_1q+i\delta)}-\frac{k_1p_2}{(q^2/2-k_1q+i\delta)(q^2/2-p_2q+i\delta)}\right] \quad (2)$$

where $q=(q_0,\vec{q})$. Compute at first the integral over q_0. As usually considering q_0 as complex variable we close the contour of integration in lower halfplane. The integrand has there several poles, but only the pole at the point $q_0=\sqrt{\vec{q}^2+\lambda^2}-i\delta$ is essential. The other singularities are situated in domain of "hard" photons($q_0\sim\mu$), and therefore they are not resonancely amplified. Thus, near resonance the exchange of real soft photon gives the main contribution to M_γ. After the integration over q_0 M_γ looks as follows

$$-\frac{\alpha}{2\pi^2}M_0(\varepsilon)((E-\varepsilon)^2-\mu^2+i\mu\Gamma)\int\frac{d\vec{q}}{\omega((E-\varepsilon-\omega)^2-\mu^2+i\mu\Gamma)}\left[\frac{k_1p_1}{(k_1q)(p_1q)}-\frac{k_1p_2}{(k_1q)(p_2q)}\right] \quad (3)$$

Here $q=(\omega,\vec{q})$, $\omega=\sqrt{\vec{q}^2+\lambda^2}$. The remaining integral over $\vec{q}$ differs from the integral in (1) only in the limits of integration. Here integration is carried out over all $\vec{q}$. Both this integrals are computed in standart way. Finally in neighbourhood of φ-peak the differential cross-section of the process $e^+e^-\to K^+K^-$ is equal to

$$\frac{d\sigma}{d\Omega}=\int_0^{\varepsilon_{max}}d\varepsilon\,\frac{d\sigma_0(\varepsilon)}{d\Omega}\left[1+\frac{4\alpha}{\pi}\ln\left(\frac{\sqrt{(\Delta-\varepsilon_{max})^2+\Gamma^2/4}}{\varepsilon_{max}-\varepsilon}\right)\ln\frac{1+v\cos\theta}{1-v\cos\theta}\right] \quad (4)$$

where $\Delta=E-\mu$, v is velocity of K-mesons, θ is the angle of flight of K^- in the respect to the electron beam, $\frac{d\sigma_0(\varepsilon)}{d\Omega}$ is resonance cross-section accounting for the doubly logarithmic corrections. The quantity $\frac{d\sigma_0(\varepsilon)}{d\Omega}$ was calculated in the works /7,8/, and therefore for the computing the coefficient of charge asymmetry which is defined as

$$\xi=(d\sigma(\theta)-d\sigma(\pi-\theta))/(d\sigma(\theta)+d\sigma(\pi-\theta))$$

one has only to take the integral in (4). So far as this integral in general case cannot be computed in analytic form (of course one can easy to carry out the integration numerically) we present the result for ξ only in the two simple cases

$$\xi = \frac{4\alpha}{\pi}\ln\frac{\sqrt{\Delta^2+\Gamma^2/4}}{\varepsilon_{max}}\ln\frac{1+v\cos\theta}{1-v\cos\theta} \quad ; \quad \varepsilon_{max} \ll \sqrt{\Delta^2+\Gamma^2/4}$$

$$\xi = 2\alpha\beta(\beta/\pi+\beta^{1-t}+t)\ln\frac{1+v\cos\theta}{1-v\cos\theta} \quad ; \quad \Delta \ll \Gamma/2 \ll \varepsilon_{max}$$

where $\beta=\Gamma/2\varepsilon_{max}$, $t=\frac{2\alpha}{\pi}\left(\ln\frac{M^2}{m_e^2}-1\right)$

It is seen that the asymmetry depends essentially on the ε_{max}, that is on the experimental resolution. For the process $e^+e^-\to\varphi\to K^+K^-$ for reasonable values of ε_{max} the asymmetry is less than 1% .

In conclusion it should be noted that because only soft photons give the contribution to the asymmetry, it is evident that result does not depend on the spin of particles. That is our results are correct for the arbitrary process of the type $e^+e^-\to X^+X^-$ near the narrow resonance. For example, they are valid for reaction $e^+e^-\to\mu^+\mu^-$ in the region of ψ'-peak (of course if ψ' has the definite C-parity), or for $e^+e^-\to\pi^+\pi^-$ in ρ-resonance.

After this work was over it became known to me that smallness of electromagnetic charge asymmetry near ψ'-resonance was marked in the work /7/.

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