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ON APPLICATION OF RADIATIVE EFFECTS TO DETERMINATION OF A RESONANCE WIDTH

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Very recently existence of a narrow resonance was discovered at the Stanford electron-positron storage ring SPEAR [1] (suggested by authers naming of this structure is ψ - particle) in the following reactions

$$e^-e^+ \to \psi \longrightarrow \text{hadrons};\ e^-e^+\ ;\ \mu^-\mu^+ + \pi^-\pi^+ + K^-K^+ \qquad (1)$$

A mass of the particle is m_ψ =(3 105$\pm$ 3) Mev,full width is $\Gamma_\psi \leq$ 1.9 Mev (1.9 Mev is the full width at half maximum of a energy distribution at SPEAR).Simultaneously the same resonance was discovered by M.I.T. group at Brookhaven [2] in reaction

$$p + Be \longrightarrow e^- + e^+ + X \qquad (2)$$

where an invariant mass of the electron-positron pair $(p_+ + p_-)^2 = m^2_{e^-e^+}$ was measured.The mass of the particle is m_ψ = 3 100 Mev, $\Gamma_\psi \leq$ 20 Mev (20 Mev is an experimental resolution).The data of both papers don't contradict assumption that full width is much narrower than the experimental resolution.There is a preliminary communication [3] about one more resonance of such kind with $m_{\psi'}$ =(3 700 $\pm$ 20) Mev and $\Gamma_{\psi'} \leq$ 4 Mev.

It is known that at production of the narrow resonances at electron-positron colliding beams (1) the peak possesses wide radiative tail the cause of which is following:at $2\varepsilon - m_\psi > 0$ (ε is the initial electron(positron) energy) emission of photon by initial particles "returns" them to the resonance energy[4] region[5]. If one presents cross section of the resonance production in standard Breit-Wigner form

$$\sigma^{Res} = 4\pi(2J+1)\frac{\Gamma_{\psi\to f}\,\Gamma_{\psi\to e^-e^+}}{(s-m_\psi^2)^2+m_\psi^2\Gamma_\psi^2} = \frac{\pi(2J+1)}{m_\psi^2}\,\frac{\Gamma_{\psi\to f}\,\Gamma_{\psi\to e^-e^+}}{(2\varepsilon-m_\psi)^2+\Gamma_\psi^2/4} \quad (3)$$

where J is a particle's spin, $\Gamma_{\psi\to f}$ is a partial width of a decay $\psi\to f$; than cross section of the process which is accompanied by the photon emission has a form[5] (see also[6])

$$\sigma^{rad} = \frac{(2J+1)}{m_\psi^2}\,\frac{\Gamma_{\psi\to f}\,\Gamma_{\psi\to e^-e^+}}{(2\varepsilon-m_\psi)^2+\Gamma_\psi^2/4}\,\alpha L\left[\frac{2\tau(0)}{\Gamma_\psi}\,\mathrm{Arc\,tg}\,\frac{2\omega\Gamma_\psi}{\tau(\omega)\tau(0)+\Gamma_\psi^2}+\ln\frac{\tau^2(0)+\Gamma_\psi^2}{\tau^2(\omega)+\Gamma_\psi^2}\right] \quad (4)$$

where $\alpha = 1/137$, $L = 2\ln(m_\psi/m_e) - 1$, $\tau(\omega) = 2(2\varepsilon - m_\psi - \omega)$, ω is the maximally permissible energy of photon[7] which is determined for the total cross section by a kinematic boundary. We omit in eq.(4) radiative effects which aren't connected with return on resonance. A logarithmic term in expression (4) is essential only not far from resonance, but at the right side in a distance from resonance the first term in a square bracket is dominant and at $2\varepsilon - m_\psi \gg \Gamma_\psi$, Arc tg $\frac{2\omega\Gamma_\psi}{\tau(\omega)\tau(0)+\Gamma_\psi^2} \to \pi$

The resonance peak is essetially asymmetrical in this region because it's left slope according to eq.(3) decreases as $(2\varepsilon-m_\psi)^{-2}$ when it's right slope according to eq.(4) decreases as $(2\varepsilon-m_\psi)^{-1}$. The experiment [1] shows that $\Gamma_{\psi\to hadr} \simeq \Gamma_\psi$, than it is evident that comparing data on the right slope of the resonance peak in the reaction $e^-e^+\to\psi\to$ hadrons with eq.(4) one can find experimental value of the partial width[8] $\Gamma_{\psi\to e^-e^+}$. Comparing the left and the right slopes of the resonance peak one can find the full width of the resonance using one exitation curve (see below).

We want to draw one's attention to the possibility of determination of the full resonance width using radiative

effects also in reaction (2). It is particulary important because in such reaction the cross section observed has no absolute calibration and it's hadron part can not be calculated theoretically. The standatd condition of the experimental determination of Γ_ψ is $\frac{\Gamma_\psi}{2} \gg \delta_{exp}$, where δ_{exp} is an experimental energy (invariant mass) dispersion. The radiative effects give a new important opportunity also in this case. The reason is that emission of the photon by the electron or positron gives the consequence - "move forward" the resonance. In this case $m_\psi^2 = (p_+ + p_- + k)^2$ while $m_{e^-e^+}^2 = (p_+ + p_-)^2 < m_\psi^2$. Another words on the plane N (events number), $m_{e^-e^+}^2$ the peak of the reaction (2) is <u>asymmetrical with gentle left slope</u>. One can easily be convinced that in this case the eq.(4) after substitution $2\varepsilon - m_\psi \to m_\psi - \sqrt{m_{e^-e^+}^2}$ is also valid. In symmetrical relatively resonance maximum points $2\varepsilon_1 - m_\psi = m_\psi - 2\varepsilon_2 > 0$ (where $2\varepsilon = \sqrt{m_{e^-e^+}^2}$) one has

$$\sigma^{rad}(\varepsilon_2) = \frac{4\alpha L\,|m_\psi - 2\varepsilon_1|}{\Gamma_\psi}\,\sigma^{Res}(\varepsilon_1) \quad (5)$$

Using this formula one can determine the full resonance width in the reaction (2), as well as in reaction (1) (where one should make a substitution $\varepsilon_1 \leftrightarrow \varepsilon_2$) if conditions are fulfilled which permit to establish the slope asymmetry.

Let us consider these conditions. Let R is the ratio of the cross section in the resonance point ($2\varepsilon = m_\psi$) to the cross section far from resonance σ^b, that is $\frac{\sigma^{Res}}{\sigma^b} = R\Gamma_\psi^2 / 4[\delta^2 + \frac{\Gamma_\psi^2}{4}]$, where $\delta^2 = (2\varepsilon - m_\psi)^2$. Than we are interesting in the region where $\sigma^{Res} > \sigma^b$, $\sigma^{rad} > \sigma^{Res}$. Using eq.(5) one has inequalities for the energy interval

$$R\Gamma_\psi^2 > 4\delta^2 > \Gamma_\psi^2/(2\alpha L)^2 \quad (6)$$

It is necessary besides that energy dispersion doesn't smooth out the effect considered, that is $\delta \gg \delta_{exp}$. Than from eq.(6) one has condition for δ_{exp}: $\sqrt{R}\,\frac{\Gamma_\psi}{2} \gg \delta_{exp}$ which is evidently much weaker than $\frac{\Gamma_\psi}{2} \gg \delta_{exp}$ .The above inequalities are satisfied well for the Stanford experiment [1].Usining the published data one can obtain $\Gamma_{\psi\to e^-e^+}$= 5 Kev (this estimation has been obtained by many people), Γ_ψ = 140 Kev.The resonance curve obtained at the Brookhaven experiment [2] is actually asymmetrical with gentle left slope,however using it one can obtain only very crude estimation.This estimation of Γ_ψ will be much more satisfactory if the energy resolution will be several times better.

References and Footnotes

1.J.E.Augustin et al.Phys.Rev.Lett in press

2.J.J.Aubert et al.Phys.Rev.Lett.in press

3.B.Richter.Private communication.

4.For processes considered it is possible to restrict oneself by region $|2\varepsilon - m_\psi| \ll m_\psi$.

5.V.N.Baier,V.S.Fadin.Phys.Lett.27B,223,1968

6.V.N.Baier.International Yerevan school 1971.Preprint I.Ja.F. 52-72 1972.

7.If one measures differential over photon energy cross section $d\sigma/d\omega$ at fixed energy of electrons and positrons,than one obtaines resonance peak with maximum in point $\omega = 2\varepsilon - m_\psi$.

8.As become known to us this method of determination of $\Gamma_{\psi\to e^-e^+}$ was discussed by Wainstein,Joffe,Lipatov,Sushkov,Khoze.

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