Contribution of the Two-photon Annihilation Process in the Measurement of σ_t ($e^+e^- \rightarrow$ hadrons at PEP)

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ABSTRACT

The possible impact of the 2γ process $e^+e^- \rightarrow e^+e^-$ + hadrons is evaluated as a source of background for the study of the one photon annihilation process. Two regions of hadron system invariant mass are considered--the resonance region with low invariant mass, and the "diffractive" region above 2 GeV hadron invariant mass. In spite of the fact that the 2γ cross-section rises with the energy of the initial e^+e^- system, it seems clear that measurements of the total energy of the final hadron system will allow the clean separation of the 2γ events from the single photon annihilation reaction.

Contribution of the Two Photon Annihilation Process in the Measurement of σ_{total} ($e^+e^- \to$ hadrons) at PEP.

It has been pointed out by Brodsky et al.(1) and others(2) that the two photon annihilation mechanism becomes increasingly more important at high energies in the hadron production from e^+e^- collisions with a cross section $\sigma \propto \alpha^4 (\ln E)^3$ where E is the beam energy. It is comparable to the total one photon hadronic cross section of 20 nb at SPEAR II energies and is expected to rise to approximately 40 nb at the maximum PEP energy.(3)

Since the two photon annihilation hadronic cross section is strongly dependent upon the energy of the hadrons due to the energy dependence of the equivalent photon flux in the e^+e^- collision, it is natural to examine the contribution of the two photon annihilation process as a function of the energy of the hadron system. We follow the treatment of Gatto and Preparata(4) and consider two regions of the hadron energies, or equivalently the two photon c.m. energy $\sqrt{s}$: (1) resonance region with $\sqrt{s}$ < 2 GeV, and (2) diffractive region with $\sqrt{s}$ > 2 GeV. The total contribution is then

$$\sigma_{total} (e^+e^- \to e^+e^- \text{ hadrons}) = \sigma_{res} + \sigma_{diff}.$$

1. Resonance contributions to the total cross section.

In the equivalent-photon approximation the electron beam is a source of photons distributed according to

$$N(\omega) = \frac{\alpha}{\pi} \ln\left(\frac{q^2}{m_e^2}\right) \frac{1}{2\omega} \left[1 + \left(1 - \frac{\omega}{E}\right)^2\right]$$

where $q^2 = 4E^2$, E = incident electron energy, m_e = electron mass, ω = photon energy. The cross section for a state X of squared mass s is

$$d\sigma_X = \int d\omega_1 d\omega_2\ N(\omega_1)N(\omega_2)d\sigma_{\gamma\gamma\to X}(s=4\omega_1\omega_2),$$

where $d\sigma_{\gamma\gamma\to X}(s)$ = the unpolarized cross section from unpolarized colliding photons of energies ω_1 and ω_2. Thus

$$\frac{d\sigma_X}{ds} \approx d\sigma_{\gamma\gamma\to X}(s) \left[\frac{\alpha}{\pi} \ln\left(\frac{q^2}{m_e^2}\right)\right]^2 \frac{1}{4s} f\left(\frac{s}{q^2}\right)$$

where $f(y) = -(2+y)^2 \ln y - 2(1-y)(3+y)$

For $s < s_o$ ($s_o = 4\ \mathrm{GeV}^2$), we have

$$\sigma_{res}(e^+e^- \to e^+e^-X) = \left[\frac{\alpha}{\pi} \ln \frac{q^2}{m_e^2}\right]^2 \int_{s_{th}}^{s_o} \frac{ds}{4s}\, \sigma^{\gamma\gamma}(s) f\left(\frac{s}{q^2}\right)$$

where $\sigma^{\gamma\gamma}(s)$ is the total $\gamma\gamma$ cross section at s with s_{th} its hadronic threshold. Gatto and Preparata obtained, using the Cabbibo-Radicati sum rules and predominance, the expression for total resonance contribution

$$\sigma_{res}(e^+e^- \to e^+e^- \text{ hadrons}) \approx 1.2\left(\frac{\alpha}{\pi}\ln\frac{q^2}{m_e^2}\right)^2 \frac{\pi^2\alpha^2}{2m_\rho^2} \frac{4\pi}{\gamma_\rho^2} f\left(\frac{\bar{s}}{q^2}\right)$$

where $\bar{s}$ is constrained to lie in $s_{th} \leq \bar{s} \leq s_o$. Upper and lower limits to σ_{res} are obtained by taking $\bar{s}$ at its extremes. These are shown in Figs. 1 and 2. The resonance contribution to total hadronic cross section is confined to lie within the shaded area in these figures. Although the magnitude of this can be as large as 20 nb, it is not expected to cause any confusion to the measurement of the total hadronic cross section due to one photon process. Since the total energy of the final hadrons is lower than $\sqrt{s} = 2$ GeV, a measurement of the hadron energy or momentum can be used to single out this contribution completely without any ambiguity.

2. Diffractive contribution to the total cross section.

The cross-section in the diffractive region, $s > s_{th}$, is given by

$$\sigma_{diff}(e^+e^- \to e^+e^- \text{ hadrons}) = \left[\frac{\alpha}{\pi} \ln \frac{q^2}{m_e}\right]^2 \frac{1}{2} \int_{s_{th}}^{q^2} \frac{ds}{s}\, f\left(\frac{s}{q^2}\right) \sigma_{\gamma\gamma}$$

where $\sigma_{\gamma\gamma} \simeq \frac{(\sigma_{\gamma p})^2}{\sigma_{pp}} \simeq 0.25 \times 10^{-30}\ \text{cm}^2$.

Therefore,

$$\sigma_{diff}(e^+e^- \to e^+e^- \text{ hadrons}) = \frac{1}{2}\left(\frac{\alpha}{\pi} \ln \frac{q^2}{m_e^2}\right)^2 \sigma_{\gamma\gamma} I\left(\frac{s_{th}}{q^2}\right)$$

where

$$I(y) = (\ln y)^2 + \ln y \cdot \left(3 + 2y + \frac{y^2}{4}\right) + (1-y)\left(\frac{37}{8} + \frac{5}{8}y\right)$$

The contributions with $s_{th} = (4m_\pi)^2$ and $s_{th} = 4\text{GeV}^2$ are shown in Figs. 1 and 2.[(1)(4)] If one requires that the measured energy of the final states hadrons exceeds half of the total e^+e^- energy in the collision, one expects the two photon annihilation contribution to be that of the curve with $s_{th} = (\frac{1}{2} \cdot 2E)^2$. This amounts to about 1% of the total cross-section if it stays constant at 20 nb at the PEP energies. The dependence on the energy of the final hadrons can be seen by comparing with the curve with $s_{th} = (\frac{3}{4} \cdot 2E)^2$ which is about an order of magnitude smaller in contribution.

Therefore it is clear that if one can measure the energy of the final hadrons and further require it to exceed half the total e^+e^- energy, one can keep the two photon annihilation cross section into hadrons to less than one percent provided the total cross section stays constant at 20 nbarn.

References

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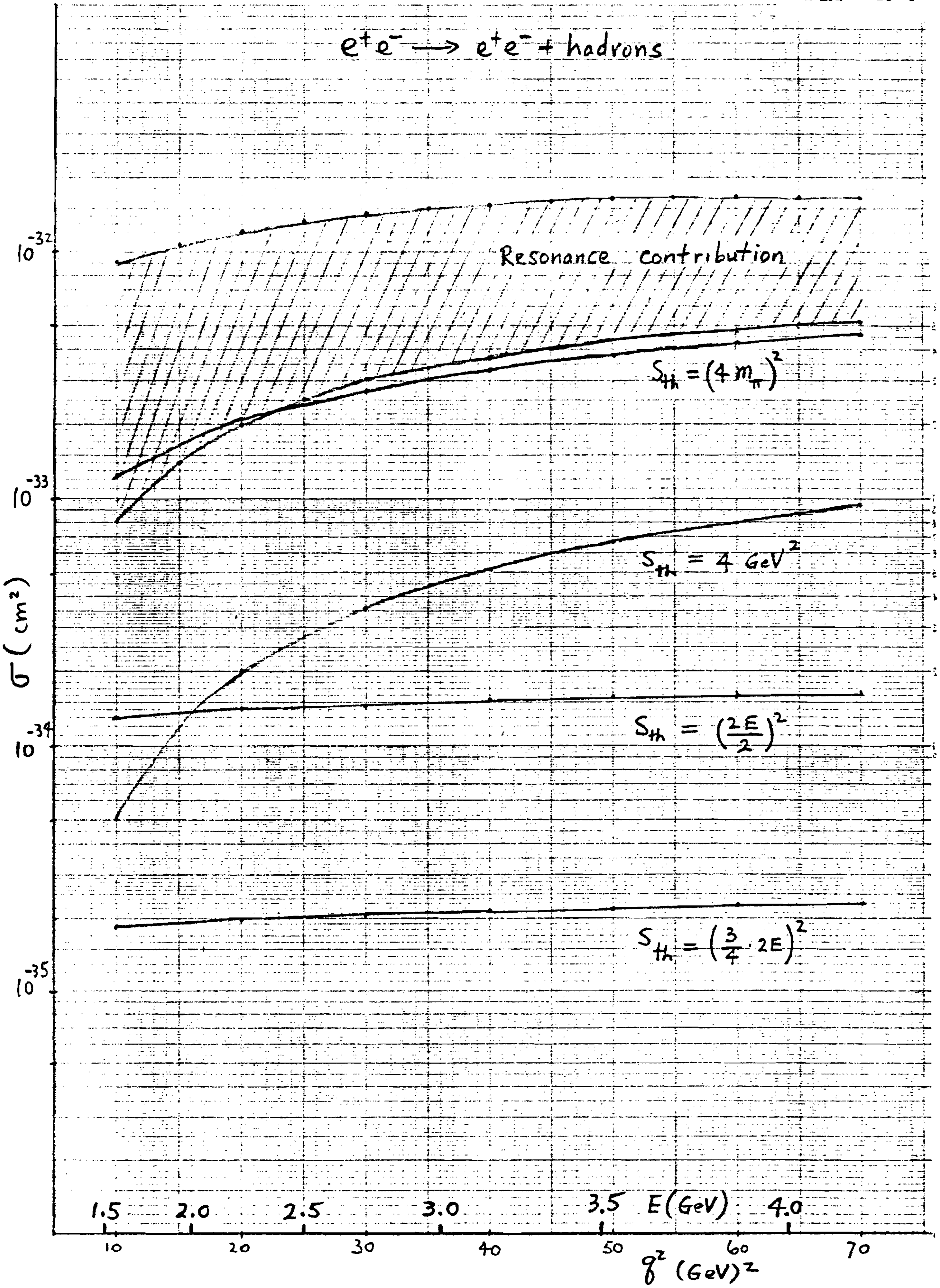
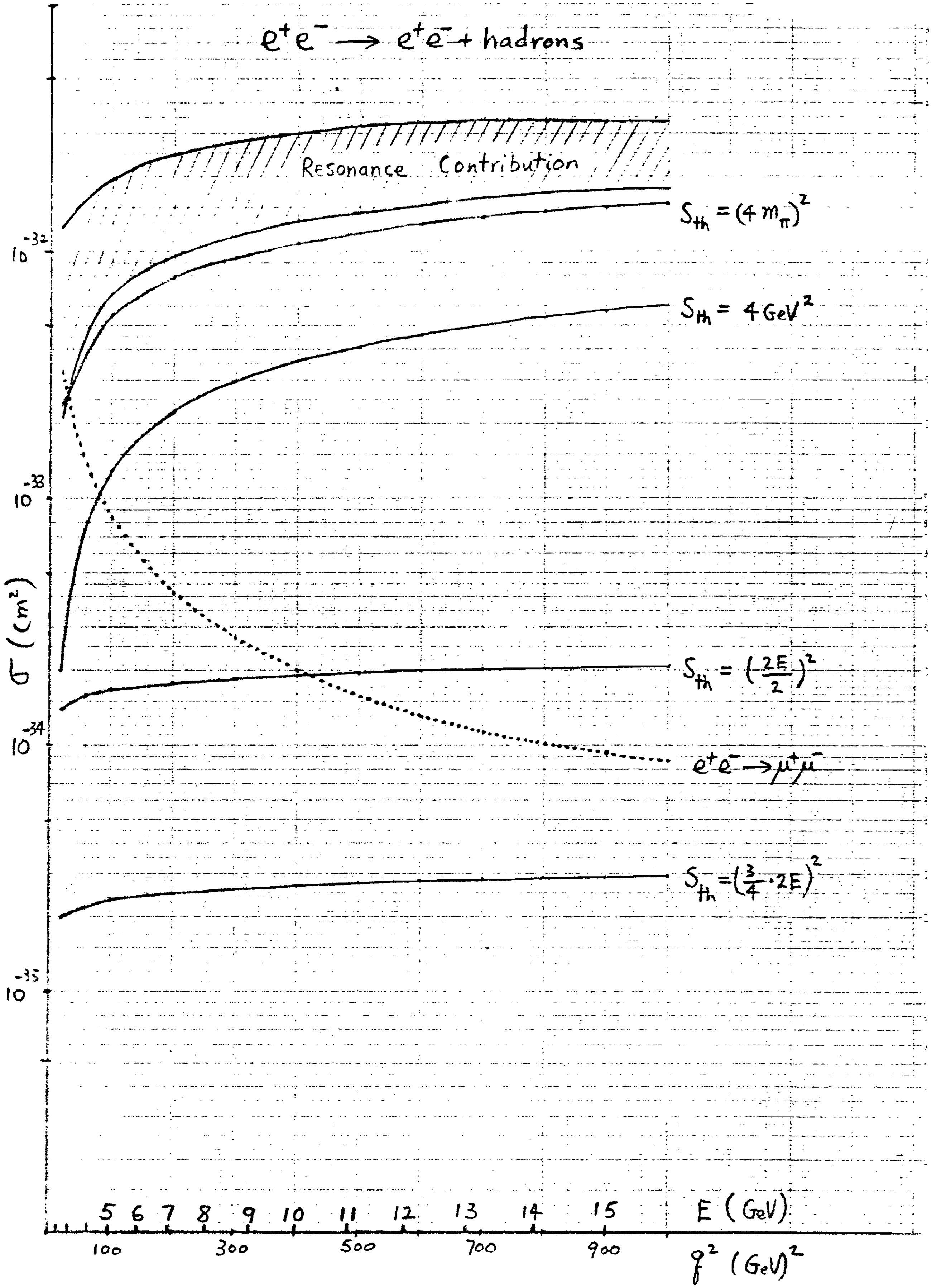
2. Arteaga-Romero et al. Compt. Read. B269, 153, 1129 (1969), PR D3 1569 (1971).

3. G. Masek, talk given at PEP Summer Study (1974).

4. Gatto and Preparata, Nota Interva n. 479, INFN, Universita de Roma (1973).



$e^+e^- \longrightarrow e^+e^- + hadrons$
Resonance contribution
$S_{th} = (4m_\pi)^2$
$S_{th} = 4\ GeV^2$
$S_{th} = \left(\frac{2E}{2}\right)^2$
$S_{th} = \left(\frac{3}{4}\cdot 2E\right)^2$
10^{-32}
10^{-33}
10^{-34}
10^{-35}
$\sigma\ (cm^2)$
1.5
2.0
2.5
3.0
3.5
E(GeV)
4.0
10
20
30
40
50
60
70
$q^2\ (GeV)^2$


e+e- → e+e- + hadrons
Resonance Contribution
S_th = (4 m_π)^2
S_th = 4 GeV^2
S_th = (2E/2)^2
e+e- → μ+μ-
S_th = (3/4 · 2E)^2
10^-32
10^-33
10^-34
10^-35
σ (cm^2)
5 6 7 8 9 10 11 12 13 14 15
E (GeV)
100 300 500 700 900
q^2 (GeV)^2