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Measurement of the Real Part of the Virtual Compton Amplitude and of the Invariant Mass Yield of the Photoproduced e^+e^- Pairs in the Mass Range 1500 < m < 2000 MeV

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Abstract

The analysis of part of the data, very recently collected (1500 e^+e^- pairs at masses between 1300 and 2100 MeV), extending our survey of the reaction $\gamma p \to p\, e^+ e^-$ to wide lepton production angles, allows some comparisons with the results recently obtained by storage ring experiments in the same e^+e^- invariant mass region.

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Our published data[1] of last year from the reaction

$$\gamma + p \rightarrow p + e^+ + e^- \qquad (1)$$

suggested, despite poor statistics, the existence of a new vector meson-like structure at $M \approx 1690 \div 1775$ MeV, of width $\Gamma = 100 \div 500$ MeV. Because of the poor statistics we had at that time, the mass and width values were strongly affected by the assumptions made to interpret the experimental distribution in the mass range between 1.2 and 1.6 GeV. Such an indication, however, seemed to be confirmed later by an experiment performed at DCI[2], where good evidence is given for a resonant structure, 150 ± 40 MeV wide, at $M = 1778 \pm 14$ MeV.

Since May 1977, we have again been taking data for the reaction (1) with the spectrometer acceptance centered around such a mass region (19^o spectrometer opening angles).

In this paper, we analyze part of the recently collected data (1500 e^+e^- pairs) in combination with the already published sample[1,3,4].

Three terms contribute mainly to the rate of the reaction (1): the Bethe-Heitler production, whose amplitude is provided by QED, the virtual Compton scattering via vector meson production and the interference between the two.
In Fig.1 the already published[1,3,4] interference spectra obtained at 13^o, 15^o, 16^o are shown again.
Fig.2a shows the interference pattern obtained by summing old and new data collected at 19^o.
The ratio rate Compton/rate Bethe-Heitler grows with the opening of the angle such that at 19^o the Compton rate distribution as a function of the mass begins itself to be statically significant on top of the B.H. distribution. We will therefore use in the present analysis also the mass yield pattern obtained at 19^o (Fig.2b).

More details on the apparatus, the experimental procedure and the theoretical background can be found in our previous publications[1,3,4].

With the newly collected statistics, no compelling evidence for a resonance at 1778 MeV is found in our data. The experimental distribution of the events rather indicate, both in the mass yield and in the interference spectra at 19^o, a structure peaking at a mass ≈ 1700 MeV. In order to see if our measured data in the mass region $1600 < m < 1800$ MeV can be accounted for only by the DCI

resonance in addition to the background from the lower mass states, we have to obtain an estimate about the effects of the low mass structure tail.

With this aim, we fitted the experimental interference spectra at 13^o, 15^o, 16^o, and 19^o, and the measured mass spectrum at 19^o (in the mass regions $1200 \div 1460$, $1200 \div 1600$, $1200 \div 1600$, $1400 \div 1600$, and $1300 \div 1600$ MeV, respectively), to the combined effects of the Bethe-Heitler process, the $\rho + \omega + \phi + 1100$[3,4] $+ \rho'(1250)$[4] resonances, and two further resonances, centered at masses around 1380 and 1550 MeV. Evidence for a structure peaking at $M \sim 1380$ MeV is contained in our published data[1,4]. The $\rho''(1550)$ is introduced in our fit as being a quite well established state[9], even though it does not show up clearly in our data. These latter two were parametrized by the standard five parameters[3] (the mass M_V, the width Γ_V, the photoproduction cross section into leptons $d\sigma/dt = C_V \cdot e^{b_V t}$, and the phase ϕ_V). The values of M_V, Γ_V, and C_V were left free in the fit, whereas the slopes b_V were fixed to 6 GeV^{-2}, and the phases ϕ_V were assumed to be $\phi_{1380} = 0^o$ and $\phi_{1550} = 20^o$. The overall contribution from the resonances below 1600 MeV to the region $m > 1600$ MeV does not depend on the chosen phase values, even though the individual resonance parameters are quite strongly correlated with them. The fit result is shown in Figs.1 and 2, and the numerical values of the fitted parameters are given in Table I.
Having fixed the contribution from the states below 1600 MeV according to the results of the above best fit, we fitted the contribution of one resonant structure to the experimental data in the mass region 1600-1800 MeV. The phase of such a resonance was kept to 0^o, and the photoproduction slope was assumed to be 6 GeV^{-2}. The fit results are listed in Table II and the contribution to the interference and mass spectra is shown in Fig.1 and 2. The best fit mass value is determined to 1707 ± 12 MeV, the width to 124 ± 51 MeV, and

$$\left.\frac{d\sigma}{dt}\right|_{t=0} (\gamma p \rightarrow p\, V_{1707}\ (V_{1707} \rightarrow e^+e^-)) \ \text{to}\ 62 \pm 8\ \text{pb GeV}^{-2}.$$

This result suggests that our data in the mass region from 1600 to 1800 MeV can be well described by a Breit-Wigner structure centered at 1707 MeV and not at 1778 MeV (mass value of the D.C.I. resonance). In fact a fit to the 19^o degrees data in a mass region centered around 1778 MeV (from 1600 MeV to 1960 MeV) for a single resonance of fixed mass equal to 1778 MeV, width and cross section variable (as usual the phase is set 0^o and the photoproduction slope to 6 GeV^{-2})

gives the $\chi^2 = 57/30$. This fit was made skipping the bins corresponding to the mass interval 1820-1860 MeV where the resonant state recently discovered at Adone[5,6,7] at a mass ~1825 MeV may influence the experimental distributions.

If we attribute the data in the mass range 1820-1860 MeV to the new resonance from Frascati, we get for its photoproduction cross section into leptons

$$\left.\frac{d\sigma}{dt}\right|_{t=o} (\gamma p \to p\, V_{1825}\, (V_{1825} \to e^+e^-)) = 9 \pm 7 \text{ pb GeV}^{-2}.$$

The fit was done in the above mass range, taking $m = 1825$ MeV, $\Gamma = 25$ MeV (mean values of the given parameters), and as usual the phase was kept 0^o, the photoproduction slope 6 GeV^{-2}. The contribution of the lower mass data was extrapolated into the region according to our best fits as in Fig.2 (including the 1707 MeV result).

Summary

In conclusion we quote our results as follows:

The high mass region $m > 1500$ MeV cannot be described by $\rho''(1550)$ alone even if allowance is made for contributions from the 1778 MeV and the 1825 MeV states. Our data give better indication for a structure at 1700 MeV.

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TABLE I

Fitted parameters (*)

M_1	1384 ± 8 MeV	
Γ_1	99 ± 27 MeV	
C_1	58 ± 27 pb GeV^{-2}	
M_2	1549 ± 12 MeV	$\frac{\chi^2}{NDF} = \frac{66}{72}$
Γ_2	100 ± 55 MeV	
C_2	53 ± 22 pb GeV^{-2}	

(*) While evidence is given by the data for a resonance at ~1380 MeV(3), it is suggestive, but to a large extent arbitrary, to account for the data in the mass range between 1500 and 1600 MeV by using a single resonance. Therefore all the values above should be taken as numerical results of a good mathematical fit to the measured data only.

TABLE II

Fitted parameters

$M = 1707 \pm 12$ MeV $\Gamma = 124 \pm 51$ MeV $\frac{d}{dt}\Big\|_{t=o} (\gamma p \rightarrow pe^+e^-) = 62 \pm 8$ pb GeV^{-2}	$\frac{\chi^2}{NDF} = \frac{33}{27}$

Figure captions

fig.1 The measured interference spectra.

K_{max} (beam top energy) = 7.2 GeV, p_o (central spectrometer momentum) = 2700 MeV.
The dashed line represents the $\rho + \omega + \phi$ contribution.
The solid line represents the 1100 + $\rho'(1250)$ contribution as from(4), in combination with the V_{1380} and V_{1550} contribution, as from the best fit described in the text.
The triangles show the contribution of the new structure at 1707 MeV, calculated according to the best fit parameters listed in table II.

a) θ (spectrometer opening angle) = 13^o,

b) $\theta = 15^o$,

c) $\theta = 16^o$.

fig.2a The measured interference spectrum at 19^o.

$K_{max} = 7.2$ GeV, $p_o = 2700$ MeV.
The dashed line is the $\rho + \omega + \phi$ contribution.
The solid line represents the 1100 + $\rho'(1250)$ + V_{1380} + V_{1550} contributions, as from our best fits.
The triangles show the V_{1707} contribution, as from our best fit.

fig.2b Experimental mass yield for the same events as above.

The open circles are the calculated contribution of the Bethe-Heitler processes.
The solid line shows the calculated contribution of the BH processes together with $\rho + \omega + \phi$ + 1100 + $\rho'(1250)$ + V_{1380} + V_{1550} diffractive photoproduction, according to our best fits. The effect of the V_{1707} in the mass spectrum is also shown.

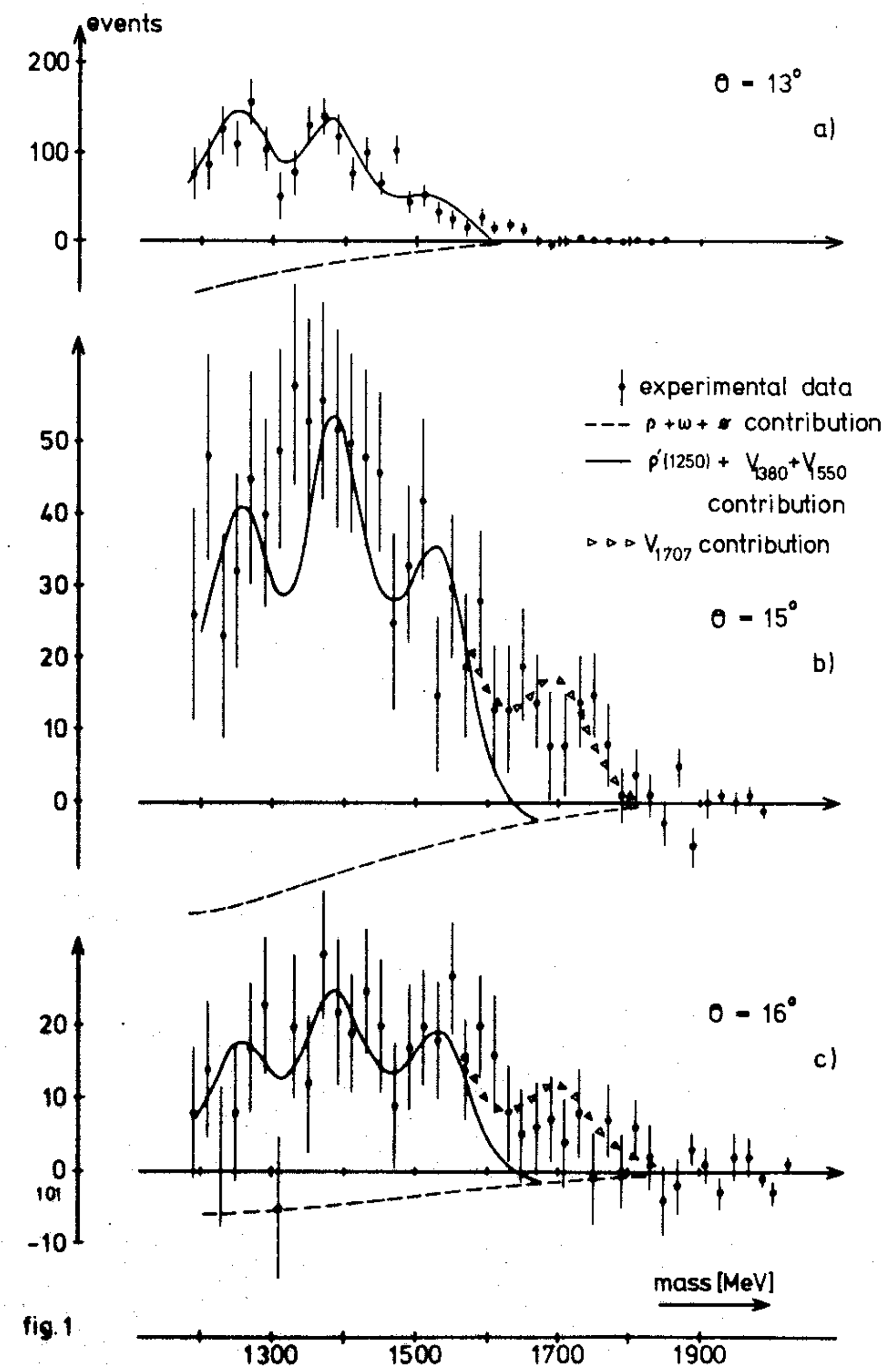

fig. 1

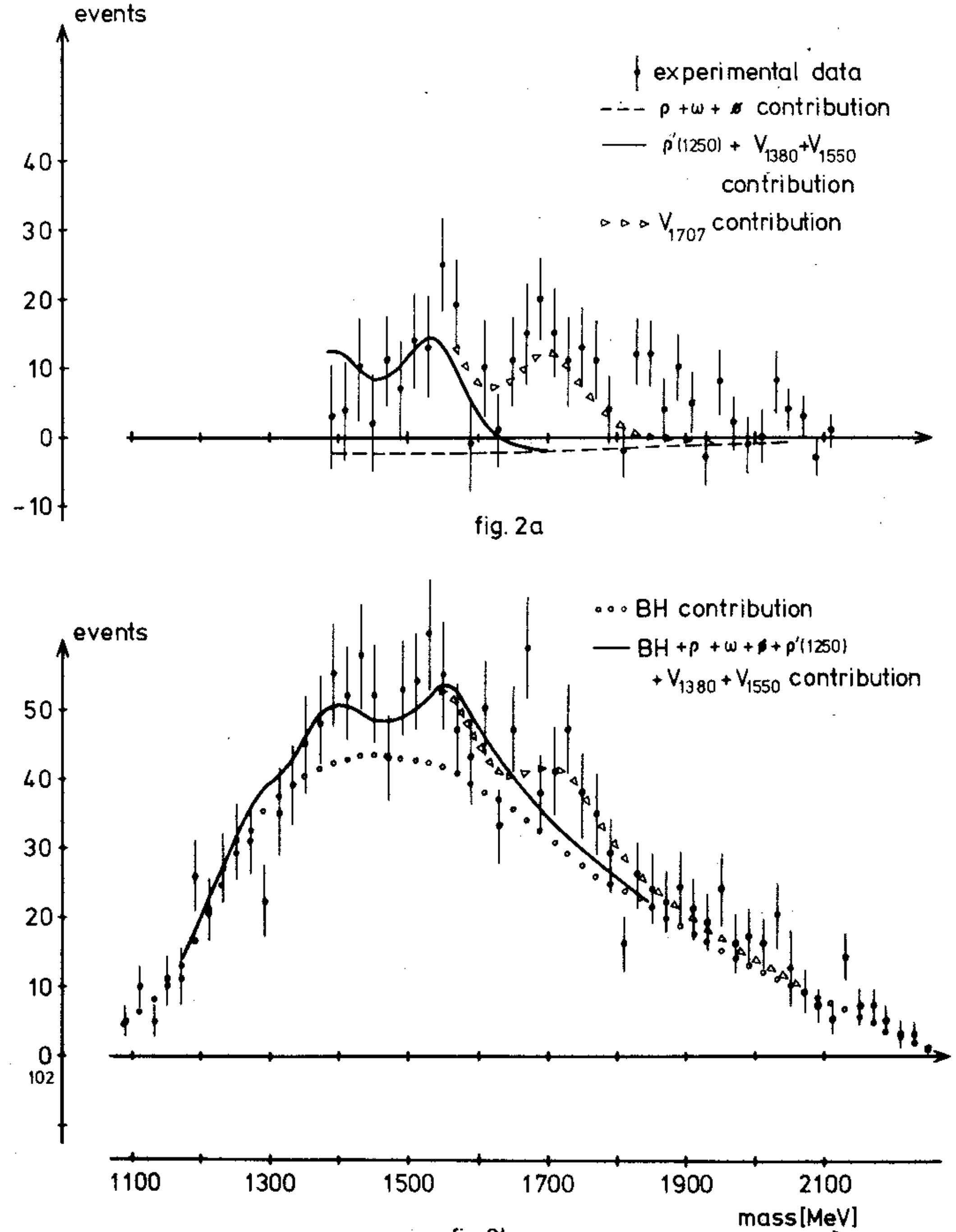

fig. 2a

fig. 2b