TAU-LEPTON PRODUCTION AND DECAY AT PETRA ENERGIES

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The production and decay of τ-pairs was studied with the JADE detector at PETRA at center-of-mass energies of $30 \leqslant \sqrt{s} \leqslant 46.78$ GeV. The total production cross section for τ-pairs agreed with QED predictions to order α^3. Lower limits on QED cut-off parameters of $\Lambda_+ > 285$ GeV and $\Lambda_- > 210$ GeV at 95% confidence level were obtained. The decay branching fractions into one and three charged particles were determined to be $(86.1 \pm 0.5 \pm 0.9)$% and $(13.6 \pm 0.5 \pm 0.8)$%. In the angular distributions a forward–backward asymmetry was observed, from which the axial-vector weak charge of the τ was determined to be $a_\tau = -0.74 \pm 0.22$ in agreement with the standard model. An analysis of the process $e^+e^- \to \tau^+\tau^-\gamma$ showed agreement with QED calculations to $O(\alpha^3)$.

The reaction $e^+e^- \to \tau^+\tau^-$ has been studied in the JADE detector at the e^+e^- storage ring PETRA at center-of-mass (CM) energies between $30.0 \leqslant \sqrt{s} \leqslant 46.78$ GeV. The data cluster around two energies: an integrated luminosity of 62.4 pb^{-1} was accumulated around $\langle\sqrt{s}\rangle = 34.6$ GeV and 26.6 pb^{-1} was collected around $\langle\sqrt{s}\rangle = 43.0$ GeV.

The JADE detector consists of a cylindrical inner track detector, the "jet-chamber" [1], which is located in a solenoidal field of 4.8 kG. The momentum resolution for tracks above 2 GeV is $\Delta p/p^2 = 1.5\%$ using the accurately known beam interaction point as a fitting constraint, the double track resolution is 7 mm. The 42 scintillation counters surrounding the jet-chamber are used for triggering and time-of-flight measurement. Outside the coil a fine grain electromagnetic shower detector is located which consists of leadglass blocks arranged in three hodoscopes. The barrel part, covering polar angles $|\cos\theta| \leqslant 0.82$, has blocks of 12.5 radiation lengths. Their energy resolution is $\sigma_E/E = 4\%/\sqrt{E} + 1.5\%$ at an average polar angle. The angular resolution is $\sigma_\theta = 0.6°$ and $\sigma_\phi = 0.7°$. The two endcap hodoscopes have coarser blocks, which cover $0.89 \leqslant |\cos\theta| \leqslant 0.97$. The outermost part of the detector is a rectangular muon filter consisting of layers of drift chambers interspersed with absorber. The detailed description of the detector parts can be found in refs. [1,2].

At PETRA energies taus have flight paths of about 1 mm and are therefore detected through their decay products. Two characteristics are important for the event selection: the small Q-value of the decay, i.e. emission of the secondaries in a narrow cone, and the low multiplicity of charged tracks. Almost 100% of the tau decays result in one or three charged tracks, which, in hadronic decays, may be accompanied by several photons (decay products of neutral pions).

Event selection. The philosophy of the event selection was to keep a high detection efficiency and to select all decay modes except for events where both taus decay into electrons or both into muons. The selection and analysis was based on "good" tracks (tracks mentioned in the subsequent text will always signify "good" tracks, unless stated otherwise). A "good" track has to fulfill the following criteria:

(1) Momentum $p > 100$ MeV;

(2) The number of measured points on the track should exceed 15 (out of the possible 48);

(3) The track should come from the "vertex region", a cylinder of 20 mm radius and 400 mm length centered on the interaction point of the beams.

Secondary products of nuclear interactions were largely excluded by this definition. The number of good tracks was required to be between two and ten and at least one track had to come from within 10 mm of the interaction point in the plane perpendicular to the beam, the r–ϕ plane. The event vertex was required to be within ±80 mm of the interaction point in the longitudinal (z) direction.

The tracks were then combined into two "jets": the vector sums of the track momenta in jet 1, j_1, and of jet 2, j_2, were required to be at least 100° apart and all tracks were required to lie within a cone of 90° opening angle with respect to the jet axes. An acceptance cut of $|\cos\theta_{1,2}| < 0.76$ was imposed on both jets, where $\theta_{1,2}$ is the angle between j_1 or j_2 and the beam axis.

After these basic cuts to select the desired event topology a number of cuts were applied to reduce backgrounds. The cuts were deliberately kept quite

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loose, in order to have a high efficiency for genuine τ events.

(1) *Visible energy.* The visible energy was defined as: $E_{vis} = \Sigma|p| + \Sigma E$, where the first sum runs over the momenta of all tracks and the second sum runs over the cluster energies in the leadglass barrel. The cut applied was:

$$E_{vis} > 0.20\sqrt{s}.$$

Rejects: Low energy background, e.g. 2γ processes.

(2) *Momentum balance.* The momentum balance in the longitudinal (z) direction was defined as:

$$p_{bal} = \left(\sum p_z + \sum E_z\right) \Big/ E_{vis}.$$

Events were accepted if they fulfilled the collinearity condition $140° < \theta_1 + \theta_2 < 220°$ or if:

$$|p_{bal}| < 0.3$$

Rejects: 2γ processes

(3) *Shower energy.*

$$E_{tot} < 0.80\sqrt{s}, \quad E_{max} < 0.45\sqrt{s},$$

$$\sum E_{charged} < 0.6\sqrt{s}.$$

Here E_{tot}, E_{max} and $E_{charged}$ signify the total leadglass energy, the energy of the biggest cluster and the energy of clusters behind tracks. *Rejects*: Bhabha events. A track was identified as an electron if the connected cluster energy in the leadglass counter was $E > 1$ GeV and the ratio $E/p > 0.60$, where p was the momentum of the track. Two-track events were rejected if both particles were identified as electrons. *Rejects*: Bhabha events and $e^+e^- \to e^+e^-e^+e^-$.

(4) *Cuts for two-track events.* Both momenta had to exceed 1 GeV. The angle between the tracks in the r–ϕ plane should be less than $\pi - 10$ mrad. The flight time of the tracks, measured with the time-of-flight counters and corrected for their inclination with respect to the beams, should be within ±4 ns of the beam crossing time. If both particles were identified as penetrating particles in the muon filter, the event was rejected. *Rejects*: Cosmic rays, $e^+e^- \to e^+e^-$, $e^+e^- \to \mu^+\mu^-$, $e^+e^- \to ee\mu\mu$.

(5) *Invariant mass of jets.* The invariant mass M_{inv} of all particles in a jet, assuming that the leadglass clusters were photons and the charged particles were pions was required to be:

$M_{inv} < 3$ GeV in both jets,
$M_{inv} < 2$ GeV in one jet.

Rejects: Multihadronic events.

After these cuts background was further reduced by a visual scan where it was verified that the selected events correspond to the desired topology. In this scan ~28% of the events were removed, they were mainly multihadronic final states and cosmic rays, and a small amount of events from Bhabha scattering and two-photon interactions. Events, which had a visible hadronic interaction in the material of the beam pipe or the detector were flagged and rejected for the determination of angular distributions and branching ratios. The final event sample consisted of 2919 events.

The efficiency for detecting $e^+e^- \to \tau^+\tau^-$ events was calculated by simulating events in a Monte Carlo program. Taus were generated by a program supplied by Berends, Kleiss and Jadach [3], which took into account pure QED terms up to order α^3. The α^3 contributions increased the cross section with respect to the lowest order by a factor 1.31 for the cuts used here.

The τ decay was then simulated including the following decay modes: $\pi\nu$, $e\nu\nu$, $\mu\nu\nu$, $A_1\nu$, $\rho\nu$, $3\pi + n\pi^0\nu$, $\pi + 2\pi^0\nu$. For the study of the topological branching fractions $\tau \to 5\pi\nu$ and $K^*\nu$ was included. Unstable particles were allowed to decay and all decay products were subjected to a full simulation of the detector, including interactions in the material of the detector. The Monte Carlo generated events were then analysed with the same programs as the data.

The calculated acceptance was 72% in the available angular region which corresponds to 52% of the production cross section in lowest order. A Monte Carlo program which took into account spin correlations has recently become available [4]. It was also tried but the resulting changes after applying the selection cuts were negligible compared to the experimental errors.

Background reactions were also simulated ‡1. The background fractions found in the scan could be veri-

‡1 See ref. [5]. The 2γ background was calculated with programs developed by the JADE Collaboration, mainly by S. Kawabata, based on calculations and programs of the author. See also ref. [6].

fied. The background estimated to be still contained in the events is 5.7% ± 0.8%, mainly $e^+e^- \to e^+e^-\tau^+\tau^-$ and multihadronic events and, to a smaller extent, $e^+e^- \to e^+e^-\mu^+\mu^-$, $e^+e^- \to e^+e^-e^+e^-$ and $e^+e^- \to e^+e^-$ hadrons.

A special effort was made to assess and reduce the contamination from Bhabha events in view of the determination of the forward–backward asymmetry. For these studies, in addition to the tau candidates themselves, selected Bhabha events were used. By applying modified tau selection cuts a maximum contamination of 0.6% ± 0.6% was estimated and corrected for. Furthermore events were selected which fulfilled all Bhabha selection cuts except that only one energetic shower was required. An examination of those events which might be mistaken for tau candidates gave a similar number for the contamination.

Event losses not included in the acceptance calculation were corrected for separately. The correction amounted to ~9%, the major contribution came from losses due to nuclear reactions in the beam pipe and the material of the detector and from events that were rejected in the scan.

The total cross section. The total cross section was determined by comparing the corrected number of events to the luminosity determined from large angle Bhabha scattering. It was corrected for $O(\alpha^3)$ QED effects. The correction due to electroweak interference was less than 0.8% even at the highest measured energies and was neglected.

The results from this analysis binned in two energy points at $\langle s \rangle = 1195.0$ GeV^2 and $\langle s \rangle = 1853.3$ GeV^2 are shown in table 1 together with data at CM energies below 30 GeV from an older similar analysis [7] of JADE data. The statistical and systematical errors are given separately. The main contributions to the systematical error are uncertainties in the efficiency corrections (2.9%), luminosity measurements (1.6% at $s = 1195.0$ and 2.5% at higher energies) and background subtraction (0.8%). In fig. 1a the data are shown in a finer binning together with the prediction of leading order QED. The agreement between data and the QED prediction is good.

The ratio $R = \sigma/\sigma_{O(\alpha^2)}$ is shown in fig. 1b together with the prediction of the standard model, which is almost indistinguishable from the prediction of pure QED even at the highest PETRA energies. Deviations from the QED prediction for $R = \sigma/\sigma_{O(\alpha^2)}$ can be parametrized by a form factor:

$$R(s) = [1 \mp s/(s - \Lambda_\pm^2)]^2 ,$$

using the cut-off parameters $\Lambda_\pm$. The data with $\sqrt{s} > 34$ GeV yield: $\Lambda_+ > 285$ GeV and $\Lambda_- > 210$ GeV at 95% CL. These limits are compatible with results from other PETRA and PEP experiments [8,9] and are also indicated in fig. 1b.

Determination of topological branching fractions. The observed multiplicity distribution of charged tracks is shown in the first line of table 2, after a correction for background the numbers in the second line were obtained. e^+e^- pairs from photon conversions have been subtracted. Beside the expected events with one, three and five tracks there are non-negligible numbers of decays into an apparently even number of tracks. They result from several sources: a track from a genuine three-track event can be lost because of the double-track resolution or because it does not satisfy the criteria of good tracks or because it interacts in the material before entering the jet chamber. On the other hand an additional track can come from a photon conversion where either the electron or the positron does not satisfy the selection cuts or from π^0 Dalitz decay.

These effects were included in the Monte Carlo

Table 1
Total cross section for $e^+e^- \to \tau^+\tau^-$.

s (GeV^2)	$\int L\,dt$ (pb^{-1})	Events	σ (pb)	$\sigma/\sigma_{O(\alpha^2)}$
144	0.097	29	770 ± 144 ± 119	1.29 ± 0.24 ± 0.20
655.4	0.742	52	154.0 ± 21.4 ± 14.8	1.16 ± 0.16 ± 0.11
936.4	2.66	117	98.2 ± 9.1 ± 8.0	1.06 ± 0.10 ± 0.08
1195.0	62.4	2275	69.7 ± 1.4 ± 2.4	0.959 ± 0.019 ± 0.033
1853.3	26.6	644	45.9 ± 1.7 ± 1.9	0.980 ± 0.037 ± 0.041

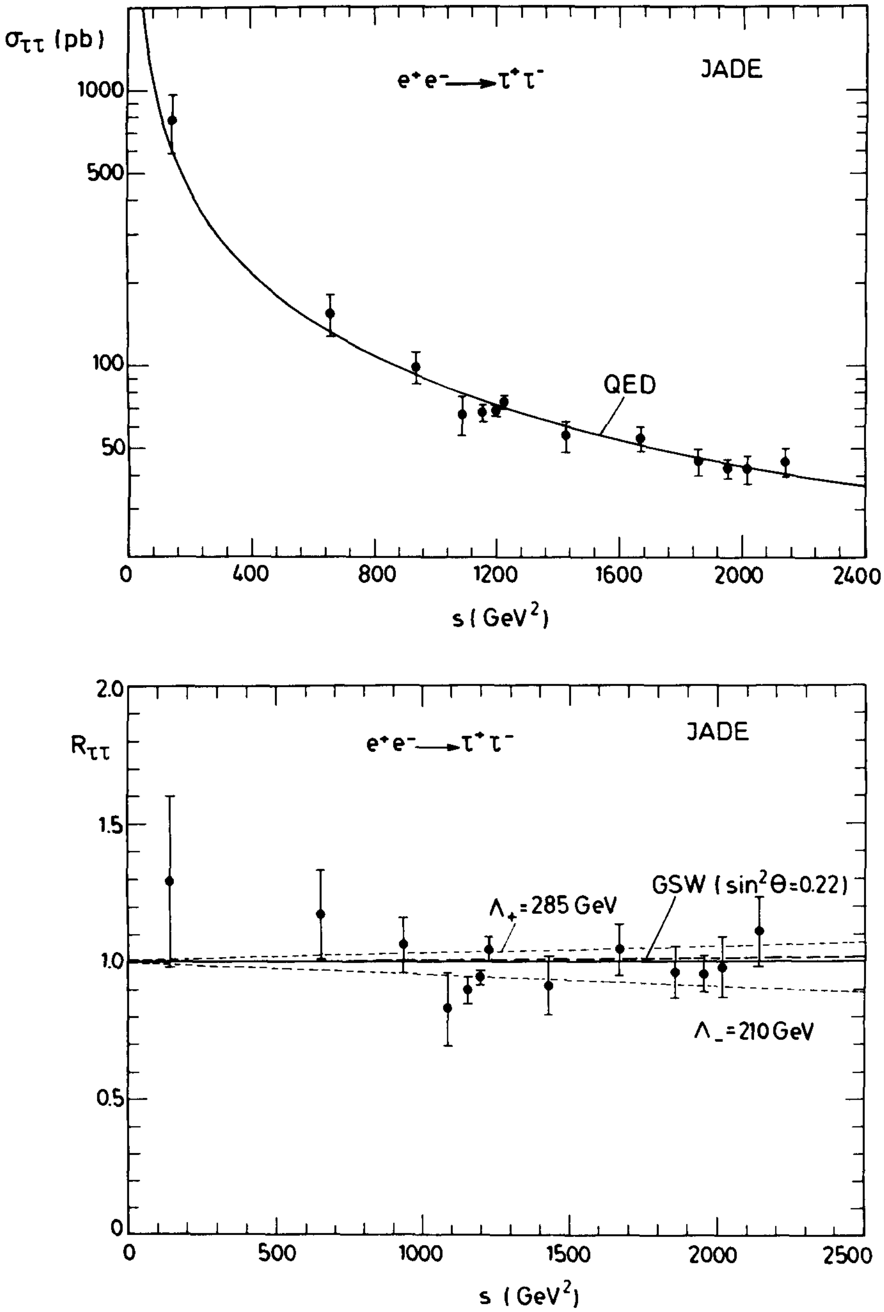

Fig. 1. (a) Total cross section for $e^+e^- \to \tau^+\tau^-$ as a function of s, corrected for QED contributions up to order α^3. The solid curve shows the lowest order QED prediction, $\sigma_{Q(\alpha^2)}$. (b) $R = \sigma/\sigma_{Q(\alpha^2)}$ with QED (full line) and standard model (dashed line) predictions; the limits for QED cut-off parameters are also indicated.

Table 2
Observed and simulated multiplicities.

	Observed multiplicity				
	1	2	3	4	5
data raw	3374	327	624	23	8
data corrected	3213.7	287.7	574.2	17.4	5.8
M-C sum	3232.9	256.2	587.9	15.5	6.4
M-C 1	3197.3	150.9	56.5	4.2	0
M-C 3	35.3	104.4	528.0	6.1	1.0
M-C 5	0.3	0.9	3.4	5.2	5.4

program, which was then used in an unfolding procedure to fit the decay branching fractions into one, three and five charged tracks. After correcting for the efficiencies, which slightly depend on the multiplicity, the following values were found:

$B_1 = (86.1 \pm 0.5 \pm 0.9)\%$,

$B_3 = (13.6 \pm 0.5 \pm 0.8)\%$,

$B_5 = (0.3 \pm 0.1 \pm 0.2)\%$.

The main contribution to the systematic errors, which is the second error quoted, is due to uncertainties in modelling the detector whereas uncertainties in background and efficiencies only lead to small systematic errors. The systematic error in B_5, however, is dominated by the uncertainty of the background subtraction.

The multiplicity distributions, generated with these branching fractions are shown in table 2 in the lines labelled "M-C" for each generated multiplicity and for the sum. The sum coincides with the corrected data.

The branching fractions values compare well with the values obtained recently by other experiments at PETRA and PEP [10]. A summary of the situation with respect to the theoretical calculations is given in ref. [11].

The differential cross section. For the angular distribution only events that had a single charged track on one side were selected, the charge of which determined whether it was classified as forward, i.e. $\cos\theta > 0$ for a positive track, or backward, i.e. $\cos\theta < 0$ for a positive track. The angle θ was measured with respect to the e^+ beam direction.

In the Monte Carlo simulation it was found that

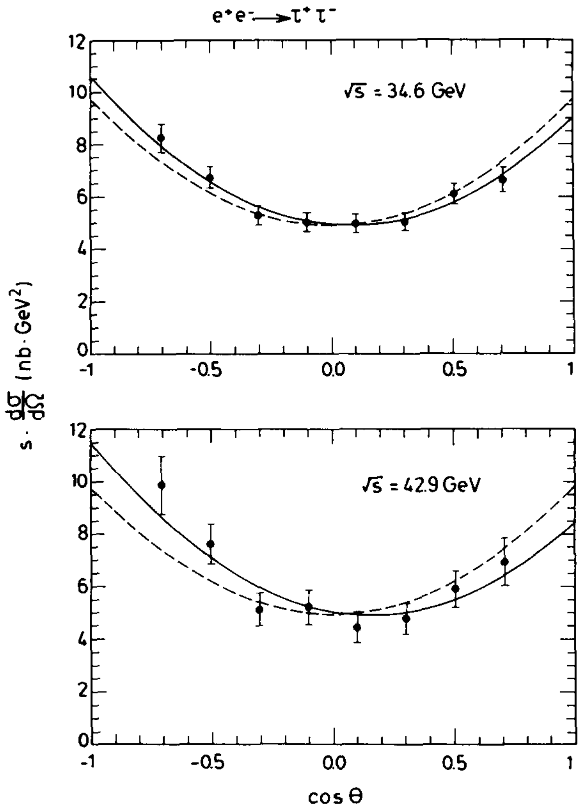

Fig. 2. Differential cross section for $e^+e^- \to \tau^+\tau^-$ corrected for QED contributions to order α^3 for two center-of-mass energies. The solid lines are results from fits allowing for an asymmetry, the dashed lines are symmetric fits.

the original flight direction of the τ was best simulated by the angle of a common event axis. It was defined by the vector difference of the two jet axes, which were calculated including all particles, neutral and charged. Other methods to determine the original τ axis, e.g. the direction of the single charged track, or the direction of the jet with the highest momentum, were also tried and the deviations were used as estimates of the systematic error. The measured differential cross sections are shown in figs. 2a and 2b. The data were corrected as described above, in particular a correction for $O(\alpha^3)$ effects from QED was applied, which had an asymmetry of $(+1.5 \pm 0.5)\%$. A fit of a function of the form $N(1 + \cos^2\theta + 3/8A \cdot \cos\theta)$ lead to the asymmetries given in table 3 as measured asymmetries, which in this way is defined for the full range of polar angles $|\cos\theta| \leqslant 1$.

Table 3
τ-pair asymmetries.

s (GeV^2)	Events	A_{measured} (%)	$A_{\text{predicted}}$ (%)
1195.0	1998	$-6.0 \pm 2.5 \pm 1.0$	-8.8
1853.3	575	$-11.8 \pm 4.6 \pm 1.0$	-14.8

The first error is statistical, the second one is the estimated systematic error. The latter is due to uncertainties in the background estimation, uncertainties in the radiative corrections and an error in the determination of the original τ direction.

The tau asymmetries are shown in fig. 3 as a function of s, together with other measurements by experiments at PETRA [8] and PEP [9]. It can be seen that the JADE data, like all data above $s \sim 1000$ GeV^2 have a tendency to be somewhat lower in magnitude than the prediction of the standard model, although well compatible with it within errors.

Comparison to the standard model. The differential cross section in the standard model is in lowest order:

$$d\sigma/d\Omega = (\alpha^2/4s)[C_1(1+\cos^2\theta) + C_2 \cos\theta],$$

where

$$C_1 = 1 + 2v_e v_\tau \chi + (v_e^2 + a_e^2)(v_\tau^2 + a_\tau^2)\chi^2,$$

$$C_2 = 4a_e a_\tau \chi + 8v_e v_\tau a_e a_\tau \chi^2.$$

a_e and a_τ are the axial-vector weak charges of the electron and tau and predicted to be -1. v_e and v_τ denote the vector weak charges of the electron and tau, which are predicted to be $v = -1 + 4\sin^2\theta_W$. χ is defined as:

$$\chi = (G_F M_Z^2 s/8\pi\alpha\sqrt{2})(s - M_Z^2)^{-1},$$

where G_F is the Fermi coupling constant and M_Z the mass of the Z^0. The forward–backward asymmetry then is:

$$A = \tfrac{3}{8} C_2/C_1 \approx 1.5\, a_e a_\tau \chi.$$

G_F is given by the muon-decay measurements [12], $G_\mu = 1.166 \times 10^{-5}$ GeV^{-2}. Using $M_Z = 93$ GeV which represents the measurements at the $p\bar{p}$ collider [13] and applying small corrections for higher-order

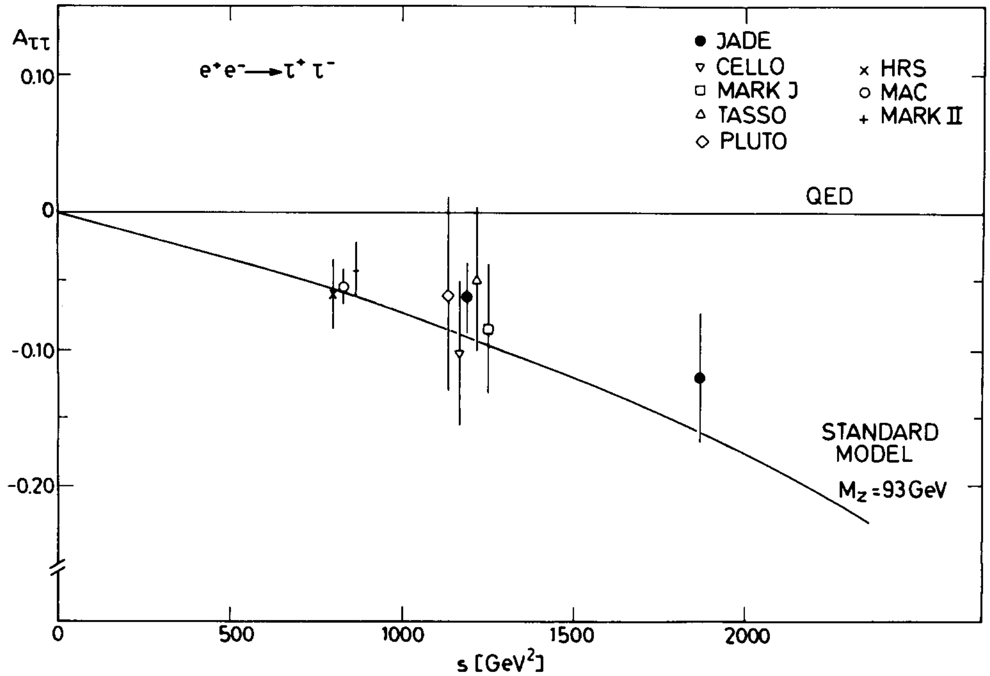

Fig. 3. Asymmetry for $e^+e^- \to \tau^+\tau^-$ as a function of s. Data from JADE are shown together with results from other PETRA and PEP experiments. Note that the data taken by several detectors at the same energy are slightly displaced in s. The full line is the prediction of the standard model with $M_Z = 93$ GeV.

weak effects [14] [‡2] one obtains the theoretically expected asymmetries shown in table 3. The measurements agree with the expectation within one standard deviation.

Assuming a_e to be -1, the axial weak charge of the tau can be calculated from the measured asymmetry; the result is:

$a_\tau = -0.74 \pm 0.22$,

compatible within ~1 standard deviation to the expectation.

The asymmetry due to the electroweak interference effect was already established for muon-pair production; the JADE measurement of the axial weak charge of the muon was $a_\mu = -1.31 \pm 0.17$ [15]. The difference between the two measurements is $|a_\mu - a_\tau| = 0.57 \pm 0.28$, within two standard deviations in agreement with universality of lepton couplings predicted by the standard model. The error, which is mainly due to statistics, is large.

Radiative tau events. The reaction $e^+e^- \to \tau^+\tau^-\gamma$ which is a process of order α^3 was investigated and compared to predictions of QED and the standard model. The events were selected with the same cuts as described above from a data sample corresponding to an integrated luminosity of 86.2 pb^{-1} at an average CM energy of $\sqrt{s} = 36.4$ GeV.

A photon of energy $E > 500$ MeV was demanded in the fiducial region of the barrel or end-cap lead–glass shower counter, at least 30° away from both jet axes. In order to reduce background from two-photon scattering, the sum of the three opening angles between the photon- and the τ-directions was required to be larger than 350°. If there was any additional photon energy between the τ jets and the selected photon, its sum was required to be less than 1 GeV. One of the τ jets was required to have one charged track only. If the other had more than one track the sum of their momenta was required to be above 1 GeV.

123 events survived these cuts. After a correction for background mainly from multihadronic and $\mu\mu\gamma$ events, 112 events remained which had to be compared to 100 ± 3 events expected from QED to order α^3.

‡2 At $s = 1195$ GeV^2 $\Delta A = 0.6\%$ and at $s = 1853$ GeV^2 $\Delta A = 1.1\%$ were used.

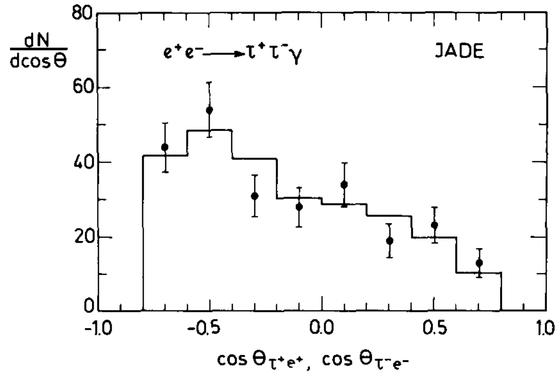

Fig. 4. The polar angle distribution of the taus for the reaction $e^+e^- \to \tau^+\tau^-\gamma$ (two entries per event). The histogram is a prediction from QED to order α^3.

The distribution of the polar angle θ is shown in fig. 4. θ is measured with respect to the direction of the e^+ beam for τ^+ and with respect to the e^- beam for τ^-. The angular distribution shows a strong negative asymmetry, which is due to the interference of photons radiated in the initial and final state and is well reproduced by the QED prediction.

Comparing the number of events in the forward and the backward direction, one finds:

$A_{\tau\tau\gamma} = (-27.6 \pm 8.7)\%$.

The expected numbers from QED are $A = -(31.4 \pm 2.2)\%$ and from the standard model $A = -(36.2 \pm 4.0)\%$, where the two latter errors are due to limited Monte Carlo statistics. The error of the measured asymmetry does not allow to distinguish between QED and standard model.

Furthermore distributions of the invariant mass of the τ–γ system and the τ–τ system and energy distributions were also found to be described well by QED.

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References

[1] JADE Collab., W. Bartel et al., Phys. Lett. 88B (1979) 171; 92B (1980) 206.
[2] H. Drumm et al, in: Wire chamber conference 1980, eds. W. Bartl and M. Regler (North-Holland, Amsterdam, 1980), p. 333;
J. Allison et al., Nucl. Instrum. Methods A328 (1985) 220, 230.
[3] F.A. Berends, R. Kleiss and S. Jadach, Nucl. Phys. B202 (1982) 63.
[4] S. Jadach and Z. Was, Acta Phys. Pol. B12 (1984).
[5] J.M.A. Vermaseren, in: Proc. Intern. Workshop on $\gamma\gamma$ collisions (Amiens, April 1980), Lecture Notes in Physics, Vol. 134, eds. G. Cochard and P. Kessler (Springer, Berlin, 1980) p. 35.
[6] F.A. Berends, H.P. Daverfeldt, R. Kleiss, Phys. Lett. 148B (1984) 489.
[7] M. Nozaki, τ production at Petra energies, University of Tokyo preprint UTLICEPP-82-02 (1982).
[8] CELLO Collab., H.J. Behrend et al., Phys. Lett. 114B (1982) 282;
MARK J. Collab., B. Adeva et al., Phys. Rep. 109 (1984) 131;
PLUTO Collab., Ch. Berger et al., DESY preprint 85-17 (1985);
TASSO Collab., M. Althoff et al., Z. Phys. C26 (1985) 521.
[9] HRS Collab., K.K. Gan et al., Phys. Lett. 153B (1985) 116;
MAC Collab., E. Fernandez et al., Phys. Rev. Lett. 543 (1985) 1620;
MARK II Collab., M.E. Levi et al., Phys. Rev. Lett. 51 (1983) 1941.
[10] MARK II Collab., C.A. Blocker et al., Phys. Rev. Lett. 49 (1982) 1369;
CELLO Collab., H.J. Behrend et al., Z. Phys. C23 (1984) 103;
TPC Collab., H. Aihara et al., Phys. Rev. D30 (1984) 2436;
TASSO Collab., M. Althoff et al., Z. Phys. C26 (1984) 521;
MAC Collab., E. Fernandez et al., Phys. Rev. Lett. 54 (1985) 1624;
PLUTO Collab., Ch. Berger et al., DESY Bericht 85-017 (1985); Z. Phys. C, to be published;
HRS Collab., M. Derrick et al., ANL-HEP-PR-85-05 (1985);
HRS Collab., I. Beltrami et al., Phys. Rev. Lett. 54 (1985) 1775.
[11] F.J. Gilman and S.H. Rhie, Phys. Rev. D31 (1985) 1066.
[12] Particle Data Book, Rev. Mod. Phys. 52 (1980) S1.
[13] UA1 Collab., G. Arnison et al., Phys. Lett. 126B (1983) 398; Phys. Lett. 129B (1983) 271;
UA2 Collab., P. Bagnaia et al., Z. Phys. C24 (1984) 1.
[14] W. Wetzel, Nucl. Phys. B227 (1983) 1; preprint Heidelberg (1983).
[15] JADE Collab., W. Bartel et al., Z. Phys. C26 (1985) 507; and to be published.