ELECTROWEAK INTERACTIONS

RECENT RESULTS FROM PETRA

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ABSTRACT

The recent work of the PETRA groups CELLO, JADE, MARK J and TASSO on studies of electroweak interactions is reviewed. The charge asymmetry in μ-pair production is established. It agrees with the prediction of the standard model of Glashow, Weinberg, and Salam. First results on the charge asymmetry in τ-pair production are presented. The data are interpreted in terms of values for $\sin^2\theta_W$ in the standard theory and of the weak coupling constants g_V and g_a. In addition a new upper limit on the beauty lifetime is discussed, and new data on the τ branching ratios and lifetime are given.

At the Bonn Conference 1981 the PETRA groups presented data [1], which show a charge asymmetry in the angular distributions of the combined PETRA data on e^+e^- annihilation into μ-pairs at a c.m. energy of 34 GeV. This charge asymmetry can be understood as an interference between electromagnetic and weak interactions as predicted e.g. by the standard model of Glashow, Weinberg, Salam [2]. In the meantime the four PETRA groups CELLO [3], JADE [4], MARK J [5], and TASSO [6] have collected enough data to establish the presence of electroweak interactions in e^+e^- annihilation into μ-pairs. Similar effects show up in τ-pair production. These effects of electroweak interference in μ- and τ-pair production will be the main topic of this report.

In addition some recent results on the limit of the B lifetime and on branching ratios and the lifetime of the τ-lepton will be discussed.

I. Tests of QED

QED has been tested by all PETRA experiments up to order α^3 by comparing measured cross sections and angular distributions for lepton pair production with theoretical predictions. Radiative corrections in this theory can in principle be calculated to all orders. Corrections up to the order of α^3 have been evaluated using the event generator of Behrends and Kleiss [7]. Wherever possible their calculations have been tested, and in all checks the QED calculations have been verified by experiments. E.g. the acollinearity distribution for Bhabha scattering as measured by the JADE collaboration shows good agreement between data and calculations as demonstrated in Fig. 1.

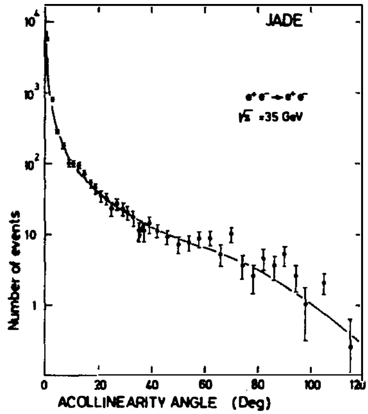


Fig. 1 Acollinearity Distribution for Bhabha Scattering

All PETRA experiments have adopted the procedure to correct the experimental data for the radiative corrections before they are compared to theoretical predictions. This allows a direct comparison of different experiments with first order QED calculations, independent of the experimental cuts (e.g. like the collinearity angle).

Deviations from QED predictions for lepton pair production are commonly parametrized in terms of form factors with one parameter, Λ :

$$d\sigma_{exp} = d\sigma_o \, (1 + \delta_{rad}) \, F_{\pm}(\Lambda) \qquad \text{with } F_{\pm} = 1 \mp s/(s-\Lambda_{\pm}^2);$$

$d\sigma_{exp}$ describes the measured differential cross section, $d\sigma_o$ describes the cross section calculated to first order in QED and δ_{rad} represents the radiative corrections including vacuum polarization.

As an example one can take a recent measurement of the TASSO group [6] of the total cross section for μ- and τ-pair production as a function of the total energy, which is shown in Fig. 2. The measured data points agree well with the line showing the QED prediction.

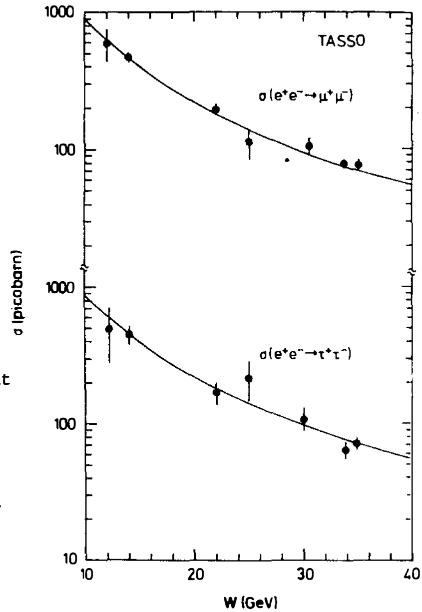


Fig. 2 Total Cross Sections for μ-pair and τ-pair Production.

None of the PETRA experiments has found a deviation from the predictions of Quantumelectrodynamics. Limits at a 95% confidence level for the Λ-parameter are listed in Table I for different reactions of lepton pair production.
A finite value of Λ would indicate a deviation from QED. A breakdown of the theory could e.g. be due to a non point-like coupling of the leptons to the electromagnetic field. In this case Λ is sometimes interpreted as a charge radius of the lepton. The present data would thus indicate radii of $r \lesssim 1.E{-}16$.

Finite values for Λ can also be observed if the pure QED calculations are no longer applicable, e.g. if weak effects become measurable. The standard model of Glashow, Salam and Weinberg represents such an extension of QED. At PETRA energies the s-dependent effect due to weak interactions is too small to be reflected in finite values of Λ. Weak neutral current contributions to lepton pair production can however be observed in the measurement of a charge asymmetry, as shown in the subsequent part.

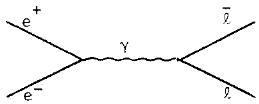
TABLE I

95% Confidence Level Lower Limits of Λ (GeV)

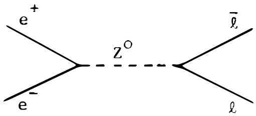
$e^+e^- \rightarrow$	e^+e^- Λ_+	Λ_-	$\mu^+\mu^-$ Λ_+	Λ_-	$\tau^+\tau^-$ Λ_+	Λ_-
CELLO	83	155	186	101	142	121
JADE	112	106	142	126	111	93
MARK J	128	161	194	153	126	116
PLUTO	80	234	107	101	79	63
TASSO	140	296	136	281	124	104

II. Electroweak Interactions

The e^+e^- annihilation into μ- or τ-pairs is dominated by the graph (a) where ℓ stand for μ or τ. The weak interaction contributes by the exchange of a virtual Z^o via the graph (b)



(a)



(b)

The standard model of Glashow, Weinberg, Salam is the simplest unified theory of weak and electromagnetic interactions. In this theory the electroweak force is mediated by two massive vector bosons of opposite charge ($W^\pm$), and two neutral vector bosons, one of which is the massive Z^o and the other the massless photon. This theory has only one free parameter, the so called weak angle θ_w.

The vector boson masses are then fixed :

$$M_w = \sqrt{\frac{\sqrt{2}\,\pi\,\alpha}{2\,G_f}} \cdot \frac{1}{\sin\theta_w} = \frac{37.3\ \text{GeV}}{\sin\theta_w}$$

$$M_z = \frac{M_w}{\cos\theta_w} .$$

The weak coupling of the Z^o to the charged lepton pairs is given by the vector and axial-vector coupling constants g_v and g_a. In the standard model one has for charged leptons

$$g_v = 1/2 - 2\sin^2\theta_w ,$$
$$g_a = -1/2$$

These coupling constants in general might differ for the different leptons.

However no different behavior of the leptons has been observed experimentally, and one assumes lepton universality :

$$g_v(e) = g_v(\mu) = g_v(\tau) = g_v \quad ,$$
$$g_a(e) = g_a(\mu) = g_a(\tau) = g_a \quad .$$

Using the measured value of $\sin^2\theta_w = 0.228$ from neutrino scattering experiments[8], one obtains $g_v = +\,0.044$ for the vector coupling of charged leptons. This value is too small to result in observable effects in the pair production cross section for leptons. However $g_a = -\,1/2$ is large enough to allow for measurable effects.

Let us consider the electron-positron annihilation into μ- and τ- pairs :

$$e^+ + e^- \rightarrow \mu^+ + \mu^-$$
$$e^+ + e^- \rightarrow \tau^+ + \tau^-$$

Neglecting threshold terms the differential cross section for these reactions is given by

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s} \cdot (F_1 \cdot (1 + \cos^2\theta) + F_2 \cos\theta_w) \qquad (1)$$

$$F_1 = 1 + 8s \cdot g \cdot g_v^2 \cdot \frac{M_z^2}{s-M_z^2} + (4sg(g_v^2 + g_a^2) \cdot \frac{M_z^2}{s-M_z^2})^2$$

$$F_2 = 16\,s \cdot g \cdot g_a^2 \cdot \frac{M_z^2}{s-M_z^2} + (8sg \cdot g_v \cdot g_a \cdot \frac{M_z^2}{s-M_z^2})^2$$

$$g = \frac{G_F}{8\sqrt{2}\pi\alpha} = 4.49 \cdot 10^{-5}\ \mathrm{GeV}^{-2} \quad .$$

The QED cross section decreases with energy like s^{-1}. This energy dependence has been taken out as a common factor in equation (1). The factor F_1 describes the magnitude of the total cross section relative to the QED cross section. It consists of three terms : the first one describing the pure electromagnetic interaction is equal to 1; the third one describes the pure weak interactions and the second one is the interference term between weak and electromagnetic interactions. The factor F_2 produces an asymmetry of the angular distribution; the two terms describe the interference between electromagnetic and weak interactions, and the pure weak interaction. All interference and weak terms contain the factor $\frac{M_z^2}{s-M_z^2}$, which is close to 1 as long as $s \ll M_z^2$. This is the case in the range of available PETRA energies. The energy dependence is such, that - relative to the QED term - the interference and the weak terms rise like s and like s^2. Therefore the biggest contribution is expected at the highest energy. At PETRA one has obtained data up to $s \approx 1200\ \mathrm{GeV}^2$. Assuming the value of $\sin^2\theta_w = 0.228$ one can estimate the contributions of the different terms as shown in Table II.

TABLE II

Relative Magnitude of the Contributions to the Cross Section at s = 1200 GeV^2.

	electromagnetic	interference	weak
σ_{tot} (ee → μμ)	1.	.001	.004
asymmetry	0.	.25	.0002

From this table it is obvious that a measurable effect of weak interaction is expected to show up in the angular distribution due to the electroweak interference term, which is proportional to g_a^2. In order to determine its magnitude one fits the differential cross section to the form

$$\frac{d\sigma}{d\Omega} = N(1 + \cos^2\theta + \frac{8}{3} A \cos\theta) \tag{2}$$

with N and A as free parameters. The parameter A corresponds to the forward-backward asymmetry

$$A = \frac{\frac{d\sigma}{d\Omega}(\theta < \frac{\pi}{2}) - \frac{d\sigma}{d\Omega}(\theta > \frac{\pi}{2})}{\frac{d\sigma}{d\Omega}(\theta < \frac{\pi}{2}) + \frac{d\sigma}{d\Omega}(\theta > \frac{\pi}{2})}$$

assuming full acceptance of all lepton pairs.
For the PETRA experiments a typical acceptance is $|\cos\theta| < 0.80$. Therefore the observable forward-backward asymmetry is about 10% lower than the parameter A as obtained from the fit to the angular distribution. For a comparison of different experiments the value of A will be used, because it is independent of the detector acceptance.

II.1 $e^+ + e^- \rightarrow \mu^+ + \mu^-$

Fig. 3 shows the differential cross sections of the four PETRA experiments CELLO, JADE, MARK J and TASSO as a function of cosθ at the highest PETRA energies. Also a fit to the data is shown as a solid line according to equation (2), as well as the result of a fit with the asymmetry set to zero as a dashed line. The data favour a fit with a negative asymmetry different from zero. In Table III all available PETRA data on the μ-pair asymmetry are summarized together with the expected values from the standard model for three ranges of c.m. energies.
The low energy data of total c.m. energies of 14 and 22 GeV do not show an asymmetry significantly different from zero. The high energy data at an average energy of about 34 GeV howerver, show a significant asymmetry for the JADE, MARK J, and TASSO data, which differ from zero by at least three standard deviations. The CELLO data, due to their large error, are compatible with zero, and

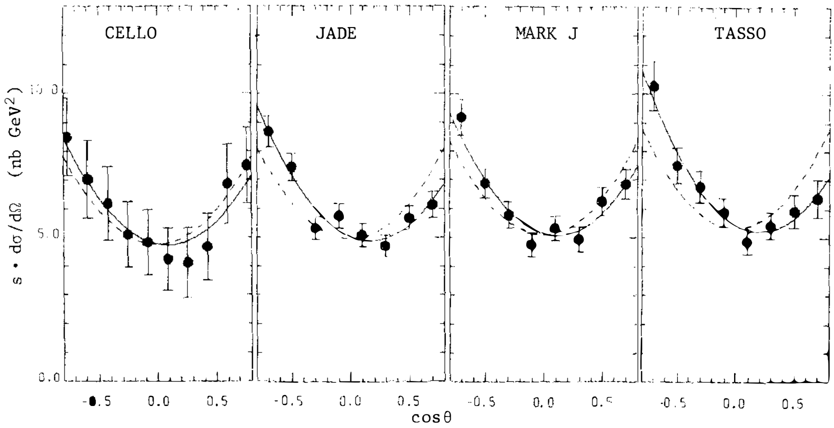


Fig. 3 Differential Cross Section for muon pair production at $s \approx 1200$ GeV^2.

TABLE III

μ Asymmetry Measurements at Different Energies

Energy	Experiment	A(μμ) (%)	A (GWS theory)
14 GeV	JADE	+ (6.8 ± 6.0)	- 1.3
	MARK J	+ (5.3 ± 5.0)	- 1.3
	TASSO	- (3.0 ± 5.0)	- 1.3
	average	+ (2.6 ± 3.0)	- 1.3
22 GeV	JADE	- (7.9 ± 6.4)	- 3.1
	MARK J	- (5.2 ± 5.6)	- 3.6
	TASSO	- (8.0 ± 6.0	- 3.1
	average	- (6.9 ± 3.4)	- 3.3
34 GeV	CELLO	- (6.4 ± 6.4)	- 9.1
	JADE	-(12.7 ± 2.7 ± 1.0)	- 9.1
	MARK J	- (9.8 ± 2.3 ± 1.0)	- 8.7
	TASSO	-(16.1 ± 3.2)	- 9.2
	average	-(11.9 ± 1.5)	- 9.0

also with the prediction of the standard model. The average asymmetry of all four experiments shows good agreement with the prediction of the standard model.
In Fig. 4 the differential cross sections of JADE, MARK J and TASSO are combined.

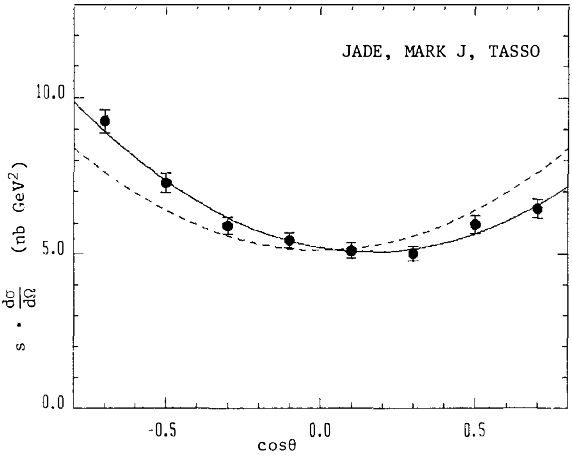


Fig. 4 Differential Cross Section for Muon Pair Production, combined data of CELLO, JADE, MARK J, and TASSO.

The agreement between the data and the fitted curve, shown as a solid line, is excellent and the symmetric behavior as predicted by QED alone (dashed line) can be excluded by seven standard deviations. This is a convincing proof for the asymmetry in μ-pair production.

Various checks for systematic errors have been done : e.g. trigger inefficiency, data selection, cosmic ray background, $\tau^+\tau^-$ background, charge determination, acceptance asymmetry. All experiments quote systematic errors to the asymmetry measurement of about 1%. Furthermore it should be mentioned that nearly all sources of systematic errors tend to reduce the magnitude of the asymmetry.

The systematic error introduced by radiative corrections deserves special attention. At present the α^3-corrections to the asymmetry are about +1.3%. Radiative corrections including weak effects have already been calculated [9] and they are known to be small at present PETRA energies. But the calculation of α^4 - corrections is still missing. They are expected to be small, but if the statistical accuracy of data is reaching 1% on the asymmetry, it will be necessary to study systematic effects more carefully including a calculation of α^4-corrections.

II.2 $e^+ + e^- \rightarrow \tau^+ + \tau^-$

In a similar fashion the PETRA experiments have analyzed the τ-pair production. However, as one does not measure τ-pairs directly, and only observes the decay products, additional problems arise :

- The selection of only specific decay channels reduces the number of observable τ-pair events.
- The correction for unobserved decay channels can introduce additional errors because of uncertainties in the branching ratios (see also chapter VI).
- The angle of the primary τ's is measured only with reduced accuracy because of unobserved neutrinos. Therefore a larger background from $\gamma\gamma$-reactions may affect the data.
- The charge determination is less accurate for final states with three charged particles. Because of the small opening angle of the secondary tracks. They might overlap in the track detector and thus reduce the measurement accuracy.

The angular distributions for the CELLO, JADE, and TASSO data are shown in Fig.5 as well as a combined distribution of the three PETRA groups. Because of low

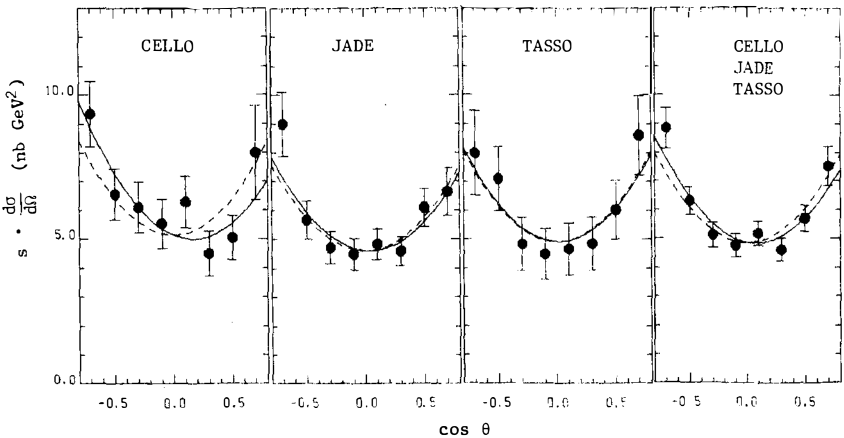


Fig. 5 Differential cross section for τ-pair Production, data from CELLO, JADE, TASSO and combined data at $s \approx 1200$ GeV^2.

statistics the data do not show as clear an effect as the muon data. Within the statistical accuracy they are, however, in good agreement with the prediction of the standard model, and all data tend to a negative value of the asymmetry parameter. The results of the different experiments are shown in Table IV, which contains also a preliminary result from the MARK J collaboration.

The combined average of $A = -(6.2 \pm 2.9)\%$ is two standard deviations from zero and agrees with the predicted value of -9.1% from the standard model.

TABLE IV

τ Asymmetry Measurements at Different Energies

Energy	Experiment	A(ττ) (%)	A(GWD theory)
14 GeV	TASSO	+ (15 ± 12)	- 1.0
22 GeV	TASSO	+ (0 ± 10)	- 3.5
34 GeV	CELLO	- (10.3 ± 5.2)	- 9.2
	JADE	- (5.6 ± 5.0 ± 1.4)	- 8.9
	MARK J	- (7.0 ± 7.2 ± 2.1)	- 9.5
	TASSO	- (0.4 ± 6.6)	- 9.1
	average	- (6.2 ± 2.9)	- 9.1

III. Determination of the Weak Coupling Constants

The data on μ- and τ-pair production may be used to determine the weak coupling constants for vector and axial-vector coupling, g_v and g_a, from a fit to the differential cross sections under the assumption $M_z \approx 90$ GeV. The results are shown in Fig. 6. The data of CELLO, JADE, TASSO and MARK J agree within errors. In Table V the numerical values for the coupling constants are shown as well as the average of the four experiments.

The vector coupling constant is compatible with zero and one obtains an upper limit of $g_v^2 < 0.08$ at the 95% confidence level. The axial vector coupling constant of $g_a = -(0.58 \pm 0.04)$ is in agreement with the prediction of $g_a = -0.5$ from the standard model. The sign of g_a has been determined by combining the PETRA results with those of neutrino electron scattering experiments [10].

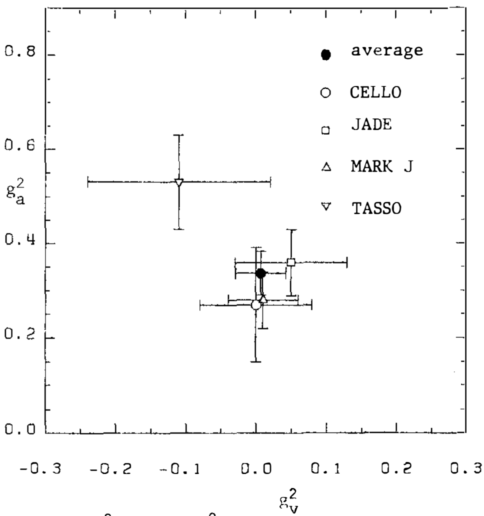


Fig. 6 g_v^2 versus g_a^2.

Furthermore one may fit all data on lepton pair production to the standard model with $\sin^2\theta_w$ as free parameter. The results from the PETRA experiments are also shown in Table V. The average of $\sin^2\theta_w = 0.26 \pm 0.06$ is in good agreement with the average of the measurements of $\sin\theta_w = 0.228 \pm 0.009$ by neutrino experiments [8].

TABLE V

Weak Coupling Constants and $\sin^2\theta_w$

Experiment	g_v^2	g_a^2	$\sin^2\theta_w$
CELLO	0.00 ± 0.08	0.27 ± 0.12	0.25 ± 0.12
JADE	0.05 ± 0.08	0.36 ± 0.07	0.25 ± 0.15
MARK J	0.01 ± 0.05	0.28 ± 0.06	0.25 ± 0.11
TASSO	- 0.11 ± 0.13	0.53 ± 0.10	0.29 ± 0.10
average	0.007 ± 0.036	0.337 ± 0.046	0.26 ± 0.06
GWS	0.002	0.250	0.228 (ν-exp.)

IV. Alternative Electroweak Models

Apart from the standard model there are alternative models which are based on a larger symmetry group SU(2) × U(1) × G. These models are constructed such that they preserve the success of the standard model at low energy, but still yield observable differences at high q^2 [11]. In analogy to the addition of electromagnetism to the weak Hamiltonian one obtains

$$H_{NC} = \frac{4G_f}{\sqrt{2}} \left| \left(j^{(3)} - j_{elm} \sin^2\theta_w \right)^2 + C\, j_{elm}^2 \right|$$

with the weak neutral current $j^{(3)}$ and the electromagnetic current j_{elm}. The coefficient C is zero in the standard model. It describes the behavior of the additional interaction represented by the group G. Such a modification leaves the predictions for neutrino scattering experiments unchanged because only the electromagnetic current is involved. It also leaves the prediction for polarized electron scattering on quarks unchanged because the additional interaction conserves parity.

The coupling constants are then

$$g_v^2 = -1/4\,(1 - 4\sin^2\theta_w)^2 + 4C$$
$$g_a^2 = 1/4$$
$$g_v \cdot g_a = -1/4\,(1 - 4\sin^2\theta_w) \quad .$$

Thus only the vector coupling constant is modified in these alternative models. Gounaris and Schildknecht [12] have given an interpretation to the parameter C in terms of a deviation from the standard model :

$$16\,C = \frac{\left|\int \frac{ds}{s}\,\sigma_{tot}\right|_{true} - \left|\int \frac{ds}{s}\,\sigma_{tot}\right|_{GWS}}{\left|\int \frac{ds}{s}\,\sigma_{tot}\right|_{GWS}}$$

Inhere 'true' stands for the real cross section and 'GWS' stands for the prediction of the standard theory of Glashow, Weinberg, Salam. The quantity 16 C is therefore a measure for the deviation of the total cross section from the prediction of the standard model.

In order to determine C the PETRA groups have assumed the standard model with $\sin^2\theta_W = 0.228$. No measurable effect for a deviation from the predictions of the standard model has been observed by fitting the data on μ-pair production and Bhabha scattering. The results are shown as upper limits for the parameter C at 95% confidence level in Table VI.

TABLE VI

Upper Limits for C at the 95% Confidence Level

Experiment	C
CELLO	0.029
JADE	0.039
MARK J	0.027
TASSO	0.020

Using the lowest limit of $C < 0.020$ as obtained by the TASSO group, one obtains $16C < 0.32$ (95% C.L.). This limit still leaves some freedom for alternative models, e.g. with multi Z^o's.

V. Lower Limit of Weak Mixing Angles from an Upper Limit of Beauty Lifetime

All measured electroweak properties of the hadrons with beauty fit into the Kobayashi-Maskawa scheme [13], or, equivalently, into the Maiani scheme [14]. In this scheme the quarks d', s', b' in the weak doublets

$$\begin{pmatrix} u \\ d' \end{pmatrix} \quad \begin{pmatrix} c \\ s' \end{pmatrix} \quad \begin{pmatrix} t \\ b' \end{pmatrix}$$

are composites of the strongly interacting quarks d, s, b, where the strong quark contamination is described by the angles θ_C, β, γ. θ_C is the Cabibbo angle, and β and γ are the so called Maiani angles, where $\sin\beta$ and $\sin\gamma$ determine the strong b-quark contamination of the weak d'- and s'-quarks. These weak mixing angles determine the lifetime of the hadrons containing a b-quark [15]:

$$\tau_B = \frac{0.93 \cdot 10^{-14}\ \text{sec}}{2.75\sin^2\gamma + 7.69\sin^2\beta - 5.75\sin^2\gamma\sin^2\beta}$$

In order to obtain an upper limit on the lifetime of the b-quark the JADE group has analyzed multihadronic events containing at least one muon [16]. A muon from a b-decay is expected to originate at some distance from the production vertex due to the finite lifetime of the b. A special event selection has been made to obtain an enriched $b-\bar{b}$ sample of 31 events. It has been verified by means of Monte Carlo simulation, that 50% of these events originate from $b-\bar{b}$ production and 50% from $c-\bar{c}$ production. The muon from the semileptonic b-decay has been used to determine the closest distance of approach (CDA) of the muon track to the event vertex. This is a measure of the lifetime of hadrons with beauty. The CDA-distribution has been analyzed, but no effect has been found within the resolution of $\sigma(\mathrm{CDA}) = 0.45$ mm. From this the JADE group determined a limit for the lifetime of hadrons with beauty

$$\tau_B < 1.4 \cdot 10^{-12} \text{ sec}$$

at the 95% confidence level. Because of the relation between the lifetime and the weak mixing angles one obtains limits for these angles. In Fig. 7, where $|\sin\gamma|$ is shown versus $\sin\beta$, the unshaded region shows the allowed values for the weak mixing angles. The lower left shaded area is excluded by the limit of the beauty lifetime. The upper right shaded area is excluded by the Cabibbo universality and the area left of the diagonal line is excluded by the CLEO experiment [17]. From this it is clear that the data are compatible with a branching ratio of 50 - 100 % for the b-decay into a c-quark. A 50% b-decay into an u-quark can, however, not be excluded by the data.

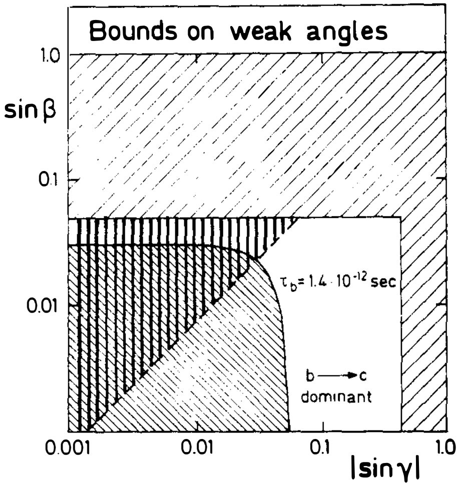


Fig. 7 Allowed Region for the Maiani Angles $|\sin\gamma|$ and $\sin\beta$: the unshaded region is the allowed one.

VI Measurement of τ Branching Ratios and Lifetime

A detailed analysis of τ-decays has been undertaken by the CELLO collaboration. The criteria for selection of τ-pair events are such that 92% of all τ-decays are accepted. Only final states with two electrons or two muons are rejected because of the background from Bhabha scattering and μ-pair production. As a result they obtained a ratio of

$$\frac{\sigma_{\tau\tau}}{\sigma_{\mu\mu}} = 1.05 \pm 0.5 \pm 0.7$$

in good agreement with the assumption that the τ is a pointlike, spin 1/2 particle.

In addition the CELLO group has determined topological branching ratios for the τ-decays into final states with one, three, and more than three charged particles. The results are shown in Table VII together with results reported at this conference by the MARK II group [18] and the averages obtained from previous experiments [19].

TABLE VII

Topological Branching Ratios of τ Decays into one (B1), three (B3) and more than three (B5) Charged Particles.

	B1	B3	B5	B1 • B3
CELLO	0.82 ± 0.02	0.17 ± 0.02	0.01 ± 0.04	0.14 ± 0.02
MARK II	0.86 ± 0.04	0.14 ± 0.04	<0.06 (95%CL)	0.12 ± 0.04
World Average	0.66 ± 0.04	0.28 ± 0.06	<0.09 (95%CL)	0.19 ± 0.02

The agreement between the new results and the old averages is not too good. The difference for the product B1 • B3, which is also shown in Table VI, is slightly above two standard deviations. This branching ratio is of special importance, because it is used by other experiments, which accept only τ-pair events with one and three charged particles in the final state, to correct the data for a determination of the total cross section. The ratio between the old world average and the new values is with 1.46 rather large and will introduce additional systematic errors to experimental results depending on this ratio. The TASSO data on τ-pair production as shown in Fig. 1, if corrected with the new ratio, would not agree well with the QED prediction. Additional high precision measurements are required to settle the question of topological branching ratios.

Furthermore the CELLO group has determined the τ lifetime [20] from a detailed analysis of decays with three charged particles in the final state to be

$$\tau_\tau = (4.9 \pm 2.9) \cdot 10^{-13} \text{ sec.}$$

This result agrees well with other measurements from MARK II [21] and MAC [22] and also with the value of $\tau_\tau = (2,8 \pm 0.2) \cdot 10^{-13}$ sec expected from μ-τ universality, assuming that the τ has the same coupling to the charged weak current as the muon.

VII Summary

The PETRA groups have measured the e^+e^- annihilation into lepton pairs. A charge asymmetry in the angular distribution has been observed in the analysis of μ-pairs. The combined data of CELLO, JADE, MARK J and TASSO yield an asymmetry of

$A = -(11.9 \pm 1.5)\%$ at a total c.m. energy of about 34 GeV, while no significant asymmetry has been found at lower energies. This result is incompatible with the expectations from pure QED. It is, however, in good agreement with the assumption of an electroweak interference as expected from the standard model of weak and electromagnetic interactions of Glashow, Weinberg and Salam.
Similar effects show up in the charge asymmetry of τ-pairs. The combined result of $A = -(6.2 \pm 2.9)$ at a total c.m. energy of about 34 GeV is not yet statistically significant, but it is compatible with the prediction of $A = -9.1\ \%$ of the standard model.
The data on lepton pair production have been used to determine the weak coupling constants to

$$g_v^2 < 0.08 \quad (95\%\ \text{C.L.}), \qquad g_a^2 = 0.337 \pm 0.046$$

Using the results of neutrino electron scattering experiments one can determine the sign of g_a and obtains

$$g_a = -(0.58 \pm 0.04) \quad .$$

Assuming the standard model, the weak mixing angle has been determined to

$$\sin^2\theta_W = 0.26 \pm 0.06$$

in accordance with the result from neutrino experiments.
The lepton production data are in agreement with the predictions of the standard model and no effect has been observed so far, which might require an extension of this model.

An upper limit of the beauty lifetime has been determined by the JADE group of $\tau_B < 1.4 \cdot 10^{-12}$ sec. As a consequence the b-quark is expected to decay rather into a c-quark than into a u-quark. However a 50% branching ratio into a u-quark cannot be excluded experimentally.

New measurements of CELLO and MARK II of the topological branching ratios of τ-decays into one (B1) and three (B3) charged particles tend systematically to lower values for the combined ratio B1 • B3. This new result is about a factor 1.5 smaller than the old world average.

The CELLO group has determined the τ-lifetime to be

$$\tau_\tau = (4.9 \pm 2.9) \cdot 10^{-13}\ \text{sec}$$

in good agreement with the experimental results from MARK II and MAC.

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