HEAVY LEPTONS

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ABSTRACT
A summary of our present knowledge about the new heavy lepton τ is given.

I. INTRODUCTION

Only a few years have passed since the third lepton τ was first observed at SLAC in 1975[1]. Yet we are already in a position to argue about the details of its properties.

The existence of this new particle has been undoubtedly confirmed in nine different experiments[2-10]. Soon it became clear that the heavy sequential lepton hypothesis[11] (standard model) was the best candidate to give a proper description of the τ.

It will be the aim of this talk to review[12,13,14] the experimental properties of the new particle, compare them to the standard model and discuss, how far other hypotheses can be excluded.

II. PRODUCTION AND DECAY IN THE STANDARD MODEL

Lepton pair production in e^+e^- reactions can be predicted with certainty by quantum electrodynamics (QED). For the production of a pair of pointlike spin 1/2 particles $\tau^+\tau^-$ we get

$$\sigma_{\tau\tau} = \sigma_{\mu\mu}\,((3\beta - \beta^3)/2) \qquad (1)$$

where

$$\sigma_{\mu\mu} = (4\pi\,\alpha^2)/(3s) = 21.71\ \mathrm{nb}/E_b^2 \qquad (E_b = s^{1/2}/2 = \text{beam energy})$$

is the cross section for $e^+e^- \rightarrow \mu^+\mu^-$ and β is the velocity of the τ. $\sigma_{\tau\tau}$ rises quickly from the threshold at $s^{1/2} = 2M_\tau$ and approaches $\sigma_{\mu\mu}$ asymptotically.

In the standard model a third sequential lepton τ is added to the old leptons μ and e. It is described by an additional term

$$\bar{\tau}\,\gamma_\alpha(1 + \gamma_5)\,\nu_\tau$$

in the weak leptonic current. This implies that a new lepton with its own massless left-handed neutrino takes part in the conventional weak interaction.

Possible decay modes of the τ into e, μ (leptonic) or hadrons (semihadronic) plus neutrinos are shown in fig. 1A,B. In first approximation, each decay mode $(e\,\bar{\nu}_e)$, $(\mu\,\bar{\nu}_\mu)$ and $d\bar{u}$ (three colours) contributes 20 % to the total branching ratio. Detailed calculations[11,14] yield a leptonic branching ratio of

$$B_e = BR(\tau \rightarrow e\nu\nu) = 16.8\ \% . \qquad (2)$$

The only uncertainty in this calculation comes from the assumptions for the hadronic part. An independent estimate of this contribution from QCD[15] yields

$$B_e = BR(\tau \rightarrow e\nu\nu) = 17.5\ \%. \qquad (3)$$

Consequently, the decay into leptons constitutes a large fraction of τ decays. Since also the hadronic system tends to contain only one charged particle, the combination of one lepton and one charged particle is often used as a clean signature for τ pair production.

III. THRESHOLD BEHAVIOUR AND PROPERTIES OF THE τ

τ mass

The basic parameter of the τ mass can be deduced from the threshold behaviour (1). Until 1977 the mass of the τ was rather unprecisely determined[12]. Mainly for this reason a certain scepticism remained that the τ might be confused with a charm particle. A major break-through in this issue came with the discovery by the DASP group that τ production was already present at the ψ' resonance[16] (fig. 2a). From the inclusive electron production of fig. 2a a mass of $M_\tau = 1.807 \pm 0.02$ GeV could be determined by the DASP group. The DESY-Heidelberg group followed very quickly with an even better determination of the mass[8]: $M_\tau = 1.790^{+0.007}_{-0.010}$ GeV. Both values were finally topped by the excellent measurement of the DELCO group[9] at SPEAR which is shown in fig. 2b. This measurement of the inclusive electron production in two-prong events sets a mass value of $1.782^{+0.003}_{-0.004}$ GeV to be compared with the D meson mass of $M_D = 1.868 \pm 0.001$ GeV.

τ spin

Another parameter that can be determined from the threshold behaviour is the τ spin. The curves in fig. 2 demonstrate the expectation for different spins of the produced pair of pointlike particles. The data confirm previous observations first

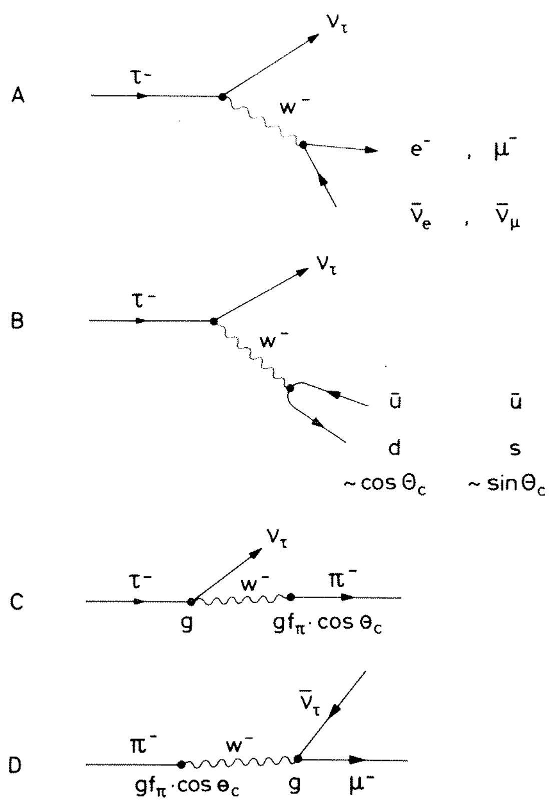

Fig. 1 Leptonic and semihadronic decays of the heavy lepton τ.

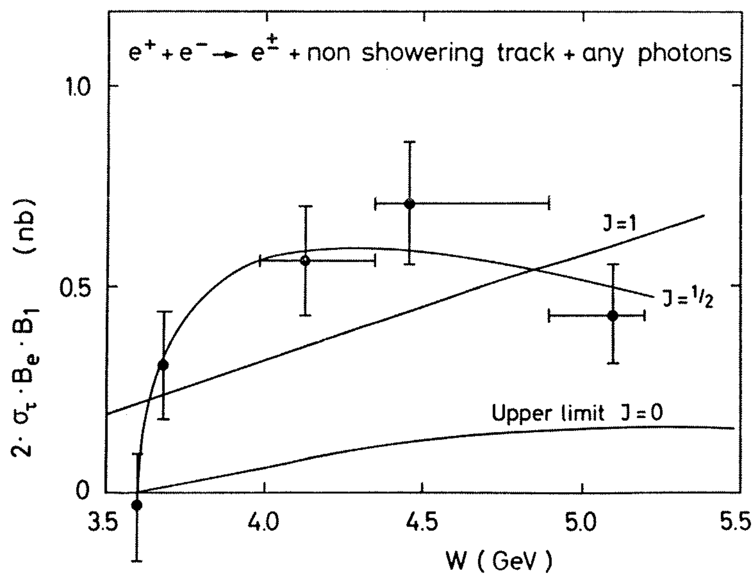

Fig. 2a DASP: cross section for inclusive electron production in the two-prong class with any number of photons. The solid curves are fits assuming pair production of pointlike particles with spin 0, 1/2 and 1.

stated by the PLUTO group[3]: spin 0, 1 and 3/2 can be excluded - spin 1 and 3/2 mainly since they deviate strongly at higher energies. Spin 0 is out anyway since it yields only 1/4 of $\sigma_{\mu\mu}$ asymptotically.

Pointlike τ structure

New data have become available very recently at energies of 9.4 GeV[17] (Table 1). The cross section is well compatible with the expectation (1) for a pointlike structure of the τ. To quantify this statement one may introduce a formfactor $F_\tau(s) = 1 \pm s/\Lambda_\pm^2$ of the τ multiplying (1) by $|F_\tau(s)|^2$.

The data of table 1 yield the following lower limits for the cut-off parameters $\Lambda_\pm$ (PLUTO[17]):

$\Lambda_+ > 22$ GeV $\Lambda_- > 19$ GeV

There is no indication for a further heavy lepton τ' in the data. With the predicted branching ratios for a new sequential lepton[11] we get a limit of:

$M_{\tau'} > 4.3$ GeV (95 % C.L.) PLUTO[17]

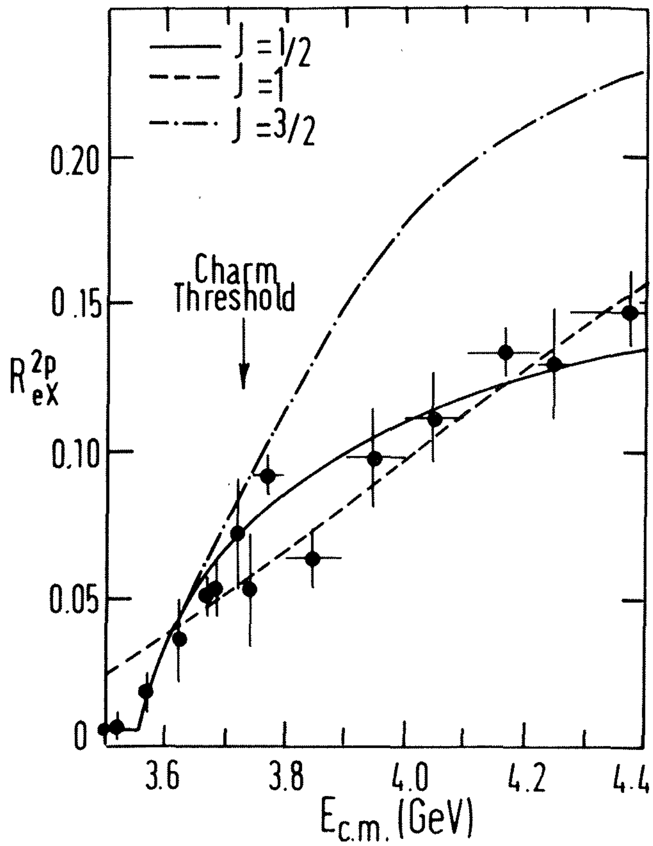

Fig. 2b DELCO: inclusive electron production in the two-prong class with any number of photons. The ratio of the electron to μ pair production is plotted versus CM energy. Data are compared with the prediction for spin 1/2, 1 and 3/2 pair production.

Table 1

PLUTO: τ production at E_{CM} = 9.45 GeV. Including radiative corrections (7 %) and systematic errors (20 %) one gets $\sigma_{\tau\tau}$ (9.4 GeV) =(0.94 ±0.25)$\sigma_{\tau\tau}$ (QED) (preliminary).

$e^+ e^- \rightarrow$	data	τ prediction
μ e	5	4.6
μ μ	3	3.0
μ hadron	5	3.5
μ ρ	7	9.2
μ + 1 track	7	7.0
μ + 3 tracks	7	4.3
background	2	
total ./. background	32 ±6	31.6

IV. LEPTONIC DECAYS

The leptonic decays can be calculated in the standard model without further assumptions. The branching ratios B_e and B_μ = BR($\tau \rightarrow \mu\nu\nu$) differ only by a small phase space correction

$$B_\mu = 0.973\ B_e . \qquad (4)$$

The DASP[4], PLUTO[3,18] and SLAC-LBL[19] groups have checked the ratio B_μ/B_e from a comparison of τ events containing e or μ. The mean value[14] of 0.99 ±0.2 is in good agreement with the expectation. One may, therefore, combine various measurements of B_μ and B_e to evaluate a world average under the assumption (4). Table 2 summarizes the results published so far. The mean value of

$$B_\mu/0.973 = B_e = 17.1 \pm 1.0\ \%$$

is in excellent agreement with the theoretical expectations (2) and (3).

Table 2

Summary of leptonic branching ratios. For the average, $B_\mu = 0.973\ B_e$ is assumed and the statistical (first) and systematic (second) errors are added quadratically.

collaboration	$B_e = BR(\tau \to e\nu\nu)$ % $B_\mu = BR(\tau \to \mu\nu\nu)$ %	reference
SLAC-LBL	$\sqrt{B_e \cdot B_\mu} = 18.6 \pm 1.0 \pm 2.8$	2
	$B_\mu = 17.5 \pm 2.7 \pm 3.0$	2
PLUTO	$B_\mu = 15.0 \pm 3.0$	3,18
	$B_e = 16.5 \pm 5.6$	3,18
Lead-Glass-Wall	$\sqrt{B_e \cdot B_\mu} = 22.4 \pm 3.2 \pm 4.4$	5
Ironball	$B_\mu = 22\ ^{+7}_{-8}$	7
MPP	$B_\mu = 20 \pm 10$	6
DASP	$\sqrt{B_e \cdot B} = 18.2 \pm 2.8$	4
DELCO	$B_e = 16.0 \pm 1.3$	9
	$B_\mu = 21.0 \pm 5.0 \pm 3.0$	20
World average	$B_e = B_\mu/0.973 = 17.1 \pm 1.0$	

Experiments always measure the simultaneous decay of a τ pair. Therefore, the branching ratios of table 2 are necessarily determined from a product of two branching fractions. Consequently a purely experimental determination of B_e and B_μ can only be achieved, if at least three products of the branching ratios B_e, B_μ, $B_{1p} = BR(\tau \to \nu + 1$ charged particle) and $B_{3p} = BR(\tau \to \nu + \geq 3$ charged particles) are measured simultaneously. (E. g. the PLUTO values of table 2 were obtained from a simultaneous measurement of $B_e \cdot B_\mu$, $B_\mu \cdot B_{1p}$, $B_\mu \cdot B_{3p}$). G. Feldman has made a constrained fit to all available data to get a consistent set of the above four branching fractions[13]. The result of

$$B_\mu/B_e = 1.13 \pm 0.16$$

is again in good agreement with the expectation (4). Therefore applying the constraint (4) he gets

$$B_\mu/0.973 = B_e = 17.5 \pm 1.2\ \%$$

in good agreement with the above mean value.

V. SEMIHADRONIC DECAYS

Since the τ mass is high enough to allow for semihadronic decays (fig. 1 B), we have an excellent tool to check whether the new particle does in fact participate in the conventional weak interaction of the standard model. If this is the case, it should couple to two kinds of hadronic currents,

vector currents $J^P = 1^-$,

axial vector currents $J^P = 0^-, 1^+$,

where J^P is the spin parity of the hadronic final state. Due to the conservation of the vector current (CVC), no scalar final states occur in the vector part.

1. Vector current

The vector current with $J^P = 1^-$ leads to a prediction of the decay $\tau \to \nu\rho$. Assuming CVC, B_e = 16.8 %, M_ρ = 0.77 GeV and M_τ = 1.8 GeV one gets[11,14)]

$BR(\tau \to \nu\rho)$ = 25.3 %.

Preliminary results on this decay mode are

$BR(\tau \to \nu\rho)$ = (24 ±9) % DASP[21)],

$BR(\tau \to \nu\rho)$ = (21.1 ±3.7) % MARK II[10)].

The mean value of (21.5 ±3.4) % agrees with the expectation.

2. Axial vector current

Since the axial vector current is not conserved, its divergence can also contribute to the hadronic current. Therefore, $J^P = 0^-$ and 1^+ final states are allowed. Consequently, the τ will decay into π and A_1 (if the A_1 exists) or other 0^- and 1^+ states.

$(\tau \to \nu\pi)$ decay

This decay plays a central rôle in the discussion of the weak current involved in τ decay since it constitutes the "inversion" of the π decay. It can, therefore, unambiguously be predicted from the pion coupling constant f_π (fig. 1 C, D). With B_e = 16.8 %, f_π = 0.129 GeV and M_τ = 1.8 GeV we get[11,14)]

$BR(\tau \to \nu\pi)$ = 9.5 %.

The PLUTO group studied inclusive pion production[22)] from the reaction:

$$e^+ e^- \to \pi^\pm + 1 \text{ charged particle} + \text{no photons}. \quad (5)$$

32 events of class (5) were seen in the 4 to 5 GeV energy range. On the other hand, only 8.9 ±1.0 events were expected from hadron misidentification, $\tau \to \nu\rho$ decay and hadronic sources. They obtain a branching ratio of

$BR(\tau \to \nu\pi)$ = (9.0 ±2.9 ±2.5) % PLUTO[22)],

where the second error indicates the systematic uncertainty. Going along very similar lines, the SLAC-LBL group found a branching ratio of

$BR(\tau \to \nu\pi)$ = (9.3 ±1.0 ±3.8) % SLAC-LBL[23,13)].

DELCO studied[20)] events of the type

$$e^+ e^- \to e^\pm + 1 \text{ hadron} + \text{no photons}. \quad (6)$$

They observed 17.4 events after background subtraction. 19.3 events are expected, out of which only 6.9 events are due to other sources than $\tau \to \nu\pi$ decay (mainly $\tau \to \nu\rho$). The resulting branching ratio is

$BR(\tau \to \nu\pi) = (8.0 \pm 3.2 \pm 1.3)$ % DELCO[20].

Preliminary results[10] from MARK II on signature (5) are

$BR(\tau \to \nu\pi) = (10.6 \pm 1.9)$ % MARK II[10].

The present world average of (9.8 ± 1.4) % is in good agreement with the theoretical expectation.

$(\tau \to \nu A_1)$ decay

This second candidate for an axial vector piece in the hadronic current can only be calculated if one introduces further assumptions about the relative size of the axial and vector current (Weinberg sum rules). With $B_e = 16.8$ %, $M_\tau = 1.8$ GeV and $M_{A_1} = 1.07$ GeV we get

$BR(\tau \to \nu A_1) = 8.1$ %.

The PLUTO collaboration has searched[24] for events from the reaction

$e^+ e^- \to e^\pm (\text{or } \mu^\pm) + \pi^\mp \pi^+ \pi^-$

in the energy range from 4 to 5 GeV. They found 40 events of this type including 13 background events (mainly from hadron misidentification).

The $\pi^+\pi^-$ mass distribution shows a strong ρ peak, indicating that the whole signal is due to the decay $\tau \to \nu\rho^0\pi$. Quantitatively the limit for uncorrelated 3π decay is

$$\frac{\Gamma(\tau \to \nu\, 3\pi,\ \text{no } \rho)}{\Gamma(\tau \to \nu\, 3\pi)} \leq 0.32 \quad (95\ \%\ \text{C.L.}).$$

Assuming $I = 1$ for the $\rho\pi$ system one can determine a branching ratio of

$BR(\tau \to \nu\rho\pi) = (10.8 \pm 2.6 \pm 2.2)$ % PLUTO[24].

The existence of a $\rho\pi$ final state with negative G-parity in itself proves that an axial piece is present in the hadronic weak current in τ decays, provided only first class currents are present (by definition of first class currents[25]). To get a statement independent of the latter assumption, the spin parity of the $\rho\pi$ system was studied. The density distribution in a 3-dimensional Dalitz plot of the masses of the two $\pi^+\pi^-$ combinations and the $\rho\pi$ system was investigated. Only the $J^P = 1^+$ s-wave and the $J^P = 2^-$ p-wave gave an acceptable description of the data. Fig. 3a shows the mass distribution of the 3π system together with the expectation from a Monte Carlo calculation for different partial waves. The p and d waves give a very bad account of the data. Only the

$J^P = 1^+$ s-wave

is acceptable. This proves again the existence of an axial part in the hadronic current. In particular, there are no indications for a 1^- s-wave from second class axial currents.

The 3π mass distribution is much better described assuming a resonance of $0.7 \leq M \leq 1.2$ GeV and $0.4 \leq \Gamma \leq 0.5$ GeV in the 1^+ s-wave (fig. 3b). This indicates that the observed decay may indeed be due to

$\tau \to \nu A_1 \to \nu\, \rho\, \pi.$

The evidence is not compelling, however.

The SLAC-LBL group has studied[26] the reaction

$e^+ e^- \to \mu^\pm + \pi^\mp \pi^+ \pi^- + \geq 0$ photons.

They found a branching ratio of $BR(\tau \to \nu + 3\pi + n\,\pi^0) = (16 \pm 6)$ %. From a comparison of $0\,\gamma$ and $1, 2\,\gamma$ data the purely charged decay mode can be estimated

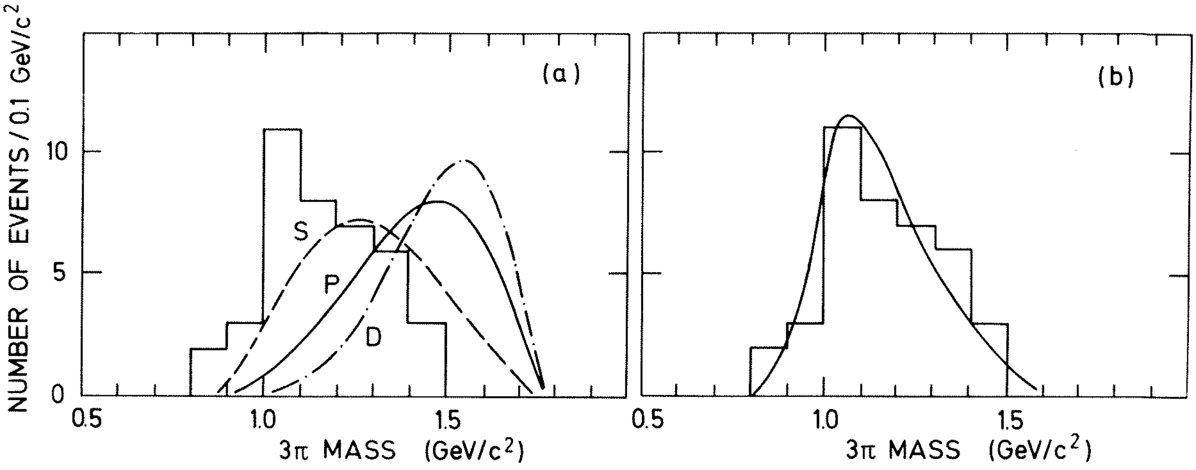

Fig. 3 PLUTO: $\rho\pi$ decay of the τ. Data corrected for background and acceptance.

a) Mass distribution of the 3π system in the ρ band ($0.68 < M_{\pi^+\pi^-} < 0.86$ GeV). The curves represent phase space calculations for different partial waves of the $\rho\pi$ system.

b) The same mass distribution with a fit of a resonant s-wave with $M_{A_1} = 1.0$ GeV and $\Gamma_{A_1} = 475$ MeV.

$$BR(\tau \to \nu + 3\pi) = (7 \pm 5)\ \% \qquad \text{SLAC-LBL}^{26)}$$

in good agreement with the PLUTO result. An acceptable description of the 3π mass distribution is again obtained from a fit assuming ($\tau \to \nu\ A_1$) decay with $M_{A_1} = 1.1$ GeV and a width $\Gamma_{A_1} = 200$ MeV.

3. Strangeness

Since the τ mass is below the charm threshold, decays involving strange particles should be suppressed by $tg^2\theta_c \simeq 5\ \%$. The DASP group measured[4] the ratio of kaon to pion production in two-prong events with one electron, which are dominated by τ production. Their result

$$\sigma(e^+e^- \to e + K)/\sigma(e^+e^- \to e + \pi) = (7 \pm 6)\ \% \qquad \text{DASP}^{4)}$$

is in accordance with theory.

4. Hadron continuum

The remaining part of the semihadronic decay modes,

$\tau \to \nu$ + hadron continuum,

can be calculated from the quark model. Using CVC, the quark model with colour amd assuming that the vector part is equal to the axial part one obtains[11,14] $BR(\tau \to \nu + \text{continuum}) = 21.8\ \%$. Only a small fraction of the hadronic final states is expected to contain a single charged particle[27]. Therefore, a rough test of this number can be obtained from a comparison with experimental results on multiprong final states:

$$BR(\tau \to \nu + \geq 3 \text{ prongs}) = (30 \pm 10)\ \% \qquad \text{PLUTO}^{3)}$$
$$= (35 \pm 11)\ \% \qquad \text{DASP}^{4)}$$
$$= (32 \pm 4)\ \% \qquad \text{DELCO}^{9,28)}$$

The constrained fit described in section IV yields

$BR(\tau \to \nu + \geq 3 \text{ prongs}) = (30.6 \pm 3.0)\ \%$ without (2) [13].

The experimental results agree quite well with the theoretical prediction since half the A_1 branching ratio ($A_1 \to \rho^0 \pi^+$) has to be added to the continuum value.

VI. 'FORBIDDEN' DECAY MODES

Several decays, which are not allowed by the standard model, have been searched for. None of them has been detected. At present the best limits are (all decays without neutrinos):

$BR(\tau \to 3$ charged particles)	$< 1.0\ \%$	(95 % C.L.)	PLUTO[14]
$BR(\tau \to 3$ charged leptons)	$< 0.6\ \%$	(90 % C.L.)	SLAC-LBL[12]
$BR(\tau \to e\gamma)$	$< 2.6\ \%$	(90 % C.L.)	SLAC-LBL[12]
$BR(\tau \to \mu\gamma)$	$< 0.35\ \%$	(90 % C.L.)	MARK II[10]
$BR(\tau \to \gamma)$	$< 0.8\ \%$	(90 % C.L.)	MARK II[10]

VII. τ NEUTRINO

Decay spectrum and properties of 'ν_τ'

The form of the leptonic decay spectrum can be calculated in the standard model. Any deviations from the assumption of a massless lefthanded neutrino will lead to a softening of the spectrum[29].

The shape of the muon spectrum in the early SLAC-LBL and PLUTO results favoured V-A coupling of the τ and set a limit of less than about half a GeV on the neutrino mass. However, conclusive data became available only recently from the DELCO group[30]. Fig. 4 shows their inclusive electron spectrum in the energy range $3.57 \leq E_{cm} \leq 7.4$ GeV excluding the $\psi''(3770)$. The expectations for V±A are indicated in the figure. The shape of the spectrum can be characterized by the Michel parameter ρ which is $\rho = 0.75$ for V-A, $\rho = 0$ for V+A and $\rho = 0.375$ for V or A. The experiment yields

$\rho = 0.72 \pm 0.15$ DELCO[30]

(including a systematic error of 0.11). This value is in good agreement with V-A, excludes V+A and disfavours V or A by 2.3 standard deviations.

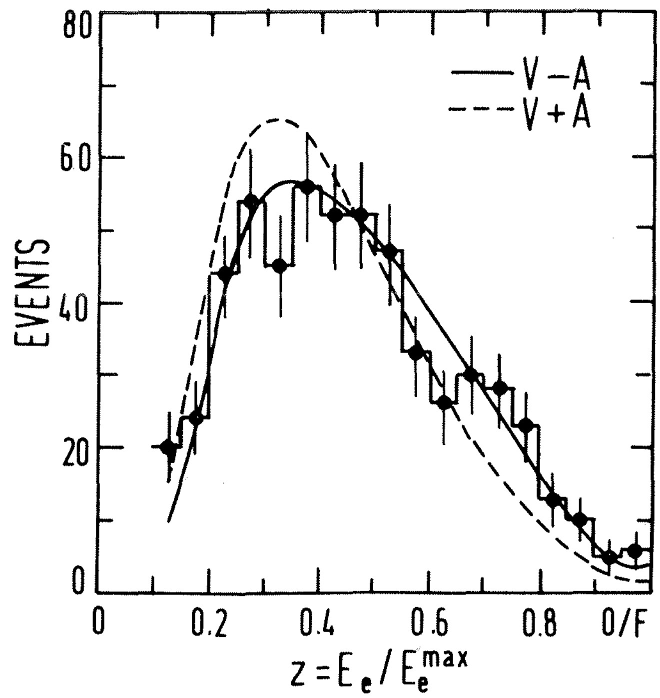

Fig. 4 DELCO: electron momentum distribution for two-prong events. Data are compared with the prediction for V-A (solid curve) and V+A (dashed curve) coupling of the τ.

If one assumes V-A interaction, the shape of the spectrum allows to set a limit on the neutrino mass. A finite mass corresponds to an effective decrease of ρ. The DELCO data yield an upper limit of 250 MeV (95 % C.L.).

Lifetime and nature of 'ν_τ'

So far all experimental findings are consistent with the τ being coupled to a massless lefthanded neutrino 'ν_τ'. Let us finally investigate, whether this could be one of the old neutrinos.

The relevant experimental information still needed is the coupling strength of the τ-'ν_τ' vertex. In the standard model a full strength would yield a lifetime

$$\tau_\tau = B_e \left(\frac{M_\mu}{M_\tau}\right)^5 \tau_\mu = 2.8 \times 10^{-13} \text{sec.}$$

Upper limits of the τ lifetime are available from the experiments PLUTO[31], SLAC-LBL[12] and DELCO[30]. From the best value given by the DELCO group[30]

$$\tau_\tau < 2.3 \times 10^{-12} \text{ sec (95 \% C.L.)} \qquad \text{DELCO}^{30)}$$

one can deduce that the coupling is at least 12 % of the full strength.

On the other hand we know from the absence of τ production in neutrino beams that the coupling to the τ is limited to less than 2.5 %[32]. Therefore, the 'ν_τ' cannot be identical with ν_μ or $\bar{\nu}_\mu$.

The possibilities of 'ν_τ' being either $\bar{\nu}_e$ (or $\bar{\nu}_\mu$) can also be excluded experimentally for massless neutrinos with V±A coupling. There would be a statistical factor of 2 in either B_e or B_μ, due to two identical neutrinos in the final state[33]. This is excluded by the data discussed in section IV.

Thus we are left with the one possibility that 'ν_τ' might be identical with ν_e. This case cannot be excluded on purely experimental grounds, since neutrino measurements are not yet available.

We can show, however, that simple mechanisms for such couplings proposed in SU(2)xU(1) gauge theories can be excluded. The simplest case would be that the τ appears in a singlet in addition to the (e ν_e) and (μ ν_μ) doublets[34]. Due to lepton number mixing this model leads to appreciable neutral current contributions:

$$BR(\tau \to {}^{e}_{\mu} + \text{hadrons}) \simeq 0.30$$

$$BR(\tau \to 3 \text{ charged leptons}) \simeq 0.05$$

This is excluded from the SLAC-LBL and PLUTO data (section VI).

Another possibility would be that the ν_τ is heavier than the τ[35]. The τ would then decay through lepton number mixing. The sum of coupling strengths to ν_e and ν_μ would have to be larger than 12 % of the full strength from the lifetime limit. With the μe universality[36] limit from π decay

$$\Gamma(\pi \to e\,\nu)/\Gamma(\pi \to \mu\,\nu) = \text{theory} \times (1.03 \pm 0.02)$$

and the upper limit on the ν_μ coupling of 2.5 % this is excluded.

VIII. SUMMARY

Table 3 gives a summary of the experimental knowledge about τ, which is now clearly established as a new heavy lepton with the mass $M_\tau = 1.782 ^{+.003}_{-.004}$ GeV. All properties of this new particle are as expected for a sequential left-handed lepton with conventional weak coupling to its own massless neutrino. It should be noted, however, that the orthoelectron hypothesis (the neutrino being of the ν_e type) as well as pure V or pure A coupling cannot firmly be excluded.

Table 3

Summary of τ parameters. World averages or best values are given.

Parameter	Units	Prediction	Exp. Value	Experiments
Mass	GeV	-	$1.782 ^{+.003}_{-.004}$	PLUTO, SLAC-LBL, DASP DESY-Heidelberg, DELCO
Neutrino mass	MeV	0	<250 (95 % C.L.)	SLAC-LBL, PLUTO, DELCO
Spin		1/2	1/2	PLUTO, DASP, DELCO, DESY-HEIDELBERG
Lifetime	10^{-13} s	2.8	<23 (95 % C.L.)	PLUTO, SLAC-LBL, DELCO
Michel parameter		0.75⁺⁺	0.72 ±.15	DELCO
Leptonic branching ratios				
$B_\mu/.973 = B_e$	%	16.8	17.1 ±1.0 17.5 ±1.2⁺	SLAC-LBL, PLUTO, Lead-Glass-Wall Ironball, MPP, DASP, DELCO
B_μ/B_e		.973	.99 ± .20 1.13 ± .16⁺	SLAC-LBL, PLUTO, DASP
Semihadronic BR				
$\tau^- \to \nu_\tau \pi^-$	%	9.5	9.8 ±1.4	PLUTO, SLAC-LBL, DELCO, MARK II
$\tau^- \to \nu_\tau \rho^-$	%	25.3	21.5 ±3.4	DASP, MARK II
$\tau^- \to \nu_\tau A_1^-$	%	8.1	10.8 ±3.4	PLUTO, SLAC-LBL
$\tau^- \to \nu_\tau + \geq 3$ prongs	%	~ 26	32 ±4 30.6 ±3.0⁺	PLUTO, DASP, DELCO
$\tau^- \to K^- \ldots / \tau^- \to \pi^- \ldots$		.05	.07 ± .06	DASP

\+ From ref. 13.
\++ V-A prediction. $\rho(V+A) = 0$ is excluded, $\rho(V \text{ or } A) = 0.375$ disfavoured by the data.

Till now the new lepton τ has remained a domain of e^+e^- physics. Within three years, most of its properties have been established. It was the particle that destroyed the four lepton - four quark symmetry (which had just been established) and gave a new impetus to the old puzzle of μ-e universality. Today it is the corner stone of a third generation of quarks and leptons.

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