ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Milano

INFN/AE-96/32
9 Ottobre 1996

W. Bonivento:

MEASUREMENT OF SPIN EFFECTS IN $Z^0 \to \tau^+\tau^-$ DECAYS AS A TEST OF THE STANDARD MODEL

PACS: 13.35

SIS–Pubblicazioni
dei Laboratori Nazionali di Frascati

INFN – Istituto Nazionale di Fisica Nucelare
Sezione di Milano

INFN/AE–96/32
9 Ottobre 1996

MEASUREMENT OF SPIN EFFECTS IN $Z^0 \rightarrow \tau^+\tau^-$ DECAYS AS A TEST OF THE STANDARD MODEL[1]

W. Bonivento
INFN–Sezione di Milano, Dipartimento di Fisica dell' Università di Milano,
Via Celoria 16, I–20133 Milano, Italy

ABSTRACT

Preliminary results on longitudinal τ polarization with data collected by the DELPHI Collaboration up to 1994, with both exclusive and hadronic inclusive one-prong decay selections, are discussed.
The first evidence of transverse spin correlation, from the acoplanarity distribution of the τ decay products, is also discussed.

[1]Talk at International Symposium on High Energy Spin Physics, **SPIN 96**, Amsterdam, Sept. 10-14, 1996

At LEP1 energies, the transition probability for fermion-antifermion production in the Standard Model(SM) can be written [1], at tree level, as:

$$\sum |M(s_1,s_2)|^2 = \frac{1}{4}|P(q^2)|^2(A + B_{1\mu}s_1^\mu + B_{2\mu}s_2^\mu + C_{\mu\nu}s_1^\mu s_2^\nu), \tag{1}$$

being $P(q^2)$ the Z^o propagator. The covariant spin vector of the fermion $s_i^\mu, i = 1,2$ can be decomposed as $s_i^\mu = s_i^L l_i^\mu + s_i^T t_i^\mu + s_i^N n_i^\mu$ into its longitudinal, transverse (within the collision plane) and normal (to the collision plane) components.
At leading order in m_f the terms linear in the spin in eq. 1 give rise to a longitudinal lepton polarisation and to a forward-backward polarization asymmetry with strength:

$$P_f = -\mathcal{A}_f = -2\frac{v_f a_f^*}{|a_f|^2 + |v_f|^2} \qquad A_{FB}^{pol} = -\frac{3}{4}\mathcal{A}_e = -\frac{3}{2}\frac{v_e a_e^*}{|a_e|^2 + |v_e|^2}; \tag{2}$$

where a_i, v_i, $i = f, e$ are the effective electroweak couplings of the SM.
From measurements of other observables, the SM prediction is $\mathcal{A}_f$=$\mathcal{A}_e$=0.144±0.003. [2]
Other terms related to transverse spin components are suppressed by m_f/M_Z factors.
The quadratic term in eq. 1 gives rise to the spin correlations. The longitudinal ones are trivial since they are given by helicity conservation; the prediction for the transverse-transverse (TT) one in the SM is $C_{TT} = (|a_f|^2 - |v_f|^2)(|a_f|^2 + |v_f|^2) \sim 1$, while the transverse-normal (TN) one is foreseen to be very close to zero.
In the leptonic sector a unique possibility to measure these observables is provided by the Z^o decay to τ pairs, since the subsequent parity violating decay of the τ acts as spin analyser. The analysing power is maximal, -1, for the decays to spin-0 mesons (π and K); the presence of two possible helicity states in the decay to spin-1 mesons reduces the analysing power (AP) to -0.67 for the $\rho(K^*)$ and to -0.15 for the a_1 (up to 10^{-3}, depending on its mass). For the decay to a spin-1/2 lepton (e, μ) the AP is +0.25, namely it has opposite sign.
The τ polarisation is then extracted from a fit of the momentum spectrum in the lab frame of the τ decay products to spectra obtained with the KORALZ [3] Monte Carlo for $P_\tau = +1$ and $P_\tau = -1$. In the case of spin-1 hadron decays, some sensitivity is recovered studying the $\rho \to 2\pi$ and $a_1 \to 3\pi$ decays [4]. Table 1 shows P_T results with 1993-94 DELPHI data, for the different decay selections. The values for $\mathcal{A}_f$ and $\mathcal{A}_e$ are eventually obtained from a fit to a theoretical expression of the τ polarisation as a function of the τ^- polar angle, as shown in fig. 1 for the full 1991-94 data sample.
The TT spin correlation gives rise to an asymmetry in the acoplanarity (ψ) distribution of the decay products of the two taus in the Z^o decay, the size of the effect depending on the product of the AP of the two decays. The largest effect is expected in the case where both taus decay to a $\pi(K)$ or to a $\rho(K^*)$ and an effect of opposite sign is expected when one of the taus decays to a lepton. Two event selections aiming at a very low external background were therefore done, named *hadron-hadron* (h-h),

selection	P_τ
$\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau$	$0.179 \pm 0.052 \pm 0.067$
$\tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau$	$0.097 \pm 0.038 \pm 0.022$
$\tau^- \rightarrow \pi^- \nu_\tau$	$0.158 \pm 0.033 \pm 0.050$
$\tau^- \rightarrow \rho^- \nu_\tau$	$0.199 \pm 0.046 \pm 0.039$
$\tau^- \rightarrow {a_1}^- \nu_\tau$	$0.103 \pm 0.050 \pm 0.038$
inclusive	$0.130 \pm 0.011 \pm 0.009$
neural net	$0.134 \pm 0.014 \pm 0.014$

TABLE 1: *P_τ measurements with 93-94 data with different decay selections*

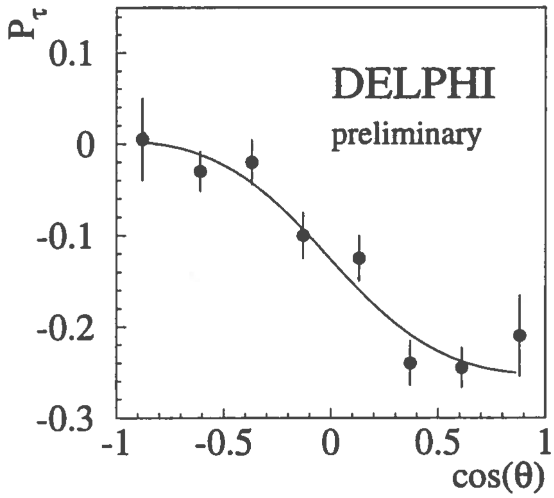

FIG. 1: *P_τ vs cosθ dependence. Only statistical errors are shown. The fit gives, after correcting for radiative effects, $\mathcal{A}_\tau = 0.138 \pm 0.009 \pm 0.008$ and $\mathcal{A}_\tau = 0.140 \pm 0.013 \pm 0.003$*

with an efficiency of $\sim$ 29% and an internal background of $\sim$ 30%, and *hadron-lepton* (h-l), with an efficiency of $\sim$ 20% and an internal background of $\sim$ 18%, both with an external background of few events.
The effect was simulated with the KORALB (5) Monte Carlo, with a parametrisation of detector effects taken from a sample of events generated with KORALZ with full detector simulation.
The fits to the acoplanarity distributions of KORALB events, KORALZ events and real data to the curve $f(\psi) = A \cdot (1 + B \cdot cos\psi)$ are reported in table 2. It can be seen that in the h-h sample, also displayed in figure , the data gave a fitted value for the B parameter which is more than 3.5 standard deviations from zero and consistent with the KORALB expectation: on the other hand the KORALZ data, which don't have

selection	sample	B
h-h	KORALB	$+0.104 \pm 0.019$
h-l	KORALB	-0.068 ± 0.018
h-h	KORALZ	-0.010 ± 0.017
h-l	KORALZ	-0.009 ± 0.016
h-h	data	$+0.136 \pm 0.036$
h-l	data	-0.069 ± 0.034

TABLE 2: *Measurements of the acoplanarity asymmetry parameter for simulated and real data*

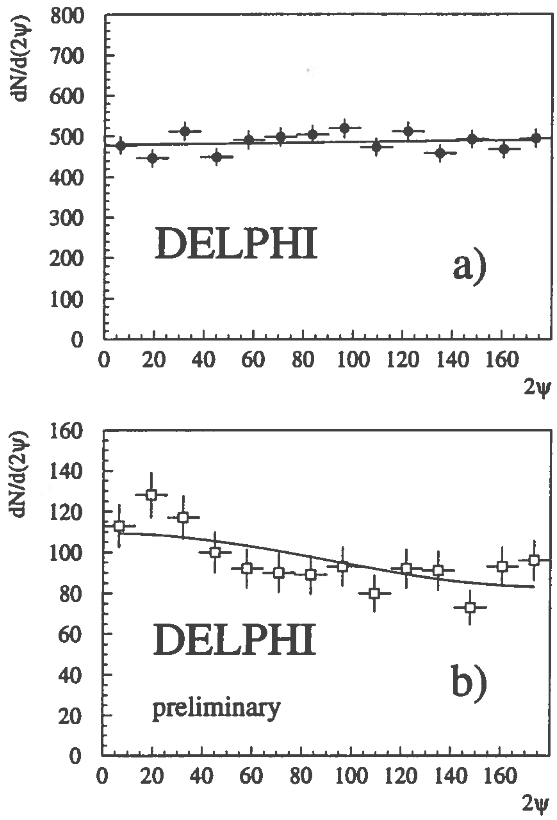

FIG. 2: *Acoplanarity distribution for selected events in the hadron-hadron topology for DELPHI simulated (with KORALZ, which doesn't include the TT spin correlation effect) (a) and real data (b). The curves are the results of the 2-parameter fit described in the text*

the effect built in, gave a result consistent with zero.

For the h-l sample the fitted value of B was negative and more than two standard deviations from zero, and consistent with the KORALB expectation: the KORALZ data gave a result consistent with zero. For real data the inconsistency between the

result of the h-l and of the h-h sample is more than 4 standard deviations.
A preliminary study of systematic effects shows that the uncertainty on the fitted B values is of the order ± 0.015 for both h-h and h-l selection.
To measure the contribution of the TN spin correlation, the acoplanarity distribution was fitted with an additional term $C * sin(\psi)$, as suggested by theory; it was found for the h-h selection $C = 0.002 \pm 0.030$, namely consistent with zero.
In conclusion, for both τ polarisation and transverse spin correlations good agreement with the SM expectations was found within errors.

REFERENCES

(1) J.Bernabeu, N.Rius and A.Pich, *Phys.Lett.B* **257** (1991)219.

(2) R.M.Barnett et al., Phys.Rev.D **54** (1996)1.

(3) S.Jadach et al., *Comp.Phys.Com.* **36** (1985)191.

(4) M.Davier et al., *Phys.Lett.* **B306** (1993)411.

(5) S.Jadach et al., *Comp.Phys.Com.* **85** (1995)453.