L3 EXPERIMENT AT LEP (CERN)

L3 Collaboration

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STATUS OF THE L3 DETECTOR

During 1990 and 1991 the L3 detector has recorded a total luminosity of about 20 pb^{-1}. This report presents the results of the analysis of the 1990 data (total luminosity of 5.5 pb^{-1} corresponding to 115000 hadronic and 10000 leptonic Z^0 decays).

In parallel to the physical runs, the construction of the L3 end caps was continued. In addition to the existing end cap hadron calorimeters, the forward/backward electromagnetic calorimeters (EC) and the forward/backward tracking chambers (FTC) were installed in the beginning of 1991. The LNPI was responsible for the design and construction of the FTC including the readout electronics. The FTC is a set of 104 rectangular drift tubes, each tube containing four signal wires. The drift time and the charge division are measured at each signal wire thus providing two-coordinate information of the tracks. The FTC showed reliable performance during the physics runs in 1991.

ELECTROWEAK PARAMETERS AND TEST OF STANDARD MODEL

From the shape of the cross sections around the Z^0 peak, the following parameters have been determined: the mass M_Z, the total width Γ_Z, the hadronic and leptonic partial decay widths of the Z^0:

Parameters	Fit results	Standard Model
M_Z (*GeV*)	91.181 ± 0.010	
Γ_Z (*MeV*)	2501 ± 17	2490
Γ_{had} (*MeV*)	1742 ± 19	1738
Γ_e (*MeV*)	83.3 ± 1.1	83.8
Γ_μ (*MeV*)	84.5 ± 2.0	83.8
Γ_τ (*MeV*)	84.0 ± 2.7	83.6
Γ_l (*MeV*)	83.6 ± 0.8	83.7

The difference between the total decay width and the sum of all observed partial decay widths gives the invisible width

$$\Gamma_{inv} = 508 \pm 17\ MeV$$

from which the number of light neutrino families is determined:

$$N_\nu = 3.05 \pm 0.10.$$

From the measurements of the forward-backward asymmetry, the vector and axial-vector neutral current coupling constants of charged leptons to the Z^0 were obtained:

Parameters	Fit results	Standard Model
g_A	−0.500 ± 0.003	−0.501
g_V	$-0.046^{+0.015}_{-0.012}$	−0.035

Combined fit to the cross sections and to the forward-backward asymmetry within the Standard Model gave the following value for the top quark mass:

$$m_t = 193^{+52}_{-69} \pm 16(\text{Higgs})\ GeV.$$

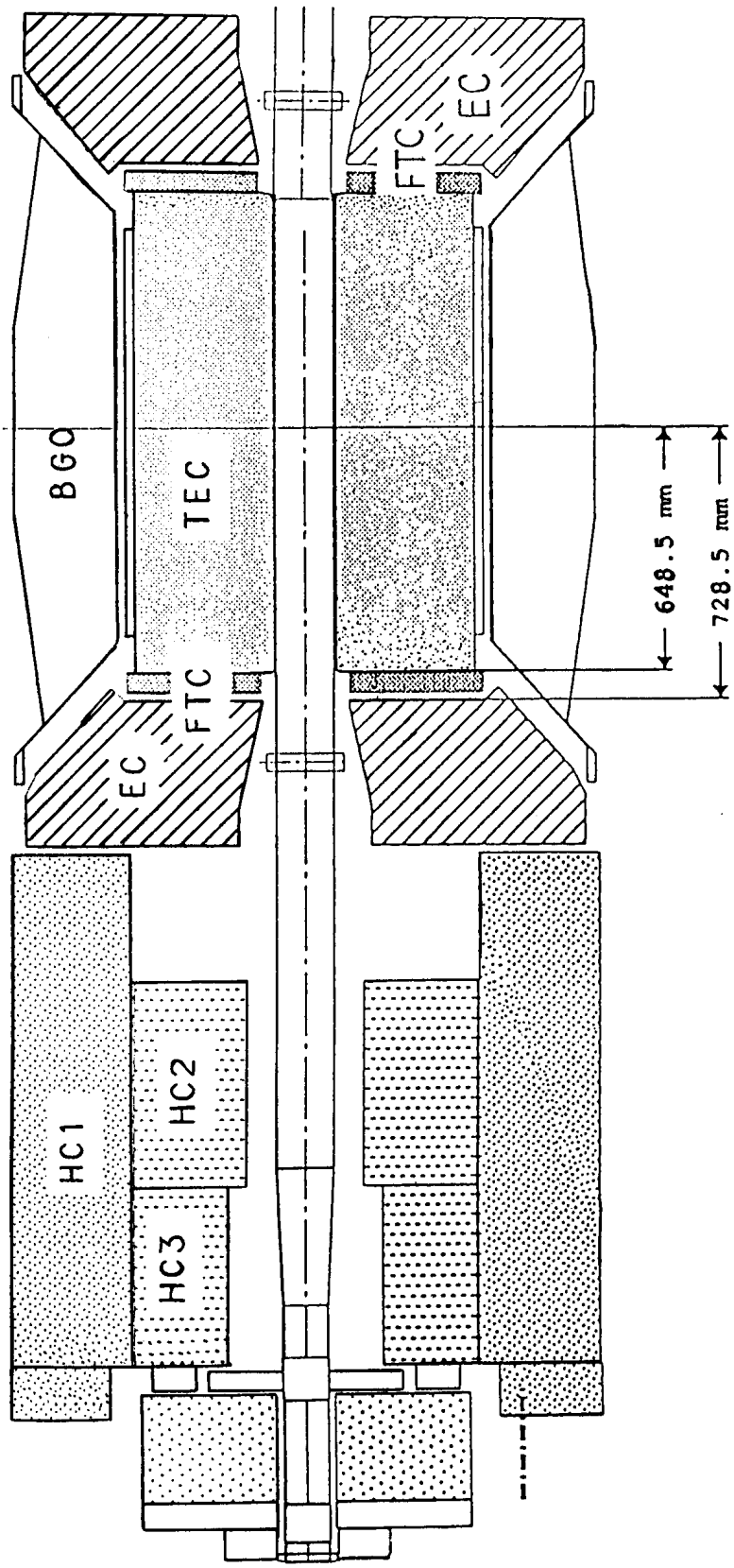
This gives also the weak mixing angle:

$$\sin^2 \Theta_W = 1 - (M_W/M_Z)^2 = 0.222 \pm 0.008$$

and the mass of W:

$$M_W = 80.44 \pm 0.45\ GeV.$$

The observation of the lepton flavour changing reactions could be a clear indication of physics beyond the Standard Model. The following upper limits (at the 95% confidence level) have been obtained from the L3 data:



Schematic view of L3 end caps.

$$Br(Z^0 \to \mu\tau) < 4.8 \cdot 10^{-5},$$
$$Br(Z^0 \to e\tau) < 3.4 \cdot 10^{-5},$$
$$Br(Z^0 \to e\mu) < 2.4 \cdot 10^{-5}.$$

SEARCH FOR NEW PARTICLES

A search for some new particles has been undertaken, and these particles were excluded in the following mass ranges.

Particles	Excluded mass range, *GeV* (95% C.L.)
Neutral Higgs h^0	$0 < M < 41.5$
Neutral Higgs H^0	$0 < M < 41.8$
Neutral Higgs A^0	$0 < M < 41.5$
Charged Higgs $H^{\pm}$	$0 < M < 36.5$
Stable Dirac neutrinos	$0 < M < 42.8$
Stable Majorana neutrinos	$0 < M < 34.8$
Unstable Dirac neutrinos	$0 < M < 46.4$
Unstable Majorana neutrinos	$0 < M < 41.5$
Heavy stable charged leptons	$0 < M < 44.6$
Unstable charged leptons	$10 < M < 44.3$
Scalar electrons $\tilde{e}$	$0 < M < 41$
Scalar muons $\tilde{\mu}$	$0 < M < 41$
Winos $\tilde{W}$	$0 < M < 44$
Scalar leptoquarks	$0 < M < 41$
Excited electrons e^*	$0 < M < 45.0$
Excited muons μ^*	$0 < M < 45.3$
Excited taus τ^*	$0 < M < 45.5$
Excited neutrinos ν^*	$0 < M < 91$

No evidence was found for narrow high-mass resonances Y in the radiative decays $Z^0 \to \gamma Y$. In the mass range from 30 to 89 *GeV* the following upper limits were obtained:

$$\mathrm{Br}(Z^0 \to \gamma Y) \cdot \mathrm{Br}(Y \to e^+ e^-) < 2.8 \cdot 10^{-4},$$
$$\mathrm{Br}(Z^0 \to \gamma Y) \cdot \mathrm{Br}(Y \to \mu^+ \mu^-) < 2.3 \cdot 10^{-4},$$
$$\mathrm{Br}(Z^0 \to \gamma Y) \cdot \mathrm{Br}(Y \to \mathrm{hadrons}) < 4.7 \cdot 10^{-4}.$$

TEST OF QED

The cross sections of the reaction $e^+ e^- \to \gamma\gamma$ have been measured around the Z^0 mass. The results are in good agreement with QED predictions. For the QED cutoff parameters the limit values are found:

$$\Lambda_+ > 103\ GeV,$$
$$\Lambda_- > 118\ GeV.$$

Also the following upper limits were set for radiative decays of the Z^0:

$$\mathrm{Br}(Z^0 \to \gamma\gamma) < 2.9 \cdot 10^{-4},$$
$$\mathrm{Br}(Z^0 \to \pi^0 \gamma) < 2.9 \cdot 10^{-4},$$
$$\mathrm{Br}(Z^0 \to \eta\gamma) < 4.1 \cdot 10^{-4},$$
$$\mathrm{Br}(Z^0 \to \gamma\gamma\gamma) < 1.2 \cdot 10^{-4}.$$

DETERMINATION OF α_S AND TEST OF QCD

The Z^0 resonance proved to be an ideal source of well defined jets that can be used for various tests of QCD. In particular, the strong coupling constant α_S has been determined at the mass scale $\sqrt{Q^2} = M_Z$ by three different methods.

Jet multiplicity:

$$\alpha_S(Q^2 = M_Z^2) = 0.115 \pm 0.012.$$

Energy-energy correlation:

$$\alpha_S(Q^2 = M_Z^2) = 0.121 \pm 0.011.$$

Asymmetry in the energy-energy correlation:

$$\alpha_S(Q^2 = M_Z^2) = 0.115 \pm 0.008.$$

Also, α_S at $\sqrt{Q^2} = m_\tau$ was determined from the leptonic branching fractions of the τ-lepton:

$$\alpha_S(Q^2 = m_\tau^2) = 0.34^{+0.07}_{-0.09}.$$

This result confirms the running of α_S as predicted by QCD.

The ratio of α_S for bottom quark and light quarks has been measured at the Z^0 resonance:

$$\alpha_S(b)/\alpha_S(\mathrm{udsc}) = 1.00 \pm 0.05(\mathrm{stat}) \pm 0.06(\mathrm{syst}).$$

The result is consistent with the flavour independence predicted by QCD.

B-PHYSICS

The decay properties of $Z^0 \to b\bar{b}$ have been studied using hadronic events containing muons and electrons, and the following quantities were determined.

The b-semileptonic branching ratio:

$$\text{Br}\,(b \to l + X) = 0.113 \pm 0.010(\text{stat}) \pm 0.006(\text{syst})\,.$$

The partial decay width of the Z^0 into $b\bar{b}$:

$$\Gamma_{b\bar{b}} = 385 \pm 7(\text{stat}) \pm 11(\text{syst}) \pm 19(\text{exp})\ MeV.$$

The average fractional energy of the bottom hadrons:

$$<X_E> = 0.686 \pm 0.006(\text{stat}) \pm 0.016(\text{syst}).$$

The average lifetime of the B-hadrons:

$$\tau_B = 1.32 \pm 0.08(\text{stat}) \pm 0.09(\text{syst})\ ps.$$

The $B^0 - \overline{B}^0$ mixing parameter:

$$\chi_B = 0.178^{+0.049}_{-0.040}.$$

The forward-backward charge asymmetry:

$$A_{b\bar{b}} = 0.130^{+0.044}_{-0.042}.$$

Combining the measurements of τ_B and $Br(b \to l + X)$, the CKM matrix element $|V_{cb}|$ was determined:

$$|V_{cb}| = 0.046 \pm 0.002(\text{exp}) \pm 0.004(\text{theory}).$$

The measurement of $A_{b\bar{b}}$ allowed to determine the effective weak mixing angle:

$$\sin^2 \Theta_W = 0.226 \pm 0.008.$$

PROPERTIES OF TAU LEPTONS

The following branching ratios have been measured in this experiment:

$$\text{Br}\,(\tau^{\pm} \to 1 \text{ charged particle} + \text{neutrals}) = 0.856 \pm 0.007,$$

$$\text{Br}\,(\tau^{\pm} \to 3 \text{ charged particles} + \text{neutrals}) = 0.144 \pm 0.007,$$

$$\text{Br}\,(\tau^{\pm} \to 5 \text{ charged particles} + \text{neutrals}) < 0.0034,$$

$$\text{Br}\,(\tau \to \mu\nu_\mu\nu_\tau) = 0.175 \pm 0.009,$$

$$\text{Br}\,(\tau \to e\nu_e\nu_\tau) = 0.177 \pm 0.009.$$

The measured ratio

$$\Gamma(\tau \to \mu\nu_\mu\nu_\tau)/\Gamma(\tau \to e\nu_e\nu_\tau) = 0.986 \pm 0.063$$

is in agreement with the expectation of 0.973 from the $e-\mu-\tau$ universality in the weak charged current.

The τ lifetime was determined both from three-prong decays and from one-prong decays, the combined result being

$$\tau_\tau = (0.309 \pm 0\ 037) \cdot 10^{-12}\ s.$$

From the measured values of τ_τ and $\text{Br}(\tau \to e\nu_e\nu_\tau)$, the ratio of the coupling constants has been obtained

$$G_F^\mu / G_F^\tau = 1.04 \pm 0.07$$

in consistency with the $e-\mu-\tau$ universality.

Reference

L3 Preprint #004 to #34. 1989 - 1991.