FIRST PHYSICS RUNS OF L3 DETECTOR AT LEP

L3 collaboration

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The construction of the electron-positron collider LEP, at CERN, was successfully completed in July 1989, and soon LEP demonstrated performances nearly matching the expectations, in terms of luminosity ($L \approx 5 \cdot 10^{30}/sm^2 \cdot s$ by the end of 1989), in terms of reliability (10% down time), and in terms of background conditions in the experimental area (negligible). The construction of the L3 detector (phase I) was also completed by July 1989 which made it possible to start physics runs as soon as colliding beams became available in the experimental area, parallel with the tuning and calibration of different parts of the detector.

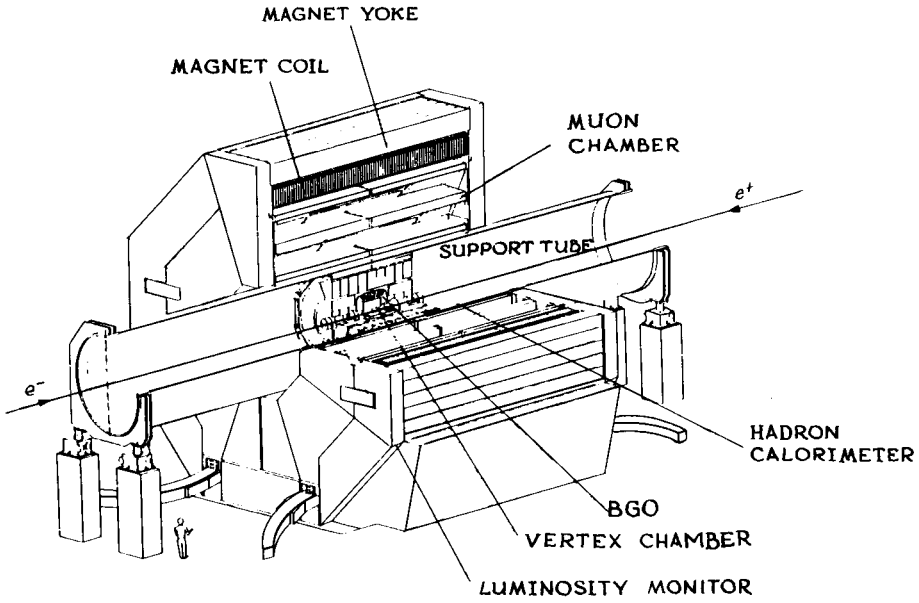

Fig. 1. Schematic view of L3 detector

The L3 detector [1] shown in fig 1 is a 4π detector with a central vertex chamber, a BGO electromagnetic calorimeter, an uranium hadron calorimeter, and a high accuracy muon chamber system. All these detectors are installed in a 12 m diameter magnet which provides a uniform of 0.5 Tesla along the beam direction. The luminosity is measured by 8 radial layers of BGO cristals at small angles on each side of the interaction point. By the end of 1989, all parts of the L3 detector were operational, except the central vertex chamber which was still under calibration.

DETERMINATION OF PROPERTIES OF Z^0 BOSON [2]

This publication was based on 2538 hadron events taken at 7 energies centered at the Z^0 mass. The measured cross section for $e^+e^- \rightarrow$hadrons is shown in fig. 2 as a function of $\sqrt{s}$. The curve shows a fit to the Cahn formula in which M_{Z^0} and $\Gamma_{invisible}$ were left free. The normalization was constrained within a 6% systematic error. The widths Γ_{ee}, $\Gamma_{\mu\mu}$, $\Gamma_{\tau\tau}$ and $\Gamma_{hadrons}$ were taken from the Standard Model. The following results were obtained from this analysis:

$$M_{Z^0} = 91.132 \pm 0.057 \text{ GeV},$$

$$\Gamma_{Z^0} = 2.588 \pm 0.137 \text{ GeV},$$

$$\Gamma_{invisible} = 0.567 \pm 0.080 \text{ GeV}.$$

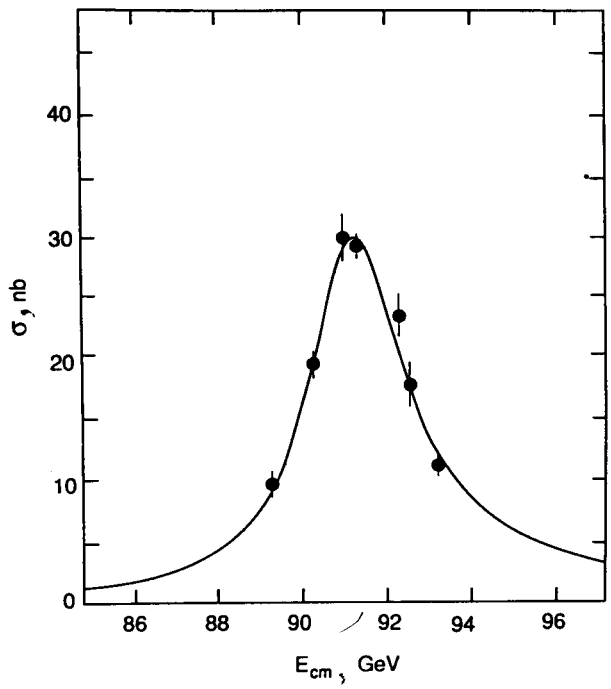

Fig. 2. Measured cross section for $e^+e^- \to$ hadrons as function of $\sqrt{s}$

which gives for the number of neutrinos:

$$N_\nu = 3.42 \pm 0.48.$$

Independently, 95 electron pairs and 97 muon pairs have been detected close to the Z^0 mass region which gives:

$$\Gamma_{\mu\mu} = 92 \pm 6 \text{ MeV},$$

$$\Gamma_{ee} = 88 \pm 9 \pm 7 \text{ MeV}.$$

in agreement with the Standard Model predictions ($\Gamma_{\ell\ell} = 83.3$ MeV).

MASS LIMITS FOR SCALAR MUONS, SCALAR ELECTRONS, AND WINOS [3]

The scalar leptons can be produced in the following reactions:

$$e^+e^- \to Z^0 \to \tilde{\mu}^+\tilde{\mu}^- \to \mu^+\mu^-\tilde{\gamma}\tilde{\gamma},$$

$$e^+e^- \to Z^0 \to \tilde{e}^+\tilde{e}^- \to e^+e^-\tilde{\gamma}\tilde{\gamma}.$$

The signature of these reactions is an acoplanar muon or electron pair with a large missing P_T. The data were obtained during the first energy scans over the Z^0 peak at LEP. The total integral luminosity was 157 nb^{-1} corresponding to a total of 2538 hadronic elents. Fig. 3 shows the measured missing P_T spectra (dark histograms) for reactions $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to e^+e^-$ together with the Monte Carlo predictions (right scales) for the missing P_T spectra in dimuon and dielectron events from reactions $e^+e^- \to \tilde{\mu}^+\tilde{\mu}^- \to \mu^+\mu^-\tilde{\gamma}\tilde{\gamma}$ or $e^+e^- \to \tilde{e}^+\tilde{e}^- \to e^+e^-\tilde{\gamma}\tilde{\gamma}$. Using the iheoretical ratios $\sigma_{\tilde{\mu}\tilde{\mu}}/\sigma_{\mu\mu} = 0.036$ and $\sigma_{\tilde{e}\tilde{e}}/\sigma_{ee} = 0.039$ for normalizations ($M_{\tilde{\mu}} \cong M_{\tilde{e}} \cong 41$ GeV, $M_{\tilde{\gamma}} = 10$ GeV), one should expect $N_{\tilde{\mu}\tilde{\mu}} = 3.5$ and $N_{\tilde{e}\tilde{e}} = 3.7$ at $P_T > 6$ GeV. Since no acoplanar dimuon or dielectron events are observed at $P_T > 6$ GeV the following lower mass limits were set at the 95% confidence level:

$$M_{\tilde{\mu}} \geqslant 41 \text{ GeV},$$

$$M_{\tilde{e}} \geqslant 41 \text{ GeV}.$$

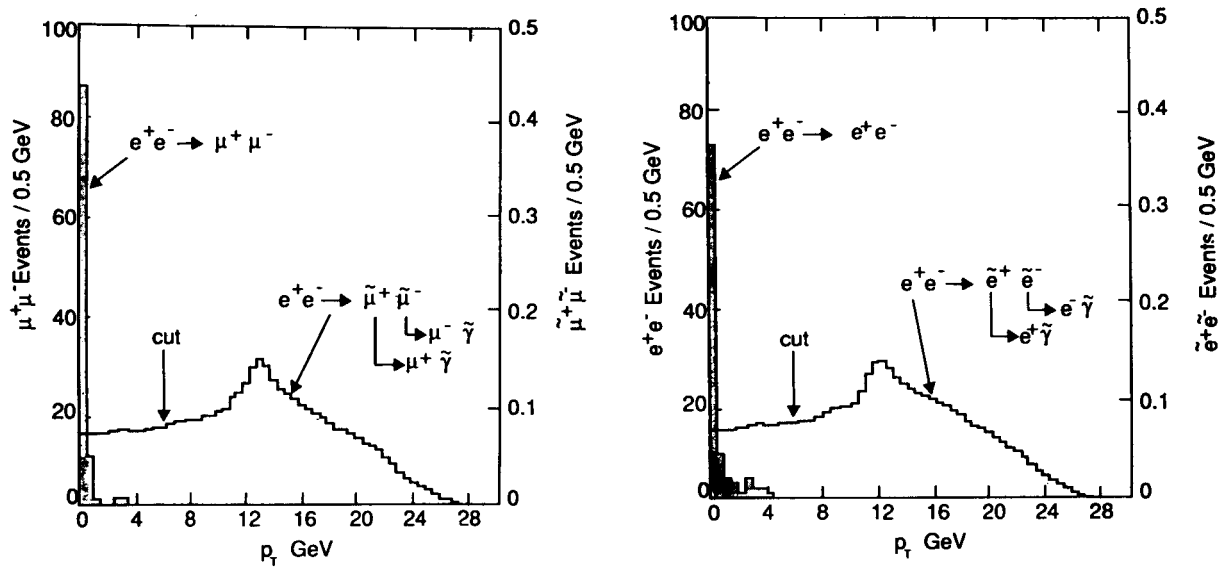

Fig. 3. Missing P_T spectra for reactions $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to e^+e^-$

This result is insensitive to the photino mass up to 20 GeV.

Another result from this analysis is the lower mass limit for Winos that can be pair-produced through the reaction

$$e^+e^- \to \tilde{W}^+\tilde{W}^-$$

and decay into ordinary leptons:

$$\tilde{W} \to e\tilde{\nu} \quad \text{or} \quad \tilde{W} \to e\hat{\nu}\tilde{\gamma}\,.$$

These are the only possible decay channels when the Wino mass is less than the masses of the scalar leptons and the scalar quarks. Therefore, the signature of the Wino pair production can be acoplanar $\mu\mu$, ee, or $e\mu$-events with high P_T values. The absense of such events sets the lower mass limit:

$$M_{\tilde{W}} \geqslant 44 \text{ GeV}\,.$$

MEASUREMENT OF g_A AND g_V, NEUTRAL CURRENT COUPLING CONSTANTS TO LEPTONS [4]

The cross section for $e^+e^- \to (Z^0, \gamma) \to l^+l^-$ with $l = \mu, \tau$ can be written as:

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4S}\{[1 + 2g_V^2\, Re(\varkappa) + (g_V^2 + g_A^2)^2\, |\varkappa|^2](1 + Cos^2\,\Theta) +$$

$$+ [2g_A^2\, Re(\varkappa) + 4g_V^2\, g_A^2\, |\varkappa|^2] \cdot 2 \cdot Cos\,\Theta\},$$

where g_A and g_V are neutral current coupling constants:

$$j_\mu = \bar{l}\,(g_V\gamma_\mu + g_A\gamma_\mu\gamma^5)\,l\,,$$

Θ is the polar angle of μ^- or τ^- with respect to the e^- direction, and $\varkappa$ is given by the formula

$$\varkappa = \frac{G_\mu M_{Z^0}^2}{2\sqrt{2}\cdot\pi\alpha} \cdot \frac{s}{(s - M_{Z^0}^2) + iM_{Z^0}\Gamma_{Z^0}}\,.$$

It follows from these expressions:

1. The rate $Z^0 \to l^+l^-$ is a measure of $g_A^2 + g_V^2$.
2. The forward-backward charge asymmetry of $Z^0 \to l^+l^-$ is a measure of the product $g_V^2 g_A^2$ if $\sqrt{s} = M_{Z0}$, and it is also sensitive to $g_A^2 \cdot Re\ (\varkappa)$ when $\sqrt{s} \neq M_{Z0}$.

In the L3 experiment the following quantities have been measured:

1. The partial width $\Gamma_{\mu\mu}$ was obtained on the bases of 97 $\mu^+\mu^-$ events:

$$\Gamma_{\mu\mu} = 92 \pm 5 \pm 3 \text{ MeV}.$$

2. The partial width $\Gamma_{\tau\tau}$ was determined by observation of 83 $e\mu$ events from the reaction $e^+e^- \to \tau^+\tau^- \to e^+\mu^-$ + neutrinos

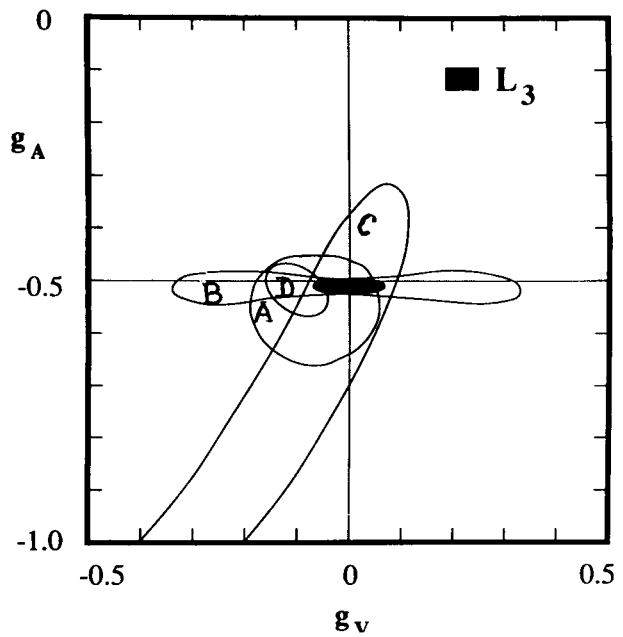

Fig. 4. Results obtained from neutrino experiments and from e^+e^- experiments expressed in 1σ limits on g_A and g_V

$$\Gamma_{\tau\tau} = 84 \pm 5 \pm 4 \text{ MeV}.$$

3. The forward-backward charge asymmetries were determined from the analysis of 241 $\mu^+\mu^-$ and 24 $\tau^+\tau^-$ events:

$$A_{FB}(\sqrt{s} = 90.00 \text{ GeV}) = (-40 \pm 19)\%,$$

$$A_{FB}(\sqrt{s} = 91.26 \text{ GeV}) = (-1 \pm 7)\%,$$

$$A_{FB}(\sqrt{s} = 92.94 \text{ GeV}) = (+23 \pm 19)\%.$$

Using all these results, the values of g_A and g_V have been determined:

$$|g_A| = 0.515 \pm 0.015,$$

$$g_V = 0.00 \pm 0.07.$$

Fig. 4 shows the $g_A - g_V$ — plane with constraints set by different experiments. Area A is the result of the CHARM collaboration, area B is the combined e^+e^- results from PETRA and PEP, area C is the $\tilde{\nu}_e$ result, and area D is the BNL result. The black area represents the L3 results.

REFERENCES

1. The construction of the L3 experiment. L3 Collaboration, submitted to NIM, 1989.
2. L3 Collaboration. L3 Preprint 001, CERN, October 11, 1989;
Phys. Lett. B, 1989, 231, №4, 509.
3. L3 Collaboration. L3 Preprint 002, CERN, October 15, 1989.
4. L3 Collaboration. L3 Preprint 003, CERN, November 24, 1989.