Determination of the Number of Light Neutrino Species

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Theoretical motivation

The Z boson is expected to decay with comparable probability into all species of fermions that are kinematically allowed.

The detection of additional neutrino species would put in evidence additional fermion families, even if the masses of their charged partners are inaccessible at presently available energies.

Signal and possible backgrounds

The signal of the experiment were showers on each side of LCAL, these showers were constructed from minimum energies (of 50MeV) deposited in the LCAL towers.

This signal had possible backgrounds, which were:

- Uncertainties in the simulation, calibration and positioning of the apparatus.
- Possible error due to neglecting higher order radiative effects, and the uncertainty in the photon vacuum polarization.
- Not knowing the optimum energy resolution.
- Beam-related background contamination from single arm, prescaled triggers, which was of the order 1% or smaller.
- Contamination by physics sources such as electron position annihilation, which was estimated to be less than $2x10^{-3}$.

Some of which where corrected and the others taken into account for statistical error.

Description and performance of the detector parts used for the analysis

We used mainly two different and independent event selections:

- The first one selected hadronic Z decays only, and was based on TPC tracks.
- The second one selected decays of the Z into hadrons as well as τ pairs, and was based on calorimetric energy.

Their performance was similar, resulting in a selection efficiency of 0.975 ± 0.006 and 0.974 ± 0.006 respectively.

Analysis

At the end combining all the measurements and subtracting background contamination we got a trigger efficiency of 0.997 ± 0.002 for our detectors.

Taking this into account, and given the number of Z events, of luminosity events, together with the cross-sections, detected by the two independent selection methods, two different fits were performed to the data:

- In the first fit, the basic parameters of the Z resonance, its mass M_z, width Γ_Z, and QED corrected peak cross-section $\sigma_f^0 = \frac{12\pi}{{M_z}^2} \frac{\Gamma_{ee}\Gamma_f}{{\Gamma_Z}^2}$ are extracted with little model dependance for given $N_v = 2, 3\ or\ 4$.

- In the second fit, the constrains from the Standard Model are applied to determine the relation of M_z and N_v.

Results

The first fit gives us that the mass of the Z boson is given by:

$$M_z = \left(91.174\ \pm 0.055_{exp} \pm 0.045_{LEP}\right) GeV$$

which agrees with the two previous best measurements, but with an uncertainty smaller by a factor of 2. For this fit, the value $N_v = 3$ is preferred.

Taking the partial widths from the Standard Model, the second, two parameter fit can be performed, leaving M_z and N_v as only free parameters, which allows us to compute our desired Number of Light Neutrino species:

$$N_v = 3.27 \pm 0.30$$

The hypothesis that the Number of Light Neutrino species is 4 is ruled out with a 98% confidence level (more than 2σ).