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Limits on Majorana neutrinos

Abstract

The limits published so far by ALEPH on extra neutrinos are valid only for Dirac neutrinos. From the measurement of the hadronic cross section, it is shown that a stable Majorana neutrino has to be heavier than 34.7 GeV at 95% C.L..

From a theoretical point of view, it is possible that neutrinos and antineutrinos are in fact the same particule (called a Majorana neutrino) instead of being two different particules (called Dirac neutrinos) [1]. Actually, in many models, it is natural for neutrinos to be Majorana particules.

However, it has been assumed so far in ALEPH publications that neutrinos are Dirac particules [2]. It would be interesting to extract limits in the case of Majorana neutrinos also. The constraint coming from the measurement of the hadronic cross section will be presented here.

Recall the decay width of the Z boson to a pair of Dirac neutrinos (formula 9 in [2]):

$$\frac{\Gamma}{\Gamma_{2e}} = \frac{\beta}{2}\left[\frac{1}{2}(3-\beta^2)v^2 + a^2\beta^2\right] \qquad (1)$$

where a,v are the axial and vector couplings and β is the velocity of the leptons.

$$\left(v = 2T_3 - 4Q\sin^2\theta_W \, , \; a = 2T_3 \right)$$

For a left – handed neutrino, it reads :

$$\frac{\Gamma_D}{\Gamma_{2e}} = \frac{\beta}{4}(3+\beta^2) \qquad (2)$$

For a Majorana neutrino, assuming the same lagrangian as for the Dirac neutrino, this formula becomes :

$$\frac{\Gamma_M}{\Gamma_{2e}} = \beta^3 \qquad (3)$$

One can understand the difference between formulae 2 and 3. First, Majorana neutrinos have no vector couplings (see [1] for details) hence one keeps only the second term in (1) and the width is proportional to β^3. In addition, the axial amplitude is twice the axial amplitude of the Dirac neutrino. Finally one has to divide by 2 because there are two identical fermions in the final state.

Notice that the difference between Dirac and Majorana disapears for small masses ($\beta = 1$).

Using formula 3 and following the method given in [2] section 6 (iv), one can compute the 95% confidence limit in the plane leptonic coupling versus mass (see Figure 1). It has been assumed that the Majorana neutrino decays as the Dirac neutrino, with twice more channels open (the Majorana neutrino decays to leptons and antileptons alike).

For a stable Majorana neutrino, the 95% confidence limit is 34.7 GeV instead of 42.7 GeV for the Dirac neutrino [2].

Because of the β^3 factor, the limit is worse in the case of a Majorana neutrino. One can therefore look for improvements in 1990, especially in the direct searches for a signal.

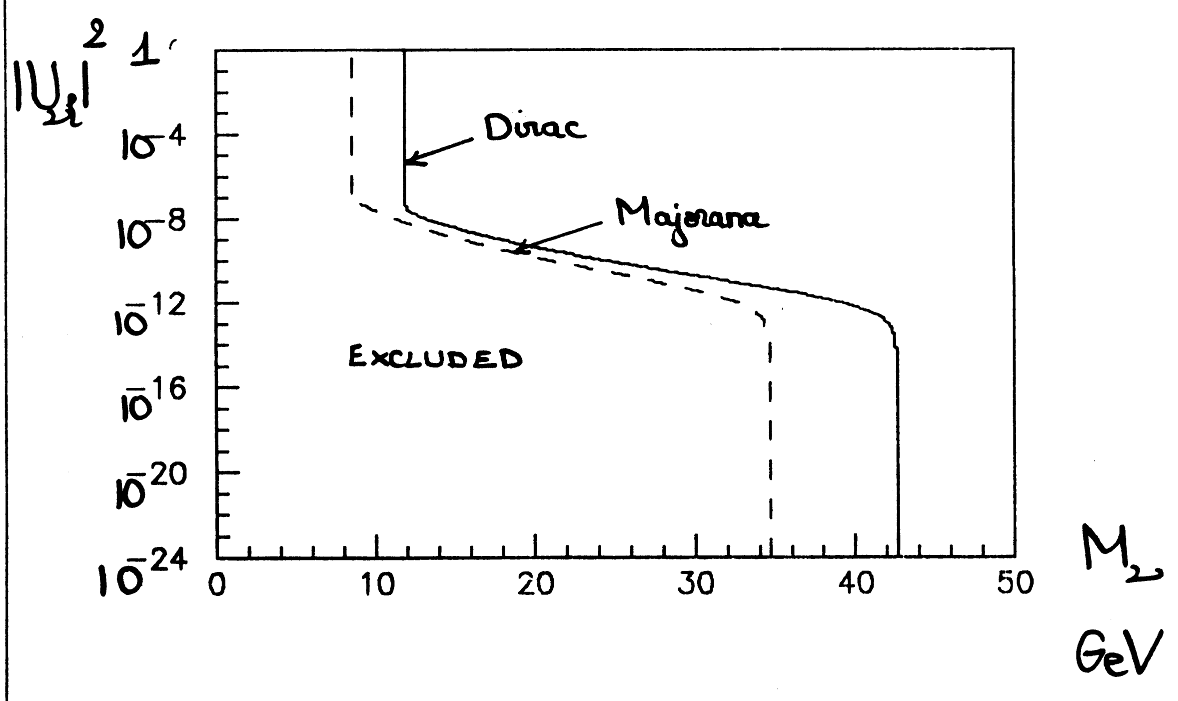

Figure 1: Constraints on neutral leptons from the measurement of the hadronic cross section.

References

1. For a pedagogical introduction see B.Kayser at al., The physics of massive neutrinos, World Scientific 1989.

2. A search for new quarks and leptons from Z^0 decay at LEP. ALEPH collaboration. Phys. Lett. B236(1990)511.