Scale of leptogenesis

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Received: 14 April 1998 / Revised version: 8 August 1998 / Published online: 11 February 1999

Abstract. We study the scale at which one can generate the lepton asymmetry of the universe which could then get converted to a baryon asymmetry during the electroweak phase transition. We consider the possibility that the Yukawa couplings could be arbitrarily small but sufficiently large to generate enough lepton asymmetry. This forbids the possibility of the (B − L) breaking scale to be less than 10 TeV.

1 Introduction

In most grand unified theories (GUTs) the baryon asymmetry of the universe is generated during the GUT phase transition [1–3]. In these models the generated asymmetry also implies an equal amount of lepton asymmetry and hence there is no net (B − L) asymmetry. On the other hand, if the electroweak phase transition is a second order phase transition, then any primordial (B + L) asymmetry generated during the GUT phase transition will be washed out [4].

This situation can be saved in models where (B − L) is broken at some intermediate scales. In this case a (B − L) asymmetry can be generated through higgs decay or heavy Majorana neutrino decay if there is appropriate CP violation. The out-of-equilibrium condition then imposes a lower bound on this symmetry breaking scale to be around 10^7 GeV [2]. This bound is dependent on the fact that the Yukawa couplings are larger than 10^-5. Although esthetically this number sounds reasonable, nothing tells us definitely that the Yukawa couplings cannot be smaller than this. For example, if the Yukawa couplings relating the left handed leptons to the first generation right handed heavy neutrinos are of the order of 10^{-7}, then the out-of-equilibrium condition can be satisfied for even a TeV scale for left-right symmetry breaking. But the same Yukawa couplings enter in the expression for the generated (B − L) asymmetry, which may then be very small.

In this article we study systematically the Boltzmann equations for the generation of the lepton asymmetry, and hence (B − L) asymmetry, to find the lowest possible left-right symmetry breaking scale which satisfies the out-of-equilibrium condition and which generates enough baryon asymmetry after the electroweak phase transition. This scale, which is the only one in our model, is the the scale of the (B − L) symmetry breaking, the scale of the breaking of the SU(2)_R symmetry breaking and is also the mass scale for the gauge bosons corresponding to these symmetries. This means that the left–right symmetric model of leptogenesis can be falsified experimentally if the right handed charged gauge bosons corresponding to the SU(2)_R symmetry are seen in the next generation experiments below the scale at which leptogenesis is possible. One would then have to look for some new scenario for generating a baryon asymmetry of the universe.

In the next section we briefly review the leptogenesis scenario, where one generates a lepton asymmetry when the right handed Majorana neutrinos decay. This then gets converted to a baryon asymmetry during the electroweak phase transition. Subsequently, we discuss the Boltzmann equations and the possible solutions for a low energy left-right symmetry breaking.

2 Model for leptogenesis

It was first proposed by Fukugita and Yanagida [5] that in extensions of the standard model, which include singlet heavy right handed neutrinos, it is possible to generate a lepton asymmetry at some intermediate scale (∼ 10^{10} GeV), which can then get converted to a baryon asymmetry during the electroweak phase transition. The out-of-equilibrium condition is satisfied with small Yukawa couplings. In this scenario the heavy right handed neutrinos decay to light left handed neutrinos in out-of-equilibrium. The amount of asymmetry thus generated depends on the amount of CP violation [5, 6].

In the following we shall consider a left-right symmetric extension [7] of the standard model, which incorpo-