BARYON NUMBER NON-CONSERVATION AT HIGH ENERGIES

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In 1976 't Hooft discovered [1] that in the standard electroweak theory both baryon and lepton numbers are in principle not conserved. However the probability of such events is rather low, given by the WKB factor $\exp(-\frac{4\pi}{\alpha}) \approx 10^{-169}$, where $\alpha = g^2/(4\pi)$ is the SU(2) weak coupling constant. Recently the interest in the baryon number violating processes (BNVP) was revived due to the observation [2—4] that an additional multiple emission of W, Z and H bosons at high energies increases drastically the above probability. The characheristic energy scale of the problem is given by the so-called sphaleron [5] mass,

$$E_0 = \frac{4\pi}{\alpha} m_W \approx 31\ TeV, \tag{1}$$

where m_W is the W boson mass.

It was shown from the dimensional analysis [6] that at high energies $\sqrt{s}$ the total cross section of the BNVP accompanied by the emission of any number of W, Z and H bosons in arbitrary kinematics is given (to the exponential accuracy) by the formula

$$\sigma_{tot} \propto \exp\left(\frac{4\pi}{\alpha} F(\varepsilon)\right) \tag{2}$$

where ε is the dimensionless energy, $\varepsilon = \sqrt{s}/E_0$, and $F(\varepsilon)$ is a function whose expansion at small ε goes in the powers of $\varepsilon^{2/3}$. Today three non-trivial terms of this expansion are known:

$$F(\varepsilon) = -1 + \frac{3^{4/3}}{2}\varepsilon^{4/3} - \frac{3}{2}\varepsilon^2 + \frac{1}{3^{1/3}}\varepsilon^{8/3}\log(\frac{c}{\varepsilon}) - \ldots \tag{3}$$

The zero term corresponds to the above WKB formula, the first term was computed in refs. [6—8] and corresponds to the classical emission of the W bosons, the second term (first quantum correction) was obtained independently in refs. [9—12], the third term which is a 2-loop quantum correction is the new result of ref. [13]. We have not determined the precise argument of the log though. Eqs. (2,3) show that the total cross sections of the BNVP are very rapidly rising with the collision energy. It is believed that once $F(\varepsilon)$ approaches zero the cross section becomes "strong", and the BNVP are then observable.

Apart from the "practical" value, our calculation has, we think, a wider theoretical significance since the function $F(\varepsilon)$ is intimately related [7,9,10] to an important theoretical concept, namely the instanton-antiinstanton ($I\bar{I}$) interaction For years it has been a mystical quantity, as I and $\bar{I}$ have the zero total topplogical charge; therefore they mix up with the perturbative configurations and are ill-defined. In particular, the $I\bar{I}$ interaction potential depends explicitly on the ansatz one chooses for the $I\bar{I}$ configuration.

Fortunately, the study of the BNVP has suggested a new and an ansatz-independent way to define the $I\bar{I}$ interaction by analyticity and unitarity [10]. In addition to the known $1/R^4$ term in the Yang-Mills $I\bar{I}$ interaction potential we have found the next $1/R^6$ term [10] (conjectured earlier by Yung [14]) and the log $(R^2)/R^8$ term [13] , where R is the pseudoparticles' separation. The method developed in refs. [10,13] is quite general: it is applicable not only to the electroweak interactions in question but also to QSD and to many other theories where instantons are essential.

In another work [15] we have given an indirect argument that the above function $F(\varepsilon)$ becomes zero, meaning that the BNVP become exponentially unsuppressed at a threshold energy corresponding to ε=1, i.e. at $\sqrt{s} = 31\ TeV$. We have given arguments that the accelerator baryon number violation is equivalent to the problem of the instability of high baryon density. It has been shown earlier that the spontaneous decay of the high baryon density becomes large at a critical density correcponding to $\varepsilon = 1$ [16]. The prediction that $F(\varepsilon)$ goes to zero at $\varepsilon = 1$ does not contradict the expansion of $F(\varepsilon)$ given by eq.(3).

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