Lower Limit on the Axigluon Mass from Υ Decay

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Consideration of the decay Υ into gluon plus axigluon, in a chiral color theory, places a lower bound on the axigluon mass of at least 9 GeV. The corresponding toponium decay will give a better mass bound on (or confirmation of) a light axigluon.

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It has recently been suggested that the color gauge group SU(3) of the standard model originates from a chiral color group $SU(3)_L \otimes SU(3)_R$ so that at energies above a few hundred gigaelectronvolts the gauge group is given by

$$R = SU(3)_L \otimes SU(3)_R \otimes SU(2)_L \otimes U(1).$$

Some chiral fermions transform under one SU(3) factor, some under the other, and (possibility) some transform under both. The QCD SU(3) group is identified as the diagonal subgroup of $SU(3)_L \otimes SU(3)_R$. Both the breaking of the electroweak $SU(2)\otimes U(1)$ group to QED, and the breaking of chiral color to QCD, is by the Higgs mechanism at the Fermi mass $\simeq 250$ GeV. This chiral color scenario can accommodate in a natural way[1] the Glashow-Iliopoulos-Maiani suppression of flavor-changing neutral currents, and hence is a viable alternative to the standard model.

Chiral color implies the existence of certain fermions and scalars beyond those of the standard model, but these particles are of unknown mass and have quantum numbers which are model dependent.[2] The most striking prediction of all chiral color models is of the color octet of axigluons with mass not greater than 300 GeV (in the simplest symmetry breakings). It is therefore important to seek tests for the existence or exclusion of such axigluons at present and upcoming accelerators. The theory gives no lower bound on the axigluon mass. Intutitively, however, one expects that an axigluon with mass as low as a few gigaelectronvolts or less would contradict the existing body of evidence for QCD at low energy. Here we shall quantify and confirm this intuition. We shall exclude any axigluon mass below 9 GeV (from Υ decay) and then examine the interesting axigluon mass range 10 to 125 GeV.

Other recent studies of chiral color include the work of Rizzo,[3] Sehgal and Wanninger,[4] and Bagger, Schmidt, and King.[5] It is shown in Ref. 3 that axigluon bremsstrahlung in Z^0 decay is compatible with UA2 data if the axigluon mass is around 50 GeV. In Ref. 4, axigluon structures in $p\bar{p}$ collisions have been calculated. The authors of Ref. 5 conclude that axigluon masses between 125 and 275 GeV are excluded by present data on the jet production in hadronic collisions.

In this paper we focus on some decay modes involving the final state gluon plus axigluon. Note that Yang's theorem[6] does not apply because of the distinguishability of the final two particles. First, consider such a decay for the upsilon. For the partial decay width of Υ into gluon plus axigluon, we find the formula

$$\Gamma(\Upsilon \rightarrow g g_A) = \frac{16}{3}\alpha_c^2 \frac{M^2 - M_A^2}{M^4} 4\pi |\psi(0)|^2, \tag{1}$$

where α_c is the strong coupling constant, M is the Υ mass, M_A is the axigluon mass, and $\psi(0)$ is the Υ wave function at the origin. Note that we assume that α_c is the same for gluon and axigluon, as in the parity-conserving case discussed in Ref. 2. In the derivation of Eq. (1), note that the Υ is orthobottomonium but the calculation is similar to that for the decay of parapositronium into two photons. For comparison the well-known partial width formula[7] for Υ into three gluons is

$$\Gamma(\Upsilon \rightarrow 3g) = \frac{40}{81}\frac{\alpha_c^3}{M^2}(\pi^2 - 9) 4\pi |\psi(0)|^2. \tag{2}$$

The ratio of Eqs. (1) and (2) gives

$$r = \frac{\Gamma(g g_A)}{\Gamma(3g)} = \left(\frac{12\times 42}{\alpha_c}\right)\left(1 - \frac{M_A^2}{M^2}\right). \tag{3}$$

From the leptonic width

$$\Gamma(\Upsilon \rightarrow e^+ e^-) = \frac{4}{9}\frac{\alpha^2}{M^2}\pi |\psi(0)|^2, \tag{4}$$

if we conservatively require $r < 1$ in Eq. (3), since standard QCD predicts the hadronic width to better than within a factor of 2, and $\alpha_c < 0.2$, we find $M_A/M > 0.99$. Allowing for the uncertainties concerning confinement and hadronization, we may say that the axigluon mass *must* be greater than at least 9 GeV.

We now entertain the amusing possibility that the axigluon lies in the interesting region between, say, 9 and 125 GeV. Of course, we may use Eq.(3) equally for toponium as for the Υ. We then find that if the axigluon weighs significantly less than topunium, the decay toponium into gluon plus axigluon will dominate toponium decay. For example, if the toponium is at, say, 60 to 100 GeV and the axigluon is at, say, 10 or 20 GeV, then the toponium width is about 100 times greater than in the standard model. This means the total toponium width would be several megaelectronvolts rather than several tens of kiloelectronvolts. This will provide a good test for a light axigluon, but is not a sufficient broadening to allow toponium to have escaped detection at existing machines.

In conclusion, the Υ partial decay widths already place a lower bound of over 9 GeV for the axigluon mass. Discovery of toponium and measurement of its partial decay widths will put severe restrictions on (or conceivably confirm) the possible existence of a light axigluon.

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