8. Charmonium

These discoveries initiated an immediate hunt for the full spectroscopy of this new 'charmonium', in complete analogy with the spectroscopy of positronium that I outlined before. This hunt, using electron–positron storage rings, has proved eminently successful. I shall not describe here the work through which the various spectroscopic states of charmonium were discovered sequentially. There are still some gaps in that spectrum, and work is in progress to fill these. Some higher energy states belong to the same family as those of the 3·1 GeV state originally discovered, and they were found simply by raising the collision energy of electrons and positrons in the storage ring, and observing further peaks. Charmonium states of different quantum numbers were located by observing the products of transitions from the directly produced states to the new states. Figure 18 shows this total spectrum as we see it today, and this figure should be compared with fig. 12 which gave the corresponding spectrum for positronium.

Note that the difference in energy scales between these two spectroscopies is a factor of about one hundred million, yet the fundamental arrangement of the lines in the two spectra is strikingly similar. This surely indicates strongly that the basic rules of quantum mechanics, which determine the existence of such discrete states and their energy, are the same whether one deals with electron volts, millions of electron volts, or thousands of millions of electron volts. Note that the proportions in spacing among the

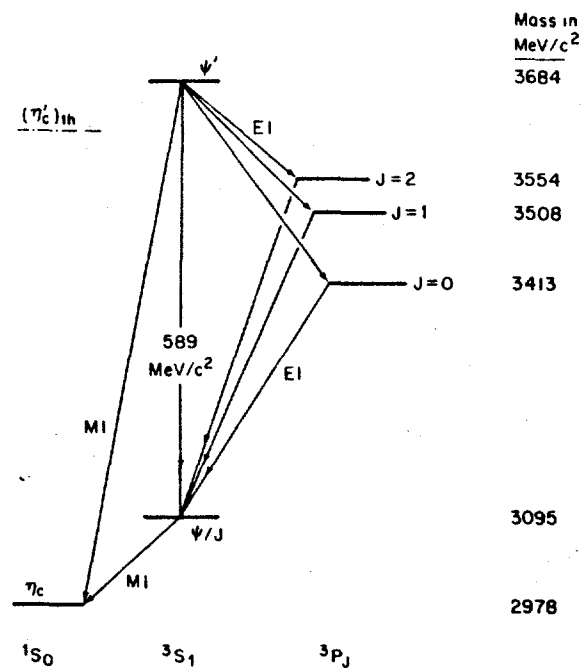

Fig. 18. The energy level spectrum of charmonium. Three classes of spectroscopic terms ($^1S_0$, $^3S_0$, ^3P_j) are shown using the usual spectroscopic notation for spin multiplicity, orbital angular momentum, and spin angular momentum. The observed masses in MeV/c^2 are shown on the right-hand side, and the observed transitions by arrows. The spectral lines in this classification are the same as those shown for positronium in fig. 12, but, the *scale* of the principal transition is different by a factor of about 100 million (589 MeV/c^2 relative to 5·1 eV/c^2). Moreover, the separations among the lines of differing angular momenta are very much larger than those for positronium.