news and views

UPSI-DESY

from David J. Miller

THE Υ (upsilon) particle was first discovered last summer (Herb *et al. Phys. Rev. Lett.* **39**, 252; 1977). Like the ψ/J particle it was found first in proton–proton collisions, it was narrow—within the resolution of the experiment—and it decayed into a pair of leptons (muon and antimuon or electron and positron). Unlike the ψ its properties were not immediately checked by seeing it in electron–positron annihilations at a colliding-beam machine. The problem was its mass. At 3.1 GeV/c^2 the ψ lay within the immediately accessible range of three electron–positron machines which were immediately able to adjust their beam energy to find the new particle. But the Υ and its two excited states the Υ' and Υ'' are in the region from 9.4 to 10.4 GeV/c^2. Last summer it seemed that the new Cornell University accelerator would be the first machine to reach the GeV/c^2 region in electron–positron collisions—sometime in mid-1978. Now the race to the Υ has been won, but not by Cornell.

At the DESY laboratory in Hamburg the accelerator engineers have rapidly rebuilt the 'DORIS' electron–positron storage rings, changing them from a double to a single ring, accelerating only one bunch of each type of particle, and achieving a new peak energy of almost 5 GeV in each beam. This has allowed them to scan the collision energy up towards 10 GeV. As the beam energies were raised through the Υ region, physicists measured the rate of production of strongly-interacting particles, detecting them in the two well tried devices called 'DASP' and 'PLUTO' which have been used for much of the recent work at DESY on ψs, charm and the τ lepton.

In two papers submitted to *Physics Letters* (Darden *et al.*, DESY, Dortmund, Heidelberg, Lund collaboration with DASP; Berget *et al.*, AAchen, DESY, Hamburg, Siegen, Wuppertal collaboration with PLUTO) both groups report a clear and sharp peak in hadron production centred at 9.46 GeV. The width of the effect is consistent with the energy resolution of the storage-ring ($\pm$8 MeV) and the integrated rate gives a partial-width for Υ to electron-positron of 1.3$\pm$0.4 keV, assuming that electron–positron is not a major decay mode. They have not yet scanned the energy through the Υ' at 10.0 GeV or the Υ'' at 10.4 GeV. (Rumour has it that they will leave these to the new storage-ring PETRA which is expected to work at DESY in July, some months ahead of schedule).

The similarities between the ψ family and the Υs are made even closer by this result. Apparently the Υ is a hadron as it decays to hadrons and has been produced by hadron collisions (proton–proton), but it is extremely narrow for such a massive particle. That is, through the uncertainty principle, it has a surprisingly long life for a particle which has available so many different decay possibilities to lighter objects such as mesons, proton–antiproton and so on. The standard explanation of the narrowness of the ψ is that it is a low-lying state of 'charmonium', being composed of one charmed quark and one charmed antiquark, bound together by a strong attractive force due to the exchange of gluons. In the same way an electron and a positron may be bound by photon exchange to form positronium. For the ψ a phenomenological rule, the Zweig rule, is invoked to inhibit all hadronic processes which do not preserve into the final state those quarks which were present in the initial state. The lightest particles which contain single charmed quarks are the D mesons, but their mass is more than half the mass of the ψ, or even of the heavier excited state the ψ'(3.7), so the ψ and ψ' cannot decay to a $D\bar{D}$ (D and anti-D) pair. They can only decay to non-charmed final states in violation of the Zweig rule, giving long lifetimes and narrow widths. All excited states of charmonium above twice the mass of the D are broad and decay rapidly to final states containing DD, but there are only narrow states below the ψ' mass.

Given the success of the charmonium picture of the ψ it is natural to interpret the Υ family in the same way. One or more new quarks are suggested, with the Zweig rule inhibiting rapid Υ decay into charmed or normal final states. The value for the Υ to electron–positron width reported from DESY supports this picture. It corresponds exactly to what would be expected if the Υ is a low-lying state of a new 'onium' formed from a quark and an anti-quark of charge 1/3 (the charmed quark has charge 2/3 like the common 'up' or 'proton' quark. The common 'down' or 'neutron' quark and the strange quark have charge $-1/3$). The most popular approach to the Υ is to introduce a pair of new heavy quarks called 'top' and 'bottom'. If the Υ is 'bottomonium' then it is expected that a more massive equivalent of the D mesons will be found at a little over 5.2 GeV/c^2—just above half the mass of the Υ''. Since the D is often described as 'naked charm', compared with the 'hidden charm' of the ψ, then these newer more massive mesons will offer our first view of 'naked bottom'.

Although the conventional approach through the Zweig rule and a minimum number of new quarks accounts for the major features of the Υ and ψ spectra so far, there are many theorists who feel unhappy about the *ad hoc* nature of many of the arguments involved. A host of alternative schemes exists, and it will be the job of the storage-ring physicists to explore the whole range of properties of the Υs in order to pin down exactly what kind of new quarks we are dealing with. □

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