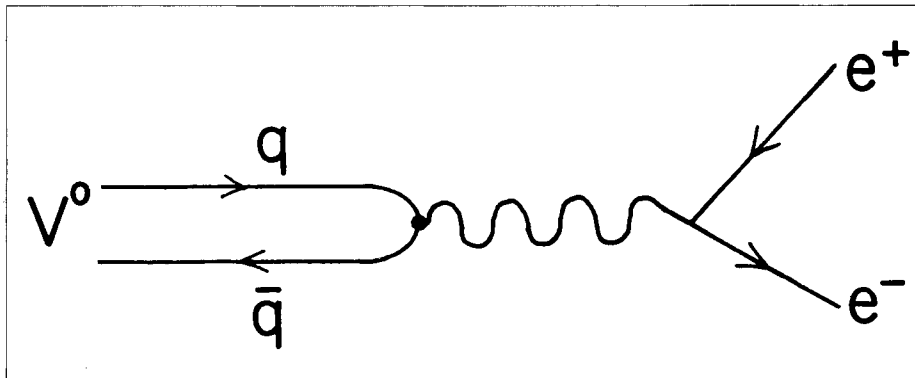


Looked at from the left, this diagram represents the decay of a vector meson, V^0 , into an electron and positron through an intermediate photon (wavy line). The meson could be a psion, an upsilon, or any other heavy vector (spin one, negative parity) particle. Looked at from right to left, the diagram shows the production of the vector meson in an electron-positron collision, via an intermediate photon.



The first opportunity to test the applicability of atomic physics ideas to hadrons came with the discovery in 1974 of the J/psi and psi prime which are long-lived by strong interaction standards. These particles could readily be interpreted as the first two levels of a charm quark-antiquark system. A natural starting point is to regard the potential as a combination of the Coulomb and linear forms, and then to vary potential strengths and the charmed quark mass to reproduce the experimental results.

The masses of the psions are eigenvalues of the Schrödinger equation. Another observable, the square of the charmonium wave function at the origin, is measured by the leptonic decay widths of the spin one levels where the quark and antiquark have their spins pointing in the same direction. In the quarkonium picture, the decay of a vector (spin one, negative parity) meson into a lepton pair is described by the annihilation of the quarks into a virtual photon, which subsequently decays into the lepton pair. The rate of the process is governed by the probability for the quarks to coincide, i.e. the square of the charmonium wave function at zero separation.

Having adjusted the potential to fit the J/psi and psi prime positions and leptonic widths, it can predict the positions of other levels and rates for radiative transitions among levels, along with other quantities. Many of

the predicted levels have been found with masses remarkably close to the theoretical expectations. For those accustomed to a purely descriptive hadron spectroscopy, this agreement supported the non-relativistic potential model approach. Inevitably, complications appeared in the form of relativistic corrections, tensor forces, and coupled-channel effects.

New opportunities arose with the discovery of the upsilon family. If these particles are a heavier quarkonium family, the non-relativistic approximation should be more reliable than for the psions, because the new quark is two or three times more massive than the charmed quark. The comparison of the psion and upsilon families should provide an incisive probe of the potential.

An elementary way to make this comparison is to exploit the variation in behaviour due to different simple potentials. So far, the only data to which these considerations can now be applied is the apparent equality of the three lowest level spacings for the psion and upsilon families. This disagrees with the prediction of the most popular charmonium potential, but is reproduced instead by a logarithmic potential, which has been adopted as a simple form useful for making predictions.

What lies ahead? Theorists are busily refining potential models and calculating the potential from the

presumed underlying field theory of the strong interactions. Many useful theorems can be proved and the use of special techniques to reconstruct the potential from the data is an appealing dream. Experiment, of course, will be the final arbiter of the value of the non-relativistic approach. With work continuing on the upsilon at Fermilab, DESY and the ISR, and with the advent of higher energy electron-positron colliding beams at PETRA, SLAC and CESR, the best is yet to come.

This article is based on material supplied by Chris Quigg.

Imps at large

The puzzle behind the success of the quark model is the continued non-appearance of any free quarks. The classic way out of this dilemma is to buy the idea of quark confinement and to believe that the quarks are there but somehow permanently trapped inside hadrons. Another way out of the quark dilemma has been suggested by Barry McCoy and T.T. Wu, who say that instead of being single particles of definite mass, quarks (and possibly other particles too) could have indeterminate mass and other unconventional properties.

In conventional field theory, the 'propagator' which describes the simplest possible interaction between two particles has in its mathematical structure a point singularity (pole). This pole is interpreted as a single particle passing between the two external particles and the position of the pole depends on the mass of the exchanged particle. Such single particle poles are the most convenient objects to handle mathematically but there is no other reason why they should be the only singularities in the mathematical description of the interaction.