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Energy Correlation of Radiative Decays of $\psi(3684)$.

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In a recent paper the author [1] has shown how the Coulomb energy correlation formula

$$E = P + Q - \frac{3}{2}\frac{PQ}{P + Q} \tag{1}$$

can be applied to evaluate the energies of psi-particles, where P and Q are the respective energies of two constituent charges of equal and opposite polarity. E is the energy of the neutral aggregation of the charged pair.

Using a basic energy quantum derived from fundamental theoretical analysis the formula was matched to $\psi(3684)$ and $\psi(3095)$, the two basic psi-particles. Emphasis was placed upon the importance of this numerical compliance between theory and observation, but much of its credibility depends upon acceptance of the independent theoretical foundations and, in particular, the prediction of the basic energy quantum of 2.587 GeV as a key threshold governing particle creation in the space medium.

Data have now been published [2] giving five radiative decay thresholds of $\psi(3684)$. These are at 3414 ± 3, 3503 ± 4, 3551 ± 4 MeV with additional evidence at 3455 and 3340 MeV. These data allow us to explore the application of the theory to examine decay thresholds as P and Q adjust in the decay process. It is found that all these decay states correspond to energy values obtained by using energy correlation formula (1).

The basis of the formula is Thomson's classic expression for the energy P of a charge e confined to a sphere of radius a

$$P = \tfrac{2}{3}e^2/a\,. \tag{2}$$

The corresponding electric energy associated with an opposite charge $-e$ bounded

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(1) H. ASPDEN: *Speculations in Science and Technology*, **1**, 59 (1978).

(2) W. TANENBAUM: *Phys. Rev. D*, **17**, 1731 (1978).

by a radius parameter b is given by

(3) $$Q = \tfrac{2}{3}e^2/b\ .$$

The Coulomb interaction energy for the charges touching at their radii is then

(4) $$-e^2/(a+b)\ .$$

Combining these three energy terms and eliminating a and b gives the total energy E according to the correlation formula (1).

The derivation of the formula is therefore quite simple and, one would think, unlikely to have meaningful application to the highly dynamic processes of particle creation. However, the results suggest otherwise and lead us to wonder whether the particle transmutations occur under static field circumstances applicable momentarily at times of these creation events. Without dwelling upon this issue, the data derived from the formula will be presented and the reader may judge whether it is worth exploring the underlying physics.

From (1), by keeping P fixed and differentiation with respect to Q, we obtain

(5) $$E_{\min} = E_0 - E_0[(\tfrac{3}{2})^{\frac{1}{2}} - 1]^2\ ,$$

which is when

(6) $$Q/P = (\tfrac{3}{2})^{\frac{1}{2}} - 1\ .$$

The first-discovered psi-particle $\psi(3095)$ was found to correspond to a value close to $E_{\min}$. Note that $E_{\min}$ is 3095 MeV when E_0 is 3259 MeV.

The second-discovered psi-particle $\psi(3864)$ was found to correspond to a value close to E for which the charges of energy quanta P and Q have a mutual interaction conducive to their quasi-stability and one has the same E_0 value of 3259 MeV. The stability condition is discussed in the referenced paper ([1]) and is

(7) $$P^3 = 2Q^3\ ,$$

from which

(8) $$Q = 2587\ \text{MeV}\ ,$$

when

$$P = 3259\ \text{MeV}\ .$$

Putting the values of (8) and (9) in (1) gives E as 3683 MeV.

In an earlier paper ([3]) the author has used the correlation formula (1) to derive a theoretical value for the proton from a dimuon energy quantum 211 MeV. With Q as 211 MeV, P becomes 938 MeV in the minimum energy state set by (6). P is then the mass

(3) H. ASPDEN and D. M. EAGLES: *Nuovo Cimento A*, **30**, 235 (1975).

energy of the proton. Note also that formula (1) has an interesting property from the point of view of particle creation. It shows that a charge having an energy quantum Q can be joined by an opposite charge of negligible energy to cause E to be virtually equal to Q, but, because the equation is quadratic in form, this energy P can adjust to a new value $\frac{1}{2}Q$ without E changing. Thus, if Q is a dimuon quantum 211 MeV, an electron joining Q can become an energy quantum of 106 MeV, so creating a muon without adding energy. It takes this energy 106 MeV to separate P from Q and so develop an independent particle but the needed energy impulse is set by the $P-Q$ system.

Any high-energy environment in which high-energy particle transformations occur appears to be influenced by the presence of muons and dimuons tending to regulate the staged decay of the particles. The ratio of hadron production to dimuon production is a parameter recognized in these decay processes. Therefore, it seems plausible to examine the decay process of ψ(3684), taking its energy quantum as the theoretical 3683 MeV to be consistent with previous theory, and also involving dimuons and muons.

Note that E was found to be 3683 MeV with P as 3259 MeV and Q as 2587 MeV.

Let Q decay to the value 211 MeV assigned to the dimuon but keep E fixed. Then P will increase, according to formula (1), to the value 3772 MeV. This is not a decay of the psi-particle, but an indication that we may expect to find a resonance at 3772 MeV. The discovery of a psi-particle ψ(3772) was reported in 1977 ([4]), a helpful pointer to support our analysis.

If E decreases then some of the energy 3683 MeV is shed. Let us suppose that it finds a home by creating a particle pair as a secondary $P-Q$ system. The particle and its antiparticle will be of identical energy, making $P=Q$ for this subsystem. Put $P=Q=106$ MeV, the muon energy, and find that this energy released is 132 MeV, from (1). The energy left in the primary $P-Q$ system is 3551 MeV.

At this 3551 MeV level of energy the P and Q constituents, having no stabilizing reference linked to the 2587 MeV quantum, may oscillate over a wide range of correlated values. When either P or Q reach a low or negligible value so as to be easily separated, the other constituent can be left in isolation as a charged particle of energy 3551 MeV. Such particles provide the stabilizing influence setting a value of P or Q. They recombine with charges of opposite polarity to process in their decay. Thus we may look for the next decay threshold by setting P at 3551 MeV and Q at 106 MeV. The value of E given by (1) becomes 3503 MeV.

By reiteration with P as 3503 MeV and Q as 106 MeV we then obtain the next decay energy level E of 3455 MeV.

Alternatively, since Q could be a dimuon at this stage, because 3683 MeV less 3455 MeV exceeds the dimuon energy quantum, we could put P as 3503 MeV and Q as 211 MeV. This gives a further energy decay level of E as 3415 MeV.

Theory	Observation
3772	3772
3551	3551 ± 4
3503	3503 ± 4
3455	3455
3415	3414 ± 3
3340	3340

([4]) P. A. RAPIDIS: *Phys. Rev. Lett.*, **37**, 526 (1977).

Still another alternative is for the 3551 MeV quantum, influenced by the near creation of the muon pair of the secondary $P - Q$ system, to shed enough energy to create and separate two further muons and halt at a decay level 211 MeV below the 3551 MeV quantum. Thus we might expect a threshold at 3340 MeV.

The six energy states deduced in the foregoing six paragraphs are tabulated below and set alongside the observed values.

The numerical correlation of these data is quite persuasive and, considered alongside the simplicity of the model used, it is submitted that it warrants attention in elementary-particle research.

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