International Journal of Theoretical Physics, Vol. 18, No. 1 (1979), pp. 17–21

Nonlocal Structures: Shell Effects

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Received October 17, 1977

Abstract

In the author's nonlocal theory, there are regions of stability or metastability associated with the completion of pairs of closed shells. These regions appear just before the even-numbered shell is completed. The masses associated with the completed shells, in GeV, are 1.12, 4.48, 10.08, 17.93, 28.01, 40.33, 54.90, and so forth, in proportion to 1^2, 2^2, 3^2, 4^2, 5^2, 6^2, 7^2, and so forth. Just below the first three limits lie the nucleons, the ψ particles, and the 9.5-GeV resonance. Islands of metastability are predicted to lie just below each of the other limits.

1. *Introduction*

In a preceding article (Clapp, 1977) it was postulated that all elementary particles and fields are built from a single primitive field, whose properties are to be inferred from its singleness. A bilocal structure representing a photon was described in detail, and trilocal structures were discussed briefly.

While detailed calculations are proceeding on the few-quantum structures, and will be described in their turn, it is possible also to take an overall look at the implications of this postulate, when applied to structures that are very much more complex than those for which the detailed calculations can be expected in the near future.

From work on the few-quantum structures, it is apparent that the N-quantum structure will always have a solution with a mass of $N\kappa$, where κ is the Fermi height characterizing the vacuum. This solution will in general represent a causal superposition of free quanta, not a physical particle with explicit correlations between the constituent quanta.

However, there may be circumstances in which this N-quantum structure is coupled with other quanta in such a way that there is established a correlation among all the quanta, and an associated coupling energy, whereby the energy associated with the full structure is less than the energy that the quanta would have if they were independently floating on the Fermi surface. In this case, the structure can represent an elementary particle.

We can expect, from experience in atomic physics and nuclear physics, that the completion of a closed shell, in quantum mechanics, will be associated with a particular stability or metastability. Closed shells in this particle theory lead to regions of stability and metastability that correspond to our observational experience and that predict the possibility of future observation of stable or metastable structures.

Examples discussed here are the nucleons, the J or psi, and the newly discovered particle or particles at 9.5 GeV. Other islands of metastability are predicted.

2. *Nucleons*

The expected value for the Fermi height κ was given in equation (6.4) of the preceding article (Clapp, 1977). Expressed in units appropriate to its role as a mass unit for the elementary-particle mass spectrum, and given to more precision, this parameter is, tentatively,

$$\kappa = 0.07002277 \text{ GeV} \tag{2.1}$$

Validation of this choice awaits the completion of the detailed few-quantum calculations.

If we anticipate this validation, we can look at the expected closed-shell regions and compare with observations.

In particular, the S and P shells combine to give a mass of

$$SP\text{: } 16\kappa = 1.12 \text{ GeV} \tag{2.2}$$

before allowing for any coupling effects. A factor of 4 is included in (2.2) to incorporate the four spin possibilities for a primitive quantum in this nonlocal theory.

Coupling effects are not expected until we remove one or more of the quanta, to allow for adjustments of the wave function that optimize the binding. Removing one quantum gives

$$15\kappa = 1.05 \text{ GeV} \tag{2.3}$$

which can be compared with the nucleon masses of 0.9382 GeV (proton) and 0.9395 GeV (neutron). Reversing the comparison, we can write the nucleon masses as

$$M(\text{proton}) = 13.399\kappa \tag{2.4a}$$

$$M(\text{neutron}) = 13.417\kappa \tag{2.4b}$$

We can interpret these nucleons as consisting of a bare-muon core, with a mass near 1.5κ, combined with a closed P shell with a mass of 12κ, the total mass being reduced a little further by coupling effects between these two constituent structures. (The trilocal structure representing the bare muon is discussed in the last section of Clapp, 1977.)

The P-shell can be interpreted as a meson cloud, primarily pions, surrounding the core, where the pions are four-quantum structures. However, the wave function will contain many terms coupled together by the wave equation, and some of these terms will be best interpreted in terms of heavier mesons, or other substructures that are not found existing independently.

In particular, the 15-quantum structure can be viewed as a combination of three five-quantum substructures, each with a spin of 1/2. Two of the three spins can be parallel, the third being antiparallel to the first two, leading to a combined spin of 1/2. This combination resembles the three-quark picture of the nucleon, where each quark is a five-quantum substructure, with no assurance that it can exist as a separate entity.

The representation of the nucleon as a structure including 15 quanta, each with a σ-spin of 1/2, is not inconsistent with the philosophy of the "bag" picture of the nucleon, since 15 is a number that is large enough to be indistinguishable from "many" in a theory that is not yet very precise in its details.

3. *J or psi*

The relatively great stability of a nucleon can be attributed here to a tight coupling between an S shell and a P shell, with one of the 15 quanta spending part of its time as the fourth quantum in a closed S shell and part of its time as the twelfth quantum in a closed P shell.

We can envision other relatively stable structures in which two nearly closed shells are adjacent and share one or several quanta that can complete one shell or can complete the other shell. It is the nature of the nonlocal Hamiltonian that it couples even-parity functions to odd-parity functions, and cannot take as an eigenfunction a wave function that describes a single closed shell. At least two shells are needed in the wave function.

When we consider the combination of a closed D shell and a closed F shell, we find the mass

$$DF\text{: } 48\kappa = 3.36 \text{ GeV} \tag{3.1}$$

We can also consider the combination

$$SPDF\text{: } 64\kappa = 4.48 \text{ GeV} \tag{3.2}$$

These are in the neighborhood of the J or ψ, at 3.095 GeV, and the ψ', at 3.684 GeV. Inverting the comparison, we get

$$M(3.095) = 44.20\kappa \tag{3.3}$$

$$M(3.684) = 52.61\kappa \tag{3.4}$$

There are other resonances in this same neighborhood, but these two are the narrowest and thus the most stable (Rapidis et al., 1977). Both are bosons, necessitating in this theory that they consist of even numbers of primitive quanta, hence at least 46 and 54 quanta, respectively.

Two other resonances, both broader, are

$$M(3.772) = 53.87\kappa \tag{3.5}$$

$$M(4.414) = 63.037\kappa \tag{3.6}$$

4. *Upsilon*

When we add higher pairs of closed shells, we find the combinations

$$GH\text{: } 80\kappa = 5.60 \text{ GeV} \tag{4.1}$$

$$DFGH\text{: } 128\kappa = 8.96 \text{ GeV} \tag{4.2}$$

$$SPDFGH\text{: } 144\kappa = 10.08 \text{ GeV} \tag{4.3}$$

The recent observation of a resonance at 9.5 GeV (Herb et al., 1977) is consistent with (4.3).

The theory would predict metastable structures with masses just below (4.2) and (4.1). However, these structures may be difficult to produce in collisions. The combination of a closed G shell and a closed H shell, in particular, is such an open, peripheral system that its production in the usual experimental situation may be extremely improbable.

5. *Further Islands of Metastability*

Inclusion of further pairs of closed shells leads to the combinations

$$SPDFGHIJ\text{: } 256\kappa = 17.93 \text{ GeV} \tag{5.1}$$

$$SPDFGHIJKL\text{: } 400\kappa = 28.01 \text{ GeV} \tag{5.2}$$

$$SPDFGHIJKLMN\text{: } 576\kappa = 40.33 \text{ GeV} \tag{5.3}$$

$$SPDFGHIJKLMNOP\text{: } 784\kappa = 54.90 \text{ GeV} \tag{5.4}$$

and so forth. It is in the mass regions just below each of these closed-shell combinations that this theory would predict the observation of one or more metastable particles or narrow-width resonances.

6. *Summary*

The completion of closed shells of electrons, and closed shells of nucleons, has provided particular stability to atoms and to nuclei, respectively. In the nonlocal particle theory described in the previous article (Clapp, 1977) there is a similar effect, but with the stable structure appearing just before the shell is completed. Furthermore, the stability appears, evidently, as pairs of shells are being completed.

The nucleons appear just before the completion of the P shell. The J or ψ, and the ψ', appear just before the completion of the F shell. The particle or particles near 9.5 GeV appear just before the completion of the H shell. Further islands or metastability are predicted to lie near 17, 27, 39, and 54 GeV.

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