Description of Elementary Particles by Stable Wave Packets - A New Attempt

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Abstract

The attempt of Schrödinger to describe elementary particles by wave packets is repeated by means nowadays available, that is to say, by applying the results of quantum field theory and especially by the explicit consideration of interaction.

1. A historical remark

After Einstein in 1905 had inferred from experimental results and theoretical reasons that there must be a particle corresponding to the electromagnetic field, de Broglie proposed to invert this relation and to assign a wave to all material objects (cf. e. g. [1]). That was the beginning of wave mechanics. It was further elaborated by Schrödinger with the equation now bearing his name. Since then the harmonic oscillator is estimated as a classical example for the transition from classical mechanics to quantum mechanics.

The next step consisted in Schrödinger's [2] attempt to describe elementary particles by wave packets. For this purpose he developed a model, in which the wave packet is constructed by superposition of eigen functions of the harmonic oscillator. The decisive point of the construction is that such a wave packet is stable. But the hope that in a similar way the electrons in the orbit of an atom can be described, too, by packets of matter waves was in vain. For Heisenberg showed in the same paper [3], in which he published the uncertainty relations, that the model of Schrödinger has an equidistant energy spectrum and hence is the only example of a stable wave packet (cf. also [4]). The usual argument against such attempts nowadays is that the wave packets are dispersing, comparable with the dispersion of a heat pole on a heat leading material.

But the question remained: What should be the physical meaning of, for instance, the solutions of the Schrödinger equation? After a period of irritation, Born proposed the probability interpretation within the general view of the axis Göttingen – Copenhagen.

2. A new attempt to describe elementary particles by stable wave packets

The ansatz of Schrödinger could not succeed, because it was undertaken in the frame of quantum mechanics. But quantum mechanics is a linear theory and only suited to describe the impact of potentials onto physical objects. But meanwhile quantum field theory has been developed. Interaction is an essential part of it, for instance, in scattering processes. In the present draft it is assumed that the attempt of Schrödinger only has failed because of the insufficient means of the year 1926. For this reason it shall be repeated here by means that nowadays are available. Hence the aim is to describe real existing elementary particles under explicit consideration of the role of interaction. As an example the electron is chosen.

Provided a wave packet is given composed of solutions of the Dirac equation with the parameters of the electron and concentrated in a region of about a Compton wave length of the electron. Then this assumption is only an illusion. In reality the electron is indivisibly coupled to its own electromagnetic field. Hence interaction takes place, which may be considered, too, as the self interaction of the whole system. Within perturbation theory the electron is surrounding itself with a cloud of virtual particles, the expression 'virtual particle' being to read as 'scattering wave'. In a further step one can consider the originally given electron as one of the virtual particles. Under the assumption that the whole object proves to be stable even beyond perturbation theory, one has gained a model for a really existing electron. It is free in the sense that it does not interact with other particles. But it is not free in so far, as it does not yield the homogeneous part of a field equation.

More cannot be given here, because theoretical physics is far away from being able to manage interaction. At a later occasion it shall be discussed, why the possibilities of experimental investigation are bounded, too. At any rate the presented ansatz, in spite of all speculative elements, seems to be better suited to describe real existing elementary particles than the ideas of the Copenhagen interpretation.

3. Inferences and open questions

(a) The necessarily speculative character of the presented draft

The ansatz concededly is somewhat speculative. But this cannot be avoided for two reasons. On the theoretical level physics is still not able to manage the problem of interaction. Perturbation theory is only an emergency program in order to get an approximation. But for the present ansatz this is not sufficient, and at most a model for some aspects of reality. Experimentally the Compton wave length is a natural barrier, because any attempt to localize an object closer than this length will afford such high energy that the object will be destroyed by it. "...the Compton wave length of the electron ... is the smallest size within which the electron can be compressed." (Thirring [5])

(b) The role of interaction in the presented draft

When two elementary particles are meeting, then interaction will occur. Then the two clouds of virtual particles, in order to remain in the picture, are penetrating and shaping a new object.

After the interaction has been, as people say, switched off', the outgoing particles are formed leaving the place of their creation. This view of interaction is suited to explain that between the outgoing particles, contrary to the ingoing ones, there is a correlation. Hence – in passing – it is shown, why the pretended paradoxon of Einstein, Podolsky, and Rosen is vanishing into thin air.

(c) The role of diffraction in the presented draft

Concerning the diffraction of the waves, out of which the elementary particles consist, there is an obvious connection between the wave length and the order of magnitude of the objects, where diffraction occurs. For light the diffracting slit still can be seen. But for the diffraction of electrons the lattice elements of a crystal are the obstacles. Thus one is lead to the supposition that deflection is a special case of interaction. But this problem shall not further be pursued here.

(a) The role of probability in the presented draft

The intention of the ansatz is to represent elementary particles by stable wave packets and to describe these by complex functions depending on the four coordinates of time and space. Physical observables are defined as weighted integrals of these functions taken over some finite region of the four dimensional space. Probability is coming in on a quite natural way. First of all there is the uncertainty of, for instance, space and momentum induced by the corresponding uncertainty of frequency and the three coordinates of space. Moreover physical observables themselves are not exactly defined. Since the interior of an elementary particle is unknown, weighted integrals over a region being included in the interior of a particle are not defined. Hence any physical observable is underlying an uncertainty.

4. Summary

The attempt of Schrödinger to describe elementary particles by wave packets has been in vain, as is well known. It has been repeated in the present paper by new means nowadays available, that is to say, by application of the results of quantum field theory and especially by explicit consideration of interaction.

References

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