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Instead of Particles and Fields: A Micro Realistic Quantum "Smearon" Theory

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A fully micro realistic, propensity version of quantum theory is proposed, according to which fundamental physical entities—neither particles nor fields—have physical characteristics which determine probabilistically how they interact with one another (rather than with measuring instruments). The version of quantum "smearon" theory proposed here does not modify the equations of orthodox quantum theory: rather it gives a radically new interpretation to these equations. It is argued that (i) there are strong general reasons for preferrring quantum "smearon" theory to orthodox quantum theory; (ii) the proposed change in physical interpretation leads quantum "smearon" theory to make experimental predictions subtly different from those of orthodox quantum theory. Some possible crucial experiments are considered.

"This is often the way it is in physics—our mistake is not that we take our theories too seriously, but that we do not take them seriously enough. It is always hard to realize that these numbers and equations we play with at our desks have something to do with the real world. Even worse, there often seems to be a general agreement that certain phenomena are just not fit subjects for respectable theoretical and experimental effort."–S. Weinberg.

1. INTRODUCTION

It is widely assumed that quantum mechanics (QM) must be interpreted as a theory restricted to predicting the outcome of performing measurements on quantum mechanically described micro systems. Many, like Bohr,(1) Heisenberg,(2) Born,(3) Dirac,(4) and others, hold that measurements occur when micro systems interact appropriately with classically describable

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macro systems. Others, like Ludwig,[5] Daneri, Loinger, and Prosperi,[6] hold that the occurence of an "irreversible process" is the key to measurement. There are even some who, like Bauer and London,[7] von Neumann,[8] and Wigner,[9] hold that measurement only occurs when a conscious person makes an observation. Others, like Popper,[10] Margenau,[11] Landé,[12] Bunge,[13] D'Espagnat,[14] Ballentine,[15] and Fine,[16] in various ways seek to defend "objective" or "realistic" formulations of QM, and yet are obliged to concede, in one way or another, Bohr's crucial point that QM must, in an essential way, presuppose some part of classical physics for a description of preparation and measuring devices. All, in short, assume that it is not possible to formulate a viable fully micro realistic version of QM, a version of QM which is, in the first instance, exclusively about how microsystems physically evolve and interact with one another, the fundamental postulates of the theory making no reference to observables, to measurement or classical physics whatsoever. It is true that some, like de Broglie,[17] Schrödinger,[18] Bohm,[19] and Vigier[20] have defended microrealism in this strong sense, or have sought to develop micro realistic versions of QM; however, these attempts have not yet met with success. It was perhaps above all Einstein who understood and deplored "the risky game" that the orthodox interpretation of QM is "playing with reality".[21] Einstein's positive idea for a micro realistic theory that made no essential reference to measurement or classical physics was, however, tentatively and skeptically, a deterministic unified field theory, from which QM would be derived as an approximation. This approach has not met with success either, and as Einstein himself remarked: "One can give good reasons why reality cannot at all be represented by a continuous field. From the quantum phenomena it appears to follow with certainty that a finite system of finite energy can be completely described by a finite set of numbers (quantum numbers). This does not seem to be in accordance with a continuum theory."[22]

This fifty year long discussion about what QM tells us about physical reality seems, however, to have overlooked one possibility: to develop a fully micro realistic "propensity" version of QM, which is about, not particle or field or measurement, but rather a new kind of physcial entity, called here the "smearon",[2] having physical properties that differ radically from both classical particle and classical field.[3]

[2] Alternative possible terms: "quanton", "propensitron", or "waviclon".

[3] This much neglected approach has been advocated in two earlier publications[23,24] where further details of the micro realistic, propensity idea are to be found: a somewhat similar approach has been advocated by Bedford and Wang.[25,26]

"Smearons", as understood here, are hypothetical fundamental physical entities, having characteristics somewhat like "the wave packets" of orthodox QM in being smeared out in space in a wave like fashion, but being unlike orthodox wave packets in having physically real nonlocal characteristics that in general exist in space and evolve in time independently of methods of preparation and measurement. What is smeared out in space is the propensity of one smearon to interact in a probabilistic, quasiparticle like way with another smearon, should the appropriate physical (smearon) conditions to do so arise. The state vectors of QM are to be interpreted as characterizing the actual physical states of smearons. The physical states of smearons evolve deterministically, in accordance with Schrödinger's time dependent equation (for elementary QM) as long as no probabilistic particle like interactions between smearons occur. Probabilistic particle like interactions between smearons involve changes of state which violate Schrödinger's time dependent equation even though no measurement is made. If appropriate physical conditions arise for an unlocalized smearon, in a state $\varnothing$, to interact in a probabilistic way with just one of many other highly localized smearons, then, roughly speaking, the probability that the unlocalized smearon interacts with the smearon localized in dV is given by $|\varnothing|^2 . dV$ (this being a microrealistic reformulation of Born's original 1926 probabilistic interpretation of wave mechanics, which appealed explicitly to measurement[(27)]). Smearon QM is thus a theory that is, in the first instance, exclusively about how smearons physically evolve and interact with one another in space and time independently of preparation and measurement. Measurements are probabilistic interactions between smearons which just happen to be recorded by physicists. Stable macro objects are the outcome of many probabilistic interactions between smearons.

In a sense, smearon QM is not a new theory at all, but rather QM as it exists at present (wave packet theory, quantum field theory) with a radically new physical interpretation. However, as I shall argue below, due to the change of physical interpretation, any precisely formulated smearon version of QM must have some experimental consequences that differ subtly, at least in principle and perhaps in practice, from predictions of orthodox QM.

My claim is that the general smearon interpretation of QM is actually superior to the orthodox interpretation *even in the absence* of solutions to the technical problems to which it gives rise. Both smearon and orthodox interpretations of QM face problems: the crucial issue is which set of problems we conjecture to be the most fruitful physically (a point well understood by Einstein). The smearon interpretation of QM ought indeed, I claim, to have been generally adopted around 1926 or 1930. Only prejudice, positivist dogma, the accidents of intellectual history, and finally mere *habit*, have prevented this from happening long ago.

In an attempt to establish this point, I make the following six remarks, and spell out a general argument in sec. 2 below:

1. A major traditional objection to regarding the "wave packets" of QM as physically real is that the wave motion of n interacting "quantum entangled" particles cannot be represented in three dimensional, physically real space, but only in $3n$ dimensional configuration space. This has been take to exclude the possibility of interpreting wave packets as physically real for $n \geqslant 2$. This objection is, perhaps, fatal for Schrödinger's original wave packet interpretation of his wave mechanics: it does not, however, at all undermine the propensity, smearon version of QM proposed here. A system consisting of two "quantum entangled" particles physically exists in space and evolves in time: what exists and evolves is the propensity of the system to interact in a probabilistic way, as two particles, should the appropriate physical conditions to do so arise. In order to represent the evolution of this propensity in physical space and time it may be convenient to resort to the mathematical fiction of a "wave packet" in six dimensional configuration space: but, according to the smearon view, this must be interpreted as describing the evolution of the physically real propensity of the quantum entangled stem in physical space and time. Smearon theory interprets the quantum state of an n particle quantum entangled system as attributing to any n points in a region of space a definite probability that the n particles will interact at these n points, should the appropriate physical conditions to do so arise.

2. Another traditional objection to regarding the wave packet of QM as physically real is that this requires that we interpret the instantaneous collapse of the wave packet whenever a position measurement is made as a physically real process. This postulate of wave packet collapse seems however entirely *ad hoc* and inexplicable; and that it should occur instantaneously seems physically implausible. Once again, this is perhaps a powerful objection to Schrödinger's original "wave packet" interpretation of QM, but it is entirely harmless when directed against the smearon version of QM proposed here. It is of the essence of the smearon idea that smearons interact probabilistically with one another. Indeed, the fundamental distinction between the classical particle and field, and the quantum mechanical smearon, is just that whereas the physical properties of the particle or field determine how these physical entities interact or evolve deterministically, the physical properties or propensities of the smearon determine how smearons interact *probabilistically*.[24] "Deterministic" equations of state evolution merely specify how propensities evolve when no probabilistic interactions occur. A precise formulation of smearon QM must include a postulate which specifies the precise physical (smearon) conditions

for probabilistic interactions to occur. From the smearon standpoint, there need be nothing *ad hoc* about this postulate whatsoever. Whether or not such a postulate is *ad hoc* will depend on the extent to which it coheres naturally with basic principles of physics, such as special relativity and the basic quantum idea. If such a postulate is non *ad hoc*, in this way, then, from the smearon standpoint, no special problem remains to provide an explanation or mechanism for probabilistic interactions. The idea that an explanation or mechanism must be provided for probabilistic interactions rests on nothing more than the refusal to tolerate the idea that propensities might be fundamental physical properties, that the universe might be fundamentally *probabilistic* rather than *deterministic*.

(3) A fundamental conceptual problem that confronted classical physics is the problem of how the continuous (electromagnetic) field can interact with discrete (charged) point particles of matter. It was an aspect of this problem—in an empirical guise—that Planck tackled in developing his empirical law of black body radiation, and in attempting to provide a theoretical derivation of this law, the step that first introduced the quantum of action into physics. Einstein's 1905 photon hypothesis paper from the outset, quite explicitly, takes as its central problem the problem of how the continuous field can interact with discrete matter. That this constitutes a fundamental problem for the whole framework of classical physics seems to have been realized by Einstein soon after Planck's trailblazing work.[28] Viewed as a sustained attempt to establish, clarify and sharpen the conflict between field and particle, electromagnetism and a mechanics of particles, Einstein's otherwise apparently diverse work published in 1905 on Brownian motion (designed to establish the existence of atoms), special relativity and the photon hypothesis, takes on a striking unity of purpose. There are grounds, then, for holding that from the outset, quantum theory arose out of concern with the field/particle problem. Subsequent developments—such as Compton's work on photon—electron scattering, de Broglie's theory of matter waves, and its experimental corroboration, Heisenberg's matrix mechanics and Schrödinger's wave mechanics, served only to deepen the conflict. It is the failure of QM to solve this fundamental, conceptual problem—the classical field/particle problem or the quantum mechanical wave/particle problem—which makes it necessary to interpret QM as a theory about "observables", about the outcome of performing measurements. As long as no consistent micro realistic ontology for the quantum domain is forthcoming, it is impossible to interpret QM as a theory that is, in the first instance, exclusively about micro systems, about how they interact and evolve in space-time. It is thus understandable why Einstein, seeking a micro realistic resolution of the field/particle problem, should judge the Heisen-

berg–Bohr interpretation of QM to be a "tranquilizing philosophy—or religion!— . . . so delicately contrived that, for the time being, it provides a gentle pillow for the true believer from which he cannot very easily be aroused",[21] an *evasion* rather than a solution of the problem. As Einstein wrote to his friend M. Besso towards the end of his life: "All these fifty years of conscious brooding have brought me no nearer to the answer to the question 'What are light quanta?' Nowadays every Tom, Dick and Harry thinks he knows it, but he is mistaken."[29]

The solution offered here to the classical field/point particle problem, and to the quantum mechanical wave/particle problem (to Einstein's problem concerning the photon) is that the universe is made up of smearons. The crucial step of this proposed solution is to adopt a probabilistic generalization of the classical (deterministic) notion of physical property. Within classical physics, physical properties of fundamental physical entities—whether charge and mass of particles, or field intensity of fields—determine how physical entities interact and evolve in space and time *deterministically*. If now we wish to retain the classical idea that the actual physical states of individual micro systems determine their subsequent evolution, and at the same time we wish to hold that Nature is fundamentally probabilistic rather than deterministic, then we are obliged to generalize the classical (deterministic) notion of physical property to form the notion of a probabilistically determining physical property or propensity (a point discussed in more detail elsewhere[24]). The outcome of this decisive step is to abandon altogether the classical field and particle, and instead adopt the new kind of entity, the smearon. According to this viewpoint, the mysteriousness of the quantum domain is to be understood as arising out of our unfamiliarity with objects that have propensities as basic properties (such familiar macro propensities as the unbiasedness of a die, for example, being explicable in terms of classical deterministic physical properties, and randomly varying initial conditions with each toss).

Thus the smearon version of QM in principle provides an acceptable micro realistic solution to two problems that lie at the heart of classical and quantum physics—the classical field/particle problem and the quantum wave/particle problem—whereas orthodox QM fails to resolve satisfactorily both problems.

4. As a result of providing a micro realistic solution to the wave/particle problem, smearon QM can immediately claim a further important advantage over orthodox QM. It is not just that the smearon version of QM entirely avoids the endlessly discussed and unresolved problem of measurement that plagues orthodox QM. Much more important, smearon QM, having its own distinctive physical ontology, enables us in principle to

explain and understand complex macro objects and phenomena as being solely the outcome of interactions between micro systems, namely smearons. This cannot be achieved by orthodox QM, since orthodox QM must presuppose the existence of complex macro objects (measuring instruments) in any actual physical application. Smearon QM thus has greater explanatory power than orthodox QM. Or, putting this point slightly differently, smearon QM can in principle fully explain the empirical success of classical physics, not needing in any way itself to presuppose some part of classical physics. Orthodox QM cannot do this, just because some part of classical physics must be presupposed by the theory for a treatment of measurement. In other words, orthodox QM is a severely *ad hoc* theory in that it consists of two conceptually inharmonious parts, (i) quantum postulates and (ii) classical or quasiclassical postulates for a description of preparation and measurement. Smearon QM is not *ad hoc* in this way, having no essential need for *ad hoc* classical or quasiclassical postulates: thus it has greater explanatory power (accepting that explanatory power is related to non *ad hocness*).

Although smearon QM makes no appeal to measurement or classical physics, nevertheless the theory is still experimentally testable. We can (conjecturally) identify photographic plates, bubble chambers etc., with complex systems of smearons: smearon QM will then make predictions about enduring smearon states which we can identify with observable tracks in photographic plates and bubble chambers. Any appeal to classical physics is, as it were, a matter of practical convenience rather than conceptual necessity.

5. The long standing failure of the physics community to accept, or even to consider, the smearon version of QM can be understood as being due to the accidents of intellectual history. During the decade 1925–35, when the problem of how to interpret QM was an alive issue for the physics community, the debate was polarized into two opposing camps. On the one hand the Bohr-Heisenberg camp advocated the abandonment of classical determinism and micro realism, and on the other hand the Einstein-Schrödinger camp advocated retaining determinism and microrealism. Both camps seem to have taken for granted that the abandonment of determinism involved the abandonment of micro realism—perhaps in part because of the general acceptance, at the time, of subjectivist conceptions of probability, which implied that a fundamentally probabilistic physics could not be microrealistic. As a result, the best possibility seems to have been overlooked entirely, namely to retain classical micro realism but to abandon classical determinism—by holding that micro realistic properties determine the physical evolution of individual micro systems *probabilistically*.

The closest approach to this "smearon" viewpoint was de Broglie's 1927 theory of the "double solution".[17] De Broglie's theory entirely fails, however, to adopt a probabilistic generalization of the classical deterministic notion of physical property. On the contrary, de Broglie's theory characterizes micro systems in terms of classical physical properties, the statistical aspects of QM being introduced somewhat analogously to the way in which statistics is introduced in classical statistical mechanics. Thus, from the smearon standpoint, de Broglie's approach fails to go to the heart of the problem.

Subsequently, some writers have introduced notions closer to the propensity notion employed here. Thus Heisenberg's[30] *potentia* view, and Margenau's[31] *latency* view, can both be understood to be attributing propensities to microsystems determining (probabilistically) the values of observables on measurement; and Popper's[10] propensity view explicitly atributes propensities to experimental set ups. However, these views all appeal, implicitly or explicitly, to measurement: they thus fail to constitute exclusively micro realistic propensity versions of QM—the crucial feature of the smearon view proposed here.

6. Elementary QM is not amenable to a micro realistic (smearon) interpretation. This is because elementary QM treats forces, for example the electromagnetic force, in a thoroughly classical way, in terms of a potential function for example. Only wave packet collision theory or quantum field theory, capable of characterizing forces in terms of interactions between microsystems (as the exchange of virtual particles for example), can be amenable to microrealistic (smearon) interpretation. The task that lies before us is thus to develop a fully fledged quantum smearon theory to replace orthodox wave packet collision theory, and ultimately orthodox quantum field theory.

We have here a further explanation for the failure of the physics community to take up the smearon idea. Initially QM was not amenable to such an interpretation. Later, when the smearon idea became viable with the development of wave packet collision theory, and quantum field theory, the Copenhagen doctrine had hardened into a dogma.

In view of points 1, 2, 5, and 6, I conclude that the smearon interpretation of QM is a viable interpretation, at least as acceptable as the orthodox and all other nonorthodox interpretations. In view of points 3 and 4, I conclude that the smearon interpretation is actually superior to the orthodox interpretation, and to most other nonorthodox interpretations.

The matter might be summed up like this. It is a long standing and fundamental aim of theoretical physics, of natural philosophy, to attempt to explain and understand diverse, complex macro phenomena entirely in terms of interactions between a very few different sorts of fundamental physical entities—whether atoms, point particles, fields or whatever. Indeed, as I have argued elsewhere,[32–34] we can scarcely understand theoretical physics as a rational enterprise unless we see it as presupposing that some kind of unified pattern or structure exists inherent in all natural phenomena—a pattern or structure to be characterized in terms of some as yet to be discovered unified, fundamental physical theory which specifies how the very few different sorts of fundamental physical entities that exist evolve and interact. Therefore, it is only with extreme reluctance that we should abandon what may be called the postulate or requirement of microrealism:

(i) Diverse, complex macro phenomena can in principle be explained and understood in terms of interactions between a very few different sorts of fundamental physical entities, no appeal being made to macroproperties in characterizing the properties of these fundamental entities. A fundamental physical theory. in order to be fully acceptable, must be realistic in this sense.

Granted that we accept (i), it is natural that we should accept:

(ii) The evolution of any isolated physical system is determined (deterministically or probabilistically) by the actual physical characteristics, the physical state, of the individual system in question, at some instant.

If, in addition to (i) and (ii), we also accept that:

(ii) Nature is fundamentally probabilistic, and not deterministic;

then our hands are tied; we are obliged to hold that:

(iv) Only theories that are micro realistic and attribute propensities to fundamental physical entities can be fully acceptable.

Smearon QM fully accords with this basic, highly plausible requirement (iv), whereas all other versions and interpretations of QM fail to satisfy this requirement. This is the great advantage of smearon QM over all other interpretations.

2. THE UNIFIED DETERMINISTIC-PROBABILISTIC PRINCIPLE

In this section I indicate an additional reason for attempting to develop a micro realistic smearon version of quantum theory.

One obvious feature of orthodox quantum theory is that it postulates both deterministic and probabilistic laws of evolution for systems. The quantum states of systems evolve deterministically if no measurement is made, probabilistically, in general, if and only if a measurement is made.

Let us conjecture that in this respect quantum theory reflects a real, objective feature of the physical universe itself. In Nature, physical systems really do evolve some of the time in accordance with deterministic laws, some of the time in accordance with probabilistic laws. Let us call the idea that the physical universe really is like this the *unified deterministic-probabilistic thesis*—the UDP thesis.

If the UDP thesis is true, then any unified fundamental physical theory will have to do justice to this aspect of Nature: the theory will have to postulate both deterministic and probabilistic laws of evolution, and show precisely how these coherently intermesh. Let us call this the UDP requirement. It can be regarded as a methodological rule: in order to be acceptable, a unified fundamental physical theory must at least satisfy the UDP requirement.

The UDP thesis and methodological rule together can be regarded as being a *physical principle*, analagous to such physical principles as Mach's principle, the special principle of relativity, the principle of Lorentz invariance, Einstein's principle of equivalence, the principles of conservation of energy, momentum and angular momentum, the principle of conservation of charge, the principle of CPT symmetry, gauge invariance. In each case (so we may hold) we have a principle which attributes a rather general characteristic to Nature, and then requires acceptable theories to conform to certain *formal* requirements in order to do justice to the postulated characteristic. Many valuable physical theories have been developed through the postulation of such principles, and the endeavour to modify existing theories so as to render the (new, modified) theory compatible with the postulated principles. This was how Einstein developed special and general relativity. Since Einstein's work symmetry and invariance principles have come to play an ever increasingly important role in theoretical physics, both for the development and for the appraisal of theories.

In sec. 1 above I put forward just such a principle: it may be called the principle of *micro realism*. This principle asserts: the universe is made up of a few different sorts of fundamental physical entities interacting in accordance with a coherent system of physical laws (all macro phenomena being the outcome of complex interactions between many such entities). According to this principle a fundamental physical theory, in order to be ultimately acceptable, must be capable of being interpreted as specifying exclusively laws of interaction between a few different sorts of basic physical entities (particles, fields, or whatever). Above (and elsewhere) I have argued in effect, that we ought to require of any acceptable fundamental physical theory that it satisfies this principle of micro realism since it is only in this case that a theory can be fully unified, conceptually coherent, non-*ad hoc*, or, in other words, fully explanatory. Orthodox QM fails to satisfy the principle of micro realism, in that it fails to resolve the wave/particle (or field/particle) dilemma in a micro realistic fashion. As a result, orthodox QM must be interpreted as specifying (in part) how micro systems interact with macro (classical) measuring instruments. Just for this reason, orthodox QM is seriously *ad hoc* (in a usually unnoticed way) in that the theory is made up of two conceptually incoherent parts, quantum postulates plus some part of classical physics for a treatment of measurement. A precise smearon version of quantum theory would however be fully micro realistic and, as a result, would be free of this *ad hoc* dependence on classical physics.

Any significant physical principle however apparently plausible, may of course be false (as the downfall of parity invariance so dramatically illustrated). Here let us conjecture that the UDP principle is true. The UDP character of orthodox QM, so obvious a feature of the theory at a superficial level at least, is, we are to suppose (in view of the great empirical success of QM) a deep objective feature of the physical universe itself. Any ultimately acceptable fundamental physical theory must specify precisely how deterministic and probabilistic laws of evolution intermesh in a consistent, conceptually coherent fashion.

Superficially, orthodox QM suggests the UDP principle: does orthodox QM precisely satisfy this principle? Does orthodox QM specify precisely how deterministic and probabilistic laws interconnect?

The answer to this question must be: No! It is just this crucial issue of how deterministic and probabilistic laws interconnect that orthodox QM fudges. (And to make matters worse, in the literature inadequate physics is covered up, "justified" even, with bad, positivistic philosophy.)

One indication of the failure of QM to satisfy precisely the UDP principle is the range of interpretations of QM that various thinkers have been able to develop, which differ radically on just the crucial point of how determinism and probabilism are interrelated.

At one extreme there is the view that everything is in a sense continuously probabilistic, so that even when the quantum state of a physical system evolves "deterministically", in accordance with Schrödinger's time dependent equation let us say, in reality, at a deeper ontological level, the system is physically evolving in a continuously probabilistic fashion, from instant to instant. De Broglie, Vigier, Popper, Landé, and others have put forward various probabilistic versions or interpretations of QM which in effect postulate physical probabilism during the deterministic evolution of the quantum state of any system. Some have even explored the possibility that space and time have a discrete character, this discreteness of space-time being responsible for the probabilistic character of all physical interactions occurring in an only approximately continuous space-time manifold. This kind of view makes it quite impossible to interpret Schrödinger's time dependent equation—or its relativistic modification—as specifying physical, ontological determinism. Schrödinger's equation can only have approximate "macro" validity, in that it is based (according to this kind of view) on the false, only approximately valid, assumption that space and time are continuous.

On the other hand, at the other extreme, there is the view that Nature is ultimately deterministic, so that orthodox QM, being probabilistic, succeeds only in giving an essentially incomplete specification of the physical state of any system. The typical (incomplete) quantum specification of the state associated with a "pure" ensemble of similarly prepared systems issues in probabilistic predictions because the actual physical conditions vary, from system to system of the ensemble, in such a way as to produce the predicted probabilistic outcome, each individually distinct initial state evolving in accordance with the same *deterministic* laws. The statistical spread of outcomes is deterministically linked, in other words, to a statistical spread in initial conditions, which orthodox QM, being incomplete, fails to capture. Orthodox QM fails to make deterministic predictions because it fails to describe precisely each distinct initial state, and fails to specify the fundamental, deterministic laws of Nature. This kind of view was advocated by Einstein. Tentatively, Einstein held that the basic deterministic laws can be formulated as a classical unified field theory.

Is everything continually probabilistic? Or is nothing probabilistic? For all we know, either one of these extreme positions may be true. Here, however, we are adopting a position that is, as it were, midway between the above two extreme positions, according to which physical systems evolve at times deterministically, at times probabilistically, roughly as orthodox QM postulates. According to this orthodox interpretation of QM, all systems evolve deterministically when no measurements are made: probabilistic events occur only when measurements are performed. This is really the heart of the Copenhagen interpretation of QM, the common assumption in the otherwise somewhat diverse views of Bohr, Heisenberg, Born, Dirac—and of most contemporary physicists.

This orthodox version of QM must fail however, to specify precisely how deterministic and probabilistic laws interconnect due to an unavoidable vagueness in the key notion of "measurement". We may seek to specify the precise necessary and sufficient physical conditions for a measurement interaction to occur in terms of: (1) personal observation and consciousness, (2) the occurrence of a classically describable process, (3) the occurrence of a "macro" phenomenon, and (4) the occurrence of an irreversible process. All these specifications must inevitably be somewhat imprecise. In order to specify *precise* necessary and sufficient physical conditions for probabilistic (measurement type) events to occur within some (composite) physical system we should have to do this in terms of some *quantum mechanical* condition of the system—specifiable in precise quantum mechanical terms. But it is just this which the orthodox standpoint does not permit. In the first place, if probabilistic events occur when some precise *quantum mechanical* physical condition is realized within a quantum system, presumably such probabilistic events will not be confined to measurement; they will occur even in the absence of measurement. This conflicts with orthodox QM. Secondly, if we are to be able to specify some *physical* condition for probabilistic events to occur within composite micro systems, in purely quantum mechanical terms, then we must be able to interpret quantum mechanics as describing the actual physical states of micro systems, independently of all macro (classical) preparation and measurement conditions. We must, in other words, be able to give a fully micro realistic interpretation to QM. But it is just this which the orthodox interpretation of QM does not permit. Thus, for these two reasons, there can be no precise, quantum mechanical specification of the physical conditions for probabilistic events to occur within the framework of orthodox QM. Orthodox QM cannot *precisely* satisfy the UDP principle it so forcefully suggests.

A precisely formulated smearon version of QM would however precisely satisfy the UDP principle. (Quantum smearon theory is indeed designed to do just this.) For any adequate quantum smearon theory must do the following:

(1) The theory must specify the micro realistic states of smearons, in terms of values of the deterministic and probabilistic physical properties of smearons—the quasiclassical and propensity states of smearons.

(2) The theory must specify deterministic laws of evolution for smearons granted that no probabilistic interactions occur. These laws specify the deterministic evolution of the values of propensities in the absence of the probabilistic "actualization" of these propensities. (In order to understand clearly what is being proposed here, consider the way in which, within elementary QM, Schrödinger's time dependent equation specifies the deterministic evolution of the value of the position probability density of an electron, for example. The position probability density can be thought of as a propensity—the propensity of the electron to interact in a small region of space in a particle like way, should the appropriate physical conditions to do so arise (a position measurement, for orthodox QM). Whenever the electron so interacts we can speak of the probabilistic "actualization" of the position probability density. In the absence of such a probabilistic event, the value of the position probability density (the value of this propensity) evolves deterministically, as specified by Schrödinger's equation.)

(3) The theory must specify precisely the physical (micro realistic, smearon) conditions necessary and sufficient for propensities to become "actualized"—for something probabilistic to occur. (According to smearon

theory, measurements are just a very small subset of all probabilistic actualizations occuring in Nature.)

From (1), (2) and (3), it must be possible, in principle, for any actual physical system, to predict precisely (i) the occurrence of probabilistic events, (ii) the range of possible outcomes, (iii) the probability of each possible outcome occurring.

Any smearon theory of this type (precisely specifying (1), (2), and (3)) automatically satisfies the UDP principle. Furthermore, so it would seem, the only way in which orthodox QM can be made to satisfy the UDP principle is to transform the theory into a smearon version of QM. For, as we have seen above, if QM is to satisfy the UDP principle then (i) a micro realistic version of QM must be developed; (ii) precise necessary and sufficient micro conditions must be specified for probabilistic events to occur—so that the vague notion of "measurement" can be eliminated from the basic postulates of the theory. This would seem to be equivalent to developing a smearon version of QM.

If, then, we take the superficial UDP character of orthodox QM seriously, as reflecting a deep, objective feature of the physical universe itself, there are overwhelming grounds for holding that only some smearon version of QM can ultimately prove to be satisfactory.

3. MICROREALISTIC CONDITIONS FOR PROBABILISTIC EVENTS

The key problem that must be solved in order to formulate a precise smearon version of QM physically and experimentally distinct from orthodox QM is to specify precise, necessary and sufficient, quantum theoretical, physical conditions for probabilistic events to occur in composite quantum systems, no surreptitious appeal whatsoever being made to measurement, to interaction with macro systems, or to irreversible processes. In tackling this problem I presuppose, as the version of orthodox QM to be modified, nonrelativistic wave packet collision theory as set out, for example, by Goldberger and Watson[35] (though the modification I propose can also be made to quantum field theory, as long as this is interpreted physically to be a refinement of wave packet collision theory). In what follows, then, the formalism and calculations of wave packet collision theory are taken for granted: I seek merely to make a very small adjustment to this formalism which enables us to interpret the formalism physically as a micro realistic propensity theory, about the evolution and probabilistic interactions of smearons, all measurements being no more than probabilistic interactions between smearons which happen to leave observable, macroscopic traces.

All versions of smearon QM include the following general postulate:

(1) Given two or more systems, there is an absolute distinction between, on the one hand, quantum "disentangled" systems, that have distinct quantum states (represented by vectors in distinct Hilbert spaces) and, on the other hand, quantum "entangled"(36) systems, that have only a joint state (represented by vectors in a joint Hilbert space), the systems not having distinct quantum states. Systems only become quantum entangled as a result of physically interacting. Spatially distinct, noninteracting systems, that have not interacted in the past, have distinct quantum states.

The problem that must be solved, in order to formulate a fully fledged smearon version of wave packet QM, capable of standing on its own feet independently of classical physics, is to specify precise physical, quantum theoretical conditions for a quantum entangled system to become, probabilistically, quantum disentangled. The essential step here is to specify precise, quantum theoretical conditions for smearons to interact probabilistically with one another (even in the absence of measurement). What I wish to advocate as a solution to this problem is that the following postulate (2) be added to the formalism of quantum collision theory.

Suppose an interaction becomes possible (one system can decay, two or more hitherto quantum distinct systems can collide) in such a way that the outcome of the interaction takes the form of two distinct channels, each channel being characterized by its distinct stable particle states. Let the sum of the rest energies of the particles in channel 1 be E_1, the sum of the rest energies of the particles in channel 2 be E_2, and let $\Delta E = |E_1 - E_2|$. Suppose the interaction persists for a period δt and then ceases at time t_1, the two channels becoming orthogonal states [reference (35), pp. 111–9 and Appendix C]. In this case:

(2) After t_1, the state of the system persists as a *superposition* of the two orthogonal channel states only for a time $\Delta t = \hbar/\Delta E$; for times greater than Δt, the state of the system is *either* the state of channel 1 *or* the state of channel 2, even though no measurement has been performed. (A little more precisely, perhaps, we may suppose that, given an ensemble of such systems, each individual superposition decays at a precise instant, statistically the ensemble of superpositions of alternative channels decaying exponentially, with a half life of Δt.) The probability of the superposition decaying into channel 1 (or channel 2) is to be calculated in the standard way, employing the formalism of orthodox QM.

Postulate (2) can be generalized to take into account interactions which produce N distinct interaction channels. We can arrange the rest energies of each channel so that $E_1 < E_2, \ldots, < E_N$, and we can postulate that if $\Delta E_r = E_{r+1} - E_r$ is larger than any other ΔE then, after a time $\Delta t_r = \hbar/\Delta E_r$, the superposition of N channels decays into either a superposition of channels corresponding to $E_1, E_2, \ldots, E_r$, *or* into a superposition of channels corresponding to $E_{r+1}, \ldots, E_N$. In this way, progressively, channels are eliminated as time passes until just one channel is left.

Postulate (2) specifies a micro realistic, quantum theoretic condition for probabilistic events to occur in composite quantum systems. It does not, however, in itself specify a condition for quantum entangled systems to become quantum disentangled. This is provided by:

(3) Given a composite quantum entangled system $S_1 + S_2$, and given that S_2 alone interacts with a third hitherto quantum distinct system S_3 in such a way that $S_2 + S_3$ evolves into N distinct channels ($N > 1$), which then decay as specified by (2), into a channel that is the outcome of an *inelastic* collision between S_2 and S_3, then (and only then) S_1 and S_2 becomes quantum disentangled, and the particles in the surviving channel resulting from the interaction between S_2 and S_3 are quantum entangled.

My claim is that postulates (1), (2), and (3), added to the formalism of quantum wave packet collision theory, enable us to interpret that formalism as a fully micro realistic, propensity, smearon version of quantum theory—a version of QM which predicts how quantum systems (smearons) evolve in time and probabilistically interact with one another. As far as the basic postulates and physical interpretation of the theory are concerned, observables, preparation and measurement can be entirely dispensed with.

Despite the fact that the theory is not, in the first instance, about the results of performing measurements on micro systems with classically described, macro measuring instruments, nevertheless (so I claim) the theory can reproduce all the successful experimental predictions of orthodox QM. This point can be informally established—or at least rendered highly plausible—as follows.

The measurement of any quantum observable—momentum, energy, spin, position—involves essentially the following. First, the ensemble of systems passes through an appropriate selection or filter device which interacts elastically with systems that pass through in such a way that eigenstates of the observable in question are, as it were, separated out spatially so that detection of a system in one such region confirms that the system has the corresponding eigenvalue of the observable in question. Position measurements are then performed on the systems to detect systems in the relevant regions. Sometimes a series of position measurements are made, in cloud chambers, photographic emulsions or bubble chambers, to ascertain paths or tracks of systems. All quantum measurements thus involve at most the following two kinds of interactions between micro systems and (approximately) classically describable macro systems (which, according to the smearon standpoint, are merely composite systems of smearons). First, there are what may be called *coherent* interactions: nonlocalizing, nonprobabilistic interactions capable of giving rise to subsequent interference effects, as when particles are reflected, deflected or diffracted by macro systems such as mirrors, prisms, crystals, large scale electromagnetic fields caused by macro charged plates or magnets. Second, there are *localizing* interactions: incoherent, probabilistic, wave packet reducing interactions capable of being macroscopically recorded as position measurements, subsequent interference effects of the kind associated with coherent interactions being absent, as when interactions are registered as dots on photographic plates, as tracks in bubble chambers, as clicks of geiger counters or as scintillations of scintillation counters.

The smearon version of wave packet collision theory outlined here becomes capable, in principle, of predicting all that orthodox QM successfully predicts if it can, of itself (without the aid of nonquantal classical physics, for a description of measurement) predict the outcome of the diverse *coherent* and *localizing* interactions found throughout quantum measurement.

According to smearon QM, coherent and localizing interactions are to be understood, in broad outline, as follows. There is, let us suppose, a micro system x (or an ensemble of such systems), initially in a quantum state ψ_x, which interacts with a macro system Y consisting of N subsystems $y_1, y_2, \dots, y_N$. Each y_i can be regarded as being confined to a micro spatial region R_i. It may be that the R_i can be regarded as being rigidly fixed in space relative to each other, even if systems vibrate, as in the case of crystals and solids. Alternatively, it may be that the R_i need to be regarded as being in relative motion, as in the case of liquids and gases. The R_i may have wave packets that are relatively coherent or quantum entangled, as in the case of liquid helium: or such overall 'macro' quantum entanglement of subsystems of Y may not exist. In the case of electromagnetic fields it may be necessary to conceive of virtual photons being rapidly created and destroyed. The essential quantum requirement for *coherent* interactions to occur is that x interacts with each y_i in such a way as to leave the relative quantum states of the y_i of Y unaffected by the interaction. This will be the case if x interacts elastically with each y_i, the interaction leaving the relative spin states of the y_i unaffected, and the relative energy states, so that the N paths through R_i ($i = 1, \dots, N$) remain indistinguishable or identical. In some cases inelastic interactions can be coherent, as when neutrons suffer inelastic diffraction through crystals: here, the relative quantum states of the y_i are such that an unlocalized persisting phonon can be created—the unlocalized state of the phonon ensuring that the interactions between x and each y_i are, to that extent, indistinguishable or identical, prior *relative* energy states of the y_i

being unchanged by the interaction. The essential quantum smearon requirement for *localizing* interactions to occur is that x interacts with each y_i elastically (no interaction) and inelastically, each y_i thus acquiring a persisting energy uncertainty ΔE, as a result of being in a superposition of these two interaction channels (at least), the relative quantum mechanical states of the y_i being such that it is not physically, quantum mechanically possible for a persisting, unlocalized entity, such as a phonon, to be created with energy ΔE. According to postulate (2), after the interaction ceases, each y_i can only be in a superposition of the two interaction channel states (differing energetically by ΔE) for time $\Delta t = \hbar/\Delta E$. Because of the relative quantum states of the y_i, no entity such as a phonon, smeared out coherently through the y_i and R_i of Y with energy ΔE, can come into existence or persist. Thus, because of postulate (2), x interacts with just one y_i: as a result, ψ_x becomes abruptly, probabilistically, localized in just one R_i (i.e. $|\psi_x|^2 > 0$ only within one R_i), even if this is not macroscopically recorded—though it is of course thus recorded in all quantum mechanical measurements.

It should be noted that it is certainly conceivable that there are interactions between appropriate x's and Y's which, though *incoherent*, are not *localizing*. Indeed, strictly, according to any orthodox quantum mechanical treatment of the interaction between x and Y, in terms of the quantum states ψ_x and ψ_{y_i}, actual probabilistic localizations, in some one R_i, only occur insofar as a further measurement is performed on the system $x + Y$ by a further measuring instrument Z. In the absence of such an additional measurement, orthodox QM can only predict that $x + Y$ evolves into a *superposition* of such 'localized' states—a superposition that may well be, as it were, incoherent in that no physically feasible selection device can reveal the existence of the superposition by means of subsequent interference effects. It is the failure of orthodox QM to predict, from "quantum mechanical" postulates alone, that *incoherent* interactions between appropriate x's and Y's evolve into *localizing* interactions that creates the traditional conceptual problem of quantum measurement.

Two rather different sorts of problems confront the attempt to give a full quantum mechanical treatment of measurement—however QM is interpreted physically. These two kinds of problems may be called *technical* and *conceptual*. The technical problems can be formulated like this. Given that systems x and Y are prepared in given quantum states (the state of Y being a mixture of possible pure states ψ_{y_i}), can the results be predicted of performing subsequent *measurements* on x and Y, by means of some additional macro measuring instrument Z? In particular, can the probabilities $P_{C'}$, $P_{C''}$,..., and $P_{L'}$, $P_{L''}$,..., be predicted, where $P_{C'}$, $P_{C''}$,..., are the probabilities of various kinds of *coherent* interactions, C', C'',..., being detected by Z (there being perhaps only one kind of elastic, coherent interaction), and $P_{L'}, P_{L''}$,..., are the probabilities of different sorts of *localizing* interactions, L', L'',..., being detected by Z? Given that some particular kind of localizing interaction L has occurred, can P_{R_i} be calculated for all i ($1 \leqslant i \leqslant N$)—the probability that Z detects x to have interacted with Y in R_i? The conceptual problem can be put like this. Granted that all relevant technical problems have been solved, of the above type, can QM predict from this that unlocalized wave packets ψ_x will be localized by all appropriate Y's, even in the absence of measurement by Z? In other words can QM predict that *incoherent* superpositions evolve, probabilistically, into one or other *localized* state?

For many cases orthodox QM can solve, though not always rigorously, *technical* problems associated with giving a quantum mechanical description of interactions between different sorts of micro systems x, and different sorts of macro systems Y. For a general account of technical problems that can be solved see Ref. 35, (Ch. 11: "Scattering of Systems of Bound States"). For a particular example of such technical problems being solved (which unfortunately does not give quite the correct answer) see Golub's and Pendlebury's discussion of the containment of ultra cold neutrons,[37] the neutrons being x, the walls of the container being Y. Here both coherent and localizing interactions occur (as is generally the case).

It must be emphasized that these "technical" problems of giving a precise quantum mechanical treatment of coherent, incoherent and localizing interactions between diverse x's and Y's really are *technical* problems, and not problems of *principle*. The problems arise because of the difficulties associated with solving dynamical laws of QM—such as Schrödinger's time dependent equation—for systems consisting of millions of interacting particles. The capacity of orthodox QM and smearon QM to solve these problems is exactly the same (even if, as we shall see, orthodox and smearon QM do not give precisely the same answers to these problems in all circumstances). Thus the present incapacity of smearon QM to solve all these technical problems as they arise in connection with quantum measurement does not constitute any sort of reason whatsoever for preferring orthodox to smearon QM.

One point does deserve, however, to be made. In a number of cases, orthodox QM can employ some measuring device M, in order to test the predictions of QM, even though a thorough quantum mechanical solution to the technical problems associated with the interaction between particles x and M are not forthcoming. This can be done whenever it can be established empirically, and perhaps by means of some unrigorous mixture of quantum and classical arguments, that localizations occurring in M correspond, quite generally, to eigenvalues of some quantum observable O. There is of course no reason why smearon QM should not also avail itself of such short cuts *in practice*, even though it will of course be desirable, in every case, to develope a full quantum mechanical treatment of the interaction between x and M, which predicts localizations produced by M, and dispenses with orthodox quantum "observables" (or introduces them only as derived concepts).

If orthodox and smearon versions of QM fare equally well as far as *technical* problems of measurement are concerned, the situation is quite different when it comes to the *conceptual* problem of measurement. Postulates (1), (2), and (3) above make it possible for smearon QM to solve the conceptual problem, in the way already indicated. Notoriously, orthodox QM cannot solve this conceptual problem[14,38]— essentially because orthodox QM cannot predict that an *incoherent* interaction between x and Y evolves into a *localizing* interaction (with just *one* y_i in R_i) even in the absence of a further measurement by means of Z.

Thus smearon QM, as formulated here, can in principle predict results for all experiments whose results can be predicted by orthodox QM: in addition smearon QM can solve the conceptual problem of measurement which orthodox QM is unable to solve.

4. ORTHODOX OR SMEARON QM: CRUCIAL EXPERIMENTS

I turn now to the question of whather it is possible to decide between orthodox and smearon versions of QM on experimental grounds.

It might be thought that the experiment of Mandel and Pfleegor[39] refutes smearon QM, in that it refutes the general postulate (1). This experiment recorded interference effects produced by two *independently operated* lasers, the beam of photons being sufficiently attenuated for only one photon to be in the apparatus at a time. Mandel and Pfleegor interpret this result along orthodox lines as being due to each photon interfering with itself, as in the two slit experiment, it being uncertain as to which laser emits each photon. Interpreted in this way, the experimental result dramatically refutes postulate (1)—a point in effect endorsed by Schlegel.[40] If however we interpret the lasers as emitting photon wave packets (smearons) it is possible to hold that two or more wave packets are present in the apparatus simultaneously, interference effects being produced by interference between two such wave packets, each produced by one laser. In this way, the postulate that quantum entanglement (producing interference) is only produced by physical interaction between smearons can be reconciled with the results of the experiment. In order to refute smearon QM it would be necessary to observe interference in a version of the experiment so modified that only one wave packet, associated with a photon, can be in the apparatus at a given time. Failure to detect interference in such a case might be taken to corroborate smearon QM and refute orthodox QM (given that these experimental conditions can be reconciled with the condition, essential for orthodox QM to be refuted, that it is not possible to know from which laser each photon comes). Here, then, is one possible crucial experiment capable, perhaps, of deciding between smearon and orthodox versions of QM.

In all ordinary scattering experiments orthodox QM and the version of smearon QM formulated here give the same results—since such experiments are not designed to detect possible interference between different channels after a period during which there has been no interaction between channels. For such experiments, the conjecture that systems jump probabilistically into just one channel after a time $\Delta t = \hbar/\Delta E$ even before measurement (postulate (2) of smearon QM) leads to the same experimental results as the conjecture that only measurement annihilates all channels but one (orthodox QM). Only a very special kind of experiment capable of deciding between these two conjectures can decide between orthodox and smearon QM (as far as postulate (2) is concerned, at least).

Such a crucial experiment must satisfy the following general requirement. A decaying, or composite, internally interacting system must evolve into a superposition of mutually noninteracting channels with a rest energy difference ΔE. After a period Δt of mutual noninteraction, with $\Delta t \gg \hbar/\Delta E$, these two channels are to interact elastically and *coherently* with some macro system Y so that the two channel states reinteract to form a common outcome, so that no subsequent measurement can determine which channel the system evolved down. In this case orthodox QM predicts interference between the two channel states, as far as the final state is concerned (analogously to the prediction of interference in the case of the two slit experiment): smearon QM, however, predicts that there is no such interference, the system being, after Δt of mutual noninteraction, in just one channel, and not in a superposition of both. Here, then, is the kind of experiment that we must perform if we are to decide experimentally between orthodox and smearon QM. The experiment exploits the general orthodox principle, explicit in Feynman's path integral formulation of orthodox QM,[41] that interference effects arise if and only if the quantum state of a system can be regarded as evolving along two or more different but ultimately indistinguishable paths to a common outcome.

An example of such an experiment might be the following. A decaying particle x is directed towards a screen in which there is a hole in the form of a circular ring with a second small circular hole at the centre. If x decays after passing through the screen, it can only have passed through the central hole: if it decays before reaching the screen, the two decay products pass through the hole in the form of a ring. For there to be interference btween the two channels (1) decay on one side of the screen (2) decay on the other side of the screen, the system must persist as a superposition of the decayed and undecayed states for Δt, the time taken for x to pass through the screen. Smearon QM predicts that there is no interference if $\Delta t \gg \hbar/\Delta E$, where ΔE is the rest energy difference between x undecayed and x decayed. Orthodox QM predicts interference for this case.

5. CONCLUSION

To sum up, in the last two sections I have not, in a sense, outlined a new physical theory: rather, I have merely supplied a new physical interpretation of an already existing physical theory—orthodox quantum wave packet collision theory, or quantum field theory interpreted as a refinement of quantum collision theory. It is for this reason that this paper consists mostly of prose rather than of equations—the task being to reinterpret physically already existing equations rather than to advance new equations. The physical interpretation of QM offered here is, however, in important respects, radically different from that of the orthodox interpretation. QM is interpreted to be a fully micro realistic theory about micro systems interacting deterministically and probabilistically with one another, no essential reference being made, as far as the basic physical interpretation is concerned, to measurement, classical macro systems or observables. I have argued that the standard formalism of quantum wave packet collision theory, interpreted in this way, and including postulates (1), (2), and (3) above, can in principle predict the outcome of all experiments which can be predicted by orthodox QM, even though QM, given this smearon interpretation, does not refer to "measurement" or "observables" as far as the basic postulates are concerned. Technical problems do arise in connection with recovering all the empirical content of orthodox QM from smearon QM alone: the difficulty of these technical problems—having to do with solving the dynamical equations of QM for millions of interacting particles— is however common to orthodox and smearon QM. It is not smearon QM but rather orthodox QM which faces problems of principle—conceptual problems—in connection with measurement.

For almost all experiments, orthodox and smearon versions of QM give precisely the same predictions. The two versions of QM do however give conflicting predictions for one special kind of experiment, designed to determine whether or not composite systems persist in a superposition of interaction channels, in the absence of measurement. To this extent, smearon QM is a theory empirically different from orthodox QM.

Smearon QM has a number of conceptual or formal advantages over orthodox QM. As already mentioned, smearon QM solves the conceptual problem of measurement which cannot be solved by orthodox QM. In addition, smearon QM is more conceptually coherent and unified, much less *ad hoc*, then orthodox QM, in that smearon QM makes no essential use of parts of classical physics clashing with QM (whereas orthodox QM is obliged to make essential use of such parts of classical physics, for a treatment of measurement). Furthermore, smearon QM, as formulated here, has much greater physical precision than orthodox QM in that physical conditions for probabilistic interactions to occur are much more precisely specified—orthodox QM specifying these physical conditions in terms of the very vague notion of "measurement" only, much more imprecise than the quantum condition specified by postulate (2). Smearon QM resolves the classical particle/field problem, and the quantum particle/wave problem, whereas orthodox QM merely evades both problems. I have argued, indeed, that smearon QM would probably have been generally accepted by the physics community long ago, were it not for the accidents of intellectual history, and the tendancy of the physics community to uphold dogmatically positivist or instrumentalist philosophies of physics, long ago discredited within the philosophy of science.[42–45]

There is a sense, however, in which the smearon version of QM proposed here creates more problems than it solves. How precisely are interactions between smearons to be conceived of and described? How, in detail, is a relativistic version of smearon QM to be formulated at least as accurate empirically as existing orthodox quantum field theory? How, for example, is the occurrence of instantaneous probabilistic disentanglements of spatially separated quantum entangled smearons to be reconciled with special relativity? In order to solve this problem, does it suffice to interpret special relativity as concerning *only* the laws of (deterministic) evolution of the states of smearons, and *not* the probabilistic disentanglement of smearons or wave packets? Can smearon QM explain anomalies of K^0 decay, in that here a superposition of two particle states of slightly different rest energy is involved? How can a smearon QM version of general relativity be formulated? One major problem that confronts the task of unifying general relativity and orthodox QM is the problem of accomodating the special role that measurement plays within orthodox QM into the framework of general relativity. This particular problem disappears if we adopt smearon QM; but other problems remain. How can a grand unified quantum smearon theory be formulated, unifying all the particles and forces found in nature? One might almost say that the smearon standpoint proposed in this paper creates so many new theoretical problems for physics that it amounts to a new possible "paradigm" for theoretical physics— to use a term popularized by Kuhn.[46] A model or "blueprint"[32] has been advanced of the ultimate unified pattern of law which, we may conjecture, runs through all natural phenomena. This blueprint asserts: all phenomena are the outcome of interactions between a very few different sorts of *smearons*, entities whose physical states evolve deterministically, and which interact probabilistically in order to avoid sustained uncertainty about the existence of smearons in alternative interaction channels. According to this blueprint, only a theory of this type can acceptably unify general relativity, quantum electroweak field theory and quantum chromodynamics.

These are the considerations which make it important to put smearon QM to the test. In particular, two important preliminary questions about actual and possible experimental data need to be answered. (1) Is there any existent experimental result that refutes smearon QM and verifies orthodox QM (or *vice versa*)? (2) What experiments are technically feasible to perform that are capable of deciding between the two theories?

It is true that the experimental differences between the orthodox and smearon versions of QM are slight: the interpretative, metaphysical and heuristic differences are however profound. If smearon QM should be verified and orthodox QM refuted, a whole new approach to theoretical physics would seem to be required. It would mean that theoretical physics, having tried out the Newtonian idea of the *particle*, the Faraday-Einstein idea of the *field*, and the Copenhagen idea of *evading the issue*, ought now to try out the idea of the *smearon* (a coherent unification of the three previous basic rival ideas of physics).

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