Let $\psi$ be the state of a system with energy operator $H$. In quantum mechanics there are two essentially different ways in which the state changes:

1. The discontinuous change brought about by measurement of quantity $x$ with operator $R$ and eigenfunctions $\{|\phi_i\rangle\}$ the state $\psi$ will be changed to the state $\phi_i$ with probability $\langle\phi_i|\psi\rangle^2$, where the $\phi_i$ are the expansion coefficients of $\psi$ in terms of the $\phi_i$: $\psi = \sum_i c_i \phi_i$.

2. The continuous, causal change in the system with time generated by the energy operator:

$$\psi(t) = e^{-iHt\hbar} \psi_0.$$
Quantum mechanics theory of measurement:

The two rules of V. N. are these: compatible - what occurs in the event that rule 2 is applied to measurement process? - no discontinuity - raises the question of consistency of these two rules.

If we were to deny applicability of rule two to measurement process we are faced with finding when it breaks down i.e. for what \( N \) can a group of \( N \) particles form a measuring apparatus and possibly be no longer subject To Quantum mechanical treatment? Leads to partition of all processes into two kinds: ordinary processes to which QM is valid and measurements where rule 1 holds & rule 2 fails.
Purpose of this note is to show that one can successfully interpret a model which postulates some sort of Universal Wave function, and in which only Rule 2 is valid, in such a way that Rule 1 appears to hold subjectively. I.e., that a completely causal theory is quite adequate, which, on the other hand, leads to an apparently probabilistic world on a subjective level in a rather novel way.

The crux of this theory is the abandonment of the concept of uniqueness of observers, i.e., that there are individual entities, masses, people, what have you, which remain single unique individual throughout periods of time. In this theory when measurements (or in general any observations or interactions) are made on systems by "observers" (by which we merely mean the systems) the observer itself splits into a number of observers each of which see a definite result for the state of the system.
Now all of this, which is seemingly quite farfetched and contrary to our experience, is actually implied if one takes seriously the foundation of Quantum mechanics (without rule 1) and we shall see that we can even recover rule 1 from this picture as a tool of practical expediency, not as a basic hypothesis.

We turn now to the formulation of QM. We shall always be using a particle model in which we envisage the universe to be composed of a large number of elementary particles, possessing a single total wave function which obeys the Schrödinger equation. No results will depend upon this however, they will hold in field theories as well and any wave equations, i.e., any system of Quantum mechanics.

The first question that arises is: what actually does happen in the process of measurement? Several authors (von Neumann, Bohm, ...) treat this question to some degree, and assume an ideal model which consists of a system $S$ and a measuring apparatus $A$. We assume that the variable of interest in the system is $x$, and that the variable of interest in the apparatus is $y$ (such as position of pointer on meter, spot on photographic film, etc.) and that prior to making a measurement the system is in a definite state $|x\rangle$ (wave function) and the apparatus in state $|y\rangle$, and furthermore that they are initially independent, so that the Wave
function of the whole system $Y$ before measurement begins is simply the product w.r.t.

$$Y_0 = \prod_{s+a} Y_0^s Y_0^a$$

The measurement is then brought about by allowing the two systems $s$ and $a$ to interact, i.e. by "turning on" a Hamiltonian $H_1(x, y)$ which is chosen so as to introduce a correlation between the system variable $x$ and the apparatus variable $y$.

However, in order that the measurement be good, the system state must not be disturbed (except in phase) i.e. if the system is in state $Y_k$, it must remain in this state after the measurement $x_i$ (with possibly changed phase)

Now, the measurement is arranged so that corresponding to each system state $x_i$, there will be a definite apparatus state $y_i$ after the measurement.

However, if the system is originally not in a definite state $x$, but has for wave function $\sum_i \alpha_i \phi_i = Y_0$, where $\sum_i |\alpha_i|^2 = 1$ then after the measurement the apparatus will have the state $y$ which will also not be a definite state! It will have as its state $\sum_i \alpha_i h_i(y)$ where $h_i$ are eigen of $y$. This follows from the linearity of the wave equation and the superposition principle. In short, nothing discontinuous has happened! the system has not been forced into an eigenstate, and, indeed, the relative amplitudes for the system have not even been changed! How can it be that rule 1 is an adequate description?
Turn so, however, the apparatus has become correlated to the system, while neither are in a definite state of the variable under discussion (reminiscent of the example of Einstein Rosen's)

This is possible since after the measurement the wave function for $\psi \pm A$ is in a higher dimension space than that of $\psi \mp A$ alone. That is, if we look at a "cross section" of the total Wf. for which the variable $A$ has definite value $\pm$, we find that apparatus has the definite value $\gamma_{\pm}$ which corresponds, while if we choose to look at the cross section for $\gamma_{\pm}$ definite we immediately find $\gamma_{\pm}$ has the definite value $\gamma_{\pm}$, etc.

So we see that from the viewpoint of Quantum Mechanics not when the measuring apparatus interacts with a system which is not in an eigenstate of the variable being measured, the apparatus itself "smears out" and is indefinite no matter how large or "classical" it is! Nevertheless, it is correlated with the system in the above sense and it is this correlation which saves this day and allows us to construct on this basis theories.

Now is it possible this smearing out of even classical objects which is implied by Quantum mechanics and which is seemingly so contrary to our experience? Does this mean that we must abandon our quantum mechanical description and say that it fails at a classical level?
Not at all. All we have to do is carry the theory to its logical conclusion, to see that it is all right after all.

Suppose a human observer sets up his apparatus and makes a measurement on a system, each in an eigenstate of the measurement; the result to appear as the position of a meter needle. According to what we have said the meter needle itself will be "smoared out" after the measurement but correlated to the system. Why doesn't our observer see a smeared-out needle? The answer is quite obvious: He behaves just like the apparatus did—when he looks at the needle (interact) he himself becomes smeared out, but strongly correlated to the apparatus and the system. If we for a moment reflect upon the total wave function of the situation (system—apparatus—observer) and again consider "cross sections" we see that for the definite value of the system, the needle has definite position $y_j$ (nice and classical) and there is a definite observer who perceived this the needle had a definite position $y_j$! And of course, similarly for all other values. In other words, the observer himself split into a number of observers, each of which saw a definite result of the measurement.
We now see that the quantum mechanical description is really compatible with our ideas of definiteness on a classical level, due to the existence of strong correlations. This is the reason for the apparent existence of a classical world.

(Examples: hydrogen atom in box, EPR correlations of us with our surroundings, def. of bodies, etc., etc.)

We see that the real essence of an interaction Hamiltonian is that it is simply a correlation producer.

We now turn around and try to see why rule 1 has been so successful. Imagine an observer making a series of quantum mechanical measurements, from the point of view of wave mechanics. He is splitting each time a measurement is made, so that over a number of measurements we could speak of his "life tree". If we focus on any single "track" of this tree, we see an observer who always perceives definite (and unpredictable) results of his measurements, and to whom the system lies with each measurement apparently popped into an eigenstate of the measurement. (Whereas from our point of view the observer himself has simply split into a number of observers, one for each eigenstate of the system, a process that is quite continuous and causal from the wave mechanical viewpoint.)
Furthermore, for almost all of the "tricks" we might consider the frequencies with which the observer sees the various results will follow the probabilistic law of rule 1. That is, that for practical considerations any observer should use rule 1 for calculating not because the system undergoes any such probabilistic jumps but simply because he himself will split into a number of observers, to each of which it appears that the system underwent probabilistic jumps.

We have, then, a theory which is objectively causal and continuous, and at the same time subjectively probabilistic and discontinuous. It can lay claim to a certain universality since it applies to all systems, of whatever size, and is still capable of explaining the classical appearance of the macroscopic world. The price however is abandonment of the uniqueness of the individual with its somewhat disconcerting philosophical implications.

As an analogy one can imagine an intelligent amoeba with a good memory. As time progresses the amoeba's constantly splits, each time the resulting amoeba having the same memories as the parent. Our amoeba line does not have a life line, but a life tree. The question of identity or non-identity of the amoeba at a later time does not mean too much. At any time we can consider two of them and they will have common memories up to a point (common ancestry) after which they will diverge.
to their separate lives up to this point. It becomes simply a matter of terminology as to whether they should be thought of as the same amoeba or not or whether the phrase "The amoeba" should be reserved for the whole ensemble. We conget a closer analogy if we were to take one of these intelligent amoebae, erase his past memories, and render him unconscious while he underwent fission, placing the two resulting amoebae in separate tanks, and repeating this process every time a fission occurred so that none of the amoebae would be aware of their splitting. After a while we would have a large number of individuals, sharing some memories with one another, differing from one another, or others. Each of which would be unaware of his "other selves" and under the impression that he was a unique individual. It would be difficult indeed to convince such an amoeba of the true situation short of confronting him with his "other selves."

The same is true if one accepts the hypothesis of the universal wavefunction. Each time an individual splits, he is unaware of it, and any single individual is unaware of his "other selves" and from then on has no interaction with them.
Summary:

We have indicated that it is possible to have a complete causal theory of quantum mechanics which simultaneously displays probabilistic aspects on a subjective level, and that this theory does not involve any new postulates, but in fact results simply by taking seriously wave mechanics and assuming its general validity. The physical reality is assumed to be the wave function itself (of the entire universe).

By properly interpreting the internal correlations in this wave function, it is possible to explain the appearance of the world to us (classical physics, etc.), as well as the apparent probabilistic aspects.