The Fourth Structure of Physical Reality

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Summary

In the course of a study of elementary particles, an analysis is given of a fundamental presupposition of many research programs, namely the belief in the ultimate unity of physics. It is argued tht this unity-idea is incorrect. By classicial physics, relativity theory and quantum theory three distinct structures of nature are revealed.

Next, the essential aspect of measurement, that a measurement always results in a record, is analysed. Recording implies irreversibility and entropy production. In modern elementary particle physics the record itself is all important, and therefore the entropy production due to measurement is essential.

It is argued that this aspect of measurement will play a central role in a distinct theory concerning fundamental characteristics of elementary particles, revealing a fourth structure of physical reality. Some basic notions of this new theory are proposed. Finally the meaning of irreversibility on the micro-level of elementary particles is discussed, in connection with the concept of time.

INTRODUCTION

A fundamental property of each measurement is that it results in a macroscopically observable effect, the *record* (e. g. registrations of a penwriter, photographs, spectral lines). By means of these records all information in physics is obtained. The recording process always implies irreversibility, and thus an increase of entropy.

The main aim of this paper is to show that this recording process is a distinct aspect of measurement and of crucial importance for a satisfactory theory of fundamental characteristics of elementary particles.

First however, I have to discuss a rather fundamental idea about progress in physics, which could lead us from the very beginning on a wrong track. A basic presupposition in many researchprograms is the idea of the ultimate unity of physics: that is, ultimately there has to be *one* (single) theory which will give a unified conceptual representation of physical reality. Accordingly, the idea about progress in theoretical physics is that earlier well established theories should be encompassed in some way in a new theory, which should originate from and build on the earlier ones.

This idea is not, as one could think, a postulate of science. A fundamental methodological principle of science is to strive for *coherent* insight. In physics this principle sometimes led to distinct theories with definite relations between each other, sometimes to unified theories (Maxwell theory is an example). The question as to whether a unified theory can be achieved or not, is only to be answered by investigation of the facts of nature.

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The history of physics in this century has witnessed two major revolutions, special relativity theory (RT) and non-relativistic quantum theory (QT). The issue which I would like to discuss is: can the theories of classical physics (CP), RT and QT ever be united, and is the idea of the ultimate unity of physics correct or not. An analysis of this problem is highly necessary, because the answer will be very important for the researchprograms on elementary particles and for research on the measurement problem.

So, first of all, I will start with this analysis. This analysis will in passing give many detail results which can be of use in later parts of this paper. After this first part I shall analyse in the second part the recording process, especially in connection with elementary particles. In the third part I will give an outline of a new research program, and I will finish in the fourth part wich some discussions, conclusions and reflexions.

1. THE BELIEF IN THE ULTIMATE UNITY OF PHYSICS

Can CP, RT QT be united, and is the belief in the ultimate unity of physics justified?

The answer to this question can be found by the following comparative analysis of these theories.

The revolutionary character of RT and QT is closely related to the essential role of the act of measurement. This manifests, as recognized by Bohr, the centrality of the relation between the measuring system (the instrument) and the observed object. In order to appreciate the essence of these theories we must consider the way instrument (i) and object (o) are related. The first aim, therefore, is to see in which ways i and o are related in CP, RT and QT.

In *CP* the observed object can consistently be said to exist independent of and separate from the instrument. Of course, for measurement some contact (e. g. a signal or interaction) is needed with the instrument. But the measurement process essentially plays no role in the theories of CP. In other words, in CP nature is conceived of as quite independent of the observer. Therefore this i–o relation Ro can be expressed briefly as follows:

Ro – *i and o are completely autonomous and separable.*

RT and QT are departures from CP as a consequence of the fact that the quantities $\frac{1}{c}$ and h, tacitly taken to be zero, are actually finite. In RT, as a consequence of the finite velocity of light, signal is a key concept. Therefore, the meaning of e. g. simultaneity must now be understood as being relative to the (speed of the) observing instruments. In general, measuring results (e. g. measurements of length and time intervals) have a corresponding relativity. In RT it is not physically meaningful to give *separate* fundamental importance to the 'observing instrument' or to the 'signal' or to the 'observed object'[1]. Further, in RT the state of a system exists independently of the measurement.

[1] M. Sachs, 'The elementary of measurement in relativity', *Boston studies in the philosophy of science*, III, R. S. Cohen and M. W. Wartowsky (eds.), (Dordrecht: D. Reidel, 1967), p. 56, 58.

So, i and o, which are still autonomously existing systems, are coupled in RT; in principle there cannot be any actual separation. In other words:
R_1 – *i and o are completely autonomous, but not separable.*
So, this i – o relation R_1 is a consequence of the fact that one specific aspect of information acquisition, namely information transport, not really relevant in CP, now becomes crucial. I call this aspect A1.

In QT, as a consequence of the quantum of action, there is a 'wholeness' (Bohr) of the i-o situation. The two are indivisibly linked during the interaction, so that it is impossible in principle to separate object from instrument. It is not relevant to speak of i and o as two systems, each having its properties autonomously. The object cannot be ascribed an independent reality in de sense of CP. The systems i and o are not autonomously existing but partly overlapping systems, and the uncertainty relations express the extent to which they overlap (as these relations express the extent complementary notions may overlap).[2] Further, to characterize a measuring situation one always needs the distinct concepts i and o. (Note that the distinction then made is not physical but logical.) Therefore the i-o relation in QT can be formulated as follows:
R2 – *i and o are not completely autonomous, they partly overlap.*
So, this i-o relation R2 is a consequence of the fact that a new aspect of measurement A2, neither relevant in CP nor in RT, now becomes crucial. This second aspect of information acquisition A2 is the information transmission, for it is by the interaction that information is transmitted to the instrument.

So there are three qualitatively different i-o relations Ro, R1 and R2. One can express the significance of R1 and R2 by saying – in a sense Bohr did– that RT and QT have given us, after CP, *two different lessons* in epistemology. But the lessons of these theories are more than only epistemological.

The epistemological aspects of the theories are closely connected with the ontological ones. To indicate this briefly: the ontology presupposed by RT is different from the classical one; one can call it a 'world' of events and relationships rather than of things and substances. And R2 also implies radical new ontological notions. It is a 'world' of probabilities and possibilities; requiring new ideas about causality etc. The ontologies of CP, RT and QT are not incompatible – though they are very different – because their validity is restricted to those levels (or structures) of nature, where the aspects A1 and A2 are pivotal.

I summarize:
Central in CP, RT and QT are respectively the qualitatively different i-o relations Ro, R1 and R2. These relations correspond to Ao (i. e., no aspect of measurement is crucial), A1 and A2 respectively. And again connected with the i-o relations are the different ontologies.

This leads to the conclusion that the fundamental theories *cannot be unified*, for the conceptual unification in one theory leaves out the real epistemological

[2] M. Jammer, the conceptual development of quantum mechanics, (New York: Mc Graw-Hill, 1966), p. 348.

and ontological differences. But these differences are real, because they are intimately connected with real distinct aspects of measurement and the fundamental constants of nature c and h.

It is in full agreement with this conclusion that classical mechanics *cannot* be deduced from QT, as many studies have shown[3]. From this conclusion it is further immediately understandable that despite many efforts no attempt to unite RT and QT in a coherent way has succeeded. There are of course relativistic quantum theories, but in these theories one has *adapted* an existing QT to the requirement of Lorentz invariance, it is not a *unification* of both theories in *one* theory. (In other words: "... to knit together the basic concepts of quantum mechanics and those of relativity in the same theory appears to be an extremely arduous programme that has not yet been achieved."[4] Thus the theories are in fact simultaneously in use and for special cases more or less well combined.

The impossibility to unify the fundamental theories implies, that the presupposition of the ultimate unity of physics is *incorrect*. Thus, also the corresponding idea about progress, namely that new fundamental theories should always encompass earlier ones, has to be given up.

This conclusion is in full agreement with the fact that QT was *not* developed according to that idea about the development of theoretical physics. QT was developed to understand the language of the spectral lines. In the decade previous to the realization of QT research had shown, that a full explanation of spectra required a relativistic atomic theory. So, Schrödinger first worked towards a relativistic theory. This approach seemed quite self-evident and was furthermore in full agreement with the unity-idea. Despite all this, QT actually emerged as a non-relativistic theory. In order to succeed Schrödinger (and others) had to abandon their earlier approach[5]. (The real reason was not that Schrödinger did not know electron spin at that time. In hindsight we now realize that QT had to be developed as a distinct (non-relativistic) theory, for it concerns a new structure of nature, a second fundamental aspect of measurement A2, distinct from A1, which is pivotal in RT only.)

A further consequence that I have to discuss briefly is that the basic but wrong presupposition is responsible for many interpretation problems, especially of QT. Many people have tried to adapt QT to a philosophy which they prejudicially cherished, instead of adapting their philosophy to the facts of nature. Acutally there exists a great variety of interpretations. I have elaborated elsewhere[6] that it is exactly the unity-idea which *causes* this variety.

[3] C. A. Hooker, 'The nature of quantum mechanical reality', *Paradigms and paradoxes*, R. G. Colodny (ed.), (Pittsburgh: University Press, 1972), p. 201, 267.

[4] R. Lestienne, 'Four ideas of David Bohm on the relationship between Quantum Mechanics and Relativity', *Quantum mechanics a half century later*, J. Leite Lopes and M. Paty (eds.), (Dordrecht: D. Reidel, 1977), p. 227.

[5] L. Wessels, 'Schrödinger's route to wave mechanics', *Stud. Hist. Phil. Sci.*, vol. 10 (1979), p. 311–340.

[6] G. J. Stavenga, 'Het geloof in de eenheid van de fysica', *Kennis en Methode*, vol. 4 (1980), p. 123–139.

For, the belief in the unity of physics entails that there must be *one* picture of physical reality, thus *one* epistemology and *one* ontology. Therefore, if your particular type of philosophy is accordant to the RT, then you have to adapt the QT (as Einstein did); if you worked out a philosophy close to QT (as e. g. Bohr), then you have to reconcile CP and RP with it; do you stick to a realistic view in the classical sense (as e. g. Popper), then the unity-philosophy forces you to some rather special interpretation of QT. So many varieties are possible. It is the one basic prejudice that is at the root of these seemingly endless discussions and debates.

In my opinion this presupposition is a tenacious relic of metaphysical ideas concerning the unity of nature. One can elaborate this with regard to the philosophical ideas of Einstein (a Spinozistic philosophy), Heisenberg, Von Weizsäcker, several positivistic thinkers, and others.

As already mentioned, this presupposition is – consciously or not – a central idea in many researchprograms. This leading idea is incorrect and – in my opinion – that is the main reason why these programs failed in their efforts to make a real breakthrough. The same holds true for the efforts to develop *one* theory of *the* measurement process (e. g. by some extension of QT).

I think, we are now well prepared to analyse, in the next part, the recording process and its connection with the elementary particle.

2.1. Information recording and increase of entropy

Whenever an experiment is performed in the laboratory, a record must be the result. Records result from complex irreversible processes. Thus, each experiment is paid for by an increase of entropy. This can be demonstrated as follows: Before the measurement is carried out, the instrument (e. g. a photographic emulsion or a Wilson cloud chamber) is brought into a thermodynamically metastable state, capable of evolving towards a stable state. During the measurement the closed system, comprising instrument and object, evolves into the more probable state of stable equilibrium. Usually this irreversible process is subsequently amplified. The result is a macroscopic effect, a record which can be used by the investigators.

In the last decades there has been much discussion on this irreversibility due to measurement, in connection with the problem of the quantummechanical measurement. However without conclusive results. The problem is: on the one hand there is this irreversibility, on the other hand the fact that the formalism of QT is completely symmetric with respect to time reversal. I note three points:

1. As discussed, in QT is central the second aspect of measurement A2. If the irreversibility is a consequence of this aspect, thus of the (quantum-mechanical) interaction, then it has to be explained by QT. In fact, all efforts failed. Whichever way one turns, from QT – however fundamental a theory it is – one cannot deduce the origin of irreversibility of nature.

2. Nevertheless, the quantum measurement process does appear to introduce irreversibility . For example, the phenomenon known as the 'collapse of the wave function'. But, as remarked by several authors, this is comparable with certain classical types of measurements. "For example measuring the temperature of a body with a thermometer involves an irreversible flow of heat from the system to the instrument (or vice versa) and this is irreversible in spite of the fact that the equations of motion for classical systems are invariant under time-reversal"[7].

3. The increase of entropy due to the irreversible measuring process plays no role in the formalisms of CP (except thermodynamics), RT and QT. As already mentioned, these formalisms are completely symmetric with respect to time reversal. Apparently this increase of entropy is negligible in these theories. In fact this increase of entropy is usually extremely small (as a consequence of the smallness of k, the constant of Boltzmann)[8]. From these three points I conclude:

Firstly, that the recording process (with its irreversibility and entropy production) is a distinct aspect of information acquisition, a third aspect A3, not deducible from other aspects.

(I think Leon Brillouin formulated the same, though in a slightly different way: "This principle (the negentropy principle of information) imposes a new limitation on physical experiments and is independent of the well-known uncertainty relations of quantum mechanics"[9]).

Secondly, that though there is in CP, RT and QT always recording and thus irreversibility, this third aspect A3 is not *crucial* in these theories, that is to say that these theories are not affected in their structure by this aspect of measurement.

Let me sum up the three aspects:

A1 information transport, central quantity signal velocity, pivotal in RT only.

A2 information transmission, central quantity quantum of action pivotal in QT only.

A3 information recording, central quantity entropy, hitherto not crucial in fundamental theories.

(Note that the distinctness of the three aspects is also illustrated by the fact that *action* and *entropy* are fundamental relativistic invariants.) That A3 is a distinct fundamental aspect of measurement does not as such mean that it will play a similar role in theoretical physics as A1 and A2. That has to be demonstrated. In fact, a characteristic of modern physics is the reflexion on the physical preconditions of experience. Let me quote here Prigogine: "In the line of thought inaugurated by the theory of relativity and followed by quantum

[7] J. M. Jauch, 'The problem of measurement in quantum mechanics', *The physicist's conception of nature*, J. Mehra (Ed.), (Dordrecht: D. Reidel, 1973), p. 686.

[8] L. Brillouin, *Science and information theory*, (New York: Academic Press, 1962), p. 184, 288, 293.

[9] *Op. cit.*, note 8, p. VII, 233.

mechanics, it is a basic objective of theoretical physics to make explicit the general limitations introduced by the measurement process"[10].

Brillouin showed[11] that the increase of entropy in a measurement is very small but *cannot be zero*, because the smallest possible amount is of the order of k. In the next section I shall demonstrate that the aspect A3 and thus this increase of entropy (however small, but non-zero) becomes all important, namely when the record itself becomes all important, as it is in modern elementary particle physics.

2.2. Records of elementary particles

In high-energy physics information of elementary particles is obtained by means of counters and track detectors. In the bubble chamber, for example, tracks of (charged) particles are formed. From pictures of these tracks the properties of elementary particles are calculated. Usually one says that the trail of bubbles is the path of a charged particle. However, one can only *interpret* that this track concerns one particle. It is not possible to demonstrate by means of measurement (i. e. by two distinct measurements) that it was one particle (i. e. one identical thing) that moved along a trajectory. Actually it is only this one particular record which defines a particle. So, a deviating trace may lead to the conclusion that a particle not yet known is concerned. It is the unique record which is now all important because from this one record only we have to deduce *all* information (of course with the knowledge of the whole experimental set up, magnetic fields etc.). So, in the modern experimental situation it is no longer adequate to speak of an object existing independently of the measuring result, the record. (Note that repetition of the experiment can never concern the same particle, but only a similar particle; and you can of course prepare a beam of elementary particles, but you cannot prepare an individual particle).

The particularity of these records and of this whole experimental situation is conspicuous when compared to the situation in CP. A measurement, for example the measurement of the temperature of a liquid by means of a column of mercury in a thermometer, can be repeated without any problems. So the record itself is not really important; it is only a means of obtaining information. This is the case because (according to Ro) in CP the objectsystem (e. g. the liquid) can be identified independently of the special record. In other words: system identification (or preparation) and system measurement are two fully separately performable activities. So, according to the measuring situation in CP, one can consistently speak of the objectsystem existing independent of the special measurement of a property. Consequently essential information, namely concerning the identity of the system, is completely independent of that special measurement. Thus the system is considered as an isolated system. Of course, this is only possible in good approximation because a system, if

[10] I. Prigogine, *From being to becoming.*, (San Francisco: W. H. Freeman, 1980), p. 44.
[11] *Op. cit.*, note 8, p. 184.

observed, is always an open system. And that is the reason why (as we have already seen) in CP entropy production due to measurement is neglected.

In this respect the situation in RT and QT is in principle not dissimilar, though measuring in QT is more complicated. In QT, according to R2, system preparation and system measurement can no longer be performed as two *fully* separate activities. But still one can speak of an existing system distinct from the record (e. g. a spectralline). Further, QT presupposes that the interaction of the object and the instrument lasts only a short time. So, still in QT the system is considered in approximation as an isolated system.

As already indicated, the measuring situation in modern elementary particle physics is a completely different matter. The relation (in QT) between the atomic system and the record (the spectralline, which supplies the information concerning the *state* of that system), essentially differs from the present relation, namely between the elmentary particle and the track. The track concerns (the existence of) the system itself. As discussed, the unique record itself is now all important. All information has to be obtained from one single measurement. System identification and system measurement, formerly more or less separately performable, must now be regarded as fully non-separate, completely overlapping, in fact as one activity. So, indeed, to speak of an object-system existing independently of the record and the recording process is no longer appropriate.

This analysis of the particularity of the experimental situation in modern elementary particle physics leads in my opinion necessarily to the following conclusions: A *separate* system identification is totally impossible, therefore *no* information concerning the identity of the system exists *independent* of the particular recording process. Thus, information concerning particle identity is intimately connected with irreversibility and entropy production. Consequently the system at this level can no longer be considered as an isolated system. Essentially it is an open system.

I conclude:

We cannot understand the most fundamental characteristics of the particles (the masses e. g.) if we disregard the recording process with its irreversibility and increase of entropy. In other words, the distinct aspect of measurement A3 is crucial with regard to these properties of elementary particles.

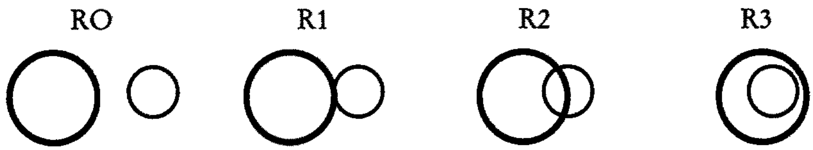
Already now it is possible to see that this measuring situation, in which A3 is crucial, means a qualitative new relation R3 between instrument and object (Just as, when A1 is pivotal we have R1 and A2 implies R2.) This new relation is already implicit in the foregoing analysis. I repeat some points briefly: Identification of the object-system independent of the one particular measurement is totally impossible. System identification and system measurement now completely overlap (and not partly as in QT). So one cannot speak of an existing object independent of the measurement. One can only conclude to a particular particle *after* the measurement is performed. (In QT one can only conclude to a particular *state* of a system *after* the measurement is performed.) Therefore this i-o relation can be described as follows:

R3 – *o is fully non-autonomous; i completely overlaps o.*

The full epistemological significance of this new relation can only be seen when a new theory is elaborated.

2.3. *A new, distinct theory*

Thus, with the distinct aspects of measurement are connected four distinct i-o relations; with R1, R2 and R3 increasingly different from the classical i-o relation Ro. A diagrammatic representation of these relations can be given by means of two circles representing i and o, with various degrees of overlap.



These diagrams do not represent spatial relationships of i and o, but only the ways they are related in the different measuring situations. (I note that the four relations form a complete set, because they are the only four possible qualitatively different relations.)

The i-o relations together with the aspects of measurement are summarized as follows:

Aspect of information acquisition	crucial quantity	constant of nature	i-o relation	theories
A0 no aspect is crucial			RO	CP
A1 inf. transport	signal velocity	c	R1	RT concerns A1 only
A2 inf. transmission	quantum of action	h	R2	QT concerns A2 only
A3 inf. recording	entropy	k	R3	?

The conclusion of the previous section was:
A3 must be pivotal in a theory concerning the most fundamental properties of elementary particles. What can now be said about this theory? I think many people would say: QT and relativistic quantum theories are indispensable for the understanding of the behaviour of elementary particles. In fact today highly developed relativistic quantum theories are rather successfully applied to modern experimental results in elementary particle reserach. Therefore the most obvious answer seems to be: one has to make in some way an extension of these theories.

However, on the basis of the given analysis I will now argue that this answer is false. Let me first remind you of my earlier remarks on the situation in the twenties: RT was indispensable and relativistic atomic theories were rather successfully applied by Sommerfeld and others. Yet there emerged a distinct,

i. e. a non-relativistic quantum theory,a distinct theory with a distinct conceptual framework, adequate to the new aspect A2 and the new measuring situation R2. Afterwards this theory was necessarily combined with RT, to explain spectral lines containing information due to relativistic effects. The present situation is, in my opinion,very similar.

A3 being pivotal means that central notions in the theory must be irreversibility, entropy production and open system. This implies that the system is in continuous contact with the outside world, and *not* only for a short time as is presupposed by QT. (Already more than then 25 years ago Günther Ludwig pointed out, that therefore at this level of elementary particles, the quantum mechanical description by means of a Hamilton operator could become meaningless[12].) The conceptual and mathematical framework of QT (and its extensions) is appropriate for describing *states of* microphysical systems and for describing interactions between them. What is needed now is to understand the existence and identity of the systems themselves. In fact, the failure of modern theories (all extensions of QT) is the inability to provide e. g. the particle masses (and also the numbers which enter into the theories of the fundamental forces).

The conclusion must be: neither QT nor an extension of it can deal with this fundamental level of nature. Therefore, again as in the twenties we have to leave the wrong unity-idea of progress in physics, which is at the basis of all the extensions. The distinct aspect A3 and the new epistomological situation (characterized by R3) require an adequate distinct new theory NT). Thus, there has to be developed a non-relativistic and non-quantum theoretical new theory, which concerns aspect A3 only.

Does this mean that QT is played out? Certainly not. On the contrary. The present records often also contain much information which must be explained by theories which are based on RT and QT. That is why already now relativistic quantum theories have some success with regard to these records (I think this is comparable to the success of Sommerfeld's work on spectral lines). Therefore, once the NT is in existence as a distinct theory, it has to be combined in some way with relativistic quantum theories. This will lead to an understanding of a much wider body of experimental results.

Starting from the general characteristics of NT discussed above, I shall point out some lines along which a physical reserach program can be conducted which may lead to the emergence of NT as a real physical theory.

3. THE STABLE ELEMENTARY PARTICLE AS STEADY STATE OF AN IRREVERSIBLE PROCESS

The central notions of the NT as a distinct physical theory of fundamental properties of elementary particles have been mentioned above: irreversibility and entropy production. Exactly these notions are central in an established

[12] Ludwig, 'Zur Deutung der Beobachtung in der Quantummechanik', *Erkenntisprobleme der Naturwissenschaften*, L. Krüger (Ed.), (Köln: Kiepenheuer & Witsch, 1970), p. 433.

theory, namely the thermodynamics of irreversible processes[13]. This theory was mainly developed in the years between 1930 and 1950. I suppose that this macroscopic theory (and its modern extension[14]) will be of great value for developing the NT. (Perhaps even the mathematical formalism can be partly used.)

In the thermodynamics of irreversible processes the entropy production is a basic quantity which plays a fundamental role. The irreversible processes are due to the presence of (generalized) forces (e. g. a temperature gradient) and corresponding flows. The mathematical expression of the entropy production due to these irreversible processes is a sum of terms each being a product of two quantities, a force and a corresponding flow. There is a steady state when the entropy production is continuously compensated by entropy-flow (entropy flowing out of the system, or, a stream of negentropy entering the system). Such a steady state is characterized by minimum entropy production (Prigogine).

These notions make it possible to understand that an elementary particle of which the identity is closely connected with irreversible processes can yet be stable. The stable particle is thus thought of as a steady state of an open system, characterized by minimum entropy production. In reverse, a particular steady state (with minimum entropy production and certain forces and flows) characterizes a particular stable particle. So a different steady state means that there is a different system, and *not* a different state *of* a system[15].

The stable elementary particle thought of as the steady state of an open system, should not be imagined as an open system in the classical sense, i. e. independent of the measuring instrument. The system is not open with regards to the surroundings, with the instrument independent of it as it is in CP. The contact is just between system and instrument, for the entropy production is connected with the measurement itself. Due to i-o relation R3, even more than is the case in QT, the theory does not concern an independent reality but a measured-reality.

[13] S. R. de Groot, P. Mazur, *Non-equilibrium thermodynamics* (Amsterdam: North-Holland, 1962).

[14] G. Nicolis, I. Prigogine, *Self-organization in nonequilibrium systems* (New York: J. Wiley, 1977).

[15] The situation in QT is different: there, stationary states are possible states *of* a system. So we easily see that e. g. Heisenberg remains inside the conceptual framework of QT when he wants to see the particles as a *spectrum* of particles; he wrote in one of his last papers: "the different particles are just different stationary states of the system matter" (W. Heisenberg, 'Cosmic radiation and fundamental problems in physics', *Naturwissenschaften*, vol. 63 (1976), p. 63–67).

In QT the state of a system is the superposition of the eigenvectors of the operators that describe the structure of the system.

It is important to distinguish between the superposable and the non-superposable properties of the elementary particle. The typical properties which characterize the particle (e. g. an electron) as a structure of individuality (e. g. charge, lepton number) are not subjected to the superposition principle. This means, for instance, that we cannot change an electron into a positron.

Therefore it is inappropriate – even in an analogical way – to concieve of the two particles merely as different states of the same system.

From the macro-theory we can learn that there is a direct connection between the entropy production and the 'generalized' forces. I conjecture that these forces are the fundamental forces or couplings in modern elementary particle physics. In fact, elementary particles e. g. hadrons and leptons, can be distinguished by their responses to the fundamental forces. Thus, in this way the forces are to be understood closely connected with the measurability of the particles. Thus, in principle this 'model' has indeed the possibility of explaining some fundamental characteristics, namely the forces, but also the particle masses as I will point out next.

In a steady state the entropy of the open is system constant. I conjecture that there is a certain relationship between this constant entropy and the rest energy of the elementary particle. This is plausible because the important quantity energy (and the specific form of energy) will be essentially connected with the specific aspect of measurement which is pivotal and with the corresponding central constant of nature. So indeed in RT and QT such relations are most important, namely $E = mc^2$ and $E = h\nu$. In NT A3 and k being pivotal suggests that the form of energy is accordant to A3 and that the energy of the elementary particle is the constant of Boltzmann times a temperature, a relation of course similar to the one well known from classical physics.

If this conjecture is correct then this would mean that in some sense the particle should be attributed a temperature. This poses the question: how can these typical macro-concepts (open system, temperature, entropy) be used in relation to the elementary particle? Does it mean that the elementary particle itself consists of many particles even more elementary? I think not.

A comparison with QT, particularly with the wave picture of the particle, can elucidate this. The wave concept of CP originates from macrophenomena (a wave due to the disturbance of e. g. a watersurface). This wave concept is used in QT. The waves in QT however' are not waves in ordinary space, but waves in an abstract mathematical space. Yet they have a real-world meaning as is shown by experiments (e. g. those of Davisson and Germer concerning diffraction phenomena of elementary particles), which can only be explained on the basis of wave characteristics. I think, the situation in NT is similar: the concepts open system, temperature and entropy production can only be applied to elementary particles in an abstract sense. The real-world meaning, however, is apparent from the experiment: the appearance of records of elementary particles. These records can only be explained by using these concepts.

4. DISCUSSIONS, CONCLUSIONS AND REFLEXIONS

Several years ago Louis de Broglie tried to develop a "thermodynamics of the isolated particle". According to him, the hypothesis of the existence of a subquantum region (a heat-reservoir) makes it possible to attribute a temperature (according to the equation $m_0c^2 = kT_0$) and an entropy to the particle[16].

[16] L. de Broglie, *La thermodynamique de la particule isolée*, (Paris: Gauthiers-Villars, 1964), p. 86, 100.

De Broglie's main aim, however, was to obtain a better interpretation of QT and an extension of this theory[17]. His approach is basically determined by the unity-idea.

The same holds true for Heisenberg. Heisenberg emphasizes that besides the fundamental units c and h there must exist a *third* fundamental unit which is, like c and h, connected with a new fundamental structure of nature[18]. To form a complete set of (natural) units of measure, we must have at least three. "There must be a third one, and only a theory which contains this third unit can possibly determine the masses and other properties of the elementary particles"[19]. However, he did not try to develop a theory with regard to that new structure. Actually he tried to develop a unified theory which encompasses earlier closed theories, and for that reason he chose as the third constant an "elementary length". One of the problems of an elementary length however is that it is not a relativistic invariant, as e. g. Gamov remarked in his article "The three kings of physics"[20].

From the foregoing it is clear that the constant of Boltzmann is a much better candidate for the third king, i. e. as the third fundamental unit of measure in nature. As argued, connected with this constant of entropy k is a third aspect A3, a third i-o relation R3, and fundamental charcteristics of matter, thus, a new fundamental structure of nature.

If this is correct, then we must conclude that there are altogether four different distinct structures of nature, namely the structures of CP, RT,QT and now the new structure.Accordingly the development of theoretical physics successively reveals these structures. In other words, it is now comprehensible why there was just this actual sequence of fundamental theories.

I have argued that now a new fundamental theory has to be developed to reveal the new structure of nature. In this paper I have presented some ideas for a reserachprogram which should lead to that theory. As already implicitly indicated, these ideas also give the possibility for the solution of a longstanding problem in physics.

A stubborn problem in theoretical physics is how to explain time asymmetry, when all known laws of physics are invariant under time reversal. If the ultimate constituents of matter are necessarily concieved of as open systems with irreversibility and continuous entropy production, then there is a possibility for a definite solution of this problem; for irreversibility is then already existent on the (most fundamental) micro-level.

Thus, I think we can say of this structure of nature, that this is the level of the genesis of time. Apparently, matter and time are most closely connected at this level. If we look at the development of theoretical physics, its essential stages from CP until now, we see that in CP matter and time can be conceived

[17] G. Lochak 'Irreversibility in physics', *Foundations of physics*, vol. 11, (1981), 593–621.

[18] W. Heisenberg, *Schritte über Grenzen*, (München: R. Piper, 1971), p. 25–33.

[19] W. Heisenberg, *Physics and philosophy*, (London: G. Allen and Unwin, 1959), p. 143.

[20] G. Gamov, "The three kings of physics', *Physics, Logic and History*, W. Yourgrau and A. D. Beck (Eds.), (New York: Plenum Press, 1970), p. 207.

of as completely separate; time is a parameter independent of the existence of matter. This changed in RT. It changed again in QT (matter with wave characteristics). In the present situation time must be understood in most intimate connection with the very existence of matter (matter as an irreversible process). From the foregoing it is obvious that these stages in the relation of matter and time are closely connected with the four i-o relations.

I conclude:

By means of records all information about matter is obtained. The main aim of my paper was to show that the recording process is of crucial importance for a satisfactory theory of fundamental characteristics of elementary particles. If this is correct then this means that the knowability of matter is most intrinsic to matter itself. Matter is fundamentally a measured, a known reality.

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