Interlacing of theory, experiment and instrument in accelerator-based experiments: the "theoretical-operational" model

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In accordance with the ideas of I.Hacking and P.Galison, and the "theoretical-operational" structure of experiment of Fock-Lipkin, a symbolic language is developed for the description of structure of a contemporary complex experiment. With its help a particle accelerator-based experiment is analysed as an example of this kind of experiments, where explication and analysis of the following essential features is performed: the roles of instrument, background, data analysis, and their theoretical components. An attempt is made to clarify the concepts of "instrument" and "complexity" of experiment.

Introduction

The issue about "theory-lading" of experiment runs all through postpositivist philosophy of science. But there is lack of accurate method and form of representation which give opportunity to mark out numerous theoretical components in experiment.

A three-part structure of experiment in quantum mechanics is done by V.A.Fock in his dispute with N.Bohr [6]. The problem of symbolic description of the micro- to macroscopic world transition was discussed by D.I. Blokhintsev [13]. A.Lipkin affirms that already in Galileo's theory of falling body (in his "*Discourses*...") there was a structure very close to Fock's one, which in [2-4] is represented as the "theoretical-operation" three-part structure of experiment:

$$\langle P|ph/T|M\rangle, \qquad (1)$$

where operation of preparing $\langle P|$ and measurement $|M\rangle$ are taken from technique, they are artificial and belong to the "second nature", and natural phenomenon *ph* (and/or its theoretical description T) belongs to the "first nature". This heterogeneous structure, where theoretical and operational parts were united, was one of the main features of the science revolution of 17th century in which natural philosophy was transformed in natural science of the New Age.

Let us try to develop this structure toward explicit introducing the theoretical components of different levels and character. First of all we have to give an answer to the following question: "Is the structure of physical experiment (1) in accordance with I.Hacking's and P.Galison's descripitons, which goes from the laboratory side, instead of theory side as in [6; 2; 5; 9]? We give a positive answer to this question. Indeed, from our point of view Hacking's "representing" and "intervening" are close to our "theoretical" and "operational" (mainly "preparing") parts in (1). Hacking fixes the same main features of the science revolution of 17th century as we did when he states that «reality as intervention does not even begin to mesh with reality as representation until modern science. The natural science since the seventeenth century has been the adventure of the interlocking of representing and interving" [7, p. 146].

J.Maxwell's division of instrument onto three functional classes: «sources of energy», «transporters of energy», and «measurements» (of phenomena) also fits into structure (1) splendidly [8, p. 23-24]. The first two classes correspond to preparing $\langle P|$ in (1), and the last one – to measurement $|M\rangle$. In measurement J.Maxwell picked out «indicator» and "scale" (he ascribes dynamometrs, thermometers, electroscopes, voltameters, photometers and photographuc appartuses to the first, and standard length, mass, time, resistance to the second). It corresponds to understanding of measurement in [2-4] if we single out not only operation of comparison (which includs Maxwell's «scale»), but also an operation of "indication". Thus an operation of measurement consists of two: operation of indication and operation of comparison with standard.

The structure (1) reveals yet another distinction. There are two types of phenomena in the middle part part of (1): the ones that don't have theory, and the ones that have theory "T", which says what to prepare and what to measure. This distinction is close to Hacking's distinction between "observation" and "experiment"**,** which by his opinion «are not one thing» [7, p. 173]. He emphasizes, that from one hand «some great experimenters have been poor observers» [7, p. 167], and from the other there is «gifted 'pure' observer», who is capable of "noting" [7, p. 179]. In the latter case he says about observation as the sourse of new phenomena, as «skilful of observer» is to note unusual («A phenomen could well be an anomaly rather than any known regularity» [7, p. 222]).

In contrast to such an "observation", the skill of experimentalist apparently consists in preparing something which is expected. I.e. in an experiment the researcher focuses on the preparing <P| of something prescribed, while in an observation he concentrates on contemplation of the existing[1]. In the pure observation the preparing <P| can be absent at all, as in the case where the phenomenon is not a product of laboratory and is taken from the Nature in a ready form, as in astrophysics. Both in experiment and in observation instruments are used [7, p. 214, 168, 182]. But in experiment except instrument and technology there are such components as "ideas" [7, p. 214], whereas in observations – skillful of observation)[2].

Hacking emphasizes that the objects and phenomena ("ph"), which are independent from theory as the observation, are made before the theory. In [2, 3, 5] a theory-centered type of experiment is considered[3]. The Gargamel experiment below belonges to the latter type. The scheme of experiment (1) encompases both cases, but it needs to be developed to include the new aspects, which are in the focus of the attention in [7; 8]: distinction between using instruments during experiment, that is the work of the «instrumentalist», and an experiment itself («experimental ideas and new kinds of technology» [7, p. 214]), that is the work of the experimentalist.

The concept of instrument (or device) is new to the structure (1). In [8] this concept is considered to be intuitively evident. Let us try to define it more concrete: the term **instrument** stands for some functional unit of the **experimental setup** used for the preparing <P| or measurement |M>, which is an invariant in the given experiment process, and is characterized only by "in – out" relation. Also the instrument work may be based on theories of any complexity, but "unproblemated", i.e. these theories are not the subject of the study and are taken as certainty.

The **complication of theory** and especially **instruments** (like in the contemporary particle accelerator) leads to division of labor between theorists, instrumentalists and experimentalists [8, p. 17] and to essential distinctions of character of contemporary "complex" experiment from the "classical" one.

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1 Besides discussing Mikelson's experiments he notes that «experiment lasted half a century, while the observations lasted maybe a day and a half» [7, p. 174]. In contrast to above here the talk is about observation as measurement.

2 I.e. by seeing of new objects without preliminary development of theory (as a discovery of satellites of Jupiter by Galileo). But frequently the derivation of new objects and phenomena is guided by theoretical models as in the case of deducing at "the end of a pen" a planet, which is than looking for and finding by telescope.

3 [3] Seemingly it correspond to the "creation of phenomena" in [7, p. 220-221].

Now we ask what is to be added to the scheme of experiment (1) in order to describe contemporary "complex" experiment analyzed in [8, p.17], and to make theoretical components of operations of preparing, and of measuring distinct?

1. Structure of a complex experiment: theory, experiment and instrument

In his analysis, Galison distinguishes the theoretical, experimental and instrumental components of the experimental procedure ("apparatus") [8, p. 24]. According to it, the so-called multilayer periodization of scientific knowledge development (Fig. 1) is the most adequate. In addition to the theoretical and experimental layers, the instrumental one is introduced in it, as related to preparation of new experimental setups, their particular units, detectors and devices.

Figure 1. Multilayer periodization of the scientific knowledge growth by P.Galison.

EXPERIMENT1	EXPERIMENT2	EXPERIMENT3	EXPERIMENT4
THEORY1	THEORY 2	THEORY 3	THEORY4
INSTRUMENT1	INSTRUMENT2	INSTRUMENT3	INSTRUMENT4

Among such types of instruments that opened new research areas there are the cathod rays, X-rays, the Zeeman effect, radioactivity etc. [8, p. 22-23, 74]. The breaks in each layer take place do not coincide in time, because happen in accordance with its own logics in respective societies. Each of the latter possesses its own features, subjects of interest, methods of task solving, journals, conferences and educational programs. I.e. in each of the layers, its specific paradigms and societies can be distinguished. Each of them has own novations, "microrevolutions" (revolutions, introducing new paradigms, by T.Kuhn) and "normal" work stages ("extensions of the craftsman's hand" [8, p.22-23, p. 74]).

According to Galison [8], the microrevolutions happen in the layers not simultaneuosly because of different motives; there are three levels of constraints of the "normal" stage in each layer: short-term, middle-term, and long-term constraints. A **long-term constrain** for the theoretical society consist of the most fundamental concepts, like the idea of unification of interactions or the conservation laws. For the experimental society this constrain refers to the particular type of instrument (bubble or spark chambers, emulsions, electronic detectors). The middle-term constrain corresponds to the programm goals, which for the theoretical society are the calibration theories, and for the experimental one are the particular setup or device. The short-term constrain refers to the models and phenomenological rules in the theoretical layer, and the individual runs – in the experimental one[4].

Probably, Figure 1 is also applicable to the earlier stages of the history of science than the second half of XX century. For instance, in the history of the electrodynamics the lower level refers to emergence of the electroscope, electrostatic machine, leiden jar, souce of electric current; the upper one – the empirical laws of interaction of currents with magnetic arrows; the middle one – the liquid theories of electricity (Franklin et al.), theories of W.Weber and F. Neuman, theories of M. Faraday and J. Maxwell. The second half of XX is marked by emergence of complex modern instruments (like elementary particle accelerators) and the use in theories of highly abstract chapters of mathematics and respective conceptions. As a result, the specialisation and the division of labour starts into the experimentalists (whose field of activity shifts toward the data analysis) instrumentalists and theoreticians[5].

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4 In our opinion such a multilayer model describes the process of a new branch of physics development (the electroweak QFT in [8], and in the case of elementary particles in general), especially at the early stage. In this respect, the Galison model and the "object theoretical-operational" model of Lipkin [2; 5], referred to the mature branch of physics, seem to be complementary and not competitive.

5 This is compared to the point of view of B.W. Lee, cited in [1, p.86] that complication of mathematics and technologies, accompanying the progress in the elementary particle physics, does not make possible for an ordinary scientist to work both in an experimental laboratory and in a quiet room as before.

In [8], the tendency of **the independent development of the experimental and theoretical activity in XX** is discussed: "… the two groups had begun to separate by 1900 – there were already a few pure theorists including Planck and Lorenz". For the most of physicists, however, conducting experiments was a necessary part of their work. The alternating competition and cooperation that characterizes the modern relation of theory and experiment began in earliest of 1920 within the new field of atomic physics. Even then, theorists remained relatively small in number and utterly dependent financially on their laboratory collegues… Their number gradually increased until, by 1968, slightly fewer than half of all advanced American graduate students were theorists (316 out of 682)… The causes of the increased separation between experiment and theory are many. Only a few of them will be suggested here. First, the skills for experiment and theory demanded longer and increasingly specialized traning, whether it was in microelectronics, cryogenics, or computers on the experoment side, or group theory or field theory on the theoretical side… Second, the demands of accelerator physics began to isolate the experimntalists from the theorists physically… Third, the time scale of experiments increased in the decades after Warld War II from several months to many years… the experimentalists had full-time jobs keeping up with their massive scientific/engineering projects…" [8, p. 138-139].

Features of the experimentalist's work mainly consist in the selection of type, development and alignment of the particular instrument, setting up the working regimes, performing the measurements and the data analysis. The latter stage (data analysis) itself in the experiments carried out before the middle of the XX century did not attract much attention, because actually reduced to the collecting of the readings of the setup's devices. Those surplus appearances which could distort the data (background) were accepted to be negligible, because the experimenters were normally able to prepare such measurement conditions that their influence did not reflect the results.

In the contemporary experimental situation, a competent selection and development of the measurement *instrument* has become so complicated and demands such large amount of research and calculation work that the part of the experimental society, spending their worktime creating detectors in the particle physics, forms their own society, called by Galison *instrumentalists*. It is characterized their specific periods of normal development (improvement of known types of detectors) and revolutions (creation of the new detector types) [1]. The tasks of the theoretician qualitatively have beared the least changes as compared to the beginning of the last century, and generally consist in the development of new theories and derivation of their observables.

With the revolutionary progress in the development of the computing in the last century and complication of the mathematical methods applied, the theoretical groups started to develop computer models for faster calculating of observables of their theories, attracting the mathematicians when necessary. Due to this reason, at present time the *mathematical modeling* society is forming, which is involved in the simulation of the observables related to particular experimental conditions with the advanced use of the existing theories within the limits of the theories' free parameters (at Fig.1 this group is not separated yet and, seemingly, is included in the other groups).

Galison assumes that the specialisation, emerged approximately starting from the second half of the last century due to complication of the investigations, lead to the fact that the societies involved in theoretical physics, experiment, computing, microelectronics worked out the sign systems (languages), which cannot be fully comprehended by the members of another society. An evident example of such circumstance, according to Galison, are the two-volume book on quantum field theory written by J.D. Bjorken and Drell in 1964. The first volume, devoted mainly to experimenters, included the concrete rules of the process diagram calculations, predicted by the theory and expected in the experiment, with the emphasis on the observables and heuristic argumentation. Limited comprehention of the information, however, did not allow the use of it for the further development of the theory, thus making the language of the book a kind of simplified one. The second volume, intended for theorists, already contained the foundations and the proof of the Feinman procedures, and a detailed explication of the formalism.

In turn, the experimentalists prepare their results to discuss them with theorists. Experimental papers contain an explication of experimental procedure in a manner similar to direct consequences, omitting many details related to functioning of a particular setup. In carrying out an experiment there are many details understood to a member of the particular society.

Another (besides the deepening of specializations) important consequence of complication of the instrument in the contemporary experiment is **the unavoidable background**, representing itself a source of the systematical error, nature of which and even its of presence or absence itself are a-priory unknown[6] to the experimentalist. Background, the "preparation" of which is defined as an effect whose observable features are difficult to distinguish from those of the one under investigation in the particular experiment, yet originating from another source.

One of the features of the accelerator experiments noticed by Galison is that several effects appear to be prepared simultaneously under the conditions of limited possibilities for varying preparation and measurement operations to separate the effect from the background – the method widely used in the simpler experiments of the past, where the problem of the background arose in the measurements of the delicate effects. As the result, this very important task of the contemporary complex experiment is set aside to the **"data analysis" stage** [1, p. 174]. It plays an important role in the formation of the theoretical components of the empirical data, because it introduces in the field of the data analysis a number of other theories with different degrees of generality and thus generates new important theoretical components of empirical data.

In accordance with the above we define the **contemporary complex experiment** as the experiment of special type based on the following features related to **complication of the apparatus (instrument and theories)**: 1) specialization, which emerges from the division of labor and leads to necessity in team-work of many groups of different specialists; 2) unavoidable background; 3) shifting of data analysis to the central part of experimentation.

2. Theories, experiment and instrument: the "theoretical-operational" model

Complication of experimental and theoretical activities (for its description Galison introduces such terms as "levels of theory" [8, p. 74, 73, 69] and "levels of apparatus" [8, p. 129]) leads to an interlacing of the theory and the experiment. Analysis of this process is very important for him for investigation of the "end of experiment", i.e. the answer to the question when the physics society makes the decision that the result has been obtained, the fact of presence or absence of the effect is established, and the respective experiment (or a series) can be considered as ended.

For such an analysis, the popular in the philosophy of science in 1960-70th "theory lading" appears to be too scarce (and [8] points out to this). Because of this we will discuss more specific theoretical components of the experiment and point to their particular places in our scheme. Allan Franklin uses the term "theoretical components" of experiment in connection with works of A.Pickering that [13] theory of instrument and theory of phenomenon are together contained in a significant experimental result. However, using this term we mean more particular theoretical components and describe their exact placement in our scheme.

2.1 Setting up of experiment

A complex interlacing of theory, experiment and instruments can be noted already at the stage of preparation of the experiment (see Figure 2). The experiment discussed in [8], has been

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[6] All possible variants of background are usually considered at the data analysis stage.

one of the first experiments on verification of the quantum-field theory of electroweak interaction, which is a **"first-level theory"** according to our classification (new branches of physics (quantum theories of field (QFT) in this case), where new primary ideal objects are created [2,3]). In the base of the experiment also lies the theoretical model including the "neutral currents" – products of a **"second-level" theory** (a theory which is a consequence of the first-level one)[7].

One point of view on the theoretical model forming process (i.e. a "second-level theory" in the course of experiment is presented in [8]. During more than thirty years after publication by Fermi his work on beta-decay, it was common to think that all the intermediate particles, by exchange of which this kind of interaction proceeds (the so called "weak currents"), are charged. All the processes, known by 1964, as noticed in [8], could be described by modifications of the Fermi's theory rather satisfactory, and the lower limit on existence of the neutral intermediate particles ("neutral currents"), description of which exceeded the scope of this theory, was very low.

In that way, by 1969 in most of handbooks on the weak interaction such neutral currents are either absent at all or exist at a level of several orders of magnitude lower than the charged ones.

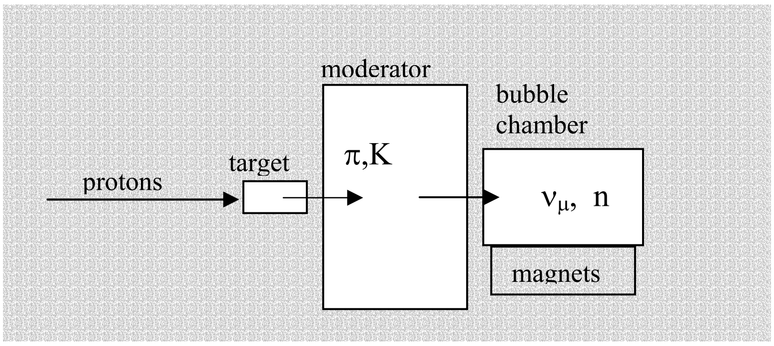

Fig 2. Scheme of the experiment Gargamelle. The accelerator proton beam hits the target, then the pions and kaons formed in it pass the moderator and decay into the muonic neutrinos, reaching the bubble chamber and cause the interactions under study, while the other particles, surrounding the chamber, such as the magnets and shielding, and generate the background neutrons. These neutrons, also penetrating the chamber, might cause the processes, looking alike the neutrino ones.

Galison mentions that during 1960[th], from time to time the experimental ideas to search neutral currents in the scattering processes appeared, and in the case of success they could introduce the higher-order corrections in the charged-current theory, but calculations showed that they could not be observed in the experiment. Theoreticians also from time to time presented the theories, in which neutral currents were presented, but the necessity of introduction of such currents in the theory was not so essential to attract much attention. One of the Fermi's theory peculiarities was that, rather that the quantum electrodynamics, it was not renormalizable.

Most of physicists supposed that introduction of an intermediate particle (also depicted as W^+ or W^-) would allow developing a renormalizable theory of weak interactions. Such a version of the theory attracted a more experimental attention after 1960 (according to [8]), when works of M. Schwartz, T.D. Lee and C.N. Young, were published. These authors underlined, that the neutrino could be an excellent particle for studying of this kind of interactions, as being an electrically neutral lepton it participates in neither the electromagnetic interaction nor in the strong one.

That is why by the end of 1960[th] the search for possible mediators of the unified electroweak interaction – charged $W^{\pm}$-bosons – was very important, while that of neutral (Z^0) one was supposed to be not significant. Especially when the "scaling" effect had been observed

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7 In [2, 3] this levels correspond to the levels of "primary" and "secondary" ideal objects. The latter represent the theoretical models of phenomena. To our opinion, these levels are fixed by Galison.

in the Stanford experiments, and the $W^{\pm}$-boson attracted much interest in connection with the investigations of the parton (quark) structure of nucleon. That is why, as mentioned in [8], those events with absence of muons were taken as initiated by the background neutrons.

Therefore, in accordance with [8], lack of interest to the neutral currents (Z^0) was caused by absence of theoretical interest, attraction to other research topics and negative indirect results from other experiments. However, after G. t'Hooft published his proof of the renormalizability of the S.Weinberg and A.Salam theory (which had been proposed in 1967) the neutral currents attracted much interest (since the spring of 1971), and new calculations predicted more valuable probabilities of the process.

Indeed, interest of experimentalists to the problem, as described in [8], arose as the result a combination of both theoretical attention to the problem and availability of the cross-section (probability) predictions of particular processes, which took place in the experimental setup. However, at the early stage the reconsideration of neutral current role did not lead to essential changes in the experimental program. Theoreticians preferred to study the clearest case – scattering of neutrino on electron, which in the Weinberg theory could proceed through the exchange by neutral Z^0-boson.

On the other side, the experimentalists [8] were not so enthusiastic about that idea, because the problem of separating such events from background seemed to be extremely difficult. In contradiction, such probability for observation of $W^{\pm}$-boson exchange (charged currents) in the scattering of the neutrinos on hadrons (protons and neutrons) was supposed to be much higher. This was also supported by the previous many-year experience of experimental groups on the neutrino problem. In turn, this situation was not what theoreticians preferred, because calculations taking into account hadrons were too complicated and unpredictable, as it was not known how high-energy neutrinos would interact with quarks. Finally, it was compromised that **search for neutral currents would be included in the common experimental program** of data analysis.

This example illustrates (see **Figure 1**) a feature of the Galison's periodisation that reflects the non-simultaneousility of breaks of in theoretical (non-cumulative transition to more common theoreies), experimental (keeping of former experimental program) and instrumental (continuation of use of present setups) layers. On the other hand, this allows to speak of "instrument-centered" set of experiments Gargamelle, including different theoretico-centered experiments, one of which – experiment on search of neutral currents – is discussing here.

2.2 A formal description of experiment

Now let us proceed to the description and formal analysis of the experiment. In our formalism, we include in our scheme a description of the effect **preparation and measurement operations** (1) **the instruments** $d_p((T)\ a;b)$ and $d_m((T)\ a;b)$, where the indeces "p" and "m" stand for the instruments in the operations of "preparation" and "measurement", respectively; T – the theory of third level (theoretical component of the instrument); "a" – the source substance, "b" – the final product of the operation. Thus, the scheme of an accelerator, described in [8, Ch.4] can be represented in the following way (see also Figure 2):

The operation of *preparation* can look like:

$$<P| = \{<P1| * <P2| * (<P3,1| + <P3,2|) * (<P4| + <P5|)\}, \quad (2.1)$$

when «+» is placed in the case of parallelism, and «*» - for their consecution.

$$<P1| = <P1\{d_p1((T1)\ p(E_1);\ p(E_2))\}|, \quad (2.2)$$

where $d_p1((T1)p(E_1);(p(E_2))$ (2.3)

– instrument-accelerator for preparation of the primary proton beam $p(E_2)$ of the necessary energy E_2 starting from the protons with the initial energy ($p(E_1)$), based on the accelerator physics and technology using theories T1,

$$<P2| = <P2\{d_p2((T2)\ p(E_2),\ Be,\ Al;\ \pi,\ K)\}|, \quad (2.4)$$

where $d_p2((T2)\ p(E_2)$, Be, Al; π, K) – instrument-target for the protons, containing the Be and Al nucleus, and providing the generation of the number of the pions (π) and kaons (K), based on the theory T2, predicting the generation of these particles in the reaction with the protons. The pions and kaons passed some distance and during this process most part of them decayed emitting muons and muonic neutrinos; we describe this with similar formulae:

$$< P3,1\ \{d_p2,1((T3)\ \pi;\ \nu,\ \bar{\nu})\}| + <P3,2\{d_p2,2((T3)\ K;\ \nu,\ \bar{\nu})\}| \quad (2.5)$$

– preparation of neutrinos, formed in decays of the pions and kaons, predicted by the weak interaction theory T3. After that the mix of the neutrinos, muons and undecayed pions penetrates many meters of a moderator, leaving mostly the flow of the muonic neutrinos. The other particles are either stopped or decayed. The flux of neutrinos, obtained in this way, interacted with the substance of the bubble chamber (an overheated liquid in the metastable state):

$$<P4| = <P4\{d_p3((T4)\ \nu,\ \bar{\nu},\ e,\ p,\ n;\ Z^0, W^{\pm})\}|, \qquad (2.6)$$

где $d_p3((T4)\ \nu,\ \bar{\nu},\ e,\ p,\ n;\ Z^0, W^{\pm})$ – instrument-target for the neutrinos ν and antineutrinos $\bar{\nu}$ (the bubble chamber), based upon the theory T4; e, p, n — the substance of the bubble chamber, including the electrons, protons and neutrons, interaction of which with the neutrino flux was expected to lead to the formation of Z^0 и $W^{\pm}$.

$$<P5| = <P5(bg(n));\ldots| \qquad (2.7)$$

where bg(n) - neutron background, without either the other reaction products or the undecayed pions nor kaons. The main background had the following origin: neutrino flux (or antineutrinos, for simplicity, only neutrinos will be indicated below) generates a large (but not exactly known) number of neutrons in the magnets and the surroundings; these neutrons also reach the inner space of the bubble chamber. When one of such neutrons hits a neutron or a proton within the chamber, a vertex arises looking similarly to muonless neutrino scattering event (manifestation of the neutral Z^0-currents). Other possible sources of background were the so-called «associated events»: the neutrons emitted among other hadrons in the neutrino events, could later also produce the hadron-bursts in other parts of the working volume, also indistinguishable from the neutrino events. It is important to mention that such a subdividion is an approximate one, and each of the terms in the equation can include a large number of more particular theories.

The situation with the *measurement operations* is still more complicated. The elementary particles in the experiments of this kind can be observed («measured») by their traces-images in the chamber. These traces-images, depending on the sort of particle, its characteristics (charge, momentum), as well as the external influences of the experimental setup (configuration of the electric and magnetic fields), represent the results of the calculations by using a theoretical model (second level theories). On the basis of the track sizes, curvatures, lengths using theoretical models one can determine the physical properties of the particles.

Using the introduced above instrument description, we have:

$$M> = |I>*|s>, \qquad (2.8)$$

where the operation of the **indication** by means of the bubble chamber:

$$|I> = |I\{d_m6((T6)\ e^{\pm},\ \mu^{\pm}, \textit{charged hadrons};\ \{photo_i\})\}>, \qquad (2.9)$$

$d_m6((T6)\ e^{\pm},\ \mu^{\pm}$, *charged hadrons*; $\{photo_i\})$ – based on the T6 theory instrument-target (the bubble chamber), in which along the trajectories of the charged particles the boiling of the working liquid (put in the heterogeneous electrical and magnetic fields) happened. The indication procedure is based on this effect. In the T6 theories used at this stage, various third-level theories, for instance, thermodinamics and mechanics (formation of the bubbles in the overheated liquid along the trajectories), atomic physics (ionization by the moving particle, which finally leads to the boiling). $\{photo_i\}$ – a photograph containing a multitude of the particle tracks $photo_i$. As a result, the experimenter obtains a photograph with the particle trace images.

In QFT, as well as in the quantum mechanics, a state can be given by a distribution of the probabilities of the measurable quantities, such states in QFT refer to the particles with a definite set of characteristics. In an experimental situation, one of the properties sought is the ratio of the probabilities of the processes, which proceeds with the formation of Z^0-bosons to the processes with formation of the $W^{\pm}$-bosons. Determination of the probability ratios, as it is in the nature of the probability, requires a **multitude of measurement acts**. In this case, each such an act refers to a separate photograph. One particular observation cannot be quantitatively interpreted within such theory.

Let us notice that there is a demarcation between appearance and instrument, accomplishing the indication[8]. The latter uses T6 theories, which are the theories of the instrument, not related to the description of the phenomenon by QFT, as they are classical theories, describing the interactions of the particles with classical and quasiclassical (ionisation) objects, and not using the wave-functions and their analogs[9]. However, photograph is not the final stage of the measurement[10], and the indication is followed by the operation of «comparison» (which were a part of Maxwell's «scale»), representing the measurement-identification of the photographed trajectories. In [8] this phase is set aside to the stage of «data analysis».

2.3 Data analysis

An important step of the «data analysis» represents the recognision of a «trace» image on a photograph, supposing the two stages: the theoretical «calculation» of the trace shape $Im_i(Ti)$ with the use of the theory Ti, taking into consideration the properties of the setup (the bubble chamber geometry and distribution of the electrical and magnetic fields in it, etc.); and its recognition in the photograph ($I\{photo_i \Leftrightarrow Im_i\ (Ti)\}$). During the accomplishment of the most difficult second stage it often appears to be possible to put an algorithm of the trace $Im_i(Ti)$ search in the computer, thus making possible corrections for many additional surplus effects.

Trace-image Im_i (an instrument-taken picture of an appearance, «event») in the described experiment represents itself an image of spreading of the particles, formed in the interaction of the particles from a definite point, a vertex. Depending on the particular theoretical model Ti there are different interpretations of the event in the photograph possible. From the point of view of various theories Ti, the same trace in the detector of the setup can often be explained by actions of different particles, having different energies and other physical properties. Moreover, the trace-image $Im_i(Ti)$ appears to be dependent on the organisation and the parameters of the particular setup. For instance, a theory can predict that the track of the particle A should have a curvature of a particular kind, and that it should be wider than that of the particle B. However, the value of the curvature, as well as the exact value the track's wideness are the functions of the working regime of the setup, moreover, it can vary from one experimental situation to another, as some $Im_i(Ti)$ standards-images are created at the stage of the data analysis.

Existence of the neutral currents thus can be reduced to verification of hypothesis of the possibility that definite kinds of particles arise in the scattering of the (anti)neutrinos, and actually it was checked in experiment if the particles with specific properties (signatures) had originated in the chamber under the neutrino beam, and in which quantities. As in the background (i.e. among the processes inevitably taking place within the chamber volume (and described above), different from the investigated one), neutrons were also present, one of the problems the expirementers encountered was to determine if there was an excess in number of such signatures, originated from the neutrino scattering over that formed by the background neutron interactions.

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8 I.e. there is no Bohr's "problem" of demarcation of studying object and "measuring instruments" in "totality of the phenomena" [Niels Bohr. Atomic Physics and Human Knowledge. N.Y., L. (1958), p. 39-40].

9 So, like in the non-relativistic quantum theory [5], nothing like the «wave-function reduction» is required here.

10 The use of the photographic images as a form of data accumulation often results in the fact that much time passes between the collecting the image and the obtaining of the physical result.

In brief, the experimenters faced the problem of distinguishing secondary neutrons, formed in one process from those formed in another. The differences themselves were at the bottom of such their characteristics that were, in the first place, very small in the magnitude and, in the second, brought by the theories describing their formation mechanisms. That is why the experimenters checking the main theory (of electroweak interactions) were compelled to use also other theories, describing formation of the background neutrons in the surroundings of the setup. Identification of background consists in search of all (if possible) appearances in every particular experimental situation capable of imitating the events under investigation, and thus requires developing of quantitative theories for each of the sources of the background. This procedure is so much complicated that it requires much more time and working effort than simple collecting of the measured events, used to be considered as experimentation before, does.

Verification of the version of the electroweak theory T4 in this experiment consisted in ascription of photographs to a definite process (exchange of a neutral Z^0 or charged $W^{\pm}$-boson) and their subsequent statistical analysis. Thereafter, ratios of the numbers of the photos, ascribed to the above processes, were calculated, characterizing their relative probabilities. These probabilities were directly calculated using the models of the theory T4. Among the photographs, obtained in the described experiment, the following events had to be picked out: 1) a single electron, resulted from the neutron current exchange (Z^0); 2) a vertex with emission of several hadrons (also neutral Z^0-currents); 3) a hadron vertex accompanied by emission of a muon (charged currents, $W^{\pm}$). Therefore, the analysis of the photos can be represented as **the search for the images** consisting with one of the three described above processes, each of them refering to a unique standard-image Im_i, and separation of such images from those fromed by the background processes, refering to a multitute of the background standard-images Im_{bg}.

Inclusion of the theoretical components Ti in the image recognision procedures, constituting core of the data analysis, results in the fact that not only technological (development of experimental techniques and data processing methods), but also theoretical considerations play determining role in formation of results. Consequently [8, p.174], different approaches to data analysis (i.e. use of different basic and supplementary theories) can lead to a notable differences in the results between, for instance, perception of particular particle footprints as a background mark before the advent of the Glashow-Weinberg-Salam theory, and perception of those as electron trace, formed in the decay of a Z^0-boson, with its development. Something similar one can meet already in the classical experiment though. So, in discussed by [8] giromagnetic ratio experiments, it revealed that not taking into account the terrestrial magnetism lead Einstain and de Haas to an incorrect conclusion about magnitude of the effect. Possibly, to a side observer it would looks similarly to the effect known in psychology as Gestalt[11], induced by the Ti theories selection at the stage of formation of the Im_i(Ti) standards-images. Galison [8], however, does not share such point of view.

Thus, general patterns of the classical physics experiments reflected in the theoretical-operational Fock-Lipkin scheme (1), remain adequate to the modern complex experiment as well. However, the latter offers a number of additional characters, which demanded development of (1) to a more complex one (2) (i.e. (2.1) – (2.9)). The scheme (2) provides a language, taking into account the transition from simple classical experiment (roughly, before the middle of XX century) to the complex contemporary one, marked by the fundamental complication of instrument and mathematical machinery of theories, depending on specialization of the experimental, theoretical, and instrumental societies; growing of the data analysis role, which becomes central part of the entire experimentation; essential additional «theory-lading» by variety of backgrounds and diversity of their sources. The scheme (2) allows performing detailed and systematical considerations of contemporary complex experiments on a more formal basis.

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[11] An integral vision, picture; the term is borrowed from the Gestalt-psychology, the classical example — a perception of an image, where either a duck or a rabbit can be seen (or, two vases or a face, etc.)

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