GETTING AND MISSING CLUE
TO NEW PHYSICS AND TECHNIQUES

Shuji Fukui

1. Introduction

In the 1950s, even from the latter half of the 1940s, many endeavours were enthusiastically made to develop instruments and techniques for the experiments of the cosmic-ray and high energy physics [1]. Among those the very interesting attempts were made to modify and to develop electric and visual detectors in which function the gaseous discharges played the essential roles.

In order to get a sharp form and fast time resolution of an output pulse of a GM counter a cylindrical electrode and a center wire were modified into two parallel thin metal plates with very small gap distances. Two parallel plate electrodes were sealed in a glass tube filled with GM counter gas mixtures, and a DC high voltage was supplied. J.Warren Keuffel initiated the development of this parallel plate counter [2] and several other physicists worked on developing the same type counters [3,4].

German physicists developed the visual detector of cosmic-ray particles, der Funkenzahler, that is, the spark counter [5]. They reported the results of their researches in the German journal, Atomkernenergie, but due to poor international circulation of the journals in the 1950s very few physicists of other countries than Germany noticed their researches. Professor E. Bagge gave me the reprints of that journal of their works on the spark counters at Kyoto International Conference on Cosmic- Rays in 1960.

Marcello Conversi originated the hodoscope chamber, later named as the flash-tube hodoscope, whose starting point was the observation on glow discharges in neon bulbs initiated by a microwave field [6].

T. E. Cranshaw and J.F. DeBeer developed the triggered spark counter whose construction of electrodes were the same as that of the spark counter used by German physicists [7]. They used the air also but they applied a high voltage pulse to the electrodes instead of a DC voltage. A high voltage pulse of a short time width was triggered by a coincidence of GM counters which were placed above and below the spark counter.

S. Miyamoto and I developed the discharge chamber, later named as the spark chamber, from the observation on gaseous discharges occurred in the Conversi's flash tubes [8].

Some of these works were initiated by the clue which physicists got from the observation on the phenomena in the course of their experiments. During constructing the hodoscope chamber and developing the discharge chamber I learned a lot of lessons. Here it will be discussed on the clue to develop new physics and new techniques, how getting and why missing such clue, and what can lead us to the success.

2. Overview of initiation of development

J. Warren Keuffel found the clue to the spark chamber during developing the parallel plate counter but he did not start a developmental work by himself immediately after getting the clue. Only he mentioned in his report the observation on the discharges in the parallel-plate counters that the discharge was localized in a fine, plainly visible streamer channel presumably in the neighborhood of the initiating ion [2.2], but he did not show any illustration of such evidence and any real confirmation by his own experiments.

Marcello Conversi described the history of the development of the hodoscope chamber in the Proceedings of International Colloquium held at Paris in July 1983 [9]. He mentioned the clue to the hodoscope chamber as follows:

(Excerption)

The starting point for the development of the new technique was the observation of Gozzini in 1954 that a neon bulb, which is known to glow when placed near an ordinary radiowave (RF) transmitter if RF emission is actually occurring, does not glow at all if the bulb is kept in the dark and irradiated by the short (1 μs), high power (1 MW), single RF pulse emitted from a radar system; whereas it glows again if it is illuminated, even when irradiated by a similar pulse of a much lower power.

When discussing this, Gozzini and I reached the conclusion that in the absence of light, and therefore of photoelectric emission from the body of the bulb, no free electron was present among the $\simeq 10^{20}$ *neon atoms filling the bulb, unless some ionizing particle had crossed the gas just before or during the 1 μs radar pulse. (Of course the luminous electric discharge of the glowing bulb is always initiated by some free electrons strongly accelerated by the intense electric field.)*

We then thought that a new type of detector of particle tracks, characterized by an unprecedently high over-all space-time resolution, *could be realized by stacking a large number of thin, wireless neon tubes covered with black paper for light screening, and subjecting them to an intense impulsive electric field, applied immediately after the passage of the particles to be detected.*

(...)

We quickly constructed and assembled all that was needed to test our idea in particular using for the high voltage pulse generator two pulse transformers of a radar modulator providing rectangular pulses of up to 20 kVolt, 2 μs duration. (...)

M. Conversi mentioned in his report in the Proceedings that the development of the discharge chamber which was, he said, initiated as the transition from the hodoscope chamber. I presented the history of the development of the discharge (spark) chamber at the International Symposium held at Fermilab May 1985 [10].

We got the clue to the discharge chamber from the observation on the discharge phenomena appeared in the Conversi's flash tubes. We observed the interesting and characteristic gaseous discharges, streamer channels, started from electrons in rare gases of high pressures by a very sharp and high voltage pulse, during preparative works on the hodoscope chamber which was to be used as one of the instruments for detecting the special distributions of electrons in the extensive air showers. One of the experimental projects in the 1960s of the Institute for Nuclear Study, University of Tokyo was the studies on the extensive air showers [11].

S. Miyamoto and I began to make flash tubes of 1 cm diameter for the hodoscope chamber at Osaka University in the middle of 1956. By the end of 1956 a first set of the hodoscope chamber was constructed and a test run was started. We applied a high voltage pulse of an exponentially decreasing form generated by a condenser discharge, instead of a square form pulse.

One day, Miyamoto operated several flash tubes without black paper to find a probability of induced firing in the adjacent tubes. We saw the discharges in the tubes showed glow discharges not in uniform. This gaseous discharge behavior was unexpected one. We had thought uniformly glowing discharges occurred in the whole volumes of the tubes. So we intended to look the discharges in detail.

The arrangement of flash tubes of the hodoscope chamber was slightly modified. Several bare tubes in the middle of the chamber were placed their axes nearly perpendicular to the chamber axis in order to observe the discharges from the side of tubes. The photographs of fired tubes were taken by a triggered signal of a cosmic-ray's passage. The trajectories of cosmic-rays were detected by the hodoscope chamber.

We were very much stimulated by the photographs showing the discharge columns, the streamer channels, parallel to the electric field appeared in the whole volumes of the tubes. We looked at the photographs and found that the streamers near a cosmic-ray's path were much brighter than others.

We discussed this discharge behavior and considered that the bright streamers near a cosmic-ray's path were initiated by ionized electrons primarily produced by a cosmic-ray, the secondary streamers were initiated by photoelectrons produced by the lights emitted from the primary streamers, but the intensity of the electric field was decreasing due to the dissipation of electric charges by the primary streamers, the secondary streamers were initiated in the lower electric field, therefore they showed less brightness.

Further studies of this discharge behavior were attempted. Several glass tubes of rather large diameter of 2 cm were prepared and filled with the gases at different pressures and arranged in the middle of the hodoscope chamber without black paper in the same way as we did previously. The pulses of various peak voltages and time constants were applied in due order.

We found that the number of brighter streamers near a cosmic- ray's path showed a tendency to decreasing in the tubes filled with higher pressure gases and to increasing according to a delay time of pulse application after a cosmic-ray's passage. The most remarkable phenomena we saw in the tube of the highest pressure, nearly one atmospheric pressure. When a pulse of a shortest time constant, 0.1 μs, and of a most critical peak voltage for initiating discharges, 2.5 kVolt/cm, were applied not later than 0.5 μs after a passage of a cosmic-ray, such bright streamers were localized into a single streamer channel exactly on a cosmic-ray's path and there occurred no additional streamer at all in the tube.

This observation gave us an important clue to start developmental works which led us to discharge (spark) chamber, a new detector of particle trajectory.

3. Getting and missing clues

I had experiences of the same kind observation on the variation of pulsed glows in neon bulbs according to the places of bulbs in the light or in the dark. In the 1950s the GM counters and the GM counter hodoscopes(*) were commonly used in the cosmic-ray experiments. When we were preparing a GM counter hodoscope to be applied in an experiment planned to measure μ meson anomalous scattering [12], I noticed that the glow efficiency of neon bulbs was almost in 100% when the bulbs were operated in the illuminated room, but the glow efficiency decreased in about two thirds when they were operated in the dark box for photographing glowed bulbs. Even we operated the neon bulbs in higher voltage levels, but we could not get 100% efficiency in the box.

We did not have time to search the reason why in the box the glow efficiency decreased. We thought that there might be something wrong in the operating circuits and we checked them, but we could not find any defects. We changed the "bad" neon bulbs for new ones and could make progress a little but not perfect. We changed the circuit elements and also employed the different circuits but the situation of glowing in the dark was not so much varied. Some day we noticed that the glow efficiency was increased suddenly up to 100%. We found that the light crept in the box through the chink at the corner of the box and illuminated the array of the neon bulbs. So we considered that the light would agitate the neon gases and so the gases could be easily glowed by the voltage application. Then we tried to operate the bulbs in decreasing light intensity and found that the glow efficiency could be kept in 100% if bulbs were illuminated even by a dim light and that the complete darkness resulted in bad efficiency by no means.

We struggled for realizing the hodoscope neon bulbs in high efficiency glowing in the dark. We did not have time to think other things than the hodoscope neon bulbs. We did not consider to have to pay attention to the variation of glowing. These our attitudes resulted completely different consequences than those M.Conversi obtained.

When the attentions and the efforts are too much concentrated in performance and operation of experiments or instrumentation towards accomplishment, a clue to open a new field will be missed even if such clue is observed.

Carlo Franzinetti, who developed the spark counters [3], told me in 1962 at

(*) Foot-note for GM counter hodoscope [13].

This idea was developed by O.Piccioni in 1948. Here the outline of its operation is briefly descrived. In order to detect the trajectories of charged particles using GM conters the small neon bulbs are connected by the electronic circuits to the respective GM counters. The neon bulbs are aranged in the respective geometrical positions of the GM conters which are put in the experimental setup, so the geometrical array of the neon bulbs are in the miniaturised array of GM counters. The set of the neon bulbs are put in the box for photographing the pattern of glowed bulbs. The voltage pulse triggered by the fired GM counter is applied to the respective bulb throgh the gate circuit opened by a signal of selected events to be detected. So the pattern of glowed bulbs coresponds to that of GM counters fired by the particles, that is, the trajectories are detected.

CERN that he noticed the sparks would be localized at the points where the cosmic-rays passed, as similarly J.W.Keuffel noticed, but he did not perform any further investigation to confirm his observation. He said repentantly that he had to do confirm his obsersation at that time, because he actually stood at the door to the spark chamber but he did not open its door by himself.

The spark counter was the instrument whose construction and operation were very difficult and critically severe. The most difficulties were to seal two parallel electrodes of a few mm gap in a glass tube and to keep smooth surfaces of electrodes whoes edges also should be smoothly rounded in order to prevent spontaneous breakdown by the DC high voltage application and also to maintain such conditions after operation of many counts. The latter was very severe, because the metal surfaces were damaged due to sparks and once the surfaces were deteriorated the spontaneous breakdowns were frequently occurred. We could imagine how C. Franzinetti struggled with these difficulties and stuck to his efforts for realizing a good quality of spark counter.

I did not know any reason why J. W. Keuffel did not develop a spark chamber from the observation, that is, the clue which he wrote in his report [2]. Probably J. W. Keuffel did more or less the same kind of struggle with difficulties of spark counters as C. Franzinetti did.

If M. Conversi observed the discharge behaviour in flash tubes he probably did start a new investigation. But there existed a remarkable difference in the operational condition of hodoscope chambers between what he employed and what we did. He applied a square shape pulse of 2 μs time width, generated by a push-pull network of delay lines and pulse transformers. When we started to construct a hodoscope chamber at Osaka University, we wanted to get this kind of pulse generator or a high voltage pulse forming network. We asked many companies for manufacturing them, but we found that any company could not make them at that time in Japan. We could buy only high voltage oil-paper condensers and hydrogen thyratrons. The latter were the production by Philips and were imported.

Using these we had to generate a high voltage pulse whose shape was of exponentially decreasing. It was clear that for operating a hodoscope chamber a high voltage pulse of a square shape was better than a pulse of sharply peaked shape in order to produce bright steady glows in neon tubes. At the beginning stage we very much doubted whether an exponentially decreasing voltage pulse could produce glows in neon bulbs or not. So eagerly we had wanted to get a pulse generator of a square shape. However, a pulse generator of condenser discharge type had a conveniency, that is, easily could be changed the CR time constant by changing the resistance. This simple pulse generator smiled on us later.

When we tried to look the discharge behaviour in flash tubes we prepared glass tubes filled with gases at three different pressures. Due to the similarity principle of the gaseous discharge phenomena, the value of E/p, the ratio of the electric field intensity and the pressure of gases is the important physical quantity ruling the gaseous discharges, that is, in the same E/p condition the behaviours of electrons and ions are observed in the same tendency even in the different pressures and therefore the same kind of the discharge behaviours are observed also.

We applied a single voltage pulse to test tubes altogether. The glass tubes of different pressures were operated by different E/p and the effective time durations for glowings were varied consequentially. The voltage applied to the tube of lowest pressure was equivalent to a higher value of E/p with longer time duration and the voltage to the type of highest pressure corresponded to a nearly critical value of E/p for starting glows with much shorter time duration. These different effective values of E/p to each test tube were produced unexpectedly by a single pulse application.

If we used a same type of pulse generator which M.Conversi used, we presumably could not observe a singly localized streamer channel, because the time duration of 2 μs would be sufficiently long and then the additional discharges would be produced in the whole volume of the tube. I can say that a high voltage pulse of exponentially decreasing shape led us to a clue with which we could start developing works on a discharge chamber and that a pulse of square shape presumably could not show any clue to direct development of a discharge chamber.

4. Ending remarks

Among the essential subjects for getting the clue, the following two most remarkable ones can be pointed.

When we are struggling for performance of experiments or instrumentation towards accomplishment, we are apt to concentrate our attentions and efforts in those experiments or instrumentation and have not time to spare for considering other things than what we are doing. If we are engrossed too much in some thing, we might lose a true way we have to do. Even during this stage there would appear a clue. Whether we could get it or not would be depended upon our attitudes, that is, how careful we are for observing every moment of phenomena and how we have time to spare for considering on that phenomena observed. We have to recall what J.W.Keuffel did and C.Franzinetti did when they were developing the parallel spark counters and what we did when we were preparing a counter hodoscope.

If we have sufficient equipments both in quality and in quantity for performing experiment or instrumentation, we are apt to neglect severe consideration on characteristics of those equipments and also to neglect further efforts for improving their characteristics. When we intend to perform an experiment and have to start it with equipments of a little low quality and a little less quantity which we could get, we have to make efforts to cover such insufficiency. During making such efforts a clue would appear by accident, of course unexpectedly, for developing or improving instrument. Such clue could be noticed by a careful and sensitive person.

In other occasion we will discuss further on the other subjects causing to getting and missing clues.

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