LETTER FROM DMITRI DIAKONOV TO ANATOLY DOLGOLENKO ON 22 AUGUST, 2003*

The following letter was emailed by Dmitri Diakonov to Anatoly Dolgolenko on 22 August, 2003. It contains the interview given by Diakonov to the journalist Sergey Petrushanko. The interview was published in Russian in the Russian journal *Atomium* as part of an article by S. Petrushanko («Small and Elegant Theta», *Atomium*, **1**, pp. 66–67, (2004)). For convenience, we present questions asked by Petrushanko in his interview:

1. How did it occur to you to "construct" a particle from five quarks?
2. Why was the pentaquark not discovered earlier?
3. How did you manage to urge the Japanese group to search for the pentaquark in the experimental data? Did they accept your proposal with a great deal of skepticism?
4. Do you think that we will face an avalanche of information on new types of pentaquarks discovered in the experimental data?
5. Is there a possibility that there can exist particles that consist of four, six, seven, *etc.*, quarks?
6. Please tell me about the group at ITEP who also discovered the pentaquark.

Dear Sergey,

Please find in the following my answers to your questions.

1. The idea appeared long ago, in 1984. In February 1984, I was lecturing at the ITEP Physics Winter School (somewhere near Kolomna). In one of the lectures, I mentioned the new exotic antidecuplet. I mentioned it also in my several talks given at that time at various events in the former Soviet Union. I must say that in late 1980s those theorists who

*From the archive of Anatoly Dolgolenko. Translated from Russian into English by Naya Smorodinskaya.

used the so-called Skyrme model for the description of proton and deuteron knew about the decuplet that something like that should exist. However, the Skyrme model is too rough and we should not believe its predictions because it does not describe correctly even those things which we already know. In 1986, V.Yu. Petrov and myself suggested a much better model which, though having features similar to the Skyrme model, described well the known reality. The name of the model is «The Quark–Soliton Model». After that, we became much more serious about the predictions the new model made about unknown things, in particular, about new particles. In 1996, I managed to convince my friends Viktor Petrov and Maxim Polyakov to complete the work, *i.e.*, to calculate the concrete values for mass, lifetime, *etc.* In 1997, we published an article. It was really not an easy decision. We could not even imagine how it could happen that during thirty previous years of intense dedicated research, no one could ever observe this particle. Therefore, we spent much time exploring the previous experimental studies in order to understand how physicists managed to miss such a bright phenomenon which they had been hunting for over many years. Only when we understood that, however strange it may seem, they could have really missed it, we decided to publish our prediction. Psychologically, it was a very difficult decision, and we realized the whole responsibility.

2. Physicists were trying to discover pentaquarks in the 1960s. The search was quite intense, especially in the 1970s. By the end of the 1970s, the international community arrived at a strong opinion that "exotic baryons", (*i.e.*, the baryons which, in principle, cannot be built of three quarks) do not exist in nature. The main reason for the failure was that people were looking for a heavier particle and a broader resonance, whereas the particle turned out to be (a) much lighter and (b) much narrower than people believed. Figuratively, it was expected to find something vague on the Moon, but the real Theta, small and elegant, was nearby.

3. Actually, everything happened by chance. My coauthors V.Yu. Petrov and M.V. Polyakov and myself were actively trying to encourage experimentalists from different countries to check our prediction. However, at first, all our efforts were in vain. The reason is that an elementary particle physics experiment is usually (a) very expensive and (b) is of high labor cost. Therefore, an experimentalist working in the field of elementary particle physics needs an extremely strong motivation to start going. Everyone knew that exotics do not exist (see the previous paragraph above) what neither stimulated any enthusiasm.

In February 2000 at a conference in Australia, an American experimenter invited me for lunch. He was interested in my old completely different prediction. The Japanese, Takashi Nakano, who was nearby, asked if he could join us because he was also interested in the subject. For some time, we were discussing the old problem and at some moment I said that in my other pocket, I had another much more interesting prediction. Then I explained to them in simple terms the logic and content of our joint work with Petrov and Polyakov. Since I already had some bad experience, I was pleased that both guys showed interest in our results. During next three years, I accidentally met both men a few times. They asked me a lot of absolutely specific questions and I understood that they were working on the problem. The American (Elton Smith) was affiliated with the Jefferson Lab. His group was late by half a year. The Japanese Nakano made a good impression on me. As far as his "old" data are concerned, it is not completely right in my opinion. The accelerator, where the result was obtained, was launched some time before 2000. Nakano did not mention a single time that he had some data which should only be analyzed. I am not sure, but it seems to me that these data were obtained after our first discussion in February 2000. However, it is not too important when the data were obtained. In the ITEP experiment, the data were obtained in 1986. It is important when people began to analyze the data already understanding what to look for. I am sure they got the understanding only after our prediction became known. Fifty more years could have passed, but without our prediction, no one could have noticed anything.

Let me remind you a text-book story about the discovery of the planet Neptune. By 1840, astronomers found out that the planet Uranus, the last planet known at that time, was moving along its orbit a little bit otherwise than it should move according to Newton's laws. The French astronomer and mathematician Le Verrier suggested that the reason for this small discrepancy was a new planet located behind Uranus. He used the observed difference to calculate the position of the new planet in the sky and wrote a letter to the German astronomer Johann Galle in Berlin. Le Verrier explained at which point in the sky the new planet should be searched for. Galle found the new planet in half an hour, its real position was within one degree of the position predicted by Le Verrier. Without Le Verrier, astronomers could have no idea about the existence of Neptune.

4. I do not think that we are going to have a whole avalanche of new particles, although the discovery of Theta will stimulate the experimenters across the world to new searches. My personal opinion is that quite a few particles will be discovered. It is much more important that we will reshape little by little (and check experimentally) our understanding of the "old" particles including the proton and neutron which are still a puzzle, and we do not have a clear idea about their structure and how they "work". In particular, the market-dominant models, which do not predict Theta, will just silently die.

5. In principle, there can exist hadrons consisting of an arbitrary number of quark–antiquark pairs (they are named mesons) and baryons which contain three quarks plus, again, an arbitrary number of quark–antiquark pairs. Actually, any statement like "a proton consists of three quarks" is not accurate because the proton always includes an admixture of one, two, *etc.*, quark–antiquark pairs. Theta is an amazing beast which due to "accidental" reasons does not have the first member of the chain. The chain starts immediately with three quarks, plus a quark–antiquark pair. Therefore, it was named a pentaquark, but this term is not accurate from the scientific point of view.

   The quark–gluon plasma is NOT located at the end of the chain. It is a different phase of matter, like vapor and ice.

6. Now, here is what you called "beyond interview". I highly appreciate the contribution which was made by the ITEP experimenters to this discovery. Actually, they are the same equal authors of the discovery as Nakano. They started the job in 1999 as soon as they learned about our prediction. Unfortunately, since they did not ever contact us, we did not have a chance to tell them that the work in Japan and Germany was already at full speed. It is a pity that we knew nothing about the ITEP work. As a result, they announced their achievement two months later than Nakano's group. However, first, they were absolutely independent of the Japanese group. Second, they studied a completely different reaction (all other groups used reactions induced by gamma-quanta) and, third, thanks to that, they obtained unique information about Theta. Fourth, the accuracy of the ITEP measurement of Theta mass and width is better than the accuracy of the results of all other groups, independently of when they were obtained — before or after the group from ITEP. Fifth, the work of the ITEP experimenters is just a human feat. A small group of already not too young people at ITEP were for three years heroically analyzing about half a billion of old films made by means of long-abandoned

xenon bubble chamber. In addition to a miserable salary, they had to endure the ridicule of their colleagues. It is a must that you contact them. The main person is Anatoly Dolgolenko.

At the end of March, I was at Jefferson Lab where I gave a talk to a very large audience and demonstrated (on permission of Dolgolenko) their ready but yet unpublished data. For a few days, I had intense discussions with the American group and saw the results they had at the end of March. I can witness that the results were still quite poor at that time. After my visit (and largely thanks to it), the group at JLab received additional funding and beam time. Owing to all this, by the end of May the group had good statistics and a good Theta bump. So, the American group started the confirmation of the discovery, whereas Dolgolenko and his colleagues are the same pioneers as Nakano and his group.

By the way, it was me who suggested the name Theta for the particle and this name was accepted by the community.

Best regards,
Dmitri