Looking into the pyramids by the nuclear emulsion detector

Tomoya Uji

About 80 years ago, nuclear emulsion particle detectors were developed by experimental particle physicists [1]. A nuclear emulsion particle detector is a device used in physics experiments and is simply like a photographic film. As you might know, the mechanism of ordinary photographic film is that photons striking the film change the chemicals on the film and create an image pattern. The mechanism of the nuclear emulsion particle detector is the same except that we can get images of electrically charged particles, not photons.

Charged elementary particles such as electrons, muons and quarks are of great importance in physics. A muon is one of the elementary particles with property very similar to electron but about two hundred times heavier. Quarks are a different kind of elementary particle from electrons, and they are the building blocks of protons and neutrons. Since everything in the world is made of atoms and atoms are made of elementary particles as described above, understanding the properties of elementary particles is necessary to answer the ultimate question, "What is the universe made of?”

The nuclear emulsion particle detector was developed in order to discover new particles and investigate the properties of already known elementary particles. As explained in the first paragraph, by using this detector under experimental environments in which particles are generated, we can take a “photograph” of flying charged particle trails. Based on the “photograph”, physicists can calculate the energy, mass, and lifetime of the particle and the results of calculations can sometimes prove the existence of new particles.

Indeed, the nuclear emulsion particle detectors contributed to great finds in particle physics. I would like to give you two examples of such discoveries. One thing is the discovery of charm quarks [2], and the other thing is discovery of tau neutrino [3]. A charm quark is a type of quark, and a quark is one of the elementary particles that make up matter. It is so unstable that it is not contained in the ordinary matter that surrounds us, but it is very important to physicists who are trying to understand the origin of matter. A tau neutrino is also one of the elementary particles. “Neutrino” is a combination of the words “neutral” and “ino”, where “ino” means “tiny” in Italian. It is difficult to capture because it is so small and does not interact with other particles.

Although these particles were postulated to exist by the theoretical predictions, the detection of them was so difficult that physicists had not come across them for a long time. However, the existence of the particles could be proved because the nuclear emulsion detector had very high spatial resolution. High spatial resolution means good image quality, as in a photograph. In the same way that a film camera has a higher image quality than a digital camera, the nuclear emulsion detector has a higher spatial resolution than other digital detectors. Because of this property, the detector contributed to discover two types of new particles and then drove the development of elementary particle physics.

Surprisingly, the detector has applications not only in physics, but also in archaeology. In 2017, a research team of Nagoya University announced the discovery of a new chamber inside Great Pyramid of Giza. The method of discovery was very interesting. With conventional methods, in order to examine inner structure of the pyramid, people or cameras would have to enter the pyramid and the inner walls of the pyramid would need to be destroyed although it is a valuable legacy. However, the research team discovered a new room without destroying anything, using detection of muons flying from space by the nuclear emulsion.

Muons are elementary particles that constantly fall to the earth as cosmic rays, passing through a palm-sized area at a rate of about one per second. As you probably know that X-rays can be used to view the internal skeleton of the human body, muons have a higher penetrating power than X-rays and they can be used to study the internal structure of buildings using a principle like that of X-ray photography. In short, muons allow us to see through the internal structure of buildings such as the pyramid. This method is called muon radiography.

However, in order to use this radiography, we must develop muon detectors which need to be small, have high observation accuracy, and able to work without a power supply. First, detectors should be highly portable because they must be transported from the pyramid to the laboratory where the data analysis is done. Second, they should be accurate enough to get information from which direction the particles came and distinguish muons from other particles. Third, they must be work without electricity because they were introduced where there is no power supply. Although these are very demanding requirements, the nucleon emulsion detector can satisfy since they were developed to discover particles difficult to find under severe experimental environments.

In this way, devices developed for basic research in physics can be useful in unexpected fields. Basic science is often said to be useless, but research done out of pure intellectual curiosity is always a valuable outcome and will be useful somewhere, someday. If you like science, I hope you learn a lot and enjoy science and even if you are not interested in science itself at this point, the study of science will help you in some way in your field of interest. So, I will be happy if you study science in high school and major in science in college!!

I would like to thank M. Vagins and Y. Sugawara for useful advice to this essay.

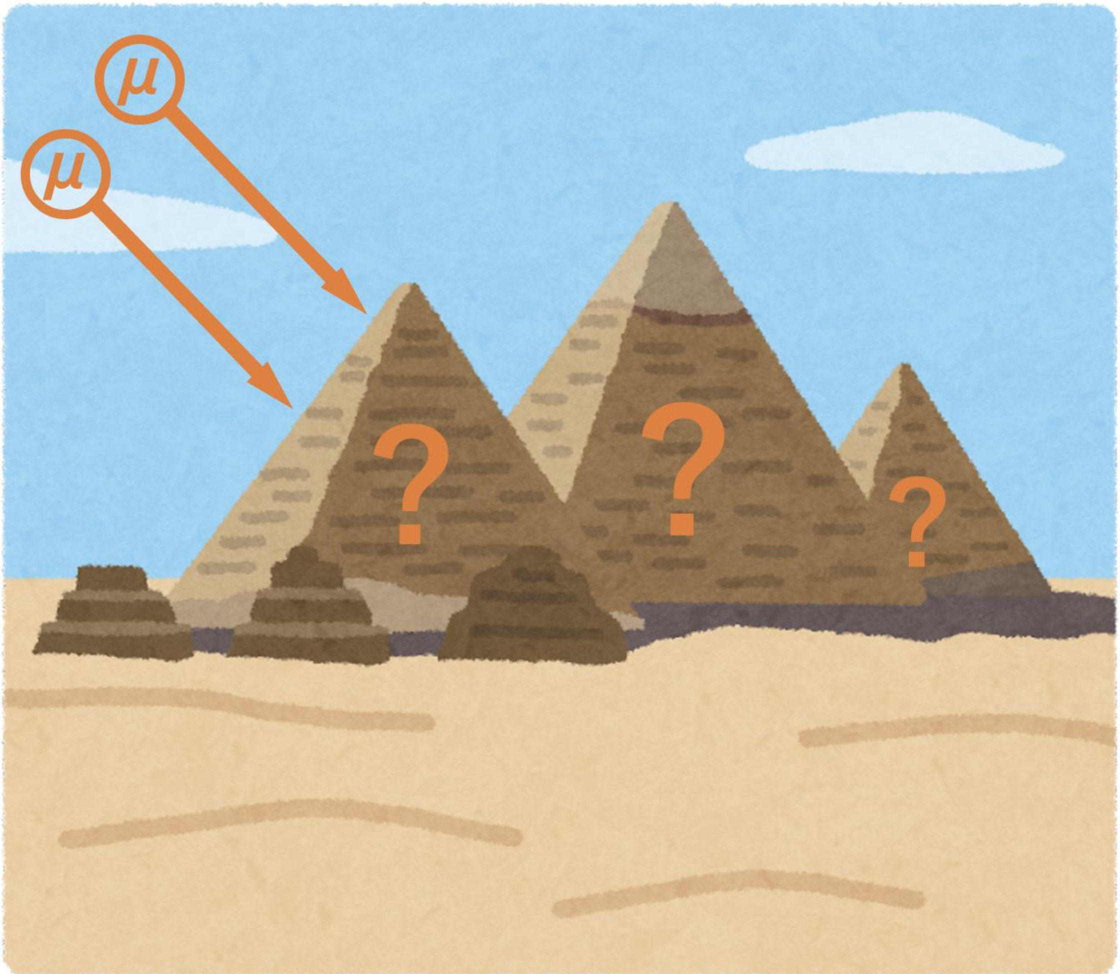
This essay was written with the Internet dictionaries "Weblio" and translation tool "DeepL". I used "Weblio" to search for words and to look up synonyms to paraphrase them and I used "DeepL" when I can't think of a good way to describe.

References

[1] C. F. Powell, G. P. S. Occhialini, D. L. Livesey and L. V. Chilton, "A New Photographic Emulsion for the Detection of Fast Charged Particles", *Journal of Scientific Instruments*, vol.23, no.5, 1946, doi:10.1088/0950-7671/23/5/304

[2] M. K. Gaillard, B. W. Lee, J. L. Rosner, "Search for Charm", *Reviews of Modern Physics*, 47 (1975) 277-310, doi:10.1103/RevModPhys.47.277

[3] DONUT collaboration, "Observation of tau neutrino interactions", *Physics Letter B*, 504 (2001) 218-224, doi:10.1016/S0370-2693(01)00307-0



Original image https://www.irasutoya.com/2015/02/blog-post_791.html