

# An Account of my Past Half

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It is a great honour for me that the editor has made this book a memorial publication to commemorate my retirement from the Institute for Cosmic Ray Research, University of Tokyo. Accordingly, I have been asked to write a short history of my life. Although there is nothing special to write about, the following is a short summary of a few of my personal matters.

## 1. Younger Age

I was born on the 3rd January, 1924, in Taichung which locates at the center of Taiwan. It is a hot place near the tropical region, and the natural surroundings; fields and rivers are all very interesting and impressive for a young boy. In primary school, I was one of the smallest in height and probably a lazy boy from the point of view of the teacher. I spent much time near a pool to get hard training for a swimming race, and our team got a champion flag against many other schools in the district. In middle school, I practiced running every day aiming to be a member of the athletic team, but I was not successful because I was so slow; more than 20 min per 5 km. At 16 years old, I skipped the last one year of middle school to proceed to high school in Taipei. When I left my home alone, I promised myself to study very hard. However, it was found soon that the circumstance in high school was completely liberalistic and even having a trend of decadence. I then started training in Japanese fencing, and was successful to become a member of the team, I also grew taller, to an ordinary height and, at the same time, I got a habit for drink. The educational system was so strict that more than half of my friends stayed in the old class. Thereafter, I entered Osaka Imperial University to study physics, since there were many active professors in the field of nuclear physics. Nevertheless, it was already war-time and Osaka City was completely destroyed by bombing. The University building just escaped from fire without serious damage, and I was able to graduate in September 1945 just after the end of the war, when I was 21 years old.

## 2. After Graduation

I studied at Osaka University for 3.5 years as a National Research Fellow under Professor T. Asada who was in charge of experimental optics and applied physics. He

gave me a research subject “Direct measurement of fine structure of hydrogen”. Though it was never completed, I studied many experimental techniques, such as high vacuum, electric discharge, microwave oscillation, fine spectroscopy and so on during this period.

In 1949, Osaka City University was rebuilt and I joined the cosmic ray group of the University conducted by Prof. Y. Watase. The physics department of the new University had a very stimulating atmosphere due to its many young members, such as Y. Nambu, S. Hayakawa, Y. Yamaguchi, K. Nishijima and so on in the theoretical group and M. Oda, K. Suga, T. Takakura, S. Fukui and so on in the experimental group.

### 3. Cosmic Ray Experiments on the Mt. Norikura

The first experiment was to study a multiple production of mesons in P-P collision by the use of high pressure cloud chamber. The chamber, having a size of 25 cm in diameter, 7 cm deep and filled with hydrogen of 100 atm., had been constructed, transported and operated at Mt. Norikura (2770 m a.s.l.). Although the phenomena of multiple meson production in hydrogen and nuclear star, electron pair production in argon gas etc are found in this observation, the rate of events are so small and we decided to make a bigger chamber. The second chamber, of 50 cm in diameter, 20 cm deep and 150 atm. was constructed and operated at the same mountain laboratory. Before we found several events of multiple meson production, an accelerator experiment by “Cosmotron” in the USA had already started and a few hundred similar type of events were easily found in a hydrogen bubble chamber. Since it was not competable, we had changed our research subject to ‘Energy spectrum of cosmic ray fast neutron in the atmosphere’. The neutrons in the energy range of 1 MeV to a few tens MeV which is a source of thermal neutrons in the atmosphere were observed by measuring recoil protons in the chamber. Later on, similar spectrum of higher energy region was obtained by analysing nuclear interactions in nitrogen gas.

After some work on hard showers observed by multiplate cloud chamber, we started a study of Extensive Air Showers. In order to study the character of the core of EAS which plays an essential role to the development of EAS in the atmosphere, we made a large multiplate cloud chamber, 2 m wide, 1.3 m high, 0.7 m deep, which contains 21 lead plates of 1 cm in thickness inside. This had been operated at Mt. Norikura Observatory together with numbers of plastic scintillators of EAS array. The cloud chamber pictures had shown large variety in the characteristics of the core: (1) there are large fluctuations in energy flow with relation to the age of EAS, (2) 10-20% of EASs have multiple core, and their relative  $P_t$  is large, (3) the total energy of hadrons is already small compared with that of electromagnetic component in an ordinary core, therefore, the attenuation length of EAS is estimated to be short ( $\sim 120$  g/cm<sup>2</sup>) compared with the value ( $\sim 240$  g/cm<sup>2</sup>) obtained from the rate attenuation of EAS, (4) however, there are special cases, though the rate of the event is small, that most of energy is still concentrated in a few high energy hadrons in the core and they are supposed to be very young showers. I thought that the main cause of such a large

fluctuation, which means the developing stage is different case by case, must be due to a level fluctuation of the starting point of EAS in the upper atmosphere. To illustrate above the features, I tried a theoretical calculation and also the direct measurement of attenuation length of each EAS through a water tank of 2 m deep.

#### 4. Underground Experiments in India

I received an invitation letter from Prof. M. G. K. Menon of Tata Institute of Fundamental Research, Bombay, India, in 1960. It was my first experience to go abroad and also the beginning of a long term collaboration with Indian scientists because I have visited India almost every year since then.

At first, I tried some experiments on EAS, for instance, the measurement of attenuation of muons in EAS comparing two rates of detection in lakes, one at mountain altitude and the other at sea level, construction of large multiplate cloud chamber, and so on. But my work was soon concentrated on underground observations, because the conditions at Kolar Gold Fields are ideal for confirming cosmic ray data underground (flat surface, uniformity of rock and great depth). An outline of the experiments there is enumerated below;

1960–1964; Depth-Intensity variation of cosmic ray muons deep underground were measured at 6 depths from 816 to 8400 hg/cm<sup>2</sup> and an empirical formula for vertical intensity of muons was obtained. At the deepest point of the experiment, the intensity of muons was so low that cosmic ray neutrino interaction could be observed in the near horizontal direction in an unambiguous manner.

1965–1970; Together with Durham University, U. K., cosmic ray neutrino observations were carried out at 7000 hg/cm<sup>2</sup> and muons produced by neutrino interactions in the rock were observed for the first time. During this period, exotic events called “Kolar events” and “Large cascades” were also observed.

1971–1974; Concerning the production mechanism of atmospheric muons, accurate observation of intensities and the zenith angular distribution of atmospheric muons, using visual detectors were carried out at 4 depths from 754 to 6045 hg/cm<sup>2</sup>. At the same time, data from parallel muons at these depths were accumulated.

1975–1980; Some of the exotic events like “Kolar event”, “Large cascades” and “Muon bundles” were observed at 1800 and 3375 hg/cm<sup>2</sup>. During this period, special types of muon bundle events and possible candidates for proton decay were recorded.

1980–1986; The experiment to verify grand unification theory by finding proton decay has been in operation at the depth of 7000 hg/cm<sup>2</sup>, and several candidate events have been obtained. In addition to the first detector operating for the past 6 years, a new one has started taking data at 6045 hg/cm<sup>2</sup> since December 1985.

The above last stage of the experiment is still continuing with the aim of;

- 1) search for proton decay, neutron oscillation and magnetic monopoles,
- 2) prompt muons produced in high energy hadron interaction,
- 3) muon bundles and parallel muons as a character of high energy interactions at the top of the atmosphere,
- 4) “Kolar events” which are a possible evidence for the existence of long-lived

and massive particles,

- 5) neutrino astronomy to detect extra-terrestrial neutrinos.

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Thinking back over the old days, I have been really fortunate to have had many excellent friends and colleagues in Japan, India, USA, UK, USSR and many other countries. It was almost impossible for me to have done any meaningful research without their kind encouragement, discussion and cooperation. I would like to express cordial gratitude to them for their kind assistance, and also to solicit their continued friendship in the future for as long as possible.

### REFERENCES

- Nucleon Decay Experiment at the Kolar Gold Fields: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *Proc. Third Workshop on Grand Unification*, North Carolina, 119 (1982).
- Proton Decay experiment in Kolar Gold Fields: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *Inter. Colloq. on Matter Nonconservation*, Frascati, 97 (1983).
- The K. G. F. Nucleon Decay Experiment: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *Workshop on Grand Unification Theory*, Philadelphia, (1983).
- Energy Spectrum of Muons at Sea Level and Limits on the Flux of Directly Produced Muons: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *Proc. 18th Inter. Conf. on Cosmic Ray*, Bangalore, 7, 46 (1983).
- Results on Cosmic Ray Neutrino Interactions from the K. G. F. Experiment: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake, *ibid.*, 7, 95 (1983).
- Limits on the Flux of GUT Monopole from the K. G. F. Experiment: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake, *ibid.*, 5, 114 (1983).
- Nucleon Decay Experiment in Kolar Gold Fields: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *First Asia-Pacific Physics Conf.*, Singapore, 2, 987 (1983).
- Limits on the Flux of Monopoles from the Kolar Gold Mine Experiments: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake, *Physics Letters*, 142 N1, 99 (1984).
- Nucleon Decay Experiment at Kolar Gold Field: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *Inter. Symp. on Cosmic Rays and Particle Physics*, 662 (1984).
- Results on Direct Production of Muons and Monopole Flux from K. G. F. Proton Decay Detector: B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake, *Inter. Symp. on Cosmic Rays and Particle Physics*, 675 (1984).
- K.G.F. Nucleon Decay Experiment: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *Proc. 11th Inter. Conf. Neutrino Physics and Astrophysics*, Dortmund, 344 (1984).
- Results from the K.G.F. Proton Decay Experiment: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake. *UP 85 Italy* (1985).

- Observation of Multiple Muons at Kolar Gold Mine: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake, *Second Asia-Pacific Physics Conf.*, Bangalore (1986).
- Underground Physics: M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, B. V. Sreekantan, Y. Hayashi, N. Ito, S. Kawakami and S. Miyake, *Second Asia-Pacific Physics Conf.*, Bangalore (1986).