

My Journey from Cosmic Rays to Elementary Particles

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I was fascinated by the study of cosmic rays after reading a B.Sc. level text book: "Modern Physics" by J.B. Rajam, which included the image of Piara Singh Gill (PS Gill). The footnote mentioned that PS Gill is the discoverer of latitude effect of cosmic rays. I was motivated to join Aligarh Muslim University (AMU), Aligarh for my Masters degree in Physics by Gurbax Singh Narang, our Physics teacher in Government Mahendra College, Patiala, who had once tried to register for Ph.D. in AMU under PS Gill. In July 1961, I was admitted to M.Sc. first year in Physics at AMU Aligarh. Just after my admission, PS Gill left for a trip to USA to carry on his research investigations on cosmic rays there. On his return after a year, he started teaching our class the special paper "High Energy Nuclear Physics", better known as elementary particles.

During the 1960s, research was yet in its infancy in Indian Universities, and infrastructure facilities were also lacking. However, Tata Institute of Fundamental Research (TIFR) in Bombay was rated among the topmost in area of cosmic rays due to Homi J. Bhabha, its director and future architect of Atomic Energy of India. Dr. PS Gill, who was my favourite teacher in AMU Aligarh, also joined TIFR during mid-1940s and started using balloons for study of high altitude effect of cosmic rays. As the saying goes "two swords cannot stay in the same sheath", the two scientists soon separated due to personal rivalry and Gill moved to AMU Aligarh in 1948 to set up his own independent cosmic ray research laboratory at Gulmarg in Jammu and Kashmir state.

I met PS Gill on 21st June 1961 at his official residence in AMU and told him about my plans to join Masters in Physics under his supervision. He was reluctant to accept my proposal and told me about his forthcoming

visit to USA for one year. I felt discouraged. But, as luck would have it, I met Bhai Amar Singh, a philanthropist of Aligarh, who offered that I stay in his house till I get admission in AMU. I joined AMU Physics Department in end of July, 1961. Dr. Gill returned from USA and started teaching us cosmic rays and particle physics. He was using his notes mostly based on Bruno Rossi's book "High Energy Particles".

The subject of cosmic rays was fascinating and we were delighted to find that Homi Bhabha had made some unique contribution to the study of extensive air showers through Bhabha and Heitler Cascade Theory of cosmic air showers theoretically and later by study of these showers experimentally. The contributions of Calcutta University for recording tracks of cosmic rays using cloud chamber and nuclear emulsion plates were also considered to be pioneer work in the area of cosmic rays. DM Bose and Biva Chowdhuri studied the meson production in cosmic rays at the same time as CF Powell in Bristol University, Bristol, who got the nobel prize in 1950 for discovery of Pi-meson.

I started my teaching career in Guru Nanak Engineering College, Ludhiana, Punjab in 1963. In 1965, I joined Punjabi University, Patiala. The research in the Physics Department was in its offing and I was assigned to teach a special paper "Cosmic Rays and Particle Physics". This experiment failed as there were no research facilities in the department. Punjabi University was set up to teach science and other disciplines in punjabi medium. To promote science in punjabi, I translated Arthur Beiser's book "The Story of Cosmic Rays" into Punjabi (*Brahmandi Kirna Di Kahani*) which was awarded the first prize of Punjabi University, Patiala under medium switch over programme.

After 5 years teaching in the university, I became eligible to go for higher studies leading to doctorate in Physics in a foreign university. I was exploring some avenues both in India and abroad. First, I contacted Prof. Swamy who was deputed by TIFR to supervise research in Punjab University, Chandigarh in high energy physics. Then I met Prof. Yog Prakash of Jammu University, a former student of PS Gill from AMU, who had post-doctoral training in cosmic ray physics from USA. Somehow, I did not feel motivated to work in India after my meetings with both Swamy and Prakash.

In 1969, I was selected under Indo-Russian collaboration to study in Moscow State University, but this scheme was cancelled at the last moment. In 1970, I qualified for Indo-French Exchange Programme and joined Pierre and Marie Curie University, Paris for my doctoral research. During the interview held in Alliance Francaise at New Delhi, I was asked about my choice of work place. I mentioned cosmic ray laboratory (Laboratoire du Rayonnement Cosmique) at Pic du Midi in South of France. But, I had no letter of recommendation from its Director. Hence, my choice fell on Laboratoire du Physique Generale, where Professor Max Morand, its Director, accepted me as his Doctoral student. I was helped in my search by Dr. Sham Lal Malick, a Scientist in Marie Curie University, who happened to know Max Morand.

Prof. Max Morand had done his doctorate on cosmic rays during the time Pierre Auger was working on extensive air showers in France. He was on the verge of retirement and not interested to undertake fresh graduates in his Laboratory. He accepted me on the condition that I shall have to work under the supervision of a Chinese scientist, Tsai Chu, who was a research scientist in his laboratory since last 20 years. He issued me a letter for my scholarship office that I need not go to an outside institute in Rouen for learning French language. I can do it in Paris alongside my scientific research. This was a great relief and time saving device for me as I could focus on my research within two days of my arrival in Paris. Ultimately, I could finish my thesis just in two years because of this arrangement, allowed as a special concession in my case.

I started my research under Tsai Chu who was a man of few words and introvert type of person. He advised me to scan nuclear emulsion plates exposed to 14 GeV proton beam available from 27 GeV CERN Synchrotron. It was a very tedious job. Ms. Thibaut was a scanner to help me learn this technique, but she never bothered to provide me assistance as she was acting as a typist to Director of our Laboratory, Max Morand. My objective was to study proton-nucleus interactions using nuclear emulsion as a detector. These interactions are recorded as nuclear stars in the emulsion plates. Most of the nuclear stars were consisting of black and grey tracks. My purpose was to find stars with least number of black tracks. After about six months, I had found nearly 200 nuclear stars with nearly a dozen of my interest, which I classified as white stars having relativistic particles as their prongs. The range and grain density of nuclear tracks was studied using Koristka Microscope, an Italian make with automatic recording facility on paper tape to be used in a computer.

This work was demanding and I had to make routine grain density and multiple small angle scattering measurements for 8–10 hours daily. The relationship between energy loss due to ionisation of charged particles and grain density of nuclear emulsions was well established and researchers had to depend upon the empirical curves provided by W.H. Barkas. I was provided a link to IBM 1620 Computer where we used punch card technique for loading our recorded data. Can you imagine the speed of this computer was so slow that I had to spend the whole night in the laboratory for running data tapes. These days a programmable calculator can prove to be more efficient compared with those IBM machines. Every month, I discussed results of my investigations with my supervisor.

Tsai Chu had spent almost 20 years working on cosmic ray and particle track studies in emulsions. He claimed to have set a world record in manual counting and measurements of track lengths using optical microscopes. His other claim was inspiring and my motivation to carry on with nuclear interactions using high energy proton beams. Tsai Chu had

predicted the existence of a heavier Lepton, L-meson particle, with mass in the range of 780 MeV and which decayed into four lighter particles, as a resonance decays. I had doubt about the prediction of Tsai Chu. Initially, I accepted his opinion and faithfully worked with full devotion to establish the validity of his prediction. But later on, I lost my faith in his proposal as all high energy particles emitted in my nuclear stars were identifiable as already discovered. Most of these proved to be relativistic Pi or K-Mesons. Tsai Chu was not prepared to accept my results. Hence, I felt frustrated and depressed.

To resolve this controversy, I planned to visit Rutherford Laboratory in Cambridge university, where a High Energy Physics Group has indirectly supported the prediction of Tsai Chu. I had no prior appointment with Cambridge group. Reaching London, I made a contact on phone and was invited for an open discussion. I presented my results with the help of slides and was curious to know the opinion of Cambridge scientists. After my presentation, they assured me that they no more support Tsai Chu as their own results were also negative. I was relieved of a great predicament.

On reaching Paris, I met Prof. Max Morand and told about my interaction with Cambridge group. He was having his own doubts about Tsai Chu's prediction and allowed me to go ahead with conclusions of my investigations in an objective manner. Since Tsai Chu was my Research Supervisor, hence his permission was obligatory to submit my doctoral thesis. As a last resort, I made up my mind to make a last attempt to reject the prediction of Tsai Chu. In a mode of prayer, I started to look for a 'White Star' in my emulsion plate and my prayers were answered when I found it with all 14 particles identifiable as already discovered, without an iota of doubt. I presented my results to Tsai Chu but he was reluctant to accept it. In a huff, I met Director of my Laboratory who encouraged me to publish my results in a research journal before submitting my Thesis. Before my return to India, I published 5 papers based on my thesis, one in Nuclear Physics and four others in the Comptes Rendus (Proceedings of the

Academy of Sciences, Paris). My thesis title reads in French: "Identification des particules elementaires produit dans p-N interaction a' 14 GeV/n dans un emulsion nucleaire", which will read in English: "Identification of Elementary Particles produced in p-N interaction at 14 GeV/n in a nuclear emulsion".

It was summer vacation and I made up my plan to write my thesis. I was not confident that I can prepare its copy in French language as per the terms and conditions of my registration in Marie Curie University. I wrote introductory chapter in English and got it translated in to French by my colleague Madame Lory. Most of the other chapters on discussion and results, I wrote myself in French. Prof. Max Morand was highly impressed by the quality of my thesis and wrote a note of appreciation that it was written in flawless French. I submitted my thesis in mid-June and went for my tour of European countries. My defence of thesis was held on 26 September, 1972 in the presence of my colleagues and other friends as the defence is open to public as per French tradition. Professors Max Morand, Mrs. Morand and Louis Avon from University of Clermont Ferrand were members of Jury. After my presentation of more than one hour, my examiners asked some questions and I had to answer in French. I managed to hold my fort during defence with flying colours. Tsai Chu asked a ticklish question about the work of a Russian scientist supporting his prediction which I could handle with utmost confidence. The jury was so much impressed that they recommended my Thesis for D.Sc. degree but my tenure in the University was less than the stipulated period of three years for this degree, hence I was denied this rare honour.

As per French custom, the award of Doctorate degree is celebrated by a champagne party. My Arab friend from Tunisia, Moncef Fekih, had made all arrangements for the party. He also acted as my Photographer. Naresh Singh and some other Indian scientists of Paris University were also invited on this occasion. My scholarship was sanctioned for three years, but I finished my assigned work leading to Ph.D. degree in just two years. I was in a trap, Prof. Max Morand was on the verge of retirement, and Tsai Chu was annoyed with me because my thesis has demolished his hopes of

getting some Award if his prediction of L-meson was established. I was away from my family and a sort of nostalgia overpowered my mind. I decided to return to India to celebrate Diwali festival on 5th November, 1972 with my family. I was in such a hurry that I failed to communicate the date of my arrival in India. I wanted to give them a big surprise!

I was not sure of my return to France as Punjabi University, Patiala, where I held my lien as Assistant Professor had advertised the post of Associate Professor. I was in queue for promotion. Unfortunately, this post was not filled up till 1975, as my senior in hierarchy could not complete his Ph.D. and he was able to get our interview postponed, till he was awarded the degree. Once in a while, I thought of going back to Paris, but then my family was not reconciled to my viewpoint. I started weighing options. Before my departure from Paris, my thesis examiner Prof. Louis Avon arranged my meeting with his mentor in research, Prof. Leprince Ringuet of College de France. He advised me to participate in K^0 - anti K^0 CERN collaboration between India and France as an Indian representative. This turned out to be an uphill task as TIFR Bombay had already recommended some Indian scientists to work in this collaboration. Punjabi University had no facility for experimental work in Particle Physics. So, my dream of continuing my research in Particle Physics was shattered due to my logistics problems.

After return to India, I borrowed a stack of emulsion plates exposed to Deuteron beam at Joint Institute of Nuclear Research (JINR), Dubna, near Moscow. My intention was to continue some work with Russian collaboration, but I found that two more universities in India, namely Jammu and Delhi University, were already working on these stacks. For a year or so, I was shuttling between Patiala and New Delhi to work under Russian collaboration but the research scholar who was employed in this project left me in the lurch. I guided one M.Sc. project in Particle Physics using nuclear emulsions, published 2–3 papers in journals and decided to abandon my field of interest. Within two years, I changed my field from Particle Physics to Geochronology under a CSIR Project "Dating of Rocks". This is how my

journey from cosmic rays to particle physics ended. To keep myself updated in this field, I subscribe to CERN Courier, a window on particle physics.

List of My Papers (Copies available on www.researchgate.net/profile/Hardev_Virk/publications)

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