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# Turning points in my career to be a physicist

**Prof. Ngangkham Nimai Singh**

I was born on November 25, 1955 (Friday), as the eldest son among five siblings (three brothers and two sisters) of my parents, Shri Ngangkham Rajmani Singh and Smt Ngangkham (Ongbi) Maipakpi Devi of Khurai Konsam Leikai, Imphal East district of Manipur. The year 1955 has many significances specially in physical science as Albert Einstein died in this year, and many creative minds were born in this year, viz., Tim Berners - Lee, founder of the World Wide Web (WWW); Steve Jobs, founder of Apple Inc; Bill Gates, founder of Microsoft, to mention a few.

**Primary Education – from class I to V:**

I first started my early informal education at home and then formal education a bit late from Khomidok U.J.B. School (morning shift), Khurai Konsam Leikai, Heigrumakhong, Imphal, from class I to class V (my academic date of birth in educational record: August 1, 1959). This was the only lower primary school in my locality on Pukhao road, about one km from my home. I remembered my teachers gave me the responsibility to bring their teas and eatable fried *pakoura* (*bora*) from a nearby hotel during half time for their refreshments, and I was advised to wear clean cloths, wash my face and hands, and tackle tea plate without trembling my hands. Near the annual examination, we also used to offer a few oranges in a plate to our beloved teachers for their kind blessings for the forthcoming annual examinations. I could also remember the frequent visits of the school inspector and his subordinate team from Education Department (Schools), Government of Manipur, and they directly entered in our classes for interactions when classes were going on. I could not see such inspections nowadays. We had enough school compound with big playground to play even football during half time.

During those days, common examinations for classes III and V were conducted directly for the whole state of Manipur by the education department, and examination results, including the merit lists of the cleared students, were published in local Newspapers. I used to get some prizes comprising a Hindustan Notebook and a pencil for appearing my name in the merit lists in these two common examinations. These examinations were the early signs of the status in performance of a particular school and also the potential of a particular good student for his future career.

My father was also a school teacher serving at Khurai Popular M. E. School (day-time shift) located on Ukhrul road, and he took me to his school to attend classes without formal admission after my morning shift classes. In this way, I attended two schools – one in morning shift and other in day-time shift. Thus I had a very wide friend circle in my locality. I completed Class V examination in July, 1969 with good performance. Arithmetic and English grammar, particularly

conjugation, active-passive voice, direct-indirect sentences, were taken extreme care during those days. My father used to teach me English grammar, particularly conjugation very well.

**High School Education – from class VI to VIII:**

The first turning point in my life was getting the admission in class VI at Lamlong High School located near Khurai Lamlong Bazar, about four km from my home. It was just climbing one layer of ladder in life with full of excitements. The overall atmosphere in education was very good there as it was competing with another neighbouring Khurai Lamlong Girls' High School. It was the right place for shaping my future academic career. I remembered how the school assembly parade at Lamlong High School, was performed majestically before starting school classes with the command of the best NCC cadet of the school, and I always arrived at school early in order to attend this assembly parade. The publication of our school magazine was another great event. I also contributed a short story and a poem. It was my initial lesson for creative writing and I continued writing from that point on. We were very strong in Manipuri literature at that time and we used to read a lot of Manipuri novels, including Dr. Kamal's *Madhabi* and Kabi Anganghal's epic, *Khamba-Thoibi*. We had so many cultural activities in the school and I also participated in some recitation competitions in the school and state functions. I could manage to get some prizes in the state level competitions.

I completed my class VIII state level common examination in 1972, securing eighth position in the merit list which was published in *Khollao Daily newspaper*. In some schools there were additional subjects like Sanskrit in which the excess marks from the pass marks, were added as extra bonus to the total marking. That facility was not there in my school. In CBSE, Delhi such system was not there and only best four subjects were picked up. I was so happy that I could answer all the questions in Mathematics paper and I got 97% as three marks were deducted for my careless handwriting. New thick books on General Science, Algebra, Arithmetic and Geometry were quite attractive to me at that stage and I felt proud of having them. We were trained to write essays on different topics and it was also compulsory in the examination. This practice helped us to impart creativity in writing skills. Another very peculiar habit we practised at that time, was to

wake up very early morning at around 3 am and concentrate in our self-study. During our time, private tuition was for mathematics subject only for one or two months to make up for the weakness in the subject.

**Higher Secondary and Intermediate Education – from class IX to XI:**

My second turning point in my career was to get admission in Class IX at Johnstone Higher Secondary School, Imphal in July 1972. It occurred by chance when I was requested by a friend of mine to accompany him to visit this school for his admission in class IX, and the principal of the school, Ohja Phanjoubam Tomchou Singh, asked me about my performance in class VIII examination, and advised me to take admission on the spot in the school as my name was in the merit list of Class VIII examination. The Vice-Principal Oja Irengbam Lukhoi Singh was so dominating in the administration of the school. He was also a towering figure. I narrated the incident to my parents and indeed, it turned out to be my best luck in life. The education system in this school was different from others. In this school, there was All India Higher Secondary Three-Years course (from class IX to XI) under Central Board of Secondary Education (CBSE), New Delhi. We were the last batch of this education system in Manipur state and the track record of this school was extremely significant. I completed my class XI Science exam in July 1975 with a high first division (probably the highest from the state of Manipur). During this period in class X, I had an opportunity to represent the state contingent in the All India Youth Cultural Festival at Lucknow. Among many senior artists, we were two from our school and other one was my classmate, Shri Moirangthem Lakhmikumar Singh from Arts Section, who became later on an IAS officer (Commissioner). Among the contingent I could also remember another girl student from Little Flower school, Sumitra Phanjoubam who is presently serving as Professor of Physics at Manipur University and Dean, School of Mathematical and Physical Sciences. This memorable journey shaped my future career to motivate me for studying outside Manipur.

My real interest in Physics originated during this three-years course under CBSE, Delhi. The moment I learnt the law of falling bodies and the famous Galileo's demonstration from the leaning tower of Pisa, I was thrilled and narrated my physics lessons to my illiterate mother at

home. My mother just smiled and had enough patience to listen to me. During my childhood I was very talkative, particularly during lunch and dinner time when all members of the family were present and I was advised many times to keep quiet. At Johnstone Higher Secondary School, we had four excellent physics teachers – Shri Sinam Achou Singh, Md. Tariq, Mr. P. B. Sen and Mr. Yumnam Kunjabihari Singh, and a very big physics laboratory with full of physics apparatus and equipment. I felt full of enjoyment in learning physics effortlessly and I could answer all questions in the examinations. During long holidays of Durga Puja, Oja S. Achou Singh handed over physics laboratory keys to me to practice physics experiments. I myself developed some experiments based on electrolysis with the changes of plate sizes and separation between the two plates. Such kind of encouragement was unbelievable to think. With the help of Oja S. Achou Singh, I could complete mathematics course up to class XI when I was just in class IX stage. One of my favourite teacher Oja Md. Tariq who came from Aligarh, advised me to be very careful with my handwriting while answering the questions in the examination so that I could score full marks. I am not mentioning many other teachers of this school, who inspired me in different ways, but the name of Oja R.K. Madhubir Singh will be always associated with my mind for his unique and rustic style of teaching English poetry. I still remember how he described the style of writing of Robert Frost compared to other poets, and the recitation of poems by Robert Frost during the celebration to the victory of John F. Kennedy as American President. Eminent poet R. K. Madhubir Singh was bestowed with Sahitya Academy Award for his contributions to Manipuri literature.

I used to subscribe the science journal "*Science Reporter*" every month to update our knowledge in science. I sent a few questions related to 'dream and its causes' also to the editor of *Science Reporter* and in subsequent issue the answers to my questions had appeared. It was a great satisfaction for me and I showed it to my classmates. In addition to our textbooks, I used to buy physics reference books written by foreign authors from P.C. Jain Book Store at Thangal Bazar, Imphal. I remembered one good Physics book, "*Physics: Foundations and Frontiers*" by George Gamow and John M. Cleveland (1969), which was so resourceful to me.

**Difference in Education System and P.U.Sc 2$^{nd}$ year:**

My next aim was to get admission to three-year B.Sc. Physics (honours), outside Manipur preferably at University of Delhi. There was a difference in education system in Delhi and Manipur at that time. The colleges in Manipur were under Gauhati University (GU), with two-year P.U.Sc. and two year B.Sc.(Hons) course i.e. 2+2 system. I was compelled to take admission in 2nd year of P.U.Sc. course before getting admission in two-year B.Sc. (Hons) course in Manipur. I somehow completed P.U.Sc. 2nd year in 1976 under G.U. from Modern College, Porompat, Imphal.

I still remember one incident in my physics class. Our beloved teacher by mistake, gave a class lecture that magnetic field so far produced, was parallel to the plane of the coil. I humbly told him that it should be perpendicular to the plane of the coil, and the teacher remarked to me that I was not regular to classes and therefore, I was confused. I kept silent, though I was quite confident in physics during those days. However, the teacher was so honest that he corrected his lecture notes during the next day lecture and smiled at me. Another interesting episode was a small question about absolute zero temperature in our half-yearly examination. I answered from Physics book by Gamow and Cleveland that the exact absolute zero temperature could not be attained theoretically, and the chemistry teacher was quite annoyed to me for writing the unnecessary wrong thing. I told him that everything what I wrote was correct.

In the same year (1976), I also qualified for the *National Science Talent Search Examination* (NSTSE) conducted by NCERT, New Delhi, and I also topped the All Manipur entrance examination for admission to MBBS course in 1976. My love for physics finally guided me to opt for three-years B.Sc. (Hons) physics course at the University of Delhi, thus losing one more year. This decision was to some extent against the wishes of my parents who advised me to take admission either in MBBS course or engineering course. This was a crucial turning point in my life. The only person who supported me was my grandfather.

The project dissertation I submitted for NSTSE was on “laws of falling bodies inside a medium”, and this was the synthesis of laws of falling bodies in vacuum, Archimedes’ principle of floating bodies and viscosity with terminal velocity. I came to Calcutta alone by train to appear for the personal (physical) interview of NSTSE at Physics Department, Calcutta University, before a group of eminent experts and professors. I was thrilled and this inspired me a lot to study physics in my

future career. I was first asked what was the field of my interest. I replied as Physics. Next question was what part of physics. I replied nuclear physics. The next question was what is nuclear physics. I answered Planck's law. Then they asked again about Planck's law and Planck's constant. Every word I uttered was the source of next question. They asked why I was not interested in biology and also about the price of rice in Manipur. I replied that it was Rs 40 per *sangpai* and they started asking me what *sangpai* means. They further asked me so many other mathematical problems to calculate on the blackboard. I could appreciate every law of physics which connects mathematics with physical world. The underlying philosophy was that the three aspects of Nature - human mind, mathematics and physical world are connected by an Eternal Triangle.

Apart from my studies, I was equally interested in sports activities. Sometimes, I was afraid that my interest in sports might take me away from my studies. It seemed to me that I was a gifted Kabaddi player at that time and I possessed a hidden sixth sense when I was in play. When my opponents attacked me during the play, I could jump above a considerable height, or even fly unconsciously as an autonomous reflect action. I was carried away by instinct. At normal times, I could not perform the same activity. I still remember I was chosen as team Captain of Kabaddi team of Johnstone Hr. Sec. School to represent the state Kabaddi tournament when I was in class IX. Other senior players of Class XII in my team were not happy. I felt that sixth sense is required in all fields at the highest level. I could also win the hundred-meter race competition in my school annual meet. This sports spirit helped me to participate in many cross country races in my future career at the University of Delhi. I used to run about 20 kms every morning during my undergraduate days. Other items of my interest were javelin throw and shot put throw, where I used to apply the physics law of parabola. Such activity supplemented my concentration and stamina in studies.

**Graduation and Post-graduation at University of Delhi:**

My third turning point was in July 1976 when I arrived alone in Delhi by train for admission to B.Sc. Physics (Hons) at the University of Delhi. I took shelter at the residence of MP Mr. Paokai Haokip at South Avenue, Delhi with other fellow Manipuri students coming for admission. Next

morning, I boarded a bus going to the Delhi University campus from South Avenue. The red-coloured building of Ramjas College in the heart of the university campus, was the first college building I saw from inside the bus on the campus. When the bus stopped there, I rushed to the college for admission, but the admission was closed as the last date for admission was already over. During those days, the announcements of GU exam results were very late. I was standing near the college corridor with a broken heart. Two college staffs called me suddenly from inside a doom through the window, and asked me to show my marks. I showed two marks sheets – one for XI class of CBSE (1975) and another for P.U. Sc. (2$^{nd}$ year) of Gauhati University (1976). After observing my high marks in both cases, they told me that my admission had been considered with hostel facility, as a special case, and I could start attending classes from next day. It was the happiest moment in my life. Thus I became a student of University of Delhi. Later on, I learnt from other fellows that there were many other better colleges on the campus and my marks was enough to get admission in any other better colleges. I did not know any other colleges on the campus at that moment. During this three-year undergraduate period, we used to read in the college library up to dinner timing, and we did not depend much on teachers. The practical classes were very serious with all teachers observing our activities and sitting throughout the practical hours. While signing the practical, the teacher used to ask many questions as viva. Most of the teachers were extraordinary in teaching and they were very serious. I would always consider Undergraduate course of the University of Delhi as one of the best in India in terms of the syllabus as well as the standard of teaching. I contested for the General Secretary post of the Physical Society of our college and my teachers helped me to win my election.

One memorable event was in my first year B.Sc (H) examination of first paper in Mathematical physics. There was a question of three marks on cross product of three vectors. Somehow I forgot the trick to solve it and I kept on trying it for almost two hours. Except for this small question, I knew all other remaining questions but I was so adamant not to surrender this small question. Somehow hurriedly, I answered some small questions in the remaining time, and the last fifteen minutes was again wasted trying the same tricky question. I thought I would fail the examination and drop the other remaining papers. My bosom friend Sri Nameirakpam Ranbir Singh of St. Stephen College, who was studying in the same course, rushed to me and persuaded me not to

drop the remaining papers and I accepted his good advice. To my surprise, somehow the examiner gave me pass marks and I managed to get first division with the other remaining papers. My close friend always advised me that we had to combat the examination system to complete the course and we should know the examination techniques. Now I remember a writing on the front door of a senior Professor of Mathematics at ICTP, Italy, "*When I learn a new trick (in Mathematics), I feel younger*".

During my undergraduate days, we also organised academic discourse beyond class room, on various topics of contemporary importance on every Sunday, known as "*Sunday Discussion*". I was allotted two topics to prepare and present in the Sunday Discussion. One was on the recent technological advancements in war, including atomic bomb, hydrogen bomb and neutron bomb, whereas the other was on Hegel's philosophy on dialectical method. Hegelian dialectic is a way of thinking that involves examining ideas by looking at their contradictions and finding a resolution. It is like playing a game of *thesis*, *antithesis* and *synthesis*. The thesis represents an idea, the antithesis represents its opposite or contradiction, and the synthesis is the resolution or new idea that combine both. I was amused to hear an important presentation given by our senior Sri R. K. Bhogindro Singh of Delhi School of Economics, on the "*Base and Superstructure model*" which is a cornerstone of Marx and Engels's materialist philosophy. Base and Superstructure are two linked theoretical concepts developed by Karl Marx. Base refers to the production forces, or the materials and resources, that governs the goods society needs. Superstructure describes all other aspects of society and ideas, including culture, institutions, rules, rituals, religion, media, laws and state. The relation of the two parts is not strictly unidirectional. The superstructure has a stagnant and retarding effect and can affect the base, which is accelerating in progress. However, the influence of the base is predominant. Such mismatch is the cause of an uprising in a stage of development in a society, the so-called revolution. My particular interest in these topics is their similarity with physics. Hegel's dialectic is almost equivalent to *falsification* of scientific method introduced by Karl Popper. The analogy was that when a ball is disturbed with an external force, it will move and ultimately settle to a more stable equilibrium position. Acquiring new a stable equilibrium position is thus the outcome of applied external perturbation on the ball.

After completion of my undergraduate course in July 1979 with high first division, I took admission in M.Sc. physics at the University of Delhi and stayed at the university post-graduate hostel, the Jubilee Hall. My experience in two-year M.Sc. physics course (1979-1981) at the Department of Physics and Astrophysics, University of Delhi, was something extraordinary. In my first semester course, we were exposed to exceptionally eminent professors, e.g. Prof. S. N. Biswas teaching classical mechanics, Prof. A. N. Mitra teaching quantum mechanics with their unique styles without a piece of notes during the lectures. This gave me lasting inspirations in physics. The conceptual clarity possessed by these teachers, was very high. I could remember one class when Prof. A.N. Mitra introduced Dirac equation – how Dirac started thinking to write this new equation based on the analogy with Maxwell's equations, and it appeared to me that he was like Dirac himself. I was attracted in theoretical particle physics and quantum field theory as my specialization papers in M.Sc. third and fourth semester. I also offered Advanced Mathematical Physics in lieu of dissertation/practical. The specialization papers dealt with the physics of nature at the most fundamental level i.e. four basic forces of nature and quarks as basic building blocks of matter.

I was fortunate to hear the lectures of many celebrated physicists coming from abroad to the physics department. I still remember the talk of Nobel laureate and founding Director of ICTP Prof. Abdus Salam from Emperial College, London, Nobel laureate Prof. S. Chandrasekhar from Maryland University, USA, Prof. E. C. G. Sudarshan from Texas University, USA, to mention a few. I could hear the talk of Prof. John Bardeen who got the Nobel prizes in physics twice.

I also took active part in the activities of the Manipur Students Association, Delhi (MASAD) at different capacities, and also served as President of MASAD during my first year of M.Sc. Course in 1979-80. I completed my M.Sc. degree in July 1981 with specializations in Quantum Field Theory and Elementary particle physics, which are collectively known as theoretical High Energy Physics (HEP).

**M.Phil. and Ph.D. Programme at Delhi University:**

The fourth turning point, which was very crucial in my life, was the choice of my research career after M.Sc. degree. I had a strong desire to go abroad for the Ph.D. course in USA. I appeared GRE

(Graduate Recording Examination) and TOEFL (Test of English as a Foreign Language) examinations for getting admission to the Ph.D. program in the universities of the United States. I taught in a higher secondary public school in Delhi for almost a year, to earn money for these examinations. Some of my classmates got admission at US universities but I was unlucky as I could not materialize it even after getting admission in New York State University, USA. Without any reason, I could not get my passport in time.

In the Department of Physics and Astrophysics, University of Delhi, there were only three fellowships for Ph.D. programme per session for internal candidates under the scheme of UGC advance study centre. It was very competitive and difficult to get it. I requested some teachers for research works but was in vain without fellowship. Finally, as forecast in my dream, I approached Prof. A. N. Mitra for my research work in high energy theoretical physics under his supervision. He did not have a research project at that time to support me financially, and he used to take toppers only as his Ph.D. scholars. He reluctantly accepted me with the condition that I should demonstrate my ability during my M.Phil. course. I accepted the condition. Thus I got admitted in one-year course on M. Phil. degree in Physics without fellowship. The course comprised of six-month theory examination and six-month writing dissertation under a supervisor. I worked under the supervision of Prof. A. N. Mitra in the topic “Review on Proton Decay”. As a first lesson to start research, he instructed me to read a review article by Paul Langackar on proton decay. He did not mention the year of publication and the name of the journal where the article was published. It took some days to trace the article in the main library. This was how I learnt to search for references in library. When I started writing my dissertation, I wrote five times with corrections and revisions from my supervisor in the first chapter. First, it was extended to ten pages and then condensed to five pages. I was asked again to extend it to seven pages. I was objected to the use of flowery languages in my writing also. This was how he trained me to write dissertation. It was my first lesson to start a research work on a given topic, though the dissertation was based on review work. Proton Decay is the decay of proton or in general a nucleon to a lepton and meson, thus violating baryon number in the process. In this way all the heavy matter made up of nucleons will be decayed from the universe. It is the

prediction of Grand Unified Theories (GUTs) and it still remains as a theoretical conjecture with a lot of efforts on the observational front.

A ray of hope in my life came to me. During my M.Phil. course, the Government of India introduced for the first time the All India common examination for research fellowship, namely Junior Research Fellowship (JRF) conducted by CSIR, New Delhi and I was fortunate to get through JRF in the sixth position, and my supervisor was so happy more than me. It thus solved the uncertainty in my fellowship during Ph.D. research works. I completed the M.Phil. exam with the highest scores in 1983. With this JRF, I continued my Ph.D. programme under the supervision of Prof. A. N. Mitra in QCD-oriented relativistic few quarks dynamics (mesons and baryons) in two-tier Bethe-Salpeter equation using Null plane (light cone) coordinates. Mesons and baryons are collectively known as hadrons, which are quarks composites. Mesons are made up of quark-antiquark pairs, while baryons with three quarks. Quarks are confined inside the hadrons due to color quantum number possessed by quarks. This phenomenon is known as quark confinement or color confinement. My work is related to the relativistic quark model based on the Bethe-Salpeter Equation with Harmonic oscillator potential as confinement mechanism in four-dimensional covariant form in the Null plane coordinates. It is a mathematical model of the Quantum Chromodynamics (QCD) at low energy scale.

During my Ph.D. program I got an opportunity to attend the "25$^{th}$ Course SUPERWORLD II of the International School of Subnuclear Physics", held at the "*Ettore Majorana Centre for Scientific Culture*", Erice, Sicily, Italy, from August 6-14, 1987, and I could meet many Nobel laureates in physics and renowned physicists including Madame Chien-Shiung Wu, Samuel C. C. Ting, Sheldon Glashow, Michel Duff, Antonio Zichichi, to mention a few. It was an eye opener for me at the right moment of my research career. The nature of this school was something different from others. Those scholars who interacted with good questions and comments during the course, were noted by a group of judges, and scholarship/prizes were given to cover their entire expenditure of attending the school. The underlying philosophy adopted there is that the art of asking question is a part of learning. We were given the tasks of a scientific secretary who collected written documents for both questions and answers. As a part of it, I was assigned the

scientific secretary of Prof. Dimitri V. Nanopoulos, a famous Greek particle physicist from the Department of Physics and Astronomy, Texas A & M University, USA. During my Ph.D., I also attended the first SERC school on HEP at IISC, Bangalore. I also participated to ICTP Summer schools on Particle physics and cosmology at Trieste, Italy and the DAE Symposium on HEP at TIFR, Bombay, to mention a few.

When I started my Ph.D. work, I faced some problems in our formalism related to the covariance of the equation while using the Null-plane (light cone) coordinates. Later on, it was rectified with the appearance of equal plus or minus sign components on both sides of the equation, known as Null-Plane covariance (NPA Covariance). With this, our relativistic two-tier Bethe-Salpeter equation with quark confinement potential (harmonic oscillator potential) in four dimension, was in good form to tackle relativistic and covariant few light quarks dynamics. I could publish seven research articles with my supervisor in highly reputed international journals including Physical Review Letters (PRL), Physical Review D, Physics Letter B. I submitted my Ph.D. thesis in April 1988, and was awarded Ph.D. degree in 1989. In the University of Delhi, all three Ph.D. thesis examiners were from outside the university, preferably two from abroad, and the supervisor was not an examiner of the thesis. My thesis examiners were Prof. Bruce McKellar from the School of Physics at the University of Melbourne, Australia, Prof. E. Predazzi from the School of Physics, University of Torino, Italy, and Prof. G. Rajasekharan from the Institute of Mathematical Sciences, Madras, India. After my Ph.D, my supervisor advised me to stay at the Delhi University as a research associate, or go abroad for post-doctoral position. But somehow I had a strong desire to come back home and it was against the wishes of my beloved teacher. It was probably my mistake at the threshold of my career and our younger generation should avoid such a hasty decision. Nowadays, post-doctoral experience is required for placement as well as independent research career.

My supervisor, Prof. Ashoke Nath Mitra (photograph enclosed) was a renowned theoretical physicist who had unique contributions in his field of research, particularly in the nuclear exact solution of three-body problems and quarks physics with the first proposition of color quantum number (further details, Ref. Current Science, Vol. 124, No. 10, 25 May 2023). He was bestowed

with several awards in India, including Shanti Swarup Bhatnagar Award, S.N. Bose Birth Centenary Award etc. He did his second Ph.D. under the joint supervision of the Nobel laureate, Hans Bethe of Cornell University, USA, who had discovered how the star shines and other luminary F. J. Dyson of Cornell University, USA. I am still keeping with me a special gift given by my supervisor, which was indeed presented to him by Hans Bethe. Before the submission of my Ph.D. thesis, my CSIR SRF fellowship was completed and my supervisor forced me to take Rs 500 every month for about five months till I submitted my thesis, from his pocket as my fellowship. I tried to decline it by telling him that I was not from a poor family. But his argument was that my father was not a business man and I should concentrate in research and writing thesis without any distraction of my mind for money. After my thesis submission, I requested my teacher not to give me money, instead I would start teaching in a college for a few months as ad-hoc lecturer. He took me in some colleges and requested the principals of the colleges for any possible accommodation of my lectureship. I served as ad-hoc lecturer in two colleges under Delhi University – K.M. College and Rajdhani College for almost a year till I got the Departmental Research Associate under the Advance Study Centre. I left the departmental RA and then joined as CSIR RA with my choice of place of work at Manipur University in March 1989 with Prof C. Amuba Singh as my mentor.


*Fig.1. Prof. A. N. Mitra with his wife during his visit at Gauhati University in 2011.*

I stayed there at MU almost one and half year. I was fortunate to have my first experience of teaching in M.Sc. Physics course during this period, and it helped me a lot in my future teaching career. Since there was no vacancy of faculty position at Physics Department, MU, I decided to go back to the University of Delhi again to join the research associate position, or try to go abroad for postdoctoral position, to save my future research career. I virtually decided not to come back to Manipur again. I started thinking in a somewhat negative way that I had come in the wrong path of my life.

**Teaching and professional career - Gauhati Univ (1991-2013) and MU (2014-2024):**

The fifth turning point of life at this crucial time, was the meeting with an old Assamese friend of mine, Mr. Amar Saikia from Gauhati University (GU), who had submitted his Ph.D. thesis in Physics at GU. He advised me to apply for a lecturer's post at GU, which was advertised some time back and the last date for submission of application form was a few days left. In fact, he was

also an applicant to the post and his chance was very bright as he was the M.Sc. topper of GU. Following his good advice, I submitted my application at the last hour and I also faced the interview within a month. I was offered the permanent faculty position as lecturer in Physics at Gauhati University in December 1991. I would like to mention a memorable event in this interview that I was asked my date of birth but I could not remember anything at that moment. The then Vice-Chancellor, Prof. Nirmal Kumar Choudhury smiled at me and offered me a glass of water to cool down. The style of this interview was unique. They were slowly trying to extract my hidden knowledge and talents. GU was the right place for doing research in HEP. Already in M.Sc. physics course, there were two specialization papers in HEP in M.Sc. Physics course namely, Quantum Field Theory and Elementary Particle Physics, which were taught by two eminent senior professors – Prof. D.K. Choudhury and Prof. S.A.S. Ahmed. Incidentally both of them had earlier completed their Ph.D. degrees under the supervision of Prof. A. N. Mitra of the University of Delhi. In addition, there were strong groups in Nuclear Physics and Astrophysics specializations led by Professor K.M. Pathak and Prof. H.L Duorah respectively. Later on, they became Vice-Chancellors of Tezpur Central University and Gauhati University respectively.

After joining GU on 6$^{th}$ December, 1991, I gradually shifted my research area on Grand Unified Theories and neutrino physics. This was a continuation of my earlier review work on proton decay in my M. Phil. dissertation. I also worked in collaboration with Prof. M. K. Parida of NEHU, Shillong and we published one research paper in Physical Review D. I had also collaboration with Prof. Anjan Joshipura of Physical Research Laboratory, Ahmedabad as I was Associate fellow at Physical Research Laboratory (PRL), Ahmedabad, and we published a paper in Nuclear Physics B. Under the leadership of Prof. D. K. Choudhury, we organised both SERC school on HEP and XII DAE Symposium on HEP (Dec. 26, 1996 – 1$^{st}$ Jan 1997) respectively. Gauhati University thus became a centre of HEP activities in the North East.

I was awarded the Commonwealth Research Fellowship in United Kingdom for one year during 1999-2000 and worked with Prof. Stephen King of Southampton University, UK. We published two papers in Nuclear Physics B on the analysis of normalization group equations for neutrino masses and mixings for both normal and inverted hierarchical models in Grand Unified Theories,

one more paper myself alone in European Journal of Physics C on the running of the vacuum expectation values in neutrino masses and mixings under radiative corrections. While in UK, I was given the opportunity to attend many seminars and conferences within UK and visited many universities at free of cost. It was quite interesting to see the University of Glasgow, where Lord Kelvin worked. Southampton is a port city on England's south coast. It is home to the SeaCity Museum, with an interactive model of the Titanic, which departed from Southampton in 1912.

After returning to India, I became Reader in 2000 at Gauhati University. I was again awarded the Regular Associateship of the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy during the period 2003-2010, giving me the opportunity to visit ICTP for every three months during summer every year. I was recommended by Prof. Sandeep Pakavasa from University of Hawaii, USA and Prof. S. F. King from University of Southampton, UK for this ICTP Regular Associateship. ICTP is a unique institution that explores fundamental scientific questions at the highest level, promotes active engagement with scientists in developing countries, and advances international cooperation through science. The Centre operates under a tripartite agreement between the Italian Government, UNESCO, and the International Atomic Energy Agency. It was founded in 1964 with its founding Director, Nobel laureate Prof. Abdus Salam of Imperial College, London.

While at GU, I along with Prof. N. Rajmuhon Singh, Prof. Debananda Ningthoujam and some other colleagues of Manipur University (MU), founded the Manipur Association for the Promotion of Sciences (MAPS) and its sister publication "People's Science Networks (PSN)" in 1993. I was also the editor of the issue of PSN Vol.4, No.3, May 2006. The main aim of the MAPS is the popularization of science to common people and school students. We also founded the Research Institute of Science and Technology (RIST) in 2010 at Imphal. I was instrumental in inviting Prof. A. Surjalal Sharma of Department of Astronomy, University of Maryland, USA, as founding Director of RIST. Under his guidance we have been working for RIST for the last fifteen years. We approached the authority of Manipur University for MoU for hosting RIST within MU campus during the initial phase. We also presented our project proposal to DST, New Delhi and met the

Chief Minister of Manipur twice, requesting him for recognition and grants to run the institute. The institute is going in the right direction.

I became Professor of physics in 2007 at GU. I served at GU for twenty-two years (1991-2013). While I was at GU, I had authored a reference book "*Quark Model and Beyond: The Eternal Quest*" published by Regency Publication, New Delhi (2003) as an outcome of my teaching particle physics at GU. During my service at GU, I had guided fifteen Ph.D. scholars (while I was at GU). Many of my Ph.D. scholars are now working in various universities such as Gauhati University, Tezpur University, Dibrugarh University, Cotton University and also in many colleges in Assam. Some of them are now eminent physicists. I took active role in running Physics Academy of the North East (PANE) as General secretary when I was at GU, along with my senior colleague, Prof. D. K. Choudhury as executive PANE President. During this period, I also earned some administrative experiences, e.g. Head of Department, Physics Department (2010-2013), HOD of Computer Centre, member of Executive Council, Chairman of some committees, and experts in selection committee meetings of some universities.

**Some inspirations from my seniors at GU:**

I have to acknowledge a few names for getting the inspirations from some of my senior colleague at Guwahati, - Prof. K.D. Krori, Prof. H.L. Duorah, Prof. D. K. Choudhury, Prof. S.A.S. Ahmed, Prof. B. K. Sarma, Prof. K. Boruah, to mention a few. I have been inspired by the interaction with Prof. Naorem Sanajaoba of Department of Law, GU during my stay of more than two decades at GU. I always considered him as a great academician and a dedicated teacher. He was so systematic in his approach and he maintained a large home library with one special section devoted to *Manipur* – its history, culture, literature and other social and political issues. He coined this section as Manipurology. I also learnt many aspects on Human Rights and International Humanitarian Law from him, including International Committee of the Red Cross and the Geneva Conventions of August 12, 1949 and its additional protocols. I also presented an article on the Human Rights abuses by Security Forces in Manipur in the Human Rights Workshop organized by Prof. Naorem Sanajaoba at Gauhati University in 1993, and the same article appeared in the book "*Human Rights: Principles, Practices, & Abuses"* by Naorem Sanajaoba, Omsons Publications, 1994, New

Delhi. Prof. Sanajaoba was not only an eminent scholar and voracious reader, he was also a great orator. His public speeches were very lively and forceful, particularly on the political issues of Manipur and its territorial integrity. His writing skills were extraordinary and he wrote many articles and books. His entire academic works can be categorised into three sections – Human Rights, laws & politics, and Manipurology, and the last one contains his books, Manipur - Past and Present Vol. (I-IV), Manipur Puwari Kunmathoishuba Chahicha, Manipur Treaties & Documents Vol.I, to mention a few. He completed his Ph.D. degree without Ph.D. guide in GU, and therefore, his way of guiding Ph.D. scholars was very rigorous. His untimely death was a great lost to academic fraternity of north east.

**Life at Manipur University**:

I joined Manipur University on December 4, 2013 as Professor of Physics with the hope to strengthen the foundation of RIST, Imphal and also to start High Energy Physics specialization papers – Quantum Field Theory and Particle Physics in M.Sc. Physics course at MU, and a research group in HEP. Subsequently five Ph.D. students had registered under my supervision at MU. Out of these, one got Ph.D. degree and others are in the pipeline for thesis submission. There I served again as Head of Department during 2017-2020. With my initiative with my faculty colleague, Prof. K. Yugindro Singh, the department also opted a specialization paper on General Theory of Relativity (GTR) in order to go along with Astrophysics and HEP papers. The department managed to employ five guest faculties and among them, Dr. Soram Robertson Singh assisted the teaching of Quantum field Theory and Elementary Particle physics in third and fourth semester courses. This strengthened the theoretical physics division. During my headship, five new faculty positions – one professor, two associates and two assistant positions, were recruited. I am very satisfied with the present scenario of physics department at MU. My retirement from my service is due on July 31, 2024. In addition to my normal duty as professor of Physics at MU, I have been assisting the university authority by serving as Controller of Examinations (i/c) since September 2020 till date. During my headship, a proposal for main frame cluster computational facility was made and I would recall the contribution of my faculty colleague, (Late) Prof. Sanasam Brajamani Singh in putting it through SAP Stage II during its presentation at UGC office. With the effort of

present HOD, Prof. Angom Dillipkumar Singh, the Physics Department has acquired a cluster computer for serious researches in non-linear dynamics and theoretical simulation works. At present, Dr. Moirangthem Shubhakanta Singh, Assistant Professor, Physics Department, is the in-charge of this cluster computer as well as the computer laboratory. I have to acknowledge the services rendered by Dr. Nungleppam Monoranjan Singh, Senior technical assistant of Physics Department, for computer hardware and software related problems in our research works.

**Extra activities in outreach programme and popularization of science to common people**:

I also wrote a Manipuri book "*Saknairabi Scientistsingi Wari*" which is based on lives and works of thirty famous women Scientists, published by Centre for Scientific Culture Manipur, Imphal (2014). This book was aimed at the popularization of science to younger generation, particularly girl students from this soil. An audio CD of this book was also released along with the book and it was serialized in radio broadcasting programmes. I also completed an edited book "*Conceptual Development in Theoretical Physics*" published jointly by Physics Academy of North East (PANE) and Pragya Mediahype Publication, Uzanbazar, Guwahati (2023). The contributors of this book, are senior professors, drawn from various institutes and universities from the North East part of India. At the moment I am trying to complete the writing of two reference books on QFT and Particle physics based on my experience of teaching the students of this region. I am now serving as President of PANE (2021-24). During my tenure as President of PANE, the XIII Biennial National Conference of Physics Academy of North-East (PANE-2022) was organized by the Department of Physics, Manipur University from 8-10 November, 2022. The Convenor of the conference was Dr. Th. Gomti Devi, Associate Professor, Department of Physics, MU. The conference papers were published in the Elsevier Journal "Materials Today: Proceedings and in the Book Chapter. The Book chapter "Recent Trends in Physics Research" was published under Allied Publishers Pvt. Ltd., Noida and I was the Editor-in-Chief of the Book Chapter. I have been nominated again as the President of PANE for the second term from 2024-2026. I was also the founder president of the Centre for Scientific Culture Manipur (CSCM), Imphal. I am also member of many professional bodies, including the American Physical Society (APS).

*Fig. 2. Former CERN Director Robert Aymer who initiated Higgs search at LHC at Geneva, Switzerland.*

**Experiences from visiting abroad:**

During my career, I had visited some places abroad to attend international conferences and workshops viz., CERN in Geneva, Switzerland (Sept 7 – 20, 1989); Ajaccio in Corsica, France (Sept. 23-27, 1989); ICTP in Trieste (2003 – 2010), Pisa (April 15 – 20, 2000), and Erice in Sicily, Italy (Aug., 6 – 14, 1987); Athens, Greece (June, 14 – 19, 2010); Royal Society of London, United Kingdom (May, 24 – 25, 2000); Singapore (Aug. 2 – 8, 1990); Thailand (April, 17 – 25, 2003); to mention a few.

Among these, Ajaccio is special to me as it is the capital of Corsica, a French island in the Mediterranean Sea, and it was the birthplace of French Emperor Napoleon Bonaparte. I was quite delighted to visit his ancestral home, Maison Bonaparte, which is now a museum displaying family heirlooms. The visit to Athens was also equally heart-touching as the playground of the genesis of Olympic games was still well preserved for visitors, in addition to other famous historical monuments there. Erice in Sicily was the place of the origin of *mafia gang* that was projected in the novel "Godfather" by Mario Puzo and I was very careful of my passport and money purse during my stay there. When I entered the conference hall of the Royal Society of London, UK, to attend the seminar, I was astonished to see the life size portraits of many great scientists starting from Issac Newton. I could guess the roles of Michael Faraday and others in shaping the history of science. Above all, the scientific atmosphere at the cutting edge research

atmosphere in CERN at Geneva and ICTP at Trieste, were extremely inspiring to my career. The library and computational facility of ICTP was amazing. The architectural beauty of Florence with sculptures of Michelangelo, the scenic view of Venice city in the sea water, the leaning tower of Pisa where Galileo performed his famous experiment on law of falling body, the Cathedral of Rome, made Italy my second home as I visited there many times. I still preserve some of my old photographs with Nobel laureate Carlo Rubia of CERN, Geneva, who discovered $W^+$, $W^-$, $Z^0$ of Standard Model; and also with Nobel laureate Martin L. Perl of Stanford Linear Accelerator (SLAC), California, USA, who discovered tau-lepton (photographs enclosed). With my capacity as Regular Associate of ICTP, Trieste, Italy, I got the chance to attend **G8-UNESCO Summit on Education, Research and Innovation in 2007** at Trieste, Italy and the theme of the discussion was on ***Triangle of knowledge*** for bringing the sustainable development of a Nation. Here the Triangle of knowledge represents three vertices of a triangle and their synergy – Higher Education, Scientific Research and Innovation.

Recently my name has been nominated in the Programme Advisory Committee (PAC) for International Cooperation in the area of Physics, Astrophysics and Laser for three years, since August, 2022, by the Department of Science & Technology (International Cooperation Division), Govt. of India.

*Fig.3. Nobel Laureate Carlo Rubia, former Director, CERN, who discovered $W^+$, $W^-$, $Z^0$ bosons.*

*Fig.4. Nobel Laureate Prof. Martin L. Perl of SLAC, California, USA, who discovered tau lepton.*

**Concluding remarks – The Road Ahead:**

At present, I am running the activities of RIST in Imphal. We are regularly organizing RIST monthly scientific Talk series. In addition, we also organized International Conferences (online mode) under banner of RIST, Imphal. Our future hope is to bring RIST as an excellent research centre in fundamental sciences on our soil. The untimely death of Prof. A. Surjalal Sharma, founding Director of RIST in January 2024, was a great loss to Manipur, particularly to RIST.

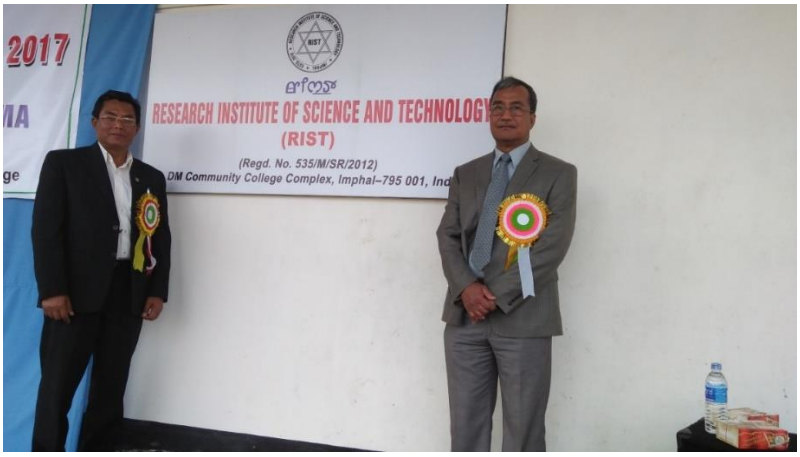


*Fig.5. Prof. A. Surjalal Sharma, Founding Director, RIST, delivering lecture on National Science Day at D. M. Community College.*

I wish to remind our younger generation to learn how to inculcate the work culture, manage time for creative works, and also to keep consistency and resilience in our approach to all life challenges, including research activity. In research, even the best ideas can be rejected and rejections are part of struggle. We need both patience and teamwork. We should have a scientific culture in our society. Scientific culture is nothing but a set of norms and practices, and an ethos of honesty, openness, originality, independence of thought and dissent. The safeguards for independence are free inquiry, free thought, free speech, and the willingness to arbitrate disputes on the basis of evidence. We should believe in four mind-sets as success factors for high achievers – intrinsic motivation, perseverance, strong foundation and continuous informal learning.

I always remember a saying from my teacher, "*For young man sky is the limit*". I wish to present a quotation from Nobel laureate Abdus Salam, "*Scientific thought and its creation is the common and shared heritage of mankind*". American philosopher and psychologist John Dewey remarked "*Every great advances in science has issued from a new audacity of imagination*". I conclude with a quotation from Irish poet Oscar Wilde, "*We all are in the gutter, but some of us are looking at the stars*".

## Appendix: A brief technical sketch of my research works in three phases based on my publications of nearly 100 articles

***First Phase****:* My research work in this phase (1984-1995) is centred around a specific model of hadrons in terms of quark composites – a QCD-motivated relativistic few-quark dynamics based on the covariant Bethe-Salpeter Equation (BSE) in the light-front (Null-Plane) coordinates. The model is characterized in a two-tier fashion where the first tier corresponds to a three dimensional reduction of a four-dimensional Bethe-Salpeter Equation through a Null-Plane ansatz in order to facilitate a good contact with mass spectra of the hadron composites. This stage is referred to as on-shell test of the model. The reduced BSE is shown to obey an explicit Null-Plane (NPA) covariance where the resulting covariant three-dimensional BS wave function thus qualifies for the applications involving hadrons in arbitrary motion. The second tier constitutes a reconstruction

of the four-dimensional BS wave amplitude, which incorporates the covariant hadron-quark vertex function from the covariant three-dimensional BS wave function. This is possible through the incorporation of the virtual sea-quark effects (higher Fock states) through the lowest order Feynman diagrams. This stage is referred to as off-shell tests of the model. With the help of such four-dimensional BS amplitude, various electromagnetic and hadronic transition form factors can be calculated in the usual field theoretic method. The formalism had been tested through actual calculations, viz., starting from low energy applications to high energy transition decay processes on one hand and from light to heavy flavours of quarks on the other. The applications include the mass spectra of hadrons both for light and heavy flavours, transition form factors and hadronic decay rates, the structure functions and fragmentation functions. The present model is comparable to other contemporary QCD-motivated models available in the literature in terms of its comprehensive conceptual framework and predictive power.

***Second phase****:* In this second phase (1996 onwards), I have been doing theoretical research work in the field of gauge theories of fundamental interactions in general and the left-right symmetric Grand Unified Theories (GUTs) with and without supersymmetry, such as SO(10) model and models based on higher rank groups in particular. One of the objectives is the calculation of the low-energy observable predictions in these models. Our research papers are connected with the renormalization of the neutrino masses with uncertainties in SUSY SO(10) model, and the question of the three gauge couplings unification and third generation Yukawa couplings unification at both intermediate scale and GUT scale. The analysis is extended to non-SUSY SO(10) model with one Higgs doublet model and two-Higgs doublet model.

***Third phase****:* My research work in this phase is also related to the question of understanding the tiny masses of three flavours of neutrinos and their mixing angles at low energy scales, as predicted by neutrino oscillations. This is needed for the explanation of the deficits in the observed solar and atmospheric neutrino fluxes as compared to the theoretical predictions. In the present work there is an attempt to generate possible textures of neutrino mass matrices and leptonic mixing matrices from GUTs with extended discrete flavour family symmetries such as $A_4$, $A_5$ etc., and this can explain the observed data on neutrino masses and mixings. Further studies are being conducted on the stability of the neutrino mass eigenvalues and mixing angles under Renormalisation Group equations (RGEs) when running from a high energy scale to low energy scale. The asymmetric

decay of the right-handed heavy neutrinos in the early universe, is responsible for Leptogenesis in the Universe. Baryogenesis is formulated from *Leptogenesis* through *Sphaleron* transition process.

I am actively engaged in the applications of neutrino physics for the explanation of matter-antimatter asymmetry of our universe, and also the application of discrete symmetry groups for the explanation of the origin of neutrino masses and mixings. Some unfinished agenda in neutrino physics are - the type of neutrino whether Dirac or Majorana, and CP violation in neutrino sector. The field is exciting with full of uncertainties. There are inputs of new physics from cosmological data such as the upper bounds on the sum of the masses of three active neutrinos, effective electron neutrino masses from tritium beta decay and neutrinoless double beta decay. Neutrino physics is now linked with dark matter, dark energy, supernova explosion and the origin of ultra-high energy neutrinos in cosmic rays, etc. The third phase is collectively known as "Beyond Standard Model (BSM)" which represents "New Physics". My other interest also includes Superstring Theory known as Theory of Everything (TOE) which attempts to unify four fundamental forces of nature, with one-dimensional "string" of length $10^{-33}$cm, as the most fundamental entity. In short, I am involved in quest for the final theory of Nature.