

Remembering my Guru – Dr Homi Bhabha



B V Sreekantan

Bhabha Fellowship Conclave
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Remembering my Guru – Dr Homi Bhabha

The great Telugu Musician and Composer, Tyagaraja starts one of his songs with the words

“Enduro Mahanubhavalu
Andariku Vandanamalu”

“There are many great men. My salutations to all of them.”

Yes. Undoubtedly Homi Bhabha was one of the Mahanu bhavas. Even among them he was exceptionally great.

Sir

C V Raman: While introducing Bhabha to the Indian Academy of Sciences, in 1941 (Bhabha was 32 yrs old)

“Bhabha is a great lover of music, a gifted artist, a brilliant engineer and an outstanding scientist..., the modern equivalent of Leonardo da Vinci.”

Smt. Indira Gandhi

“To be a ^{first} ranking scientist, a teacher and administrator is remarkable enough; but Dr. Bhabha’s creative impulse could not be contained in these three roles; He was one of our leading Social Engineers”

Sri. J. R.D. Tata

“The most outstanding of the distinguished men I have known was undoubtedly Dr Homi Bhabha. In addition to unique intellectual gifts Nature had bestowed on him, he was in the mould of Jamsetji Tata, a visionary with boldness, relentless energy and drive to convert vision to reality”

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The Tata Institute of Fundamental Research which was founded in 1945 by Dr Bhabha. I joined TIFR as Dr. Bhabha’s PhD as student in 1948 and stayed on in the same institution till 1992. I never applied for any job anywhere and things automatically happened at the right times. I can attribute this only to his grace.

1
had the good fortune of joining

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I know quite clearly what I want out of life. Life and my emotions are the only things I am conscious of. I love the consciousness of life and I want as much of it as I can get. But the span of one's life is limited. What comes after death no one knows. Nor do I care. Since, therefore, I cannot increase the content of life by increasing its duration, I will increase it by increasing its intensity. Art, music, poetry and everything else that I do have this one purpose – increasing the intensity of my consciousness of life.

Home Bhabha

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24th January 1966

- I was on Sabbatical at MIT Boston ^a ~~during~~ ^{from} Aug. 65 to Feb. 67
- On 24th January 66, my colleague George Clark called me in the morning at 7 am to ask me whether I was following the news. I said "No". He said something terrible has happened. An Air India plane has ~~crashed~~ ^{crashed} in the Alps and it is reported that Dr Homi Bhabha was ~~as~~ ^{on} that flight
- Soon, the news was confirmed and I was completely rattled.
- I was to give that afternoon the Physics colloquium on "current status of anti-particles in cosmic rays".
- I rushed to MIT and went to room of Prof. Phil Morrison who was in charge of physics colloquium and told him that this tragic news has come and I am in no position to give the talk that afternoon.

crashed

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- Prof. Morrison advised me that I should give the talk and dedicate it to the memory of Dr. Bhabha, whom he had also known personally. You will see you will be able to do it.
- I gave the talk, went home and had a quick dinner with my wife and daughter and went to bed crying uncontrollably.
- Then a wonderful thing happened. I had a dream in which Dr. Bhabha was dressed in a white Parsee dress and a black cap and was driving away in a golden chariot drawn by four white horses, high in the sky.
- I woke up with a start remembering myself the lines from the Geetha

जातस्य हि भ्रुवो मृत्युपूर्वं जन्म मृतस्य च ।
तस्मादपरिहार्येऽर्थे न त्वं शोचितुमर्हसि ॥

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Darlan

Line to go 4

Dr Bhabha's visit to KGF and Ooty and Holiday at Ooty during Dec. 64 – Jan. 65.

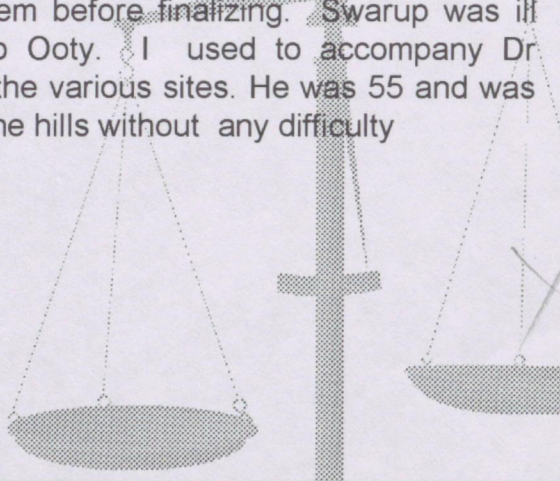
Towards the end of December 1964, Dr Bhabha came to KGF to inaugurate our Extensive Air Shower Laboratory there. He had come from Delhi and Prof. Menon had also come from Bombay. I received them at the entrance to the mining town Oorgam and got into the same car. Prof. Menon was telling him that he had a rough flight and the air craft was jumping up and down quite a bit. Dr. Bhabha remarked under those circumstances what also can you do except close your eyes and pray.

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Dr Bhabha gave a lecture at the KGF club on "Nuclear Energy" and left for Bangalore in the evening. Next day he came to Ooty and stayed for three weeks in Hampton Court at Conoor on a holiday.

Dr Bhabha's visit to KFG and Ooty and Holiday at Ooty during Dec. 64 – Jan. 65.

That was the two time when Prof. Swarup had surveyed several sites in the Ooty area for his Radio Telescope. Dr Bhabha wanted to see all of them before finalizing. Swarup was ill and could not come to Ooty. I used to accompany Dr Bhabha on his visits to the various sites. He was 55 and was very fit and climbed all the hills without any difficulty



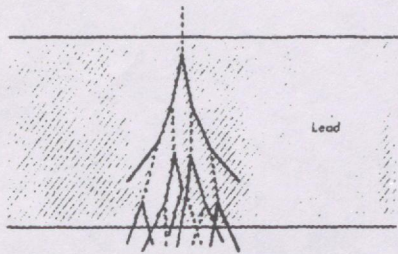
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One morning, I got a call from his secretary at Coonor to informed me that Dr Bhabha and Mrs. Wadia want to have a typical South Indian Lunch at our guest house. We were happy, but at the same time in a dilemma. Though we had a number of South Indians in our group, none of the wives were there at that time. Also we were ill equipped with proper crockery and cutlery. Well, somehow our cook managed. Bhabha and Mrs Wadia were very happy with whatever lunch was provided.

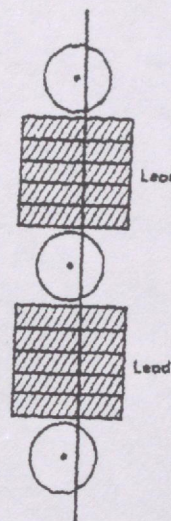
I remember on the 1st January 1965, when he came to our Lab, I gave him as a new year present the book of cartoons by R. K Laxman "you said it"

and had no decent

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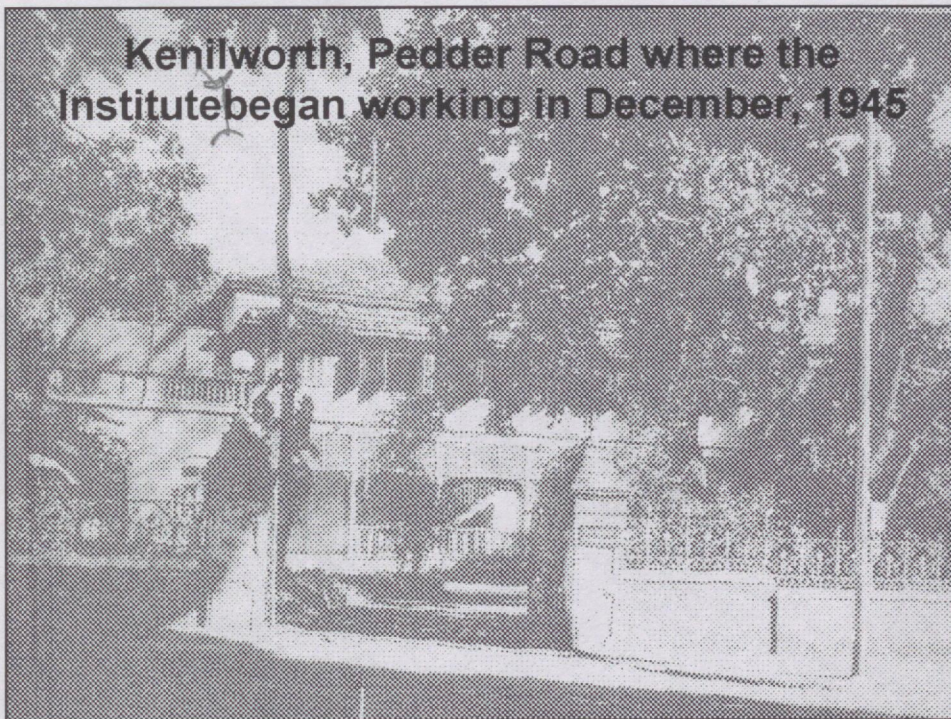
Development of a shower in matter through successive events of pair production and radiation. Dotted lines represent photons, solid lines electrons.



Experimental arrangement used to demonstrate penetrating power of cosmic-ray particles. The number of lead bricks between counters can be varied to form an absorber as much as 1 meter thick. Only charged particles capable of traversing the absorber produce coincidence.

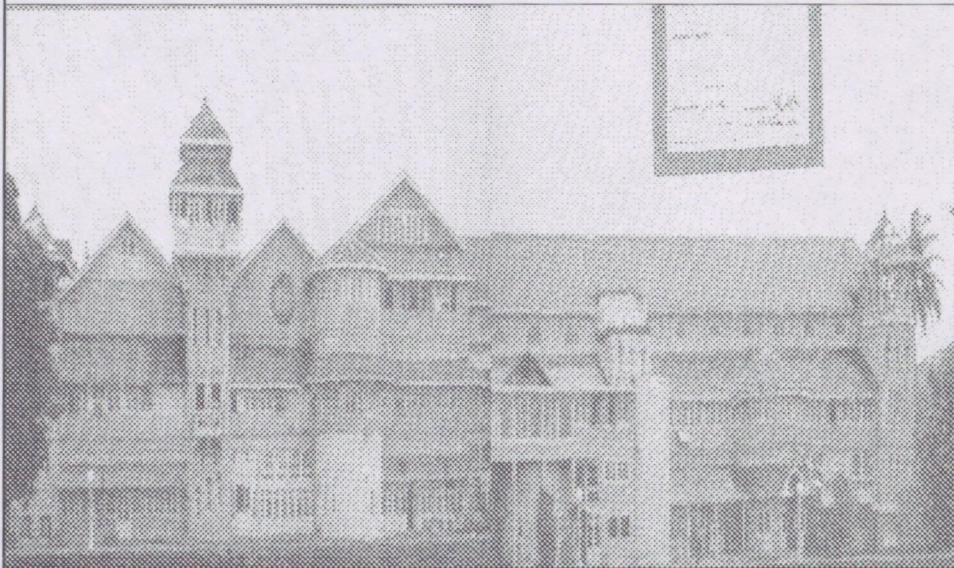
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Kenilworth, Pedder Road where the Institute began working in December, 1945



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Old Yacht Club (1949-1962)



(5)

Homi Jehangir Bhabha (1909-1966)

- 1909
 - Born 30th October 1909
 - Grand Father : H J Bhabha – Inspector General of Education Mysore State
 - Father: Jehangir Hormusji Bhabha – Lawyer – Bangalore
 - Mother: Daughter of Sir. Dinshaw Manekji PETIT educated in Bangalore
 - School Education: Cathedral and John Cannon, Flora Fountain, Bombay
- 1924
 - Passed Senior Cambridge Exam (He had studied Special Theory of Relativity at the age of 16), Elphinstone College, Royal Institute of Science
- 1927
 - Joined Gonville and Caius College, Cambridge *Letter to a friend.*
 - Engineering Tripos (1st Class) **Letter to his parents – Passion for physics**
 - Mathematics Tripos (1st Class)
- 1932
 - Rouse Ball Travelling Fellowship: Copenhagen, Zurich; Niels Bohr, Pauli
- 1935
 - Ph.D. Under R.H. Fowler
- 1851: Exhibition Scholarship – continued work in theoretical physics – Dirac
- 1939: September : World War II breaks; Bhabha returns to India on a short holiday
- But had to stay on because of the war.
- He joins the physics Department of IISc at the invitation of C.V.Raman
- 1941: FRS
- 1942 Professor at IISc
- 1943 Letter to Sir Dorabji Tata Trust
- 1945: June 1st. Founding of the TIFR
- 1948: Atomic Energy Department – Commission

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1932: Bhabha's Letter to his Parents Cambridge

"I seriously say to you that business or job as an engineer is not the thing for me. It is totally foreign to my nature and radically opposed to my temperament, and opinions. Physics is my line. I know I shall do great things here. For, each man can do best and excel in only one thing of which he is passionately fond, in which he believes, as I do, and that he has the ability to do it, that he is in fact born and destined to do it. My success will not depend on what A or B thinks of me. My success will be what I make of my work. Besides India is not a land where science cannot be carried on.

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1932: Bhabha's Letter to his Parents (contd)

Cambridge

I am burning with a desire to do **physics**. I will and must do it some time. It is my only ambition. I have no desire to be a successful man or the head of a big firm. There are Intelligent people who like that and let them do it. I hear you saying "But you are not Socrates or Einstein" No ... and that is what Berlioz's father said to Berlioz. He called him a useless musician when he was young.... Hector Berlioz who is now accepted as one of the world's greatest geniuses and France's greatest musician. How can anybody else know at what time what one will do, if there is nothing to show? It is no use saying to Bethovan 'your must be a scientist for it is a great thing' when he did not care two hoots for science; or to Socrates "Be an engineer; It is the work of an intelligent man'. It is not in the nature of things. I therefore earnestly implore you to let me do physics".

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Status of Modern Physics by 1935

- Production and detection of Electromagnetic waves by Hertz (1885)
- Discovery of X-rays (1896), Radioactivity (1897) and Electron (1898)
- Max Planck's Quantum Hypothesis (1900)
- Einstein's Theory of special Relativity (1905)
- Discovery of the Nucleus: Rutherford (1910)
- Discovery of Cosmic Rays: Victor Hess (1912)
- Bohr's Atomic Hypothesis
- Postulation of the spin of the electron
- Quantum Mechanics – Schrodinger, Heisenberg , De Broglie
- Quantum Electrodynamics
- Dirac's Equations for electron – Positron prediction; Anti particles
- Discovery of Neutron (1932)
- Discovery of Positron (1932)

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Anomalies in Cosmic Radiation

- Are the extraterrestrial, extra-solar particles established by Hess, Charged? or Neutral?
Millikan – Compton controversy
- Penetrating component and soft components (Rossi)
Penetrating more than a meter of lead.
Soft component absorbed in a few millimeters of lead or multiplies into several particles
- Simultaneous discharge of widely separated (several meters) GM counters – Auger
- showers of particles seen in cloud chambers also (Skobelzyn)
- For equivalent amount of grammage more absorption of the penetrating component in air than in lead

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- Dr Bhabha's paper in the Proceedings of Royal Society "On the penetrating of Cosmic Radiation" : After analysing the experimental results and the theoretical papers on QED, Bhabha came to the conclusion:

Either (i) Quantum Electro-Dynamics breaks down at high energies

Or (ii) There exists in cosmic rays a particle of mass intermediate between electron and proton of the order of 100 Mev mass.

In parallel, Anderson Discovers the *Mesotron* in a cloud chamber experiment.
(Mesotron – name given by Millikan)

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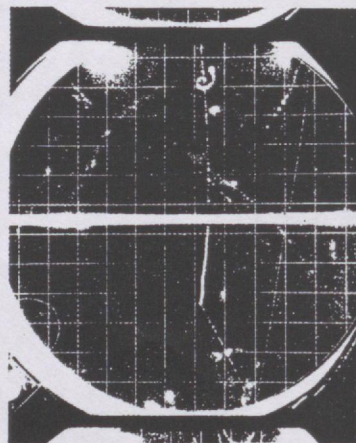
Meson as penetrating component of Cosmic Rays

- Absorption anomalies explained on the hypothesis of Meson Decay
- Meson Decay registered in cloud chamber
- Bhabha points out in brief letters in Nature
 - (i) Meson Decay should lead to electron + neutrino or neutrinos
 - (ii) Meson Decay can be used to test relativistic elongation of time.

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Properties of the Penetrating Component

- Can easily penetrate a meter of lead
- Arrives mostly as single particle
- Both positive and Negative charged particles
- Anomalous absorption – in equal grammage of condensed matter like graphite and extended matter like air, more absorption noticed in air.
- Mass of particle $\sim 210 m_e$
- Non-nuclear interacting.



Decay of μ -Meson, R W Thompson,
The Phys. Rev., V. 74, p. 490, 1948

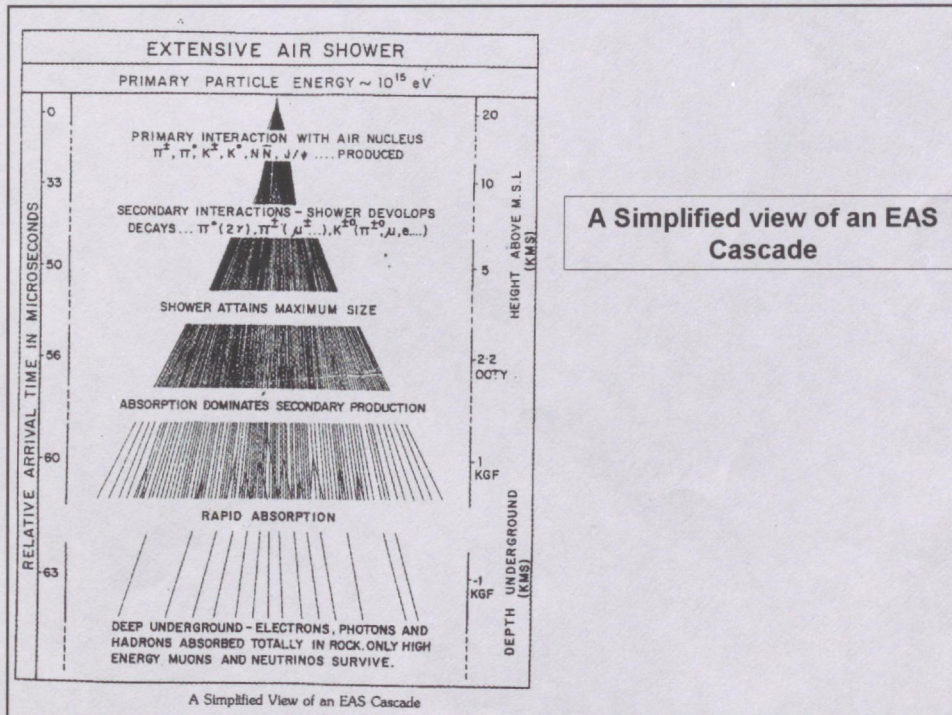
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- Bhabha-Heitler Cascade Theory

- (i) The behavior of the soft component explained
- (ii) The atmospheric showers of Auger explained

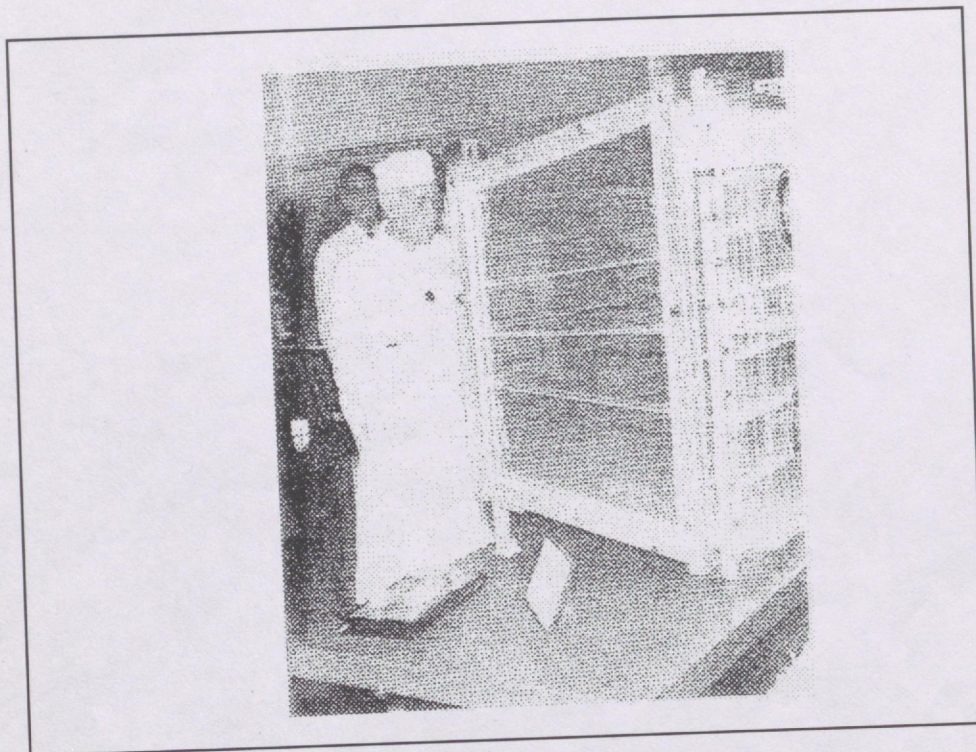
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- Bhabha scattering – electron-positron scattering with exchange. Theory verified experimentally after 15 years



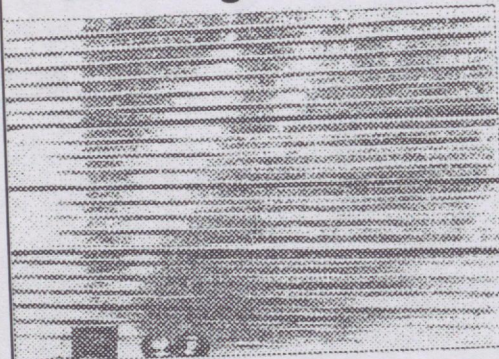
A Simplified view of an EAS Cascade

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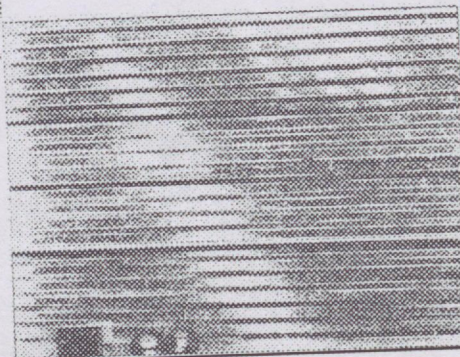
Core Regions of Extensive Air Showers



A cascade which develops from the first plate of the chamber and shows a rapid absorption after the maximum. The method of cascade widths has been used for energy estimation which is 750 GeV.

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Several cascades having elongated tube-like structures not completely absorbed even after 20 radiation lengths. The estimated energy of the largest cascade is 2.4 TeV.

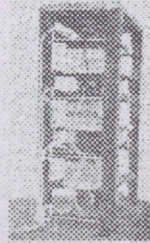
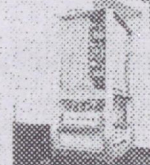
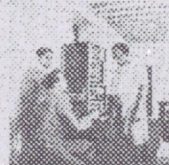
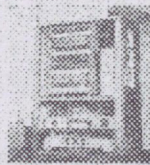


Bhabha at Bangalore IISc

- In 1939 Bhabha came back to India for a holiday. The second world war intervened and could not go back to Europe or USA.
- C.V. Raman offered him a positron at I.I.Sc. Dr Bhabha spent the next 6 years at IISc and this proved to be a very productive period.
- Bhabha and Chakrabarty published several papers on detailed calculations of atmospheric cascades as a function of energy.
- Bhabha's work on meson theory – Extension of Dirac's theory for spin-1/2 particles to particles of other spin values, and charges.
- Bhabha's experimental work on latitude effect of penetrating component at higher altitudes – 5000 ft to 20,000 ft with B-29 air craft. Bhabha initiates work on the scattering of muons with a cloud chambers.
- Harish Chandra was one of his students in theoretical physics.
- Millikan-Bhabha correspondence of this period brings out the importance of the cosmic ray work Dr Bhabha carried out while at IISc.

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Experimental set-up for the experiment on the Penetrating component.

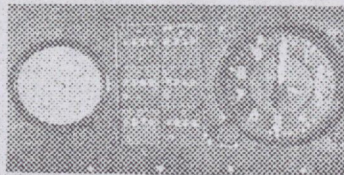


1. The vertical column of the setup is 20000 cm high. The top of the column is situated in the atmosphere. The column is supported by a central rod. The column is supported by a central rod. The column is supported by a central rod.

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Bhabha's Letter to Saklatvala – 12th March '44

**More than a year before the Hiroshima Bomb
Sir Dorab Saklatvala, Chairman, Sir Dorabji Tata Trust**

"I had the idea that after the War I would accept a job in a good university in Europe or America, because universities like Cambridge or Princeton provide an atmosphere which no Indian university provides at the moment. But in the last two years I have come more and more to the view that provided proper appreciation and financial support are forth coming, it is one's duty to stay in one's own country and build up schools comparable with those that other countries are fortunate in possessing.

.....the scheme I am now submitting to you is but an embryo from which I hope to build up in course of time a school of physics comparable to the best any where.

.....The subjects on which research and advanced teaching would be done would be theoretical physics, especially on fundamental problems and with special reference to Cosmic Rays and Nuclear Physics, and Experimental research on Cosmic Rays. "

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Bhabha's Letter (contd..)

"It is absolutely in the interests of India to have a vigorous school of research not only in less advanced branches of physics, but also in problems of immediate practical application to industry. If much of the applied research in India is disappointing or of very inferior quality it is entirely due to the absence of a sufficient number of outstanding pure research workers who would set the standard of good research and act on directing boards in an advisory capacity..... Moreover, when nuclear energy has been successfully applied for power production in a couple of decades from now, India will not have to look abroad for its experts, but will find them ready at hand"

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- TIFR was founded with Tata support in 1945
- TIFR became the "CRADLE" of ATOMIC ENERGY PROGRAMME

Dr Bhabha and TIFR (1945-1966)

- TIFR – initially at Kenilworth, Pedder Road (1945) and then moved to Yacht club in 1949 and then to its present premises in 1962.
- At Pedder Road, Dr Bhabha initiated research work in
 - (i) Theoretical Physics
 - (ii) Pure Mathematics (Kosambi and Levy)
 - (iii) Cosmic Rays – Rubber Balloon Flights at various latitudes, cloud chamber on scattering of muons, Nuclear Emulsion chambers for study of nuclear interactions and particles produced in high energy interactions.

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Bhabha and the Rubber Balloon Flight



Homi Bhabha in preparation for flying a cluster of balloons carrying the payload for a cosmic ray experiment from the Central College grounds, Bangalore (late 1940s)

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↑ Burden up

Sudden expansion of activities After moving to Yacht club

- Mathematics
- Cosmic Rays
- Nuclear Physics, Chemical Physics
- Computers
- Accelerators

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a number

- At this stage ~~lot~~ of new scientists mostly trained in Europe and USA and in their early 30's were inducted by Dr. Bhabha to TIFR
- I might mention here – Prof. K Chandrasekharan, Prof. K G Ramanathan, Dr Raja Ramanna, Dr Singhvi, Dr Thosar, Dr Dharmuthi, Prof. Bernard Peters, Dr M G K Menon, Dr R Narasimhan, Dr Sukumar Biswis, Dr Jha, Dr Ambuj Mukherjee, Dr Bibha Chowdhuri, Dr Yodh.

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Towards the end of 1950, Dr Bhabha organized the first ever Elementary Particles Conference which was attended by Prof. Blackett, Prof. Leprince Ringuet, Prof. Amaldi, Prof. Rudolf Peierls, Prof. Wentzel, Dr Peter Fowler, Prof. Rosenfeld, Prof. Bernard Peters, Prof. Auger, Prof. Megnad Saha and many others. This was just at the beginning of the new era of elementary particle physics with Cosmic Rays.

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Following this International Conference on Elementary Particles large scale experimental activities were started in the field of cosmic rays at TIFR Plastic Balloon Flights with Nuclear Emulsion stacks for study of (i) primary cosmic rays, (ii) nuclear interactions, (iii) new elementary particles.

□ Deep underground Experiments at the Kolar Gold Mines –studies on

□ Muons and Neutrinos

□ Air shower Experiments at KGF in association with deep underground

□ muons

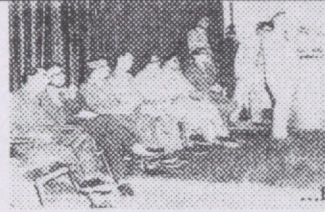
□ Cloud chamber and Air Shower Experiments at Ooty

□ Studies on Cosmic Rays induced isotopes.

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□ L Spaa

- Very impressive new results on k-mesons were reported by the Bombay group at the Bagnere de Begore Cosmic Ray Conference in 1953.



- In 1963, the 7th International Conference on Cosmic Rays was held at Jaipur which was attended by more than 200 delegates from outside. On the last day Pandit Jawahar Lal Nehru addressed the delegates.
- At the London Conference in 1965, the TIFR groups reported two important results
 - First detection of Cosmic Ray Neutrinos
 - Increase in the cross-section for the production of nucleons and antinucleons in high energy collisions (before the advent of CERN accelerators of 25 GeV.)

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Activities in the area of Nuclear Physics (1950 onwards)

- Nuclear Reactions and Nuclear Physics – the cascade generator at
- TFR and Van de Graaff at BARC
- Nuclear Spectroscopy
- Nuclear Magnetic Resonance – Chemical Physics, Solid State Physics groups emerged out of these activities
- Theoretical Nuclear Physics

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