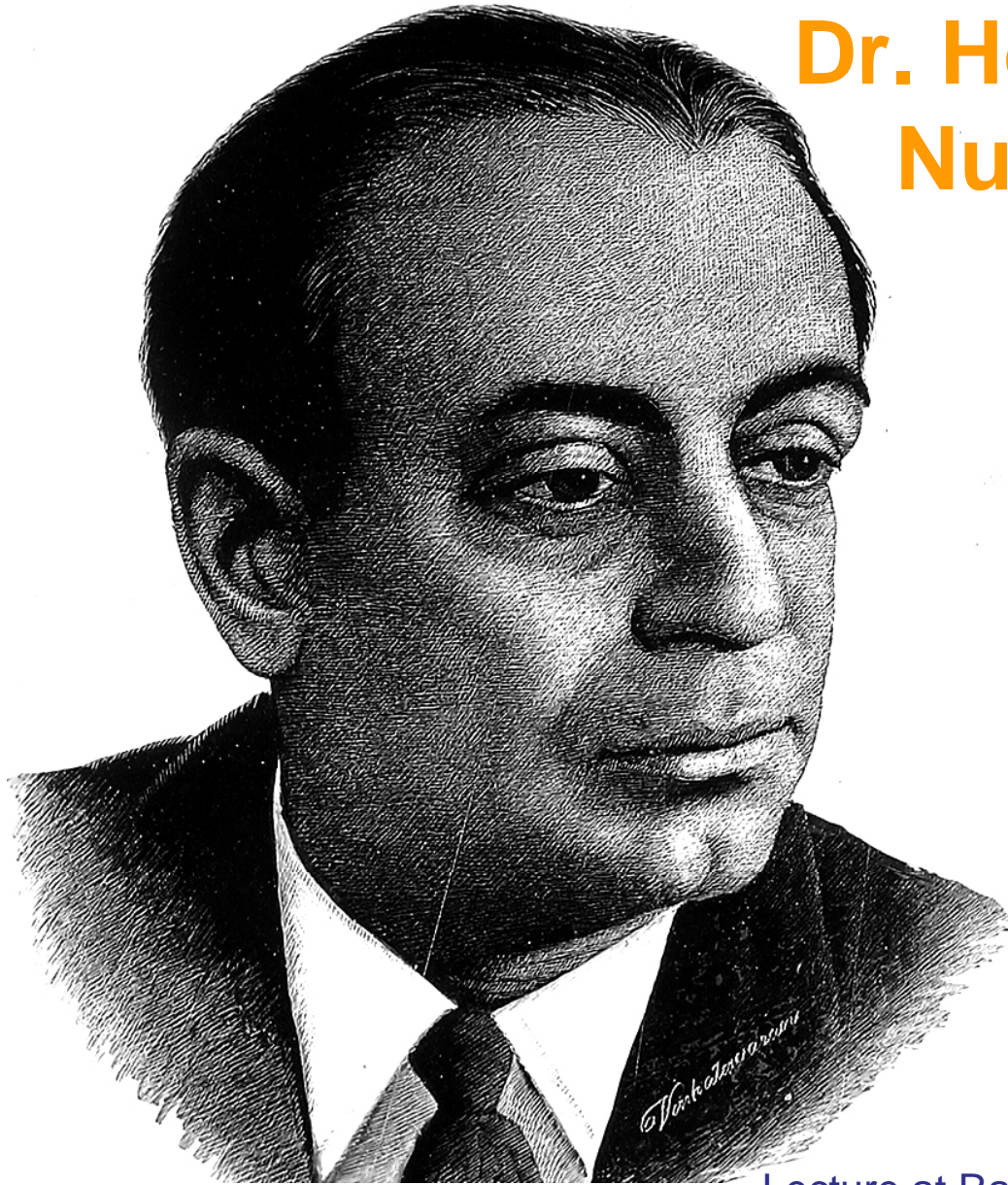


Dr. Homi Bhabha and the Nuclear, Elementary Particle Era



B V Sreekantan
NIAS, Bangalore

Lecture at Raja Ramanna Centre for Advanced Technology
Indore, 20 February, 2009

First of all, I would like to thank Dr Sahni for inviting me to participate in the annual day function of the Dr Raja Ramanna Centre for Advanced Studies and give a lecture. Being the Homi Bhabha birth Centenary year, he suggested that I could talk on my interactions with Dr Bhabha.

I had the unique privilege and opportunity of joining the Tata Institute of Fundamental Research as early as 1948 and doing my Ph.D. in the field of Cosmic Rays under the guidance of Dr. Bhabha himself and spending the next 44 years at TIFR till I retired and was invited by Dr. Raja Ramanna in 1992 to join the National Institute of Advanced Studies, as Radhakrishnan Visiting Professor, where I am still continuing, I came to know Dr. Ramanna in 1950 when he joined TIFR and have had close interaction with him for over fifty years. So it is a particular pleasure for me to give this lecture at the RRCAT in the Bhabha Centenary year.

The topics I propose to cover in this Lecture:

- A brief account of Dr Bhabha's early life
- Dr Bhabha as a student at Cambridge
- Dr Bhabha as a researcher at Cambridge
- Dr Bhabha at the Indian Institute of Science – Research in Particle Physics and Cosmic Rays
- Founding of TIFR – Cosmic Ray Research, Mathematics, Theoretical Physics
- Other Research and Development activities at TIFR initiated by him
- The Atomic Energy Programme
- Tributes to Dr. Bhabha by various scientists
- Reminiscences

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
- Engineering Tripos (1st Class)
- Mathematics Tripos (1st Class)

Letter to his parents – Passion for physics

■ 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

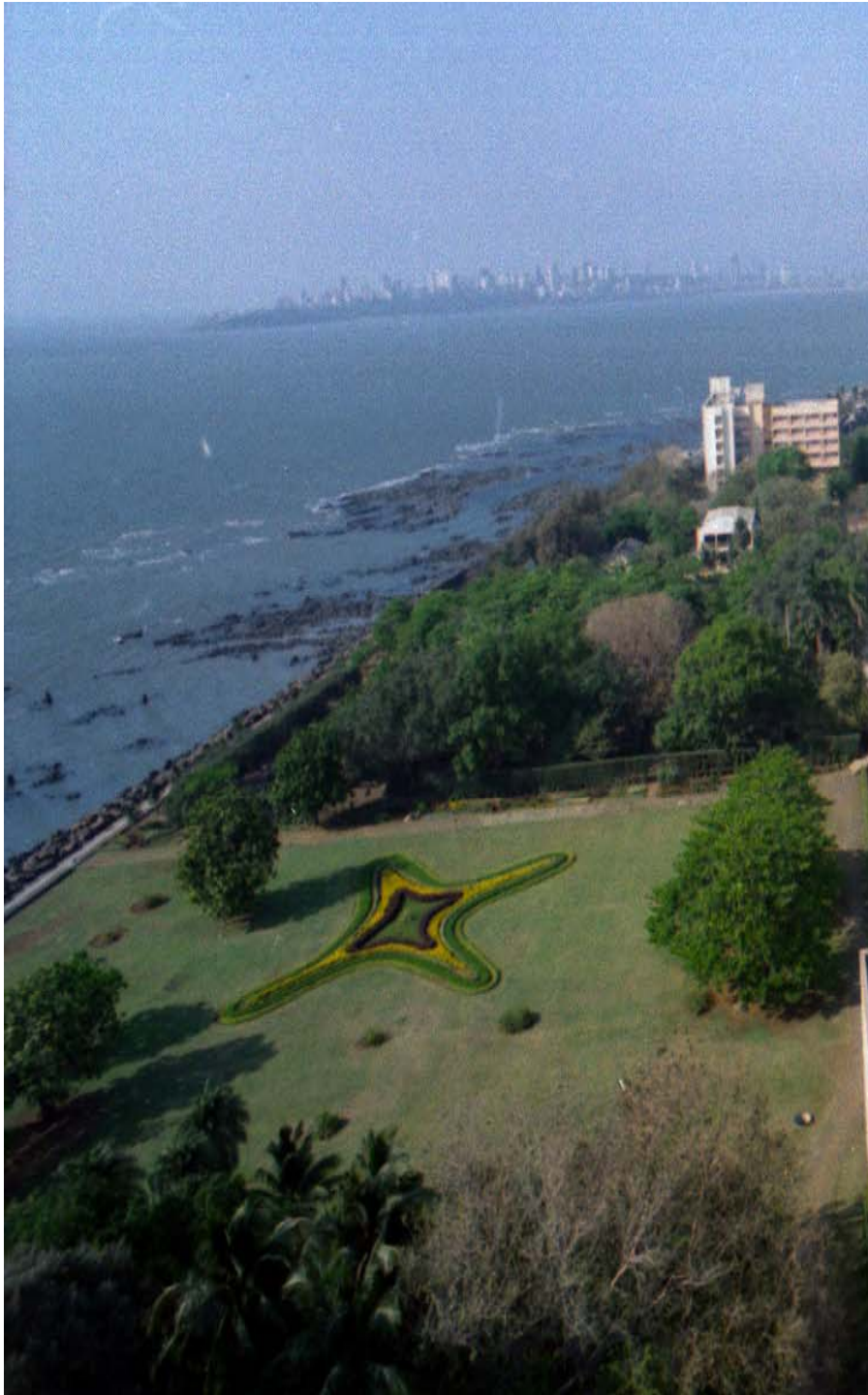
■ 1941: FRS

1942: Professor at IISc.

■ 1943: Letter to Dorabji Tata Trust

■ 1945: June, Founding of the TIFR

■ 1948: Atomic Energy Department – Commission



Family group photograph of 1933



Dr. Bhabha painting a portrait of a scientist with a Rococo background at the age of 21



Dr. Bhabha in the family library at home at the age of 31

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.

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".

What he wanted out of Life

In 1934, when Dr Bhabha was only 25 years old, he wrote to a friend

- “I know quite clearly what I want out of my 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 life is limited. What comes after death, one does not know; nor do I care.
- Since, therefore, I cannot increase the content of my 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 – of increasing the intensity of my conscious life.”

Homi Bhabha died prematurely at the age of 56 in the tragic air crash of Air India over Mont Blanc on 24th Jan 1966.

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. ”

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”

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

Research contribution of Dr Homi Bhabha

Collected scientific papers published by TIFR in 1985 (BVS, VS, BMU)

- 64 papers
- 1st paper: Zur absorption der hohenstrahlung, Zeit. F. Physik
- Last paper: On multiple meson production, Theoretical Phys., Tokyo
- Research areas: (1) Cosmic Rays, (2) Elementary particles

Cosmic Rays: 1930's : the soft component
 the penetrating component
 showers – simultaneous incidence of several particles

The only fundamental particles known : the electron, the proton, the photon

1932- discovery of the positron; discovery of the neutron

Bhabha's work on Cascade theory in collaboration with Heitler, identification of the soft component with $e^+ \cdot e^-$

Showers from the Cascade process $\gamma \rightarrow e^+ \cdot e^-$



Bhabha's paper: "On the penetrating component of cosmic radiation" , Proc. Roy. Society (1973)

Prediction of a particle of mass intermediate between that of proton and electron.

1937 : discovery of the mu-meson by Carl Anderson and Neddermeyer

Elementary Particle Physics

- Meson Theory --- three schools
 - Yukawa, Sakata, Taketani
 - Kemmer, Frohlich, Heitler
 - Bhabha

Dirac's theory was for particles of spin $\frac{1}{2}$ (electron, proton, neutron)

For particles of other values of spin [Dirac-Fierz – Pauli (DFP) equation (0,1/2,1)]

- Bhabha generalized the DFP to particles of arbitrary spin

Elementary particles of higher spin, according to this theory could have several spin states and several mass states.

These could be particles of multiple integral charges.
(No experimental confirmation so far)

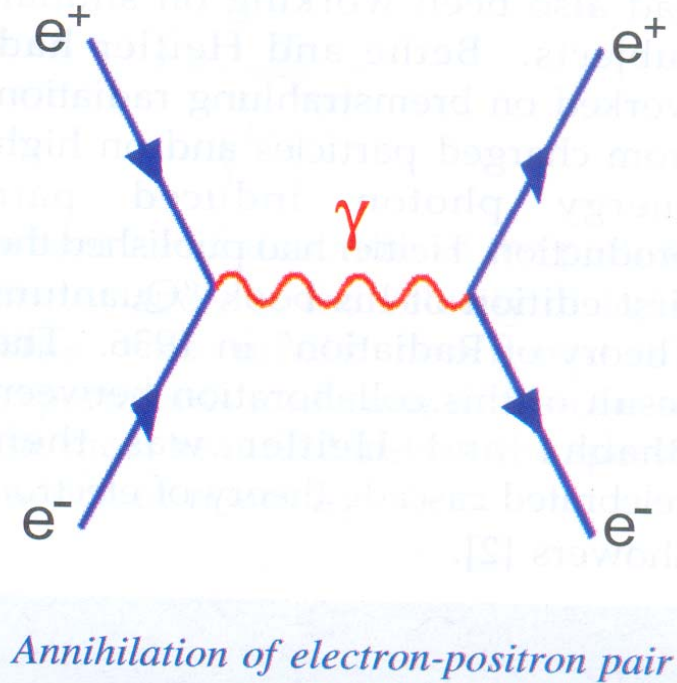
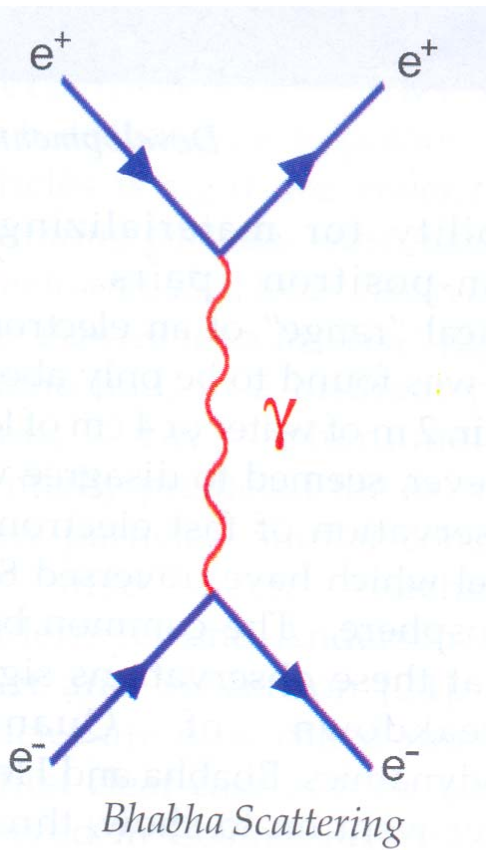
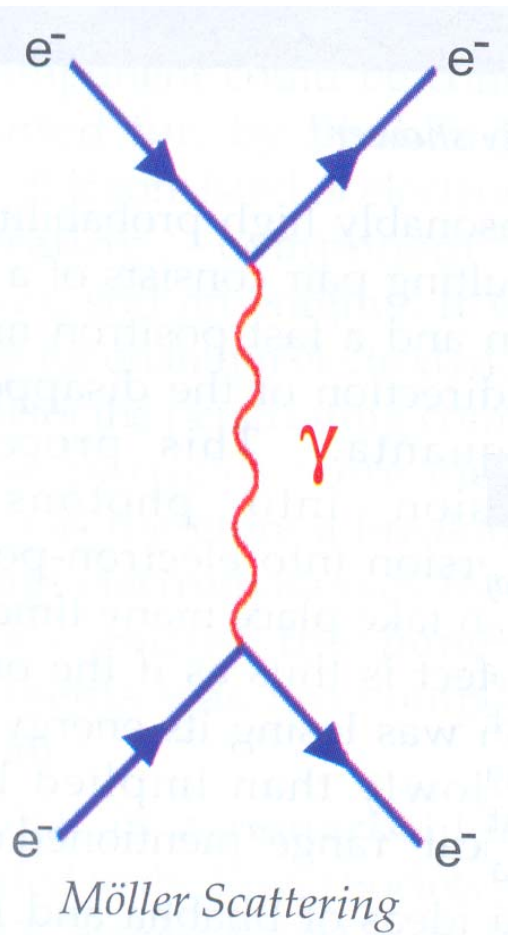
- Meson production

Meson production at very high energies shows two types of phenomena:

- (i) Excitation and subsequent decay of nucleons producing pions, kaons,
- (ii) Production of fire balls which evaporate into mesons.

Bhabha's theory of meson production provided a physical basis for the two modes of production
– collision of nucleon core with pion cloud
- pion cloud – pion cloud collision

Positron Theory: Bhabha Scattering



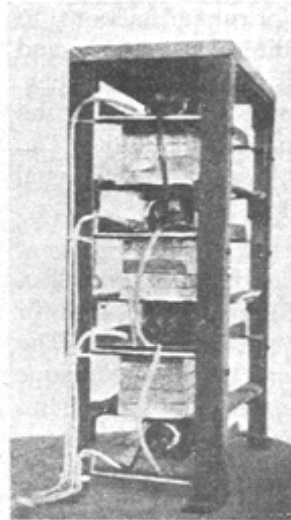
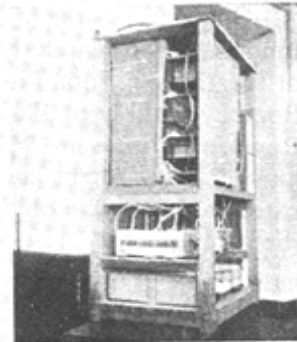
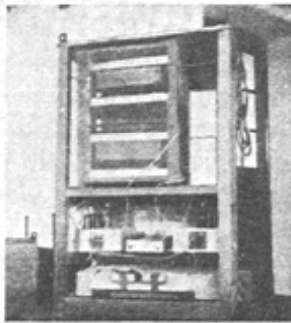
- Decay of the meson: Bhabha was the first to point out that the mu-meson should spontaneously decay into electron and neutrinos.
- The relativistic time dilatation of the mu-meson: First pointed out by Bhabha in a note in Nature
 2×10^{-6} seconds in the rest system \rightarrow milliseconds in the lab ($\tau = \tau_0 / \sqrt{1 - v^2 / c^2}$)
- Bhabha Scattering:
 “The scattering of positrons by electrons with Exchange
 Bhabha pointed out that this extra exchange (virtual electrons in negative energy states) contribution is to be regarded as due to annihilation of $e^+ e^-$ pair and again pair creation.

The practical result of the extra scattering is that when positrons pass through matter, the number of slow secondary and ionization electrons produced is not changed, but the number of fast secondary electrons is considerably increased for high initial energy of positrons.

Routinely used to calibrate energy of beams at large accelerators.

Bhabha and Experimental Cosmic Ray Research

1. Air craft experiments: 1st measurement of meson intensities at high altitudes at equatorial latitudes (5000; 10,000; 15,000; 20,000 ft) ; At Bangalore, IISC, Cosmic Ray Research Unit
2. Cloud Chamber experiment on the Scattering of Mesons, 12” dia circular cloud chamber built at IISc was brought to Bombay

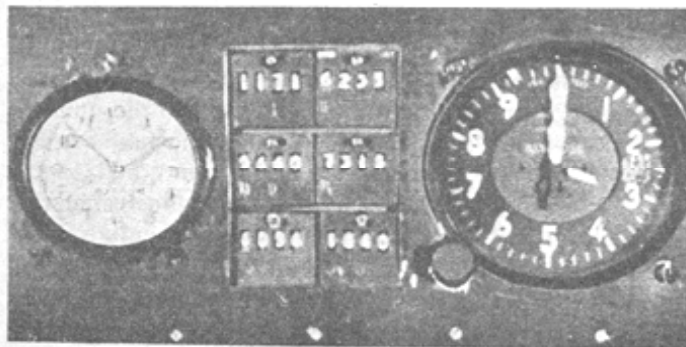


Top : Views of one of the units sent up to 32,000 feet with its sides removed. The top of the unit contains two cosmic ray telescopes. The electrical amplifiers are on the lower shelf. The dry batteries are at the bottom.

Left : A cosmic ray telescope with four counters. The three thick lead blocks traversed by the cosmic rays are seen between the counters.

Bottom right : The new anti-coincidence method for excluding the soft component.

Bottom left : A photographic record taken during the high altitude experiment. The six cosmic ray readings are shown in the middle. The altitude indicated by the altimeter on the right is 30,000 feet.

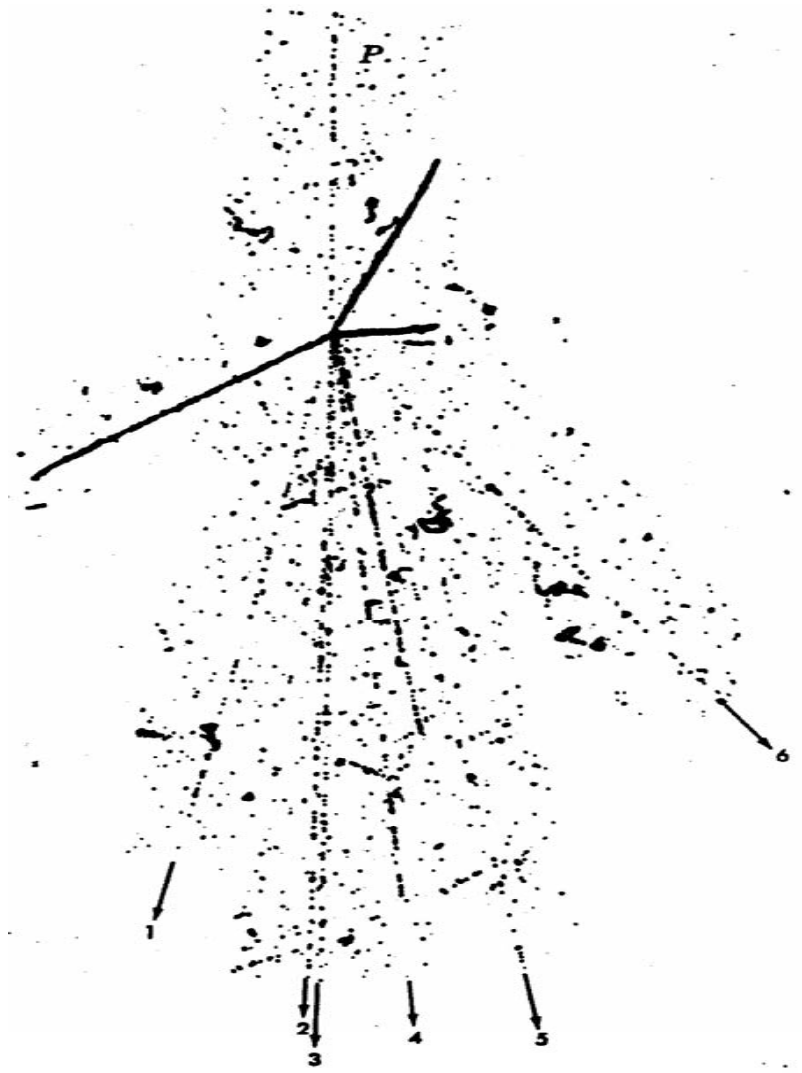


Properties of the Penetrating Component

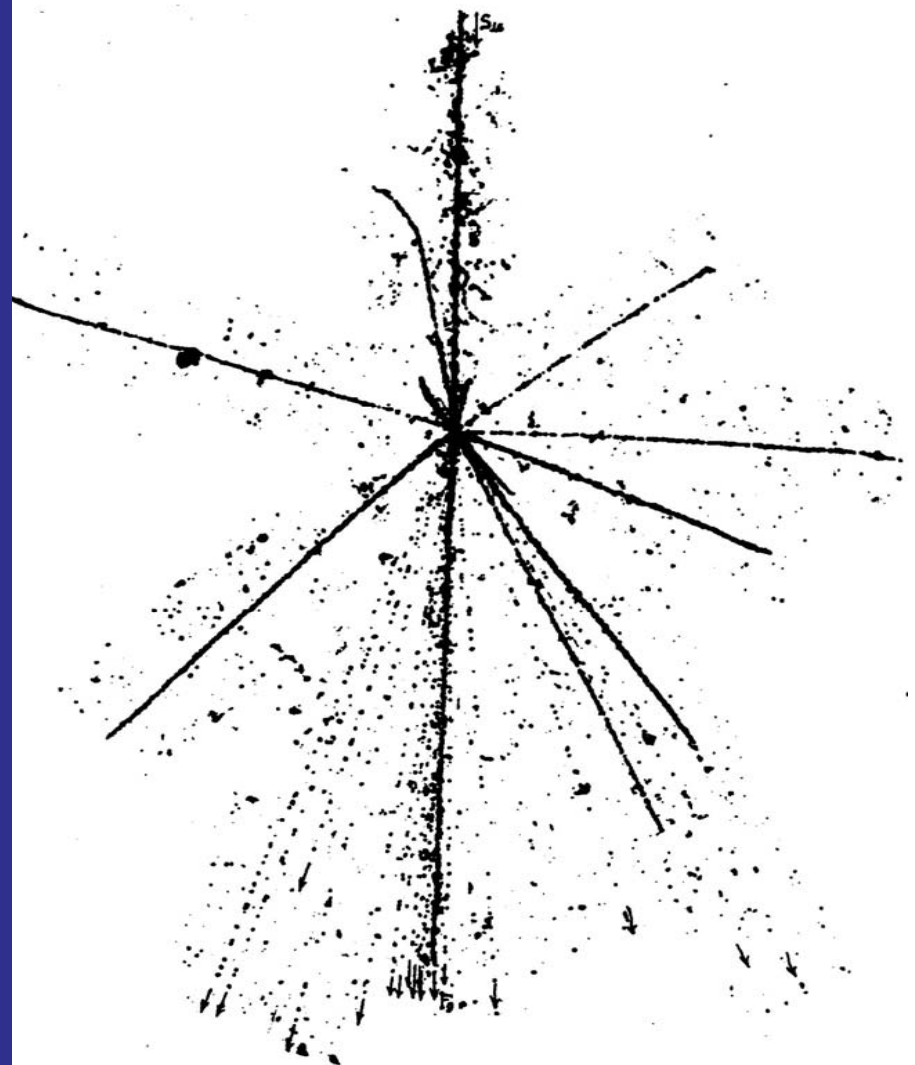
- Can easily penetrate a meter of lead
- Arrives mostly as single particles
- Both positive and Negative charged particles
- Anomalous absorption – in equal grammage of condensed matter like graphite and extended matter like air, more absorption noticed in air.
- Mass of particle in $\sim 210 m_e$
-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



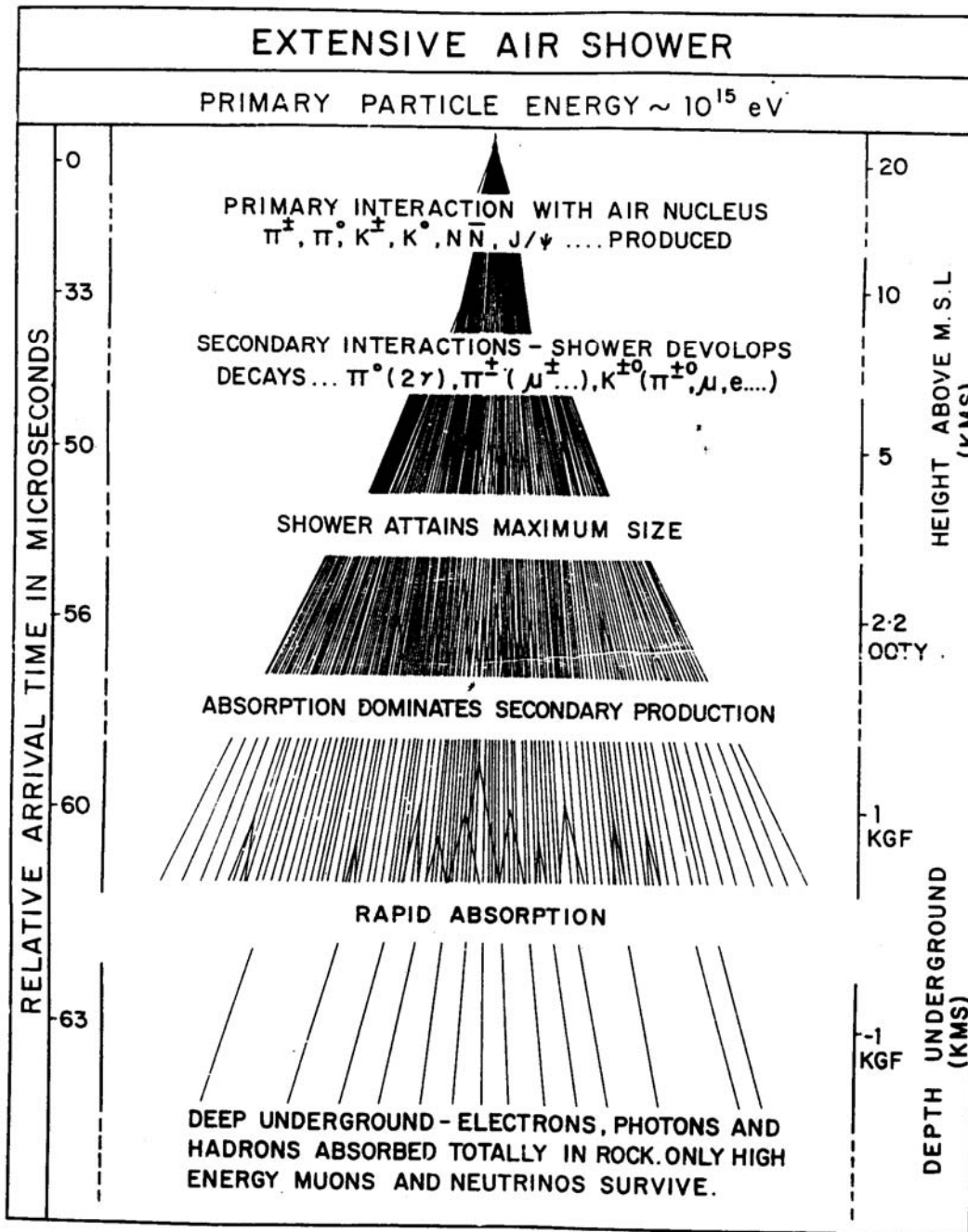
Decay of μ -Meson, R W Thompson,
The Phys. Rev., V. 74, p. 490, 1948



A Proton or a Pi-meson collides with a Silver or Bromine nucleus of the emulsion and produces 6 high energy secondaries and 3 heavy fragments.



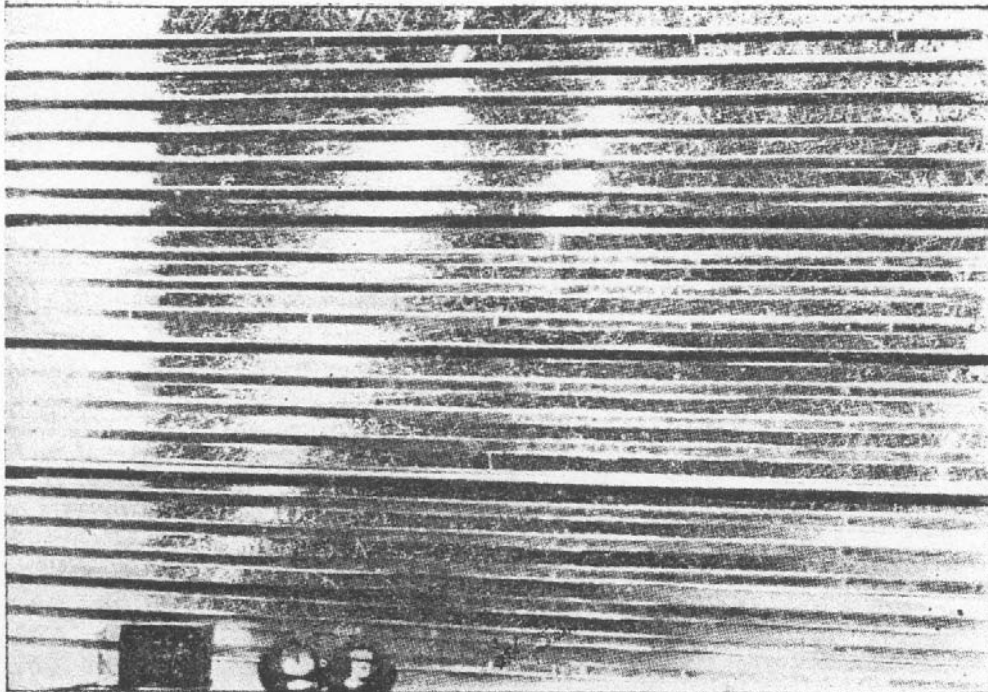
A sulphur nucleus ($Z = 16 \pm 1$) collides with one of silver or bromide in the emulsion. As a result of the encounter a fluorine nucleus and twenty-five 'shower' particles-protons and pi-mesons-emerge



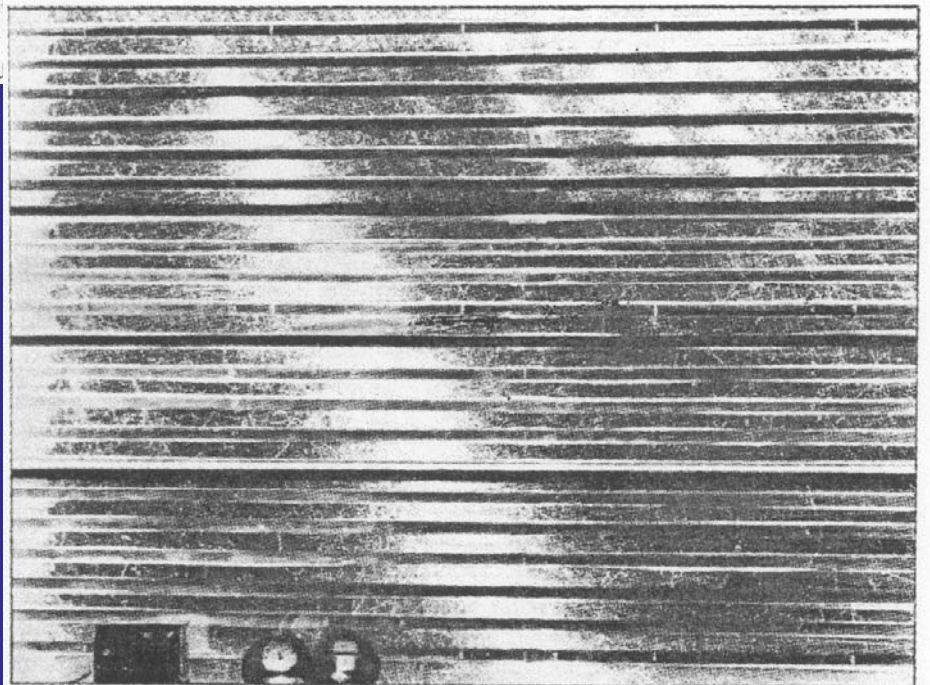
A Simplified View of an EAS Cascade

A Simplified view of an EAS Cascade

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.



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.

Dr Bhabha's interest in Accelerator Development at the TIFR.

Activities in the area of (i) Construction of a cyclotron, (ii) A Linear Accelerator, had been initiated in the early 1950's. The cyclotron project was discontinued in favour of a plasma project since there was an indication from the Harwell group in England that they had recorded neutrons in fusion experiments. Dr Bhabha felt that this should get priority.

A Linear Accelerator project was also started and this was responsible for the development of microwave activities which later led to many defence projects (TR switches etc.), construction of linear accelerators for medical purposes and finally to the formation of SAMEER the Society for Microwave Engineering and Research which became a separate institution under the Department of Electronics

First Computer in India TIFRAC

It should also be mentioned that around the same time the construction of an indigenous digital computer was taken up and the TIFRAC became operational in early 60's. With the acquisition of a CDC3600, the TIFR also became the National Centre for Computer Facilities and Software Training and Research. This unit then was transferred to the Department of Electronics and became the NCST.

Activities in the area of Nuclear Physics (1950 onwards)

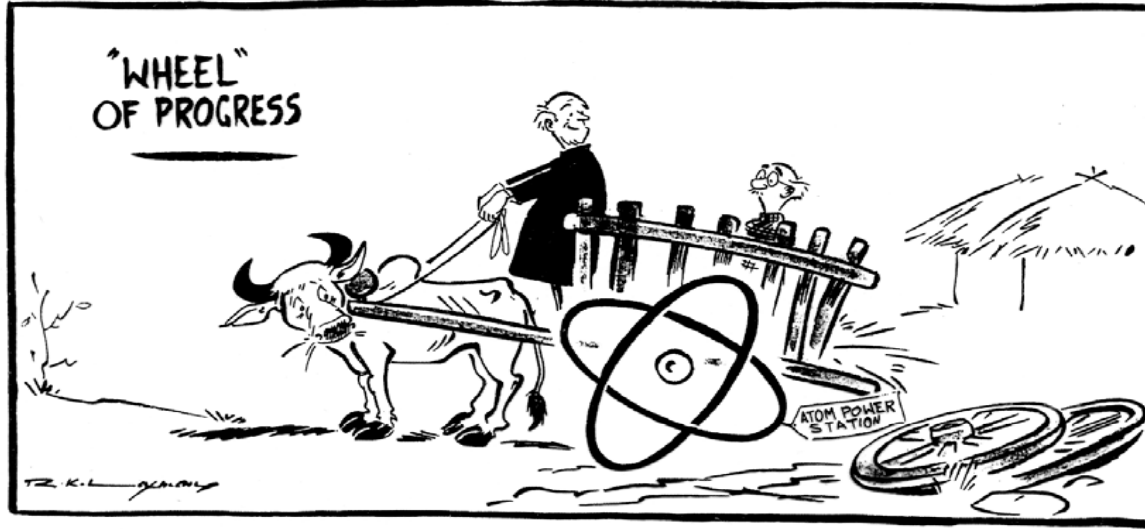
- Nuclear Reactions and Nuclear Physics – the cascade generator, Van de Graaff at BARC
- Nuclear Spectroscopy
- Nuclear Magnetic Resonance – Chemical Physics, Solid State Physics groups emerged out of these activities
- Theoretical Nuclear Physics

Homi Bhabha and Atomic Energy

- 1947-48: Atomic Energy Commission (Chairman); Dept. of Atomic Energy (Secretary)
 - Atomic Energy work: Starts at TIFR – “the cradle of the atomic energy programme”
- 1949: Rare Earth Minerals Survey – Atomic Minerals division (Kerala)
- 1953: Atomic Energy Establishment, Trombay
- 1955: Bhabha – President of the first Conference on peaceful uses of Atomic Energy, Geneva
- 1956: Apsara Swimming Pool Reactor goes critical (4th August)
- 1958: The Atomic Energy Training School
- 1960: Canada India Reactor CIR goes critical (Nuclear spectroscopy)
- 1959: Indigenous fabrication of nuclear fuel rods
 - Negotiations for Tarapur Atomic Power Reactor
 - Chairman of the Scientific Advisory Committee to the Cabinet
- 1959: DAE in charge of SPACE programme in the country, The Thumba Equatorial Launch Station
- 1963: Launch of 1st rocket from Thumba – 22nd Nov. 1963
- Bhabha report on Electronics – ECIL
- 1966: Air India Crash – 24 Jan. 1966
- Lover of Gardens, Paintings, Musician, Architect, Renaissance Man
- BARC (faces Elephanta Caves)
- Helmut Bartsch (Chicago architect for TIFR): “In this development, the architect worked with the client rather than for a client”

THE PEACEFUL USES OF ATOMIC ENERGY

Two Cartoons by
R. K. LAXMAN



Dr Homi Bhabha

“Human progress has always depended on the achievements of few individuals of outstanding ability and creativeness. Homi Bhabha was one of them”

Sir. John Cockroft

“Affectionate and sensitive, elegant and humorous, dynamic, one of the few people who enhance life whatever the content of their living – fantastically talented, but so fastidious about standards that he was never a dilettante ... He stood out as a world citizen qualified in all three subjects education, science, culture”

Lord Redcliffe . Maud

“To be a front-rank 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**”

Smt. Indira Gandhi

“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 his vision into reality.

Homi was one of those who made me believe that some men in human history are born with the stamp of predestination on them which leads them to accomplishments beyond ordinary human capabilities.

Some of them – and Homi alas was one are also predestined to die young, an unconscious premonition which drives them to superhuman effort to complete their task in the short time allotted to them. scientist, engineer, master-builder, and administrator steeped in humanities, in art, music, Homi was truly a complete Man”.

J.R.D. Tata

“Homi Bhabha was best known for his contribution to the field of science. Among those that will live for ever as his monuments are:

(i) his theory of electron showers

(ii) TIFR

(iii) First conference on Peaceful uses of Atomic Energy

(iv) The Indian Atomic Energy Agency with its outstanding laboratory at Trombay

Homi abandoned a very promising career in fundamental physics at a time when the excitement of discovery was at a feverish pitch and when it must have been obvious to him that he could compete on highly favourable terms for the intellectual joy and immortality that were certain to flow from the discoveries vaguely visible in the clearing intellectual mist....

The TIFR is his dream come true. It is an outstanding centre of fundamental research which fulfils all the roles Bhabha imagined it would.

Bhabha’s life demonstrated that a single human being is capable of creativity and understanding in both modes of the mind. An eminent theoretical physicist, he was also an artist of rare skill and feeling He was versed in Western culture as he was in that of his native land and he derived joy and guidance from both”

Jerome B Wiesner (Provost MIT)

Reminiscences

B V Sreekantan

- The interview with Dr. Bhabha that did not take place in 1947.
- Three interviews with Dr. Bhabha on the same afternoon. (August 6, 1948)
- One Wednesday colloquium at Peddar Road (1948); Stretches to 3 – colloquia on mu-e decay, Wednesday – TIFR Day for Dr Bhabha
- Nehru, Bhatnagar, Krishnan and Bhabha See cosmic ray tracks in cloud chamber (Non-existent tracks!)
- First International Conference on Elementary Particles held at Yacht club December 1949
- Initiation of KGF experiments on Muons
- Bhabha's visit with Goudschmidt on Christmas Eve 1951
- Bhabha inaugurates the KGF Air Shower Laboratory in December 1964
- Bhabha's annoyance with Reines who tried to bypass TIFR to initiate neutrino experiments at KGF.
- Bhabha's Holiday at Coonoor and Ooty – December '64-Jan. 65. Search for sites for Ooty Radio Telescope and the Inter-University Centre
- Largest Multiplate Cloud Chamber tracks
- Message from Bombay regarding approval of a power project - My goofing
- The dream on 24th January '66 Night
- The gift from Oliphant – sketch by Bhabha

Lessons From Dr Bhabha's Life and works

- Set your goal high and follow the dictum that nothing is impossible provided you have selected the right type of people and created the right kind of atmosphere and motivation.
- Do not compromise on mediocrity
- Place full confidence in youth. Support them to the hilt. Inexperience may lead to some mistakes initially. It does not matter.
- Build activities around people. Not the other way round
- Judge people by their performance. Do not let hierarchy come in the way of recognizing the true performers.
- There is no substitute for hard work.
- Get the Best out of your Life.
- Inheritance is important, but what you make of inheritance is even more important.



Thank You

