

International Linear Collider Project – A New Voyage in Elementary Particle Physics Research

The International Linear Collider (ILC) Project is a follow up of the now well-known and famous Large Hadron Collider (LHC) experiment. The reader will recall, the great excitement last year of the discovery of the Higgs particle, whose existence had been predicted nearly half a century ago. This particle is associated with the mechanisms that give masses to the force carriers of the weak interactions as well as to other elementary particles in the most economical realizations. Thus a full exploration of its properties is necessary to check the theoretical ingredient that goes into the mechanism, which can only be vindicated experimentally. Because the LHC has a noisy environment, due to collision of protons on protons in it, a clean environment provided by electron–positron is required, which is expected to be achieved at the ILC.

The ILC is expected to probe the nature of matter and interactions at the smallest length scales. Indeed, large energies are needed to probe small lengths, as there is an inverse relation between the two. It may be recalled that in LHC there is collision of protons on protons in circular colliders at much higher energies, but the available energy for a given event is small, as protons are composite and the energy available for a constituent in a collision event is significantly low. Because the proton is nearly 2000 times heavier than the electron, it is possible to reach such high energies in circular colliders, as the synchrotron losses associated with keeping protons in these circular orbits are much less. Thus even though the ILC will have significantly smaller energies than the LHC, as the electron is not composite, all the energy will be available for the collision. But a circular design will not be possible as the synchrotron losses will be prohibitive and only a linear accelerator design is feasible for the design energies. Concomitantly the luminosities will be smaller, but large enough to do exciting physics.

The new ILC programme is another major journey in the field of particle physics. The Technical Design Report for the proposed ILC prepared after many years of deliberations of technical committees and teams of physicists was handed over to the Chair of the International Committee on Future Accelerators on 12 June 2013 at ceremonies that took place back to back in Japan, Switzerland and the USA. A one-day workshop was held on the same

day at the Centre for High Energy Physics at the Indian Institute of Science, Bangalore, to commemorate the event along with a webcast of the event. More significantly, the re-affirmation of India's commitment to the project was beamed live from the workshop in Bangalore to Japan, which in turn was beamed to the rest of the world in a speech by Amit Roy, Director, Inter-University Accelerator Centre, New Delhi.

The ILC proposal is based on proven technologies and it is worth noting that an alternative proposal known as CLIC (Compact Linear Collider) which is even more ambitious in its energy and luminosity reach, is also being honed further to bring it to a more realistic stage. The enormous scale of the project and the truly international nature of the enterprise are evident. To reiterate, ILC is a proposed electron–positron collider in which these particles will collide at very high energies and large luminosities to carry out precision studies of the properties of the Higgs particle that was recently discovered at LHC and whose properties are being explored.



International Linear Collider

Research in science is driven by curiosity. It is a quest for knowledge. Researches in basic sciences are expected to result not only in improving our knowledge about our universe, but also in bringing about technological revolution. Past experience shows that seemingly esoteric research projects have led to extraordinary breakthroughs in technology, in what has come to be known as spin-offs. As pointed out in 'Science in India, 2004–2013, Decade of Achievements and Rising Aspirations' – a

report prepared by the Science Advisory Council to the Prime Minister in 2013, results from basic sciences lead to developments in technology for the benefit of mankind, although such applications may not be apparent at the time when the experiments are done and the results are first published. The work of Jagadish Chandra Bose, more than a hundred years ago, is at the core of the communication technology today as seen in mobile phones, satellite communication systems and remote sensing. C. V. Raman's Nobel Prize-winning work on optical effect has found application, after 70 years, in the development of inexpensive powerful lasers, fast digital image processing applied in space and communication industries and surface-enhanced spectroscopy. A hand-held device developed on the basis of the Raman Effect can detect a wide variety of molecules, whose abundances are less than one part per billion. The technology, likely, will have increased application in the field of health care and security. The work of Srinivasa Ramanujan in the field of mathematics finds applications in modern cryptography, population dynamics and theoretical physics. Recent experiences at CERN in Geneva have had important implications in the development of the World Wide Web. The phrase 'space-age' materials, itself, suggests that such materials are a spin-off of space exploration. Without research in nuclear physics, the world would not have had radiation therapy for cancer. Today, proton therapy is becoming more widespread, having its origins in the work of the pioneers of great elementary particle physics, Roberth Rathbun Wilson, who later became the Director of Fermilab. The foregoing examples underscore the importance of basic research in sciences for technological development.

In the modern era, the enterprise of science is highly collaborative with teamwork as a necessary component. Furthermore, basic and applied sciences, necessarily go hand in hand. Large scientific projects are interdisciplinary and require versatility and flexibility and have a large number of personnel trained in such capacities. Training is a necessary ingredient for building the talent pool of the country. Considering that India has over the decades built up considerable strength in basic sciences, future planning must be aimed at consolidating these strengths as well as in identifying suitable directions for the future. It may be emphasized here that while the participation in large international projects is necessarily an important part of the scientific enterprise, it needs to go hand-in-hand with domestic scientific projects. Policy makers must continue to plan in-house projects for institutions in the country both on large and small scales. These projects could be at several scales, from large projects at home to laboratory and table top scale.

It is likely that as the ILC gets off the ground, and as the challenges are being met, the coming together of physicists, engineers and others will give rise to new technologies on an unprecedented scale. India has been

an active participant in many international projects in various fields of science and technology at all levels – individual scientists, teams of scientists and institutions. In particular, Indian scientists in the post-independence era have built up a tradition in elementary particle physics research, guided by eminent scientists like Homi Bhabha. These traditions made it possible for the Indian scientists to reach sufficient maturity to set-up their own research facilities, including for example, cosmic-ray physics, underground physics, nuclear physics laboratories in different parts of the country. They have also had the expertise in participating in international projects for decades now. For instance, Indian institutions have participated in the LHC-related experiments such as A Large Ion Collider Experiment (ALICE), Compact Muon Spectrometer (CMS), Large Ion Collider and also in the precursor to the LHC known as the Large Electron Positron collider at CERN. They have also participated in Tevatron at Fermilab, USA.

India under the ILC programme has proposed to embark on one such journey again in the area of particle physics by participating in the spheres of physics, accelerator and detector design as well as execution. Should the project become viable through the support of the Governments, with Japan being the forerunner now, and should it be commissioned, there would be a plethora of opportunities for our scientific talent to learn, collaborate and contribute. Furthermore, as in the past, Indian industry would be able to demonstrate its maturity and bid and win global tenders for manufacture of components. Laboratories in India would be able to use existing infrastructure and also augment them to meet the challenges.

The ILC would be the key instrument to settle many of the outstanding questions that engage physicists today. What is the nature of the Higgs particle? Are there other particles in nature, so heavy and unstable that the only time they were produced was at the time of the big bang (having subsequently decayed into more familiar particles), that no environment since that time has been available for their production? If such particles exist, what are their interactions? Do they reveal something about the nature of the only fundamental forces or are there more? If so, what is their imprint? What is the nature of the dark matter? Can we study it in man-made environments? Are there questions that no one has thought of so far? Such is the ambitious scope of the ILC programme. The Indian scientific community must join in this remarkable voyage! The scientific community must also explain to the policy makers and the educated public the manifold reasons for joining this enterprise.

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