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GUEST EDITORIAL

The International Linear Collider: A new paradigm for doing science globally

This editorial talks about the International Linear Collider, one of the mega facilities that the world high energy physics community is convinced it needs and the innovative strategies it is evolving to achieve it. Particle physicists, in the quest of the fundamental physical laws which govern the working of the universe, have needed to probe physics at distance scales smaller than atomic and nuclear sizes. This requires particle beams of shorter and shorter wavelengths, hence of higher and higher energies. Beginning with Lord Rutherford who said 'It has long been my ambition to have available a copious supply of atoms and electrons which have energies transcending those of the alpha particles from the radioactive bodies', particle theorists have been setting challenges to their colleagues in the accelerator community, and they have responded magnificently.

Compared to the first Cockroft–Walton accelerator which could be housed in a room, the modern day accelerators are gigantic. The large hadron collider (LHC), the highest energy *pp* collider at CERN (Geneva), for example, has a circumference of 27 kilometers and straddles two countries. This will accelerate protons to 7000 GeV (7 TeV). It is all geared to go in action in 2007 and probe laws of physics at distances about 1000th of a femtometer. The results obtained there may hold clues to the happenings in the first three minutes of the existence of our Universe!

Collaborative efforts of tens of laboratories around the world, from hundreds of physicists and engineers, are required to perform experiments with these gigantic facilities. The particle physics community has devised efficient management structures to do this. Actually the 'World Wide Web' and the 'HTML' were invented by particle physicists to facilitate data sharing and communication among the participants of a given experimental group. It is a moot question whether the particle physicists will still be needing to ask for grants for their accelerators and experiments if they had charged even a token royalty for the WWW!!

The types, energy and intensity of the beams required for experiments have to be determined by critically evaluating the physics needs, the capabilities of the detectors to perform measurements and of course the technical feasibility of designing/constructing the necessary accelerators to deliver the beams. Hence, the design of the machines and the detectors, requiring close collaborative efforts among theorists, experimentalists and accelerator physicists alike, can easily take more than a decade.

However, all big accelerators till now were projects of a given laboratory; the Intersecting Storage Ring *pp* collider which first proved existence of quarks, the $\bar{p}p$ collider which discovered the W/Z boson and the large electron positron collider LEP, which produced millions of Z bosons for precision measurements, were all CERN projects. The Stanford Linear Accelerator pioneered the design of a linear e^+e^- collider: the SLC. The top quark was discovered at the American $\bar{p}p$ collider TEVATRON. The electron–proton collider HERA which studied proton structure to distance scales never before probed, was a German project at DESY; similarly the e^+e^- colliders TRISTAN, BELLE projects of the Japanese Accelerator Physics Laboratory KEK. Of course the facilities were used internationally; the detectors used were designed and fabricated by international teams; the physics experiments, analyses were done internationally and publications have been in the name of the entire team. However, the accelerator design, planning was done by the teams from these regional/national laboratories.

As a result of the long time required for the planning and design of these big machines, when the experiments at the LEP were going on and planning for the LHC machine and detectors was on, the international particle physics community was already busy evaluating the need, the physics potential and the technical feasibility for the next generation e^+e^- colliders, which *have* to be linear for technical reasons. A series of International Linear Collider Workshops started in Saarsielka, Finland in 1991. Three regional Linear Collider (LC) working groups: loosely knit collaborations of over 200/300 particle theorists and experimentalists, worked on this. These functioned under the aegis of bodies such as the European Committee for Future Accelerators (ECFA) or its Asian counterpart ACFA, which in turn worked in coordination with the International Committee for Future Accelerators (ICFA), a body which was formed by the IUPAP: the International Union of Pure and Applied Physics. They established the physics case for a TeV range, Linear, e^+e^- collider as a machine that would be required after the LHC; preferably with time overlap. While the LHC, we all hope, will discover the Higgs boson, one will need the ILC to study its properties with great precision, just like the LEP did with the Z-boson. Such a machine will be capable of studying 'directly' in the laboratory the 'dark matter' which, as established by astrophysicists, makes up most of the mass of the Universe. It may also be able to tell us whether the world we live in is three dimensional or has 'small' (smaller than a micron) additional dimensions. Exciting physics prospects for a machine indeed!

The origin of the paradigm shift, which is one of the focal points of this editorial, can be traced to the concluding remarks made by Bjorn Wiik (later to be DESY director) at the first workshop in Saarsielka.

'The complexity and the cost of this collider makes it unlikely that more than one such facility will be constructed. An interregional collaboration will not only allow us to pool technical and financial resources, but it may also serve as a model for other large scientific or technical enterprises. We must discuss the organization of such a facility. Should it only make use of the facilities of an existing laboratory but be independently organized, or should it be a new laboratory? At some stage these discussions must clearly involve the funding agencies. The final and most difficult question is one of site. This is clearly a political and financial question. Setting up this new kind of interregional collaboration is in itself both a challenge and a goal.'

However, in spite of this, from 1991 to around early 2001 three independent projects for designing the American Next Linear Collider (NLC), Japan Linear Collider (JLC) and the European, TeV Energy Superconducting Collider (TESLA) went on. The three groups were frequently meeting and talking, but these were still pursued as separate projects in the older paradigm.

In 1994, the process of globalization of the activity got a nudge when the Nobel Laureate and SLAC director, later IUPAP president, Burt Richter prompted formation of an International Linear Collider Technical Review Committee (ILC-TRC), a truly International body to assess the issues. It made its first joint report in December 1995, about the feasibility and desirability of such a machine.

The true globalization began in 2001 by which time the European group, in a program led by Bjorn Wiik at DESY, had prepared a Technical Design Report for the proposed TESLA and submitted the request for funding of about 3000 Million Euros, to the German Government. The Scientific Advisory Committee to the German Government, graded the project as excellent, recognizing it to be of utmost scientific importance for furthering the boundaries of our knowledge of fundamental physics; but it also recommended that this be a truly joint international effort.

Around the same time, the ICFA asked the TRC for a second report. The Japanese and American teams were using the so called 'Warm' technology, using non-superconducting cavities and the Europeans were working on the 'Cold' superconducting (SC) technology. The ICFA formed an 'International Technology Recommendation Panel (ITRP)' to evaluate the two. In 2004 the ICFA received the recommendation of this panel for the SC technology of TESLA; but not for the TESLA design. The community was so convinced of the need for an ILC that these two groups working on completely different technologies started now working together in the Global Design Effort (GDE) for designing the International Linear Collider. A virtual accelerator laboratory, as it were, has been formed in the form of GDE; its current director being Caltech physicist Barry Barish, with three regional directors, one from the America, Europe and Asia each.

Now the community has embarked on the truly challenging task of designing and building an international facility. The current agreement being that different places can bid for hosting the collider; the host would need to contribute 60% of the cost of the machine. The GDE is expected to bring out a document containing the design and cost estimate by the end of 2006. The community has started discussing how to integrate the funding agencies collectively at a working level and devising international management structures which might be acceptable to the governments before considering funding such a global enterprise. A GDE meeting was held in Bangalore (9–13 March 2006) concurrently with the IX workshop in the series which began in Saarsiekla, where some of these issues were discussed and debated.

The 2000 budget estimate of TESLA of about 3000 billion Euros, is the only indicator at present of the expected cost estimates. It should take about seven years for the accelerator to be ready from the day the funding is sanctioned. To put the expected cost of the machine in perspective, the international project ITER for Plasma Physics, of which India is a partner, has similar budget. The cost of the LHC machine has been 3 billion Swiss Francs (about 2 billion US$) and the cost of each detector at the LHC is about 500 million Swiss Francs! Indian accelerator community and industry (one of them based in Bangalore) have participated in the construction of LHC, by making the 'precision magnet position system jacks', whereas the high energy physicists are part of the experimental collaborations. It is to be hoped that the Indian community gets involved in the ILC now at the design stage itself and participate effectively taking advantage of our huge IT potential.

Early days indeed to know what all these efforts will bring! As an interested party, I can wish only success to this new paradigm that is evolving!

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