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GUEST EDITORIAL

Nobel Prize in Physics–2013: Triumph of mind over matter

On 8 October 2013, the world greeted the news of the award of the 2013 Nobel Prize in Physics to François Englert of the Université Libre de Bruxelles, Brussels, Belgium and Peter Higgs of the University of Edinburgh, Scotland, UK, for the work of the former done in collaboration with Robert Brout (since deceased) and the latter in 1964. While the citation reads '*for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider*', the news has not come as a surprise to most observers of the Nobel Prize, which has traditionally honoured path-breaking fundamental discoveries in science. Indeed one may even say that this is a telling example of triumph of mind over matter!

In the recent past, elementary particle physics has received due recognition through the award of the 2004 Nobel Prize to David Gross, Frank Wilczek and David Politzer for discovering the properties of the strong interactions at the fundamental level, and the 1999 Nobel Prize to Gerardus 't Hooft and Martinus Veltman for proving the renormalizability of spontaneously broken gauge field theories. It may be recalled that the 1979 Nobel Prize to Sheldon Glashow, Abdus Salam and Steven Weinberg for the construction of the electroweak theory has as an essential ingredient, of the mechanism of generating masses for force-givers of the weak interaction, and it therefore, seemed anomalous that those who had given the mass generation mechanism, should remain unrecognized. Nevertheless, being true to the original mandate that theoretical predictions must be validated by experimental discoveries is what has led to this seemingly inordinate delay of the 2013 award.

Englert born on 6 November 1929 is a Belgian physicist who spent most of his working life at the Université Libre de Bruxelles. During the tragic years of the Second World War he had to live in hiding and eventually obtained his Ph D degree in 1959 in physical sciences. He began his collaboration with Brout (1928–2011) at Cornell University, USA and together they authored a paper entitled 'Broken symmetries and the mass of gauge vector mesons' (received on 26 June 1964 and published in *Phys. Rev. Lett.*, 1964, **13**, 321–323). Higgs was born on 29 May 1929 and spent most of his working life at the University of Edinburgh. His Nobel Prize-winning paper was entitled 'Broken symmetries and the masses of gauge bosons' (received on 31 August 1964 and published in *Phys. Rev. Lett.*, 1964, **13**, 508–509). It may also be noted here that soon after these papers were published, the team of Carl R. Hagen, Gerald Guralnik and T. W. B. Kibble (Madras-born) also published a comprehensive paper entitled 'Global conservation laws and massless particles' with results which corroborated the findings of Englert, Brout and Higgs (received on 12 October 1964 and published in *Phys. Rev. Lett.*, 1964, **13**, 585–587).

It may be recalled that particles such as electrons and neutrinos, and quarks that constitute particles such as protons and neutrons interact via the familiar electromagnetic interactions when they are electrically charged and also via the sub-nuclear 'weak interaction'. Among other things, the weak interactions are responsible for radioactive beta decay of medical isotopes and radiocarbon, and also participate in processes that power the Sun. The weak interactions render particles such as free neutrons unstable. A free neutron decays to a proton with the emission of an electron and an anti-neutrino. The reason why these forces are called weak, is because their force carriers – analogs of photons in electromagnetism are very massive. The question was, why are these force carriers very massive, weighing as much as about 100 times the proton? The very short range of the force is inversely related to the largeness of the mass of the force carrier. The force carrier of the electromagnetic interactions, the photon, on the other hand, is massless and the force itself has infinite range. The phenomenon responsible for generating masses for the force carriers is known as spontaneous symmetry breaking, where the 'symmetry' in question was deduced from the fact that there were certain conservation laws, and are described in terms of precise mathematical formulation known as group theory. Thus the puzzle that required resolution was the mass generation mechanism, since until that time it was believed that force carriers associated with symmetries must be necessarily massless. It is in this manner that the 'Higgs mechanism' gives masses to force carriers. A price to be paid for the Higgs mechanism is the introduction of a new particle that has come to be known as the Higgs boson, whose mass was unknown until 4 July 2012.

At the Large Hadron Collider (LHC), for the first time, in man-made machines high energies were made available under controlled conditions to produce Higgs boson in sufficiently copious numbers and to also record the details of the products of the disintegration of the Higgs boson that were produced, using the powerful detectors CMS and ATLAS. It may also be mentioned that prior studies on properties of electromagnetic and weak interactions at high precision, pointed to the existence of the Higgs boson compatible with its mass of 125 GeV/c^2 (note that a proton is about 1 GeV/c^2), since in quantum field theory, vacuum processes involving virtual particles make their presence felt in collision processes, even if particles are not directly produced. This mass is also compatible with analysis of the data from Tevatron, a US-based proton anti-proton collider, which did not achieve as high energies as the LHC, but served as a notable precursor to the LHC.

While the story of the Higgs mechanism and its protagonists has captured the public imagination in an unparalleled manner, it may also be an opportune moment to ponder on the nature of the scientific enterprise that motivates the individual scientist. This story in particular, has elements of romance and mystery, of human qualities and patience. It also reveals that the nature of the scientific enterprise has changed dramatically, especially with the rise of large cooperative projects which are hard to imagine. Today, at LHC, a machine that lies in a 27 km long tunnel below international borders in Europe, with thousands of persons working on it, using components developed by researches from across the world and bought in response to competitive global tenders, the search for individual glory is no longer an imperative. There are those who advocated that the award of the Nobel Prize itself could have been made to CERN, just as the Nobel Peace Prize was awarded to an organization for the prevention of chemical war. However, the Swedish Academy apparently did not consider this possibility, because it would have been impossible to recognize the efforts of any one experimentalist in this gigantic collective endeavour.

An important question for mankind and policy makers is to deliberate on the short-term and long-term benefits, with fixed resources, and how they wish to deploy them. Such questions will become important as we contemplate on how to proceed in the post-Higgs world and search for answers to questions such as – what lies beyond the electromagnetic, weak and strong interactions? What is dark matter and why things are the way they are? Governments will have to decide how to go ahead with new projects, as for example in the much anticipated International Linear Collider. There is little doubt that such projects will generate massive technological spin-offs heralding new technological revolutions. Thus, investment in scientific projects is also an investment into the future of countries and of mankind in general, and is therefore a must.

Particle physicists will also have to be wary of being over aggressive and are often perceived as arrogant and acerbic, motivated in part by their phenomenal successes. This was best captured in the well-known article 'More is different' by P. W. Anderson, a pioneer in the theory of broken symmetries and an author of prescient article in the context of superconductivity, predating the Englert, Brout and Higgs' articles. Furthermore, it has been argued here that especially in the context of symmetry breaking, the reductionist approach of particle physicists will not suffice in uncovering all the laws of nature, a point well worth ruminating on, as we enter the post Englert–Higgs Nobel Prize era.

It may also be worth keeping in mind that many generations have worked hard to make the LHC a reality. A failure to continue on this path could very well mean the loss of all the knowledge and technology that arose in this context. Furthermore, during the same period, astronomy and cosmology have become precision sciences on an unparalleled scale. Ideas originating in particle physics such as the inflationary paradigm for the early universe have shown that a fertile cross-pollination of fields is possible. There are many unanswered questions in these realms and at the interface of these subjects. It is imperative that mankind continues on this path of enquiry. It is also imperative that scientists and educators go out and explain the significance of the Nobel prize winning work of Englert and Higgs to the younger generations and inspire them to think hard about the outstanding problems in the natural sciences so that the success of the 2013 Laureates may be replicated time and again in the years to come.

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