

The scope of fundamental research

- I am pleased and honoured to be here in this magnificent center devoted to fundamental research. It exemplifies the impressive commitment of Vietnam to support the highest level of education and its endeavour to promote the humanistic dream of rational knowledge.
- To underscore the scope and the social implications of fundamental research, I will briefly review its history.
- Surrounded by the mysteries of nature and scared by their weakness and their own impermanence, men in all civilisations have searched for the understanding of this threatening unknown. Supernatural powers have been called for help but from their failure to provide satisfactory answers and remedies surged the vision of a world freed from them. This is the vision uncovered and developed by fundamental research in physics. I will evoke this extraordinary intellectual adventure and put in that perspective the contribution rewarded by the 2013 Nobel Prize.
- Physics, as we know it today, is an attempt to interpret the diverse phenomena as particular manifestations of general testable laws. For instance the behaviour of falling bodies, the revolution of planets, the unfolding of the tides are all explained and quantitatively accounted for by the general Newtonian law of gravitation, namely by an attractive force between massive objects proportional to the product of their masses and inversely proportional to the square of the distance separating them.
- Although it was prepared by centuries and even millenaries of experimental and theoretical inquiries, the very concept of a world ruled by general and experimentally testable laws is astonishingly recent in the history of mankind. It started essentially in Europe at the Renaissance and experienced a rapid development. The crucial ingredient was the inertial principle, initiated by Galileo (1564-1642), which essentially states that the uniform motion of a physical system has no effect within the system and hence cannot be detected by an experiment performed within the system. This was a profound idea: the very fact that we do not feel such a motion reveals the universality of the Galilean approach to the understanding of nature: we ourselves are viewed as a physical system and physics should apply to any system, inanimate or animate.
- The universality of Galilean's approach led to a rapid development of the physics interpretation of nature. To the point that less than four centuries later, after impressive achievements obtained in the first half of the 20th Century, one could conceive that all phenomena from the atomic level to the edge of the visible universe be governed solely by two known laws: *general relativity*, Einstein's generalisation of Newtonian gravitation, and *quantum electrodynamics*, the modern version of Maxwell's electromagnetic theory formulated in the 19th century; it explains all electric and magnetic interactions, and all the properties of light.

- But gravitational and electromagnetic interactions are long range interactions, meaning they are felt by objects, no matter how far they are separated from each other. But the discovery of subatomic structures revealed the existence of other fundamental interactions that are short range, being negligible at larger distance scales. In the beginning of the nineteen sixties, the theoretical interpretation of these interactions seemed to pose insuperable obstacles.

- In 1964 Brout and Englert, and independently Higgs, postulated the existence of particles, labeled “scalar bosons”, or Brout-Englert-Higgs bosons (BEH bosons), which condense to produce a field pervading the universe. This field can generate masses for elementary particles interacting with it. In this way, it can transmute long range forces, transmitted by massless particles (similar to photons), into short range ones by giving mass to these particles. This is the BEH mechanism which explains the origin of elementary particle masses. The impressive recent discovery at CERN of a particle identifiable to a BEH boson provides a direct proof of its correctness.

- The mechanism initiated the Standard Model of elementary particles that contains all known constituents of matter and the laws governing them. The Model appears now to be confirmed or more precisely, it delineates the known from the unknown at higher yet unexplored energies. Moreover, knowledge of the “small world” of elementary particles appears linked to that of the “large” universe. We know indeed that the universe was primordially hot and cooled down due to its expansion: the BEH mechanism became operative at a temperature of roughly a million of a billion of degrees. This temperature was reached in the universe about a hundredth of a billion of a second after its birth. This is when the mass of the known elementary constituents appeared. We thus know essentially the structure of the universe at later times. Direct observation of the sky allows to explore even earlier times. Will further development of “small” and “large” physics allow us to understand in rational terms the very origin of our universe? Only future research might tell.

- The scientific understanding of the world sketched here is the fruit of a fundamental research which has shaped our society. This research led to nearly all technical aspects of the civilisation we are living in. Such impact of fundamental research on society is of course due to the technical applications that follow from it, directly or often indirectly (e.g. the internet), but it is also, and perhaps even more, the result of its constant requirement of creative thinking. This renders fundamental research exemplary. Without creativity, there is no real technical progress. Without creativity, applied research leads only to copies, soon to be outdated, and which may then signal a slip towards a scientific and technical underdevelopment.

- It is mandatory to promote fundamental research, experimental and theoretical, and its diffusion to all levels of learning. The issue is to reach a **lasting** scientific and technical development, and to value knowledge and rational thinking towards a more civilised and more human world.