Fundamental Research and Developing Countries

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Abstract

In the first part of this report, I discuss the sociological rôle of fundamental research in Developing Countries (DC) and how one can eventually realize this program. In the second part, I give a brief and elementary introduction to the field of high-energy physics (HEP), accessible to a large audience not necessarily physicists. The aim of this report is to make politicians and financial backers aware on the long-term usefulness of fundamental research in DC and on the possible globalisation of HEP and, in general, of science.

1 Introduction

Fundamental research, like High-Energy Theoretical Physics (HEP), is a missing field in Developing Countries (DC) like Madagascar, Africa and other third world countries. Traditionnally reserved to rich or industrialised countries, this field of research is now becoming accessible to DC thanks to the progress of communications via Internet, fax and the uses of personal computers. However, the most efficient way for realizing this program is a joint collaboration between the DC and industrialised countries, where the former can only bring brains and works, while the latter, in addition, can help for giving funds or/and fellowships.

HEP research consists for studying the constituents of matter and the different laws governing the mechanism of the universe. In the first part of this report, we shall discuss the sociological rôle of the fundamental research in DC. In the second part, we present in a very simple and pedagogical way (without any formulae!) an introduction to the field of HEP, in the aim that it will be accessible to a large audience not necessary physicists.

1 This an english version of the communications in french: Rôle de la Recherche Fondamentale dans les Pays en voie de Développement (Press: Tribune de Madagascar n. 4212: 26 November 2002) and Vers une Mondialisation de la Physique des Hautes Energies (to appear in Tribune de Madagascar: December 2002).
2 Sociological Rôle of Fundamental Research in DC

2.1 Fundamental research and education

In most of DC, one has the tendency to favour the applied and technical formation which is the goal for forming in a short period the maximum of young peoples for training applied science and technical professions rapidly exploitable for the country. Though this short term formation is an useful initiative, one should not also neglect the formation of few young elite which will be useful at medium and long-terms in order to maintain the DC at a high intellectual and technical levels, the most possible way for the DC to reach the level of industrialised countries. One good possibility for realizing this high-level formation is the fundamental research. One can take the example of India and Pakistan which are a rich reserve of researchers despite the poor economical situation of these countries. Thanks to their traditional philosophy and culture, one can find their some good scientists known in the world though most of them are expatriate either in Europe or in the USA. For instance, the physics Nobel price 1979, Pr. Abdus Salam ex-director and founder of the International Center for Theoretical Physics (ICTP) of Trieste-Italy is a pakistani. Thanks to the creation of the ICTP, now named Abdus Salam Center, Pr. Salam has participated in a long term to the development of science in all DC, because most of thirld world scientists go regularly to this center for recycling and for getting informed on the last progress of science.

This short introduction shows quite well, how scientists can bring a lot to the society. A similar example should also be applied to the DC, and particularly to Madagascar. Therefore, it is the duty of the political decision-makers to encourage science in DC. However, this is a medium and long-term objectives, which one can essentially realize by the improvement of the educational system, which unfortunately has declined during the last thirty years in Madagascar for various reasons. Indeed, science should belong integrally to our general culture. Unfortunately, at present, fewer students choose the scientific fields, perhaps, because science needs some particular effort, or, because our society has not yet understood the rôle of science in our culture and civilisation. Ironically, our society is more and more dependent on the technological developments issued from the science discovery ( for instance, Internet has been discovered by the CERN-Geneva physicists (not by Microsoft!) as a tool for communicating experimental data between the different international teams), but in the same time, the scientific education declines. The russian academician Lev Okun told in 1995 during the HEP international conference in Marseille: More peoples are ignorant, more they hate the spirit of scientific curiosity, and more the processus of intellectual deterioration is irreversible.

It appears to me that this remark especially applies to the DC, and in particular to Madagascar, when one observes the majority of young peoples taking the direction towards the study which is useful at short term but often at a low level. This choice, one should say, is mostly influenced by the political and socio-economical environments where these youths are living. In particular, it is the obligation of the financial backers and of the government, not only to financially support the oriented and applied education and researches which yield well at short term, but, it is also especially important to encourage the long term education by providing fellowships and/or training courses. In parallel, they should also take all opportuinities for popularizing the science and the fundamental research using the modern media (press, radio, television,...) for communicating to the others the enthusiasm for the science and for explaining its interest. Fundamental science has a vital rôle for this development, because, contrary to applied sciences (ingeneering and
technologies), the researcher is able to form the youths at different scientific and technical
levels, from the secondary school to the engineering studies and PhD scientific diploma.
This rôle becomes feasible, because physicists have a strong basis and deep knowledge
of sciences (mathematical tools, informatics,...) combined with their talent of researcher
or/and teacher. Indeed, in his profession, a physicist should know how to use these ba-
sic knowledges for explaining observable and measurable natural phenomena. This is an
important aspect differentiating a physicist from a mathematician. For instance, for a
mathematician, a sinusoidal function is \( \sin \theta \) or \( \cos \theta \), while for a physicist, this function
illustrates different phenomena like the alternate electric current or the wave propaga-
tions...

2.2 Science and technology: responsibility of the scientist

Most part of our modern society does not even know the traditional goal of science, which
is to understand the nature, the universe and the different laws which govern them. There-
fore, it is not surprising that there is a confusion between science and its utilisation., i.e.
between science and technology, between the knowledge attainments and the utilisation
which the society decides to do with. When, one talks, for instance, about nuclear physics,
most of us thinks to nuclear power station, nuclear tests or massive destructive bombs,
and believe that the science is guilty and socially irresponsible. When the utilisation of
knowledge is an ethical problem, the research of these knowledges should be absolutely
free, and it is advisable not to mix the two things. The preparation of an atomic bomb
was due to technology (applied science), an actual product of engineers, though based on
the fundamental principles of physics. However, the decision to build the hydrogen bomb
was political, but not scientific. Robert Oppenheimer, one of the assumed “fathers” of
the american atomic bomb, explained clearly that:

\emph{The scientific is not responsible of the natural laws, but his job is to discover how these
laws work. However, it is not the responsibility of the scientific to determine if it is suit-
able or not to use the hydrogen bomb.}

The dictates of defense have led the politicians to ask physicists to prepare massive de-
structive arms. But some other physicists have also contributed for establishing bridges
and links between two adverse countries during the war. The rôle of CERN-Geneva and
the ICTP-Trieste on the relations with the former Soviet Union are concrete examples.
However, science should not apologize to the world on what it brings. On the contrary,
its contribution represents one of the most noble and ambitious efforts of the humanity:

\emph{In trying to discover the nature of the Universe, the scientific attempts to discover himself
in this fascinating and extremely embarrassing world.}

It is the responsibility of the scientist to let known to the society the true rôle of science,
not only as a responsibility to the taxpayers, but as the basis of the intellectual values.
The scientific has the duty to inform the society, on the existence of tools or methods
allowing to analyze complex situations, in order to find an appropriate solution to the
hot problems raising the question of our survival. Therefore, the scientists should inform
themselves on the nature of important problems to which our society is confronted; in
other respects, they should be able to predict the eventual problems of the future, and
inform the society if an appropriate answer already exists. This is indeed their duty in the
crucial domains like the needs of new energy sources, the planet pollution, the decrease
of the ozone layer around the world, the demographic boom, the unproductiveness of the
grounds, the decreases of biological species,...But it is neither the rôle nor the respon-
sability of the scientist (this does not mean also that the scientist is not sensitive to this
crucial problem) to resolve the unemployment problem, the famine,...that can only be solved from political decisions. The scientist rôle is at the same time crucial and modest, in the sense that scientists should not use science for settling a new type of power, the scientific power. The scientist should encourage the scientific attitude based on facts, on curiosity and on audacious search for new fundamental concepts. Michael Faraday has discovered the electricity by his own intellectual curiosity which guided his fundamental research on the electricity while the society has asked him at that time to improve the lighting with candles of lighthouses. Reciprocally, the history of sciences has many bitter examples, when one thinks about the Arab culture of the pre-medieval era, which brought to Europe wide knowledges such as medicine, mathematics and astronomy. But, for different reasons, this inquisitiveness of mind disappeared, letting the Arab modern society very poor.

For this reason, and despite the social context of our country, one should encourage the fundamental and free research though its technological implications are at a long term, because it is a secure value. It is as expensive as other cultural values like literature, arts and some other national patrimony, which one should preserved.

2.3 How to do a fundamental research in DC?

When I have finished my degree of physics at the University of Antananarivo, I got a fellowship by the European Commussion to prepare a diploma of ingeneer at the Ecole Centrale or Supelec of Parish. However, when I have hesitated between this choice and the PhD thesis in Theoretical Physics, my former professor of quantum mechanics Pr. Raoelina Andriambololona has convinced me by these words: *For doing Theoretical Physics, one only needs a pencil and a sheet of paper*...

These words perfectly summarize the profession of theoretical physicist in the years of 70 and show the cheap cost of the formation for this advanced profession, which is then feasible in DC, contrary to that one may a priori think. However, within the development of the modern society, and for doing fundamental research, one should add to these, the unavoidable computers as tools for calculations,...and communications (Internet), which hopefully we already have in Madagascar (note that the insulation was the major handicap for doing a research in our country during the pre-Internet period before 90). To these tools, one should add the bi- or multi-lateral scientific cooperations with advanced laboratories and institutes, because the exchanges between researchers are necessary at different viewpoint in order to have a competitive research work at the international level. Though the DC cannot bring funds (which are expected to be obtained from industrialised countries) for a such cooperation, they can instead bring brains and works, which are always useful inside a collaboration. Indeed, these means are relatively cheap and, a priori, feasible for a DC like Madagascar.

2.4 Can one do HEP in Madagascar?

Working in advanced domains needs a strong international competitiveness. And for being competitive, one needs a good scientific environment and the possibility to visit regularly big research centers in order to be informed on new experimental data and new theoretical progresses. Unfortunately our country, was an inauspicious place (geographical and economical situations), and then, you can understand immediately, why I did not come back to Madagascar, despite my deep wishes to serve my nation. However, this choice of foreign residence should not lead to a total desinterest to the country but on the contrary
should stimulate finding a way to contribute to its recovery. This is the reason why I have
decided to create the HEP-MAD institute, project one which we have started to work in
collaboration with the national teachers and researchers since last year. This institute
will be useful for forming young students at high level and will serve as a platform to
different international cooperations and HEP-MAD conferences. We have initiated the
latter in september 2001 (HEP-MAD 01 conference).
We wish sharply that the new government and the financial bakers give all means for
concretising rapidly this project because it goes along the lines of their program for render
Madagascar a competitive country at the international level.

3 Towards a globalisation of HEP

In this second part, we try to vulgarize this advanced research of HEP by limiting ourselves
to the basic concepts and illustrative explanations in the aim to present a very elementary,
pedagogical and qualitative report accesible to the majority of the population who are
not necessarily physicists.

3.1 The structure of matter

In Fig. 1, one explains, from the example of hand (matter), the exploration of the
underlying structure of matter before reaching the fundamental constituents (elementary
particles) named leptons and quarks.
Imagine that you have started at the university to study the macromolecules of ADN (Acid
DesoxyriboNucleic) in biochemistry. After, you go to the degree in chemistry (organic
chemistry) where you study the properties of desoxyribose and of benzen molecules and
their by-products. You continue your way and, with more energy, you succeed to bring the
molecule into an atom of carbon ( Avogadro and Gay-Lussac laws). With a more energy,
you can break the atom for studying its nucleus and the electrons which orbit around it
(atomic physics). You continue your breakage and you will discover that the nucleus is
composed by protons and neutrons linked together by the nuclear force (nuclear physics).
Finally, bombing the proton, you will find that it is made by elementary particles which
are quarks glued together by gluons (HEP area). The particle accelerators are conceived
that you can do in practice the exploration of matter thanks to the energy which these
accelerators communicate to particles. As you can see in Fig. 1:

- The electron is the 1st elementary particle known since a century. It is the 1st
  member of the particle family called leptons, where the other members differ from
  the electron by their masses (the muon and the tau are respectively 200 and 3600
times heavier than the electron). To these three particles of electric charge -1, are
  associated electric neutral particles (neutrinos) lighter and which do not interact
  with matter. These particles existed after the Big Bang and are produced by particle
  accelerators or cosmic rays.

- The proton and neutron are composed by elementary particles called quarks
  which have frictional electric charge and possess three colours. The quarks are also
  constituted of three couples (up, down), (charm, strange) and (beauty, top). Each
  quark differs by their masses while in each couple (........), quarks have respectively
electric charges 2/3 (u, c, t) and -1/3 (d, s, b). Then, a proton is constituted by
two quarks $u$ and one quark $d$ ($uud$) which the sum of charge is +1. The neutron is neutral and composed by $ddu$.

- To these particles are associated anti-particles which form the anti-matter.

- The repartition of charges and the correspondence between lepton and quark families are essential for having mathematical consistent theories (renormalizability,...)

### 3.2 The fundamental forces of nature and the HEP theories

Nature is governed by four fundamental forces, which by order of decreasing range are classified as:

- **The strong interaction nuclear force** mediated by eight coloured massless gluons responsible for the cohesion of quarks inside the nucleus has a range of $10^{-12}$ cm. To this force and to the properties of quarks is associated the *theory of Quantum ChromoDynamics (QCD)*.

- **The electromagnetic force** mediated by the photon is responsible of the light and has a range $10^{-3}$ weaker than the previous one. To this force and to the properties of leptons is associated the *theory of Quantum ElectroDynamics (QED)* tested, at present, with very high-precision.
• **The weak interaction force** mediated by the gauge bosons having masses 160,000 times the one of the electron is responsible for the β radiactivity and has a short range of about $10^{-17}$ cm. To this force is associated the *theory of Weak Interactions.*

• **The gravitational force** eventually mediated by the gravitons has a macroscopic range of about $10^{-50}$ cm and is responsible of our weight (recall the story of the famous Newton’s apple). Its corresponds to the *theory of Gravitation.*

QED and the theory of weak interactions, which, a priori, correspond to completely different forces are put together in a unique theory called commonly the *Standard Model of Electroweak Interactions (SM).* The discovery of the SM has led to the attribution of a Nobel price to their discoverers: Prs. S. Glashow (Harvard Univ.-USA), S. Weinberg (Austin Univ.-USA) and A. Salam (ICTP-Trieste-Italie), while more, recently, the physics Nobel price 1998 has been attributed to Prs. G. ’t Hooft and M. Veltman of the Utrecht Univ-Holland, who have proved the mathematical consistencies of the SM, rendering it to be a theory not only a phenomenological model. QCD belongs to the strong link of the the SM, where the theory possesses the asymptotic freedom property at high-energies rendering easier different approximate perturbative calculations within QCD. There also exist some *Grand Unified Theories (GUTS)* like for instance *supersymmetry* which can unify these three forces to one force at higher energies. In fact, the goal of HE Physicists is to understand the laws governing the universe within a simple and elegant theory. The search for an unified and mathematically consistent theory, including the gravitational force is the present challenge of HE Physicists.

### 3.3 The particle accelerators

![Aerial view of the LEP underground tunnel of CERN-Geneva.](image)

Today, science has important means for supporting advanced fundamental research, in particular, in the physics of space (Voyager, Hubble telescope,...) and in the field of HEP (which I know better) for studying the fundamental constituents of matter (quarks, leptons, gauge bosons,...) and their rôle in the birth of the universe. These domains need gigantic instruments, that a unique country cannot finance, like the large electron-positron collisionner LEP (and in the near future the Large hadron Collider (LHC)) at CERN-Geneva, in an underground tunnel of 9km diameter, straddling the France-Switzerland
border. One can see in Fig. 4, an aerial view of CERN and the LEP tunnel where the airport of Geneva is visible in front.

In Fig. 3, one shows the reaction inside the LEP detector after the collision of the electron with its anti-particle, the positron, where new heavier particles are produced.

![Figure 3: Schematic view of the LEP-detector after the electron-positron collision.](image)

Though apparently expensive, these experiments are far from being useless, as these are material and intellectual tools which allow the humanity to make up all challenges to which it is, at present, confronted.

### 3.4 What are the socio-economical implications of HEP?

Apparently, this fundamental research is far from the every days life applications. However, this is not really true as any applied science and technologies need results from fundamental research. There are many indirect consequences of this research:

- Electricity which we use everyday comes from the discovery of the electron (1st elementary particle) and of its properties.

- TV screen is the smallest accelerator of particle (electron). It is a mini-LEP where LEP energy is about $5 \times 10^6$ the one of the TV. The similarity of the technologies behind the TV and LEP is commented in Fig. 4.

- Detector buildings stimulate high-technology in industry and in other branches of physics (semi-conductors,...) ; Charpak type-detectors are used in the container-custom controls (le Havre),...

- Accelerator technology is used in medicine for e.g. the cancer treatment (Orsay,...)...

- Internet Web pages were discovered at CERN (Geneva) being originally used for communicating data and informations between members of experimental groups.

- The treatment of HEP data needs powerful computers.

- ...

### 4 Summary and conclusions

In this short report, I have presented the social rôle of fundamental research in DC by emphasizing on its long-term usefulness and on the possible realization of the project...
in DC. I have also given a very elementary introduction to high-energy physics at the level accessible to a majority of readers not necessarily physicists. The aim of this report was to make politicians and financial backers aware on the long-term usefulness of the fundamental research in DC. I wish that after reading it, they have been convinced on the feasibility of the project in DC.

References

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