Articoli

Mobility and international cooperation: the foundation for a European science[1]

Mobilità e collaborazione internazionale: la base per una scienza europea

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ABSTRACT

Drawing on a series of historical and more recent examples of actual researches across several empirical fields, from particle physics to astronomy, this article argues that the enhancement of both the mobility of researchers and the international collaboration represents a crucial driver for the progress of science and for the promotion of a shared ethical perspective.

ABSTRACT

A partire a una serie di esempi storici e più recenti di ricerche condotte in diverse scienze empiriche, dalla fisica delle particelle fino all'astronomia, questo articolo mostra perché il potenziamento della mobilità dei ricercatori e della collaborazione internazionale può rappresentare uno degli aspetti cruciali per il progresso della scienza e la promozione di una prospettiva etica condivisa.

KEYWORDS

Science
Scienza

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Mobilità dei ricercatori

International cooperation
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Aerial view of the CERN, Geneva (*fonte CERN*)

In the Seventeenth Century, Galileo Galilei launched the Scientific Revolution, inaugurating a new style of doing research: «Misura ciò che è misurabile, e rendi misurabile ciò che non lo è».

Galileo's teaching hinged on: exploiting all opportunities; constantly improving our instruments; treasuring our talents; and publishing and disseminating our achievements. He gave the world a living proof of such teachings through the invention of his telescope and his writings entitled *Dialogo sopra i due massimi sistemi del mondo*, drafted in his charming Italian.

Galileo's success prompted an enormous progress in the resolving power of telescopes, which is defined by the area where the incoming light is collected. In the four centuries following his breakthrough work, the surface area of telescopes increased exponentially, from the size of a coin to hundreds square meters, and it is bound to keep growing in the future, thanks to the diffusion of telescope arrays.

The energy reached by particle accelerators experienced a similar stunning progress. Particle accelerators are instruments that regulate our capability to explore the structures of the Microcosm of *subnuclear particles* and to discover new particles of increasing mass (following Albert Einstein's mass-energy relation).

The latest leap forward in this field was the invention of *particle colliders*. Instead of sending energy particles to a dense material target (what in English-language newspapers is known as an *atom smasher*), colliders foresee head-on collisions between particles from two different beams travelling in opposite directions. This concept was first developed in Italy, at the Frascati Laboratories, by the Austrian physicist Bruno Touschek, who settled in Rome after the Second World War. Touschek's work led to the construction of the first electron-positron collider, called AdA (*Anello di Accumulazione*), an instrument that he would describe, with his charming Austrian accent, as the collision of a "treno contro treno".

AdA measured just about one meter, yet the underlying concept was so revolutionary and effective that since then, electron-positron colliders of increasing size have been built in laboratories all over the world, up to the Large Electron Positron (LEP) collider built at CERN in the 1980s and installed in a circular tunnel with a 27-kilometre circumference.

The first collider of protons with anti-protons was built at CERN in the late 1970s by Carlo Rubbia and Simon Van der Meer, and in 1983 it led to the discovery of particles which mediate weak forces, the so-called *Intermediate Vector Bosons.*

In 2012, the largest proton-proton collider in the world, the Large Hadron Collider (LHC) built at CERN inside the LEP tunnel, led to the discovery of the Brout-Englert-Higgs boson by the ATLAS and CMS Collaborations.

INTERNATIONAL COOPERATION IN SCIENCE

International cooperation in physics started in Europe after the Second World War, from the need to build a large and complex research infrastructure to explore the world of sub-nuclear particles. This sector had been unveiled by the reactions produced by Cosmic Rays in the Earth's upper atmosphere, and could be explored only by resorting to big particle accelerators that no country in Europe could afford to build using only its own resources.

The vision of a European laboratory dedicated to fundamental physics with large scale infrastructures had been outlined by the Nobel Laureate Luis De Broglie, one of the founding fathers of Quantum Mechanics, in a letter read at the European Cultural Conference held in Lausanne on December 8th, 1949, by Raoul Dautry, then General Administrator of the "Commissariat à l'Énergie Atomique" (CEA). De Broglie envisaged «…a laboratory or institution where it would be possible to do scientific work, but somehow going beyond the framework of the different participating states. Being the product of a collaboration between a large number of European countries, this body could be endowed with more resources than national laboratories and could, as a result, undertake tasks which, by virtue of their size and cost, would be beyond their scope».

The vision of distinguished European scientists and statesmen, including Edoardo Amaldi, Pierre Auger, Lew Kowarski, Alcide De Gasperi, Robert Schuman, and Konrad Adenauer, led to the establishment of CERN in 1954, only five years after De Broglie's prophetic letter. Founded by twelve Member States, CERN is now led by 22 Member States[2].

Shortly after, similar organizations followed, devoted to the study of the outer space (European Space Agency - ESA), molecular biology (European Molecular Biology Laboratory - EMBL), and of astronomy on a large scale (European Southern Observatory - ESO), respectively.

THE USERS COMMUNITY

In the 1980s, CERN underwent an important change following the construction of the Large Electron Positron collider (LEP).

Experiments with the LEP required very large and sophisticated detectors, and correspondingly large human and financial resources, which were more than CERN could afford. Hence, universities and Associated Countries formed four large-scale collaborations, with extended funds for the construction and operation of detectors, also supporting the travels to Geneva of professors and students, the CERN *users*, who would collect, interpret and finally translate into new physics the large mass of data produced by LEP.

The same happened, on a larger scale, for the Large Hadron Collider, which was installed in the LEP tunnel at the beginning of the years 2000.

CERN users amount today to well over 10,000 physicists and engineers from all over the world.

Cooperation at an international facility like CERN also has a positive ethical connotation. Young students visiting this facility as Users can regularly work at the forefront of their disciplines (which would be impossible if they remained home), but are still connected to their home institutions and can bring back to their countries the know-how they have acquired. Provided that mobility towards the facility remains available even when students acquire a permanent position in their home country, no brain drain (from less advanced to more advanced countries) will occur. Therefore, working at CERN is very different from moving, say, to a US University and becoming a visiting professor there. As Giorgio Salvini used to remind us: «We are proud to go to CERN, because it is also "our" laboratory».

BRINGING LATIN AMERICA TO EUROPE (2005-2016 AND BEYOND)

At the end of 2003, Juan Antonio Rubio, Veronica Riquer and I realized that a major obstacle for Latin American scientists to take part in the experiments at the LHC was the lack of funds for their participation in CERN experiments, especially for students: *mobility was the key.*

Project HELEN (High-Energy physics Latin-American European Network) was born as a result of that realization. In Europe, the project focused on the large Laboratories of CERN, DESY, and Gran Sasso.

On the other side of the Atlantic, the Pierre Auger Observatory, located in Malargüe (Argentina), had already attracted a large European participation from CERN Member States (e.g., France, Germany, Italy, Spain, Portugal), creating the Latin American pole of HELEN and, later, of EPLANET.

HELEN started in July 2005 and ended in April 2009. HELEN was financed by ALFA (America Latina Formacion Avanzada), a program established by the European Commission to facilitate the scientific interchange between Europe and Latin America.

Prompted by HELEN's success, in 2009 we proposed a new project which began in February 2011. It was called EPLANET (European Particle physics Latin-American NETwork), and is funded by the European Union through the Marie Curie-People action within the European Commission 7th Framework Program. Supported by EPLANET, professors and graduate students from Latin America have been able to participate in the exciting exploration of the Microcosm, which started in 2010, when the LHC began its first physics run.

Below, I shall illustrate the adventure of creating a Latin American community in the very scientific heart of Europe, as Juan Antonio Rubio, Veronica Riquer, and I experienced it, first with HELEN and subsequently with EPLANET.

HELEN, JULY 2005-APRIL 2009

HELEN' s declared objectives were:

- To train young generations of physicists in High Energy Physics, thereby promoting fundamental physics in Latin American countries and contributing to the modernization of physics education there. CERN, DESY, and Gran Sasso facilities, in particular the Large Hadron Collider, HERA and their experiments, as well as the Auger experiment in the Pierre Auger Observatory for Cosmic Rays, located in Malargüe, Argentina, were designated as the fundamental tools for an advanced training program.
- To facilitate access of Latin American countries to the technological benefits in the accelerator, detector, and information technology domains (the global LHC data GRID, for instance).
- To strengthen the integration of the European and Latin American Physics communities.

The institutions participating in HELEN formed a large network of 22 Universities/Research Institutions from 8 Latin American countries, 16 Universities/Research Institutions from 6 European countries, the European Intergovernmental Organization, CERN (Switzerland), and the international Pierre Auger Observatory, Argentina. This network has been essential to integrate, consolidate and boost the collaborations in the field of High Energy physics, which have already been in place between Latin America and Europe for several decades.

Personnel mobility was used as a means to:

1. provide specialized training to young Latin American scientists;

2. contribute to the modernization of physics education in Latin America;

3. foster the scientific collaboration in Fundamental Physics between Latin America and Europe by using the existing or planned large, expensive facilities; and

4. contribute to the technological development of Latin America through the HEP associated technologies.

Mobility was achieved, in project HELEN, thanks to a large number of grants, totaling 1596 person-months over the full period, of which 1354 from Latin America to Europe, 119 from Europe to Latin America, and 64 within Latin America. The latter grants were essentially a novelty for Latin American countries and have been quite successful in fostering collaboration there. The total cost of HELEN amounted to about 3 million euro, including about 2.7 million financed by the EU.

The first HELEN grant holders from Latin America arrived at CERN in January 2006. In June of the same year, the CERN Courier reported: «Now a small but active HELEN community is building up at CERN, and has established a HELEN club to allow the exchange of views and to help newcomers in the complex CERN environment». Interesting events were organized by HELEN in Argentina and in Mexico, aiming at transferring CERN technologies on accelerator physics and computing.

In an important case, CMS researchers were able to travel to Brazil to help set up a CMS Computing Centre of the LHC Data GRID at UERJ and in Sao Paulo. The upgrade of the Center was eventually approved in Brazil with the financial support from FAPERJ and CNPq, which has allowed our Brazilian colleagues to increase their participation in CMS.

All in all, HELEN was perceived, in the High Energy Physics community, as an unprecedented and successful effort to integrate the Particle Physics communities of Europe and Latin America.

In a speech delivered in 2007, Peter Jenni, Spokesperson of the ATLAS experiment, described the times before HELEN and the times after HELEN for ATLAS in Latin America. In his words, «HELEN has definitely helped foster and consolidate the very fruitful collaboration with Latin American colleagues and Institutions in the case of ATLAS. In particular – Jenni continued – the contributions from students and young researchers are a strong asset to the experiment, in addition to the institutional strengthening of the Collaboration and its resources».

EPLANET, FEBRUARY 2011-JANUARY 2016

The objective of EPLANET is to provide the scientific personnel of the Beneficiary and Partner Institutions (see Tab. III) with training activities through the participation in world class experiments performed in two of the most advanced research infrastructures for particle physics: (i) CERN, for Particle Physics at the Large Hadron Collider, Geneva, Switzerland, and (ii) the Pierre Auger Observatory, for the observation of Ultra-High Energy Cosmic Rays, Malargüe, Argentina.

According to the rules of the EU Framework Program, only four Latin American countries were eligible to become partners, namely Argentina, Brazil, Chile, and Mexico. CERN provided additional funds to continue the cooperation with Colombia, Peru, and Venezuela, which had started with HELEN and could not be continued in EPLANET due to lack of specific agreements between those countries and the European Union.

Exchanges among Latin America (LA) and CERN and other European Institutions, and among European countries and the AUGER Observatory, were generally short (1-2 months) for senior investigators and longer (2-12 months) for junior ones, for a total of about 1,500 months. The total financial support from the EU, which covered stay, but not travel expenses, amounted to about 3.2 million euro during four years. An extension to a fifth year, within the same budget, was approved in 2014.

EPLANET programs hinged on Nine Work Packages, which included: participation in the four LHC and other CERN experiments; research in theoretical physics; accelerator technologies; medical physics; scientific computing; and participation in the Auger experiments.

Most importantly, the years 2011 and 2012 witnessed the coming into full operation of the Large Hadron Collider at CERN, as well as the data collection and analysis from the four large experiments, which led to a substantial number of technical reports and papers being published. EPLANET participants have largely contributed to the discovery of the candidate Brout-Englert-Higgs boson, the new particle identified by ATLAS and CMS with a mass of about 125 GeV. Major discoveries achieved through the AUGER experiment during the EPLANET period include: (i) the confirmation of a High Energy cutoff in the spectrum of Ultra High energy Cosmic rays; (ii) the first determination of the particle composition of Cosmic Rays in the cutoff region (i.e. proton vs nuclei abundances); and (iii) the first indication of point-like extragalactic sources.

Moreover, EPLANET, like HELEN, led to the draft of a remarkable number of high quality degree theses, originating from research carried out in world-class facilities with highly qualified supervisors. Trainees generated a large number of very high quality publications, see Tab. I.

Secondments (months)	Researchers involved	Gender distribution	Workshops & Schools	Seminars & Conferences	Scientific Publications (*)	Citations (**)
1448	509	F/M=0,23	18	124	1132	55,128

Tab. I: Key figures from the EPLANET- IRSES Marie Curie program, 2011-2016.
NOTES: (*) where EPLANET support is acknowledged; (**) Source: http://inspirehep.net

TEN YEARS OF SCIENCE DIPLOMACY

HELEN and EPLANET established an important network of formal links between CERN and Latin American countries, extending also to the latter the tradition of *Science Diplomacy* inaugurated by CERN over sixty years ago.

Important Cooperative Agreements were signed between CERN and CONICYT, Chile, and CONACYT, Mexico. The LHC experimental Collaborations welcomed groups from Universities in Chile, Argentina, Brazil, and Colombia. Two experimental detectors for ALICE, *V0* and *ACORDE*, were built in LA, particularly in Mexico, also thanks to HELEN's financial support for the travel expenses of teachers and students. CMS researchers helped creating a CMS Tier2 center of the LHC Data Grid in UERJ and Sao Paulo.

The possibility to send students to the largest facilities in Europe and Latin America has greatly enhanced the joint activities of the two regions, changing the historical inclination towards the United States of HEP groups in Latin America.

More specifically:

- HELEN and EPLANET involved the most advanced institutions and the best research infrastructures for particle physics of the two continents;

- promoting regional LA-LA integration through internal mobility has been one of HELEN's most remarkable achievements;

- EPLANET allowed scientists and students from Latin America to participate in the discoveries of the first LHC years, bringing new ideas as well as an enormous drive;

- teaching and outreach were strongly promoted;

- commitment towards CERN and Europe was consolidated in view of the future upgrades: the High Luminosity LHC and, perhaps, the LHC energy increase;

- experimental laboratories were established in Mexico, Brazil, Chile, Colombia, and Peru, which will be the natural starting points to develop technology transfer in these countries;

- *no brain drain!* Within HELEN, we have witnessed postdoc student become professors and group leaders for EPLANET, and others finding positions in the industry, in their own countries;

- sustainability of the collaboration has (almost) been achieved by Brazil and Mexico.

EPLANET-UP (2017-2021)?

In April 2017, we submitted a new project, EPLANET-UP, to the Marie Curie-Sklodowska Research and Innovation Staff Exchange (RISE), within Horizon 2020. If approved, EPLANET-UP will be co-financed by Mexico and Brazil, a crucial step towards sustainability, which will almost double its value, from the funds requested to the EC, of about 2.3 million euro, to a total value of about 4.3 million euro.

EPLANET-UP will allow the participation of Latin America in the post-Higgs research, the exploration of the unchartered energy region beyond what was predicted by the current theory of Elementary Particles, and the study of the extragalactic sources of the highest energy cosmic rays.

PARTICLE PHYSICS BEYOND THE PILLARS OF HERCULES

With the observation of the Higgs boson and of the Cosmic Ray cutoff, we are now sailing beyond the Pillars of Hercules, into an unknown ocean where we hope to witness new phenomena. Earth and Satellite based Astronomy, and large distance Cosmology, also offer many unexplored paths. We are now aiming at a more comprehensive vision of the Micro and Macro Cosmos, characterized by many prejudices and conflicting ideas. We cannot be sure of where we will land, but we know it will be more surprising and fascinating than we may imagine. There are already plans to build machines that can bring us into new energy regions, that we believe may point out new phenomena that could possibly show us the direction of the new physics. On the short term, in the next 15-20 years, the LHC will dominate the scene, and plans were already made to increase its potential, bringing it first to higher luminosity, and later to higher energy.

After that, the course of action is still unknown.

A large collaboration is proposing the construction of the International electron-positron Linear Collider (ILC), which would be located in Japan. Another possibility is to implement the LEP-LHC strategy on a larger scale: building a 70-100 km long tunnel to host, as a first step, an electron-positron collider, a Super LEP, which would allow a precision study of the Higgs particle. The second step could be the replacement of the electron-positron ring with a large proton-proton collider, with energy one order of magnitude larger than the LHC[3], a Very Large Hadron Collider (VLHC). A machine of this size was envisioned (dreamed of?) long ago by a group led by Nino Zichichi and given the poetic name Eloisatron.

The project of a large tunnel with a Super LEP and a VLHC is currently being studied at CERN and at the Institute for High Energy Physics (IHEP) in Beijing, China. Building a 100 TeV proton Collider would be a fantastic challenge, requiring new innovative technologies involving material science, low temperatures, electronics, computing, big data, and the like.

It would be a powerful pole of attraction for new physics ideas and young talents, called to face the hardest scientific problems which have been confronting us over the last 100 years. At this level, research is undoubtedly a global enterprise and will most likely require new organization models. The vision that De Broglie had outlined in 1949 may return, this time at a global rather than regional scale.

As I pointed out at the beginning, in the 1950s we witnessed national laboratories (in Italy, France, United Kingdom, Germany, etc.) join forces to establish CERN: a European laboratory. In the 2030s, progress will require regional laboratories of Europe, America, Asia, etc. to join forces and form a Global Accelerator Network: a World laboratory?

CONCLUSION

We are convinced that the Mobility of researchers and the International Collaboration are crucial for the progress of science and for the promotion of an ethical perspective.

The CERN model was adopted for almost all large scale research: Space, Astronomy, Cosmic Rays, and it is being considered in new fields such as the exploration of the Cosmos through neutrinos and gravitational waves.

Joining forces at an international level is easier for fundamental research rather than for applied research, where national interests and economic problems play a bigger role (as already pointed out by De Broglie in 1949!). This is why we are all looking forward to the construction of the International Thermonuclear Experimental Reactor (ITER), the first large scale experiment on nuclear controlled fusion.

In a world were nationalistic forces are growing stronger again, the success of ITER and the resulting new energy production model would open up new ways for the unification of world economies, a crucial step towards the (utopian?) world government which another great mind of our times, Albert Einstein, considered the last remedy to prevent a thermonuclear war and the ensuing destruction of humankind and our planet.

NOTE

1. Part of the material contained in this article has been presented at the conference: *Sixty Years of Romea Treatises and Ten years of ERC*, Italian National Research Council - CNR, Rome, 7 April 2017.

2. The CERNThe 12 founding states of CERN were: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and Yugoslavia. CERN became effective as of, and entered into force on September 29, September 1954. The Organization was subsequently joined by: Austria, Spain, Portugal, Finland, Poland, Czechoslovak Republic, Hungary, Bulgaria, Israel, and Romania. The Czech Republic and Slovak Republic re-joined CERN after obtaining their mutual independence in 1993. Yugoslavia left CERN in 1961. Turkey, Pakistan, Ukraine, and India are Associate Members, while Serbia and Cyprus are Associate Members in the pre-stage to membership.

3. The LHC energy is about 14 TeV, corresponding to 14,000 times the energy associated to the mass of the proton; the VLHC under considerationbeing considered hasve an energy of 100 TeV.