The European Strategy in Particle Physics

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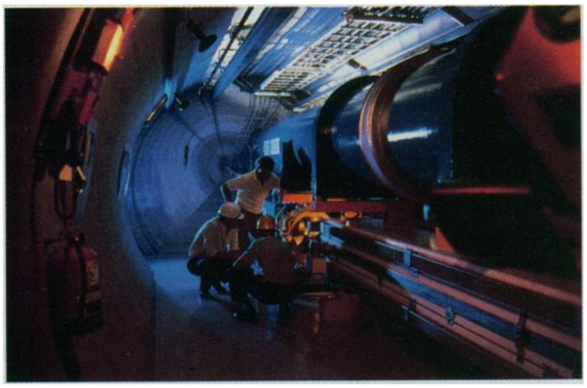
CERN, the European Laboratory for Particle Physics, is an outstanding example of the success of international cooperation in science. More than half of the world's particle physicists are now working on experiments at CERN. They come from the organization's 17 member states and from 22 other countries. For example, there are over 500 U.S. scientists involved in CERN collaborations, bringing their participation to the same level as that of a major European country. The world's physicists have gravitated toward CERN because of the extraordinary wealth of experimental facilities offered by the laboratory. The recent call for participation at the planned Large Hadron Collider (LHC) has received a response from scientists from over 180 institutions worldwide, of which 46% are not in the member states.



Model of the proposed Large Hadron Collider. The CERN Council recommended in December 1991 that the laboratory proceed toward LHC, which will generate 7.7-TeV colliding proton beams. [CERN photo]

To understand particle physics in Europe, we must briefly trace its long history. Its past evolution toward internationalization may constitute as well a valid bench-mark for future enterprises on a global scale. Until 1940 almost all major progress in the field had come from Europe, from the discovery of the electron to the model of the atom, from the atomic nucleus to its constituents, including its theoretical frameworks of special relativity and quantum mechanics.

These were the achievements of physicists at universities all over Europe, working with extremely simple means. There was no formal coordination between programs. However, I would hesitate to qualify this as fragmentation. There were very lively exchanges of ideas and competition between scientists and the emergence of a truly "European" spirit, best represented by Niels Bohr and his institute in Copenhagen.

The disastrous political situation in Europe in the 1930s, which led to World War II, ended all this. Scientific exchanges were interrupted and many scientists were forced to emigrate to the United States and elsewhere. However, the turning point was not only the war but also the fact that the Americans were the first to realize that further progress required more sophisticated and powerful instruments. They also understood that the necessary investments that society should grant for its scientists would turn out to be one of the most important driving forces of material progress. In particular, while European science had relied on simple equipment based on the use of radioactivity and cosmic rays, powerful and large particle accelerators were being developed in the United States.

In the fifties, no one could have predicted in detail how these new facilities necessary for research into the structure of matter would eventually develop in Europe. There were, however, a few far-sighted physicists such as Rabi, Amaldi, and Auger who had witnessed how frontline research had evolved during the war from small table-top experiments to quasi-industrial efforts involving large collaborations of scientists and engineers. They perceived it as a lasting trend and thus realized that a bold extrapolation was needed. Europe had great intellectual traditions, but no single European country could be expected to cope alone with the magnitude of the task. It was clear that the only way forward was a cooperative effort between several countries. The idea of "burden-shared" large research projects was born.

At that time, Europe as a whole was looking for joint projects and not merely in scientific circles. The scientists therefore found themselves in concert with a small number of eminent politicians of great vision, who welcomed the idea of a worthy common enterprise that could contribute to the building of a united Europe. Less than 3 years passed between the Unesco meeting of June 1950 in Florence, recommending the creation of a European laboratory and the signing of a convention by 12 European countries. This is how CERN was founded.

Even before the European Community, CERN had been the prototype of a successful chain of European institutions in space, molecular biology, and astronomy. But the convergence from national university-based research to a common European "coherence of intents" has been neither abrupt nor absolute. In retrospect, this prudent course of action proved to be very effective. The main strength of European science lies in its intellectual traditions, linked to its many centuries old and prestigious university system. Concentrating the best scientists in a single place in Europe where they would have the tools necessary for their research would also have had the disastrous and deplorable effect of isolating them from the academic world. This was not desirable and was never even attempted.

Today there is coexistence and complementarity between European facilities and national research institutes. The metaphor is the one of a "pyramid of facilities" of increasing power at regional, national, and European levels. This scheme has worked in the field of particle physics, but other fields are following similar lines—essentially for three main reasons. First, many national efforts have been channeled within a global strategy of a sharing of facilities based exclusively on perceived merit and minimal duplication. The "coherence of intents" of a highly diversified scientific community within a strongly competitive environment has permitted Europe to do more with less. CERN is very cost-effective and operates within a strictly constant budget (inflation-corrected), in which its next large project—LHC—is included.

The second crucial element is that European centers of excellence are not closed, but have deep roots that penetrate within the whole of Europe. CERN has a strongly user-oriented structure. All major decisions are taken by consensus with the help of leading figures of the national communities. Top ranking jobs are strictly rotational. As a consequence, CERN is not perceived as an alternative to existing European institutes and academia but as the focal point of the scientific effort of the community.

Finally there is a strong commitment to human resources and to excellence. The best young people in the field are naturally attracted to CERN because of the success of its programs, which are at the frontier of our knowledge, and because of the availability of unrivaled research tools. Because of its uniqueness, CERN has become an almost obligatory worldwide crossroads for the best physicists in the field. This would

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suggest a simple conclusion: an international scientific institution will not be justified as such unless its related benefits to the community are vastly superior to those achievable by the national laboratories.

To answer many compelling questions of physics, Europe has an evolutionary strategy of providing accelerators able to meet the demands of research. The main impetus at the moment is from the Large Electron-Positron storage ring (LEP). By the end of 1991, each of the four LEP detectors had observed the decays of about half a million Z^0 particles and measured many properties of the Z^0 with extreme accuracy. For example, its mass has now been measured with a precision of 2 parts in 10,000 and its lifetime to an accuracy of 5 parts in 1,000. Perhaps the most important result, so far, is the discovery that for some as yet unknown reason there are only three kinds of neutrinos in the universe, implying that there are just three types of matter particles. Our next step in exploiting LEP is to increase the machine's energy to around 90 GeV per beam by the beginning of 1994. LEP II will be able to find new particles weighing less than about 90 GeV and extend precision measurements, such as those on the *W* particle.

These remarkably accurate data have clarified the way forward for particle physics and highlighted the possibility of exciting discoveries, such as the Higgs particle and supersymmetry. The next stage in the strategy for European particle physics is the new accelerator project, the LHC, which has the potential to make some of the most important scientific breakthroughs of our era. The LHC is a technologically challenging superconducting particle accelerator that will bring 7.7-TeV proton beams into head-on collision at higher energies than ever achieved before. It will be installed above the LEP collider in the same 27-kilometer tunnel, designed to accommodate the two rings.

The preparatory work for the LHC is going ahead and a milestone was passed in December 1991 with the unanimous agreement of the CERN Council that the machine is right for the future of particle physics and of CERN. The excitement generated by the LHC was demonstrated at a physics meeting in Evian at the beginning of March 1992, when 650 scientists from 29 countries met to discuss various experimental scenarios. There is great interest not only in colliding protons but also heavy nuclei, to generate "beauty" particles and neutrino beams. At a later date, proton beams from LHC can be collided with electron beams from LEP, opening up a whole new range of research. The LHC will be the most versatile accelerator ever available to particle physicists. The research potential of the machine is enormous and the most exciting prospect of all is the possibility that some of the discoveries that will be made will come as a complete surprise.

As well as CERN, there are other remarkable laboratories in Europe making major contributions with highly internationalized first class work. At the DESY Laboratory in Hamburg, the first collisions between electrons and protons took place in October 1991 in the HERA accelerator. This very exciting machine, with the most advanced superconducting proton ring in the world at present, will allow physicists to examine the inner structure of the proton with unprecedented accuracy.

A clear trend in particle physics research is the evolution away from separate experiments to general facilities where international cooperation has become absolutely essential. The desire to understand is universal, making science intrinsically international. The great discoveries made by scientists throughout history are the common property of all humanity and scientists have always sought collaboration beyond their own frontiers.

This thirst for collaboration has been highlighted by the political changes in Europe, and CERN has opened its doors to the East. Poland and the Czech and Slovak Federal Republic have become member states and final negotiations are under way for the accession of Hungary. Cooperation agreements have been signed with Bulgaria, Croatia, Romania, Serbia, and Slovenia. CERN's international standing has been reinforced by the observer status granted to Israel and the Russian Federation and by the cooperation agreements signed with Argentina, Australia, Brazil, Chile, China, India, Israel, and the Russian Federation. I see this as an important step toward profiting from the immense creativity generated by international scientific collaboration.

The strategy we adopted in Europe, to pool both financial and intellectual resources, has been enormously successful. We will continue to follow this strategy in the years to come. With our unrivaled range of existing facilities and our proposed new equipment, we can look forward to maintaining our position at the forefront of research well into the next century.

European Astronomy

Martin Rees

European cooperation in astronomy is so well developed that even the insular British will soon depend on international partnerships for their premier observing facilities. This trend toward collaborative projects is especially advanced in optical-band astronomy. This has come about because modern large telescopes are costly, and also because the best sites are remote from the European mainland.

The major optical partnership is the European Southern Observatory (ESO), with its suite of telescopes at La Silla in Chile. ESO's most recent success has been the New Technology Telescope (NTT). This instrument has a thin, somewhat flexible, 3.5-m mirror whose figure can be adjusted by active optics. This capability, combined with a unique building design that minimizes atmospheric turbulence, allows the NTT to obtain sharp images that take full advantage of the qualities of the site. The techniques will be incorporated in the Very Large Telescope (VLT), ESO's project for a telescope array comprising four separate, but linked, 8-m telescopes. This is the most ambitious project in the world in optical astronomy. The challenge is greater because of the decision to open up a completely new site in Cerro Paranal in northern Chile, where atmospheric conditions are even better than at La Silla.

Europe's prime Northern Hemisphere site is the Observatorio del Roque de los Muchachos at 2500-m altitude on La Palma in the Canary Islands. This was formally established in the 1970s as an international observatory. The host institution is the Instituto de Astrofisica de Canarias (IAC) on Tenerife which has, under the sustained leadership of Francisco Sanchez, become a major research center in its own right. The largest telescope at La Palma is the William Herschel 4-m, primarily a U.K. facility, but with 20% Dutch participation. There are also smaller telescopes, owned by the United Kingdom and by Scandinavian countries (most recently, the Nordic Optical Telescope). The Italians recently decided to place on La Palma their planned 3.5-m Galileo telescope, a clone of ESO's NTT.

La Palma, already Europe's premier Northern Hemisphere observatory, has obvious potential for further development, so that it becomes a counterpart for what ESO

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