

PHYSICS IN LATIN AMERICA COMES OF AGE

At the end of the 20th century, a large “science gap” still exists between Latin America and the developed countries of the North. One major reason for this disparity is economic: Poor economic conditions in most Latin American countries have seriously restricted their capability to invest in science and technology. However, the rich natural resources of the region—including oil, copper, nickel, cobalt, and other minerals—provide a solid economic base, and many countries are following the examples of Brazil, Mexico, and Argentina in recognizing that scientific research and technological development are necessary to achieve social and cultural progress. At present, prospects look good for growth in science and technology during the next century.

Latin America, a large geographic area of about 20 million square kilometers including 33 countries with a population of more than 500 million people, has at most 40 000 physicists (with at least a bachelor's degree in physics). Only about 10 000 of those physicists are involved in research. In contrast, the US membership of the American Physical Society alone is more than 33 000. (Of the more than 42 000 APS members worldwide, most of whom have PhDs, about 650 reside in Latin America.) Traditionally, the primary role played by physicists in Latin America has been in education. Physicists teach the basic physics courses in most universities for nonphysics majors (for example, chemistry, engineering, biology, and computation). Latin America also boasts a few basic research groups that contribute at the highest international level. However, because of the physics community's small size, its impact on technological development has been limited.

Here, I present some statistics about, and examples of, the work being done by physicists in Latin America. The description is not intended to be a complete analysis, but may give a sense of the significant development that has occurred in the past half century and of what might be needed to make the 21st century a flourishing epoch for science in Latin America.

In the beginning

The first physics research activity in Latin America dates from the late 1940s and early 1950s. With the exception of some experiments on cosmic radiation, early physics research was almost completely theoretical. The first groups were founded by persons who went to the US or Europe for graduate and postgraduate studies and then returned to their home country. One example is Enrique Gaviola, who left Argentina in the 1920s to study physics in Göttingen and Berlin. After learning the latest ideas on

In just over 50 years, the physics community throughout Latin America has grown to include advanced education programs, major research facilities, and industrial development. An aggressive program for science and technology may lead to a flourishing epoch in the next century.

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relativity and quantum mechanics from Max Born, Max Planck, and Albert Einstein, Gaviola collaborated with Robert Wood at The Johns Hopkins University in Baltimore, Maryland on the development of atomic spectroscopy. In 1930, Gaviola returned to Argentina, where he worked to establish world-class institutions for educating scientists. Other pioneering physicists included Manuel Sandoval Vallarta (see box 1 on page 42), Carlos Graef, and Marcos Moshinsky in Mexico; Cesar Lattes (see box 2 on page 43), José Leite Lopes, Jaime Tiommo, and Mario Schenberg in Brazil; and José Balseiro and Juan José Giambiagi in Argentina.

Following World War II, many European scientists moved to the Americas. A few prominent scientists settled in Latin American countries, especially Argentina and Brazil. For example, the first nuclear physics groups in Argentina were started by Austrian émigré Guido Beck; and Gleb Wataghin, a Russian-Italian émigré, directed the first research projects in astrophysics in Brazil.

Not all of the postwar émigrés were honest scientists. One notorious case of deception was that of the Austrian Roland Richter, who convinced Argentinean President Juan Perón that he could produce energy through controlled nuclear fusion. Perón backed Richter, who constructed a research complex on Huemul Island in San Carlos de Bariloche. In March 1951, Perón called a press conference where he startled the world by declaring that, “In the experimental nuclear plant [at Bariloche], thermonuclear reactions were performed under controlled conditions.”¹ The fraud was discovered by a commission of Argentinean scientists established in September 1952 to validate Richter's project.

A small physics community in a large region

The number of physicists in Latin America is still too small to contribute significantly to the economic development of this large region. Individual countries, however, vary considerably in the size and influence of their physics community. Latin American countries can be divided into four groups, based on the number of PhD physicists and overall scientific output; the groups are indicated by color on the map in figure 1. The most developed group includes Brazil, Mexico, and Argentina, which have, respectively, about 3000, 2200, and 2000 PhDs involved in physics research. The second group includes Cuba, Chile, Venezuela, and Colombia, each with 100–500 physics PhDs. The third group consists of Costa Rica, Peru, Uruguay, Ecuador, Bolivia, Guatemala, Nicaragua, Honduras, El Salvador, Panama, and the Dominican Republic, where the number of active physicists is finite but fewer than 100. The fourth group includes the remaining countries, where research in physics is negligible. It is evident from the map that two regions, Central America

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and the Andean countries, have a particularly small physics community.

In all the countries with active physicists, national physical societies have been organized to foster academic activities and promote a scientific community. The oldest such associations are the Argentinean Association of Physics (founded in 1944) and the Mexican Physical Society (founded in 1950). The newest is the Physical Society of Panama (founded in 1998). Connecting all of the national societies is the Federation of Latin American Physical Societies (FELASOFI), founded in 1984, whose governing board consists of the presidents of the member national societies. The objectives of the federation are to promote scientific exchange among Latin American physicists, to improve physics education, to promote research in areas of special regional interest, and to advocate the construction and use of large research facilities in the most developed countries. FELASOFI supports the Iberoamerican Physics Olympiads, the Central American and Andean workshops on telecommunications, and regional schools of physics, and offers scholarships for undergraduate and graduate programs in the region. In recent years the federation's annual budget has been about \$40 000.

Another prominent contributor to the development of physics in the region is the Latin American Center for Physics (CLAF). CLAF is an intergovernmental organization, founded in 1962 in Rio de Janeiro, Brazil, at the initiative of the Brazilian government and UNESCO. Twenty countries were signatories to the agreement, including all members of FELASOFI as well as Haiti and Paraguay. Operating funds come from member nations, UNESCO, the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy, the Third World Academy of Sciences, which is located at the ICTP campus in Trieste, and the Latin American Academy of Sciences in Caracas, Venezuela. CLAF maintains a scholarship program and supports academic meetings, including the Latin American Symposium on Solid State Physics, which has been held approximately biennially since 1969. CLAF is also a supporter, with the Organization of American States and others, of the Latin American School of Physics, an important symposium on advanced physics that has been held more than 35 times, in locations throughout Latin America, since 1959.

In 1994, CLAF and FELASOFI joined forces to form the Latin American Physics Network (RELAFI). This network is a framework for cooperation that should help the two organizations to more effectively accomplish their similar objectives. RELAFI is similar to other networks that have been formed in Latin America for astronomy, biology, chemistry, mathematics, and earth sciences.

Undergraduate and graduate programs

Although some universities in Latin America date from the 16th century—Santo Domingo in the Dominican Republic was founded in 1538; Lima, Peru, in 1551; and Mexico in 1553—the European concept of university as a



FIGURE 1. Extent of physics development in Latin American countries is indicated in the map by color shading. Countries are divided into four groups, based on population of physicists and overall scientific output. The most developed group (yellow) includes Brazil, Mexico, and Argentina. The intermediate group (green) includes Cuba, Chile, Venezuela, and Colombia. The third group (red) has a small physics community and includes Costa Rica, Peru, Uruguay, Ecuador, Bolivia, Guatemala, Nicaragua, Honduras, El Salvador, Panama, and the Dominican Republic. The remaining countries (gray) have a negligible physics community.

research center was implemented only about 50 years ago. Undergraduate programs in physics first appeared in the 1940s, starting with Mexico, Argentina, and Brazil, and graduate programs appeared only in the 1950s. The number of Latin American institutions that offer either undergraduate or graduate programs in physics is still very small.

FELASOFI, in collaboration with the Mexican Physical Society, publishes an annual catalog of undergraduate and graduate physics programs in Latin America.² This publication lists for each program the academic staff, papers published, degrees awarded, and laboratory and computation facilities. Not all programs are listed because some institutions still do not provide information, but the number of respondents grows each year.

In Mexico, the oldest and largest center for undergraduate education in physics is the Faculty of Science of the National University of Mexico (FC-UNAM).³ FC-UNAM awarded its first BSc in physics in 1942 and its first PhD in physics in 1956. Although at first only a few bachelor's degrees were granted each year, the number rose steeply in the 1960s, and today an average of 55 degrees are awarded annually. Between 1942 and 1998, 1914 physics bachelor's degrees were awarded by FC-UNAM.

In Argentina, the Balseiro Institute (IB) was founded in 1955 at the Atomic Center in Bariloche, in facilities that had been assigned to Richter's project. After cancellation of the nuclear fusion project, Gaviola convinced government authorities to move the high-temperature plasma equipment off Huemul Island and to open the institute on the shore of the lake. Today, IB is one of the most prestigious institutes in Latin America. It has offered under-

Some representative Latin American institutions, and their expertise.

Argentina	The Balseiro Institute, Atomic Center Bariloche (condensed matter, materials) The University of La Plata (high energy) The Atomic Energy Commission, Buenos Aires (nuclear, materials) The University of Buenos Aires (theoretical physics)
Brazil	The University of São Paulo, São Paulo (nuclear, medical physics) The State University of Campinas (solid state) The Laboratory of Synchrotron Radiation, Campinas (biophysics, materials) The Brazilian Center for Research in Physics, Rio de Janeiro (statistical mechanics) The University of San Carlos (medical physics, optoelectronics) The University of Rio de Janeiro (solid state)
Mexico	The National University, Mexico City (astronomy, condensed matter, mathematical physics, high energy, materials, nuclear) The Center for Research and Advanced Studies, Mexico City (solid state, high energy, solar energy) The National Institute of Astronomy, Optics and Electronics, Puebla The University of San Luis Potosí (condensed matter, statistical mechanics)
Colombia	The National University, Bogotá (solid state) The University of El Valle, Cali (solid state)
Cuba	The University of La Habana (medical physics, optoelectronics, solar energy, materials)
Chile	The Catholic University of Chile, Santiago (astronomy, solid state, mathematical physics) The University of Chile, Santiago (cosmology, nuclear)
Venezuela	The Central University, Caracas (materials science) The Venezuelan Institute of Scientific Research, Caracas (condensed matter) The Andean University, Merida (solid state)
Bolivia	The San Andres University (cosmic radiation)
Costa Rica	The University of Costa Rica (solid state, astrophysics, medical physics)
Dominican Republic	The Nuclear Energy Commission (applied nuclear physics)
Guatemala	The San Carlos University (physics of radiation)
Honduras	The National University (high energy)
Panama	The University of Panama (materials)
Peru	The San Marcos University (condensed matter, quantum optics)
Uruguay	The University of the Republic (theoretical physics, materials)

graduate and graduate studies in physics since 1955, and established a nuclear engineering program in 1977. An average of 10 students obtain bachelor's degrees in physics each year, and 481 degrees were awarded between 1958 and 1997. About 25% of IB graduates have gone abroad for graduate work; after obtaining their doctorates, many of them have remained outside of Latin America.

Relatively few PhD degrees are awarded in Latin America. In Mexico, the most important graduate institutions are FC-UNAM and the Department of Physics of the Center for Research and Advanced Studies (DF-CINVESTAV),⁴ both located in Mexico City. Between 1956 and 1998, FC-UNAM awarded a total of 167 doctorates in physics. The first PhD degree at DF-CINVESTAV was granted in 1964, and a total of 103 degrees were awarded through 1998. In Argentina, the most important institution is the Balseiro Institute, which awarded 244 doctorates in physics between 1958 and 1998.

In Brazil, a major center of graduate education is the Brazilian Center for Research in Physics in Rio de Janeiro. The Center granted its first PhD in physics in 1965 and awarded a total of 161 doctorates in physics between 1965 and 1996. Other Brazilian institutions have recently improved their graduate programs and significantly increased PhD output; for example, the University of São Paulo awarded 235 doctorates in physics between 1989 and 1998. Advances in the level of physics education are continuing throughout the region. In recent years, some countries have awarded their first physics PhD

degrees, namely Colombia and Peru in 1990 and Ecuador in 1999.

Despite continued growth and improvement, the production of trained physicists remains low. The number of undergraduate and graduate degrees in all of Latin America is dwarfed by that in the US, where, in 1998 alone, institutions awarded 3821 bachelor's degrees and 1323 doctorates in physics. Clearly, several Latin American institutions offer very good undergraduate and graduate programs, but the number of graduates is insufficient to serve the needs of the region.

Topics of research

The first research groups in Latin America worked mainly in theoretical physics, including cosmic radiation⁵ (see box 2 on page 43); gravitation; and nuclear, atomic, and high-energy physics. Research in optics, statistical physics, and solid-state physics developed in the 1970s, and these have now become the most popular subjects. Funding for research comes primarily from national governments, although in some cases collaborative programs with the US and Euro-

pean countries are an important source of support.

The principal areas of research in Latin American countries are shown in the table above, which lists the major research centers in each country and their fields of expertise. Countries are listed in the table according to the groups defined in the caption for figure 1. The field with the largest number of researchers in the region is condensed matter physics and its subdiscipline, solid-state physics (together cited by 13 institutions in the table). There is also considerable activity in materials science, including development of optoelectronic materials. Lack of modern equipment has hampered applied research in the less-developed countries, but a few groups have nonetheless managed to pursue successful experimental programs. For example, researchers in El Salvador are investigating applications of solar energy and geophysics, and in Honduras and Costa Rica small groups are dedicated to meteorology and to developing medical applications of nuclear physics.

South America, especially in Chile, has excellent international astronomical observatories at sites well suited to observe the southern skies. However, Latin American scientists historically have not been much involved with those large facilities, and the observatories have not contributed much to the education and training of physicists in the region. Doctoral programs in astronomy are offered only in Argentina, Brazil, and Mexico.

Despite the economic difficulties of the past decades in Latin American countries, initiatives have been

launched to construct large facilities for international use. Examples are the Tandem heavy ion accelerator in Buenos Aires, Argentina, the Brazilian National Synchrotron Light Laboratory (LNLS) in Campinas (about 70 miles west of São Paulo), and the Large Millimeter Telescope, a 50-meter wide radio telescope in Puebla, Mexico.

Brazil's LNLS, the first synchrotron light source to be constructed in the Southern Hemisphere,⁶ was officially opened to users on 1 July 1997. A photograph of the facility is shown in figure 2. The source is based on a 1.3 GeV electron storage ring designed and built by laboratory staff. LNLS has 10 beam lines that collectively span the photon spectrum from 10 eV to more than 10 keV. Beam lines are available for x-ray structural and spectroscopic studies—including small-angle scattering, diffraction, fluorescence, absorption spectroscopy, protein crystallography, and deep lithography—as well as for ultraviolet and soft x-ray spectroscopy. New beam lines for x-ray powder diffraction and infrared spectroscopy are in the planning stages. The beam lines, like the storage ring, were designed and built in-house. More than 500 projects have been performed at LNLS since its opening. Although 80% of the projects originated within the Brazilian scientific community, a significant fraction (15%) were led by scientists from neighboring Argentina, who have free access to the facility. Other projects have come from several countries in the Americas and Europe, and strong emphasis is given to international collaborations within Latin America. Materials scientists are the largest segment of users, followed by biologists, physicists, and chemists.

The facility was built by the Brazilian Council for Scientific and Technological Development, and is now funded by the Ministry of Science and Technology. Management is by the Brazilian Association for Synchrotron Light Technology, a private, nonprofit organization which also manages two other facilities on the LNLS campus: a National Center for High Resolution Electron Microscopy, the centerpiece of which is a 300-keV transmission electron microscope, and a new Structural Molecular Biology Center. With more than 150 staff members, superb technical infrastructure, and more than 14 000 square meters of laboratories and auxiliary facilities, LNLS is a world-class facility and is the largest and most modern national laboratory for materials and biological research in Latin America.

Basic science and industry

Most research carried out in Latin America is performed in the academic sector. However, there is growing interest at some universities and research centers in building bridges with industry, and such efforts are being promoted by national scientific and technical organizations. Unfortunately, there have been few successful collaborations so far, because of the small number of well-trained applied physicists and engineers in academia and the low level of industry interest in physicists.

A rare success in industrial research (though not a complete success) is the development of optical materials and communications in Brazil. José Ripper, who had worked at Bell Laboratories before returning to Brazil in 1971, convinced the Brazilian Telecommunication Company (Telebras) to launch a program to develop local optical communications technology, including research on optical fibers and continuous-wave semiconductor lasers. The project was supported by a research group at the State



FIGURE 2. NATIONAL SYNCHROTRON LIGHT LABORATORY (LNLS) in Campinas, near São Paulo, Brazil. This facility, the first synchrotron light source in the Southern Hemisphere, has a 1.3 GeV electron storage ring and 10 beam lines providing access to photon energies from 10 eV to more than 10 keV. Active research at LNLS includes chemistry, biology, physics, and materials engineering.

University of Campinas that then served as the seed for CPqD, the corporate host of the Telebras research laboratory. Following the successful American experience, CPqD was founded close to the university campus.

By the 1980s, the project was producing fibers, cables, lasers, detectors, and other equipment. In addition to its industrial production, CPqD attracted bright students and produced high quality research papers. Unfortunately, when the Brazilian government opened the markets in the 1990s, the small CPqD enterprise was practically annihilated. The problem was not that it couldn't produce components competitively, but rather that the market for components disappeared when equipment was imported already assembled. To survive, CPqD had to abandon its component manufacturing and move to production of optical communication equipment. CPqD was spun off from Telebras in 1998 and is now, with over 900 employees, the largest telecommunications research and development center in Latin America.

Toward the 21st century

For Latin America to become a developed region in the coming century, a coherent program must be implemented to develop science and technology in each country. Such a program must be multifaceted, including better physics education at all levels, programs that popularize science, and increased financing for scientific research and for developing its technological applications. Finding funding for such programs is a challenge in the difficult economic circumstances and instability that prevail in Latin America. In recent years, the World Bank and the Inter-American Development Bank have given special loans to support scientific and technological activities. These loans are intended to insulate those programs from economic instability by providing guaranteed support for periods from 5 to 10 years.

One recent program that has successfully fostered applied research and technological development is the Iberoamerican Program of Science and Technology for

Box 1. Manuel Sandoval Vallarta: A Founder of Modern Physics in Latin America

Manuel Sandoval Vallarta was born 100 years ago in Mexico City. At a time when Mexico was embroiled in a revolution, Manuel was a high-school student with a marked interest in mathematics and physics. Despite the lack of scientific tradition in his family, his parents supported his desire to go to the US to study physics. In 1924, at age 25, he received his PhD at MIT. His dissertation, on Niels Bohr's atomic model from the standpoint of general relativity, was written under the guidance of Edgar Bright Wilson. After postdoctoral studies in Berlin and Leipzig, Sandoval Vallarta was appointed a professor at MIT.

Sandoval Vallarta made basic contributions in several fields, including the theory of electric circuits, relativistic and nonrelativistic quantum mechanics, and gravitation, but his main impact was in the study of cosmic radiation. His studies on the nature and composition of cosmic radiation and on geomagnetic effects on its constituents gave him a distinguished place in the international scientific community and recognition as one of the authorities in the field. Georges Lamaitre and Sandoval Vallarta developed a theory of the latitude and azimuthal dependence of cosmic radiation, which was later corroborated experimentally by Luis Alvarez (working under the guidance of Arthur Compton). Sandoval Vallarta was interested in the extragalactic origin of cosmic rays and, in collaboration with Richard Feynman (then one of his students) he analyzed the scattering of cosmic rays by the stars of a galaxy.

Sandoval Vallarta often visited Mexico while he was a professor at MIT. He kept in constant touch with young Mexicans



interested in physics, and supervised some of them in their graduate work at MIT. For example, Alfredo Baños, who in 1938 became the first director of the Institute of Physics of the National University of Mexico, received his PhD under Sandoval Vallarta's supervision.

After returning permanently to Mexico in 1943, Sandoval Vallarta was a leader in the formation of the first organization to promote science in Mexico. He was the president of the

Commission for the Promotion of Scientific Research from 1943 to 1951, when the commission became the National Institute of Scientific Research; he then continued on in the presidency until 1963, when the institute was replaced by the present National Council of Science and Technology. During his 20 years of service, he advanced the cause of science and laid the groundwork for the modern scientific establishment in Mexico.

He recognized international collaboration as a key ingredient for creating and enriching the precarious scientific communities in the Southern countries. He collaborated with Abdus Salam, Robert Oppenheimer, and Victor Weisskopf to develop the project that gave rise to the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. The ICTP is now one of the most important centers for the development of science in the third world.

The photograph shows Sandoval Vallarta (seated, upper left) at a meeting in Vienna on 28 May 1964 to discuss formation of the ICTP with Sigvard Eklund (at blackboard) and, proceeding clockwise, Weisskopf, Salam, Seligman, and Oppenheimer.

Development (CYTED), an intergovernmental program founded in 1984 with the participation of 19 Latin American countries, plus Spain and Portugal. All participants contribute financially, but most funding comes from Spain, Brazil, and Mexico, which individually contributed \$4 million, \$790 000, and \$320 000, respectively, in 1999. In 15 years of CYTED operation, more than 10 000 scientists and technicians have been involved in its 16 subprograms, 85 cooperation projects, 65 thematic networks, and 124 innovation projects. One additional benefit of CYTED is the link it provides with the European Union of Scientific and Technological Collaboration.

A highly developed society requires many scientists and technicians to maintain and improve the technological infrastructure. At present, the number of scientists per capita in Latin America is about three orders of magnitude smaller than that in the US or Europe. Clearly, a substantial increase in the size of the Latin American scientific community is required. One way to improve this situation would be to increase the availability of educational resources to young students. More fellowships could be offered for study abroad, either at qualified institutions in Latin America or in advanced countries. (For example, Mexico has signed special agreements with some US universities, including the University of California and the University of Texas.) Another option is to use sandwich

programs, in which a student enrolls in a program at a foreign institution but does much of the work in the student's home country, or vice versa. For the home country, this modality has the advantage of reducing the risk that the student will remain abroad after completing the program.

Another way to increase the number of scientists in Latin America is to encourage highly trained Latin American scientists now living abroad to return home. A program in Mexico that includes an academic position and grants for continuation of research has been very successful.⁷ From 1991 to 1998, about 2000 scientists returned under the program from research laboratories and universities in the US and Europe and are now working in Mexican research centers.

The present employment situation for physicists in Latin America is good. Growing numbers of students, particularly in science and engineering programs, have boosted demand at universities and elsewhere for qualified teachers. Industrial need for physicists is also growing as economic globalization leads companies to relocate to Latin America.

Latin America has unique needs and opportunities that its scientific community should address. Research and development could greatly improve access to and use of the region's rich natural resources, and could increase the role of local industry in manufacturing goods pro-

Box 2. From Chacaltaya to the Auger Project

The research field with the most tradition in Latin America is the study of cosmic rays. Many cosmic ray studies have been performed in the region, and now there is a proposal to conduct part of one of the most ambitious projects yet in the southern part of South America.

One of the first international laboratories in Latin America was the Cosmic Ray Laboratory on Mount Chacaltaya in Bolivia (shown in the photograph). At a height of 5200 meters in the Andean high plains close to La Paz, the laboratory was established in January 1952 on a site that had been used 10 years previously as a station of the Bolivian Meteorological Service. The idea to perform experiments at this location came from Cesar Lattes, a Brazilian physicist who was a professor at the University of São Paulo. He convinced a British group headed by Cecil Frank Powell to study the effect of stopping cosmic rays in photographic emulsions exposed at high altitudes. Lattes, Giuseppe Occhialini and Powell performed experiments at Chacaltaya that showed that charged mesons brought to rest in photographic emulsions lead to the production of secondary mesons. They identified the primary particle as the π meson, predicted by Hideki Yukawa in the 1930s, and the secondary particle as the μ meson that had been observed by Carl Anderson and Seth Neddermeyer in 1936. This was the key discovery that led to Yukawa and Powell receiving the Nobel Prize in 1949 and 1950, respectively.

One can also say that the discoveries of the decay processes of the π meson had an important effect on the development of science in Latin America. These pioneer studies motivated the foundation of the Brazilian Center for Research in Physics in Rio de Janeiro in 1948, and led to establishment of the Chacal-



CHACALTAYA LABORATORY OF COSMIC PHYSICS

taya Laboratory of Cosmic Physics, associated with the University of San Andres. The result was a fruitful collaboration between Brazil and Bolivia. In the 50 years since its foundation, the Chacaltaya laboratory has been used extensively by the international scientific community. Scientists from Argentina, England, India, Italy, Japan, and the US, among others, have made contributions there to the knowledge of cosmic radiation.

Important questions about cosmic radiation remain. In particular, the existence of ultra-high-energy cosmic rays (UHECR) poses several unsolved questions in astrophysics (see the article in *PHYSICS TODAY*, January 1998, page 31). An international group, the Pierre Auger Collaboration, has been established to carry out a systematic study of UHECR with energies greater than 10^{19} eV. The group consists of about 300 scientists from 18 countries, including Argentina, Brazil, Chile, and Mexico. The collaboration is named for Pierre Auger, who in 1938 observed cascades of particles induced by a single high-energy cosmic ray. Auger called such a cascade an extensive air shower (EAS). The Auger group will search for EASs produced by UHECR. (See *PHYSICS TODAY*, February 1997, page 19.)

The EAS flux from UHECR is very small, and so observations will require fast electronics and large area coverage. The goal is to register about 1000 events during a period of 20 years; to meet this objective, the Auger group will install detectors at two sites with a combined area of 6000 square kilometers. In order to detect particles coming from all directions in the sky, one of the sites will be in the Northern Hemisphere (Utah, in the US) and the other in the Southern Hemisphere (Mendoza, in Argentina).

duced with the region's own resources. Materials research should include development of special alloys with unique magnetic, optical, or superconducting properties. The petroleum industry is of particular importance because of the vast identified oil reserves in Latin America and because of the environmental issues associated with the manufacture and consumption of hydrocarbons. Energy production is essential for economic development, but innovative technical solutions are needed to provide energy throughout the region in an environmentally sound and economically feasible way. In addition, because of its location, particular political and economic circumstances, and other factors, Latin America can offer a unique perspective on global subjects such as the physics of climate change, continental dynamics, oceanography, and astronomy.

Many indicators of science and technology⁸ show that Latin America will play an increasingly important role in the world scientific community in the next century. To make this future a reality, an aggressive program must be created to capitalize on the experience and infrastructure developed over the past 50 years. A robust scientific and technological community will be a powerful contributor to a healthier and more competitive region.

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