Survey of High-Energy Physics in Latin America

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Abstract: Some landmarks of elementary particle and cosmic physics in Latin America are reviewed, followed by a general description of the present situation and a sketch of new projects in the region.

1. History

From the very beginning, elementary particle and cosmic physics appeared in Latin America intimately linked with some relevant contributions to the universal knowledge.

The birth of strong interactions may be dated back to 1947 when the existence of pion was confirmed by the observations made by the Brazilian 23-years old César Lattes in the Bolivian mountain of Chacaltaya.

Cesare Mansueto Giulio Lattes was born in Curitiba from a family originary from Turin. He was student in São Paulo of Giuseppe Occhialini who had escaped from the fascist Italy. Before the end of the Second World War, Occhialini went to Bristol to work in the well equipped laboratory of Cecil Powell and in 1946 Lattes joined them.

Occhialini found some evidence of a particle decaying to the muon from cosmic rays in the Pic du Midi in France. Immediately afterwards Lattes went to the higher mountain of Chacaltaya at 5,200 m of altitude with emulsion plates which recorded several events. They where seen in Rio de Janeiro by Leite Lopes and Guido Beck - an Austrian theoretician that before and after this year was professor of several Argentine and Brazilian physicists including José Antonio Balseiro who in 1955 founded the institute of Bariloche - with the feeling that the intermediate meson predicted by Hideki Yukawa for strong interactions had been discovered. An accurate analysis of the plates at the Bristol laboratory confirmed this result.

Lattes afterwards went to Berkeley where he produced artificially by accelerators pions of both charges and also the neutral one. Yukawa received the Nobel prize in 1949 and Powell alone that of 1950.

The discovery of the pion had a deep impact on the research activities in the involved countries: the foundation of the Centro Brasileiro de Pesquisas Físicas (CBPF) in Rio de Janeiro in 1949 and that of the Laboratorio de Física Cósmica of Chacaltaya in 1951 where experiments were performed mainly in collaboration with Brazil and Japan, observing in 1972 the not yet understood Centauro event.

One of the directors of CBPF was the Recife-born José Leite Lopes who had studied at Princeton. Leite, inspired by the existence of the three-charge pions mediating the strong interactions, proposed in 1958 that also the weak interactions had three intermediate bosons including the neutral Z with a coupling to fermions equal to the electric charge but with a very large mass. The electroweak model elaborated with these ingredients in the frame of a gauge theory gave in 1979 the Nobel prize to Sheldon Glashow, Abdus Salam and Steven Weinberg.

For the consistency of this theory is was necessary to prove that it is renormalizable, which was done by Gerard 't Hooft and Martinus Veltman, recipients of the Nobel prize 1999. For that they used a technique to eliminate infini-

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ties called dimensional regularization which was independently invented by the Argentineans Carlos Bollini and Juan José Giambiagi in 1972 during a stay in La Plata. They had been professors of the University of Buenos Aires, and forced to resign due to the irruption of a military dictatorship in 1966. Before that they established tight links with Brazilian and Mexican theorists.

Theoretical physics had been initiated in Mexico by Manuel Sandoval Vallarta who had studied in the Massachusetts Institute of Technology where in 1933 predicted in collaboration with Georges Lemaitre the geomagnetic effect on cosmic rays. This was immediately confirmed by the observation made by Luis Alvarez in Mexico City showing that cosmic rays consisted of positively charged particles. The impact of this result fostered the foundation of the Faculty of Sciences in 1939. An outstanding physicist that subsequently emerged was Marcos Moshinsky who mastered the group theory necessary for the symmetry considerations which were becoming crucial in the description of the fundamental interactions.

The collaboration among Giambiagi, Leite Lopes and Moshinsky was extremely fruitful. In 1959 they started in Mexico the Escuela Latinoamericana de Física (ELAF) to be organized yearly in different countries to update the knowledges of young physicists, and in 1962 they inspired the creation of the Centro Latinoamericano de Física (CLAF) to promote research and postgrade formation in the region.

During the years when Giambiagi was head of the department of physics of Buenos Aires University (UBA) and systematically published with Bollini, who is currently active as researcher in the University of La Plata, several brilliant students were trained. One of them was Miguel Angel Virasoro, now director of the International Centre for Theoretical Physics (ICTP) of Trieste, who also left Argentina after the coup of 1966 and very soon elaborated the algebra which wears his name and has been largely used in string theory. In this attempt to unify all the fundamental interactions, the former student of the Instituto Balseiro and now professor at Harvard Juan Martín Maldacena became famous in 1998 by his celebrated conjecture connecting gravity with the quantum chromodynamics (QCD) responsible for the strong nuclear forces.

Individual Latin American experimental physicists had worked in high-energy accelerators in US and Europe. But the systematic involvement began in 1982 due to the initiative of Leon Lederman who fostered a Panamerican meeting at Cocoyoc, Mexico. Immediately after that, high-energy groups were organized in Mexico and Colombia to participate in experiments of Fermilab. A few years later also Brazil established groups to work both at Fermilab and CERN and the same happened much more recently in Argentina.

2. Present situation

There are currently around 800 active physicists, including graduate students, working in high-energy and cosmic physics in Latin America of which 150 are experimentalists. This represents about 10% of the total Latin American community of physicists. A 75% of them is concentrated in three countries: Argentina, Brazil and Mexico.

Regarding the predominant theoretical research there are groups devoted to mathematical physics and others concerned with phenomenology. The former line is stronger in Argentina, Brazil, Chile, Venezuela and Cuba. The latter, fostered by a Latin American network, is comparatively more relevant in Mexico, Colombia and Uruguay.

In Argentina the largest theoretical group is at the University of La Plata, followed by those of Bariloche, Buenos Aires and Córdoba, the last one devoted to General Relativity.

In Brazil the activity is mostly concentrated in São Paulo and Rio de Janeiro. In the former at the Universidade de São Paulo (USP) and the Instituto de Física Teórica (IFT). In the latter at the CBPF, the Universidade Federal (UFRJ), the Universidade Estadual (UERJ) and something at the Pontificia Universidade Católica (PUC-RJ). Smaller groups exist in Campinas, Porto Alegre, Brasilia and São Carlos.

In Mexico the larger groups are at the Universidad Nacional Autónoma (UNAM) in Mexico City, the Centro de Investigaciones y Estudios Avanzados (CINVESTAV) of Mexico and

Merida, and also in Leon, Puebla, San Luis Potosí and Zacatecas.

In Colombia there are active groups, mainly in phenomenology, at the Universidad Nacional and the Universidad de Los Andes (UNIANDES) of Bogotá, at the Universidad de Antioquia of Medellín, and also at the Universidad del Valle of Cali and the Universidad Industrial de Santander of Bucaramanga.

In Chile well established groups are at the Pontificia Universidad Católica and Universidad de Chile of Santiago, the Universidad Federico Santa María of Valparaíso and the Centro de Estudios Científicos now at Valdivia directed by Claudio Teitelboim.

In Venezuela there is theoretical activity at Caracas in the Universidad Central where Ana María Font was recipient of an ICTP prize, the Universidad Simón Bolivar and the Instituto Venezolano de Investigaciones Científicas (IVIC), and in the Universidad de Los Andes of Merida.

In Uruguay a small but qualified group works at the Universidad de La República of Montevideo.

In Cuba mathematical physics is developed at the Instituto de Cibernética, Matemática y Física of La Habana.

There are individuals, working at the Universidad de San Andrés of La Paz in Bolivia, at the Universidad Nacional de Ingeniería of Lima in Peru, at the Universidad de San Francisco of Quito in Ecuador and at the Universidad de San José in Costa Rica. Attempts to begin some activity are made in the Universidad de San Carlos of Guatemala, where the also ICTP prizer Fernando Quevedo studied, and in that of Tegucigalpa in Honduras.

As for the increasing experimental work, a list of experiments and number of participants of the different Latin American institutions includes:

i) Experiments in phase of data analysis

- D0 (Fermilab); proton-antiproton interactions at 2 TeV Brazil (CBPF, UERJ) 14, Colombia (UNIANDES) 7, Mexico (CINVESTAV) 5, Argentina (UBA) 3

- DELPHI (CERN); electron-positron interactions at 170 GeV Brazil (UFRJ, UERJ) 10

- E791 / E831 (Fermilab); charm hadro and photoproduction Brazil (CBPF) 10, Mexico (CINVESTAV) 7

- SELEX (Fermilab); charm hadroproduction Brazil (USP, Campinas) 8, Mexico (San Luis) 2

- E690 (Fermilab); hadron exclusive production Mexico (Leon) 4

- L3 (CERN); electron-positron interactions at 200 GeV Argentina (La Plata) 2

ii) Experiments in phase of data acquisition

- KTeV (Fermilab); CP violation with kaons Brazil (Campinas, USP) 4

- Hyper CP (Fermilab); CP violation with hyperons Mexico (Leon) 2

iii) Experiments in phase of construction

- D0 II (Fermilab); proton-antiproton interactions at 2 TeV Brazil (CBPF, UERJ, IFT) 15, Mexico (CINVESTAV) 2, Colombia (UNIANDES) 5, Argentina (Bariloche) 1

- Auger (Malargüe); ultra-high energy cosmic rays Brazil (Campinas, CBPF, UERJ, USP) 20, Argentina (Buenos Aires, La Plata, Bariloche) 20, Mexico (Puebla, CINVESTAV, Morelia) 10

- SLIM (Chacaltaya); light magnetic monopoles Bolivia (La Paz) 5

iv) Experiments in phase of project

- LHC - CMS (CERN); proton-proton interactions Brazil (CBPF, UERJ, IFT) 20

- LHC - b (CERN); B meson physics Brazil (UFRJ) 10

- LHC - Atlas (CERN); proton-proton interactions Brazil (UFRJ) 5

- Alice (CERN); heavy ions physics Mexico (CINVESTAV) 4

- CKM (Fermilab); kaons at the main injector Mexico (San Luis) 2

- HECRE (Chacaltaya); high energy cosmic rays Bolivia (La Paz) 2

Apart from the above organized national groups, there are some experimentalists working abroad from Peru, Ecuador, Venezuela, Belice and Paraguay.

3. New projects

Of the above experimental endeavours, two will take place in Latin America and will be discussed in some detail.

i) Auger observatory for ultra-high energy cosmic rays (UHECR)

In the last years a dozen of events have been observed of cosmic rays with energy above $10^{20}eV$ and without identification of their origin.

This rises a number of unanswered questions. The standard mechanism of acceleration does not allow to reach these energies in our galaxy which has not enough size and magnetic field. Therefore the origin should be extragalactic but there are no astrophysical objects nearby which can be identified as sources. One would then infer that these sources are at cosmological distances from us. But again an obstacle appears in the fact that normal primary cosmic rays coming from distances larger than 50 Mpc would interact with the photons of the microwave background (CMB) degrading their energy which could not then be the one detected on earth.

Several nonstandard possibilities appear to solve this apparent mystery. One is that the UHECR come from far away but they do not interact too much with the CMB because are neutrinos or nonordinary particles, or even because relativity does not hold at these extreme energies! Another possibility is that they come from sources close to our galaxy so far not identified because the extragalactic magnetic field is larger than what is generally believed, deflecting appreciably charged particles even if they are very energetic, or otherwise from the same phenomena which give rise to gamma ray bursts. Finally, UHECR might come from the galactic halo according to the top-down mechanism i.e. produced by the decay either of superheavy particles quasistable because do not feel standard model interactions, or of defects formed in earlier phase transitions and stabilized due to topological reasons.

The situation may be clarified with a larger statistics thinking that the flux on earth for UHECR of $10^{20}eV$ is around one event per square km and century!

Therefore the Auger project led by the Nobel prizer Jim Cronin, of the University of Chicago, approved in 1995 at the UNESCO headquarters to build a large observatory in Argentina, covering a surface of 3,000 square km. The collaboration includes so far 19 countries of which 4 from Latin America: Argentina, Bolivia, Brazil and Mexico.

The system will be hybrid with a surface array of 1,600 water Cherenkov detectors and four telescopes to measure the fluorescence radiation, in order to optimize the determination of energy and direction of showers.

During the first year of construction at the beginning of 2001 it is expected to complete the central station at Malargüe, the installation of an initial set of 40 Cherenkov detectors and of the prototype fluorescence detector on the Los Leones hill.

The total cost of the observatory, whose whole construction will require five years, is estimated in 50 million dollars of which 15 will be supplied by Argentina.

Data will determine the energy spectrum above $10^{19}eV$ showing if there is a cutoff due to interaction with CMB, eventual directions to astrophysical objects or isotropy if sources are cosmological or anisotropy if they are concentrated in the galactic halo. The identification of the primary composition will be important because e.g. the top-down mechanism predicts a large contribution of gammas and neutrinos. For horizontal showers due to the latter the Auger observatory will be equivalent to a cubic km water detector.

The formation of Latin American participants in the project at PhD level is supported by an exchange programme of CLAF.

ii) New experiments at Chacaltaya

In February of this year the installation of the first part of the 400 square m detector for light magnetic monopoles began at Chacaltaya, corresponding to the SLIM project approved by the Italian INFN. Apart from looking at monopoles lighter than 10^6GeV, SLIM might detect the so-called strangelets perhaps related to unexplained balloon observations. This experiment is open to the participation of a few young Latin American researchers.

A larger project would be the High Energy Cosmic Ray Experiment (HECRE) which might use 100 scintillator counters and 70 AIROBICC detectors of the HEGRA collaboration at La Palma which now shuts down. In this way gamma-ray astronomy in the Southern hemisphere would be performed with the advantages of the observation of a large part of the galactic disk and that for identifying gamma-ray bursts because of Chacaltaya altitude. For these goals also a Cherenkov telescope might be installed.

Another purpose would be to elucidate the nature of the so-called knee in the spectrum of cosmic rays around 10^{15} eV which is not clear whether it is due to a change in the primary composition or in the interaction with the atmosphere. For this aim an upgrading would consist in adding a hadron calorimeter so that direct observation of protons up to 100 TeV, so far only possible with balloons, could be performed again thanks to the hight of Chacaltaya.

For the international coordination of the new experiments at Chacaltaya, an agreement has been signed between CLAF and Bolivia.

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