HIGH-ENERGY PHYSICS IN SPAIN

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Abstract

The present situation of Spanish High-Energy Physics (HEP) is reviewed. The actions since 1983 when Spain rejoined CERN, which have contributed to its development, are analyzed. This includes the Mobilizing Plan (1984–1988), the national programme of HEP (1988–1991) and the proposal for the creation of a national institute (IFAE). The theoretical and experimental groups located in universities and research centres are considered in their human resources and geographic distribution. The article also makes a concise description of the physics activities of the Spanish groups and their responsibilities in international collaborations.

1. Introduction

The re-incorporation of Spain to the European laboratory for particle physics (CERN) in 1983 led to an important development of the field of HEP in Spain. This was due to two reasons. First, the possibilities offered by CERN to the participation of Spanich groups in the programme of this institution. Second, this event triggered the internal creation of a mobilizing plan of HEP with the objective to promote this field in Spain, particularly exprerimental physics, and get an optimal exploitation of the membership of CERN.

In this article, a presentation of the actions of scientific policy made in Spain, related to the field of HEP, will be made in sect. 2. These include the mobilizing plan from 1984 to 1988, the Interministry Commission for Science and Technology (in Spanish: CICYT) programme of HEP within the national plan of research, with its first phase from 1988 to 1991 and the second phase from 1992 to 1995, as well as the proposal presented to the Spanish authorities to create the HEP institute (IFAE). In sect. 3 an analysis is made of the Spanish HEP groups in theoretical and experimental physics and their geographical distribution, as well as the global research outputs, exchange projects and related matters. The physics activities of theoretical and experimental groups are discussed in sect. 4, including their responsibilities in international collaborations. Finally, a summary of the situation of HEP in Spain will be given in sect. 5.

2. Scientific policy

Before 1983, theoretical HEP has ~ 15 years of development in Spain, with its activities and actions coordinated by Inter-University Group of Theoretical Physics (in Spanish: GIFT). This institution established joint efforts of Spanish groups for:

(a) the formation of scientists, such as the interuniversity post-graduate courses and the annual international seminar;
(b) the promotion of research in theoretical physics;
(c) the drive of international collaborations and post-doc fellowships in foreign centres.

About 10 groups of different size sitting in the universities and Scientific Research Council (in Spanish: CSIC) were active in theoretical HEP, with a number of Ph.D. theoretical physicists around 80. The Junta de Energía Nuclear (JEN) today CIEMAT, had played a very important role during the seventies through the funding, by means of Instituto de Estudios Nucleares, of most of the activities of GIFT; its theoretical group, however, had disappeared very early, its members having joined university or other research centres. Already at that time (1983), Spanish theoretical physics had a significant international impact.

When Spain rejoined CERN there was one experimental group of HEP at JEN, in Madrid, and two small groups in the universities of Valencia and Santander. Only the first group had a regular participation in international collaborations of HEP experiments and a regular funding for this activity. The Valencia and Santander groups had expertise in emulsion techniques and had participated occasionally in emulsion or hybrid experiments.

The duration of the mobilizing plan of HEP, established in 1984, was coincident with the transitory period 1984–1988 for the Spanish contribution to CERN, with a reduced share to the CERN budget and its gradual increase. Among the scientific objectives of the mobilizing plan, described in the document for its preparation [1], one can select the following:

(a) the push of the experimental groups of CIEMAT, university of Valencia and university of Santander;
(b) the increase in the number of experimental groups to at least six;
(c) the development of the groups so that, in 1988, one should reach two groups with at least 20 physicists (including Ph.D. students), two groups with a size between 10 and 20 members and about three groups with ~ 10 members;

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(d) the increase in the total number of experimental physicists from about the existing 40 up to ~ 100;
(e) the creation, or increase, of technological infrastructure, such as mechanical workshops, a network of computing and communications, etc.;
(f) a moderated increase of theoretical physicists in HEP.

In fact, the evolution of the theorists has been continuous and essentially linear during its whole history as shown in fig. 1.

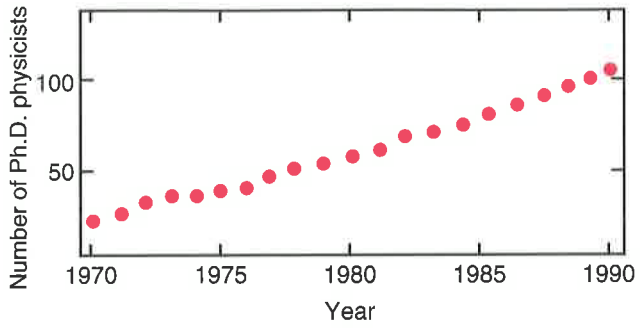

FIGURE 1

Evolution of theoretical physics.

At the beginning of 1988 the mobilizing plan of HEP was replaced by the national programme of HEP, included in the national plan of science and technology of the CICYT. The definition of the objectives and the development of actions continued the trend established in the preceding years and they were contemplated, together with the budget to develop them [2]. In its first phase, from 1988 to 1991, the objectives of the national programme have been accomplished in a large proportion. The methodology which has been followed to manage the scientific projects, for one, two or three years, and the special actions combines the refereeing system, of the Spanish National Agency for Evaluation and Prospective (in Spanish: ANEP), with the specific work of an international advisory board for HEP. The first step determines the quality and feasibility of the project, whereas the advisory board makes proposals to the CICYT to select the projects and recommendations to the groups to improve their research activity. During the first phase of the national programme, the members of the HEP board have been F. Dydak, A. De Rújula, L. Foà, G. Hansen, J.A. Rubio, E. de Rafael, G. Wolf and the author of this article.

The second phase of the national programme of HEP, from 1992 to 1995, has now been approved by the CICYT.

In September 1989 the programme committee of Spanish HEP transmitted to the permanent committee of CICYT the convenience to study the creation of IFAE, motivated by the following considerations:

(a) the consolidation of the scientific accomplishments and the adequacy to the European levels;
(b) the specificity of the research in experimental HEP, due to the role of CERN and the international collaborations;
(c) the coordination of the research activity by means of an institution able to be the scientific-technical partner in national and international levels. Taking into account the decentralized character of this research field in Spain, the proposal has some features similar to those adopted by the INFN in Italy or the IN2P3 in France. The possibility to coordinate the HEP activities by means of an institute had been mentioned before in the document of the mobilizing plan [1], in the proposal of the national programme [2] and in the meeting sponsored by the ANEP in 1987 with the aim of performing the evaluation and prospective of physics in Spain [3].

The history of the proposal of the institute is up to now the following. During 1990, the CICYT recognized the interest to prepare a proposal for a national HEP institute and appointed the committee to do it. This committee presented the first version of the proposal to the CICYT in 1990 and, after an indication of the CICYT asking for some modifications and additions, the second version of the proposal [4] is in the hands of the Spanish scientific authorities since 1991. At the time of the writing of this article (beginning of 1992), the creation of the IFAE is pending approval.

The priorities of the institute would be to develop and coordinate the research in the HEP field, to manage its own budget and the funding for HEP research, to create and distribute the positions of personnel among the different local sections, to define the distribution in centres or research groups, to represent scientifically to the Spanish HEP community and to promote scientific and technological initiatives. The internal structure of the institute contemplates the council, the directory and the local sections. It would have three divisions of scientific nature, theoretical physics, experimental physics and instrumentation and development, and one division of administration nature. The directorate will be advised by a scientific policy committee.

The local sections will be associated with the laboratories of the institute, the university departments and other centres of research, such as the CSIC and the CIEMAT. The proposal [4] considers the possibility to create the IFAE as an autonomous institution, depending on the Ministry of Education and Science, and the scientific, technical and administrative positions will have the same cathegories as the ones of the CSIC.

3. Groups and human resources

At the time of the end of the first phase of the national programme of HEP (1991), theoretical HEP has a significative activity in 11 different institutions: Autónoma Madrid, Complutense Madrid, CSIC Madrid, Autónoma Barcelona, universities of Barcelona, Valencia, Santiago de Compostela,

Zaragoza, Salamanca, Granada and Bilbao. This geographical distribution is shown in fig. 2, where the number of Ph.D. theoretical physicists is in each town explicitly indicated.

The total number of Ph.D. physicists in theoretical HEP is thus ~ 110, which becomes 140 when the Ph.D. students are included. If these figures are normalized to the number of Spanish inhabitants, one finds that the Spanish theoretical physics is at the level of 90% of the average value of theoretical physicists in Europe.

FIGURE 2

Geographical distribution of theoretical physicists.

The experimental HEP groups existing now in Spain are those of the CIEMAT and the universities of Valencia, Santander, Autónoma Barcelona, Autónoma Madrid, Santiago de Compostela, Zaragoza and Complutense of Madrid. There are also two experimental groups in nuclear physics in connection with HEP, those of the CSIC (Valencia–Madrid) and the university of Sevilla. This geographical distribution is shown in fig. 3, where the number of Ph.D. experimental physicists is in each group explicitly indicated.

The total number of Ph.D. physicist in experimental HEP is thus ~ 75, which becomes ~ 120 when the Ph.D. students are included. If these figures are normalized to the number of Spanish inhabitants, one finds that the Spanish experimental physics is at the level of 40% of the average value of experimental physicists in Europe.

The observation of figs 2 and 3 tells us that the polygon defined by Madrid, Valencia, Barcelona and Zaragoza concentrates 80% of the total resources in experimental and theoretical HEP.

FIGURE 3

Geographical distribution of experimental physicists.

One of the parameters to discuss the research output provided by the groups can be measured as their efficiency in the number of international publications. For theoretical physics, this number is given in fig. 4 along the years 1970 to 1990. For the years before the onset of the national HEP programme, we have used the information provided by the annual reports of the GIFT [5].

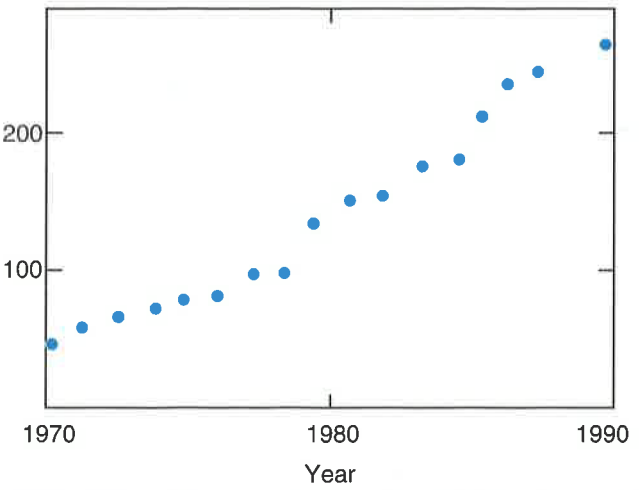

FIGURE 4

Number of international publications in Spanish theoretical physics along the recent history.

If one defines the ratio R between the number of international publications in theoretical physics and the number of Ph.D. theoretical physicists, the value of R has increased monotonically with time with values of R = 1.2 in 1970 and R = 2.2 in 1990.

The evolution of the research outputs for experimental physics is, as expected, not so regular. The value of the ratio R was R = 26/42 in 1986 and it was essentially constant before 1990. With the advent of the physics results produced by the collaborations at LEP, the years 1990 and 1991 have seen an explosion of scientific papers, leading to values of R around 2.

The collaboration of the Spanish HEP groups with foreign groups is in very good health. In fact, these collaborations are more intense than those associated with internal (within Spain) relations. This statement is valid for both experimental and theoretical HEP. Among the experimental groups, only those of Valencia and Santander coordinate their participation in the same (DELPHI) experiment of LEP.

There are official exchange agreements of the Spanish HEP programme, through the CICYT, with the French institute IN2P3 and the Italian institute INFN for short and medium term visits in both ways. The theoretical GIFT group has also an agreement with the international centre of Trieste (ICTP) for research stays there.

The funding provided by the national programme of HEP to the Spanish groups includes the current projects, infrastructure such as computing, and special actions such as the organization of conferences or the research and development projects for detectors for LHC. The ratio R′, defined by the number of millions of pesetas assigned per year in current projects divided by the number of Ph.D. physicists, has on the average the value $R' \approx 0.38$ MPtas y^{-1} $(PhD)^{-1}$ [≈ 5.4 KCHF y^{-1} $(PhD)^{-1}$] for theoretical groups and the value $R' \approx 4.1$ MPtas y^{-1} $(PhD)^{-1}$ [≈ 59 KCHF y^{-1} $(PhD)^{-1}$] for experimental groups. The projects for the participation in physics activities and detectors include the chapters of personnel (neither the salaries of permanent staff nor the regular fellowships), equipment, travel money and others.

4. Physics

The research in theoretical particle physics in Spain covers a general international spectrum of subjects: field theory, theoretical structure of models for fundamental interactions, phenomenology of particle physics within and beyond the standard theory of strong and electroweak interactions, soft physics of hadronization, non-perturbative methods, etc. A study made a few years ago [3] showed that the proportion of activity in each of these domains was for the Spanish groups quite similar to the international spectrum as extracted from the publications in the scientific journals of higher impact. Related to different aspects of phenomenology, the groups of the universities of: Autónoma Madrid, Valencia, Autónoma Barcelona, Zaragoza, Santiago de Compostela, Barcelona and that of the CSIC Madrid have an important contribution to particle physics research. The healthy situation of theoretical particle physics in Spain is a product, among other ingredients, of the moderated but continuous increase in its human resources, which allows the incorporation of brilliant and motivated physics students to this field. The conditions to continue with this situation in the coming years should be met by the Spanish scientific policy, in particular in connection with the research fellowship programme.

The research programme in experimental HEP is at present in a good level of international collaborations, with LEP, HERA and other experiments. In the following, a selection of the responsibilities of the Spanish groups in the detectors and the physics for these experiments is reviewed.

(a) The CIEMAT

This group has been involved in the L3 experiment of LEP since the preparation of the technical proposal (1983). By then, they were participating in the MARK-J experiment.

The responsibilities of the CIEMAT to the L3 experiment have been of high level, with a major contribution to the muon detector. The group made the design and construction of all drift chambers (Z type), the construction of parts of the precision chambers (P type), the fabrication and assembly of the support structure, the alignment, test and calibration of the 16 octants and the monitoring of the whole detector. With respect to software and physics analysis for the L3 experiment, the CIEMAT group has contributed to Monte Carlo event generators, to the simulation and reconstruction program, as well as to data analysis. Their expertise in the analysis of dimuon events, for the Z lineshape, the partial width Γ_μ of the Z, the forward/backward asymmetry A_μ of the muon channel, etc., and of inclusive muons, for partial width Γ_b into the bottom quark, the asymmetry of the b channel, the $B\bar{B}$ mixing, etc., are of particular relevance for the L3 experiment.

The CIEMAT group has also been involved in last years in the CERN experiments of the collider (UA1) and of heavy ions (NA36). Until recently, these two small projects of the CIEMAT have been working in the analysis and presentation of the corresponding results.

(b) University of Valencia

The main research work of the Valencia group is in the DELPHI experiment of LEP. They have full responsibility of the time-of-flight (TOF) detector. This implies the design, construction, electronics (Fastbus modules), installation, maintenance and operation of the detector. The trigger and data acquisition systems have been developed. Besides its role for cosmics, the TOF detector has been crucial in the first LEP physics run, to trigger the Z signal with high efficiency.

The Valencia group has also collaborated with Italian groups for the construction and installation of the forward electromagnetic calorimeter (FEMC) detector. Their contribution to the

physics analysis of DELPHI includes the study of multiparticle (fragmentation) hadronic states, the extraction of the τ branching ratios and τ polarization as produced at the Z peak, the identification of the b channel, etc.

The group of the IFIC, university of Valencia CSIC centre, has also a participation in the UA4/2 experiment in the collider, to determine the real part of the $\bar{p}p$ scattering amplitude in the forward region. Their responsibility appears in the fiber detectors, the electronics, data taking and the analysis.

(c) University Autónoma of Barcelona

The activity of this group has concentrated on its responsibilities in the ALEPH experiment of LEP. They include the Bhabha Calorimeter (BCAL), the FALCON (facility for ALEPH computing and networking) and the physics analysis.

The BCAL is a very small angle luminosity monitor, designed, constructed and operated with high efficiency to identify the Bhabha events $e^+e^- \rightarrow e^+e^-$. The first data taking with the BCAL took place with the first LEP physics run of ALEPH.

FALCON's aim is to deliver reconstructed data (as quickly as possible) after data taking. The event reconstruction is made in a cluster of DEC workstations connected through a local area network to the on-line ALEPH data-acquisition cluster. They operate with 12 FALCON processors. The result is that FALCON has been fully operational since the first day of LEP. Its operation is entirely automatized.

The contribution of the Barcelona group to the ALEPH physics analysis has covered an intense and interesting work on precision tests of the electroweak theory and it has been influencial on the analysis of the leptonic decay channels of the Z. This includes the flavour-blind analysis, the τ partial width of the Z, the τ polarization from its decay channels, the τ lifetime and branching ratios, etc.

(d) University Autónoma of Madrid

Besides the earlier work of the group of Autónoma Madrid for the analysis of TASSO data at DESY, the main activity of this group is connected to its responsibility in the ZEUS experiment at the HERA Facility.

The ZEUS detector is a depleted uranium scintillator sandwich calorimeter, for which the participation of the Autónoma Madrid group has been in the construction of the forward calorimeter (FCAL) as well as in the forward drift chambers. About 1000 light guides and 1500 light guides mechanical supports inside the FCAL have been prepared and assembled by the group, together with the construction of the controllers for the active photomultiplier bases. They have also made the front electronics of the calorimeter. The group has set up a clean room at Madrid and wired all forward drift chambers, and coordinated the beam tests of these chambers.

The group has prepared the physics analysis at HERA with an excellent and systematic study of the production characteristics for heavy c, b, t quark pairs via boson–gluon fusion mechanisms at the relevant energies.

(e) University of Santiago de Compostela

This group is involved at present in the Spin-Muon Collaboration (SMC) experiment at CERN. Its aim is the determination of the spin-dependent structure functions of the proton and the deuteron, in particular at low values of the scaling variable x. This experiment will clarify the issue to the so-called "proton spin crisis", motivated by the results of the EMC collaboration.

The Santiago group collaborates in the construction and electronics of the streamer tubes, the design of a forward detector and in the software for the SMC experiment.

The group was involved before in the heavy ion experiment (NA36) at CERN, with a contribution to the TPC and to the physics analysis for strangeness production.

(f) University of Cantabria

The group of the university of Santander participates in the DELPHI experiment of LEP. Their work has been related to the off-line software for the TOF detector, constructed by the Valencia group, and to the studies for lepton–hadron separation in the FEMC.

The physics analysis of this group for the DELPHI collaboration has mainly concentrated on the $\tau^+\tau^-$ channel of the Z decay.

(g) University Complutense of Madrid

This group is participating in the DELPHI experiment, coordinated with the activities of the Valencia group and in the High Energy Gamma-Ray Astronomy (HEGRA) experiment at La Palma island. Their responsibility includes data taking at La Palma, data analysis in Madrid, Monte Carlo reconstruction of events and a participation in the Cherenkov counters, in collaboration with the Munich group.

(h) University of Zaragoza

The Zaragoza group is currently doing an underground experiment in the Canfranc tunnel, under the Pyrinees. They have completed a coincidence $2\beta/\gamma$ neutrinoless double-beta decay experiment in Ge, leading to a nuclear excited state and are running for dark matter searches. The Zaragoza group is a member of the International Germanium Experiment (IGEX), with Russian and American groups, which will install 15 kg of enriched germanium in the Canfranc laboratory, as detectors for high-precision double-beta decay.

The groups of CIEMAT, Valencia and Autónoma Barcelona have initiated in 1991 R&D projects for detectors at LHC.

5. Summary

The present situation of the HEP field of research in Spain corresponds to that of a positive evolution although there are still structural problems to be solved.

The definite actions which, since 1983, have contributed essentially to this field are the participation in the CERN programme, the mobilizing plan of Spanish HEP (1984–1988) and the programme of HEP (1988–1991) of the national plan of research in science and technology of the CICYT.

Theoretical HEP has had a continuous positive trend in Spain in the last twenty years and it can be considered, at present, highly competitive at the international level.

Experimental HEP shows a situation of excellence for some Spanish groups, but one needs the consolidation of all groups. The expansion should also continue at an important rate.

Spanish HEP needs a decentralized institute (IFAE) to develop and coordinate the research activities in theoretical physics, experimental physics and instrumentation and development, along the lines proposed to the Spanish authorities.

There is a need to integrate, within the Spanish activity in HEP, more technical aspects into research and development projects of CERN and other laboratories, such as the on-going R&D project for detectors at LHC at present.

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