PHYSICS IN CATALONIA: 1990-1995

We present a short summary of the Report on Physics in Catalonia: 1990-1995, written by the Institut d'Estudis Catalans*, with comments and statistical data concerning the researchers, topics of research, publications, and budget, providing an overview of the research activity in Physics in Catalonia.

Centers, researchers, topics

The researchers in physics in Catalonia are mostly found in three universities that have physics departments: Universitat de Barcelona (250 researchers), Universitat Autònoma de Barcelona (150 researchers), and Universitat Politècnica de Catalunya (115 researchers), and in the CSIC (Consejo Superior de Investigaciones Científicas, Council for Scientific Research) (55 researchers), which has several institutes in Barcelona (mainly Institutes for Microelectronics, Material Sciences, Marine Sciences, and Geology, as far as it concerns the research related to physics). Smaller groups working in physics are also found at the universities of Girona (15 researchers), Rovira i Virgili, in Tarragona and Reus (15 researchers), and the private University Ramon Llull (10 researchers). The number of physicists working in industry is very small.

The total number of researchers is some 400 Ph D and 200 doctoral students (the total population of Catalonia is approximately 6 million people, and therefore this figures mean one researcher in physics per 10 000 inhabitants). These researchers form some 60 research groups, which are sometimes subdivided into smaller subgroups.

Between 1988 and 1994, there was an important increase in the number of researchers, which grew from 400 to 600. This increase is not exclusive to Physics, but it has been due to a continued action of the Spanish goverment –stimulated by the entrance of Spain in the European Community in 1982– to promote research. This increase in the budget and the number of researchers was rather steady between 1980 and 1992, but after this period, the situation has stagnated. Unfortunately, both the budget and the number of scientists

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is still significantly lower in Catalonia (and in general in Spain) than the European average.

The distribution of the number of researchers according to research areas is presented in Table 1. The predominant topic is condensed-matter physics and material sciences, followed by the fields of high-energy physics, statistical physics and optics (high-energy physics has been studied for 30 years in Barcelona, while the latter two fields have undergone rapid growth in recent years). Nuclear physics, astronomy and astrophysics are third in the number of researchers, the latter having the longest tradition. Electronics would be a larger field if researchers involved in technological developments, mainly in the CNM (National Center for Microelectronics, which belongs to the CSIC, and the severals groups of the Polytechnic University of Catalonia) were included. Physics of fluids, atmospheric physics, geophysics, physical oceanography and biophysics are areas with less tradition and with a lower number of researchers.

Table 1. Distribution of physics researchers (Ph D and doctoral students) by research area. Here, electronics includes only basic physical electronics, but not technological applications, which will be considered in a separate report.

Area	*Number of researchers*
Condensed matter	153
High-energy physics	85
Statistical physics	75
Optics	60
Nuclear physics	45
Astronomy and astrophysics	40
Electronics	30
Fluids	25
Oceanography	25
Earth sciences	25
Atmospheric sciences	25
Biophysics	15

Condensed-matter physics and material sciences is the field with the highest number of researchers, however it is dispersed in a dozen of small groups which have few ties between them. The creation of the Institute of Material Sciences of the CSIC in 1991 must be highlighted since it has contributed to development in this field. The foundation of this Institute (together with the Institutes of Microelectronics, and Artificial Intelligence, amongst others) is the result of the decentralization process in Spain since the beginning of the democracy in 1977. The main topics of research are superconductivity and magnetism, electric and electronic properties of superconducting devices, giant magnetoresistance, electronic structure and coupling mechanisms in high Tc superconductors, amorphous materials, thermodynamic transitions in solids, and crystallography.

High-energy physics includes research on elementary particles (approximately 70 researchers) and in gravitation and cosmology (approximately 15 researchers). Elementary particles and fields has a relatively long tradition in Barcelona where it was stimulated by a small group belonging to the Spanish GIFT (Grupo Interuniversitario de Física Teórica) at the end of the 1960s. Some recent governmental programs have complemented the initial theoretical groups with an experimental group. In 1991, the researchers in this field in Catalonia were organized around the IFAE (Institut de Física d'Altes Energies, an organization which stimulates research), to ensure contact between research groups. Theoretical groups work on the physics of heavy quarks and QCD at low energy, phenomenology of electroweak interactions, lattice-gauge theories and other topics. The experimental group participates in the ALEPH (LEP) and ATLAS (in the future LHC) projects in CERN (Centre Européen pour la Recherche Nucléaire, in Geneva). Gravitation and cosmology have a shorter tradition; the main topics are inhomogeneous cosmological models, detection of gravitational waves, quantum gravity, and dissipative effects in cosmological models.

Thermodynamics and statistical physics, together with optics, have experienced a rapid increase in the number of researchers. The groups in statistical mechanics study stochastic processes, hydrodynamics of complex fluids, neural networks, and transport processes; in thermodynamics, nonequilibrium thermodynamics and thermodynamics of phase transitions in solids. The main research topics in optics are lasers, nonlinear optics (higher-harmonic generation, chaos in optical passive systems) and image processing (color pattern recognition), both from a basic and an applied perspective.

Astronomy and astrophysics groups work in stellar formation and evolution, galaxy formation and distribution, solar wind, and gamma-ray astronomy. In 1995 the Institut d'Estudis Espacials de Catalunya was founded to optimize the participation of Catalan researchers in the use of satellites for land, sea and space observation. In nuclear physics there are two main lines: a fundamental line which concentrates on the application of many-body techniques to nuclear matter and quantum liquids; and an applied line which is related to the effects of ionizing radiation, both in medical applications and in environmental sciences.

Applied electronics will be the topic of another report. Here, we have only considered those researchers working on basic electronics, the main topics of which are simulation of nanometric electronic devices, tunnel microscopy, and the application of material sciences to microelectronics.

Atmospheric physics, earth physics and oceanography still have a relatively low number of researchers. The respective main topics of research can be summarized as follows: radar analysis of water distribution in the atmosphere, the study of variations in sea level from satellite measurements, analysis of intense rainfalls in Mediterranean areas (atmospheric physics); crystallography, seismology in the Pyrenees and the Antarctics, variations in the geomagnetic field and its relation with solar activity (geophysics); dynamics of sea surface, coastal dynamics, transport of radioactive wastes, and limnology (physical oceanography). Biophysics has few researchers, in contrast to the long tradition and development of biomedical sciences in Barcelona. The research lines are

biomembranes and the physics of the respiratory system, and furthermore this field is involved in collaborations with engineering groups in the development of artificial biomaterials.

Results: publications, impact, relations with industry

In this section we briefly present the results of research in terms of publications, impact and patents.

Table 2 shows the number of articles on physics in Catalonia (where at least one of the authors belongs to a university in Catalonia) and in Spain (including Catalonia) in the periods 1985-1989 and 1990-1995, according to the data obtained from the Science Citation Index. A large increase in the total number of papers can be observed in both Catalonia and Spain; this is partly due to the previously mentioned increase in the number of researchers. However, the increase in the number of papers is greater than the increase in the number of researchers: a stronger tendency towards publication and a higher productivity due to enhanced relations between groups may account for the additional increase.

Table 2. Total number of physics publications.

	Total physics publications		*% with respect to total world number*	
	1985-1989	1990-1995	1985-1989	1990-1995
Catalonia	918	2 555	0.224	0.390
Spain (including Catalonia)	4 628	12.793	1.128	1.961

Furthermore, it should be noted that this increase concerns not only the total number of papers published in Catalonia and Spain, but also the increase in the number of publications in Catalonia and in Spain is greater than the world average, as it is evidenced in the last two columns of Table 2. Note finally that the relative number of publication Catalonia/Spain is of the 20 %, somewhat higher than the 16 % proportion in the number on inhabitants. This may be explained by the fact that most researchers concentrate in Barcelona and Madrid (and at present also in Valencia, Seville and Santiago de Compostela). The average productivity is approximately 1.2 papers per Ph.D. per year.

In Table 3 we present the number of publications by research areas, in the world (Total), in Spain and in Catalonia, according to the SCI classification of journals. As in Table 2, the increase in the number of publications in Spain and Catalonia is greater than the world average.

Table 4 provides the number of publications in several well-known physics journals, in the above mentioned periods (1985-1989 and 1990-1995). The increase in publications in all the journals mentioned can be clearly noted. The participation in review journals and in letter journals is still significantly lower than that in regular journals. The number of books published is also relatively low: during 1990-1995, eight books in English, two in Spanish and four in Catalan (and, furthermore, a dozen of proceedings) were edited.

Both impact and the number of publications increased. According to SCI, the relative increase of the impact factor was 17% for Spain (and also for Catalonia) between the periods 1981-1985 and 1988-92. This increase was among the highest in the world during this period. Thus, the increase in research activity appears to be not only quantitative but also qualitative.

In Table 5 we show some of the most cited physics papers with at least one author working in a Catalan university. High-energy physics, statistical physics, optics, astrophysics and nuclear physics are the branches related to these papers.

Some findings –such as the magnetic tunnel effect in 1996– have received special international attention in *Nature*,

Table 3. Publications of physics articles by areas according to the SCI classification in the periods 1985-1989 and 1990-1995 (for each period we give the total for the world, the total for Spain and the total for Catalonia).

Area	*1985-1989*			*1990-1995*		
	Total	*Spain*	*Cat*	*Total*	*Spain*	*Cat*
Astronomy and astrophysics	32 906	616	61	48 841	1 653	221
Mechanics	17 455	69	11	33 601	315	63
Atmosphere sciences	16 850	53	6	25 878	217	51
Nuclear technology	35 285	173	26	45 314	554	67
Oceanography	12 967	69	22	17 203	273	113
Optics	26 533	268	37	47 168	824	132
General physics	84 963	1 117	280	108 239	2 406	615
Applied physics	66 017	472	165	116 199	1 434	310
Atomic, molecular and chemical physics	35 656	492	98	48 368	1 138	212
Condensed matter	54 619	827	110	95 295	2 289	379
Fluids and plasmas	8 143	60	7	18 349	383	75
Mathematical physics	8 799	150	34	20 010	557	123
Nuclear physics	21 852	217	28	33 353	767	133
Particles and fields	13 062	291	82	23 845	552	167

Science and *Physics Today*. The organization of international colloquia (for instance, the Sitges Conference on Statistical Mechanics has a long tradition and has been hold every two years since 1969) and more than a dozen international meetings in different areas of physics from 1990-1995 are another indicator of the scientific activity of physicists in Catalonia.

Relations with industry are not yet sufficiently developed. Indeed, though Catalonia is a heavily industralized area, its industry is mainly chemical, textile, pharmaceutical and metallurgical, and is not directly connected with physics. Moreover, the electronic industry, whose presence in Catalonia has increased considerably, belongs to multinational firms

Table 4. Number of physics publications in several high-impact journals. The ratios S/W and C/W indicate the proportion of the number of publications in Spain (S) , and respectively in Catalonia(C), to that of the total number in the world (W)

Journal	*Impact*	*1985-1989*		*1990-1995*		*1985-1989*		*1990-1995*	
	1993	*Spain*	*Cat*	*Spain*	*Cat*	*S/W (%)*	*C/W (0/00)*	*S/M (%)*	*C/W (0/00)*
Phys.Rev.Lett	7.11	56	10	148	22	0.64	1.14	1.11	1.65
Nucl.Phys.B	4.54	49	9	225	45	1.67	3.06	4.22	8.44
J.Chem.Phys.(*)	3.62	47	6	80	12	1.23	1.56	1.78	2.67
Appl.Phys.Lett.	3.50	22	4	130	16	0.32	0.16	1.00	1.23
Astrophys.J.	3.39	84	11	296	58	1.23	1.61	2.69	5.26
Phys.Rev.B	3.16	234	22	701	148	1.50	1.41	2.67	5.64
Phys.Lett.B	3.08	263	40	670	194	3.27	4.97	6.59	19.08
Phys.Rev.D	3.01	128	33	165	54	2.52	6.49	2.19	7.18
Europhys.Lett.	2.78	34	4	93	25	2.34	2.76	3.48	9.35
Physica C	2.30	36	13	137	58	1.26	4.56	1.70	7.18
Phys.Rev.A	2.27	145	37	312	54	1.97	5.03	3.07	5.31
Phys.Rev.E (*)	—	0	0	125	31	—	—	4.91	12.18
Z.Phys.C	2.22	96	14	128	34	6.17	9.00	6.78	18.00
Astron.Astrophys.	2.12	241	16	518	47	5.14	3.41	7.56	6.86
J.Phys.A	2.06	60	8	154	31	1.83	2.44	3.43	6.91
Phys.Rev.C	1.97	28	0	83	13	0.82	0.00	1.82	2.86
J.Appl.Phys.	1.78	80	13	306	65	0.75	1.22	1.89	4.01
Nucl.Phys.A	1.75	77	10	168	22	2.52	3.27	3.94	5.16
Class.Quant.Grav.	1.49	14	4	66	25	1.77	5.04	4.36	16.52
Mod.Phys.Lett.A	1.40	0	0	31	19	0	0	4.66	2.86
Physica A	1.18	39	12	67	26	2.98	9.16	2.50	9.70
Nucl.Instr.Meth.B	1.16	25	3	132	19	0.58	0.69	2.01	2.90
Phys.Lett.A	1.15	87	15	170	39	2.05	3.53	2.83	6.50
Opt.Commun.	1.11	42	13	125	33	2.07	6.40	3.33	8.79
Appl.Opt.	0.91	50	1	152	20	1.12	0.22	2.60	3.42
J.Math.Phys.	0.90	76	16	98	15	3.60	7.59	3.55	5.43

Note that in J. Chem. Phys. we have included only the papers written by researchers from Physics departments, but not those written by researchers from Chemistry departments.

Table 5. Most cited physics papers with at least one of the authors belonging to a university in Catalonia (until June 1996).

Reference	*Area*	*Citations*
– Phys. Rev. A 26 (1982) 1589	Statistical physics	255
– Phys. Lett B 231 (1989) 519	High energy	230
– Phys. Rep. 5 (1979) 267	Nuclear physics	216
– Rep. Progr. Phys. 51 (1988) 1105	Statistical physics	215
– Z. Phys. C 52 (1991) 13	High energy	210
– Phys. Rev. Lett. 51 (1983) 1022	High energy	195
– Physics Letters B 41 (1972) 609	High energy	167
– Nuclear Physics B 272 (1986) 413	High energy	160
– Nuovo Cimento B 36 (1976) 5	Optics	125
– Nuovo Cimento B 53 (1979) 1	Optics	122
– Nuclear Physics B 183 (1981) 384	High energy	120
– Phys. Lett. B 278 (1992) 457	High energy	115
– Nucl. Phys. B 384 (1992) 3	Theoretical physics	115
– Lettere al Nuovo Cimento 17 (1976) 333	Optics	115
– Astron Astrophys 46 (1976) 229	Astrophysics	115
– J.Phys.A 13 (1980) 275	Statistical physics	101

which base their research in laboratories in other countries. Thus, almost all physics research is done in universities rather than in industry. Only ten patents (seven in material sciences, and three in optics) were obtained by researchers in physics between 1990-1995. The physics areas with most relations with industry are material sciences, environmetal physics, optics and microelectronics. Moreover, contact between university departments and industries has increased in the last ten years. During 1990-1995, there were 90 collaboration projects. Electrical, optical and metallurgical industries, as well as public administrations (Ministries of Environment, Industry and Energy, Cartographical Institute, ...) have most relations with these departments.

Financial resources

Another essential variable in research is the availability of financial resources. Traditionally, the funding of research in Spain has suffered from two drawbacks: a small percentage of the gross national product (in 1992, it was half the average percentage of the European Union, whereas in 1980 it was less than a quarter of the European average) and a small participation of private (for instance, industrial) funding.

Research in Catalonia is supported by funds from the Spanish Government, the Catalan Government and from the programs of the European Union (SCIENCE, ESPRIT, RACE, BRITE-EURAM, MAST, CLIMATE, ...). The total amount dedicated to physics research in the six years examined (1990-1995) was approximately 4100 million pesetas (approximately 24.3 million Euros). This amount does not include the salaries of researchers, which are usually paid by the Spanish Ministry of Education, though the universities depend on the Generalitat of Catalonia (the Catalan autonomous government). The quantities from the different sources are presented in Table 6.

Table 6. Financial support for physics research in Catalonia (1990-1995) broken down into the different funding sources (in million of Euros).

Spanish Government	12.8
Catalan Government	2.8
European Union	5.1
Industry	3.2
Universities and others	0.4
Total:	24.3

In summary, the number of researchers and the total funds for research approximately doubled between 1980-1992 in Catalonia (as well as in Spain). At present, the situation is stagnant, the universities are overstaffed, and it is difficult for young researchers to get a permanent position. The community of physicists is close to a sufficient critical mass for the first time in the history of Catalonia, where physics (in contrast to biomedical sciences) does not have a strong tradition, but this is not well known by the general public because of an insufficient effort in the popularization of science. The physicists have one of the lowest indices of association in Europe (only a small proportion of them belong to Catalan or Spanish Societies for Physics).

Physicists are an active and enthusiastic community, but their activity is mainly academic. It is believed that stronger ties with industries are necessary; however, these are difficult to establish owing to the lack of expenditure of industries on physics-related research. However, it should be said that these relations are steadily but slowly improving.

Address for correspondence: Institut d'Estudis Catalans, Carme 47, 08001 Barcelona, Catalonia, Spain.

David Jou
Universitat Autònoma de Barcelona
and
Institut d'Estudis Catalans, Barcelona