TIARA-REP-WP5-2012-006

Test Infrastructure and Accelerator Research Area

Status Report

Education and Training Survey Report

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23 April 2012

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Test Infrastructure and Accelerator Research Area

TIARA WP5
Deliverable 5.1 - ETR
Education and Training Survey Report

25 June 2012

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Content

EXECUTIVE SUMMARY

- 88 institutes from Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom completed the TIARA survey on education and training in accelerator science. A total of 3060 personnel at these institutes are engaged in accelerator science activities.
- 75 institutes (85%) provide training of some kind in some aspects of accelerator science to their own students or staff. 195 personnel are involved in providing training. 49% of institutes provide training to undergraduates, 64% to master's students, 70% to PhD students; 44% to postdoctoral fellows, and 24% to staff.
- 83 institutes (94%) send people for training to accelerator schools and workshops, and 30 institutes (34%) have staff members who provide training at the schools and workshops.
- 1371 people per annum currently receive training, which comprises: 34% undergraduates, 26% master's students, 14% PhD students, 7% postdoctoral fellows and 17% staff.
- 55 institutes reported the number of formal training hours provided per annum. Currently a total of 62,777 training hours per annum are given: 46% to master's students, 27% to undergraduates, 13% to PhD students, 10% to staff and 3% to postdoctoral fellows.
- Accelerator science typically represents a small fraction (below 30%) of total formal training time for undergraduate, master's and PhD students, and typically a larger fraction for postdoctoral fellows and staff. There are only a handful of dedicated full-time formal training programmes in accelerator science.
- The majority of trainees receive training in five main areas: particle sources, accelerating structures, magnets, beam dynamics, instrumentation and controls. More than 50% of institutes offer training in one or more of these areas.
- 53% of institutes that provide formal training to undergraduates offer examinations on accelerator science coursework; the corresponding figure for master's students is 55%, and for PhD students it is 45%.
- 35% of institutes that train undergraduates participate in ECTS; the corresponding figure for master's students is 46%.
- More than 339 people each year receive training by attending international and/or national accelerator schools. The most attended international schools are the CERN Accelerator Schools (CAS), the Joint Universities Accelerator School (JUAS), the U.S. particle accelerator Schools (USPAS) and the Linear Collider School.
- For the available dataset, although a majority of each category of trainee goes on to pursue work in the academic/research sector, 28% of the undergraduates, 31% of the master's students, 34% of the PhD students, and 38% of the postdoctoral fellows go on to find employment in the manufacturing, medical, financial and services sectors.

1. INTRODUCTION

A survey of the provision of training in accelerator science was performed between September 2011 and January 2012. Approximately 100 institutes were contacted in the TIARA member states: Denmark, Finland, France, Germany, Italy, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom. In addition to those from the TIARA member states responses were received from several institutes in Greece and the Netherlands. A total of 88 institutes provided data for the survey; the institutes and respective contact-persons are listed in Appendix 1.

A web-based survey was conducted. A representative of each institute contacted was requested to provide responses to straightforward questions concerning training in accelerator science at her/his institute. Information was requested about the institute and its staff, whether training is provided, and if so the type of training and the recipients of the training. A text version of the survey is given in Appendix 2.

In each country the survey was targeted primarily at those institutes known to be engaged in accelerator science activities, but an attempt was made also to advertise the survey more widely so as to allow the potential for capturing a more complete picture. Given the very high response rate, and the fact that in each country essentially all institutes known to be engaged in accelerator science responded, we believe that we have captured a comprehensive and almost ‘complete’ dataset on education and training in accelerator science among the countries surveyed.

2. INSTITUTES AND PERSONNEL

The number of personnel (defined as physicists and engineers) engaged in accelerator science activities, summed over the responding institutes, is shown by country in Figure 2.1. Several countries have large national accelerator-related laboratories, most notably France, Germany and Switzerland (which, for these purposes is defined to include CERN). A total of 3060 personnel are engaged in accelerator science activities, of which 195 are involved in providing training.

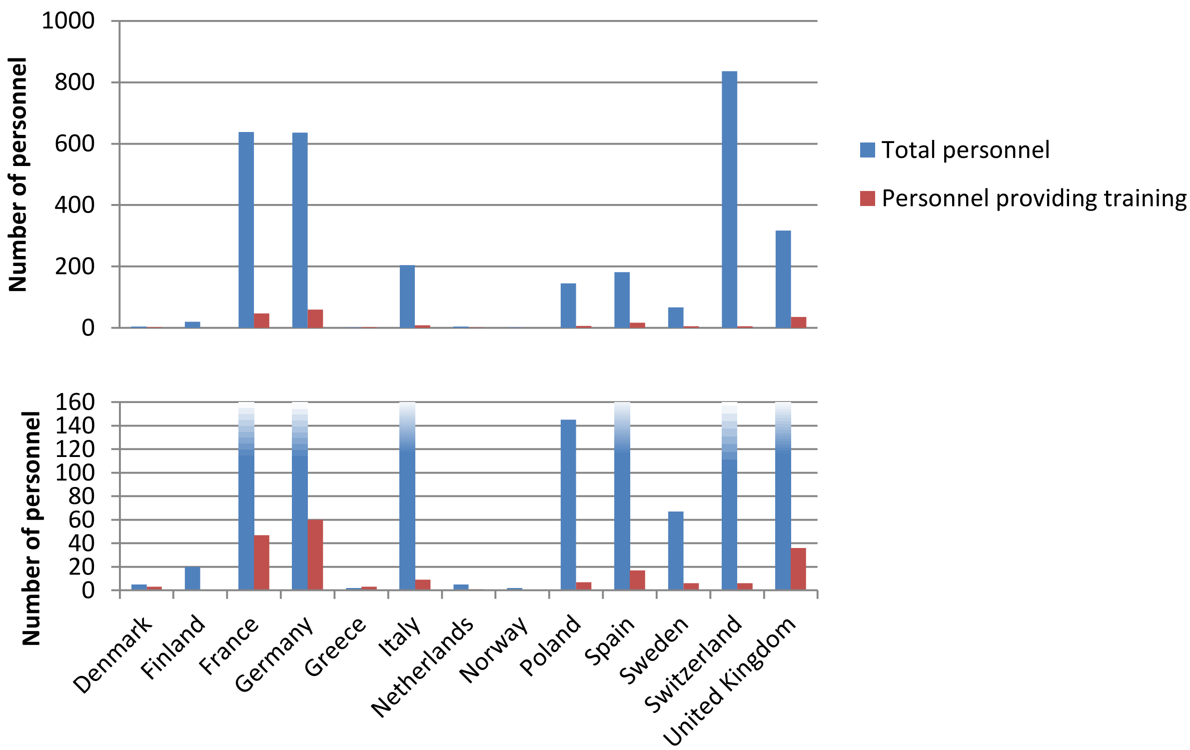


Figure 2.1: Top: total number (blue) of personnel (physicists and engineers) engaged in accelerator science activities by country. For each country the number of personnel engaged in training in accelerator science is also shown (red). Bottom: a 'zoom' into the region below 160 personnel per country.

The distribution of the number of accelerator science personnel per institute is shown in Figure 2.2. A typical institute has fewer than 20 such personnel, but the number of personnel ranges from a handful (typically universities) to several hundred (the large national/international laboratories).

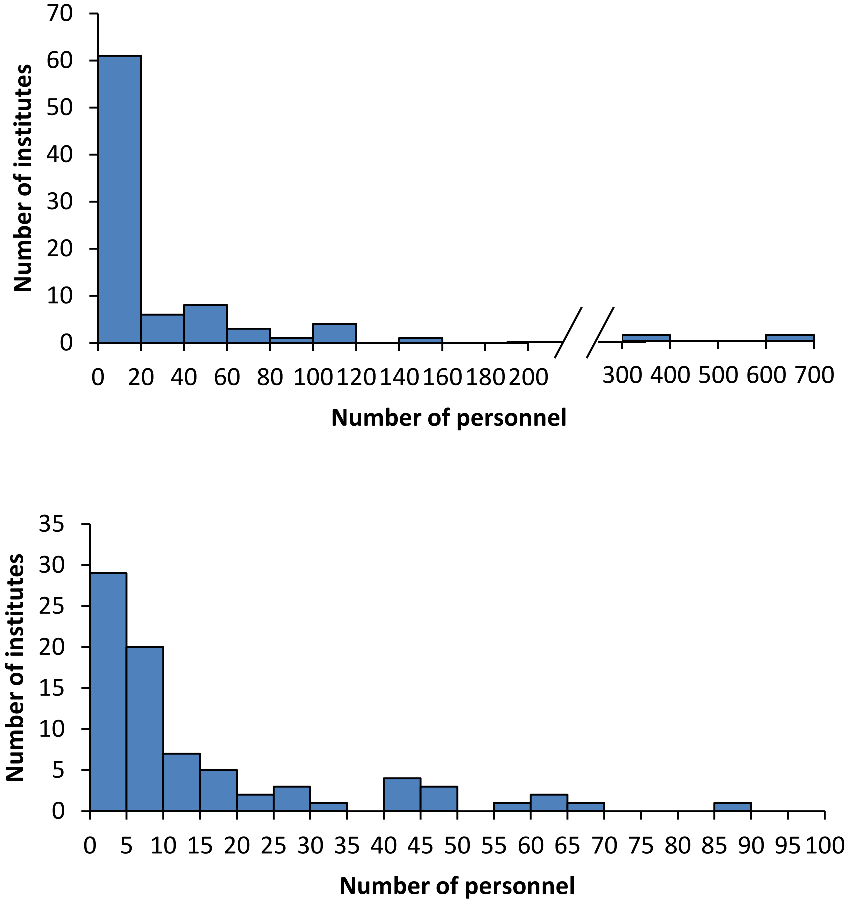


Figure 2.2: Top: distribution of the total number of accelerator science personnel per institute. Note the break in scale at 200 personnel. Bottom: a 'zoom' into the distribution for those institutes with fewer than 100 personnel.

3. INSTITUTES' PROVISION OF TRAINING

Of the 88 responding institutes, 75 replied affirmatively that they provide training of some kind in some aspects of accelerator science. This should therefore be regarded as a firm lower bound on the number of institutes engaged actively in providing training in this discipline among the countries surveyed. The number per country is shown in Figure 3.1. Of the thirteen institutes that do not currently offer training, three indicated plans to do so in future, and nine of the remaining ten indicated a desire to do so in future. Also, all of these thirteen institutes do send people for training at accelerator schools and workshops, which are a key vehicle for provision of 'centralised' training to people drawn from many institutes. For example, in 2011 a total of 83 institutes (94%) sent people for training to accelerator schools and workshops, and 30 institutes (34%) have staff members who *provide* training at the accelerator schools. The percentages of institutes participating in, and providing training at, schools and workshops are shown by country in Figure 3.2. Accelerator schools will be discussed further in Section 7.

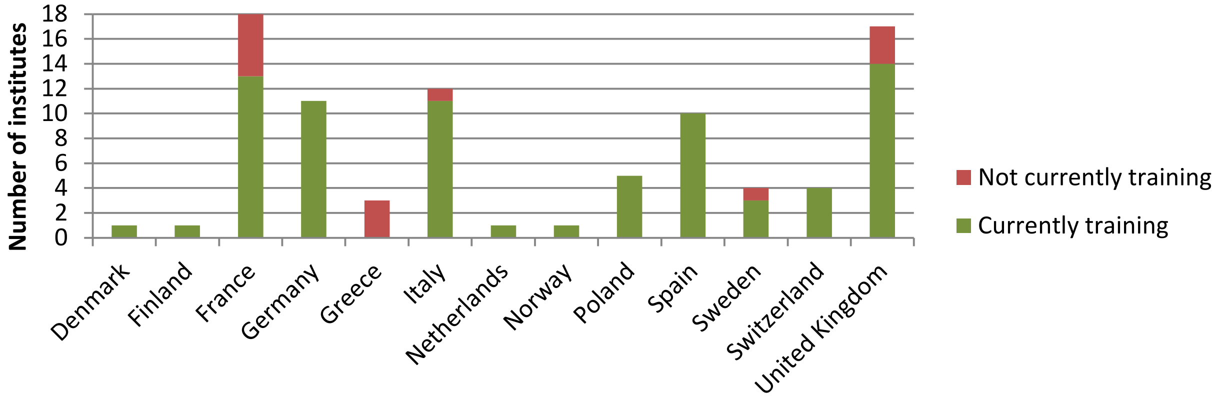


Figure 3.1: The number of institutes per country that responded to the survey. Those institutes that currently offer training in accelerator science are represented in green, and those that do not are represented in red.

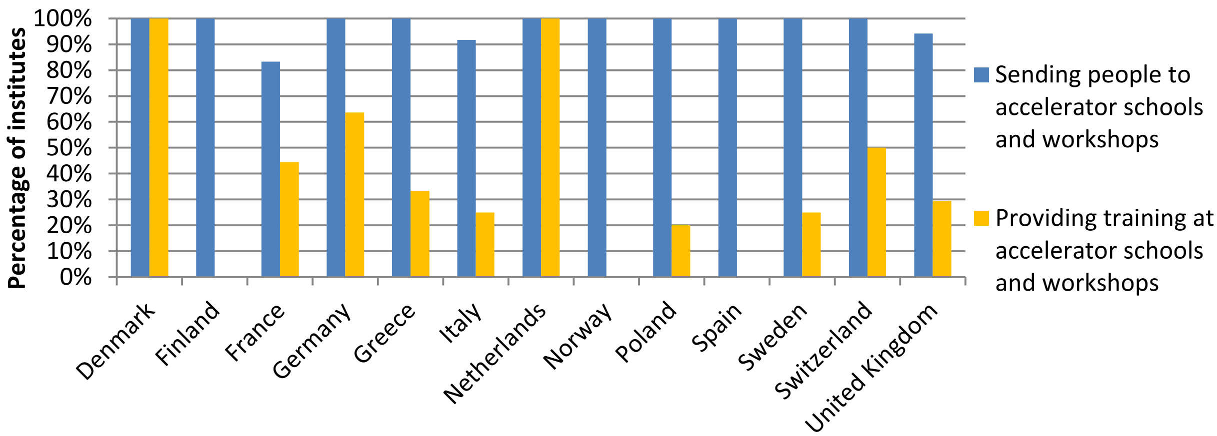


Figure 3.2: The percentage of responding institutes in each country that send people for training to accelerator schools and workshops (blue), and that provide training at accelerator schools and workshops (orange).

The percentage of responding institutes that currently offer training to each category of trainee (undergraduate, master's, PhD, postdoctoral fellow, staff) is shown by country in Figure 3.3. Provision of training is most common at the master's and PhD level, though many institutes provide training at the undergraduate level, as well as to postdoctoral fellows and staff. Overall, 49% of institutes provide training to undergraduates, 64% to master's students, 70% to PhD students; 44% to postdoctoral fellows, and 24% to staff.

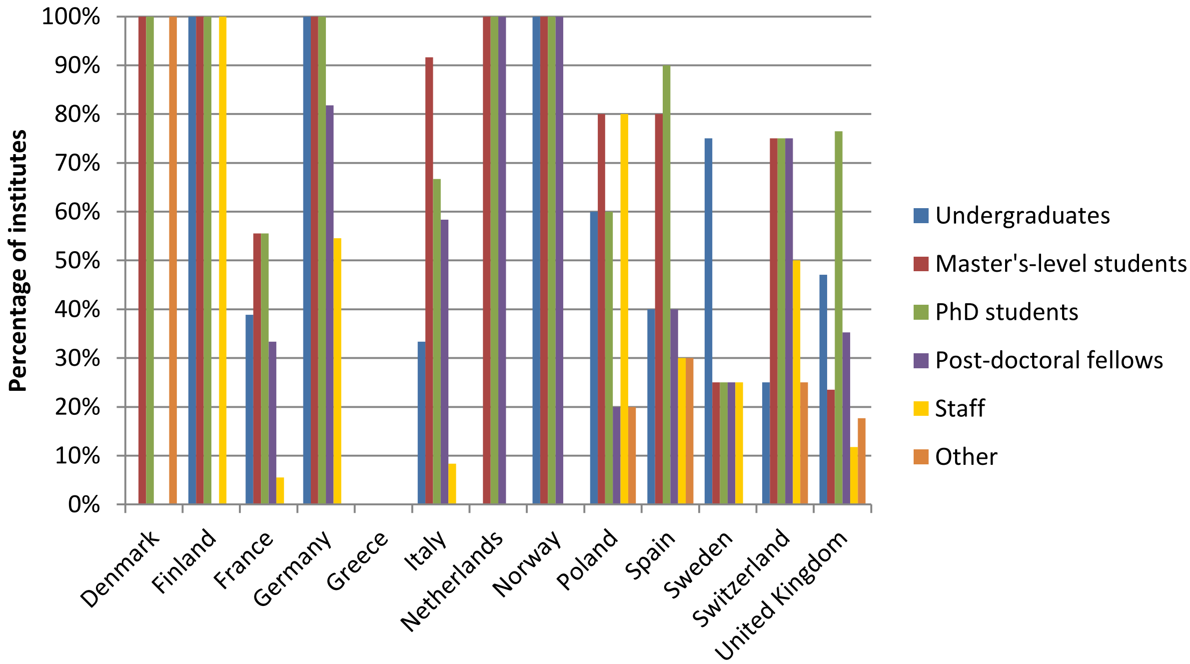


Figure 3.3: The percentage of responding institutes in each country that currently offer training to each category of trainee.

4. TRAINEE NUMBERS

Integrated over all institutions, the number of people receiving any training in accelerator science is shown, by trainee type, in Figure 4.1. For example, in 2011, 1371 people received training, which comprised: 466 undergraduates (34%), 356 master's students (26%), 198 PhD students (14%), 95 postdoctoral fellows (7%), 230 staff (17%) and 26 others (2%); these data are represented in Figure 4.2. The category 'others' includes, for example, visiting overseas students and industry employees. The numbers did not change dramatically during the period 2005–2011, though there is evidence of a modest increase in the numbers of undergraduates (+40%), master's students (+31%), PhD students (+26%) and post-doctoral fellows (+38%) that were trained between 2005 and 2011.

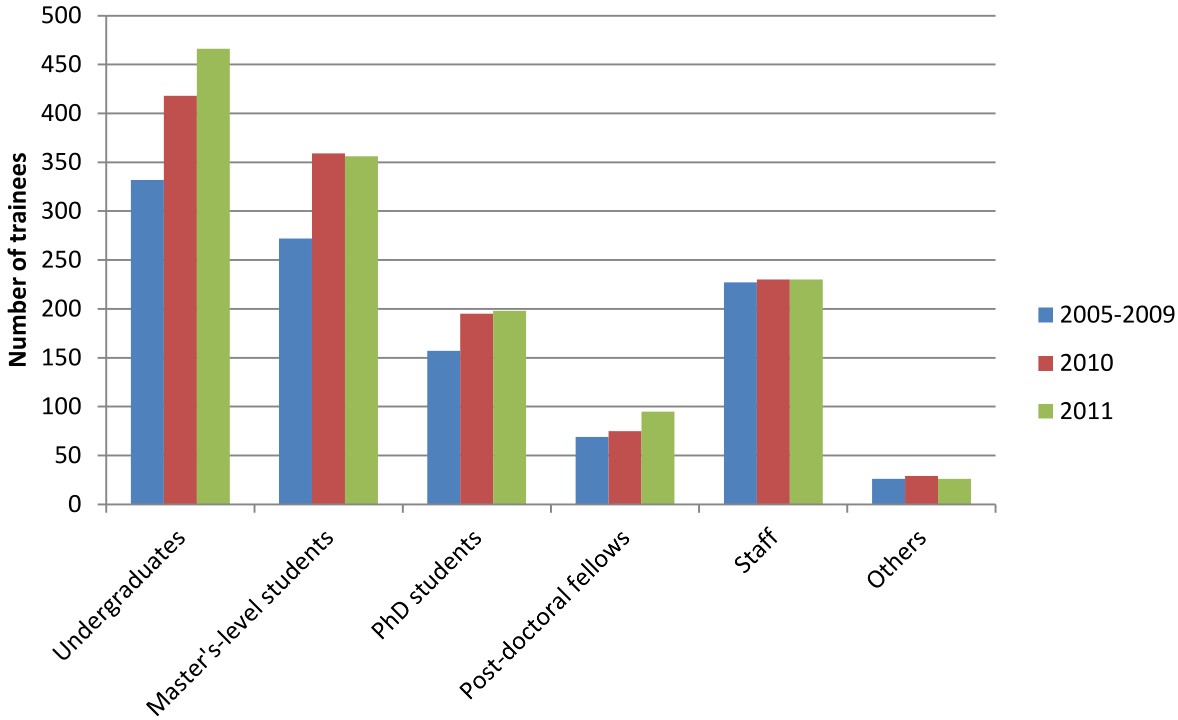


Figure 4.1: The total number of accelerator science trainees, by trainee type. Data are shown for the academic year 2011 (green), 2010 (red) and the average over the 5 years 2005-2009 (blue).

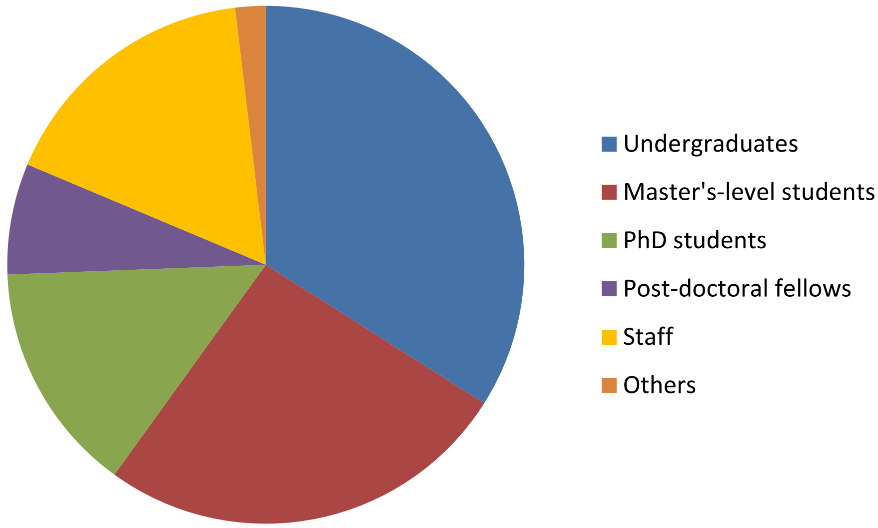


Figure 4.2: The relative proportions of trainee types in academic year 2011.

The total number of trainees in each country is shown in Figure 4.3. Clearly there is a large spread in numbers between countries that partly reflects the spread in populations. In order to account for the population differences, the number of trainees for the year 2011 was normalised by the population of each country; this is shown in Figure 4.4. With this normalisation, the spread in accelerator science student numbers between countries is much reduced, though there are still large differences between the relative populations being trained in different countries. An alternative normalisation, by the total number of accelerator science personnel in each country (Figure 2.1), is shown in Figure 4.5. This normalisation tends to enhance the visibility of countries with smaller staff numbers. An analysis of the situation in each country is provided in Appendix 3.

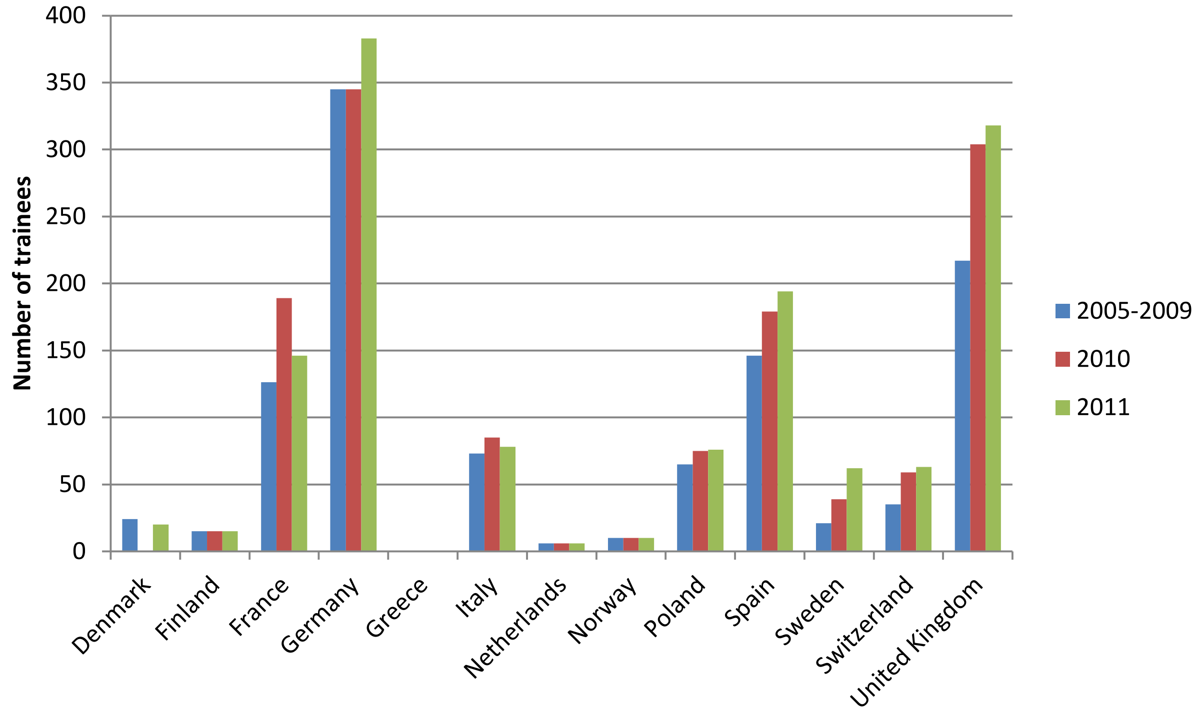


Figure 4.3: The total number of trainees in each country. Data are shown for the academic year 2011 (green), 2010 (red) and the average per year over the 5 years 2005-2009 (blue).

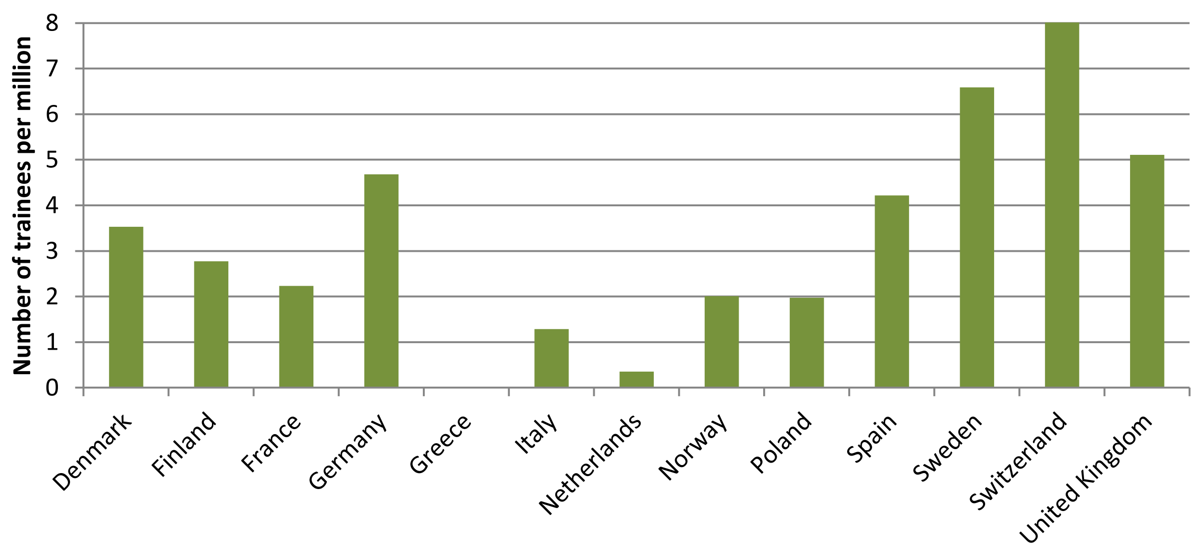


Figure 4.4: The total number of trainees in each country (for academic year 2011) normalised by the population of that country, expressed in trainees per million.

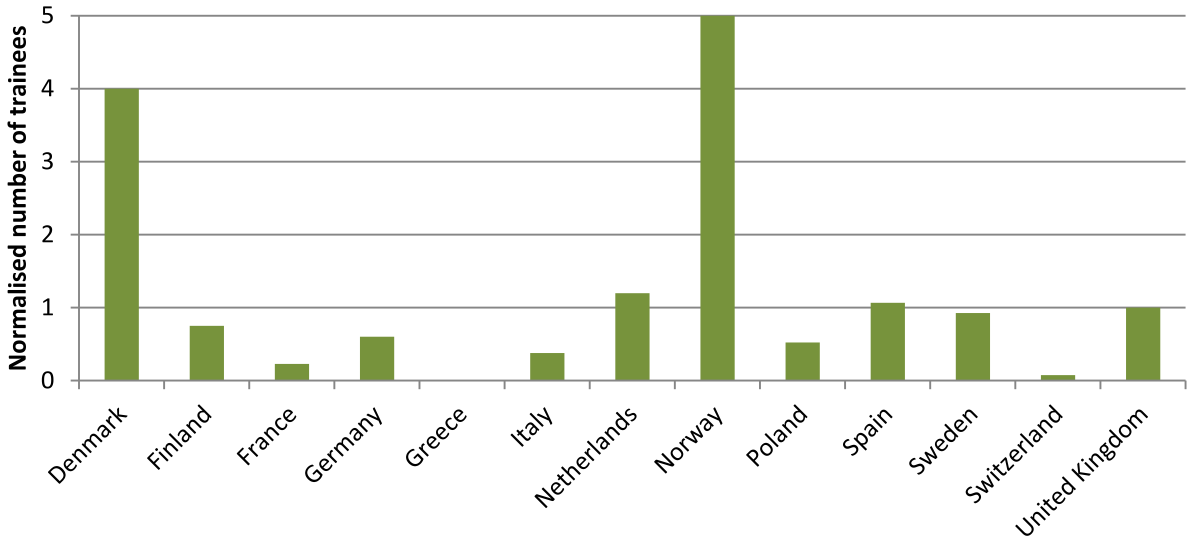


Figure 4.5: The total number of trainees in each country (for academic year 2011) normalised by the respective number of accelerator science personnel.

For each country, the percentage of the accelerator science population of each trainee type (for academic year 2011 as an example) is represented in Figure 4.6. A comparison between countries of the six different trainee types is shown in figure 4.7. Because the situation is different in each country, a brief discussion of student numbers and country-specific issues is given in Appendix 3.

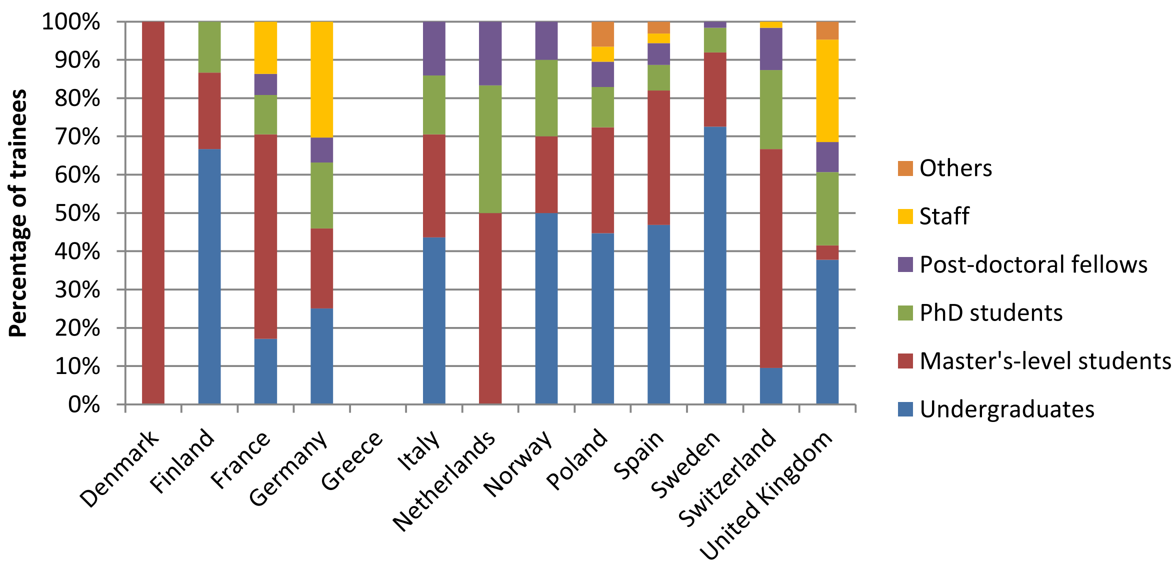


Figure 4.6: Representation of the percentage of trainees in each country (for academic year 2011) that is of each type.

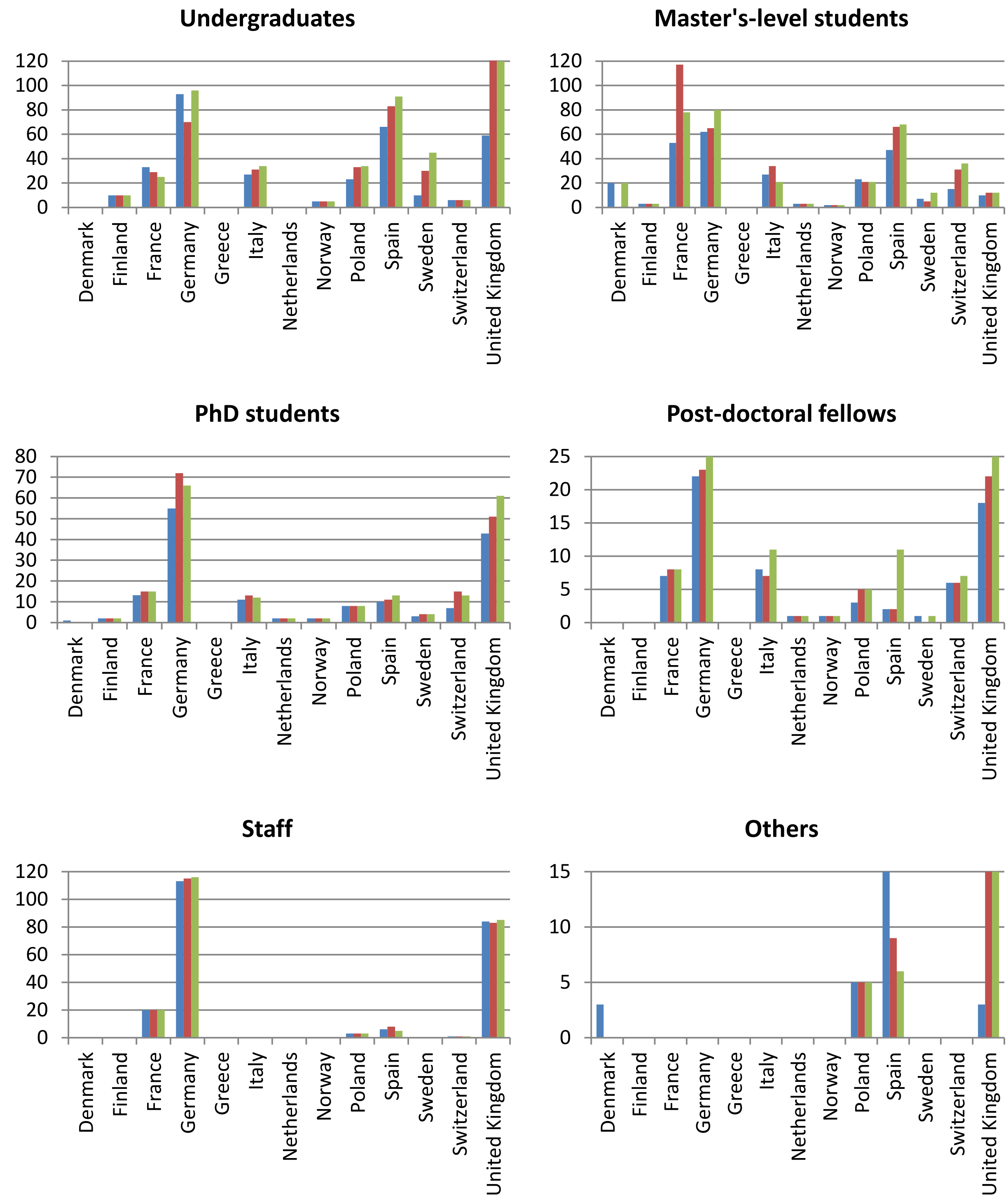


Figure 4.7: For each country, the total number of trainees in each category. Data are shown for the academic year 2011 (green), 2010 (red) and the average per year over the 5 years 2005-2009 (blue). (a) Undergraduates; (b) master's students; (c) PhD students; (d) postdoctoral fellows; (e) staff; (f) others.

5. FORMAL TRAINING TIME

55 of the 75 institutes that provide training reported the number of formal training hours provided. Formal training is defined to be instructive training provided in a lecture, class or tutorial environment. The distribution of the number of formal training hours is shown in Figure 5.1; training hours are shown separately for the different categories of students. For any student type the amount of training varies considerably, from between a few hours to hundreds of hours, though the majority of institutions provide of order a few tens of hours of such training. 11 institutes provide more than 100 hours of training to master's students:

1. University of Manchester
2. Universitat Autónoma de Barcelona
3. IKP, TU Darmstadt
4. Institut für Kernphysik der Johannes Gutenberg-Universität Mainz
5. University Paris-Sud
6. IKP, FZ Jülich
7. DELTA, TU Dortmund
8. INFN - Milano & Università degli Studi di Milano
9. EPFL: Swiss Institute of Technology Lausanne
10. Università di Roma "La Sapienza"
11. Hamburg University

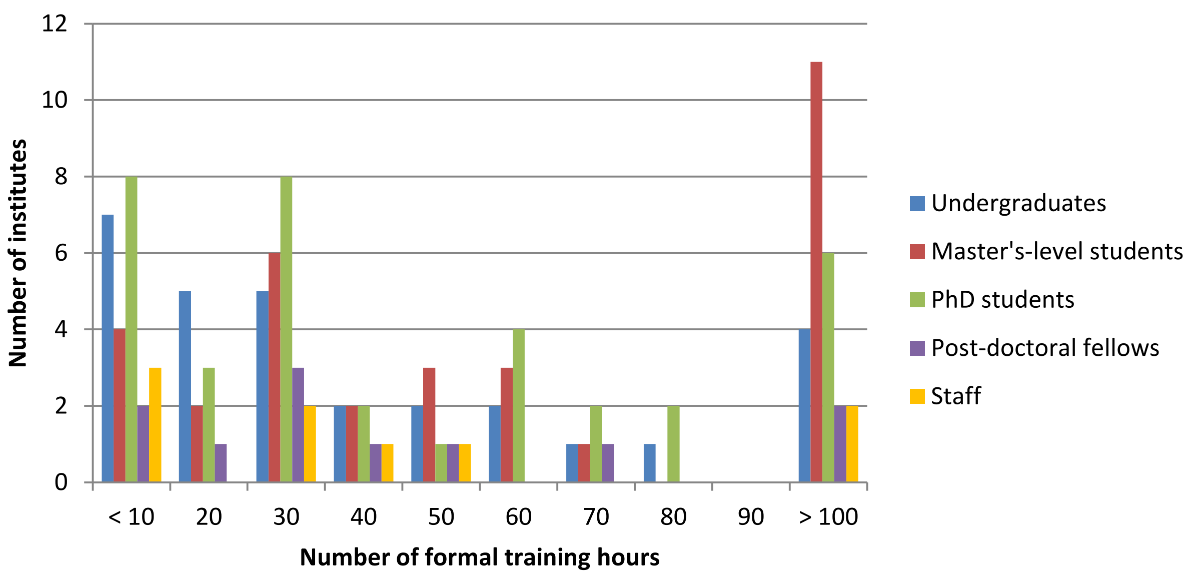


Figure 5.1: Distribution of the number of formal training hours provided. Data are shown for separate categories of trainee. Zeroes have not been displayed. The bin width is 10 hours.

The total number of trainees (for academic year 2011 as an example) vs. number of formal training hours is shown in Figure 5.2; 1177 students received any formal training, of which 412 (35%) were undergraduates, 324 (28%) were master's students, 151 (13%) were PhD students, 50 (4%) were post-doctoral fellows and 218 (19%) were staff members. 841 (181) students received more than 10 (100) hours of formal training, respectively. The number receiving more than 10 hours of training is shown by trainee type and academic year in Figure 5.3.

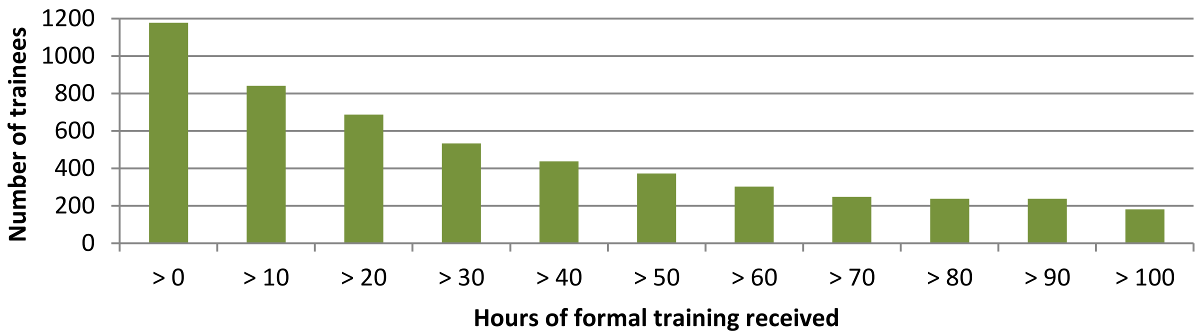


Figure 5.2: Number of trainees (academic year 2011) vs. hours of formal training in accelerator science.

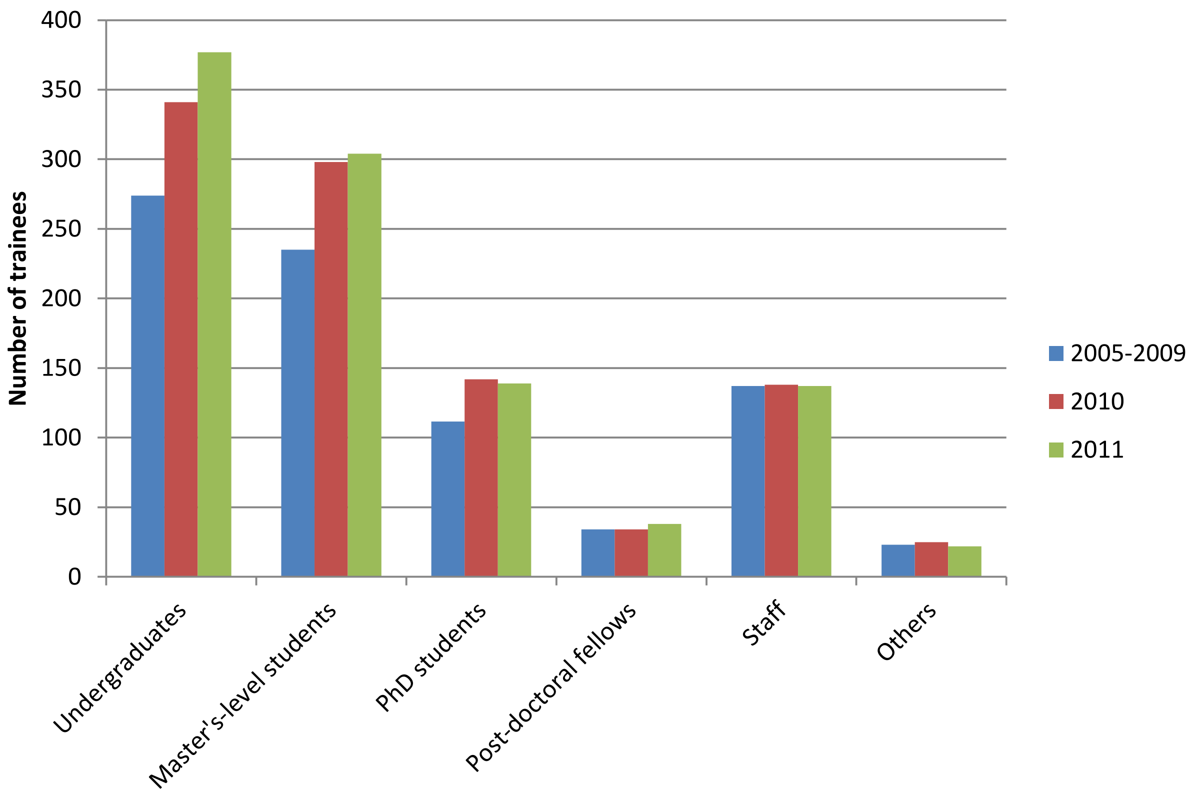


Figure 5.3: The total number of trainees who received at least 10 hours of formal training in accelerator science, by trainee type. Data are shown for the academic year 2011 (green), 2010 (red) and the average per year over the 5 years 2005-2009 (blue).

The total number of reported formal training hours per annum currently provided is shown by country in Figure 5.4. Note that, since 20 institutes did not provide data on the number of hours, these numbers represent lower bounds, and the real totals will be larger. In some countries (France, Germany, Italy, Spain, Switzerland) the dominant number of training hours is provided to master's students; in the UK the largest number of hours is provided to PhD students. The total number of reported training hours by country is shown in Figure 5.5, and by category of trainee in Figure 5.6. Overall, of the 62,777 total reported training hours provided per annum, 46% are currently given to master's students, 27% to undergraduates, 13% to PhD students, 10% to staff and 3% to post-doctoral fellows.

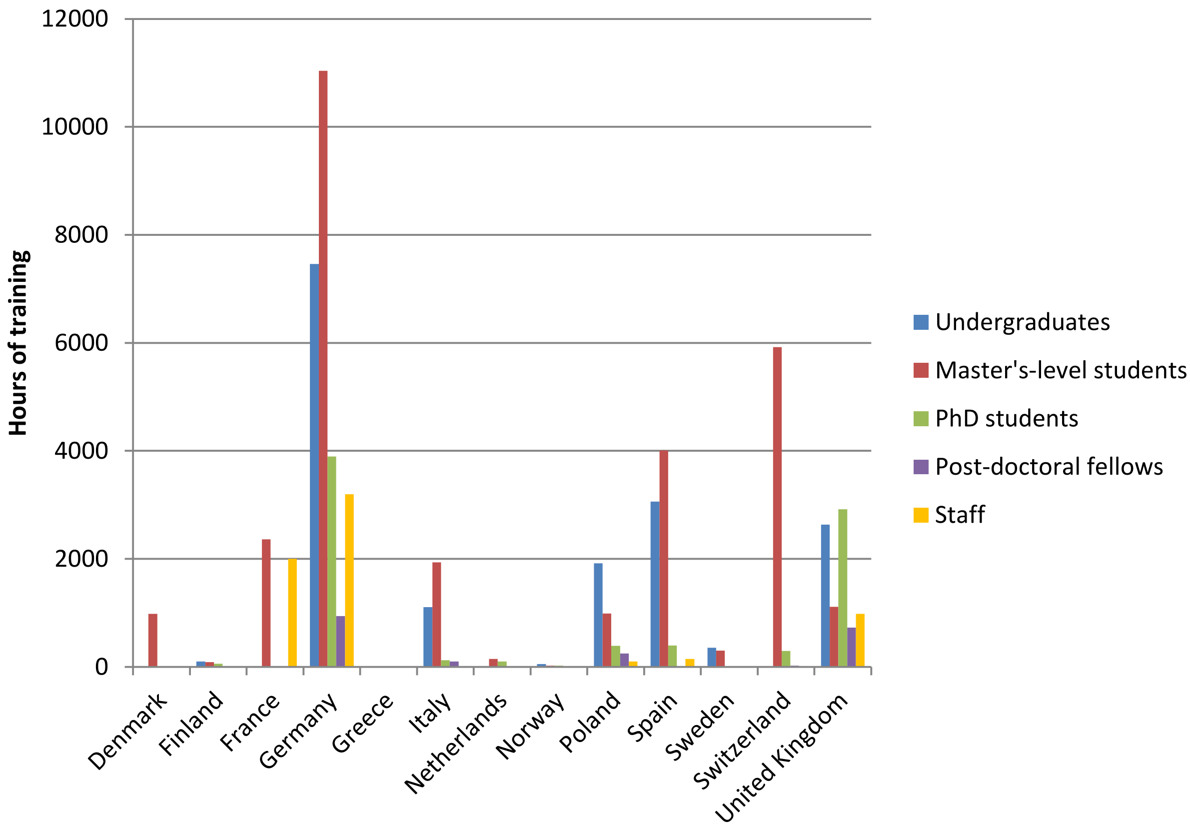


Figure 5.4: The total number of accelerator science formal training hours reported by institutes that offer training to each category of trainee, by country.

The distribution of the percentage of formal training time that is spent on accelerator science is shown by category of trainee in Figure 5.7. Accelerator science typically represents a small fraction (below 30%) of total training time, which reflects the fact that it is often a small component of a more general training in physics and/or engineering disciplines. This is particularly evident for undergraduate, master's and PhD students. For postdoctoral fellows and staff a noticeably higher fraction of their total training time is spent on accelerator science, reflecting the fact that they are professionals in this discipline.

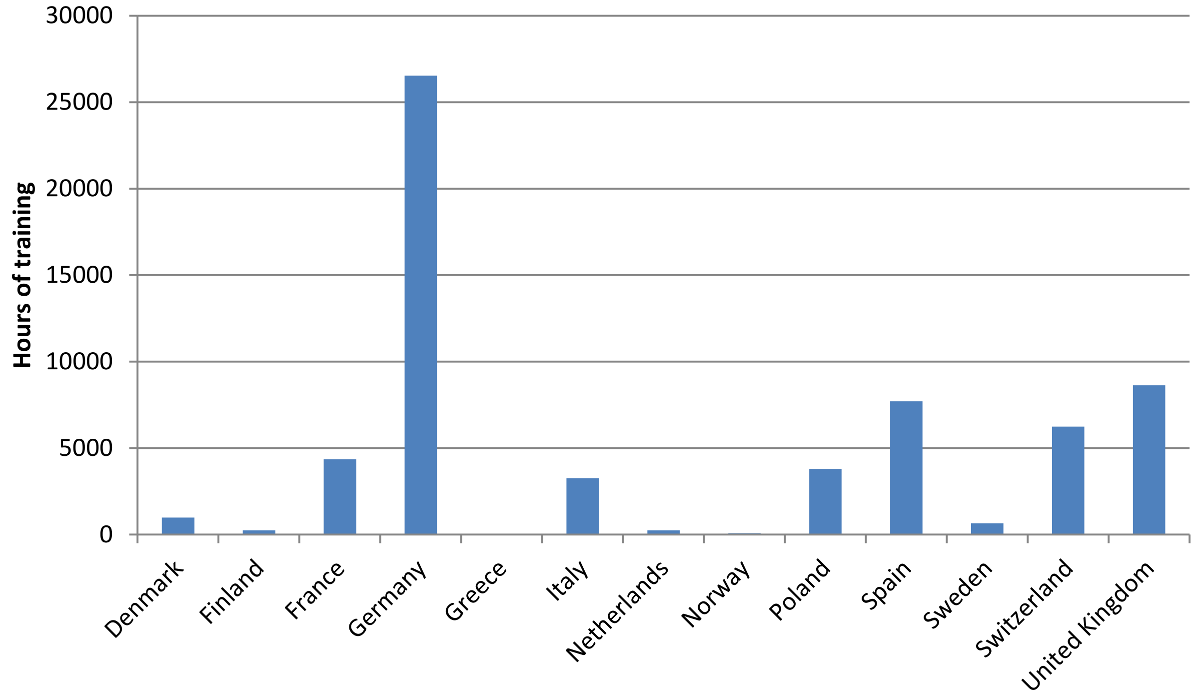


Figure 5.5: Total reported formal training hours spent on accelerator science per country.

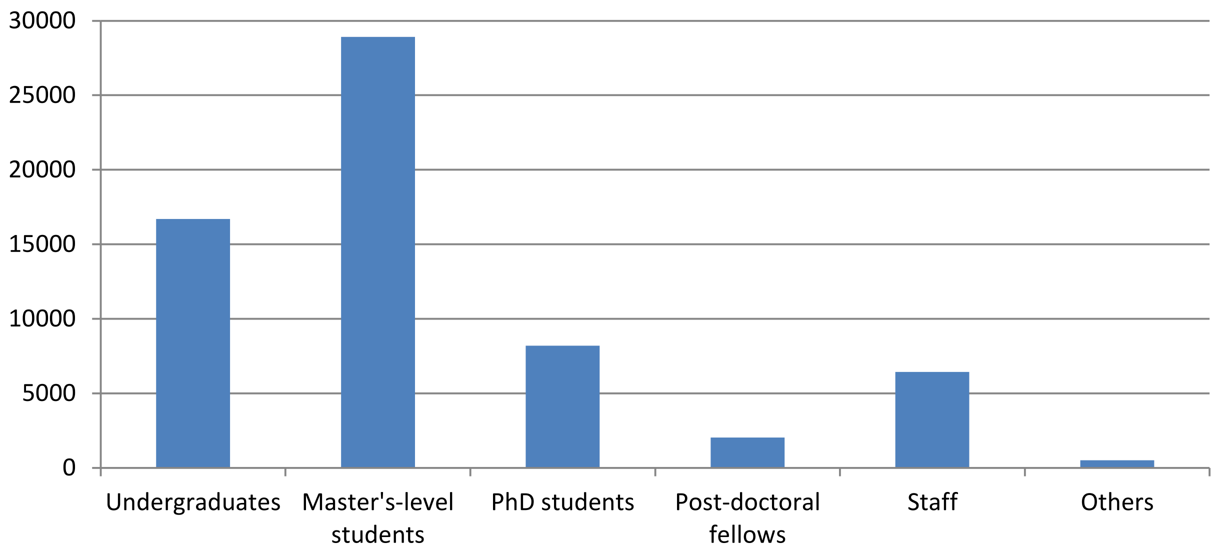


Figure 5.6: Total reported formal training hours spent on accelerator science by category of trainee.

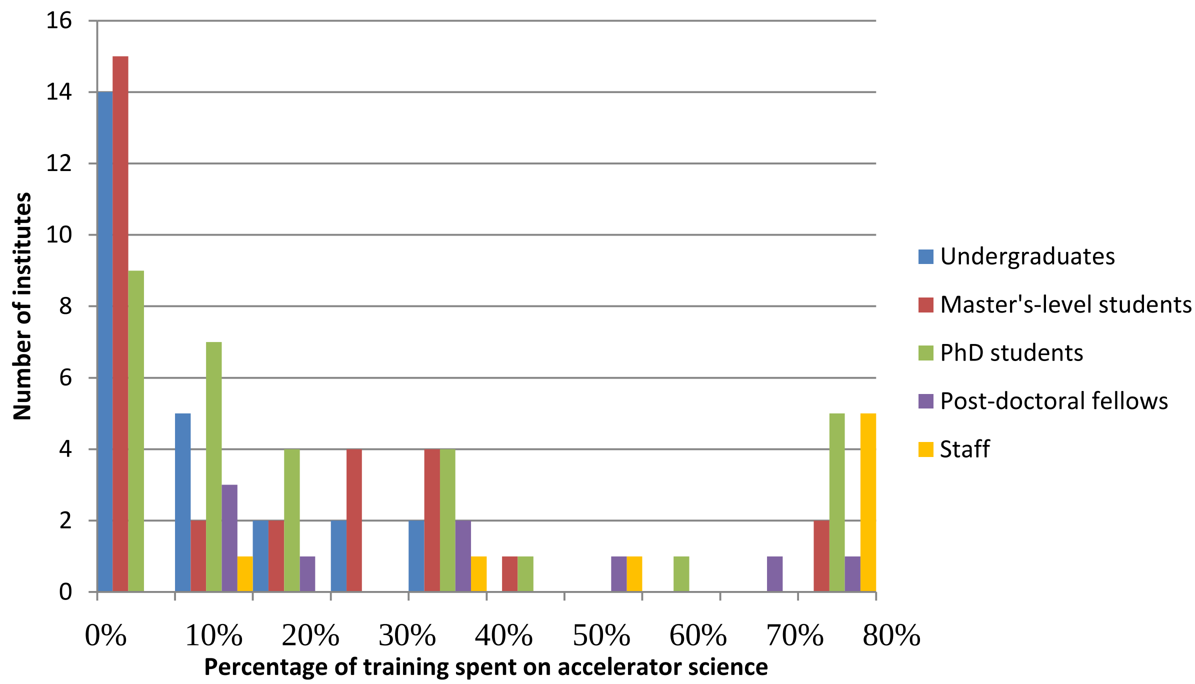


Figure 5.7: Distribution of the percentage of formal training time that is spent on accelerator science, reported by institutes that offer formal training to each category of trainee.

6. TRAINING SUBJECTS

For the 72 institutes that reported on training areas provided, the number of trainees by subject area is shown in Figure 6.1. The majority of trainees receive training in the five areas:

- particle sources
- accelerating structures
- magnets
- beam dynamics
- instrumentation and controls

Figure 6.2 shows the percentage of institutes that offer training in each subject area; more than 50% of institutes offer training in one or more the five main areas listed above. In addition, a significant fraction of institutes offer training in laser systems and cryogenics for accelerators.

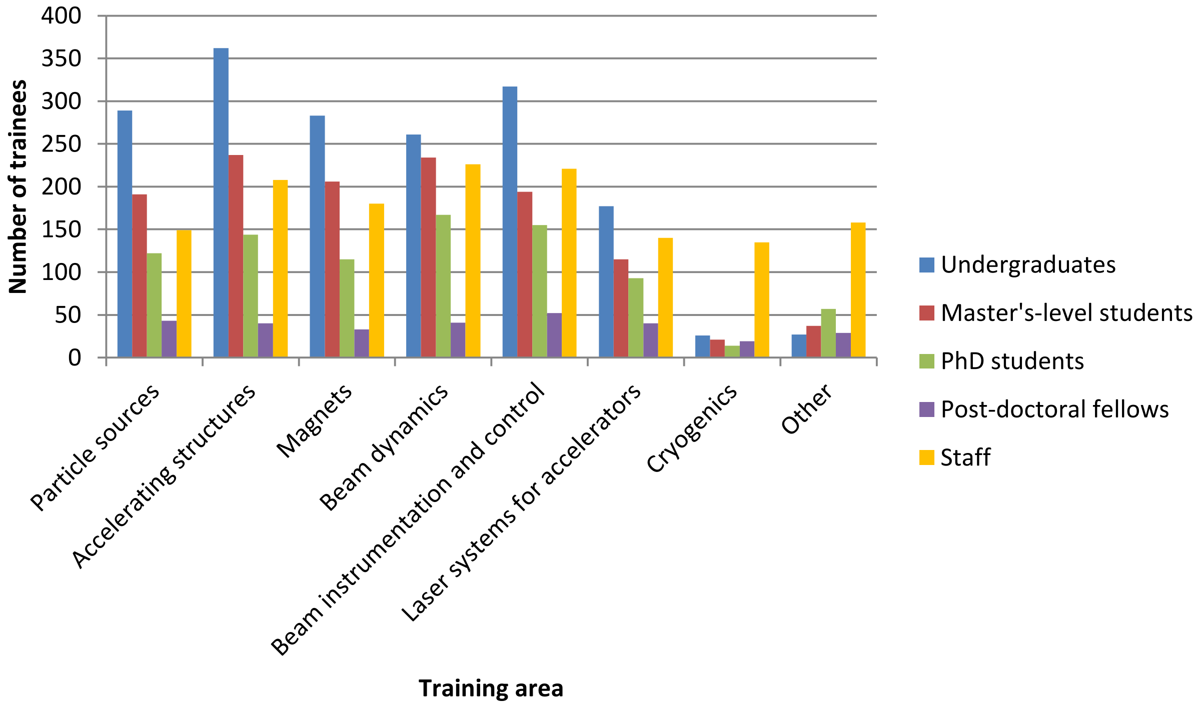


Figure 6.1: Number of trainees versus training area and by category of trainee.

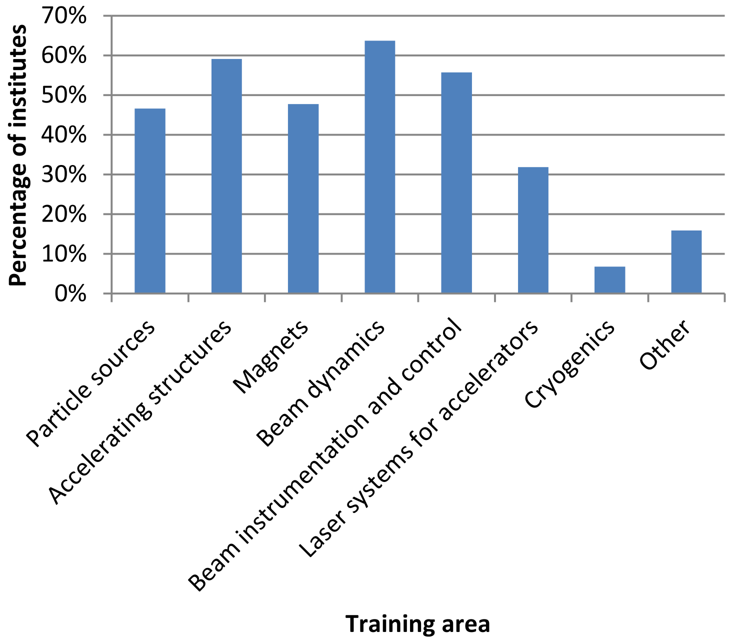


Figure 6.2: Percentage of institutes that offer training in each area.

The percentage of institutes that reported offering formal examinations on accelerator science coursework is shown by country and student type in Figure 6.3. In total, 53% of institutes that train undergraduates offer formal examinations; the corresponding figure for master's students is 55%, and for PhD students is 45%. Participation in the European Credit Transfer Scheme (ECTS) is shown in Figure 6.4. In total, 35% of institutes that train undergraduates participate in ECTS; the corresponding figure for master's students is 46%.

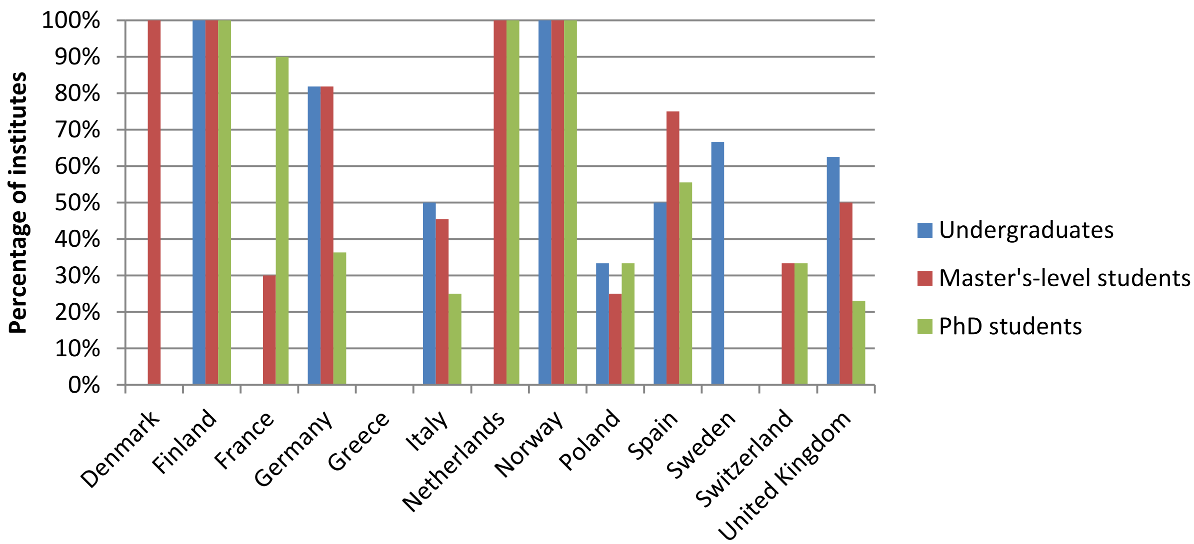


Figure 6.3: Percentage of institutes that offer formal examinations, by country.

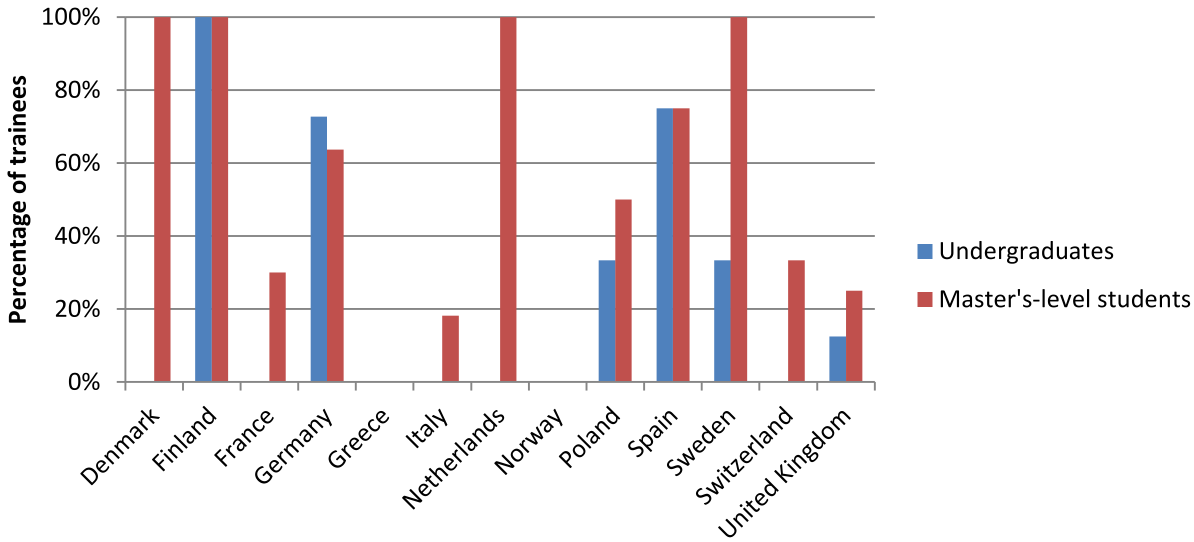


Figure 6.4: Percentage of institutes that report participation in the ECTS scheme, by country: undergraduate training (blue) and master's level training (red).

7. ACCELERATOR SCHOOLS AND THE CERN DOCTORAL STUDENT PROGRAMME

Accelerator schools represent an important training mechanism. In 2011 institutes reported sending 339 people to attend international and/or national accelerator schools. The number of attendees by country is shown in Figure 7.1. The most attended international schools are the CERN Accelerator Schools (CAS), the Joint Universities Accelerator School (JUAS), the U.S. Particle Accelerator Schools (USPAS) and the Linear Collider School. CERN sends a significant number for training to the CAS. Poland sends a significant number for training at its WILGA school.

The CAS and USPAS are organized as intensive residential schools, held twice per year and typically of two weeks duration. Each school provides some 50 hours of teaching. The Linear Collider School is similar, but shorter and held yearly. The JUAS provides 2 courses of 110 hours of teaching each, supplemented by several days of practical work and visits to various experimental facilities (CERN, ESRF, PSI, Geneva hospital), over a period of ten weeks. Additional statistics on CAS and JUAS are shown in Appendices 4 and 5 respectively. The total number of trainees per country attending schools, normalised by population, is shown in Figure 7.2.

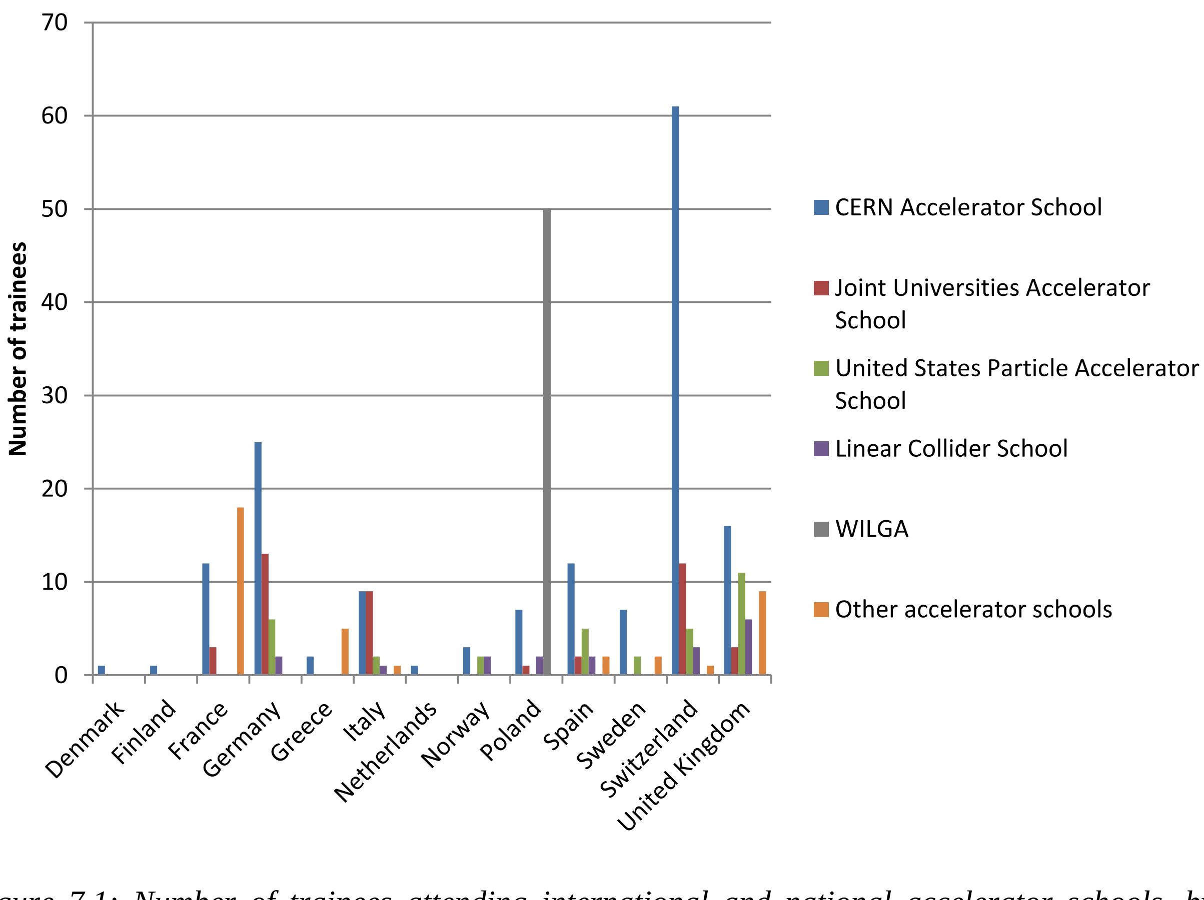


Figure 7.1: Number of trainees attending international and national accelerator schools, by country.

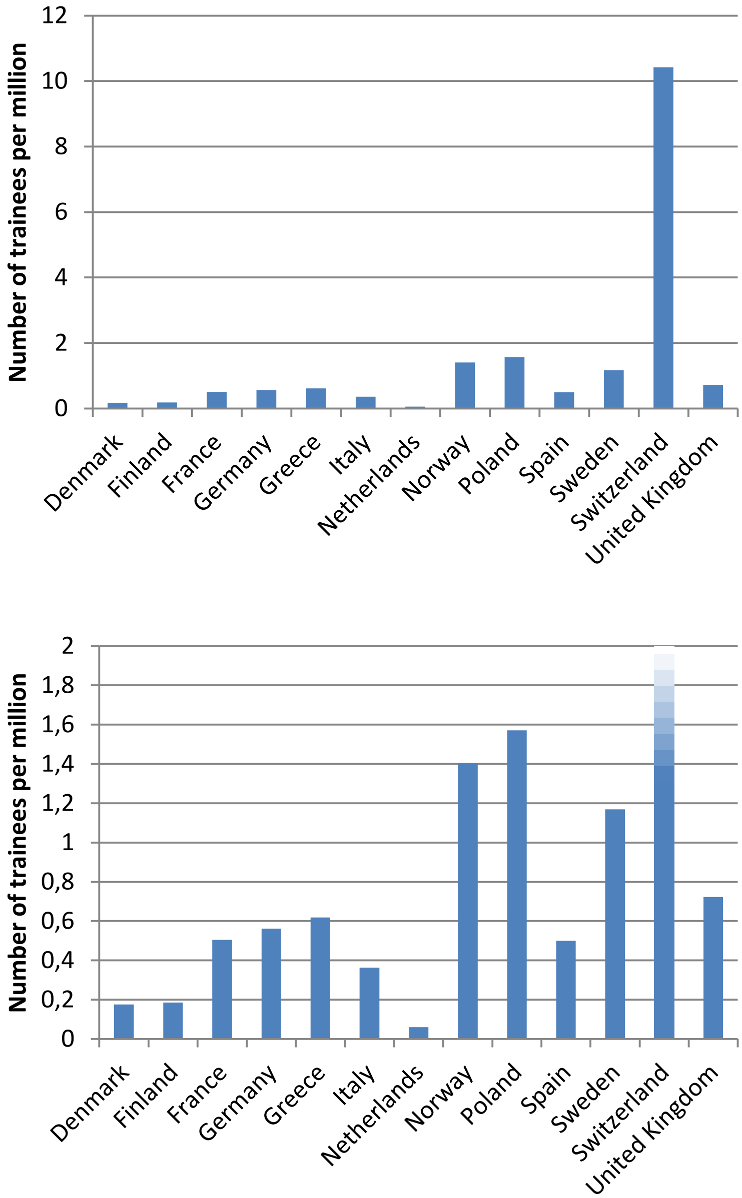


Figure 7.2: Top: number of trainees per million sent to accelerator schools. Bottom: a 'zoom into the region below 2 students/million.

In addition, the CERN Doctoral Student Programme (DSP) provides an important mechanism for the hands-on training of PhD students in accelerator science at CERN. Figure 7.3 shows participation in the DSP by country. In 2011, for example, 19 people from the responding institutes commenced training in the DSP.

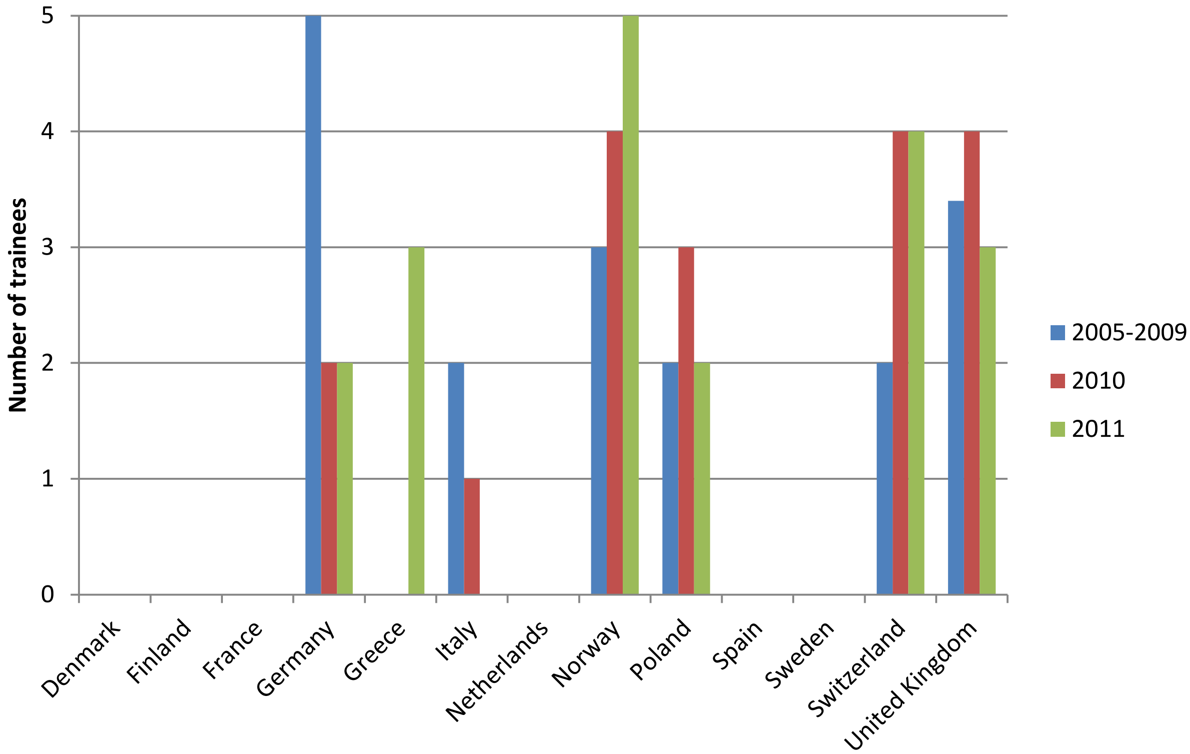


Figure 7.3: Numbers of trainees reported as participating in the CERN Doctoral Student Programme, by country. Data are shown for trainees commencing in the academic year 2011 (green), 2010 (red) and the average commencing per year over the 5 years 2005-2009 (blue).

8. TRAINING MATERIALS AND USE OF FACILITIES

A number of standard text books are used in accelerator science training:

- An Introduction to Particle Accelerators (E. Wilson)
- An Introduction to the Physics of High Energy Accelerators (D.A. Edwards and M.J. Syphers)
- Beam instrumentation and diagnostics (P. Strehl)
- Fundamentals of Beam Physics (J. Rosenzweig)
- Handbook of Accelerator Physics and Engineering (A.W. Chao and M. Tigner)
- Measurement and control of charged particle beams (M.G. Minty and F. Zimmermann)
- Particle Accelerator Physics (H. Wiedemann)
- The Physics of Particle Accelerators (F. Hinterberger)
- The Physics of Particle Accelerators: an Introduction (K. Wille)

The number of institutes using each text book is shown by category of student in Figure 8.1. The books are widely used for training all categories of trainee. Additional books and materials that were reported include:

- R.F. Superconductivity (H. Padamsee)
- High Voltage Vacuum Insulation (R.V. Latham)
- The Physics and Technology of Ion Sources (Ian Brown)
- CAS Proceedings
- Biomedical particle accelerators (W. Scharf)
- Principles of Particle Accelerators (W.A. Benjamin)

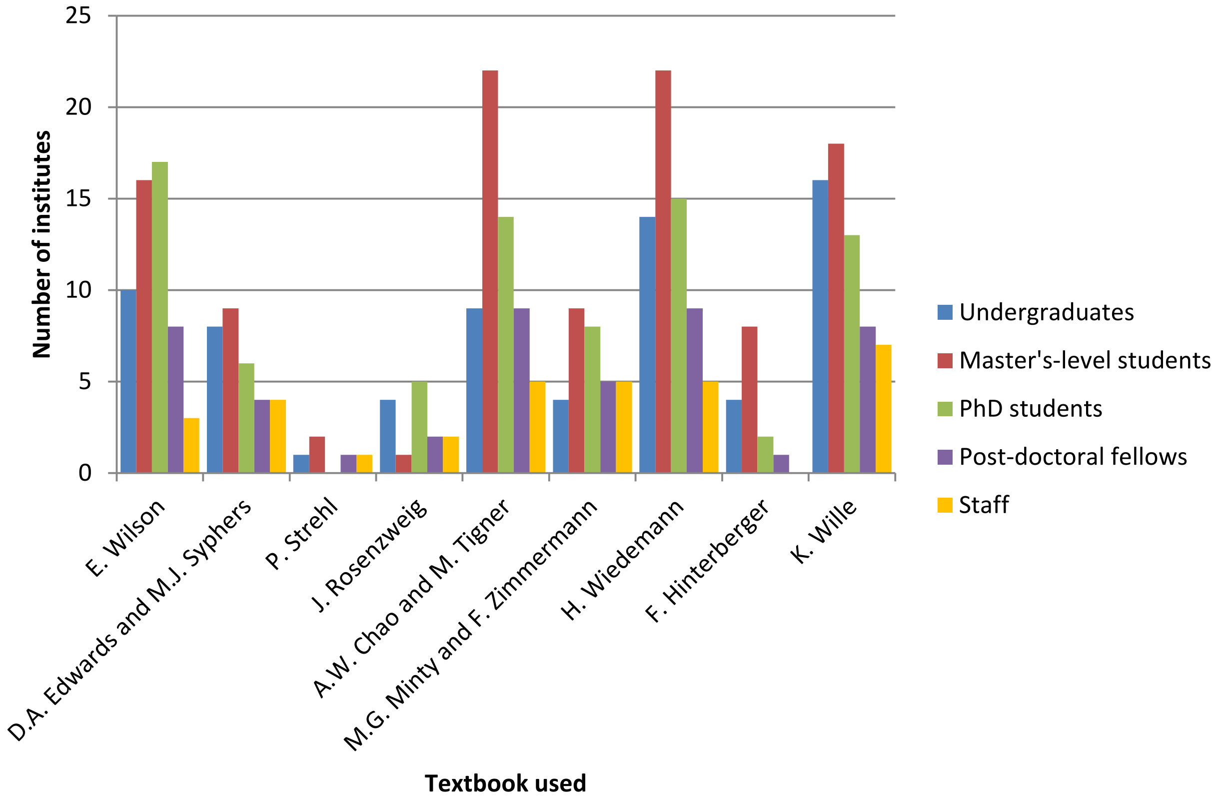


Figure 8.1: Number of institutes using well known accelerator text books for training, by category of trainee.

59 institutes reported on their use of national and/or international laboratories and facilities as part of their training programmes. A total of 51 such facilities were reported; these are listed in Appendix 6. Those facilities being used by at least two institutes are represented in Figure 8.2. CERN is the most-used facility, with major national laboratories being reported by users in each respective country.

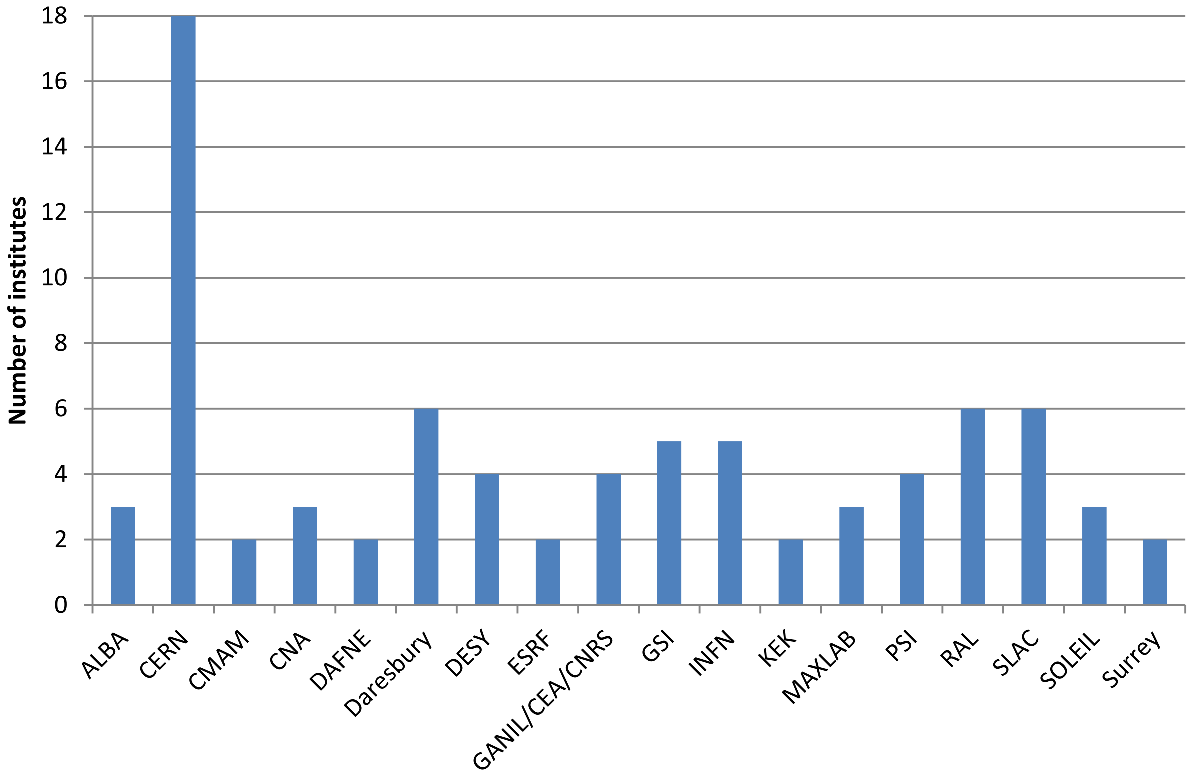


Figure 8.2: Number of institutes using the listed international and national facilities for training in accelerator science.

9. CAREER DESTINATIONS

41 institutes provided information on career destinations for the different categories of accelerator science trainee. The percentages of each population moving into:

- postgraduate studies (relevant for undergraduates and master's students)
- employment in the university sector
- employment at national or international laboratories
- employment in the medical sector
- employment in the manufacturing sector
- employment in the financial sector (e.g. banking)
- employment in the services sector (e.g. information technology)

are shown in Figure 9.1. For example, 64% of the undergraduates, and 59% of the master's students, go on to pursue postgraduate training. 66% of the PhD students, and 63% of the postdoctoral fellows, go on to find employment at universities and national or international laboratories. For each category of trainee, significant numbers go on to find employment outside the academic research sector: 28% of the undergraduates, 31% of the master's students, 34% of the PhD students, and 38% of the postdoctoral fellows, go on to find employment in the manufacturing, medical, financial and services sectors.

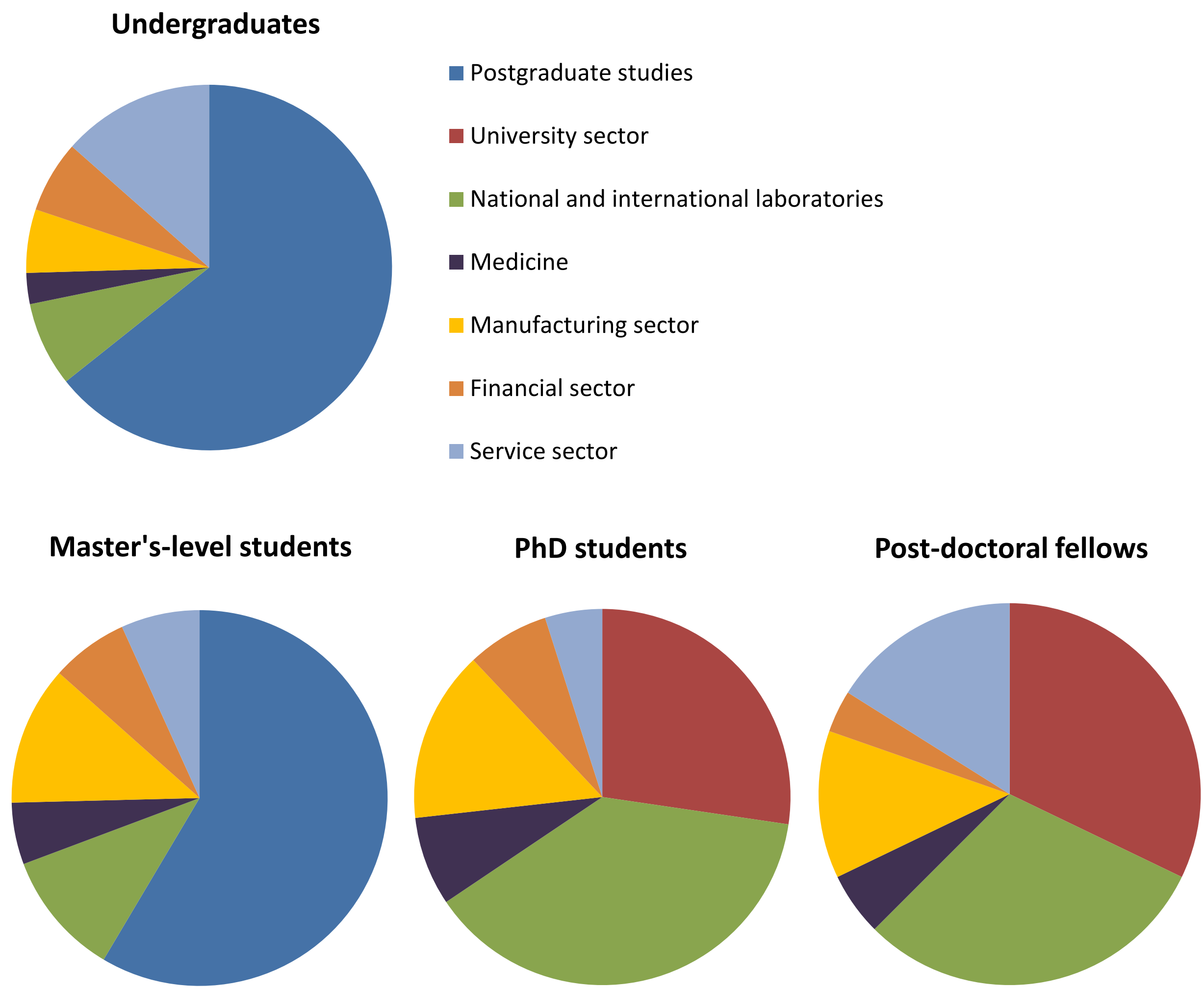


Figure 9.1: Percentage of trainees by career destination for each category of trainee.

10. SUMMARY OF MAIN FINDINGS

- 88 institutes from Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom completed the TIARA survey on education and training in accelerator science.
- A total of 3060 personnel at these institutes are engaged in accelerator science activities, of which 195 are involved in providing training.
- 75 institutes (85%) provide training of some kind in some aspects of accelerator science to their own students or staff. Of the 13 institutes that do not currently offer such training, 3 indicated that they have plans to do so in future, and 9 of the remaining 10 indicated a desire to do so in future.
- 83 institutes (94%) send people for training to accelerator schools and workshops, and 30 institutes (34%) have staff members who *provide* training at the accelerator schools and workshops.
- 49% of institutes provide training to undergraduates, 64% to master's students, 70% to PhD students; 44% to postdoctoral fellows, and 24% to staff.
- 1371 people per annum currently receive training, which comprises: 34% undergraduates, 26% master's students, 14% PhD students, 7% postdoctoral fellows and 17% staff.
- 55 institutes reported the number of training hours provided per annum. Currently a total of 62,777 training hours per annum are given: 46% to master's students, 27% to undergraduates, 13% to PhD students, 10% to staff and 3% to postdoctoral fellows.
- Accelerator science typically represents a small fraction (below 30%) of total formal training time for undergraduate, master's and PhD students, and typically a larger fraction for postdoctoral fellows and staff. There are only a handful of dedicated full-time formal training programmes in accelerator science.
- The majority of trainees receive training in five main areas: particle sources, accelerating structures, magnets, beam dynamics, instrumentation and controls. More than 50% of institutes offer training in one or more of these areas.
- 53% of institutes that provide formal training to undergraduates offer examinations on accelerator science coursework; the corresponding figure for master's students is 55%, and for PhD students it is 45%.
- 35% of institutes that train undergraduates participate in ECTS; the corresponding figure for master's students is 46%.
- More than 339 people each year receive training by attending international and/or national accelerator schools. The most attended international schools are the CERN Accelerator Schools (CAS), the Joint Universities Accelerator School (JUAS), the U.S. particle accelerator Schools (USPAS) and the Linear Collider School.

- In 2011, the responding institutes reported that 19 PhD students joined the CERN Doctoral Training Scheme for hands-on training in accelerator science at CERN.
- For the available dataset, although a majority of each category of trainee goes on to pursue work in the academic/research sector, 28% of the undergraduates, 31% of the master's students, 34% of the PhD students, and 38% of the postdoctoral fellows go on to find employment in the manufacturing, medical, financial and services sectors.

11. OUTLOOK

The survey has provided a remarkable 'snapshot' of training provision in accelerator science within the participating European states. The response rate has been extremely high. However, it cannot be excluded that additional training is being provided at institutes that did not respond to the survey; the statistics presented here should therefore be considered as a firm 'lower bound' on the amount and type of training. Furthermore, it is possible that training provision in accelerator science is considered desirable additionally at institutes that were not surveyed. It could well be appropriate to repeat the survey periodically in the future, in which case an attempt could be made to gather data on these points.

APPENDIX 1: RESPONDING INSTITUTES AND CONTACT PERSONS

Denmark

ISA, Aarhus University, Søren Pape Møller

Finland

Department of Physics, University of Jyväskylä, Pauli Heikkinen

France

C2RMF, Claire Pacheco

CEA/INAC/SBT, Alain Girard

CEA/DSM/IRFU/SACM, P.A. Phi Nghiem

CNRS/IN2P3/CENBG, Laurent Serani

CNRS/IN2P3/CSNSM, Cyril Bachelet

CNRS/IN2P3/IPN, Patrick Ausset

CNRS/IN2P3/IPNL, Marcel Bajard

CNRS/IN2P3/LAL, Alessandro Variola

CNRS/IN2P3/LAPP-Universite de Savoie, Andrea Jeremie

CNRS/IN2P3/LLR, Catherine Clerc

CNRS/IN2P3/LPSC, Maud Baylac

CNRS-LPGP, Brigitte Cros

ESRF, Jean-luc Revol

GANIL/CEA/CNRS, Frederic Chautard

SOLEIL, Jean-Claude Denard

Université et Ecole des Mines de Nantes/CNRS/IN2P3/SUBATECH, Freddy Poirier

Université Paris 11, Costel Petrache

Université Paris 11/Paris 6/Paris 7/INSTN, Alessandro Variola

Germany

DELTA, TU Dortmund, Thomas Weis

DESY, Alexander Gamp

Goethe-Universität Frankfurt,

GSI Helmholtzzentrum für Schwerionenforschung GmbH, Oliver Kester

Hamburg University, Joerg Rossbach

Helmholtz-Zentrum Berlin, Andreas Jankowiak

Institut für Kernphysik der Johannes Gutenberg-Universität Mainz, Kurt Aulenbacher

Institut für Kernphysik, FZ Jülich, Andreas Lehrach

Institut für Kernphysik, TU Darmstadt, Ralf Eichhorn

TEMF, TU Darmstadt, Thomas Weiland

University of Wuppertal, Günter Müller

Greece

Aristotle University of Thessaloniki, Petridou Charikleia

Inst. of Nuclear Physics, National Center for Research 'Demokritos', Petros Rapidis

University of Crete, Giorgos Tsironis

Italy

ENEA, Luigi Picardi

Fondazione CNAO, Marco Pullia

INFN - Laboratori Nazionali del Sud, Luciano Calabretta

INFN - Laboratori Nazionali di Frascati, Andrea Ghigo, Maria Enrica Biagini, Caterina Biscari, Massimo Ferrario

INFN - Laboratori Nazionali di Legnaro, Andrea Pisent

INFN - MILANO & Università degli Studi di Milano, Paolo Pierini, Angelo Bosotti, Dario Giove, Giovanni Volpini

INFN - NAPOLI & Università degli Studi di Napoli Federico II, Maria Rosaria Masullo

INFN - PISA & Università degli Studi di Pisa, Franco Cervelli, Danilo Giulietti

Sincrotrone Trieste, Gerardo D'Auria

Università degli Studi di Torino, Mauro Gallio

Università di Bologna, Giorgio Turchetti

Università di Roma "La Sapienza", Luigi Palumbo

Netherlands

Kernfysisch Versneller Instituut, University of Groningen, Sytze Brandenburg

Norway

University of Oslo, Steinar Stapnes

Poland

Cracow University of Technology/ Faculty of Mechanical Engineering, Blazej Skoczen

Institute of Nuclear Physics, Polish Academy of Sciences, Piotr Malecki

National Centre for Nuclear Research, Slawomir Wronka

Technical University of Lodz, Department of Microelectronics and Computer Science, Dariusz Makowski

Warsaw University of Technology, Ryszard S. Romaniuk

Spain

ALBA CELLS, Gaston Garcia

Centro Nacional de Aceleradores, CNA, Joquin Gomez Camacho

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas, CIEMAT, Marisa Marco

European Spallation Source of Bilbao, FJ Bermejo

Instituto de Física Corpuscular, Angeles Faus-Golfe

Technical University of Catalonia (Universitat Politecnica de Catalunya), Yuri Kubyshin

Universidad Autónoma de Barcelona, Manel Sabés

Universidad Autónoma de Madrid, Angel Munoz-Martin

Universidad de Huelva, Ismael Martel

Universidad Nacional de Educación a Distancia, UNED. (ETS Ingenieros Industriales), Javier Sanz Gozalo

Sweden

European Spallation Source ESS AB, Håkan Danared

Lund University/MAX-lab, Sverker Werin

Stockholm University, Ansgar Simonsson

The Svedberg Laboratory, Uppsala University, Björn Gålnander

Switzerland

CERN, Roger Bailey

EPFL: Swiss Institute of Technology Lausanne, Lenny Rivkin

LHEP, Uni-Bern, Antonio Ereditato

Paul Scherrer Institut, Terence Garvey

United Kingdom

Brunel University, Akram Khan

Diamond Light Source, Riccardo Bartolini

Dundee University, Allan Gillespie

Glasgow University, Paul Soler

Huddersfield University, Roger Barlow

Imperial College London, Juergen Pozimski

John Adams Institute, University of Oxford, Riccardo Bartolini

John Adams Institute, Royal Holloway, University of London, Pavel Karataev

Lancaster University, Amos Dexter

Liverpool University, Andy Wolski

Manchester University, Roger Jones

Science and Technology Facilities Council, Greg Diakun

Sheffield University, Chris Booth

Strathclyde University, Alan Phelps

Surrey University, Karen Kirkby

Warwick University, Paul Harrison

University College London, Matthew Wing

APPENDIX 2: Survey

The web survey can be found at:

tiara.physics.ox.ac.uk/tiara-survey/

A text version of the survey is given below.

TIARA Survey

You & Your Institution

Your Name

Your Email

Your institution

Type of institution (University/National Laboratory/Other)

Address

City

Postcode

Country

How many staff (i.e. physicists and engineers) at your institution are engaged in accelerator science activities?

Does your institution currently offer training in any aspect of accelerator science? *(Yes/No)*

(if "No" to above)

Have you offered training in accelerator science in the past? (Yes/No)

Do you plan to offer training in the future? (Yes/No)

(if "No" to above)

Would it be desirable to offer such training? (Yes/No)

Even if your institution does not provide training in accelerator science, do any of your faculty members provide training in accelerator science at other institutions or workshops? *(Yes/No)*

Do you send any people to accelerator schools and workshops? *(Yes/No)*

Training

To which groups do you offer training? (Undergraduates/Master's-level students/PhD students/Post-doctoral fellows (not permanent appointments/Staff (permanent appointments)/Others)

Students *(this section is repeated for each of the student types selected above)*

In which areas do you provide training? (Particle sources/Accelerating structures/Magnets/Beam dynamics/Beam instrumentation and control/Laser systems for accelerators/Cryogenics)

Other training areas (please specify)

Names of training programmes

How many students received training in academic year 2010/11?

How many students will receive training in academic year 2011/12?

Approximately how many students PER YEAR received training, averaged over the 5 years 2005-2009?

Teaching

How many hours of lectures or other formal training (in accelerator science) did the students receive in 2010/11? (e.g. 100)

What is the total number of hours of instruction (in all subjects) during the academic year? (e.g. 500)

Do you participate in the European Credit Transfer and Accumulation System scheme? *(Yes/No/Don't know)*

If applicable, how many ECTS credits does your accelerator training amount to?

Are there formal examinations in accelerator science? *(Yes/No)*

Which books do you use for teaching?

- An Introduction to Particle Accelerators (E. Wilson)
- An Introduction to the Physics of High Energy Accelerators (D.A. Edwards and M.J. Syphers)
- Beam instrumentation and diagnostics (P. Strehl)
- Fundamentals of Beam Physics (J. Rosenzweig)
- Handbook of Accelerator Physics and Engineering (A.W. Chao and M. Tigner)
- Measurement and control of charged particle beams (M.G. Minty and F. Zimmermann)

- Particle Accelerator Physics (H. Wiedemann)
- Physik der Teilchenbeschleuniger (F. Hinterberger)
- The Physics of Particle Accelerators: an Introduction (K. Wille)

Other books (please specify)

Do you use local, national or international accelerator facilities for 'hands-on' training? *(Yes/No)*

(if “Yes” above)

Which facilities?

Faculty

How many faculty members provide formal training in accelerator science?

Do your faculty members provide accelerator training at other institutions? (e.g. national laboratories or other universities) *(Yes/No)*

(if “Yes” above)

Which other institutions?

Do your faculty members provide training at any accelerator schools? *(Yes/No)*

(if “Yes” above)

Which accelerator schools?

Accelerator Schools

How many people do you send to the following accelerator schools?

CERN Accelerator School

Joint Universities Accelerator School

United States Particle Accelerator School

Linear Collider School

Other accelerator schools

(If “Other accelerator schools” is completed above)

Which other accelerator schools?

Meetings and Workshops

Which meetings, workshops or similar educational events do you send people to?

Doctoral Training Programmes

Do you participate in any doctoral training programmes? *(Yes/No)*

(if "Yes" above)

CERN Doctoral Training Programme

How many students joined the programme in academic year 2010/11?

How many students do you expect to join in academic year 2011/12?

How many students joined per year, averaged over the 5 years 2005-2009? (approximate)

Other Doctoral Training Programmes (if applicable)

Please specify

Career Destinations

Please provide information on the career destinations of your leavers in the following categories, averaged over the 5 years 2005-2009 (if known).

(repeated for each student type)

Postgraduate studies (or "University sector" for postgraduate alumni)

National and international laboratories

(if "National and international laboratories" completed)

Which?

Medicine

Manufacturing sector

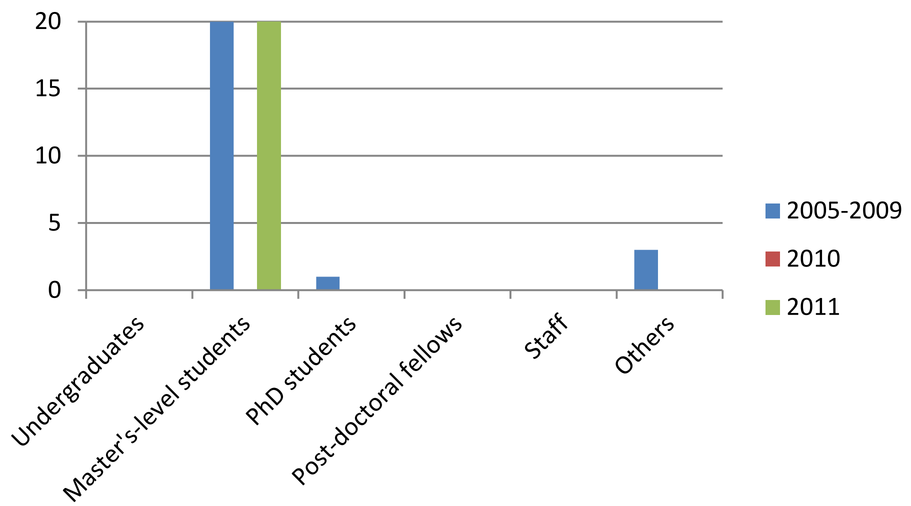
Financial sector (e.g. banks)

Service sector (e.g. IT)

Comments - Comments (if any)

APPENDIX 3: country-specific analysis

Denmark



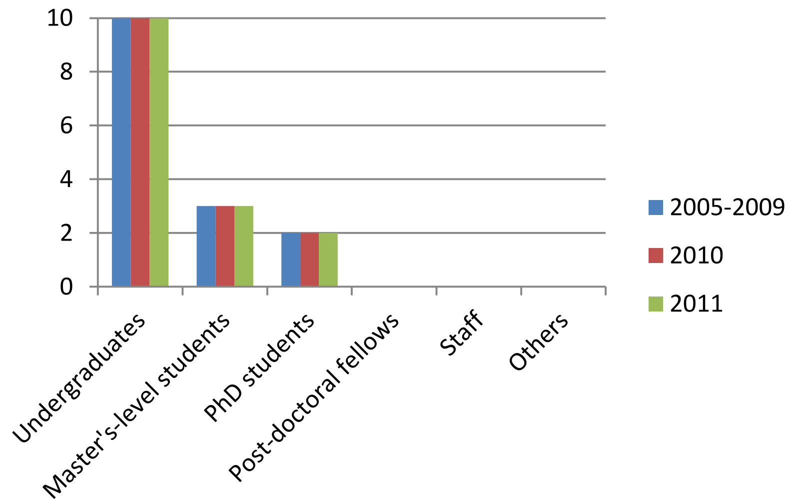
Denmark is a minor player in the accelerator world, in particular due to the size of the country.

The only university where accelerator research and training is going on, is Aarhus University. Previously some activity also existed at Copenhagen University, but accelerator research and development proper is not existing, only use of accelerators like at CERN, DESY and many other places. At Aarhus University, several smaller accelerators have existed for many years, and in 1990 the ASTRID storage ring, with its associated injectors, initially provided research with ion beams and in the last 10 years only with synchrotron radiation. The first electrostatic storage ring was invented and built at AU more than 10 years ago, and new electrostatic storage rings are being built. Finally a new low-emittance synchrotron radiation source, ASTRID2, is presently being constructed and starting commissioning in 2012. Aarhus University has also been and is involved in several external accelerator projects including ANKA in Karlsruhe, the Canadian Light Source, the Australian Light Source, the Particle Therapy machines at Siemens and lately the European Spallation Source in Lund.

Two well-known companies are engaged in designing and building accelerator components and complete accelerators (DANFYSIK and SIEMENS). Finally, we should mention the hospitals in Denmark which have a large staff of medical physicists for both cancer treatment and diagnostics etc. These physicists, including accelerator physicists, are partly trained at the universities partly during courses abroad at foreign companies and hospitals.

Aarhus University is the only University in Denmark giving formal training in accelerator science. Every second year, a 6 ECTS course in accelerator physics is filled with the available 20 places for students. In addition over the last years, around 5 students have obtained their PhD degree in accelerator science, two as industrial PhDs.

Finland



The only laboratory in Finland with major activities in accelerator physics and training is at the University of Jyväskylä. The facility is based on a cyclotron used very actively in nuclear physics. The first cyclotron, MC20, at the Department of Physics (JYFL) was installed in the mid-1970s. It served the laboratory until 1992. A heavy-ion cyclotron, K130, was installed 1990-1991. It was partly designed by JYFL and manufactured by Scanditronix AB. The cyclotron is a multi-particle, variable energy machine. It is used for nuclear physics research and for applications, such as isotope production, space electronics radiation damage tests and some other commercial applications. Since 1996 the cyclotron has been used for 6000–7500 hours/year.

A new 30 MeV negative ion cyclotron for protons and deuterons was installed in 2008-2009. The cyclotron (MCC30/15) will be used for nuclear physics experiments and isotope production.

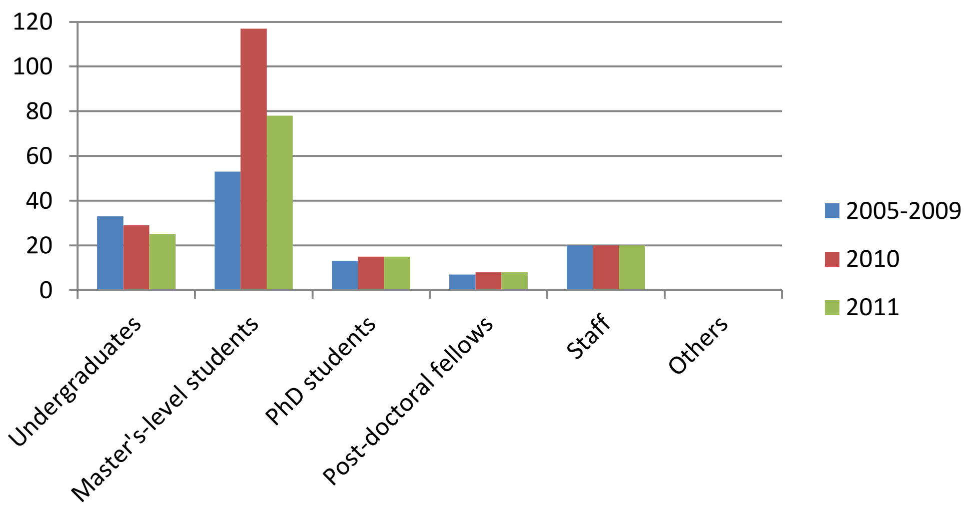
In addition to two operating cyclotrons the laboratory houses also a 1.7 MV Pelletron accelerator (tandem). It is used for materials physics research and applications, such as fabrication and modification of nanoscale materials, elemental profiling of thin films and different materials, experimental characterization of fundamental ion-matter interaction processes in nanometric materials and proton lithography.

There are two different levels of accelerator-oriented training. The cyclotrons are operated by three permanently employed operators and by student operators. Annually, some ten students are trained as operators. The training consists of about 10 hours of theoretical training and practical training with the cyclotron. Until now, about 100 students have been trained as student operators for the K130 cyclotron.

In addition to the operator training there are three different accelerator physics and accelerator techniques courses (Accelerator Physics, Cyclotron Physics and Accelerator Techniques). All these courses are worth 5 credit points (30–32 hours of lectures and 16 hours of exercises). The Accelerator Physics course is based on the CERN Accelerator Physics course, Cyclotron Physics and Accelerator Techniques courses have been composed to meet the requirements of the JYFL Accelerator Laboratory. Normally one of the three courses is offered every second year. If there are enough requests the courses are provided more often. If there is at least one student who cannot follow the course in Finnish the courses are provided in English.

The laboratory has a very active ion source group. Several Masters theses and PhD theses have been completed related to light ion sources and ECR ion sources. Until now, no special ion source courses have been offered.

France

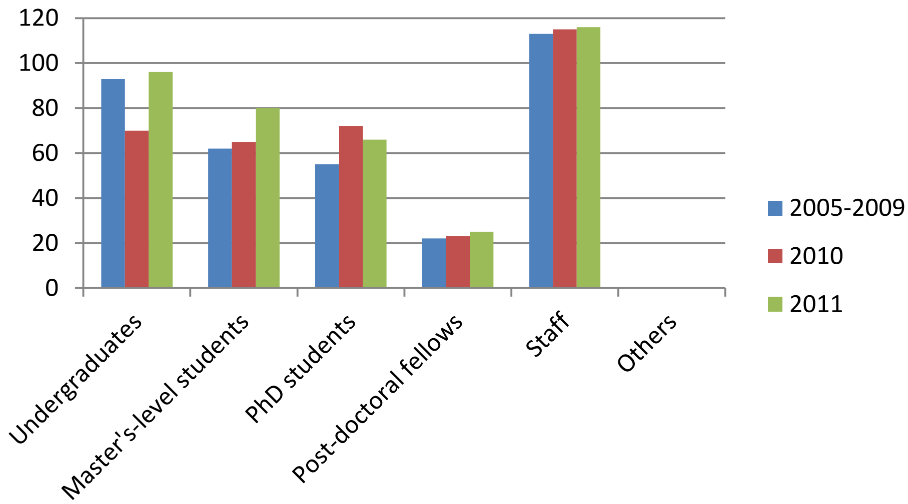


In France, two types of institutions are involved in training in accelerator fields; "Universities" and "National Laboratories", which are administratively independent.

Formal training and formal examination are given only at the level of a Master’s Degree. This is done in Universities in specific structures and organisations as is the case for every Master’s-level student. The lecturing faculty and other teachers are provided by the National Laboratories working in accelerators. For these Master’s-level students, lectures on accelerators are only a part of all the given lectures. Due to the decreasing number of students interested in accelerator fields, the proportion of accelerator-related lectures is also decreasing.

On their side, accelerator laboratories offer internships at Undergraduate and Master levels (mandatory in these curricula), as well as PhD and Post-doc positions. These laboratories also organise regular or unique training sessions for their members, on specific accelerator topics.

Germany

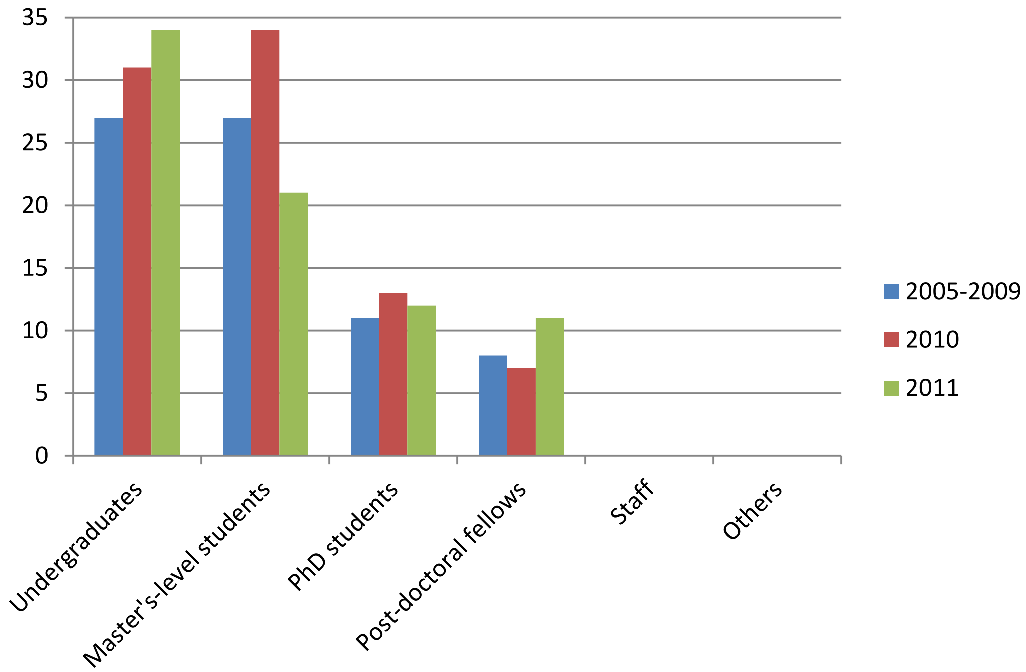


The numbers shown in Figure 2.1 included national accelerator laboratories (labs) and universities. Only universities contribute to the official education for bachelor and master students and only the universities can award bachelor, master's and PhD degrees. In recent years, most of the German universities have changed from the diploma system to the bachelor and master's systems, however some students will still obtain a diploma degree. At some of the German technical universities (TUs) the diploma degree can again be obtained. For the education in accelerator physics the universities have close collaborations with nearby labs or they have their own accelerator facilities on site. University professors, and in some cases scientists from the labs, hold lectures in accelerator physics at the universities for undergraduates and master's-level students. The labs offer practical training in terms of student trainees for bachelor and master's students. In addition the students can perform their bachelor, master's or PhD work in the labs' departments, guided by a university professor and a local supervisor. The duration of a master's thesis is between half and one year and between 3-5 years for a PhD thesis.

The labs and the universities both train their technical staff that operates their accelerators. In Germany 636 staff members (Figures 2.2 and 3.1) are engaged in accelerator science activities. 300 physicist and engineers working in accelerator physics and technology are employed at DESY, 120 at GSI, 50 at the IKP (FZ Jülich) and 166 at the universities. German professors and lab scientists participate in the training at universities and in the international schools (CAS, JUAS). Figure 4.1 shows a smaller number of PhD students compared to the number of master's students, which can be explained by the excellent job market in Germany for physicists and engineers with a master's degree.

Figure 5.1 includes the numbers for students (~210 per year) and technical staff (~120 per year). Most of the lectures are for undergraduates (~80 per year) and master's students (~75 per year). PhD students (~65 per year) use most of their time to work on their research project and spend much less time in training programmes. To support a more structured PhD education, in particular for research projects associated with the labs, graduate schools were established at some universities. They provide mandatory training in the form of block seminars (one block of up to one week). The PhD students receive training in accelerator physics, related physics fields and soft skills organized by the graduate schools (typically 2-3 seminars per year, ~20 people). In addition the German universities and the labs send their PhD students and postdocs to the international accelerator schools.

Italy



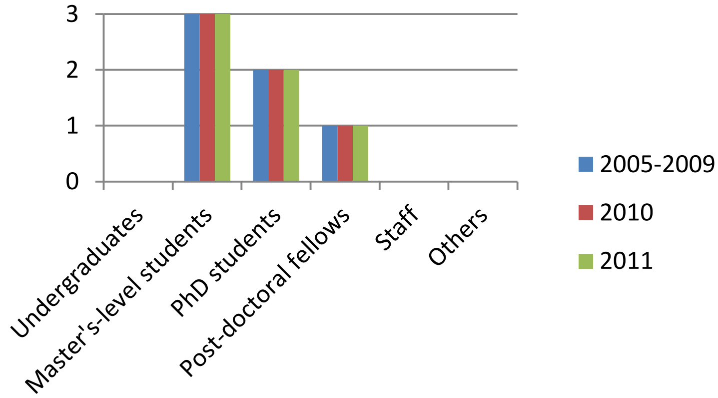
In contrast with the trend of other countries (Fig. 4.3), the number of Italian undergraduate students trained in accelerator physics exhibits a remarkable increase between 2005 and 2011.

On the other hand it should be noticed that no staff were trained in the surveyed period, in striking contrast to what happens in other countries like France or Germany, and in contrast with the average of 6% of scientific staff being trained every year. This is partially due to the ageing of the personnel. In recent years, due to a generalized recruitment freeze, in Italy very few people were hired.

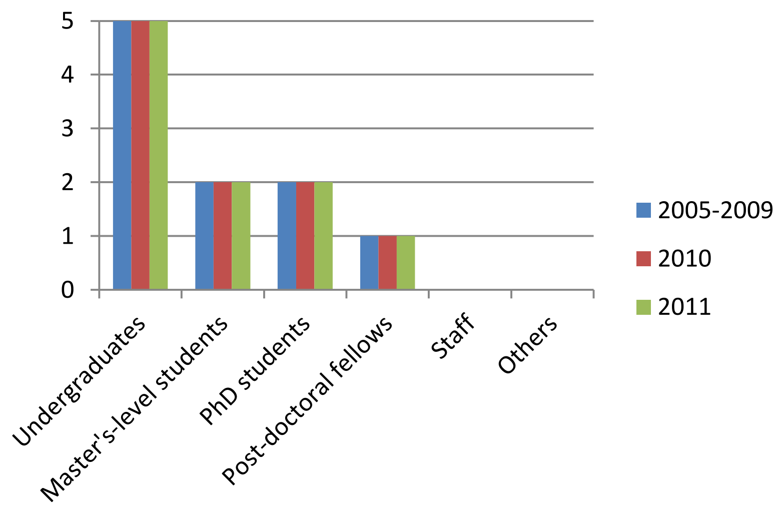
It is difficult for Italian students to profit from the CERN doctoral program. In Italy, the access to the doctoral program and its structure is such that in most cases it has little compatibility with the CERN doctoral program.

Furthermore, most of the Italian universities do not participate in the ECTS scheme, to the detriment of the internationalization of education.

Netherlands



Norway



In Norway, only one university—the University of Oslo—is offering education within the field of accelerator science.

At Master's-level, this teaching is limited to parts of a course and only technical students at CERN spend any extended time on accelerator science issues. Also, at PhD level, the activities are linked to CERN where some students carry out their projects there, following courses in Norway. The total number of students and faculty within this field is low, with about 5 new students at master level and 2 new students at doctoral level every year.

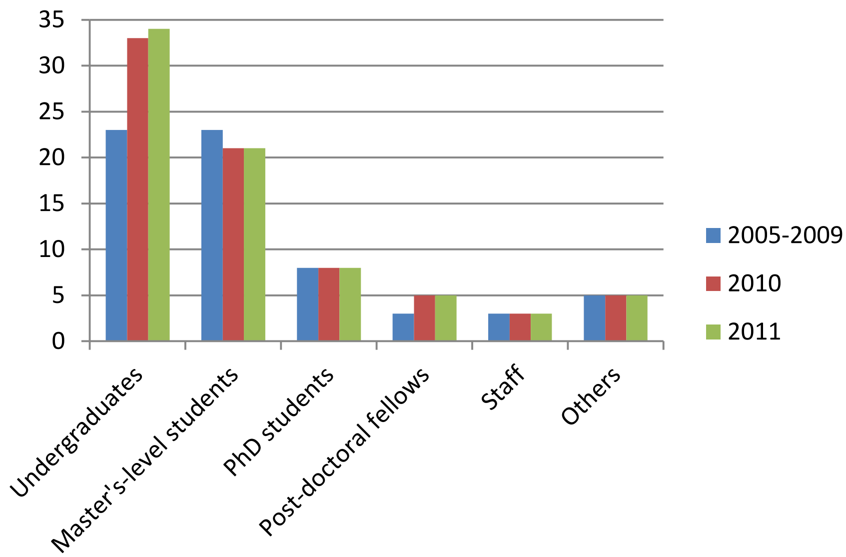
A dedicated faculty position will be opened in 2013 for an accelerator physicist, opening for an improved accelerator science programme.

The accelerator infrastructure at the University is limited with only one cyclotron. The Oslo Cyclotron Laboratory (OCL) houses the only accelerator in Norway. The laboratory serves as an experimental centre for various fields of research and applications. The main field of research is within nuclear physics and nuclear chemistry. In addition, isotopes are produced for nuclear medicine. Accelerator physics projects are generally not carried out there.

Since the infrastructure at the university is limited most of the doctoral students and faculty works on projects related to CERN or other accelerators outside Norway.

There are no companies in Norway which specialise in delivering accelerator components.

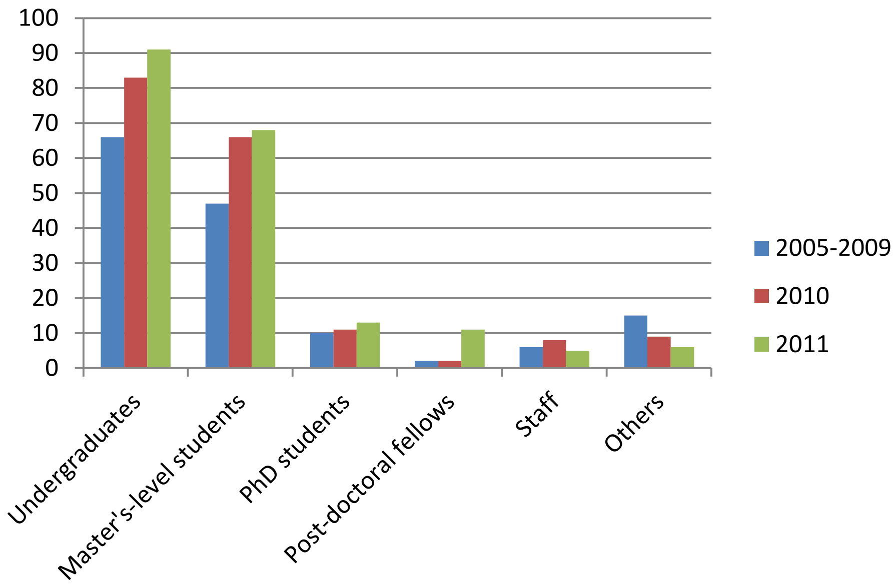
Poland



Looking at the WP5 survey results for Poland, one can formulate the following brief remarks:

1. There are almost no regular university courses on accelerator physics.
2. There is considerable engagement of technical universities and research institutes in acceleration techniques (mechanical constructions, control systems, cryogenics).
3. Accelerator schools play a fundamental role, particularly CAS.
4. There are large groups of engineers and technicians with long-term experience in accelerator maintenance and R&D (in INP Krakow, UST Krakow, NCBJ).
5. Local schools and workshops play a considerable role– oriented on accelerator techniques rather than on accelerator physics itself.

Spain



Introduction

From an historical point of view, academic education at University level was built in the 1970´s around the main branches of Theoretical Physics, Applied Physics, and other derived fields, such as Meteorology, Electronics & Computing, and Material Science, which have evolved into their own disciplines.

These subjects subsequently evolved, and have given rise to various specialized Degrees in Physics and Engineering. They now provide an excellent base for education in Accelerator Physics.

Physics Accelerator Infrastructures

The Spanish commitment to the field and its development has been an intense and lengthy effort in the past decade. It has culminated on the current on-line facilities of ALBA CELLS (third generation Synchrotron Light Facility, 3GeV), CMAM (Tandem 5MV, Crockcroft-walton), CNA (Tandem 3MV Peletron, and 1MV Crockcoft-Walton). Much effort has been focused into various projects, to develop and construct two superconducting Linacs in Bilbao and Huelva, a superconducting cyclotron at CIEMAT, and an electron race-track microtron (6, 8, 10, 12 MeV) at UPC.

Figure 1: Accelerator infrastructure in Spain

Framework for Higher Education Qualifications

Spanish Universities have recently had to adapt to the EU agreement regarding the framework of qualifications for European Higher Education, as outlined in the Bergen Declaration of 2005. Under such provisions, the Degrees in Physics have been adapted to three cycles of higher education qualification. These are defined in terms of qualifications and European Credit Transfer and Accumulation System (ECTS) credits:

- *1st cycle*: Bachelor in Science (B.Sc.) 4 years, generic approach
- *2nd cycle*: Master in Science (M.Sc.) 1/2 years, specialized
- *3rd cycle*: Doctor of Philosophy in Science, 3 /4 years.

First cycle qualification: Bachelor in Science

As the B.Sc. Degree is based on a generic approach, students are encouraged to enter the field via summer schools, etc… In some Universities, an effort is made to introduce Accelerator Physics at the B. Sc. level, providing students with a choice of subjects, such as "*Synchrotron Engineering"* (UPC) and "*Applied Techniques of Particle Accelerators*" (UPC), within the engineering field.

Degree students have the option to enroll in European summer schools at CERN, DESY, GSI, etc. They can also take part in Erasmus intensive programs, in order to get hands-on experience in IBA, photon and hyperfine techniques.

In addition to Bachelor Degrees, some Spanish institutions offer training with the possibility of writing a Bachelor thesis.

Second cycle qualification: Master in Science

There is only one Master's degree in Spain devoted entirely to accelerator physics:

Master: "Synchrotron Radiation and particles accelerators"
Offered by*:* Universidad Autónoma de Barcelona (UAB), Universidad Politécnica de Cataluña (UPC), ALBA CELLS.
Duration*:* 60 ECTS.

Along with Degree level syllabuses, several Masters contain subjects which familiarize students with problems and methodologies related to accelerators and other similar installations.

Master: "R&D of industrial technology"
Offered by*:* Universidad Nacional de Educación a Distancia (UNED)
Subjects*:*

- *Safety and environment impact of nuclear fusion facilities:* Research on irradiation sources for material development and production, especially those with low activation levels. Within this context the IFMIF facility is presented, its goals and the foundations laid by IFMIF on both Security and Radiation Protection studies.
- *Technologies for nuclear waste managements and disposal:* Study on the technology of transmutation systems using accelerators is emphasized. In this subject students are introduced to accelerators as main components of these systems, their function within and the computational tools created to describe both interaction and transport of particles and the intended transmutation.

Master: "Nuclear engineering"
Offered by*:* Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Universidad Autónoma de Madrid.
Subjects:

- Technology of particle accelerators

Master: "Technology and nuclear instrumentation"
Offered by: Universidad de Huelva (HU).
Subjects:

- Technology of particle accelerators
- Control and instrumentation

Master: “Physics engineering” (next year)
Offered by: Universidad del Pais Vasco/Euskal Herriko Uniberstsitatea (UPC/EHU), European Spallation Source of Bilbao (ESS- Bilbao)
Subjects:

- Control and instrumentation for particle accelerators
- Components and power systems for particle accelerators.
- Neutron techniques
- Industrial, medical and research facilities.
- Radiation protection in particle accelerators.

Third cycle qualification: Philosophical Doctor of Science

Some Spanish research institutes offer PhD training: ALBA CELLS, Universidad Nacional de Educación a Distancia (UNED), Universidad Politécnica de Cataluña (UPC), Universidad de Valencia (UV, Instituto de Física Corpuscular, IFIC), European Spallation Source of Bilbao (ESS-Bilbao), Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT).

Other accelerator training

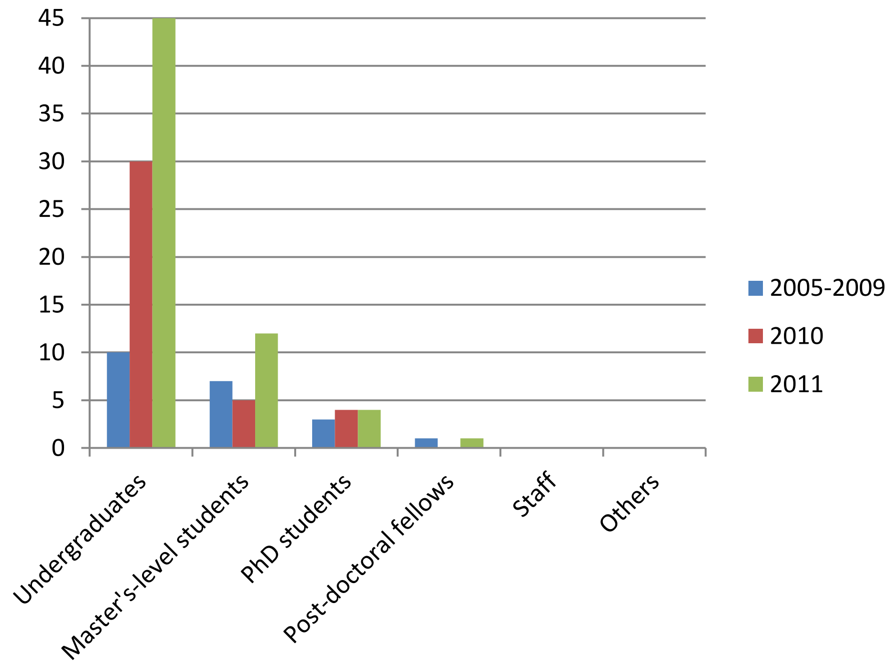
Further specialization is provided thanks to the enormous effort of the Spanish government financing scholarships to do training in some interesting accelerator physics topics on the framework of the program of specialization on scientific facilities and international organism. Some examples are shown in the next table.

International Institute	Project
CERN	Cryogenics for linear research facility of Huelva
CERN	ECR ion source for linear research facility of Huelva
CERN	Beam dynamics and magnet design.
CERN	Beam dynamics for linear research facility of Huelva
ESRF	Control systems for light synchrotron light
ESRF	Scientific instrumentation in the field of synchrotron radiation
ITER	Integration and development of diagnostics systems
ILL	Design of Neutron beam-lines infrastructures

Contribution of Spanish universities, UPC, UV and UAB to Joint Universities Accelerator School, JUAS.
ALBA CELLS has activities of training and transfer of knowledge between research centres, mainly in these 3 areas:

- Accelerators
- Lines/experiments of synchrotron light
- Other tasks, like computing

Sweden



Accelerator research and training in Sweden has taken and is taking place in several places including the Universities in Stockholm, Uppsala and Lund and additionally at Royal Institute of Technology. Two very major accelerator laboratories are presently being built in Sweden, both in Lund; namely the world's most intense neutron source, the European Spallation Source, and the world's brightest synchrotron radiation light source, the MAX IV project.

At Stockholm University, the accelerator scientists originate mainly from the former National Laboratory "Manne Siegbahn Laboratory", where an ion storage ring for atomic physics, CRYRING, was operated for many years; this machine will now be included in the FAIR project at GSI. A new cryogenic storage ring, DESIREE, is presently close to completion. The accelerator physicists count up to around 10 people.

At Uppsala University, the accelerator scientists originate mainly from the former The Svedberg Laboratory, which is now closed. A cyclotron facility is still operating, to be closed down when the proton therapy facility becomes operational. A tandem accelerator is also still operating. In addition, Uppsala University has invested in RF test facilities for the European Spallation Source in Lund. Around 10 accelerator physicists and engineers are working at the university. A course in Accelerator physics is regularly given on under graduate level and PhD students study Accelerator physics.

At Lund University, several electron accelerators have been built over the years at the so called MAX IV laboratory (former MAX-lab). Formal training and teaching has been ongoing for many years in accelerator physics and technology. A large number of students have been trained and obtained their degrees at all levels. Recently a new set of educations have started: a Bachelor program in "Science with photons and neutrons", a Master program in "Synchrotron radiation based sciences" and a specialization at the Lund Institute of Technology (LTH) in "Accelerators

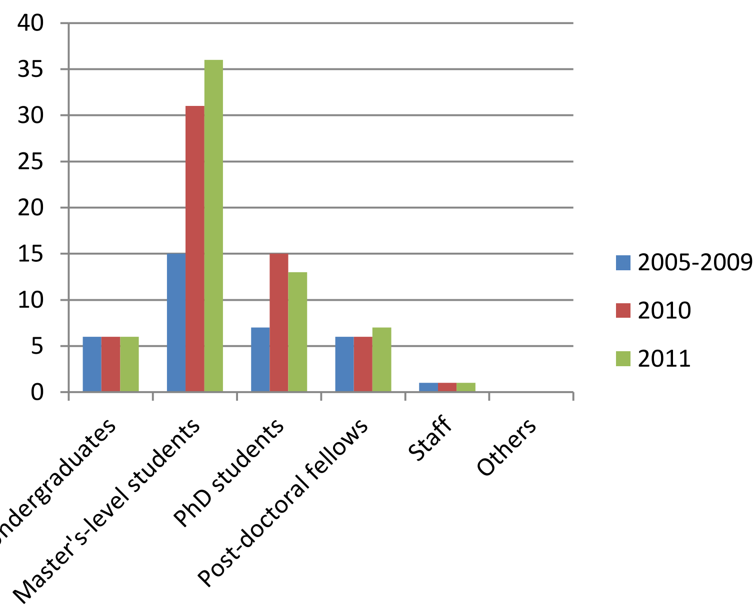
- physics and technology”. In 2011 the construction of the MAX IV project started. At present 10 PhDs in accelerator physics are working at the laboratory. In addition there are around 5 PhD students and more than 10 scientists and engineers working closely with accelerator technology. These numbers include the staff at Lund University. The design team for the Polish light source, SOLARIS, has placed five accelerator scientists at the MAX laboratory.

Recently, it was decided to locate the European Spallation Source, a very major accelerator facility, in Lund in Sweden. Already now more than 100 persons are employed, to increase to maybe 400 in a few years. A significant fraction of these will be accelerator physicists, at present maybe 20 increasing to maybe 40 in the next years.

The Royal Institute of Technology in Stockholm had for many years their own accelerators including staffs for research and development. These facilities have now closed down, but basic training is apparently still taking place, although this was not included in the present survey.

Finally, we mention a couple of companies delivering accelerator products exist in Sweden, namely Scanditronix Magnets and ScandiNova.

Switzerland

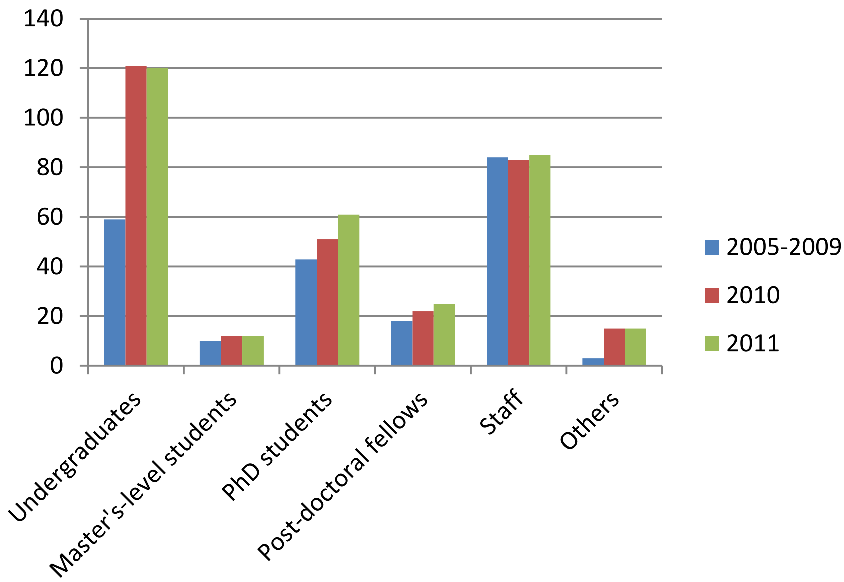


Accelerator science teaching and training in Switzerland is concentrated around the two large centres, CERN and PSI.

In 2004, the Swiss Federal Institute of Technology in Lausanne (EPFL) and Paul Scherrer Institute (PSI) jointly created a chair for accelerator physics. The Particle Accelerator Physics Laboratory (LPAP) offers courses on accelerator physics at Master and Doctoral level. Master students are given an opportunity to have practical training and Master’s thesis projects based at CERN and PSI.

CERN Doctoral Students program is a very important resource supporting PhD study, working closely with European universities, and in particular, with EPFL.

United Kingdom



The United Kingdom operates large accelerator facilities at the Rutherford Appleton Laboratory and Daresbury Laboratory sites. The largest of the facilities are the ISIS spallation neutron source and the Diamond Light Source. Several universities also have local accelerator R&D facilities.

A major new initiative in accelerator science was launched approximately 10 years ago with two main aims: 1) investment in R&D in accelerator science in key areas of interest to the UK community; 2) regeneration of accelerator science as an academic training discipline in the UK.

Two new university-based institutes, the John Adams Institute (Oxford University and Royal Holloway, University of London) and the Cockcroft Institute (Lancaster, Liverpool and Manchester Universities) were formed with the explicit task of rejuvenating formal training in accelerator science. Both institutes have set up training programmes at the undergraduate, master's and PhD levels. In addition, a number of other universities (see Appendix 1) have started their own academic training programmes. This national initiative, combined with the funding of R&D programmes that provide opportunities for PhD students and post-doctoral fellows to work on research projects, accounts for the increase in the numbers of UK trainees during the survey period.

APPENDIX 4: CAS statistics

The CERN Accelerator School holds training courses for physicists and engineers twice per year. The courses take place in conference centres in different member states of CERN and consist of a programme of lectures and tutorials spread over a period of two weeks. Participants are welcome from member states of CERN and other countries world-wide.

The present pattern is to hold a course in the spring on a specialist topic, and a course on general accelerator physics in the autumn. The general course is at an introductory level in even years and at an advanced level in odd years. Average attendance at a school is around 100 students; in some schools the participation has to be limited. Each school provides some 50 hours of teaching.

More details can be found at https://cas.web.cern.ch/cas/

A summary of the CAS student institute national affiliations, and student nationalities, is given in the tables below for schools between 2006 and 2010.

Student Home Institute Country at CERN Accelerator Schools 2006 to 2010													
	Total	%	Average/yr	Poland06	Spain06	UK07	Sweden07	Italy07	France08	Germany09	Belgium09	Bulgaria 10	Denmark10
	952												
SWITZERLAND	320	33.6	64	44	22	29	29	51	24	26	16	42	37
GERMANY	190	20.0	38	14	20	14	27	14	19	16	14	35	17
UNITED KINGDOM	101	10.6	20.2	22	3	11	4	14	10	13	13	3	8
FRANCE	72	7.6	14.4	12	4	7	3	6	16	2	7	6	9
ITALY	59	6.2	11.8	3	7	6	11	8	3	4	7	6	4
SPAIN	44	4.6	8.8	4	13	5	1	6	7	0	3	1	4
UNITED STATES	18	1.9	3.6	1	8	0	1	0	3	0	3	1	1
POLAND	14	1.5	2.8	4	1	0	3	0	1	0	0	2	3
DENMARK	13	1.4	2.6	4	1	0	2	2	2	0	2	0	0
SWEDEN	13	1.4	2.6	0	5	0	1	0	0	0	1	4	2
RUSSIA	12	1.3	2.4	2	1	0	3	0	3	2	0	0	1
CANADA	10	1.1	2	1	1	0	0	1	2	1	0	1	3
AUSTRALIA	8	0.8	1.6	0	0	0	0	2	3	0	0	1	2
BELGIUM	8	0.8	1.6	0	0	0	0	1	1	1	3	2	0
TAIWAN	7	0.7	1.4	0	2	0	3	0	0	0	2	0	0
TURKEY	6	0.6	1.2	1	0	1	0	2	1	0	0	1	0
INDIA	6	0.6	1.2	1	1	0	0	0	1	0	2	0	1
SLOVENIA	6	0.6	1.2	1	0	0	2	0	1	0	0	0	2
CZECH REPUBLIC	4	0.4	0.8	0	0	1	2	0	1	0	0	0	0
NETHERLANDS	4	0.4	0.8	0	0	0	2	1	1	0	0	0	0
AUSTRIA	4	0.4	0.8	0	0	0	0	1	1	0	2	0	0
PORTUGAL	3	0.3	0.6	0	1	0	0	2	0	0	0	0	0
BULGARIA	3	0.3	0.6	0	0	1	0	0	0	0	0	2	0
IRAN	3	0.3	0.6	0	0	3	0	0	0	0	0	0	0
JAPAN	3	0.3	0.6	0	0	0	1	0	1	0	0	0	1
UKRAINE	2	0.2	0.4	1	0	0	0	0	0	0	0	1	0
FINLAND	2	0.2	0.4	0	0	2	0	0	0	0	0	0	0
KOREA	2	0.2	0.4	0	0	0	0	0	0	0	0	0	2
GREECE	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
HUNGARY	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
JORDAN	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
BRAZIL	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
SOUTH AFRICA	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0
LITHUANIA	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
ARMENIA	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
CHINA	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
UZBEKISTAN	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
SUDAN	1	0.1	0.2	0	0	0	0	0	1	0	0	0	0
NORWAY	1	0.1	0.2	0	0	0	0	0	1	0	0	0	0
MEXICO	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0
MALAYSIA	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0
VIETNAM	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0
KENYA	1	0.1	0.2	0	0	0	0	0	0	0	0	0	1
43	952	100	190.4										

Student Nationality Distribution at CERN Accelerator Schools 2006 to 2010													
	Total	%	average/yr	Poland06	Spain06	UK07	Sweden07	Italy07	France08	Germany09	Belgium09	Bulgaria10	Denmark10
	930												
German	169	18.2	33.8	14	18	11	20	16	19	17	14	22	18
French	122	13.1	24.4	21	13	10	13	10	18	5	7	10	15
Italian	120	12.9	24	10	10	15	12	19	8	6	11	16	13
British	77	8.3	15.4	16	3	5	4	17	6	8	10	3	5
Spanish	72	7.7	14.4	8	14	6	4	8	11	3	5	6	7
Polish	33	3.5	6.6	6	1	0	9	4	3	2	1	4	3
Swiss	30	3.2	6	2	1	3	5	5	4	0	1	4	5
Austrian	26	2.8	5.2	5	0	4	1	2	3	4	2	2	3
Belgian	26	2.8	5.2	3	4	3	0	4	3	1	5	3	0
Russian	22	2.4	4.4	4	2	2	4	2	3	2	0	1	2
Danish	14	1.5	2.8	3	1	0	2	2	2	1	2	1	0
American	14	1.5	2.8	1	5	0	2	0	3	0	3	0	0
Swedish	14	1.5	2.8	1	5	0	2	0	0	0	2	1	3
Canadian	13	1.4	2.6	2	1	1	0	1	2	1	1	2	2
Dutch	13	1.4	2.6	2	2	0	4	0	2	0	3	0	0
Indian	12	1.3	2.4	1	1	1	0	0	2	0	2	2	3
Chinese	12	1.3	2.4	1	1	0	0	2	0	3	0	2	3
Greek	11	1.2	2.2	3	1	1	0	2	0	2	0	0	2
Portuguese	9	1.0	1.8	3	2	0	0	3	0	0	1	0	0
Turkish	9	1.0	1.8	1	0	1	1	2	2	1	0	1	0
Australian	9	1.0	1.8	0	0	1	0	2	2	1	0	1	2
Ukrainian	7	0.8	1.4	1	1	0	0	1	0	0	0	3	1
Taiwan	7	0.8	1.4	0	2	0	3	0	0	0	2	0	0
Iranian	7	0.8	1.4	0	0	3	0	0	0	0	1	2	1
Romanian	7	0.8	1.4	1	0	1	0	0	1	0	0	2	2
Czech	6	0.6	1.2	0	0	1	3	0	1	0	0	1	0
Bulgarian	5	0.5	1	1	0	1	0	0	0	0	1	2	0
Norwegian	5	0.5	1	0	0	1	0	1	1	1	0	1	0
Japanese	5	0.5	1	0	0	0	1	0	1	0	1	1	1
Slovenian	4	0.4	0.8	1	0	0	1	0	0	0	0	0	2
Hungarian	4	0.4	0.8	1	1	1	0	0	0	0	0	0	1
Irish	4	0.4	0.8	1	0	1	1	0	0	0	0	1	0
Slovak	3	0.3	0.6	1	0	0	0	0	1	0	0	1	0
New Zealand	3	0.3	0.6	0	0	2	0	0	1	0	0	0	0
Finnish	3	0.3	0.6	0	0	2	0	1	0	0	0	0	0
Armenian	3	0.3	0.6	0	0	1	0	1	0	1	0	0	0
South Korean	3	0.3	0.6	0	0	0	0	0	0	0	0	1	2
Pakistani	2	0.2	0.4	0	0	1	0	0	0	0	0	1	0
Thai	2	0.2	0.4	0	0	0	0	2	0	0	0	0	0
Cypriot	2	0.2	0.4	0	0	0	0	0	0	1	0	1	0
Mexican	2	0.2	0.4	0	0	0	0	0	0	1	0	1	0
Macedonian	1	0.1	0.2	1	0	0	0	0	0	0	0	0	0
Jordanian	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
Brazilian	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
Moroccan	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
Singapore	1	0.1	0.2	0	0	1	0	0	0	0	0	0	0
Peruvian	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0
Argentinian	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0
South African	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0
Serbian	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0
Lithuanian	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
Sudanese	1	0.1	0.2	0	0	0	0	0	1	0	0	0	0
Malaysian	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0
Nigerian	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0
Vietnam	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0
Colombian	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0
Filipino	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0
Lebanese	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0
Kenyan	1	0.1	0.2	0	0	0	0	0	0	0	0	0	1
Tunisian	1	0.1	0.2	0	0	0	0	0	0	0	0	0	1
60	930	100	186	115	92	80	96	108	100	63	75	103	98

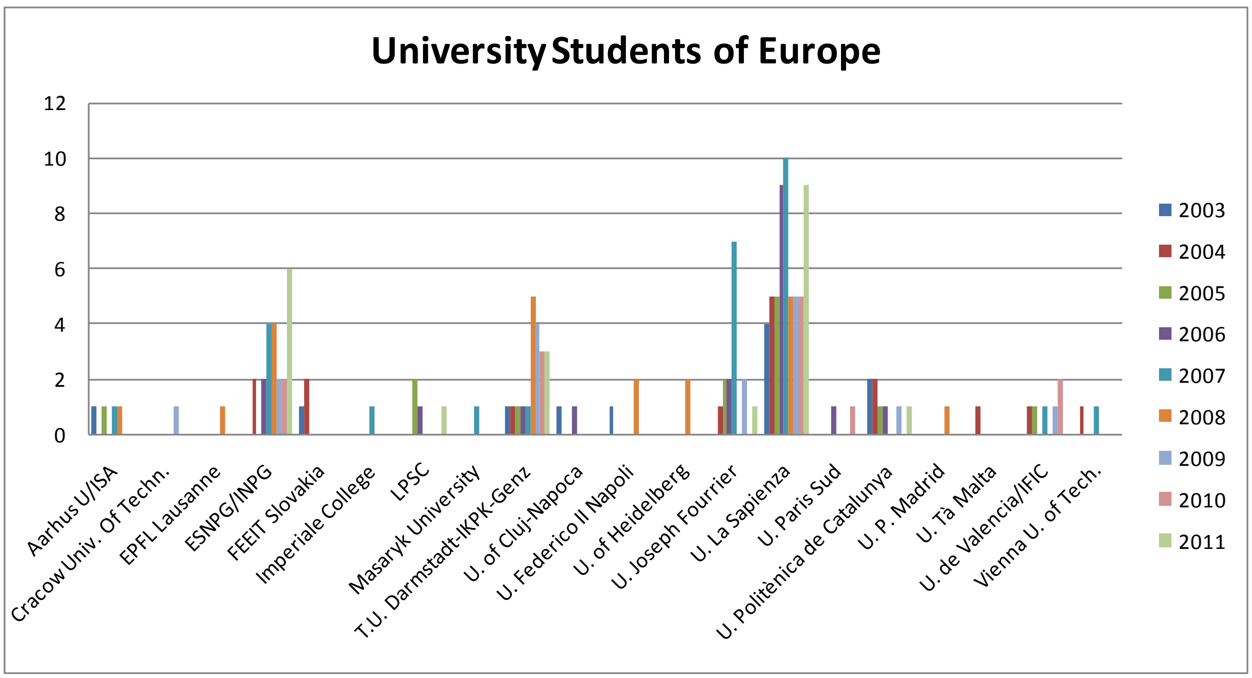
APPENDIX 5: JUAS statistics

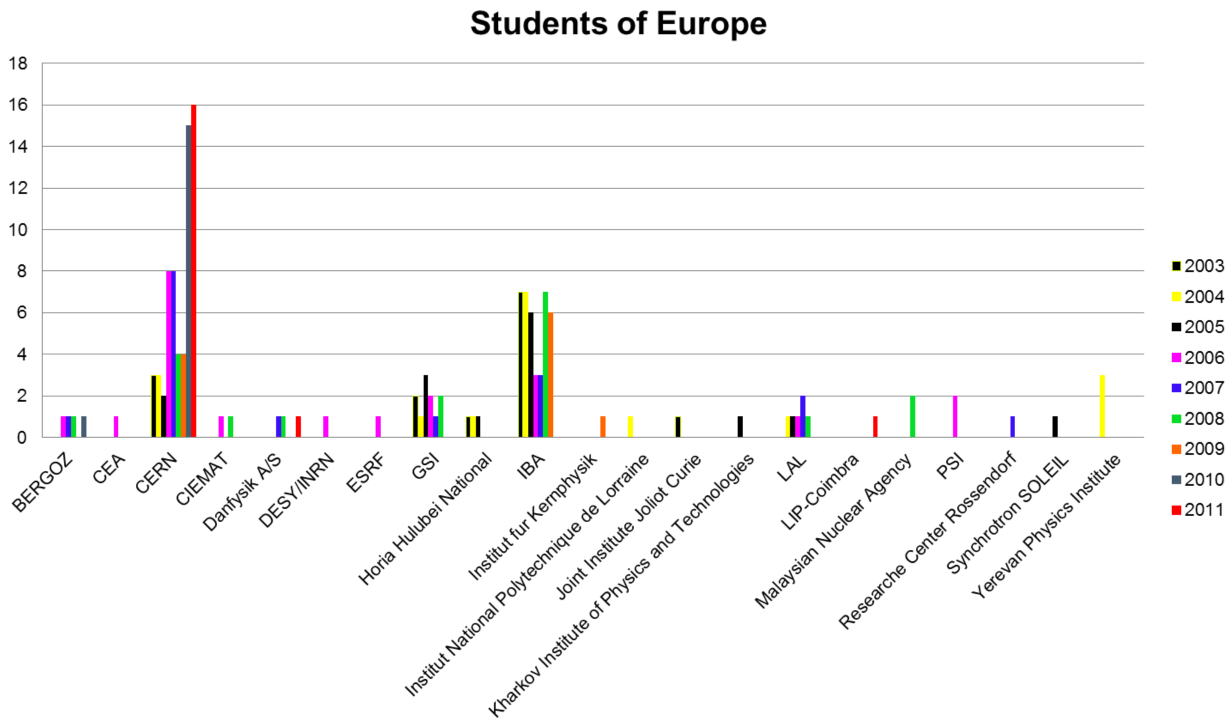
The Joint Universities Accelerator School holds training courses for Master's students, PhD students and engineers once per year. The courses take place in the "Centre Universitaire"-Archamps (Haute-Savoie) in France, 15km from CERN. They consist of a programme of lectures and tutorials spread over a period of 10 weeks. Participants are welcome from European universities, European Institutes and other countries world-wide.

The first course "Sciences & Physics of Particle Accelerators" runs, each year, at the beginning of January followed by the second one "Technology & Applications of Particle Accelerators". Students could present examinations at the end of each course and could obtain a total of 20 ECTS (European Credit Transfer System) credits, recognised by the 14 European university partners of JUAS.

The first figure below shows universities students who have followed JUAS courses between 2003 and 2011; the second figure shows the number of students coming from the various European laboratories and institutes for the same period. In 2012, there were 60 students coming from 22 different countries world-wide. Presently more than 800 students have followed JUAS courses since 1994.

The JUAS web site at http://cern.ch/juas provides more details.




Students of Europe
18
16
14
12
10
8
6
4
2
0
BERGOZ
CEA
CERN
CIEMAT
Danfysik A/S
DESY/INRN
ESRF
GSI
Horia Hulubei National
IBA
Institut fur Kernphysik
Institut National Polytechnique de Lorraine
Joint Institute Joliot Curie
Kharkov Institute of Physics and Technologies
LAL
LIP-Coimbra
Malaysian Nuclear Agency
PSI
Researche Center Rossendorf
Synchrotron SOLEIL
Yerevan Physics Institute
2003
2004
2005
2006
2007
2008
2009
2010
2011

APPENDIX 6: NATIONAL AND INTERNATIONAL FACILITIES

The following facilities were reported as being used for provision of training. Where they were identified in the survey, specific projects at the respective facility are listed in brackets.

Finland

Jyvaskyla University

France

CEA/DSM/IRFU/SACM

CNRS/IN2P3/LPSC

ESRF

GANIL/CEA/CNRS

Germany

DESY (FLASH, PETRA III, DORIS III)

GSI (UNILAC, SIS, ESR)

FZ Jülich (COSY)

Helmholtz-Zentrum Berlin (BESSY-II, HoBiCaT, MLS)

TU Darmstadt (S-DALINAC)

TU Dortmund (DELTA)

Universitat Mainz (MAMI-C)

Italy

CNAO (hadron therapy facility)

ENEA (proton and electron linacs)

INFN-LNF (DAFNE, SPARC, BTF)

INFN-LNS (Tandem Van der Graaf, superconducting cyclotron, ECR ion sources)

Università di Napoli (Tandem)

Japan

J-PARC

KEK

UVSOR

Poland

IPJ

Warsaw Heavy Ion Cyclotron

Spain

ALBA

Sweden

Lund (MAX-lab)

Switzerland

CERN

PSI

United Kingdom

Daresbury Laboratory (ALICE, EMMA)

RAL (Diamond, FETS, ISIS, MICE)

Strathclyde University

Surrey Ion Beam Centre

United States

ANL

FNAL

SLAC (FACET, LCLS)

UCLA