Physics on Course to Bologna

A survey of the Konferenz der Fachbereiche Physik (KFP, German Physics Faculties' Conference) provides an overview of the implementation of the new Bachelor and Master degree courses in Germany.

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The Bologna Process has launched extensive reforms of the university study courses in Germany. By 2010, essentially all previous physics courses of study will be replaced by Bachelor and Master courses throughout the country, including professional physicist (diploma degree) and physics teacher (state examination) programs. In May 2005, the Konferenz der Fachbereiche Physik (KFP, German Physics Faculties' Conference) issued recommendations for the new Bachelor and Master curricula in physics. (1) A detailed survey about the progress of the transition and organization of the new programs within the German physics faculties was made in June 2007; it provides an overview of the development. In the following, I would like to summarize the results.

In the Bologna Declaration of 1999, the European countries – there are presently 46 member states – agreed upon the creation of a common European higher education area by 2010. (2) An essential objective of the development of a European network of university education is to create transparent and comparable academic degrees, thereby furthering the international competitiveness, employability and mobility of students and graduates.

Fundamental elements of the Bologna Process are:

- Implementation of a two-stage system of curricula (Bachelor/Master),
- comprising topically defined modules with credit points (CP) that reflect the effort required to meet the goals of the courses.
- Standards and guidelines for quality assurance are introduced to ensure national and European comparability of modules and degrees.

Implementation of the Bologna Process demanded a reorganization of the physics programs to conform to the Bachelor/Master system, which initially generated controversial discussions among physicists, since the Diploma degree in physics had been appreciated for decades as a "trademark" by science and economy, both at home and abroad. This is also reflected by the low unemployment rate of physicists that was only slightly above three per cent in 2006. (3)

For many years, KFP had the important function to coordinate the standards of physics degree programs in order to ensure comparable quality standards throughout Germany. In 2005, KFP passed guidelines for the organization of the new Bachelor/Master curricula at German physics faculties. According to these recommendations, the Bachelor course shall impart a broad, general physics education in six semesters and ensure a fundamental professional qualification. On this basis, the consecutive, four-semester Master course offers specialized knowledge in sub-disciplines of physics and leads to an education at the highest international level. An overall one-year research period shall qualify the student for independent scientific work. The Master degree is comparable to the present Diploma and is the standard entry degree into a PhD program.

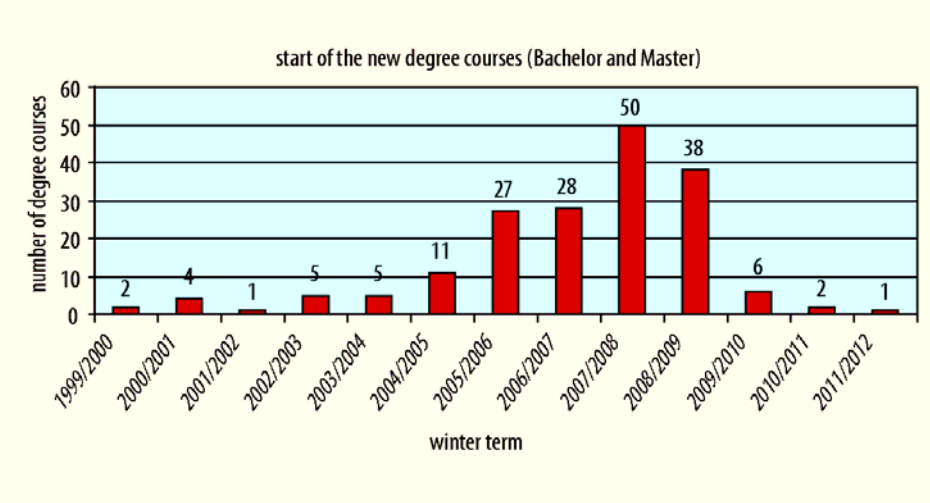

Fig. 1 *The restructuring of the new courses hits its peak in the winter semester 2007/08.*

Successful snap-shot

The conversion of the physics programs at German universities is currently in its critical phase (Fig. 1). For the winter semester 2007/2008, the majority of the physics curricula were already turned into Bachelor/Master degree courses. This process shall be finished by 2010 and, therefore, this milestone of the Bologna Process will be met. In the summer term 2007, the reform process had proceeded sufficiently far that the time was ripe for a first assessment. To this end, the KFP Executive Board developed a questionnaire for collecting data about the planned and already realized curricula (professional physicists' courses, teachers' education, and trans-disciplinary courses with main focus on physics). Besides organizational questions (e.g., type/name of the course, date of conversion, capacity, accreditation, language of instruction, admittance tests), this questionnaire contained mainly questions about the content

of the courses (emphasis on the sub-disciplines within physics, mathematics, lab courses, voluntary courses, final theses).

53 physics faculties at German universities (of a total of 58) provided data on 184 courses which included 50 courses for physics teachers. Consequently, a nearly complete snap-shot of the conversion to Bachelor/Master degree physics courses at German universities has been attained. The main focus of this report is on the professional physicists' courses. The survey on physics teachers' courses yields a very heterogeneous pattern which is not suitable for a comprehensive report. Universities' legislation is within the responsibilities of the individual states in Germany's federal system and, apparently, there are largely different notions among the federal states about the implementation of the transition.

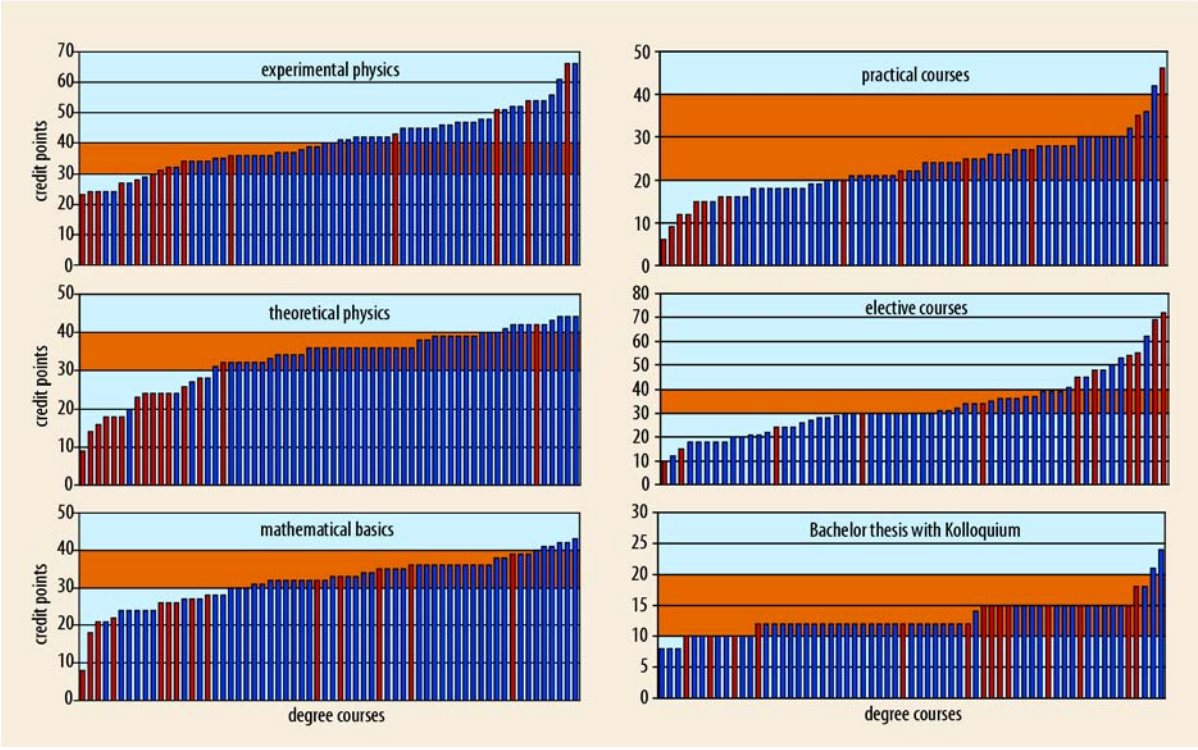

Fig. 2 *Compared with the explicit physics courses (blue), courses with special titles (red) diverge more from KFP recommendations for the Bachelor (orange band).*

Bachelor courses

All registered Bachelor courses comprise six semesters each. 50 courses lead to the university degree "Bachelor of Science" (all participating faculties except for one intend to offer this degree). Additionally, there are 13 courses with special titles which are in many cases interdisciplinary in character. Nevertheless, they have their focus on physics, e.g., physics in computer sciences, materials science, and physics in economy. (4) Moreover, the faculties

reported 22 Bachelor courses for physics teachers. Each topical course consists of 22 modules on average. 87 per cent of the courses consist of 15 to 30 modules.

KFP recommendations for the structure of physics degree programs	
Bachelor program	
lectures / tutorials in experimental physics	30 – 40 CP
lectures / tutorials in theoretical physics	30 – 40 CP
lectures / tutorials in mathematical basics	30 – 40 CP
basic lab course	10 – 20 CP
advanced lab course	10 – 20 CP
elective lectures / tutorials	30 – 40 CP
Bachelor thesis with colloquium (max. 3 months)	10 – 20 CP
Total:	180 CP
Master program	
advanced study phase:	
lectures / tutorials in experimental physics	10 – 20 CP
lectures / tutorials in theoretical physics	10 – 20 CP
elective and advanced courses (lectures, project/advanced lab courses, tutorials)	30 CP
research phase:	
introductory modules	30 CP
Master thesis	30 CP
total:	120 CP

According to the KFP recommendations, key curricular activities should be represented in the new courses with specific weighting factors (see table). Figure 2 shows that the faculties mainly followed these recommendations while realizing the Bachelor course (without teaching). Significant variations are noted only for the category “experimental physics”, for which 45 per cent of the courses allocate more than the recommended 40 credit points. Red columns denote special courses with focus on physics. They are predominantly found at the edge, as they may deviate from the norm due to their non-physics components. Apart from some exceptions, 10 – 15 credit points are assigned to the Bachelor thesis. In the elective courses, the overall number of credit points ranges between 10 and 70. Here, more than 50 per cent of all courses deviate from the KFP recommendation. In the vast majority of Bachelor courses, the essential fields of physics – mechanics, electrodynamics, optics, thermodynamics, statistics, nuclear and molecular physics, physics of condensed matter, nuclear and elementary particle physics as well as quantum mechanics – are covered as recommended (Fig. 3). Pronounced deviations can only be found in nuclear and elementary particle physics. However, seven out of the twelve courses without this topic belong to courses with special orientation.

The comparison of the Bachelor courses allows one to conclude that similarly designed physics courses will exist within Germany so that a similar knowledge standard and proficiency level of the graduates can be anticipated.

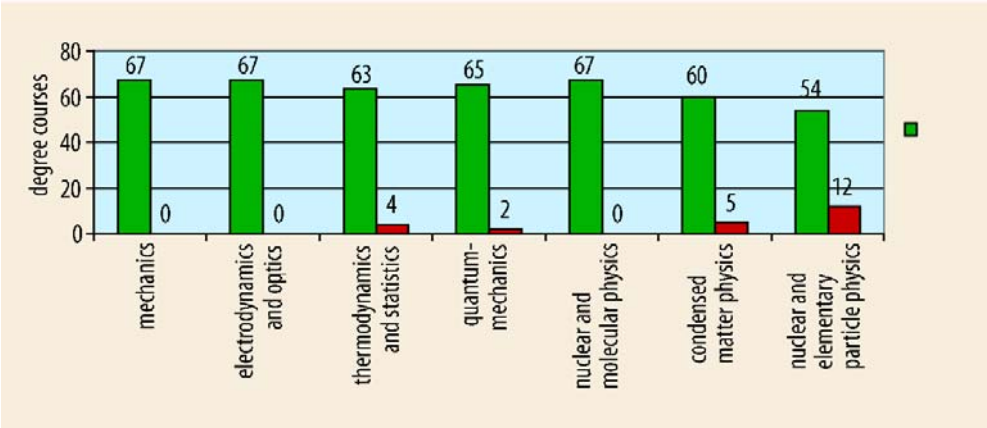

Fig. 3 *Most Bachelor courses cover the major sub-disciplines of physics.*

Master courses

A total of 94 Master courses were reported, 91 of them consecutively build upon the Bachelor degree; 91 are designed for four semesters. 42 of these courses lead to a Master degree in physics; another 24 courses have a topical orientation in, for example, astrophysics, biophysics or technical physics. (4) Thus, the relative fraction of these specialized courses is much higher than at the Bachelor level and reflects the anticipated specialization in the Master course. Nearly 90 per cent of the professional physicists programs were classified as research-oriented rather than application-oriented. 28 of the Master courses are for physics teachers. Concerning the educational content, KFP recommended to design Master courses in such a way that they consist of a one-year advanced study phase followed by a one-year research period during which the Master thesis has to be written (table). The graphs in Fig. 4 show very broad distributions of the credit points in the three categories: experimental and

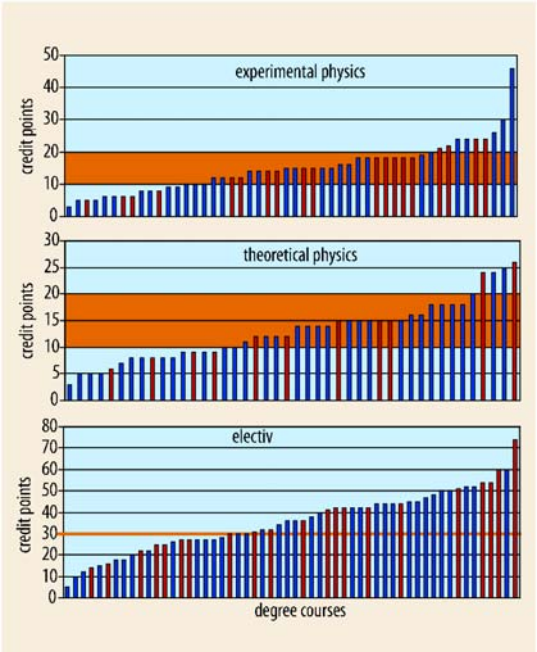

Fig. 4 *During the one-year advanced studies period of the Master course, the electives show an enormous range of credit points (orange: KFP recommendation).*

theoretical physics as well as voluntary and advanced study courses in the advanced study phase. Apart from a few exceptions, the reference points for experimental and theoretical physics were met. For the electives and advanced study courses, the enormous bandwidth of 5 – 74 credit points reflects the increasing specialization in the curricula. The research period consists of introductory modules with altogether 30 credit points, followed by the actual Master thesis with another 30 credit points. The faculties followed the KFP recommendation for the creation of four-semester Master courses with only one exception.

Further aspects of the reform

It is a distinct aim of the Bologna Process to encourage mobility and the development of international networks. Interestingly, German remains the language of instruction for the majority of the registered courses; only 11 are taught in English and 22 are bilingual.

In the framework of the Bologna reform, miscellaneous tools are foreseen for the quality management of university study courses. First of all, an entry examination may be required for admittance, which is the case for only 37 per cent of the Bachelor and Master courses. In the past, physics classes were rarely overcrowded, so that an initial restriction of admittance may not be desirable. Rather, many faculties intend to counteract proficiency deficits of students entering the programs at an early stage by keeping strict progress control and offering student tutoring, in addition to the course-related module exams. In this way, one aims to keep the drop-out rate of students at a minimum. Many possibilities of early consulting (tutorials, mentoring) as well as monitoring (examinations to help orientation, number of credit points at certain study stages, examinations across the modules) are foreseen. Not only the students are continuously assessed, but also the courses themselves are inspected within the accreditation by independent external agencies, e.g., ASIIN. At present, 59 Bachelor and Master courses in physics have gone through this procedure and, so far, no course has been refused accreditation. Another 38 courses are amidst the process of accreditation; 58 courses are presently in preparation of accreditation. In the meantime, the replacement of program accreditation by system accreditation is being discussed. Reasons for this development are, amongst others, the tremendous expenditures. While each single course is reviewed in a program accreditation, system accreditation reviews primarily the implementation of internal quality control management within a university. Already ten faculties aim at a system accreditation.

Clear profile for career opportunities

The character of the discipline “physics” defines itself by the kind of academic education in this subject. Therefore, it is understandable that the study reforms caused by the Bologna Process have been discussed passionately and controversially among the physicists. The physics faculties utilize the transition to the Bachelor/Master scheme judiciously to adjust their courses to the constant changes within the field as well as to adapt them to an ever-changing environment. The data presented here offer an outlook on the future development of physics university studies in Germany.

The guidelines of the Bologna Process require the Bachelor degree to be the first degree representing a professional qualification. Indeed, the Bachelor curricula in this survey cover all essential fields of physics and impart knowledge which is necessary for job qualification. To realize this goal, courses which usually cause problems for the students (mathematics, theoretical physics) are arranged in a temporally more concentrated manner during the six semesters of the Bachelor courses as compared to the traditional Diploma courses. This problem requires special attention by the faculties to keep the drop-out rate as low as possible. As the structure of the Bachelor courses is quite tight, it may lead to longer overall study periods if students have to repeat courses.

In the Bachelor education, an in-depth exploration of subfields of physics and, particularly, a longer research period are absent. These curricular activities already provide students with job experiences; they were a significant part of the previous (Diploma) physicist education and were likely responsible for the high attraction of physicists on the job market. It is for this reason that KFP and the Deutsche Physikalische Gesellschaft (DPG, German Physical Society) (5) recommend physics students to complete their education by continuing in a consecutive Master course. Our survey reveals that the student capacity in the Master programs will be one-third less than in the Bachelor programs. Assuming that one third of the entering freshmen will drop out of physics, there will, however, be enough room for the remaining students to continue toward a Master degree.

The examination modalities will experience a fundamental change by adapting to the Bachelor and Master system. In the spirit of an efficient study progress, the Bologna Reform is asking for course-related module examinations so as to continuously provide feedback to the students concerning their level of achievement. Thereby, students have the possibility to realize and compensate their deficits instantly. Within the Diploma courses, such exams were already established in the form of numerous written tests. However, exams covering a broad range of topics, as it was the case in the intermediate Diploma and final Diploma

examinations, will no longer exist. Some professors are concerned that the students may only concentrate in future exams on narrowly focused topics, and that they may no longer acquire a broad view across the subfields that reveals the coherences of physics. The consequences of these changes should be monitored carefully.

The study reform in physics will replace the Diploma degree by two new degrees. It remains to be seen whether the Bachelor degree in physics will be a success. From the conceptional design of the courses it is evident that the previous Diploma physicist will be replaced by the physicist with a Master degree, with an equivalent professional profile. While a specialization in the Master study is desirable, one should be cautioned about too many different titles for physicists' degrees. As with the Diploma, a clear profile of the Master degree in physics largely defines the physicist's profession, and can guarantee excellent chances on the job market for the well-trained and versatile university graduates in physics.

Acknowledgement

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References

(1) The exact wording of the decision (in German) can be found at www.kfp-physik.de.

(2) A comprehensive description (in German) is provided by the German University Rectors' Conference (HRK) at www.hrk-bologna.de.

(3) U. Weigelt: "Arbeitsmarkt für Physikerinnen und Physiker", Physik Journal, November 2006, p. 27.

(4) A comprehensive listing can be found in: G. U. Nienhaus, "Physikstudium im Wandel", Physik Journal, August/ September 2007, p. 29.

(5) DPG press release 12/2004: "Für eine Neuordnung des Physikstudiums".

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