High school students' exposure to modern particle physics

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Modern physics of the 20th and 21st century is hardly taught in science courses at high schools in Europe. Nevertheless, introducing results of modern physics research at high-school level could positively influence the students' perception of today's role of physics, and along with it, their general interest in physics. On the other hand, discussing modern physics in too much detail or on too high a level might have the opposite effect. Therefore, appropriate topics and teaching material have to be identified and developed in close collaboration between scientists and educators. An evaluation is needed to assess the success and to optimize both the material and its channels of distribution.

Like all of us, young people from time to time seek to answer fundamental questions, such as what are we made of, where did matter come from, how did the Universe begin and how will it end? This would suggest that particle physics and cosmology is a topic of modern physics well suited for high schools. In recent years a wide range of material for the public understanding of particle physics has been developed, e.g. UK masterclass workshop exercises [1], German web-based teaching systems [2], or the material described by K.E.Johannson in this issue. This article will focus on evaluations of such material with 16-19 year-old high-school students, recently performed at several locations in the UK and Germany. The spectrum of these events covers visits to exhibitions, "masterclasses" at universities, and particle physics in the classroom as a part of the curriculum, thus ranging from mainly passive visits, through active but short-term workshops, to longer-term science teaching and assessment.

"TESLA—Light of the Future", an exhibition on particle physics and more

From 16.1. to 17.2.2002 a "journey to the origin of matter" and "insights into the most tiny dimensions of life" were offered to about 22,000 visitors to an exhibition in the centre of Berlin [3]. Among them were more than 70 school classes, mostly from grades 12 and 13 (17-19 year-olds). The topics of the exhibition were the forefront of particle physics research with the planned Electron-Positron Linear Collider TESLA, along with the exploitation of its accelerator technology for a Free Electron Laser light source with unprecedented brilliance, having applications in chemistry, biology and material science. The exhibition was realized by DESY in the basement of the Volkswagen Automobile Forum where original equipment, models, posters, videos, and hands-on material were displayed in an area of 700 m^2.

More than 250 students were interviewed [4] after the visit, which included an introductory talk and a tour guided by particle physicists or Ph.D. students. On a scale from 1 to 5 the students ranked particle physics to be quite interesting, with an average score of 3.9 for the male and 3.6 for the female students. Although this score is less enthusiastic than the one from the other visitors (4.3 and 3.9, respectively), the general physics interest of the students increased about 8% more than that of the public: 45% of the male and 52% of the female students responded that their general interest in physics had grown strongly during the visit. This increase was highly correlated (correlation coefficient ρ=26%) to the ability of the guides to stimulate this interest. In turn, the success of the guides was very much facilitated (ρ=42%), if the physics interest of the students before the visit was already large. Independent of the guides' explanations, those students who knew least about particle physics before coming to the exhibition gained most in their general interest in physics (ρ=–13%). Regarding the type of presentation, apart from the guides, the 3-dimensional models, the videos, and the eight hands-on stations (Figure 1) were the clear favourites. All visitors agreed, that only a few things could be improved, and that even more hands-on exhibits would be very good.

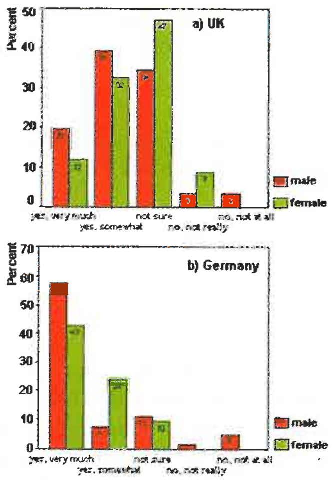
▲ Fig. 1: "Hands-on" activities at the TESLA exhibition in Berlin:
a) accelerating a ball surfing on a wave with adjustable phase velocity
b) focussing an electron beam using quadrupole magnets

Particle physics masterclasses

For about 6 years particle physics groups at universities in the UK have invited 17-18 year old high school students to spend a day in the university [5], for a mixture of talks and practical computer activities [1], such as identifying particles. After relatively little training the students are able to recognize various types of particles through real images of their tracks on computer, in a way that mirrors exactly the activities of working particle physicists. Deep insights into the properties of elementary particles, such as the universality of the three types of leptons in Z^0 decays, can be obtained this way.

This idea has begun to be copied by German universities, using translations of the UK material [1]. In the UK, whole A-level science classes, for which some particle physics is part of the physics curriculum, usually attend together with their teacher. The German masterclasses ("Schnuppertage") are based on voluntary attendance by individual high-school students. Particle physics, apart from radioactivity, is generally not taught in physics classes at German schools.

The evaluation [4] was based on interviews at London and Bonn masterclasses with a total of about 100 students, each. Although the basic knowledge was similar at both locations, quite substantial differences were observed. The UK students found the masterclass program in general more challenging ("right level" UK: 42%, D:65%, "difficult" UK: 41% D:15%), and judged that they had increased their knowledge in physics more strongly, with an average of 3.9 on a scale from 1 to 5, compared to 3.3 in Germany. In contrast to that finding, the German students gained more general interest in physics. Even more pronounced than at the TESLA exhibition, 39% of the male and 62% of the female stu-



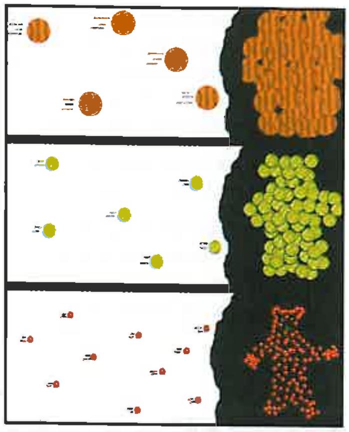
◀ **Fig. 2:** Response to the question, if 17-18 year-old students would like to deal more often with modern physics in their science classes, after having taken part in a particle physics masterclass at universities in the UK (a) and in Germany (b)

dents of the Bonn masterclasses reported that their general interest in physics had increased strongly or very strongly, resulting in an average change of +2.4 and +2.7, respectively, on a scale from 0 to +4. In the London masterclasses a somewhat smaller increase was observed with +2.1 and +1.8 for the male and female students, respectively. Although the differences between girls and boys are statistically not very significant in this one question, a synopsis of all answers shows that on average the British girls were less enthusiastic than the boys, while in Germany the opposite effect was found. A further large difference between London and Bonn was that 34% of the British students would have liked to sacrifice some lectures in favour of more computer activities, while only 17% would have preferred to do so in Germany. As a result of the particle physics masterclasses, the German students in particular would like to deal more often with modern physics at school (Figure 2).

Particle physics in the high school curriculum for 15-16 year-old students

At German High Schools the students have to select their spectrum of subjects for their last two or three years themselves. A nation-wide survey in the year 2000 [6] has revealed that 2 in 3 of the students drop physics at the earliest possible opportunity, which in some of the states already happens after the 10th grade, at an age of 15 to 16 years. The only modern physics topic the students are confronted with by that time is the physics of nuclear reactors. Recently, several "first theses" of student teachers at Bonn university tried to broaden the spectrum of modern physics available for this age [2]. Teaching concepts of particle physics [7], and of the impact of particle physics on medical applications and cosmology [8] were developed, supported by interactive Web Systems (Figure 3), and accompanied by background information for the teachers. For a trial conducted in four 10th grade classes, teaching units ranging from 8 to 26 lessons, depending on the available time, were formed by merging the previously existing material on nuclear physics with the new particle physics material...

The teachers who carried out the respective units clearly concluded in their evaluation [10,11] that modern particle physics can successfully be taught to students of this age. Written and oral tests of the students showed no difference in the distribution of grades compared to standard subjects of the curriculum. On a scale from 1 to 5, the students rated their interest in this teaching unit very highly with an average of 4.0, with more than half of the students of the shorter units demanding more time for questions and deeper discussions. While the level of difficulty was judged completely appropriate, three quarters of the students criticized a lack of practical experiments which could not be compensated by the few interactive simulations in the supporting Web system. The immediate influence of this modern physics teaching unit on the general physics interest of the students remained very small, according to their own judgement, but about 80% of the students would support the idea that particle physics should become a part of the 10th grade physics curriculum.



▶ **Fig. 3:** Example of an illustration about resolution power for 15-16 year-old students in Germany: A structure in a cave is resolved best using the smallest probes, from [9].

Summary

About 25 years after the Standard Model of particle physics was established, scientists and educators have started to develop material suited to bring high school students in contact with the fascinating world of the fundamental building blocks of matter and their interactions. Evaluations have proven to be helpful in revealing strengths and weaknesses of the projects, in order to carefully adjust the material and the ways of presentation to the respective target group. The most difficult, but perhaps most rewarding, effort will be to implement this exciting field of contemporary physics as a part of the curriculum for 15-16 year old high school students.

Exposure of young people to modern physics, such as particle physics and its technological applications, is possible in a broad range of channels from exhibitions to classroom lectures, and can contribute to promoting the general interest of young people in physics.

References

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