

Introducing an Innovative Approach of Teaching the Standard Model of Particle Physics at High School

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Abstract. The role that is assigned to elementary particle physics in high school education differs all over the world. Even within a single country like Germany there are major differences in the depth of discussion. To help teachers to address the fundamental concepts of elementary particles and their interactions and to reduce the subject didactically in respect to the given general conditions, Netzwerk Teilchenwelt has developed teaching material with an innovative didactic spiral approach. This concept is being presented and discussed during further trainings for teachers all over Germany.

1 Introduction – Why to Teach Particle Physics

Particle physics is one of the most emerging fields of physics research and recent achievements have frequently been in the media lately. But especially the research at CERN (European Organization for Nuclear Research) has also regularly caused dystopic concerns.

Under the given circumstances, it is hardly possible not to get in touch with particle physics in one way or another, which, of course, also applies to high school students. Therefore, one goal when teaching students about particle physics has to be to enable them to some degree to distinguish scientific facts or possibilities from pure science fiction and to participate in public discussions on this matter. Whether the engagement with particle physics is suitable to increase students' critical thinking skills, is presently being investigated [1].

Furthermore, especially mysteriously sounding terms and ideas like dark matter, dark energy and antimatter often arouse students' interest [2]. All in all, there are many aspects that make particle physics a valuable topic in high school education.

2 Outline of the Didactic Concept

German physics teachers want or even have to discuss aspects of the Standard Model of particle physics (SM), the most precise theory we have at the moment to describe elementary particles and the fundamental processes happening in our universe, at school to various degrees. In the state of North Rhine-Westphalia (NRW) for example, the SM has recently been added to the core curriculum in a comprehensive way [3]. In order to support teachers, Netzwerk Teilchenwelt, a Germany-wide network of scientists, teachers and also students, has developed different teaching materials, including a textbook [4] on the theoretical background of the SM with didactic suggestions and advice implemented in a spiral teaching approach with consistent terminology. This material is the basis for further training of teachers, which Netzwerk Teilchenwelt has been providing in an extensive way all over Germany since 2017. A deeper discussion of some aspects outlined here can also be found in [5].

One major goal of the development of this concept, the didactic approach and the material as such was to point out, find and emphasize points of contact and analogies between particle

physics and common contents of physics curricula. With these connections, teachers will be able to integrate aspects of particle physics in other subject areas.

The special idea of the developed approach is to shift the focus from the spectrum of existing matter particles to the properties that cause and the laws that govern their interactions, just like explaining an unknown game to someone. The most important thing to start with is explaining some essential rules for player interactions. In the case of soccer, for example, for the game to be considered a soccer match, it does not matter too much how many people and in which formation they are playing, as long as the rules of the game are obeyed.

Furthermore, all the stable matter in the world around us is only built by very few elementary particles. Most of the others do not play a direct role for our daily lives. So declaring the learning of their names as the main goal in the engagement with the SM – an approach often used – does not seem to be highly motivating. In addition to that, the spectrum of elementary matter particles is one of the aspects of the SM we cannot predict or explain by theory at all. In contrast to that, the three fundamental interactions of the SM, namely electromagnetism, the weak and the strong interaction, are theoretically understood to a very high degree.

All these interactions are caused by charges. One of them, the electric charge as the reason for electromagnetic interactions, is discussed at school in great detail. To understand the other two fundamental interactions of the SM, the concept of charge has to be transferred to them. In the described approach, the fundamental interactions and the respective charges are the pivot of all argumentation and the description of the rules of the elementary particle world.

Further key parts of the concept are to show the limits of the field line model and the introduction of the messenger particle model to describe the fundamental interactions as well as a comparison of both concepts, which, for example, is part of the curriculum in NRW.

3 Perception of the Concept

The received feedback from high school physics teachers after the presentation of the concept during further trainings has overall been very positive. After the training the participants were asked to fill out an evaluation form by expressing their agreement with given statements on a five-level Likert scale. A total of 148 teachers attended these further trainings in 2017. 66 % of them stated that the topic has high or rather high relevance for their work at school with 6 % giving no answer. 75 % agreed or rather agreed with the statement, that they feel capable of teaching particle physics after the training with 5 % giving no answer.

These numbers and the received individual oral feedback indicate that the chosen approach to teaching the SM can be viable in high school education. Whether this is true in practice will hopefully be shown within the next years, when the participants will have implemented the ideas into their teaching and direct feedback out of the classroom can be gained.

References

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