

## International Masterclasses in Particle Physics - expanding geographically and broadening in scope

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The flagship activity of the International Particle Physics Outreach Group (IPPOG) is International Masterclasses (IMC) in particle physics. This very successful programme brings cutting-edge science to high-school students. Invited to a university or laboratory, the students spend a day of immersion in particle physics, learning about the Standard Model, open research questions, experimental methods, detectors, and accelerators. The hands-on part involves analysis of data from an experiment. The IMC programme started in Europe, was later joined by America, and has now expanded to all continents. The data used were initially from LEP; with the turn-on of the LHC, measurements with data from ALICE, ATLAS, CMS and LHCb were introduced. In recent years, there has been a spectacular broadening of the physics content of the IMC, with data from Belle II at KEK, from neutrino experiments (MINERvA and NOvA at Fermilab), from astroparticle physics (Pierre Auger), and medical applications (Particle Therapy).

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## 1. The success of International Masterclasses

Masterclasses are extracurricular programmes for young people, especially high school students and, to some degree, undergraduate students, which have been organised and carried out by the particle physics community since 2005. Each Masterclass deals with a specific topic from current research in particle physics. The core of a Masterclass involves working with real data, mentoring by researchers, and discussing the results. What makes a Masterclass part of the International Masterclasses (IMC) programme is that the discussion of the results is embedded in a video conference with participants from all over the world. A Masterclass lasts about 6-8 hours and takes place directly at research institutes or universities. By joining a video conference with other locations at the end of the event, participants become scientists for a day and experience a hands-on approach to current research. The Masterclasses are free of charge and are offered at more than 200 research sites in 64 countries [1]. Based on feedback from participants and former participants of the Masterclasses, the overall impact is positive and indicates lasting benefits. A study by Kekelakova and Tomasik indicates a positive influence on participants towards pursuing a physics career [2]. The direct engagement of young people in modern research could be a promising way to recruit more people for a physics career [3]. An unpublished survey<sup>1</sup> of PhD students who are running Masterclasses in Germany found that 38% of them attended a Masterclass in high school.

## 2. The many flavours of Masterclasses

The diverse research areas of the particle physics community are reflected in the many Masterclass topics. While the basic structure of a Masterclass is always the same, consisting of an introductory talk, data analysis and a video conference, the topics are adapted to the current state of research in a variety of ways. Masterclasses are usually based on data and research priorities from the international collaborations ALICE, ATLAS, CMS, LHCb, Belle II, MINERvA, NOvA and Pierre Auger. Recognizing that particle physics is not limited to these experiments, new topics have been added, such as the Particle Therapy IMC introduced in 2020 [4]. It is important to note that there are still many more topics for International Masterclasses in development.

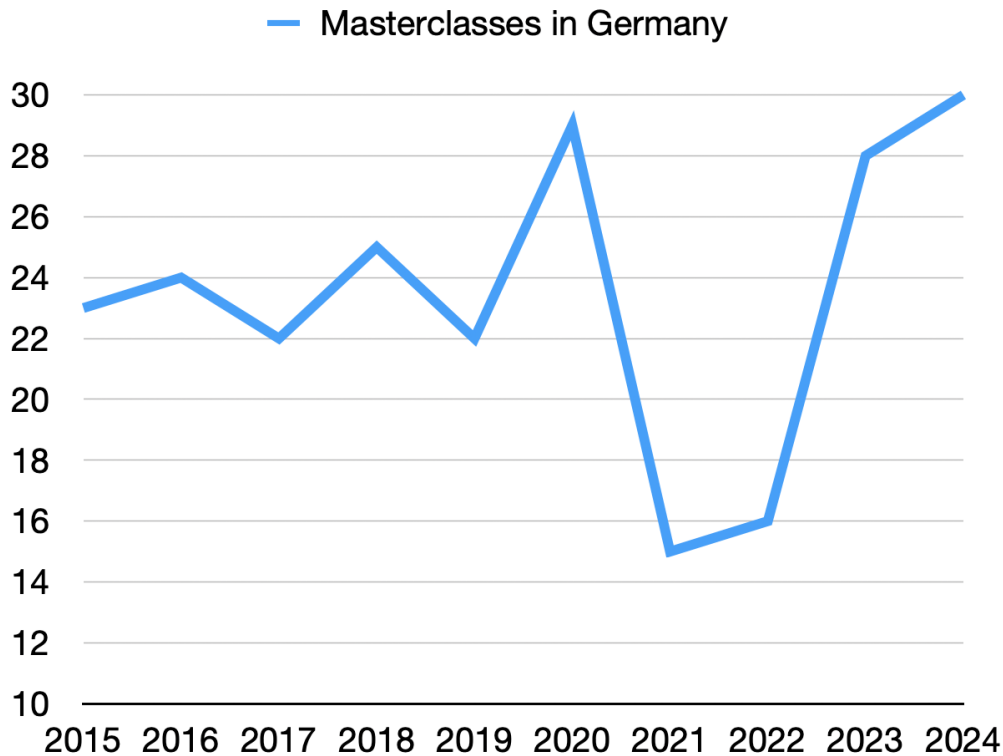
## 3. Masterclasses depend on scientists

Germany has long participated in the IMC programme, with over 20 Masterclasses held annually by institutes and more than 100 in schools through the Netzwerk Teilchenwelt outreach programme [5]. As seen in Figure 1, the German programme has suffered due to the COVID-19 pandemic. But the community, as in other countries, was able to recover and even outdo their performance. This was only possible thanks to committed research groups and persons who took the initiative in organising and running them. Motivated research groups are particularly important for International Masterclasses, as the video conferences require organisation between several locations. In the video conference with groups from several countries, high school students can experience the international aspects of particle physics research. The International Particle Physics Outreach Group (IPPOG) facilitates networking and serves as a point of contact for organization, but the implementation at the

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<sup>1</sup>Survey 2024 in Germany with 323 individuals contacted, 34 responses received.

local sites can only be done by the scientists on site. It is therefore of fundamental importance for the IMC that motivated scientists continue to act as tutors, helping to communicate their research to interested participants, acting as moderators for video conferences or even providing (digital) laboratory guidance, and generally making the Masterclasses possible.



**Figure 1:** An overview of Masterclasses conducted in Germany. The data comes from Netzwerk Teilchenwelt. The significant drop is caused by the COVID-19 pandemic. It was still possible to organise digital Masterclasses using the videoconference app *Zoom*.

## References

- [1] physicsmasterclasses.org, *Hands-on Particle Physics Masterclasses, Map World*, <https://physicsmasterclasses.org/index.php?cat=home&page=map>, accessed 24.09.2023.
- [2] Julia Kekelakova, Boris Tomasik, *On the long-term impact of non-formal learning in particle physics*, arXiv:2307.15906 [physics.ed-ph], 2023.
- [3] Borgelt et. al., *Engaging young minds with particle physics*, ICHEP, 2024.
- [4] Ł. Graczykowski, P. Nowakowski, P. Foka, *New developments for ALICE MasterClasses and the new Particle Therapy MasterClass*, arXiv:2005.02215 [physics.ed-ph], 2020.
- [5] U. Bilow and M. Kobel, *Netzwerk Teilchenwelt: An outreach network in Germany*, PoS(LHCP2020)197, published June 2020.