

## International Masterclasses: Forward from Pandemic

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International Masterclasses (IMC) is a program to engage high school students in authentic one-day particle physics analysis experiences at universities and laboratories worldwide. The program is run under the aegis of the International Particle Physics Outreach Group (IPPOG). The COVID pandemic created challenges for IMC in trying to reach the participants and excite them about cutting-edge science. Meeting those challenges not only addressed immediate issues but also expanded the capacity of IMC to deliver its program in the future. The authors will share what they have learned and prospects for the future.

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## 1. Introduction

International Masterclasses (IMC) [1] is a well-established program that offers high school students the possibility to gain insight into methods and tools of cutting edge research in high energy physics and to perform measurements on real data from particle physics experiments [2]. Universities and research labs invite high school students (15-19 y.) to be “particle physicists for one day”. The program includes lectures on topics such as standard model, detectors and accelerators, guided tours and hands-on activities with data from particle physics experiments. The day concludes with an international videoconference, where up to five groups from different countries participate – this conveys the international spirit of particle physics. The videoconference is moderated by two physicists at a research centre (CERN, Fermilab, KEK, GSI, TRIUMF).

The program aims to inform students about central findings, open questions and research methods of HEP research in order to inspire the next generation of scientists and to encourage appreciation and support for basic research. It is the flagship activity of the International Particle Physics Outreach Group (IPPOG) [3] and organized each year in spring.

### 1.1 Scope of Masterclasses

In a Particle Physics Masterclass, high school students perform measurements and work with real data collected by experiments. The results of these analyses are then discussed and combined in the videoconference. The program started in 2005 with data from the OPAL [4] and DELPHI [5] experiments, which were situated at the Large Electron-Positron (LEP) collider that operated at CERN until 1999 [6]. Since then, the program has continued to evolve, broadening its physics scope, adapting to the state of the various experiments, and thus always communicating cutting-edge research to students. From 2011 on, measurements with data from the four major LHC experiments (ALICE [7], ATLAS [8], CMS [9], LHCb [10]) have been made available for the program. In 2019, Masterclasses with data from the MINERvA neutrino experiment [11] were held for the first time. Since 2020, Belle II Masterclasses [12] have expanded the program offerings. In addition, a particle therapy Masterclass [13] has been developed, in order to highlight some of the benefits for society from the technology developed for particle physics research.

More neutrino Masterclasses are currently under development, with data from e.g. NOvA or ProtoDUNE. And it should be mentioned that other Masterclasses exist that are currently not held under the umbrella of IPPOG / IMC (e.g. IceCube, Pierre Auger, DarkSide).

### 1.2 Organisation

IMC is organized every year in spring and covers a period of  $\sim 7$  weeks around March. The main coordination is shared between University of Notre Dame and Technische Universität Dresden. More than 220 research labs from 60 countries are involved in the worldwide outreach program and offer Masterclasses for high school students on their premises. In 2019, under pre-COVID conditions, around 15.000 high school students participated.

## 2. Before the pandemic

Since the start of the program in 2005, Masterclasses have always been held in-person at universities and laboratories. High school students would come to the research facility where they would learn from and work shoulder-to-shoulder with physicists. Consequently, participants connected to the final videoconference as a group with a broad size distribution (10-300 students per location). Likewise the moderators were sitting preferentially together in one room.

## 3. During the pandemic

### 3.1 Year 2020

In 2020, the first Masterclasses with CERN videoconference were scheduled for February 26. By that time, the pandemic was already on the rise. As a consequence, a number of IMC institutes, especially from Asia and Italy, cancelled their scheduled Masterclasses. The program coordinators monitored the situation and saw a huge increase in cancellations. All videoconferences were suspended by March 18. By that time, 25% of the program with CERN videoconferences had been completed (66 Masterclasses). All other programs with videoconferences at Fermilab, KEK, or GSI had accomplished less than 20%, due to their later start.

IMC coordination offered two programs as compensation. In late spring 2020, teachers and students around the world – many new to IMC – took advantage of the Big Analysis of Muons in CMS (BAMC). This was an online Masterclass in webinar form, with lectures from particle physicists, local mentoring by teachers via Zoom, and a large webinar videoconference [14]. IMC also offered a summer program with Masterclass videoconferences that was announced and offered to the institutes, but this met with little interest. Only four institutes registered for the videoconferences on June 26 or 27. In these sessions the use of the mobile telephone app slido [15] was introduced to foster engagement with the audience in a pure Zoom setting, with students connecting individually.

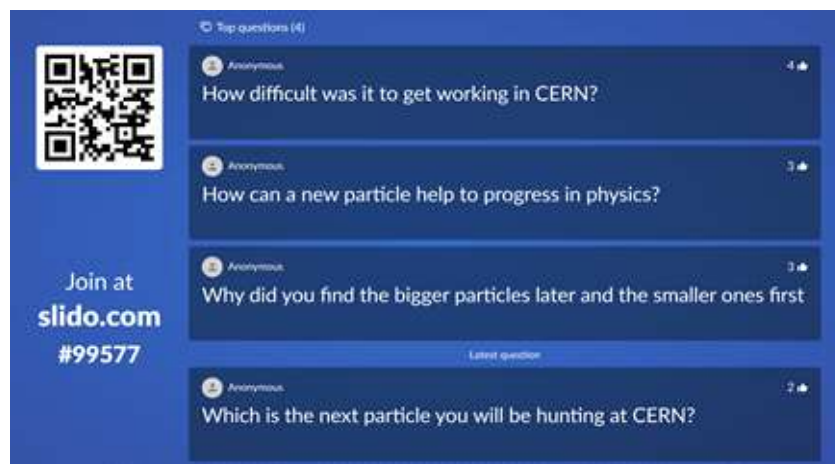


Figure 1: Q&A session using the slido app.

### 3.2 Year 2021

Due to the ongoing COVID-19 pandemic, an edition of Masterclasses adapted to the situation was announced. It was foreseeable in advance that most universities and research labs would not be able to accommodate groups of students on-site, so that participants would need to work from home. In this situation, a concept for fully virtual International Masterclasses was developed, including remote lectures and hands-on work with tutors in Zoom breakout rooms. The success of the online edition was ensured through increased support and the provision of various tools. IMC coordination developed recommendations for online Masterclasses for the institutes which covered the technical and organizational aspects. Guidelines for the physicists and tutors in the research institutes, including detailed information for each measurement, were updated. Special attention was paid to the fact that high school students had to install the software and data packages on their own computers. To help students and teachers with the installation, instructional screencasts were created and made available. Likewise, the preparation of the moderators had to be adapted to the new circumstances. Moderators' orientation was organized with prerecorded videos, which can also be used in the future as comprehensive documentation for moderators' training.

CERN and Fermilab videoconferences were set up as Zoom webinars in order to avoid disturbance and ensure a trouble-free process. These webinars were each able to accommodate up to 250 unique viewers. To effectively engage with the audience, Zoom polls and the Q&A function were used and the final quiz was played via the app kahoot. However, the level of satisfaction with the webinar setting was mixed. Several institutes complained about the anonymous setting, compared to a Zoom videoconference.

IMC coordination again offered BAMC in 2021, this time as BAM: the C specifying CMS in the main title was dropped as an ATLAS version had also been developed. [16] The need for and the subscription to this edition was greatly reduced from 2020.

### 3.3 Year 2022

It was clear that most of the institutes wanted to invite students to come to universities and research labs, so these would benefit from a direct exchange with physicists. However, since the pandemic was still ongoing and since an online version of the Masterclass has certain advantages, a dedicated online week (7.3.-12.3.2022) was part of the overall schedule.

During the IMC period it often happened that institutes had registered for a normal Masterclass, but due to external circumstances could only conduct an online Masterclass. Thus, there were also online Masterclasses outside the dedicated online week, and in many videoconferences both groups and individual students were dialed in. All videoconferences were set up as Zoom webinars. Moderators were recommended to upgrade groups to be webinar panelists, thus making it possible for them to share their audio and video and thus overcome the anonymous setup.

BAM, no longer needed, was discontinued in 2022.

#### 4. Results and experience

Since the start of the program in 2005, it has experienced growth every year. This development came to a halt with the pandemic. Figure 1 shows the number of videoconferences scheduled for IMC with CERN or Fermilab from 2018 – 2022. A large drop after 2020 can be seen, when registrations occurred on a lower level (actually, the drop occurred in 2020 as most of the videoconferences were canceled but it only showed in the registrations the following year).

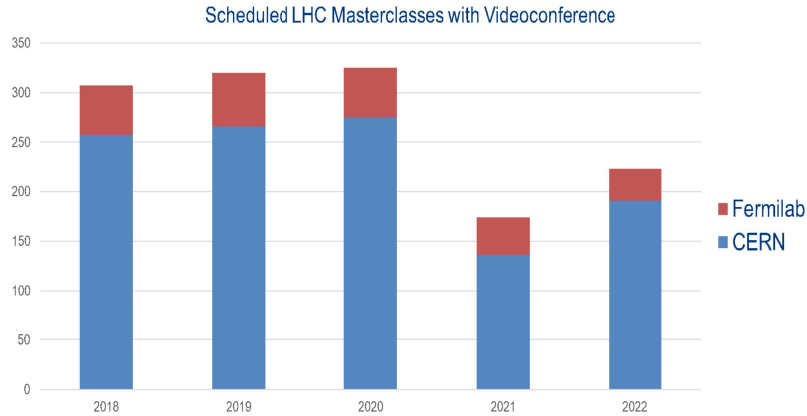


Figure 2: IMC registrations by year for CERN and Fermilab.

The overall participation in 2021 was 50-70% compared to 2019. A considerable number of institutes withdrew their initial registrations, often on short notice. This was certainly an effect of the pandemic and rapidly changing conditions. In 2022, registration numbers went up again. Thus it can be concluded that institutes adapted quickly to the new situation. It has been shown that Masterclasses are a robust tool for outreach.

Remote versions of Masterclasses have several advantages: they reach more people and are open to students without regional restriction. In addition, tutors and moderators can engage from everywhere. Various tools allow an increased interaction during the videoconference: all students get involved via Zoom polls, and the Zoom Q&A function produced lively discussion and many questions. On the other hand, online Masterclasses require an increased coordination and support effort. The use of Zoom webinars has to be reconsidered, as several institutes and moderators mentioned that the webinar style lacks personalization.

#### 5. Outlook

Based on the overall experience during the pandemic, the plans for IMC 2023 are built on two main aspects. First, an online week will be a continued offering to the institutes to allow for either in-person and online Masterclasses in the future. A strict separation in the schedule is foreseen. Second, the Zoom setting will be changed from webinar to videoconference. This will allow all participating groups and individuals to share their audio and video. Interactive tools like kahoot quiz or slido will be included in the sessions.

IMC has developed tools and techniques that, even if they are needed less as the pandemic recedes, increase its capacity to offer solutions to problems institutes may encounter in the future. Some of these, such as online moderator orientations, are expected to be of ongoing use.

## References

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