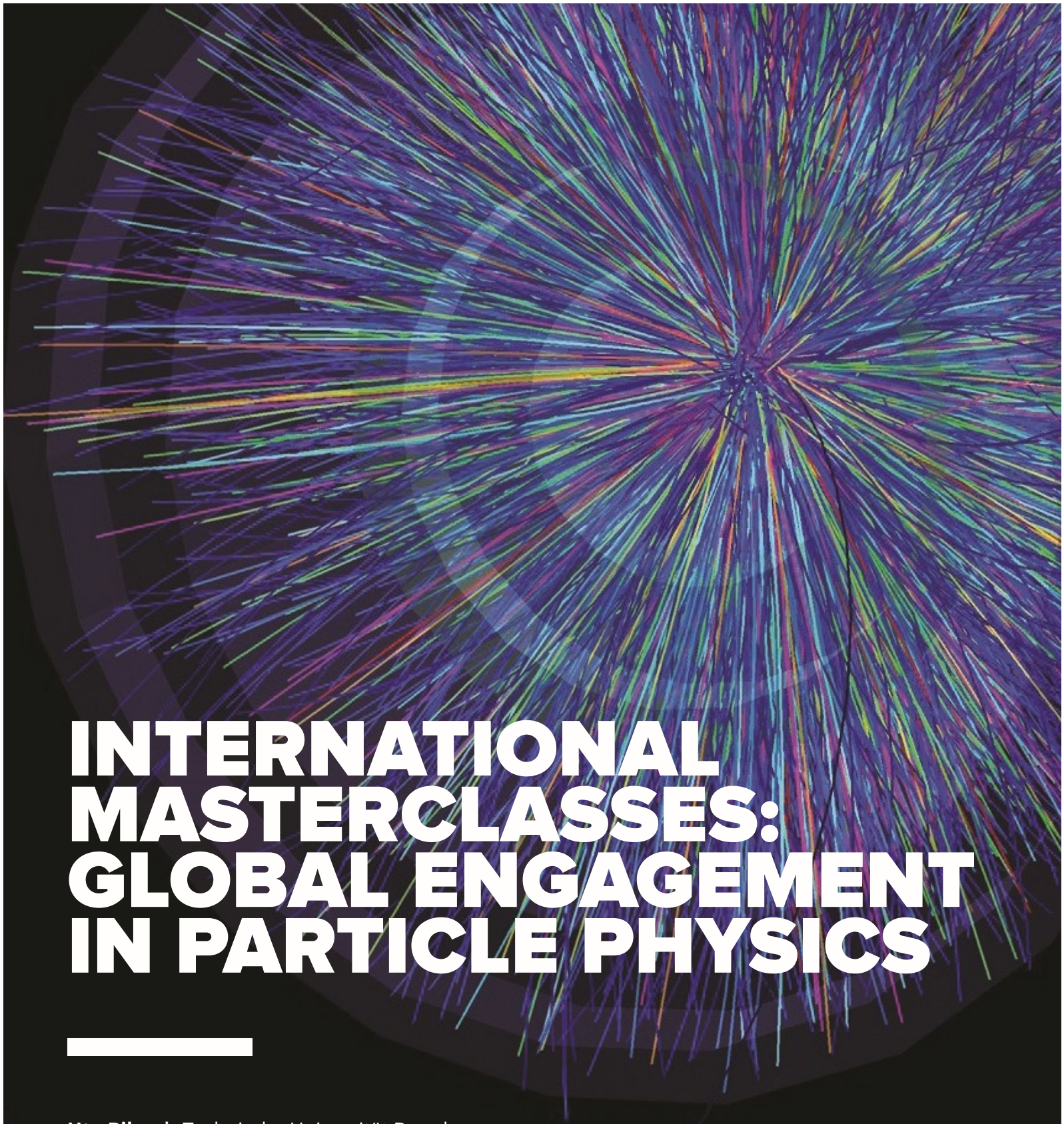

INTERNATIONAL MASTERCLASSES: GLOBAL ENGAGEMENT IN PARTICLE PHYSICS

Uta Bilow*, Technische Universität Dresden
Kenneth Cecire*, University of Notre Dame
Joel Klammer, Concordia International School Shanghai
Marzena Lapka*, CERN
Brendan Madden, Qingdoa Amerasia School

*On behalf of the International Particle Physics Outreach Group

The What and Why of International Masterclasses

Hands-on activities promote the interest of students and are therefore important elements for successful learning and academic success. While there are suitable and proven experiments in the teaching collections for many areas of the STEM subjects, particle physics is not accessible to them. Yet the cutting-edge research carried out at CERN, just outside Geneva, Switzerland, for example, is meeting with great interest among young people. Therefore, this branch of physics research is suitable for increasing students´ interest in physics and promoting their learning success. Particle Physics Masterclasses make it possible to treat particle physics as a hands-on activity in the classroom. The program brings data, methods and tools from modern particle physics research to schools and enables students to participate in the research process. International Masterclasses (IMC) are organised by IPPOG, the International Particle Physics Outreach Group, an international network of scientists, science educators and communication specialists with the goal of conveying particle physics to the general public and to improve science education. Two particle physics education programs, QuarkNet, based at the University of Notre Dame and the Fermi National Accelerator Laboratory (Fermilab) in the U.S., and Netzwerk Teilchenwelt, based at the Institut für Kern- und Teilchenphysik at Technische Universität Dresden in Germany, provide Central Coordination and foster development of International Masterclasses.

Imagine that you are a high school student who excels at science. In chemistry, you learned that matter is made of atoms, which are in turn composed of protons, neutrons, and electrons. You've gotten high marks in physics by solving all problems about sliding blocks of wood, light bulbs strung together, and steam pistons. If your teacher prepares you for a masterclass, you first learn of particles that make up protons and how scientists measure things too small to measure. Prepped or not, when you get to the university with your classmates as well as bright students from other schools, you learn from particle physicists, interact with them, and then analyse authentic experimental data as you become a "particle physicist for a day". At the end of that day, you videoconference with students at other locations who have made the same measurements, moderated by physicists at CERN or Fermilab in Batavia, Illinois, U.S.A.

What have we, as scientists and educators, learned from this? First, students are capable of great sophistication as

Students at Concordia work on measuring data from the Large Hadron Collider.

they "get into the swing" of data analysis. Because the data is authentic, it is not always textbook-clean and students must make decisions based on what the physics tells them is most probable. Disputes arise as they do between physicists in their natural habitat every day and often, when students ask advice, they do not get "the answer" but valid ways to look at the question. Surveys have shown that students increase their interest in physics and their understanding of the importance of basic research. They also often leave masterclasses with a new understanding data and of particle concepts. Almost every masterclass institution has stories of students who found inspiration in the masterclass to pursue physics in university.

Geneva-area students come to CERN

Masterclass day at CERN is, for students and physicists alike, no ordinary day. The adventure begins as the bus enters the main CERN entrance. The students are welcomed by CERN physicists, who have taken a break from their daily activities to guide the students. A morning session introduces the basics – and then it is off to lunch.

For a physicist, lunchtime is where critical physics discussions take place. This is no less true for the masterclass: students and scientists gather over pizza to discuss questions like: "How can I become a physicist?" and "What will discovering the Higgs Boson change in physics?"

In the afternoon session, the budding scientists look at real data, using online event displays based on software used by physicists. Then, as members of an international research collaboration do, the participants discuss the combination of their results over a videoconference. At the end of no ordinary day, the young researchers return home, enriched by their new experience. For some, this day may have an impact on their career choices, and it may not be their last visit to CERN!

Students at Qingdao Amerasia School comment

The Qingdao Amerasia International School in Qingdao, China, follows the International Baccalaureate (IB) program. International Masterclasses have allowed IB Physics students to interact with scientists and other high school students as they illuminated one of the most difficult units of their two-year study: Core 7 Particle Physics. This opportunity brought collaboration on a global scale to life.

After analysing their results, the students posed questions and discussed particle physics with current worldwide leaders in the field. A Junior commented by saying "I have always been fascinated by the colliders and having the opportunity to look at the data was an amazing experience."

Another Junior student said, "The process was clear-cut…It was interesting to hear the analyses from the other schools and from CERN." .One of his peers also said, "At the onset of learning particle physics, it felt like you are standing at the edge of a dense forest looking in, trying to figure out what was happening inside, but the [video]conference allowed us to follow a path through the forest, and now it is a little clearer."

A growing program at Concordia International School Shanghai

Concordia International School Shanghai started its Masterclass program eight years ago with the realisation that students needed the opportunity to explore topics and data that went beyond their curriculum into current research fields. We partnered with the International Particle Physics Masterclass, CERN, Fermilab, QuarkNet, and the Shanghai Synchrotron Radiation Facility to make this a possibility. Each March we invite physics students from schools around China to a one-day Particle Physics event. We started out small but have grown to a group of 100+ students from a variety of schools. All start with knowledge of the basic conservation laws, but very little background in particle physics. We have four primary goals for the program: an increase in the knowledge of particle physics, a realisation that physics is a dynamic and growing field, the ability to analyse large current research data sets, and the ability to communicate and collaborate with large groups and with physicists at research institutions.

An opportunity for International Schools

Particle Physics Masterclasses have been successfully organised in many places around the world, among them in International Schools. Students appreciate the direct interaction with scientists, learning about cutting-edge physics, and seeing how particle physics research is organised. Teachers benefit from the library with valuable information on classroom preparation and orientation. International Masterclasses are organised by IPPOG each year around March. The free program is open for new institutes and schools to join. If you are interested, contact coordinators Ken Cecire (kcecire@nd.edu) or Uta Bilow (uta.bilow@tu-dresden.de).

Relevant links

International Masterclasses:
http://physicsmasterclasses.org/

LHC Masterclass Library:
http://tiny.cc/mc2019lib

Neutrino Masterclass Library:
http://tiny.cc/numc19

Concordia Shanghai Masterclass 2019:
http://cern.ch/go/B9Xt