PROCEEDINGS OF SCIENCE

IPPOG : The International Particle Physics Outreach Group - Engaging the world with science

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(author list: https://cds.cern.ch/record/2903278/files/IPPOG-AuthorList-2024-V2.pdf)

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The pillar for outreach in particle physics, which is nowadays an integral part of our work as researchers, is IPPOG, the International Particle Physics Outreach Group. IPPOG is a network of scientists, science educators and communication specialists working across the globe in informal science education and public engagement for particle physics. The flagship activity of IPPOG is the International Particle Physics Masterclasses programme, to which other activities such as the Worldwide Data Day, the International Muon Week and International Cosmic Day organisation have been added. IPPOG members also participate in a wide range of events: public talks, festivals, exhibitions, teacher training, student competitions, and open days at local institutes. A resource database has also been developed containing a wealth of material for the dissemination of particle physics. In this paper the history and evolution of IPPOG is presented briefly, and its various activities are discussed, with emphasis on the masterclasses, which have been expanding both geographically and in scope during the years.

The 41st International Symposium on Lattice Field Theory (LATTICE2024)
28 July - 3 August 2024
Liverpool, UK

*Speaker

PoS(LATTICE2024)014

1. Introduction

Communication and outreach are an inseparable part of our work as researchers. Our targets are a multitude of audiences: the general public, school children - both in elementary and secondary education - and their teachers, as well as the broader scientific community. Some more special categories are the media (journalists, reporters etc) and the stakeholders (funding agencies and politicians).

Demystifying science is one of our main aims. The myth of unapproachable scientists who, cut off from real life, in their ivory tower, spend public money doing things that no one understands, does not hold any longer. The public should not be in awe of the world of scientific research. It is the duty of scientists to be open about what they are doing and offer to the public as much information as possible and as often as possible. For one thing, the tax payers have the right to know how their taxes are used. Direct consequence of this will be an increase of the scientific literacy of the public. Being aware of what science is about will also help the general public appreciate scientific research. Communication with pupils aims to inspire them, to stimulate their curiosity and motivate them, by giving them opportunities to directly engage with the world of science. Inspiring teachers is equally if not more important, since they propagate the love of science and are thus a strong multiplication factor. The same applies to journalists who have an incredible power over the public through press, television and online media. Informing the stakeholders about our work and especially our results is also essential; it helps ensure funding and support.

The messages delivered are many different ones. One of our priorities is to convince the public about the necessity of scientific research for society; to convey the fact that pure science, seeking answers to fundamental questions and not primarily geared towards applications, is indispensable and not a luxury; and that this quest for knowledge, driven by curiosity, which is part of our human nature, leads to applications improving our quality of life. We want to explain the impact of science on society, especially when it comes to developments in technology and medicine, as well as the benefits of peaceful international collaboration.

In our effort to lift the veil that covers scientific research, we try to explain our methods, show the instruments we use and obviously explain our results.

By sharing our enthusiasm and love of science, and our excitement when we are lucky enough to make ground-breaking discoveries, we hope to inspire the youth, the next generation of scientists.

Another message that we want to convey is that science is for all and not only for the elected few. We try to emphasize the importance of diversity, be it cultural, religious, political etc. CERN and the LHC experiments' collaborations, bringing together scientists, engineers, technicians and students from about hundred different nationalities, is an indisputable example of what such a diverse community can achieve. In an effort to increase female participation in the scientific and technological sector, we try to avoid presenting the stereotype of the male scientist; instead, we emphasize female presence and show female role models.

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2. The International Particle Physics Outreach Group - past and present

IPPOG, the International Particle Physics Outreach Group, is a network of scientists, science educators and communication specialists who work across the globe in informal science education and public engagement in particle physics[1].

EPOG, the European Particle Physics Outreach Group, was established in 1997 after a proposal by the CERN Director General at the time, Chris Llewellyn Smith, and under the auspices of ECFA (the European Comittee for Future Accelerators) and EPS-HEP (the High Energy Physics Division of the European Physical Society). EPOG members were representatives from the CERN member states, from CERN and DESY. Soon afterwards representatives from the four large LHC experiments joined; also EPOG became EPPOG. In November 2010 EPPOG evolved from European to International, becoming IPPOG. In 2012 the USA joined; Israel, Ireland, Slovenia, Australia and South Africa joined soon after.

In December 2016 IPPOG became an international collaboration, similarly to the international collaborations of the particle physics experiments. More countries and experiments joined in the course of the years and nowadays IPPOG has 42 members, shown in Figure 1 : 34 countries, one international laboratory (CERN) and seven international collaborations (ALICE, ATLAS, CMS, LHCb, Belle II, HAWC, Pierre Auger Observatory). In addition, two national laboratories, DESY and GSI, are associate members.

All IPPOG members sign an MoU (Memorandum of Understanding); the countries contribute financially, the experiments "in kind" and CERN both financially and "in kind".

IPPOG meetings are held twice a year, in the spring, usually organised by a member and

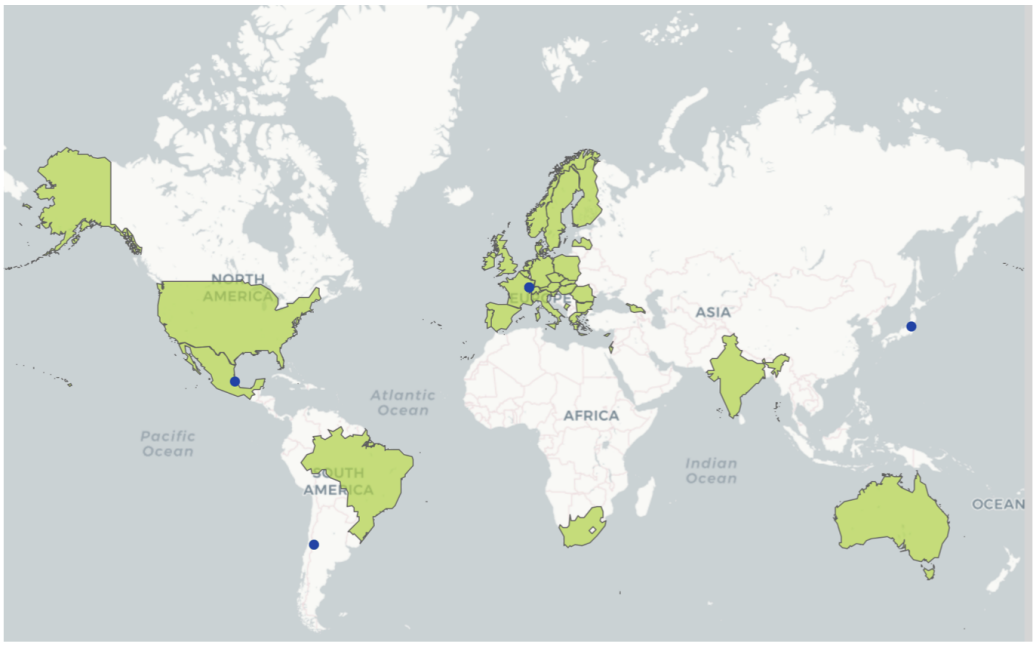

Figure 1: Map of the world showing the IPPOG members : countries, laboratories, international collaborations.

Figure 2: Group photo, 26th IPPOG Autumn Collaboration meeting at CERN, November 2023.

in the autumn, usually at CERN (Figure 2). The purpose of these meetings is the exchange of ideas and best practices, the sharing of experiences and material, the definition of common goals and the coordination of the IPPOG programmes. The participants, the collaboration forum, are the members' representatives and other colleagues active in outreach and communications. An indispensable work is done by the Working Groups (WG) who also meet online during the year. WGs include Explaining Particle Physics to the Public, Outreach of Applications for Society, Exhibitions and Public Events, International Masterclasses to New Countries, and Diversity, Inclusion and Accessibility.

Well-established IPPOG activities are the International Particle Physics Masterclasses and Global Cosmics, which are discussed in the following sections. New activities, undertaken recently by IPPOG members, such as participation in conferences and music festivals, are also discussed.

In October 2022 IPPOG celebrated 25 years of engagement with an event in the Globe of Science and Innovation at CERN[2]. Chris Llewellyn Smith gave a talk on the birth of IPPOG, and all previous and current chairs gave presentations, covering the whole history and evolution of IPPOG.

3. International Particle Physics Masterclasses

The flagship activity of IPPOG is the International Masterclasses in Particle Physics (IMC)[3]. This very successful programme is addressed to high-school students, usually 16-18 years old, and

Figure 3: Lecture, hands-on data analysis and video conference during IMC.

is basically a day of immersion in particle physics. The aim is to inspire and motivate them by introducing them to the world of research. Students are invited to a university or research institute where they first follow lectures on the standard model and beyond, accelerators and detectors. The lectures are followed by a hands-on activity : analysis of real data from an experiment. This is done using dedicated software packages provided by the experiments. At the end of the day they join a video conference, together with a total of up to five institutes and two moderators. During the video conference they merge and discuss their results, ask questions and finish the day with a light-hearted quiz.

IMC are organized every year during a period of 6-7 weeks, typically between February and April and ending just before Easter.

3.1 History of particle physics masterclasses

Particle physics masterclasses were first launched in 1996 in the UK[4]. In 2005 the programme was adopted by EPPOG for all of Europe using LEP data[5]. Two measurements were proposed, "Identifying Particles" with data from the OPAL experiment and "Hands-on CERN" with data from the DELPHI experiment. The students were looking at Z^0 decays and calculating branching ratios. In 2006 the US joined the programme.

In 2010, with the start of the LHC and all the publicity around it, it was decided to move on and start using data from the LHC experiments. Indeed in 2011 the masterclasses proposed measurements with data from ALICE, ATLAS and CMS. In 2014 the LHCb experiment joined the game proposing a measurement[6]. In the following years measurements with data from other experiments (Belle II, MINERvA, Pierre Auger) were introduced, as well as a Particle Therapy masterclass, on medical applications of accelerators. All these are briefly presented in the following subsection.

In Figure 4 we see the evolution of masterclasses from when they were first launched in 2005 until 2018. In 14 years, there has been a spectacular increase in the number of participating institutes, countries and students.

In 2020, when the COVID pandemic started, the IMC stopped half-way as universities and countries were closing down. The next couple of years most masterclasses were held online and from 2023 on the situation is back to normal. Nowadays some institutes hold online masterclasses, giving the opportunity to students in remote places to participate. In 2024 almost 15 000 students participated in more than 350 masterclasses organised by more than 220 institutes in 60 countries.

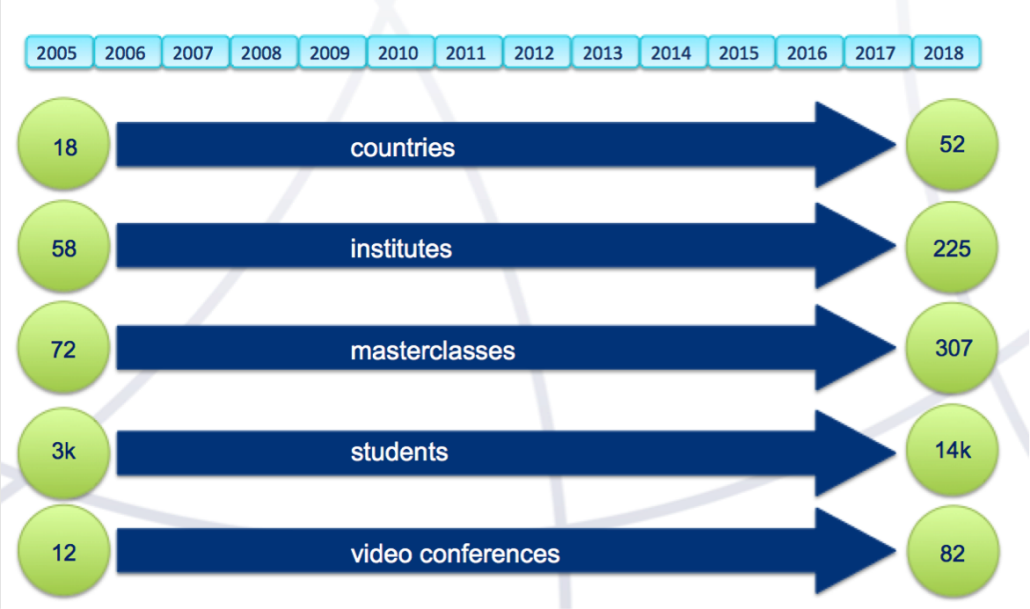

Figure 4: Evolution of International Materclasses.

3.2 The analysis exercises

During the hands-on part of the activity - the data analysis which leads to a measurement - the students are exposed to a variety of topics; the choice is up to the institute organising each masterclass session.

The ATLAS experiment offers two measurements[7]: The Z-path, using the HYPATIA package, where the students visually identify muons, electrons and photons and try to find Z^0 and Higgs based on the invariant mass calculation. The W-path, using the MINERVA package, where the students study decays of the W boson and calculate the ratio W^+/W^- which is correlated with the quark content of the proton.

The CMS experiment offers a measurement where the students again identify visually muons, electrons and photons, using the web-based i-spy package and look for J/Ψ, W, Z, Higgs[8]. CIMA is used for making plots.

ALICE, the heavy-ion LHC experiment, offers two measurements. One is the study of decays of Kaons and Lambdas leading to observation of strangeness enhancement in lead-lead collisions[9], one of the first signals for the Quark Gluon Plasma. A ROOT-based package has been used for many years but this has been replaced by a web-based package. The other measurement is the nuclear modification factor R_{AA}[10] which is a measure of the difference in particle production in pp and PbPb collisions using the idea that a collision of two lead ions is the superposition of a number of proton collisions.

Analysing data from the LHCb experiment, the students look at decays of the D^0 meson, produce mass distributions and measure the D^0 lifetime[11].

MINERvA is the Main Injector Neutrino ExpeRiment to study v-A interactions using the neutrino beam at Fermilab. The students study interactions of muon neutrinos with carbon nucleons,

where a muon and a proton are produced from the neutrino-neutron interaction[12].

Students doing the masterclass proposed by the Pierre Auger Observatory[13] use an interactive tool to visualise events and find the direction of arrival and the energy of primary cosmic rays and select events pointing to the sky.

In addition to this big variety of masterclasses covering different particle physics topics, a particle therapy masterclass[14] was introduced some years ago, bringing to students applications of particle accelerators in medicine. The hands-on activity is treatment planning, based on a simplified version of MatRad[15]. The students calculate the dose prescription using photons, protons and carbon ions and observe the difference due to the different way of interaction.

3.3 More on masterclasses

In addition to the IMC programme, special masterclasses for girls are organised on the occasion of the International Day of Women and Girls in Science[16], February 11. By inviting mainly or only girls and having exclusively, when possible, female lecturers, tutors and moderators as role models, we try to inspire girls, as part of the effort to increase their participation in STEM.

The "Masterclasses-to-New-Countries" Working Group of IPPOG has been coordinating efforts to expand the IMC programme, bringing it to new countries, which do not necessarily have particle physics. In 2024 masterclasses took place for the first time in Kenya, in Nairobi. Many of the students who participated, from poor areas, had never used a computer before, but they did very well, according to the organisers of the event.

The idea and the tools used for the IMC are also occasionally used for other audiences; for example, for physics teachers, to familiarise them with the programme and encourage them to involve their students or to use the masterclass exercises as an extracurricular activity. Such masterclasses are held at CERN in the frame of some of the national teachers programmes.

During IPPOG meetings at CERN masterclasses were organised for CERN non-scientific personnel, in order to give those in administration, finance, etc. hands-on experience of what the experiments actually do.

During conferences, demonstrations are done for the participants, to make them aware and encourage them to get involved with this programme.

Some years ago, World Wide Data Day[17] had been launched and since then it takes place every year on a specified day in November. A simplified measurement with data from ATLAS and CMS is proposed; it is done at school, facilitated by the teacher. The students look at dimuon events and determine the direction of muon tracks. This is typically a two-hour activity, and the participants have the possibility to join a videoconference with physicist moderators during a 24-hour span.

It is worth mentioning that the EPS outreach Prize in 2021 was awarded to Uta Bilow and Kenneth Cecire for the long-term coordination and major expansion of the International Particle Physics Masterclasses; and also to Sascha Mehlhase for the design and creation of the ATLAS lego model and later also other detector models with (lego) bricks[18]. (The ATLAS and ALICE models are shown in Figure 5).

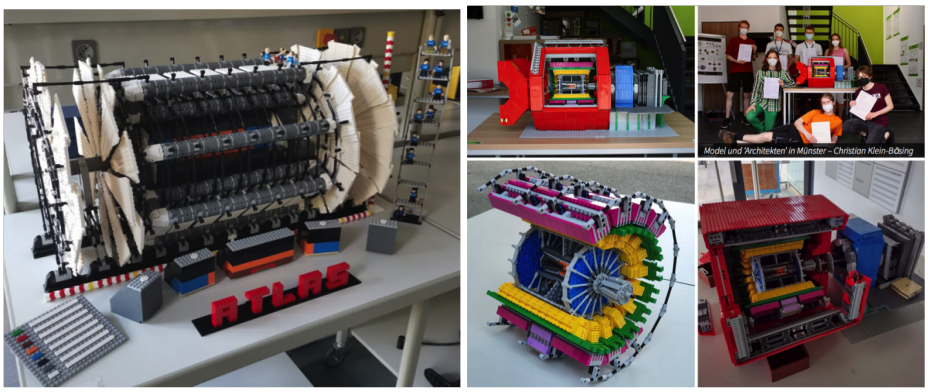

Figure 5: Left: ATLAS model, right: ALICE model.

4. Global Cosmics

Cosmic ray detectors are used at schools for extra-curricular outreach and educational activities and there are such projects and networks in many countries. To bring all such projects under a common umbrella, a workshop on "High School Cosmic Ray Experiments" was organised at Centro Fermi, Rome, in February 2017[19]. As a result a portal was created[20], which is part of the IPPOG web site, where all these projects are listed and links to their web sites are given. Nowadays there are around 20 projects from 11 countries. The Global Cosmics steering group promotes events such as International Cosmic Day and International Muon Week and facilitates exchange of measurement techniques between projects.

The International Cosmic Day[21], organised every year in November by DESY, is a day devoted to cosmic rays. It is a free-format event, each organising institute deciding on the agenda. Typically the students follow lectures on cosmic rays, do measurements if they have equipment, analyse data and join a video conference.

The International Muon Week[22] is organised by Quarknet every year in spring. Students do experiments using cosmic ray detectors and measure the muon time of flight, the muon lifetime or the cosmic ray flux. They can discuss with scientists and ask questions via zoom.

5. Resource database

More than ten years ago the idea was launched within IPPOG to create a database of resources, material for dissemination of particle physics. The target is mainly people involved with outreach and educational activities such as scientists and teachers; but it is also useful for students, media and the general public. A wealth of material was collected - articles, presentations, videos, posters, games - and some years ago everything went through a curation process before including them in the new web site of IPPOG[23].

Figure 6: Left:Cloud chamber workshop; right: physics talk at the Big Bang Stage at the Colours of Ostrava music festival.

6. Other activities

In an effort to reach new audiences, IPPOG members started going to places where people do not really expect physics-related events, such as music festivals. The first such presence of physicists with talks on various particle physics topics was at the WOMAD (World of Music, Arts and Dance) 2016 music festival, with great success. Physics related events were also organised at the Pohoda festival in Slovakia and the Colours of Ostrava festival in the Czech Republic (Figure 6).

In recent years, during the IPPOG spring meetings outside CERN, outreach events were included in the agenda. In Sofia, in May 2023, talks about IPPOG and the Bulgarian participation at CERN were given for physics teachers; masterclasses were also organised for teachers and students. An outdoor event, "The music of physics", took place, including talks about cosmic rays and demonstration of the Cosmic Piano, a set of muon detectors producing sounds when muons go through them, while a piano player was improvising at the same time.

In the last years, IPPOG is present in most High Energy Physics major conferences with outreach talks in plenary sessions and dedicated parallel sessions.This is done in an effort to motivate and encourage our colleagues to get involved in outreach. Making them aware of the existence of IPPOG and its activities is an important step in this direction.

The Beamline for Schools competition[24], addressed to high-school students, was launched by CERN more than a decade ago. Student teams, with the help of a coach - physics teacher or researcher - submit proposals for an experiment at a beamline; the winning teams are invited to CERN, and recently also to DESY, to perform their experiment, with help from physicists. IPPOG forum members are involved as contact persons, to answer students' questions during the preparation of the proposals; also as evaluators of the proposals during the pre-selection process.

7. Conclusion

A big variety of activities and material has been developed and is used by the members of our community to meet our different goals and reach out to diverse audiences. In the limited space of this presentation it is not possible to cover and give credit to all outreach projects; a personal selection has been presented here.

As a conclusion, we can say that significant progress in outreach has happened these last years and new audiences have been reached. IPPOG has a central role in this.

However, we can do more, keeping in mind that doing outreach is a rewarding experience; also, as Victor Weisskopf wrote more than half a century ago: "More concerted and systematic effort toward presentation and popularisation of science would be helpful in many respects; it would provide a potent antidote to over-specialisation; it would bring out clearly what is significant in current research, and it would make science a more integral part of the culture of today"[25].

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