

Future Challenges in Particle Physics Education and Outreach

IPPOG Collaboration

IPPOG, the International Particle Physics Outreach Group, is a collaboration comprising 27 signing member-organizations (countries, laboratories, experiments) whose goal is to maximize the impact of education and outreach efforts related to particle physics.

IPPOG members from:

Australia, Austria, Belgium, Brazil, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden, Switzerland, USA; and CERN, ALICE, ATLAS, Belle II, LHCb

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Abstract

This document is meant to serve as input from the IPPOG Collaboration for the open call for the European Particle Physics Strategy Update 2020. It emphasises the strategic relevance of concerted, global outreach activities in particle physics today and beyond when envisaging new large-scale projects.

1 Introduction

The European Particle Physics Strategy Update 2020 will discuss among a number of options what Europe, and hence, the international community, will see as its most important projects in the quest for exploring the basic building blocks of matter, the structure of time and space, and with it the origins of our Universe. Large-scale facilities will be required to make significant steps in deepening our understanding and for opening new paths for future research. The duration of the planning, construction, commissioning, and operation stages of such large-scale facilities, regardless of the prioritisations and decisions that will be made among the candidate options of today, will span many decades.

The execution of these programmes thus relies heavily on support from key stakeholders and decision makers, including politicians, funding agencies and, underlying all, the public. Furthermore, the success of such large-scale projects depends heavily on the talents of a skilled, enthusiastic, and diverse new generation of physicists, engineers, and developers.

The International Particle Physics Outreach Group (IPPOG) [1] has built a world-wide education and outreach programme that is uniquely situated to address these challenges. Given adequate support, its educational methods, platforms and strategic global network of researchers and educators can serve to maximize the impact of outreach efforts around the world. In coordination with the efforts of the communication experts in the European Particle Physics Communication Network (EPPCN) [2], we have the potential to reach key world-wide audiences effectively. However, recognition of these outreach and communication programmes as key pillars to an overall strategy must be maintained and adequate support for these must be an integral element of any particle physics strategy update.

2 Outreach and Communication

Scientific outreach and communication both fulfil important and necessary obligations to society. They are complementary methods to bring knowledge and expertise to a broad world-wide audience. For the purpose of this document, we define communication to be those activities focusing on the prompt reporting of activities, plans, and scientific results to the public in an effective manner, through the usage of existing platforms, such as newspapers, magazines, radio, television, social media, etc., as well as through the development of dedicated platforms hosted by experiments, laboratories and educational institutions. It is expected that EPPCN will provide its own input on activities in particle physics communication to the EPPSU 2020, so they will not be discussed further here. Rather, this document will focus on the education and outreach efforts of the particle physics community and on their strategic importance for future planning.

Scientific education and outreach activities are characterized by the direct involvement of scientists active in current research to develop content, methods, and activities that engage deeper and adequately its intended audiences. By engaging people across the planet, scientists have the ability to improve public understanding and appreciation of the benefits of fundamental research, to spark interest and enthusiasm among young people, and to strengthen the integration of science in society. Effective education and outreach help to lay

down the educational foundation and value structures needed to secure support for future research.

Current efforts in particle physics education and outreach raise awareness, appreciation and understanding of the field and its current state of research to a variety of audiences. These include primary and secondary school students, teachers, journalists and communicators, key stakeholders and policy makers, as well as the general public. Education and outreach programmes include activities that impart practical science knowledge and skills within the presenters' field of expertise to eager minds in venues such as museums, science festivals, and school settings. They provide the possibility for audiences to dig deep into the underlying process of the science behind the results. IPPOG members develop tools, platforms, and national networks to facilitate these efforts on a large, global scale.

Particle physics outreach is thus developing broad, long-term impact, using current research to grab and maintain audience interest, but taking the time to address the underlying nature of the scientific process and its key role in society. It is during these close interactions between scientists and their audiences that trust can be gained and positive attitudes fostered. In this manner, IPPOG not only motivates, inspires, and educates our youth in the field of particle physics, but it develops personal awareness of the value of science and of the process of evidence-based decision making, regardless of age or discipline. This is a key strategical element necessary for developing global support of fundamental scientific research.

3 Large-Scale Global Science

Particle physics research has a long tradition of making important scientific advancement through large-scale collaborative efforts. Many of these projects started at the national level, but quickly grew to become international in scope and, by pure necessity to master the complexity that arises when large-scale projects are realised successfully, have evolved into fully global enterprises.

In the ever-deepening quest to attain a solid understanding of nature, its elementary building blocks, and the structure of space and time, particle physics research has demanded the construction of larger, more complex, and higher energy devices. With this comes the need for a large diverse set of expertise, covering a full range of technical and scientific skills. It also necessitates the pooling of monetary resources that go beyond the capability of most individual nations. Only a truly global effort made it possible for the successful design, construction, commissioning, and operation of the LHC and its experiments at CERN.

With the unprecedented global scale of the LHC came a real and explicit need for extensive efforts in communication, education, and outreach. This in turn led to the creation of new communication and outreach networks. The European Particle Physics Outreach Group (EPPOG) was formed in 1997 [3] under the joint auspices of the European Committee for Future Accelerators and the High Energy Particle Physics Board of the European Physical Society. EPPOG widened its regional scope to become an international player in 2005 with the development of the International Particle Physics Masterclass programme [4], then became officially known as the International Particle Physics Outreach Group (IPPOG) in 2011. With

the growing global scale of IPPOG activities, and taking into consideration recommendations of the 2013 European Particle Physics Strategy Update [5], IPPOG became an international collaboration based on a memorandum of understanding in 2016 [6] [7]. This has enabled IPPOG to secure limited financial support at a critical time, allowing it to continue to extend its network and develop much-needed infrastructure.

All of the major experimental particle physics projects on the horizon, regardless of which will finally be chosen and realised, must involve new long-term global efforts. They will be designed to endure many decades and will require major investment. This necessitates the commitment of financial and human resources, including physicists, engineers, technicians and support staff over a period of several decades. Politicians, who control the flow of resources to the funding agencies, will need to be convinced of the value of these investments, as will their constituents. This is no simple task, as typical political lifetimes are shorter than the duration of the experiments themselves. It is for this reason that current, well-focused efforts to engage the public are already today of vital strategic importance.

It is important to note that these global outreach activities foster the acceptance and value of the scientific method and evidence-based decision making in society. These not only pave the way for large-scale global research, but also help to curb the effects of nationalistic and anti-science political tendencies threatening our world today. That is no small consideration. Large-scale global research, and the scientific breakthroughs that often accompany it, teach our world of the benefits of world-wide cooperation in science and beyond.

4 Outreach Today in Particle Physics

Scientists and science managers over time have realized the important role outreach plays in the training of researchers. Public engagement not only improves a scientist's teaching and communication skills, it also clarifies overall perspective and contextual understanding of the material, thus improving her/his research capabilities. As a result, the researcher becomes a better teacher who is also more skilled at preparing grants for new projects and running a research team.

As the number of scientists engaged in outreach increases, so do the variety and ingenuity of their efforts. More and more research laboratories, experiments, universities, and institutes offer a wide selection of activities, ranging from Open Days to Public Lectures, from facility tours to Saturday Morning Physics. Traveling and standing exhibitions attract broad audiences and various events are organised at schools, universities, museums, and science cafes to raise interest and engage the audience in competitions.

Universities and dedicated outreach centres offer projects primarily aimed toward high school students and teachers. The activities range from training teachers in the field to helping high school students create their own particle physics experiments. Large international collaborations often offer their own outreach programs at the experimental site, providing support for their members in the form of online platforms, tools, and material. Most experiments also work closely together with the host laboratory in order to maximize the reach of the effort. A good example are the experimental visits during laboratory tours.

In support of these efforts, IPPOG provides a platform for the sharing of this wealth of resources, methods and tools, in the form of a public online database [8]. Networks formed within the various member countries and experiments allow for the rapid communication of both local and global outreach events, while periodic meetings among the members provide a means to share expertise, examine feedback, analyse impact, optimise methodologies, and expand the global reach of all scientists engaged in outreach.

A direct result of the implementation of these best practices in outreach is IPPOG's flagship activity, the International Particle Physics Masterclass programme [4]. Secondary students from around the world assemble to analyse data from a variety of experiments, including those of the LHC, under the direct supervision of scientists that are active in the research. As "scientists for the day," the students learned the fundamentals of the field, the scientific process, and the methods that are leading to headline-making discovery. The programme, which is a natural culmination of the tools, methodologies, and networks developed by IPPOG, continues to broaden in scope and global reach. In 2018, the masterclasses were attended by over 14,000 students from 225 institutes in 52 nations.

IPPOG members have also continued to make the case for outreach being recognised as a key component of research by pushing for visibility within experiment collaborations, and in the major conferences they attend. Outreach parallel sessions, plenary talks, and public events are now common in international conferences, such as ICHEP, LHCP, EPS HEPP, APS, and CHEP. Talks are frequently given at these conferences by IPPOG members on behalf of their experiments or on behalf of IPPOG, itself. Dedicated awards, such as the EPS HEPP outreach prize or the IoP Kelvin Medal and Prize, provide recognition for exceptional outreach efforts.

While funding for outreach remains cumbersome and minimal, with agencies providing only modest amounts for specific projects, the situation with some countries and institutes is beginning to improve. Certain national funding programmes now demand that a component of their requested research funds be used for outreach. Other agencies require a measurement of the public impact of the research and provide funding dedicated toward those efforts. These trends are welcome and need to be supported at the highest level. Recognition of outreach as a strategic pillar of the field will play a major role in attaining this support.

5 IPPOG as a Strategic Pillar for Particle Physics

The mission of IPPOG is "***to maximize the impact of education and outreach efforts related to particle physics.***" In 2016, IPPOG became an official scientific collaboration following the template of other scientific collaborations at CERN and elsewhere, with the signing of a Memorandum of Understanding [6] between 10 of its original member nations. The remaining members have since signed or pledged to sign and several other new nations have joined in. This current total of signatories is 22 nations, 4 experiments, and one laboratory, CERN, with others in the process. The signature for each country is provided by a single entity (e.g. a ministry, lead scientific institution, or in some cases a university that has a national leading role) that oversees or coordinates the efforts of particle physics outreach in that country. The signature for each experiment is typically the collaboration spokesperson or a member of

management responsible for the outreach programme. CERN's signature comes from the head of International Relations. These bodies each select representatives who are identified as main actors in the field of particle physics outreach.

The people who make up the IPPOG collaboration thus come from different cultural and educational backgrounds, bringing a large and important variety of skills to the table. Within the collaboration are researchers (both experimental and theoretical), outreach professionals and teachers. It is this heterogeneous combination of expertise and diverse points of view that allow for the effective development of novel outreach activities with maximal impact.

As a collaboration between different national and international entities, IPPOG is able to go beyond the capabilities of a single member in maximizing its outreach. A prime example is given by the International Particle Physics Masterclass programme, described above. This activity can only be organised when the data and expertise provided by the experiments are combined with local networks and enthusiastic scientists in the individual countries through infrastructure supplied by the laboratories.

The infrastructure formed by IPPOG facilitates outreach on a truly international scale. This is recognised by CERN, which is a member of IPPOG and uses the IPPOG network to help spread knowledge on its own outreach activities such as Beamline for Schools (BL4S) [9].

In addition to its twice-annual meetings, the IPPOG collaboration board has set up several active working groups: *Bringing Masterclasses to New Countries*, *Explaining Particle Physics Hot Topics to a Lay Audience*, and *Exhibits*, as well as a *Global Cosmic Steering Group*. These groups focus on specific issues and develop best practices to be shared within IPPOG and with other outreach and education experts around the globe.

IPPOG's *Global Cosmic Steering Group* spawned recently from meetings involving key players in cosmic-ray related outreach efforts around the world, including *HiSPARC* [10], *EEE* [11], *CREDO* [12], *Netzwerk Teilchenwelt* [13], *Cosmos à l'Ecole* [14], and *Quarknet* [15]. One concrete result from this group is the exchange of information and data between the Italian-based *EEE* and *HiSPARC* from the Netherlands. There is also now an enlarged geographical base for both the *International Muon Week* [16], organized by *QuarkNet*, and *International Cosmic Day* [17], organised by *Netzwerk Teilchenwelt*, DESY.

The *Bringing Masterclasses to New Countries* Working Group actively seeks out new countries and new target populations around the globe to introduce *International Masterclasses*. This group often works hand-in-hand with strategic partners, such as *CERN International Relations* or *Physics Without Frontiers* [18] to identify target audiences that would most benefit from participation. Installation of an *International Masterclass* programme in a country requires the identification of qualified researchers, teachers, and facilities to take part each year. This, in turn can lead to the development of long-lasting partnerships and networks. Such an infrastructure is often the pre-cursor to a country's more advanced participation in large-scale collaborations.

In summary, the participation of a broad, diverse base of scientists and outreach experts, coupled with a growing international network, put IPPOG in a key position to foster support for fundamental scientific research around the world. The usage of authentic scientific

techniques, coupled with best practices in educational methodology make it possible to instill audiences everywhere with a deep appreciation of particle physics, as well as the need for large-scale international collaboration.

Often, as a result of these efforts, younger audiences might become more inclined to choose a career in physics or engineering. They might even go on to join the next generation of particle physicists. What is most important, however, is the fact that they will be more educated and appreciative of the importance of research, and thus more suited to make informed decisions about science and scientific questions for their nations and their peoples in the future.

In here lies the role of IPPOG as a pillar of particle physics: **IPPOG is capable of reaching out to large international audiences about particle physics activities in a manner that fosters long-term, sustainable support.** As such, IPPOG is a natural partner to any current or future endeavours in the field, and shall be a strategic element in the European Particle Physics Strategy Update, for the required broad, multi-national backing that will be needed.

6 Future challenges

Today, science, technology and innovation are among the most powerful forces driving social change and development. Science is also at the heart of producing new solutions to many of the challenges posed, for example, by the increasing risk of climate change, poor water management, or misguided applications of new technology.

Unscrupulous actors with short-sighted monetary or ideology-driven motives increasingly circulate fake news, misinformation, and disinformation with the help of trolls, bots, and respondent-driven algorithms. The only way fake news and mistrust in science can be countered is through dialogue and education, engaging the target audience in the scientific method and the argumentation behind evidence-based decision making. Particle Physics plays a crucial role in this process, as fundamental science is, by necessity, free from ideology-driven biases.

In a world which threatens on occasion to diminish reason, rationality and common-sense, particle physics helps to preserve the international fellowship of science, to **defend the scientific method** and to **keep the light of science shining** brightly, as Isidor Rabi put it in his famous speech [19] at the UNESCO General Assembly in Florence in 1950, which led to the foundation of CERN. To spread this message is one of the goals of IPPOG.

It is important in outreach not only to talk to an already scientifically educated and endorsing audience, but also to address educationally distant audiences. In a confusing world of endangered reasoning we have to **strengthen the trust in science and its method of evidence-based decision making** to offer future generations a meaningful base that generates supportive structure in their life. Without compromising established methods, IPPOG is exploring new paths to engage citizens – especially the young. Reaching out to high-school students and their teachers to convey the methods and tools used in fundamental science is a strong investment in the future. While only a fraction of young students will become

scientists, and fewer still will become particle physicists, all will become ambassadors for the scientific method and evidence-based decision-making.

In many of the developed countries, interest in STEM-related studies is declining, leading to economic problems in the near and long-term future. Large-scale flagship projects in fundamental research are big drivers for creating interest in young and talented students, but these need to be triggered and brought to attention. IPPOG, with its global activities, **motivates, inspires, educates and fascinates younger generations** with the goal of attracting them to stay attentive to STEM, and is there for those who want to engage deeper in particle physics and related topics.

Following the Higgs discovery in 2012, there has been a tendency in the **public to criticize** the abundance of elaborate **theories** which could not be verified during the last decades, like supersymmetry, superstrings, grand unification or extra dimensions, and to impatiently expect further discoveries. IPPOG outreach strategy is to convey the message that research is an open process and that **Nature does not guarantee spectacular new discoveries** at all steps of the research process, but it guarantees new insights and deeper understanding with every research paper accomplished. Such messages are not conveyed through communication alone. Rather, they require the deep-seated understanding and appreciation for science that only well-designed, comprehensive programmes, authenticated through the participation of scientists, can convey.

7 Conclusions

Whatever directions the European Particle Physics Strategy Update process will propose, the development of multi-decade, large-scale, globally collaborative projects will be on the horizon. The projects will require a long-term, world-wide commitment of significant monetary resources and human expertise. Furthermore, it can be guaranteed that, during its lifetime, the economies and politics of the various nations involved will vary in unpredictable manners.

The success of such an endeavour therefore depends greatly on the establishment of broad public support, as well as the commitment of key stakeholders and policy makers throughout Europe and the world. IPPOG is already laying down the ground work for this support, both through the training of the next generation of scientists and engineers, and through education of the public on the values of basic research; it is well-placed to act as a strategic partner for any of the proposed future efforts.

The European Particle Physics Strategy Update 2013 provided important recommendations concerning the support of education, outreach, and communication for particle physics. The document explicitly mentioned both IPPOG and EPPCN as relevant groups for public engagement, stating that *“Outreach and communication in particle physics should receive adequate funding and be recognised as a central component of the scientific activity”*. These recommendations and follow-up to the document led IPPOG to pursue the writing of our memorandum of understanding and to evolve into a global scientific collaboration with a modest, but very-much appreciated budget.

We propose the European Particle Physics Strategy Update 2020 build upon this important foundation with the following recommendations:

1. The relevant roles of particle physics outreach and communication shall be considered in all discussions leading to the development of the EPPSU 2020.
2. Particle physics outreach and communication shall be explicitly recognised as strategic pillars in the EPPSU 2020 document.

Concerted and global efforts in education, outreach, and communication are indeed essential strategic components of any roadmap to be laid out defining the future of particle physics in Europe and world-wide. Securing and increasing the available funds to IPPOG further means strengthening particle physics globally, which also sends a clear signal to our learning institutions, experiments, and laboratories to hire and provide support for researchers who spend significant effort on outreach activities.

References

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