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IPPOG and spin-offs from nuclear and particle physics

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The main mission of IPPOG, the International Particle Physics Outreach Group, is to bring the excitement of particle physics to the public and especially to the young generation. In the last years, IPPOG has undertaken to emphasize also the benefits to society from fundamental research. A tangible example is the particle therapy masterclass, an integral part of the masterclasses programme, which introduces high-school students to applications of accelerators in the fight against cancer. Another example is the effort of the working group "Outreach of applications for society". Its objective is to create a collection of short stories, covering a wide spectrum of spin-offs from our field. The ultimate goal is to connect fundamental research to everyday life and provide a practical communication tool for the science outreach community.

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1. International Particle Physics Outreach Group

IPPOG, the International Particle Physics Outreach Group, is by now an International Collaboration which is fostering long-term, sustainable support for fundamental scientific research around the world. First established in 1997 as a European network (EPPOG, and since 2010 IPPOG) it celebrated its 25th anniversary in October 2022 with a Symposium presenting its evolution and key contributions. Since then, IPPOG has been making concerted and systematic efforts to present and popularize fundamental physics principles across all audiences and age groups with the aim to maximize the impact of education and outreach activities. The primary goals of the IPPOG programmes and activities are summarized below:

- Instill and foster an appreciation for fundamental scientific research;
- Establish a firm understanding of the scientific process and evidence-based reasoning;
- Build trust with a broad and diverse set of worldwide communities;
- Inform and motivate future generations of scientists and citizens.

To work more effectively towards its aims IPPOG has developed an appropriate structure which comprises formal governing bodies and embraces IPPOG friends, partners and contributors. Its two major Programmes, the "International Masterclasses" and "Global Cosmics" are managed by their respective steering groups to ensure concrete and coherent activities world-wide. Several IPPOG Working Groups were established to develop or expand different activities and work on various deliverables; among which the WG "Outreach of Applications for Society".

Particular emphasis has been put recently on enhancing awareness of fundamental research benefits for society. The Particle Therapy MasterClass, PTMC, developed in 2019 and integrated in the "International Masterclasses" IMC programme in 2020, introduces high-school students to applications of accelerators in the fight against cancer. The WG Outreach of Applications for Society collects and makes available short stories, covering a wide spectrum of applications. Thus, IPPOG conveys to the public the beauty of understanding nature from the interactions of its most fundamental constituents – the elementary particles – and, at the same time, provides tangible examples of benefits for society from fundamental research. Indeed, while the mandate of research institutes is fundamental research, the developed technologies often find applications in every-day life. Even technologies developed for future research projects find already applications in hospitals. IPPOG, through its targeted activities, aims at making this a common knowledge.

2. Particle Therapy MasterClass

International MasterClasses IMC Every year some 15,000 high school students from more than 60 countries have the opportunity to immerse themselves for a day in the fascinating world of Quarks and Leptons. Hosted by local universities and research centres around the world, reaching up to 300 institutes in 2024, these masterclasses offer a unique chance to unravel the mysteries of matter and forces, enabling the students to perform measurements on real experimental data themselves. At the end of each day, like in an international research collaboration, the participants join in a video conference for discussion of their results. Thus, IMC offer annually the opportunity to 15- to 19-year-old students to become scientists for a day, and get a hands-on experience, highlighting the benefits and need of International Collaborations, as presented in numerous IMC publications. They make science come alive in a way that textbooks never could, bringing students to the forefront of scientific exploration.

IMC Evolution In 1997 the IMC programme started in the UK see report by Roger Barlow in CERN courier 2014. The first European-wide Masterclass event was organnised in 2005, the World Year of Physics, by EPPOG. In 2006, U.S. institutes joined IMC which used initially LEP and then LHC experimental data. The last few years the IMC has expanded and includes data of BELLE II, MINERvA and Pierre Auger Observatory. Since 2020 the Particle Therapy MasterClass has been integrated in the IMC programme as a concrete example of medical applications of accelerators and technologies developed at research laboratories.

PTMC Typical Day A PTMC day follows the main programme of a typical IMC day integrating and enhancing the IMC well-established pedagogical elements. In a nut-shell, the PTMCs are performed during pre-defined days in the IMC period, mid-February to Easter. During each one of these days, 3-5 institutes participate as hosts and invite school children of their areas to their premises giving them the opportunity to realize "what physics has to do with medicine". Alternatively, scientists of the host institute organizing the PTMC event may go to the schools. During the covid pandemic it was adapted for online participation and several institutes still resort to online or hybrid modes in order to provide this opportunity to students in remote places.

The PTMC day starts typically with a video to ignite curiosity and motivate the students. Animations, mostly prepared by the ENLIGHT network, also give them a visual impression of a particle therapy centre and treatment procedure making it easier to follow the lectures and put the new information into a general context. The morning session finishes with a visit to the institutes laboratories or alternatively with a real-time virtual visit to the ALICE heavy-ion experiment. The highlight of the day is the opportunity to handle real data during the hands-on session in the afternoon. And then, students prepare a presentation with their results for discussion, in a common video-conference, with particle therapy experts and all other institutes that performed the PTMC the same day, which is moderated by GSI. They realize that scientists routinely exchange information remotely and not only during the covid times. This already makes clear to the students the importance of collaborating for common projects and highlights the multi-disciplinary aspects of particle therapy. For the PTMC hands-on session, the matRad open source professional Treatment Planning toolkit is used, developed by DKFZ, the German cancer research centre, specifically for research and training. For the PTMC, a simplified version is used. The students prepare Treatment Plans, for different cases (head-and-neck, liver, prostate etc) which are prescriptions of the therapeutic dose that the accelerator has to deliver, using photons, protons or carbon ions. Students can choose the best angles to precisely target the tumour in such a way that the therapeutic dose is deposited in the tumour avoiding organs at risk. They can easily then compare the different plans and see for themselves the differences between photons and hadrons.

At the end of the day, students really appreciate the common video-conference where they discuss their results with experts and enjoy virtual visits of their institutes; for example, the historic GSI treatment room, where 440 patients were treated in the 90s, or the accelerators of the CNAO hadron therapy center. In some of them Prof Ugo Amaldi, one of the fathers of Hadron Therapy in Europe, shared his experiences also highlighting the fact that studying physics opens up many opportunities, including medical applications. They also have the opportunity to learn about capacity budling initiatives, such as the HITRIplus EU-funded project, that provides educational materials via its YouTube channel and clearly demonstrates the multi-disciplinary aspects of the field as well as the need of close collaborations of different disciplines for coherent advances. The video-conference finishes with a quiz which is a fun way to finish the day.

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PTMC Information A lot of material is provided via the PTMC webpages, including the PTMC in a KIT, that contains the necessary and sufficient material to run it. About five training sessions are organized every year on zoom to support the host institutes. Recordings, written instructions and presentations are available in English and other languages. Training teachers is also very important and training sessions were organized during the IPPOG meetings in Sofia and Madrid. Exemplary is the approach of the UNSA Sarajevo university that created a pool of trained teachers who perform PTMCs in their schools, following remotely the introductory lectures. Those are also given by UNSA students engaged in related studies in international institutes, thus providing an inspirational example to the high-school participants.

PTMC Impacts Targeted efforts are made to encourage female participation, providing role models and celebrating women's days on 11 February and 8 March. Every year the PTMC reaches more than 1500 high-school students hosted, in 2024, by 48 institutes in 22 countries, spanning from Japan to Latino-America. Importantly, many assistant tutors have been motivated to follow related studies and become active members of the community being also supported by the Heavy Ion Therapy Research Infrastructure HITRIplus project and its partners. The Heavy Ion Therapy MasterClass HITM, organized within the framework of HITRIplus for early stage researchers and up to professionals, following the PTMC methods and tools adjusted at appropriate levels, attracted 1050 participants world-wide, many of them becoming, subsequently, PTMC tutors. Further details on PTMC/HITM are given in references [1-5] and on matRad in [6].

3. Outreach of Applications for Society Working Group

Concrete examples of successful applications for the benefit of society from (particle) physics and related sciences are among the most effective means to communicate the positive impact of fundamental research to society when approaching the non-scientifically educated public. In addition to the quest for knowledge and satisfying natural human curiosity, there is a growing pressure, from taxpayers, for the justification of fundamental research funding, requesting tangible examples of return to economy and society. A particularly important target group is the young generation, who needs to be motivated and inspired to engage in STEM studies. Furthermore, the ones who engage with STEM studies need to be exposed to perspectives on potential careers and to examples of the impact of fundamental research to applied sciences.

Thus, the aim of the Working Group "Outreach of Applications for Society" is to offer a structured and categorized online collection of short stories with clear messages and explanations of "science at work" in the applications and spin-offs. The ultimate goal is to connect fundamental science to everyday lives of citizens and solutions for global societal challenges.

Out of a wide range of working documents and even more ideas, the stories available at the time of writing are listed below and they are available via the: IPPOG witness stories web page

- Unraveling Cosmic Mysteries: The collaboration between International Space Station and CERN
- Superconductivity – quantum mechanics at work
- Medipix detectors, from colour X-ray imaging to education
- Muography - Invisible particles help to reveal invisible structures
- Searching for hidden cavities inside the Sun pyramid in Mexico
- Einstein's Relativity in Action – the GPS Navigation System knows it
- Positron Emission Tomography: Can crystals used in particle detectors save lives?
- Accelerators to reduce pollution of maritime traffic

Indeed, in today's pragmatic, technocratic society, accustomed to flow of information, concrete examples on the impact of science, readily available, are needed to reach different target groups. The WG set itself the challenge of providing engaging stories with a human touch, trying to inject a personal note and trigger the so-called emotional memory; thus, approaching audiences and inspiring the young generation through "story-telling".

After collecting materials, from sources such as Books, Accelerating News, CERN knowledge transfer, GSI news and press releases, but also individual contributions, the WG works on story-building around the available facts while trying to find anecdotes and add a human touch to each one of them. Certainly, the idea is not to re-write what exists, but to present the existing material in a way that further triggers curiosity and motivates individual research; that approaches the reader injecting something personal, when possible.

The WG provides guidelines for anyone wishing to contribute, and a lot of accumulated resources as a starting point. The initial idea was to keep the stories short and simple; however, they also need to be accurate giving credits and highlighting the importance of collaborative efforts. Indeed, the final outcome is usually the result of ideas and work of many different groups which culminates often in large research laboratories. Each "story" focusing on a certain application has to explain what it is good for, how it works (limiting to the necessary technical details that physicists are always eager to provide), and if possible, to mention a personal connection, a human aspect. The initial idea was to address "general public" which, however, contains a very broad spectrum of target audiences. Hence, the WG had to take a pragmatic approach, addressing primarily students and teachers; and, therefore, the "stories" provide links to further materials, for those wishing to go into more details.

In practice, the work had to be adapted "on the go" and the WG tried different formats. For example, the explanation of the general principle of "muon tomography" is presented in one story. Then, as an application of this general principle, the explorations of the ALICE/UNAM group, searching for hidden chambers in the "sun pyramid" in Teotihuacan, Mexico, is presented in a different story. And those are, then, cross-referenced. Another example is the PET story, where the first page presents general information; and then, further details are given, like "addenda".

In addition to the above list of stories, which is the outcome of two dedicated hackathons, the current list of topics in the pipe-line includes subjects spanning from the well-known development of www, to cancer therapy, UNOSAT, touch screen, and many more. Almost unnoticed, about 30 000 accelerators are operating worldwide for the benefit of society based on the breakthrough developments of a handful of them dedicated to fundamental research. They are used for medical, industrial, security, environmental applications including possibilities to more effectively treat wastewater or sewage sludge. The ambition of the WG is to make such facts easily accessible to non-experts while presenting human aspects of scientists at the same time.

The stories are available for everybody to use to stimulate interest for STEM studies: for example, a colleague in Mexico presents them to school children motivating them to become ambassadors; another one extends the WG impact participating to a broader project, Youth@STEM4SF piloted in Switzerland supported by BeLearn, that explores the possibilities to enrich high-school curricula by including modern physics and creating digital materials. The aim is to develop new teaching tools, including the topic of hadron therapy, to enable physics high-school teachers to connect basic sciences with societal challenges and sustainable development.

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