XVIII International Conference on Topics in Astroparticle and Underground Physics TAUP



International Masterclasses - from collider physics to neutrinos and cosmic rays

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International Particle Physics Masterclasses (IMC)





http://www.physicsmasterclasses.org/

High school students become 'particle physicists' for one day

Programme (9 am – 5 pm):

- Lectures about particles and their interactions
- Hands-on analysis of real data from large particle experiments
- International videoconference: 3 5 universities join with CERN, Fermilab, GSI, KEK, Pierre Auger

Held annually in the spring over 6 weeks: 13 000 students, 225 institutes, 60 countries



Masterclasses is the flagship activity of IPPOG Collaboration







IPPOG Collaboration – International Particle Physics Outreach Group (1997 -)

Years IPPOG

International Scientific Collaboration (since 2016)

- active researchers experienced in outreach and informal science education in particle physics
- educators and communication specialists

Global network

- Members: 41 members: 33 countries, 7 experiments and CERN (international laboratory)
- Associate members: DESY (national laboratory), GSI (national laboratory)
- National networks





IPPOG Goals



- Raise the standards of science education and public engagement
 - discussion forums
 - working groups
 - database of best practices and resources
- Inspire the next generation of researchers
- Better public understanding of the scientific method and appreciation of evidence-based decision making
- Extend the global reach, expansion to
 - new countries and audiences
 - new methods and activities



Masterclasses in Podgorica, Montenegro



IPPOG: Means to achieve goals

Organization (and support) of global activities

- International Particle Physics Masterclasses, World Wide Data Day
- Global Cosmics, Girls, do Physics!,...

Support of local activities

Exhibitions, music/cultural festivals, competitions ...

Resources Database for outreach material in particle physics

- materials related to particle physics outreach and informal education
- to assist scientists, teachers and communicators in finding effective ways/tools to teach/communicate physics

Collaboration Forum meetings (to develop and share ideas, coordination of the programmes)

- held twice a year
- presentations of key activities, topical panel sessions

Working groups (WG) work throughout the year

- Explaining Particle Physics to a lay audience
- Outreach of Applications for Society
- Exhibits and Exhibitions
- Bringing Masterclasses to New Countries
- Diversity, Inclusion and Accessibility



http://ippog.org http://facebook.com/ippog http://facebook.com/groups/friends.ippog http://twitter.com/ippogOrg http://instagram.com/ippogOrg ippog-friends@cern.ch



(a sample of) Activities 2022



Higgs anniversary event in Valencia



International Cosmic Day: Winners of the Cosmic Selfie



CERN Portuguese Language Teachers Programme



Cultural Collisions Students at work in Austria



Show «One step away from the Big Bang» in Bologna during ICHEP conference.



Quantum and Dark Matter Road Trip team in Australia

Activities 2022



Virtual tour of CERN in Bulgaria



Outreach activities in schools in Réunion (Indian Ocean) parallel to the EDSU2022 conference



Illustration of the journey of a proton in the LHC in a



Cosmic ray workshops for schools in Brazil



Music and Higgs boson meet at a cultural centre in Slovakia



with ALICE LEGO

dance performance, <u>Science & Nature festival</u> in Zurich

Masterclasses - UK beginnings 1997

Roger Barlow and Ken Long suggested programme for high school students with a hands-on experience with modern research

Data from LEP at CERN and use of emerging computer clusters and the World Wide Web





Key success elements (R. Barlow)

- 1. balance between national organization and local university teams (spread of huge workload to manageable level)
- 2. measurement on real data with guidance of masters (physicists) brings students into direct contact with the cutting edge research.
- 3. organisers are enthusiasts who do it purely for fun and because they want to.

European LEP Masterclasses (2005 - 2010)

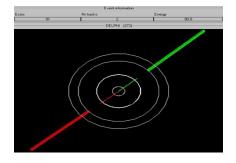


2005: 3000 European high school students, 58 universities, 18 countries

- students' task: to study the decay products of the Z⁰ particle (Fig.)
- videoconference at the end of the day was introduced

2006 – 2007: Masterclasses expanded to the United States and to South Africa

→ International Masterclasses (IMC)



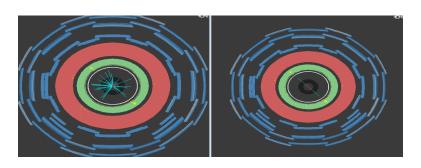
Zº decay into pair of electrons at DELPHI detector at LEP

International LHC Masterclasses (2011 - 2023)

The LHC Collider at CERN started in 2010 - exciting opportunity for IMC

2011: students analysed data released by ATLAS, CMS and ALICE (LHCb joined in 2014)

2023: IMC organized by 225 institutions in 60 countries, 13,000 participants



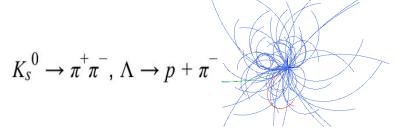
Zº decay into a pair of electrons at the LHC

International LHC Masterclasses (2011 - 2023)





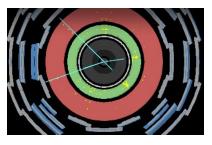
ALICE MC: Strangeness suppression and R_{AA}



Both visual and large scale analysis

ATLAS and CMS MC: reconstruction of Z_0 , W⁺, W⁻ bosons

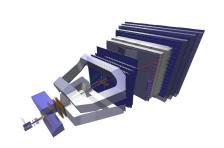
and search for the Higgs boson, discovered at CERN in 2012



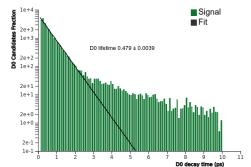
Visual analysis of 50 events

LHCb MC:

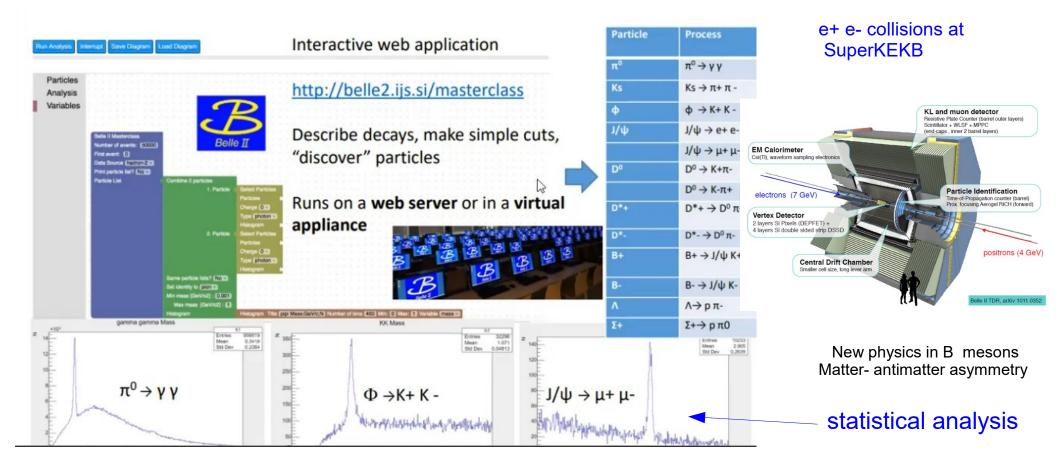
lifetime of the charm particle D⁰



Both visual and large scale analysis



Belle II (KEK, Japan)

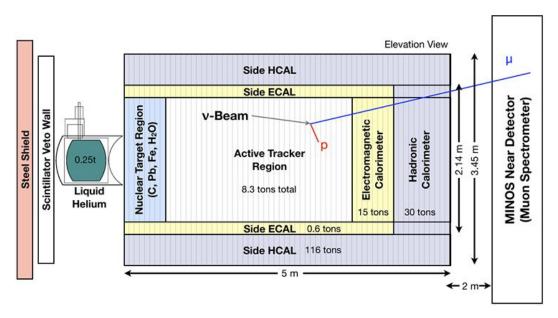


MINERvA Neutrino Masterclass

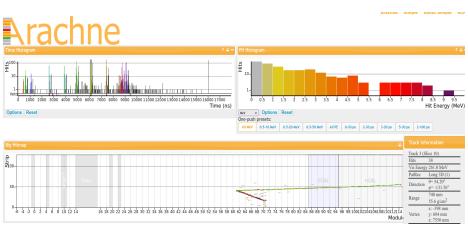
MINIENA

coordinated by QuarkNet & Fermilab

Interactions of muon neutrinos with carbon nuclei – input for neutrino oscillations at DUNE



MINERva experiment at Fermilab



50 events each pair of students histograms of net momentum:

- neutrino beam energy
- neutron momentum Fermi gas behaviour

Particle Therapy Masterclass

coordinated by GSI, Germany



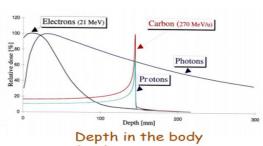
Demonstration of impact of fundamental research on medical applications

Students plan treatment for cancer therapy using

X rays

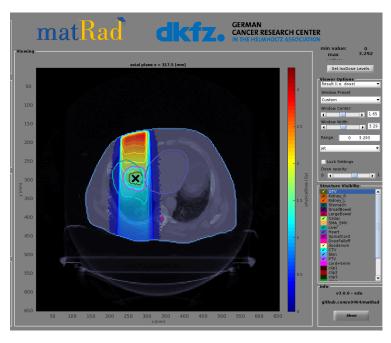
protons

carbon ions



(mm)





Pierre Auger Masterclass

coordinated by LIP, Portugal

What is the origin of ultra-high-energy cosmic rays?

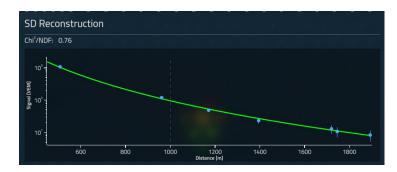
Visualization of events using an interactive display of the observatory

Separation of stations with signal from those with background

Visual reconstruction of the arrival direction of the primarycosmic ray

Fitting the data to determine the energy of the primary cosmic ray

Application of criteria to select events which point to the source



Statistics for IMC 2023

numbers from 2022 in brackets



CERN LHC Masterclasses

211 MCs (191):

- 99 ATLAS (94)
- 56 CMS (51)
- 26 LHCb (22)
- 30 ALICE (24

Fermilab LHC Masterclasses 40 MCs (32):

- 29 CMS (22)
- 11 ATLAS (10)

MINERVA
Masterclasses
8 MCs (9)

NOvA Masterclasses 2 MCs new!

KEK
Belle II
Masterclasses
16 MCs (11)
5 VCs (3)

Malargue
Pierre Auger
Masterclasses
12 MCs new!
3 VCs

GSI Hadron Therapy Masterclasses 30 MCs (28) 9 VCs (5)

New countries, audiences and formats

years IPPOG

IMC continue to expand to new countries and new institutions

We have reached African teachers through African School of Physics

A cooperation with Physics Without Frontiers brought masterclasses to Palestine and Nepal

World Wide Data Day – IMC at high schools rather than universities, guided by physics teachers







New in 2023

- Quito, Ecuador, Escuela Politécnica Nacional
- Maputo, Mozambique, Universidade Eduardo Mondlane
- Ben Guerir, Morocco, Mohammed VI Polytechnic University
- Lusaka, Zambia, University of Zambia
- Patra, Greece, Hellenic Open University
- Kharkiv, Ukraine Kharkiv National University

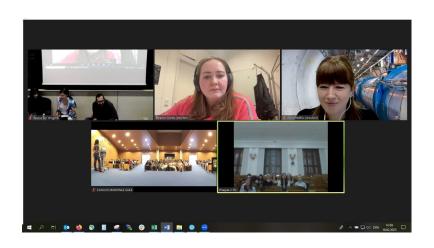


International Day of Women and Girls in Science

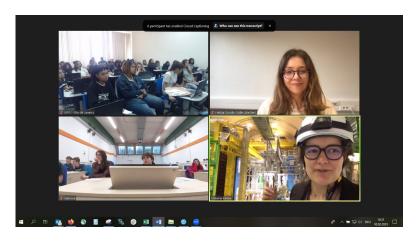




- LHC MCs for girls http://physicsmasterclasses.org/index.php?cat=women_in_science
- On Feb 10th (Friday)
- 14 groups participating (11)
- ~ 500 students (550)
- Female lecturers and tutors (as much as possible)
- 5 videoconferences at CERN (4)
- 10 female moderators (8)







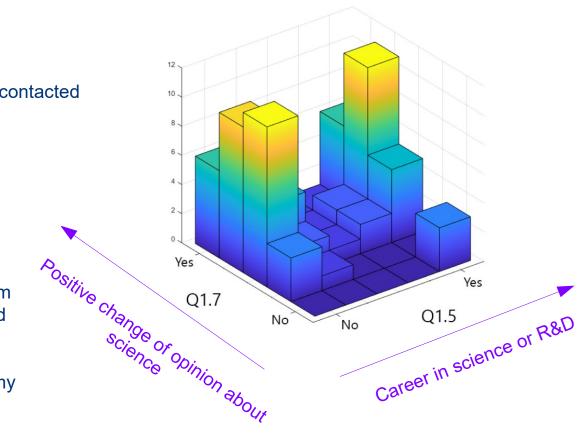
Study of long-term impact of IMC in Slovakia and the Czech Republic

"On the long-term impact of non-formal learning in particle physics" Júlia Kekeláková and Boris Tomášik, https://arxiv.org/abs/2307.15906

- Survey in April May 2023
- 351 former participants from 2011 2015 were contacted
- 71 participants responded
- 55% outside science and R&D
- 35% reported IMC influenced their decision to study physics or related subject

Q1.5 I contribute to the development of science—I am scientific associate, or I work for a company focussed on R&D

Q1.7 Thanks to Masterclasses I positively changed my opinion about science, research, and physics



Conclusions

Since 2011, more than 100,000 high school students participated in the IMC from 60 countries 8 different topics under the IMC umbrella: from LHC to neutrinos, particle therapy and cosmic rays IMC owe much of their success to the spirit of cooperation in particle physics and IPPOG IMC is fun for both organizers and the participants

We inspire the next generation





Back-up slides

IPPOG members

33 countries, 6 experiments and CERN (international laboratory)







Countries

Welcome Pierre Auger Observatory!

CERN

Associated members (DESY, GSI)

International Experiments (ALICE Collaboration, ATLAS Collaboration,
Belle II Collaboration, CMS Collaboration, HAWC Collaboration,
LHCb Collaboration)

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