International Particle Physics Outreach Group

25 years IPPOG

IPPOG – International Particle Physics Outreach Group

An international collaboration for education and outreach in particle physics

P. Abreu, *LIP and IST, Co-Chair*

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IPPOG Public Event@Sófia, Bulgaria,

12 May 2023

Outline

- ECO – Education, Communication, Outreach
- IPPOG – Timeline
- IPPOG – Main activities
- IPPOG – The future…for you!

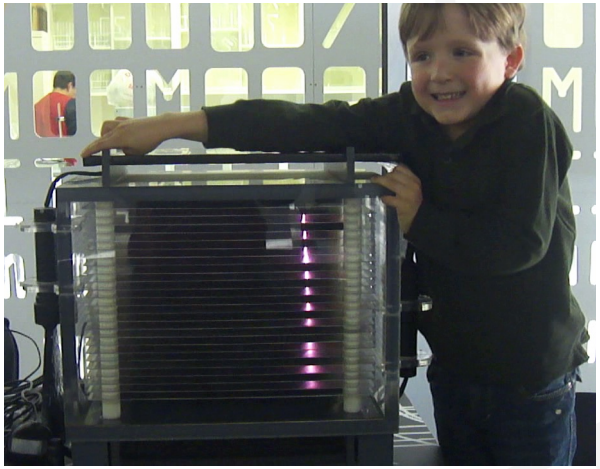
Education, Communication, Outreach

Communications

- **Report Goals and Results** to the public
- **Extend Reach** through methods & networks

Education & Outreach

- **Establish Understanding** of scientific process
- **Instil Appreciation** of fundamental research
- **Engage** with communities
- **Train the Next(*) Generation** of scientists



(*)...and the next-to-next generation

The Education, Communication & Outreach we do **today** lays the foundation for **tomorrow**'s support and secures the **next generation** of scientists.


OUR Universe!
Why?!
Universe!
What?
How?


Universe!
This is NOT our universe!
We are NOT seeing all that exists out there!

(the Higgs field exists EVERYwhere!

if we would see the Higgs field, this would be an image of our Universe)


Universe!
So, what do we “see” in our Universe?

Universe!

Stars (including black holes), Galaxies? 10%

Interstellar/intergalactic gas and dust? 84%

of which…

- Hydrogen 74%
- Helium 25%
- Lithium <1%
- Beryllium trace elements

(*Gas and dust only visible in wavelengths different than those of visible light*)

What else?!

Neutrinos? 6%

But... this is only the part of matter known to us!


THIS? We don’t know!
We know nothing!
We really don’t know anything!
(DARK ENERGY)
68,5%
DARK MATTER
26,5%
DARK MATTER
Normal matter
5%

THE STANDARD MODEL OF
FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model is a quantum theory that summarizes our current knowledge of the physics of fundamental particles and fundamental interactions (interactions are manifested by forces and by decay rates of unstable particles).

FERMIONS
matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor	Mass GeV/c²	Electric charge
ν_L lightest neutrino*	$(0-2)\times10^{-9}$	0
e electron	0.000511	−1
ν_M middle neutrino*	$(0.009-2)\times10^{-9}$	0
μ muon	0.106	−1
ν_H heaviest neutrino*	$(0.05-2)\times10^{-9}$	0
τ tau	1.777	−1

Quarks spin = 1/2

Flavor	Approx. Mass GeV/c²	Electric charge
u up	0.002	2/3
d down	0.005	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	173	2/3
b bottom	4.2	−1/3

*See the neutrino paragraph below.

Spin is the intrinsic angular momentum of particles. Spin is given in units of ħ, which is the quantum unit of angular momentum where ħ = h/2π = 6.58×10^{-25} GeV s = 1.05×10^{-34} J s.

Electric charges are given in units of the proton's charge. In SI units the electric charge of the proton is 1.60×10^{-19} coulombs.

The energy unit of particle physics is the electronvolt (eV), the energy gaine… crossing a potential difference of one volt. **Masses** are given in GeV/c² (rememb… where 1 GeV = 10^9 eV = 1.60×10^{-10} joule. The mass of the proton is 0.938 GeV/c² = 1.67×10^{-27} kg.

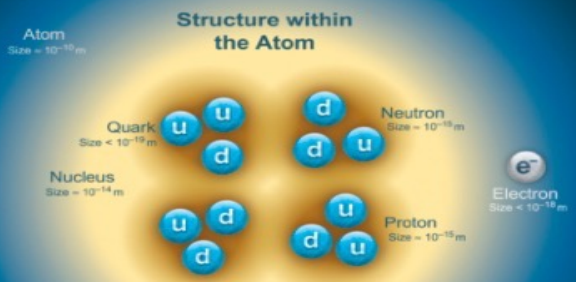
Neutrinos

Neutrinos are produced in the sun, supernovae, reactors, accelerator collisions, and many other processes. Any produced neutrino can be described as one of three neutrino flavor states ν_E, ν_M, or ν_T, labelled by the type of charged lepton associated with its production. Each is a defined quantum mixture of the three definite-mass neutrinos ν_L, ν_M, and ν_H, for which currently allowed mass ranges are shown in the table. Further exploration of the properties of neutrinos may yield powerful clues to puzzles about matter and antimatter and the evolution of stars and galaxy structures.

Matter and Antimatter

For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or − charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0, γ, and $\eta_c = c\bar{c}$ but not $K^0 = d\bar{s}$) are their own antiparticles.

Structure within the Atom



If the proton and neutrons in this picture were 10 cm across, then the quarks and electrons would be less than 0.1 mm in size and the

BOSONS
force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1

Name	Mass GeV/c²	Electric charge
γ photon	0	0
W^-	80.39	−1
W^+ W bosons	80.39	+1
Z^0 Z boson	91.188	0

Strong (color) spin = 1

Name	Mass GeV/c²	Electric charge
g gluon	0	0

Higgs Boson spin = 0

Name	Mass GeV/c²	Electric charge
H Higgs	126	0

Higgs Boson

The Higgs boson is a critical component of the Standard Model. Its discovery helps confirm the mechanism by which fundamental particles get mass.

Color Charge

Only quarks and gluons carry "strong charge" (also called "color charge") and can have strong interactions. Each quark carries three types of color charge. These charges have nothing to do … Just as electrically-charged particles interact by exchanging photons, …charged particles interact by exchanging gluons.

…Mesons and Baryons

…ks and gluons cannot be isolated – they are confined in color-neutral …les called **hadrons**. This confinement (binding) results from multiple …nges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs. The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge.

Two types of hadrons have been observed in nature **mesons** ($q\bar{q}$) and **baryons** (qqq). Among the many types of baryons observed are the proton (uud), antiproton ($\bar{u}\bar{u}\bar{d}$), and neutron (udd). Quark charges add in such a way as to make the proton have charge 1 and the neutron charge 0. Among the many types of mesons are the pion π^+ ($u\bar{d}$), kaon K^- ($s\bar{u}$), and B^0 ($d\bar{b}$).

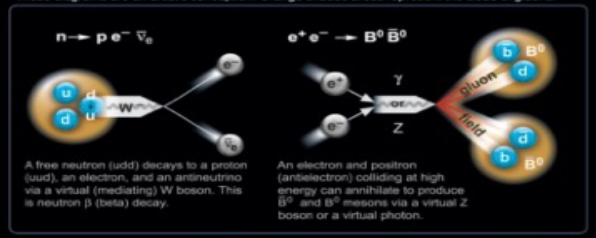
http://www.cpepphysics.org/particles.html

Property	Gravitational Interaction	Weak Interaction (Electroweak)	Electromagnetic Interaction	Strong Interaction
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge
Particles experiencing:	All	Quarks, Leptons	Electrically Charged	Quarks, Gluons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons
Strength at 10^{-18} m	10^{-41}	0.8	1	25
Strength at 3×10^{-17} m	10^{-41}	10^{-4}	1	60

Learn more at ParticleAdventure.org

Particle Processes

These diagrams are an artist's conception. Orange shaded areas represent the cloud of gluons.



A free neutron (udd) decays to a proton (uud), an electron, and an antineutrino via a virtual (mediating) W boson. This is neutron β (beta) decay.

An electron and positron (antielectron) colliding at high energy can annihilate to produce B^0 and $\bar{B}^0$ mesons via a virtual Z boson or a virtual photon.

Unsolved Mysteries

Driven by new puzzles in our understanding of the physical world, particle physicists are following paths to new wonders and startling discoveries. Experiments may even find extra dimensions of space, microscopic black holes, and/or evidence of string theory.

Why is the Universe Accelerating?

The expansion of the universe appears to be accelerating. Is this due to Einstein's Cosmological Constant? If not, will experiments reveal a new force of nature or even extra (hidden) dimensions of space?

Why No Antimatter?

Matter and antimatter were created in the Big Bang. Why do we now see only matter except for the tiny amounts of antimatter that we make in the lab and observe in cosmic rays?

What is Dark Matter?

Invisible forms of matter make up much of the mass observed in galaxies and clusters of galaxies. Does this dark matter consist of new types of particles that interact very weakly with ordinary matter?

Are there Extra Dimensions?

An indication for extra dimensions may be the extreme weakness of gravity compared with the other three fundamental forces (gravity is so weak that a small magnet can pick up a paper clip overwhelming Earth's gravity).

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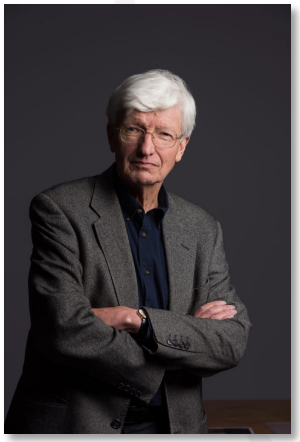
U.S. Department of Energy, U.S. National Science Foundation, & Lawrence Berkeley National Laboratory.

IPPOG – Timeline

1997 Birth of European Particle Physics Outreach Group (EPOG)

formed under the joint auspices of ECFA and EPS-HEPP

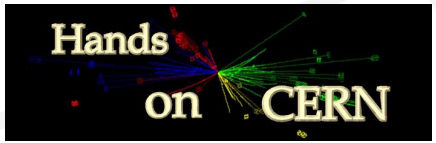
> *"…the particle physics community has a moral obligation to inform the public on its activities. To do this well, experiences must be shared among countries in view of the need to optimize the use of resources."*
>
> - Chris Llewellyn-Smith, CERN DG



as a forum for exchange of ideas, best practices, tools, etc…

2005 Launch of **IMC** – International MasterClasses in Particle Physics

based on real data from DELPHI and OPAL experiments (experiments at LEP, the accelerator before LHC)



EPPOG European Particle Physics Outreach Group (EPOG => EPPOG in ~2006)

IPPOG – Timeline

2009 First election of **2 Chairs**

Shared management at IPPOG

2011 Real data from ATLAS and **CMS** experiments at the **IMC** (Int'l Masterclasses)

2011 Global Expansion "E" => "I" (EPPOG => IPPOG)

Israel, Australia, USA (Brazil, South Africa, India, Mexico, …)

2012 First presentation of the IMC + hands-on sessions in an international conference

1st World Conference in Physics Education, Istanbul, Turkey

2012 ICHEP2012, Melbourne, Australia

Announcement of the **Higgs Boson** discovery, 1st Outreach Track in a big conference

2016 Formalization of an **International Collaboration**

MoU (Memorandum of Understanding) came into force on December 2016

2017 Launch of the **Global Cosmics portal**

2022 Symposium of the 25th Anniversary, celebrating also pandemic survival

IPPOG Today

International Scientific Collaboration

- Active Researchers with Experience in Education & Outreach
- Experts in Communication & Education

Global Network

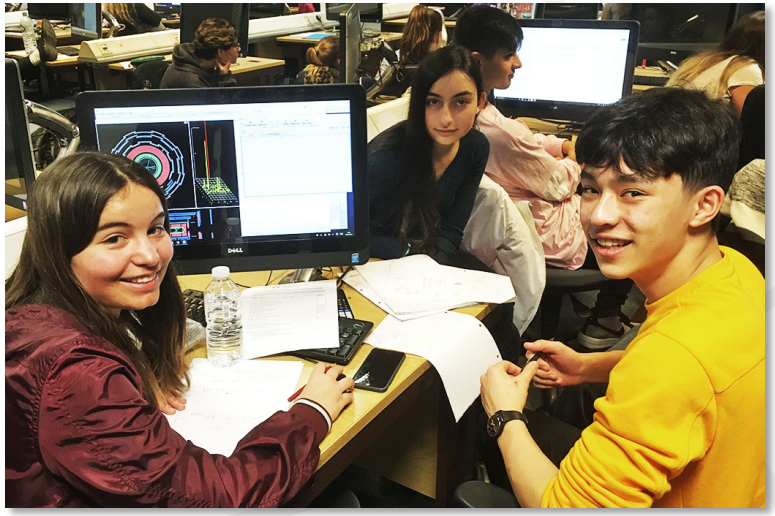
- 33 countries, 7 experiments, 1 int'l lab (CERN)
- 2 associate members: 2 national labs (DESY, GSI)
- A link to national networks

Organise Global Activities

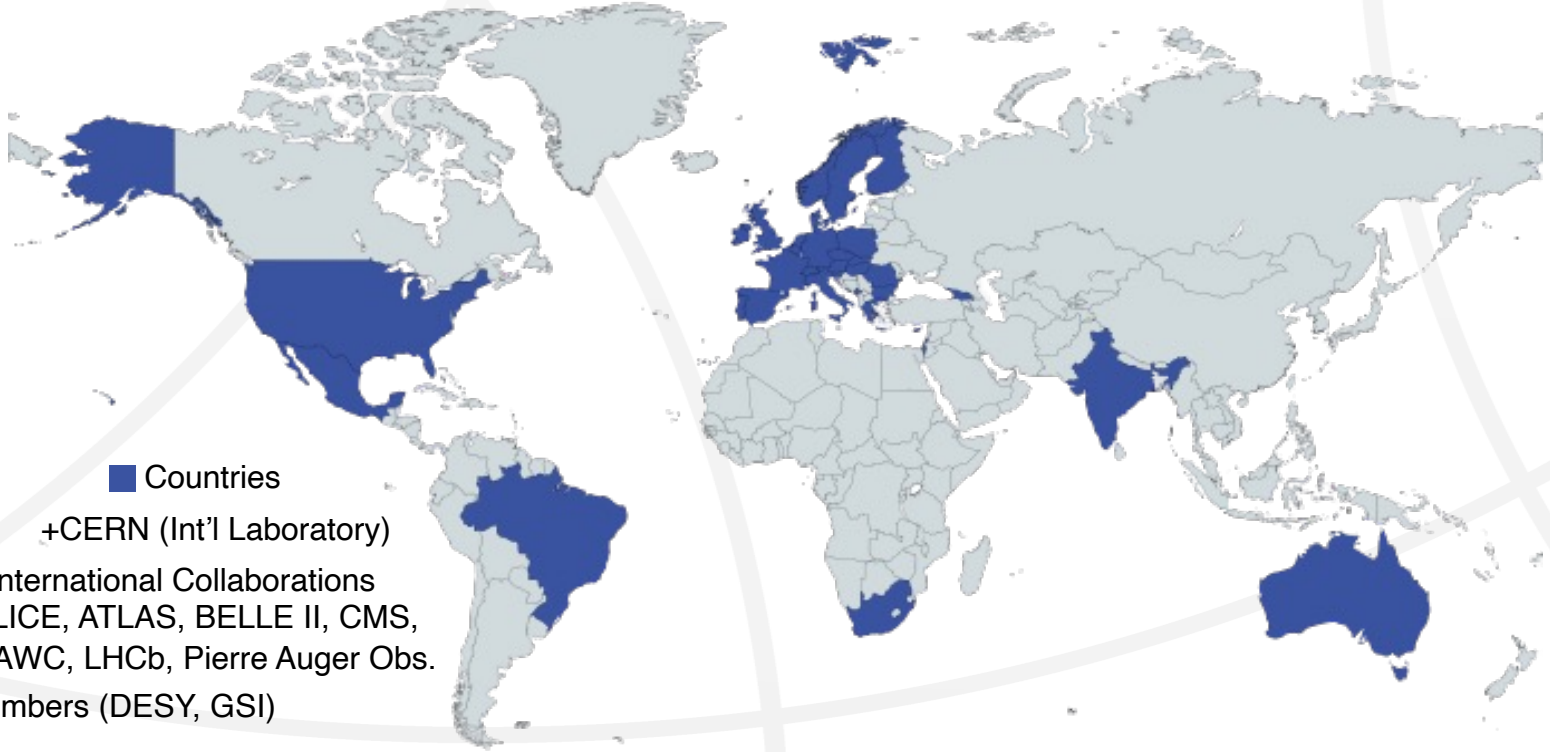
- International Particle Physics Masterclasses
- World-Wide Data Day, Global Cosmics, etc.

Support Local Activities

- Sharing of expertise, best practices, material database
- Resources to support events, kick-start activities
- Link to interview with Claire Adam and Zory Zaharieva on Bulgarian National Radio



IPPOG Today



Countries

+CERN (Int'l Laboratory)

+International Collaborations
ALICE, ATLAS, BELLE II, CMS,
HAWC, LHCb, Pierre Auger Obs.

+Associated Members (DESY, GSI)

IPPOG main activities – meetings

24th IPPOG Meeting @CERN, 26-28 Oct 2022

https://indico.cern.ch/e/ippog-2022-autumn

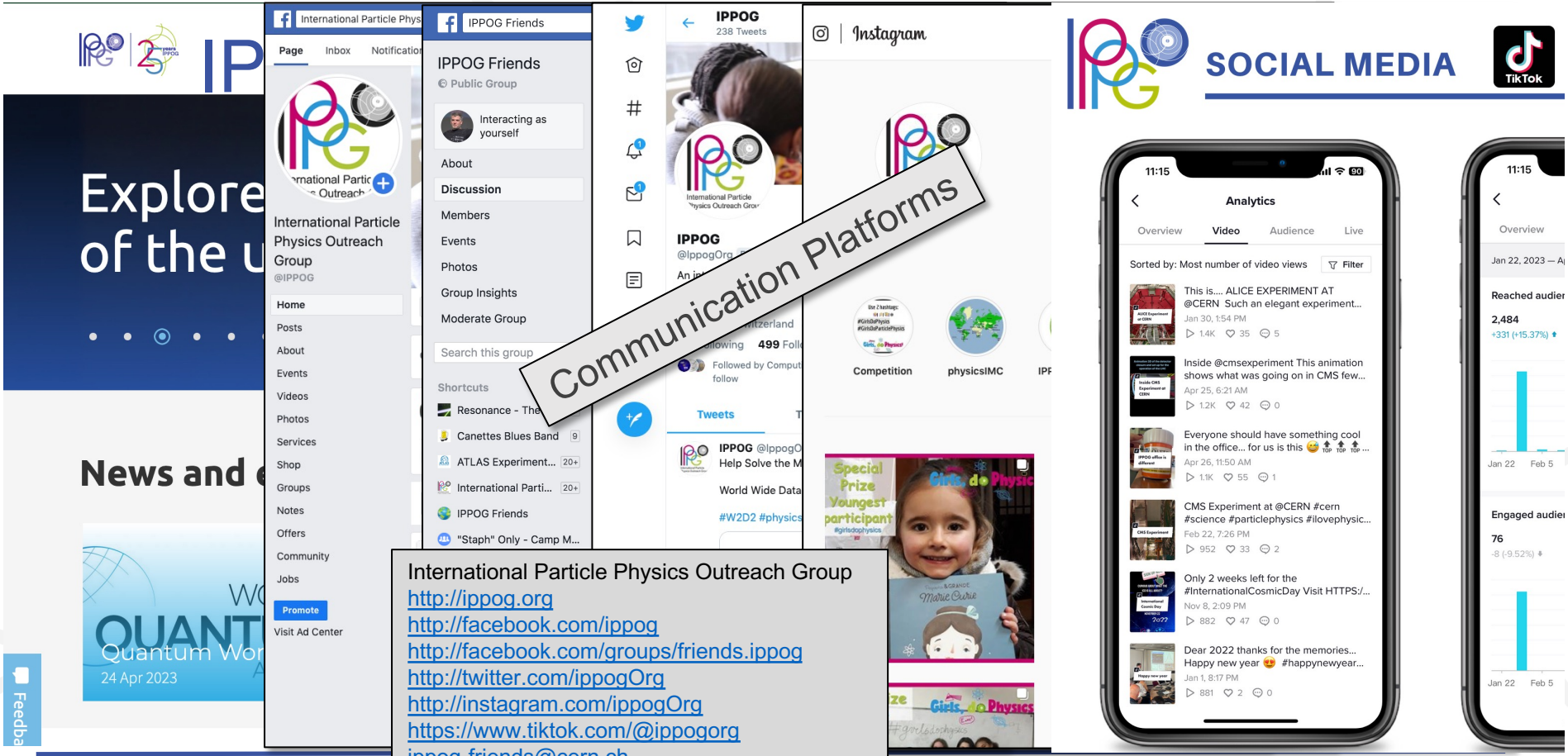
- Working Group Meetings & Reports:
  - Masterclasses Steering Group&to new countries WG
  - Exhibitions and Public Events
  - Diversity, Inclusion & Accessibility
  - Outreach of Applications for Society
  - Explaining Physics to Lay Audiences
- Inspiring success stories
- Panel Discussion: “Masterclasses for future instal.”
  - CERN, FCC, DUNE, Muon Collider, etc

Intensive 2.5-Day Meetings

25th IPPOG Meeting @Sófia (BG), 9-12 May 2023

- Steering/Working Groups Meetings & Reports:
  - Masterclasses and Global Cosmics
  - Expanding Masterclasses to New Countries
  - Outreach of Applications for Society
- Inspiring success stories
- Panel Discussion: “Quantum Computing”
  - Specialists on quantum computing (theory, applications, finance, education&outreach)

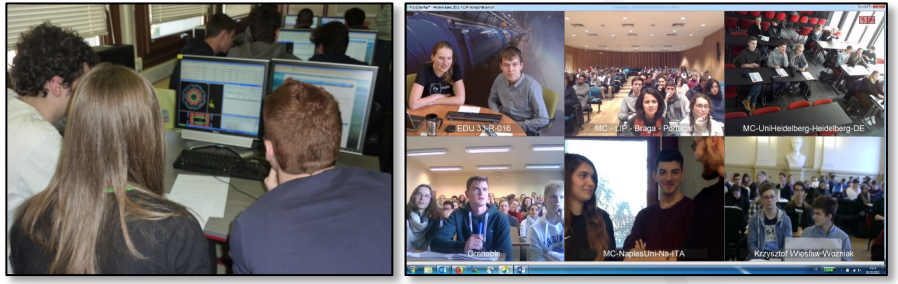
https://indico.cern.ch/e/ippog-2023-spring


SOCIAL MEDIA
TikTok
Communication Platforms
International Particle Physics Outreach Group
http://ippog.org
http://facebook.com/ippog
http://facebook.com/groups/friends.ippog
http://twitter.com/ippogOrg
http://instagram.com/ippogOrg
https://www.tiktok.com/@ippogorg
ippog-friends@cern.ch

IPPOG – International Masterclasses

The Flagship Activity of IPPOG

- Students become “Scientists for a Day” at a Research Inst.
- Introduction to Particle Physics, Detectors, etc.
- Analyse real data provided by experiments
- Discuss results via videoconference with other students around the world



Global Reach (2019; recovering after pandemic)

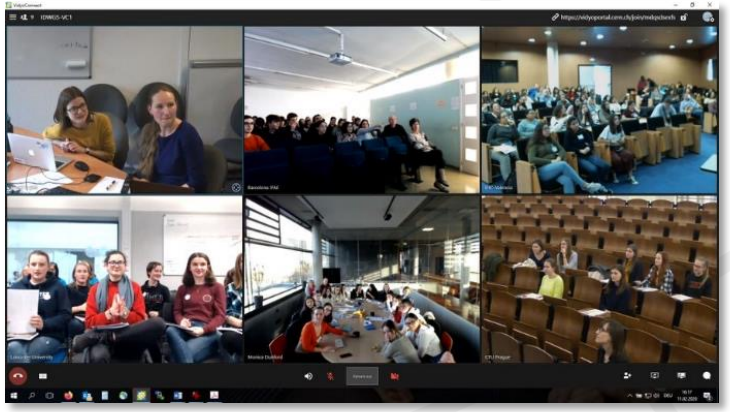
- 60 countries
- 220 research labs
- 14,000 Students
- Videoconferences with moderators at CERN, FNAL, KEK, GSI, TRIUMF

IPPOG – International Masterclasses

U.N.'s International Day of Women and Girls in Science 11 Feb => Campaign start

"support and promote the access of girls to science education and research"

- Masterclasses for Women and Girls
  - 17 groups participating
  - 600 students
  - Primarily women lecturers and tutors
  - 4 videoconferences at CERN with women moderators
    - incl. presentation on situation of women in physics
  - **Next: ~11 Feb 2024 (to be confirmed)**

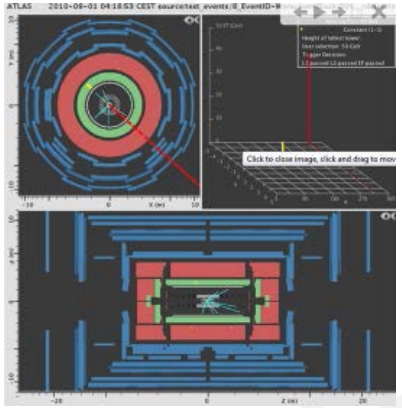


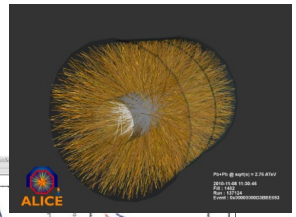
"My institution (Lancaster University in the UK) took part for the first time, last Tuesday on the International Day of Women and Girls in Science. We hosted a school group and had a great day - thanks very much!"

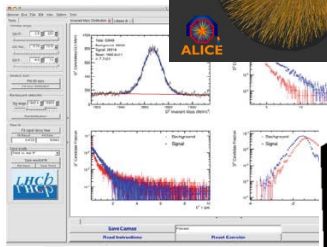
IPPOG – International Masterclasses

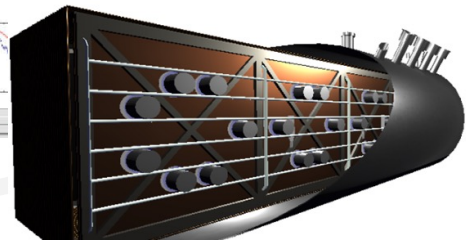
The Measurements

- ATLAS W-Path (Ratio of the W^+ / W^- bosons, with a H→ WW taste)
- ATLAS Z-Path (Z boson mass, Higgs search in photons and 4 leptons)
- CMS (Decays of the W, Z, and Higgs bosons, Mass of the Z boson)
- ALICE (Strange particles)
- ALICE (Measurement of Nuclear Properties)
- LHCb (Study of the particle decay: $D^0 \rightarrow K\pi$)
- MINERνA (Neutrino studies)
- Belle II (Particle reconstruction)
- Particle Therapy (GSI/FAIR)
- Pierre Auger Observatory (Cosmic Rays)









In development

- Darkside, MicroBooNE
- OPERA, DUNE

IPPOG – International Masterclasses

physicsmasterclasses.org

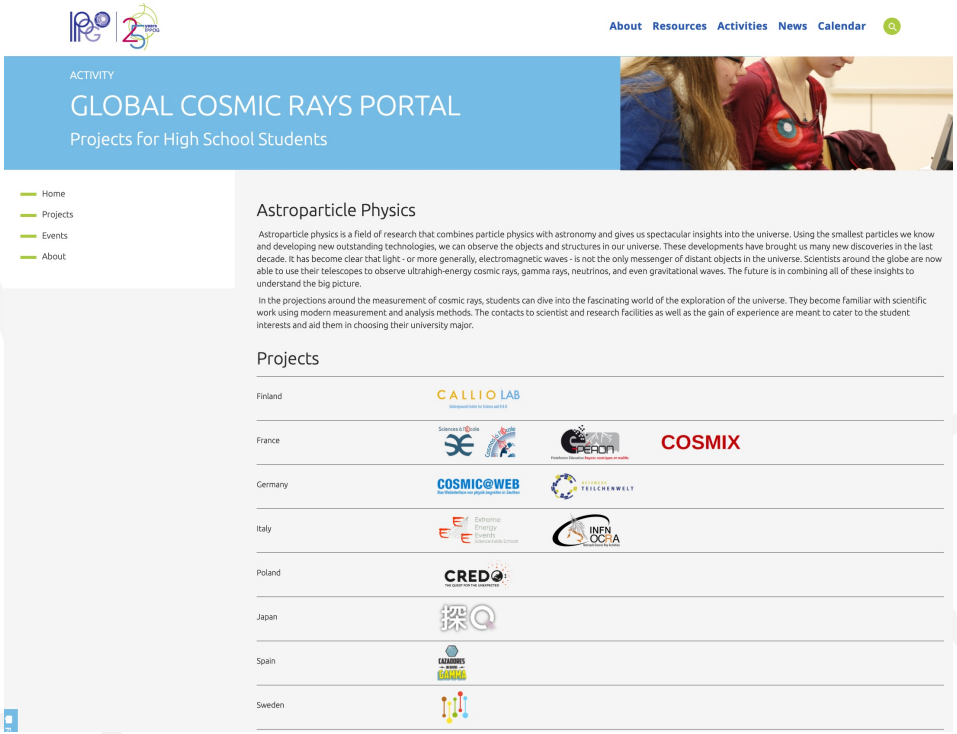
Next edition: **2024**
From ~11 February
to a few days before
(catholic) Easter
(31 march)

IPPOG – Global Cosmics

ippog.org/global-cosmic-rays-portal

International Cosmic Day

International Muon Week

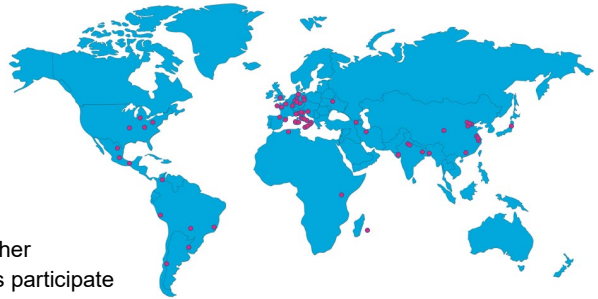


IPPOG – International Cosmic Day

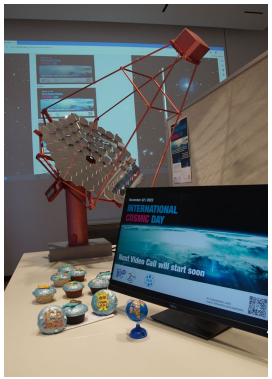
https://ippog.org/global-cosmic-rays-portal/international-cosmic-day/

International Cosmic Day 2022

Topic: Investigating the particles from the cosmos



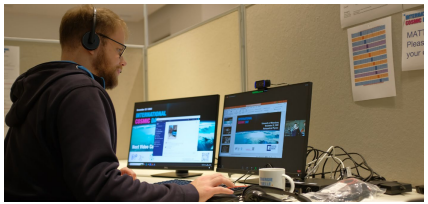
98 groups of students, teacher and scientist in 23 countries participate



© Heike Prokoph, DESY

© I.I.S.S. Aldo Moro Margherita

12 Video Calls throughout the day



© Carolin Gnebner, DESY

In cooperation with many networks and partners:

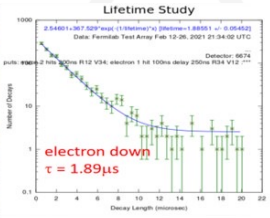
Report Global Cosmic Group | Sabine Hemmer, Carolin Gnebner, May 2023

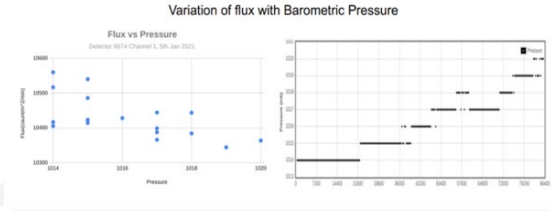
IPPOG – International Muon Week

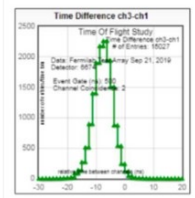
https://quarknet.org/content/international-muon-week

Usually
in Spring

Measurements



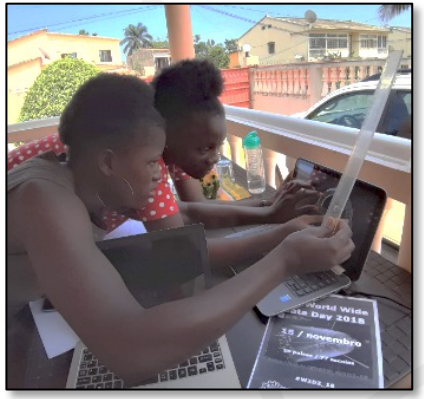




IPPOG – World Wide Data Day (W2D2)

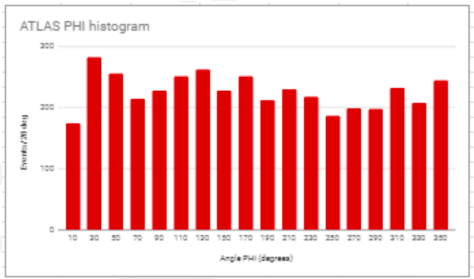
10 November 2022 (24h)

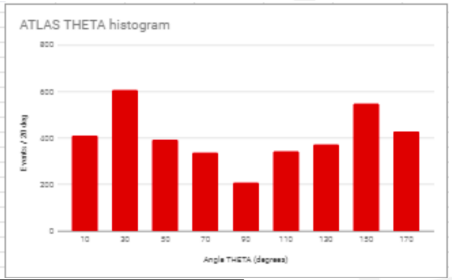
- Participating groups: 42 in 11 countries – 6 from Bulgaria!
- for high school students, guided by physics teachers
- simplified measurement with data from ATLAS and CMS



Measurement

- Students worldwide analyse data from LHC events
- Data analysis at school, physics discussion in Video-Conference (Zoom)





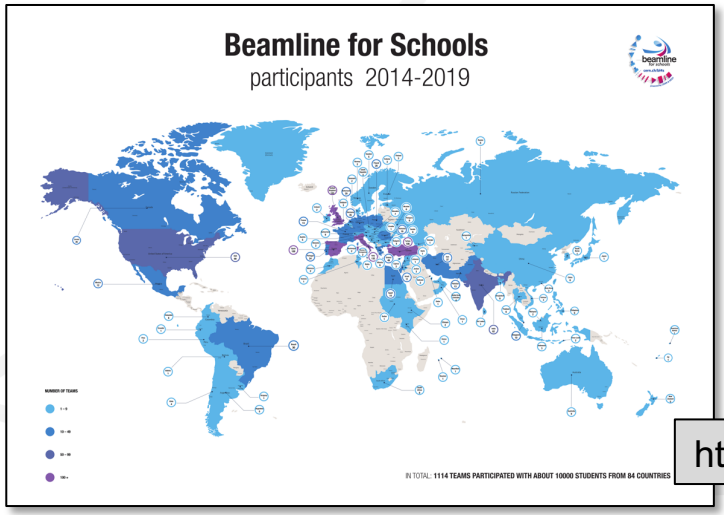
https://quarknet.org/content/world-wide-data-day

Next: Oct/Nov 2023

IPPOG – Support to BL4S Competitions

IPPOG Participation

- Local Contacts to Schools
- Help Remove Language Barrier
- Give Guidance for Physics, Feasibility



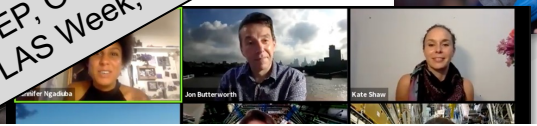
http://beamlineforschools.cern

IPPOG – Public events & Festivals (examples)

Colours of Ostrava
Czech Rep, 2019, 2022

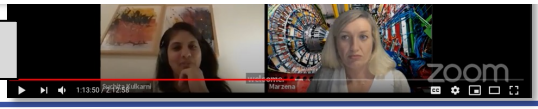
Pohoda Festival
Slovakia, 2019

Universal Science
CHEP, Sofia, Bulgaria, 2018
CHEP, Adelaide, Australia, 2019
ICHEP, Online, 5 Aug 2020
ATLAS Week, Lisboa, 16 Oct 2022



Music for Physics, Sófia, TONIGHT/tomorrow

http://universalscience.web.cern.ch



IPPOG – the future…for you!

Many challenges ahead

- Scale of [new] projects (timespan, cost, size, …)
- Wide[r] recognition of the value of [Fundamental] Science in the Society
- Increase the reach of our activities – geography, diversity, inclusion, age
- Train the trainers – Teachers, Educators, Tutors, Motivators
- Introduce High Energy and Particle Physics in school curricula,
  either adiabatically or with a swift phase transition (aka revolution)

Education and Outreach are more important than ever.
We need to work on how the public perceive scientific knowledge and the scientific process.

Conclusions

- Education, Communication and Outreach are essential pillars for the development of High Energy and Particle Physics.

- Many scientists/teachers , at different levels of commitment, are already carrying outwards the excitement of the field with many activities.

- Our field needs the support and contribution of **all**,
  - as an active teacher engaging your students in classes and activities,
  - as an active student involved in activities and engaging friends and family,
  - as actively being an ambassador of the field,
  - and/or helping creating the conditions for a better Edu-Comm-OR in PP.

O_TREACH *is not complete without* U

Thank you for your attention!

...and

Planting a future

Thanks!

(this is a big thanks!)

to all the people collaborating in all these activities!

Any questions?

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LIP

TÉCNICO LISBOA