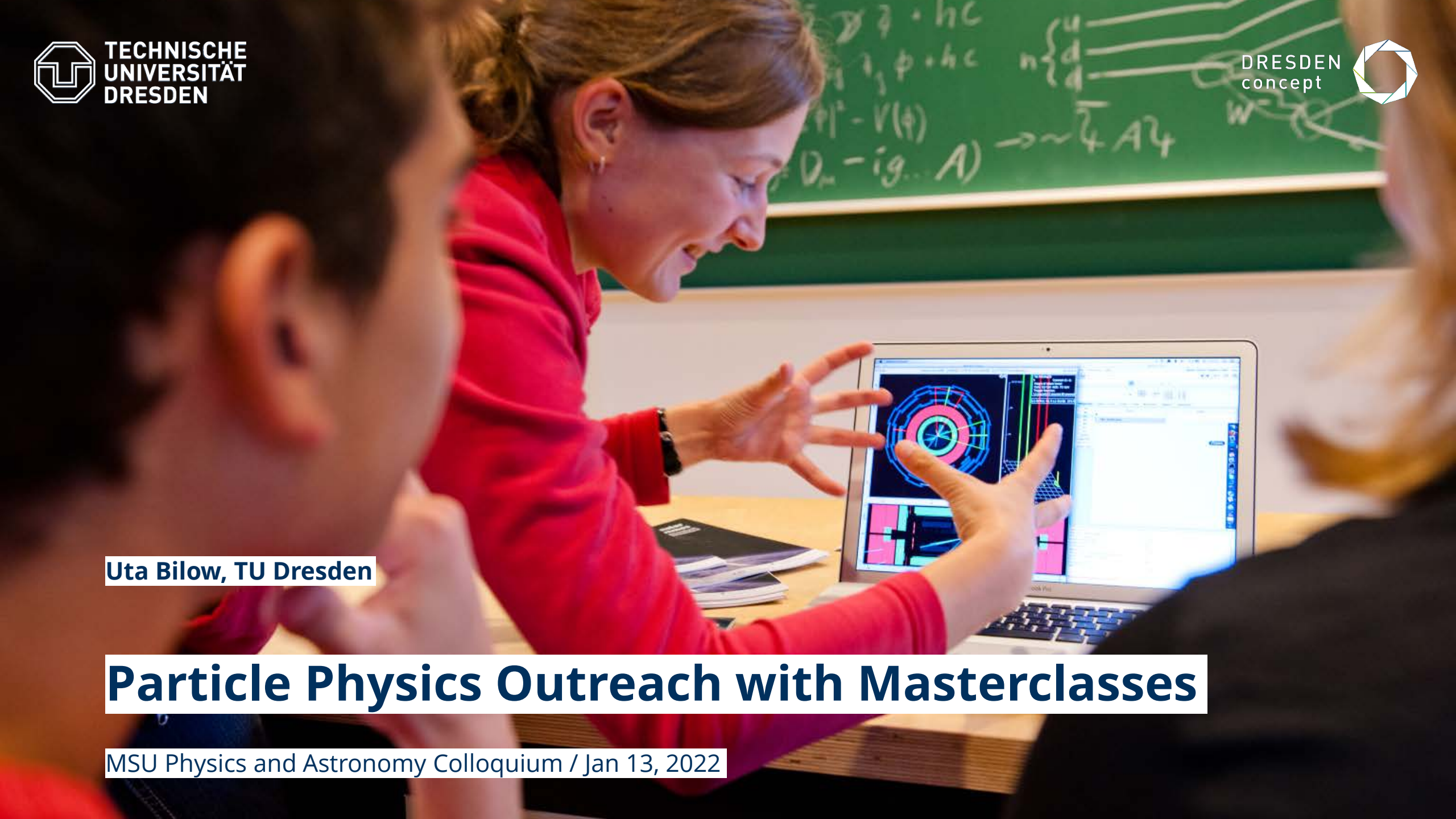


TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Uta Bilow, TU Dresden

Particle Physics Outreach with Masterclasses

MSU Physics and Astronomy Colloquium / Jan 13, 2022

CERN Media coverage

Media echo on Higgs discovery

Abonnemente

Neue Zürcher Zeitung

Menü | Startseite

«NZZ Digital»: Das neue Deutschland-Abo. Zum Angebot

«Ich glaube, wir haben es»

Forscher am Teilchenphysik-Laboratorium Cern in Genf haben ein neues Elementarteilchen entdeckt, bei dem es sich womöglich um das ominöse Higgs-Teilchen handelt. Auf diesen Tag hatte die Forschergemeinde lange hingefiebert.

4.7.2012, 11:03 Uhr

NEWS

2013 Nobel Prize in Physics goes to Englert and Higgs

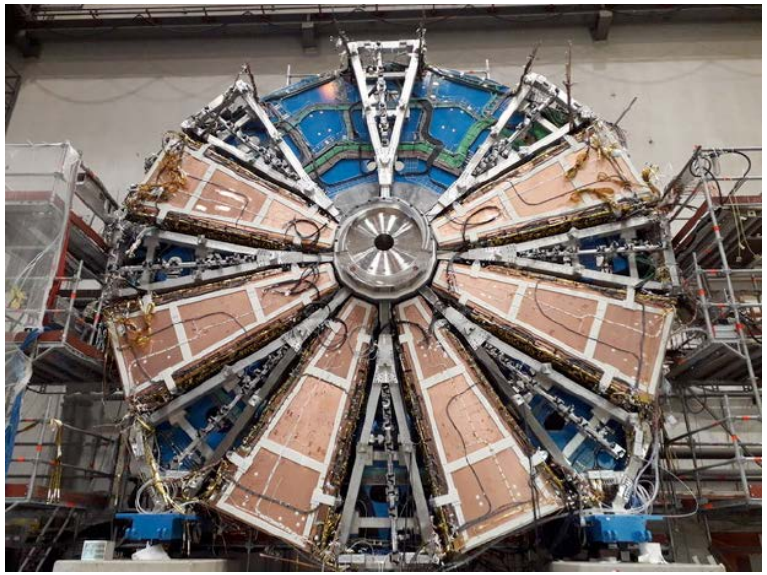
20 November 2013

2013 Nobel Prize in Physics

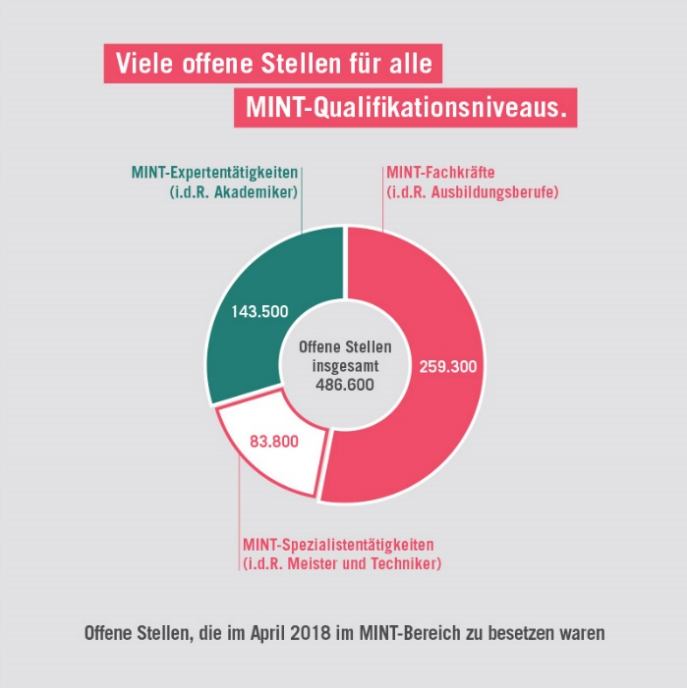
Champagne corks popped at CERN on 8 October, to celebrate the award of the 2013 Nobel Prize in Physics to François Englert, professor emeritus at the Université libre de Bruxelles, and Peter Higgs, professor emeritus at the University of Edinburgh. They received the honour "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider". The announcement of the discovery by the ATLAS and CMS collaborations took place at CERN on 4 July last year (CERN

LHC schedule

HL-LHC: High Luminosity LHC
LS: Long Shutdown
TeV: Tera electron Volt

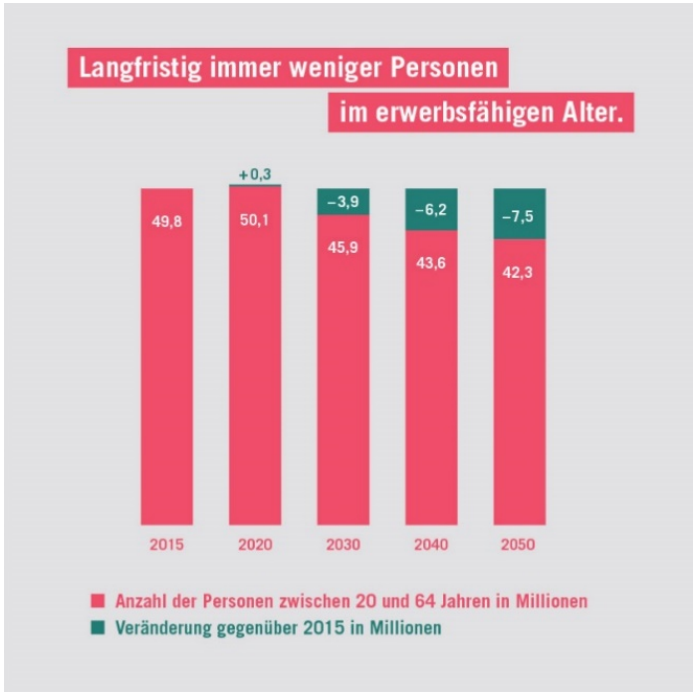


Shortage of STEM Specialists



490.000 open positions in STEM
Green: academic background

Number of open positions
is growing

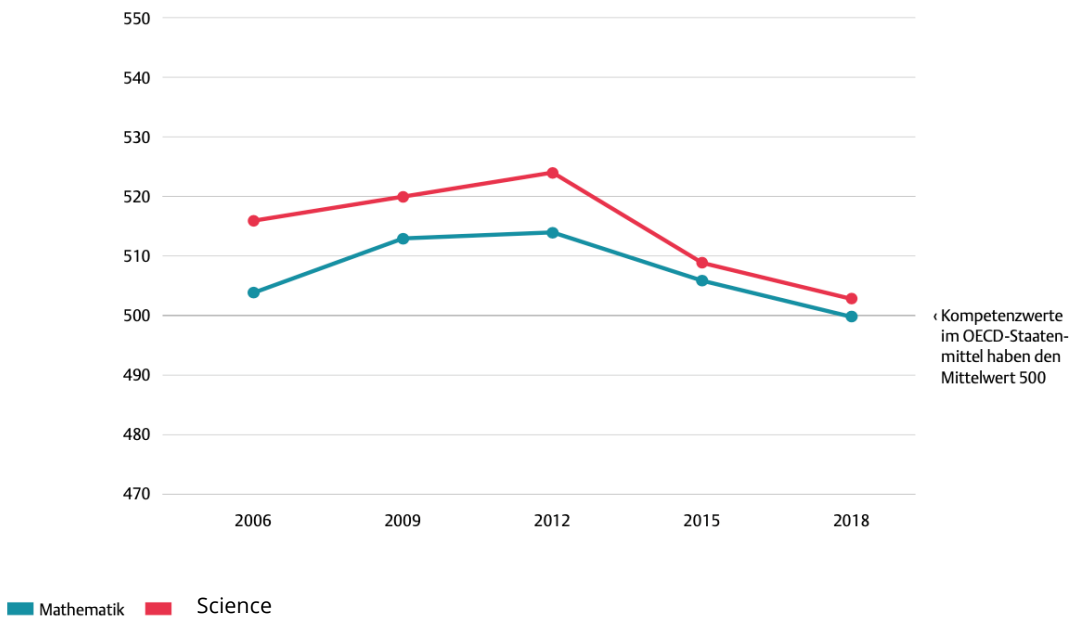


Number of working-age
persons is decreasing

https://www.insm.de/insm/themen/arbeit/fakten-fachkraeftemangel

STEM Young talent barometer

Performance of 15-year-olds in Germany



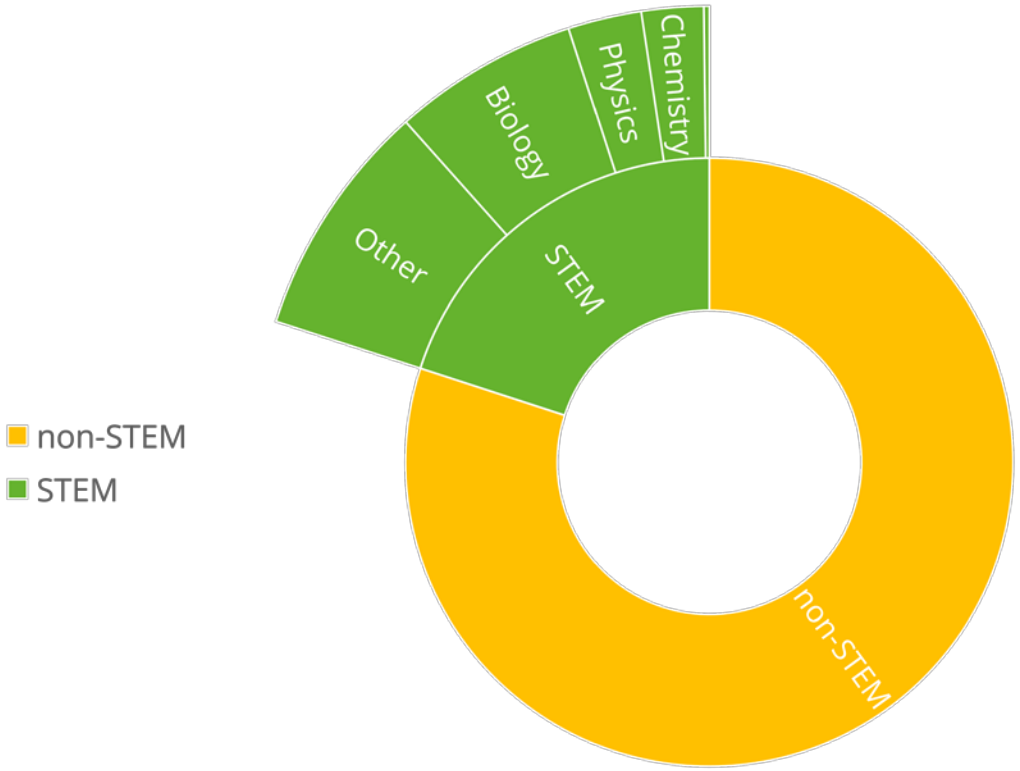
Datenbasis: Reiss et al. 2019

- performance of 15-year-olds declining since 2012
- Girls' and boys' performance is similar, but mainly because boys' performance deteriorates
- Girls have less interest and self-confidence in mathematics, chemistry and physics than boys, despite comparable performance
- Motivation, interest and professional self-confidence decreased

https://www.koerber-stiftung.de/mint-nachwuchsbarometer

More findings from STEM Young talent barometer

20 % of high school students choose science on a higher level (advanced course or “Leistungskurs”)



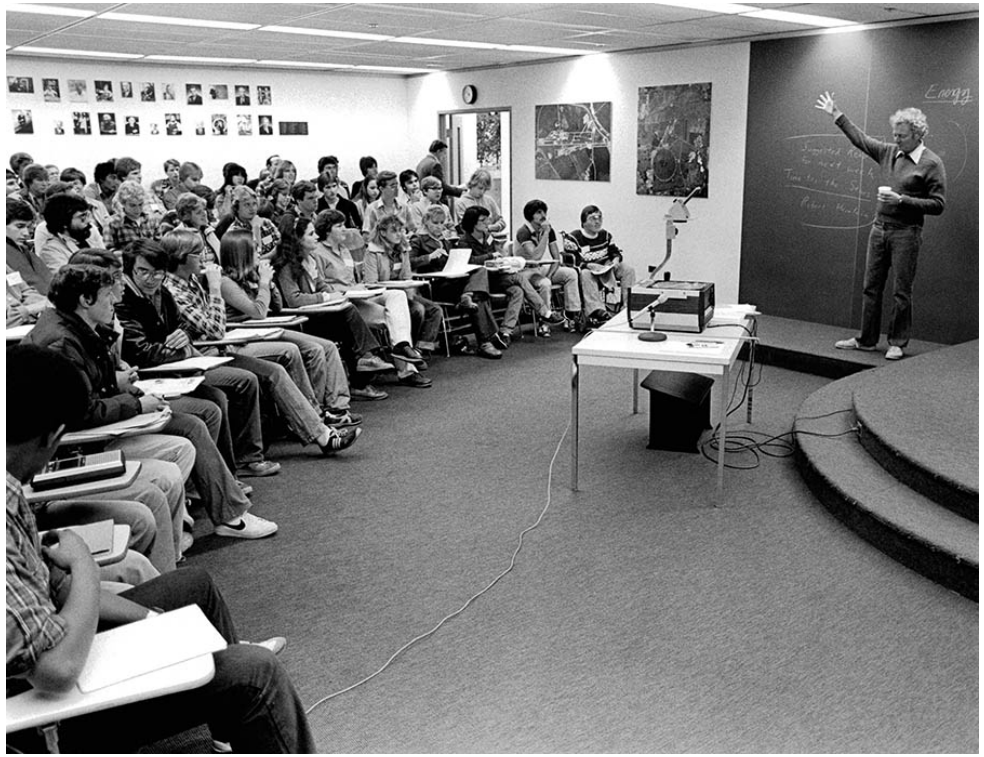
Low percentage of girls in physics and computer science courses:

- Biology: 60 %

- Physics: 26 %

- Computer Science: 15 %

Motivation for outreach

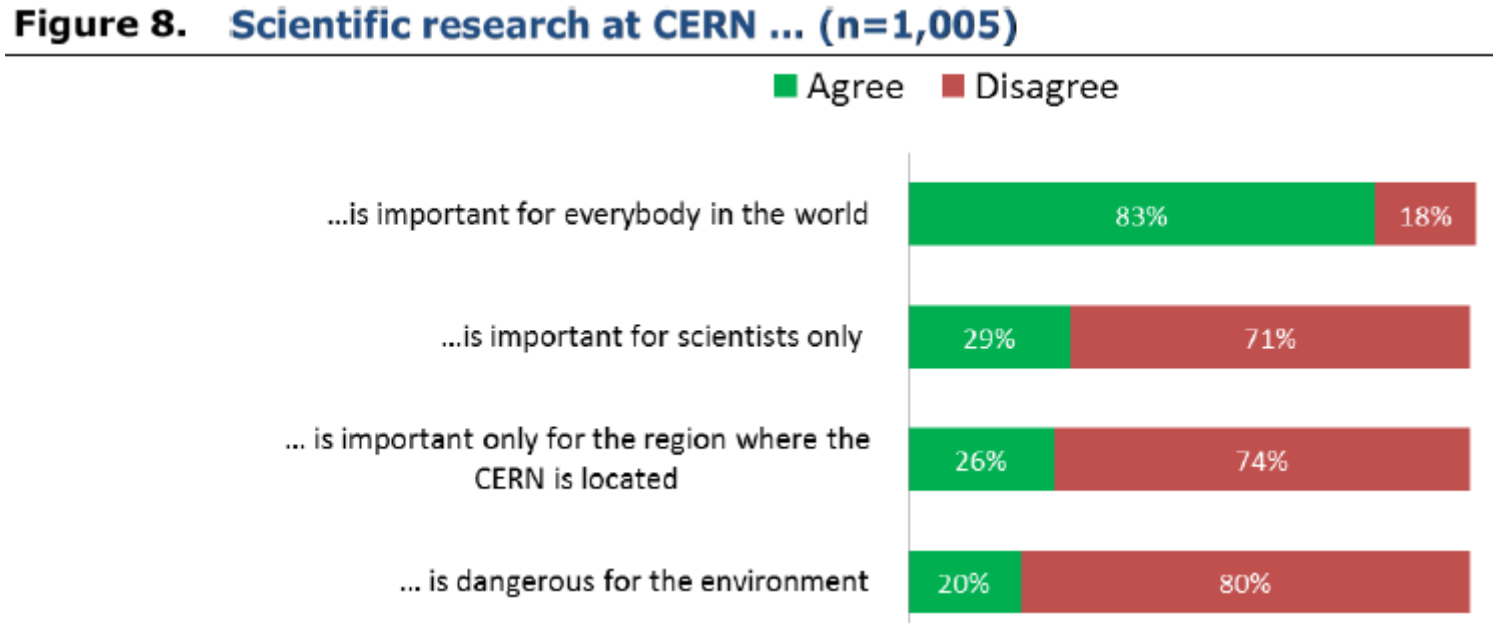


Leon Lederman, 1980ies

Recruitment of
future scientists

Motivation for outreach

- secure funding for our projects (“1 coffee/year”)
- **A price worth paying** R. Heuer (2020) https://cerncourier.com/a/a-price-worth-paying/
- **Scientific Research at CERN as a Public Good: A Survey to French Citizens** M. Florio et al. (2018) http://cds.cern.ch/record/2635861

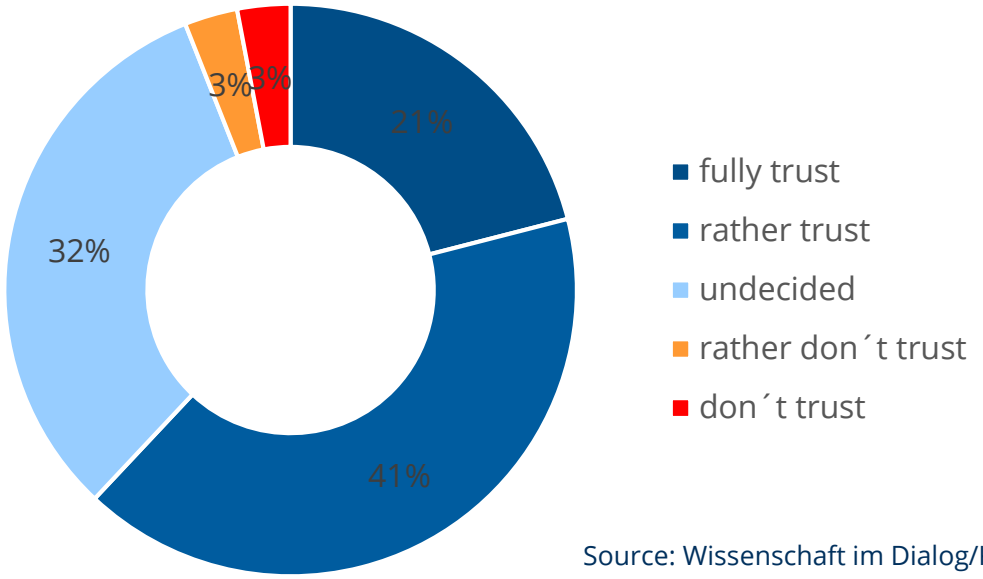


Recruitment of future scientists

Explanation & legitimation

Motivation for outreach

"How much do you trust science and research?"
Wissenschaftsbarometer 2021



Source: Wissenschaft im Dialog/Kantar

Recruitment of future scientists

Explanation & legitimation

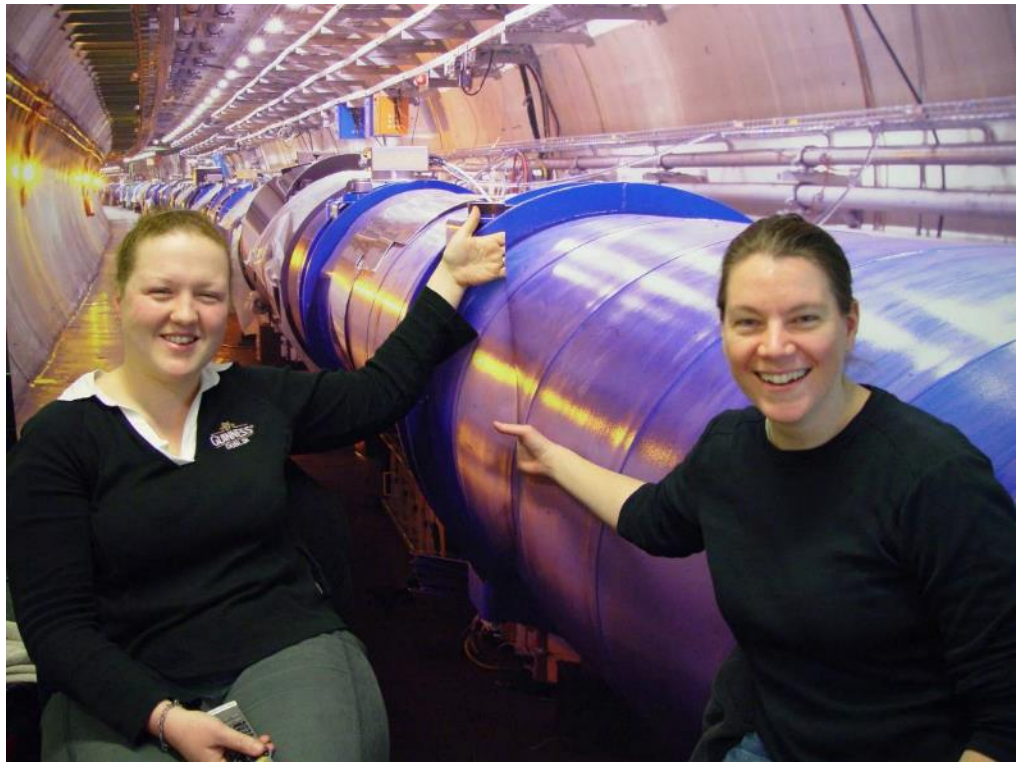
Create trust in science

Motivation for outreach

Quotes from Masterclasses moderators:

"The best thing is actually answering the questions and seeing how excited and how happy they are, waving at the camera. They're really excited to be talking to physicists based at CERN!"

"It is very satisfying, because we do many video conferences and rarely do people cheer on the other side if you say something. Here they do!"



Recruitment of future scientists

Explanation & legitimation

Create trust in science

Intrinsic motivation

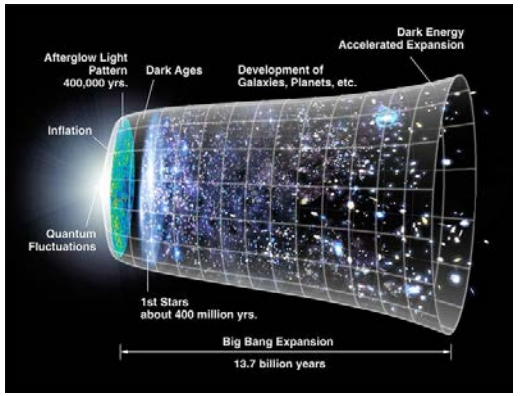
A research area with a lot of potential

Strength and chances:

- Strong media interest
- Many people are interested in fundamental questions
- Unique research methods and experimental setups
- Is connected to captivating terms, e.g. Big Bang, Antimatter

Challenges:

- Modern physics often not in school curricula
- Many new concepts and perceptions
- Large number of new terms
- Connection to everyday experience



The idea behind Masterclasses

Act as a "scientist for a day"

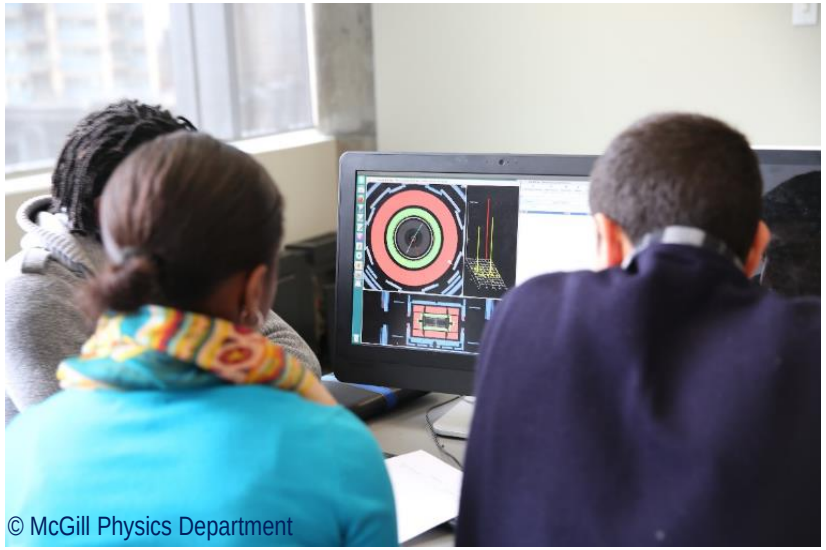
- Close to current research
- Own "hands-on" activities (listen = forget, see = remember, do = understand)

Get insight into the research process

- Use of relevant methods and tools
- Comparisons between experiment and theory

Authentic experiences

- Analysis of real scientific data
- Meeting and discussion with scientists


© McGill Physics Department


© Marzena Lapka

Why “Masterclass”?

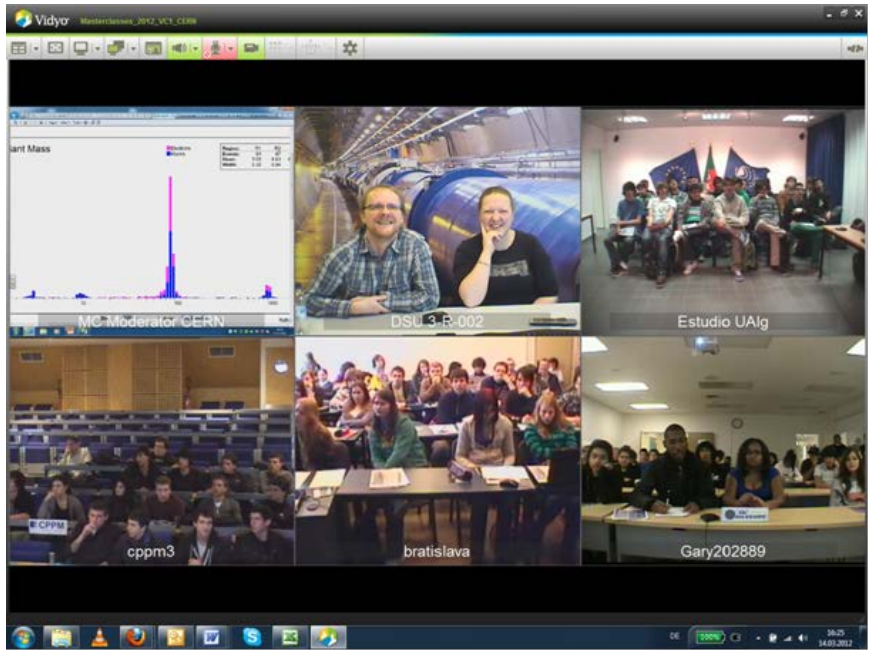
As in a Masterclass in the arts, students work with an expert

Expert = particle physicist

Instead of, say, a violin, the subject is particle physics data analysis

Concept of International Masterclasses

- High school students (15 – 19) are „scientists for one day“
- Get invited to a research institute or university
- Introductory talks (standard model, detectors, accelerators)
- measurement with HEP data
- International video conference (3 – 5 inst. + moderators)



Sample Agenda

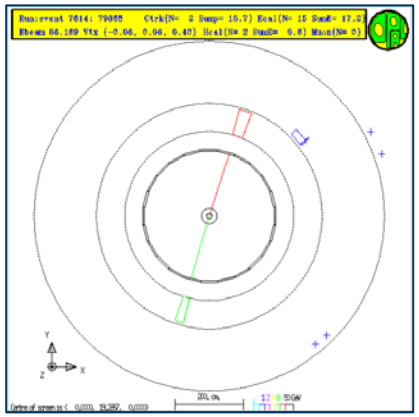
Local time	Activity
8:30 - 9:00	registration & welcome
9:00 - 10:00	introduction to Particle Physics
10:30 - 11:30	second talk or tour
12:00 - 13:00	lunch
13:00 - 15:00	data analysis
15:00 - 16:00	local combination + discussion
16:00 - 17:00	international video conference

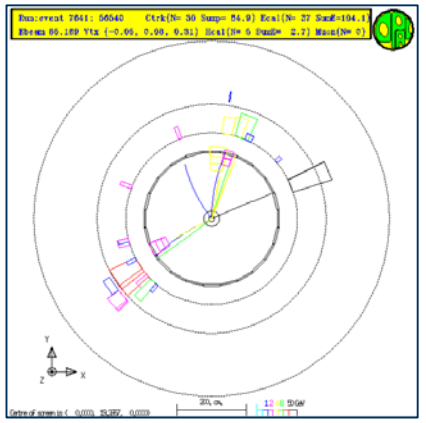
Videoconference

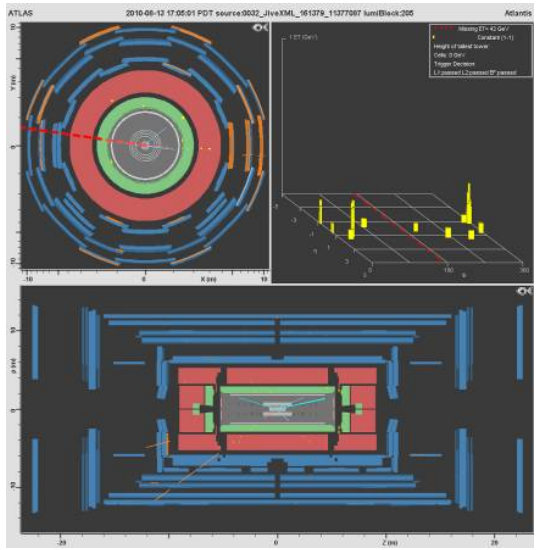
- 45-60 min
- 3-5 institutes, reflecting international collaboration
  - Same measurement, different data
- 2-3 Moderators (PhD students, Postdocs)
- Moderation centers: CERN, Fermilab, KEK, GSI, TRIUMF
- Agenda of the videoconference
  - Welcome
  - Combination and discussion of results
  - General Q & A
  - Quiz

Brief History of Masterclasses

- 1996: Idea from R. Barlow et al.
- 1997: 1. Masterclass in UK with 7 institutes
- 1998: nationwide uptake
- 2005: Adopted by EPPOG/IPPOG for all Europe
- Use of LEP data
  - OPAL Identifying Particles
  - DELPHI Hands on CERN
- 2006: U.S. joined program (QuarkNet)
- 2011: LHC-based Masterclasses only
- 2014: all 4 LHC experiments







http://cerncourier.com/cws/article/cern/55890 (How it all begun)
http://cerncourier.com/cws/article/cern/57305 (MC in the LHC era)

Worldwide program

- Organized by IPPOG (International Particle Physics Outreach Group)
- 60 countries involved
- 220 research labs
- 2019: 15.000 high school students
- Coordination: Ken Cecire (QuarkNet) / TU Dresden

Broad Physics Scope

Today:

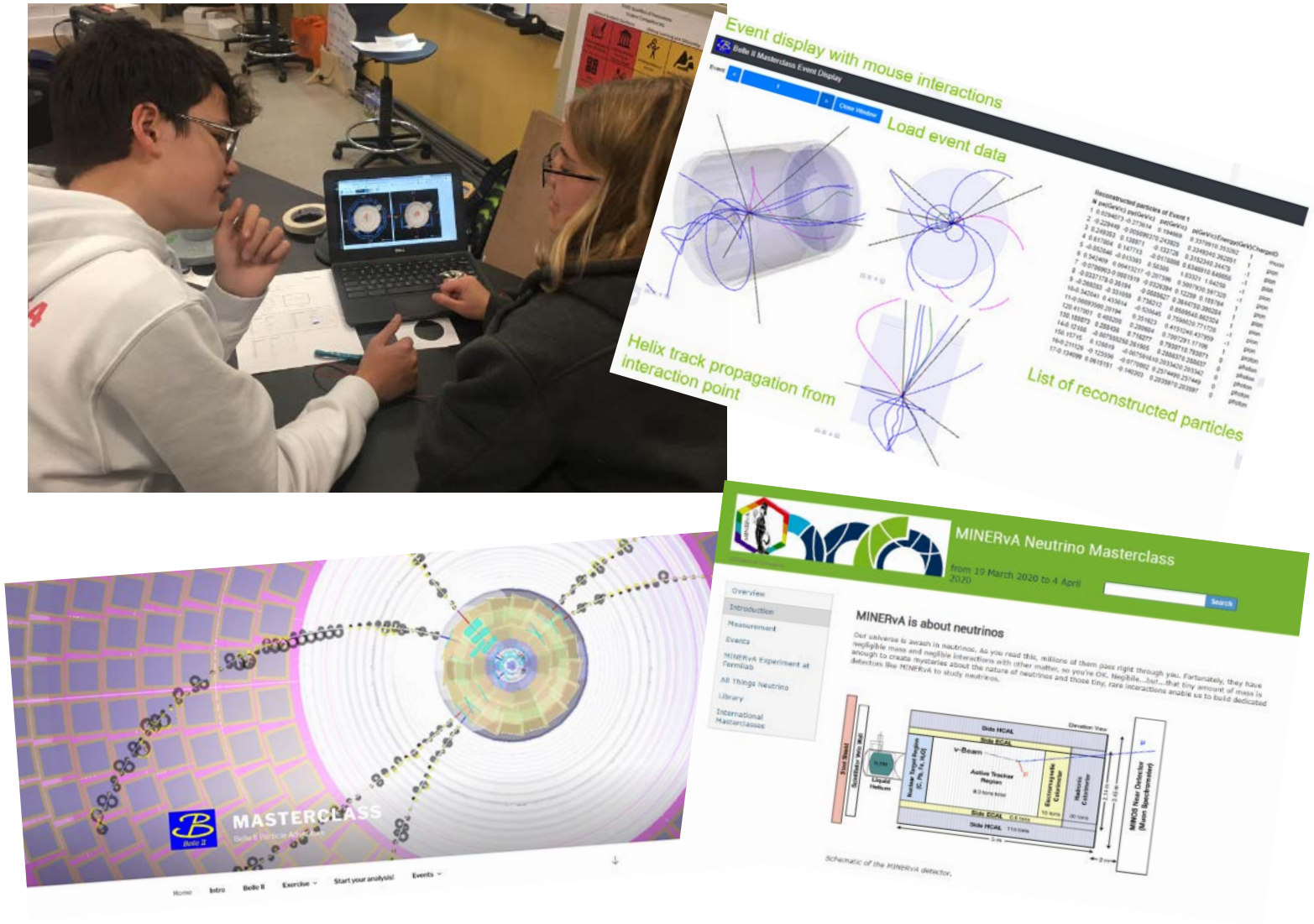
- LHC (since 2005)
- MINERvA (since 2019)
- Belle II (since 2020)
- Particle Therapy (since 2020)

Under development:

- NOvA
- MicroBooNE

More Masterclasses:

- IceCube
- Pierre Auger
- DarkSide
- …



ATLAS W path

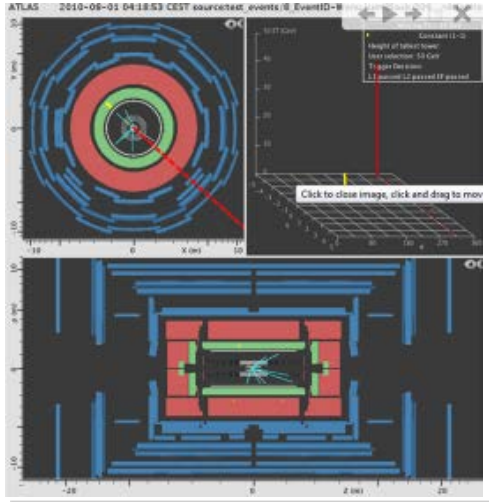
Students analyze event displays (50 collision events per pair of students)

2 tasks:

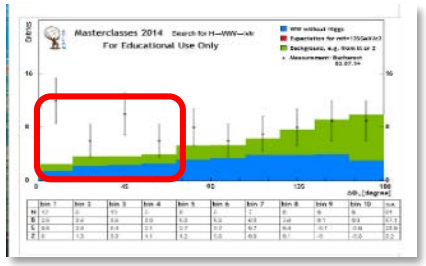
- Identify W bosons, determine type and electric charge of leptons
- Resulting W+/W- is used to reveal the inner structure of the proton (and compared to results from ATLAS)

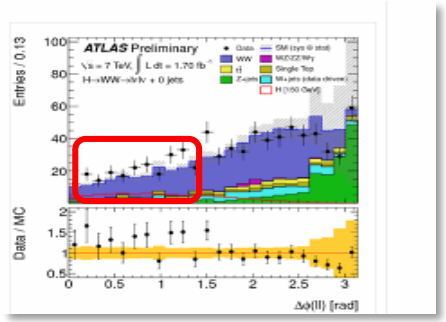
- Identify W pairs and measure azimuthal opening angle Δφll
- Resulting histogram is used to provide insight into Higgs discovery process at CERN

https://atlas.physicsmasterclasses.org/en/wpath.htm



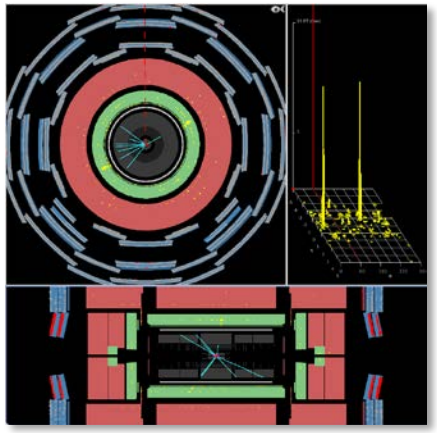
Total #	W → ... + ν				Background
532	e^+	e^-	μ^+	μ^-	
group A	9	4	10	1	24
group B	11	12	13	10	19
group C	5	3	1	1	19
group D	7	4	11	5	21
group E	11	10	3	2	31
group F	15	3	3	1	26
group G	6	4	3	5	27
group H	15	10	3	2	13
group I	5	3	3	4	5
group J	4	0	1	0	21
group K	5	1	5	3	18
group L	4	7	4	2	31





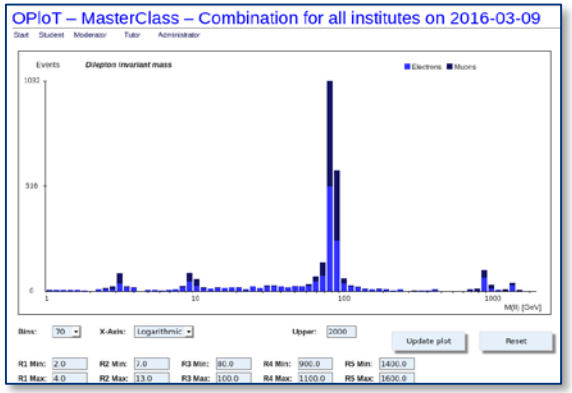
ATLAS Z path

- Students search for 2-lep, yy, or 4-lep events
- Calculate invariant mass, upload results to a plotting tool
- Results are combined, invariant mass distributions are built



2-lep invariant mass distribution:

- Resonance peaks of known particles: Z^0, J/Ψ, Y
- Search for new particles: Z‘, graviton



4-lep, di-photon:

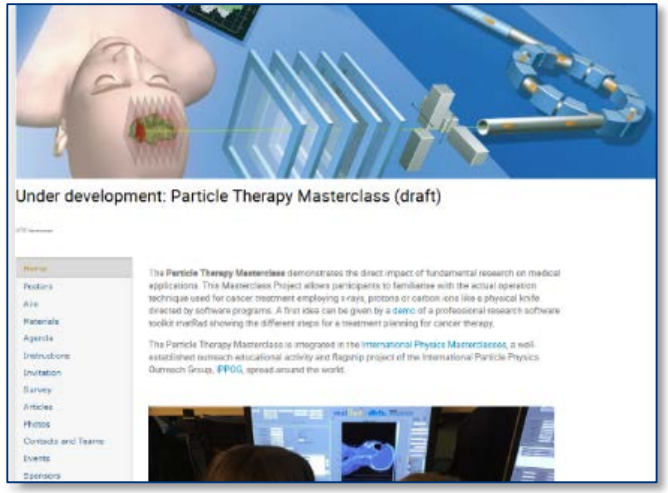
- Provide insight into the process of discovering the Higgs at CERN
- Explain concepts of statistics, modelling, signal significance

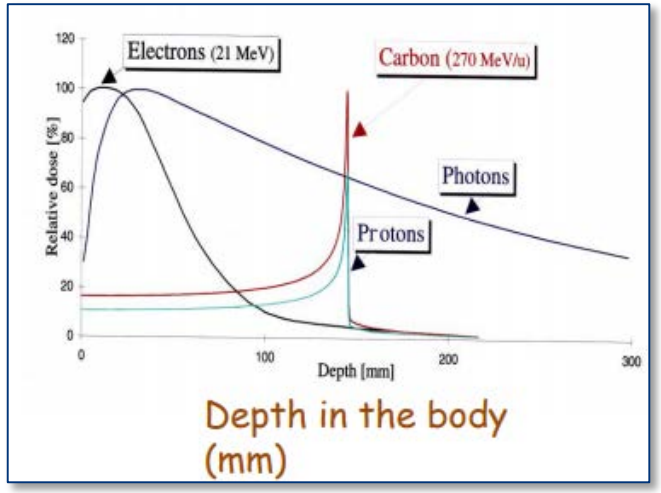
https://atlas.physicsmasterclasses.org/en/zpath.htm

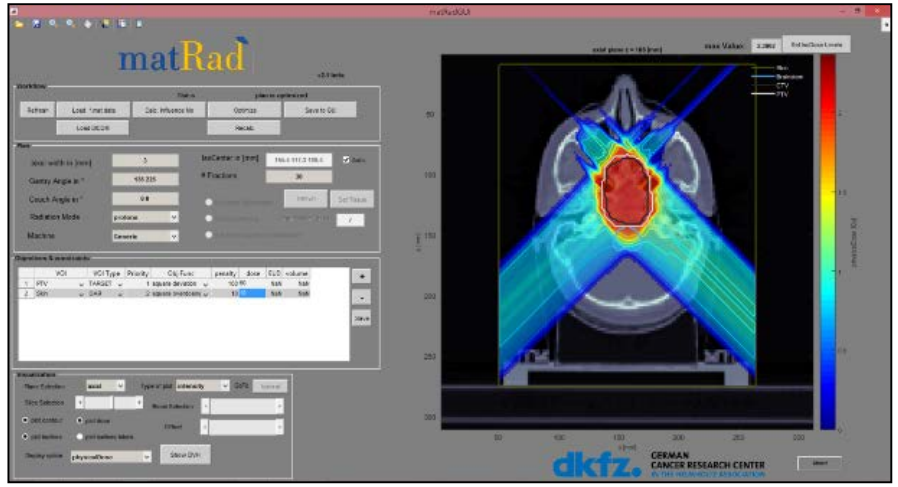
Particle Therapy Masterclass

- Particle treatment planning
- highlights some of the benefits for society from the technology developed for particle physics research

https://indico.cern.ch/event/840212/





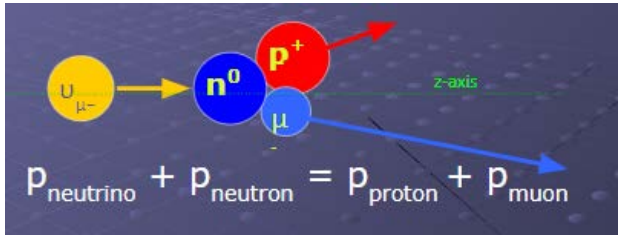


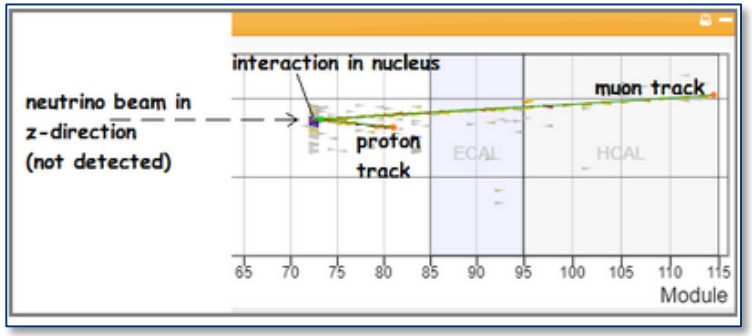
MINERvA Masterclasses

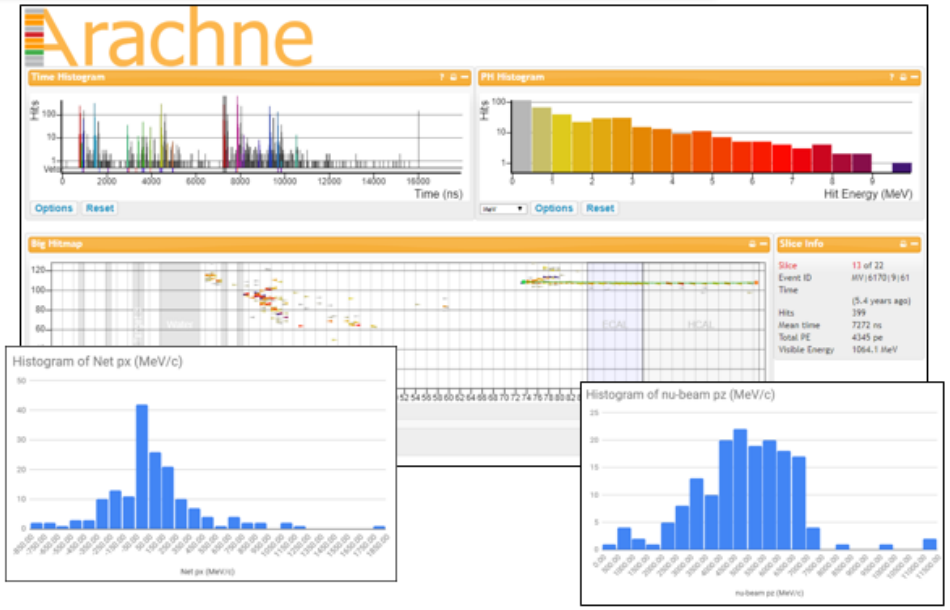
- Measure carbon nucleus to test interaction model
- Discover Fermi motion

- Muon neutrinos interact with carbon target
- $\nu + n \rightarrow p + \mu$
- Measure px and py of proton and muon
- momentum distribution → Δp
- Fermi motion, nucleus is active place
- $\Delta px \rightarrow \Delta x \rightarrow$ bound on neutron motion → radius of nucleus

https://indico.fnal.gov/event/22340/



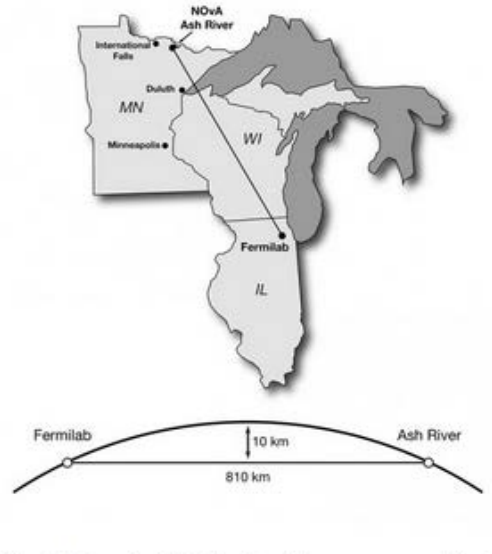




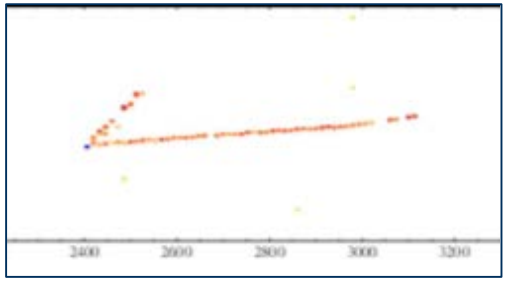
NOvA Masterclass

- New Masterclass under development by Greg Pawlowski (QuarkNet mentor) , Mike Plucinski (Neutrino fellow), QuarkNet staff
- Find ratio of Neutral Current (NC) to Charged Current (CC) events
- Compare CC:NC in FD vs in ND → evidence of oscillations
- Combine Far Detector event display analysis (small number) with python notebook (many events from Near Detector)
- Under development, concept tested with teachers
- Limited trial Masterclasses in IMC22

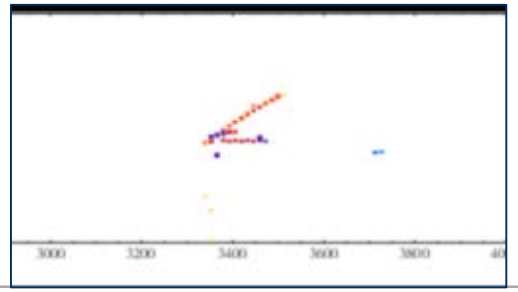
https://quarknet.org/content/nova-masterclass-development-resources-links



The 500-mile (800 km) subterranean path of the NOvA neutrino beam (Fermilab)



CC event: muon (long) and proton (short)



NC event: short tracks, multiplicities

Special events

Girls Masterclasses

- UN International Day of Women and Girls in Science
- Feb 11
- Masterclasses targeting girls
- involving female scientists

World Wide Data Day

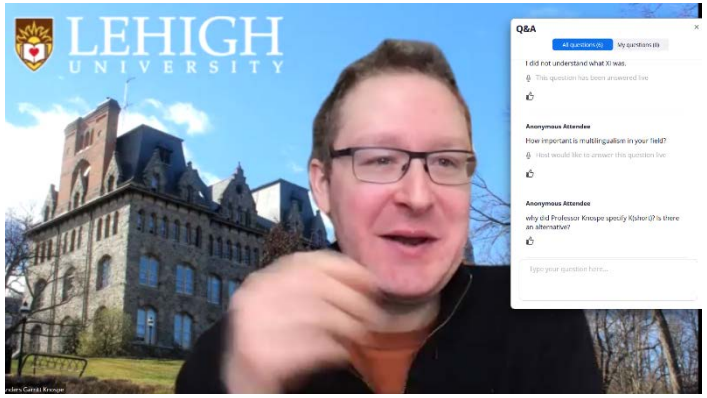
- Students worldwide analyse data from LHC events
- Data analysis at school, physics discussion in VC
- Simplified Measurement

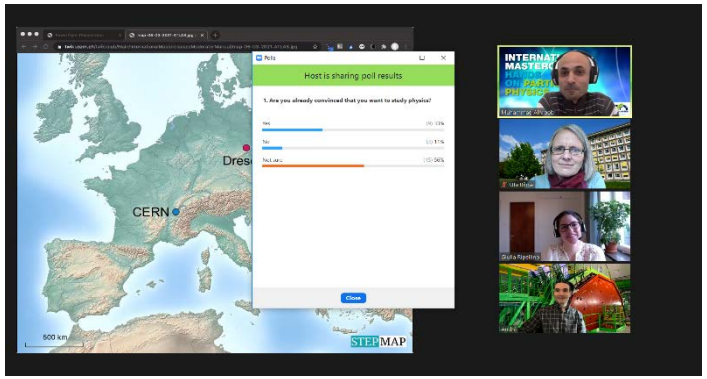
Impact of the COVID-19 pandemic

2020: program suspended by March 18, only ~ 25 % of MC completed

2021: Masterclass@home

- remote lectures
- Hands-on part in breakout rooms
- Final videoconference as Zoom webinars, up to 250 unique viewers
- Teams of 3 moderators, incl. 1 technical moderator
- Zoom polls and Q&A function





Outcome

- Reaches more people
  - Open to students without regional restriction
  - Tutors and moderators could engage from everywhere (home, office,...)
- Increases interaction during Videocon
  - All students involved via polls
  - Lively discussion and many questions via Q&A function

IPPOG

International Scientific Collaboration

- Active Researchers with Experience in Education & Public Engagement
- Experts in Communication & Education

Global Network

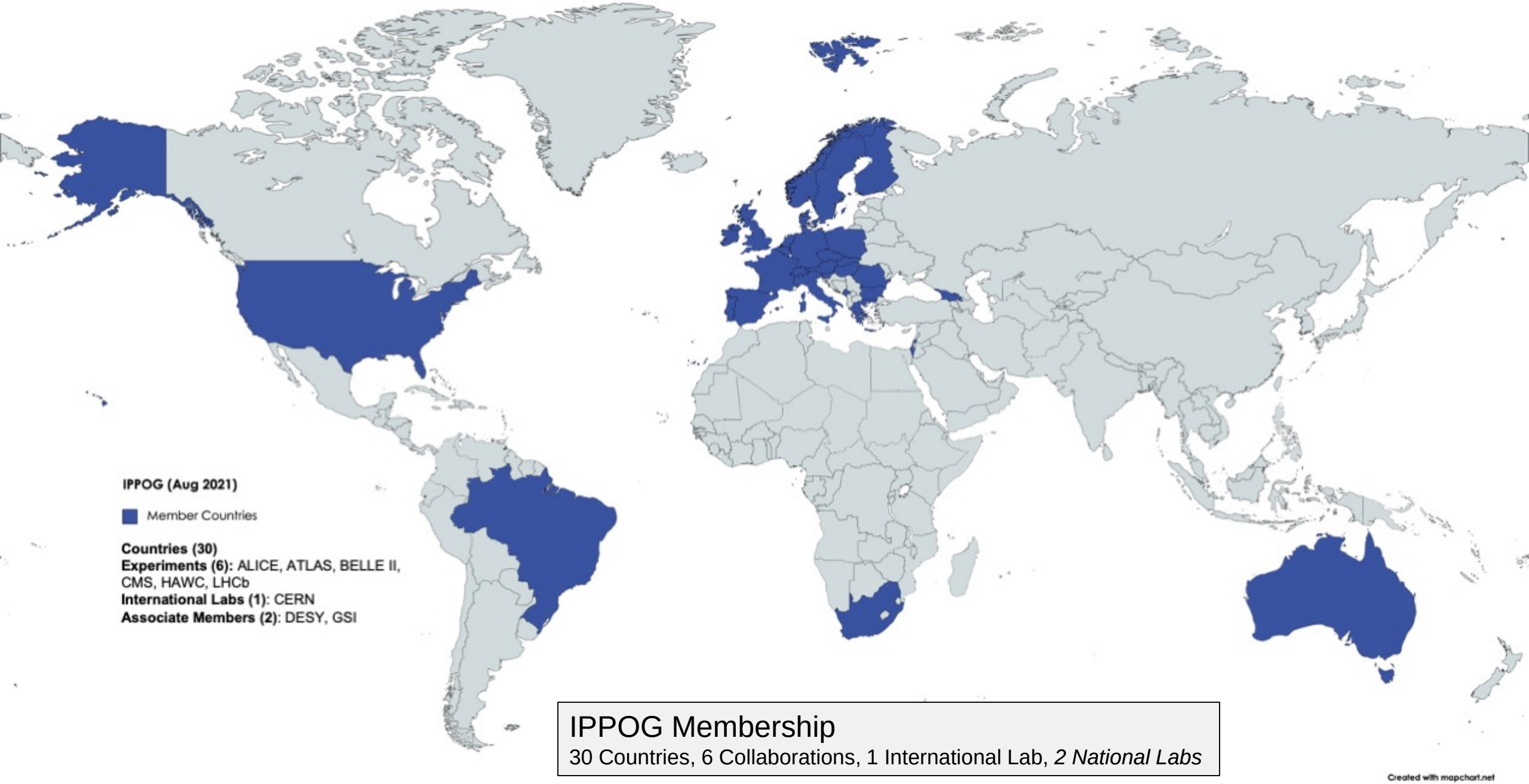
- 37 members: 30 countries, 6 experiments, 1 intl lab (CERN)
- 2 associate members: 2 national labs (DESY, GSI)

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



IPPOG Membership

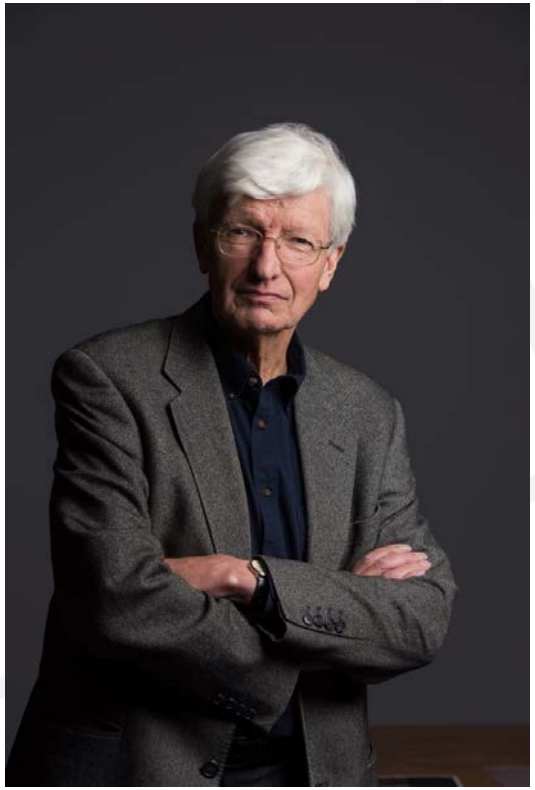
30 Countries, 6 Collaborations, 1 International Lab, *2 National Labs*

IPPOG Origins

1997 Birth of European Particle Physics Outreach Group (EPPOG)

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



2005 Launch of International Masterclasses

2011 Global Expansion to IPPOG

Israel, Australia, USA (now South Africa, Brazil,…)

2016 Formal Scientific Collaboration

Memorandum of Understanding

IPPOG Goals

Sustainable Development of Particle Physics Outreach

- Discussion forums for scientists active in Education and Public Engagement
- Information exchange between individuals, institutions and laboratories
- Active working groups addressing specific challenges of global Outreach

Improving Outreach Standards Worldwide

- Development of strategies based on current best practices and experience
- Long-Term links between scientists and education specialists
- Continual development & improvement of explanatory material

Extending Global Reach

- Expansion to countries and peoples underrepresented in particle physics
- Usage of new methods, activities and topics to reach broader audiences
- Active online communication platforms

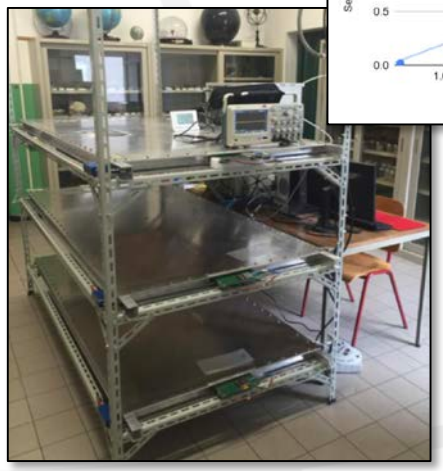
Activitites

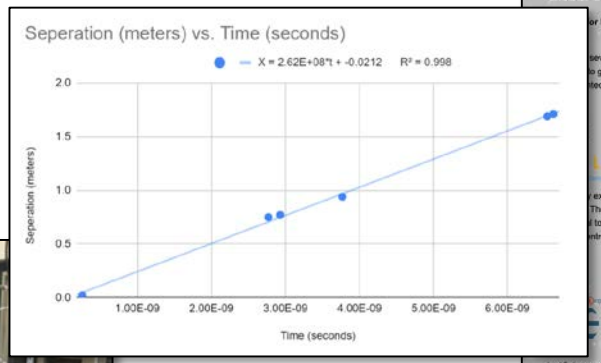
International Masterclasses

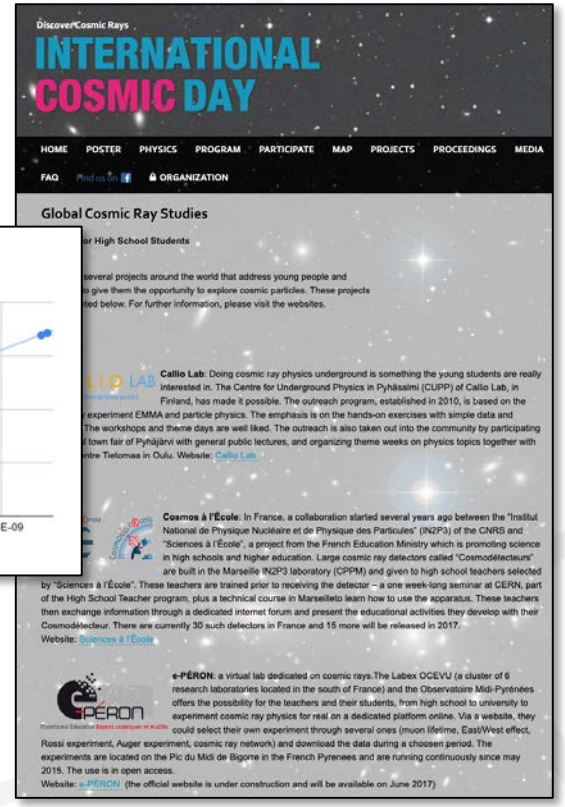
Global Cosmics

- High School Initiatives Exploring Cosmic Rays
  - International Muon Week
  - International Cosmic Day

Resources Data Base







Netzwerk Teilchenwelt

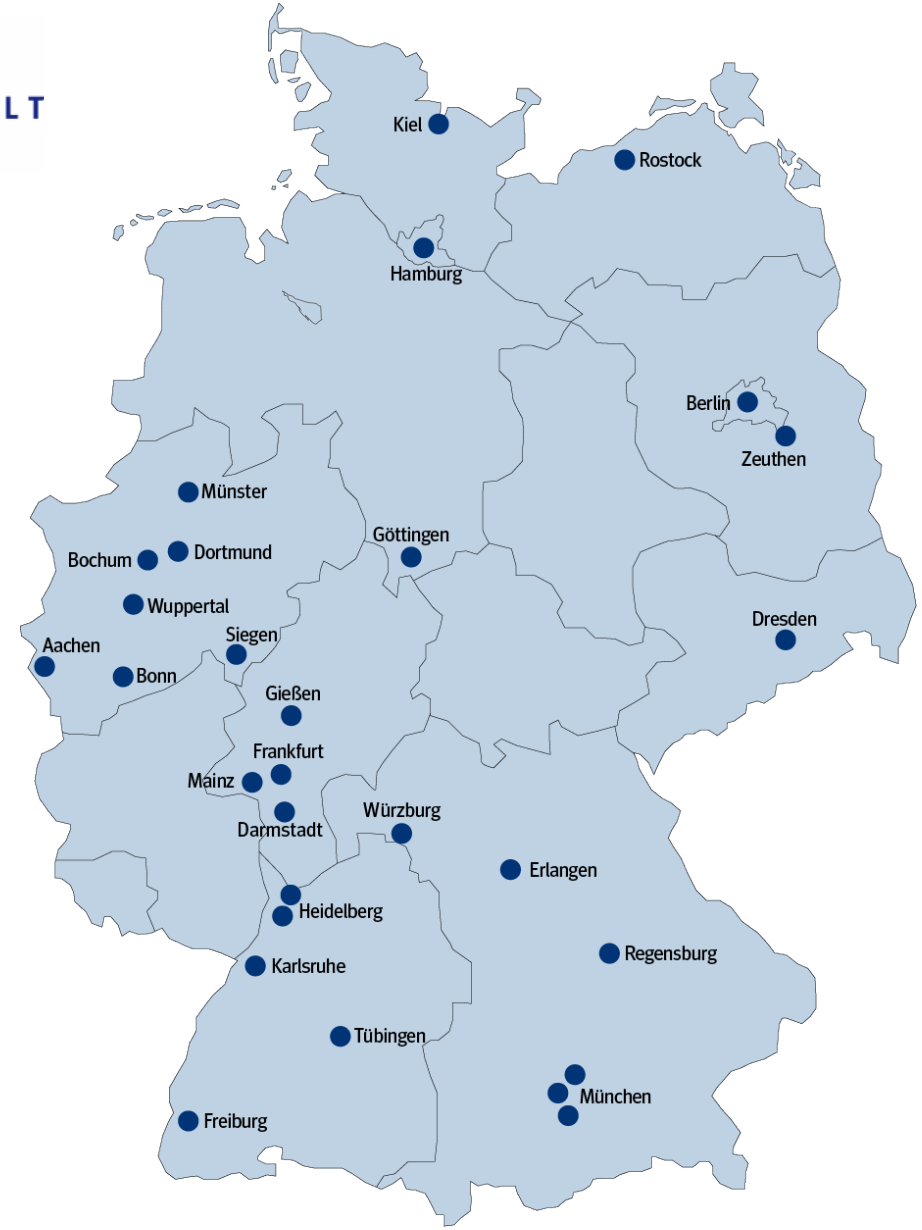
NETZWERK TEILCHENWELT

- 30 universities/research labs + CERN
- Joint outreach
  - Bundle existing activities
  - Share structures and programs
  - → **High visibility and impact**

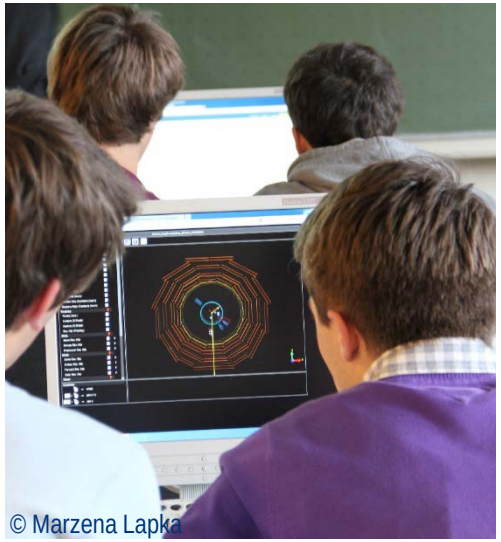
- Project team: TU Dresden / DESY / CERN
- + hubs in U Bonn, U Mainz, U Münster

- 2010: Particle and Astroparticle Physics
- 2019: Nuclear and Hadron Physics

- Funded as integral part of research by the German Ministry of Education and Research

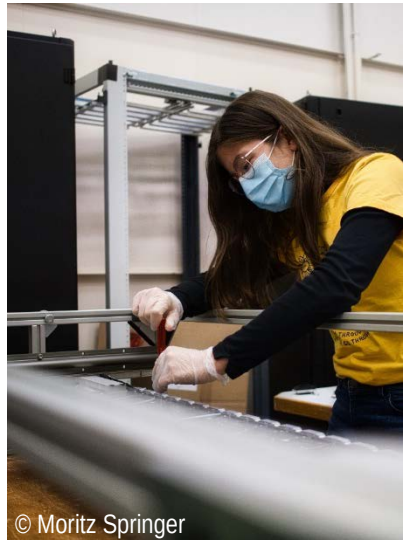


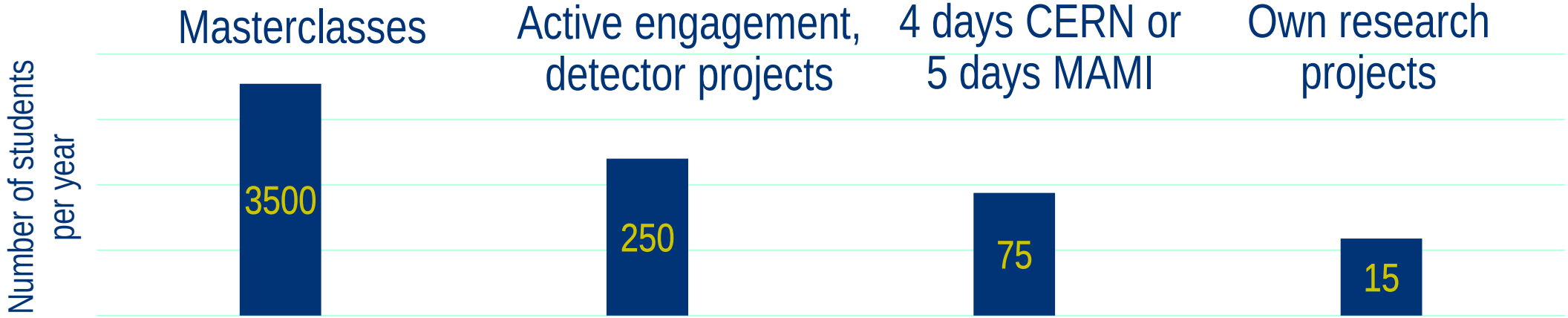
Core: multi-step program for high school students


© Marzena Lapka


© Netzwerk Teilchenwelt

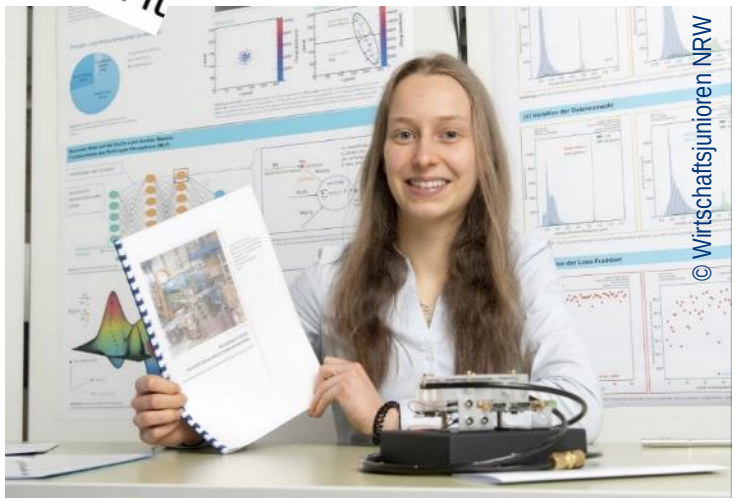

© Netzwerk Teilchenwelt


© Moritz Springer



Own research projects: examples

- Deep Learning Models for Energy Estimation in CMS HGCAL L1 Trigger (Felix Hansen)
- First data classification at the InGrid detector at the CAST experiment using deep learning (Carolin Kohl)
- The AWAKE experiment (Björn Dörschel)
- The effects of radiation on the CMS pixel detector (Katharina Ploog)
- Machine-learning based identification of highly collimated electron pairs from boosted Z boson decays (Sophia Veneris)



Facilitators

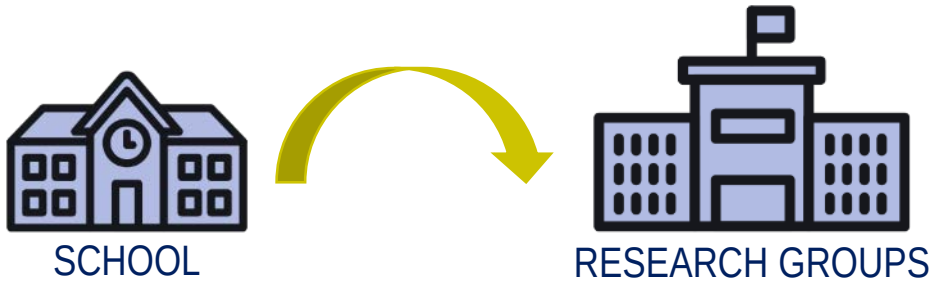
- ~ 150 PhD and Master students
- guide Masterclasses, supervise students´ research projects
- influence students´ career-related aspirations and choices

- reimbursement of expenses and travel cost
- get training courses on communication, didactics, and presentation techniques

- acquire soft skills, for personal and professional development
- experience interest in own research
- practice supervision

win-win

Fellow program



- 200 people, 50% female
- Mainly alumni of CERN workshops
  - Now often studying physics or shortly before that

→ Close connection between highly motivated students and research groups

Central offers: Fellow physics schools (HEP, detectors),"Ask the expert" sessions (online), national physics conference attendance, etc.

Local offers: internships, excursions, invitation to outreach events, colloquia, regulars´ table, etc.

Teachers as multipliers

- Development of material
  - Teaching material for schools, 4 volumes (>20k printed, >35k downloaded)
  - Portal Leifi Physik: Chapter on particle physics
  - Particle profile cards
  - GeoGebra Analysis of Bubble Chamber images
  - Context material
- Teacher training „Forschung trifft Schule“, funded by: Dr. Hans Riegel-Stiftung
  - 2-day training: Introduction to particle physics, 6 trainings p.a.
  - Summer School at CERN: 6 days, once per year

Big Bang on the Road (Urknall Unterwegs)

- Interactive mobile exhibition modul on particle physics
  - Tunnel: time travel through the history of the universe
  - Columns: Interactions and particles, Research methods, spin-offs
  - Pavilion with games (Particle Twister, Particle Yenga)
- Target audience: general public, people with less affinity for science
- On the road since the end of July 2021

Week of Particle World (Woche der Teilchenwelt)

- 1 week in November 2020
- Research institutes organised events
  - Public lectures
  - Virtual visits
  - Masterclasses
  - Science Café
  - Science Slam
- 20 events in 5 days, despite lockdown
- YouTube playlist

Summary

- Informing the **public** is our duty as scientists
- Inspiring the **next generation** is an important task
- **Masterclasses** are a proven and robust (COVID19!) tool for outreach and comes in many flavours
- **IPPOG** is a collaboration working on sustainable development of particle physics outreach and improving outreach standards worldwide
- The German network **Netzwerk Teilchenwelt** uses Masterclasses as the basic stage in a sustainable program to attract and promote young STEM talent
- Existing programs and structures create **multiple benefit**
  - win for **high school students**: experience modern research first-hand
  - win for **facilitators/PhD students**: train their communication skills, participate in a rewarding activity
  - win for **physicists**: get young talents for the research groups

Thanks to/for

People

- Ken Cecire, QuarkNet
- International Masterclasses Steering Group
- IPPOG (esp. coordination team, chairs Steve Goldfarb + Pedro Abreu)
- Michael Kobel, TU Dresden
- Team from Netzwerk Teilchenwelt
- numerous people involved in and supporting Masterclasses (physicists, tutors, moderators, IT support, teachers, administration…)

Funding

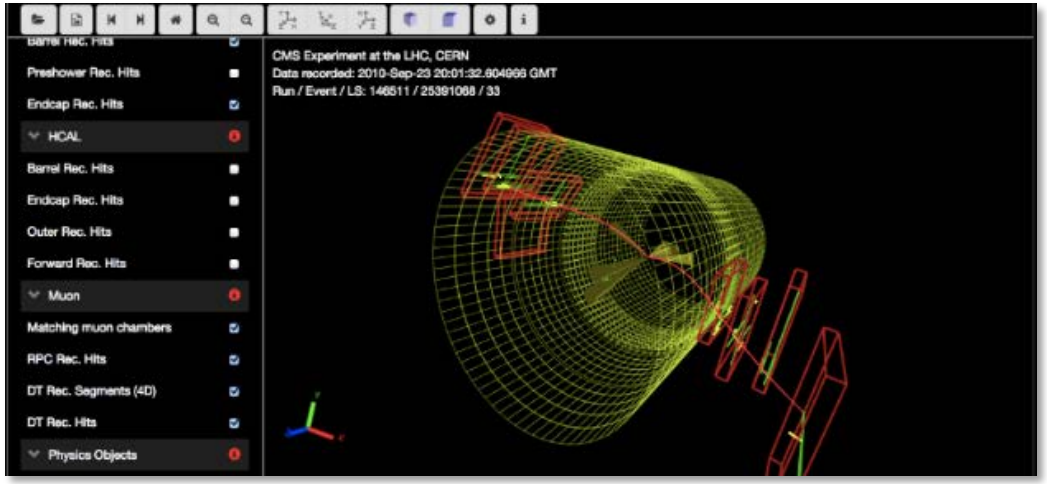
- CERN
- BMBF (German Ministry of Education and Research)

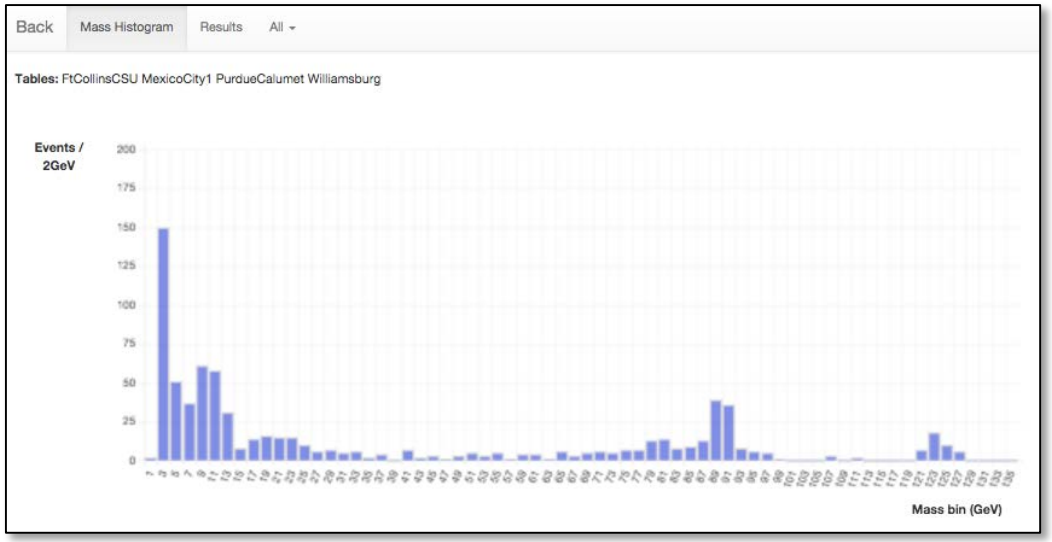
Backup slides

CMS WZH measurement

- WebGL 3D event display
- 1-, 2-, and 4-lepton events
- Students characterize W, Z, and Higgs candidates
- Create 2-l and 4-l mass plots of standard model particles, plus Higgs
- Ratios W+/W-, e/m

https://web.quarknet.org/mc/cms/imc2021/cms.html

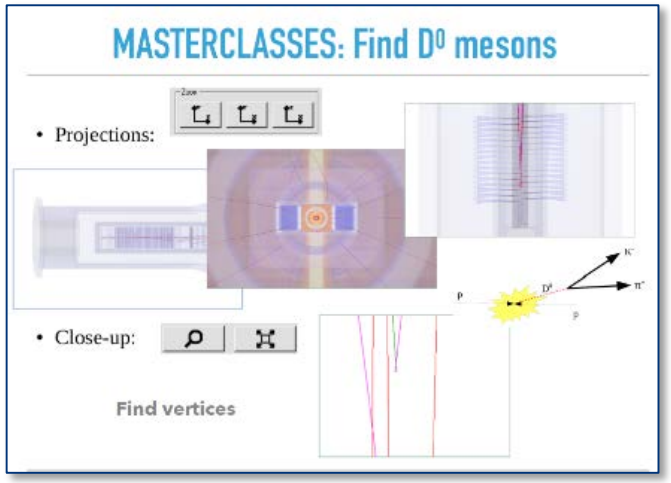


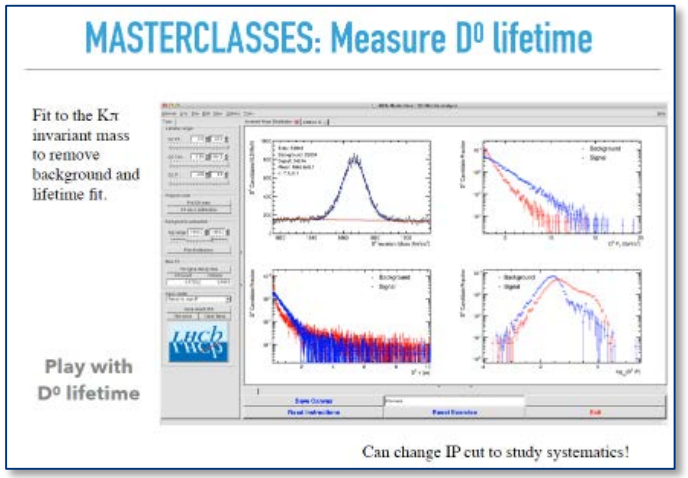


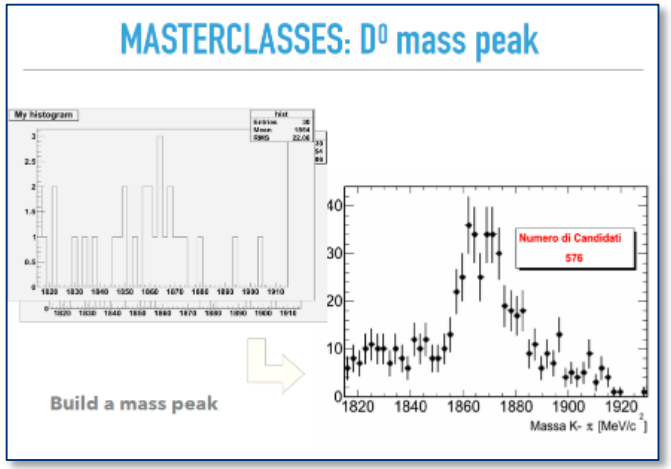
LHCb Masterclass

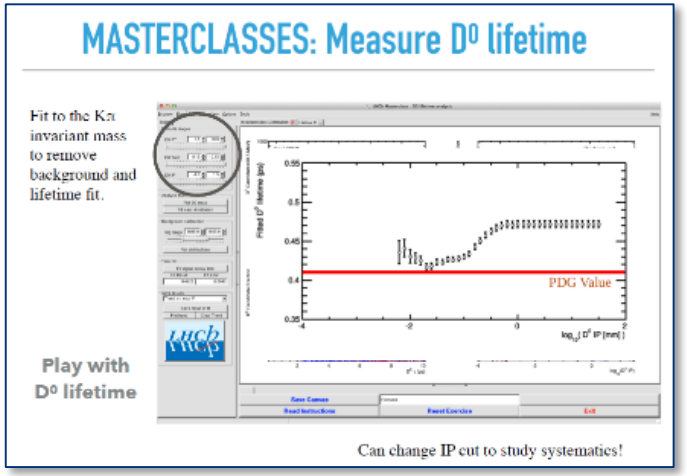
- Students search for the $D^0 \rightarrow K\pi$ decay using an event display
- Students perform a lifetime measurement at the 1 % level
- Live merging of histograms from all groups in the VC

https://lhcb-public.web.cern.ch/en/LHCb-outreach/masterclasses/en/





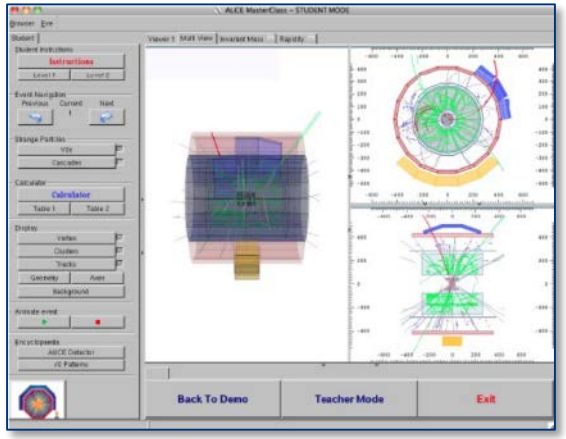


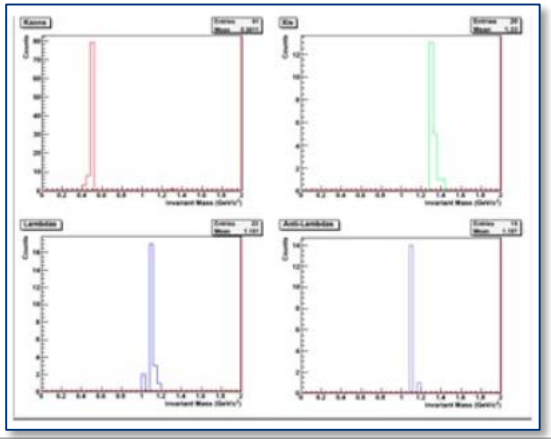


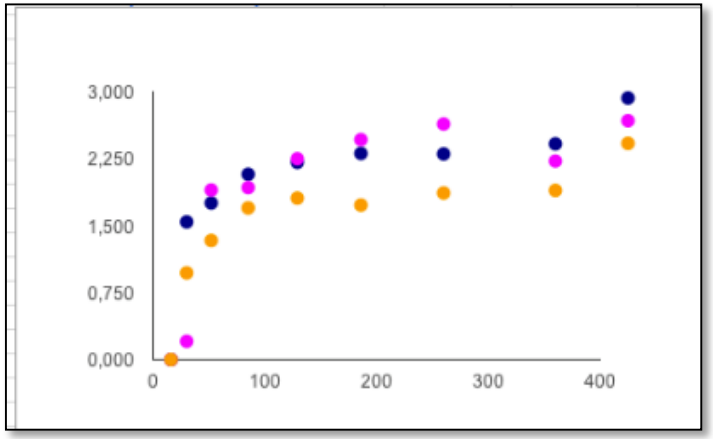
ALICE I: Looking for Strange Particles

- Visual identification of V0s from decay pattern, invariant mass calculation
- First part: visual analysis of ~ 15 events per group
- Second part: Calculation of numbers of Ks, Λ , anti Λ from invariant mass distributions (fit gaussian/ polynomial to peak/background; subtract background) for different centrality regions in lead-lead collisions
- Concepts conveyed: invariant mass; centrality of PbPb collisions; background
- Results: observe strangeness enhancement in PbPb collisions comparing with pp collisions

https://alice-masterclass.web.cern.ch/



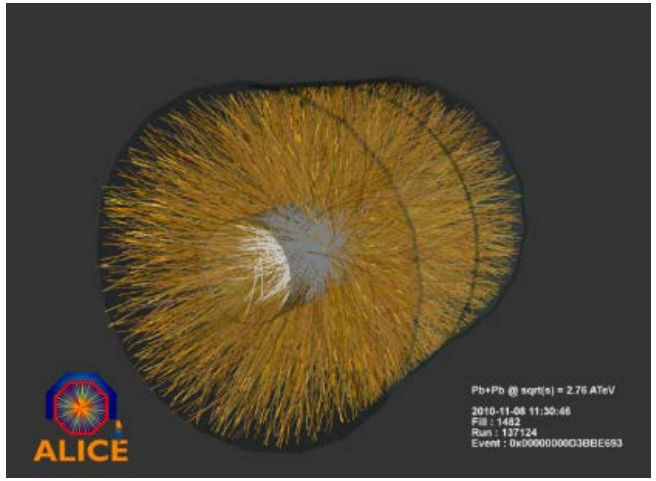


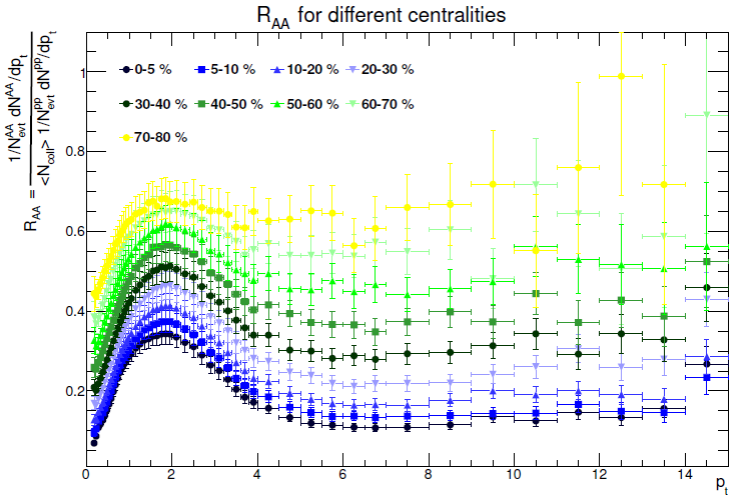


ALICE II: Nuclear Modification Factor

- event-display based visual analysis
- RAA simply via counting of tracks
- ROOT based large scale analysis
- RAA as a function of momentum in various Pb-Pb centrality classes
- students discover jet suppression!

http://www-alice.gsi.de/masterclass/

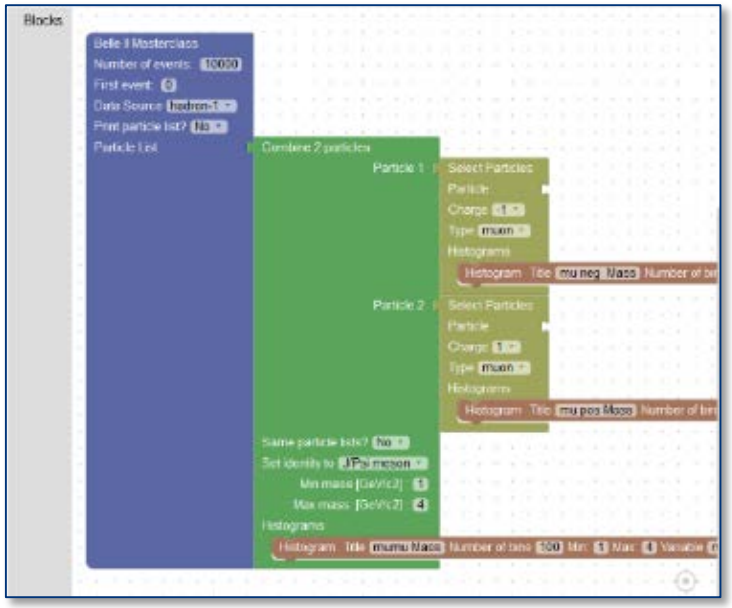


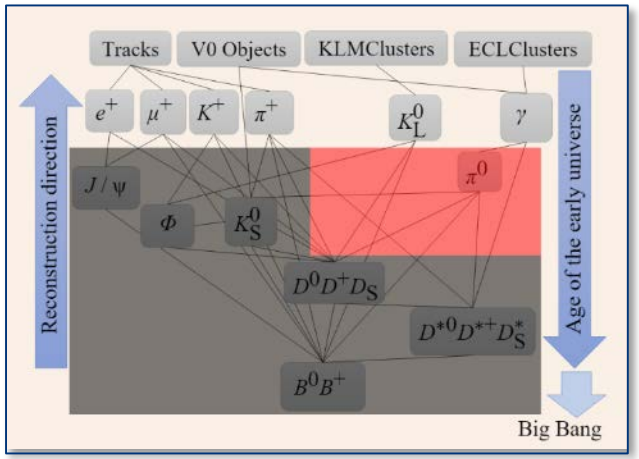


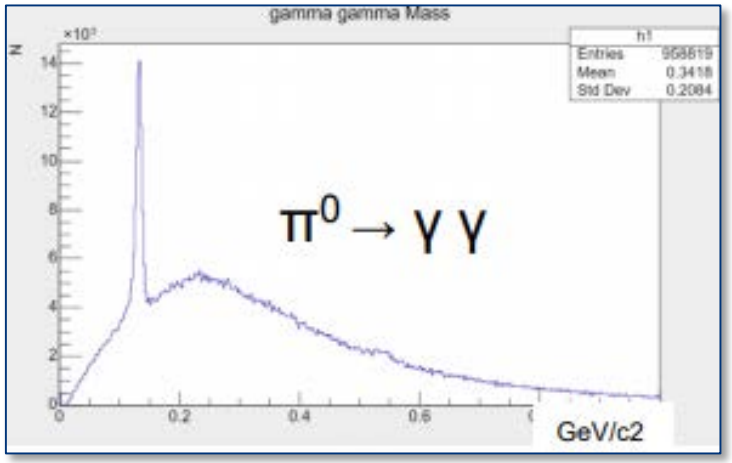
Belle II Masterclass

- Shows students how to code B-physics analysis
- Students describe decays, make simple cuts, “discover” particles
- Visual code editor Blockly
- Running from the web or download virtual machine
- Analysis of 6M clean reconstructed events
- Basic/advanced level (fit peaks, determine width)
- Videoconference with KEK

http://belle2.ijs.si/public







Darkside Masterclass

- By Francesca Carnesecchi, University and INFN of Bologna, Centro Fermi Roma, et al.
- Darkside experiment at Gran Sasso
- Dark Matter / WIMPs in a dual phase Ar TPC
- Talks on DM and Darkside experiment
- Data analysis via excel
- Reconstruction position part (few events): to exclude background signals
- Analysis of events (~20000) of background and few “good” WIMPs.
- Plot of f90 vs S1 and then apply some cuts: to select WIMPs signals

https://sites.google.com/unisa.it/darksidemasterclass/home-page