International Masterclasses in Particle Physics

A tool to engage physics appreciation by students

Pedro Abreu

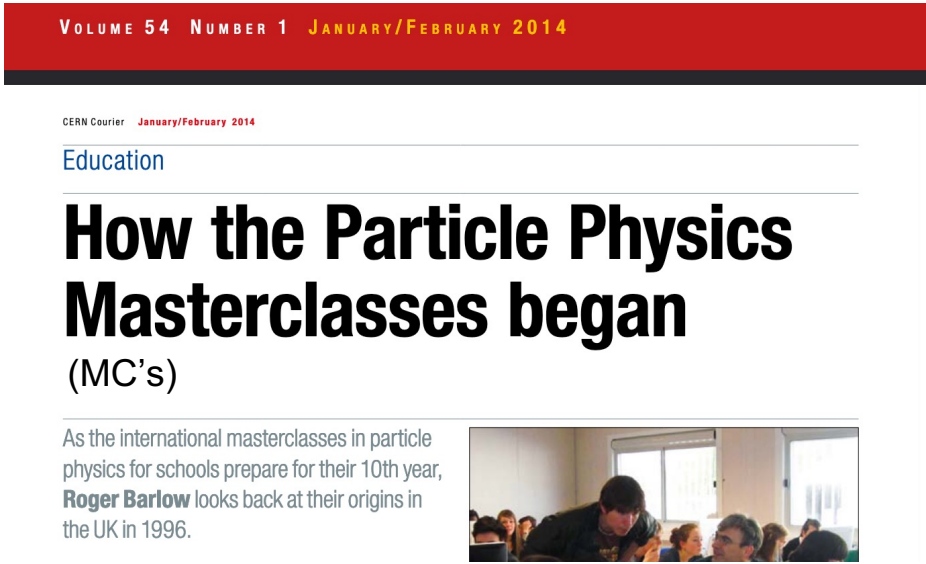
LIP / TÉCNICO LISBOA

LIP Seminar, February 2nd, 2023

Contents

// Masterclasses in Particle Physics

- **Be a scientist for a day…with Hands-on Particles**
  - Programme launched in the UK in 1997 by Roger Barlow (U.Manchester) and Ken Long (Imperial College, London), with a pilot organized with 5 institutes (U.M.,I.C., Durham, Liverpool, Oxford).
    Roger Barlow won the IOP's Lise Meitner prize in 2022 for his outreach contributions
  - Students go for an University/Research Institute to spend a day learning how scientists work



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CERN Courier January/February 2014

Education

How the Particle Physics Masterclasses began

(MC's)

As the international masterclasses in particle physics for schools prepare for their 10th year, **Roger Barlow** looks back at their origins in the UK in 1996.

// Masterclasses in Particle Physics

- **Be a scientist for a day...with Hands-on Particles**
  - Students spend the morning in talks about particle physics, tours of the laboratory, the software and tools, in a plenary session in a large auditorium
  - Lunch with scientists in a regular time (1h) and move to the rooms of computers

IST, 2007

Fernando Barão, IST, 2007

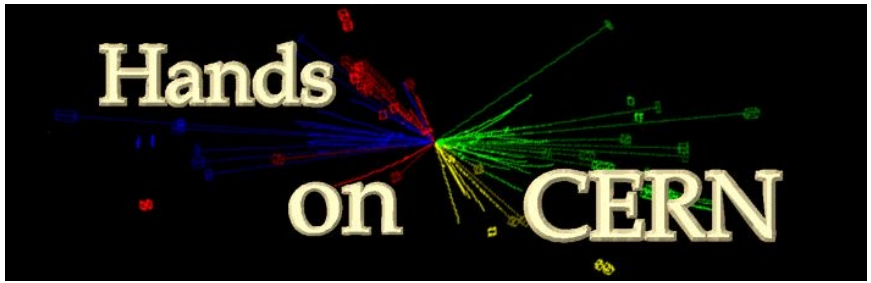
// Masterclasses in Particle Physics

- **Be a scientist for a day…with Hands-on Particles**
  - Measurements based on real data from OPAL (Terry Wyatt's web-based package "Identifying interesting events at LEP"), to be carried out by pairs of students supported by tutors (a pair per computer), including analysis of their own results
  - Programme run nationally in the UK, by the HEPP group of IOP, since 1998 involving all the U.K. Universities featuring HEP Groups, with small variations in content and activities

Credit: QMUL

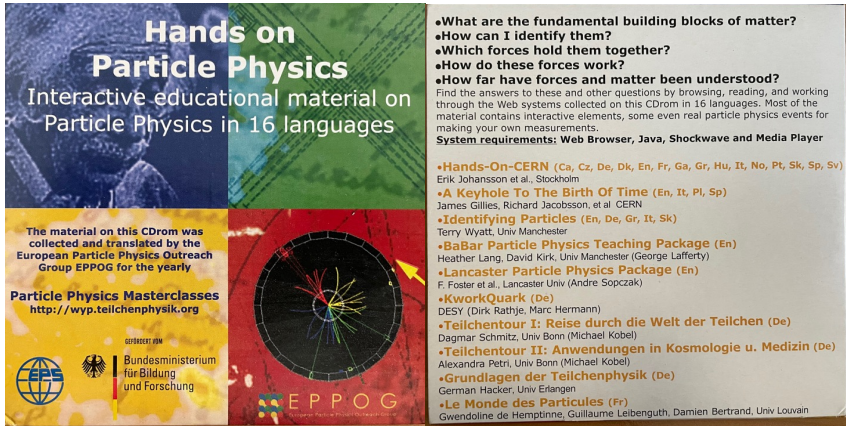
// Internationalization of the MC's

- **The path to the International Masterclasses in Particle Physics (IMC)**
  - Motivation: to celebrate the UNESCO's 2005-World Year of Physics
  - 2003–2005: development within EP[P]OG of the translation of software packages to be used by the University/Institutes
  - Package used in PT: "Hands-on CERN", built upon the web-based Wired visualization package, allowing the classification of Z boson decays into hadrons/taus/muons/electrons, to measure its branching ratios and estimate the number of possible colours for quarks.
    All texts translated to portuguese by Dário Passos (then at Univ.Algarve) and P.A.



// Internationalization of the MC's

- Website prepared with a page per country and a page per institute (still in use today), and the software packages in the different languages
  CD offered with all the software packages, the needed real data, and the website

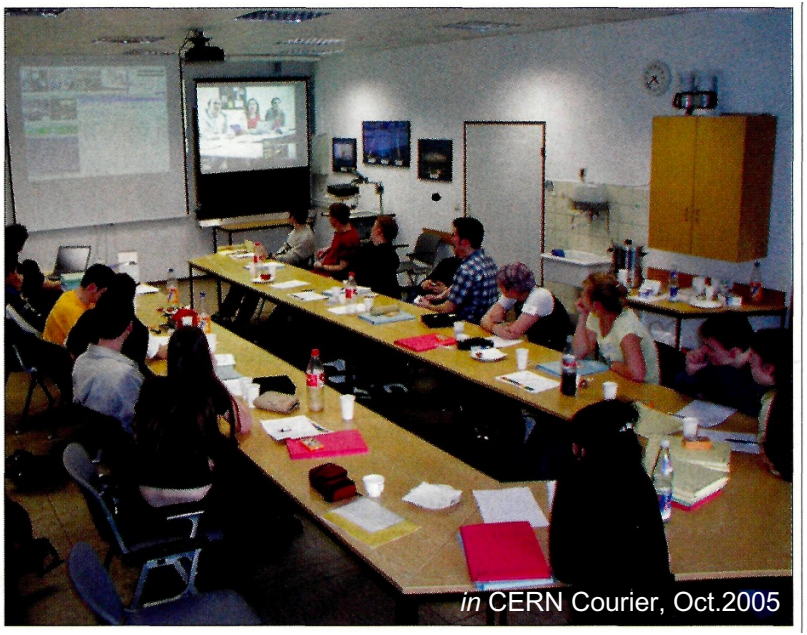


- Novelty: the video-linkup at the end of the day, which implied a big risk and a lot of coordination

// Internationalization of the MC's

- Videoconference with the duration of 90 minutes, featuring discussion of results from the students, questions and answers, and ending with a quiz (from 2006 on).
- VRVS as video-conferencing system, limiting the participation of up to 5 institutes.

- "Professional" hardware required for efficient eco-suppression (phoenix devices – the "magic box" – available at CERN stores)
- Winners of the quiz won a T-Shirt


in CERN Courier, Oct.2005

- Certificates and CD's offered to all participants

// Internationalization of the MC's

- **The first 'run'**
  - 7–19 March, 2005

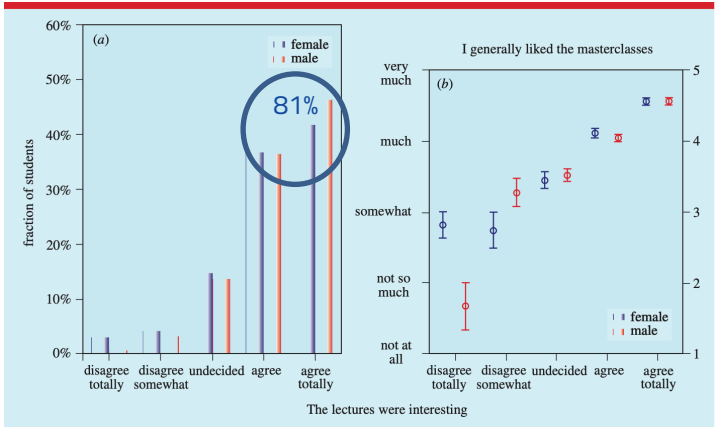
participants

he [Technical] University of Lisboa, 40 participants

sed on DELPHI Z data, 100 evts.(images)/group

// The follow-up

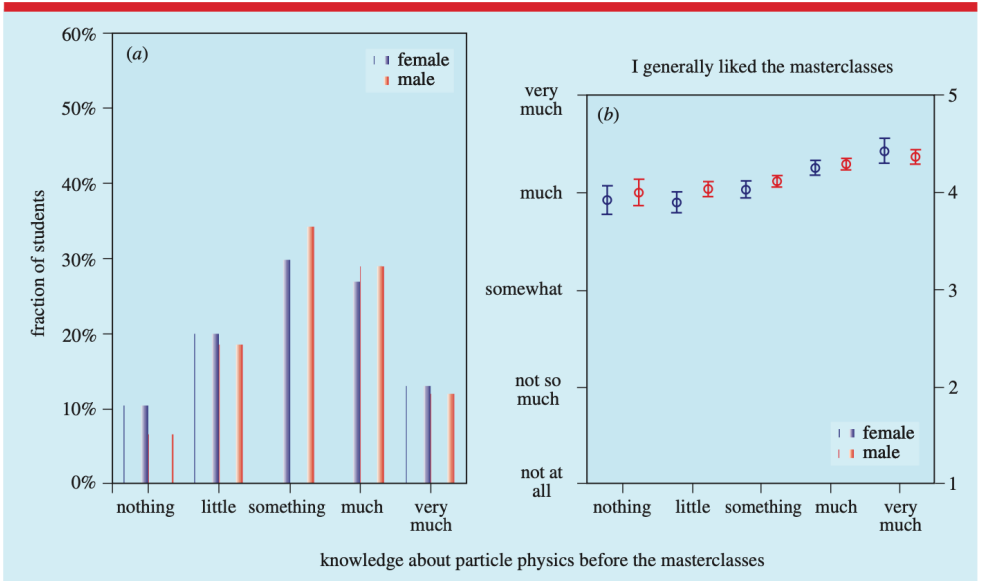
- **Evaluation**
  - performed by a professional education team, results published in the CERN Courier (October 2005) and in Physics Education (K E Johansson *et al.* (2007) *Phys. Educ.* **42**, 636)
  - ~1200 respondents aged 16-19 years old
  - 31% female, 69% male
  - And from the CERN Courier:



Moreover, there was significantly higher enthusiasm in Finland, **Portugal** and the Czech Republic with **96%** choosing "much" or "very much", which can mostly be attributed to particularly interesting lectures and a bigger increase in knowledge of particle physics.

// The follow-up

- pre-knowledge with little influence in the appreciation of the Masterclasses



// The following years

- **2006**
  - 6–18 March, 2006
  - 18 Countries
  - 59 Universities/Institutes
  - 3140 participants
  - **Portugal**
  - 11 March, 2006
  - 3 sites: FCTUC – Coimbra, FCUL and IST, Lisboa
  - 140 participants
- **2007**
  - 15–30 March, 2007
  - 20 Countries
  - 74 Universities/Institutes
  - 4590 participants
  - **Portugal**
  - 24 March, 2007
  - 3 sites: FCTUC – Coimbra, FCUL and IST, Lisboa
  - 220 participants
- **But...**

Contents

// (the role of the teacher...

CERN Teachers Programmes

- **High School Teachers Programmes at CERN started in 1998 (3 weeks long, 1/year)**
- **International, [now] 2 weeks long, 2 editions/year (July, August), holidays time**
- **Up to 48 teachers from many countries, in particular 1-2 from CERN member states**

Jeff Wiener

1 PT Teacher

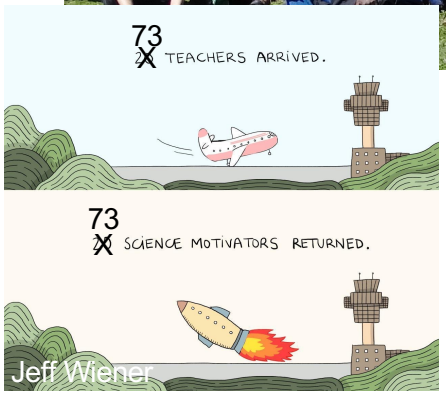
// 2007 – National Teachers Prog.'s

- National Teachers programmes launched in 2006 @ CERN for Member States
- One pilot programme in 2006 (Hungary) and since 2007 about 35 programmes / year
- One week only, in formation time, credits awarded to the teachers
- In the language of the Member State and many more opportunities per country
- PT started in 2007, project setup by Gaspar Barreira (middle), coordinated by P.Abreu
- Support from Ciência Viva Agency (+LIP, CERN)

43 PT Teachers, Gaspar (white circle), 2 researchers, 1 Minister (José Mariano Gago (0))

// 2009 – +PT-Speaking Countries

- **2009 – Invited Teachers from Brazil and Mozambique to join the PT [Language] TP**
- **2011 – the full house – 73 Teachers from all-pt-speaking countries**

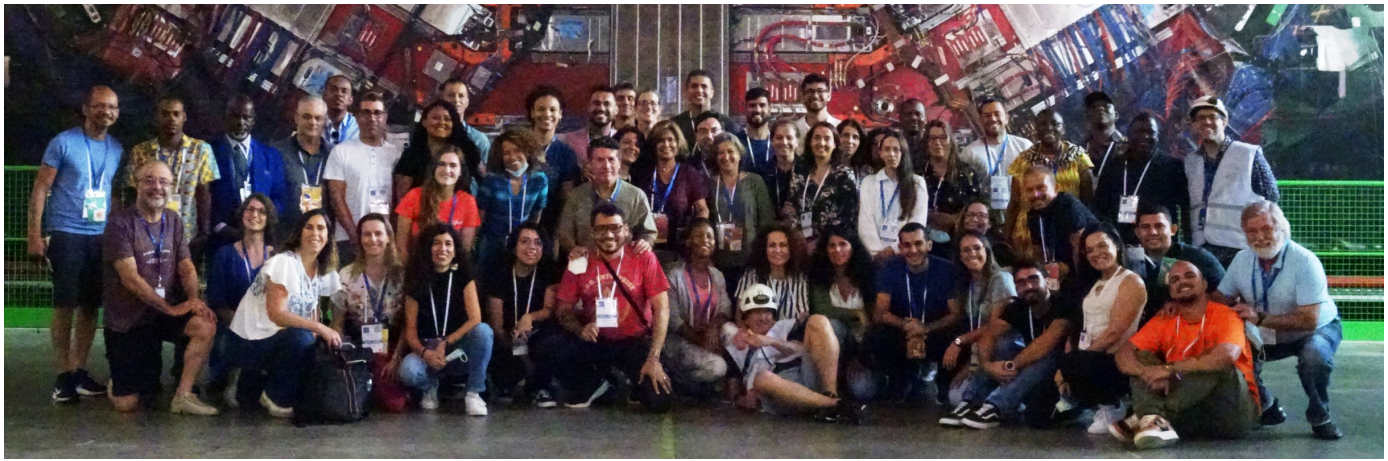


41 Pt, 20 Br, 4 Ao, 4 Mz, 1 CV, 1 STP, 1 GB, 1 TL
Very rich session about teaching conditions in all the countries

"The most important training programme that I have participated in my life" as spoken by many teachers.

// 2022 – Full house again!

- **Support for travels of African+Asian teachers from Instituto Camões**



20 Pt, 20 Br, 2 Ao, 2 Mz, 1 CV, 1 STP, 1 GB, 1 TL

(+2 guides and 3 coordinators)

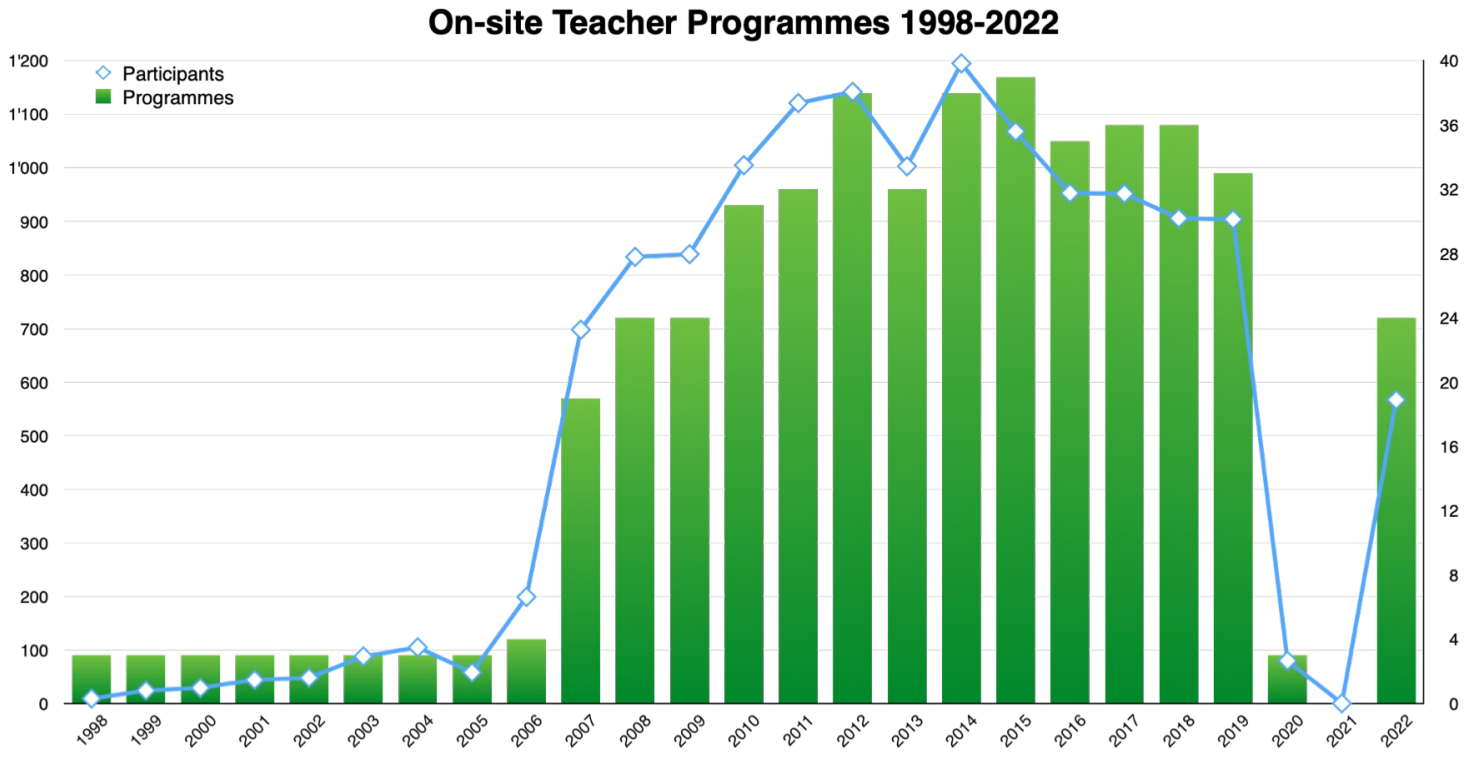
// CERN PTLTP – Participants (*)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2022	Total
Datas	10-14/9	1-5/9	30/8-4/9	5-10/9	4-9/9	26-31/8	1-6/9	24-29/8	30/8-4/9	28/8-2/9	3/9-8/9	2/9-7/9	1/9-6/9	4/9-9/9	
Candid.(**)	205	241	191	218	190	250	162	236	187	183	170	181	222	91	2154
Candid.(new)	205	169	78	130	98	165	57	121	96	63	40	48	77	18	1200
Pt.	**43**	**45**	**44**	**45**	**41**	**35**	**34**	**35**	**24**	**22**	**20**	**20**	**20**	**20**	**448**
Br.		**1**	**11**	**20**	**20**	**30**	**31**	**30**	**22**	**20**	**20**	**20**	**20**	**20**	**265**
Mz.			**5**	**4**	**4**	**4**		**2**	**2**	**1**				**2**	**24**
TL					**1**	**3**	**3**		**2**					**1**	**10**
STP				**1**	**1**	**1**	**1**	**1**	**1**	**1**				**1**	**8**
An.					**4**								**2**	**2**	**8**
CV				**1**	**1**	**1**		**1**	**1**					**1**	**6**
GB					**1**									**1**	**2**
Total	**43**	**46**	**60**	**71**	**73**	**74**	**69**	**69**	**52**	**44**	**40**	**40**	**42**	**48**	**771**

(**)Candid. only in the PT programmes

(*)only in the PT programmes

// 1998–2022 – Teachers@CERN



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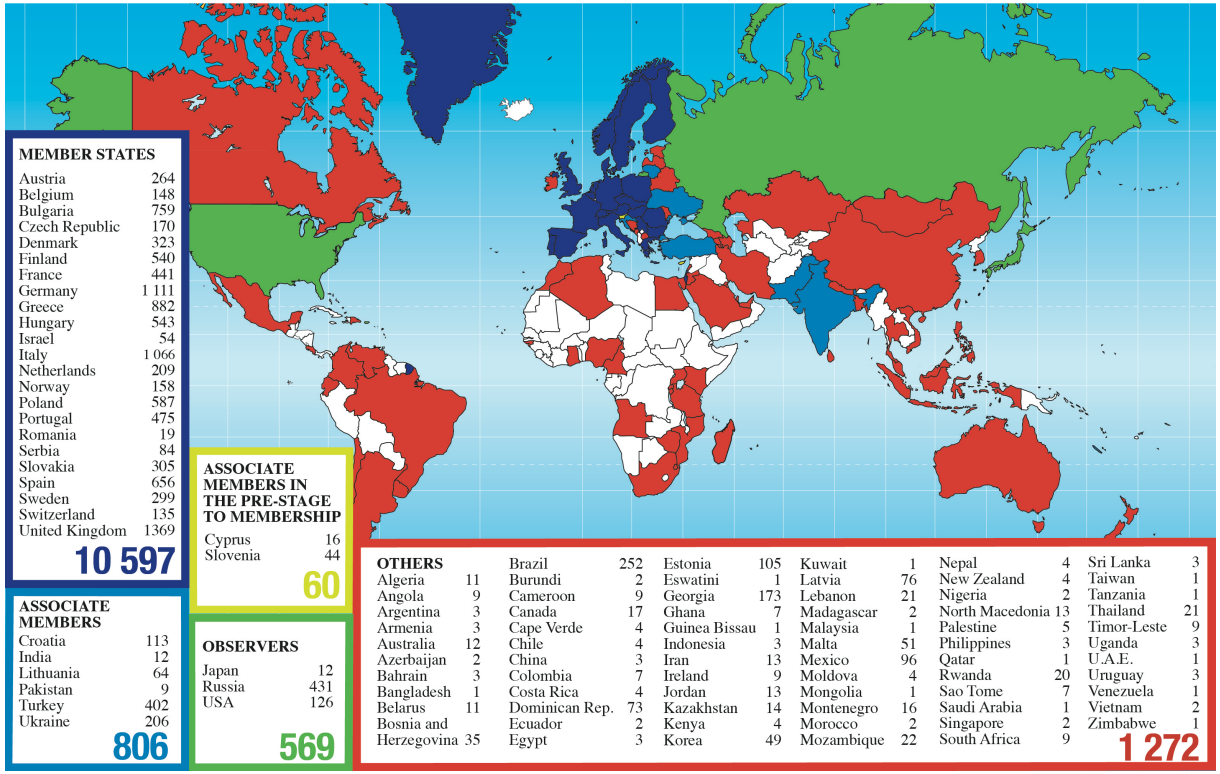
// 1998–2020 – Teachers@CERN

Teacher Programme Participants 1998 - 2020 (Total: 13 304)



MEMBER STATES

Austria	264
Belgium	148
Bulgaria	759
Czech Republic	170
Denmark	323
Finland	540
France	441
Germany	1 111
Greece	882
Hungary	543
Israel	54
Italy	1 066
Netherlands	209
Norway	158
Poland	587
Portugal	475
Romania	19
Serbia	84
Slovakia	305
Spain	656
Sweden	299
Switzerland	135
United Kingdom	1369

10 597

ASSOCIATE MEMBERS

Croatia	113
India	12
Lithuania	64
Pakistan	9
Turkey	402
Ukraine	206

806

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

Cyprus	16
Slovenia	44

60

OBSERVERS

Japan	12
Russia	431
USA	126

569

OTHERS

Algeria	11	Brazil	252	Estonia	105	Kuwait	1	Nepal	4	Sri Lanka	3
Angola	9	Burundi	2	Eswatini	1	Latvia	76	New Zealand	4	Taiwan	1
Argentina	3	Cameroon	9	Georgia	173	Lebanon	21	Nigeria	2	Tanzania	1
Armenia	3	Canada	17	Ghana	7	Madagascar	2	North Macedonia	13	Thailand	21
Australia	12	Cape Verde	4	Guinea Bissau	1	Malaysia	1	Palestine	5	Timor-Leste	9
Azerbaijan	2	Chile	4	Indonesia	3	Malta	51	Philippines	3	Uganda	3
Bahrain	3	China	3	Iran	13	Mexico	96	Qatar	1	U.A.E.	1
Bangladesh	1	Colombia	7	Ireland	9	Moldova	4	Rwanda	20	Uruguay	3
Belarus	11	Costa Rica	4	Jordan	13	Mongolia	1	Sao Tome	7	Venezuela	1
Bosnia and Herzegovina	35	Dominican Rep.	73	Kazakhstan	14	Montenegro	16	Saudi Arabia	1	Vietnam	2
		Ecuador	2	Kenya	4	Morocco	2	Singapore	2	Zimbabwe	1
		Egypt	3	Korea	49	Mozambique	22	South Africa	9		

1 272

Jeff Wiener

// 1998–2022 – Teachers@CERN

Teacher Programme Participants 1998-2022 (Total: 13 871)

Member States 11 056
Austria 300 – Belgium 149 – Bulgaria 821
Czech Republic 171 – Denmark 348 – Finland 550
France 465 - Germany 1142 – Greece 952
Hungary 561 – Israel 56 – Italy 1139
Netherlands 227 – Norway 158 – Poland 588
Portugal 495 – Romania 20 – Serbia 84
Slovakia 307 – Spain 705 – Sweden 311
Switzerland 135 – United Kingdom 1372

Associate Member States in the pre-stage to Membership 165
Cyprus 16 – Estonia 105 – Slovenia 44

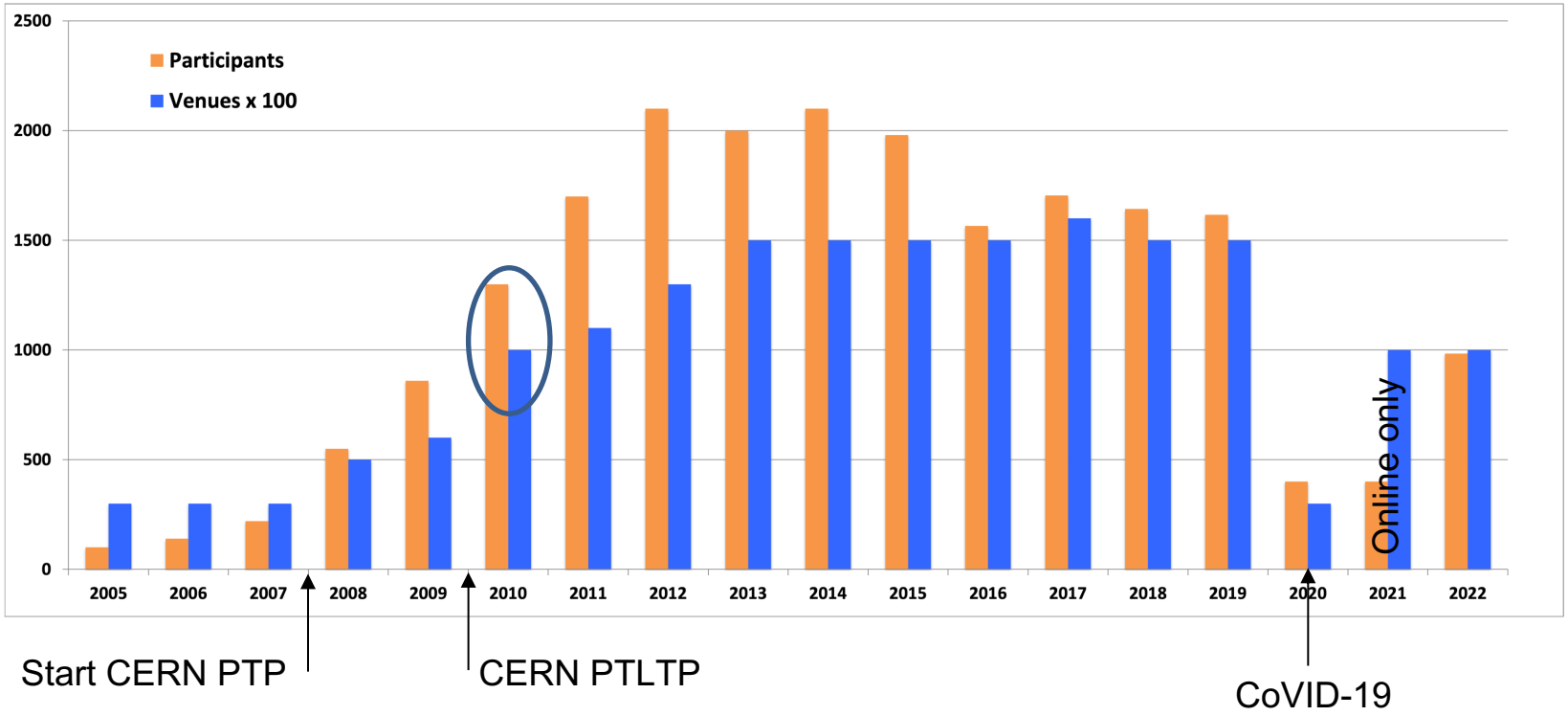
Associate Member States 889
Croatia 114 – India 15 – Latvia 76 – Lithuania 64
Pakistan 9 – Türkiye 403 – Ukraine 208

Observers 579
Japan 12 – Russia (suspended) 431
United States of America 136

Non-Member States and Territories 1182
Algeria 11 – Angola 11 – Argentina 3 – Armenia 3 – Australia 14 – Azerbaijan 2 – Bahrain 3 – Bangladesh 1 – Belarus 11
Bosnia & Herzegovina 36 – Brazil 273 – Burundi 2 – Cameroon 11 – Canada 20 – Cape Verde 5 – Chile 4 – Colombia 8
Costa Rica 4 – Dominican Republic 73 – Ecuador 2 – Egypt 3 – Eswatini 1 – Georgia 194 – Ghana 7 – Guinea Bissau 2
Indonesia 3 – Iran 15 – Ireland 10 – Jordan 13 – Kazakhstan 14 – Kenya 4 – Kuwait 1 – Kyrgyzstan 1 – Lebanon 21
Madagascar 2 – Malaysia 3 – Malta 51 – Mexico 113 – Moldova 4 – Mongolia 1 – Montenegro 17 – Morocco 2
Mozambique 24 – Nepal 6 – New Zealand 5 – Nigeria 2 – North Macedonia 13 – Palestinian Territories 5
People's Republic of China 3 – Philippines 2 – Qatar 1 – Republic of Korea 49 – Rwanda 20 – Sao Tome 8
Saudi Arabia 1 – Singapore 2 – South Africa 9 – Sri Lanka 3 – Taiwan 1 – Tajikistan 1 – Tanzania 1 – Thailand 23
Timor-Leste 10 – Uganda 3 – United Arab Emirates 1 – Uruguay 3 – Venezuela 1 – Vietnam 2 – Zimbabwe 1

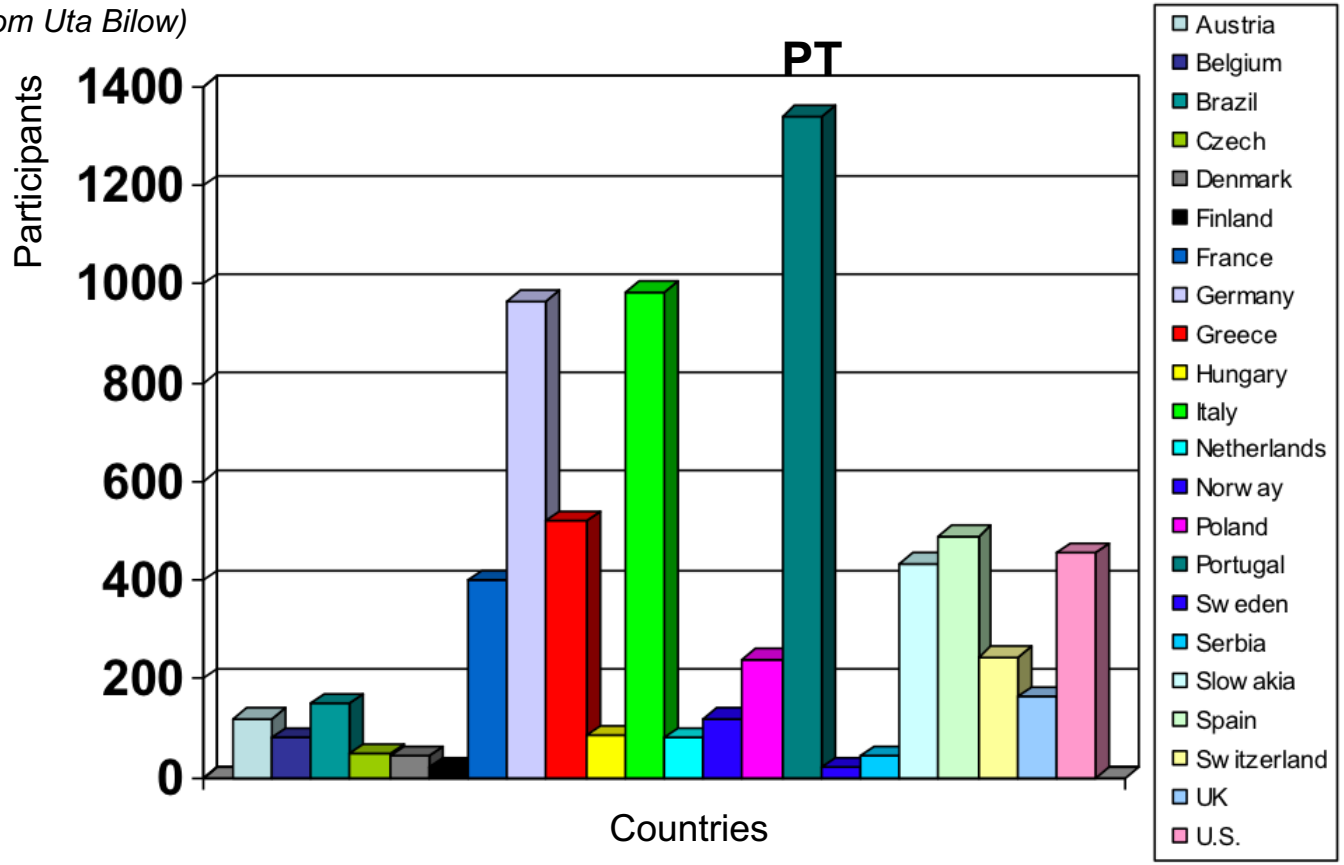
Contents

// IMC@PT 'Exploded'



// IMC@PT vs Others in 2010

(from Uta Bilow)

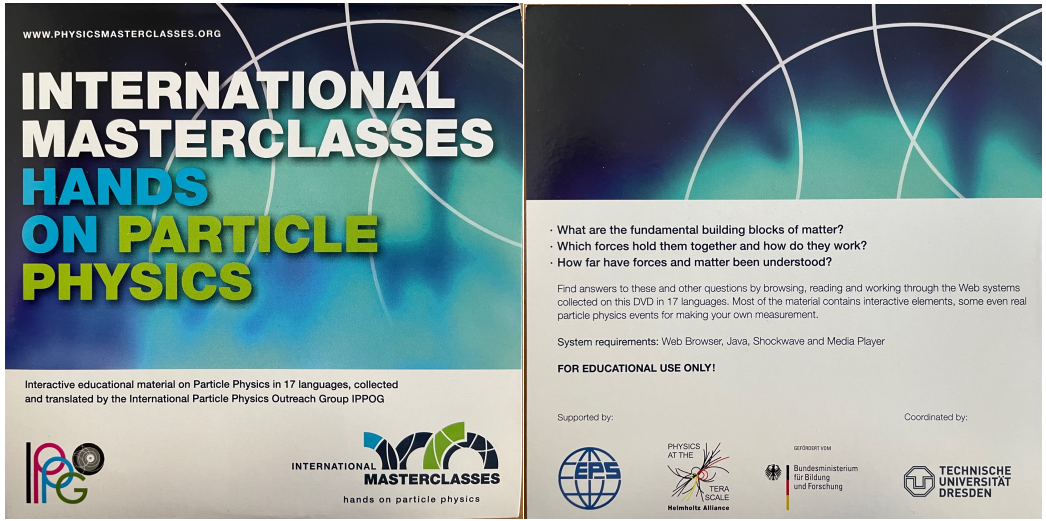


(note that MC's also happen outside the calendar of the IMC, locally at institutes and schools, and are NOT included in these data.
Namely in the UK and Germany)

// 2011–IMC move to LHC

- New website prepared with new measurements for LHC Experiments
- New ATLAS Z-Path and W-Path measurements fully translated to Portuguese (by P.A.)
- In line with the move of EPPOG => IPPOG (and new logo)

International Particle Physics Outreach Group

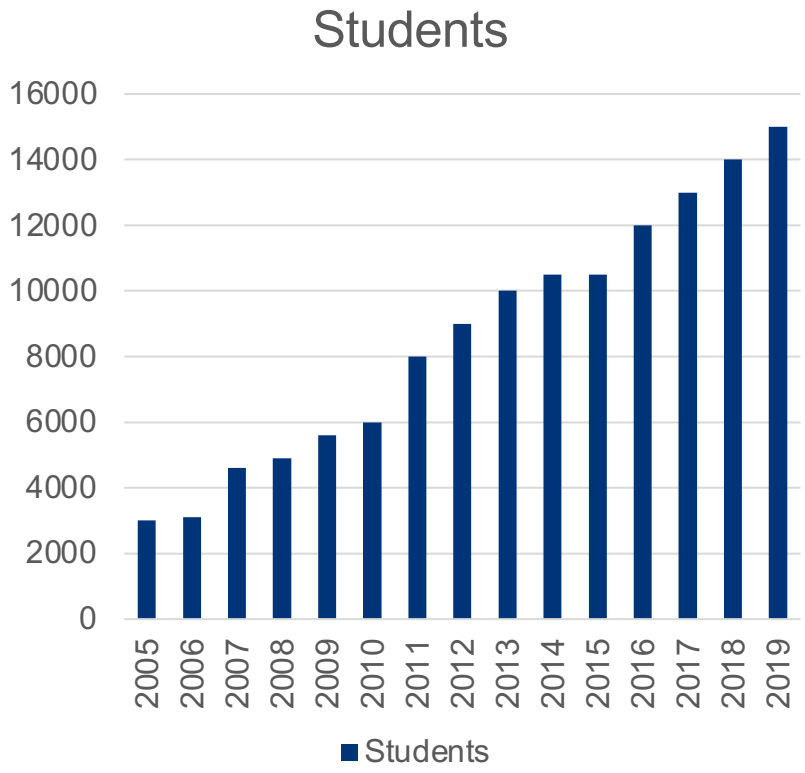


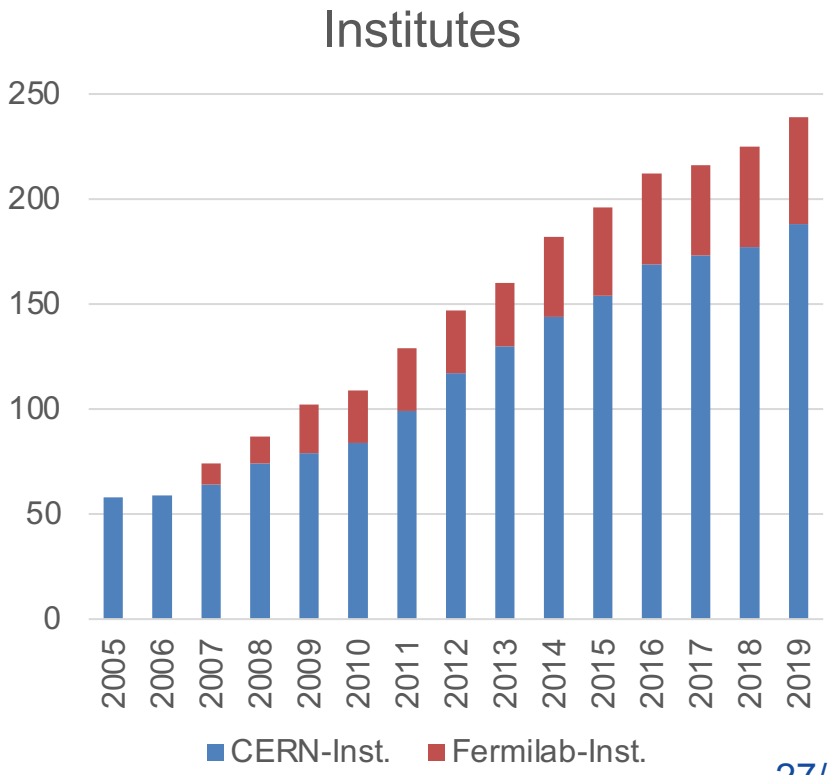
// IMC Evolution (until CoVID-19)

(from Uta Bilow)

// IMC Evolution/year (until CoVID-19)

(from Uta Bilow)





// IMC 2019 (last year bef.CoVID-19)

(from Ken Cecire)

7.3. - 16.4.2019

+ satellite dates

+ Spanish VCs

(to accommodate all needs)

54 countries involved

Coord.: QuarkNet / TU Dresden

Fermilab VC's (Incl. TRIUMF program)

- 51 institutes (48)(*)
- 54 LHC Masterclasses (50)
  - 22 ATLAS (19)
  - 32 CMS (31)
- 12 MINERvA Masterclasses

- 188 institutes (177)(*)
- 266 LHC Masterclasses (257)

CERN VC's

- 30 ATLAS W (35)
- 101 ATLAS Z (104)
- 64 CMS (58)
- 41 LHCb (39)
- 27 ALICE SP (18)
- 3 ALICE R_AA (3)

((*)numbers from 2018)

// Int'l Day of Women and Girls in Sc.

(from Ken Cecire)

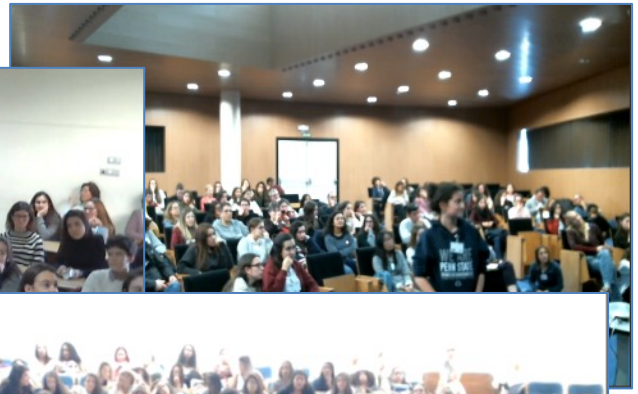
- Proclaimed by the UN in 2016 (Feb 11th)
  www.un.org/en/events/women-and-girls-in-science-day/
- To support and promote the access of women and girls to science education and research activities
- IMCs for girls on Feb 11th http://physicsmasterclasses.org/index.php?cat=women_in_science
  - 11 institutes participating (8)
  - 600 students (250)
  - Female lecturers and tutors (as much as possible)
  - 3 videoconferences at CERN with female moderators, incl. presentation on situation of women in physics

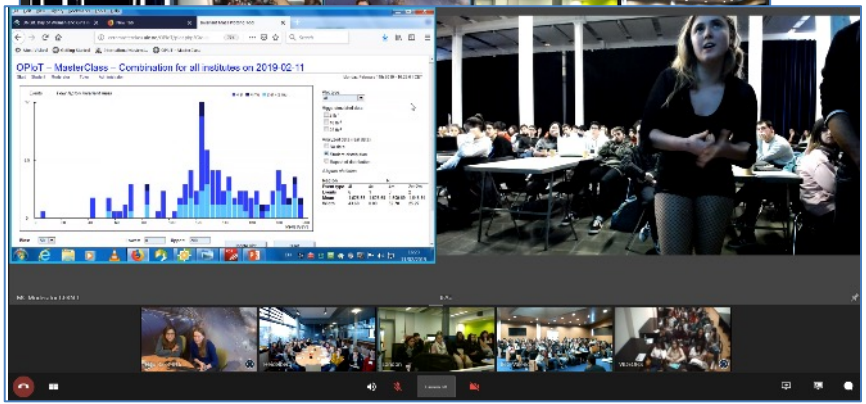
(PT not participating in this special MC's)

	Mon, Feb 11	Mon, Feb 11	Mon, Feb 11
	VC 1 ATLAS Z	VC 2 ATLAS W	VC 3
moderators	Adelina	Estel	Francesca
moderators	Ina	Rosa	Leonora + Tara
	Santiago de Compostela webpage	CTU Prague webpage	Cagliari University (LHCb)
	Valencia webpage	Cosenza	Cagliari INFN (ALICE)
	London UC	Lund webpage	Madrid CIEMAT (CMS) webpage
	Barcelona IFAE webpage		São Paulo SPRACE (CMS)
	Heidelberg		

// Int'l Day of Women and Girls in Sc.

(from Ken Cecire)





// More and more measurements

- **Historically LEP=>LHC**
- **Today**
  - LHC (since 2011) (ATLAS, CMS, ALICE, LHCb)
  - MINERvA (since 2019)
  - Belle II (since 2020)
  - Particle Therapy (since 2020)
- **New**
  - Pierre Auger (Cosmic Rays) (in 2023)
  - NOvA (to come)

// Measurements – ATLAS W, Z(+H)

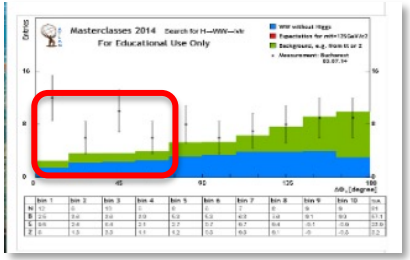
(from Ken Cecire+Uta Bilow, ICHEP2020)

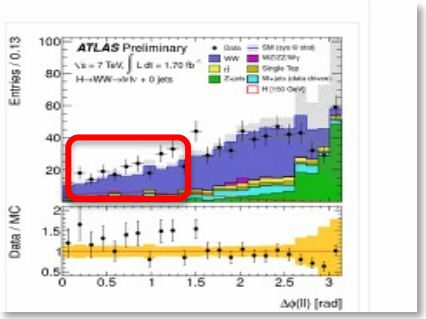
W-path

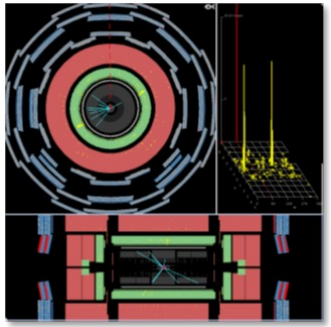
- Students analyze event
- Identify W bosons
  - W+/W-
- Identify W pairs and measure azimuthal opening angle $\Delta\varphi_{ll}$
  - Gain insight into the process of discovering the Higgs at CERN

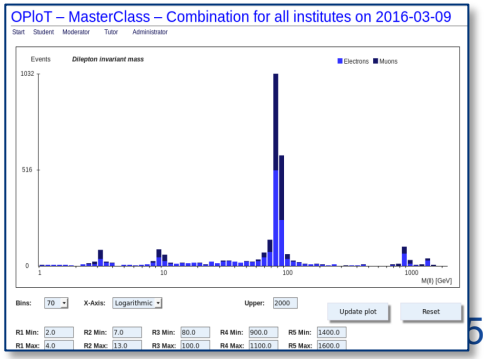
Z-path

- Students search for 2-lep, γγ, or 4-lep events, build invariant mass distributions
- Find 2-lep particles: Z^0, J/ψ, Υ
- Search for new particles
- Gain insight into the process of discovering the Higgs at CERN







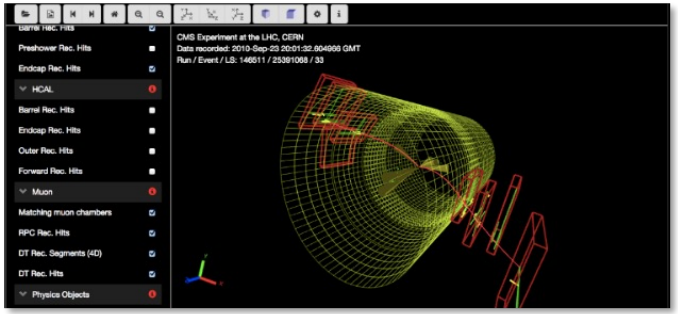


// Measurements – CMS and LHCb

(from Ken Cecire+Uta Bilow, ICHEP2020)

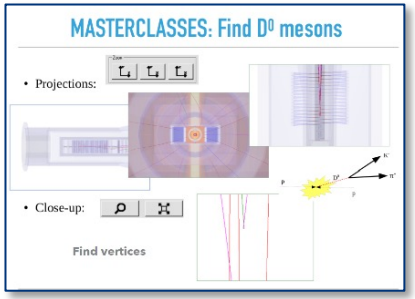
CMS

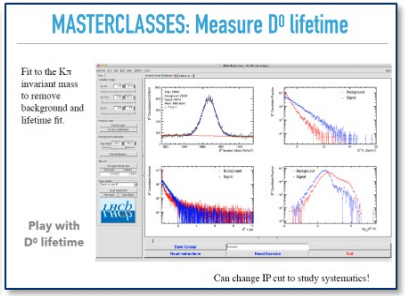
- 1-, 2-, and 4-lepton events
- 1-lep (plus ν): W boson
- 2-lep and 4-lep: mass plots of standard model particles, plus hint of Higgs
- Ratios W+/W-, e/m



LHCb

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

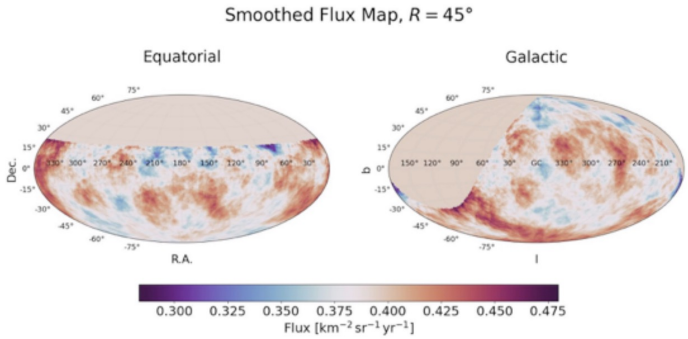




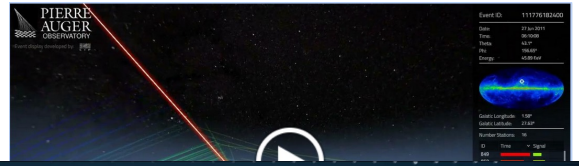
// Measurements – Cosmic Rays

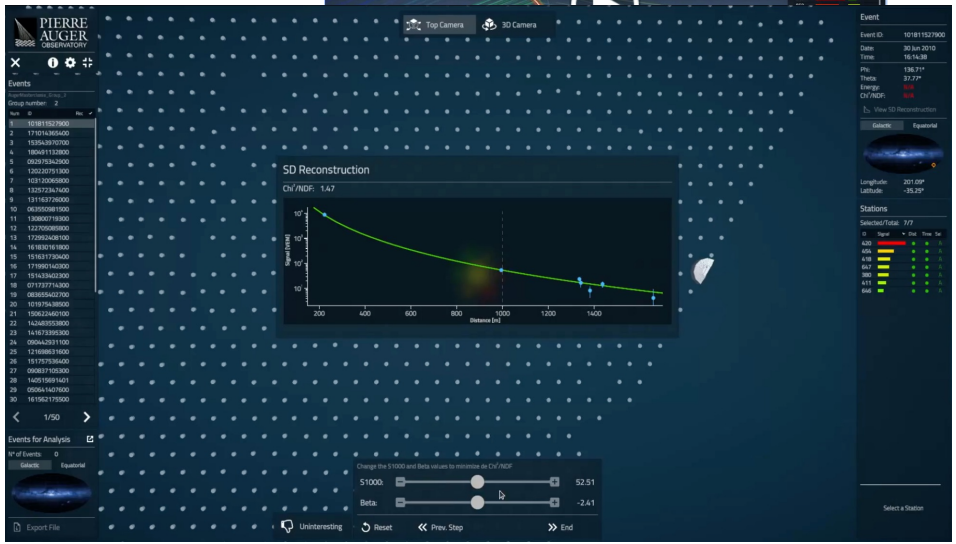
Pierre Auger Observatory

- By Raul Sarmento, Henrique Carvalho (+Sofia Andringa, P.A.)
- Public data from the Pierre Auger Observatory
- Software developed at LIP-Minho
- Visualization of events
- LDF Fit to obtain energy and selection of high-energy events
- Construct map of the sky



NEW IN 2023! => 18 & 24 / Mar





// Measurements – ALICE in 2,5 flav.

(from Ken Cecire+Uta Bilow, ICHEP2020)

Strange particles

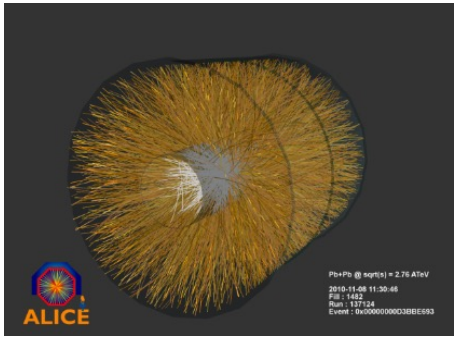
- First part: visual analysis of ~ 15 V0 events per group
- Second part: Calculate numbers of Ks, Λ , anti-Λ from different centrality regions in Pb-Pb collisions
- Observe strangeness enhancement

Nuclear modification factor

- event-display analysis
  - R_{AA} simply via counting of tracks
- ROOT based large scale analysis
  - R_{AA} from various Pb-Pb centralities
  - students discover jet suppression!

New J/ψ measurement

- Electron identification via dE/dx measured in TPC
- Workflow:
  - load charged-particle tracks
  - fill PID and inverse mass histograms
  - extract J/ψ yield
- Standalone app

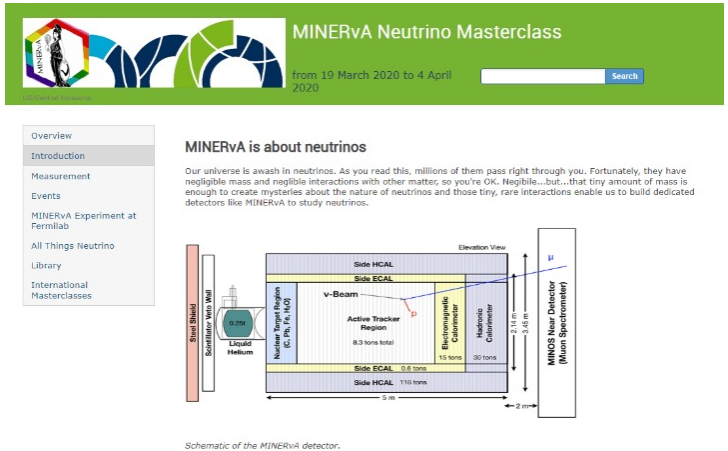


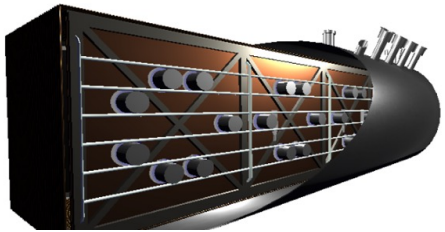
// Measurements – Neutrinos

(from Ken Cecire+Uta Bilow, ICHEP2020)

MINERvA

- Muon neutrinos interact with carbon target
- Discover Fermi motion
- Measure carbon nucleus to test interaction model
- https://indico.fnal.gov/event/22340/





In development

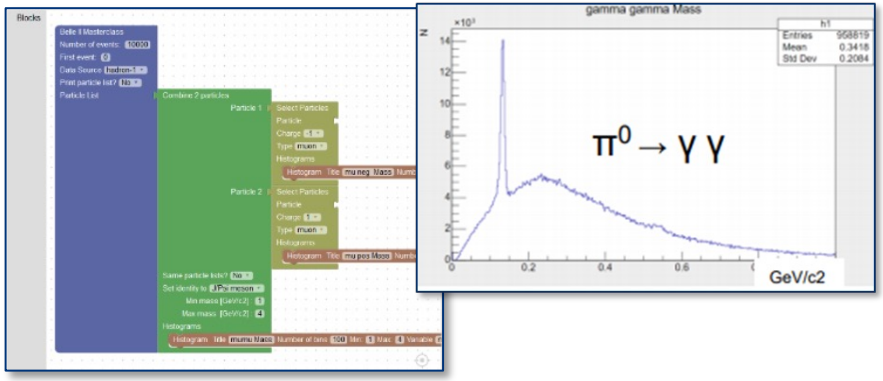
- MicroBooNE instrumentation masterclass
  - Argon purity
  - Electron drift velocity
- NOvA neutrino oscillation (just starting)

// Measurements – BELLE-II+Pt.Th.

(from Ken Cecire+Uta Bilow, ICHEP2020)

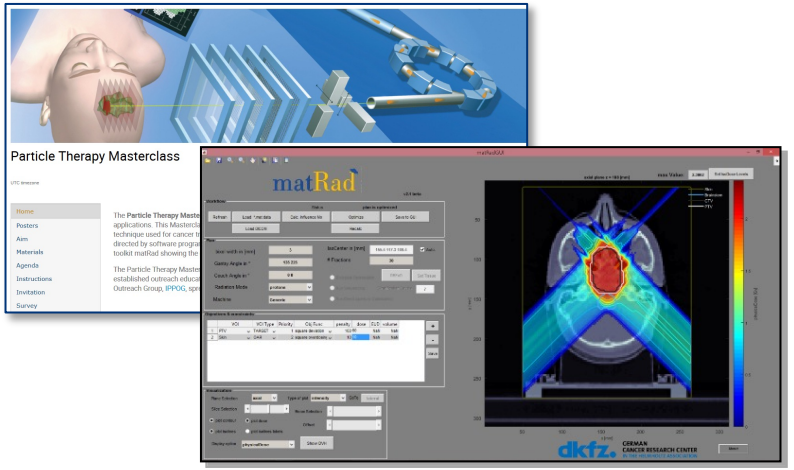
Belle II

- Students code B-physics analysis
  - Describe decays, make cuts, “discover” particles
  - Visual code editor Blockly
- Run from the web or virtual machine
- Analysis of 6M clean reconstructed events
- Basic/advanced level; KEK videocon



Particle Therapy

- Particle treatment planning
- highlights benefits for society from the particle physics technology
- Particularly in demand in Latin America



// Measurements – Darkside

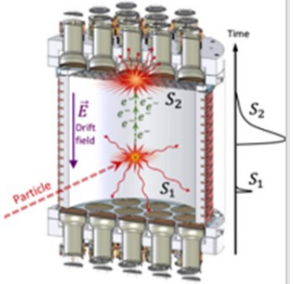
(from Ken Cecire+Uta Bilow, ICHEP2020)

Darkside (Gran Sasso)

- By Francesca Carnesecchi, University and INFN of Bologna, Centro Fermi Roma, et al.
- Dark Matter / WIMPs in Ar TPC
- Data analysis via excel
  - Reconstruction position part (few events): exclude background
  - Analysis of ~20000 events: background and few “good” WIMPs
  - pilot in Jan 2020, 2 remote events during lockdown

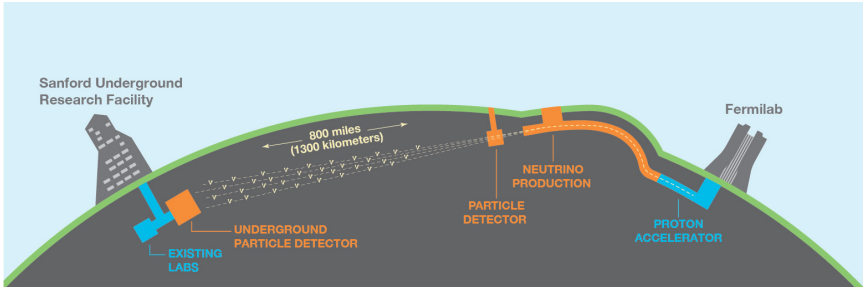
Darkside experiment: how to detect WIMP

- WIMP-nucleus elastic collisions revealed by a detector capable of unambiguously identifying a small number of nuclear recoils
- **Dual phase (gas + liquid) Argon TPC** for direct detection of WIMPs



Further neutrino masterclasses

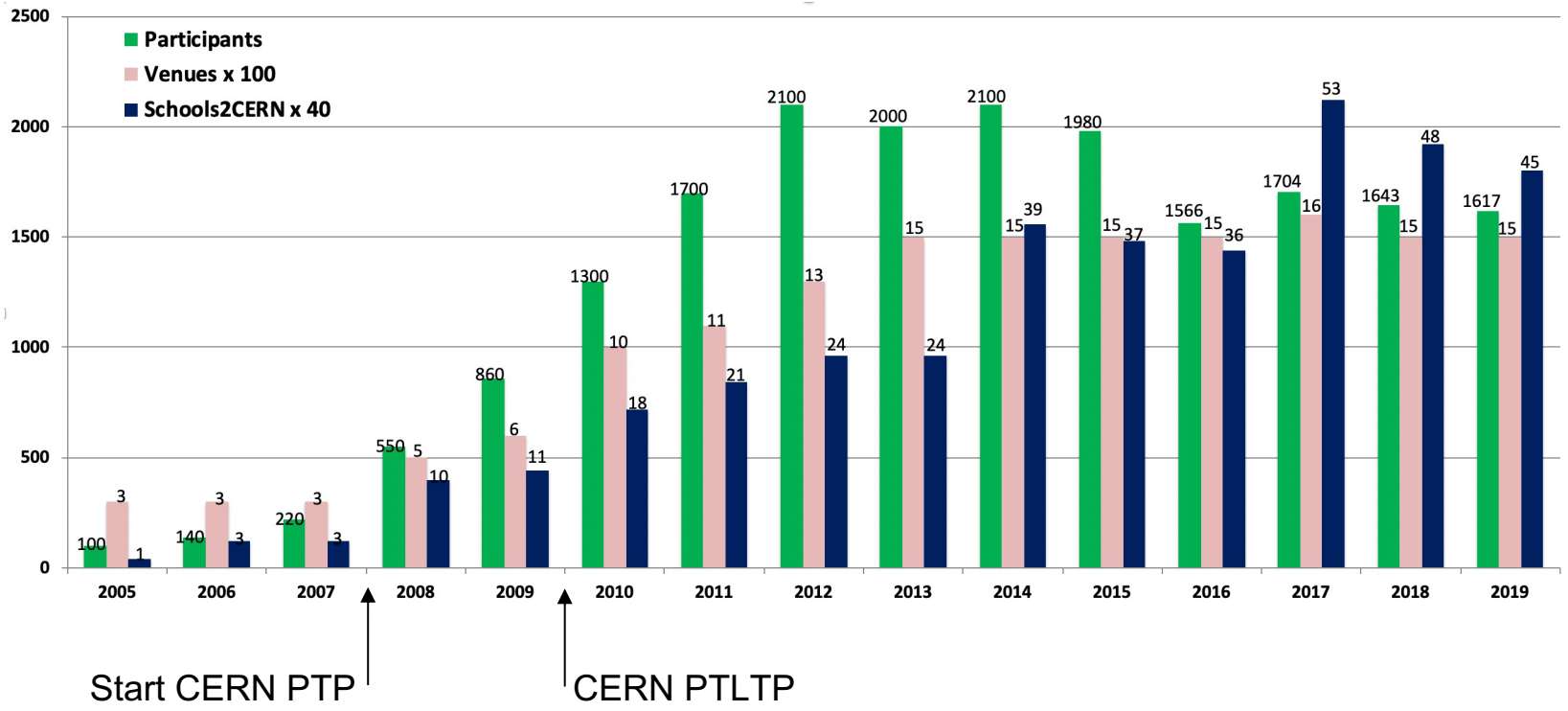
- OPERA discussed
- DUNE is the goal



Contents

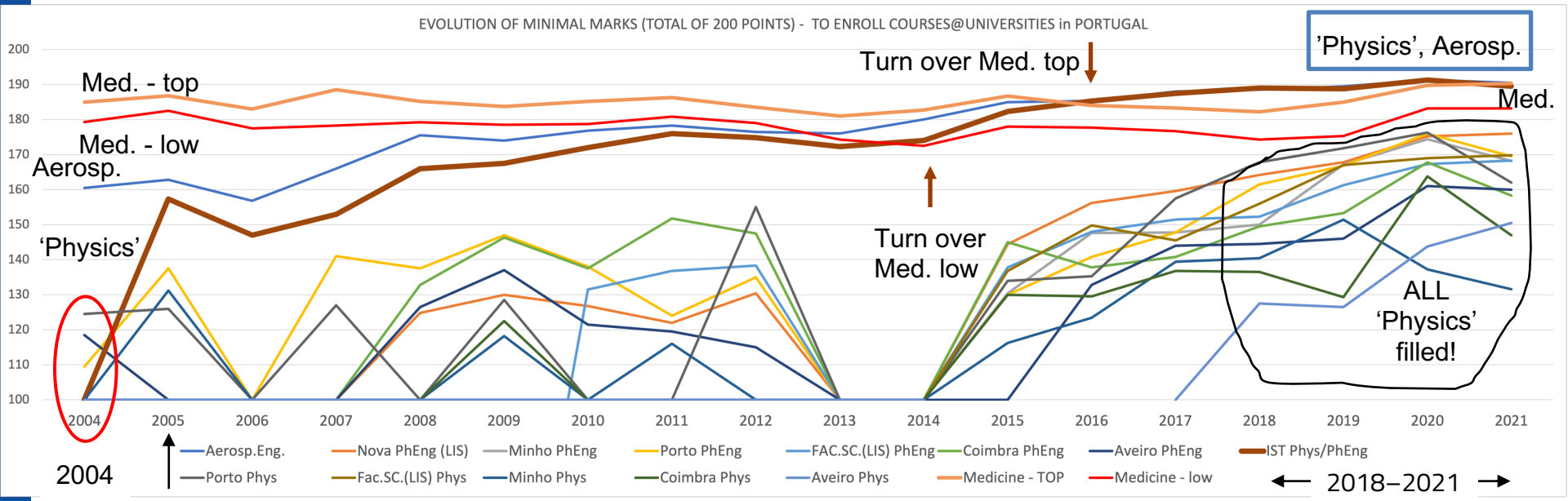
// The growth in PT (up to CoVID-19)

Piers publicity effect (mouth to ear): *It is fun to go to the Masterclasses*



// Time correlation w/ stds. interests

Evolution of Threshold Marks to enter PT Universities



WYP'2005 (Launch of IPPOG's Int'l Masterclasses in Particle Physics)

- Threshold marks range from 100 to 200, being set at 100 for courses with vacancies left
- Note that different #places in different courses does hinder the threshold marks analysis
- This is also a result of MANY OTHER activities/groups (unrelated to Particle Physics)
- **It does pay off to engage, to go to schools, to talk to the young**

Contents

// Conclusions (a series of opinions...)

Programme very successful from its very start

- worldwide
- in Portugal

Expansion since its beginning and continuing

- +countries
- +institutes
- +measurements
- +audiences

Positive feedback with other programmes/activities

- +participants in other activities
- ++participants in MC's

Visibility towards Outreach and to IPPOG

- Flagship activity of IPPOG
- IPPOG formalized into an international collaboration

Other activities stemming from MC's

- W2D2 – World Wide Data Day
- BAMC/BAMA – Big Analysis of Muons in CMS/ATLAS

Very strong impact in the schools communities

- Eagerly waiting for next programme(s)…
- Connections Scientists–Teachers–Students

Very strong impact in the science communities

- Scientists more keen/open to outreach
- Experiments/Labs more aware/conscious of the need to outreach and engage the public

// The near future: IMC 2023 @ PT

25/February	**FCUL**	Lisboa	**ATLAS Z-path**
01/March	ECT/**UTAD**	Vila Real	**ATLAS Z-path**
02/March	ESTIG/**IPB**	Bragança	**ATLAS Z-path**
03/March	ECUM/**Uminho**	Braga	**ATLAS Z-path**
11/March	ESTG/**IPBeja**	Beja	**ATLAS Z-path**
11/March	FC/**UBI**	Covilhã	**ATLAS Z-path**
18/March	**UMa**[deira]	Funchal	**PIERRE AUGER MC (NEW!!!)**
18/March	**IST**/ULisboa	Lisboa	**PIERRE AUGER MC (NEW!!!)**
24/March	ECUM/**Uminho**	Braga	**PIERRE AUGER MC (NEW!!!)**
25/March	FCT/**UC**[oimbra]	Coimbra	**ATLAS Z-path**
25/March	ECT/**UE**[vora]	Évora	**ATLAS Z-path**
25/March	**IST**/ULisboa	Lisboa	**ATLAS Z-path**
29/March	**UAç**[ores]	Ponta Delgada	**ATLAS Z-path**
29/March	**FCUP**	Porto	**ATLAS Z-path**

https://www.lip.pt/masterclasses

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Amélia Maio

Catarina Espírito Santo Sofia Andringa

Daniel Galaviz Henrique Carvalho

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E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Nuno Castro Fernando Barão Mário Pimenta

Carlos Manuel

Maria Teresa Godinho

Ricardo Gonçalo

Thanks!!!...But

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+all the students and teachers!
+all the tutors and speakers!!
…and all others that I forgot!!!

Sandra Soares

Francisco Serafim

Robertus Potting

Helmut Wolters

André David

Discovery through science

Innovation through technology

Sharing with People

Filipe Veloso

João Veloso

Ana Pereira

Carla Veiga