






INTERNATIONAL MASTERCLASSES

hands on particle physics

LHC Masterclasses, Present and Future
Bringing Particle Physics into the Classroom

V. V. Gligorov, LPNHE & LHCb, LHCP 2016

ALICE

ATLAS EXPERIMENT

LHCb

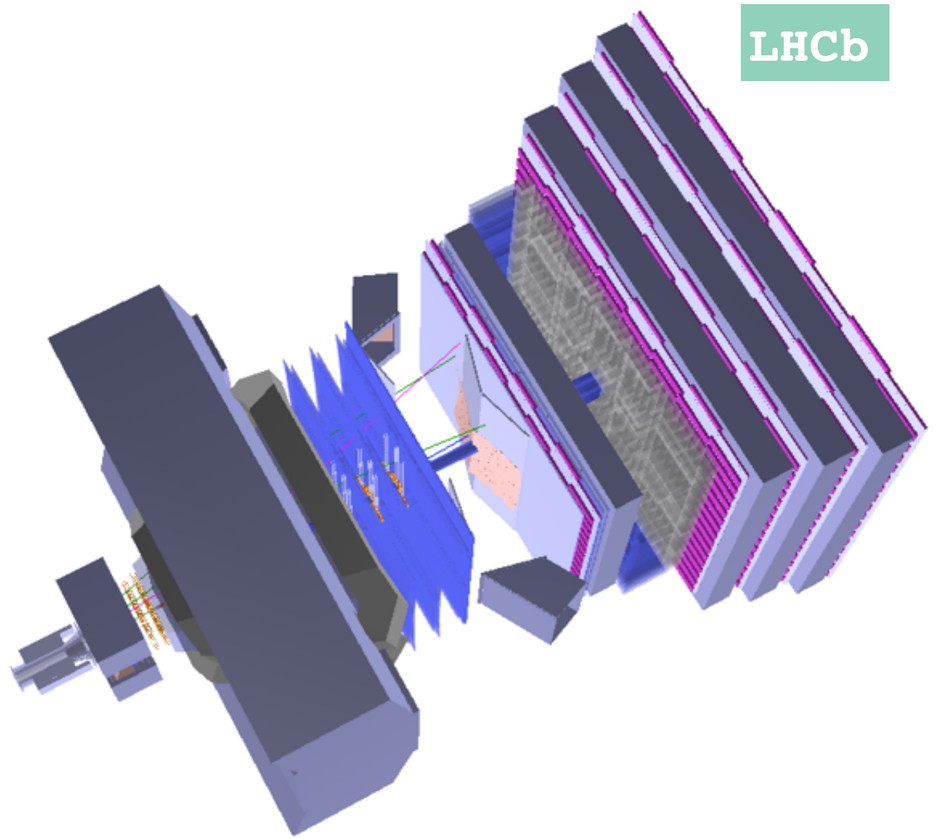
CMS

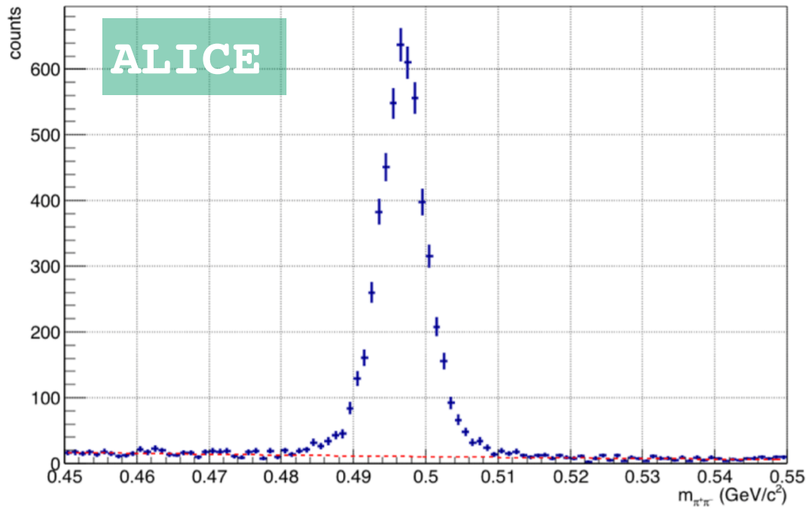
What are masterclasses?

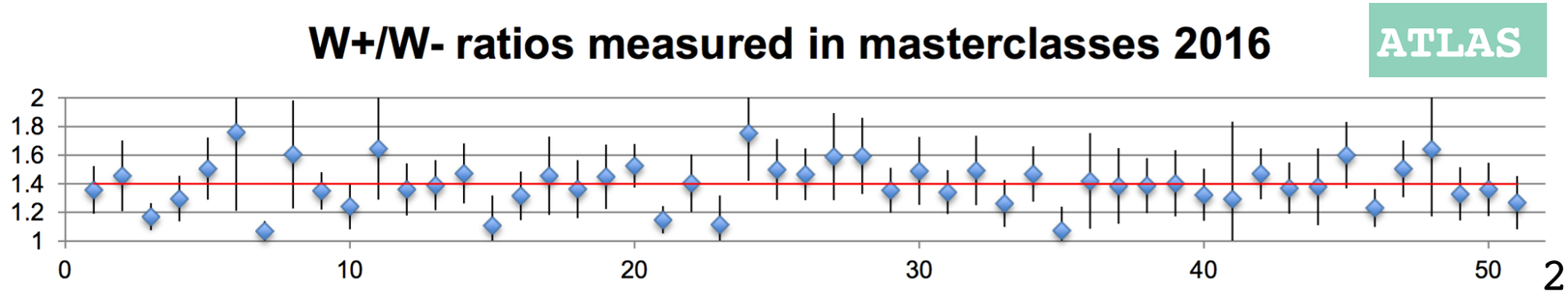
A chance for high-school students to work with real LHC data, select particles and measure their properties

A chance for students to experience the collaborative international nature of HEP work through videoconferences with other schools and CERN/Fermilab

A chance for us to rediscover how magical our day-to-day work can seem when seen outside of the daily grind.







www.physicsmasterclasses.org

International Particle Physics Outreach Group

INTERNATIONAL MASTERCLASSES

hands on particle physics

Operating since 2005*!

- Home
- Participate!
- Schedule
- My Country
- Physics
- Local Organisation
- In the Media
- Teachers and Educators

International Masterclasses

12th International Masterclasses 2016

Each year about 10.000 high school students in 47 countries come to one of about 200 nearby universities or research centres for one day in order to unravel the mysteries of particle physics. Lectures from active scientists give insight in topics and methods of basic research at the fundaments of matter and forces, enabling the students to perform measurements on real data from particle physics experiments themselves. At the end of each day, like in an international research collaboration, the participants join in a video conference for discussion and combination of their results. See here for media coverage.

*Actually started 1997 in UK, Europe-wide since 2005, USA joined in 2006

Masterclass coordination

Uta Bilow, TU Dresden

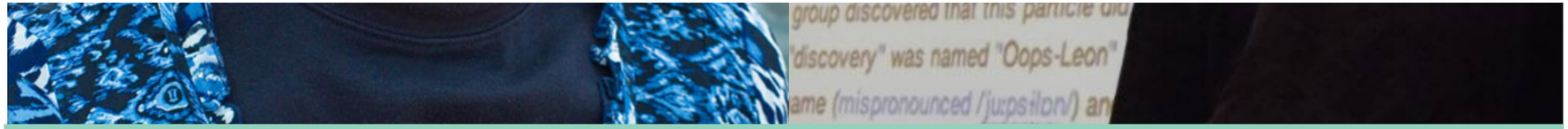
Ken Cecire, QuarkNet Notre Dame

Masterclass coordination

IMC steering group contains representatives of all LHC experiments and oversees the running of masterclasses.

Steering group establishes and maintains guidelines and quality control when approving new masterclass exercises.

Central coordination and planning of the schedule greatly reduces workload on individual experiments/institutes



Uta Bilow, TU Dresden
Ken Cecire, QuarkNet Notre Dame

Example of schedule from 2016

Masterclasses last around 6 weeks and end just before Easter.

Institutes asked to sign up around October so important to contact schools before this!

One or two videoconferences per day with up to 5 institutes per videoconference.

date	Mon 7.3.	Tue 8.3.	Wed 9.3.	Thu 10.3.	Fri 11.3.
	VC 1	VC 1	VC 1	VC 1	VC 1
measurement	ATLAS Z	ATLAS W	ATLAS Z	ATLAS Z	ATLAS W
	Grenoble	Valencia	Athens	Rabat	Paris
	Sandomierz	Saclay	Katowice	Marseille	Saclay
	Genova	Clermont-Ferrand	Faro	Thessaloniki	Braga U Minho
	Nis	ATLAS Z	Poznan	Orsay LAL	Presov
	Clermont-Ferrand	Freiburg	Oslo	Grenoble	
	5	4	5	5	4

date	Wed 9.3.	Thu 10.3.	Fri 11.3.	Sat 12.3.
	VC 2	VC 2	VC 2	VC 2
measurement	LHCb	CMS	LHCb	CMS
	Dortmund	Lyon IPNL	Orsay LAL	Warsaw
	Milano	Palaiseau	Genova	Antwerpen
	Cincinnati AHS	Santander	Barcelona	Cyprus
	Cincinnati MHS	Helsinki	Bielsko-Biała	Évora
	Rio de Janeiro UFR	Alexandria	Clermont-Ferrand	Rijeka
	1	5	5	5

date	Mon 14.3.	Tue 15.3.	Wed 16.3.	Thu 17.3.	Fri 18.3.	Sat 19.3.
	VC 1	VC 1	VC 1	VC 1	VC 1	VC 1
measurement	ATLAS W	ATLAS Z	ATLAS W	ATLAS Z	ATLAS Z	ATLAS Z
	Wuppertal	Ankara METU	Orsay LAL	Berlin/Zeuthen	Strasbourg	Coimbra
	Geneva CERN	Marseille	Bonn	Ankara METU	Prague CTU	Louisiana Tech
	Madrid IFT	Rehovot	Rome Tor Vergata	Dortmund	Zaragoza	Lisbon IST
	Dresden	Annecy	Wuppertal	Uppsala	Al-Hoceima	Crete
		Oujda	Hamburg DESY	Strasbourg	Trencin	Lisbon FCUL
	4	5	5	5	5	5

date	Mon 14.3.	Tue 15.3.	Wed 16.3.	Thu 17.3.	Fri 18.3.
	VC 2	VC 2	VC 2	VC 2	VC 2
measurement	CMS	ALICE	CMS	LHCb	ALICE
	Padova	Padova	Firenze	Perugia	Cape Town
	Dublin UCD	Maynooth	Lyon IPNL	Frascati	São Paulo
	Genova	Nantes	Torino	Ferrara	Prague
	São Paulo SPRACE	Copenhagen	Cyprus	Marseille	Nantes
	Požega	Bari	Padova	Padova	Orsay IPN
	5	5	5	5	5

Scale and evolution with time

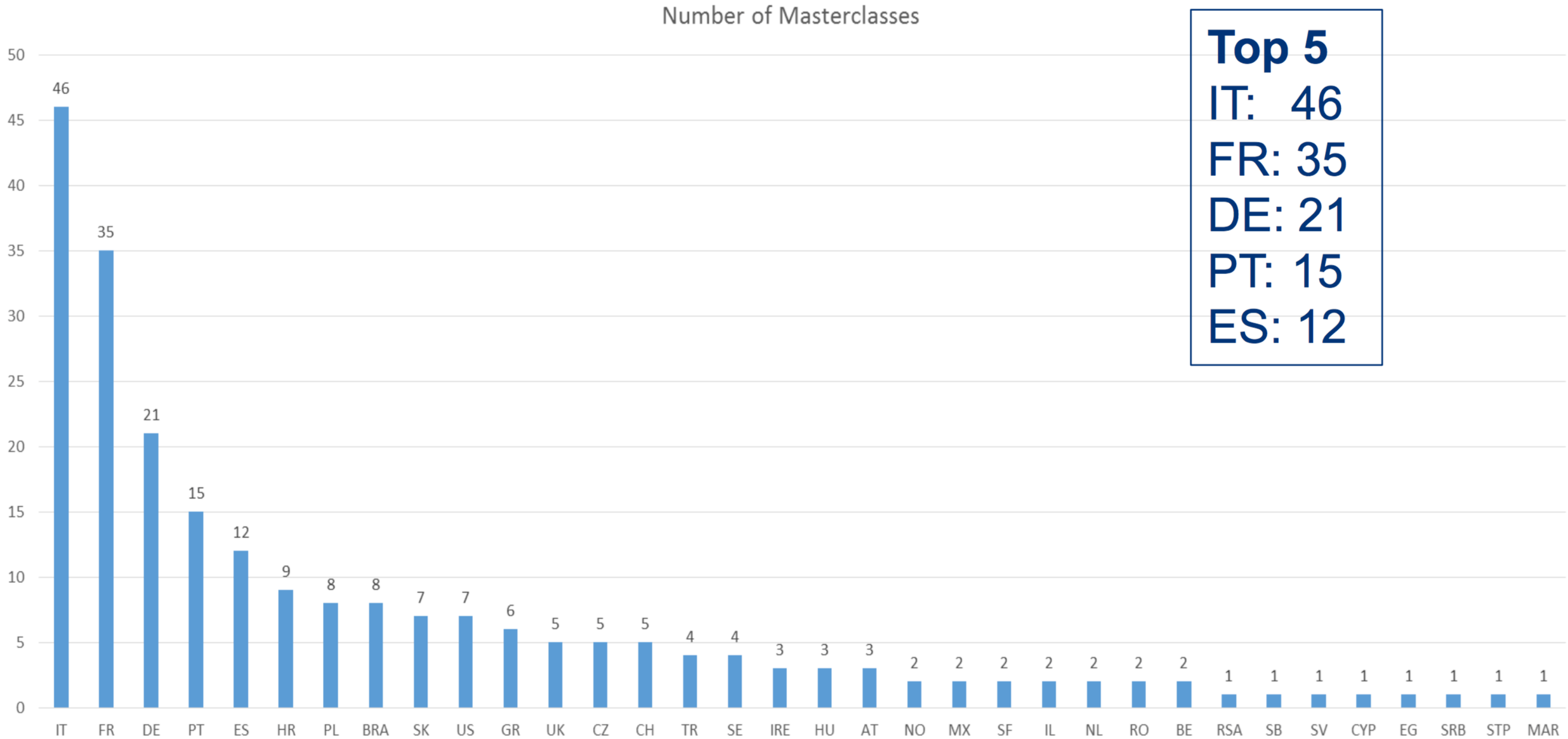
11 Feb – 23 Mar 2016
46 countries
213 institutes
276 masterclasses
54 w/CERN, 21 w/Fermilab

Masterclasses by experiment
140 ATLAS
82 CMS
34 LHCb
20 ALICE

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016

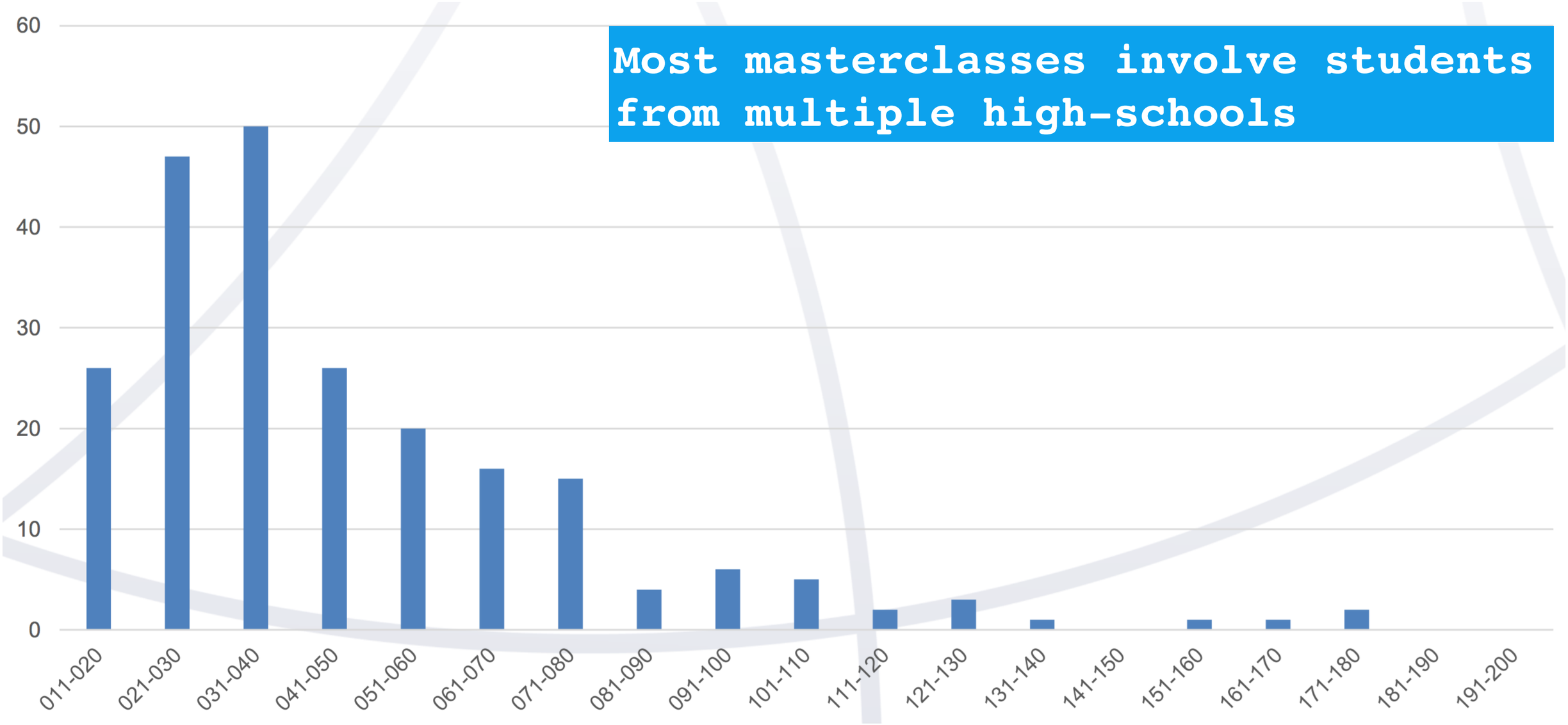
18	countries	46
58	institutes	213
72	masterclasses	276
3k	students	14k
12	video conferences	75

Masterclasses per country



Top 5
IT: 46
FR: 35
DE: 21
PT: 15
ES: 12

Students per masterclass



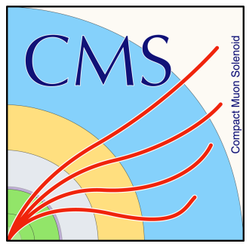
What exercises are available?

Strange particles : search for K_S^0, Λ^0, and Ξ^- candidates

Nuclear modification : measure ratio of particle yields in pp and PbPb collisions

W-path : selection of W candidates
discrimination of W^+/W^-

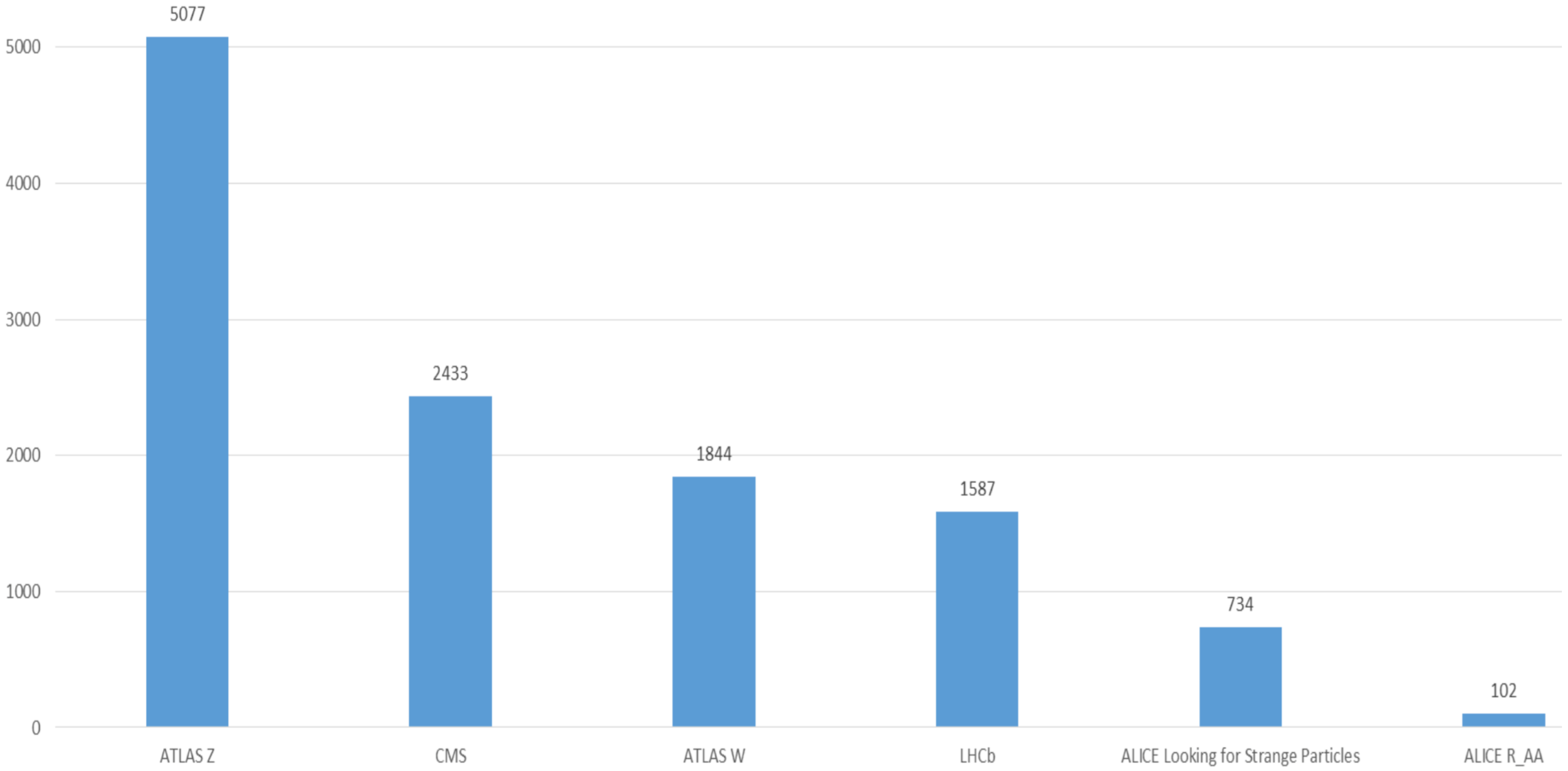
Z-path : selection of Z/H candidates



Selection of W/Z/H candidates
Discrimination of W^+/W^- and electrons/muons
Build a mass plot of Z/H candidates

Selection of D^0 mesons
Measurement of the D^0 lifetime

Students per exercise in 2016



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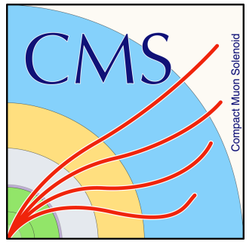

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Illustrate further with reference to the LHCb exercise

Typical structure of a masterclass day

09:00 - 09:30 Participants arrival

09:30 - 11:15 Lectures

- Introduction in elementary particle physics - 55 *min* (A. Micu, IFIN-HH)
- LHCb experiment at CERN - 50 *min* (B. Popovici, IFIN-HH)

11:15 - 13:30 Visit on M'agurele scientific campus

- Ciclotron (L. Craciun, IFIN-HH)
- Tandem (3 linear accelerators 9MV, 3MV, 1MV) (D. Ghita, IFIN-HH)

13:30 - 14:30 Lunch

14:30 - 16:40 Working session: Measurement of the lifetime of D^0 meson with LHCb data (B. Popovici, F. Maciuc - IFIN-HH; V. Bercu, Fac. of Physics)

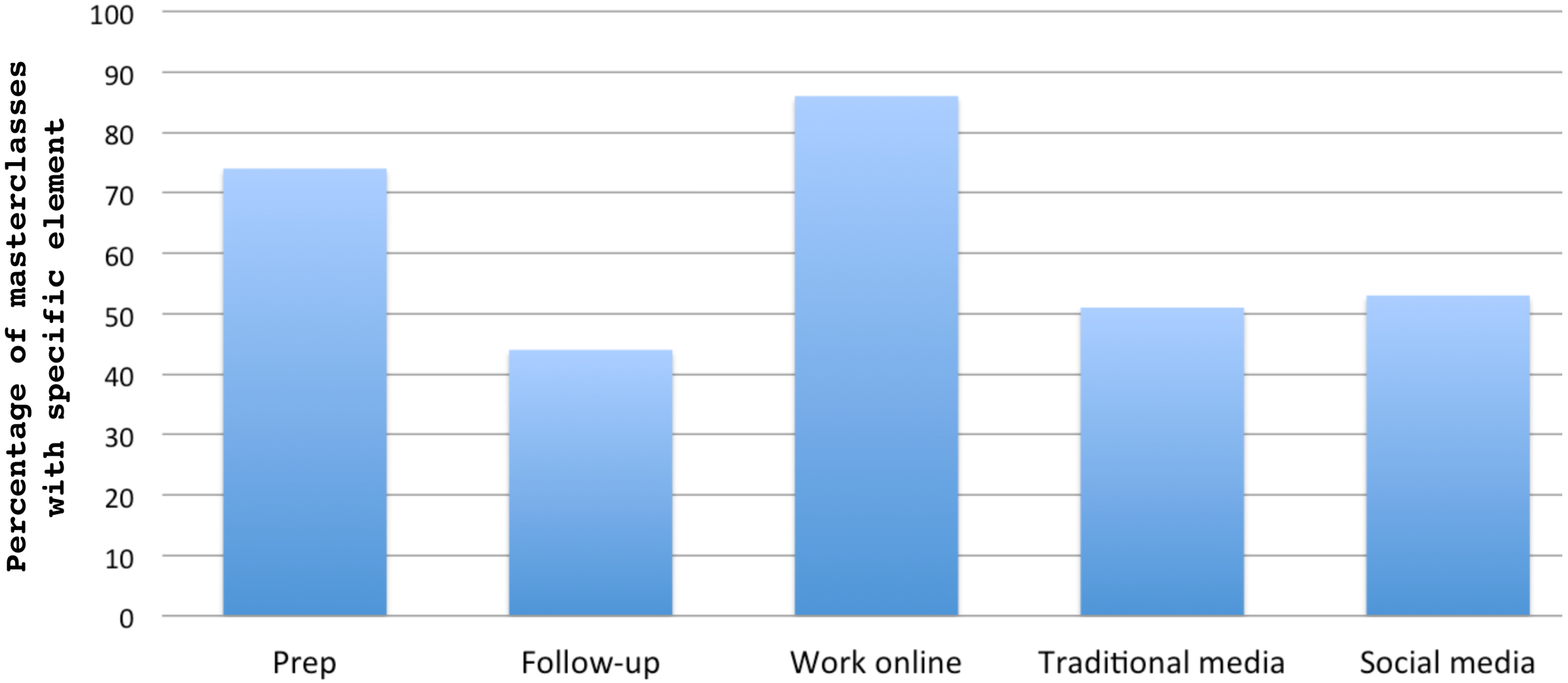
- **`Measurement presentation (30 min)`**
- Data analysis (1*h*40)

16:40 - 17:00 Break

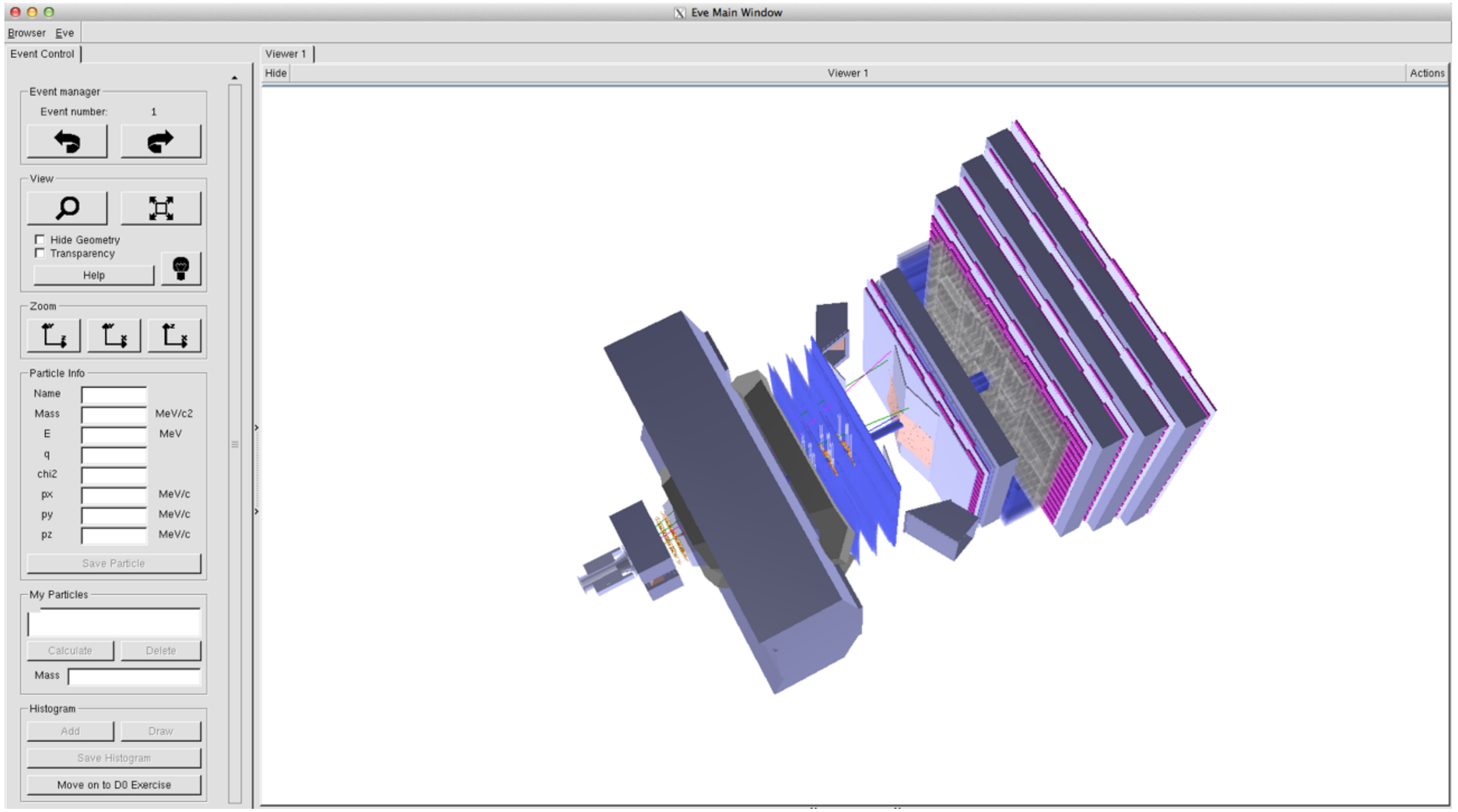
17:00 - 18:30 Discussion of the results

- Discussion of the results and interpretation
- Videoconference with CERN and partner institutions (CERN, Bristol, Padova)
- Quiz tests (awarding participation certificates)

2016 Fermilab masterclasses structure



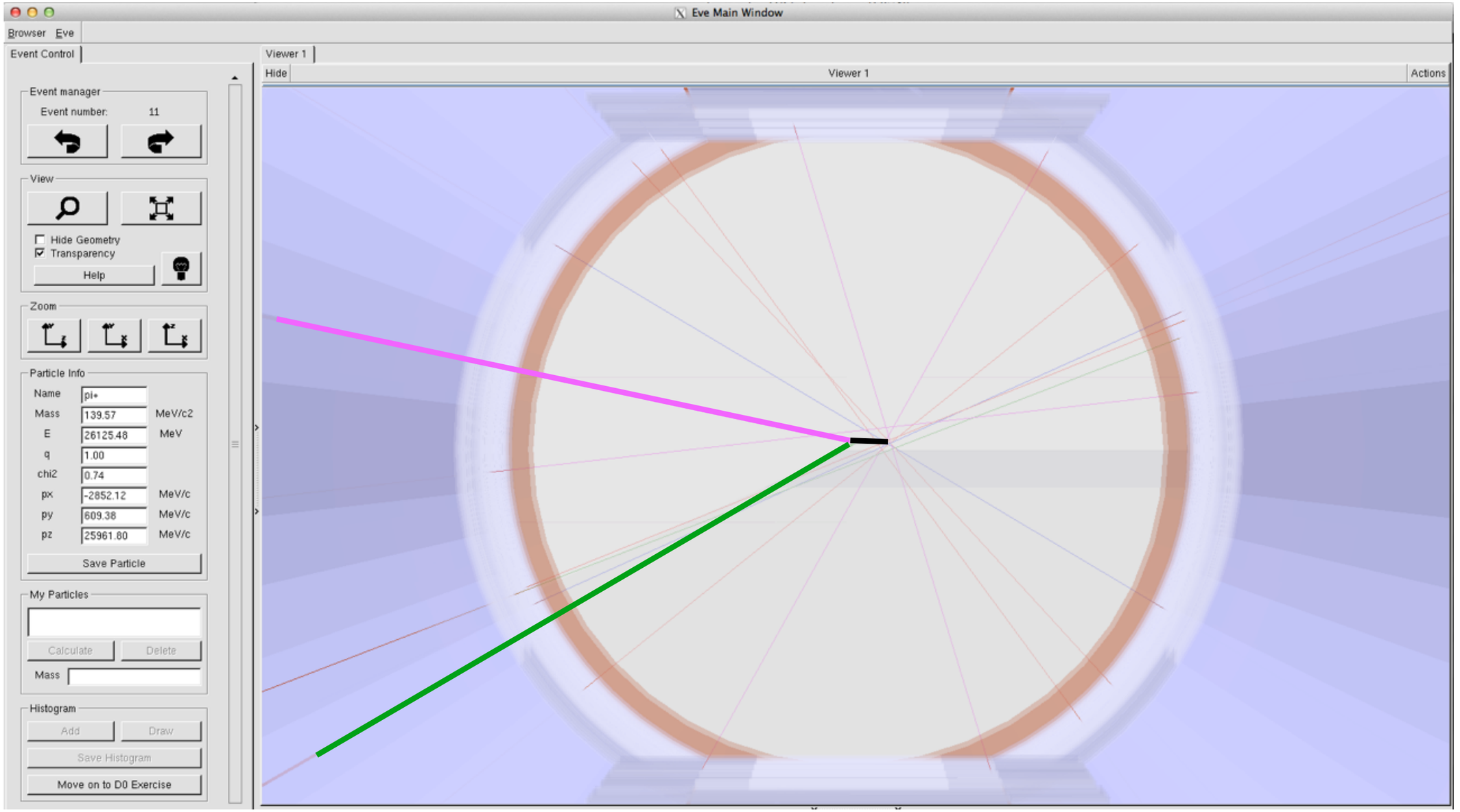
The LHCb exercise itself



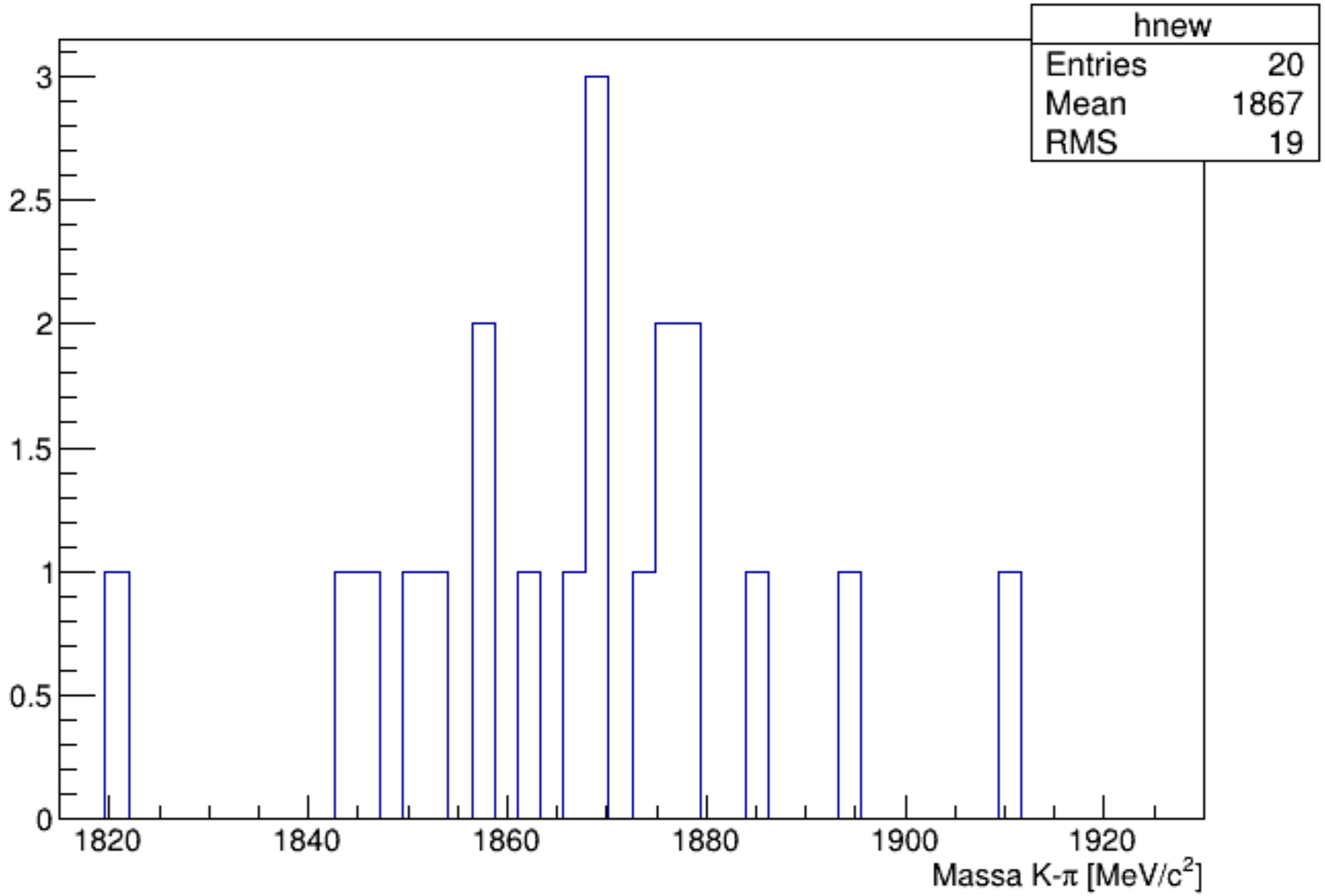
Search for $D^0 \to K\pi$ decays using an event display

Event display is crucial for students to visualize the physics

Finding D^0 mesons

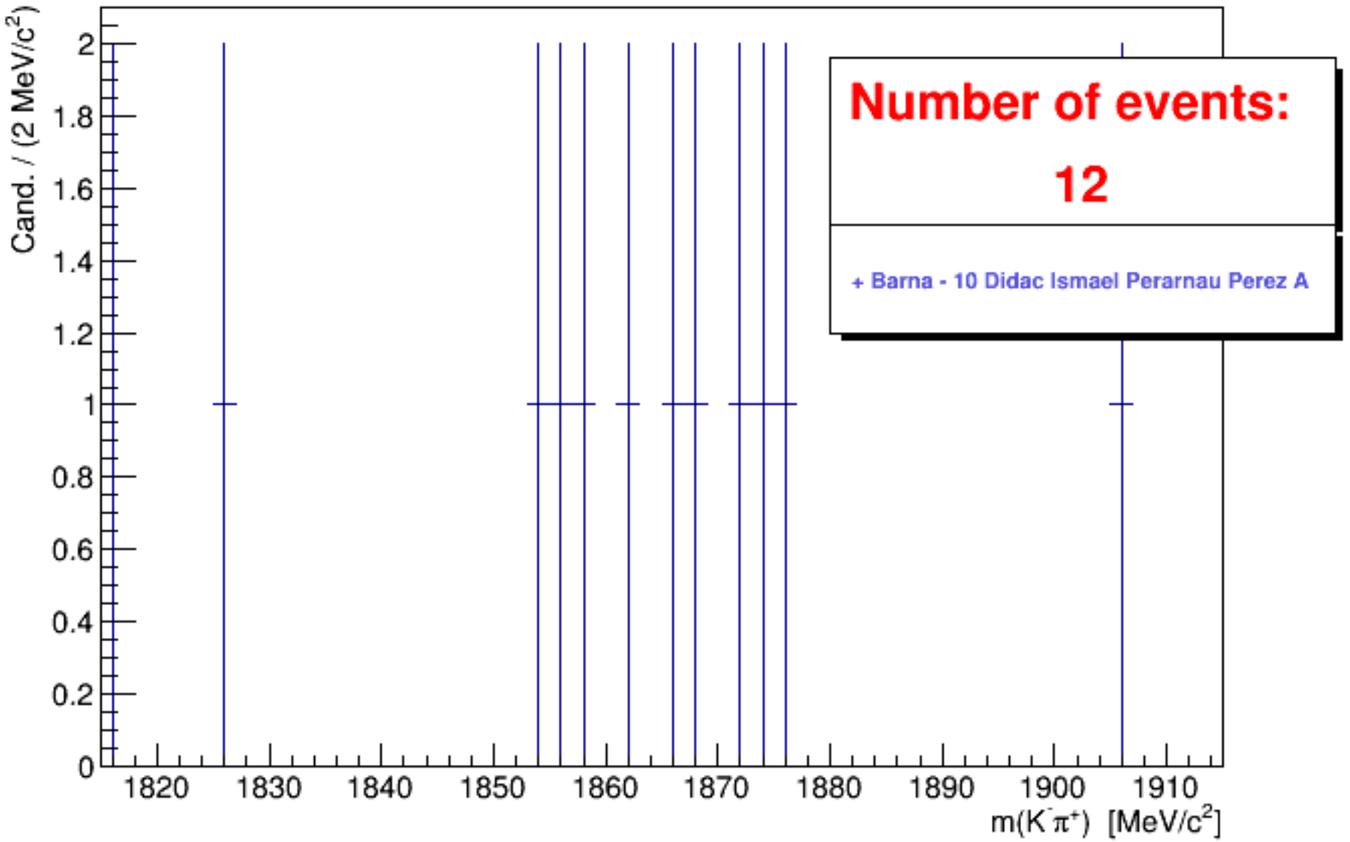


D^0 mass histogram



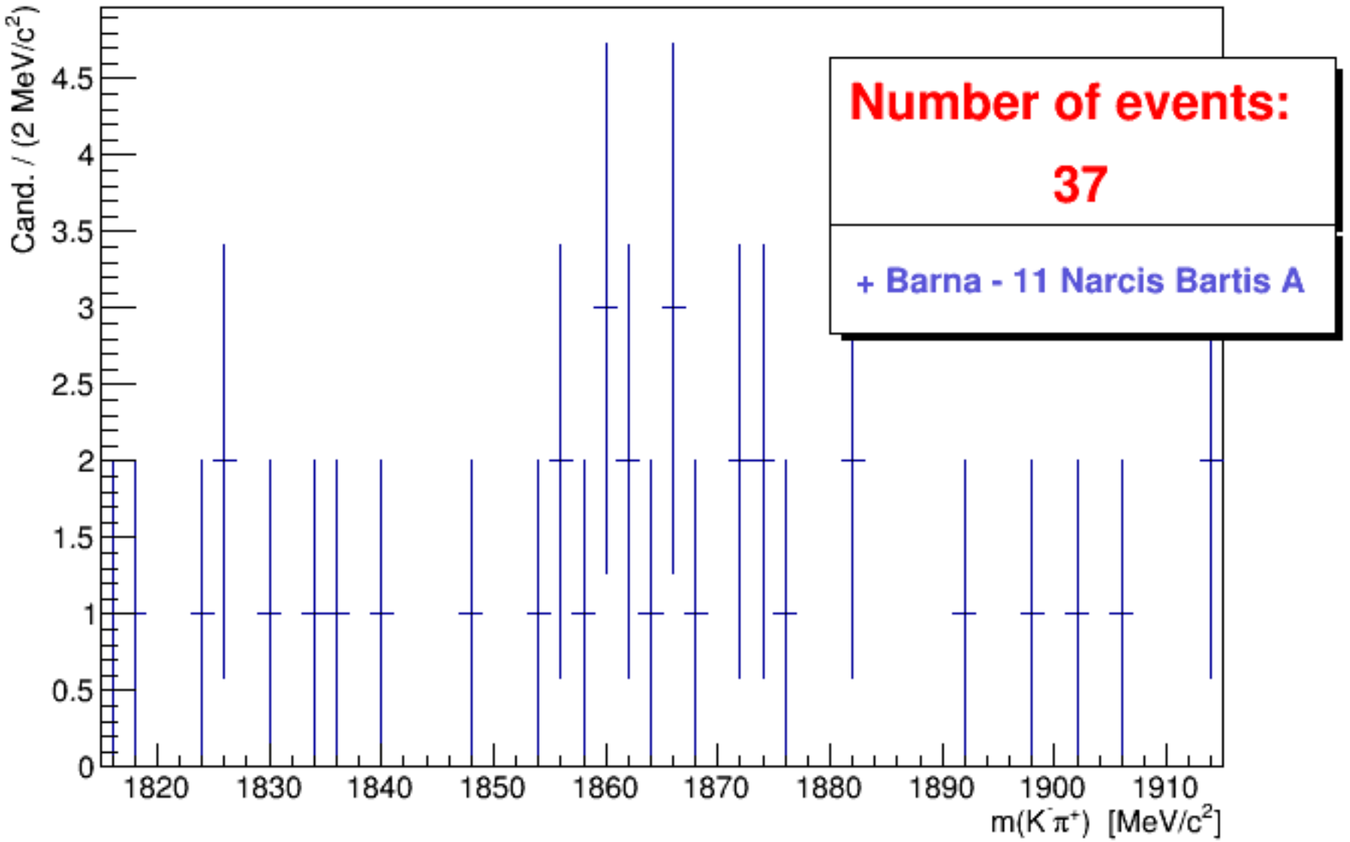
Each student's histogram contains 30 events
Allows them to see the hint of a signal

D^0 mass histogram



Added up for the whole class, it allows students to appreciate power of statistics

D^0 mass histogram



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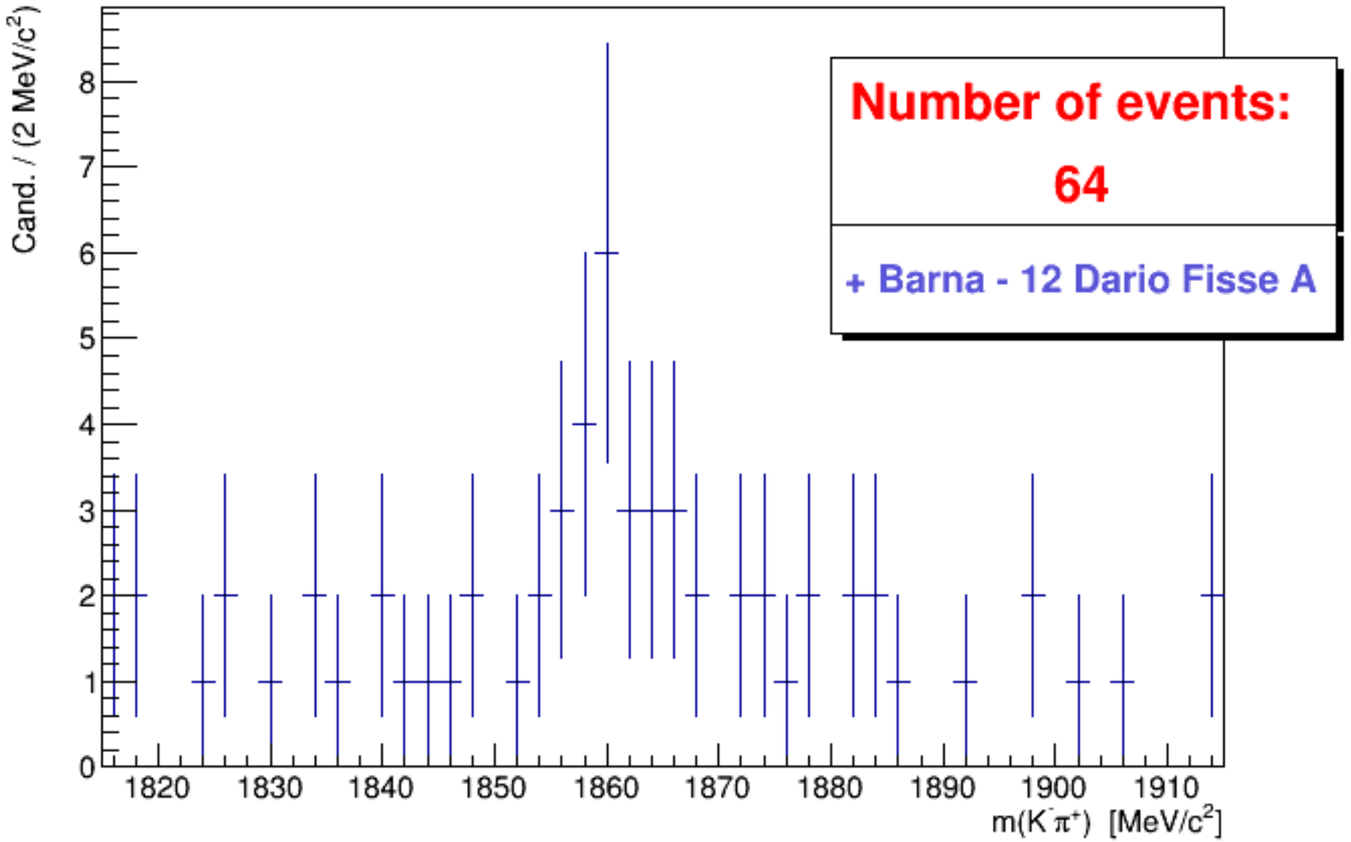

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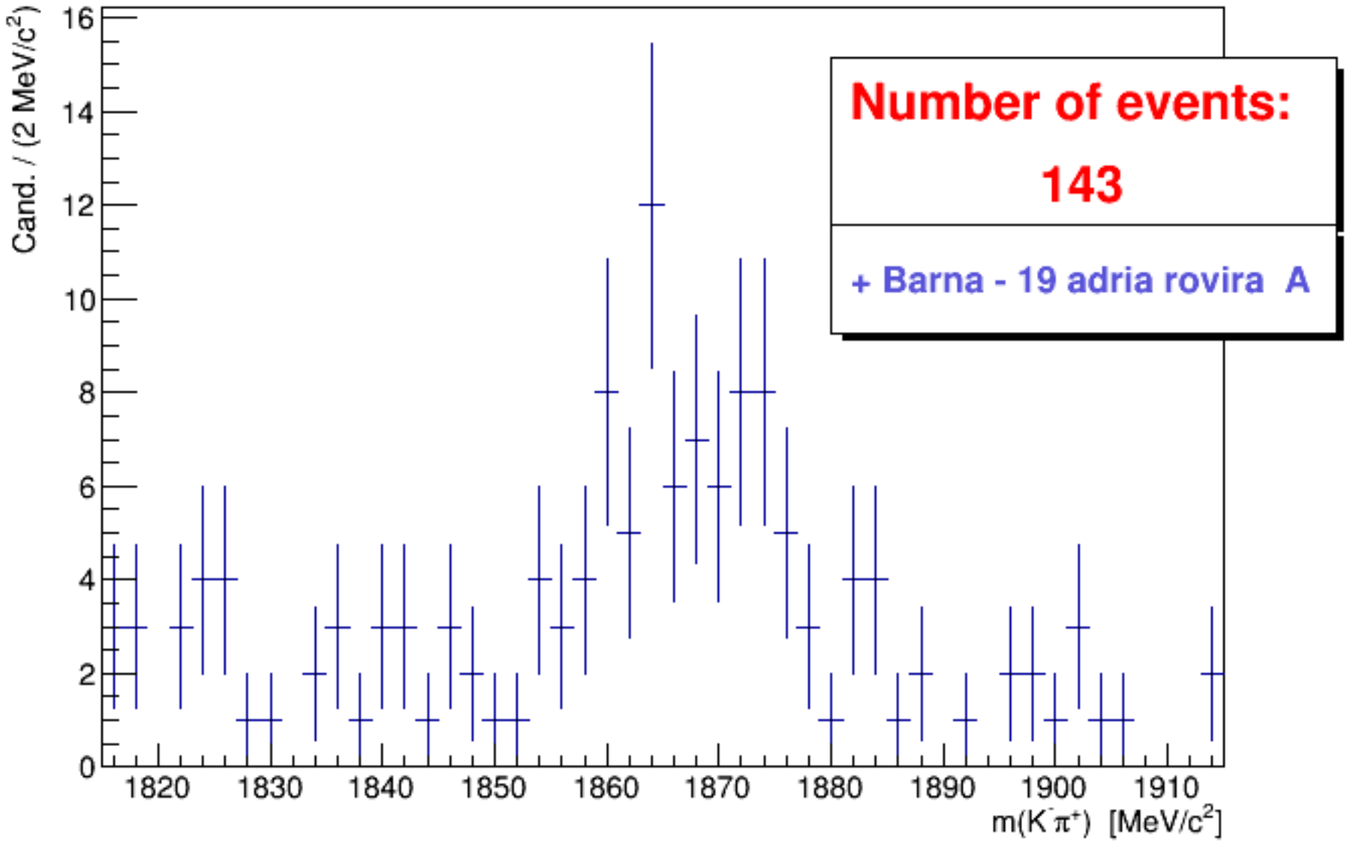

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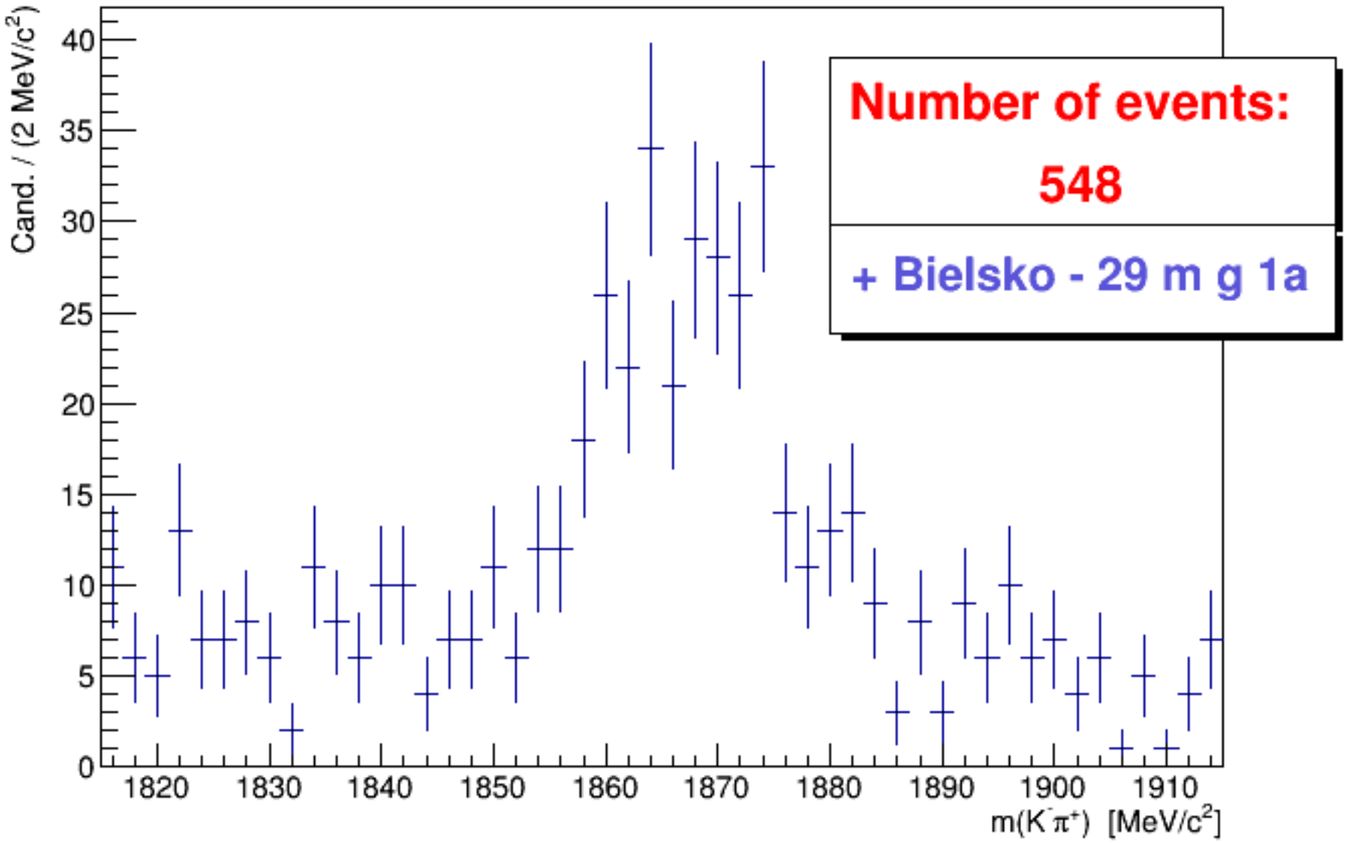

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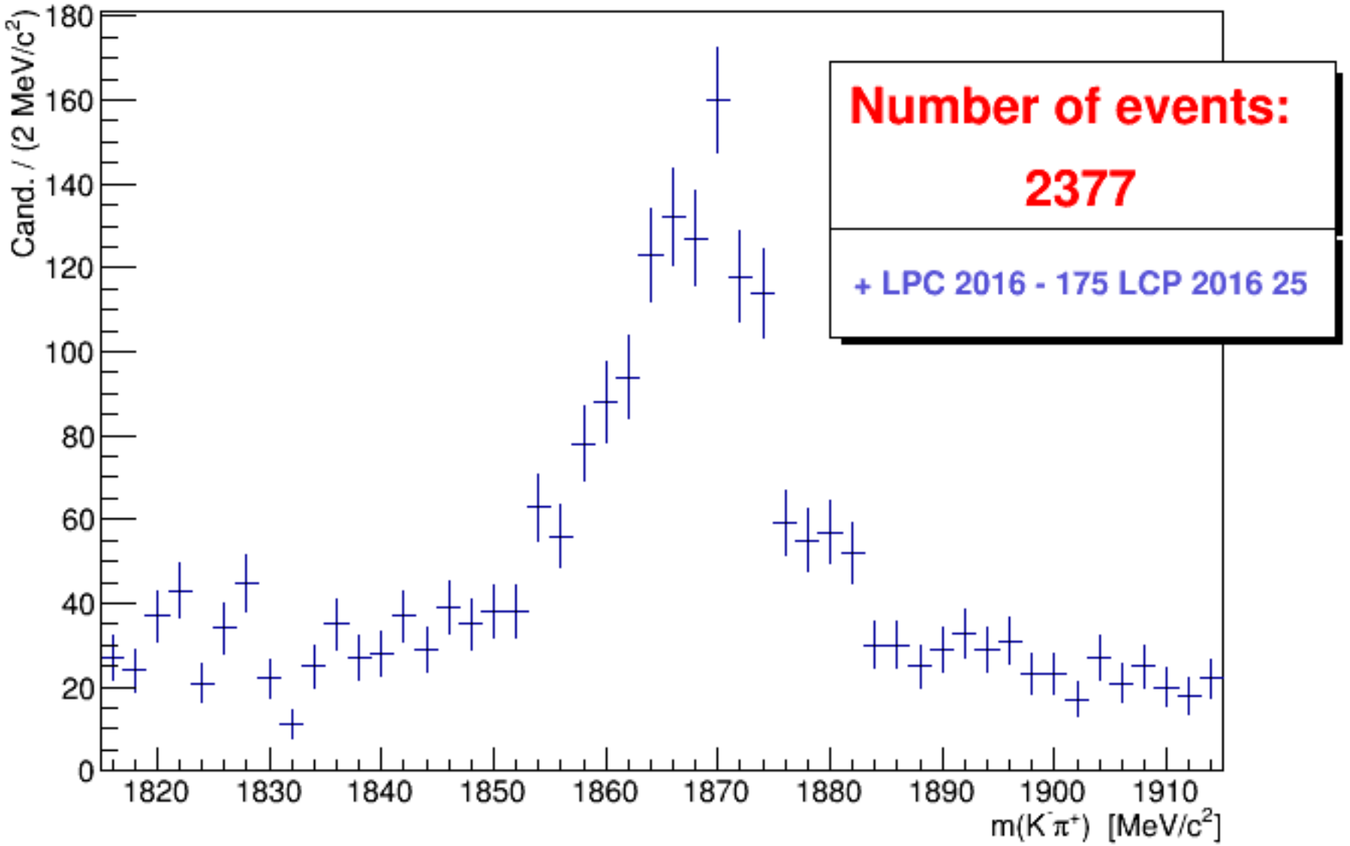

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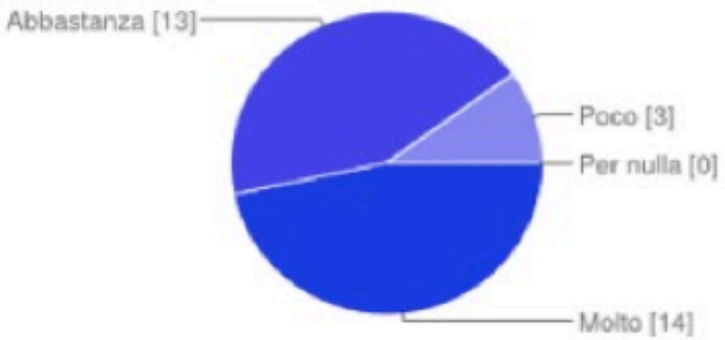
Feedback

Was the event display easy to use?

Very easy	6	20%
Easy	20	67%
Not so easy	4	13%
Too hard	0	0%

Was the event display useful to understand how particles in HEP experiments are selected?



Very useful	14	47%
Useful	13	43%
Not so useful	3	10%
Useless	0	0%

Important to collect feedback from students and teachers, plays a big role in future development of exercises

Future plans and developments

Continue to improve existing measurements

=> New event display technologies are being investigated to make it even easier to install/run the masterclasses at each instutute

Add additional measurements/exercises

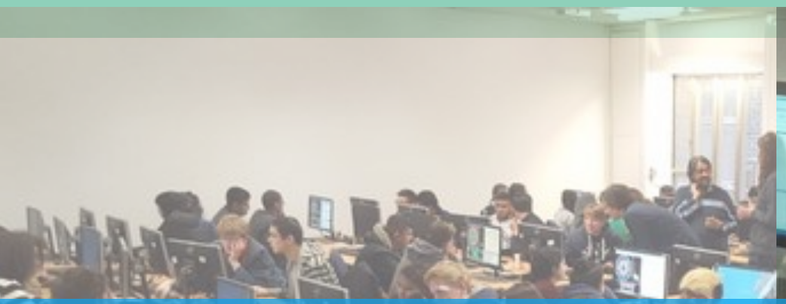
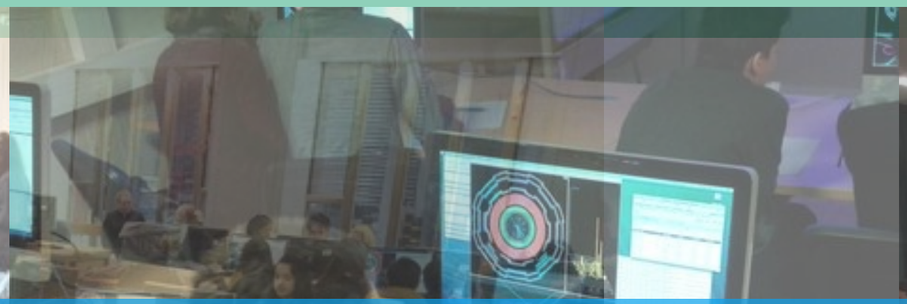
=> LHCb is working on an exercise which would allow the students to “discover” CP violation in B meson decay

=> Extend ATLAS Z-path to contain SUSY searches

Expand number of countries and schools participating in the masterclasses

After this year’s very successful first try of using Twitter, continue to develop social media presence and integration with the typical student experience of a masterclass day

So in summary…

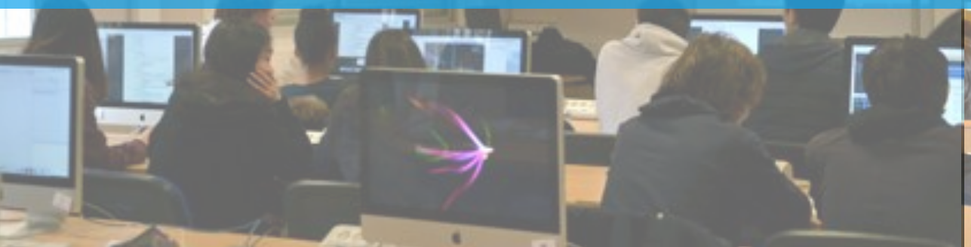



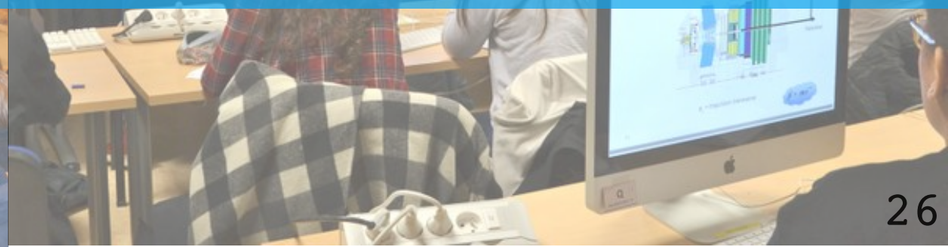

The international masterclass programme is a huge success

Going from strength to strength, bringing physics to tens of thousands of high-school students each year across the world

Team of developers across the different experiments makes it easy to improve measurements or add new ones

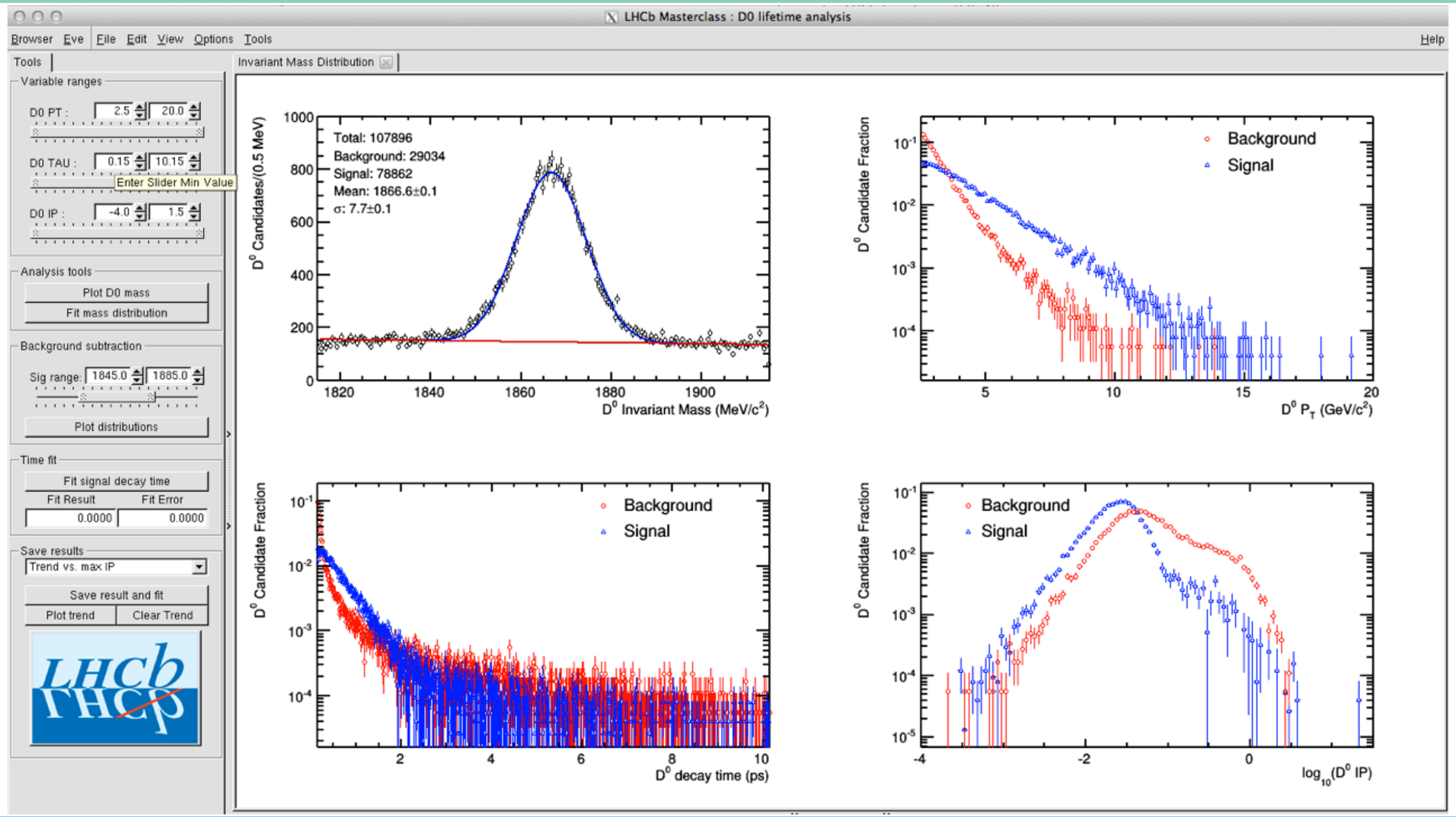
Get involved!





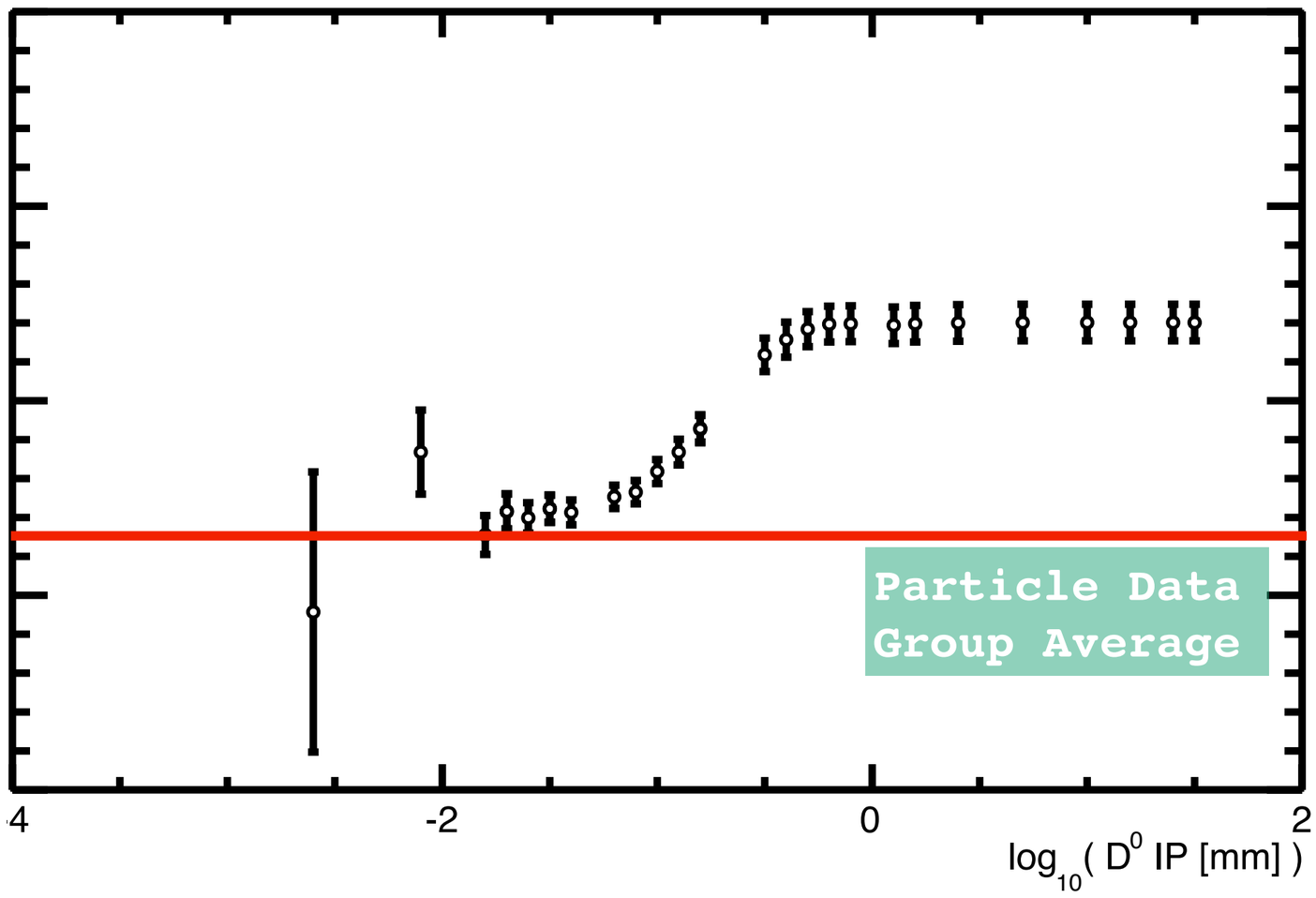
BACKUPS

Measuring the D^0 lifetime



Students are then given a larger dataset, learn to subtract background and make a 1% measurement of the D^0 lifetime

Systematic uncertainties



Students initially measure the wrong lifetime; they then learn to remove D^0 mesons coming from B decays and it improves