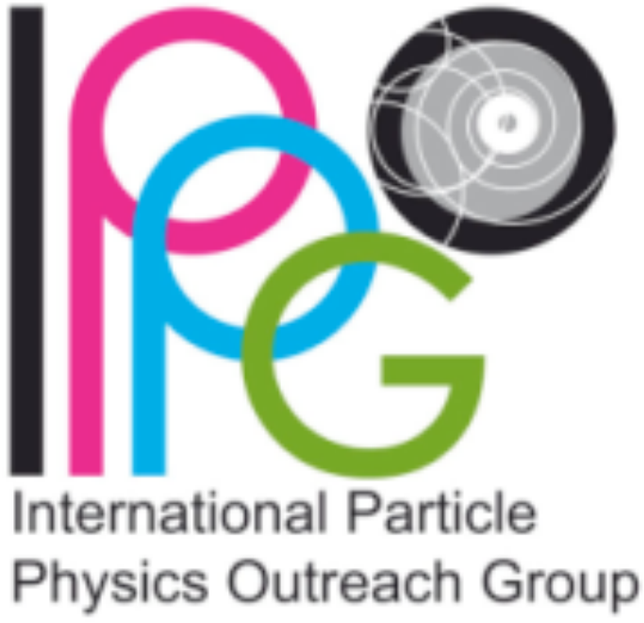


IPPOG International Masterclasses

Katharine Leney

18th April 2017

What is IPPOG?

<u>IPPOG</u>: International Particle Physics Outreach Group

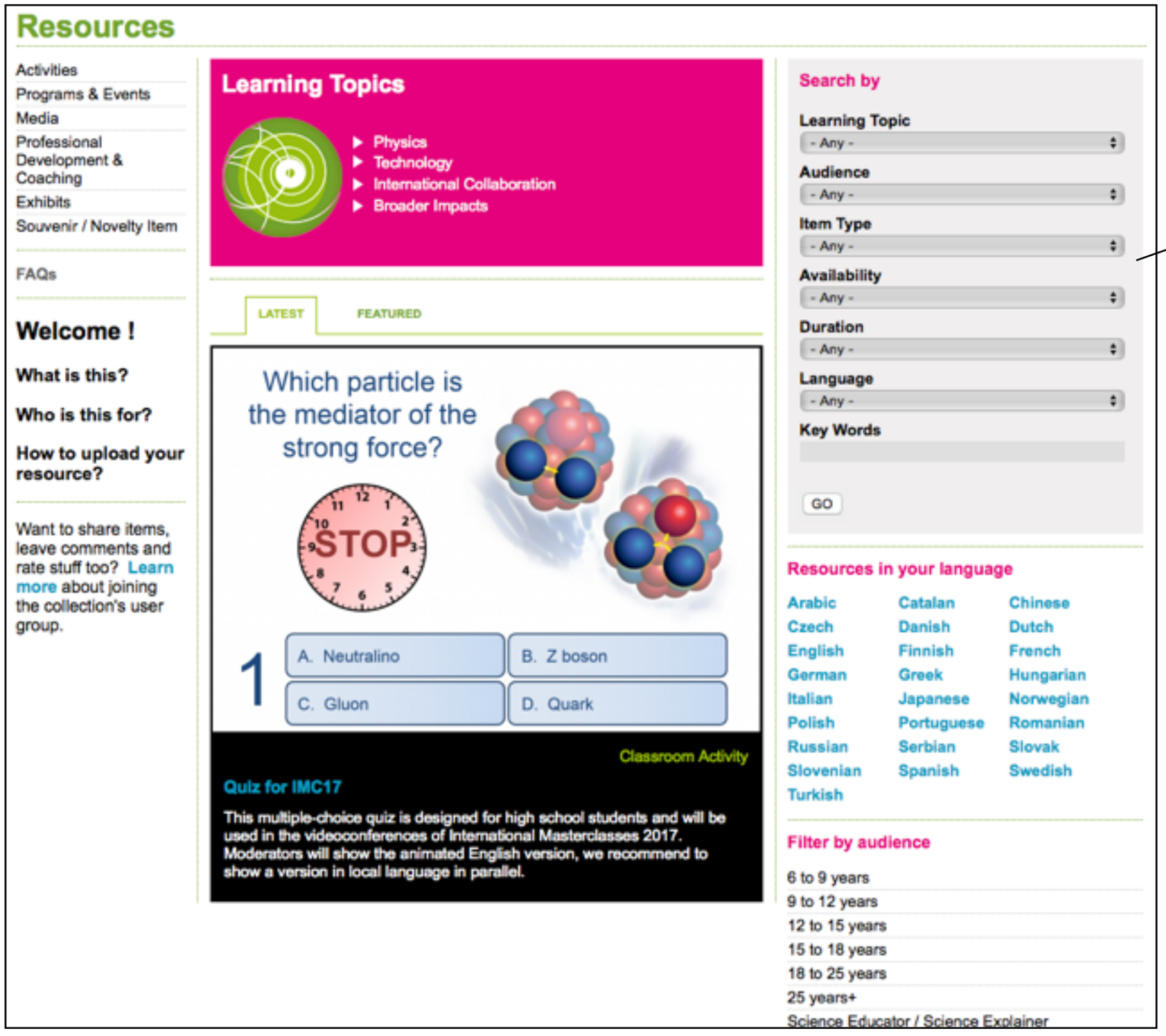
- Network of scientists, educators and communicators.
- Purpose is to raise standards of public outreach and science education efforts.
- Contribute to global efforts in:
  - Strengthening cultural awareness.
  - Understanding and support of particle physics and related sciences.
  - Inspiring the next generation of researchers.

International Particle
Physics Outreach Group

- Organise and support the International Masterclasses programme.
- Are a source of resources for all particle physics outreach.

IPPOG Resources

http://ippog.org/resources



Filter by topic, audience, type of resource (movie, exhibit, factsheet etc), duration, language

IPPOG Resources

e.g. Show me “games” about “Physics” in “English”

Results

THE LHC AND THE HIGGS BOSON: COMMUNICATING SCIENCE

steven.goldfarb@cern.ch

use To download

Buried about 100m below the French / Swiss countryside, between the Alps and the Jura Mountains, is a 27km tunnel housing the Large Hadron Collider at CERN. This chain of superconducting magnets accelerates protons to very high energies and then collides them at four different places....

Presentation, Game
English

QUARK-TZEE DICE GAME

Helio Takai

Quark-Tzee is a dice game that plays following Yahtzee rules. The idea is that you start with 6 dies, and you can roll three times. On each roll you keep the dies that you consider the best to make certain particles. First roll - all dies, keep as many you want to create mesons and baryons; ...

Game
English

THE QUARK CARD GAME

Helio Takai

use To buy

The Quark Card Game was created to convey students the concept of the Standard Model - the existence of quarks, substructure of mesons and baryons, particle decay, and the concept of color charge.
It addresses the population of students in Junior and Senior years, in the US Educational...

Game
English

CARD GAMES WITH PARTICLES

Judit Csörgo, Tamás Csörgo, Csaba Török

use To buy

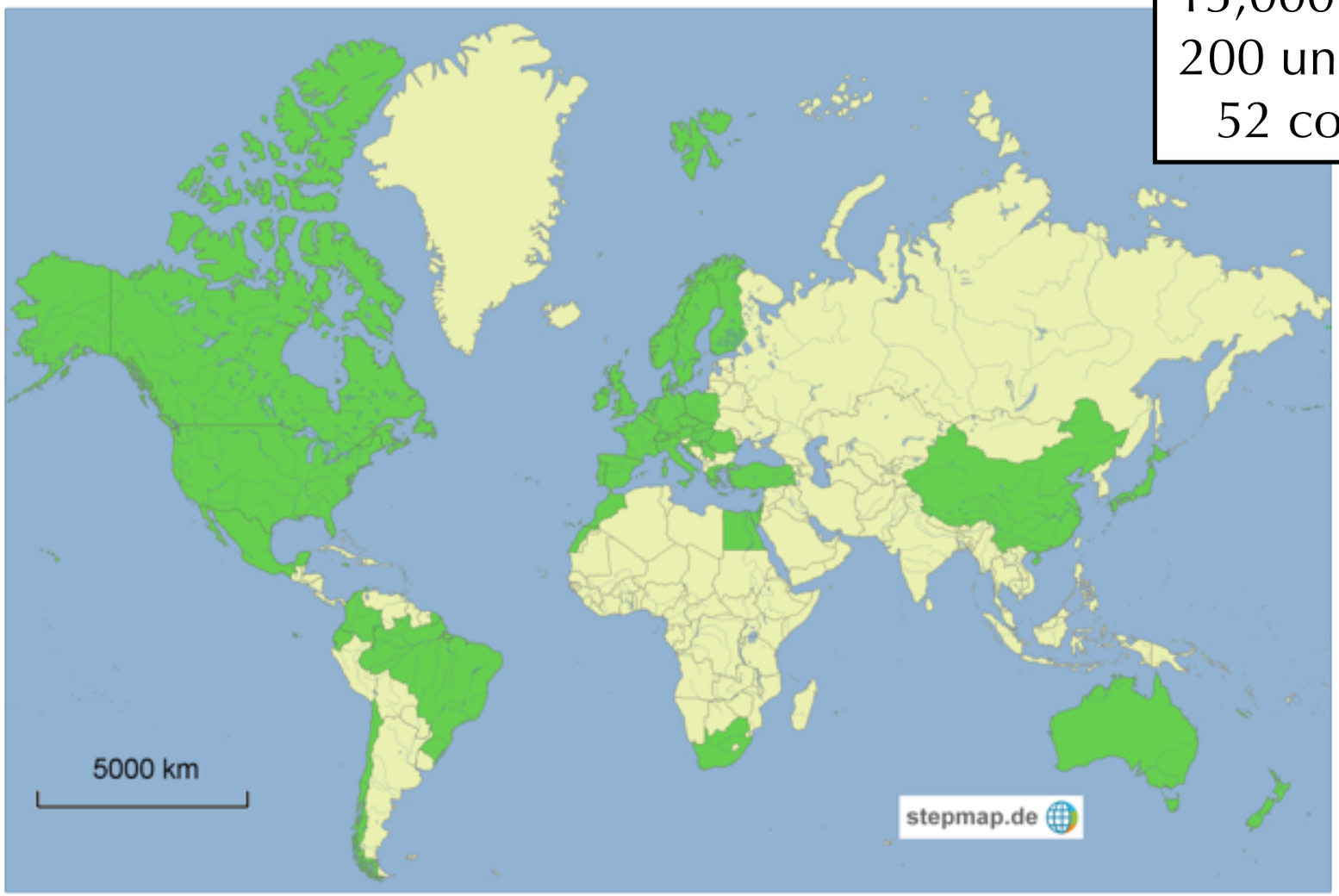
An award winning card game to learn about particles from the standard model. The set includes a book of games with playing cards included. The book explains rules to several different games that can be played of different complexity and for different age groups. Rules of the games follow the...

Game
English, Hungarian

+20 other results

International Masterclasses Programme

2017:
13,000 students
200 universities
52 countries



- Organised by IPPOG (International Particle Physics Outreach Group)
- Runs for 6 weeks every year in March/April.
- High school students (15-19) get to be “Researchers for one day” at their local university or research institute.

INTERNATIONAL MASTERCLASSES
hands on particle physics

Why Masterclasses?

- Hands-on activity using the same tools and data as real scientists.
- Gives students an insight into what research actually involves.
- Teaches students something *beyond* what they would learn in the classroom
- Helps cement their understanding of more basic concepts.

- Learn about collaboration and team-work.
- Students get to meet other students from local schools.
- Fosters links between schools and universities

Typical Masterclass Programme

- Lectures to introduce particle physics, experiments and detectors.

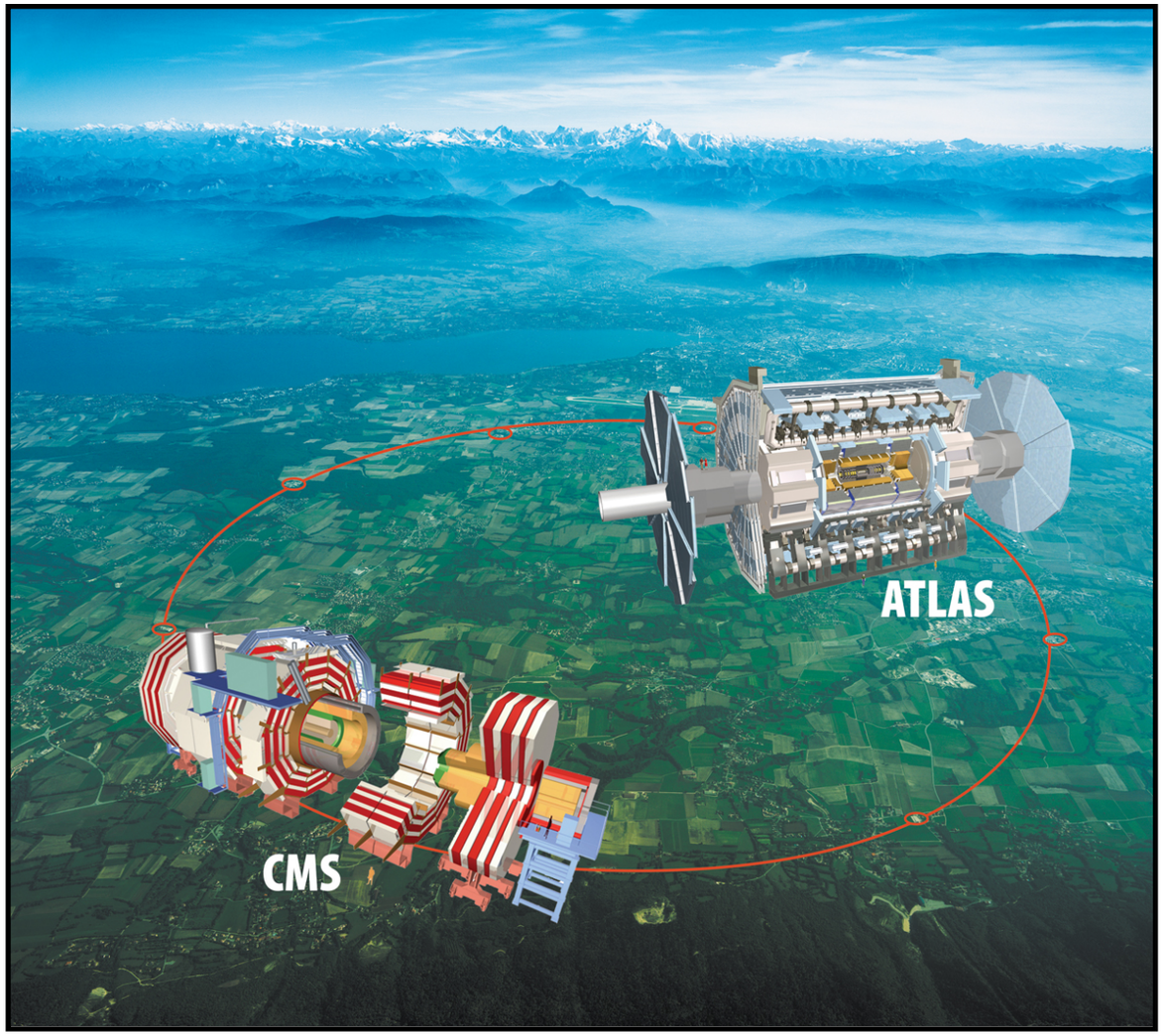
- Sometimes includes a guided tour of local labs (if available/time allows).

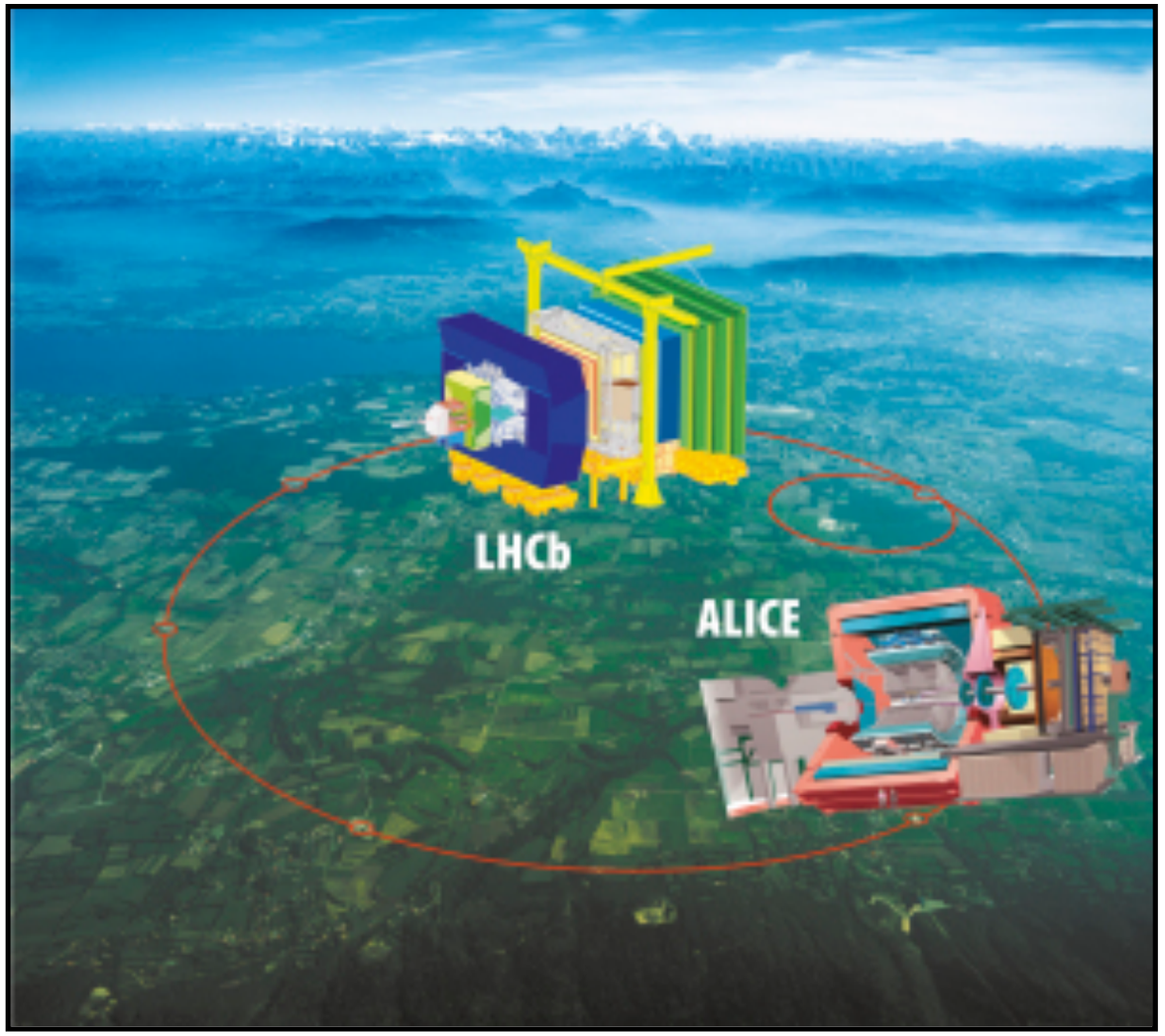
- Lunch with lecturers, staff, PhD students.

- Hands-on session where students work in pairs to make measurements on data.

- Discussion and combination of results, together with other institutes from around the world, via video conference.

Hands On Session

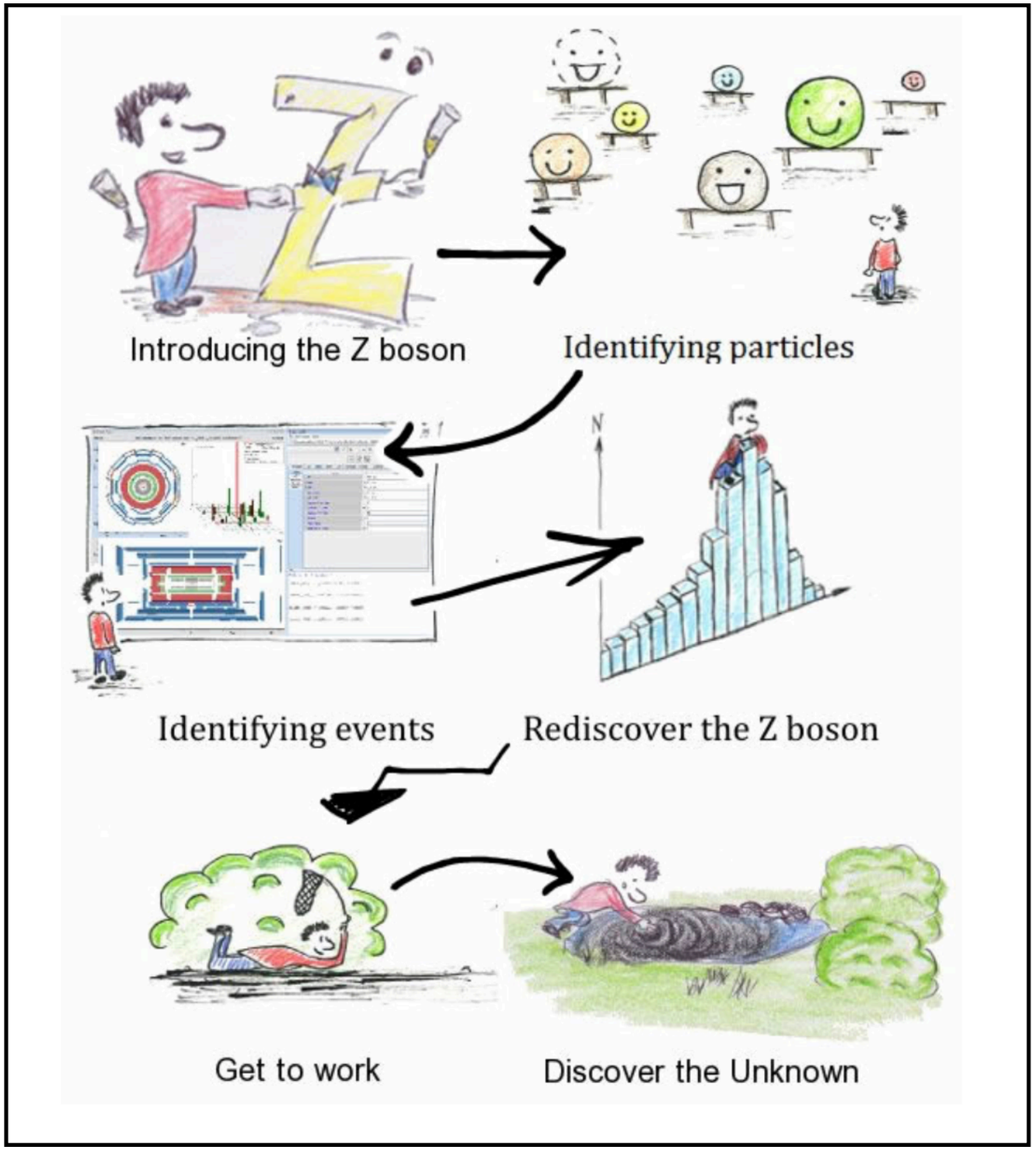




Students analyse data and do a measurement using real data from one of the four main experiments at the LHC.

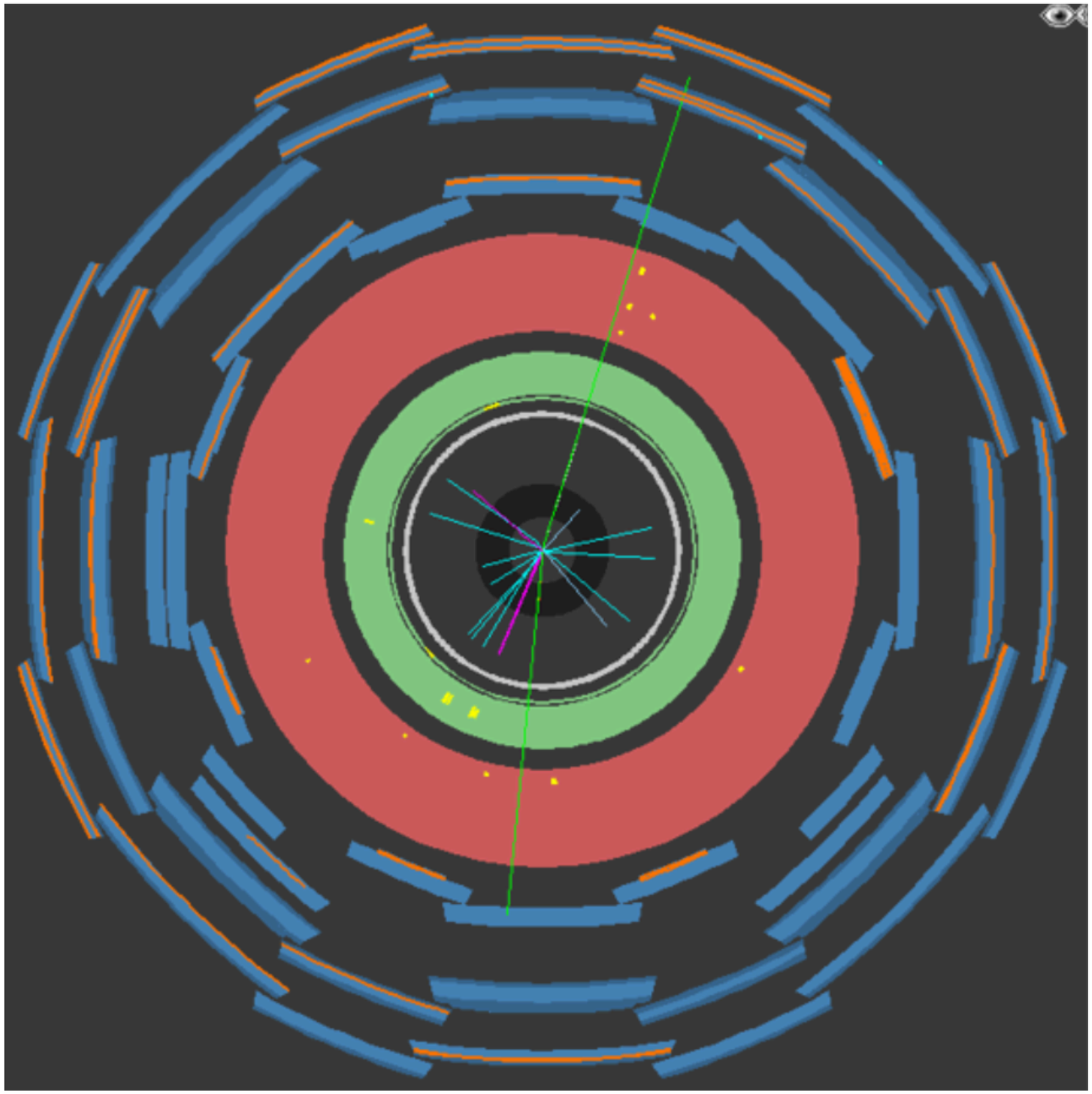
Example: ATLAS Z Boson Measurement

- Search for pairs of leptons (e/μ) or photons, and events with 4 leptons.
- Use di-lepton invariant mass spectrum and identify J/Ψ, ϒ, Z-boson, and simulated Z′ events.
- Search for Higgs bosons in $H \to \gamma\gamma$ and $H \to ZZ \to \ell\ell\ell\ell$ events.



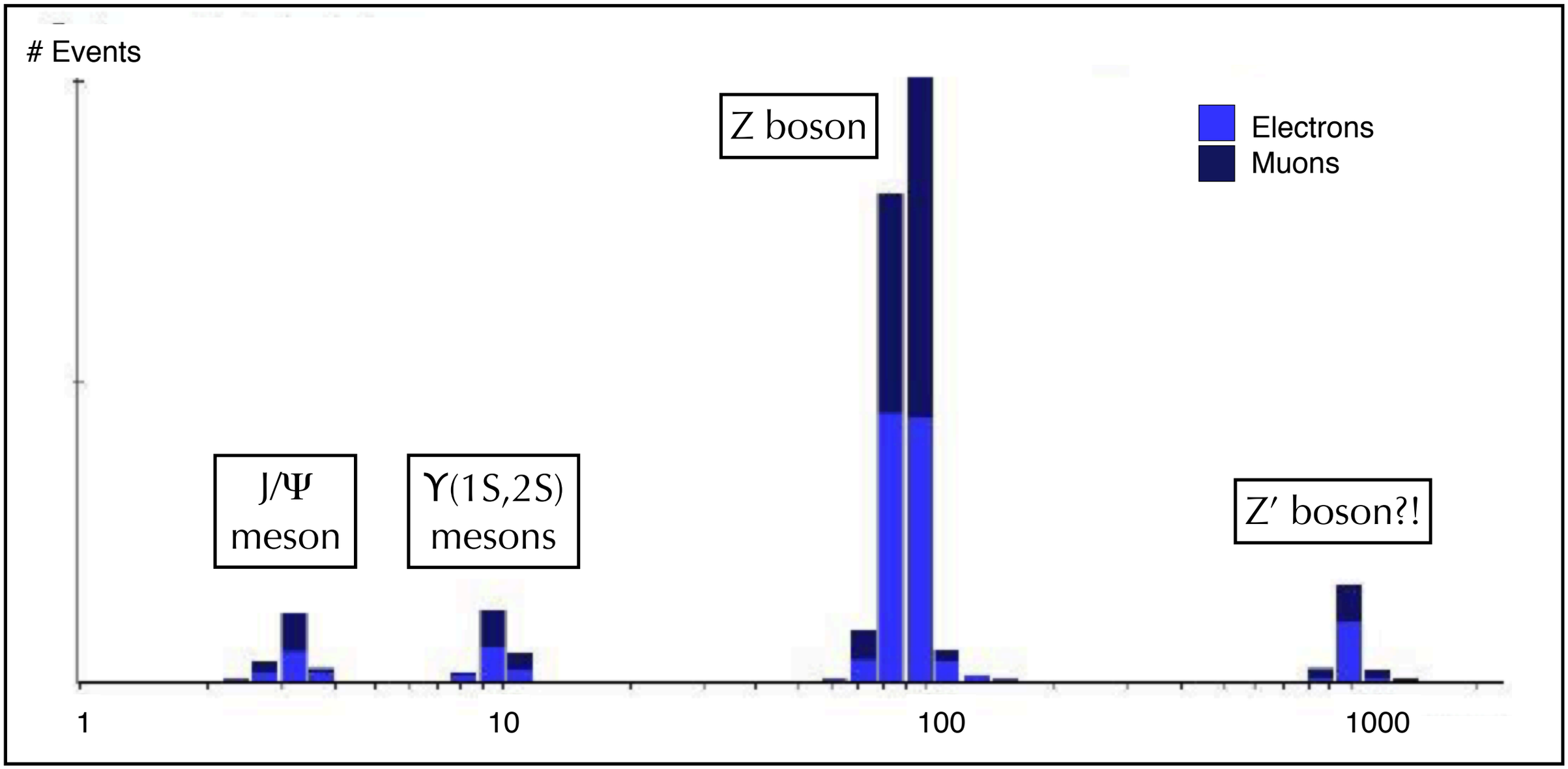
ATLAS Z Boson: Identifying Events

- Learn what signatures different particles leave in the detector.
- Use visualisations of events to identify different processes.
- Calculate the invariant mass of the two "interesting" particles.



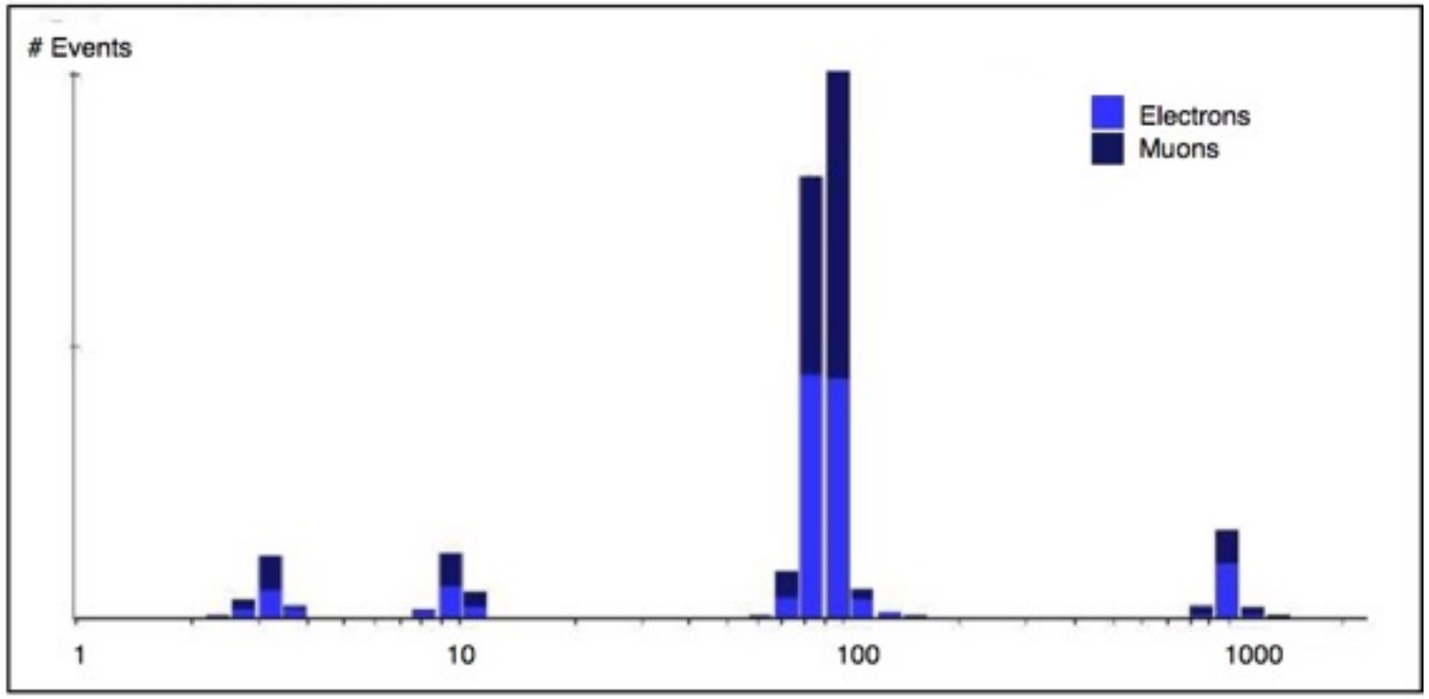
ATLAS Z Boson: Analysing Results

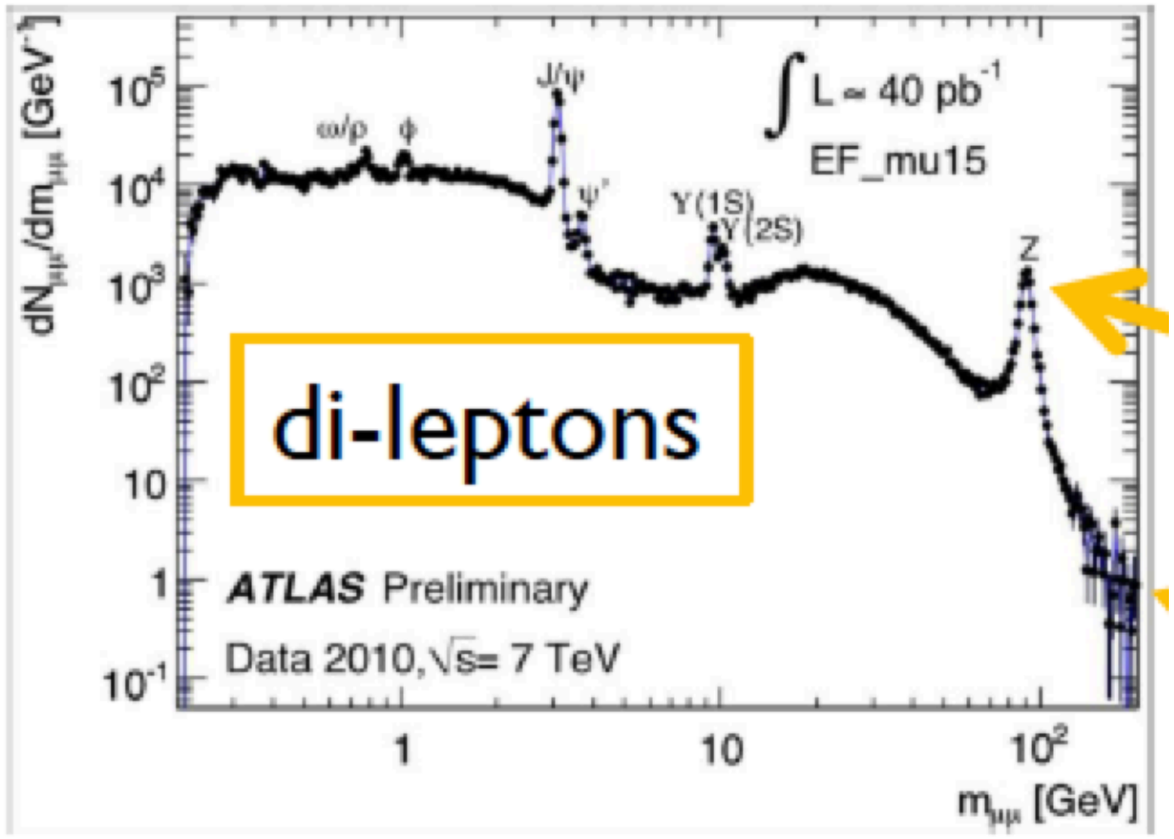
- Create a histogram of invariant masses of all $e^+e^-/\mu^+\mu^-$ pairs.
- Identify the different resonances/particles.



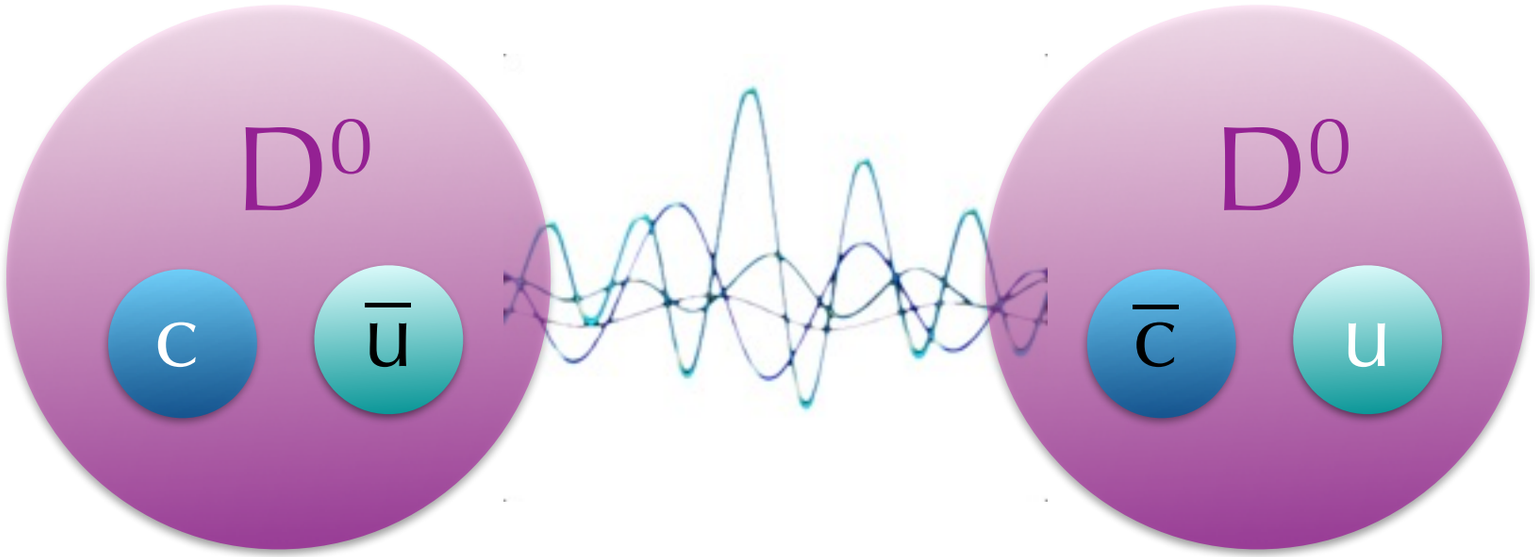
ATLAS Z Boson: Analysing Results

- Compare to ATLAS collaboration results.
- Discuss how with more data (and time and resources!) we can reduce the uncertainties to make more precise measurements.

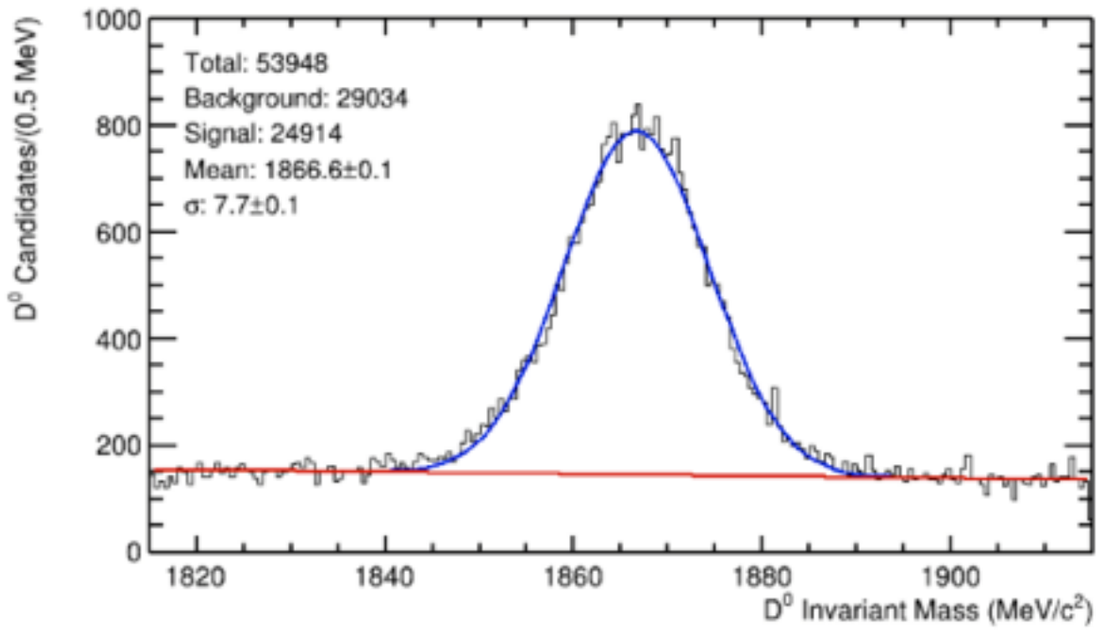




Example: LHCb D^0 Lifetime Measurement



Measurement uses real $D^0 \to K\pi$ events collected by LHCb during 2012 data-taking ($\sqrt{s}$ = 8 TeV)

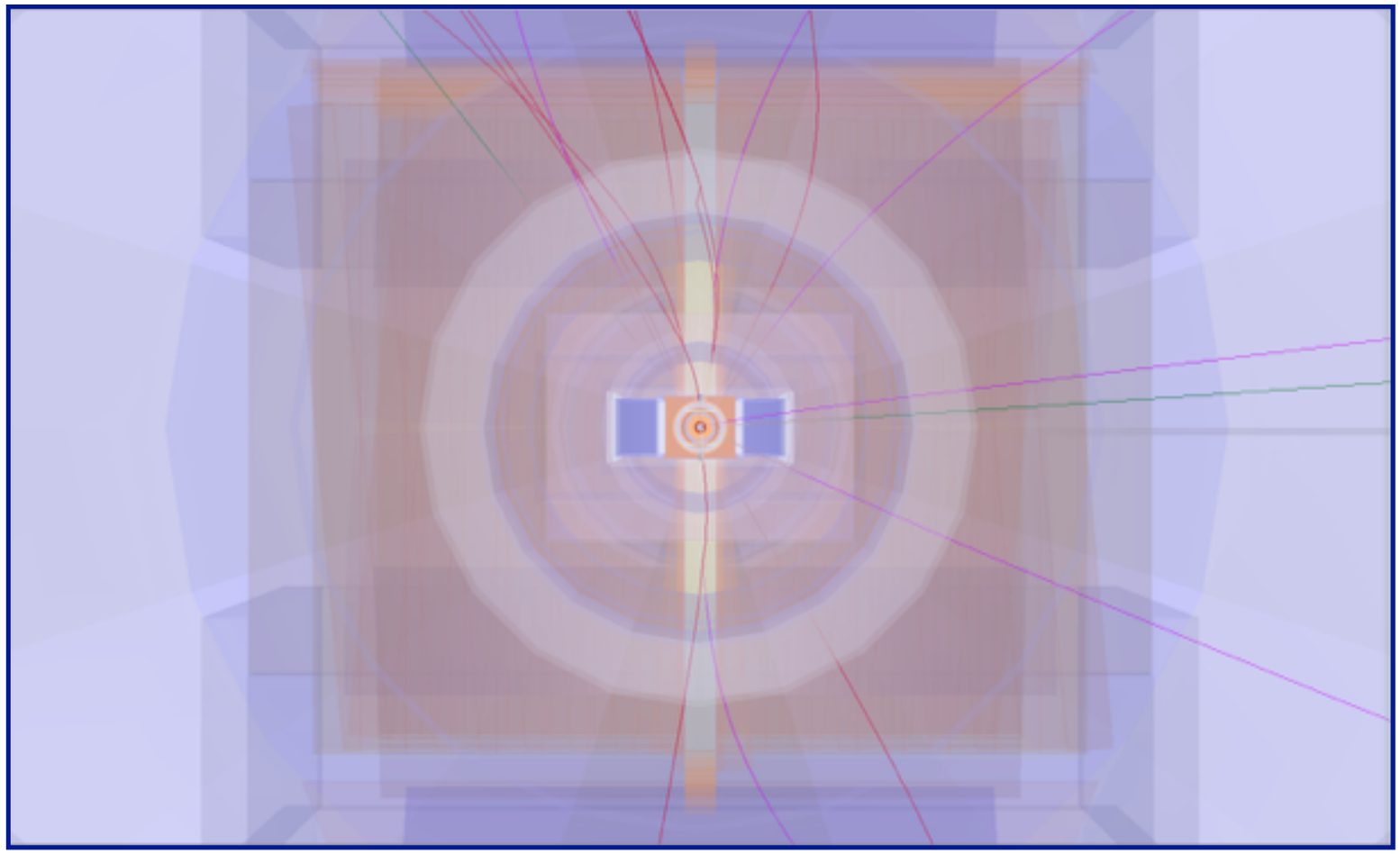


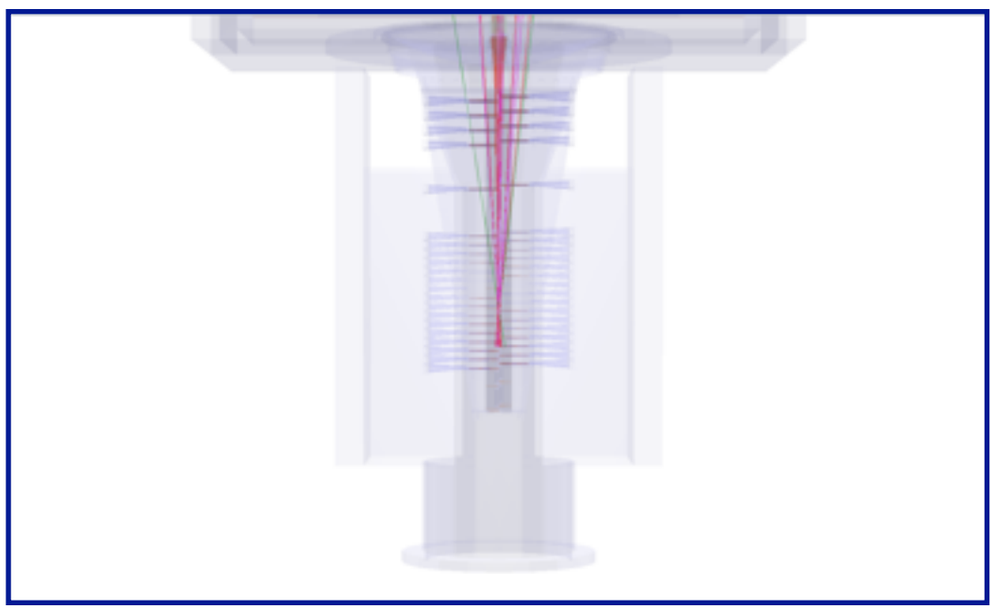
Students are introduced to the concepts of:

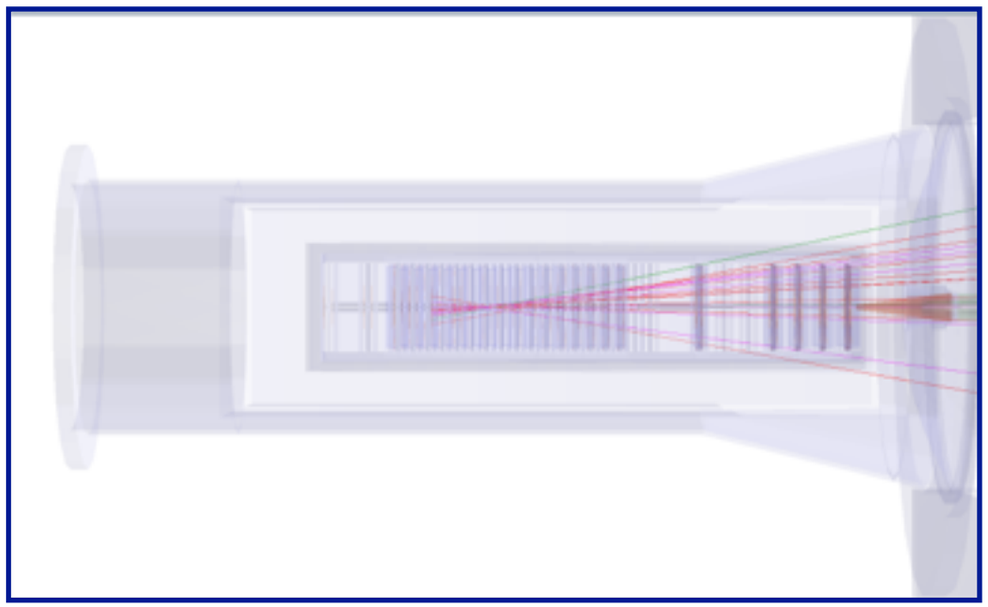
- Particle lifetimes:
  - Ranges, e.g. Z boson has lifetime of 10^{-25} seconds, proton has lifetime > 10^{29} years)
  - How to measure these experimentally (lifetime ⟺ decay length in the detector)
- Particle oscillations (e.g. D^0 oscillations between charm/anti-up and anti-charm/up states)
- Anti-matter; why it's important and what we can learn from it

LHCb D^0 Lifetime: Identifying Events

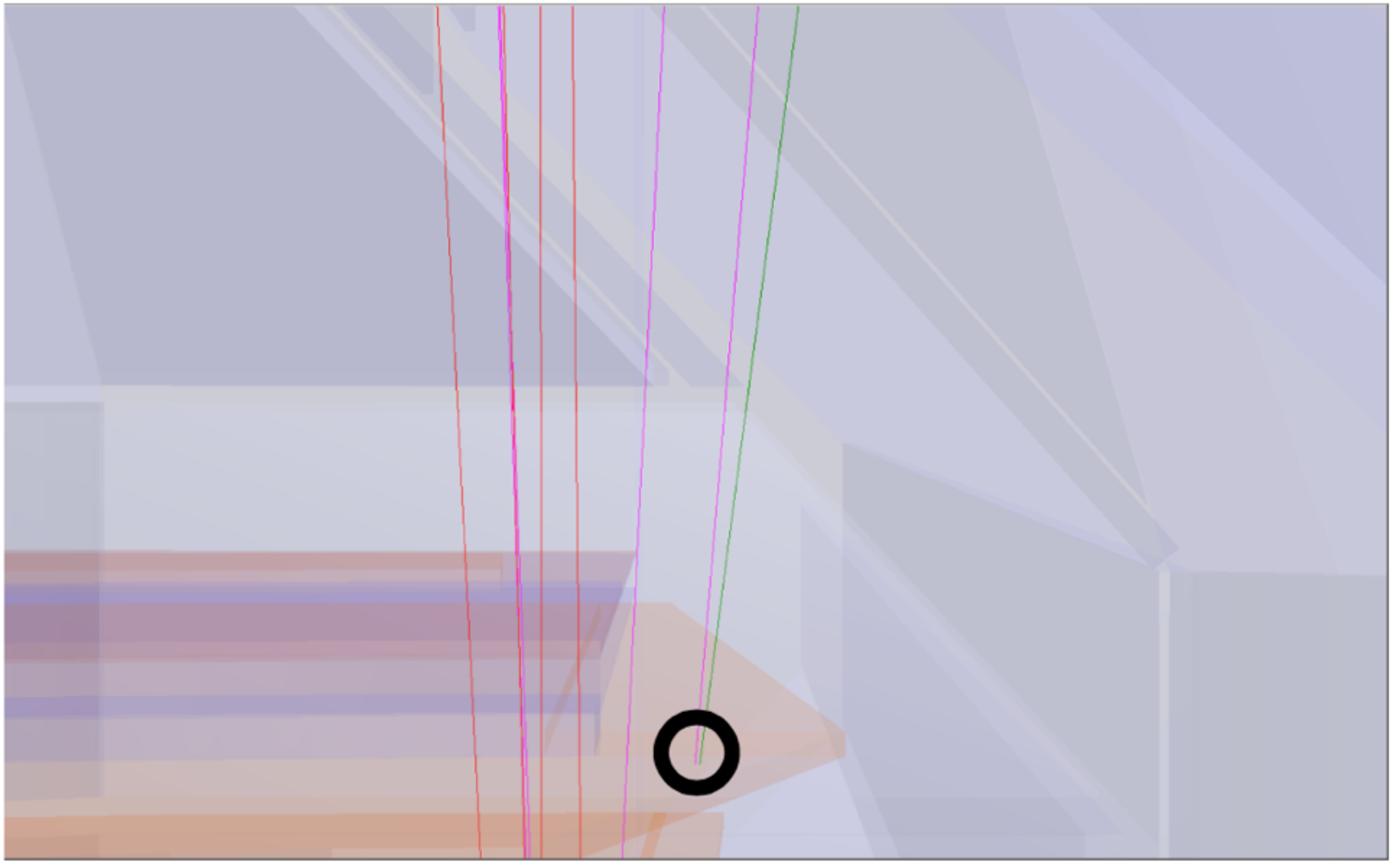
- Students use event displays to identify D^0 decays.
- Tools are provided so that they can zoom in around the interaction region to look for displaced vertices.
- Tracks are colour-coded to aid with identification.



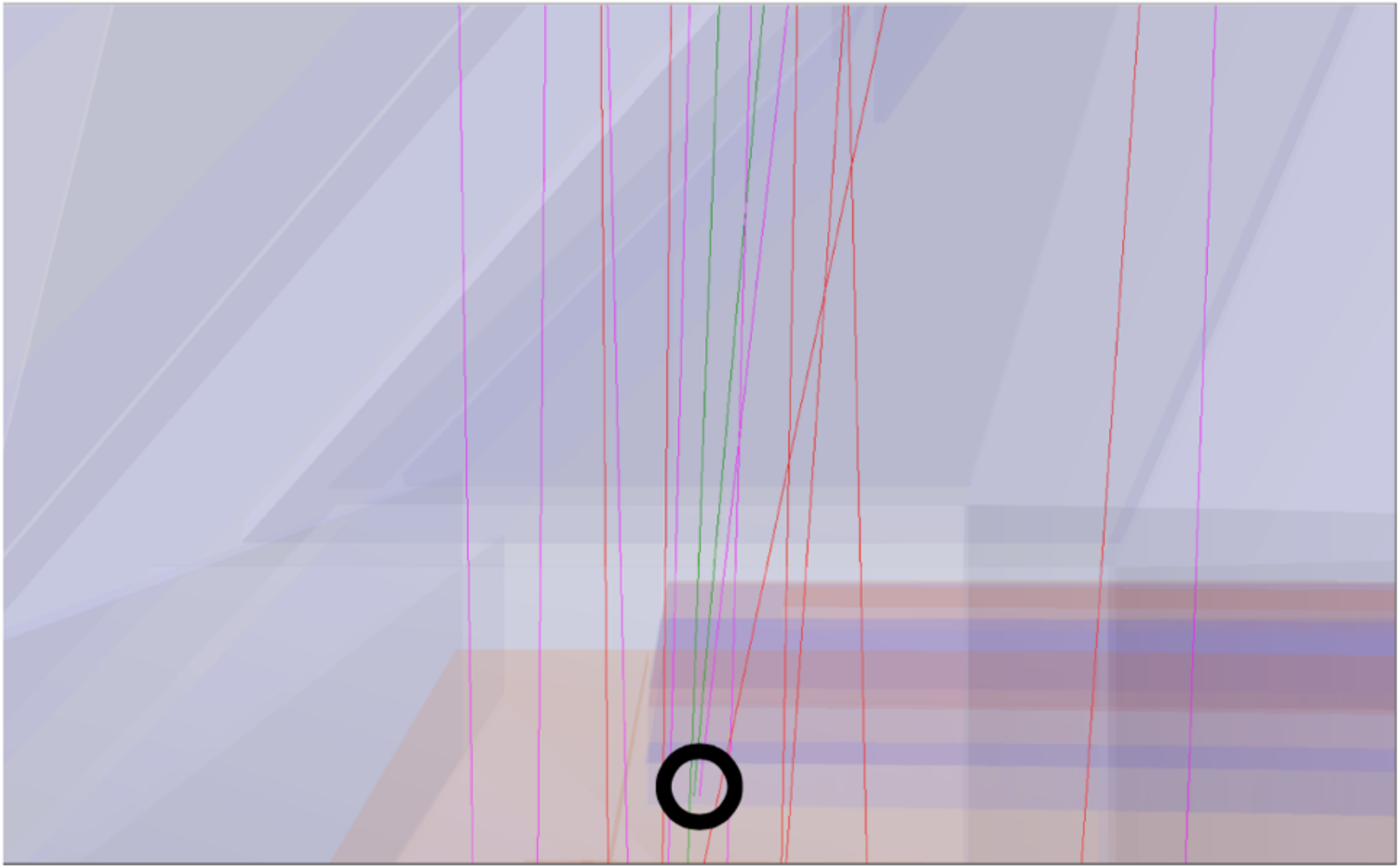




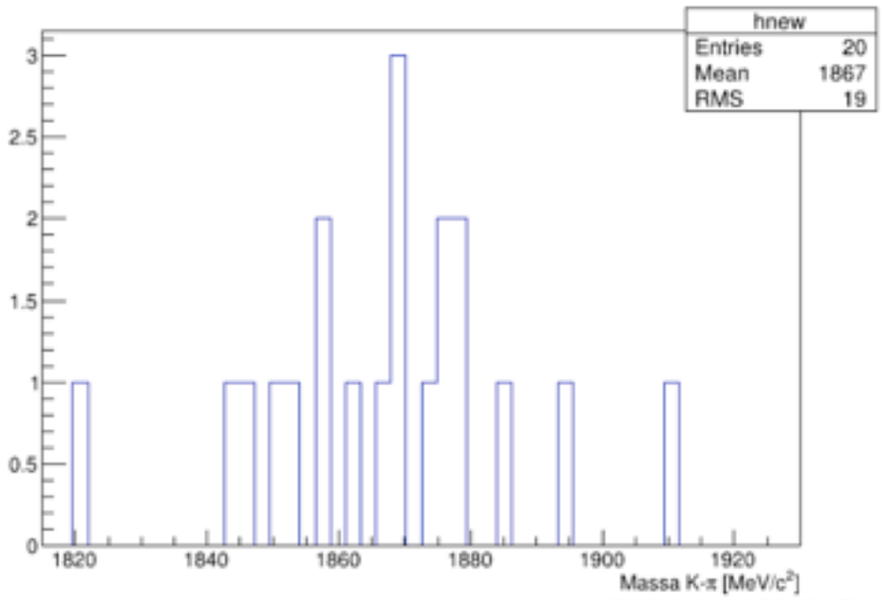
LHCb D^0 Lifetime: `Easy' Event



LHCb D^0 Lifetime: `Hard' Event

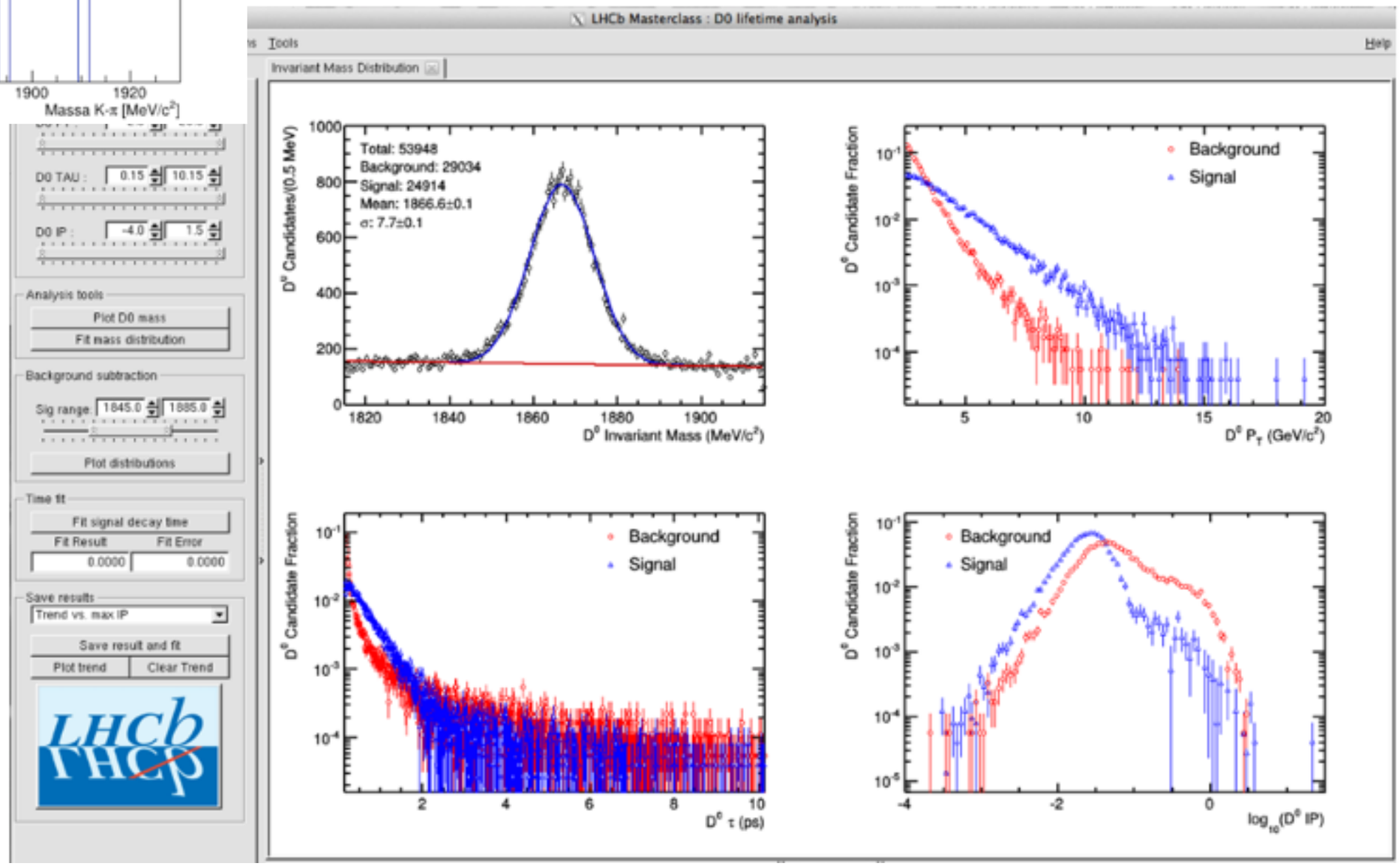


LHCb D^0 Lifetime: Fitting



- Students create their own plot of the D^0 mass distribution.
- Then given more data to do fits to mass, and lifetime distributions.

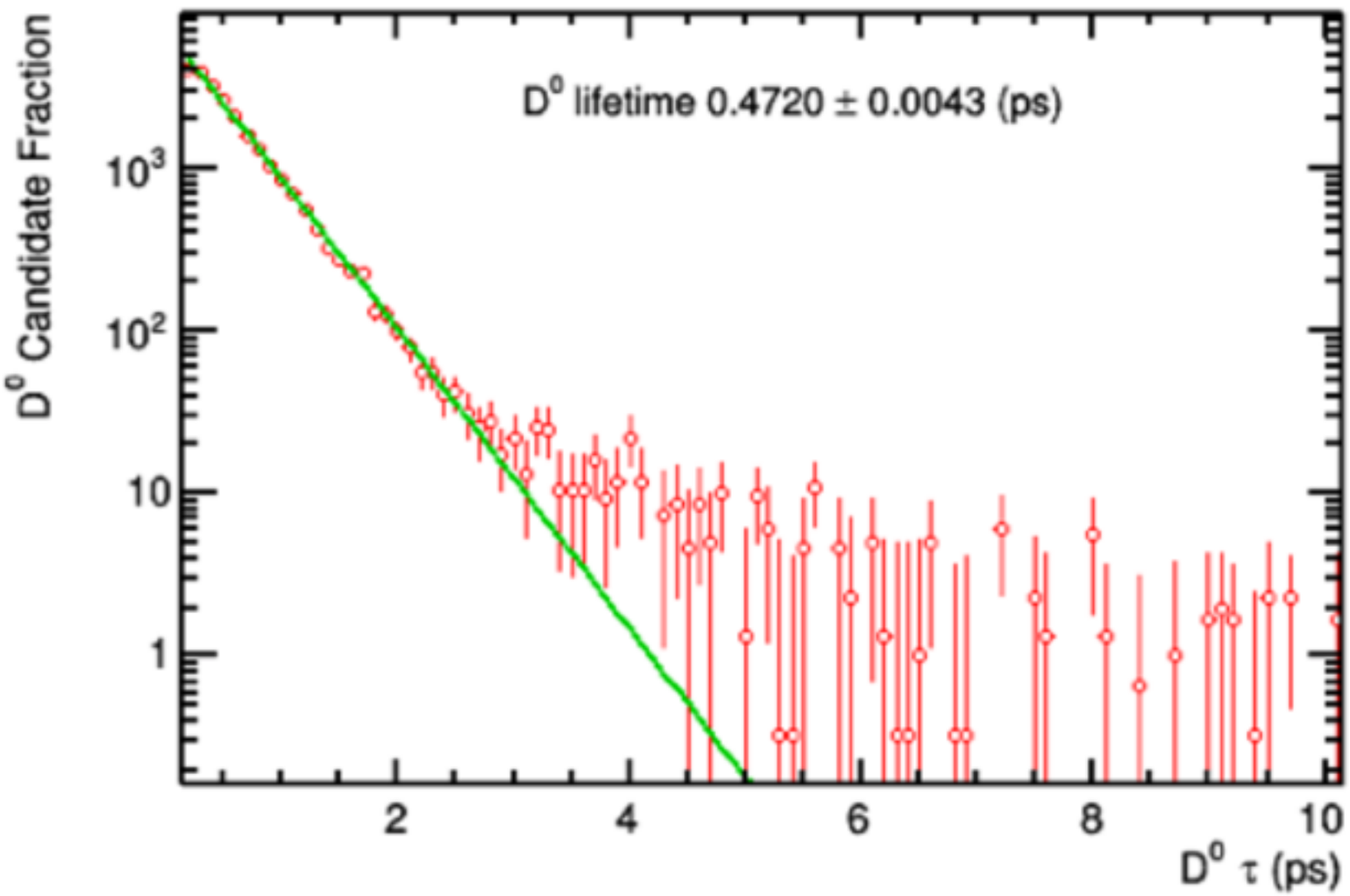
- Can apply cuts on D^0 p_T, mass etc to select data-sample



LHCb D^0 Lifetime: Results

- Students compare their lifetime measurement with those measured by LHCb, and the world average.

- Discussions about systematic uncertainties, and changing signal selection criteria.



Other Masterclass Measurements

CMS: W and Z boson measurements

- Distinguish W from Z boson candidates from event displays.
- Look at ratio of number of W^+ and W^- events
- Make invariant mass plot and identify J/Ψ, ϒ, and Z-boson.
- Find Higgs candidates from 4-lepton and di-photon events.

ALICE: Strange particle

- Identify strange particles (K_s, Λ, anti-Λ) from their decay patterns and calculation of invariant mass.
- Count numbers of strange particles in different centrality regions (Pb-Pb data).
- Calculate strangeness enhancement factors by comparing to p-p data.

ATLAS: W boson measurements

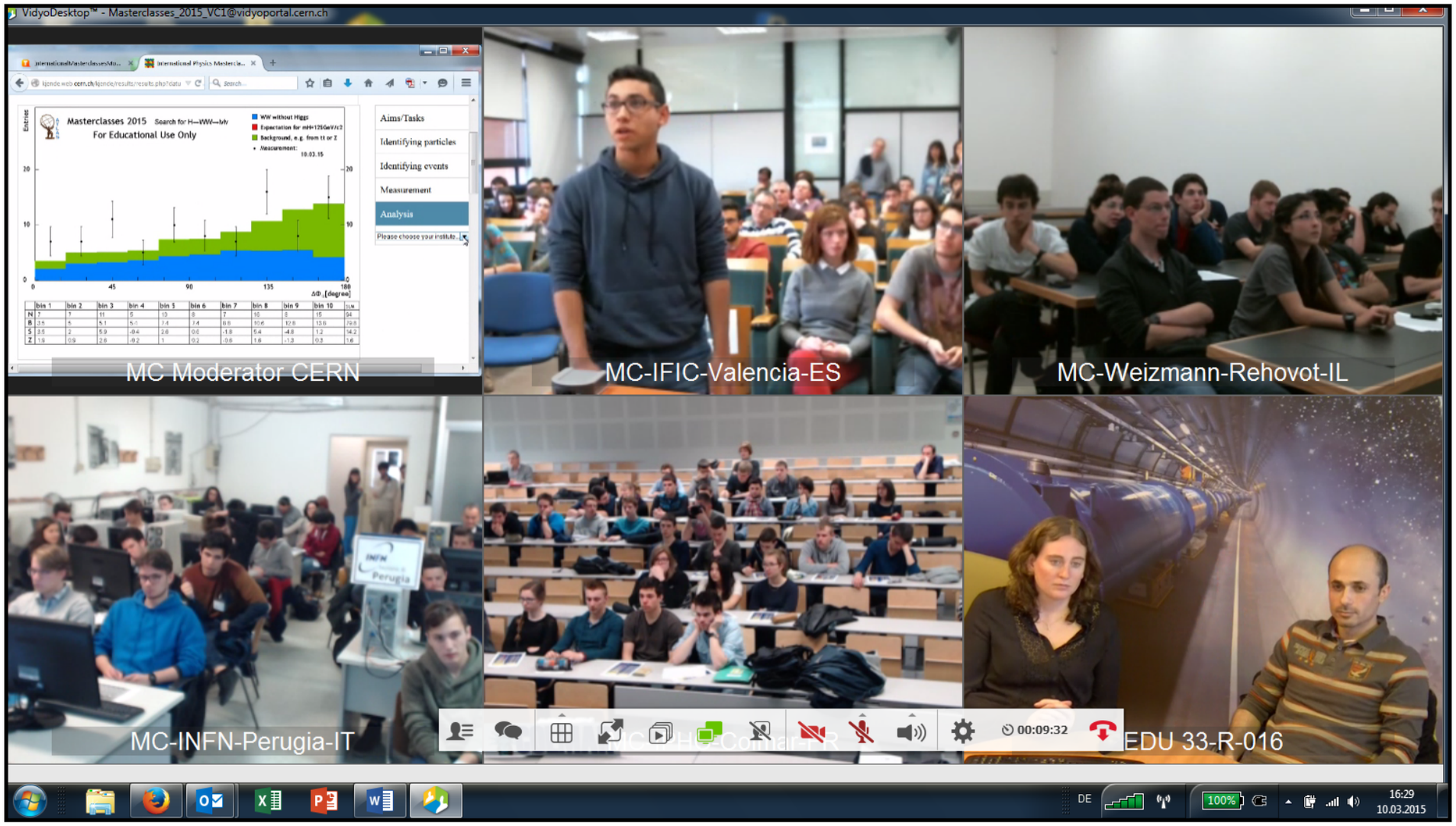
- Look at ratio of number of W^+ and W^- events to explore the structure of the proton.
- Search for Higgs events in $H \rightarrow WW \rightarrow \ell\nu\ell\nu$ decay channel by measuring the opening angle (ϕ) between the charged leptons.

Video Conference with CERN

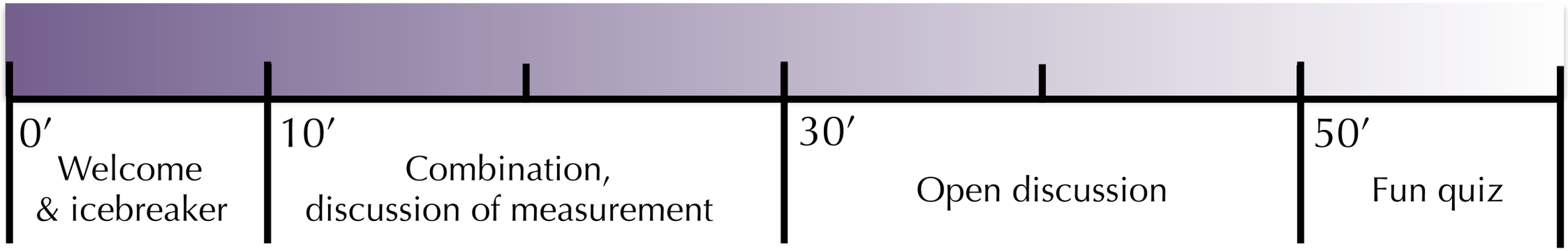
Aims of the video conference:

- Convey the internationality of the event.
- Demonstrate how particle physicists work together internationally.
- Encourage students to share their experiences with each other
- Demonstrate how combining datasets improves accuracy.
- Be a fun end to a long day!

4-6 institutes participating in each session



Video Conference with CERN/Fermilab



- Introduce all groups
- Explain what will happen in the next hour.

- Combine results and summarise.
- Compare to theory/ experimental results.
- Talk about why combining results from different sources is good.
- Questions from students about the measurements.

- Questions, about *anything, e.g.*
  - Big bang, dark matter, black holes etc.
  - How to get into physics.
  - Are we really sitting in the LHC tunnel!

- `Who wants to be a millionaire' style quiz.
- No prizes, just for fun!

Masterclasses in Lebanon

- NEW for Lebanon!!
- Lebanese University have recently joined CMS and we hope will join the International Masterclasses programme for the Spring 2018 round.
  - From our side we will be doing everything we can to help set this up.
  - Feel free to get in contact yourselves to express enthusiasm for participating in the programme!

Address book:

- National contacts:
  - Ahmad Zein-Assi (ahmad.zein-assi@cern.ch)
  - Kate Shaw (kate.shaw@cern.ch)
  - Haitham Zaraket (haitham.zaraket@cern.ch)
- International Masterclasses Programme Coordinator:
  - Uta Bilow (uta.bilow@tu-dresden.de)

الجامعة اللبنانية
Lebanese University

Summary

- Masterclasses are an excellent way to engage students and inspire them to study Physics at a higher level.
- Very rewarding experience, both for students and teachers.
- Evaluations show that events have a relatively strong influence on the students´ long-term interest development in particle physics.
  - Independent of gender and level of education.