Inspiring Students Through Masterclasses

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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 (two lectures, 45 min each has been shown to work well).

- Could also include a guided tour of your labs, if appropriate.

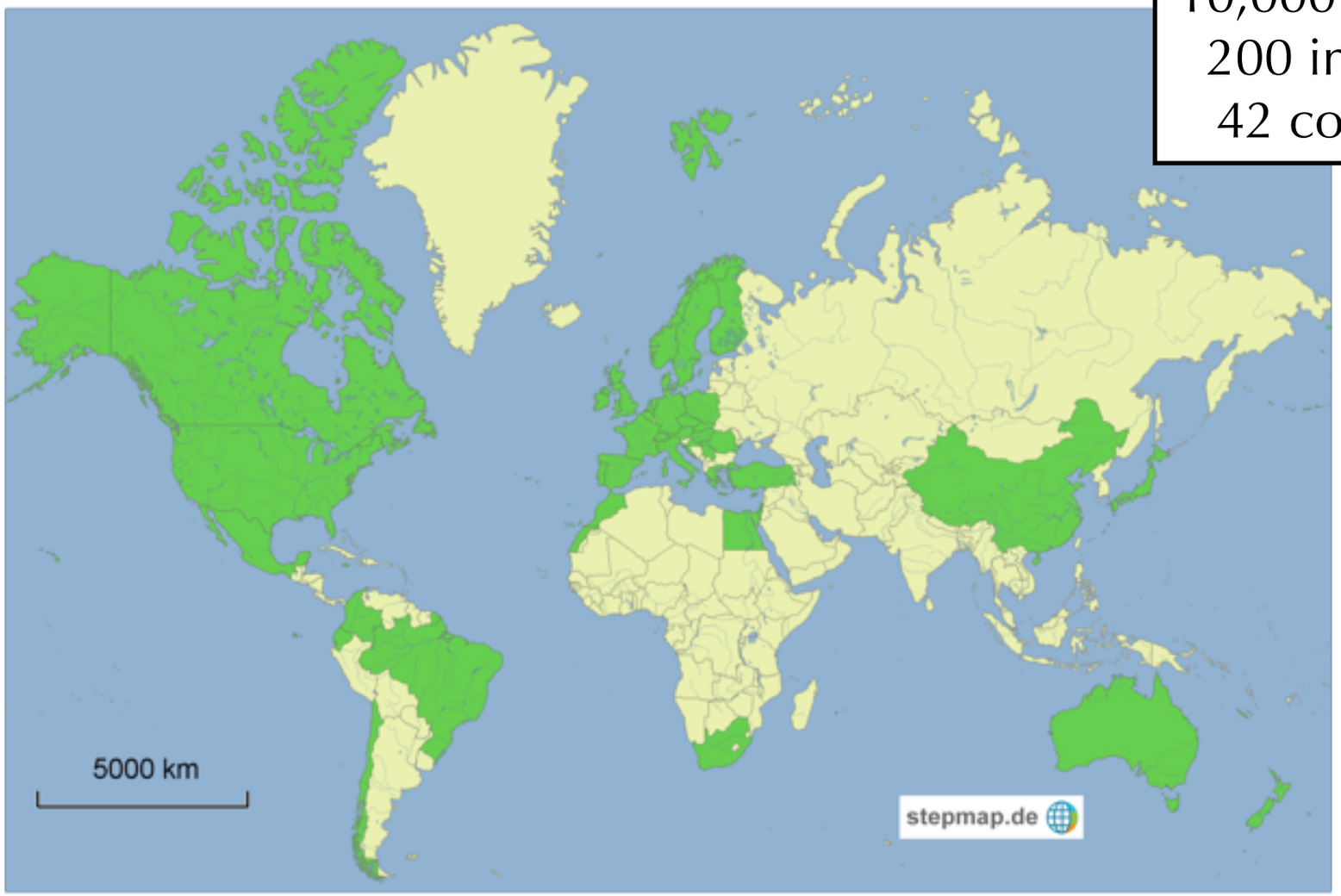
- Lunch with lecturers, staff, PhD students.

- Students work in pairs to make measurements on data → need pool of PCs and ~1 tutor per ten students.

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

International Masterclasses Programme

2015:
10,000 students
200 institutes
42 countries

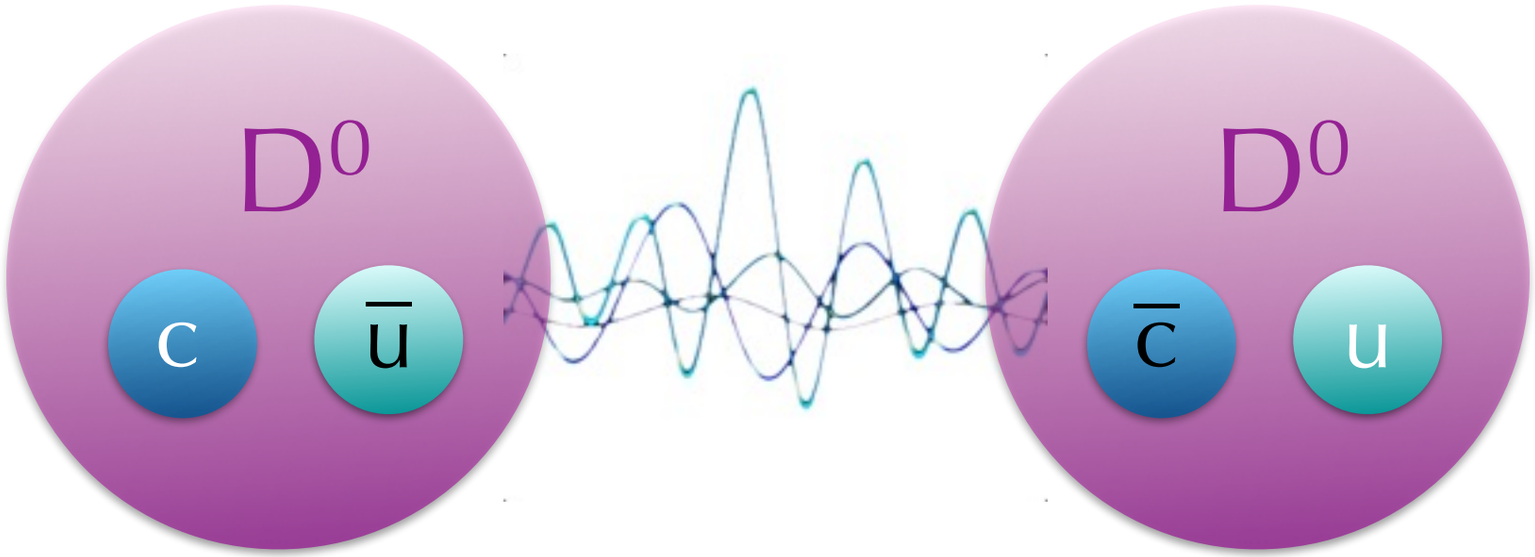


- Organised by IPPOG (International Particle Physics Outreach Group)
- Runs every year in March.

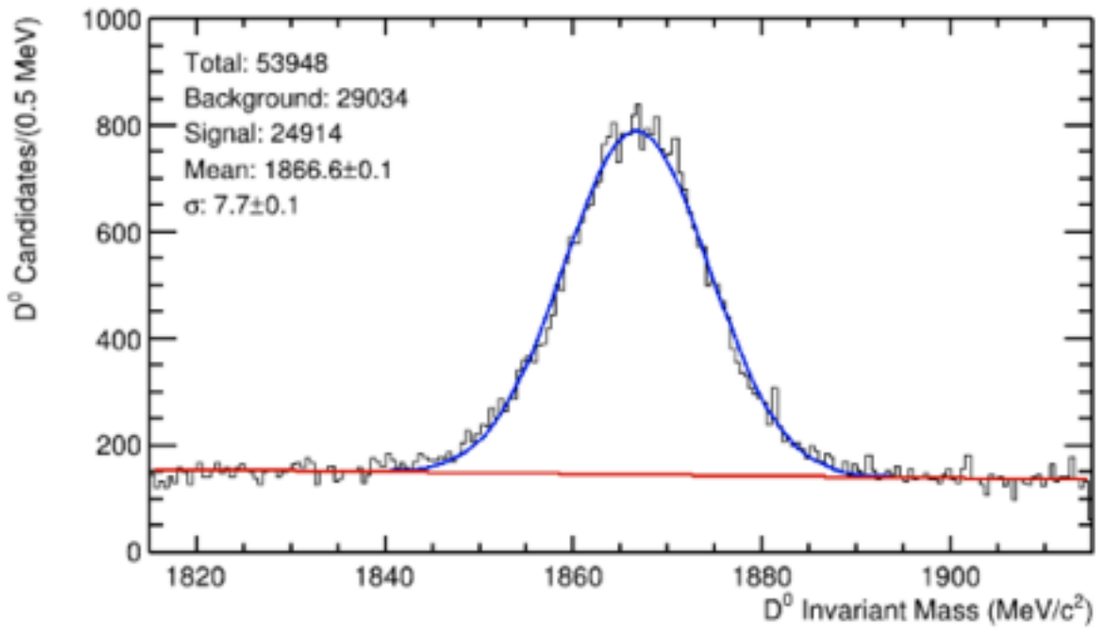
International Particle Physics Outreach Group

INTERNATIONAL MASTERCLASSES
hands on particle physics

Example Measurement: LHCb D^0 Lifetime



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

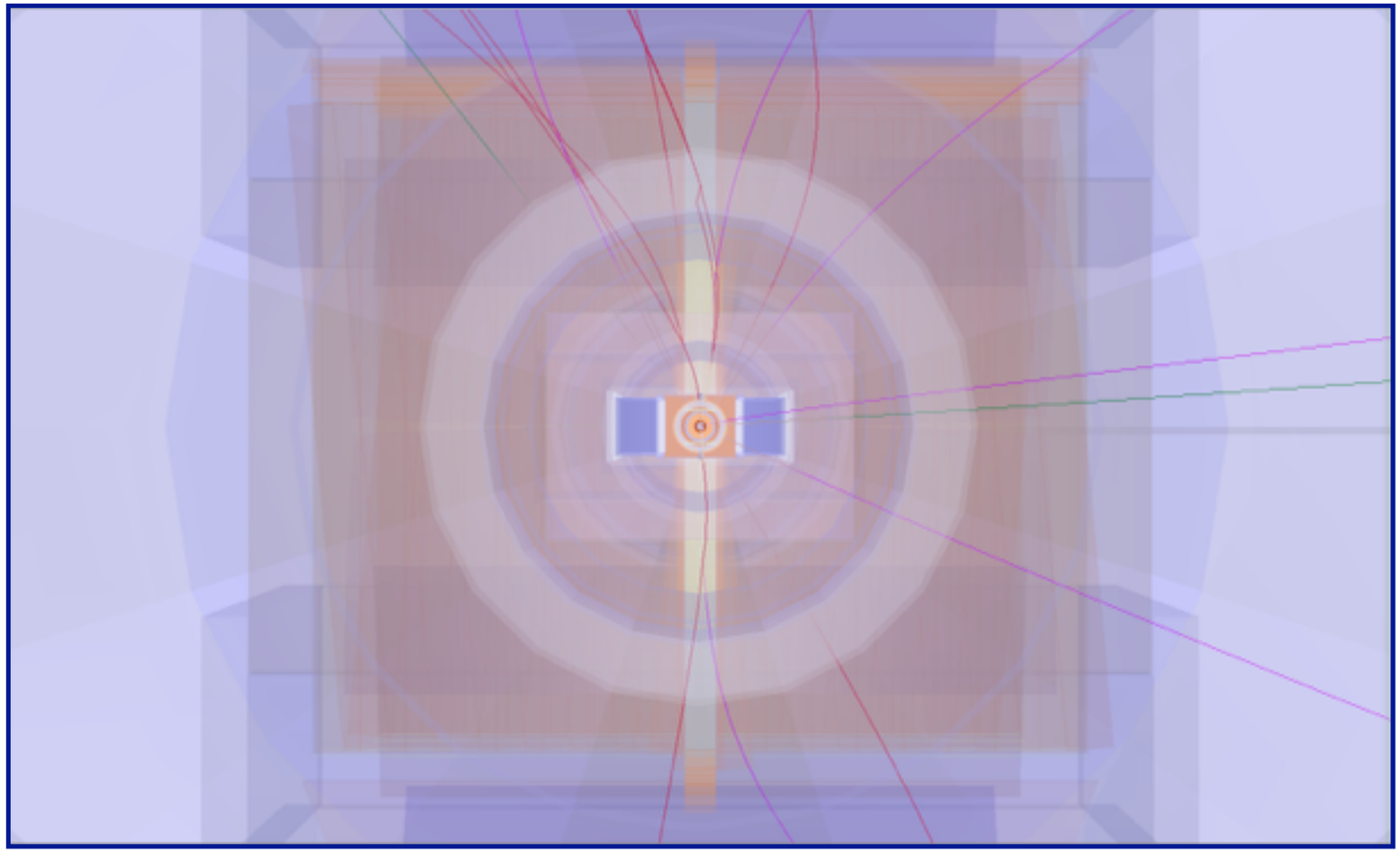


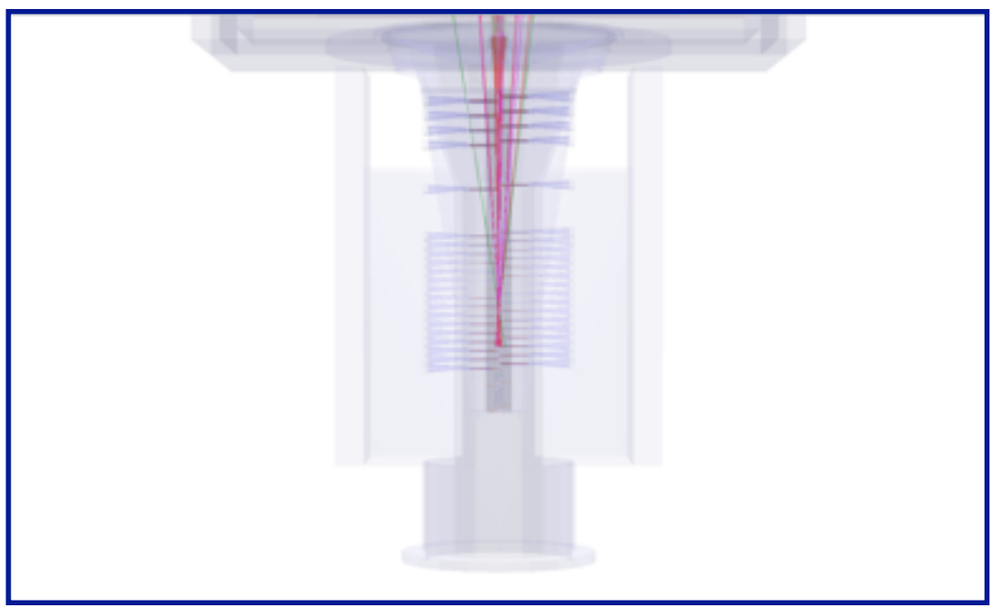
Students are introduced to the concepts of:

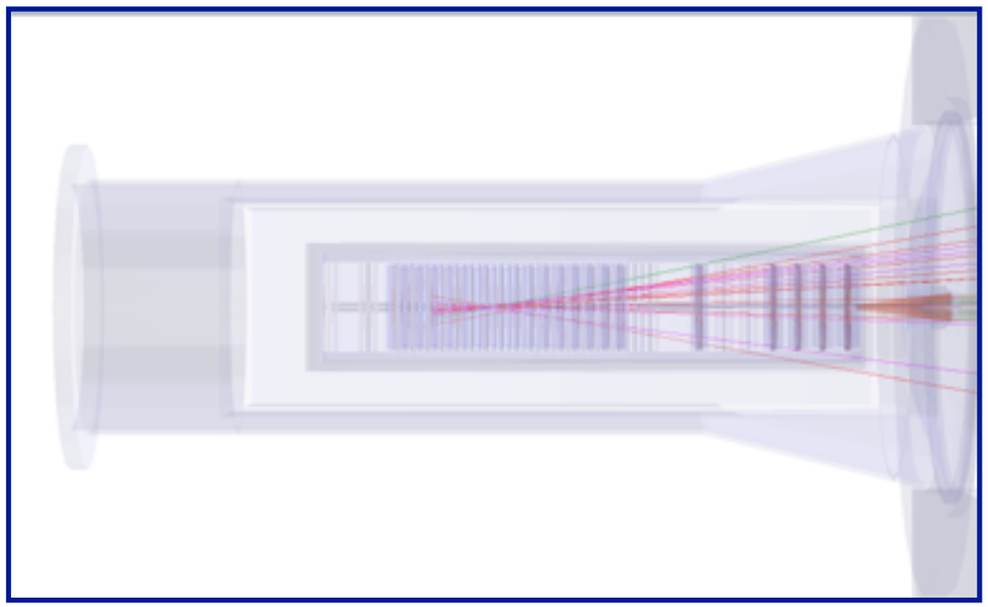
- Particle lifetimes:
  - Ranges, e.g. Z boson has lifetime of 10^{-25} seconds, proton has lifetime > 10^{29} years)
  - How to measure these experimentally (lifetime ⟺ decay length)
- Particle oscillations (e.g. D^0 oscillations between charm/anti-up and anti-charm/up states)
- Anti-matter; why it's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

LHCb D^0 Lifetime: Identifying Events

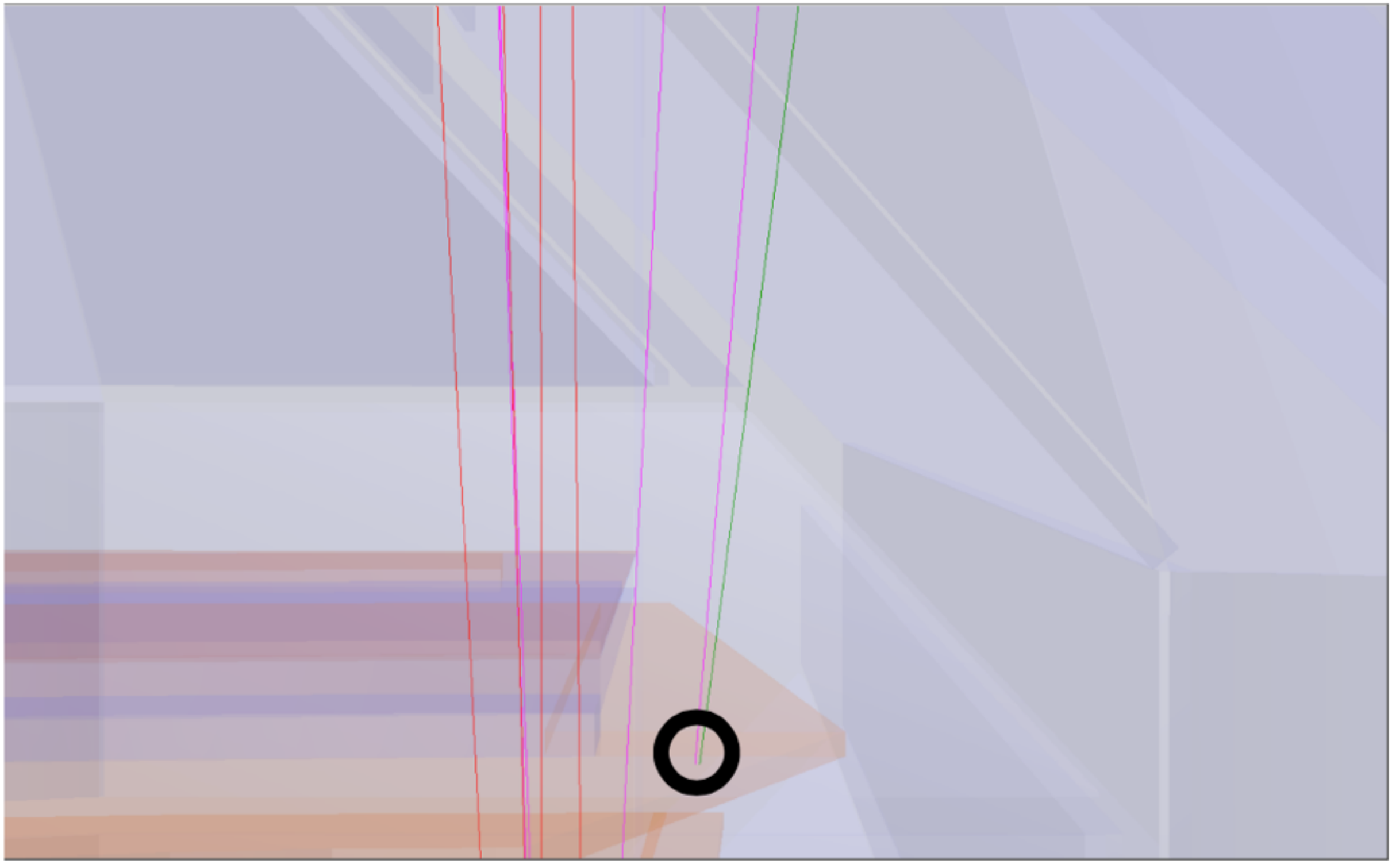
- Students use event displays to identify D^0 decays.
- Tools are provided so that they can zoom in around the interaction region to look for displaced vertices
- Tracks are colour-coded to aid with identification.



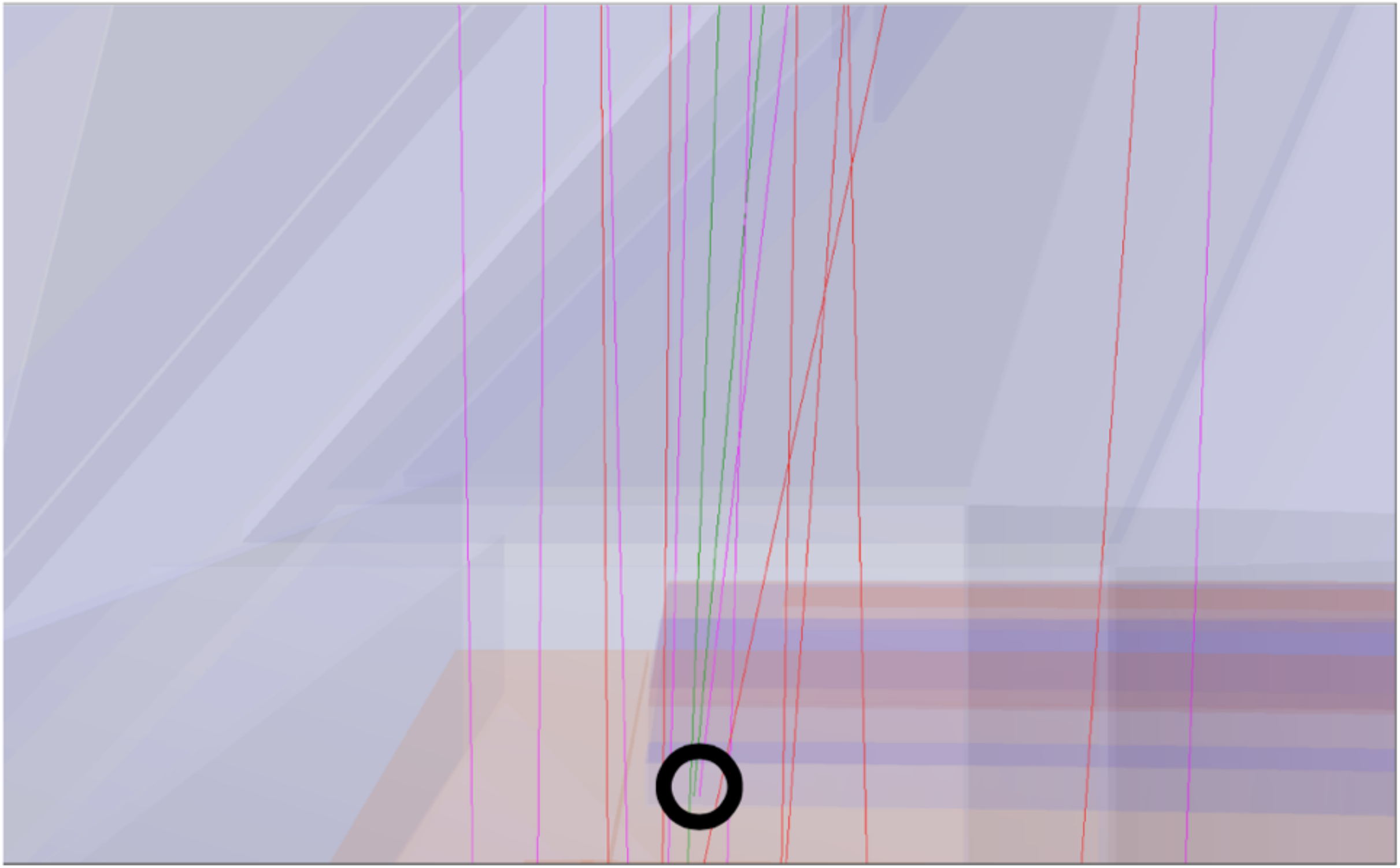




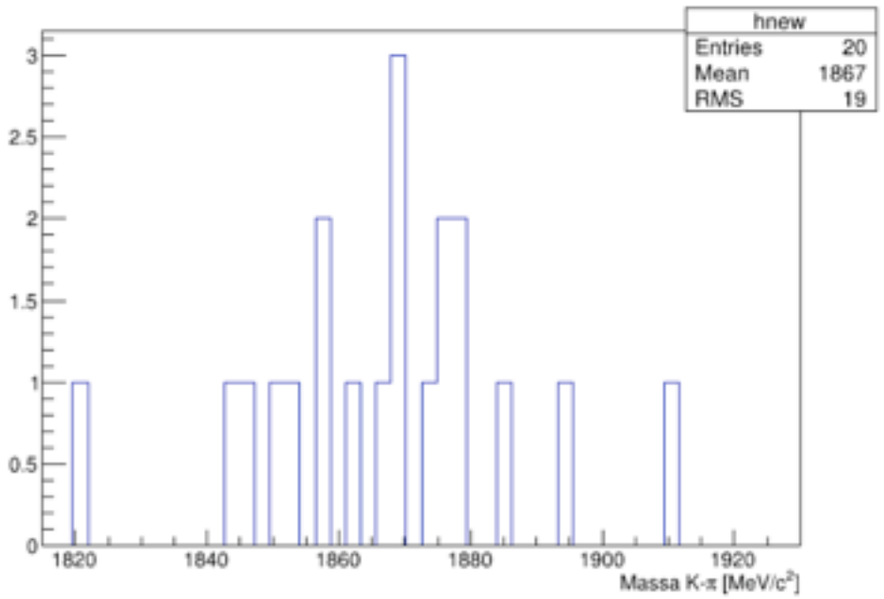
LHCb D^0 Lifetime: `Easy' Event



LHCb D^0 Lifetime: `Hard' Event

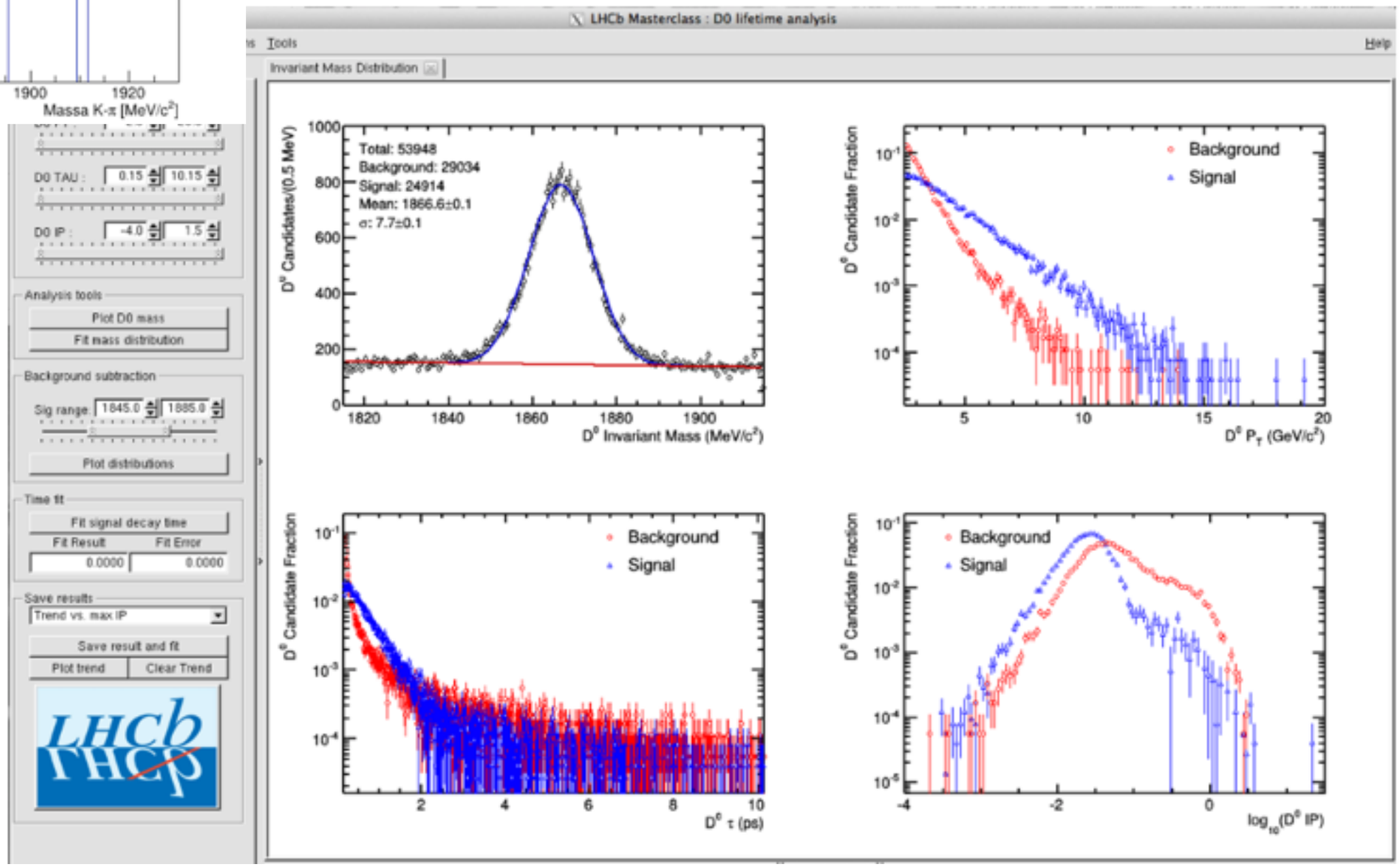


LHCb D^0 Lifetime: Fitting



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

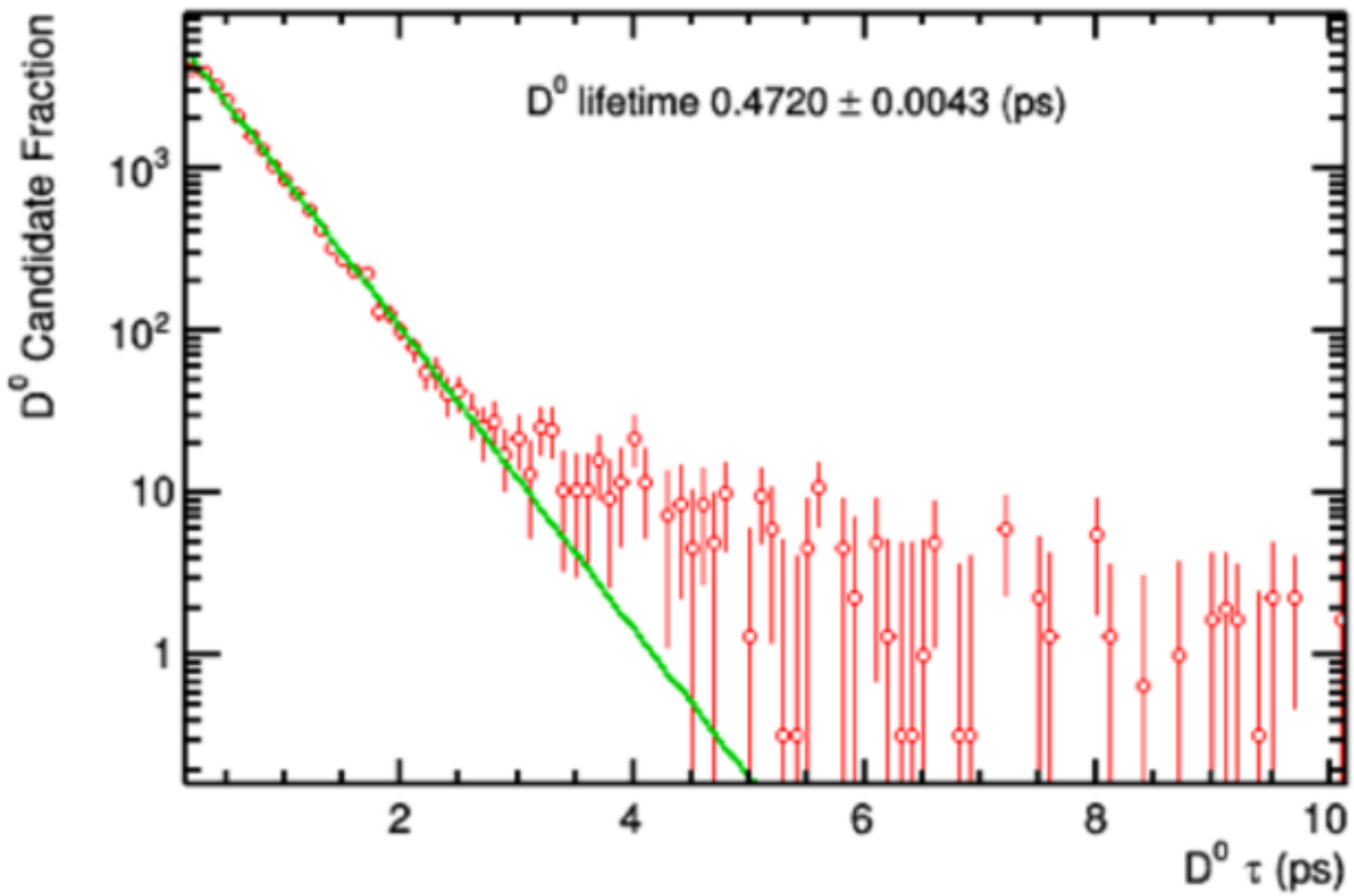
- Can apply cuts on D^0 p_T, mass etc to select data-sample



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: Z boson measurements
- 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 $H\rightarrow\gamma\gamma$ and $H\rightarrow ZZ\rightarrow\ell\ell\ell\ell$ events.

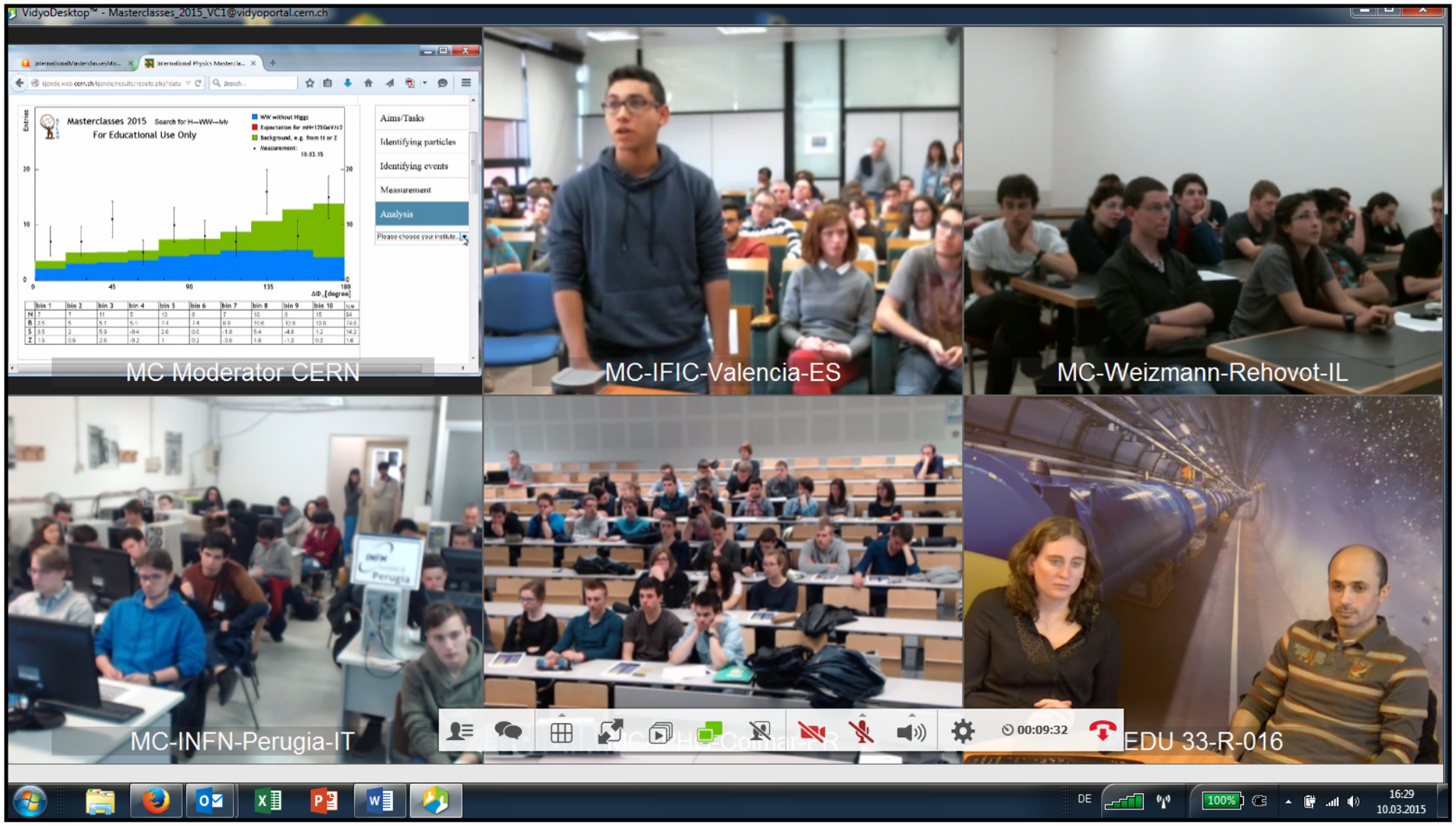
ATLAS: W boson measurements
- Look at ratio of number of W^+ and W^- events to explore the structure of the proton.
- Search for Higgs events in $H\rightarrow WW\rightarrow\ell\nu\ell\nu$ decay channel by measuring the opening angle (φ) between the charged leptons.

Video Conference with CERN/Fermilab

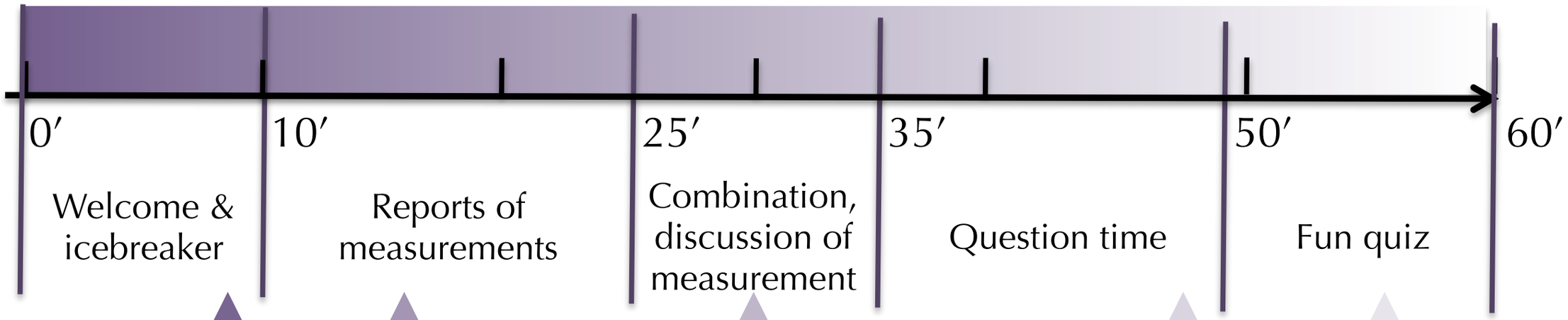
Aims of the video conference:

- 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.

- Volunteer student from each institute presents their results to everyone else.
- Chance to talk about any difficulties or problems they had.

- 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, Chez Vous

What you will need:

- A group of students (aged 15 - 19)
- At least 1 scientist, holding the lecture
- Tutors for students during the measurement (1 tutor per 10 students)
- Lecture hall
- PC-pool (students work in groups of 2)
- Facility for video conferencing, if possible

Calendar for preparation (for International Masterclasses)

Now: Contact your national representative or Uta Bilow to register your interest.
October: You will be contacted to register your preferred dates and measurement.
November: Preliminary schedule is created by organisers - make local reservations for facilities (e.g. lecture hall, PC pool).
December: prepare your local agenda and a link for registration.
January: send invitation letters to schools and students.
February: Plan preparation talks, introduce tutors to measurement.
March: Masterclass event.

For more details: http://physicsmasterclasses.org

Summary

- Masterclasses are an excellent way to engage students in your research field and inspire them to study Physics at a higher level.
- Several schemes already exist for High Energy Physics (including the International Masterclasses organised by IPPOG) that will help you get started with your own event.
- Very rewarding experience, both for students and local organisers.