Inspiring Students Through Masterclasses

Katharine Leney

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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 teamwork.

• 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

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

2015:
- 10,000 students
- 200 institutes
- 42 countries

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Example Measurement: LHCb $D^0$ Lifetime

Measurement uses real $D^0 \rightarrow K\pi$ 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 $\Rightarrow$ 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 D⁰ Lifetime: Fitting

- Students create their own plot of the D⁰ mass distribution.
- Then given more data to do fits to mass, and lifetime distributions.

- Can apply cuts on D⁰ p_T, mass etc to select data-sample.

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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 $J/\Psi$, $\Upsilon$, and Z-boson
- Find Higgs candidates from 4-lepton and di-photon events

**ALICE: Strange particle**
- Identify strange particles ($K_s$, $\Lambda$, anti-$\Lambda$) 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/\(\mu\)) or photons, and events with 4 leptons.
- Use di-lepton invariant mass spectrum and identify $J/\Psi$, $\Upsilon$, 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 ($\varphi$) 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

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

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

25' Combination, discussion of measurement
- 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.

35' Question time
- 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!

50' Fun quiz
- ‘Who wants to be a millionaire’ style quiz.
- No prizes, just for fun!

60'
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

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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.