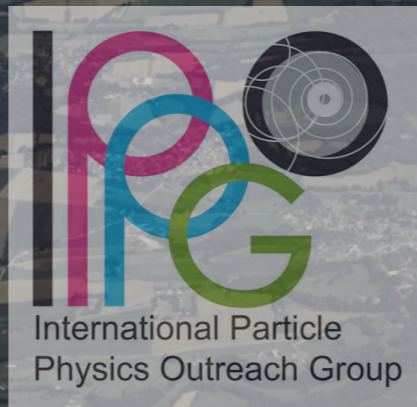
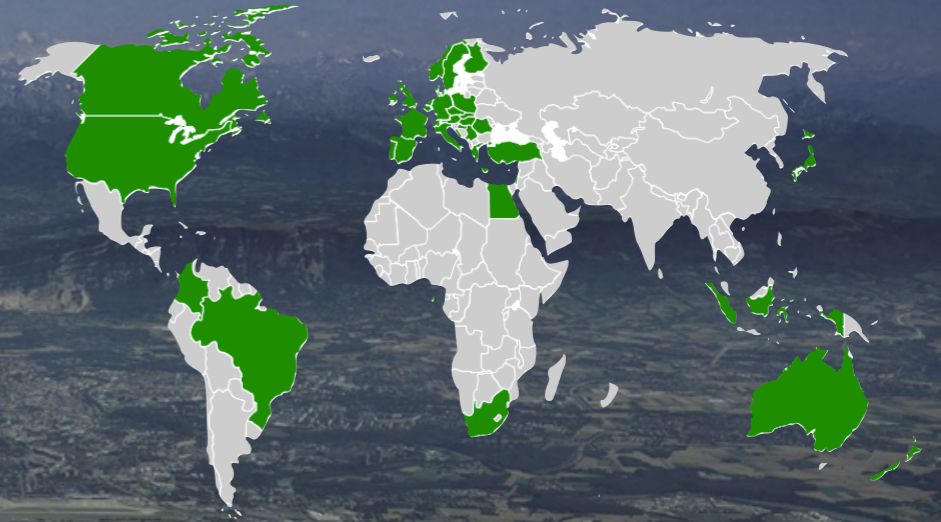
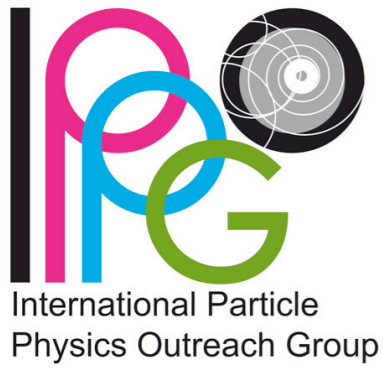


# Bringing the world's largest science experiment into the "classroom"



Konrad Jende, TU Dresden on behalf of the International Particle Physics Outreach Group (IPPOG)  
HST, July 8 2013



# Outline

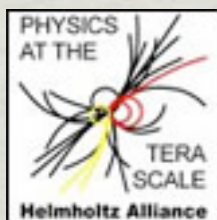
- \* Introduction
- \* IPPOG's International Masterclasses
  - \* Physics Analyses
  - \* Evaluation
  - \* Participation
- \* Summary



International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses

## FUNDED BY:



**COORDINATOR**



Federal Ministry  
of Education  
and Research

**MASTERCLASSES  
LHC UPGRADE**



**DVD  
PRODUCTION**



**US PARTNER  
PROGRAMME**



**EXPERIMENTAL DATA  
VIDEOCONFERENCE**

**+  
NATIONAL  
FUNDING  
AGENCIES**

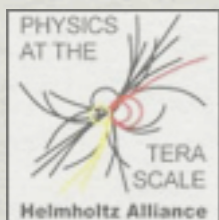


# IPPOG's International Masterclasses

## \* Concept

- \* Students (15 -19 years old) spend 1 day at research institute,
- \* experience science from scientists “The Master” and
- \* carry out measurements based on analyses of real data from particle physics experiments,
- \* discuss their results with colleagues
- \* basic idea from UK (1996, Roger Barlow et al.)

## FUNDED BY:



COORDINATOR



Federal Ministry  
of Education  
and Research

MASTERCLASSES  
LHC UPGRADE



DVD  
PRODUCTION

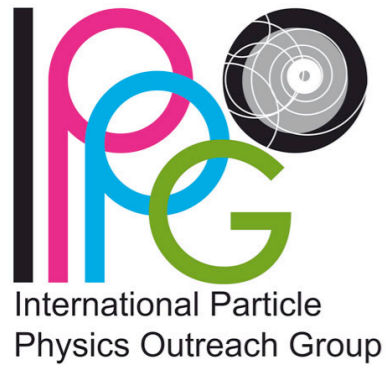


US PARTNER  
PROGRAMME



EXPERIMENTAL DATA  
VIDEOCONFERENCE

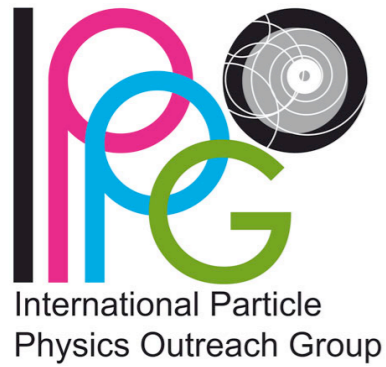
+  
NATIONAL  
FUNDING  
AGENCIES



# IPPOG's International Masterclasses

## \* Objectives

- \* stimulate students interest in physics
- \* demonstrate scientific research process
- \* let students explore fundamental forces and building blocks of matter
- \* offer authentic experience



# IPPOG's International Masterclasses

- \* **Event** - create an International Collaboration among students (together with U.S. partner QuarkNet)
- \* ~4 weeks period in March every year
- \* 130 (+30 from U.S. partner) institutes from 37 countries
- \* central organization at TU Dresden: Michael Kobel and Uta Bilow
- \* Website: <http://www.physicsmasterclasses.org>



International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses

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■ # of participants in International Masterclasses

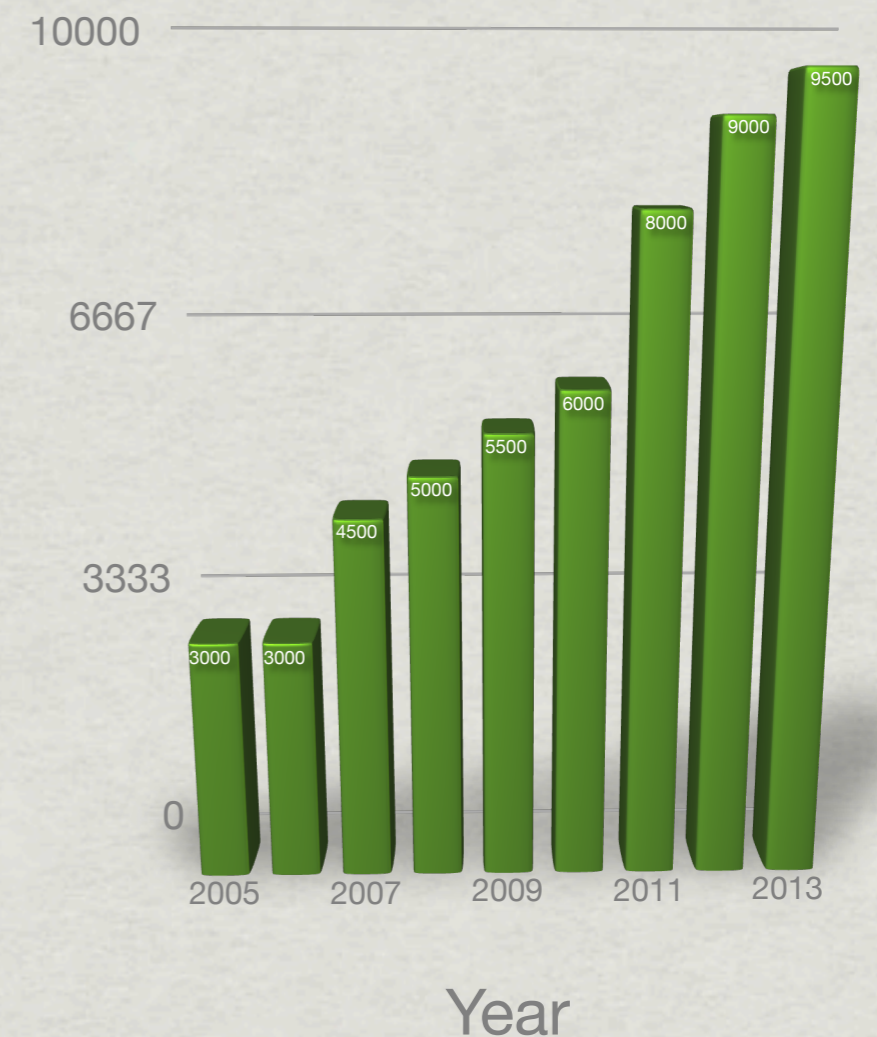
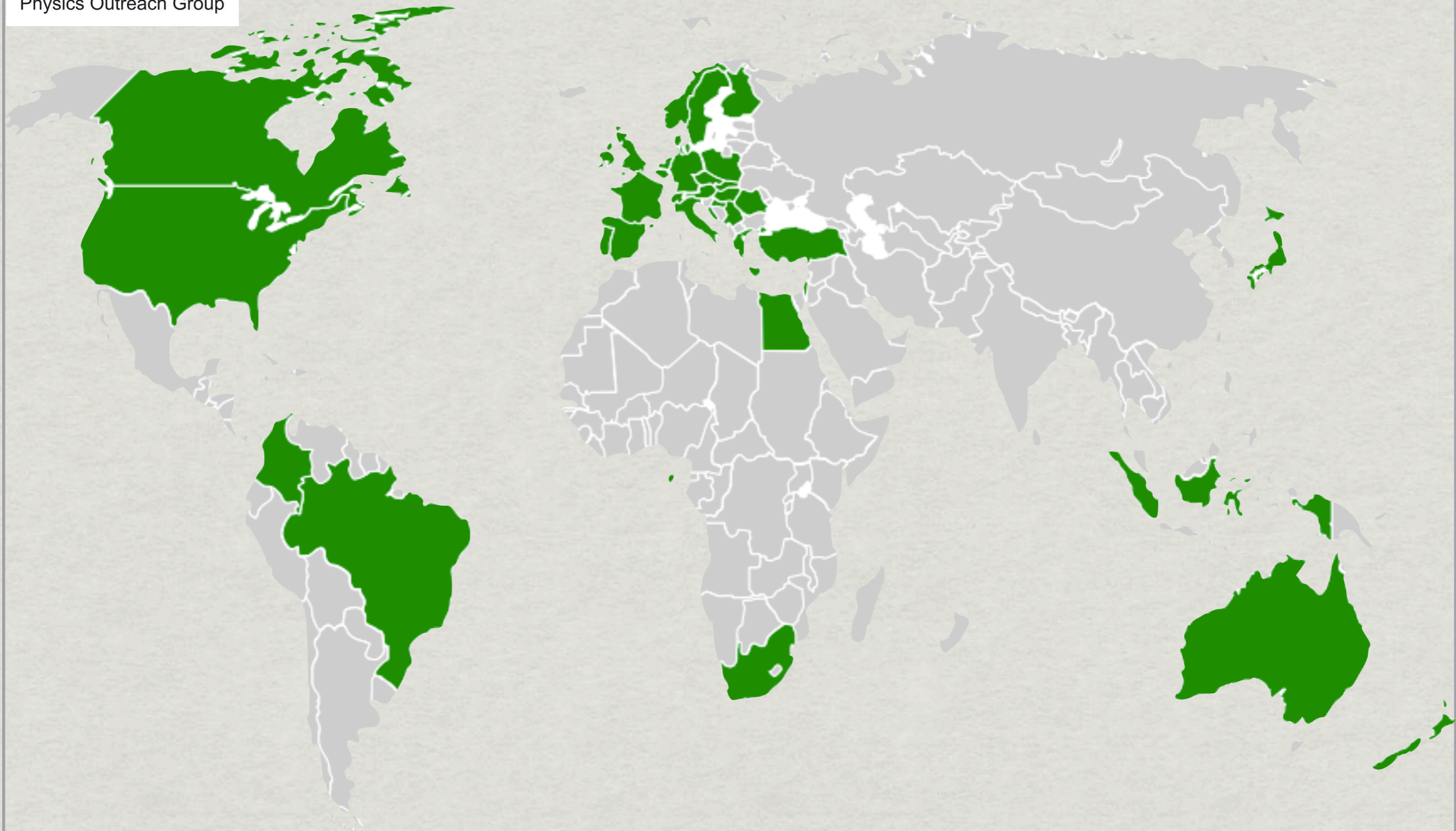


Fig. 2 - Number of participants in International Masterclasses over the years



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# IPPOG's International Masterclasses









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# IPPOG's International Masterclasses

9:30  
Lunch  
break  
1:30  
3:30  
4:30



**Lectures**

9:30  
Lunch  
break  
1:30  
3:30  
4:30



**Measurement on real data**

9:30  
Lunch  
Break  
1:30  
3:30  
4:30



**Combination of measurement's results**

9:30  
Lunch  
break  
1:30  
3:30  
4:30



**Videoconference**



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# IPPOG's International Masterclasses

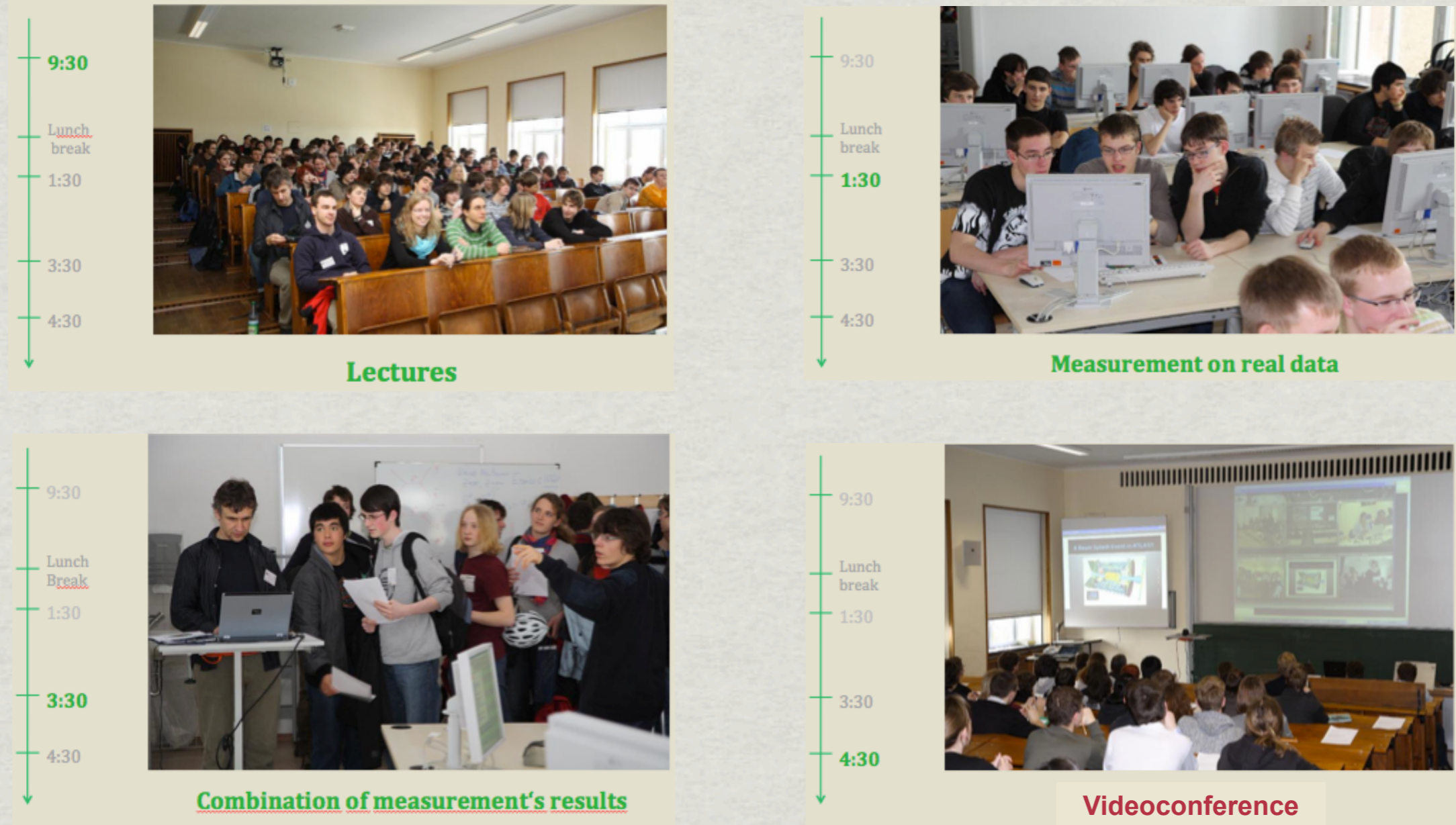


Fig. 4 - Typical Masterclasses day



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# IPPOG's International Masterclasses

## Physics Analyses

# IPPOG's International Masterclasses

## Physics Analyses

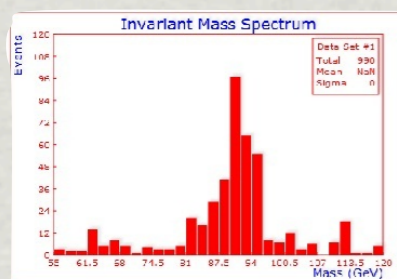
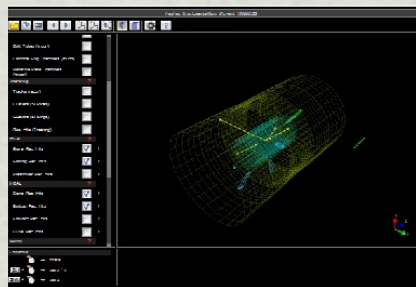


Fig. 5 - Process during data analysis in Masterclasses

# IPPOG's International Masterclasses

## Physics Analyses

- \* students work in pairs in front of computers, where

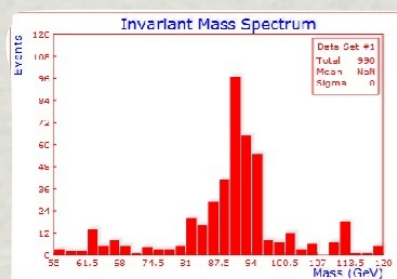
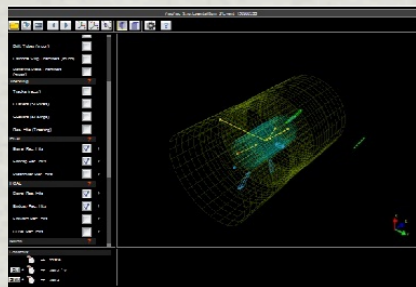
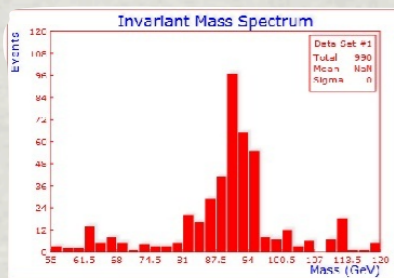
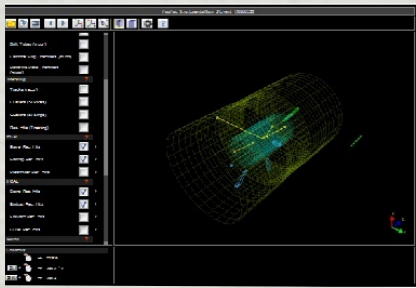


Fig. 5 - Process during data analysis in Masterclasses

# IPPOG's International Masterclasses

## Physics Analyses

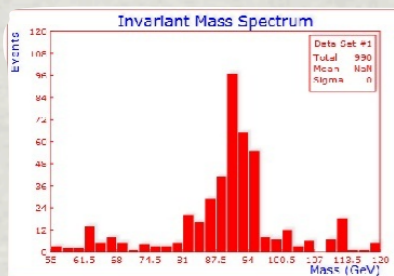
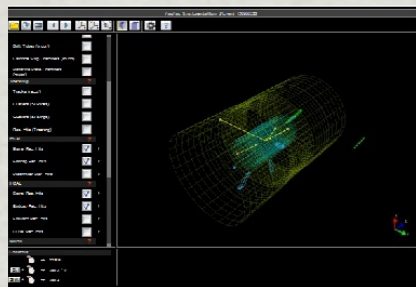


- ✱ students work in pairs in front of computers, where
- ✱ they identify particles visually in event displays of proton-proton-collisions and thus assign an event to predetermined classes of events

**Fig. 5 - Process during data analysis in Masterclasses**

# IPPOG's International Masterclasses

## Physics Analyses



**Fig. 5 - Process during data analysis in Masterclasses**

- ✱ students work in pairs in front of computers, where
- ✱ they identify particles visually in event displays of proton-proton-collisions and thus assign an event to predetermined classes of events
- ✱ produce plots (histograms) out of their results and



# IPPOG's International Masterclasses

## Physics Analyses

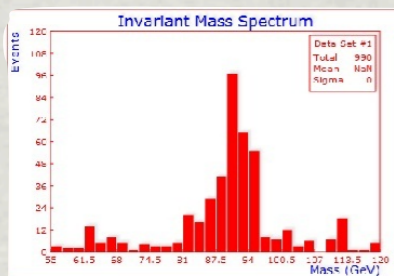
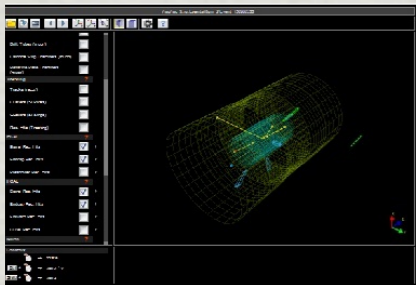
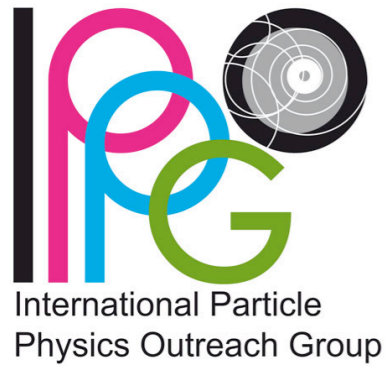


Fig. 5 - Process during data analysis in Masterclasses

- \* students work in pairs in front of computers, where
- \* they identify particles visually in event displays of proton-proton-collisions and thus assign an event to predetermined classes of events
- \* produce plots (histograms) out of their results and
- \* discuss them afterwards at the venue and during the videoconference



# IPPOG's International Masterclasses

## Physics Analyses

- ✳ **based on visual event identification of event displays of proton-proton-collisions using tools of physicists**

# IPPOG's International Masterclasses

## Physics Analyses

- ✦ based on visual event identification of event displays of proton-proton-collisions using tools of physicists

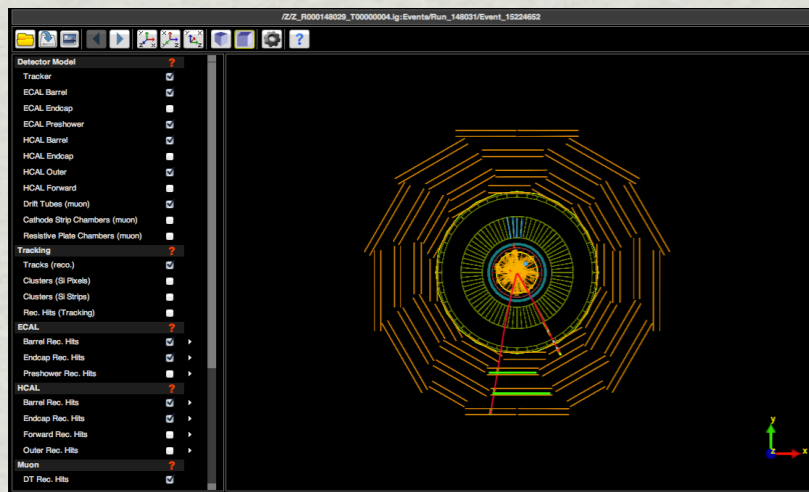


Fig. 6 - CMS event display

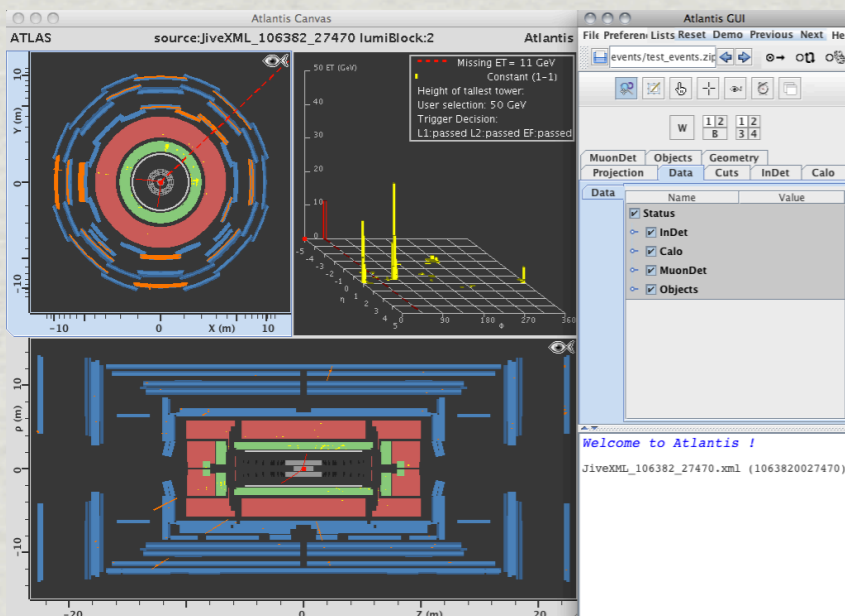


Fig. 7 - ATLAS event display

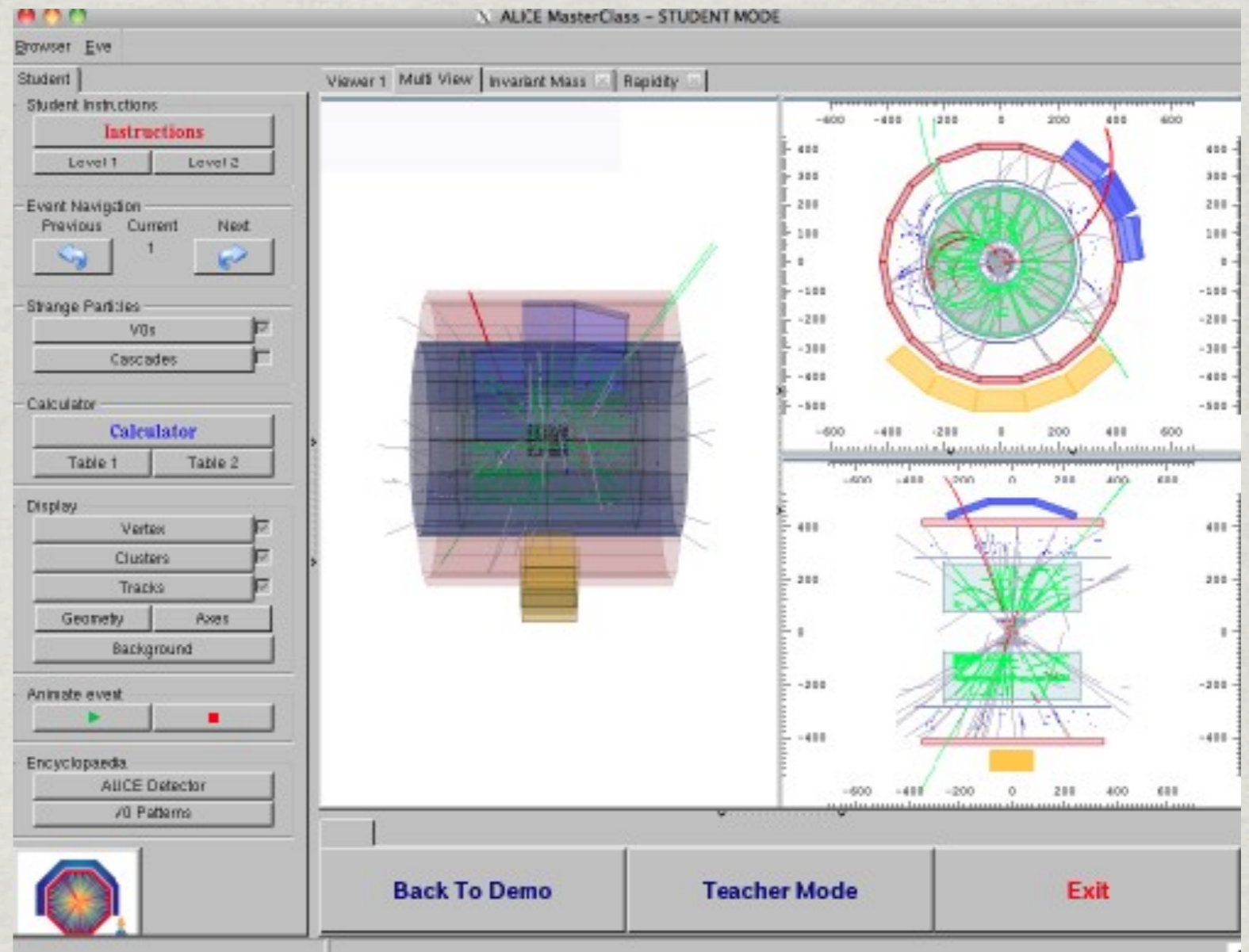


Fig. 8 - ALICE event display

# IPPOG's International Masterclasses

## Physics Analyses

- ✳ based on visual event identification of event displays of proton-proton-collisions using tools of physicists



Fig. 6 - CMS event display

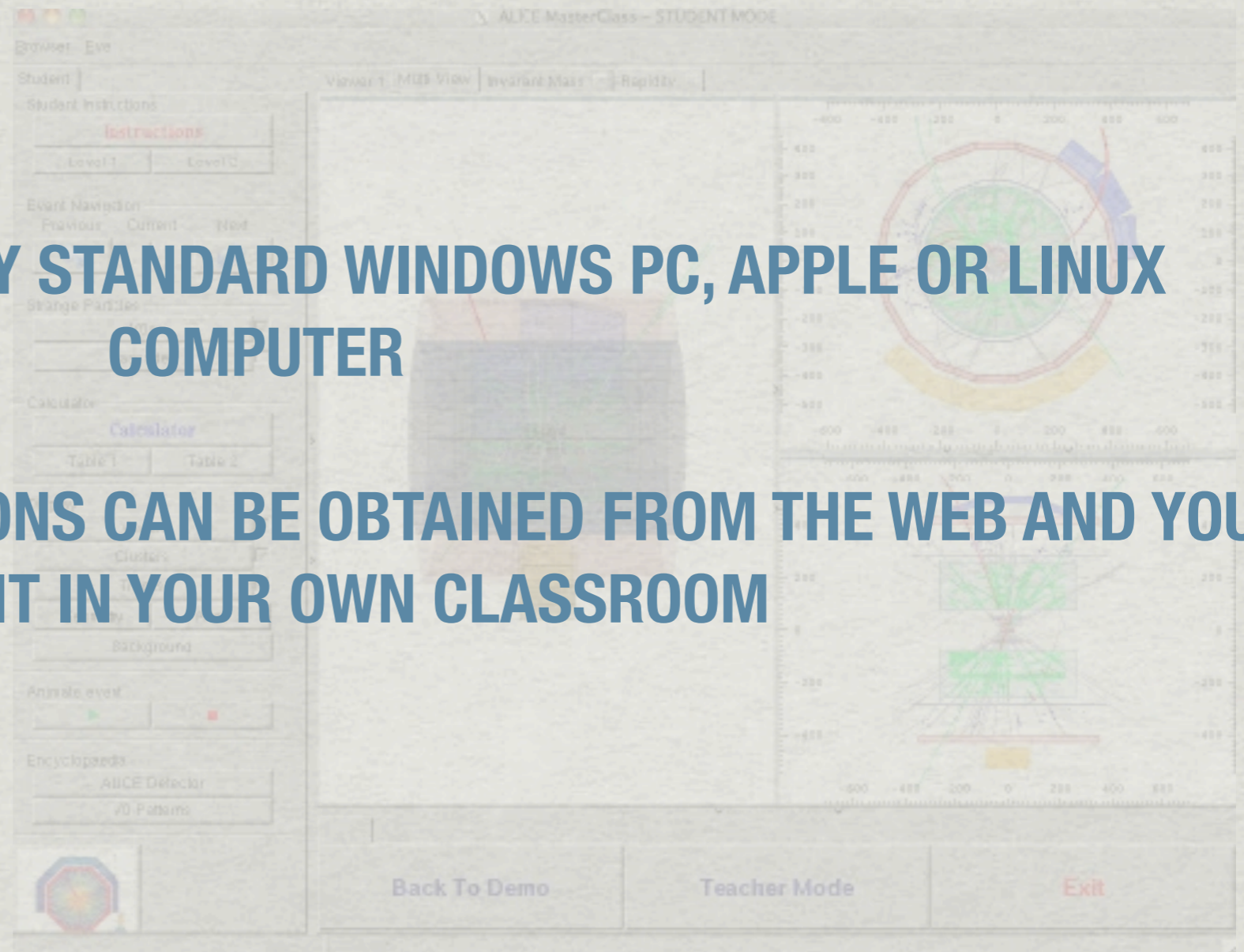


Fig. 8 - ALICE event display

**SOFTWARE AND INSTRUCTIONS CAN BE OBTAINED FROM THE WEB AND YOU CAN USE IT IN YOUR OWN CLASSROOM**

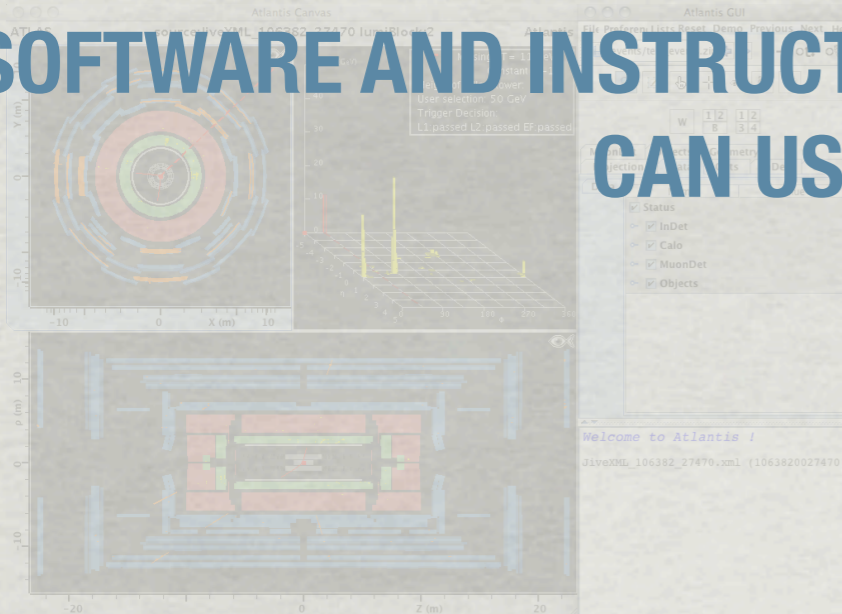
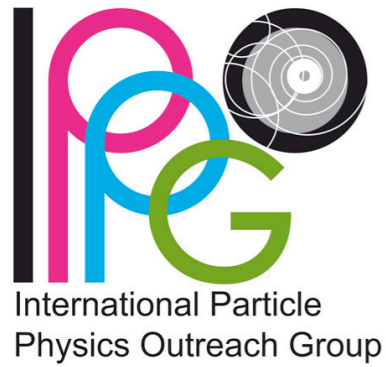


Fig. 7 - ATLAS event display



# IPPOG's International Masterclasses

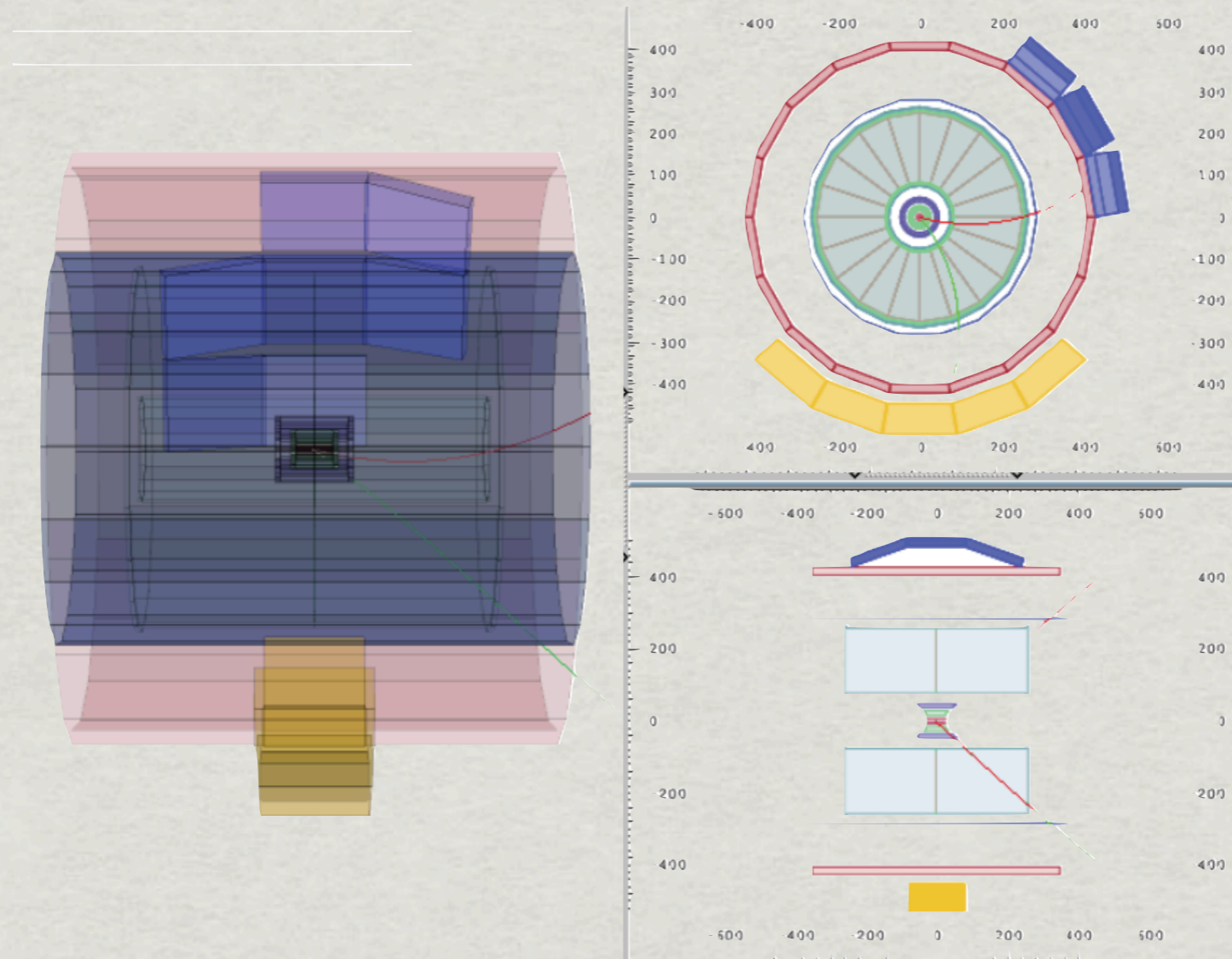
## Physics Analyses

- \* based on visual event identification of event displays of proton-proton-collisions using tools of physicists
- \* various exercises/measurements on real data are provided by the LHC experiments ALICE, ATLAS and CMS, where students:
  - \* identify particles/events by using different techniques (e.g. invariant mass calculation, looking at momentum conservation)
  - \* identify particles/events in order to explore the inner structure of the proton, search for not yet discovered particles (with the help of simulated data)

# IPPOG's International Masterclasses

## Physics Analyses

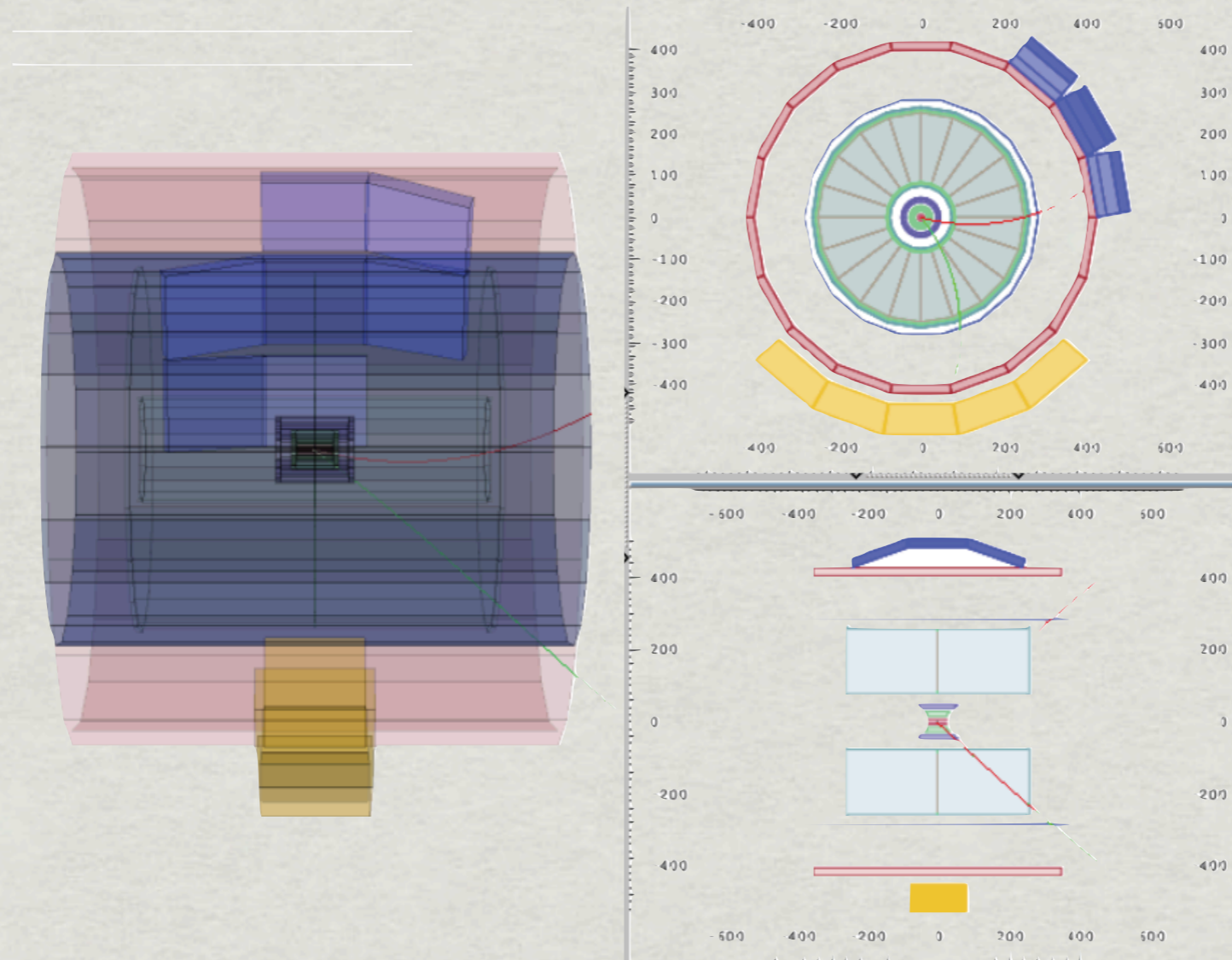
### ALICE measurement (D. Hatzifotiadou et al., 2012)



# IPPOG's International Masterclasses

## Physics Analyses

### ALICE measurement (D. Hatzifotiadou et al., 2012)



**Fig. 9 - Electric neutral particles can be only seen in the inner detector when they decay into electric charged particles, where the tracks build a “V” - that is why we call them V0 events**

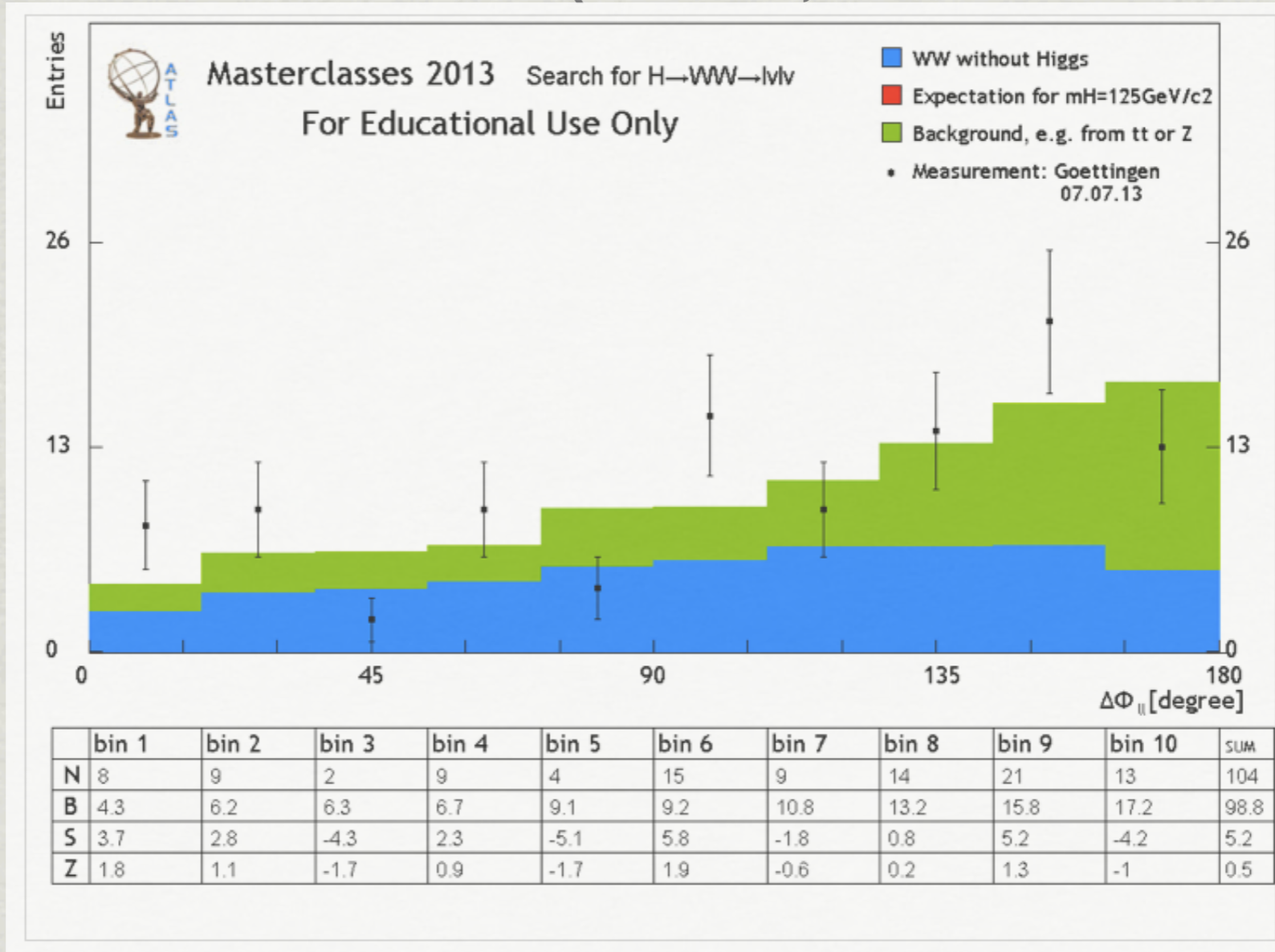


International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS W measurement (K. Jende, M. Kobel et al. 2013)





# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS W measurement (K. Jende, M. Kobel et al. 2013)

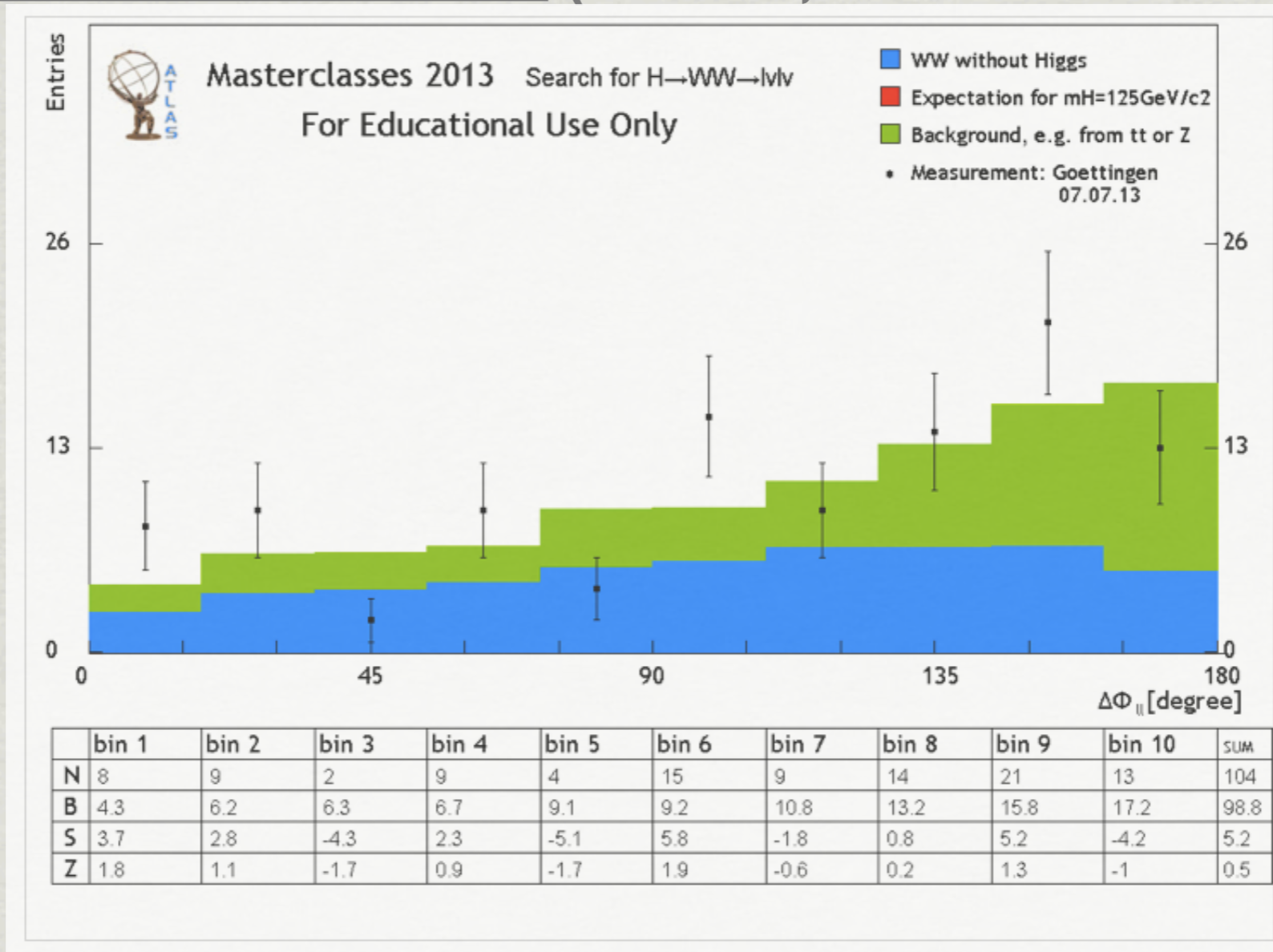
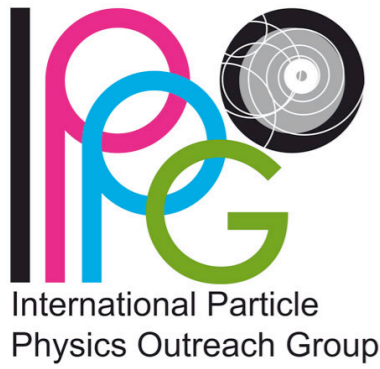


Fig. 10 - using histograms to determine selection criteria like physicists do



# IPPOG's International Masterclasses

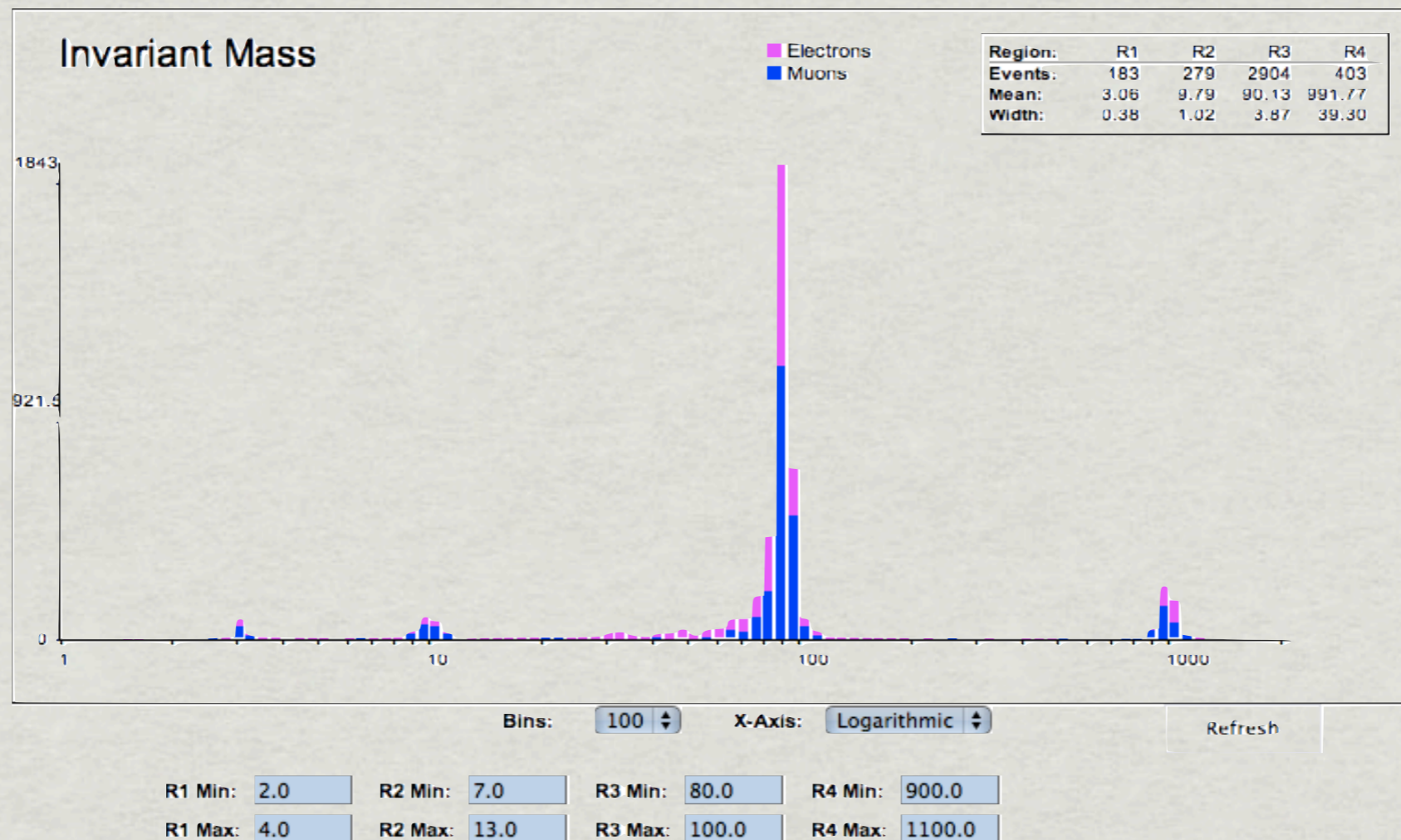
## Physics Analyses

### ATLAS Z measurement (Farid Ould-Saada, Maiken Petersen et al. 2012)

OPlOT - MasterClass – Combination for all institutes on 09.03.2012

Start Student Moderator Administrator

Choose new date



# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement (Farid Ould-Saada, Maiken Petersen et al. 2012)

OPlOT - MasterClass – Combination for all institutes on 09.03.2012

Start Student Moderator Administrator

Choose new date

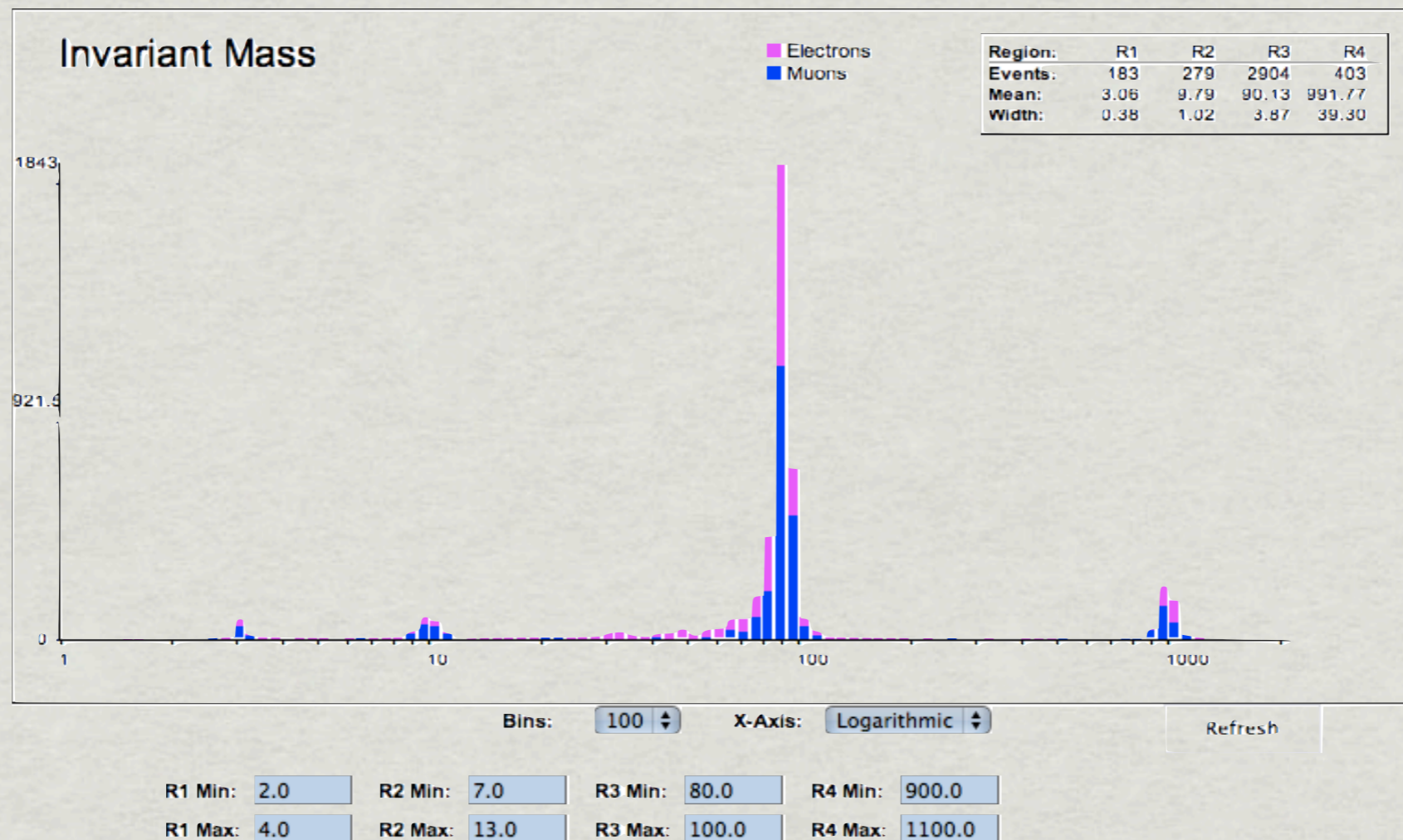


Fig. 11 - Building histograms and identify particles like physicists do

# IPPOG's International Masterclasses

## Physics Analyses

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OPlOT - MasterClass – Combination for all institutes on 09.03.2012

Start Student Moderator Administrator

Choose new date

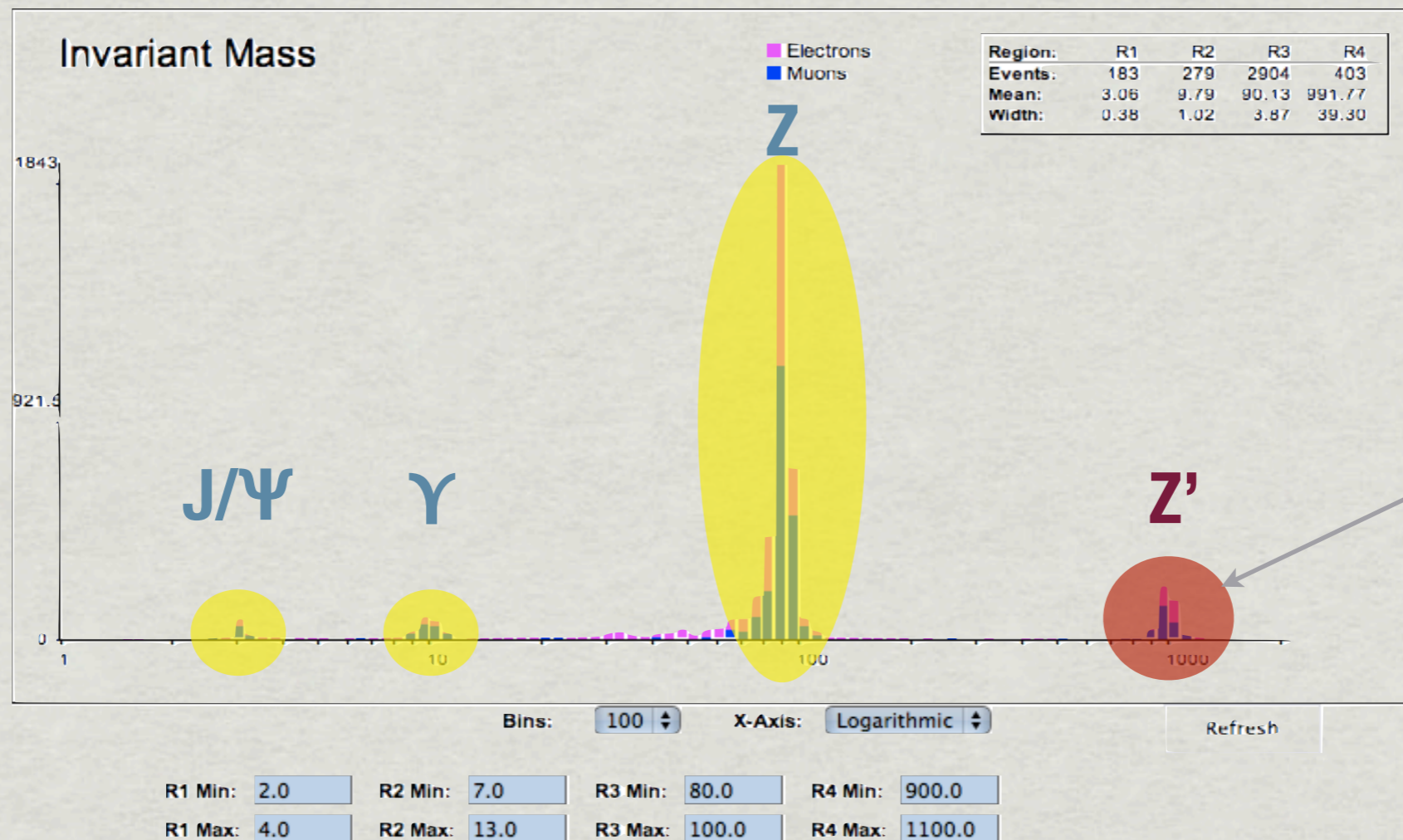
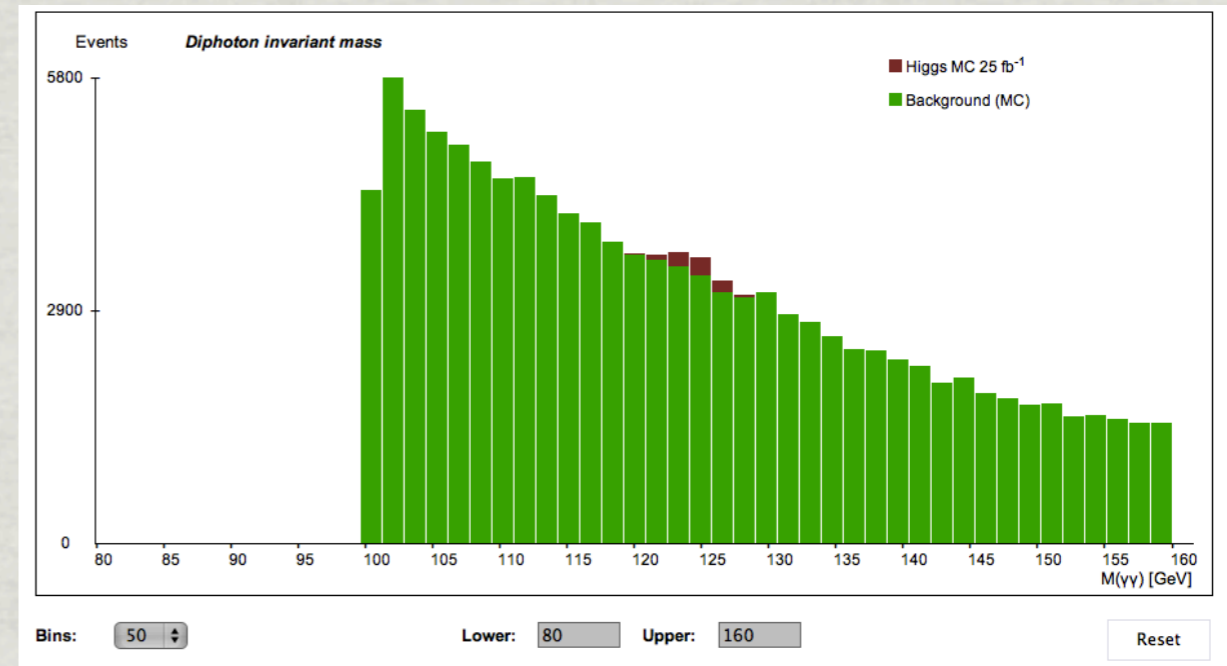
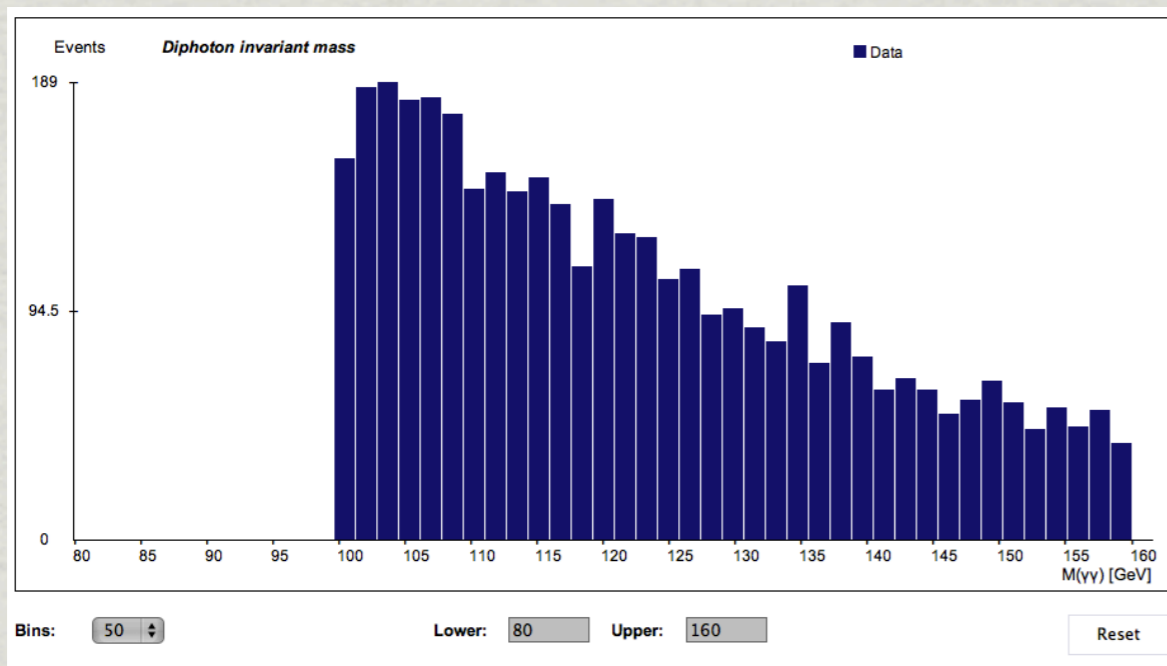


Fig. 11 - Building histograms and identify particles like physicists do

# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement (Farid Ould-Saada, Maiken Petersen et al. 2012)



# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement (Farid Ould-Saada, Maiken Petersen et al. 2012)

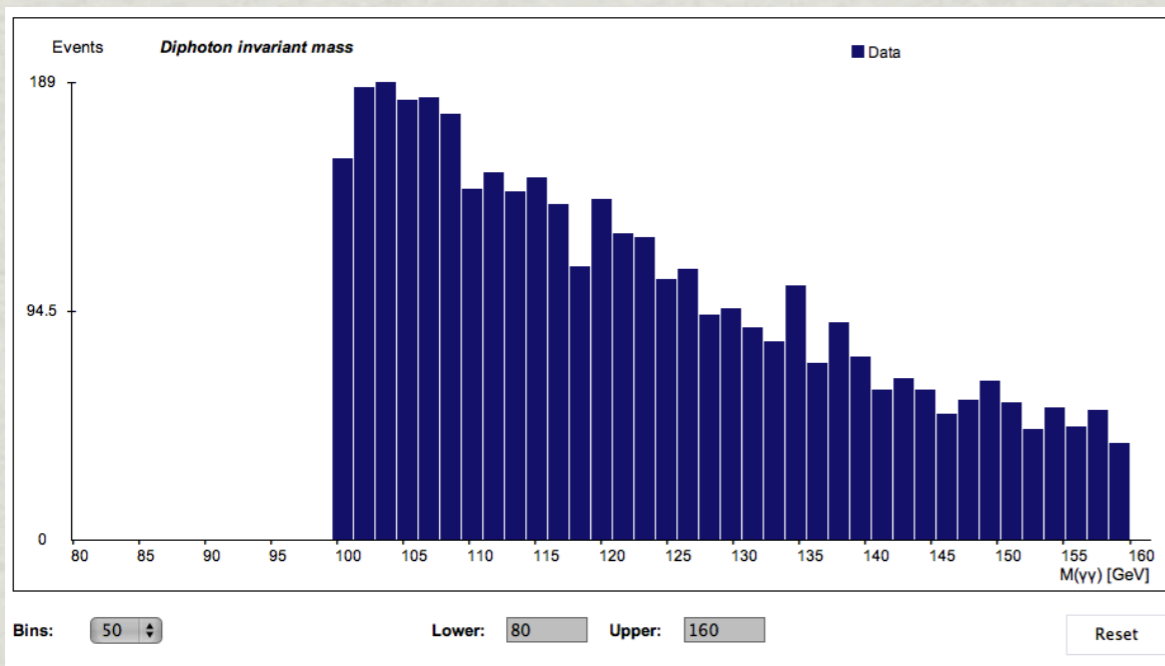


Fig. 12 - Invariant Mass distribution in the di-photon channel - Ideal results for the whole Masterclasses data set

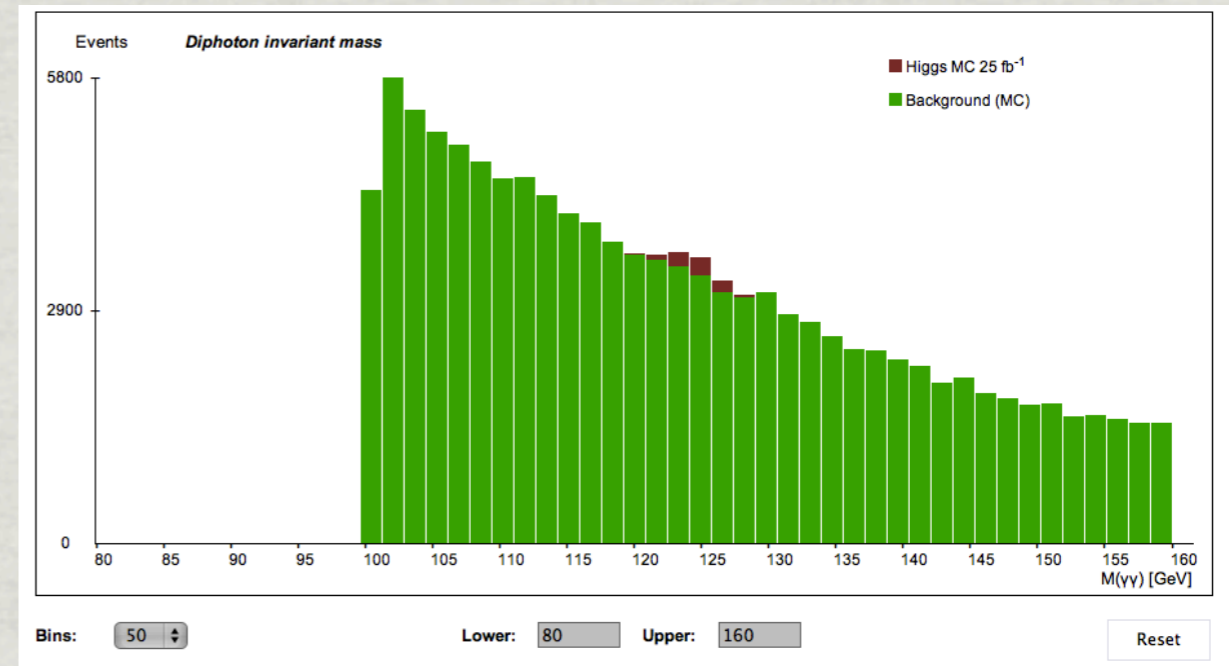
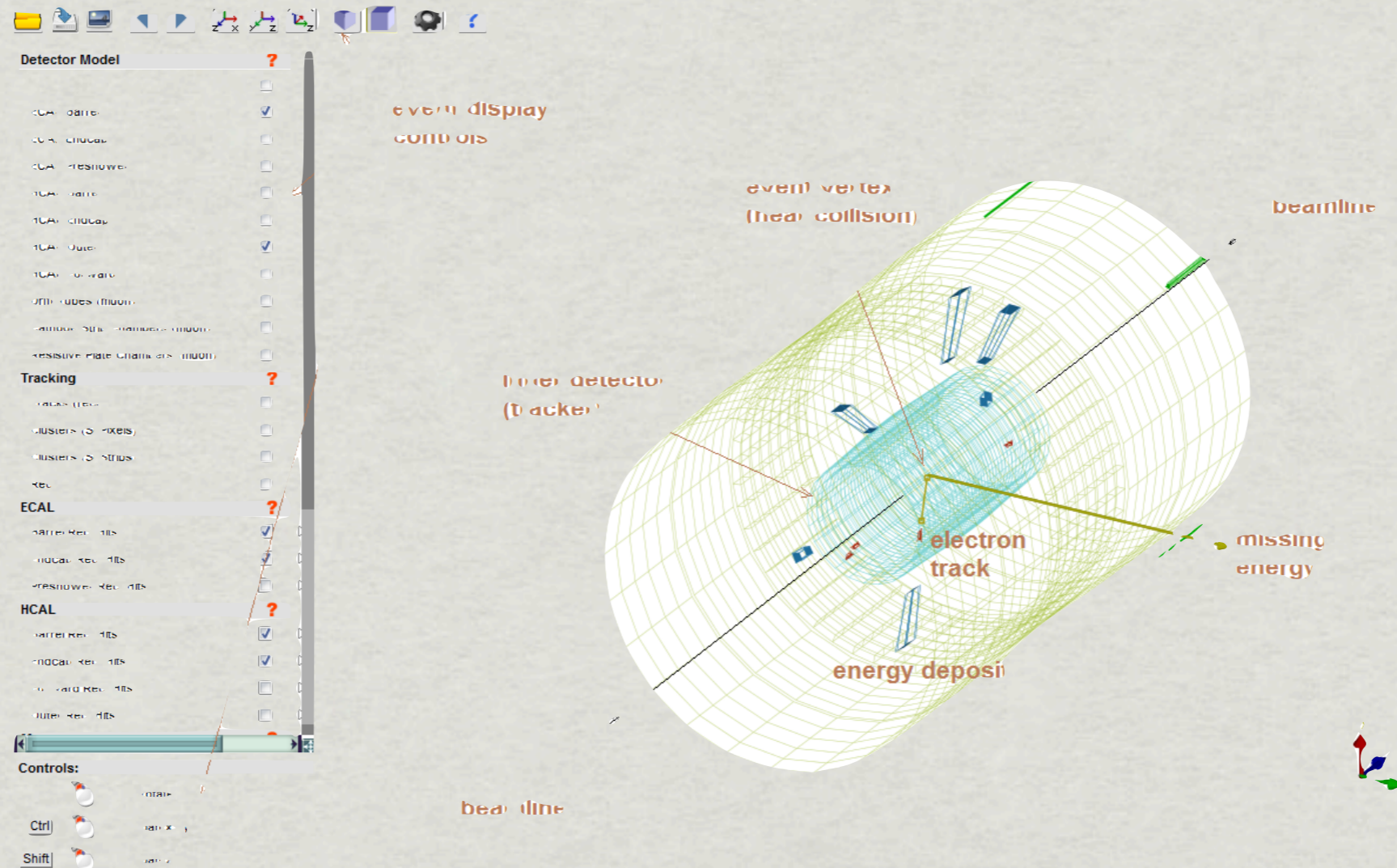


Fig. 13 - Invariant Mass distribution in the di-photon channel - Expectations for the whole ATLAS data set (2012 data) with the same selection criteria

# IPPOG's International Masterclasses

## Physics Analyses

### CMS measurement (M. Hategan, K. Cecire et al. 2012)



# IPPOG's International Masterclasses

## Physics Analyses

### CMS measurement (M. Hategan, K. Cecire et al. 2012)

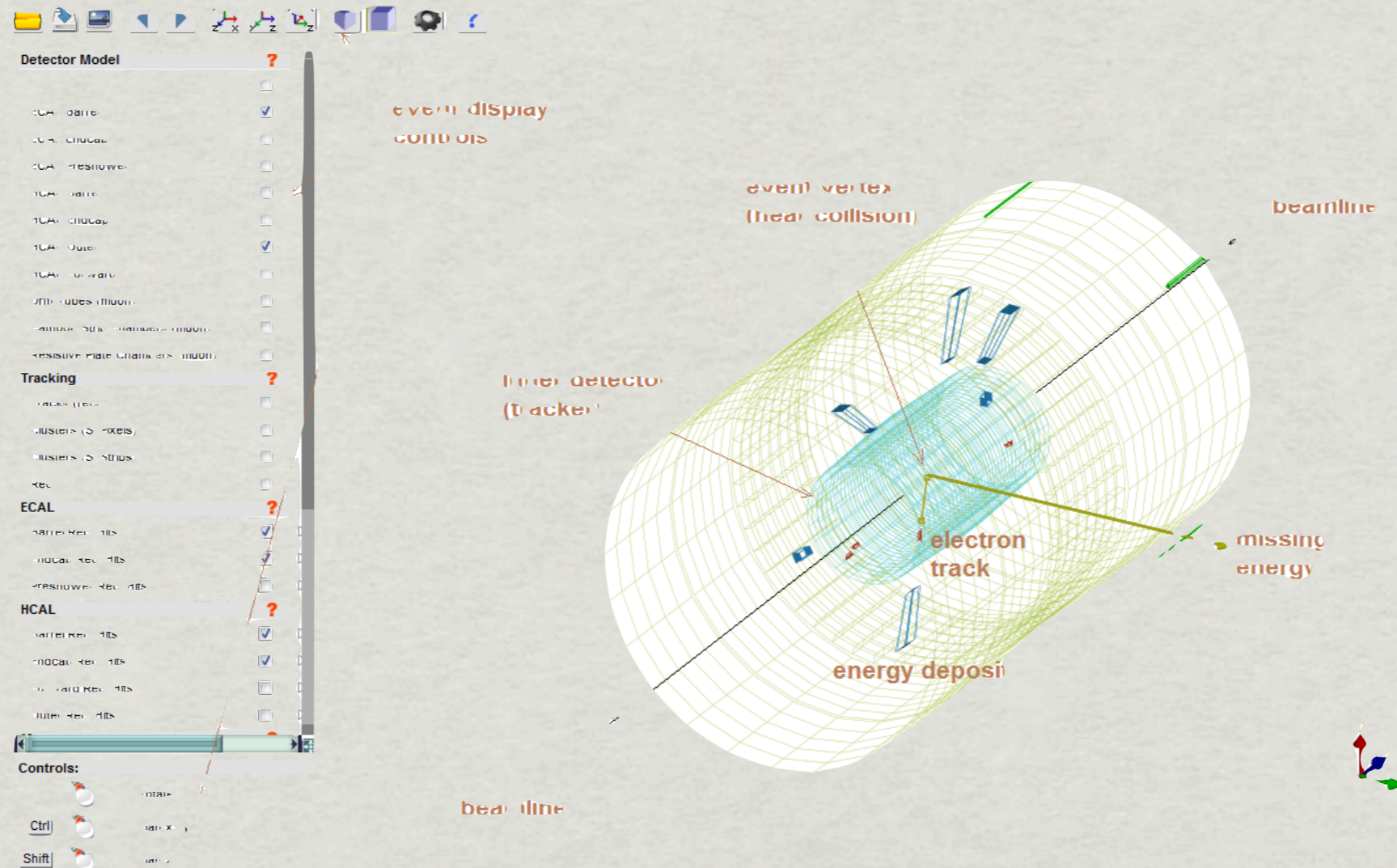
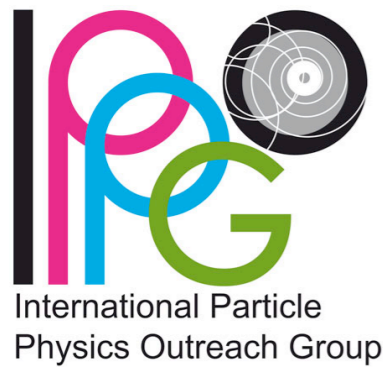


Fig. 14 - using 3-D event displays



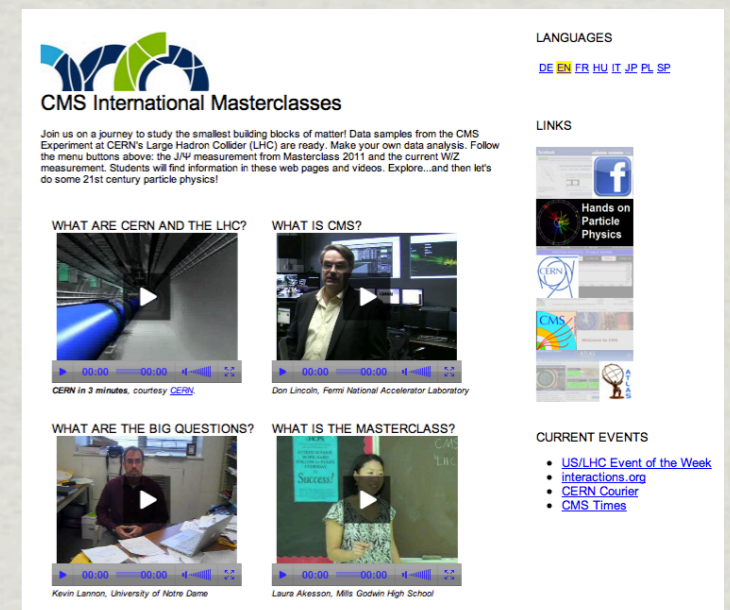
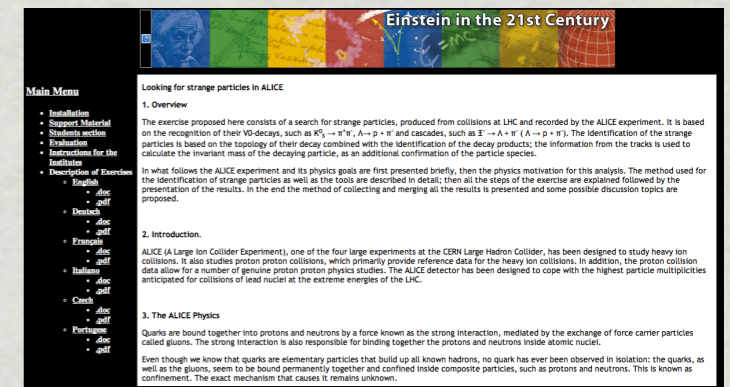


# IPPOG's International Masterclasses

## Physics Analyses

\* documentation online:

- \* ALICE: <http://aliceinfo.cern.ch/public/MasterCL/MasterClassWebpage.html>
- \* ATLAS: <http://www.cern.ch/kjende/elisa.htm>
- \* CMS: <http://www.physik.uzh.ch/lectures/MC2012/dvd/exercises/CMS/cms.html>
- \* available in 13 languages (translated by IPPOG members)
- \* contains: descriptions, animations, measurement's tasks, public real data events,



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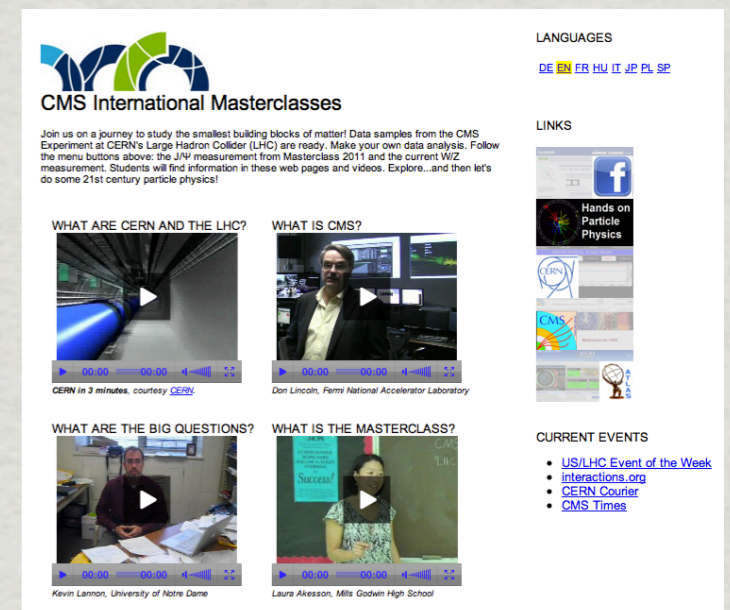
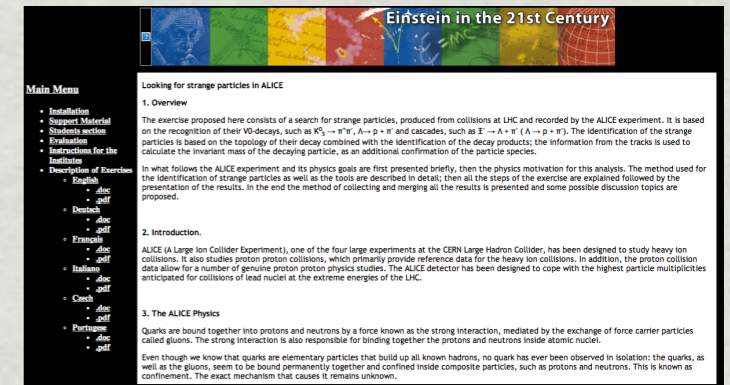
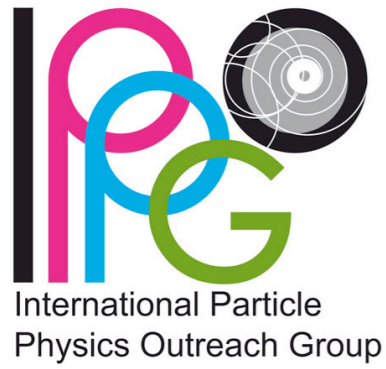


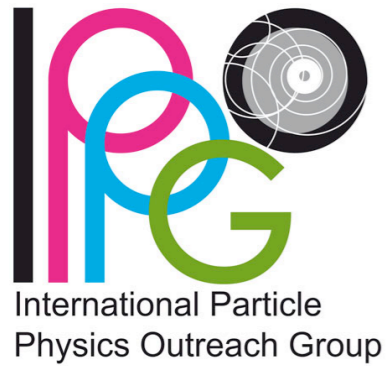
Fig. 15 - Screenshots of websites



# IPPOG's International Masterclasses Evaluation

- \* Surveys in 2005, 2007 (published), 2009 (QuarkNet), 2010, 2012 (to be published)

## **What students say about Masterclasses**



# IPPOG's International Masterclasses

## Evaluation

- Surveys in 2005, 2007 (published), 2009 (QuarkNet), 2010, 2012 (to be published)

### What students say about Masterclasses

**GREAT EXPERIENCE! Thanks a lot.**

**MASTERCLASS IS Totally AWESOME!**

***It was great!***

I think it was great! You should organise more, in different topics too! :) and advertise it more! (so every student will have the opportunity to take part in it)

**Die Umfrage ist vorzüglich, abwechslungsreich und spannend.  
(The survey is excellent, varied and exciting.)**

**This was an amazing  
experience and I'm so  
excited to come back  
tomorrow.**

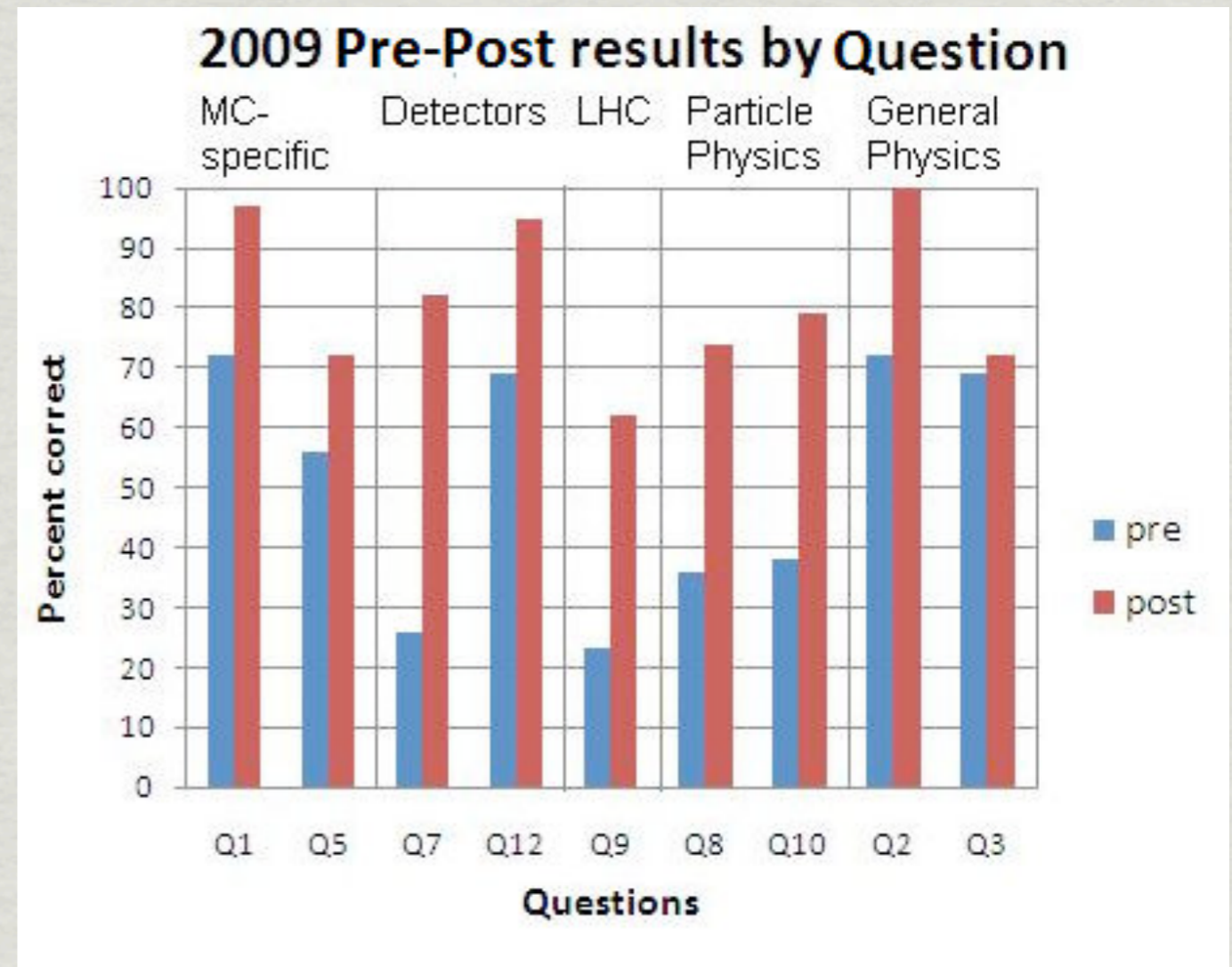
**Réduire la théorie pour plus d'experiences.  
(Reduce theory for more experiments.)**

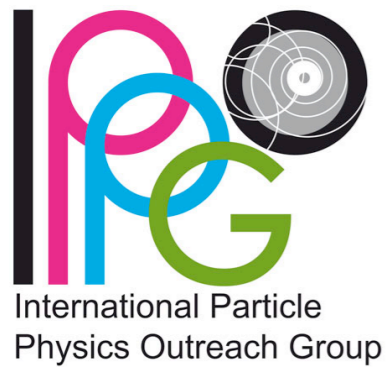


# IPPOG's International Masterclasses

## Evaluation

- \* Surveys in 2005, 2007 (published), 2009 (Quarknet), 2010, 2012 (to be published)
- \* QuarkNet study





# IPPOG's International Masterclasses Evaluation

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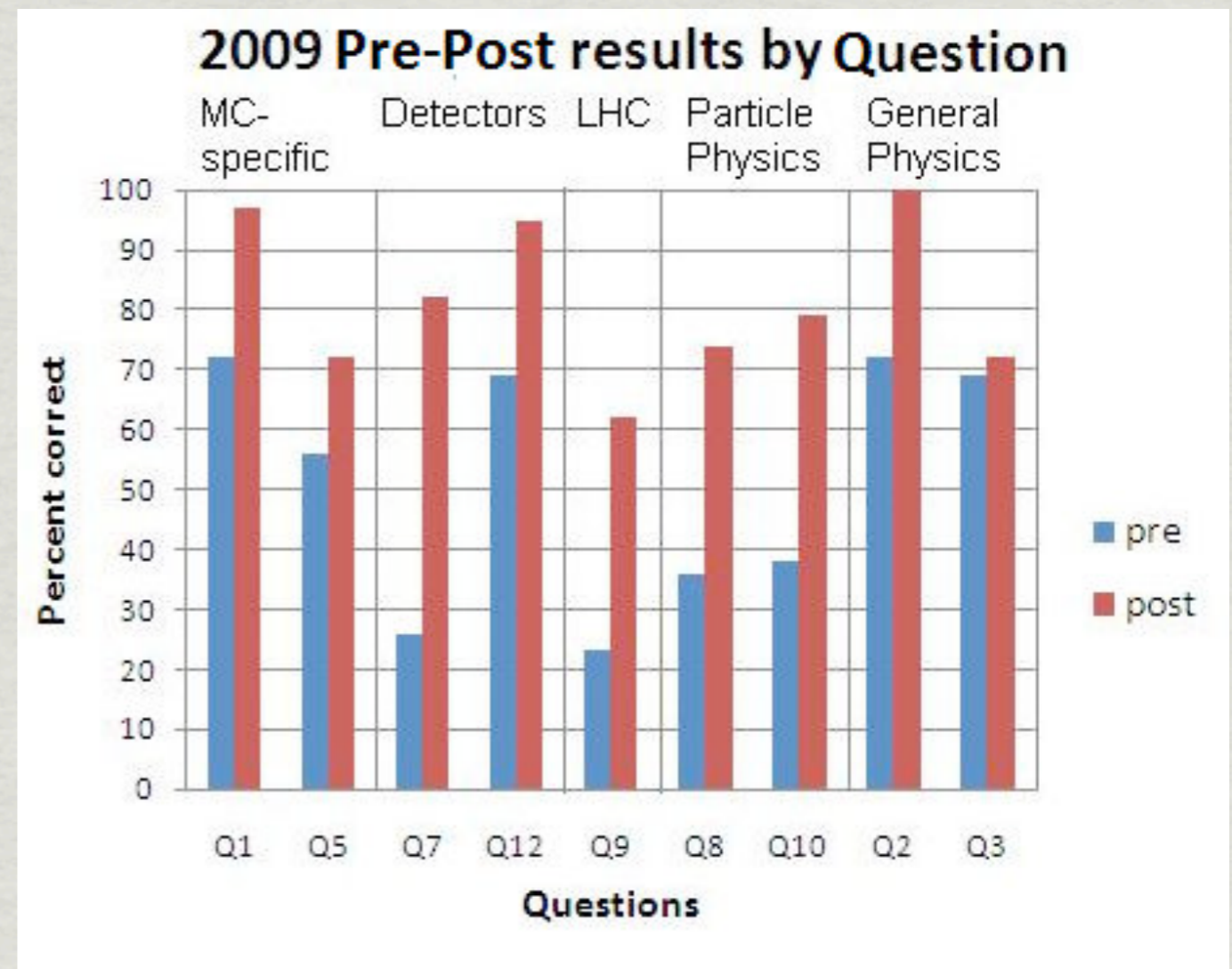
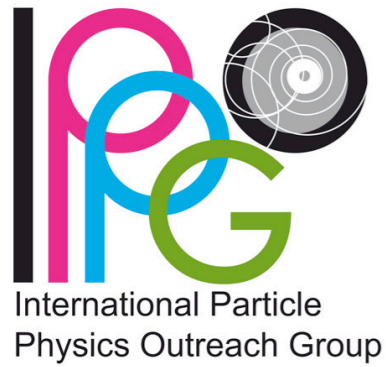


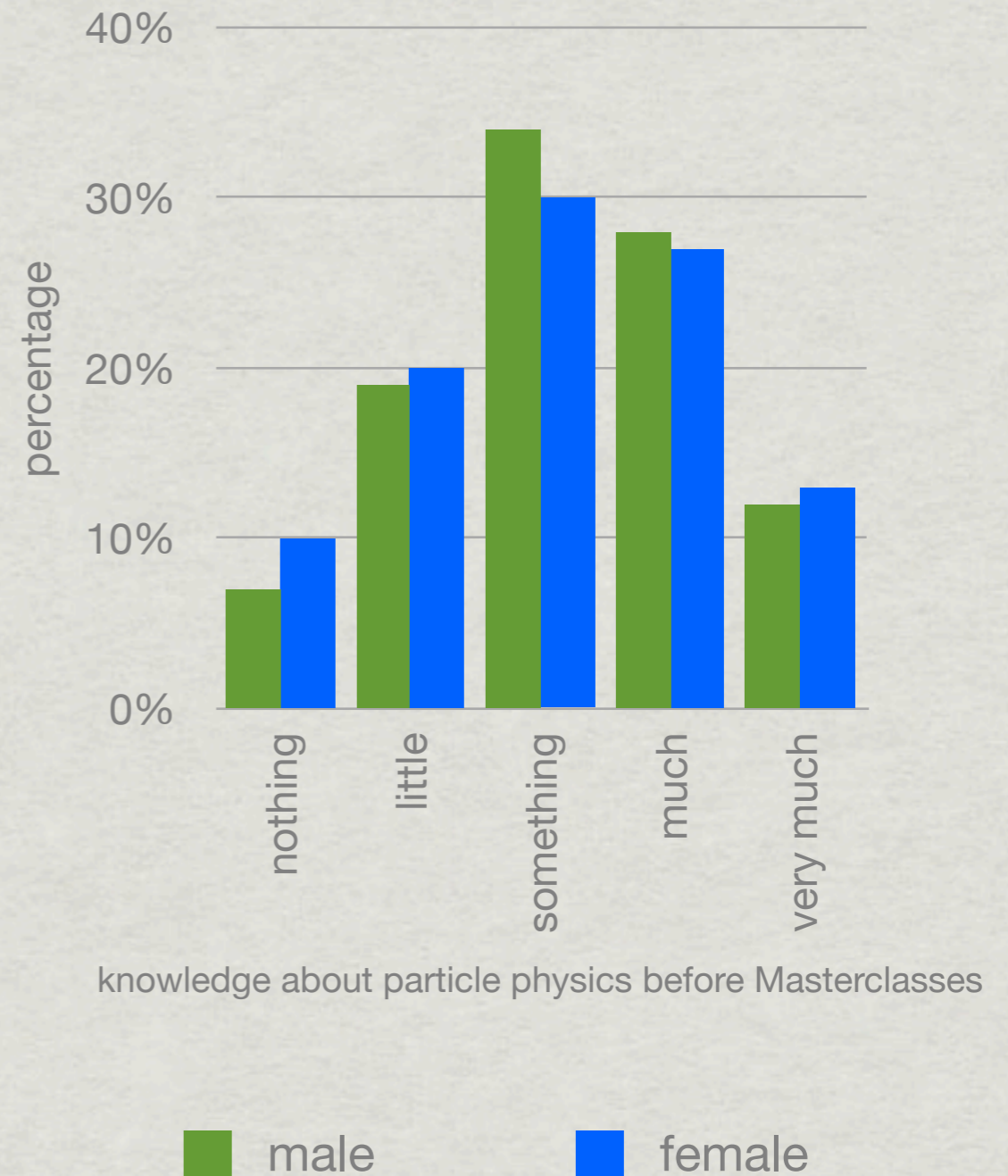
Fig. 16 - pre and post test performed by QuarkNet



# IPPOG's International Masterclasses

## Evaluation

- \* Surveys in 2005, 2007 (published), 2009 (Quarknet), 2010, 2012 (to be published)
- \* Publication: K.E. Johansson, M. Kobel, D. Hillebrandt, K. Engeln, M. Euler: European Particle Physics Masterclasses make students Scientists for a Day. In: Phys. Educ. 42 No 6 (November 2007) 636-644.



# IPPOG's International Masterclasses

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- \* Publication: K.E. Johansson, M. Kobel, D. Hillebrandt, K. Engeln, M. Euler: European Particle Physics Masterclasses make students Scientists for a Day. In: Phys. Educ. 42 No 6 (November 2007) 636-644.

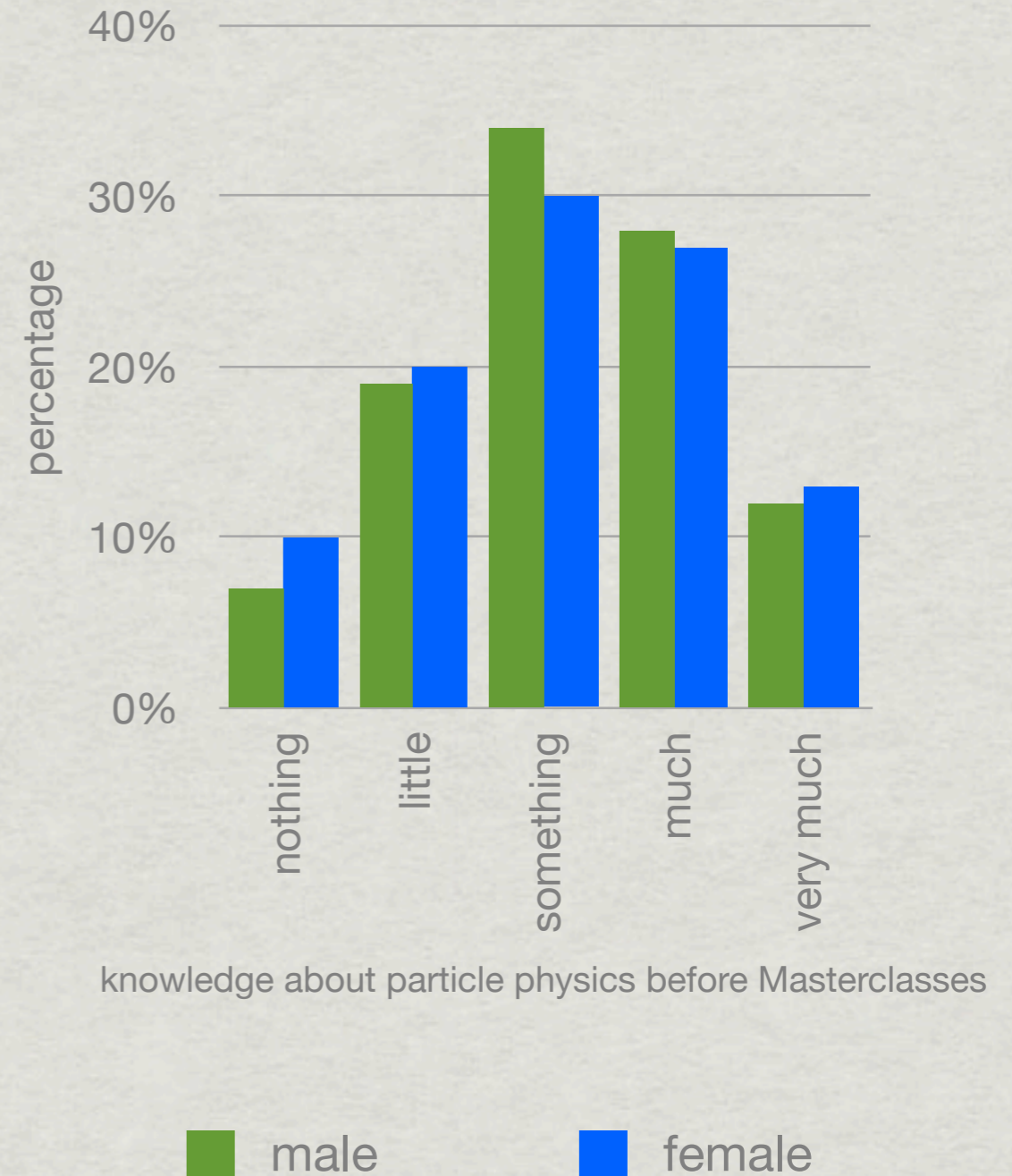
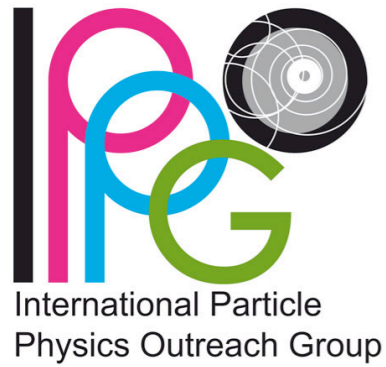


Fig. 17 - Gender independence of previous knowledge of attendees

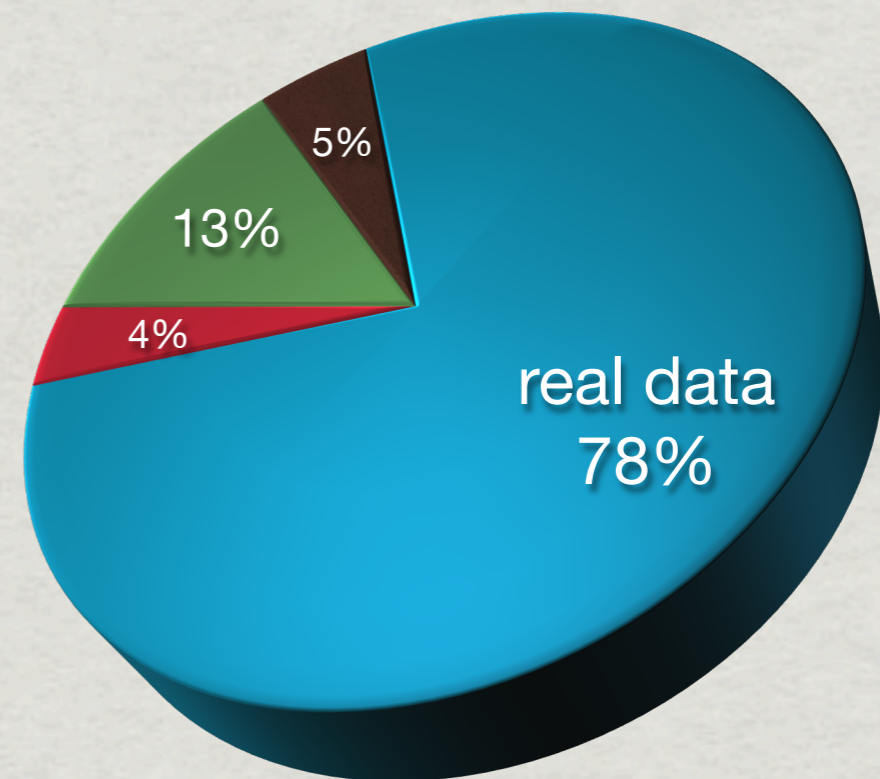




# IPPOG's International Masterclasses Evaluation

- \* Surveys in 2005, 2007 (published), 2010, 2012 (to be published)
- \* Online survey in 2010 to understand what students wish to do in LHC Masterclasses

## WHAT KIND OF DATA DO YOU PREFER TO WORK WITH?

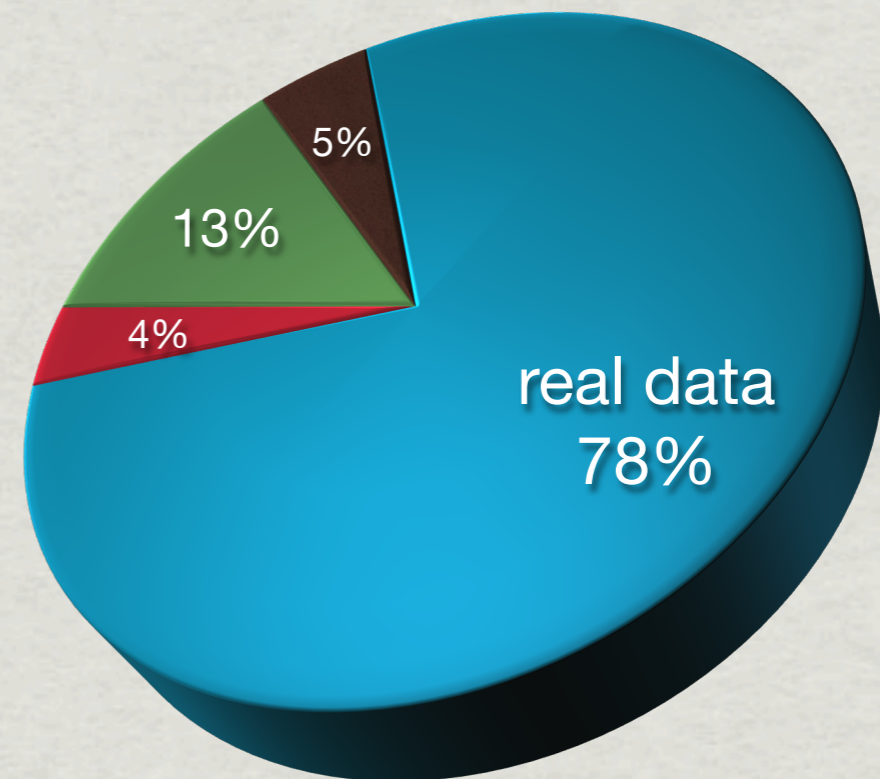


SURVEY: KONRAD JENDE, 2010

# IPPOG's International Masterclasses Evaluation

- \* Surveys in 2005, 2007 (published), 2010, 2012 (to be published)
- \* Online survey in 2010 to understand what students wish to do in LHC Masterclasses

## WHAT KIND OF DATA DO YOU PREFER TO WORK WITH?



**SURVEY: KONRAD JENDE, 2010**

Fig. 18 - Student wish to work with real data from the experiments



# IPPOG's International Masterclasses Participation



# IPPOG's International Masterclasses Participation

How you can get involved ...



# IPPOG's International Masterclasses Participation

How you can get involved ...

- \* Physics Institutes willing to host a Masterclass ...



# IPPOG's International Masterclasses Participation

How you can get involved ...

- \* Physics Institutes willing to host a Masterclass ...
- \* Schools, teachers, students who want to attend a Masterclass ...



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Please see our website <http://www.physicsmasterclasses.org> or contact the organizer by e-mail via [masterclass@physik.tu-dresden.de](mailto:masterclass@physik.tu-dresden.de)



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## How we can benefit from each other ...





# IPPOG's International Masterclasses Participation

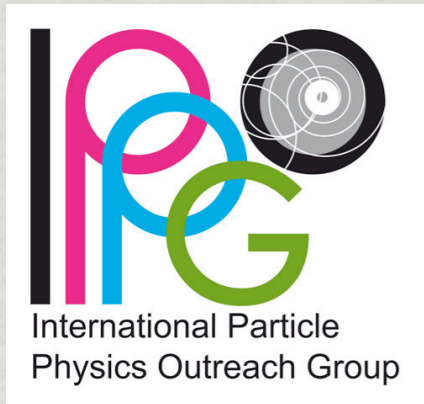
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## How we can benefit from each other ...

- \* Outreach Database was established to share material related to particle physics (videos, brochures, ideas for hands-on activities, posters, talks available in various languages): Use it, share it, upload your material!



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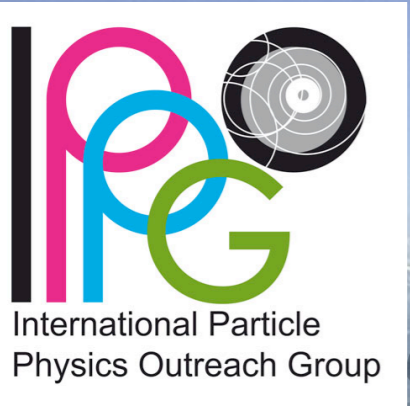
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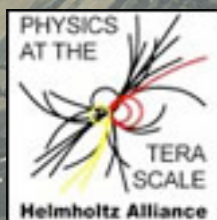
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- \* Please see: <http://ippog.web.cern.ch/resources> or send an e-mail to [ippog.admin@cern.ch](mailto:ippog.admin@cern.ch)



# IPPOG's International Masterclasses Summary



**FUNDED BY:**



**COORDINATOR**



Federal Ministry  
of Education  
and Research

**LHC UPGRADE**



**DVD  
PRODUCTION**

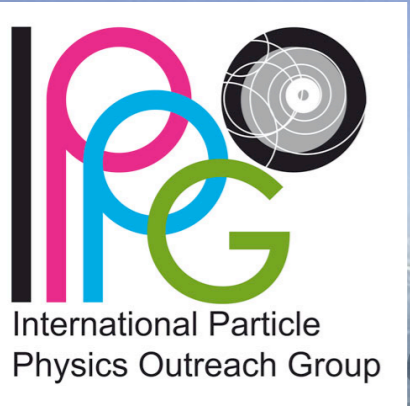


**US PARTNER  
PROGRAMME**



**EXPERIMENTAL DATA  
VIDEOCONFERENCE**

**+  
NATIONAL  
FUNDING  
AGENCIES**



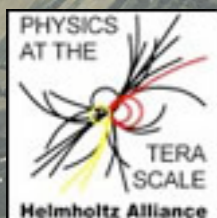
# IPPOG's International Masterclasses

## Summary

- world-wide collaboration of 15-19 years old high-school students experiencing cutting-edge particle physics
- analyzing real data from “today” and largest science experiments on earth
- discussing results and reflecting activities
- going home with the feeling “we learned something about today’s research”
- hopefully coming back to universities to study physics or science subjects



### FUNDED BY:



COORDINATOR



Federal Ministry of Education and Research

LHC UPGRADE



DVD PRODUCTION

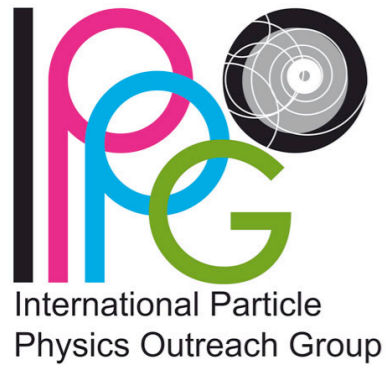


US PARTNER PROGRAMME



EXPERIMENTAL DATA VIDEOCONFERENCE

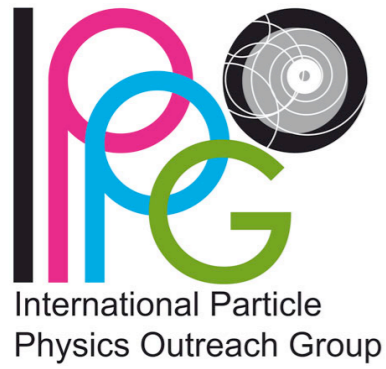
+ NATIONAL FUNDING AGENCIES



# IPPOG's International Masterclasses

## Back up slides

- \* Cool stuff from ATLAS
- \* Taking the idea further (by IPPOG members)
- \* International Masterclasses - Physics Analyses - Technical Platforms and tools

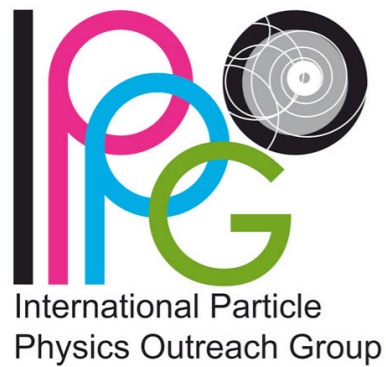


# IPPOG's International Masterclasses

## Cool stuff from ATLAS

[Applet on particle identification](#) with the ATLAS experiment

3-D ATLAS event display [CAMELIA](#)



# IPPOG's International Masterclasses

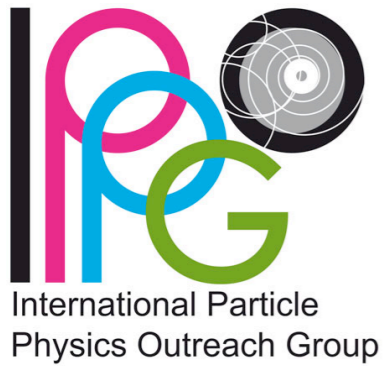
## Taking the idea further (by IPPOG members)

### Germany - Netzwerk Teilchenwelt (ran since 2010)

- \* Masterclasses-like activity (Ph.D. students go into schools; 120 MC in 2011)
- \* 2011: eight (further developing) teacher programmes in Germany, two Teacher Programmes at CERN, two programmes for students at CERN, 9 research projects done by students
- \* Please see: <http://www.teilchenwelt.de> for further information

### CMS (under development)

- \* toolkit with software, real data
- \* toolkit + local physicist are sent to school



# IPPOG's International Masterclasses Physics Analyses - Technical Platforms and tools

## ATLAS

- \* **MINERVA** (M. Wielers, P. Watkins, T. McLaughlan et al.) based on ATLANTIS: <http://atlas-minerva.web.cern.ch>
- \* **HYPATIA** (C. Kourkouvelis et al.) based on ATLANTIS: <http://hypatia.phys.uoa.gr>

## CMS

- \* **iSpy** online (P. Nguyen, T. McCauley et al.) in collaboration with QuarkNet (US): <http://iguana.web.cern.ch/iguana/ispy/>

## ALICE

- \* **ALICE** masterclass application (P. Debski, Y. Foka et al.) simplified ALICE event display in ROOT environment: <http://aliceinfo.cern.ch/public/MasterCL/MasterClassInstallation.html>