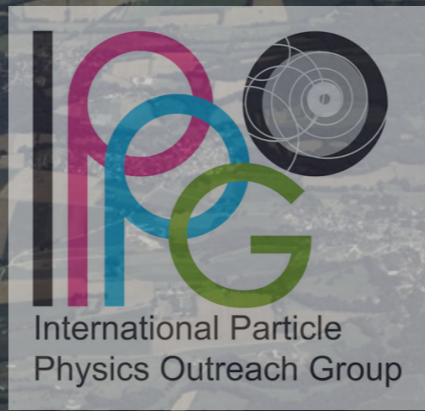
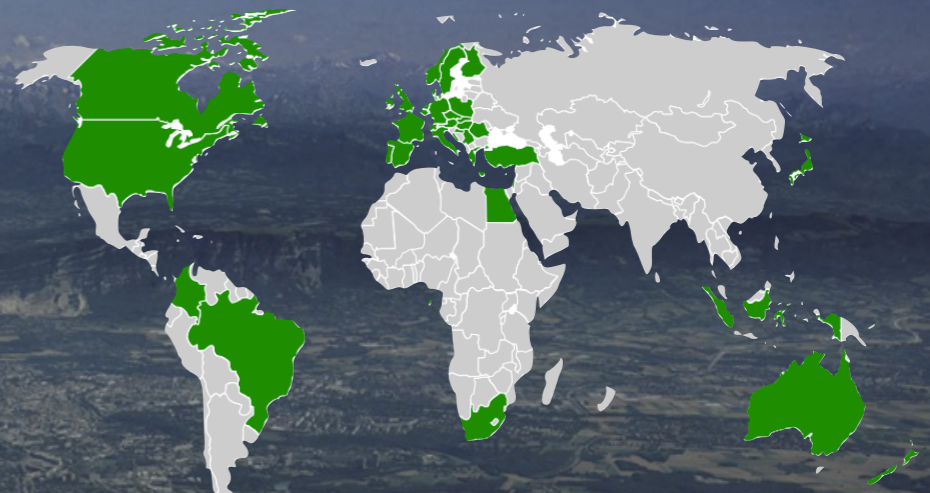
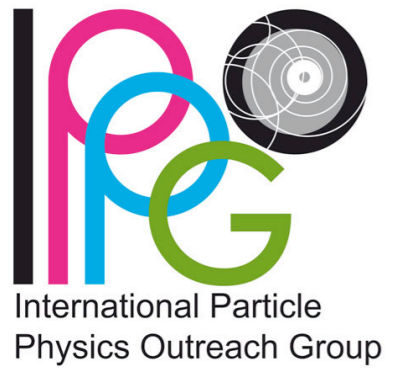


# Bringing the world's largest science experiment into the "classroom"



Konrad Jende, TU Dresden on behalf of the International Particle Physics Outreach Group (IPPOG)  
NTP, October 4 2013





# Outline

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

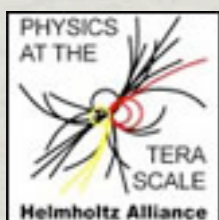




International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses

## FUNDED BY:



COORDINATOR



Federal Ministry  
of Education  
and Research

MASTERCLASSES  
LHC UPGRADE



DVD  
PRODUCTION



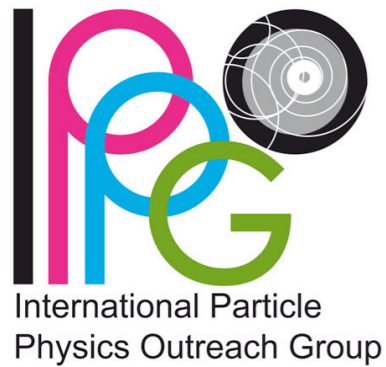
US PARTNER  
PROGRAMME



EXPERIMENTAL DATA  
VIDEOCONFERENCE

+  
NATIONAL  
FUNDING  
AGENCIES



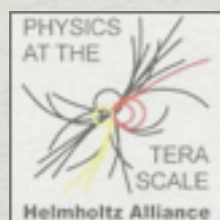


# IPPOG's International Masterclasses

## \* 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



MASTERCLASSES  
LHC UPGRADE



DVD  
PRODUCTION



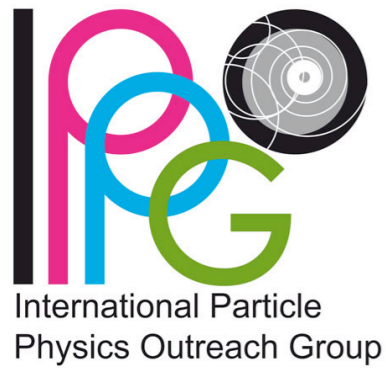
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PROGRAMME



EXPERIMENTAL DATA  
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+  
NATIONAL  
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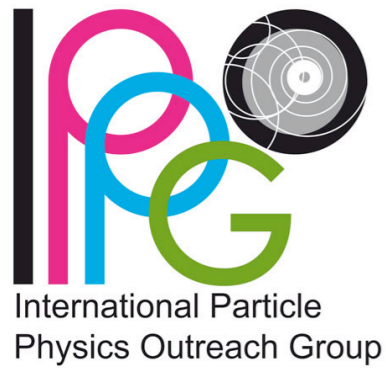


# IPPOG's International Masterclasses

## ✱ Objectives

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

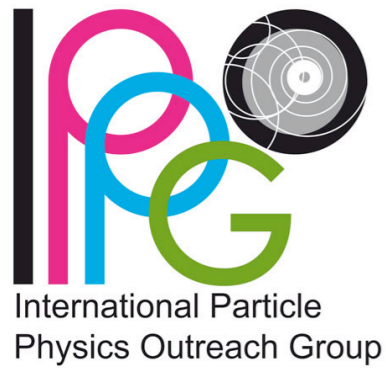




# IPPOG's International Masterclasses

- \* **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>





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■ # of participants in International Masterclasses

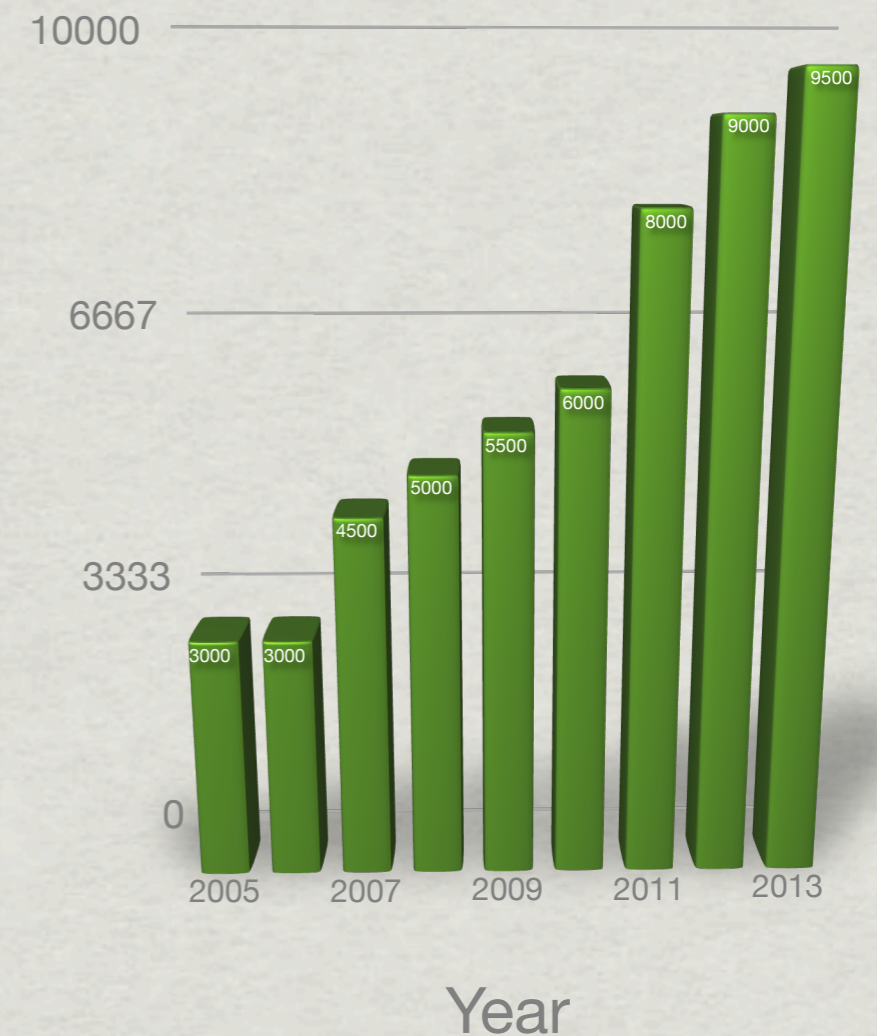


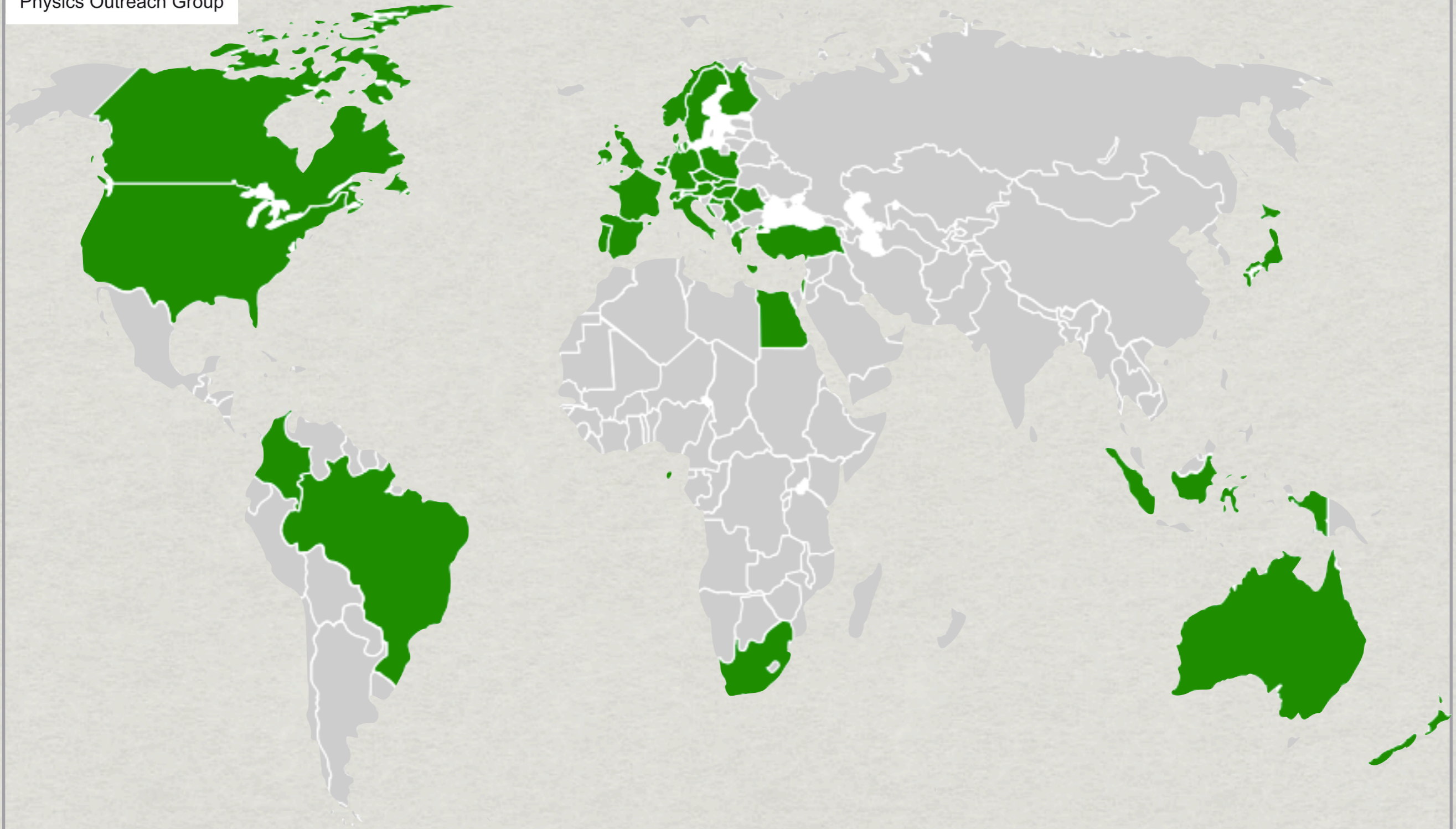
Fig. 2 - Number of participants in International Masterclasses over the years





International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses







International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses

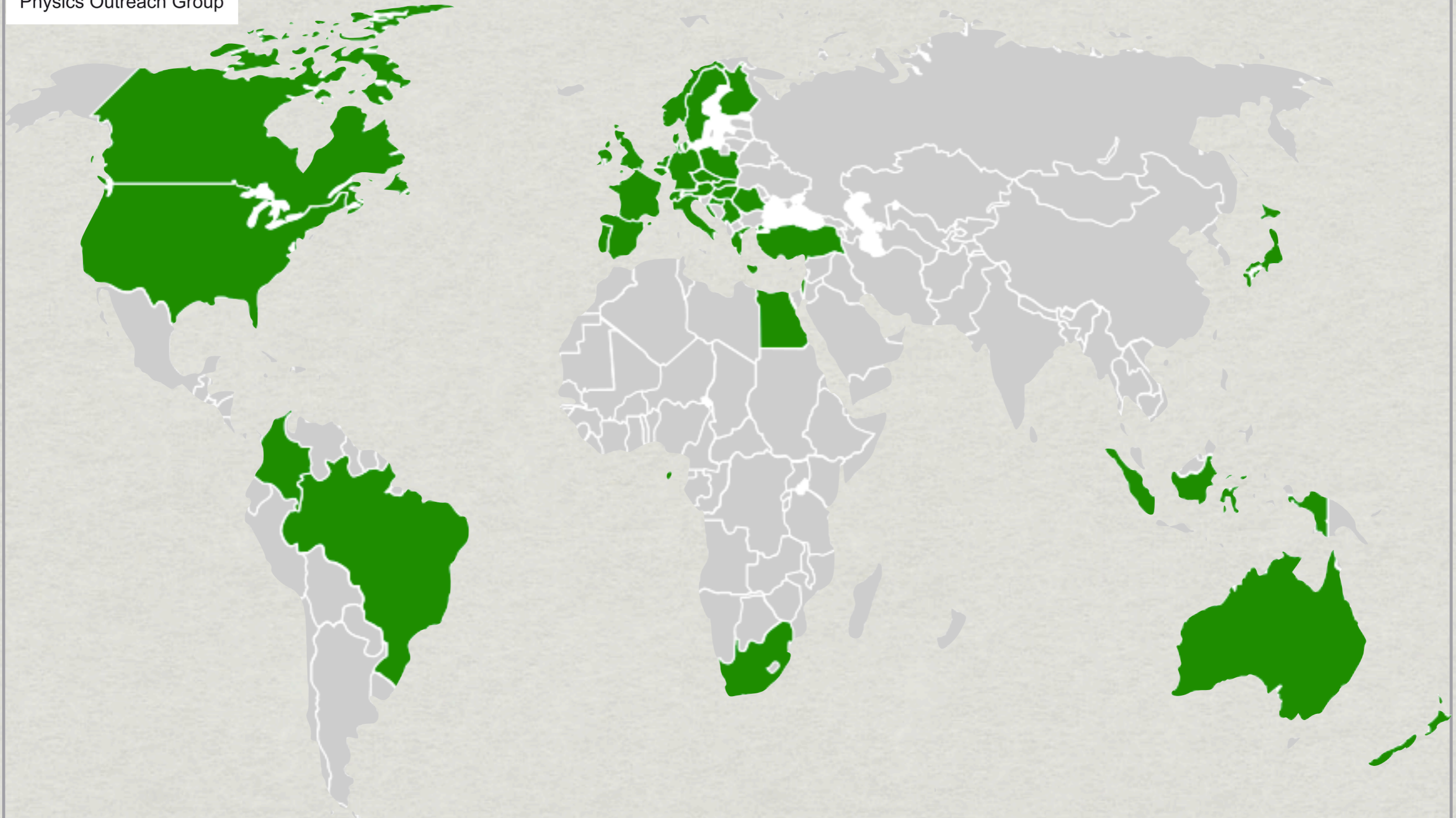


Fig. 3 - World Map of Masterclasses attendees





International Particle  
Physics Outreach Group

# 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**





International Particle  
Physics Outreach Group

# IPPOG's International Masterclasses

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**Combination of measurement's results**

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4:30



**Videoconference**

Fig. 4 - Typical Masterclasses day





# IPPOG's International Masterclasses

## Physics Analyses



# IPPOG's International Masterclasses

## Physics Analyses

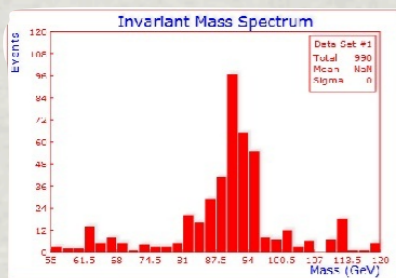
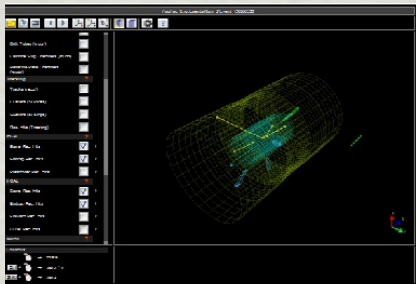


Fig. 5 - Process during data analysis in Masterclasses



# IPPOG's International Masterclasses

## Physics Analyses



- ✱ students work in pairs in front of computers, where

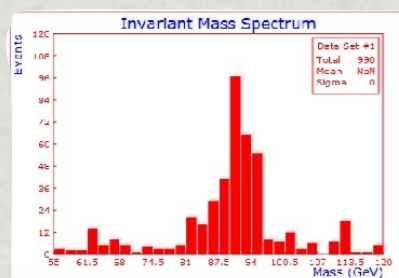
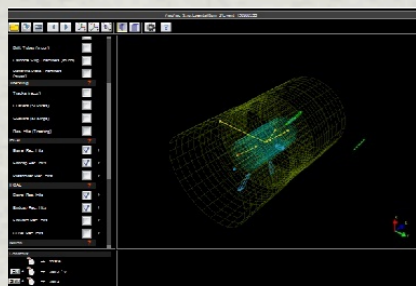
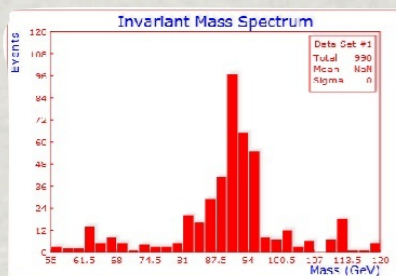
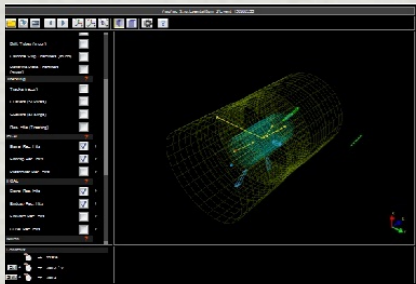


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# IPPOG's International Masterclasses

## Physics Analyses



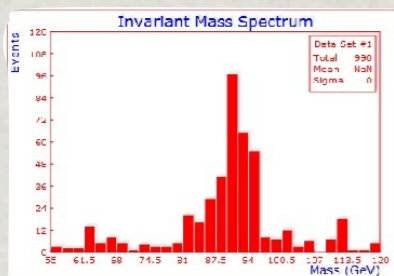
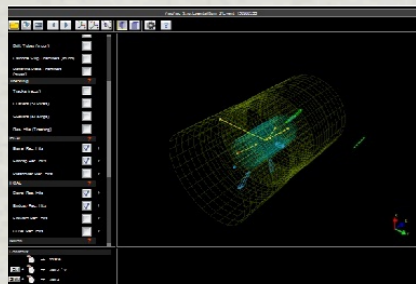
- ✳ students work in pairs in front of computers, where
- ✳ they identify particles visually in event displays of proton-proton-collisions and thus assign an event to predetermined classes of events

Fig. 5 - Process during data analysis in Masterclasses



# IPPOG's International Masterclasses

## Physics Analyses



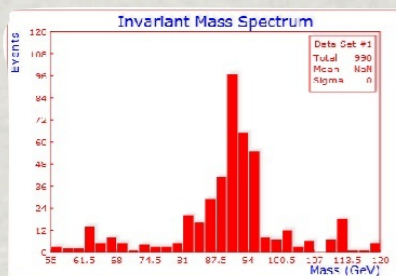
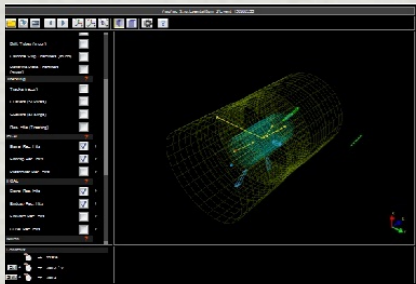
- ✱ students work in pairs in front of computers, where
- ✱ they identify particles visually in event displays of proton-proton-collisions and thus assign an event to predetermined classes of events
- ✱ produce plots (histograms) out of their results and

Fig. 5 - Process during data analysis in Masterclasses



# IPPOG's International Masterclasses

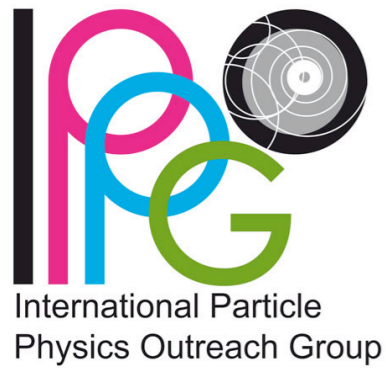
## Physics Analyses



- ✳ 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
- ✳ produce plots (histograms) out of their results and
- ✳ discuss them afterwards at the venue and during the videoconference

Fig. 5 - Process during data analysis in Masterclasses





# 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

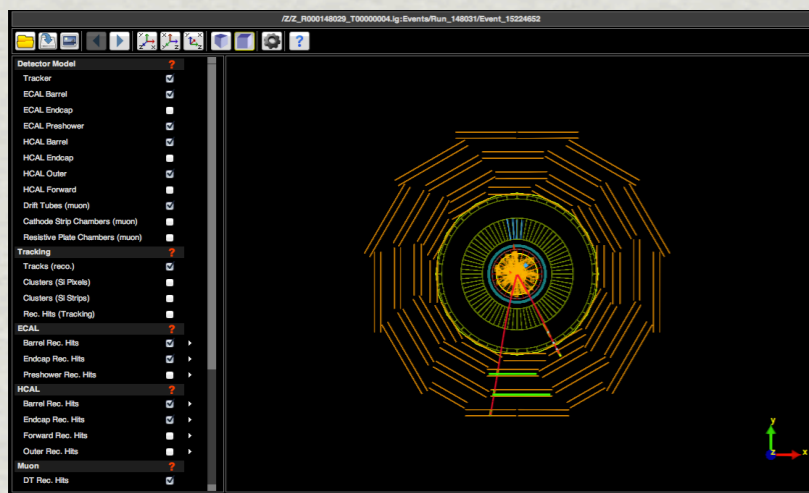


Fig. 6 - CMS event display

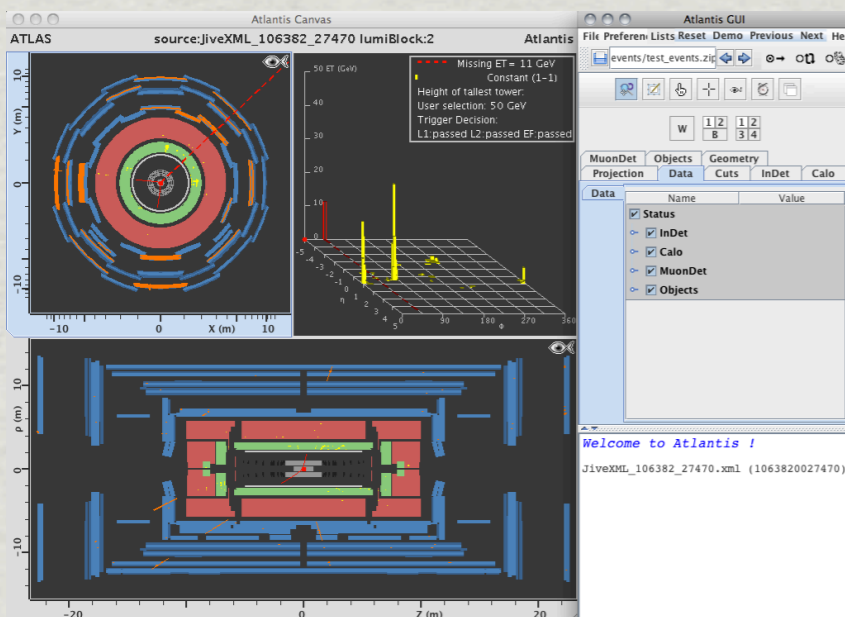


Fig. 7 - ATLAS event display

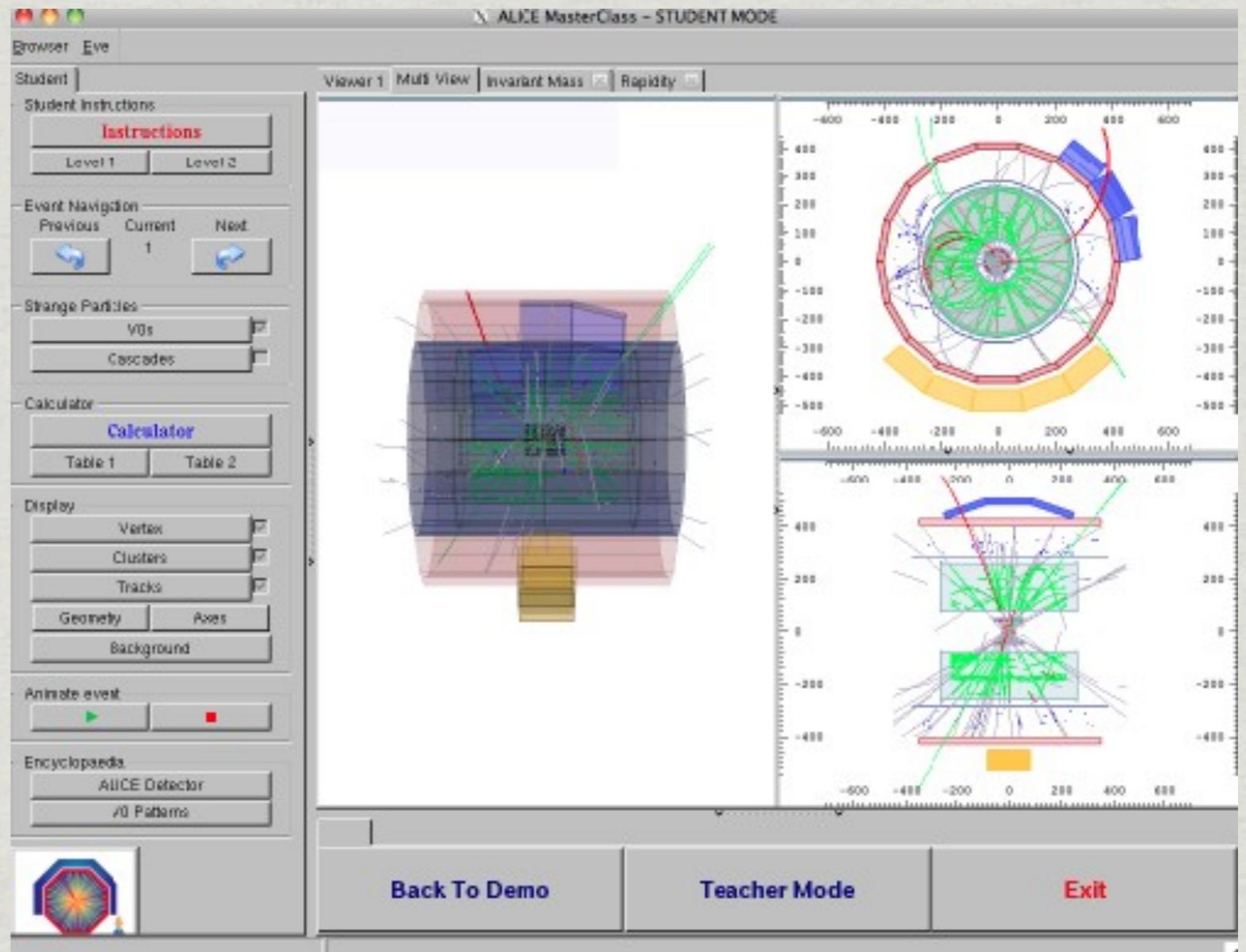


Fig. 8 - ALICE event display



# IPPOG's International Masterclasses

## Physics Analyses

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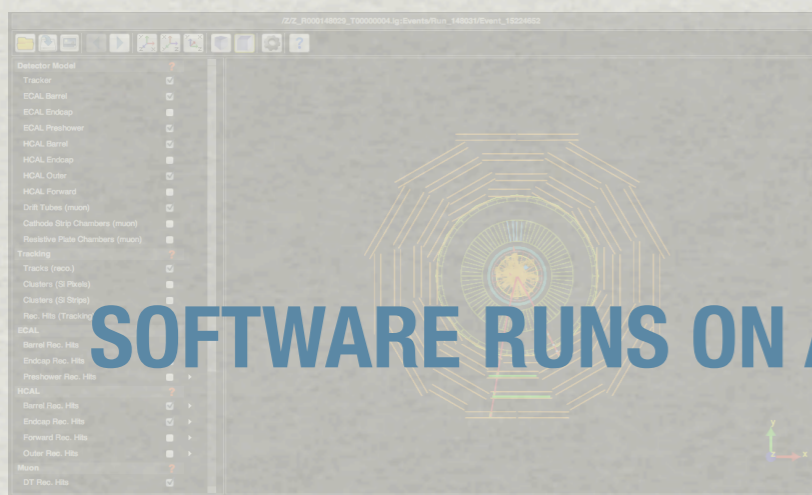


Fig. 6 - CMS event display

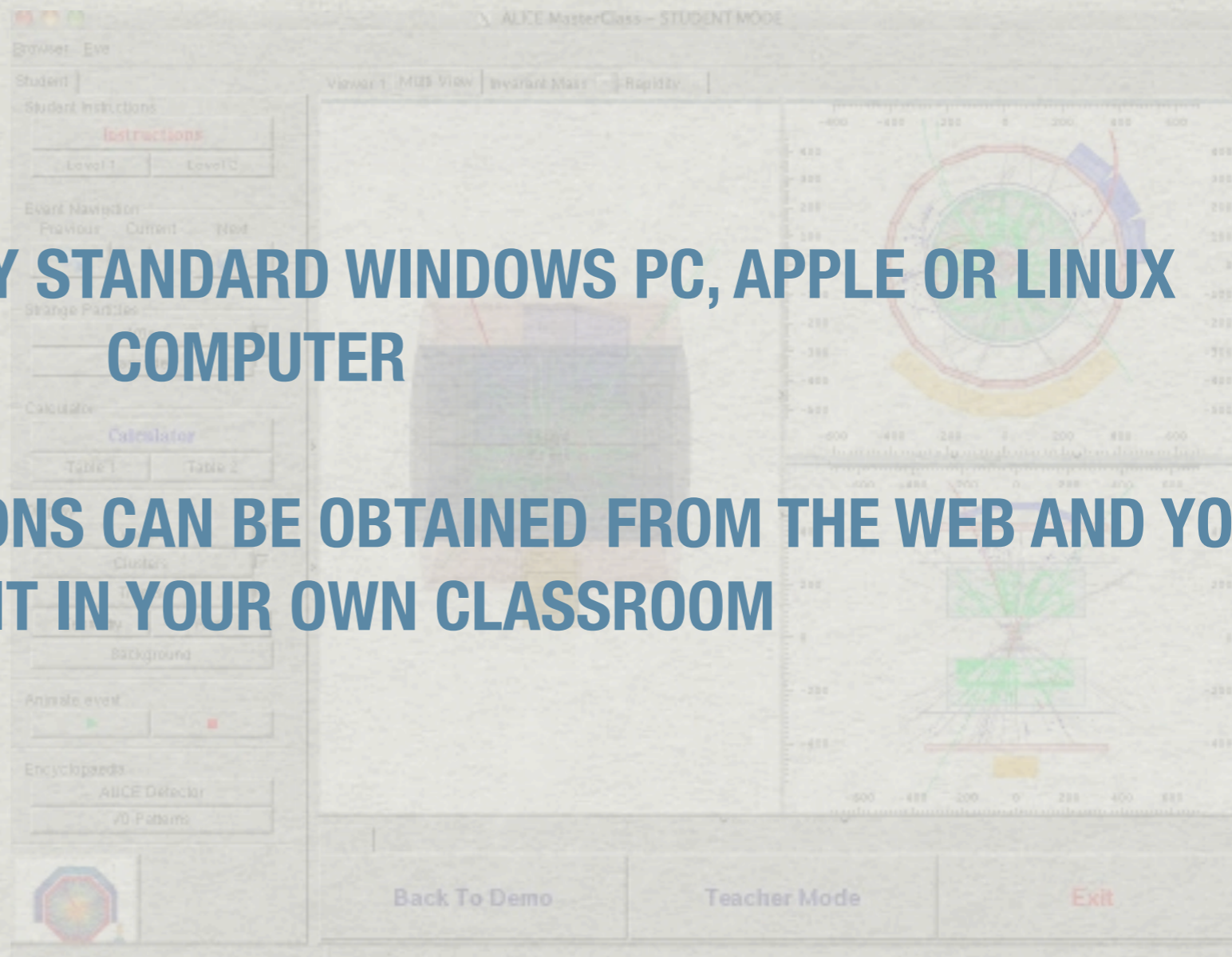


Fig. 8 - ALICE event display

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

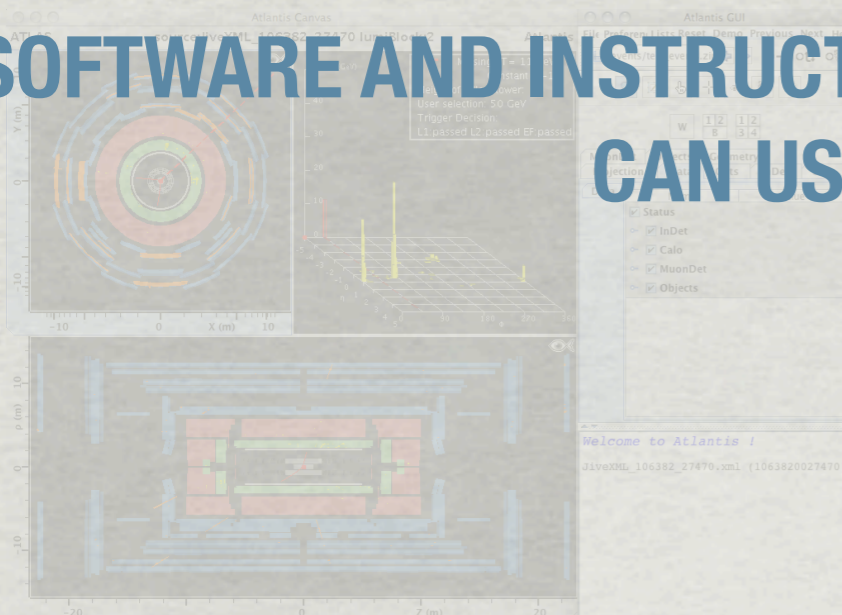
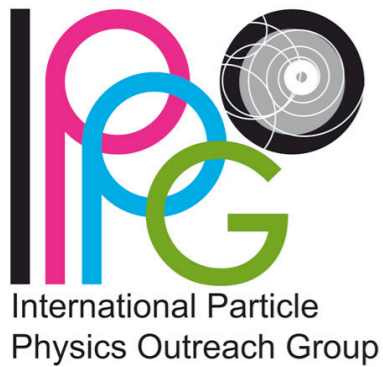


Fig. 7 - ATLAS event display





# IPPOG's International Masterclasses

## Physics Analyses

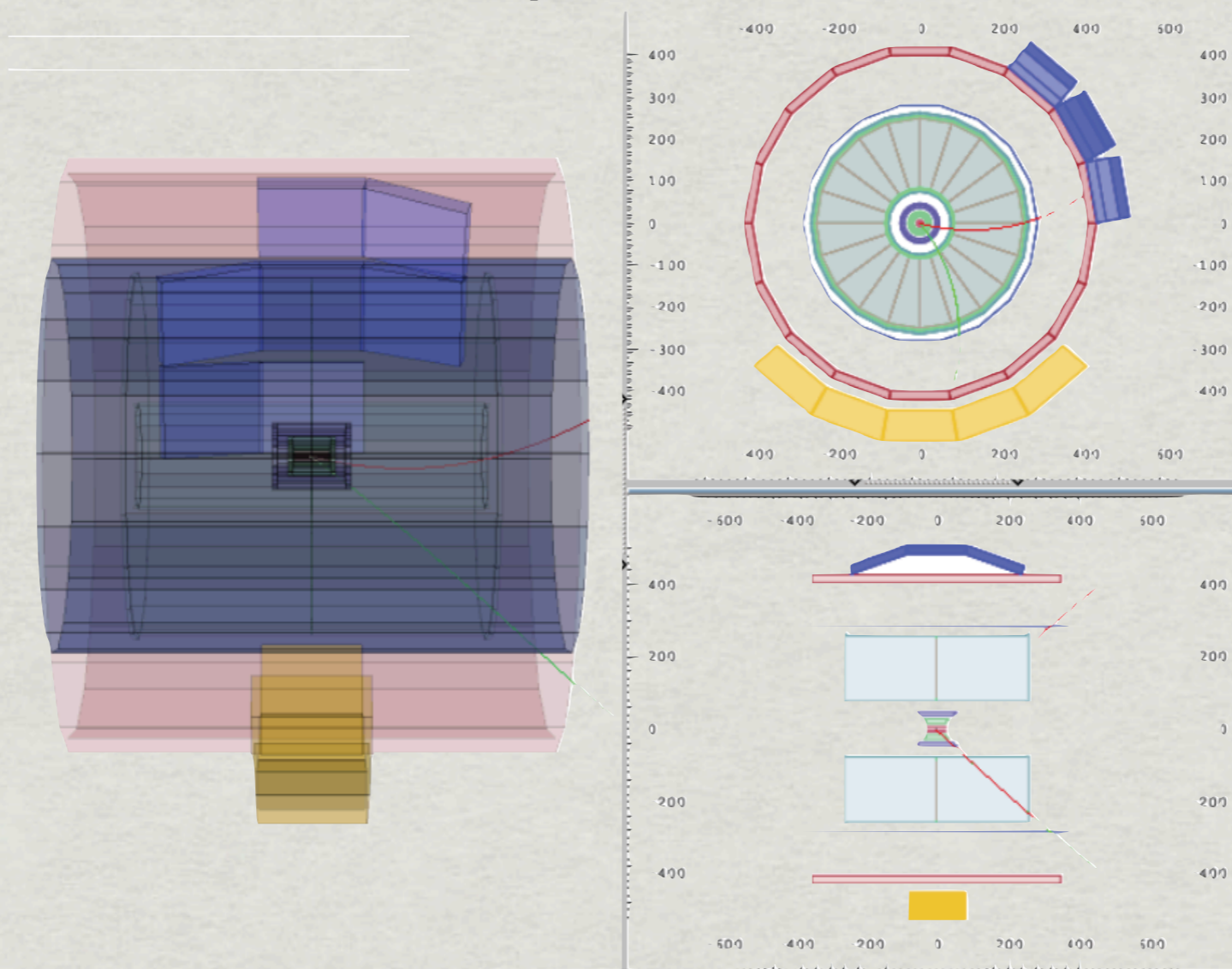
- \* based on visual event identification of event displays of proton-proton-collisions using tools of physicists
- \* various exercises/measurements on real data are provided by the LHC experiments ALICE, ATLAS and CMS, where students:
  - \* identify particles/events by using different techniques (e.g. 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)

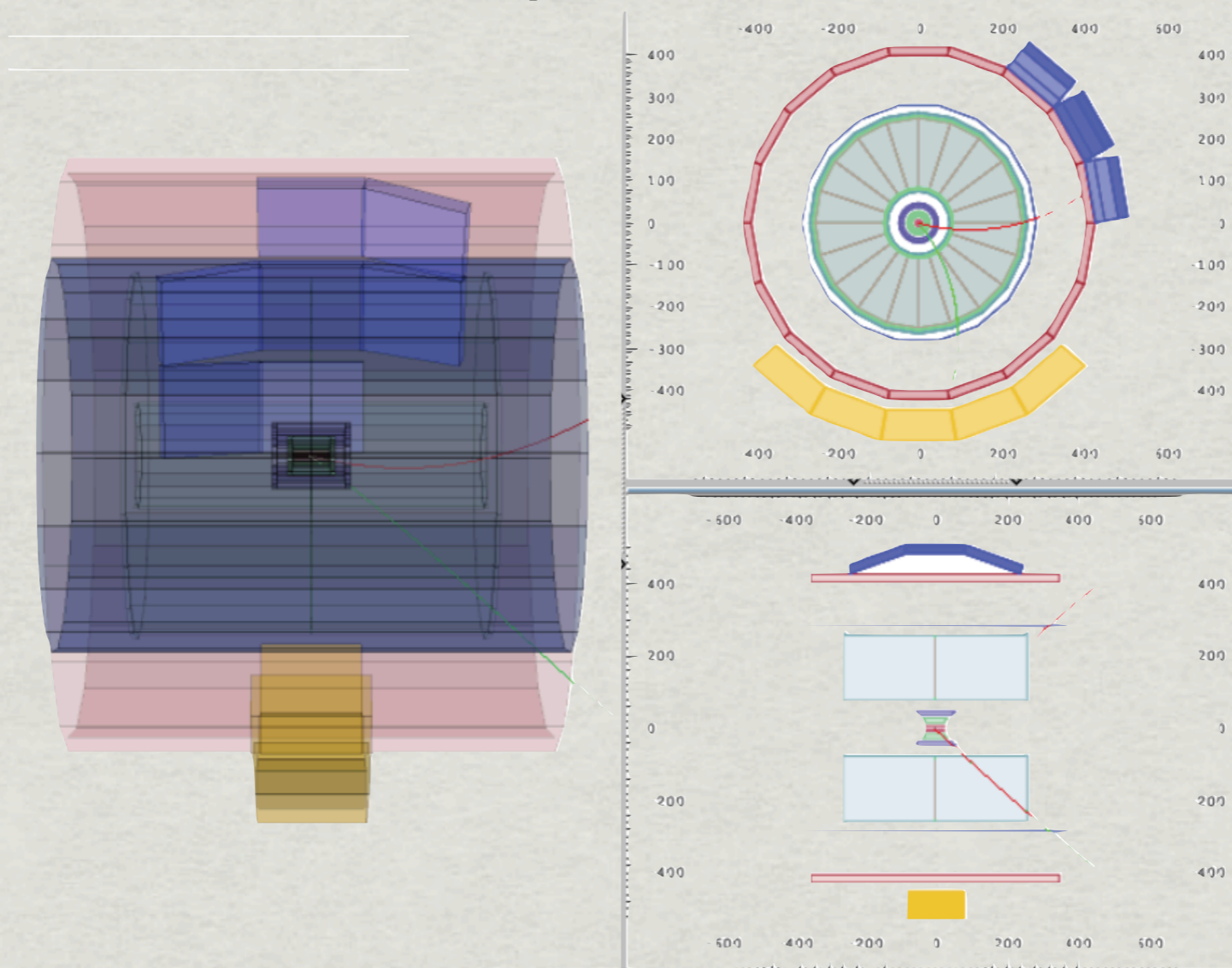




# IPPOG's International Masterclasses

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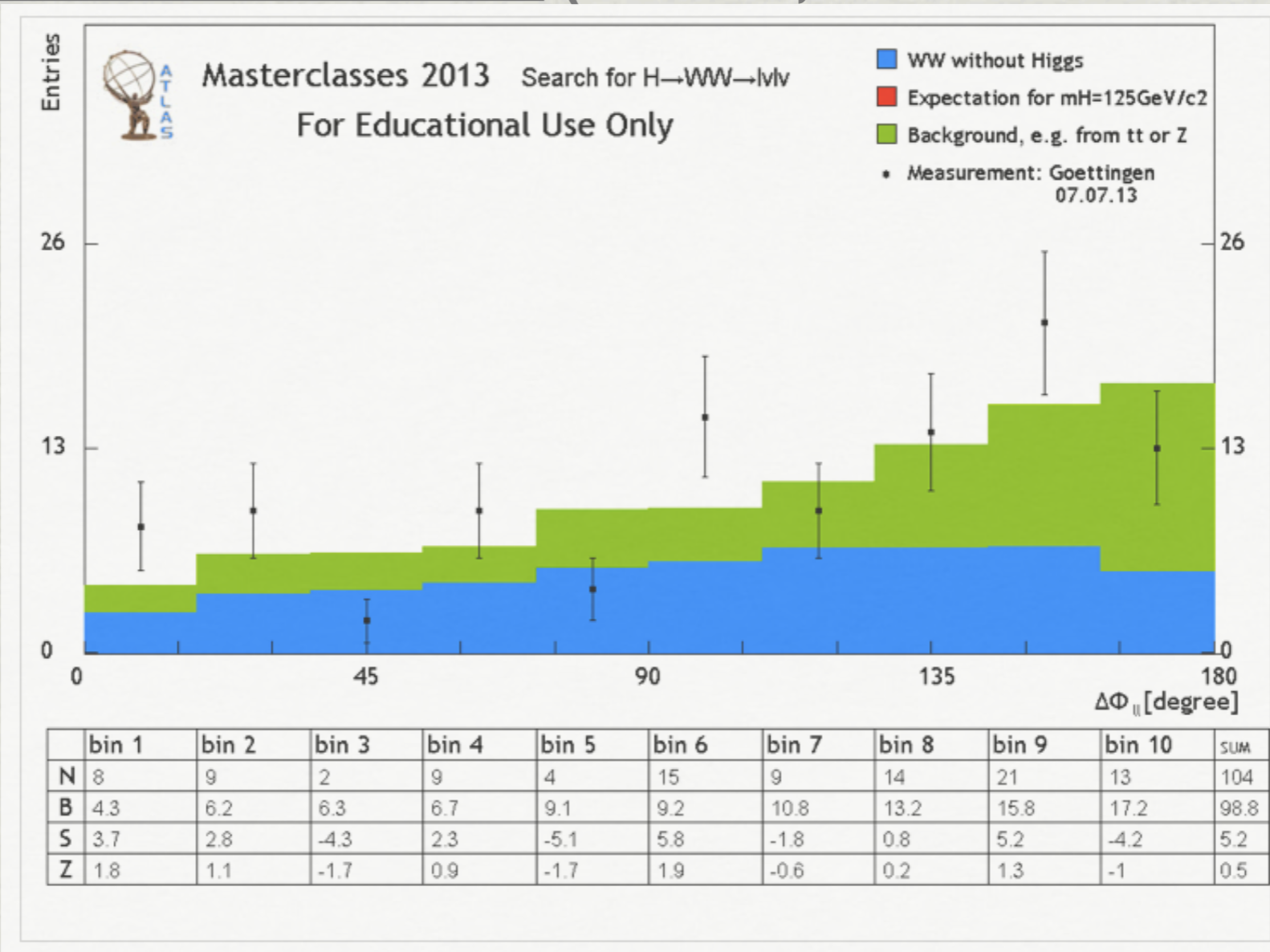
**Fig. 9 - Electric neutral particles can be only seen in the inner detector when they decay into electric charged particles, where the tracks build a "V" - that is why we call them V0 events**



# 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)

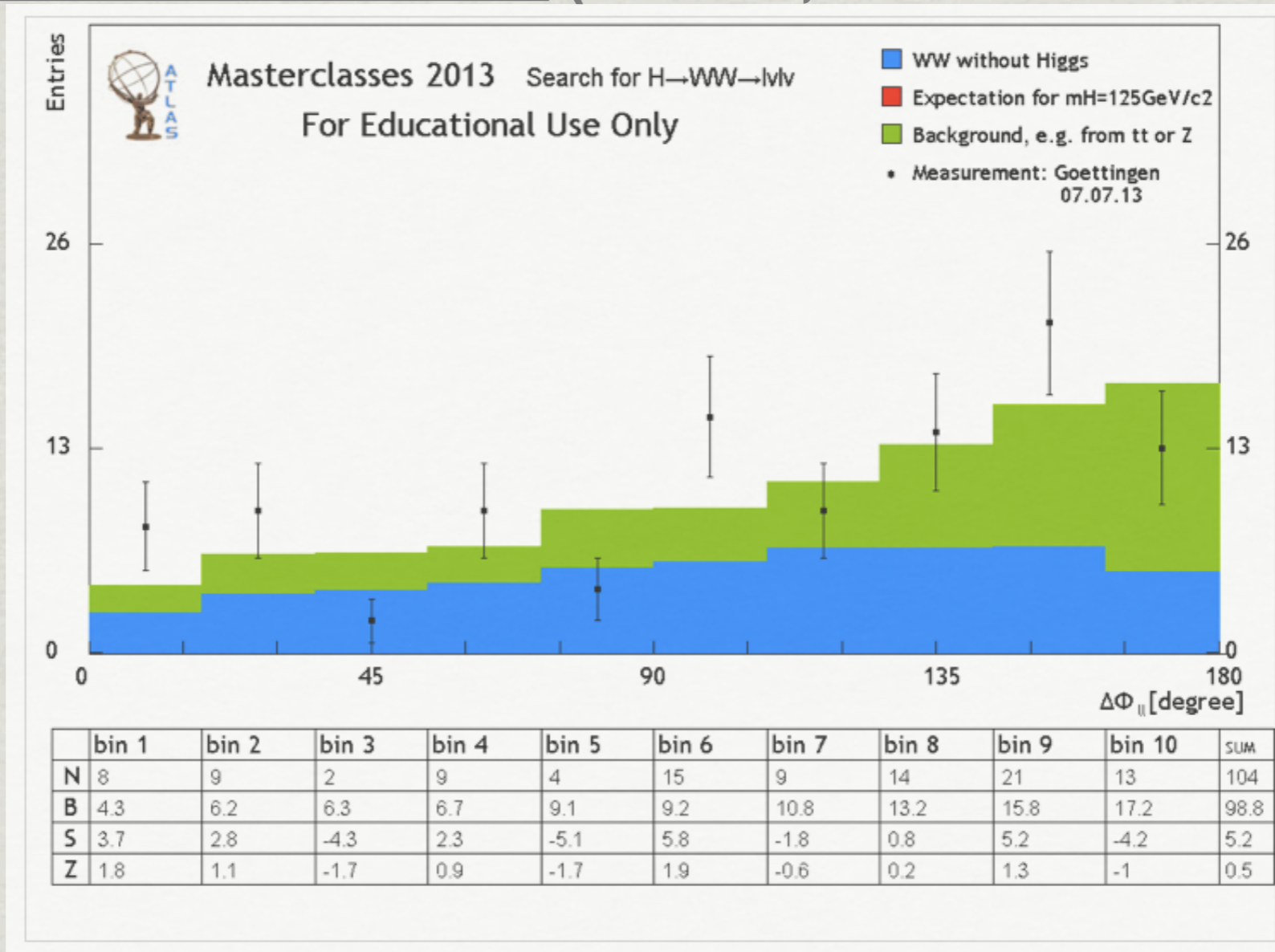
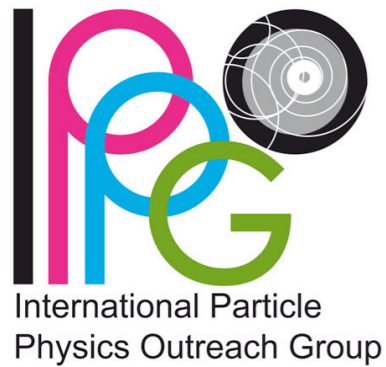


Fig. 10 - using histograms to determine selection criteria like physicists do





# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique





# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique

$$E_0, m_0, p_{0,x}, p_{0,y}, p_{0,z}$$





# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique

$$E_0, m_0, p_{0,x}, p_{0,y}, p_{0,z}$$



$$E_1, m_1, p_{1,x}, p_{1,y}, p_{1,z}$$

$$E_2, m_2, p_{2,x}, p_{2,y}, p_{2,z}$$



# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique

$$E_0, m_0, p_{0,x}, p_{0,y}, p_{0,z}$$

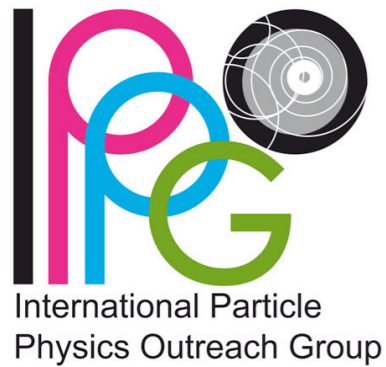


$$E_1, m_1, p_{1,x}, p_{1,y}, p_{1,z}$$

$$E_2, m_2, p_{2,x}, p_{2,y}, p_{2,z}$$

$$E_0^2 = m_0^2 c^4 + \mathbf{p}_0^2 c^4$$





# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique





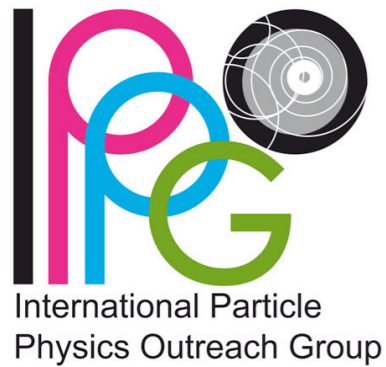
# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique







# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement - Invariant mass technique

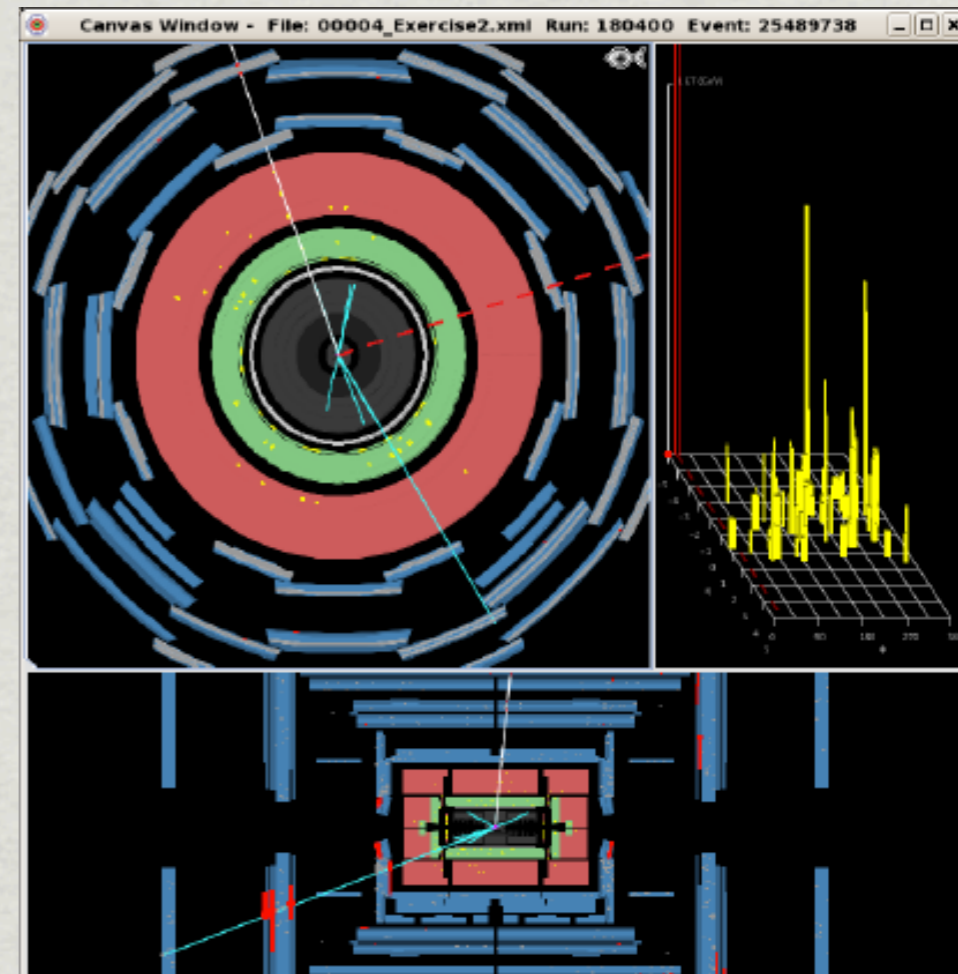
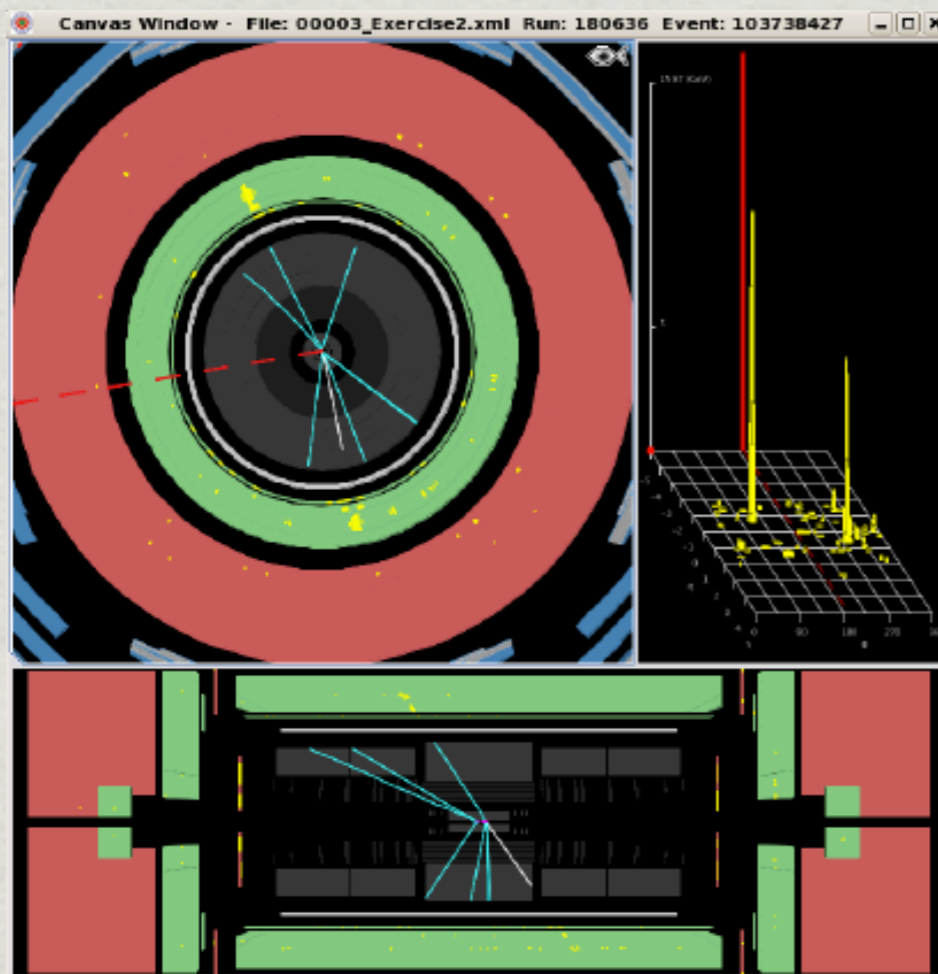
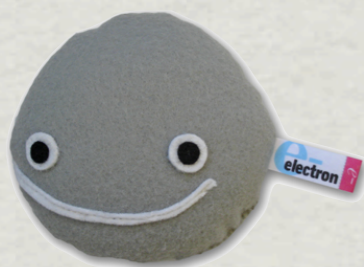




# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement invariant mass technique





# IPPOG's International Masterclasses

## Physics Analyses

### ATLAS Z measurement invariant mass technique

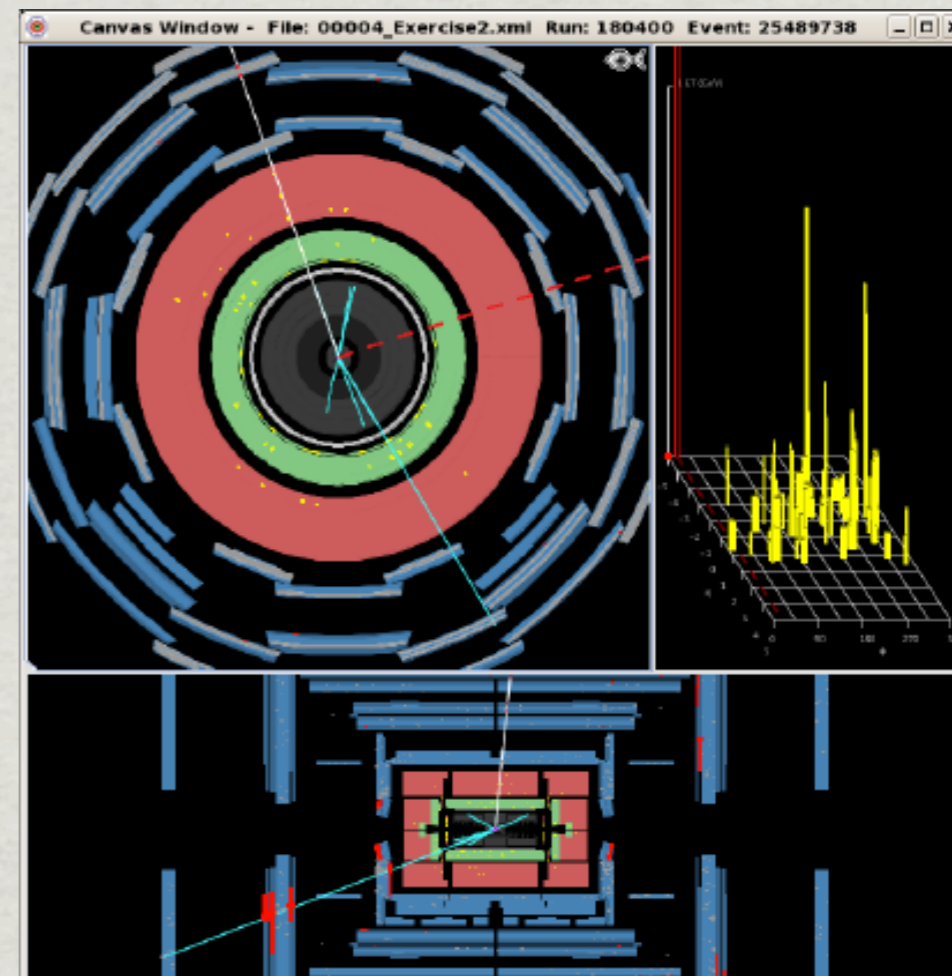
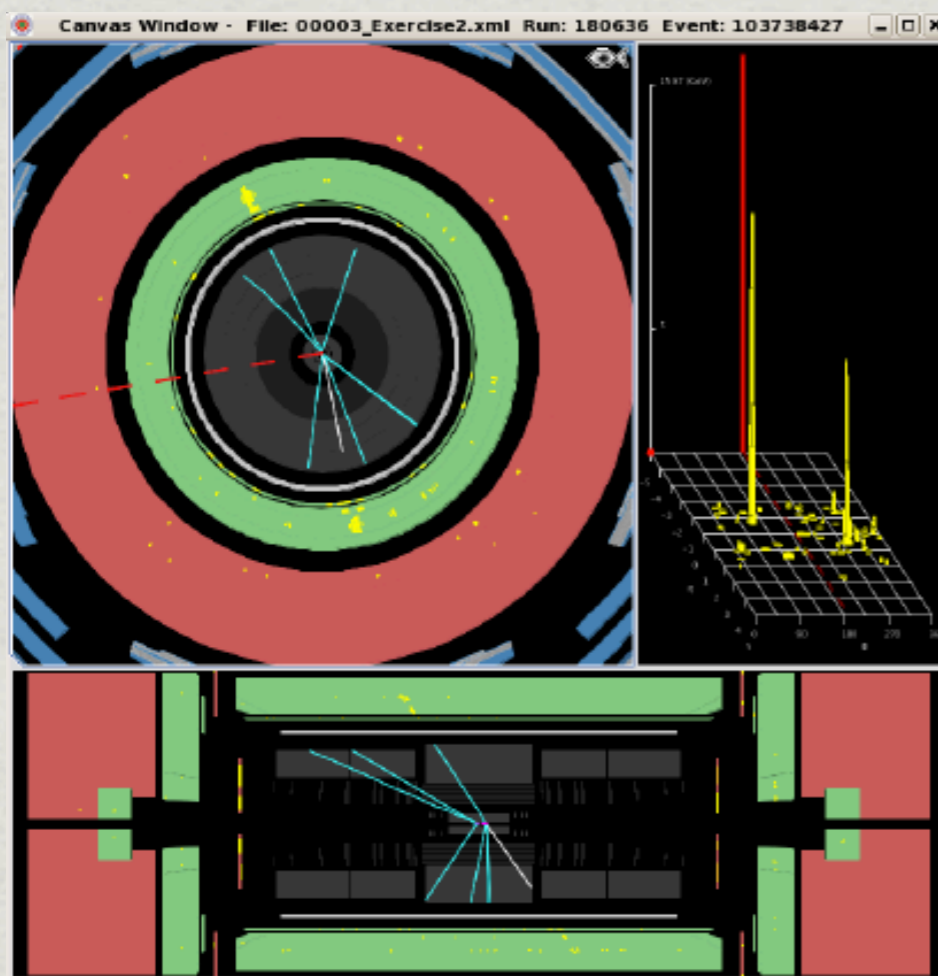
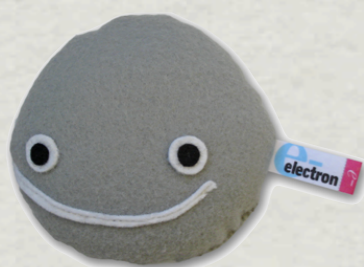
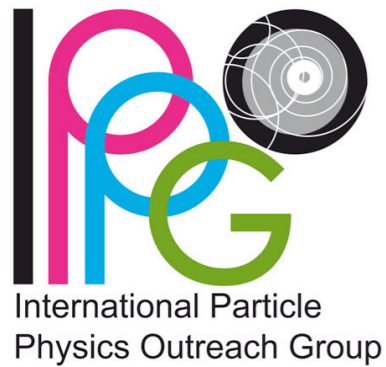


Fig. 11 - event display showing the decay of a Z boson into a pair of electron and positron

Fig. 12 - event display showing the decay of a Z boson into a pair of muon and antimuon



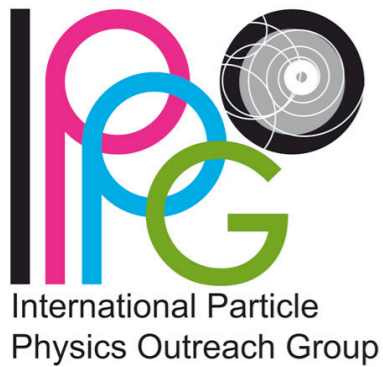


# IPPOG's International Masterclasses

## 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)

OPIoT - MasterClass – Combination for all institutes on 09.03.2012

Start Student Moderator Administrator

Choose new date

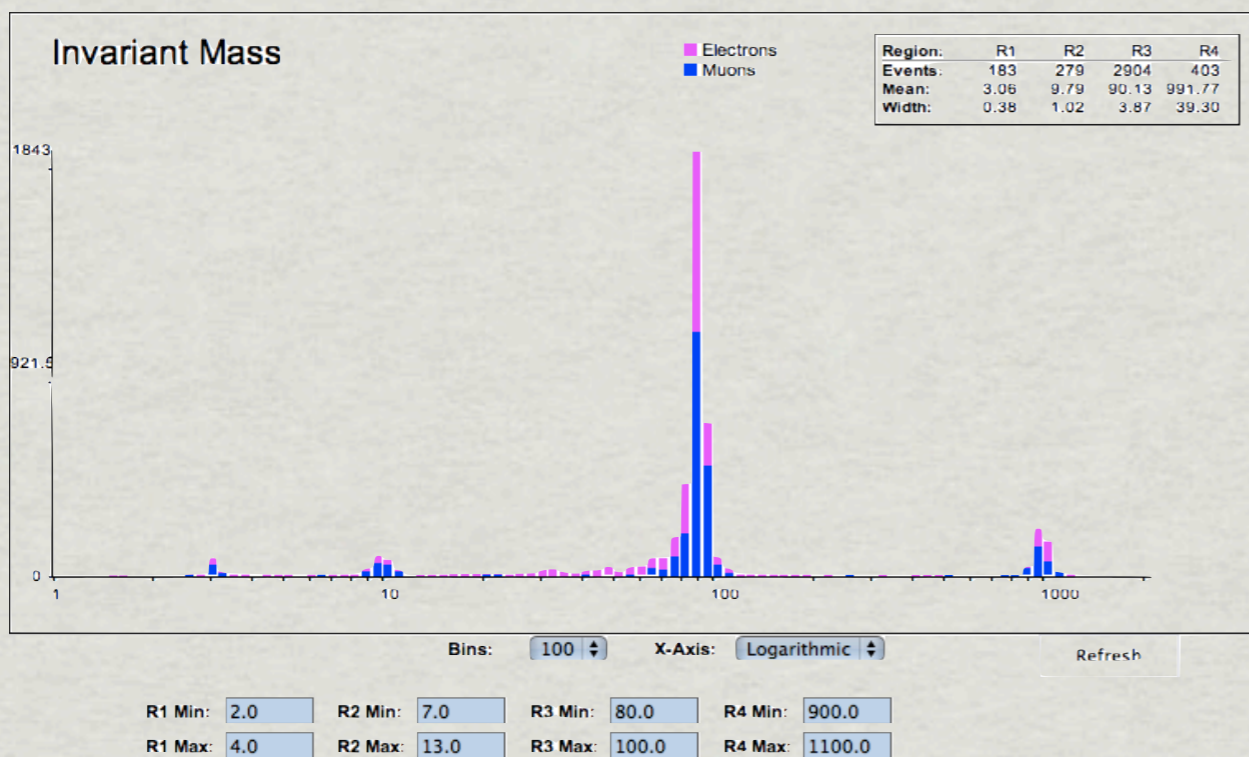


Fig. 13 - Building histograms and identify particles like physicists do



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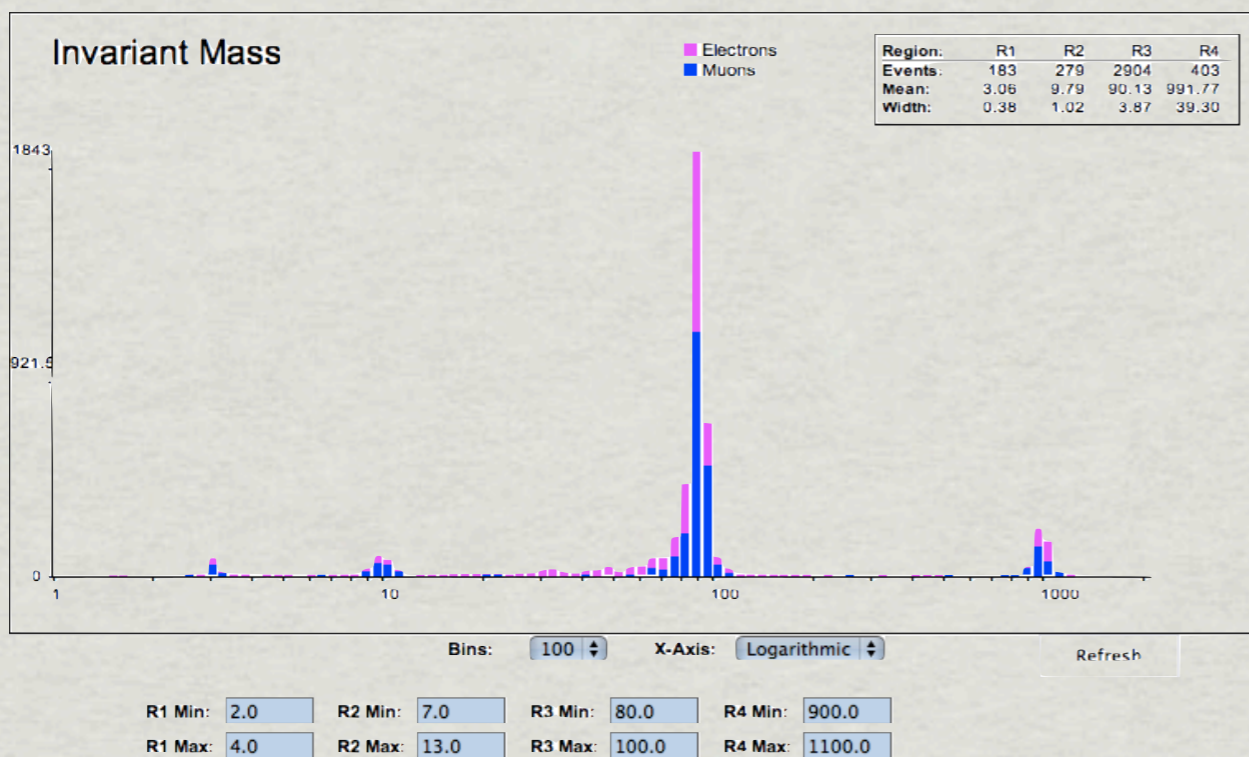


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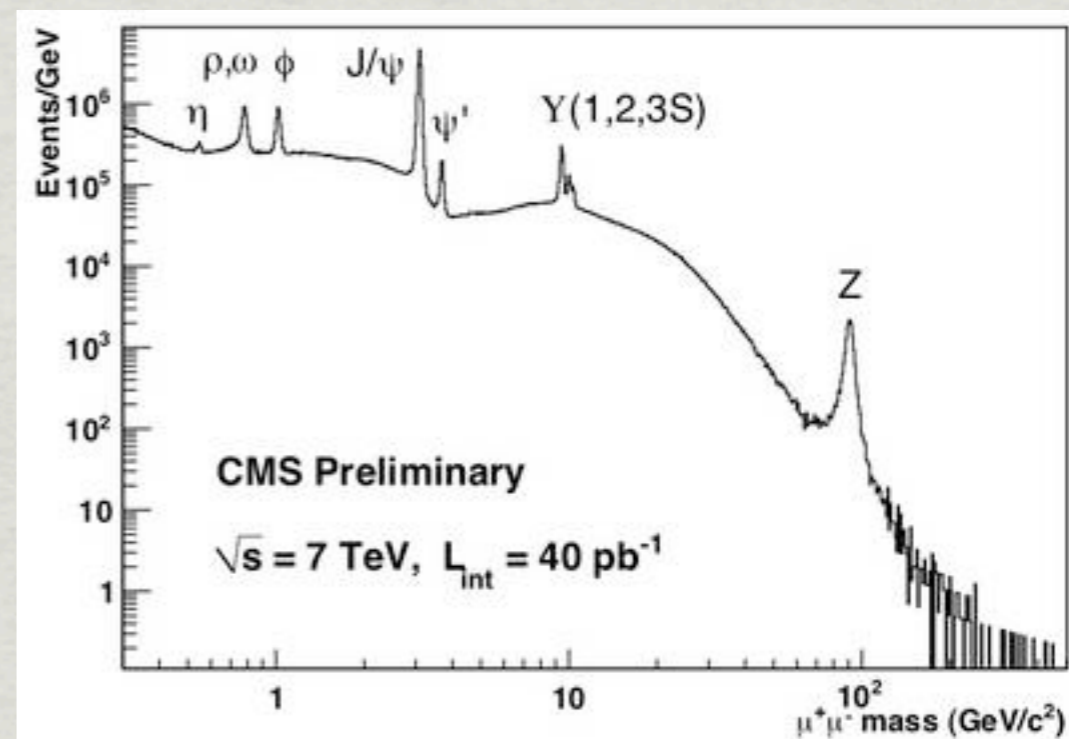


Fig. 14 - Building histograms and identify particles like physicists do



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## Physics Analyses

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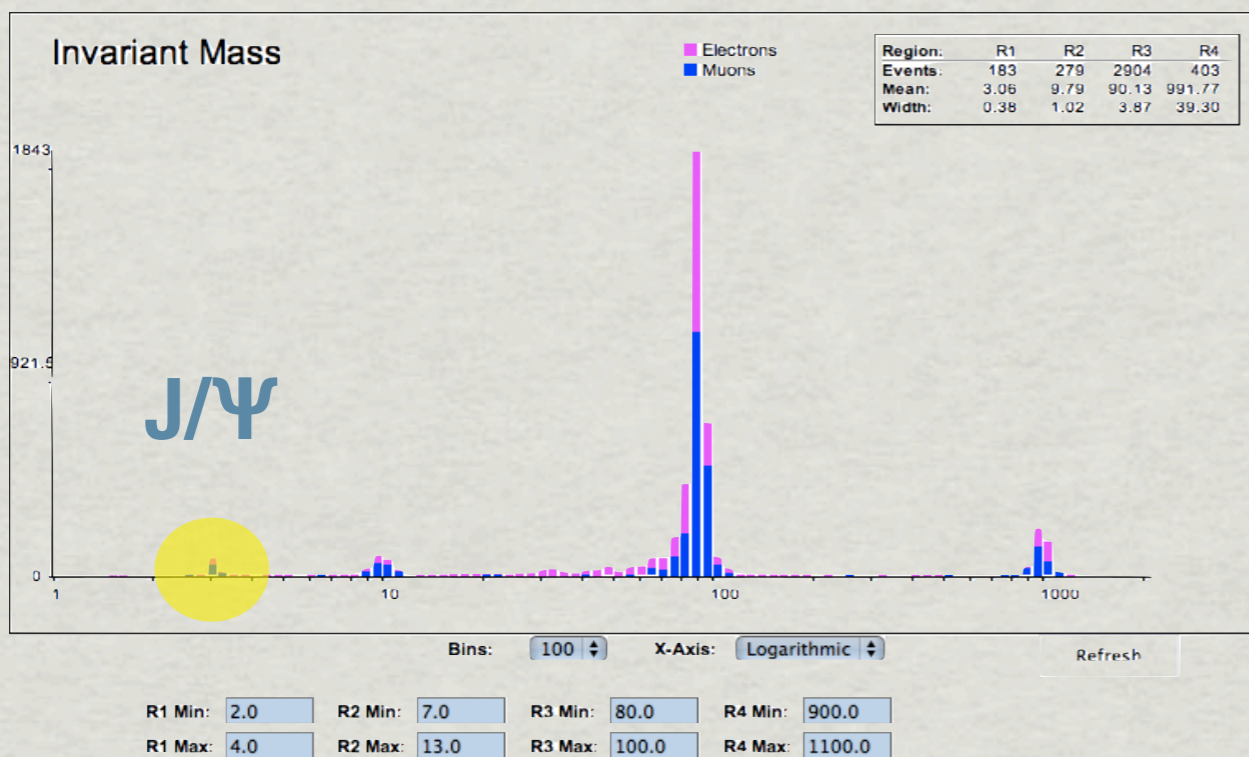


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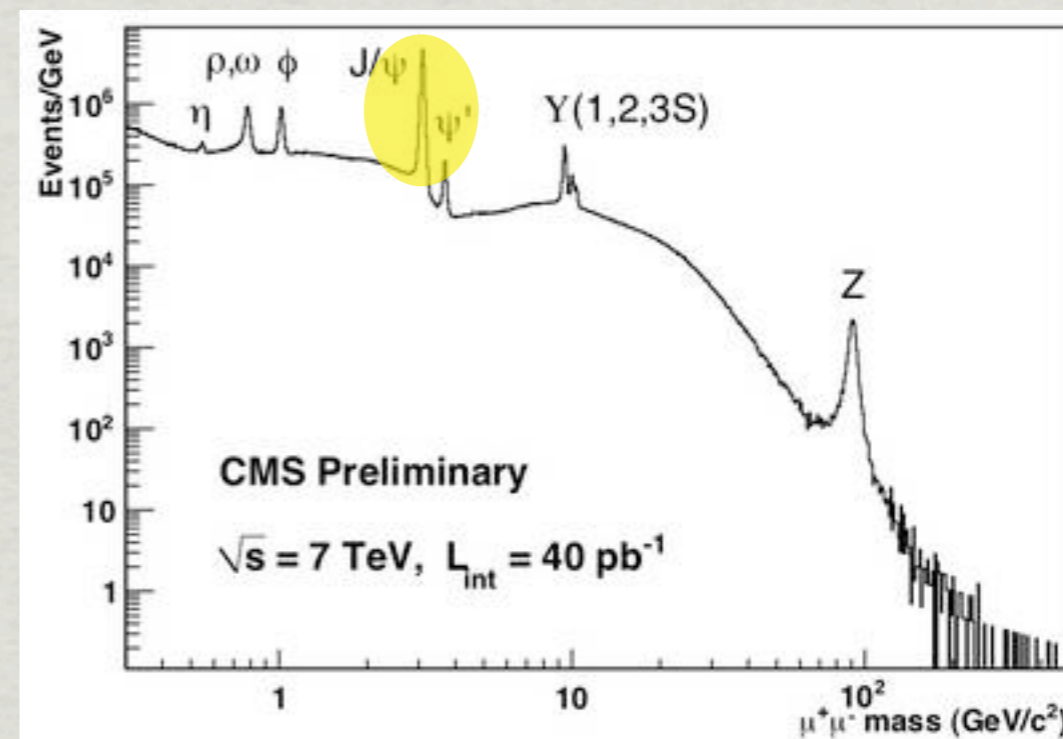


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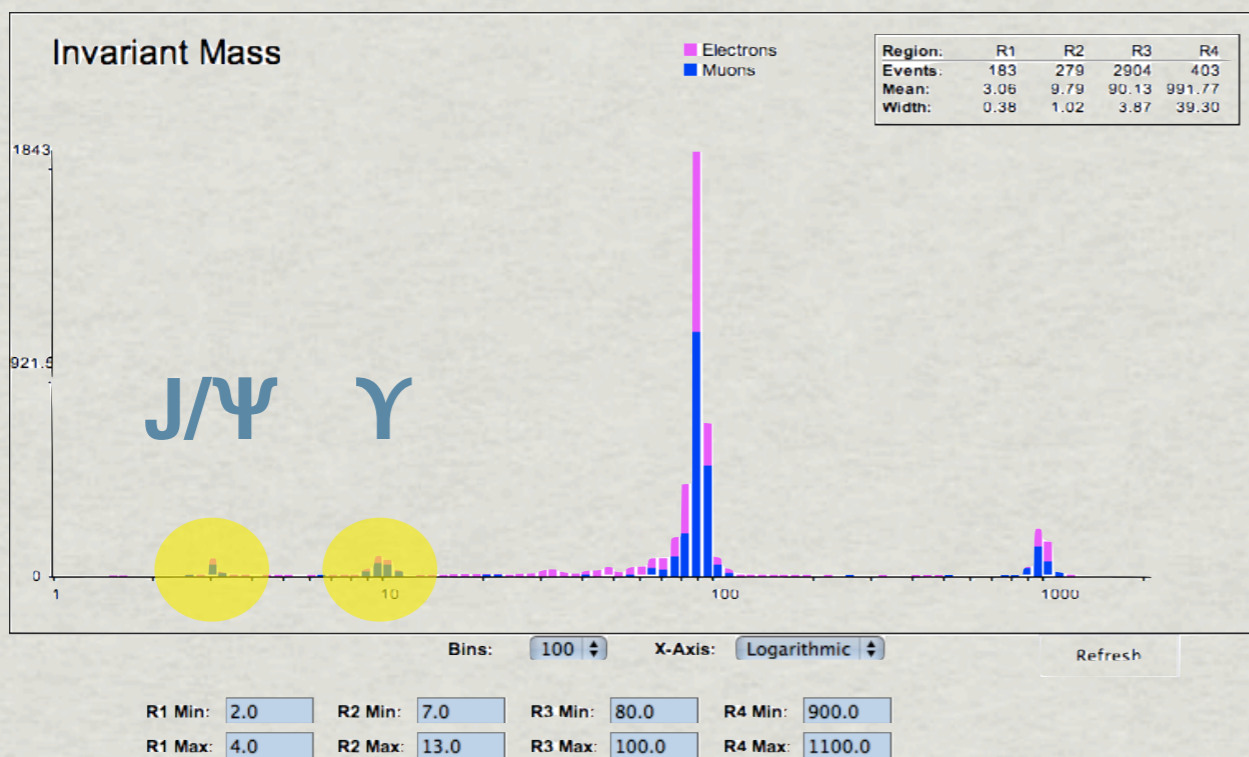


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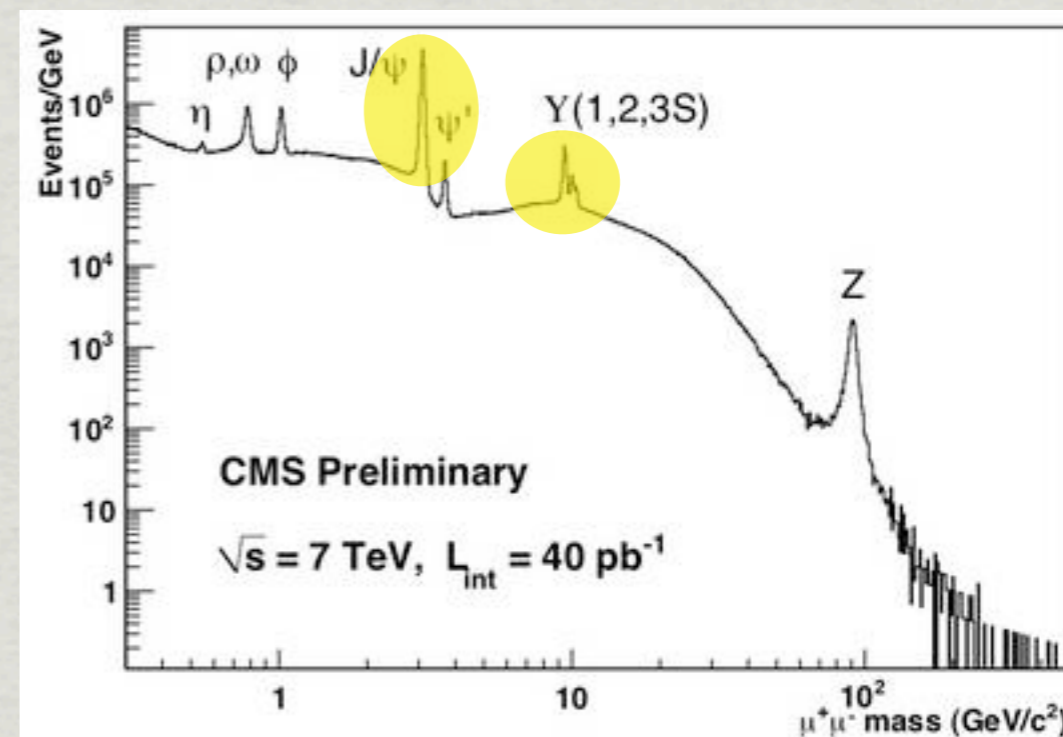


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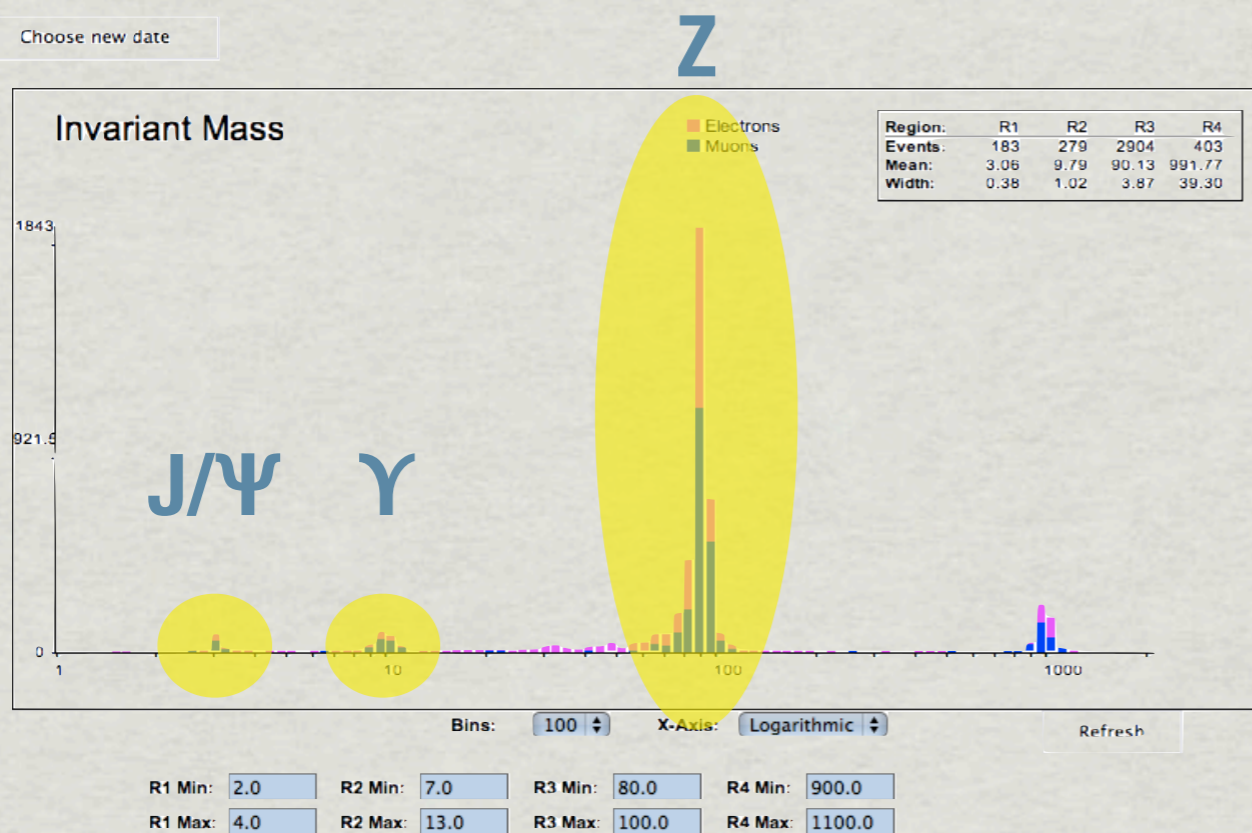


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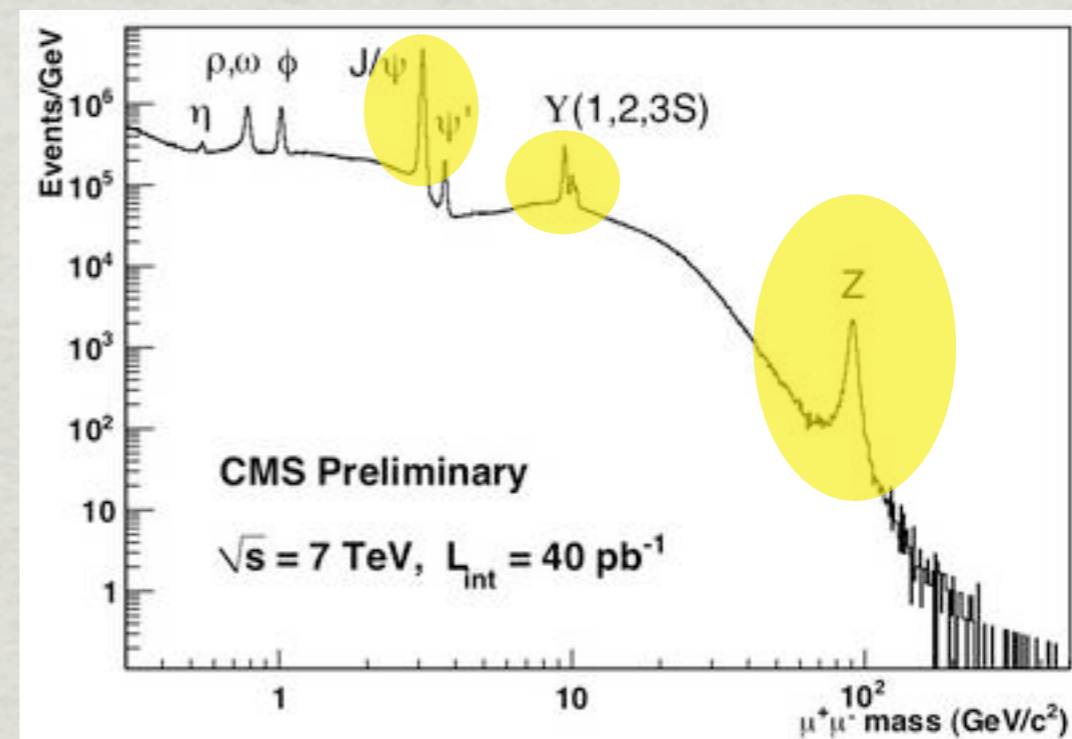


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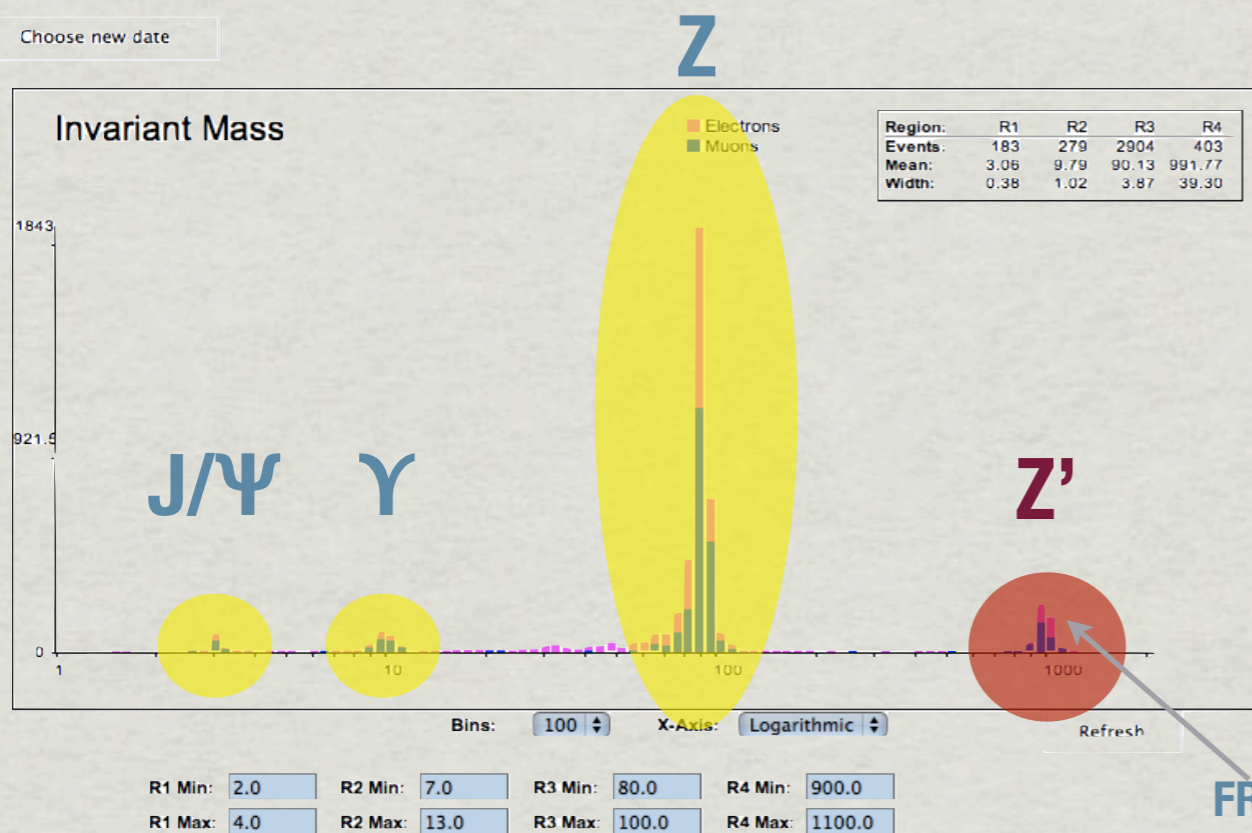


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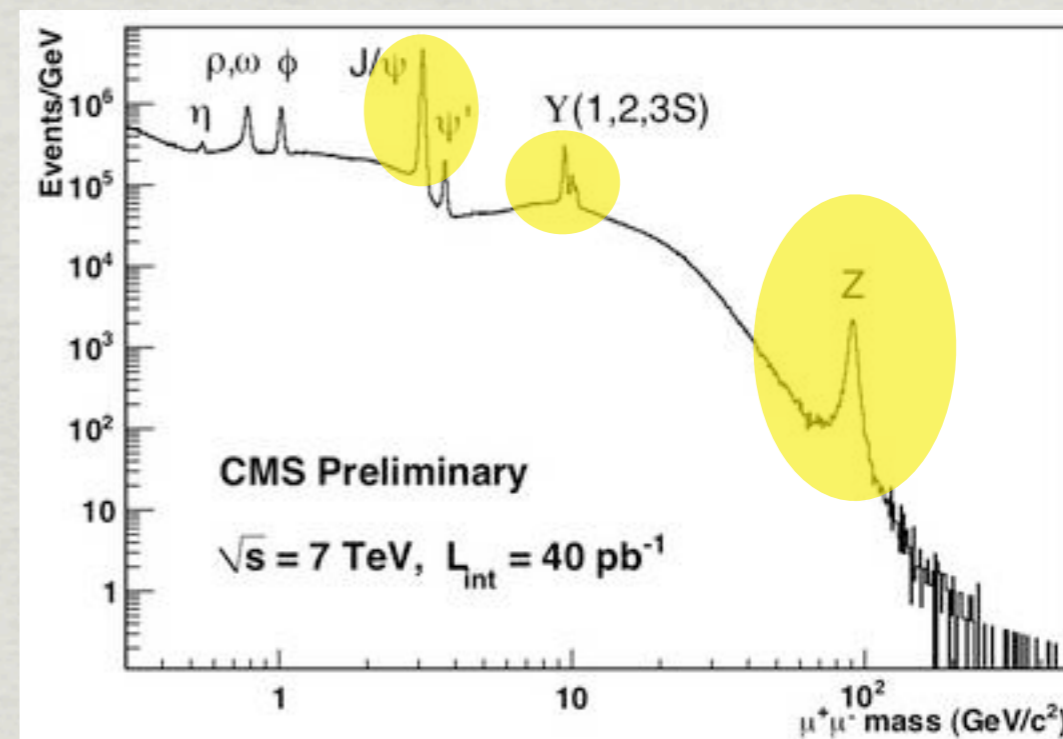
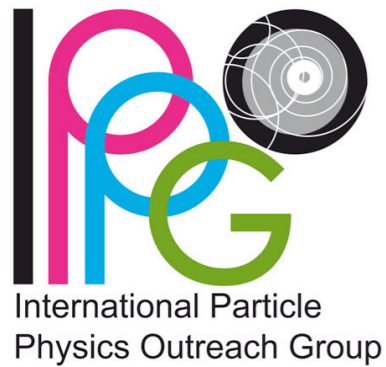


Fig. 14 - Building histograms and identify particles like physicists do

FROM  
SIMULATED  
DATA





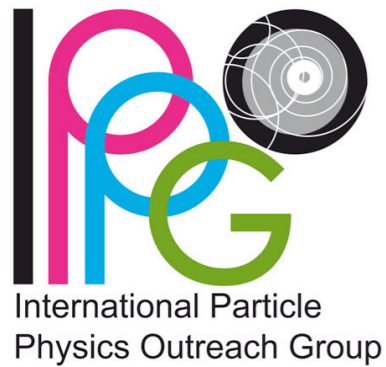
# IPPOG's International Masterclasses

## 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)**





# IPPOG's International Masterclasses

## Physics Analyses

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

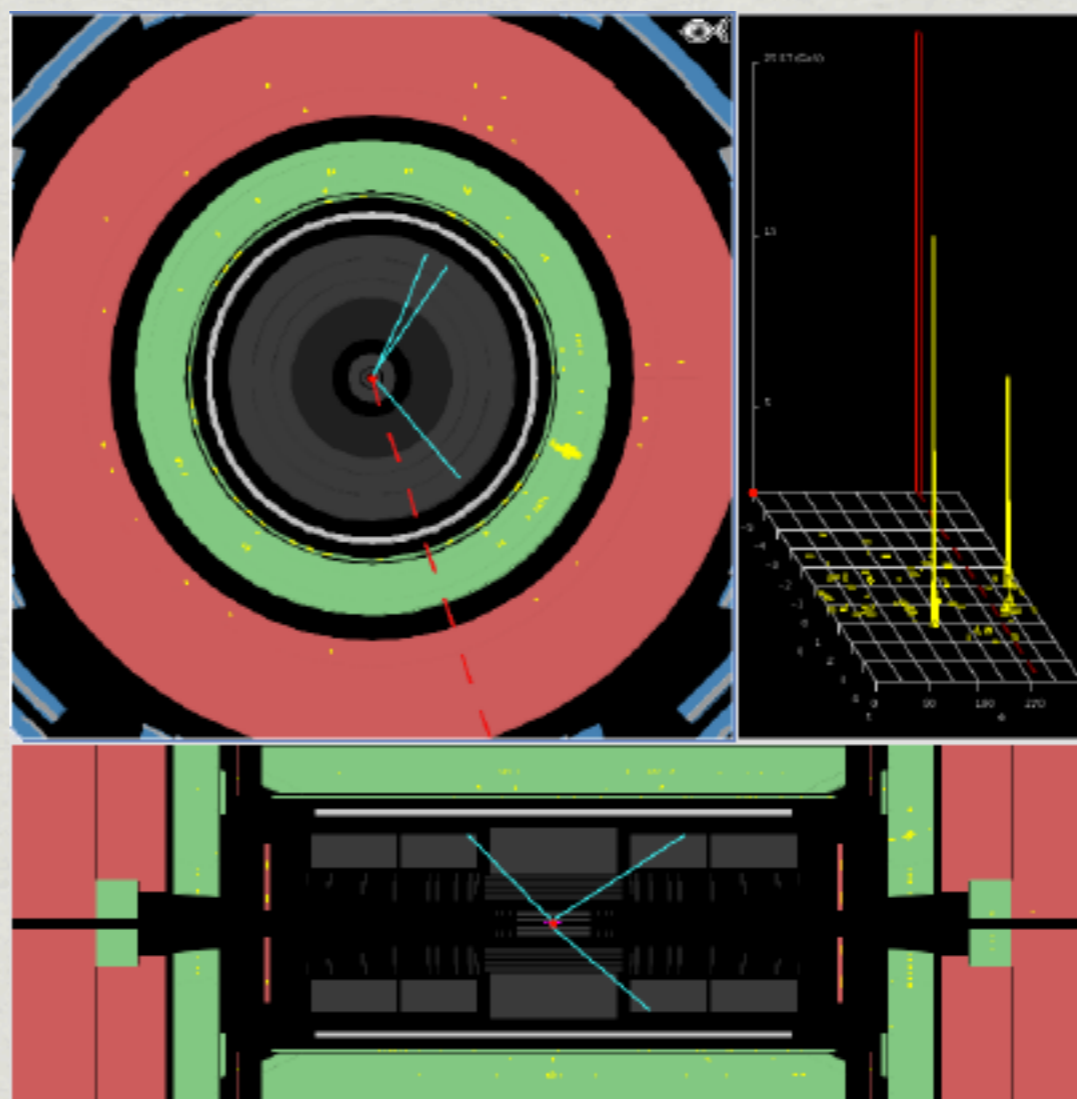


Fig. 15 - event display with two photons

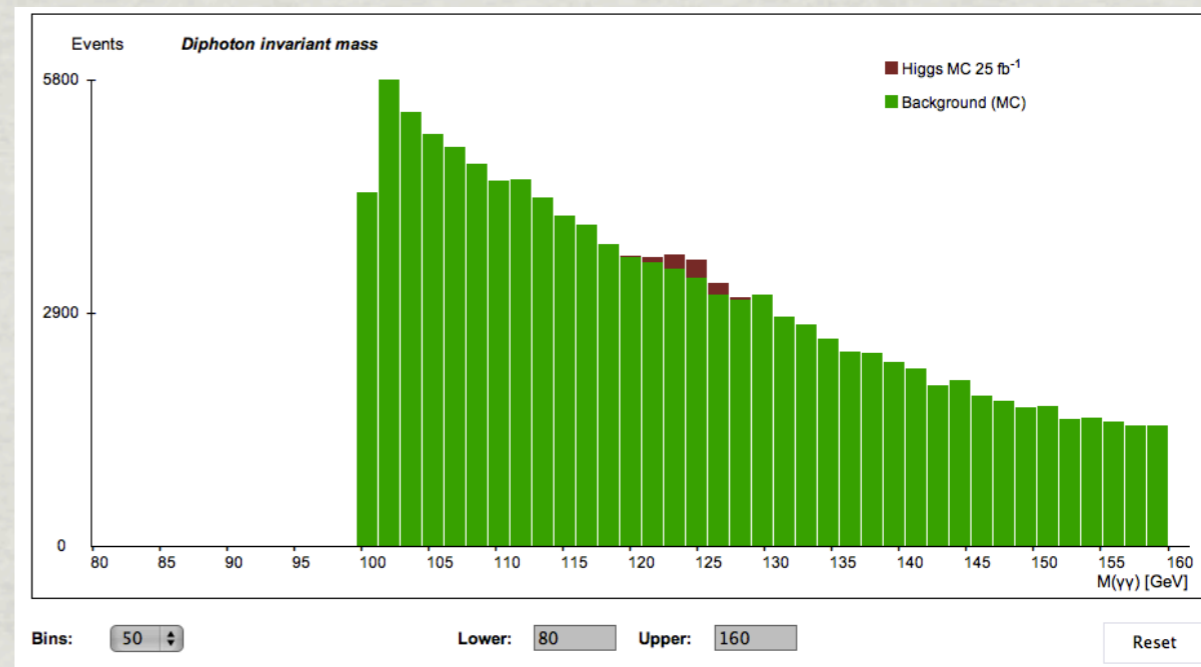
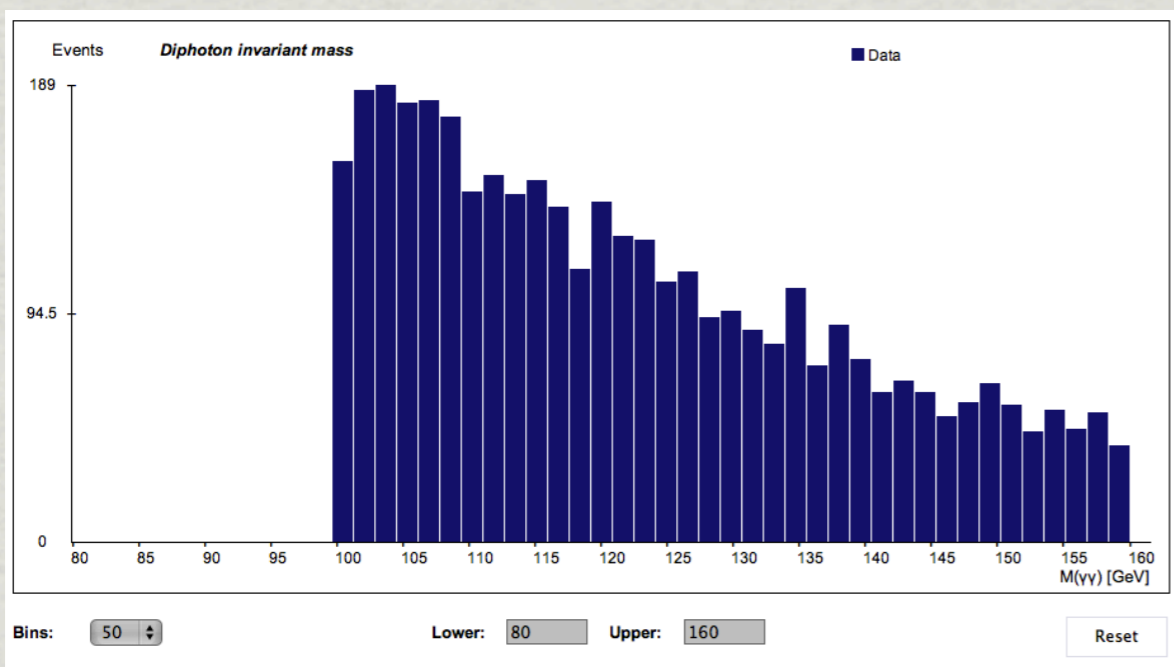




# IPPOG's International Masterclasses

## Physics Analyses

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





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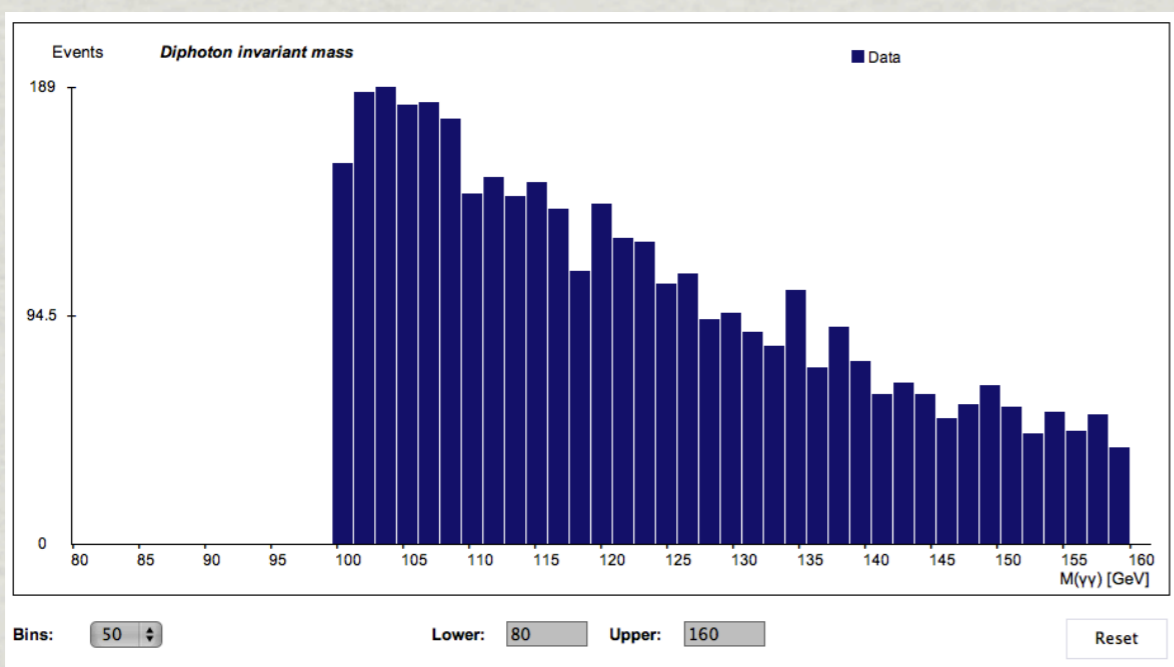


Fig. 16 - Invariant Mass distribution in the di-photon channel - Ideal results for the whole Masterclasses data set

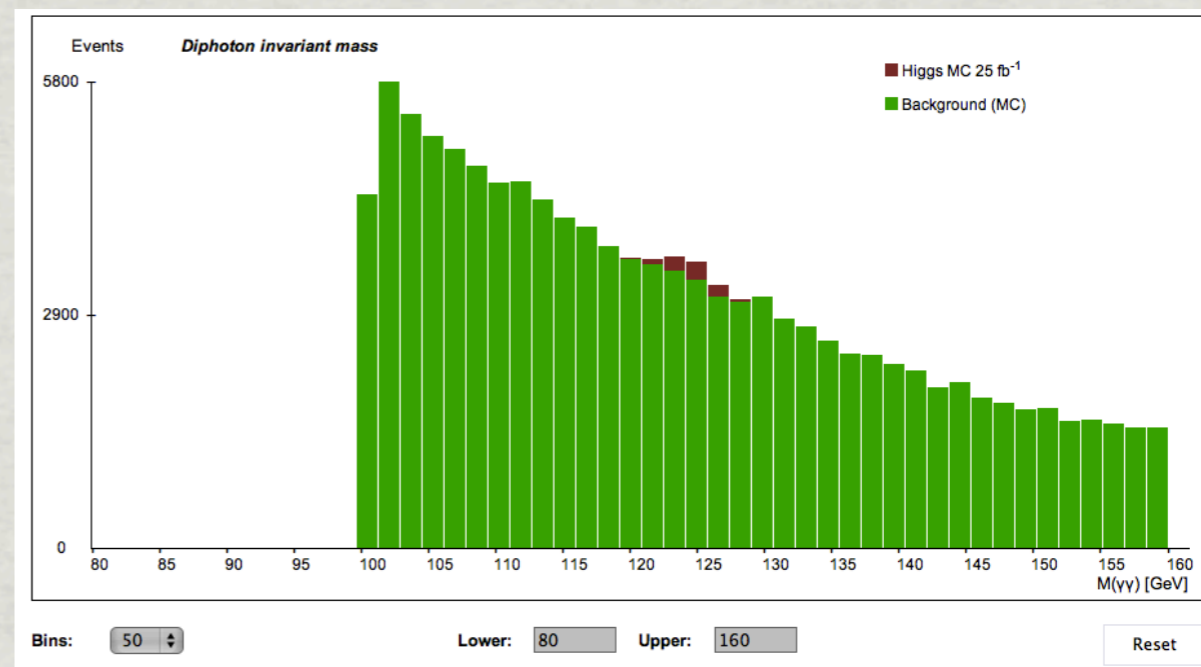


Fig. 17 - Invariant Mass distribution in the di-photon channel - Expectations for the whole ATLAS data set (2012 data) with the same selection criteria







# IPPOG's International Masterclasses

## Physics Analyses

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

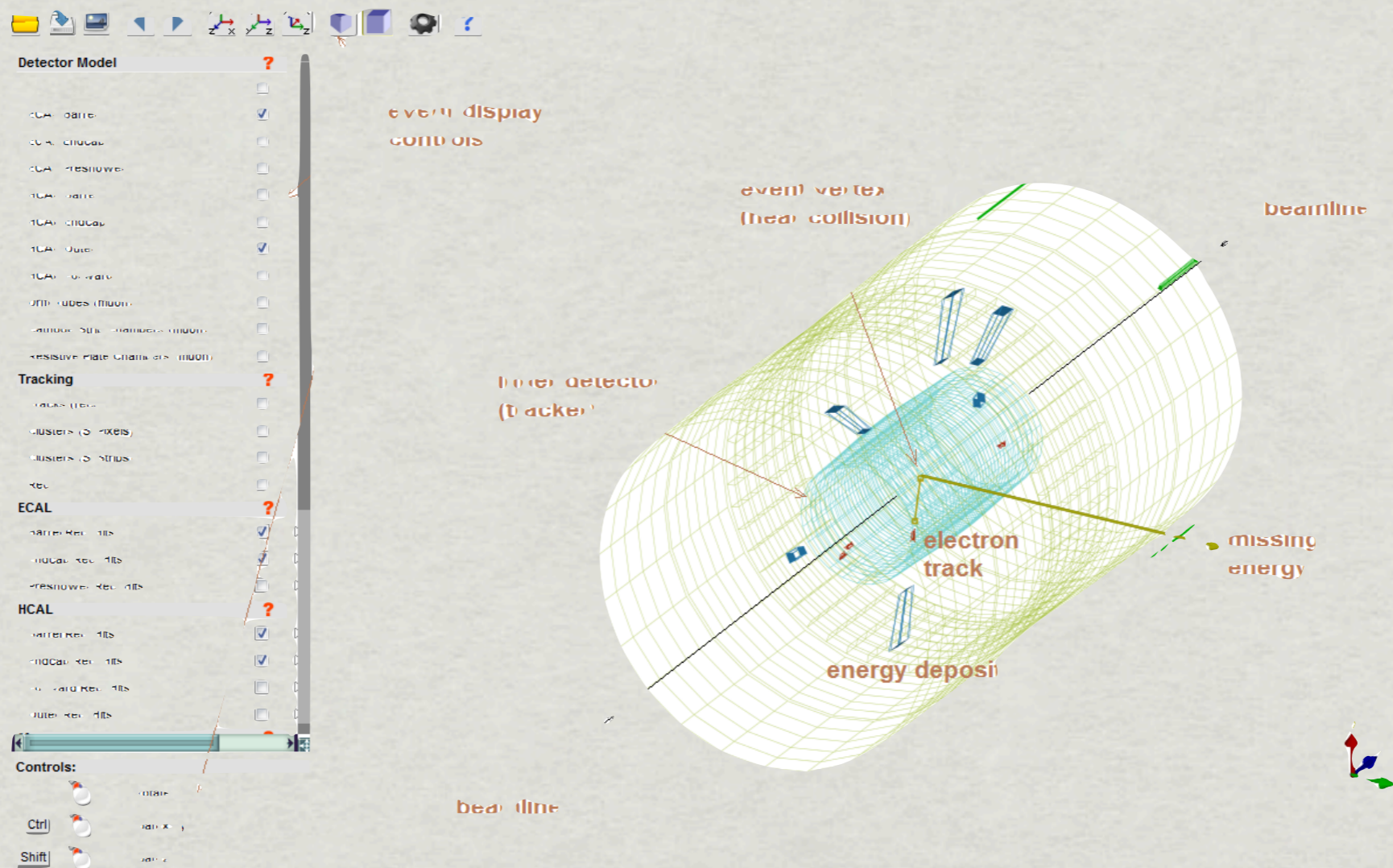


Fig. 18 - using 3-D event displays

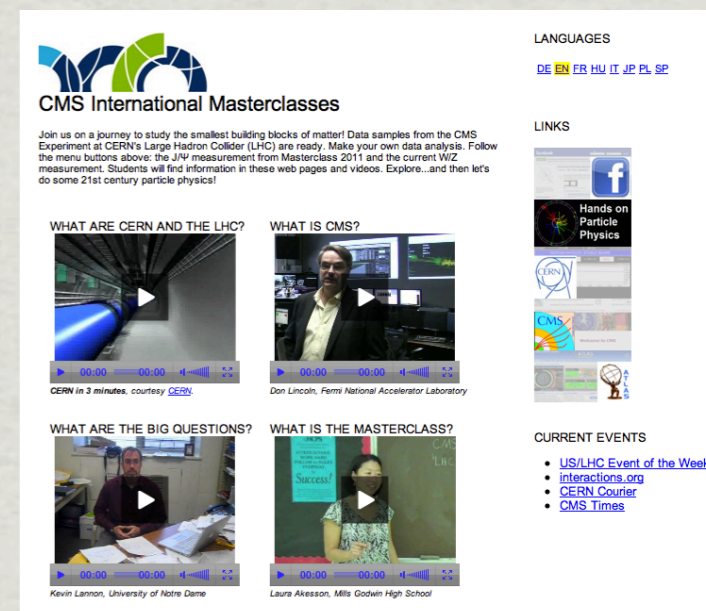
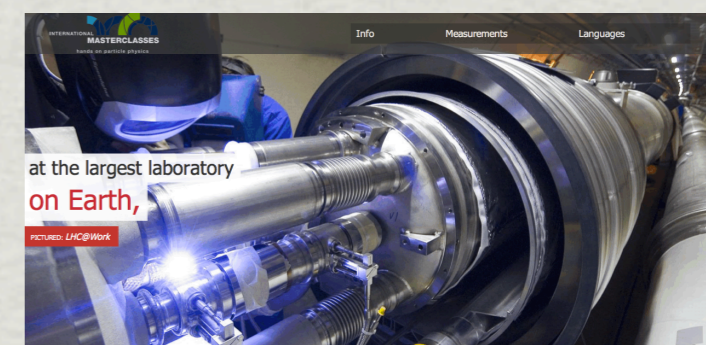
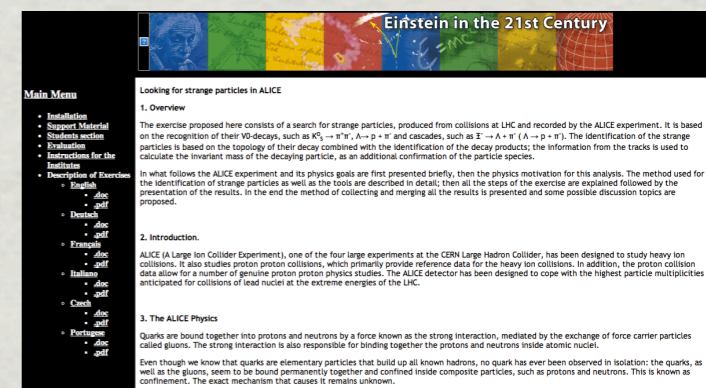


# IPPOG's International Masterclasses

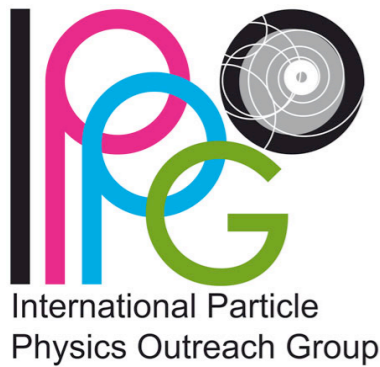
## Physics Analyses

✱ 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,







# IPPOG's International Masterclasses

## Physics Analyses

✱ documentation online:

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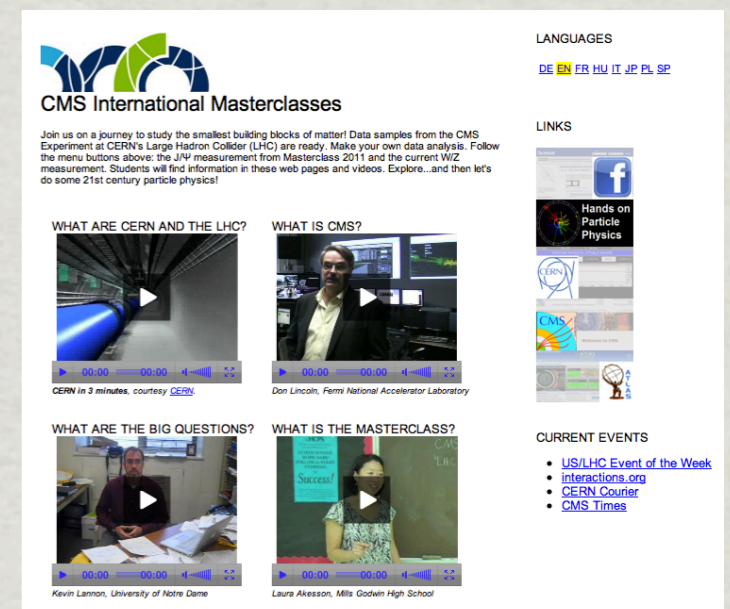
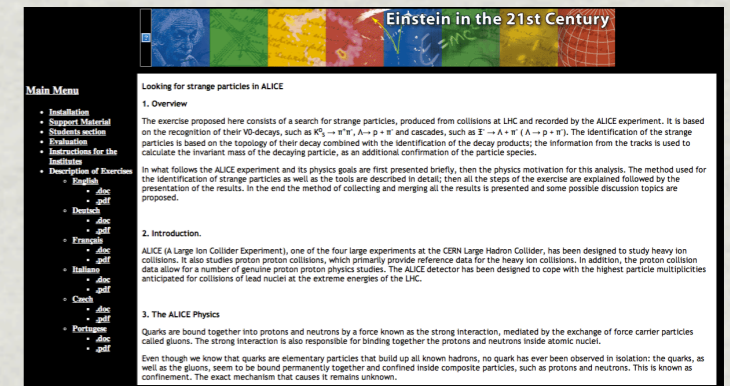
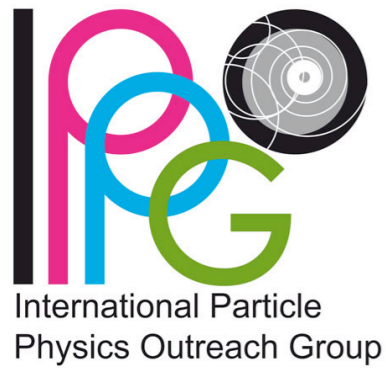


Fig. 19 - Screenshots of websites



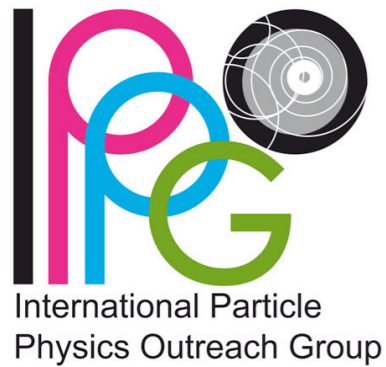


# IPPOG's International Masterclasses Evaluation

- \* 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!***

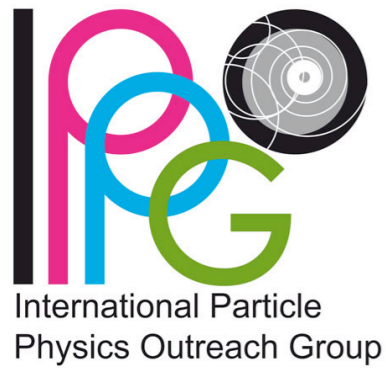
I think it was great! You should organise more, in different topics too! :) and advertise it more! (so every student will have the opportunity to take part in it)

**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.**

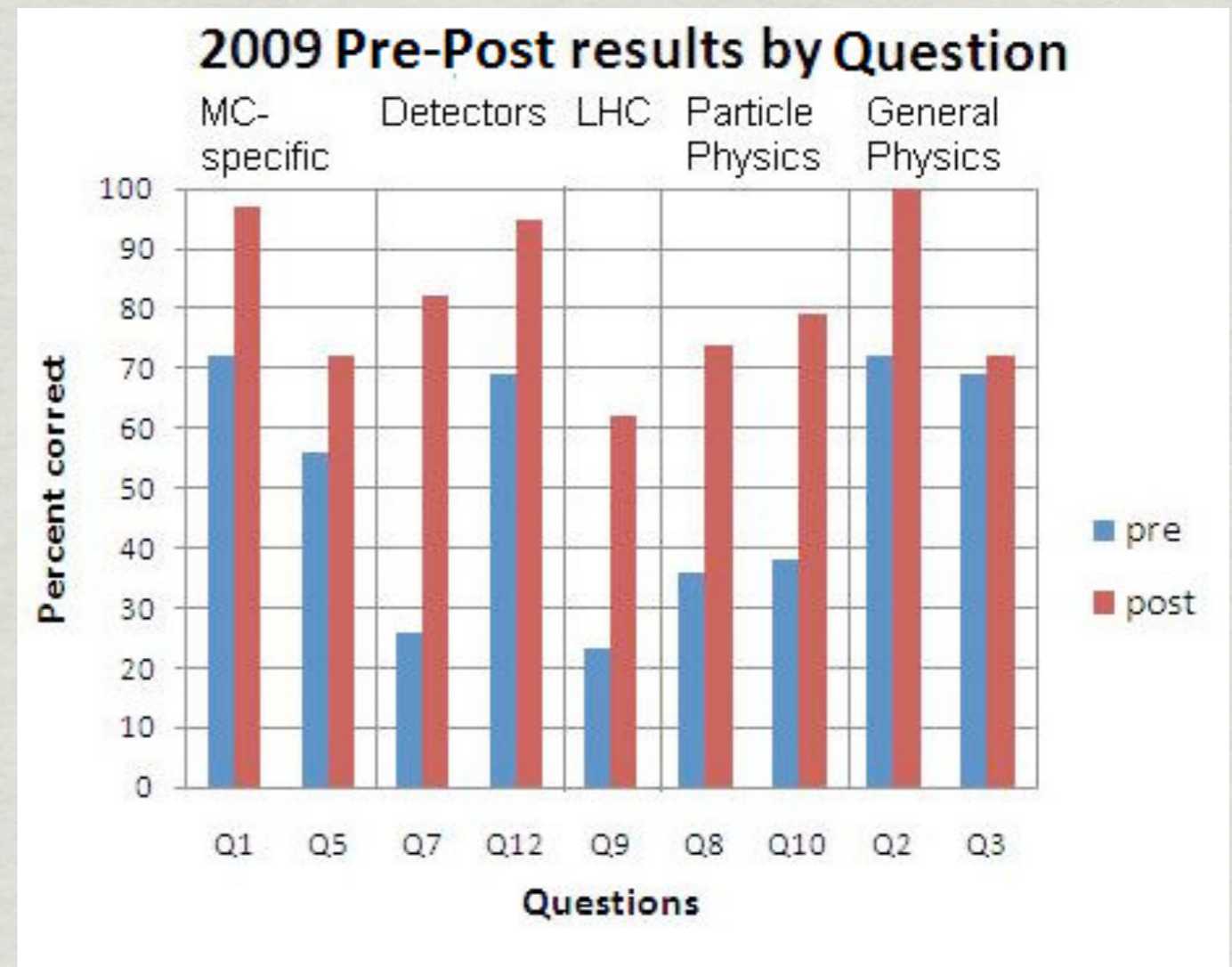
**Réduire la théorie pour plus d'experiences.  
(Reduce theory for more experiments.)**



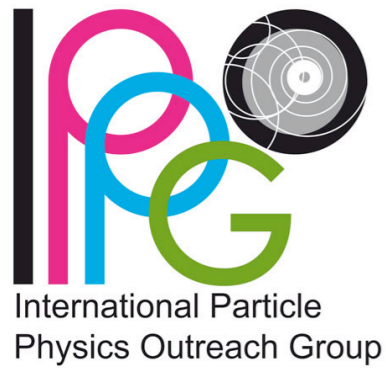


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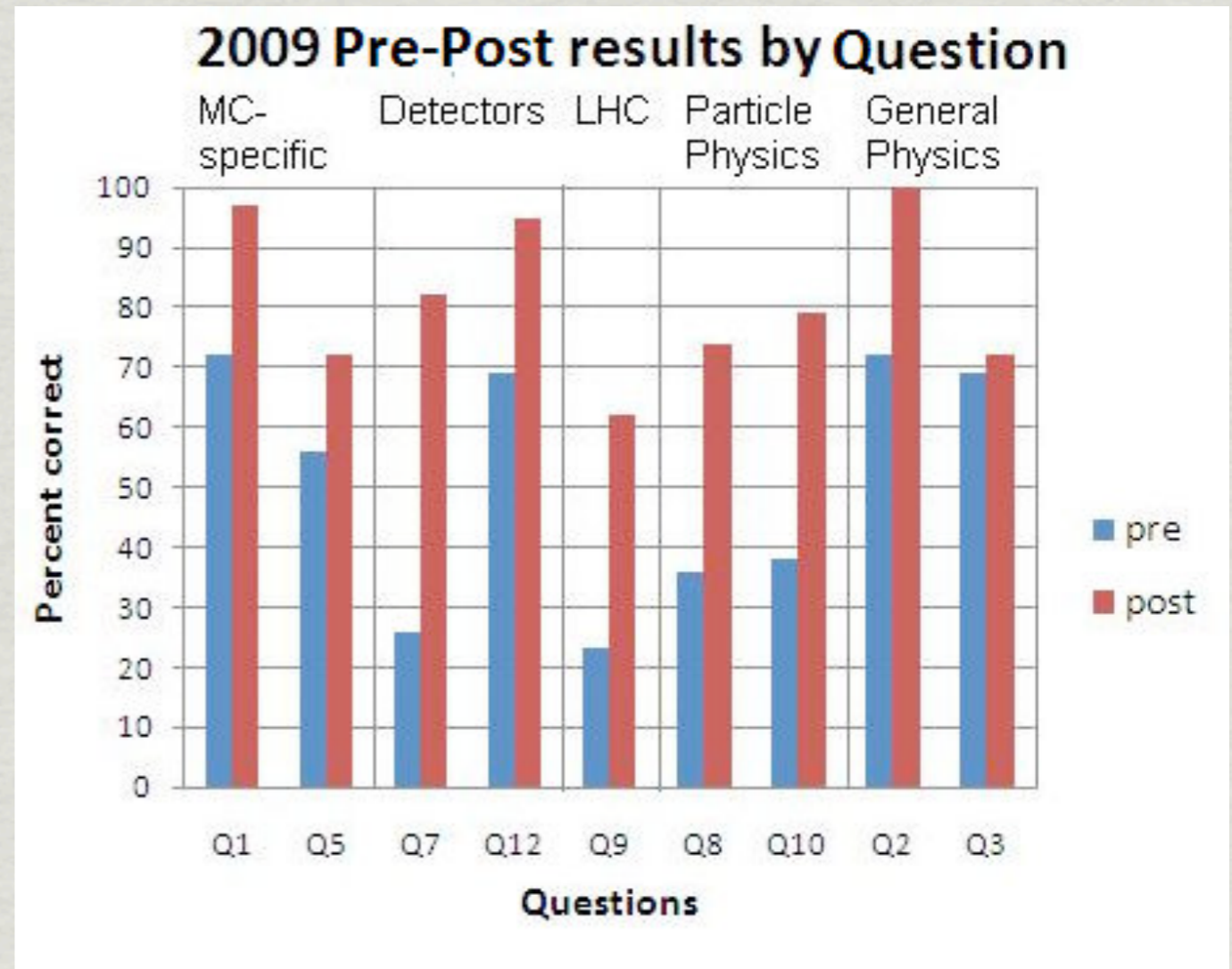
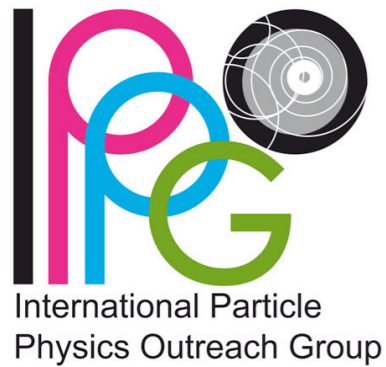


Fig. 20 - pre and post test performed by QuarkNet

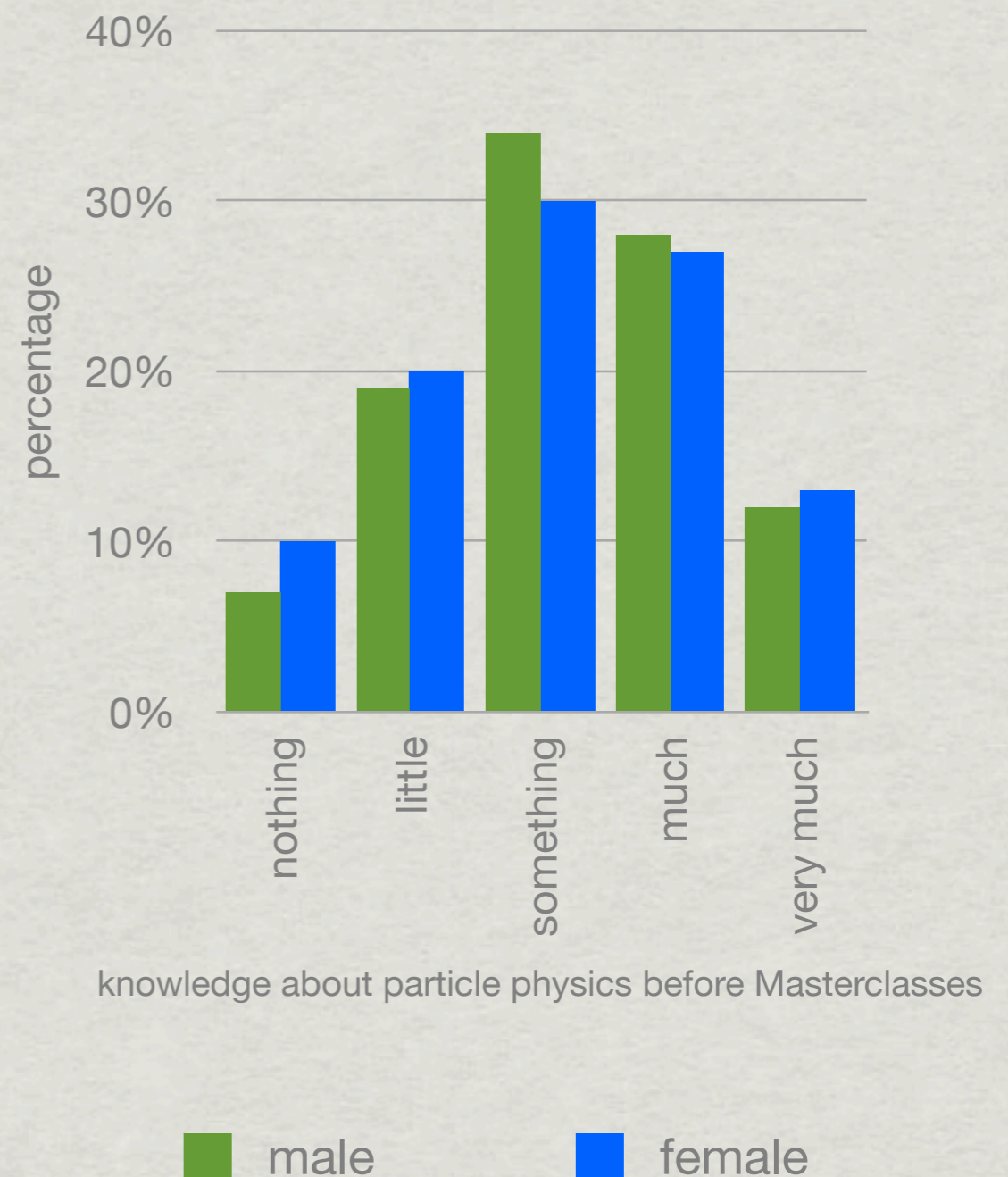




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## Evaluation

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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.





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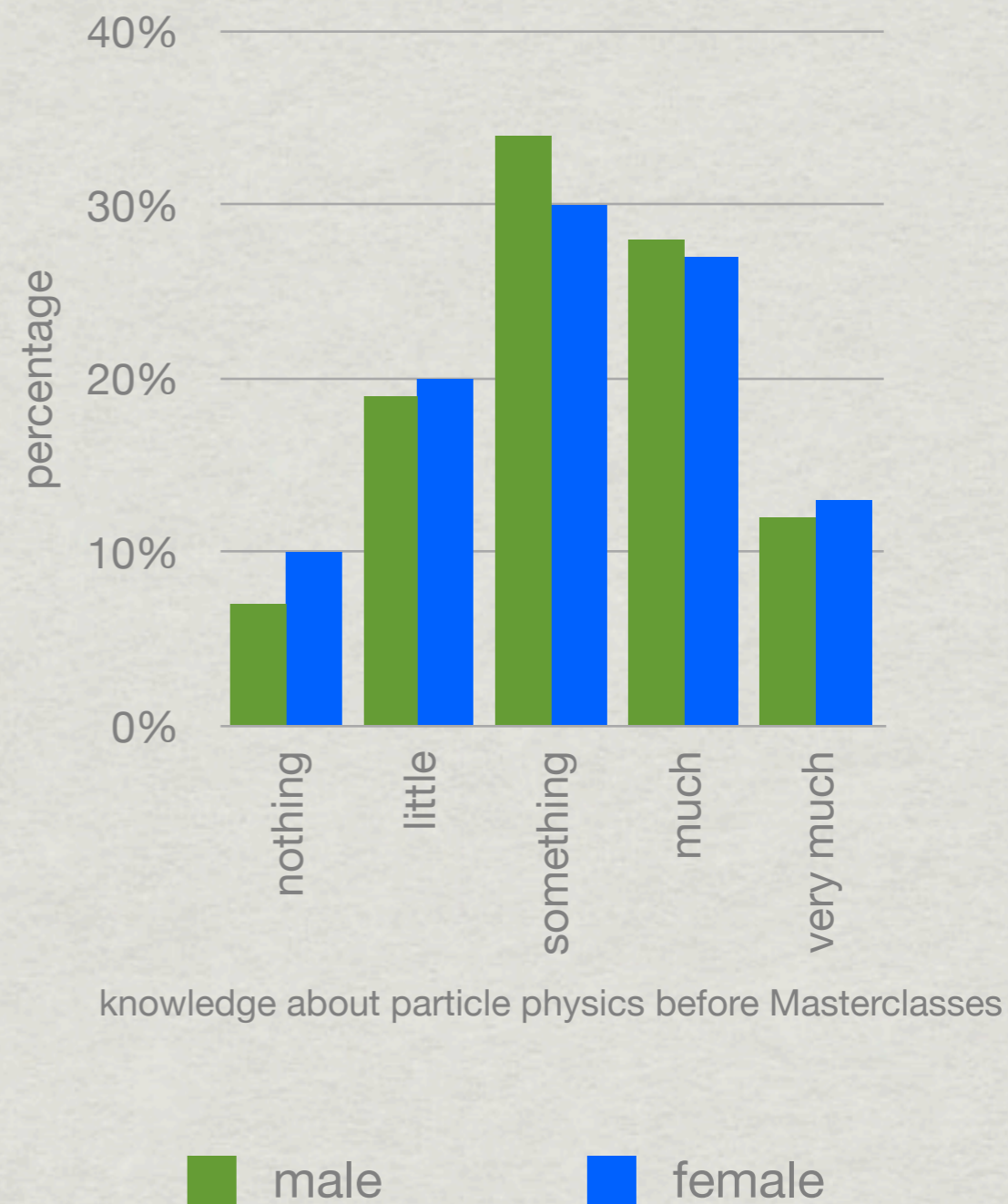
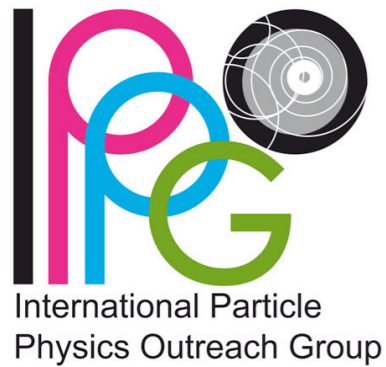


Fig. 21 - Gender independence of previous knowledge of attendees

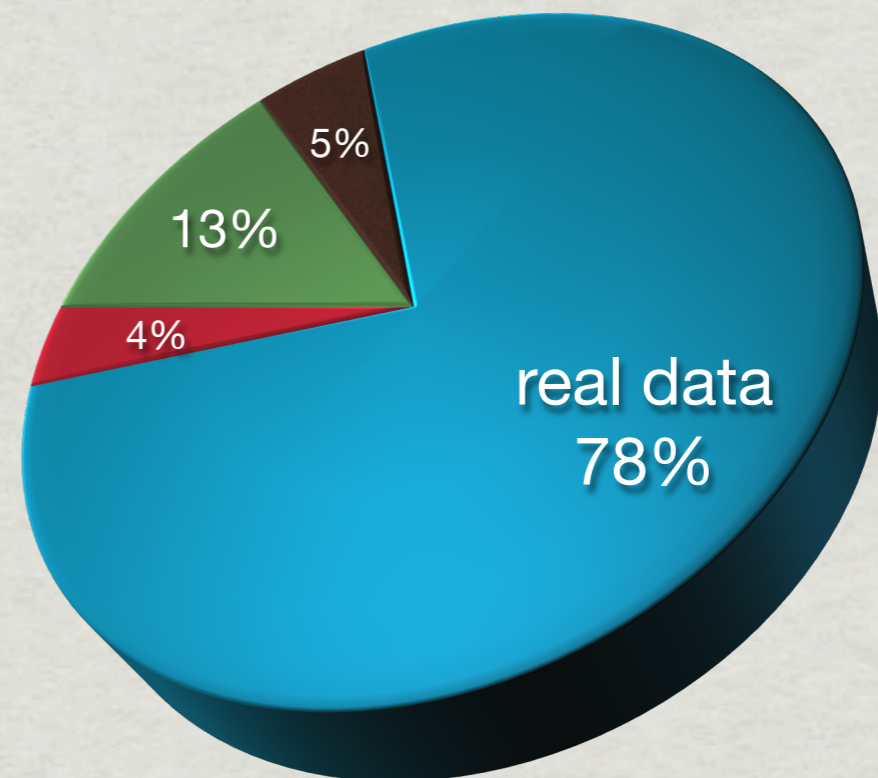




# IPPOG's International Masterclasses Evaluation

- \* 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?



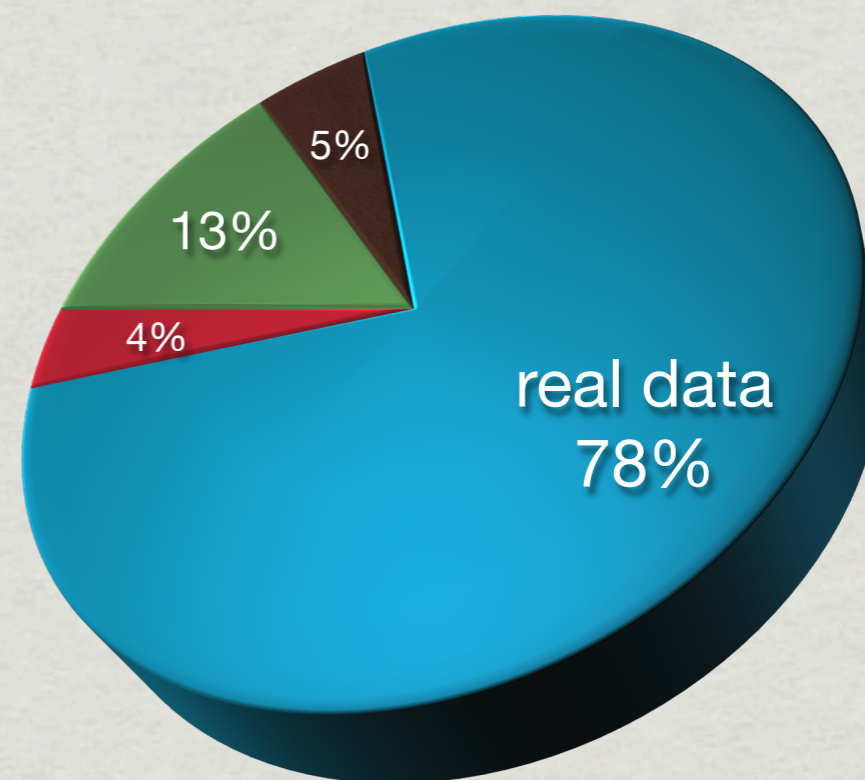
SURVEY: KONRAD JENDE, 2010



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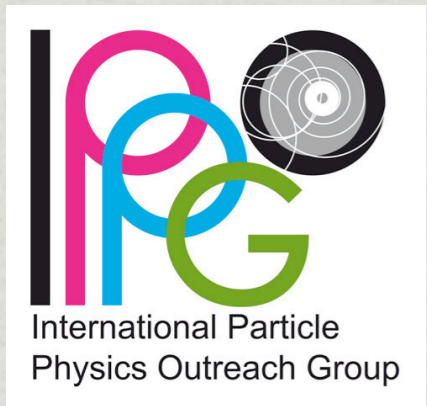
## WHAT KIND OF DATA DO YOU PREFER TO WORK WITH?



**SURVEY: KONRAD JENDE, 2010**

Fig. 22 - 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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- \* 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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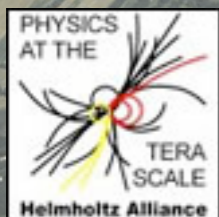


International Particle  
Physics Outreach Group

# 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**





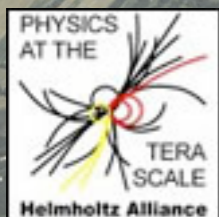
# IPPOG's International Masterclasses

## 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

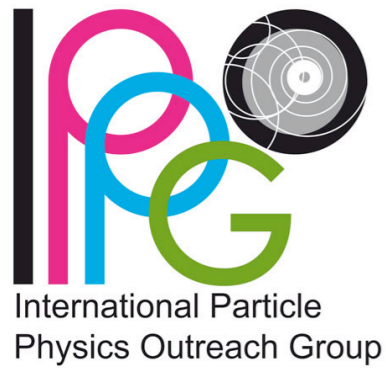


EXPERIMENTAL DATA VIDEOCONFERENCE

+

NATIONAL FUNDING AGENCIES



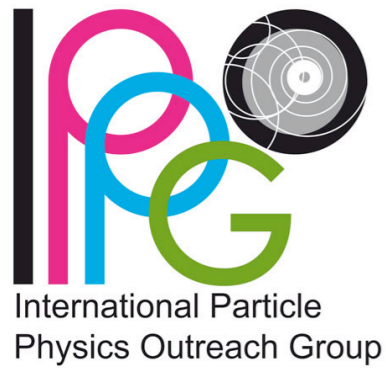


# IPPOG's International Masterclasses

## Back up slides

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





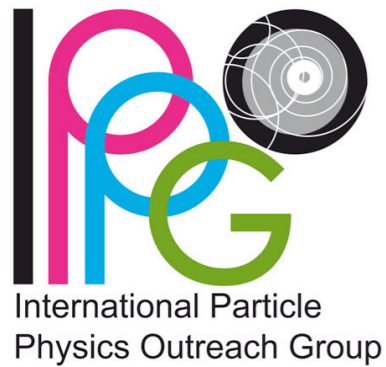
# IPPOG's International Masterclasses

## 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)

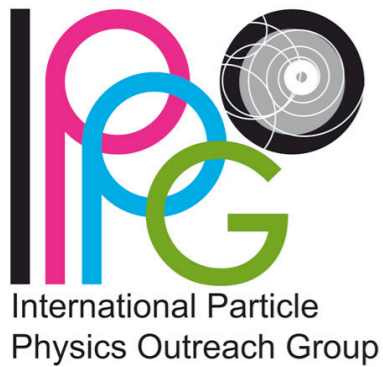
### Germany - Netzwerk Teilchenwelt (ran since 2010)

- \* 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. Kourkoumelis 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>