EPPOG International Masterclasses
“Hands on Particle Physics“

www.physicsmasterclasses.org

Incontri di Fisica, INFN-LNF, 9.10.2009
Uta Bilow, TU Dresden
Outline

- Introduction
- History
- Participation
- A masterclass day for students
- Press review
- Evaluation
- Future plans
Introduction
Introduction
Introduction
Introduction
Introduction
Introduction
Introduction
History

- 1997: started in U.K.
- 2005: 1. International EPPOG-Masterclasses
- 2009: large subprogram in USA

Central Organisation: Prof. Michael Kobel, TU Dresden
Project Manager: Dr. Uta Bilow, TU Dresden
European Particle Physics Outreach Group

- 32 members
- Italian representative: Catia Peduto
  (INFN press office)
Participation 2009

23 nations

USA

Brazil

South Africa
Participation

![Bar chart showing participation over years 2005 to 2009.]
NEW: INFN Roma / Università degli Studi di Roma „La Sapienza“
## Italy

### Italian students in Masterclasses 2009

<table>
<thead>
<tr>
<th>City</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catania</td>
<td>60</td>
</tr>
<tr>
<td>Ferrara</td>
<td>125</td>
</tr>
<tr>
<td>Frascati</td>
<td>40</td>
</tr>
<tr>
<td>Napoli</td>
<td>120</td>
</tr>
<tr>
<td>Padova</td>
<td>330</td>
</tr>
<tr>
<td>Pisa</td>
<td>80</td>
</tr>
<tr>
<td>Roma</td>
<td>90</td>
</tr>
<tr>
<td>Torino</td>
<td>80</td>
</tr>
</tbody>
</table>

\[ \sum = 925 \text{ students} \]
Why Masterclasses?

- Stimulate interest in science
- Demonstrate the scientific research process
- Make data from modern particle physics experiments available for students
- Explore the fundamental forces and building blocks of nature
Agenda

- Lectures
  - Standard model, Accelerators, Detectors
  - Institute’s activities, cosmology etc.
- Lunch with physics students and tutors
- Exercises
- Video conference
Exercises

- PC-pool
- working in pairs
- Introduction
- working largely independently
- 10 tutors / 100 students
Exercises

- Z⁰-decays at LEP
- Lifetime: 3 x 10⁻²⁵ seconds

\[ Z^0 \rightarrow e^+e^- \]
\[ Z^0 \rightarrow \mu^+\mu^- \]
\[ Z^0 \rightarrow \tau^+\tau^- \]
\[ Z^0 \rightarrow 2q \]
Exercises

Measurement of branching ratios

\[ Z^0 \rightarrow e^+e^- \]
\[ Z^0 \rightarrow \mu^+\mu^- \]
\[ Z^0 \rightarrow \tau^+\tau^- \]
\[ Z^0 \rightarrow 2q \]
Exercises

[Image of a website interface]

Find the answers to these and other questions by browsing, reading, and working through some of the educational materials on particle physics which is collected here. Most of the material contains interactive elements, some even real particle physics events for making your own measurements, and understanding particle physics "hands-on". The material was collected for the EPPOG Particle Physics Masterclasses, where some of the measurements form the practical exercises for high school students spending a day at one of the Research Institutes. More info on the teaching systems, which are suited for a wide range of readers, is accessible via the menu in the left column.

[Image of a table with options like "Hands-On-Cern", "A Keynote to the Birth of Time", "Identifying Particles"]

www.physicsmasterclasses.org

CD
Exercises

Hands-on-CERN (DELPHI)
Exercises

Hands-on-CERN (DELPHI)

1 out of 1000 events
## Exercises

LEP results published in:  
Physics Report, May 2006

<table>
<thead>
<tr>
<th>Group</th>
<th>Electrons</th>
<th>Myons</th>
<th>Taus</th>
<th>Quarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (1-100)</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>B (101-200)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>94</td>
</tr>
<tr>
<td>C (201-300)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>91</td>
</tr>
<tr>
<td>D (301-400)</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>87</td>
</tr>
<tr>
<td>E (401-500)</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>88</td>
</tr>
<tr>
<td>F (501-600)</td>
<td>3</td>
<td>10</td>
<td>7</td>
<td>80</td>
</tr>
<tr>
<td>G (601-700)</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>H (701-800)</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>86</td>
</tr>
<tr>
<td>I (801-900)</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>92</td>
</tr>
<tr>
<td>J (901-1000)</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sum all</th>
<th>Sum e</th>
<th>Sum μ</th>
<th>Sum τ</th>
<th>Sum q</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>31</td>
<td>44</td>
<td>43</td>
<td>882</td>
</tr>
<tr>
<td>Sum corr</td>
<td>Sum e corr</td>
<td>Sum μ</td>
<td>Sum τ</td>
<td>Sum q</td>
</tr>
<tr>
<td>1018,6</td>
<td>49,6</td>
<td>44,0</td>
<td>43,0</td>
<td>882,0</td>
</tr>
</tbody>
</table>

| Stat. Uncertainty | 8,9 | 6,6 | 6,6 | 29,7 |

<table>
<thead>
<tr>
<th>Fract. of Visible</th>
<th>e / all</th>
<th>μ / all</th>
<th>τ / all</th>
<th>q / all</th>
<th>q / ((e+μ+τ)/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0,049</td>
<td>0,043</td>
<td>0,042</td>
<td>0,866</td>
<td>19,4</td>
</tr>
</tbody>
</table>

| Stat. Uncertainty | 0,009 | 0,006 | 0,006 | 0,011 | 2,1 |

<table>
<thead>
<tr>
<th>Theory</th>
<th>0,04212</th>
<th>0,04212</th>
<th>0,04212</th>
<th>0,8736</th>
<th>20,74</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEP Result</td>
<td>0,04200</td>
<td>0,04204</td>
<td>0,04208</td>
<td>0,8738</td>
<td>20,77</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>0,00005</td>
<td>0,00008</td>
<td>0,00010</td>
<td>0,0012</td>
<td>0,03</td>
</tr>
</tbody>
</table>
Exercises

Identifying Interesting Particle Physics Events at LEP

The purpose of these web pages is to allow you to identify some interesting particle physics interactions or "events" for yourself. These events were observed using experiments called OPAL and ATLAS at CERN near to Geneva. The OPAL Experiment ran from 1989-2000 at LEP (Large Electron Positron Collider) which was at the time the largest particle accelerator of the world. The ATLAS detector is located at the new LHC (Large Hadron Collider). In the LHC, in contrast to LEP, the colliding beams consist of protons.

The emphasis is very much on your active participation. I have tried to explain as simply as possible a few important things you need to know about our experiment and the different types of events that can occur. But the main parts are where you play the role of "particle detective" and identify for yourself pictures of different types of event.

Table of Contents

- Introduction
- The OPAL Detector and How to Understand the Event Pictures
- The ATLAS Detector and How to Understand the Event Pictures
- The Challenge (Part 1)
- How to Identify Events Containing a Particle-Antiparticle Pair
- The Challenge (Part 2)
- How to Identify Events Containing a Pair of W Particles
- The Challenge (Part 3)
- The Challenge (Part 4)
- How to Identify Slightly More Complicated Types of Event
- The Challenge (Part 5)
- A Different Sort of Challenge: Making Measurements
  - Measuring J/ψ Decays at LEP
  - Measuring Z° Decays at LEP
  - Drell-Yan Masses at LEP

"Hands on Particle Physics" International Masterclasses
Exercises
Exercises

- LHC start up in Sept. 2008
- Include LHC in masterclasses
- lectures
- exercises

first beam event seen in ATLAS
Exercises
### Introduction by moderators
### Combination of results
### Discussion
### Quiz
### Q+A-Session
## Moderators 2009

<table>
<thead>
<tr>
<th>Moderator</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jula Draeger</td>
<td>CMS Experiment</td>
</tr>
<tr>
<td>Zoe Matthews</td>
<td>ALICE Experiment</td>
</tr>
<tr>
<td>Sue Cheatham</td>
<td>ATLAS Experiment</td>
</tr>
<tr>
<td>Sam Harper</td>
<td>CMS Experiment</td>
</tr>
<tr>
<td>Michael Hauschild</td>
<td>ATLAS Experiment</td>
</tr>
<tr>
<td>Vicki Moeller</td>
<td>ATLAS Experiment</td>
</tr>
<tr>
<td>Peter Steinbach</td>
<td>ATLAS Experiment</td>
</tr>
<tr>
<td>Matthew Tamsett</td>
<td>ATLAS Experiment</td>
</tr>
<tr>
<td>Tom Whyntie</td>
<td>CMS Experiment</td>
</tr>
</tbody>
</table>
Video Conference

EVO video
global combination of results

http://www.physicsmasterclasses.org/downloads/Zcombine

<table>
<thead>
<tr>
<th>Town (COUNTRY)</th>
<th>DELPHI</th>
<th>OPAL</th>
<th>Electrons</th>
<th>Muons</th>
<th>Taus</th>
<th>Quarks</th>
<th>Z / (Z + &amp; #134; + &amp; #134; / 3)</th>
<th>Statistical Uncertainty ±</th>
<th>Systematic Uncertainty ±</th>
<th>Combination ±</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athens (GR)</td>
<td>1</td>
<td>0.034</td>
<td>0.032</td>
<td>0.034</td>
<td>0.031</td>
<td>0.029</td>
<td>0.011</td>
<td>0.005</td>
<td>0.007</td>
<td>0.018</td>
</tr>
<tr>
<td>Berlin (DE)</td>
<td>1</td>
<td>0.044</td>
<td>0.033</td>
<td>0.044</td>
<td>0.043</td>
<td>0.039</td>
<td>0.016</td>
<td>0.005</td>
<td>0.005</td>
<td>0.011</td>
</tr>
<tr>
<td>Brussels (BE)</td>
<td>0</td>
<td>0.049</td>
<td>0.040</td>
<td>0.049</td>
<td>0.047</td>
<td>0.040</td>
<td>0.013</td>
<td>0.005</td>
<td>0.005</td>
<td>0.010</td>
</tr>
<tr>
<td>Budapest (HU)</td>
<td>0</td>
<td>0.050</td>
<td>0.040</td>
<td>0.050</td>
<td>0.049</td>
<td>0.040</td>
<td>0.014</td>
<td>0.005</td>
<td>0.005</td>
<td>0.014</td>
</tr>
<tr>
<td>Catania (IT)</td>
<td>0</td>
<td>0.030</td>
<td>0.020</td>
<td>0.030</td>
<td>0.029</td>
<td>0.020</td>
<td>0.010</td>
<td>0.005</td>
<td>0.005</td>
<td>0.011</td>
</tr>
<tr>
<td>Ioannina (GR)</td>
<td>1</td>
<td>0.033</td>
<td>0.020</td>
<td>0.033</td>
<td>0.029</td>
<td>0.020</td>
<td>0.011</td>
<td>0.005</td>
<td>0.005</td>
<td>0.011</td>
</tr>
</tbody>
</table>
Our detector shows a signal *only* in the hadronic calorimeter (no signal in the tracker, electromagnetic calorimeter or muon chambers). Therefore, this signal is most likely

Nuestro detector muestra señal *solamente* en el calorímetro hadrónico (no en el detector de trazas, calorímetro electromagnético, ni cámaras de muones). Por lo tanto, esta señal es probablemente debida a

Il rivelatore ha un segnale nel calorimetro adronico e nessun segnale nel rivelatore centrale e nelle camere per muoni. Cosa stiamo osservando?

A. a NEUTRON
B. a PION
C. an ELECTRON
D. a PHOTON
How do we see “quarks” in a detector?

¿Cómo se observan los “quarks” en un detector?

Come osserviamo i “quarks” in un rivelatore?

A. De ningún modo
B. Por su trayectoria espiral, característica
C. Mediante los “chorros” de hadrones que producen
D. Como dos trazas rectas individuales en direcciones opuestas

A. Sono invisibili
B. Hanno una caratteristica traccia a spirale
C. Formano “jets” di adroni
D. Danno luogo a due traccie dritte in direzioni opposte

a. Not at all
b. By their characteristic spiral trajectory
c. Via “jets” of hadrons they generate
d. As two individual straight tracks in opposite directions
Approximately how many times do the protons in the LHC fly around the accelerator ring in 1 second?

¿Cuántas vueltas por segundo dan, aproximadamente, en el acelerador, los protones en el LHC?

Quanti giri dell’acceleratore LHC fanno all’incirca i protoni in un secondo?

A. 1  
B. 100  
C. 10 000  
D. 1 000 000
Superconducting magnets bend the protons around the LHC ring. What do you think is the temperature of these magnets?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Room temperature, 300K</td>
</tr>
<tr>
<td>B.</td>
<td>Colder than outer space, 1.9K</td>
</tr>
<tr>
<td>C.</td>
<td>Temperature of outer space, 2.7K</td>
</tr>
<tr>
<td>D.</td>
<td>163.2K</td>
</tr>
</tbody>
</table>

Imanes superconductores curvan los protones en el anillo del LHC. ¿Cuál es la temperatura de estos imanes, en su opinión?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Temperatura ambiente, 300K</td>
</tr>
<tr>
<td>B.</td>
<td>Más frío que el espacio exterior, 1.9K</td>
</tr>
<tr>
<td>C.</td>
<td>La del espacio exterior, 2.7K</td>
</tr>
<tr>
<td>D.</td>
<td>163.2K</td>
</tr>
</tbody>
</table>

I magneti superconduttori di LHC guidano 100,000 milioni di protoni lungo 27km. Quale pensate sia la loro temperatura? (degli magneti)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Temperatura ambiente, 300K</td>
</tr>
<tr>
<td>B.</td>
<td>Più freddi dello spazio, 1.9K</td>
</tr>
<tr>
<td>C.</td>
<td>Temperatura dello spazio, 2.7K</td>
</tr>
<tr>
<td>D.</td>
<td>163.2K</td>
</tr>
</tbody>
</table>
Quiz

Prizes funded by CERN
Press review

A day in our shoes
6 April 2009

A group from Rutherford Appleton Laboratory’s program

While many students aren’t introduced to particle physics until they reach university, the International Particle Physics Masterclasses are on a mission to change that, offering students between 15 and 18 years of age the chance to step into a researcher’s shoes. This year’s international program involves 6000 students from over 80 institutes in 23 countries, including much of Europe, with groups in Brazil, South Africa, and the US. A local sub-program run by QuarkNet in the US includes another 22 institutes.

“Students should come as early as possible in contact with the fundamental questions about our universe, get their hands on real data, come in contact with scientists, and experience how fascinating physics can be,” says Michael Kobel, the global organiser of the masterclasses. Within the European Particle Physics Outreach Group (EPPoG), he worked, alongside Christine Sutton of the CERN Press Office and Erik Johansson of ATLAS to first extend the Particle Physics Masterclasses to Europe in 2006: the World

ATLAS e-News

“Hands on Particle Physics”
International Masterclasses

ATLAS news
Press review

Physik in unserer Zeit

Universitätsjournal TU Dresden
Evaluation

- "Physical Education" June 2007
- K.E. Johansson, M. Kobel, D. Hillebrandt, K. Engeln and M. Euler
- 373 female / 825 male students, aged 16 to 19, 18 countries
Evaluation

The lectures were interesting

The lectures were interesting

I generally liked the masterclasses
Evaluation

![Graphs showing time spent using a computer at home and general liking of masterclasses by gender.](Image)
Evaluation

I learned about the organisation of scientific research
- nothing
- little
- something
- much
- very much

number of students

general interest in physics after attending the masterclasses

I learned about the organisation of scientific research
- nothing
- little
- something
- much
- very much

number of students

more modern physics at school

Hands on Particle Physics
International Masterclasses
Evaluation

- Outstanding appreciation
- Independent of gender and pre-knowledge
- Important: lectures
- More modern physics at school
Future plans

- Masterclasses at school
- 4 hours
- Ph.D. student and teacher
- Small groups (~ 20 students)
- No video conference
Future plans

- National program in Germany „Netzwerk Teilchenwelt“ in the framework of „Lernwelten der Physik“
- Application in preparation
- Hierarchical program for teachers and students
- 4 levels with decreasing number of participants
  - Basic training: 400 teacher + 6000 students / year
  - Reinforcement program
  - Active Cooperation
  - Research: 5 teachers + 30 students / year
Masterclasses 2010

- 17.2. – 5.3.2010
- Contact institute near to you
- Some institutes hold special teacher day

www.physicsmasterclasses.org

Institute for Nuclear and Particle Physics, TU Dresden