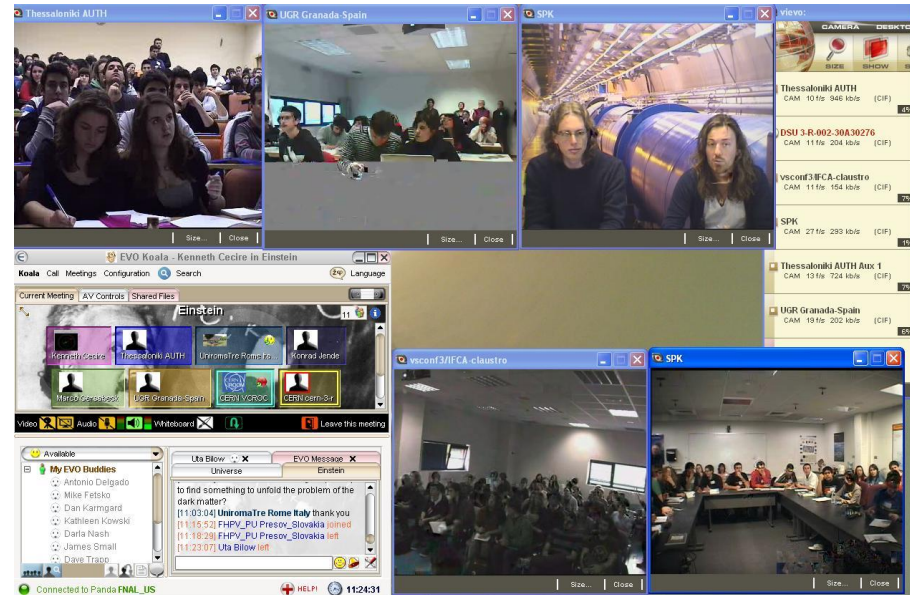


Use of LHC data, e.g. in Masterclasses, by high school students (and teachers)



Joint EPPCN/IPPOG meeting, CERN, 4.11.2011

Michael Kobel, TU Dresden
(Co-Chair of IPPOG)

1) The masterclass idea

- Basic idea from UK 1996 (R.Barlow et al.)

- Students (16-19 year-olds) spend 1 day at research institute
- **Listen to scientists'** introduction to particle physics
- **Work like and with scientists („masters“):** measurements with real particle physics data

- **Why Masterclasses?**

- Make modern **particle physics data available** to students
- Let **students explore** fundamental forces and building blocks of nature
- Demonstrate the **scientific research process**
- **Stimulate interest** in science
(proven in refereed evaluation [Physics Education 42 \(2007\) 636-644](#))

The EPPOG international masterclass idea

● Create an international collaboration of students

- Join institutes worldwide with 300-400 students per day
- Since 2005: all w/in 3 weeks each year
- Meanwhile over 130 institutes from 28 countries taking part
- Over 8000 students participating
- ~ 5 masterclasses join in video conference at the end of the day
 - ✦ Discuss results and differences
 - ✦ Combine results (better accuracy)
 - ✦ Quiz and prizes
 - ✦ Questions to scientists

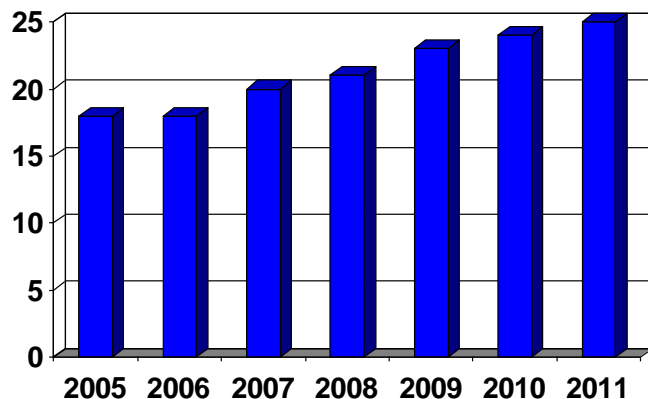
- schedule, real LHC and LEP data, physics framework (in 17 languages!)
description of all participating institutes:

www.physicsmasterclasses.org

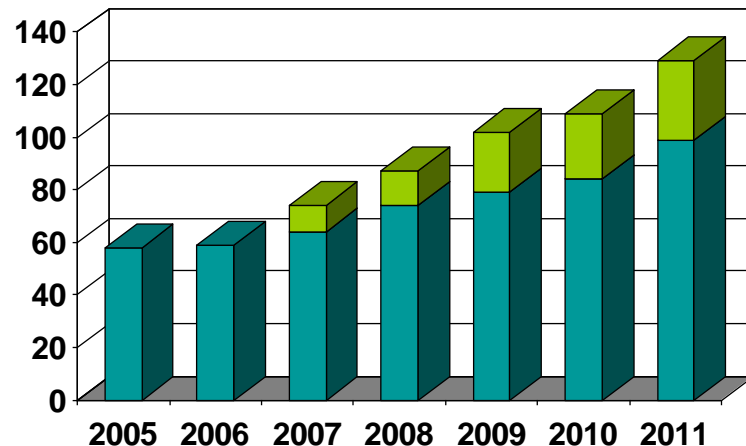


The screenshot shows the IPPOG website interface. At the top left is the IPPOG logo (International Particle Physics Outreach Group). At the top right is the 'INTERNATIONAL MASTERCLASSES' logo with the tagline 'hands on particle physics'. Below the logo is a navigation menu with 'Home', 'Participate!', 'Schedule', and 'My Country'. The 'My Country' section is expanded, showing a list of countries: Austria, Belgium, Brazil, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, and Portugal. The 'Italy' section is selected, showing a list of participating institutes: Bologna (University of Bologna - INFN), Catania (University of Catania - INFN), Ferrara (University of Ferrara - INFN), Frascati (INFN Frascati), Lecce (University of Salento - INFN), Napoli (University of Napoli - INFN), Padova (University of Padova - INFN), Pisa (University of Pisa - INFN), Rome (University Roma Tre and Sapienza Rome University), Torino (University of Torino - INFN), Trieste (University of Trieste - INFN), and Udine (University of Udine - INFN). Below the list of institutes is the 'National Responsible' section, which identifies Catia Peduto as the contact person for the Office of Communication of INFN at Piazza dei Caprettari 70, 00186 Roma.

Participation EPPOG international masterclasses



■ Countries



■ Institutes ■ US program

US
(Quarknet)

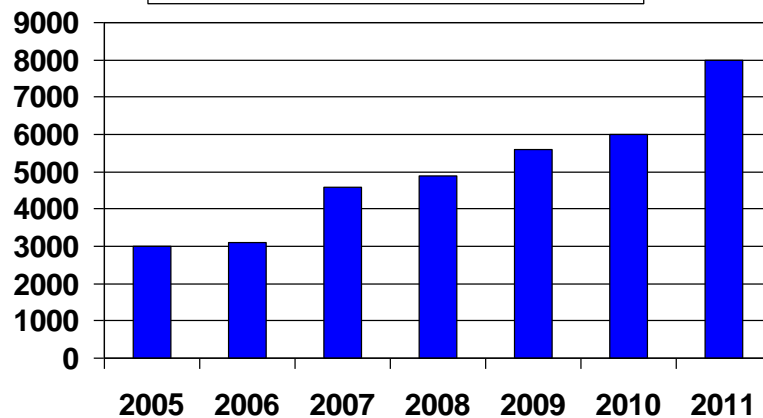
adding
-Canada
-Columbia
-China
-Japan

Brazil



South Africa

Israel



■ Participants

Other Big Programs using real LHC data

----- masterclass – like -----

● UK National Particle Physics Masterclasses

- www.particlephysics.ac.uk/teach/master-classes.html
- at 19 institutes, 25-30 events / year (mostly March/April)



● German „Netzwerk Teilchenwelt“ (Dresden et al.)

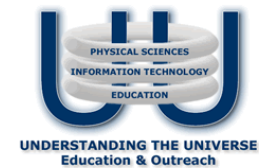
- www.teilchenwelt.de (masterclasses, cosmic rays and more)
- 22 institutes send Ph.D. students to schools (> 100 / year !)
- Funded w/ 0.35M€/year over 3 years by German Ministry of R&E



----- other formats -----

● Interactions in Understanding the Universe I2U2 (FNAL et al.)

- Among it: CMS E-lab: www18.i2u2.org/elab/cms/home/project.jsp
- student-led, teacher-guided online project in the class-room
- Funded w/ 0.48M€/year over 3 years by NSF



● Learning with ATLAS@CERN (Athens et al. : finished)

- www.ea.gr/ep/lacern and www.learningwithatlas-portal.eu
- develop frameworks and educational resources for teachers and students
- Funded w/ 0.30M€/year over 2 years by European FP7



More

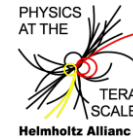
- PATHWAY to Inquiry Based Science Teaching (Bayreuth et al.)
 - www.pathway-project.eu
www.bayceer.uni-bayreuth.de/pathway/en/allgemein/gru/html.php
 - educational resources, teaching practices and instructional models for teachers
 - Covering all sciences, also HEP(Athens),
 - funded w/ 3.4 M€ for 24 partners for 3 years (01/2011 – 12/2013)
- DISCOVER THE COSMOS (Athens, CERN, Dresden, Birmingham...)
 - www.discoverthecosmos.eu
 - innovative ways to involve teachers and students in eScience in particle physics and astronomy
 - Original data from: International masterclasses, Hands-on Universe, ...
 - Funded w/ 0.9 M€ for 15 partners for 2 years (09/2011 - 08/2013)
- LHC Masterclasses at Science Centres (Oslo)
 - Collaboration w/ at least 4 science centres in Norway
- ... for sure more (Poland, Canada, ...) ...



3) International Masterclass setup

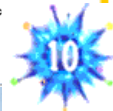
- All frameworks (ATLAS, CMS, ALICE...) collected by IPPOG at <http://physicsmasterclasses.org/neu/index.php?cat=physics>

- Central Organisation:
TU Dresden (M.K., Uta Bilow)
- Quarknet-lead US partner program since 2007 (Ken Cecire)

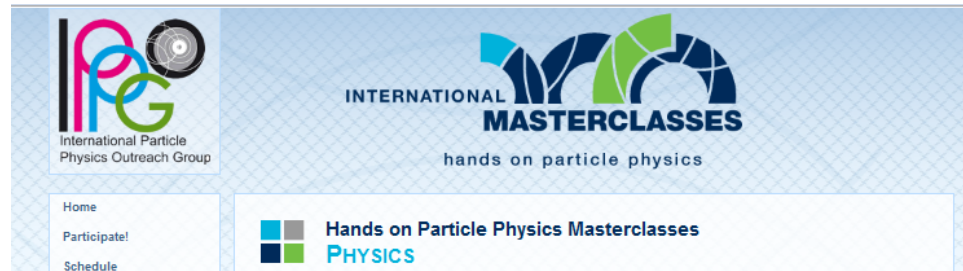


SPONSORED BY THE

Federal Ministry of Education and Research



Office of Science
U.S. Department of Energy



- Descriptions for local organizers at http://physicsmasterclasses.org/neu/index.php?cat=local_organisation&page=exercises
- Translation via IPPOG → Available in 4 (ALICE) to 11 (ATLAS) languages
- free to use outside international masterclass program!

	BaBar	Le Monde des Particules	KworkQuark	Teilchentour I	Teilchentour II	Unischule	Local Organisation	Press Review	Archive	Imprint	Contact Us
ALICE	-	-	x	x	x	-	x	-	-	x	-
ATLAS	-	x	x	x	x	-	x	x	-	x	x
CMS	-	-	-	x	x	-	x	-	-	-	x
Hands On Cern	x	x	x	x	x	x	x	x	x	x	x
A Keyhole to the Birth of Time	-	-	-	x	-	-	-	-	x	-	x
Identifying Particles	-	-	-	x	-	-	x	x	-	x	-
Particle Physics Package	-	-	-	x	-	-	-	-	-	-	-
BaBar Particle Physics	-	-	-	x	-	-	-	-	-	-	-
Le Monde des Particules	-	-	-	-	x	-	-	-	-	-	-
DESY's KworkQuark	-	-	-	-	-	-	x	-	-	-	-



4) Technical Platforms and Tools used

● ATLAS

- **Minerva** (M. Wielers, P. Watkins, T. McLaughlan et al) based on ATLANTIS

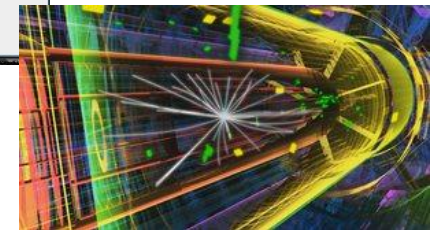
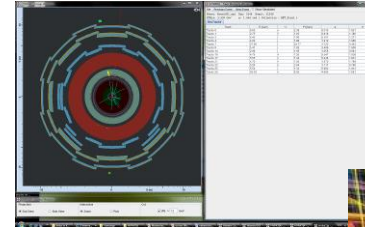
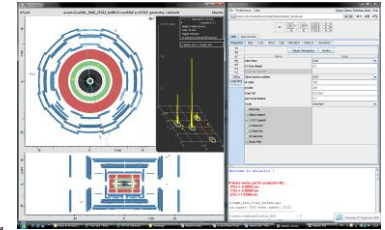
<http://atlas-minerva.web.cern.ch>

- **Hypatia** (C. Kourkoumelis et al.) based on ATLANTIS

<http://hypatia.phys.uoa.gr>

- Under construction: **Camelia** (J. Pequenao)

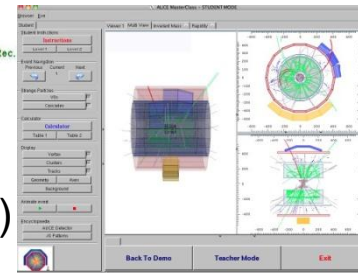
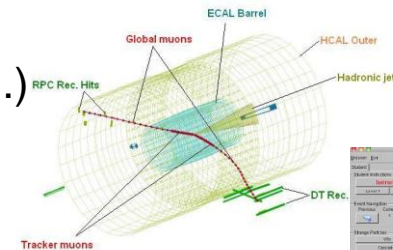
<http://pdgusers.lbl.gov/~pequenao/camelia/>



● CMS

- **iSpy online** (M. Hategan, K. Cecire et al.) in collaboration with Quarknet (US)

www12.i2u2.org/elab/cms/event-display



● ALICE

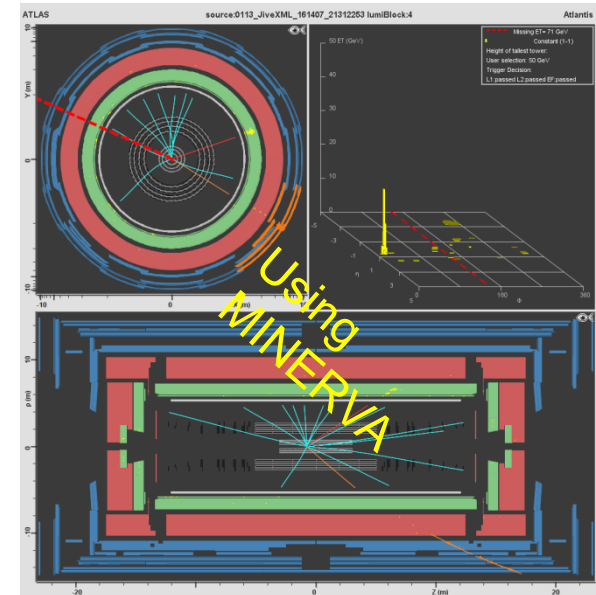
- **ALICE masterclass application** (P. Debski, Y. Foka et al.) simplified ALICE event display in ROOT environment

http://aliceinfo.cern.ch/static/Pictures/pictures_High_Resolution/MasterClassWebpage.html

5) Measurements done by Students

- ATLAS W-Path (K.Jende, M.K. et al., TU Dresden)
 „ELISA I“ (<https://kjende.web.cern.ch/kjende/en/wpath.htm>)
 - 1000 *real data* preselected events ($\sim 40\% W \rightarrow \ell\nu$)
 - W charge asymmetry \rightarrow structure of the proton
 - Few *simulated* $H \rightarrow WW$ \rightarrow search for yet undiscovered
 - Simplified interpretation:

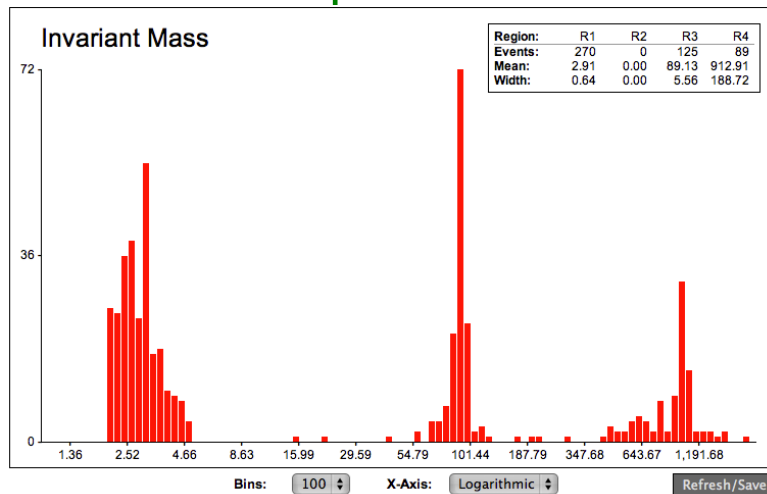
interaction process	W ⁺	W ⁻	theory: proportion in %
Quark gluon interaction			66%
	44%	22%	
Gluon gluon interaction			34%
	: 17%	: 17%	
measurement	61%	39%	100%



- Expected raw student measurement: $\#W^+/\#W^- = 1.56 \pm 0.17$
- Compare to first ATLAS paper: $\#W^+/\#W^- = 1.52 \pm 0.07$
 CERN-PH-EP-2010-037 (October 2010)

● ATLAS Z-Path (F.Ould-Saada, M.Pedersen, Oslo Univ)
„ELISA II“ (<https://kjende.web.cern.ch/kjende/en/zpath.htm>)

- 700 *real data* preselected events ($\sim 300 Z \rightarrow \ell\ell$)
- Find Dilepton events \rightarrow calculate invariant mass
- 300 *simulated* $Z' \rightarrow \ell\ell$ \rightarrow search for yet undiscovered
- Derive mass spectrum



- Discuss importance of invariant mass concept
- Discuss meaning of finite width
- Discuss meaning of new mass peaks

● CMS: J/Ψ Reconstruction (K.Cecire et al.)

www.physicsmasterclasses.org/exercises/CMS/cms.html

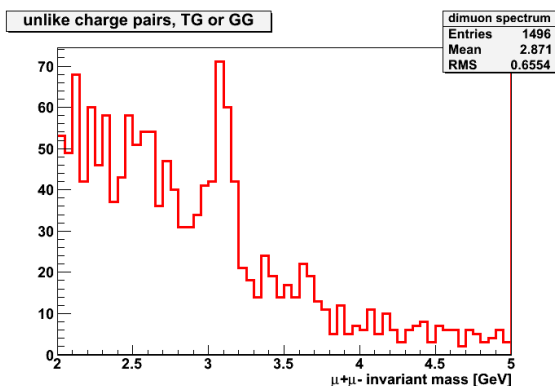
● 2000 preselected *real data* (~100 J/Ψ)

● Find opposite sign Dileptons

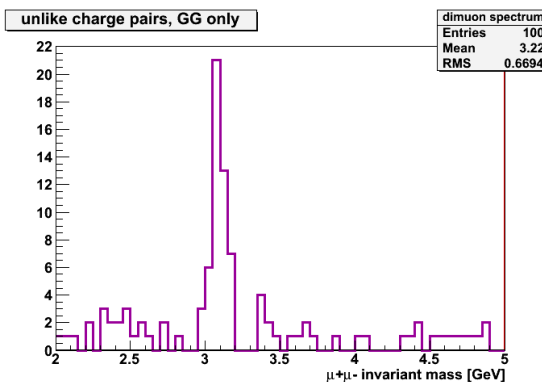
→ rate via quality criteria

● Reconstruct J/Ψ

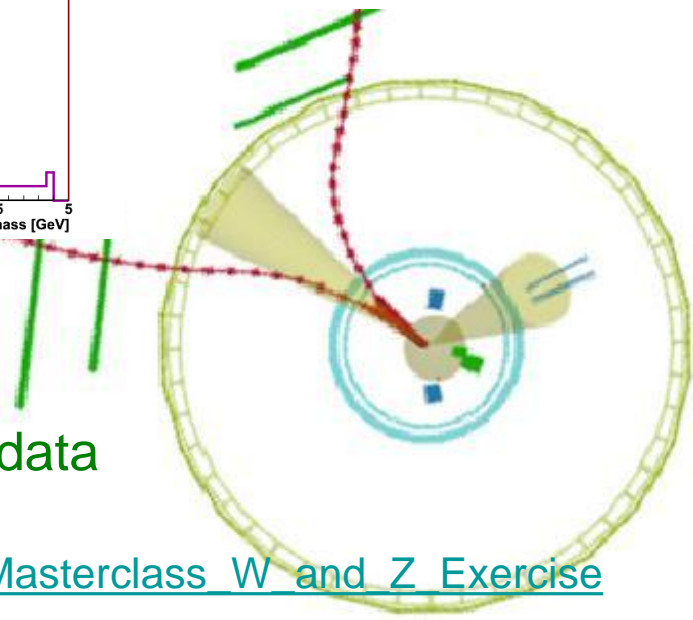
→ invariant mass



all qualities



good quality



● W/Z measurement with real CMS data under development:

http://quarknet.us/library/index.php/CMS_Masterclass_W_and_Z_Exercise

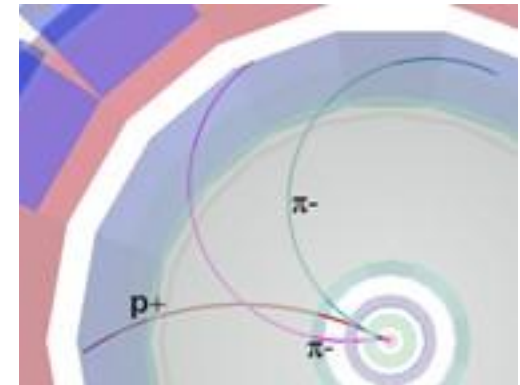
ALICE: looking for strange particles

http://aliceinfo.cern.ch/static/Pictures/pictures_High_Resolution/MasterClassWebpage.html

- Using 900 GeV proton proton (!) data
- Measure the numbers of K^0_s , Λ , anti- Λ and Ξ^-
- Calculate yields : number of particles /interaction
- Compare with Monte Carlo predicted yields

➤ Monte Carlo simulation : No exotic phenomena (such as QGP) included

Dataset	N(K0s)	N(Λ)	N(anti- Λ)	N(Ξ^-)	N(events)	error(K0)	error(Λ)	error(Λ)	error(Ξ^-)
1	19	4	5	6	100	4.359	2.000	2.236	2.449
2	19	4	5	4	100	4.359	2.000	2.236	2.000
3	23	5	3	5	100	4.796	2.236	1.732	2.236
4	19	7	6	5	100	4.359	2.646	2.449	2.236
5	20	3	3	6	100	4.472	1.732	1.732	2.449
6	21	6	4	5	100	4.583	2.449	2.000	2.236
7	19	2	4	2	100	4.359	1.414	2.000	1.414
8	21	5	3	2	100	4.583	2.236	1.732	1.414
	161	36	33	35	800	12.689	6.000	5.745	5.916
Yields	0.201	0.045	0.044	0.004		0.016	0.008	0.007	0.002
MC yields	0.134	0.039	0.035	0.006					
ALICE put	0.184	0.048	0.047	0.010		0.002	0.001	0.002	0.002



- discrepancy between experimental data and Monte Carlo
- Production of strangeness under-predicted in the MC
- Agreement w/ ALICE paper (accepted by EP Journal C)


Schedule

• www.physicsmasterclasses.org/index.php?cat=schedule

	Fri, March 4	Mon, March 7	Tue, March 8	Wed, March 9	Thu, March 10	Fri, March 11
topic	ATLAS W	ATLAS W	ALICE	ATLAS Z / CMS	ATLAS Z / CMS	ATLAS Z / CMS
Moderator	Andrée N.N.	Michael Paul	Despina Mario	Sarah Michael	Paul Moritz	Andrée Adi
	Innsbruck	Valencia	Graz	London Queen Mary	Rome	Dortmund
	Madrid IFT	Marseille	Bergen	Wuppertal	Vienna Univ.	Strasbourg
	Barcelona	Hamburg	Oslo	Stockholm	London Univ. College	Debrecen
	Erlangen		GSI Darmstadt/Frankfurt	Strasbourg	Udine	Zurich
	Orsay		Copenhagen	Helsinki	Strasbourg	Santander
				Athens, Demokritos	Palaiseau	

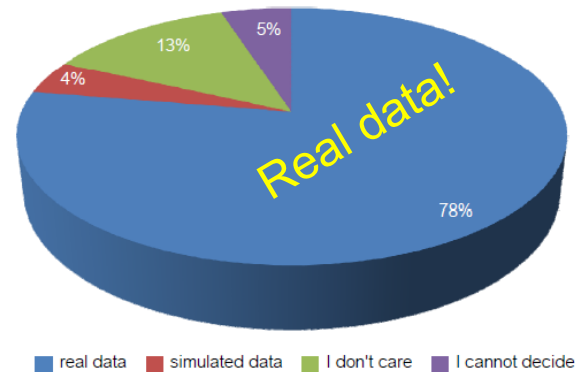
	Sat, March 12	Mon, March 14	Mon, March 14	Tue, March 15	Wed, March 16	Wed, March 16
topic	ATLAS W	ATLAS W	ATLAS Z / CMS	ATLAS Z / CMS	ATLAS W	ATLAS Z / CMS
Moderator	Liv Sahal	Katharine José	Rachel Sarah	Sarah Christian	Liv Paul	Adi Mario
	Braga	Orsay	Copenhagen	Oslo	Bratislava	Athens Nat. Tec. Univ.

• Lots of friendly engaged young video conference moderators

	Kate Shaw (ATLAS)		Katharine Leney (ATLAS)		Michael Hauschild (ATLAS)
	José Guilherme Milhano (Theory Unit)		Silvia Schuh-Erhardt (ATLAS)		Andrée Robichaud-Veronneau (ATLAS)
	Mario Campanelli (ATLAS)		Petra Haefner (ATLAS)		Liv Wiik (ATLAS)
	Paul Laycock (ATLAS)		Sahal Yacoub (ATLAS)		Christian Barth (CMS)
	Moritz Guthoff (CMS)		Adi Bornheim (CMS)		Despina Hatzifotiadou (ALICE)

Use of real data

- one of the key elements of all programs!
 - what kind of data do you prefer to work with?
(survey K.Jende, 425 students answered)



- ATLAS policy:
 - published data
 - good data quality
 - caveat on the DVD: for educational purposes only
 - From 2012: password protected

Plans for 2012 (examples)

W-path (ATLAS):

- 6 000 *real data* preselected events ($\sim 2000 W \rightarrow \ell n$)
→ different set of data for each institute, can be compared for consistency and combined in the video conference.
- Mix with 250 candidates $H \rightarrow WW$ at an early selection stage i.e. including (considerable) background corresponding to about 0.3 fb^{-1} (6 % of 2011 data)
→ students measure opening angle between 2 leptons and combine their results in histogram for angular distribution
- Probably too early for 2012 !? -> Fallback solution: MC data

Z-path (ATLAS and CMS):

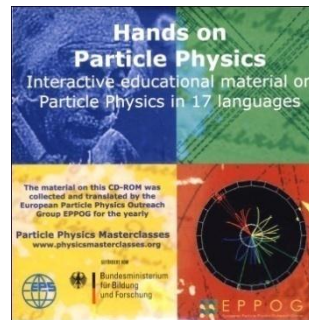
- larger data sample
- general search for dilepton events (Also J/Ψ and Υ)
- php tool for mass plots under development
- Automatic tool for analyzing larger amount of data for 2013 ?

Summary

- Since 2005 IPPOG's International masterclasses are an ongoing huge success
- March 2011 saw the first IMCs with 100% real LHC data
 - Worked w/o huge problems, despite all worries !
 - National schools (e.g. in Netzwerk Teilchenwelt) meanwhile also prefer LHC (70%) over LEP (30%)
- LHC data + Masterclasses in new EU projects
 - PATHWAY to Inquiry Based Science Teaching
 - DISCOVER THE COSMOS (one of its key projects)
- Continuous, „realistic“ upgrades ongoing
- Executive coordination by
 - Uta Bilow (Helmholtz Alliance, Dresden) for Europe, Africa, Middle East
 - Ken Cecire (Quarknet, Notre Dame) for US, America, Far East

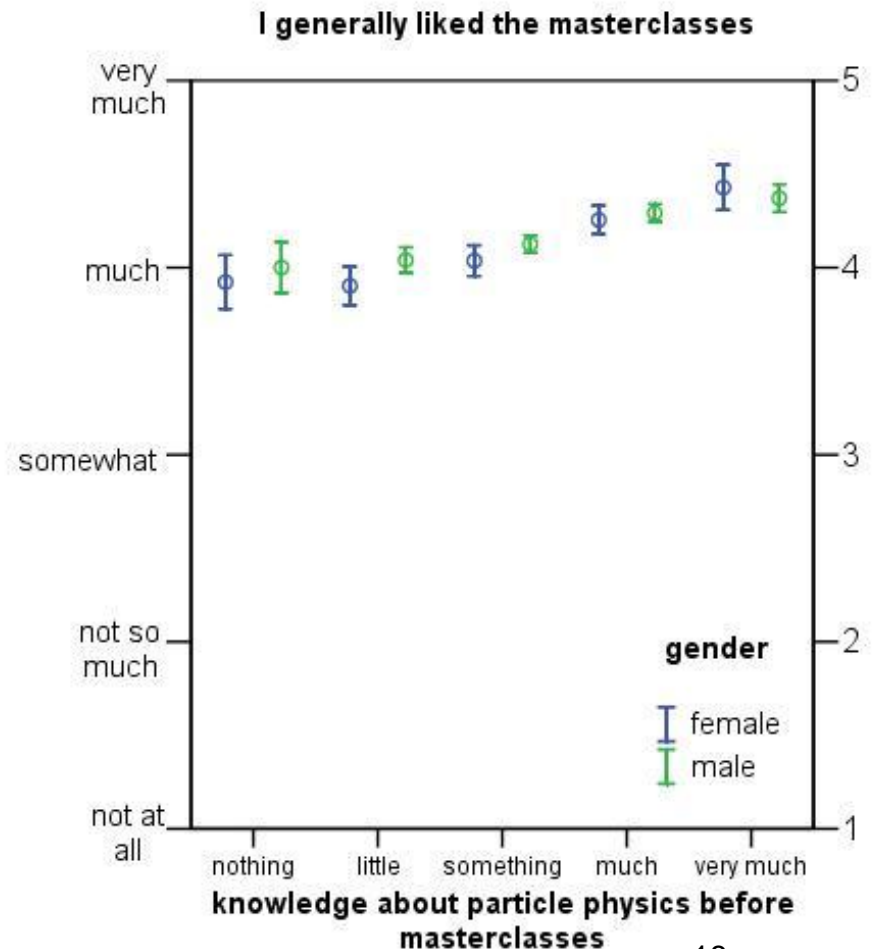
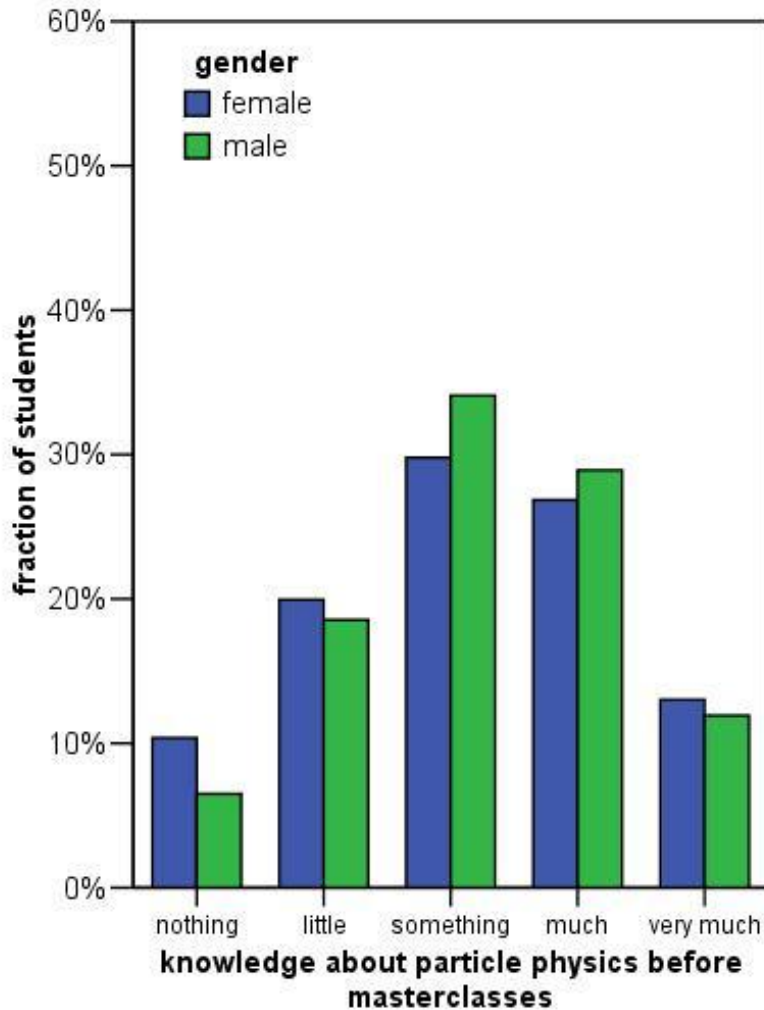
Masterclass Day – sample agenda

LOCAL TIME:	ACTIVITY:
8:30-9:00	Registration & Welcome
9:00-10:00	Introduction to Particle Physics
10:30-11:30	Second Talk or Tour
12:00-13:00	Lunch
13:00-15:00	Data Analysis, including Introduction
15:30-16:30	Information about Particle Physics, Studying physics,...
16:30-17:30	EVO Video Conference



Refereed evaluation in Physics Education 42 (2007) 636-644

- severity: just right
- success independent of a-priori knowledge and gender



Most important correlation

- Understanding the scientific research process generates interest in (especially modern) physics

