

Hunting for the Z and Higgs boson an IPPOG ATLAS Masterclass ... and brief overview of other Masterclasses

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M. Pedersen, F. Ould-Saada, E. Gramstad, M. Bugge, V. Morisbak, S. Raddum

2 γ selection: S. Raddum and F. Ould-Saada

4l selection: M. Bugge and F. Ould-Saada

OPloT: V. Morisbak, M. Pedersen, F. Ould-Saada

Web-pages and Z-path concepts: F. Ould-Saada and M. Pedersen

Overview

- ▶ What are the IPPOG Masterclasses
- ▶ Briefly about the ATLAS W-path, CMS and ALICE Masterclasses
- ▶ ATLAS Z-path past and future
- ▶ Conclusion

IPPOG Masterclasses

- ▶ Yearly event arranged by International Particle Physics Outreach Group ([IPPOG](#))
 - ▶ Started in 2005 and used LEP-data
- ▶ Large: 4 weeks, > 30 countries, > 10000 students
- ▶ Maximally 5 countries/institutes per day
- ▶ Main incentive
 - ▶ Introduce the exciting world of particle physics to high school students
 - ▶ Have fun!
- ▶ [IPPOG Masterclasses](#) inspired by similar activities started up in the UK
- ▶ In addition to the IPPOG Masterclasses, there are many stand-alone MC's following the same concept
- ▶ Here: will present the status of the ATLAS IPPOG Masterclasses, and mostly focus on the [Z-path](#) developed by the Oslo group



IPPOG Masterclasses cont.

High school students invited to nearby University or research institute to learn

- ▶ about particle physics
- ▶ how detectors identify particles
- ▶ how to identify selected signal events from background events, by use of the signals decay products

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The students get to work hands-on with real data, and meet with other Masterclass institutes and CERN

- ▶ Through event displays, analyze real data from the LHC experiments (ATLAS, CMS, ALICE)
- ▶ Analysis depends on the type of Masterclass
 - ▶ ATLAS: Z-rediscovery, discovery of new particles, proton structure through charge asymmetry in W-decays, Higgs search
- ▶ Join a video-conference moderated by CERN, to present and discuss results with other institutes joining that day

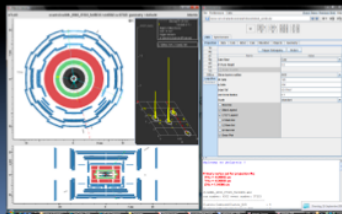
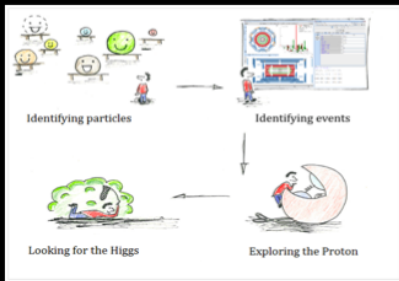


Quick overview of the different Masterclasses

W-path with ATLAS

[Link to W-Path](#)

- W charge asymmetry and structure of proton
 - Measure W^+/W^- charge ratio
- Search for Higgs: $H \rightarrow WW \rightarrow l\nu l\nu$
 - Measure angle between leptons
- **Minerva** event display
 - Histogram plotting
 - Online spreadsheets **EditGrid**



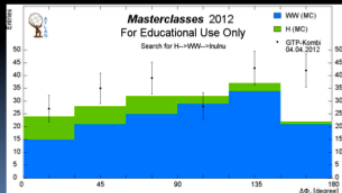
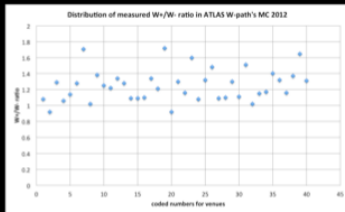
- 6000 events
 - W-events
 - High- p_T electron or muon
 - Missing transverse energy
 - Background (jets, Z, top, ...)
 - 250 simulated $H \rightarrow WW$

W-path 2012 results

- W^+/W^- ratio
 - proton= uud (+sea of quarks-antiquarks)



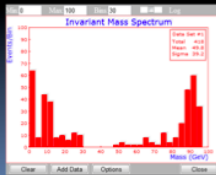
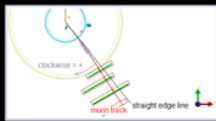
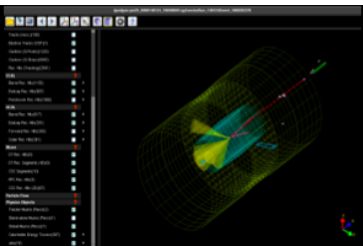
- $\Delta\Phi$ distribution between leptons in
 - $pp \rightarrow WW+X \rightarrow l\nu l\nu + X$
 - $pp \rightarrow H+X \rightarrow WW+X \rightarrow l\nu l\nu + X$



Development of W-path for 2013 Masterclasses - no more simulated Higgs, but real Higgs-candidate events!

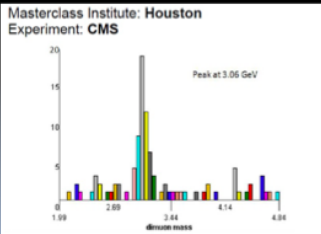
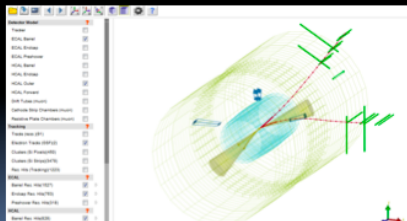
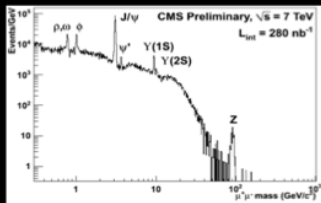
CMS – W&Z (2012)

- Distinguish between Z and W bosons
 - W^+/W^- , e/μ ratios
 - Z-mass
 - Unexpected particles (J/ψ , Υ)
- [iSpy online](#) event display
- 1900 Events:
 - W and Z, Background, "Mystery" events 2-12 GeV
 - Students sort events by:
 - Lepton flavor (e or μ).
 - Candidacy (W or Z).
 - Charge (W^+ or W^-).



CMS - J/ψ (2011)

- Students rate di-muon events, 2-5 GeV.
- Choose which to use based on muon track quality.
- J/ψ mass plot

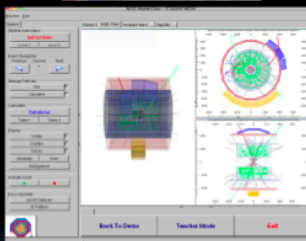


ALICE - strange particles

[Link](#)



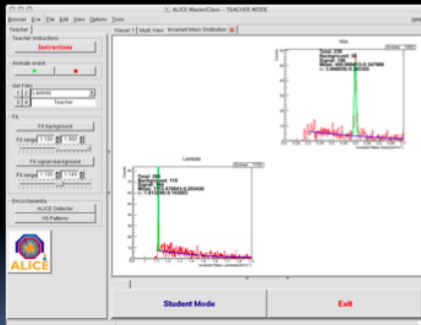
- ALICE analysis tool
 - [Simplified ALICE event display based on ROOT](#)
- Proton-proton data
- V⁰ finder and cascade finder
- Recognize from decay pattern
 - $K_s^0 \rightarrow \pi^+ \pi^-$
 - $\Lambda \rightarrow \pi^- p$
 - $\text{Anti-}\Lambda \rightarrow p \pi^-$
 - $\Xi^- \rightarrow \pi^- \Lambda \rightarrow \pi^- p \pi^-$
- Calculate invariant mass
 - Classify according to mass, fill tables & histograms
- Compare with Monte Carlo: Production of strangeness under-predicted in the MC (agrees with [ALICE paper](#))
 - strangeness enhancement as a telltale signal of Quark Gluon Plasma



Dataset	N(K ⁰)	N(Λ)	N(anti-Λ)	N(Ξ)	N(events)	error(K)	error(Λ)	error(anti-Λ)	error(Ξ)
1	39	4	5	4	320	4.859	2.000	2.236	2.449
2	39	4	5	4	330	4.359	2.000	2.236	2.000
3	29	5	3	5	300	4.796	2.236	1.732	2.236
4	39	7	6	5	320	4.859	2.686	2.686	2.236
5	30	3	3	6	300	4.472	1.732	1.732	2.449
6	21	6	4	5	300	4.583	2.449	2.000	2.236
7	39	2	4	2	300	4.359	1.424	2.000	1.424
8	21	5	3	2	300	4.583	2.236	1.732	1.424
	361	36	33	35	300	12.689	6.000	5.745	5.950
Yield	0.201	0.045	0.044	0.004		0.016	0.008	0.007	0.003
MC yield	0.134	0.033	0.035	0.006					
ALICE p+p	0.184	0.048	0.047	0.010		0.002	0.001	0.002	0.002

ALICE 2012 – strange particles

- Analyze big event sample (2000 events)
- Invariant mass histograms for K_s , Λ , anti- Λ
- Fit 2nd degree polynomial to background + Gaussian to peak
- Get number of K_s , Λ , anti- Λ after background subtraction
- Introduced later
 - Sample with 21000 pp events
 - Sample of 1500 PbPb events



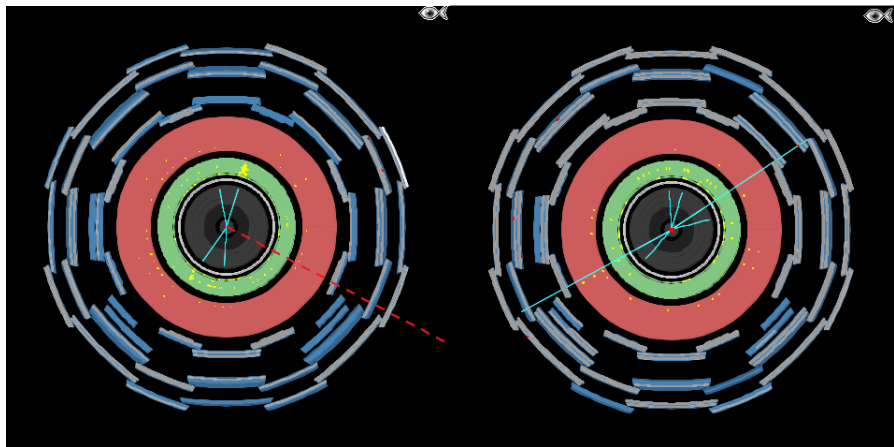
The ATLAS Z-path

The ATLAS Z-path

- ▶ Use of [HYPATIA](#) Event Display (based on ATLANTIS, the official ATLAS event-display).
 - ▶ Separate version specially developed for IPPOG Masterclasses.
- ▶ The Z-path is built around the Invariant Mass technique
 - ▶ Rediscover already known particles such as J/ψ , Υ and the Z boson
 - ▶ Discover completely new, so-far hypothetical particles, such as the Z' boson (MC events...)
- ▶ 10 000 real data events including signal and background. Some simulated Z' events.
- ▶ Event selection closely follows the official ATLAS analysis
- ▶ New of this year
 - ▶ Hunt for the Higgs boson - up until recently could go as “hypothetical”
 - ▶ $H \rightarrow \gamma\gamma, H \rightarrow ZZ \rightarrow 4l$

Z path with ATLAS 2011-version

- ▶ Students visually analyze 50 events each with HYPATIA
 - ▶ Mixed data-sample ee , $\mu\mu$, and some simulated $Z' \rightarrow ee/\mu\mu$
- ▶ Distinguish interesting events from background events
 - ▶ Background events include QCD and W events
- ▶ Distinguish electrons from muons

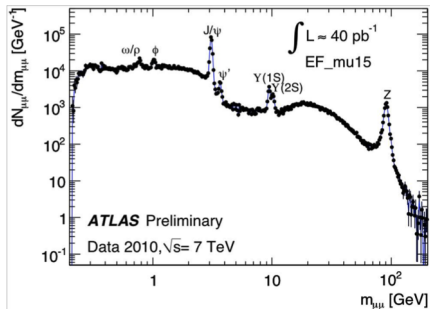


$Z \rightarrow ee$

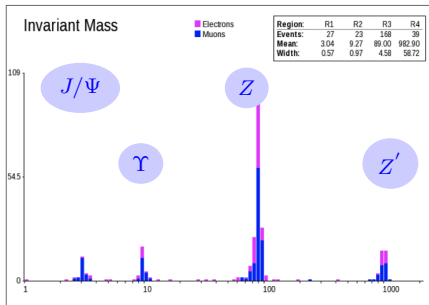
$Z \rightarrow \mu\mu$

Combination of results, example last year

- ▶ In HYPATIA make an invariant mass-table from identified signal events
- ▶ Upload invariant mass-table to OPlOT (web-interface)
- ▶ Results automatically combined by OPlOT
- ▶ Results discussed at institute level before joining video-conference with CERN
- ▶ Comparison with ATLAS official results



ATLAS Official



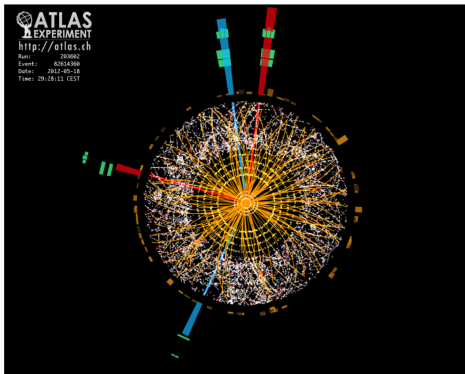
Masterclass [OPlot](#)

The new Z-path including Higgs

Now a more general “Invariant Mass Path”

Highlights

- ▶ More challenging for students
- ▶ Students will work on real data
Higgs-candidate events!

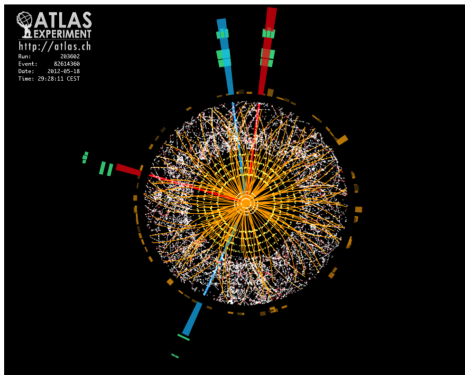


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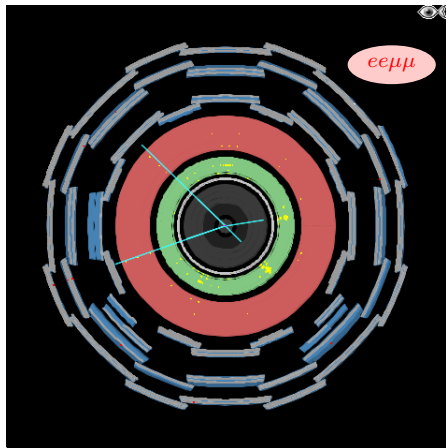
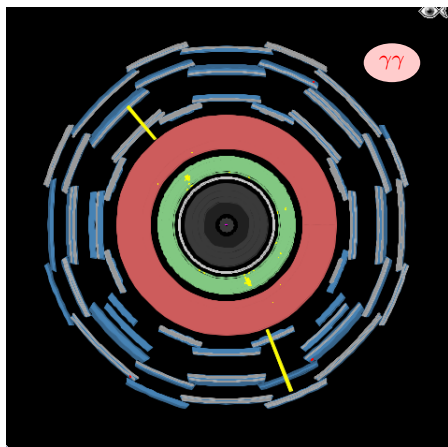
Highlights

- ▶ More challenging for students
- ▶ Students will work on real data Higgs-candidate events!
- ▶ Students visually analyze 50 events
 - ▶ Mixed sample, ll, gg, 4l
 - ▶ 45 % Z, 5% Υ , 5% J/Ψ , 5% Z'
 - ▶ Higgs candidate events from $1fb^{-1}$ 2011 ATLAS data (with appropriate event-selection)



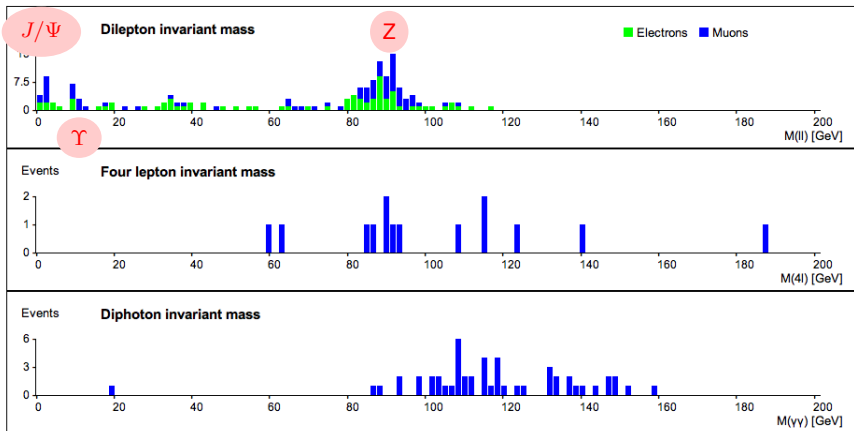
- ▶ Distinguish interesting events from background events
 - ▶ Background events include QCD and W events
- ▶ Distinguish electrons from photons, identify muons
- ▶ Distinguish converted photons from electrons
- ▶ Distinguish 2 lepton events from 4 lepton events

Example of Higgs candidate events



Example results

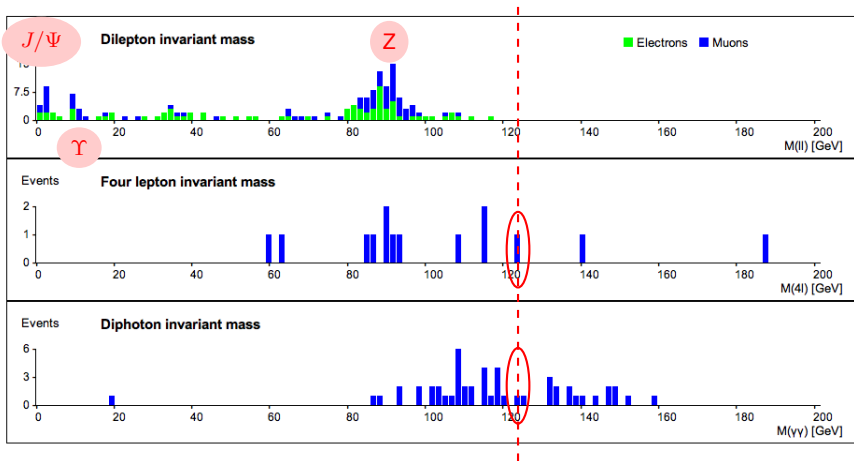
- ▶ The Z, J/Ψ and Υ signals are easily detectable in an invariant mass plot
- ▶ In the small $1fb^{-1}$ data-sample, the Higgs candidates are not so obvious



NB! Here only a small sub-selection of the data is shown for illustration purposes

Example results

- ▶ The Z , J/Ψ and Υ signals are easily detectable in an invariant mass plot
- ▶ In the small $1fb^{-1}$ data-sample, the Higgs candidates are not so obvious
- ▶ However there is a highlight: 1 official $H \rightarrow ZZ \rightarrow 4l$ event is present in the sample



NB! Here only a small sub-selection of the data is shown for illustration purposes

Discussion of results

OPlot features an “Add-signal-button” and “Add-background-button” in the $\gamma\gamma$ plot

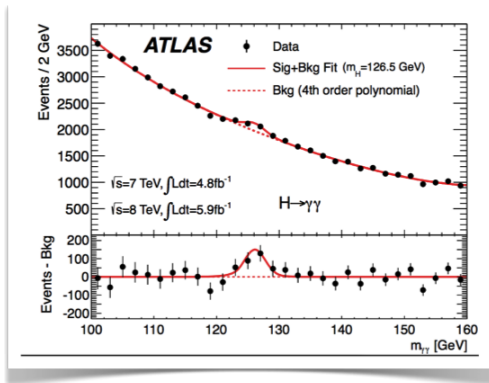
- ▶ Will be used to show how sufficient statistics leads to result close to official ATLAS

Plot type:

Higgs MC small

Higgs MC large

Perfect $\gamma\gamma$



Conclusions

Masterclasses are popular, and continuously under development!

- ▶ New Masterclasses developed for LHC data in 2011
- ▶ IPPOGs Masterclasses have undergone changes to account for the Higgs-like discovery for Masterclass 2012
- ▶ ATLAS Z-path migrating to a more general Invariant Mass Path
 - ▶ Lots of work done, we are almost there!
 - ▶ Web-pages in progress of being updated
 - ▶ Data-samples almost ready
 - ▶ HYPATIA event-display developed to include invariant-mass options for photons and 4-lepton events
 - ▶ OPIoT provides a versatile web-interface for combination and discussion of results