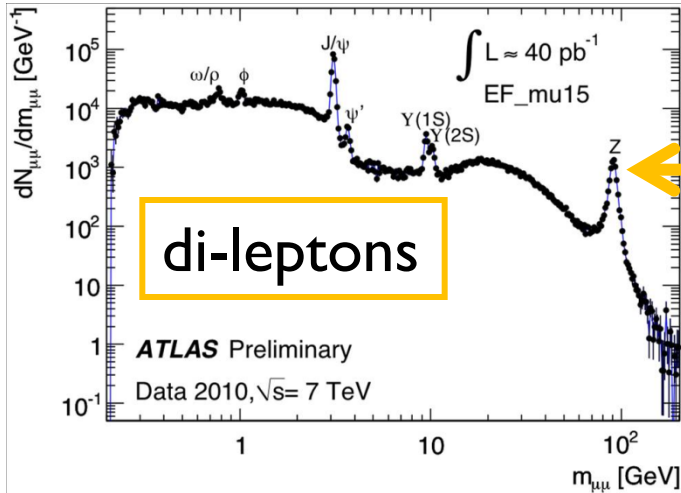




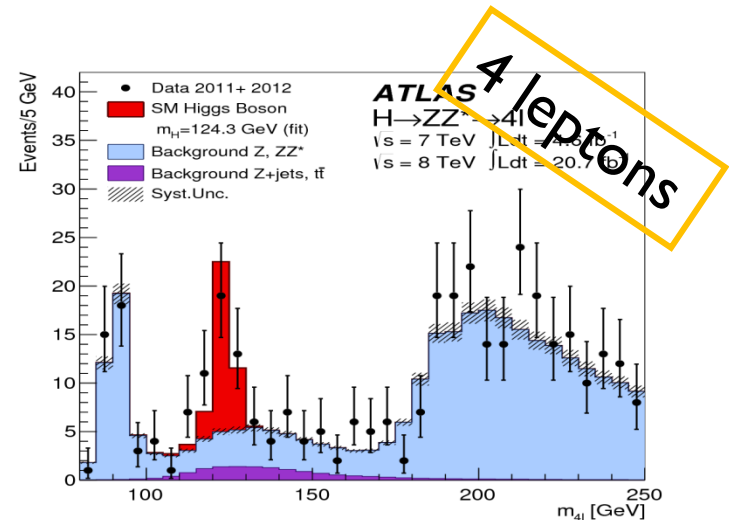
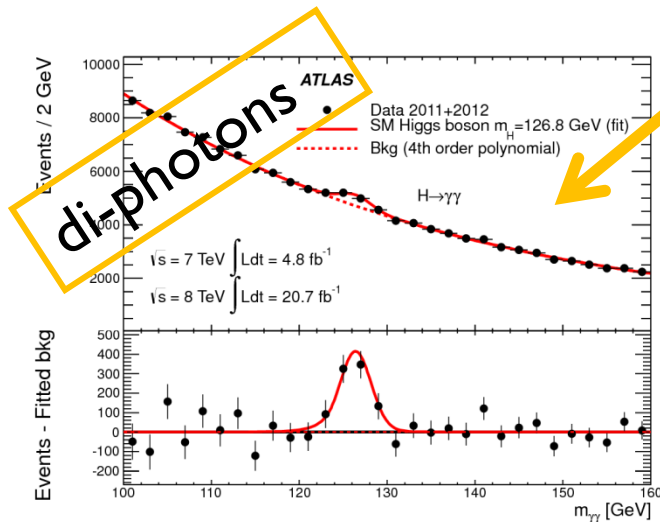
Physics of the ATLAS Z measurement

Eirik, Farid, Magnar, Maiken, Vanja



The Z-path



- ▶ Use the invariant mass technique to
 - ▶ measure mass of short-lived particles
 - ▶ search for exotic particles – Z', Graviton **New!**
 - ▶ discover new particles – Higgs



Z-path measurement

- ▶ each pair of students go through 50 collision events
- ▶ identify ll , $4l$ and $\gamma\gamma$ events and calculate invariant masses (in HYPATIA)
- ▶ resulting di-lepton invariant mass distribution is used to
 - ▶ measure mass and width of Z^0 boson, J/Ψ and Y mesons
 - ▶ look for new particles (Z' @1 TeV and Graviton@1.5 TeV) 
- ▶ di-photon and four lepton invariant mass distributions are used to
 - ▶ provide insight into the process of discovering the Higgs boson at the LHC
 - ▶ look for new particles (Graviton@1.5 TeV) 

HYPATIA

Hybrid Pupils' Analysis Tool for Interactions in ATLAS – version 7.4 – Invariant Mass Window

File View Histograms Preferences Help

File Name	ETMis [GeV]	Track	P [GeV]	+/-	Pt [GeV]	φ	η	M(2) [GeV]	M(eeee) [GeV]	M(eemm) [GeV]	M(mmmm) [GeV]	e/m	
JiveXML_204910_22993546.xml	34.339	Tracks 248	60.2	+	59.2	2.327	0.185	88.544	124.959			e	
		Tracks 27	81.9	-	63.9	-2.815	-0.733					e	
		Tracks 10	66.6	-	66.2	2.937	-0.109			22.153			e
		Tracks 282	18.0	+	15.5	3.079	0.555						e

Canvas Window – File: JiveXML_204910_22993546.xml Run: 204910 Event: 22993546

HYPATIA – Track Momenta Window

File Previous Event Next Event Electron Muon Photon Delete Track Reset Canvas

ETMis: 34.339 GeV φ : -0.605 rad Collection: MET_RefFinal

arido/Downloads/Hypatia_7/events/4lep/JiveXML_204910_22993546.xml

Track	+/-	P [GeV]	Pt [GeV]	φ	θ
Tracks 10	-	66.56	66.17	2.937	1.679
Tracks 11	-	67.90	33.24	-0.081	2.630
Tracks 27	-	81.89	63.94	-2.815	2.246
Tracks 43	+	14.62	5.29	0.378	2.771
Tracks 62	+	67.66	34.86	-0.001	2.600
Tracks 96	+	17.72	6.26	-0.097	2.780
Tracks 216	+	67.90	34.86	-0.006	2.602
Tracks 217	+	67.90	33.30	0.020	2.629
Tracks 248	+	60.23	59.22	2.327	1.387
Tracks 282	+	18.00	15.54	3.079	1.042

HYPATIA – Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

Category	Name	Value
InDet		
Calo		
MuonDet		
Objects		
ATLAS		
	<input checked="" type="checkbox"/> Pt	> 5.0 GeV
	<input type="checkbox"/> Pt2	< 700.0 MeV
	<input checked="" type="checkbox"/> d0	< 2.5 mm
	<input checked="" type="checkbox"/> z0	< 20.0 cm
	<input type="checkbox"/> d0 Loose	< 2.0 cm
	<input type="checkbox"/> z0-zVtx	< 2.5 mm
	<input type="checkbox"/> Layer	> 0
	<input checked="" type="checkbox"/> Number Pixel Hits	>= 2
	<input checked="" type="checkbox"/> Number SCT Hits	>= 7

More on how to identify events:

<http://cernmasterclass.uio.no/material/Zpath-SignalEvents.pdf>

<http://cernmasterclass.uio.no/material/Zpath-Cuts.pdf>

ATLAS Z-path data 2014

- ▶ each institute is initially assigned 2 dataset packages with 20 datasets in each package.
- ▶ each dataset contains 50 events, for a group of two students to analyze.
 - ▶ this means that each institute has a default of 40 datasets available, which is enough to accommodate 80 students.
- ▶ Some further MC data is used in the online plotting tool, OPlOT
 - ▶ to show expected di-photon and 4-lepton distribution at higher luminosities
- ▶ Data distributed as event mixtures in XML format available from
 - ▶ <http://cernmasterclass.uio.no/datasets/>
 - ▶ Accessible from: http://atlas.physicsmasterclasses.org/en/zpath_data.htm

The plotting tool - OPloT

OPloT - MasterClass – Combination Page

Start Student Moderator Tutor Administrator

Wednesday, March 5th 2014 - 11:55:34 CET

Moderator Tasks

1) click on "Moderator"

2010 Month Day

- Slides comparing IMC2013 with official ATLAS Results - slide 2 most relevant

Groups that have uploaded their files:

2) choose today's date

3) Check what the the different institutes of that day have uploaded

OPloT - MasterClass – Combination Page

Start Student Moderator Tutor Administrator

Wednesday, March 5th 2014 - 11:56:44 CET

Moderator Tasks

4) Choose "combination plot – all institutes"

2014 March 12

- Institute combination
 - Vila Real
 - Pisa
 - Graz
 - Thessaloniki
 - U. California Riverside
- **Combination plot - all institutes**
- Slides comparing IMC2013 with official ATLAS Results - slide 2 most relevant

Groups that have uploaded their files:

Graz

Pisa

Thessaloniki

Vila Real

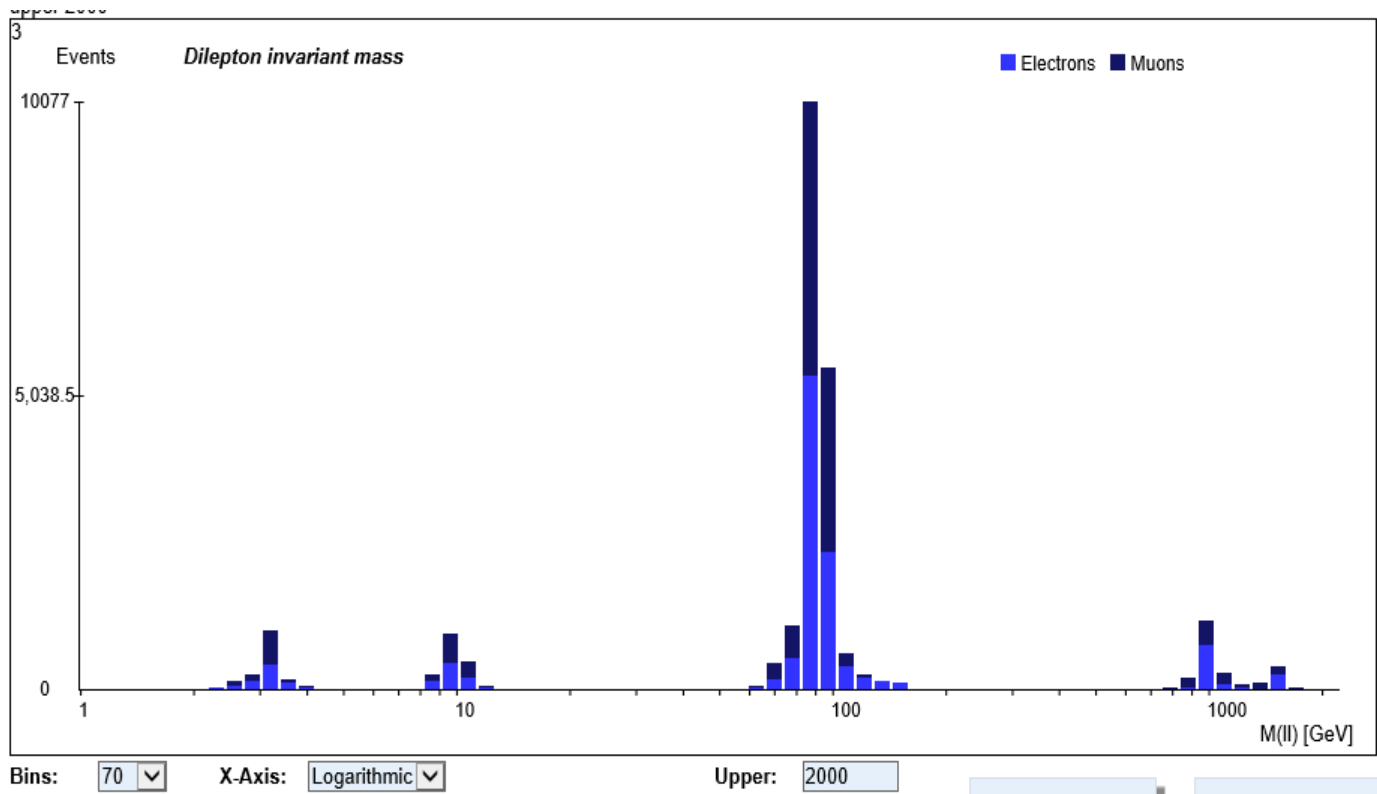
U. California Riverside

Detailed descr.: <http://cernmasterclass.uio.no/material/ModeratorInstructions-Zpath.pdf>

Example distributions

- ▶ the following few slides will show some example distributions for di-leptons, 4-leptons and di-photons
 - ▶ these are “perfect” distribution – student’s results may contain more noise
 - ▶ di-lepton plot:
 - ▶ all available data + MC is used
 - ▶ expect less statistics in a real IMC event (not enough students to cover the complete dataset)
 - ▶ di-photon, 4-lepton:
 - ▶ half of the available data (1fb^{-1}) is used in the examples

Di-leptons



Plot type:

Dilepton statistics

Electrons					
Region	R1	R2	R3	R4	R5
Events	871	888	7844	850	274
Mean	3.12	9.68	89.67	994.99	1,496.20
Width	0.37	0.84	3.61	31.07	14.23

Muons					
Region	R1	R2	R3	R4	R5
Events	864	926	7948	662	161
Mean	3.08	9.86	90.50	995.50	1,489.59
Width	0.26	0.70	3.59	51.10	51.36

statistics, mean and width of mass peaks

R1 Min: R2 Min: R3 Min: R4 Min: R5 Min:
 R1 Max: R2 Max: R3 Max: R4 Max: R5 Max:

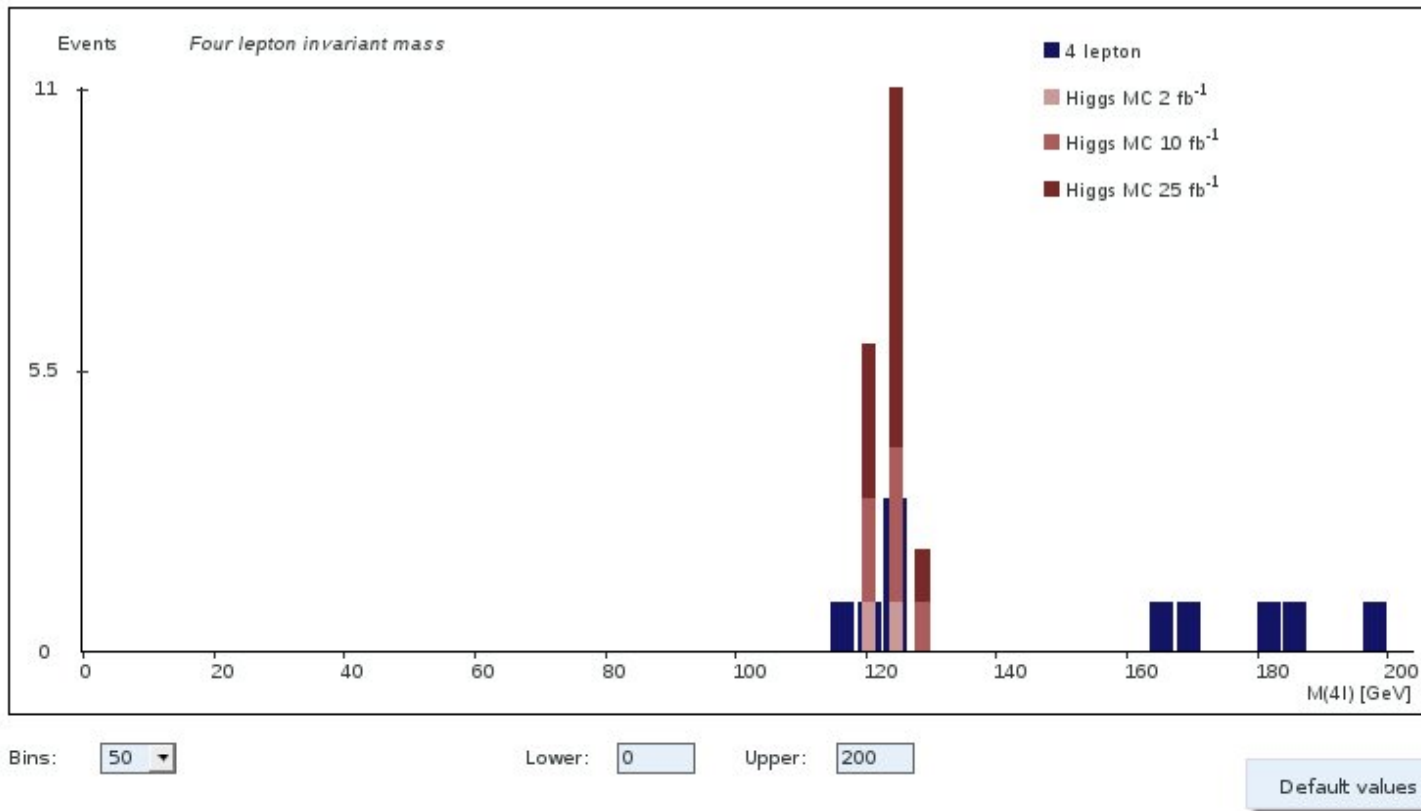
plotting options and defining mass ranges

4 leptons

add simulated 4-lepton events for different luminosities

OPlOT - MasterClass – Combination for all institutes on 2014-01-01

Start Student Moderator Tutor Administrator



choose to plot "student distribution" or "expected distribution"

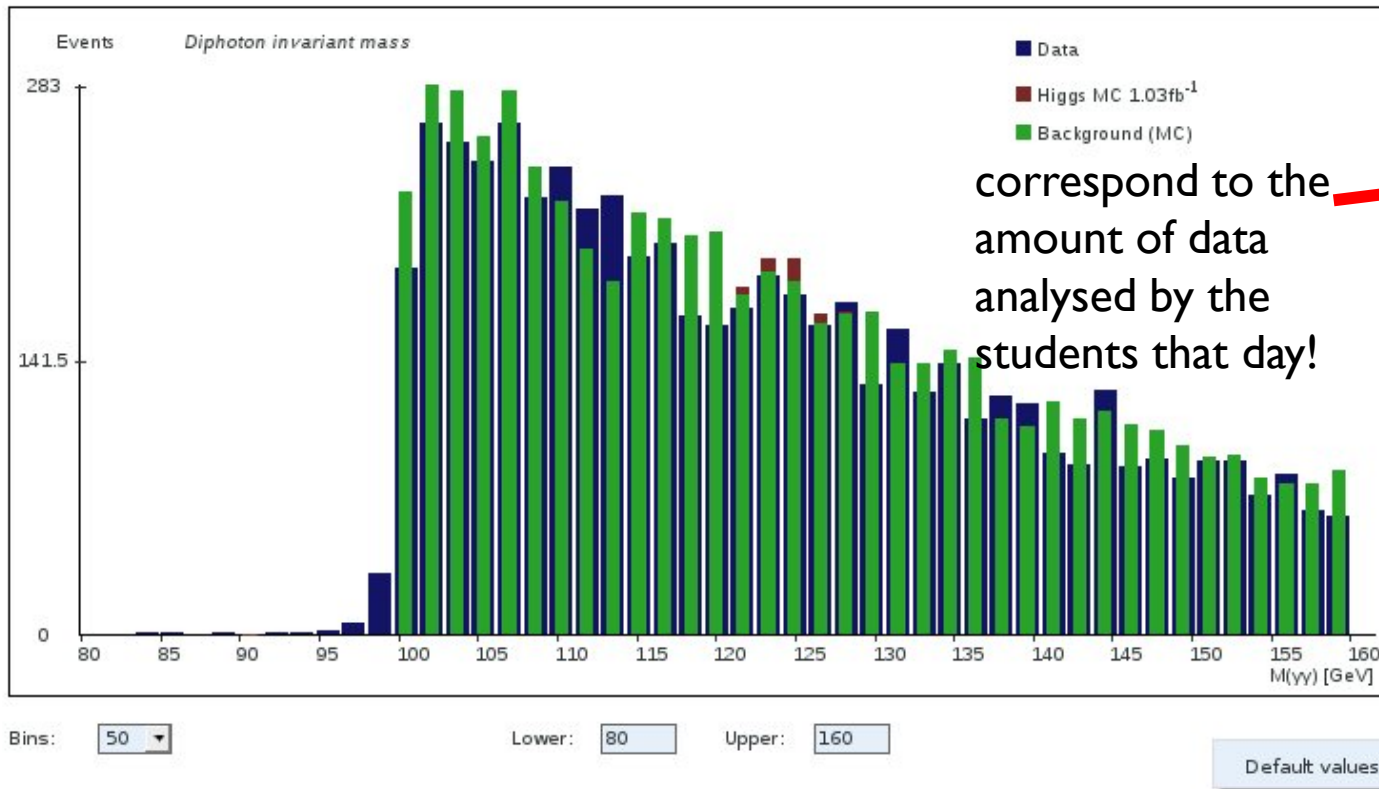
expected dist.: what to expect if all students had identified all the events correctly

Di-photons

add simulated di-photon events and Higgs signal for different luminosities

OPlot - MasterClass – Combination for all institutes on 2014-01-01

Start Student Moderator Tutor Administrator



Plot type: YY

Signal and background (simulated data):

- Nothing
- 1.03 fb⁻¹
- 2 fb⁻¹
- 10 fb⁻¹
- 25 fb⁻¹

Analyzed data (real data):

- Nothing
- Student distribution
- Expected distribution

choose to plot "student distribution" or "expected distribution"

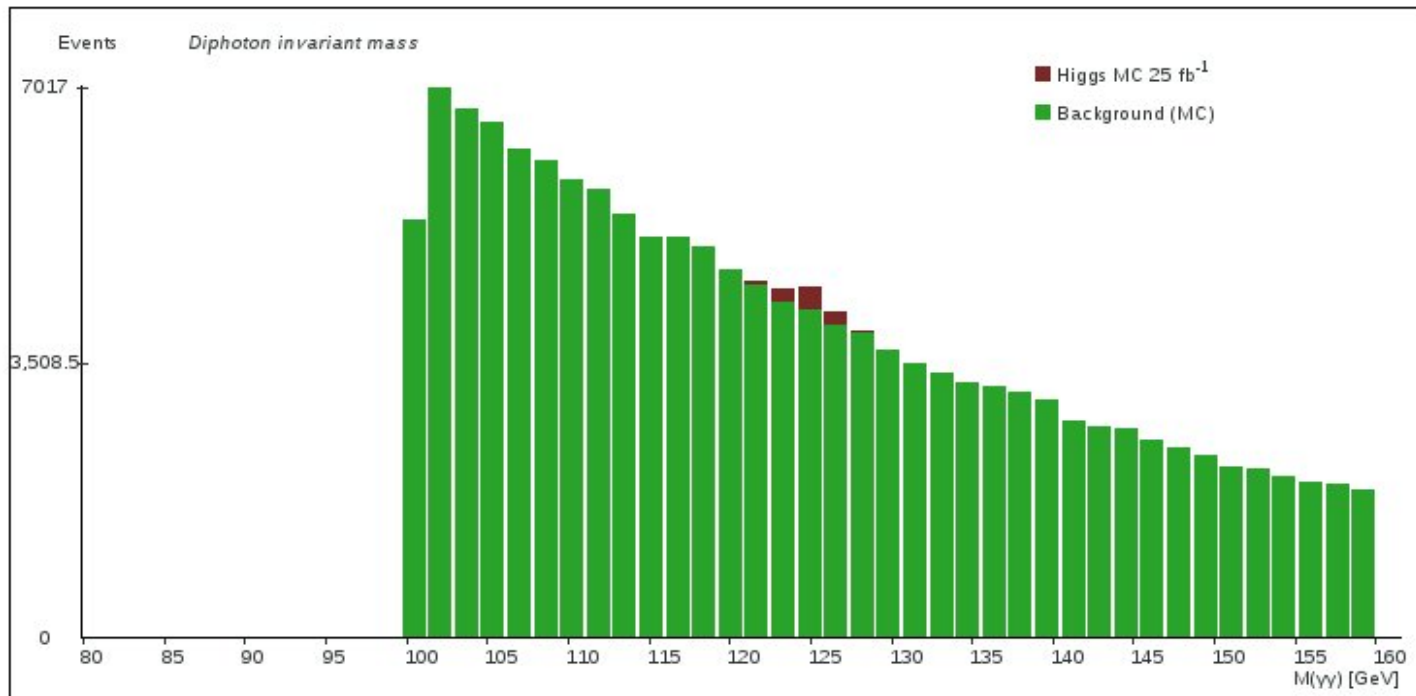
expected dist.: what to expect if all students had identified all the events correctly

Di-photons

- ▶ Can also show only simulated data with the full ATLAS luminosity (25 fb⁻¹)
 - ▶ to illustrate that we need more data than we have at the IMC to discover Higgs!

OPlOT - MasterClass – Combination for all institutes on 2014-01-01

Start Student Moderator Tutor Administrator



Plot type:

YY

Signal and background (simulated data):

- Nothing
- 1.03 fb⁻¹
- 2 fb⁻¹
- 10 fb⁻¹
- 25 fb⁻¹

Bins: 50

Lower: 80

Upper: 160

Default values



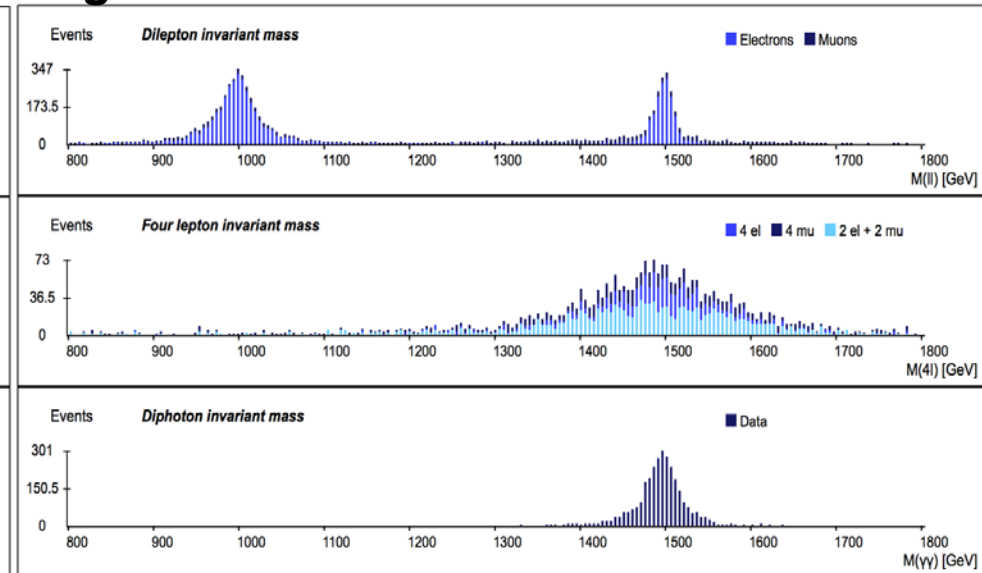
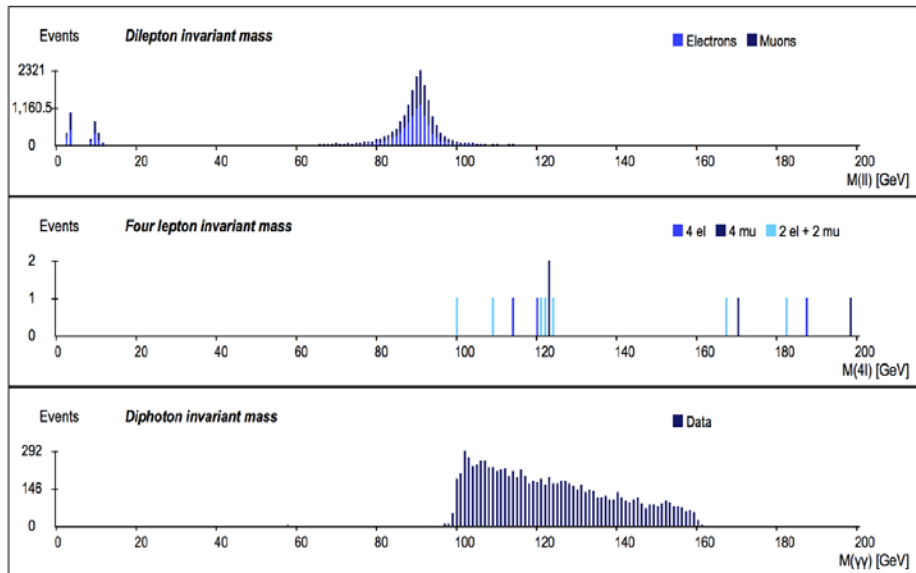
11

04.02.2016

New particles/new physics?

Low mass

High mass



▶ Spin-0 (Higgs-like)

- ▶ decays to di-photons, ZZ, WW, di-leptons (suppressed for electron and muon)

▶ Spin-1 (Z,Z'-like)

- ▶ decays to di-leptons, **not** to di-photons, ZZ, WW

▶ Spin-2 (Graviton-like)

- ▶ decays to di-photons, di-leptons, ZZ, WW

More information

- ▶ Detailed description for moderators:
 - ▶ <http://cernmasterclass.uio.no/material/ModeratorInstructions-Zpath.pdf>
 - ▶ Section 8: Keywords for discussion
- ▶ Slides to compare student's result with official ATLAS results
 - ▶ <http://cernmasterclass.uio.no/material/Zpath-ATLAS.pdf>
- ▶ Identifying events with HYPATIA
 - ▶ <http://cernmasterclass.uio.no/material/Zpath-Cuts.pdf>
 - ▶ <http://cernmasterclass.uio.no/material/Zpath-SignalEvents.pdf>
- ▶ Instructions for institutes:
 - ▶ <http://cernmasterclass.uio.no/material/InstituteInstructions-Zpath.pdf>
- ▶ Instruction for students (cheat sheet):
 - ▶ http://cernmasterclass.uio.no/material/cheat-sheet_en.pdf
- ▶ If there are any questions do not hesitate to contact us:
 - ▶ epf-mc@fys.uio.no

BACKUP

ATLAS Z-path data 2016

- ▶ Allowed to use 2 fb^{-1} for Higgs selections: $\gamma\gamma$ and $4l$
 - ▶ Sequential run range 204769 – 206971
 - ▶ 2007 pb^{-1} in period B12 – C6 from June – July 2012
- ▶ Moriond 2013 candidates list following official Higgs selections:
 - ▶ **40 H** $\rightarrow l^+l^-l^+l^-$ candidates with 6 having an invariant mass in the range 120-130 GeV
 - ▶ evenly shared between $e^+e^- \mu^+\mu^-$, $e^+e^- e^+e^-$ and $\mu^+\mu^- \mu^+\mu^-$
 - ▶ some events are replicated in the student's data sets
 - ▶ **11.100 H** $\rightarrow \gamma\gamma$ candidates (4100 fully unconverted, 5400 mixed, 1800 double conversions)
 - ▶ data sets with double converted photons are not used unless there are exceptionally many students
- ▶ Same data period as above used for di-lepton selection
 - ▶ **18500 Z, 1850 J/ ψ , 1850 Y** events (modest fraction, still larger than Higgs)
 - ▶ 50% share between e^+e^- and $\mu^+\mu^-$

ATLAS Z-path MC 2016

- ▶ MC for **Z'** events (**1850**) mixed in the real data analyzed by students
 - ▶ 50% share between e^+e^- and $\mu^+\mu^-$
 - ▶ mc12_8TeV.158020.Pythia8_AU2MSTW2008LO_Zprime_ee_SSM1000.recon.ESD.e1242_s1469_s1470_r3542/
 - ▶ mc12_8TeV.158026.Pythia8_AU2MSTW2008LO_Zprime_mumu_SSM1000.recon.ESD.e1242_s1469_s1470_r3542/
- ▶ MC for **Graviton** events (**1400**) mixed in the real data analyzed by students
 - ▶ 600 into di-leptons (50% share between e^+e^- and $\mu^+\mu^-$)
 - ▶ locally simulated
 - ▶ 400 into di-photons
 - ▶ mc12_8TeV.158708.Pythia8_AU2CTEQ6LI_Ggammagamma_01_1500.evgen.EVNT.e1507
 - ▶ 400 into ZZ (which subsequently decay into electrons and muons)
 - ▶ mc12_8TeV.158280.CalcHepPythia8_AU2CTEQ6LI_KKGravitonZZ_III_m1500_4LeptonPt8.evgen.EVNT.e1370