

The Z path measurement – introduction and demo session

Magnar K. Bugge

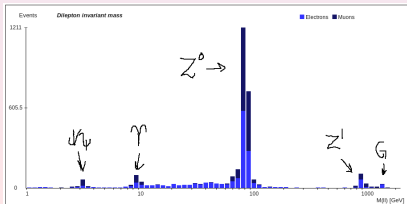
University of Oslo

vConf21

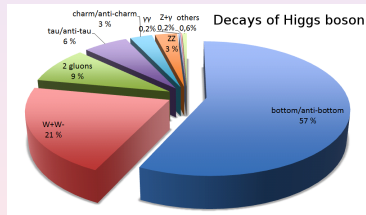
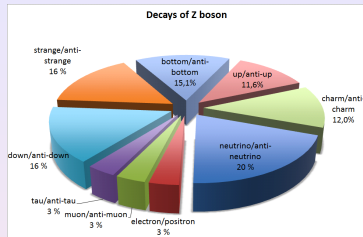
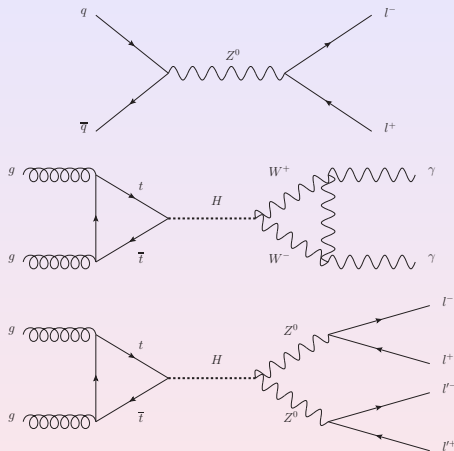
August 3rd 2021

Overview and goals

- The students go through events using event displays
 - Looking for good electron, muon, and photon candidates
 - Identifying events with dileptons ($e^+e^-/\mu^+\mu^-$), diphotons ($\gamma\gamma$), or 4 leptons ($e^+e^-e^+e^-$, $e^+e^-\mu^+\mu^-$, $\mu^+\mu^-\mu^+\mu^-$)
 - Calculating invariant masses and uploading these in the end to a plotting tool
- In the end, results are combined, and invariant mass distributions are built, where the students may have
 - Identified and measured masses(/widths) of well-known particles such as the J/ψ , Υ , and Z^0
 - Identified good Higgs-boson candidates
 - Discovered new particles (Z' , Graviton)

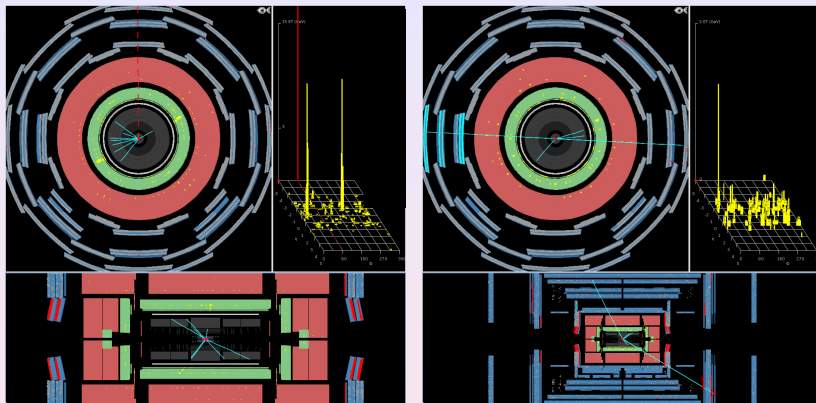


Physics background



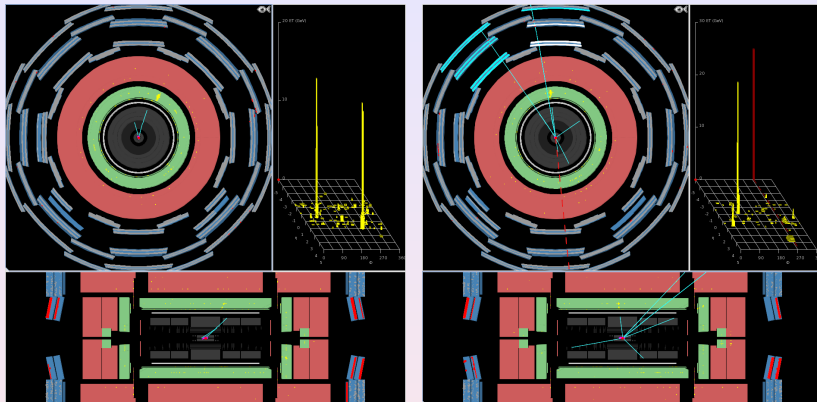
- Looking for rare decays (especially for Higgs) which are easily distinguishable from background

Identifying events in HYPATIA



- Electron: concentrated energy deposit in EM calorimeter and associated track
- Muon: long track through whole detector

Identifying events in HYPATIA



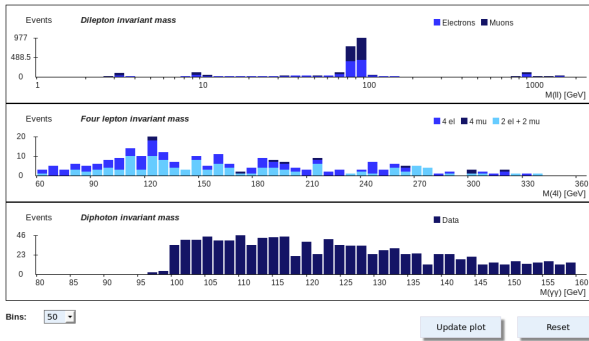
- Photon: electron-like EM energy deposit, but no track (unless converted)
- In all cases, students select objects which they identify as electron, muon, or photon, and HYPATIA calculates the corresponding invariant mass

The online plotting tool (OPlot)

OPlot – MasterClass – Combination for all institutes on 2016-03-09

Start Student Moderator Tutor Administrator

Monday, February 20th 2017 - 13:38:51 CET



Plot type:

ll+4l+yy overview

Dilepton statistics

Region	Electrons				
	R1	R2	R3	R4	R5
Events	104	122	768	76	31
Mean	3.14	9.77	89.86	999.46	1,496.29
Width	0.47	1.31	3.66	32.99	17.06

Region	Muons				
	R1	R2	R3	R4	R5
Events	73	90	874	65	14
Mean	3.07	9.97	90.46	997.90	1,479.29
Width	0.26	0.73	3.69	52.32	54.88

Number of events

Student distribution Expected		
ll	3118	4225
4l	347	40
yy	1092	1950
Sum	4557	6215

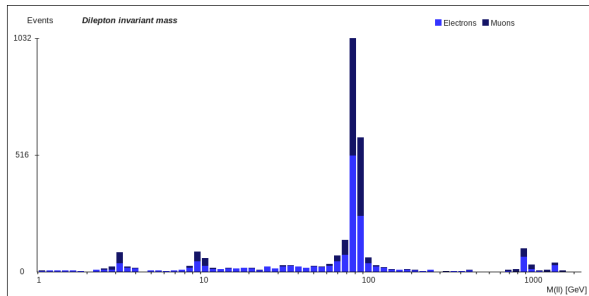
- “All institutes combination” start page
- Invariant mass distributions for all final states
- Table with estimated masses and widths
- Table with event counts compared to expectations

The online plotting tool (OPloT)

OPloT – MasterClass – Combination for all institutes on 2016-03-09

Start Student Moderator Tutor Administrator

Monday, February 20th 2017 - 13:42:20 CET



Plot type:

II

Dilepton statistics

Region	Electrons				
	R1	R2	R3	R4	R5
Events	104	122	768	76	31
Mean	3.14	9.77	89.86	999.46	1,496.29
Width	0.47	1.31	3.66	32.99	17.06

Region	Muons				
	R1	R2	R3	R4	R5
Events	73	90	874	65	14
Mean	3.07	9.97	90.46	997.90	1,479.29
Width	0.26	0.73	3.69	52.32	54.38

Bins: 70

X-Axis: Logarithmic

Upper: 2000

Update plot

Reset

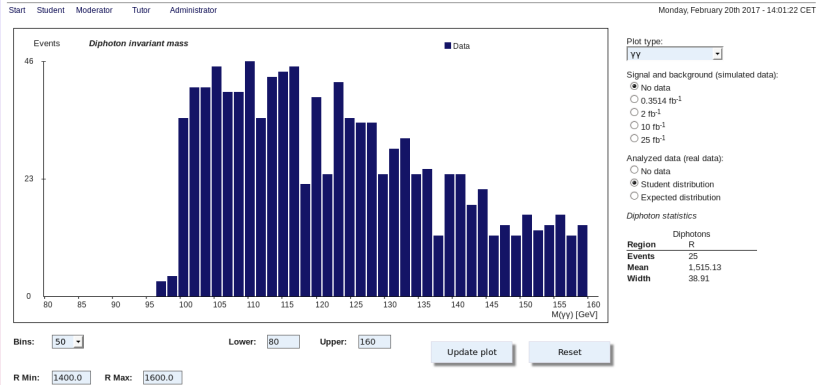
R1 Min: 2.0 R2 Min: 7.0 R3 Min: 80.0 R4 Min: 900.0 R5 Min: 1400.0

R1 Max: 4.0 R2 Max: 13.0 R3 Max: 100.0 R4 Max: 1100.0 R5 Max: 1600.0

- Dilepton invariant mass distribution
- Can identify J/ψ , Υ , Z^0 , Z' , and graviton
- The latter two come as a surprise to the students

The online plotting tool (OPloT)

OPloT – MasterClass – Combination for all institutes on 2016-03-09



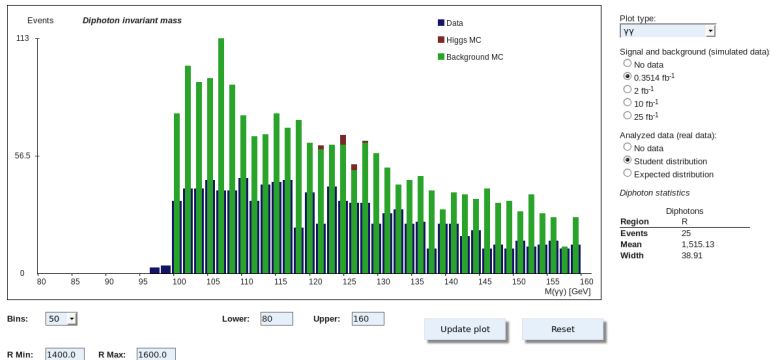
- Diphoton invariant mass distribution
- In principle sensitive to Higgs contribution
- Statistics is too low to make a discovery

The online plotting tool (OPloT)

OPloT – MasterClass – Combination for all institutes on 2016-03-09

Start Student Moderator Tutor Administrator

Monday, February 20th 2017 - 14:04:02 CET



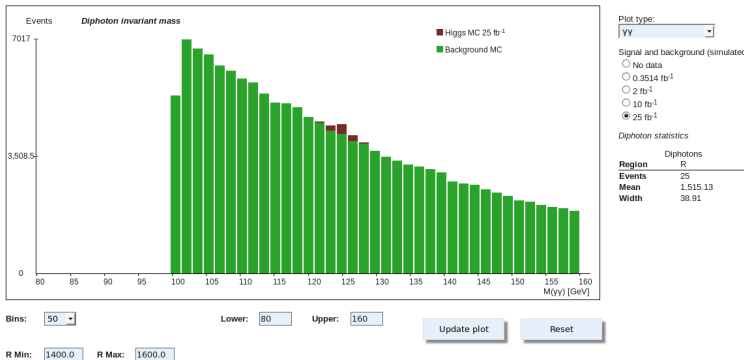
- Compare students' results to simulated background and signal corresponding to the analysed integrated luminosity

The online plotting tool (OPloT)

OPloT – MasterClass – Combination for all institutes on 2016-03-09

Start Student Moderator Tutor Administrator

Monday, February 20th 2017 - 14:05:35 CET



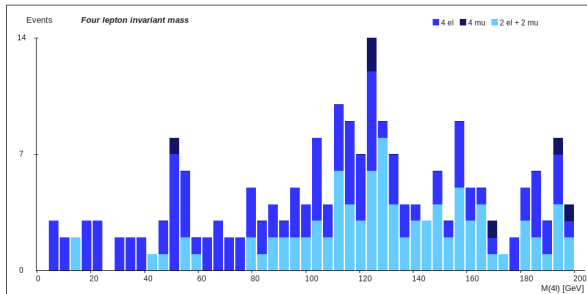
- Look at simulated background and signal for larger amounts of integrated luminosity
- ⇒ we could have seen the Higgs, we just need more data...

The online plotting tool (OPlot)

OPlot – MasterClass – Combination for all institutes on 2016-03-09

Start Student Moderator Tutor Administrator

Monday, February 20th 2017 - 14:06:37 CET



Plot type:

4l

Higgs simulated data:

- ☐ 2 fb^{-1}
☐ 10 fb^{-1}
☐ 25 fb^{-1}

Analyzed data (real data):

- ☐ No data
☒ Student distribution
☐ Expected distribution

4-lepton statistics

Region	R			
Event type	4l	4e	4m	2e+2m
Events	19	6	7	6
Mean	1,488.24	1,512.22	1,471.38	1,483.6
Width	44.86	43.31	40.18	41.08

Bins: 50

Lower: 0

Upper: 200

Update plot

Reset

R Min: 1400.0

R Max: 1600.0

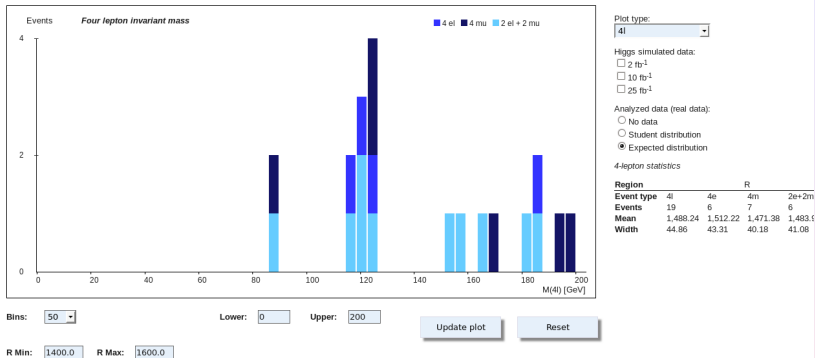
- 4-lepton invariant mass distribution
- Huge number of events (remember table in overview page)
- Notice composition in terms of $4e$, $2e2\mu$, 4μ
- Much easier to find fake electrons

The online plotting tool (OPlot)

OPlot – MasterClass – Combination for all institutes on 2016-03-09

Start Student Moderator Tutor Administrator

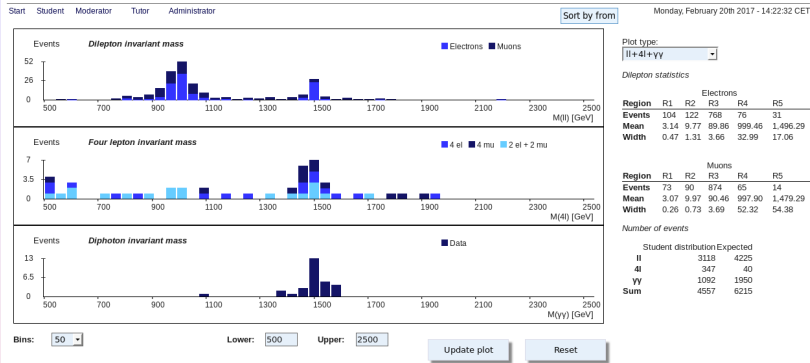
Monday, February 20th 2017 - 14:14:08 CET



- Expected distribution shows what the students would find with “perfect event identification”
- A few nice Higgs candidates with very little background
- Many participating students looked at these prime candidates during the day!

The online plotting tool (OPlot)

OPlot – MasterClass – Combination for all institutes on 2016-03-09



- Investigate high mass range in all final states simultaneously
- Z' seen only in dilepton distribution
- Graviton shows up in all of them!
- A manifestation of spin

- Students look for dilepton, diphoton, and 4-lepton events to search for
 - $Z^0 \rightarrow l^+ l^-$ (and other dilepton resonances)
 - $H \rightarrow \gamma\gamma$ (and other diphoton resonances)
 - $H \rightarrow l^+ l^- l'^+ l'^-$ (and other 4-lepton resonances)
- Invariant masses are calculated in HYPATIA and uploaded to OPloT
- Invariant mass distributions are built for the combination of all students' data, showing resonance peaks corresponding to known and new particles

Contact us: epf-mc@fys.uio.no

Hands-on session – instructions

- Go to the [Z-path pages](#)
- Download and unzip [HYPATIA](#)
- Click on the “Download Data Samples” picture, or directly [here](#)
- Go to the [root directory containing all datasets](#)
- Download and unzip a random dataset (choose a random “dir” and “group”)
- Open Hypatia via the .jar file
 - If double clicking does not work on Linux/Mac, try
“java -jar Hypatia_7.4_Masterclass.jar”
- Open the downloaded dataset and analyze some events
- Export invariant masses and upload to [OPloT](#)
 - user: ippog
 - pwd: imc

More detailed information and instructions [here](#)