# 8.882 LHC Physics

*Experimental Methods and Measurements*

# Higgs Analysis – Details

*[Lecture 25, May 11, 2009]*

# *Organization*

## Project 3

- should be complete by now....

## Course evaluation

- please fill in the Web forms at: http://web.mit.edu/subjectevaluation/
- high participation would be very desirable

## Conference

- all set for May 19 at 12:00am in 26-528

# *Final Conference Project*

## LHC Physics: "Experimental Methods and Measurements"

Plenary Session (12:00–13:30, May 19, 26-528)

- Welcome and LHC Overview (C.Paus)
- Search for Standard Model Higgs Boson: Overview (M.Klute)
- Search for Higgs in $H \rightarrow ZZ^*$ (M.Chan)
- Search for Higgs in $H \rightarrow WW^*$ (H.Gray)

# *Lecture Outline*

## Higgs Analysis – Details

- Higgs Searches in the Standard Model
- Search for Higgs in $H \rightarrow ZZ^*$
- Search for Higgs in $H \rightarrow WW^*$
- ( Search for Higgs in $qqH \rightarrow WW^*$ )

## Analysis information will be complete

- each analysis TWiki has detailed instructions
- signal and background samples are completely copied
- new updated analysis examples are provided

# *Standard Model Higgs Search*

## Conference organization

- there is an overall introductory talk
- for the Standard Model Higgs analyses there is a specific overview presentation (?)
  - idea: no presentation afterwards explains theory/general again
  - theory of Standard Model Higgs (1/2 slide)
  - theory constraints on its mass
  - explain status of the Standard Model Higgs searches before LHC
  - what else do we know about the Standard Model Higgs? radiative corrections, electroweak data
  - what can we expect from the LHC?

# *Analysis: Generic Instructions*

## Two different types of analyses

- pure Higgs search in a given channel
  - make mass plot
  - optimize selection cuts to get the "best" mass plot
  - number of signal and background event
  - signal significance
  - luminosity needed to make 5 standard deviation discovery
- identify of Vector Boson Fusion (VBF) Higgs production
  - tag a forward jet
  - measure forward jet tagging efficiency with Monte Carlo info
  - measure rate of gluon fusion Higgs events passing forward jet tag
  - extract ratio of gluon fusion and VBF Higgs events after before and after the forward jet tag

# *Analysis: Overview*

## New with respect to previous projects

- there is no data yet
  - I doubt we could be easily allowed to use it if this was next year
  - so we have to use Monte Carlo
  - which of course has a Higgs signal
- Monte Carlo description is complete
  - signal has various mass assumptions [GeV]: 130, 140, 150 ....
  - full background description also given
    - only real leptons are properly covered
    - does not include complete *'fake'* leptons
    - needs to be tested and adjusted to data
    - substantial amount of work
  - main background sources: multi-bosons to leptons (*WW, WZ, ZZ*)
  - fakes come from heavy quark decays, usual QCD events, ....

# *Analysis: Overview, continued*

## Outline of analysis sequence

- more complex than other projects before
- step 0: look at general analysis selection code and tune cuts as needed
- step 1: submit condor jobs to produce histograms for each Monte Carlo contribution
- step 2: merge all Monte Carlo contributions
  - sometimes there are several files per Monte Carlo contribution
  - simple root function used: hadd, but combined in script
- step 3: make plot and determine number of events from each Monte Carlo contribution

# *Analysis: Install Software*

## Unfortunately CMS has another software

- login to MIT cluster at CERN
  - login to MIT cluster at CERN: ssh pcmit00.cern.ch
  - only from CERN machine: for externals pass through lxplus.cern.ch
- use tar ball: ~paus/cms.tgz
  - cd ~/; tar fzx ~paus/cms.tgz
- setup the CMS software
  - cd ~/8.882/cms; source INIT
  - ready to go to the next step

# *Analysis: Creating Primitives*

## Common analysis primitives are prepared

- separate muon and electron identification
  - large number of criteria used
  - optimal point tricky to choose: high efficiency but little fake
  - optimal point analysis dependent: full optimization required
  - often similar id requirements are nevertheless used
- also photon, tau, jet and met ids are applied
  - after Id phase various objects have to be 'cleaned'
  - jets should not contain identified muons to avoid double counting
- merging phase to collate the identified objects

## See examples

- ~/8.882/cms/root/runHww.C
- ~/8.882/cms/root/runHzz.C

# *Analysis: H → WW*

## Objects to consider

- Higgs decays to 2 *W* bosons
- each *W* boson decays leptonically
  - muon + neutrino  or  electron + neutrino
  - two lepton types bring a number of coding complications with it
- basic observables
  - 2 leptons: muon/muon, electron/electron, muon/electron
  - missing $E_T$ in the event
- form approximation of Higgs mass: transverse mass
  - peaks at real Higgs mass but has a long tail
  - check documentation on *Jacobian peak* for *W* boson mass measurement
  - already done in the selection code for you
- observation is counting experiment: signal *vs* background

# *Analysis: step 0 – adjust selection*

*WW* analysis: MitHiggs/HwwMods/*/HwwExampleAnalysisMod.*

- histograms are booked here
- check what they are, add what you would like to look at
- selection details (~optimal), total of nine cuts applied
  - presel: highest lepton pT > 20, lowest lepton pT > 10, MET > 30, dilepton mass > 12
  - number of central jets (<1)
  - MET (min < MET < max, depends on final state)
  - delta phi between leptons (<max, depends on final state)
  - dilepton mass (<max, depends on final state)
  - highest lepton pT (min < pT < max, depends on final state)
  - lowest lepton pT (>min, depends on final state)
  - dirty muons (<1)
  - clean extra tracks (<4)

# *Analysis: $H \rightarrow ZZ$*

## Objects to consider

- Higgs decays to 2 *Z* bosons
- each *Z* boson decays leptonically
  - muon + muon  or  electron + electron
  - two lepton types bring a number of coding complications with it
- basic observables
  - 3 permutations: mmmm, mmee, eeee
  - no missing $E_T$ in the event
- form Higgs mass
  - peaks at real Higgs mass tails determined by detector
  - already done in the selection code for you

# *Analysis: step 0 – adjust selection*

## *ZZ* analysis: MitHiggs/HwwMods/*/HzzExampleAnalysisMod.*

- histograms are booked here
- check what they are, add what you would like to look at
- selection details (~optimal), total of 3 cuts explicitely applied
  - lepton flavor conservation: no $Z \rightarrow$ mu e
  - opposite charge for *Z*
  - lowest lepton pT > 15
  - dilepton mass *Z*1 > 12
  - dilepton mass *Z*2 > 12
- selection is very clean: *not much to do*

## Re-compile all libraries once complete

- cd ~/8.882/cms/; source INIT
- cd $CMSSW_BASE/src; scram b -j4

# *Analysis: step 1 – submit condor jobs*

## *WW* or *ZZ* analysis: submitHist.sh ( hzz | hww )

- cd ~/8.882/cms/root; ./submitHist.sh hzz
- a given list of Monte Carlos will be analyzed
- jobs are submitted to the cluster
- your tar ball contains a set of histograms which will be overwritten
  - only if you re-run the processing of the data your new histograms will become available of course
  - histograms are stored in: ~/8.882/cms/hist/hzz/filler/009/*
  - there might be several files for one given Monte Carlo, they have to be merged, see step 2
- basic histograms ready, this was time intensive step
- check progress of your job by doing: condor_q

# *Analysis: step 2 – merging files*

## *WW* or *ZZ* analysis: mergeHist.sh ( hzz | hww )

- cd ~/8.882/cms/root; ./mergeHist.sh hzz
- in the list of Monte Carlo samples some might have several output files
- all files will be merged such that each Monte Carlo sample has one histogram file
- histograms are moved to: ~/8.882/cms/hist/hzz/filler/009/merged
  - these are the files which will be picked up by the following plotting step

# *Analysis: step 3 – plotting histograms*

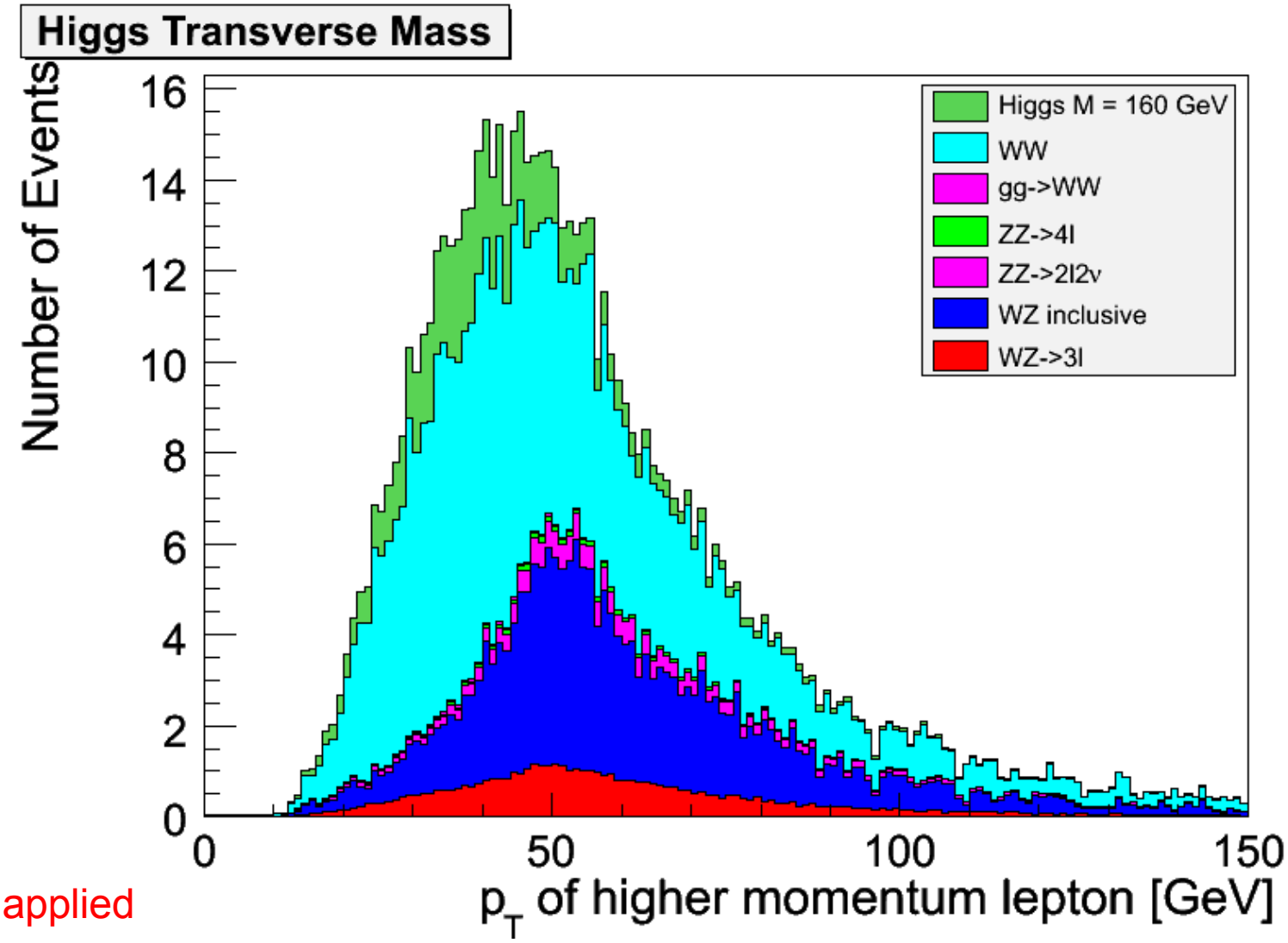
## *WW* or *ZZ* analysis: plothzz.C | plothww.C )

- cd ~/8.882/cms/root; root -l plothzz.C
- a given histogram will be plotted
- a .gif file for the two plots will be made, ready for the presentation
- check the plot code which is self explanatory: well it is a bit long but you should quickly understand what is going on
- most importantly, it is here that the histograms are properly normalized to a given luminosity: 200 $pb^{-1}$
- cross section for each Monte Carlo are kept in: ~/8.882/cms/root/xs.dat

# *Analysis: step 3 – example Hww*

## *WW* analysis: plothww.C (use leptonPtMax section)

- cd ~/8.882/cms/root; root -l plothww.C

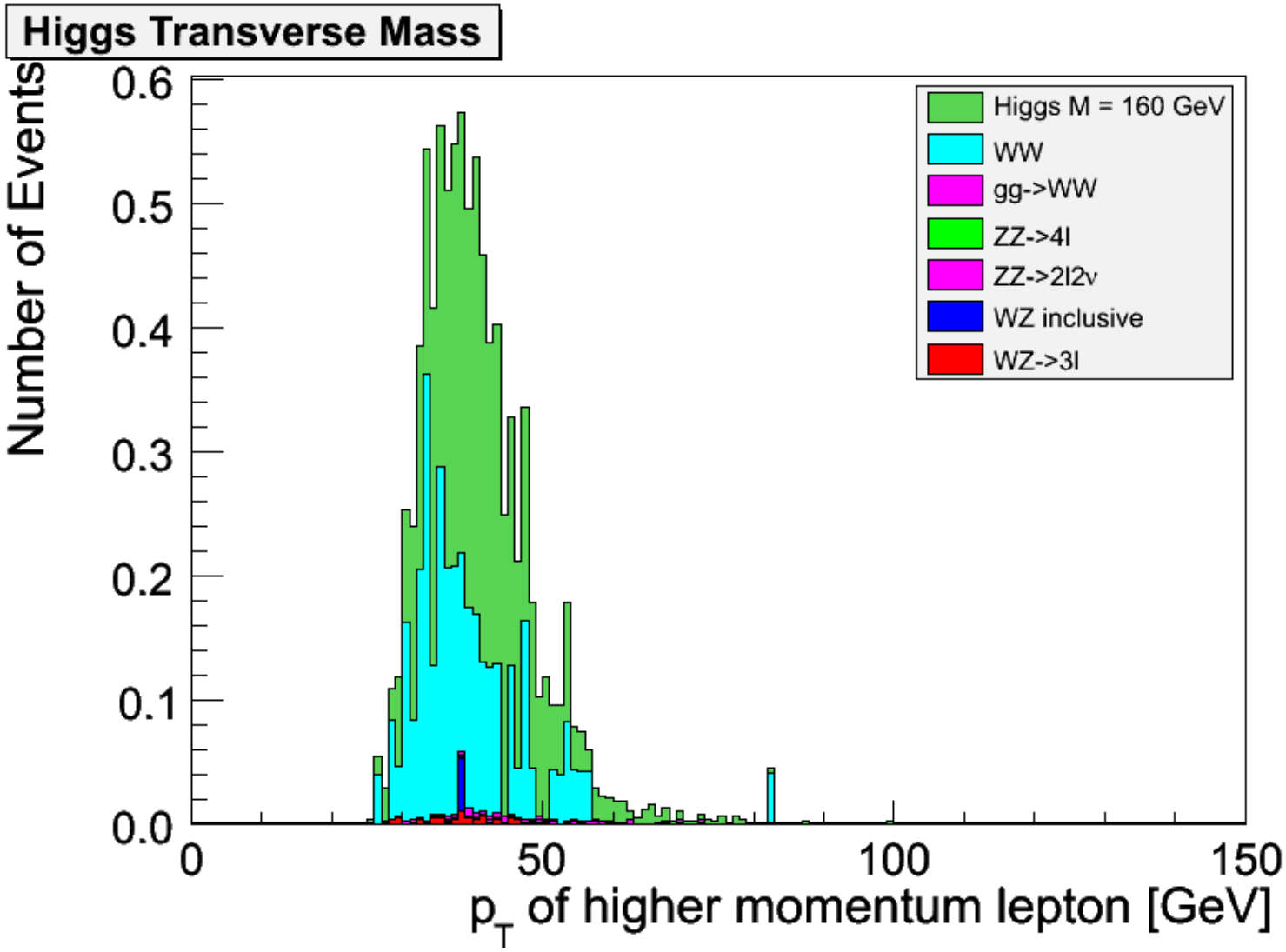



careful: not yet all cuts applied

# *Analysis: step 3 – example Hww*

## *WW* analysis: plothww.C (use leptonPtMax section)

- cd ~/8.882/cms/root; root -l plothww.C

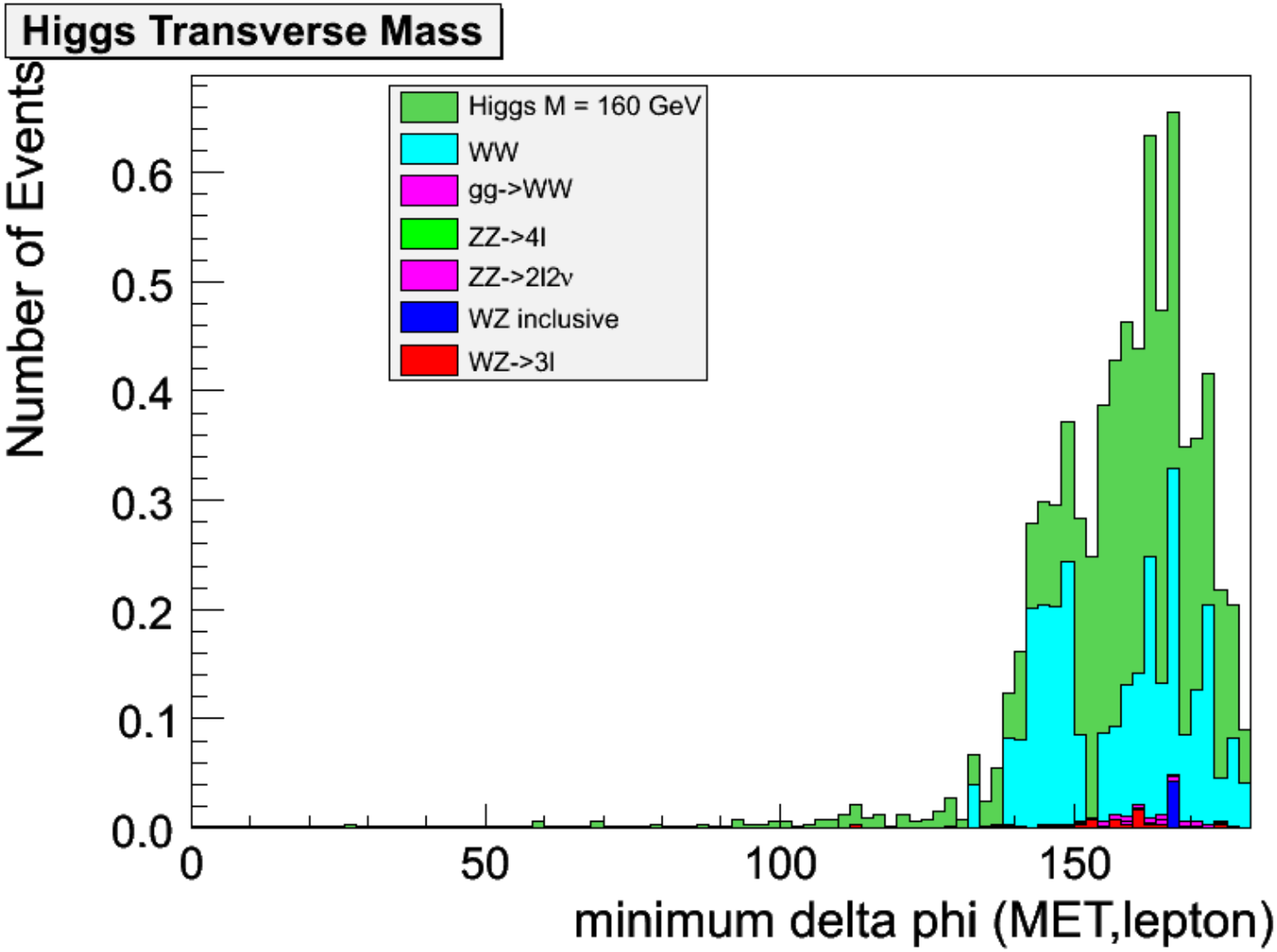



careful: after all cuts

# *Analysis: step 3 – example Hww*

## *WW* analysis: plothww.C (use minimum dPhi section)

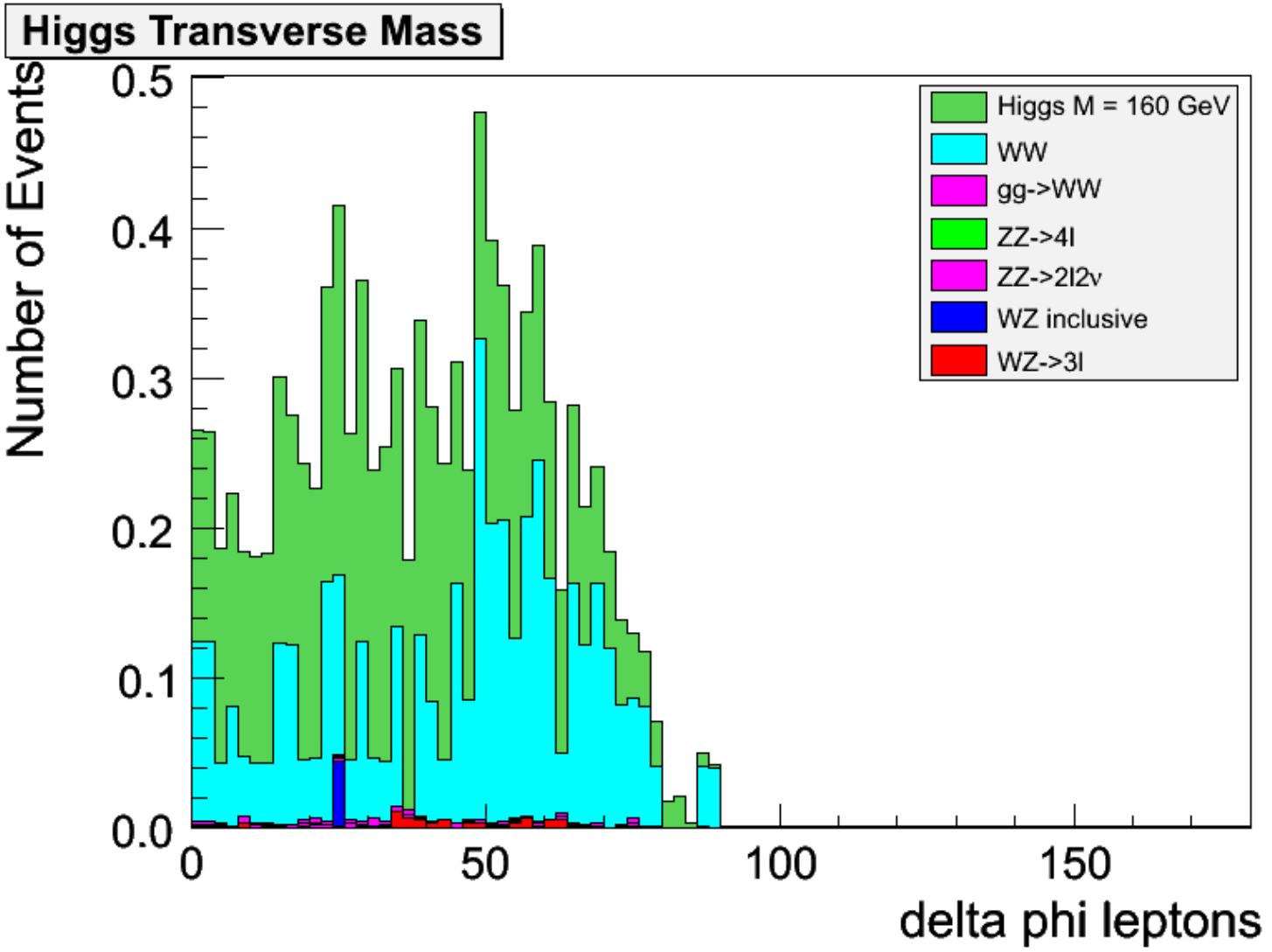
- cd ~/8.882/cms/root; root -l plothww.C



# *Analysis: step 3 – example Hww*

## *WW* analysis: plothww.C (use dPhi section)

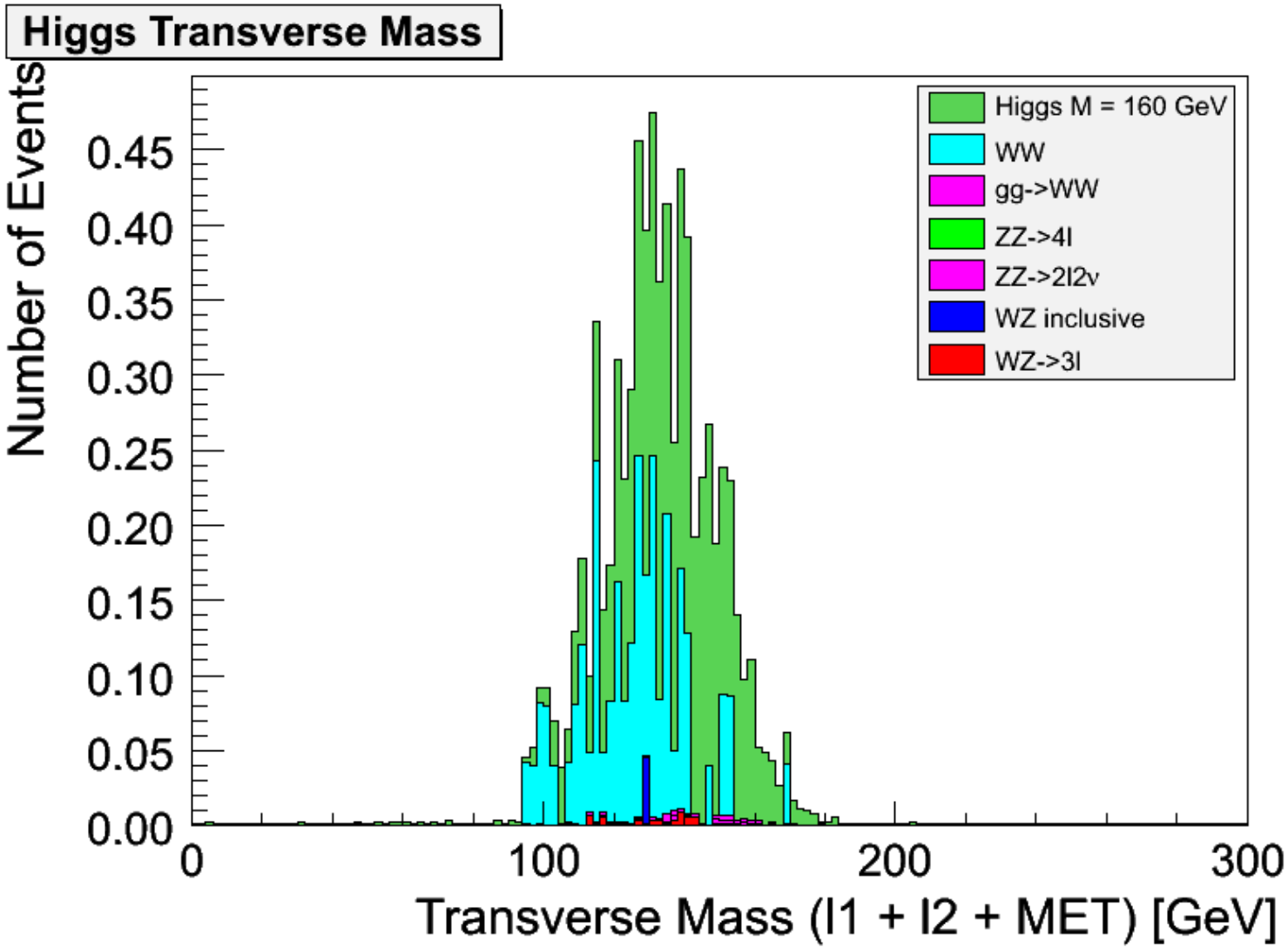
- cd ~/8.882/cms/root; root -l plothww.C



# *Analysis: step 3 – example Hww*

## *WW* analysis: plothww.C (use mT section)

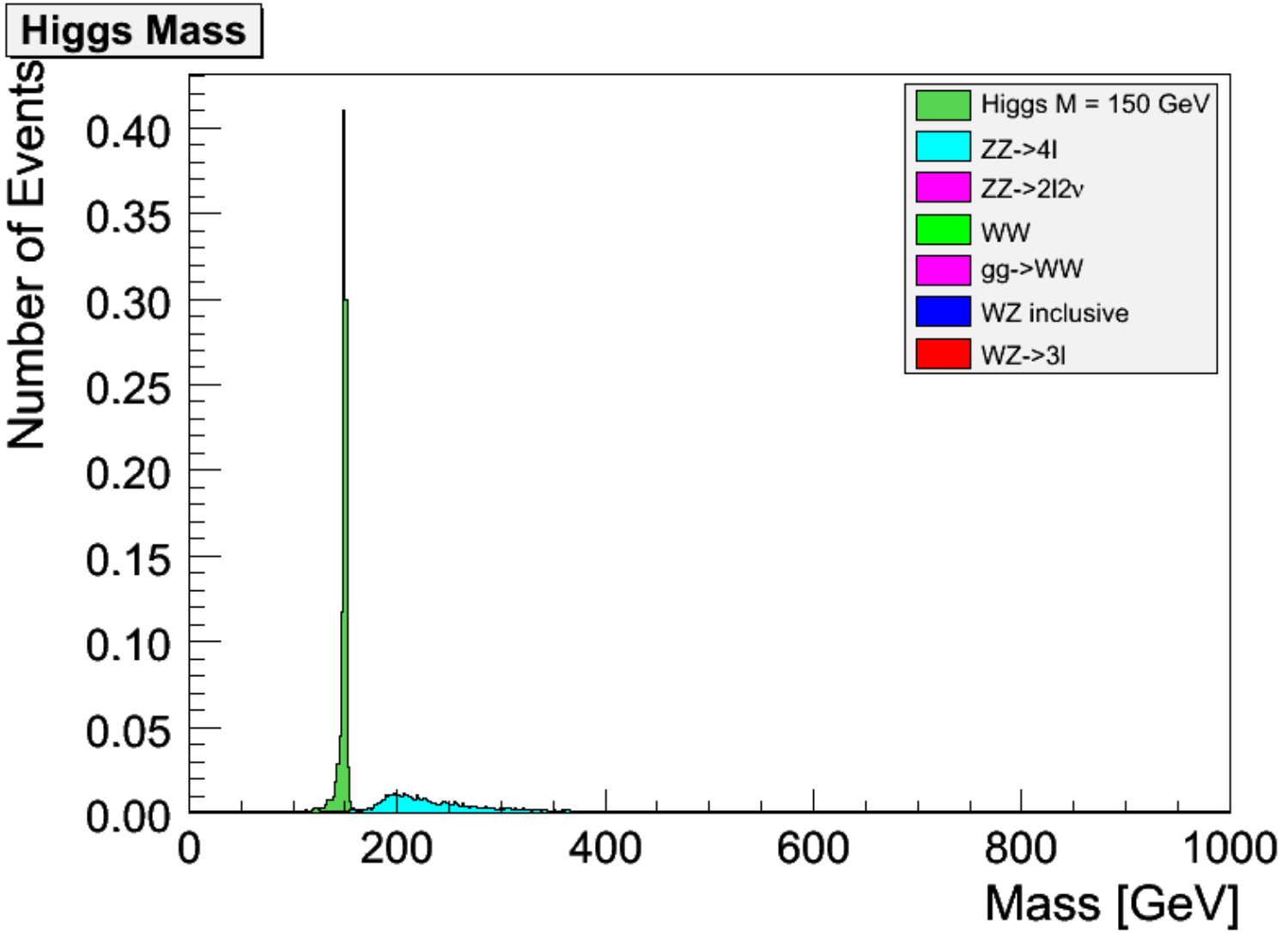
- cd ~/8.882/cms/root; root -l plothww.C



# *Analysis: step 3 – example Hzz*

## ZZ analysis: plothzz.C (use histogram _106: mmmm)

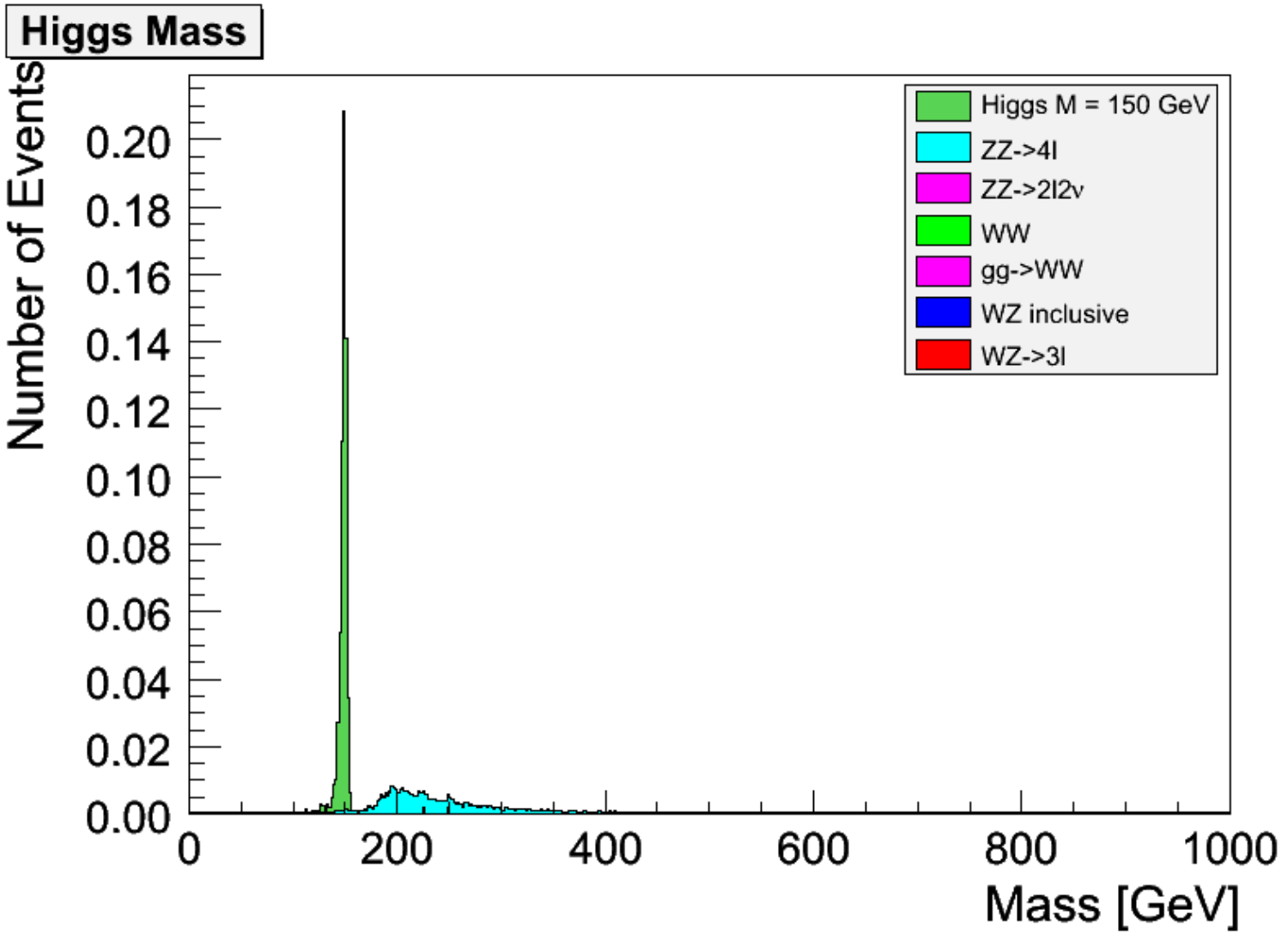
- cd ~/8.882/cms/root; root -l plothzz.C



# *Analysis: step 3 – example Hzz*

## ZZ analysis: plothzz.C (use histogram _206: eeee)

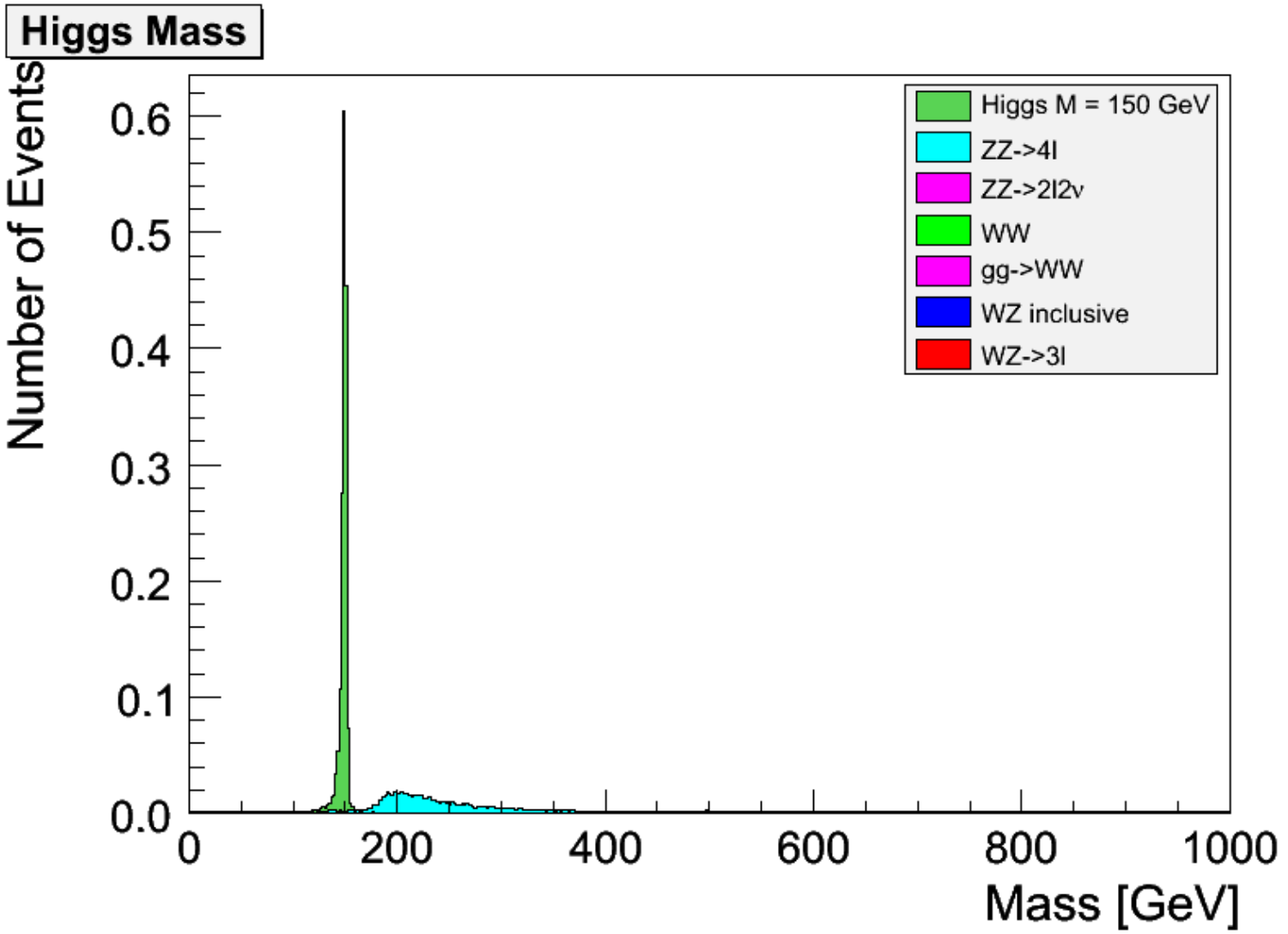
- cd ~/8.882/cms/root; root -l plothzz.C



# *Analysis: step 3 – example Hzz*

## ZZ analysis: plothzz.C (use histogram _6: mmee)

- cd ~/8.882/cms/root; root -l plothzz.C



# *Conclusion*

## Higgs analysis details

- detailed outline of the expected analysis content has been discussed
- new software pieces have been provided:
  - base analysis “modules”
  - base set of scripts to produce histograms for all signals and backgrounds
  - utilities for histogram adding are going to be added soon
- if you have questions:
  - important: ask questions soon: Si Xie (sixie@mit.edu is the expert)
  - presentations need to be prepared well in advance of the conference
  - plan on a rehearsal before the weekend of the 16/17 May

# *Next Lecture*

## Discussion of the presentation

- style and content ....
- question and answer session for the conference presentations: please send in you questions and comments well in advance so they can be explicitly addressed