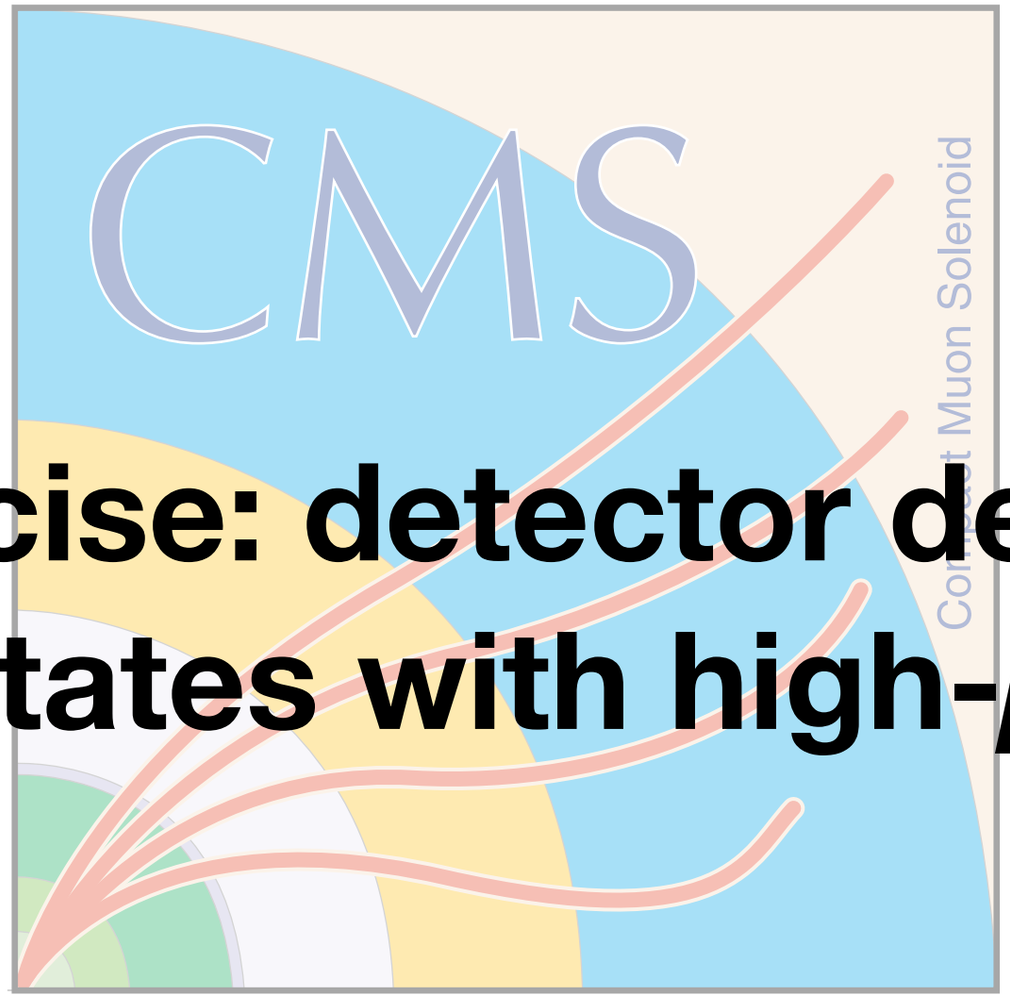
CMS Upgrade School
19.11.2014



long exercise: detector design tune for final states with high-p_T muons

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goal

- understand how much identifying and measuring a muon relies on two main aspects
  - muon momentum measurement
    - *part 1* of this long exercise
  - muon reconstruction efficiency and acceptance
    - *part 2* of this long exercise
      - so, at the end you will get yourselves to define realistic detector performance and tune it to enhance signals with high-p_T muons in the final state

part 1: muon momentum reconstruction

- effect of tracker pitch size in 10-100 GeV p_T muons

- effect of material on muon p_T resolution — i.e. number of tracker layers, number of available hits, multiple scattering etc.

- effect of granularity of muon detectors on resolution on O(100) GeV p_T muons

- understand domains where tracker is dominant and where muon detector is dominant

muon momentum reconstruction howto 1/2

- run Delphes on the two signal samples provided
  - SM H(125 GeV)→$\mu\mu$ for 10-100 GeV p_T muons
  - Z'(2.5 TeV)→$\mu\mu$ for 100 GeV-1 TeV p_T muons
- check muon p_T resolution for different ranges, as a function of both generated muon p_T and η
- compare different configurations to each other, introducing one different feature at a time and checking the effect
  - extra: DY(m>20 GeV)→$\mu\mu$ can be used to check muon momentum resolution over a typical background muon momentum range if needed, but only if you have time left

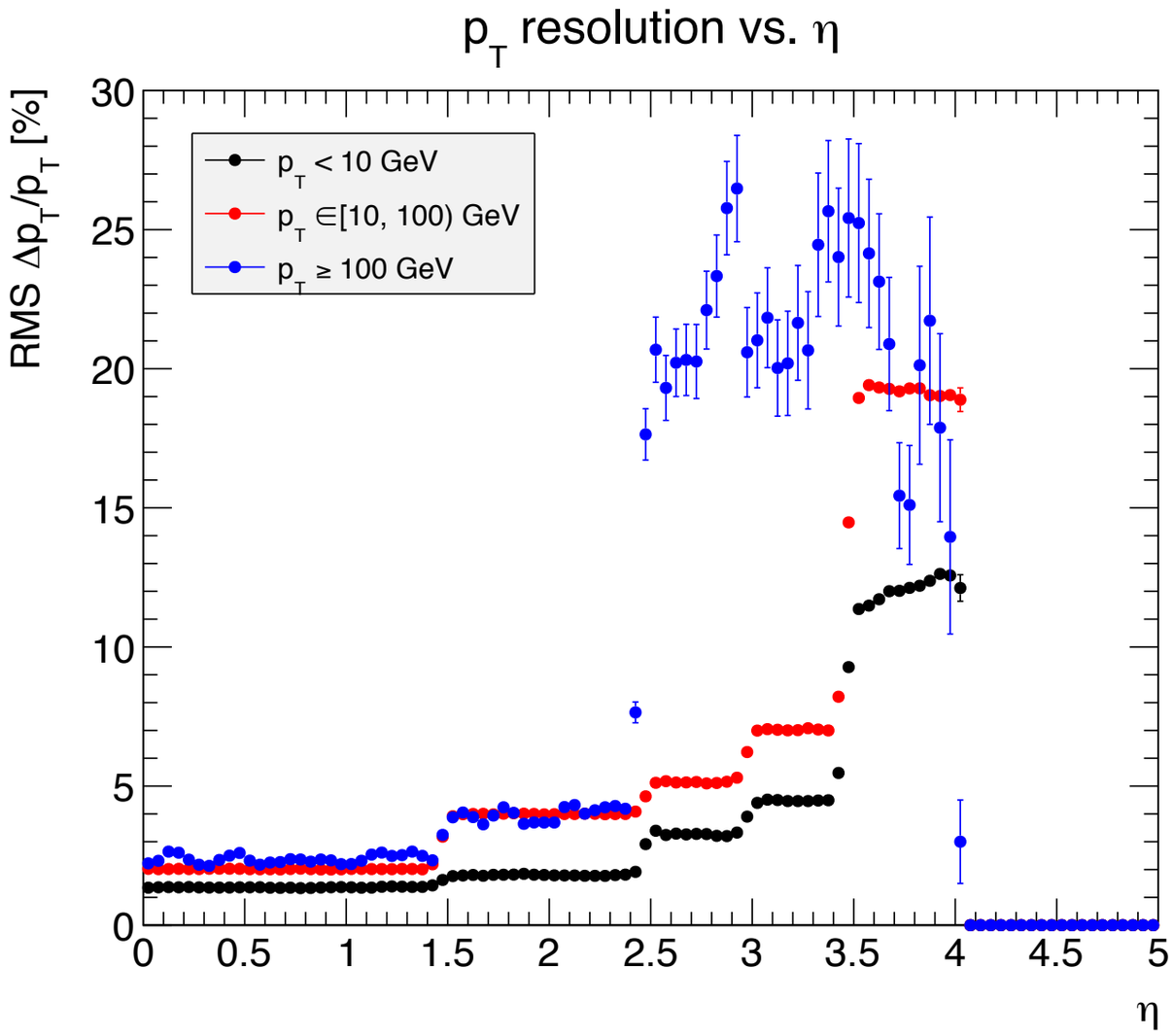
muon momentum reconstruction howto 2/2

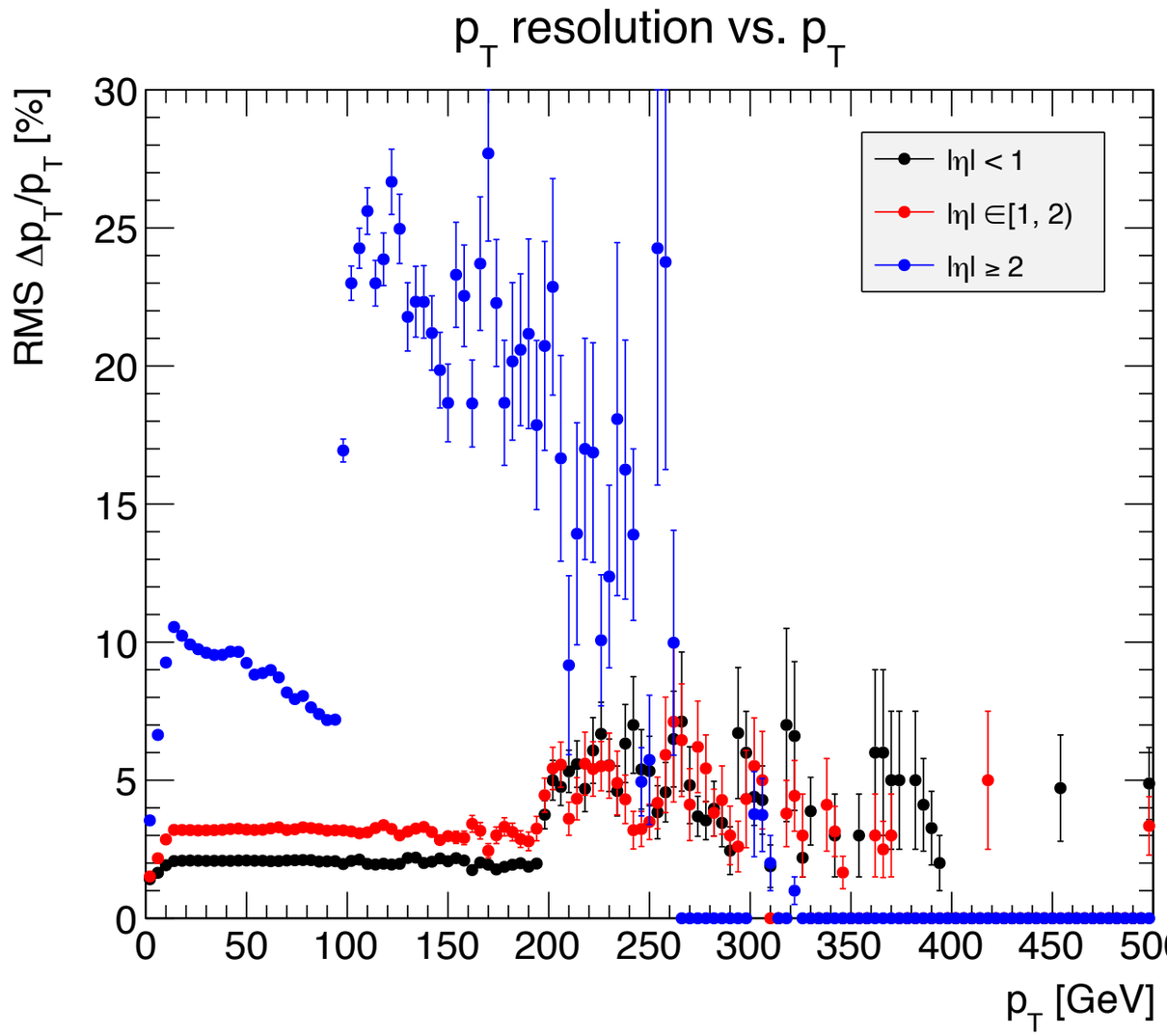
- extract dimuon mass spectra and find resolution for different pseudo-rapidity regions (apply reasonable thresholds to mimic event selection), e.g.:
  - “barrel” may mean $|\eta| < 1.0$
  - “overlap” may mean $1.0 < |\eta| < 1.8$
  - “endcap” may mean $1.8 < |\eta| < 2.5$
  - “very forward” may mean $|\eta| > 2.5$

- one “barrel” + one “barrel”
  one “barrel” + one “overlap”
- both “overlap”
  one “barrel” + one “endcap”
- one “endcap” + one “overlap”
  one “endcap” + one “endcap”
  one “very forward” + one “barrel”
  one “very forward” + one “overlap”
- both “very forward”
  one “very forward” + one “endcap”

- find your best way to divide muon pairs into such categories, i.e. "leading muon defines the region", or "η of dimuon system defines the region" or whatever you prefer: just be clear

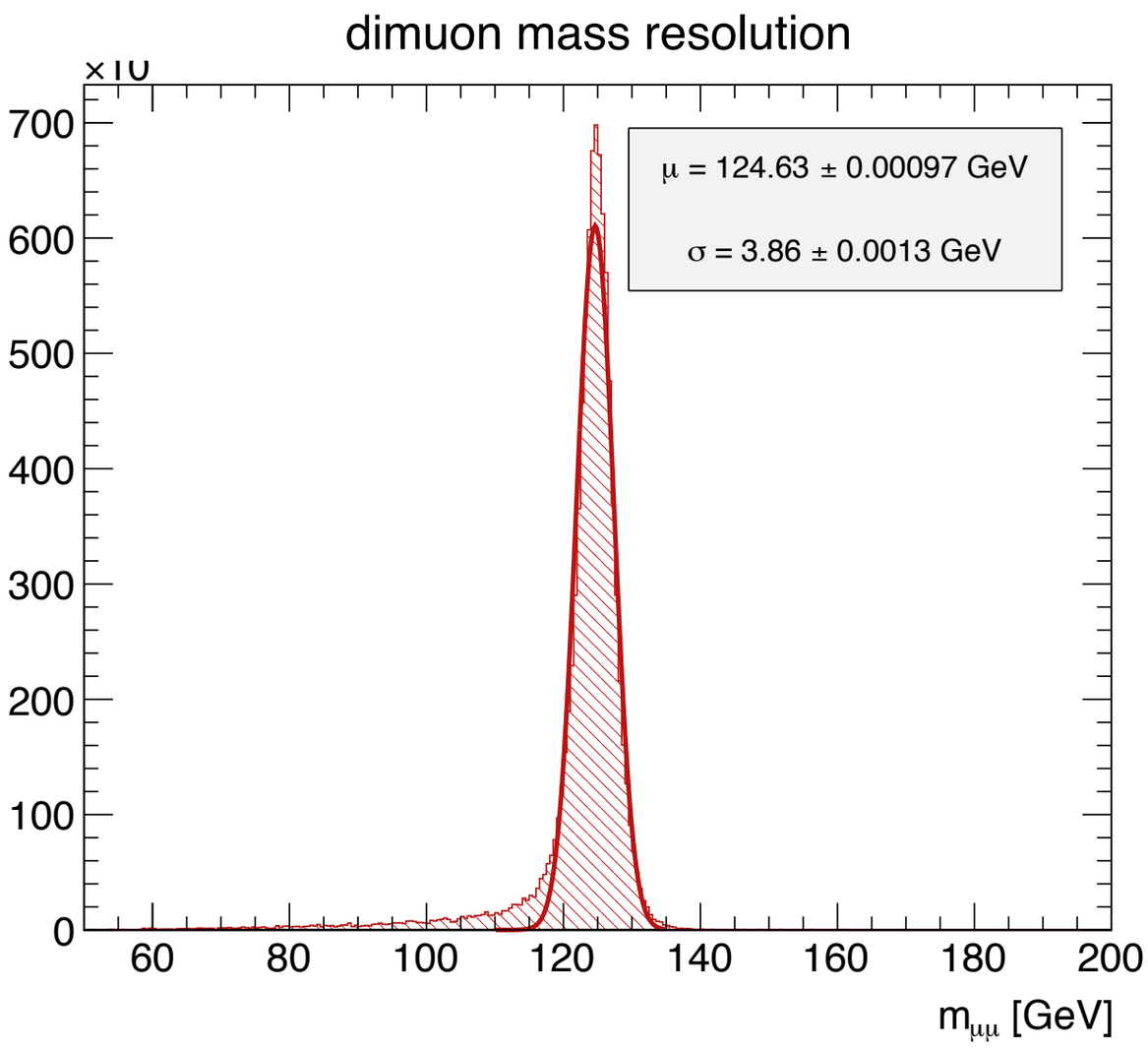
part 1: example p_T resolution

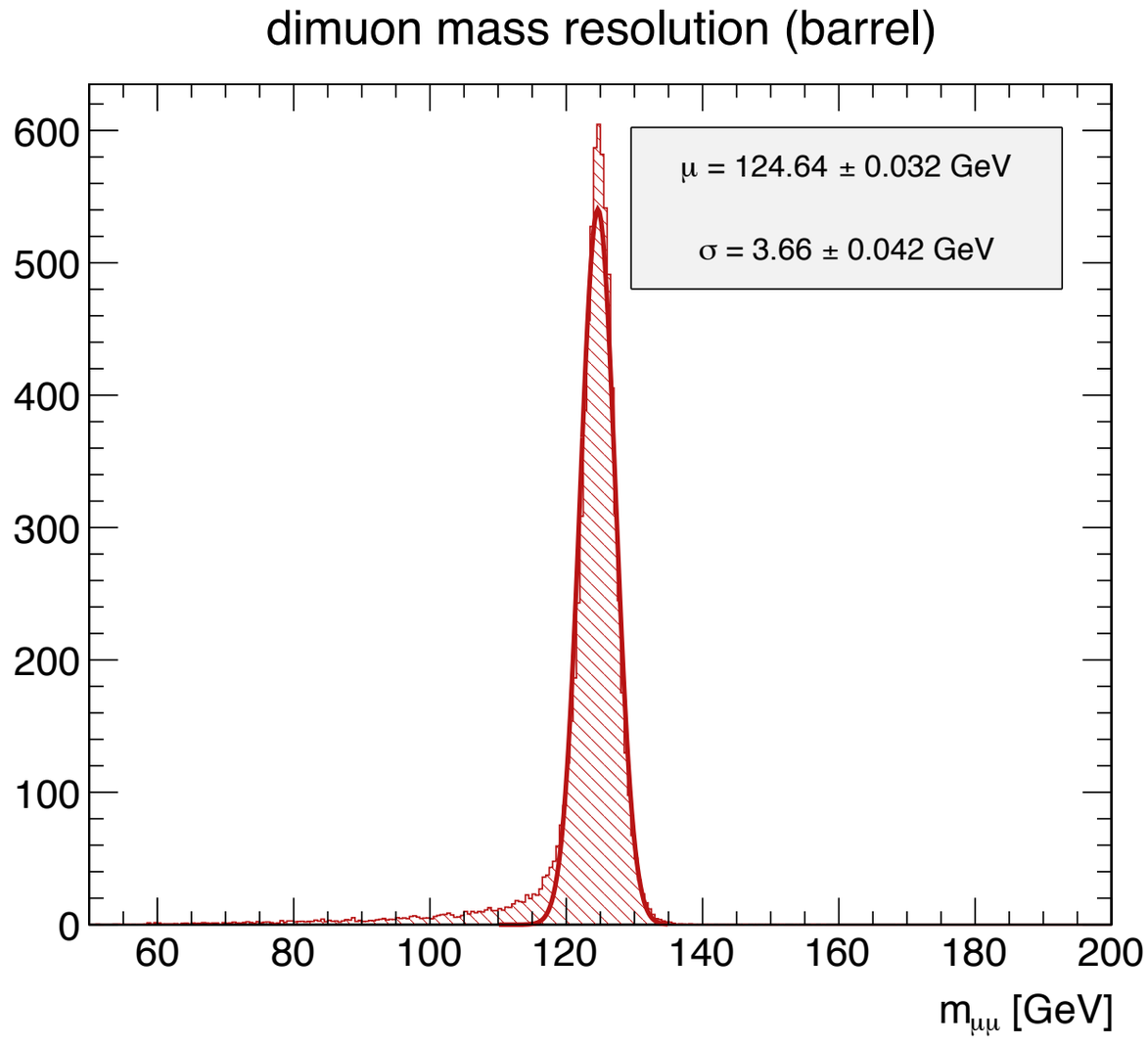




- example resolution from DY at 14 TeV

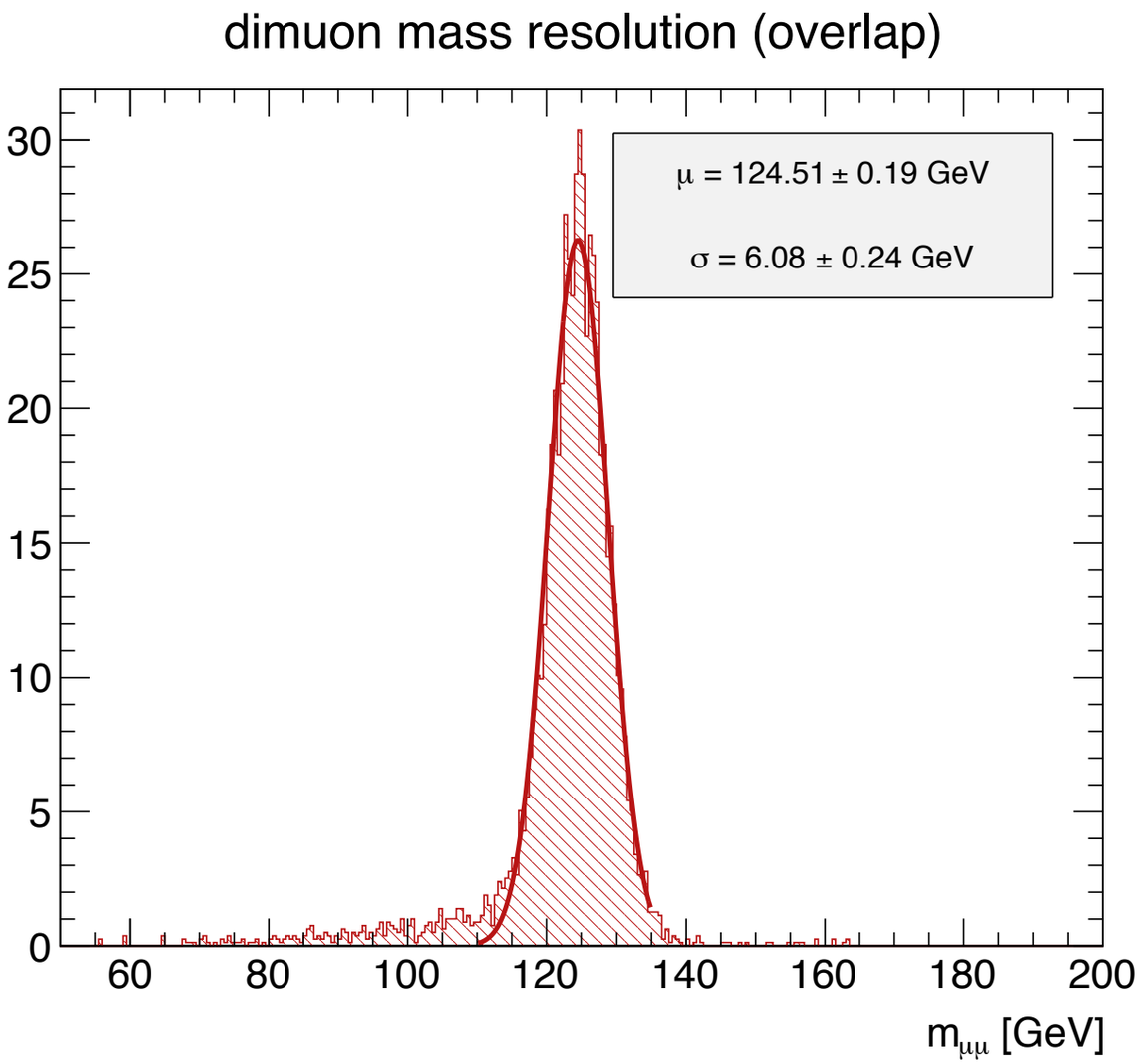
part 1: example dimuon mass resolution 1/2

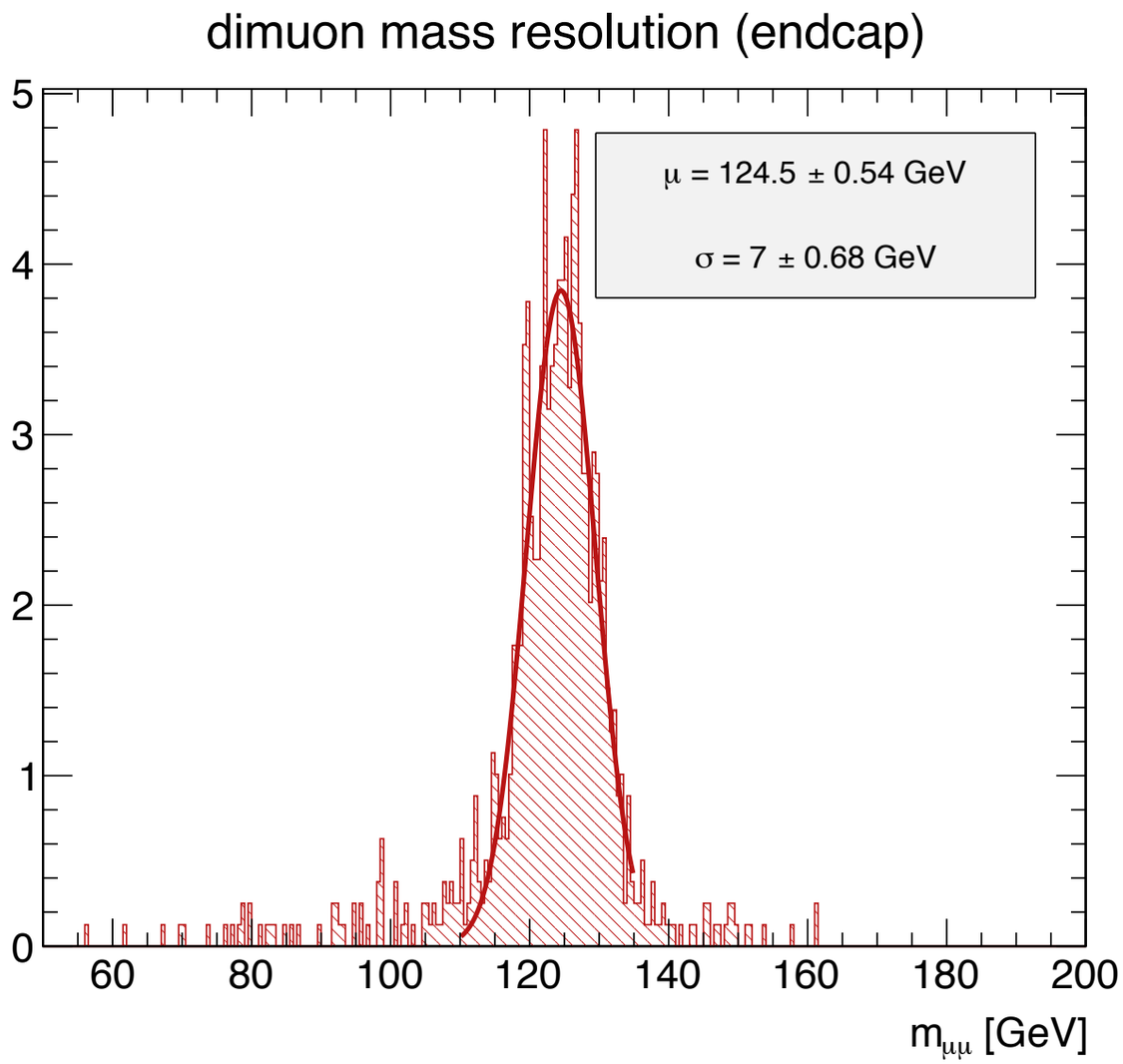




- example resolution from *ggH* and VBF*H* at 14 TeV, after pseudo-trigger and event selection

part 1: example dimuon mass resolution 2/2





- worse momentum resolution at larger η means worse dimuon mass resolution

part 2: muon efficiency and acceptance

- the purpose of the detector is to do measurements!
  - search for rare processes means that lots of muons must be collected and signal fraction must be measured over a large background
    - high efficiency is needed
    - high coverage is needed
      - play with pseudo rapidity coverage in order to find the best compromise between detector performance and physics reach

muon efficiency and acceptance howto 1/2

- pick the best two configurations you designed in *part 1* and play with acceptance (i.e. best invariant mass resolution)

- run Delphes on the two signal samples provided, and on the two backgrounds as well
  - SM *ggH*(125 GeV)→*μμ* (4.2 fb, including BR)
  - SM VBF *H*(125 GeV)→*μμ* (0.33 fb, including BR)
    - DY(m>20 GeV)→*μμ* (3205.6 pb, including BR)
    - $t\bar{t}$ (inclusive) (689.1 pb)

muon efficiency and acceptance howto 2/2

- mimic single muon trigger with p_T and η cuts on the first muon, assume sharp trigger threshold
  - mimic event selection with few constraints on muon and dimuon p_T and η
    - try different values for the efficiency as a function of η in order to enhance the sensitivity figure of merit
      - use $S/\sqrt{B}$ = number of pseudo-sigmas distance between expected signal and background fluctuation (observation-oriented evaluation)

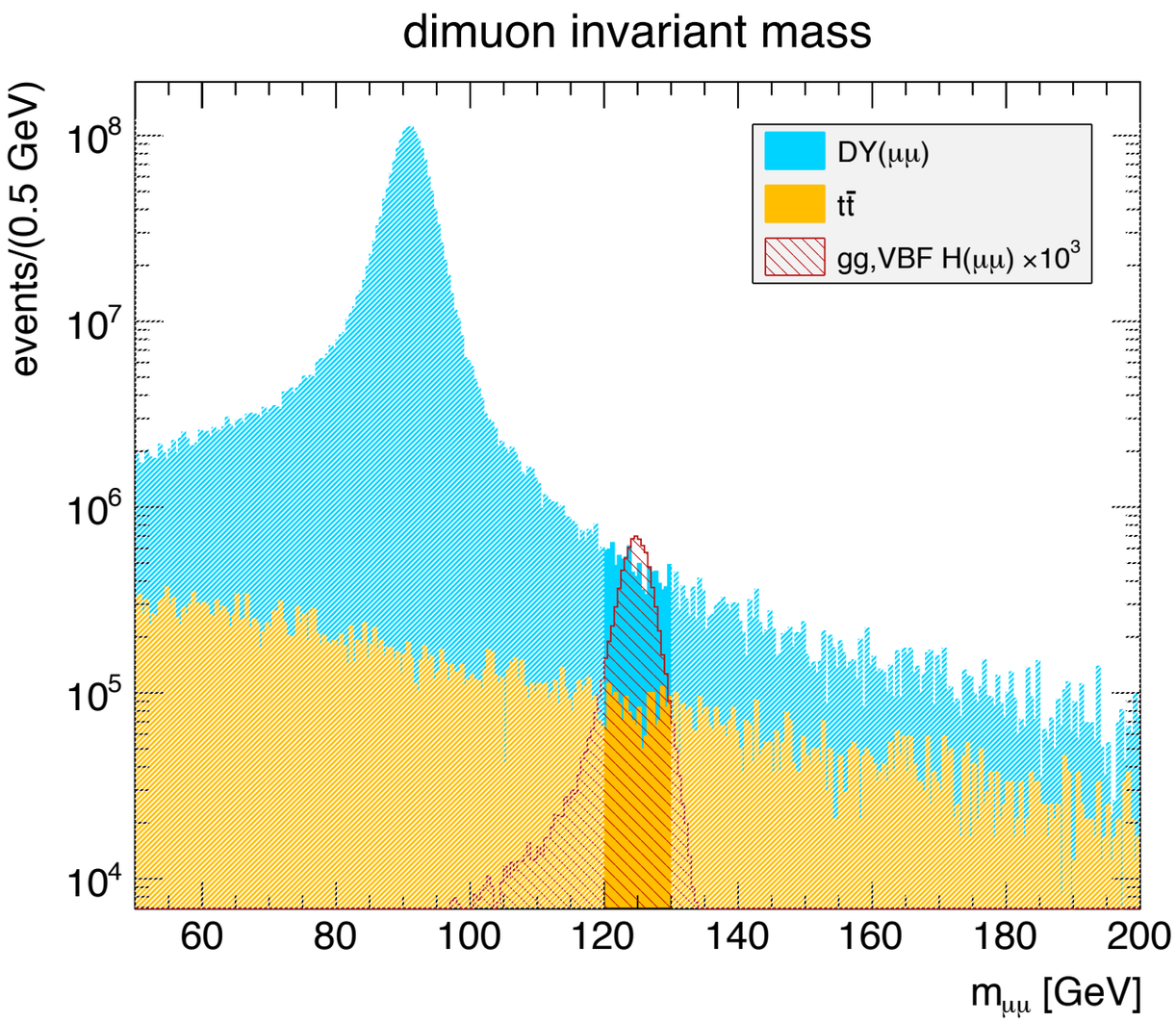
part 2: example selection cuts

- muon trigger p_T threshold = 20.0 GeV
  muon trigger acceptance $|\eta|$ = 3.0

- leading muon p_T threshold = 25.0 GeV
  sub-leading muon p_T threshold = 15.0 GeV
  muons acceptance $|\eta|$ = 3.5

- min. dimuon mass preselection = 50.0 GeV
  dimuon mass signal region = from 120.0 to 130.0 GeV
  dimuon p_T threshold = 10.0 GeV

part 2: example counting events in signal region

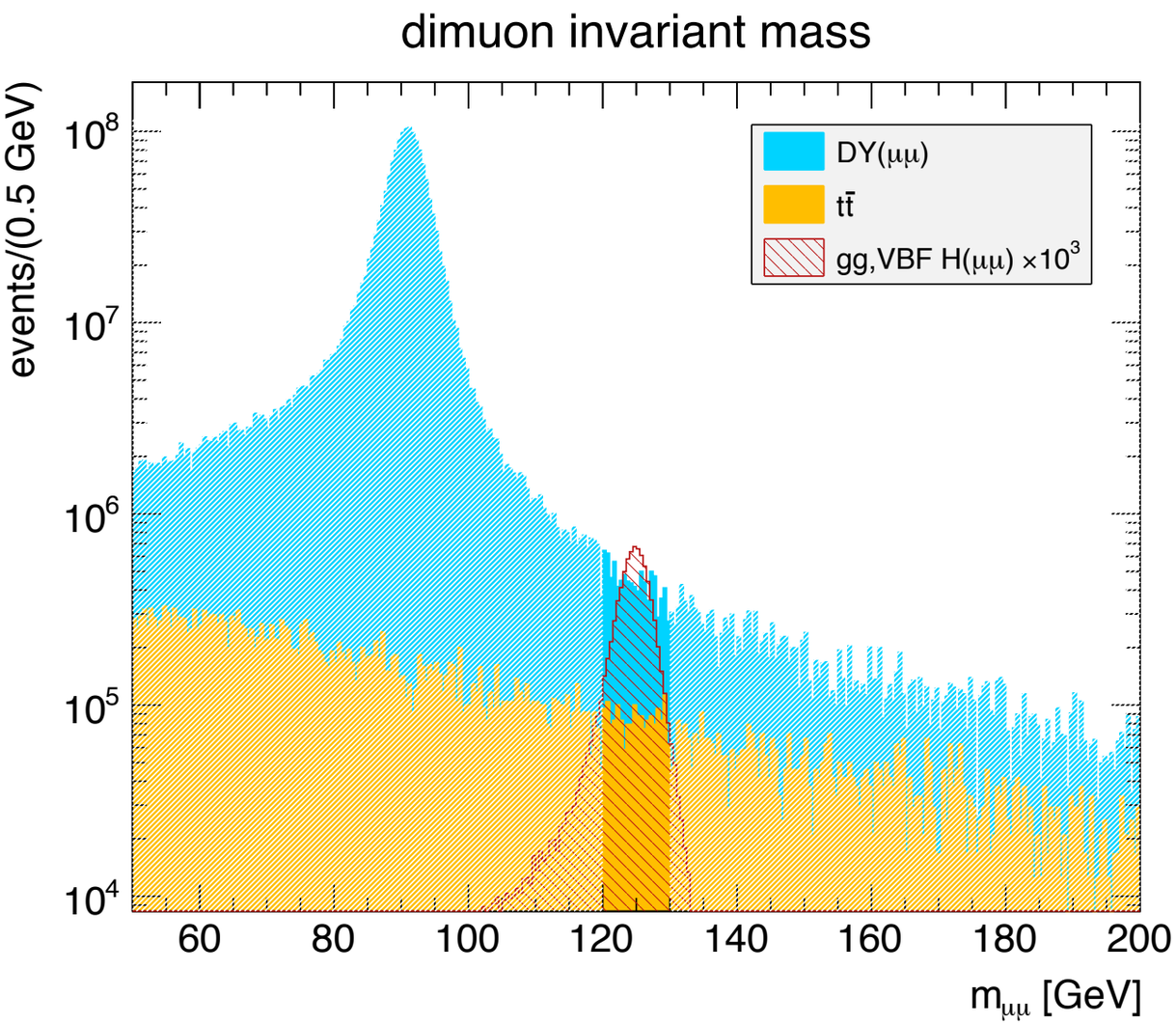


- selection efficiency [%]
  DY: 0.0852 ± 0.003
  $t\bar{t}$: 0.0835 ± 0.004
  ggH: 57.1 ± 0.15
  VBF*H*: 67.5 ± 0.15

- expected events
  signal: 7858.7
  background: 9.92 M

- $S/\sqrt{B} = 2.50$

part 2: example counting events in signal region



- selection efficiency [%]
  DY: 0.0778 ± 0.003
  $t\bar{t}$: 0.0851 ± 0.004
  ggH: 54.0 ± 0.16
  VBF*H*: 64.1 ± 0.16

- expected events
  signal: 7442.7
  background: 9.24 M

- $S/\sqrt{B} = 2.44$

- reduced efficiency at $\eta > 1.2$

few remarks

- presentation is important as the results themselves
  - be clear and clean in showing results
    - include correct error propagation as well
  - go to the main point but be prepared to defend your work in the details as well
    - explain the reason of your choices
    - include the source of any additional information you are making use of

setup Delphes

```
git clone https://github.com/sethzenz/Delphes.git
git checkout tags/31Jul2014
cd Delphes
./configure
sed -i '/lFWCoreFWLite/ s/$/ -lGenVector/' Makefile
make clean
make
```

tools

- input datasets (ASCII-hepmc in .dat format)

```
/nfs/dust/cms/group/cups2014/longexercises/DYMuMu20_14TeVPythia6
/nfs/dust/cms/group/cups2014/longexercises/TTbar_14TeVPythia6
/nfs/dust/cms/group/cups2014/longexercises/VBFHMuMu_14TeVPythia6
/nfs/dust/cms/group/cups2014/longexercises/ggHMuMu_14TeVPythia6
/nfs/dust/cms/group/cups2014/longexercises/ZprimeMuMu2500_14TeVPythia6
```

- example Delphes card

```
/nfs/dust/cms/group/cups2014/longexercises/DESYCards/CMS_UpgradeSchool_BASE.tcl
```

- script to split Delphes over all input files

```
/nfs/dust/cms/group/cups2014/longexercises/Utils/launchMultipleDelphes.sh
```

tips

- take a look at Delphes **Example1** which comes as a compiled macro

- background samples are quite large to be processed by Delphes in short time (< 1 hr) even after splitting on the same machine: try first on small sub-samples

references: search for SM $H \rightarrow \mu\mu$

- CMS CADI HIG-13-007 (paper is recommended over PAS) **http://cms.cern.ch/iCMS/analysisadmin/cadilines?line=HIG-13-007&tp=an&id=1078&ancode=HIG-13-007**

- more details in AN-2012/459 **http://cms.cern.ch/iCMS/jsp/db_notes/noteInfo.jsp?cmsnoteid=CMS%20AN-2012/459**

- Delphes study for the TP in AN-2014/150 **http://cms.cern.ch/iCMS/jsp/db_notes/noteInfo.jsp?cmsnoteid=CMS%20AN-2014/150**

references: muon and tracker

- detector performance studies in public PhysicsResults CMS TWiki (and then browse freely to plots and papers)
  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults#Physics_Objects

- our beloved Technical Proposal
  https://cms-docdb.cern.ch/cgi-bin/DocDB/RetrieveFile?docid=12143