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Search for a Z′ boson in the dimuon channel in p-p collisions at $\sqrt{s}$ = 7TeV with CMS experiment at the Large Hadron Collider

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Outline

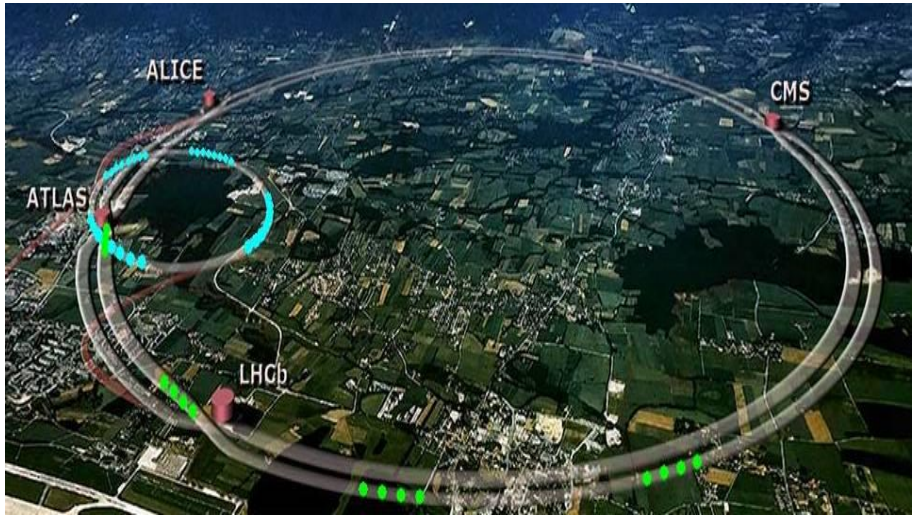
- LHC and CMS Detector
- Standard Model
- Z′ boson
- Physics analysis of 40 pb^{-1} data
- Summary

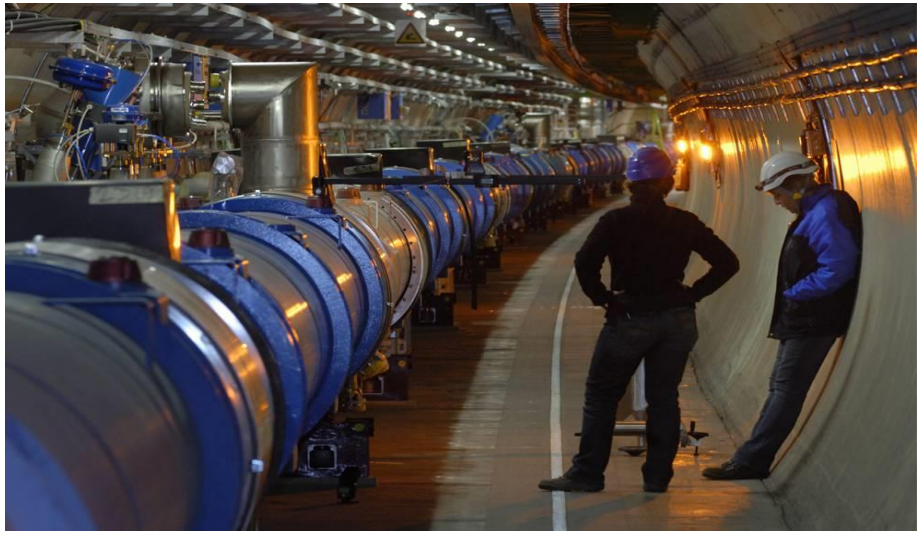
Large Hadron Collider(LHC)

- World's Largest and highest energy particle accelerator
- Built at CERN(European Center for Nuclear Physics).
- 27 km long, 50-175 m underground.

Six Detectors:

- ATLAS: **A** **T**oroidal **L**HC **A**pparatu**S**
- ALICE: **A** **L**arge **I**on **C**ollider **E**xperiment
- **CMS: Compact Muon Solenoid**
- LHCb: **L**arge **H**adron **C**ollider **b**eauty
- LHCf: **L**arge **H**adron **C**ollider **f**orward
- TOTEM: **Tot**al **E**lastic and diffractive cross section **M**easurements

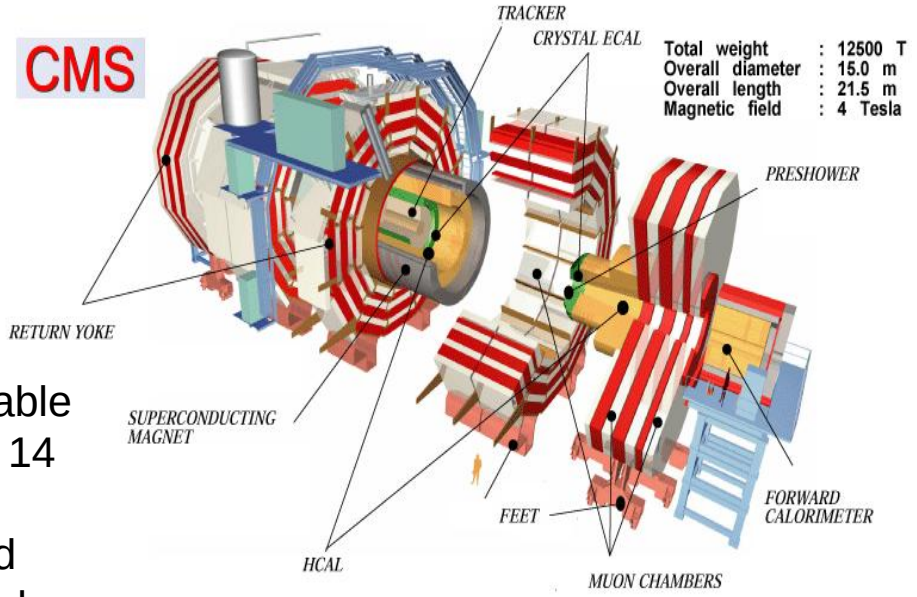




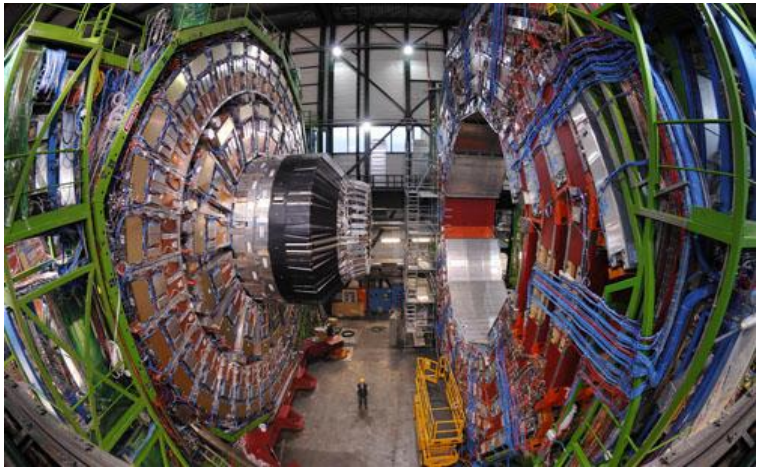
LHC tunnel ←

Compact Muon Solenoid(CMS)

Compact: Compact in size
Muon: Special focus on precise measurement of muons
Solenoid: Super conducting Magnet

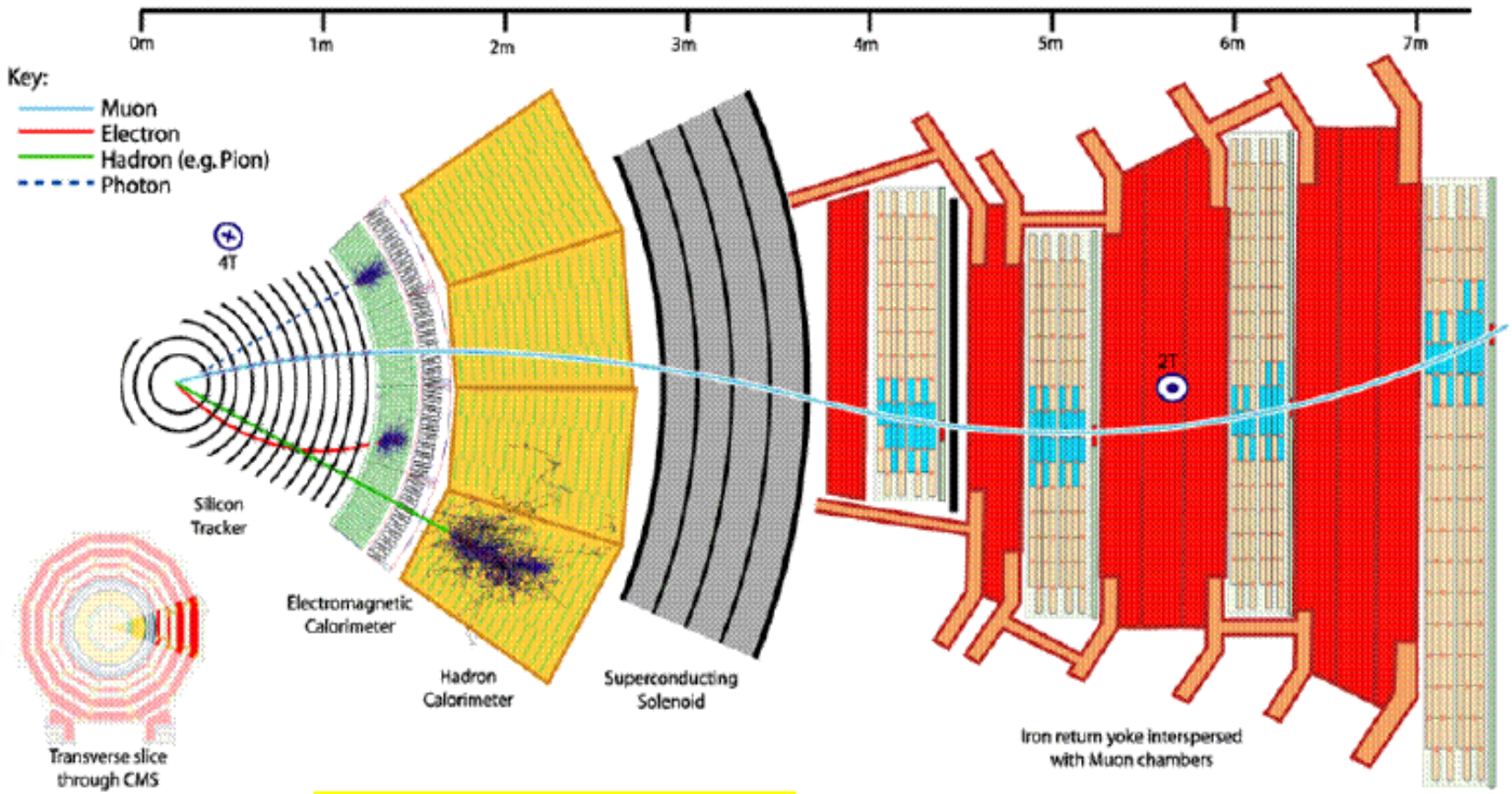


Detector:
- Designed as general - purpose detector capable of studying many aspects of p-p collision at 14 TeV CM energy.
- Contains subsystems to measure energy and momentum of photons, electrons , muons and other products of collisions.



Goal:
- To explore physics at TeV scale
- To discover Higgs boson
- To look for evidence of physics beyond standard model such as Super Symmetry (SUSY) and extra dimensions.
- To study aspects of heavy ion collisions

Particle Detection in CMS



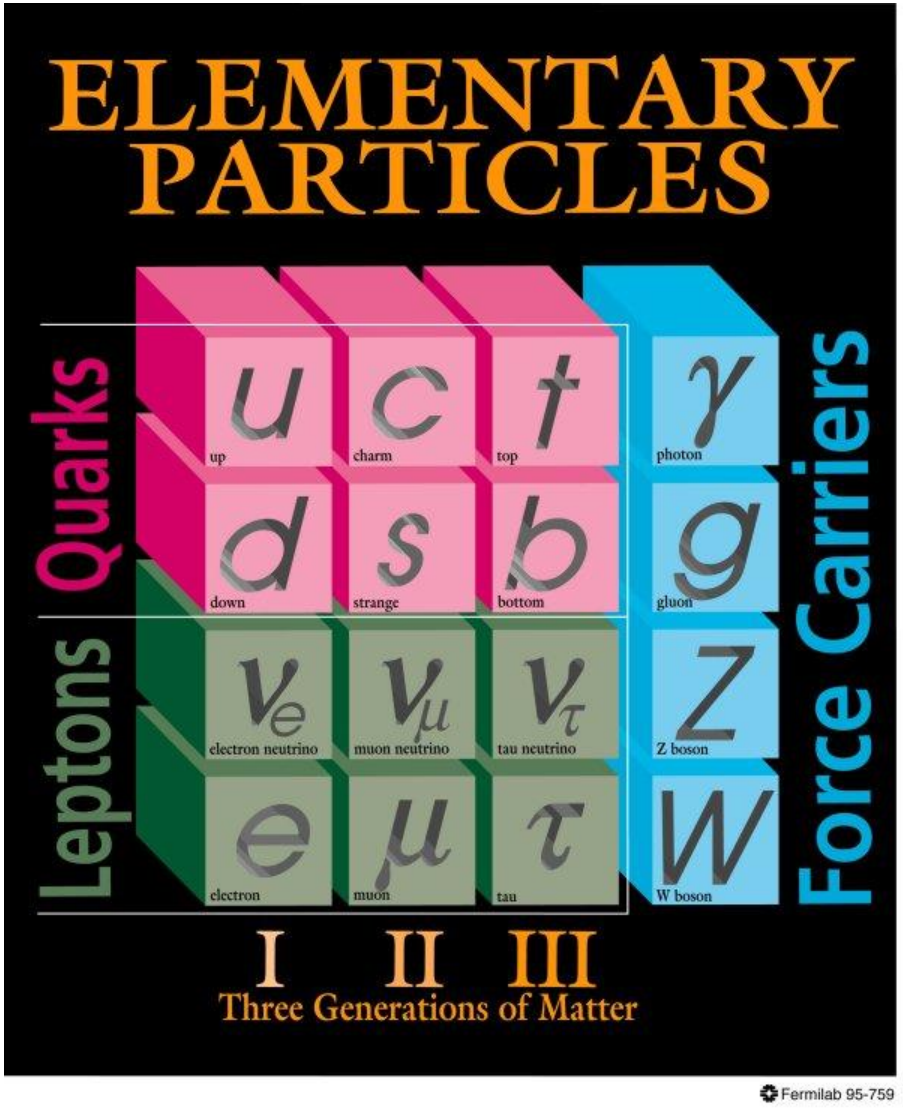
Particle detection strategy

Standard Model and Elementary Particles

- Current knowledge of fundamental particles and their interaction.
- Theory of strong interactions, unified theory of electromagnetic and weak interactions .
- SM is a gauge theory with symmetry group SU(3) X SU(2) X U(1).

Elementary Particles:
Fermions: Leptons, quarks (Spin ½)
Bosons: Gauge Bosons (Spin 1)

Force Carriers:
photon, gluons(8)
W^+,W^-, Z^0 ,H
H: Higgs boson(not discovered yet)



Proposed heavy boson(Z')

- Many proposed models of new physics includes particles that shows up as resonance in dimuon invariant mass spectrum.
- An extended gauge model predicts a neutral and heavy gauge boson, Z′.

- **Sequential Standard Model(SSM)**
  Z'_{SSM}: Same coupling with fermions as in SM Z.
- **$U(1)_Z$**: new force carrier of an additional U(1) gauge symmetry $SU(3)_C$ X $SU(2)_W$ X $U(1)_Y$ X $U(1)_Z$.

- No theoretical prediction of Z′ mass

- Current mass limit is > 1071 GeV/c^2 at Collider detector at Fermilab (CDF) (arXiv:1101.4578v1[hep-ex] Jan 24, 2011)

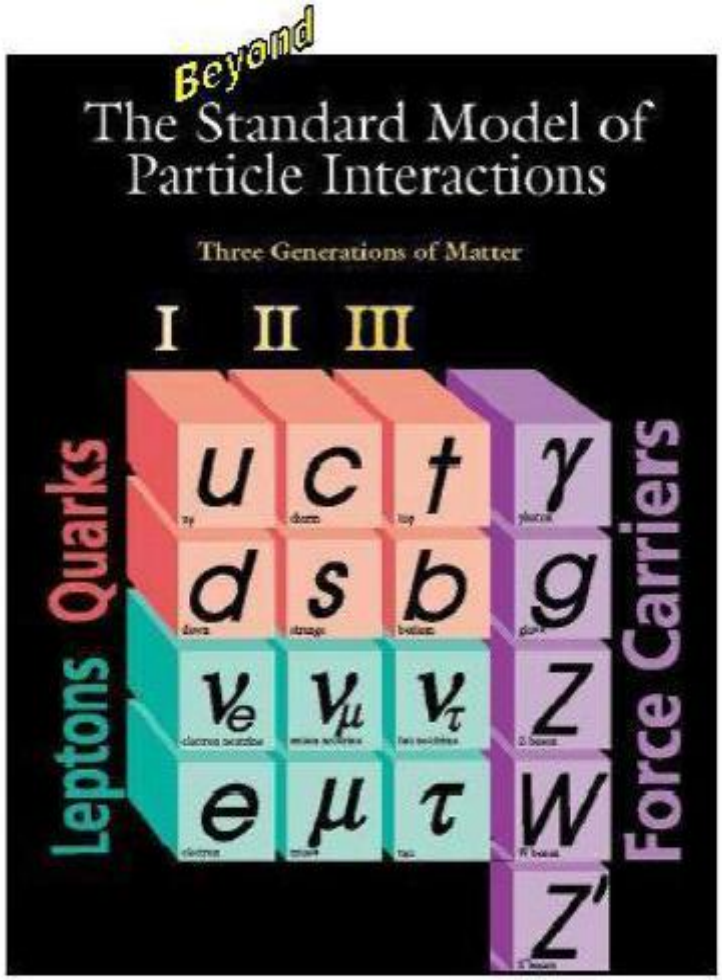


Table from H. Lee's talk

Z′ search

Direct search:

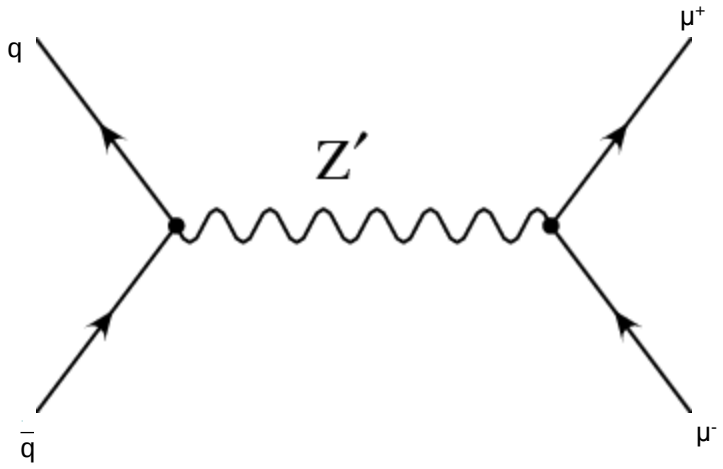
- Looking for high-mass dilepton resonances

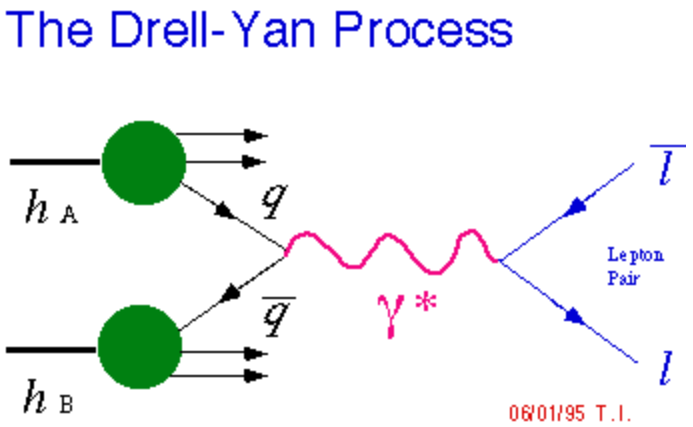
- Quark- antiquark annihilation and decay to opposite charge muons

$pp \rightarrow Z' \rightarrow l^+ l^- + X$, where l = e, μ

- LHC is the first opportunity to search for Z' in a high-mass (TeV/c^2) range.

- $Z' \rightarrow \mu^+ \mu^-$ is one of the most promising channel for its discovery (clear signature, low background).





Physics analysis of 40pb^{-1}data at $\sqrt{s}$ = 7 TeV

- **Run/Event Selection:**
- Good runs of Muon Physics(official)
- 40 pb^{-1} of data (2010).
- **Luminosity:** The number of particles per unit area per unit time.
- **Integrated Luminosity ($\int$L dt)**: Measure of total data collected in an accelerator

N = σ $\int$L dt (No of events = Cross section x Integrated luminosity)

- 1 pb^{-1} of data will give 1 event for a process that has cross section of 1pb.
- Example : $Z^0 \rightarrow \mu^+\mu^-$

  N = 1998931, σ = 1631 pb

  $\int$**L dt = N / σ** = 1998931/1631 = 1225.58 pb^{-1}

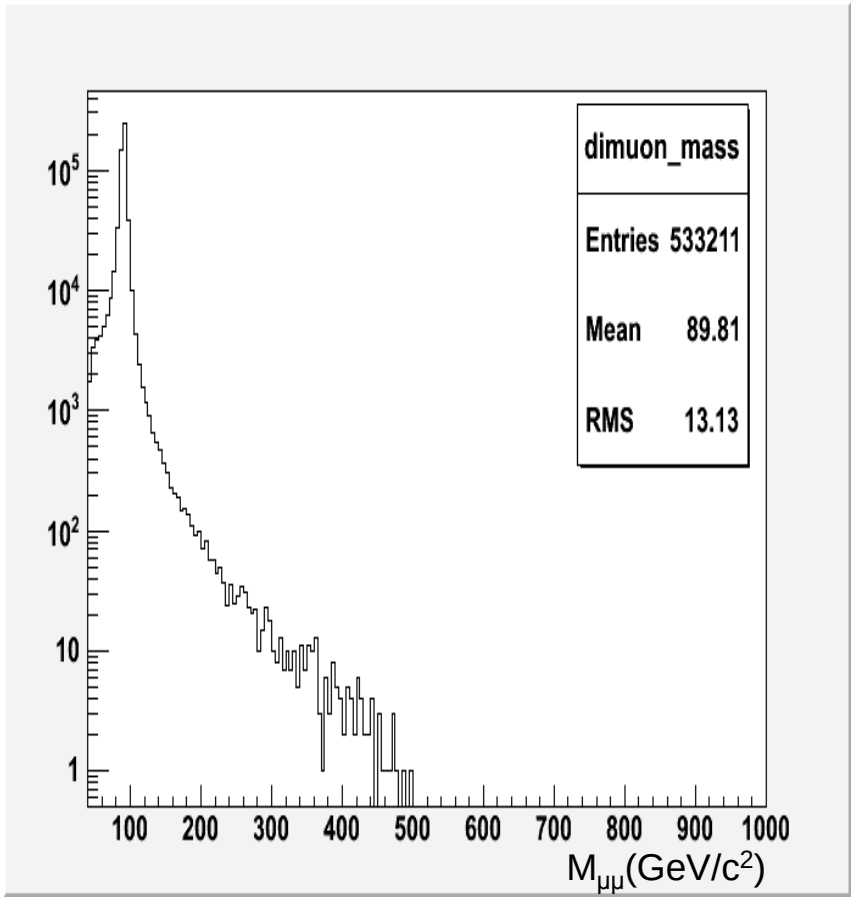
Data / Backgrounds

- The biggest background in our search is **Drell-Yan**.
- **ttbar** : 11% of Drell-Yan above 120GeV
- **ttbarlike**: 5%(tW, WW, WZ, ZZ, $Z \rightarrow \tau^+\tau^-$)
- Sources with misidentified muons:1%(W+jets, QCD)
- Dimuons from cosmic ray muons: removed by cut

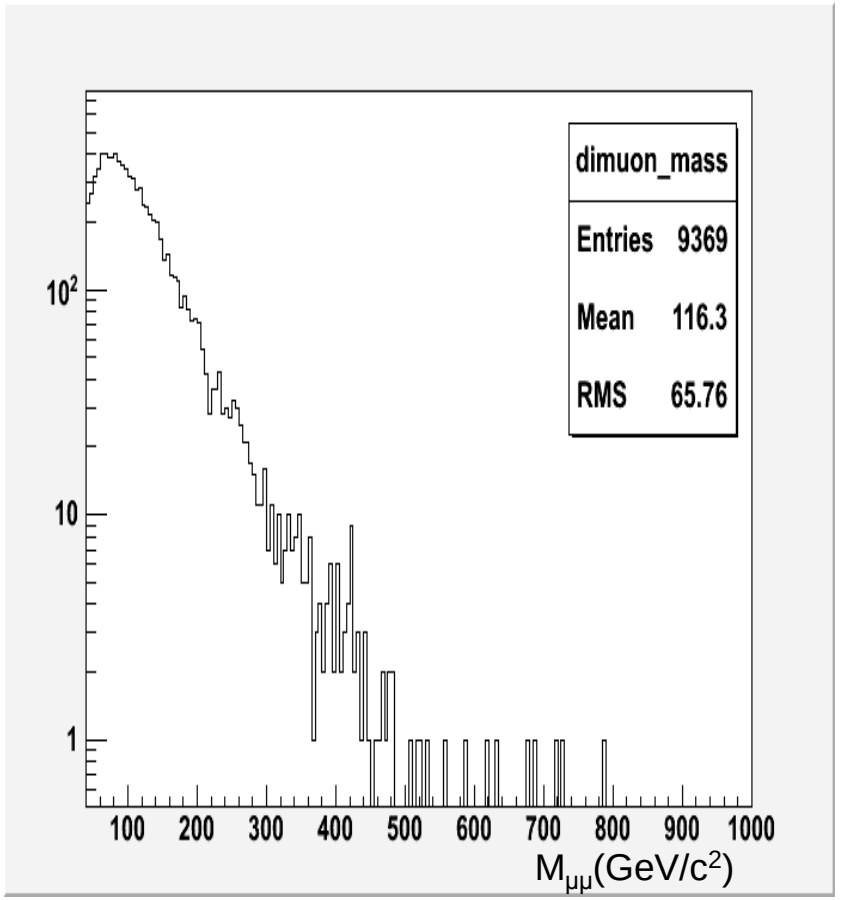
source	number of events	
	$120 < m_{\mu^+\mu^-} < 200$ GeV	$m_{\mu^+\mu^-} > 200$ GeV
CMS data	227	35
MC prediction total	204 ± 28.1	36.4 ± 4.6
$\gamma^*/Z \rightarrow \mu\mu$	187 ± 28	30.2 ± 4.5
$t\bar{t}$ production	12.3 ± 2.3	4.2 ± 0.8
$t\bar{t}$-like production (tW, VV, $Z \rightarrow \tau\tau$)	4.4 ± 0.4	1.7 ± 0.2
dimuons from jets (QCD dijets, W+jets)	0.5 ± 0.2	0.2 ± 0.1
$Z'_{SSM}(M = 750\ \text{GeV}/c^2) \rightarrow \mu^+\mu^-$	-	13.6 ± 2.0

MC histogram

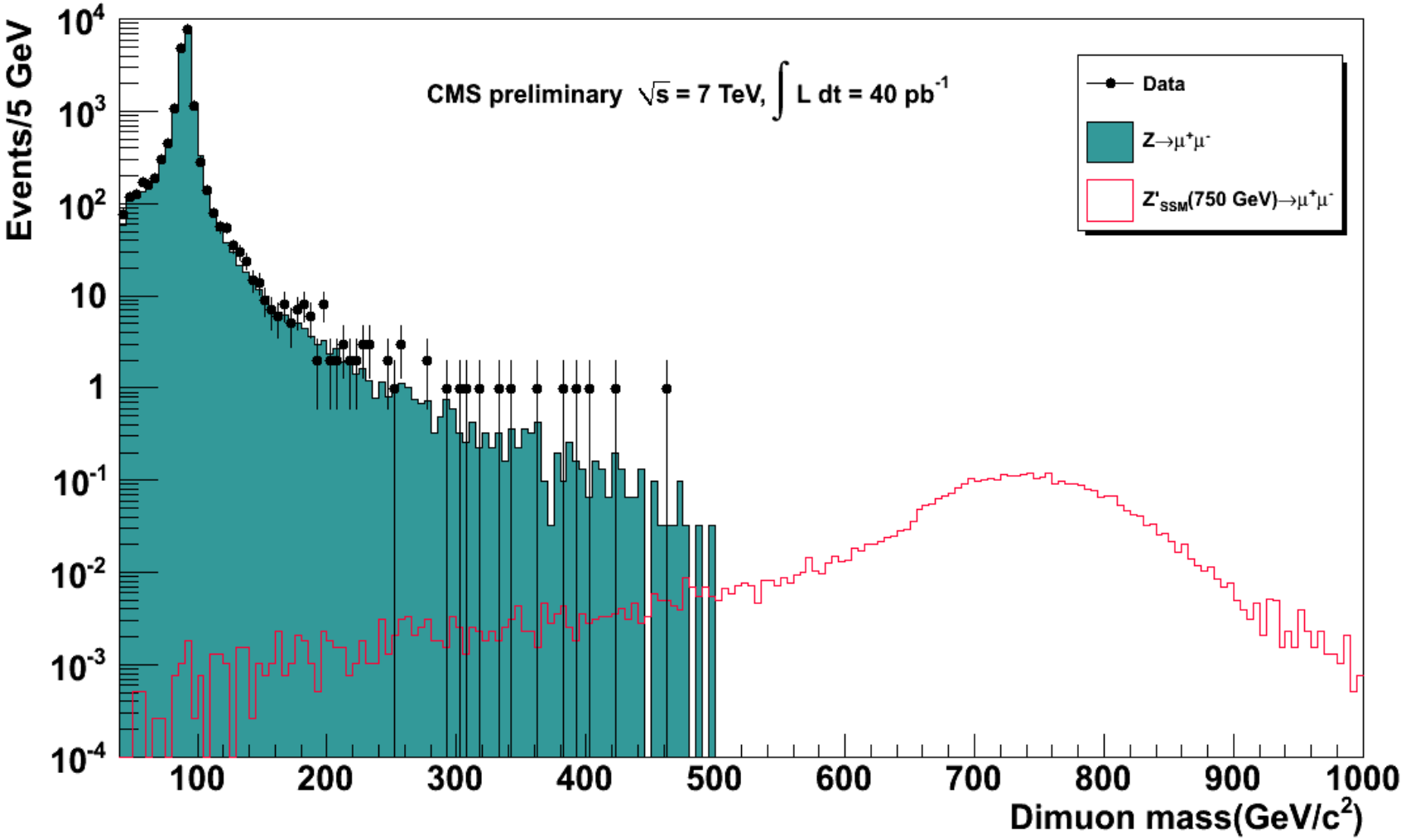
Drell -Yan



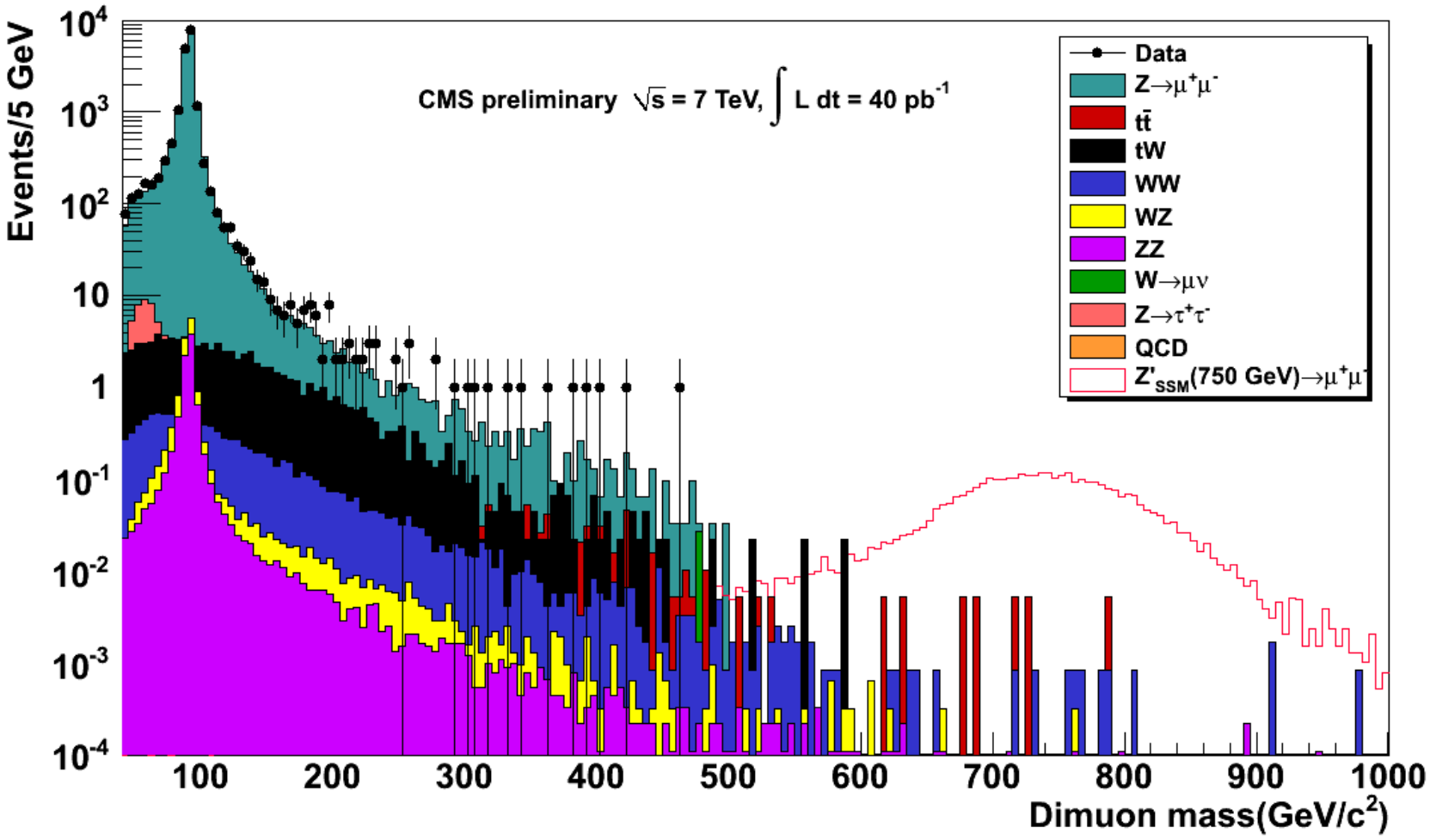
ttbar



Dimuon Mass Spectrum(1)



Dimuon Mass Spectrum (2)



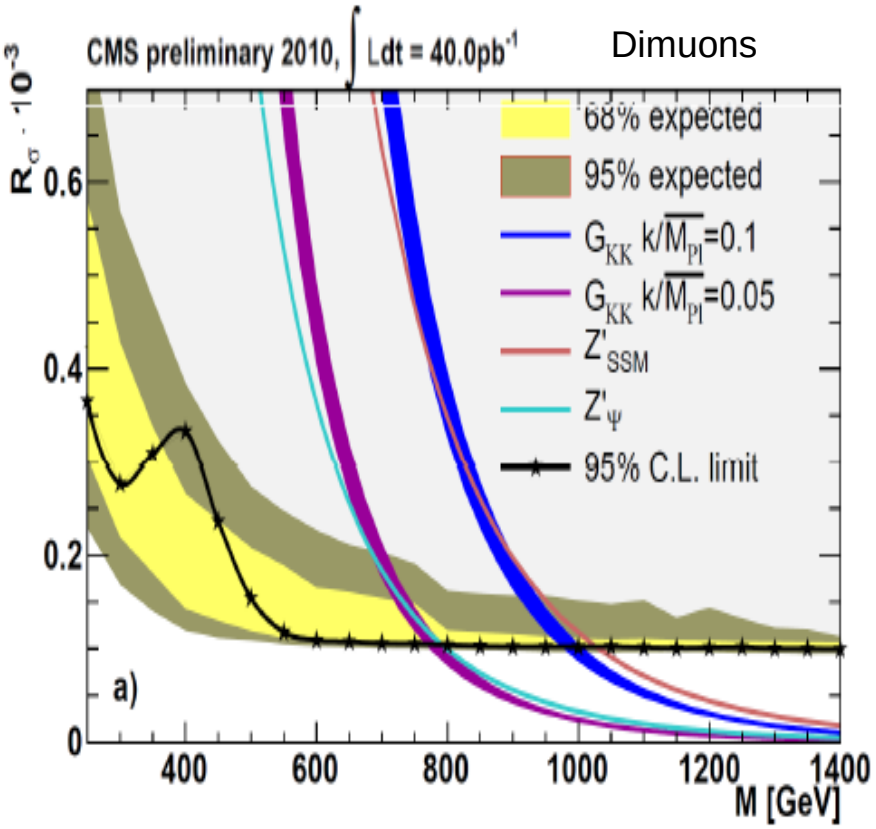
Current lower Z′ mass limit

$$R_\sigma = \frac{\sigma(pp \to Z' + X \to \ell\ell + X)}{\sigma(pp \to Z + X \to \ell\ell + X)}$$

- As there is no resonance in dimuon mass spectrum we set limit on Z′mass .
- There are different methods of limit setting. The limit reported here for LHC result are using Bayesian method.

Recent CDF result:
With 4.6 fb^{-1} of data at CDF at √s = 1.96 TeV
At 95% C.L: Z'_{SSM} = 1071GeV/c^2 (dimuons)

Recent LHC result:
With 40 pb^{-1} of data at LHC at √s = 7TeV
At 95% C.L:
Z'_{SSM} = 1027 GeV/c^2 (dimuons)
Z'_{SSM} = 1140 GeV/c^2 (combined dileptons)



Ref: AN2010_317_v9
2010/12/25

Summary

- The data and MC samples in the dimuon mass spectra are consistent.

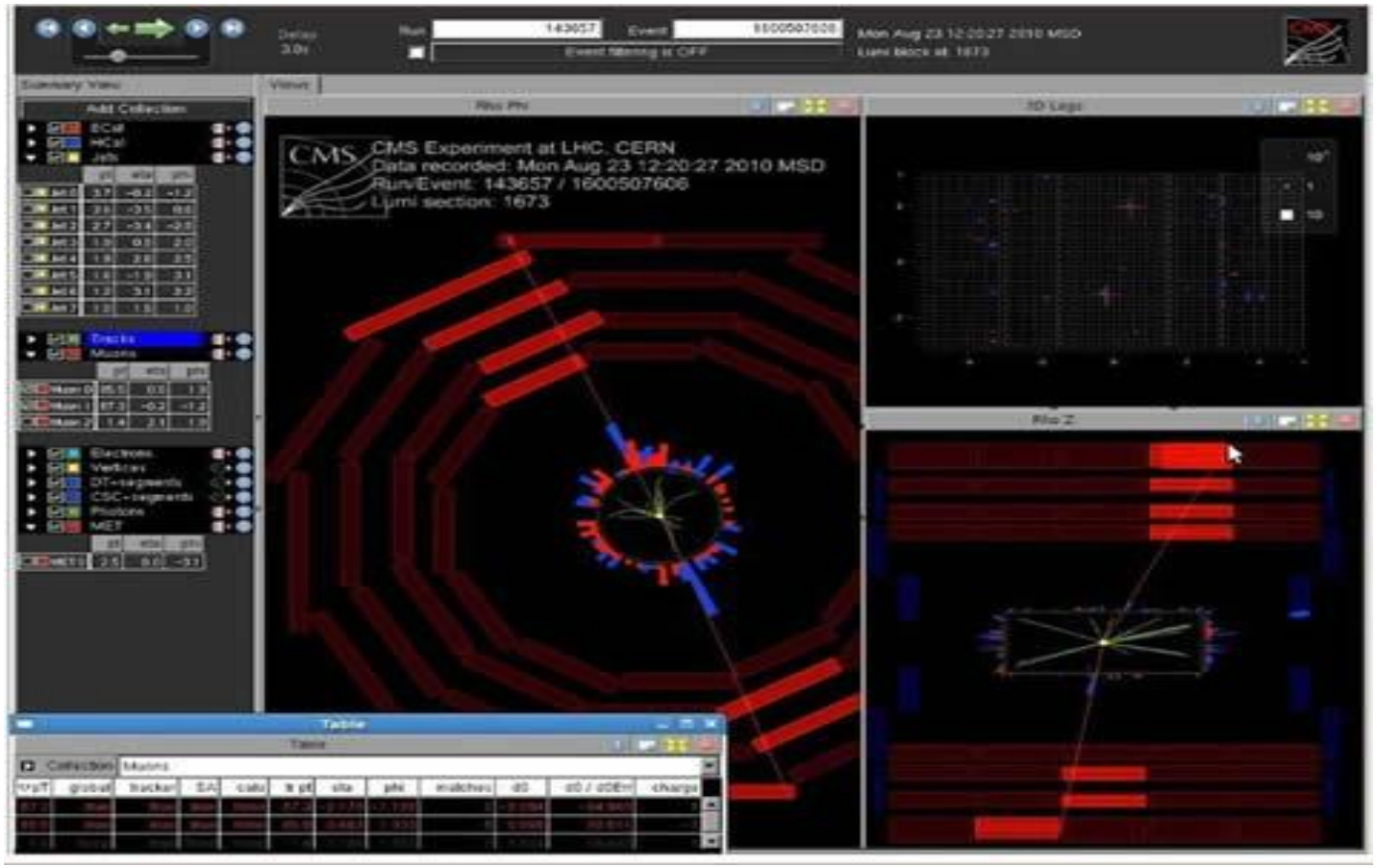
- We do not find evidence of resonance decaying to dimuons in the analyzed 40 pb^{-1} of data.

- The limit for lower Z′ mass at 95% C.L, for dimuons is 1027 GeV/c^2 where as for combined dileptons is 1140 GeV/c^2.

- Hope to see Z′ bump in more data (~fb^{-1}) in 2011.

Back- up

A CMS collision event display



An event display of two opposite sign muons in pp collision at √s = 7 TeV

Datasets

Data:

Sept 17th reprocessing for runs 136097-144114: /Mu/Run2010A-Sep17ReReco_v2/RECO

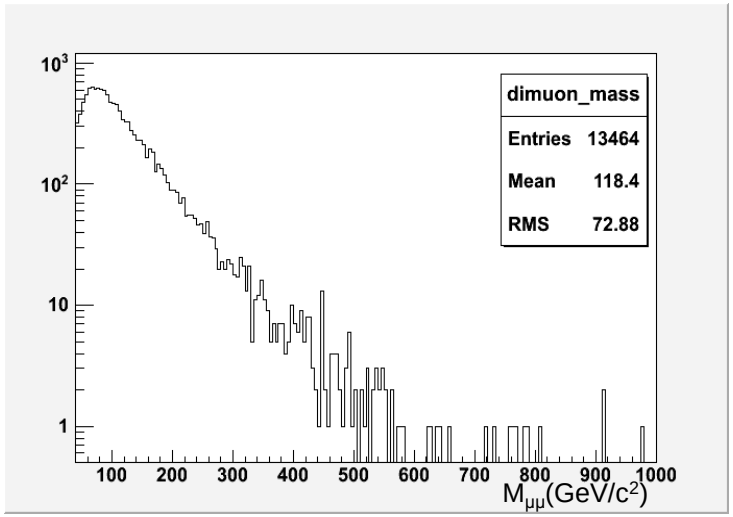
Run2010B prompt-reco for runs > 146427: /Mu/Run2010B-PromptReco-v2/RECO

MC simulation:

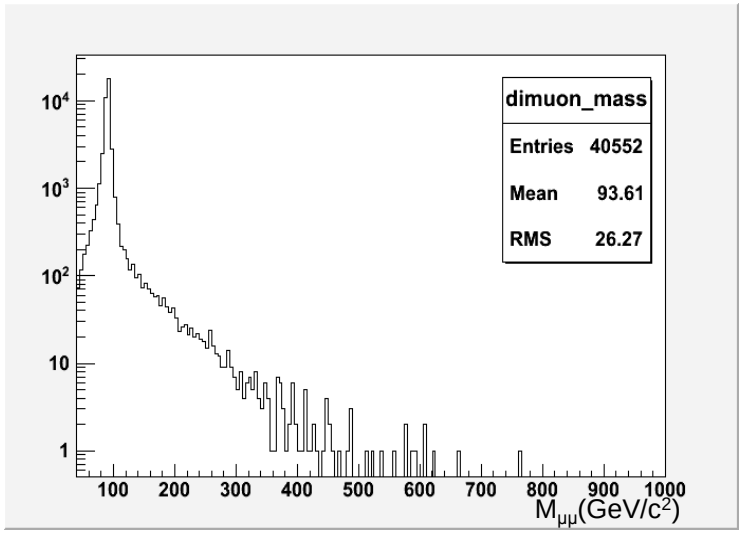
Generator	Process	Kinematic cuts	σ (pb)	Events	PDF set
POWHEG	$Z^0 \to \mu\mu$	$M_{\mu\mu} > 20\ \mathrm{GeV}/c^2$	1631	1998931	CT10
PYTHIA	$Z^0 \to \mu\mu$	$M_{\mu\mu} > 200, 500, 800\ \mathrm{GeV}/c^2$	10.3	3×55000	CTEQ66
MADGRAPH	$t\bar{t}$+jets	-	152	1167759	CTEQ6L1
MADGRAPH	tW	-	10.6	494961	CTEQ6L1
PYTHIA	WW	-	43	2061760	CTEQ6L1
PYTHIA	WZ	-	18	2194752	CTEQ6L1
PYTHIA	ZZ	-	5.9	2113368	CTEQ6L1
MADGRAPH	W+jets	-	1.04×10^4	15168266	CTEQ6L1
PYTHIA	$t\bar{t}$	-	162	1099550	CTEQ6L1
POWHEG	$Z^0 \to \tau\tau$	$M_{\tau\tau} > 20\ \mathrm{GeV}/c^2$	1631	1994719	CT10
PYTHIA	Inclusive μ QCD	$\hat{p}_T > 20\ \mathrm{GeV}/c$, $\lvert\eta_\mu\rvert < 2.5$, $p_T^\mu > 15\ \mathrm{GeV}/c$	8.5×10^4	29504866	CTEQ6L1

MC histogram(1)

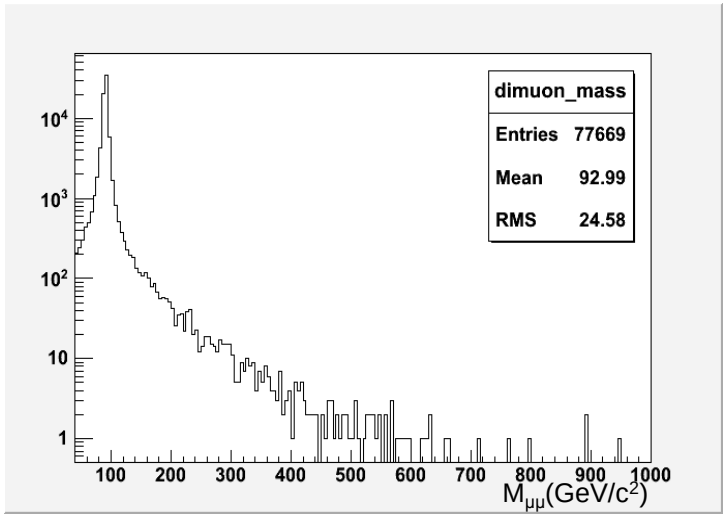
WW



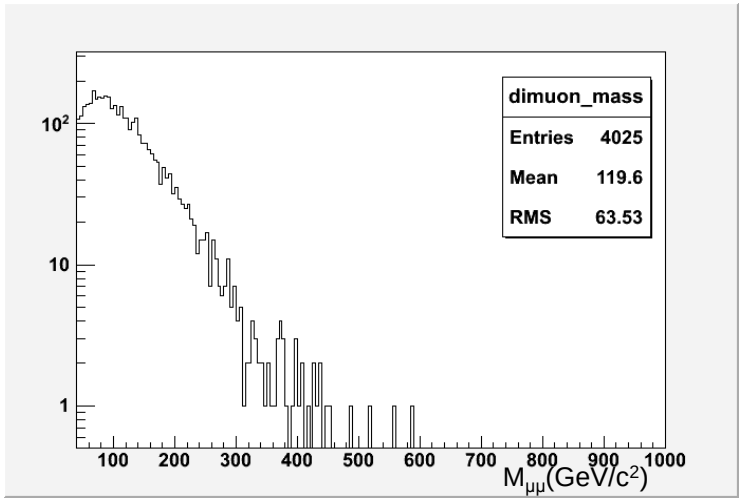
WZ



ZZ

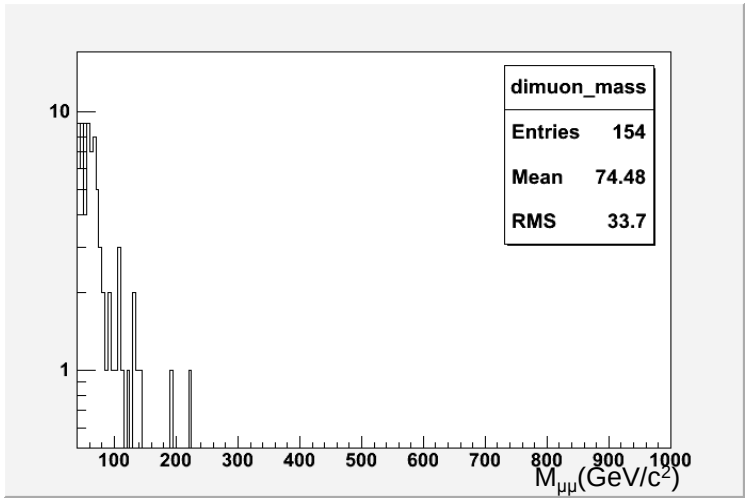


tW

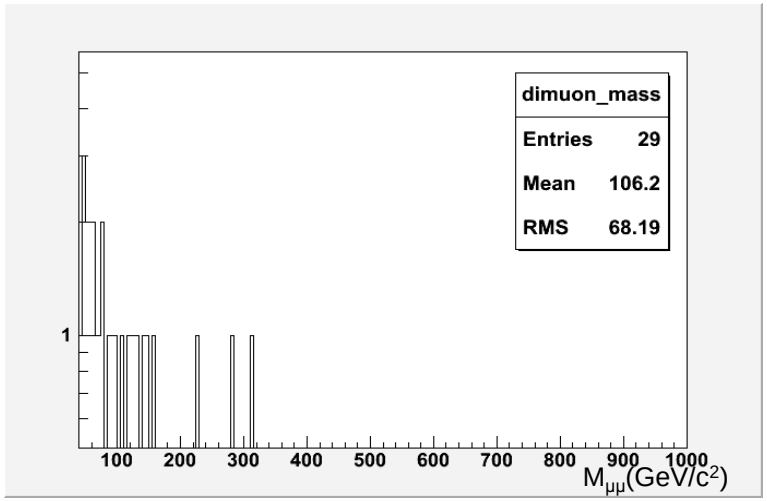


MC histogram(2)

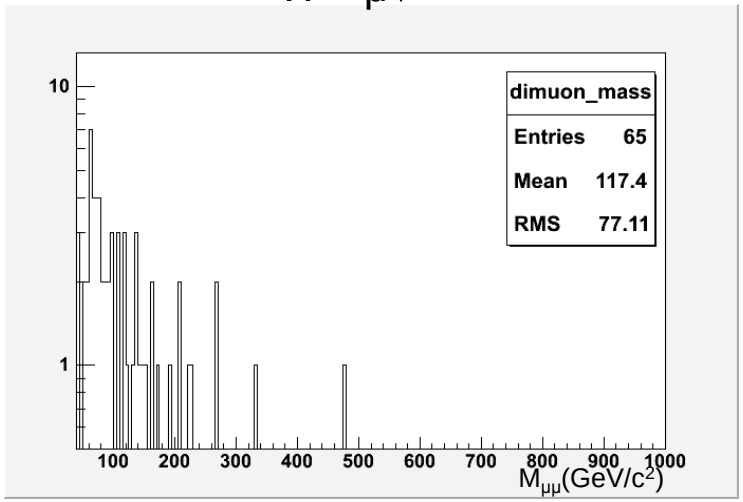
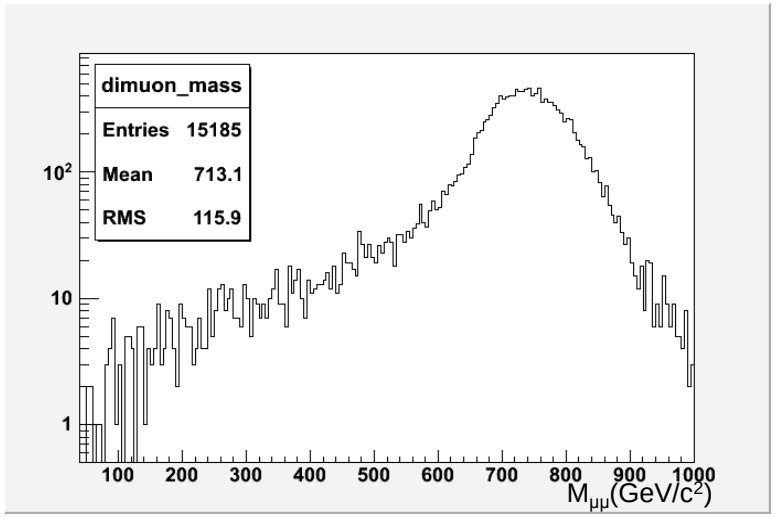
QCD



WJets



W→μν



Z'