Search for high mass resonance decaying to Muon pairs at 13 TeV in LHC

Ahmed Qamesh

Centre for Theoretical physics (The British university in Egypt)

5th school for High energy physics at Zewail City

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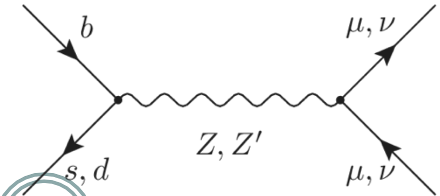
CMS AN-15-061

Z' Resonance BSM



Weak Hypercharge

Week IsoSpin

Strong interaction

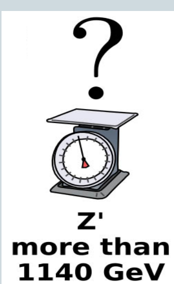
- Standard model gauge groups $[SU(3)_C \times SU(2)_L \times U(1)_Y]$
- the success of the electroweak theory opened the possibility of another unification between the strong interaction and EW interaction.
- The minimal simple group which contains the standard model gauge groups is SU(5) $SU(5) \supset SU(3) \times SU(2) \times U(1)$

$E_{GUT} \sim 10^{15}$Gev

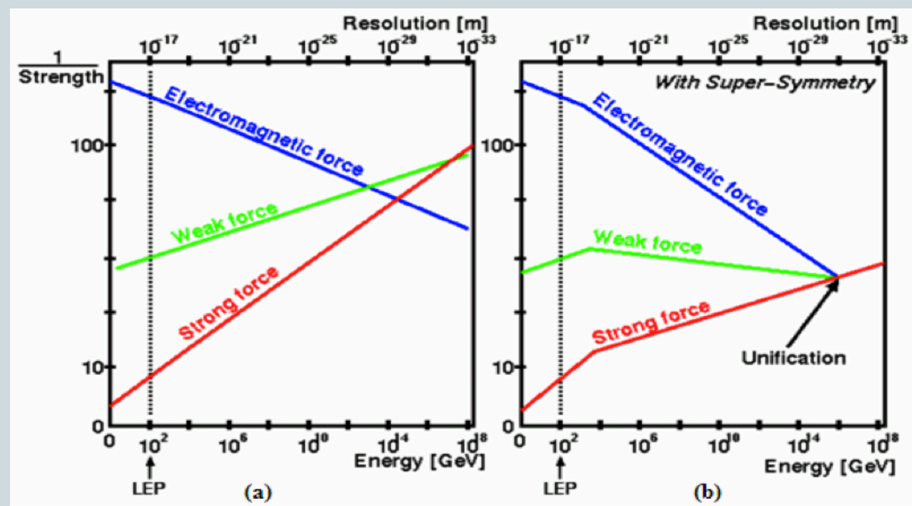
- Most of BSM expects the existence of an extra gauge boson
- The new gauge boson behaves like

The standard model Z boson

$SO(10) \supset SU(5) \supset SU(3) \times SU(2) \times U(1)$

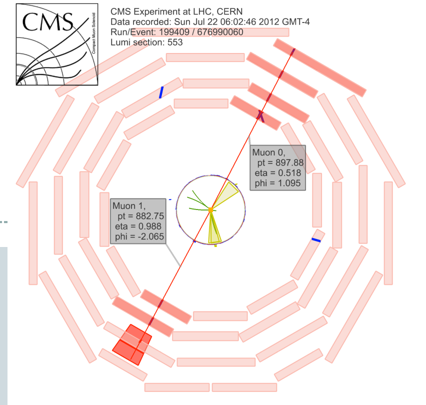


Additional $U(1)'$



Z' search at CMS

we are looking for [two Muons with opposite charge]



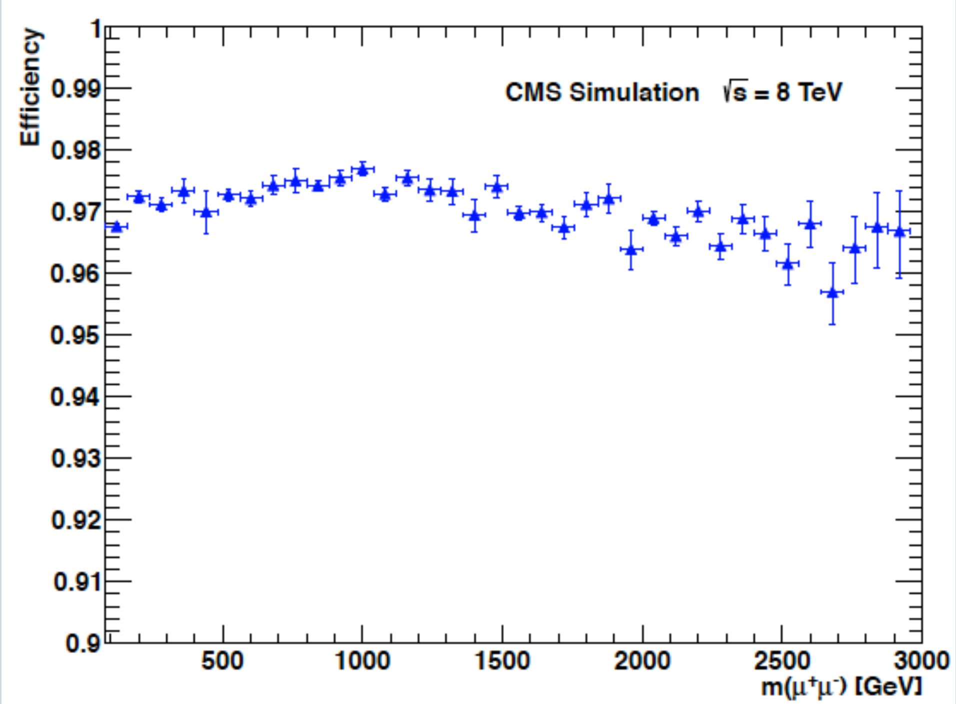
Higher in Mass than the SM Z Boson
gives the same final state as the SM Z boson
Neutral
Spin 1

1. Trigger requirements (Run1 vs Run2)

- The trigger path used at 8 TeV is:

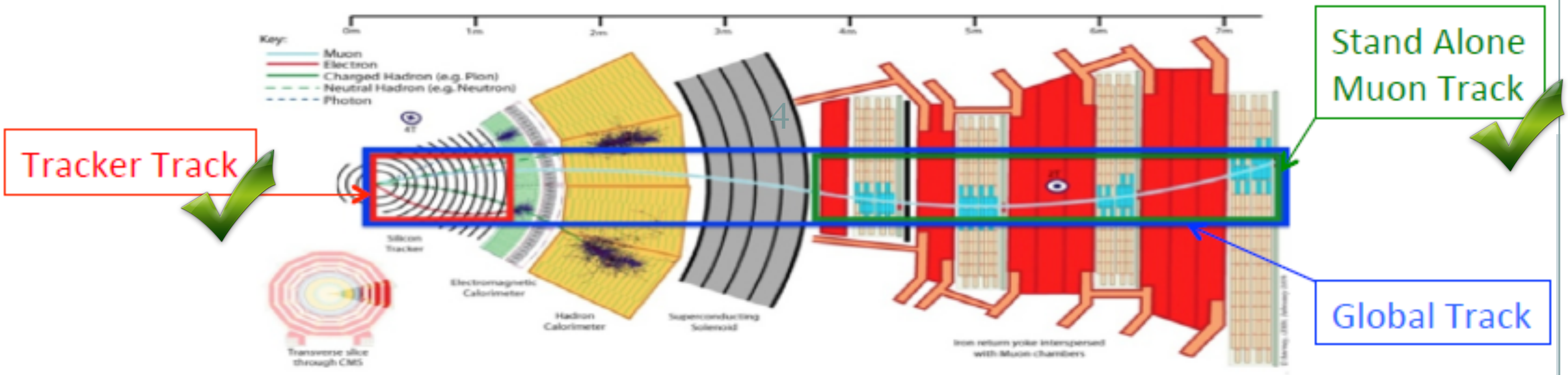
  HLT Mu40 eta2p1

  It requires the presence of at least one Muon candidate with $p_T > 40$GeV in the region of $0 < |\eta| < 2.1$



- The new trigger used at 13 TeV will select the muon candidate at higher $P_T > 45$ GeV covering the full range of η

2. High pt Muon reconstruction



(1) Muon must be reconstructed as global muon and tracker muon

(2) Number of Valid Pixel Hits >0

(3) Number of Valid Muon Hits>0

(4) Number of Matched Stations > 1

(5) Number Of Tracker Layers With Measurement > 5

(6)Relative track isolation < 0.10 $\frac{\sum p_T}{p_T}$

$$\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.3$$

(7) |dxy| < 0.2 cm

(8) pt > 48.0 GeV

(9) $\delta p_T/P_T<0.3$

Extra cuts on the dimuons

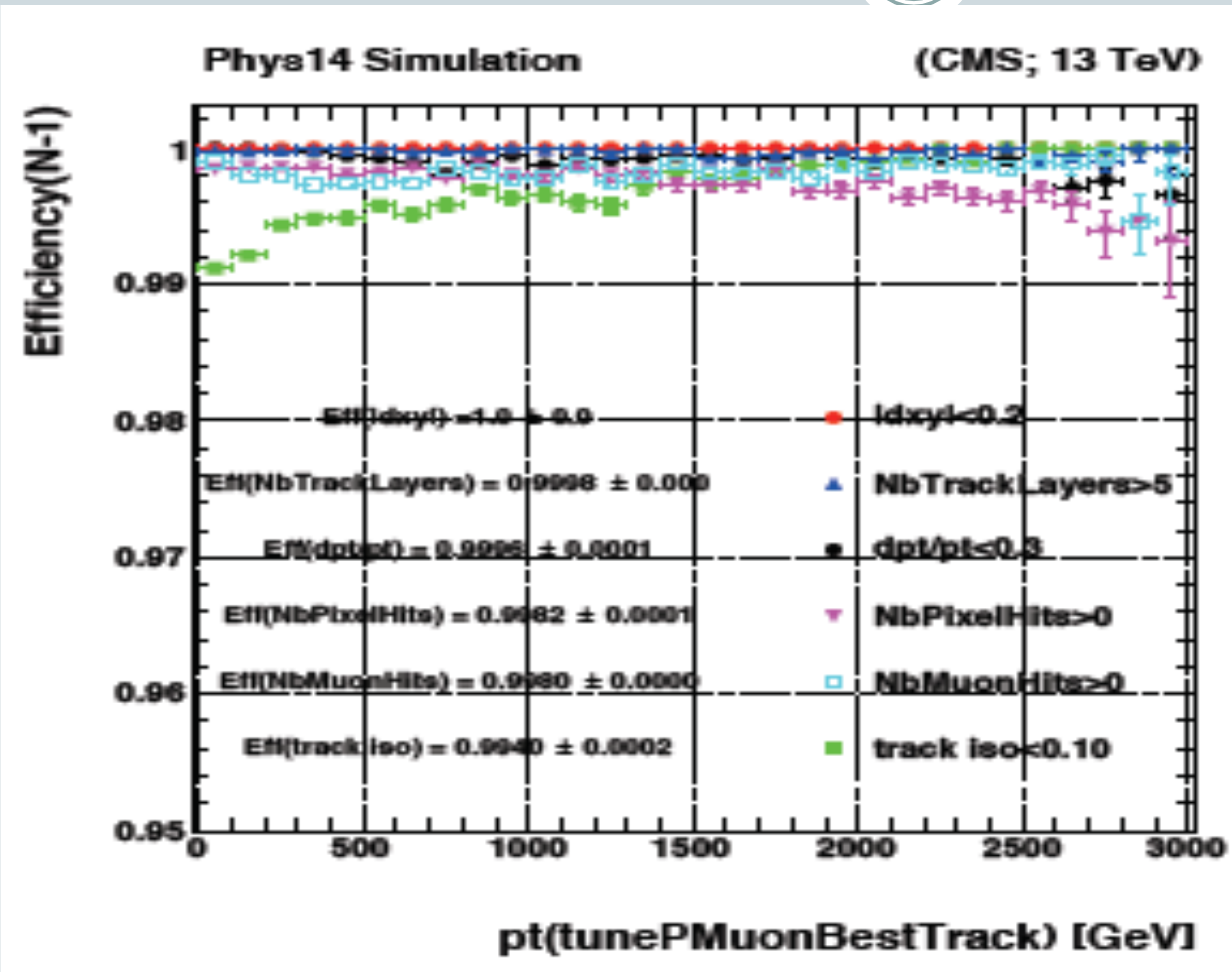
(1)2 Muons with opposite charge.

(2) 3D angle between two muons' momenta < pi-0.02.

(3) mass is computed from vertex fit ($\chi^2/d.o.f<10$)

N-1 Efficiency

According to old selections for different analysis with looser requirements on the number of track layers with fit



$$\text{Eff} = \frac{\text{No. of events passing all cuts}}{\text{No. of events passing all cuts but the one indicated}}$$

Measuring high pt muon ID efficiency (using Tag and probe Method)

Data

Estimating efficiency of Trigger and offline reconstruction

- **Calculation Strategy**

$$\varepsilon=\varepsilon_{Trigger} \times \varepsilon_{Id-Reco} \times \varepsilon_{Iso}$$

Full cuts except the isolation cut

Isolation Cut only

$$\varepsilon_{Id+Reco} = \frac{\text{Number of probes passing all Id cuts}}{\text{Total number of all probes}}$$

Tag Muon

Passes the full Id cuts

Probe muon

Muon with a very loose cut

1. Any muon with P_t>20 GeV.
2. pairs with opposite charge.
3. Within a specific mass window

- the efficiency of all selection criteria except isolation is measured

Region	$\lvert\eta\rvert < 0.9$	$0.9 < \lvert\eta\rvert < 1.2$	$1.2 < \lvert\eta\rvert < 2.1$	$2.1 < \lvert\eta\rvert < 2.4$
8Tev	$95.9 \pm 0.0(stat.)\%$	$95.8 \pm 0.0(stat.)\%$	$95.4 \pm 0.0(stat.)\%$	$94.8 \pm 0.0(stat.)\%$
13Tev	$98.611 \pm 0.00024\%$	$98.89 \pm 0.000534\%$	$98.439 \pm 0.000423\%$	$94.843 \pm 0.00216\%$
Difference	2.711%	3.09%	3.0%	0.04%

- the efficiency of the tracker –only isolation cut

$$m = \sqrt{(p_{tag} + p_{probe})^2}$$

98.6 %

$$\varepsilon_{Track.Iso} = \frac{\text{Number of probes passing relative track isolation cut}}{\text{Total number of all probes}}$$

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1. The efficiency calculations shows an improvement in phy14 if compared with 2012 Data with a little small differences. About 3-8% better than the previous analysis (ICHEP2012 version)
2. Gives a better agree with simulation

- the efficiency of the tracker –only isolation cut

98.6 %

$$\varepsilon_{Track.Iso} = \frac{\text{Number of probes passing relative track isolation cut}}{\text{Total number of all probes}}$$

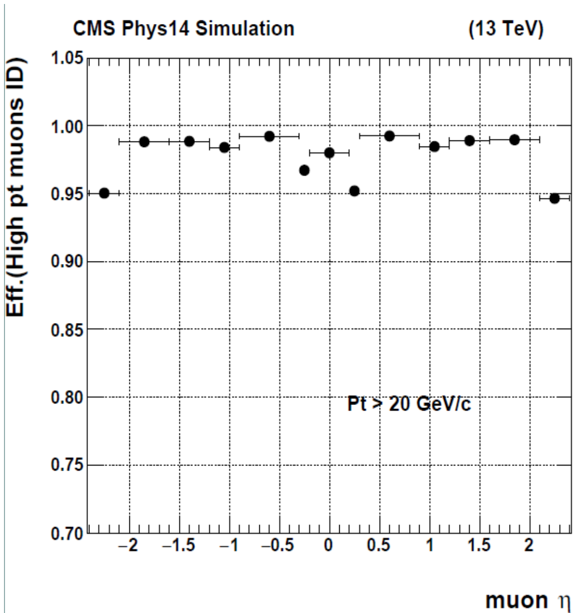
$$m = \sqrt{(p_{tag} + p_{probe})^2}$$

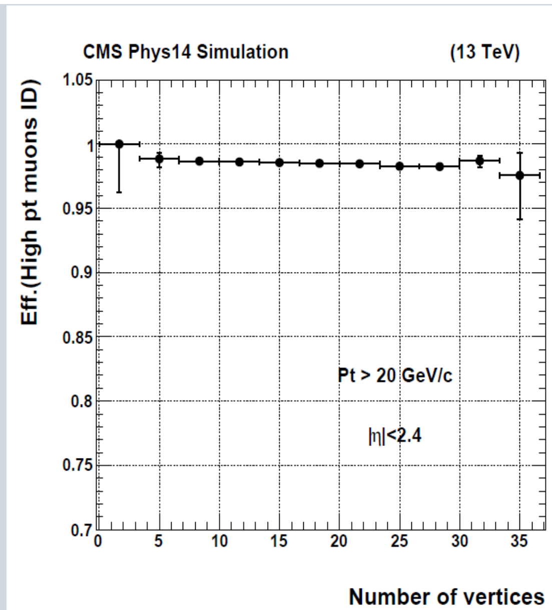
T&P results using PHy14 MC (13Tev)

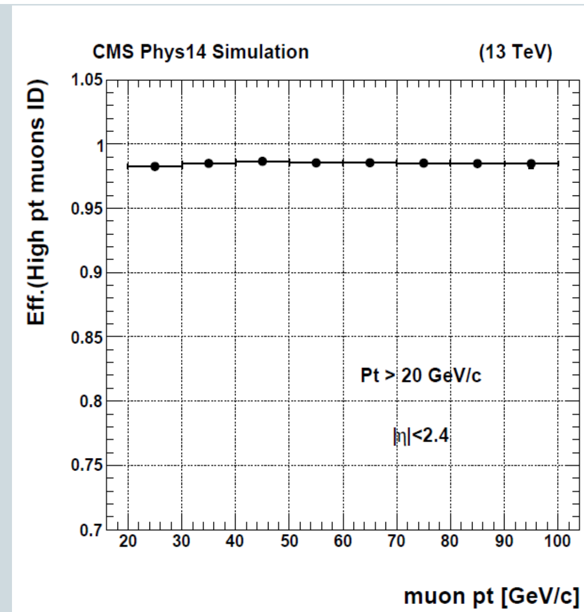
the efficiency of all above selection criteria except isolation is measured

Region	$-2.4<\eta<-2.1$	$-2.1<\eta<-1.6$	$-1.6<\eta<-1.2$	$-1.2<\eta<-0.9$	$-0.9<\eta<-0.3$	$-0.3<\eta<-0.2$
Efficiency	95.0396 ± 0.003	98.8219 ± 0.001	98.856 ± 0.001	98.406 ± 0.001	99.225 ± 0.000	96.723 ± 0.002

Region	$-0.2<\eta<0.2$	$0.2<\eta<0.3$	$0.3<\eta<0.9$	$0.9<\eta<1.2$	$1.2<\eta<1.6$	$1.6<\eta<2.1$	$2.1<\eta<2.4$
Efficiency	98.012 ± 0.001	95.201 ± 0.002	99.252 ± 0.000	98.470 ± 0.001	98.910 ± 0.001	98.973 ± 0.001	94.654 ± 0.003



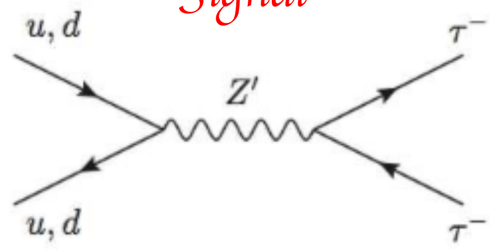




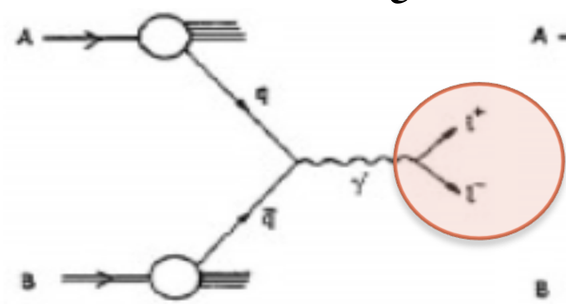
The efficiency with respect to the number of vertices & pt shows a flat behavior.

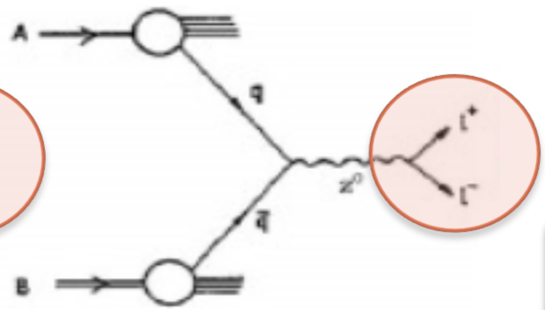
Dataset path : /DYJetsToLL M-50 13TeV-madgraph-pythia8/Phys14DR-PU20bx25 PHYS14 25 V1-v1

Expected background



1. *Irreducible background* (*Drell Yann process*)





Obeys the same selections of Z'

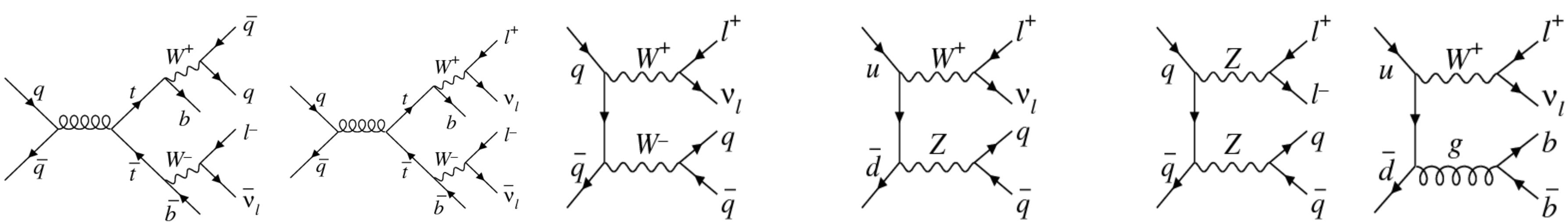
- The contribution from DY decreases at the tail of the mass distribution

2. *Reducible background*

$$Z/\gamma^* \to (t\bar{t},\ \tau^+\tau^-, tW, \bar{t}W, WW, WZ, ZZ,\ W+Jets, QCDJets)$$

13% | 5% | 1%

$e\mu$ *method* | Data vs MonteCarlo | Isolation cut



$t\bar{t}$ Background Estimation (using eμ method)

$$p(e\mu) = 2p(\mu\mu) = 2p(ee)$$

MC

- **Aim**: Estimate the contributions from any process with two real leptons in the final state where the number of dimuon events is estimated from the electron-muon spectrum

- **Selections (as pioneered by HEEP group)**

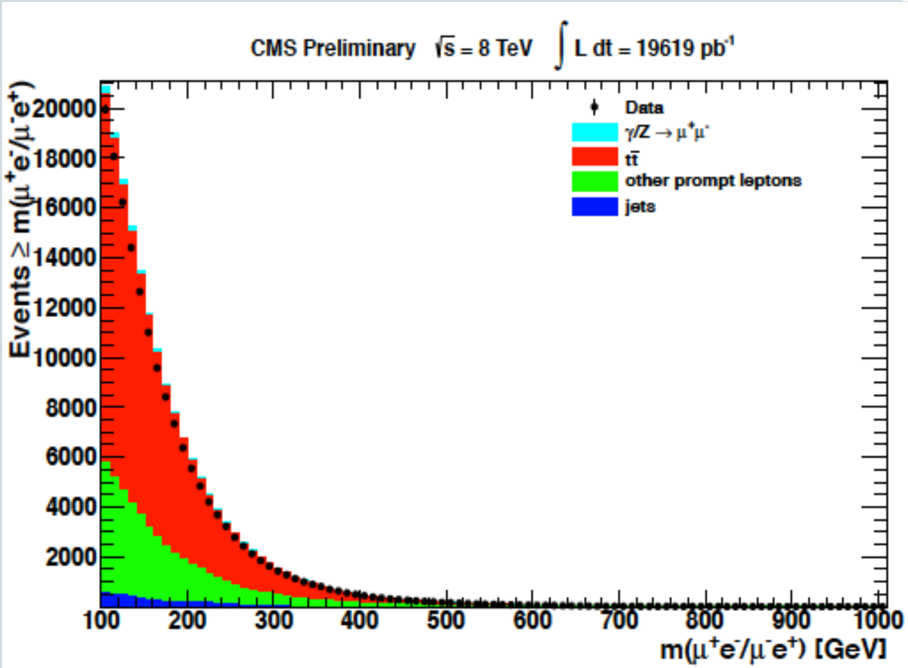
1. The first muon is chosen such that it passes the high P_T muon identification criteria
2. The second object is an electron passing HEEP V5.1 selection
3. Both leptons are required to have P_T>35 GeV
4. The invariant mass of opposite sign pairs exceeds 60 GeV

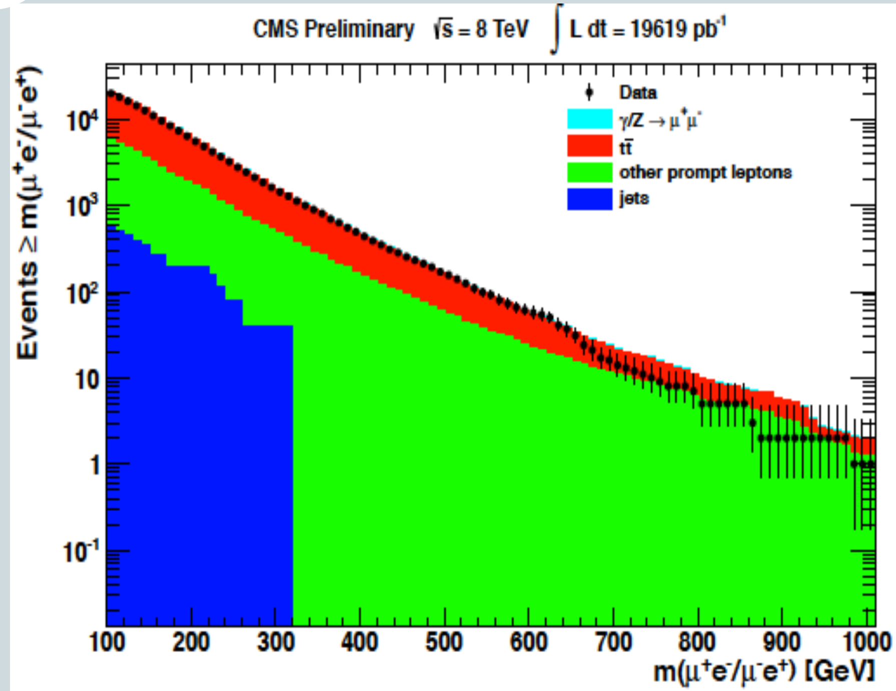
$$N^{est}_{BG\to\mu^+\mu^-} = N^{obs}_{e^\pm\mu^\mp} \times \frac{N_{BG\to\mu^+\mu^-}}{N_{BG\to e^\pm\mu^\mp}}$$

- **Pure MonteCarlo Method**

$e\mu$ method results at 8 TeV

$Z \longrightarrow \tau\tau, WW, WZ, ZZ \text{ and } tW$

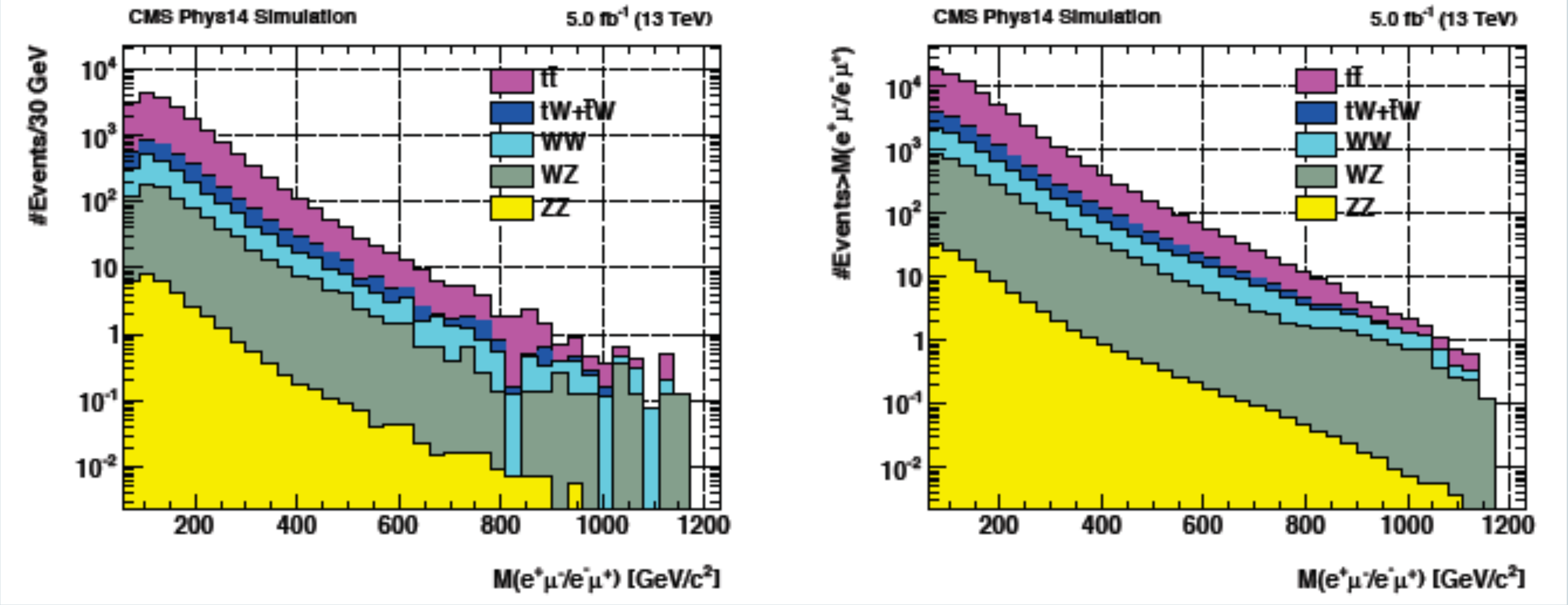




Mass range	$N(e^\pm\mu^\mp)$ observed	$\mu\mu/e\mu$ scale factor	$N(\mu^+\mu^-)$, $e\mu$ prediction	$N(\mu^+\mu^-)$, sim. prediction
120–200 GeV	10684	0.533 ± 0.005	5695 ± 77	5912 ± 391
200–400 GeV	5111	0.602 ± 0.007	3077 ± 56	3223 ± 214
400–600 GeV	381	0.665 ± 0.031	253 ± 18	257 ± 18

eμ method at 13 TeV

$Z \longrightarrow \tau\tau, WW, WZ, ZZ$ and tW



Jet Background Estimation (using Fake rate method)

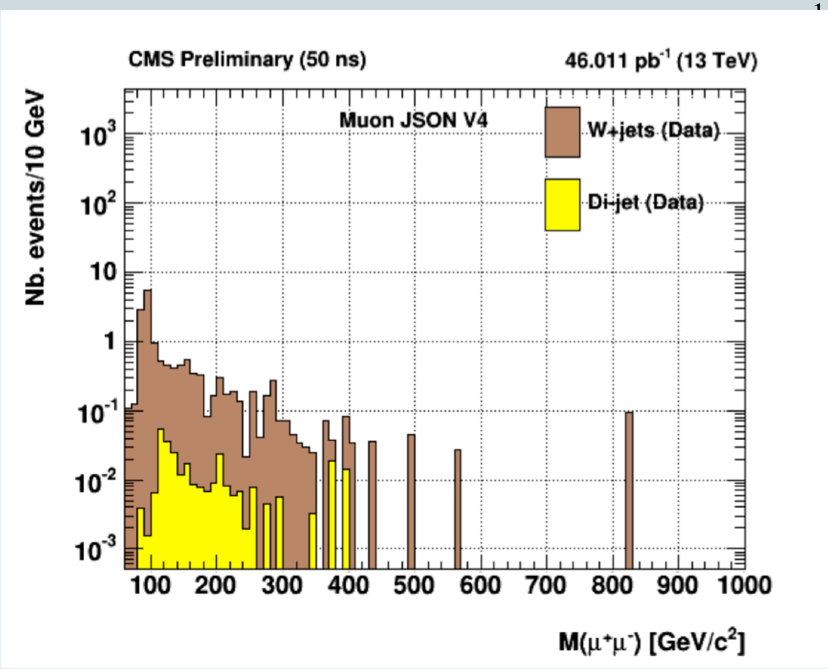
Aim: Estimating the Jets misidentified as Muons (contamination from Jets)

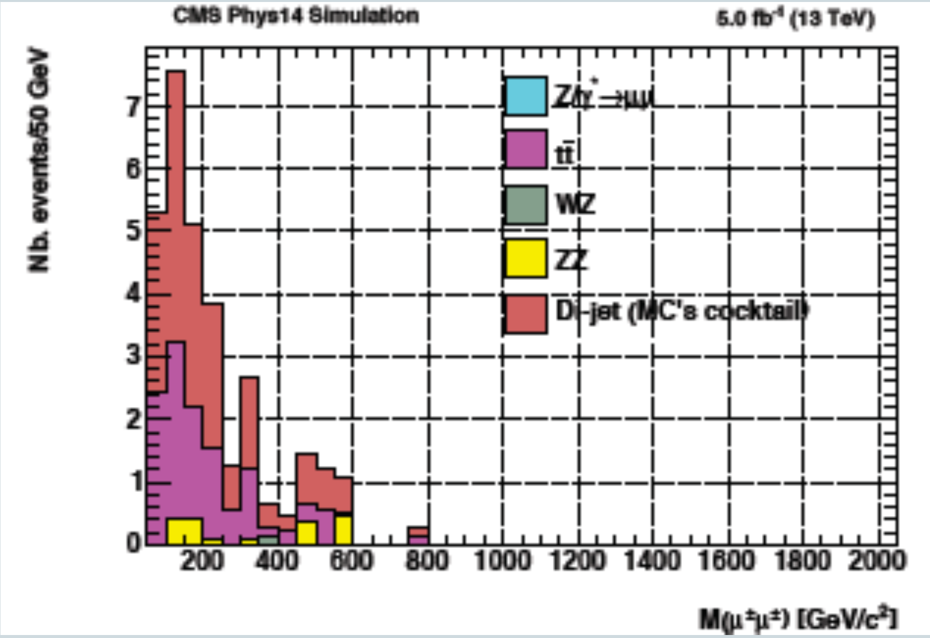
- always estimated from Data

Single Jet | QCD diJet

$$Fake\ Rate = \frac{\text{No. of Muons passing all cuts[Id and isolation]}}{\text{No.of Muons passing loosly isolation cut}}$$

W+Jet and diJet





From 8 TeV data

Mass region (GeV)	W+jets opp.-sign	W+jets same-sign
120–200	40 ± 7	25 ± 5
200–400	20 ± 3	12 ± 5
400–600	2 ± 1	1 ± 1
> 600	1 ± 0.4	0.1 ± 0.1

Mass region (GeV)	dijets opp.-sign	dijets same-sign
120–200	19 ± 1	8 ± 1
200–400	6 ± 0.4	3 ± 0.3
400–600	0.4 ± 0.1	0.1 ± 0.1
> 600	0.1 ± 0.1	0.03 ± 0.03

Mass region (GeV)	W+jets opp.-sign	W+jets same-sign
120–200	40 ± 7	25 ± 5
200–400	20 ± 3	12 ± 5
400–600	2 ± 1	1 ± 1
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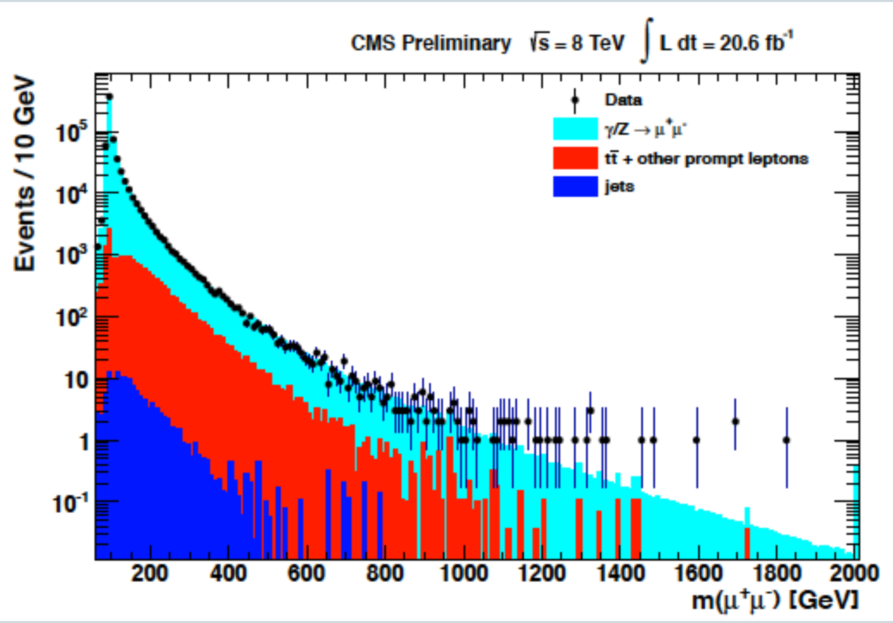
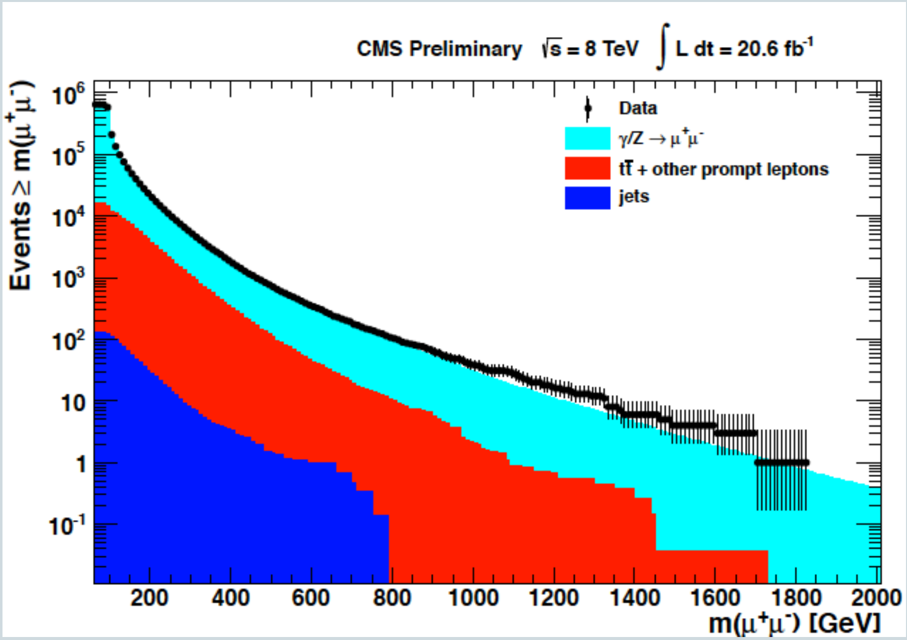
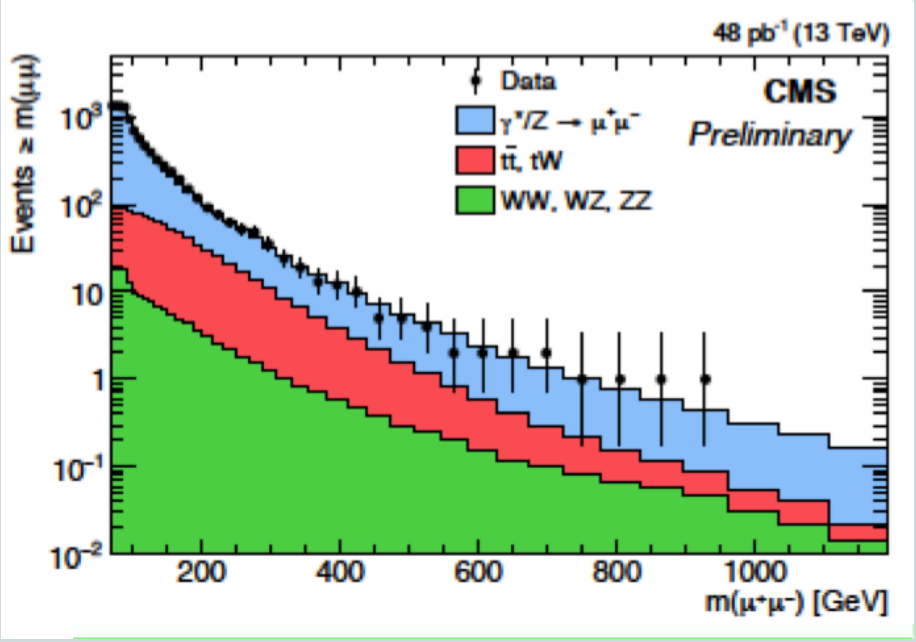
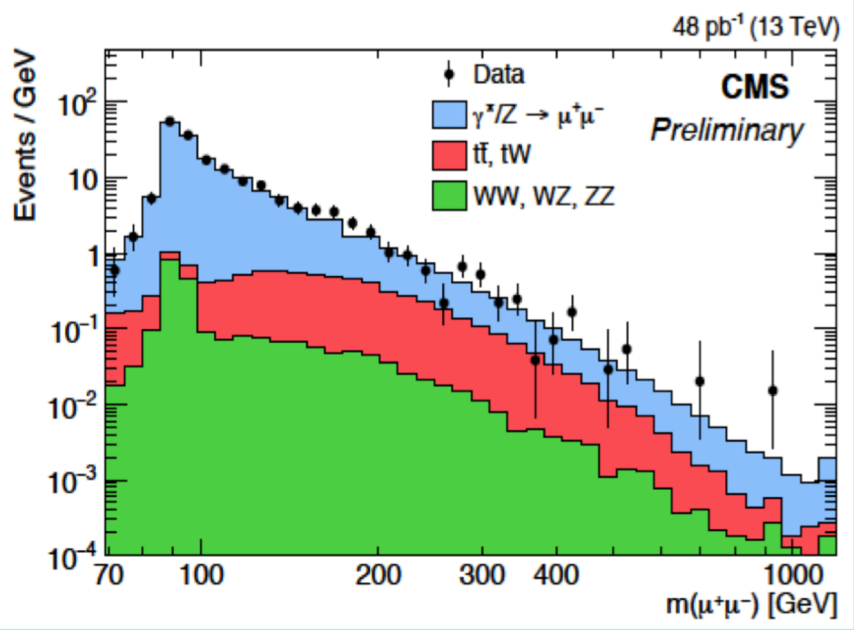
Invariant mass spectrum at 8 TeV





Invariant mass spectrum at 13 TeV

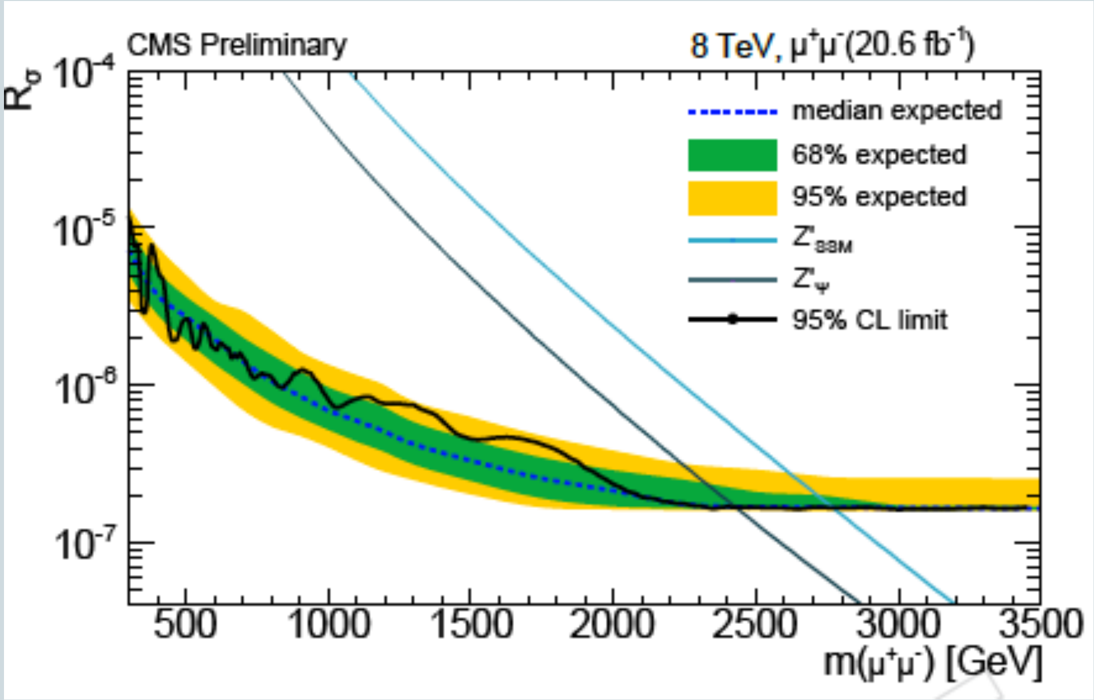




Conclusion

- Based on the data samples corresponding to integrated luminosity 20.6fb^{-1} collected at 8Tev in 2012,the analysis excludes with 95%

1. the sequential standard model Z'_{SSM} lighter than 2770 GeV .
2. Superstring-inspired Z'_{ψ} lighter than 2430 GeV



Present work and progress

- $Z^{/}$ search continues with much higher motivation in Run2.
- The dimuon group in CMS collaboration working on this analysis at 14 Tev.
- Comparisons between Run1 results and Monte Carlo samples(phys14 and spring15) have already finished.
- These results are already certified by CMS and part of it has already introduced in LHCB conference http://www. lhcp2015.com
- Waiting for more data, to complete the analysis.

Data

Data

Data

"Data are coming! Data are coming!"

References

2014/02/18
Head Id: 225275
Archive Id: 157905:228126M
Archive Date: 2014/01/31
Archive Tag: trunk

CMS Draft Analysis Note

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Search for High-Mass Resonances Decaying to Muon Pairs in pp Collisions at $\sqrt{s} = 8$ TeV

G. Alverson[1], I. Belotelov[2], D. Bourilkov[3], D. Brandenburg[3], R. Cousins[4], I.K. Furić[3],

2015/07/21
Head Id: 290074
Archive Id: 286968:297570MP
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Search Strategy for High-Mass Resonances Decaying to Muon Pairs at $\sqrt{s} = 13$ TeV in Preparation of the Run2

G. Abbiendi[4], G. Bagliesi[6], L. Benato[5], D. Bourilkov[11], S.S. Chhibra[3], A. Colaleo[3], R. Cousins[10], G. Daskalakis[2], N. De Filippis[3], S. Elgammal[1], V.A. Giakoumopoulou[2], A. Lanyov[9], K.A Larson[12], K.P. Lee[8], S. Marcellini[4], A. Meneguzzo[5], K.W. Nam[8], N. Neumeister[12], A. Perrotta[4], F. Primavera[12], A. Qamesh[1], R. Radogna[3], F. Simonetto[5], P. Spagnolo[6], P. Traczyk[7], V. Valuev[10], and H.D. Yoo[8]

[1] CTP, British University, ENHEP and Cairo University, Cairo, Egypt

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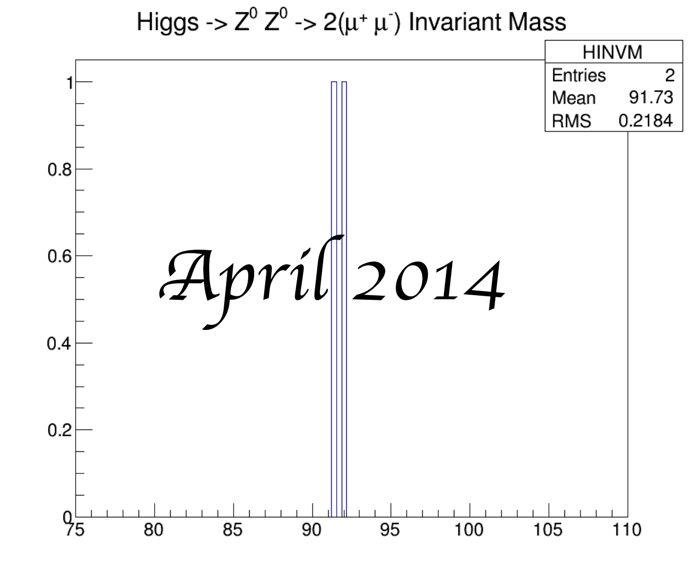
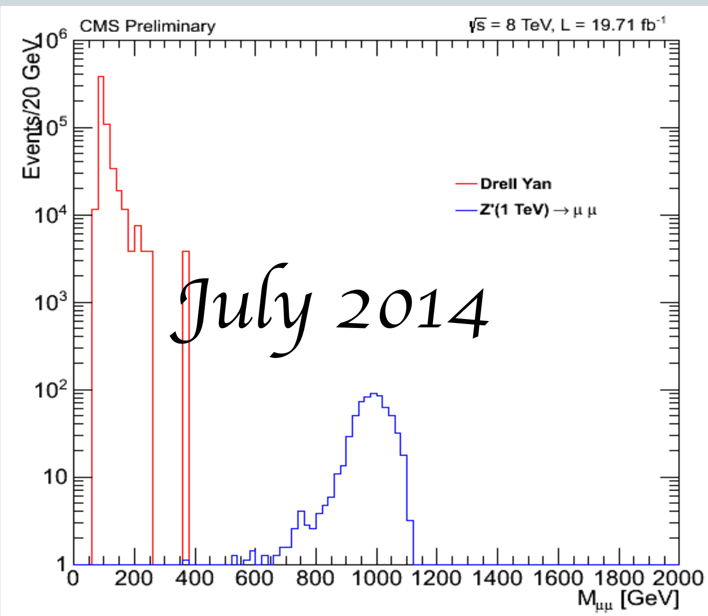


April 2014



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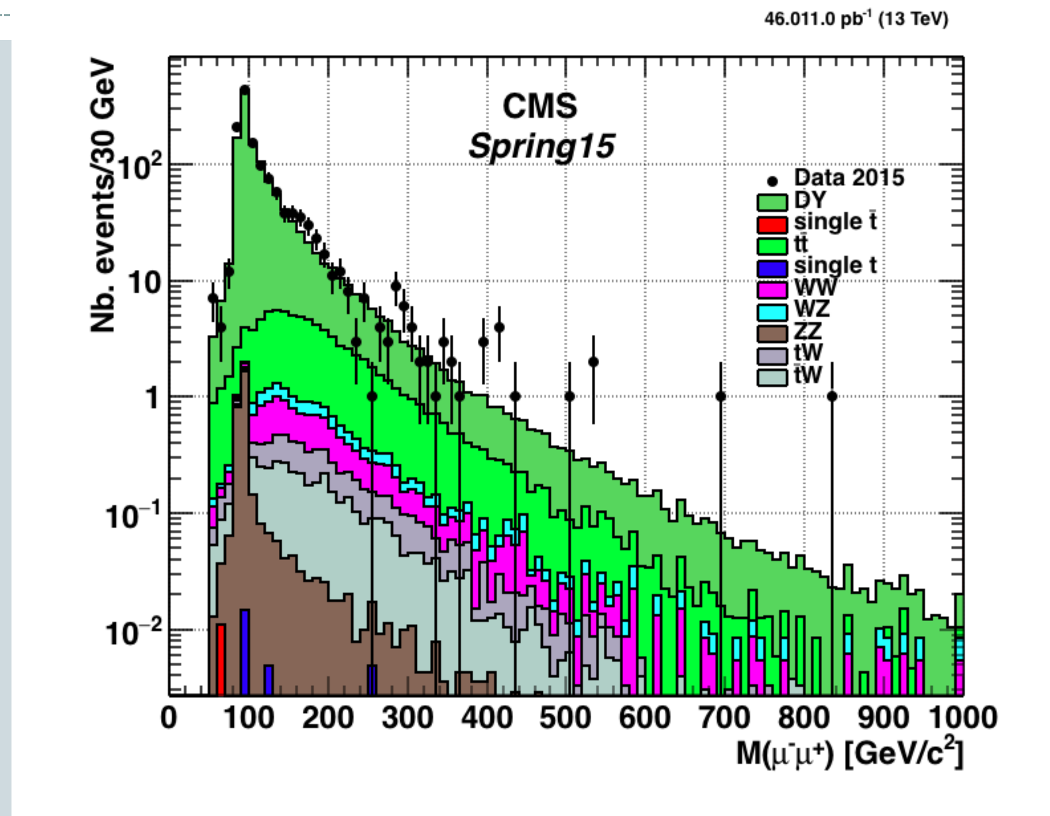

November 2015

Thank you