Search for $Z^{\prime}$ boson decaying to Muon pairs at LHC [Run1]

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“Diffractive and electromagnetic processes at high energies”

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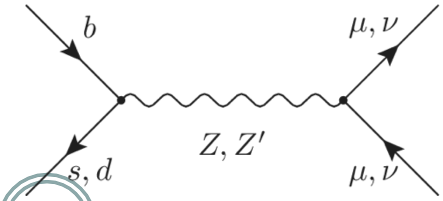
Z' Resonance BSM



- Weak Hypercharge
- Week IsoSpin
- Strong interaction

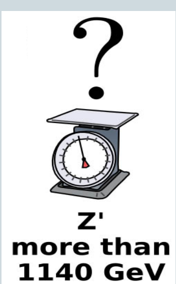
- Standard model gauge groups $[SU(3)\times SU(2)_L \times U(1)_Y]$
- the success of the electroweak theory opened the possibility of another unification between the strong interaction and EW interaction.
- The minimal simple group which contains the standard model gauge groups is SU(5) $SU(5)\supset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

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

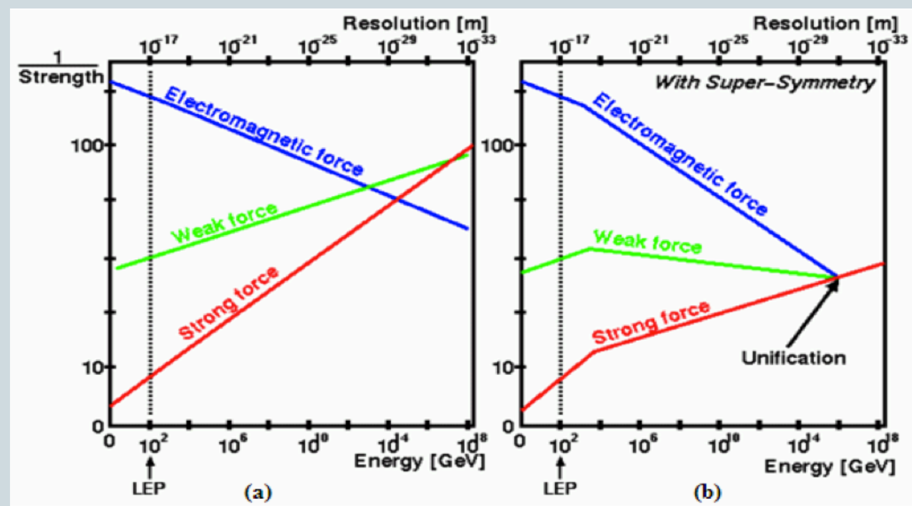
- Most of BSM expects the existence of an extra gauge boson
- The new gauge boson behaves like

The standard model Z boson

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

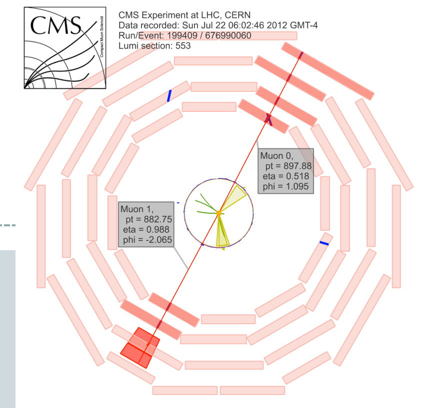


Additional $U(1)'$



Z' search at CMS

what we are looking for [two muons with opposite charge]



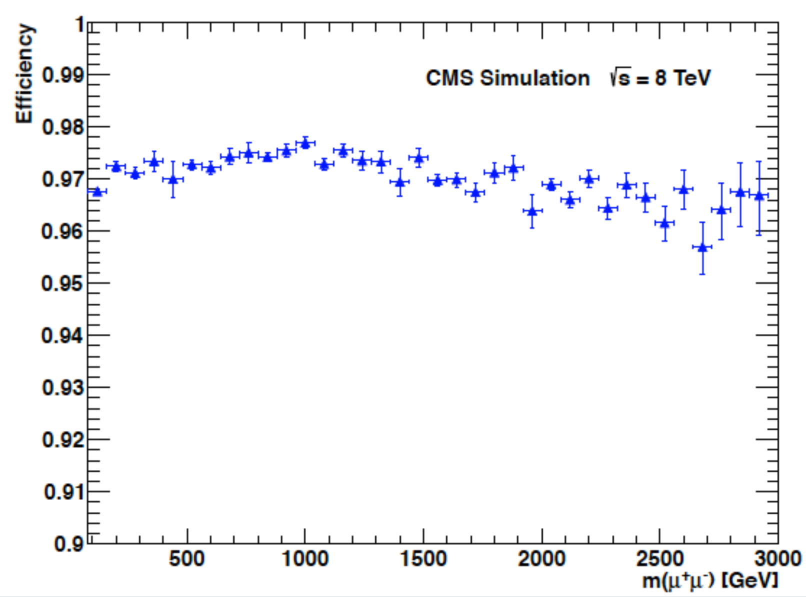
Higher in Mass than the SM Z Boson
gives the same final state as the SM Z boson
Neutral
Spin 1

1. Trigger requirements (Run1 vs Run2)

- The trigger path used at 8 TeV is:

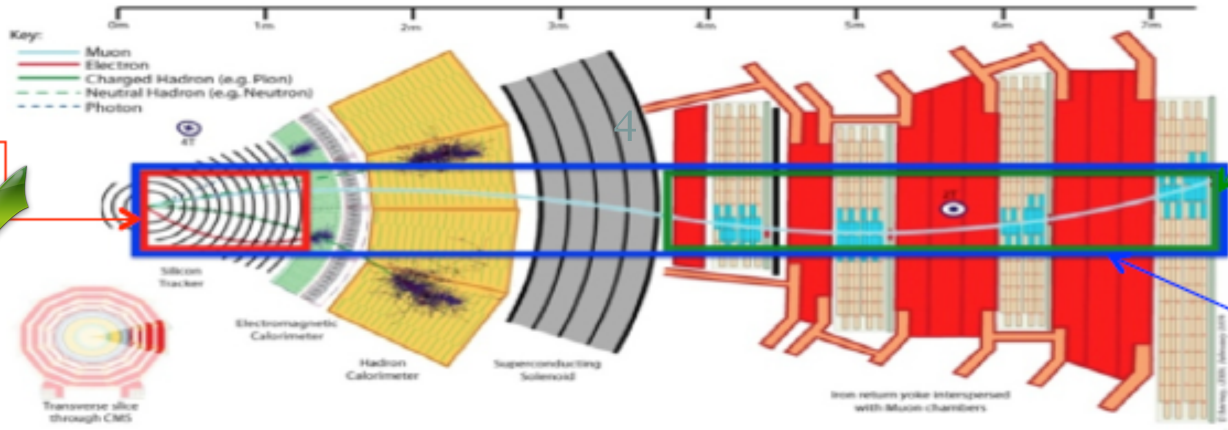
  HLT Mu40 eta2p1

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



- New Muon station have been installed during the long shutdown ME4/2, which covers the region $2.1 < |\eta| < 2.4$
- 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 $\frac{\sum p_T}{p_T}$

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

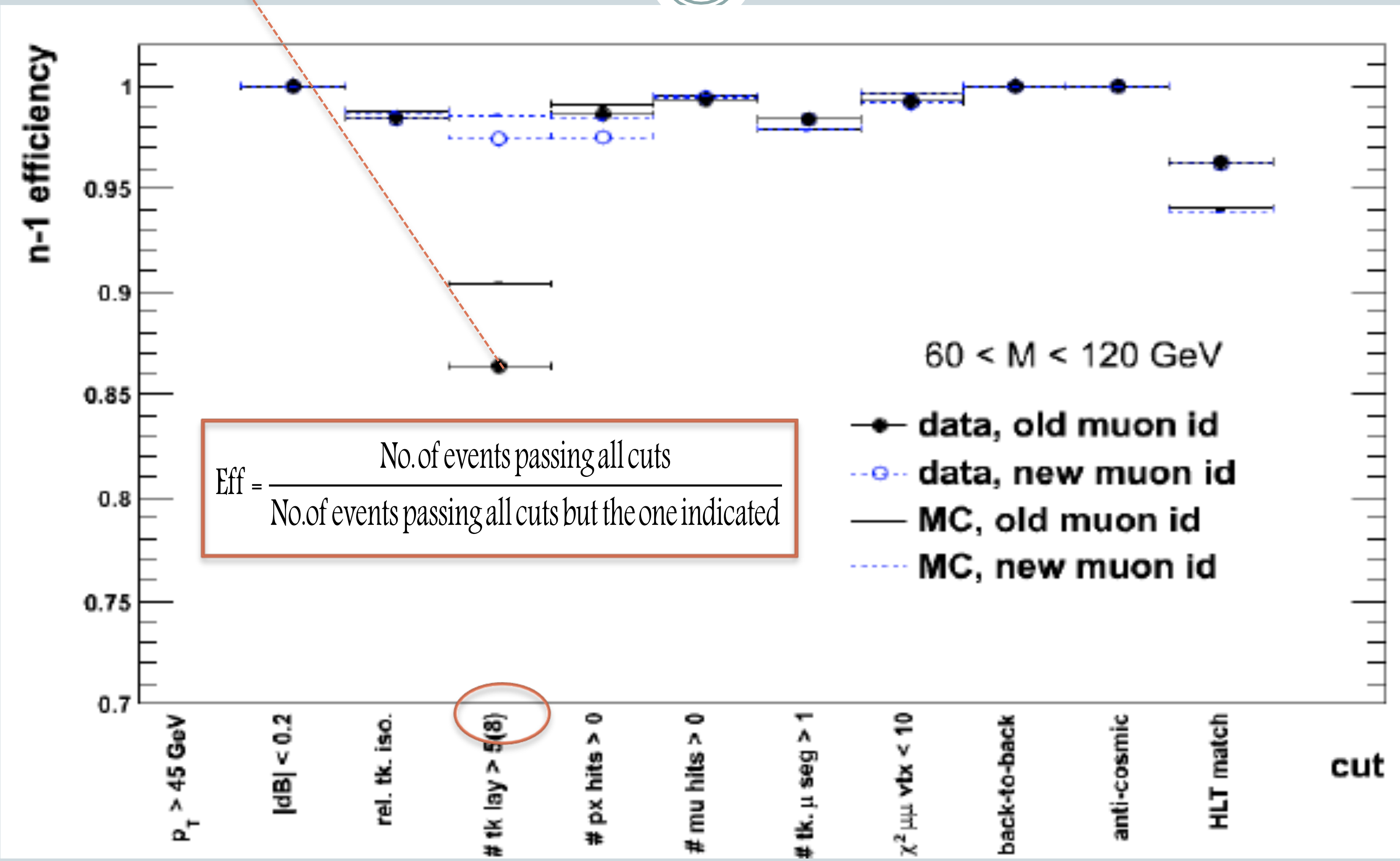
(7) |dxy| < 0.2
(8) pt > 45.0 GeV
(9) $\delta p_T/P_T$<0.3

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



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

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	$95.9 \pm 0.0(stat.)\%$	$95.8 \pm 0.0(stat.)\%$	$95.4 \pm 0.0(stat.)\%$	$94.8 \pm 0.0(stat.)\%$

1. About 3-8% better than the previous analysis (ICHEP2012 version)
2. Gives a better agree with simulation

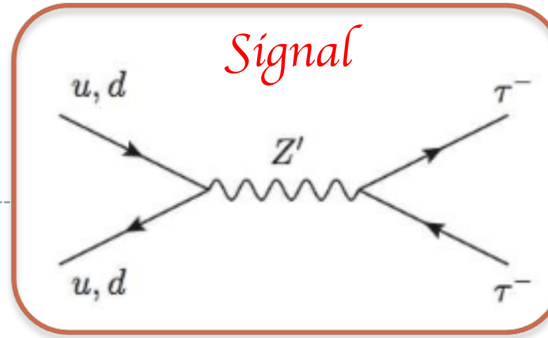
- the efficiency of the tracker –only isolation cut

98.6 %

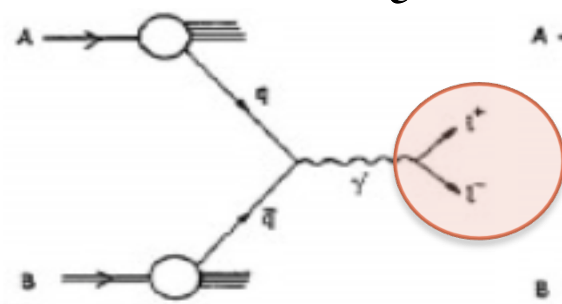
$$\varepsilon_{Track.Iso} = \frac{\text{Number of probes passing relative track isolation cut}}{\text{Total number of all probes}}$$

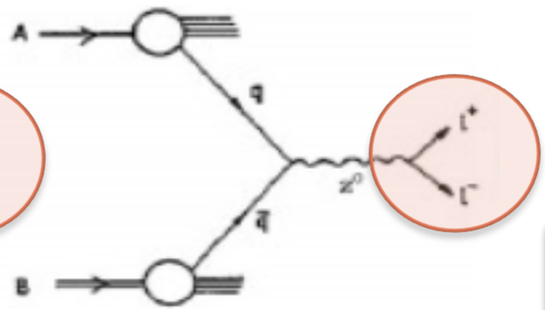
$$m = \sqrt{(p_{tag} + p_{probe})^2}$$

Expected background



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





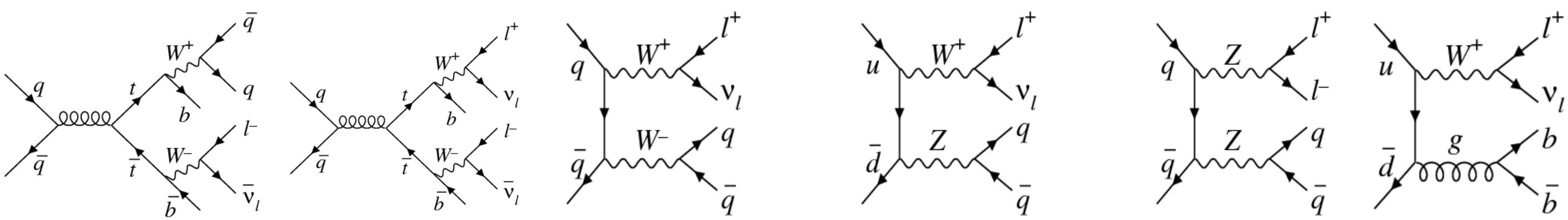
Obeys the same selections of Z'

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

2. *Reducible background*

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

$t\bar{t}$	$\tau^+\tau^-, tW, \bar{t}W, WW, WZ, ZZ$	$W + Jets, QCDJets$
13%	5%	1%
$e\mu$ *method*	Data vs MonteCarlo	Isolation cut



$t\bar{t}$ Background Estimation (using $e\mu$ 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)

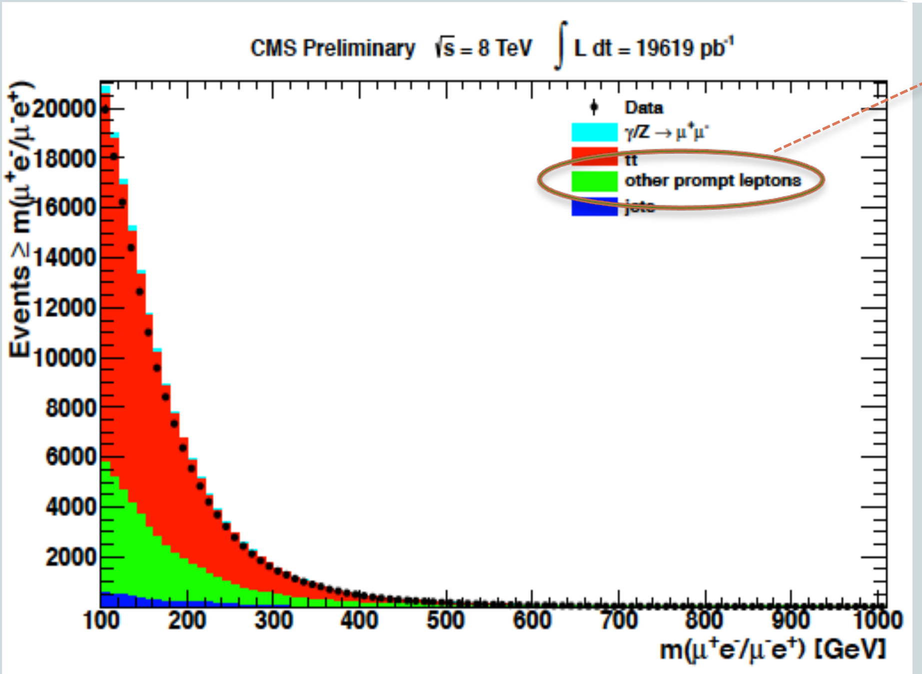
1. The first muon is chosen such that it passes the high P_T muon identification criteria
2. The second object is an electron passing HEEP V5.1 selection
3. Both leptons are required to have P_T>35 GeV
4. The invariant mass of opposite sign pairs exceeds 60 GeV

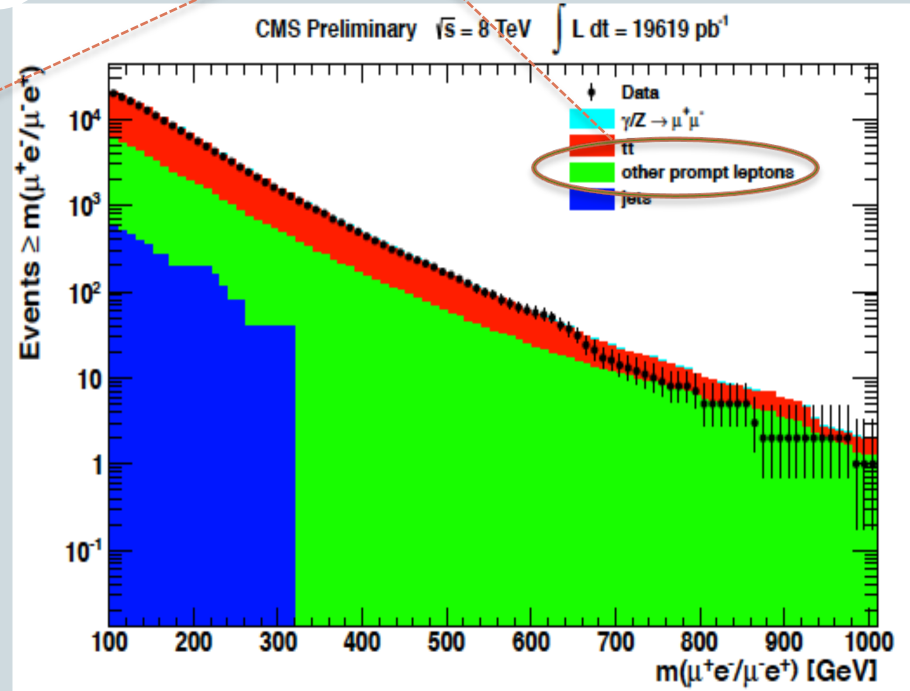
$$N^{est}_{BG\to\mu^+\mu^-} = N^{obs}_{e^\pm\mu^\mp} \times \frac{N_{BG\to\mu^+\mu^-}}{N_{BG\to e^\pm\mu^\mp}}$$

- Pure MonteCarlo Method

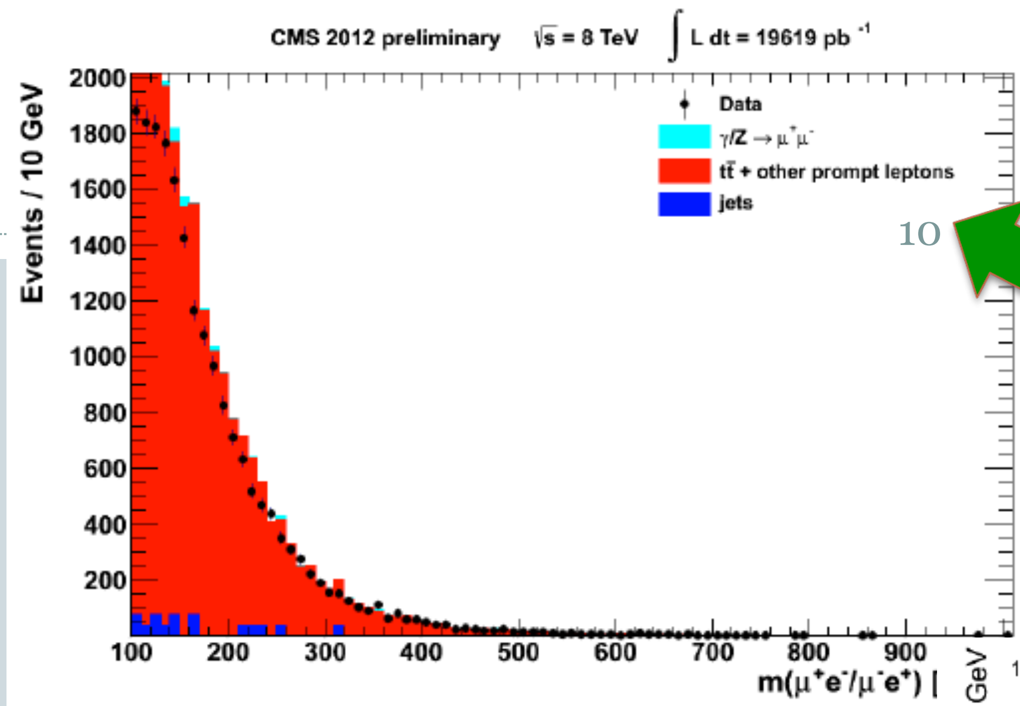
$e\mu$ method results at 8 TeV

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

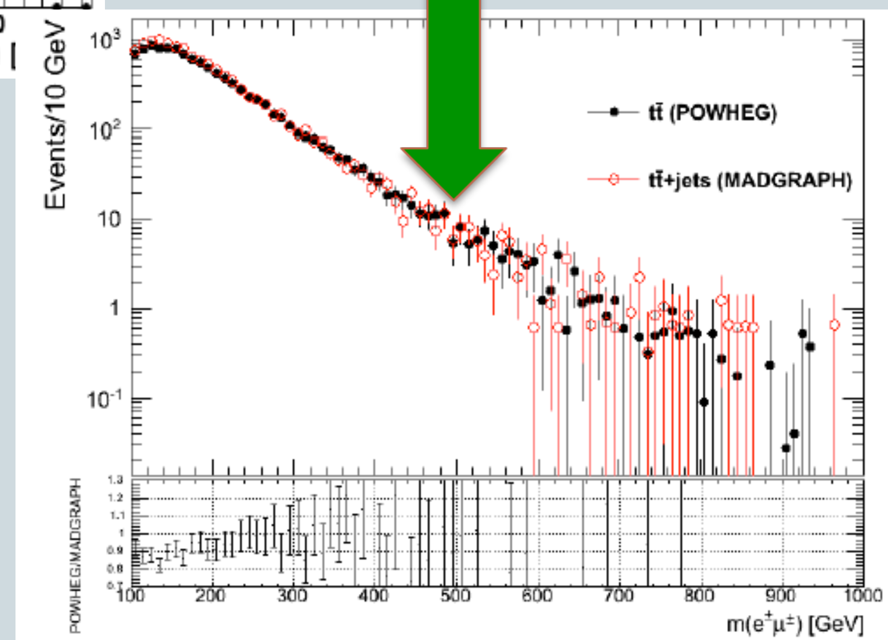




Mass range	$N(e^\pm\mu^\mp)$ observed	$\mu\mu/e\mu$ scale factor	$N(\mu^+\mu^-)$, $e\mu$ prediction	$N(\mu^+\mu^-)$, sim. prediction
120–200 GeV	10684	0.533 ± 0.005	5695 ± 77	5912 ± 391
200–400 GeV	5111	0.602 ± 0.007	3077 ± 56	3223 ± 214
400–600 GeV	381	0.665 ± 0.031	253 ± 18	257 ± 18



$t\bar{t}$ *with Madgraph*



Jet Background Estimation (using Fake rate method)

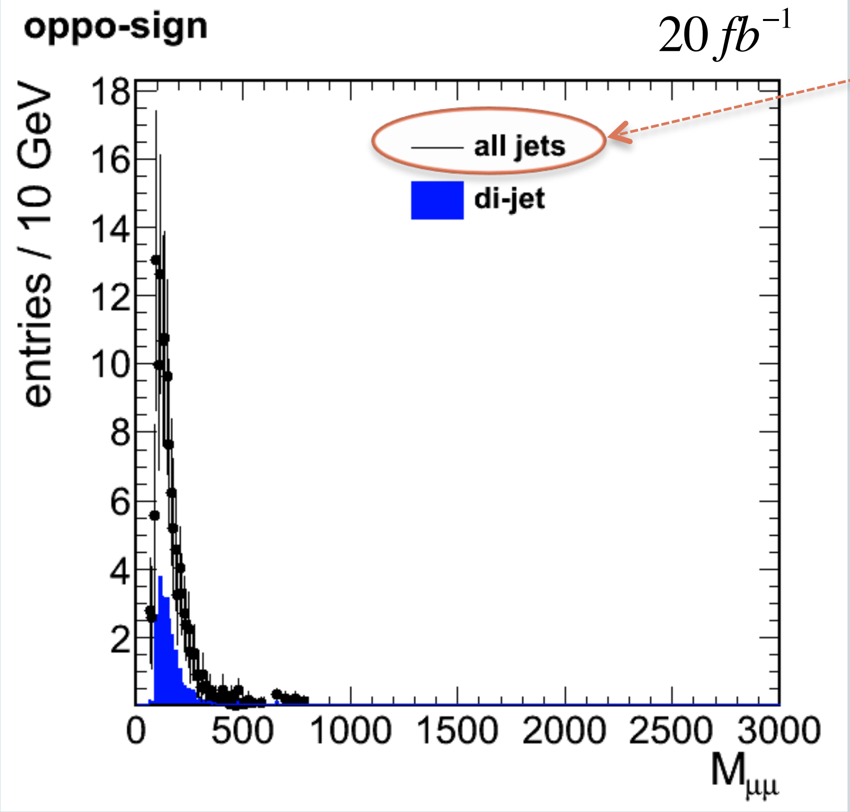
Aim: Estimating the Jets misidentified as Muons (contamination from Jets)

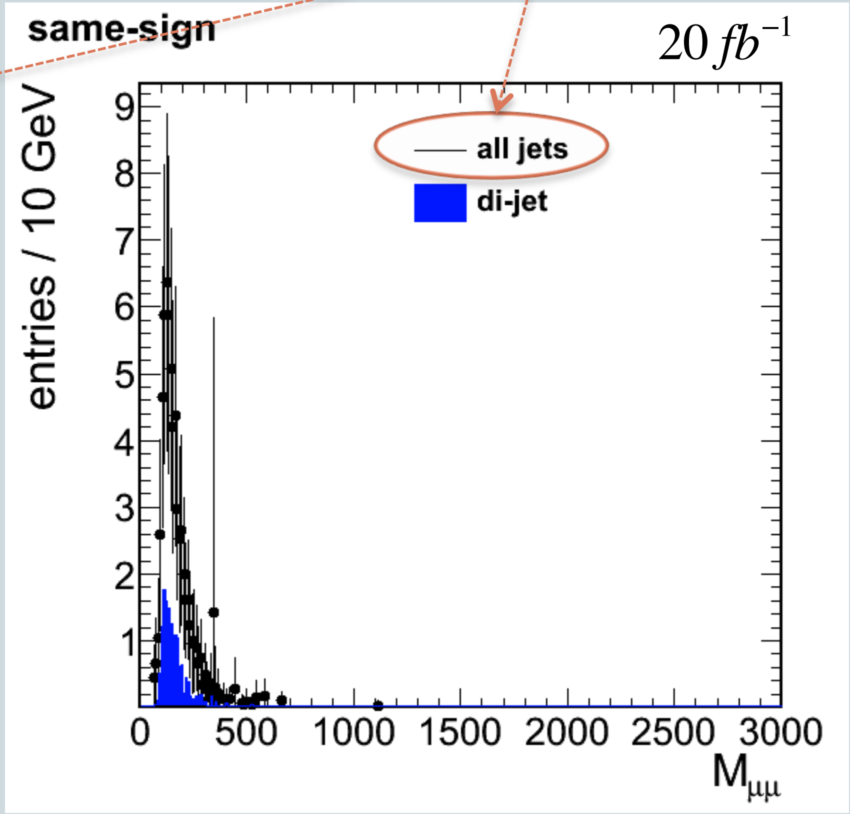
- always estimated from Data

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





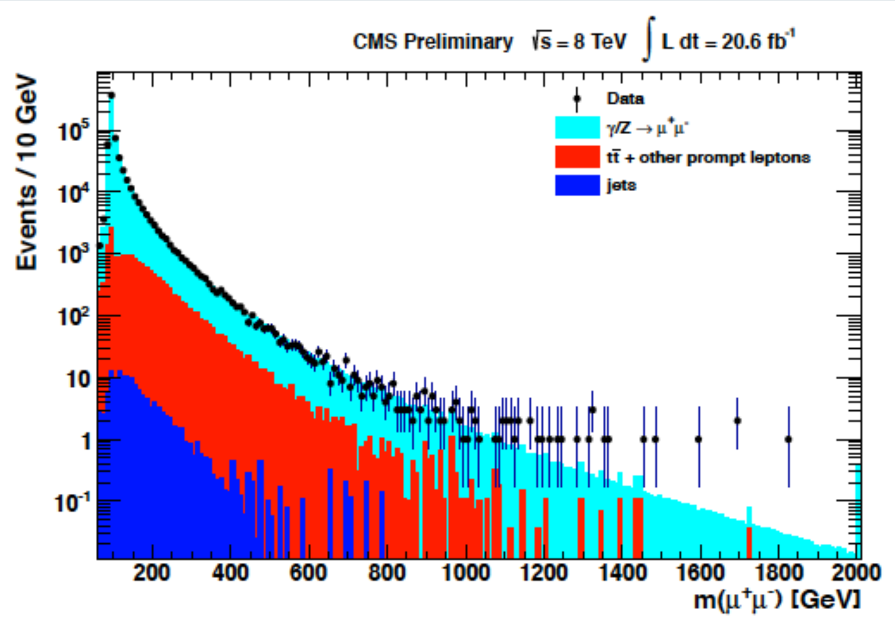
Mass region (GeV)	W+jets opp.-sign	W+jets same-sign
120–200	40 ± 7	25 ± 5
200–400	20 ± 3	12 ± 5
400–600	2 ± 1	1 ± 1
> 600	1 ± 0.4	0.1 ± 0.1

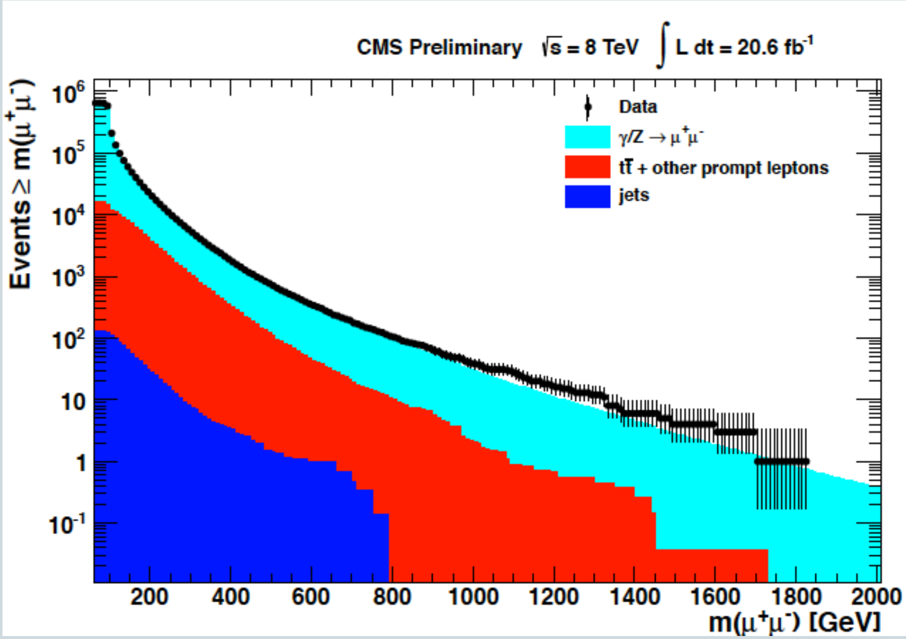
Mass region (GeV)	dijets opp.-sign	dijets same-sign
120–200	19 ± 1	8 ± 1
200–400	6 ± 0.4	3 ± 0.3
400–600	0.4 ± 0.1	0.1 ± 0.1
> 600	0.1 ± 0.1	0.03 ± 0.03

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
> 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

Invariant mass spectrum

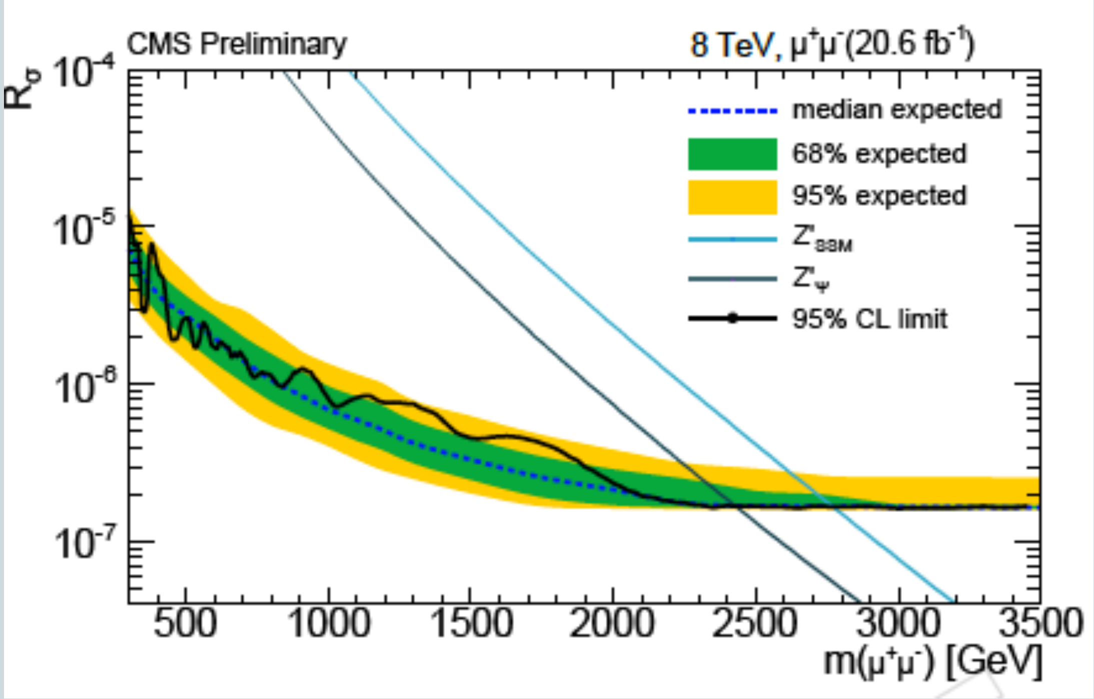




Conclusion

- 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 MonteCarlo samples(phys14 and spring15) have already finished.
- Waiting for more data, to complete the analysis.

Data

Data

Data

References

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

CMS Draft Analysis Note

The content of this note is intended for CMS internal use and distribution only

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
Archive Date: 2015/05/25
Archive Tag: trunk

CMS Draft Analysis Note

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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],

Backup

MontCarlo Data sets for background

$Z/\gamma^* \to \mu^+\mu^-$	/DYToMuMu_M-20_CT10_TuneZ2star_8TeV-powheg-pythia6/Summer12_DR53X-PU_S10_START53_V7A-v1
	/DYToMuMu_M-120_CT10_TuneZ2star_8TeV-powheg-pythia6/Summer12_DR53X-PU_S10_START53_V7A-v1
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	/DYToMuMu_M-500_CT10_TuneZ2star_8TeV-powheg-pythia6/Summer12_DR53X-PU_S10_START53_V7A-v1
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	/DYToMuMu_M-2000_CT10_TuneZ2star_8TeV-powheg-pythia6/Summer12_DR53X-PU_S10_START53_V7C2-v1
$Z/\gamma^* \to \tau^+\tau^-$	/DYToTauTau_M-20_CT10_TuneZ2star_8TeV-powheg-pythia6/Summer12_DR53X-PU_S10_START53_V7A-v1
$t\bar{t}$	/TT_CT10_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v2
tW	/T_tW-channel-DR_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1
$\bar{t}$W	/Tbar_tW-channel-DR_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1
WW	/WW_TuneZ2star_8TeV_pythia6_tauola/Summer12_DR53X-PU_S10_START53_V7A-v1
WZ	/WZ_TuneZ2star_8TeV_pythia6_tauola/Summer12_DR53X-PU_S10_START53_V7A-v1
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W+jets	/WJetsToLNu_TuneZ2Star_8TeV-madgraph-tarball/Summer12_DR53X-PU_S10_START53_V7A-v1
Incl-μ QCD	/QCD_Pt_20_MuEnrichedPt_15_TuneZ2star_8TeV_pythia6/Summer12_DR53X-PU_S10_START53_V7A-v3

Thank you