Search for dilepton heavy resonances in CMS

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On behalf of the CMS collaboration

OUTLINE

LHC and CMS

Electron, muon, missing energy and jet identification

Z' and Randall-Sundrum search (1.1 fb^{-1})

W' search (1.1 fb^{-1})

Excited electron search (36 pb^{-1})

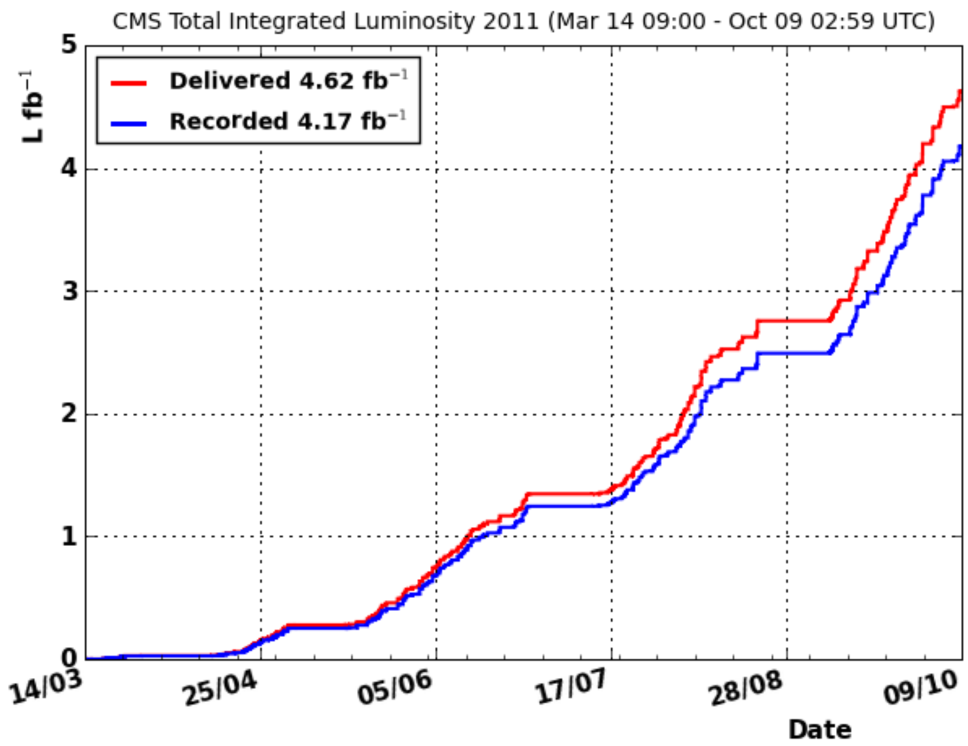
LHC

LHC (re)started in October 2009
(900 GeV, then 2.38 TeV)

Switched to 7 TeV on March 2010

Delivered 47.03 pb^{-1} in 2010

Peak luminosity in 2011
3.3 nb^{-1} s^{-1}

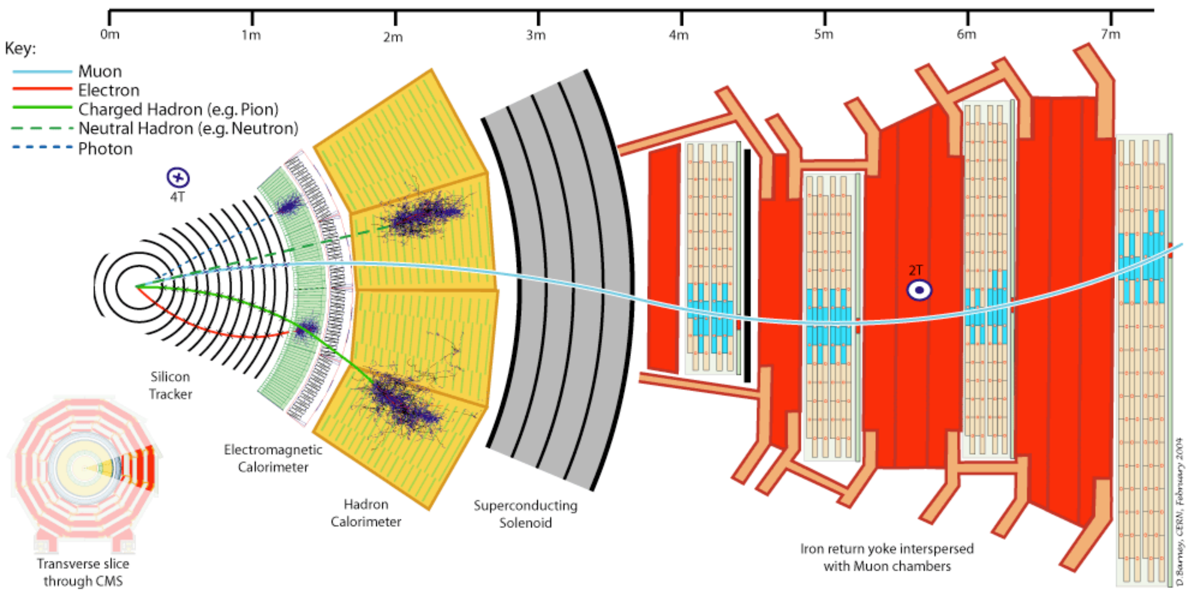


CMS

- Fine-grained crystal ECAL, $\Delta E/E < 0.5\%$ for $E > 100$ GeV

- Inner tracker in 3.8 T magnetic field + magnetic system outside solenoid, $\Delta p_T/p_T < 10\%$ at $p_T \sim 1$ TeV

- Muon identification easier than electron, background smaller, but worst resolution for high mass resonances



LEPTON ID

Both analyses use official CMS high energy electron and muon identification

Selection optimized for high efficiency at high energy
Lowest E_T unprescaled (di)photon and muon trigger
Offline E_T cut above trigger turn-on
- electron: E_T > 25 GeV (2010), > 35 - 40 GeV (2011)
- muon E_T > 20 GeV (2010), > 35 GeV (2011)

Energy scale correction applied for end-cap electrons (π^0 and Z)

Identification and trigger efficiencies measured with the tag and probe method

Scale factor to account for data – Monte Carlo (MC) efficiency difference applied

JET BACKGROUND

A jet can fake an electron or a muon

Measure this contamination by the “fake rate “ method:

- Measure the probability for a jet reconstructed as a lepton or photon, (with loosened cuts) to pass the rest of the selection

- Apply to get the mass spectrum from jets and compare to MC

- Estimate systematic uncertainty from different methods and jet thresholds

NEUTRAL BOSONS

New gauge boson Z' or Randall-Rundrum graviton G_{KK}
- new narrow high mass neutral resonance

Results normalized to the Z peak
- luminosity and other systematic effects cancel or are reduced

Dielectrons
- no charge requirement
- endcap-endcap pairs rejected (higher background)

Dimuons
- looser cuts (less background from jets)
- cosmic muons used to understand high p_T muons
- reject background from cosmic muons

DILEPTON BACKGROUND

Dominant: irreducible Drell-Yan (DY) production
- estimate by MC and low mass control region

Next biggest (10% of DY above 120 GeV) t tbar and other sources of prompt leptons
- estimate by MC and checked by e μ method (next slide)

Dileptons from misidentified jets
-“fake rate” method (slide 6)
- negligible for dimuons (1% of DY rate above 120 GeV)
- more important for dielectrons: about 5% of DY above 120 GeV

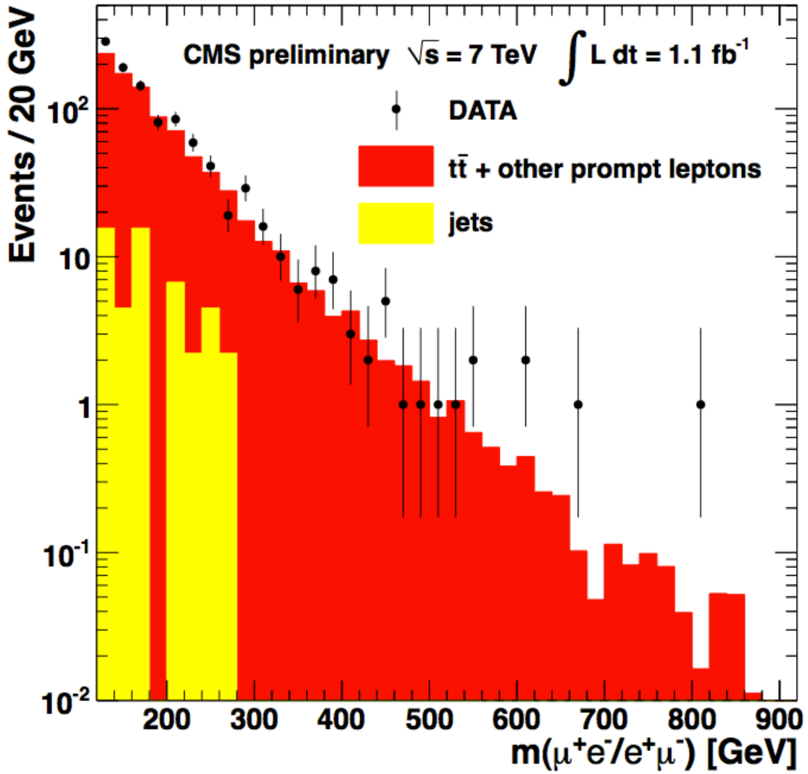
Cosmic rays muons
- using sidebands, estimate less than 0.1 event above 120 GeV

e μ METHOD

From t tbar, one expects two e μ events for each e e or μ μ, scaled by different efficiencies

Scale factors are extracted from MC in mass bins

Currently a cross-check, although this BSM channel is interesting by itself

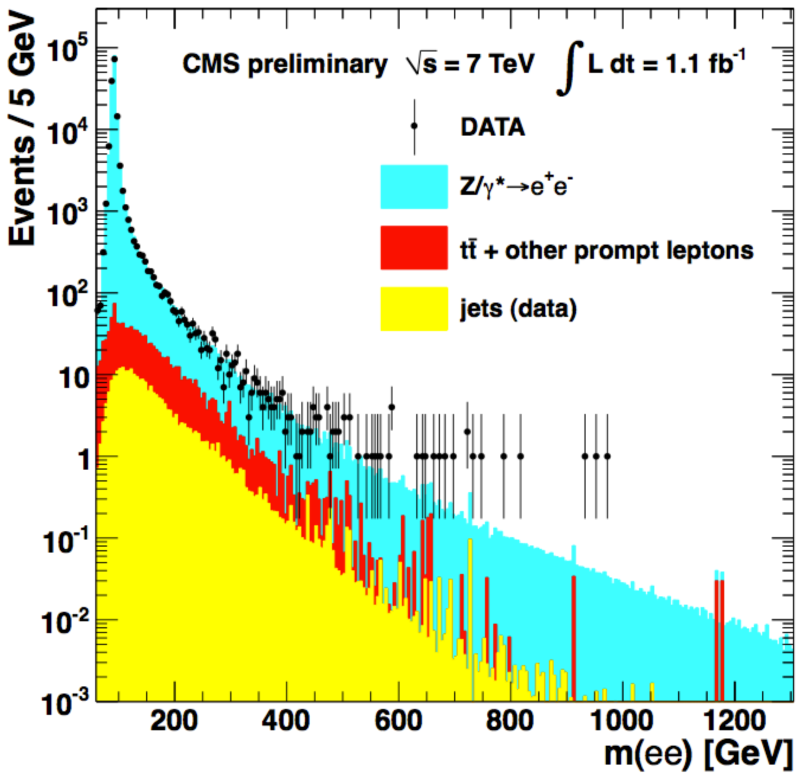


DIELECTRON

MC distributions normalized to NLO cross sections, then overall to the data at Z peak between 60-120 GeV

Uncertainties in table: statistical ⊕ systematic.

Source	Number of events	
	(120 – 200) GeV	>200 GeV
CMS data	3410	809
Total background	3375 ± 161	787 ± 67
Z/γ^*	2992 ± 149	622 ± 62
$t\bar{t}$ + other prompt leptons	275 ± 41	118 ± 17
Multi-jet events	107 ± 43	46 ± 18

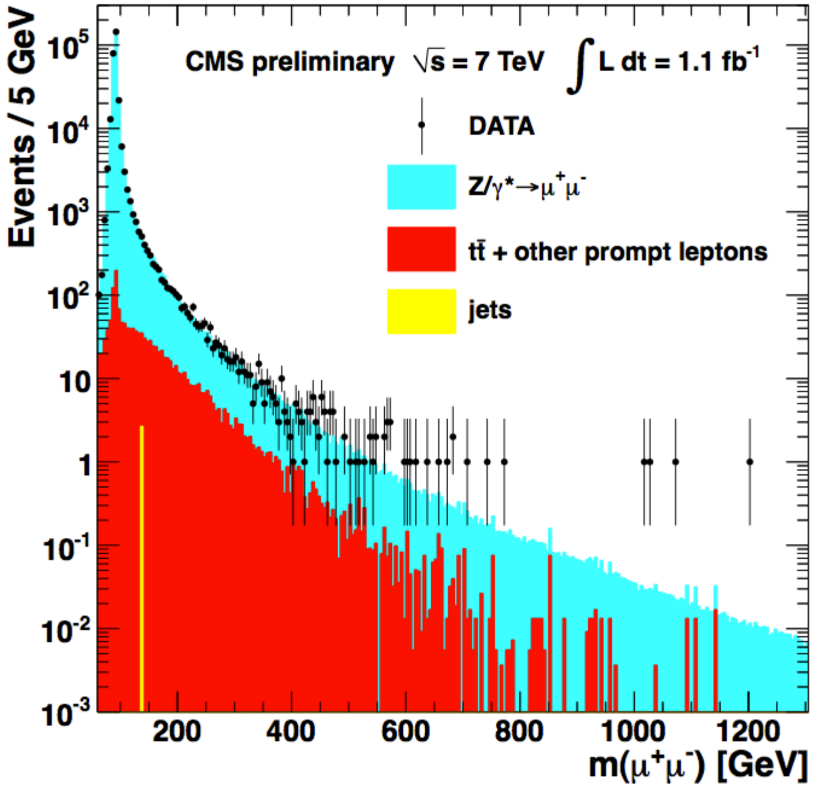


DIMUON

MC distributions normalized to NLO cross sections, then overall to the data at Z peak between 60-120 GeV

Uncertainties in table: statistical ⊕ systematic.

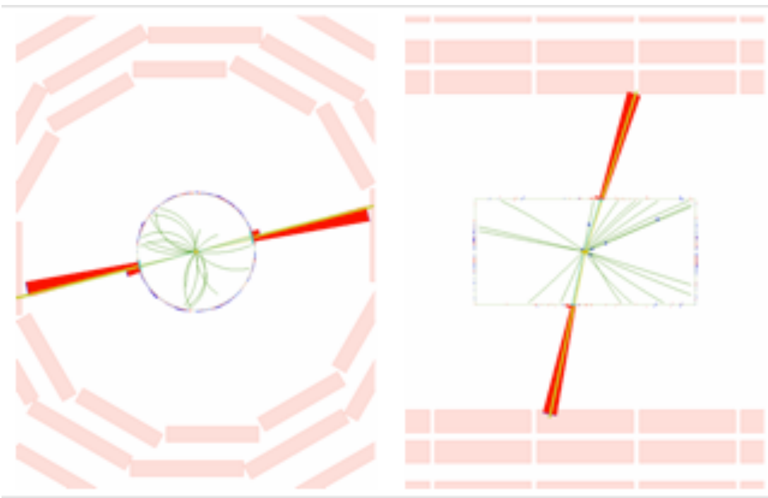
Source	Number of events	
	(120 – 200) GeV	>200 GeV
CMS data	5216	1095
Total background	5537 ± 250	1100 ± 48
Z/γ^*	5131 ± 246	922 ± 44
$t\bar{t}$ + other prompt leptons	404 ± 46	178 ± 20
Multi-jet events	3 ± 3	0



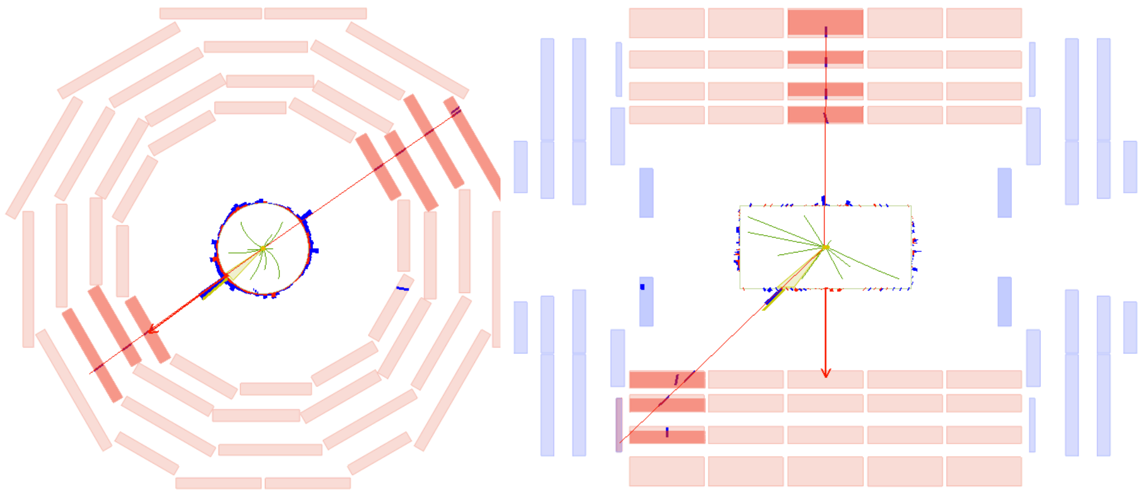
DISPLAYS

Highest mass events

dielectron



dimuon



RESONANCES

Simple signal and background pdf, with shape parameters from MC

Use likelihood ratio to calculate significance S_L as a function of mass M

Correct for "Look Elsewhere Effect"

$$\mathcal{L} \sim \prod_i f_{\text{signal}} + f_{\text{background}}$$

$$f_{\text{signal}} \sim \text{Breit-Wigner}(m|M,\Gamma) \otimes \text{Gaussian}(m|M,w)$$

$$f_{\text{background}} \sim \exp\left(-am\right)/m^b$$

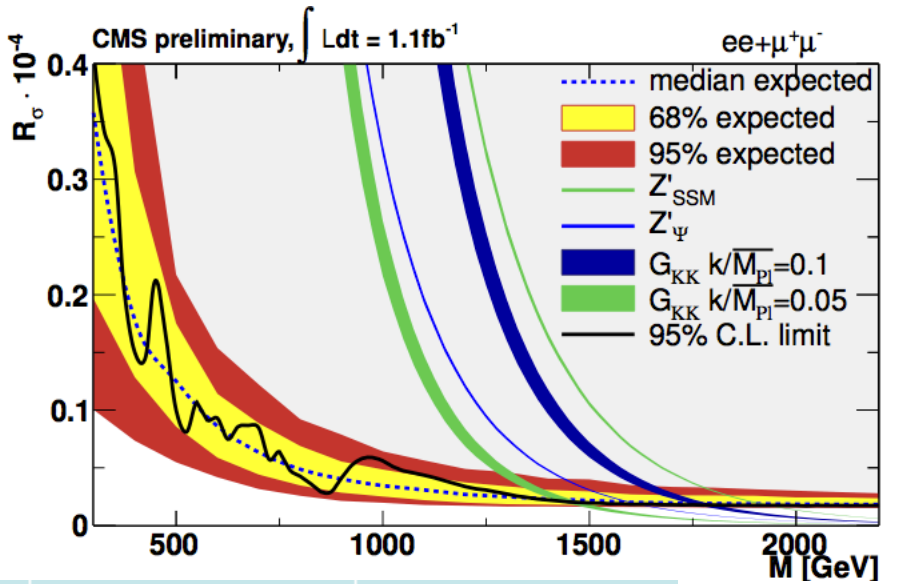
$$S_L = \sqrt{2\ln\frac{L^{\max}_{S+B}(f_s)}{L_B}}$$

channel	most significant bump	local Z (σ)	LEE corrected Z (σ)
ee	950 GeV	2.2	0.2
μμ	1080 GeV	1.7	0.3
ee+μμ combined	970 GeV	2.0	0.2

LIMITS

Limits (95% CL) on ratio of cross sections Z'/Z using a Bayesian method

RooStats

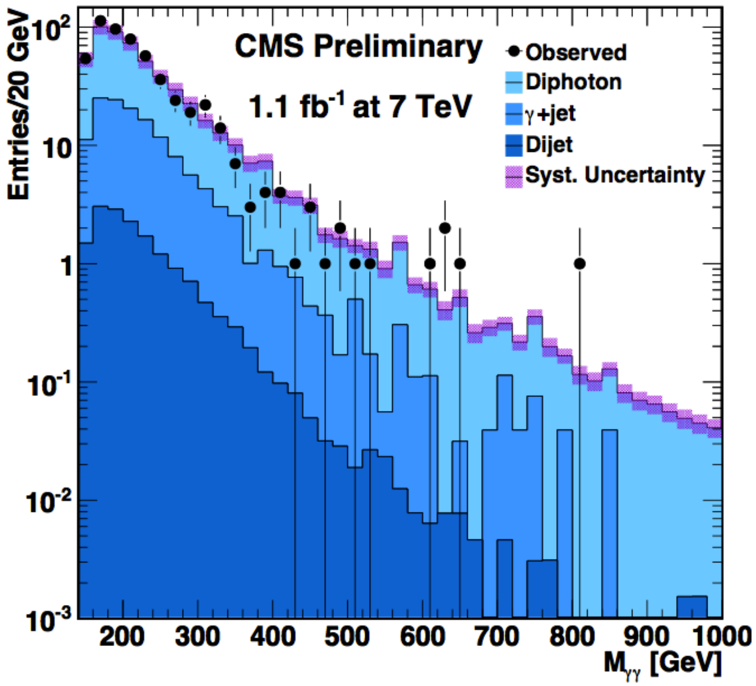


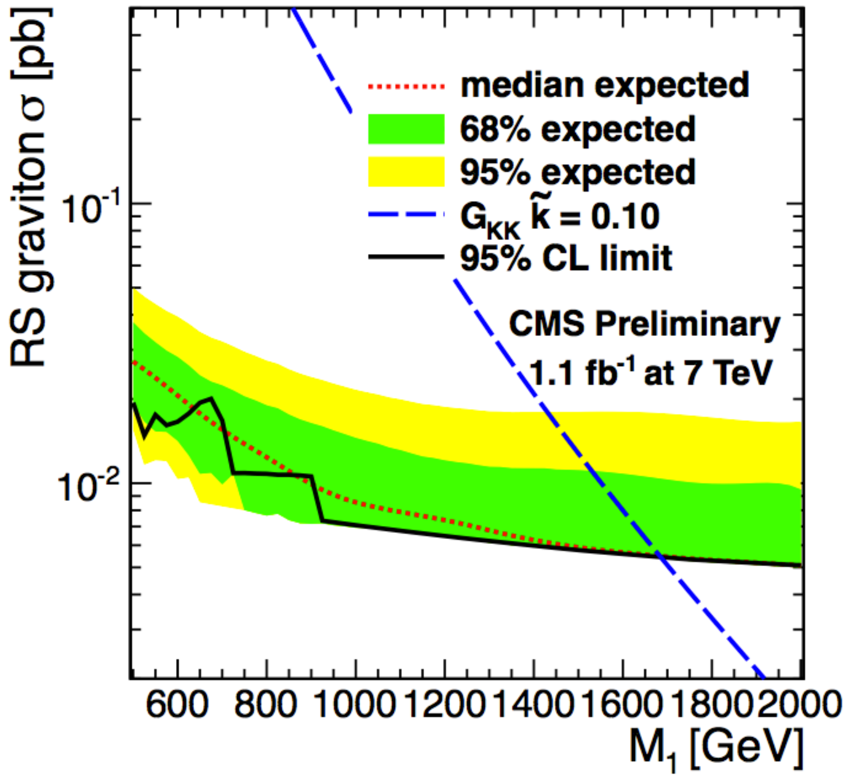
channel	μμ	ee	μμ + ee
Z'_{SSM}	1780 GeV	1730 GeV	1940 GeV
Z'_ψ	1440 GeV	1440 GeV	1620 GeV
G_{KK}, c=0.05	1240 GeV	1300 GeV	1450 GeV
G_{KK}, c=0.1	1640 GeV	1590 GeV	1780 GeV

DIPHOTON

Can discriminate Randall-Sundrum graviton from Z'

Selection: $E_T > 70$ GeV and $|\eta| < 1.44$



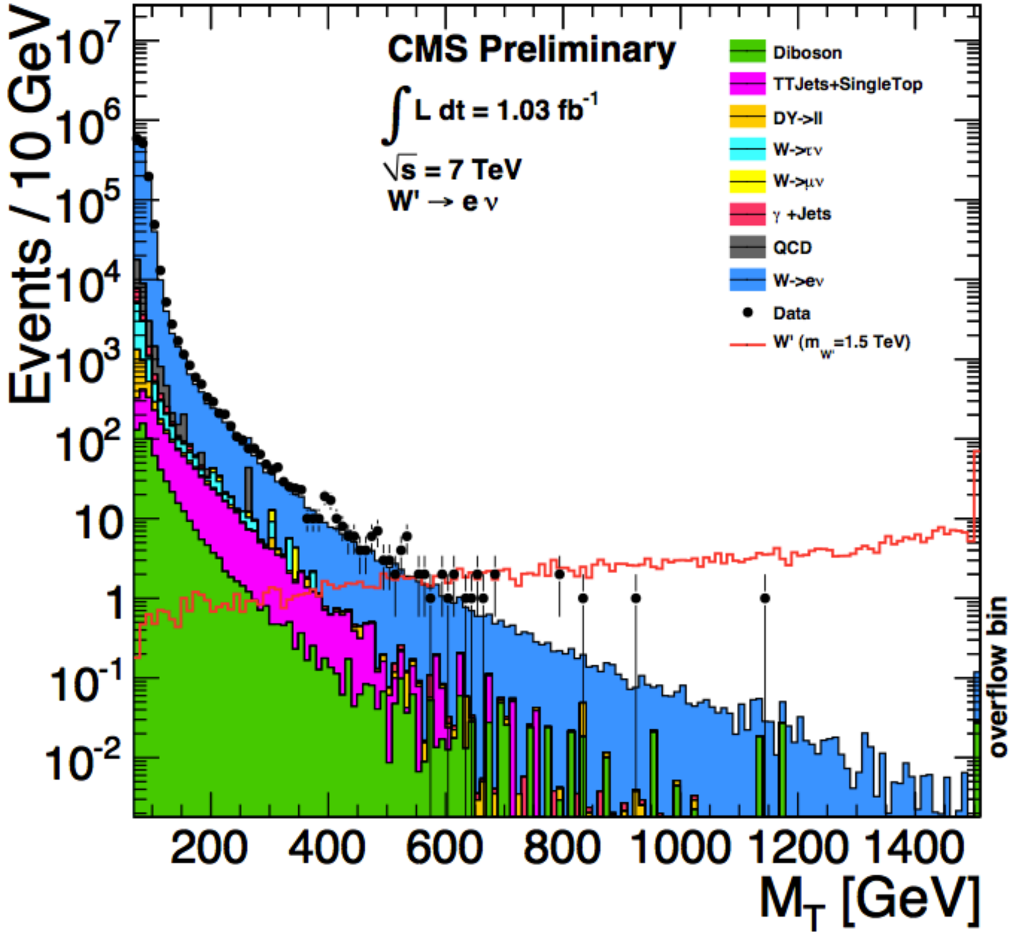


$W' \rightarrow e\,\nu$

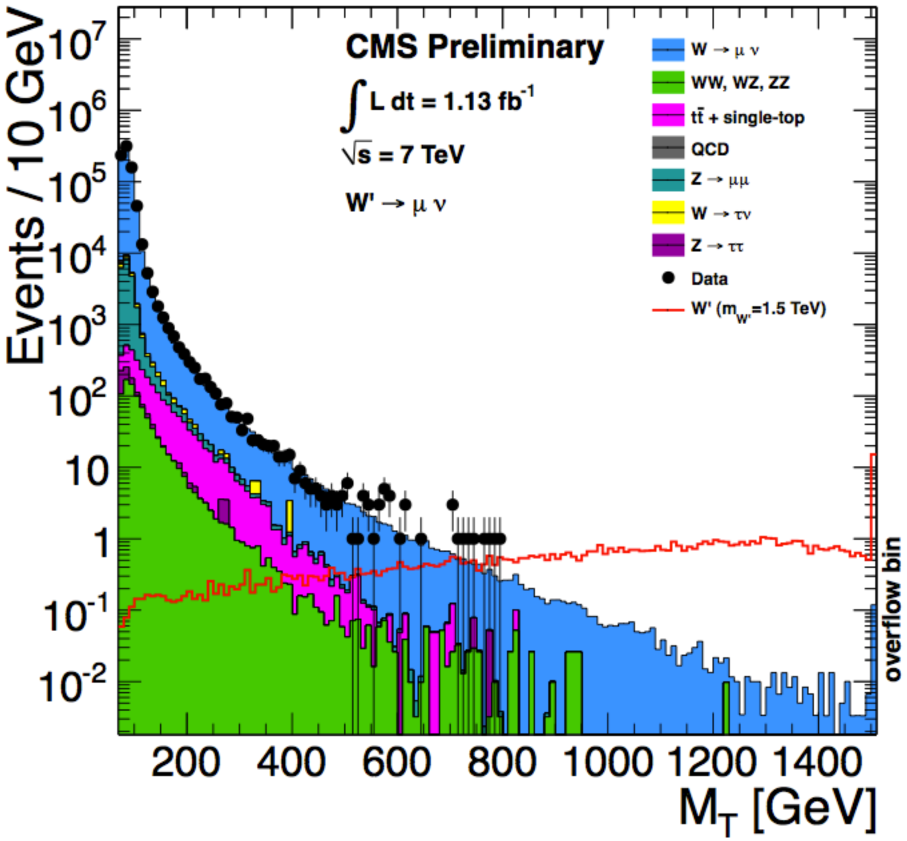
Measure transverse mass M_T

Selection on electron E_T, missing transverse energy and $\Delta\varphi$

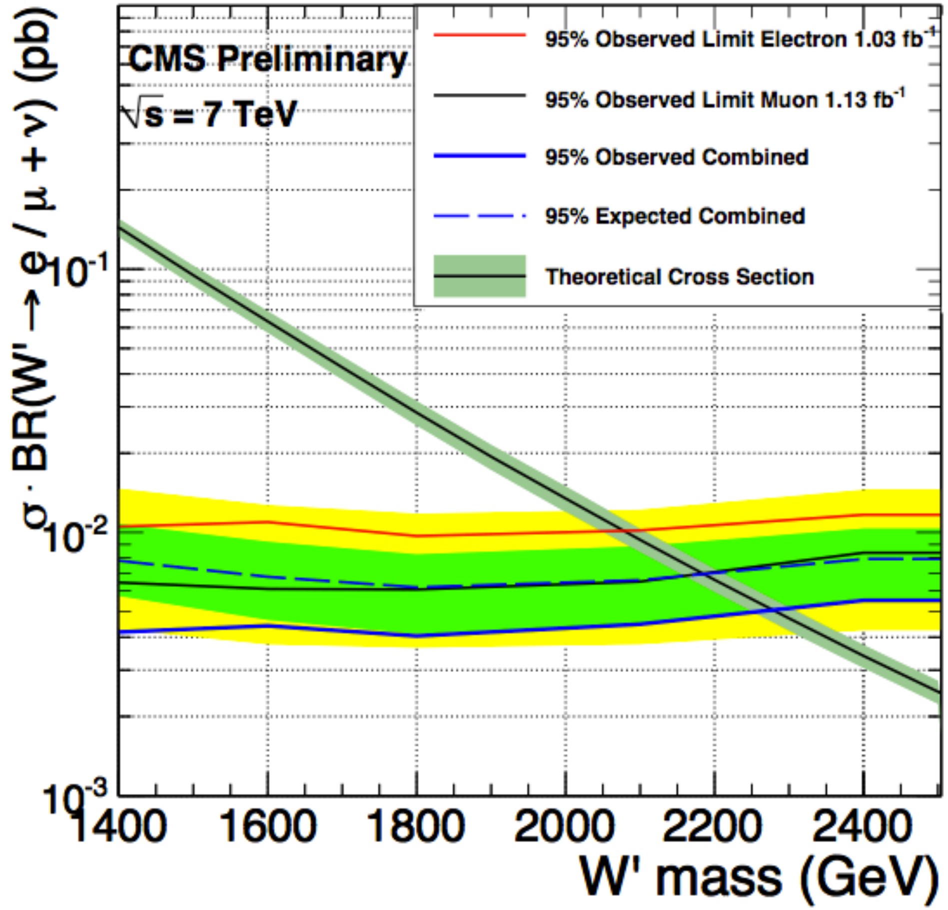
The main background is due to the W tail



W’ → μ ν



CMS Preliminary
∫L dt = 1.13 fb-1
√s = 7 TeV
W' → μ ν
W → μ ν
WW, WZ, ZZ
tt̄ + single-top
QCD
Z → μμ
W → τν
Z → ττ
Data
W' (mW'=1.5 TeV)
Events / 10 GeV
overflow bin
MT [GeV]



CMS Preliminary
√s = 7 TeV
95% Observed Limit Electron 1.03 fb-1
95% Observed Limit Muon 1.13 fb-1
95% Observed Combined
95% Expected Combined
Theoretical Cross Section
σ · BR(W' → e / μ + ν) (pb)
W' mass (GeV)

EXCITED LEPTONS

Search the production of an excited lepton (e*, μ*) in association with a SM lepton via a novel contact interaction (scale determined by parameter Λ)

The excited lepton decays via the electroweak interaction in a final state made of two high E_T leptons (e e or μ μ) and one high E_T photon

Two parameters in the theory: Λ and excited lepton mass M*

Event selection:
-Two muons/electrons. One photon with $E_T > 20$ GeV in $|\eta| < 1.4$
- M(2 leptons) > 60 GeV to eliminate low mass Drell-Yan
- Lower mass cut (value depends on M* hypothesis) on the minimum lepton - γ mass

BACKGROUND

Background
$Z\gamma \rightarrow l + l + \gamma$ estimated from simulation
Also $Z \rightarrow \tau\tau$, t tbar, W W, W Z, Z Z, $W \rightarrow l\nu$, $\gamma\gamma$, taken into account

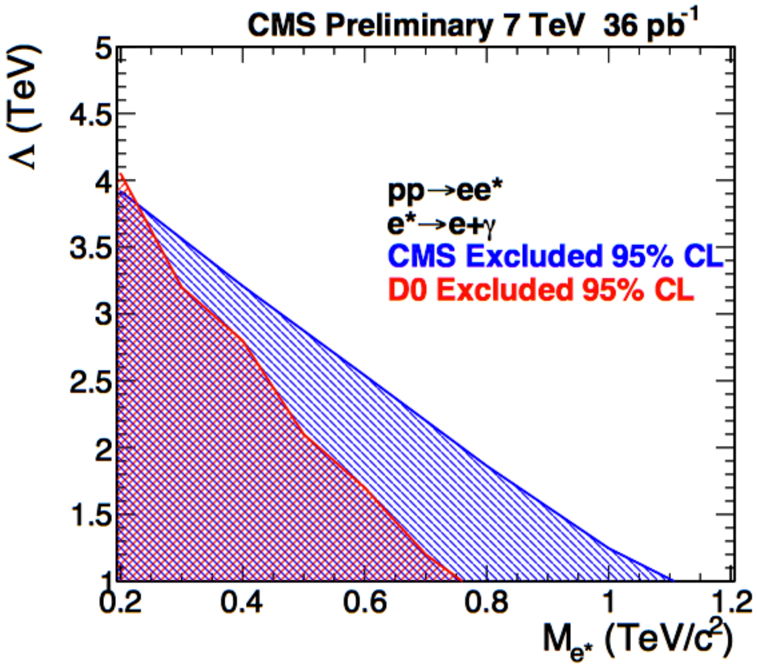
Fake γ dominated by Z + jet : use photon fake rate
Fake lepton dominated by W γ + jet : use lepton fake rate

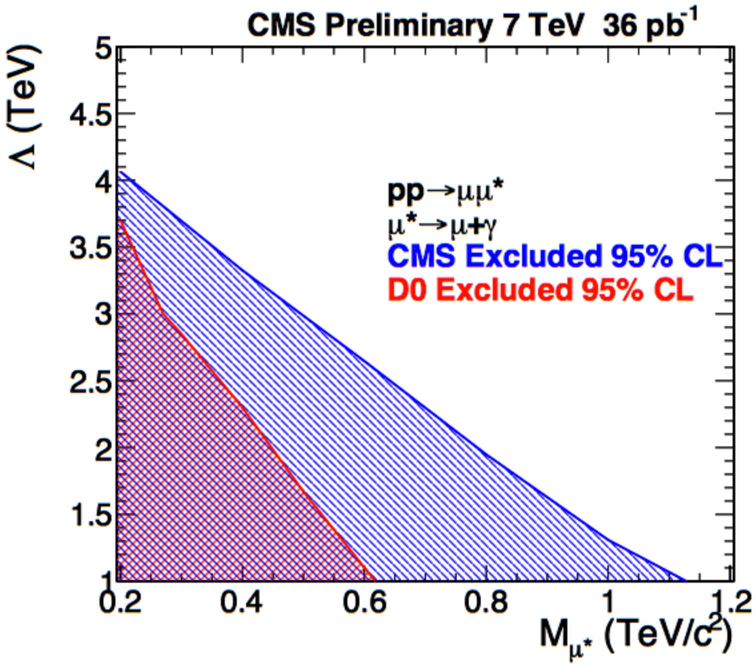
Data (M*=200 GeV)	0 (e*)	0 (mu*)
Expected Bkg	0.68 ± 0.20	0.98 ± 0.22
Z γ	0.36 ± 0.12	0.75 ± 0.15
Fake γ	0.10 ± 0.07	0.22 ± 0.14
Fake e (mu)	0.22 ± 0.11	0.00 ± 0.06

LIMITS

No signal candidate observed in data

Perform a counting experiment and set 95% CL limits using the standard Bayesian method





CONCLUSION

Limits for Z', Randall-Sundrum graviton (1.1 fb^{-1} , e e + μ μ)
SSM 1940 GeV G_{KK} c = 0.1 1780 GeV

Limit for Randall-Sundrum graviton (1.1 fb^{-1} , γ γ)
G_{KK} c = 0.1 1730 GeV

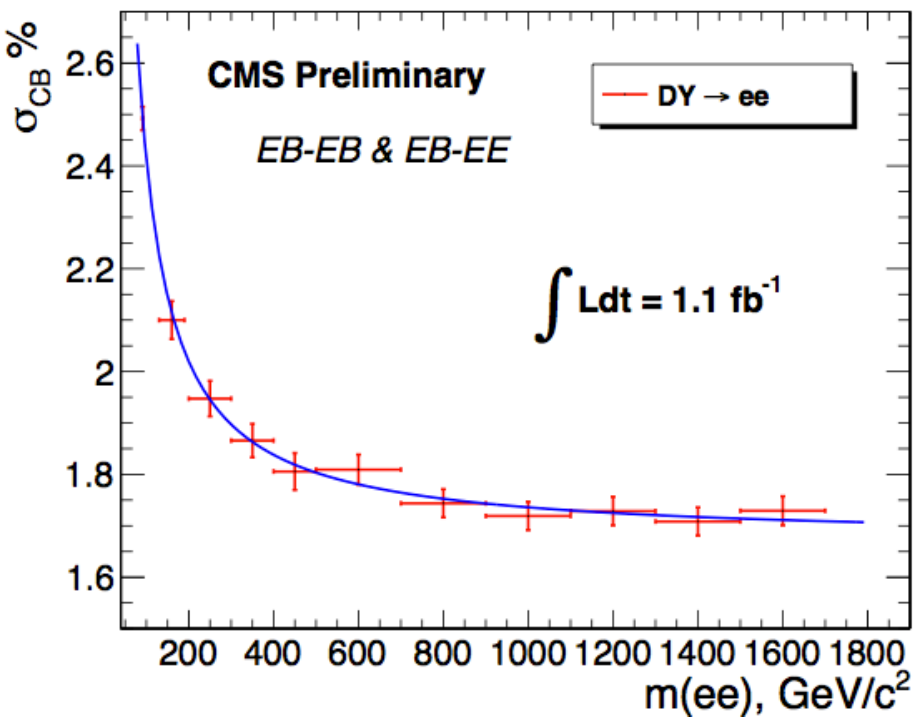
Limit for W' (1.1 fb^{-1} , e e + μ μ)
SM like couplings 2.27 GeV

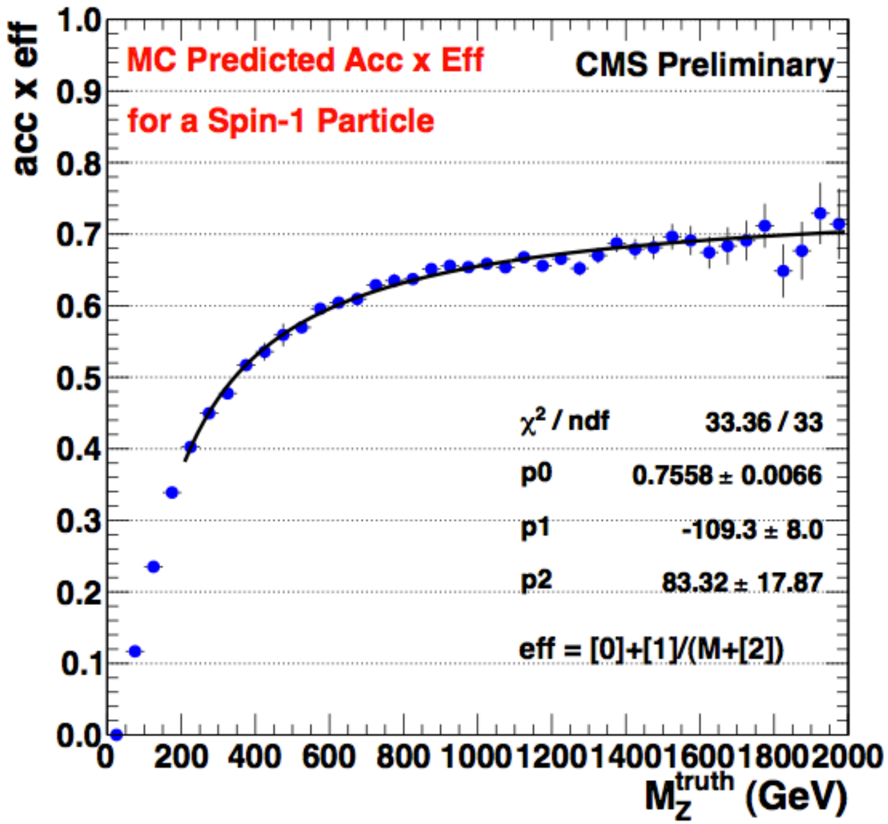
Limits for excited leptons (36 pb^{-1}) with Λ = 2 TeV
e* 760 GeV μ* 785 GeV

CMS recorded integrated luminosity 4.2 fb^{-1}, expected end 2011 5 fb^{-1}

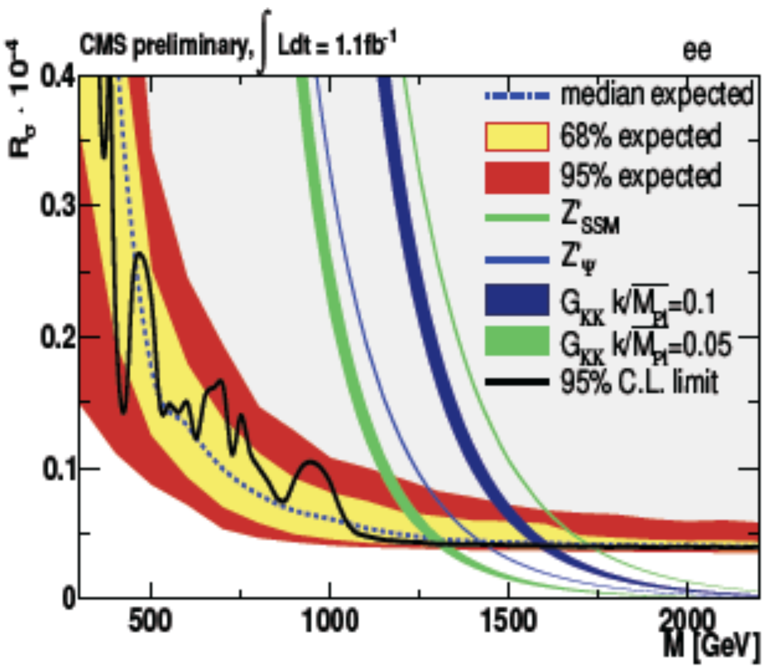
BACKUP

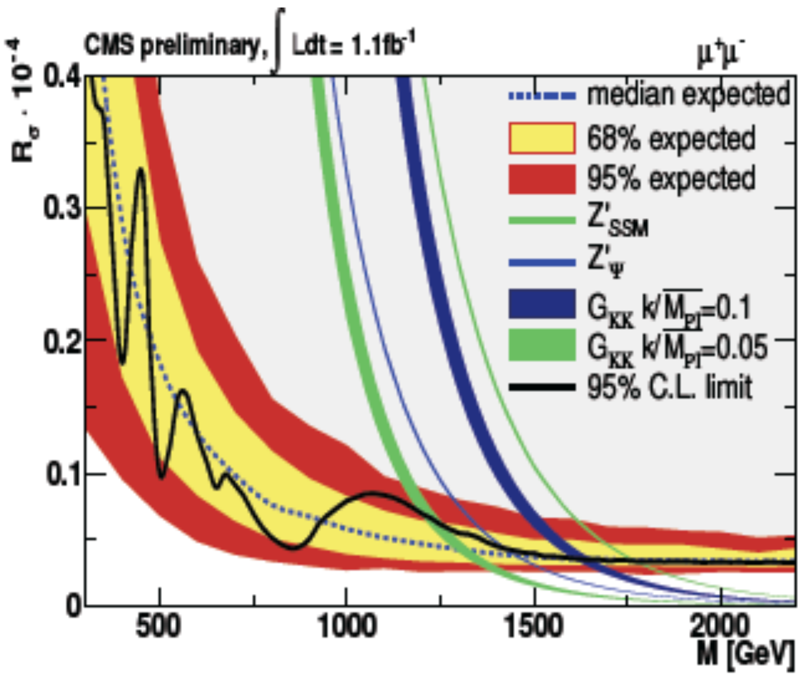
ECAL PERFORMANCE





INDIVIDUAL CHANNELS





DILEPTON SYSTEMATICS

- 3% (8%) on the acceptance times efficiency ratio evolution from low to high mass for dimuons (dielectrons), which includes PDF uncertainties (relevant to the acceptance) and the mass dependence of K-factors.
- For dimuons, sensitivity study to mass scale uncertainty (affecting only the region below 1250 GeV where there are events) showed negligible impact up to the maximum possible from alignment effects; for dielectrons, study at Z0 peak results in 1% for barrel and 3% for endcap.
- For dimuons, effect of possible χ2-invariant "weak mode"in alignment, which corresponds to a muon tracking curvature bias, folded into estimate of Gaussian width for signal pdf.
- Shape systematics explored:

  – include an extra background shape representing the ttbar component and varying its amplitude;

  – trying a different functional form for the background pdf;

  – and changing the low-mass cut-off point for the DY shape fit from 200 GeV down to 150 GeV, which changes the background shape parameters.

PHOTON ID

Photon ID Variable	Cut Threshold
$\|\eta\|$	< 1.4442
E_T	$> 20.$ GeV/c
H/E	< 0.05
Tracker Isolation	$< 2.0 + 0.001 * E_T$
ECAL Isolation	$< 4.2 + 0.006 * E_T$
HCAL Isolation	$< 2.2 + 0.0025 * E_T$
$\sigma_{i\eta i\eta}$	0.013
hasPixelSeed	No Requirement

- Tight ID
- Only ECAL barrel photons
- Data/MC scale factor applied to account for the difference between data and MC: 0.967 ± 0.025

EXCITED LEPTON SYSTEMATICS

Source	Magnitude	Error on signal efficiency (%)	Error on bkgd. expectation (%)
Luminosity	11%	-	8.5
Photon Fake Rate	46%	-	10
Muon Fake Rate	50%	-	6.2
Ecal Energy Scale	1.3%	0.1	0.4
Photon ID	0.025	2.6	1.9
Muon ID	0.01	2.1	1.6
PDF and scales	-	0.8	3

The decay width for other decay modes, taken into account:
BR($l^* \rightarrow l + \gamma$) = 25% for low M^* / Λ

EXCITED ELECTRON