Search for Z′ and W′ at CMS

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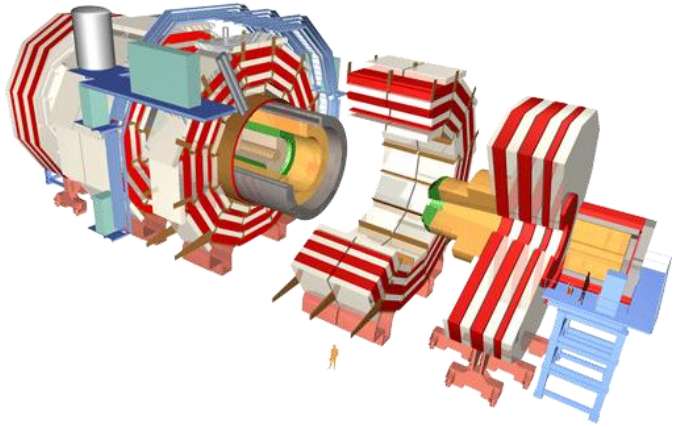
for the CMS Collaboration

BNL Forum 2011

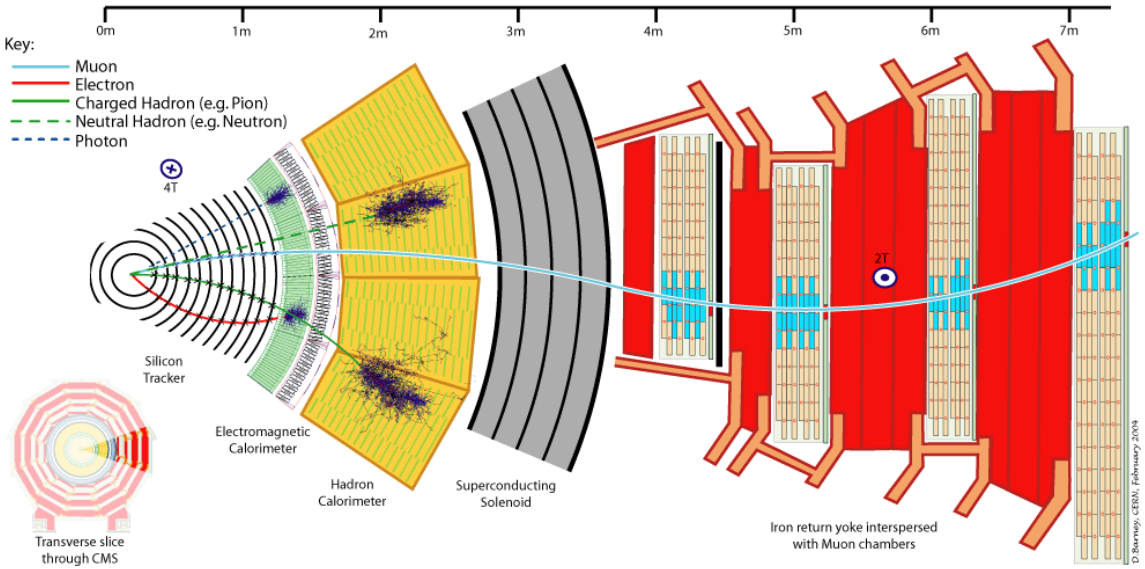
- Heavy resonances are a powerful probe of new physics at the Terascale
  - Common to many different models
- Heavy resonance decays with leptons offers a sensitive tool for discovery

The CMS Detector

- 3.8 T internal field: Silicon strip and pixel tracking
- Crystal EM calorimetry; brass/scintillator hadronic calorimetry
- Drift tubes + RPC surrounding toroid (barrel); cathode strips + RPC in endcaps
- Forward detectors

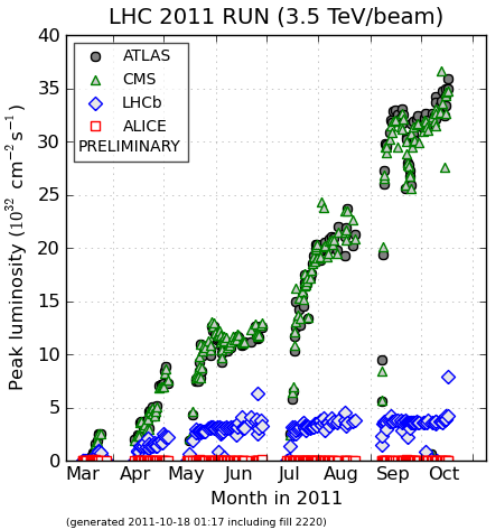


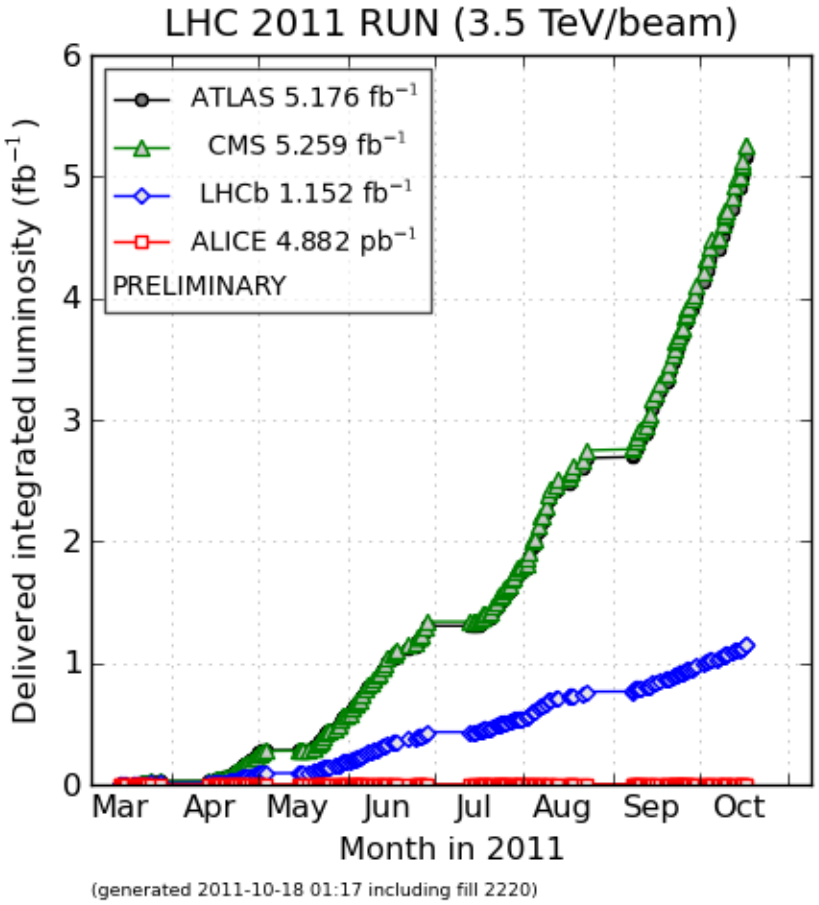
Dilepton Resolution:
Muons
~6% (500 GeV)–10% (1 TeV)
Electrons
~1% (500 GeV) –1% (1 TeV)



Evolution of ∫ Luminosity

- First Z' paper: 40/35 pb^{-1} (2010 sample) JHEP05(2011)093
- Latest public Z' result: 1.1 fb^{-1} (July) CMS-PAS-EXO-11-019
- Current dataset size: (see right)
- (Current running period to end of October; resumes in new year)





lpc.web.cern.ch/lpc/lumiplots.htm

Z’→ee/μμ

Z´ Taxonomy

Many different models give rise to a Z-like resonance ($pp \rightarrow \ell^+\ell^- + X$). Some commonly considered ones are:

- *Sequential Standard Model (SSM)*: not much motivation, but provides a known benchmark. Same couplings as SM Z, but with higher mass. Generalized version = GSM.
- *Left-Right Symmetric Model (LR)*: [GUT motivated: $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$]. Generalized version has not just B-L, but also, R, LR, and Y.
- *E_6*: [GUT motivated: $E_6 \rightarrow SU(5) \times U(1)_\psi \times U(1)_\chi$]. At low mass, produces one-parameter class of models: $\cos(\theta)\, U(1)_\psi - \sin(\theta)\, U(1)_\chi$.
- Many, many others…

Other Z´-like signal-producing models:

- Randall-Sundrum Kaluza-Klein graviton (spin-2)
- KK SM boson (spin-1)
- RPV SUSY sneutrino (spin-0)

Lepton Selection

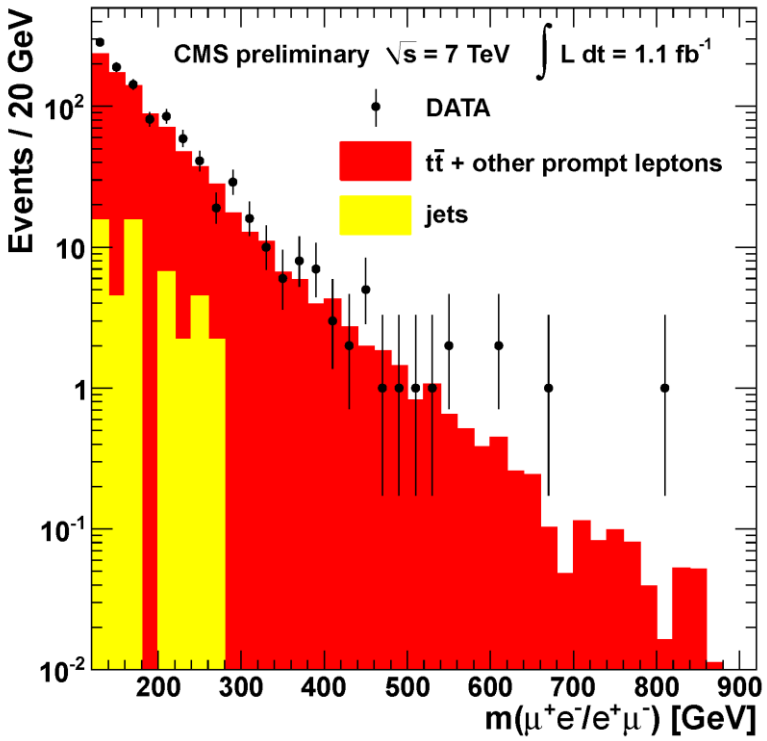
- Selection optimized for high efficiency at high energy
- Use rather restrictive γ(e)/μ trigger:
  - e: double EM cluster
  - μ: single μ with p_T> 30 GeV
- Offline cuts:
  - e: E_T > 25 GeV (2010)
    > 35-40 GeV (2011)
  - μ: E_T > 20 GeV (2010)
    > 35 GeV (2011)

    opposite signs required
- Corrections:
  - e Energy scale (esp. endcap)
  - Data/MC efficiency scale factor
  - Remove cosmic μ
- Efficiency for ID and trigger measured with tag-and-probe method

Dilepton Efficiencies & Bkgnd

Check understanding by comparing eμ spectrum with MC

- Good agreement; extract N(ee,μμ)/N(eμ) scaling factor.

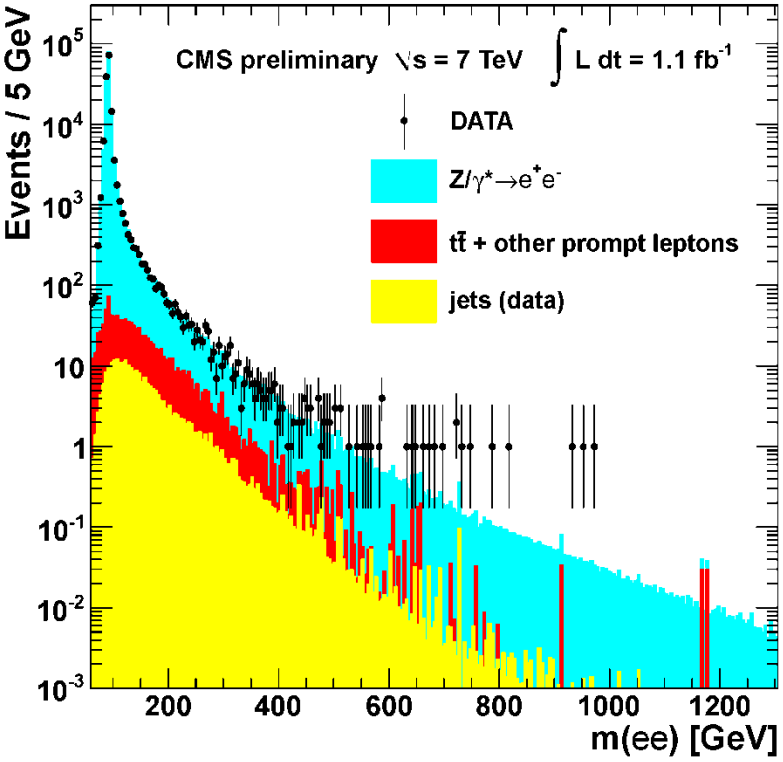


Individual checks:

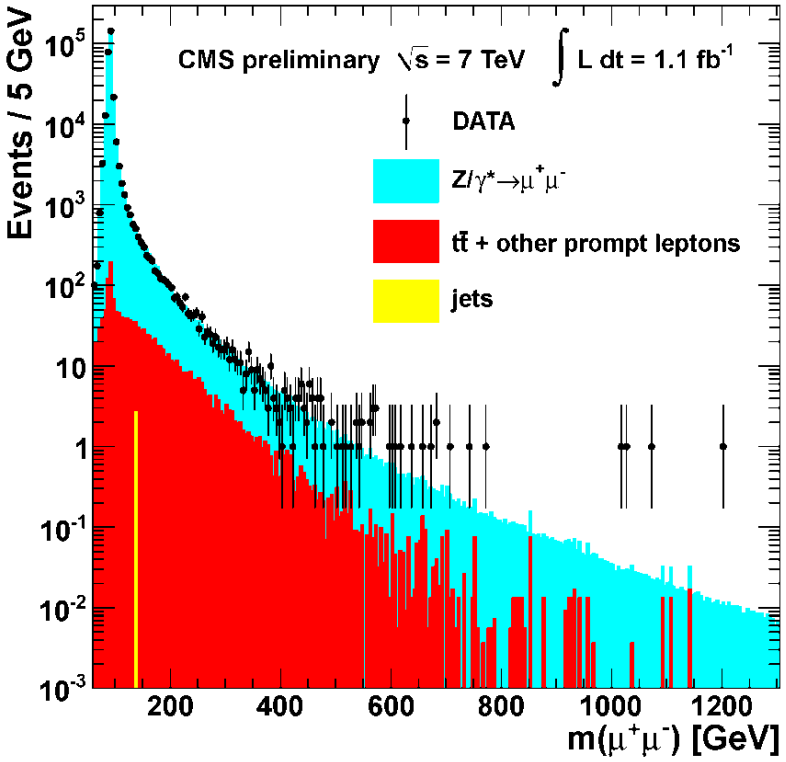
- e mis-ID (e from jets: check with fake rate)
- μ contamination from cosmics

Dilepton Spectra

ee



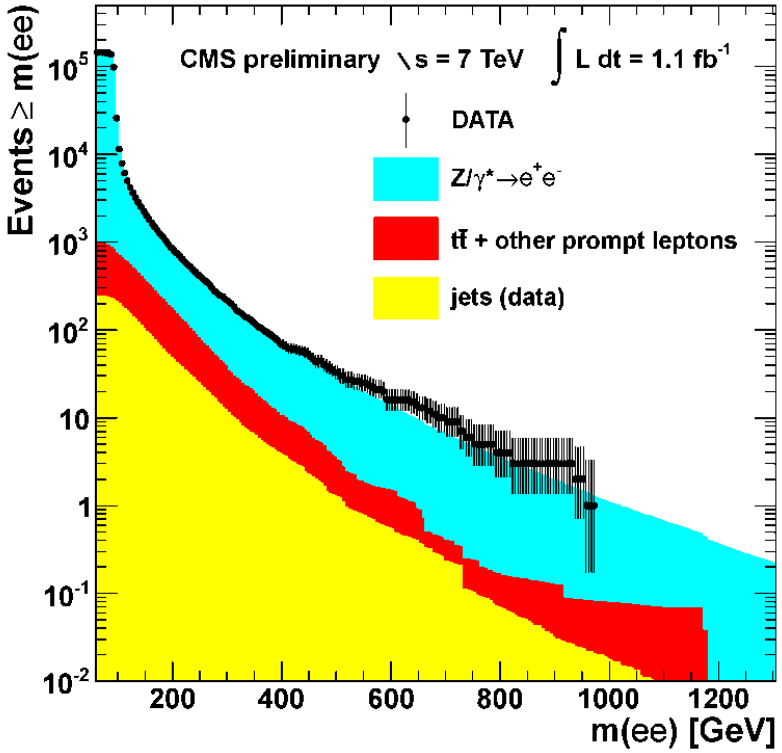
$\mu^+\mu^-$



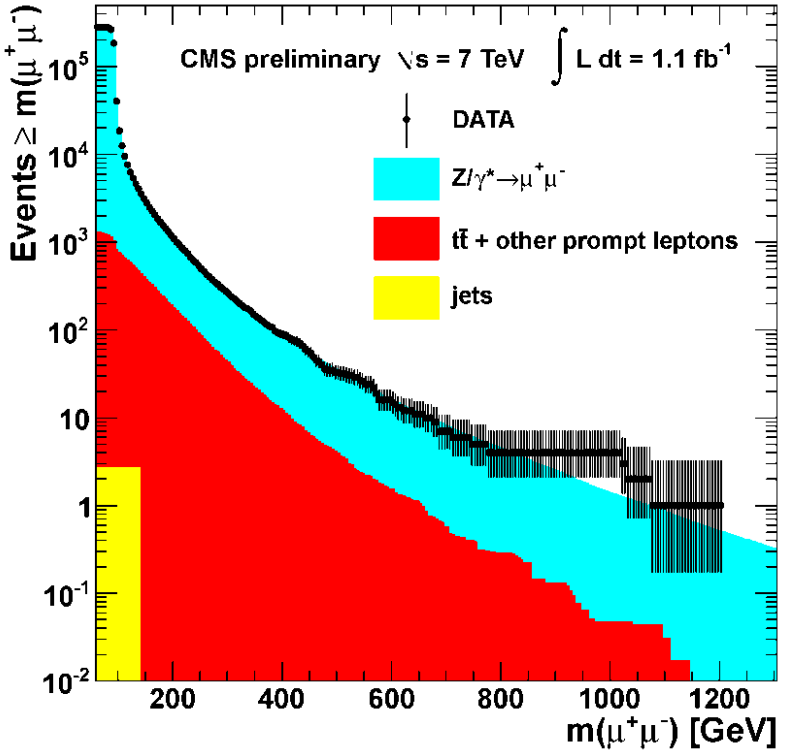
MC (solid area) normalized to Z´ peak (60-120 GeV);
Note difference in jet contamination.

Dilepton Spectra (Integral)

ee



$\mu^+\mu^-$



Searching for heavy dilepton resonances

1. Normalize ee/μμ spectra to Z peak (cancels some systematics)

2. Fit MC DY spectrum to parameterized function over range
   $200 < m_{\ell\ell} < 2500$ GeV, using

   $f_B(m|\alpha,\kappa) \sim \mathrm{Exp}(-\alpha m)\, m^{-\kappa}$

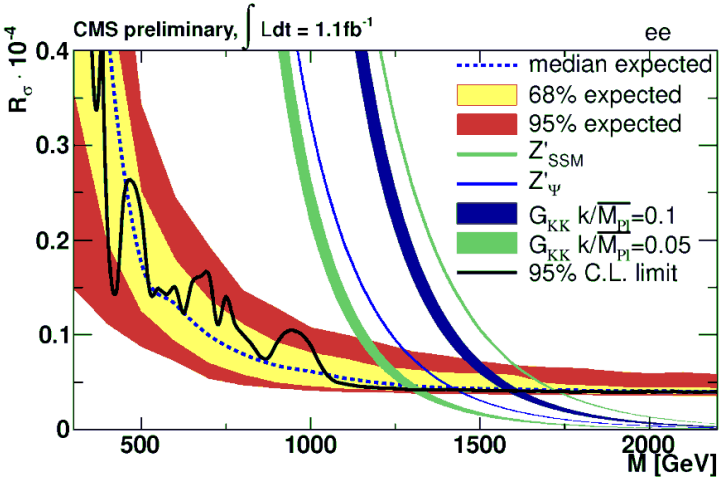
3. Parameterize resolution-smeared resonance (Breit-Wigner convoluted with Gaussian):

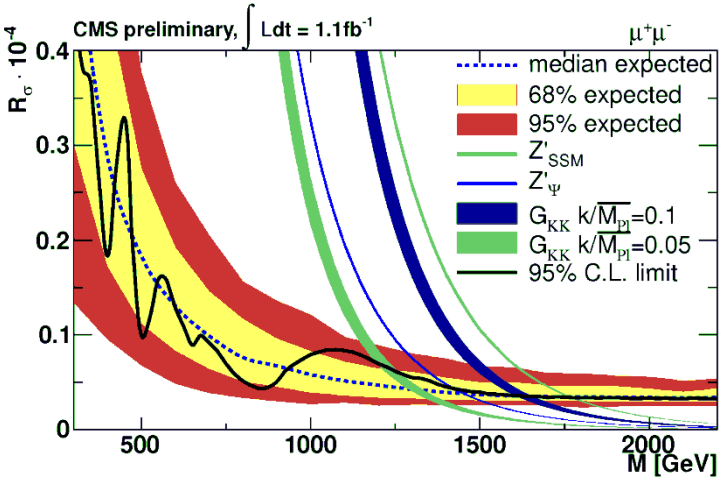
   $f_S(m|M,\Gamma,\sigma) = BW(M,\Gamma) \otimes G(0,\sigma)$

4. Calculate extended likelihood and set limit using both frequentist and Bayesian approaches

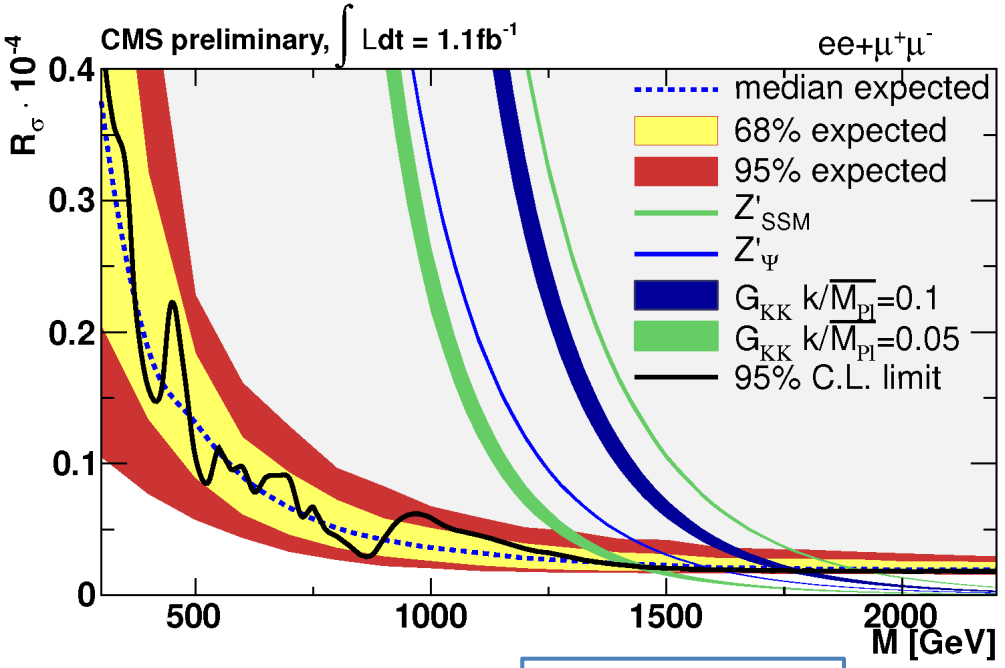
Z´ Limits [σ(Z´)·BR(ℓ⁺ℓ⁻)]

ee





μ⁺μ⁻



ee | μ⁺μ⁻

Current Limits

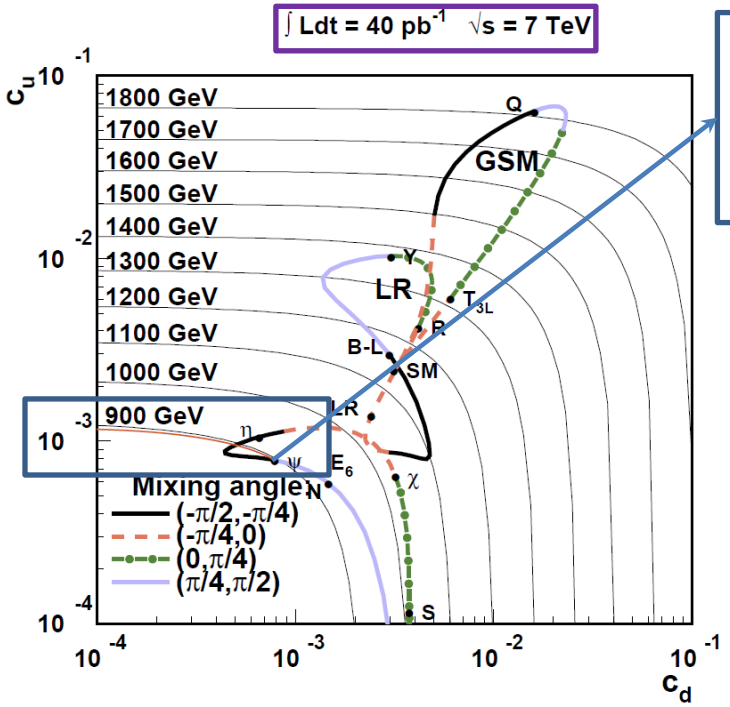
95% CL Exclusions based on a Bayesian calculation
(frequentist calculation gives v. similar numbers)

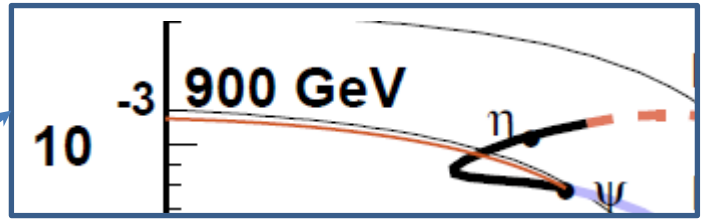
Channel	M_{ee} [GeV]	$M_{\mu\mu}$ [GeV]	$M_{\mu\mu\|ee}$ [GeV]
Z'_{SSM}	1730	1780	1940
Z'_{ψ}	1440	1440	1620
G_{KK} ($k/\overline{M}_{PL}$=0.05)	1300	1240	1450
G_{KK} ($k/\overline{M}_{PL}$=0.1)	1590	1640	1780

CMS-PAS-EXO-11-019

C_u-C_d space

- Handy way to present the limits: express Z´ in terms of couplings to u/d quarks [Carena, et al., 10.1103/PhysRevD.70.093009]
- $\sigma_{LO} \approx \pi(w_u(s,M_z^2)\, c_u + w_d(s,M_z^2)\, c_d)/48s$ [in narrow width approximation],
  w_u, w_d related to u/d structure f'ns, act as flux factors



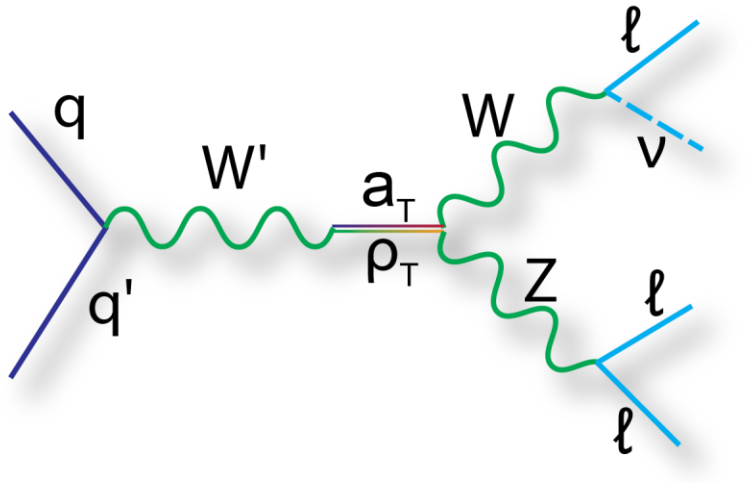


To determine the 95% CL mass limit, find isobar line. Example: $m(Z'_\psi) > 887$ GeV. A Z´ with larger couplings can be excluded to a higher mass. Increased luminosity results in new isobar positions.

JHEP05(2011)093

W’

- As for Z´, W´ is present in many SM extensions. Benchmark remains Sequential Standard Model W´: probe with W'→ℓν
- Some models (notably Technicolor) suppress W'→WZ →3ℓν mode: probe with W'→WZ →3ℓν
  - Low Scale Technicolor (LST): case with a_T and ρ_T ~ degenerate, of recent interest



W'→ℓν

CMS-PAS-EXO-11-024

μ selection:

- Least restrictive single μ trigger w/o isolation criteria.
- Offline, globally reconstructed w/ isolation & quality requirements

e selection:

- Early/late mix of (27-35 GeV e) : (25 GeV e & E_{cal} > 40 GeV)

For both, offline requirement of near back-to-back ℓ-E_T^{miss}

E_T^{miss}:

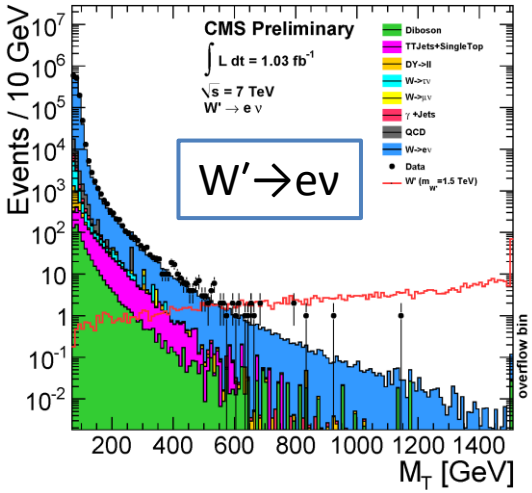
- Based on Particle Flow technique

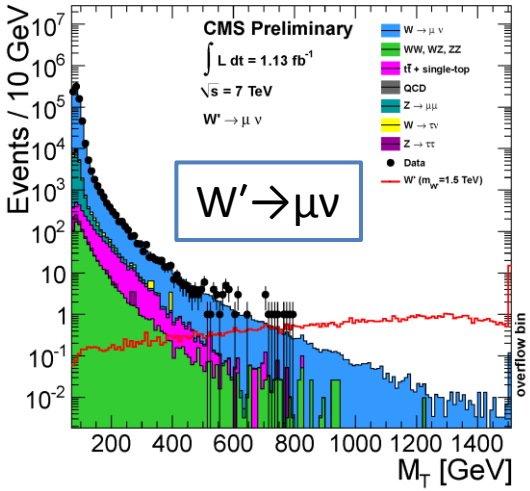
Background: parameterized based on 180 GeV < M_T < 600 GeV

W′→ℓν Limits

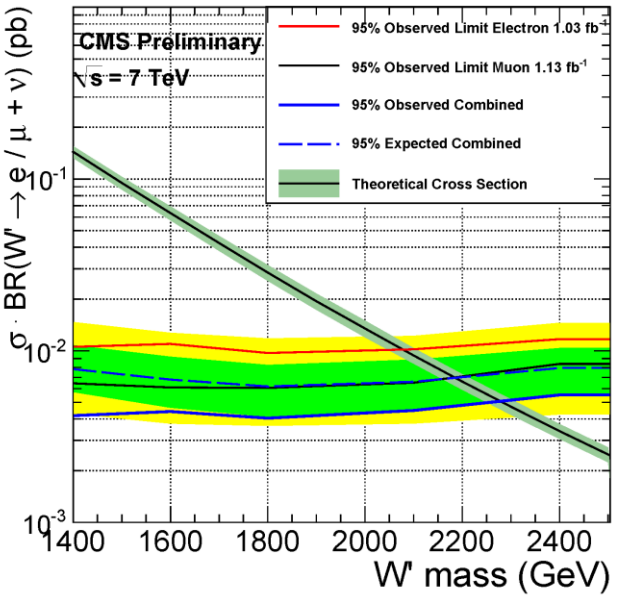
Example W′ signal with m = 1.5 TeV superimposed in red

CMS-PAS-EXO-11-024

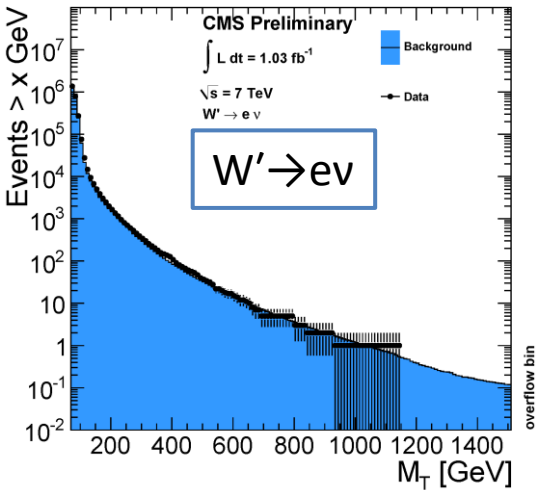


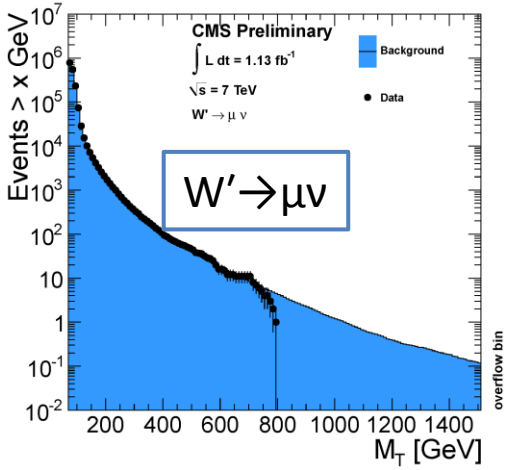


2.27 TeV, 95% limit



Dominant bgnd: W→μν (solid blue)



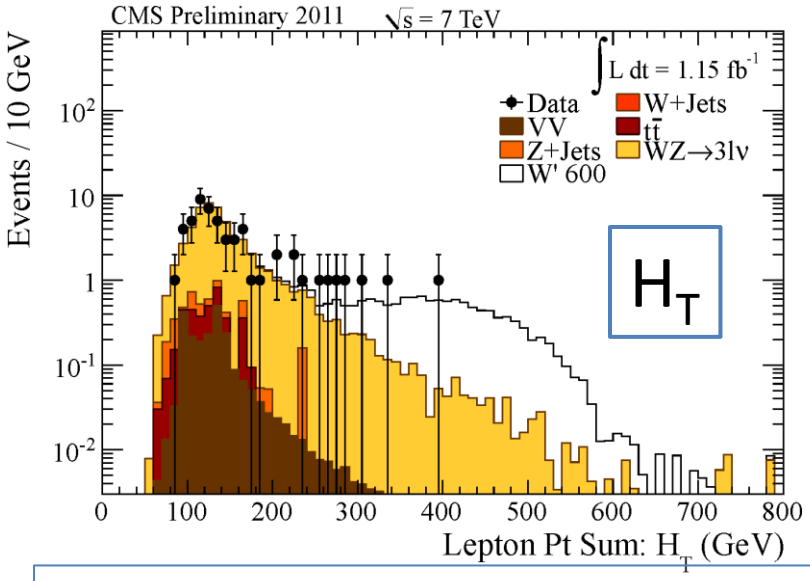


W'→WZ →3ℓν

CMS-PAS-EXO-11-041

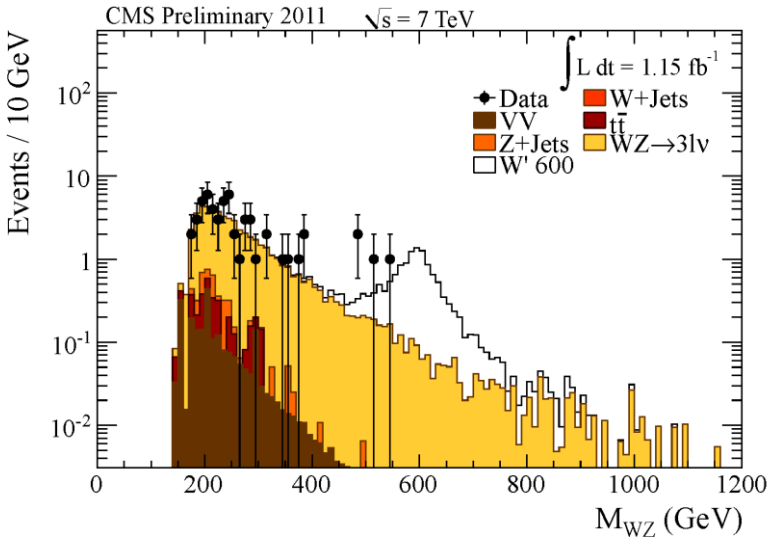
Require good Z →ℓℓ candidate, plus

- Additional good lepton with isolation,
- E_T^{miss} > 30 GeV,
- H_T (scalar sum of 3ℓ transverse momenta) > cut value (300 GeV for $M_{W'}$=600 GeV)

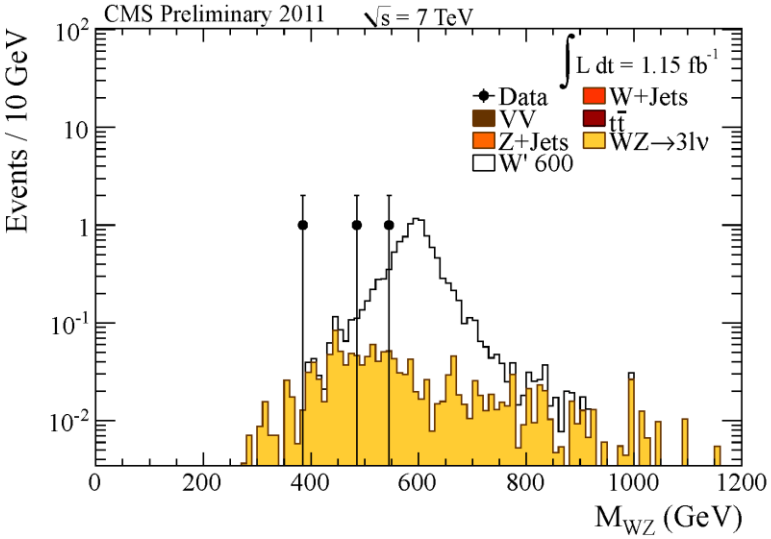


Open histogram: sample 600 GeV W' signal

all candidates

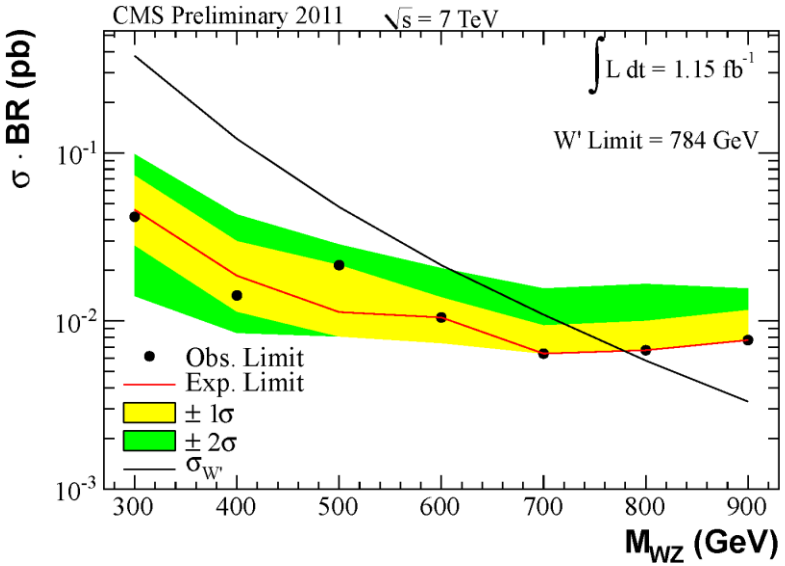


After selections



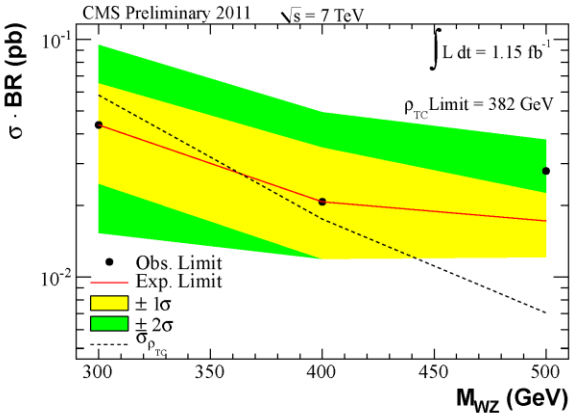
W′→WZ →3ℓν Limits

CMS-PAS-EXO-11-041

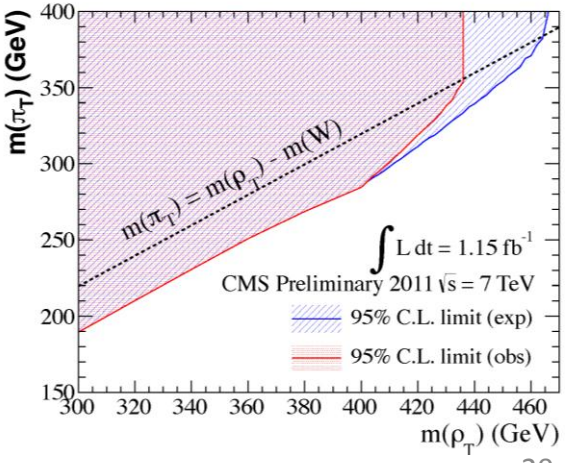


W′→WZ →3ℓν Limit: SSM $M_{W'}$ > 784 GeV (95% CL)

$M_{\pi_T} = \frac{3}{4}M_{\rho_T} - 25$ GeV :
M_{ρ_T} > 382 GeV (95%)



$M_{\pi_T} = M_{\rho_T} - M_W$:
M_{ρ_T} > 436 GeV



Backup

References

- Z’: 1.1 fb-1 sample: CMS-PAS-EXO-11-019
  40/35 pb-1 sample: doi:10.1007/JHEP05(2011)093 (EXO-10-013)
- W’: CMS-PAS-EXO-11-024
  -> 3l, CMS-PAS-EXO-11-041
- Not included: CMS-PAS-EXO-10-022 (Z’ to ττ)