Search for W' bosons at the CMS Experiment

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(on behalf of the CMS Collaboration)

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W' searches

- New heavy gauge bosons (W', Z') predicted by many new physics theories
  - Little Higgs, Extra Dimensions, GUT, Technicolor, etc.

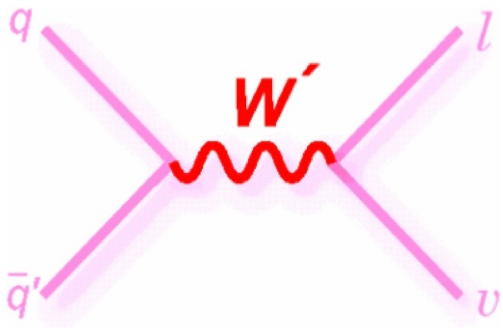
- W' signatures
  - Leptonic: $e + \nu$, $\mu + \nu$, $\tau + \nu$
  - Bosonic: WZ, $W\gamma$
  - Hadronic: qq', tb

- This talk focuses on the $e + \nu$, $\mu + \nu$ channels (~ 1 fb^{-1})

- Previous CMS W´ search (2010) with 36 pb^{-1} of data
  - W´$\rightarrow e\nu$ EXO-10-014, Phys. Lett. B698:21-39,2011
    - 1.36 TeV limit
  - W´$\rightarrow \mu\nu$ and e+μ combination, EXO-10-015, Phys. Lett. B701, 160-179, 2011
    - 1.58 TeV combined limit

W' → l ν model

- Concentrate on the Sequential Standard Model for now
  - "Reference model" (G. Altarelli et al.)
- W' boson is a copy of the SM W boson (same couplings to fermions)
- Neutrino is light & stable
- No mixing between W' and other bosons (W, Z, Z')
- WZ channel is suppressed



Analysis Outline

- Spectacular signature:
  - One very energetic lepton in event ("straight track")
  - Plus "nothing else"

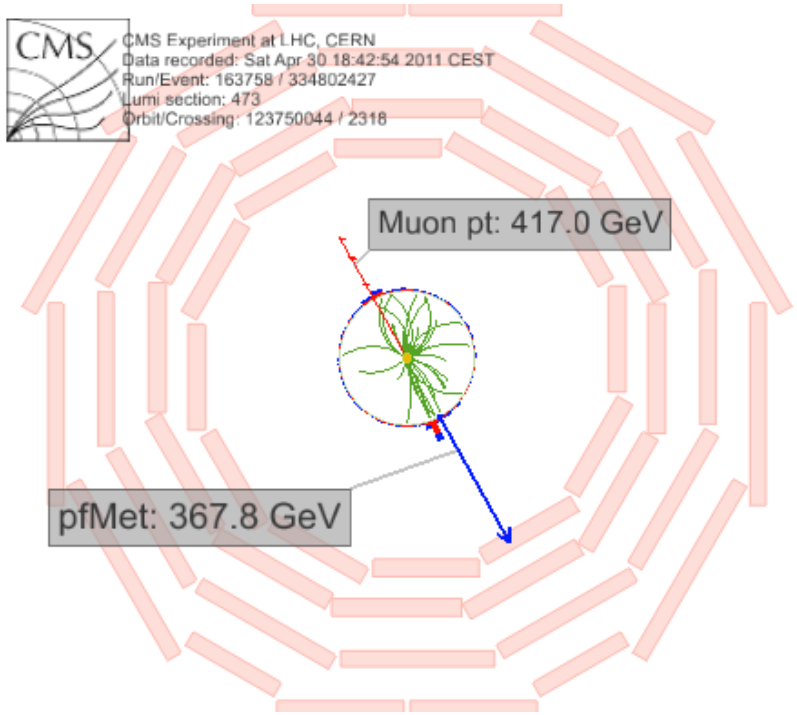
- Very similar event selection & analysis cuts for e, μ channels
  - Trigger:
    - Highest p_T/E_T unprescaled single lepton trigger
    - Plus M_T condition for electron channel
  - Only one (good quality) isolated high-p_T/E_T lepton
  - And "nothing else" in the event
    - Apply kinematic cuts (e.g. lepton p_T and MET are similar in magnitude and back-to-back in xy plane)

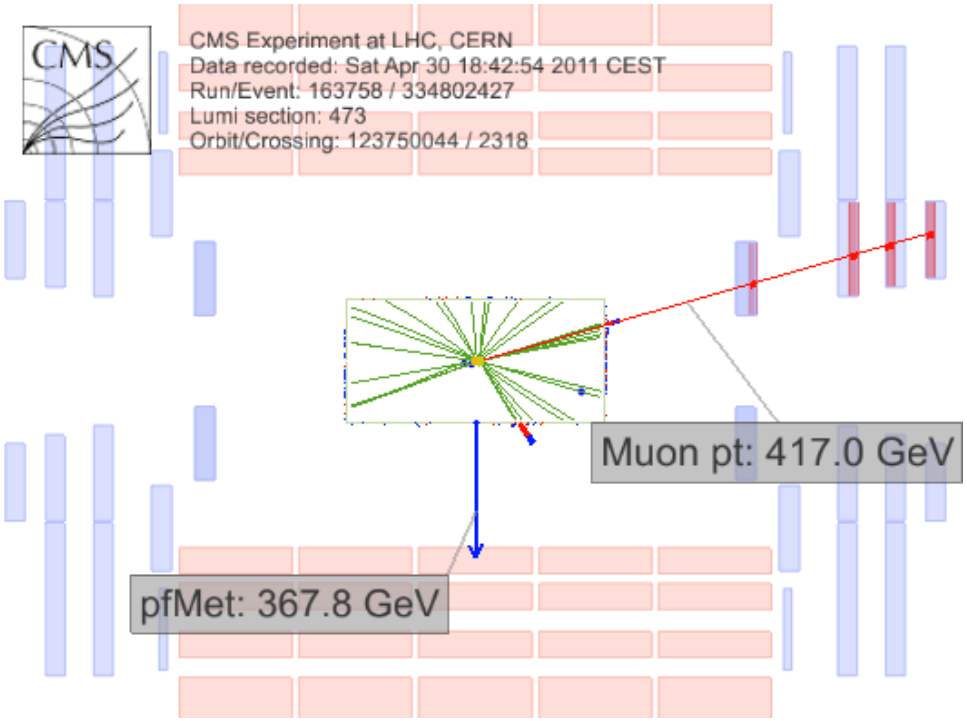
Signature

Spectacular signature

- One high-p_T lepton in event (“straight track”)
- Plus “nothing else”

Muon channel: Event with M_T = 783 GeV

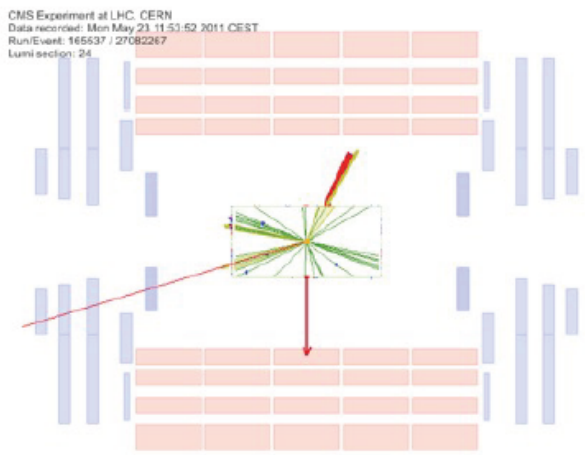




Signature

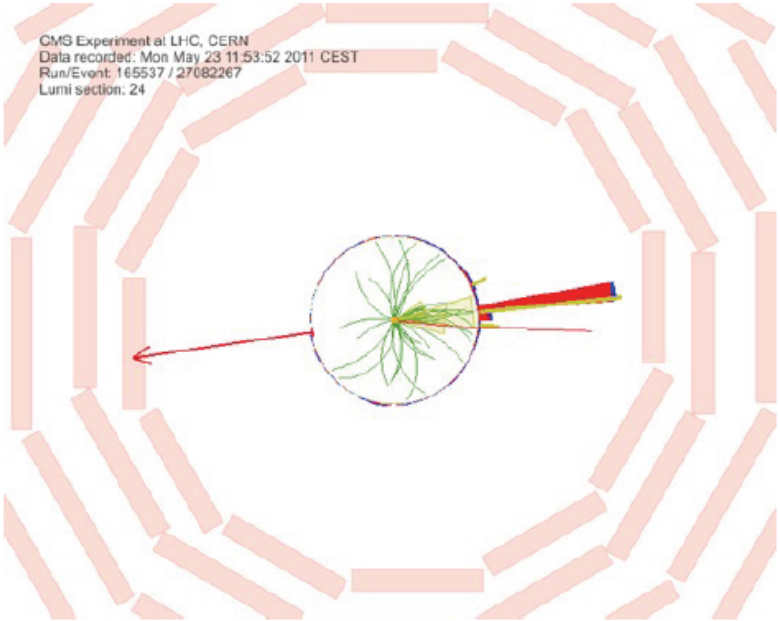
Spectacular signature

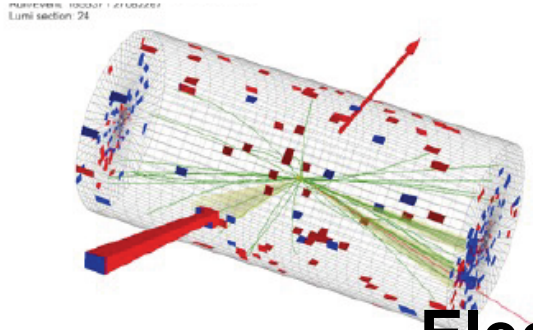
- One high-p_T lepton in event ("straight track")
- Plus "nothing else"



- mt = 922.0 GeV

- one 19 GeV muon inside a jet in EE





Electron channel: Event with M_T = 922 GeV

Signal simulation

- Signal samples generated with PYTHIA6 in LO

- Determination of NNLO k-factors for each W´ mass point using FEWZ 2.0
  - Calculated LO cross-section for CTEQ6L1 (used for generation) and NNLO cross-section for MSTW2008 PDF-sets for masses 600-2500 GeV in steps of 100 GeV

- Analysis uses NNLO = LO × *k*-factor

$$K_{Factor}^{NNLO} = \frac{\sigma_{FEWZ}(NNLO; MSTW2008)}{\sigma_{FEWZ}(LO; CTEQ6L1)}$$

- NNLO W' → lν production cross sections range from 0.346 pb (for $m_{W'}$ =1.2TeV) to 0.0025pb (for $m_{W'}$ =2.5TeV)

- **Signal efficiencies > 80% for both electron and muon channels**
  - **Fairly independent of W' mass**

Transverse mass distributions

$$M_T = \sqrt{2 \cdot (p_T^{\mu} \cdot c) \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - \cos \Delta\phi_{\mu,\nu})}$$

Transverse mass (electron channel)

1.03 fb^{-1}

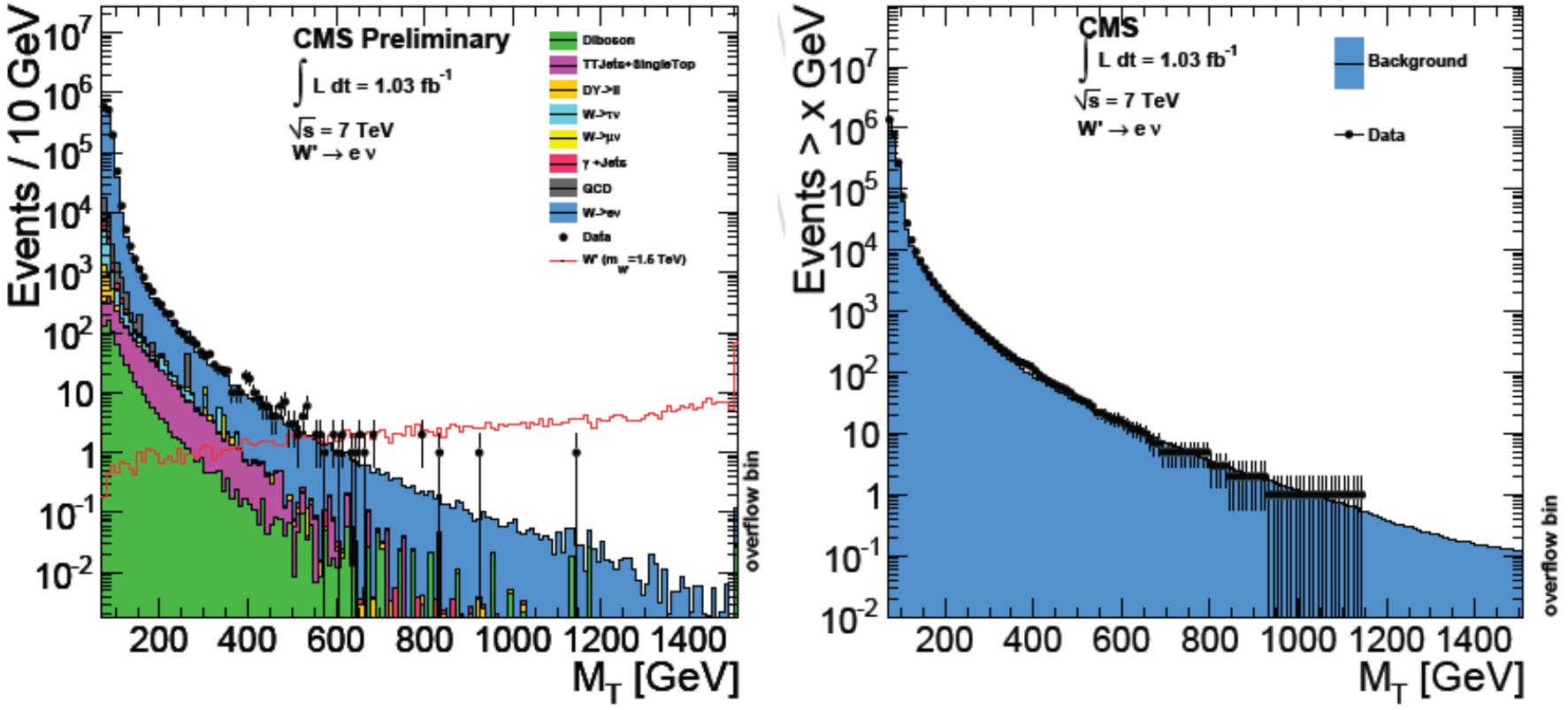


Figure 2: Transverse mass distribution (left) and cumulative distribution (right) for the electron channel.

No excess observed in data when compared to SM background expectation

Transverse mass (muon channel)

1.13 fb^{-1}

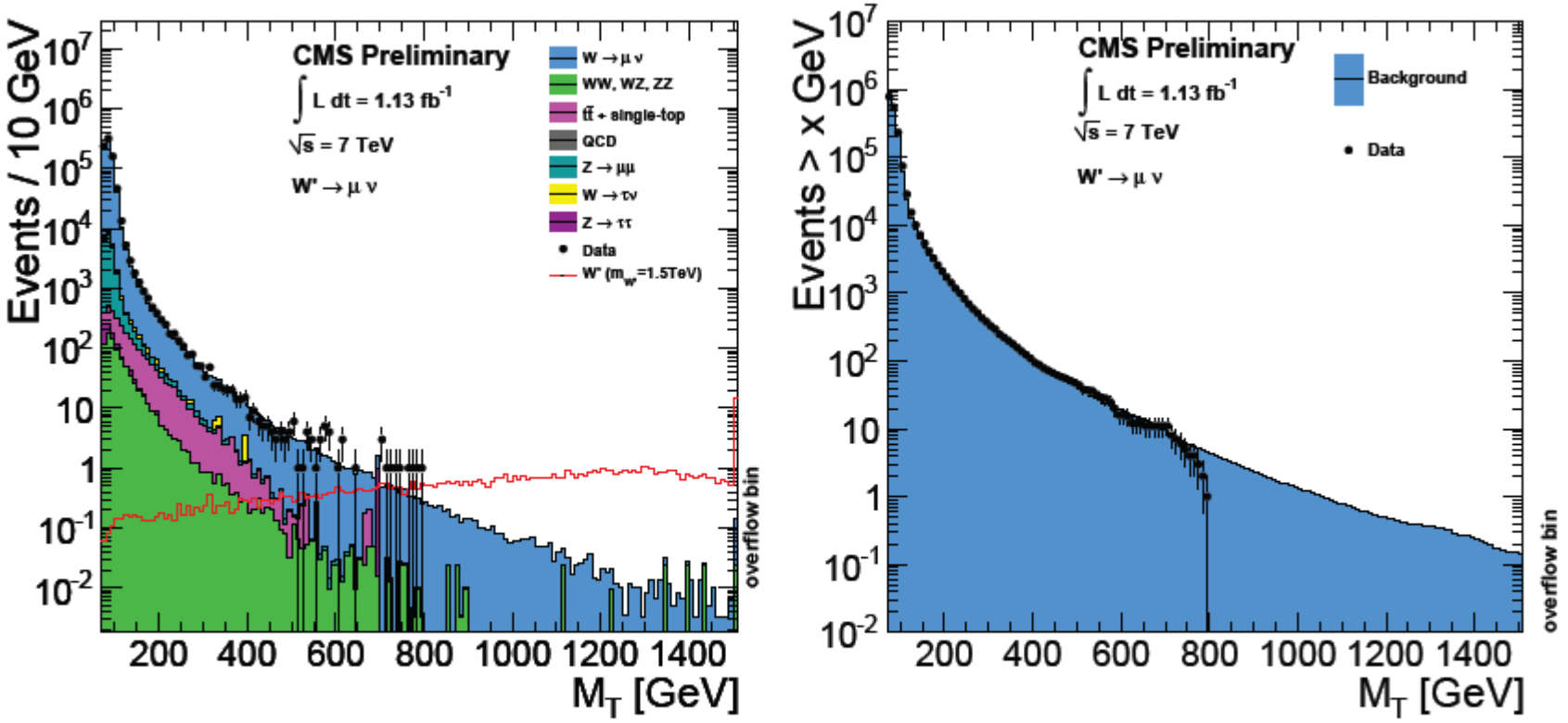


Figure 3: Transverse mass distribution (left) and cumulative distribution (right) for the muon channel.

No excess observed in data when compared to SM background expectation

Analysis Strategy

- No excess found => calculate exclusion limit

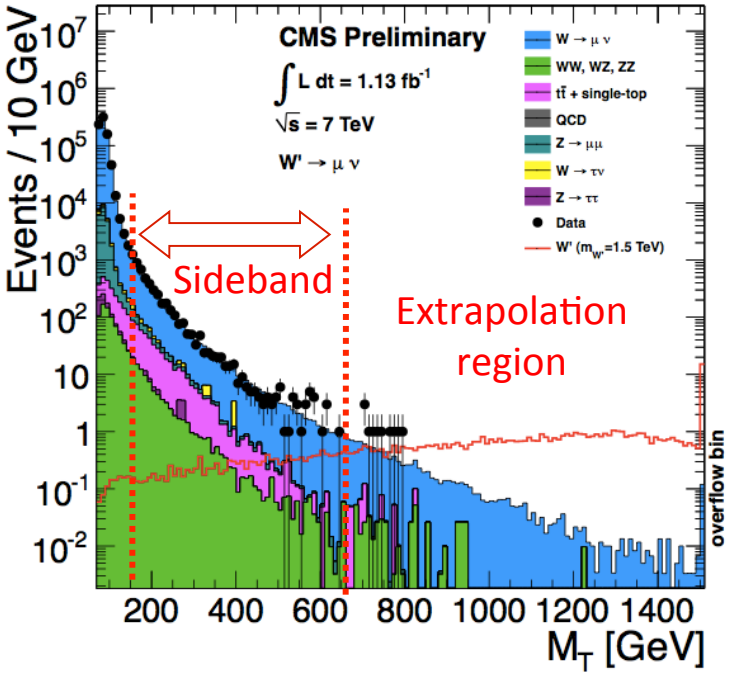
- Look at tail of M_T distribution and obtain:
  - Total number of expected signal events
    - Cross sections, k-factors, efficiencies
  - Total number of expected background events
    - How confident are we that we understand the composition of the background in the M_T spectrum?
    - What is the *expected* background in the signal region?
  - Total number of observed events in the data

- Event-counting for setting exclusion limit
  - Bayesian method with flat prior for signal cross section
  - Use "Sliding search" window optimized for best expected limit

Background Determination

Background Determination

- Data-driven method for combined (beam-induced) bgd
  - Find "signal-free" region of M_T spectrum [signal contamination << 1%]
    - (170-210 < M_T < 550-650 GeV)
  - Fit sideband & use parameters to model background shape
  - Extrapolate bgd to "region of interest" (e.g. M_T>1 TeV)
  - Estimate # of bgd events in signal region (w/o relying on MC)



Method proven to work in MC

- Background in MC is sum of all SM contributions (but mainly off-peak W→μ/e ν)

Background determination: Fit functions

Tested several fitting functions

Function 1:

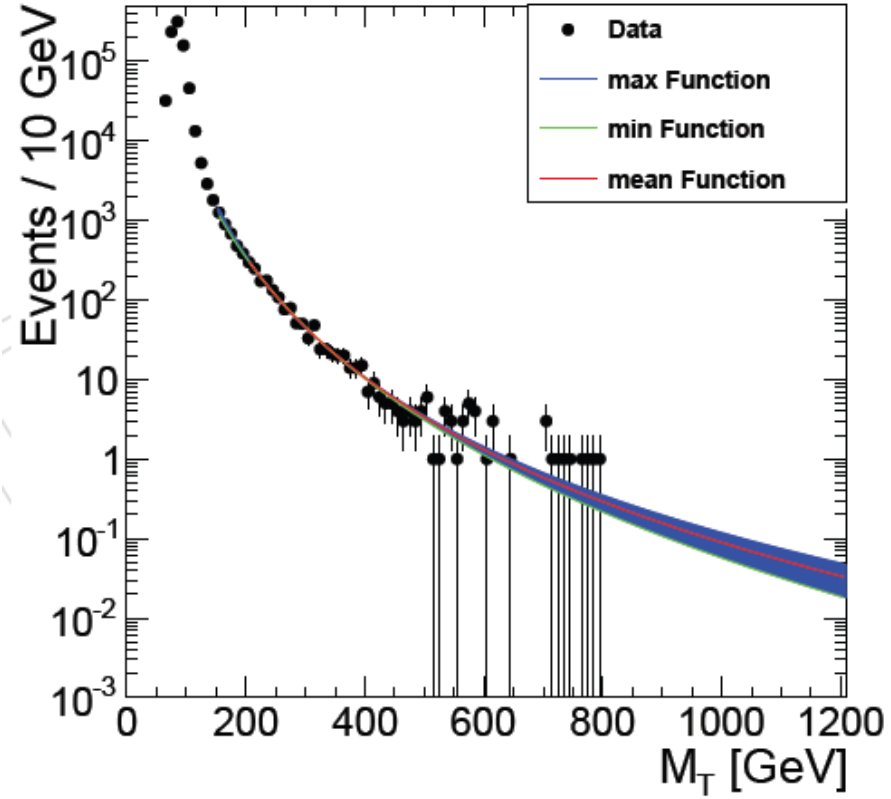
$$\frac{a}{(M_T + b)^c}$$

Function 2:

$$\frac{a}{(M_T)^2 + b \cdot M_T + c)^d}$$

Function 3:

$$\frac{a(1 + M_T)^b}{(M_T^{c+d \cdot log M_T})}$$



Example: muon channel

Tested varying sideband

Lower edge varied between 170 and 210 GeV.

Upper edge (rather insensitive) varied between 550 and 650 GeV.

Cross check with MC: functions describe simulation very well

Systematic Uncertainties

Signal

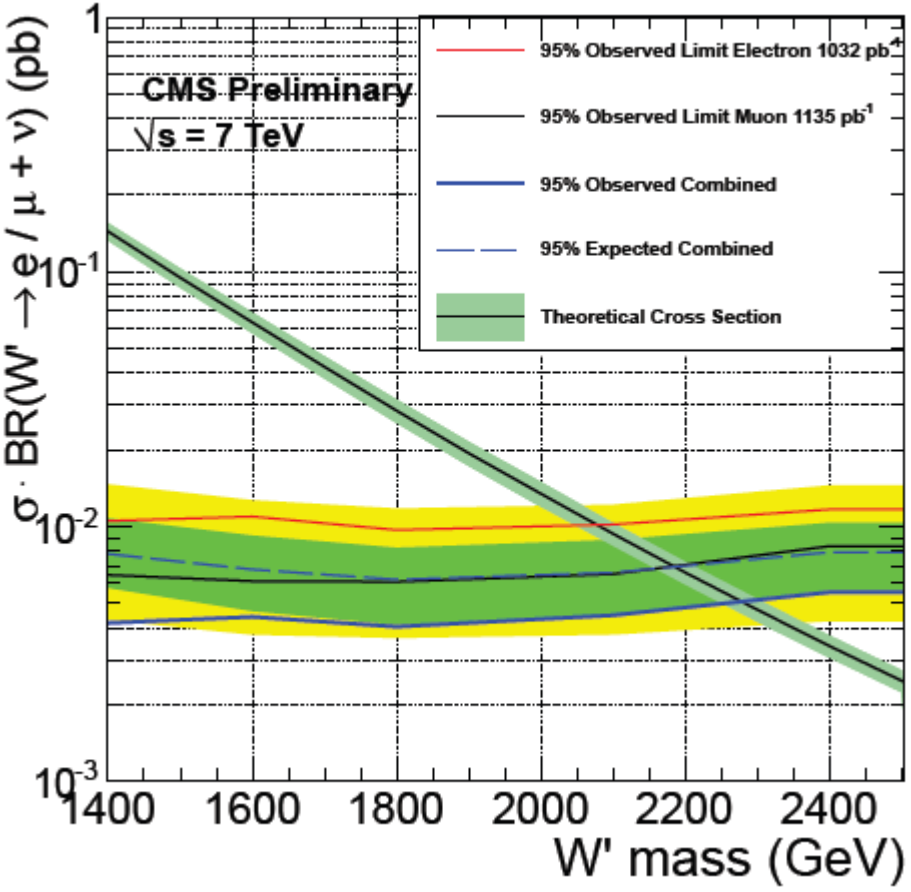
Systematic uncertainty	Value	Impact on signal
Luminosity	6 %	6 %
Muon p_T resolution and Momentum scale	0.14 TeV^{-1} (pT) 0.4% (scale)	10 %
MET resolution, hadronic component	10 %	2 %
Muon trigger efficiency	3 %	3 %
Combined electron efficiency (trigger, ID and reconstruction)	2 %	2 %
Electron energy scale	1% EE, 3% EC	<1%

Background

Taking into account uncertainties due to fit parameter errors in extrapolation, sensitivity of fit on range of sideband, choice of fitting function and discrepancy between MC and sideband fit prediction

Combined Exclusion Limit

- Fully correlated luminosity uncertainty
- Fully uncorrelated background uncertainty (correlated also tested, yields same result)



W′ mass (GeV)	σ_{theor} (pb)	Exp. Limit (pb)	Obs. Limit (pb)
1400	0.1440	0.0078	0.0042
1600	0.0633	0.0068	0.0044
1800	0.0285	0.0062	0.0040
2100	0.0094	0.0066	0.0045
2400	0.0034	0.0079	0.0055

Combined limit (SSM):

Expected: m(W') > 2.20 TeV
Observed: m(W') > 2.27 TeV

Significant improvement over 2010 results (1.58 TeV)

Summary

- We have performed a search for W' bosons decaying to the lepton + MET final state using ~1 fb^{-1} of data

- No significant excess above the SM background expectation is observed in the data

- We set a lower bound on the W' mass, assuming SM-like couplings and no interference with other bosons:

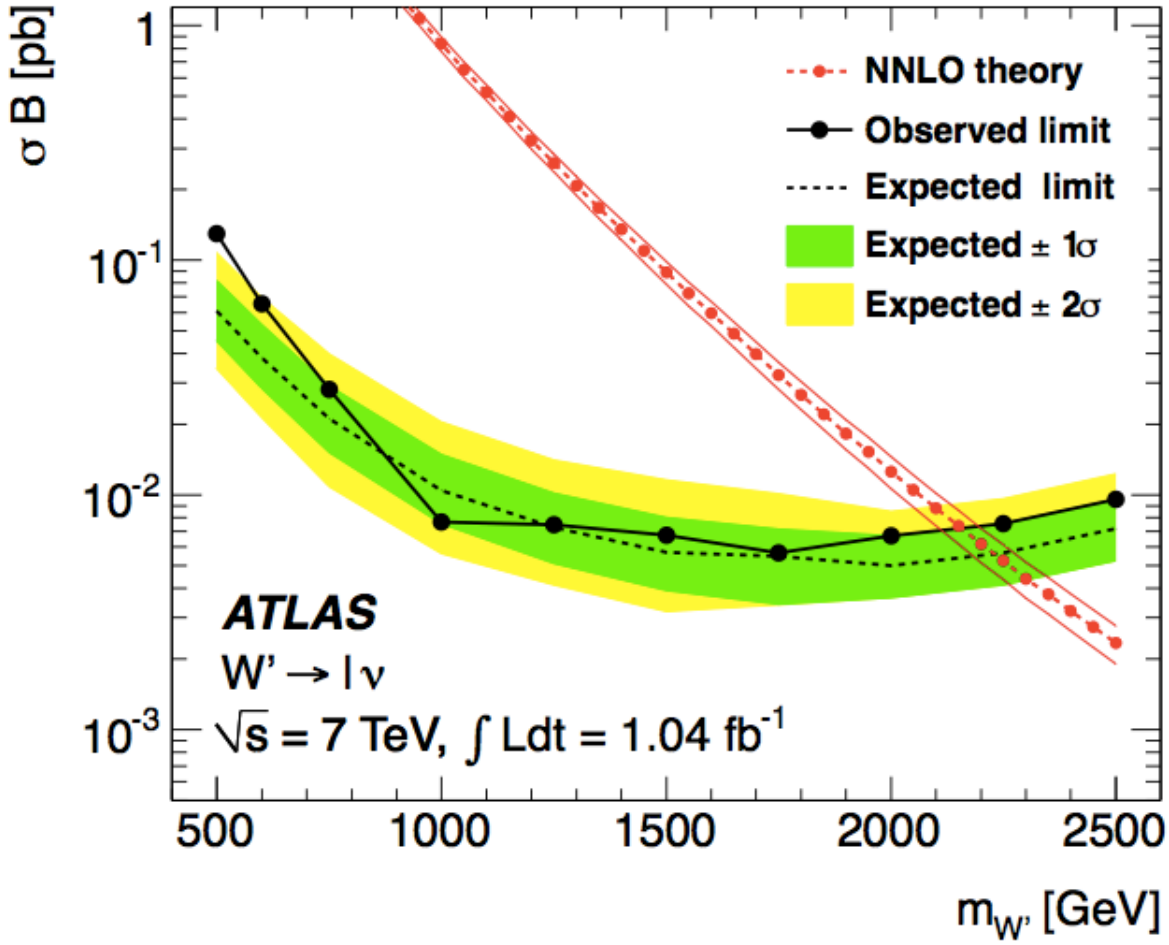
M(W') > 2.27 TeV

- Significant improvement over the 2010 result.

Backup

ATLAS W' (2011)

arXiv:1108.1316



A W ' with SSM couplings is excluded for masses up to 2.15 TeV at the 95% CL.