Search For a Heavy Neutrino and a Right-Handed W of the Left-Right Symmetric Model with the CMS Detector

(CMS EXO-11-02)

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For the CMS Collaboration

Motivation

	Standard Model	Left-Right-Symmetric Extension (LRSM)
Gauge group	$SU(2)_L \times U(1)_Y$	$SU(2)_L$ **X $SU(2)_R$** X $U(1)_{B-L}$
Fermions	LH doublets: $Q_L = (u^i, d^i)_L$, $L_L = (l^i, \nu^i)_L$ RH singlets: $Q_R = u^i_R$, d^i_R , $L_R = l^i_R$	LH doublets: $Q_L = (u^i, d^i)_L$, $L_L = (l^i, \nu^i)_L$ RH doublets: $Q_R = (u^i, d^i)_R$, $L_R = (l^i, N^i)_R$
Neutrinos	ν^i_R do not exist ν^i_L are massless & pure chiral	N^i_R are heavy partners to the ν^i_L N^i_R Majorana in the Minimal LRSM
Gauge bosons	$W^\pm_L$, Z^0, γ	$W^\pm_L$, $\mathbf{W^\pm_R}$, Z^0, $\mathbf{Z'}$, γ

- Parity violation is built-in for the SM
    - Parity violation in LRSM via symmetry breaking at intermediate mass scale
- Neutrino oscillations require massive neutrinos
    - Forbidden in SM
    - "See saw" mechanism in LRSM

Left-Right symmetric model

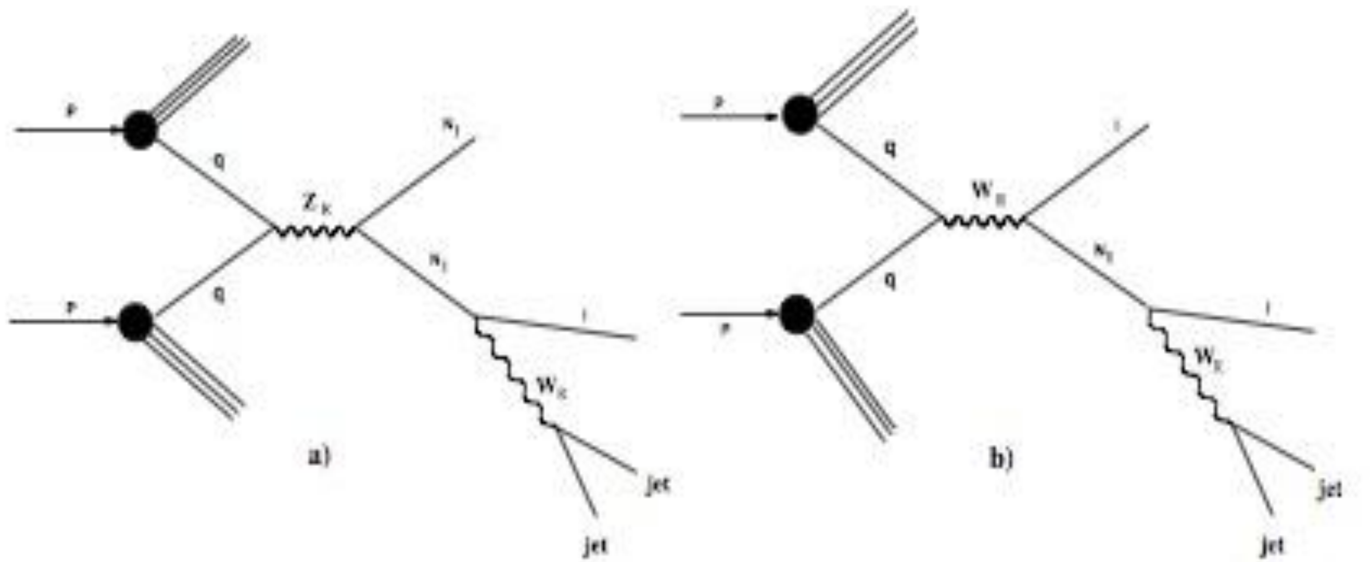
- **Gauge group**: $SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$

- **Fermion fields** $\begin{pmatrix} u_L \\ d_L \end{pmatrix} \overset{P}{\Leftrightarrow} \begin{pmatrix} u_R \\ d_R \end{pmatrix} \quad \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \overset{P}{\Leftrightarrow} \begin{pmatrix} \nu_R \\ e_R \end{pmatrix}$

- **New gauge bosons** $W^{\pm}{}_R,\ Z`$

- **Higgs fields:** $\phi(2,2,0) \quad ; \Delta_R(1,3,+2) \oplus \Delta_L(3,1,+2)$

Production and signature at pp colliders



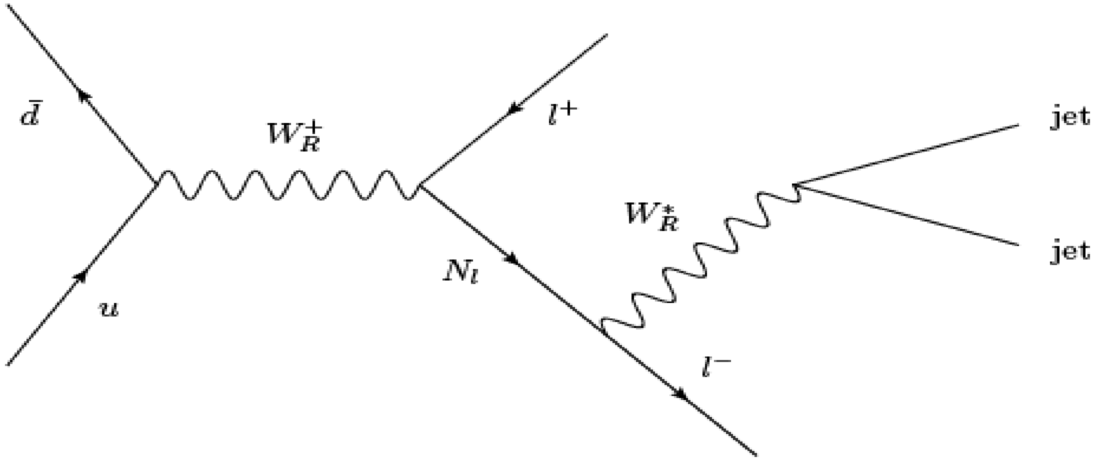
Drell-Yan production:

- pp → Z\` → N_l + N_l + X
- pp → W_R → l + N_l + X
- N_l → l + jet + jet

Signatures:

- two high-Pt isolated lept.
- two high-Pt jets
- $M(W_R)$,$M(N_l)$ peaks

- Very similar to heavy gauge boson production (e.g. W'_L)
- Search for $W_R \rightarrow \ell N$ decay, additional decay of heavy neutrino
  - No L-R mixing implies N decay via virtual W^*_R
- Production cross section depends on mass of W_R and N
- Final state: two (same-flavor) leptons, two jets
  - Leptons not back-to-back, different p_T



Direct W_R mass limits from Tevatron

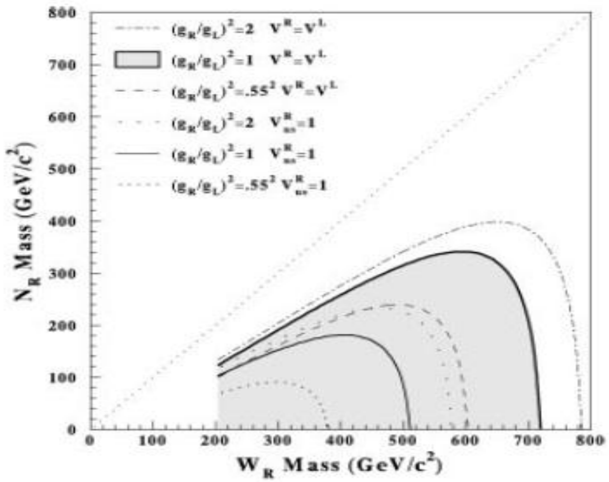


FIG. 3. 95% CL excluded W_R mass region from the *peak search*. The lines represent the contours for different values of the LRM parameters. The diagonal line is the kinematic limit for the $W_R \to eN_R$ decay.

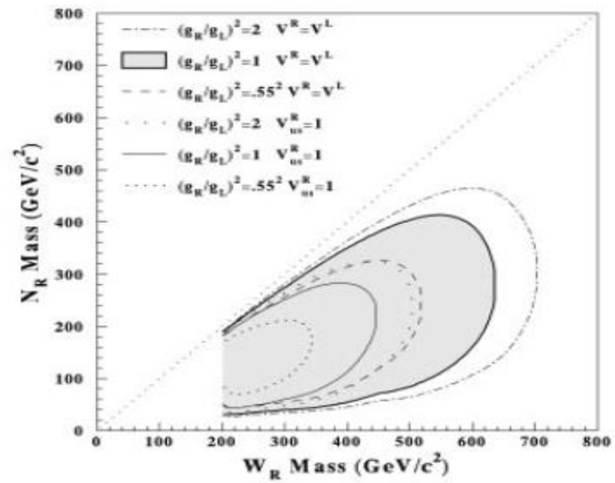


FIG. 4. 95% CL excluded region of W_R mass from the *eejj* search for the no mixing case.

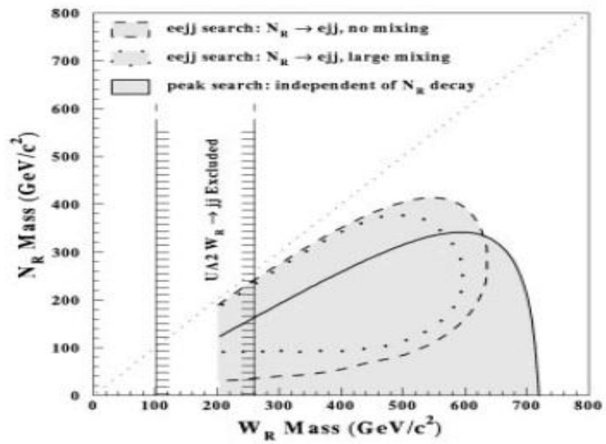


FIG. 5. Excluded regions of W_R mass at the 95% CL assuming $g_R = g_L$ and $V^R = V^L$.

$M(W_R) > 780$ GeV

$M(N) > 400$ GeV

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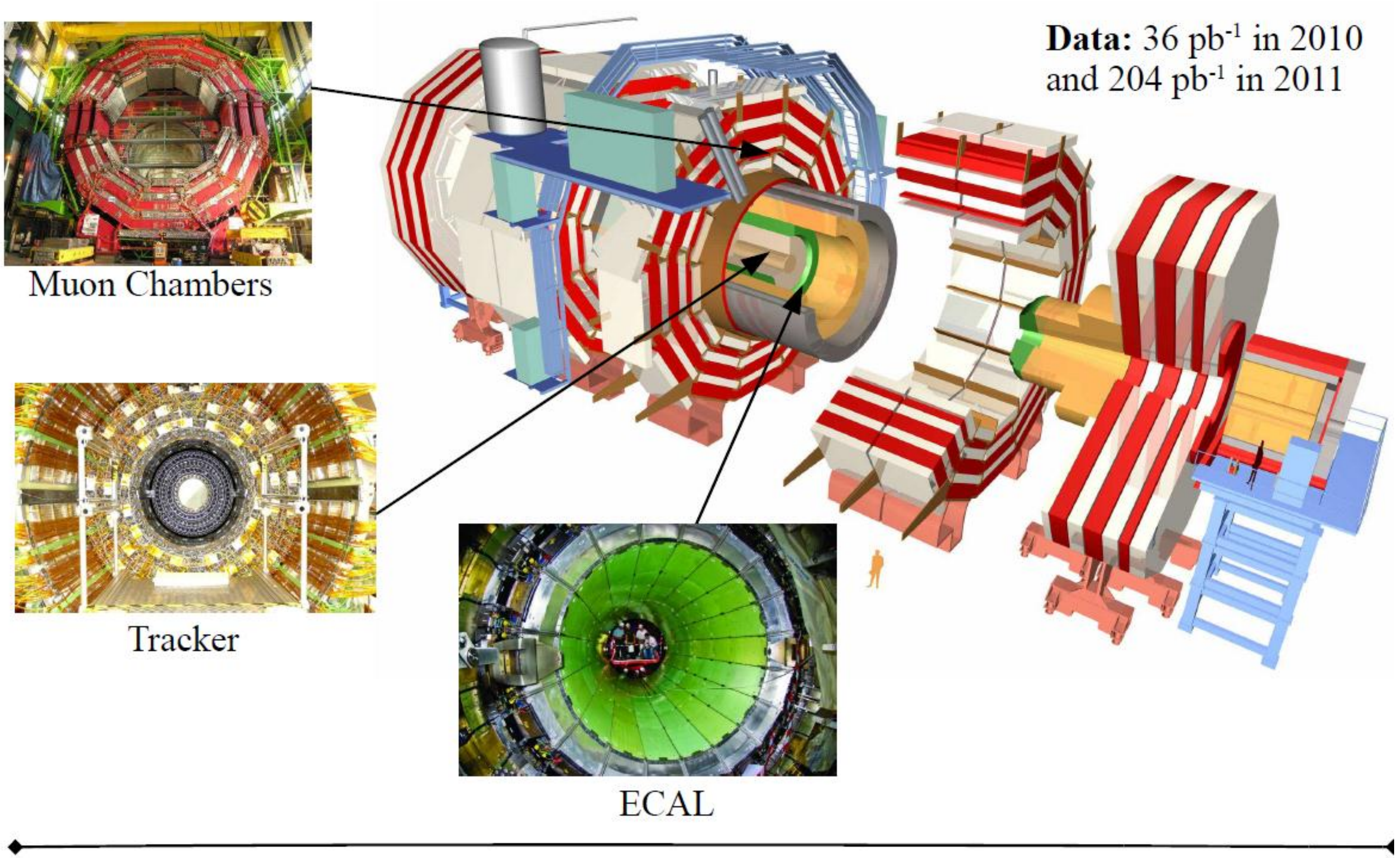
COMPACT MUON SOLENOID



Events selection

- Preliminary: isolated lept., jet ID, pT > 20 GeV, efficiency check, Z control sample. Typ. : e > 70 %, mu > 80 %

- Primary: at least 2l, pT > 40 GeV (of any flavour and sign) and 2 jets.

  signal jet pair: 2highest pT j1, j2, eff. 90%

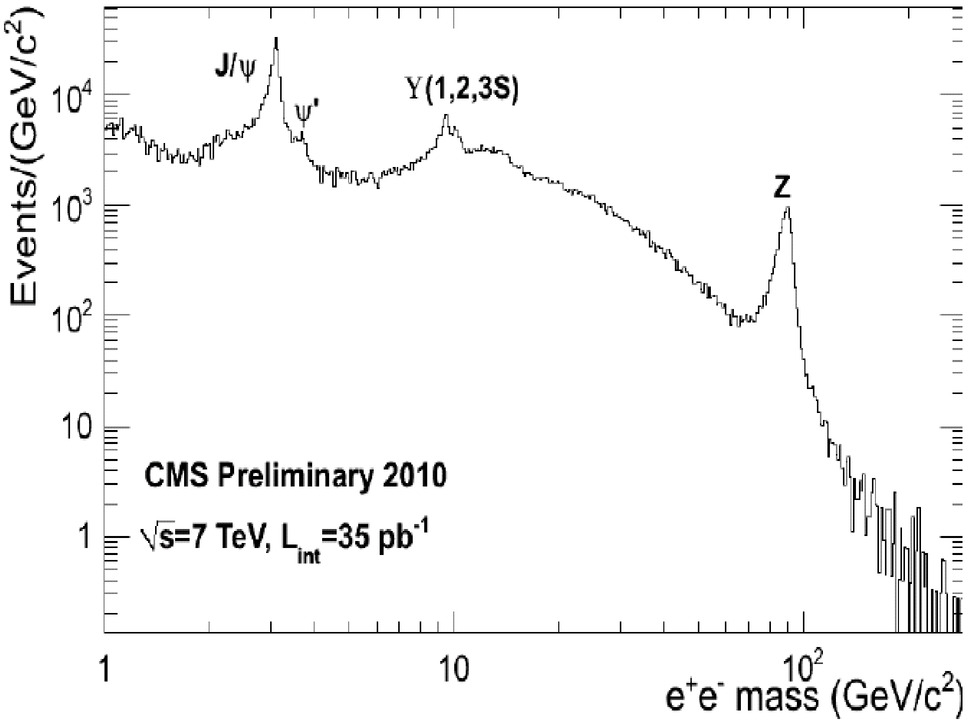
  signal lepton pair: only 2high pT l1, l2 to avoid combinatorial bckg.

M_N = M(l2 j1 j2), 3 – 10 % eff. loss vs M_N

M_{WR} = M(l1 l2 j1 j2)

EVENT RECONSTRUCTION

- Only consider two leading leptons and two leading jets
- For leptons: E_T or $P_T > 30(20)$ GeV for 2011 (2010)
- For jets: $P_T > 40$ GeV, no leading lepton in jet cone



Estimating Backgrounds

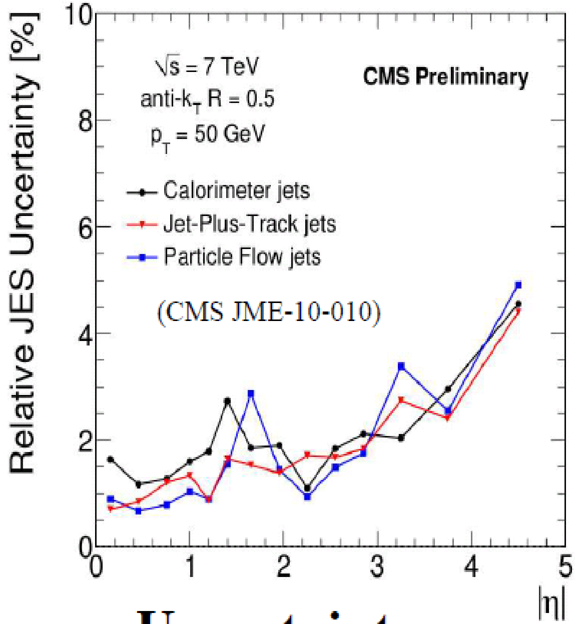
- Dominant Standard Model backgrounds from Top, Z+jets
  - Background shape taken from fits to Monte Carlo after full selection applied
  - Background normalization via comparison to data
- Remaining backgrounds
  - QCD: Estimated from data
  - W+jets, VV, tW (shape and normalization) estimated from simulation

SYSTEMATICS

Electron		
	Signal	**Background**
Jet Energy Scale	2-20%	7%
Reco/ID/Iso	10%	10%
Theory	5%	14%
Total	**11-25%**	**23%**

Muon		
	Signal	**Background**
Jet Energy Scale	0.5-20%	5%
Reco/ID/Iso	6-10%	1%
Theory	5%	14%
Total	**8-25%**	**17%**

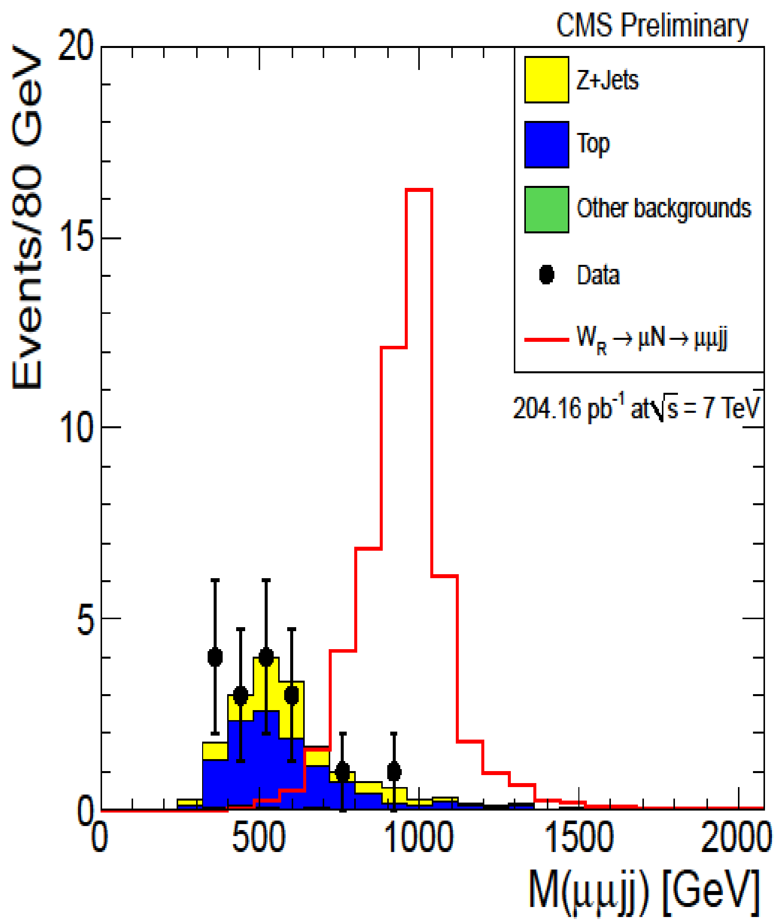
Jet Energy Scale

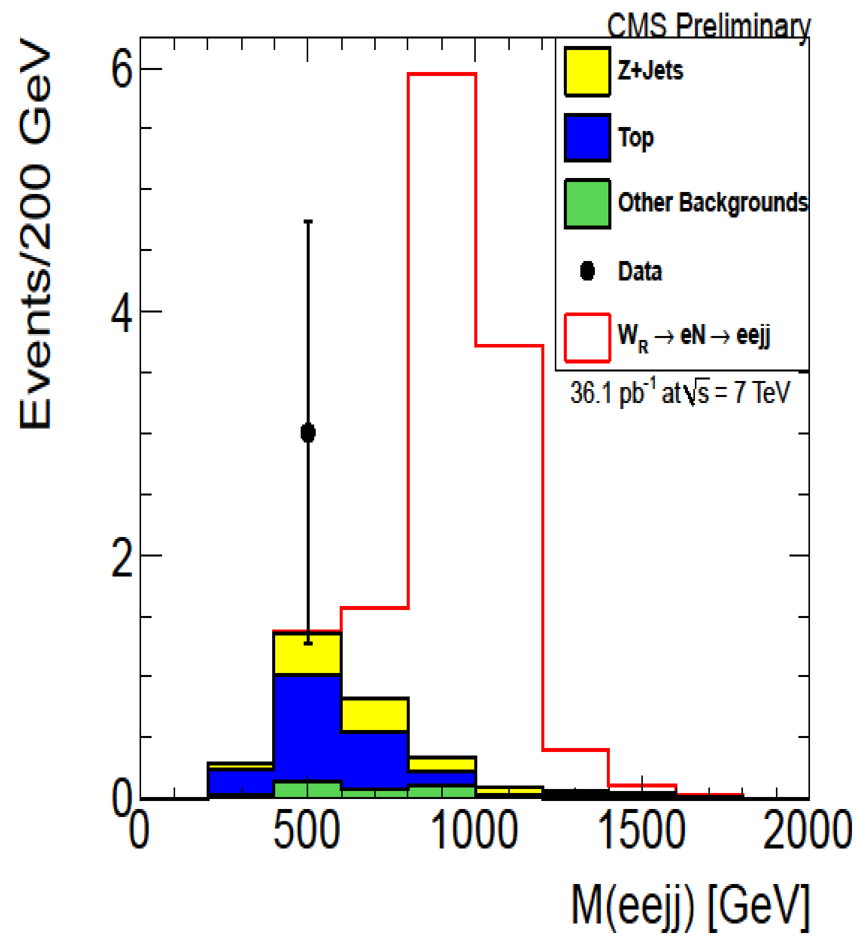


Theory Uncertainty

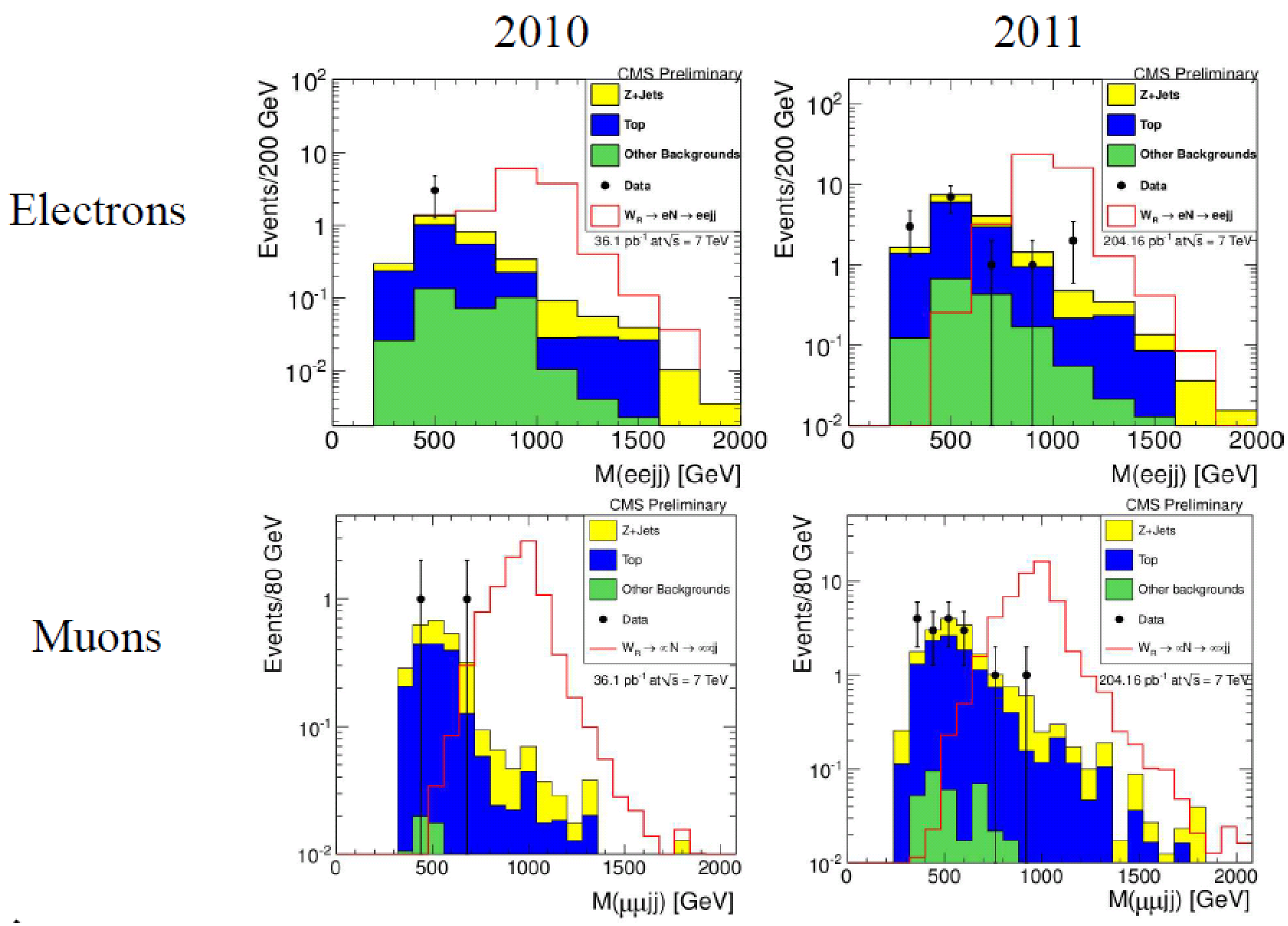
- Scale Uncertainty
- PDF
- ISR, FSR

WR SPECTRUM

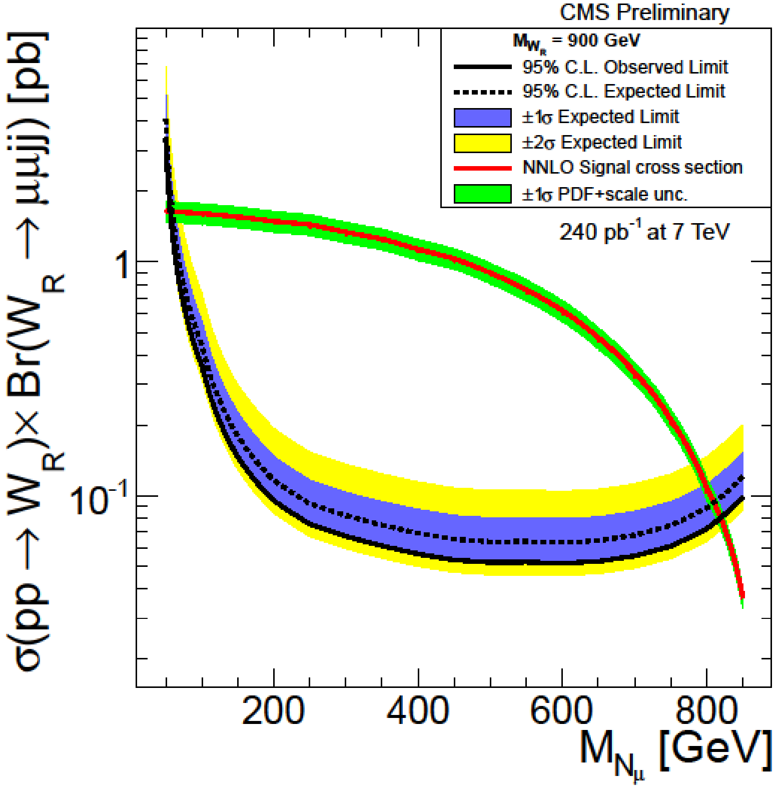

CMS Preliminary
Z+Jets
Top
Other backgrounds
Data
$W_R \to \mu N \to \mu\mu jj$
204.16 pb^{-1} at $\sqrt{s}$ = 7 TeV
Events/80 GeV
M(μμjj) [GeV]
0
5
10
15
20
500
1000
1500
2000

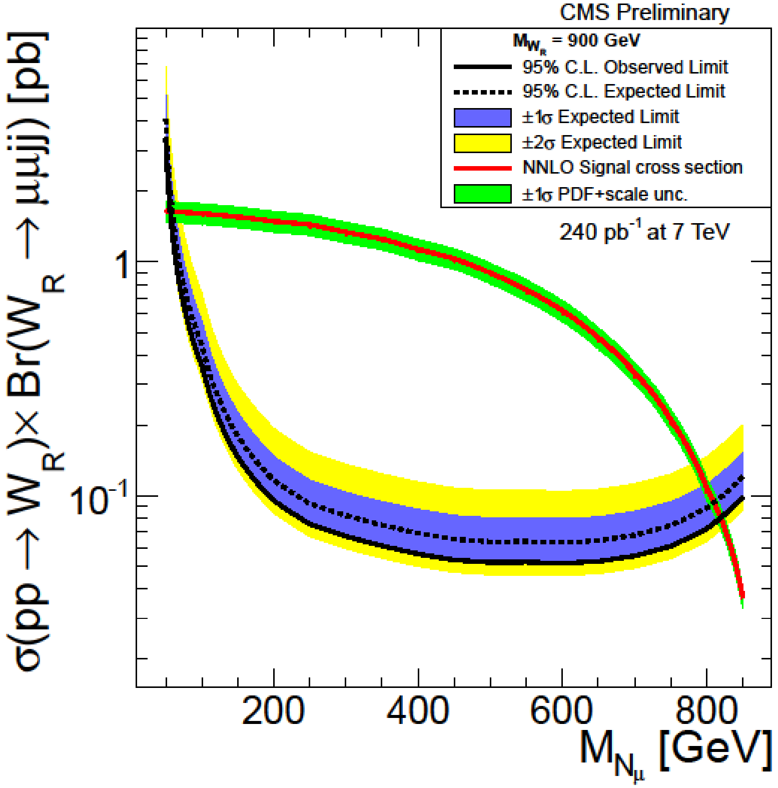

CMS Preliminary
Z+Jets
Top
Other Backgrounds
Data
$W_R \to eN \to eejj$
36.1 pb^{-1} at $\sqrt{s}$ = 7 TeV
Events/200 GeV
M(eejj) [GeV]
0
2
4
6
500
1000
1500
2000

WR SPECTRUM

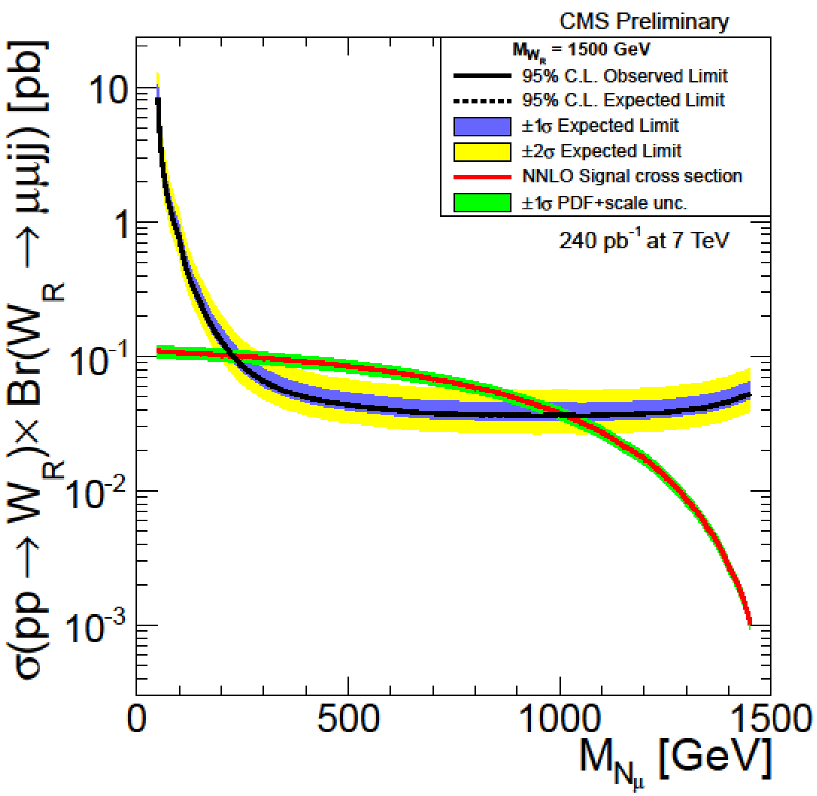

2010
2011
Electrons
Muons
CMS Preliminary
Z+Jets
Top
Other Backgrounds
Data
36.1 pb⁻¹ at √s = 7 TeV
204.16 pb⁻¹ at √s = 7 TeV
Events/200 GeV
M(eejj) [GeV]
Events/80 GeV
M(μμjj) [GeV]

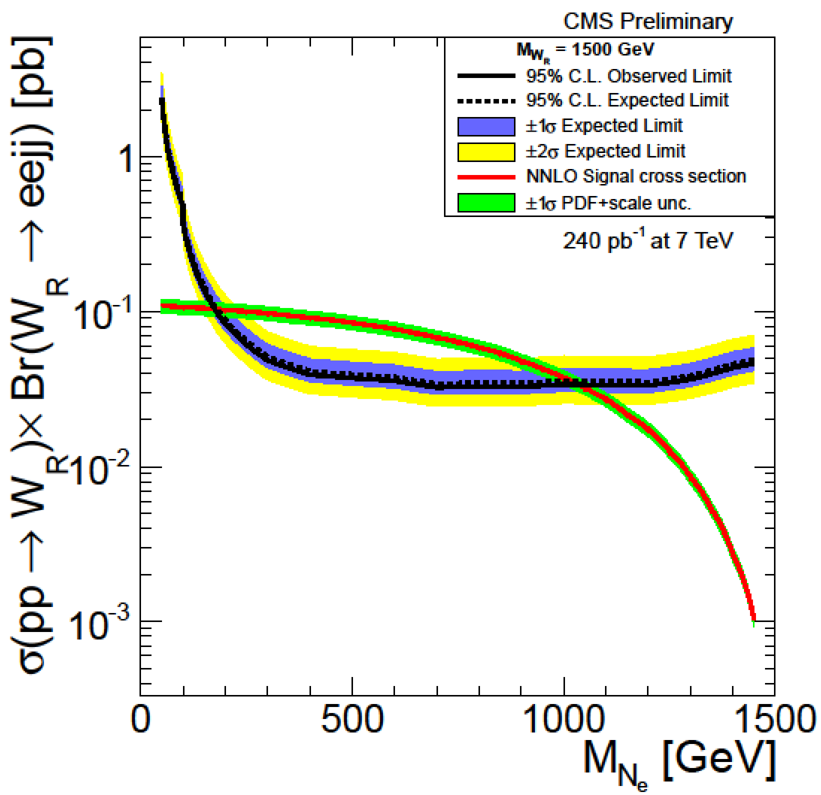
CMS exclusion plots



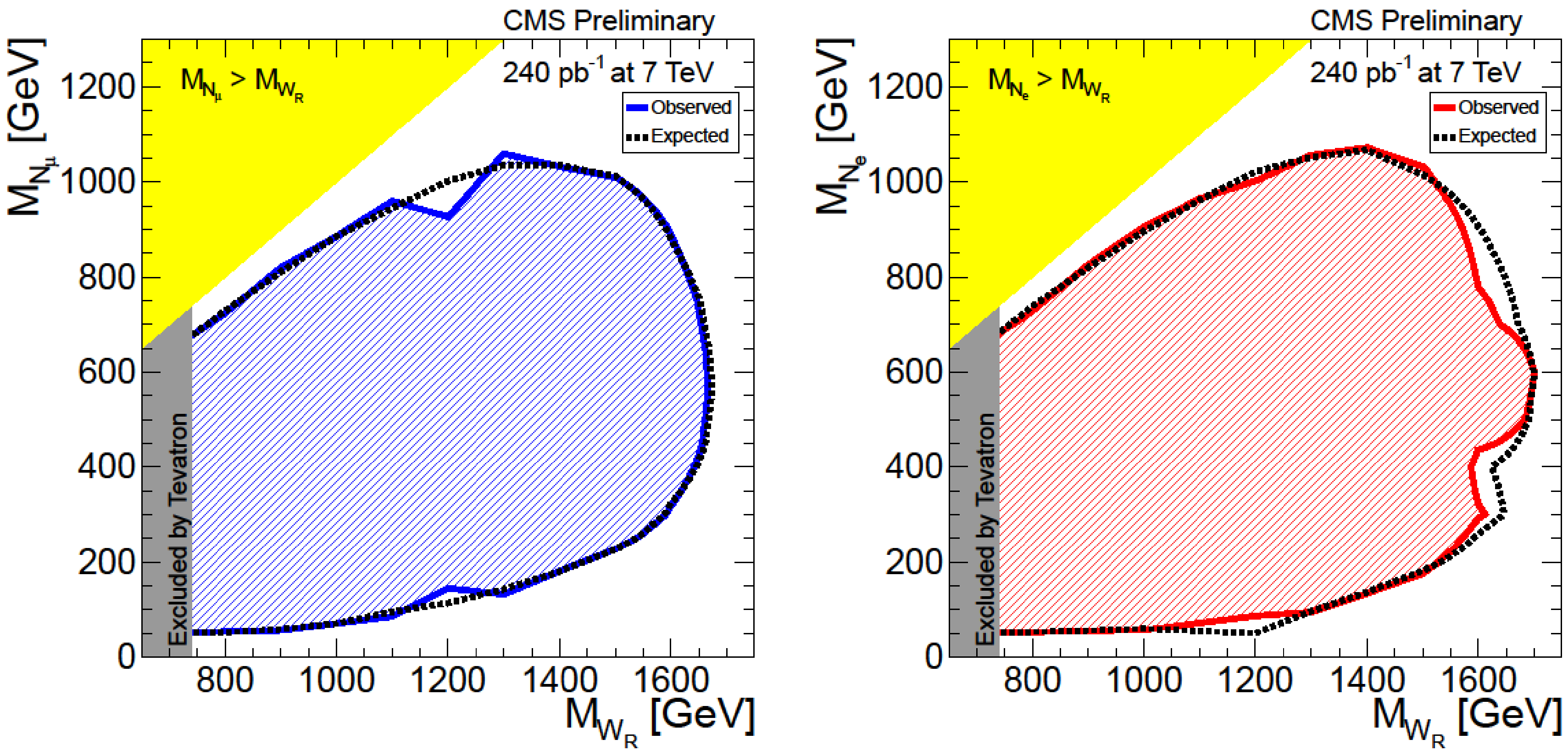


CMS exclusion plots





CMS exclusion plots for e and mu



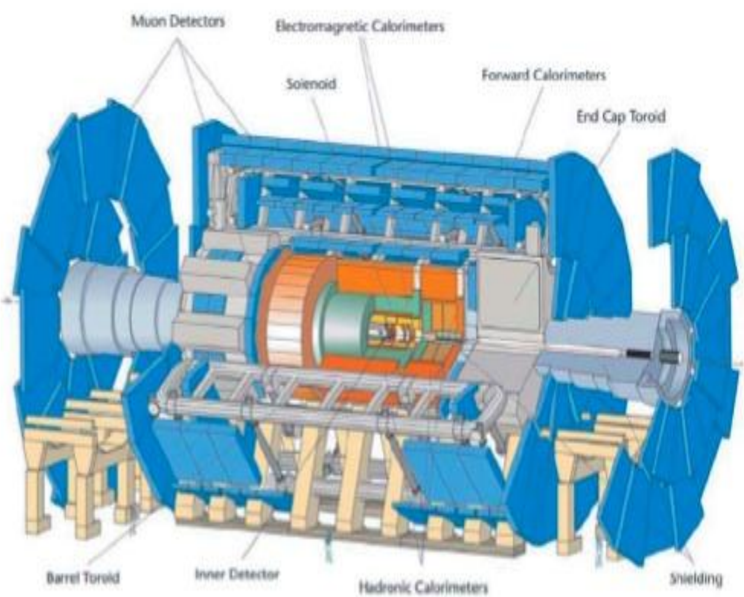
Conclusion

- CMS has performed a search for W_R and heavy neutrinos (N) using 240/pb collected in 2010 and 2011
- No evidence observed for the presence of W_R in the datasets
- Limits set using , extending well beyond 780 GeV limit from Tevatron
    - Exclusion extends to W_R = 1700 GeV

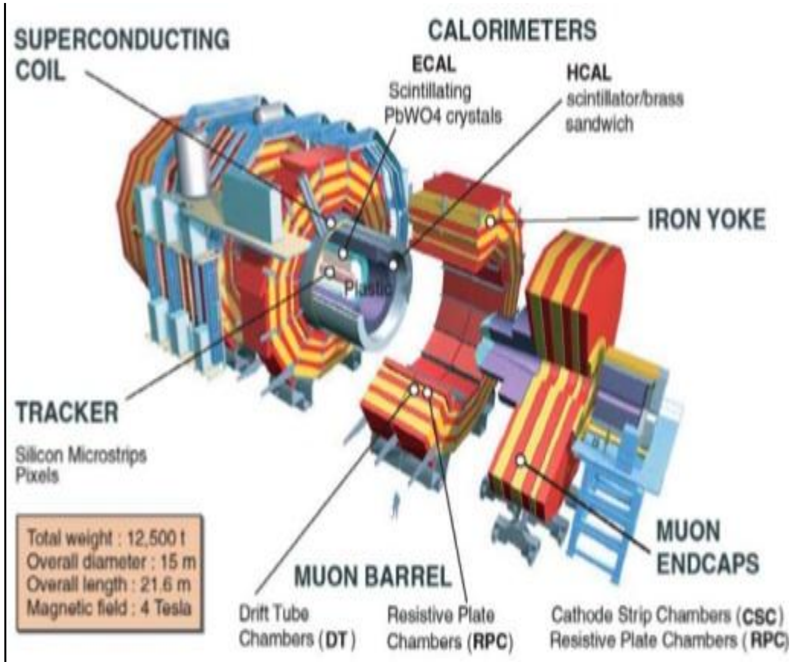
BACKUP SLIDES

The LHC Detectors

ATLAS



CMS



Well equiped to search for New Physics :

- reconstruction: l’s, γ’s, jets, missing E_T
- understanding of the background

Background reduction table, electrons

Table 2: Evolution of the numbers of signal and background events versus selection criteria (electron channel, electron trigger stream used). The window for the 2D peak for LRRP1 are: $1250 < M^{c}_{W_R} and < 1720$, $480 < M^{c}_{N_l} and < 710$. The numbers correspond to the statistics collected by the CMS detector for the integrated luminosity of $\mathcal{L}_{int} = 100\, pb^{-1}$

Most dangerous

Step	Signal LRRP1	$t\bar{t}$	Z jets ee	W jets e	QCD	WW jets	WZ jets	Others
Events in CMS	6.72	16200	167000	10^6	$2.8 \cdot 10^{10}$	4300	1800	1600
Simulated	2000	627000	2539000	2078000	$7.7 \cdot 10^7$	120000	114000	145000
Primary selection	4.86	133	413	1.5	33	2.1	5.5	3.9
Two isolated $e^{\pm}$	4.7	44.7	360	0.5	2.5	0.7	4.4	3.25
M_{ll} cut	4.4	5	2.7	0	0	0.13	0.06	0.025
$M^{cand}_{W_R} > 500$ GeV	4.4	3.2	2.2	0	0	0.13	0.06	0.032
Within the 2D peak	3.28	0	0	0	0	0	0	0.004

Indirect W_R mass limits

- parity transformation: $\phi \to \phi^{+}$
- then Yukawa coupling matrices

$$L_Y = h_{ab} \overline{Q}_{L\,a} \phi Q_{R\,b} + h.c.$$

are hermitean to be parity invariant

- This implies that the quark mass matrices are hermitean provided the vacuum expectation values are real.

↓

Left and Right CKM are the same

Indirect W_R mass limits

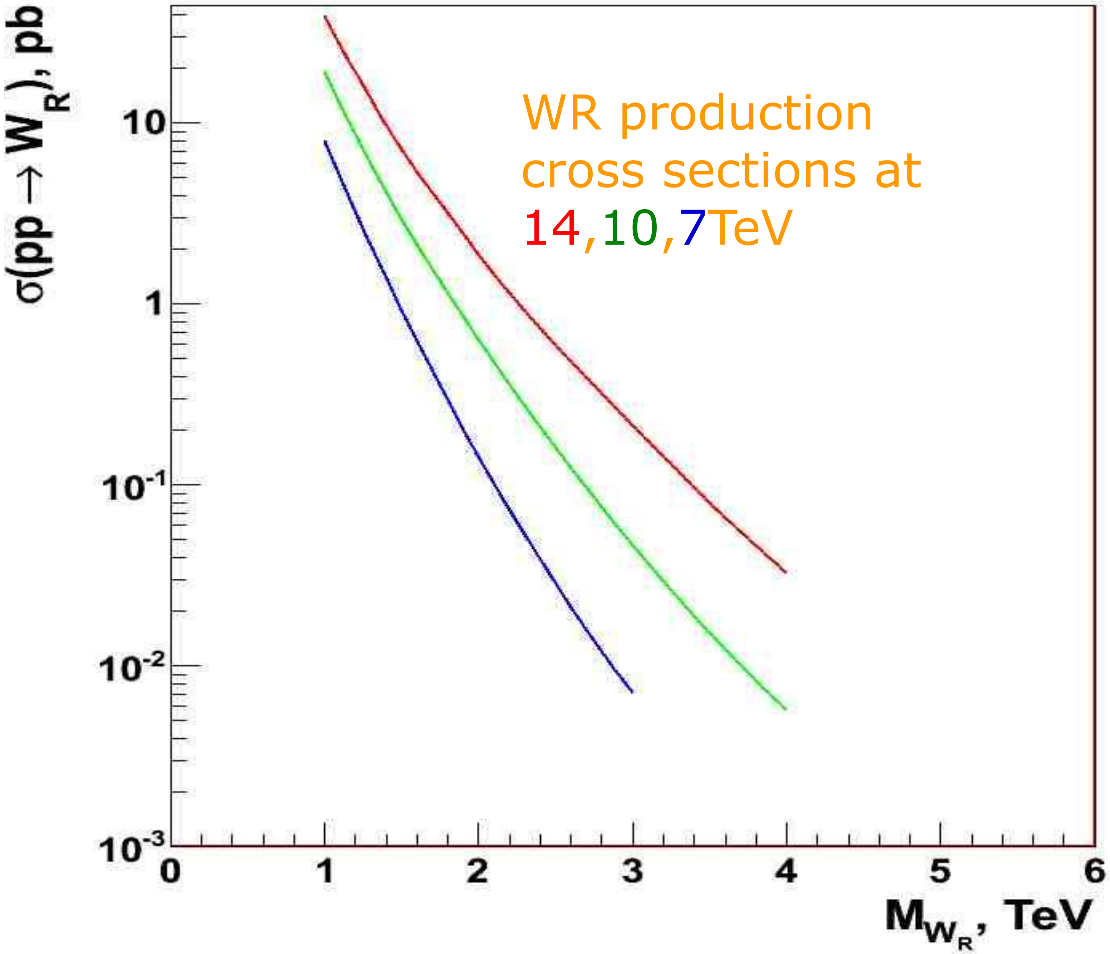
- beta decays: $M(W_R)>230$ GeV — J. Deutsch et al.`03
- muon decays: $M(W_R)>325$ GeV — TWIST coll.`06
- pol.n decays: $M(W_R)>270$ GeV — M.Schuman et al.`07

- K,B mixing, n-EDM: $M(W_R)>2.4$ TeV
- $\Delta M_{K,B}$, ε, ε', n-EDM: $M(W_R)>2.5$ TeV

Y. Zhang et al.`07; `08.

Can these limits can be evaded ?

cross section $pp \to W_R$



difference about factor 2 at 1 TeV

W_R Interest

Such a final state with any-sign lepton pair was used recently by the CMS collaboration to search for pair production of scalar leptoquarks, for both electron and muon lepton flavors [16]. We thus use these data to impose an improved limit on the masses of W_R and N [17].

arXiv.org > hep-ph > arXiv:1103.1627
Search or Article-id
High Energy Physics - Phenomenology

First Limits on Left-Right Symmetry Scale from LHC Data

Miha Nemevsek, Fabrizio Nesti, Goran Senjanović, Yue Zhang

(Submitted on 8 Mar 2011 (v1), last revised 28 Mar 2011 (this version, v2))

We use the early Large Hadron Collider data to set the lower limit on the scale of Left-Right symmetry, by searching for the right-handed charged gauge boson W_R via the final state with two leptons and two jets, for 33/pb integrated luminosity and 7 TeV center-of-mass energy. In the absence of a signal beyond the Standard Model background, we set the bound M_WR > 1.4 TeV at 95% C.L.. This result is obtained for a range of right-handed neutrino masses of the order of few 100 GeV, assuming no accidental cancelation in right-handed lepton mixings.

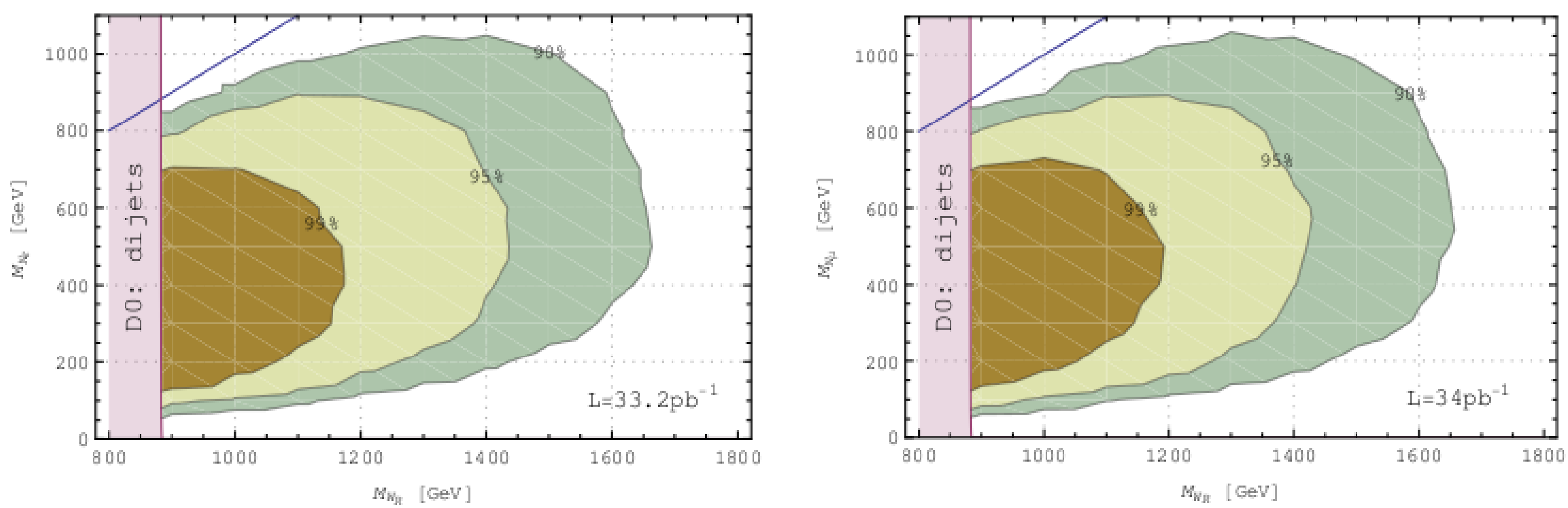
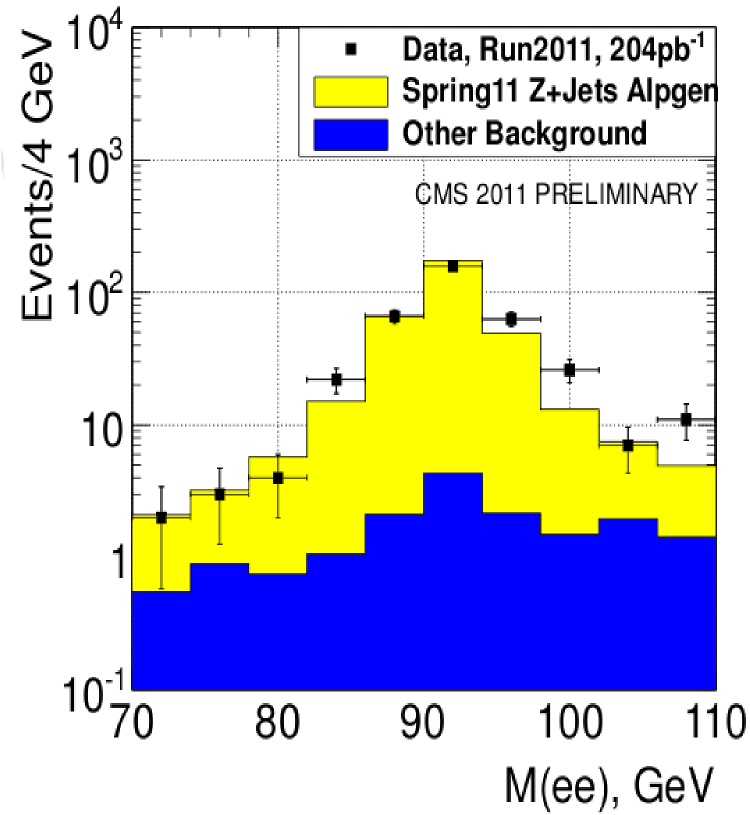
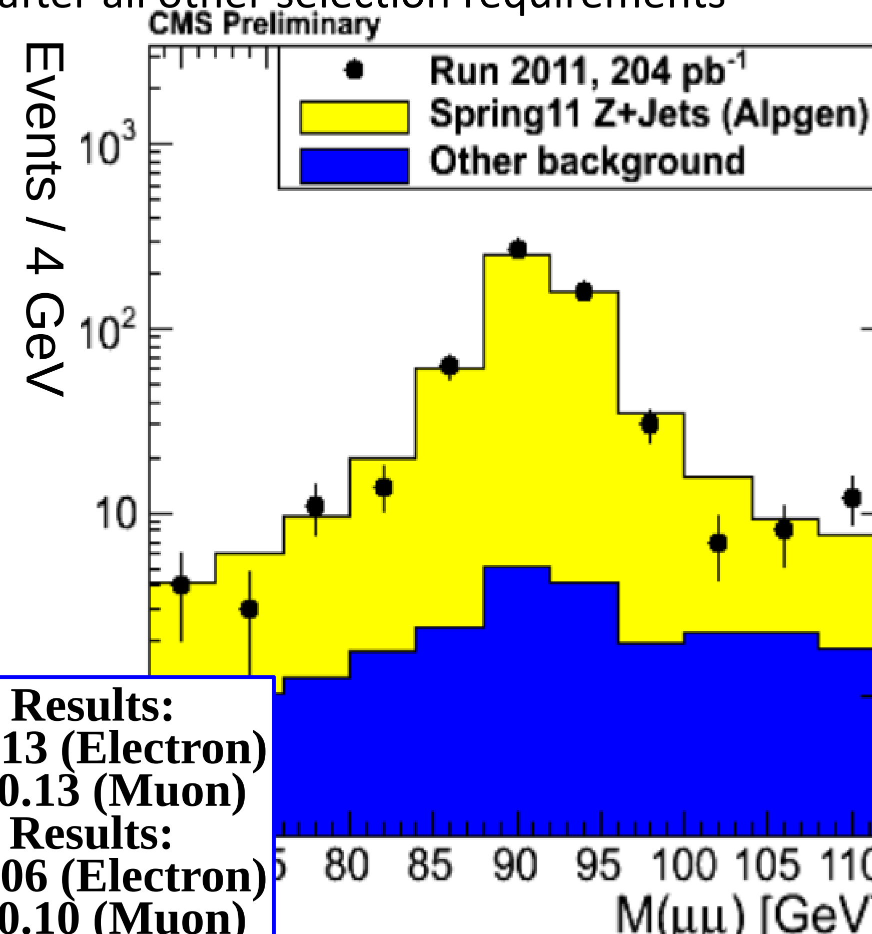


FIG. 1. Exclusion (90%, 95%, 99% CL) in the M_{W_R}–m_N plane from the $eejj$ (left) and $\mu\mu jj$ (right) channel. We assume no accidental cancelation in the RH lepton mixings. The 2σ lower bound $\sim$1.4 TeV is valid over a range of RH neutrino masses of order several hundred GeV.

Electroweak Backgrounds

- Dominant Electroweak backgrounds from Z+jets
- Normalize Monte Carlo to fit from Z peak region, compare to NNLO cross section
    - Examine dilepton mass distribution after all other selection requirements





2010 Results:
0.82+/- 0.13 (Electron)
1.01 +/- 0.13 (Muon)
2011 Results:
0.99+/- 0.06 (Electron)
1.13 +/- 0.10 (Muon)