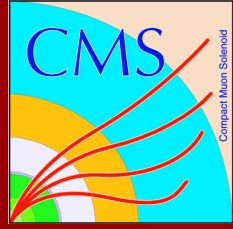


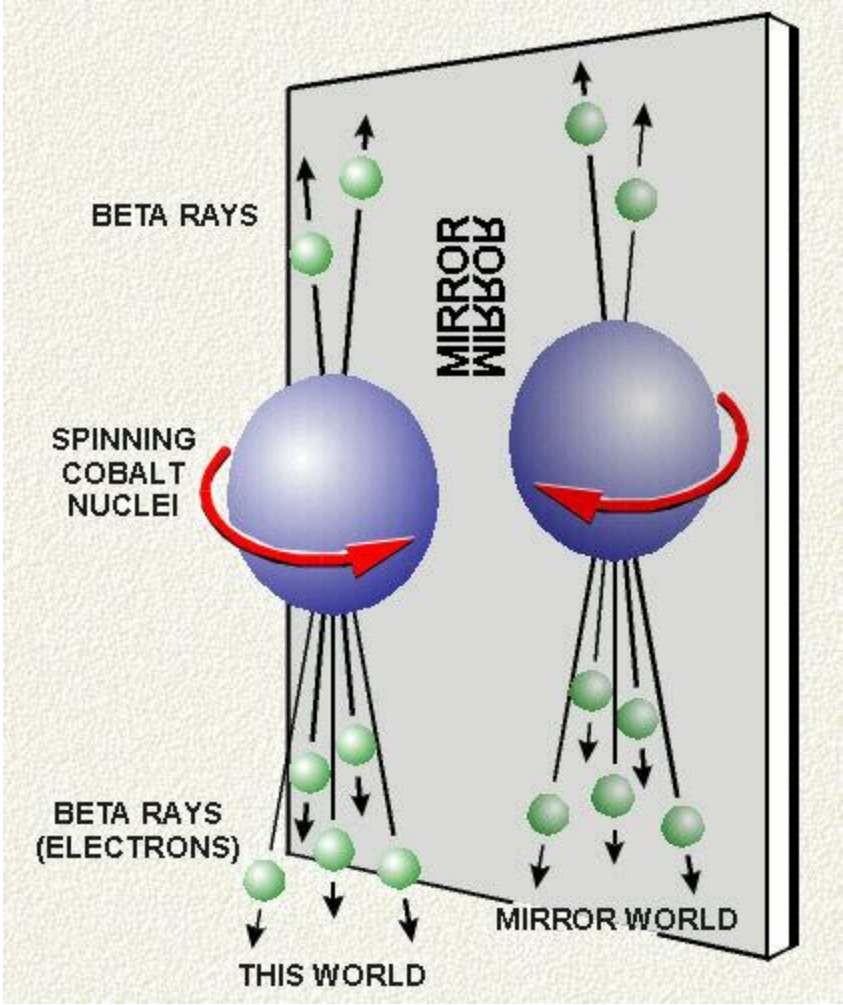
Search for a heavy neutrino and right-handed W of the left-right symmetric model with CMS detector

(CMS-PAS-EXO-11-002)

Joe Pastika
University of Minnesota
on behalf of the CMS Collaboration

Parity Violation

- Parity is the symmetry of mirror reflection(+ rotation).
- Parity violation first by Lee and Yang to describe the “T-Θ Puzzle” in 1956.
- First confirmed by Wu in 1957.
- Parity violation later integrated as a feature of the SM



(NIST, *Parity: What's Not Conserved?*)

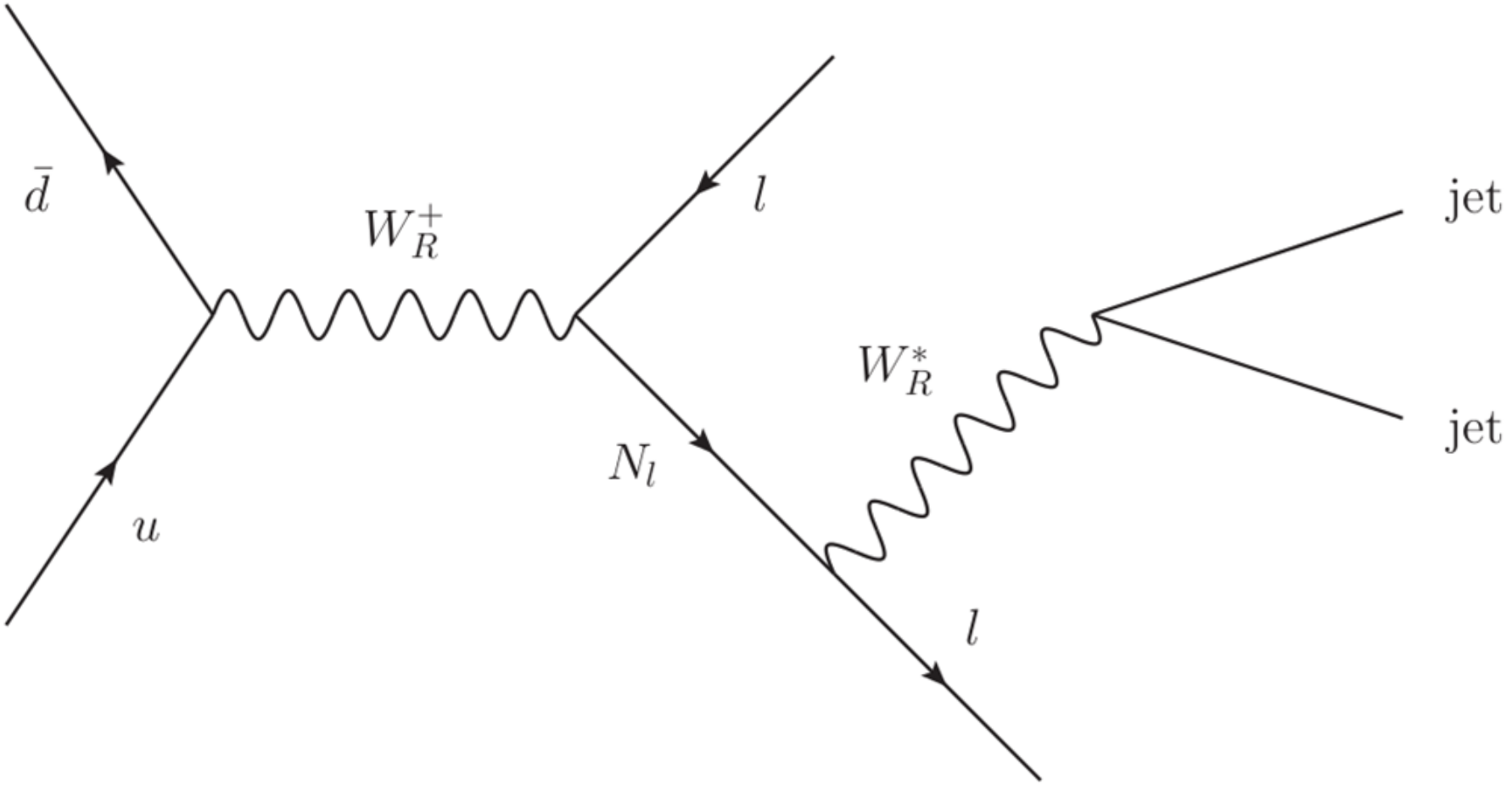
Left-Right Symmetric Model

	Left-Right Symmetric Model
Gauge Group	$SU(2)_R \times SU(2)_L \times U(1)$
Fermions	$Q_L=(u^i,d^i)_L$, $L_L=(l^i,\nu^i)_L$ $Q_R=(u^i,d^i)_R$, $L_R=(l^i,N^i)_R$
Gauge Bosons	$W^{\pm}_L, W^{\pm}_R, Z_0, Z', \gamma$

- In the LRS extension to the Standard Model parity is expressly conserved

- Parity becomes a spontaneously broken symmetry as some energy scale
- If we assume majorana neutrinos the lightness of the SM neutrinos is explained through the Seesaw Mechanism
- We gain 3 additional gauge bosons and 3 heavy right-handed neutrinos

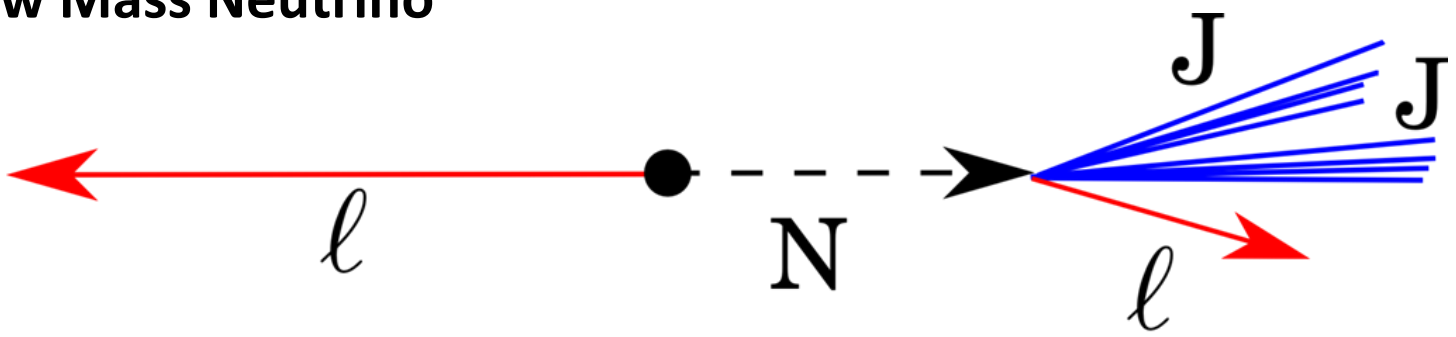
Heavy Neutrino Production



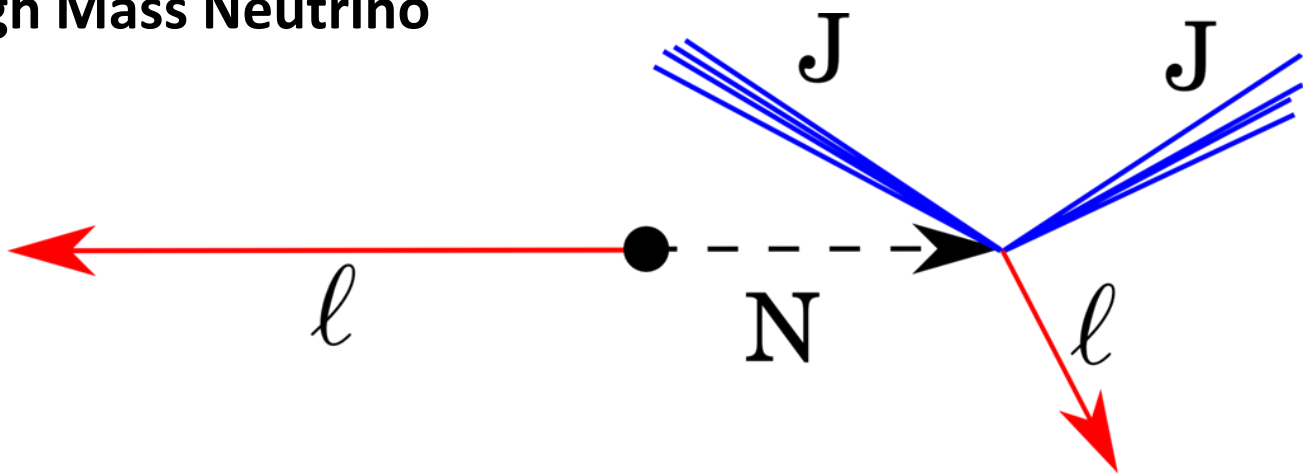
Previous limits: D0 Collaboration set a limit on WR mass of 739–786 GeV, dependent on the masses of the various flavors of N. (Phys. Rev. Lett. 100 (2008) 211803)

$W_R \rightarrow N_\ell \ell$ decays

Low Mass Neutrino

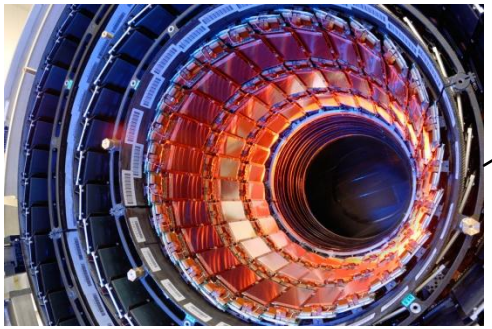


High Mass Neutrino

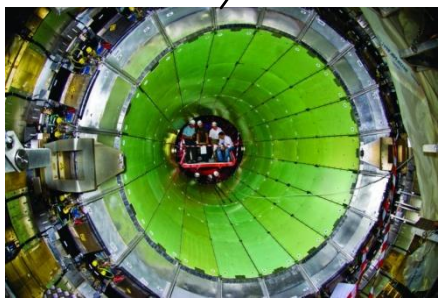


Compact Muon Solenoid

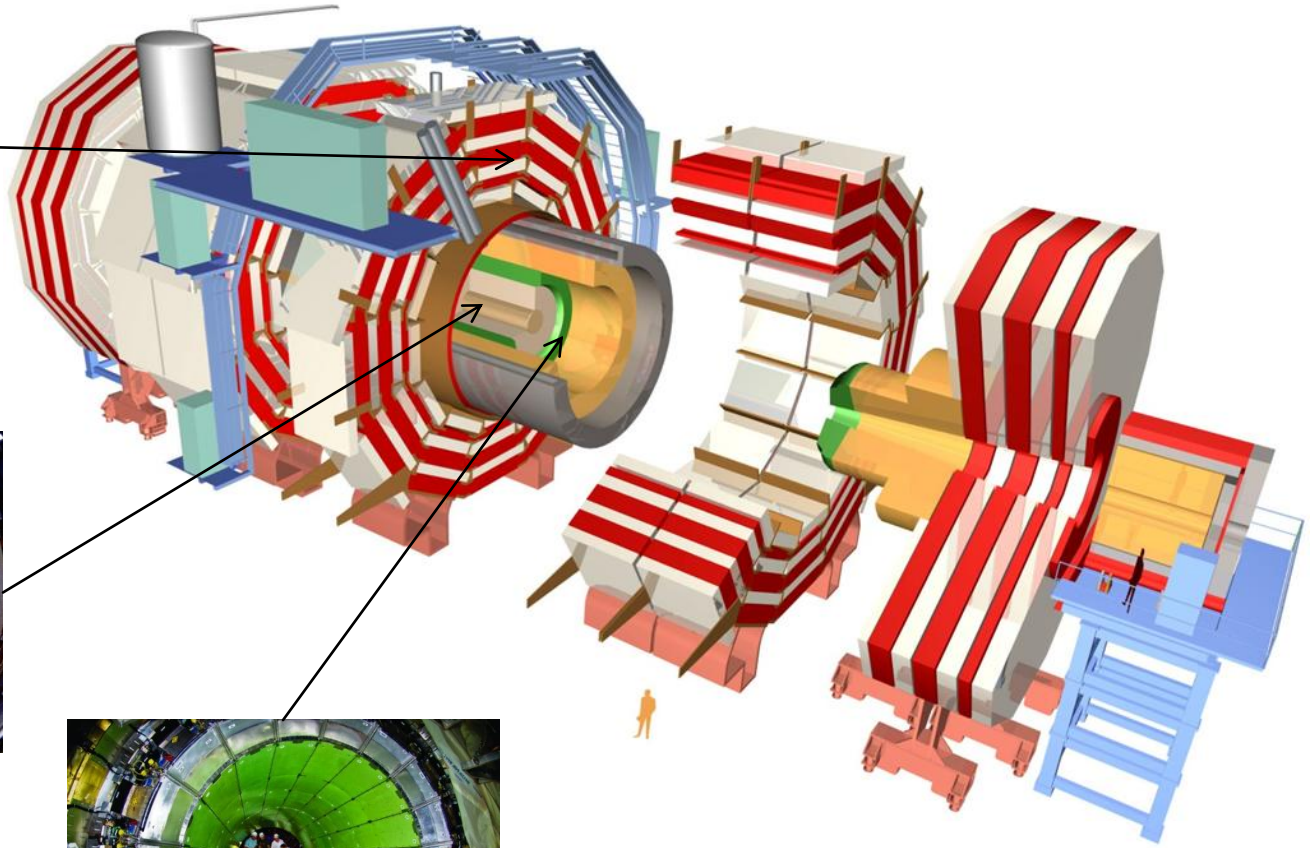
Muon Chambers



Tracker



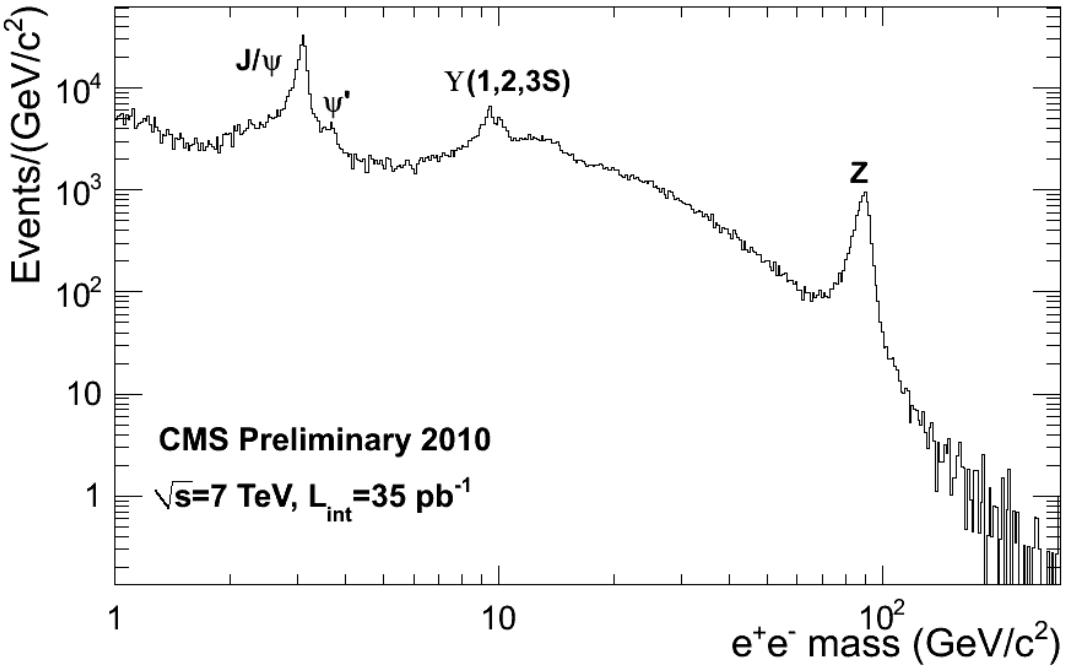
ECAL



Data: 36 pb^{-1} in 2010 and 204 pb^{-1} in 2011

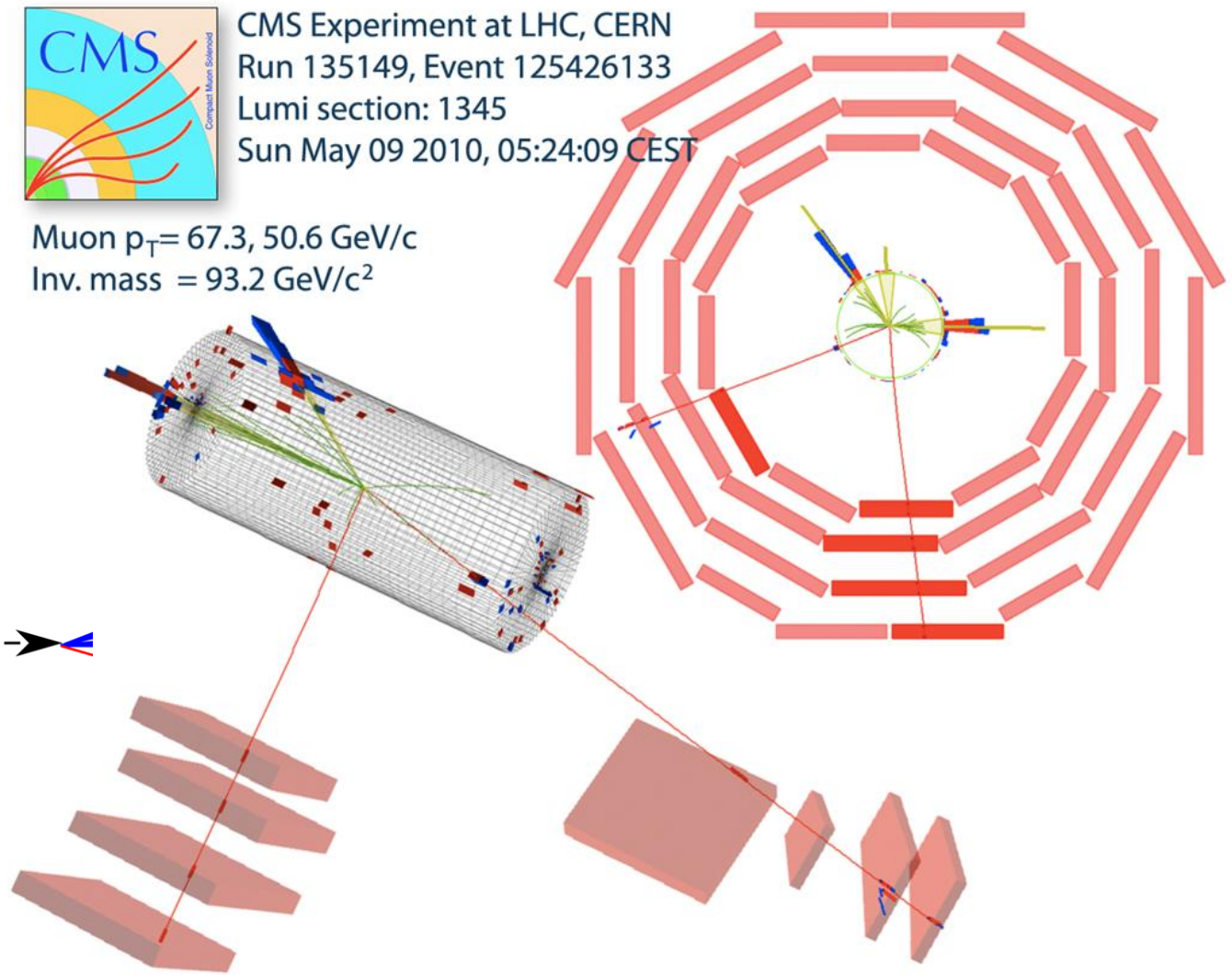
Event Reconstruction

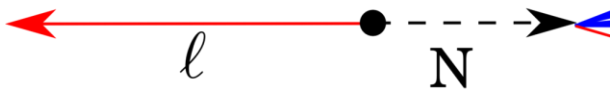
- Select two leading p_t leptons and two leading p_t jets
- Leptons: p_t > 30(20) GeV for 2011(2010)
- Jets: p_t > 40 GeV
- Require $\Delta R > 0.5$ between jets and either jet and lepton
- All objects must pass basic quality requirements



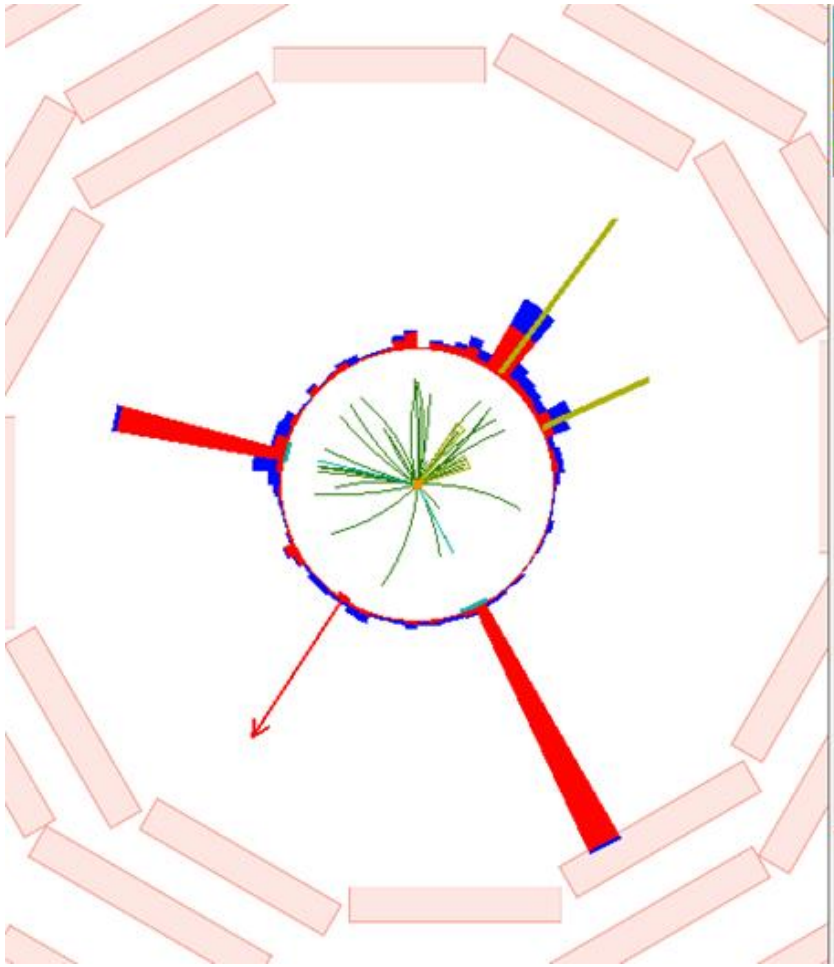
Event Selection

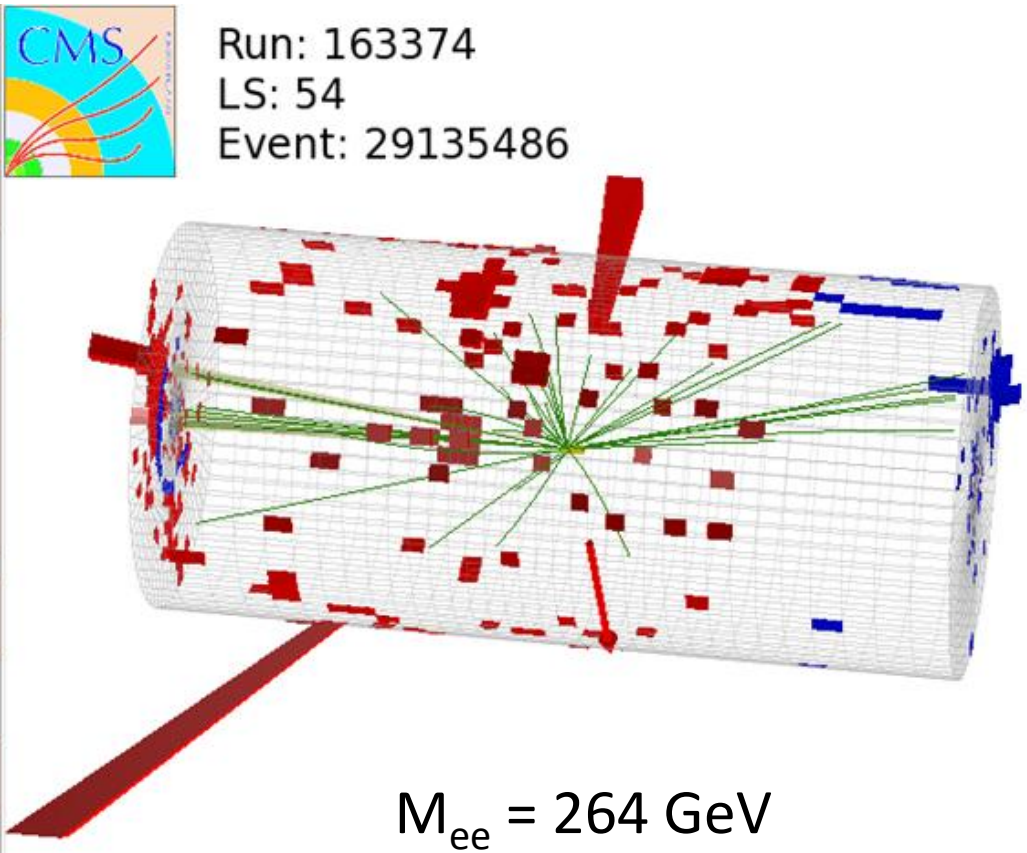
- For one electron (muon), $E_T(P_T) >$ 60 GeV, and one electron in barrel
- $M_{ll} > 200$ GeV
- $M_{lljj} > 520$ GeV





Candidate Event

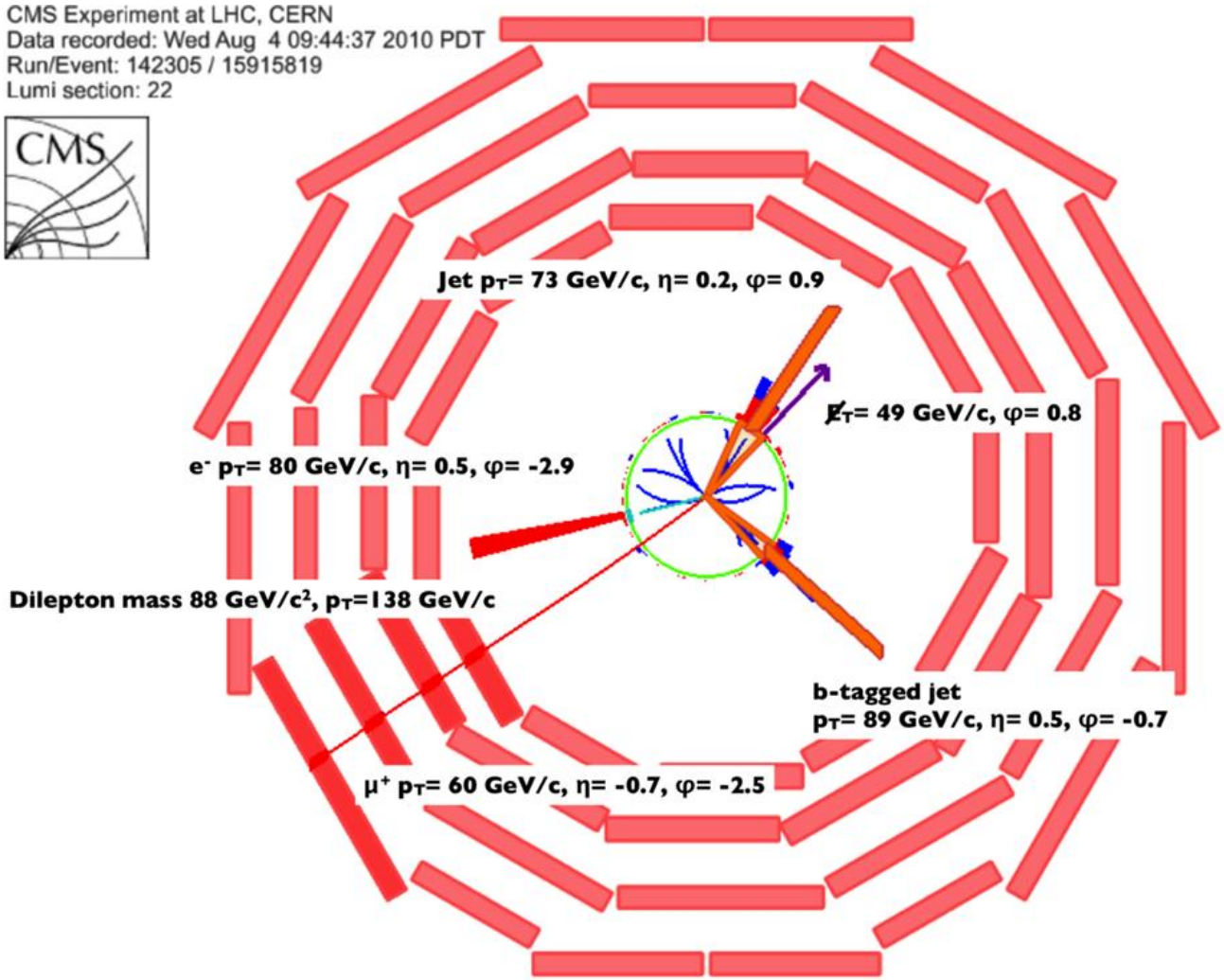




M_{ee} = 264 GeV

M_{eejj} = 1009 GeV

Backgrounds



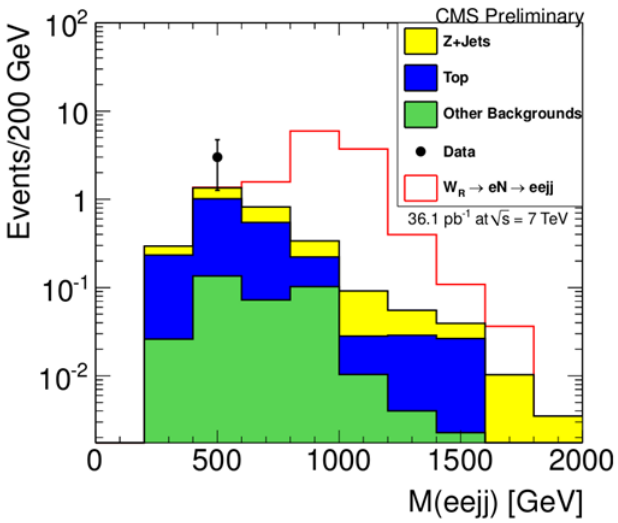
- TTbar – normalized in e-μ channel
- Z+Jets – normalized in region around Z-peak
- Shapes estimated from MC

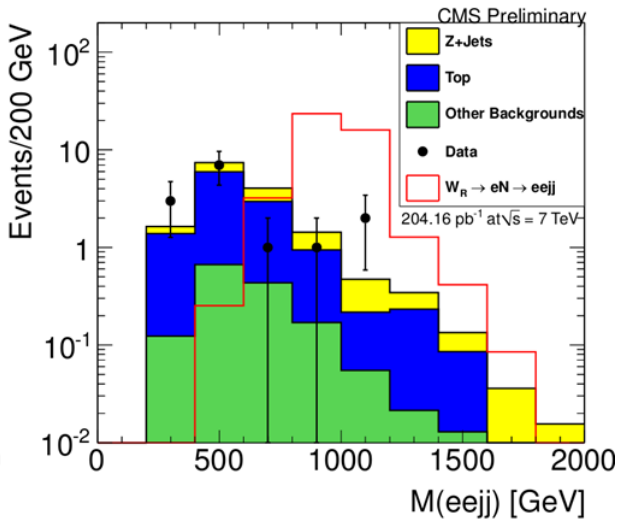
- QCD – Lepton fake rate measured in dijets, then applied to quadjets

Resulting 4 Object Invariant Mass

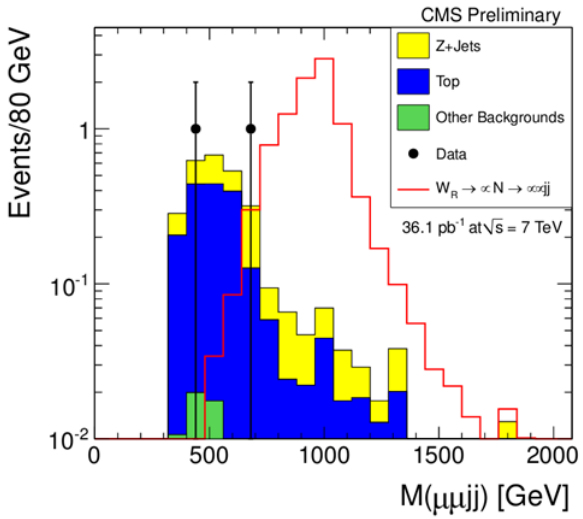
2010 2011

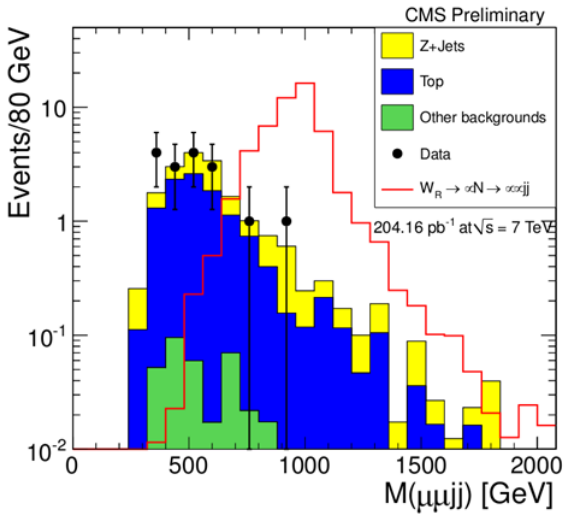
Electron channel





Muon channel

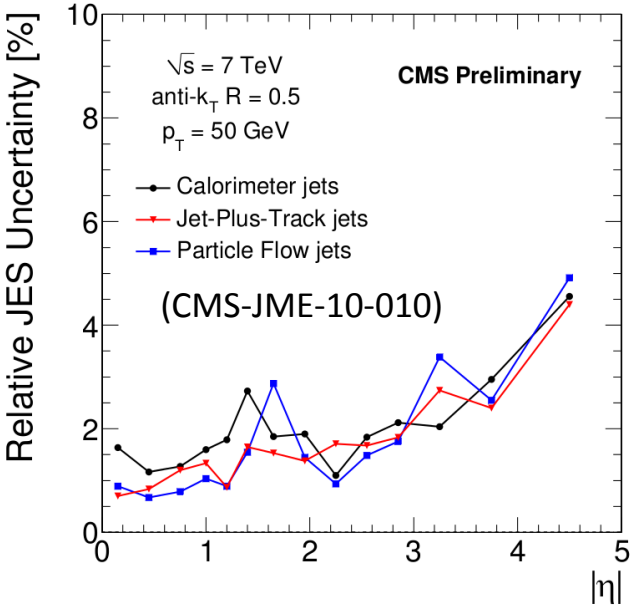




Systematic Uncertanties

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

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



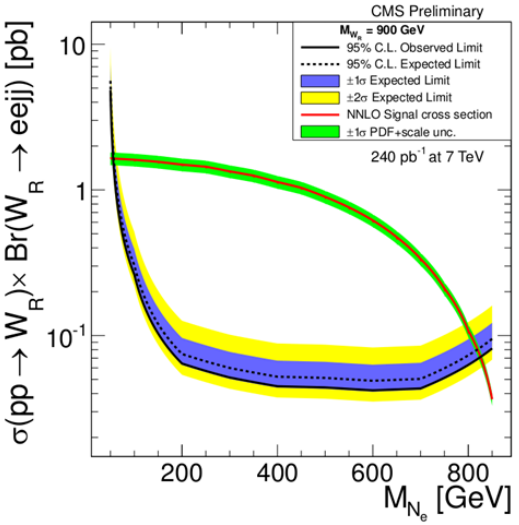
- Theory Uncertainties
  - Factorization/ Renormalization Scale
  - PDF
  - ISR, FSR

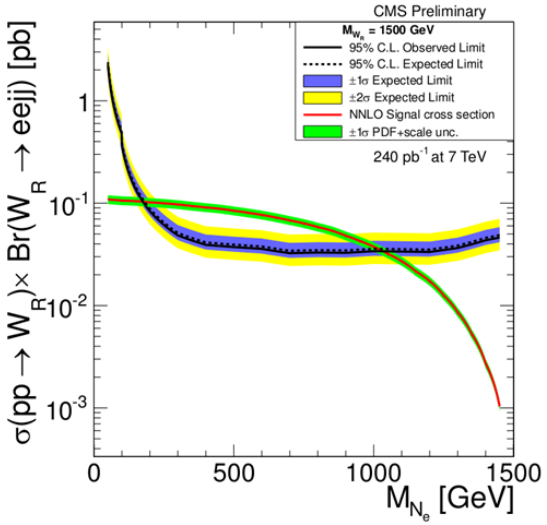
Cross-Section Results

MW = 900 GeV

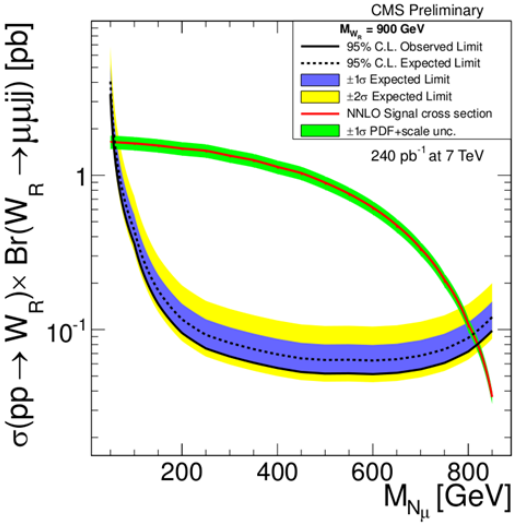
MW = 1500 GeV

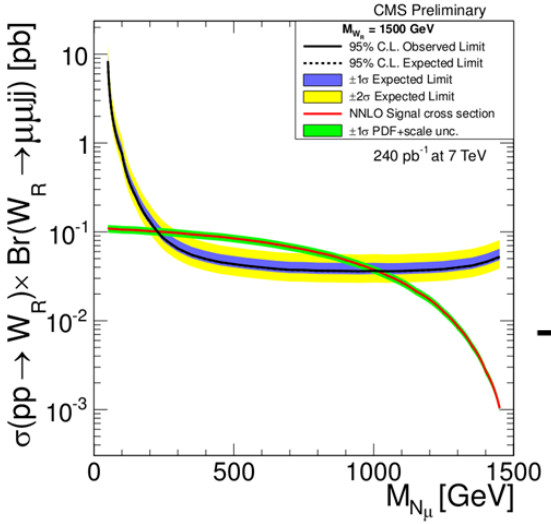
Electrons





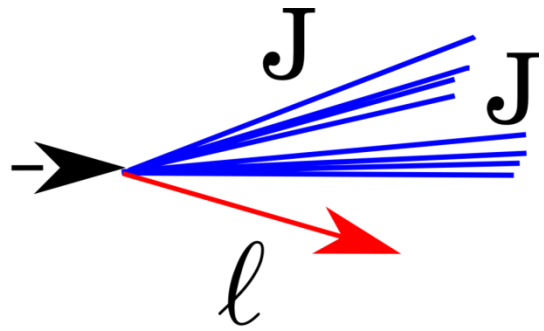
Muons



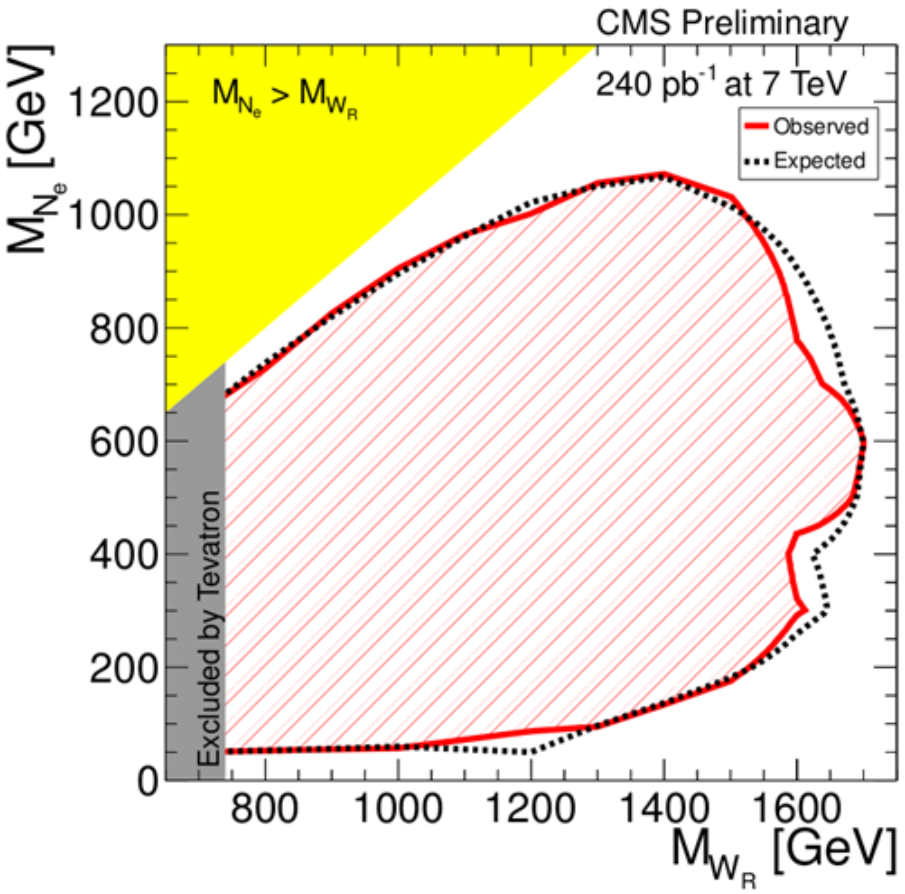


Theoretical Model Assumptions

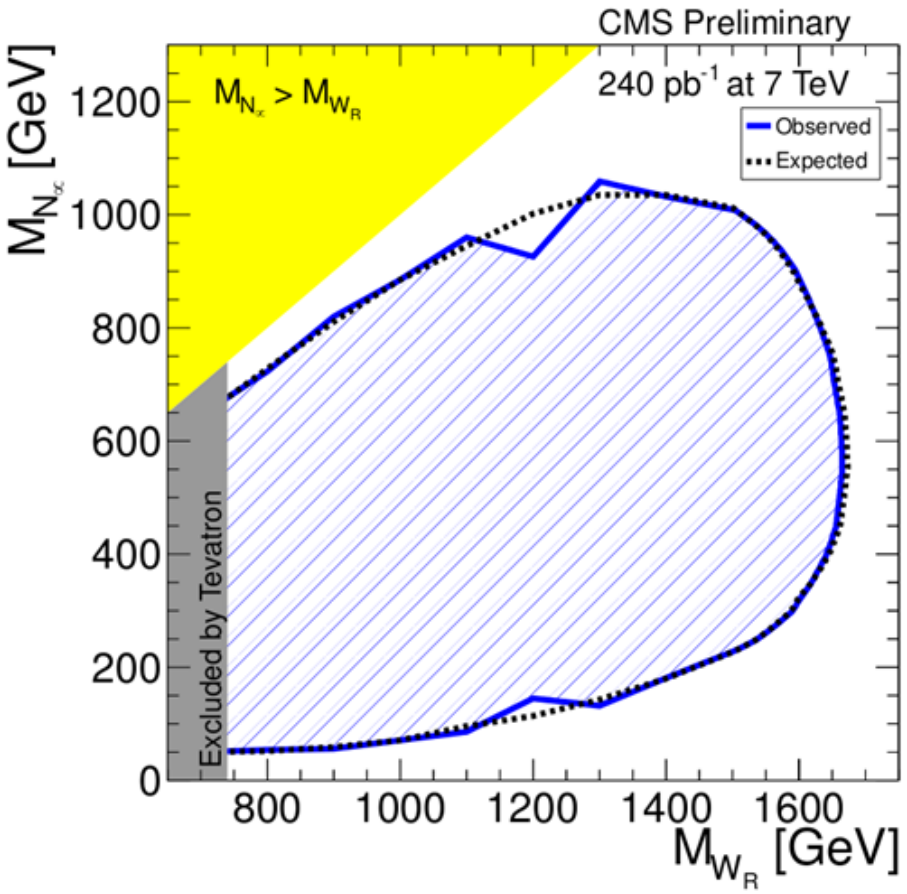
- $g_L = g_R$
- right and left CKM matrices are equal
- Negligible mixing angle between right and left states



W_R , N_ℓ Limits



Electron Channel

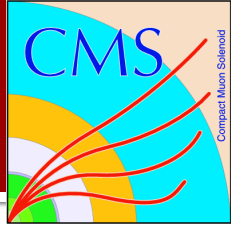


Muon Channel

Conclusion

- We have conducted a search for a Heavy Right-handed neutrinos and W boson in a Left-Right Symmetric extension of the Standard Model.
- We have placed a 95% confidence level limit on the existence of a W_R independently in the electron and muon channels at around $M_{WR} < 1700$ GeV for a wide range of heavy neutrino masses.
- We have also placed on the existence of electron and muon flavor heavy neutrinos spanning from 50 to 1000 GeV dependent on M_{WR}

Backup Slides



Electron Cuts

Electron Channel (2010, 36 pb^{-1})

	Data	Signal	$(\epsilon \times A)(\%)$	Tot. BG	$t\bar{t}$	Z+jets	Other
E1	219	13	61	207	20	180	6.7
E2	117	13	61	120	12	107	3.3
E3	106	13	60	111	11	96	2.6
E4	3	12	53	2.42	1.8	0.9	0.3
E5	3	12	53	1.9 ± 0.5	1.0	0.6	0.2

Electron Channel (2011, 204 pb^{-1})

	Data	Signal	$(\epsilon \times A)(\%)$	Tot. BG	$t\bar{t}$	Z+jets	Other
E1	1282	64	51	1126	99	992	34
E2	490	64	51	470	60	395	14
E3	445	63	50	433	51	372	10
E4	14	56	45	15	10	3.8	1.5
E5	8	56	45	9.4 ± 2.0	5.7	2.7	1.0

Designator	Meaning
E1	Two electrons and two jets with object requirements applied
E2	Transverse energy cut of the first electron increased to $E_T > 60$ GeV
E3	At least one electron must be in the ECAL barrel
E4	$M_{ee} > 200$ GeV
E5	$M_{eejj} > 520$ GeV

Muon Cuts

Muon Channel (2010, 36 pb^{-1})

	Data	Signal	$(\epsilon \times A)(\%)$	Tot. BG	$t\bar{t}$	Z+jets	Other
M1	296	11	65	275	27	242	5.6
M2	168	11	65	164	14	146	4.0
M3	2	9	56	3.0	1.8	1.0	0.2
M4	1	9	56	1.6 ± 0.4	0.9	0.6	0.1

Muon Channel (2011, 204 pb^{-1})

	Data	Signal	$(\epsilon \times A)(\%)$	Tot. BG	$t\bar{t}$	Z+jets	Other
M1	1264	60	63	1132	95	1019	18
M2	694	60	63	668	60	596	12
M3	16	52	55	17	10	6.4	0.8
M4	5	52	55	9.9 ± 2.2	5.5	4.0	0.4

M1	Two muons and two jets with object requirements applied
M2	Transverse momentum cut of the first muon increased to $p_T > 60$ GeV/c
M3	$M_{\mu\mu} > 200$ GeV
M4	$M_{\mu\mu jj} > 520$ GeV