LHC searches for BSM physics in events with multiple leptons

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on behalf of ATLAS and CMS collaborations

- Model independent searches
  - 3 or more leptons
- Model testing :
  - excited leptons
  - LRSM, W_R, heavy neutrinos
  - Heavy fermion triplet

8 TeV results !

Leptons beyond SM

4th generation leptons

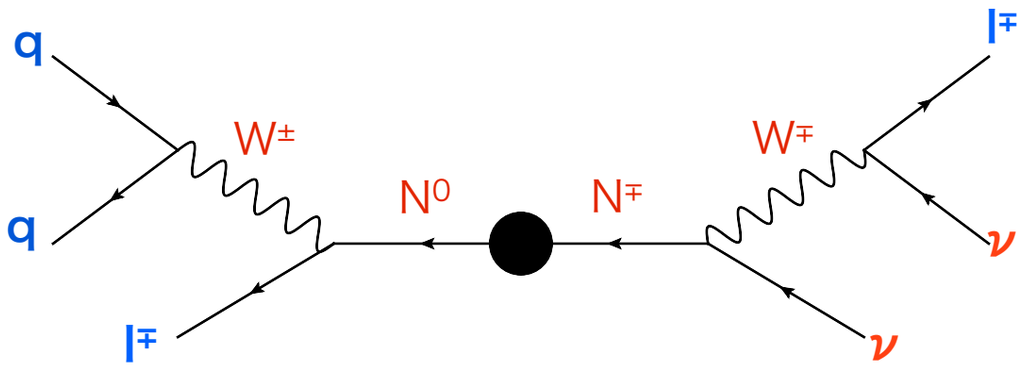
$$\begin{pmatrix} N \\ E \end{pmatrix}_L; \quad N_R; \quad E_R$$

Vector leptons

$$\begin{pmatrix} N \\ E \end{pmatrix}_L; \quad \begin{pmatrix} N \\ E \end{pmatrix}_R;$$

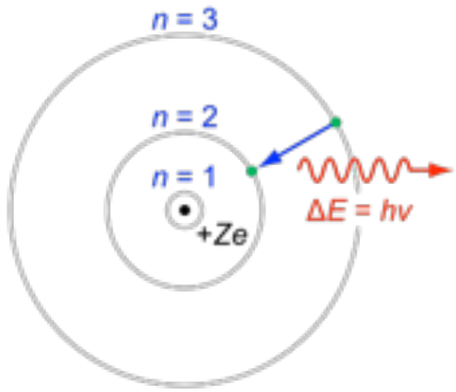
Heavy neutrinos

Heavy Lepton triplet



Excited leptons, ℓ^*

lepton substructure exist

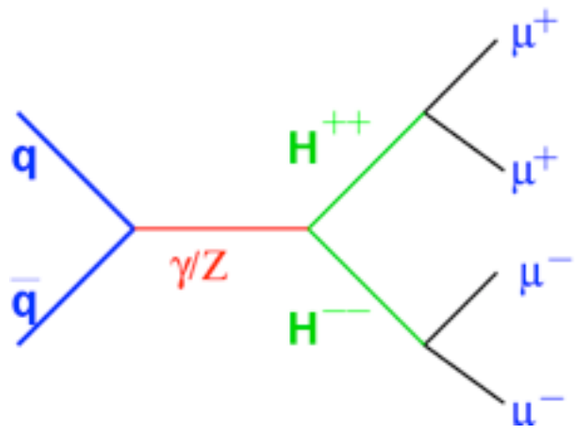


Supersymmetry

see also SUSY LHC talks

Higgs triplet

doubly charged Higgs bosons



Leptons beyond SM

4th generation leptons

$$\begin{pmatrix} N \\ E \end{pmatrix}_L;\quad N_R;\quad E_R$$

Excited leptons, ℓ^*

lepton substructure exist

Vector leptons

$$\begin{pmatrix} N \\ E \end{pmatrix}_L;\quad \begin{pmatrix} N \\ E \end{pmatrix}_R;$$

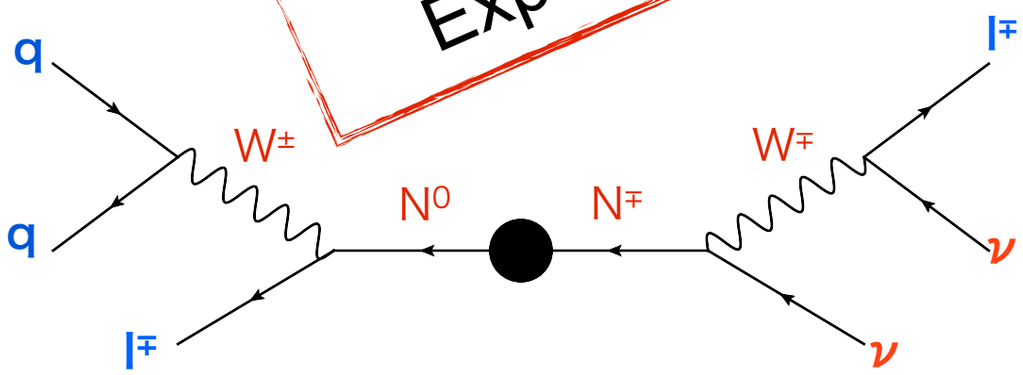
Typically new particles are produced in pairs
Expect large multiplicity of leptons in final state

Supersymmetry

see also SUSY LHC talks

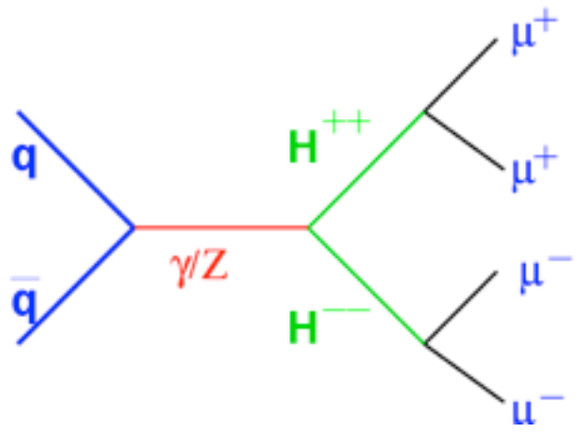
Heavy neutrinos

Higgs triplet



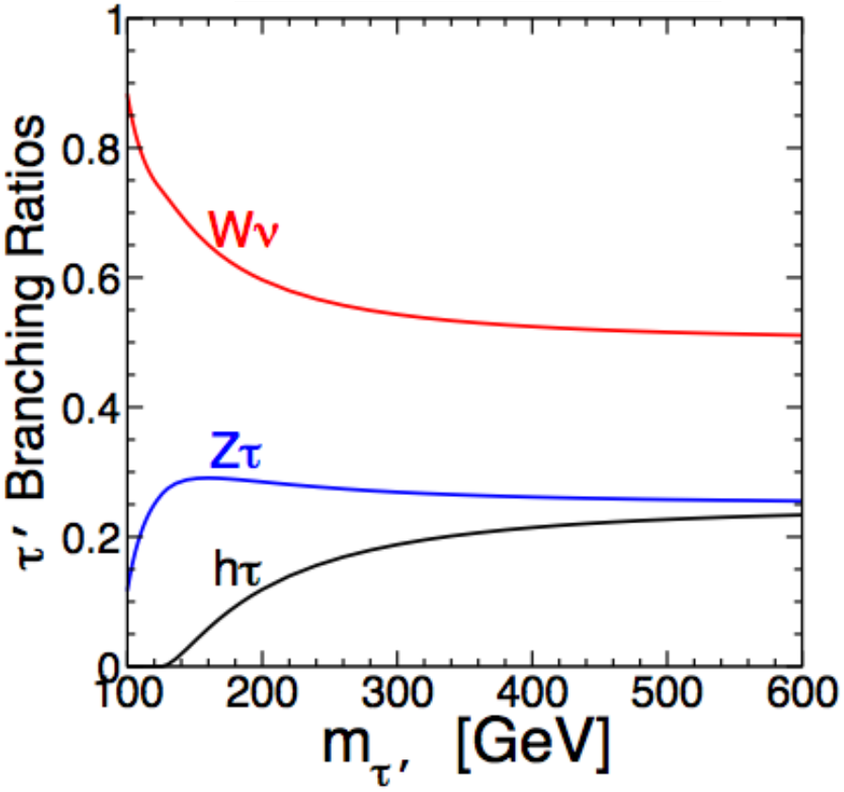
Higgs triplet

doubly charged Higgs bosons

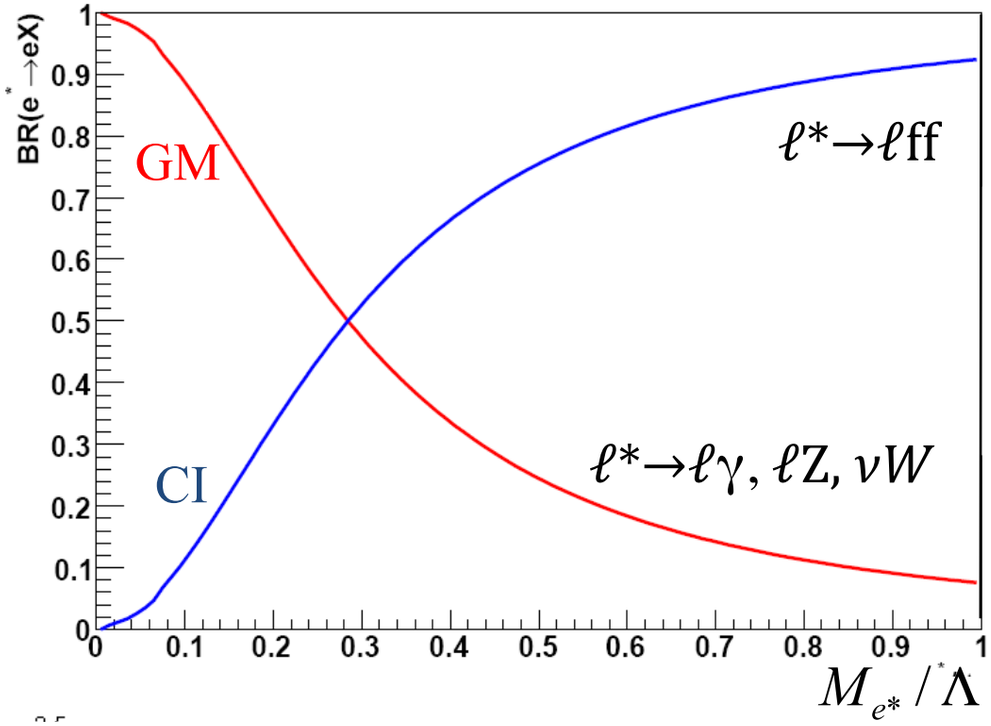


Leptons beyond SM

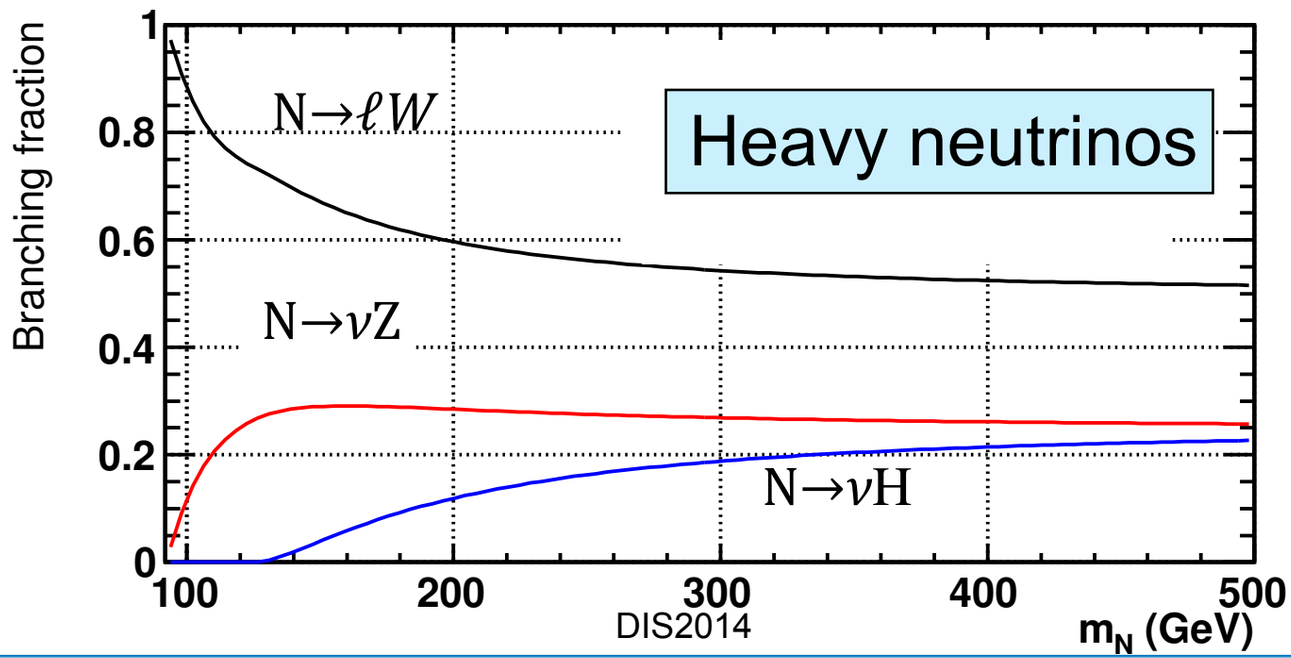
Vector leptons



Excited leptons, ℓ^*



Heavy neutrinos



Similar decay tables
$\ell\gamma, \ell Z, \nu W, \nu Z, \ell W,$
but different Br values

first - general search, model independent

Looking for events with multiple leptons

- CMS (8TeV): CMS-PAS-SUS-13-002
- ATLAS (8TeV): ATLAS-CONF-2013-070

CMS multiple leptons SR

A: 3 or 4 leptons (e,μ,τ_{had})

B: 0 or 1 τ_{had}

C: number of Opposite-Sign - Same Flavor pairs

D: on/off-Z: m($\ell^+\ell^-$)<75 / [75,105] / > 105 GeV

E: Large or small hadronic H_T (sum of jets p_T, >30GeV)

F: 0 or ≥1 b-jets

G: Missing E_T < 50 / [50,100] / > 100 GeV

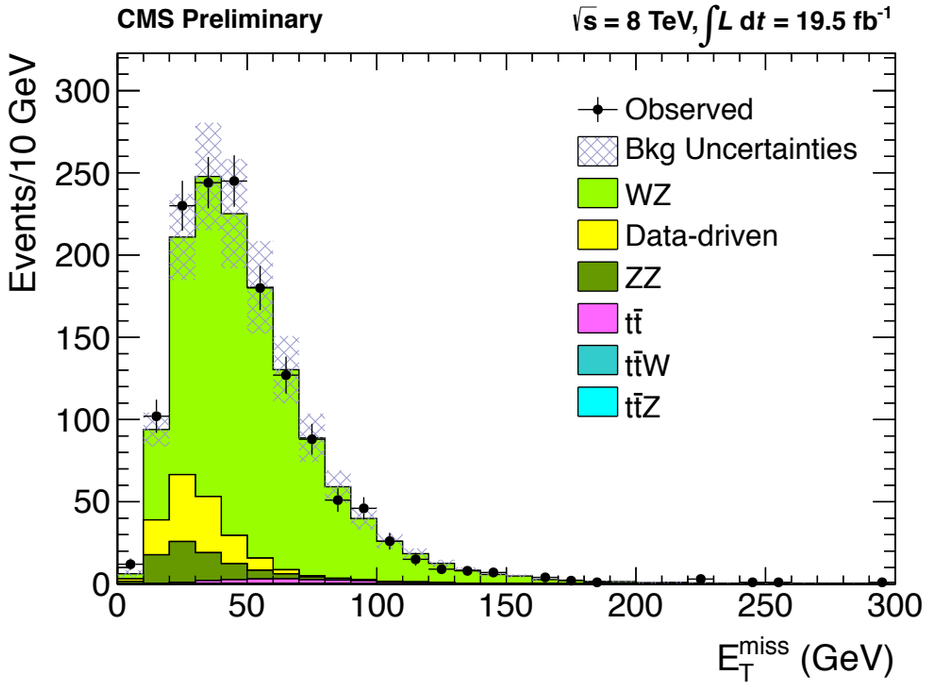
64 signal regions (AxBxCxDxExFxG) with different number of expected events populated with different backgrounds

Leading lepton: p_T>20GeV
Other leptons : p_T>10GeV
$p_T(\tau_{\mathrm{had}})$>20GeV
All prompt and isolated

CMS Backgrounds

Background composition varies strongly between signal regions

- Irreducible background: WZ/ZZ, $t\bar{t}$+V
  - estimated from MC , validated on data
- Reducible background with fake lepton (W/Z/WW+jets, $t\bar{t}$, etc)
  - estimated from data



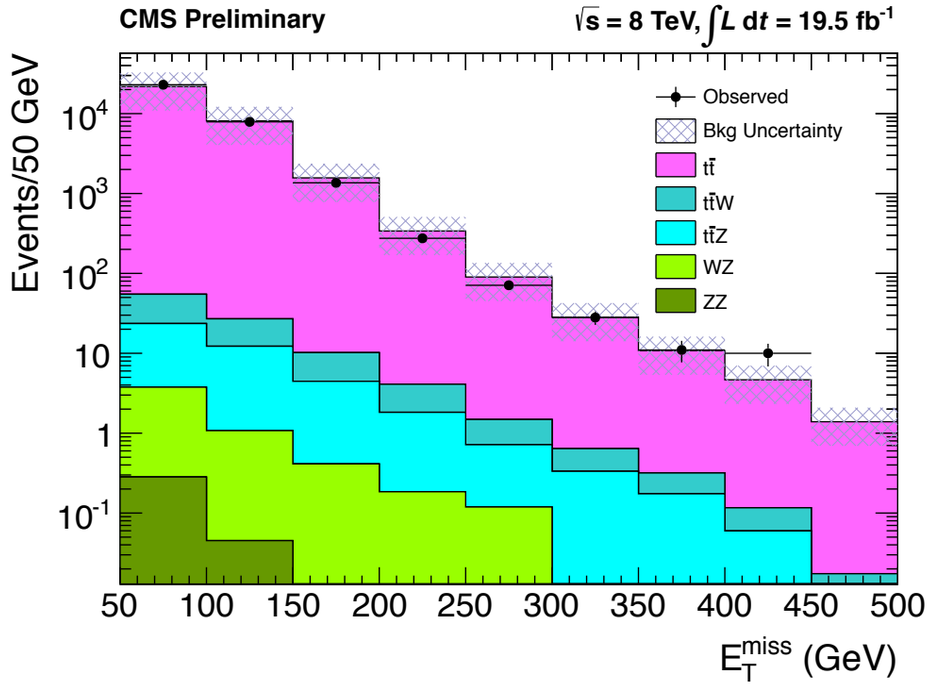


Figure 1: Distributions for $E_{\mathrm{T}}^{\mathrm{miss}}$ in the WZ and opposite sign $e\mu$ dilepton $t\bar{t}$ control regions.

CMS results

3 leptons

Selection 3 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	exp	N(τ_h)=1, N_{b-jets}=0 obs	exp
OSSF0 $H_T < 200$	NA	(100,∞)	7	11 ± 4.9	101	111 ± 54
OSSF0 $H_T < 200$	NA	(50,100)	35	38 ± 15	406	402 ± 152
OSSF0 $H_T < 200$	NA	(0,50)	53	51 ± 11	910	1035 ± 255
OSSF1 $H_T < 200$	above-Z	(100,∞)	18	13 ± 3.5	25	38 ± 18
OSSF1 $H_T < 200$	below-Z	(100,∞)	21	24 ± 9	41	50 ± 25
OSSF1 $H_T < 200$	on-Z	(100,∞)l	150	152 ± 26	39	48 ± 13
OSSF1 $H_T < 200$	above-Z	(50,100)	50	46 ± 9.7	169	139 ± 48
OSSF1 $H_T < 200$	below-Z	(50,100)	142	125 ± 27	353	355 ± 92
OSSF1 $H_T < 200$	on-Z	(50,100)	*773	777 ± 116	1276	1154 ± 306
OSSF1 $H_T < 200$	above-Z	(0,50)	178	196 ± 35	1676	1882 ± 540
OSSF1 $H_T < 200$	below-Z	(0,50)	510	547 ± 87	9939	8980 ± 2660
OSSF1 $H_T < 200$	on-Z	(0,50)	*3869	4105 ± 666	*50188	50162 ± 14984

Selection 3 Lepton Results		E_T^{miss}	N(τ_h)=0, $N_{b-jets}\geq1$ obs	exp	N(τ_h)=1, $N_{b-jets}\geq1$ obs	exp
OSSF0 $H_T < 200$	NA	(100,∞)	13	10 ± 5.3	87	119 ± 61
OSSF0 $H_T < 200$	NA	(50,100)	29	26 ± 13	269	298 ± 151
OSSF0 $H_T < 200$	NA	(0,50)	29	23 ± 10	237	240 ± 113
OSSF1 $H_T < 200$	above-Z	(100,∞)	10	6.5 ± 2.9	24	35 ± 18
OSSF1 $H_T < 200$	below-Z	(100,∞)	14	20 ± 10	42	54 ± 28
OSSF1 $H_T < 200$	on-Z	(100,∞)l	15	14 ± 4.8	19	23 ± 11
OSSF1 $H_T < 200$	above-Z	(50,100)	20	18 ± 8	85	93 ± 47
OSSF1 $H_T < 200$	below-Z	(50,100)	48	48 ± 23	140	133 ± 68
OSSF1 $H_T < 200$	on-Z	(50,100)	56	47 ± 13	81	75 ± 32
OSSF1 $H_T < 200$	above-Z	(0,50)	17	18 ± 6.7	115	94 ± 42
OSSF1 $H_T < 200$	below-Z	(0,50)	34	42 ± 11	226	228 ± 63
OSSF1 $H_T < 200$	on-Z	(0,50)	*148	156 ± 24	906	925 ± 263

Selection 3 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	exp	N(τ_h)=1, N_{b-jets}=0 obs	exp	N(τ_h)=0, $N_{b-jets}\geq1$ obs	exp	N(τ_h)=1, $N_{b-jets}\geq1$ obs	exp
OSSF0 $H_T > 200$	NA	(100,∞)	5	3.7 ± 1.6	35	33 ± 14	1	5.5 ± 2.2	47	61 ± 30
OSSF0 $H_T > 200$	NA	(50,100)	3	3.5 ± 1.4	34	36 ± 16	8	7.7 ± 2.7	82	91 ± 46
OSSF0 $H_T > 200$	NA	(0,50)	4	2.1 ± 0.8	25	25 ± 9.7	1	3.6 ± 1.5	52	59 ± 29
OSSF1 $H_T > 200$	above-Z	(100,∞)	5	3.6 ± 1.2	2	10 ± 4.8	3	4.7 ± 1.6	19	22 ± 11
OSSF1 $H_T > 200$	below-Z	(100,∞)	7	9.7 ± 3.3	18	14 ± 6.4	8	9.1 ± 3.4	21	23 ± 11
OSSF1 $H_T > 200$	on-Z	(100,∞)	39	61 ± 23	17	15 ± 4.9	9	14 ± 4.4	10	12 ± 5.8
OSSF1 $H_T > 200$	above-Z	(50,100)	4	5 ± 1.6	14	11 ± 5.2	6	6.8 ± 2.4	32	30 ± 15
OSSF1 $H_T > 200$	below-Z	(50,100)	10	11 ± 3.8	24	19 ± 6.4	10	9.9 ± 3.7	25	32 ± 16
OSSF1 $H_T > 200$	on-Z	(50,100)	78	80 ± 32	70	50 ± 11	22	22 ± 6.3	36	24 ± 9.8
OSSF1 $H_T > 200$	above-Z	(0,50)	3	7.3 ± 2	41	33 ± 8.7	4	5.3 ± 1.5	15	23 ± 11
OSSF1 $H_T > 200$	below-Z	(0,50)	26	25 ± 6.8	110	86 ± 23	5	10 ± 2.5	24	26 ± 11
OSSF1 $H_T > 200$	on-Z	(0,50)	*135	127 ± 41	542	543 ± 159	31	32 ± 6.5	86	75 ± 19

4 leptons

Selection 4 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	exp	N(τ_h)=1, N_{b-jets}=0 obs	exp	N(τ_h)=0, $N_{b-jets}\geq1$ obs	exp	N(τ_h)=1, $N_{b-jets}\geq1$ obs	exp
OSSF0 $H_T > 200$	NA	(100,∞)	0	0.01 ± 0.03	0	0.01 ± 0.06	0	0.02 ± 0.04	0	0.11 ± 0.08
OSSF0 $H_T > 200$	NA	(50,100)	0	$0.0^{+0.02}_{-0.00}$	0	0.01 ± 0.06	0	$0.0^{+0.03}_{-0.00}$	0	0.12 ± 0.07
OSSF0 $H_T > 200$	NA	(0,50)	0	1e-05 $\pm$ 0.02	0	0.07 ± 0.1	0	$0.0^{+0.02}_{-0.00}$	0	0.02 ± 0.02
OSSF1 $H_T > 200$	off-Z	(100,∞)	0	0.005 ± 0.02	1	0.25 ± 0.11	0	0.13 ± 0.08	0	0.12 ± 0.12
OSSF1 $H_T > 200$	on-Z	(100,∞)	1	0.1 ± 0.06	0	0.5 ± 0.27	0	0.42 ± 0.22	0	0.42 ± 0.19
OSSF1 $H_T > 200$	off-Z	(50,100)	0	0.07 ± 0.06	1	0.29 ± 0.13	0	0.04 ± 0.04	0	0.23 ± 0.13
OSSF1 $H_T > 200$	on-Z	(50,100)	0	0.23 ± 0.11	1	0.7 ± 0.31	0	0.23 ± 0.13	1	0.34 ± 0.16
OSSF1 $H_T > 200$	off-Z	(0,50)	0	0.02 ± 0.03	0	0.27 ± 0.12	0	0.03 ± 0.04	0	0.31 ± 0.15
OSSF1 $H_T > 200$	on-Z	(0,50)	0	0.2 ± 0.08	0	1.3 ± 0.47	0	0.06 ± 0.04	1	0.49 ± 0.19
OSSF2 $H_T > 200$	off-Z	(100,∞)	0	0.01 ± 0.02	-	-	0	0.01 ± 0.06	-	-
OSSF2 $H_T > 200$	on-Z	(100,∞)	1	0.15 ± 0.16	-	-	0	0.34 ± 0.18	-	-
OSSF2 $H_T > 200$	off-Z	(50,100)	0	0.03 ± 0.02	-	-	0	0.13 ± 0.09	-	-
OSSF2 $H_T > 200$	on-Z	(50,100)	0	0.8 ± 0.4	-	-	0	0.36 ± 0.19	-	-
OSSF2 $H_T > 200$	off-Z	(0,50)	1	0.27 ± 0.13	-	-	0	0.08 ± 0.05	-	-
OSSF2 $H_T > 200$	on-Z	(0,50)	5	7.4 ± 3.5	-	-	2	0.8 ± 0.4	-	-

Selection 4 Lepton Results		E_T^{miss}	N(τ_h)=0, N_{b-jets}=0 obs	exp	N(τ_h)=1, N_{b-jets}=0 obs	exp	N(τ_h)=0, $N_{b-jets}\geq1$ obs	exp	N(τ_h)=1, $N_{b-jets}\geq1$ obs	exp
OSSF0 $H_T < 200$	NA	(100,∞)	0	0.11 ± 0.08	0	0.17 ± 0.1	0	0.03 ± 0.04	0	0.04 ± 0.04
OSSF0 $H_T < 200$	NA	(50,100)	0	0.01 ± 0.03	2	0.7 ± 0.33	0	$0.0^{+0.02}_{-0.00}$	0	0.28 ± 0.16
OSSF0 $H_T < 200$	NA	(0,50)	0	0.01 ± 0.02	1	0.7 ± 0.3	0	0.001 ± 0.02	0	0.13 ± 0.08
OSSF1 $H_T < 200$	off-Z	(100,∞)	0	0.06 ± 0.04	3	0.6 ± 0.24	0	0.02 ± 0.04	0	0.32 ± 0.2
OSSF1 $H_T < 200$	on-Z	(100,∞)	1	0.5 ± 0.18	2	2.5 ± 0.5	1	0.38 ± 0.2	0	0.21 ± 0.1
OSSF1 $H_T < 200$	off-Z	(50,100)	0	0.18 ± 0.06	4	2.1 ± 0.5	0	0.16 ± 0.08	1	0.45 ± 0.24
OSSF1 $H_T < 200$	on-Z	(50,100)	2	1.2 ± 0.34	9	9.6 ± 1.6	2	0.42 ± 0.23	0	0.5 ± 0.16
OSSF1 $H_T < 200$	off-Z	(0,50)	2	0.46 ± 0.18	15	7.5 ± 2	0	0.09 ± 0.06	0	0.7 ± 0.31
OSSF1 $H_T < 200$	on-Z	(0,50)	4	3 ± 0.8	41	40 ± 10	1	0.31 ± 0.15	2	1.5 ± 0.47
OSSF2 $H_T < 200$	off-Z	(100,∞)	0	0.04 ± 0.03	-	-	0	0.05 ± 0.04	-	-
OSSF2 $H_T < 200$	on-Z	(100,∞)	0	0.34 ± 0.15	-	-	0	0.46 ± 0.25	-	-
OSSF2 $H_T < 200$	off-Z	(50,100)	2	0.18 ± 0.13	-	-	0	0.02 ± 0.03	-	-
OSSF2 $H_T < 200$	on-Z	(50,100)	4	3.9 ± 2.5	-	-	0	0.5 ± 0.21	-	-
OSSF2 $H_T < 200$	off-Z	(0,50)	7	8.9 ± 2.4	-	-	1	0.23 ± 0.09	-	-
OSSF2 $H_T < 200$	on-Z	(0,50)	*156	159 ± 34	-	-	4	2.9 ± 0.8	-	-

Data agrees with expectation.
One significant deviation, but consistent with expectations given large number of Signal Regions

ATLAS multiple leptons SR

Lepton category

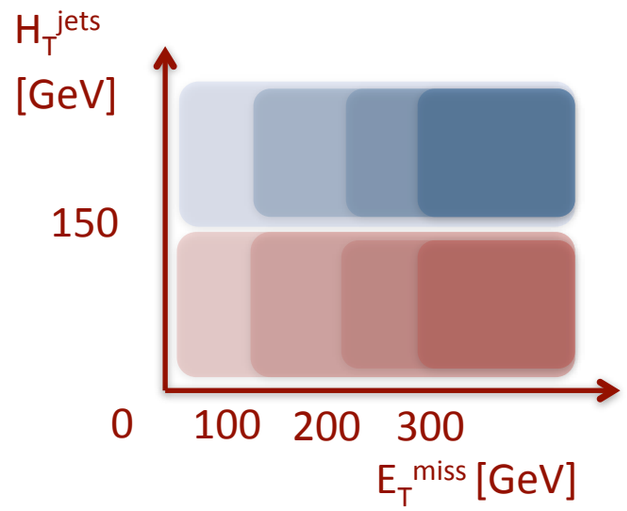
- On-Z 3e/μ
- On-Z 2 e/μ + τ_{had}
- Off-Z 3e/μ
- Off-Z 2 e/μ + τ_{had}

with on-Z : $|m_{\ell\ell} - m_Z| < 20$ GeV

and off-Z : $|m_{\ell\ell} - m_Z| > 20$ GeV

Other variables

- $H_T^{leptons}$: Sum of 3 lepton p_T
- H_T^{jets}: Sum of all jet p_T
- E_T^{miss}: Missing transverse energy
- m_{eff}: $H_T^{leptons} + H_T^{jets} + E_T^{miss}$
- Min. $p_T(\ell)$: p_T of 3rd lepton
- b-tags: number of b-jets



94 signal regions in total

4 signal regions X

Variable	Signal Region Definition				Additional Requirements
$H_T^{leptons}$	Inclusive	≥200 GeV	≥ 500 GeV	≥ 800 GeV	
Min. p_T^{ℓ}	Inclusive	≥ 50 GeV	≥ 100 GeV	≥ 150 GeV	
E_T^{miss}	Inclusive	≥100 GeV	≥ 200 GeV	≥ 300 GeV	$H_T^{jets} < 150$ GeV
E_T^{miss}	Inclusive	≥100 GeV	≥ 200 GeV	≥ 300 GeV	$H_T^{jets} \geq 150$ GeV
m_{eff}	Inclusive	≥600 GeV	≥1000 GeV	≥1500 GeV	
m_{eff}	Inclusive	≥600 GeV	≥1200 GeV		$E_T^{miss} \geq 100$ GeV
m_{eff}	Inclusive	≥600 GeV	≥1200 GeV		$m_T^W \geq 100$ GeV, on-Z
b-tags	Inclusive	≥ 1	≥ 2		

Table 1: Kinematic signal regions defined in the analysis.

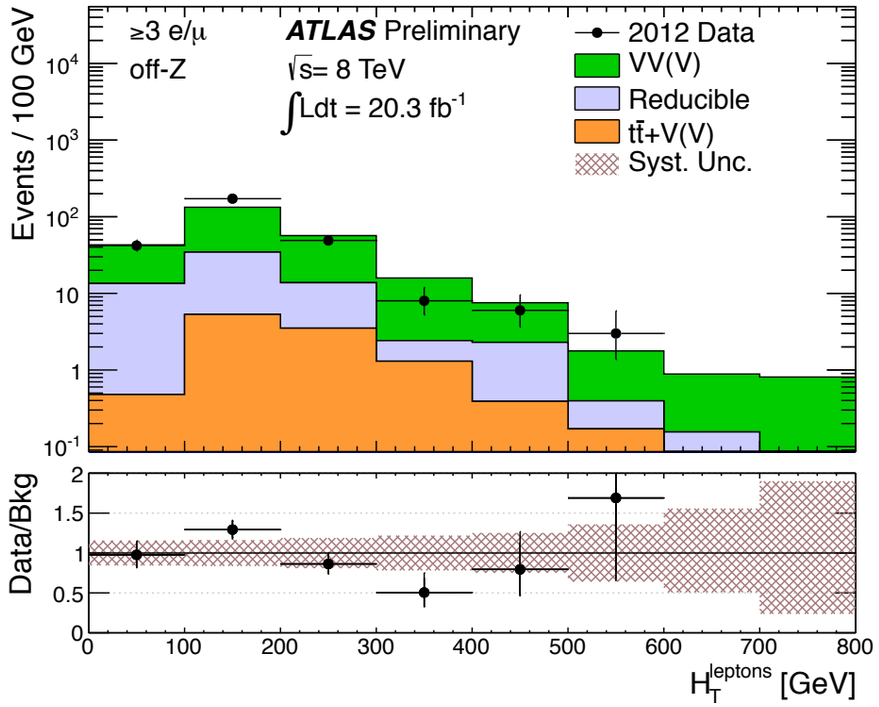
Fewer lepton categories, but more kinematic variables than in CMS paper

Leading lepton: p_T>26GeV
Other leptons : p_T>15GeV
$p_T(\tau_{had})$>20GeV
All prompt and isolated

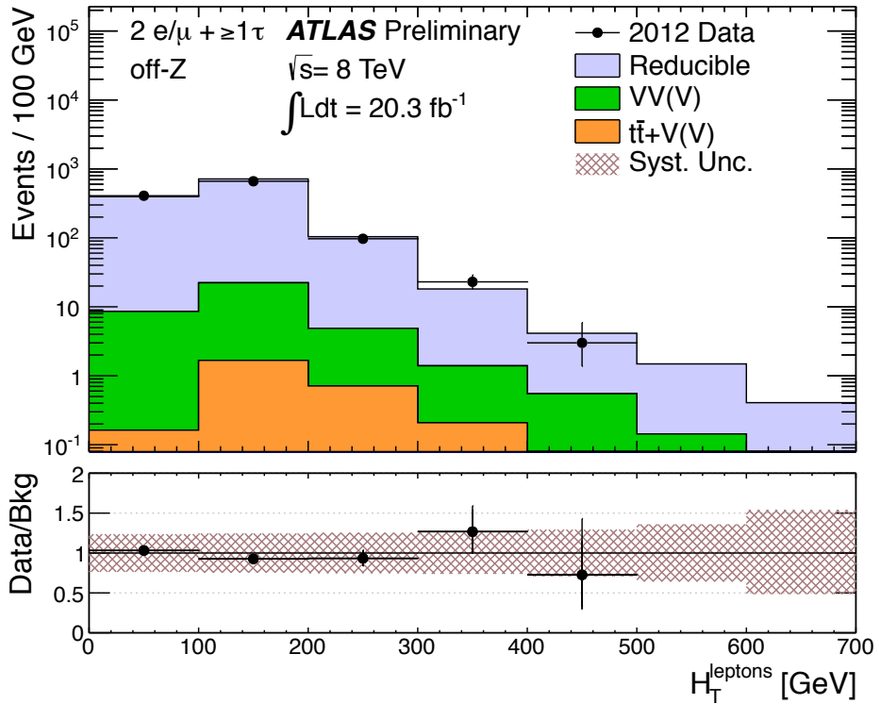
ATLAS Backgrounds

- Irreducible background: WZ/ZZ ($t\bar{t}$+W/Z,Zγ) – major in 3 e/μ regions
  - estimated from MC
- Reducible background with fake lepton (W/Z+jets, $t\bar{t}$, etc)– major in 2 e/μ + τ - estimated from data

≥ 3 e/μ



2 e/μ + 1 τ



ATLAS multiple leptons results

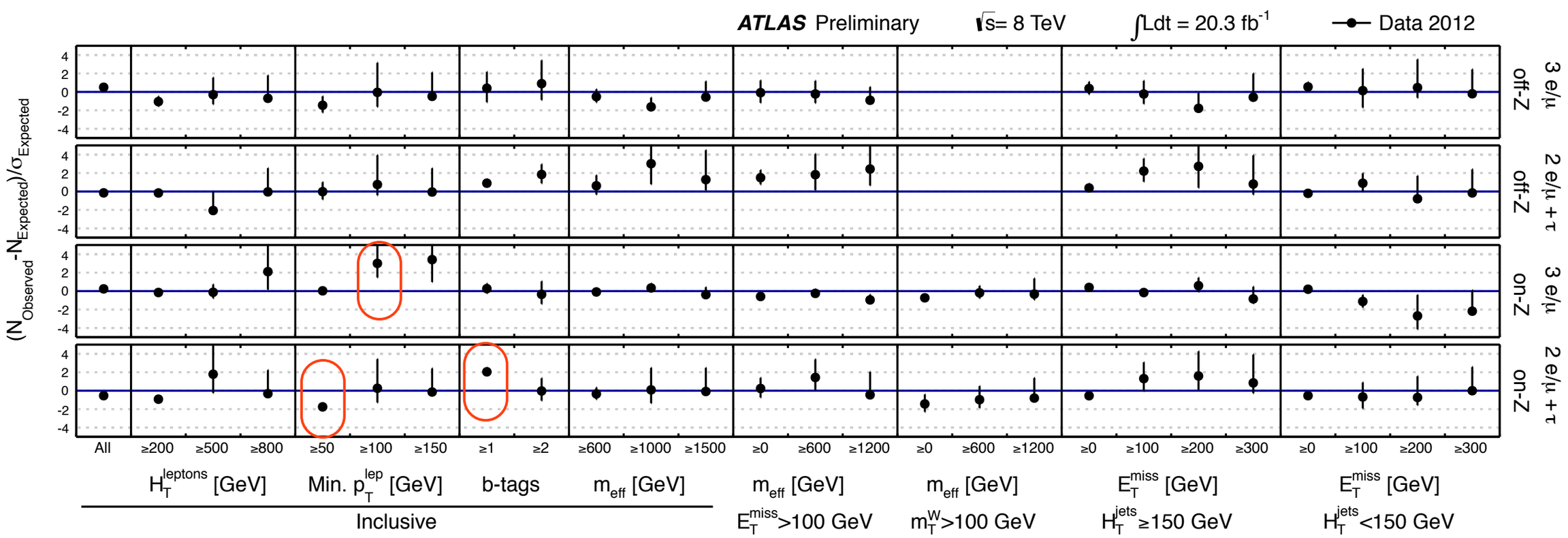


Figure 17: Deviations of observed yields from expected yields, in units of the total uncertainty on the expected yield, for all signal regions under study.

ATLAS multiple leptons: UL on N_{events}

Number of events expected/observed

$H_T^{leptons}$ ≥ [GeV]	$t\bar{t}+V(V)$	$VV(V)$	Reducible	Total	Observed
		≥ $3e/\mu$, off-Z			
200	5.5 ±0.2 ±1.7	64 ±1 ±15	13.6 ±1.9 ±2.3	83 ±2 ±16	66
500	0.29 ±0.04 ±0.09	2.9 ±0.2 ±1.4	0.29 ±0.23 ±0.69	3.5 ±0.3 ±1.5	3
800	0.02 ±0.01 ±0.01	0.5 ±0.1 ±0.2	$0\ ^{+0.69}_{-0}$	0.5 ±0.1 ±0.7	0
		$2e/\mu+$ ≥ 1τ, off-Z			
200	1.01 ±0.07 ±0.31	6.0 ±0.2 ±1.3	121 ±3 ±31	128 ±3 ±31	123
500	0.02 ±0.01 ±0.01	0.14 ±0.02 ±0.03	1.7 ±0.4 ±0.8	1.9 ±0.4 ±0.8	0
800	0.00 ±0.00 ±0.00	0.01 ±0.00 ±0.00	0.02 ±0.03 ±0.71	0.03 ±0.03 ±0.71	0
		≥ $3e/\mu$, on-Z			
200	12.1 ±0.2 ±3.6	389 ±4 ±98	28 ±4 ±6	429 ±6 ±99	414
500	0.46 ±0.05 ±0.14	11.0 ±0.6 ±5.3	2.2 ±1.3 ±0.7	13.7 ±1.5 ±5.3	13
800	0.03 ±0.01 ±0.01	0.9 ±0.2 ±0.4	0.3 ±0.2 ±0.7	1.2 ±0.3 ±0.8	3
		$2e/\mu+$ ≥ 1τ, on-Z			
200	0.67 ±0.06 ±0.21	20.2 ±0.9 ±5.6	256 ±4 ±66	276 ±4 ±66	215
500	0.02 ±0.01 ±0.01	0.5 ±0.1 ±0.2	1.8 ±0.3 ±0.9	2.3 ±0.3 ±0.9	4
800	0.00 ±0.00 ±0.00	0.14 ±0.07 ±0.04	0.1 ±0.1 ±0.7	0.2 ±0.1 ±0.7	0

Tables are available for all kinematic regions

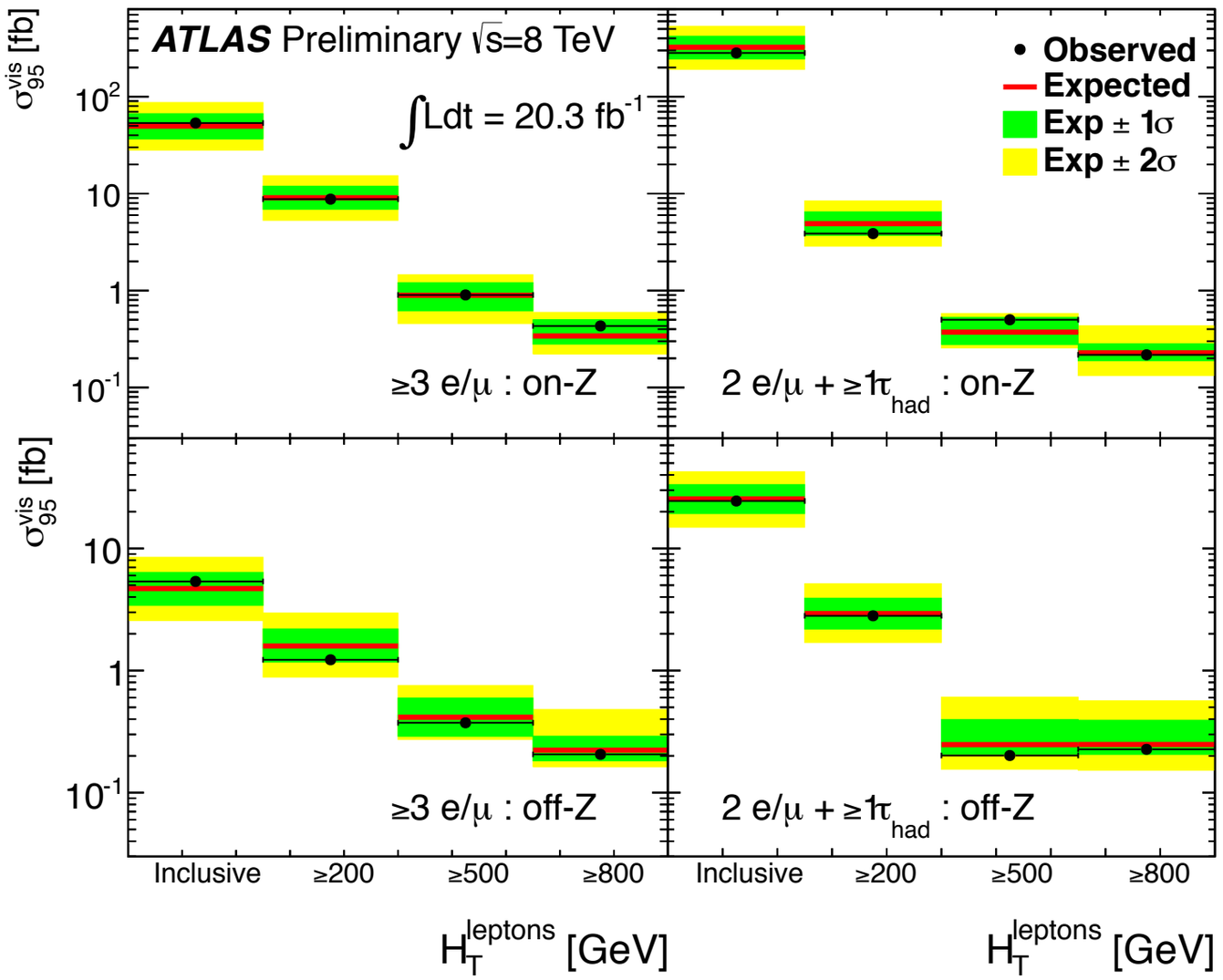
95%CL Upper Limit on number of BSM events (N_{95} / 1 fb^{-1})

$H_T^{leptons}$ [GeV]	Observed	Expected	$^{+1\sigma}_{-1\sigma}$	$^{+2\sigma}_{-2\sigma}$
		≥ $3(e,\mu)$, off-Z		
Inclusive	5.4	4.7	$^{1.7}_{1.3}$	$^{3.8}_{2.1}$
≥ 200	1.2	1.6	$^{0.6}_{0.42}$	$^{1.4}_{0.71}$
≥ 500	0.37	0.41	$^{0.18}_{0.13}$	$^{0.34}_{0.14}$
≥ 800	0.21	0.22	$^{0.068}_{0.041}$	$^{0.26}_{0.059}$
		$2(e,\mu)+$ ≥ $1(\tau)$, off-Z		
Inclusive	24	25	$^{7.9}_{6.1}$	$^{17}_{11}$
≥ 200	2.8	2.9	$^{0.99}_{0.74}$	$^{2.2}_{1.2}$
≥ 500	0.2	0.25	$^{0.15}_{0.042}$	$^{0.36}_{0.092}$
≥ 800	0.23	0.25	$^{0.14}_{0.042}$	$^{0.32}_{0.095}$
		≥ $3(e,\mu)$, on-Z		
Inclusive	54	50	$^{17}_{13}$	$^{37}_{22}$
≥ 200	8.8	9.1	$^{2.9}_{2.2}$	$^{6.2}_{3.8}$
≥ 500	0.9	0.89	$^{0.31}_{0.27}$	$^{0.57}_{0.44}$
≥ 800	0.43	0.34	$^{0.16}_{0.06}$	$^{0.26}_{0.12}$
		$2(e,\mu)+$ ≥ $1(\tau)$, on-Z		
Inclusive	280	320	$^{97}_{77}$	$^{210}_{130}$
≥ 200	3.9	4.9	$^{1.6}_{1.2}$	$^{3.5}_{2}$
≥ 500	0.5	0.37	$^{0.16}_{0.093}$	$^{0.21}_{0.12}$
≥ 800	0.22	0.23	$^{0.056}_{0.039}$	$^{0.21}_{0.095}$

ATLAS multiple leptons: UL on σ

Upper limits on available phase space are also given, the fiducial efficiencies are provided as function of p_T and **η** on all leptons

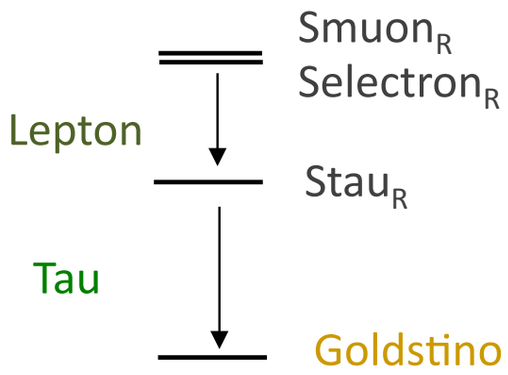
$$\sigma_{95}^{\text{fid}} = \frac{N_{95}}{\epsilon_{fid} \int L\mathrm{d}t} = \frac{\sigma_{95}^{\text{vis}}}{\epsilon_{fid}}.$$



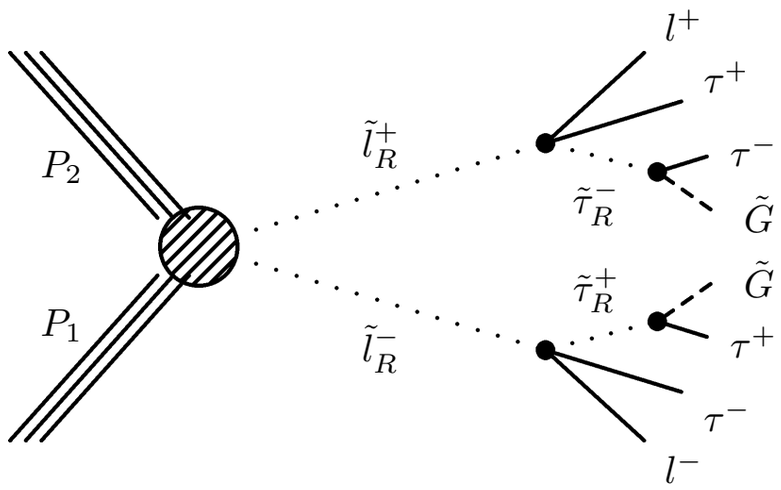
Tables, plots are available for all kinematic regions

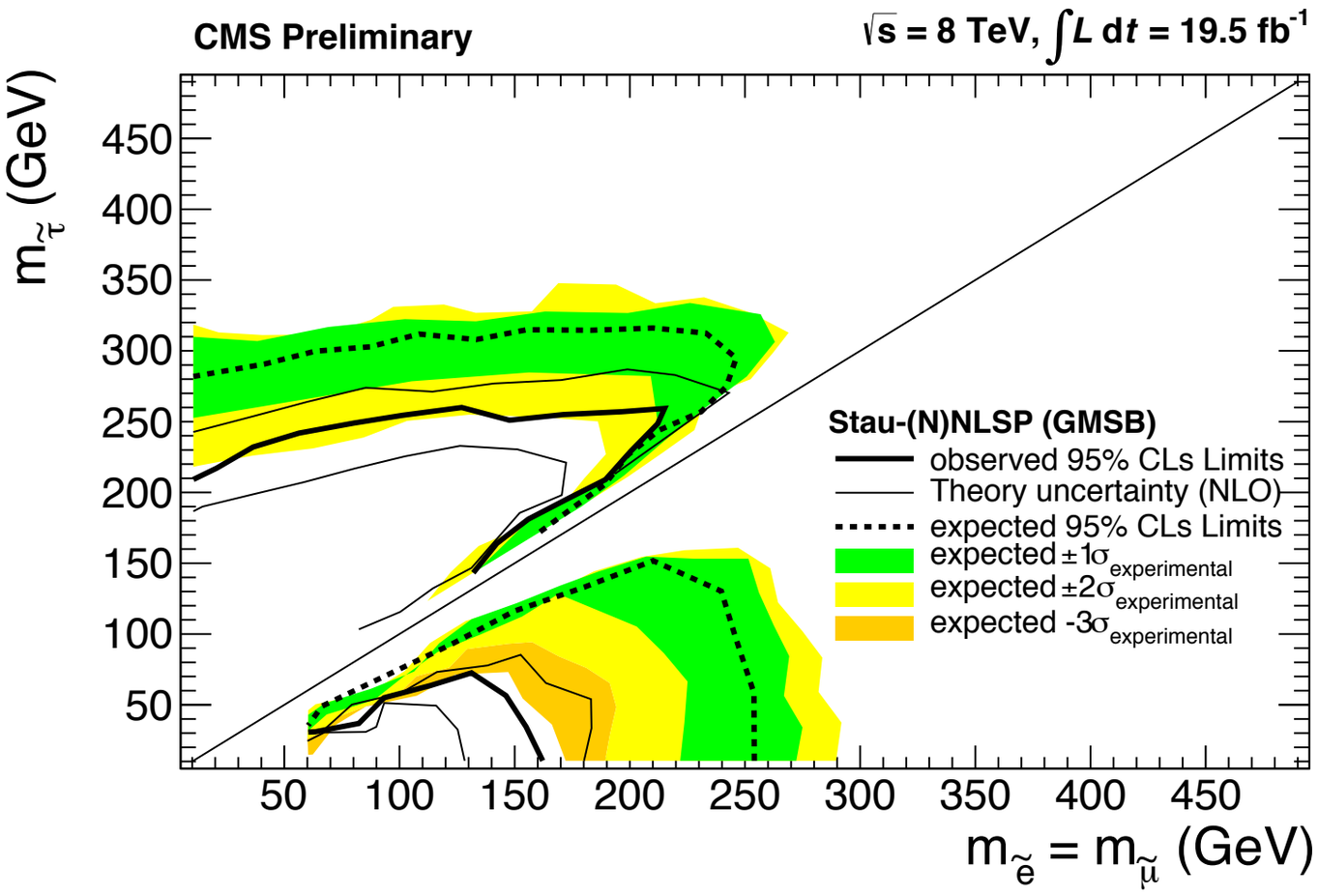
All tables are made available as HEPDATA and as RIVET routine (7TeV)

CMS SUSY exclusions



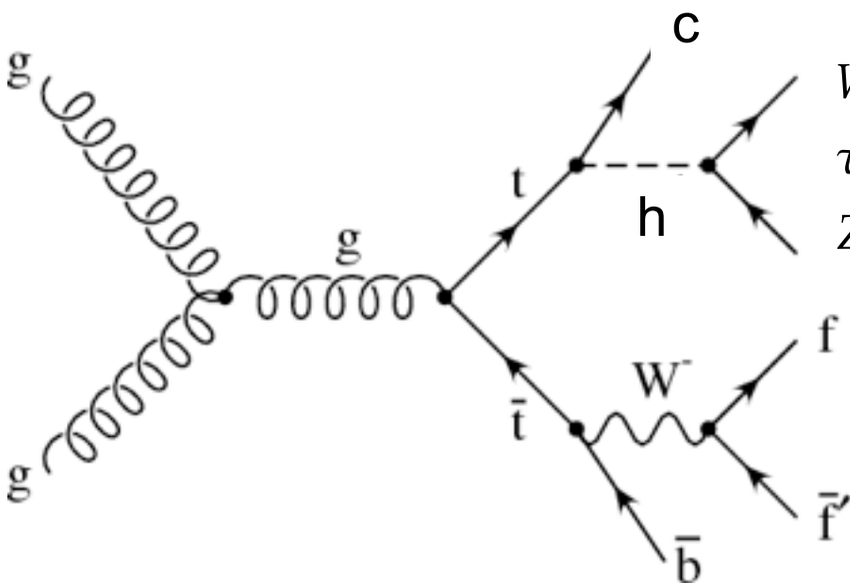
Stau (N)NLSP





Also available for scenario with natural Higgsino NLSP (GMSB), slepton co-NLSP (GMSB); T1tttt (SMS) and T6ttWW (SMS)

CMS t→ch exclusion



$WW^* \to \ell\nu\ell\nu,$

$\tau\tau,$

$ZZ^* \to jj\ell\ell, \nu\nu\ell\ell, \ell\ell\ell\ell.$

$$\sqrt{|\lambda^h_{tc}|^2 + |\lambda^h_{ct}|^2} < 0.21$$

SM BR < 10^{-13} - 10^{-15}

Higgs Decay Mode	obs	exp	1σ range
$h \to WW^*$ (BR = 23.1 %)	1.58 %	1.57 %	(1.02–2.22) %
$h \to \tau\tau$ (BR = 6.15 %)	7.01 %	4.99 %	(3.53–7.74) %
$h \to ZZ^*$ (BR = 2.89 %)	5.31 %	4.11 %	(2.85–6.45) %
combined	1.28 %	1.17 %	(0.85–1.73) %

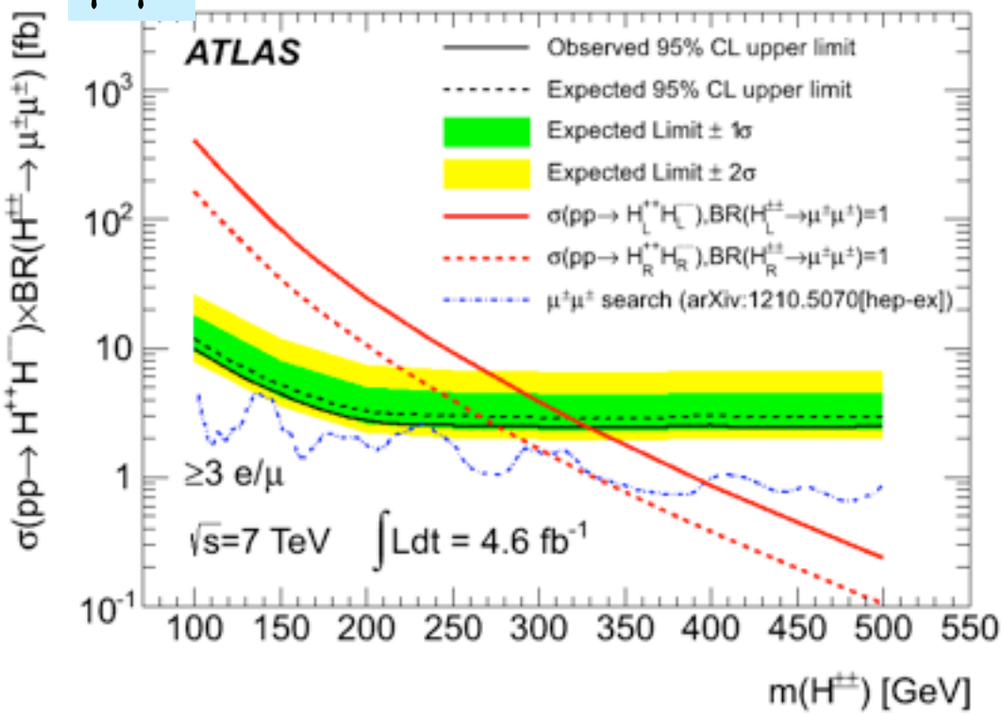
Table 7: Comparison of the observed and median expected 95% C.L. limits on BR$(t \to ch)$ from individual Higgs decay modes along with the 1σ uncertainty ranges.

CMS-PAS-SUS-13-002

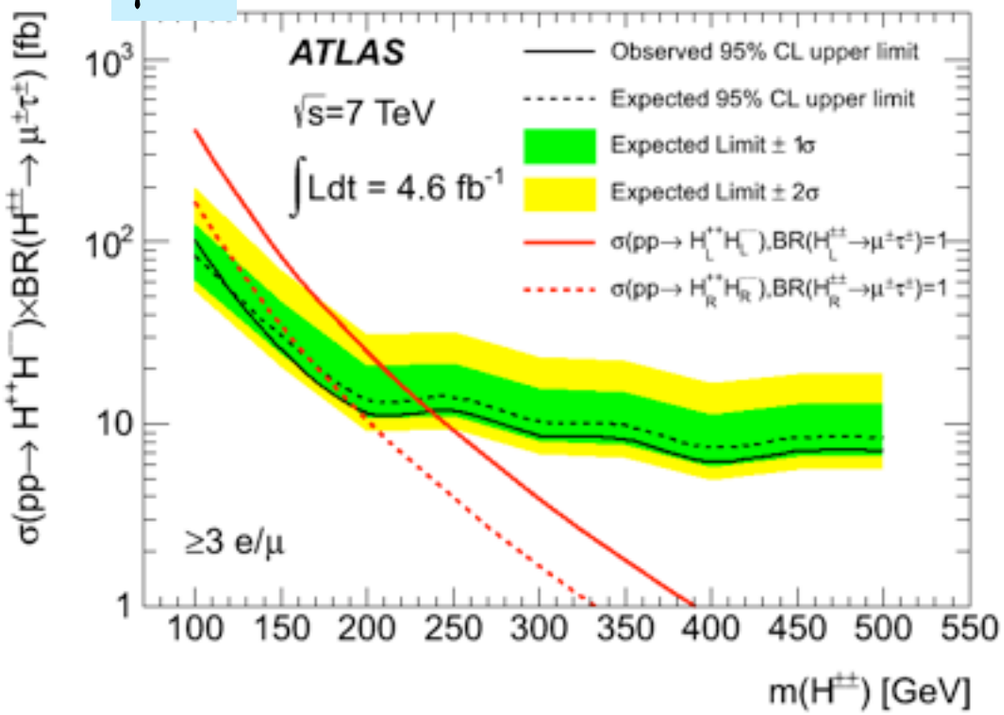
ATLAS exclusions

- Only model independent limits are given in 8 TeV CONF note
- 7 TeV paper contained **doubly charged Higgs** exclusion limits
- **RIVET** code for 7 TeV analysis is available – very easy to apply to Monte Carlo generation of any model

$\mu^{\pm}\mu^{\pm}$



$\mu^{\pm}\tau^{\pm}$



Updates are coming – Watch this space

DCH exclusion is also done by CMS, 7TeV

second - more focused (model-dependent) search

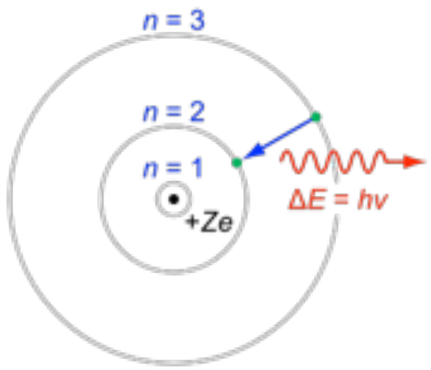
Looking for specific final state

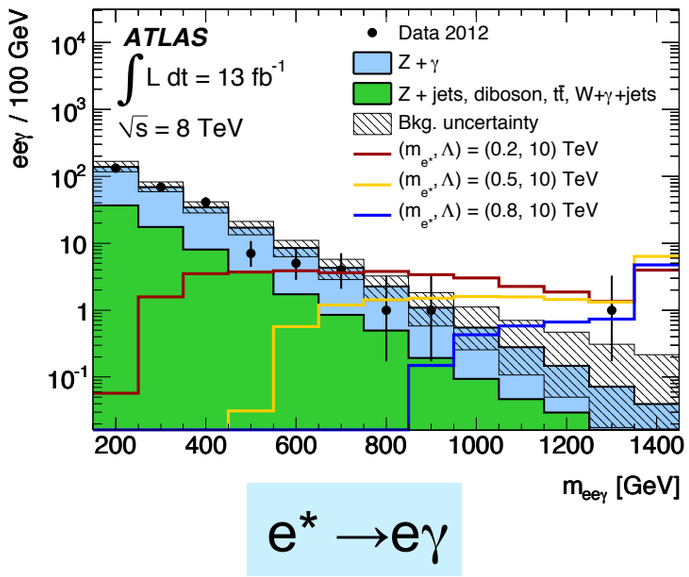
- Excited leptons: ATLAS (8TeV) New J. Phys. 15 (2013) 093011; CMS (7TeV) Phys.Lett. B720 (2013) 309
- LRSM, W_R, heavy neutrinos: ATLAS(7 TeV) Eur.Phys.J. C72 (2012) 2056; , CMS(8 TeV) CMS-PAS-EXO-12-017
- Majorana neutrinos: both 7 TeV (backup)
- Heavy fermion triplet: ATLAS(8 TeV) ATLAS-CONF-2013-019 , CMS(7 TeV) Phys.Lett. B718 (2012) 348

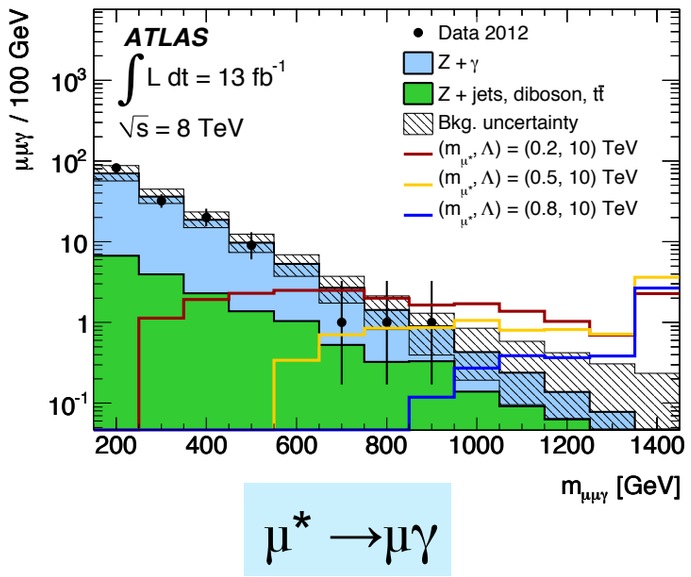
Excited leptons

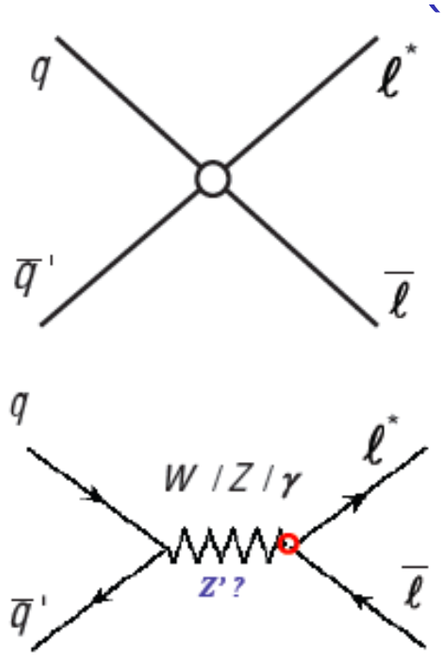
$e^+e^-\gamma$, $\mu^+\mu^-\gamma$ (p_T>40,30,30GeV)

ATLAS, **8TeV**, 13 fb^{-1}

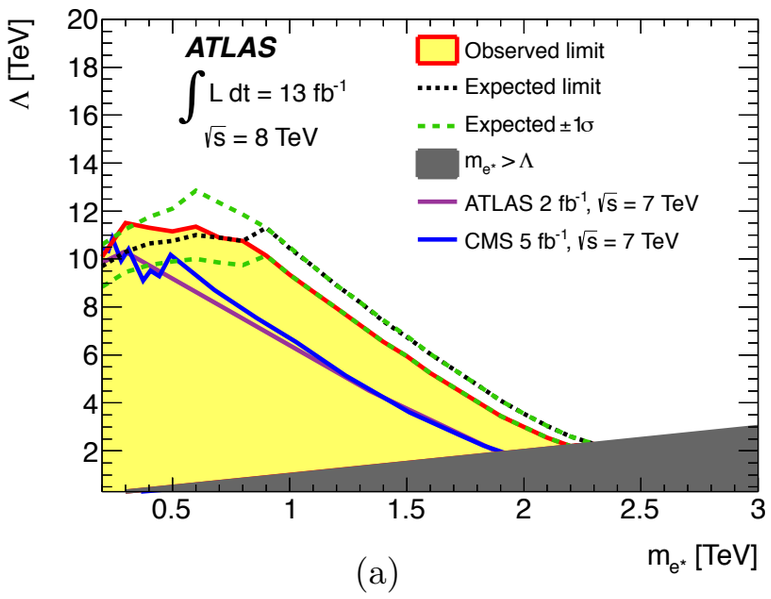






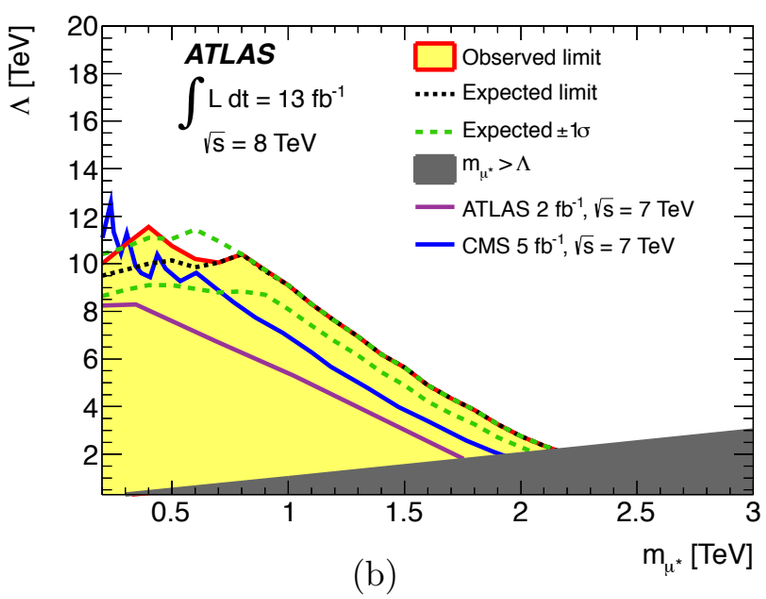


e* →eγ



(a)

μ* →μγ



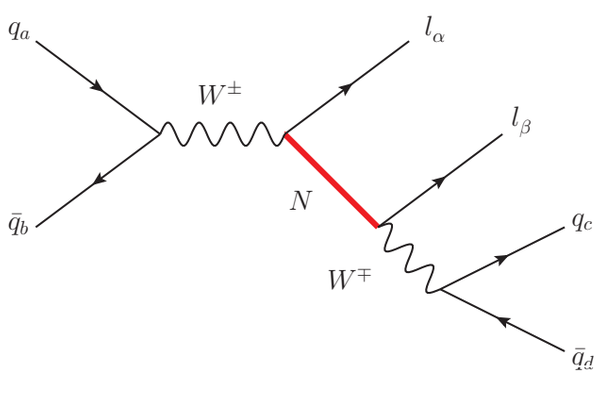
(b)

CMS, **7TeV**, 5 fb^{-1} :

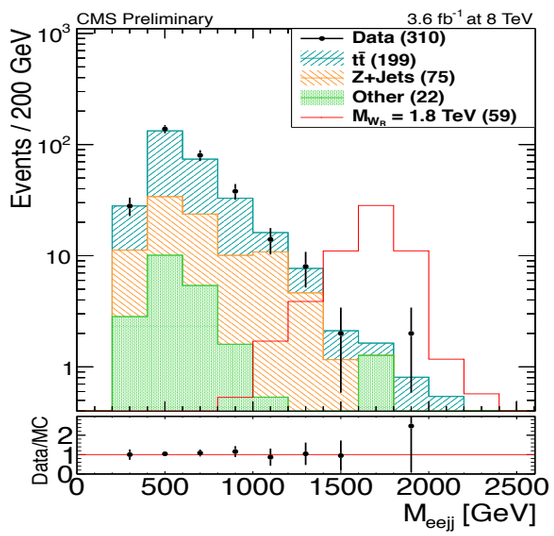
CMS: Phys.Lett. B720 (2013) 309

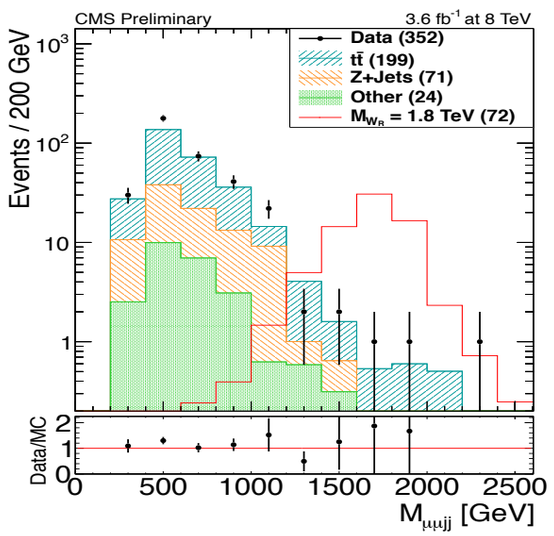
LRSM: W_R and heavy neutrinos

LRSM :
SUC (3) ⊗ SUL (2) ⊗ SUR (2) ⊗ U(1):
$W^{\pm}_R$, Z', N_1, N_2, N_3

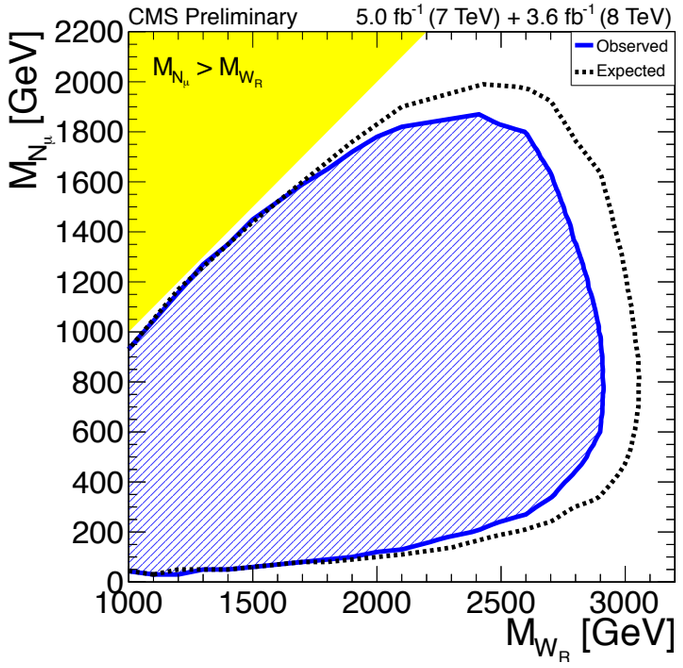


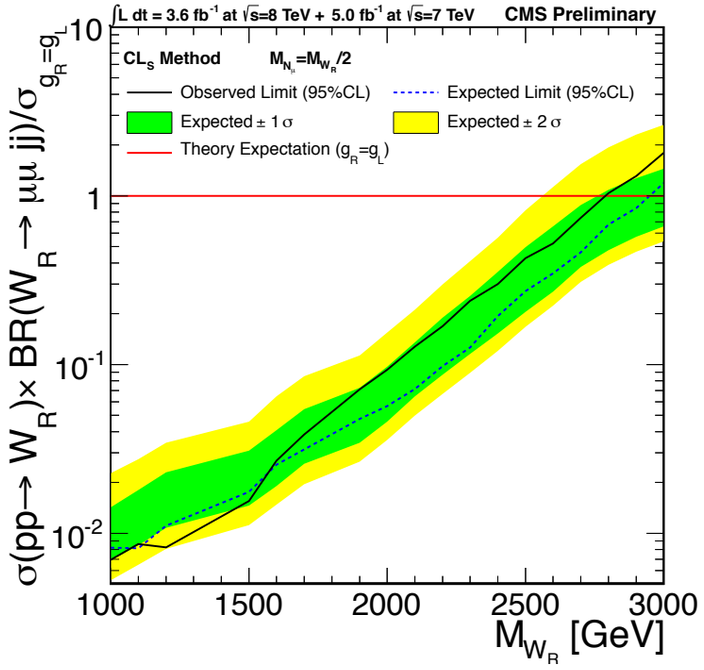
CMS 8 TeV, 3.6 fb^{-1}





2 leptons + 2 jets
$p_T(\ell)$>60,40GeV,
p_T(jet)>40GeV





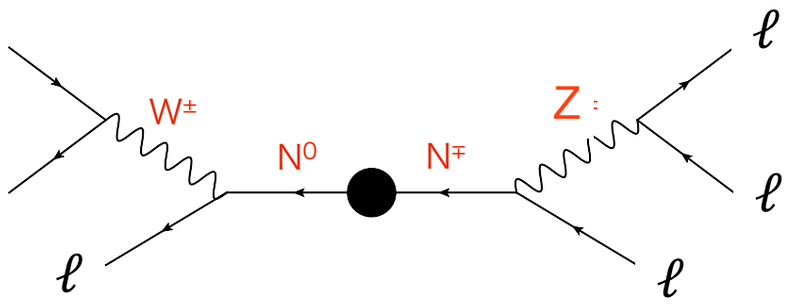
ATLAS: 7 TeV, 2.1 fb^{-1}(Majorana & Dirac)

ATLAS: Eur.Phys.J. C72 (2012) 2056

CMS-PAS-EXO-12-017

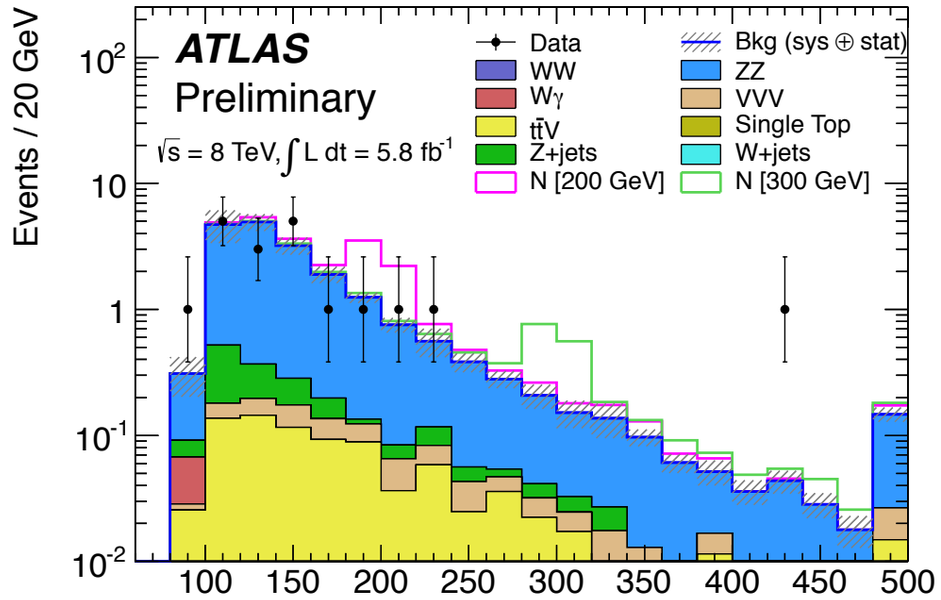
Heavy fermion triplet (N^0, $N^\pm$)

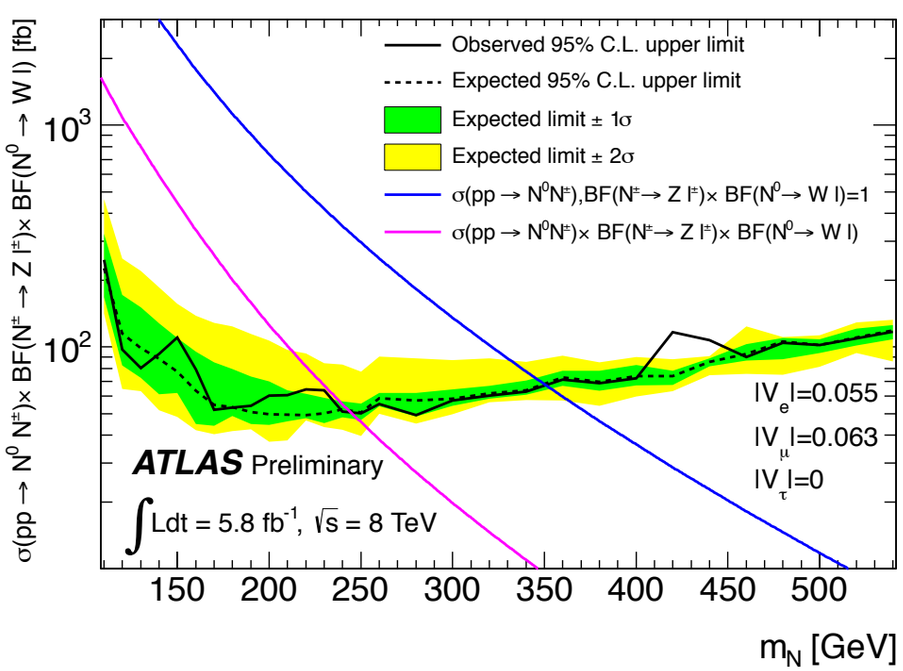
ATLAS, 8 TeV, 5.8 fb^{-1}

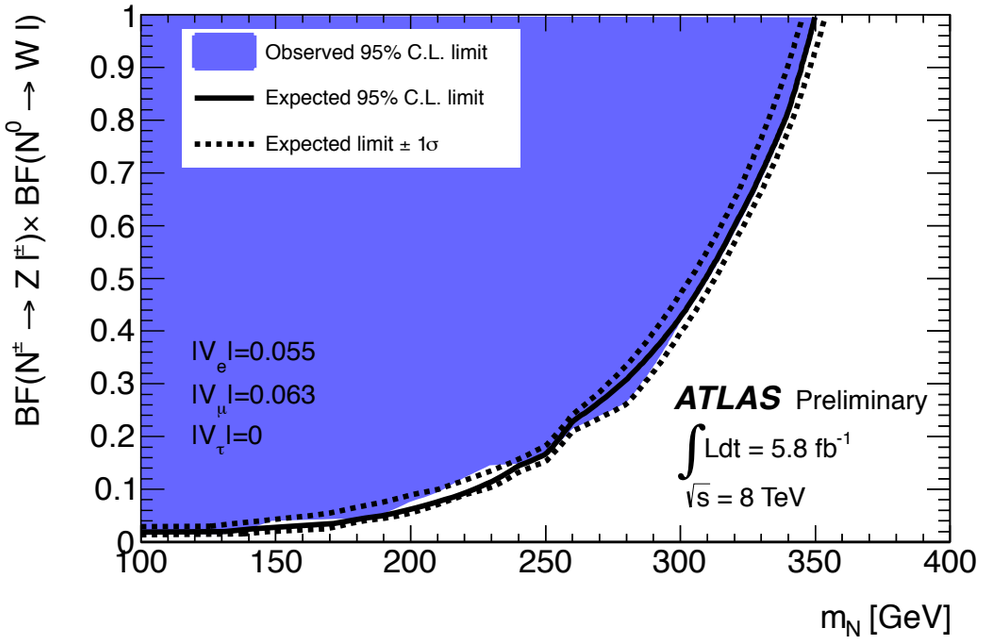


$Z(\ell\ell)+\ell+\ell$

$p_T(\ell)$>25,10,10,10 GeV







CMS, 7 TeV, 4.9 fb^{-1}: 3ℓ+MET

Summary

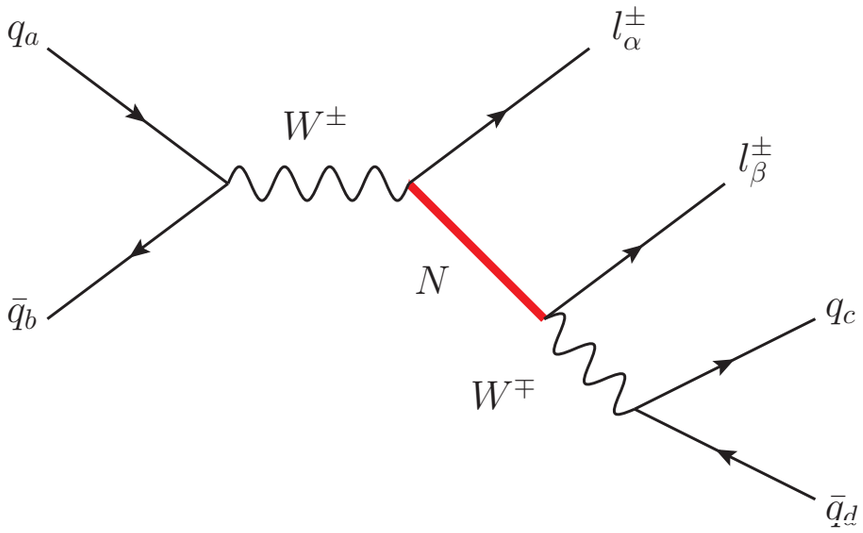
- Both experiments have many results on events with many leptons
  - probing wide range of models
- Model-independent 3 or more lepton searches do not reveal BSM yet
  - see SUSY and BSM Higgs interpretations
  - **your model test here** ? - use our RIVET routine for quick results
- A number of model-oriented searches are performed :
  - search for excited leptons
  - search for right-left SM extension, W_R and heavy neutrino
  - search for heavy lepton triplet
  - search for Majorana neutrino
    - and others

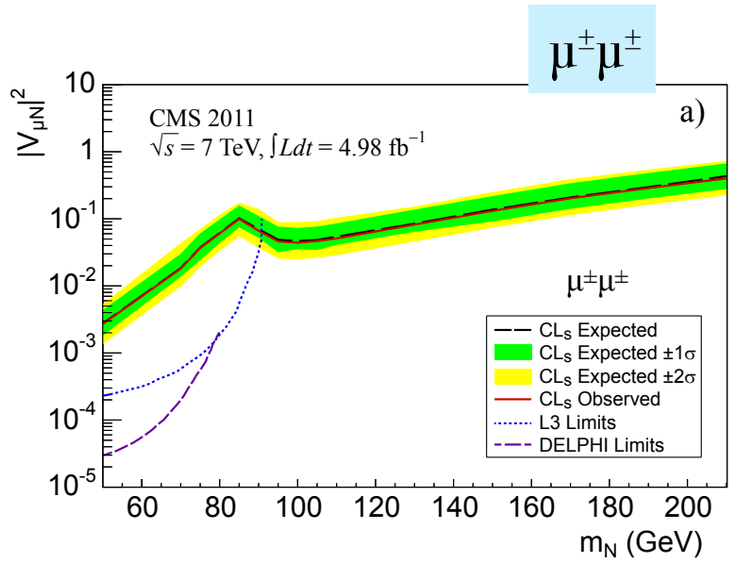
Looking forward to LHC Run 2!

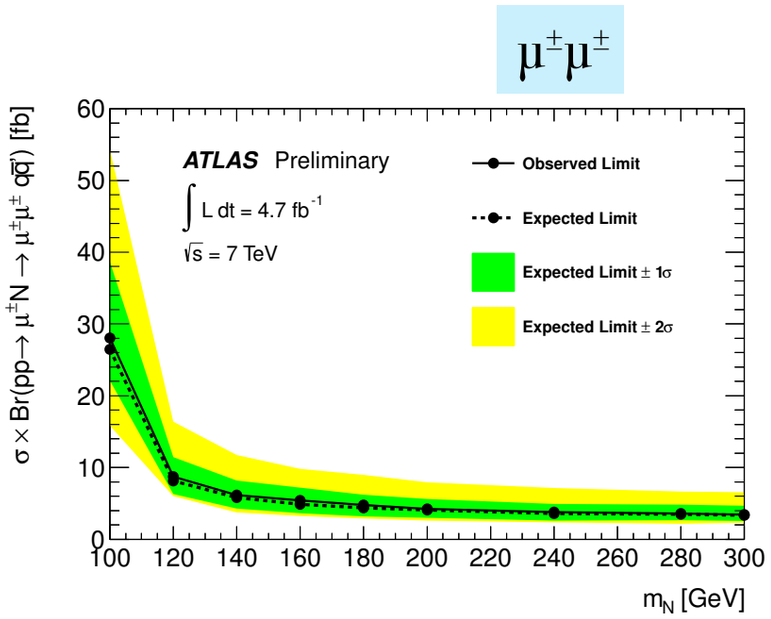
Backup

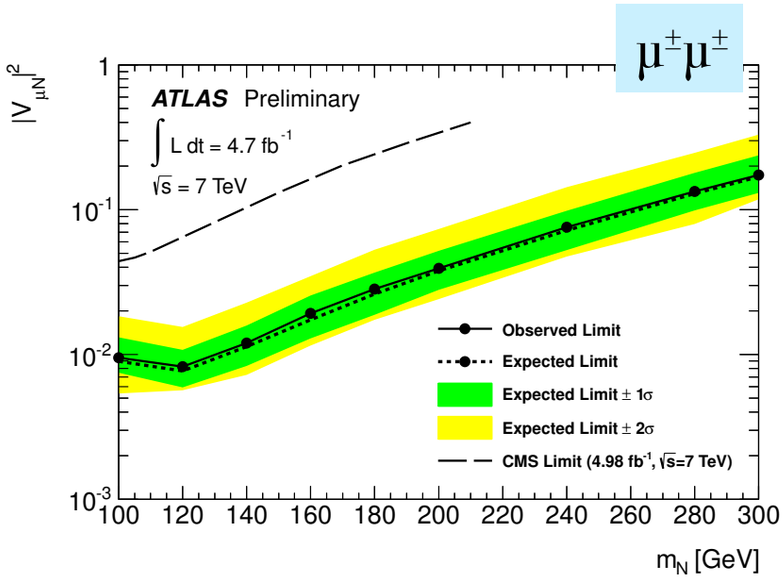
Seesaw I Majorana neutrino

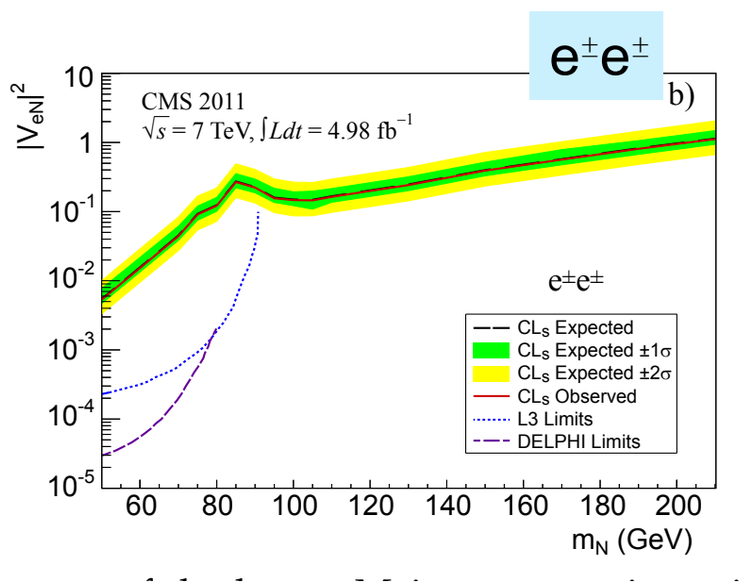
Both collaborations : 7 TeV







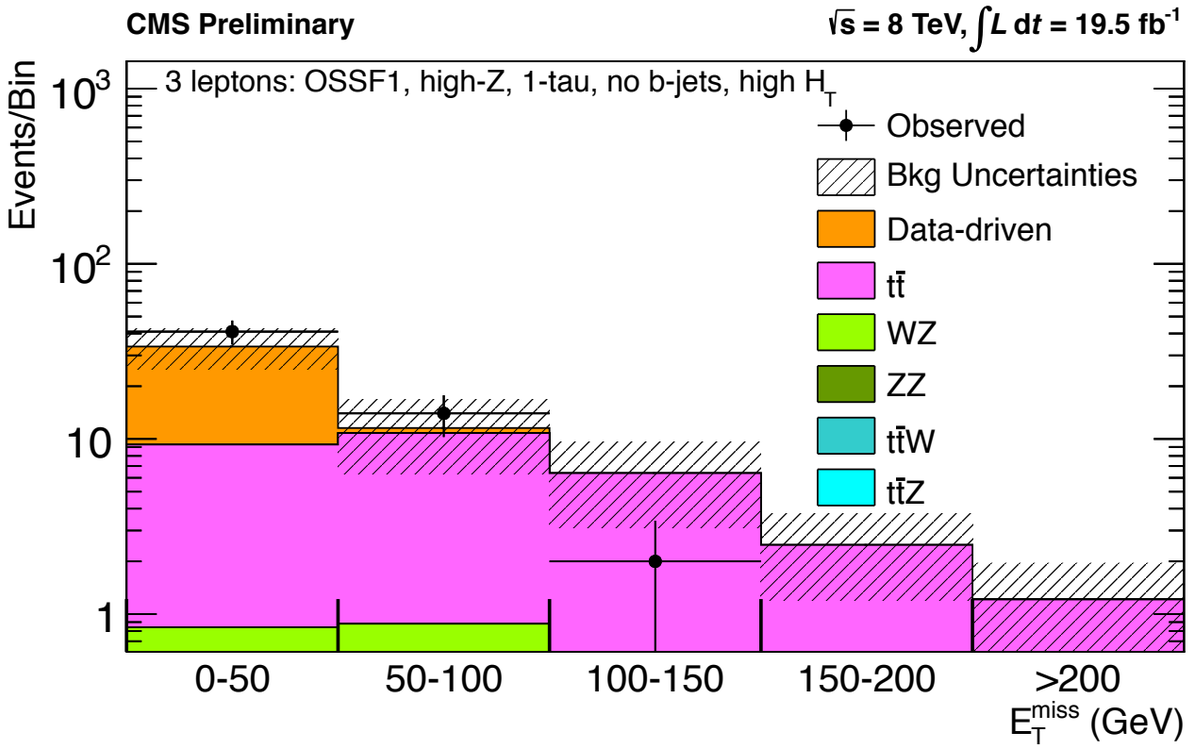


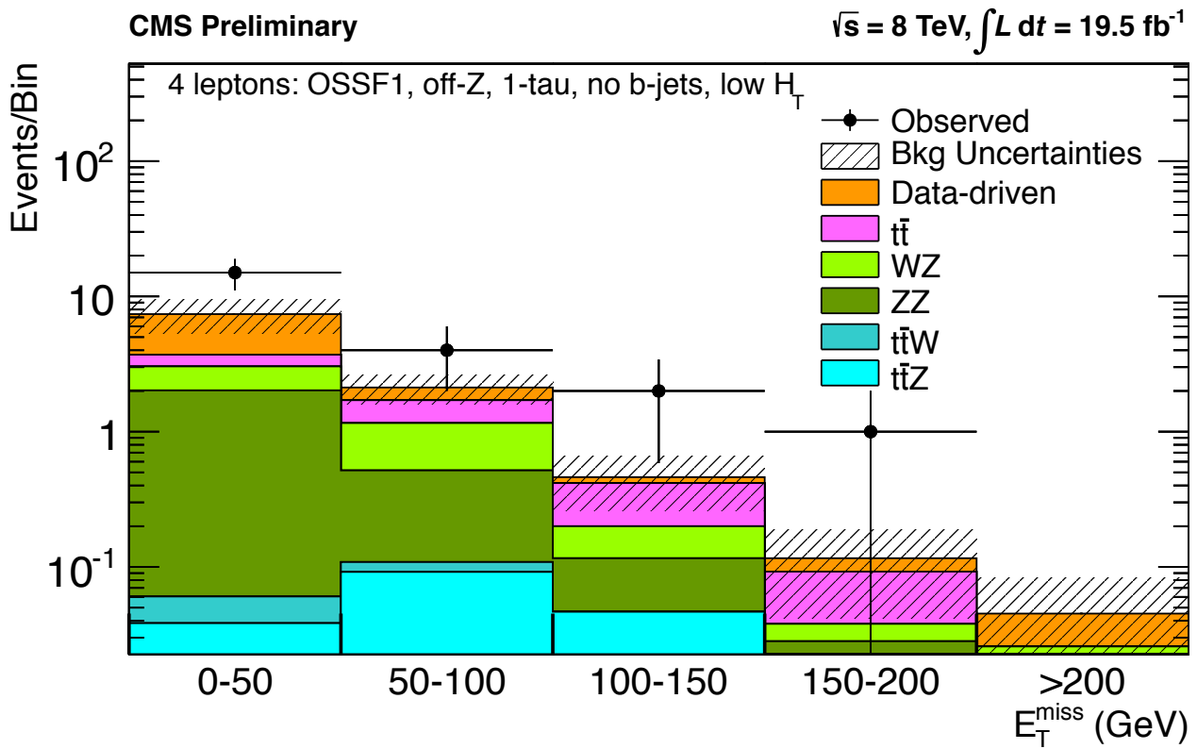


ATLAS-CONF-2012-139

CMS: Phys.Lett. B717 (2012) 109

CMS multiple leptons





Probability of funding upward fluctuation of this size given 64 regions is ~ 5%