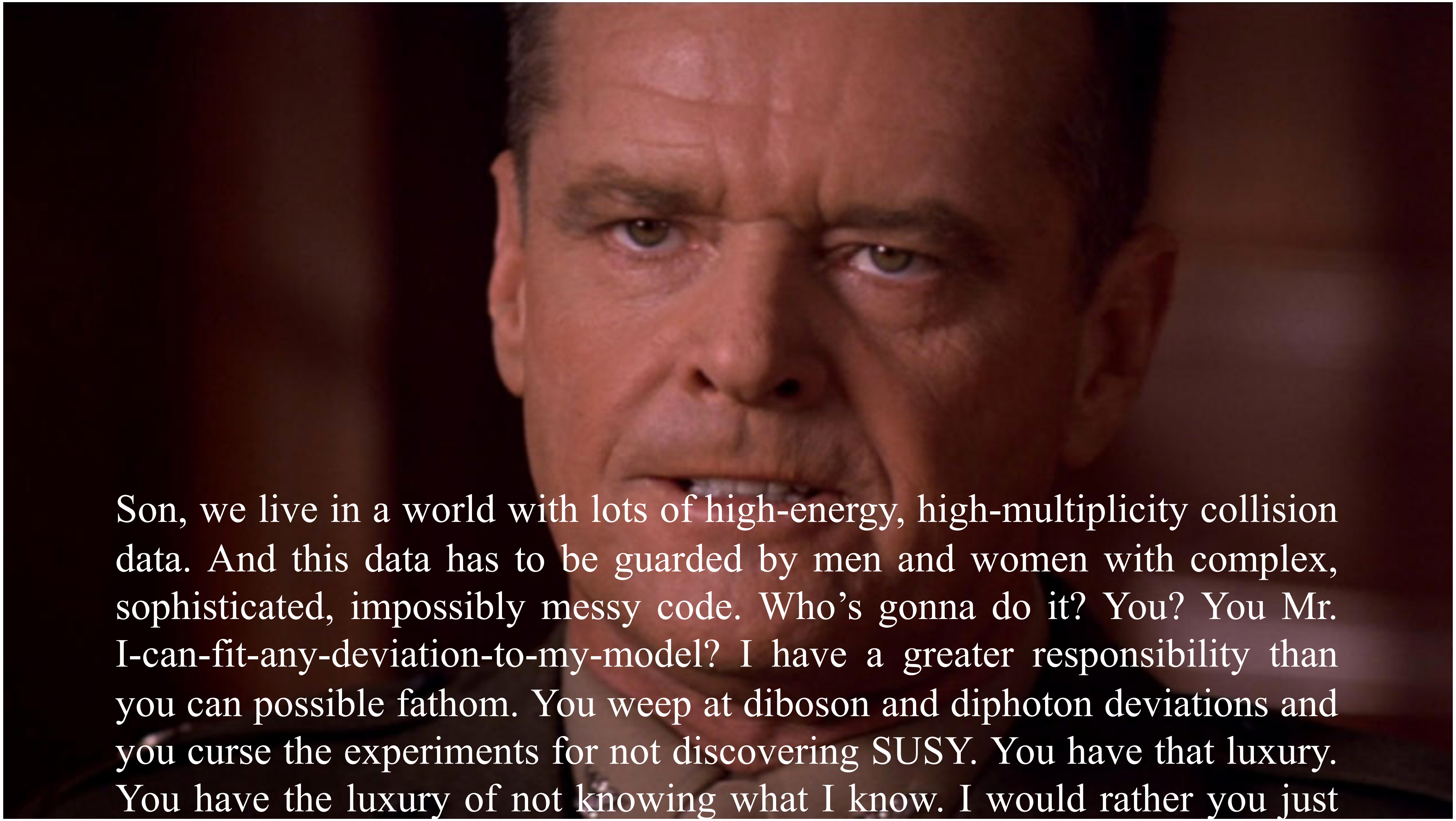
You can’t handle the 2016 results!



Son, we live in a world with lots of high-energy, high-multiplicity collision data. And this data has to be guarded by men and women with complex, sophisticated, impossibly messy code. Who’s gonna do it? You? You Mr. I-can-fit-any-deviation-to-my-model? I have a greater responsibility than you can possible fathom. You weep at diboson and diphoton deviations and you curse the experiments for not discovering SUSY. You have that luxury. You have the luxury of not knowing what I know. I would rather you just said thank you and went on your way. Otherwise, I suggest you pick up an application form and join one of the LHC experiments. Either way, I don’t give a damn what you think you are entitled to.

Search for New Physics in multilepton final states at ATLAS and CMS

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THE UNIVERSITY *of* EDINBURGH

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CHICAGO

What searches this talk will cover

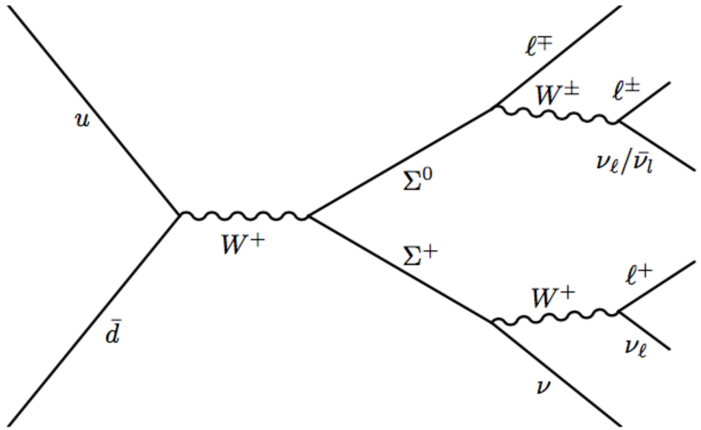
Mostly "unconventional" signatures with > 1 charged leptons:

- Type-III seesaw heavy fermions with multileptons
- Same-sign dilepton resonances
- Dilepton resonances in LFV decays
- Leptonic decays of resonances in VBF

What searches this talk will NOT cover:

- Heavy new bosons (W′, Z′)
- Leptoquarks
- SUSY RPV signatures

Type-III seesaw heavy fermions (CMS)



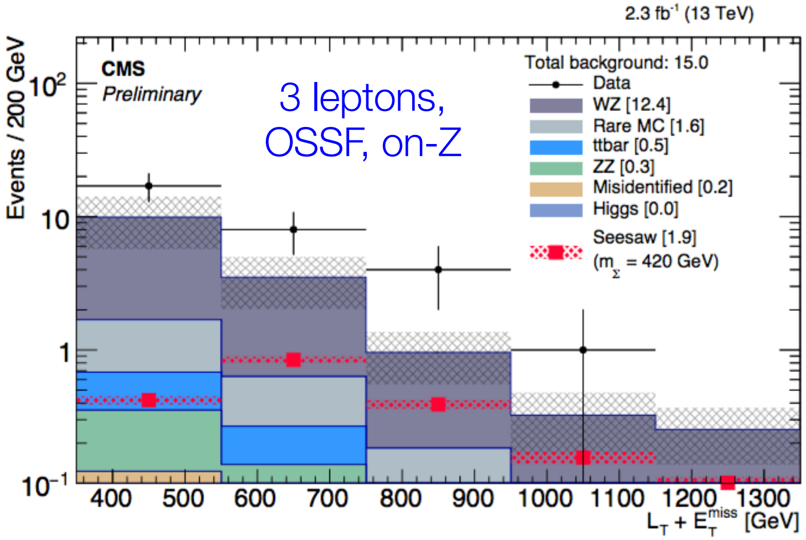
Theoretical motivation:

- SU(2) symmetry: $\Sigma^{\pm}$ (heavy Dirac charged leptons) and Σ^{0} (heavy Majorana neutrinos)
- Couplings to leptons and Higgs doublets

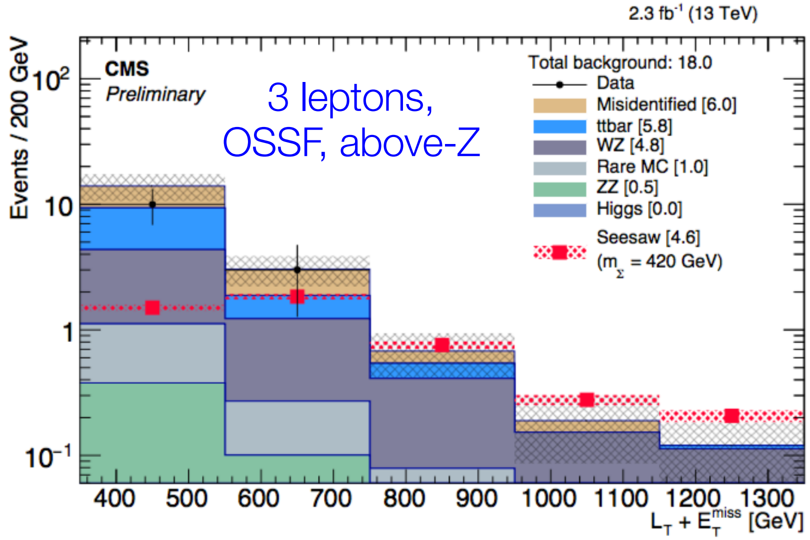
Experimental considerations:

- Largest backgrounds: Leptonic *WZ* (~51%), leptonic $t\bar{t}$ (~21%), Z+jets (~17%)
- *Looking for final states with three or more charged leptons*
- Analysis channel classification: # of leptons, lepton flavour, lepton relative charges, charge and flavour combinations

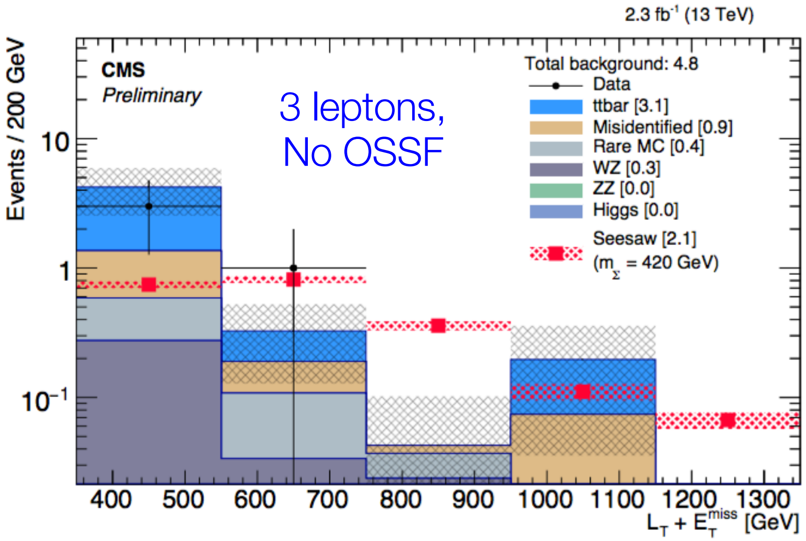
Type-III seesaw heavy fermions (CMS)



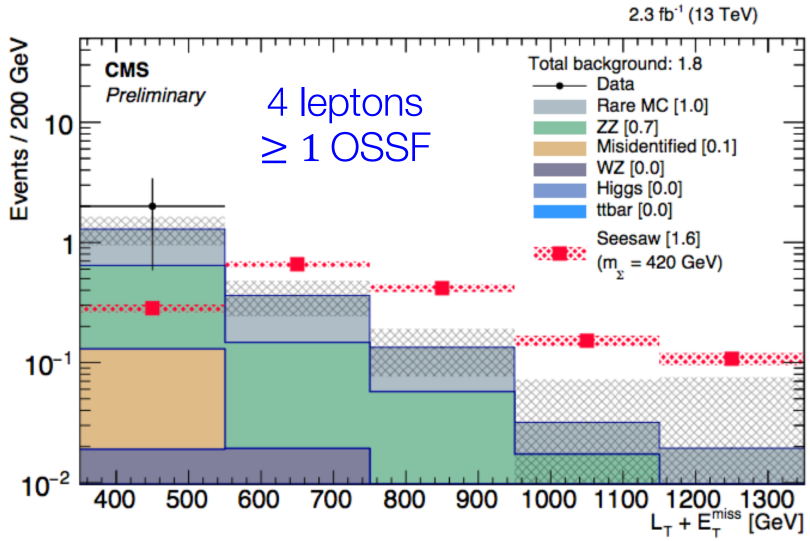
(a)



(b)



(c)

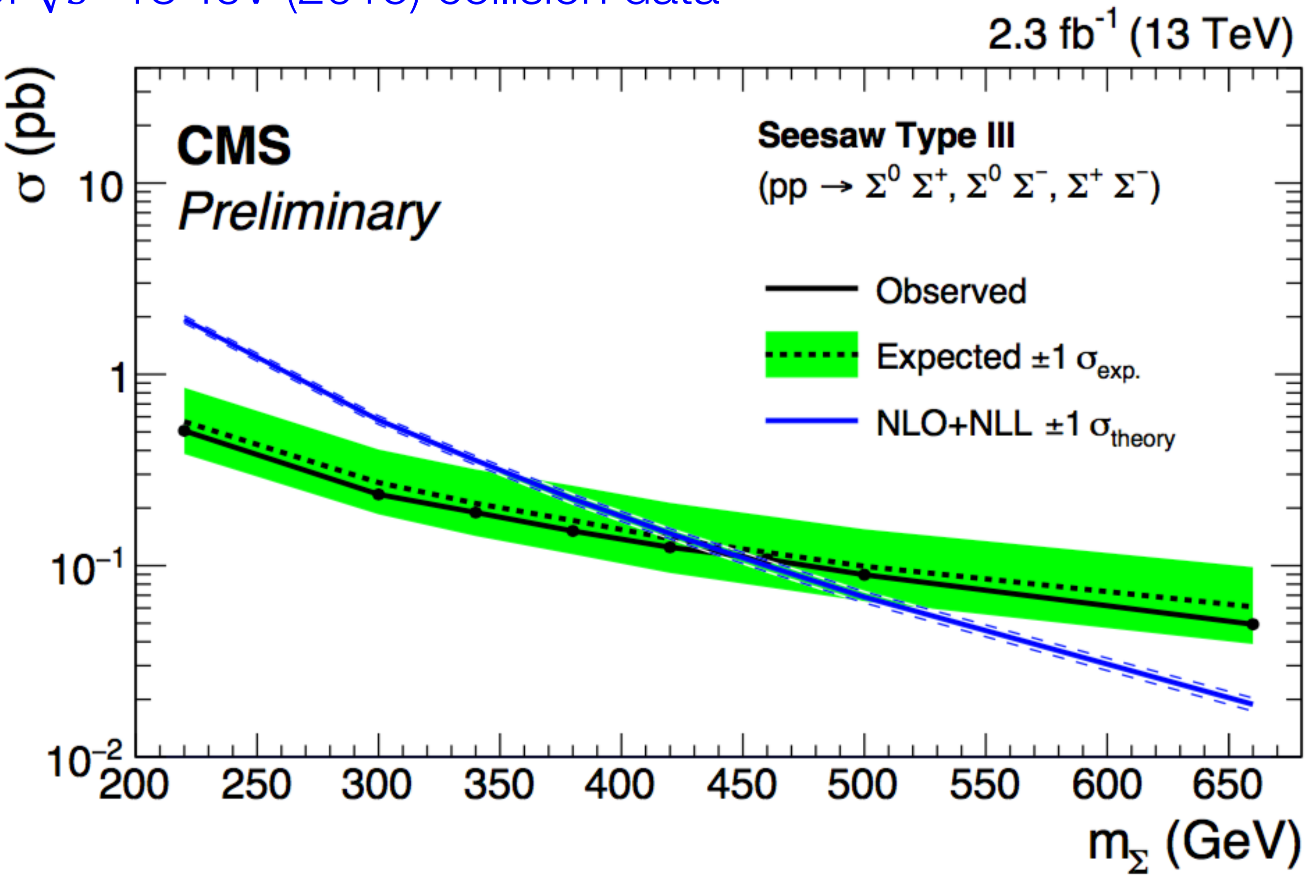


(d)

$\sum_{lepton} p_T + ME_T$ distributions

Type-III seesaw heavy fermions (CMS)

2.3 fb^{-1} of $\sqrt{s}$=13 TeV (2015) collision data

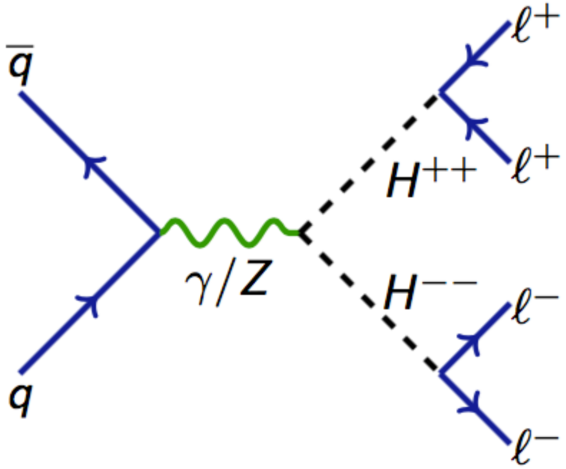


Observed 95% CL exclusion limits on heavy fermions masses:

- 440 GeV (430 GeV expected)

CMS-PAS-EXO-16-002

Same-sign dilepton searches (ATLAS)



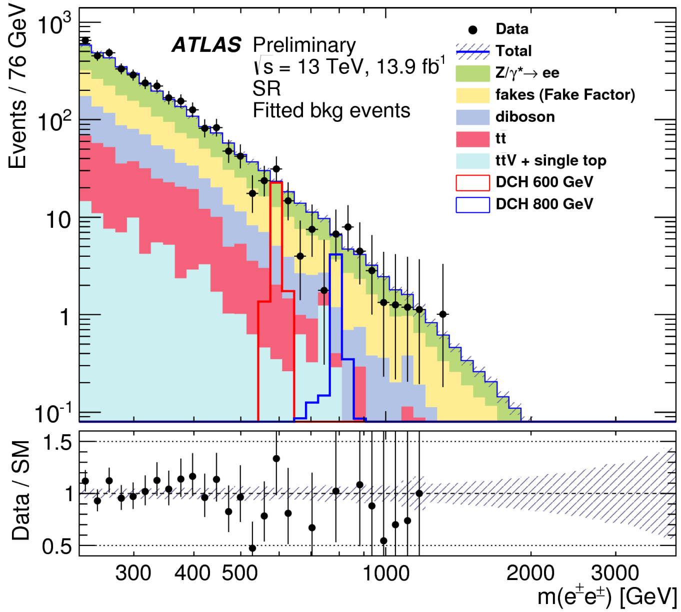
Theoretical motivation:

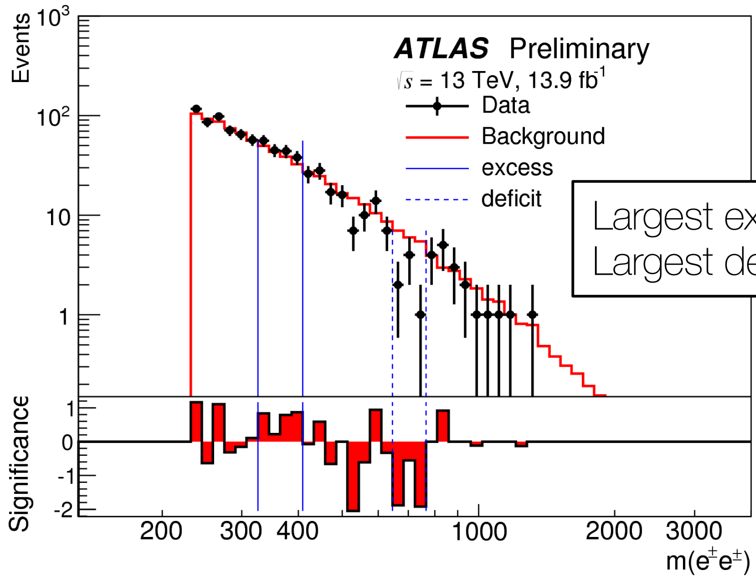
- LRSM, Higgs-triplet, little Higgs, Type-II seesaw models
- Pair production of charged Higgs bosons via Drell-Yan

Experimental considerations:

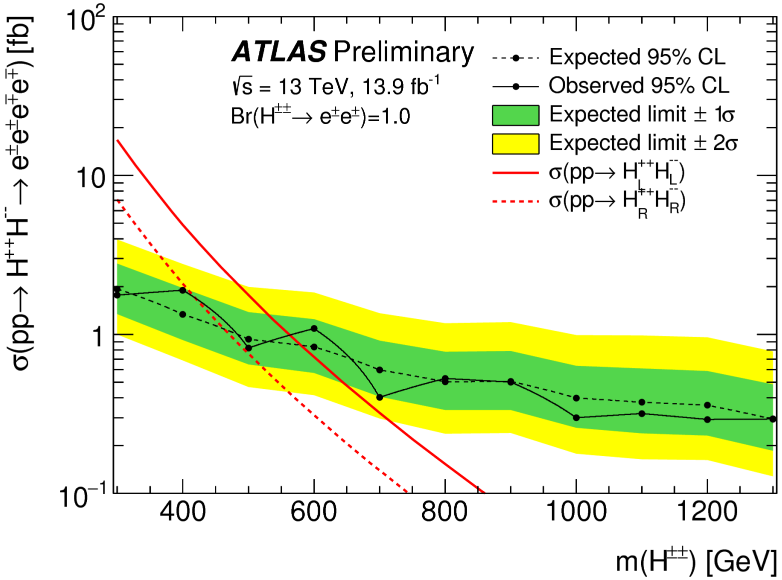
- Largest backgrounds: charge mis-identification of DY, $t\bar{t}$, dibosons, and jets faking electrons
- *Only results in di-electron channel reported here*
- Charge mis-identification: (1) bremsstrahlung leading to electron-positron photon conversion (2) wrong-charge for poorly-measured track of very energetic electron

Same-sign dilepton searches (ATLAS)





Largest excess: 1.5 sigma
Largest deficit: 1.3 sigma



10.1 fb^{-1} of $\sqrt{s}$=13 TeV collision data (di-electrons)

Observed 95% CL exclusion limits on Higgs masses assuming $B(H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm})$=100%:

- $H_R^{\pm}$: 420 GeV (right-handed leptons)
- $H_L^{\pm}$: 570 GeV (left-handed leptons)

ATLAS-CONF-2016-051

Dilepton resonances in LFV searches (ATLAS)

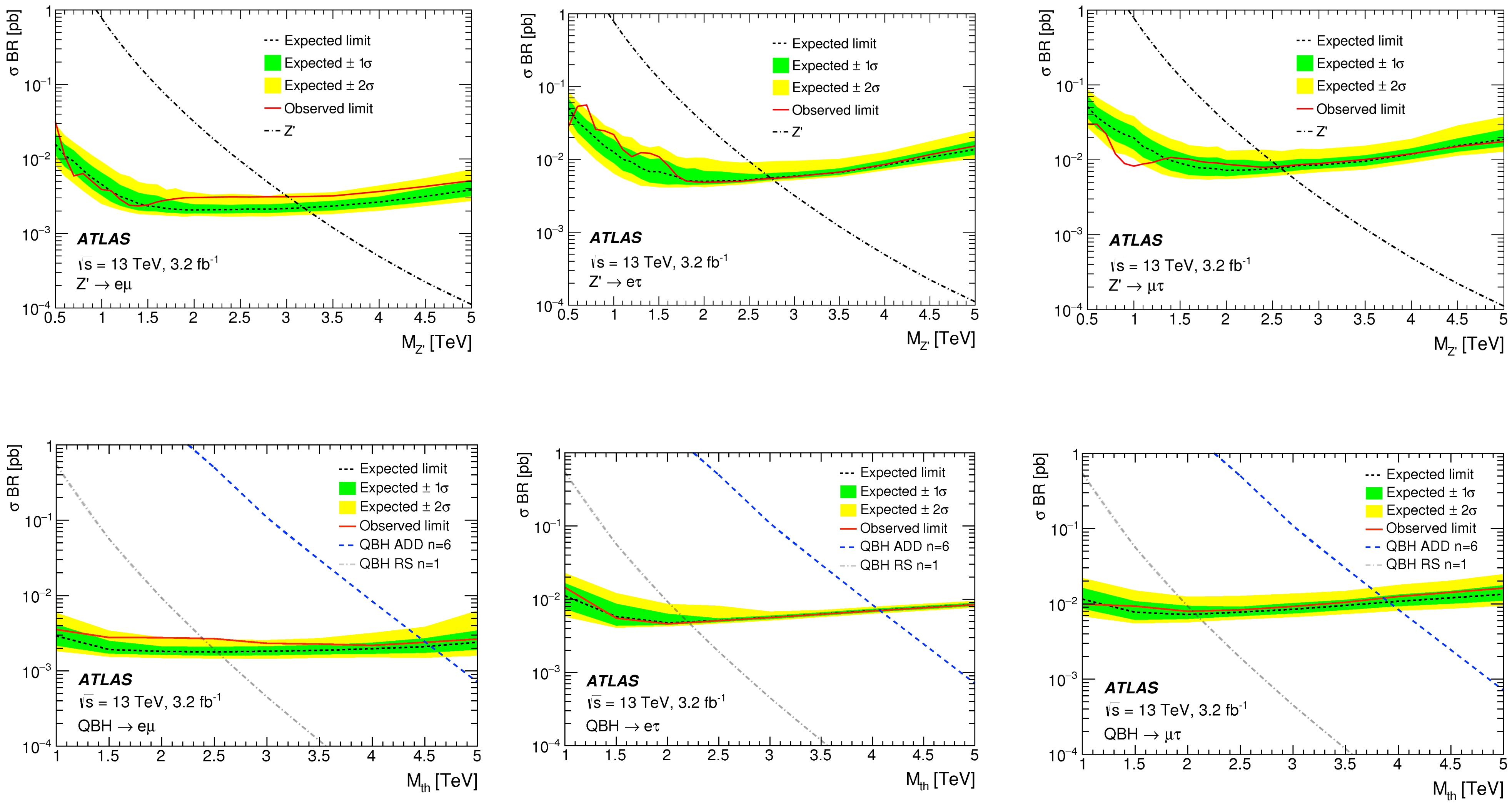
Theoretical motivation:

- Additional U(1) gauge symmetry: $Z' \rightarrow e\mu, e\tau, \mu\tau$
- Black holes: ADD (n=6 extra dimensions), RS (n=1 extra dimension); LFV initial state $q\bar{q}$ *or* gg giving QBH → $\ell\ell'$
- R-parity violating SUSY (not discussed here)

Experimental considerations:

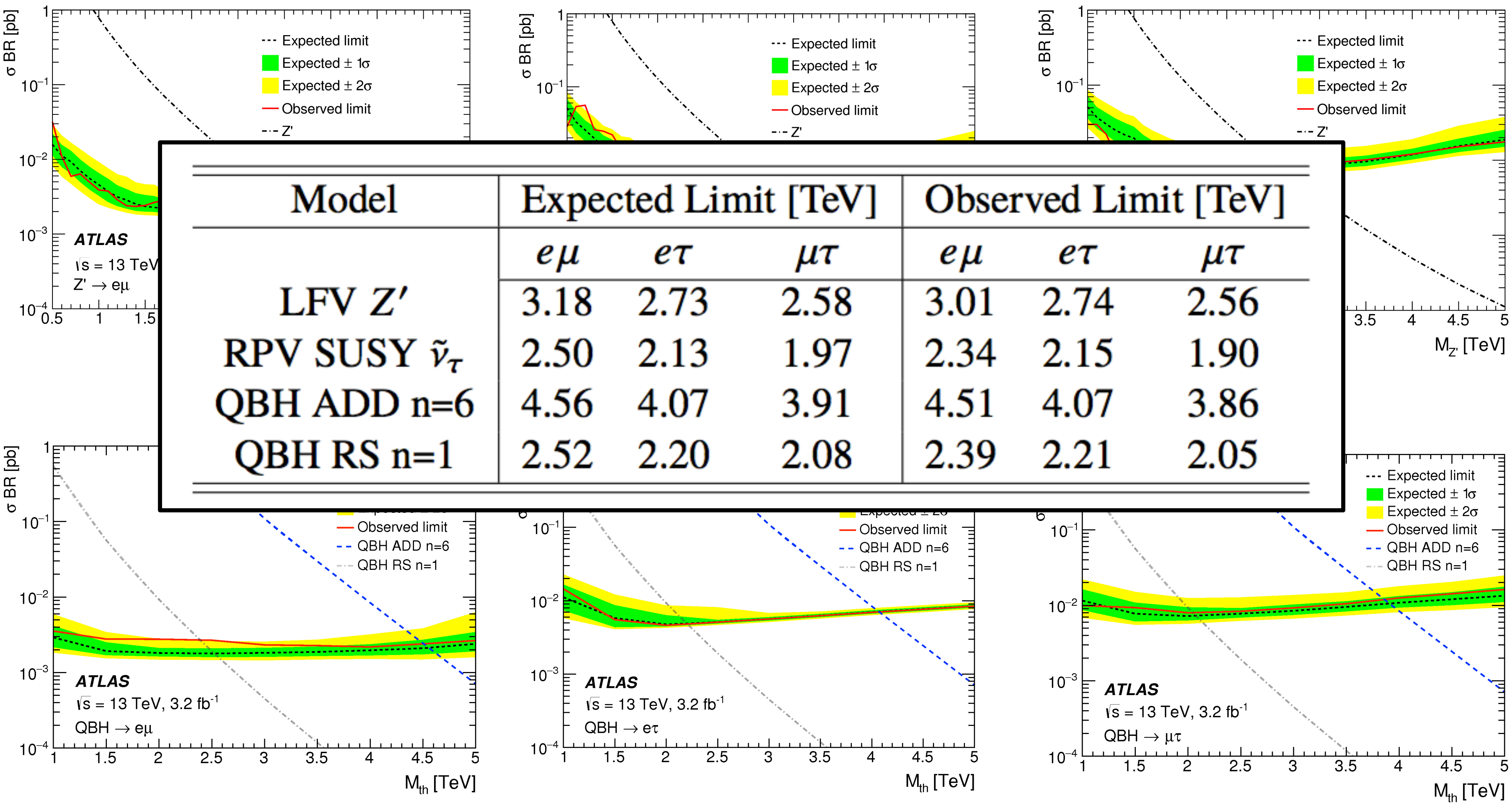
- Distinct signature and low (SM) background
- Backgrounds: $t\bar{t}$ and single-top, dibosons, DY→ $\tau^+\tau^-$; largest uncertainties: eμ and μτ: top background, eτ: multi-jet and W+jets
- 3% width for m(Z')=2 TeV; detector resolution: 8% (eμ), 12% (μτ), 4% (eτ)

Dilepton resonances in LFV searches (ATLAS)



3.2 fb^{-1} of $\sqrt{s}$=13 TeV collision data

Dilepton resonances in LFV searches (ATLAS)



Model	Expected Limit [TeV]			Observed Limit [TeV]		
	$e\mu$	$e\tau$	$\mu\tau$	$e\mu$	$e\tau$	$\mu\tau$
LFV Z'	3.18	2.73	2.58	3.01	2.74	2.56
RPV SUSY $\tilde{\nu}_\tau$	2.50	2.13	1.97	2.34	2.15	1.90
QBH ADD n=6	4.56	4.07	3.91	4.51	4.07	3.86
QBH RS n=1	2.52	2.20	2.08	2.39	2.21	2.05

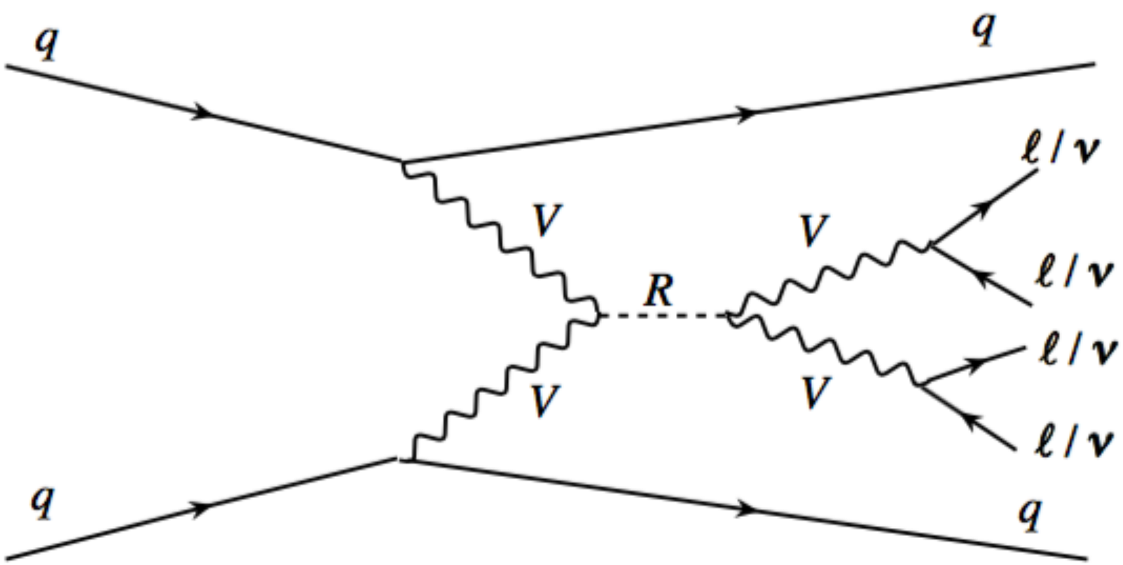
3.2 fb^{-1} of $\sqrt{s}$=13 TeV collision data

CERN-EP-2016-168, arXiv:1607.08079

Leptonic decays of resonances in VBF (ATLAS)

<u>Theoretical motivation:</u>

- Vector boson scattering: sensitive to BSM physics; New resonances may be needed to restore unitarity in V-V scattering amplitude
- Composite Higgs, triplet Higgs, extra dimensions models



Leptonic decays of resonances in VBF (ATLAS)

Theoretical motivation:

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Type	Spin J	Isospin I	Electric Charge	Γ/Γ_0
σ	0	0	0	6
ϕ	0	2	$--, -, 0, +, ++$	1
ρ	1	1	$-, 0, +$	$\frac{4}{3}(\frac{v^2}{m^2})$
f	2	0	0	$\frac{1}{5}$
t	2	2	$--, -, 0, +, ++$	$\frac{1}{30}$

Leptonic decays of resonances in VBF (ATLAS)

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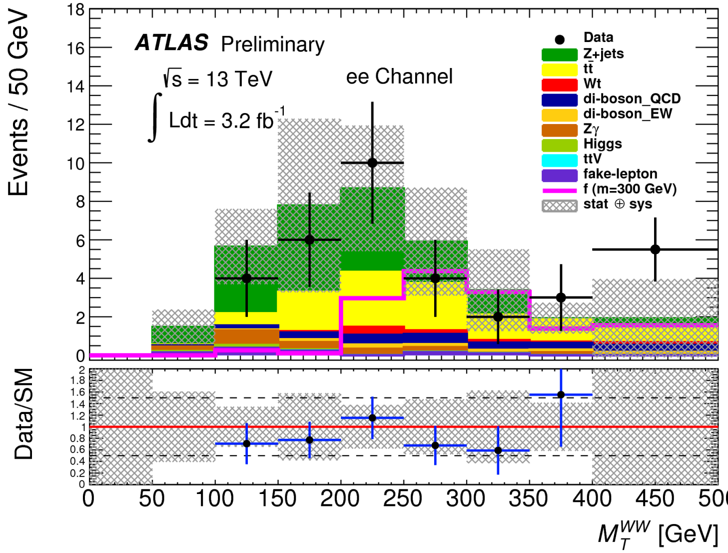
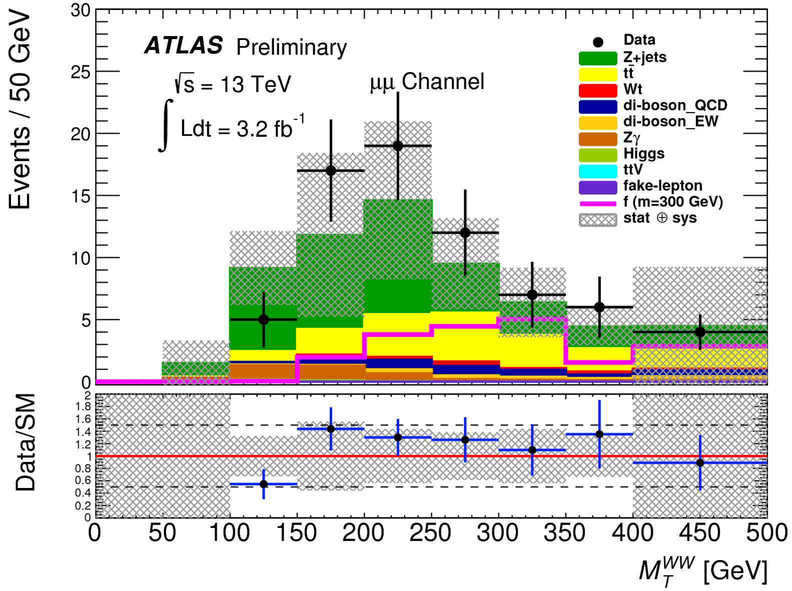
- Composite Higgs, triplet Higgs, extra dimensions models

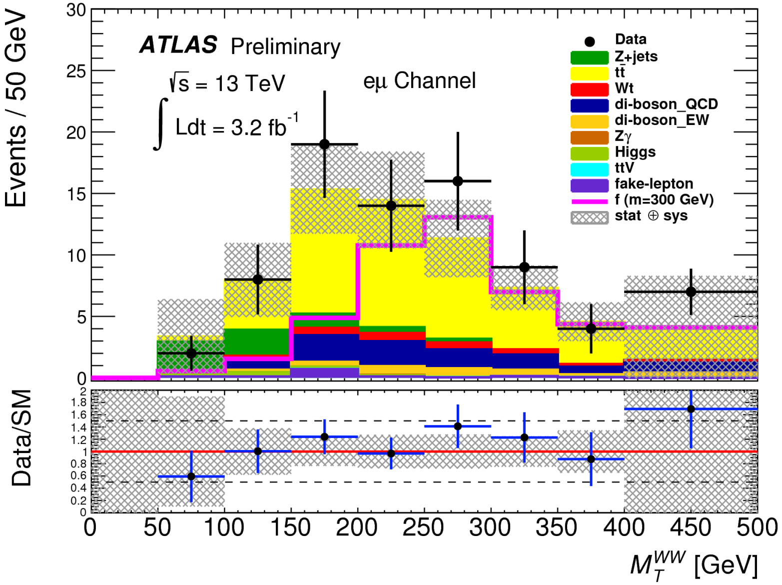
Experimental considerations:

- Signature: two charged leptons, ME_T, two forward jets
- Main backgrounds (and uncertainties): Z+jets for ee, μμ, $t\bar{t}$ for eμ channel

Leptonic decays of resonances in VBF (ATLAS)







Observed 95% CL exclusion limits in 200-500 GeV mass region:

380 – 220 fb for the σ particle

460 – 240 fb for the ϕ particle

330 – 270 fb for the ρ particle

340 – 260 fb for the f particle

310 – 260 fb for the t particle

3.2 fb^{-1} of $\sqrt{s}$=13 TeV collision data

ATLAS-CONF-2016-053

Summary

- ATLAS and CMS have published several new results on searches in "unconventional" final states with >1 charged leptons
- Results include 2015 and (part of) 2016 $\sqrt{s}$=13 TeV datasets
- No evidence for New Physics observed in several channels and model interpretations

Backup

Type-III seesaw heavy fermions (CMS)

Table 2: Systematic uncertainties. The channels listed here have three leptons and 550 GeV < $L_T + E_T^{miss}$ < 750 GeV.

Source of uncertainty	Magnitude	Impact on background/signal estimate in channel with: no OSSF pair	OSSF pair above-Z	OSSF pair on-Z
WZ normalization	50 %	13 %	2.8 %	41 %
ZZ normalization	16 %	0.1 %	0.5 %	0.4 %
Integrated luminosity	2.7 %	0.6 %	0.2 %	0.3 %
Lepton ID and isolation	3 %	3 %	3 %	3 %
E_T^{miss} resolution/smearing	50 %	4.1 %	6.3 %	0.6 %
Pile-up reweighting	5 %	1.5 %	0.3 %	1.3 %
$t\bar{t}$ misidentification rate	50 %	21 %	11 %	1.8 %
Z + jets background	14 %	9.2 %	1.1 %	1.0 %
Rare MC cross section	50 %	11 %	2.7 %	5.2 %
Signal cross section	10 %	10 %	10 %	10 %
Background (for comparison)		0.3 events	3.0 events	3.5 events
Signal ($m_\Sigma = 420$ GeV, for comparison)		0.8 events	1.8 events	0.8 events

Dilepton resonances in LFV searches (ATLAS)

Source	1 TeV			2 TeV			3 TeV		
	$e\mu$	$e\tau$	$\mu\tau$	$e\mu$	$e\tau$	$\mu\tau$	$e\mu$	$e\tau$	$\mu\tau$
PDF Uncertainty	17%	15%	15%	35%	38%	35%	70%	75%	70%
Luminosity	5%	5%	5%	5%	5%	5%	5%	5%	5%
Statistical	18%	11%	15%	80%	27%	27%	120%	28%	30%
Reducible background	5%	29%	40%	5%	35%	75%	5%	45%	85%
Top quark production Modelling	5%	3%	4%	12%	4%	5%	15%	10%	8%
Electron Trigger Efficiency	1%	1%	N/A	1%	1%	N/A	1%	1%	N/A
Electron Identification	2%	2%	N/A	2%	2%	N/A	2%	2%	N/A
Electron energy scale and resolution	3%	3%	N/A	3%	3%	N/A	3%	3%	N/A
Muon Reconstruction Efficiency	2%	N/A	2%	4%	N/A	4%	6%	N/A	6%
Muon scale and resolution	4%	N/A	4%	12%	N/A	12%	20%	N/A	20%
Muon Trigger Efficiency	2%	N/A	2%	2%	N/A	2%	2%	N/A	2%
Tau Identification	N/A	4%	4%	N/A	5%	5%	N/A	6%	6%
Tau Reconstruction	N/A	3%	3%	N/A	4%	4%	N/A	4%	4%
Tau Momentum resolution	N/A	2%	2%	N/A	3%	3%	N/A	4%	4%
Total	27%	35%	44%	90%	59%	90%	140%	90%	120%

Table 1: Quantative summary of the systematic uncertainties taken into account for background processes. Values are provided for $m_{\ell\ell'}$ values of 1, 2 and 3 TeV. The statistical error includes the extrapolation uncertainties of the top-quark background in the high $m_{\ell\ell'}$ region together with the uncertainty related to the MC statistics. Uncertainties are quoted with respect to the total background. N/A means the systematic uncertainty is not applicable.

Leptonic decays of resonances in VBF (ATLAS)

Source	ee	$\mu\mu$	$e\mu$
JES and JER	33%	29%	12%
b-tagging	8%	7%	16%
E_T^{miss} modelling	7%	6%	1%
Lepton	3.1%	2.2%	1.5%
Trigger	0.1%	0.5%	0.5%
Matrix method	0.2%	0.0%	0.1%
Z boson p_{T} reweighting	0.5%	0.4%	0.0%
MC statistics	4.1%	3.7%	2.6%
Luminosity	2.1%	2.1%	2.1%
Total experimental uncertainty	35%	31%	20%

Table 7: Summary of experimental systematic uncertainties on the number of predicted SM background events in the signal region.