Searches for new phenomena in leptonic final states using the ATLAS detector

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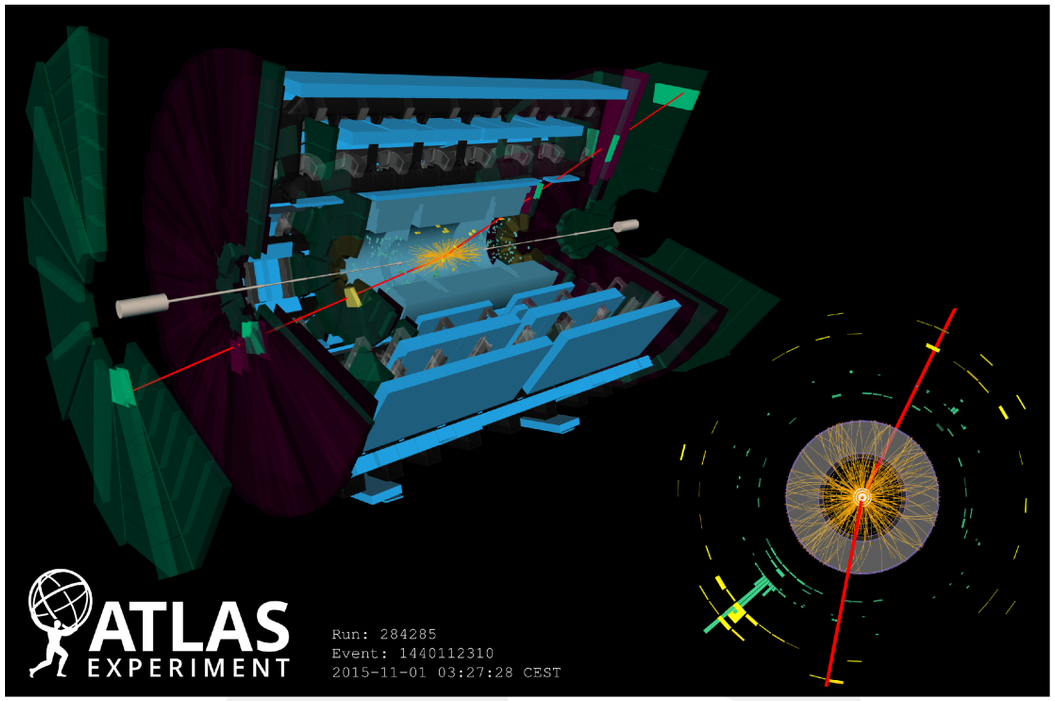
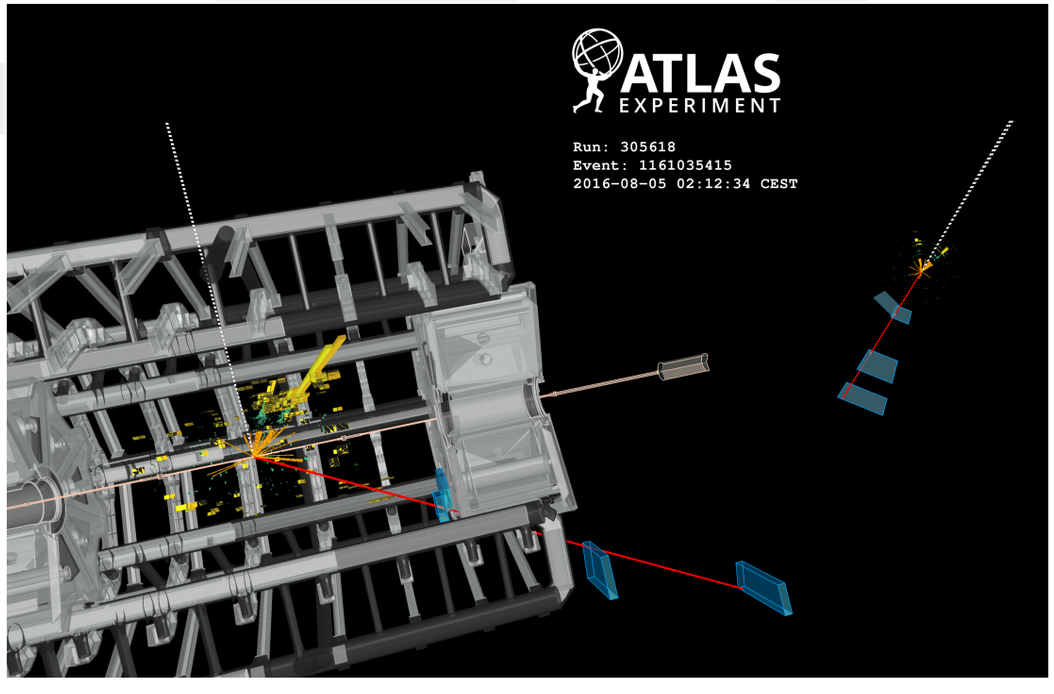
on behalf of the ATLAS Collaboration

Introduction and Motivation

- Isolated, high-p_T leptons: a powerful probe for new physics!
  - Electrons: exploit best resolution at high energies
  - Muons: ensure reliable sagitta measurement using three-station tracks in the muon spectrometer
- Many BSM models predicting heavy states, detectable at the LHC via their decays to electrons/muons/taus

  E_6-motivated theories, Sequential Standard Model, Randall-Sundrum model, quantum black hole model, minimal walking technicolour, *R*-parity-violating supersymmetry, left-right symmetric models, Higgs triplet models, only to name a few!





Introduction and Motivation

- Isolated, high-p_T leptons: a powerful probe for new ph
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      Randa
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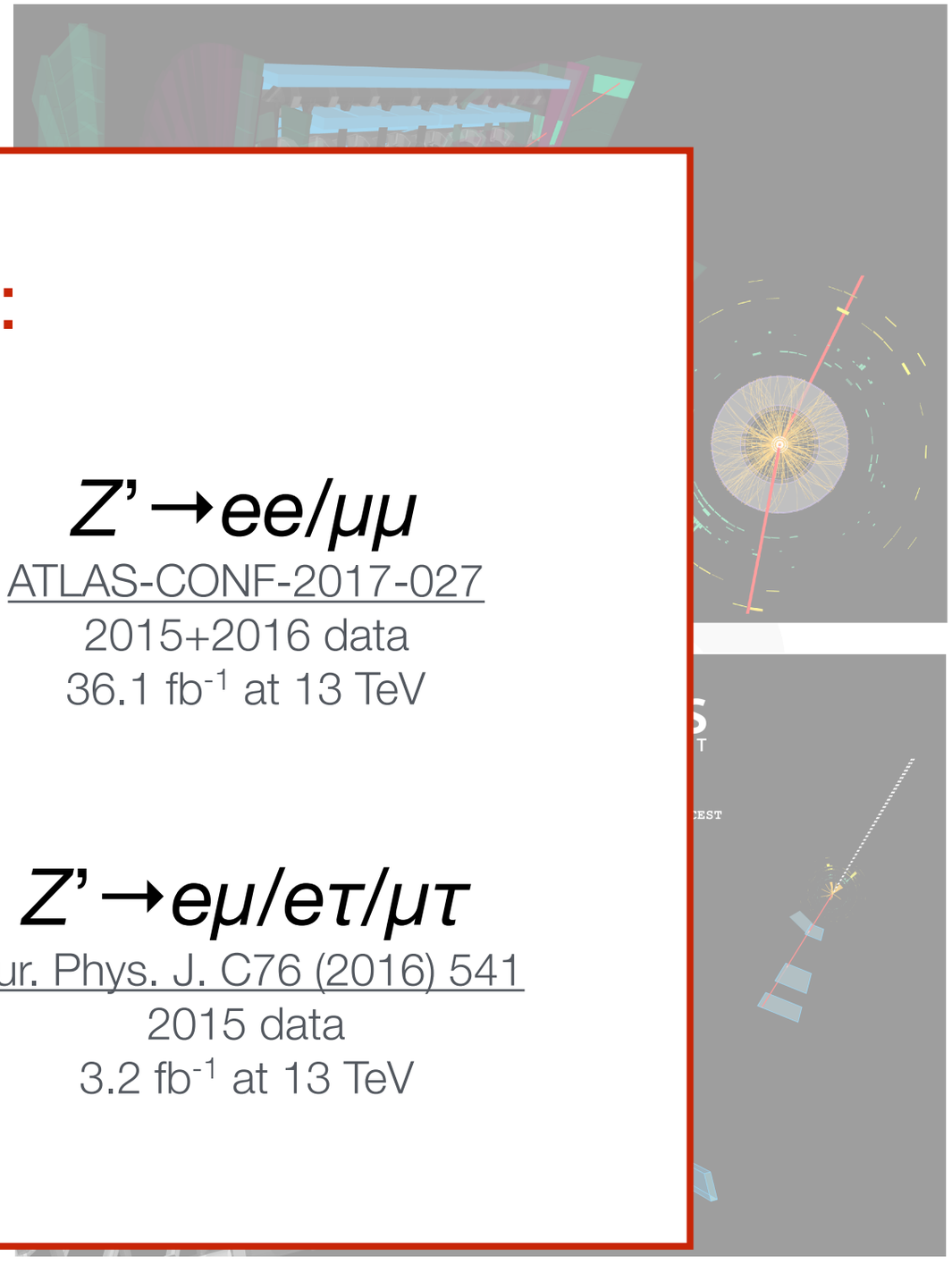


In this talk:

$W' \rightarrow e\nu/\mu\nu$
arXiv:1706.04786
2015+2016 data
36.1 fb^{-1} at 13 TeV

$Z' \rightarrow ee/\mu\mu$
ATLAS-CONF-2017-027
2015+2016 data
36.1 fb^{-1} at 13 TeV

$Z' \rightarrow \tau\tau$ NEW!
ATLAS-CONF-2017-050
2015+2016 data
36.1 fb^{-1} at 13 TeV

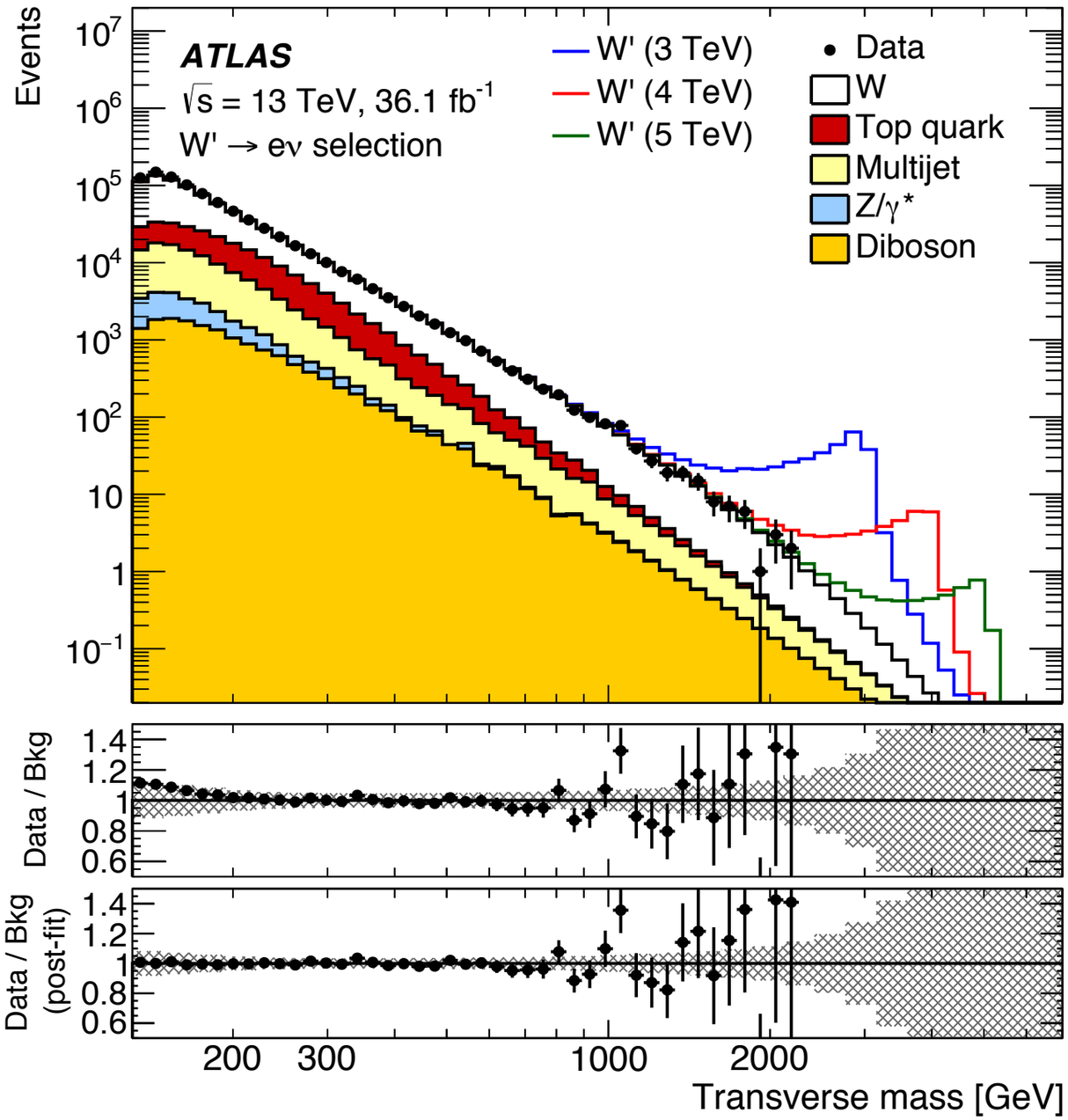
$Z' \rightarrow e\mu/e\tau/\mu\tau$
Eur. Phys. J. C76 (2016) 541
2015 data
3.2 fb^{-1} at 13 TeV

Looking for a *W*': e/μ + ME_T search

arXiv:1706.04786
2015+2016 data
36.1 fb^{-1} at 13 TeV

- Select exactly one isolated electron (muon) with p_T>65 (55) GeV and large missing transverse momentum
  - Transverse mass of the system (m_T) used as discriminant
  - Acceptance at 4 TeV: 47% for muons, 77% for electrons
- Minor backgrounds:
  - ttbar: POWHEG+PYTHIA, cross-section normalised to NNLO in pQCD
  - Multi-jet background: data-driven estimate with "matrix method"

    using loose→tight ID probability



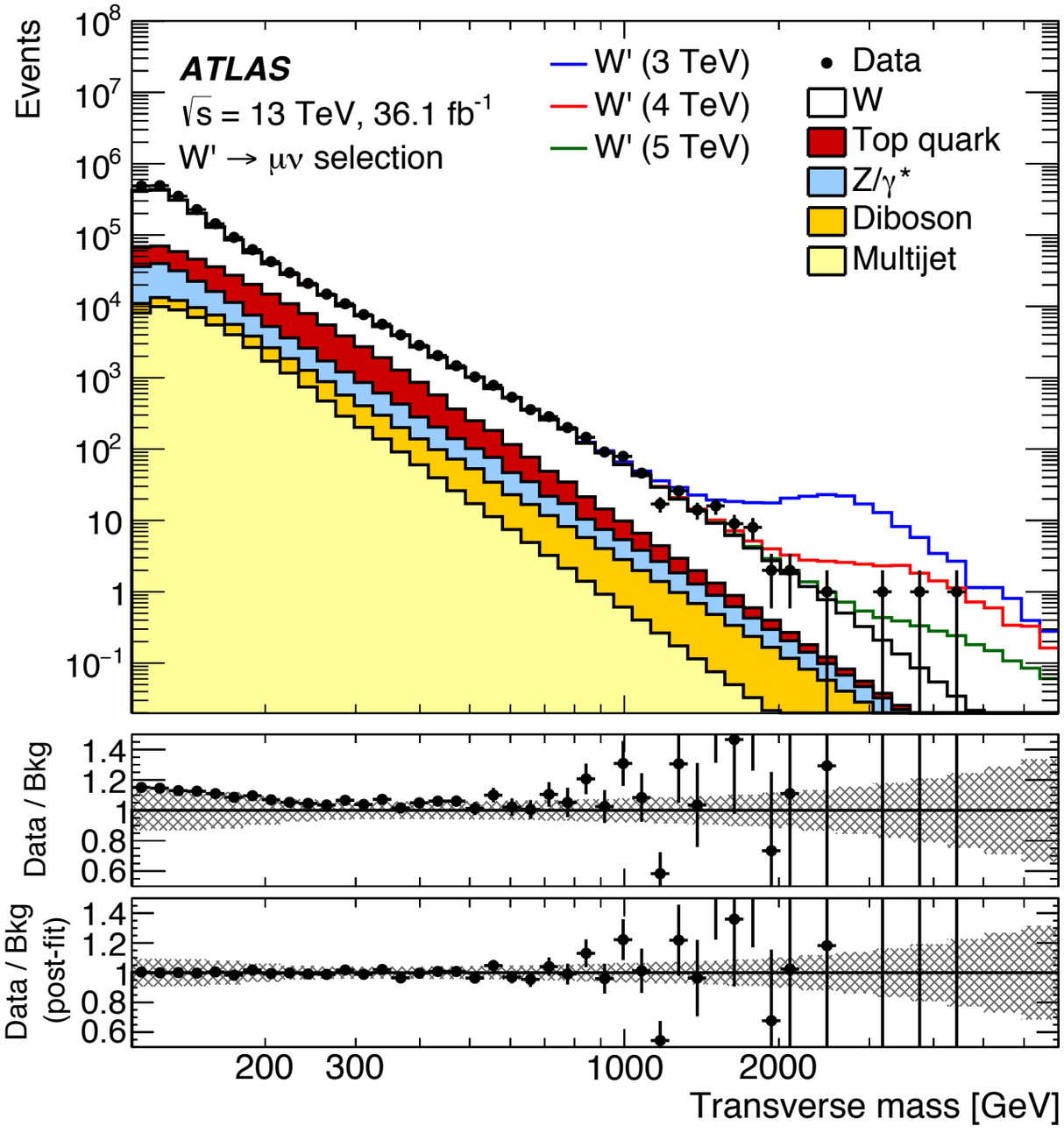
Looking for a *W*': *e*/*μ* + ME_T search

arXiv:1706.04786
2015+2016 data
36.1 fb^{-1} at 13 TeV

- Irreducible background: $W \rightarrow l\nu$
  - Generated using POWHEG (NLO in pQCD) with the CT10 PDF set (+Pythia8+Photos)
  - Normalised to NNLO in pQCD (+CT14NNLO PDF) with mass-dependent *k*-factor

    increasing cross-section by 5% (10%) for a 1 (5) TeV mass
  - Also applying NLO EW mass-dependent *k*-factor

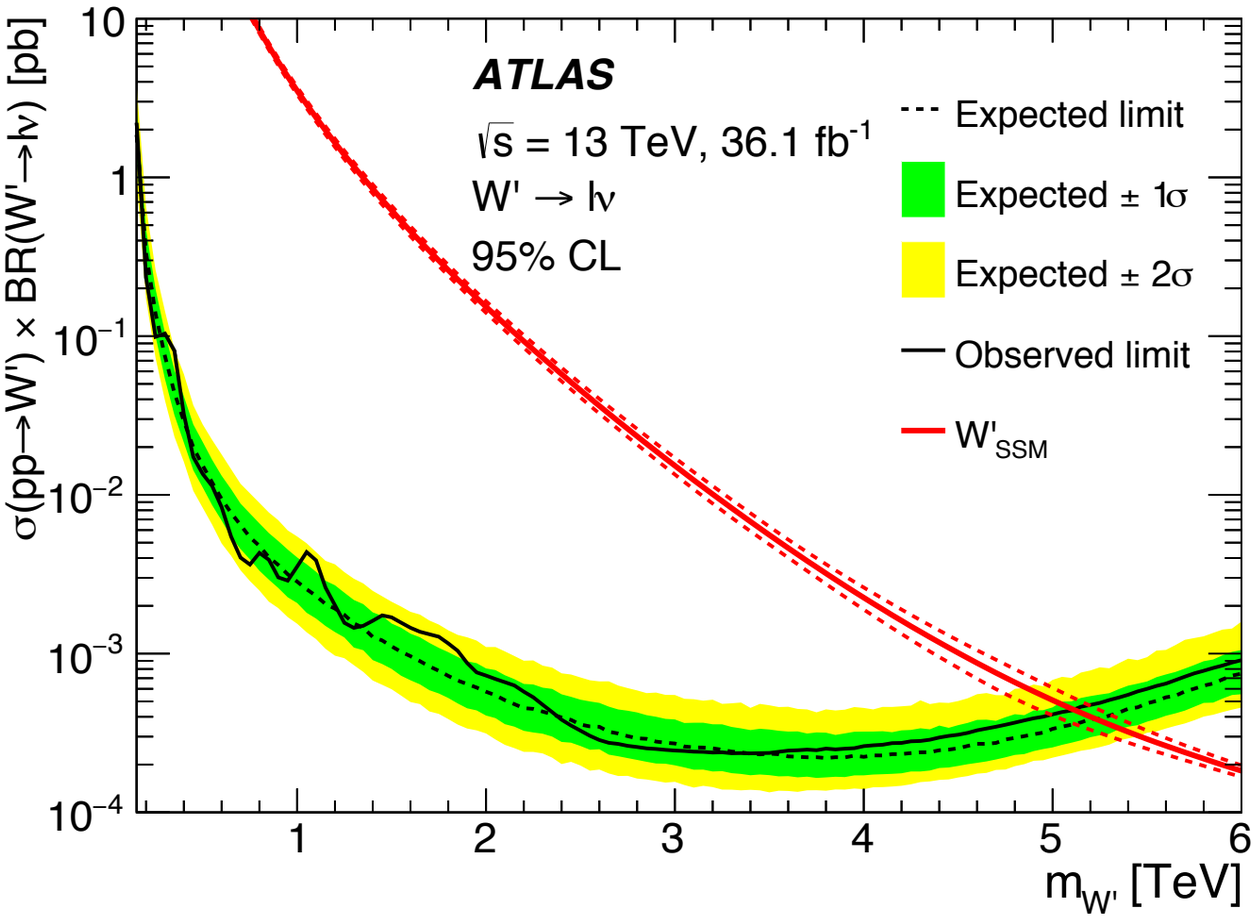
    lowering predicted cross-section by 10% (20%) at 1 (5) TeV



Looking for a *W*': *e*/*μ* + ME_T search

arXiv:1706.04786
2015+2016 data
36.1 fb^{-1} at 13 TeV

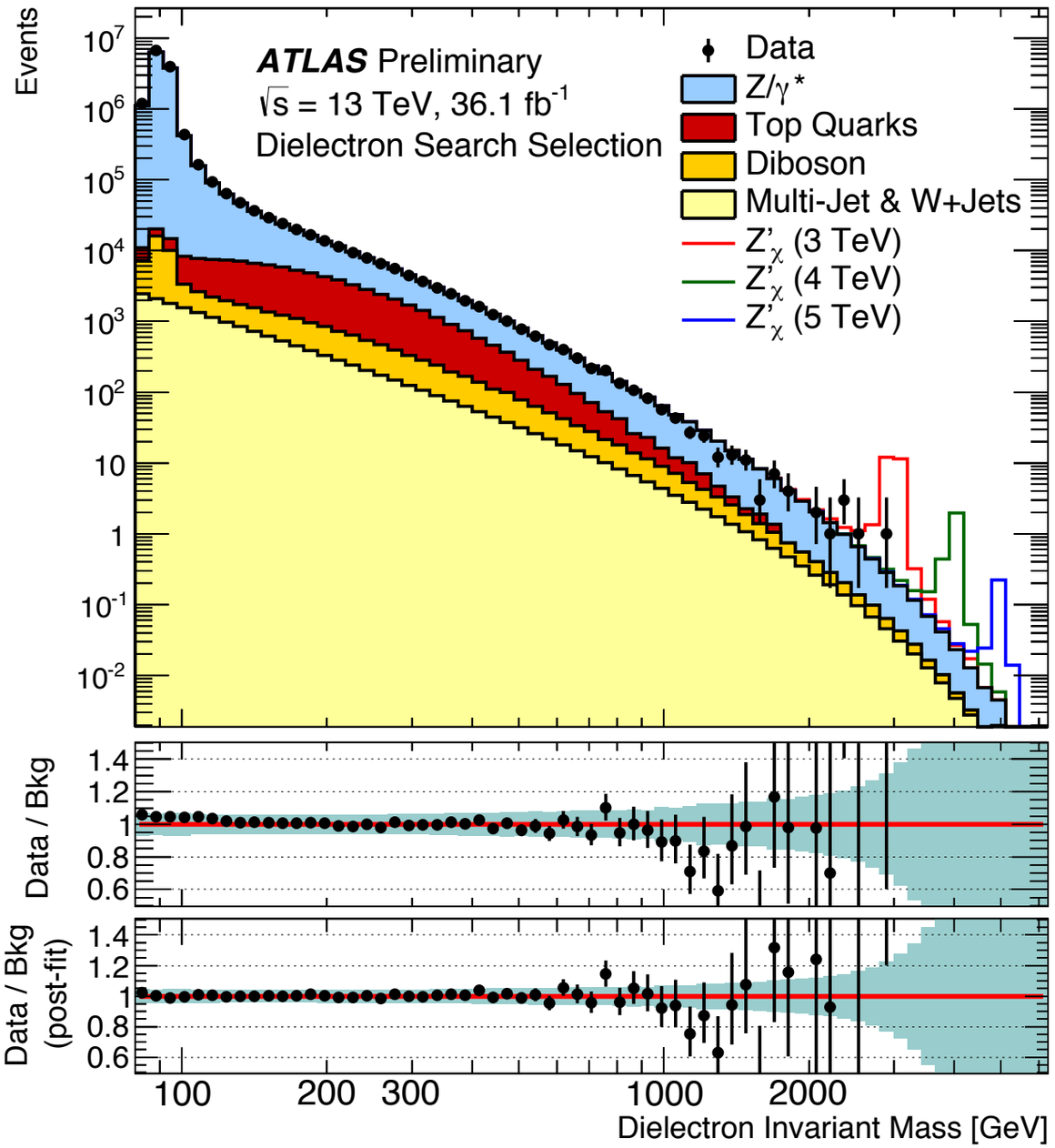
- No significant excesses, excluding masses below 5.1 TeV (SSM *W*')
- Main systematics (background):
  - PDF variation/choice: 90% CL CT14NNLO uncertainty set/difference with NNPDF3.0
  - EW corrections
- Main systematics (signal):
  - Electron energy scale and resolution
  - Muon identification and isolation efficiencies



Looking for a *Z*': *ee*/*μμ* search

ATLAS-CONF-2017-027
2015+2016 data
36.1 fb^{-1} at 13 TeV

- Select one pair of isolated electrons (muons) with p_T>30 GeV
  - Acceptance at 3 TeV:
    40% for muons, 71% for electrons
- Irreducible DY from simulation:
  - POWHEG at NLO in pQCD, with NNLO (QCD) and NLO (EW) corrections
- Other backgrounds with real leptons from simulation (diboson/ttbar)
- Background from fakes (*ee* only):
  - using again "matrix method" (extension to dilepton case)



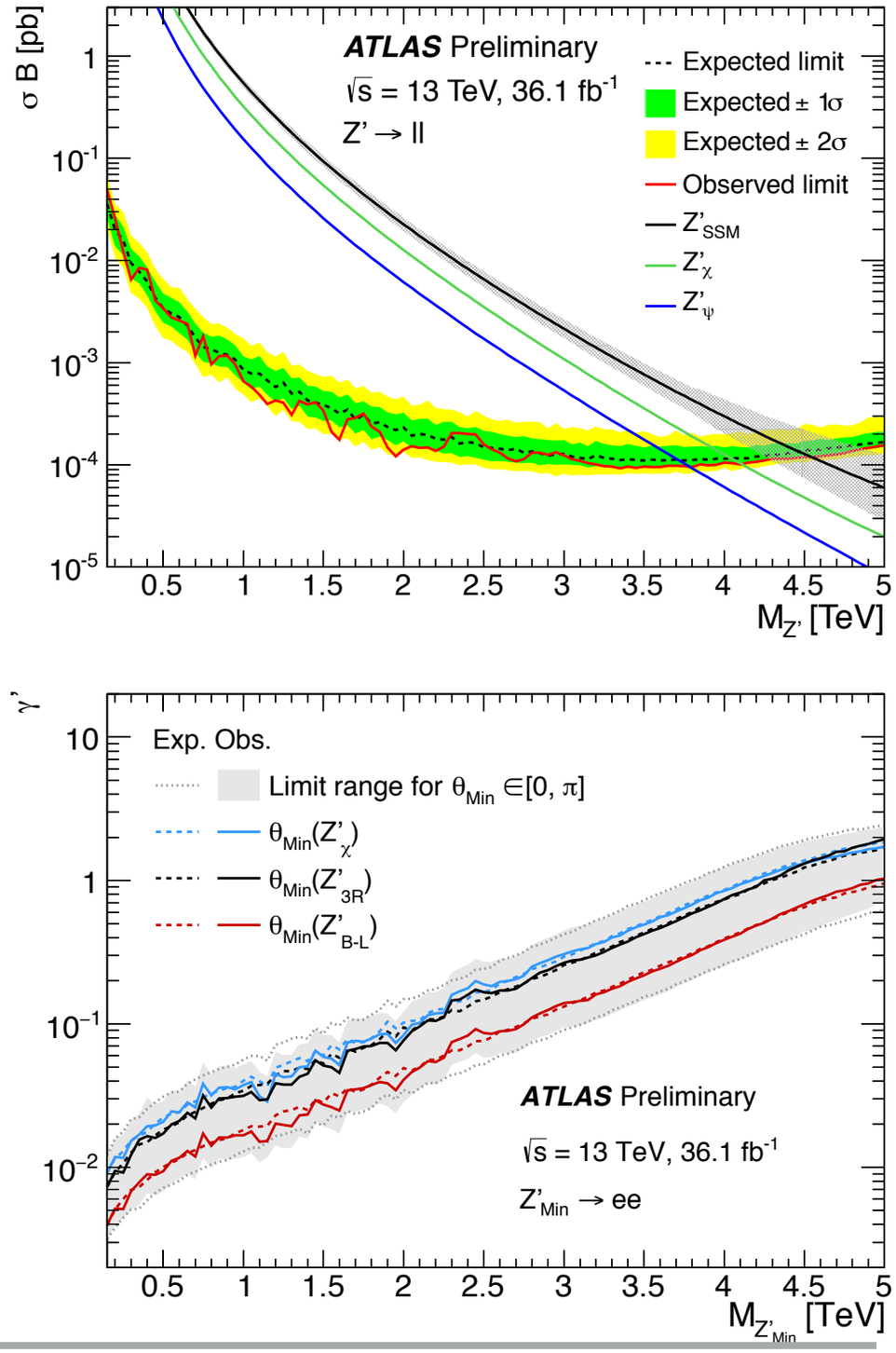
Looking for a *Z*': *ee*/*μμ* search

ATLAS-CONF-2017-027
2015+2016 data
36.1 fb^{-1} at 13 TeV

- No significant excesses, excluding masses below 4.5 TeV (SSM *Z*')
  - Comparable limits on E_6-motivated models!
- Also setting:
  - limits on the ratio of coupling strengths between the *Z*' boson and the *Z* boson, as a function of the *Z*' mass in the context of minimal *Z*' models
  - model-independent limits

    fiducial cuts p_T>30 GeV, $|\eta|$<2.5, mass window 2x true signal width

    anybody with a *Z*' model outside ATLAS can re-interpret our results!

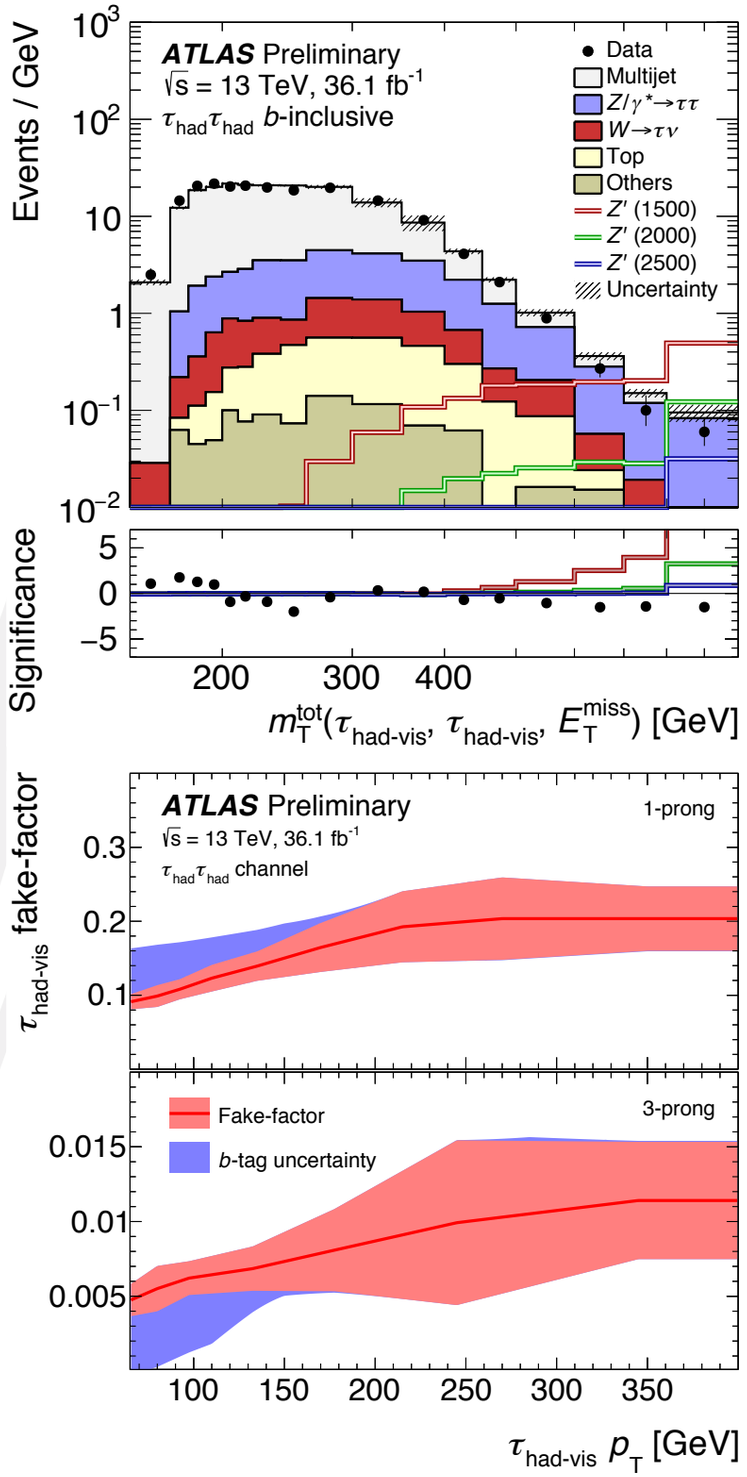


Looking for a Z': $\tau\tau$ search

NEW!

ATLAS-CONF-2017-050
2015+2016 data
36.1 fb^{-1} at 13 TeV

- Re-interpretation of the MSSM Higgs search (see talk by *G. Barone*)
- Analysis split into $\tau_{had}\tau_{had}$ and $\tau_{lep}\tau_{had}$ final states (but no b-jets splitting), using total transverse mass as final discriminant
- $\tau_{had}\tau_{had}$ selection: use single-τ triggers, require opposite-charge, back-to-back τ_{had} pairs
- multijet background: use dijet control region by inverting identification on the τ_{had}s and apply "fake-factor" parametrised as a function of p_T and track multiplicity of the τ
- non-multijet backgrounds: using simulation corrected with fake-rates extracted from W+jets and ttbar control regions

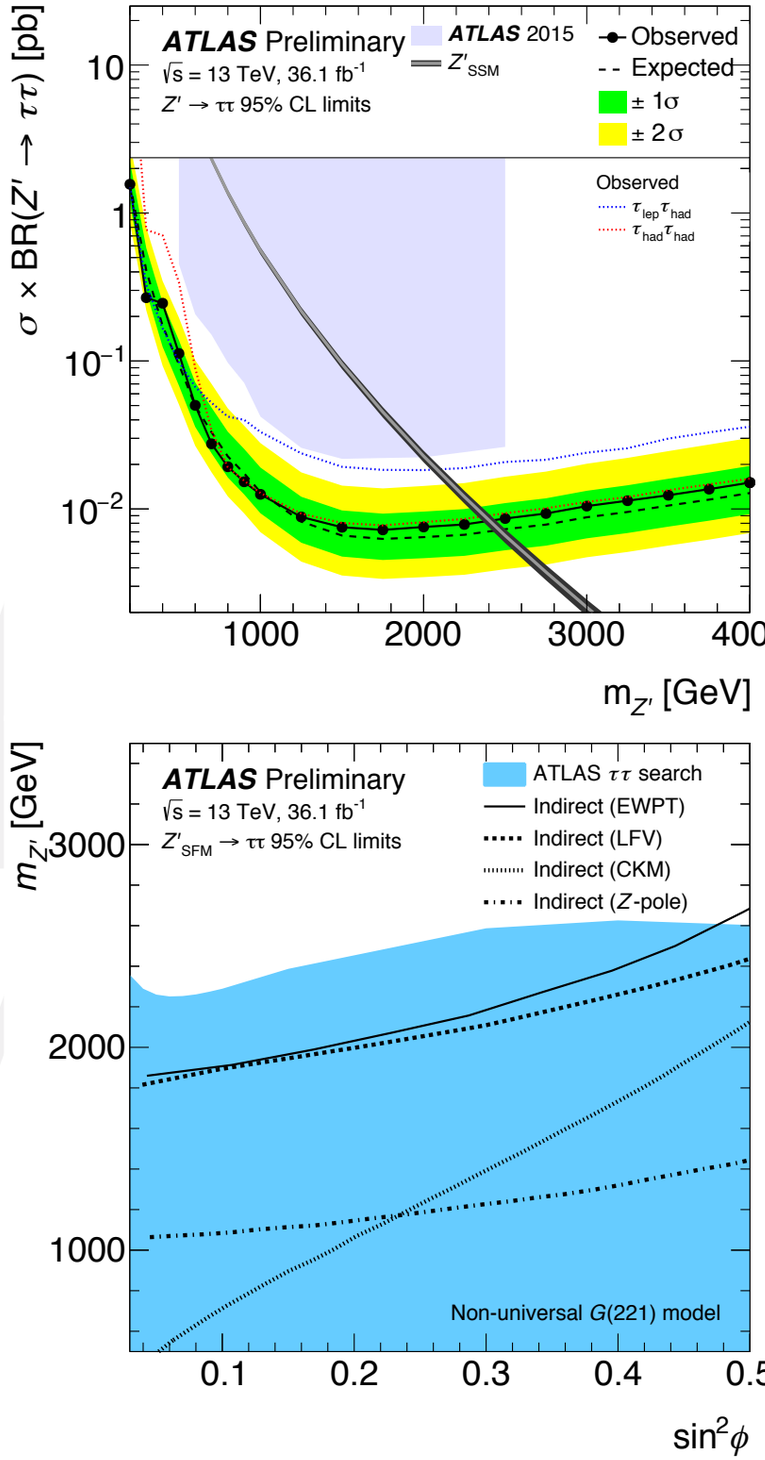


Looking for a Z': $\tau\tau$ search

NEW!

ATLAS-CONF-2017-050
2015+2016 data
36.1 fb^{-1} at 13 TeV

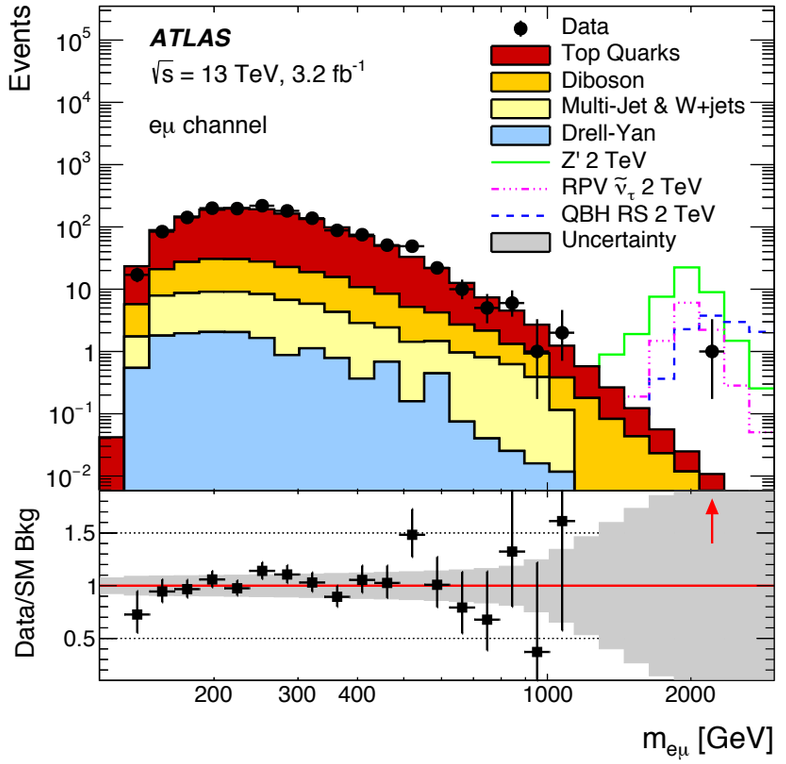
- $\tau_{lep}\tau_{had}$ selection: use single-lepton triggers, require lepton (ℓ) and τ_{had} to be back-to-back, veto W+jets events with $m_T(\ell, ME_T)$ cut and Z+jets events with $m(\ell, \tau_{had\text{-}vis})$ cut
- $\tau_{lep}\tau_{had}$ backgrounds: jets mis-identified as τ_{had}s using data-driven fake-factor technique, other contributions (real leptons) from simulation
- No excess found, limits set on a SSM Z' and SFM Z'
  - $\tau_{had}\tau_{had}$ dominating channel

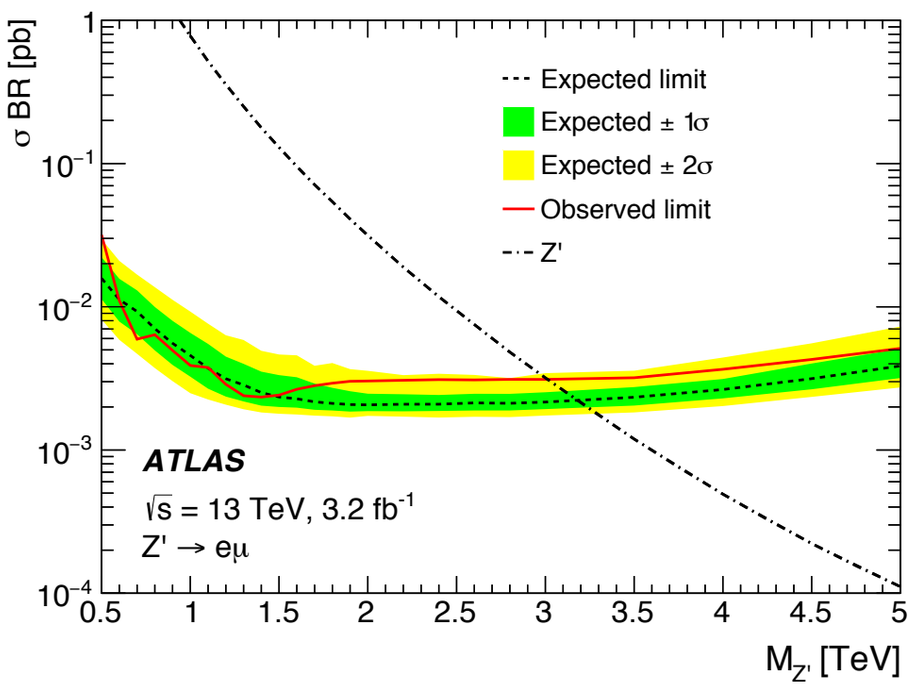


Looking for LFV: $e\mu$, $e\tau$, $\mu\tau$ search

Eur. Phys. J. C76 (2016) 541
2015 data
3.2 fb^{-1} at 13 TeV

- Requiring a pair of different-flavour leptons with p_T>65 GeV (40 GeV for τ), back-to-back in ϕ and no charge requirement
  - Acc. x eff.: 50%, 25% and 20% ($e\mu$, $e\tau$, $\mu\tau$)
- Irreducible backgrounds: DY→$\tau\tau$, ttbar, diboson
  - contribution estimated from simulation
- Reducible backgrounds: W+jets and multi-jet
  - matrix method for $e\mu$, MC corrected with measured τ fake-rate on data for $e\tau$/$\mu\tau$
- No significant excesses observed, limits extracted on the mass of a Z' boson (with lepton-flavour-violating couplings) or a supersymmetric τ sneutrino (with R-parity violating couplings)
  - results also interpreted as limits on the threshold mass for quantum black hole production





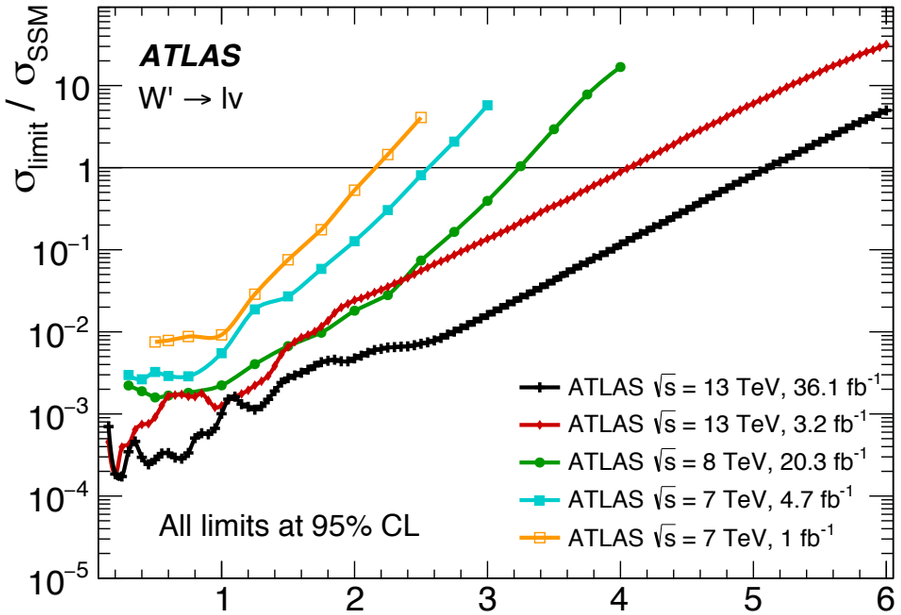
Conclusions

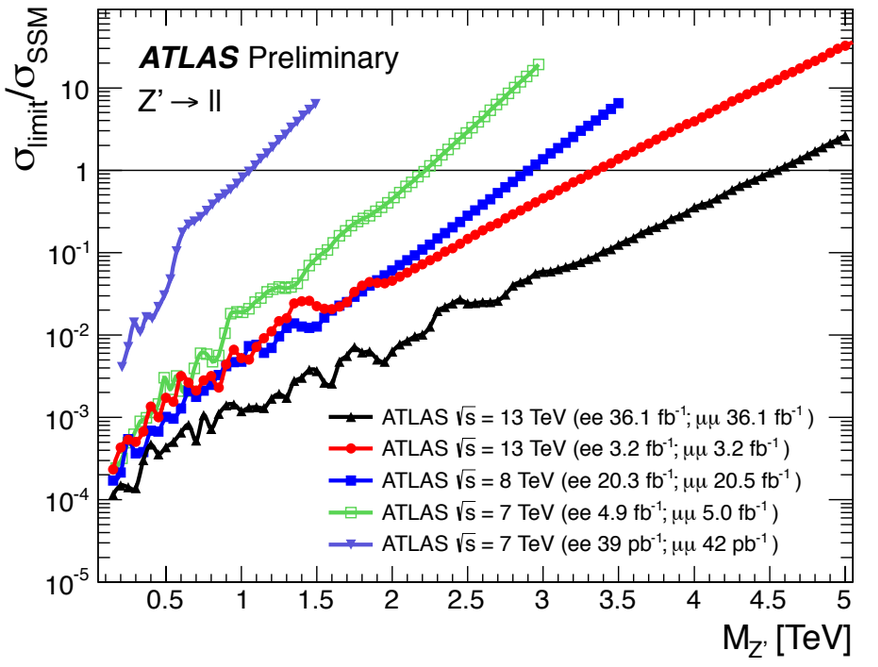
- Presented searches for new physics with leptonic final states
  - Small backgrounds/good resolution, ideal to look for new physics at the LHC!
- Most searches available with full 2015+2016 statistics

  No significant excess found…

  …setting more and more stringent limits
- Let's stay positive!

  A lot more data coming…





Conclusions

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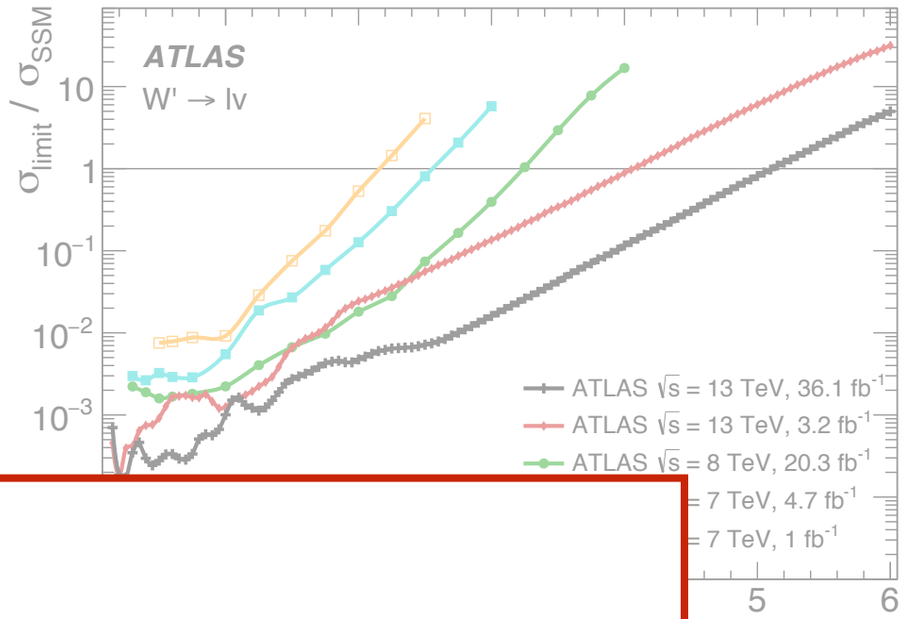
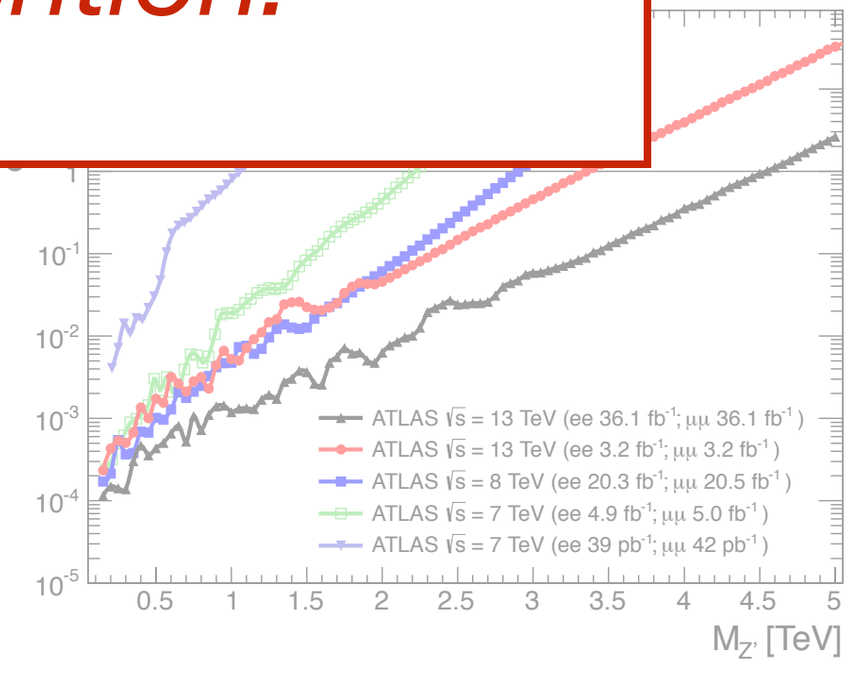
  - Small backgrounds/good resolution, ideal to look for new physics at the LHC!



- Most s
  statistic
  - No s
  - …setting more and more stringent limits

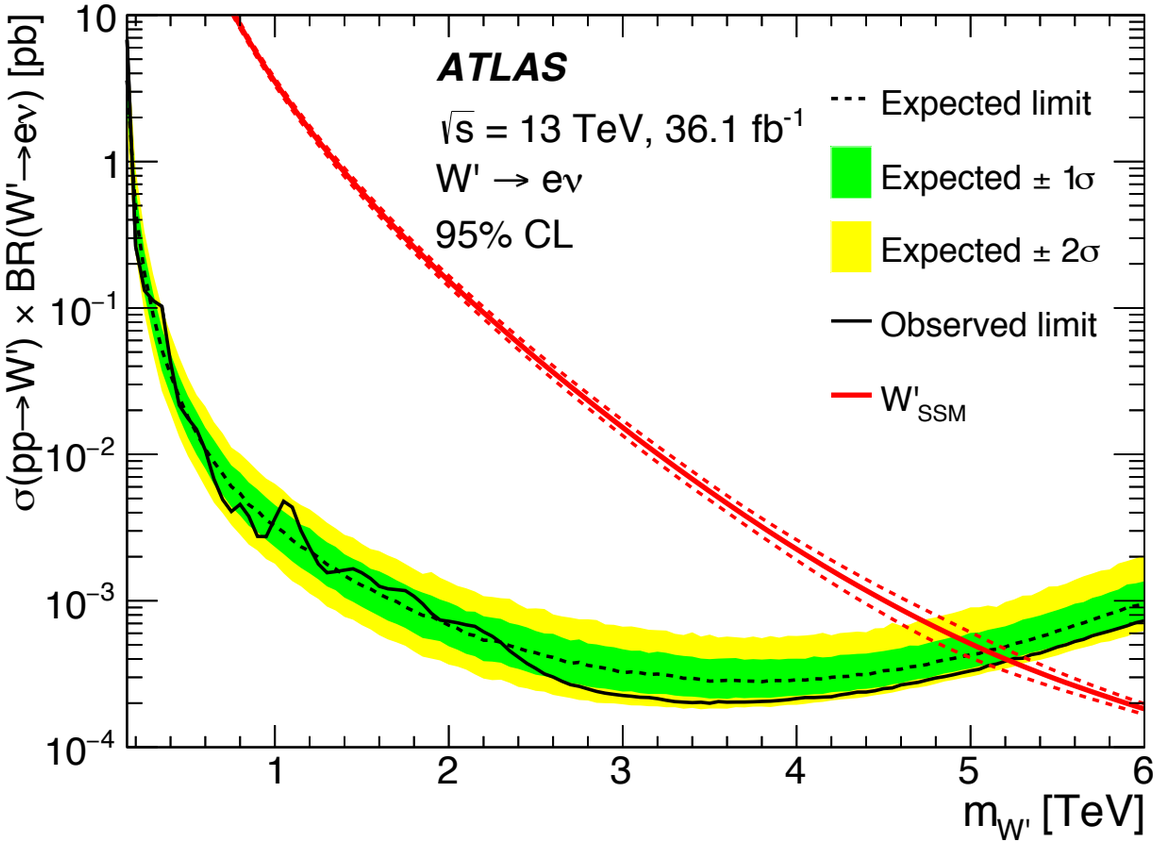
Thanks for the attention!

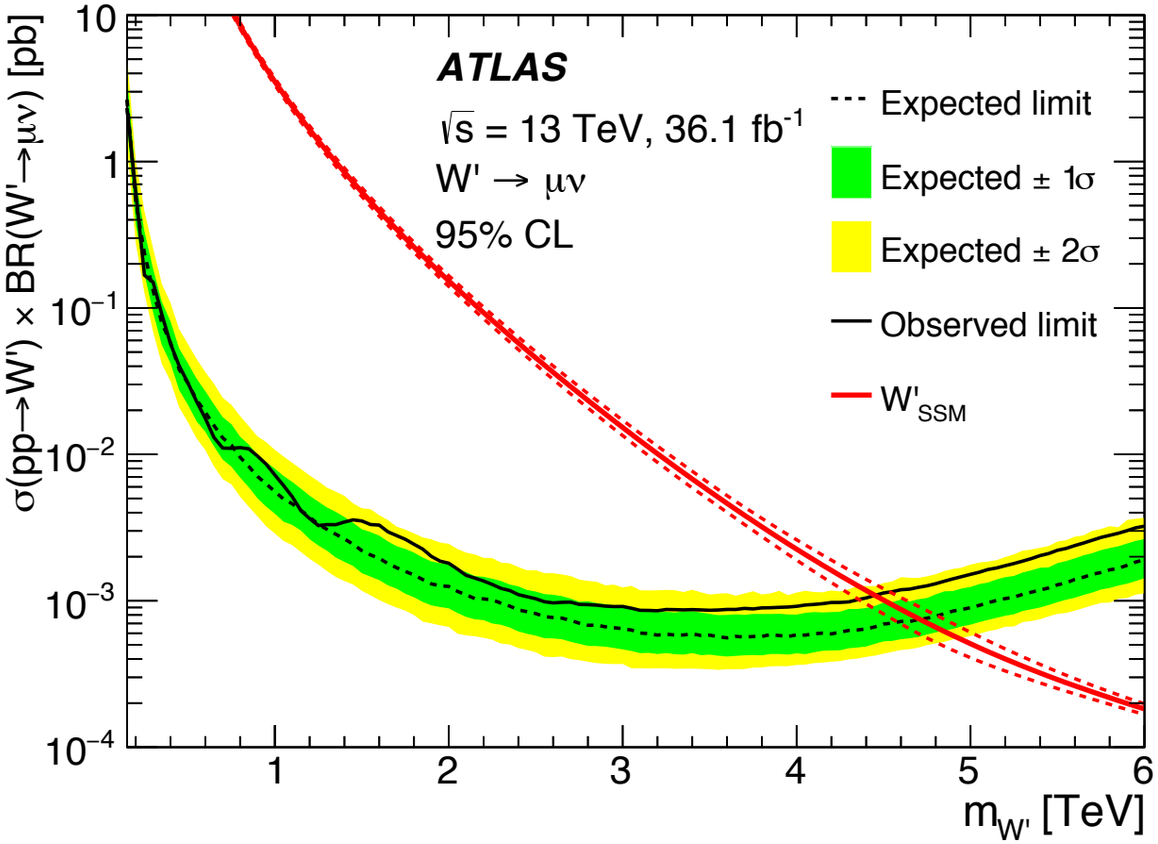
- Let's stay positive!
  - A lot more data coming…



Backup Slides

W': limits split per channel





W': observed yields

Electron channel

m_{T} [GeV]	130–200	200–400	400–600	600–1000	1000–2000	2000–3000	3000–7000
Total SM	620 000 ± 70 000	168 000 ± 10 000	9700 ± 500	2010 ± 140	232 ± 24	5.9 ± 1.4	0.4 ± 0.4
W' (2 TeV)	24.3 ± 0.9	126 ± 3	199 ± 5	614 ± 14	3280 ± 50	330 ± 70	0.85 ± 0.04
W' (3 TeV)	3.83 ± 0.08	14.2 ± 0.2	16.1 ± 0.4	35.7 ± 0.4	122 ± 2	229 ± 4	24 ± 5
W' (4 TeV)	1.18 ± 0.02	4.06 ± 0.03	3.58 ± 0.03	5.92 ± 0.03	12.1 ± 0.1	13.5 ± 0.2	23.3 ± 0.2
W' (5 TeV)	0.476 ± 0.008	1.62 ± 0.01	1.35 ± 0.01	1.95 ± 0.01	2.64 ± 0.01	1.56 ± 0.01	3.72 ± 0.02
Data	671 128	169 338	9551	1931	246	4	0

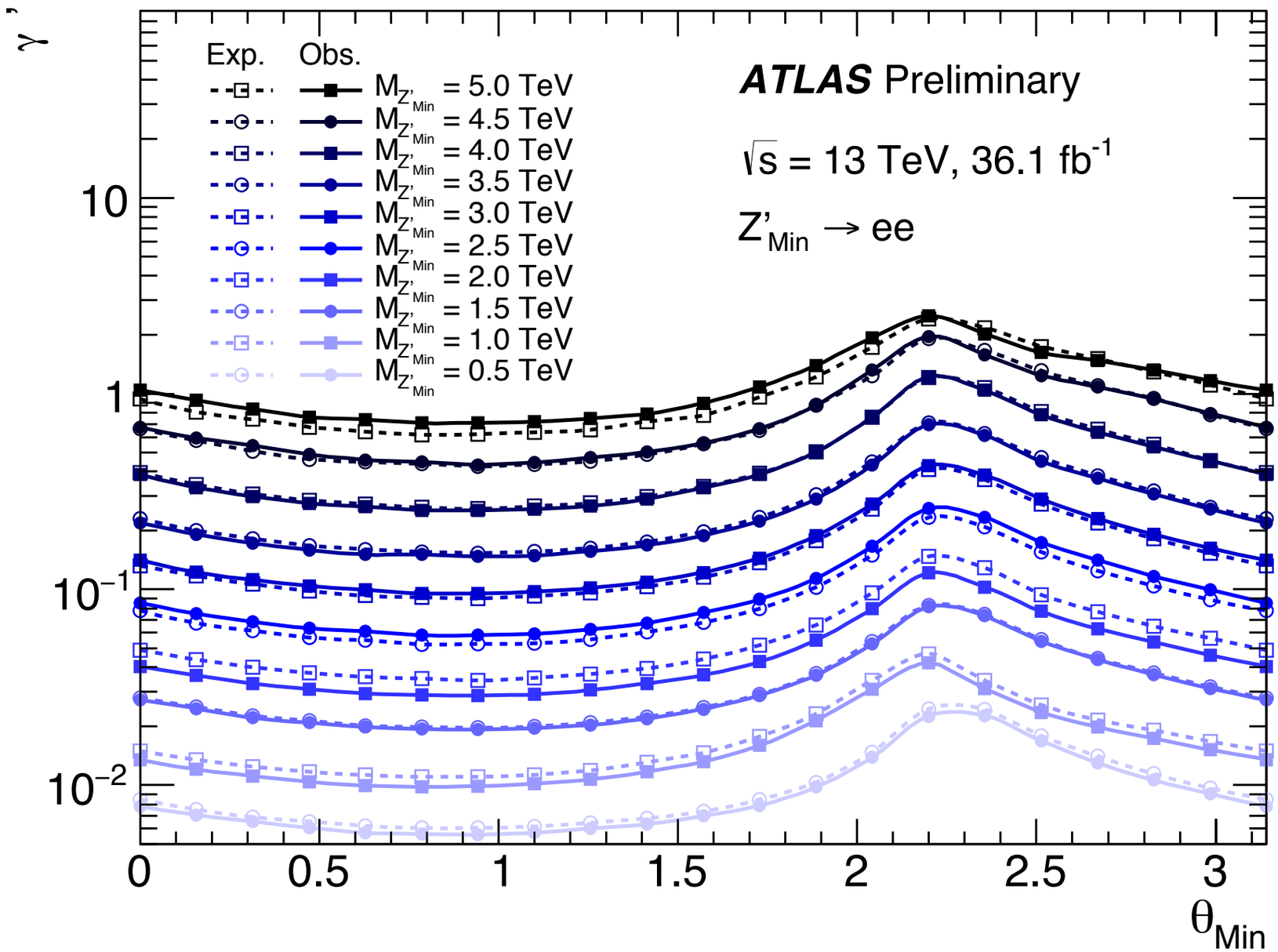
Muon channel

m_{T} [GeV]	110–200	200–400	400–600	600–1000	1000–2000	2000–3000	3000–7000
Total SM	1 640 000 ± 200 000	122 000 ± 8000	6460 ± 330	1320 ± 90	150 ± 13	4.7 ± 0.6	0.63 ± 0.13
W' (2 TeV)	25.0 ± 1.5	102 ± 6	143 ± 9	420 ± 22	1720 ± 90	369 ± 28	17 ± 4
W' (3 TeV)	3.98 ± 0.12	10.3 ± 0.3	10.7 ± 0.5	26.3 ± 1.5	84 ± 5	98 ± 6	39.3 ± 3.4
W' (4 TeV)	1.20 ± 0.03	2.80 ± 0.07	2.36 ± 0.09	4.07 ± 0.19	8.1 ± 0.5	8.8 ± 0.6	11.1 ± 0.9
W' (5 TeV)	0.485 ± 0.012	1.12 ± 0.03	0.88 ± 0.03	1.27 ± 0.05	1.7 ± 0.1	0.99 ± 0.07	1.7 ± 0.1
Data	1 862 326	128 155	6772	1392	177	3	3

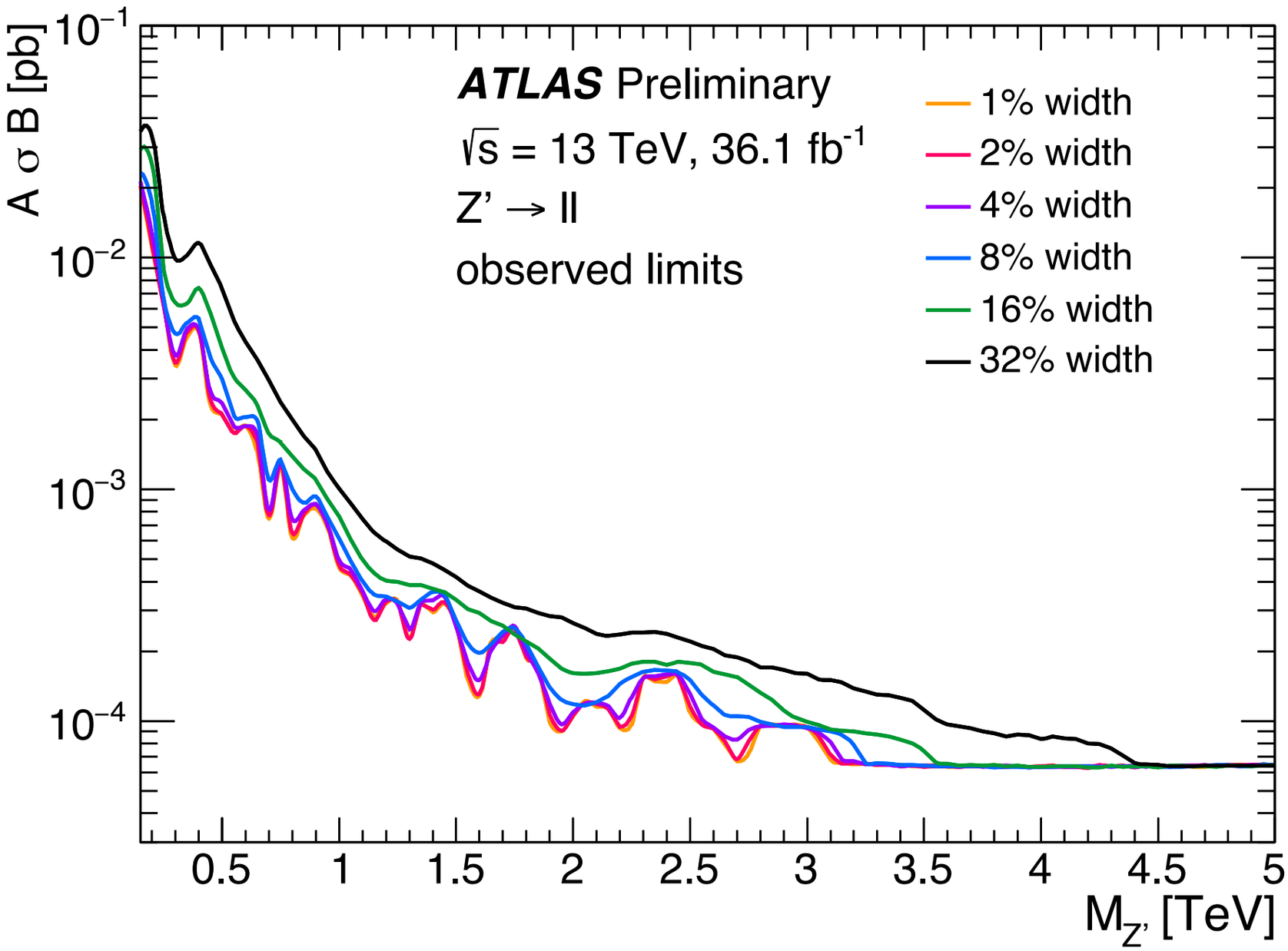
W': main systematic uncertainties

Source	Electron channel		Muon channel	
	Background	Signal	Background	Signal
Trigger	negl. (negl.)	negl. (negl.)	2% (2%)	2% (2%)
Lepton reconstruction and identification	negl. (negl.)	negl. (negl.)	5% (6%)	5% (7%)
Lepton momentum scale and resolution	3% (3%)	4% (3%)	3% (9%)	1% (1%)
$E_{\mathrm{T}}^{\mathrm{miss}}$ resolution and scale	$< 0.5\%$ ($< 0.5\%$)	$< 0.5\%$ ($< 0.5\%$)	$< 0.5\%$ (1%)	1% (1%)
Jet energy resolution	$< 0.5\%$ ($< 0.5\%$)	$< 0.5\%$ ($< 0.5\%$)	$< 0.5\%$ ($< 0.5\%$)	$< 0.5\%$ ($< 0.5\%$)
Pile-up	1% ($< 0.5\%$)	1% ($< 0.5\%$)	$< 0.5\%$ (1%)	1% ($< 0.5\%$)
Multijet background	7% (70%)	N/A (N/A)	1% (1%)	N/A (N/A)
Top extrapolation	1% (1%)	N/A (N/A)	4% (8%)	N/A (N/A)
Diboson extrapolation	4% (20%)	N/A (N/A)	4% (10%)	N/A (N/A)
PDF choice for DY	1% (13%)	N/A (N/A)	$< 0.5\%$ (1%)	N/A (N/A)
PDF variation for DY	8% (15%)	N/A (N/A)	7% (11%)	N/A (N/A)
EW corrections for DY	4% (7%)	N/A (N/A)	4% (5%)	N/A (N/A)
Luminosity	3% (3%)	3% (3%)	3% (3%)	3% (3%)
Total	13% (76%)	5% (5%)	12% (21%)	6% (8%)

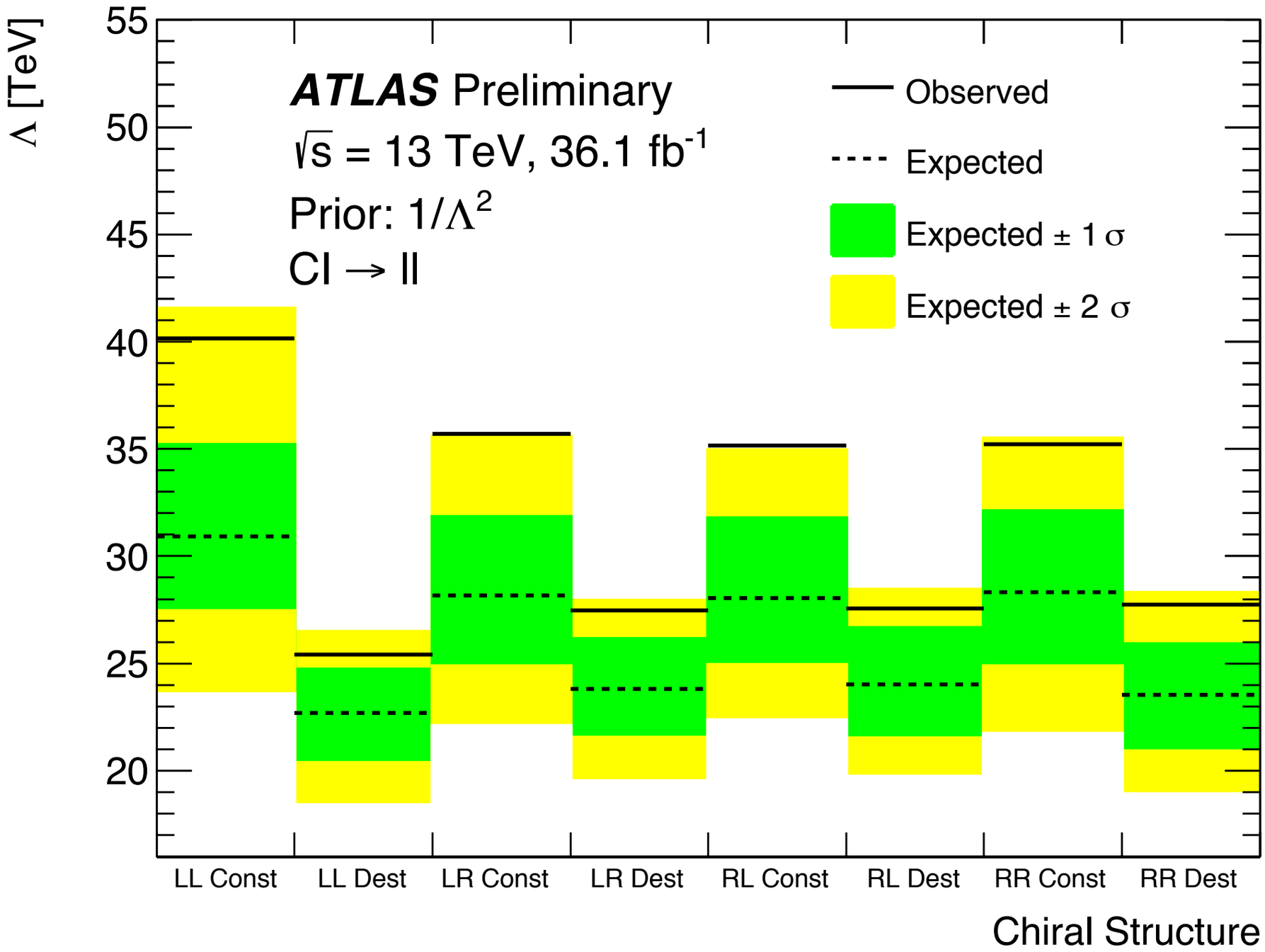
Z': more limits



Z': model independent limits



Z': CI limits


ATLAS Preliminary
√s = 13 TeV, 36.1 fb-1
Prior: 1/Λ2
CI → ll
Observed
Expected
Expected ± 1 σ
Expected ± 2 σ
Λ [TeV]
55
50
45
40
35
30
25
20
LL Const
LL Dest
LR Const
LR Dest
RL Const
RL Dest
RR Const
RR Dest
Chiral Structure