# ATLAS Searches for new phenomena in leptonic final states

SUSY 2017

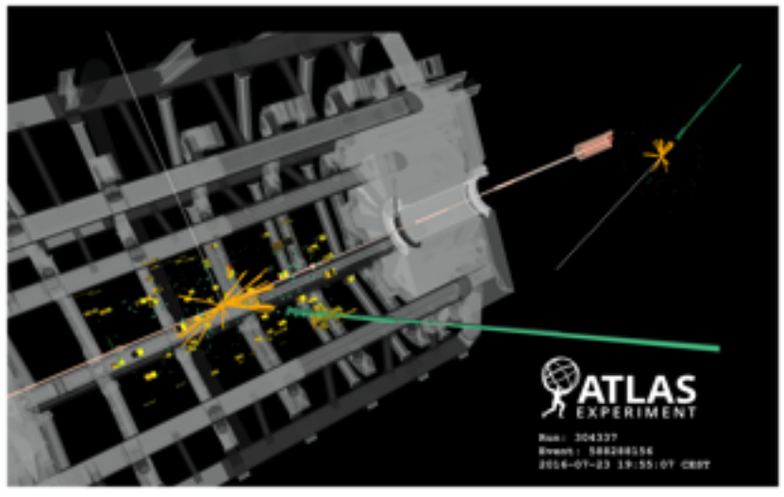
Oct. 24th, 2017

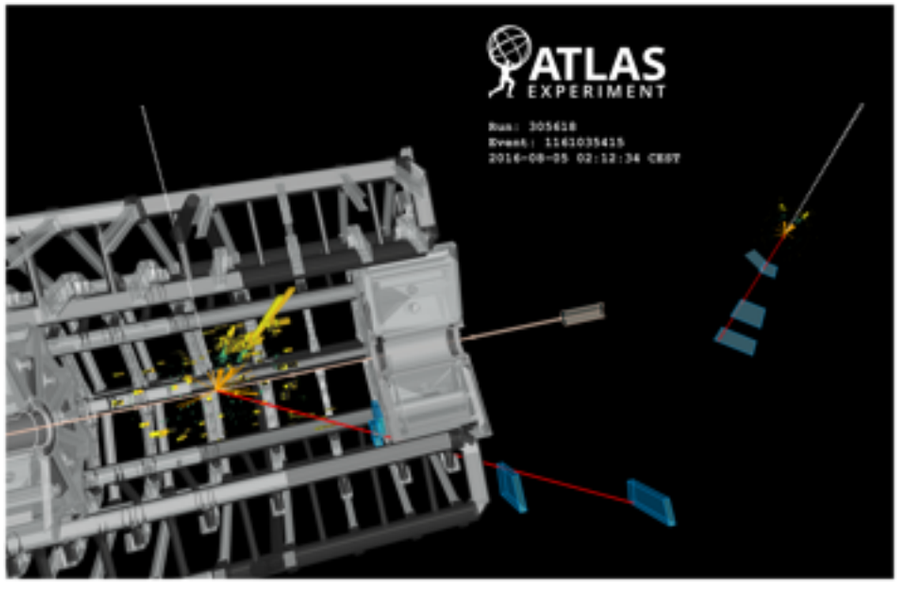

**Simone Amoroso**

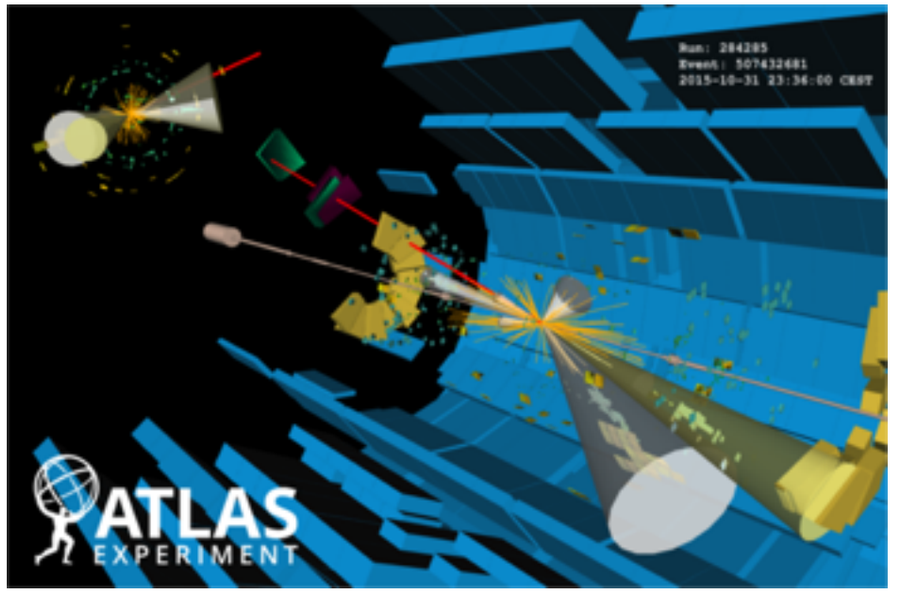
on behalf of
the ATLAS Collaboration


# Introduction

- New resonances decaying into leptons are ubiquitous in BSM theories
  - Almost any GUT predicts an additional Z prime (Z')
  - Or in Randall-Sundrum, technicolour, Higgs triplet models
  - Can also appear in SUSY scenarios as in U(1)MSSM, RPV SUSY, LR symmetric models, …
- Isolated high-$p_T$ leptons are a powerful tool to find them
  - **Electrons**: exploit best resolution at high energy
  - **Muons:** ensure a reliable sagitta measurement by requiring three hits in the muon system
  - **Taus**: Hard to reconstruct, but best sensitivity if couplings to 3rd generation enhanced



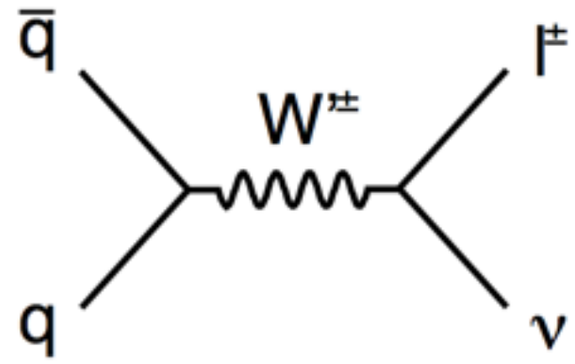



# Introduction

- Will present results of five ATLAS searches for new physics in leptonic final states using 13 TeV data:
  - Search for a new heavy gauge-boson resonance decaying into a lepton and missing transverse momentum in 36 fb-1 of pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS experiment
  - Search for new high-mass phenomena in the dilepton final state using 36 fb-1 of proton-proton collision data at $\sqrt{s}$ = 13 TeV with the ATLAS detector
  - Search for new phenomena in different-flavour high mass dilepton final states in pp collisions at a centre-of-mass energy of 13 TeV with the ATLAS detector
  - Search for doubly charged Higgs boson production in multi-lepton final states with the ATLAS detector using proton-proton collisions at $\sqrt{s}$ = 13 TeV
  - Search for additional heavy neutral Higgs and gauge bosons in the ditau final state produced in 36 fb-1 of pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

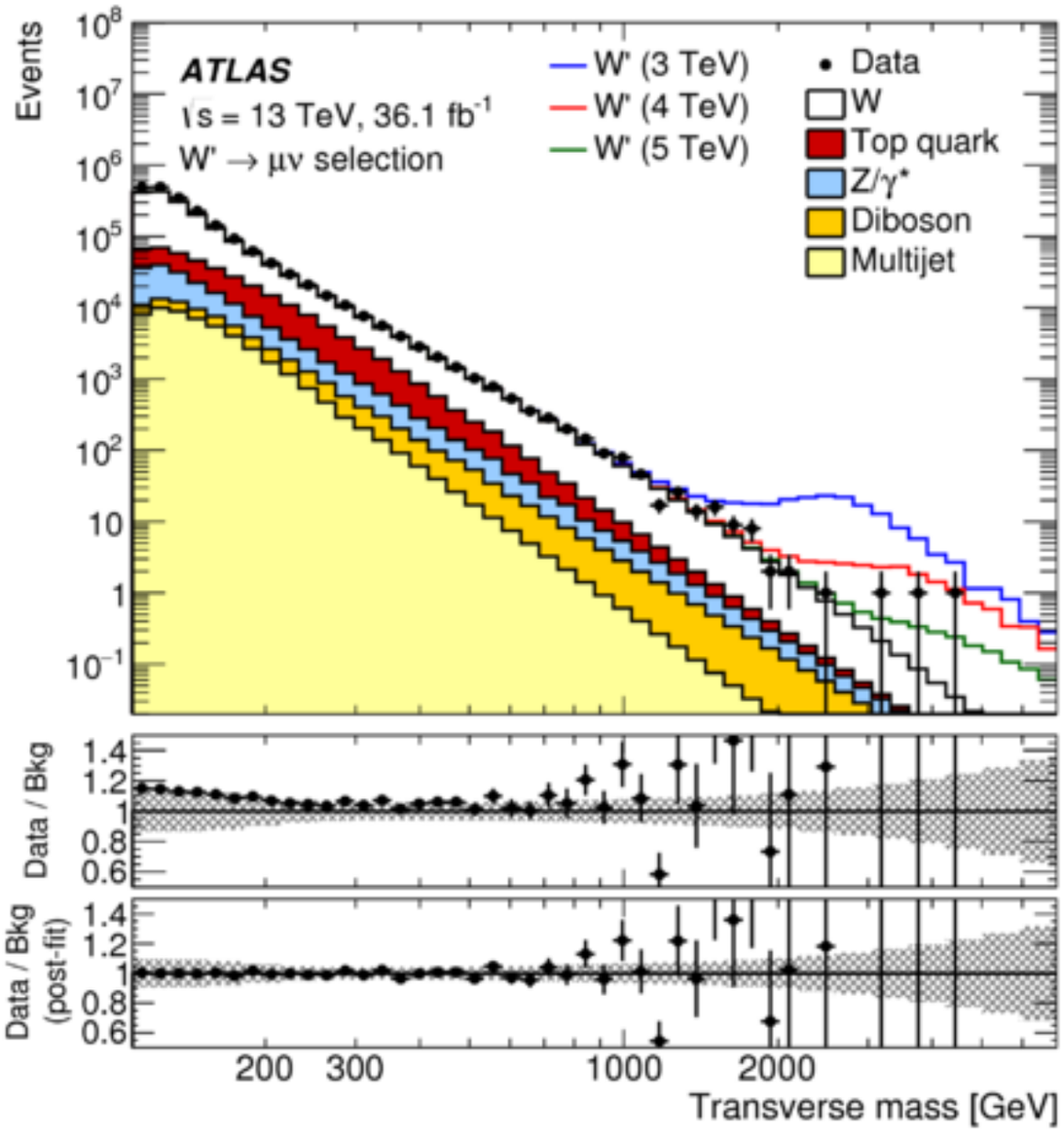
# W'→LNU (E/MU)

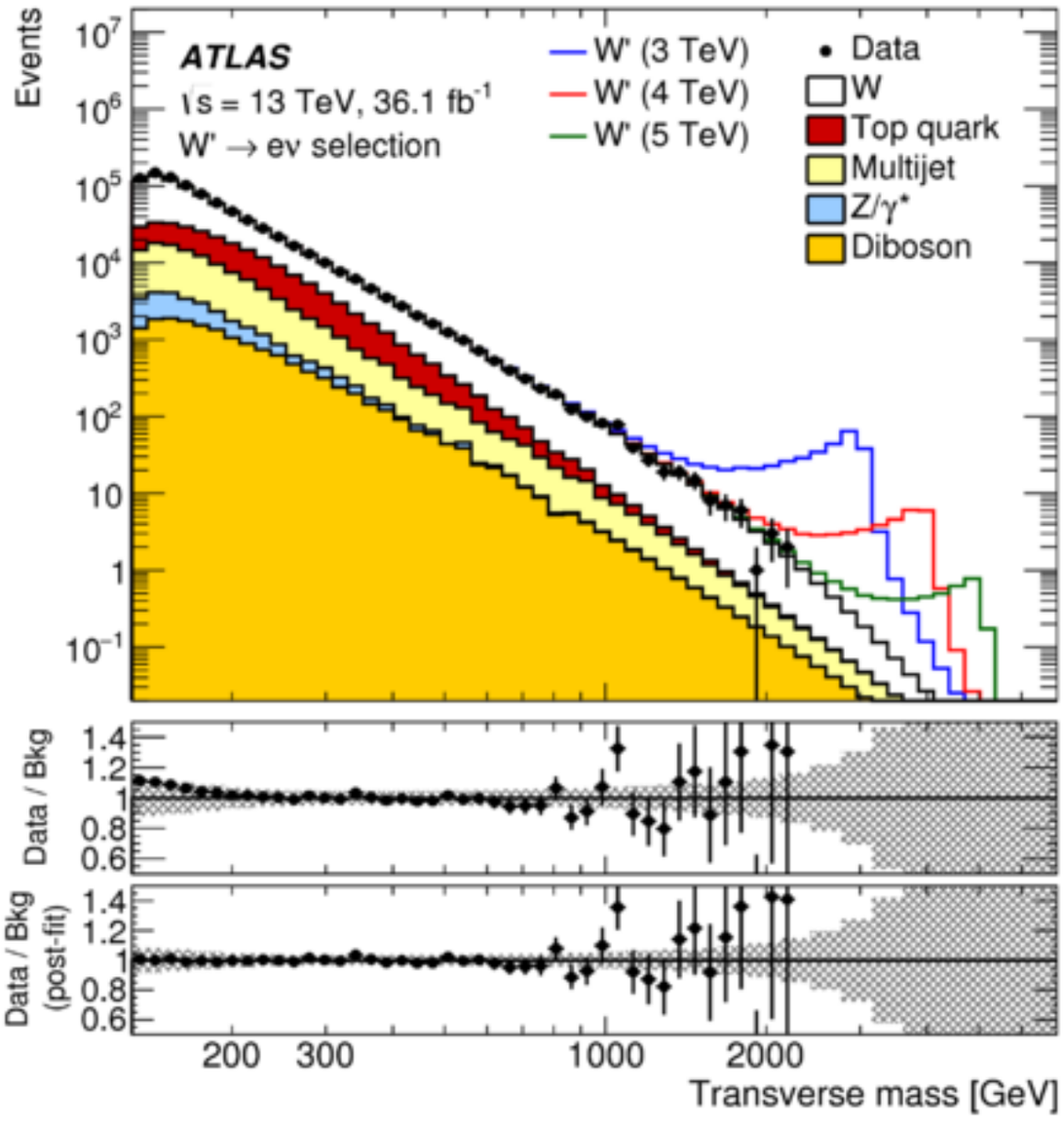



- Search for additional gauge bosons decaying into a lepton and a neutrino
- Selects one isolated electron (muon) with $p_T$>65 (55) GeV and large missing transverse momentum
  - The transverse mass of the system is used as discriminant: $m_T = \sqrt{( 2p_T E_T^{miss}(1-\cos\varphi_{lv}))}$
  - Signal acceptance on a 4TeV W' is of 47% for muons, 77% for electrons
- The **irreducible background** from ***W→lv*** is estimated from MC
  - Generated with Powheg+Pythia8, the CT10 PDF set and the AZNLO tune
  - Normalised to ***NNLO QCD*** using mass dependent k-factors
    - Increase the cross-section by 5% (10%) at invariant mass of 1 TeV (5 TeV)
  - In addition ***NLO EWK*** k-factors are applied additively
    - They lower the predicted cross-section by 10% (20%) at 1 TeV (5 TeV)
- Other minor backgrounds (ttbar, dibosons) are obtained from MC and extrapolated to the high-$m_T$ region
- Lepton fakes are data-driven using the "matrix method"; estimated at low $m_T$ and extrapolated to the high $m_T$ region

# W'→LNU (E/MU)

- No significant excess is observed
  - Largest deviation of 2.3 local (0.6 global) significance is found at $m_{W'}$=1.1 TeV in the enu channel



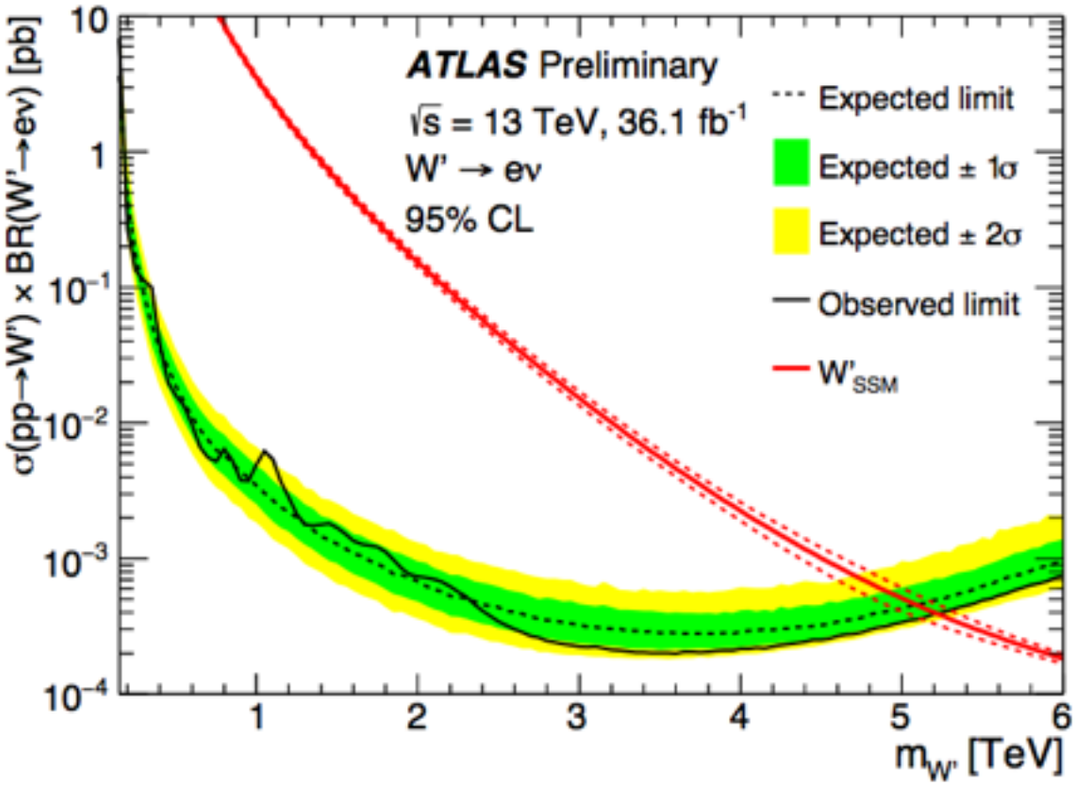

Background uncertainty increasing from 7% to 100% from $m_T$ of 2 TeV to 4 TeV

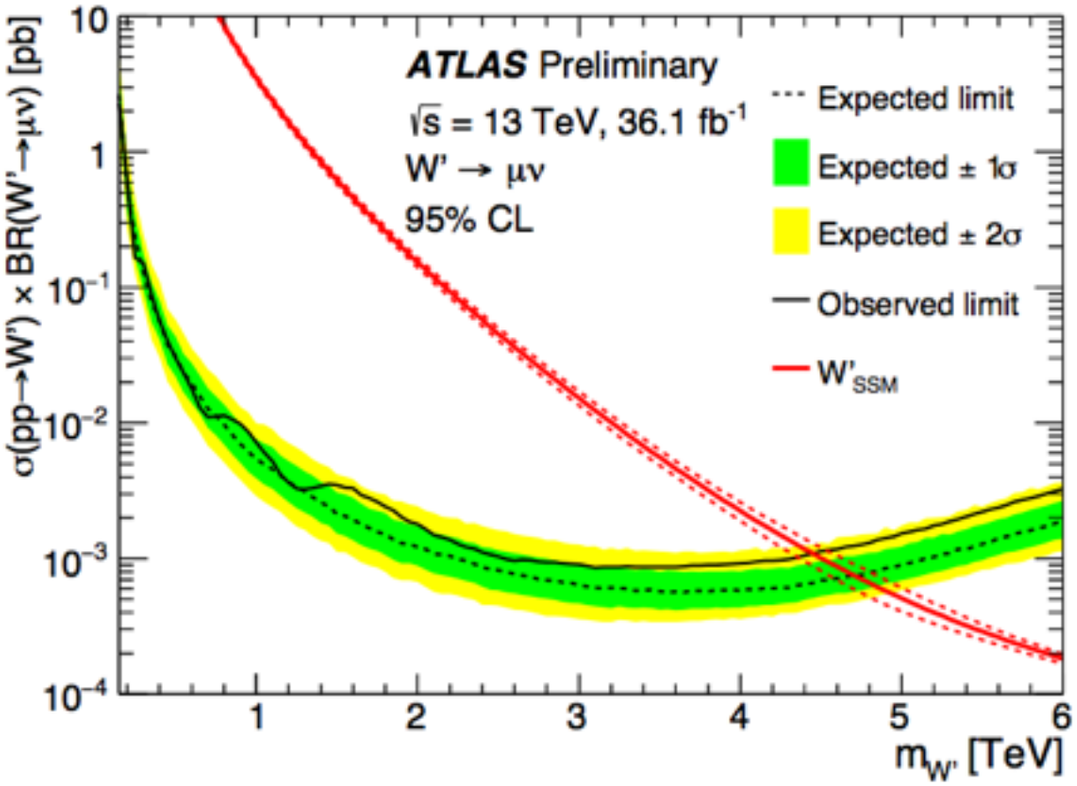
# W’ → LNU (E/MU)

- No significant deviation is observed, and limits are set on the production of additional W’ bosons

- The benchmark scenario is a W’ in the Sequential Standard Model
  - Same fermion couplings as the SM W boson
  - No couplings of the W’ to SM W, Z
  - The interference between the W and W’ is neglected

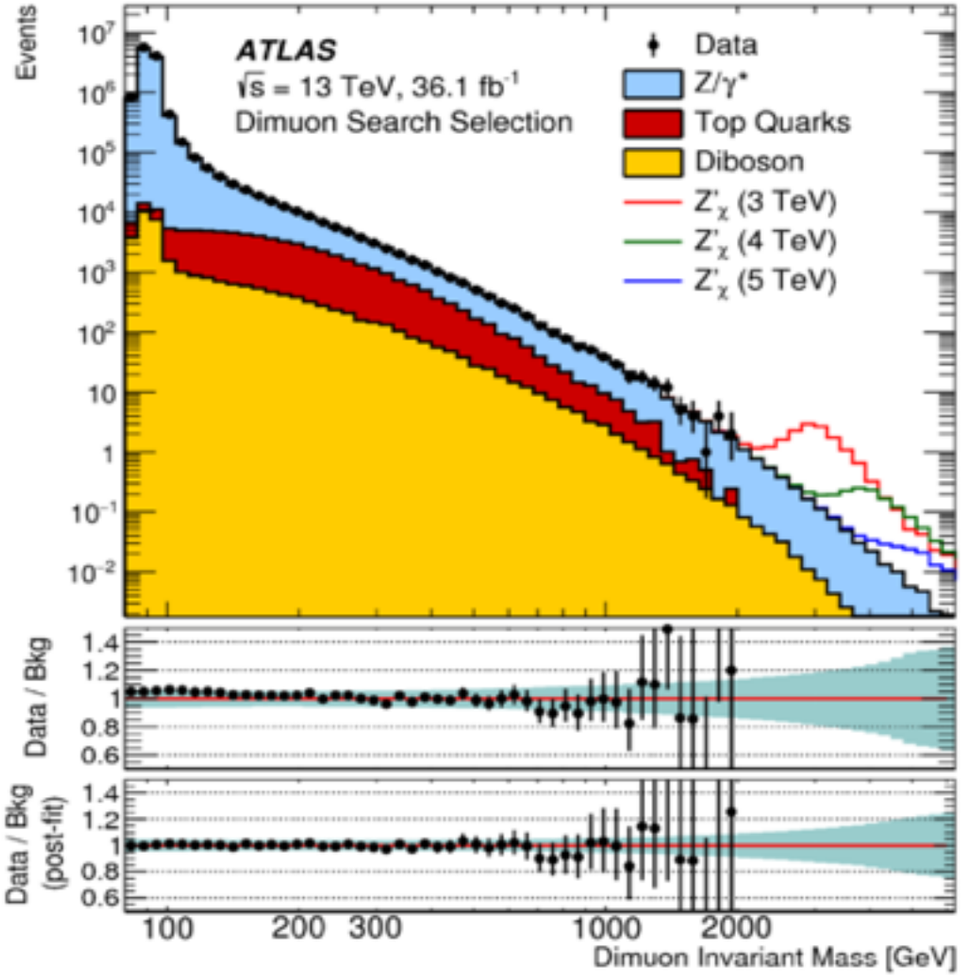
- W’ masses up to 5.1 TeV are excluded combining the to channels

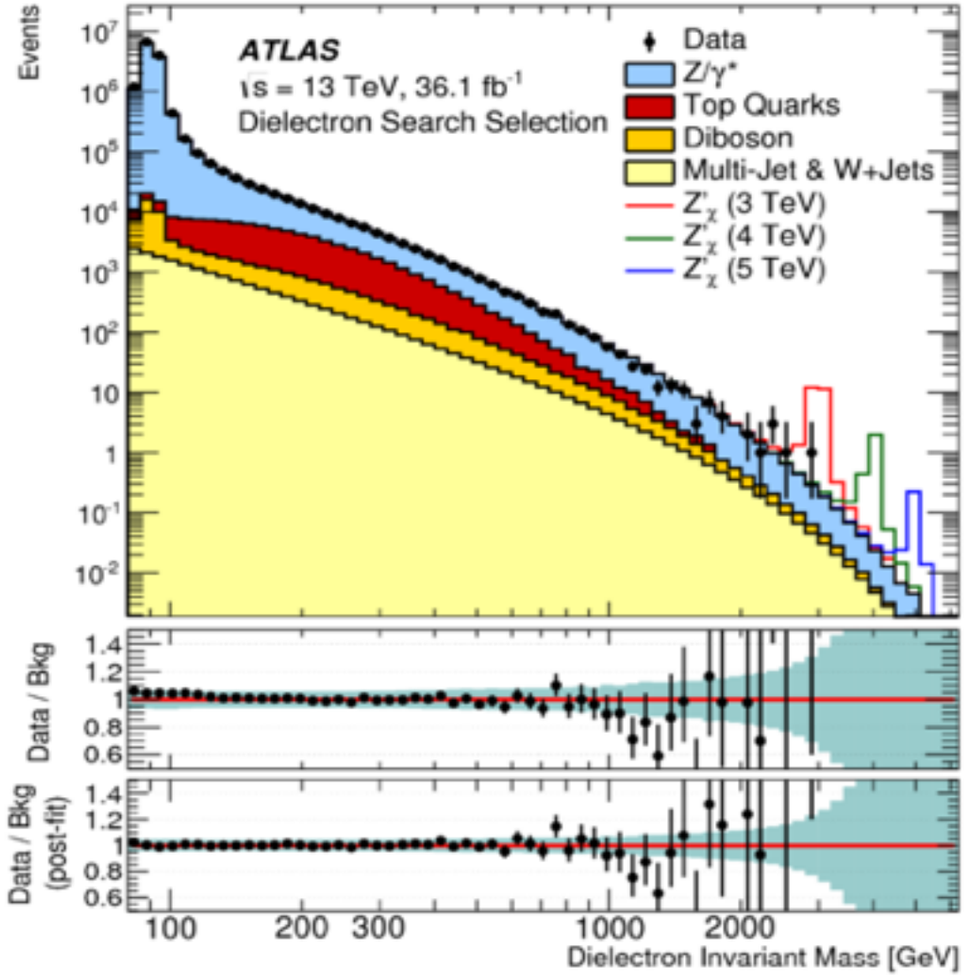


# $Z' \rightarrow LL$ (e/mu)

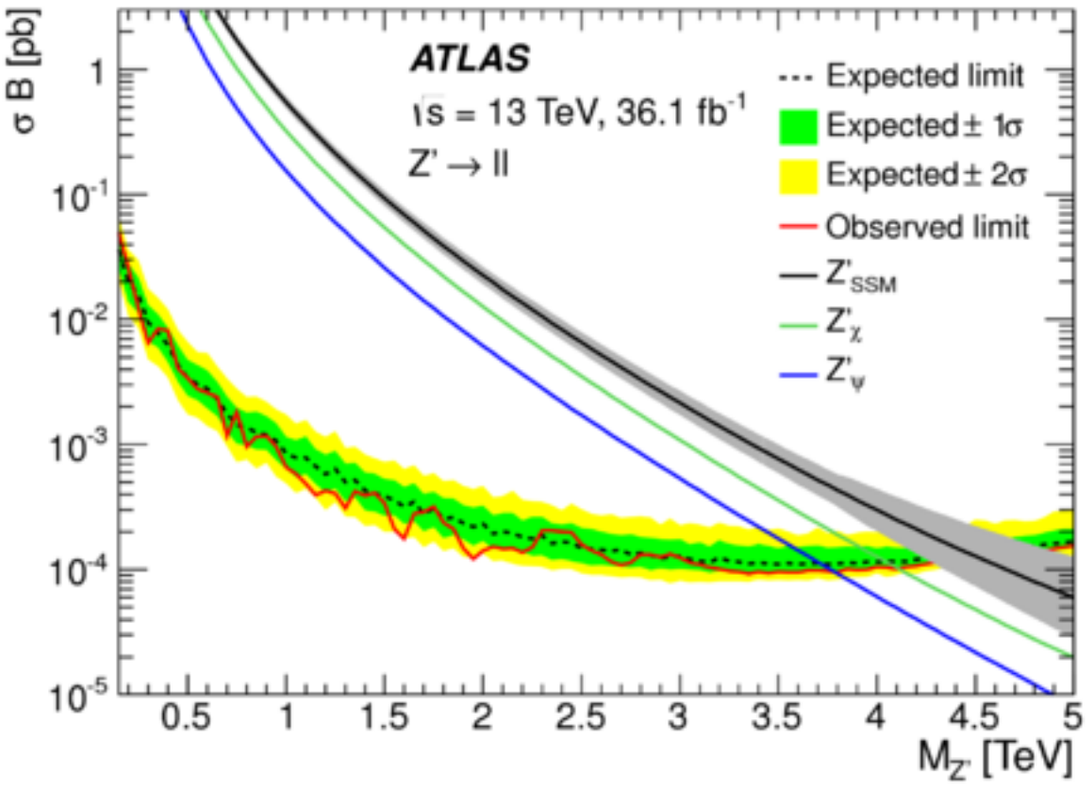
- Search for a heavy neutral gauge boson decaying into lepton pairs
- Selects a pair of isolated electrons or muons with $p_T$ > 30 GeV
  - The irreducible Drell-Yan background is estimated from simulation similarly to the W' search
  - Other backgrounds with real leptons (dibosons and ttbar) from simulation
  - The fake lepton background from multijets and W+jets in the electron channel is estimated from data using the matrix method (negligible in mumu)

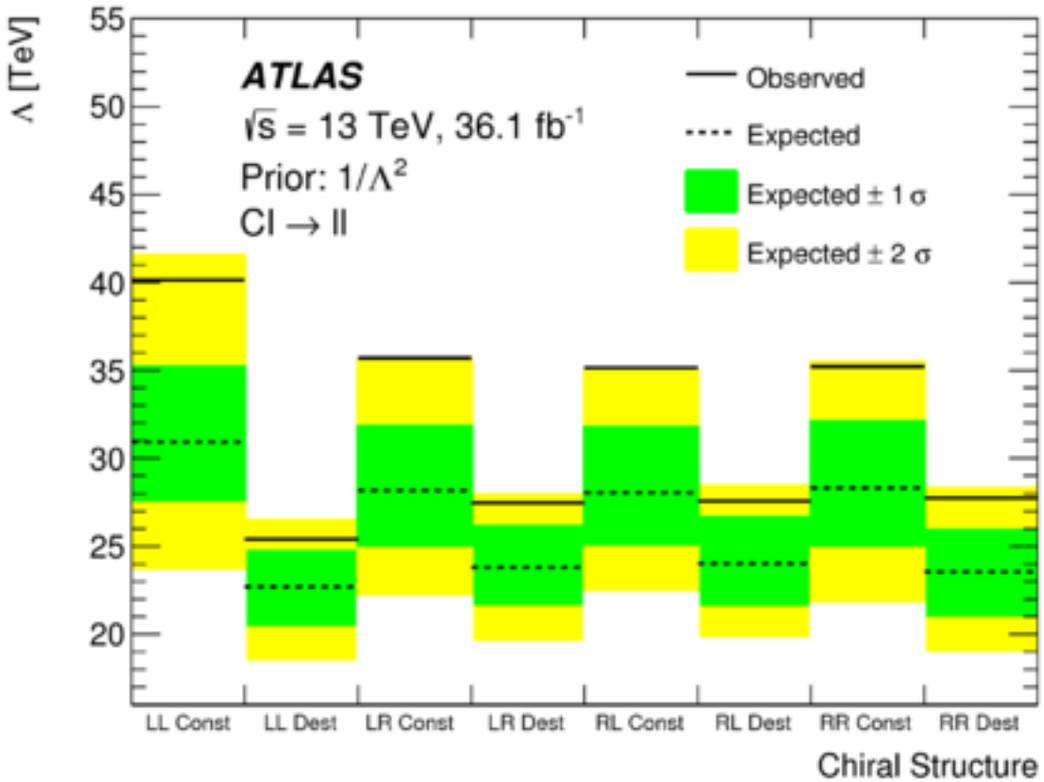


# Z’→LL (E/MU)

- No significant excess is observed
  - Largest deviation of 2.5 local significance at 2.37 TeV in the ee channel
- Limits on Z’ in the SSM are set excluding masses up to 4.5 TeV at 95% CL
- Additionally providing limits on the ratio of coupling strengths between the Z’ and the SM Z boson



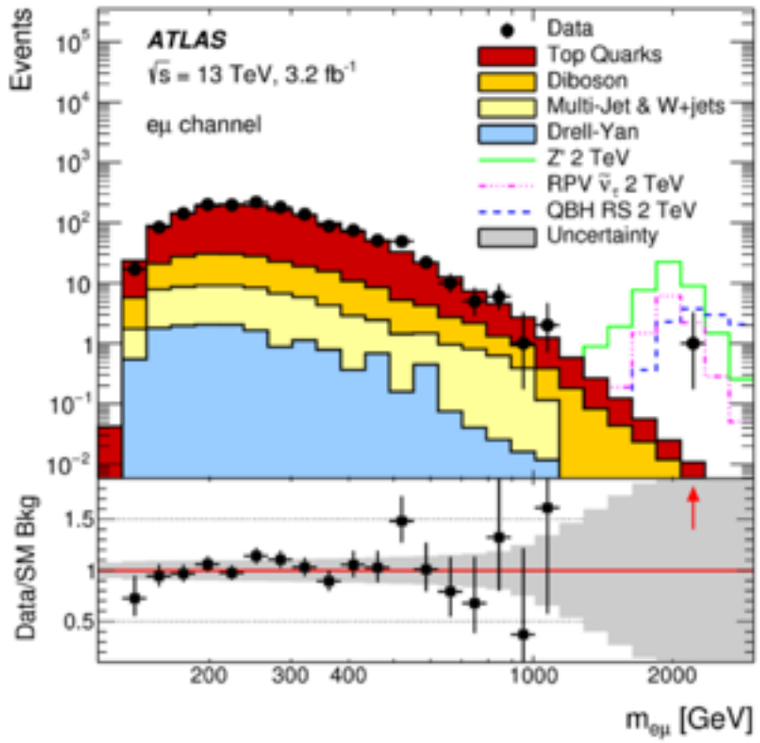




$$\mathcal{L} = \frac{g^2}{\Lambda^2}[\eta_{LL}(\bar{q}_L\gamma_\mu q_L)(\bar{\ell}_L\gamma^\mu\ell_L) + \eta_{RR}(\bar{q}_R\gamma_\mu q_R)(\bar{\ell}_R\gamma^\mu\ell_R) + \eta_{LR}(\bar{q}_L\gamma_\mu q_L)(\bar{\ell}_R\gamma^\mu\ell_R) + \eta_{RL}(\bar{q}_R\gamma_\mu q_R)(\bar{\ell}_L\gamma^\mu\ell_L)]$$

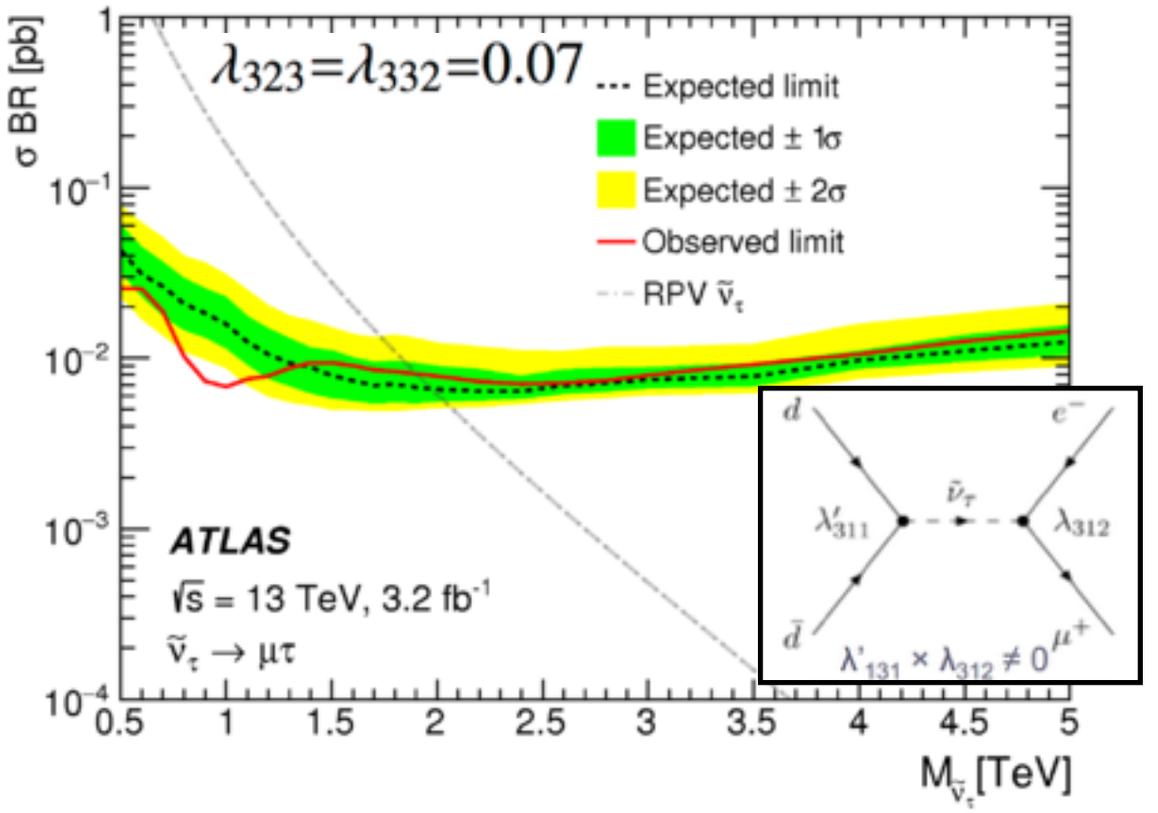
- Limits are also set on the scale of potential four-fermion contact interactions (CI)
- Limits on the CI scale ranging from 25 TeV to 40 TeV depending on the coupling

# LFV Z'→eμ/μτ/eτ

- Requiring a pair of different-flavour leptons with $p_T$>65 GeV (40 GeV taus)
- Irreducible backgrounds from DY, ttbar, dibosons are estimated from simulation
- Reducible backgrounds from multijets and W+jets
  - Matrix-method for eμ
  - Simulation corrected for the measured tau fake-rate for the τμ/τe channels

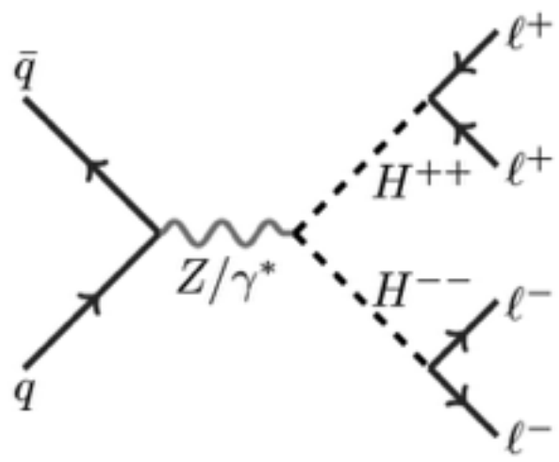



- No significant excess is observed
- Limits are set on the production of a Z' with LFV couplings excluding masses up to 3.0, 2.7 and 2.6 TeV for the eμ, τe, τμ final states
- Results also for the production of sneutrinos in RPV SUSY, excluding masses up to 2.3, 2.1 and 1.9 TeV

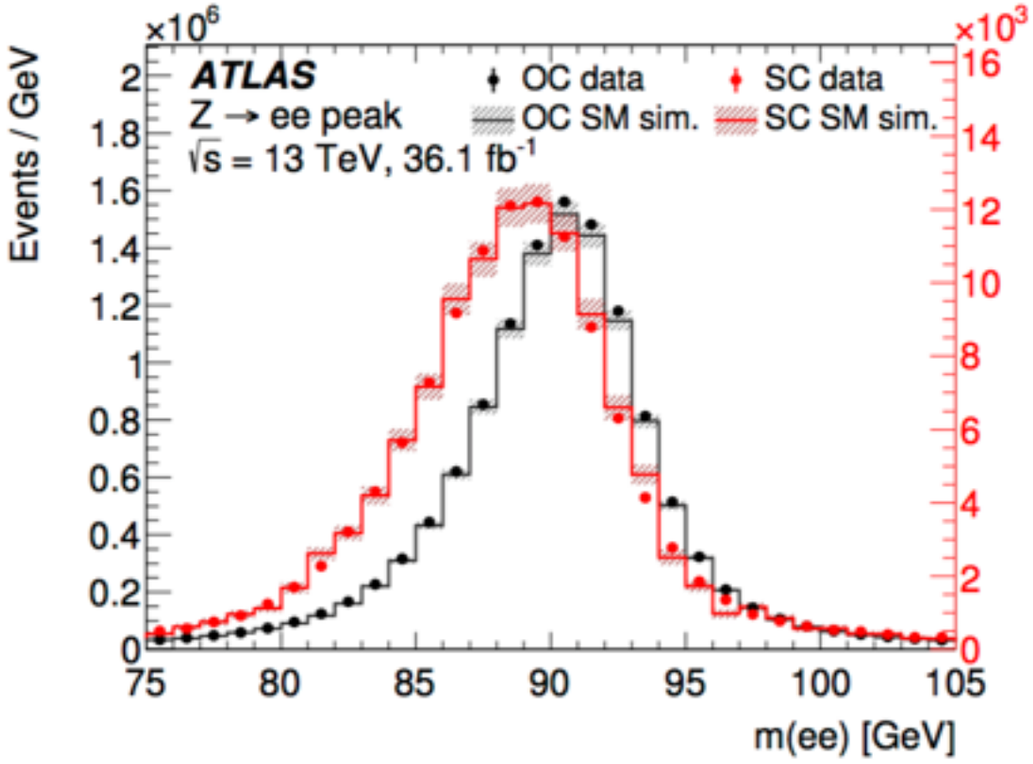


# Doubly charged Higgs

- Search for doubly charged Higgs bosons with decays into a pair of same charge energetic leptons (e/mu)
  - Defines signal regions with two-, three- and four-leptons with at least one same charge lepton pair
  - Top background is reduced requiring a b-tag veto
  - A Z-veto is applied on the three and four lepton regions
  - In addition requirements of high invariant masses and $p_T$ of the leptons to enhance the signal fraction

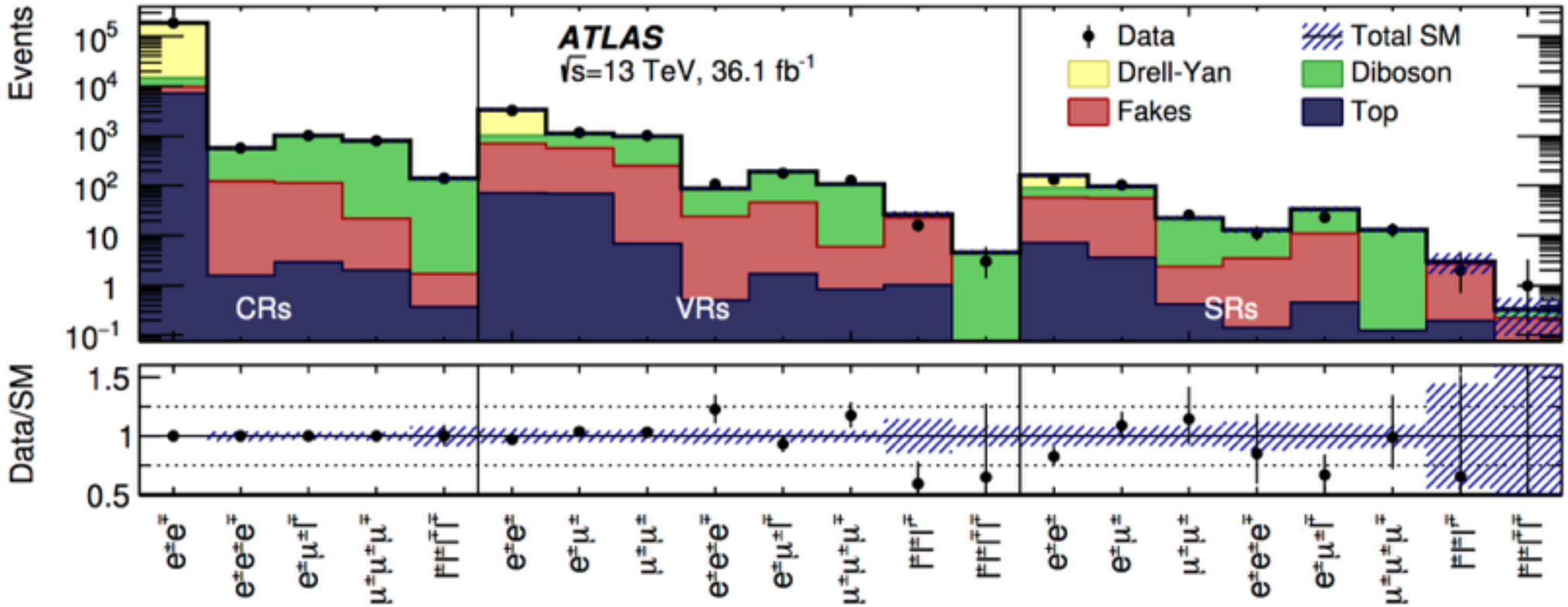



- The dominant backgrounds from diboson and Drell-Yan are normalised to data in dedicated control regions
- The fraction of charge mis-id leptons is extracted from data in a Z→ee sample and parametrised as a function of $p_T$ and eta
- Fake-leptons are estimated correcting the simulation with lepton "fake-factors" derived in fake-enriched regions with leptons failing ID cuts

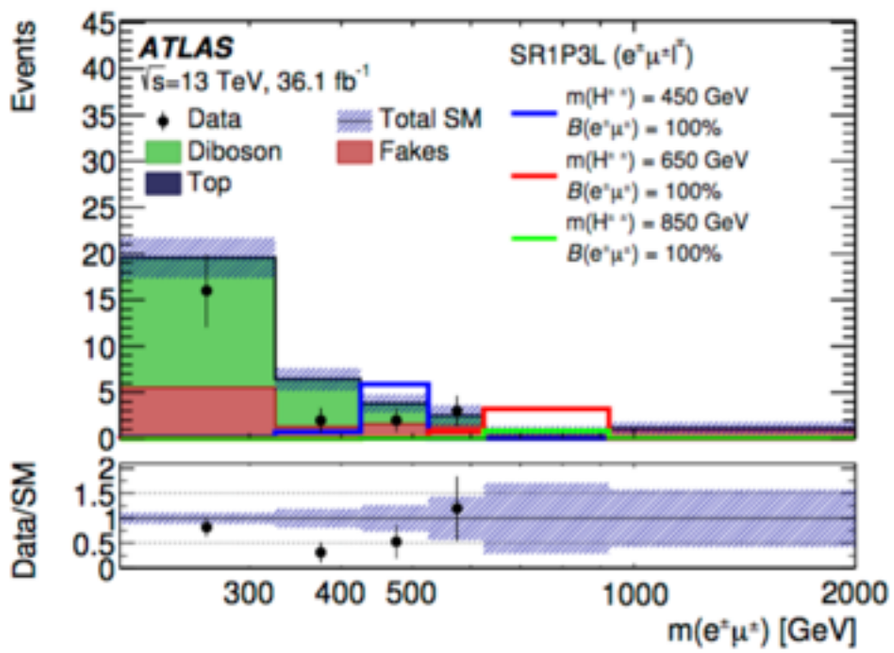


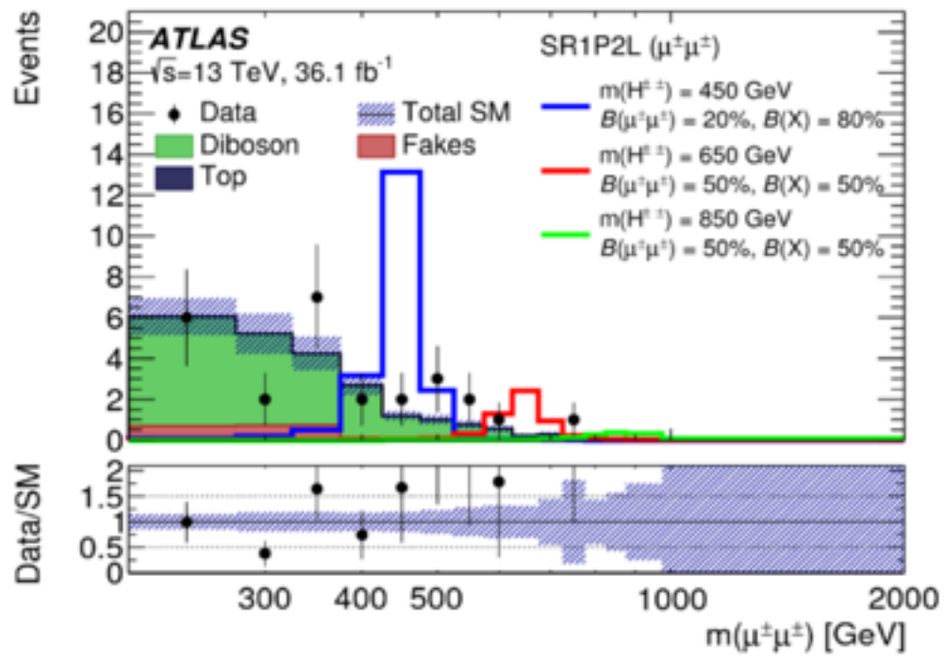
# Doubly charged Higgs

* The final Bkg yields are obtained in a simultaneous fit to 5 CRs and validated in eight signal depleted validation regions



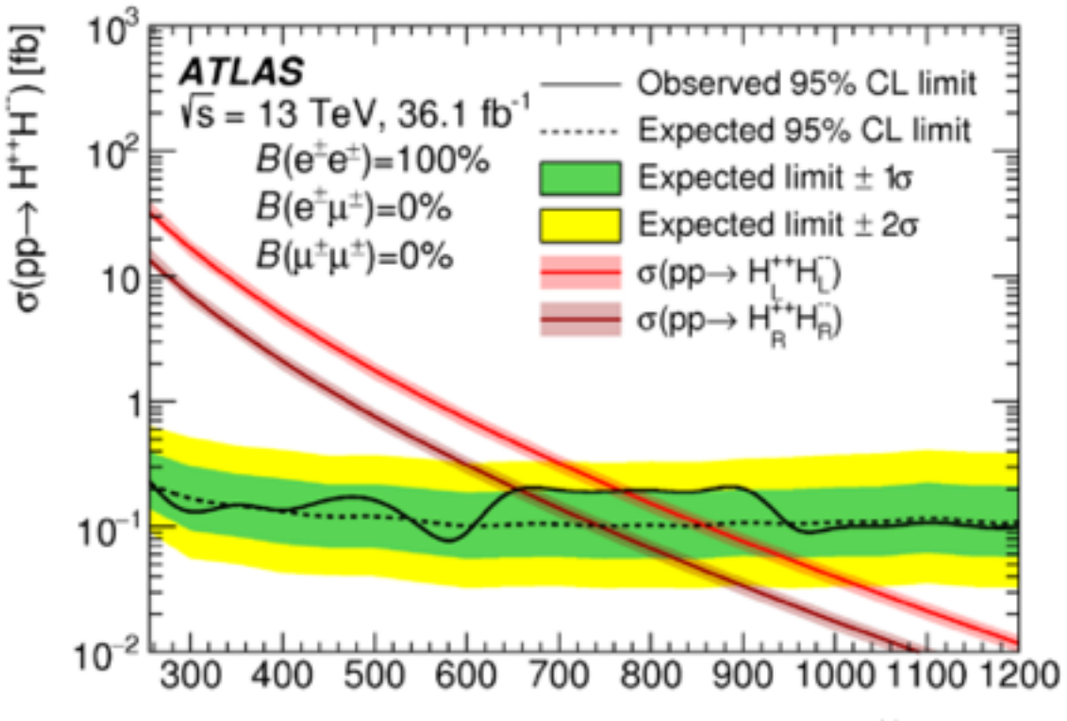

* No excess is observed in any of them



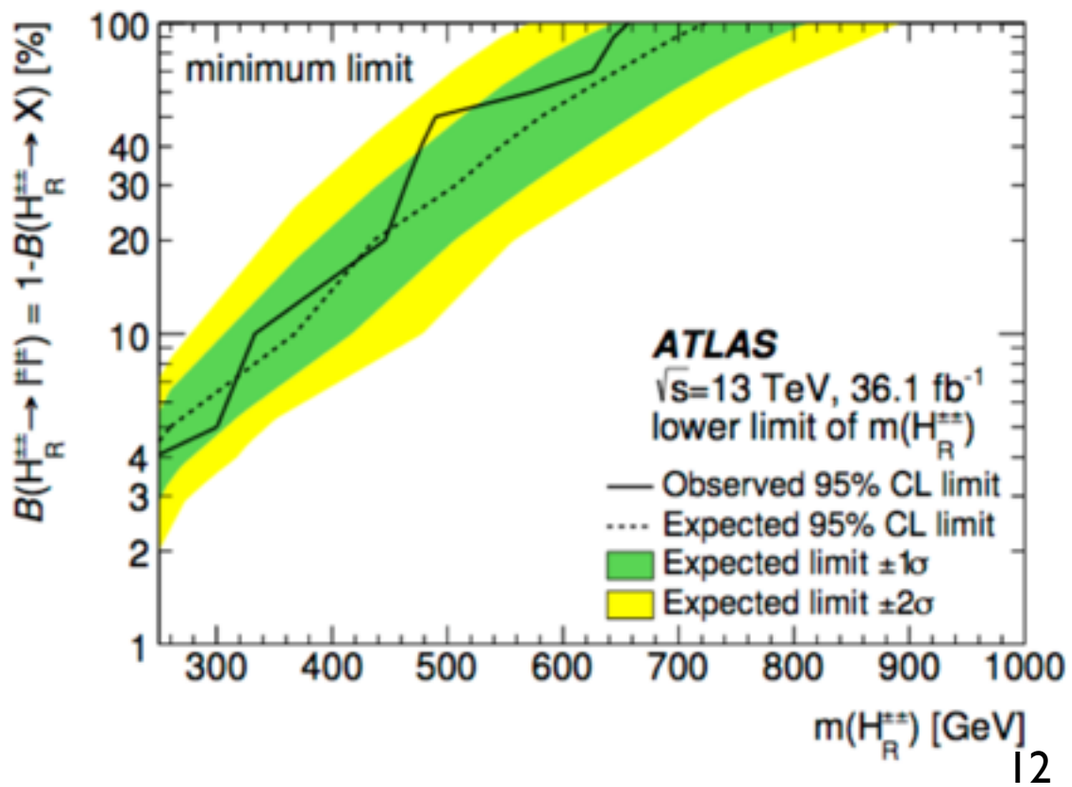
# Doubly charged Higgs

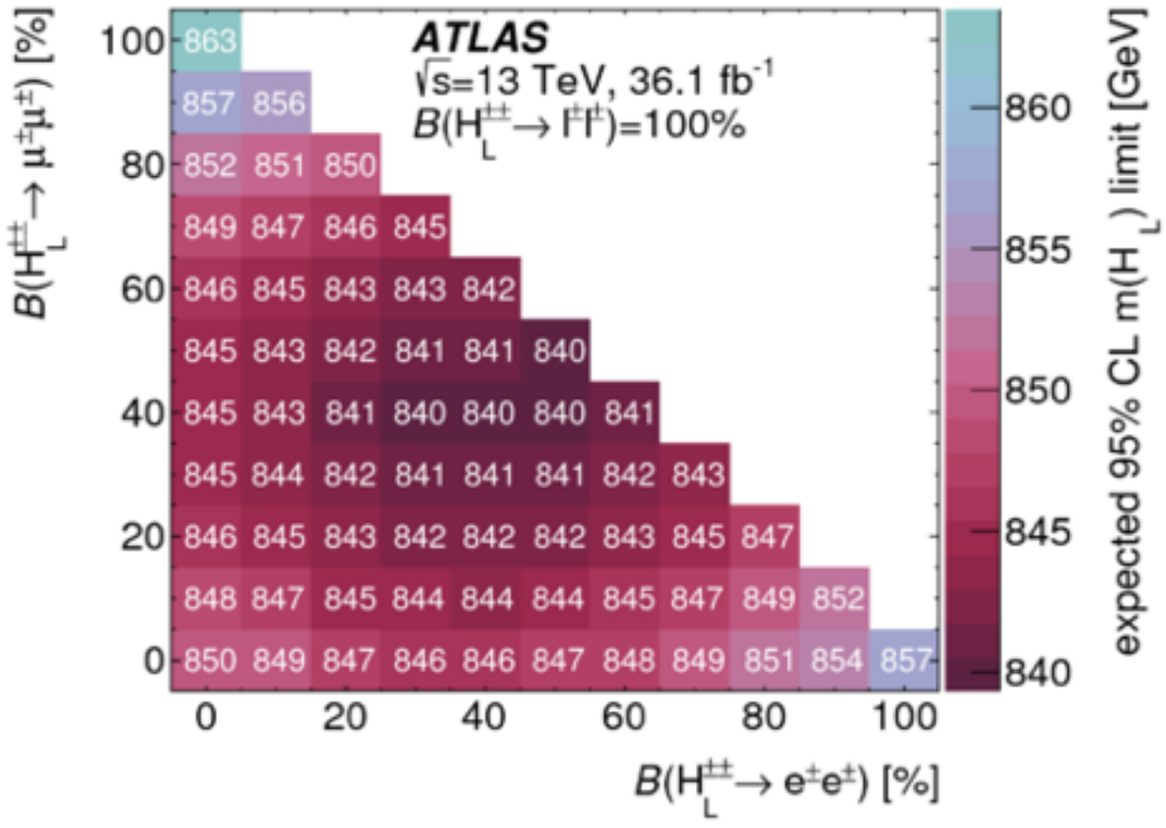
- Limits are set on the production of a doubly-charged Higgs boson coupling to either left handed or right-handed leptons




- They reach up to masses of 870 GeV for a $H_L$ with a 100% BR into leptons

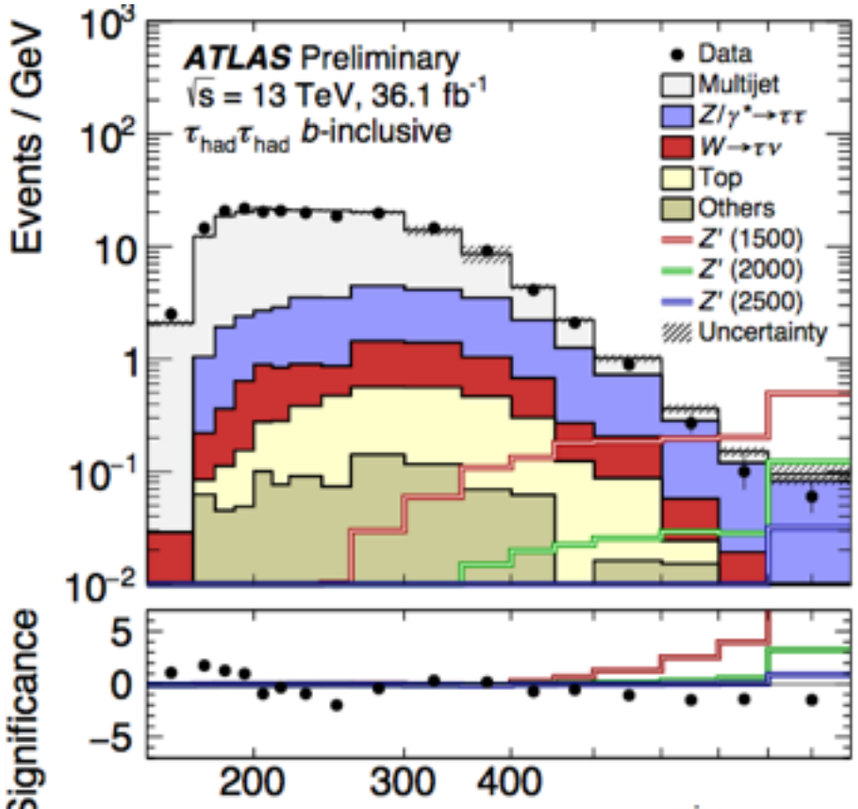
- If the BR into leptons is larger than 10% the excluded mass is larger than 450 GeV for any combination of partial branching ratios (320 GeV for an $H_R$)

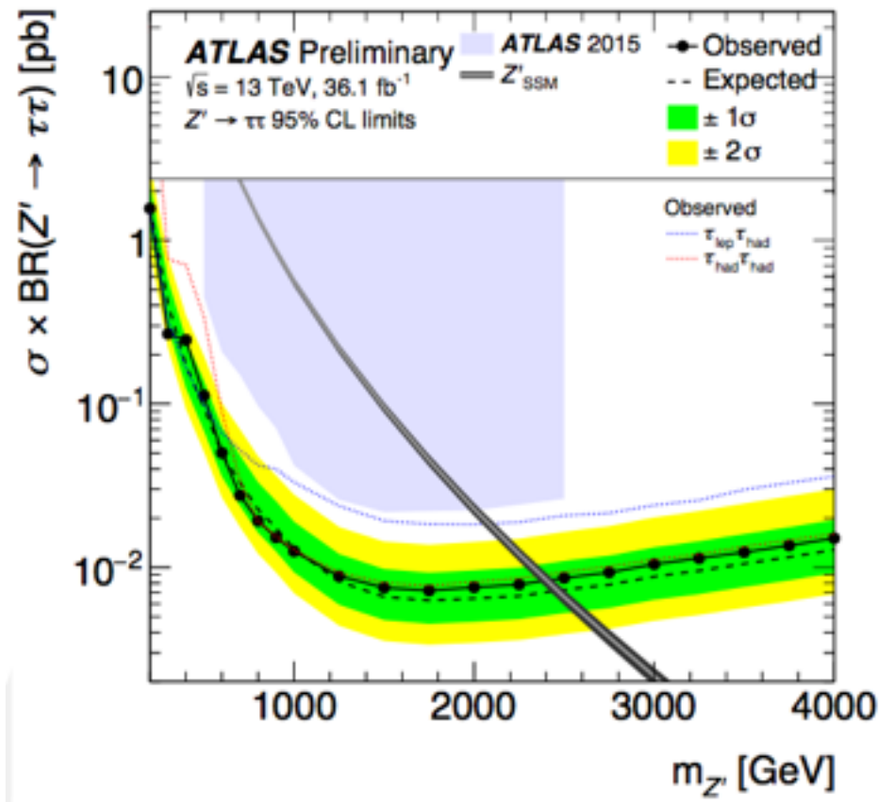


# H/Z'→TAUTAU

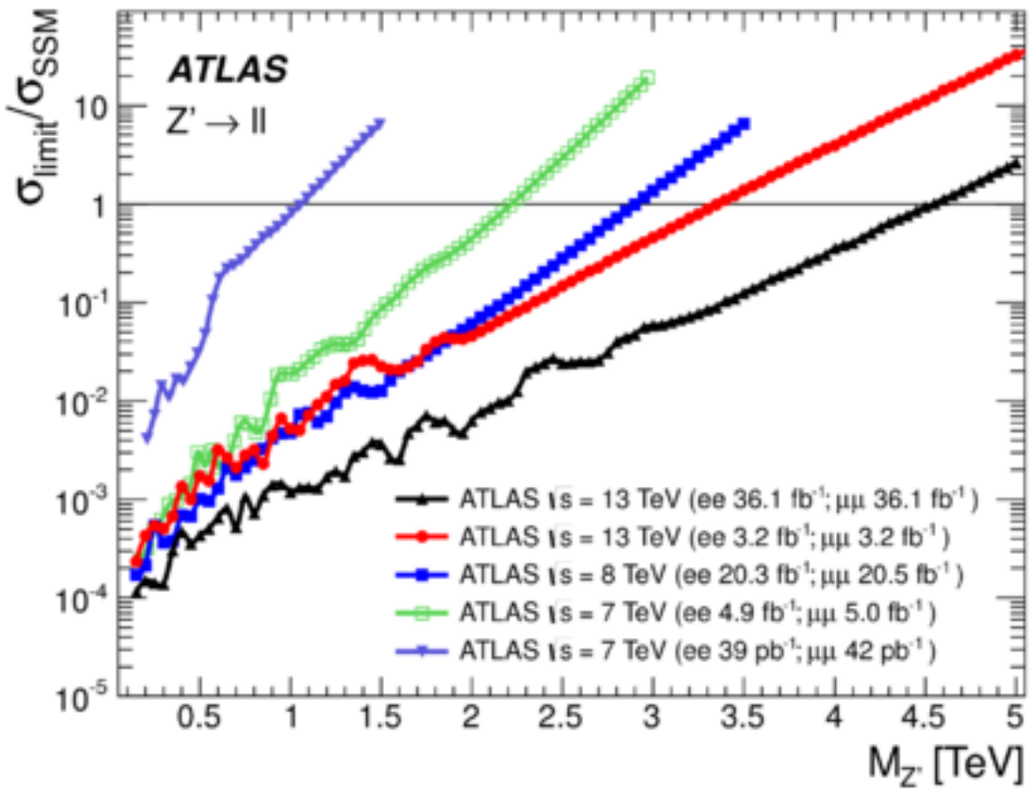
- Search for high mass resonances decaying into tau pairs (BSM H, Z')
  - Analysis considering both $\tau_{had}\tau_{had}$ and $\tau_{had}\tau_{lep}$ final states
  - The selection use single-$\tau_{had}$ triggers and requires a back-to-back opposite charge pair of hadronic taus
  - The total transverse mass is used as final discriminant $m_{\mathrm{T}}^{\mathrm{tot}} \equiv \sqrt{(p_{\mathrm{T}}^{\tau_1} + p_{\mathrm{T}}^{\tau_2} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - (\mathbf{p}_{\mathrm{T}}^{\tau_1} + \mathbf{p}_{\mathrm{T}}^{\tau_2} + \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}})^2}$
  - The multijet background is estimated in a dijet control region with inverted $\tau_{had}$ identification, j→τ fake-factors parametrised as a function of $p_T$ and track multiplicity of the τ
  - Other backgrounds from simulation, corrected with fake factors extracted in W+jets and ttbar control regions
- No excess is observed and limits are set on the Z' mass reaching up to 2.42 TeV



# Summary

- Presented results of ATLAS searches for exotic phenomena in leptonic final states
  - W'→lnu 36fb$^{-1}$ [**EXOT-2016-06**]
  - Z'→ll 36fb$^{-1}$ [**EXOT-2016-05**]
  - Z'→eμ/τμ/τe 3.2fb$^{-1}$ [**EXOT-2015-20**]
  - H$^{++/--}$→l$^{+}$l$^{+/-}$l$^{-}$l$^{-}$ 36fb$^{-1}$ [**EXOT-2016-07**]
  - Z'→ττ 36fb$^{-1}$ [**HIGG-2016-12**]




- Unfortunately no interesting excess observed in any of the analyses
- Constraints the scale of new physics reaching up to scales of tens of TeVs in specific models
- Not yet the end of the game, the full Run2 dataset promises still a significant sensitivity gain