# Result on Exotics searches at ATLAS

V.Maleev

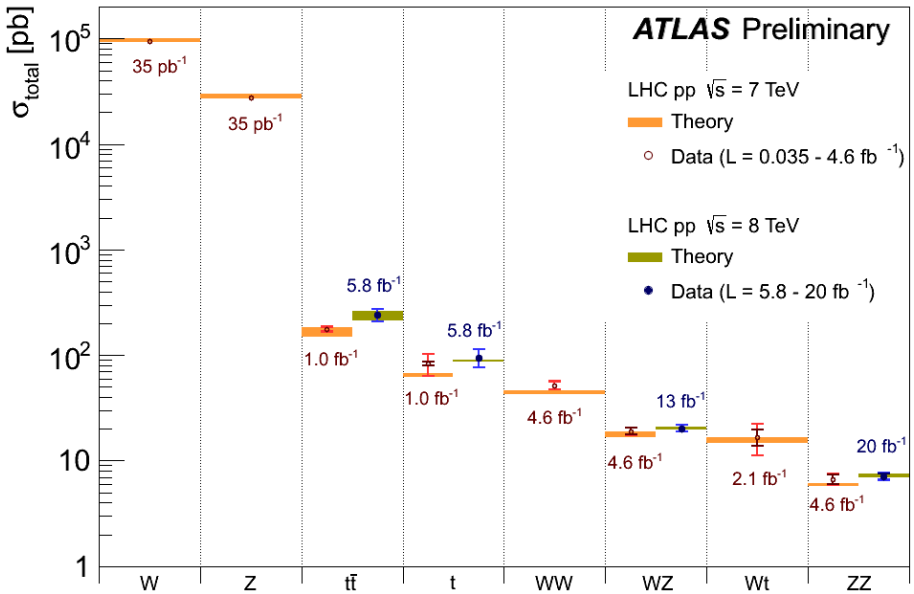
Petersburg Nuclear Physics Institute

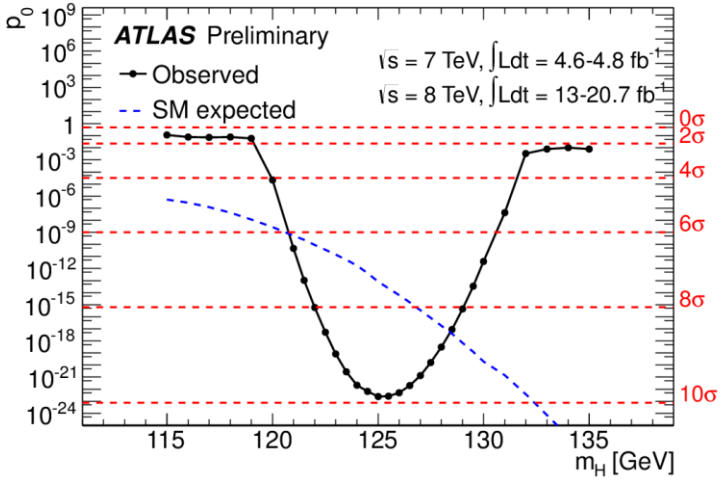
on behalf of the ATLAS collaboration,

IMPW2013


# Motivation

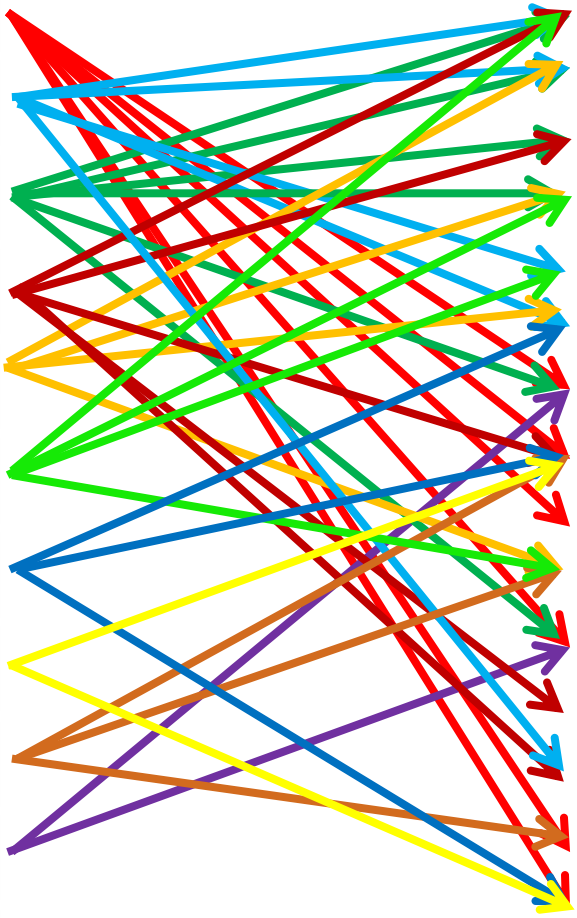
- SM works well, and even better with the discovery of the Higgs boson
- But Higgs is light and needs large corrections → new particle with mass ~ TeV is needed
- Other not answered questions
  - Hierarchy problem
  - Dark matter
  - Gravity
  - Number of generations
  - Extra dimensions
  - …



# Signatures

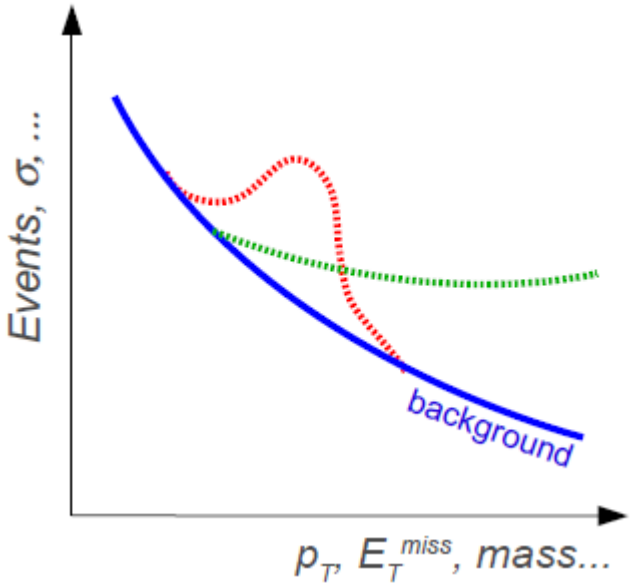
- Supersymmetry
- Heavy gauge boson
- Extra dimensions
- Compositeness
- Technicolor
- Little Higgs
- Left-right symmetry
- Heavy neutrino
- Vector-like quark
- Dark Matter
- and more …

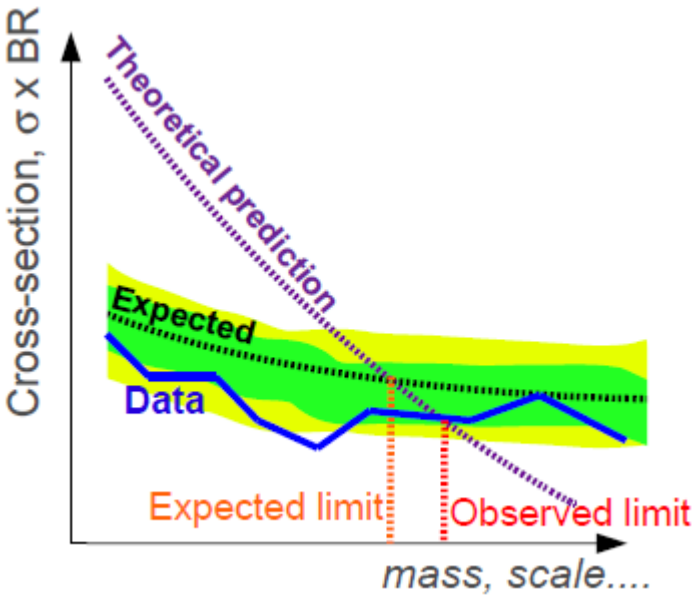


- Dijet
- Dilepton
- Diphoton
- Diboson
- Ditop
- Lepton + $E_t^{miss}$
- Photon + $E_t^{miss}$
- Same-sign dilepton
- Long-lived particles
- W/Z + Jets
- Jet + $E_t^{miss}$
- Lepton + Photon
- Top + Jets
- Multijet
- Multilepton
- and more …

# Analysis strategy

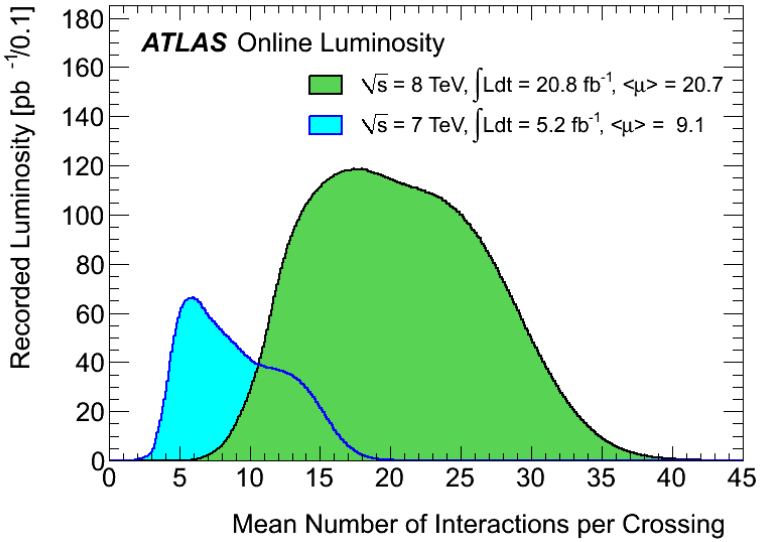
- Look at some characteristic distribution (invariant mass, transverse mass, $p_T$ spectrum etc.)
- Search for deviation from known background
  - Bump for resonant phenomena
  - Excess in the tail for non-resonant phenomena
- In case no deviation found, set a limit
  - Calculate expected cross-section with all uncertainties
  - Calculate observed cross-section from data
  - Find observed and expected limits using theoretical prediction

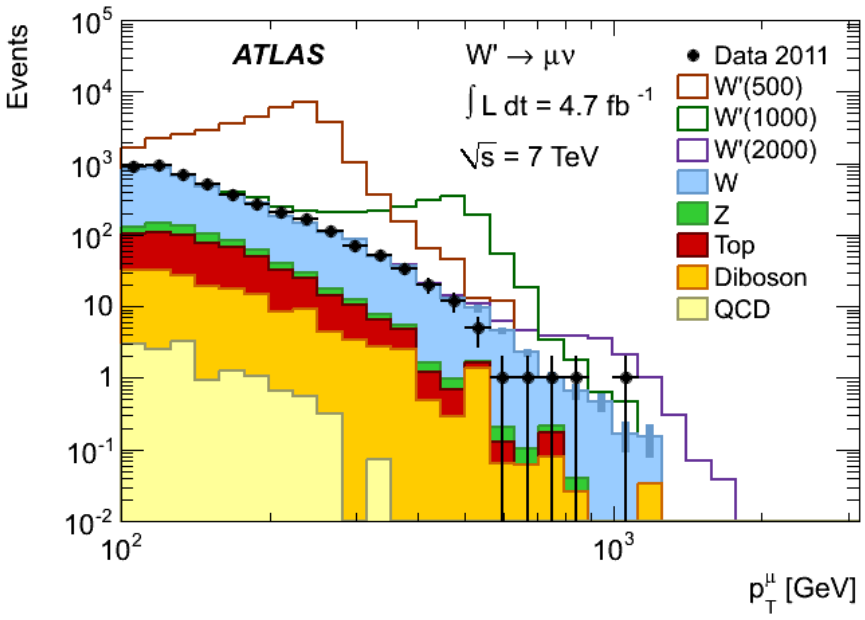


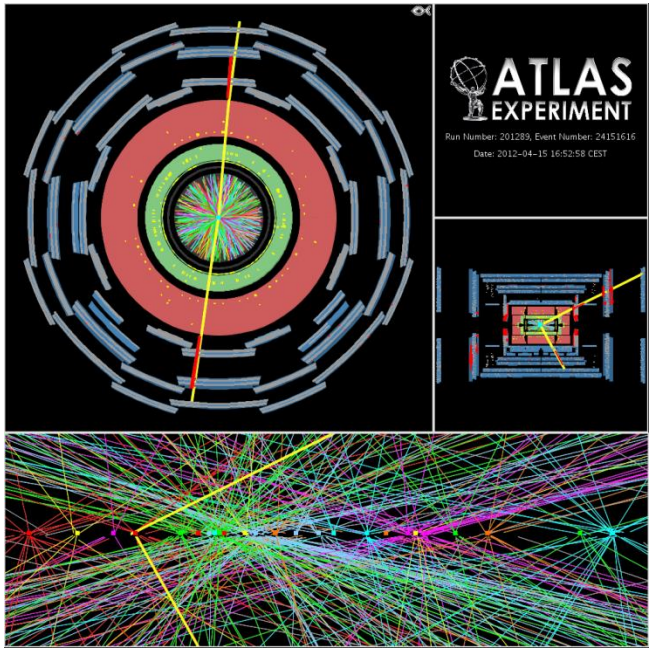



# Analysis challenge

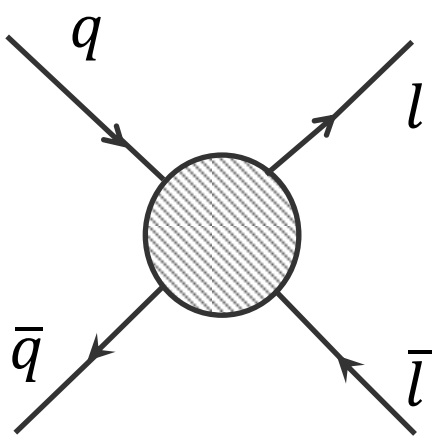
- About 23 $fb^{-1}$ delivered by LHC to the ATLAS experiment in 2012 ($\sqrt{s}$ = 8 TeV) and ~21 $fb^{-1}$ recorded by ATLAS
- Extremely high luminosity – 7.7 $10^{33}$ $cm^{-1}s^{-1}$
- Very high pile-up – up to 40 collisions/bunch crossing
- Electrons and muons reach $p_T$~ 1 TeV



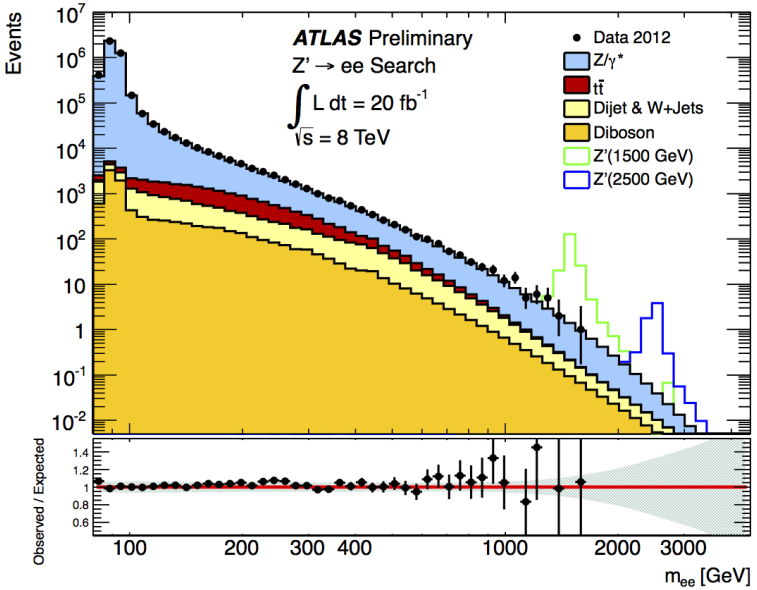



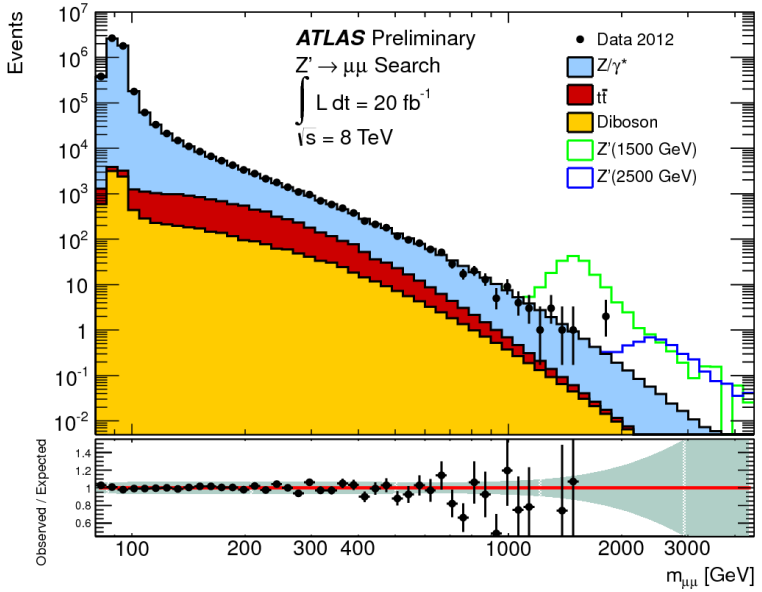
# Dilepton search: ATLAS-CONF-2013-017




- Heavy gauge boson Z' inspired by GUT, E6 models, Sequential Standard Model …
- Little Higgs
- Randal-Sundrum graviton, UED
- Technicolor

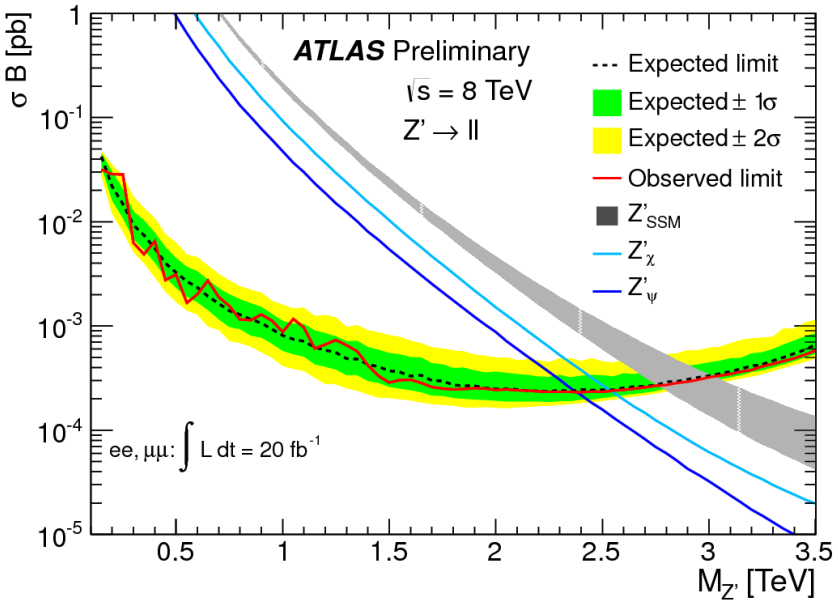


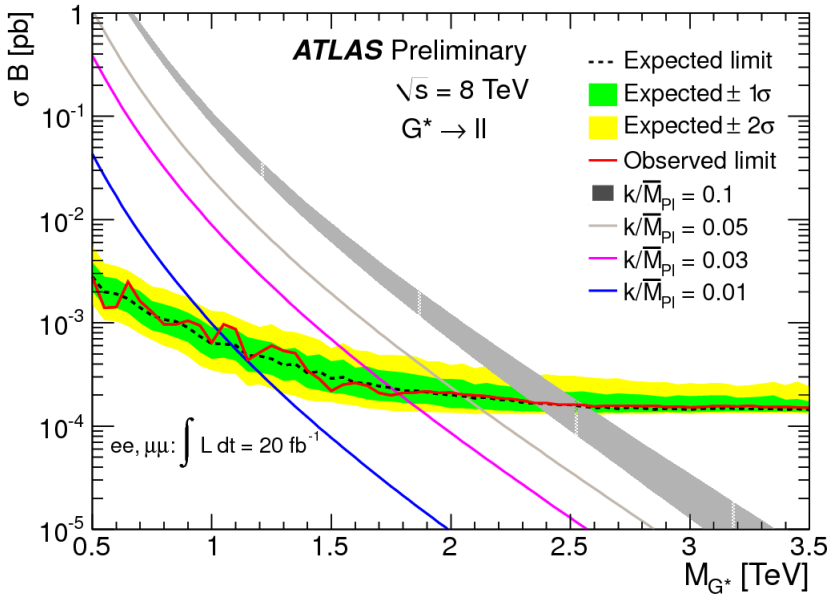

Highest mass event $m_{ee}$ = 1.541 TeV




Highest mass event $m_{\mu\mu}$ = 1.844 TeV

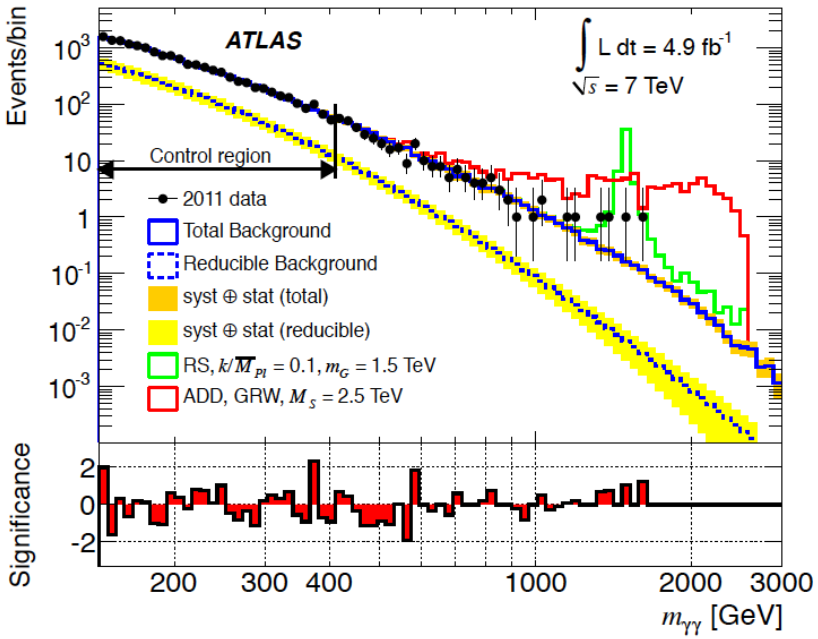
# Dilepton limits

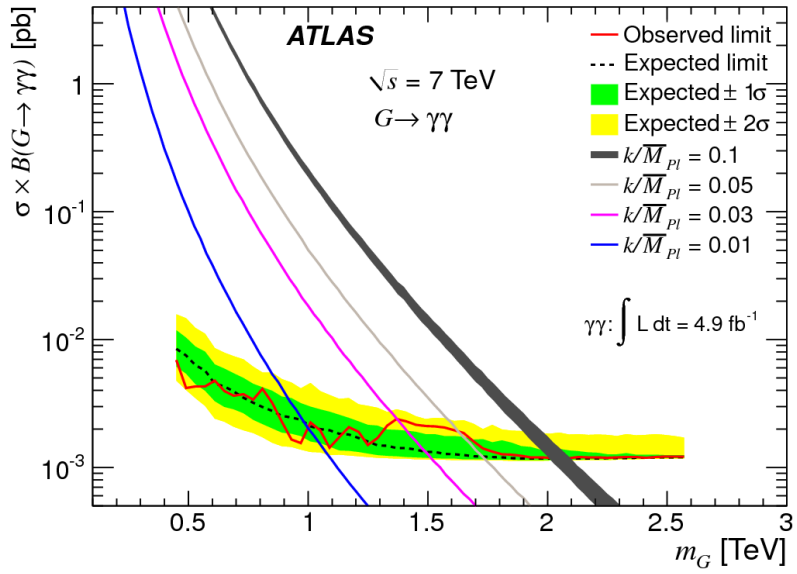



| | Expected | Observed |
|---|---|---|
| SSM Z' | 2.85 TeV | 2.86 TeV |
| $E_6$ motivated Z' | 2.37-2.54 TeV | 2.38-2.54 TeV |
| G* ($k/\overline{M}_{Pl}$ = 0.1) | 2.47 TeV | 2.47 TeV |

# Diphoton search:

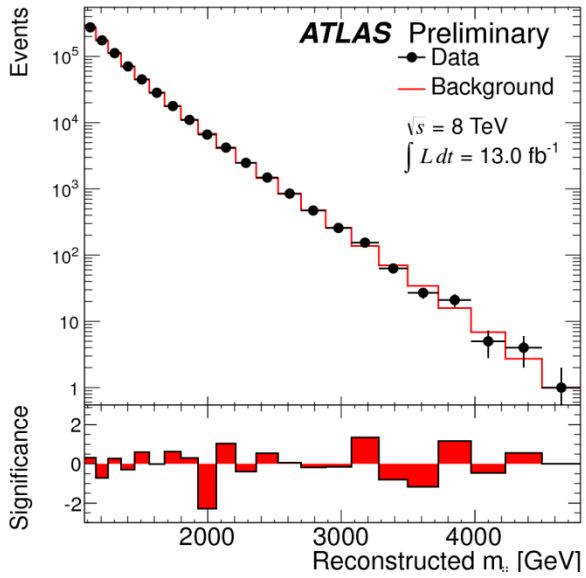



- ADD model: continuous spectrum
- RS model: resonances

arXiv:1210.8389; NJP 15, 043007 (2013)

# Dijet search

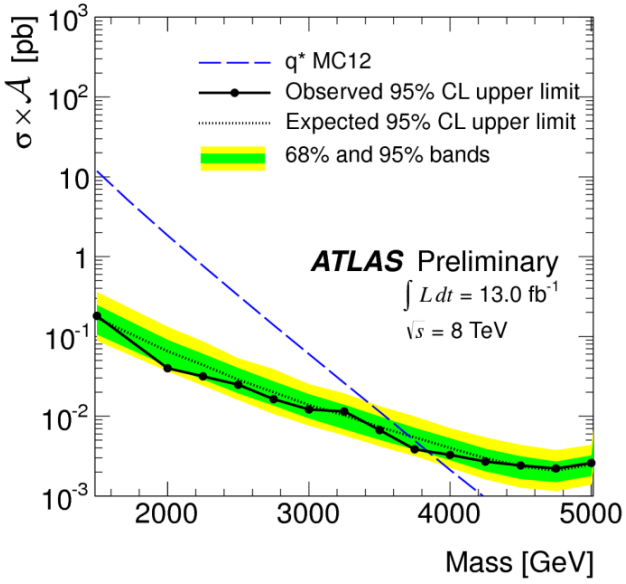


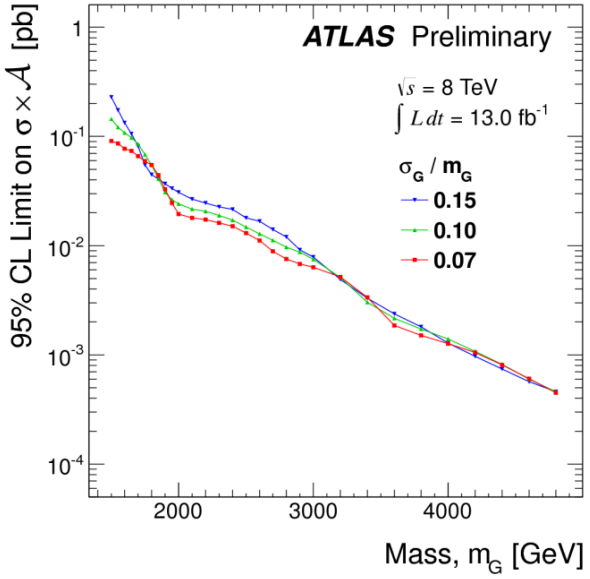

- Sensitive to highest mass scales accessible with hadronic final states
- Search for difference between data and dijet fit

$$f(x) = p_1(1-x)^{p_2}x^{p_3+p_4 lnx}$$

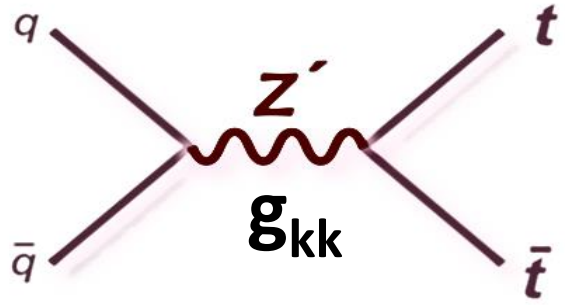
- Highest mass event $m_{jj}$ = 4.47 TeV

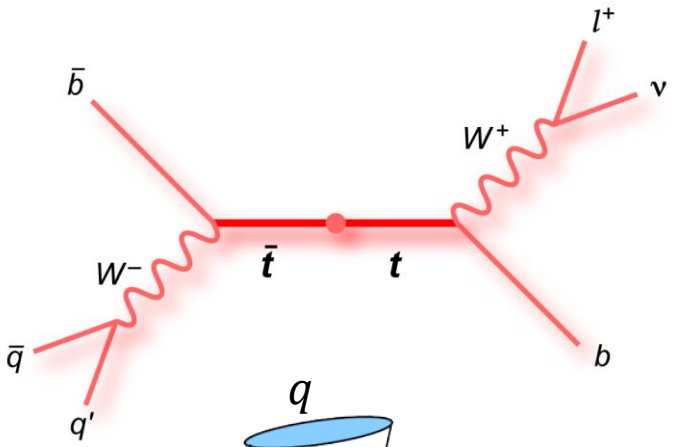
arXiv:1210.1718; JHEP 01 (2013) 029



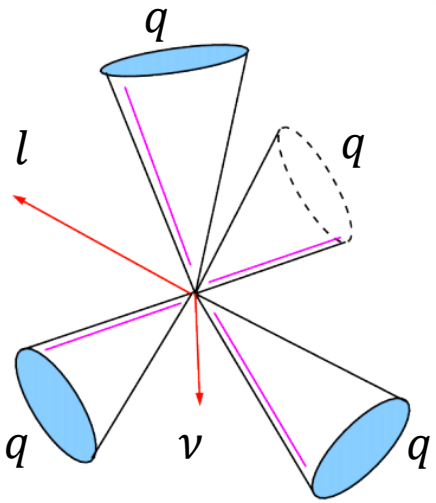



# ttbar search: ATLAS-CONF-2013-052

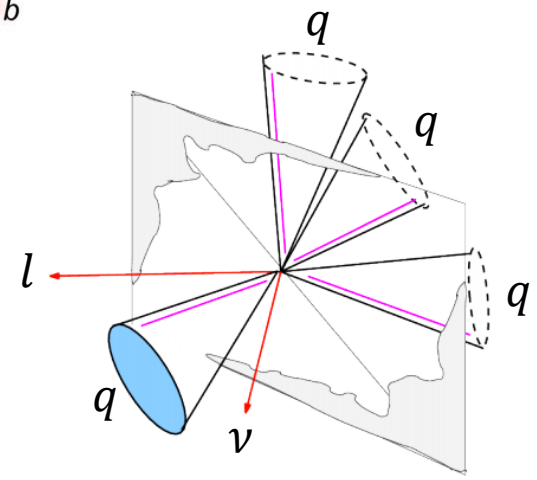


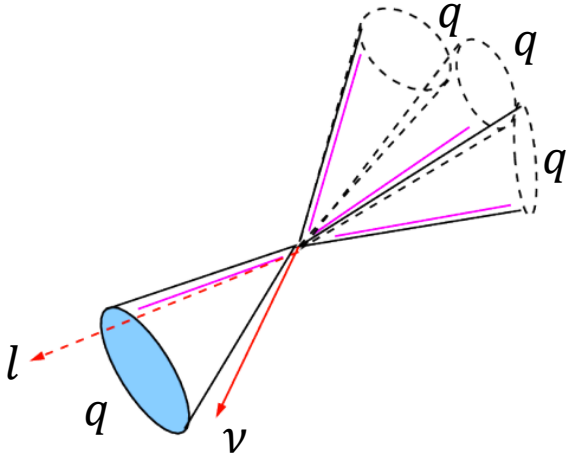




- Very complicated analysis with new reconstruction techniques
- Different final states topologies for increasing accessible $m_{tt}$
  - "resolved" topology for low $m_{tt}$ *masses*
  - "top monojet" for boosted object
  - combination of both in the intermediate range



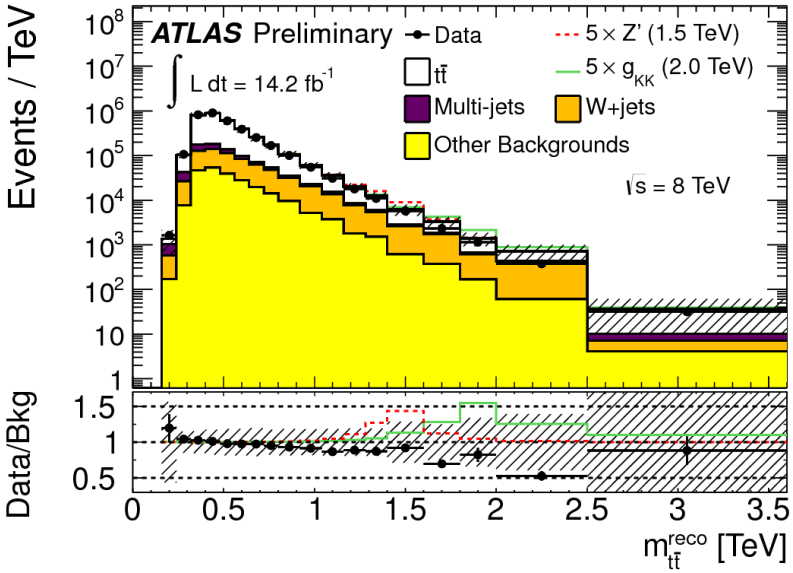

$m_{tt}$< 0.5 TeV

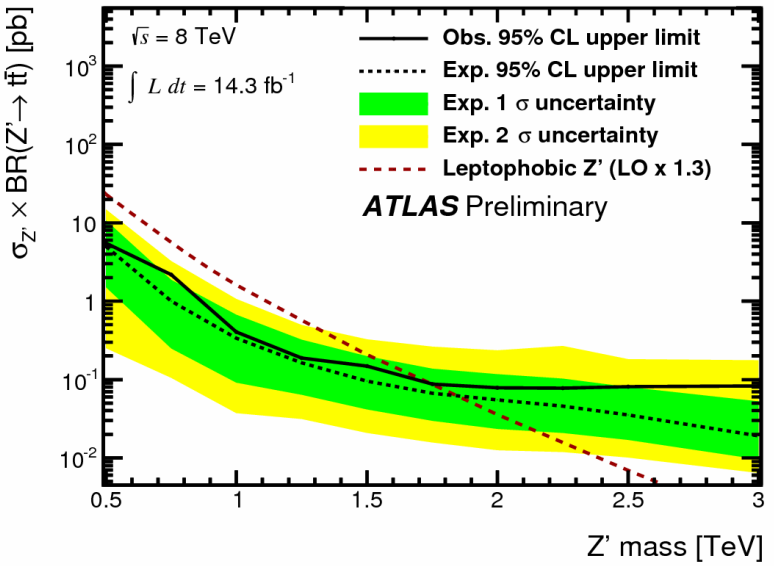



$m_{tt}$ > 1 TeV

# ttbar search

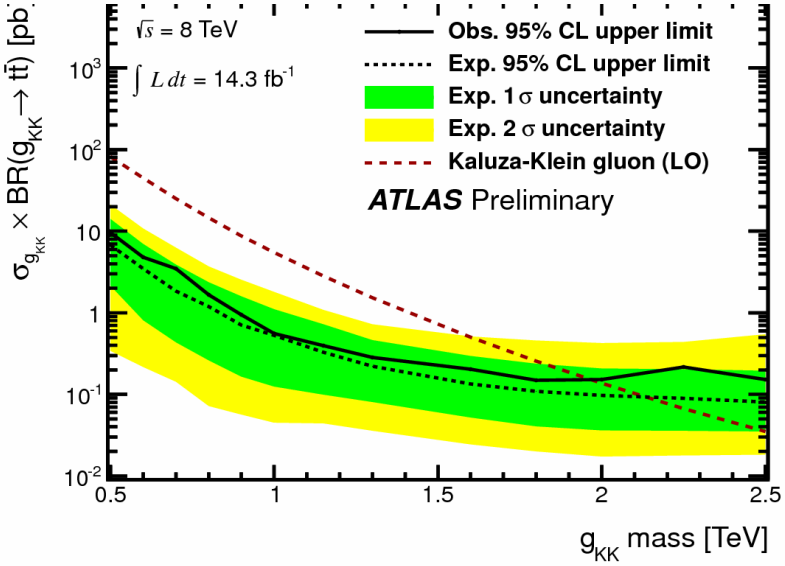


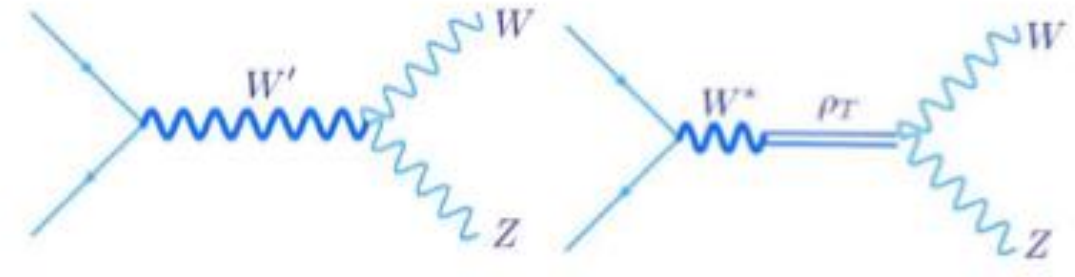

- Exclusion limits at 95% CL

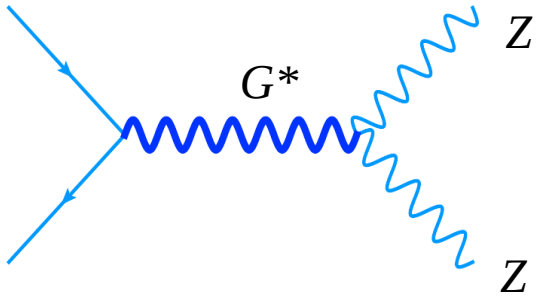
  Z' – 1.74 TeV

  $g_{kk}$ – 2.07 TeV



# Diboson searches




WZ [ATLAS-CONF-2013-015]

Extended gauge models

Little Higgs

low scale technicolor

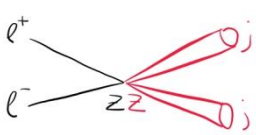
technirho (ρT)

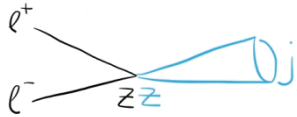
Look resonance in three lepton final state

ZZ [ATLAS-CONF-2012-150]

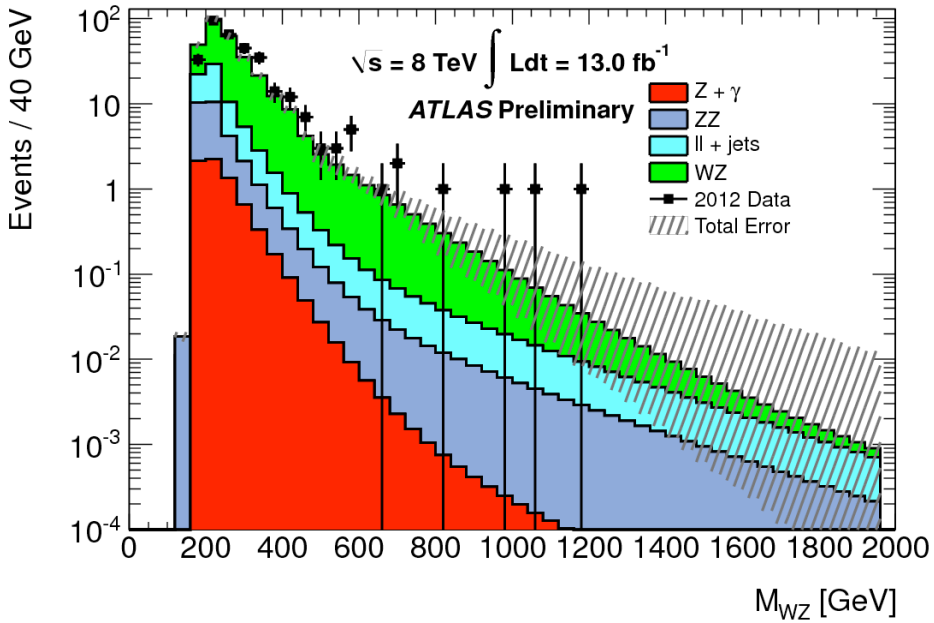
bulk RS-graviton

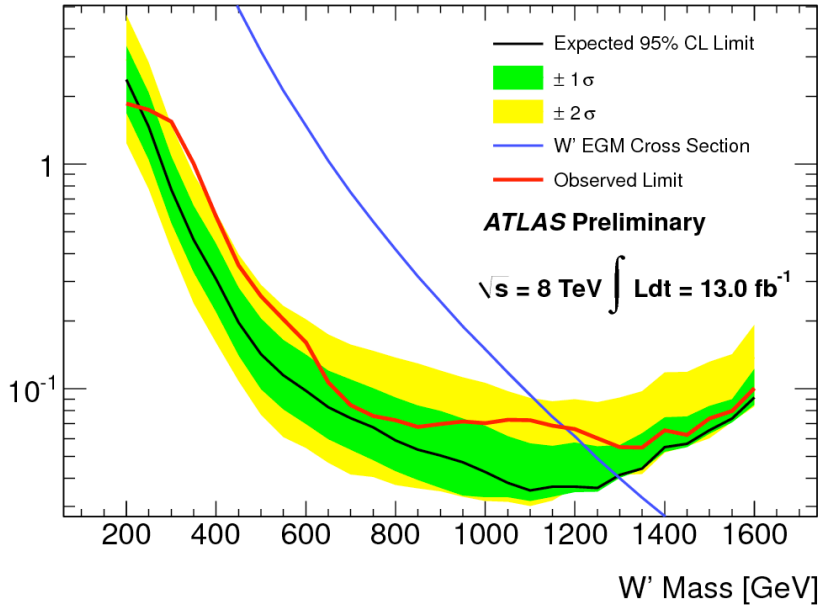
Look at *lljj* or llj final state



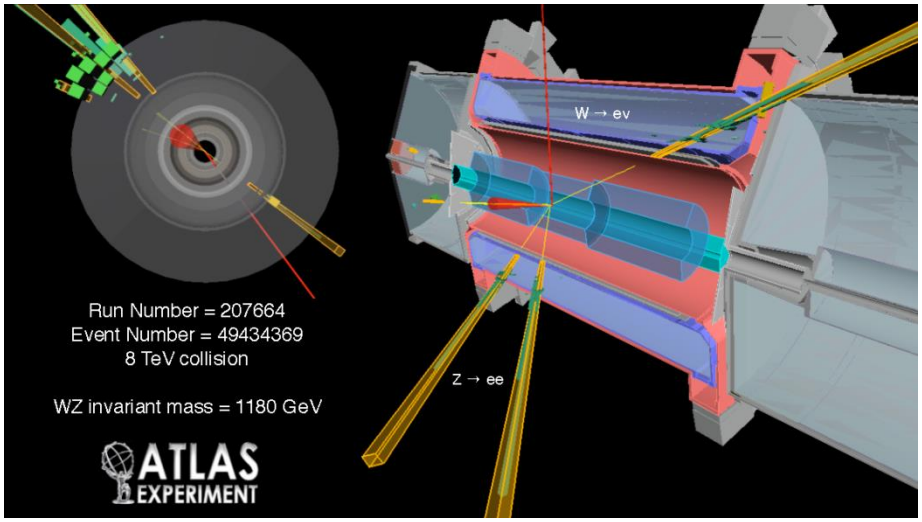



# WZ results

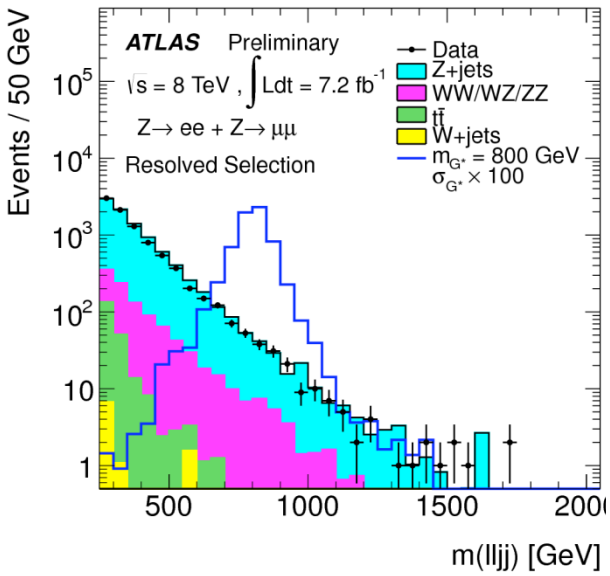


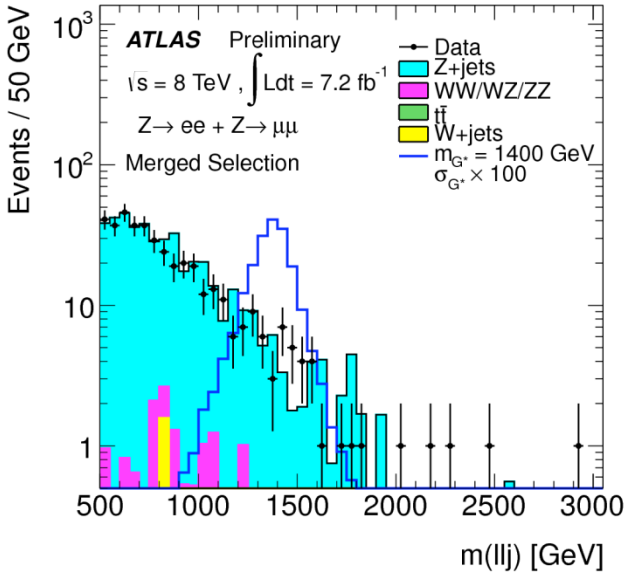



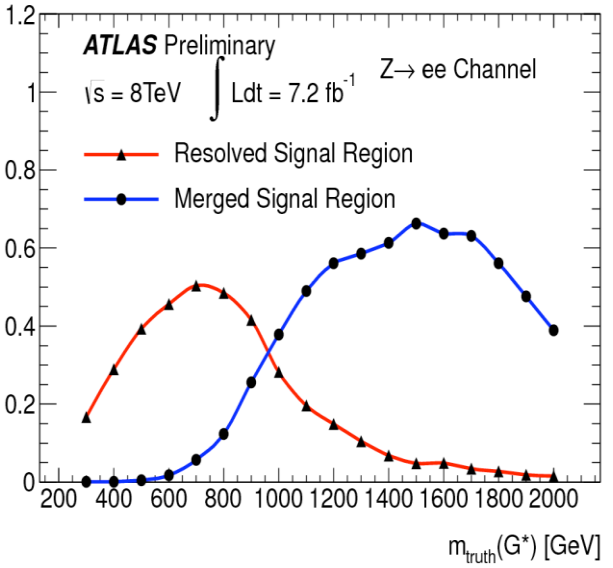

- Exclusion limit at 95% CL
- **$M_{W'}$ < 1.18 TeV**
- **$M_{\rho T}$ (technimeson)<920 GeV**

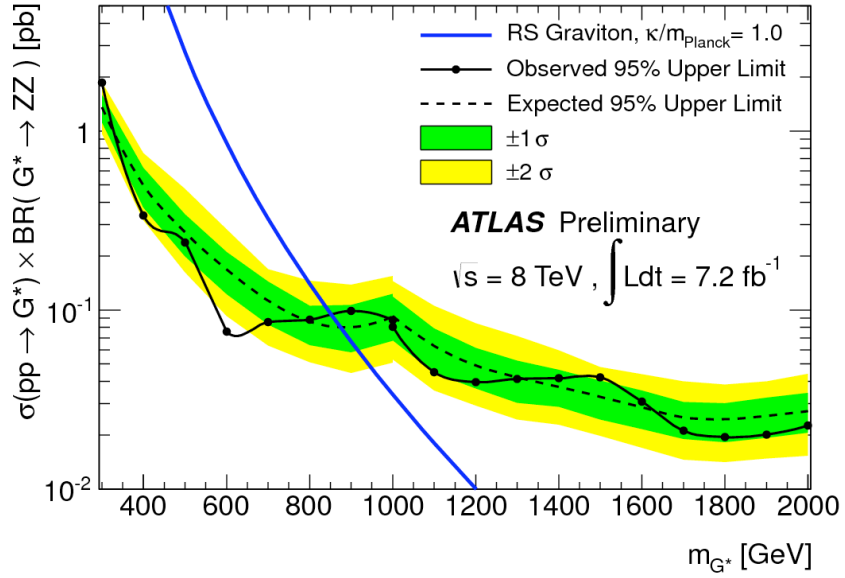


# ZZ results



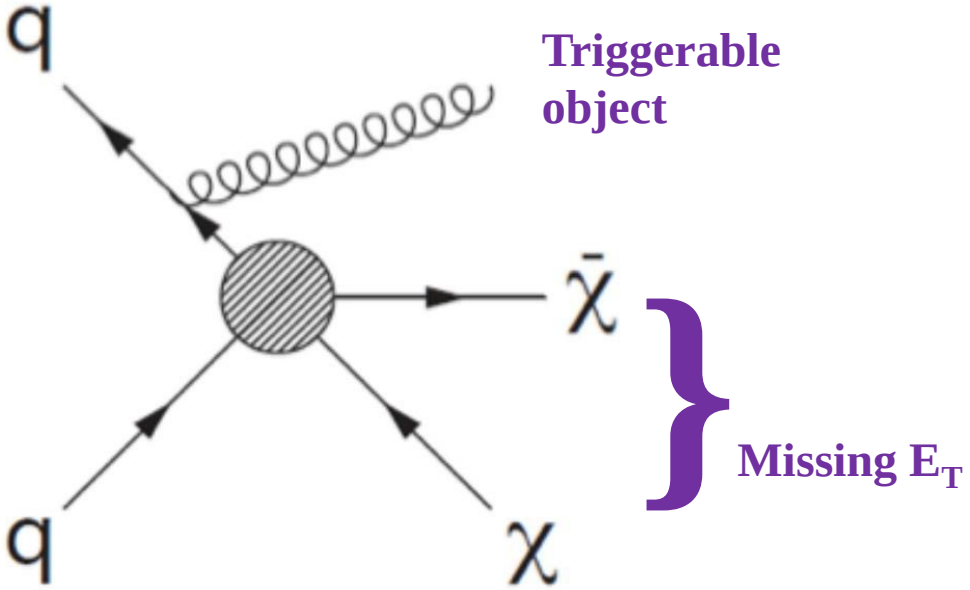




- Exclude @ 95% CL bulk RS (RS1) model (coupling parameter $k/M_{Pl}=1.0$) with $m_{G^*} < 850$ GeV

# MonoX : ATLAS-CONF-2012-147



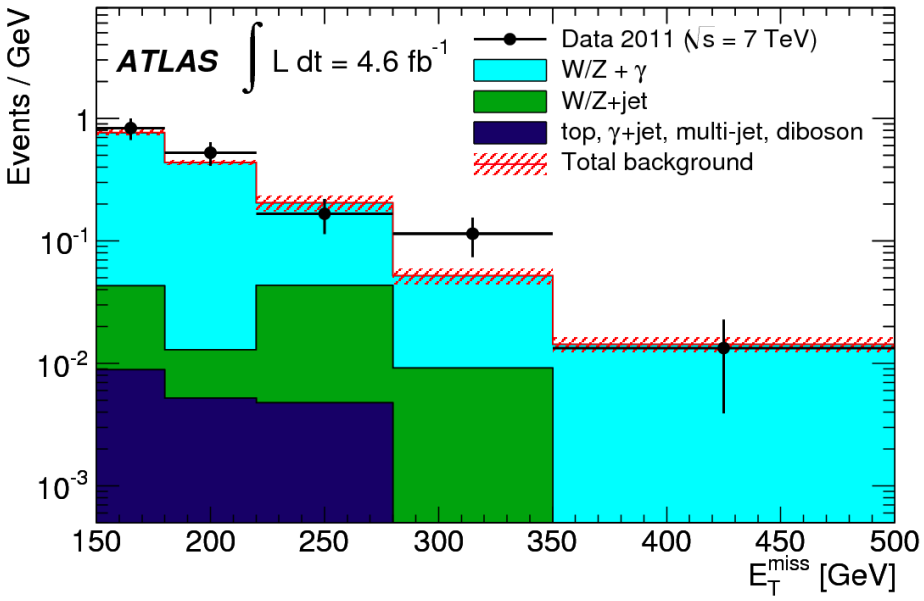

- Dark Matter particles can be produced in pp – collision at the LHC
- The Dark Matter should appear as missing energy
- Some SM particle, produced as recoil object for missing $E_T$, may be used as trigger
- Triggerable object can be jet, photon, Z, ….

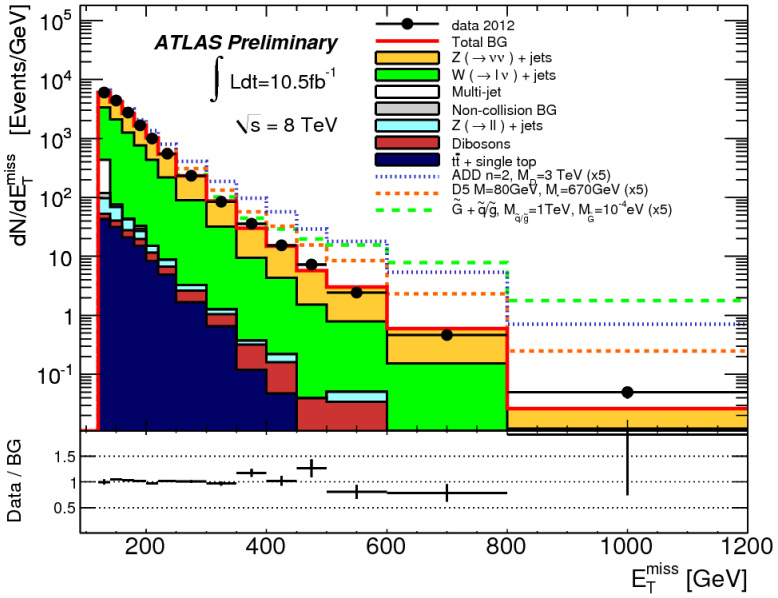
Goodman et al., Phys. Rev. D82, 116010 (2010)

- Dark Matter particles can SUSY WIMPS (neutralino and gravitino)
- EFT considers possible contact interactions of g, q producing WIMP pairs (χχ) suppressed by a mass scale *M** (i.e. intermediate particles too massive to be created directly)
- Limits on σ(pp→χχ) can be converted to elastic scattering xsection σ(χp→χp) to compare with direct searches

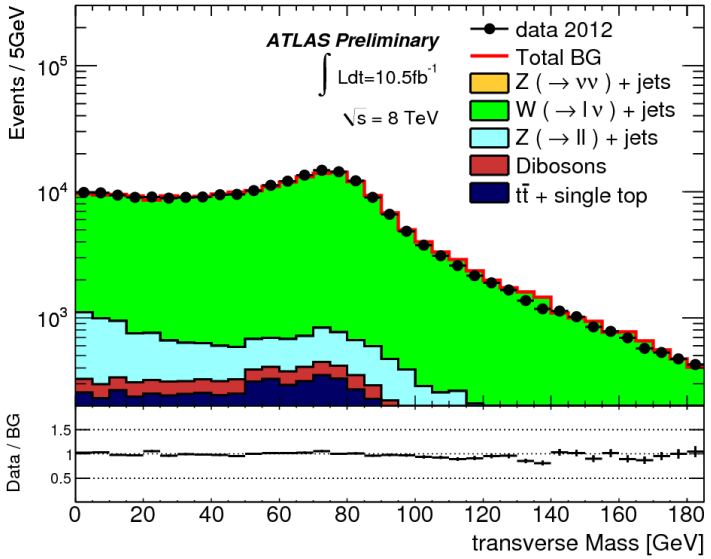
| Name | Initial state | Type | Operator |
|---|---|---|---|
| D1 | $qq$ | scalar | $\frac{m_q}{M_\star^3}\bar{\chi}\chi\bar{q}q$ |
| D5 | $qq$ | vector | $\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$ |
| D8 | $qq$ | axial-vector | $\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$ |
| D9 | $qq$ | tensor | $\frac{1}{M_\star^2}\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$ |
| D11 | $gg$ | scalar | $\frac{1}{4M_\star^3}\bar{\chi}\chi\alpha_s(G^a_{\mu\nu})^2$ |

# MonoX

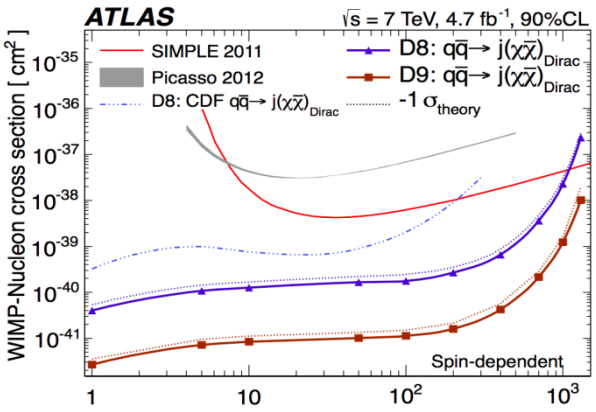


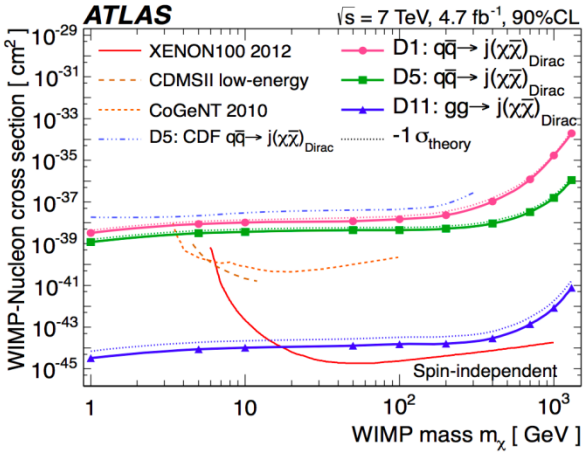




- Monophoton + $E_t^{miss}$ has one signal region due to low statistics
- Monojet + $E_t^{miss}$ has 4 signal region: $E_t^{miss}$ and jet pT large than 120, 220, 350, 500 GeV



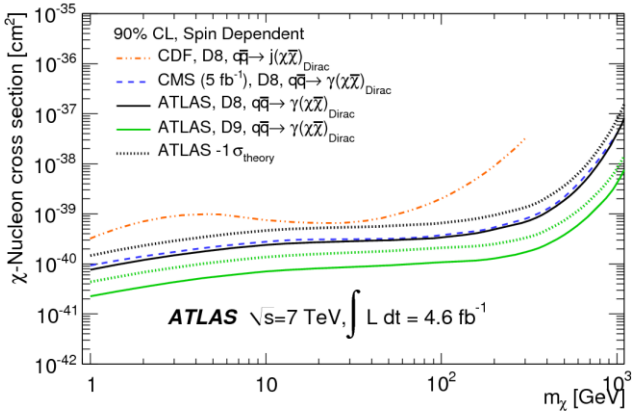
# Monojet/Monophoton + MET comparison to direct WIMP detection

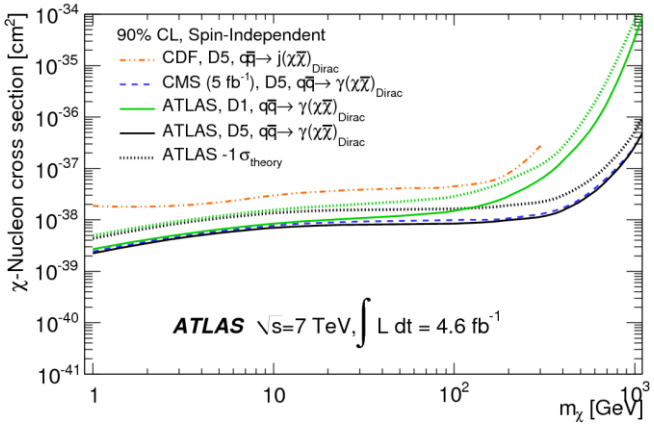



**Spin dependent**

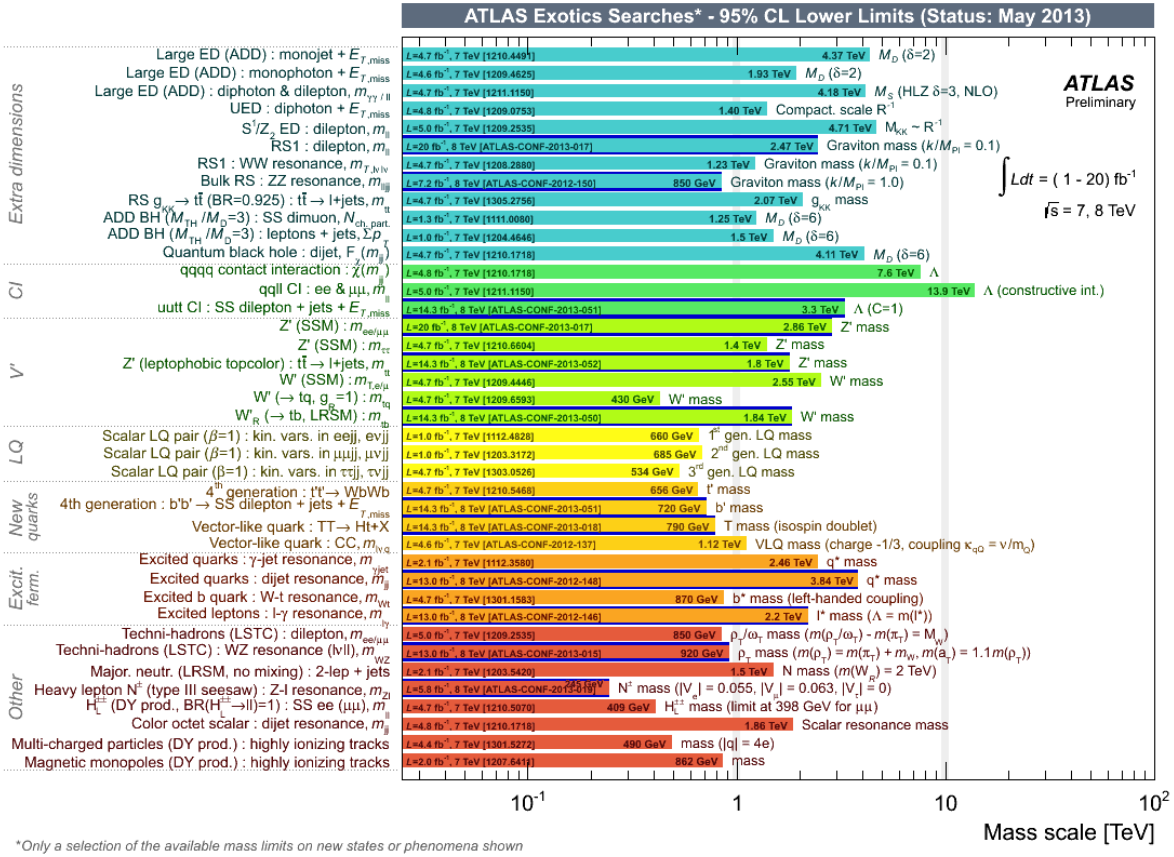
**Spin independent**




- Sensitive to low χ mass range, at $m_\chi$<10 GeV. (No kinematic suppression.)
- For some kind of interactions production search can be very competitive with direct detection.

# Recent results on Exotics Searches

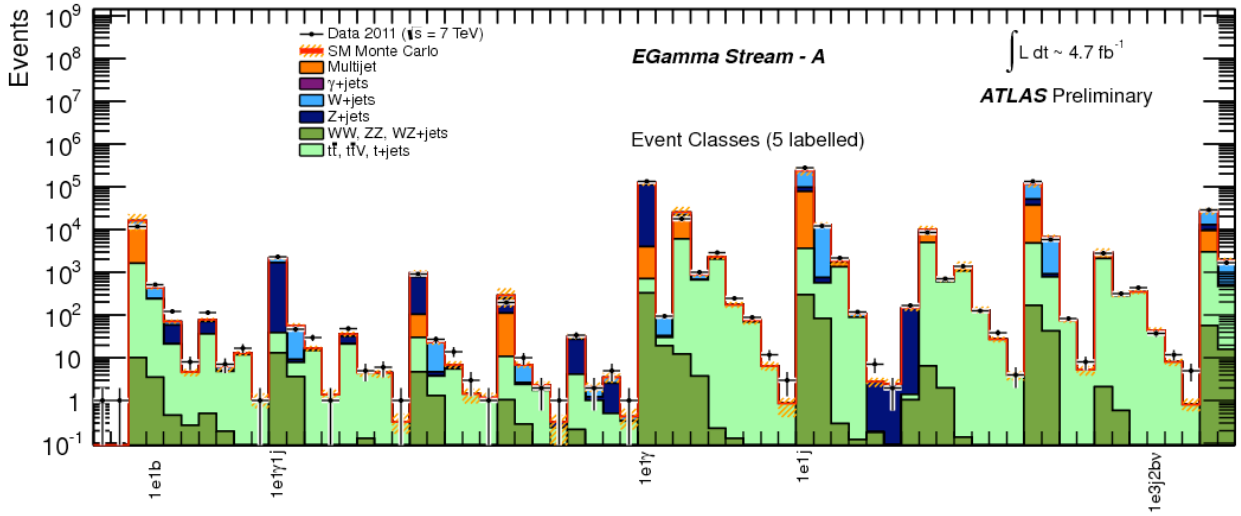


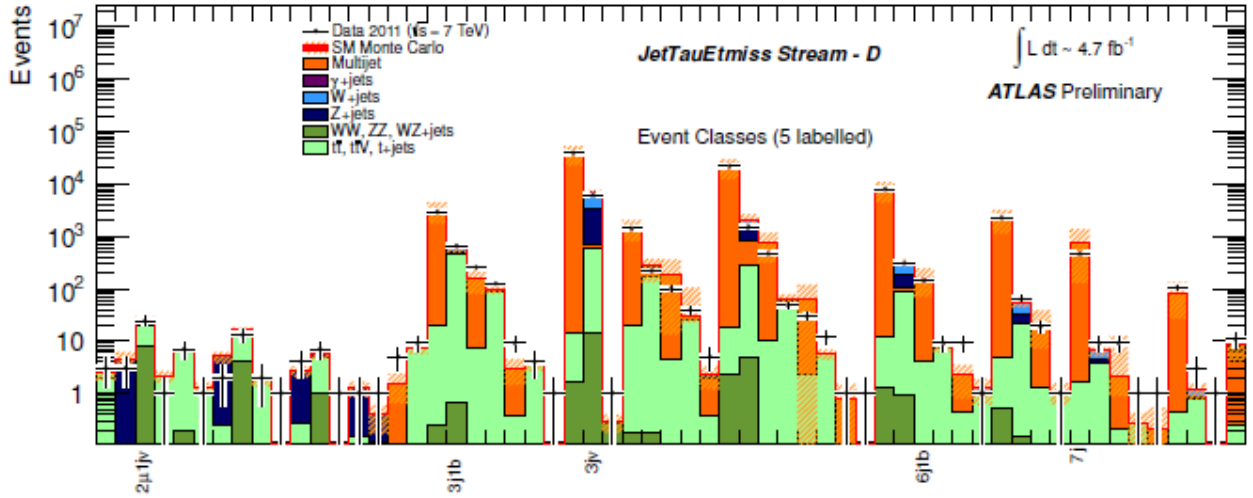

*Only a selection of the available mass limits on new states or phenomena shown

~50 Exotics analysis performed by ATLAS

Have we missed something?

# **Search everywhere:** ATLAS-CONF-2012-107




- Search in exclusive channels based on events topology (655 channels!!!)
  - No optimization
  - Model independent
- Compare with simulated backgrounds
- Check for deviation between data and SM background
  - Could manifest what to look at

# Conclusion

- **ATLAS performed as much Exotics searches as can**
- **No evidence of the New Physics yet**
- **More results on https://twiki.cern.ch/twiki/bin/view/AtlasPublic**

**Looking for but not finding is not the same as not looking**