
# The ATLAS Exotics Search Program

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UNIVERSITÉ DE GENÈVE

# Out to Catch Big Fish

# Out to Catch Big Fish

- Search wide, deep & fast
- Best fishing grounds?
  - The “theory guide” – you tell us ☺
  - Start with the classics – resonances
  - Non-standard reconstruction like highly displaced vertices take a bit langer
  - Something missing? Tell us! We need to have a trigger for it!
- Interpretation: what fish did we (not) catch

# ATLAS Exotics Searches* - 95% CL Exclusion

**ATLAS** Preliminary

Status: ICHEP 2014

$\int \mathcal{L}\, dt$ = (1.0 - 20.3) fb$^{-1}$ $\sqrt{s}$ = 7, 8 TeV

| | Model | $\ell, \gamma$ | Jets | $E_T^{miss}$ | $\int \mathcal{L}\, dt$[fb$^{-1}$] | Mass limit | | Reference |
|---|---|---|---|---|---|---|---|---|
| Extra dimensions | ADD $G_{KK} + g/q$ | – | 1-2 j | Yes | 4.7 | $M_D$ 4.37 TeV | $n = 2$ | 1210.4491 |
| | ADD non-resonant $\ell\ell$ | 2$e,\mu$ | – | – | 20.3 | $M_S$ 5.2 TeV | $n = 3$ HLZ | ATLAS-CONF-2014-030 |
| | ADD QBH $\rightarrow \ell q$ | 1 $e,\mu$ | 1 j | – | 20.3 | $M_{th}$ 5.2 TeV | $n = 6$ | 1311.2006 |
| | ADD QBH | – | 2 j | – | 20.3 | $M_{th}$ 5.82 TeV | $n = 6$ | to be submitted to PRD |
| | ADD BH high $N_{trk}$ | 2 $\mu$ (SS) | – | – | 20.3 | $M_{th}$ 5.7 TeV | $n = 6$, $M_D = 1.5$ TeV, non-rot BH | 1308.4075 |
| | ADD BH high $\sum p_T$ | $\geq 1$ $e,\mu$ | $\geq 2$ j | – | 20.3 | $M_{th}$ 6.2 TeV | $n = 6$, $M_D = 1.5$ TeV, non-rot BH | 1405.4254 |
| | RS1 $G_{KK} \rightarrow \ell\ell$ | 2 $e,\mu$ | – | – | 20.3 | $G_{KK}$ mass 2.68 TeV | $k/\overline{M}_{Pl} = 0.1$ | 1405.4123 |
| | RS1 $G_{KK} \rightarrow WW \rightarrow \ell\nu\ell\nu$ | 2 $e,\mu$ | – | Yes | 4.7 | $G_{KK}$ mass 1.23 TeV | $k/\overline{M}_{Pl} = 0.1$ | 1208.2880 |
| | Bulk RS $G_{KK} \rightarrow ZZ \rightarrow \ell\ell qq$ | 2 $e,\mu$ | 2 j / 1 J | – | 20.3 | $G_{KK}$ mass 730 GeV | $k/\overline{M}_{Pl} = 1.0$ | ATLAS-CONF-2014-039 |
| | Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$ | – | 4 b | – | 19.5 | $G_{KK}$ mass 590-710 GeV | $k/\overline{M}_{Pl} = 1.0$ | ATLAS-CONF-2014-005 |
| | Bulk RS $g_{KK} \rightarrow t\bar{t}$ | 1 $e,\mu$ | $\geq 1$ b, $\geq$ 1J/2j | Yes | 14.3 | $g_{KK}$ mass 2.0 TeV | BR = 0.925 | ATLAS-CONF-2013-052 |
| | $S^1/Z_2$ ED | 2 $e,\mu$ | – | – | 5.0 | $M_{KK} \approx R^{-1}$ 4.71 TeV | | 1209.2535 |
| | UED | 2 $\gamma$ | – | Yes | 4.8 | Compact. scale $R^{-1}$ 1.41 TeV | | ATLAS-CONF-2012-072 |
| Gauge bosons | SSM $Z' \rightarrow \ell\ell$ | 2 $e,\mu$ | – | – | 20.3 | $Z'$ mass 2.9 TeV | | 1405.4123 |
| | SSM $Z' \rightarrow \tau\tau$ | 2 $\tau$ | – | – | 19.5 | $Z'$ mass 1.9 TeV | | ATLAS-CONF-2013-066 |
| | SSM $W' \rightarrow \ell\nu$ | 1 $e,\mu$ | – | Yes | 20.3 | $W'$ mass 3.28 TeV | | ATLAS-CONF-2014-017 |
| | EGM $W' \rightarrow WZ \rightarrow \ell\nu\,\ell'\ell'$ | 3 $e,\mu$ | – | Yes | 20.3 | $W'$ mass 1.52 TeV | | 1406.4456 |
| | EGM $W' \rightarrow WZ \rightarrow qq\ell\ell$ | 2 $e,\mu$ | 2 j / 1 J | – | 20.3 | $W'$ mass 1.59 TeV | | ATLAS-CONF-2014-039 |
| | LRSM $W'_R \rightarrow t\bar{b}$ | 1 $e,\mu$ | 2 b, 0-1 j | Yes | 14.3 | $W'$ mass 1.84 TeV | | ATLAS-CONF-2013-050 |
| | LRSM $W'_R \rightarrow t\bar{b}$ | 0 $e,\mu$ | $\geq 1$ b, 1 J | – | 20.3 | $W'$ mass 1.77 TeV | | to be submitted to EPJC |
| CI | CI $qqqq$ | – | 2 j | – | 4.8 | $\Lambda$ 7.6 TeV | $\eta = +1$ | 1210.1718 |
| | CI $qq\ell\ell$ | 2 $e,\mu$ | – | – | 20.3 | $\Lambda$ 21.6 TeV | $\eta_{LL} = -1$ | ATLAS-CONF-2014-030 |
| | CI $uutt$ | 2 $e,\mu$ (SS) | $\geq 1$ b, $\geq 1$ j | Yes | 14.3 | $\Lambda$ 3.3 TeV | $\|C\| = 1$ | ATLAS-CONF-2013-051 |
| DM | EFT D5 operator (Dirac) | 0 $e,\mu$ | 1-2 j | Yes | 10.5 | $M_*$ 731 GeV | at 90% CL for $m(\chi) < 80$ GeV | ATLAS-CONF-2012-147 |
| | EFT D9 operator (Dirac) | 0 $e,\mu$ | 1 J, $\leq 1$ j | Yes | 20.3 | $M_*$ 2.4 TeV | at 90% CL for $m(\chi) < 100$ GeV | 1309.4017 |
| LQ | Scalar LQ 1$^{st}$ gen | 2 $e$ | $\geq 2$ j | – | 1.0 | LQ mass 660 GeV | $\beta = 1$ | 1112.4828 |
| | Scalar LQ 2$^{nd}$ gen | 2 $\mu$ | $\geq 2$ j | – | 1.0 | LQ mass 685 GeV | $\beta = 1$ | 1203.3172 |
| | Scalar LQ 3$^{rd}$ gen | 1 $e,\mu$, 1 $\tau$ | 1 b, 1 j | – | 4.7 | LQ mass 534 GeV | $\beta = 1$ | 1303.0526 |
| Heavy quarks | Vector-like quark $TT \rightarrow Ht + X$ | 1 $e,\mu$ | $\geq 2$ b, $\geq 4$ j | Yes | 14.3 | T mass 790 GeV | T in (T,B) doublet | ATLAS-CONF-2013-018 |
| | Vector-like quark $TT \rightarrow Wb + X$ | 1 $e,\mu$ | $\geq 1$ b, $\geq 3$ j | Yes | 14.3 | T mass 670 GeV | isospin singlet | ATLAS-CONF-2013-060 |
| | Vector-like quark $TT \rightarrow Zt + X$ | 2/$\geq$3 $e,\mu$ | $\geq$2/$\geq$1 b | – | 20.3 | T mass 735 GeV | T in (T,B) doublet | ATLAS-CONF-2014-036 |
| | Vector-like quark $BB \rightarrow Zb + X$ | 2/$\geq$3 $e,\mu$ | $\geq$2/$\geq$1 b | – | 20.3 | B mass 755 GeV | B in (B,Y) doublet | ATLAS-CONF-2014-036 |
| | Vector-like quark $BB \rightarrow Wt + X$ | 2 $e,\mu$ (SS) | $\geq 1$ b, $\geq 1$ j | Yes | 14.3 | B mass 720 GeV | B in (T,B) doublet | ATLAS-CONF-2013-051 |
| Excited fermions | Excited quark $q^* \rightarrow q\gamma$ | 1 $\gamma$ | 1 j | – | 20.3 | $q^*$ mass 3.5 TeV | only $u^*$ and $d^*$, $\Lambda = m(q^*)$ | 1309.3230 |
| | Excited quark $q^* \rightarrow qg$ | – | 2 j | – | 20.3 | $q^*$ mass 4.09 TeV | only $u^*$ and $d^*$, $\Lambda = m(q^*)$ | to be submitted to PRD |
| | Excited quark $b^* \rightarrow Wt$ | 1 or 2 $e,\mu$ | 1 b, 2 j or 1 j | Yes | 4.7 | $b^*$ mass 870 GeV | left-handed coupling | 1301.1583 |
| | Excited lepton $\ell^* \rightarrow \ell\gamma$ | 2 $e,\mu$, 1 $\gamma$ | – | – | 13.0 | $\ell^*$ mass 2.2 TeV | $\Lambda = 2.2$ TeV | 1308.1364 |
| Other | LSTC $a_T \rightarrow W\gamma$ | 1 $e,\mu$, 1 $\gamma$ | – | Yes | 20.3 | $a_T$ mass 960 GeV | | to be submitted to PLB |
| | LRSM Majorana $\nu$ | 2 $e,\mu$ | 2 j | – | 2.1 | $N^0$ mass 1.5 TeV | $m(W_R) = 2$ TeV, no mixing | 1203.5420 |
| | Type III Seesaw | 2 $e,\mu$ | – | – | 5.8 | $N^\pm$ mass 245 GeV | $\|V_e\|$=0.055, $\|V_\mu\|$=0.063, $\|V_\tau\|$=0 | ATLAS-CONF-2013-019 |
| | Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$ | 2 $e,\mu$ (SS) | – | – | 4.7 | $H^{\pm\pm}$ mass 409 GeV | DY production, BR($H^{\pm\pm} \rightarrow \ell\ell$)=1 | 1210.5070 |
| | Multi-charged particles | – | – | – | 4.4 | multi-charged particle mass 490 GeV | DY production, $\|q\| = 4e$ | 1301.5272 |
| | Magnetic monopoles | – | – | – | 2.0 | monopole mass 862 GeV | DY production, $\|g\| = 1g_D$ | 1207.6411 |

$\sqrt{s}$ = 7 TeV $\sqrt{s}$ = 8 TeV

$10^{-1}$ 1 10 **Mass scale [TeV]**

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

# https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

## Results based on the 8 TeV 2012 Data Taking Period

***Papers with 2012 data***

| Title | Journal | Papers and Plots | Int. luminosity | Date |
|---|---|---|---|---|
| Search for long-lived neutral particles decaying into lepton jets in proton-proton collisions at √s = 8 TeV with the ATLAS detector NEW! | Submitted to JHEP | Plots and more Info; arXiv:1409.0746 | 20.3/fb | Sep 2014 |
| Search for the lepton flavor violating decay Z→eμ in pp collisions at √s = 8 TeV with the ATLAS detector NEW! | Submitted to PRD | Plots and more Info; arXiv:1408.5774 | 20.3/fb | Aug 2014 |
| Search for W' → tb → qq'bb decays in pp collisions at √s = 8 TeV with the ATLAS detector NEW! | Submitted to EPJC | Plots and more Info; arXiv:1408.0886 | 20.3/fb | Aug 2014 |
| Search for new resonances in Wγ and Zγ final states in pp collisions at √s = 8 TeV with the ATLAS detector NEW! | Submitted to PLB | Plots and more Info; arXiv:1407.8150 | 20.3/fb | July 2014 |
| Search for new particles in events with one lepton and missing transverse momentum in pp collisions at √s = 8 TeV with the ATLAS detector NEW! | Published in JHEP | Plots and more Info; arXiv:1407.7494; JHEP 09 (2014) 037 | 20.3/fb | July 2014 |
| Search for contact interactions and large extra dimensions in the dilepton channel using proton-proton collisions at √s = 8 TeV with the ATLAS detector NEW! | Submitted to EPJC | Plots and more Info; arXiv:1407.2410 | 20.3/fb | July 2014 |
| Search for new phenomena in the dijet mass distribution using pp collision data at √s=8 TeV with the ATLAS detector NEW! | Submitted to PRD | Plots and more Info; arXiv:1407.1376 | 20.3/fb | July 2014 |
| Search for WZ resonances in the fully leptonic channel using pp collisions at √s = 8 TeV with the ATLAS detector | Published in PLB | Plots and more Info; arXiv:1406.4456; PLB 737, 223 (2014) | 20.3/fb | June 2014 |
| Search for microscopic black holes and string balls in final states with leptons and jets with the ATLAS detector at √s = 8 TeV | Published in JHEP | Plots and more Info; arXiv:1405.4254; JHEP 08 (2014) 103 | 20.3/fb | May 2014 |
| Search for high-mass dilepton resonances in pp collisions at √s = 8 TeV with the ATLAS detector | Accepted by PRD | Plots and more Info; arXiv:1405.4123 | 20.3/fb | May 2014 |
| Search for dark matter in events with a Z boson and missing transverse momentum in pp collisions at √s = 8 TeV with the ATLAS detector | Published in PRD | Plots and more Info; arXiv:1404.0051; PRD 90, 012004 (2014) | 20.3/fb | April 2014 |
| Search for quantum black-hole production in high-invariant-mass lepton+jet final states using proton-proton collisions at √s = 8 TeV and the ATLAS detector | Published in PRL | Plots and more Info; arXiv:1311.2006; PRL 112, 091804 (2014) | 20.3/fb | November 2013 |
| Search for dark matter in events with a hadronically decaying W or Z boson and missing transverse momentum in pp collisions at √s =8 TeV with the ATLAS detector | Published in PRL | Plots and more Info; arXiv:1309.4017; PRL 112, 041802 (2014) | 20.3/fb | September 2013 |

# Philosophy of Exotics Searches

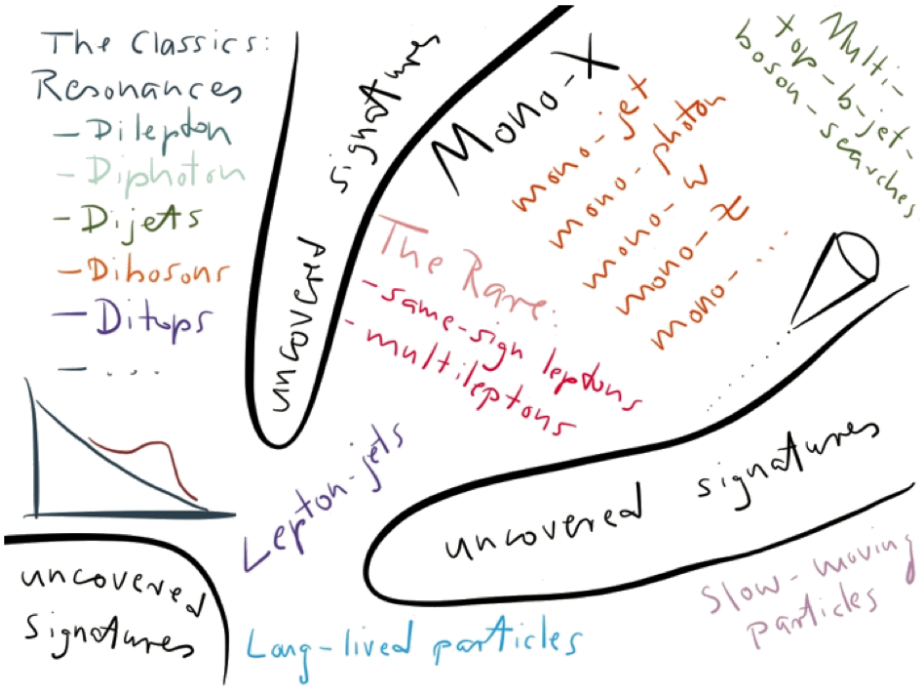
- **Motivation**: problems / open questions of the SM
  - Naturalness
  - DM
  - Higgs = SM Higgs?
  - Neutrino mass, Baryogenesis,…
  - SM ≠ "final theory" (Mass spectrum, Flavor mixing,…)
- Theorists' solution: **models**
  - Composite Higgs
  - ED
  - WIMPs
  - Hidden Sector, Exotic Higgs decays
  - LFV, technicolor, TeV gravity,…
- Interface with experimentalists: **signatures**
  - Resonances: Z', W', $g_{KK}$, "Mono-X",…
  - Pair-production: VLQs, LQs,…
  - Unconventional signatures: Exotic Higgs decays,…
  - Experimentalists' contribution: stay agnostic: fully exploit LHC's energy & lumi
- Connect back with theorists: **interpret results using benchmark models**
  - Which model to pick? One vs. many?
- For discovery most important: **are we missing a signature?**

# Exotics Philosophy

(Hitoshi Murayama)

# (Simplified) Model- vs Signature-Based

(Hitoshi Murayama)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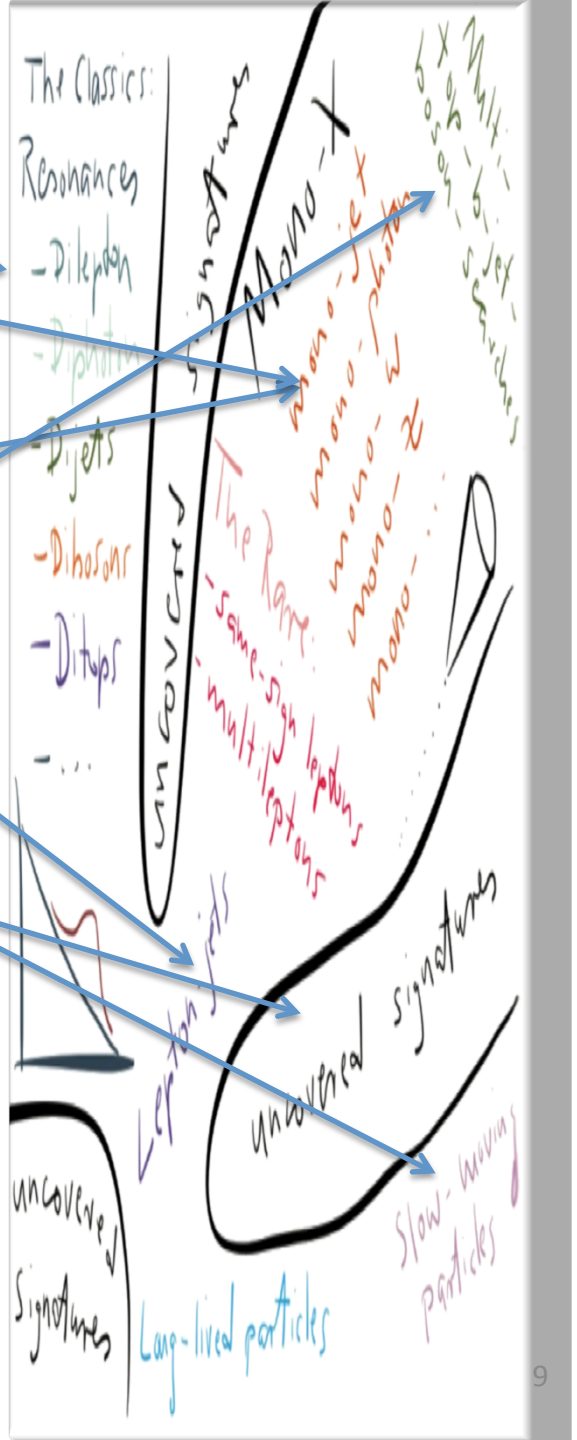
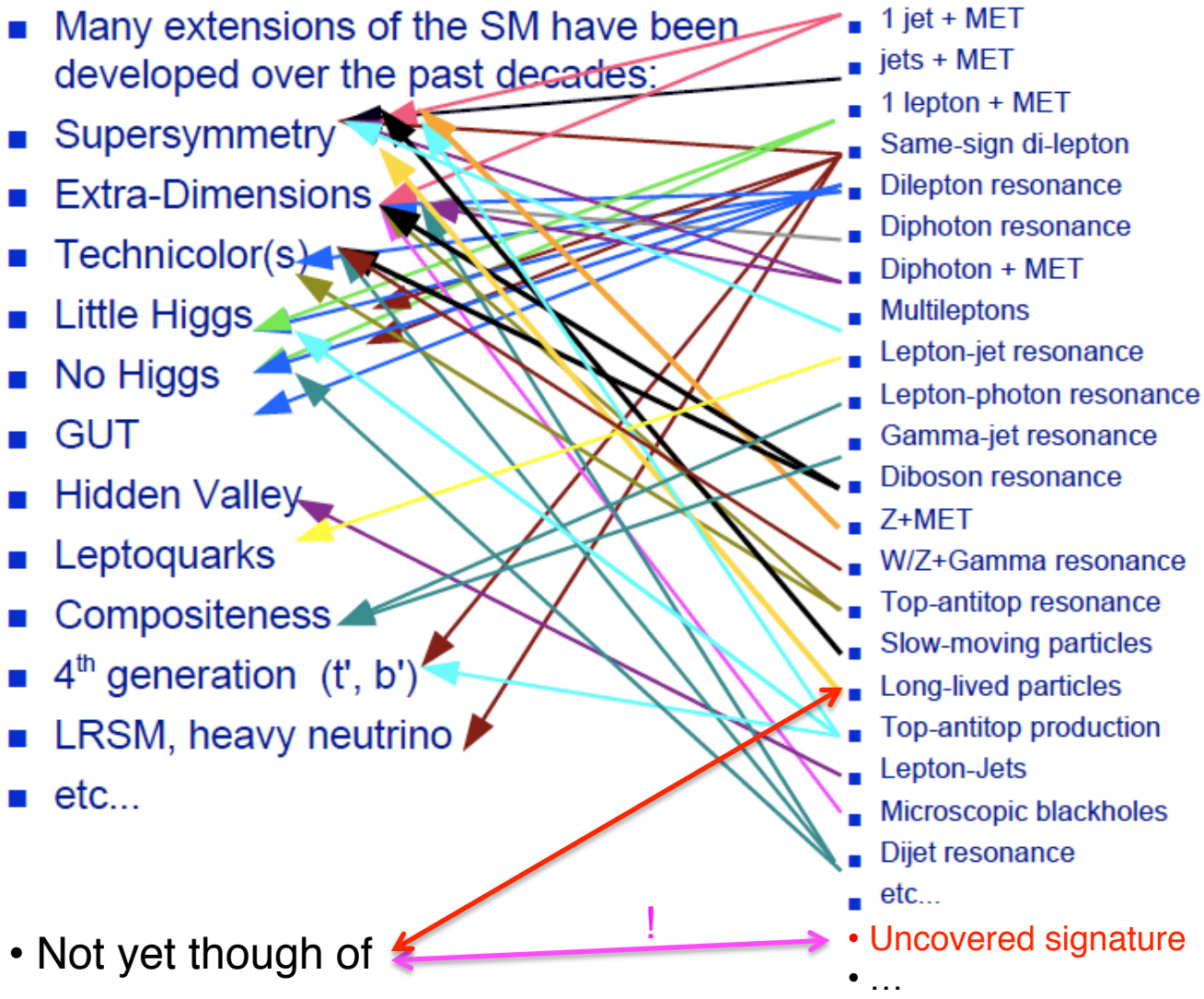

The Classics:
Resonances
-Dileptons
-Diphotons
-Dijets
-Dibosons
-Ditops
-...
unconvered signatures
Mono-X
Mono-jet
Mono-photon
Mono-W
Mono-Z
Mono-...
The Rare:
-Same-sign leptons
-Multileptons
-...
Certain jets
unconvered signatures
Slow-moving particles
uncovered signatures
Long-lived particles

# Signature-Driven Searches




(Henri Bachacou)

# What do we spend all our time on?

- Understanding the detector & squeeze out best performance
- Trigger design & tests
- Physics object reconstruction, calibration,…
  - Isolation (e.g. in boosted objects)
  - Substructure: boosted top/W/Z/H tagging
  - Unconventional signatures: highly displaced vertices, Exotic tracking, lepton-jets,…
- Benchmark MC model validation / production
- Analysis optimization
- Estimation of SM BG, often data-driven
- Assess systematic uncertainties
  - Experimental
  - Theory
- Present results à la limits on cross section * BR
- Interpret results: limits on parameters of benchmark model(s)

# Resonances – Experimenters' View

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
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- γ


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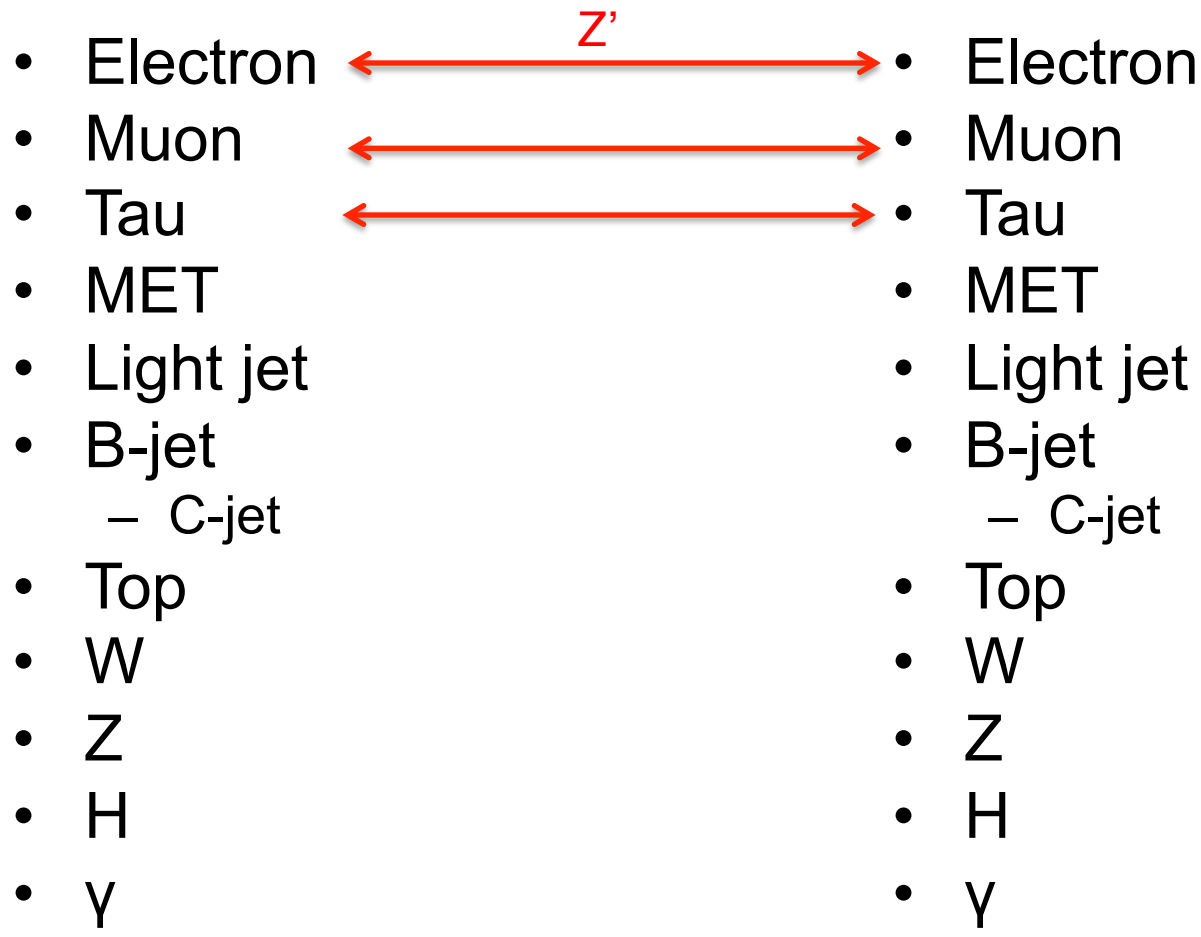
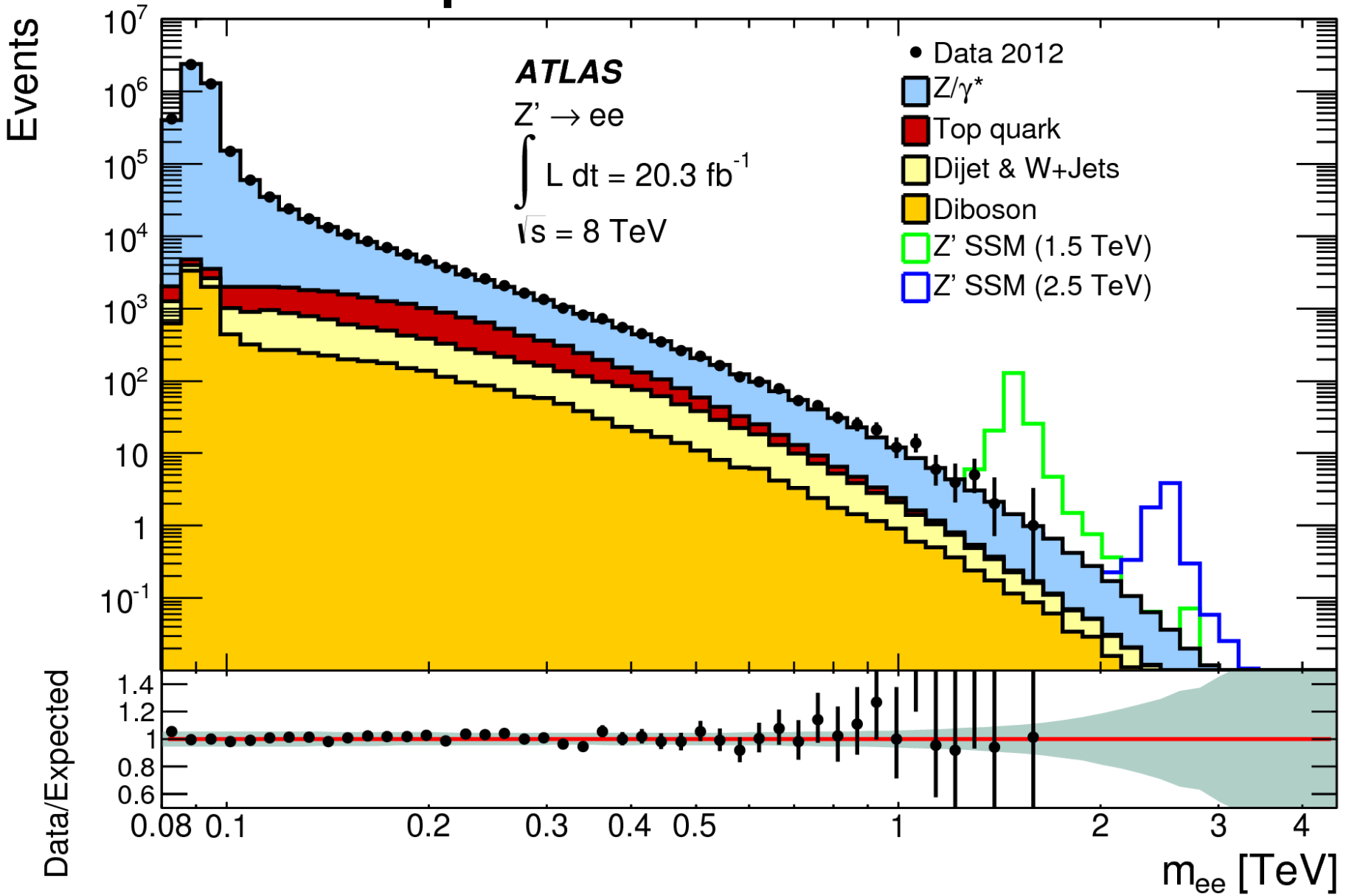
# Resonances – Experimenters' View



# Dilepton Resonances



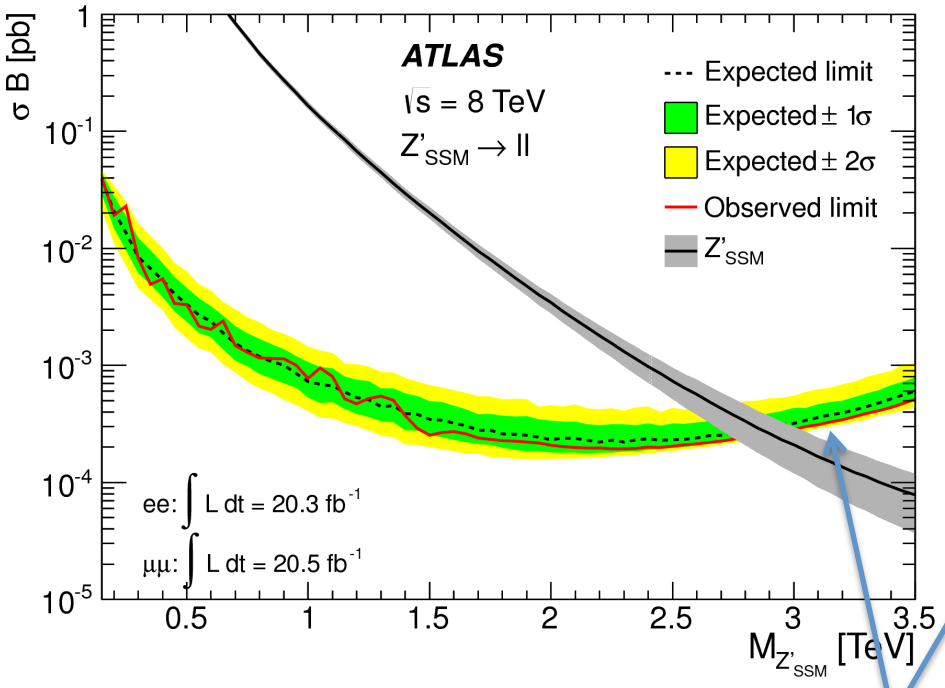

[1405.4123]

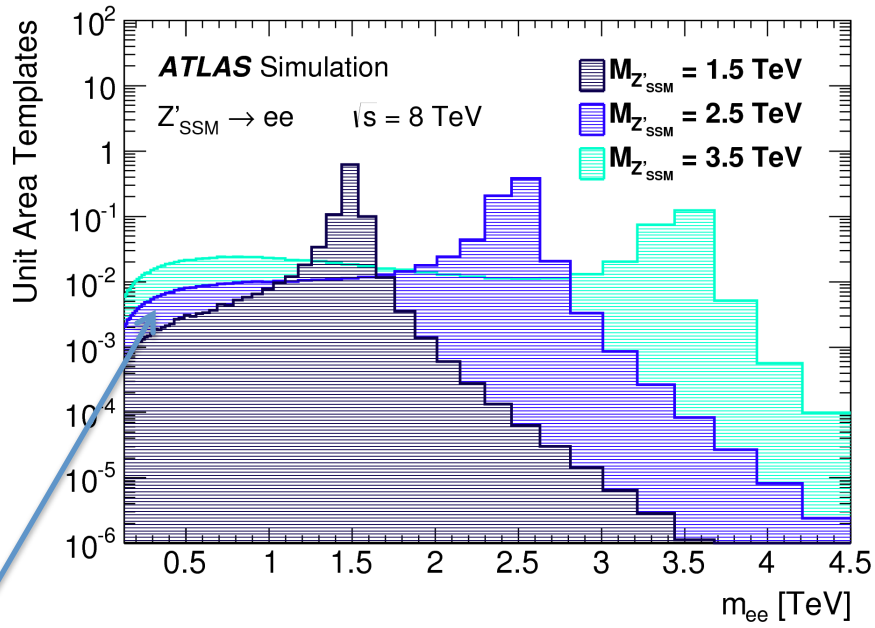
# Limit Setting

Upper limit (95% CL) on σB

Lower mass limit (95% CL) on $Z'_{SSM}$ is 2.79 TeV (2.9 TeV when combined with muons)

Limits set using MC templates taking into account actual signal shape on reconstruction level:



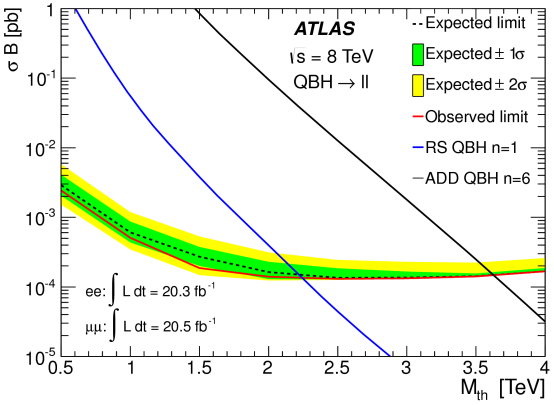

Could go less model-dependent:
Fiducial cross section limit

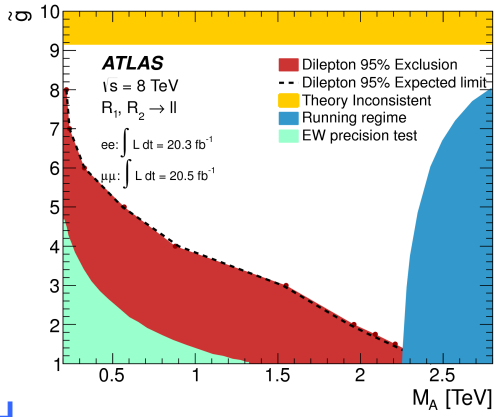
Large off-shell production

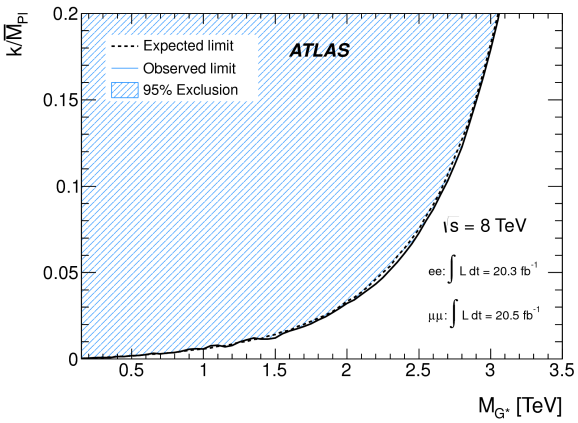
- Limit degrades for high masses
- Time for higher beam energy!

[1405.4123]

# Benchmark Interpretation



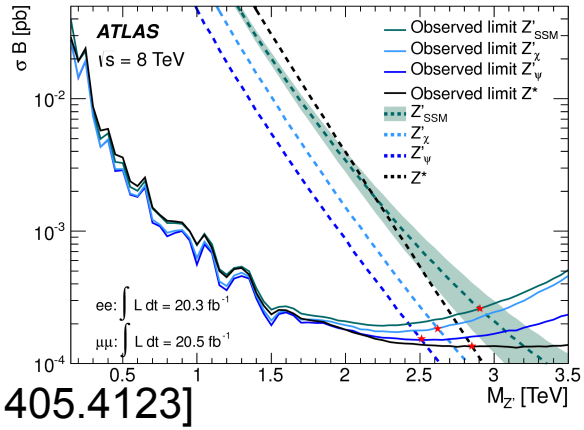



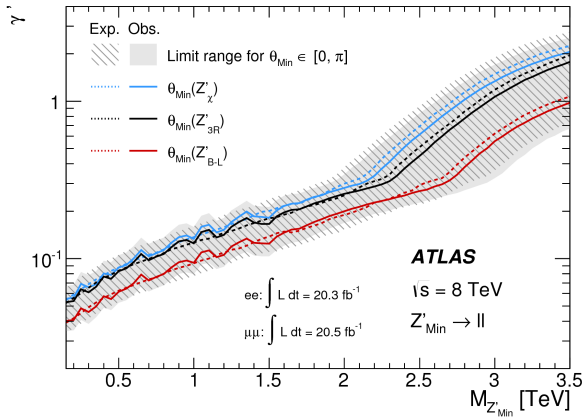

- Extra Dimensions QBH
- Technicolor
- GUT
- Z*
- Z'$_{SSM}$
- E6
- …

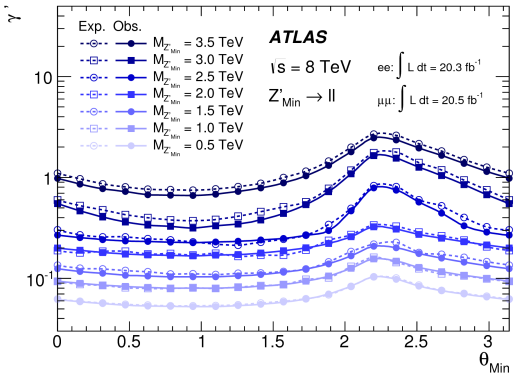
- Dilepton resonance

How many is enough?




[1405.4123]



# Different Benchmark Interpretations

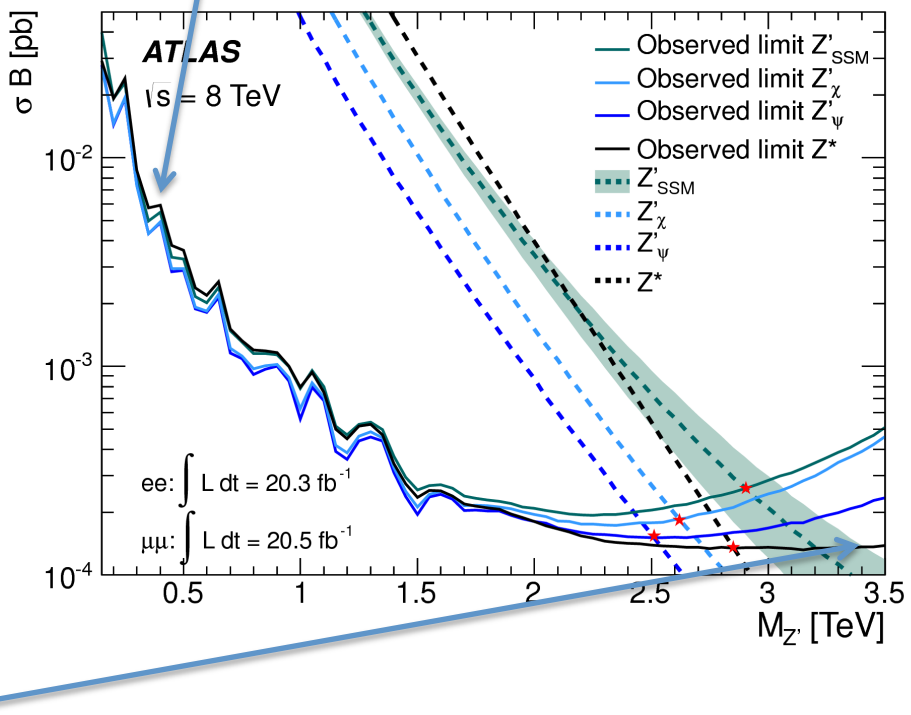
Additional neutral gauge bosons:

- $Z'_{SSM}$
- E6 $Z'_{\chi}$ and $Z'_{\psi}$, GUT motivated
- Z*, appear as doublet (Z*,W*) in various solutions to hierarchy problem, anomalous couplings to fermions

| Model | Width [%] |
|---|---|
| $Z'_{SSM}$ | 3.0 |
| $Z'_{\chi}$ | 1.2 |
| $Z'_{\psi}$ | 0.5 |
| $Z^*$ | 3.4 |

Low mass:

- Limits get stronger with decreasing width, but effect small…




High mass:

- Off-shell production leads to weaker limits
- Off-shell production increases with increasing width
- No off-shell production in Z*

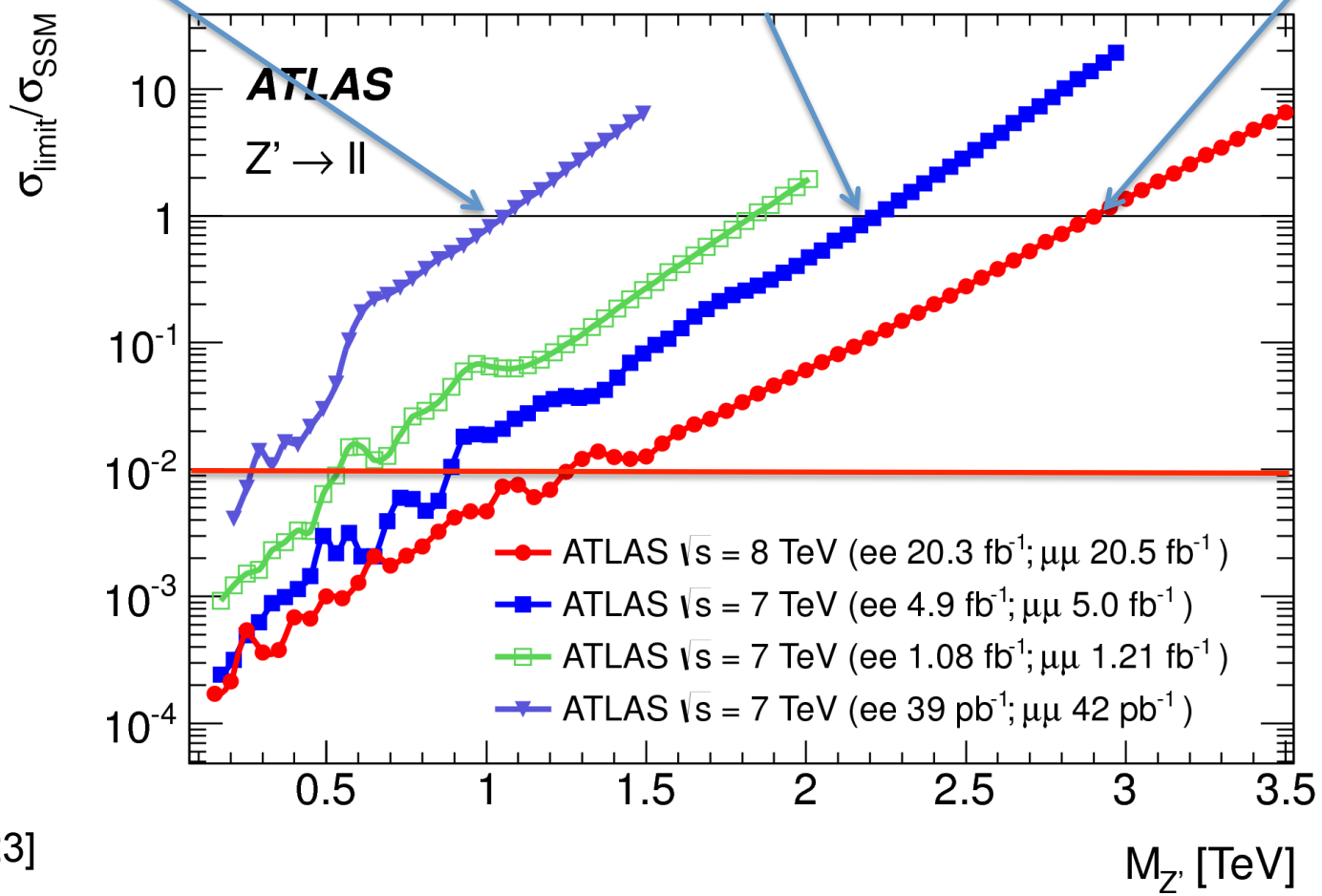
[1405.4123]

# Development Over Years

Tevatron limits (approx. 1 TeV) reached with 2010 data

2012 data → 2.9 TeV limit

2011 data → 2.2 TeV limit



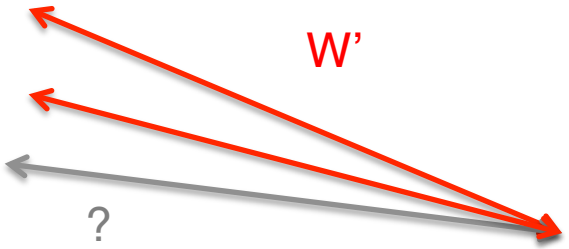

[1405.4123]

Fast increase in limits (1 TeV → 3 TeV) in short period of time

Also, narrow resonances with 100 times smaller cross section than SSM excluded up to 1.4 TeV

# Resonances – Experimenters' View

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

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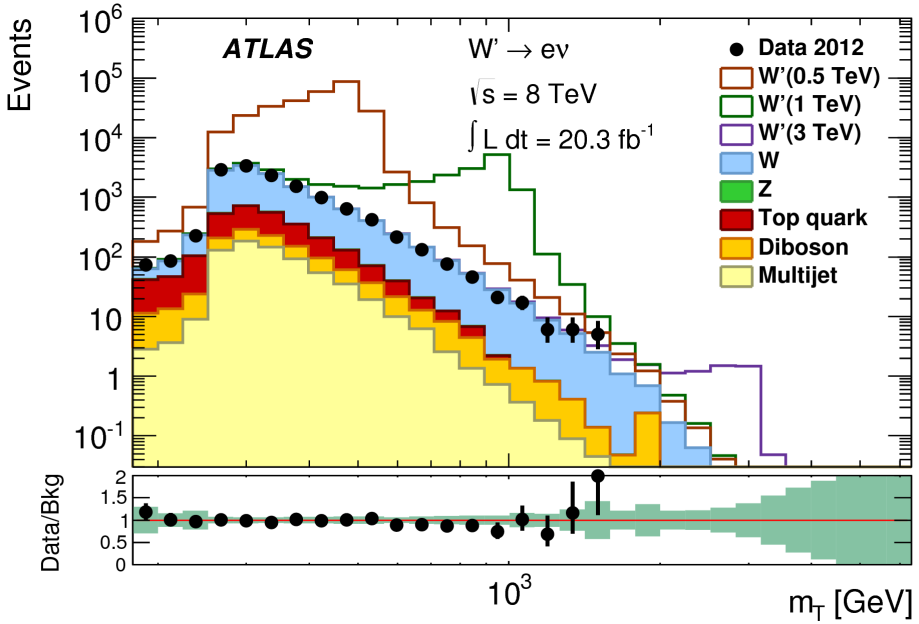
# Lepton+$E_T$miss Resonance Search

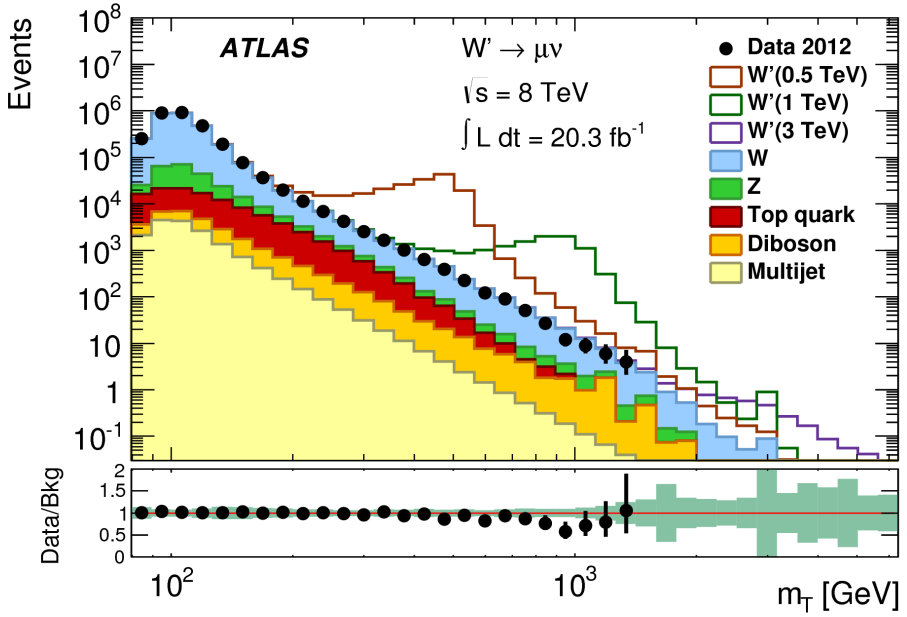
Charged (spin-1) gauge bosons:

- $W'_{SSM}$, same couplings as W
- W*, appear as doublet (Z*,W*), anomalous couplings to fermions

Also mono-W reinterpretation

$$m_T = \sqrt{2 p_T E_T^{miss} (1 - \cos \varphi_{\ell\nu})}$$




- EW backgrounds from MC
- Multijet BG from data driven matrix-method

[JHEP09(2014)037, 1407.7494]

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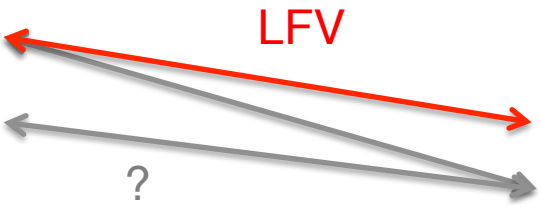


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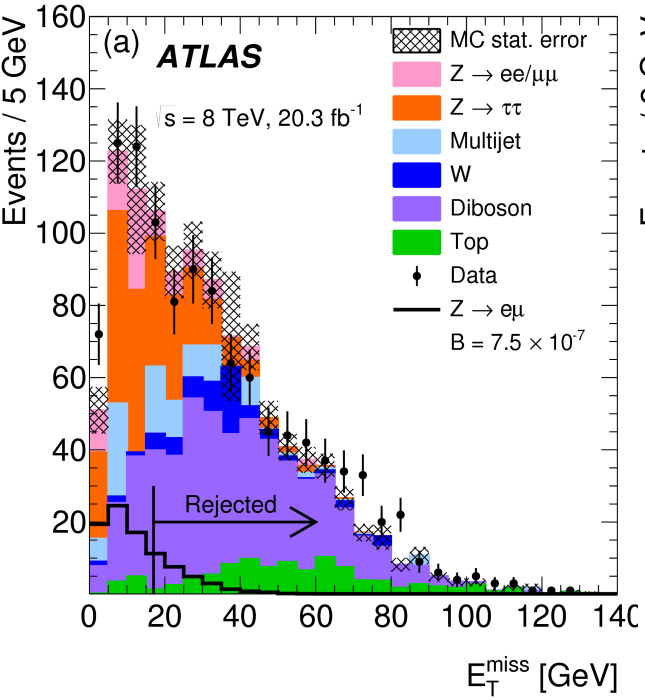
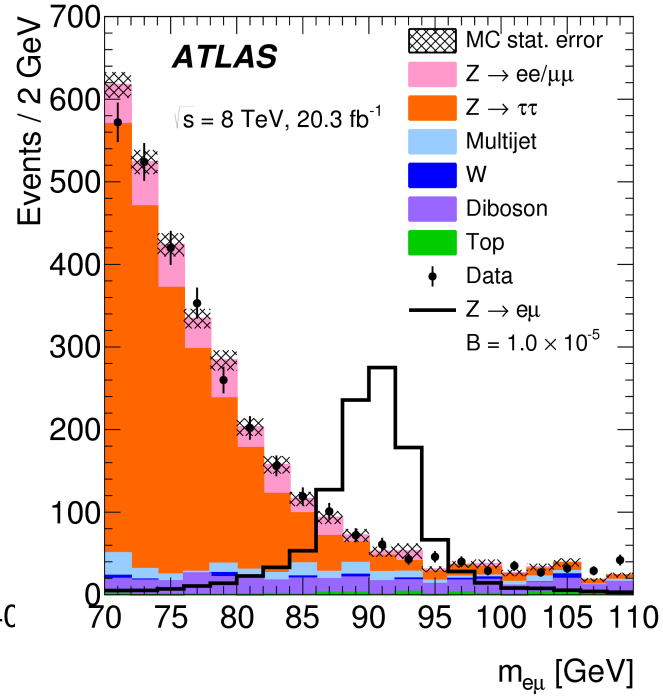
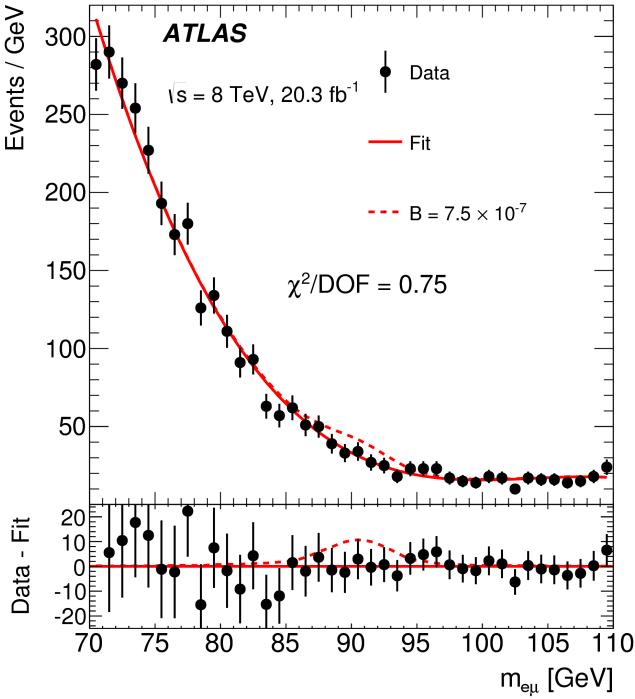
# Lepton Flavor Violation

$$\mathcal{B}(Z \rightarrow e\mu) < 7.5 \times 10^{-7}$$ (more than factor of 2 better than LEP)

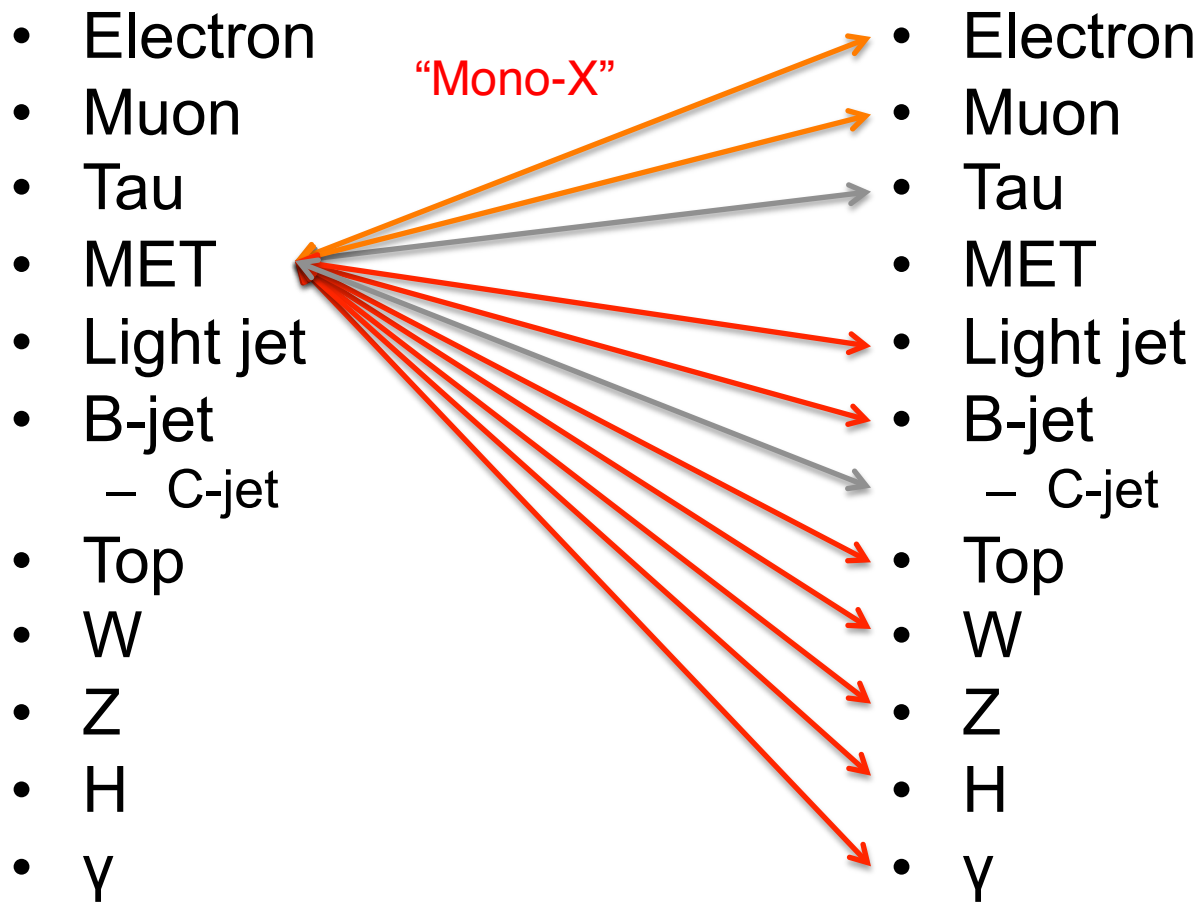


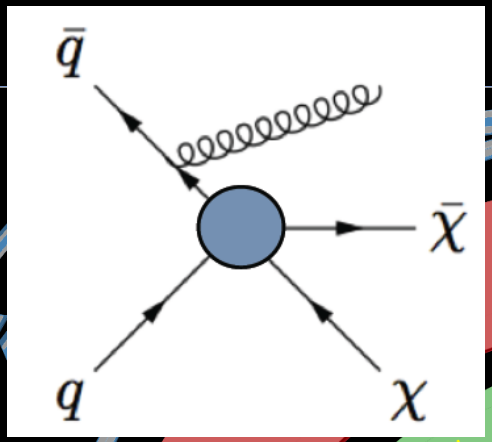



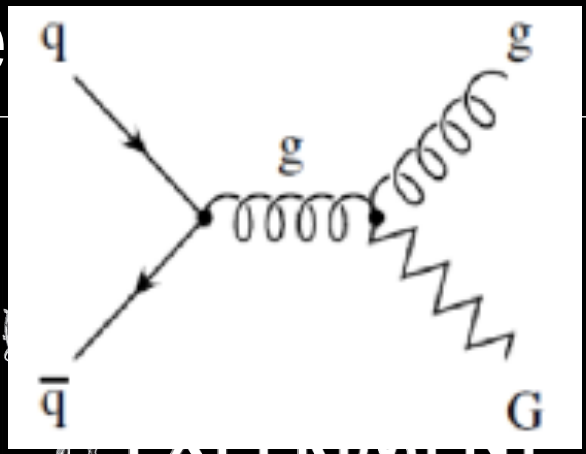

[1408.5774]

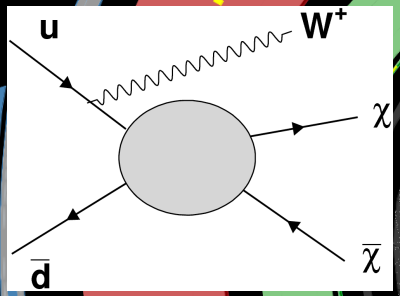
# “Resonances” – Experimenters’ View

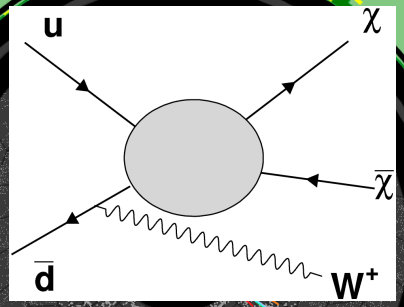


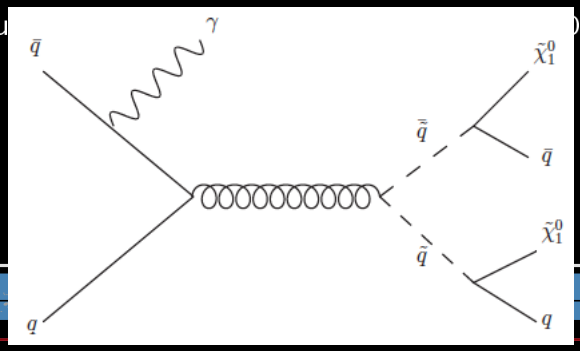
# Mono-X Searche

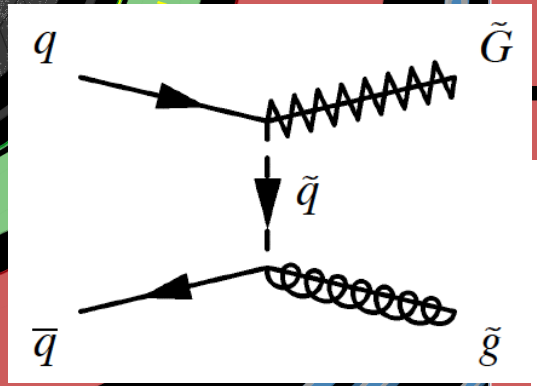


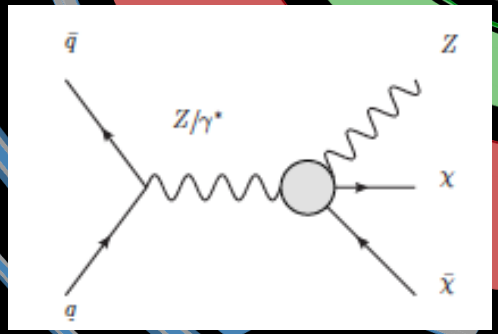



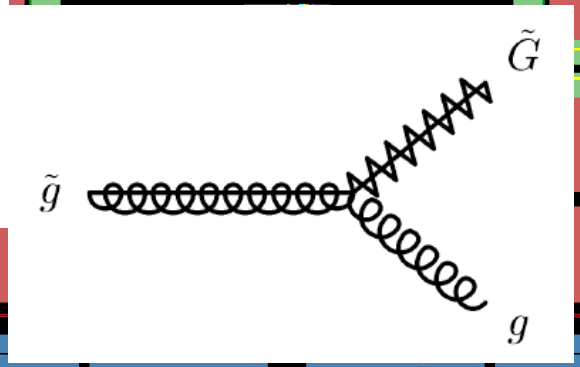



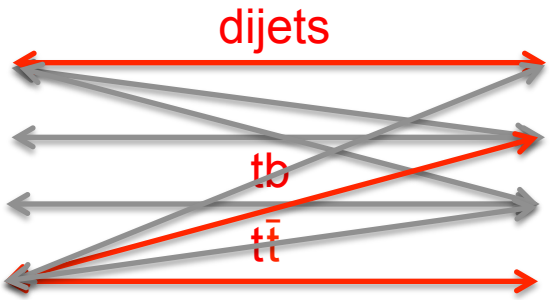



# Resonances – Experimenters' View

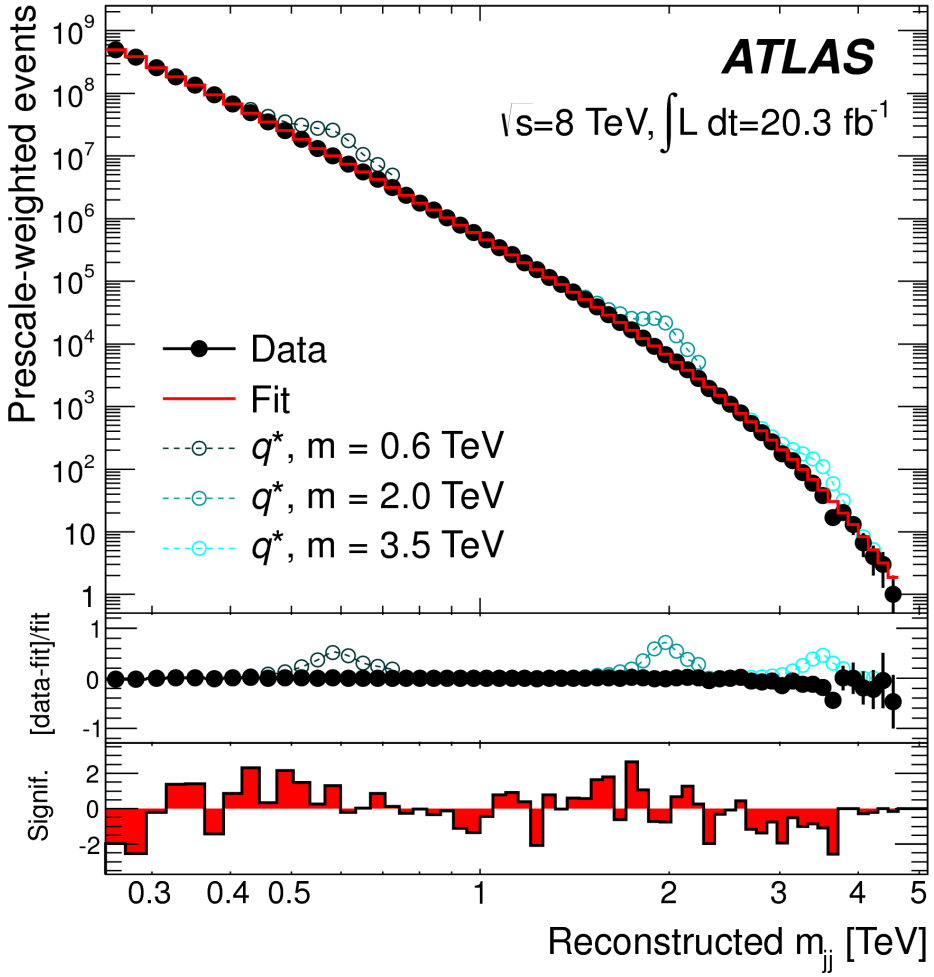
- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

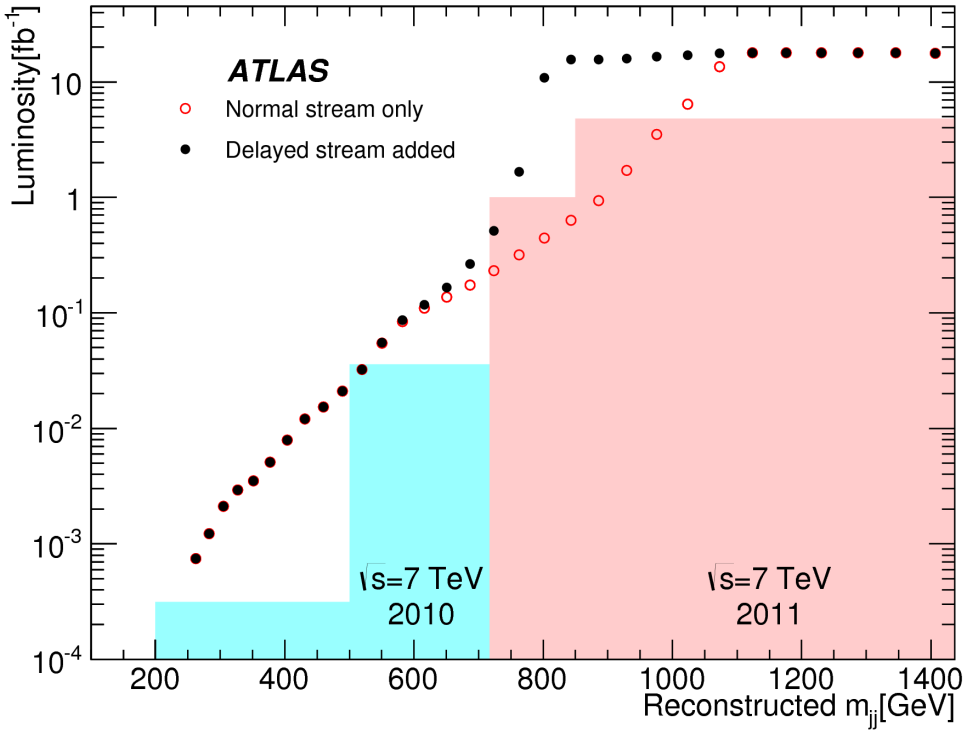




- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

# dijets

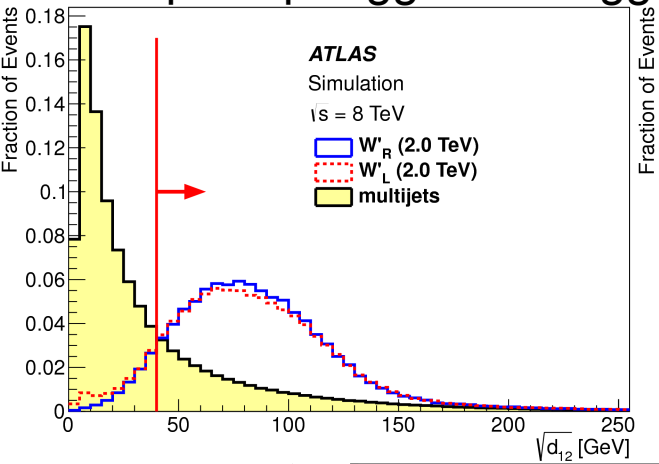


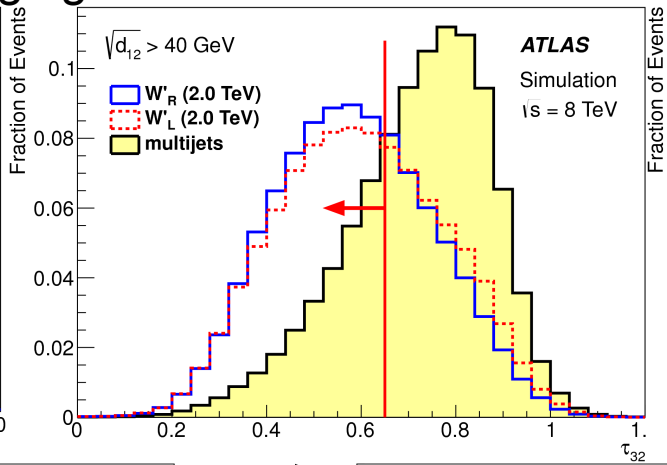



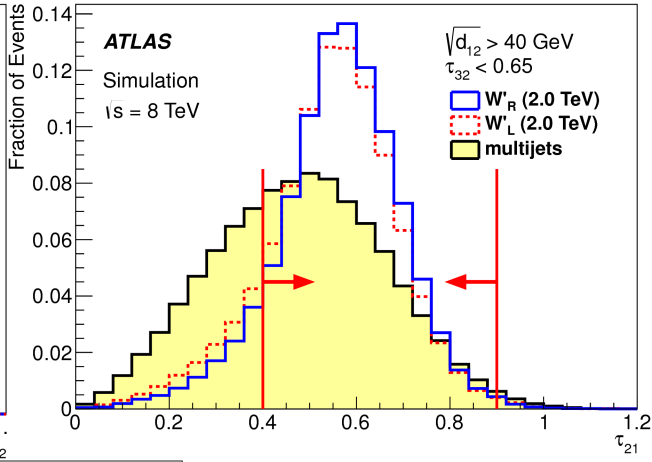

[1407.1376]

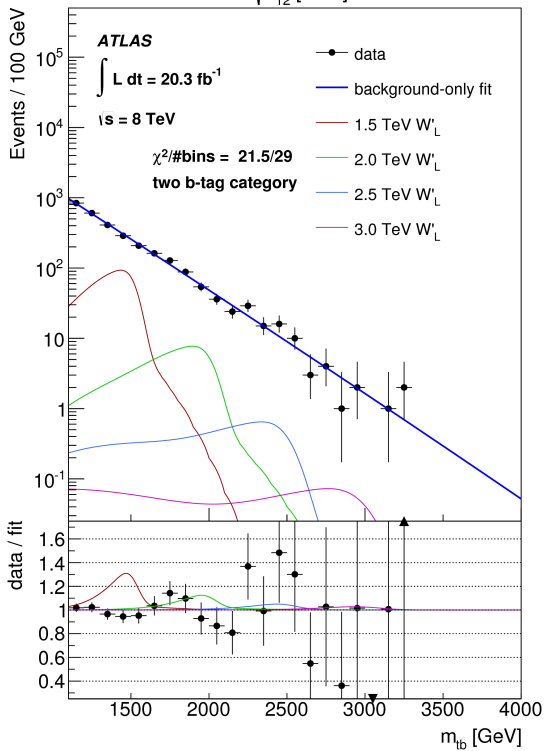
# W'→tb

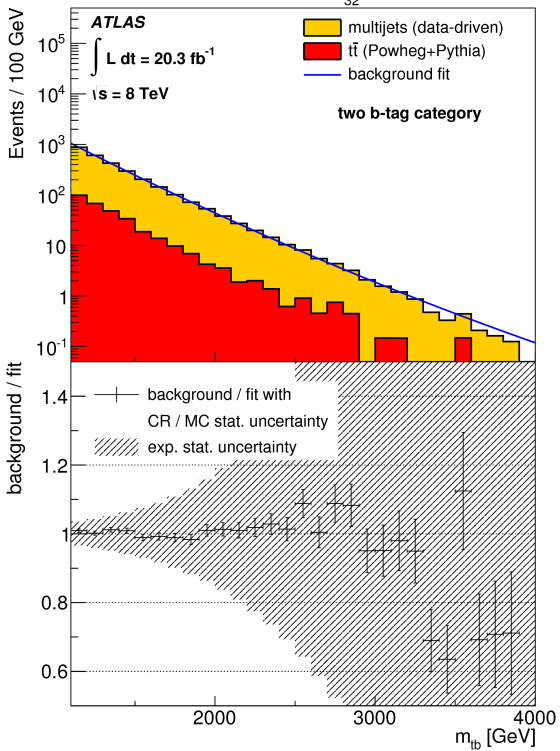
Simple top-tagger + b-tagging:



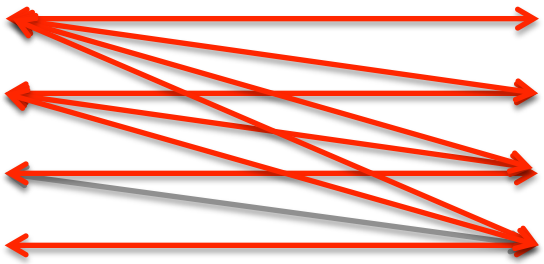




[1408.0886]

# Resonances – Experimenters' View

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

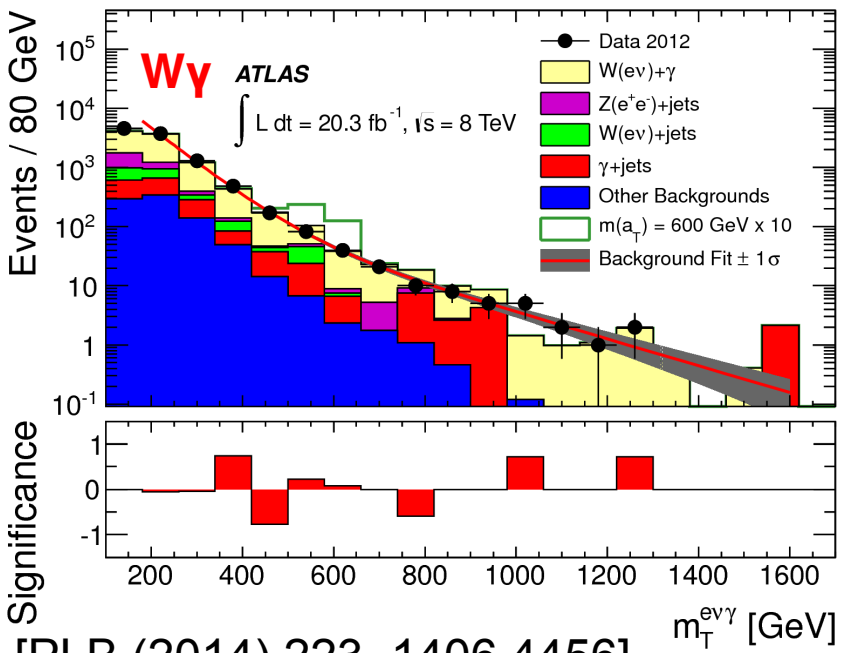


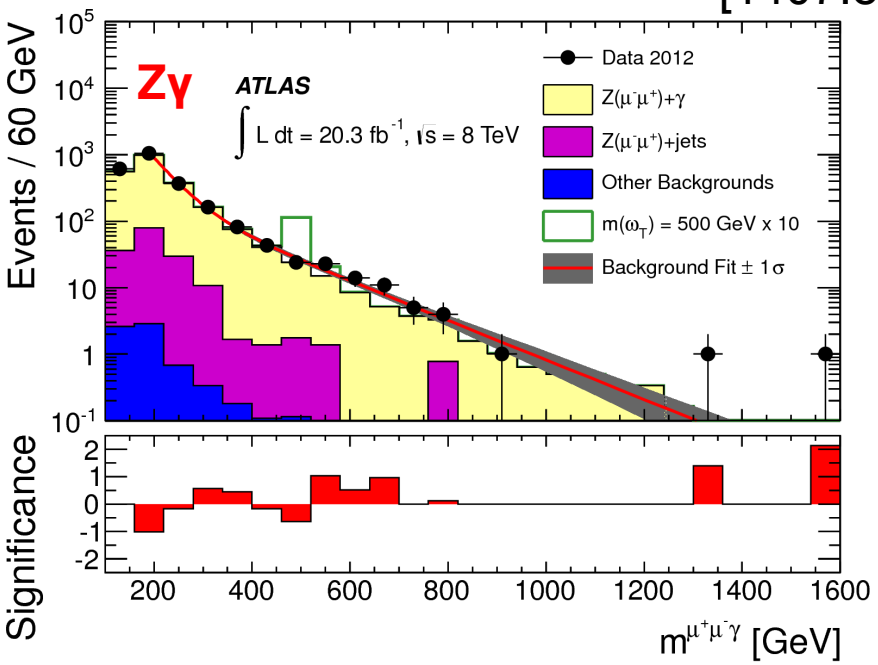
Only Hγ missing!

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

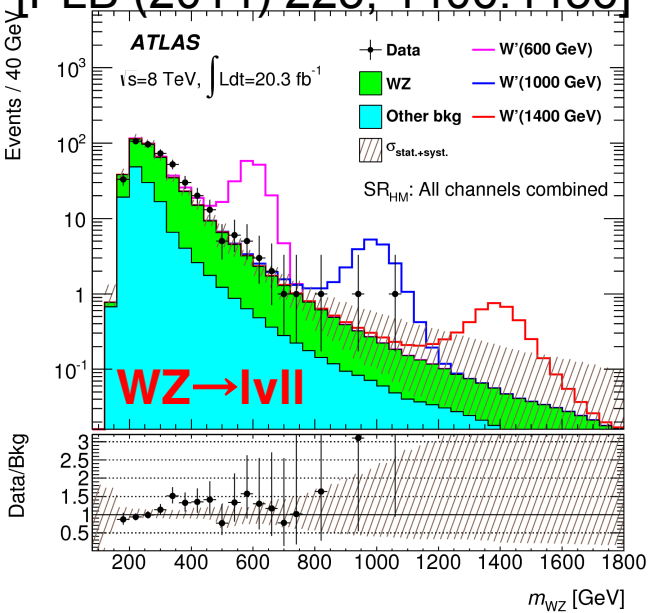
# Diboson Resonances

[1407.8150]

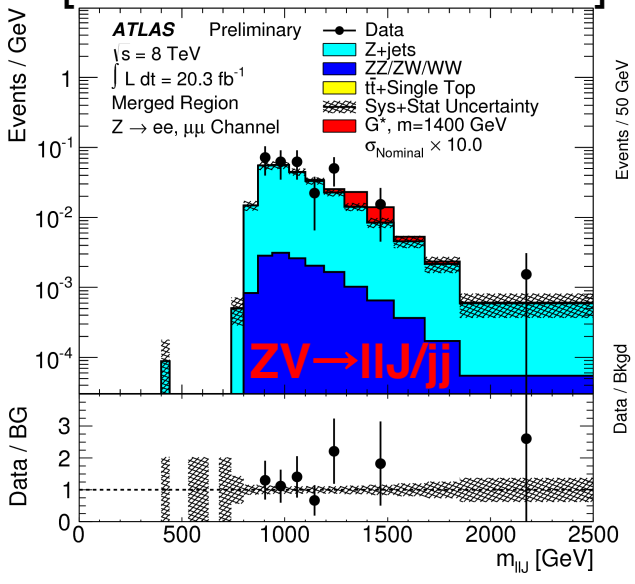


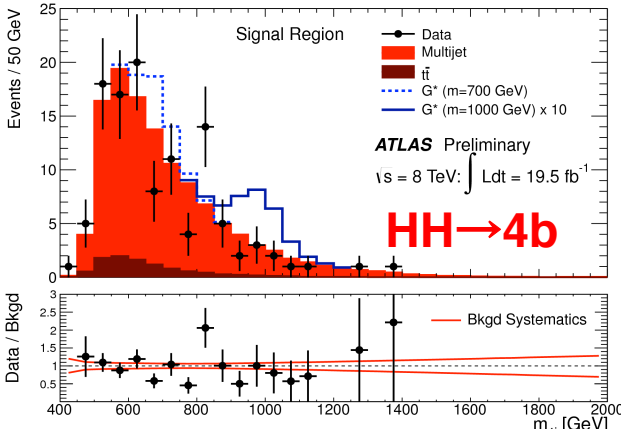

[PLB (2014) 223, 1406.4456]




[ATLAS-CONF-2014-039]

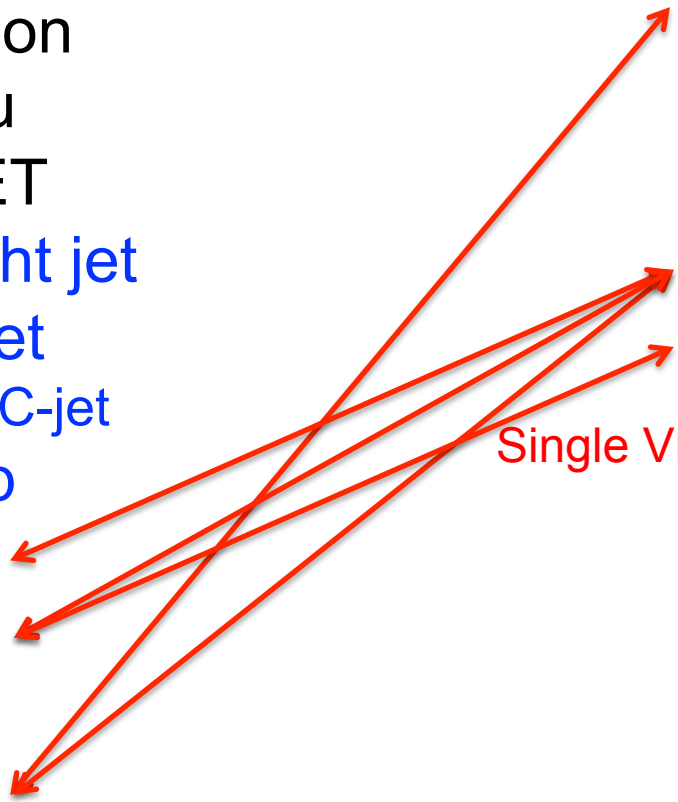



[ATLAS-CONF-2014-005]



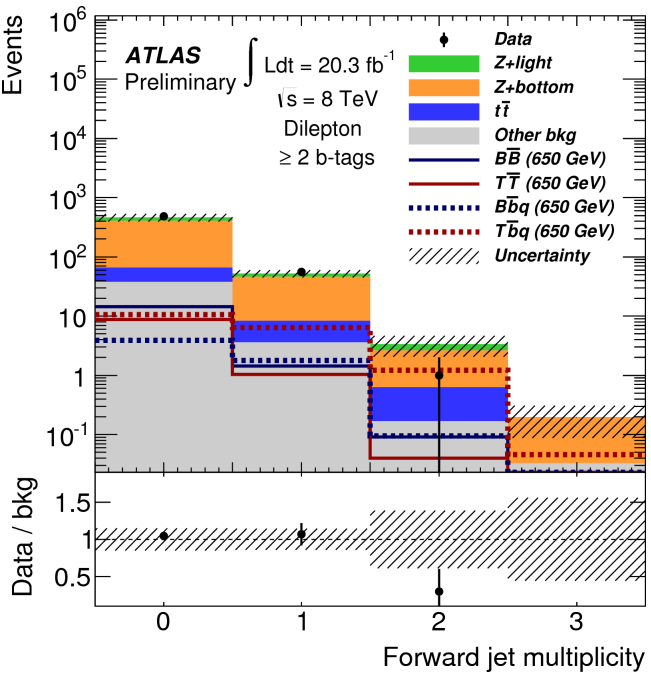
# Resonances – Experimenters' View

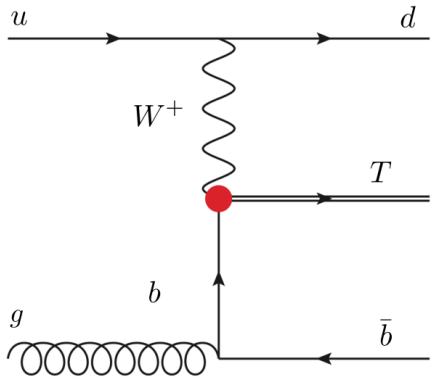
- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

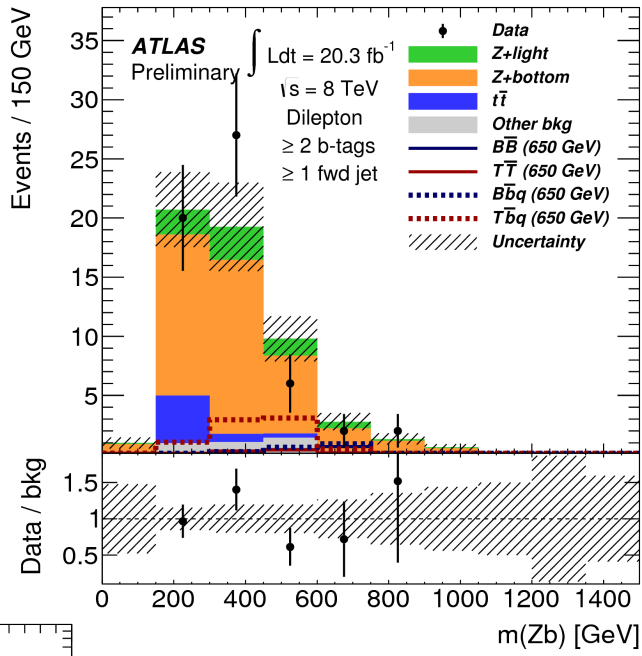


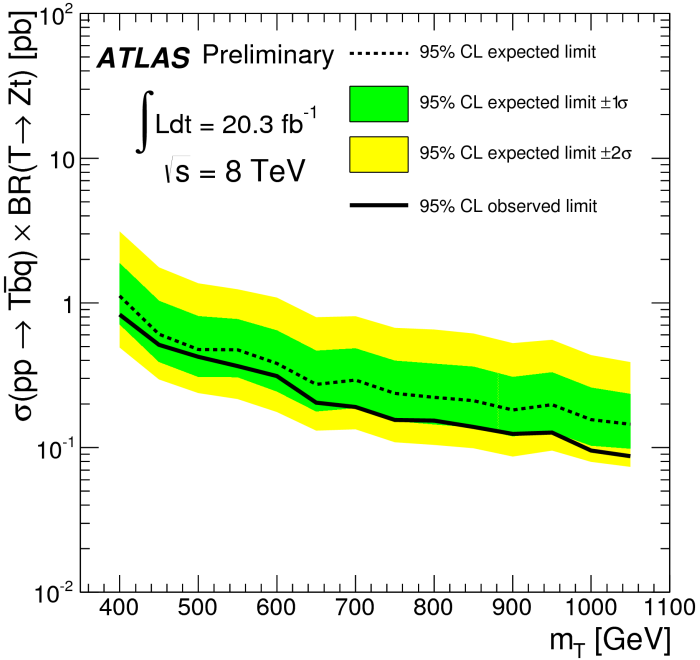

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

# Single VLQ (T/B→Zt/b)



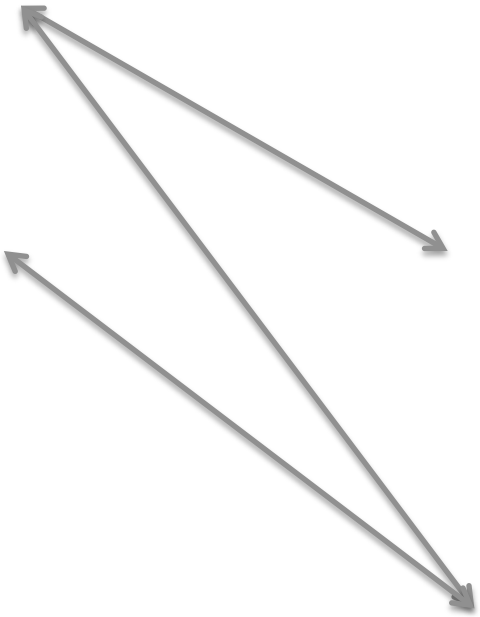




[ATLAS-CONF-2014-036]

# Resonances – Experimenters' View

What about the rest?

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ



- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ

Lepton-quark? → single LQ

Lepton-boson? → Excited/Heavy leptons

Quark-boson? → Single VLQ / excited quark

We can do ANY combination! Anything missing?

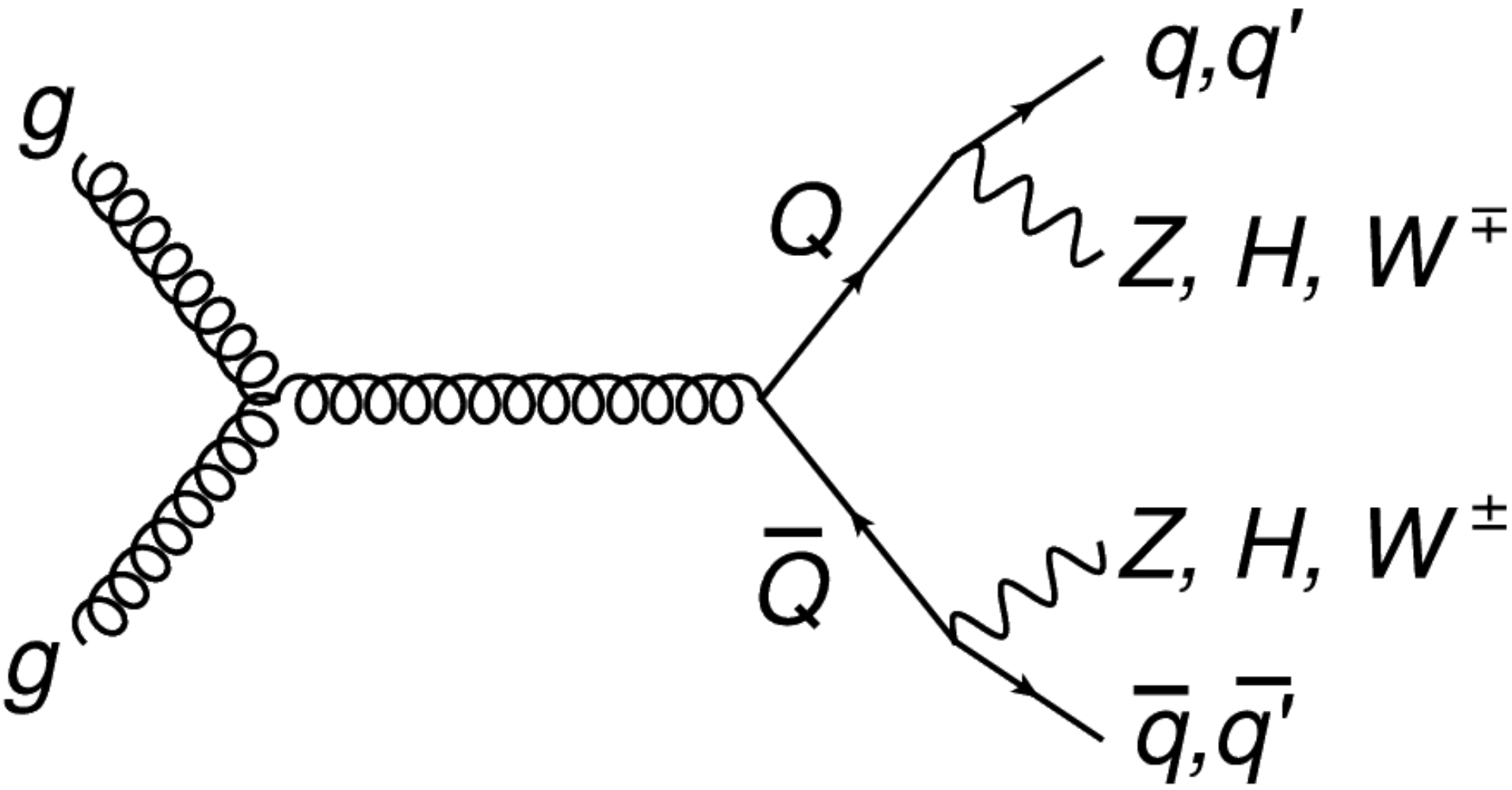
# Resonance Summary

- Anything missing?
- Should we re-prioritize?
- We need a benchmark = signal MC
- Non-resonant extension much harder!
  - How to control BG's in tail?
  - Exclusion ok, but how to establish a signal?
- Black Hole searches similarly difficult
  - How to establish signal in tail?

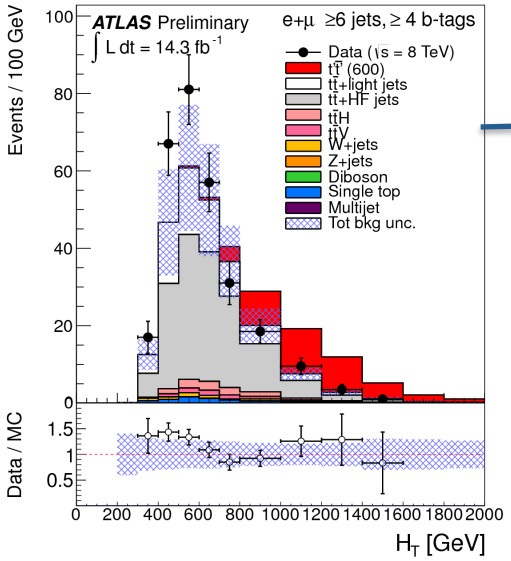
- Other big topic: pair production ⇒ next

# VLQ Pair Production

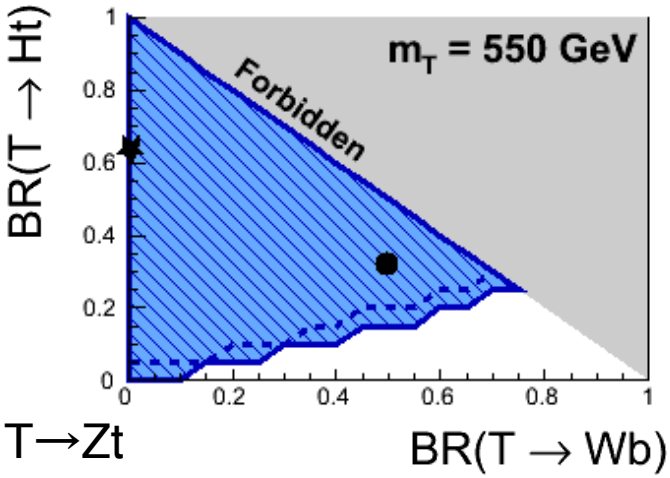
**Spectacular signatures: boosted b-jets, tops, W, Z, H bosons**



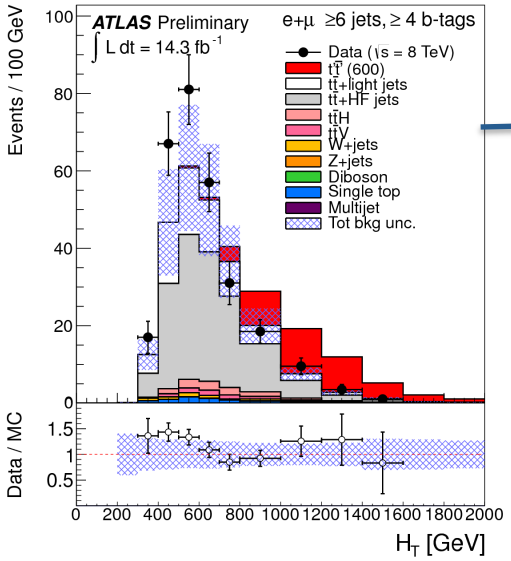
# VLQ TT̄ Search Strategy




Ht+X (l+jets)

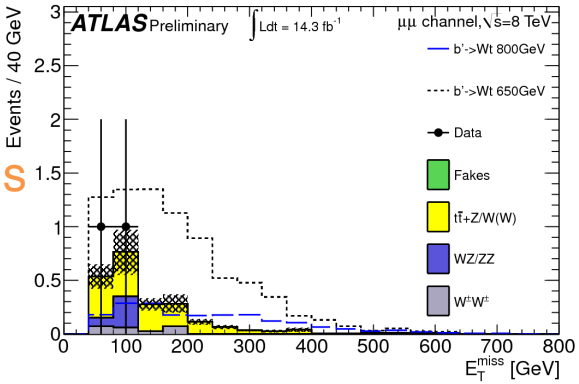


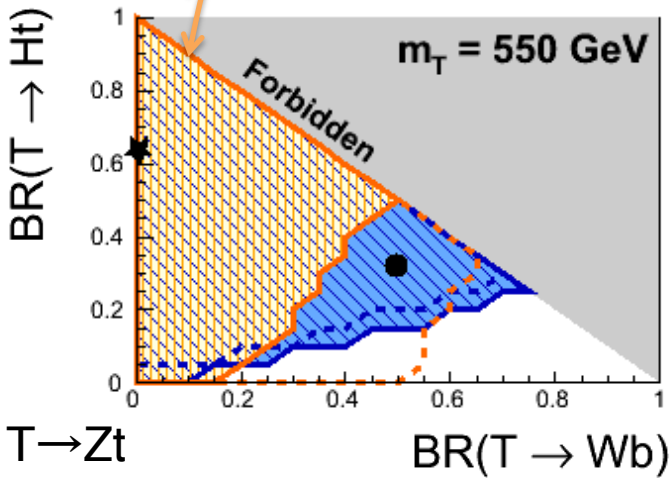
# VLQ TT̄ Search Strategy




Ht+X (l+jets)

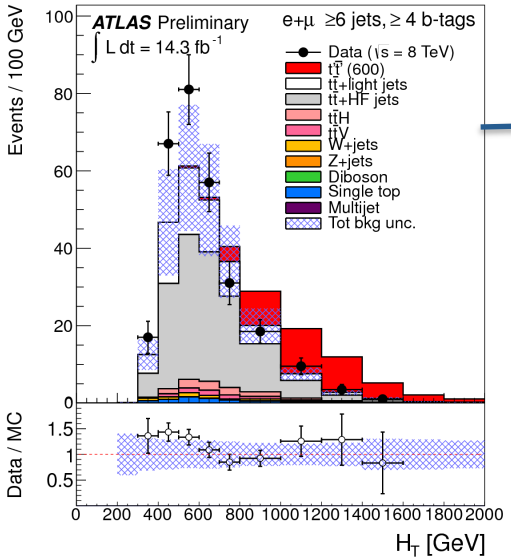
Same-sign leptons



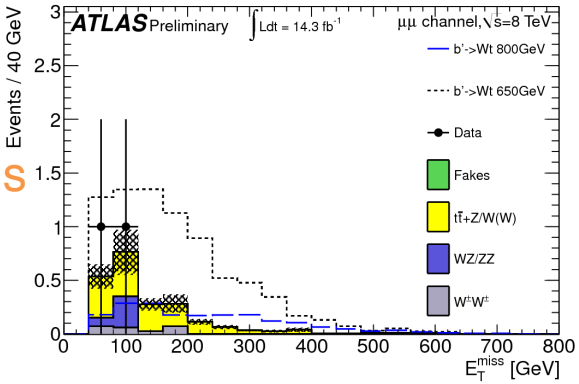

(not a combination, just overlaying results)

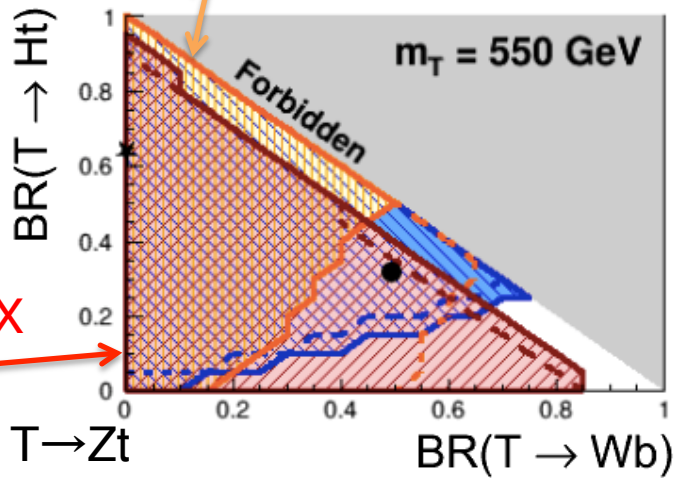
# VLQ TT̄ Search Strategy



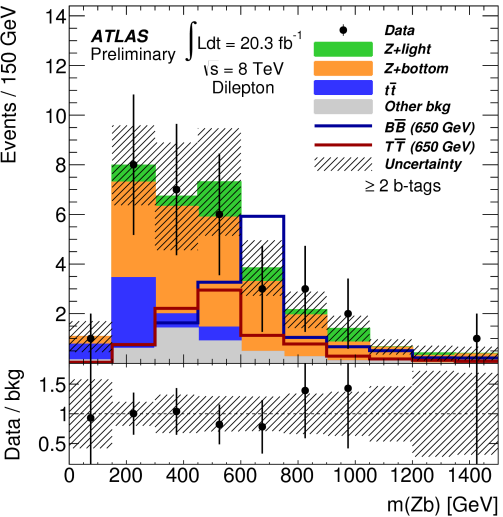

Ht+X (l+jets)

Same-sign leptons



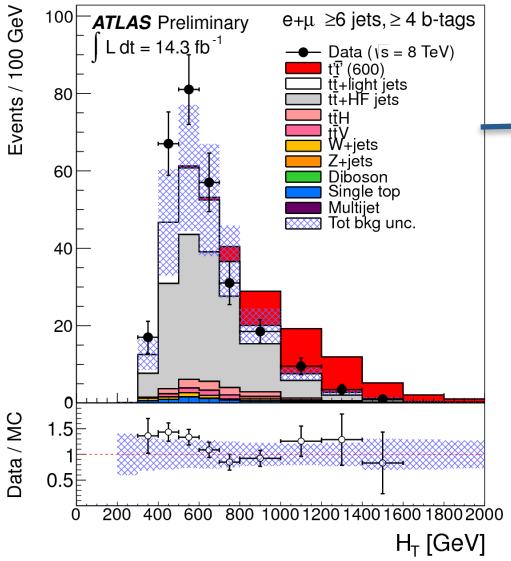




Zt+X

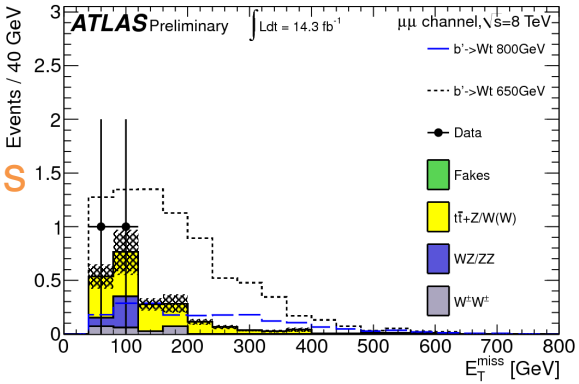


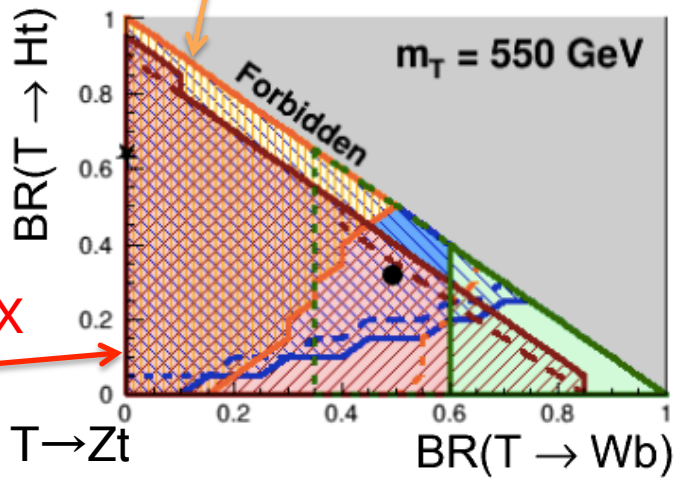
# VLQ TT̄ Search Strategy

Ht+X (l+jets)

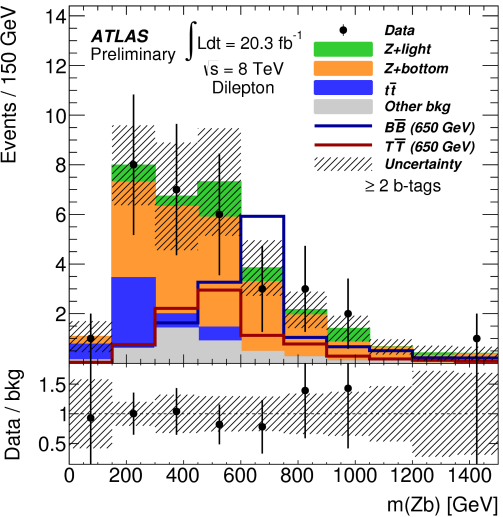



Same-sign leptons

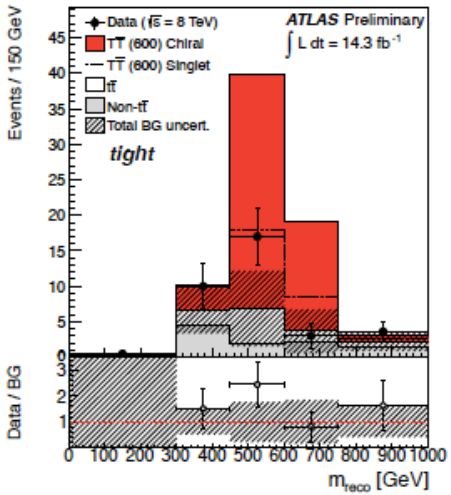


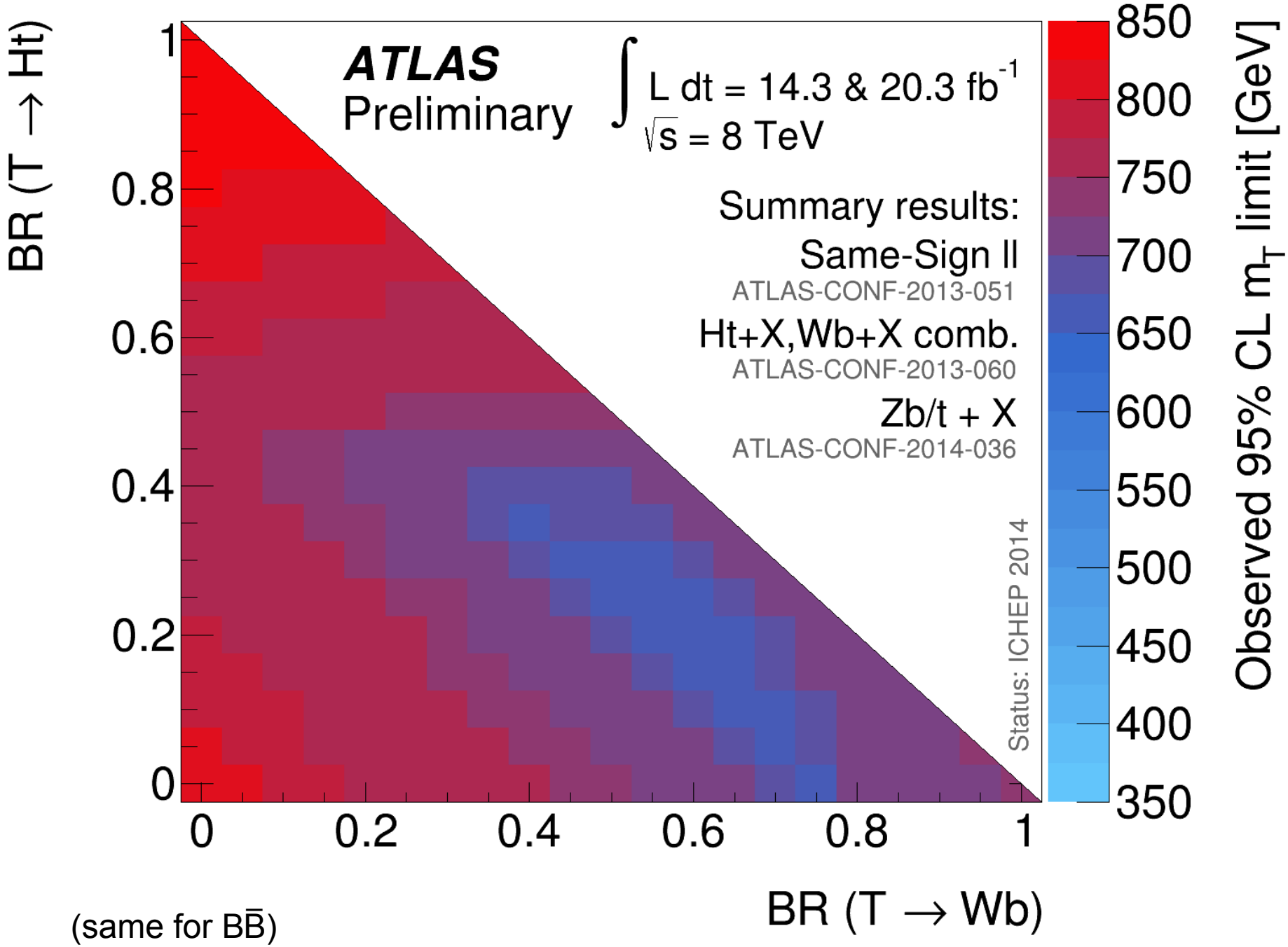




Zt+X




Wb+X (l+jets)






(same for $B\bar{B}$)

# Pair Production – there is more!

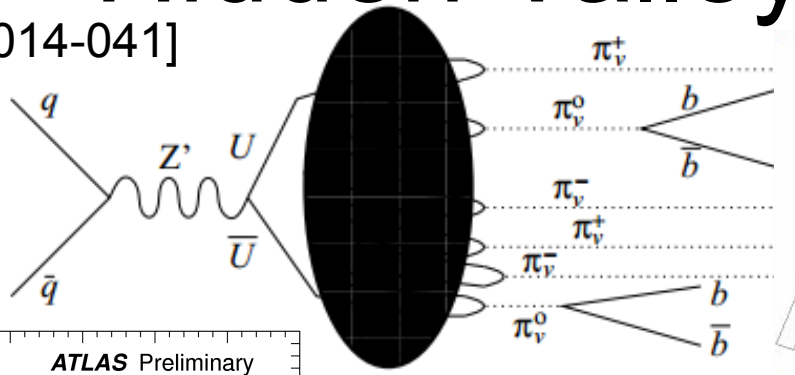
- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ
- LLP
- Lepton-jets
- Exotic tracks
- …

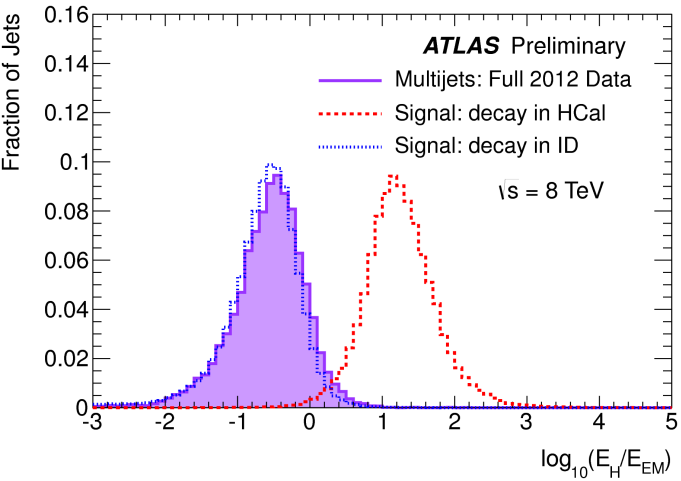

- Electron
- Muon
- Tau
- MET
- Light jet
- B-jet
  - C-jet
- Top
- W
- Z
- H
- γ
- LLP
- Lepton-jets
- Exotic tracks
- …

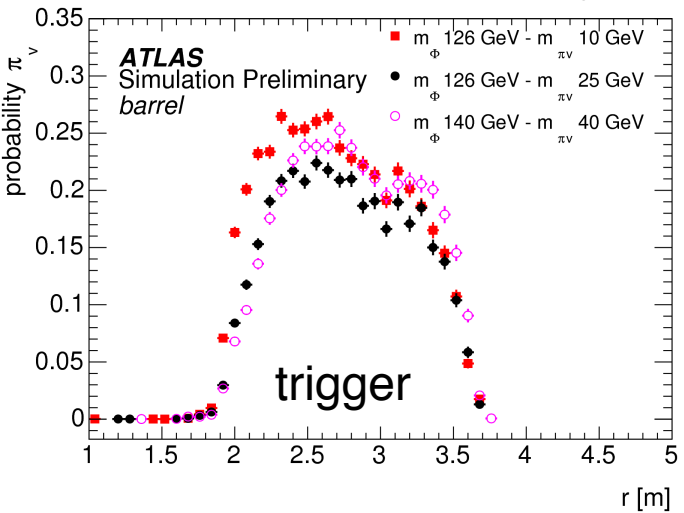
# Hidden Valley: LLP

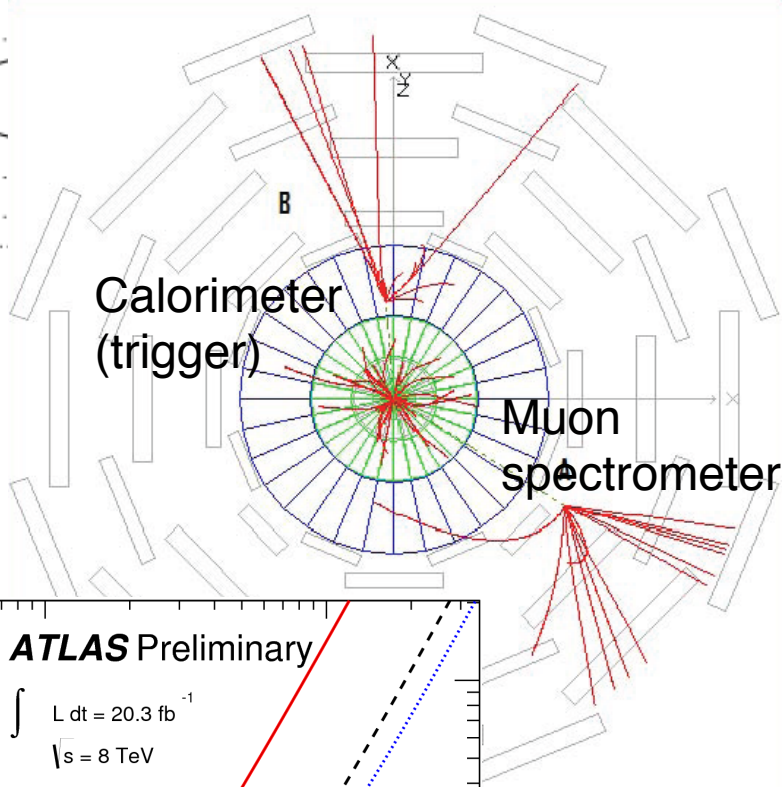
[ATLAS-CONF-2014-041]

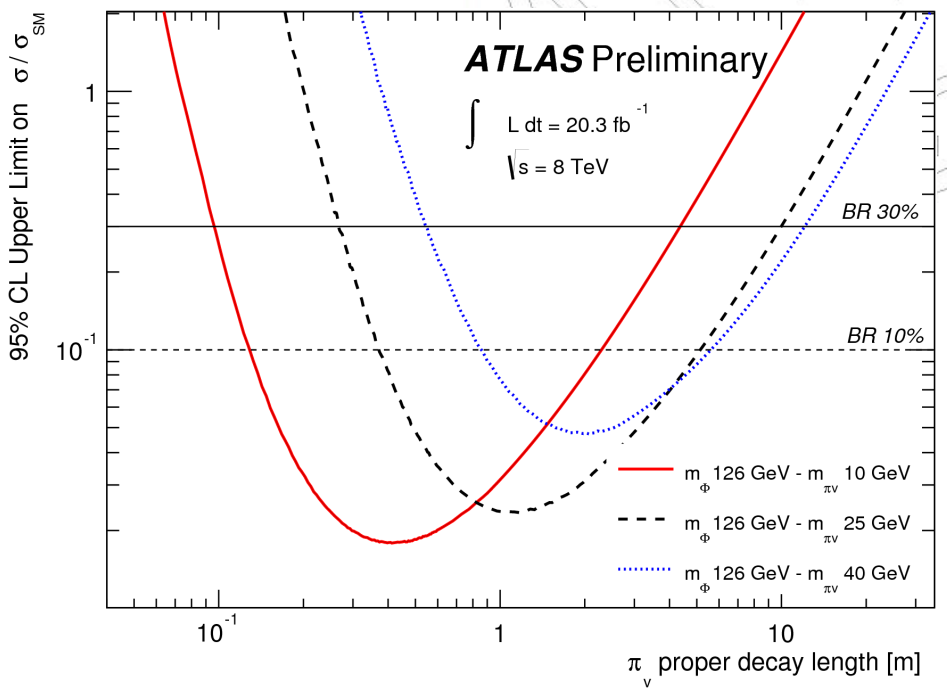
Jets in HCal:
- Narrow
- No tracks
- And:



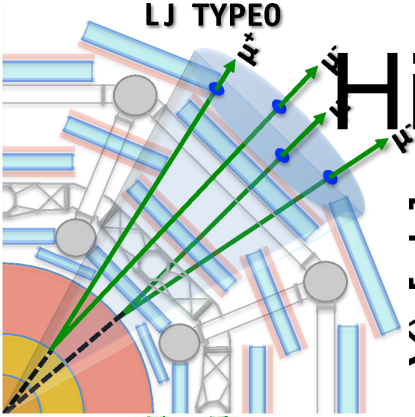



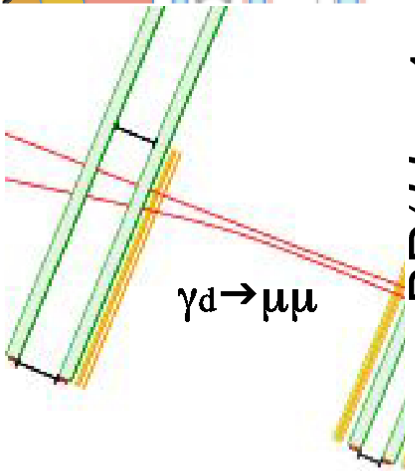



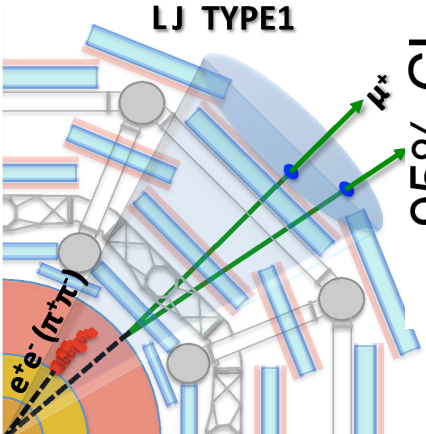



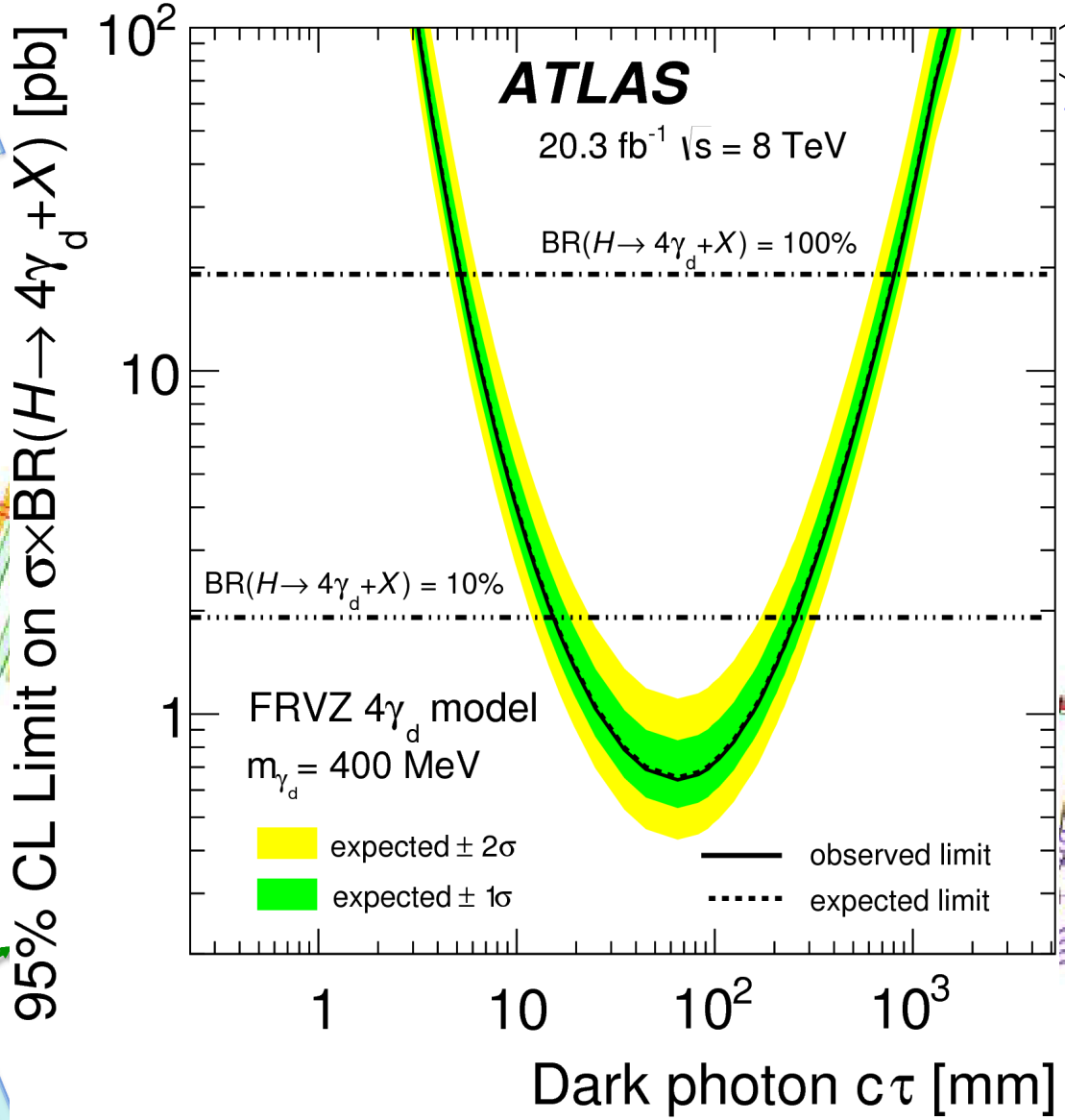



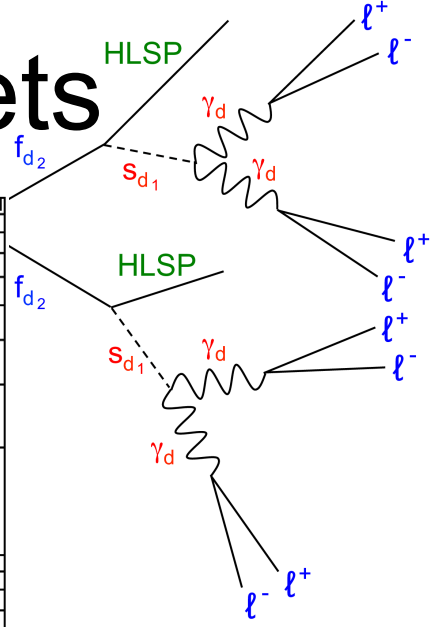
# Hidden Sector: Lepton-jets



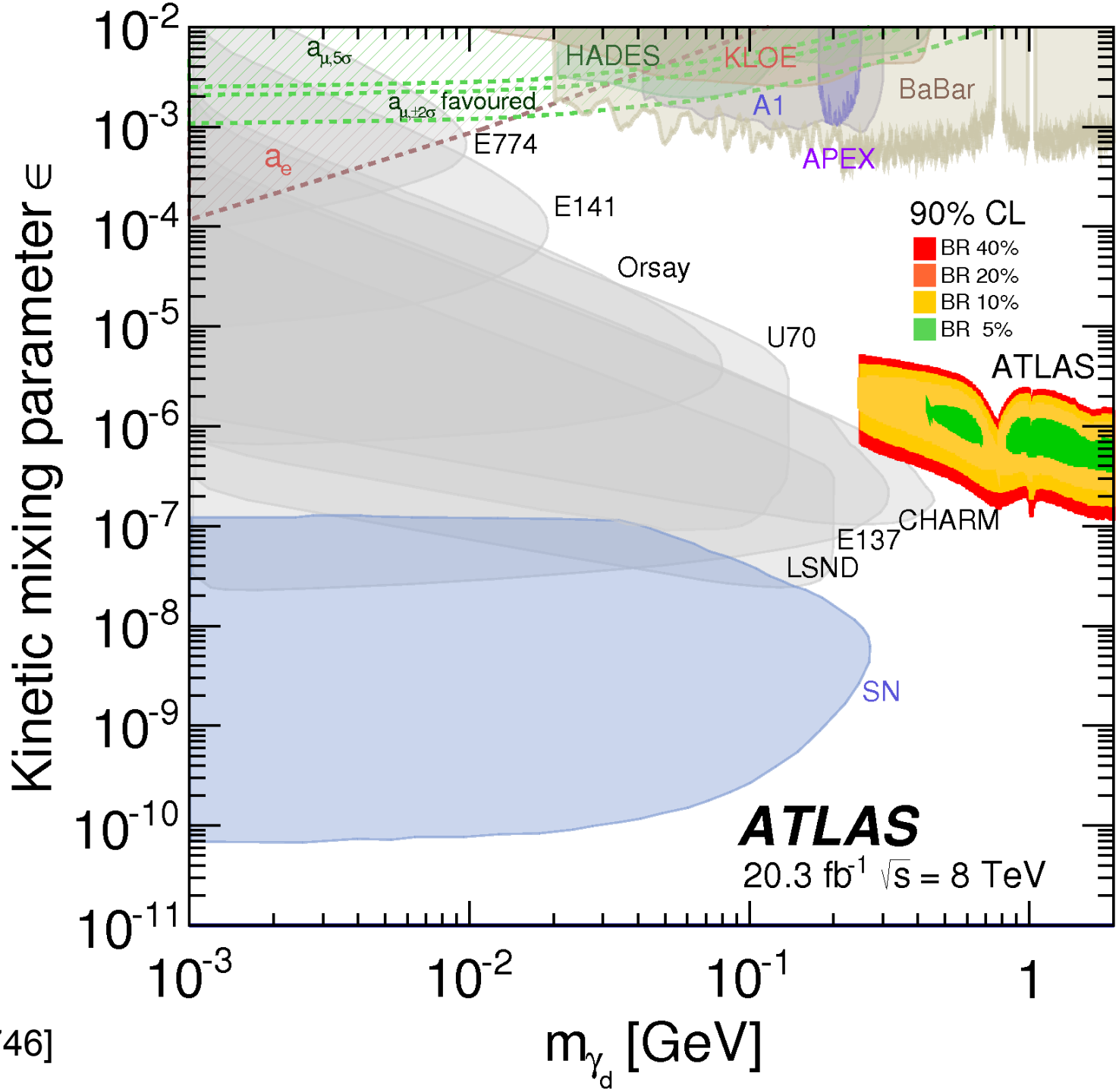




Falkowski–
Ruderman–
Volansky–Zupan


[1409.0746]

Vector Portal Model

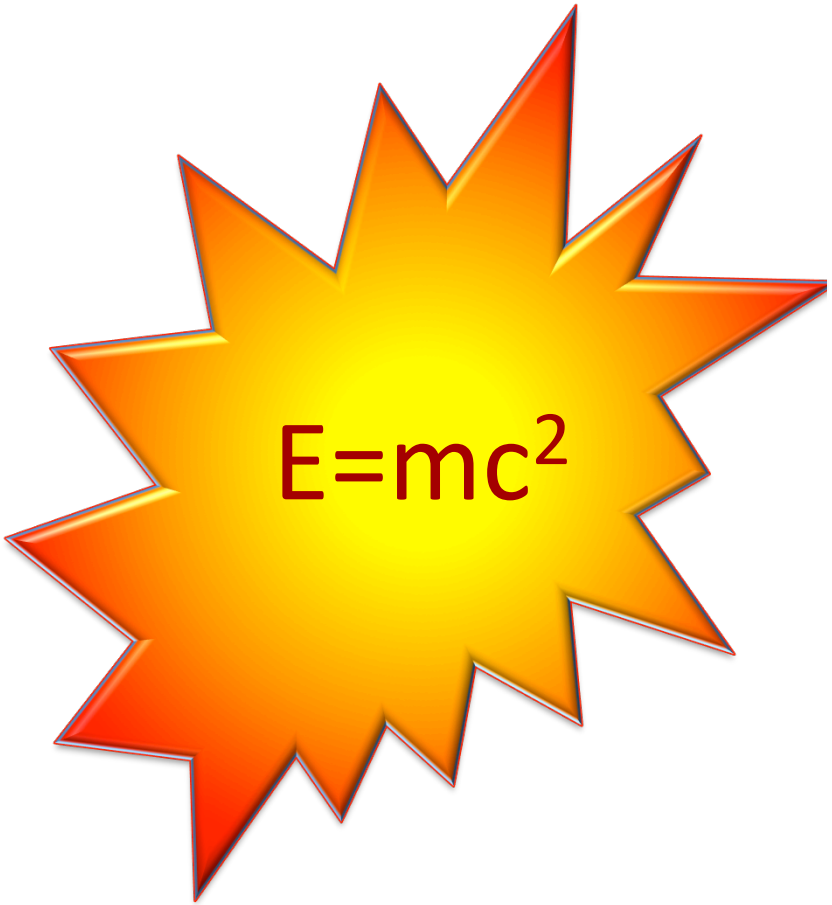


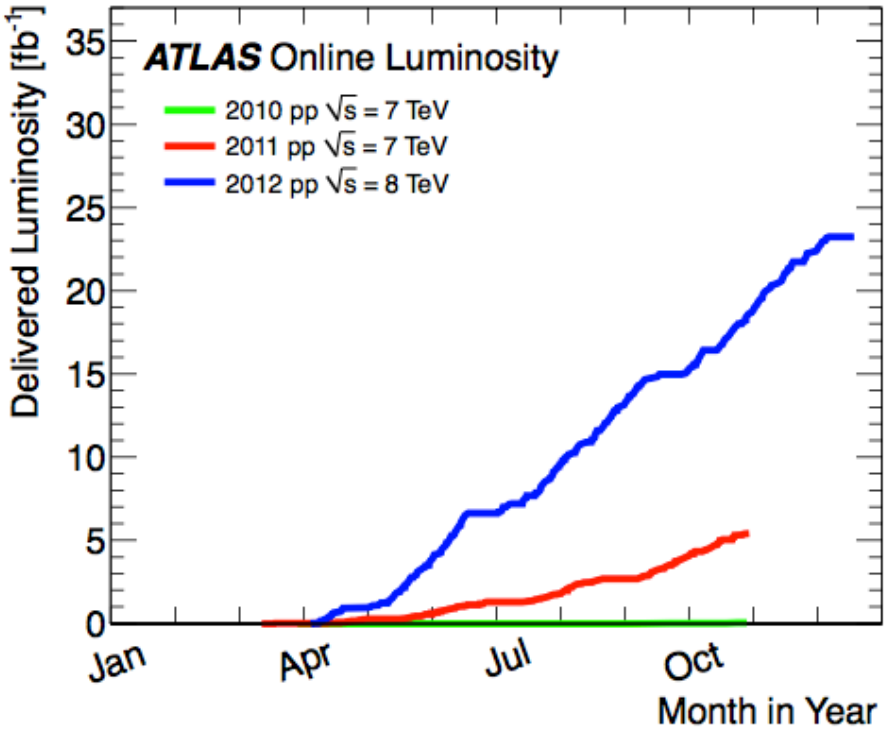

[1409.0746]

# Conclusion

- Leave no stone unturned
- Search for NP signatures motivated by open questions of SM
- Complement with additional signatures – do all that is possible?
  - Where to start?
- Preference for total or fiducial cross section limits?
- Interpret results using benchmark models
  - Preference for one model or another? More systematic approach possible?
- For discovery most important: are we missing a signature?
  - You tell us?
  - Re-prioritize?
  - There will be more focus on boosted objects in Run II
- Combinations necessary?
  - If we take models seriously we should combine different search results: e.g. WIMP mono-jet and mediator di-jets combination,…

# Run II Outlook:
# Improved Sensitivity for All Exotics!



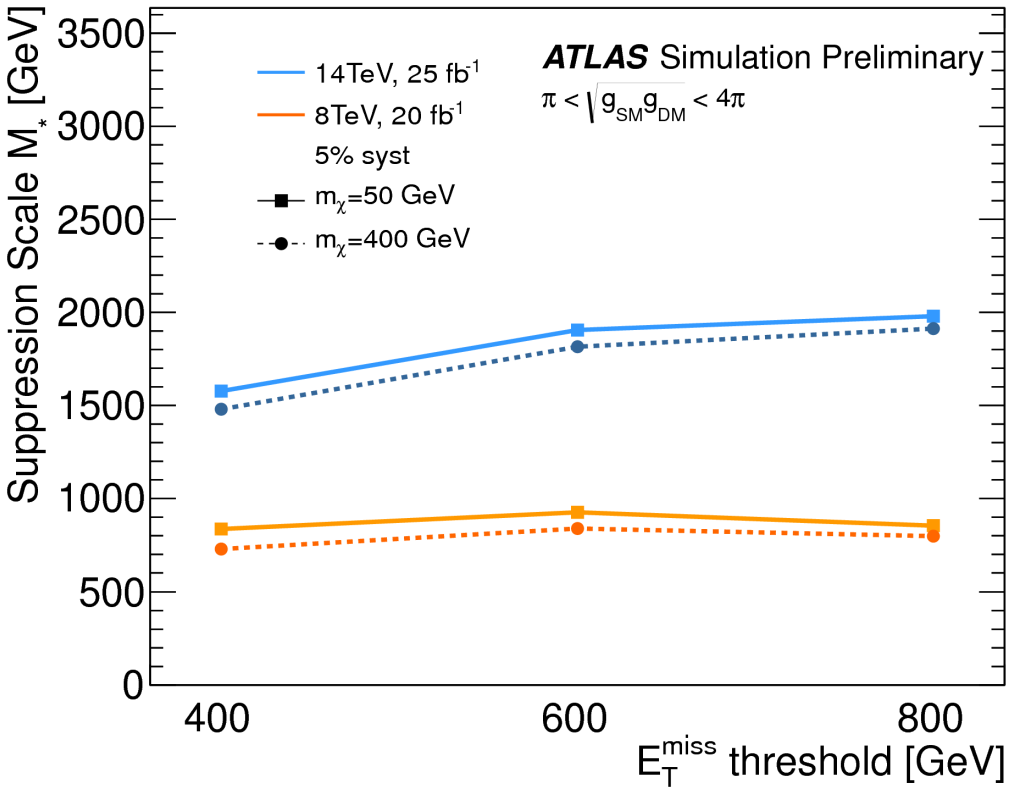



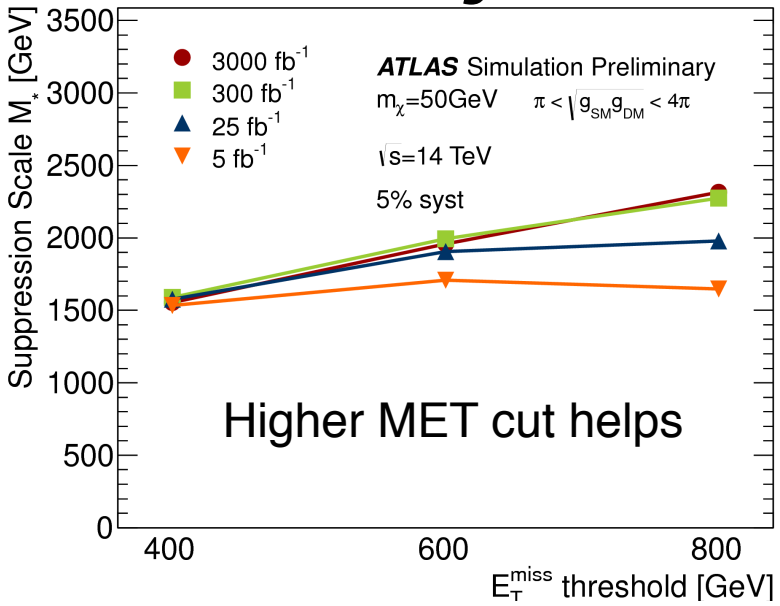

Energy √s

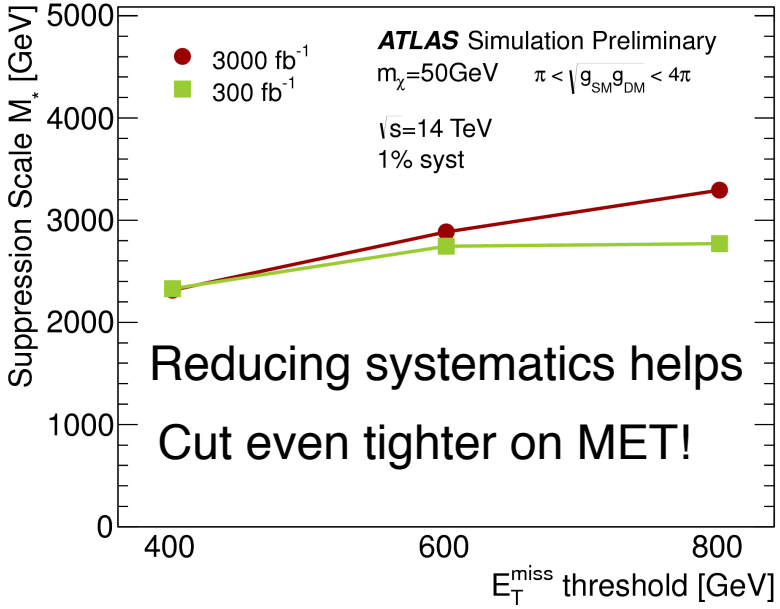
Luminosity L

# Run II Preparation: mono-jet

Huge improvement: Run I → Run II




[ATL-PHYS-PUB-2014-007]

# Where are you hiding?


(Markus Luty, LHCP 2014)

# We Might be this Close!

Thank You!