Thoughts About Run 1 Excesses

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Interpreting Run 1

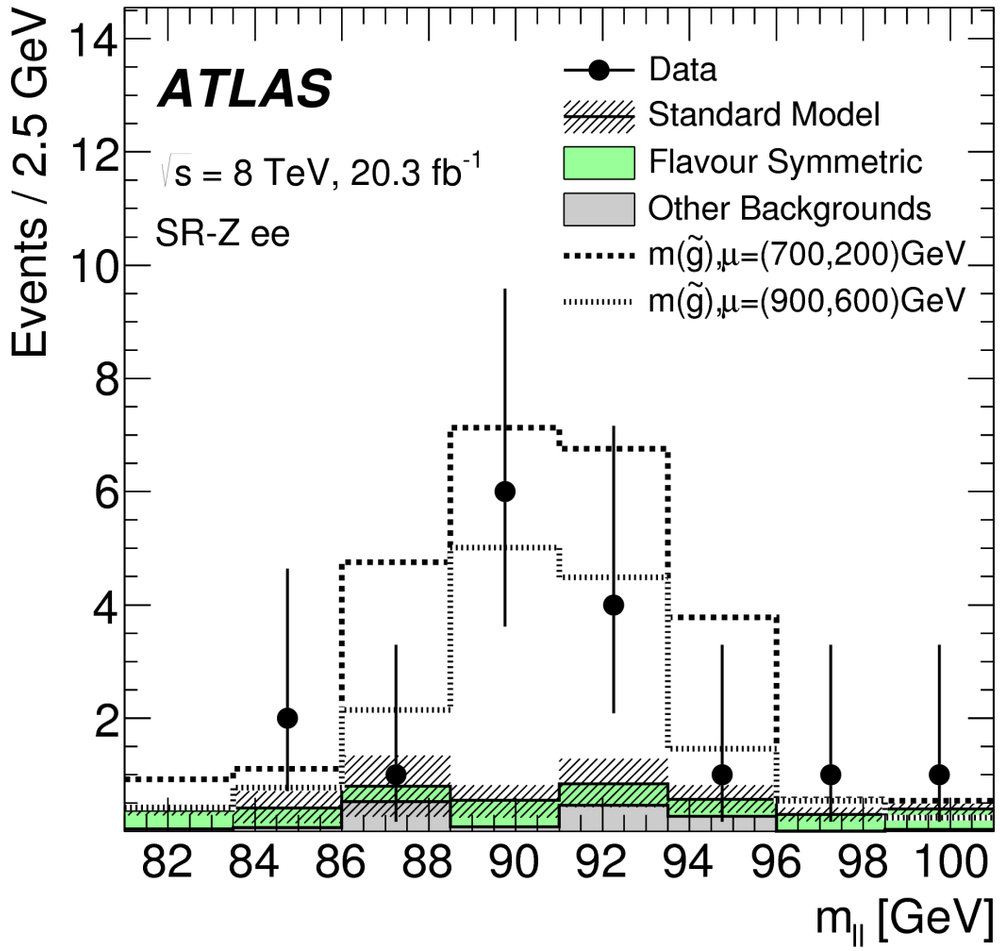
- Experimentally, techniques have evolved significantly during run 1
  - And certainly wrt Tevatron
- Aside from jet substructure etc, treatment of systematics far more sophisticated
  - Many more systematic uncertainties are considered
  - But systematics profiling now generalized
- "Overall LHC χ^2" probably too good
  - Standard Model measurements all agree very well
- But searches often limited by statistics
  - ATLAS: ~50 exotics + ~40 susy papers @ 8 TeV
  - CMS: ~50 exotics + ~25 susy papers @ 8 TeV
  - Expect ~eight false positive 2σ excesses and maybe one 3σ

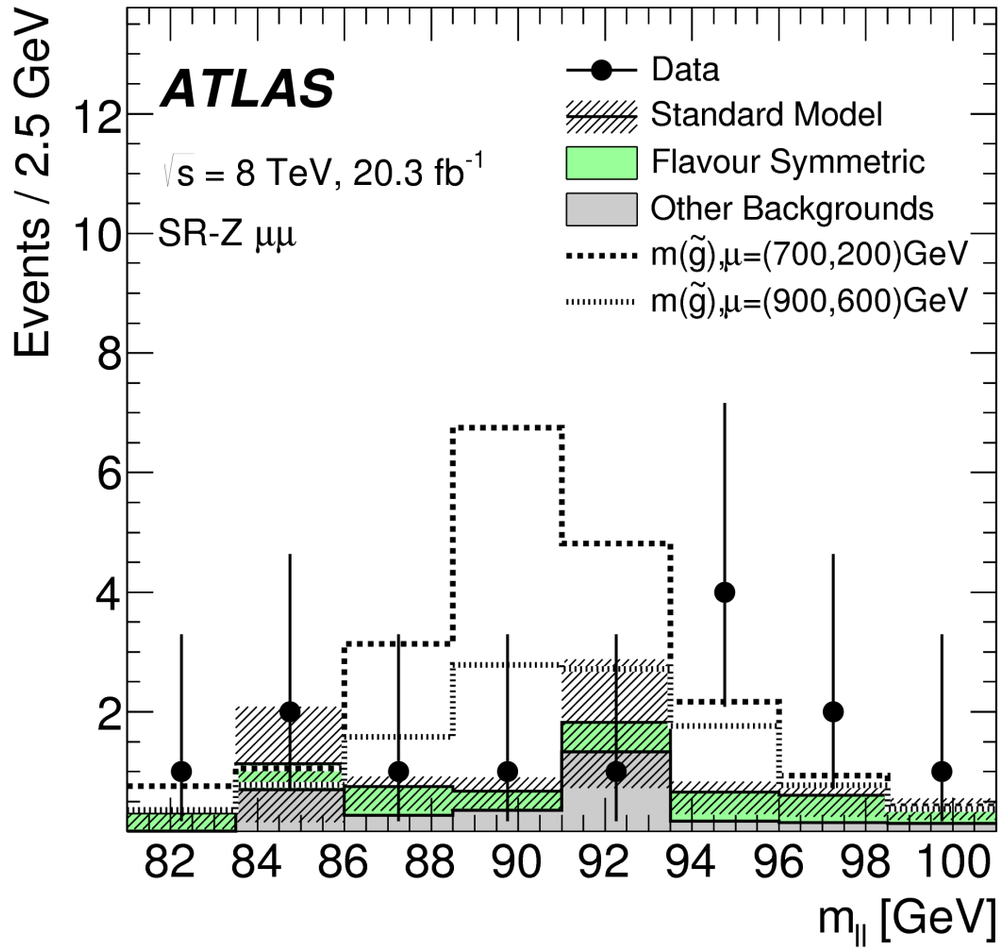
ATLAS Z+MET

- A lonely 3.0σ effect in SUSY searches
  - A few interpretations that evade all other searches
    - But not trivial…
  - And it has a twist:

MET > 225 GeV, 2 jets
H_T > 600 GeV

arXiv:1503.03290





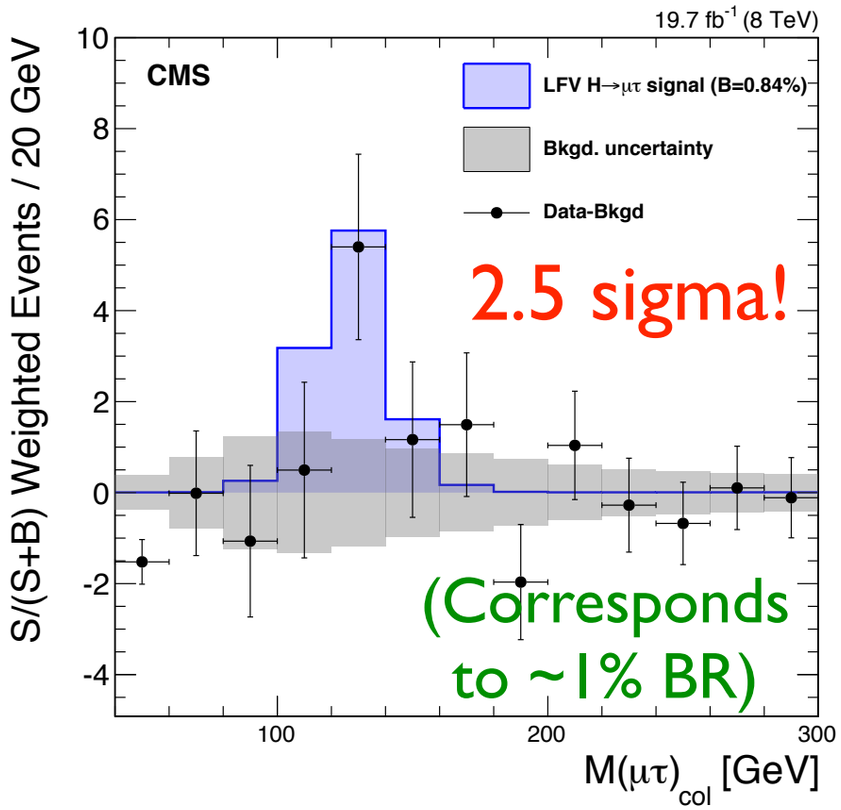
Higgs → μτ

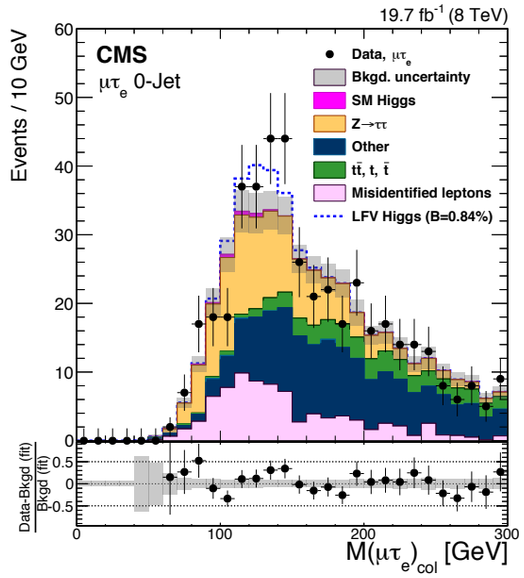
- Indirect constraints fairly weak (as opposed to e.g. e+μ
  - Indirect: BR(μτ) < ~10%; BR(eμ) < ~10^{-8}
- Lepton Flavor remains a mystery
  - Observing LFV crucial in understanding origin
  - *Know it exists* in the neutrino sector
- Experimentally:
  - With 400k Higgses produced,1% BR yields 4000 signal events (x efficiency)
  - Two “leptons” ⇒ manageable background

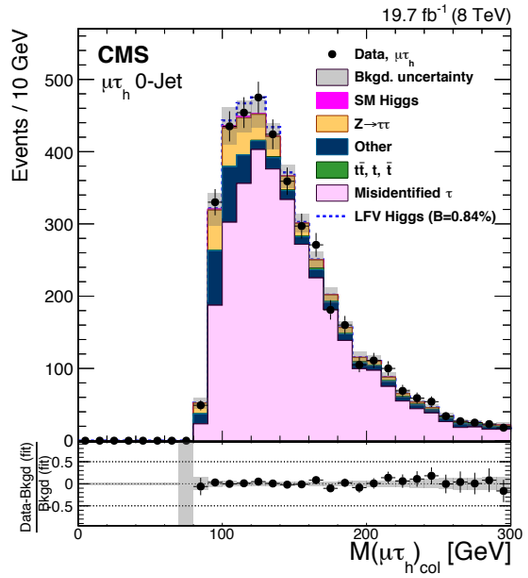
CMS Result

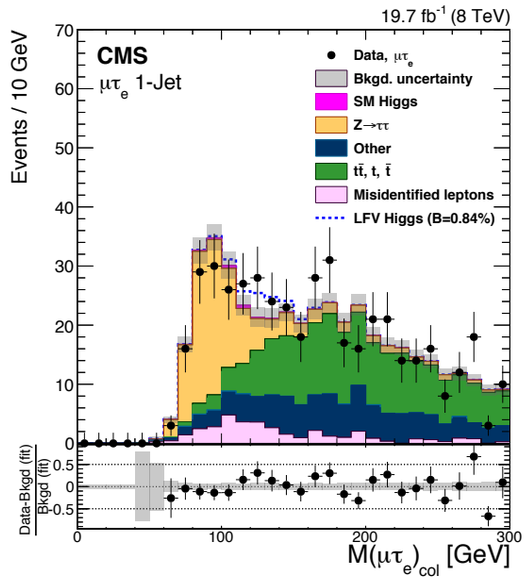
- Search done in collinear mass
- Categorized as a function of tau decay mode, number of jets

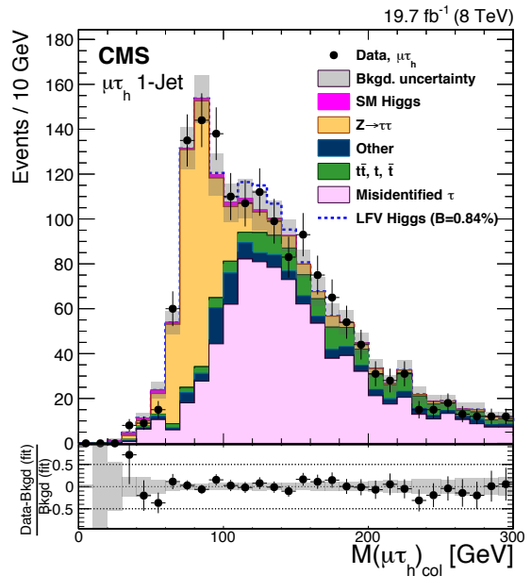
CMS: arXiv:1502.07400

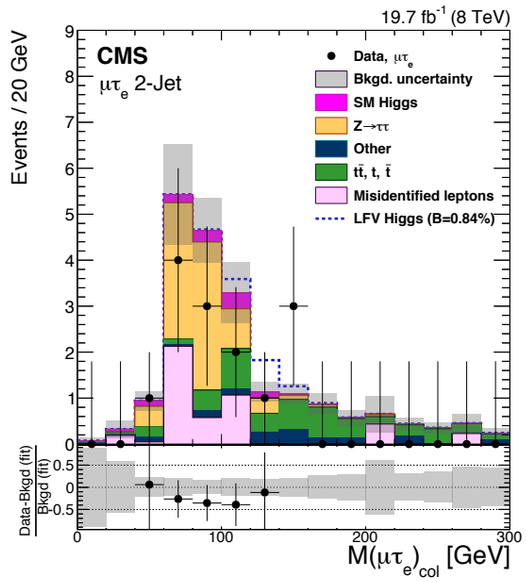


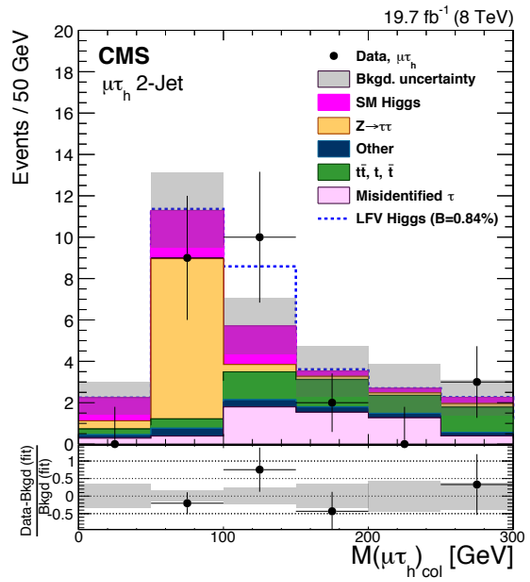












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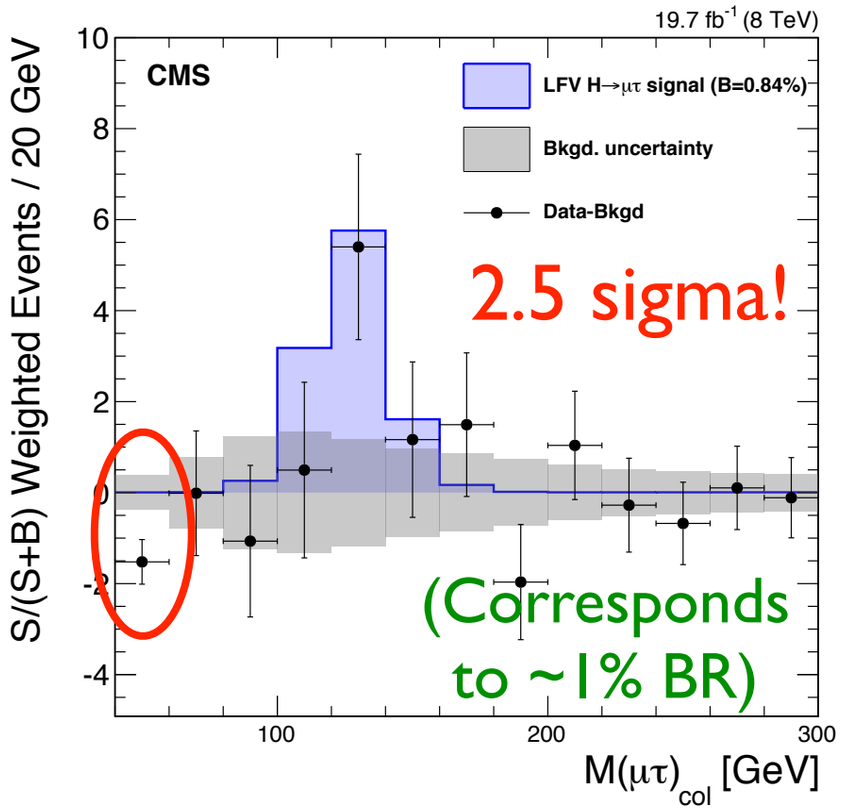
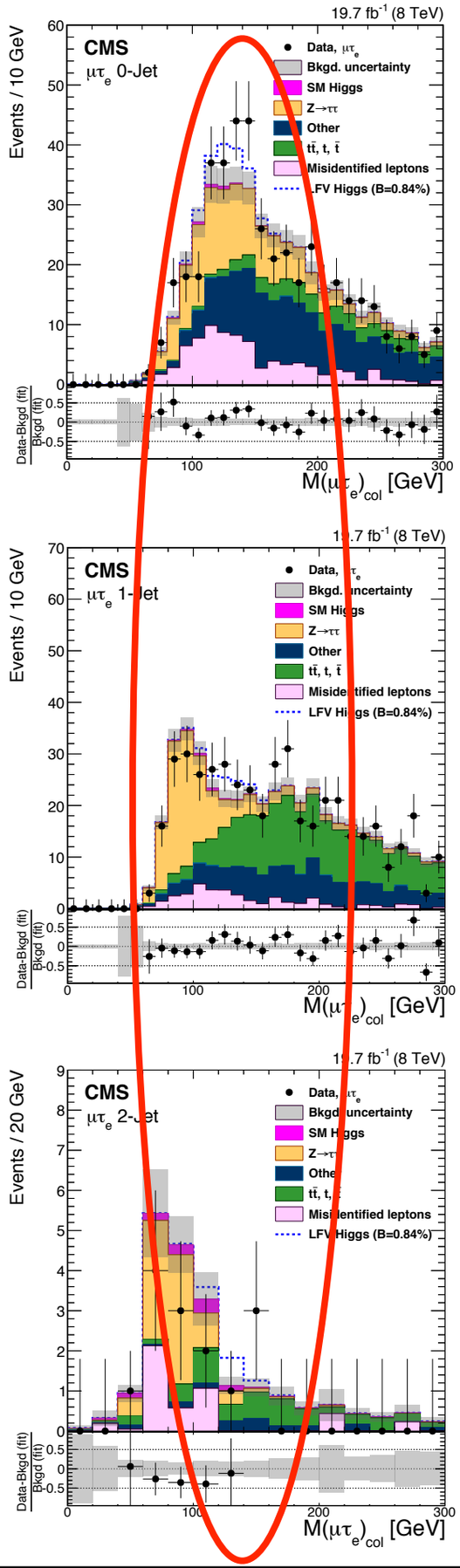
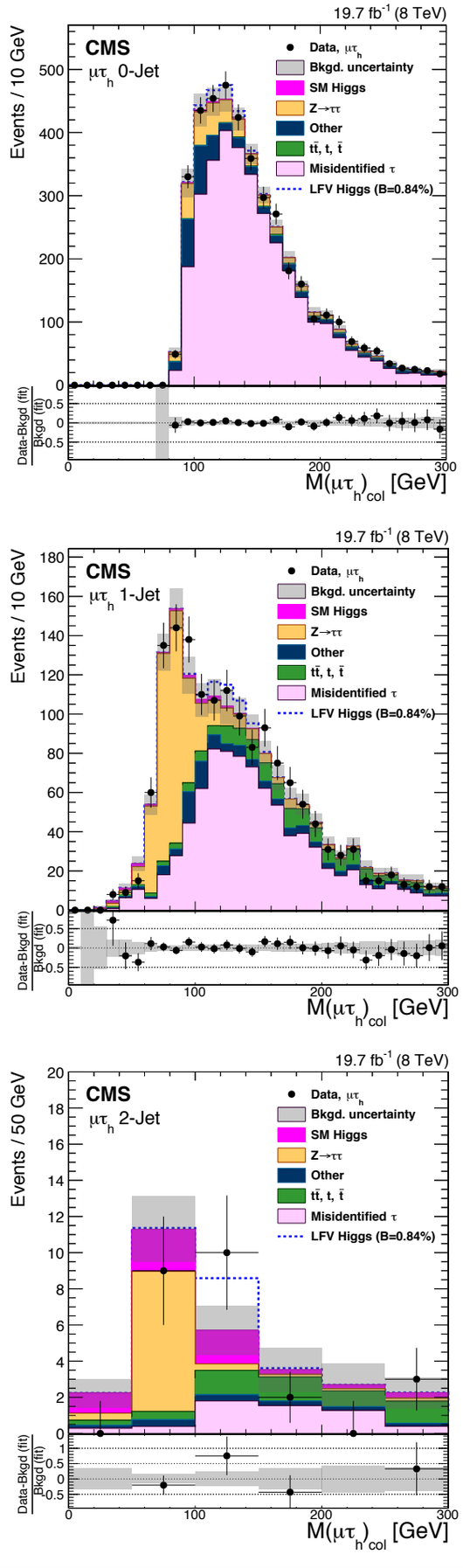
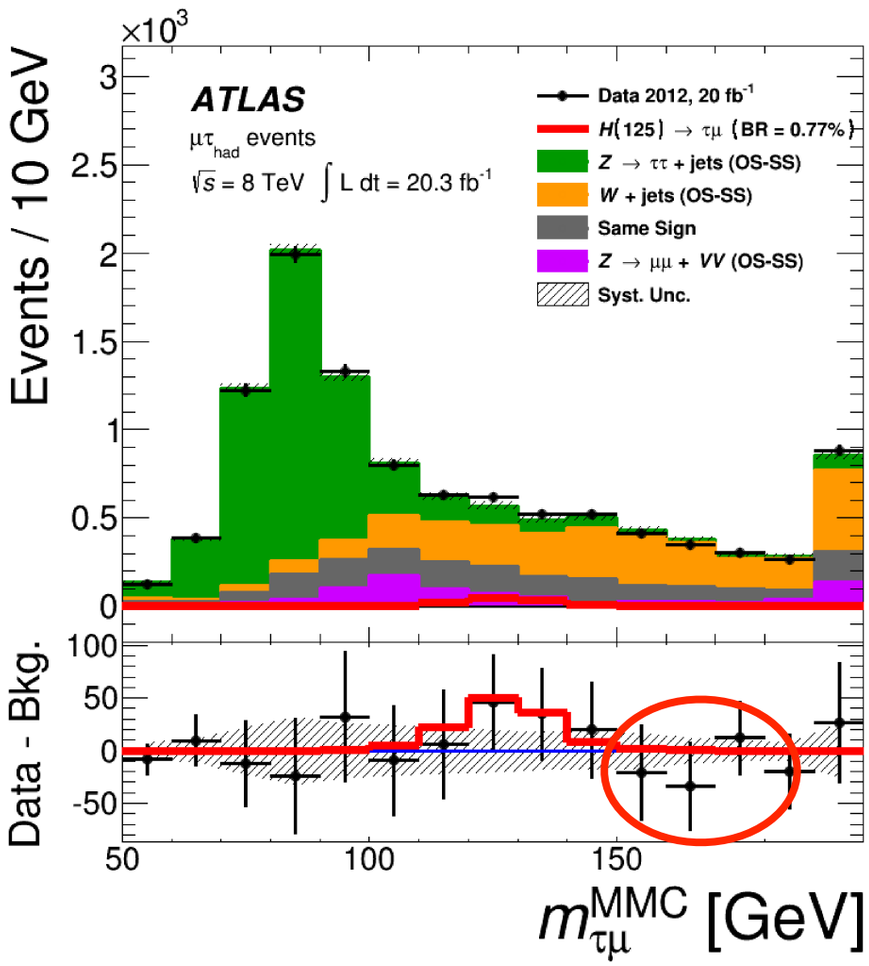




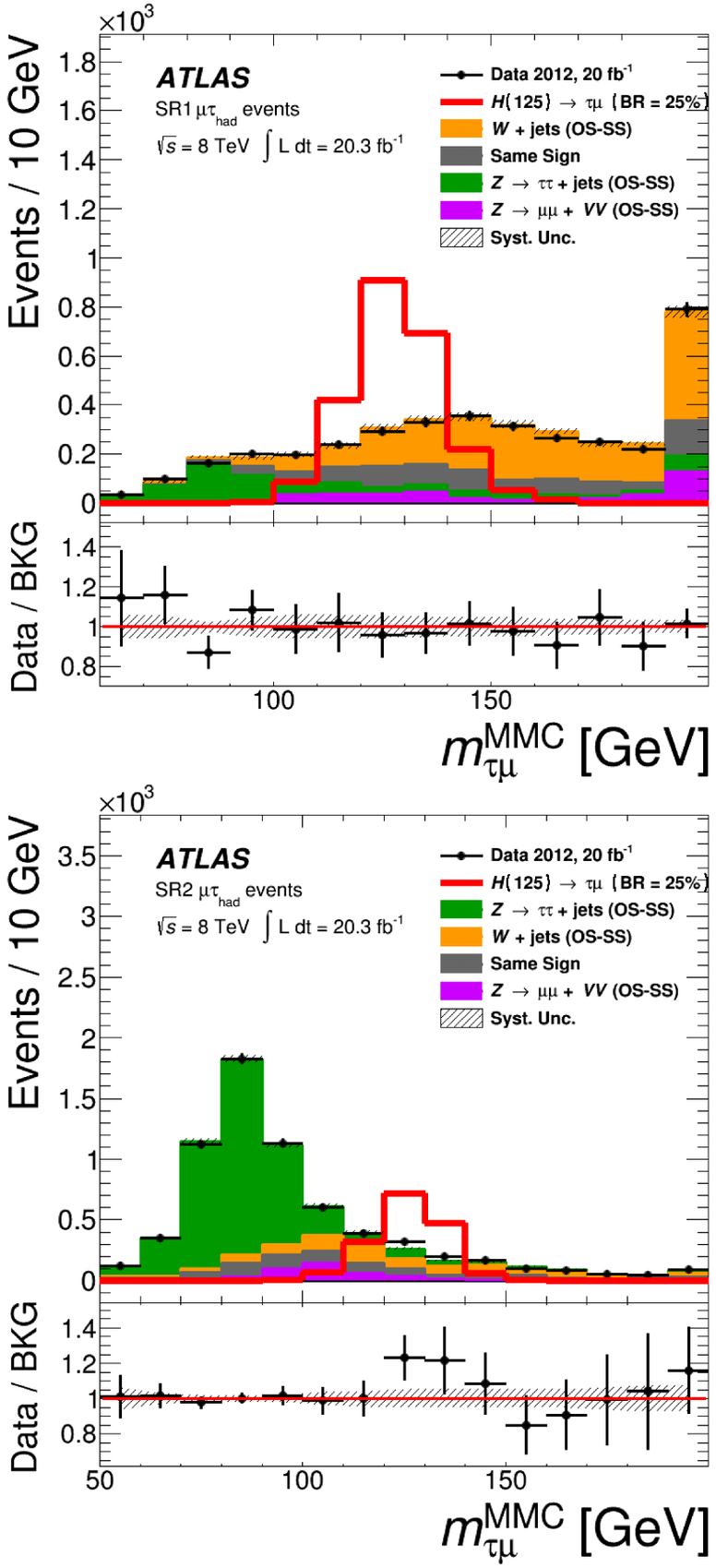


ATLAS

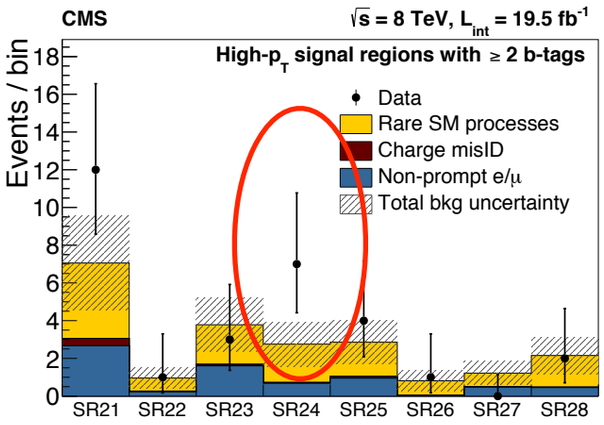
- Only hadronic tau decays
- "Missing Mass Calculator"
- Two signal regions
  - Differ mainly in m_T(mu,MET)
- One σ, also ~1% BR

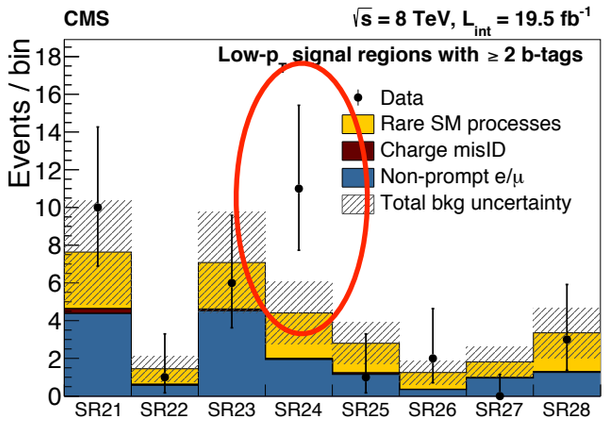


ATLAS: arXiv:1508.03372



Same Sign Lepton Excesses

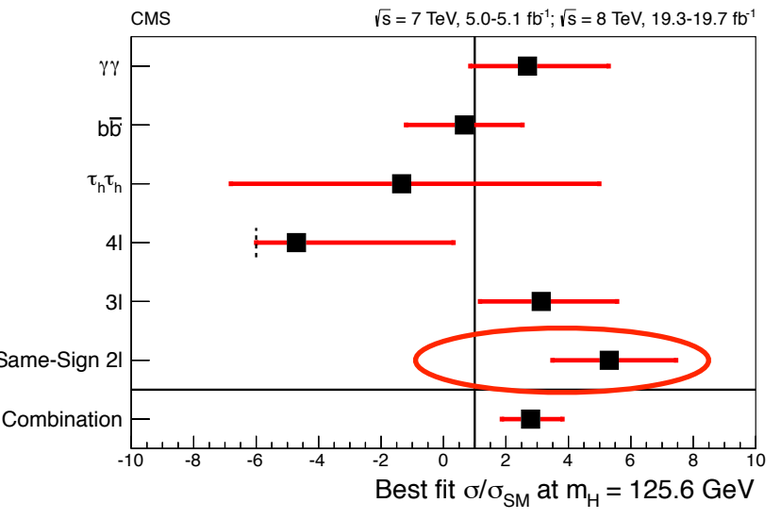




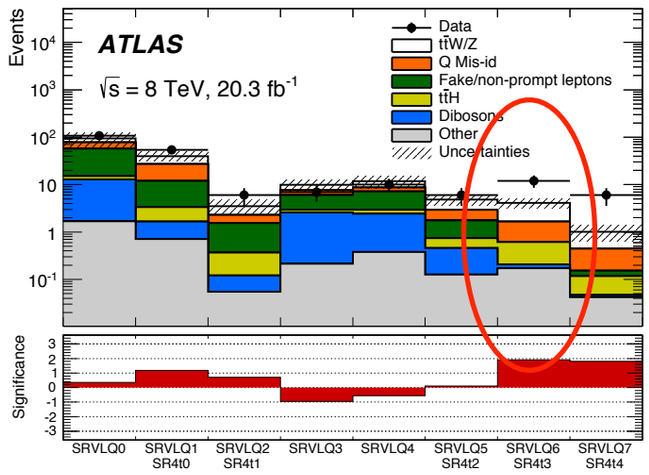
CMS (SUSY), http://arxiv.org/abs/1311.6736 (24 signal regions in paper)

SR1b $_{1bin}$	Total	ee	$e\mu$	$\mu\mu$
Observed events	10	6	4	0
Total expected background events	4.7 ± 2.1	1.4 ± 0.8	2.1 ± 1.1	1.2 ± 0.4
Components of the background				
$t\bar{t}V$, $t\bar{t}H$, tZ and $t\bar{t}t\bar{t}$	2.5 ± 1.7	0.6 ± 0.3	1.2 ± 1.0	0.7 ± 0.3
Dibosons and tribosons	0.9 ± 0.4	0.10 ± 0.04	0.3 ± 0.1	0.5 ± 0.3
Fake leptons	$0.8^{+1.2}_{-0.8}$	$0.4^{+0.7}_{-0.4}$	$0.4^{+0.5}_{-0.4}$	< 0.1
Charge-flip electrons	0.5 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	–
$p(s = 0)$	0.07	0.01	0.18	0.50

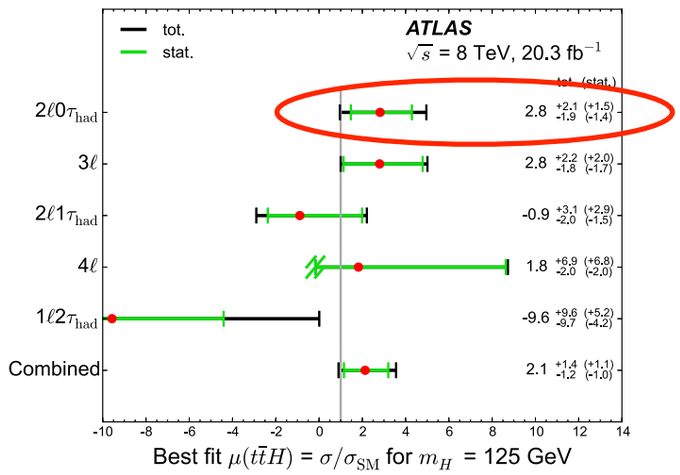
ATLAS (SUSY), http://arxiv.org/abs/1404.2500 (5 signal regions in paper)



CMS (ttH), http://arxiv.org/abs/1408.1682



ATLAS (TT), http://arxiv.org/abs/1504.04605



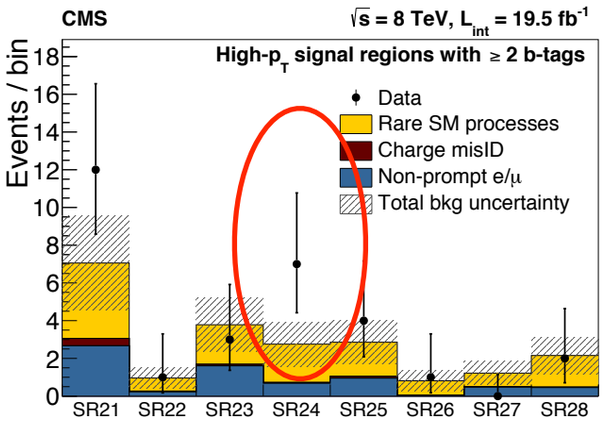
ATLAS (ttH), http://arxiv.org/abs/1506.05988

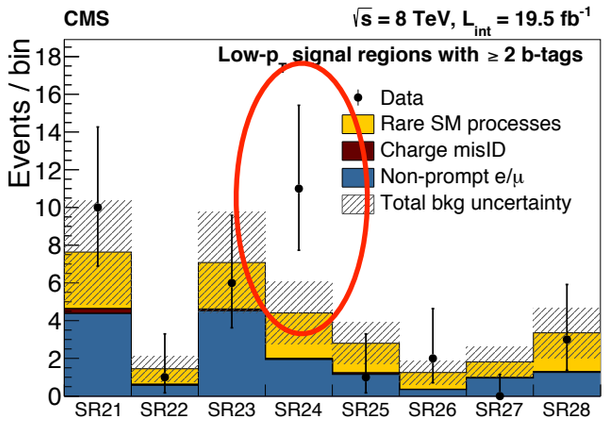
It certainly looks like multiple analyses looking at same sign leptons and b-jets see excesses!

Could it be SUSY? E.g. $\tilde{t}_R \to t + \tilde{B} \to t + (\tilde{W}^{\pm} + W^{\mp})$

Huang et al, http://arxiv.org/abs/1507.01601

Same Sign Lepton Excesses





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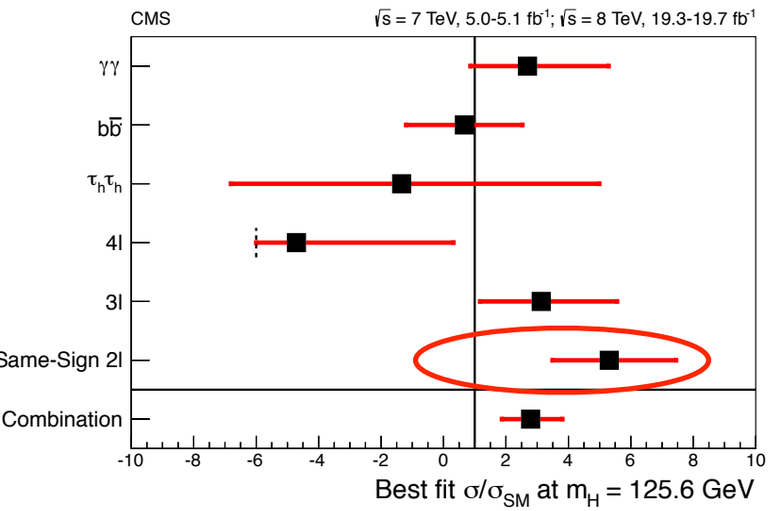

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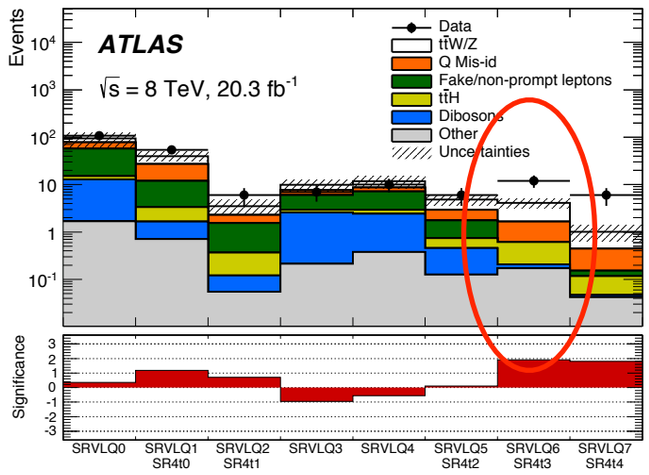

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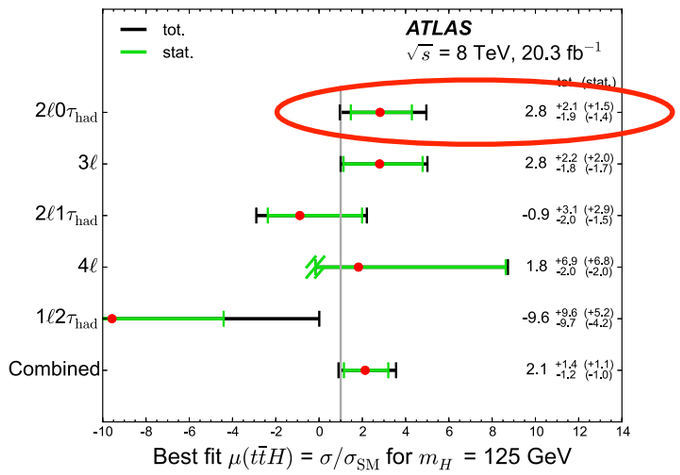

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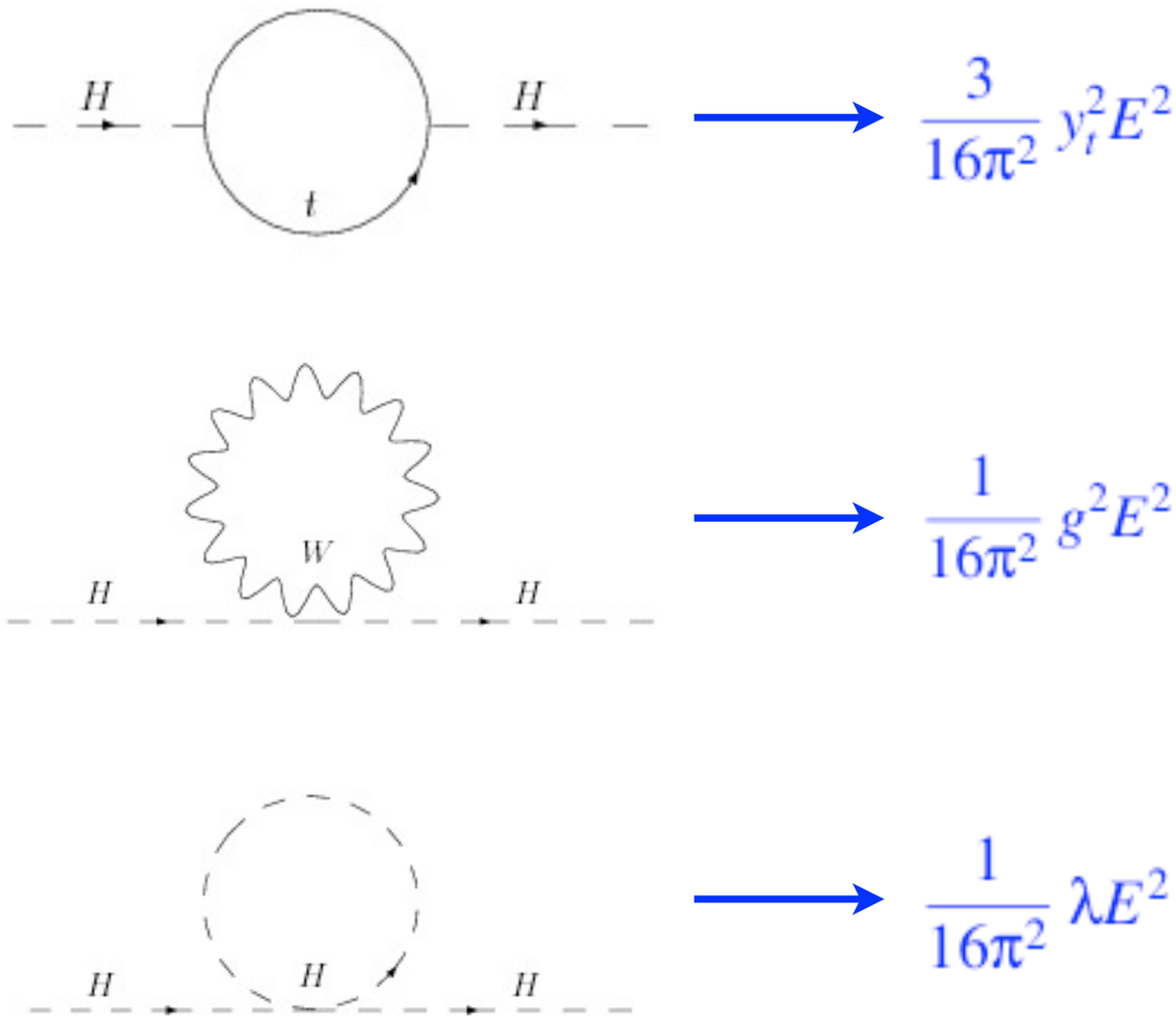
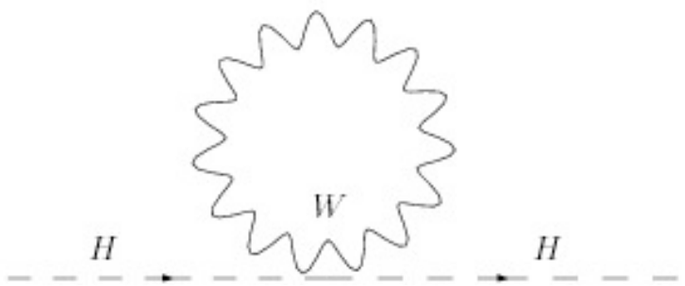
The ATLAS analyses are correlated, and same for CMS
So, ~2 analyses and excesses are < 3 σ
Worth keeping an eye on? Sure.

We've Found a Higgs!



We've Found a Higgs!

No top partners below ~750 GeV

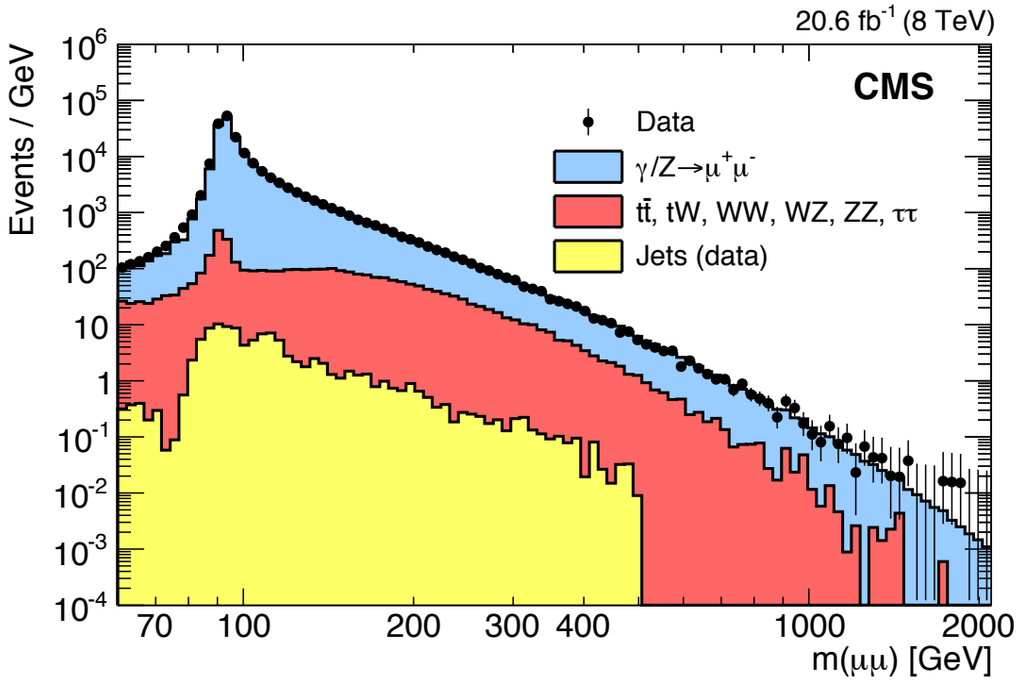


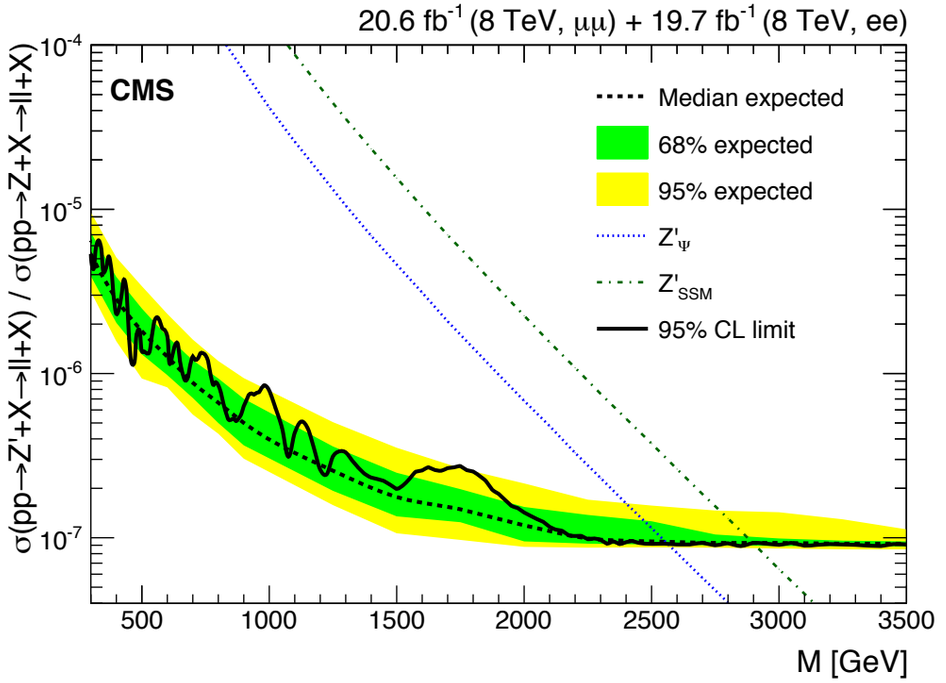
$$\longrightarrow \frac{1}{16\pi^2} g^2 E^2$$

$$\longrightarrow \frac{1}{16\pi^2} \lambda E^2$$

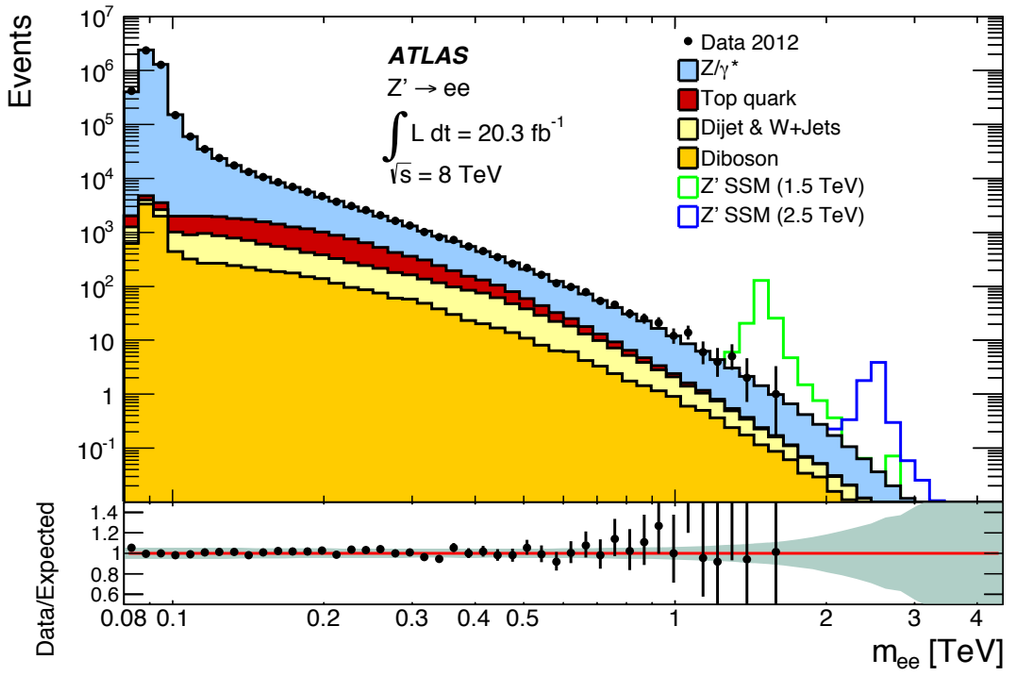
Z' → ee/μμ

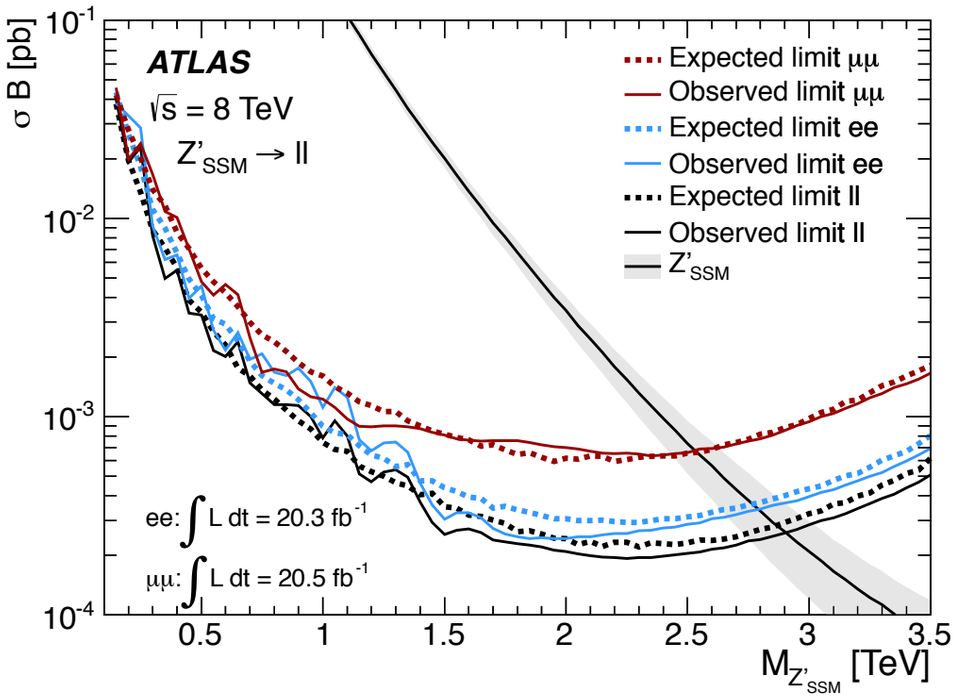
CMS, J. High Energy Phys. 04 (2015) 025





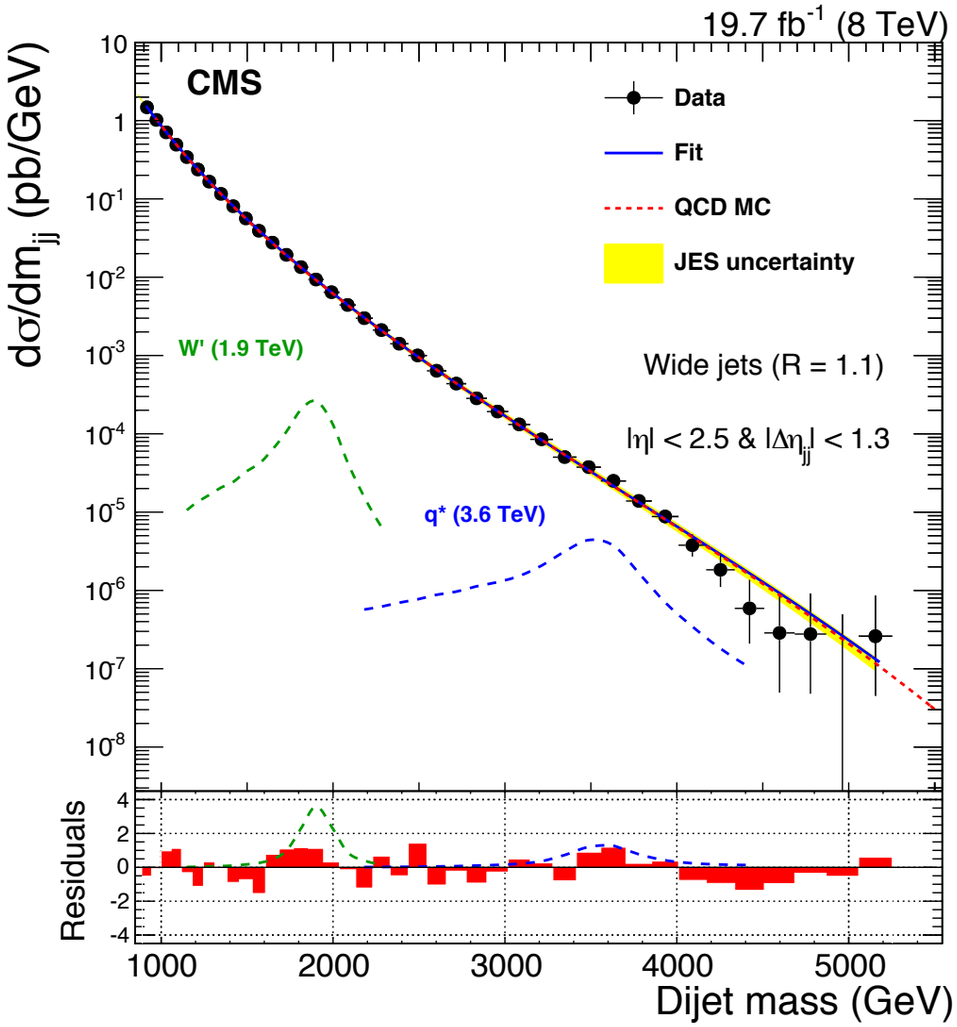
ATLAS, Phys. Rev. D. 90, 052005 (2014)

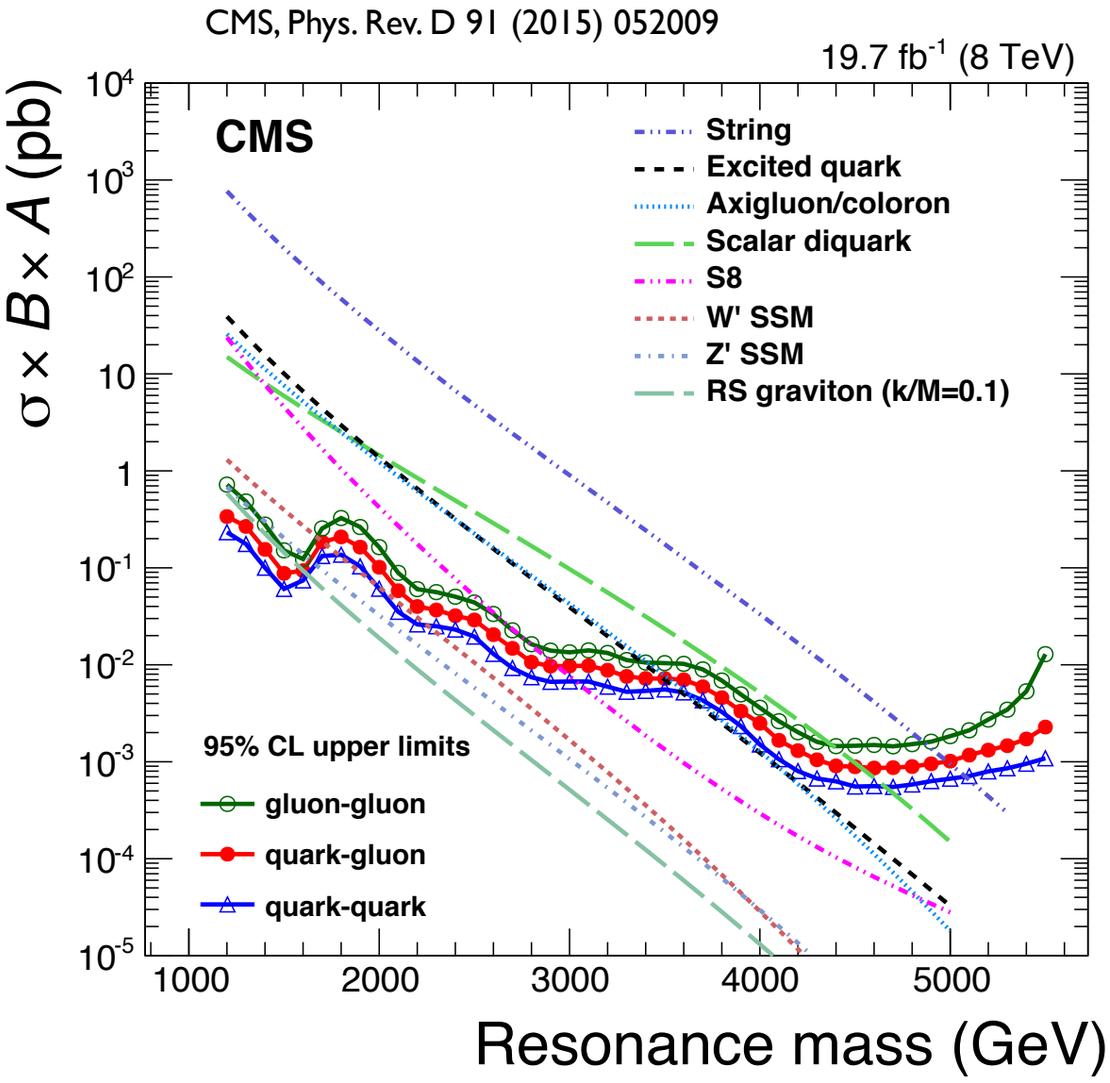




Dijets

- SM Background obviously much larger
  - But single source
  - (For a while dijets best W' limit at Tevatron.. run1)





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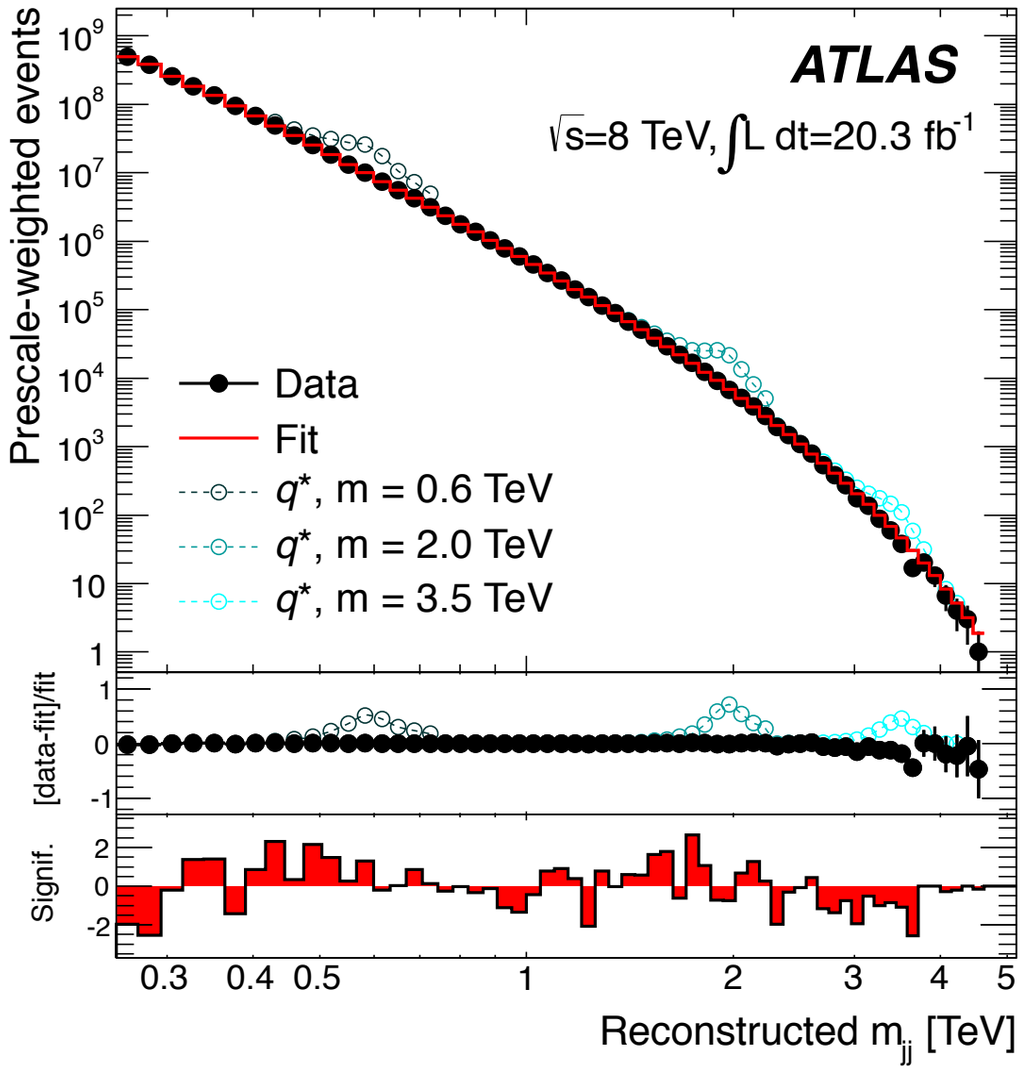
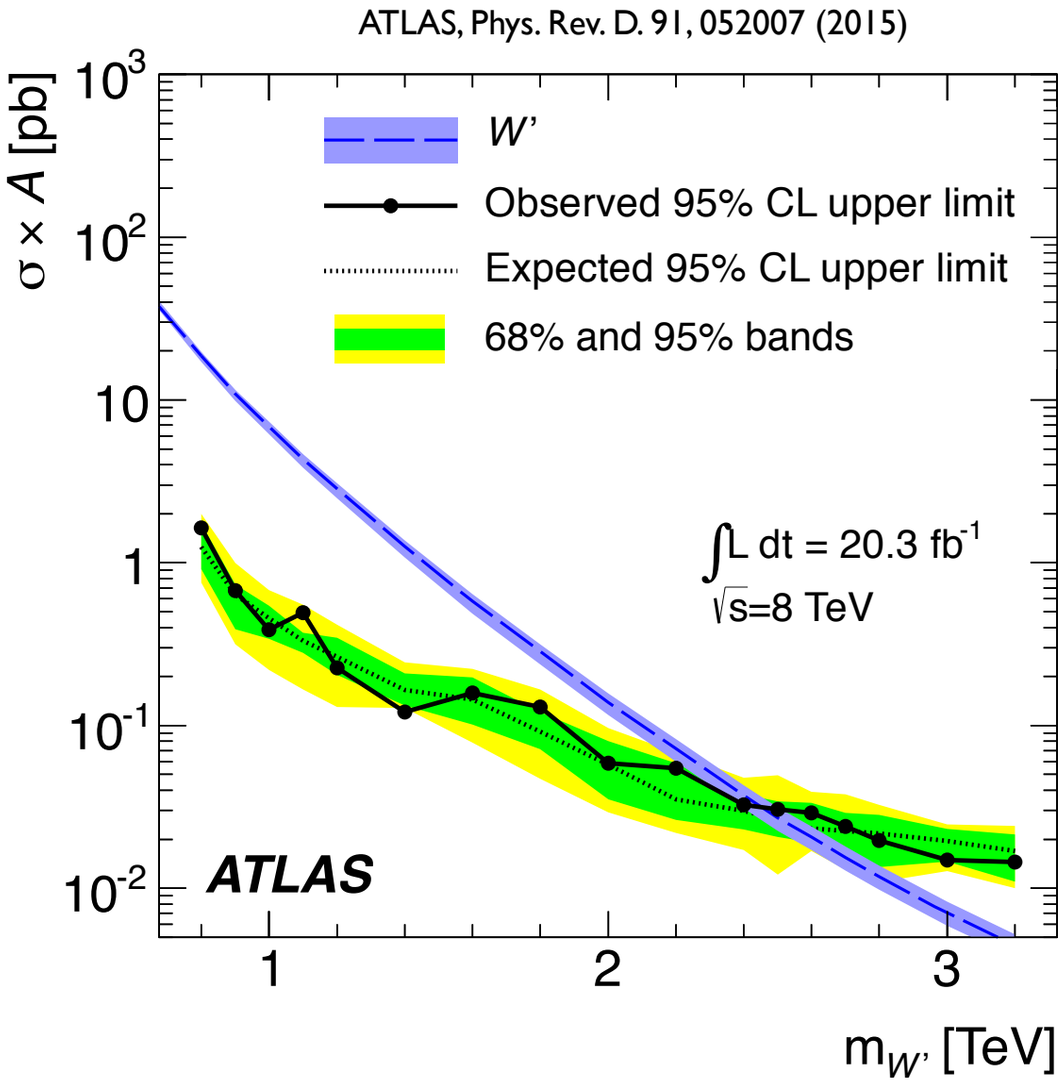
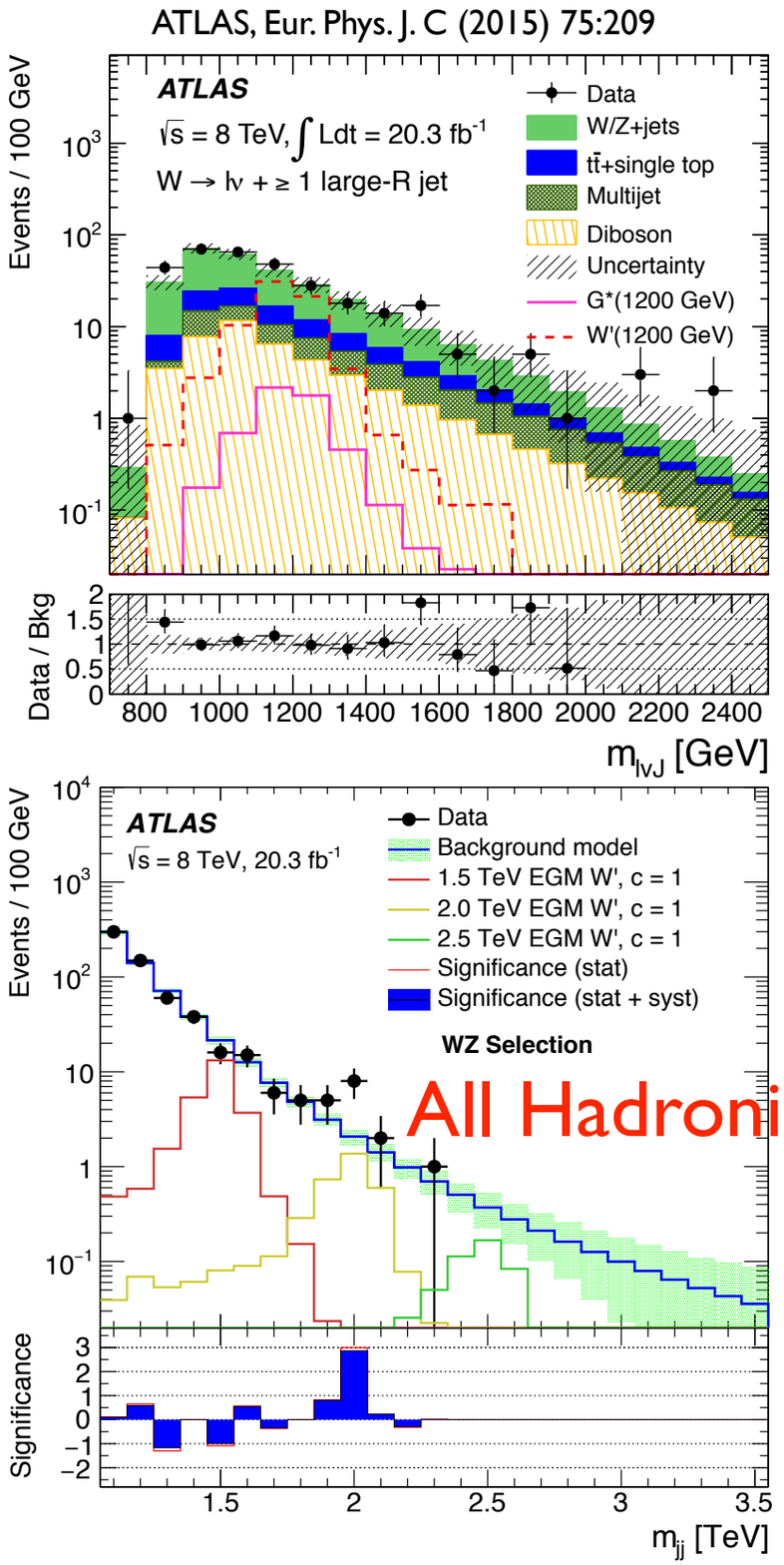
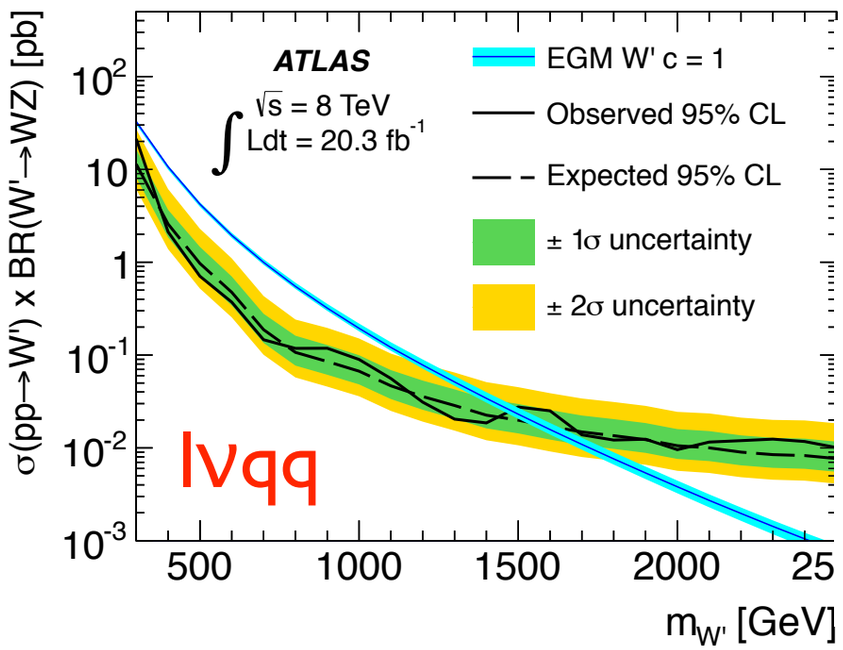
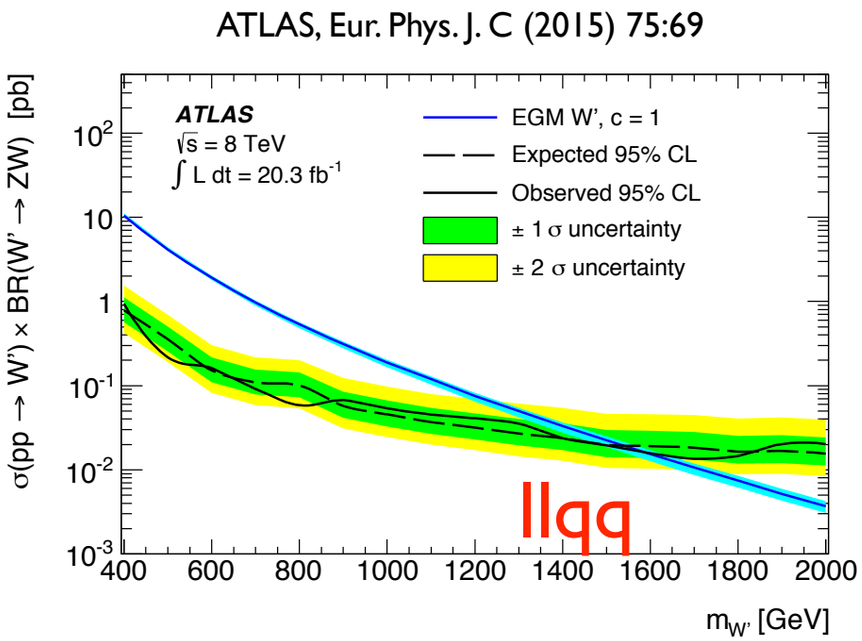


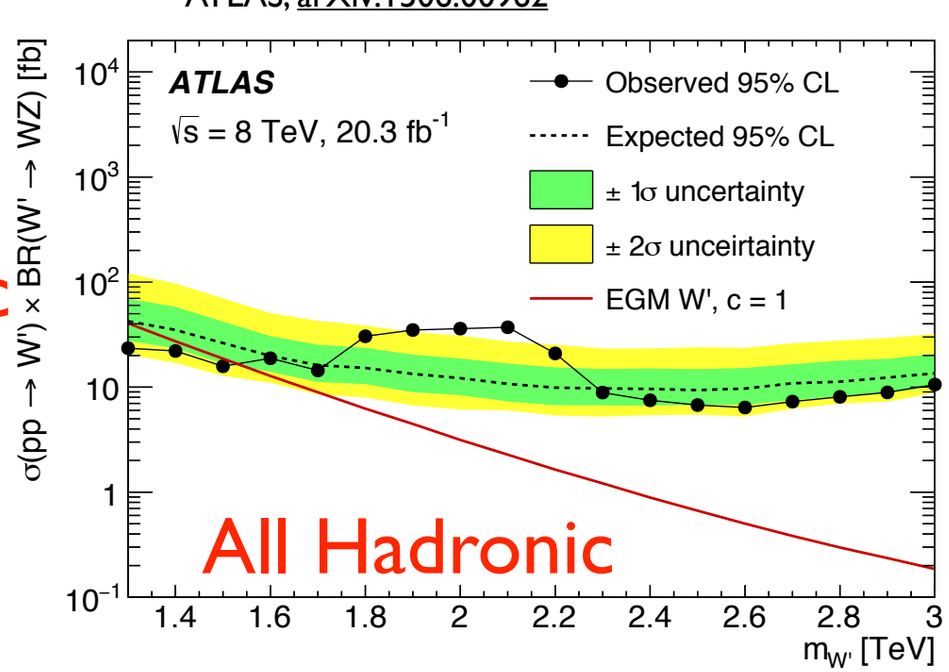


Diboson Resonance Results: ATLAS





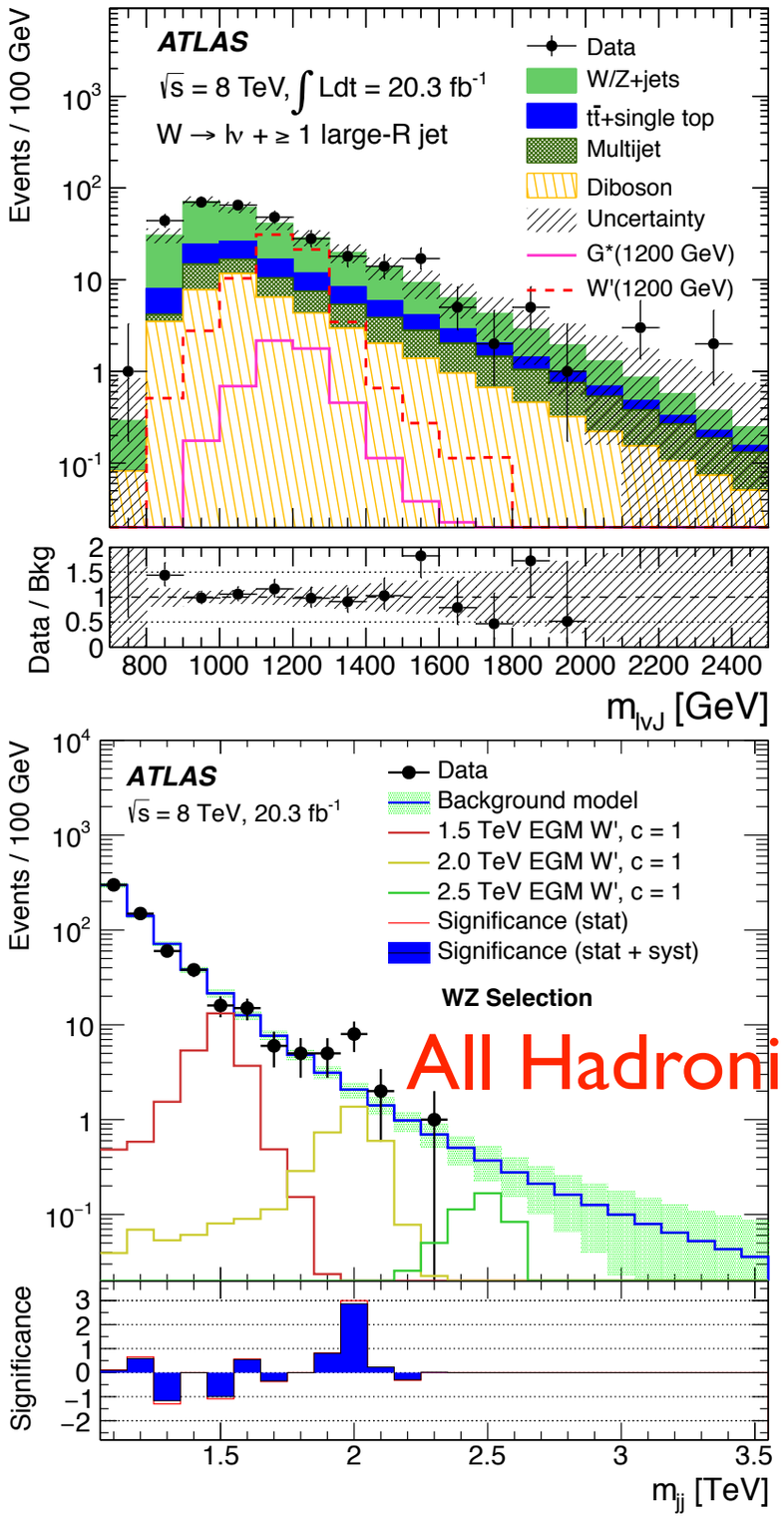




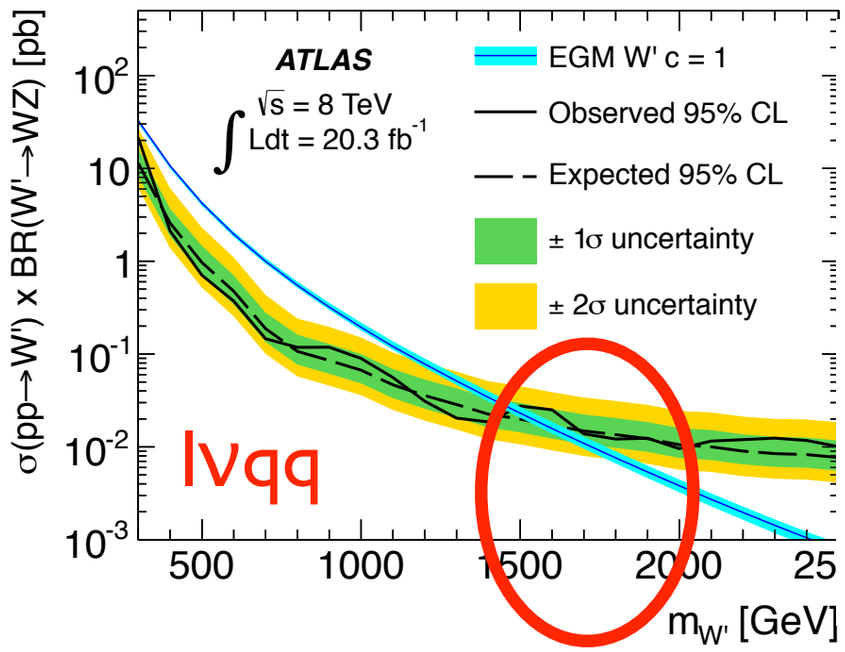
No evidence…

Diboson Resonance Results: ATLAS

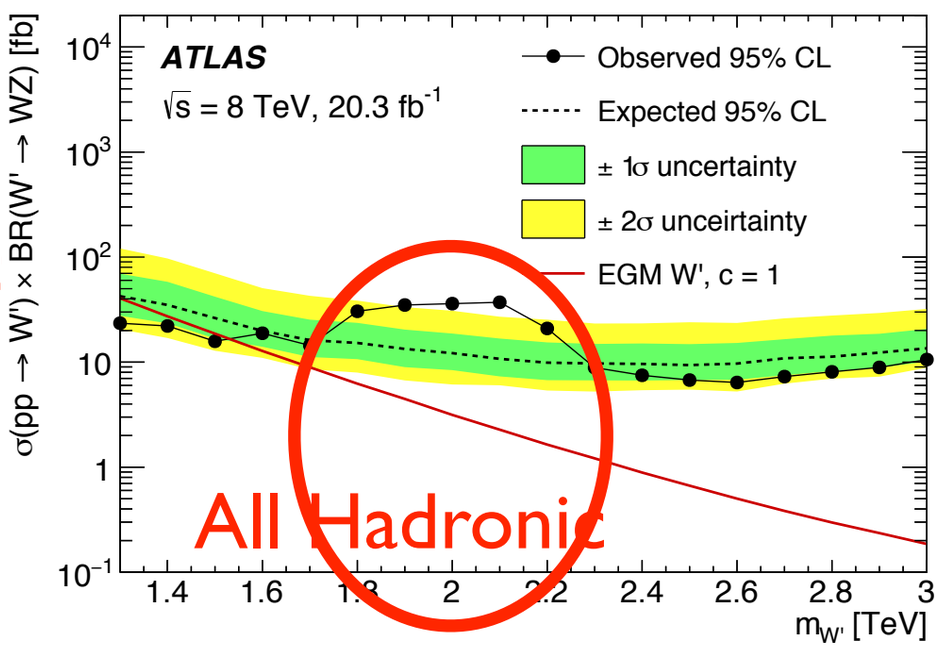
ATLAS, Eur. Phys. J. C (2015) 75:209



All Hadronic

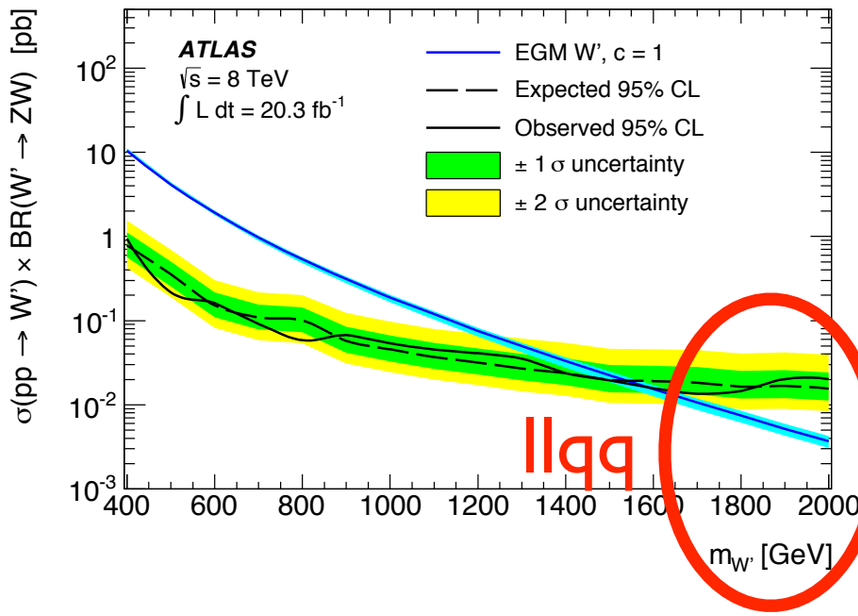


ATLAS, arXiv:1506.00962



All Hadronic

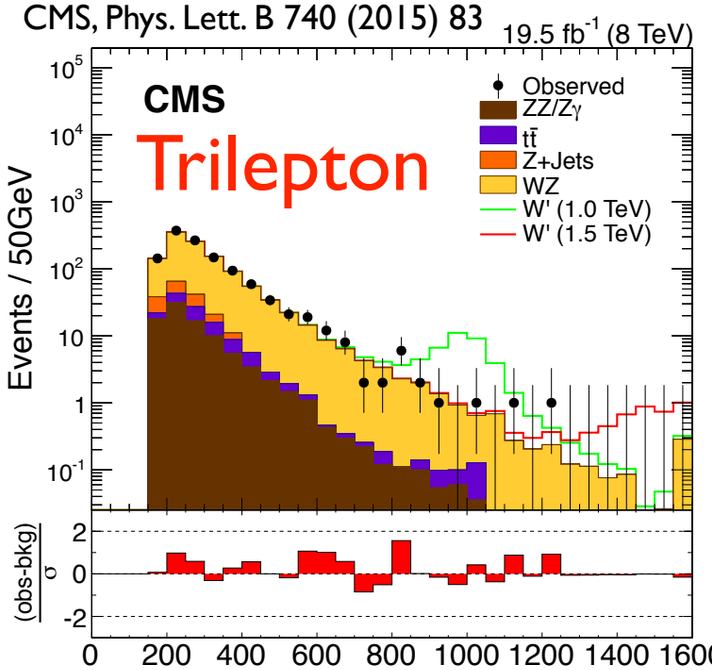
ATLAS, Eur. Phys. J. C (2015) 75:69

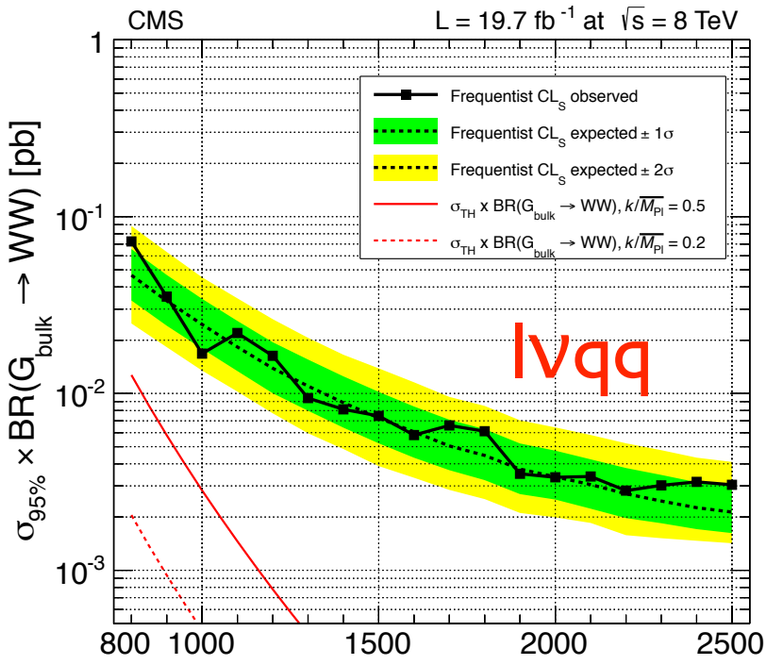


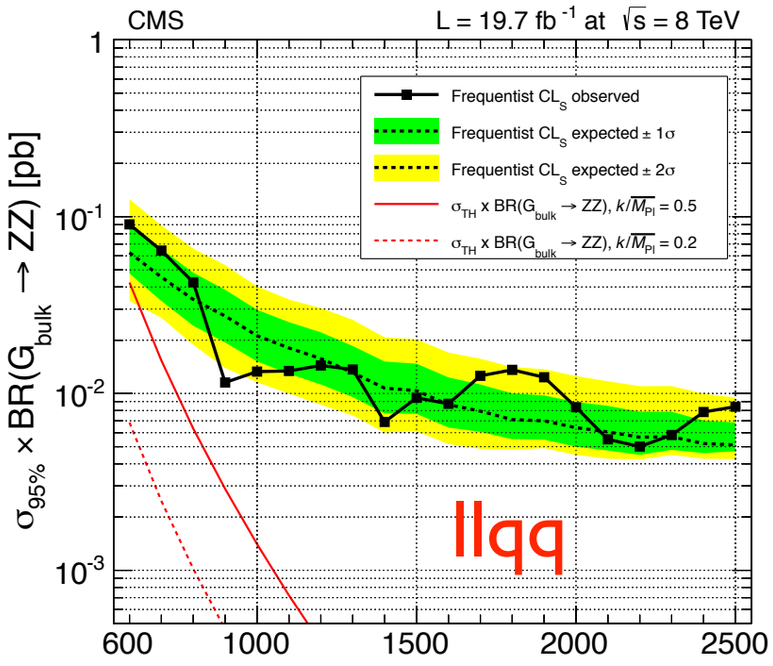
No evidence…

…one nice excess

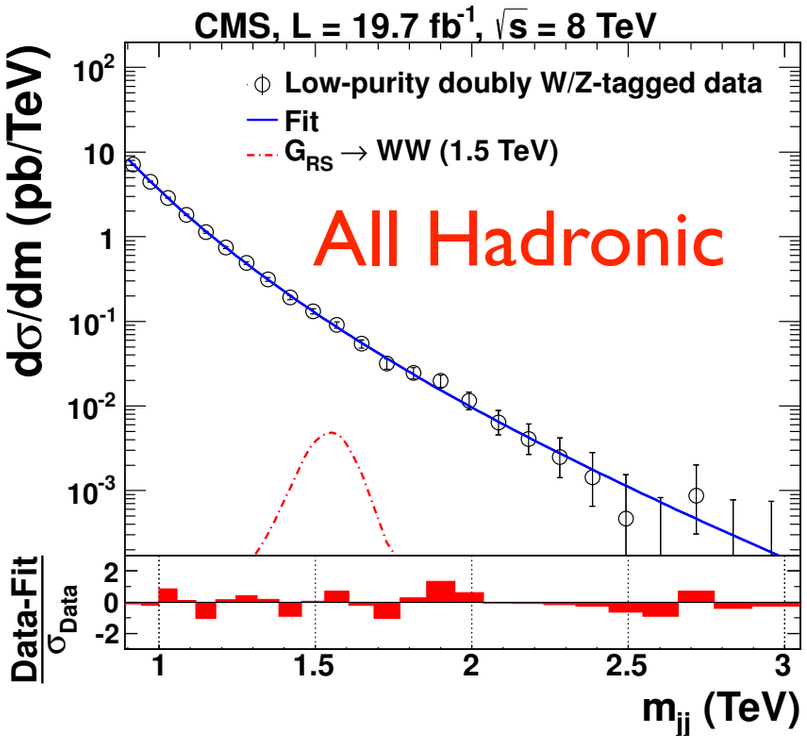
Diboson Resonance Results: CMS



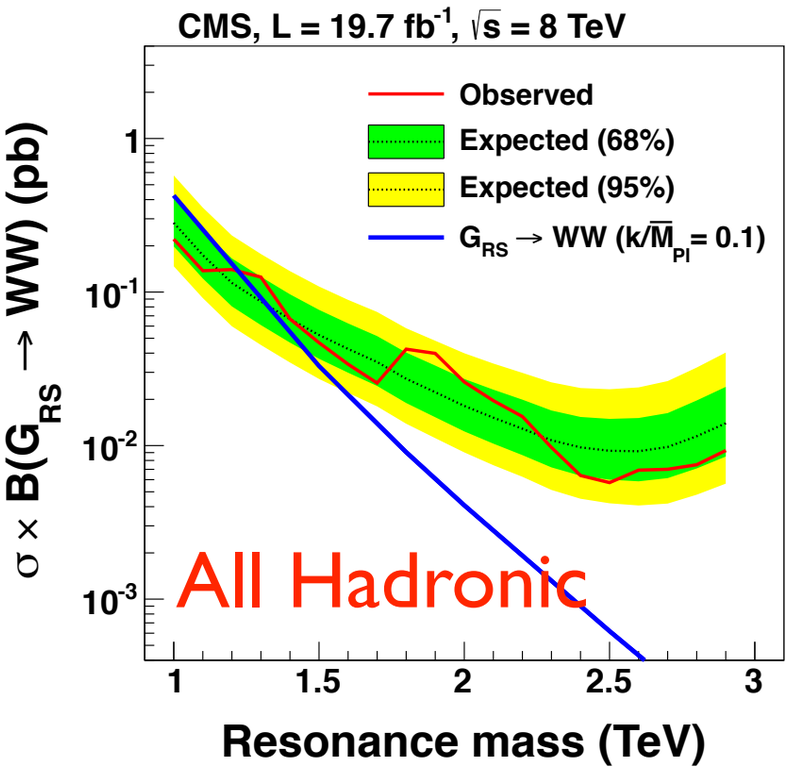




CMS, J. High Energy Phys. 08 (2014) 174



CMS, J. High Energy Phys. 08 (2014) 173



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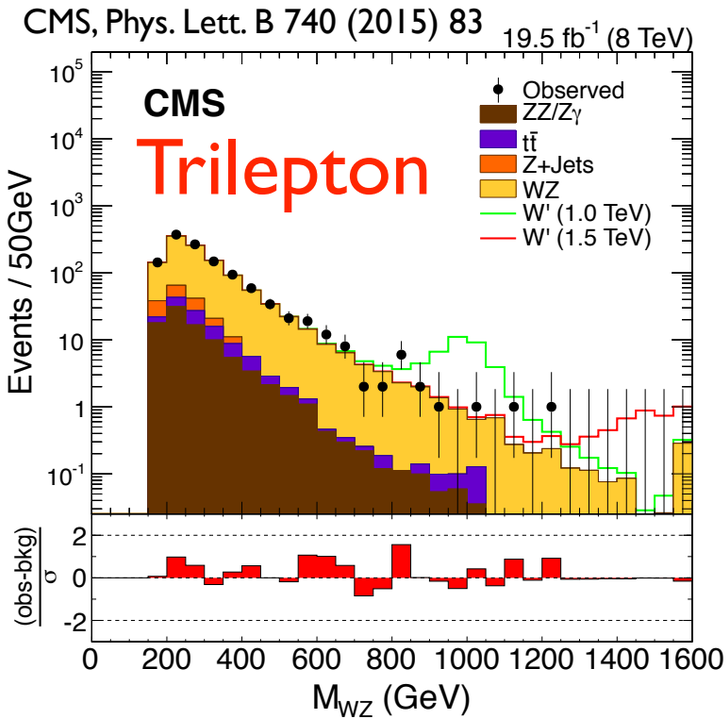
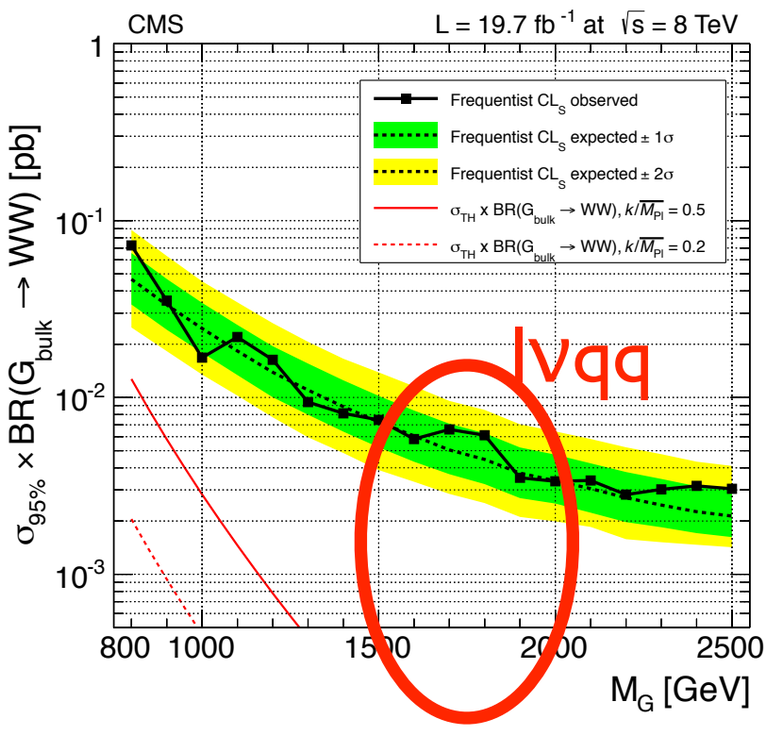
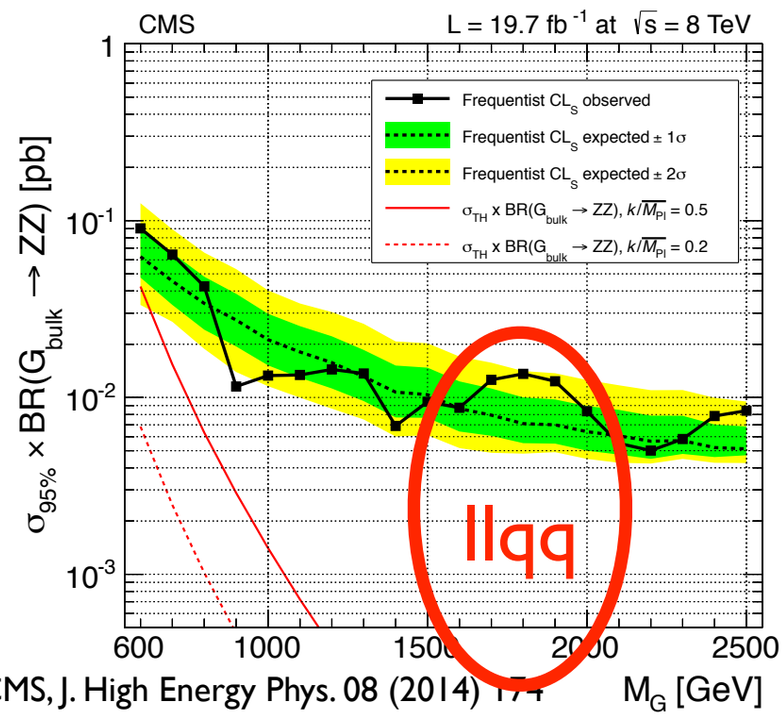
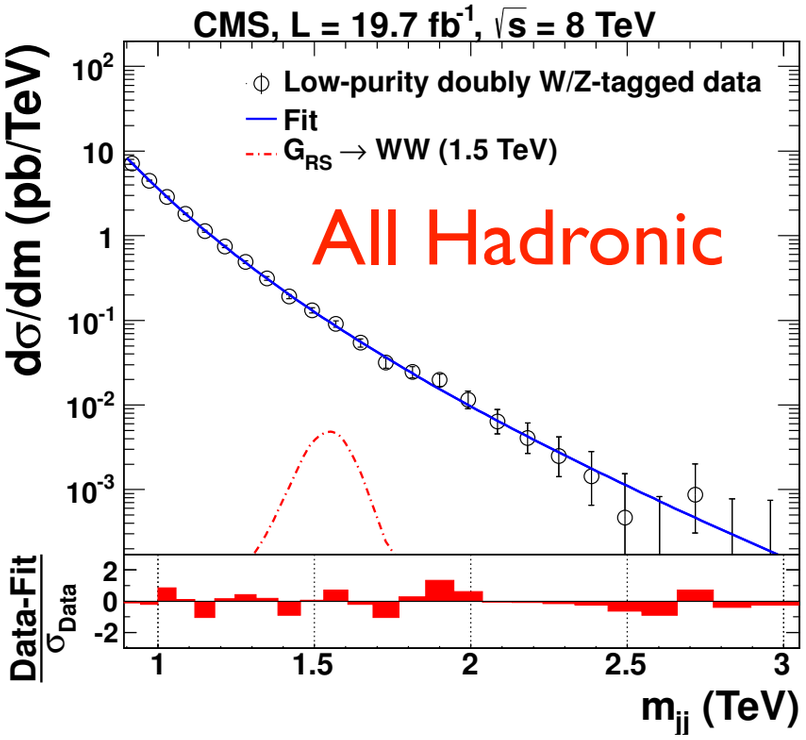
Diboson Resonance Results: CMS

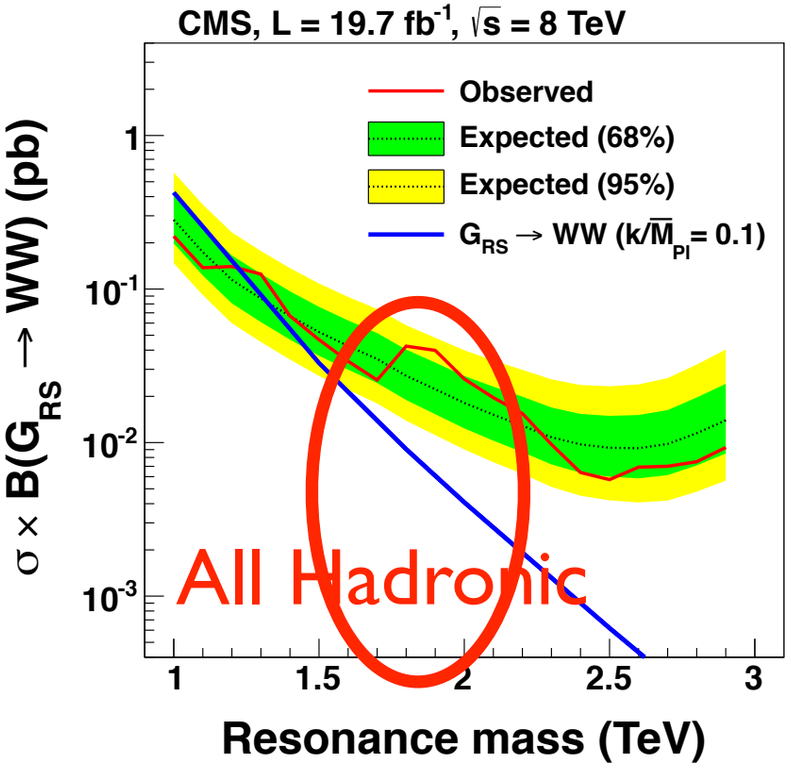








CMS, J. High Energy Phys. 08 (2014) 173



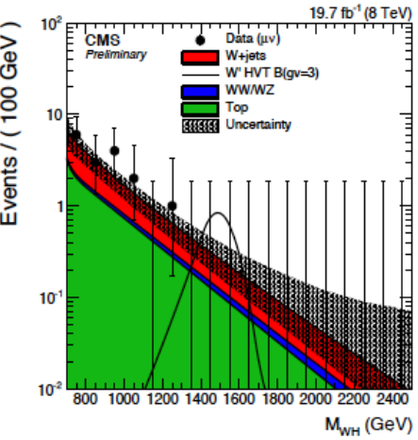
No evidence…

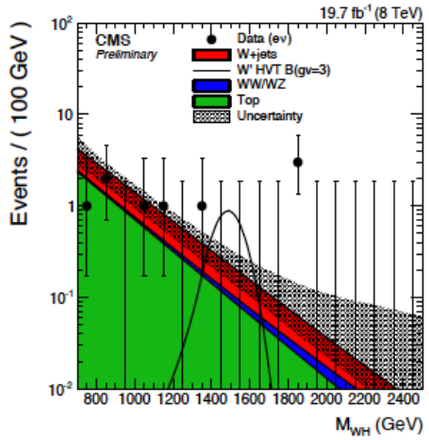
but a coincidence?

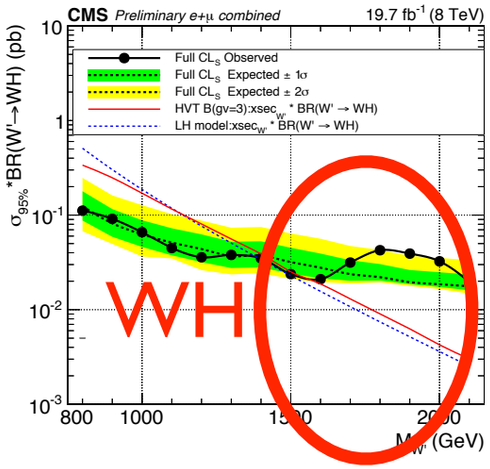
Decays to VH?

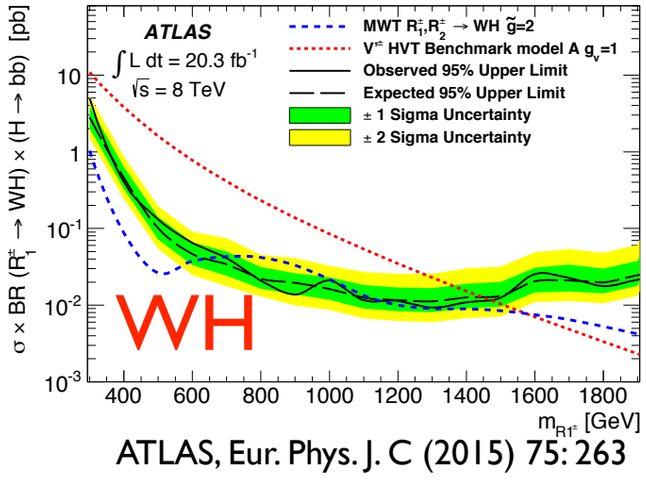
- Both ATLAS & CMS have analyses with b-tags ⇒ reduced acceptance

CMS-PAS-EXO-14-010

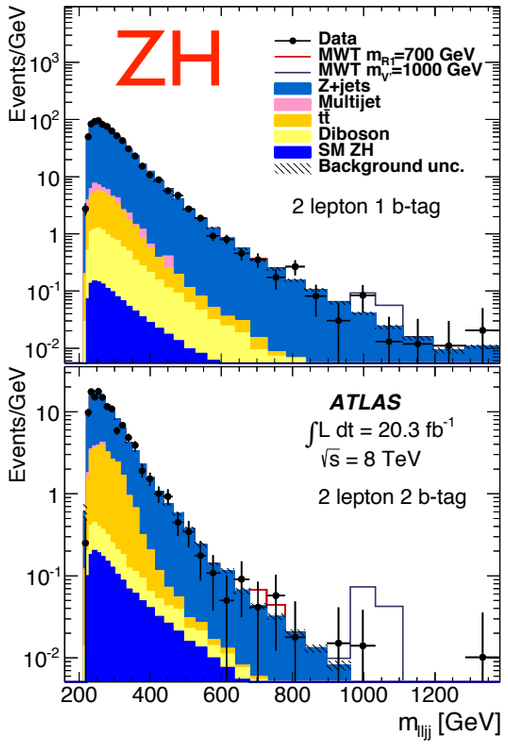






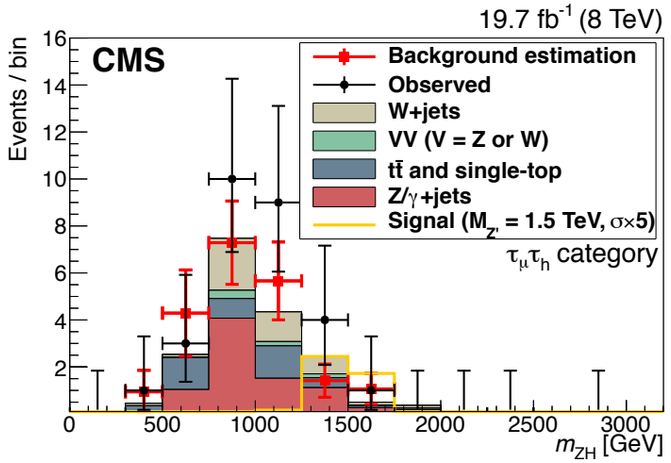


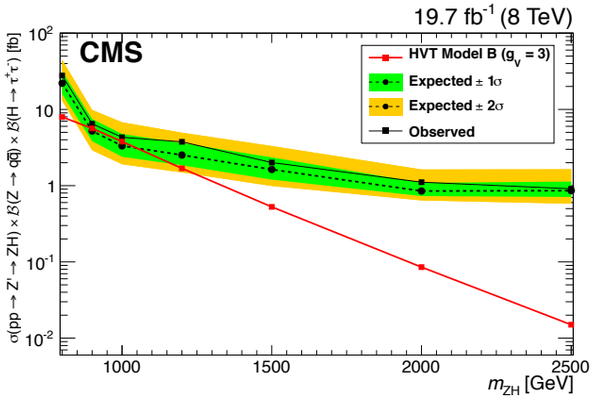
ATLAS, Eur. Phys. J. C (2015) 75: 263



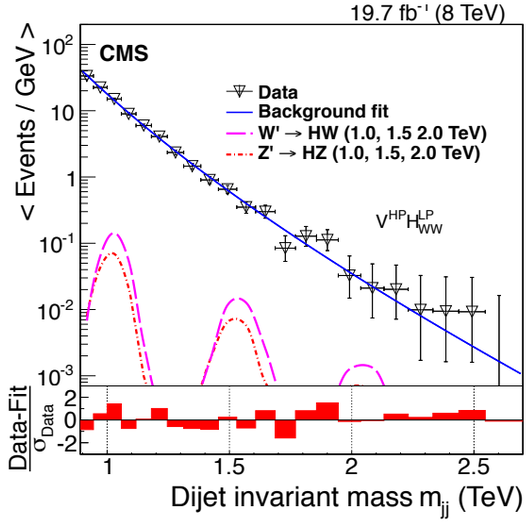
- CMS ZH ⇒ ττJ and all-hadronic VH

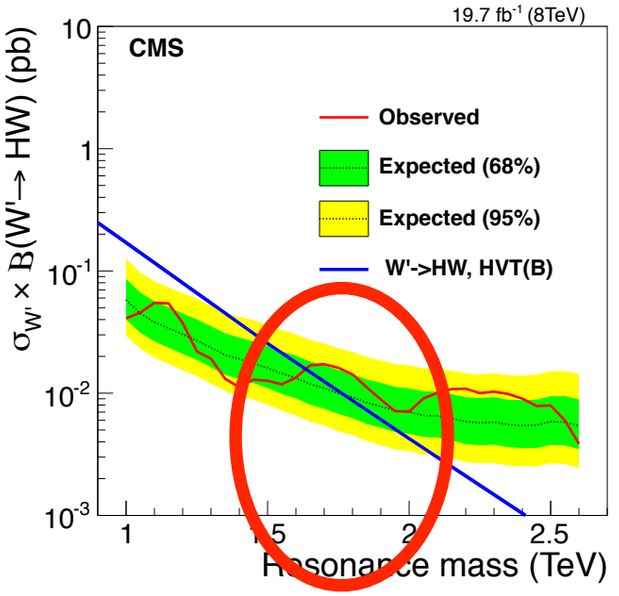
CMS, arXiv:1506.01443





CMS, arXiv:1502.04994

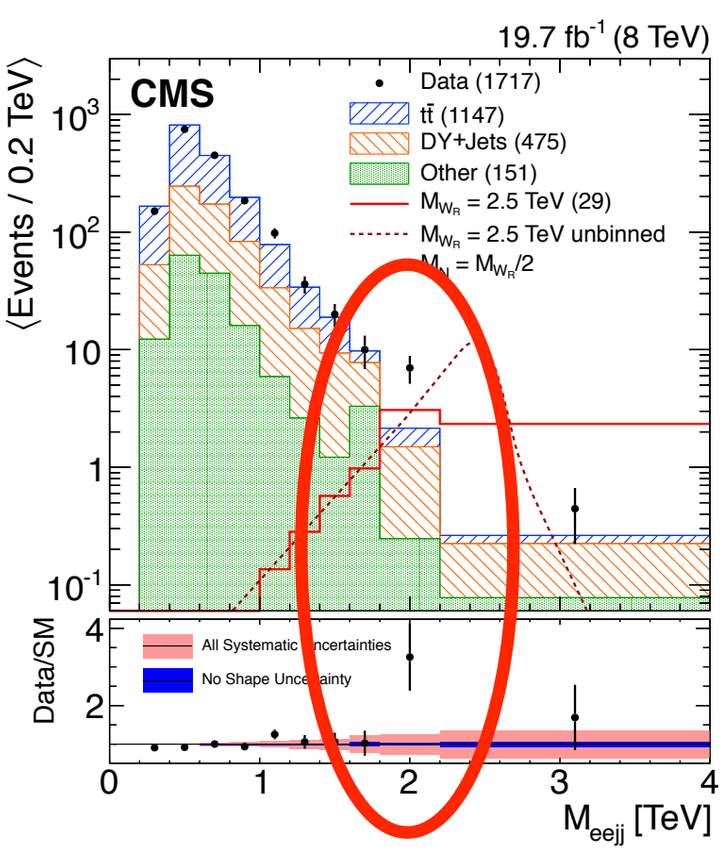


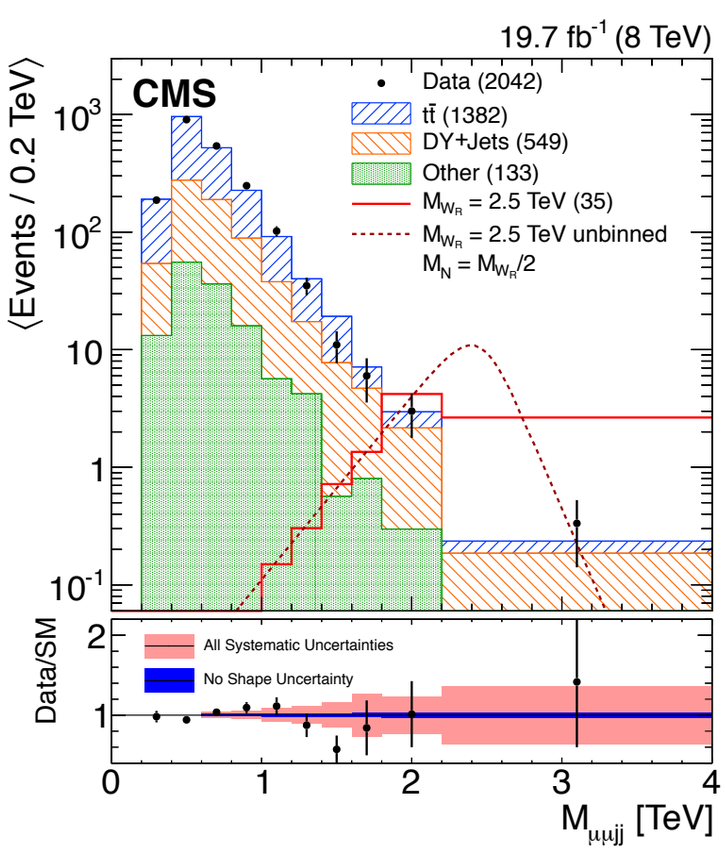


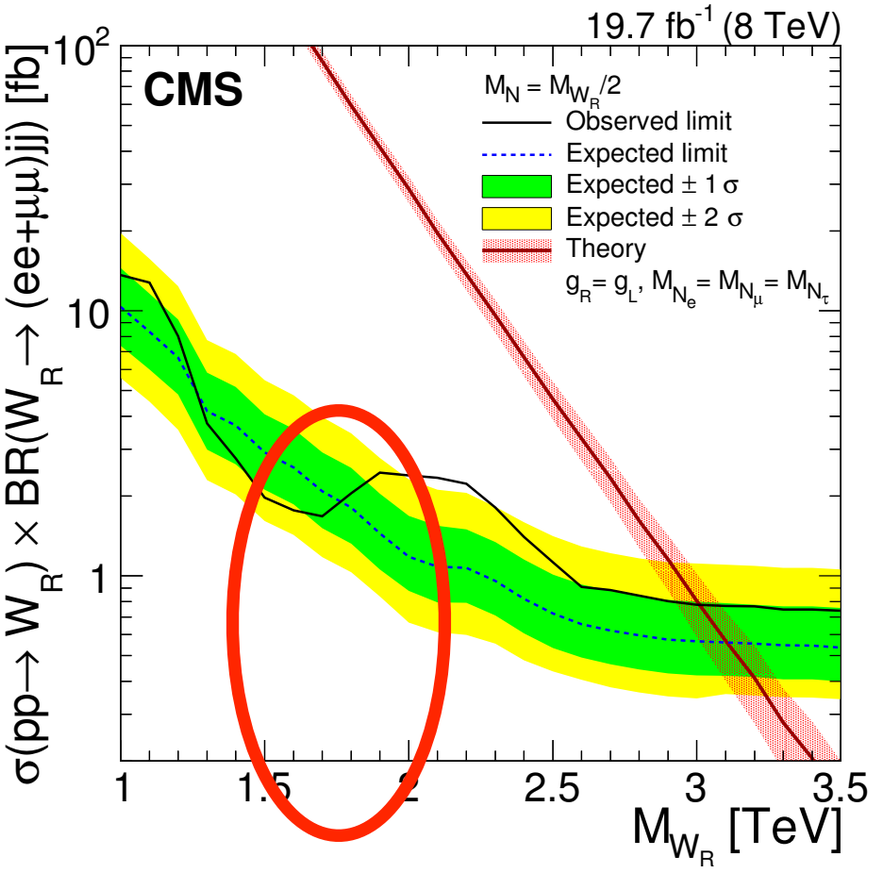
Speculating…

- If it's WZ, hints to a W'?
  - CMS W_R via ν_R search $\quad W_{\rm R} \to \ell \nu_{\rm R}^{(*)} \to \ell(\ell W_{\rm R}^{*}) \to \ell(\ell(q\bar{q}'))$
    - Dilepton + two jets final state

CMS, Eur. Phys. J. C 74 (2014) 3149







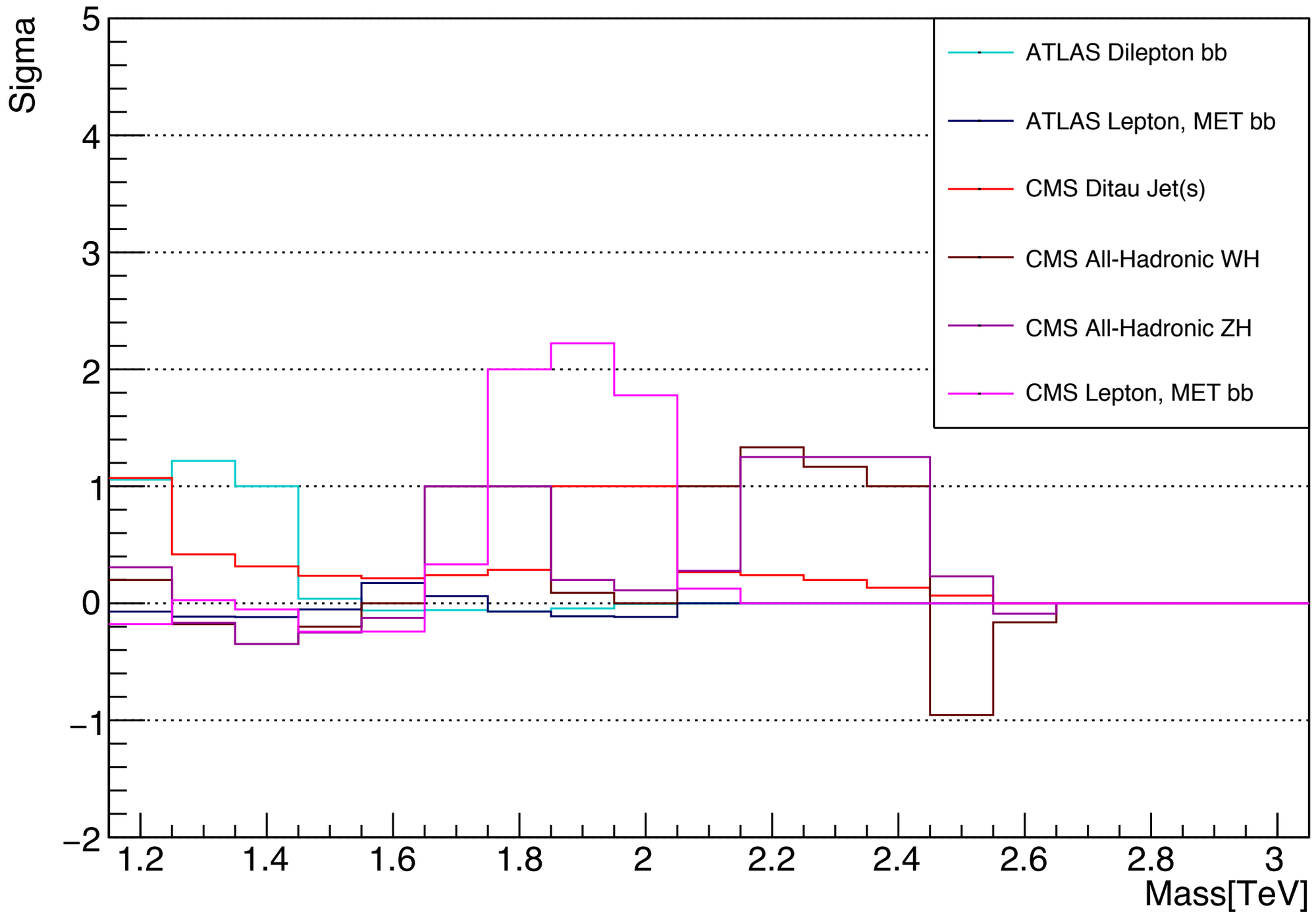
W'/Z'-Type Resonances

➡ Intriguing number of 1-2 sigma excesses at ~1.9 TeV (mostly at edge of kinematic range):

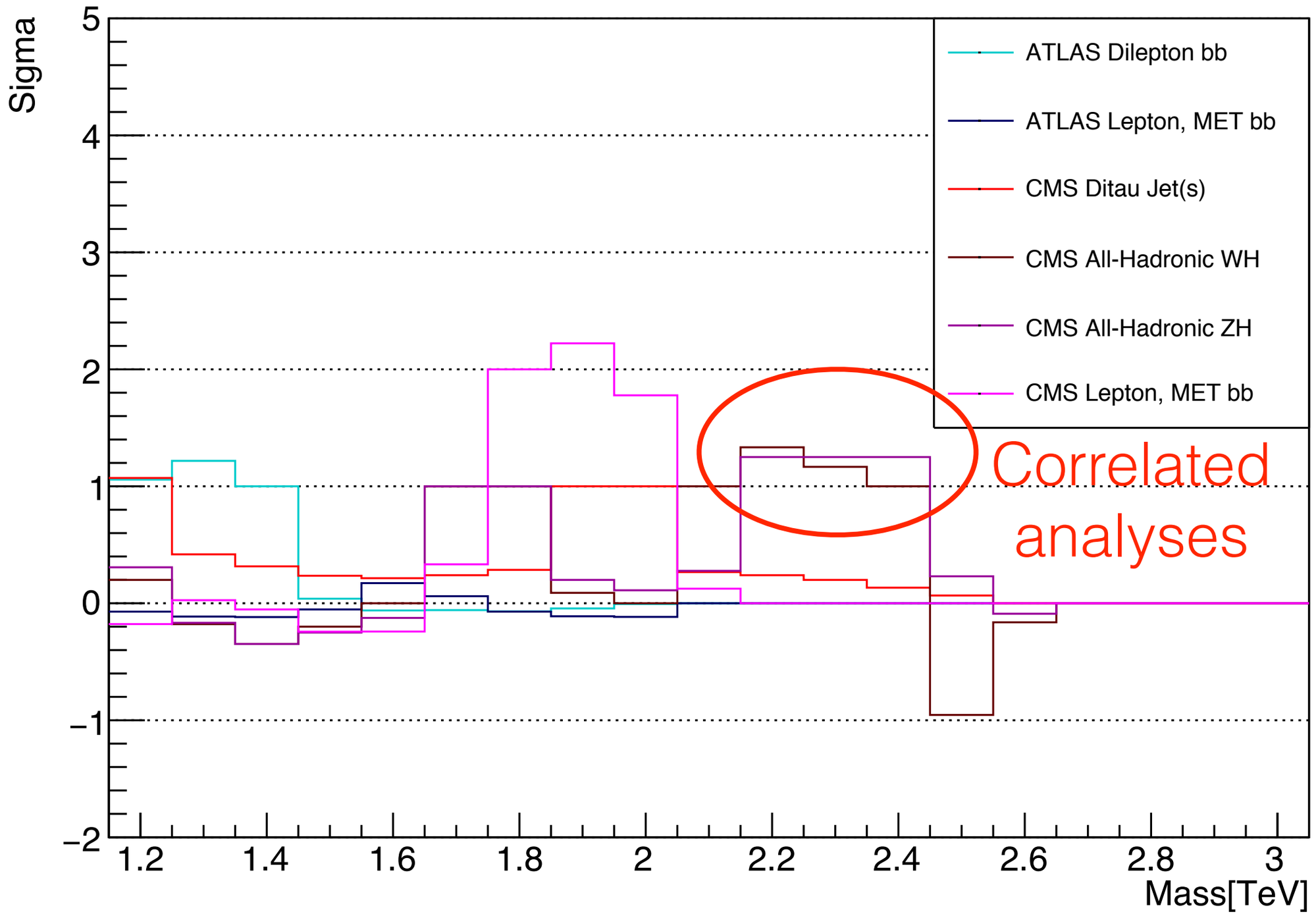
- 2 in ATLAS: all-hadronic diboson, dijet
- 6 in CMS: all-hadronic, lIJ, WH diboson, W_R, dijet, dilepton

- Are they compatible?
  - Combining requires BR assumptions, so look at correlation
  - Digitized limit plots with J. Tattersall
  - Overlay excesses
- Not ready yet: "signal" cross-sections

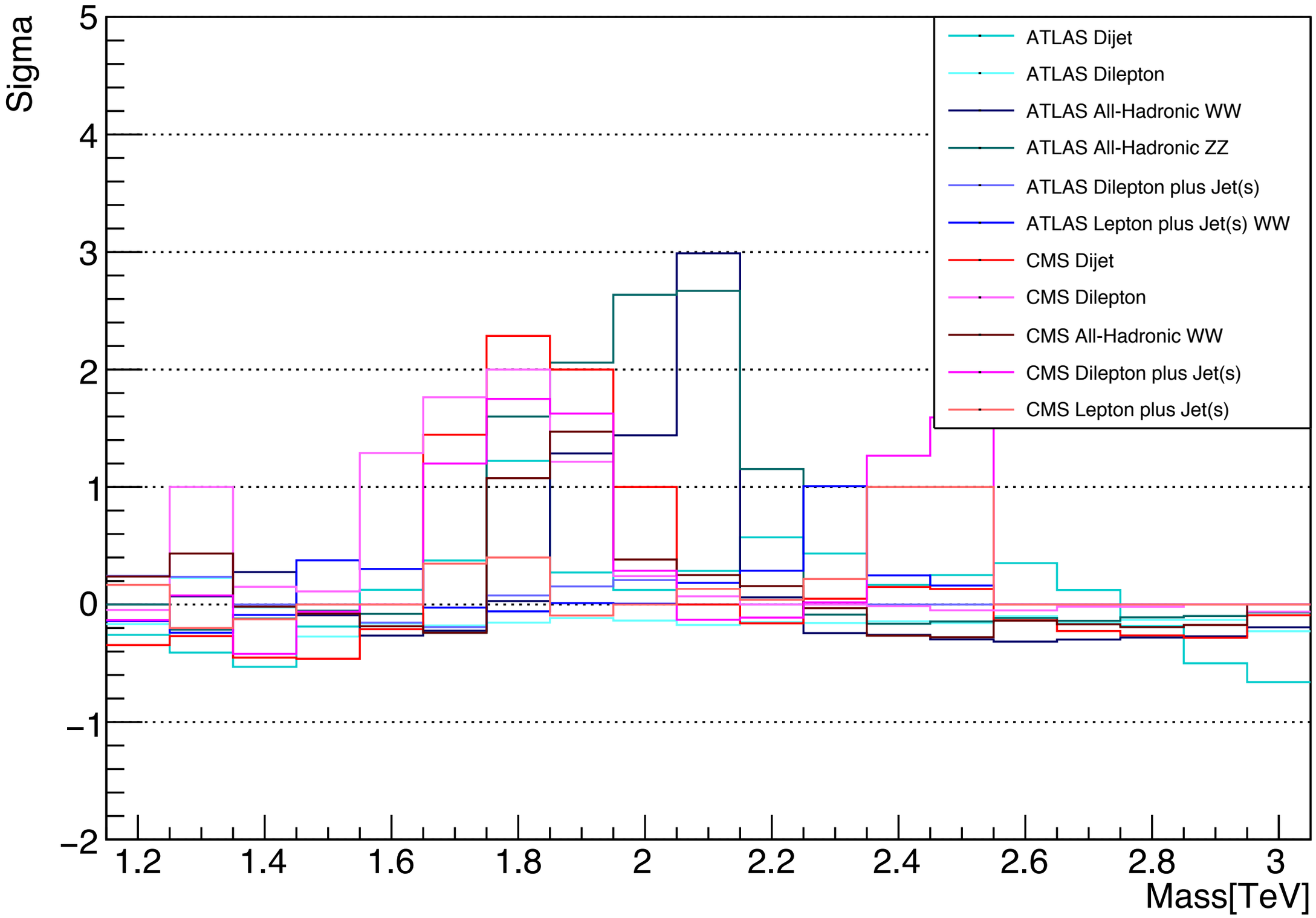
Decays With a Higgs Candidate



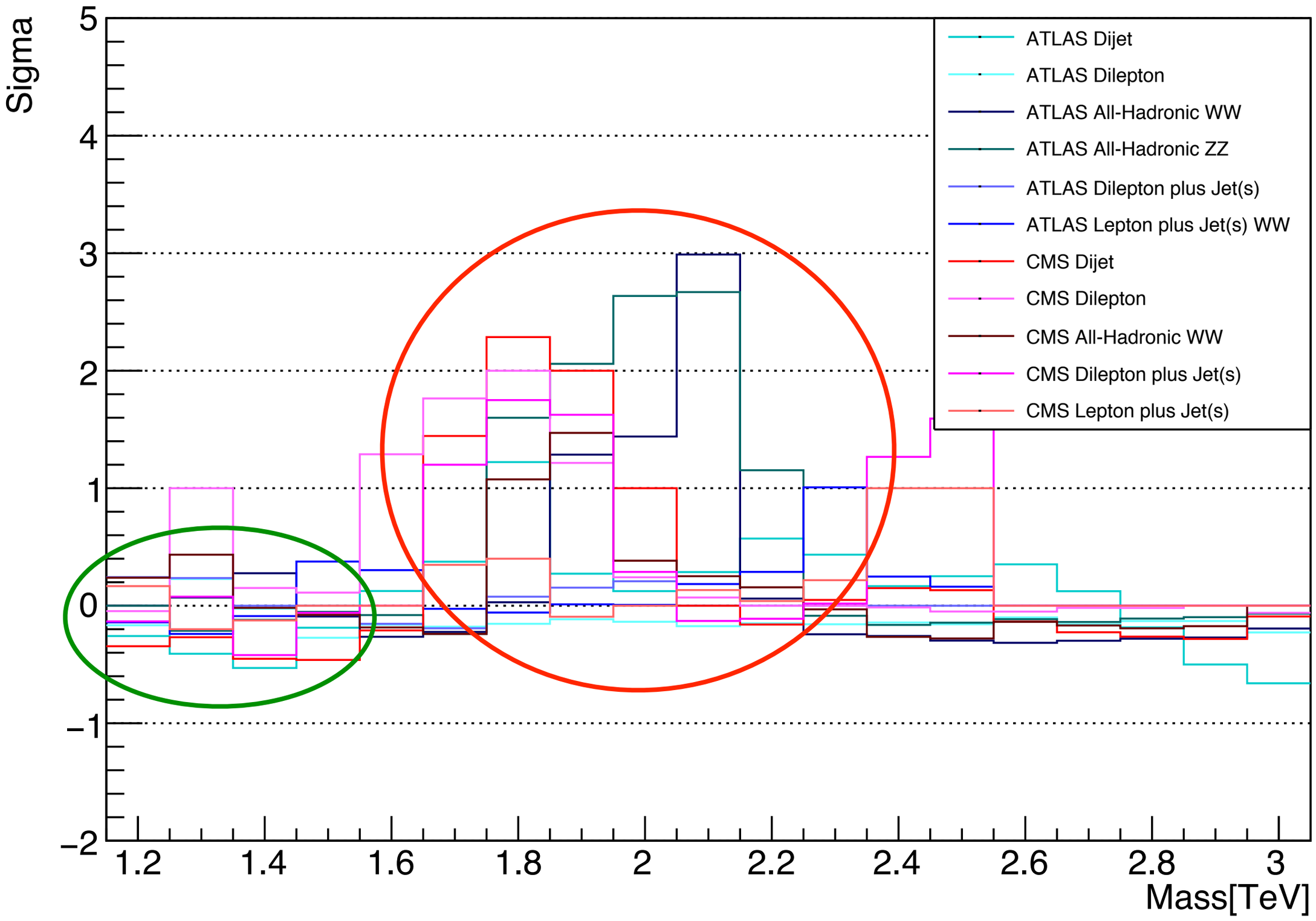
Decays With a Higgs Candidate



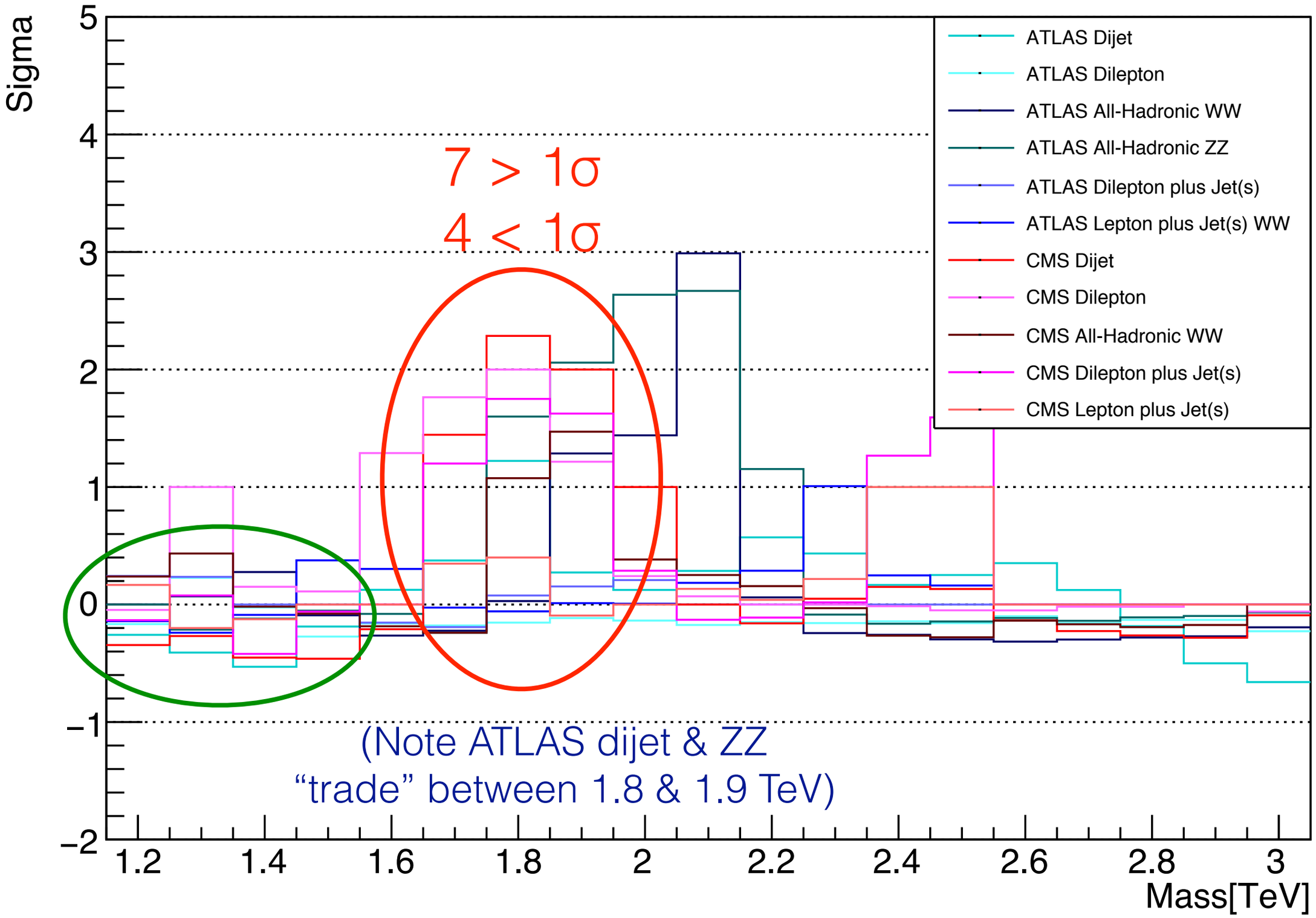
Neutral Resonance



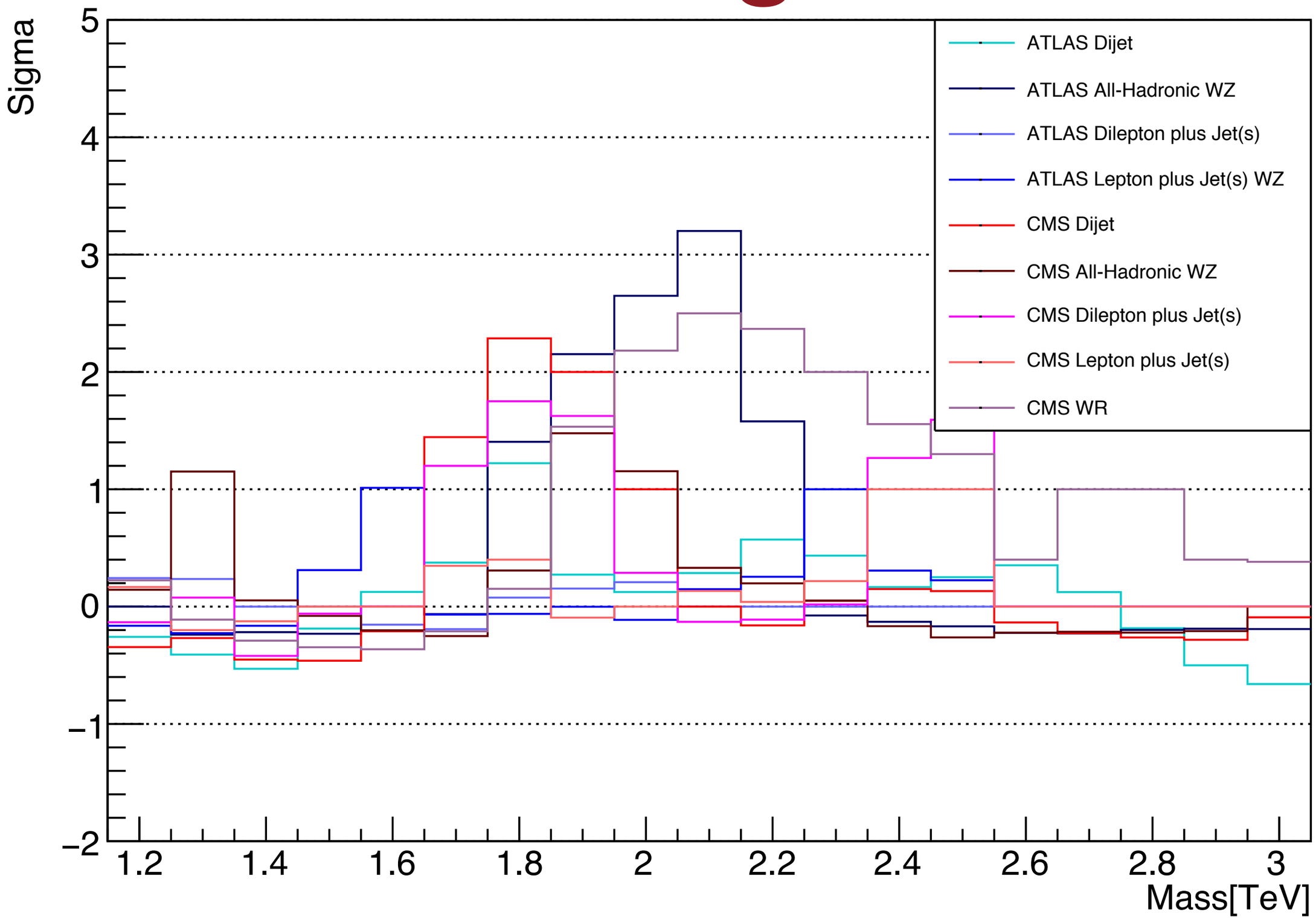
Neutral Resonance



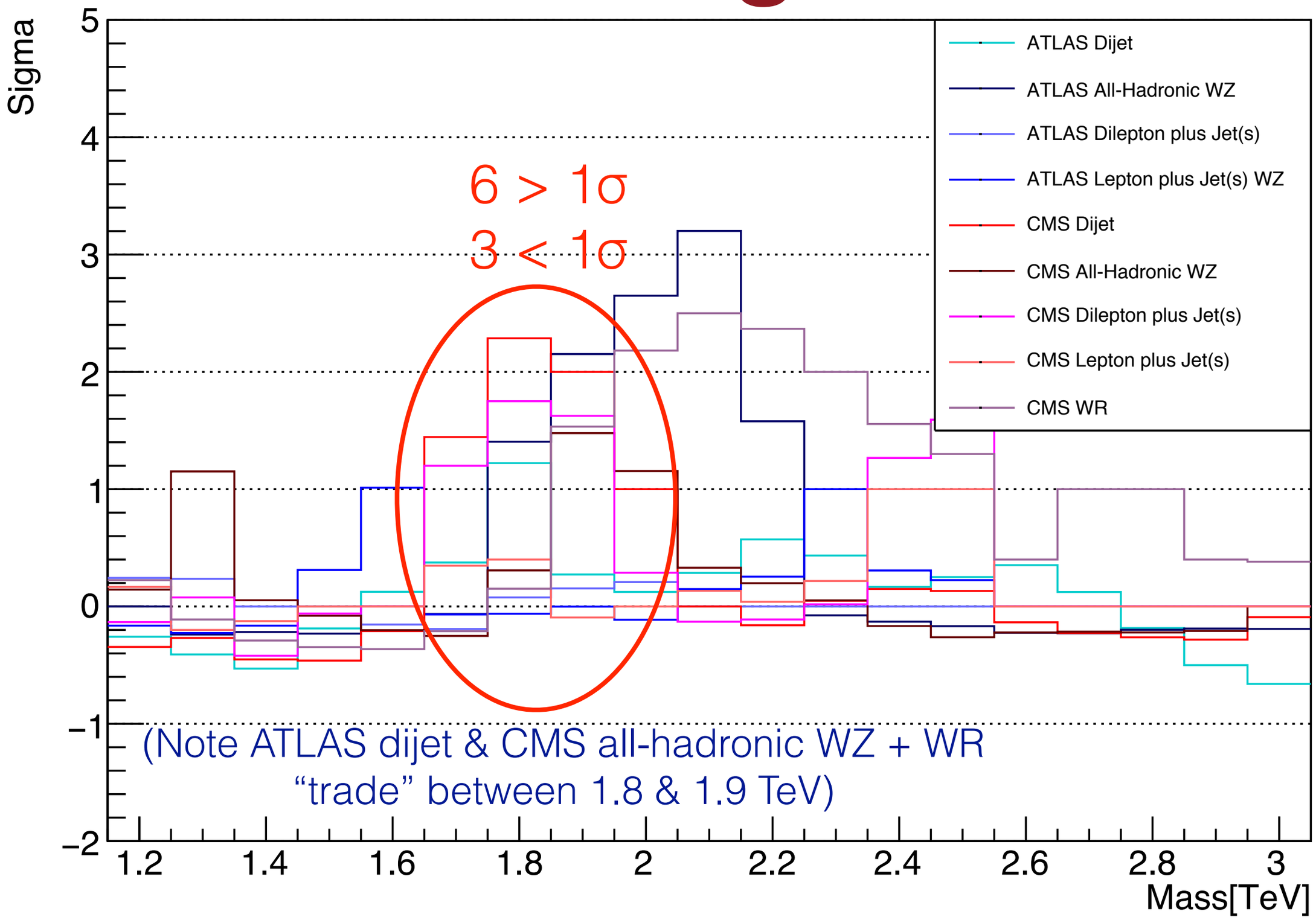
Neutral Resonance



Charged


Sigma
5
4
3
2
1
0
−1
−2
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Mass[TeV]
ATLAS Dijet
ATLAS All-Hadronic WZ
ATLAS Dilepton plus Jet(s)
ATLAS Lepton plus Jet(s) WZ
CMS Dijet
CMS All-Hadronic WZ
CMS Dilepton plus Jet(s)
CMS Lepton plus Jet(s)
CMS WR

Charged


Sigma
5
4
3
2
1
0
−1
−2
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Mass[TeV]
6 > 1σ
3 < 1σ
(Note ATLAS dijet & CMS all-hadronic WZ + WR
"trade" between 1.8 & 1.9 TeV)
ATLAS Dijet
ATLAS All-Hadronic WZ
ATLAS Dilepton plus Jet(s)
ATLAS Lepton plus Jet(s) WZ
CMS Dijet
CMS All-Hadronic WZ
CMS Dilepton plus Jet(s)
CMS Lepton plus Jet(s)
CMS WR

Final Comments

- Expect ~eight >2σ and one >3σ false positive
- 3σ:
  - ATLAS Z+MET
- 2+σ:
  - $H \rightarrow \mu\tau$
  - ~2 in same-sign dileptons
  - ~4 in W'/Z'-type searches
- Count is right…
- … but false positives not expected to cluster…