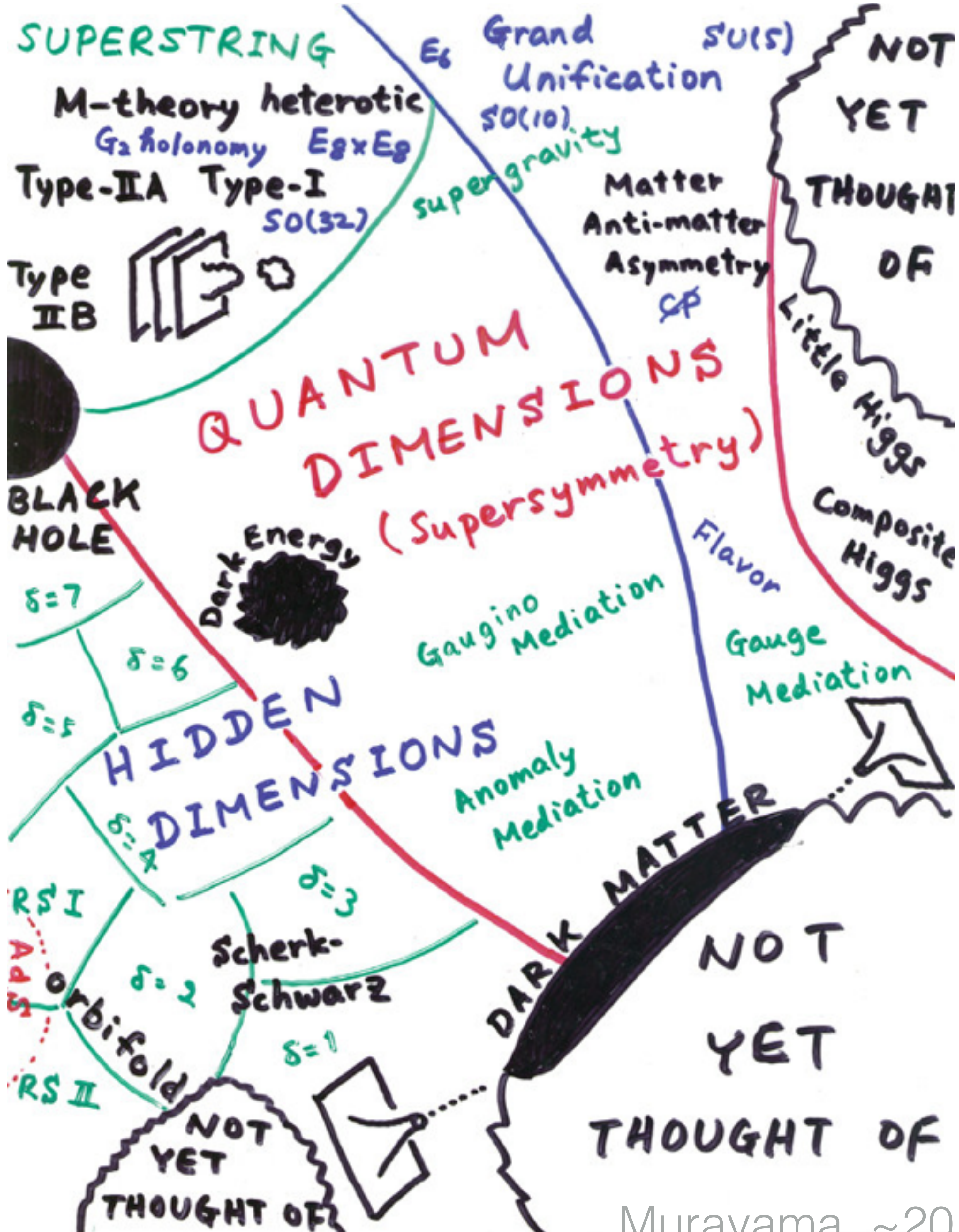
Simplified Collider Limits on New Interactions

R. Sekhar Chivukula
Michigan State University
May, 2016

Outline

- New Interactions *typically* imply new resonances
- Traditional “model-independent” Limits
- Simplified Models for s-channel resonances
- “Simplified Limits” from Simplified Models
- Example: Diboson Resonances

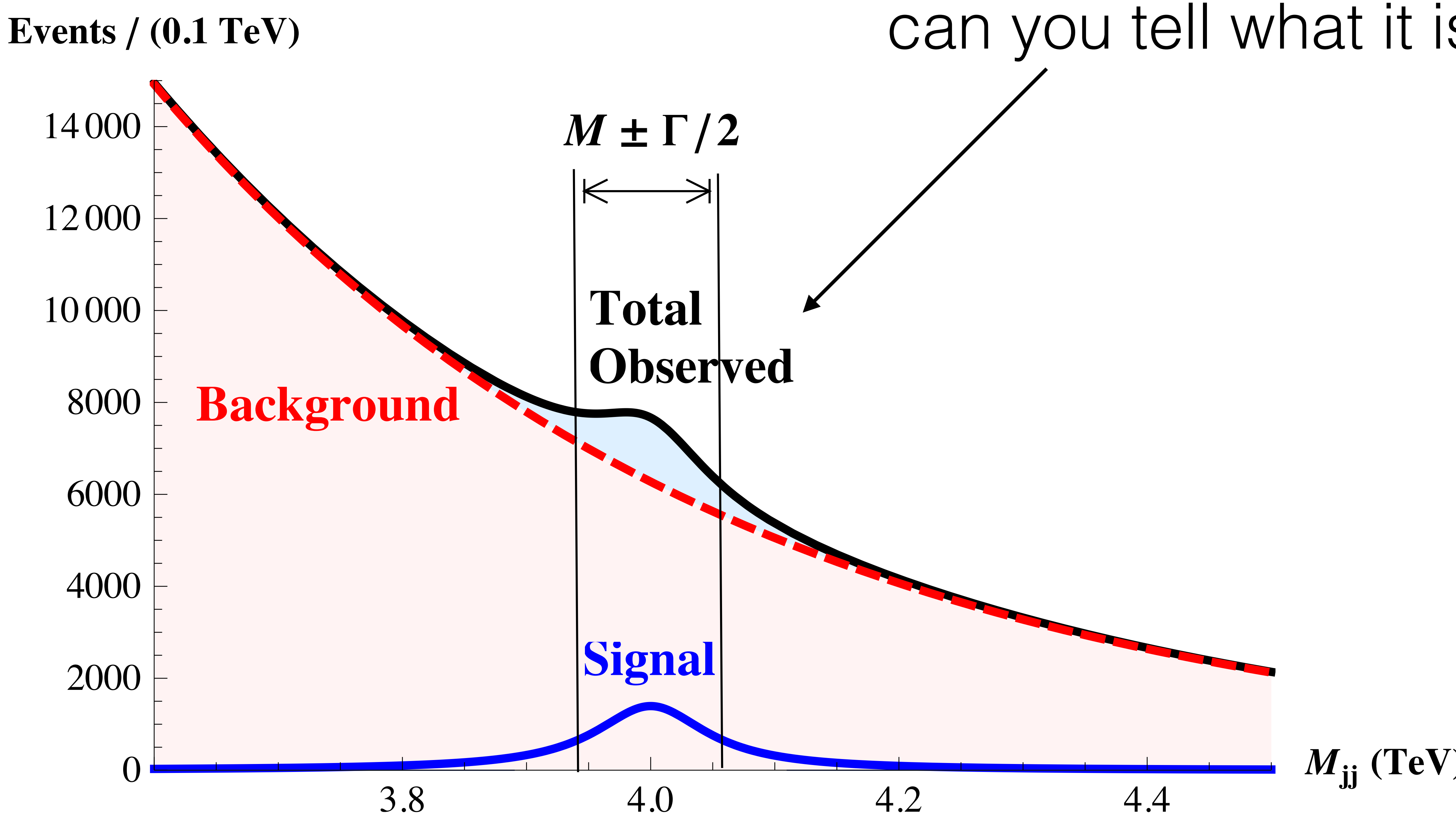
New Physics *typically* implies the existence of new resonances!



Murayama, ~2010

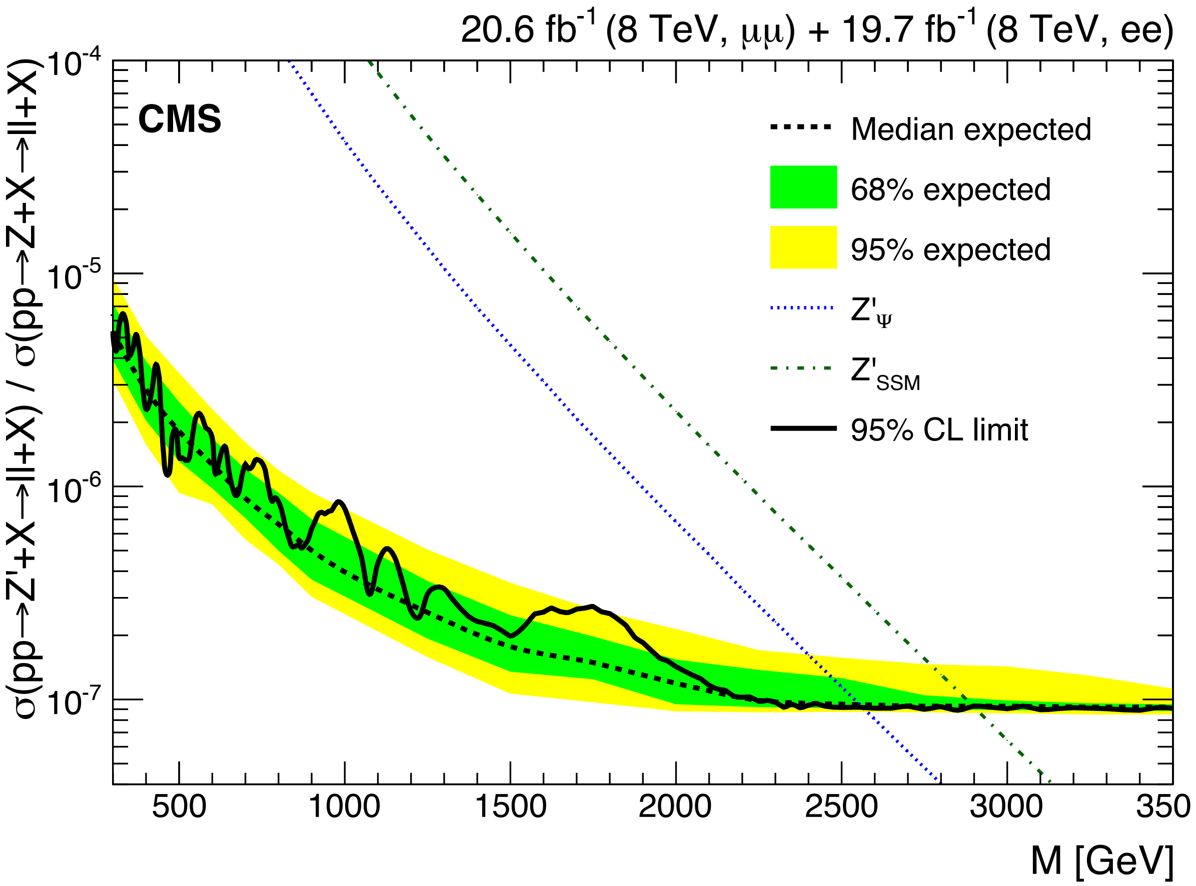
“s-channel” Resonance

If you can see it,
can you tell what it is?



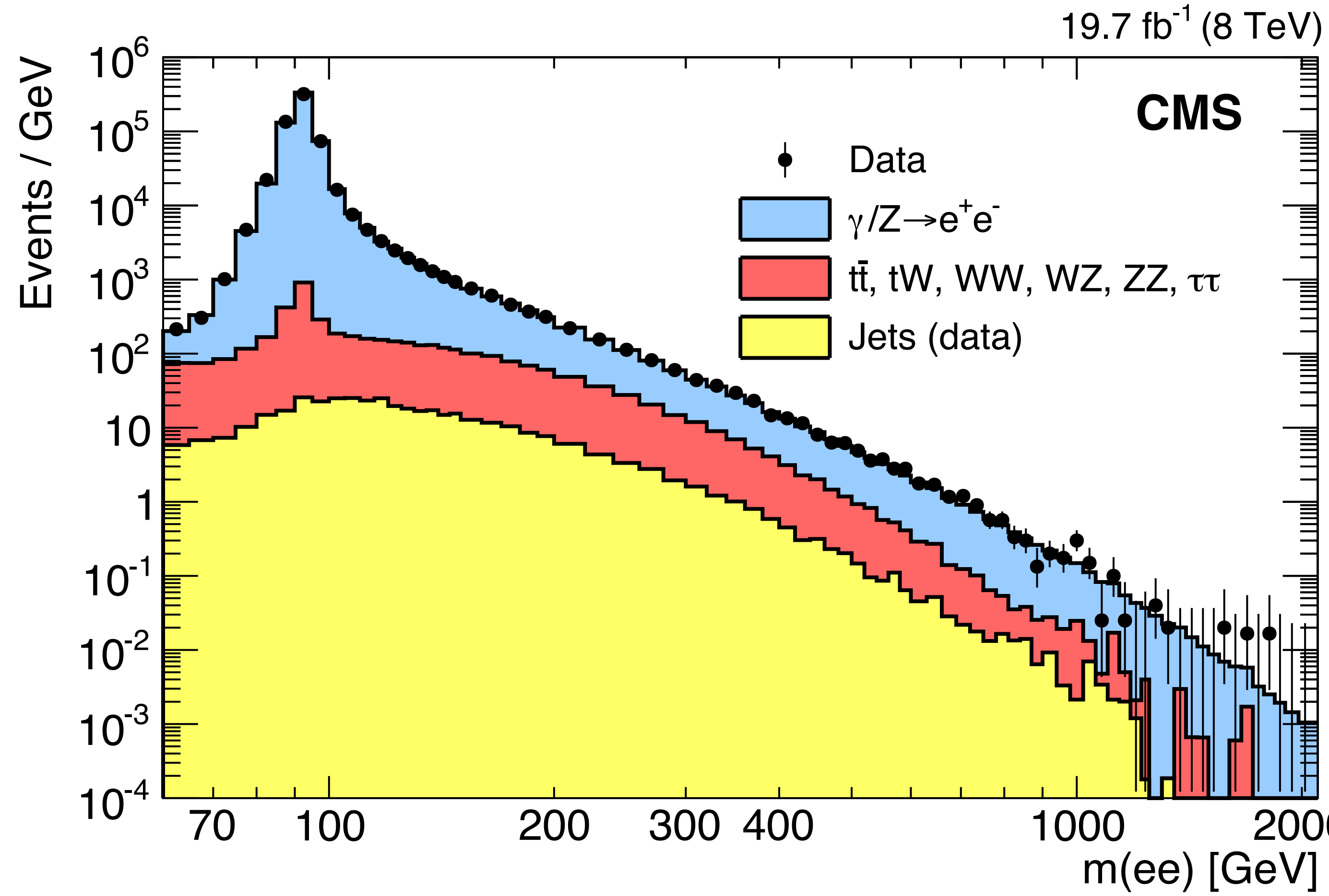
Dilepton Resonances

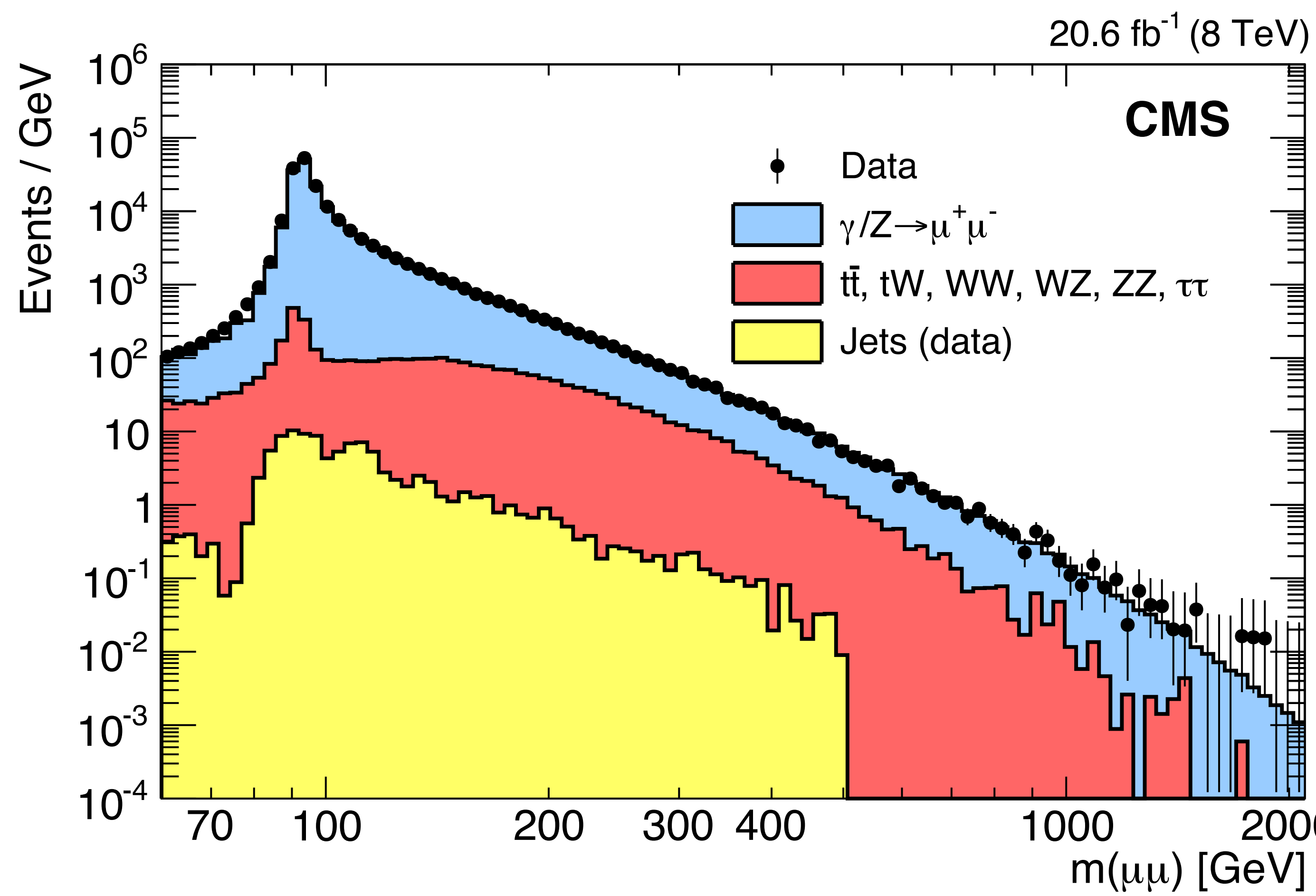
Flavor-independent Z’



Limits: 2.5-3 TeV

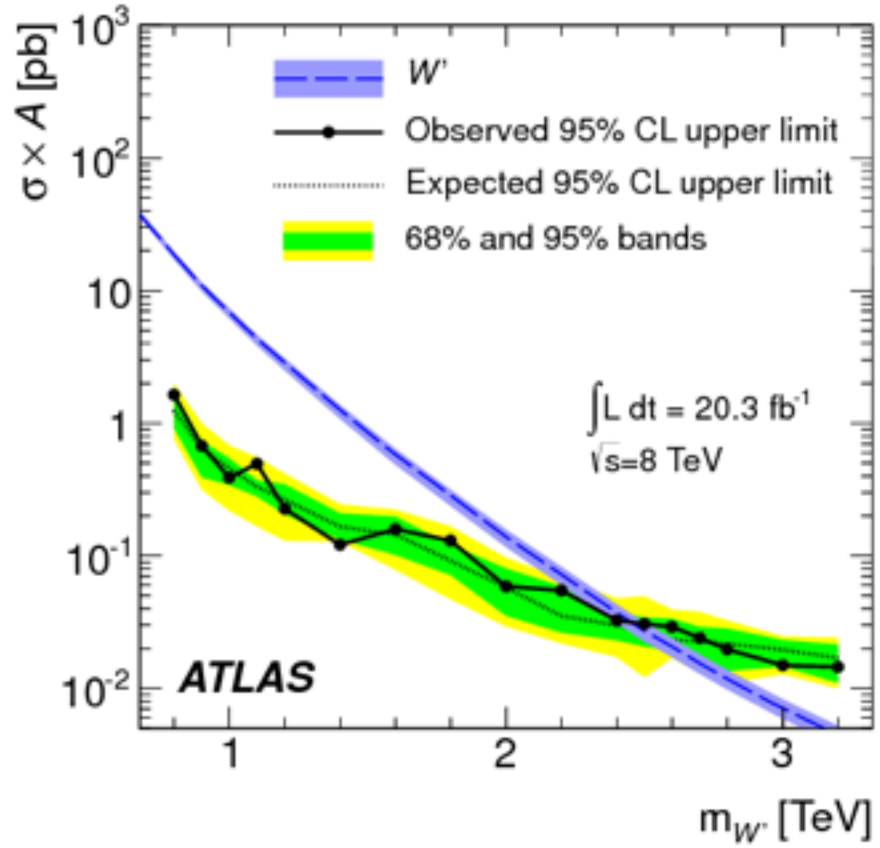
CMS EXO-12-061

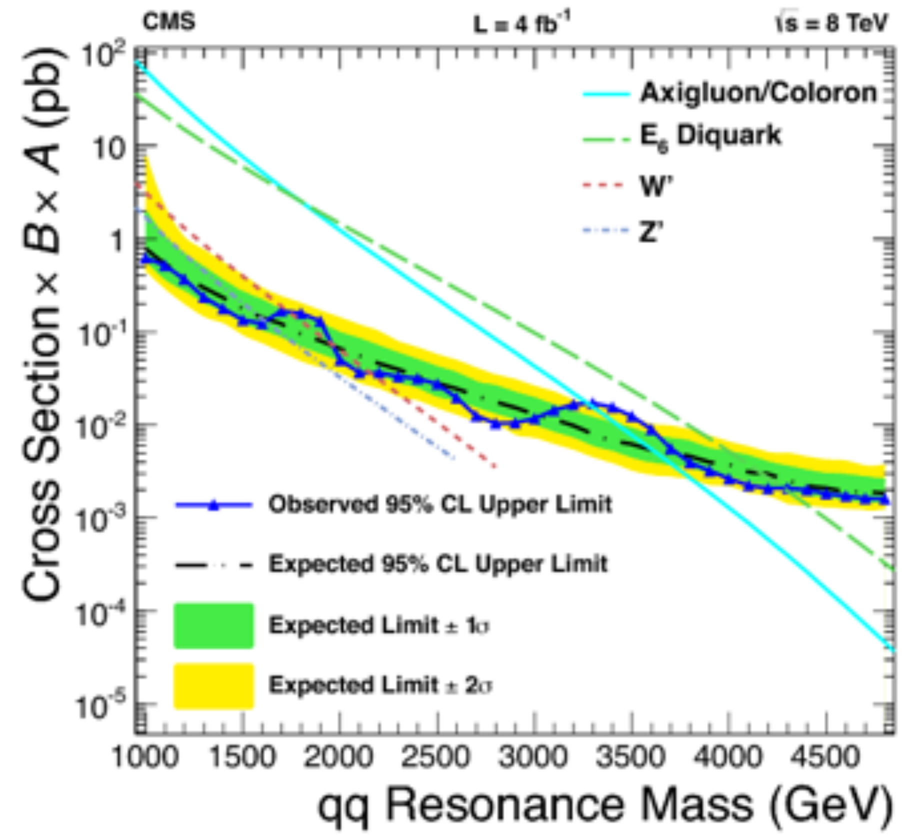


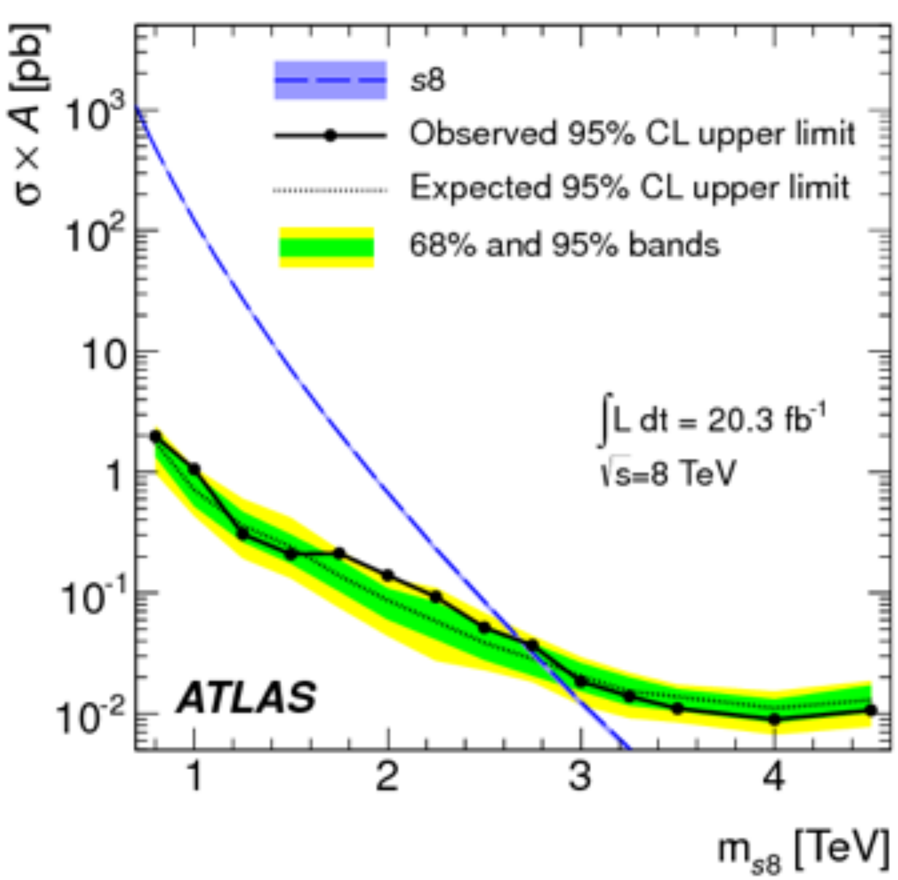


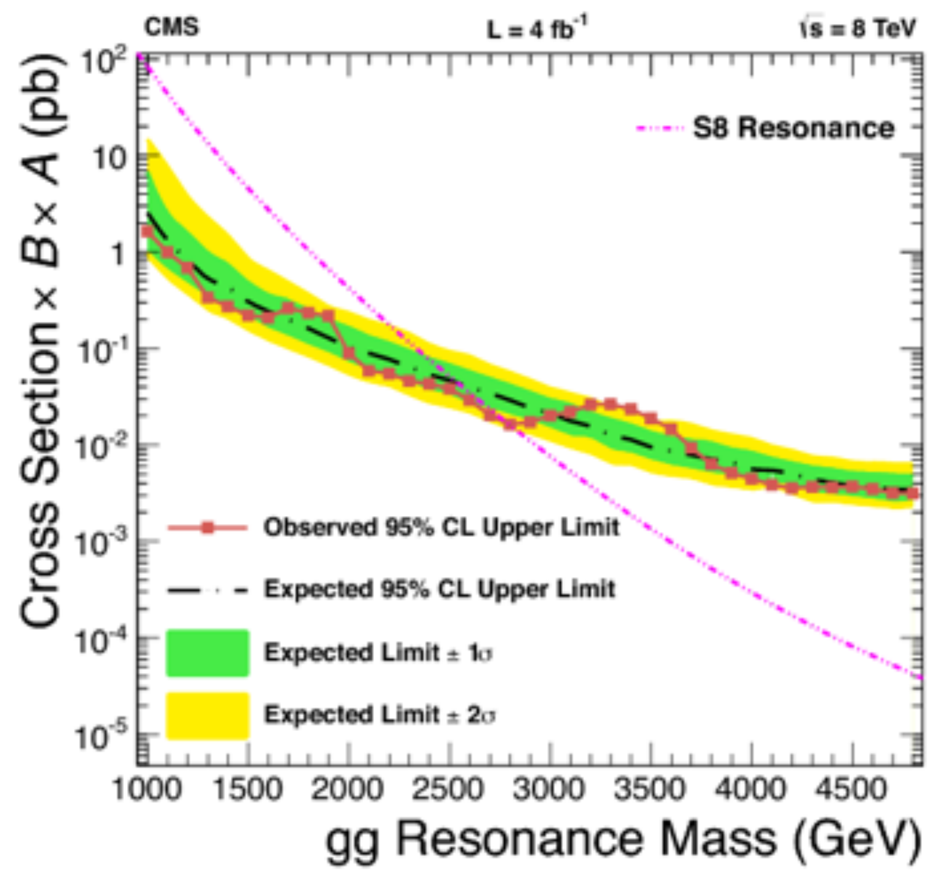
Dijet Resonances

ATLAS CERN-PH-EP-2014-147
CMS EXO-12-016

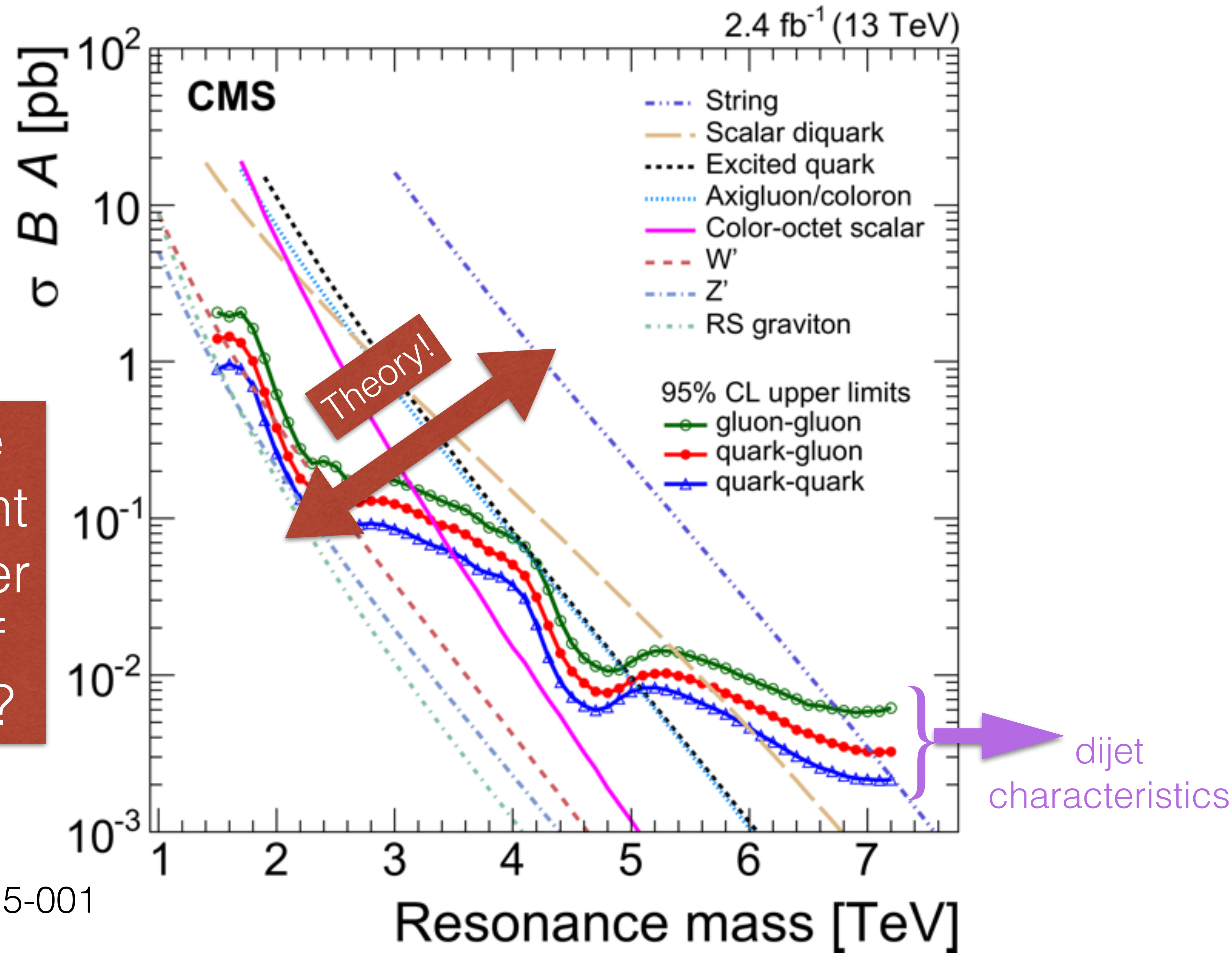








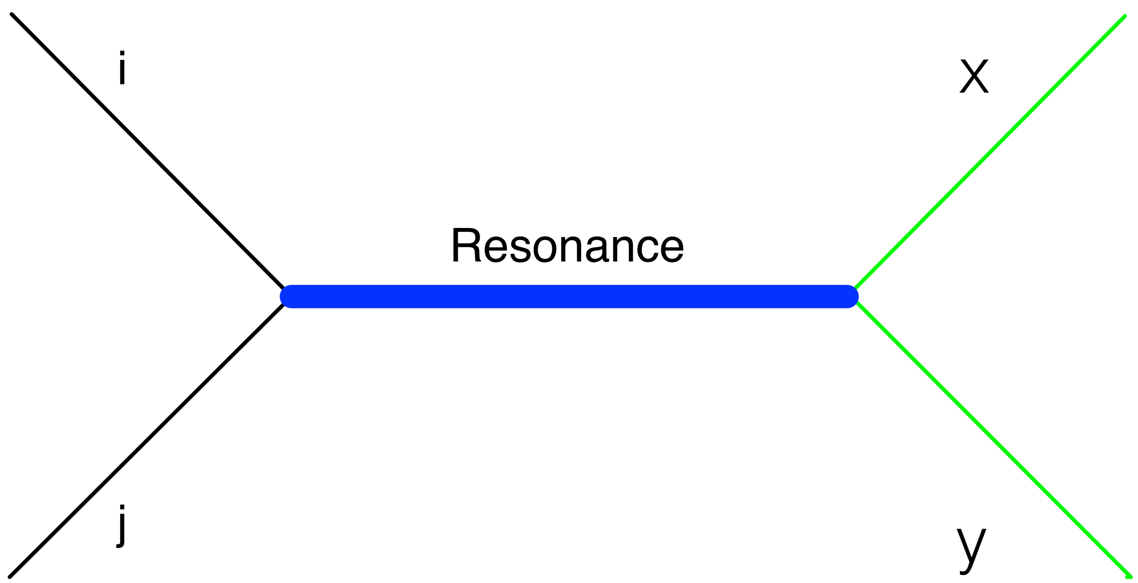
“Model-Independent” (dijet) Limits



Can we represent a broader class of models?

CMS EXO-15-001

Simplified s-channel Model



$i,j = u,d,g,\gamma,W,Z$

$x,y = j,t,b,g,\gamma,W,Z,h$

Characteristics vs. Observables

- *i,j*: event characteristics
- *Couplings*: BR, σ * BR
- *Mass and width*: $d\sigma/dm_{ab}$
- *Spin*: $d\sigma/d\cos\theta_{ab}$
- *x,y*: in each decay channel
  - flavor tagging
  - jet substructure

NB: If x,y can be light quarks,
t-channel process may be relevant

Narrow Width Approximation

$$\sigma_R(pp \to x + y) = \int_{s_{min}}^{s_{max}} d\hat{s}\, \hat{\sigma}(\hat{s}) \cdot \left[\frac{dL^{ij}}{d\hat{s}}\right]$$

$$\hat{\sigma}_{ij\to R\to xy}(\hat{s}) = 16\pi(1+\delta_{ij}) \cdot \mathcal{N} \cdot \frac{\Gamma(R \to i+j) \cdot \Gamma(R \to x+y)}{(\hat{s}-m_R^2)^2 + m_R^2\Gamma_R^2} \;, \quad \mathcal{N} = \frac{N_{S_R}}{N_{S_i}N_{S_j}} \cdot \frac{C_R}{C_iC_j}$$

$$\frac{1}{(\hat{s}-m_R^2)^2 + m_R^2\Gamma_R^2} \approx \frac{\pi}{m_R\Gamma_R}\delta(\hat{s}-m_R^2)$$

$$\sigma_R(pp \to x+y) = 16\pi^2 \cdot \mathcal{N} \cdot \frac{\Gamma_R}{m_R} \cdot (1+\delta_{ij}) BR(R \to ij) \cdot BR(R \to xy) \left[\frac{1}{s}\frac{dL^{ij}}{d\tau}\right]_{\tau=\frac{m_R^2}{s}}$$

(Note: Can be corrected for K-factor(s) & Acceptance)

RSC, E.H. Simmons, K. Mohan

Simplified Limits

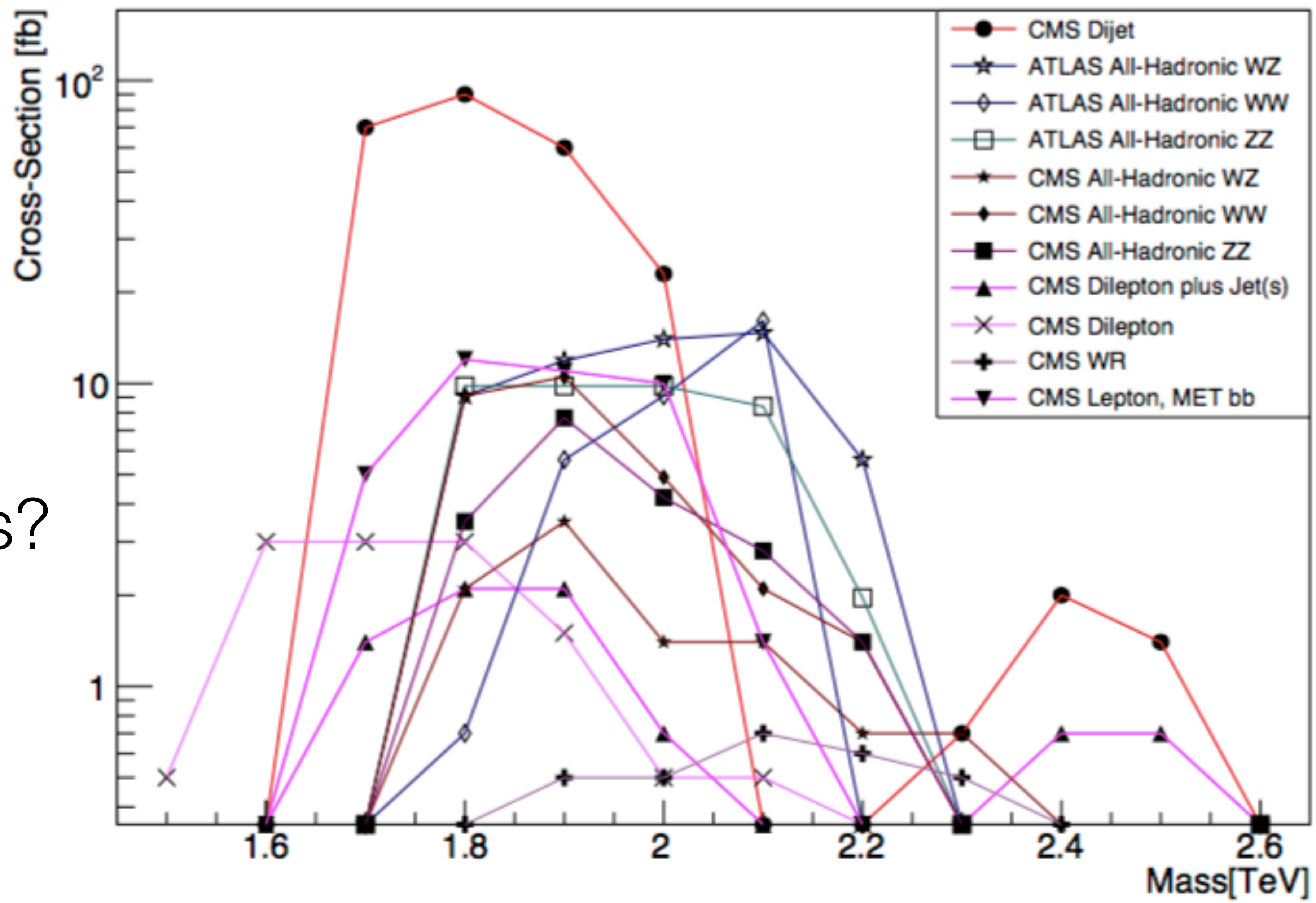
$$\sigma_R(pp \to x + y) = 16\pi^2 \cdot \mathcal{N} \cdot \frac{\Gamma_R}{m_R} \cdot (1 + \delta_{ij}) BR(R \to ij) \cdot BR(R \to xy) \left[\frac{1}{s}\frac{dL^{ij}}{d\tau}\right]_{\tau = \frac{m_R^2}{s}}$$

In the narrow-width approximation, for a given i & j, a bound on σ_R is a limit on

$$\mathcal{N} \cdot \frac{\Gamma_R}{m_R} \cdot BR(R \to i + j) \cdot BR(R \to x + y)$$

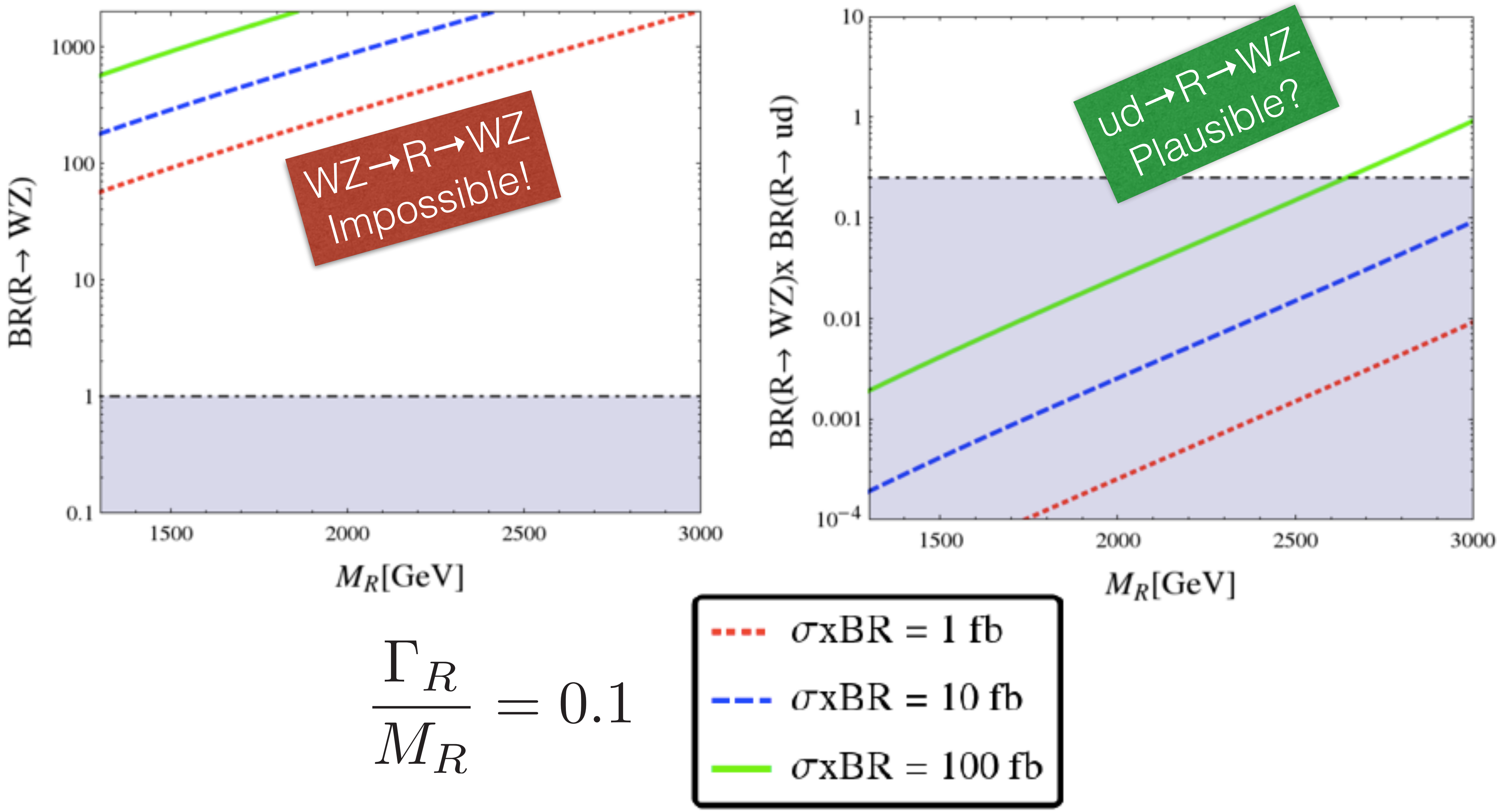
Diboson Excess

1-100 fb
"WZ" excess?



Les Houches 2015 - arXiv:1512.04537

DiBoson Vector Resonances

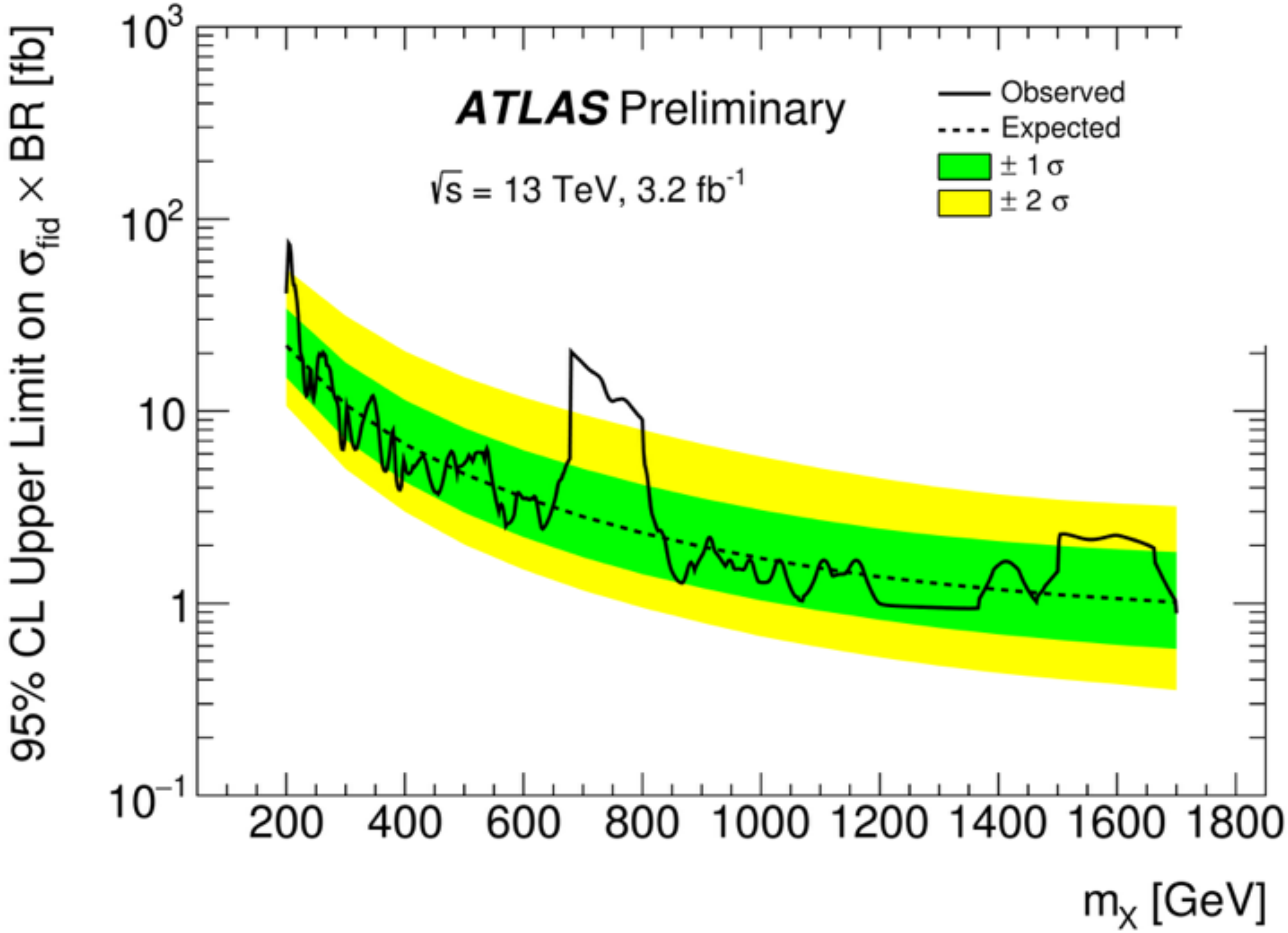


$$\frac{\Gamma_R}{M_R} = 0.1$$

CTEQ6L1

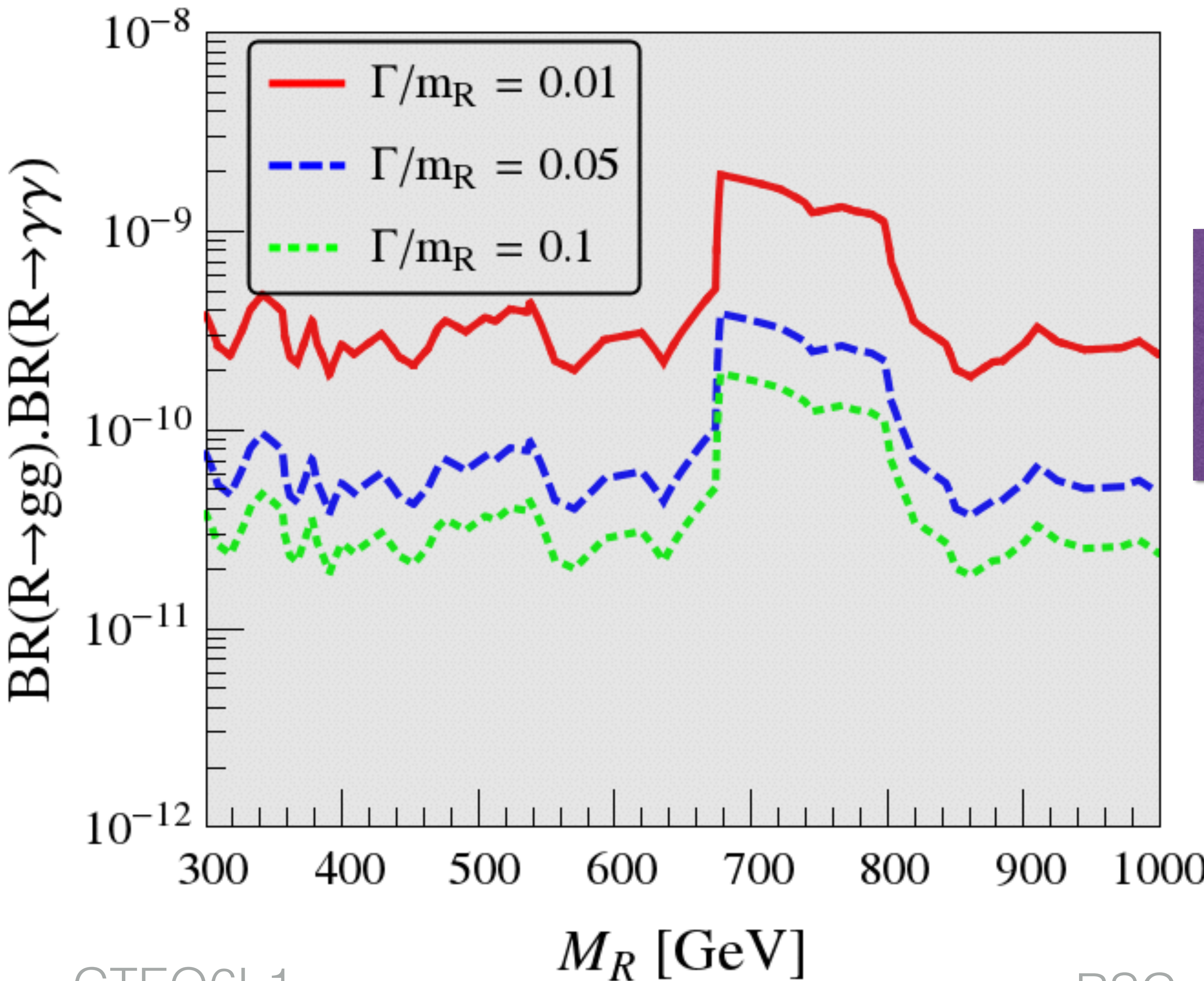
RSC, E.H. Simmons, K. Mohan

Diphoton Resonance



ATLAS-CONF-2015-081

Simplified Limits on Scalar Diphoton Resonances



gg→S→γγ
BR(gg)*BR(γγ)
for various Γ/M

CTEQ6L1

RSC, E.H. Simmons, K. Mohan

Simplified Limits on Scalar Diphoton Resonances: *Diphoton Production*

$$\sigma_R(pp \to \gamma\gamma) = 32\pi^2 \cdot \left(\frac{1}{4}\right) \cdot \frac{\Gamma_R}{m_R} \cdot BR(R \to \gamma\gamma)^2 \cdot \left[\frac{1}{s}\frac{dL^{\gamma\gamma}}{d\tau}\right]_{\tau=\frac{m_R^2}{s}}$$

To be consistent with observed signal a scalar *produced* through photon fusion (since BR(s→γγ)<1), $\Gamma/M > 3 \times 10^{-4}$

Using simplified models based on the narrow width approximation we can derive model-universal "simplified limits": *model-independent limits on branching ratios for different production mechanisms.*