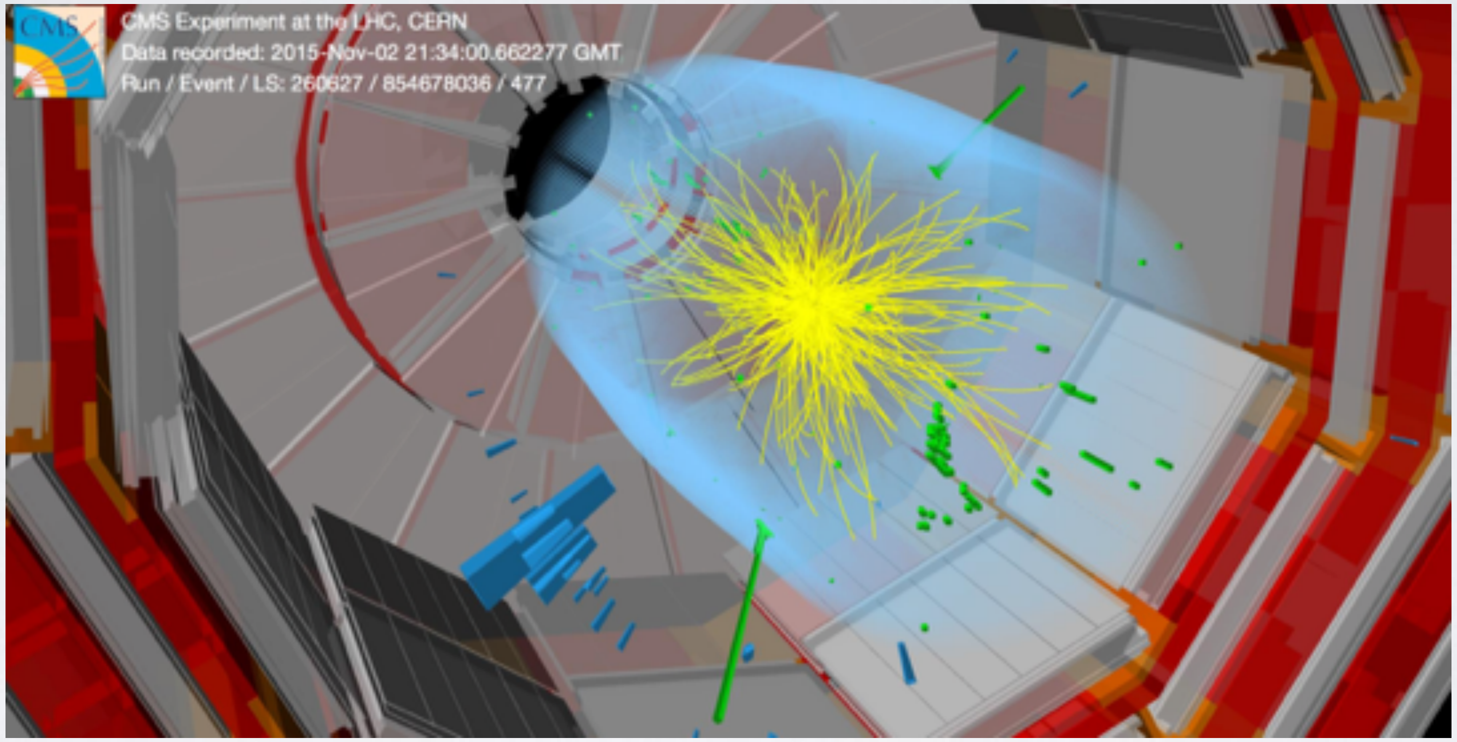
The non-resonant production of the diphoton excess



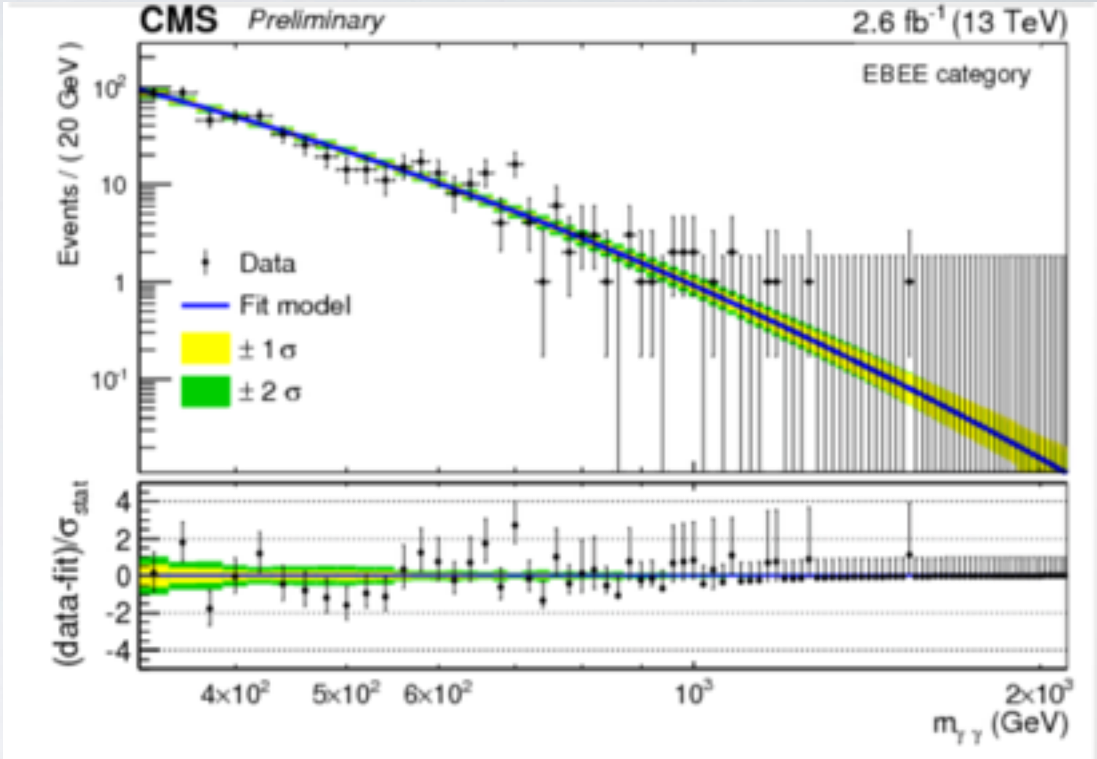
Jürgen R. Reuter, DESY

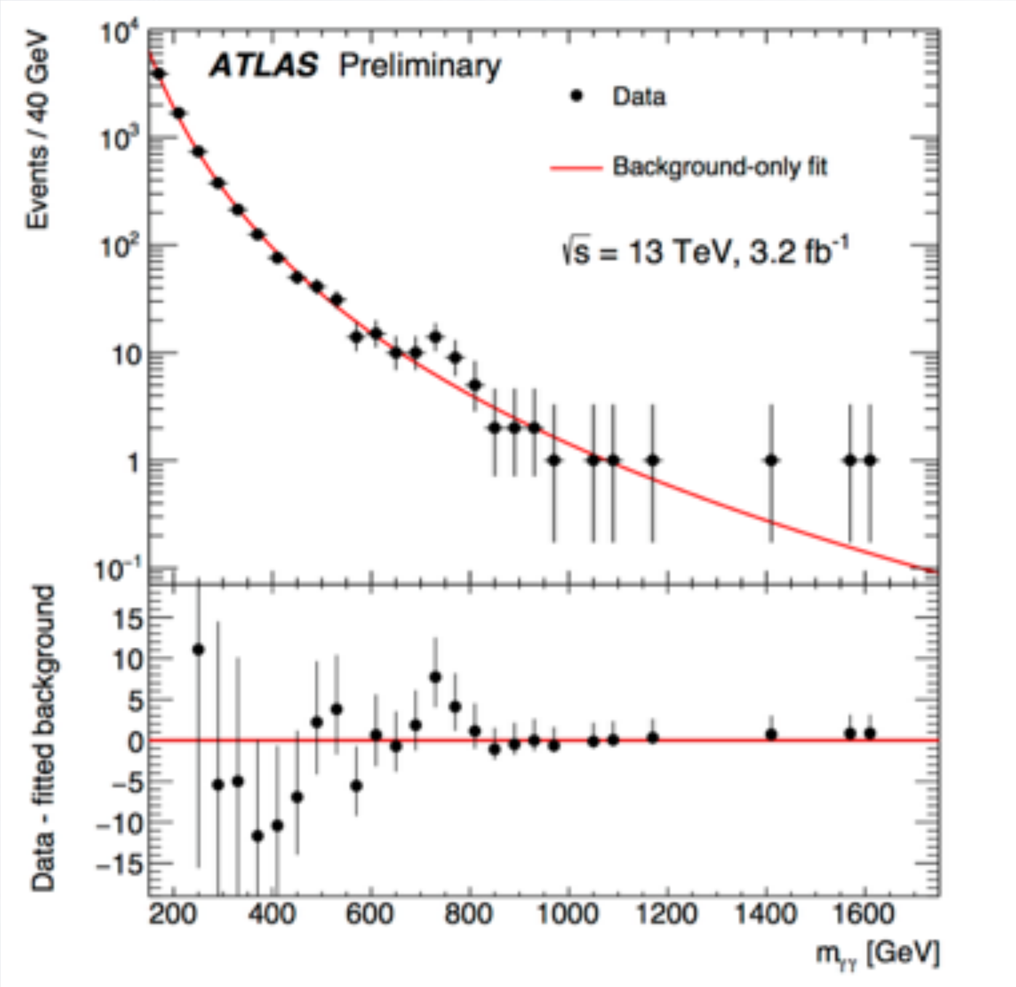
work together with Jong-Soo Kim, Krzysztof Rolbiecki and Roberto Ruiz de Austri

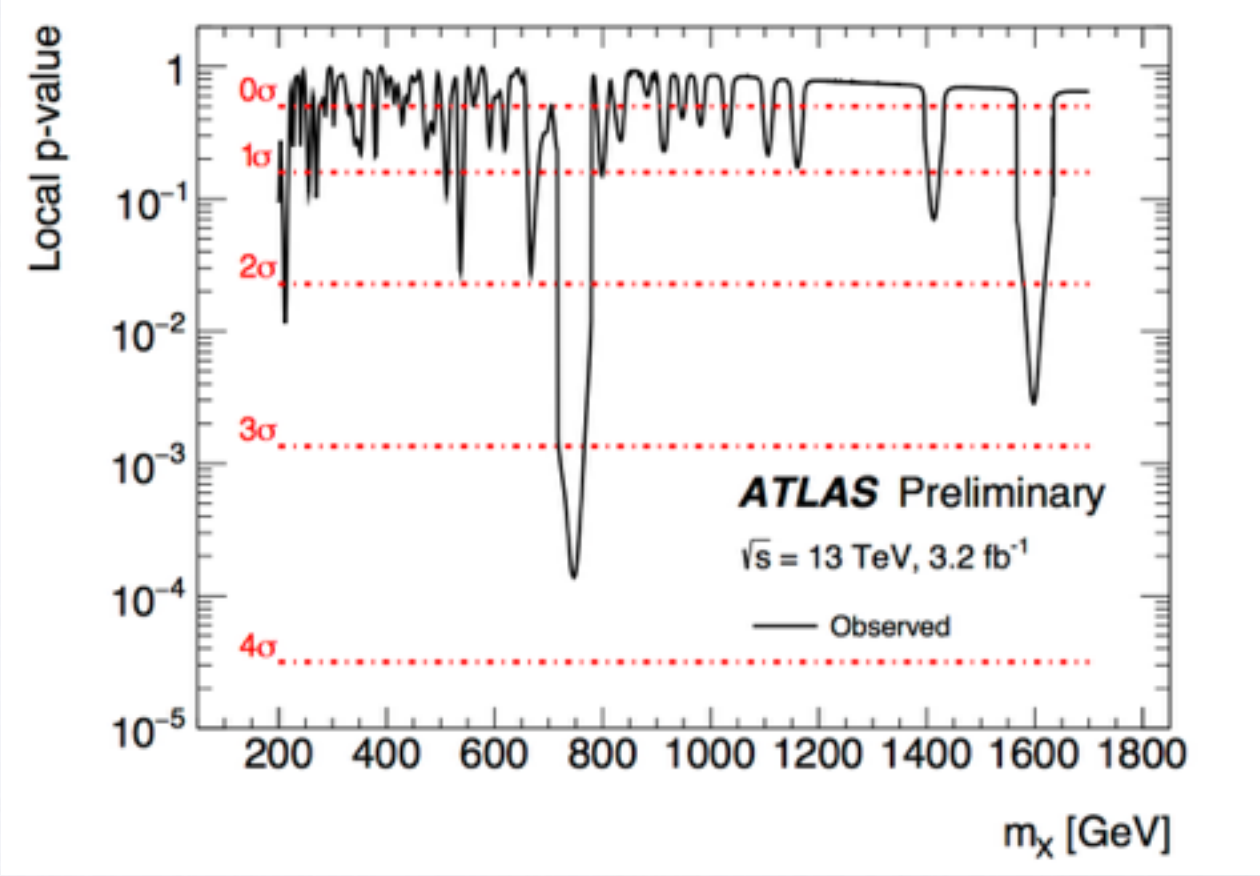
based on arXiv:1512.06083

Recap of the events

ATLAS	CMS
$p_T(\gamma) \geq 25$ GeV	$p_T(\gamma) \geq 75$ GeV
$\lvert\eta^\gamma\rvert \leq 2.37$	$\lvert\eta^\gamma\rvert \leq 1.44$ or $1.57 \leq \lvert\eta^\gamma\rvert \leq 2.5$ at least one γ with $\lvert\eta^\gamma\rvert \leq 1.44$
$E_T^{\gamma_1}/m_{\gamma\gamma} \geq 0.4$, $E_T^{\gamma_2}/m_{\gamma\gamma} \geq 0.3$	$m_{\gamma\gamma} \geq 230$ GeV







The model setup

- Assume composite model with pseudoscalars η, σ

$$\mathcal{L} = \frac{1}{2}\left(\partial_\mu \eta \partial^\mu \eta - m_\eta^2 \eta^2\right) + \frac{1}{2}\left(\partial_\mu \sigma \partial^\mu \sigma - m_\sigma^2 \sigma^2\right) + \lambda \sigma \eta \eta$$

- Couplings to SM gauge bosons via dim-5 operators (WZW anomaly)

$$\mathcal{L}_{\eta VV} = \sum_{V=g,W,B} \kappa_V^\eta \frac{{g_V}^2}{32\pi^2} \frac{1}{F_\eta} \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu}^V F^{V,\mu\nu} \, \eta$$

- Underlying model with 2-3 fundamental fermions: Q_1 , Q_2
- more details: Cacciapaglia/Deandrea/Hashimoto, 1507.03098; Harigaya/Nomura, 1512.04850

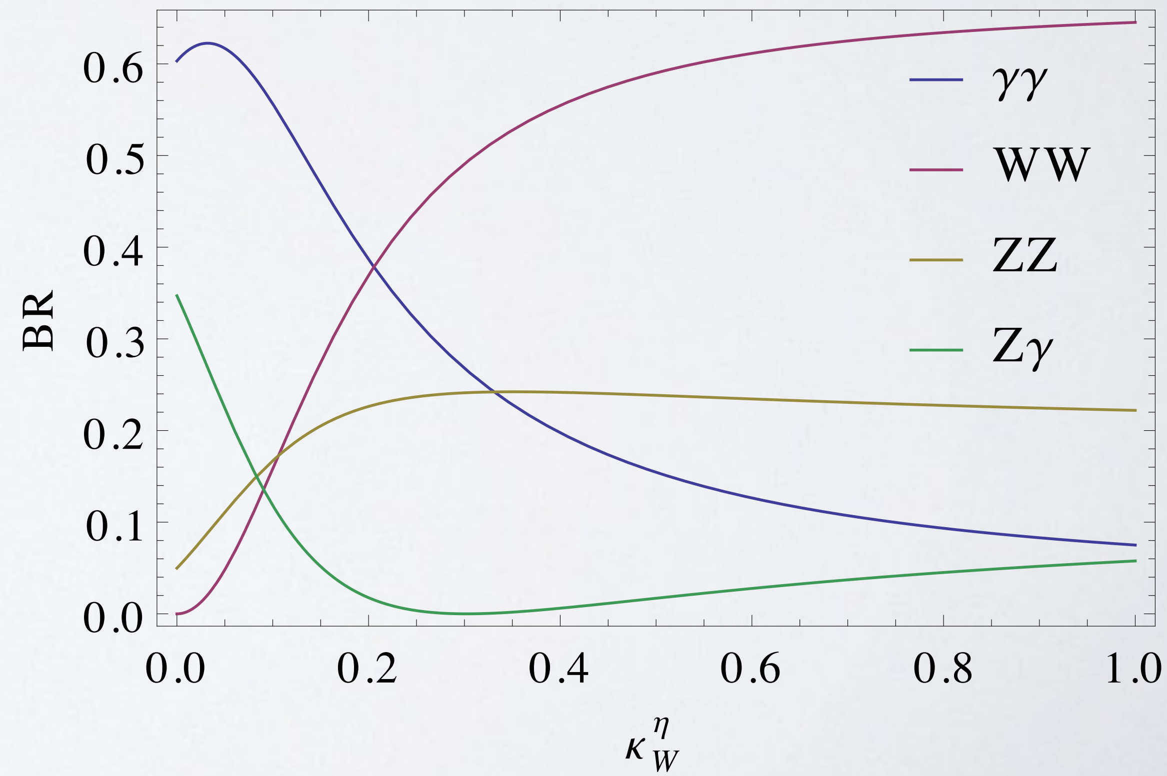
Gauge group: $SU(N) \times SU(3)_c \times SU(2)_L \times U(1)_Y$

$$Q_1: \ (\mathbf{N}, \mathbf{1}, \mathbf{2}, a) \qquad Q_2: \ (\mathbf{N}, \mathbf{3}, \mathbf{1}, b)$$

$$\eta \sim \langle Q_1 Q_1 \rangle \qquad \sigma \sim \langle Q_2 Q_2 \rangle$$

Trilinear coupling $\sigma\eta\eta$ e.g. in Little Higgs models

Chiral perturbation theory: $\sigma(\partial_\mu \eta \partial^\mu \eta)$



Recast and scan procedure

- Simulation with `FeynRules 2.3.13, Madgraph 5.2.2.3, WHIZARD 2.2.8, Pythia 6.427`
- Fast detector simulation with `Delphes 3.10`
- ATLAS and CMS diphoton searches implemented in `CheckMate 1.2.2 / AnalysisManager`
- Defining signal region 700 GeV < $m_{\gamma\gamma}$ < 800 GeV [ATLAS / CMS didn't provide any]
- CMS regions divided into barrel and endcap regions (EBEB and EBEE)
- Due to non-resonant nature: $\gamma\gamma$ pair can have considerable p_T (vanishing close to threshold)
- Using a χ^2 test statistic

$$\chi_i^2 = \frac{(n_i - \mu_i)^2}{\sigma_{i,\text{stat}}^2 + \sigma_{i,b}^2}$$

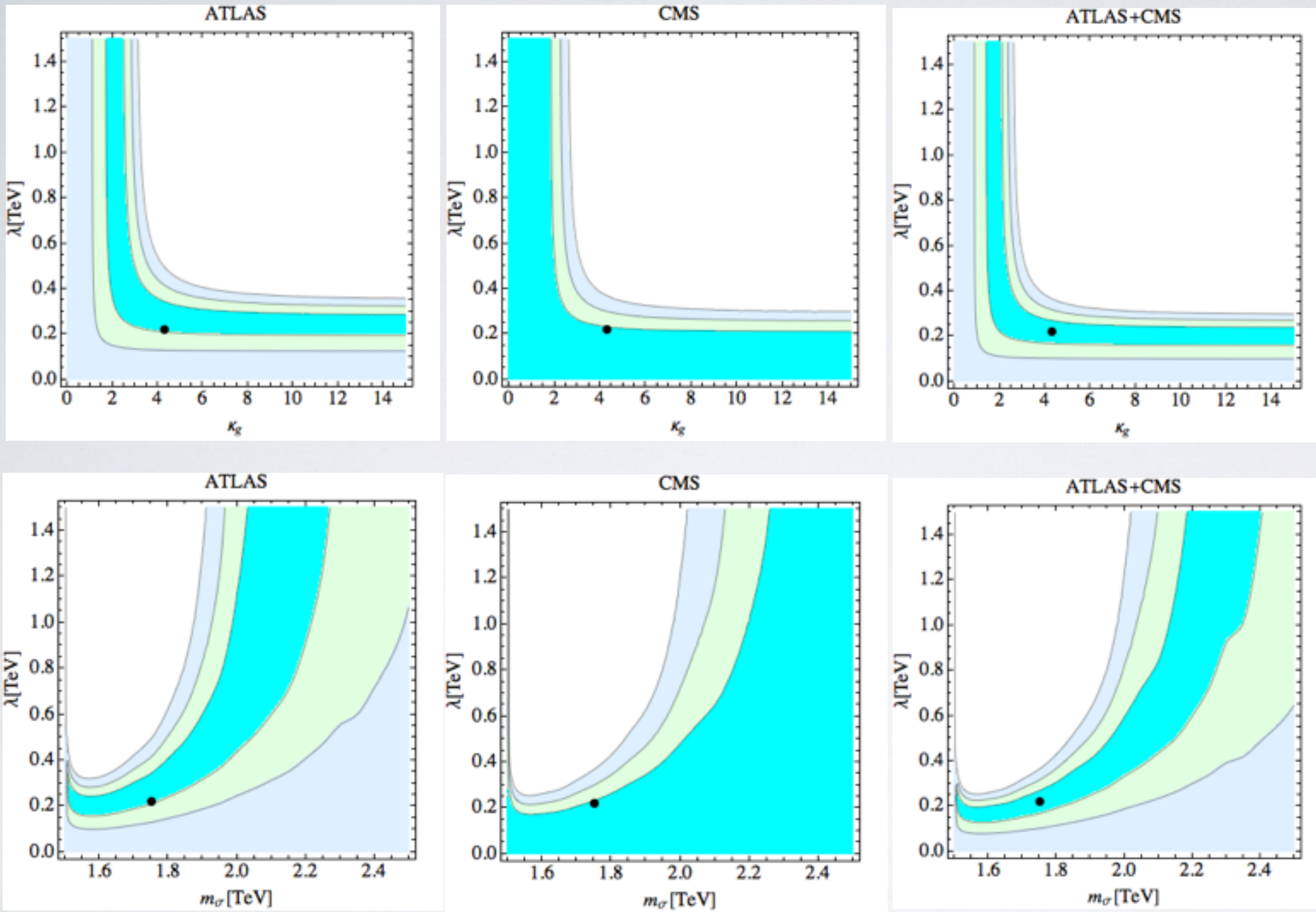
$$\mu_i = \mu_{i,b} + \mu_{i,s}$$

i : ATLAS, CMS EBEB, CMS EBEE

Systematic errors combine experimental ones with 10% on event yield from `CheckMate`

Parameter	Description	Value or range
m_σ	mass of heavier resonance	[1.5 TeV, 2.5 TeV]
m_η	mass of lighter resonance	750 GeV
λ	dimensionfull $\eta\sigma\sigma$	[0. TeV, 1.5 TeV]
F_η	η decay constant	1 TeV
F_σ	σ decay constant	1 TeV
κ_g^η	anomaly coefficient	0
κ_W^η	anomaly coefficient	0
κ_B^η	anomaly coefficient	1
κ_g^σ	anomaly coefficient	[0, 15]
κ_W^σ	anomaly coefficient	0
κ_B^σ	anomaly coefficient	0

Recast of the events: fitting



$\Delta\chi^2$ above minimum =
1 cyan,
4 light green,
9 light blue

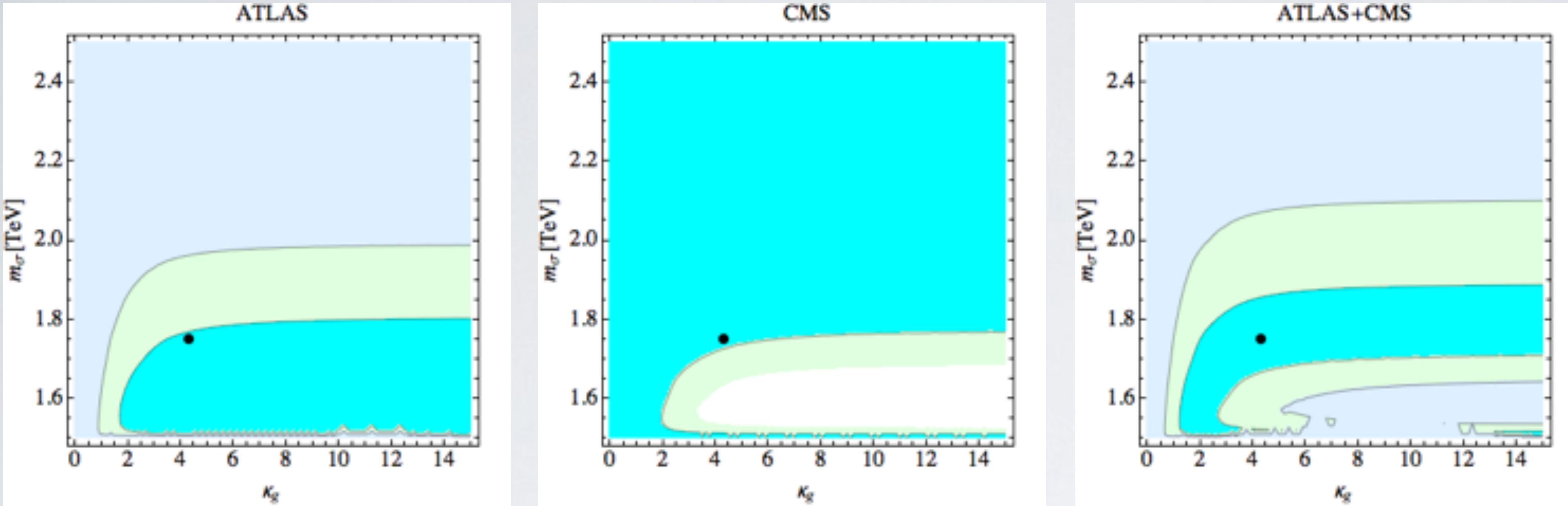
χ^2_{min} = 1.8

χ^2_{SM} = 8.8

only one observable $\Longrightarrow$ flat direction (${\kappa^\sigma}_g$ enhances σ production rate, λ decreases $\eta\eta$ decay rate

Best fit point: m_σ = 1.75 TeV, ${\kappa^\sigma}_g$ = 4.3, λ = 0.22 TeV

Checks and consistencies

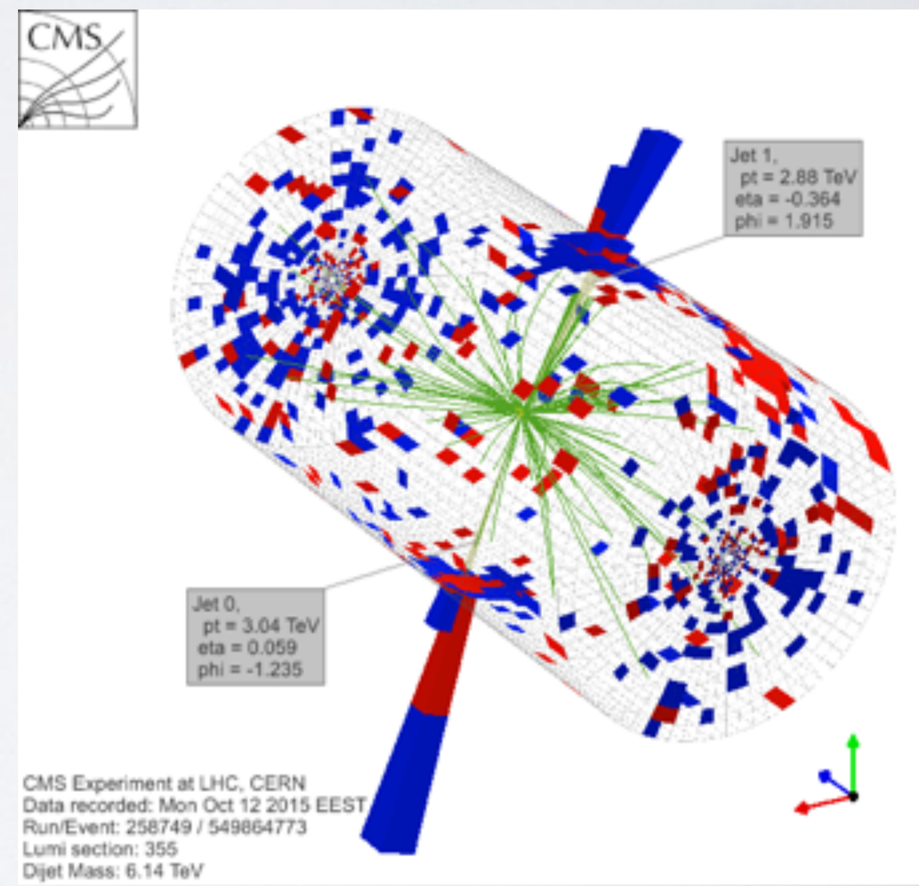


CMS more consistent with no-signal hypoth.

ATLAS prefers higher events yields

signal region	observed	background	best fit	$\Delta\chi^2$
ATLAS	28	11.4 ± 3	12.0	0.56
CMS EBEB	14	9.5 ± 1.9	8.1	0.74
CMS EBEE	16	18.5 ± 3.7	1.3	0.48

Degeneracy can be broken by looking for σ in dijets



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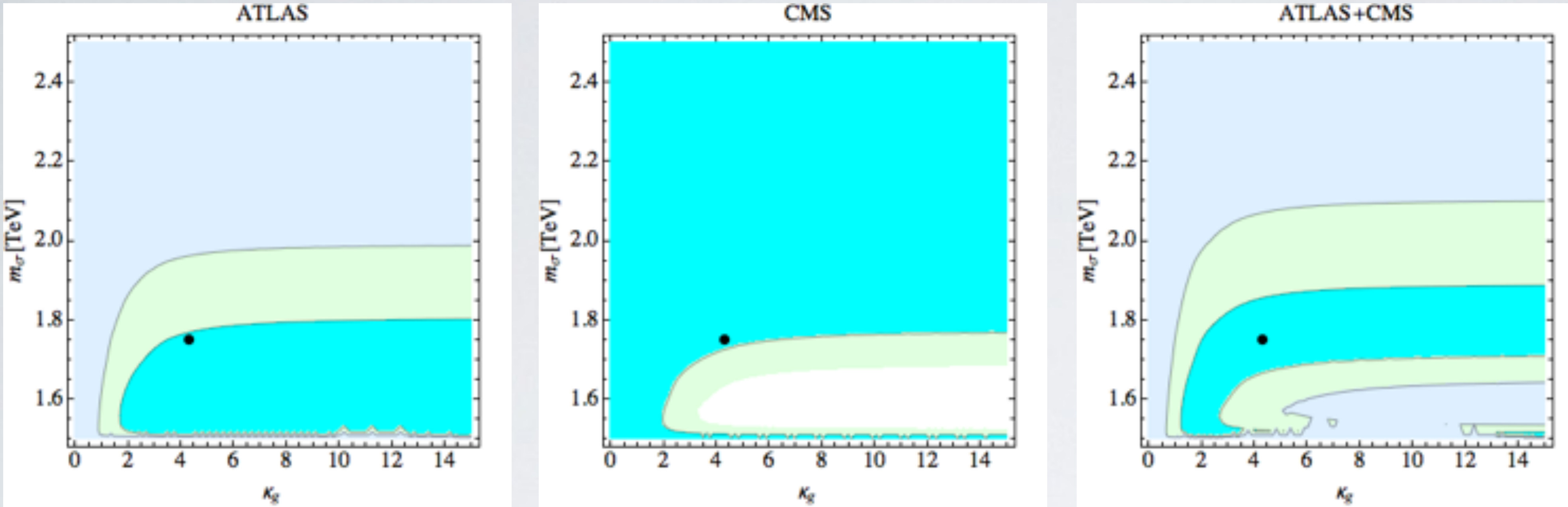

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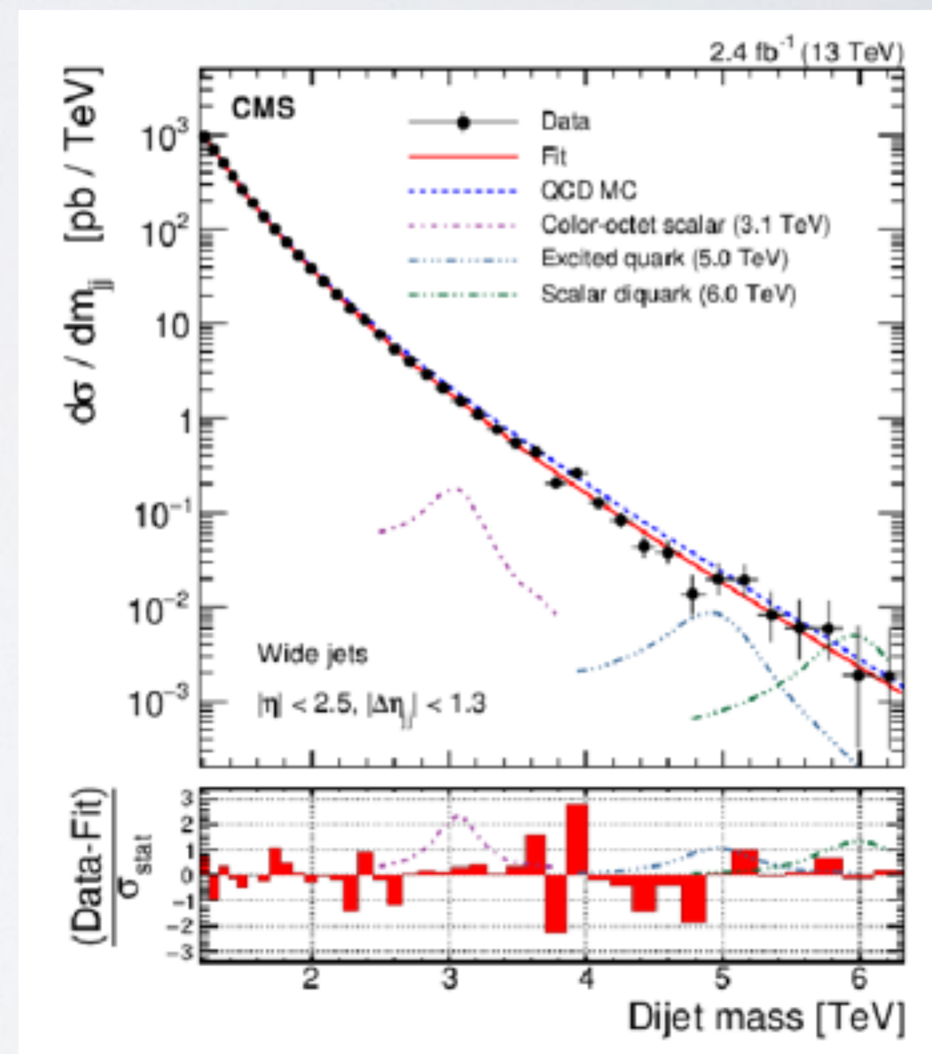

Degeneracy can be broken by looking for σ in dijets

CMS dijet limit [$m_\sigma = 1.75$ TeV]: 1.8 pb visible xsec.,
60% efficiency: $\sigma < 3$ pb $\Longrightarrow$ $\kappa^{\sigma}_{g} \lesssim 25$

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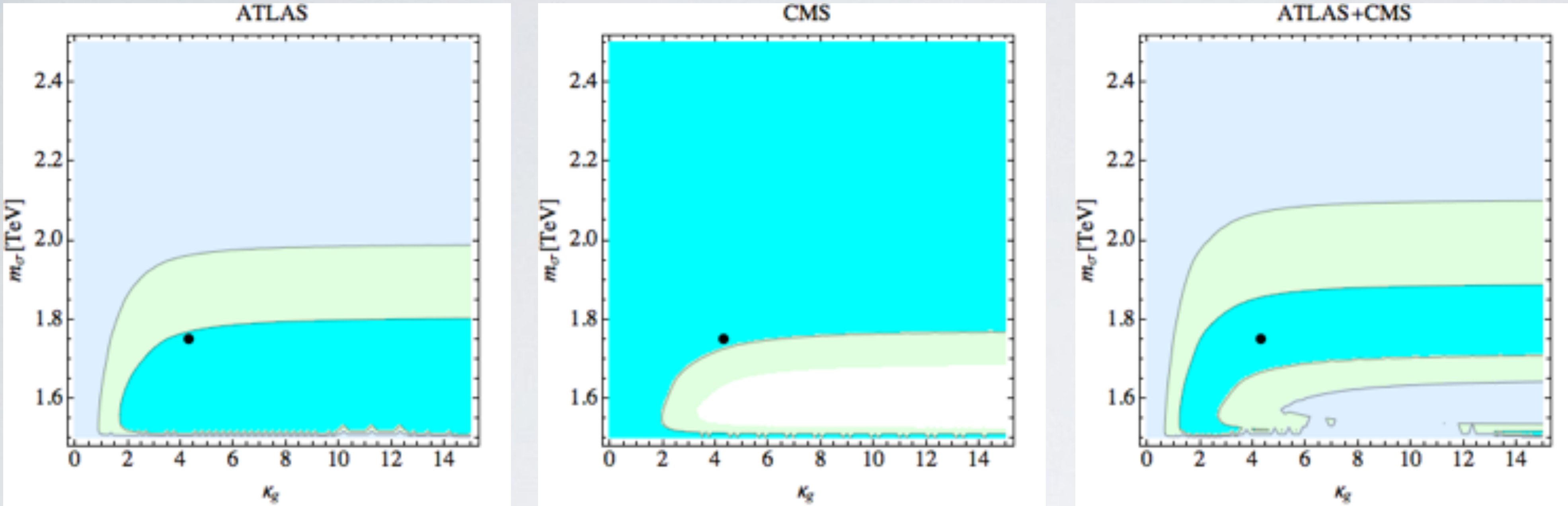

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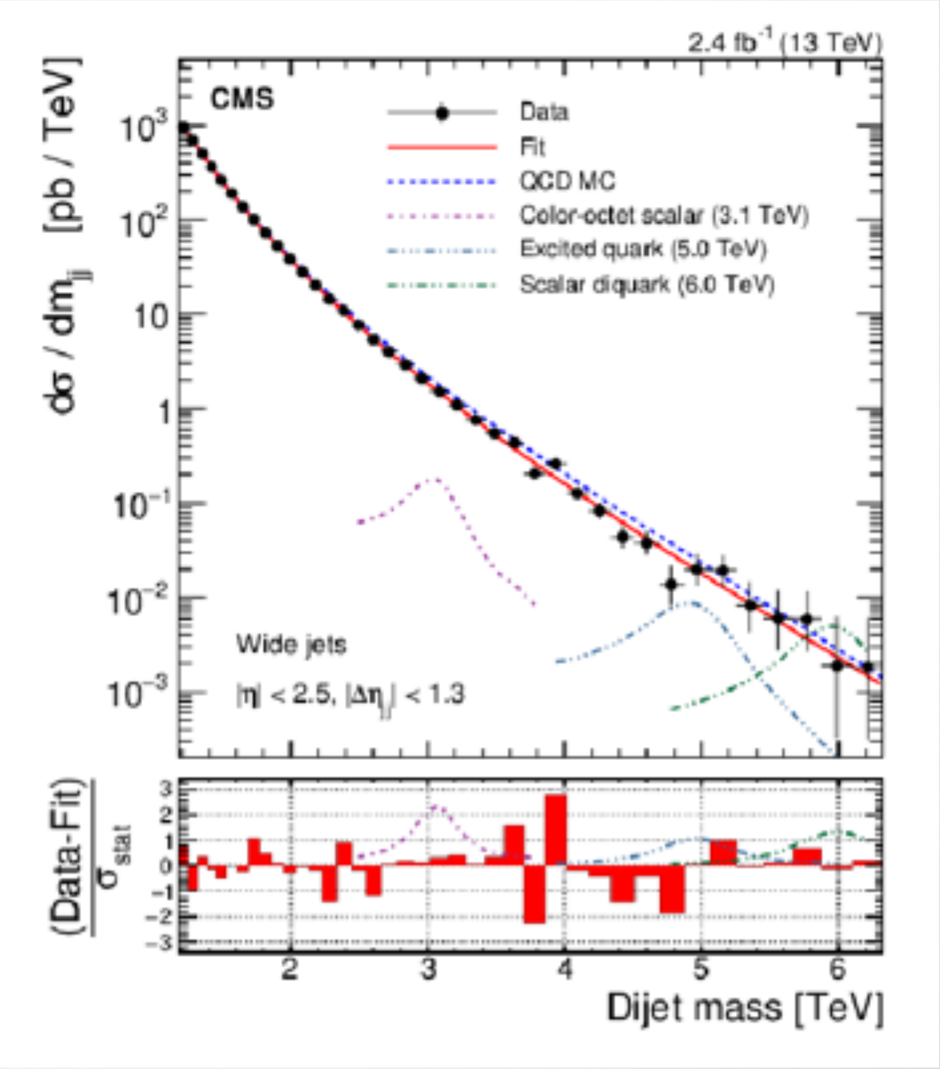

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Diphotons in 8 TeV: gg xsec. 15x smaller, lumi 6x larger,
event yield in ATLAS for best fit: 4.8 events, 23.1/21.9 obs./exp.

Summary

- Interpretation of ATLAS/CMS diphoton excess as simplified composite model
- Non-resonant production through heavier (pseudo-)scalar state
- Original motivations: tension with 8 TeV data, connection to [gone] 2 TeV excess
- Recast of ATLAS / CMS analysis
- Fit prefers rather light additional resonance: 1.75 TeV
- Operator coefficients of 'usual' size
- No information on p_T spectrum of photons and additional event activity
- One observable effectively: no sensitivity e.g. to structure of trilinear coupling