Search for high-mass diphoton resonances

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LHC Physics Discussion

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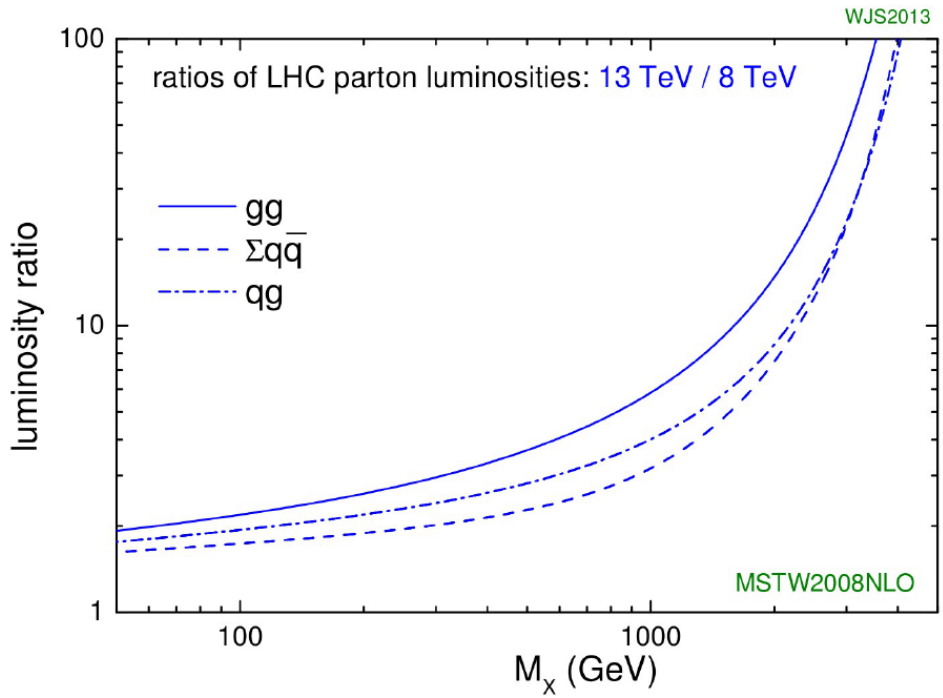
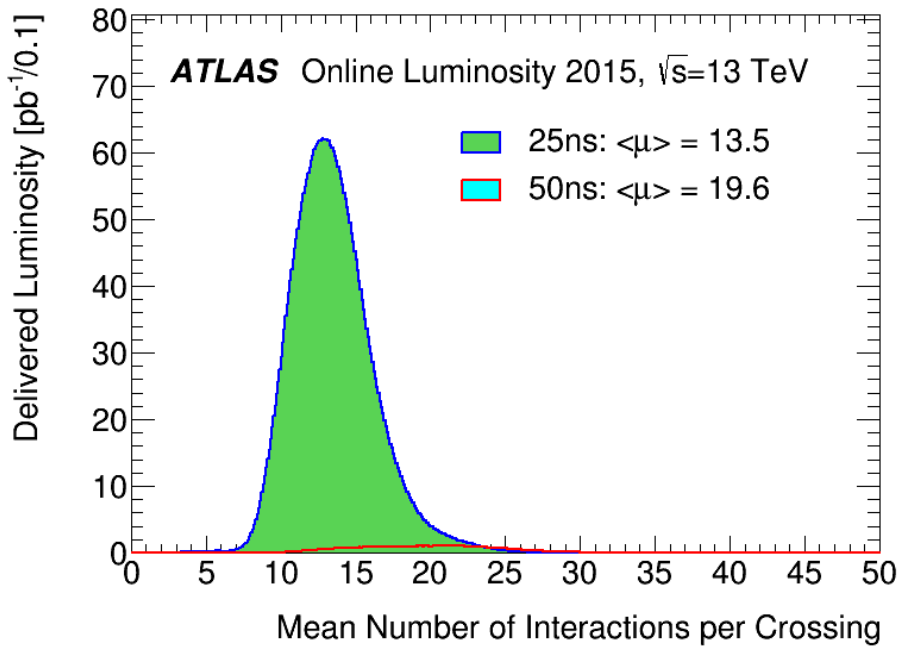
Motivation.

- Increase in $\sqrt{s}$ from 8 to 13 TeV opens door for interesting New Physics searches despite the still limited 13 TeV dataset

Search for narrow diphoton resonances

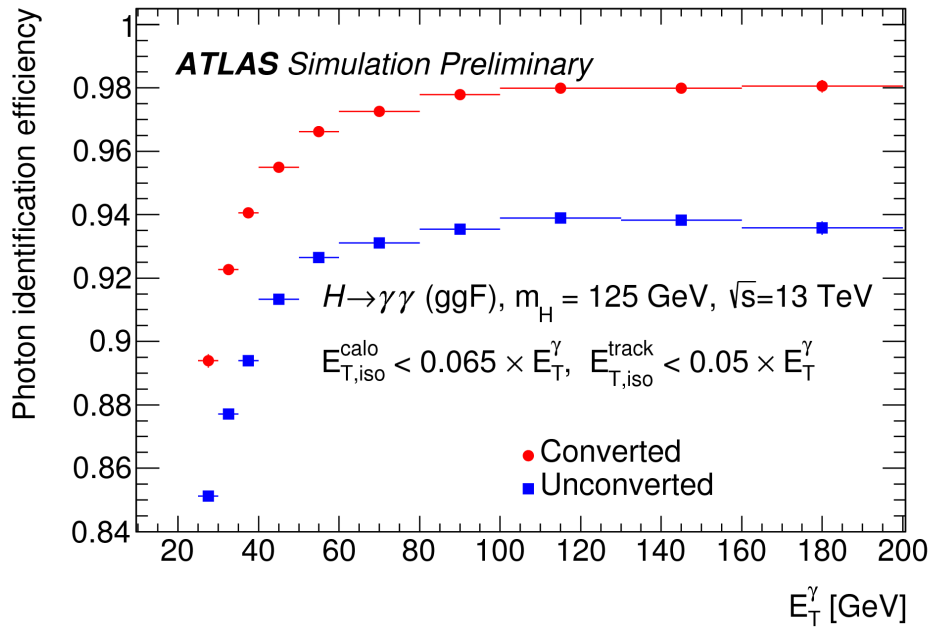
- Can be carried out in a fairly model-independent way
- Clear and experimentally robust signature
- Two analyses, which follow closely the Run1 $H \to \gamma\gamma$ analyses:
  - ⋆ CMS, 2.6 fb^{-1}
  - ⋆ ATLAS, 3.2 fb^{-1}

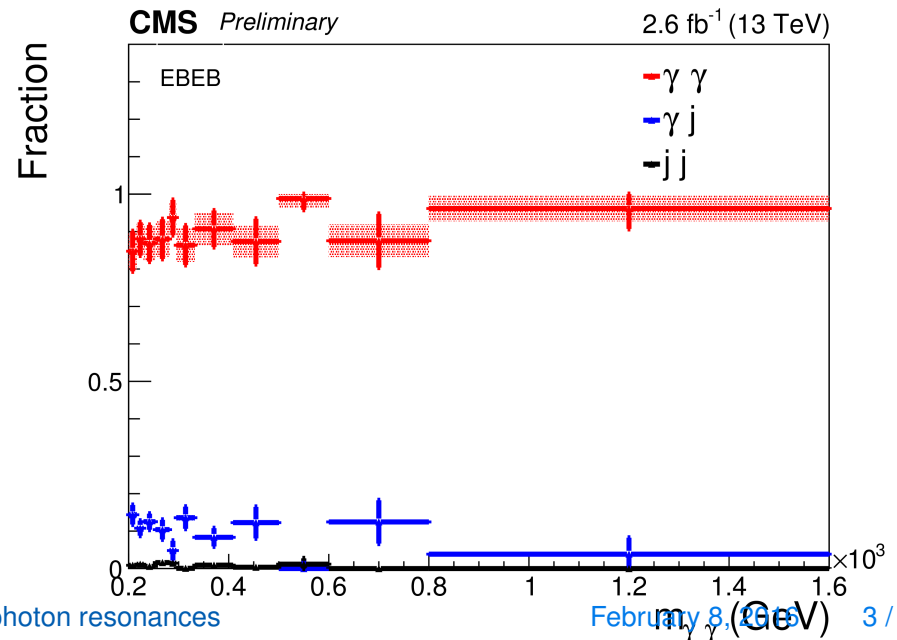




Event selection.

- Analyses optimized for RS gravitons ($\tilde{\kappa}$ =0.01, 0.1, 0.2) and scalar resonance (width up to 10%$m_{\gamma\gamma}$)
- Isolated and identified photons with p_T^{γ} >75 GeV and $p_T^{\gamma 1(2)}$ > 0.4 (0.3) $m_{\gamma\gamma}$
- Diphoton fraction in selected event sample typically 90% (85% when one photon in CMS ECAL endcap)
- CMS splits events into 2 categories
  - ⋆ both photons in ECAL barrel
  - ⋆ one photon in ECAL barrel, one photon in ECAL endcap

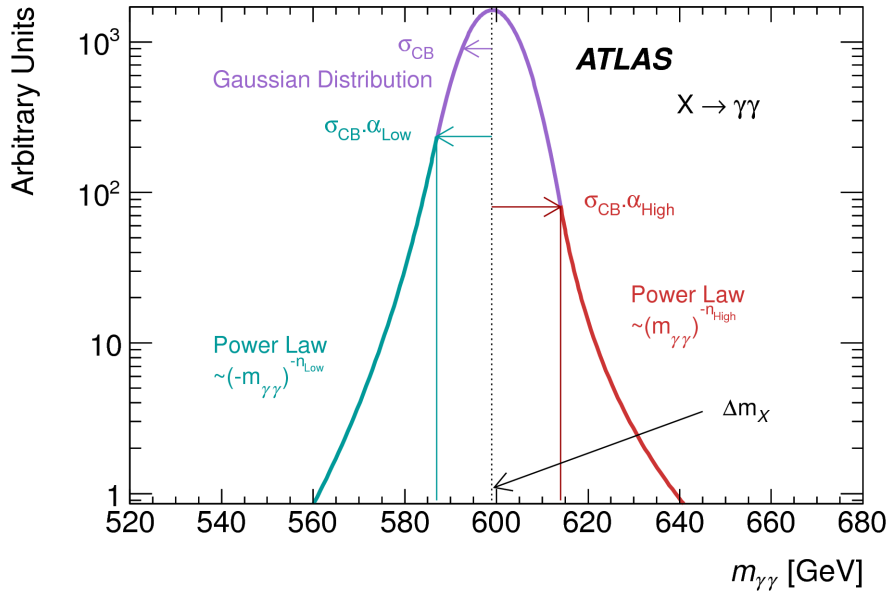




Signal modeling.

ATLAS

- Narrow width: $H \to \gamma\gamma$ samples with $\Gamma = 4$ MeV
- Detector response parameterized with double-sided Crystal Ball function
  - ⋆ $\sigma_{\mathrm{CB}} = 2$ GeV (13 GeV) at $m_H = 200$ GeV (2 TeV)



- Larger width ($\Gamma = 1$-$10\%\ m_{\gamma\gamma}$) by convoluting detector response with Breit-Wigner function

CMS

- Intrinsic signal shape determined from Pythia, using "moment morphing" to interpolate between different graviton masses
- Detector response modeled from fully simulated samples

m_G (GeV)	category	$\tilde{\kappa}$	FWHM (GeV)	$\tilde{\kappa}$	FWHM (GeV)
500	EBEB	0.01	14	0.2	36
500	EBEE	0.01	22	0.2	42
1000	EBEB	0.01	27	0.2	74
1000	EBEE	0.01	43	0.2	85
2000	EBEB	0.01	54	0.2	147
2000	EBEE	0.01	76	0.2	163
3000	EBEB	0.01	96	0.2	225
3000	EBEE	0.01	110	0.2	254
4000	EBEB	0.01	121	0.2	320
4000	EBEE	0.01	150	0.2	326

Background parametrization.

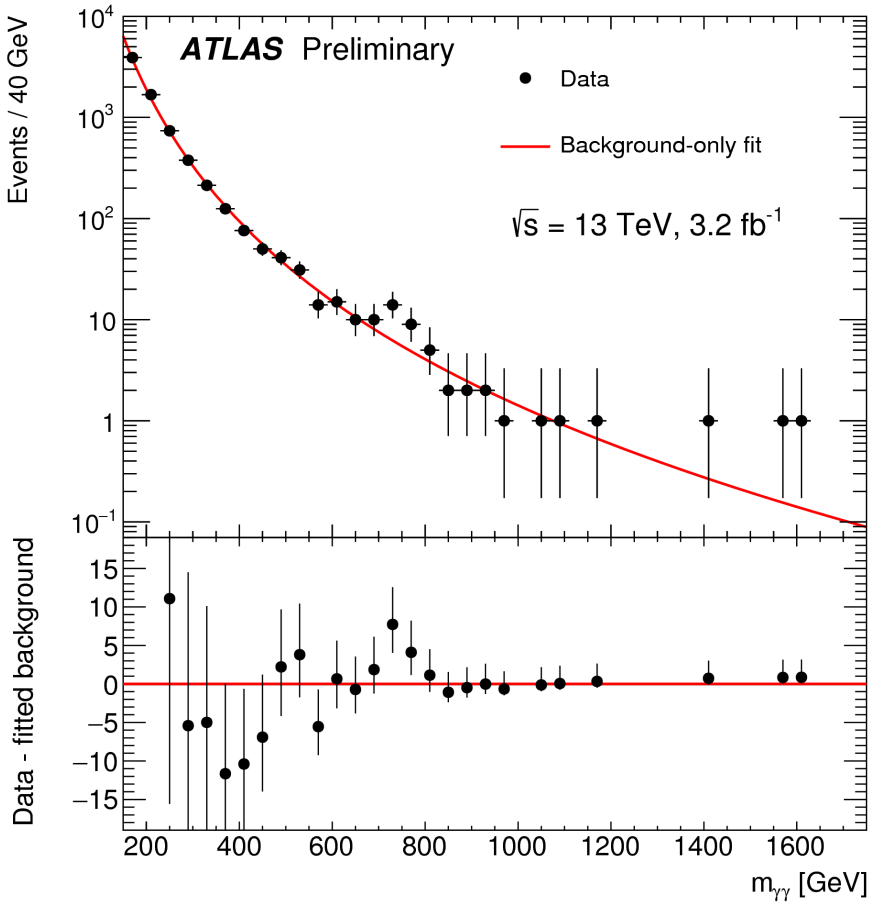
- Background is parametrized by analytical function, and the shape parameters are determined on data

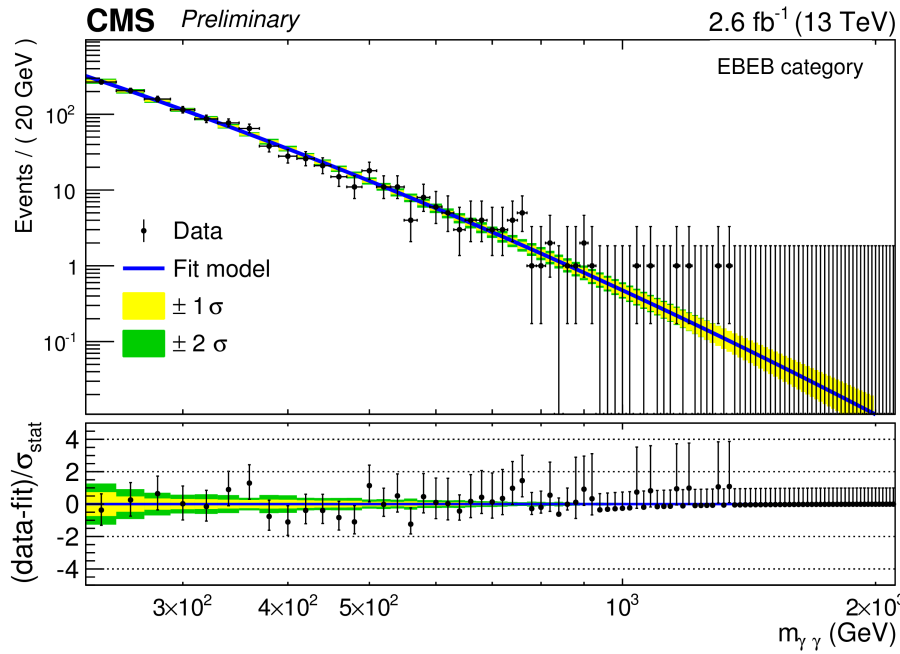
  CMS $\quad f(m_{\gamma\gamma}) = m_{\gamma\gamma}^{a+b\log m_{\gamma\gamma}}$

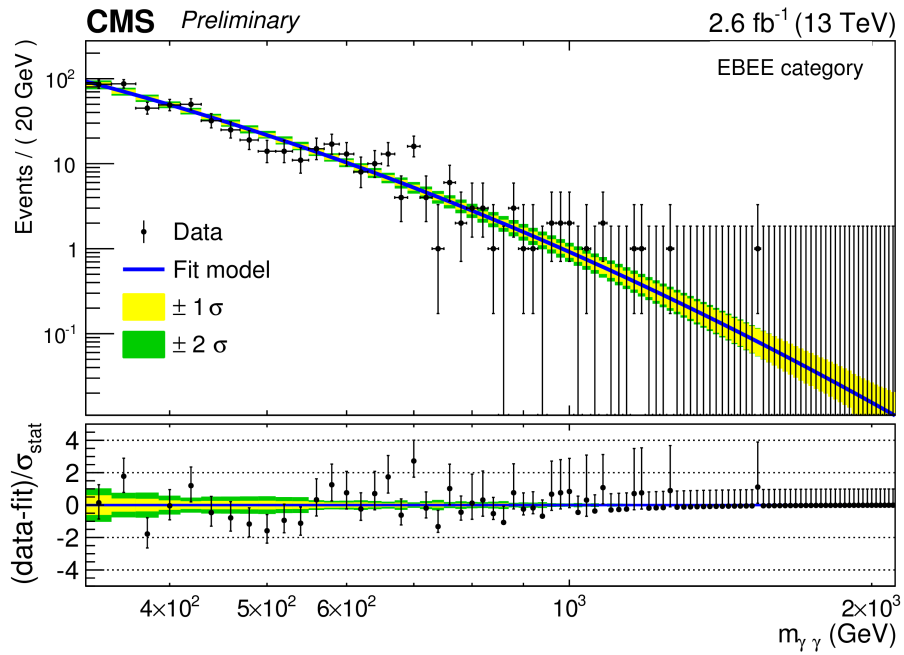
  ATLAS $\quad f(x) = (1-x^{1/3})^b x^{a_0}$ with $x = m_{\gamma\gamma}/\sqrt{s}$

- Parametrization is tested on MC, and potential biases are assigned as systematic uncertainty
- ATLAS checked need for additional free parameters ($a_0 \to \sum_{j=0}^{k} a_j (\log x)^j$) on data and concluded that no additional parameters are needed

Invariant mass spectra.







Uncertainties.

ATLAS

Source	Uncertainty
Background modeling °•	
Spurious signal	$2-10^{-3}$ events, mass-dependent
Background fit	$\leq 50\%$–$\leq 20\%$ of the total signal yield uncertainty, mass- and signal-dependent
Signal modeling °•	
Photon energy resolution	$^{+[55-110]\%}_{-[20-40]\%}$, mass-dependent
Signal yield •	
Luminosity	$\pm 5\%$
Trigger	$\pm 0.63\%$
C_X *factors* •	
Photon identification	$\pm(3$–$2)\%$, mass-dependent
Photon isolation	$\pm(4.1$–$1)\%$, mass-dependent
Production process	$\pm 3.1\%$

CMS

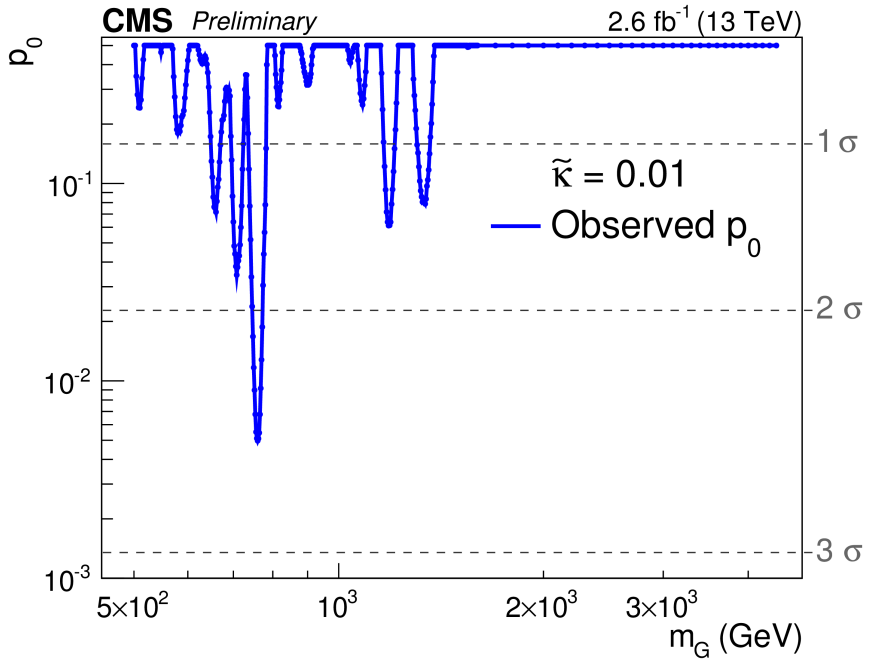
Luminosity	4.6%
Trigger and photon id efficiency	10%
PDF	6%
Photon energy scale	1%

Narrow width p values.

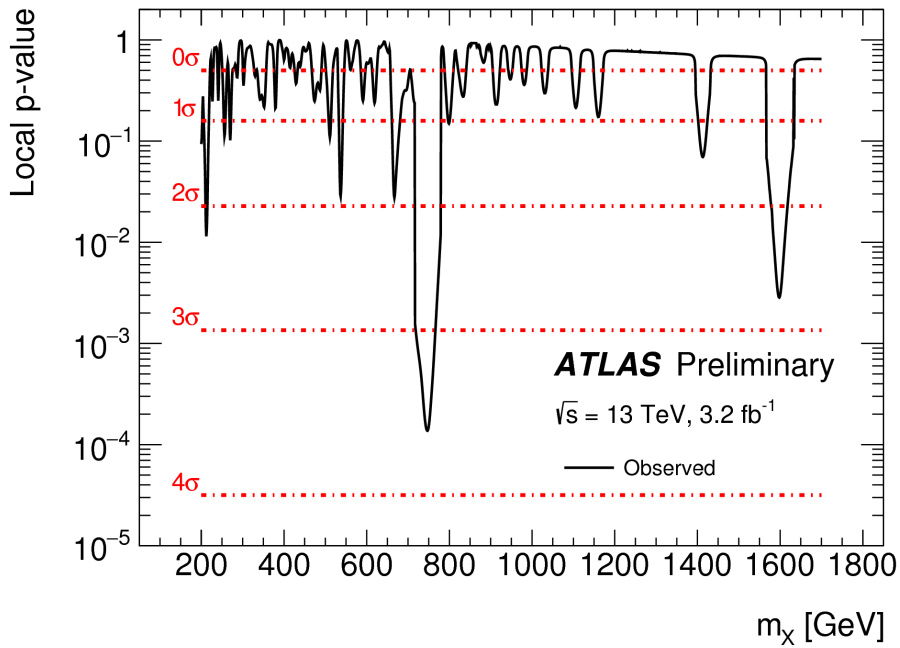
Searches for a narrow (width dominated by resolution) diphoton resonance

No really significant excess over the whole mass range:

CMS



ATLAS

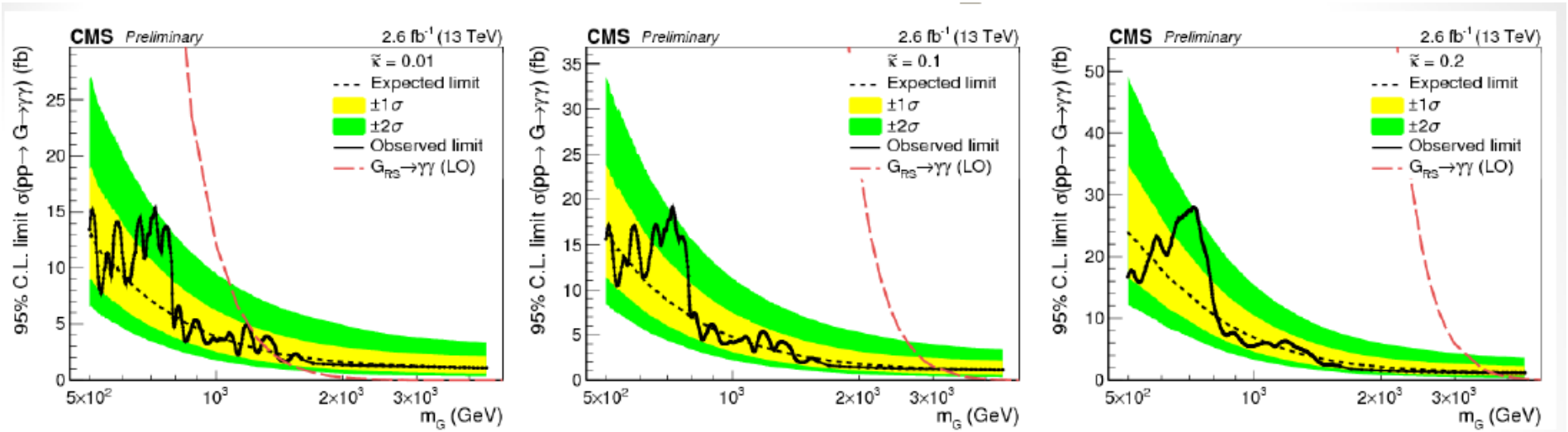


2.6 σ local excess at 760 GeV
1.2 σ with LEE (500 GeV - 4.5 TeV)

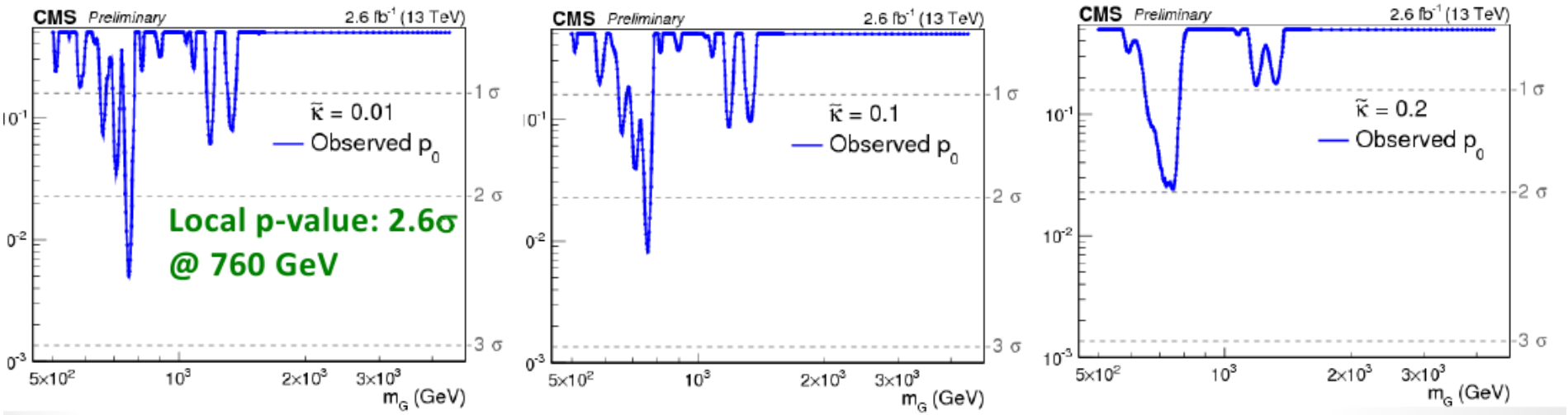
3.6 σ local excess at 750 GeV
2.0 σ with LEE (200 GeV - 2 TeV)

- Not very significant! But excess in a similar place.

Non-narrow width (CMS).



Narrow Width → **Wide (6%) Width**



Including LEE (0.5 - 4.5 TeV; narrow width), global p-value < 1.2σ

RS graviton limits (CMS).

Limits on RS graviton masses

$\tilde{\kappa}$	0.01	0.1	0.2
expected	1.35 TeV	3.1 TeV	3.8 TeV
observed	1.3 TeV	3.1 TeV	3.8 TeV

- Graviton mass limits based on LO cross section predictions
- Improved limits compared to (LO) 8 TeV search

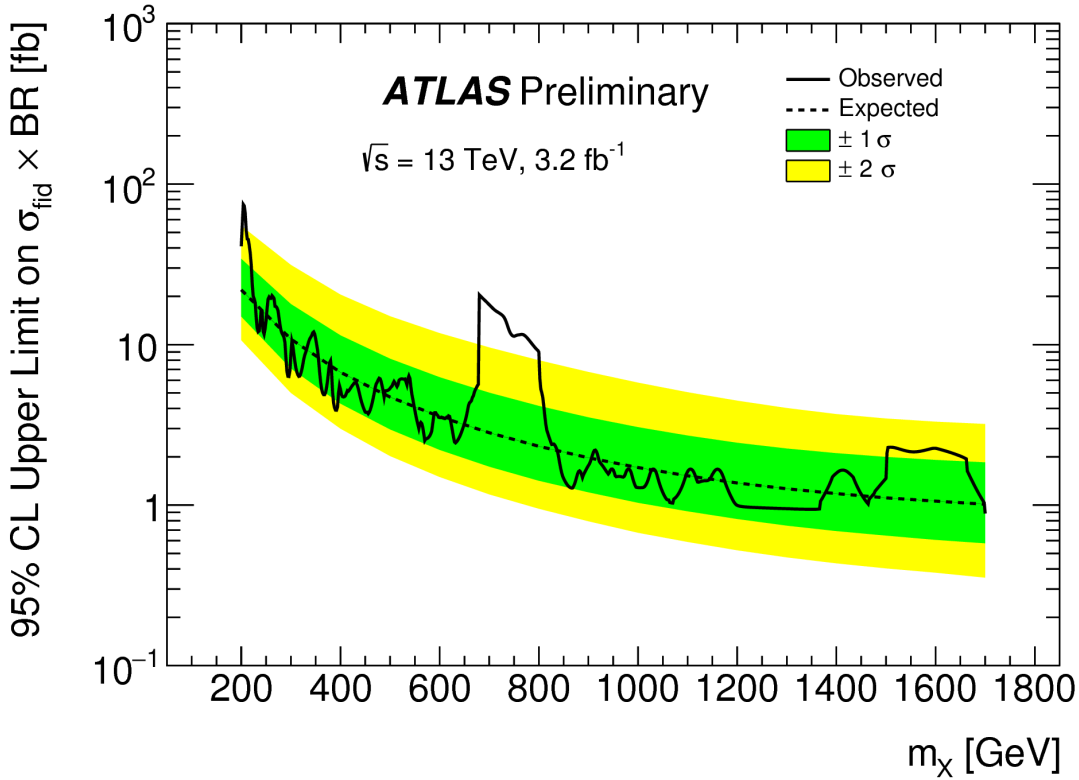
Non-narrow width (ATLAS).

- Photon energy resolution nuisance parameter pulled by $\sim$1.5 σ in narrow-width fit
- Largest deviation from background-only hypothesis found for a width of 6%$m_{\gamma\gamma}$ ($\Gamma = 45$ GeV):
  - ⋆ 3.9 σ local
  - ⋆ 2.3 σ with LEE (200 GeV - 2 TeV in mass and 1-10%$m_{\gamma\gamma}$ in width)

- Photon energy resolution uncertainty is very conservative, ranging from $^{+55\%}_{-20\%}$ at 200 GeV to $^{+110\%}_{-40\%}$ at 2 TeV, dominated by differences between 8 and 13 TeV detector and reconstruction
  - ⋆ Measurement of energy resolution corrections uses 8 TeV $Z \to ee$ reconstructed with 13 TeV reconstruction
  - ⋆ Resolution is cross checked with 13 TeV $Z \to ee$ events

Cross section limits.

- Fiducial cross section
  $\sigma_{\mathrm{fid}} = N_{\mathrm{sig}}/(C_X \mathcal{L})$
  - ⋆ C_X correction factor, computed from $gg \to H \to \gamma\gamma$

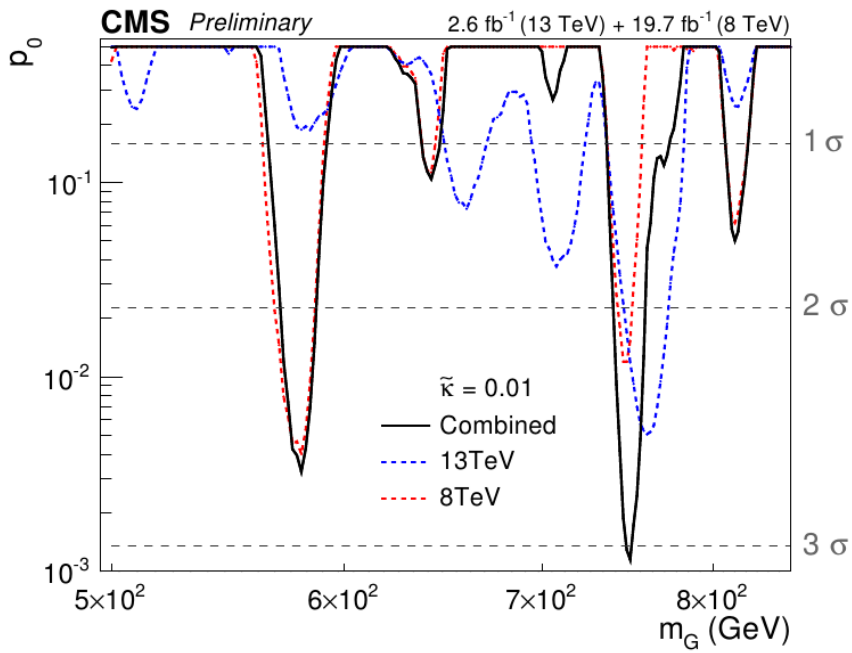


- Fiducial volume
  - ⋆ $p_T^{\gamma 1(2)} > 0.4\ (0.3)\ m_{\gamma\gamma}$
  - ⋆ $|\eta^{\gamma 1(2)}| < 2.37$
  - ⋆ $E_T^{\mathrm{iso}} < 0.05\ p_T^{\gamma 1(2)}$ + 6 GeV

Looking at 8 TeV data.

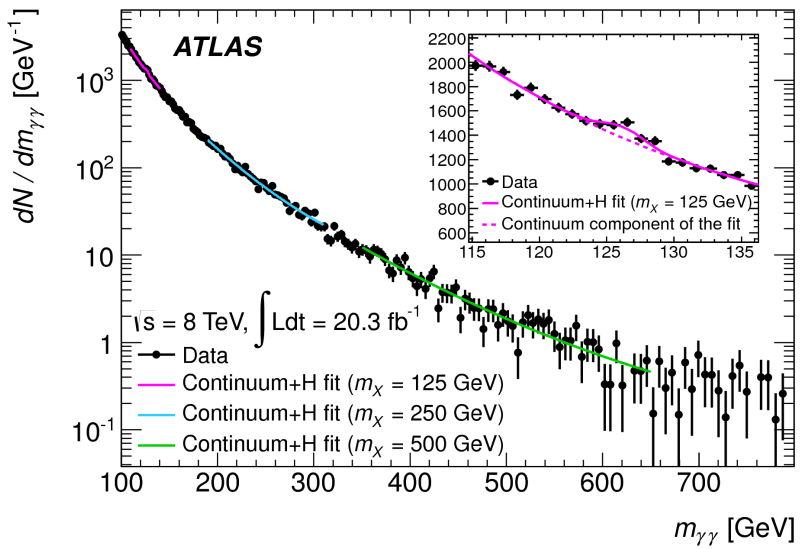
CMS

- Combination with Higgs (RS interpretation) and exotics in different mass ranges for $\tilde{\kappa} = 0.01$
  - ⋆ Background treatment revisited for 8 TeV exotics analysis
- $\sigma^{8\ \mathrm{TeV}}/\sigma^{13\ \mathrm{TeV}}$ =0.24
- 3.0 σ local excess at 750 GeV
  1.7 σ with LEE (500 GeV - 4.5 TeV)
- 8 TeV and 13 TeV results compatible



ATLAS

- 8 TeV extra scalar resonance search extended to higher masses
- 8 TeV and 13 TeV compatible within 2.2 (1.4) σ for narrow width (6%$m_{\gamma\gamma}$) for s-channel gg production ($\sigma^{13\ \mathrm{TeV}}/\sigma^{8\ \mathrm{TeV}}$ =4.7)



Summary and outlook.

- Search for diphoton resonances in 2015 13 TeV data
  - ⋆ CMS Search for RS gravitons, setting mass limits at 1.3 TeV ($\tilde{\kappa} = 0.01$), 3.1 TeV ($\tilde{\kappa} = 0.1$) and 3.8 TeV ($\tilde{\kappa} = 0.2$)
  - ⋆ ATLAS search for scalar resonances, setting limits on fiducial production cross section times branching ratio
- Largest deviation from SM background expectation around
  - ⋆ 750 GeV with 3.6 σ local and 2.0 σ global significance
  - ⋆ 760 GeV with 2.6 σ local and 1.2 σ global significance
  - ⋆ No obvious detector or reconstruction effect, no unusual kinematic properties on excess region compared to other regions within statistical uncertainties

- Expect 10 fb^{-1} by summer, and 30 fb^{-1} during 2016

Backup

Notes, plots and talks.

- Jim Olsen's LHCC seminar talk: `link`
- CMS note and public plots: `link`
- Riccardo Paramatti's talk at DESY seminar: `link`

- Marumi Kado's LHCC seminar talk: `link`
- ATLAS note and public plots: `link`
- Elisabeth Petit's talk at DESY seminar: `link`

How about other channels?

- KK Graviton$\rightarrow t\bar{t}$ search at 8 TeV
- $Z' \rightarrow \ell\ell$ search at 13 TeV
- Dijet search at 8 TeV (Breit-Wigner resonance from gg initial state)