

# Mini Workshop on the diphoton excess

HEP@VUB – 28/01/2016

## The references :

# CMS Results

- The CMS Collaboration, “ Search for new physics in high mass di-photon events in pp collisions at 13 TeV”,  
Physics Analysis Summary – PAS EXO-15-004

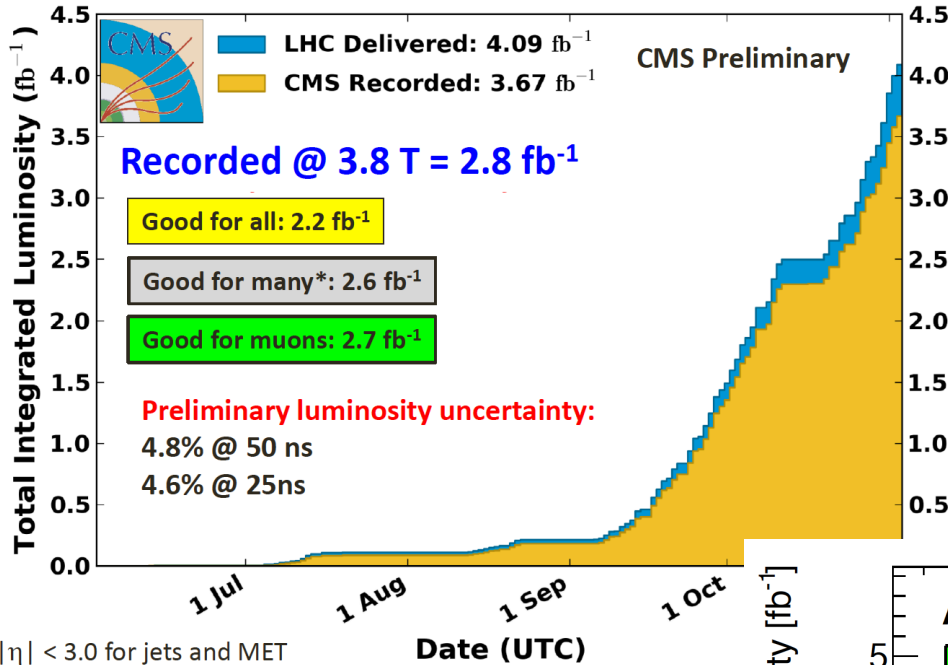
# ATLAS Results

- The ATLAS Collaboration, “ Search for resonances decaying to photon pairs in  $3.2 \text{ fb}^{-1}$  of pp collisions at 13 TeV with the ATLAS detector”,  
ATLAS NOTE – ATLAS-CONF-2015-081

Many slices from CERN JAMBOREE (LPCC Special Seminar) – 15/12/2015  
TALKS FROM JIM OLSEN (CMS) and MARUMI KADO (ATLAS)

# CMS Integrated Luminosity, pp, 2015, $\sqrt{s} = 13$ TeV

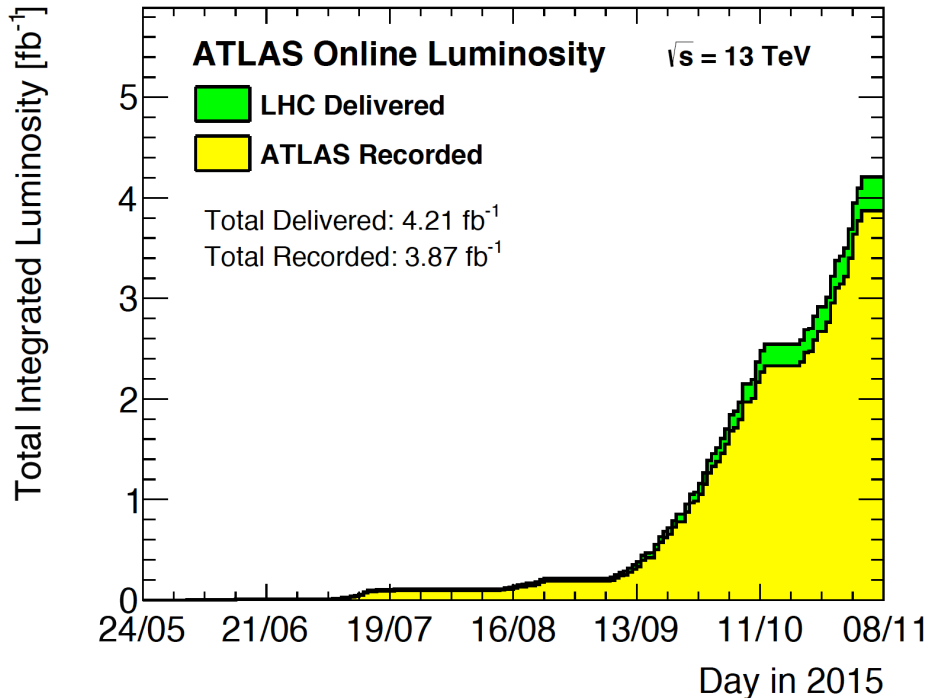
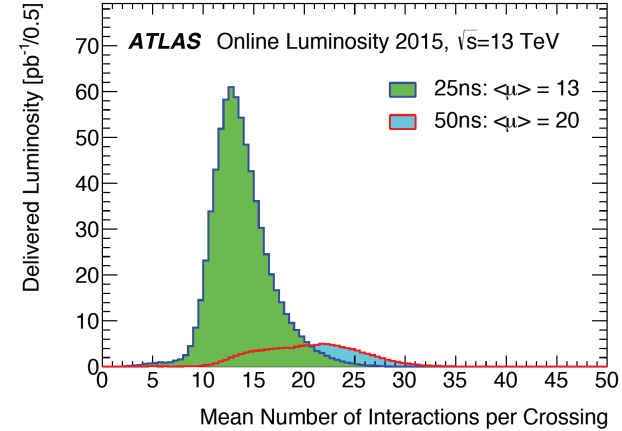
Data included from 2015-06-03 08:41 to 2015-11-03 06:25 UTC



**CMS : L=2.6 fb<sup>-1</sup>**

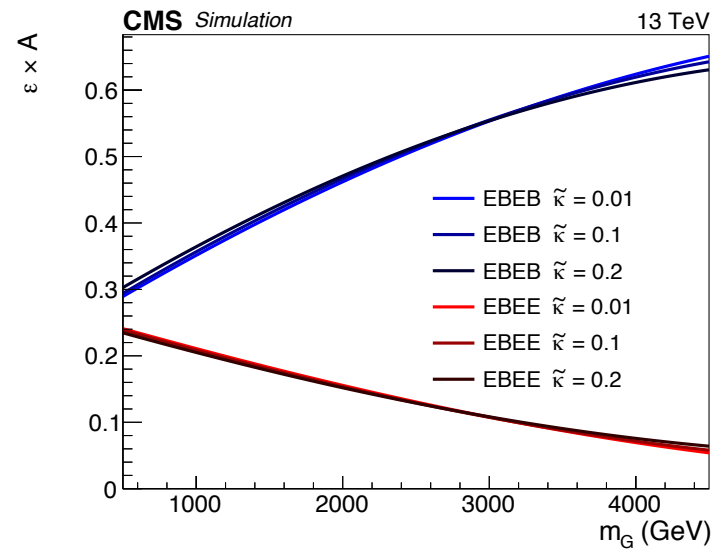
**ATLAS: L=3.2 fb<sup>-1</sup>  
 25 ns data, mu = 13**

# The 2015 dataset



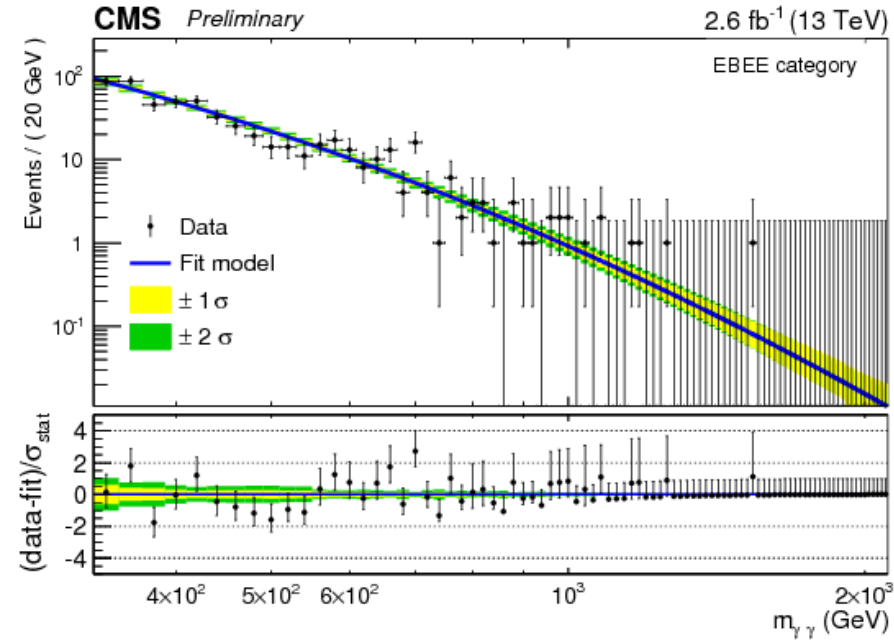
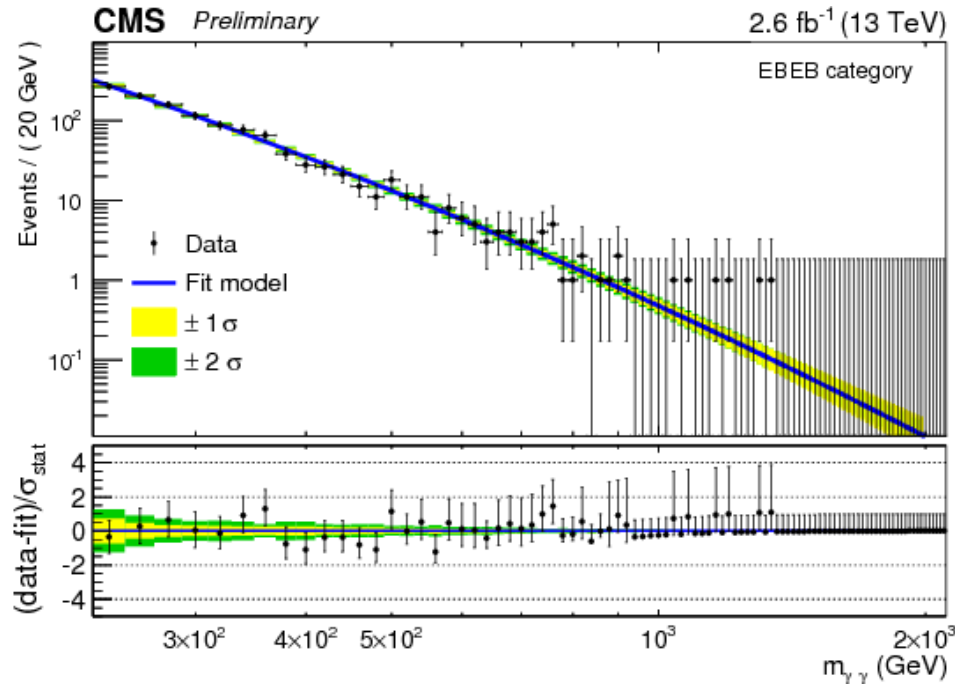
# CMS Results

- **Di-photon trigger :**  
Pt > 60, 60 GeV (100% efficient for events passing the final selection  $m > 500$  GeV)
- **Photon candidates :** pt > 75, 75 GeV, EM shower shape, H/E, isolation in ECAL, tracker iso (PU correction)
- **Pseudorapidity :** At least one photon in the ECAL Barrel (**EBEB and EBEE categories**)
- **Mass :**  $m > 230$  GeV (320 GeV if EBEE)
- **Search region :**  $M > 500$  GeV
  
- **Average  $\gamma\gamma$  purity :** about 80-90% (from data driven method) – see next
- **Selection optimized for signal**  
RS Graviton resonances generated at mass 500-4500 GeV , coupling : 0.01-0.2
- **Blind analysis :** no change have been made to the analysis since unblinding data in the signal region



**Energy calibration** at the Z peak (DY events) and at high mass

# CMS Results : mass spectrum



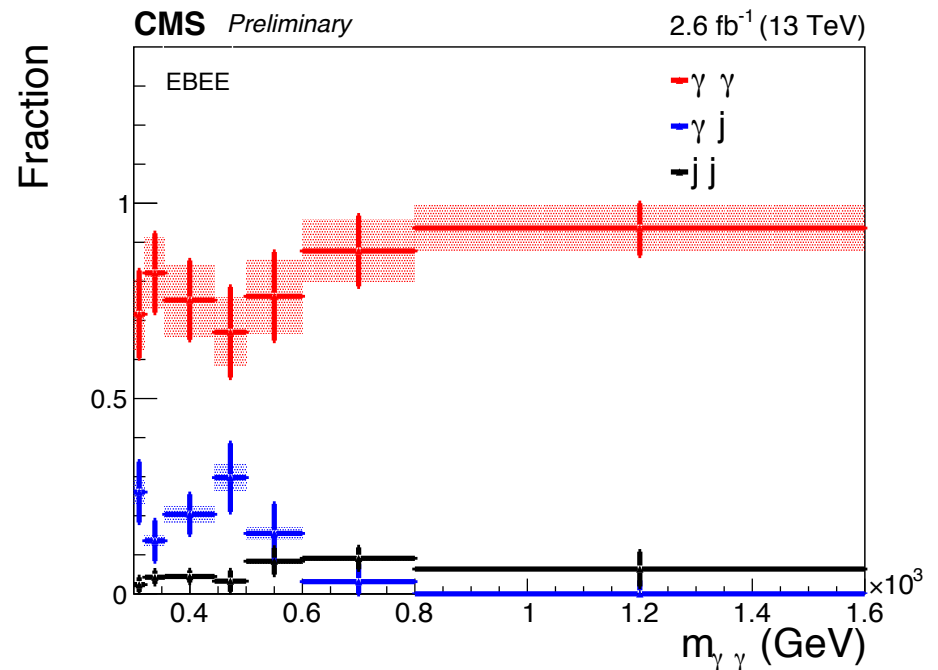
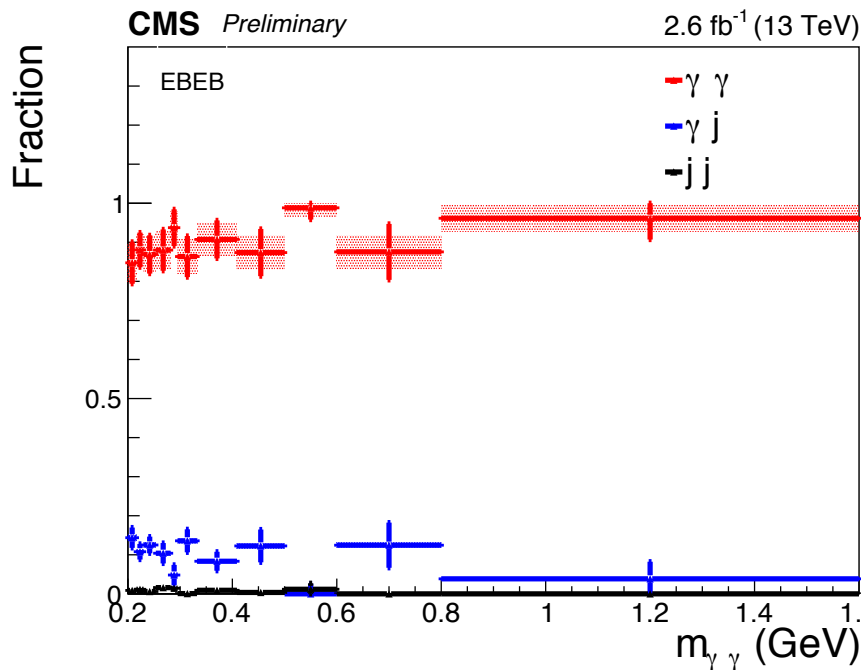
Warning : empty bins  
at high mass

**Parametrisation of the spectrum** : the following function is fit to the selected events:

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

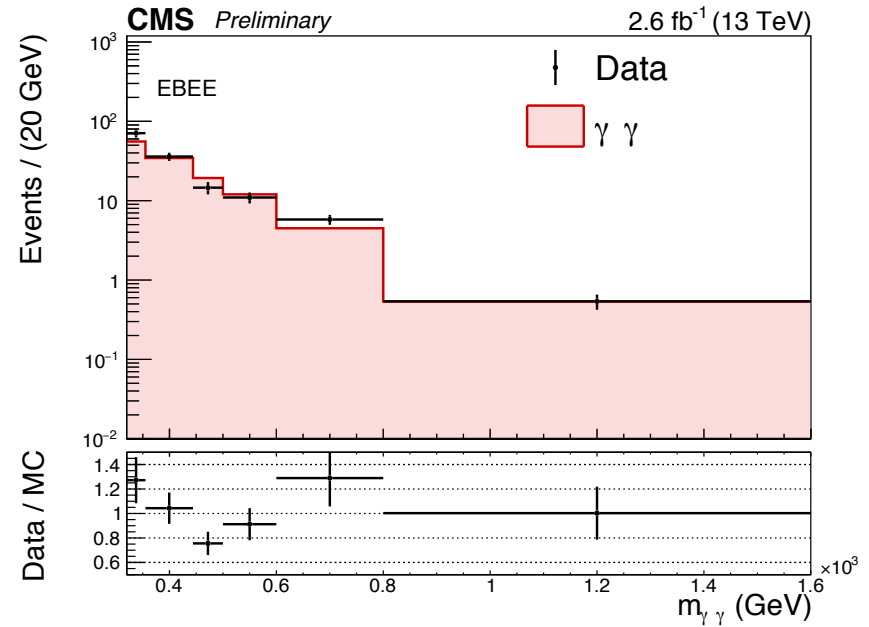
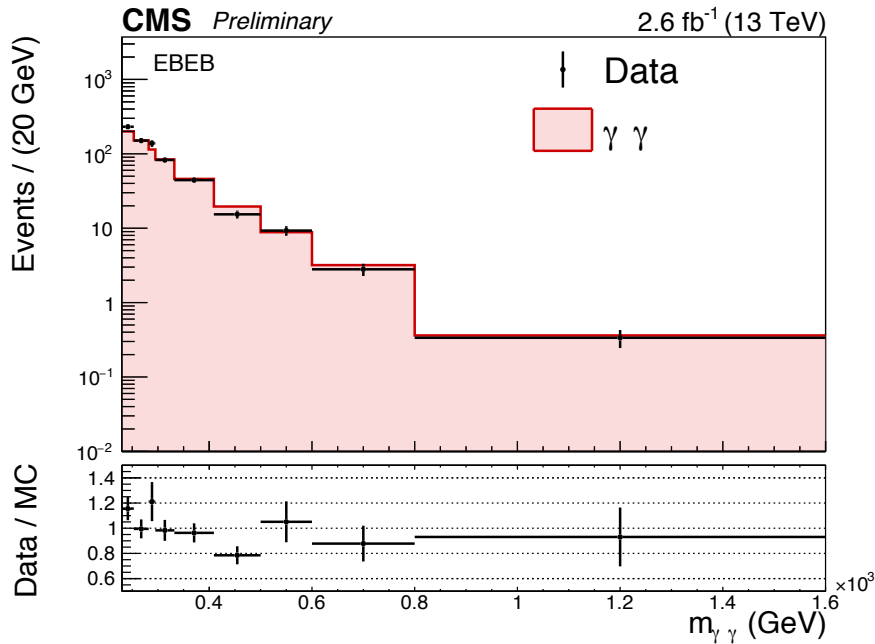
# CMS Results

Measured composition of the background  
for the EBEB and EBEE categories :  
(not used in the analysis results)



# CMS Results

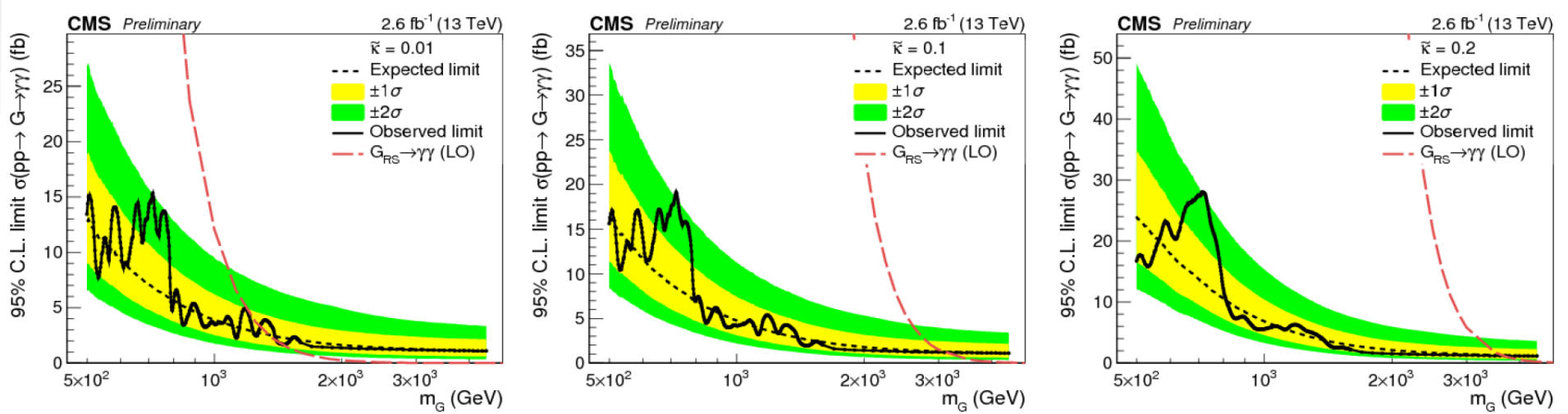
Comparison between the measured and the predicted invariant mass spectrum of the non resonant photon-photon bg



Take the data : correct for the fake bg (from previous slide)  
Compared to MC sherpa spectrum, rescaled to NNLO prediction

(not used further in the analysis results)

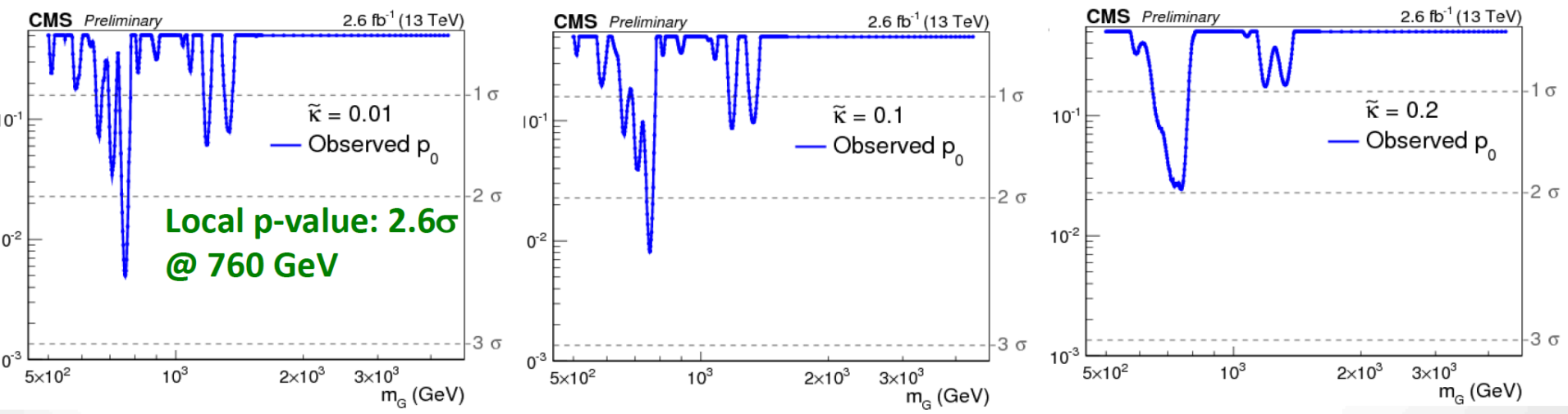
# Combined limits and p-values



**Narrow Width**



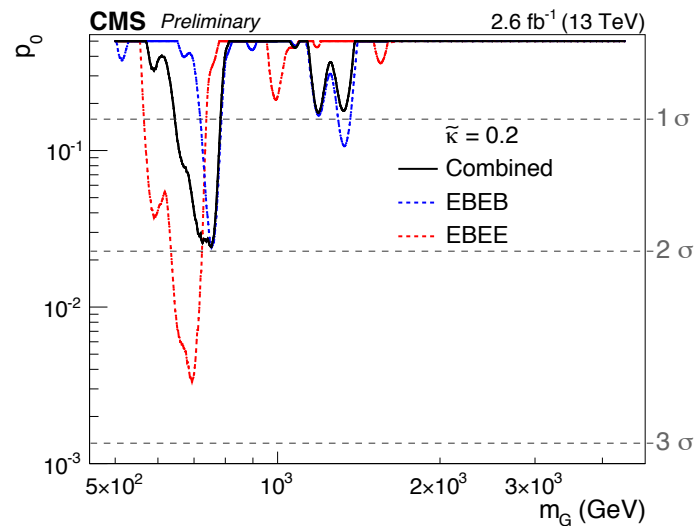
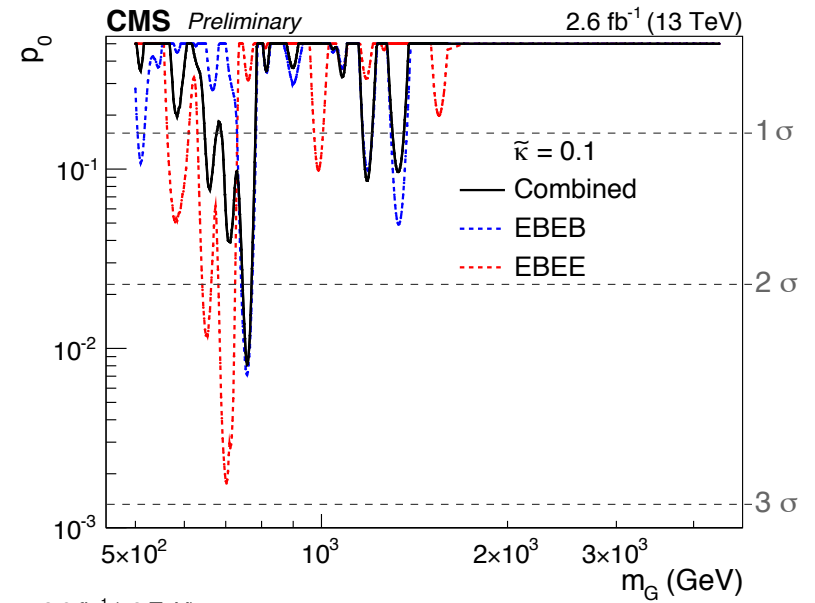
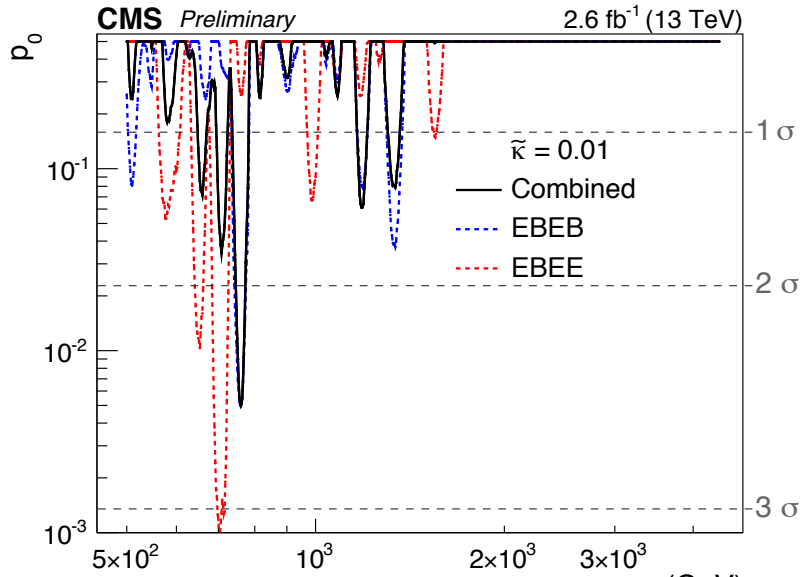
**Wide (6%) Width**



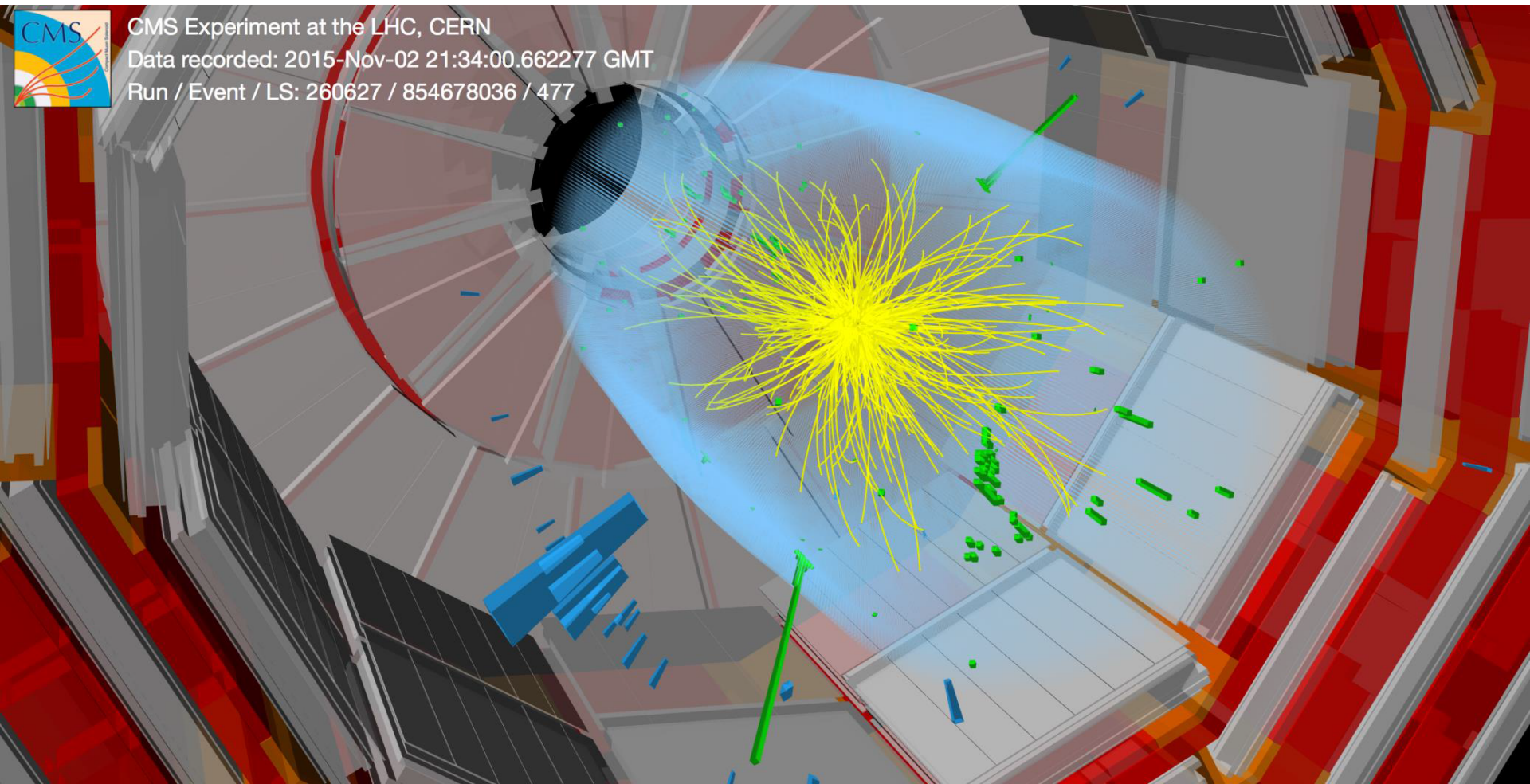
**Including LEE (0.5 - 4.5 TeV; narrow width), global p-value <  $1.2\sigma$**



# CMS Results : EBEB and EBEE



# CMS Results



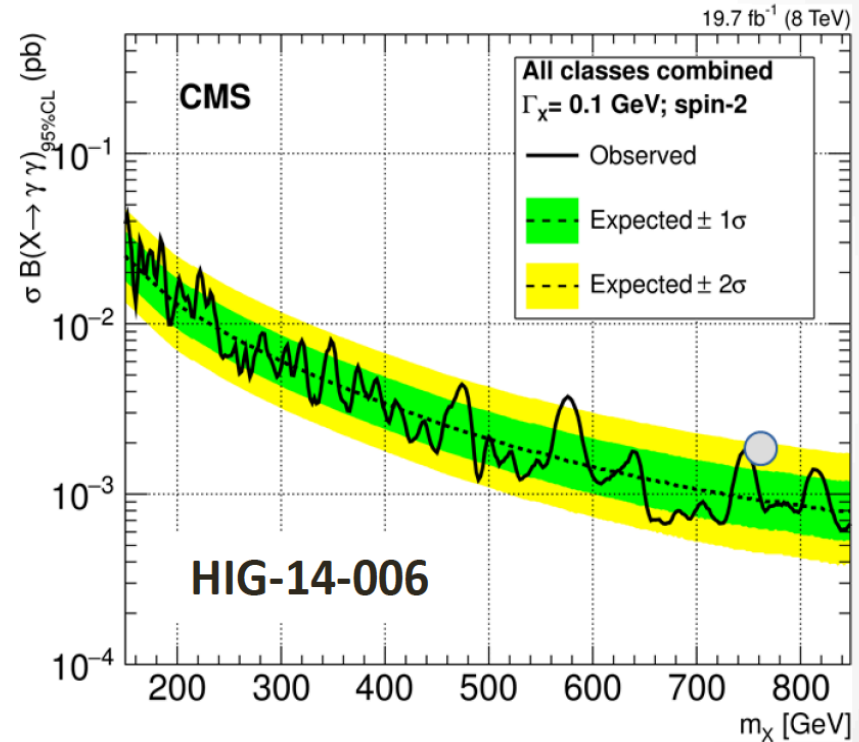
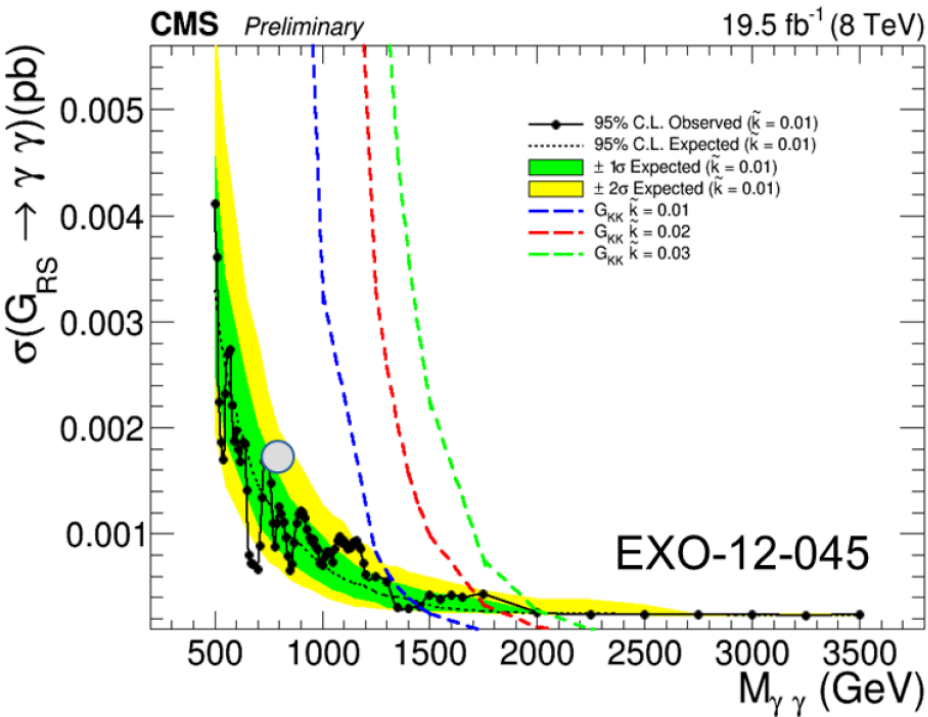
**Diphoton event with mass = 745 GeV**

# CMS Results

## Cross checks done :

- **Other objects in the final state**
- **Event display**
- **Characteristics of the 750 GeV events (kinematics etc ...) compared to the rest of the spectrum (this in only about 10 events ...)**
- **Careful checks ECAL Energy scale at Z peak and at high mass**
- **Cross check on the backgrounds composition and closure test**
- **No other excess of events at 750 GeV in dileptons/dijets analyses**

# Compatibility with Run 1



Excess not excluded by Run 1 searches

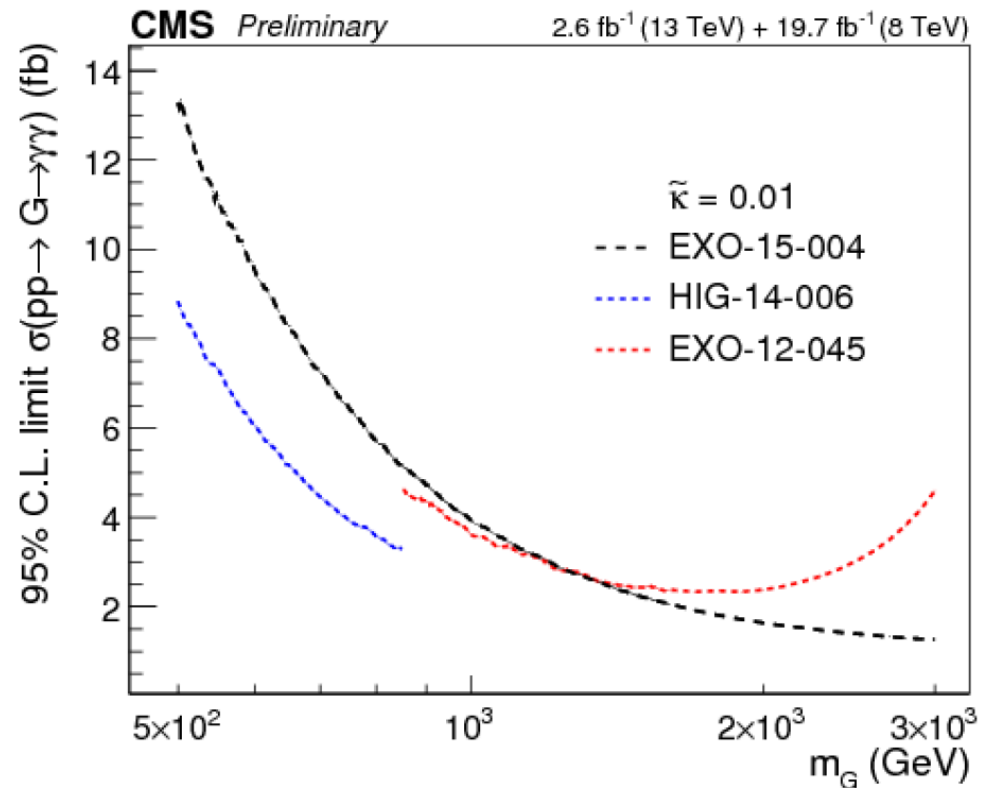
# Combination of 8TeV and 13TeV results

- Combination performed assuming narrow RS graviton hypothesis.

- Results expressed in terms of equivalent 13TeV cross sections.

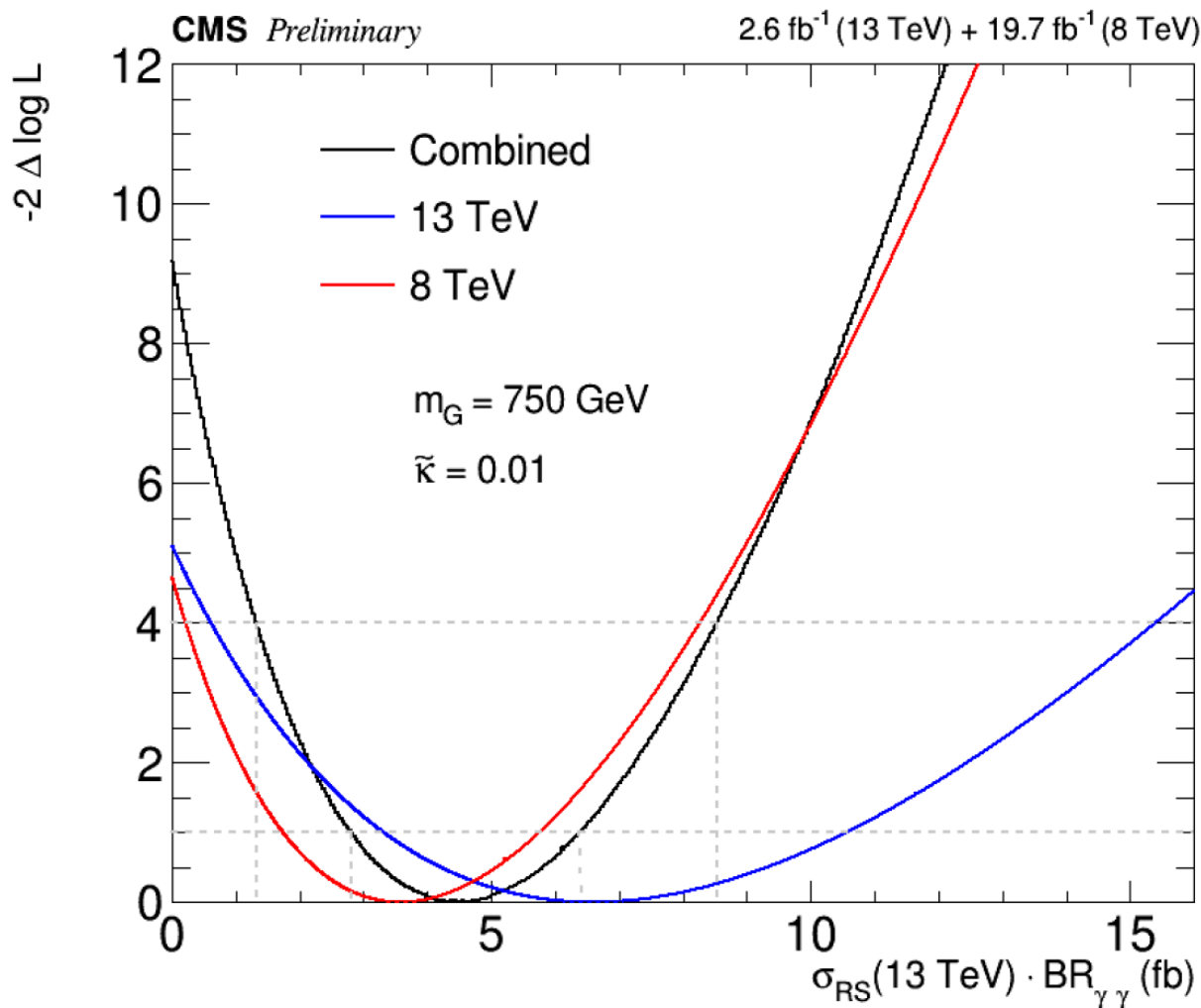
- Two analyses at 8TeV.

- HIG-14-006 and EXO-12-045
- HIG-14-006 is the most sensitive in the covered range (larger acceptance, plus categorization).



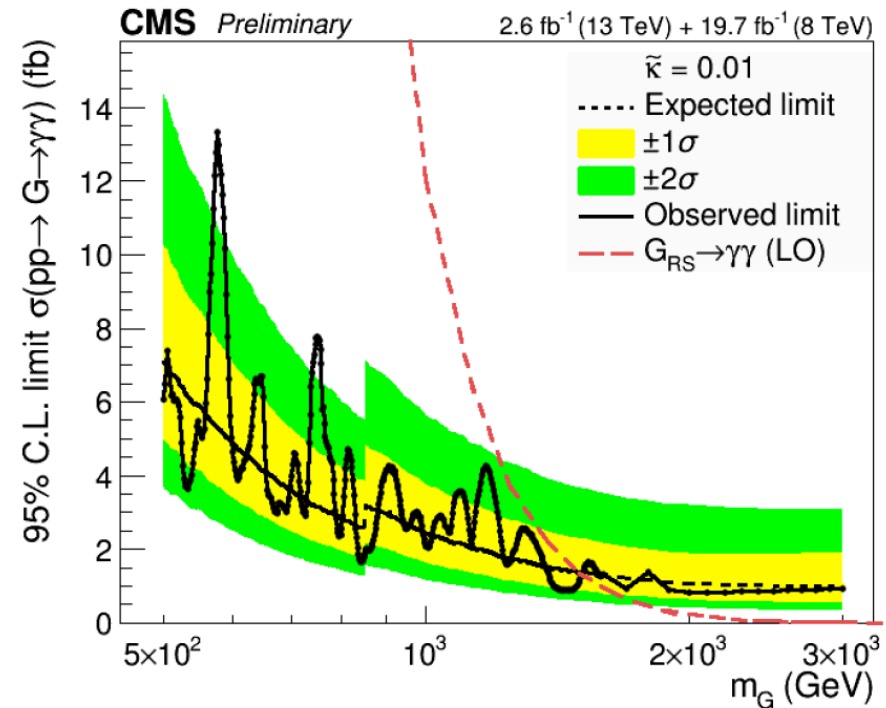
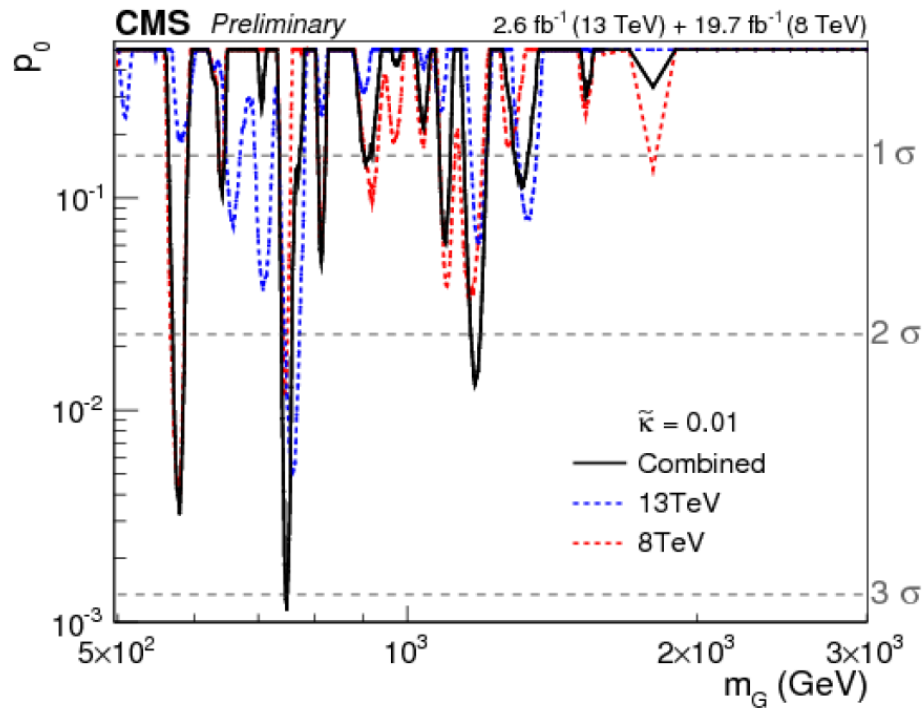
# Log-likelihood scan at 750 GeV

- Results are expressed in terms of equivalent 13 TeV cross sections.

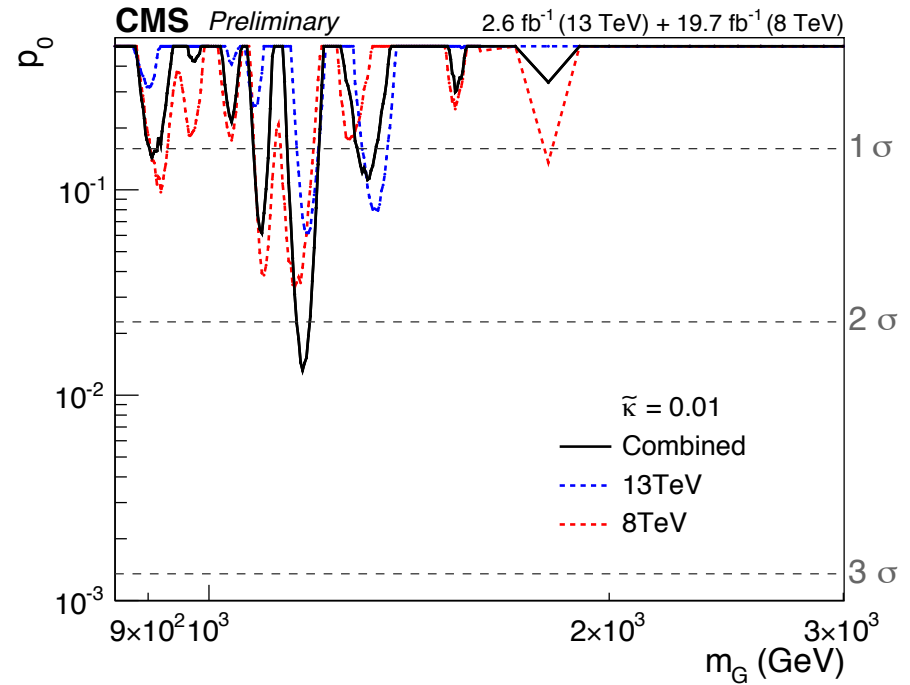
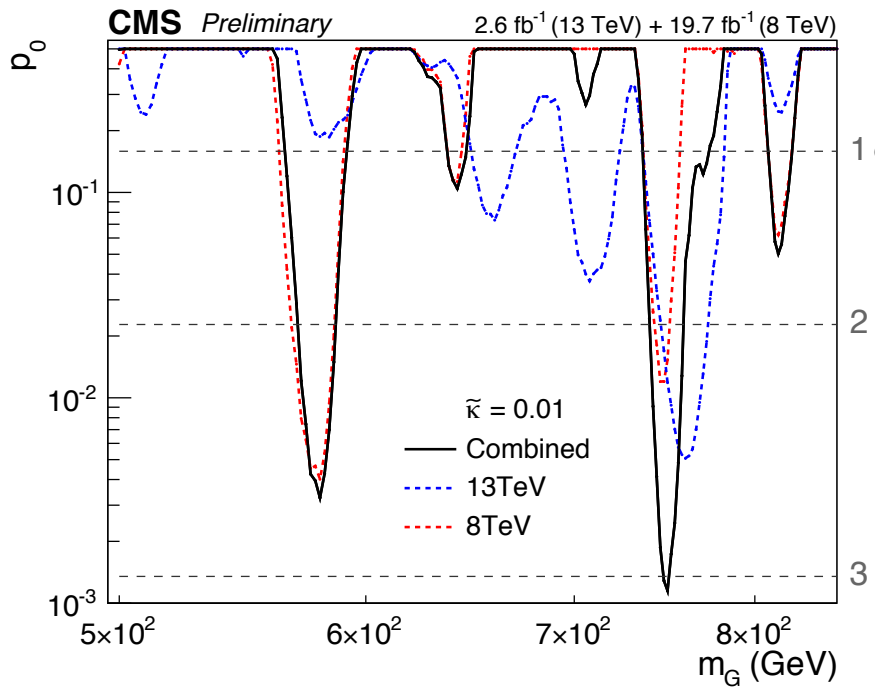


# Combined limits and p-values

- Combined limit improves single analyses sensitivity by 20-30%.
  - Largest excess:  $M_G=750\text{GeV}$ , local significance  $3\sigma$
  - global significance  $< 1.7\sigma$



# CMS Results





# ATLAS Selection

- **Di-photon trigger :**  
Pt > 35, 25 GeV (99% efficient for events passing the final selection)
- **Photon candidates :** EM shower shape, H/E, isolation in ECAL, tracker iso (PU correction)
- **Optimised cuts :**  $E_t(\gamma)/m(\gamma\gamma)$  above 0.3 and 0.4  
Pt dependent calorimeter and track isolation criteria
- **Average  $\gamma\gamma$  purity :** about 90% (from data driven method)
- Z vertex estimation
- **Mass ( $\gamma\gamma$ ) :** energy+azimuthal angle+eta separation between the photons (using Zvertex)  
mass resolution : from 2 GeV (at  $m=200$  GeV) to 13 GeV at 2 TeV

**Optimised cut :** Using a SM Higgs-like resonance decaying into 2 photons, with  $m > 200$  GeV - Signal : in mass range 200-2000 GeV

**2 cases are considered:**

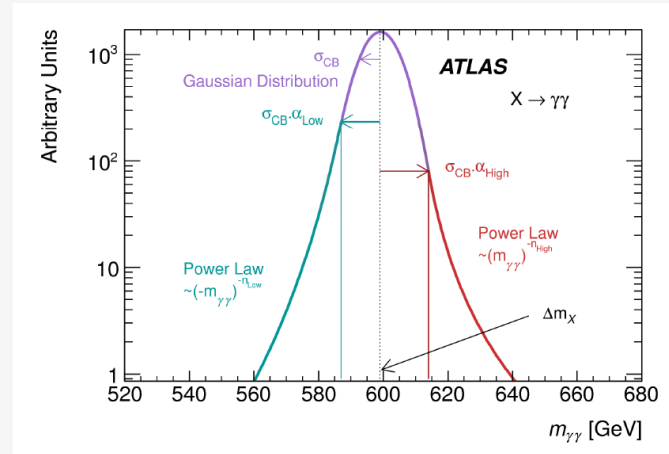
- a width of 4 MeV (constant) - NWA – Narrow Width approx
- Large width (double-side crystal ball + BW with a mass dependent width)

**Energy calibration** at the Z peak (DY events) – eta dependent factor

# ATLAS RESULTS

## Signal Model

- **NWA:** Use Double Sided Crystal Ball function
- **LW:** Use DSCB fitted from simulated samples with different widths with up to 25% of the resonance mass



## Background from a functional

Similar to the dijet search but chosen using the Fisher F-test and the spurious signal method measured in events from Sherpa, DiphoX and Jetphox:

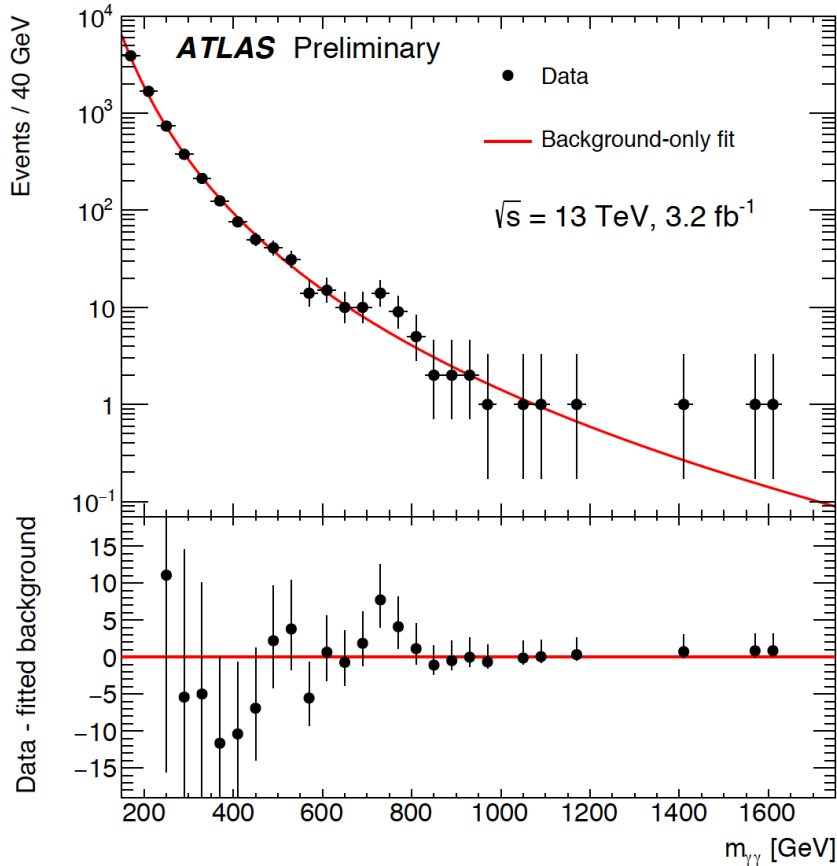
$$f_{bkg}(x; b, \{a_k\}) = (1 - x^{1/3})^b x^{\sum_{j=0}^k a_j \log(x)^j}$$

$$x \equiv \frac{m_{\gamma\gamma}}{\sqrt{s}}$$

Here a simple form with  $k=0$  is used

# ATLAS RESULTS

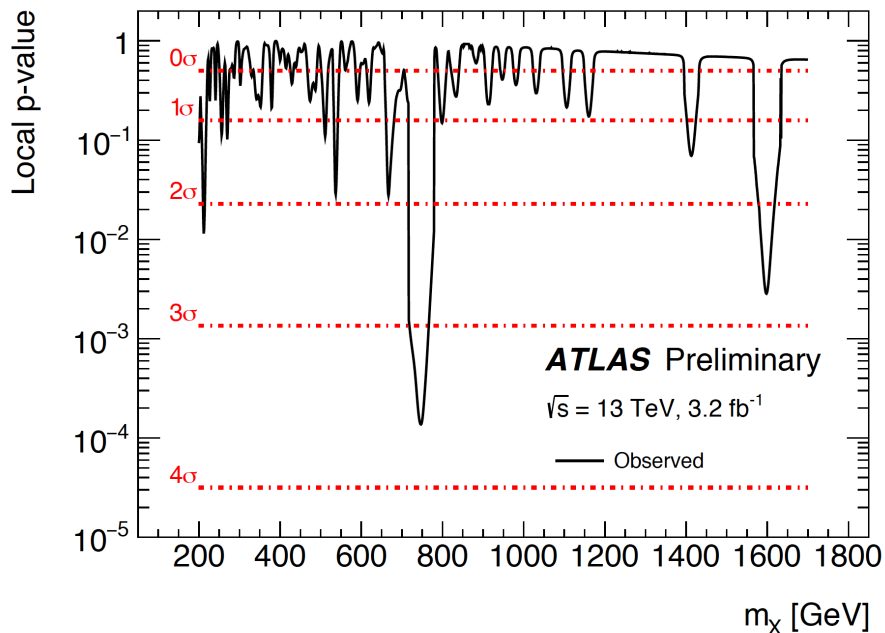
**Results:** Events with mass in excess of 200 GeV are included in **unbinned fit**



- In the NWA search, an excess of  $3.6\sigma$  (local) is observed at a mass hypothesis of minimal  $p_0$  of 750 GeV
- Taking a LEE in a mass range (fixed before unblinding) of **200 GeV to 2.0 TeV** the **global significance** of the excess is  **$2.0\sigma$**

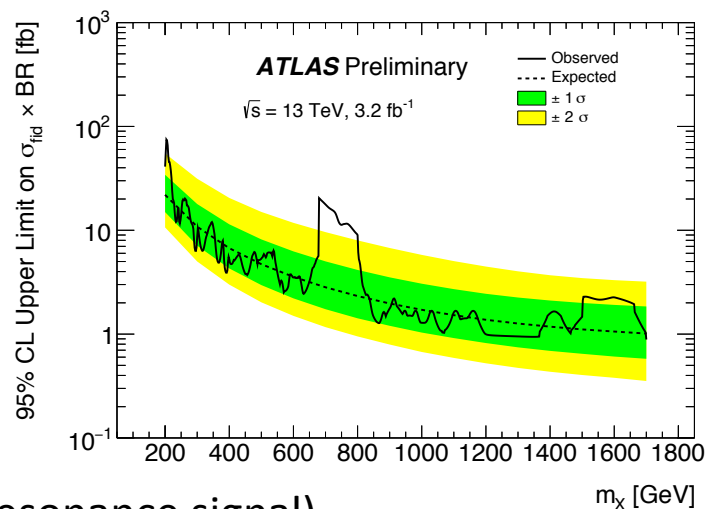
# ATLAS RESULTS

P-value of the the bg only hypothesis  
(of a probed NWA resonance signal)



The data was then fit under a **LW hypothesis** yielding a width of approximately 45 GeV (Approx. 6% of the best fit mass of approximately 750 GeV)

- As expected the local significance increases to  **$3.9\sigma$**
- Taking into account a LEE in mass and width of up to **10%** of the mass hypothesis of  **$2.3\sigma$**  (Note: upper range in resolution fixed after unblinding)



(assume NWA resonance signal)

# ATLAS 8 TeV RESULTS

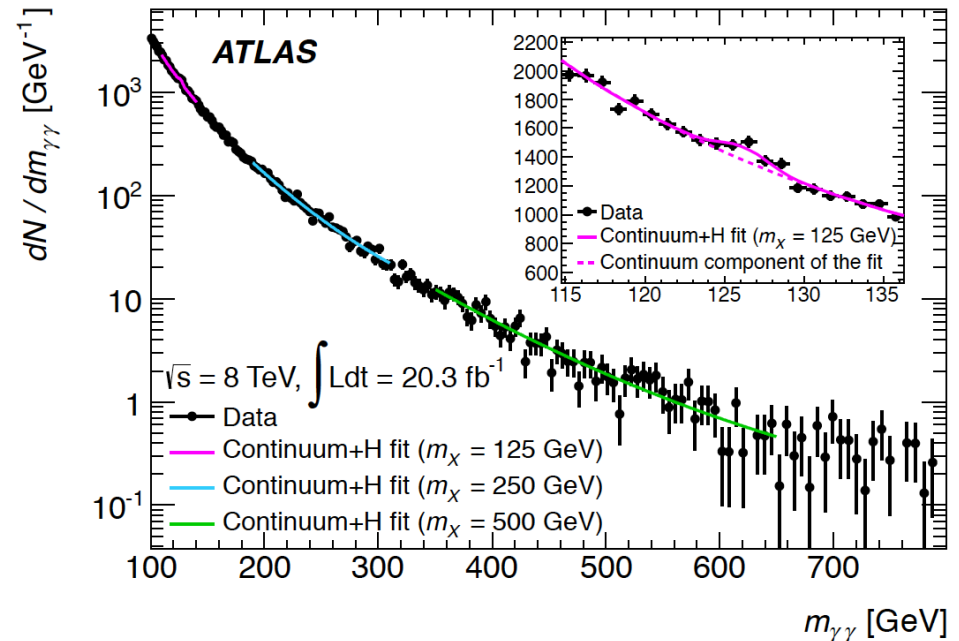
Search for Scalar Diphoton Resonances in the Mass Range 65–600 GeV  
with the ATLAS Detector in pp Collision Data at 8 TeV

arXiv:1407.6583v2 [hep-ex] 8 Sep 2014

Extension to higher mass  
using the new bg modeling

Compatibility :

- estimated for NWA and 6% width
- For s-channel g-initiated process and with parton-lumi ratio of 4.7
- Compatible within 2.2 sigma (NWA) and 1.4 sigma (large width of 6%)



# Comparison of the mass spectra:

