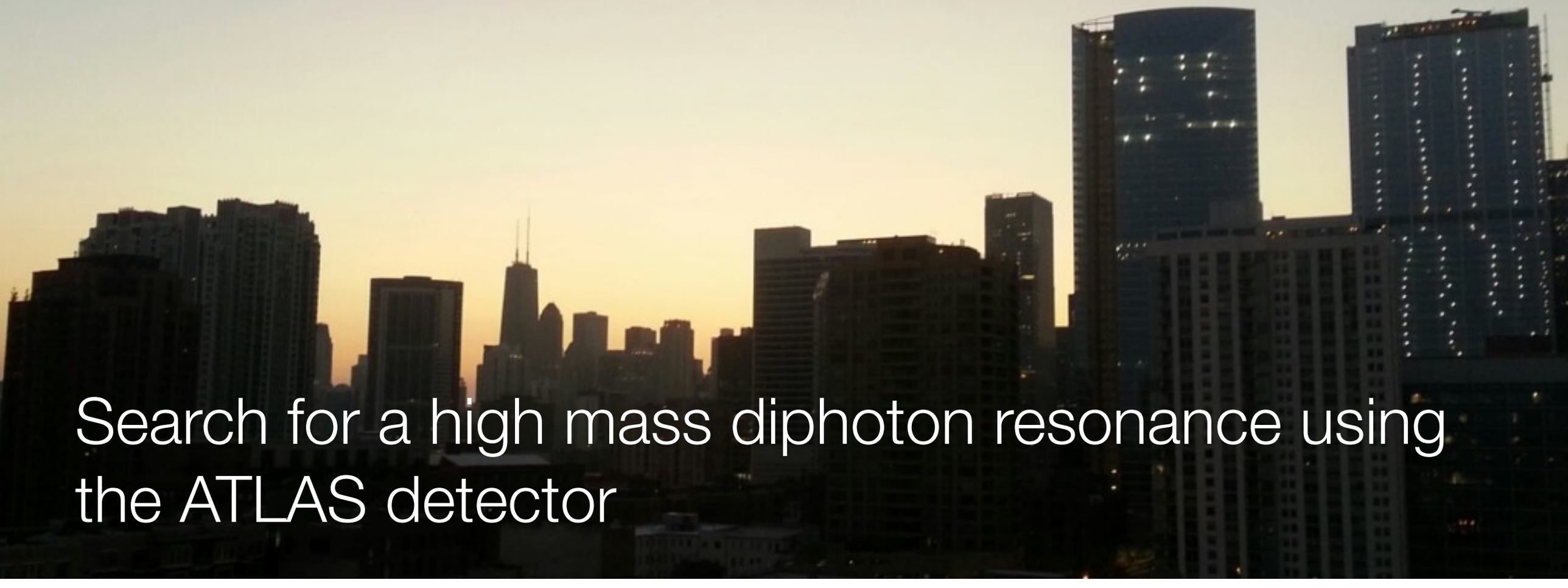


Search for a high mass diphoton resonance using the ATLAS detector

Bruno Lenzi (CERN)
on behalf of the ATLAS collaboration

38th international conference on high energy physics, ICHEP
Chicago, USA

05/08/2016

Introduction

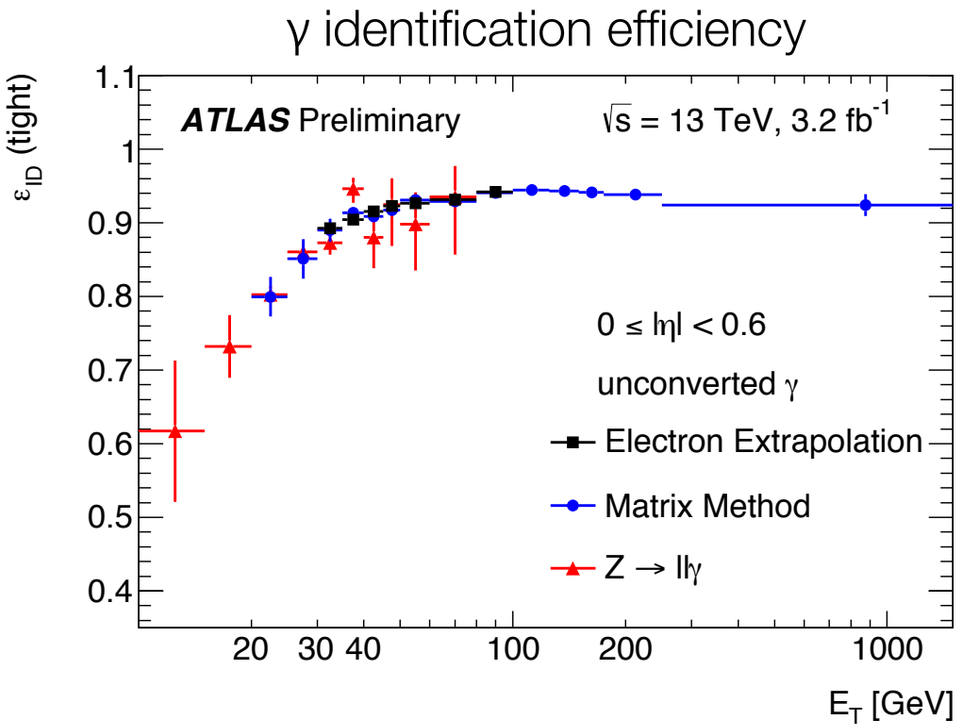
- Resonances decaying to diphotons predicted by several BSM models
- Search for peak (width ~ few %) over smoothly falling background

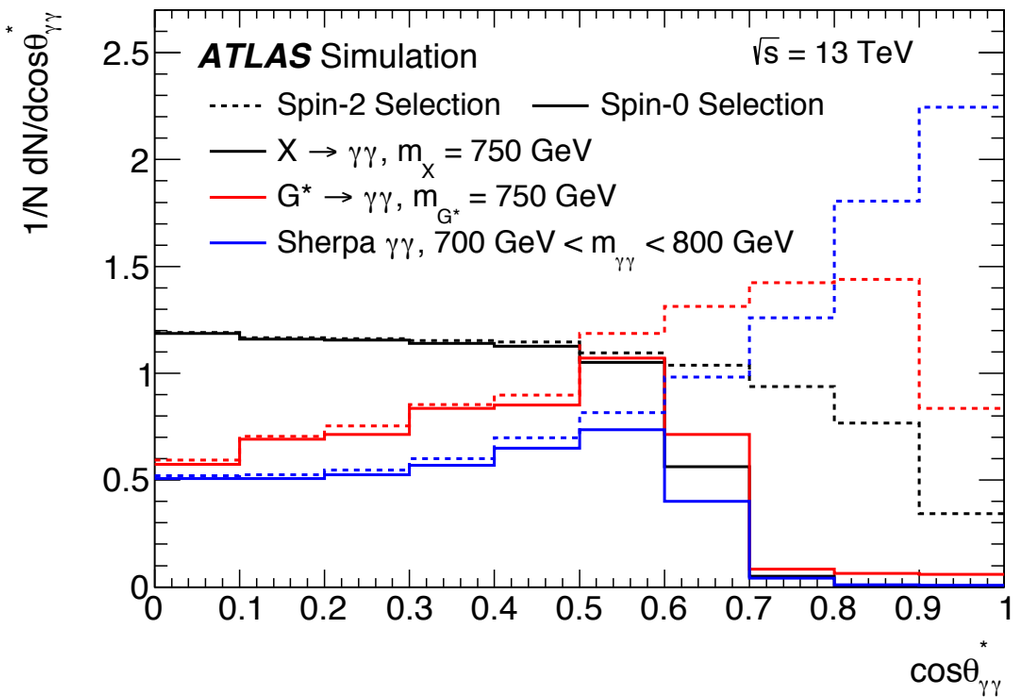
	Benchmark model	Search range (mass / additional parameter)	
Spin-2 (G)	RS graviton	500 GeV - 5 TeV	k/Mpl = 0.01-0.3
Spin-0 (X)	Higgs-like	200 GeV - 2.4 TeV	$\Gamma/m < 10\%$

- Results with 2015 data (3.2 fb^{-1}), submitted to JHEP (arxiv:1606.03833)
- New results with 15.4 fb^{-1} of reprocessed 2015 data + 2016 data presented for the first time (ATLAS-CONF-2016-059)

Overview of the analyses

- Common event selection:
  - Diphoton trigger (35/25 GeV), 99% efficient
  - 2 tightly identified photons, isolated using calorimeter and tracks (> 90% purity)
- Different kinematic selections:
  - Spin-2: $p_T > 55$ GeV
  - Spin-0: $p_{T1} / m_{\gamma\gamma} > 0.4$, $p_{T2} / m_{\gamma\gamma} > 0.3$ → suppresses small scattering angles, i.e. large $\cos\theta_{\gamma\gamma}^*$ (or $\Delta\eta_{\gamma\gamma}$)
    - +20% sensitivity w.r.t. fixed p_T cuts beyond 600 GeV

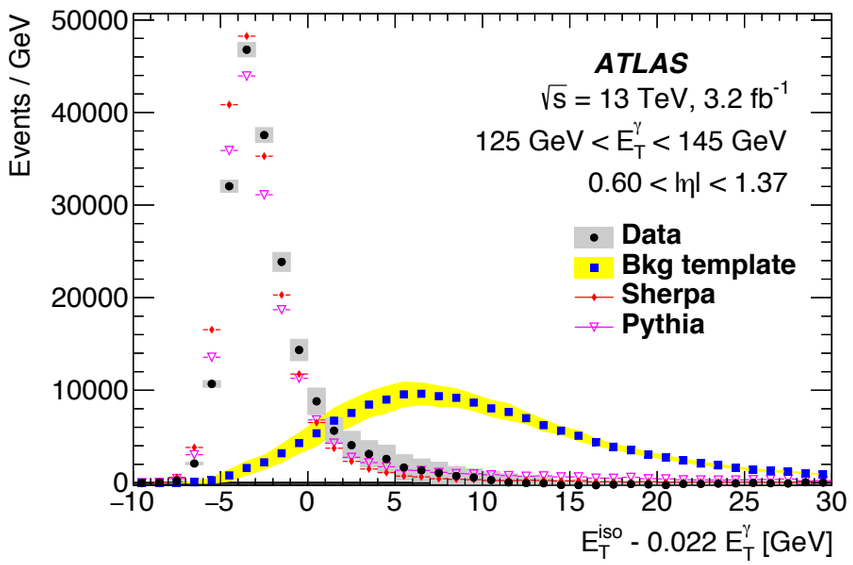




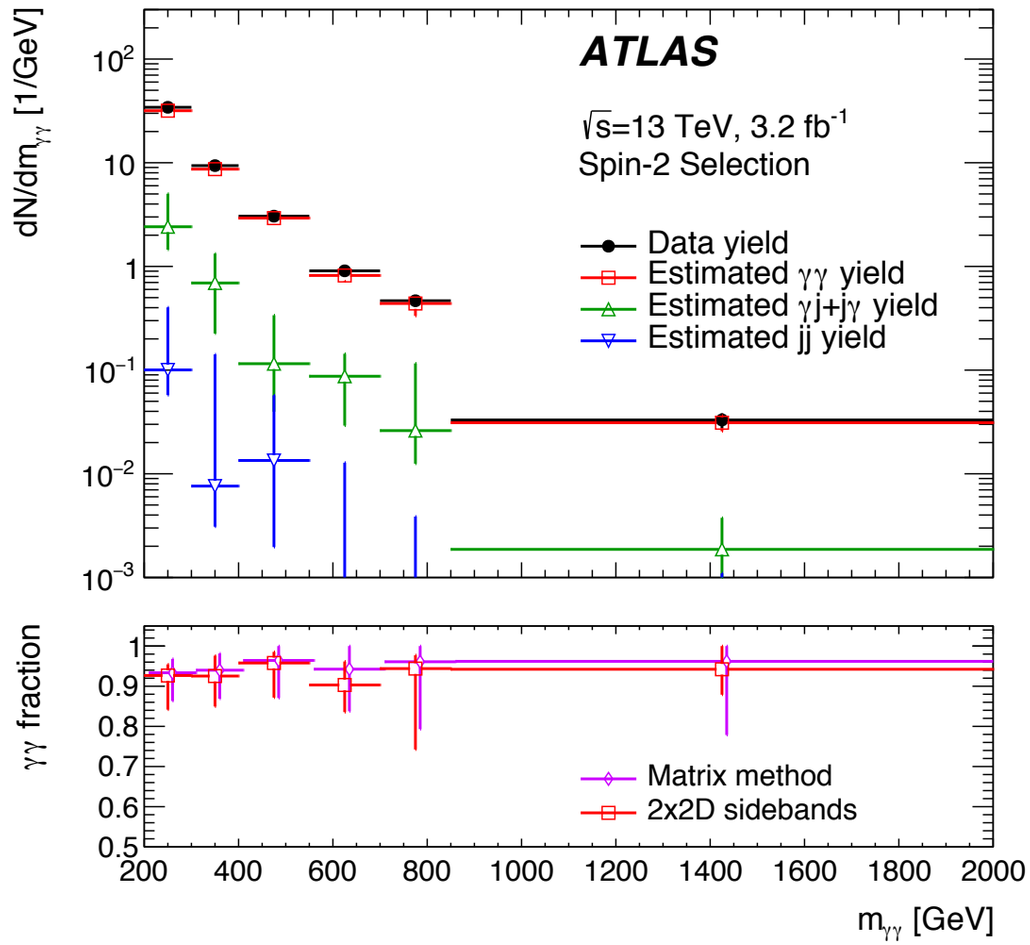
Identification, isolation, sample composition

- Backgrounds from γγ, γ+jet, jet+jet. Processes with $e^{\pm} \rightarrow \gamma$ negligible
- Photon ID and isolation used for background rejection and purity estimate
  - Isolation studied with $Z \rightarrow e^+e^-$, $\ell\ell\gamma$ and γ+X
  - High γγ purity, checked with different methods
    - Spin-2 selection: $(94^{+3}_{-7})\%$
    - Spin-0 selection: $(93^{+3}_{-8})\%$

Isolation E_T distribution

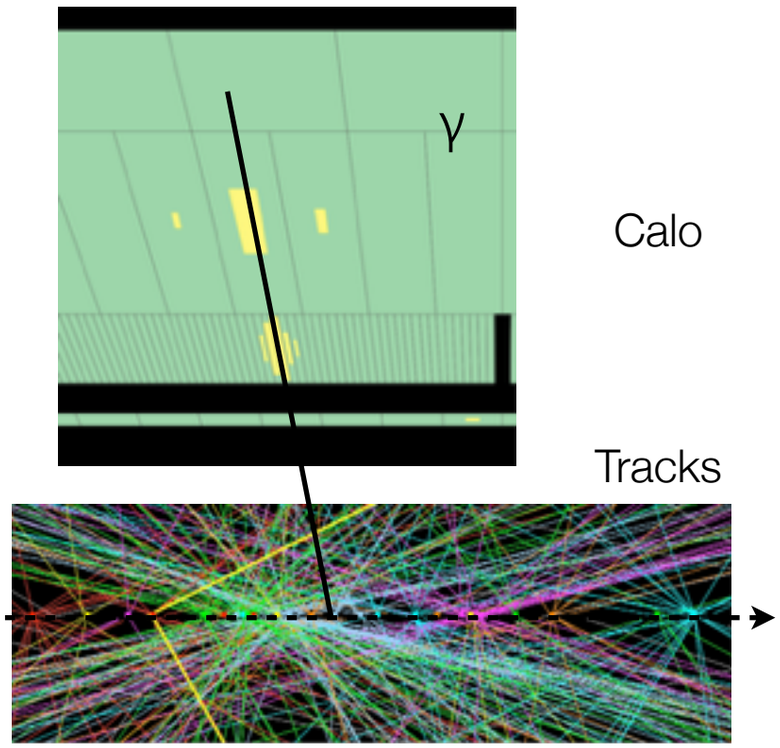


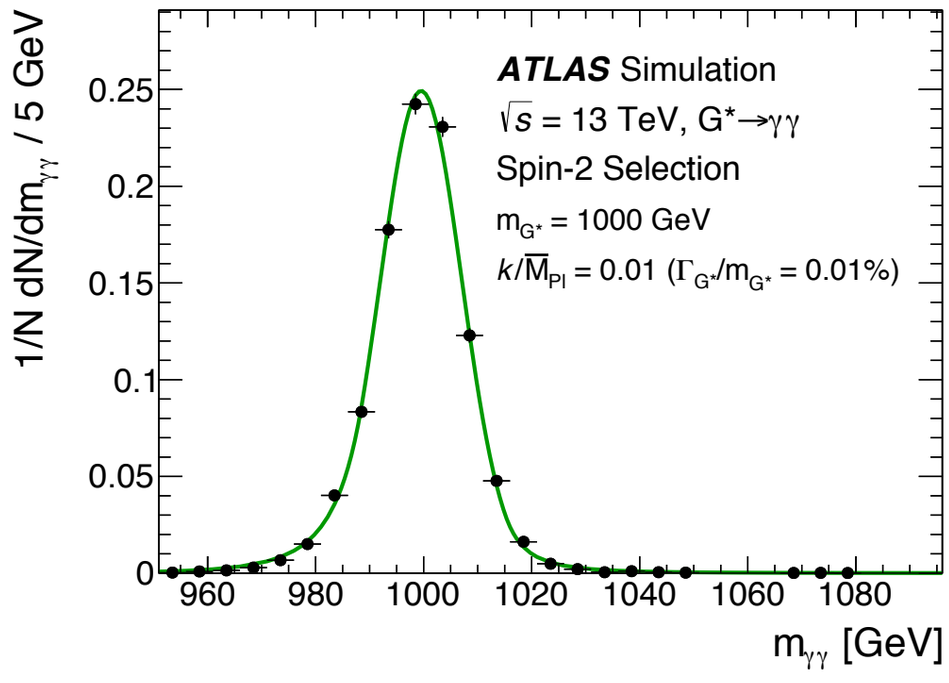
Background composition

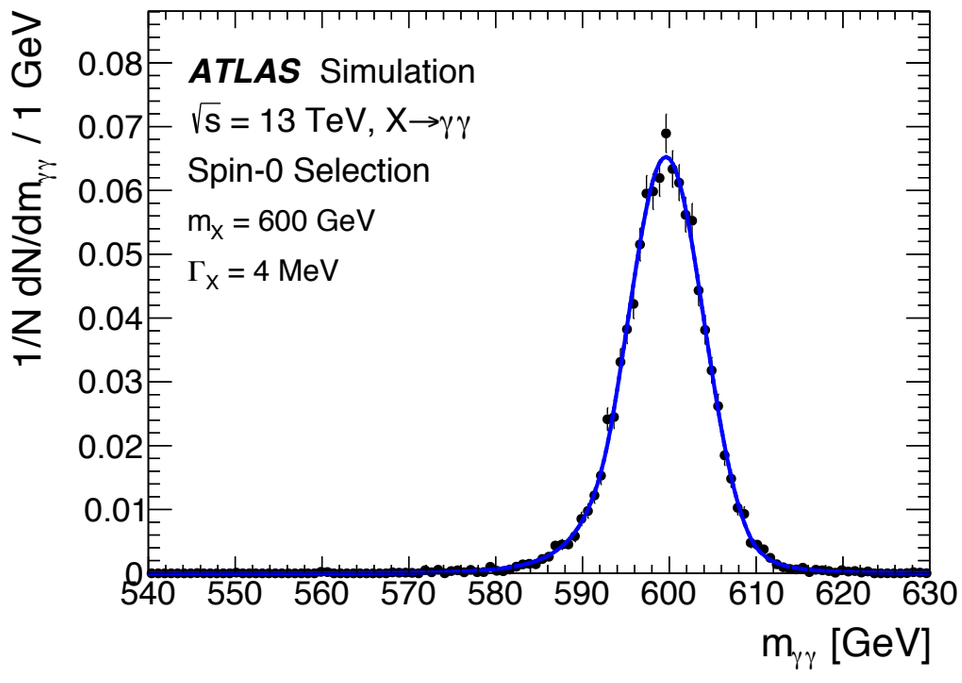


Signal modelling: narrow width

- Invariant mass reconstruction ($m_{\gamma\gamma}$):
  - Energy and impact point from EM calo
  - Vertex from NN developed for H→ γγ
    - Selection efficiency (±0.3 mm): 88%, $m_{\gamma\gamma}$ resolution dominated by E
  - Both quantities studied with $Z \rightarrow e^+e^-$ in data and MC
- Double-sided Crystal-Ball (DSCB) to account for detector effects
  - σ_{CB} = 2.3 GeV @ m = 200 GeV, 15 GeV @ m = 2 TeV
  - Uncertainty on mass resolution: ±17% @ 200 GeV, ±40% @ 2 TeV

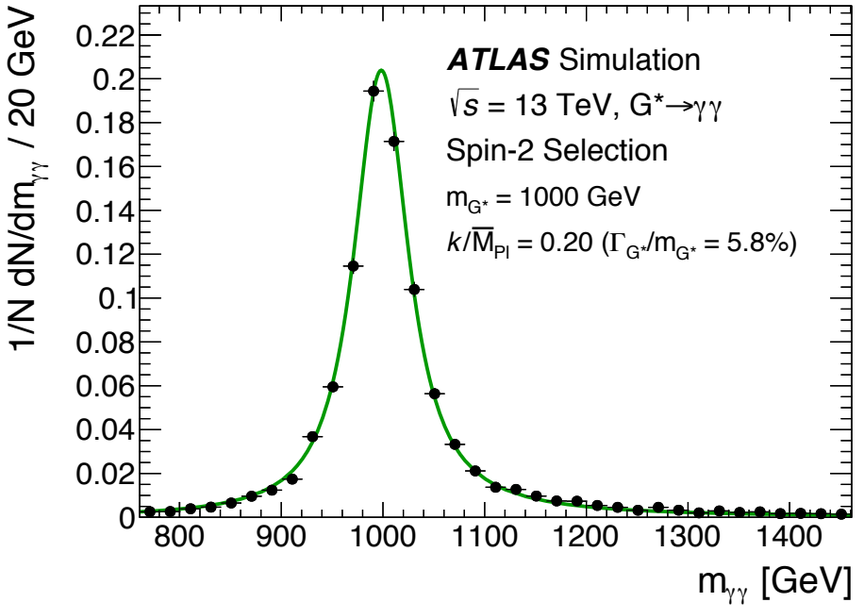


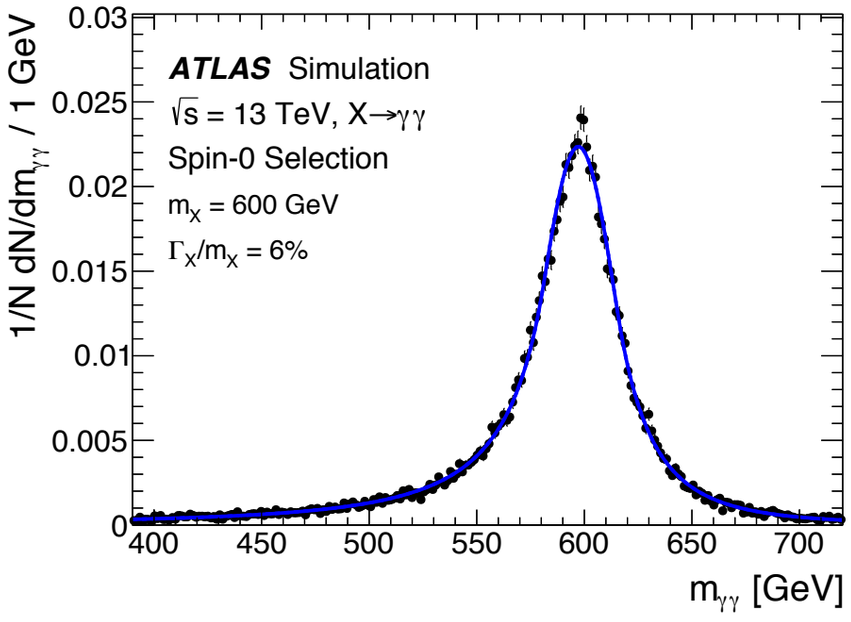




Signal modelling: large width

- $m_{\gamma\gamma}$ parameterised as a function of mass and width ($\Gamma_{G^*} = 1.44 \cdot (k/\overline{M}_{\mathrm{Pl}})^2 m_X$)
  - Theoretical line-shape from:
    - Breit-Wigner
    - Squared matrix element
    - Parton luminosity
  - Spin-2: Pythia samples
  - Spin-0: Powheg-Box
    - Madgraph/aMC@NLO using EFT approach for new results
  - Convoluted with DSCB





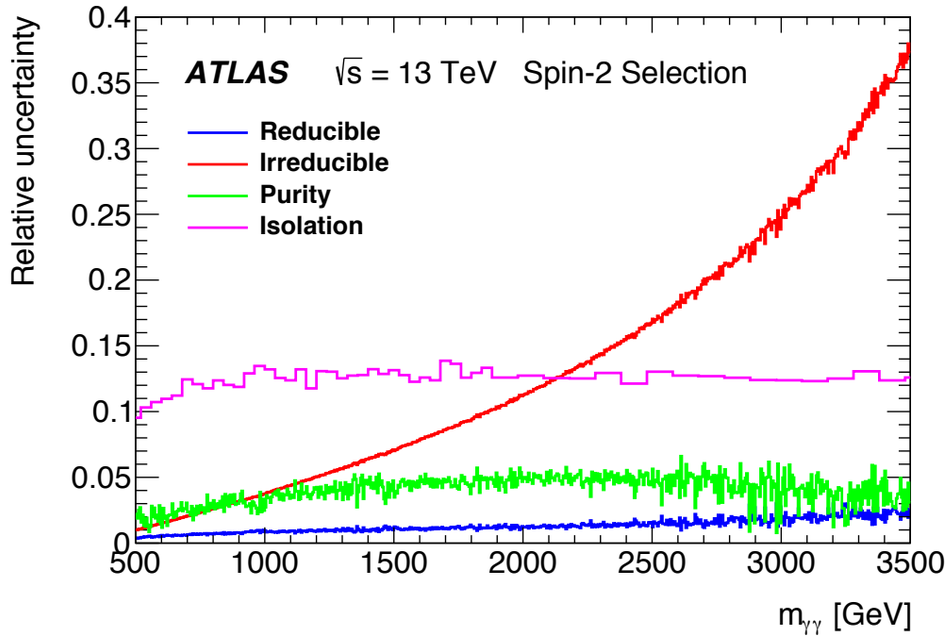
Background modelling

- Spin-2: MC template (extend to multi-TeV range)
  - γγ shape from DIPHOX NLO parton level calculation, re-weight Sherpa full-sim
    - Uncertainties from isolation (±7%), scale variations (±5%), PDF (2-35%)
  - γ+jet, jet+jet shape from control regions, normalisation from purity estimate
  - Overall normalisation from data
- Spin-0: fit to data

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

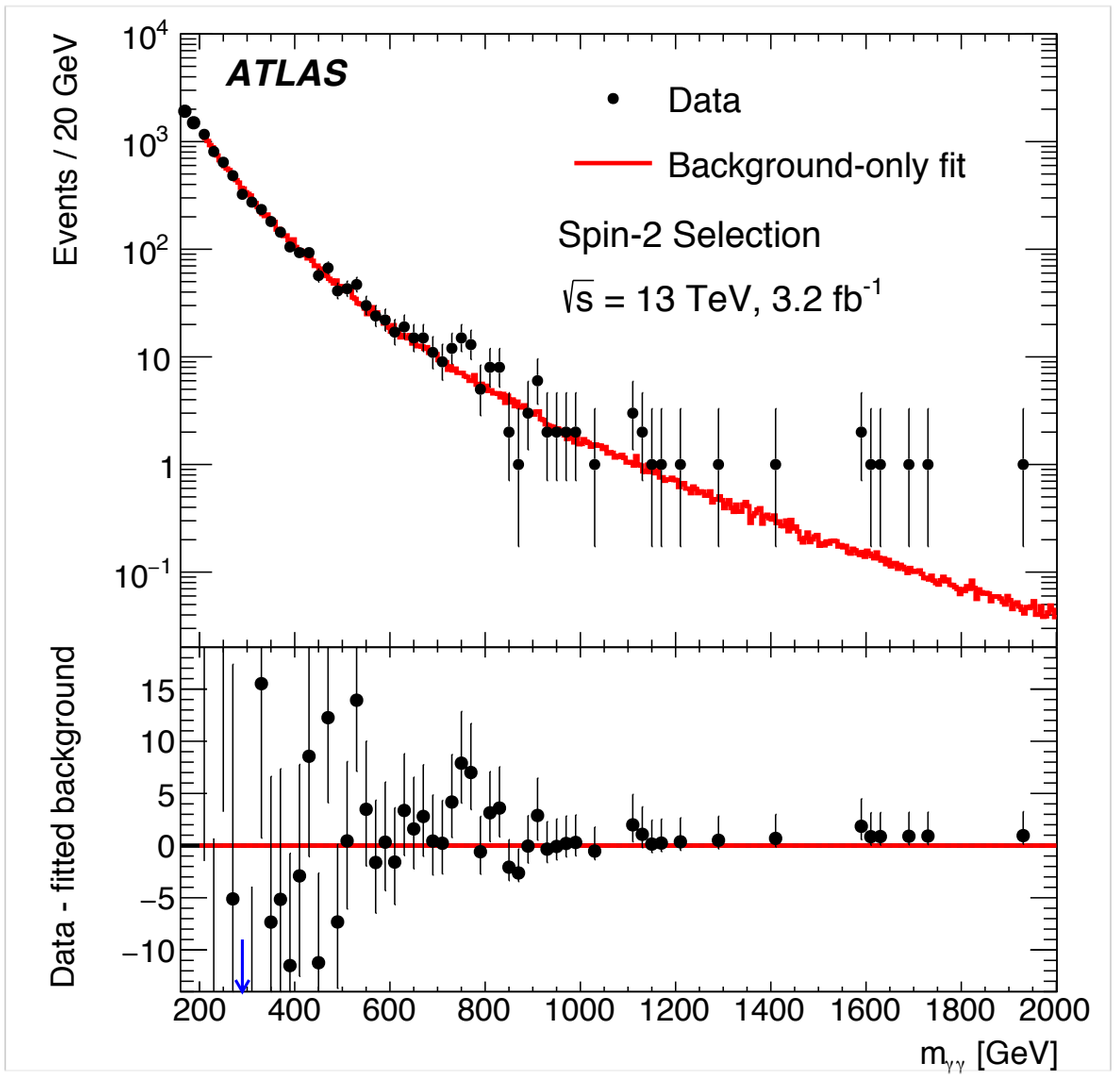
$$f_{(k)}(x; b, \{a_k\}) = N(1 - x^{1/3})^b x^{\sum_{j=0}^{k} a_j (\log x)^j}$$

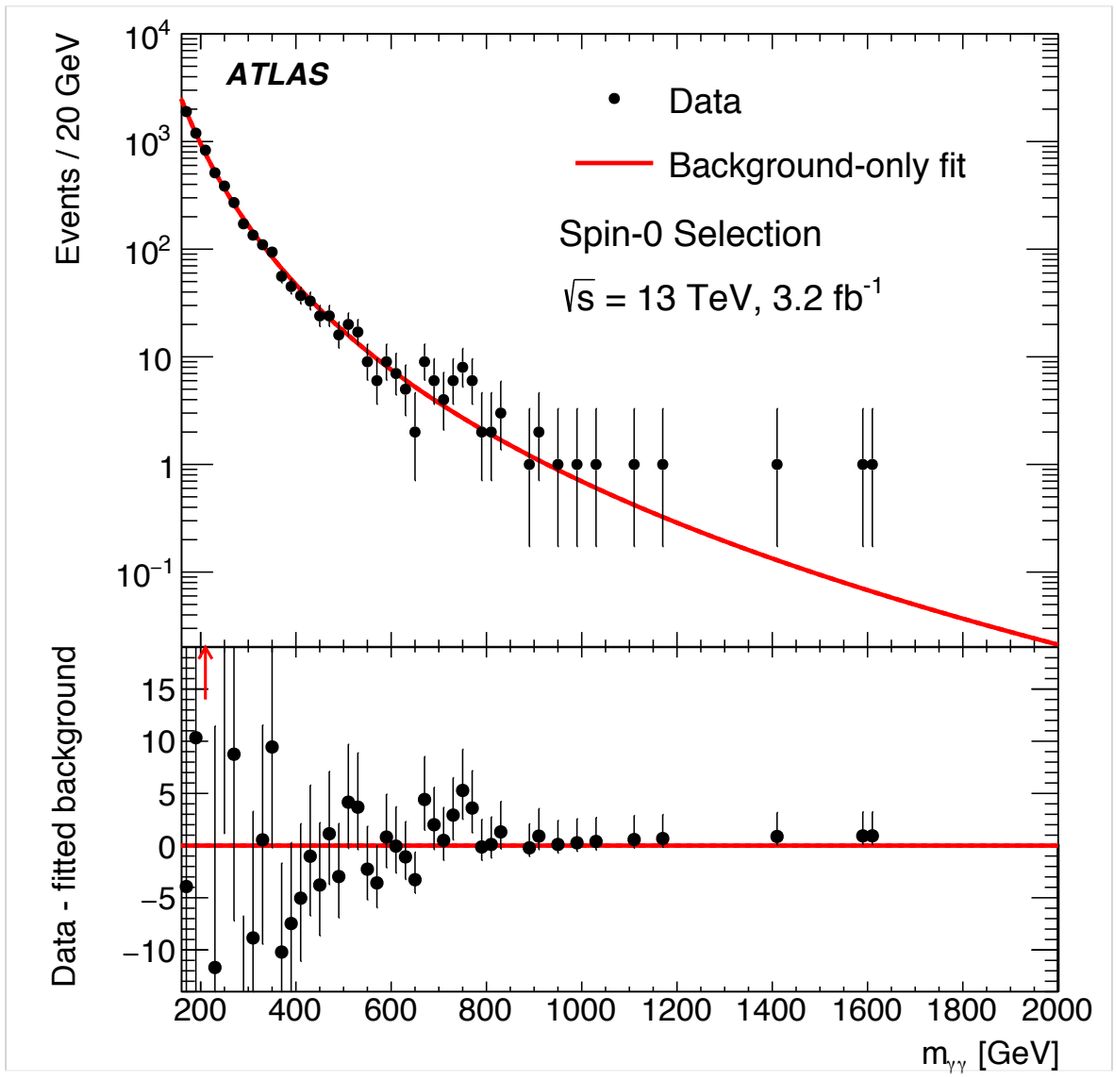
Uncertainties on the bkg model



- Validation of functional form and uncertainty from simulation + variations above
  - Systematics smaller than 30% of statistical error and decreasing with mass

Results from 2015 data (arxiv:1606.03833)

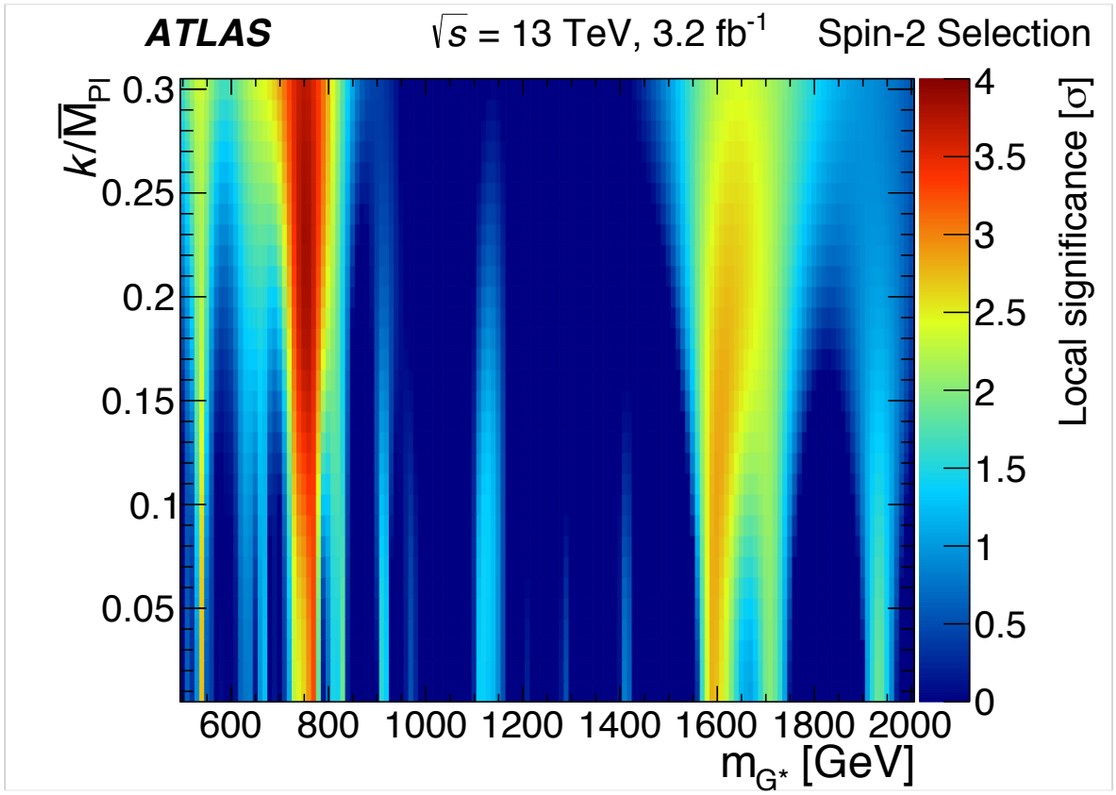


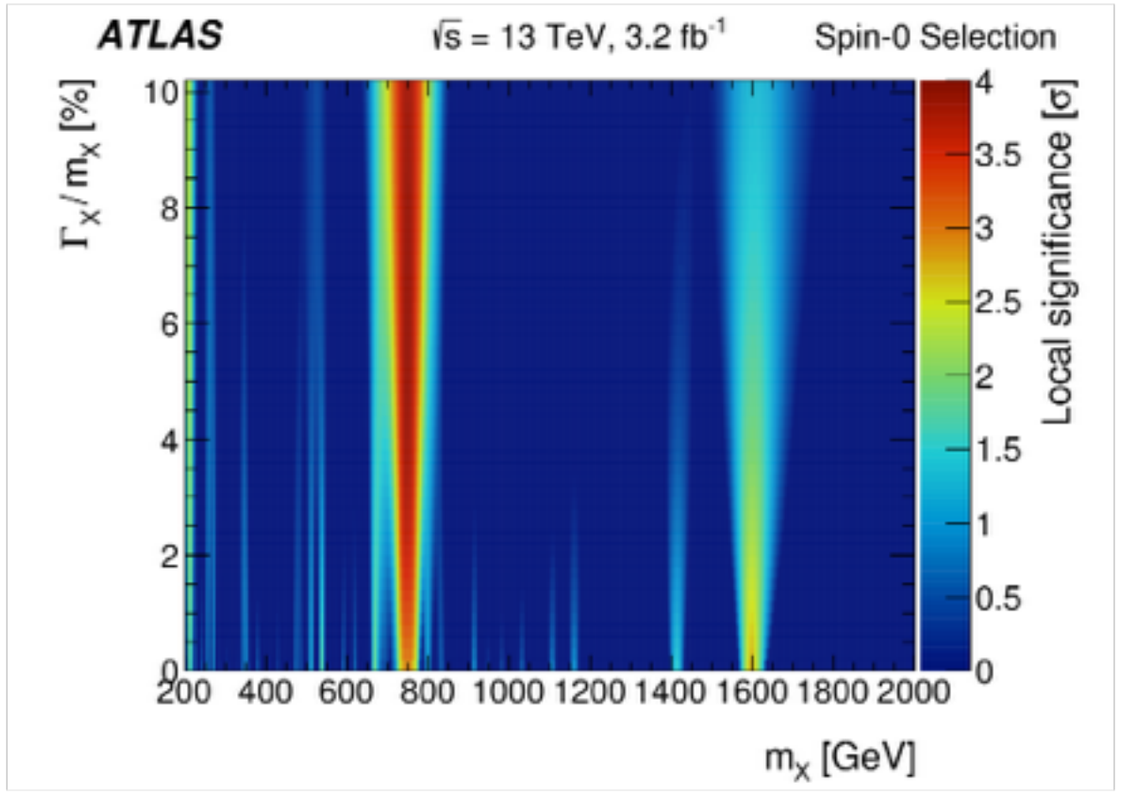


Broad excesses around $m_{\gamma\gamma}$ = 750 GeV

Results from 2015 data (arxiv:1606.03833)

Significances in the mass vs. k/Mpl (width) plane

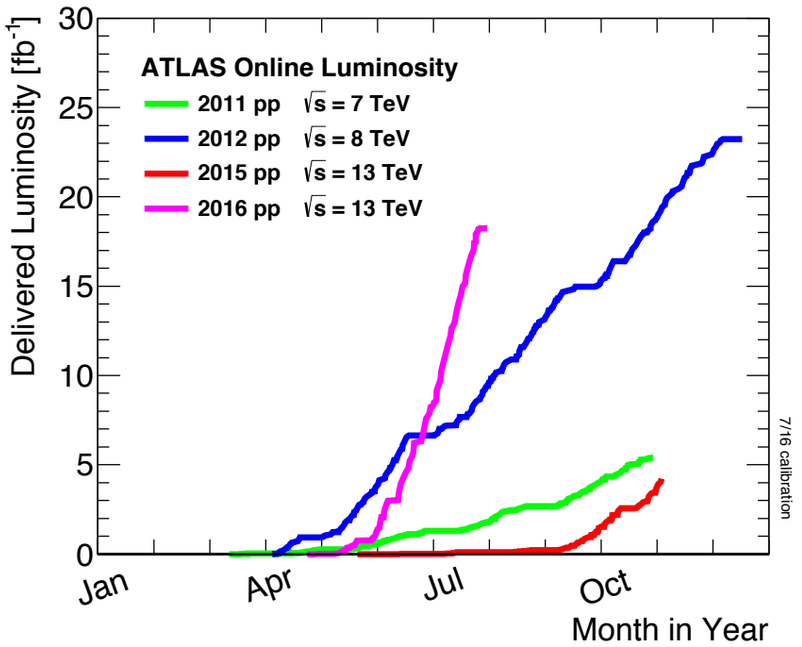




Broad excesses around $m_{\gamma\gamma}$ = 750 GeV
3.8-3.9σ local significance
(2.1σ global, i.e. to find such excess anywhere in the search region)

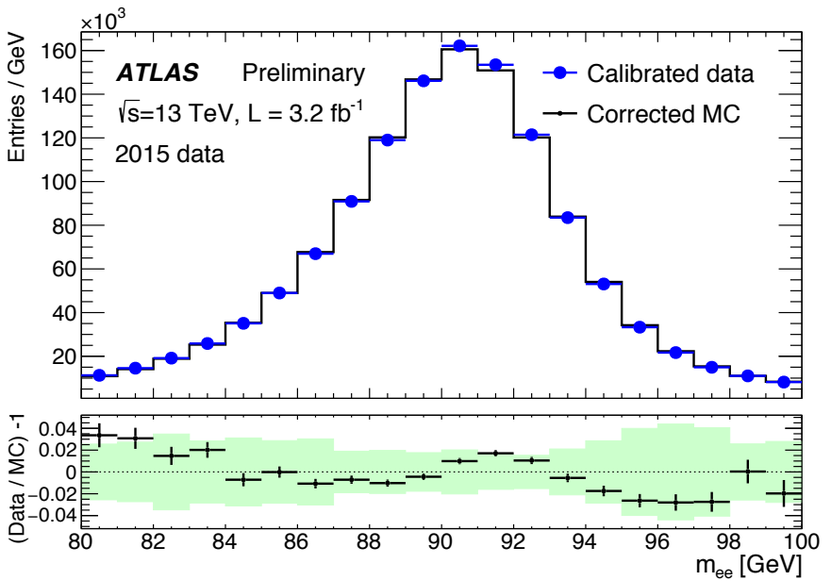
Since then…

- Impressive performance of the LHC
  - Peak luminosity beyond design
  - ATLAS data-taking efficiency > 90%
  - 12.2 fb^{-1} of 2016 data analysed
    - Data taken until July 16 (< 3 weeks ago!)

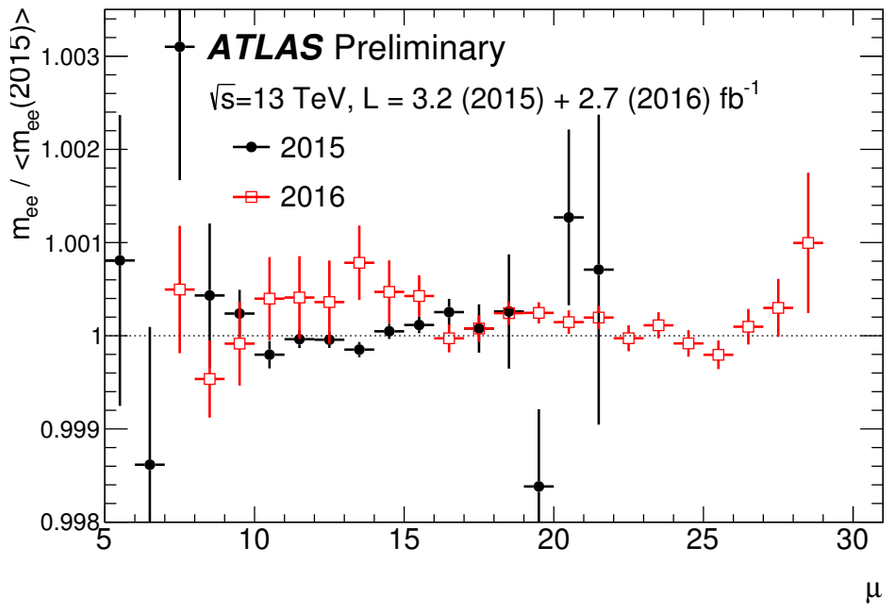


- Improved reconstruction and energy calibration, based on experience with 13 TeV data

Inv. mass (m_{ee}) from Z decays



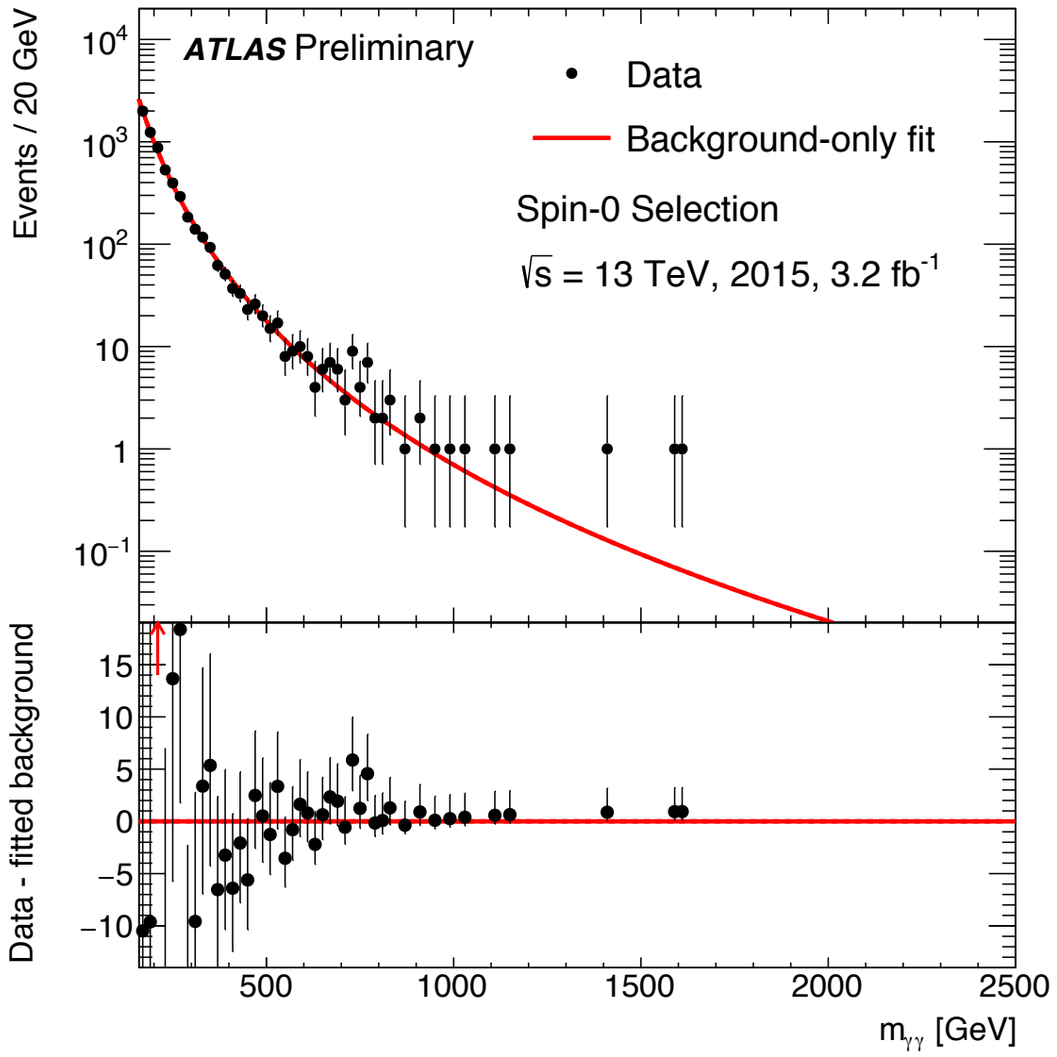
Stability of m_{ee} vs. pileup



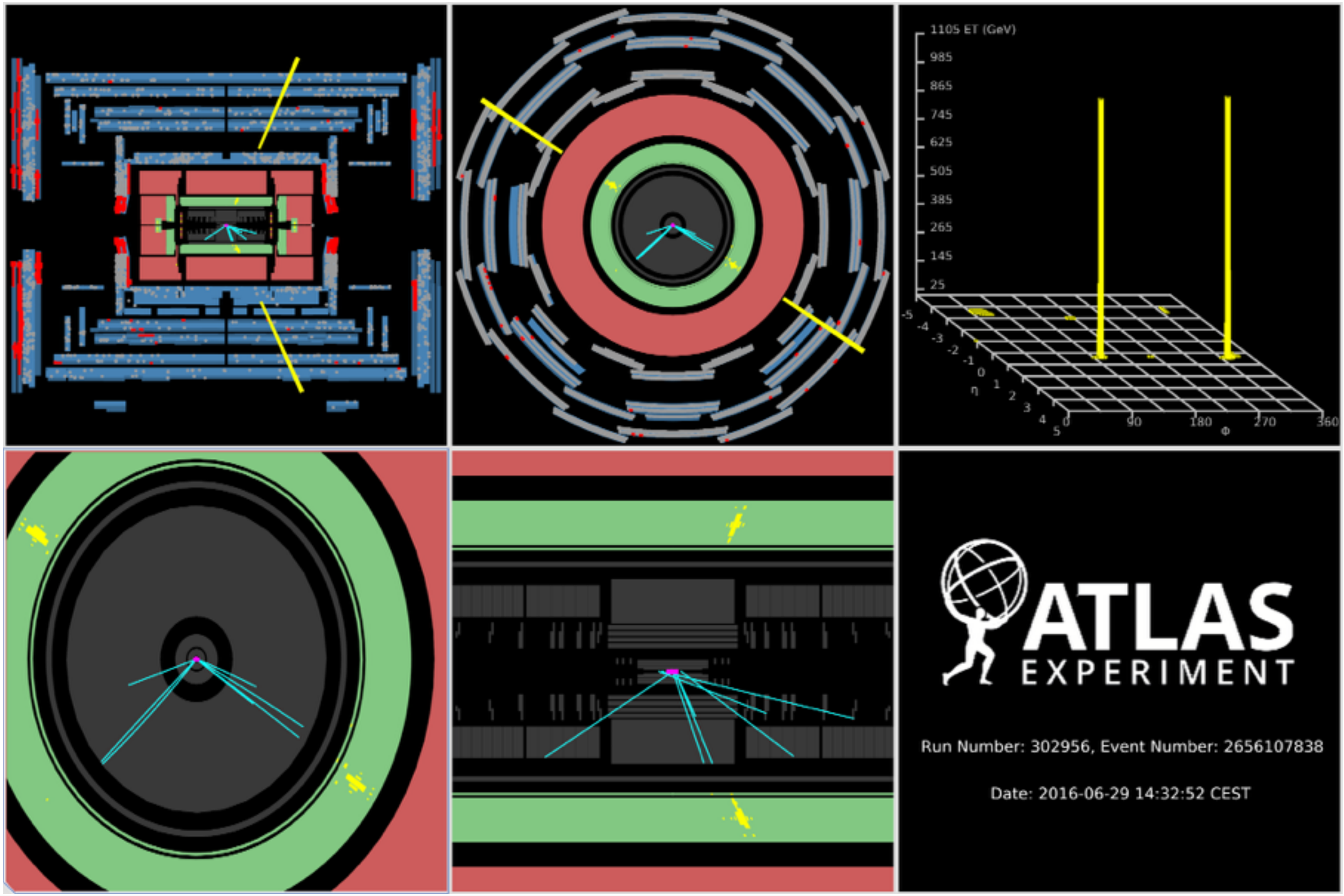
The "new" 2015 data: spin-0 analysis

- 2015 reprocessed and reanalysed
  - Excess @ 750 GeV → 730 GeV
  - 3.9σ → 3.4σ local significance
    - Basically 2 events affected by new reconstruction and calibration

With the higher pileup conditions of the 2016 data, more work is needed to complete the analysis in the extended acceptance of the spin-2 selection

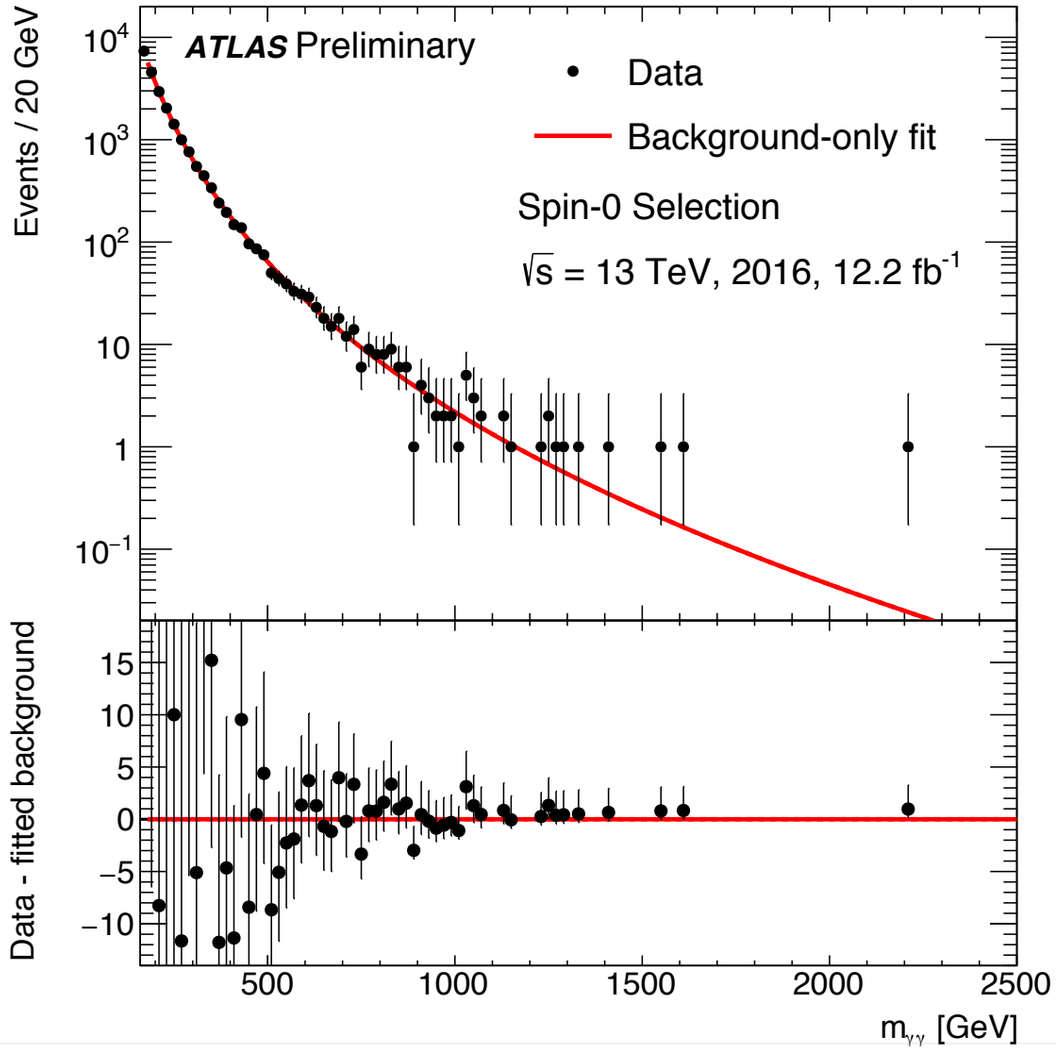


A diphoton candidate with $m_{\gamma\gamma}$ = 2.2 TeV

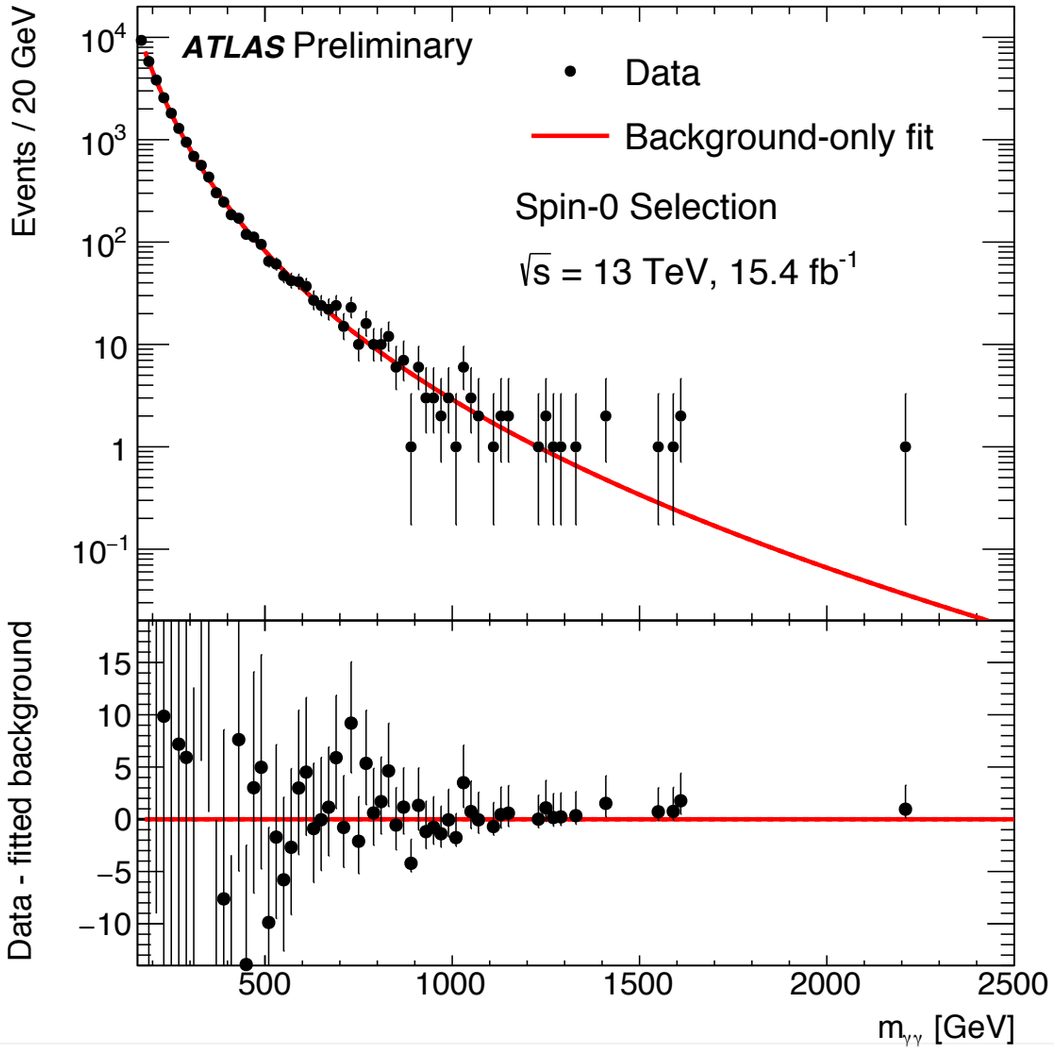


Spectra for 2016-only and 2015 + 2016 data

2016-only



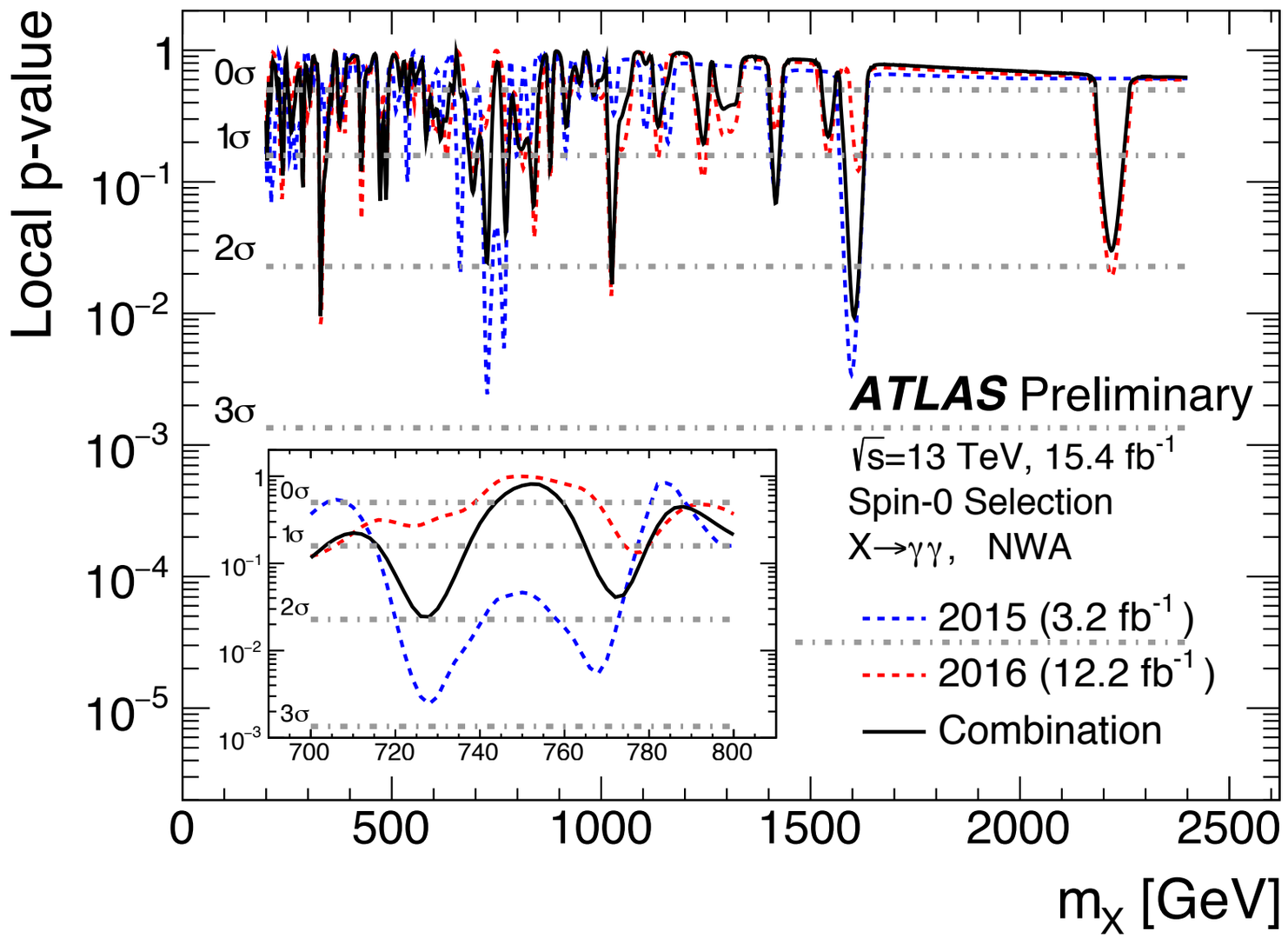
2015 + 2016



No significant excess in 2016 data, compatibility between 2015 and 2016 datasets for signal cross-section @ 730 GeV: 2.7σ

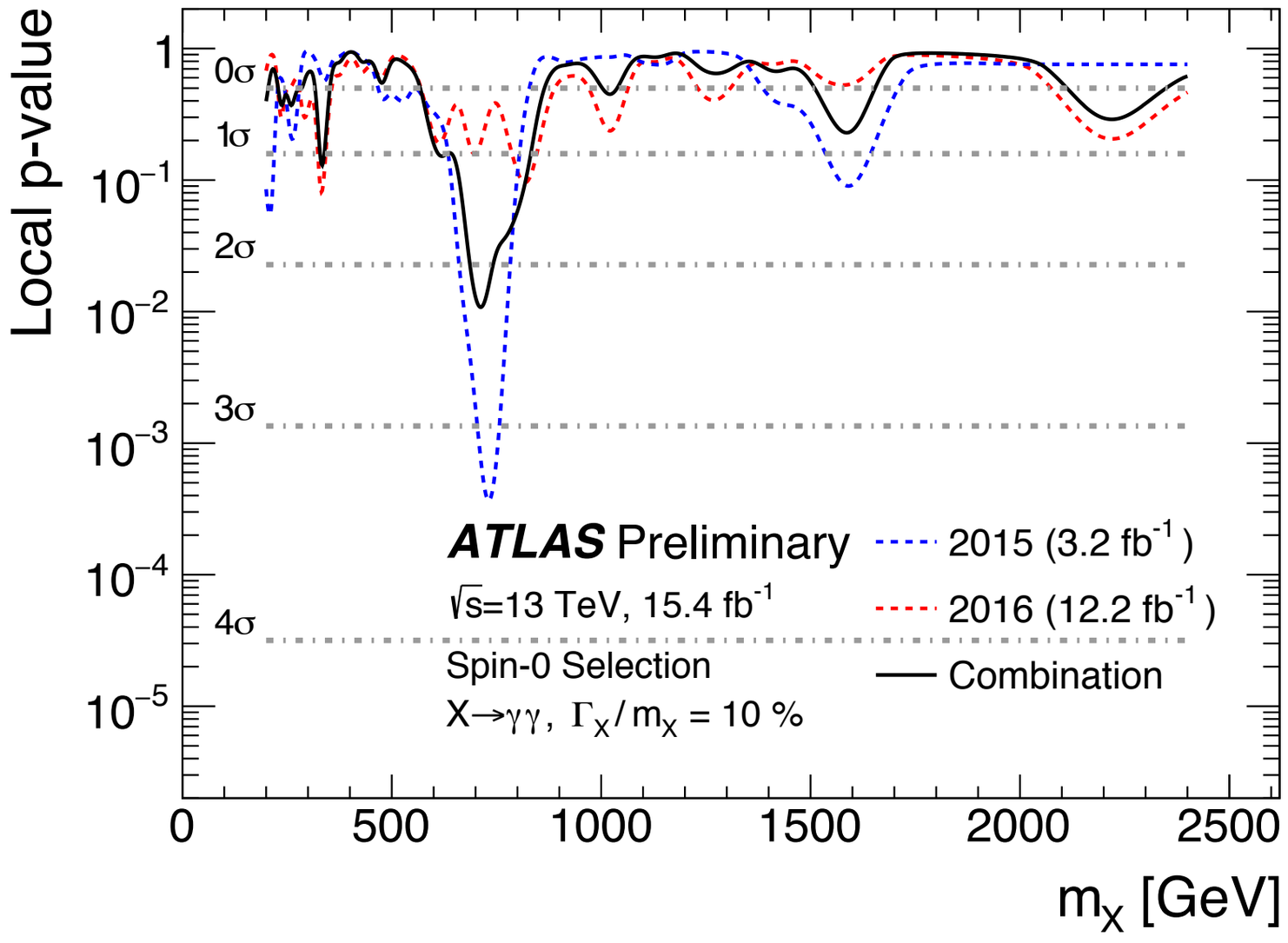
New results: significances for narrow-width signal

Largest significance for combined dataset @ 1.6 TeV (2.4σ local)



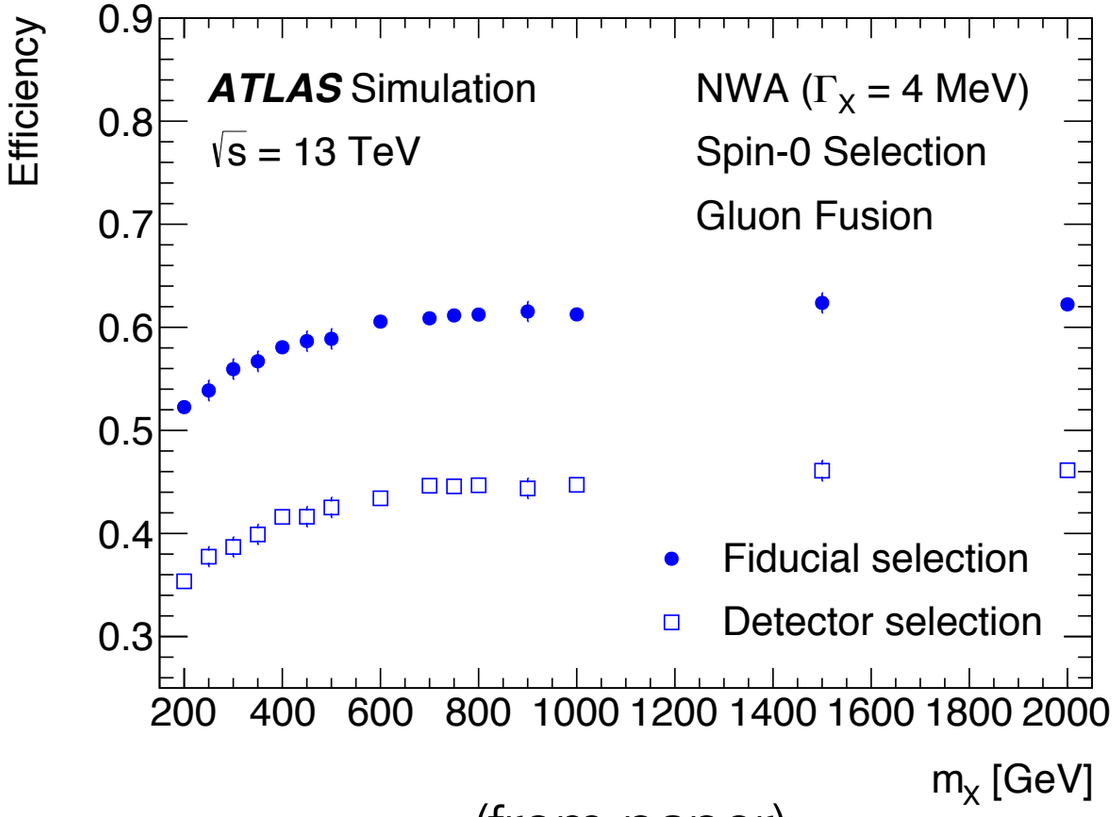
New results: significances for wide signal (10%)

Around 700-800 GeV: 2.3σ local significance @ 710 GeV for combined dataset

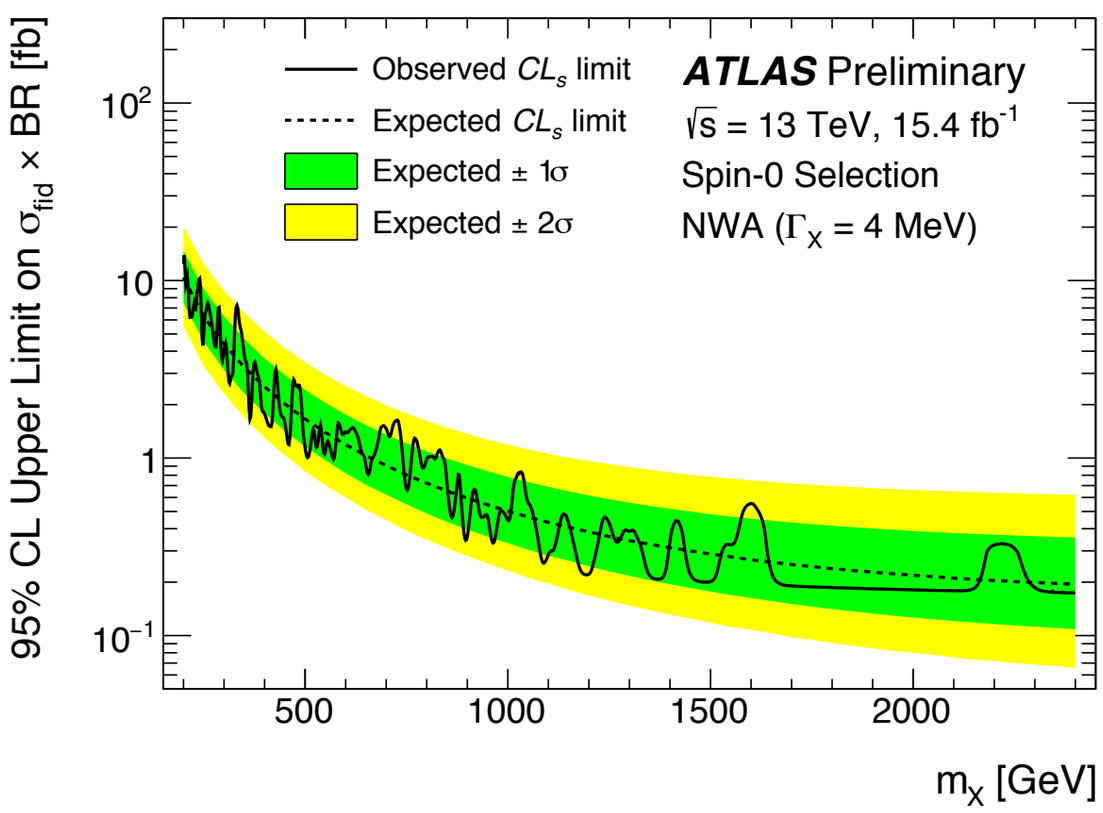


Signal efficiency and limits on cross sections

- Limit setting based on fiducial cross-section to minimise model dependence
  - Fiducial volume: ~same kinematic selection, isolation at particle level
  - Limits extended from 2 to 2.4 TeV with 2016 data

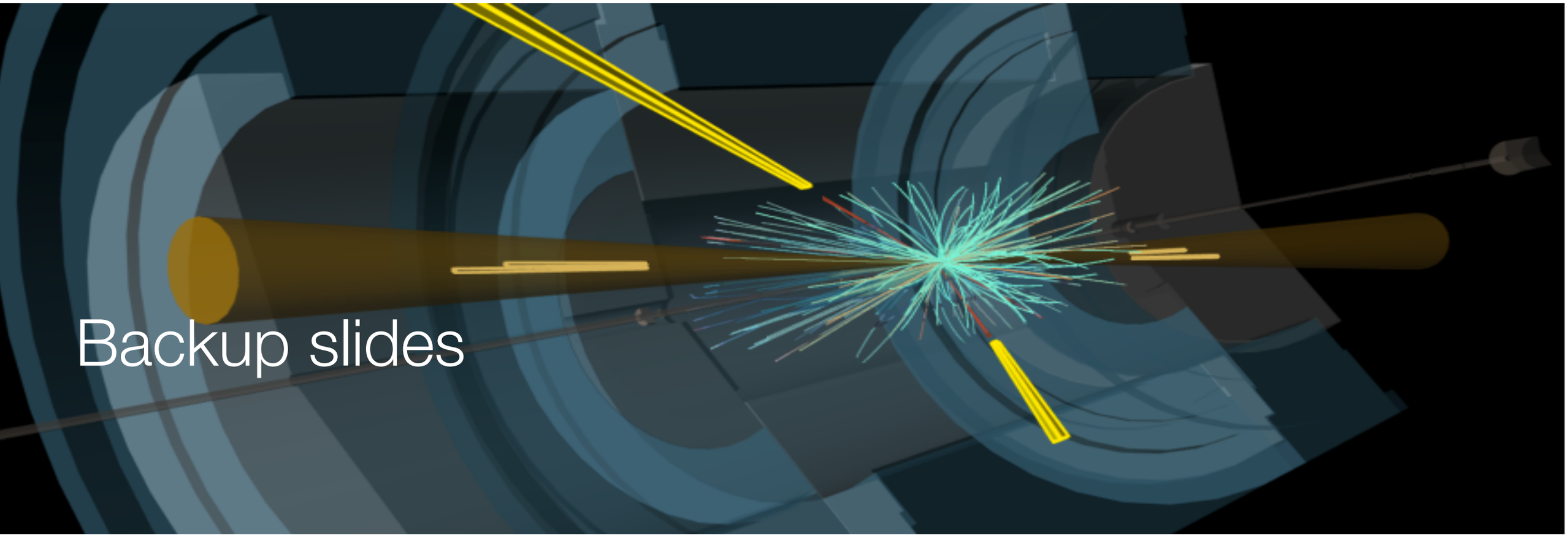


(from paper)



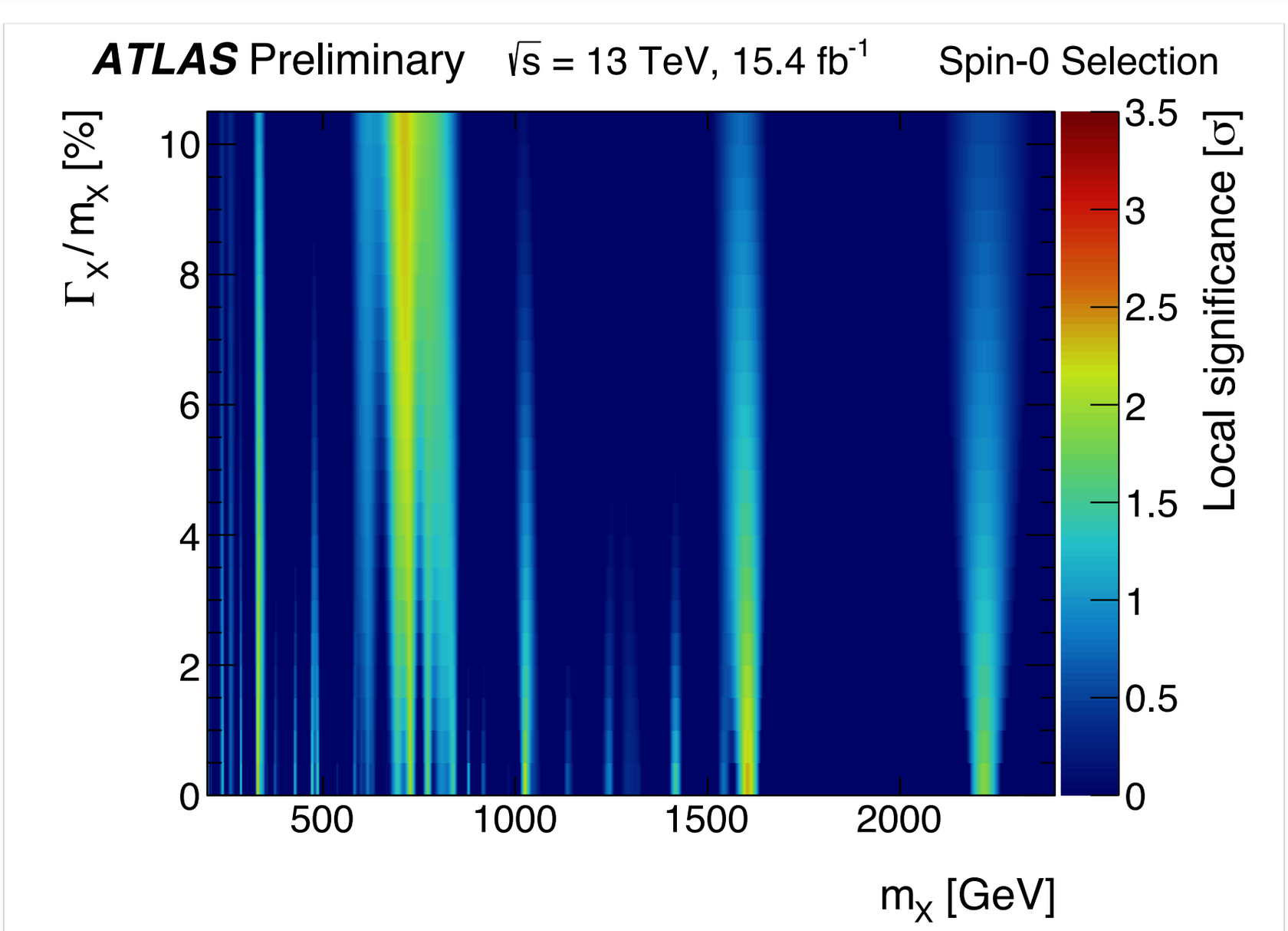
Summary

- Search for new resonances in diphoton final state (2015 data)
  - Spin-2: Randall-Sundrum graviton
  - Spin-0: Higgs-like
- Spin-0 analysis updated with combined 2015 + 2016 dataset
  - Data consistent with background-only hypothesis over the full mass range
    - No excess with a global significance above 1σ
  - Broad excess around 750 GeV in 2015 data not seen in 2016 data for spin-0 analysis
- More work needed to complete the analysis in the extended acceptance of the spin-2 selection



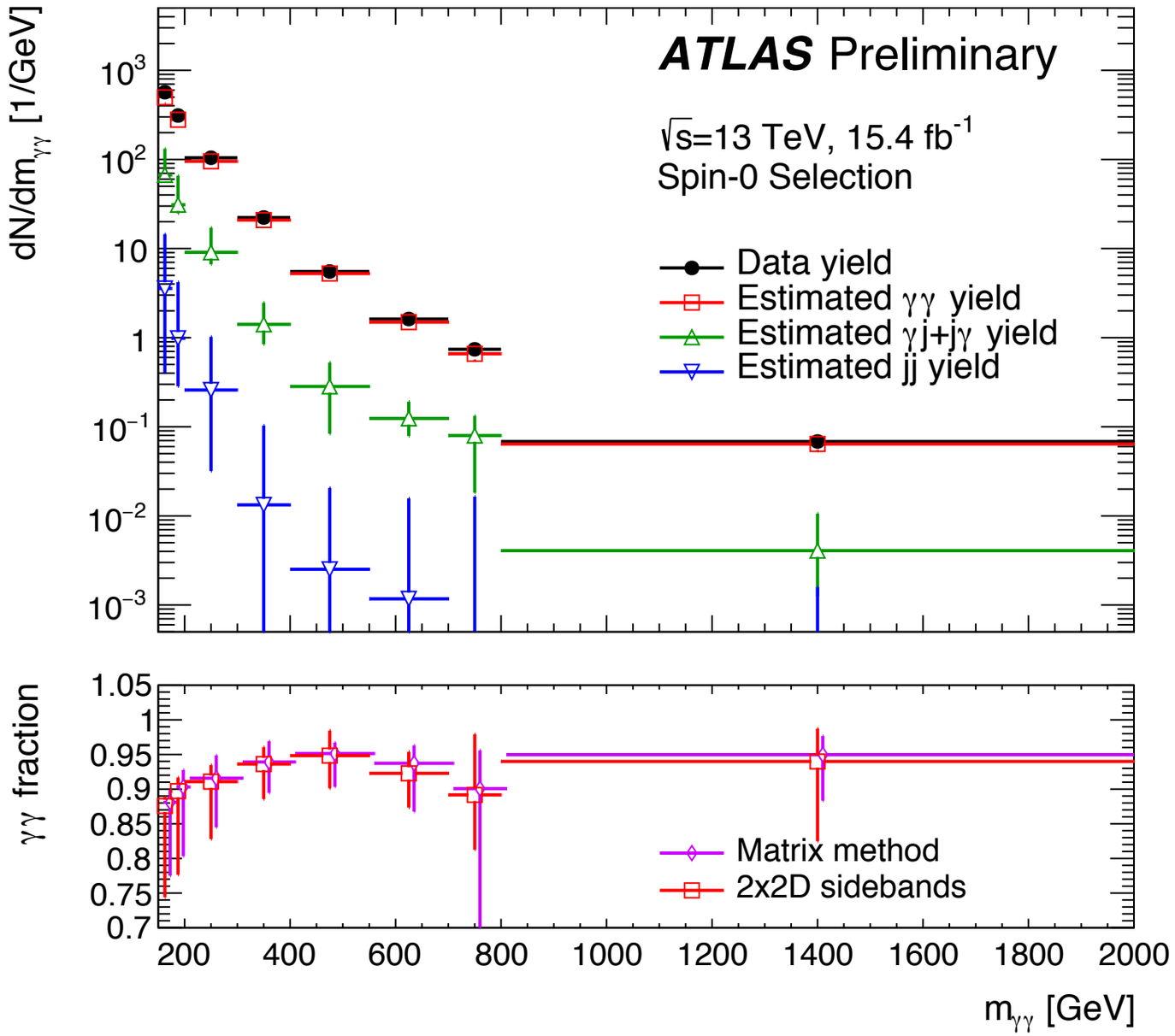
Backup slides

New results: significances vs mass and width

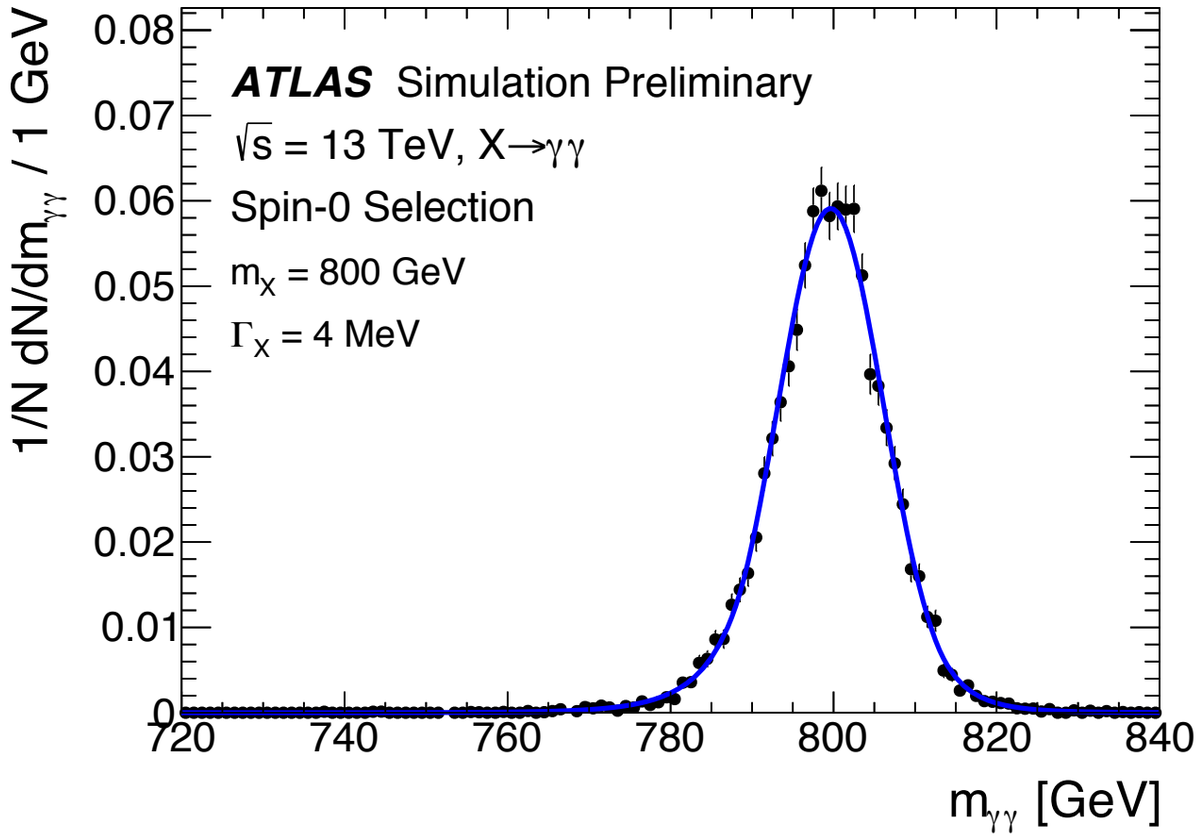


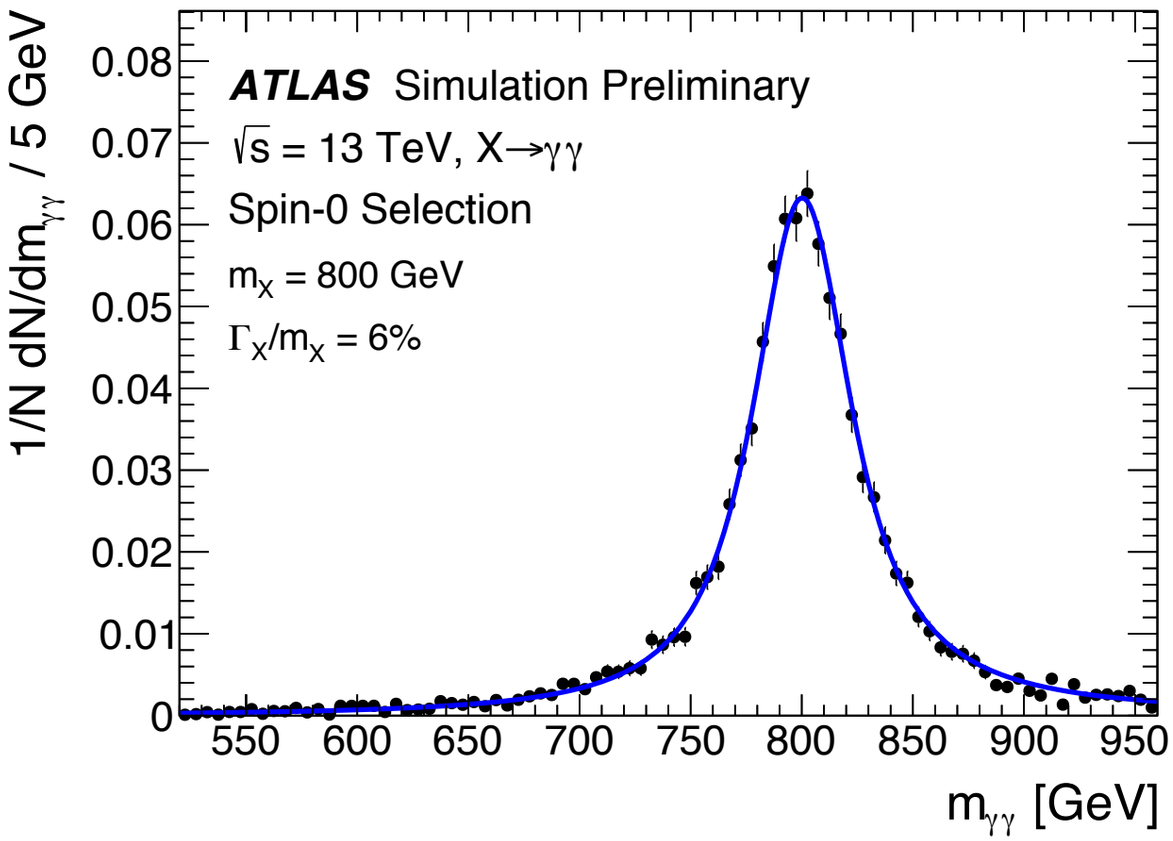
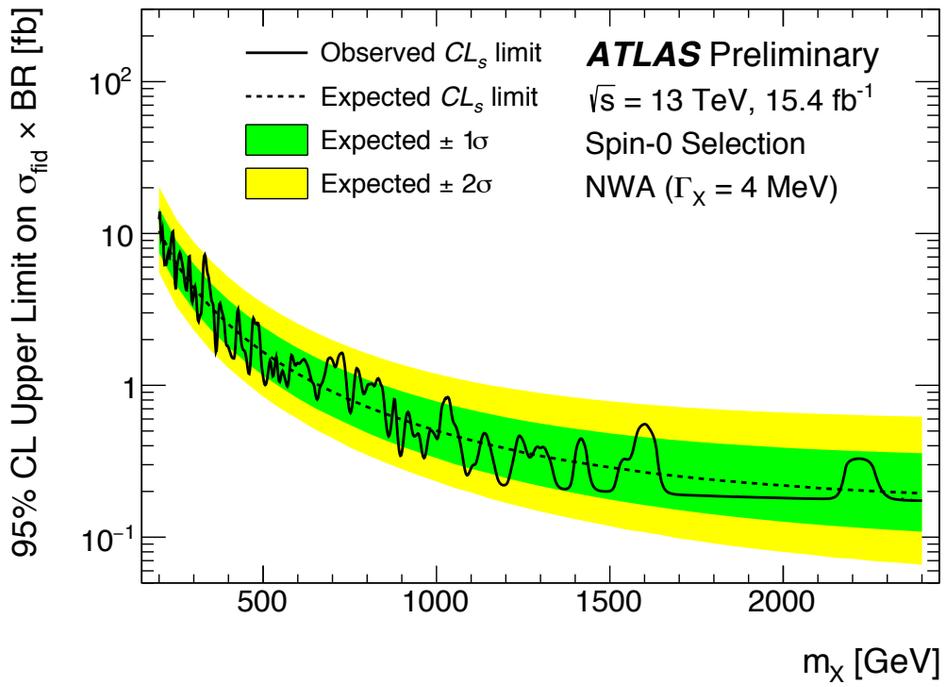
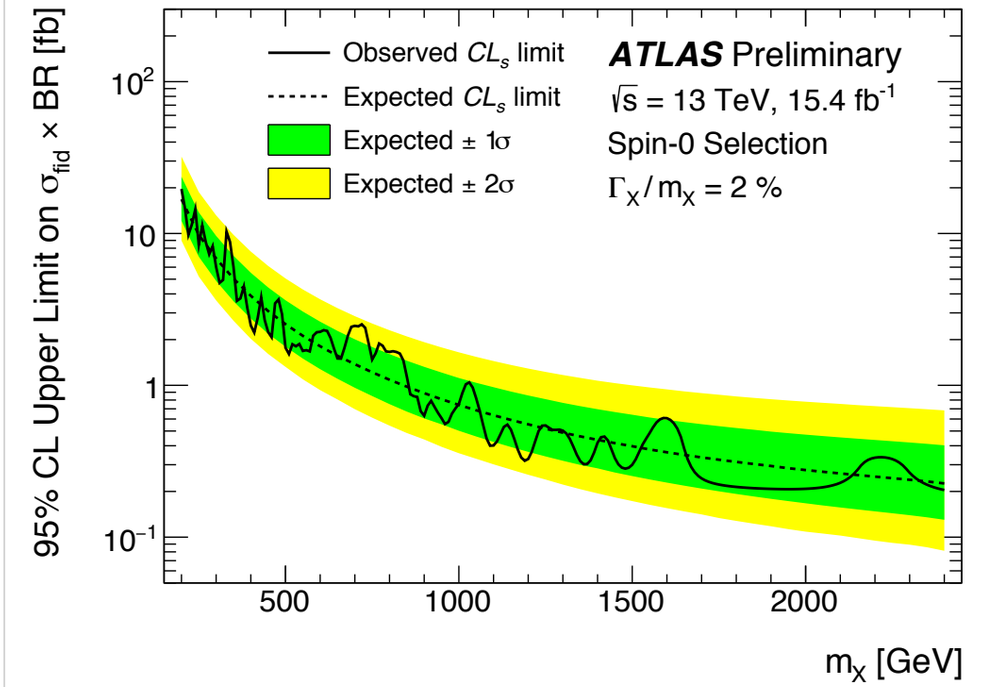
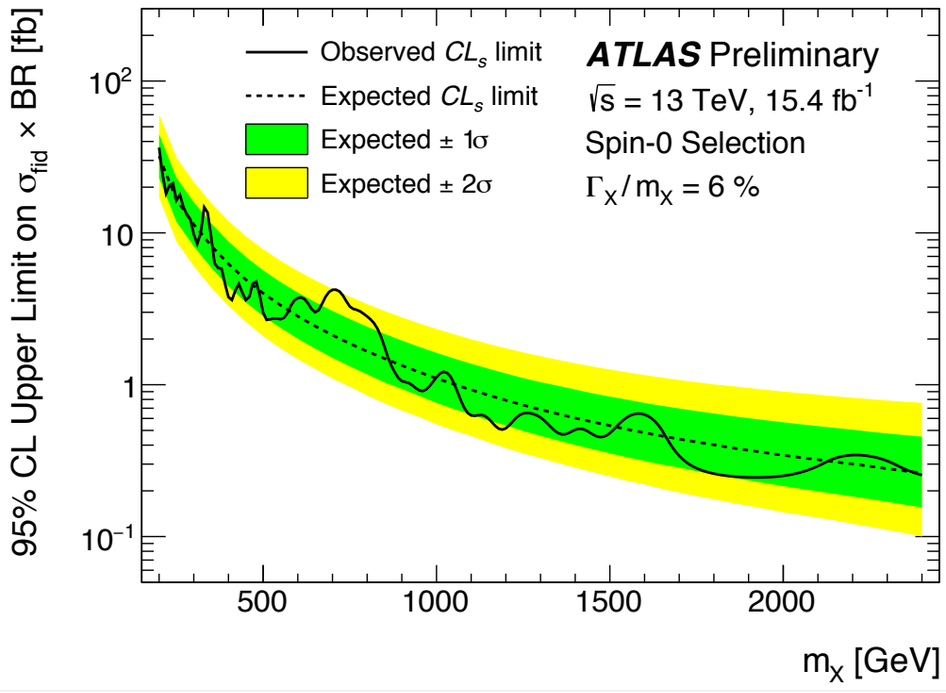
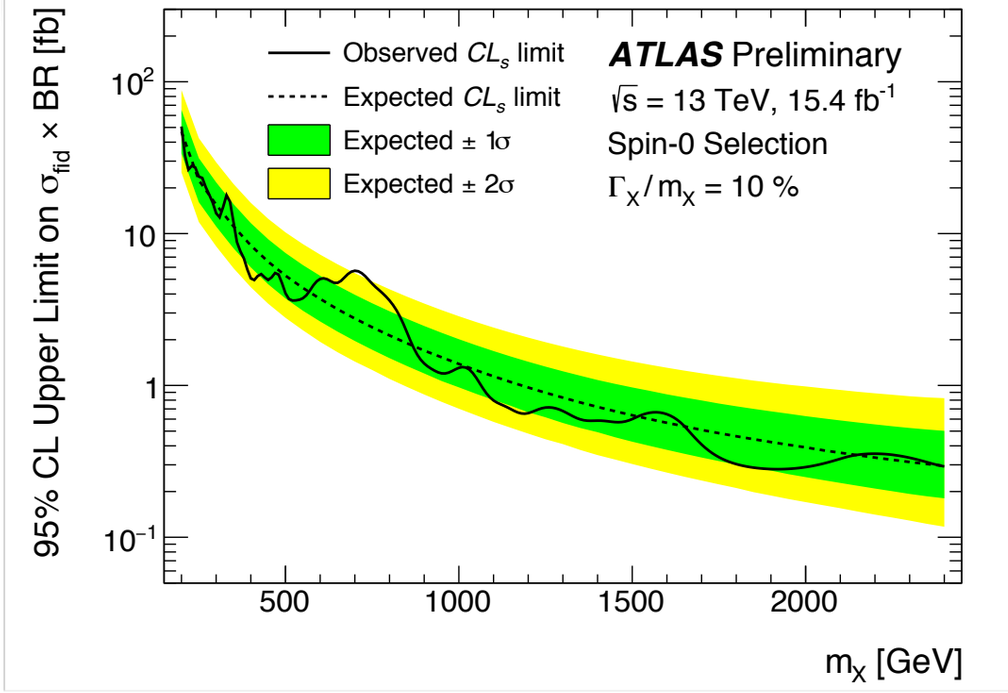
New results: purity

- Purity of γγ selection: (90 +3/-10) %



New results: signal modelling





New results: limits for spin-0