Search for new phenomena in high-mass final states with a photon and a jet from *pp* collisions at 13 TeV with the ATLAS detector

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on behalf of the ATLAS collaboration

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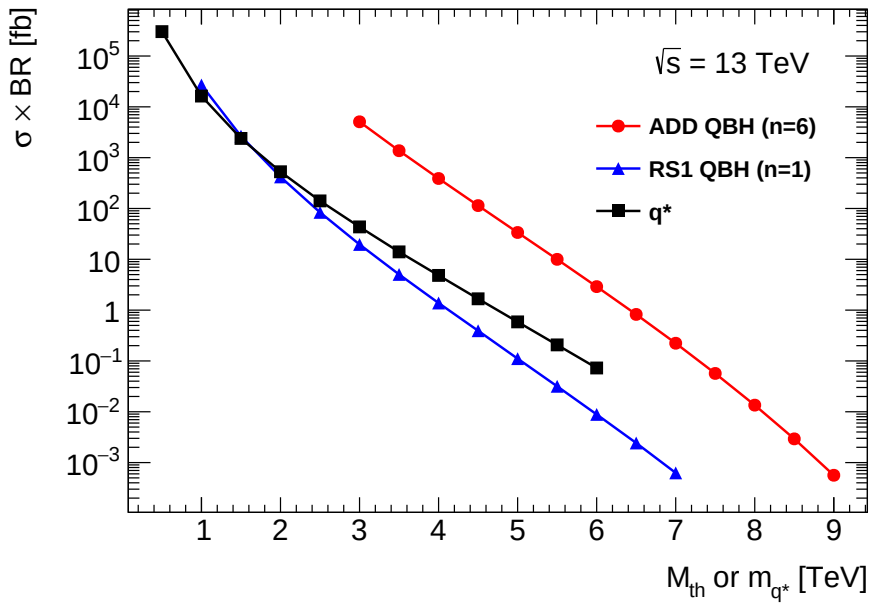
Overview

- Search for exotic $\gamma +$ jet resonances in the steeply falling background from SM $\gamma +$ jet production
- Focus on s-channel production of a resonance
- Strategy: Shape analysis (bump in $m_{\gamma j}$ spectrum)

- Signals:
  - Evaporation of non-thermal quantum black holes:
    - QBH ADD with 6 extra dimensions
    - QBH RS1 with 1 extra dimension
  - Decay of excited quark (q^*)
- Background: estimated w/ data-driven method

JHEP03(2016)041



- No significant deviation from the background-only hypothesis is observed
- Upper limits on the signal strength and lower limits on the masses are set
- Cross-section limits for generic Gaussian-shaped resonances are extracted

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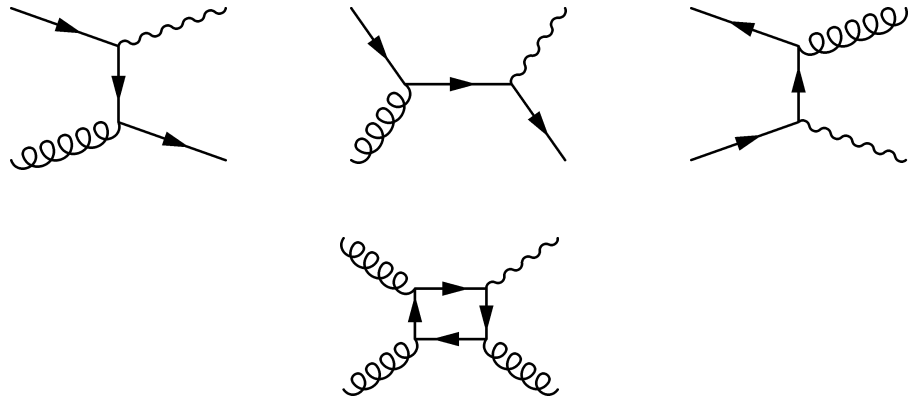
Event, photon and jet selections

Events selected with a trigger requiring at least one photon candidate with $E_{\mathrm{T}} > 140\,\mathrm{GeV}$ which satisfies loose identification conditions

- Signal photon:
  - $E_{\mathrm{T}} > 150\,\mathrm{GeV}$ and $|\eta| < 1.37$
  - Tight γ identification & isolation requirement
  - Take highest E_{T} candidate
- Signal jet:
  - Reject event if jet with $p_{\mathrm{T}} > 30\,\mathrm{GeV}$ and $\Delta\mathrm{R}(j, \gamma) < 0.8$
  - Take highest p_{T} candidate (satisfying $p_{\mathrm{T}} > 60\,\mathrm{GeV}$)
- Reject event if $\Delta\eta(\mathrm{jet}, \gamma) > 1.6$ to enhance s-channel signals

Background

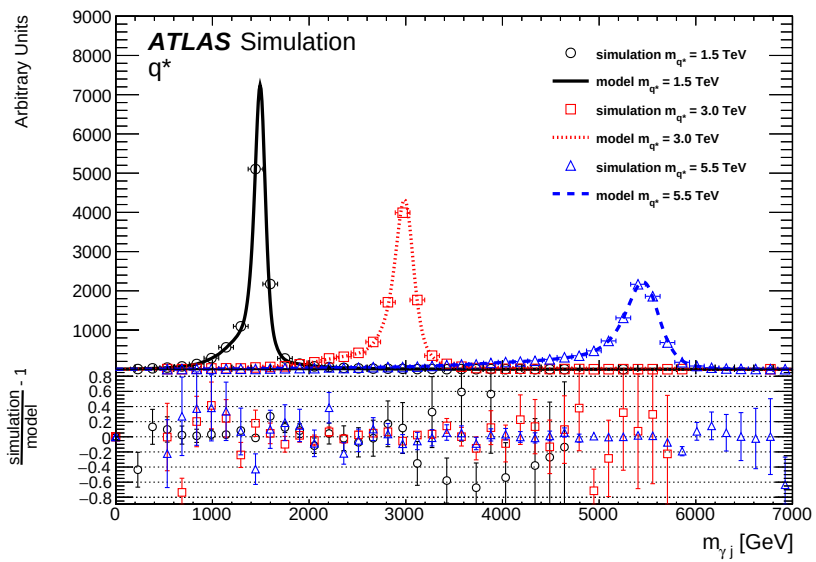
- **Irreducible background:**
  - "Prompt" production:
    - "Compton scattering" of a quark and a gluon
    - quark-antiquark annihilation
    - gluon annihilation (not at tree-level)
  - "Fragmentation" production:
    - Photons from hadron decays
    - Photons radiating off a quark

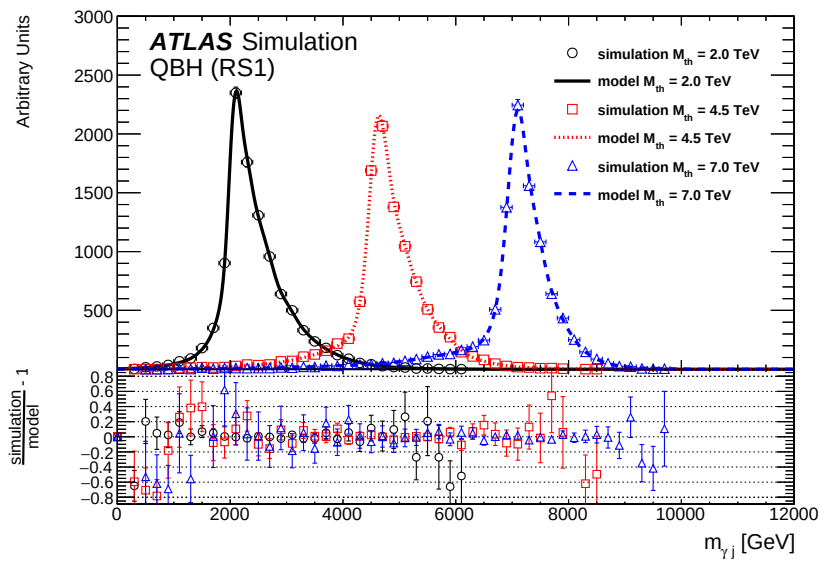


- **Reducible background:**
  - *Fakes:* Events with a jet but without a photon (for instance dijet events)
  - Significantly reduced by using tight photon ID and isolation selection

Signal Modelling

- Decay of excited quarks:
  - Pythia 8.1 + NNPDF 2.3 + A14 tune
    - M_{q*} : 0.5 to 6 TeV (in steps of 0.5 TeV)
- Evaporation of non-thermal quantum black holes:
  - QBH 2.02 + Pythia (hadronization and UE) + CTEQ6L1 + A14 tune
    - ADD (n=6): M_{th}: 3 to 9 TeV (in steps of 0.5 TeV)
    - RS1 (n=1): M_{th}: 1 to 7 TeV (in steps of 0.5 TeV)
- Non-parametric distribution at a certain mass point is estimated using a kernel density estimation (KDE)
- Global model created by morphing all the pdfs at fixed mass





Figures from EXOT-2016-26

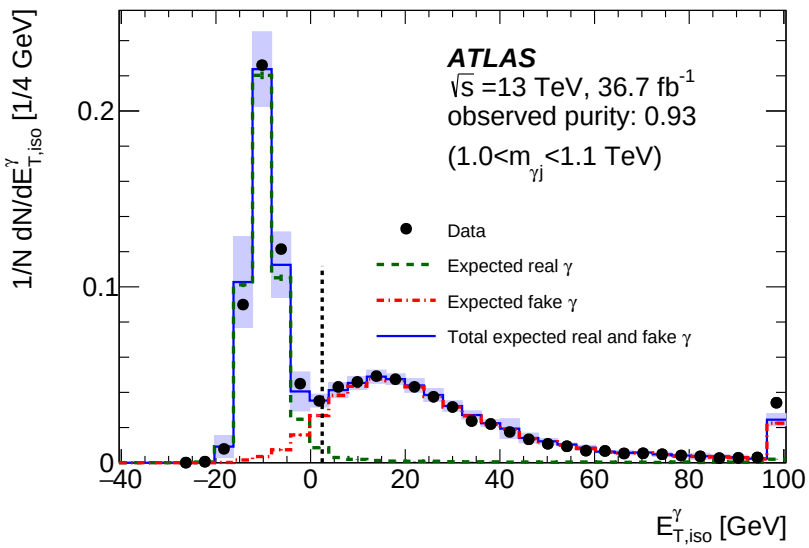
Purity Measurement

True and fake photon contributions evaluated with template fit on photon isolation distribution ($E^{\gamma}_{T,iso}$):

- Fakes: Data in a CR (orthogonal to SR)
- True photons: MCs
- $E^{\gamma}_{T,iso} = E_{T,iso} - 0.0022 \times E^{\gamma}_{T}$
- $E_{T,iso}$: Energy around the photon within $\Delta R = 0.4$. Contribution from the photon & pileup is subtracted
- The purity is $\sim 93\% \pm 4\%$

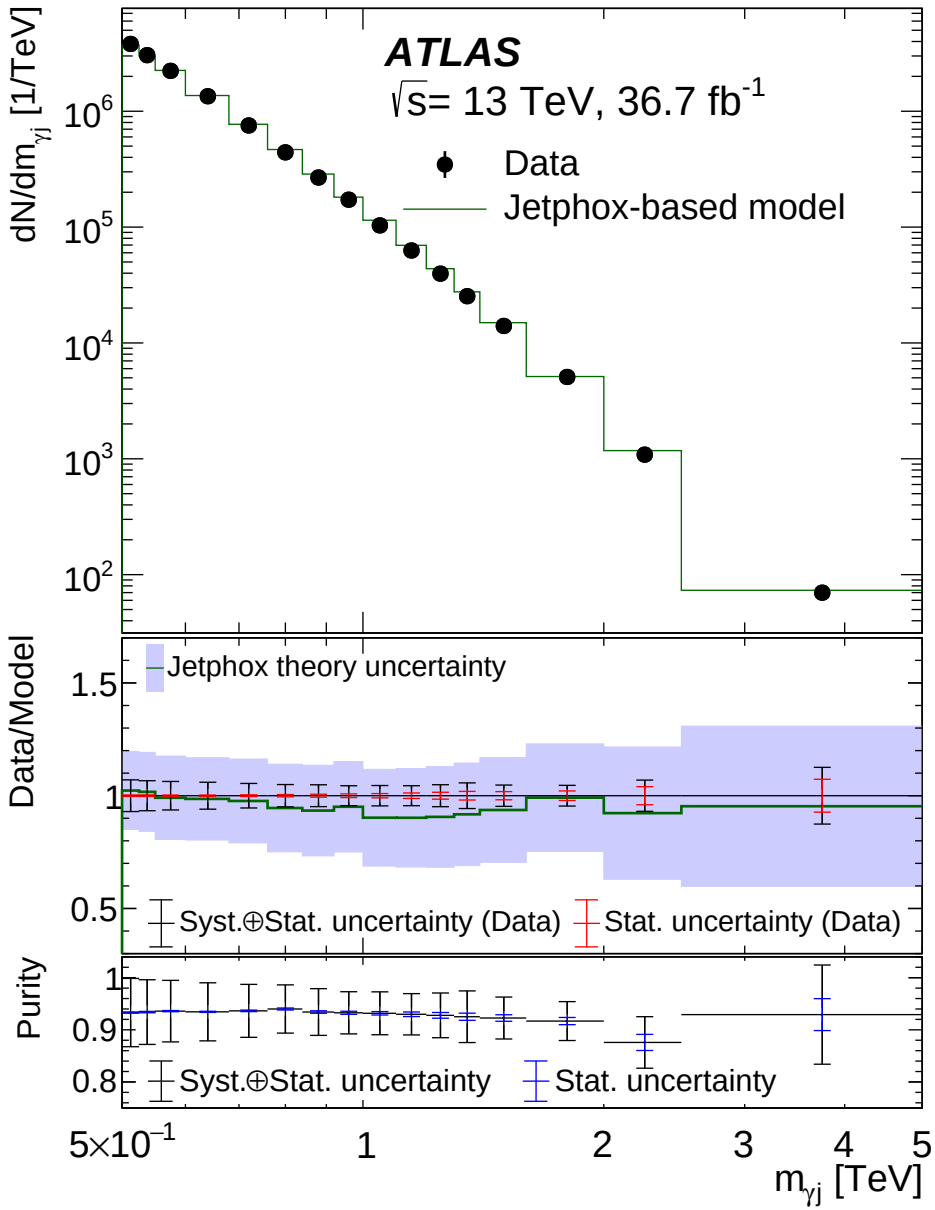
The purity measurement is used only for the spurious signal evaluation (see slide 8)

Template fit



Measured $m_{\gamma j}$ distribution vs purity-corrected theory prediction

Validation of the JETPHOX sample used in the spurious signal evaluation (see slide 8)



Background Modelling

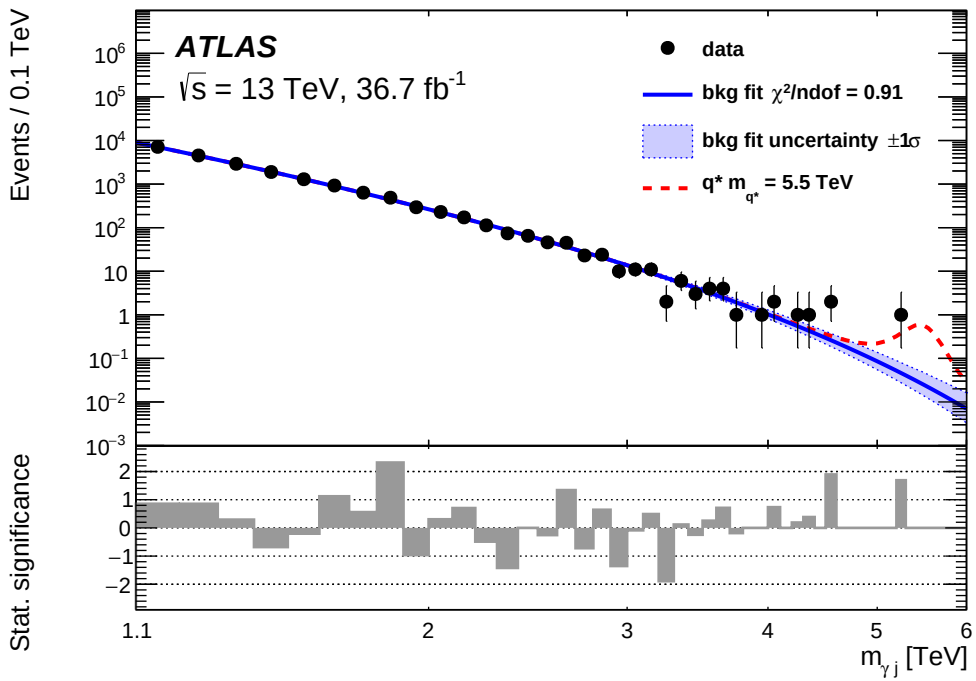
Fit function to data:

$$f_b(x \equiv m_{\gamma j}/\sqrt{s}) = p_a(1-x)^{p_b} x^{-\sum_{n=0}^{k} p_n \log^n x}$$

Allows to modify the functional form simply by adding or removing dof

Optimization of the functional form and fit range based on:

- Uncertainty on the background model (spurious signal)
- Statistical uncertainty on the fit window



Uncertainty on the Background Modelling

Non-closure from the choice of the functional form (spurious signal):

- σ_{spurious} evaluated with a s+b fit on bkg-only simulated dataset
- Number of signal events is taken as possible bias due to non perfect modelling of the background shape

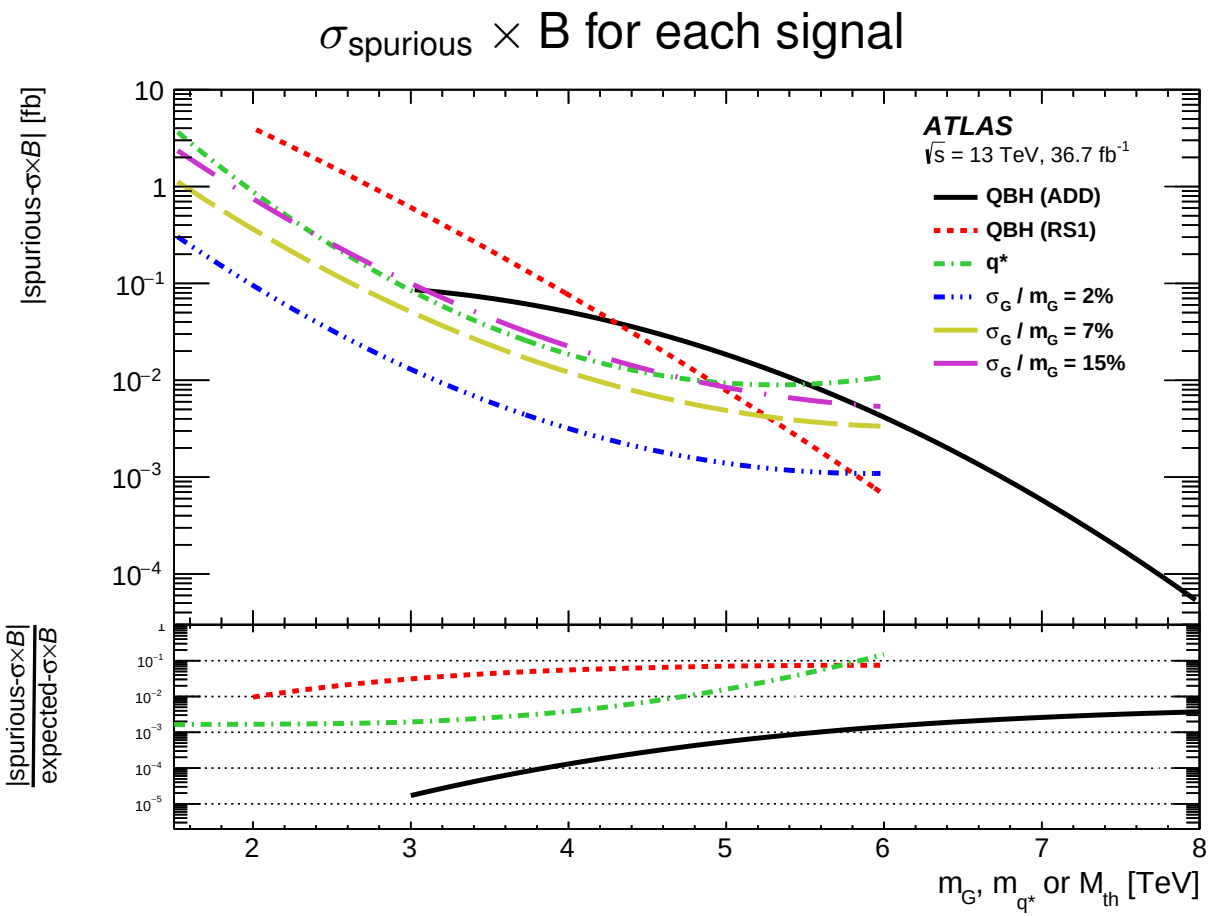
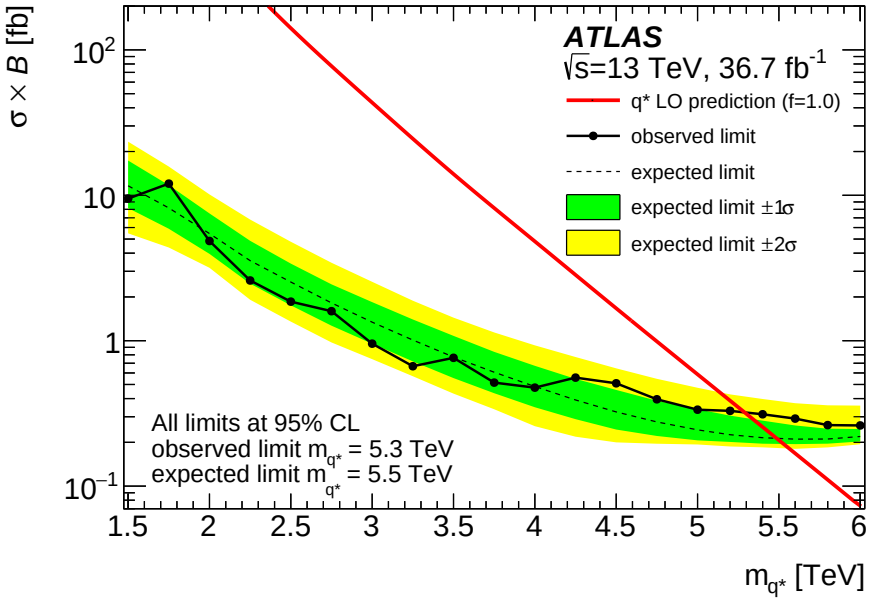


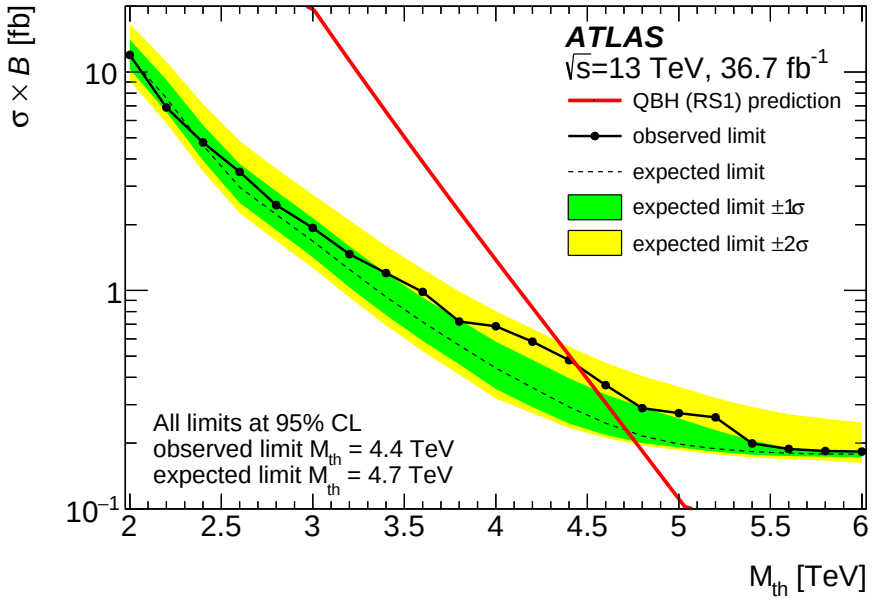
Figure from EXOT-2016-26

Upper limits on cross-sections and lower limits on the masses

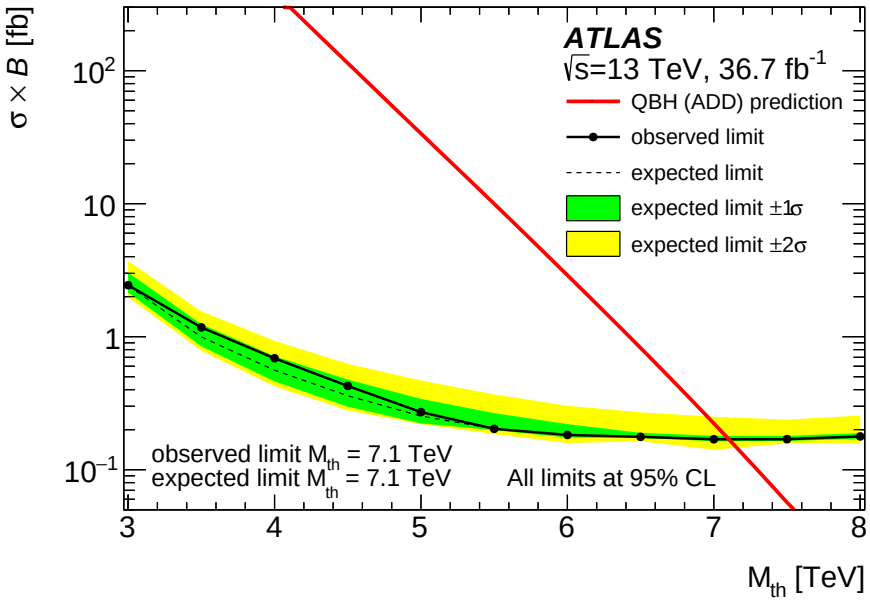
q^*



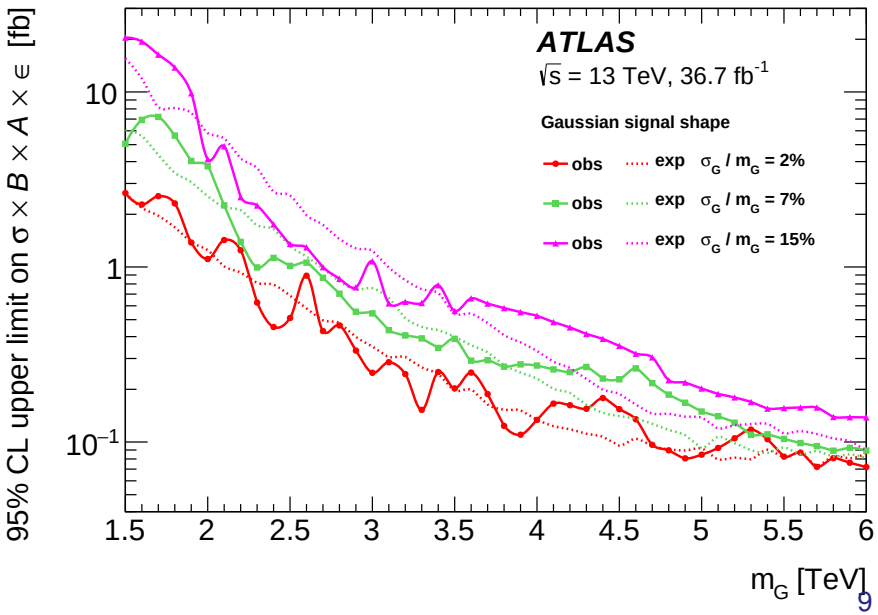
RS1



ADD



Gaussian signals



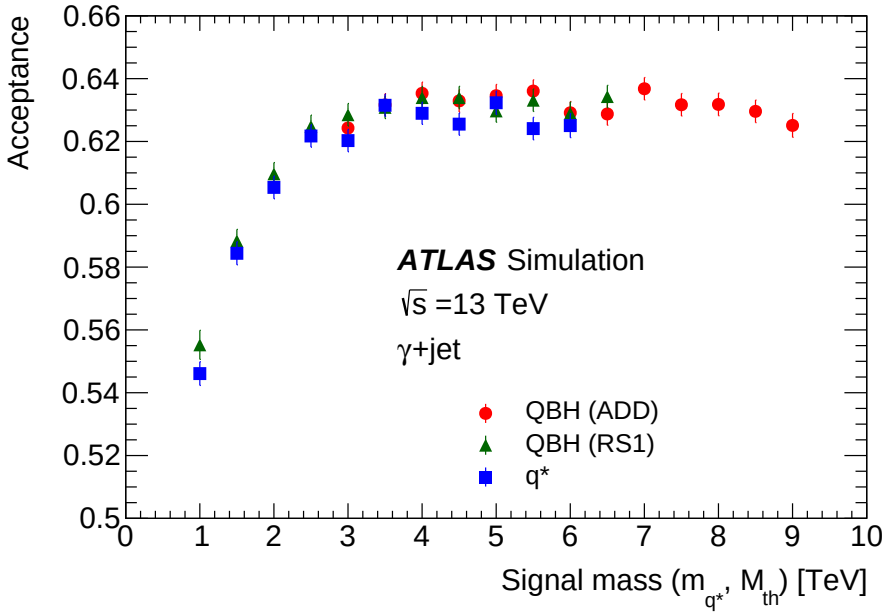
Conclusions

- The search for exotic $\gamma +$ jet resonances was presented
- No significant deviation from the background-only hypothesis is observed
- Cross-section limits for generic Gaussian-shaped resonances were extracted
- Upper limits on the signal strength and lower limits on the masses are set for different BSM models:
  - ADD and RS1 (evaporation of non-thermal quantum black holes)
  - Decay of excited quark (q^*)
- The data exclude, at 95% CL, the mass range below 5.3 TeV for excited quarks and 7.1 TeV (4.4 TeV) for QBH in the ADD (RS1) model

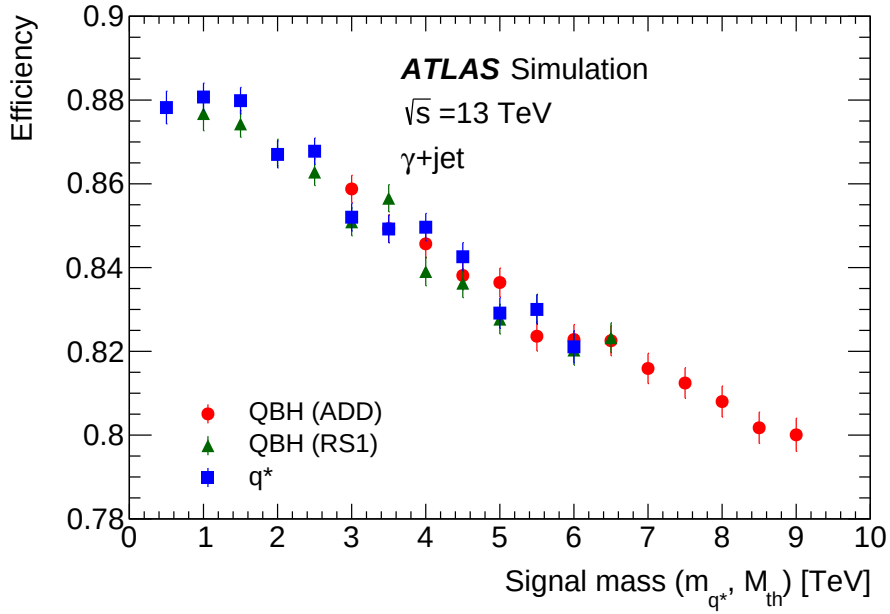
Back-up slides

Fiducial acceptance and selection efficiency

Fiducial acceptance



Selection efficiency



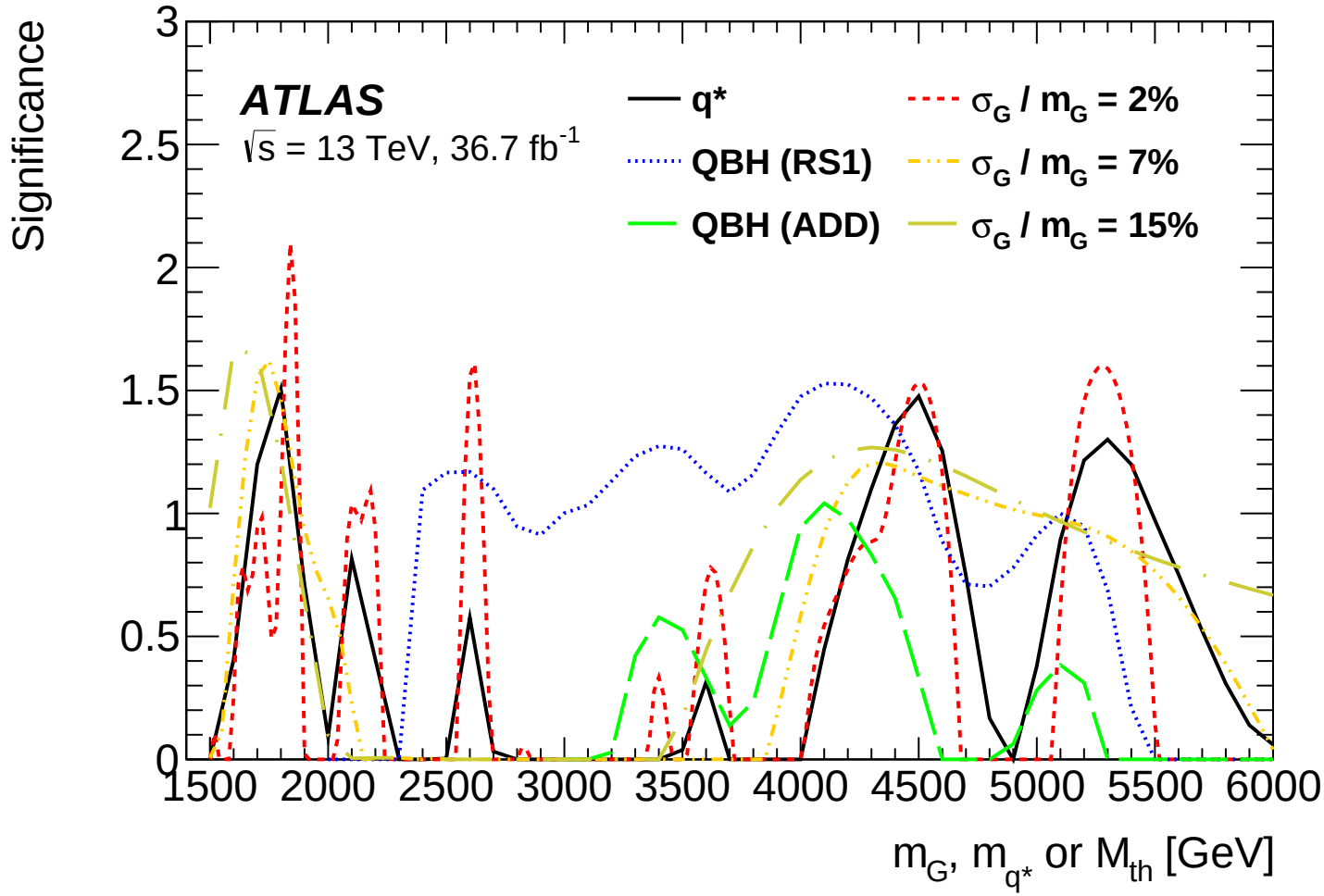
Particle-level selection for fiducial region
Photon : $E_{\mathrm{T}}^{\gamma} > 150$ GeV, $\lvert\eta^{\gamma}\rvert < 1.37$
Jet : $p_{\mathrm{T}}^{\mathrm{jet}} > 60$ GeV, $\lvert\eta^{\mathrm{jet}}\rvert < 4.5$
Photon–Jet η separation : $\lvert\Delta\eta_{\gamma j}\rvert < 1.6$
No jet with $p_{\mathrm{T}}^{\mathrm{jet}} > 30$ GeV within $\Delta R < 0.8$ around the photon
Detector-level selection for selection efficiency
Tight photon identification
Photon isolation
Jet identification including quality and pile-up rejection requirements

Systematic uncertainties included in the fit model

Uncertainty	q^* and QBH	Generic Gaussian
Signal mass resolution	N/A	$\pm 2\% \cdot m_{\mathrm{G}}$
Photon identification	$\pm 2\%$	N/A
Trigger efficiency	$\pm 1\%$	N/A
Pile-up dependence	$\pm 1\%$	N/A
MC event statistics	$\pm 1\%$	N/A
Luminosity	$\pm 3.2\%$	

Significance

Compatibility in terms of observed local significance σ with the background-only hypothesis



Uncertainty on the Background Modelling

- Evaluated with spurious signals
- σ_{spurious} evaluated with a s+b fit on bkg-only dataset (JETPHOX)
- JETPHOX is corrected by $p_{\text{T}}^{\text{reco}}/p_{\text{T}}^{\text{parton}}$ ratio from Sherpa.
- JETPHOX is corrected by purity measurement
- The following variations are considered:
  - PDF uncertainty
  - No Reco/Parton correction from Sherpa
  - Signal purity uncertainty
- Largest absolute σ_{spurious} is assumed as final systematic uncertainty

Optimization of the Functional Form and Fit Range

Find compromise between:

- Uncertainty on the background model (spurious signal)
- Statistical uncertainty on the fit window

Fit range:

- s+b fit to JETPHOX. Candidate function discarded if
  - $\frac{N_{SS}}{\sigma_{SS}} > 0.4$ (at any point in the fit window)
  - We favor bigger windows to make stat uncertainty as small as possible

Functional form:

- Number of degrees of freedom chosen with a F-test.
- $k = 0$ (1) is used for QBH (q^*) signal search