Search for new physics in dijet resonant signatures and recent results from Run2 with the ATLAS experiment

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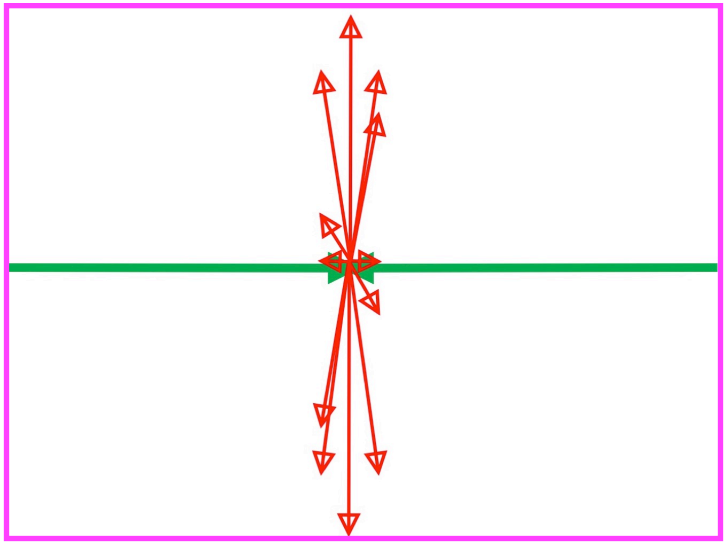
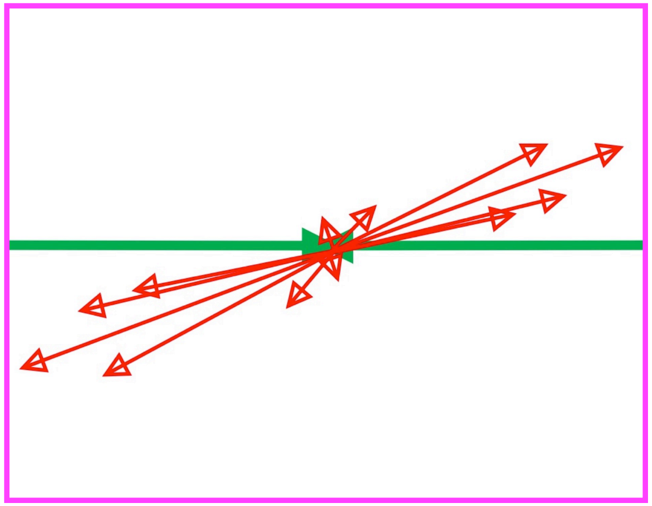
Introduction

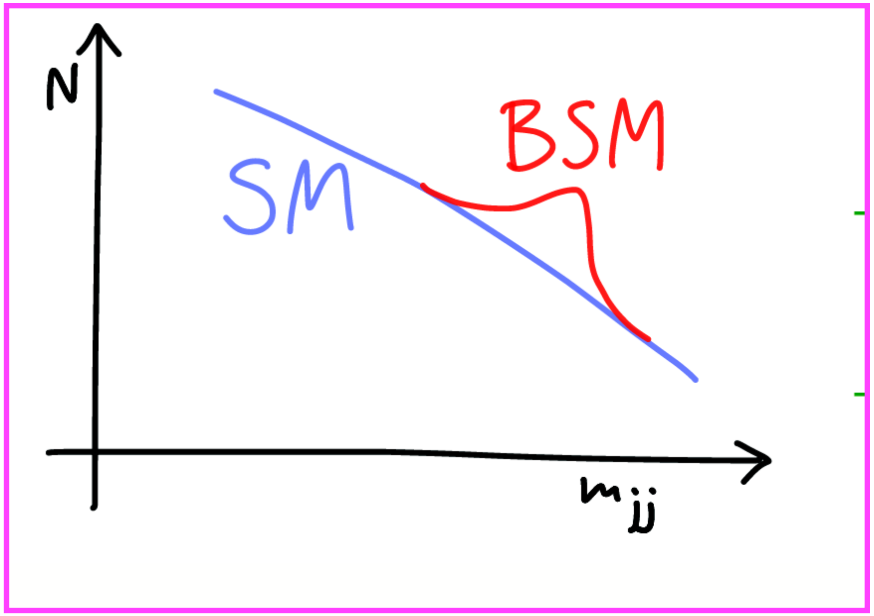
- In proton-proton collisions, we can use parton-parton s-channel production to produce a single particle.
  - Then this particle can decay to quarks and gluons.
- Many models beyond the standard model (BSM) predict new particles, or excitations, decaying to partons that can produce hadronic jets.
- High-p_T jets access the highest mass scales at the LHC.
- QCD scattering is t-channel, leading to angular distributions peaking at small scattering angles.





Method

- We perform search in two-jet (dijet) invariant mass, m_{jj}, spectrum.
- SM spectrum at high mass totally dominated by QCD processes.
- If BSM resonance width narrow, it can produce local excess (bump) in dijet mass spectrum over the smooth SM background.

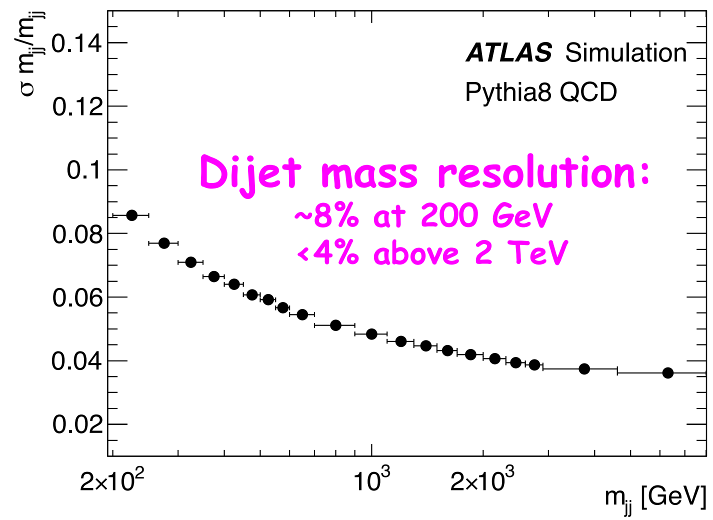


History

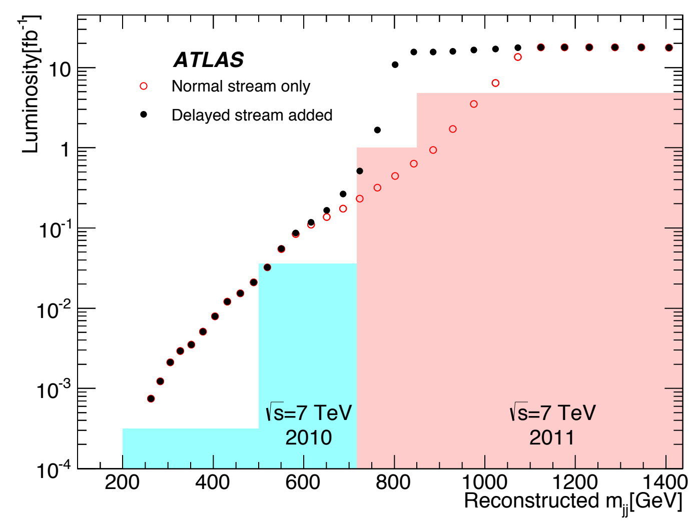
- Excesses in the dijet spectrum have been search for by all collider experiments: CDF, D0, CMS, ATLAS.
- In 2010, ATLAS and CMS published first results.
- In 2011, ATLAS used 4.8 fb^{-1} at $\sqrt{s}$ = 7 TeV.
- I will cover ATLAS results for 20.3 fb^{-1} at $\sqrt{s}$ = 8 TeV (full 2012 dataset).
- I will also cover ATLAS results for 80 pb^{-1} of $\sqrt{s}$ = 13 TeV (August).
- No significant excess observed above background.
- We set limits on a number of BSM models and generic resonance shapes.

ATLAS detector/trigger

- ATLAS consists of tracking detectors, calorimeters, muon chambers.
- High-p_T hadronic jets are reconstructed using a finely segmented calorimeter system.



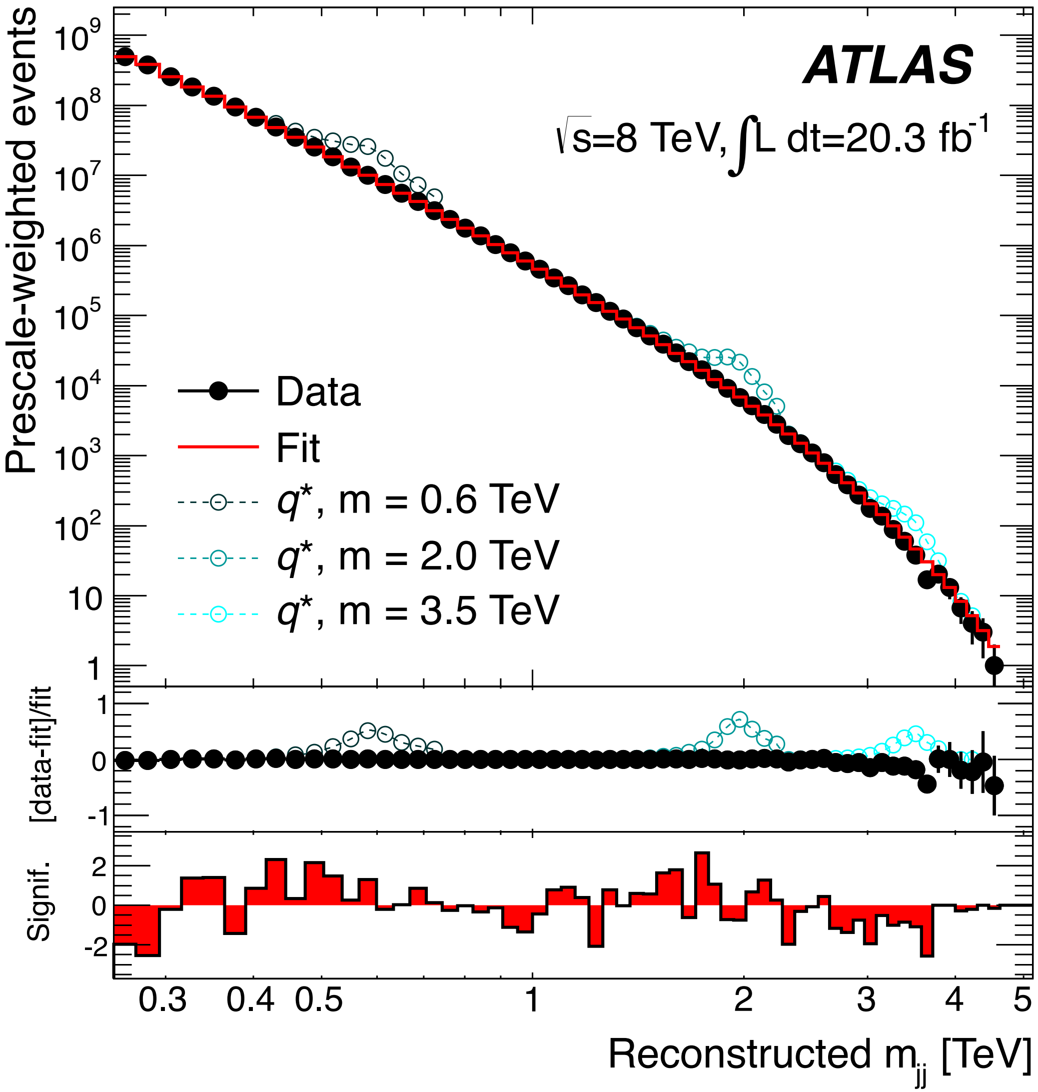
- Use single-jet triggers.
  - Low-p_T threshold triggers pre-scaled.
  - Combination of pre-scaled triggers used to cover low-mass part of dijet spectrum.
- Use a delayed trigger stream.
  - Increase luminosity in region 0.75-1 TeV by order of magnitude.



Jet and event selection

- Jets are reconstructed using anti-k_t jet algorithm with R = 0.6 on topological calorimeter clusters with energy significantly above noise.
- The effects of other bunch crossings corrected for.
- Jet cleaning is performed.
- Require at lease 1 collision vertex defined by 2 or more charged tracks.
- Rapidity of two leading jets $|y| < 2.8$.
- Two leading jets $p_T > 50$ GeV.
- Event cuts (to reduce background from QCD processes to resonant BSM physics):
  - $|y^*| = 0.5|y\_leading - y\_subleading| < 0.6$.
  - $m_{jj} > 250$ GeV.

Dijet spectrum



- Bin width chosen by dijet mass resolution.
- Data-driven background estimate.
- Fit smooth functional form to data.

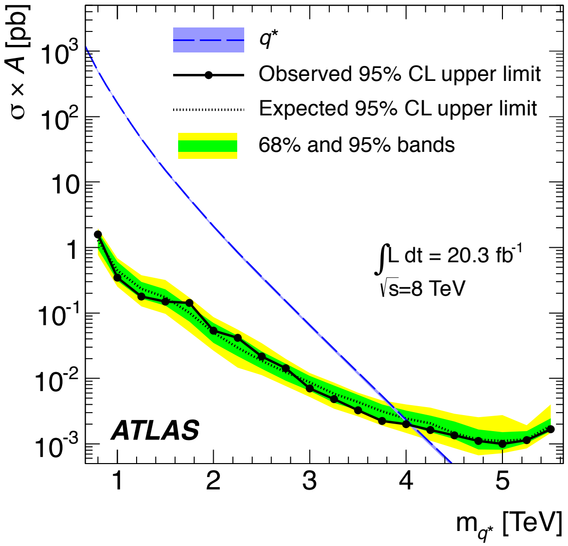
$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x},$$
$$x \equiv m_{jj}/\sqrt{s}.$$

- χ^2 = 79/56 dof.
- p-value of fit 0.027.
- No evidence for a resonant signal in observed m_{jj} spectrum.

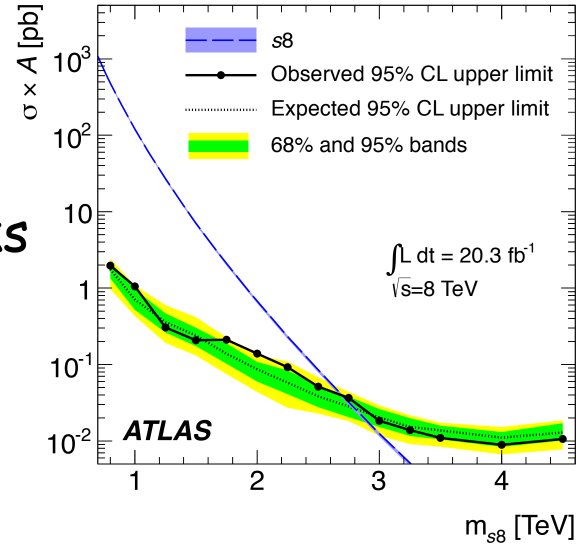
Limit setting

- Use a Bayesian method.
- Set 95% credibility-level upper limits on cross section times branching ratio times acceptance ($\sigma \times B \times A$).
- Use constant prior for signal strength and Gaussian priors for nuisance parameters corresponding to systematic uncertainties.
- Full template shape is considered in the limit-setting.
- Set lower-limits on mass, or energy scale, as appropriate.
- Models span a range of characteristic masses (or energy scales) and cross sections, and are complementary in terms of the flavour of their final-state partons.

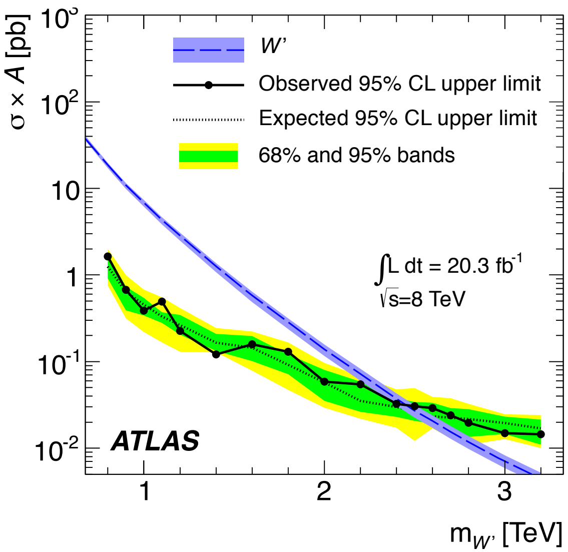
Limits on new resonant phenomena



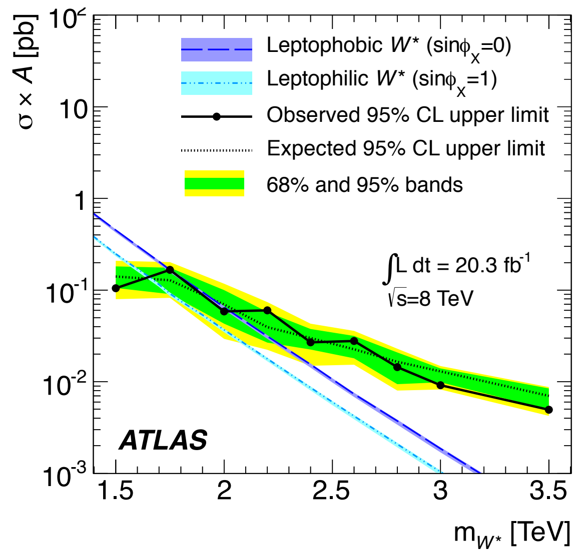
Excited quarks
4.06 TeV



Colour-octet scalars
2.70 TeV

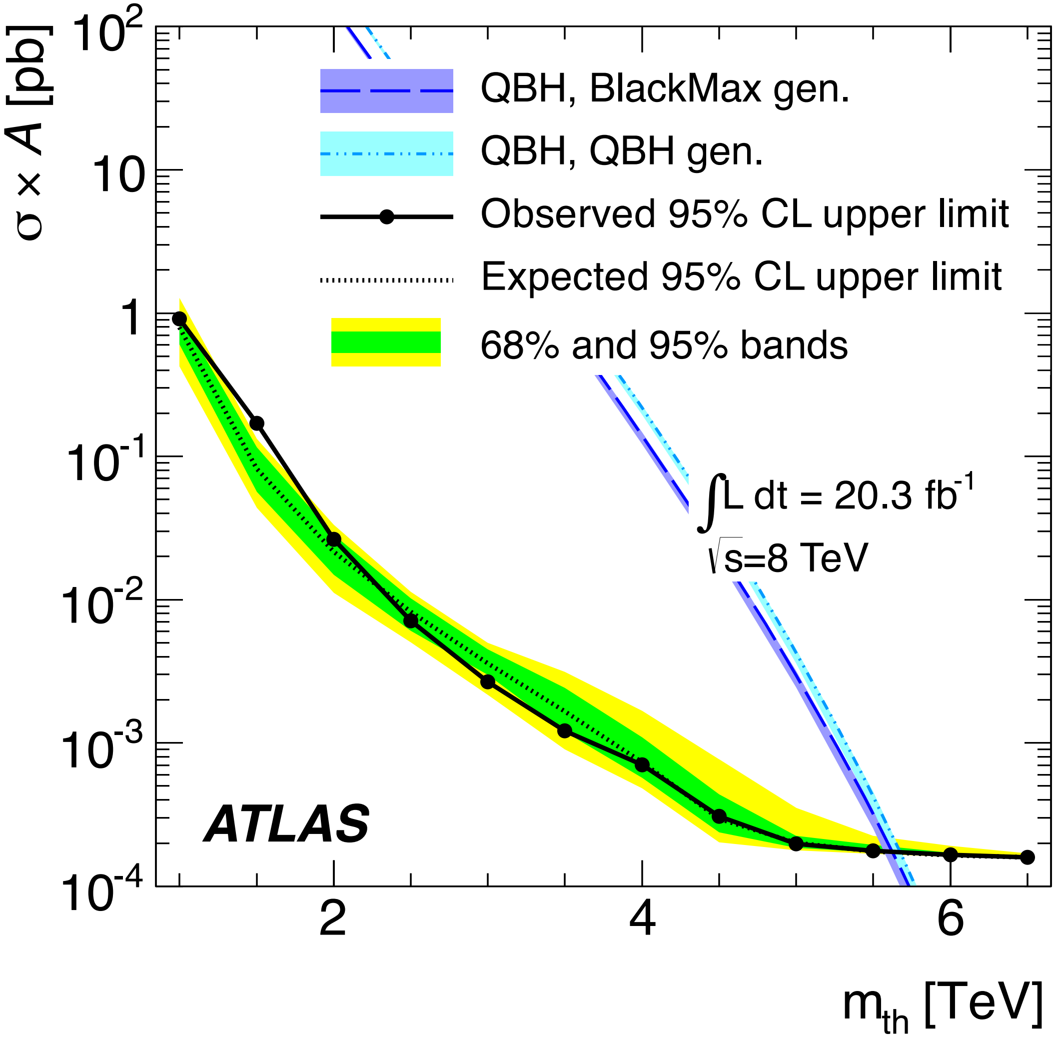


Heavy W'
2.45 TeV



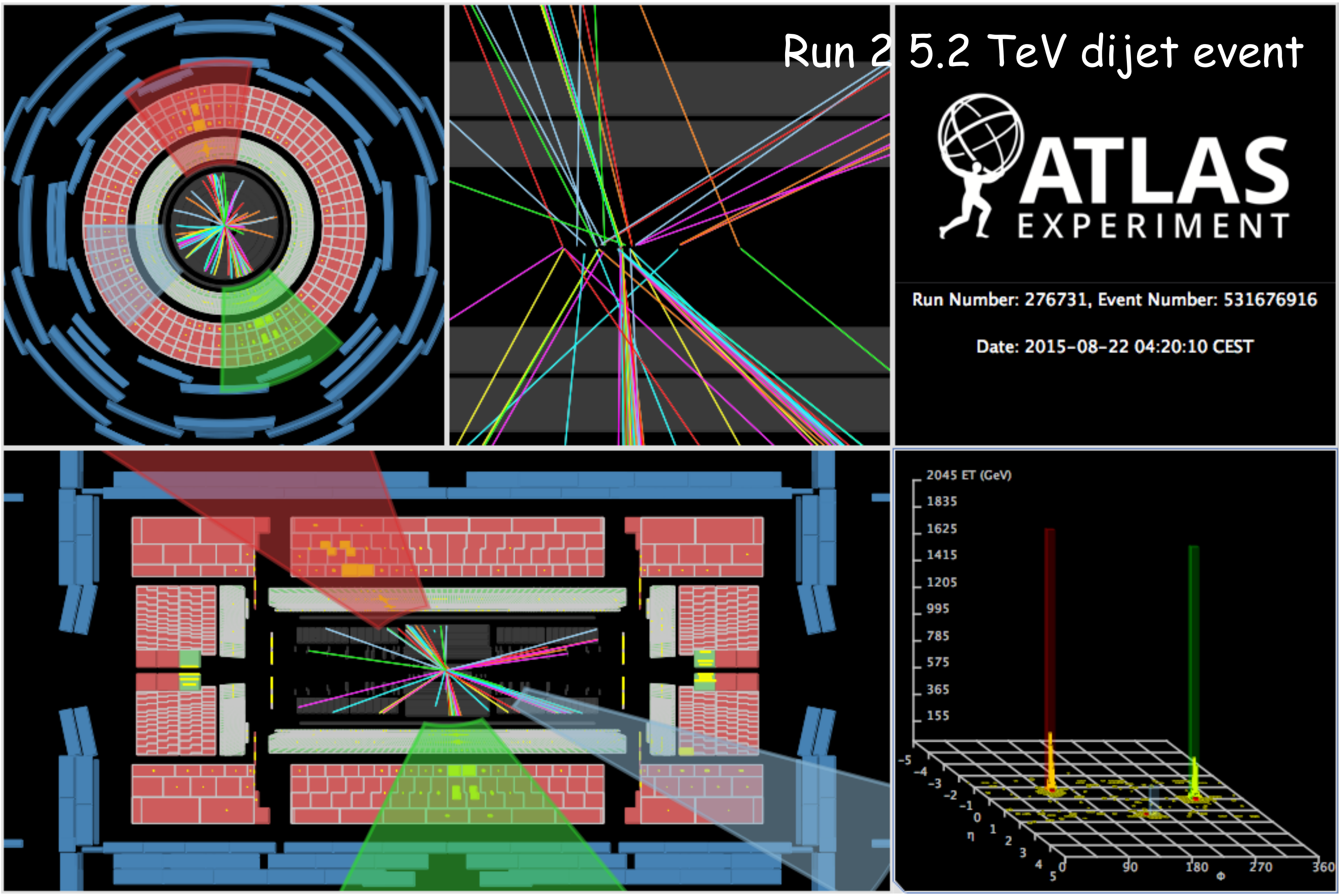
Chiral W* leptophobic
1.75 TeV

Limits on quantum black holes

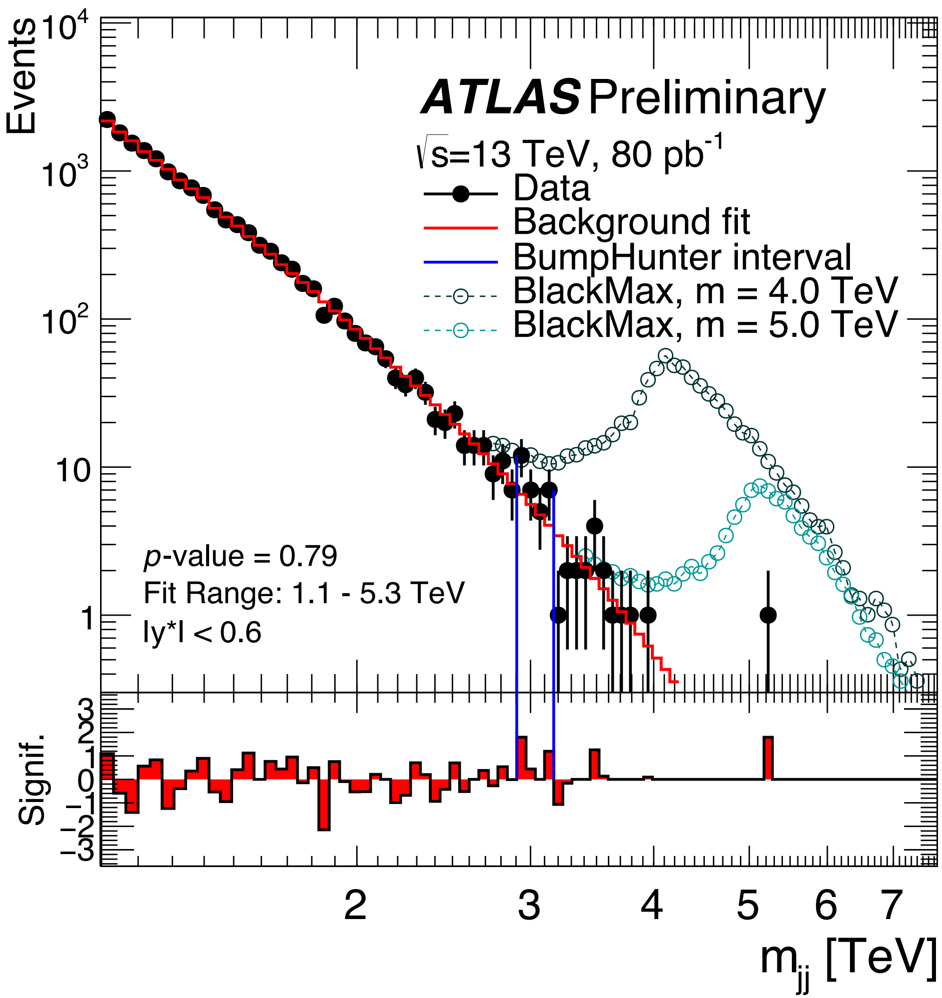


- ADD model, n = 6.
- Threshold mass set to Planck scale, $M_{th} = M_D$.
- Thermal black hole decays to 2-body:
  - BlackMax: 5.62 TeV.
- Non-thermal black hole decays to 2-body:
  - QBH: 5.66 TeV.

ATLAS 13 TeV results

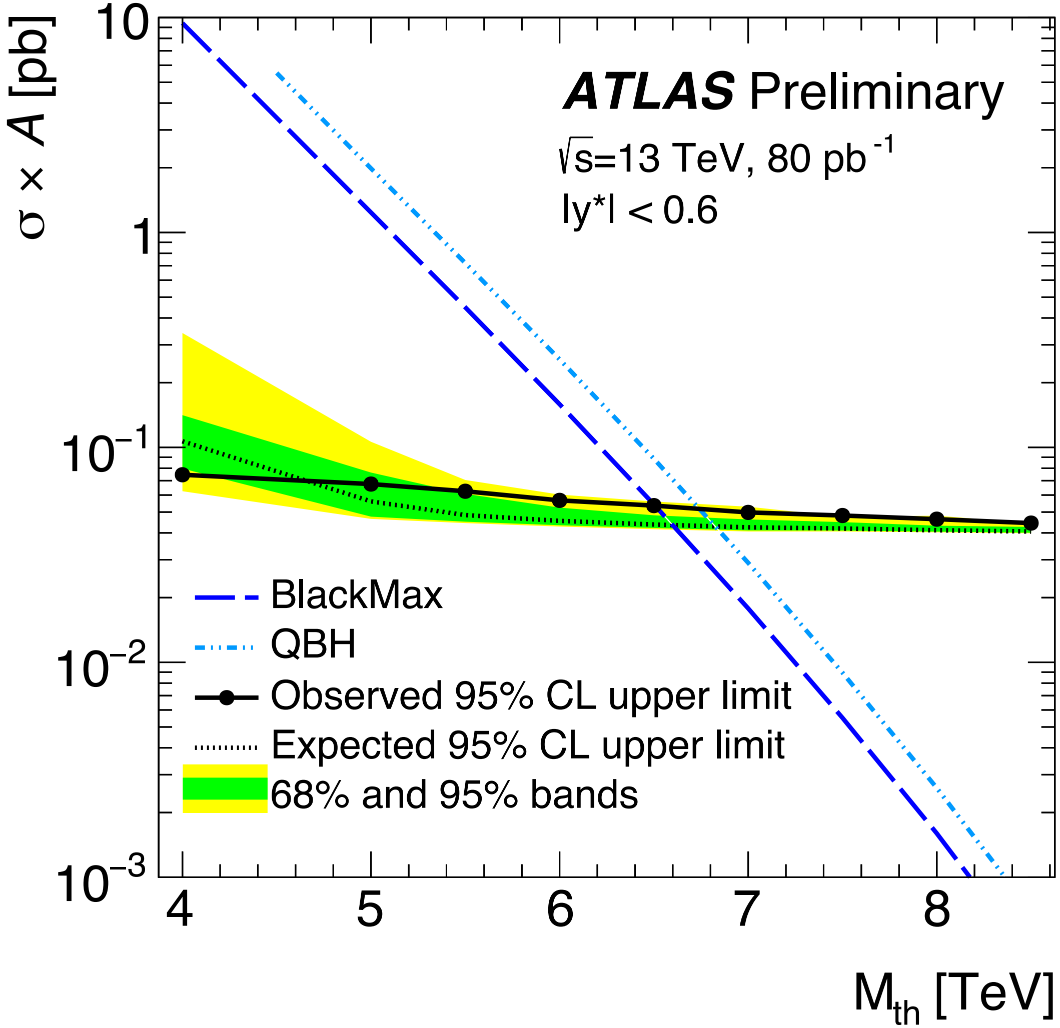


13 TeV dijet mass specturm



- 80 pb^{-1} of data at $\sqrt{s}$ = 13 TeV (includes August 50 ns data).
- Does not include Toroid-off data.
- Trigger p_T > 360 GeV.
- Require 2 jets:
  - p_T > 410 GeV leading,
  - p_T > 50 GeV subleading.
- Require m_{jj} > 1.1 TeV.
- Remove log factor from fit function.

13 TeV QBH limits

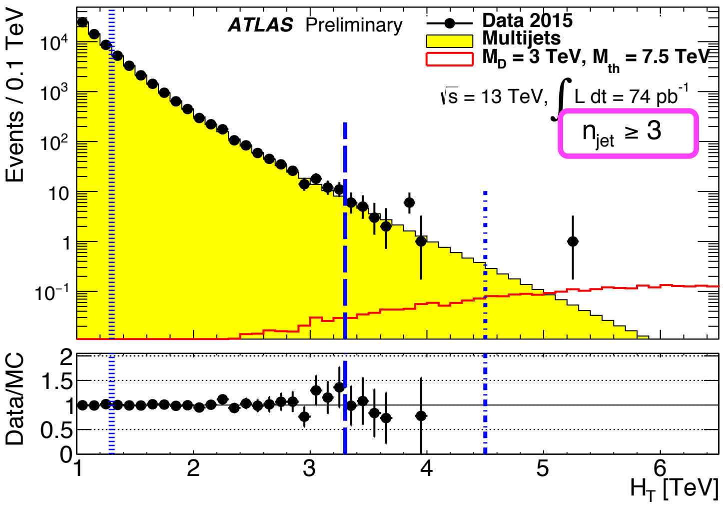


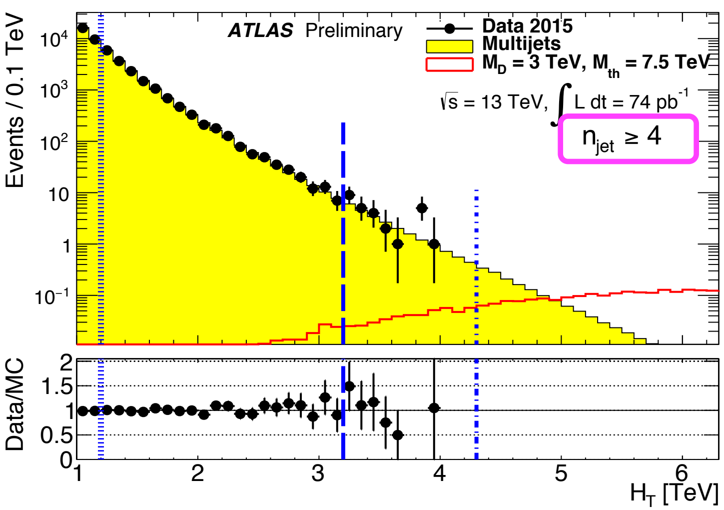
- ADD, $n = 6$, $M_D = M_{th}$.
- Signal acceptance ~50%.
- 95% CL mass limits:
  - 6.8 TeV QBH
  - 6.5 TeV BlackMax.
- cf. previous ATLAS limits of 5.66 (5.62) TeV.

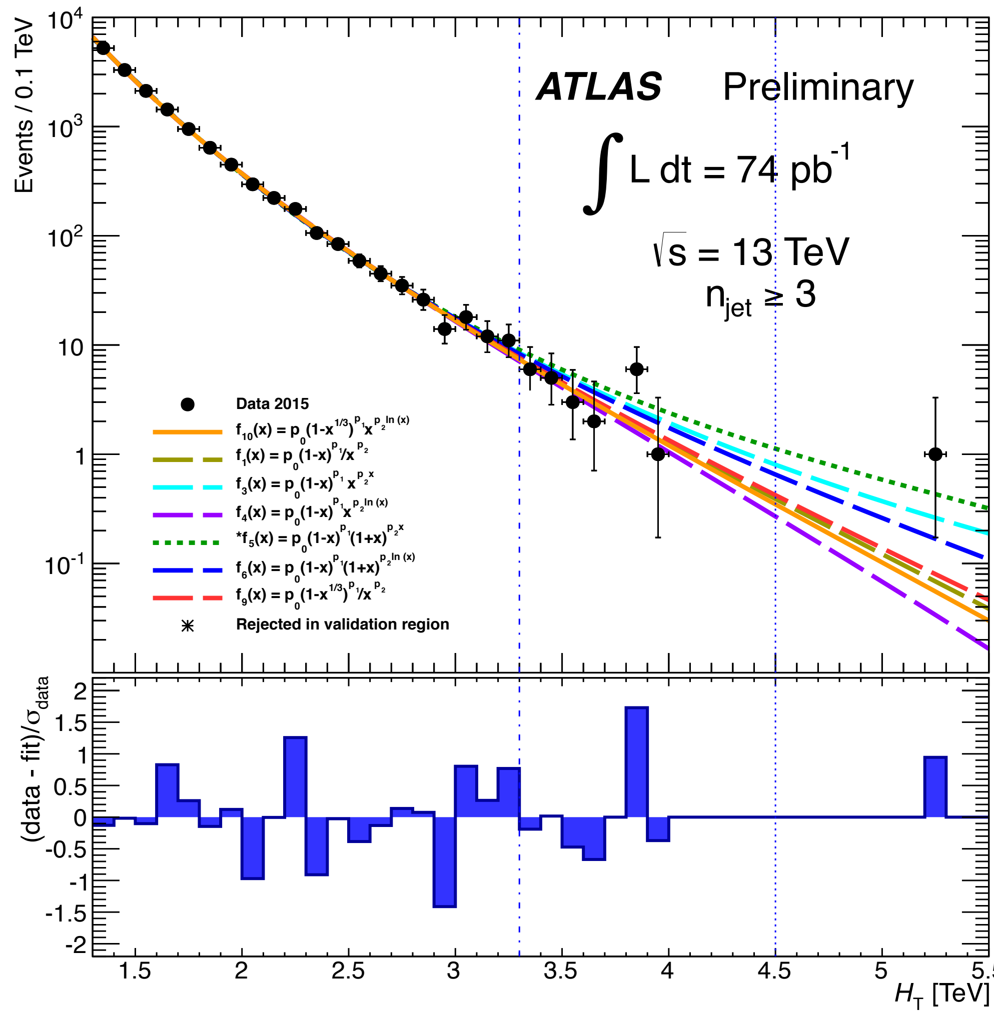
13 Multijet search

- Search for low-scale gravity in final states with multiple jets.
- Dominant black hole decay mode, thought to be to partons, leading to hadronic jets. This search uses jets only.
- Perform search in scalar sum of jet transverse momentum, H_T, for several inclusive jet multiplicities.
- Define three regions:
  - Control ($C < H_T < V$): used to fit data
  - Validation ($V < H_T < S$): used to validate fit
  - Signal ($H_T < S$): used to predict background
- Data fit to empirical function in CR.
- Extrapolated to predict number of events in VR and CR.
- To avoid signal contaminations use a 2-step bootstrap procedure.
  - CR, VR, SR boundaries depend on integrated luminosity and inclusive jet multiplicity.

Step 2: 74 pb^{-1} results

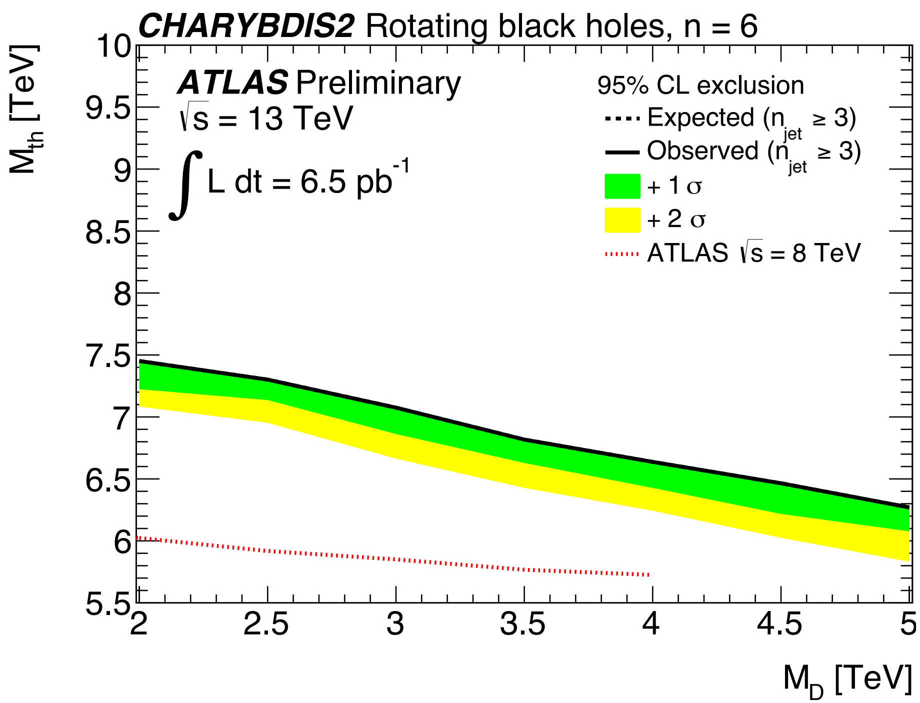


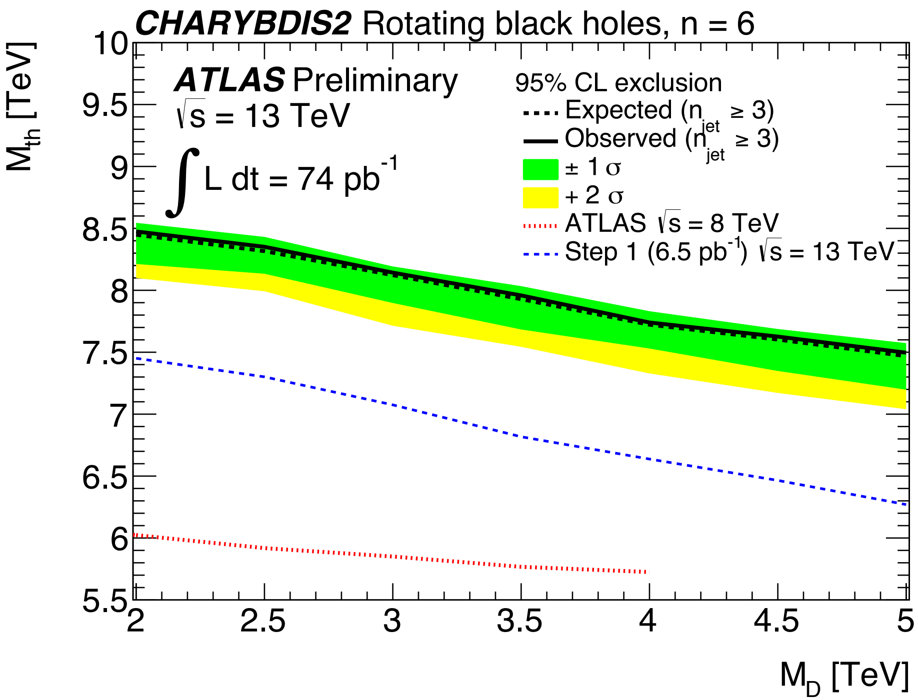




13 TeV multijet limits

Run1: M_{th} > 5.9 TeV at 95% CL for M_D = 3 TeV.





M_{th} > 7.3 TeV at 95% CL for M_D = 3 TeV.

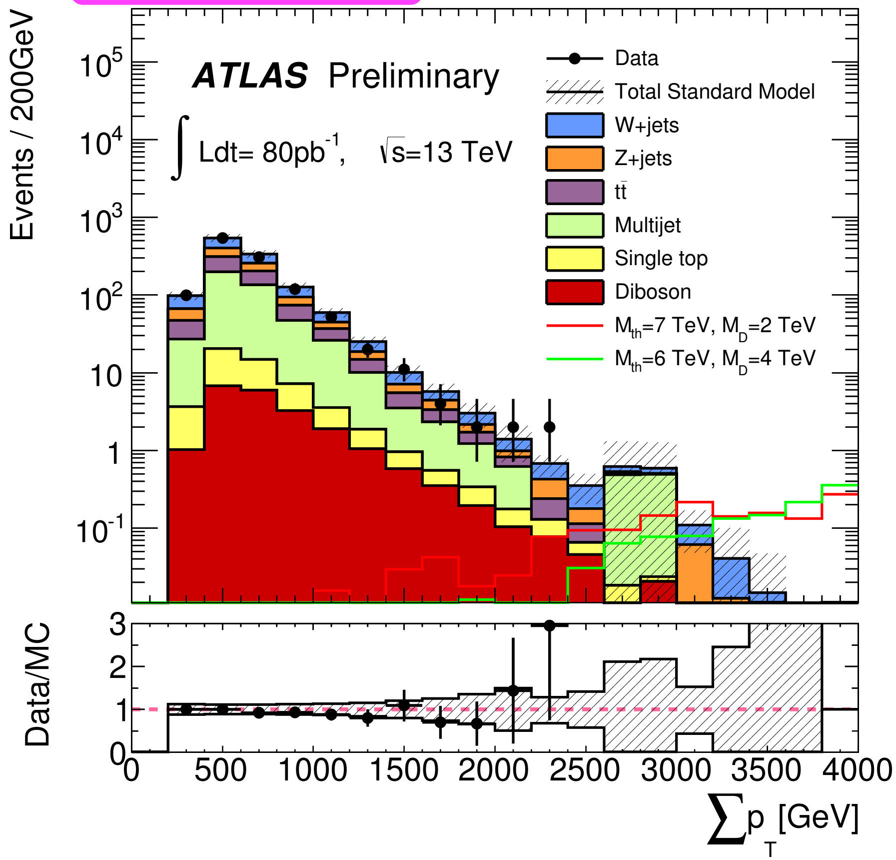
M_{th} > 8.3 TeV at 95% CL for M_D = 3 TeV.

Final states with leptons and jets

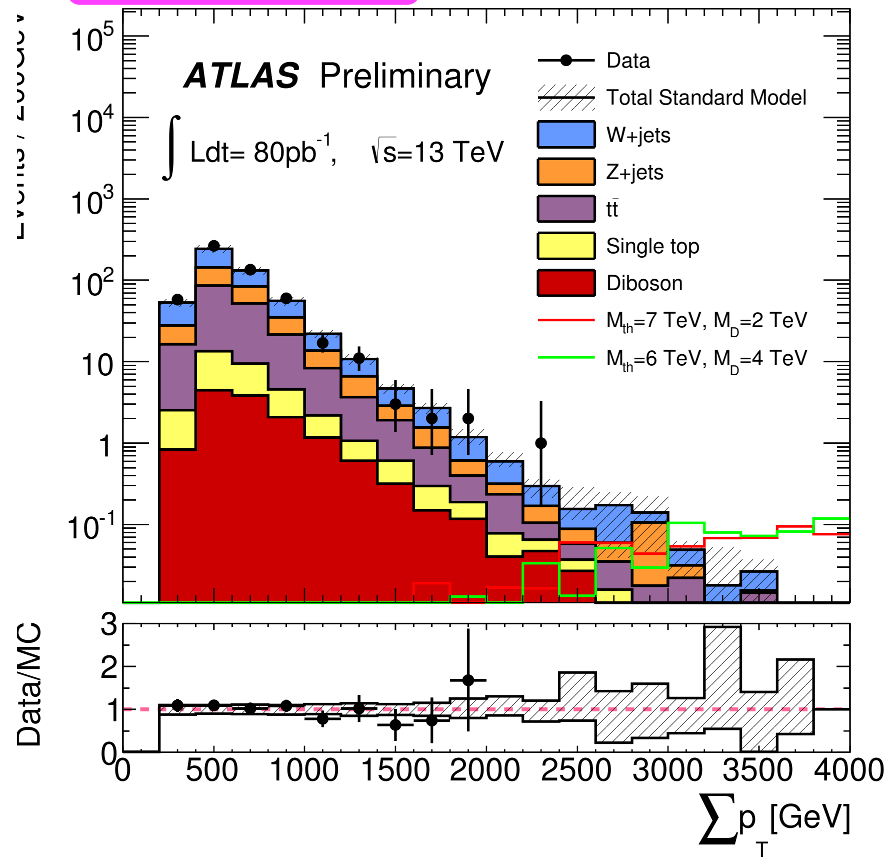
- Search for low-scale gravity in final states with leptons and jets.
- Lepton requirement reduces QCD backgrounds.
- Require at least 3 high p_T objects of which one must be a lepton (electron or muon) and the others are hadronic jets.
- Scalar sum of the p_T of these objects, Σp_T, is the discriminating variable of the search.
- Signal region requirements:
  - p_T(lepton) > 100 GeV
  - p_T(2 other objects) > 100 GeV
  - Σp_T > 2 (3) TeV
- Backgrounds are W+jets and Z+jets, and ttbar production.
  - Shapes taken from MC and normalized to data in control regions.
- Also fake electrons (hadronic jets incorrectly reconstructed as electrons)
  - Estimated from data.

Leptons + jets results

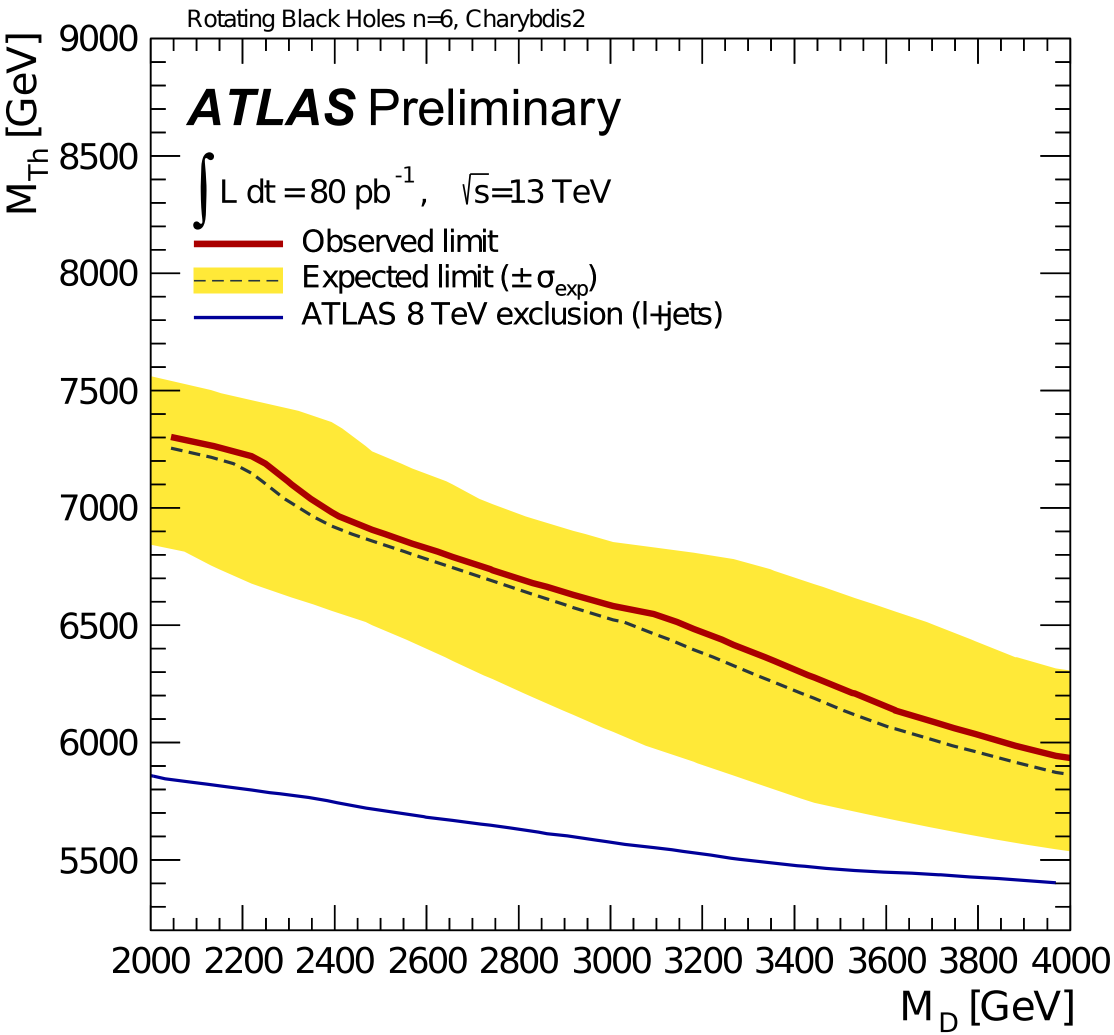
Electron channel



Muon channel



Leptons + jets limits on BH



- Rotating classical black hole.
- ADD, n = 6 extra dimensions.
- Charybdis2 generator.
- M_{th} > 6.5 TeV @ 95% CL for M_D = 3 TeV
- cf. 5.6 TeV in Run 1.

Conclusions

- ATLAS 20.3 fb^{-1} of data at $\sqrt{s}$ = 8 TeV LHC.
  - No resonance-like features observed.
  - 95% credibility limits set for several BSM models:
    - m_{jj} > 1.65 - 5.66 TeV.
  - References:
    - Phys. Rev. D 91, 052007 (2015)
- ATLAS 80 pb^{-1} of data at $\sqrt{s}$ = 13 TeV LHC.
  - No BSM signal observed in 3 searches.
  - 95% CL limits set on black holes:
    - Non-thermal (6.8 TeV); thermal (8.3 TeV at M_D = 3 TeV).
  - References:
    - ATLAS-CONF-2015-042 dijet
    - ATLAS-CONF-2015-043 multijet
    - ATLAS-CONF-2015-046 lepton+jet

Backup slides

Simulation

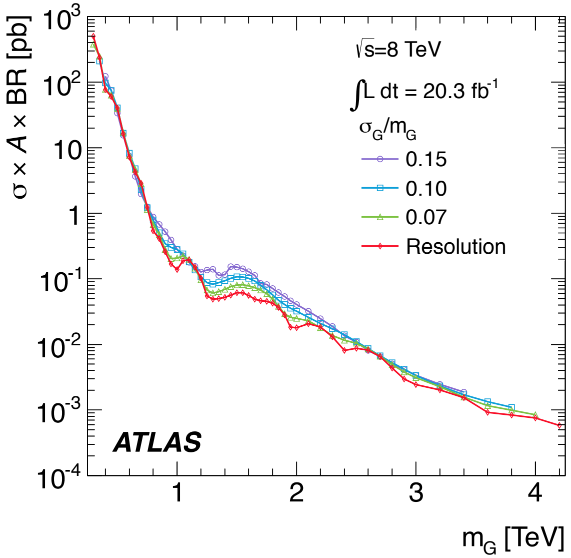
- Background:
  - Simulate QCD using Pythia 8.160 with CT10 PDF and AU2 tune.
- Signals:
  - Excited quarks, q^*
  - Colour-octet scalar model, s8
  - Heavy charged gauge bosons, W'
  - Excited W^* boson
  - Quantum black holes, QBH
- Detector effects simulated with Geant4.
- Minimum bias events are overlaid on hard scattering.
- Simulation calibrated to agree with data.

Systematic uncertainties

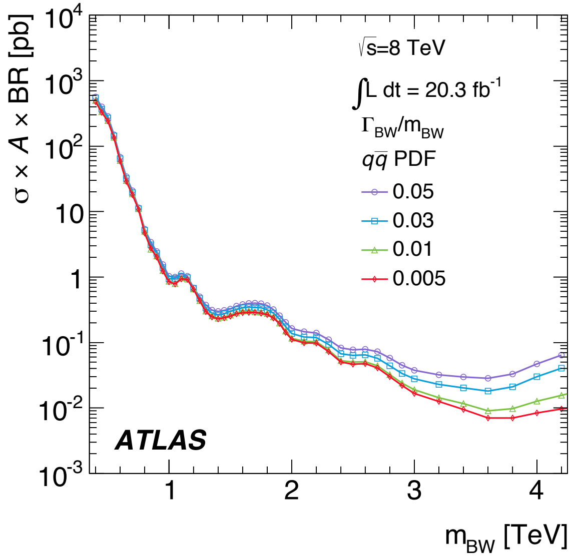
- Background uncertainties:
  - Background fit quality (statistical uncertainty).
    - Systematic uncertainty estimated from pseudo-experiments.
  - Choice of fit function.
    - Add a parameter in function.
- Signal uncertainties:
  - Jet energy scale.
  - Luminosity.
  - Some PDF, renormalization, factorization scale uncertainties.

Generic limits

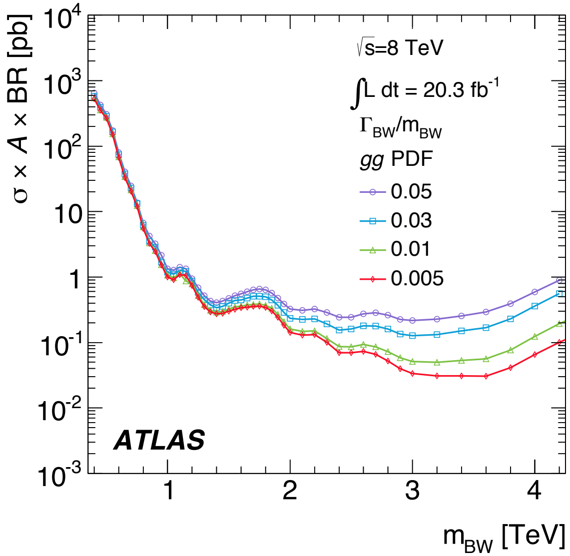
Gaussian m_{jj} distribution



Convolution of Breit-Wigner m_{jj} distribution and CT10 PDF



q q-bar



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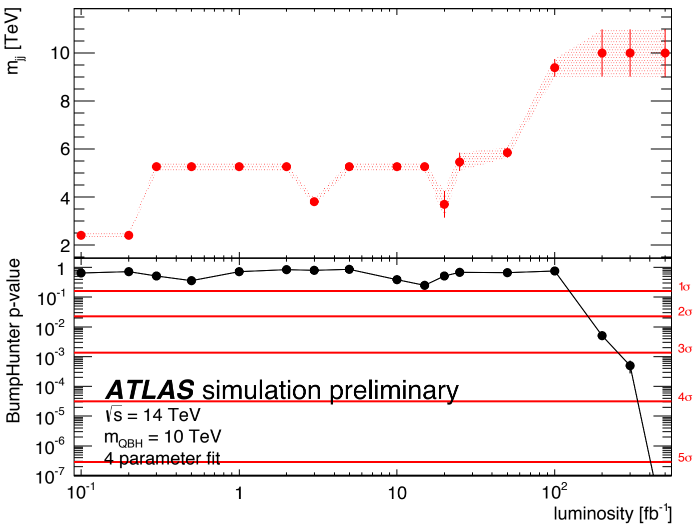
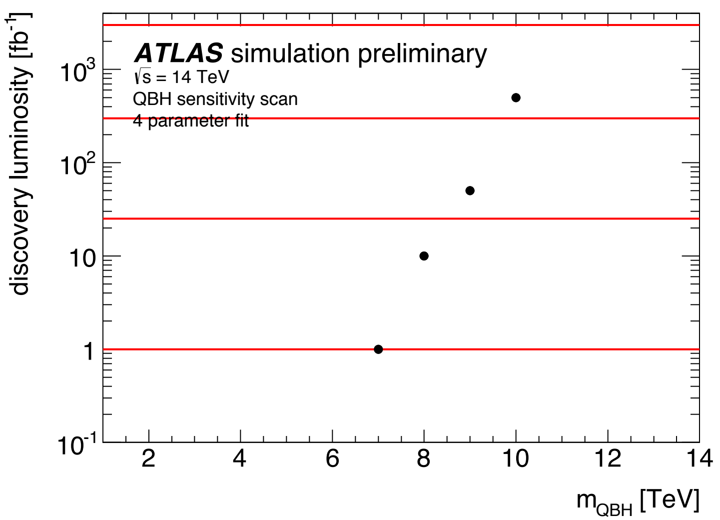
14 TeV dijet QBH expectations

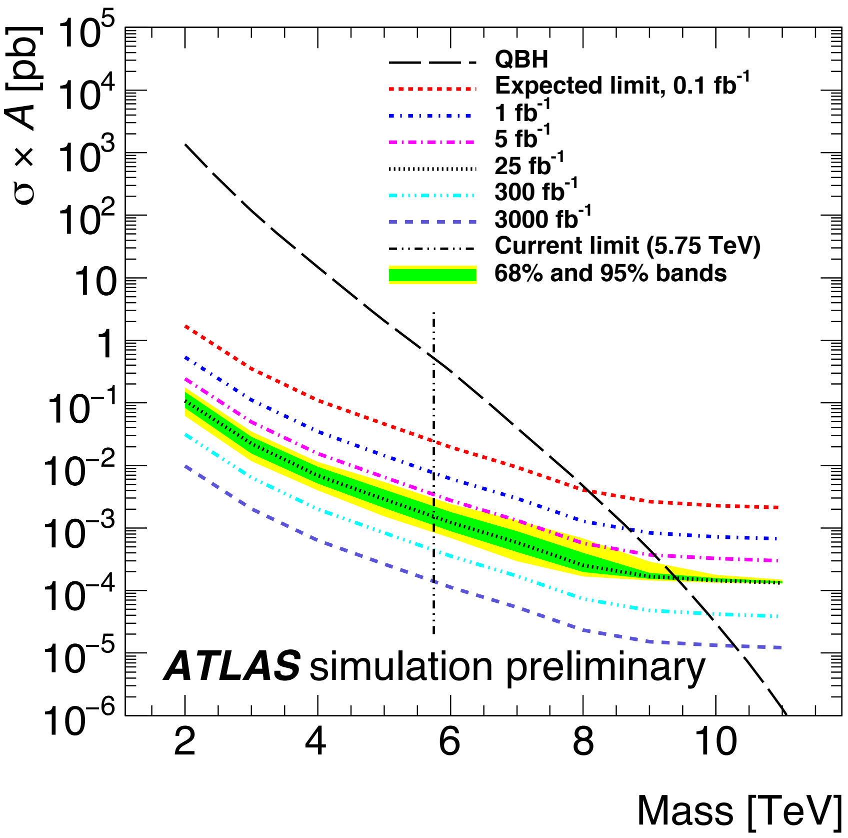


Luminosity scan

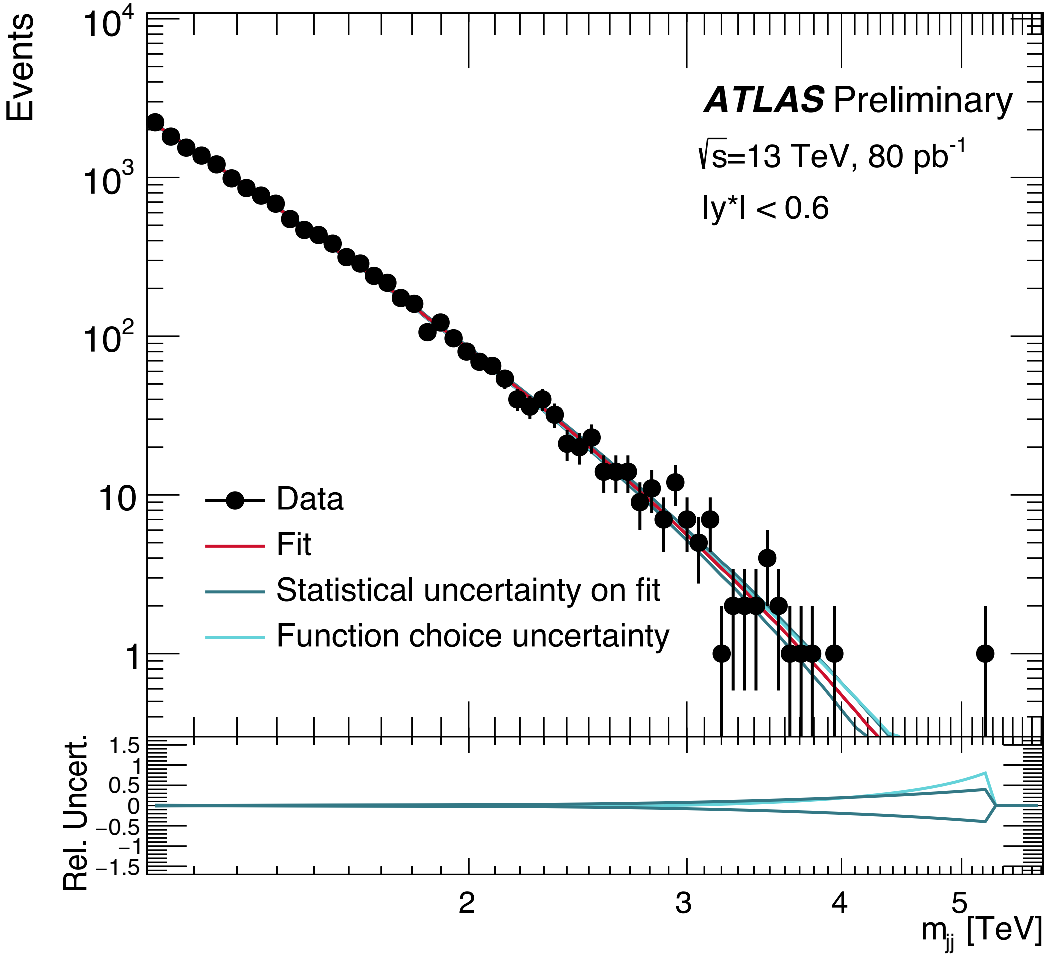


Sensitivity scan

Expected limits

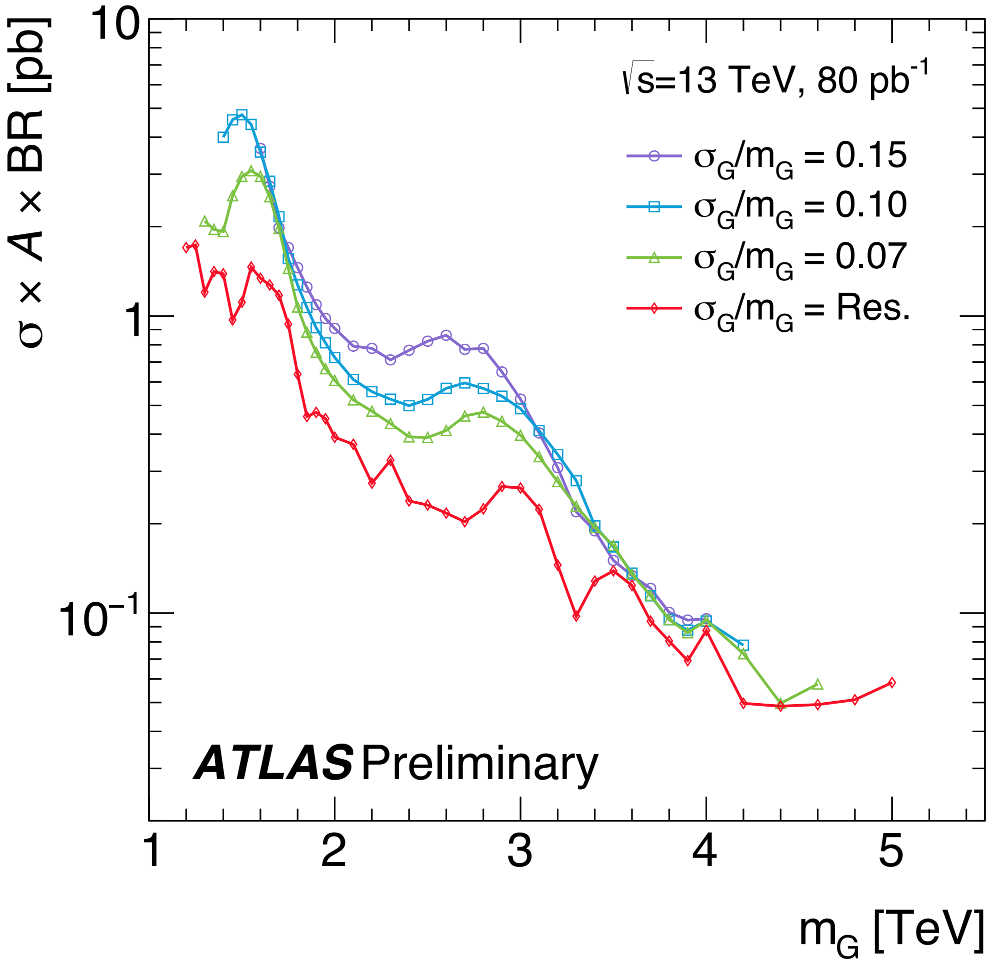


13 TeV dijet mass Results



- χ^2 ~ 60.6/64 dof.
- p-value = 0.75 from BumpHunter search.
- Corresponding z-value is -0.68.
- No evidence for resonance enhancements.

13 TeV Gaussian limits



- Exclude at 95% CL cross sections:
  - 1 – 4 pb at 1.2 – 1.4 TeV,
  - 0.2 – 0.5 pb above 3 TeV.

Multijet analysis strategy

- A series of 10 analytic functions are used.
  - Functions are ranked on goodness of their extrapolation.
  - Baseline function used to predict background and others used to estimate systematic uncertainty.

Step 1: 6.5 pb^{-1} results