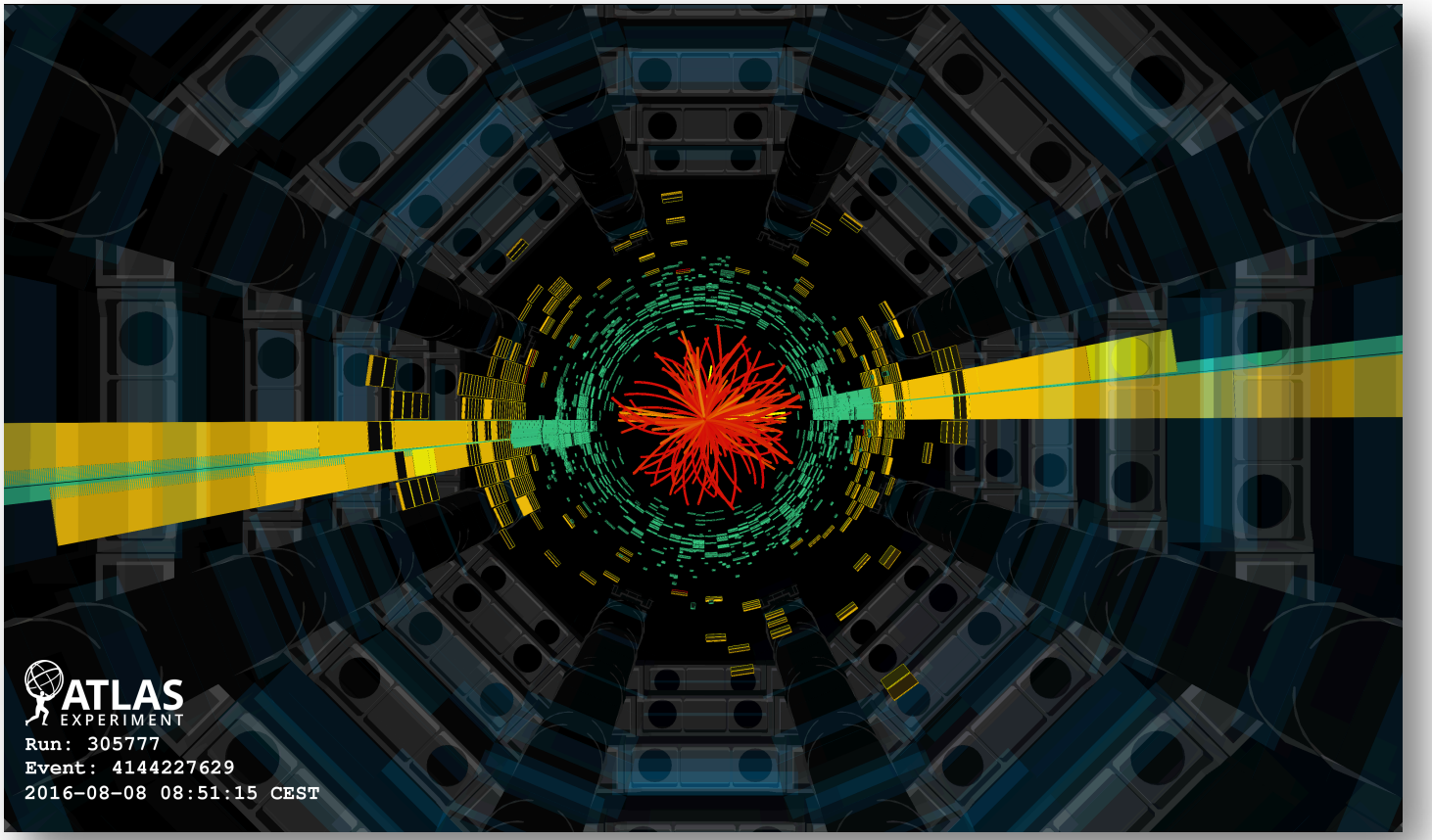
Search for New Phenomena with Dijets @ ATLAS



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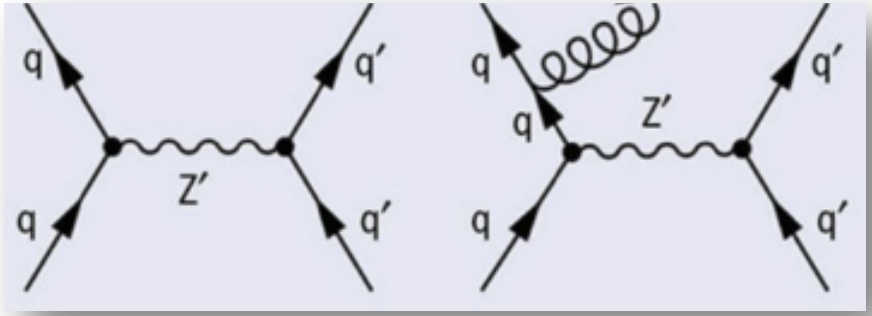
on behalf of the ATLAS Collaboration

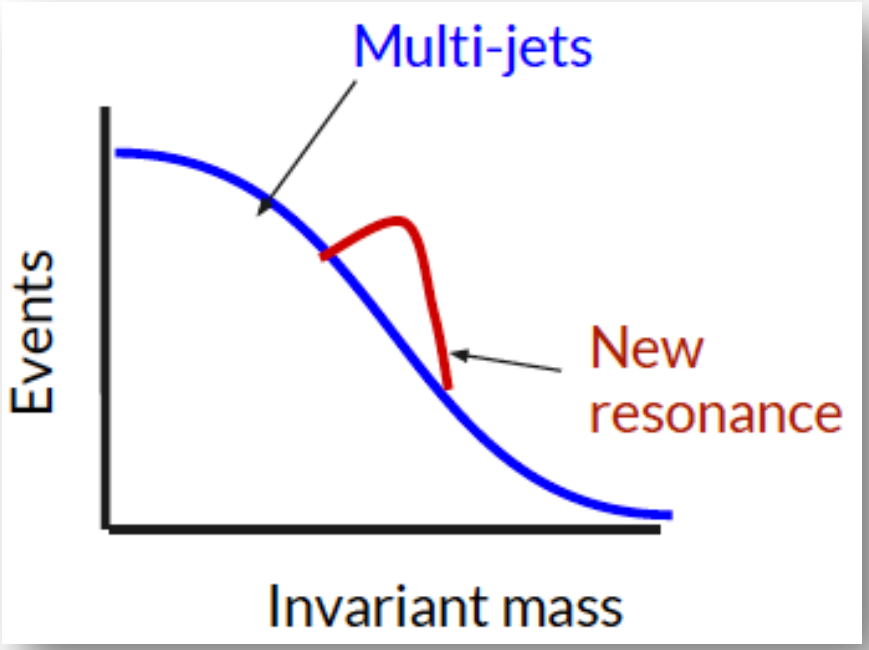
Pheno 2019

Introduction

- **Beyond Standard Model (BSM) physics predicts new resonances decay to a pair of objects**
  - **Di (b)-jet final states with or without associated ISR object**
  - **Dark Matter mediators may show as a resonance in SM particles**



- **Standard Model background processes produce smoothly falling invariant mass spectra**
  - **Look for narrow peak signal**
  - **Model background with parametric function from data**



- **Searches:**
  - **Model independent analyses**
  - **Limits on specific models**

Experimental ingredients

- **Select final state and resonance mass range**
  - **Low mass or high mass in these cases**
- **Look for appropriate trigger and physical objects, select events in unbiased way**
  - **Small-R jets (resolved topologies) / large-R jets (boosted topologies)**
- **Estimate background and systematic variations to be used as nuisance parameters in a fit**
  - **MC statistically limited due to high rate for these final states**
  - **Data-driven background estimation, brings challenges when fitting high statistics distributions**
- **Use favorite peak searching algorithm on invariant masses**
  - **Narrow or wide resonances**
  - **Global fit challenging, sliding window methods**
  - **Local significance of a peak. Set limits if no significant peak found**
- **Compare to simulated signal and put limits on specific models. One dimensional vs mass or two dimensional (coupling-mass plane)**
  - **95% CL limits on σ *X* BR**

Dijet resonances at low mass

Submitted to: Phys. Lett. B.

arXiv:1901.10917

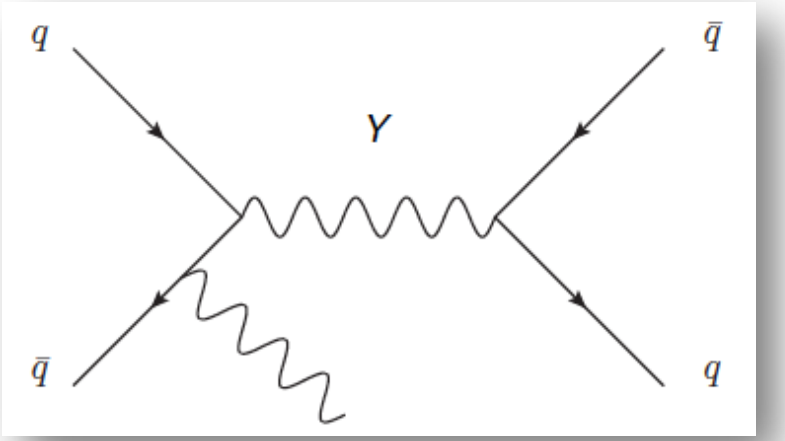
CERN-EP-2018-347
4th February 2019

Search for low-mass resonances decaying into two jets and produced in association with a photon using pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS Collaboration

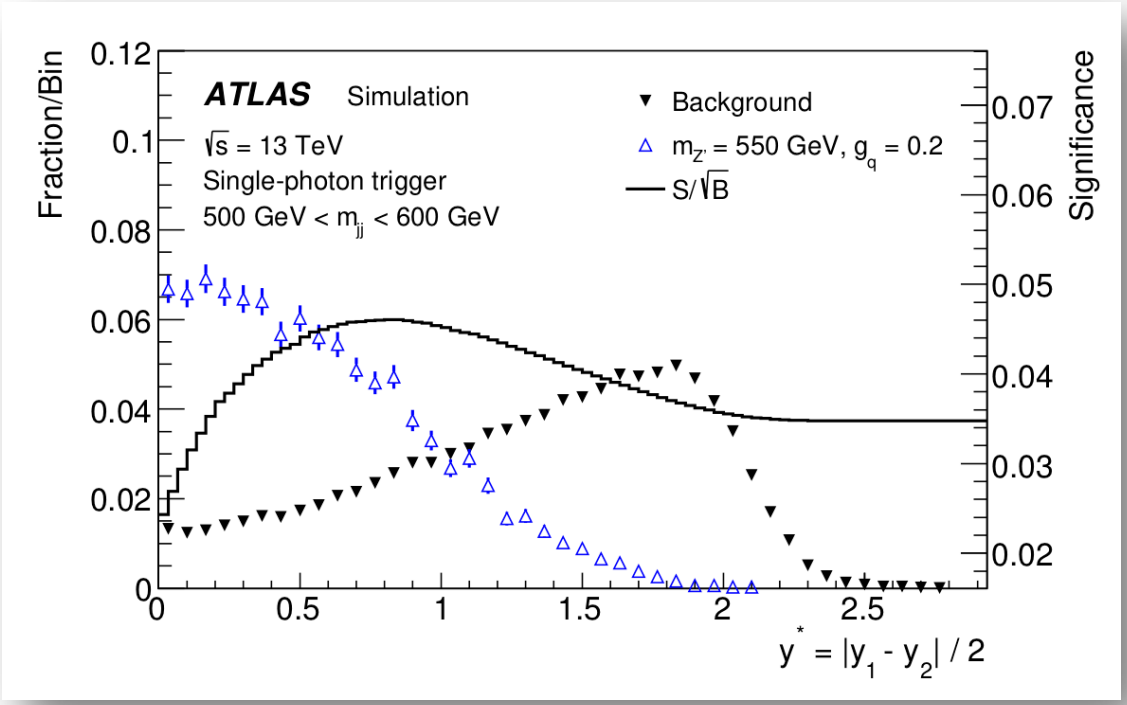
Dijet resonances at low mass

arXiv:1901.10917



- 2015 + 2016 + 2017 data
- Flavor inclusive and 2-btag selections
- SM dijet suppression with y* < 0.75

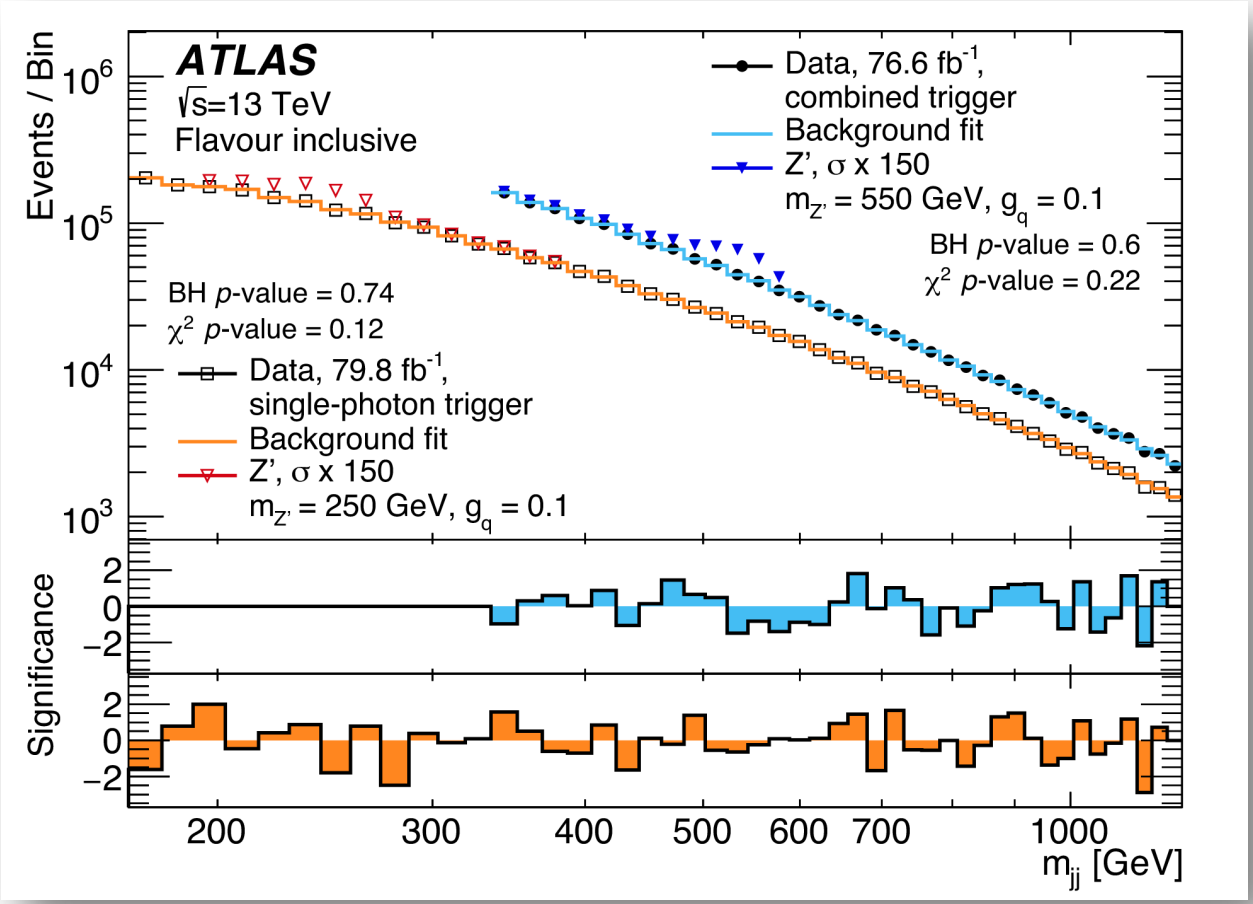
- Trigger on radiated photon to circumvent trigger limitations and explore the low invariant mass region
  - Single-γ trigger for Mjj < 450 GeV
  - γ+2-jets trigger for Mjj > 450 GeV



Dijet resonances at low mass

arXiv:1901.10917

- **SWIFt (sliding windows) background estimate**
  - Choose a “standard” function
  - select a window width around each bin
  - Use largest possible width with a fit p-value > 0.5
  - repeat for each bin
  - Choose function with largest p-value (3-5 parameters)
  - Function with lowest χ^2 (with p-value>0.05) as systematic estimate

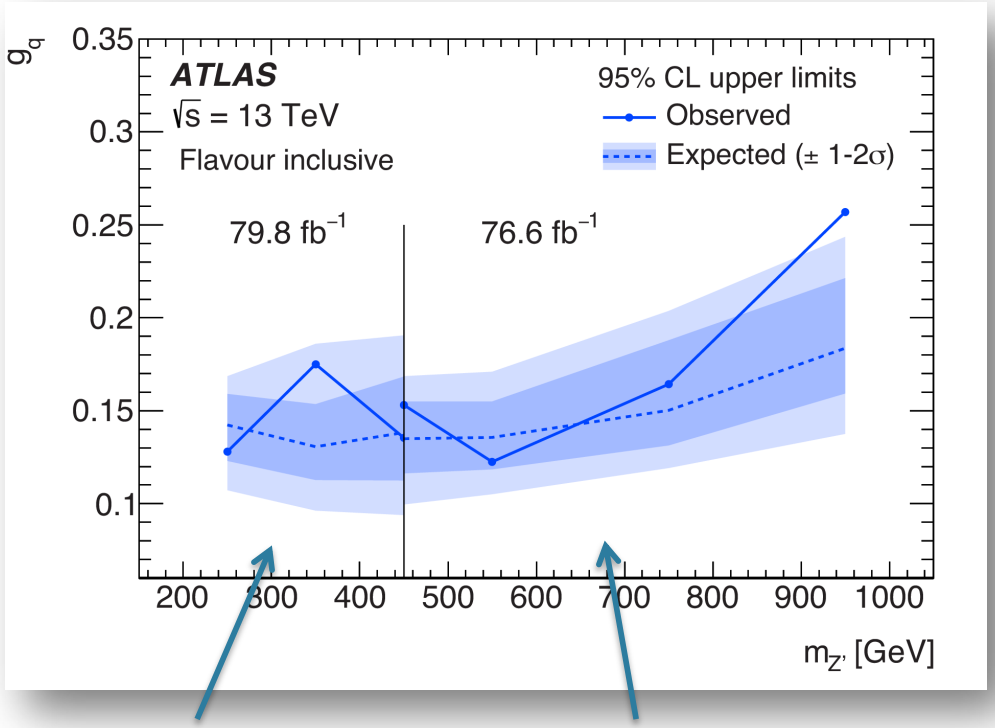


$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x + p_5 (\ln x)^2}$$

Dijet resonances at low mass

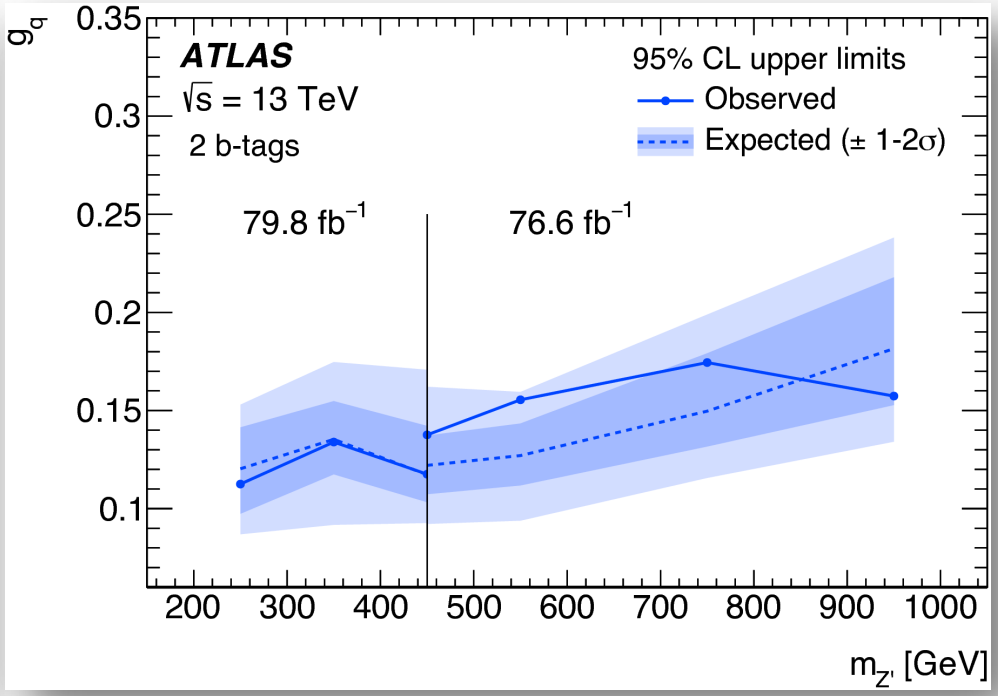
arXiv:1901.10917

- **Excluded values of the coupling between a Z' and quarks @ 95% CL**
- **2 b-tag selection sensitive to models with enhanced couplings to heavy quarks, slightly better sensitivity than flavor-inclusive couplings**



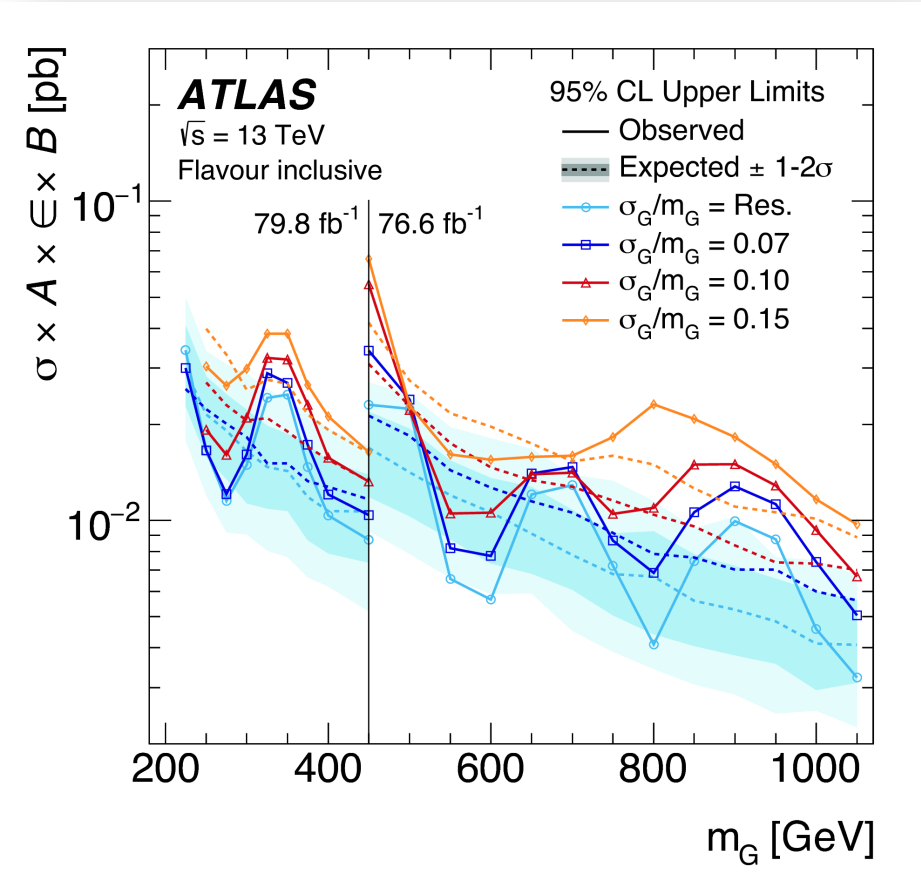
Single photon trigger

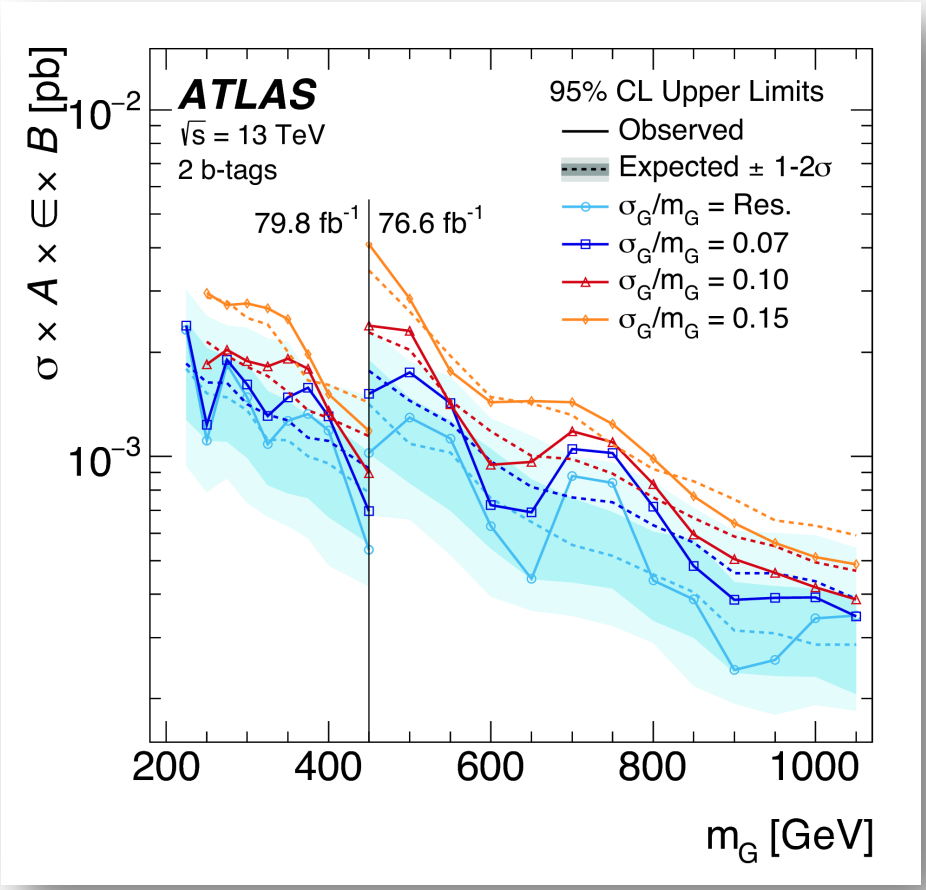
Combined trigger



Dijet resonances at low mass

arXiv:1901.10917





- **Upper limits on Gaussian-shape contributions to the dijet mass distributions**
- **Limits on intrinsically narrow contributions with Gaussian mass resolution ranging from 8% to 3%**

Dijet resonances at high mass

ATLAS CONF Note

ATLAS-CONF-2019-007

17th March 2019

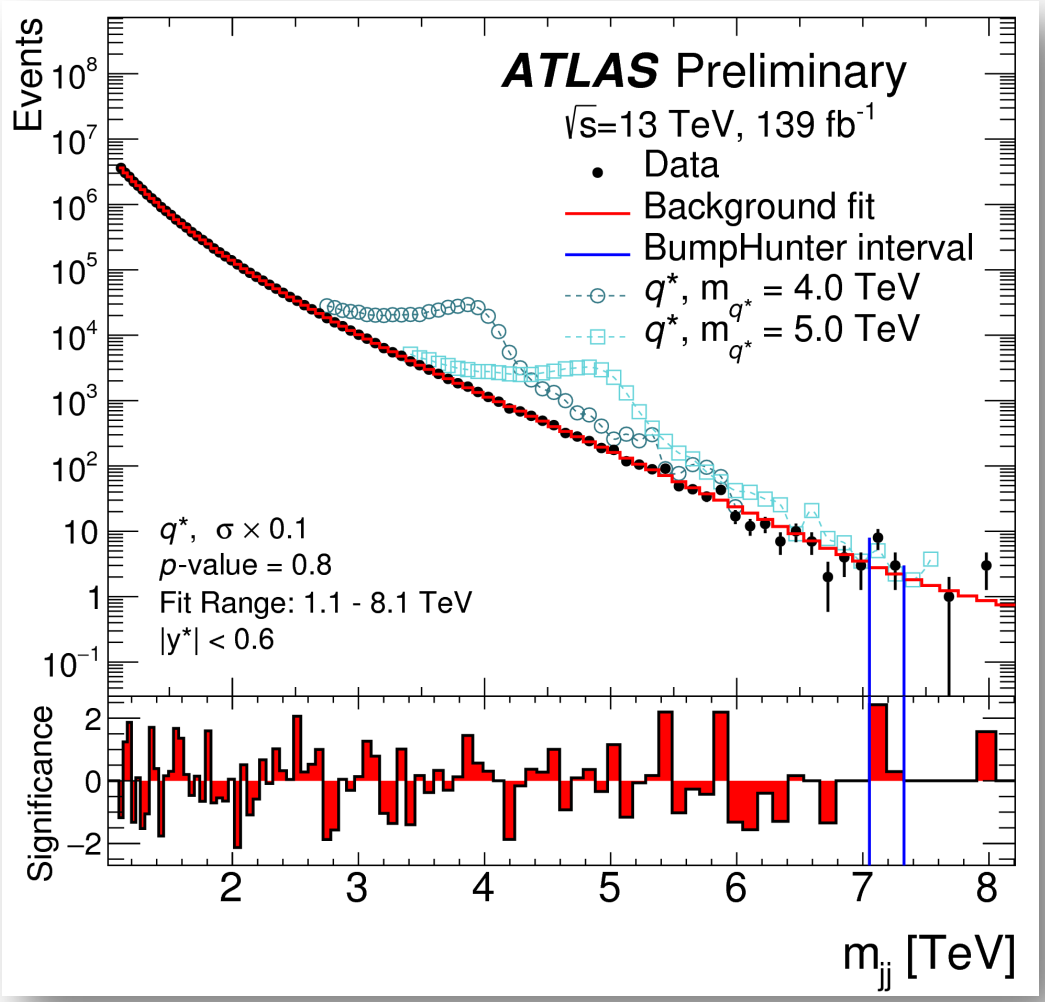
Search for New Phenomena in Dijet Events using $139\,\mathrm{fb}^{-1}$ of pp collisions at $\sqrt{s} = 13\,\mathrm{TeV}$ collected with the ATLAS Detector

The ATLAS Collaboration

Dijet resonances at high mass

ATLAS-CONF-2019-007

- Searches for BSM signals at high masses (large fraction of collision energy)
- Smoothly falling (QCD) dijet invariant mass spectrum
- New resonant state may appear as localized excess (probe high mass region)



- Full Run2 data (139 fb^{-1})
  - Single jet trigger requirement ($p_T^{\text{lead-jet}}$ > 420 GeV)
  - Low end mass range determined by trigger threshold
  - y* < 0.6 (reduce QCD)
- Variable binning accounting for detector resolution
- Background estimate with SWIFt
  - 4-parameter fit function
- Look for localized excesses with BumpHunter

Dijet resonances at high mass

ATLAS-CONF-2019-007

- Searches for BSM signals at high masse
- Smoothly falling (QCD) dijet invariant ma
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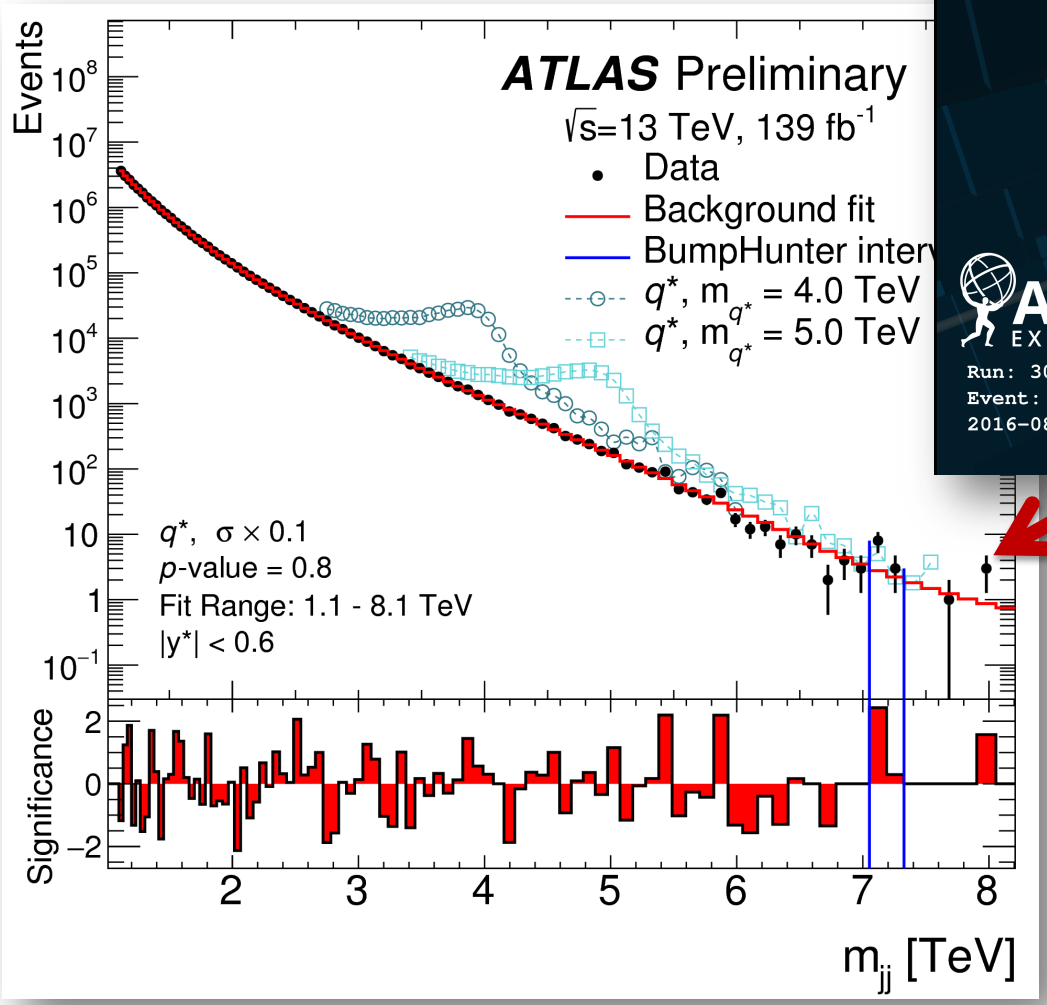
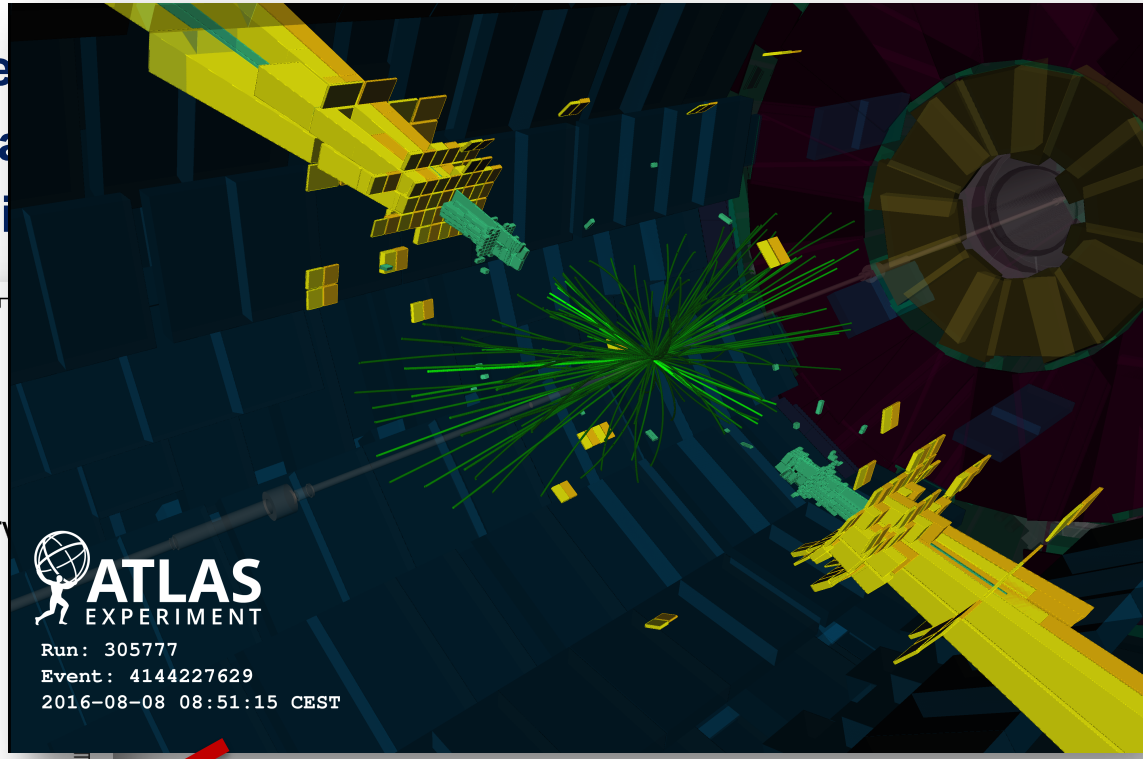


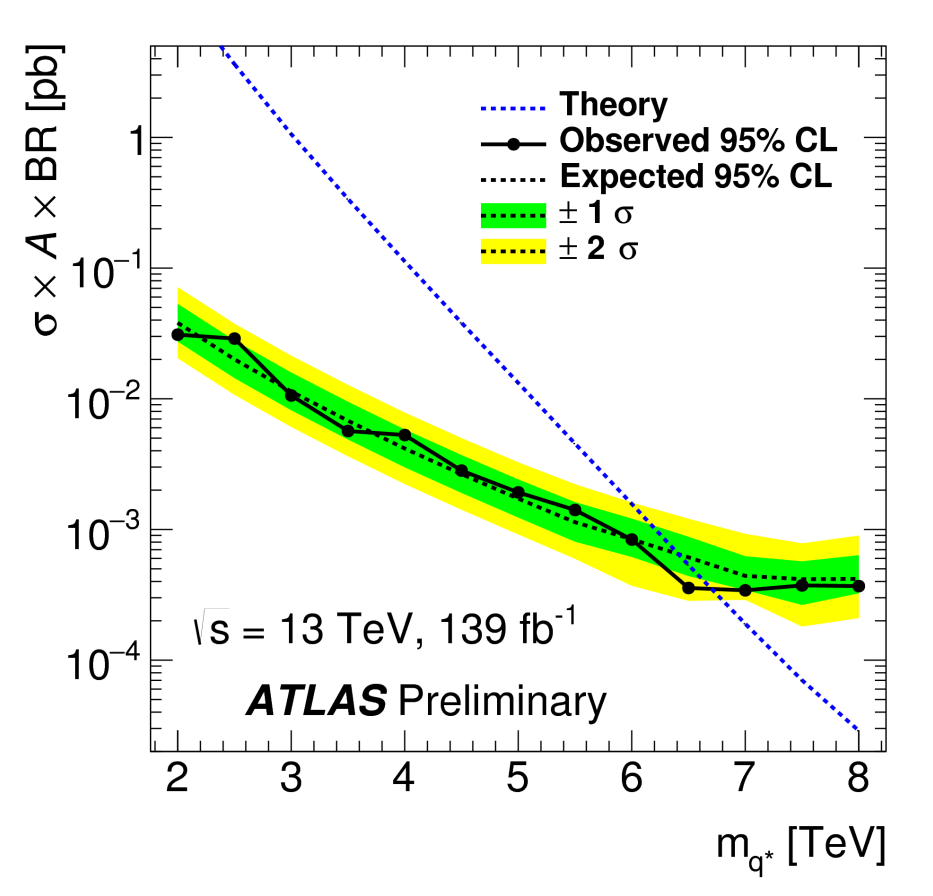


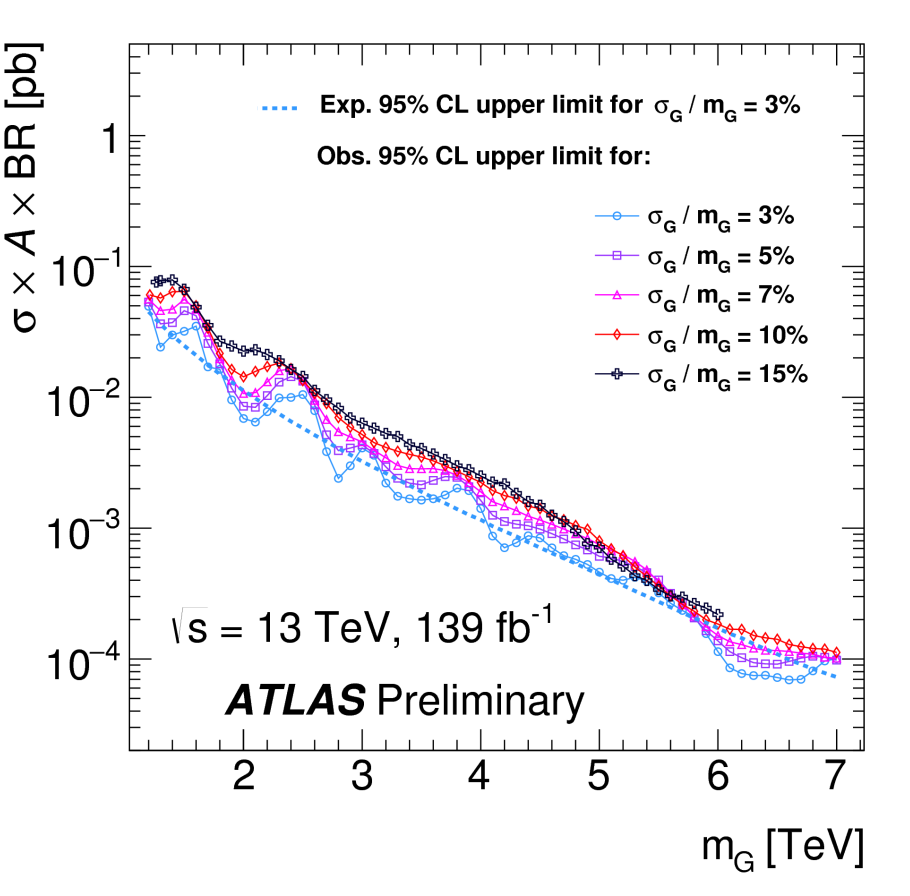
- Variable binning accounting for detector resolution
- Background estimate with SWIfT
  - 4-parameter function fit
- Look for localized excesses with BumpHunter

Dijet resonances at high mass

ATLAS-CONF-2019-007

- **Benchmark model q* excluded up to 6.7 TeV**
- **Search also for generic Gaussian shaped signals with different widths**
  - **(excluded up to 6 TeV)**





(boosted) $b\bar{b}$ low mass resonances

ATLAS CONF Note

ATLAS-CONF-2018-052

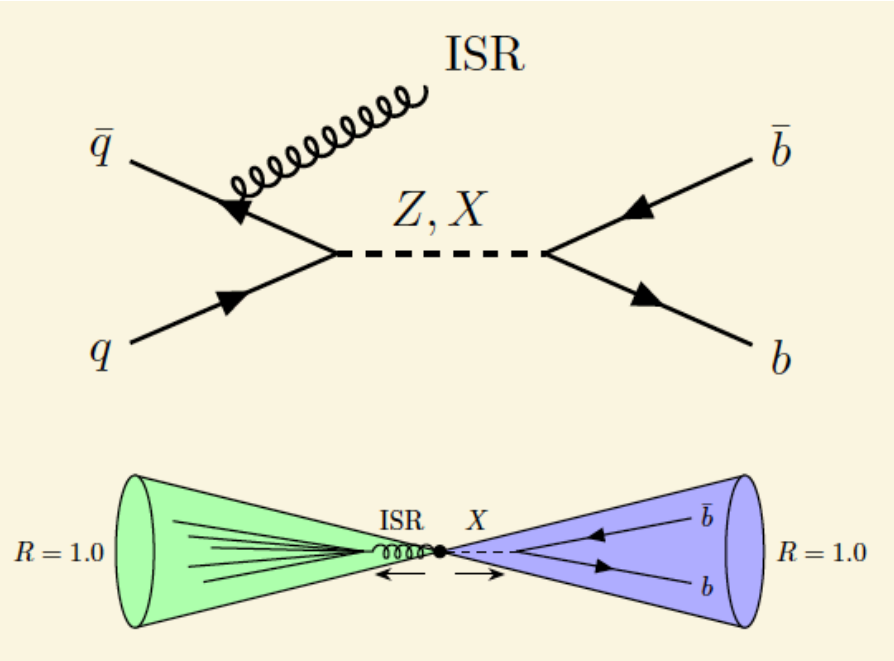
26th November 2018

Search for boosted resonances decaying to two b-quarks and produced in association with a jet at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

$b\bar{b}$ low mass resonances

ATLAS-CONF-2018-052



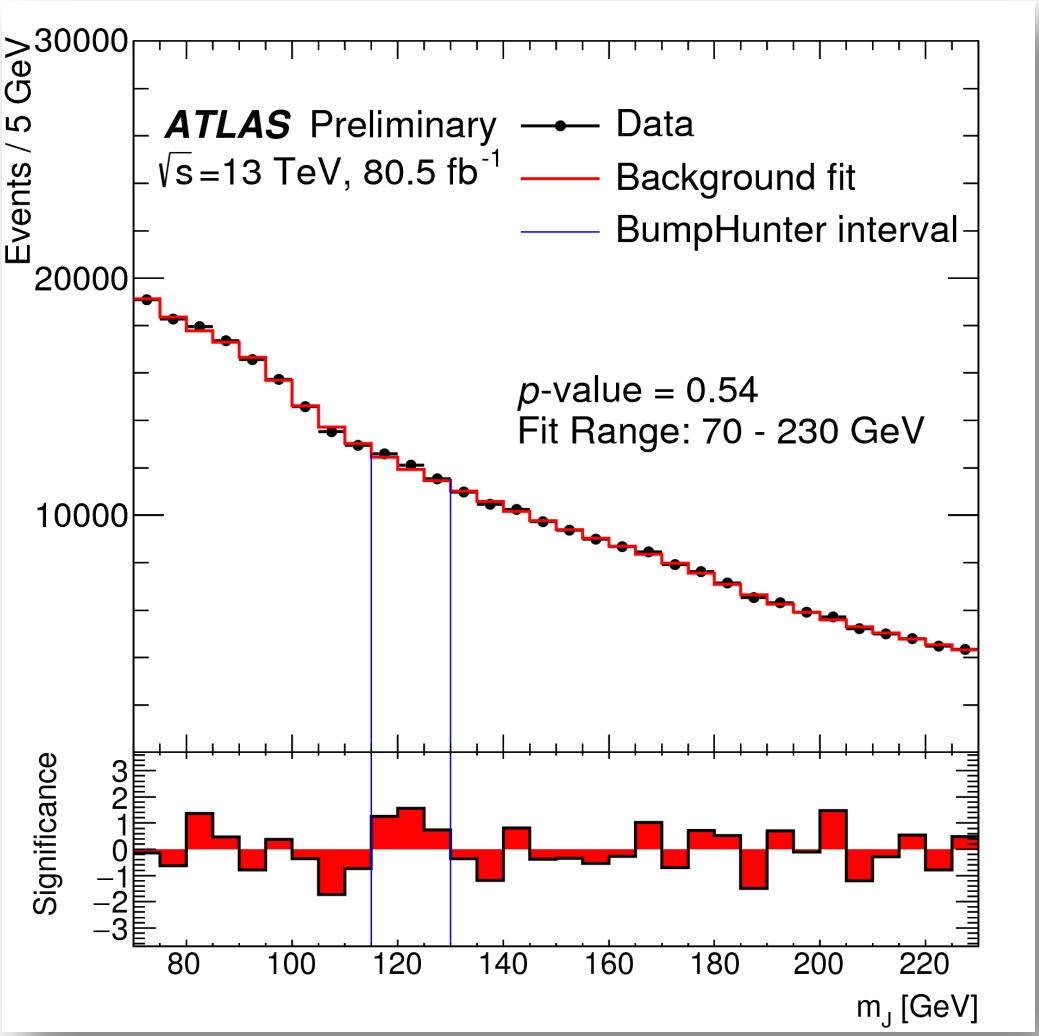
- **Search for dark matter through boosted decays to $b\bar{b}$ + ISR jet / photon**
  - **ISR trigger event allowing low mass mediator search**
- **Sensitive to new mediators with Higgs-like couplings through $\bar{X}$->bb decays**
  - **Benchmark Z' model with democratic couplings**
- **Signature: two large-R jets (1 b-tagged)**

- **Many choices in reconstructing large-R jets**
  - **radius:** increasing containment of signal
  - **Grooming:** remove pile-up cluster and soft radiation
  - **Use of tracking information:** better angular resolution for substructure

$b\bar{b}$ low mass resonances

ATLAS-CONF-2018-052

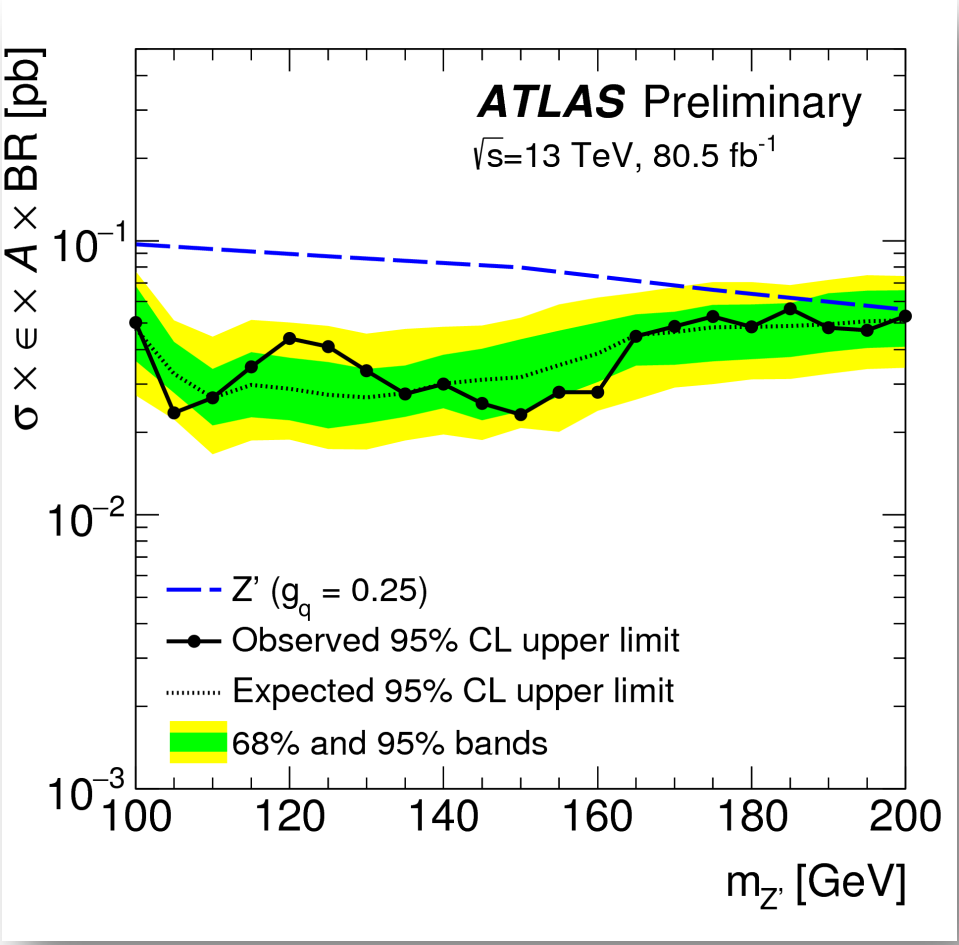
- **Search for new physics with model-independent tools**
  - **SWIFt + BumpHunter**
  - **Model quite consistent with data (BH p-value = 0.54)**

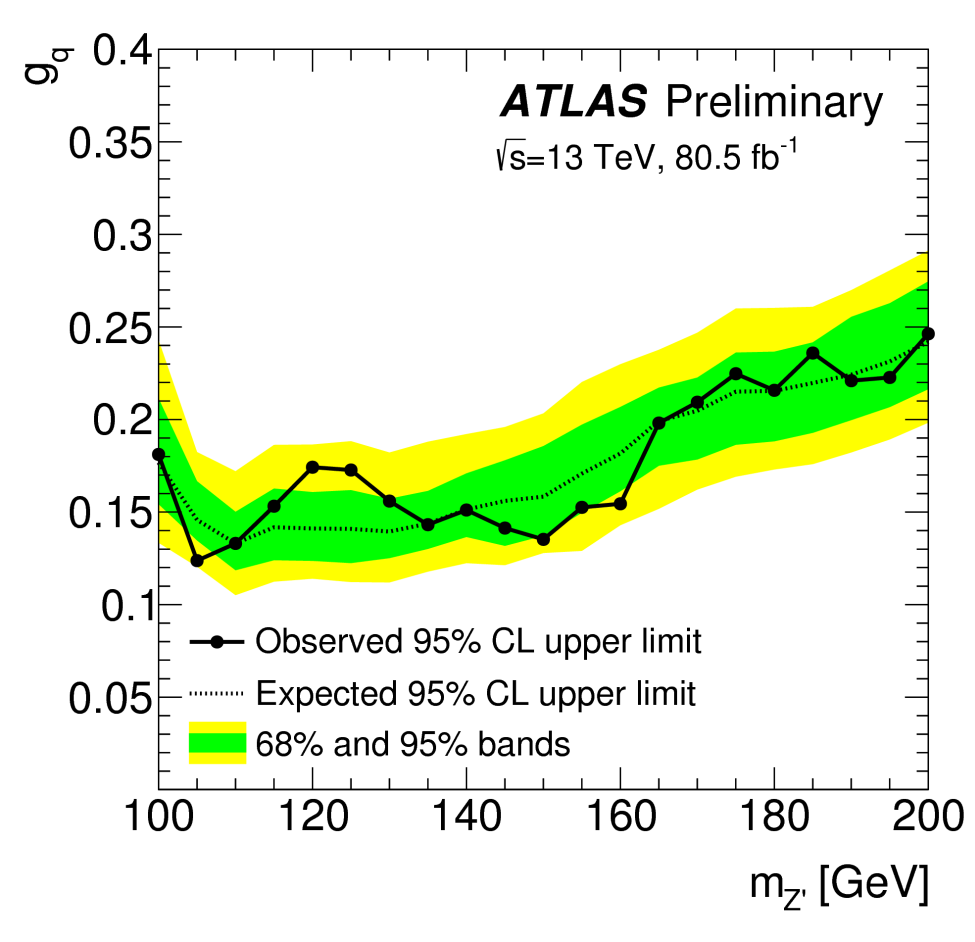


$b\bar{b}$ low mass resonances

ATLAS-CONF-2018-052

- **Axial Z' exclusion limits translated into limits function of the DM coupling**





$b\bar{b}$ low mass resonances

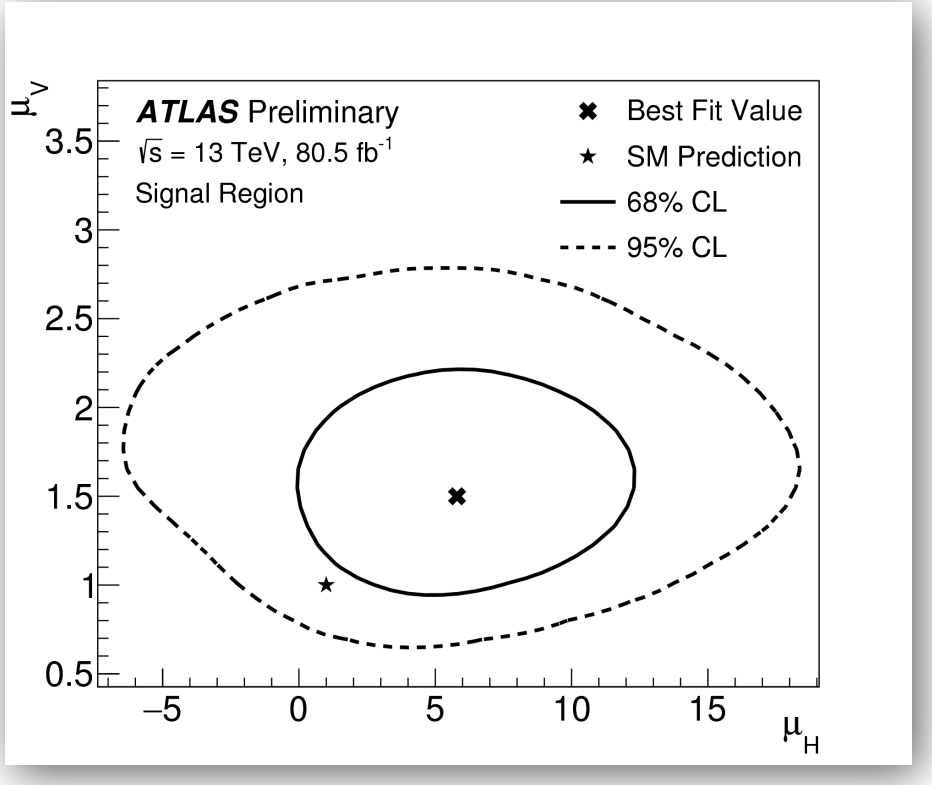
ATLAS-CONF-2018-052

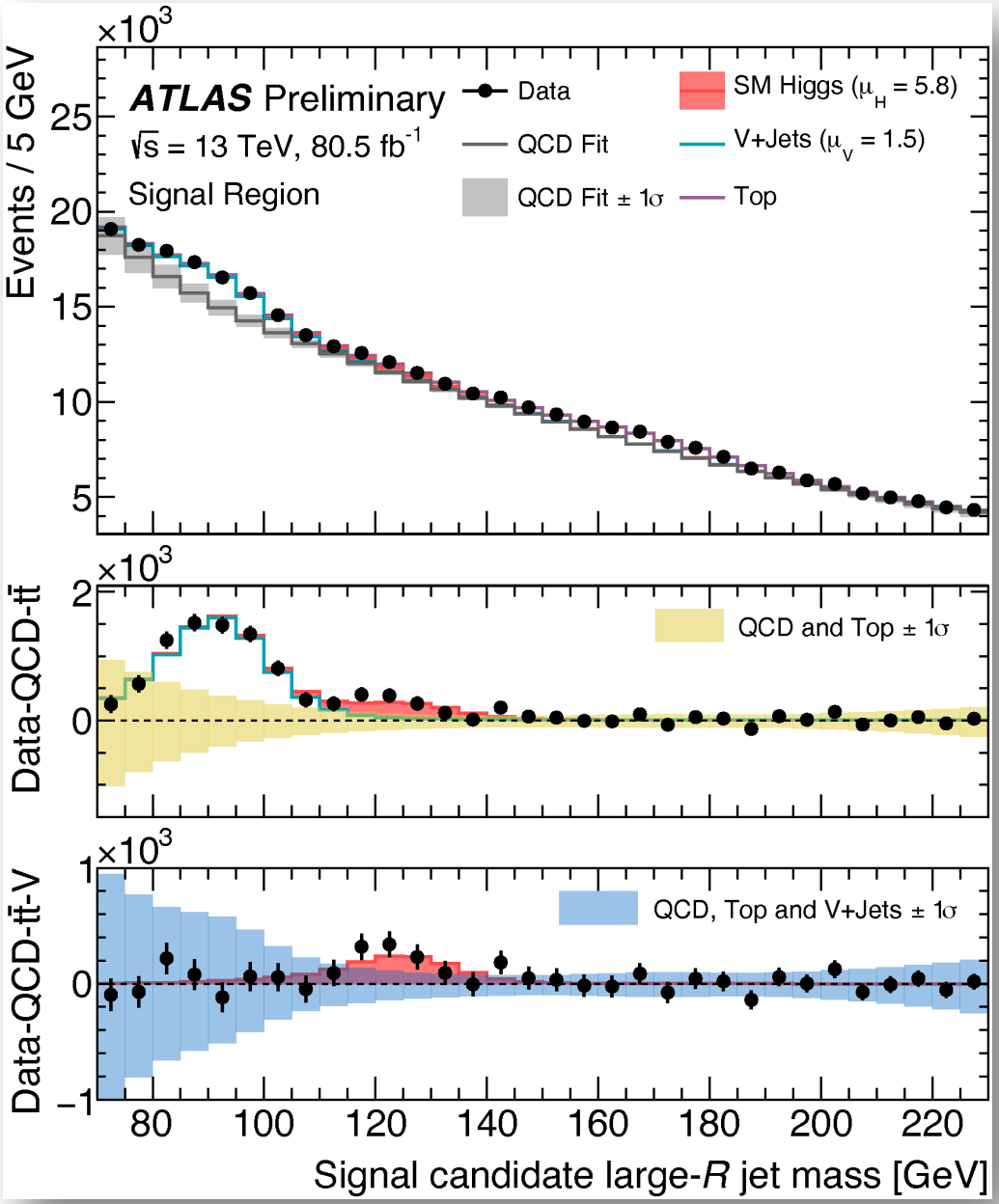
- **V+jets μ measurement: 5 σ significance**

$$\mu_V = 1.5 \ \pm 0.22 \pm 0.29/0.25 \ (\text{syst.}) \ \pm 0.18 \ (\text{th.})$$

- **H+jets μ measurement: 1.6 σ significance**

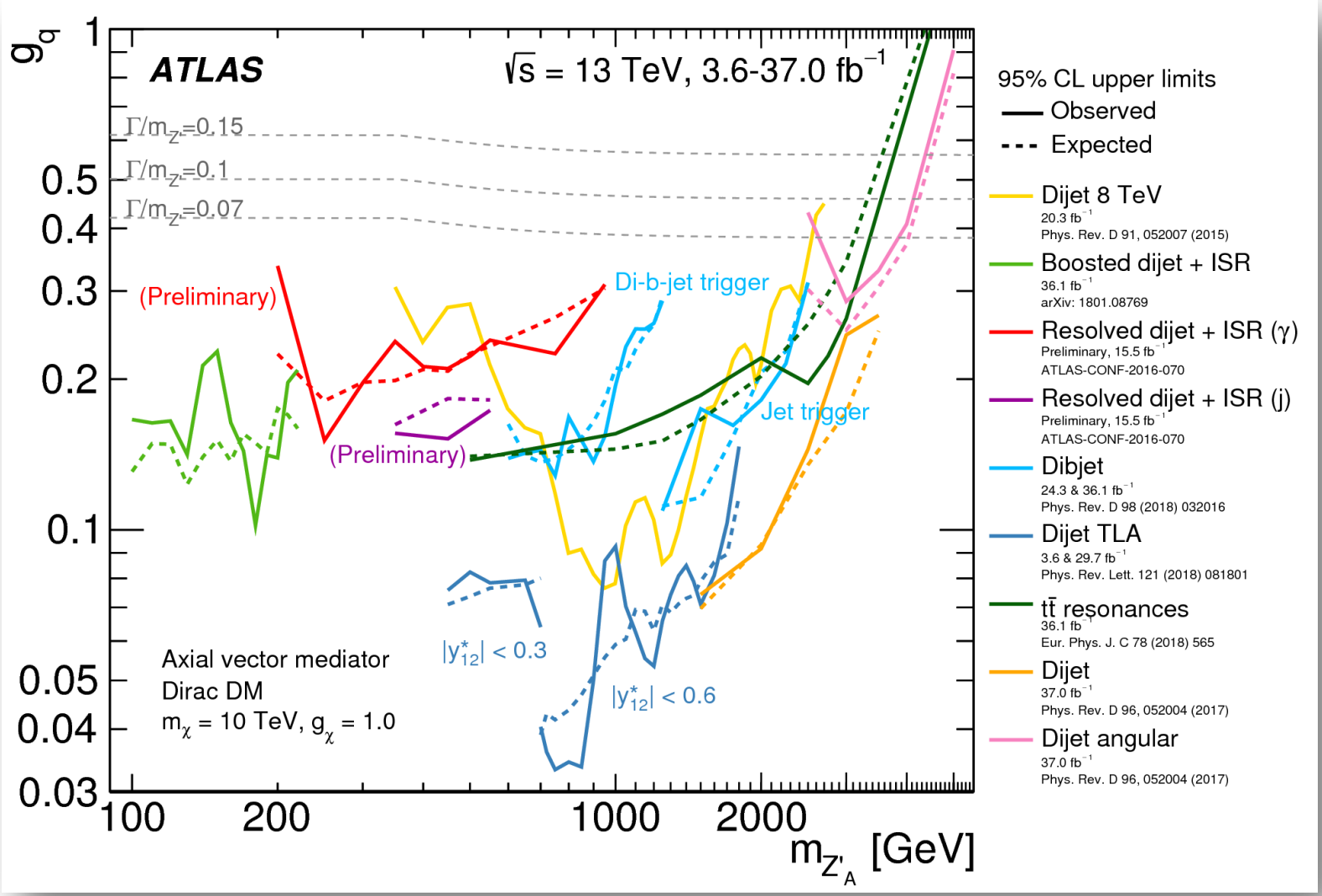
$$\mu_H = 5.8 \ \pm 3.1(\text{stat.}) \pm 1.9 \ (\text{syst.}) \ \pm 1.3 \ (\text{th.})$$





Dijet search status

Dijet search contours for 95% CL upper limits on the coupling g_q as a function of the resonance mass $m_{Z'}$ for the leptophobic axial-vector Z' model



Conclusions

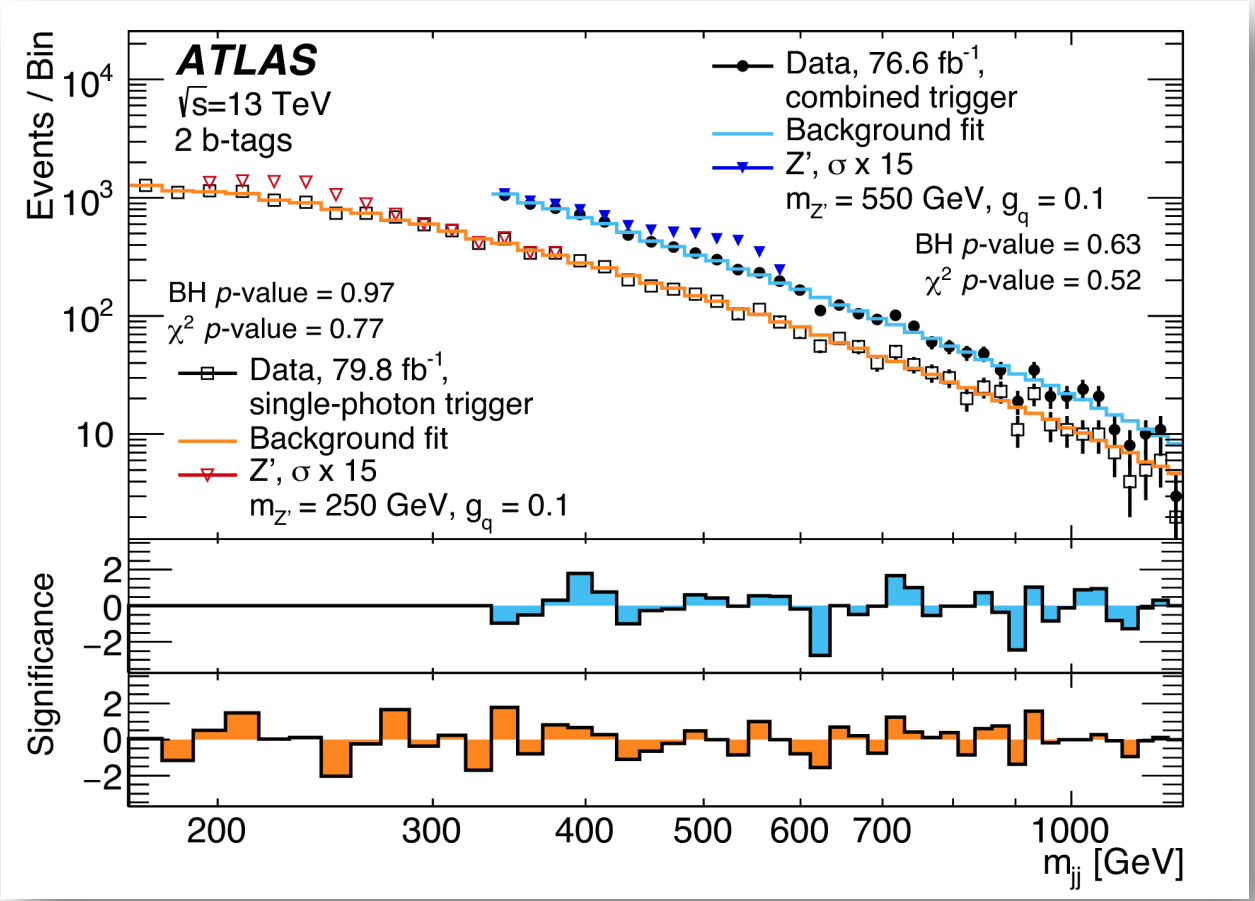
- Search for new resonances is a key goal of LHC experiments
- New results in BSM resonances searches decaying to a pair of SM objects
  - No excesses in ATLAS data so far
  - Constraints in several benchmark models
- Significant improvements due to
  - increased datasets (full Run 2)
  - Better understanding of detectors, better triggers and object definitions
  - Boosted and resolved topologies
  - Sensitivity to heavy quarks couplings
  - Improved background model and fitting techniques
  - Unexpected findings can be around the corner!

Back Up

Dijet resonances at low mass

arXiv:1901.10917

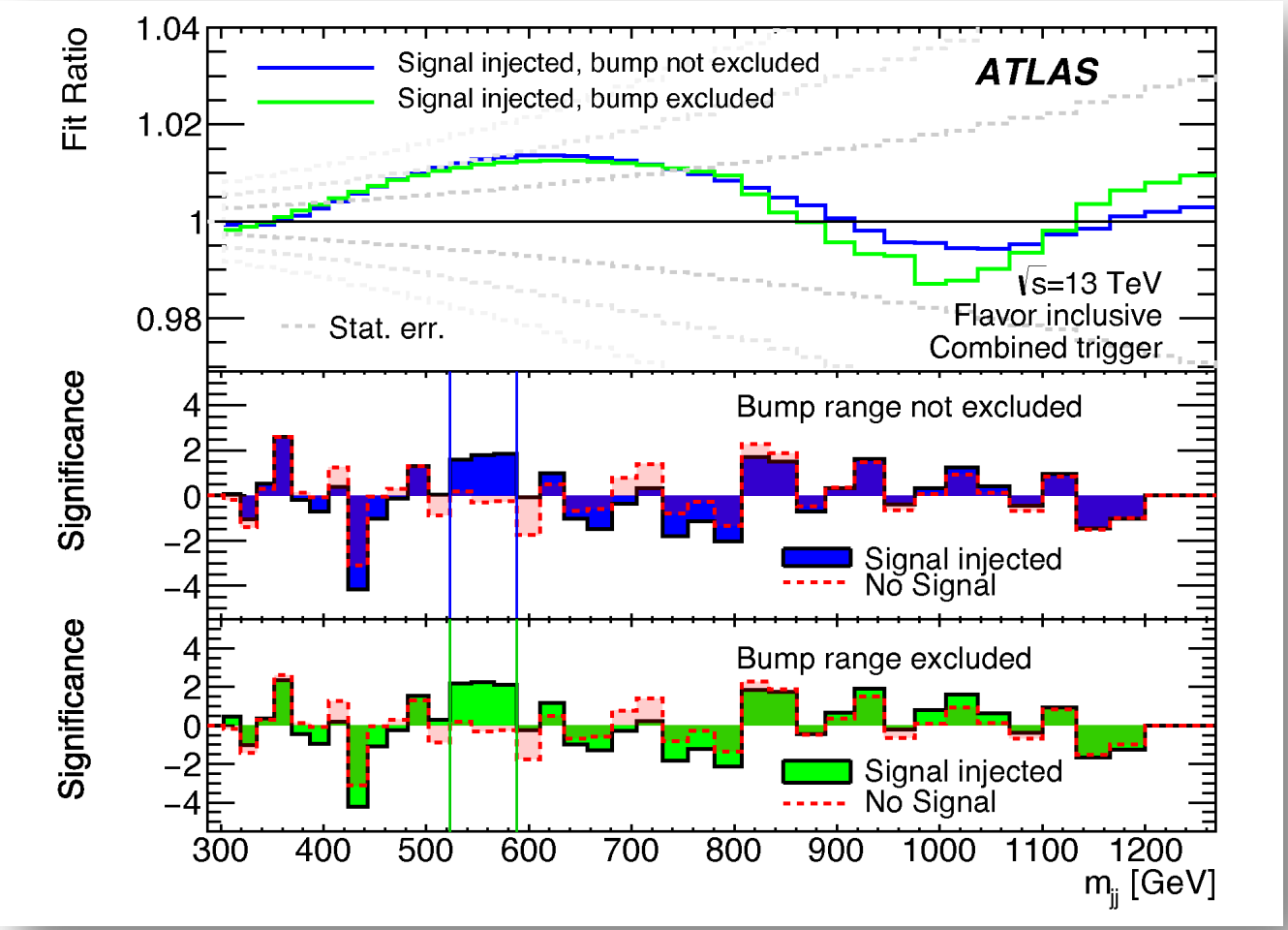
- **SWIFt (sliding windows) background estimate**
  - **Choose a "standard" function**
  - **select a window width around each bin**
  - **Use largest possible width with a fit p-value > 0.5**
  - **repeat for each bin**
  - **Choose function with largest p-value (3-5 parameters)**
  - **Function with lowest p-value as systematic estimate**



$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x + p_5 (\ln x)^2}$$

Dijet resonances at low mass

arXiv:1901.10917

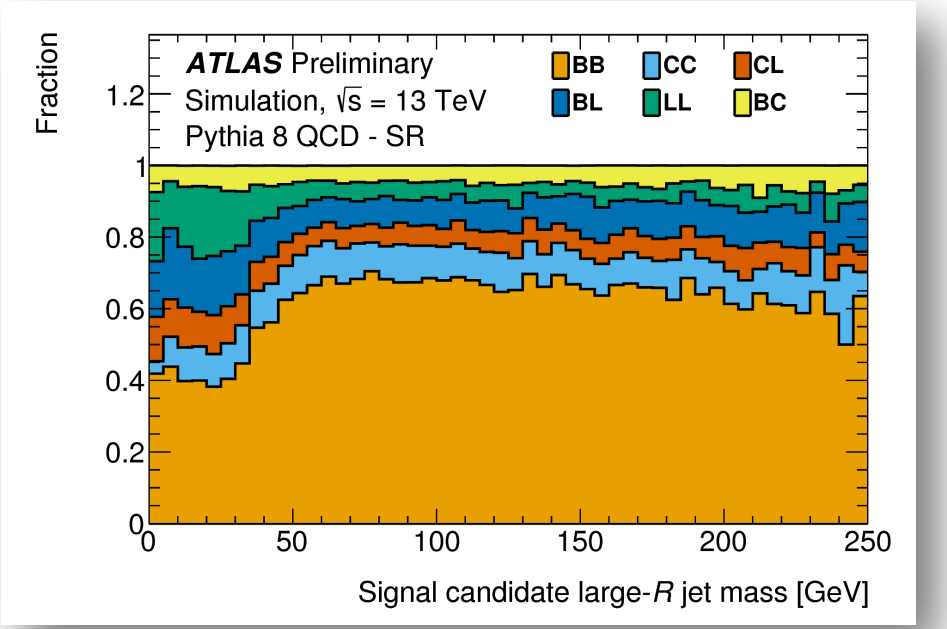


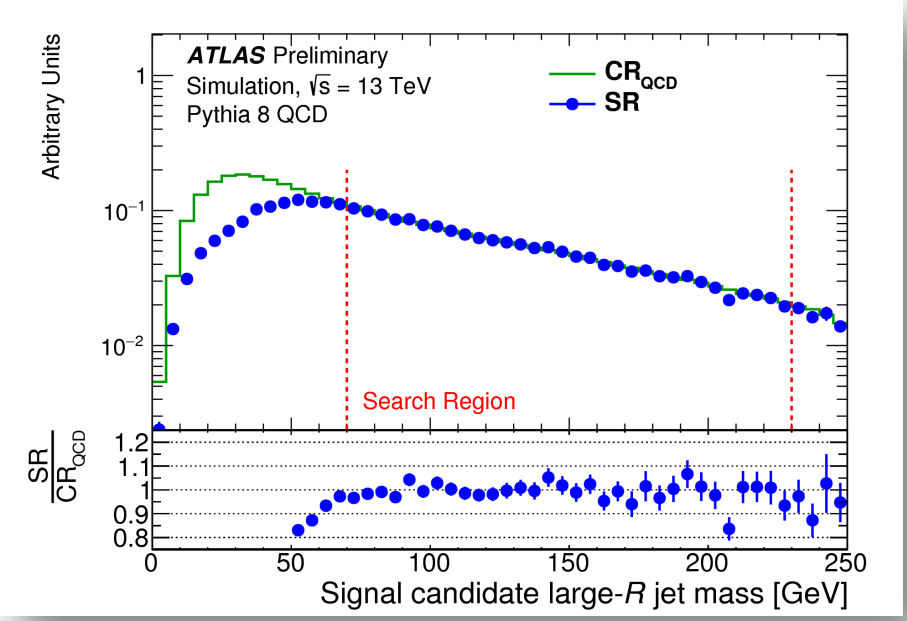
Signal injection test: test robustness of background estimation method within the search phase. The test demonstrates that the presence of a nearly detectable signal, namely one with a signal strength slightly below the threshold needed by the BumpHunter algorithm to trigger exclusion of the corresponding mjj window from the fit range, does not significantly change the background estimation with respect to the background-only case.

$b\bar{b}$ low mass resonances

ATLAS-CONF-2018-052

- **Event classification**
  - Signal and validation regions defined based on number of b-tagged sub-jets
  - Predict flavor composition of dijet background in the SR





- **Dijet background**
  - Modeled with exponential polynomials
  - Found to be unbiased in SR and CR within the search region

Dijet resonances with an isolated lepton

ATLAS CONF Note

ATLAS-CONF-2018-015

May 29, 2018

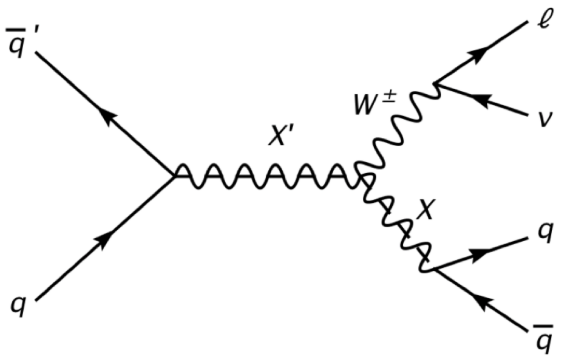
Search for dijet resonances in events with an isolated lepton using $\sqrt{s}$ = 13 TeV proton–proton collision data collected by the ATLAS detector

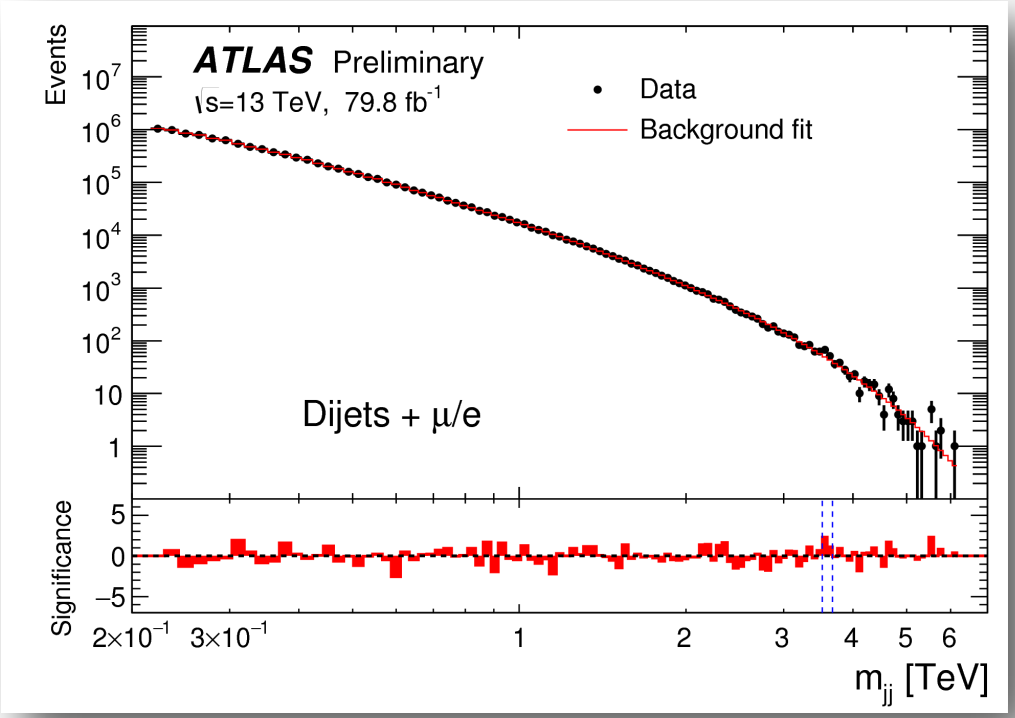
The ATLAS Collaboration

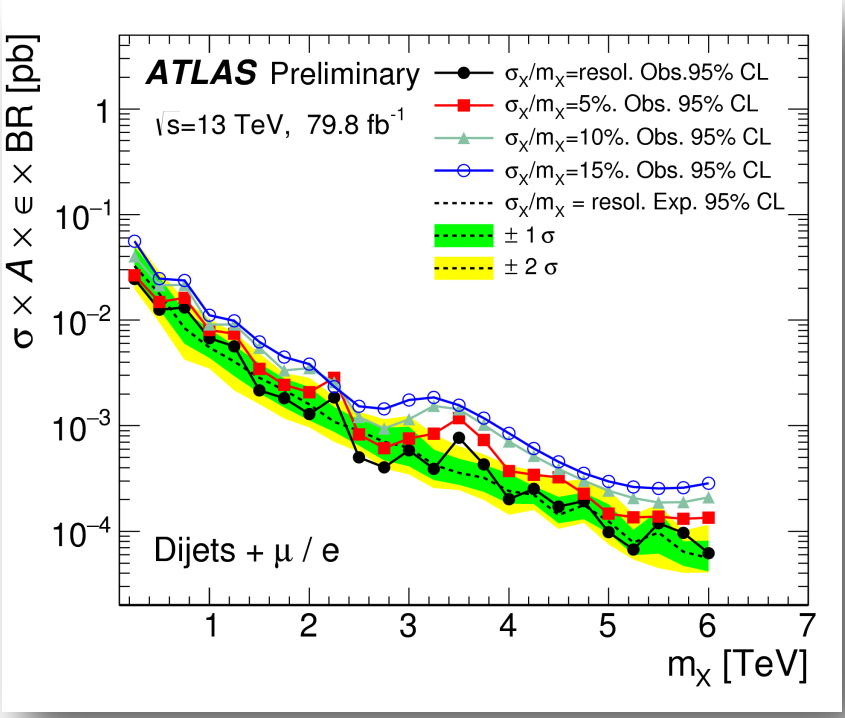
Dijet resonances with a lepton

ATLAS-CONF-2018-015

- New experimental signature
- Use single electron or muon trigger to extend m_{jj} region below 1 TeV
- Background model based on 5 parameter fit function and SWIFt







Limits on BSM signal approximated by Gaussian contributions of various widths