Boosting the Search for New Physics in $b\bar{b}$ Events

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APP and HEPP Conference 2019

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Overview

NEW ATLAS result using 80 fb^{-1} sqrt(s) =13 TeV dataset

ATLAS CONF Note

ATLAS-CONF-2018-052

26th November 2018

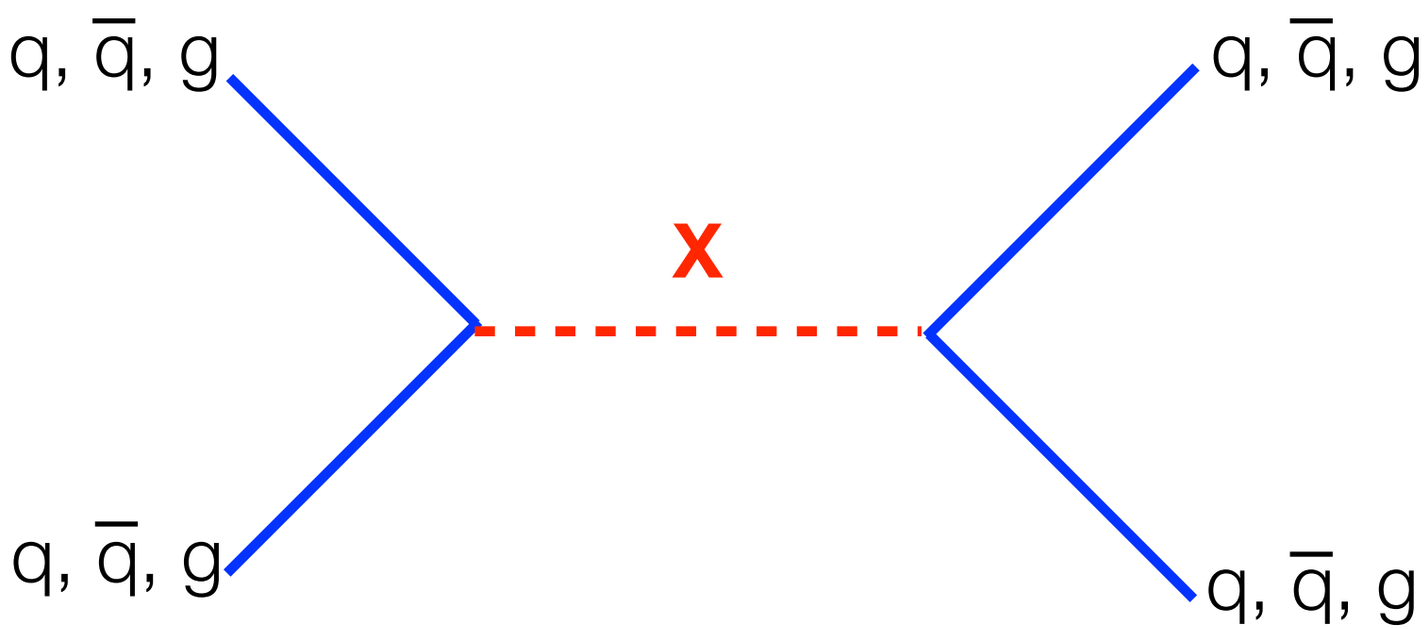
Search for boosted resonances decaying to two b-quarks and produced in association with a jet at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

ATLAS-CONF-2018-052

Motivation - Why pairs of quarks?

LHC collides protons (quarks & gluons)



New particles directly produced must couple to quarks or gluons

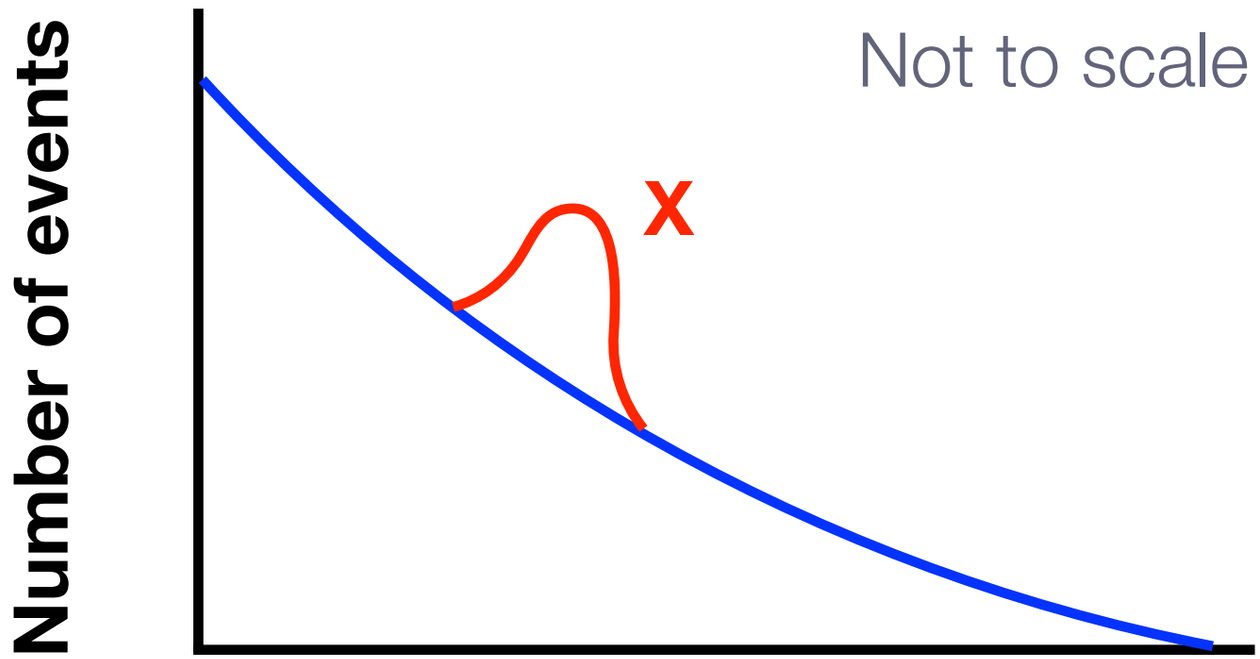
Expect them to decay to quarks or gluons too

Quarks are special

Only particles which couple to EM, Weak, Strong Force & the Higgs

Motivation - Why pairs of quarks?

Powerful model independent search for new physics



… But we have to fight huge QCD background!

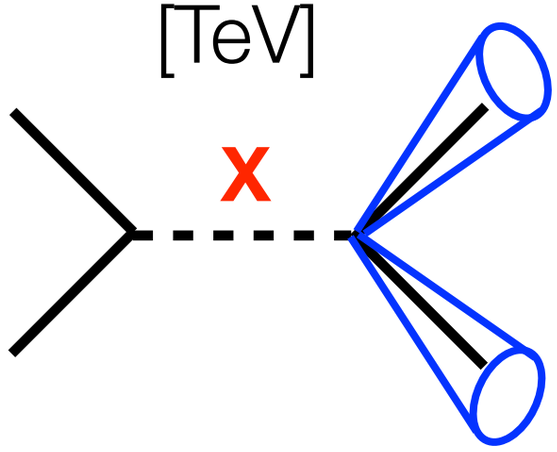
New physics could be hiding under there

Boosting to combat QCD

Boost rule of thumb

$$\Delta R(qq) \sim 2m/p_T$$

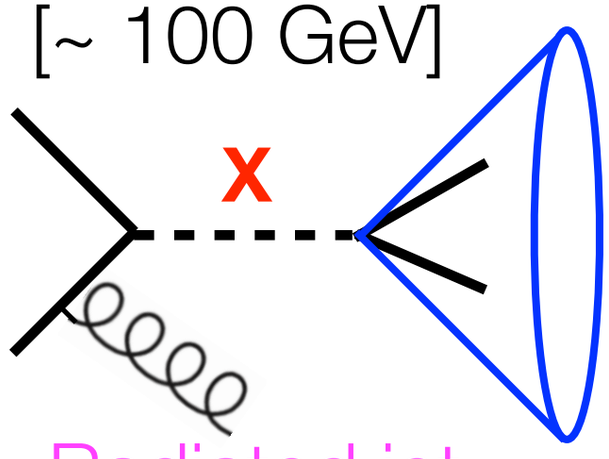
High mass X [TeV]



X→ Pair of high p_T quarks

- Reconstruct as 2 small R jets
- Trigger on small R jet

Low mass X [~ 100 GeV]



X →Pair of low p_T quarks

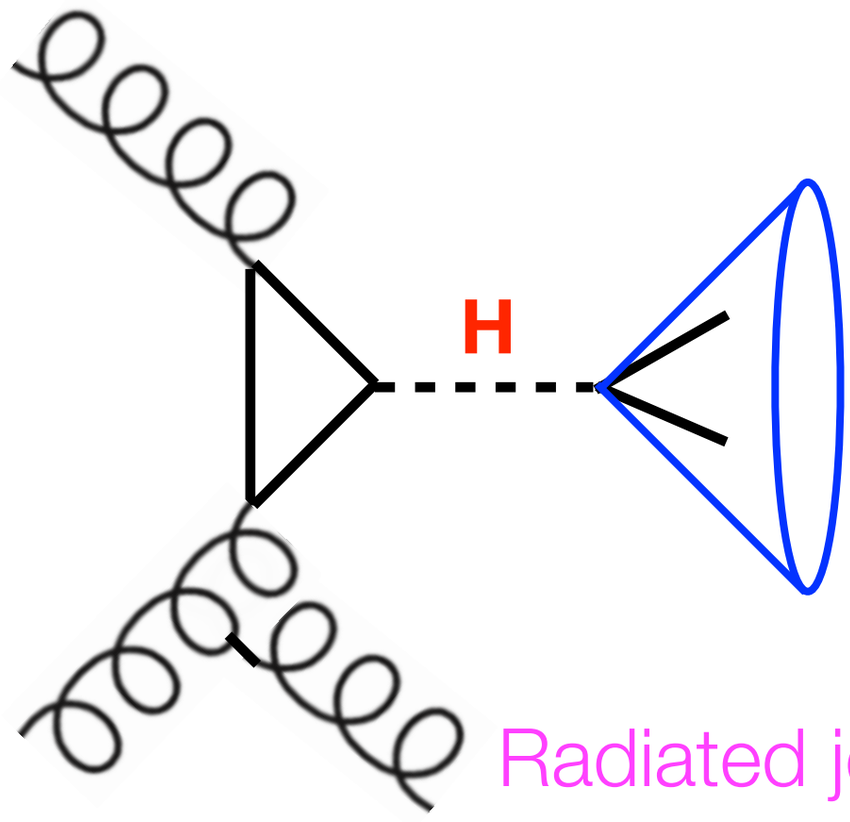
- Boost from radiated jet increases p_T
- Reconstruct as single large R jet
- Trigger on large R jet
- Enhance S/B using jet substructure

Why $b\bar{b}$ events?

NEW Light (< 250 GeV) resonances → $b\bar{b}$ unexplored by ATLAS

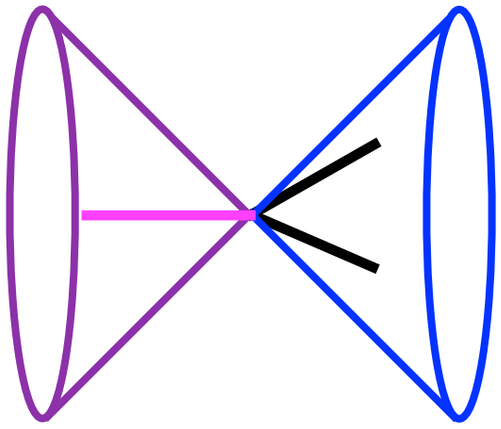
- Enhanced sensitivity to particles with preferential coupling to b's

- Currently only potential way to target ggF H → bb



Analysis Strategy

Radiated large R jet



Signal large R jet

At least two sub-jets (VR trk jets)

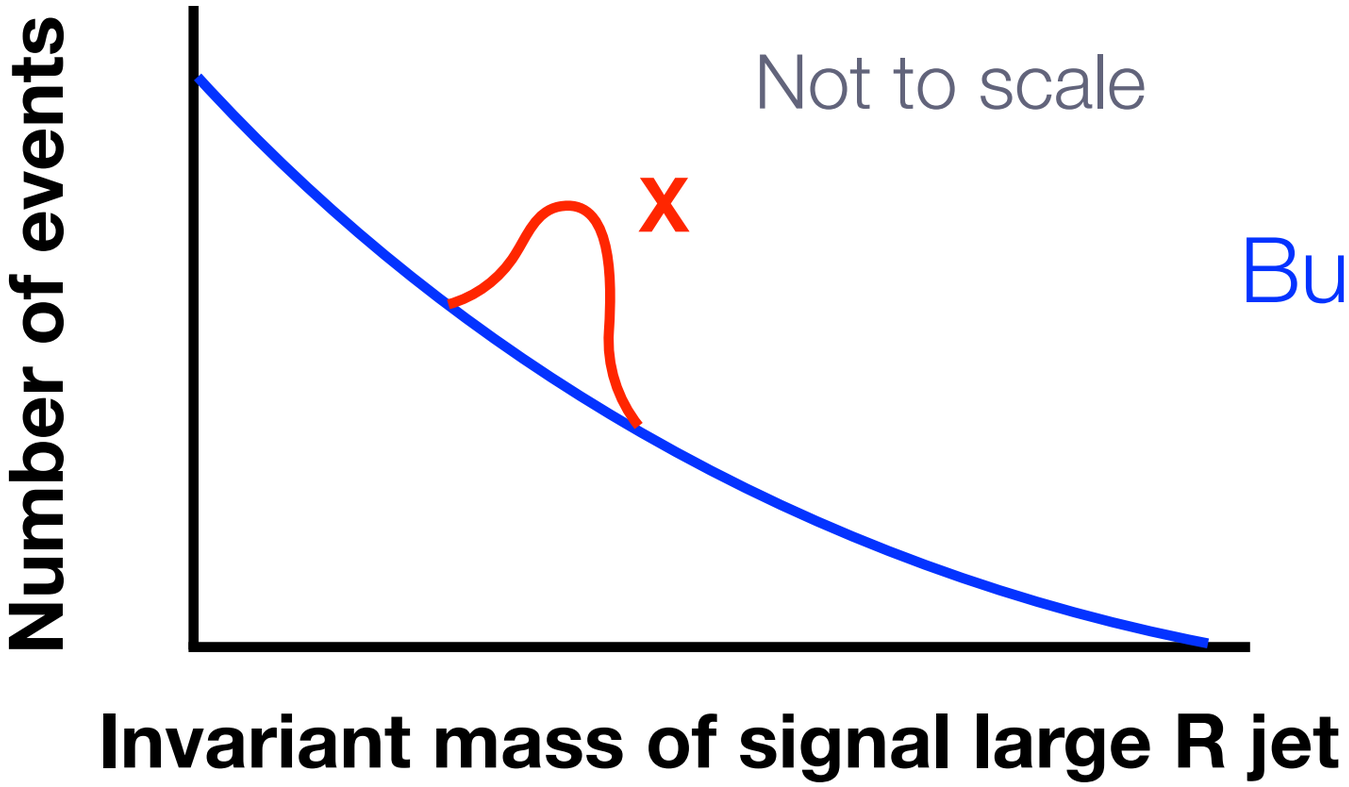
$2m/p_T < 1$ (boosted)

Leading large R jet

$p_T > 480$ GeV

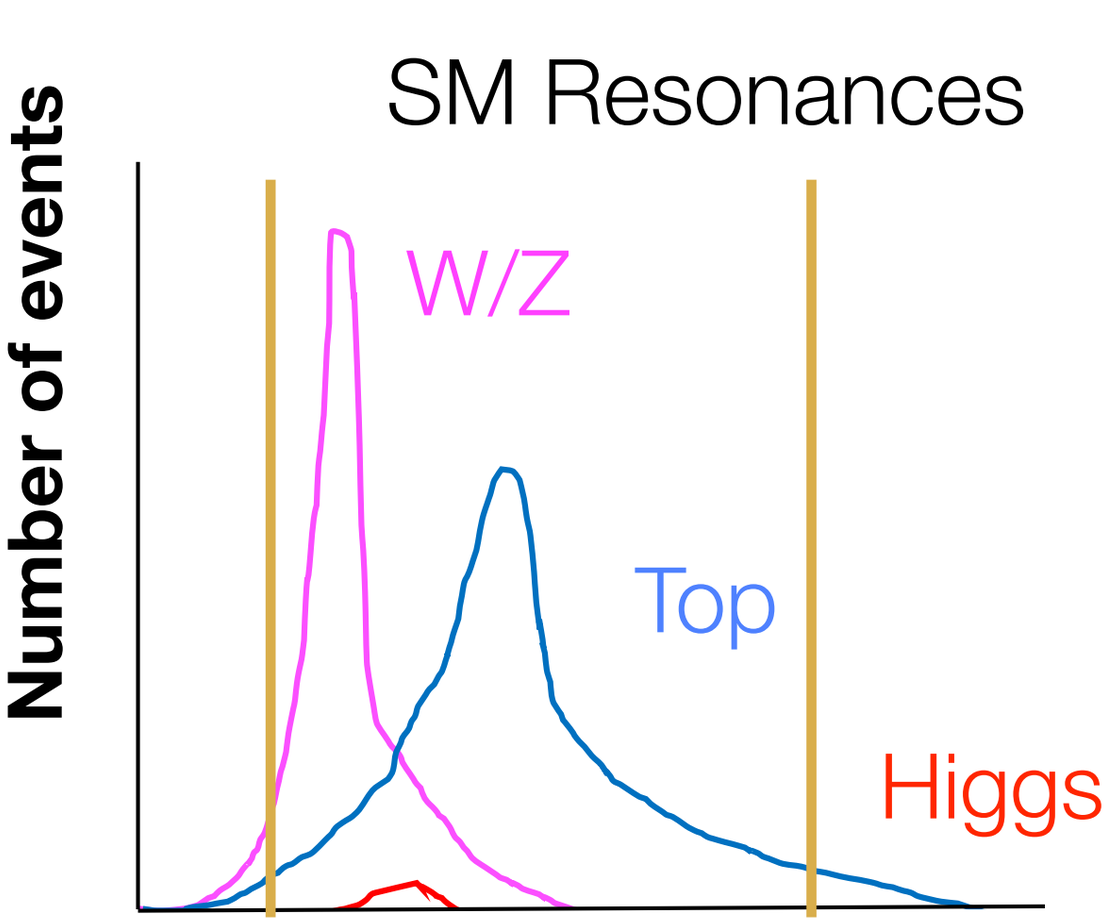
2 b-tags

Not to scale

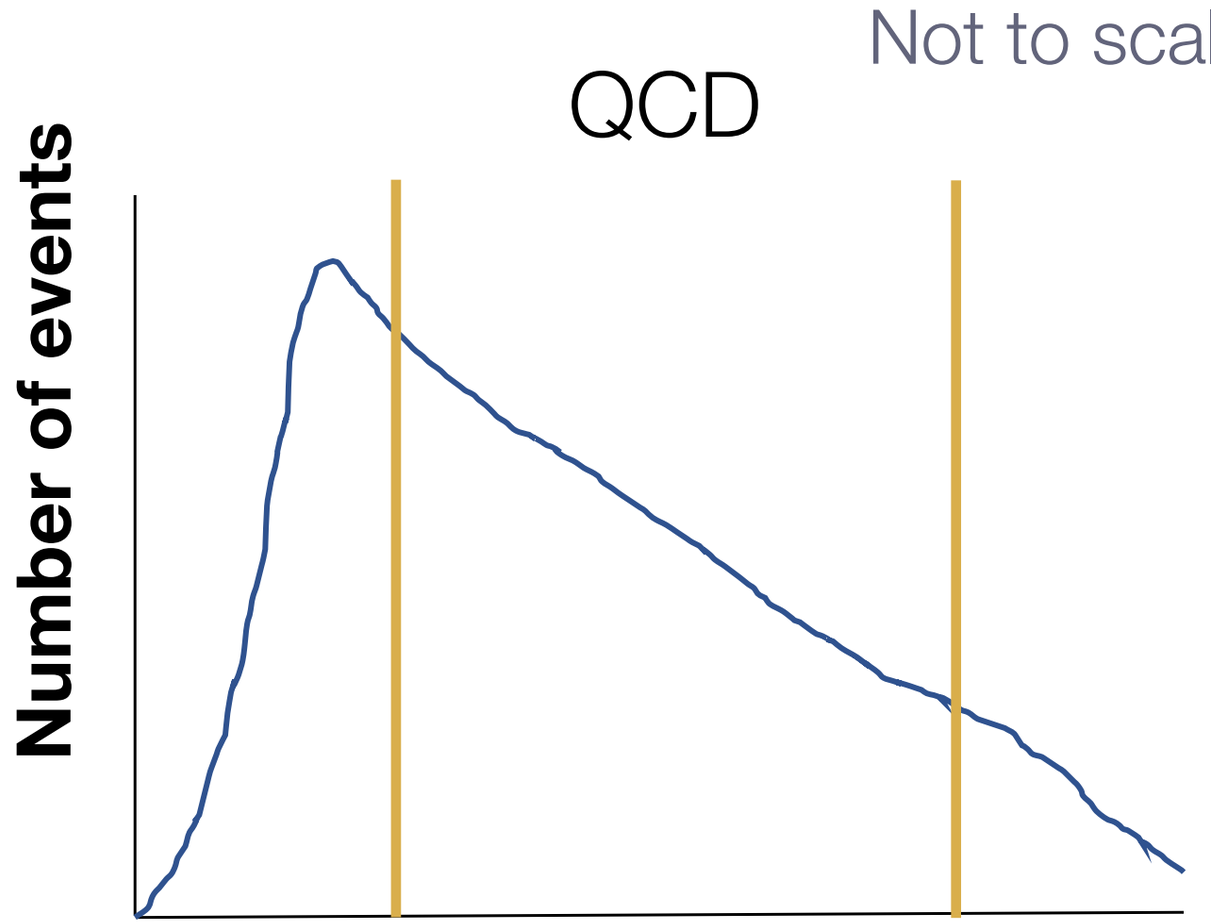


BumpHunt invariant mass of signal large R jet

Background Composition



- Several peaks
- W/Z close to turn on



- Smoothly falling **70 - 230 GeV**

Background Estimate

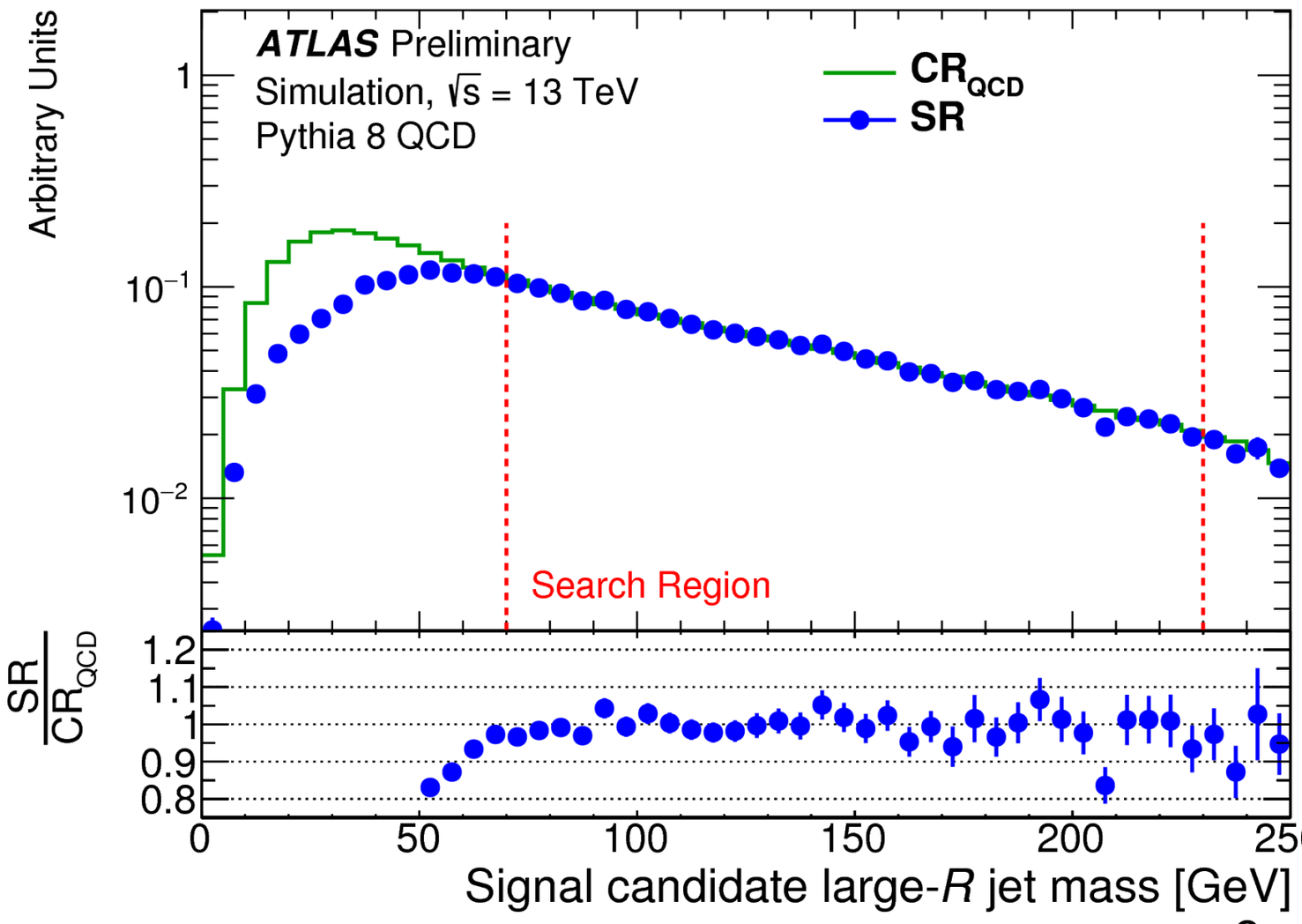
Background estimate is a key challenge for this analysis

→ Develop robust bkg estimation strategy while keeping SR blinded

QCD Insufficient QCD MC to model SR precisely

Use data-driven approach

Use 0 b-tag region as approx to 2 b-tag SR to develop strategy



Background Estimate

QCD Parametric fit to 2 b-tag SR data

poly exp: $f(x\,|\,\vec{\theta}) = \theta_0 exp\left(\sum_{i=1}^{4} \theta_i x^i\right), \quad x = \frac{m_J - 150\ \text{GeV}}{80\ \text{GeV}}$

Include ttbar & W+Z for new physics search

Include ttbar & W+Z & Z'/H for model dependent

ttbar Monte Carlo, normalisation from ttbar control region
(muon in opposite hemisphere to signal jet)

W+Z Monte Carlo, normalisation floating in fit
→ Use W+Z as standard candle
→ Cross-check before unblinding full region

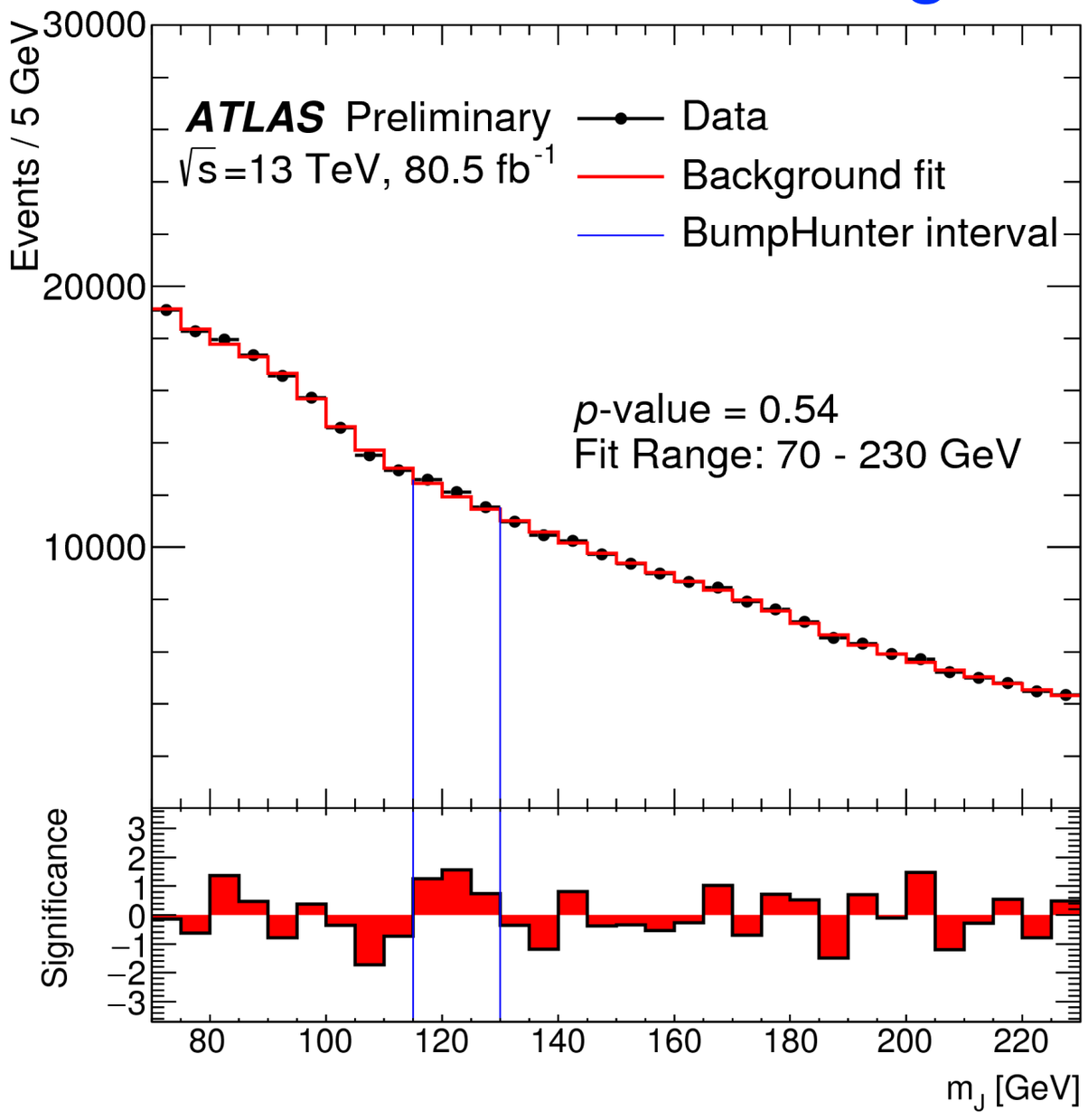
Search for New Physics

Search for excesses above bkg (QCD + W/Z + ttbar)
in model independent way using BumpHunter

2 b-tag SR

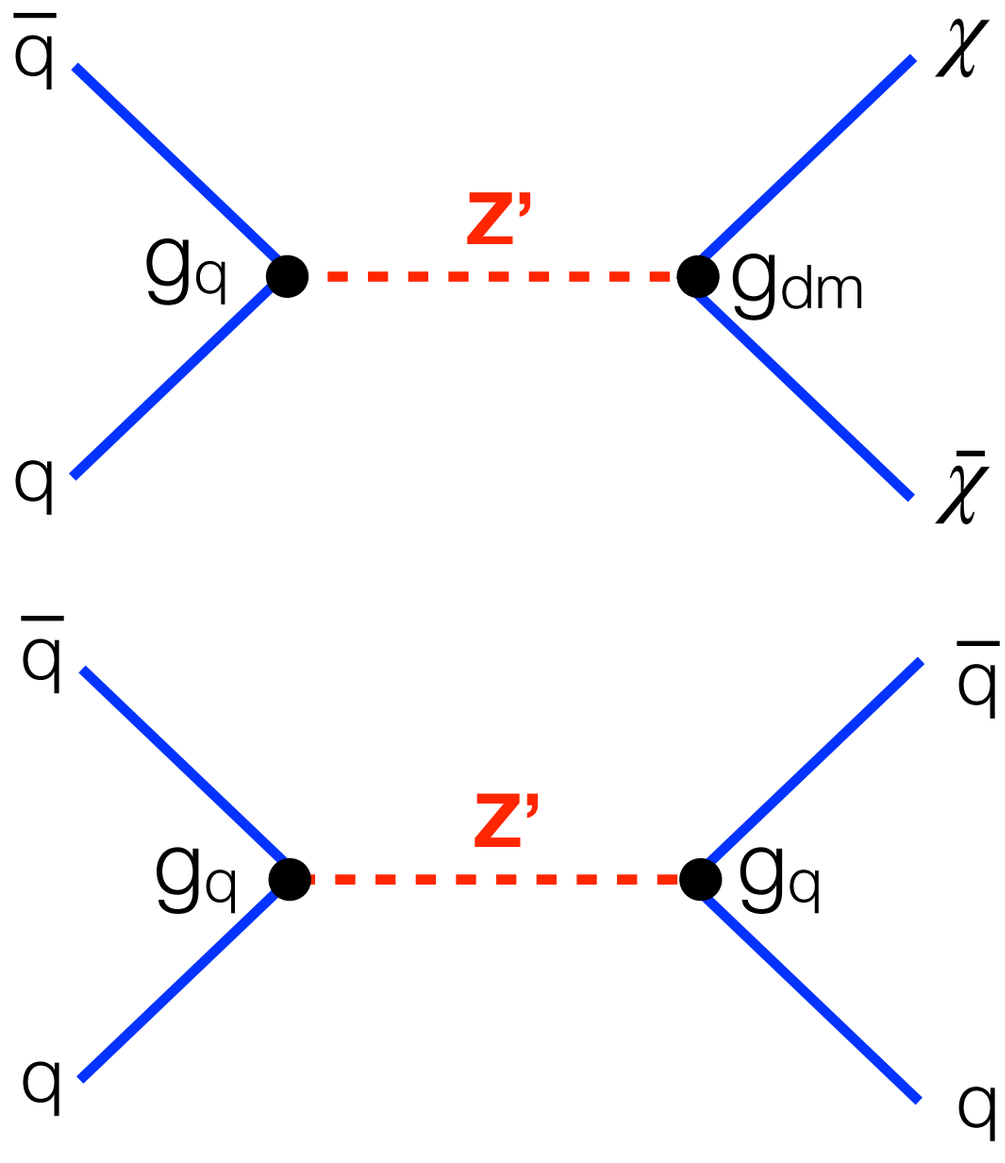
Most significant excess at
~ 125 GeV

Global p-value of 0.54
→ No significant excess



Z’ Exclusion Limits

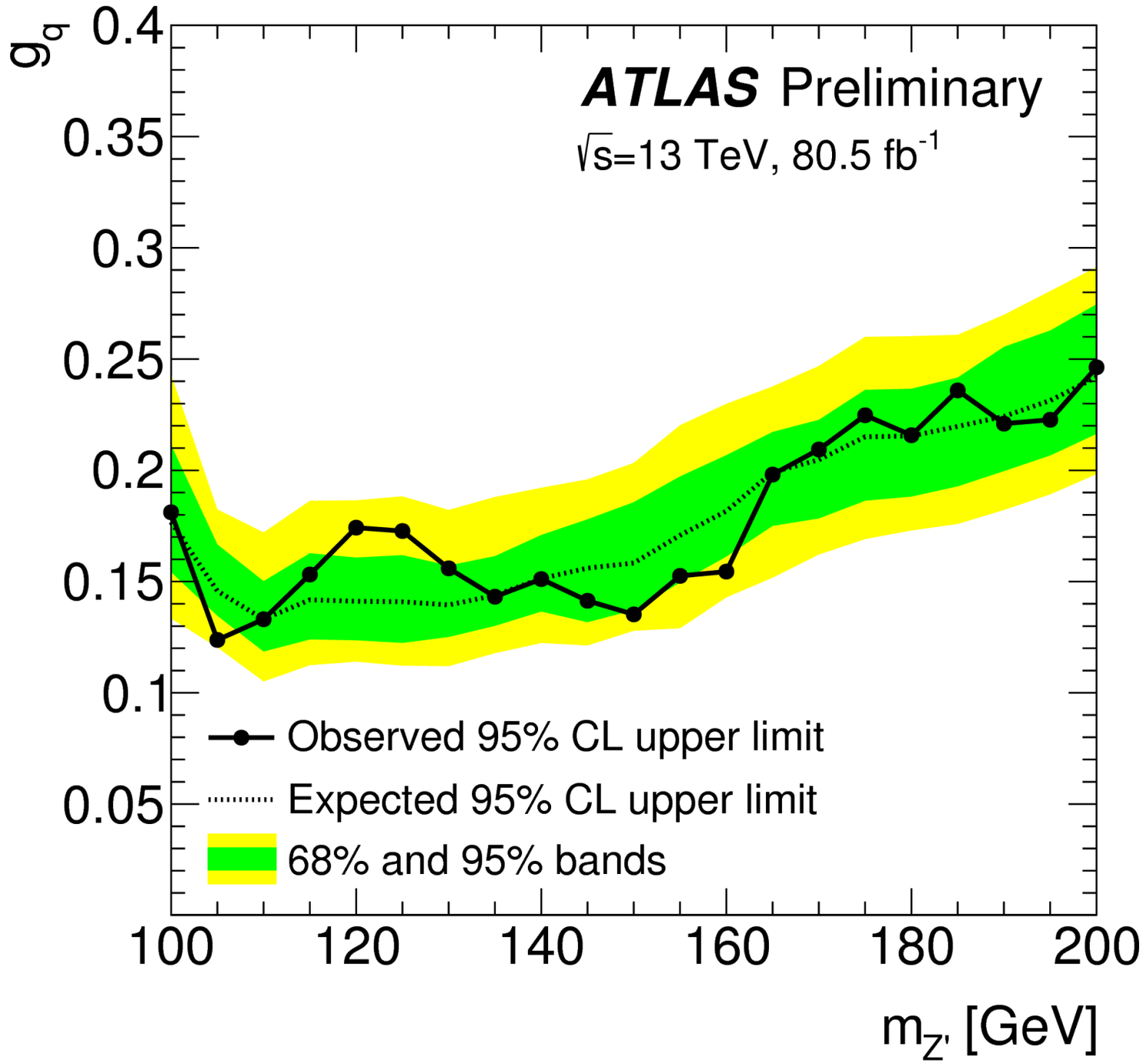
Set limits on Z’ dark matter mediator



Decay to dark matter

Decay to quarks

Z’ Exclusion Limits

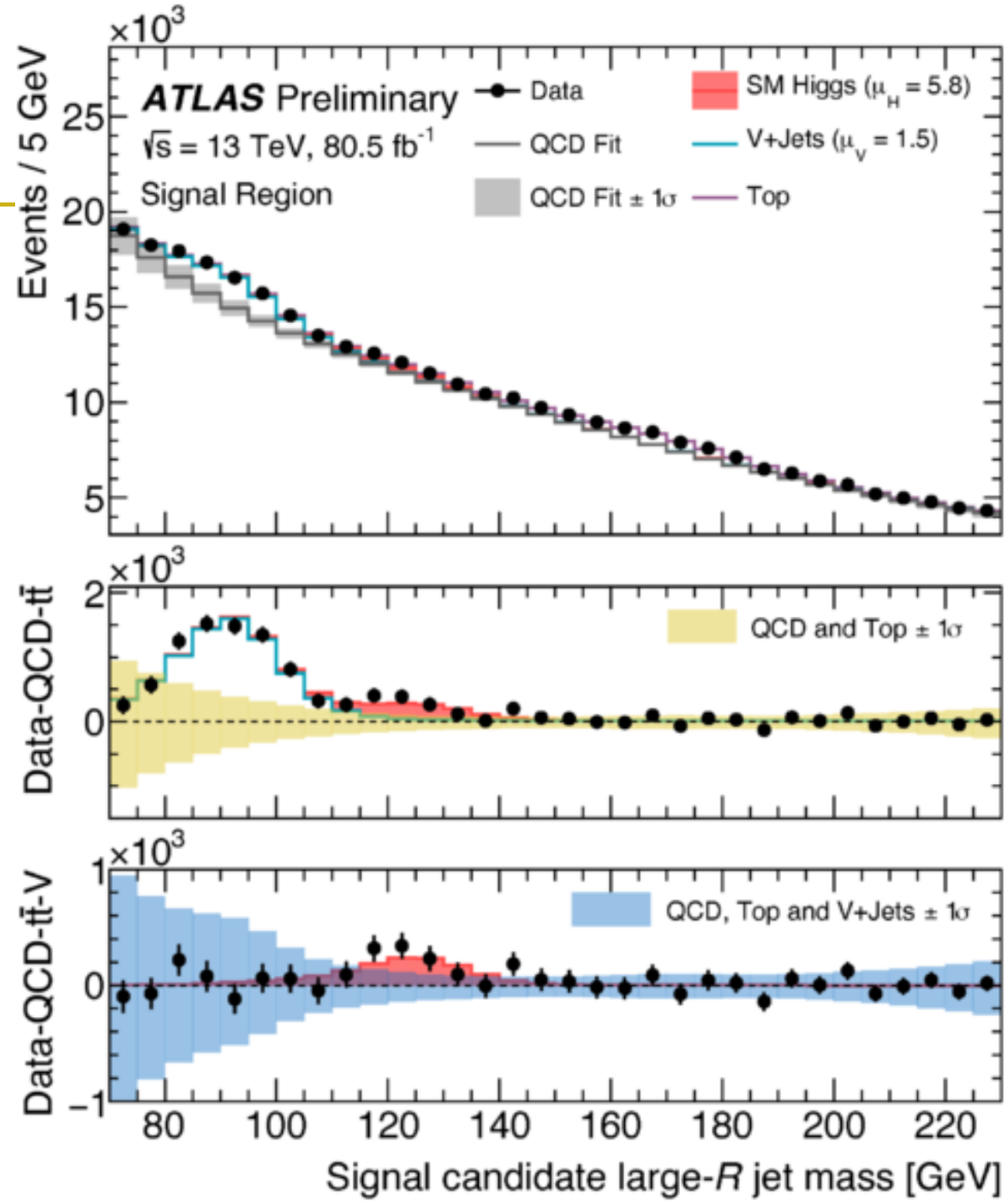


Search for $H \to b\bar{b}$

Bkg fit QCD + W/Z + ttbar + H

$W+Z \to b\bar{b}$:
80% Z, 20% W
5 sigma, 4.8 expected
Observation in large R jet

$H \to b\bar{b}$:
53% ggF, 25% VBF, 22% VH
1.6 sigma, 0.28 expected



Start of Run II: common belief QCD bkg so overwhelming
we could not observe W/Z peak … we are now searching for H peak :)

Summary

- Searched for resonances decaying to pairs of b-quarks using 80 fb^{-1} dataset ATLAS-CONF-2018-052

- New analysis in ATLAS probing unexplored low mass phase space down to 70 GeV in mass

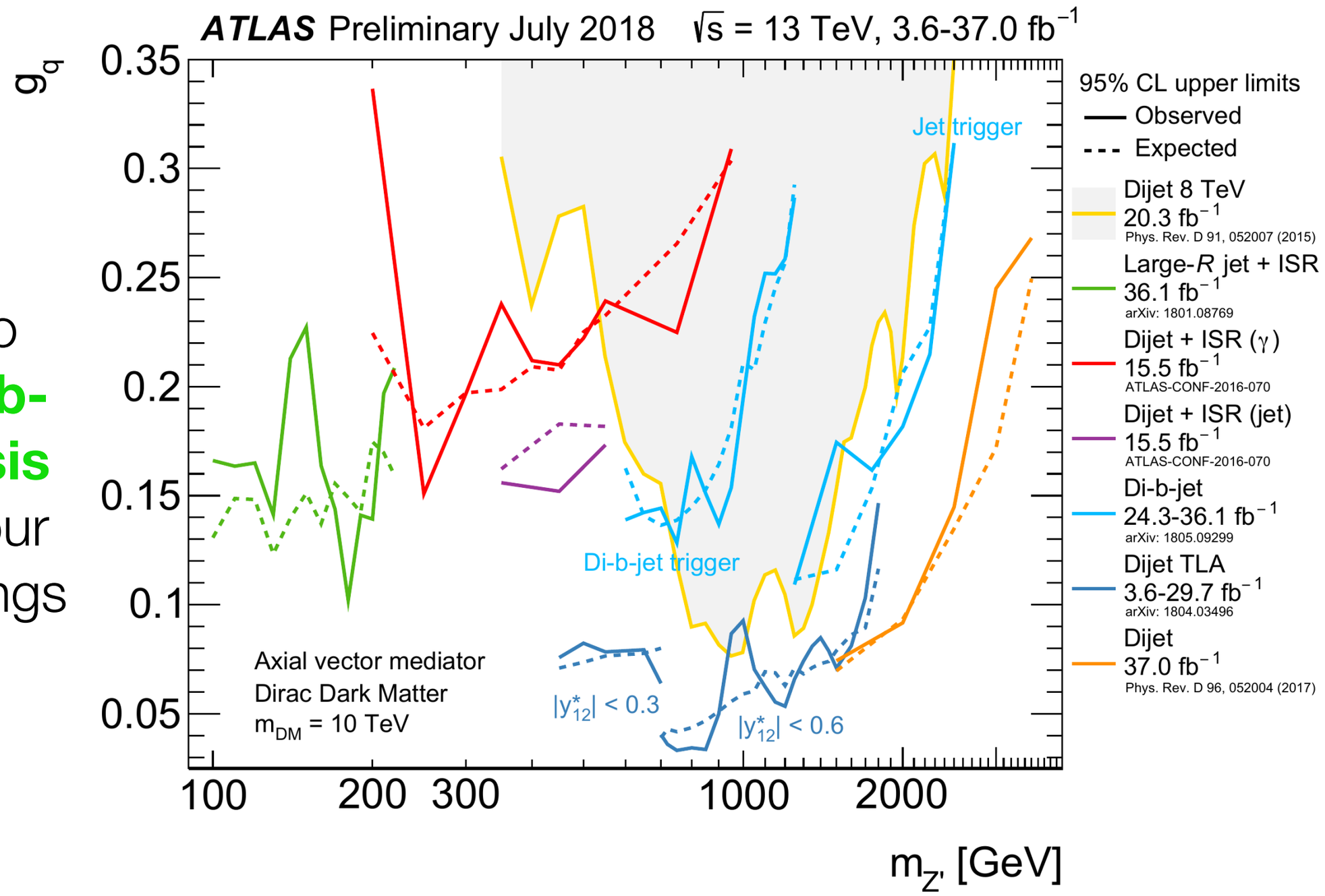
- Excluded light Z' dark matter mediators with couplings below 0.25 in mass range probed

- Observed W+Z peak in large R jet at 5 sigma significance
  1.6 sigma significance for H→bb

Backup

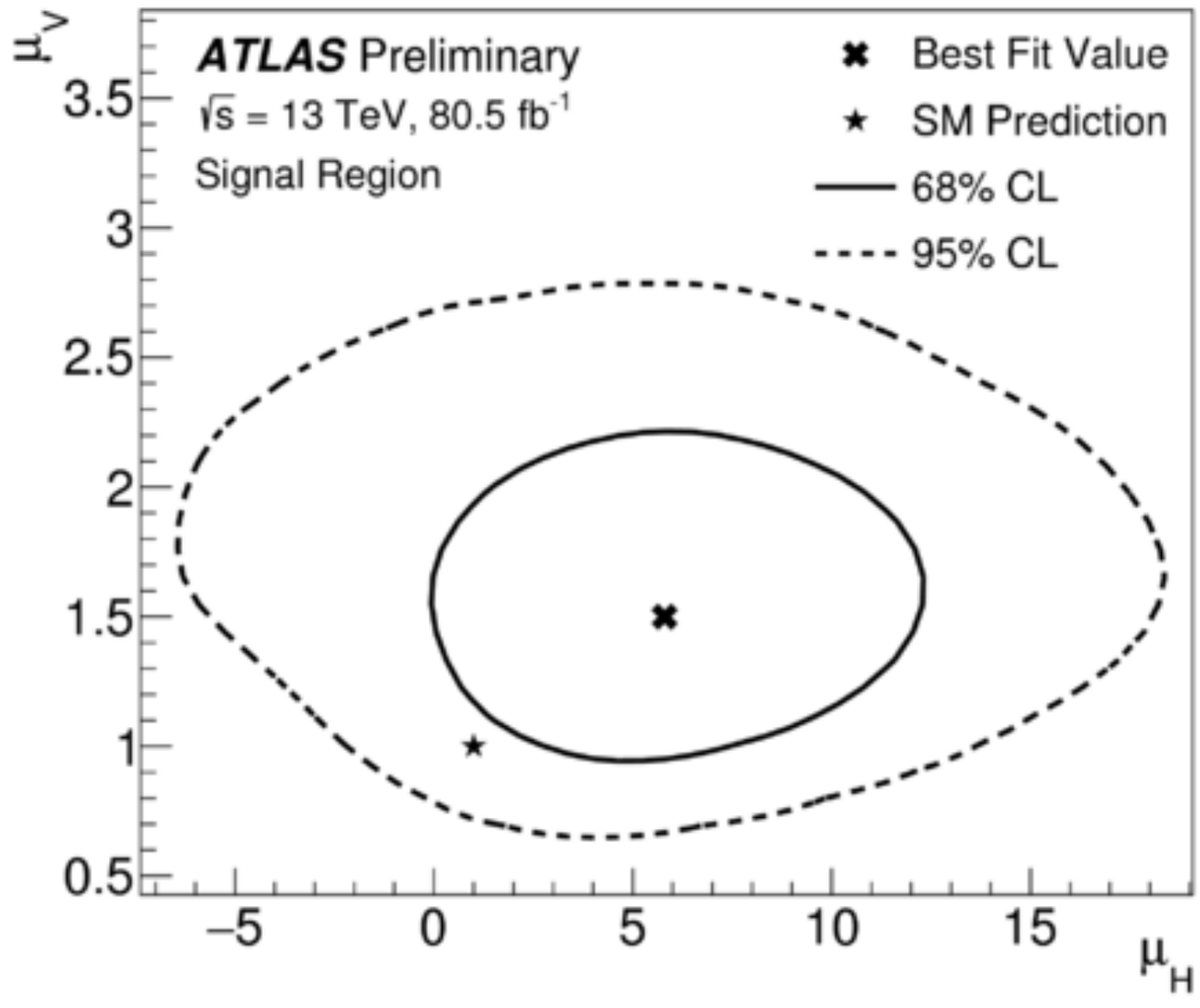
Existing Z' Exclusion Limits

Our limits comparable to **boosted non-b-tagged analysis** for Z' with flavour agnostic couplings



Search for H→bb:

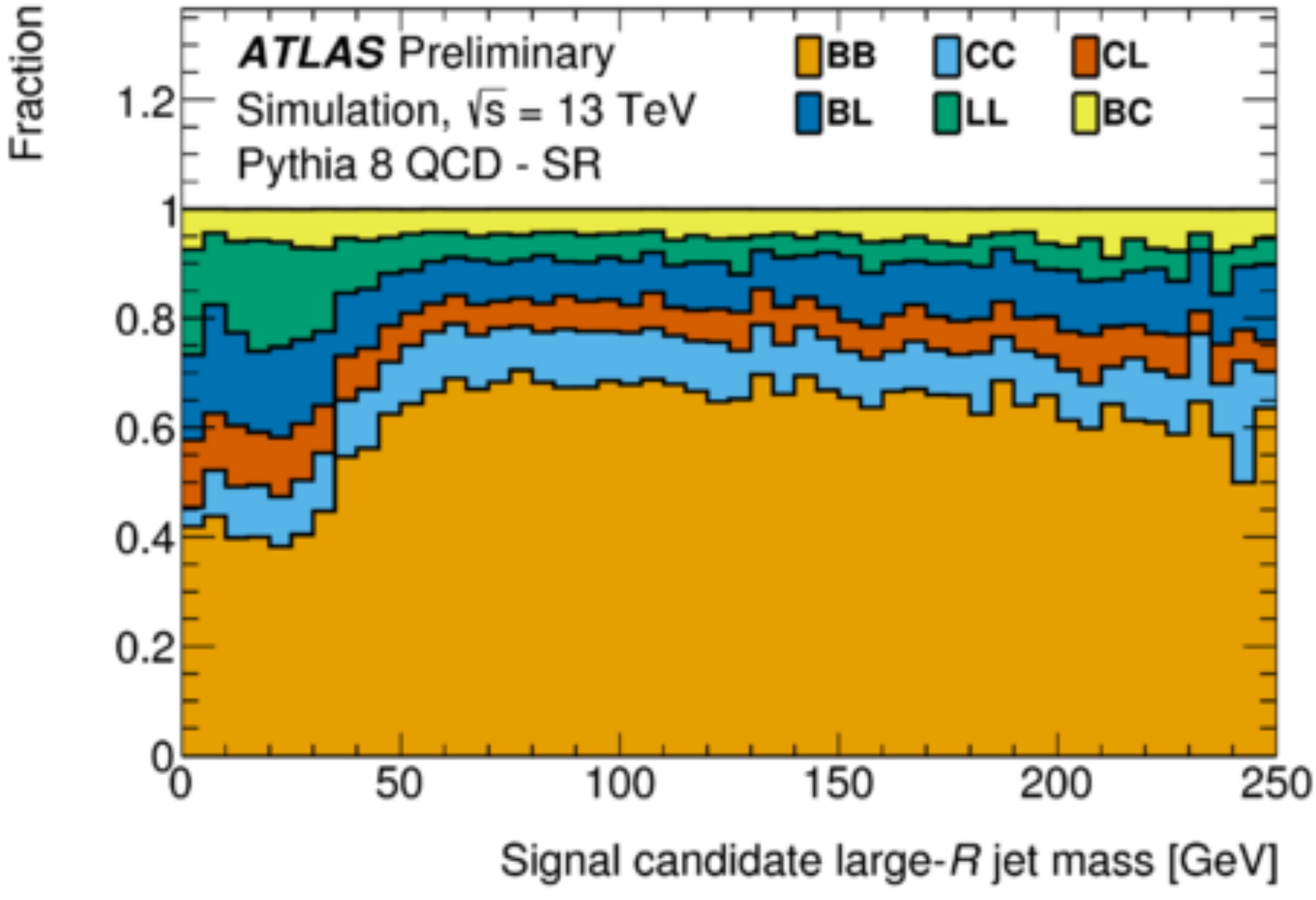
Signal strength: $\mu = \frac{N_{obs}}{N_{exp}}$



$$\mu_v = 1.5 \pm 0.22\ (stat.)^{+0.29}_{-0.25}\ (syst.) \pm 0.18\ (th.)$$

$$\mu_H = 5.8 \pm 3.1\ (stat.) \pm 1.9\ (syst.) \pm 1.7\ (th.)$$

Predicted flavour composition of the dijet background in the SR based on the truth-matched hadron content of the two leading-p_T track-jets associated to the signal candidate large-*R* jet, with the B/C labels indicating the presence of a b/c-quark and L indicating the presence of a light quark or a gluon.



		Impact on Signals ($\sqrt{\Delta\sigma^2}/\mu$)			
Source	Type	V+jets	Higgs	Z' (100 GeV)	Z' (175 GeV)
Jet energy and mass scale	Norm. & Shape	15%	14%	23%	18%
Jet mass resolution	Norm. & Shape	20%	17%	30%	20%
V + jets modeling	Shape	9%	4%	4%	$< 1\%$
$t\bar{t}$ modeling	Shape	$< 1\%$	1%	$< 1\%$	11%
b-tagging (b)	Normalisation	11%	12%	11%	15%
b-tagging (c)	Normalisation	3%	1%	3%	5%
b-tagging (l)	Normalisation	4%	1%	4%	7%
$t\bar{t}$ scale factor	Normalisation	2%	3%	2%	58%
Luminosity	Normalisation	2%	2%	2%	3%
Alternative QCD function	Norm. & Shape	4%	4%	3%	17%
W/Z and QCD (Theory)	Normalisation	14%	–	–	–
Higgs (Theory)	Normalisation	–	30%	–	–