Dijet and Diboson resonances at ATLAS

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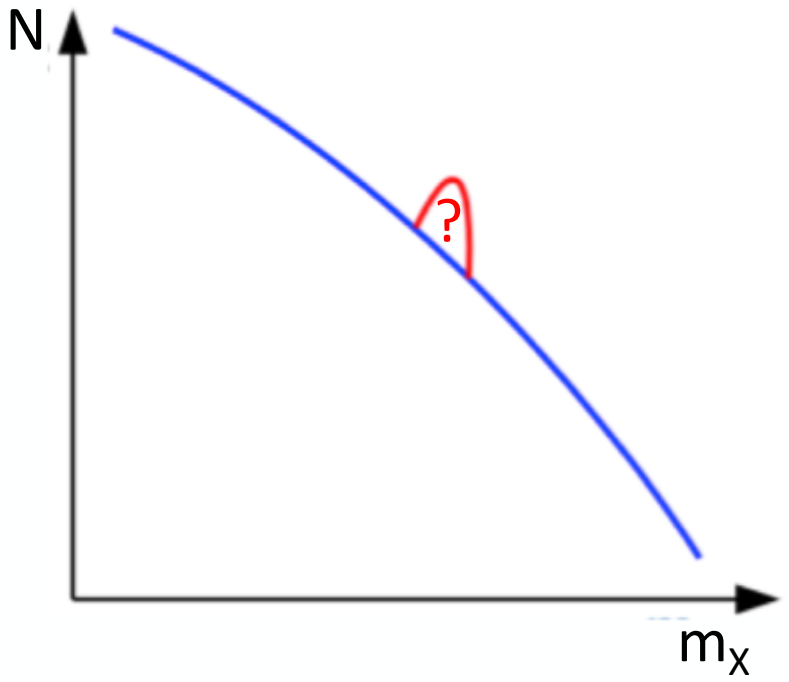
Motivation

- Searches for new resonances are critical part of LHC programme
  - Generic signature for many BSM physics models



Dijet resonances

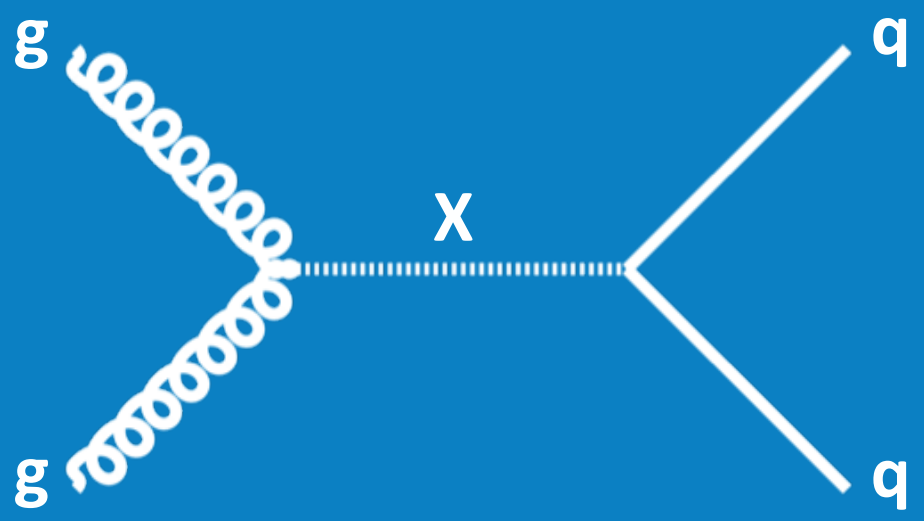
- Natural LHC search channel for NP with strong interactions
  - If new particles directly produced in pp collisions, they must couple to partons, and hence decay to jets
- Novel techniques allow us to extend sensitivity to lower mass
  - Focus: new 2015+16 trigger-level object search

Dibosons resonances

- Already proved their potential in Higgs discovery (ZZ/WW/γγ)
  - Boosted techniques push to higher mass (see Dermot's talk)
- Higgs provides interesting new diboson search channels
  - Focus: new 2015+16 hh → 4b search

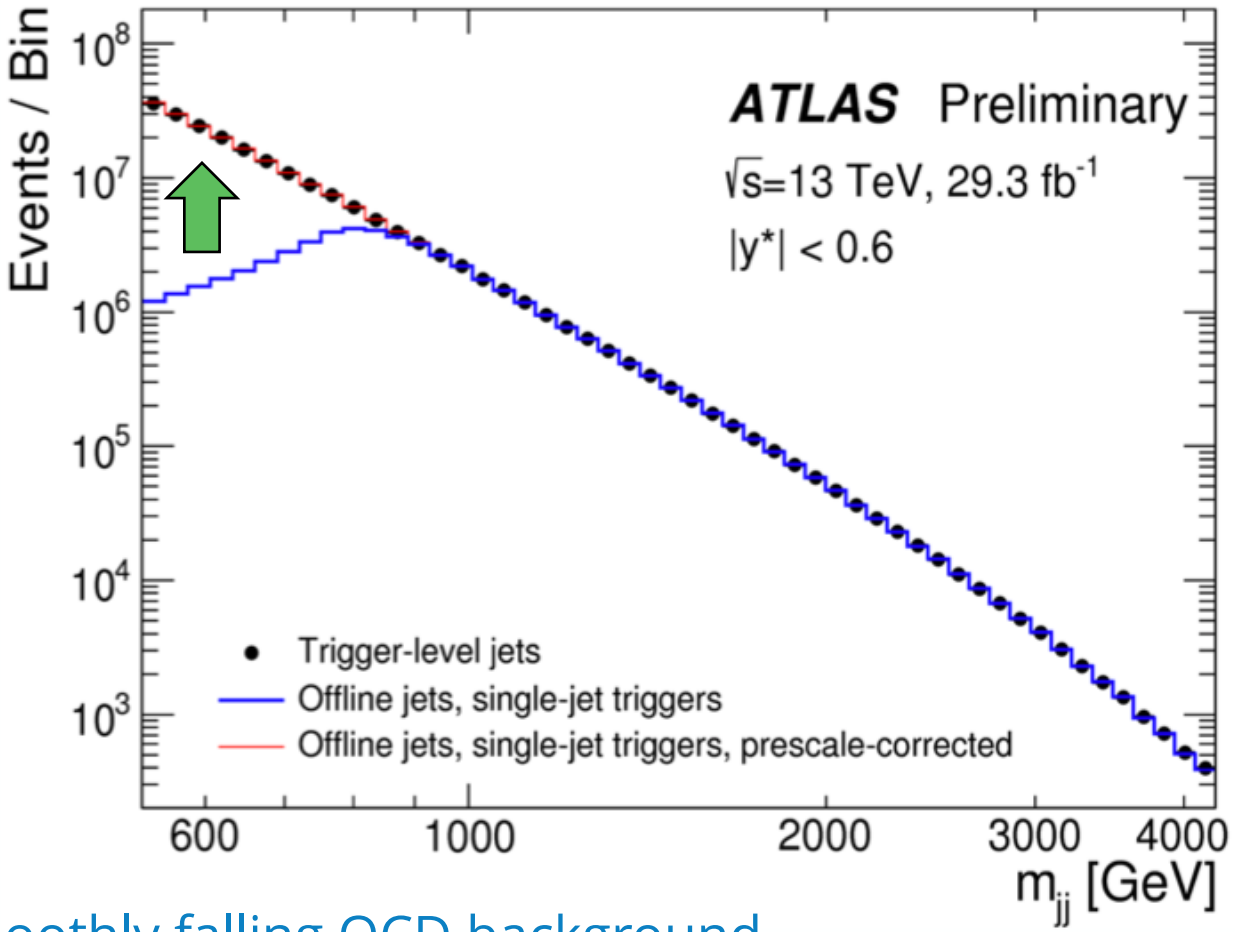
- References:
  - TLA: EXOT-2016-20
  - hh→4b: EXOT-2016-31
  - Both to be submitted to arXiv imminently

Dijet Resonances: Trigger-level object Analysis



Trigger-object Level Analysis (TLA)

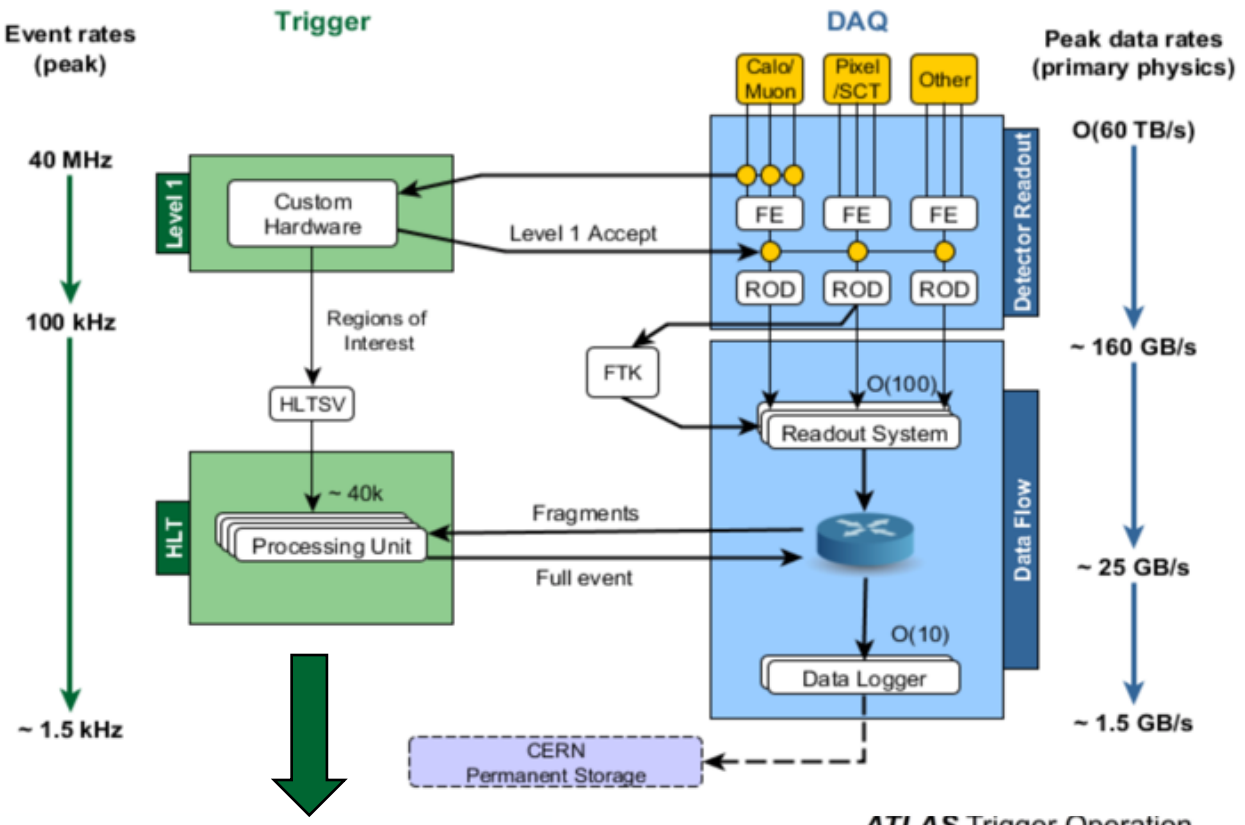
- Traditional dijet searches target m_{jj} > 900 GeV
  - Not competitive with pre-LHC at low m_{jj} due to high trigger thresholds or prescales at lower p_T
- Novel TLA analysis records reduced trigger info
  - Enables twice rate of standard approach within bandwidth and hence access to low m_{jj} region
- Search for resonance over 450 < m_{jj} < 1800 GeV
  - Various width assumptions
  - Neglecting interference



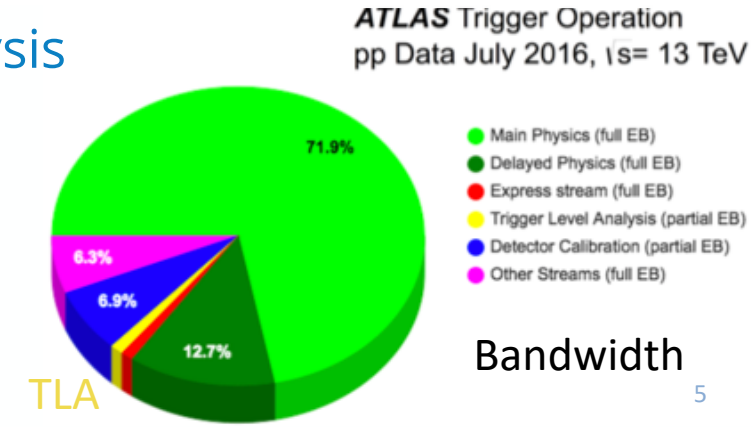
- In principle, "simple" search for m_{jj} peak over smoothly falling QCD background
  - But lots of work behind this to make the analysis possible

ATLAS Jet Trigger

- L1 identifies jets via sliding window
  - Based on $\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$ calo segments
- HLT reconstructs R=0.4 jets with anti-k_t algo
  - Based on topoclusters formed looking at significance of calo E deposits over noise

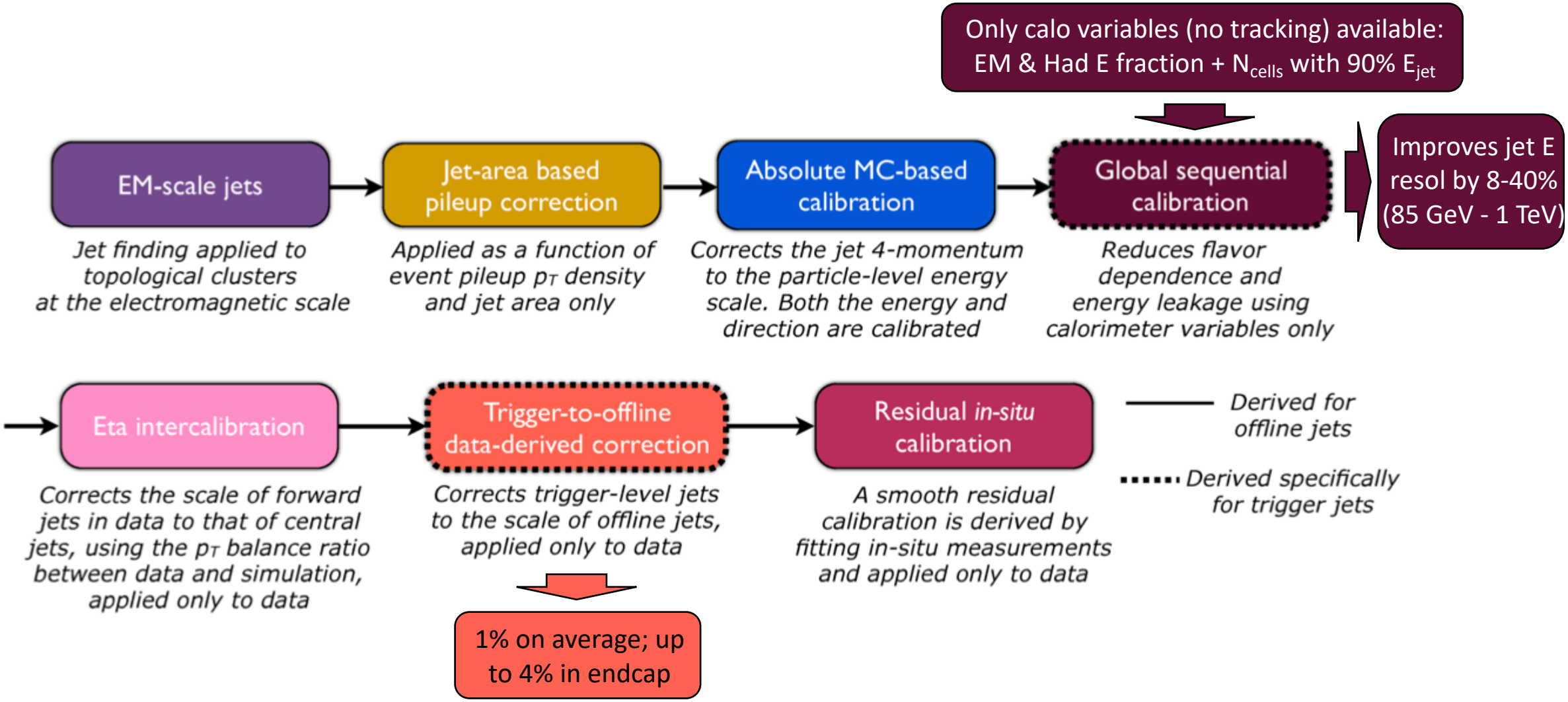


- Only p_T > 20 GeV trigger-level jets with minimal info stored for analysis
  - Just keep jet four-momentum + calo variables to characterise jet
  - Reduces size to < 0.5% of full events!
- The challenge is to calibrate these trigger-level jets …
  - Pre-calibration jet p_T response is 0.95 – 1.05 wrt matched offline jets



Trigger-jet Calibration

- Follow offline procedure to calibrate E_{jet} to particle-level jets built from stable particles



Trigger-jet Calibration (2)

- Final calibration of trigger-jets using p balance of offline jets recoiling against calibrated objects
  - Z→ee/μμ
  - Photons
  - Lower p_T jets

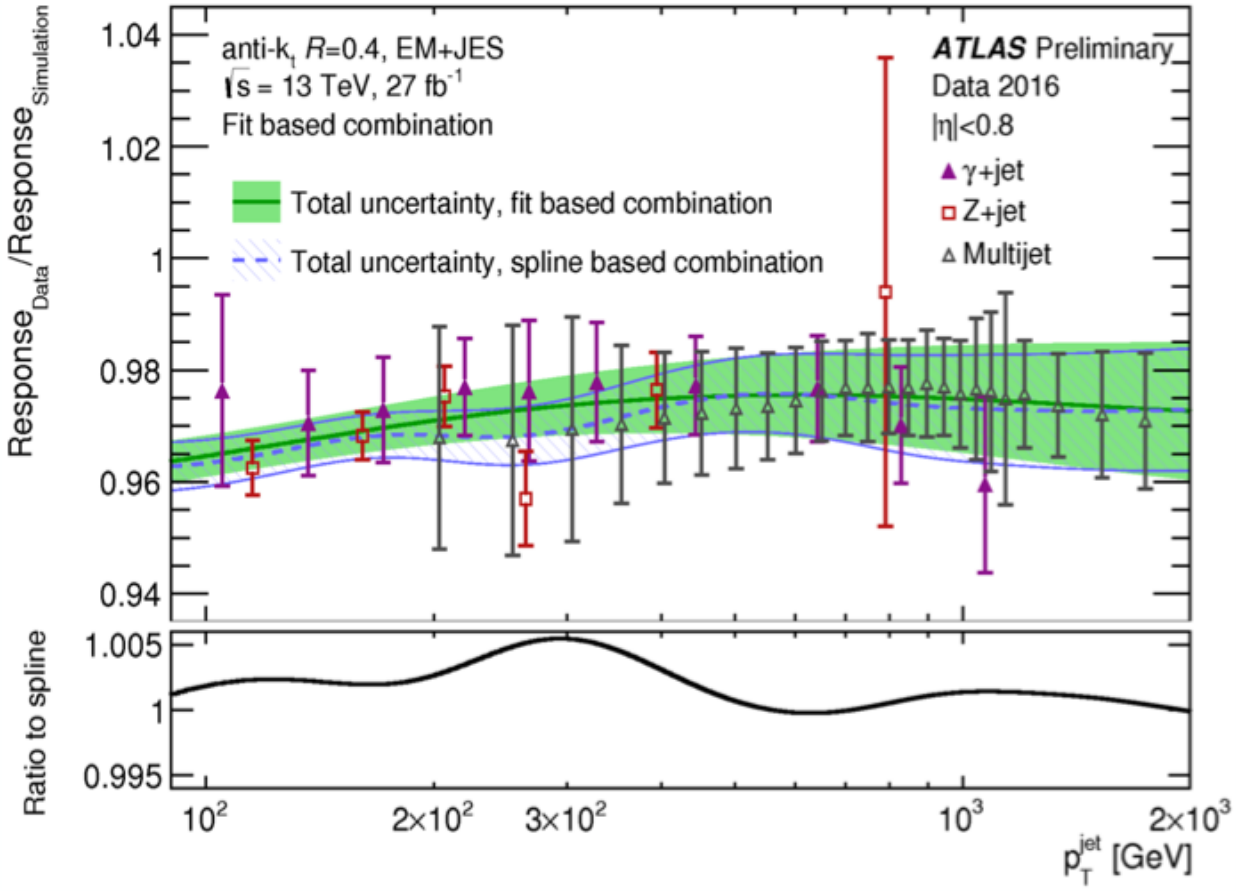
  } Span full jet p_T range from low to high p_T

- Challenge: smoothly fit measurements w/o introducing local p_T & hence m_{jj} fluctuations
  - Fit to log p_T rather than offline spline
  - Compare various methods on data & MC

- Final $E_{trig\text{-}jet}$ reproduces offline jets within 0.05%

- Total JES uncertainty 3.5 (4.5) % central (fwd)
  - Derived from offline + specific trigger systs
    - Breakdown in backup

Residual *in-situ* calibration



$$f(p_T) = a_{n1} \cdot (\log p_T)^{-1} + a_0 + a_1 \cdot \log p_T + a_2 \cdot (\log p_T)^2$$
$$+a_3 \cdot (\log p_T)^3 + a_4 \cdot (\log p_T)^4 + \text{high-pT constraint}$$

Selection and Background Modelling

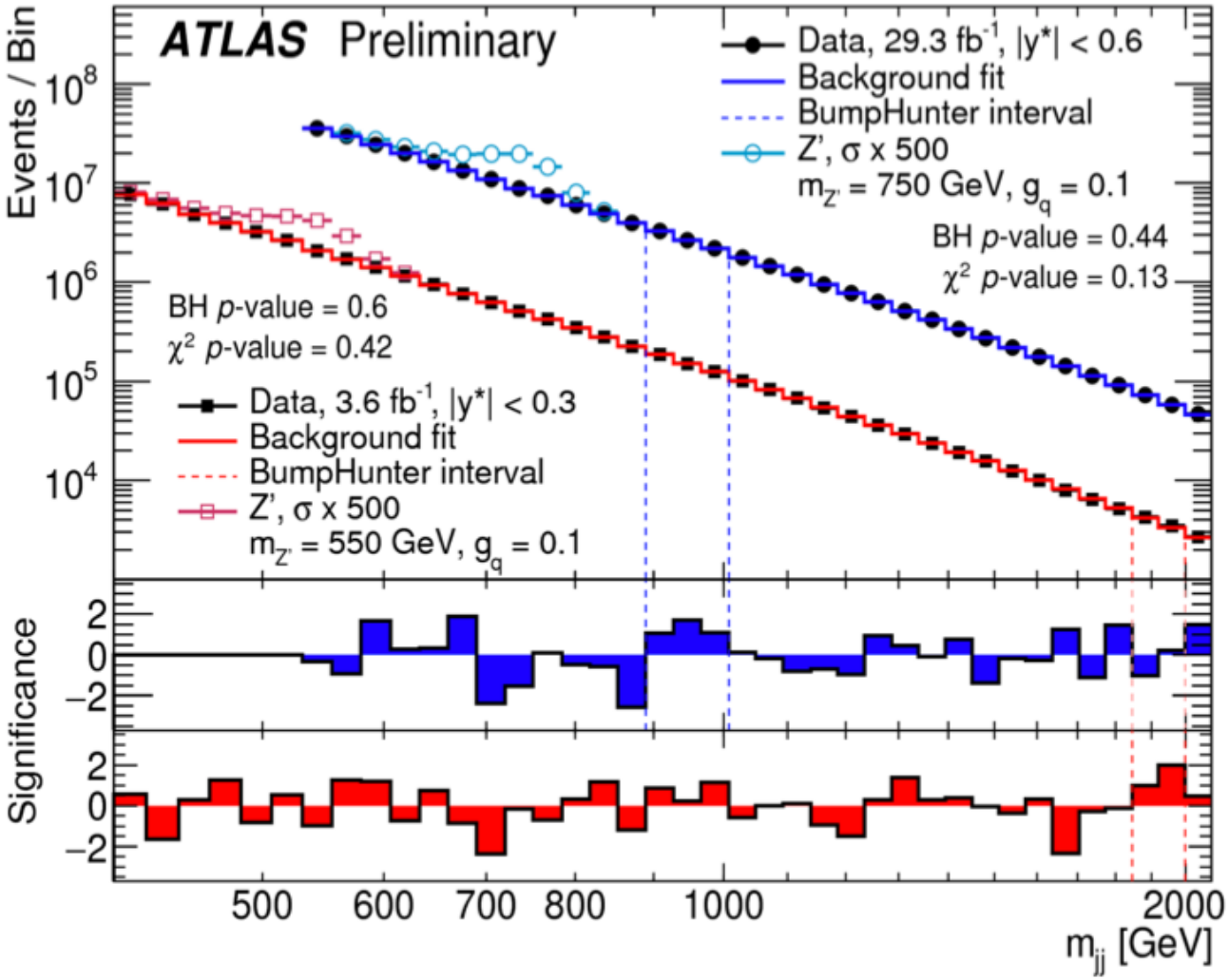
- Analyse 29.3 fb^{-1} (3.6 fb^{-1}) of data containing L1 jet with E_T > 100 GeV (75 GeV) and require:
  - ≥ 2 trig-jets with p_T > 85 GeV in $|\eta|$ < 2.8
  - Lead jet p_T > 220 (185) GeV
  - Two m_{jj} regions based on $y^* = (y_1 - y_2)/2$

m_{jj} > 450 GeV	m_{jj} > 700 GeV
E_T^{L1} > 75 GeV	E_T^{L1} > 100 GeV
$\|y^*\|$ < 0.3	$\|y^*\|$ < 0.6

- Fit background in sliding window
  - Optimise window (ensuring larger than signal width) and functional form by minimising χ^2
    - 4 (5) parameter function for $|y^*|$ < 0.3 (0.6) evaluated at centre (vary form as systematic)

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

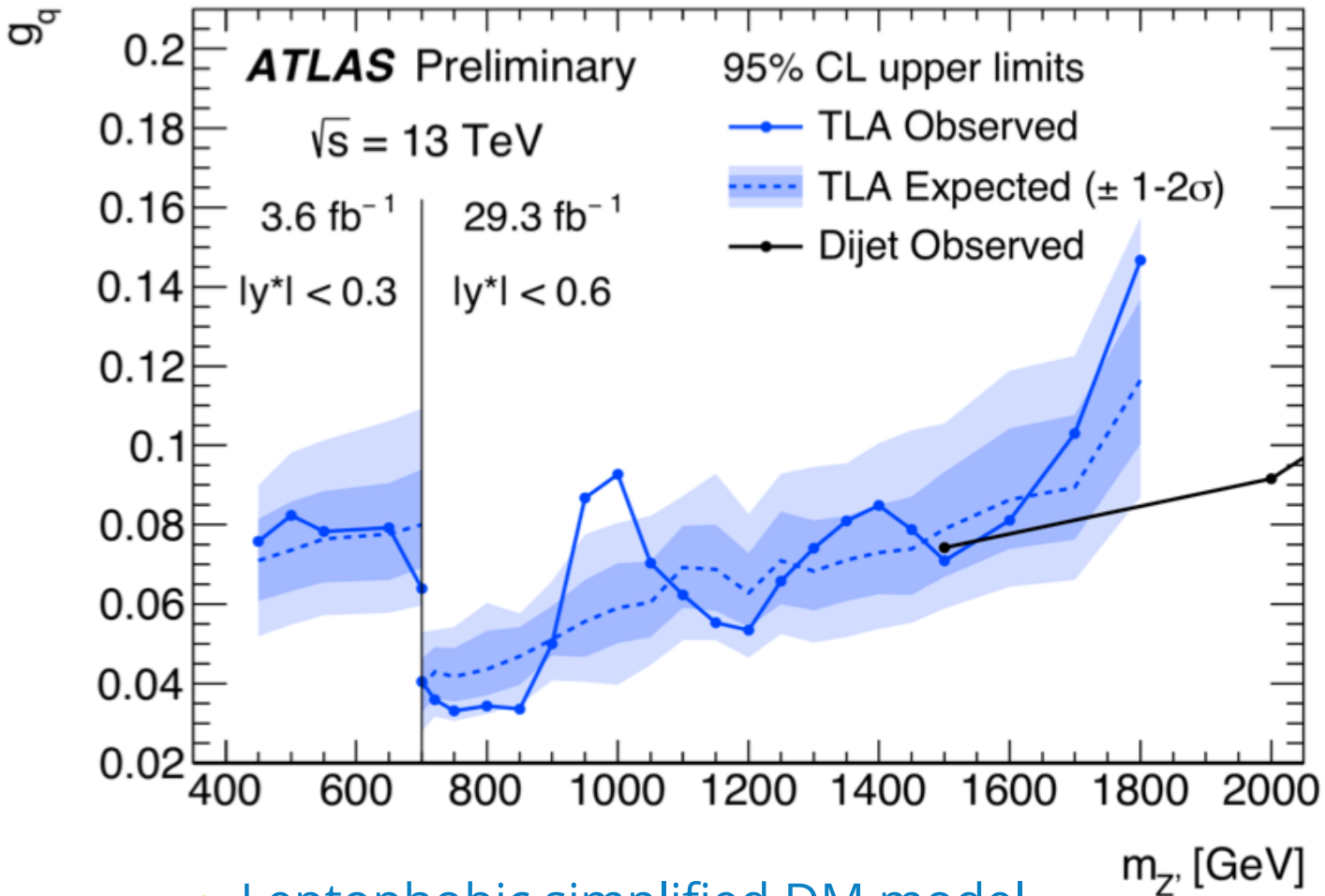
  - Slide along m_{jj} in one-bins steps
    - Binning based on simulated m_{jj} resolution



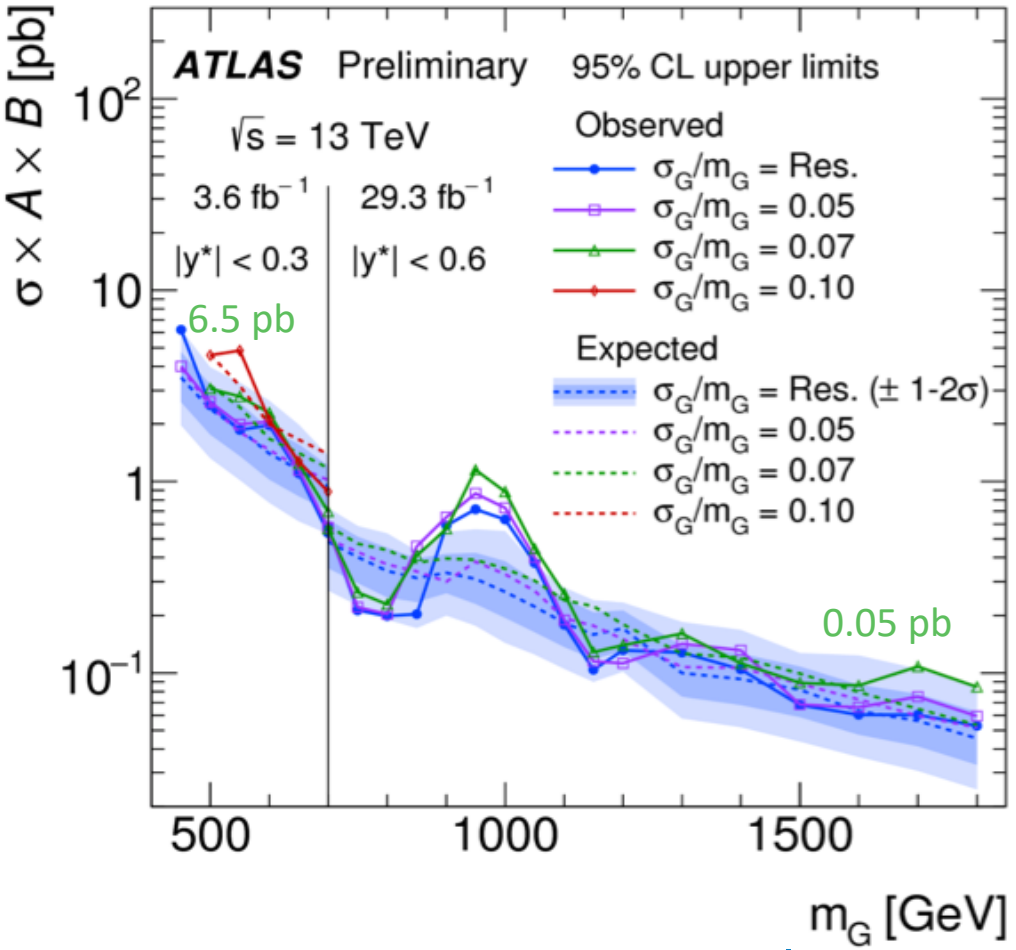
$$x = m_{jj}/\sqrt{s}$$

TLA Results

- Bayesian limit based on S+B fit for each signal hypothesis via pseudo-experiments



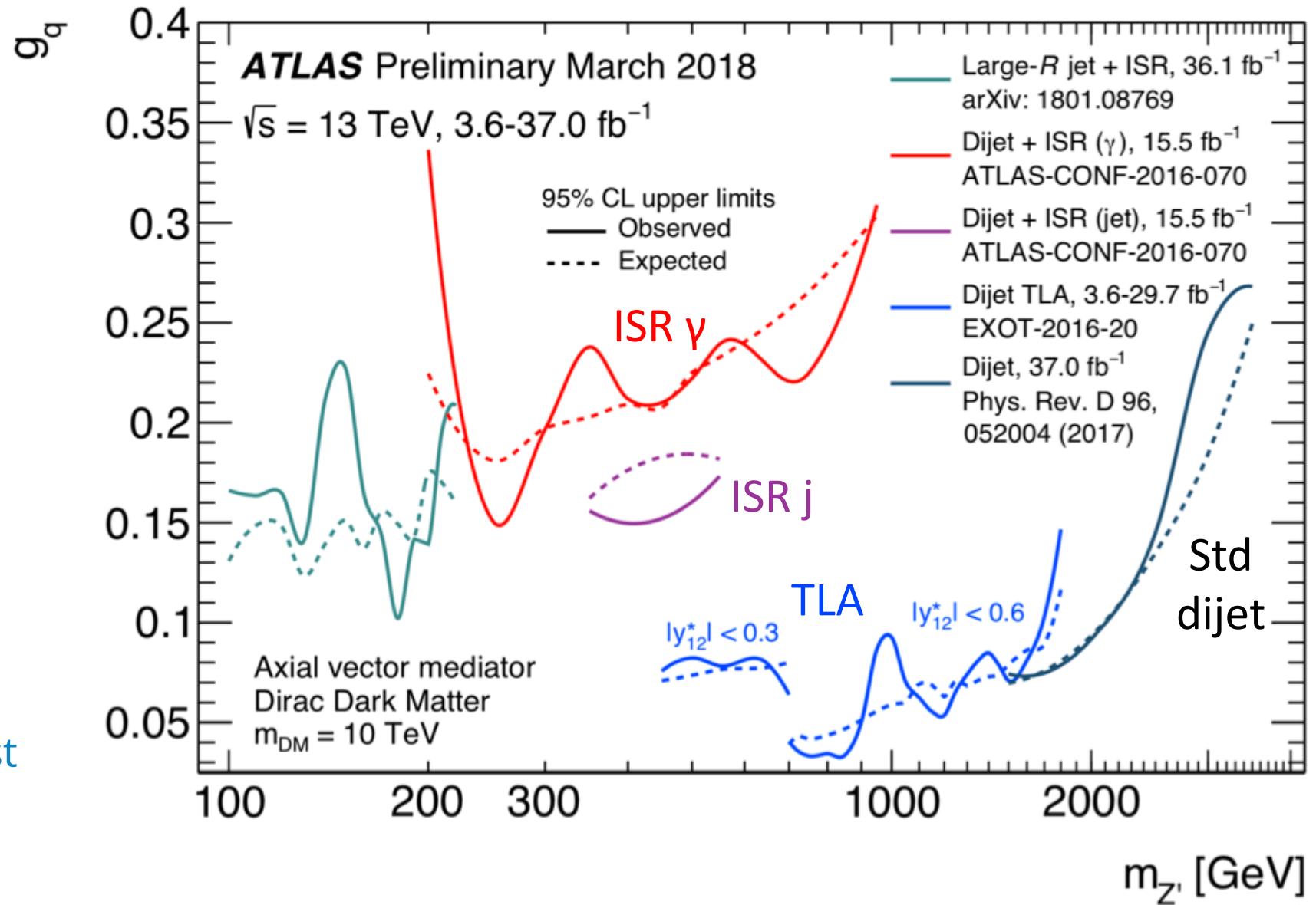
- Leptophobic simplified DM model
  - Axial-vector mediator (Z') to fermion DM
  - A*ε -20 (41) % for $m_{Z'}$ = 550 (750) GeV



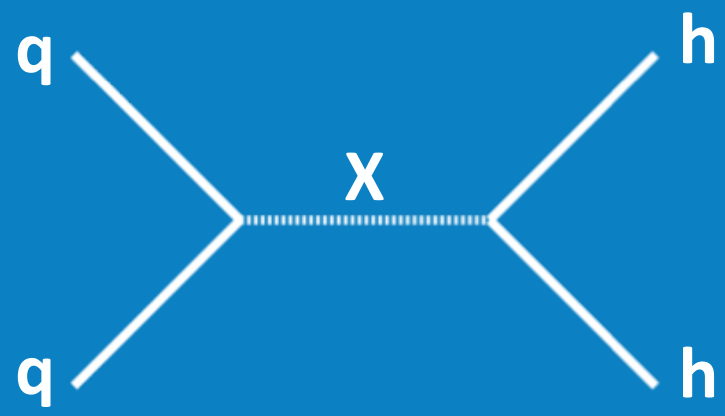
- Generic Gaussian signal
  - Widths set to experimental resolution or 5,7,10% of m_G

Summary of Dijet Resonances

- Summary of various dijet searches in DM context
- Standard dijet analysis most sensitive at high m_{jj}
  - See Reza's talk
- TLA analysis extends m_{jj} significantly lower
  - Improves sensitivity by factor ~2 compared to pre-LHC and previous ATLAS results
- Using dijets recoiling against ISR can push to lower m_{jj}
  - Analyses to be updated with more data

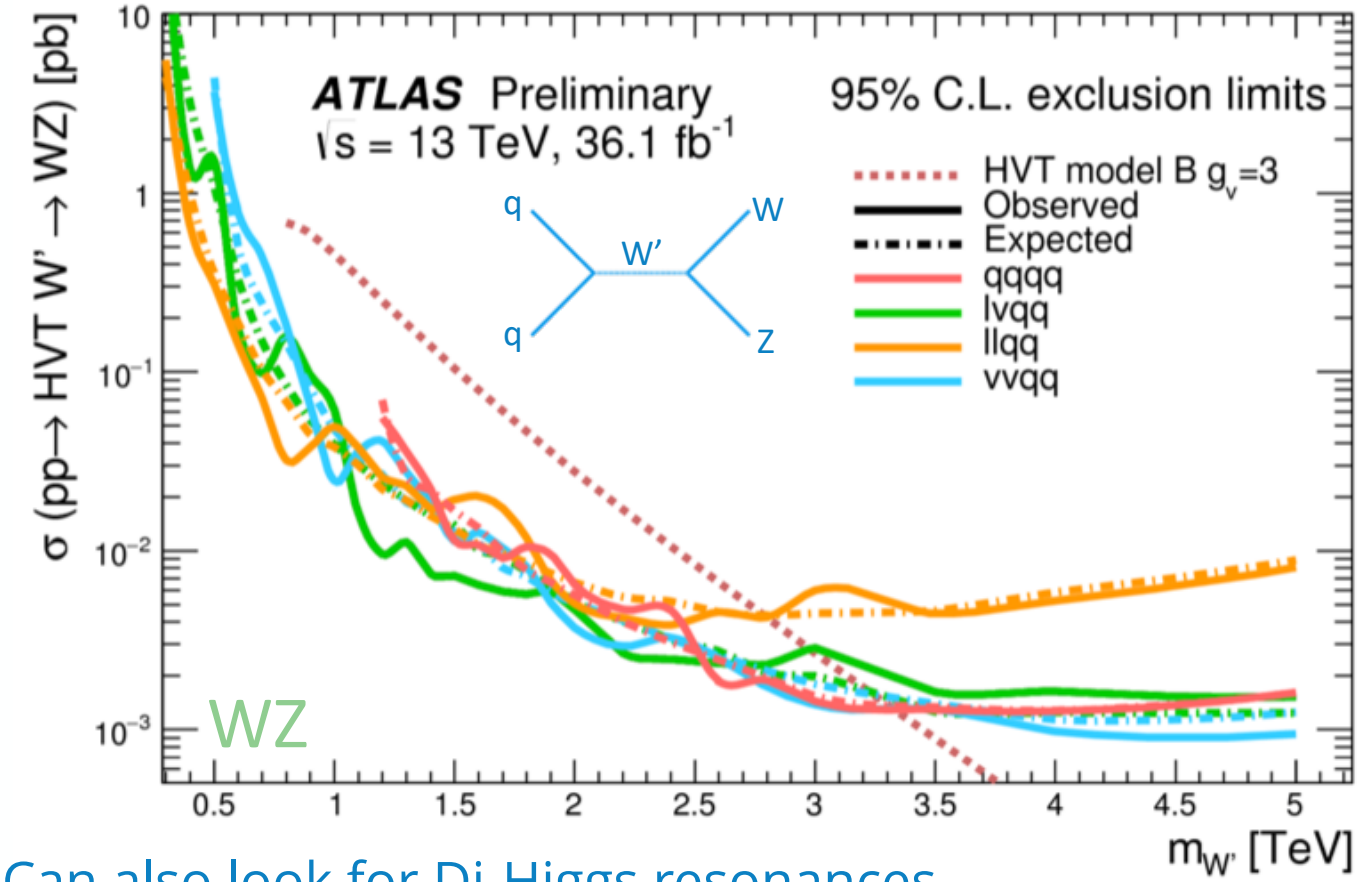


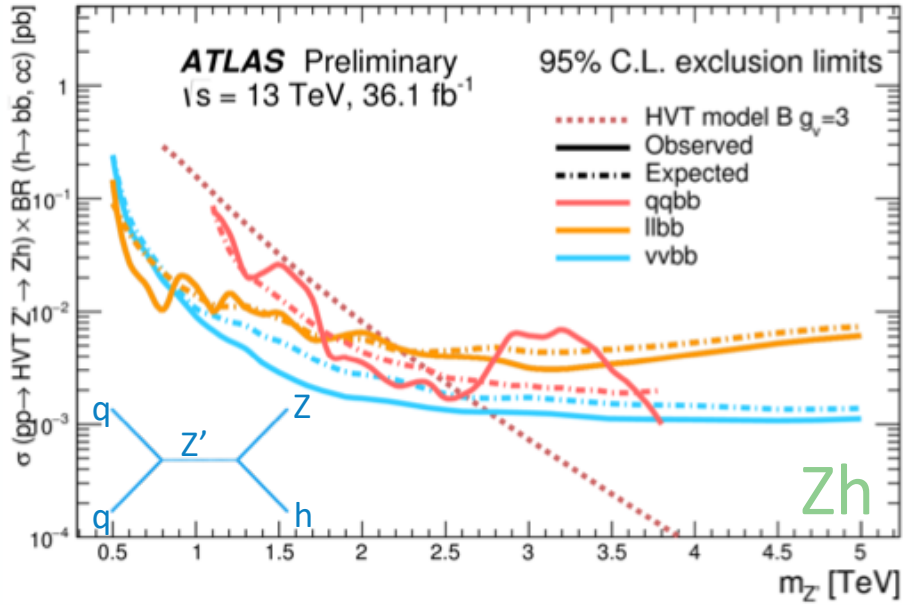
Diboson Resonances: hh → 4b Analysis

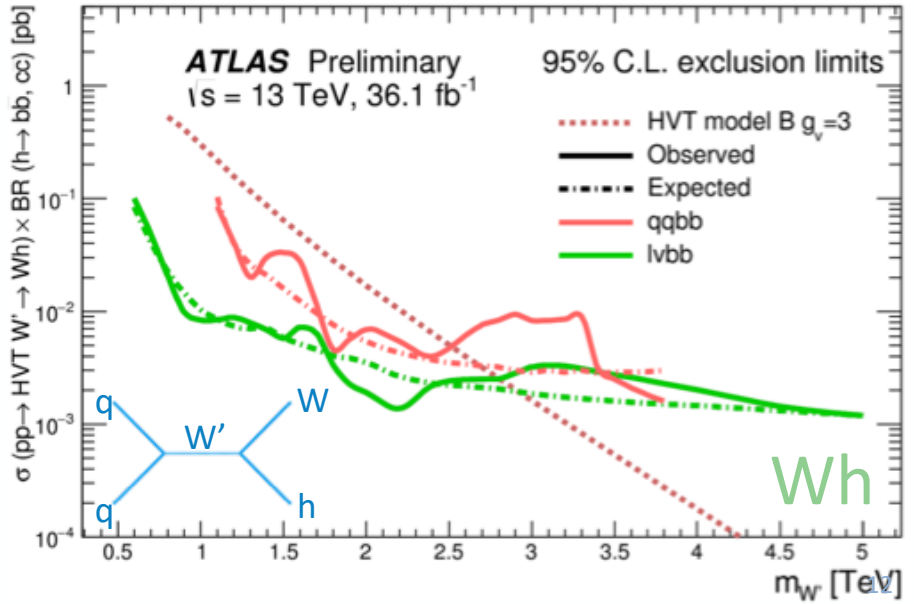


Summary of VV/VH resonances

- Wide variety of searches for diboson resonances in VV/VH
  - Leptonic decays at low mass (see Viviana's talk)
  - Semi-leptonic and fully-hadronic at higher mass
    - Push to highest masses using boosted techniques (Dermot's talk)



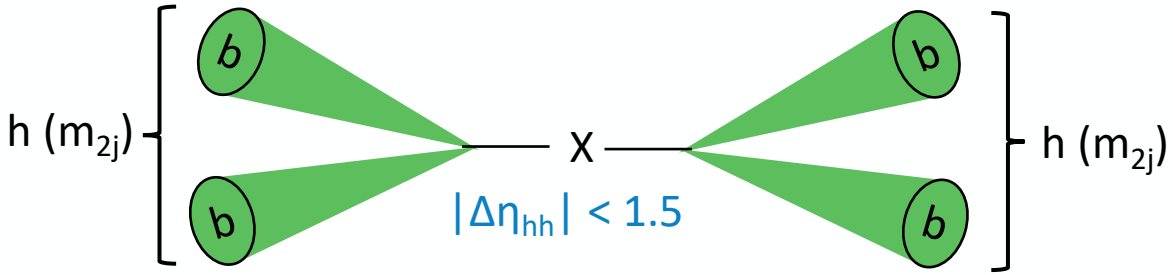




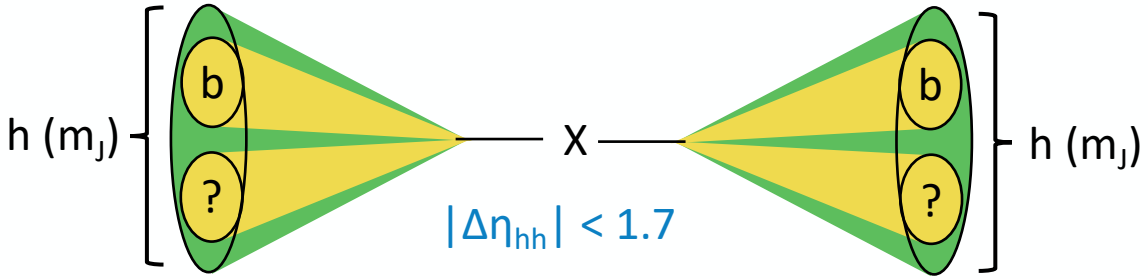
- Can also look for Di-Higgs resonances …

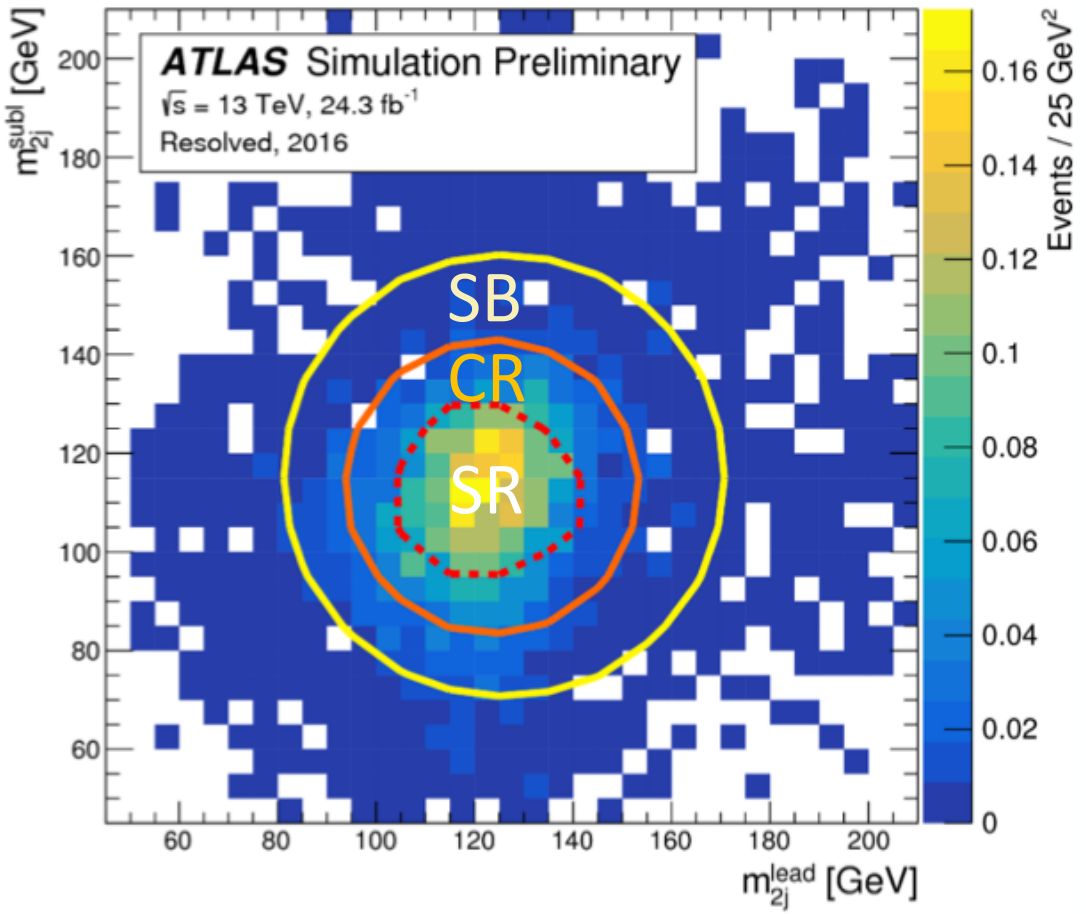
Event Selection

- Resolved (27.5 fb^{-1} from b-jet trigger)
  - ≥ 4 R=0.4 b-jets (j) with p_T > 40 GeV in $|\eta|$ < 2.5
  - Pair 4 highest score b-jets based on ΔR_{jj} and Δm_{2j}
  - m_{4j}-dependent p_T^h cuts + top veto + QCD cuts



- Boosted (36.1 fb^{-1} from fat-jet trigger)
  - ≥ 2 R=1.0 jets (J) with p_T > 450,250 GeV in $|\eta|$ < 2.0
  - Ghost-match to ΔR=0.2 track-jets
  - Categorise into 2,3,4 b-tagged track-jets





- Split into signal and control regions based on m_{2j} (m_J)

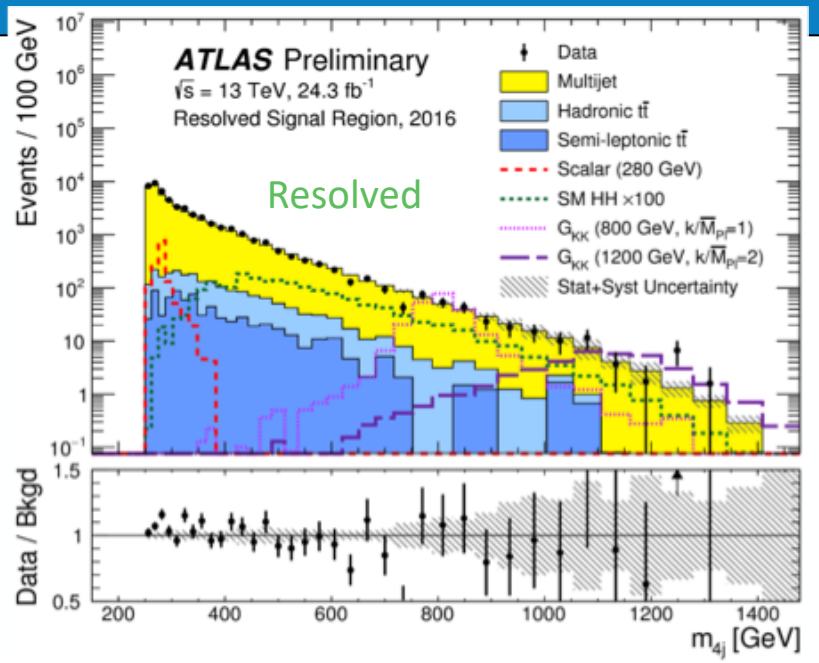
Background Modelling

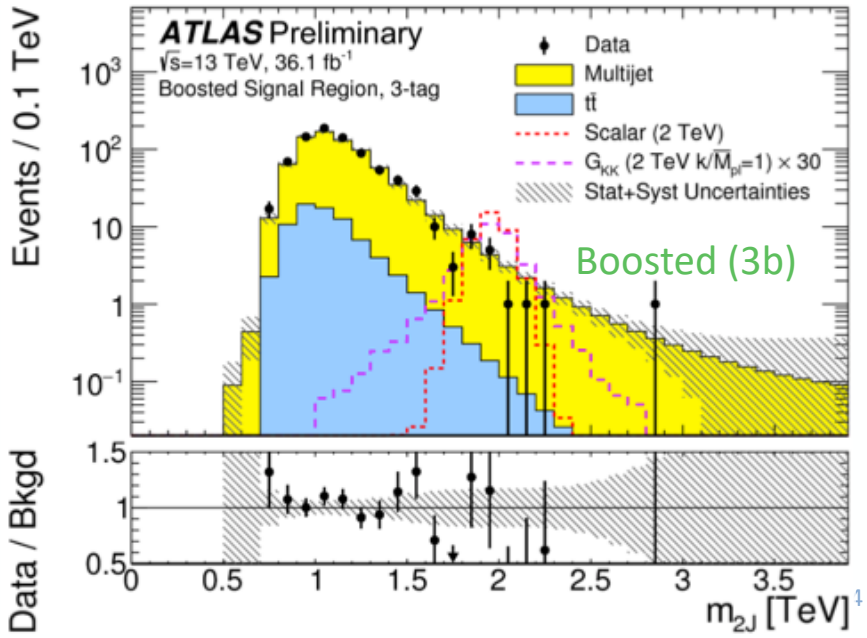
- Main background is QCD mulijet, followed by ttbar
- Extract m_{hh} templates
  - MJ taken from lower b-tag data
  - ttbar taken from simulation

  } Fit with function for $m_{2J} > 1.2$ TeV
- Correct MJ kinematics
  - Account for differences in kinematics of lower b-tagged sample to due to b-tagging and additional jet activity
  - Reweights derived from SB data iteratively
- Simultaneous fit of MJ and ttbar normalisation
  - Resolved: fit yields in SB split based on compatibility with ttbar topology
  - Boosted: fit leading large-R jet mass

$$N_{\text{bkg}}^{\text{n-tag}} = \mu_{MJ}^{\text{n-tag}} N_{MJ}^{\text{lower-tag}} + \alpha_{t\bar{t}}^{\text{n-tag}} N_{t\bar{t}}^{\text{n-tag}}$$

- Validate method in CR

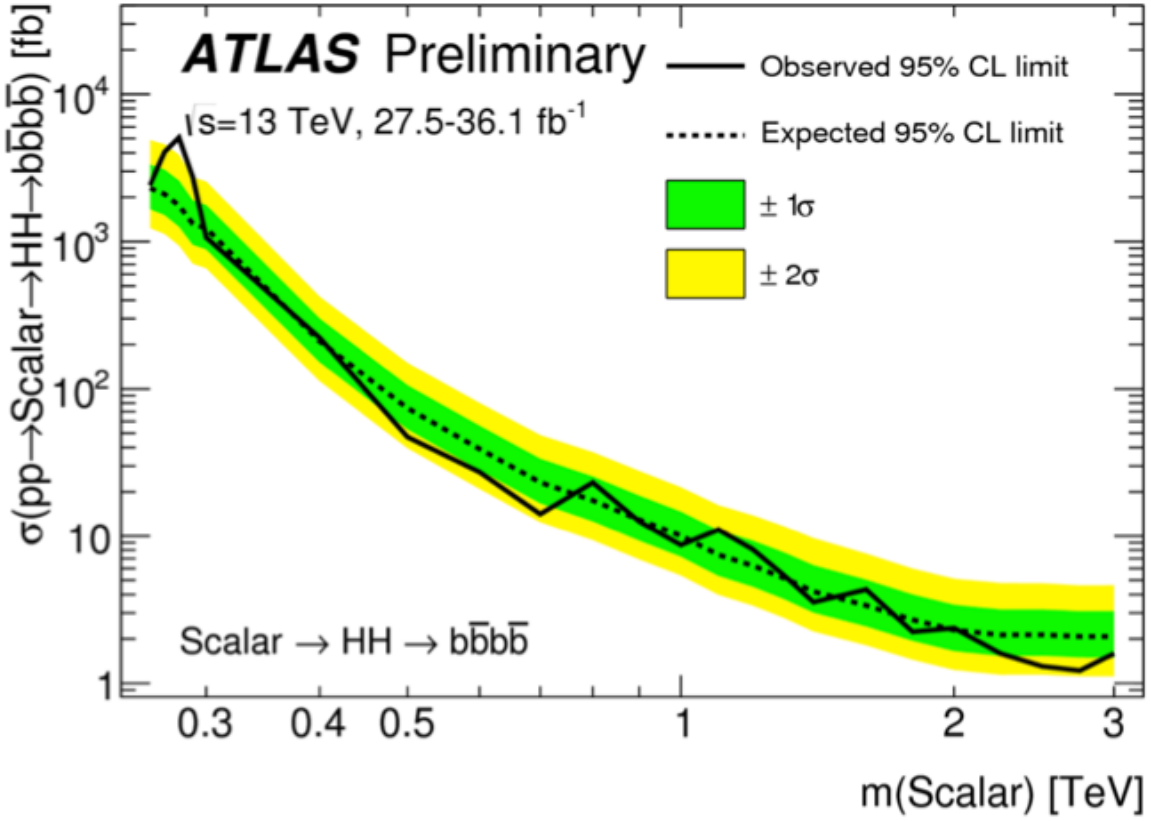


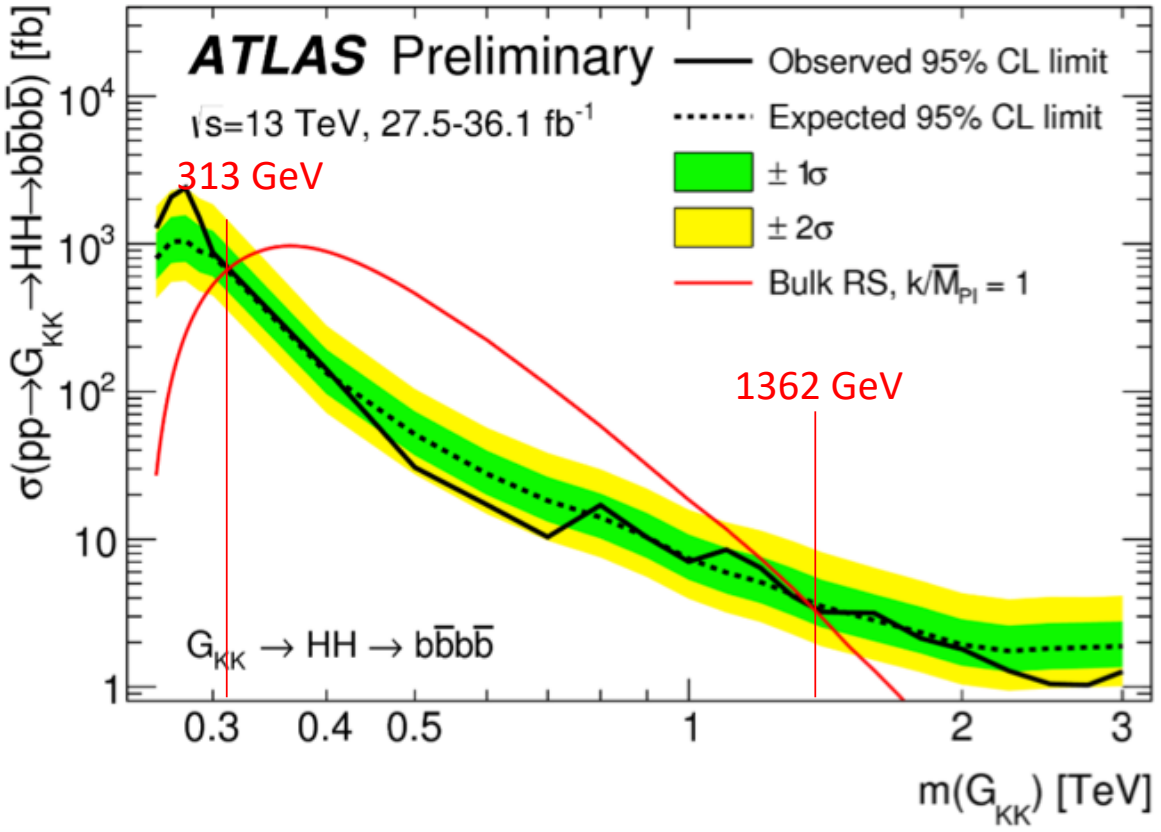


X → hh → 4b Results

- Simultaneous fit to m_{4j} (m_{2J}) in resolved and boosted categories, with resolved having priority
  - Range: 260 – 1400 GeV (800 – 3000 GeV) for resolved (boosted)

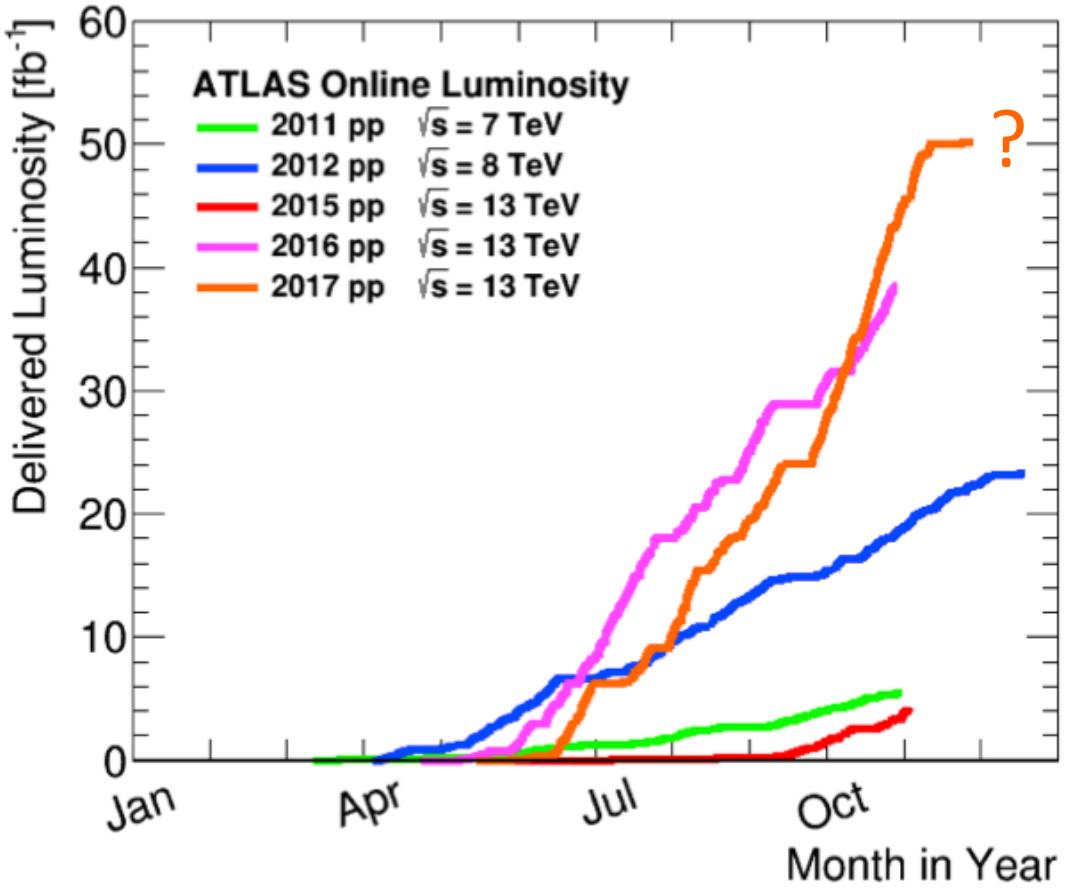
- Set limits on narrow scalar and spin-2 bulk RS gravition using CLs method
  - Maximum local deviation is 3.6σ (2.5σ) for H (G) @ m_{hh} = 280 GeV → 2.3σ global





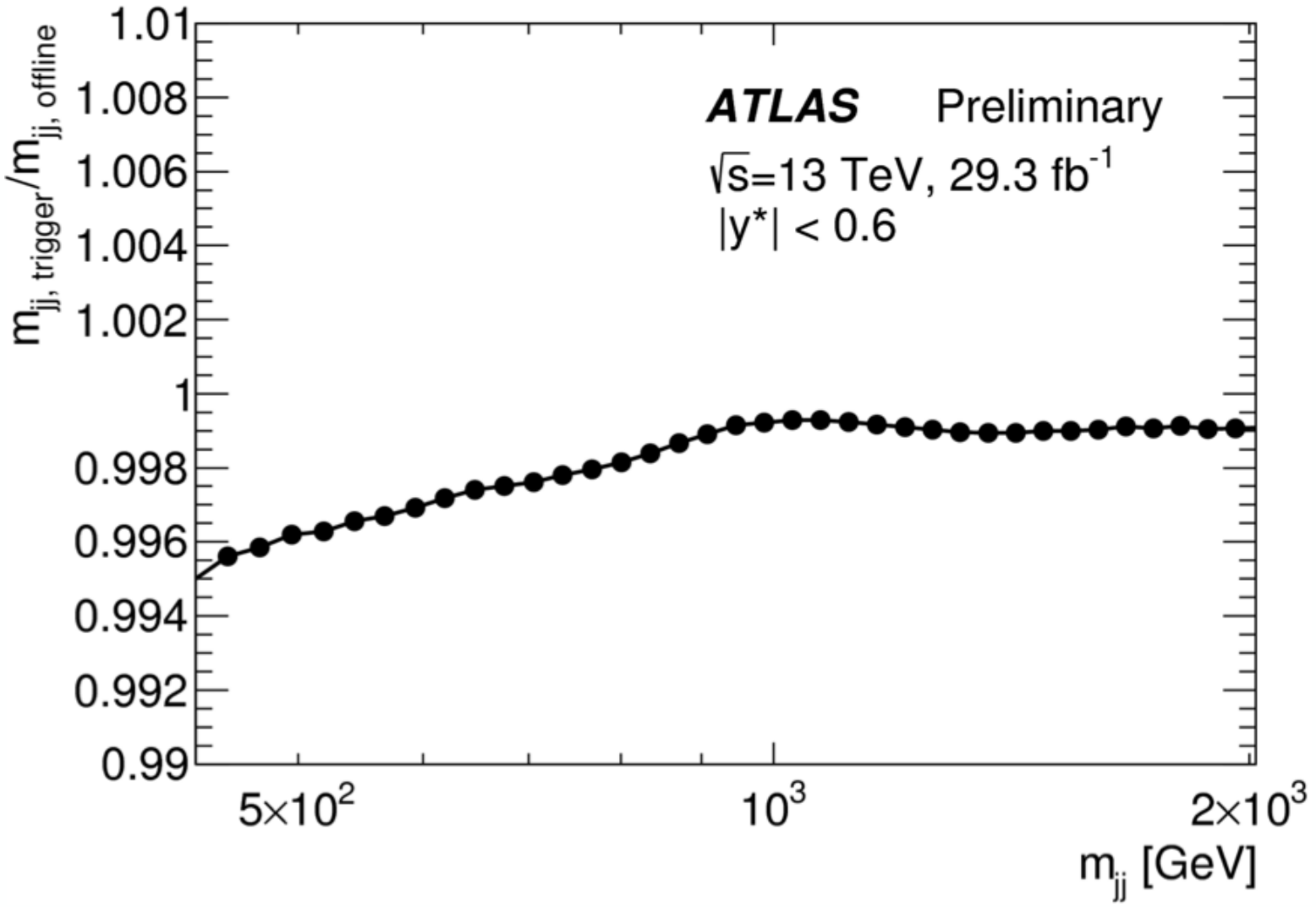
Summary

- Wide programme of dijet/diboson resonance searches at ATLAS
  - Not only probe BSM frontiers at multi-TeV scale but push new areas too
  - See the many talks this week for a flavour
- Focused on two new results with full 2015+16 data
  - Novel TLA dijet analyses opens up new phase space
  - hh resonances searches utilise newest piece of SM
- Significantly more data to analyse with full run 2
  - Expect around 4x the luminosity (~120 fb^{-1})
  - Coupled with innovative new techniques (TLA, ML, …)
- Probe even higher masses and lower couplings
  - Hopefully next results won't only have limits to show ☺

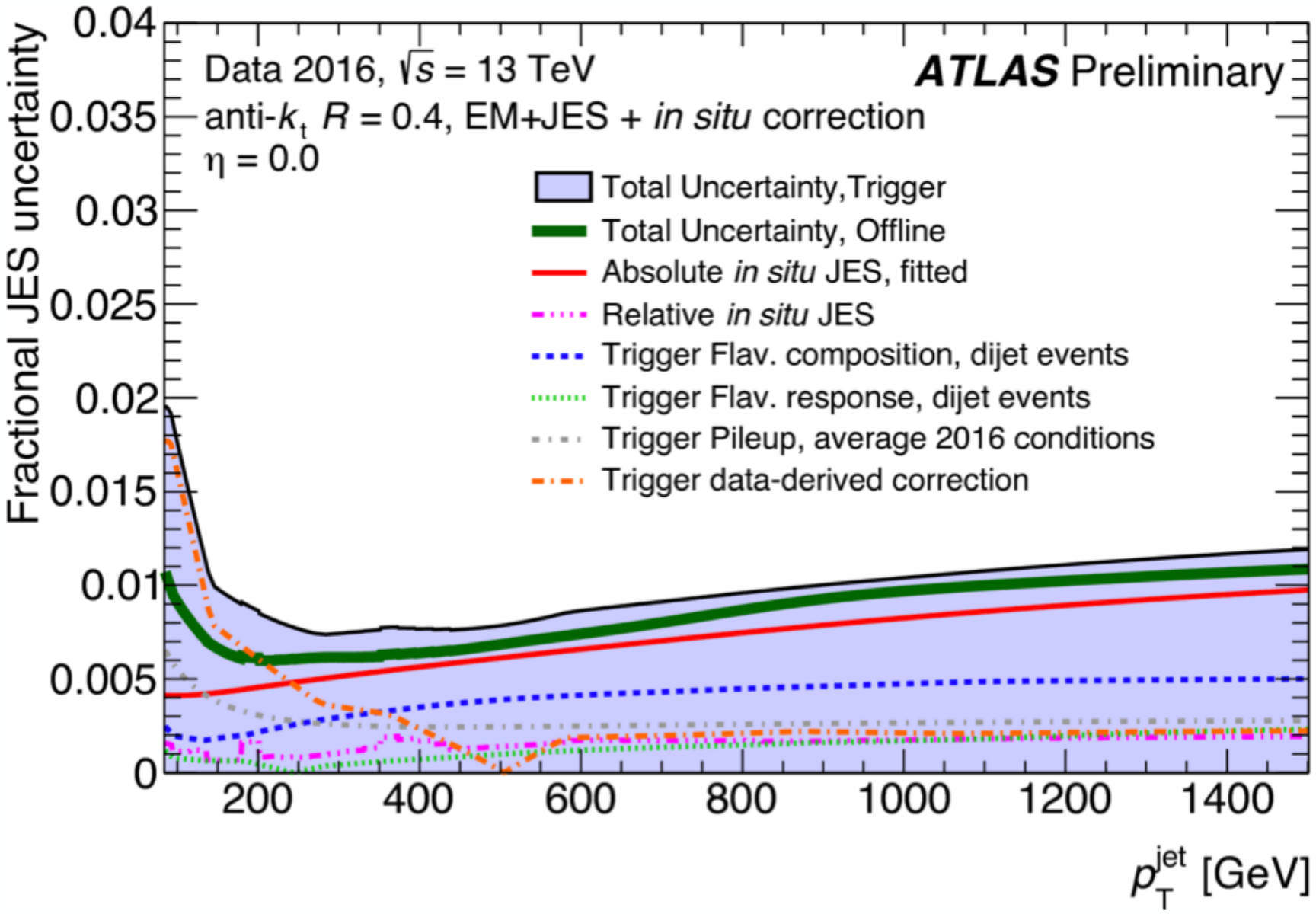


Additional Information

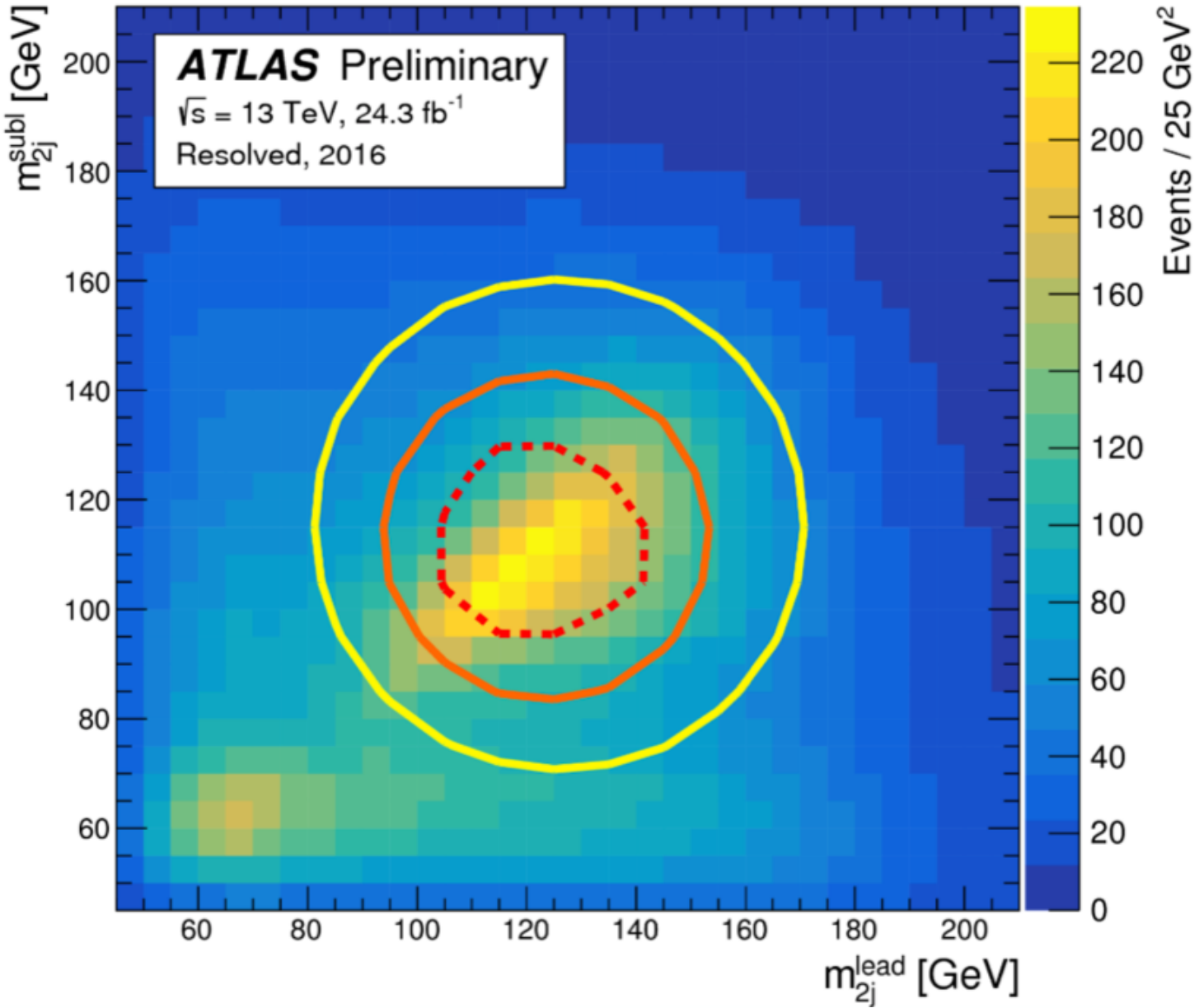
TLA: m_{jj}


ATLAS Preliminary
√s=13 TeV, 29.3 fb-1
|y*| < 0.6
mjj, trigger/mjj, offline
1.01
1.008
1.006
1.004
1.002
1
0.998
0.996
0.994
0.992
0.99
5×10^2
10^3
2×10^3
mjj [GeV]

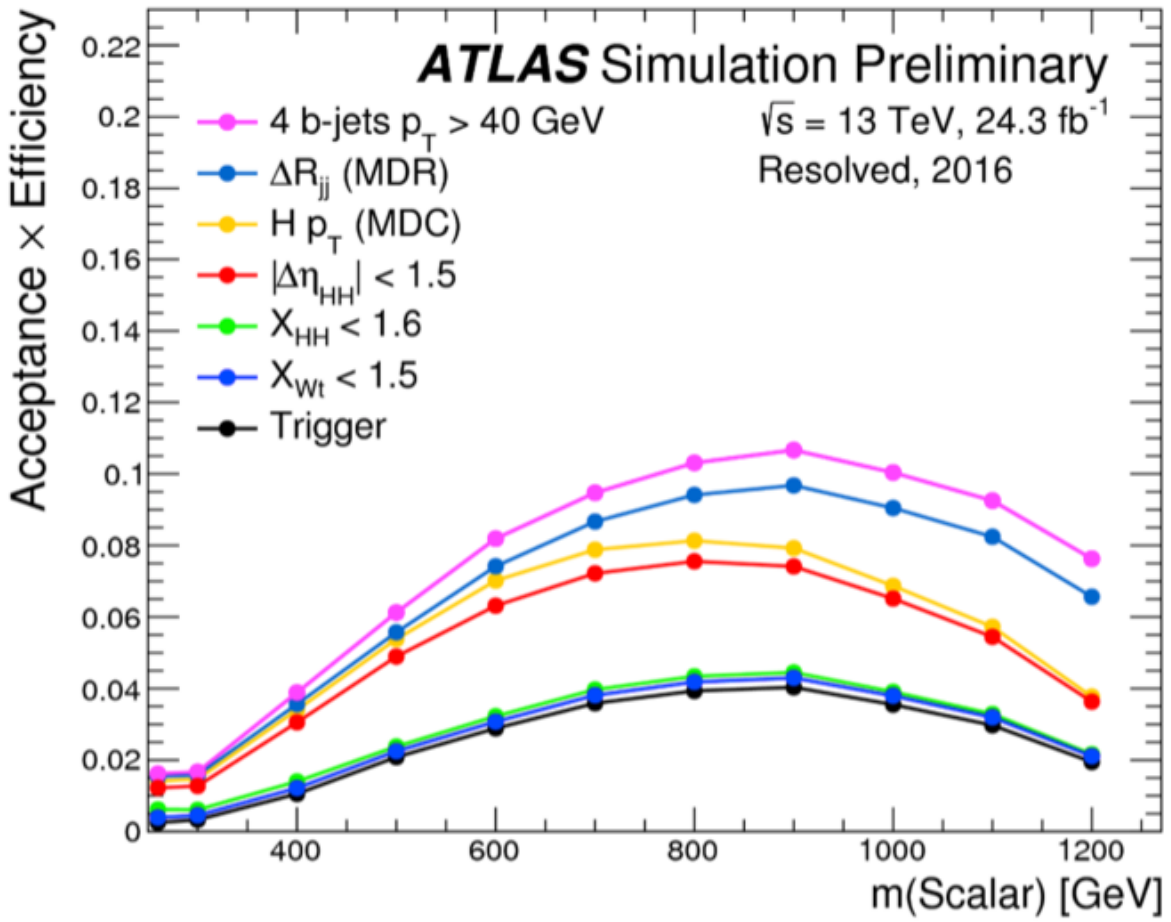
TLA: JES Uncertainty

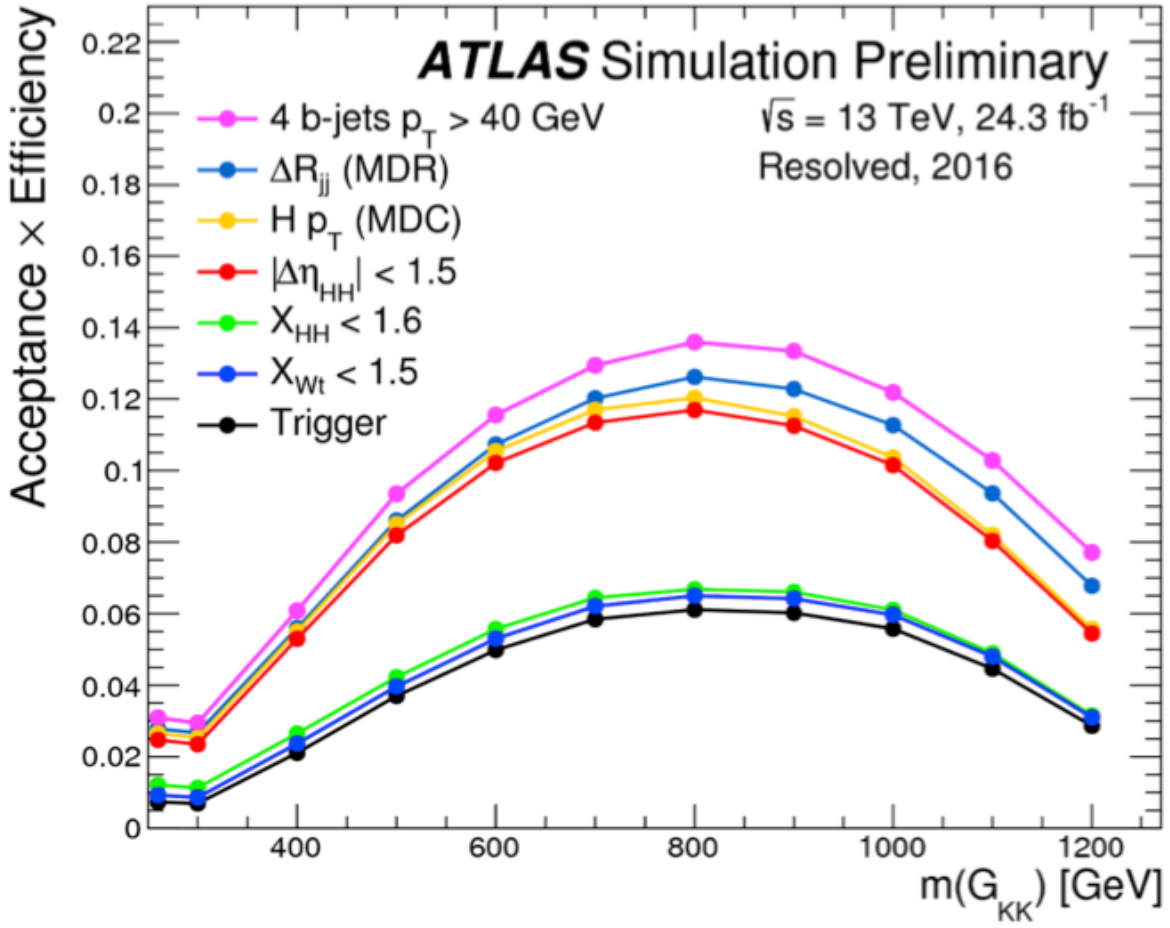


4b: QCD Background

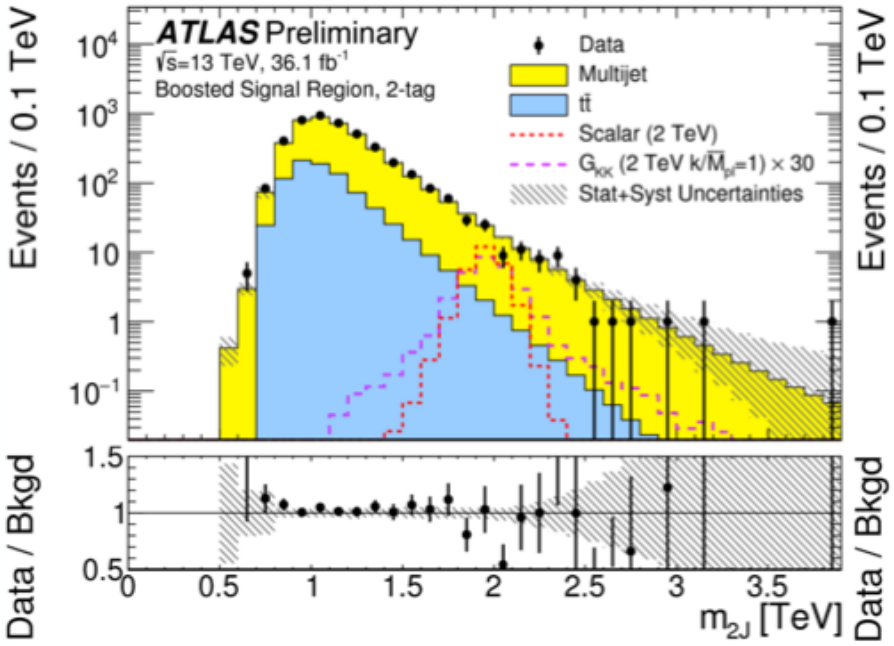


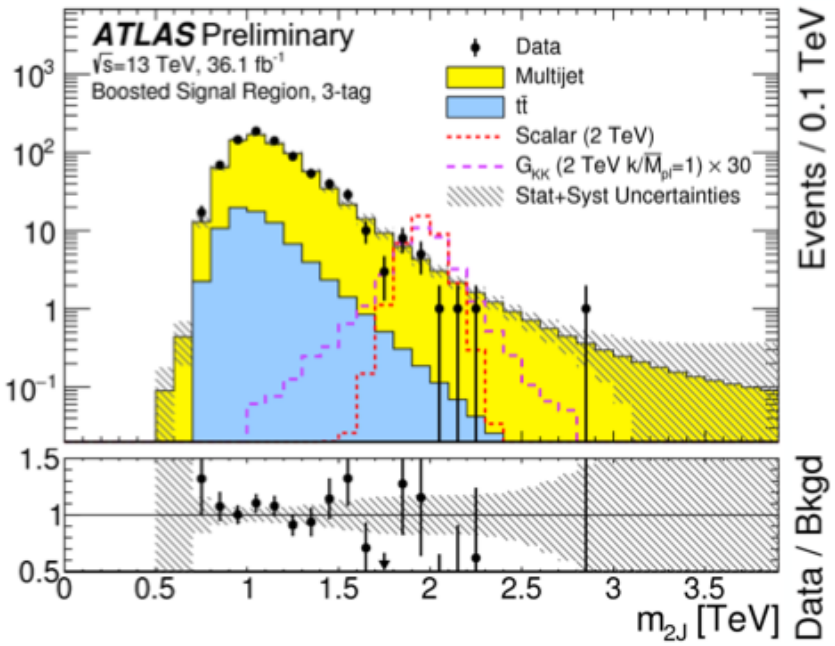
4b: Efficiency

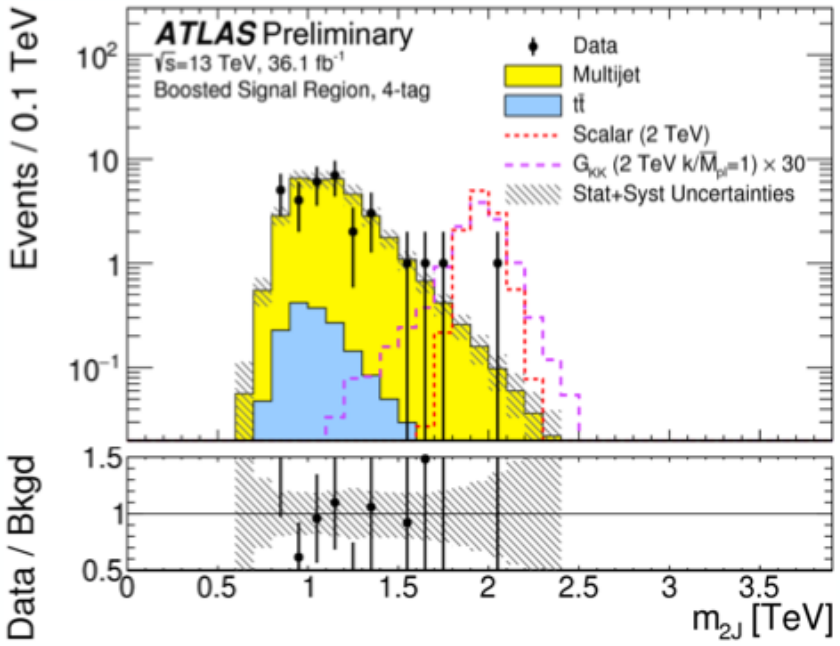




4b: Boosted m_{2J}







4b: RSG $k/M_{Pl} = 2$ Limits