Search for low mass dijet resonances in association with ISR at ATLAS

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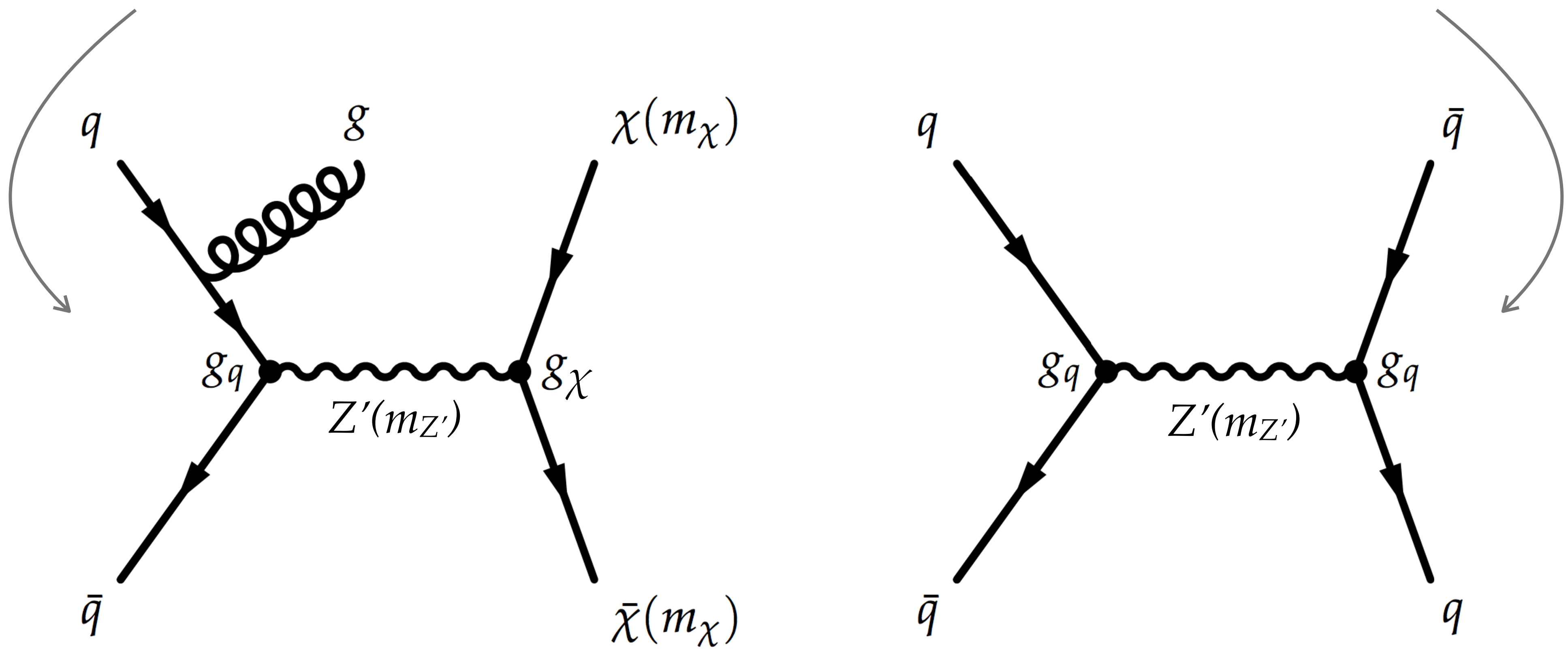
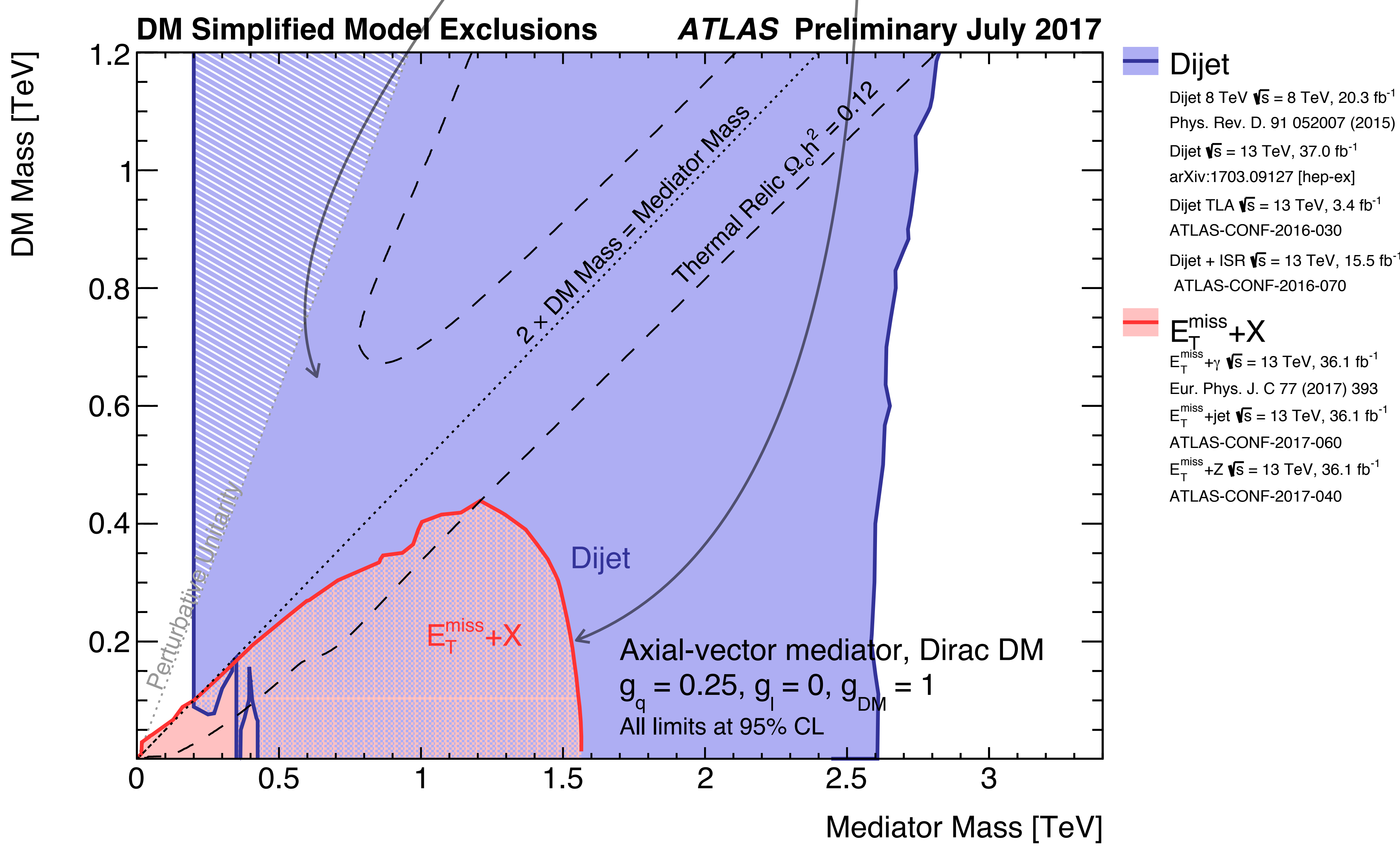
Motivation

- **Simplified models of Dark Matter** (DM):
  DM particle χ and **mediator Z'**, parametrised by g_q, g_χ, $m_{Z'}$, and m_χ
- If mediator couples to SM quarks ($g_q \neq 0$) it can be **produced in *pp* collisions**; can be probed by LHC experiments, e.g. ATLAS
- Can **decay to DM pair** (E_T^{miss} + recoil, X) or **back to quarks** (dijet)



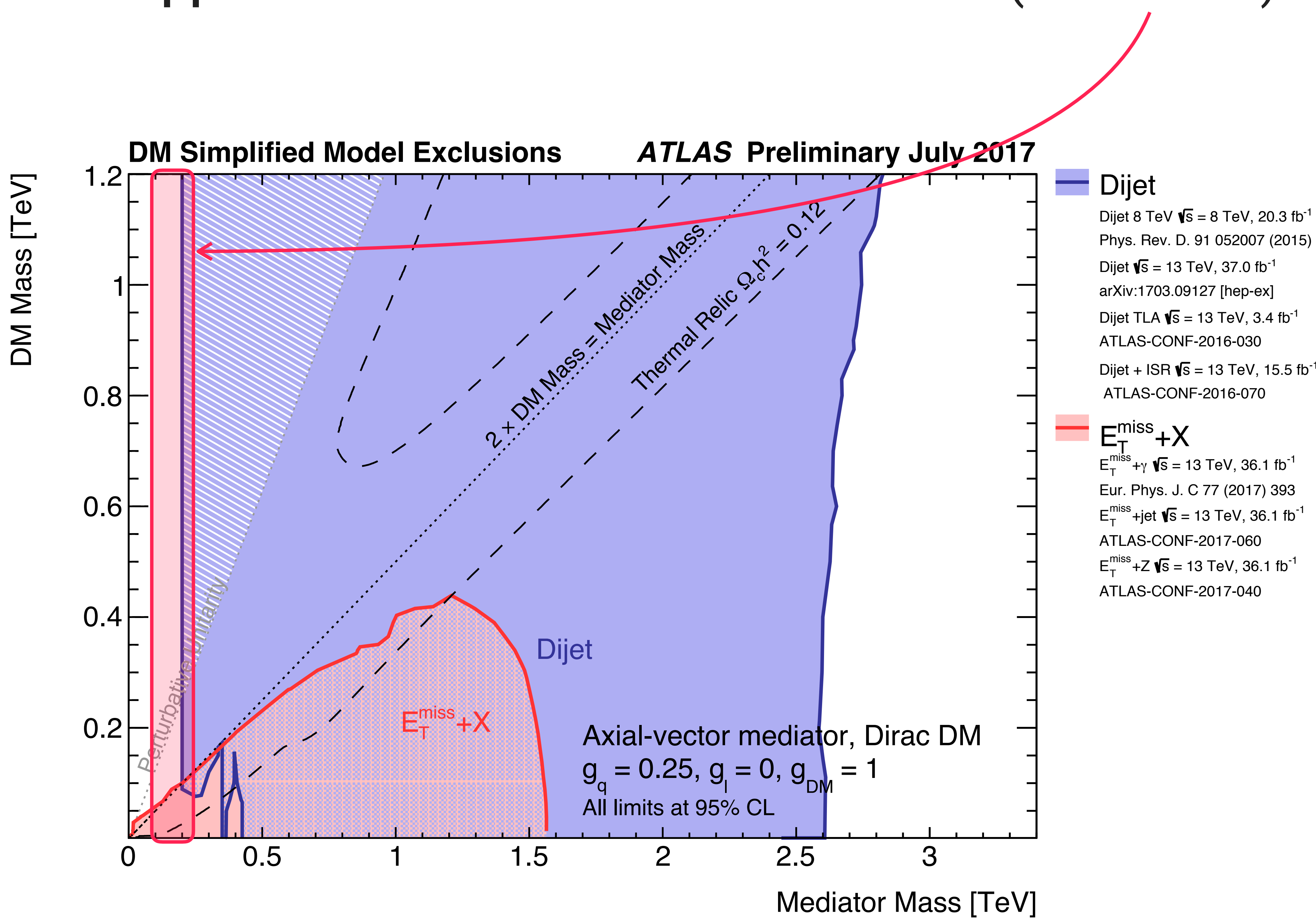
Motivation

- Existing ATLAS limits for **dijet**- and ***E*$_T^{miss}$ + *X*** searches, covering vast region of simplified model phase space



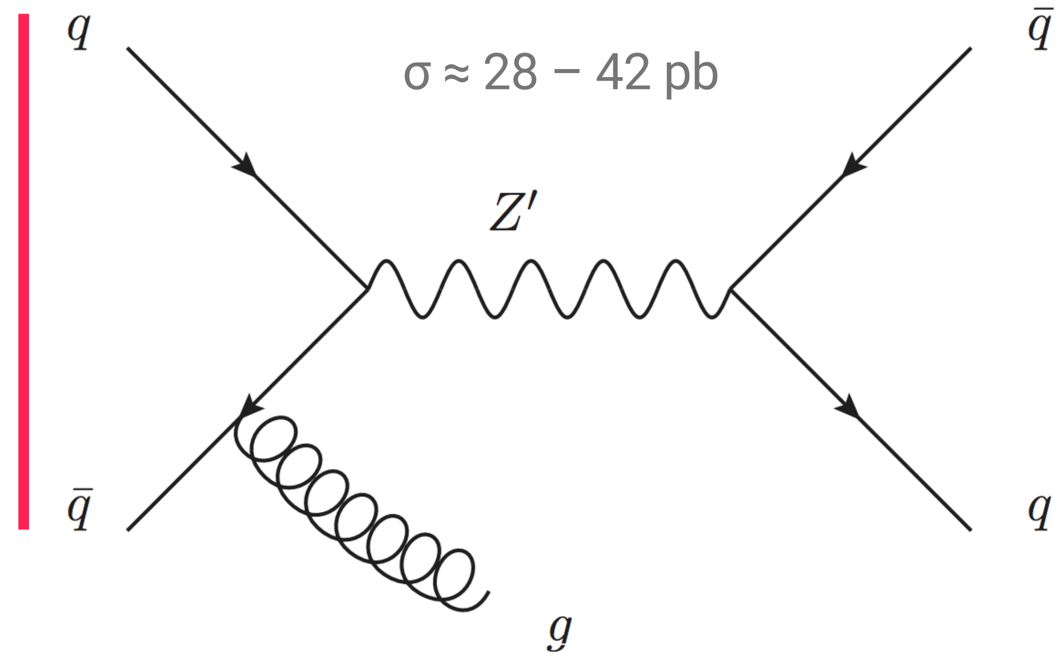
Motivation

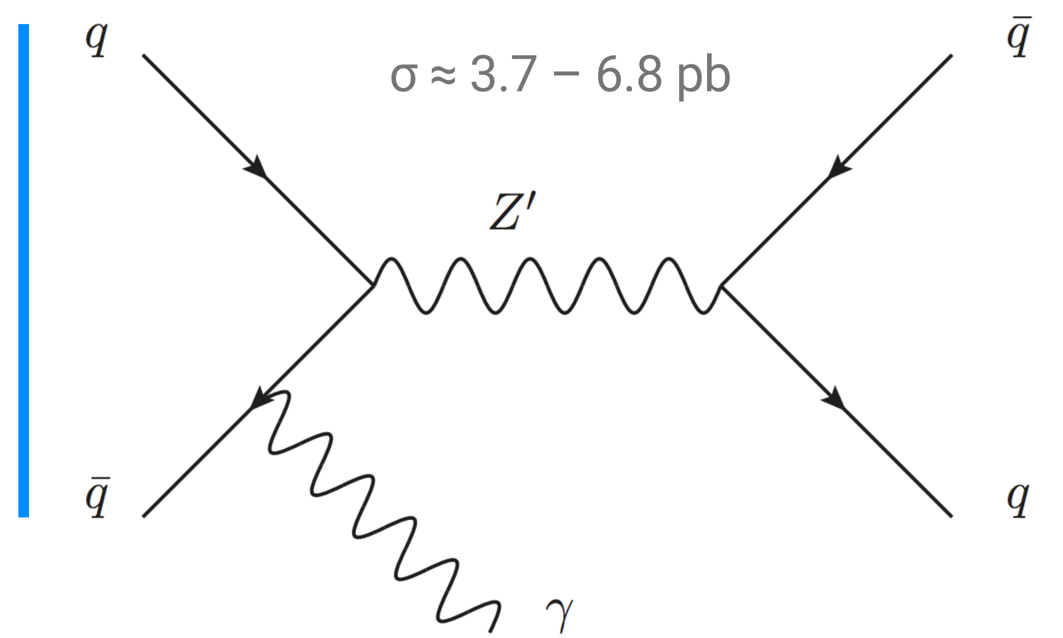
- Need **new approach** for lowest mediator masses (≲ 200 GeV)



Motivation

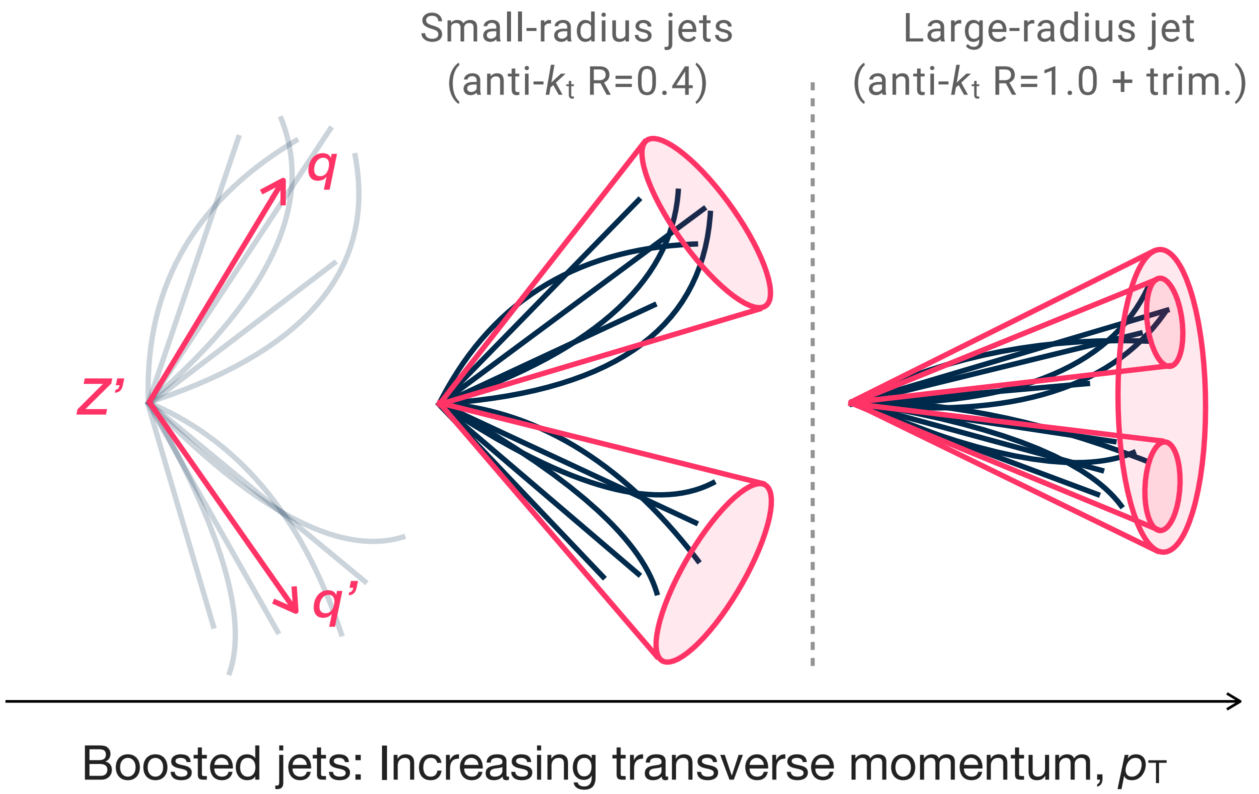
- Dijet searches **limited by jet trigger thresholds** at low mediator masses (< 450 GeV)
- Search for hadronically decaying mediator (*Z'*) **produced in association with recoil** **jet** or **photon**
- **Initial state radiation (ISR)** in context of signal model





Overview

- Search for **generic low-mass leptophobic resonances** *Z'*
- Trigger on recoil (ISR) **jet** or **photon**
- Reconstruct signal candidate as large-*R* jet (“**boosted regime**”)
- Use **jet substructure** to distinguish *Z'* candidates from non-resonant jets



- **First boosted dijet + ISR search** in ATLAS
- Using 36 fb^{-1} 13 TeV *pp* data
- Recently public [1801.08769], submitted to Phys. Lett. B

Search backgrounds

- Dominant:
  - **Jet ch.:** QCD multijets
  - **Photon ch.:** γ + jets
- Sub-dominant:
  - **Jet ch.:** W/Z + jets
  - **Photon ch.:** Incl. $W/Z + \gamma$
- Sub-dominant backgrounds estimated from Monte Carlo simulation (Sherpa 2.1.1 LO + NLO cross-section correction)
- Dominant background estimated using **data-driven approach**, also used by CMS
- **Jet substructure (τ_{21})** used to reduce leading backgrounds, perform background estimate
  - τ_{21}: Ratio of energy correlation functions, expressing "two-pronginess"

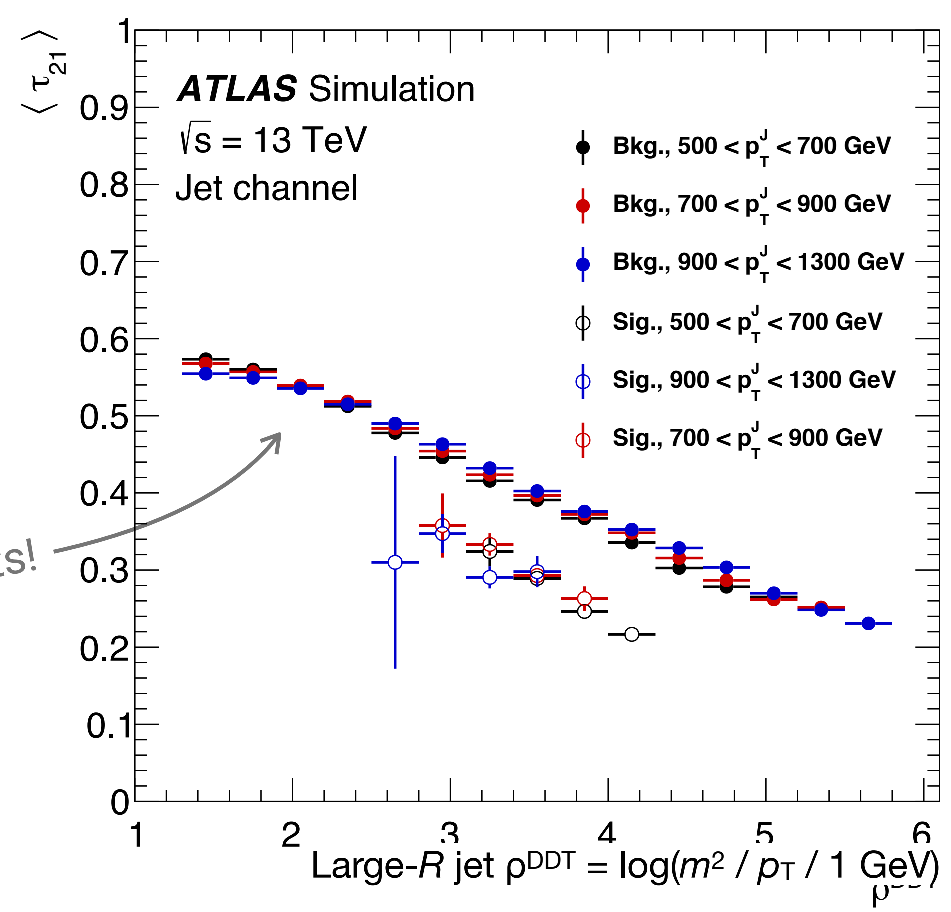
J. Dolen *et al.* [1603.00027]
ATLAS Collaboration [1801.08769]

Substructure decorrelation

- Non-flat profile of τ_{21} wrt. m_J → **cut sculpts m_J distribution**
- Need to remove correlation → **new variable τ_{21}^{DDT}**
- Decorrelation enables robust data-driven background estimate

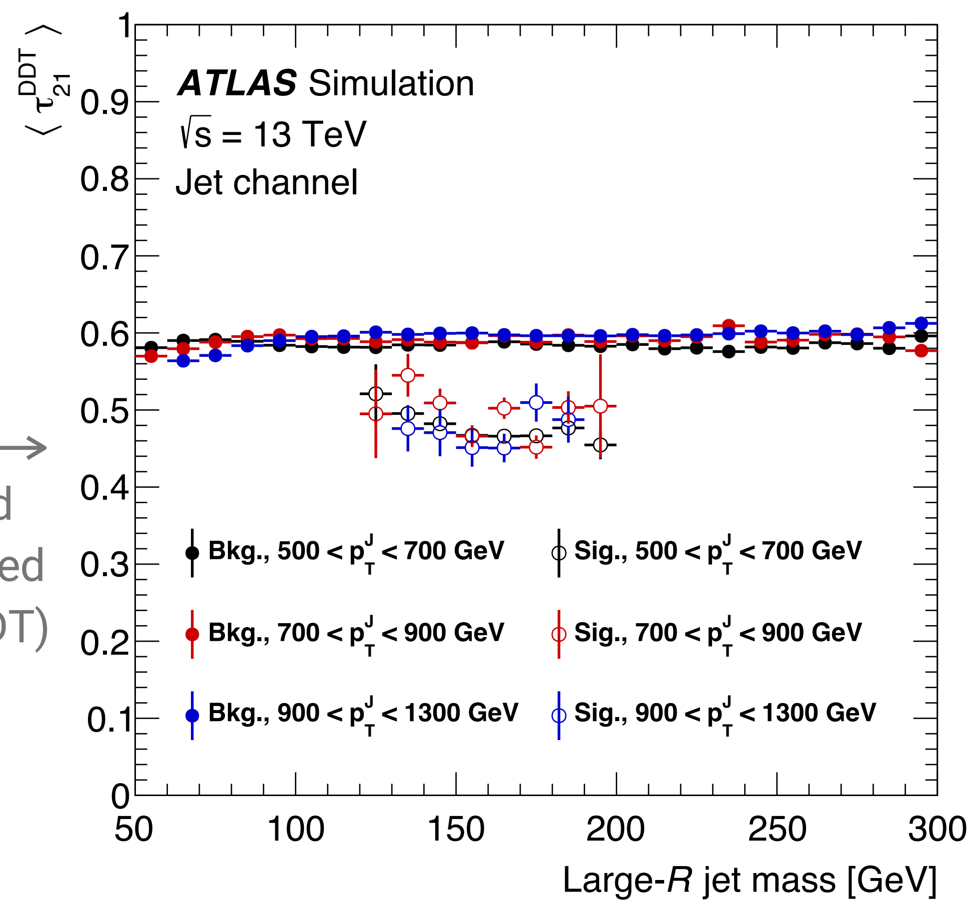
Before decorrelation

Profile plots!



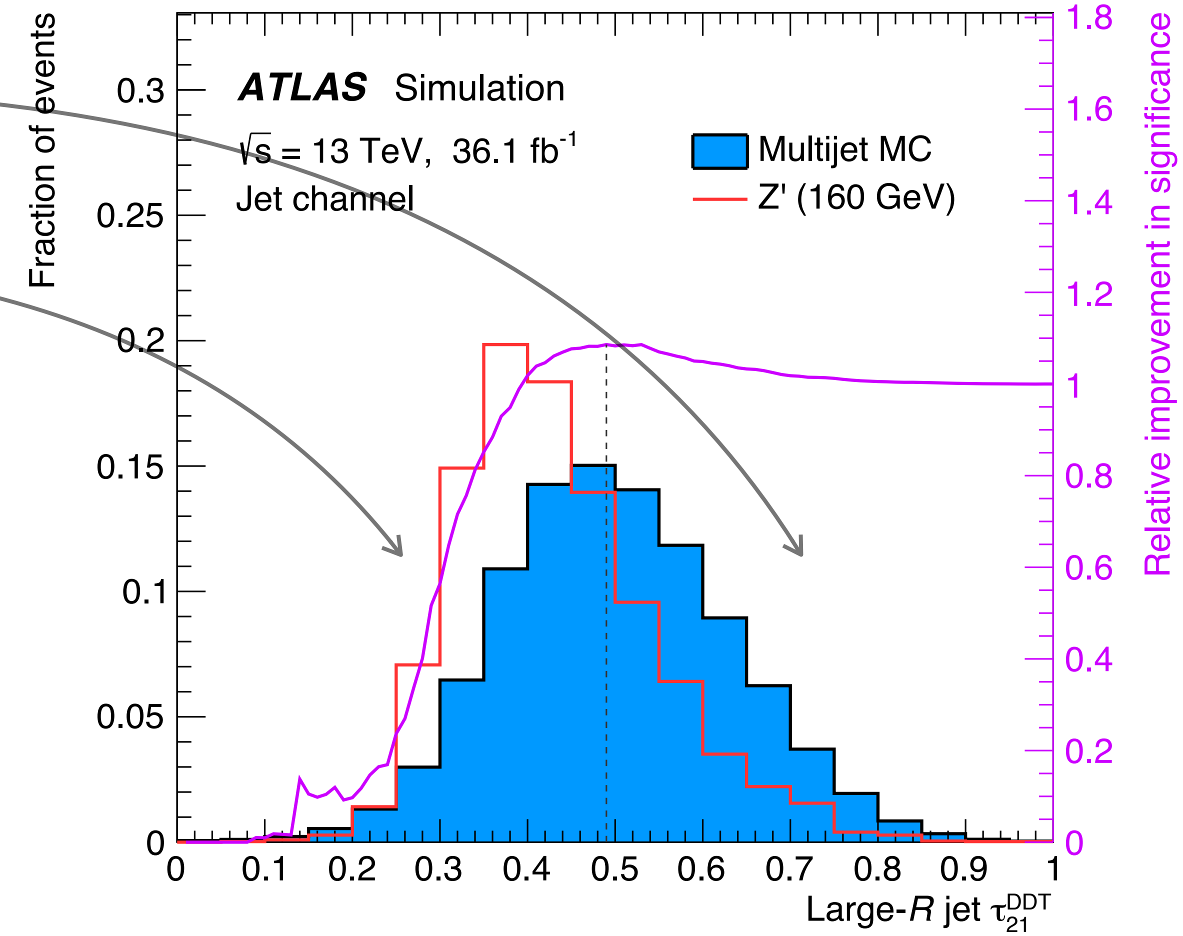
Designed decorrelated tagger (DDT) method

After decorrelation



Background estimation

- **Fail:** $\tau_{21}^{DDT} > 0.5$
- **Pass:** $\tau_{21}^{DDT} < 0.5$
- **Transfer factor (TF):**
  Ratio of events passing / failing
- Parametrised by kinematic variables (p_T, ρ^{DDT})



- Estimate background in search region as:

$$N_{\text{pass}}\,(p_T,\rho^{DDT}) = \text{TF}\,(p_T,\rho^{DDT}) \times N_{\text{fail}}\,(p_T,\rho^{DDT})$$

Background estimation

- **Signal region** (SR): 20% window in m_J around each $m_{Z'}$ hypothesis
- Fit 2D TF histogram with Gaussian process (GP), **interpolate from side-bands**
- For each signal hypothesis: **Unique signal region, background estimate**

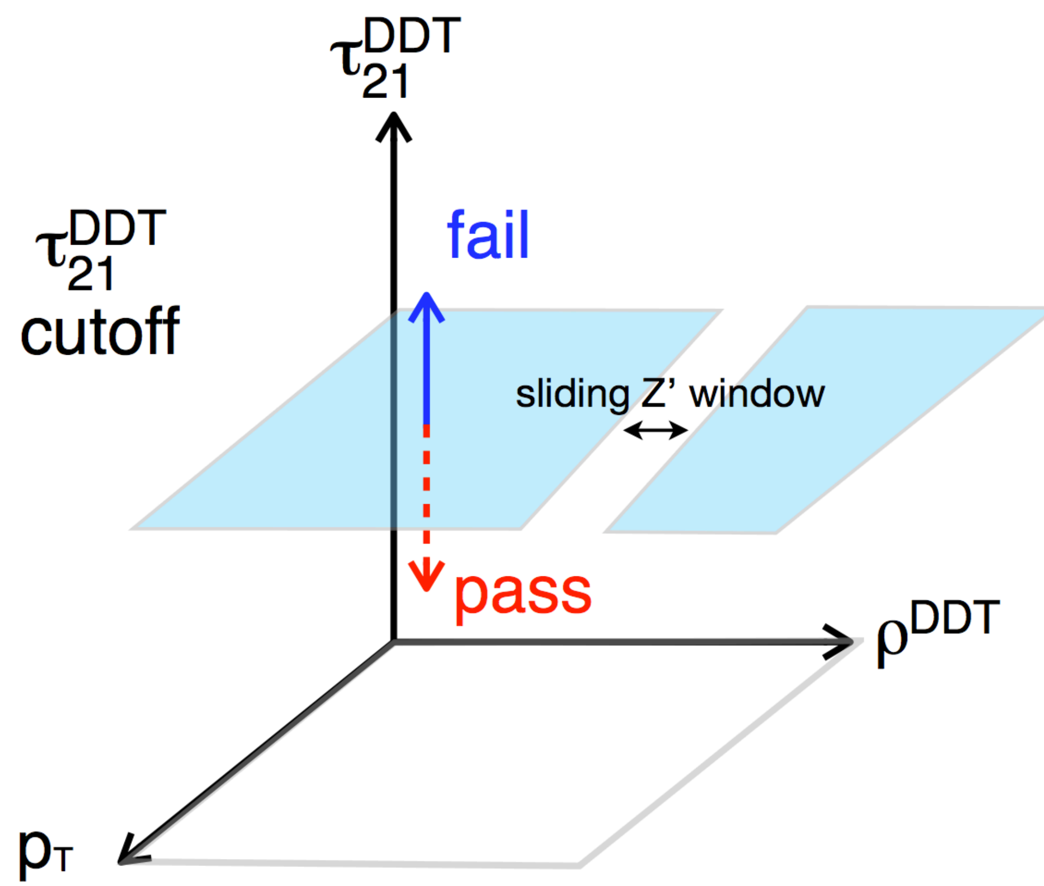
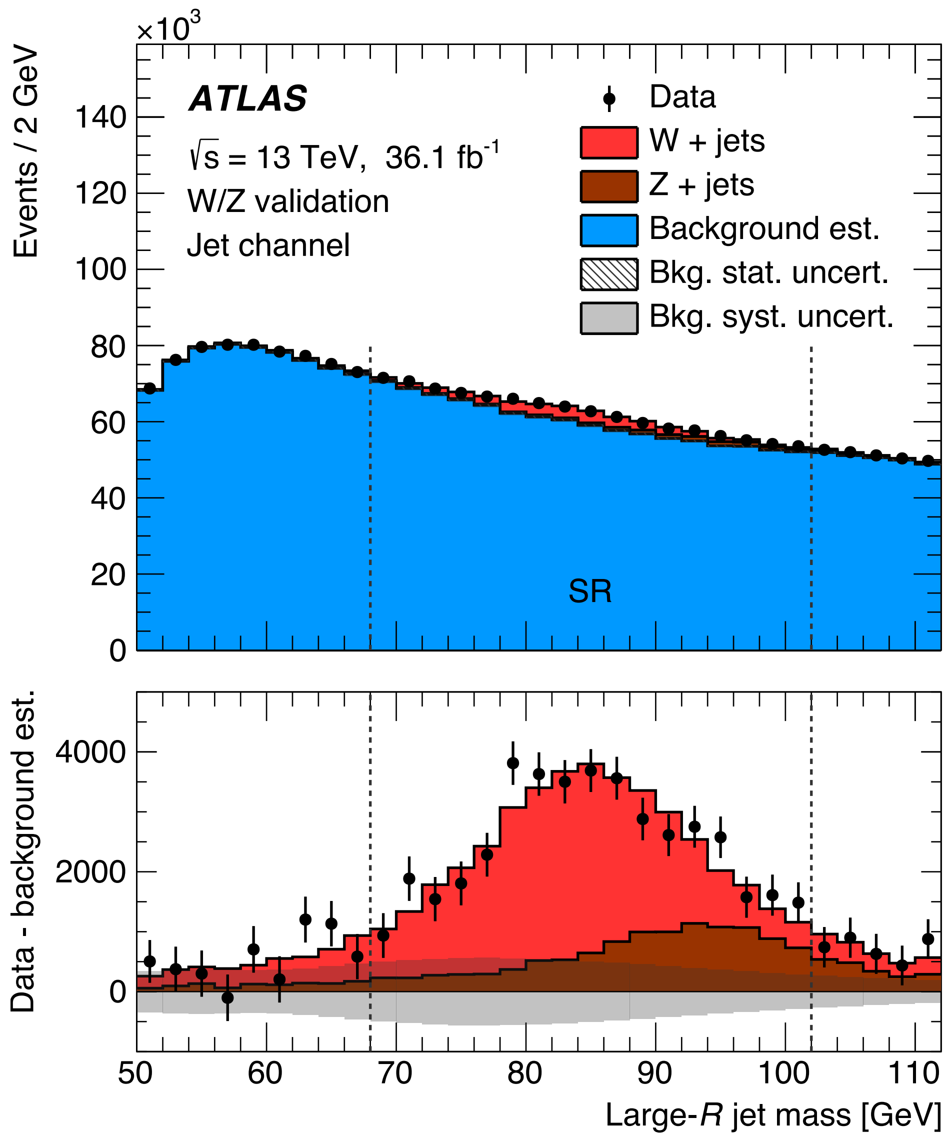


Figure from [1705.10532]

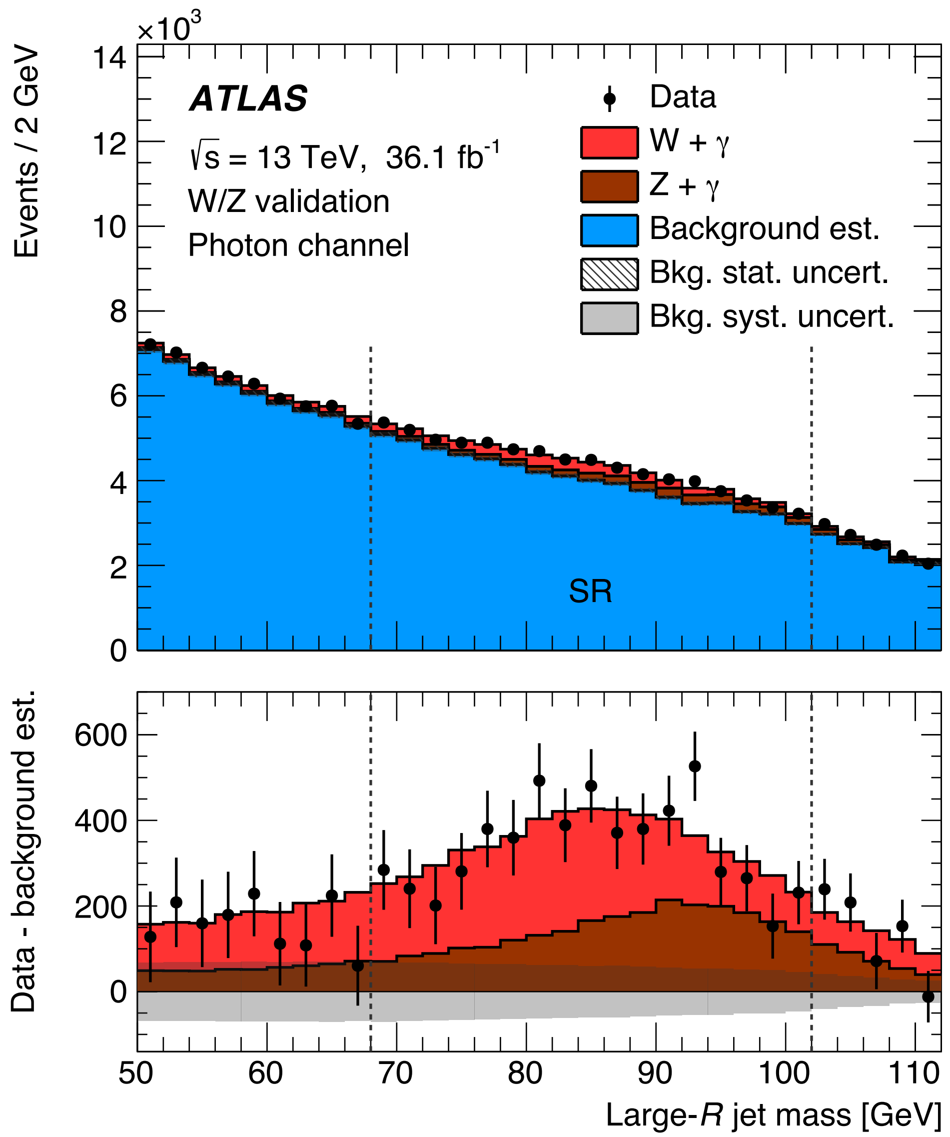
Validation on *W/Z* peak

- Full analysis chain validated on *W/Z* peak in data
- Best-fit signal strength $\hat{\mu}$ consistent with 1 in both channels

Jet channel



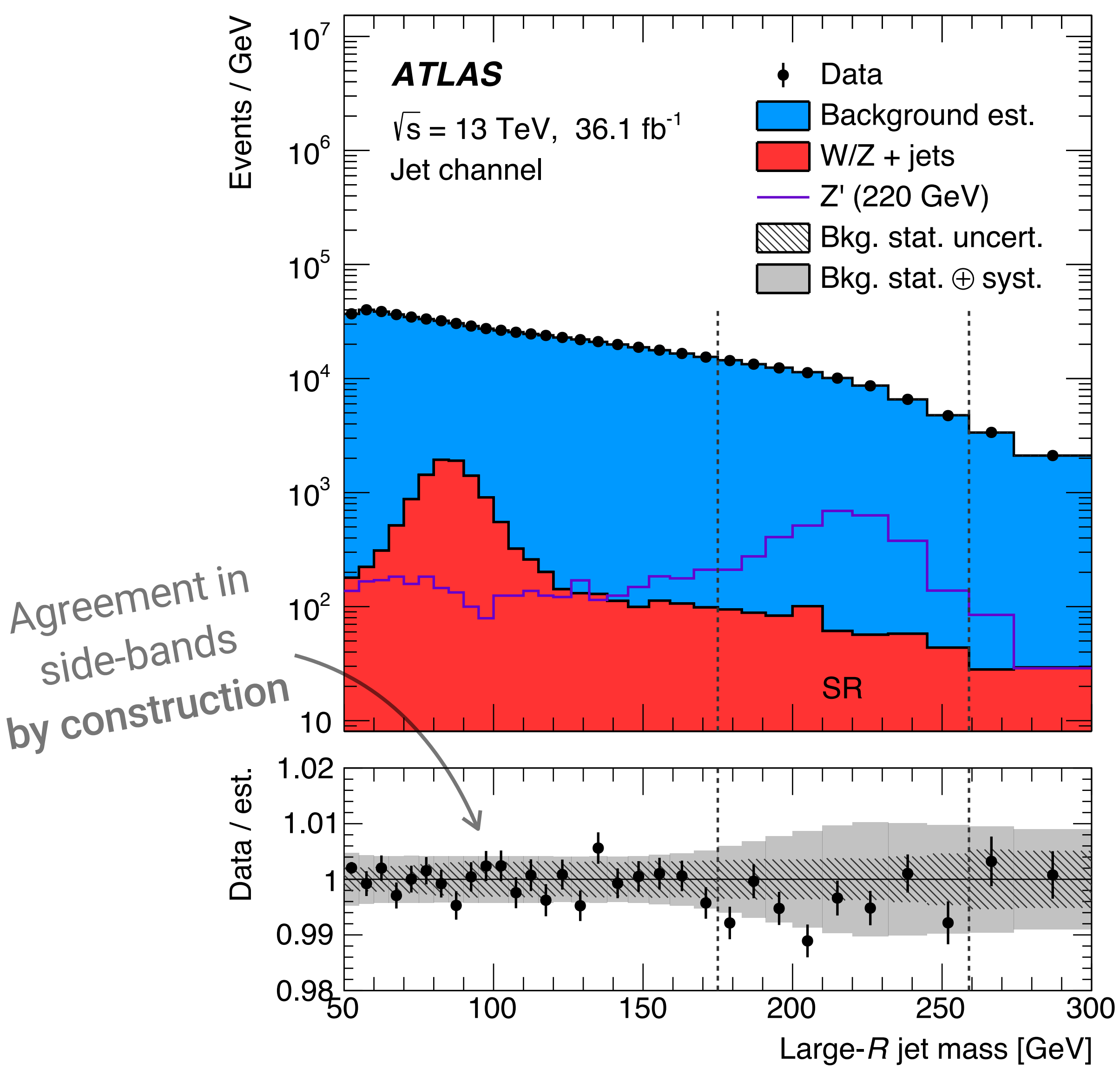
Photon channel



Discriminant distributions

- Large-*R* jet mass distributions in the jet (*left*) and photon (*right*) channel for $m_{Z'}$ = 220 GeV simulated signal mass point

Jet channel



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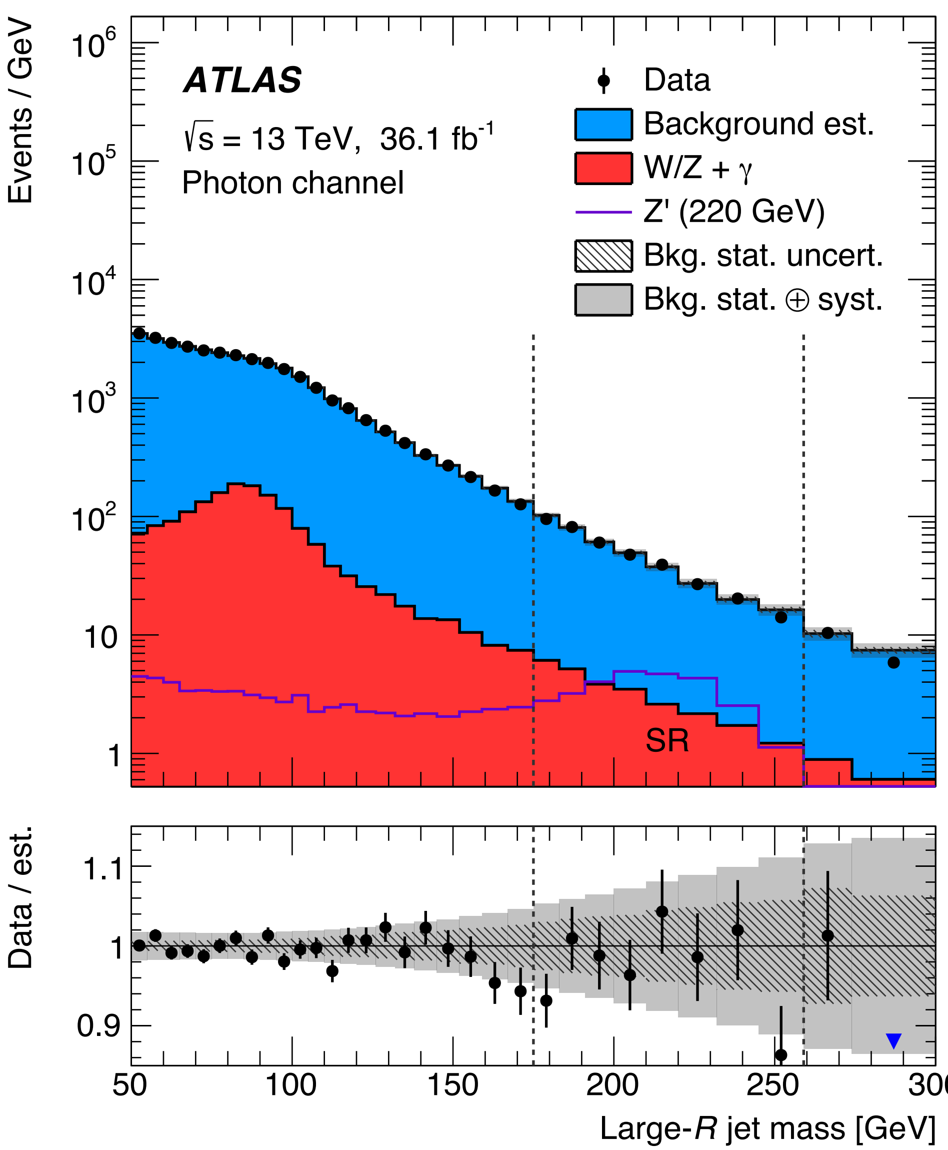


Systematic uncertainties

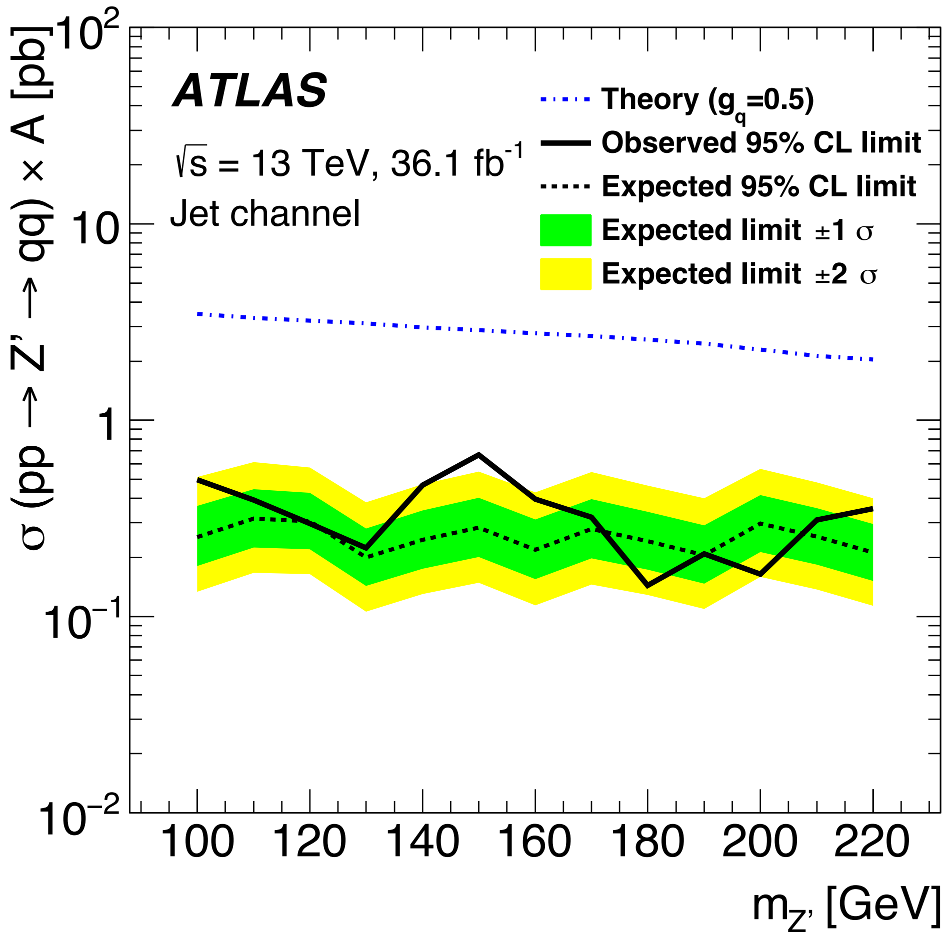
- Search **sensitivity dominated by TF systematic** (ca. 90%)
  - Improve search → reduce this uncertainty → more uniform TF profile → **better decorrelation procedure**

Uncertainty source	$\Delta\mu/\mu$ [%] (← Impact on best-fit signal strength μ)	
	$m_{Z'} = 160$ GeV	$m_{Z'} = 220$ GeV
Transfer factor	90	88
Large-R jet	25	17
Total systematic uncertainty	93	91
Statistical uncertainty	10	11

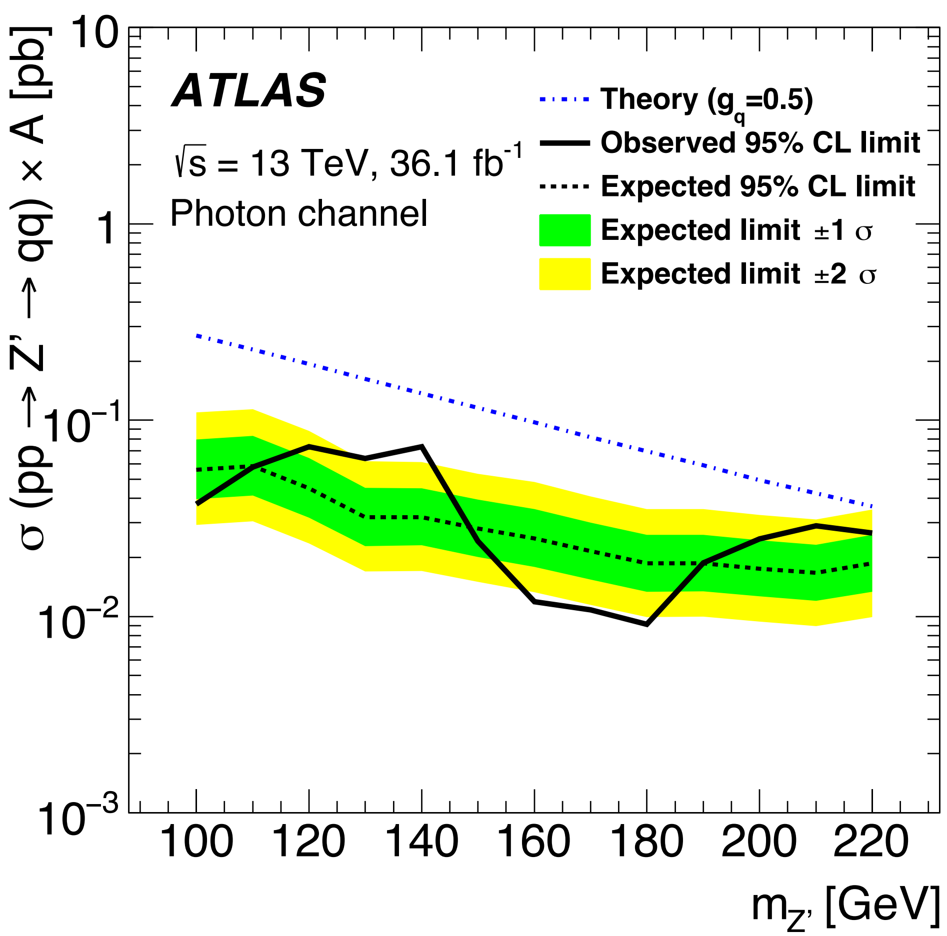
Cross-section limits

- Expected, observed 95% CL exclusion limits on cross-section times acceptance of *Z'* resonance as a function of the resonance mass $m_{Z'}$ in jet (*left*) and photon (*right*) channel

Jet channel



Photon channel



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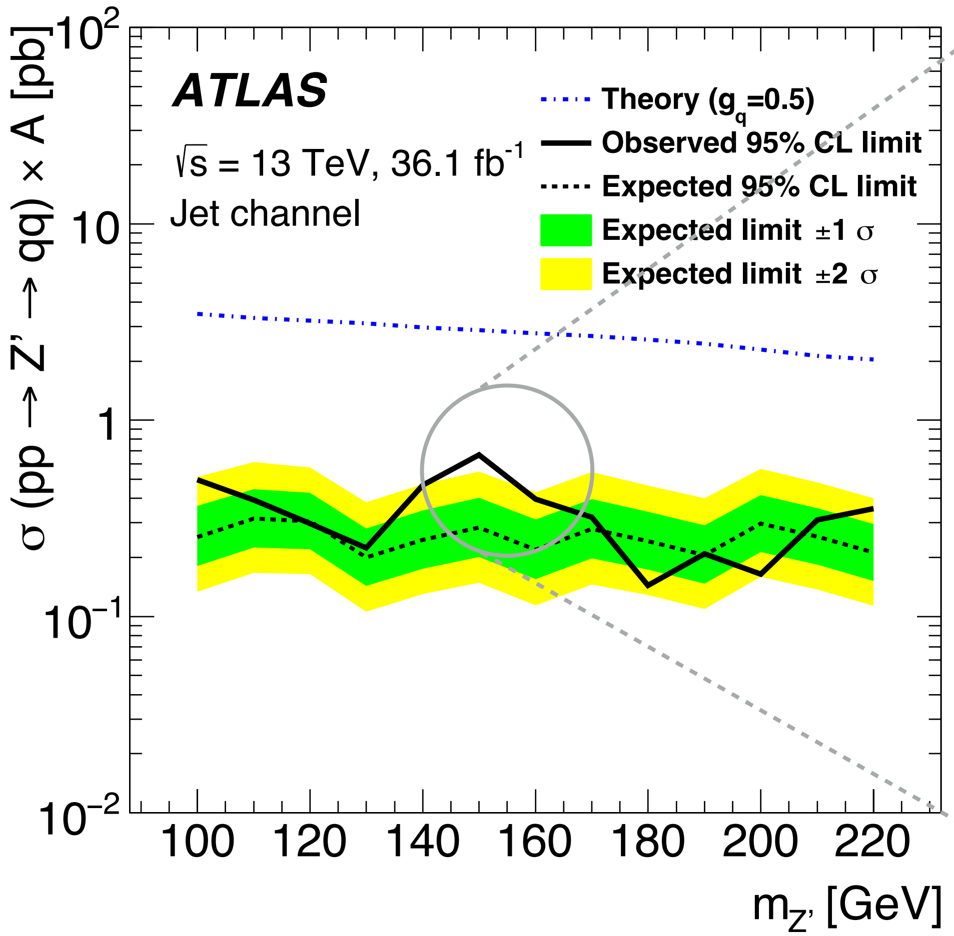
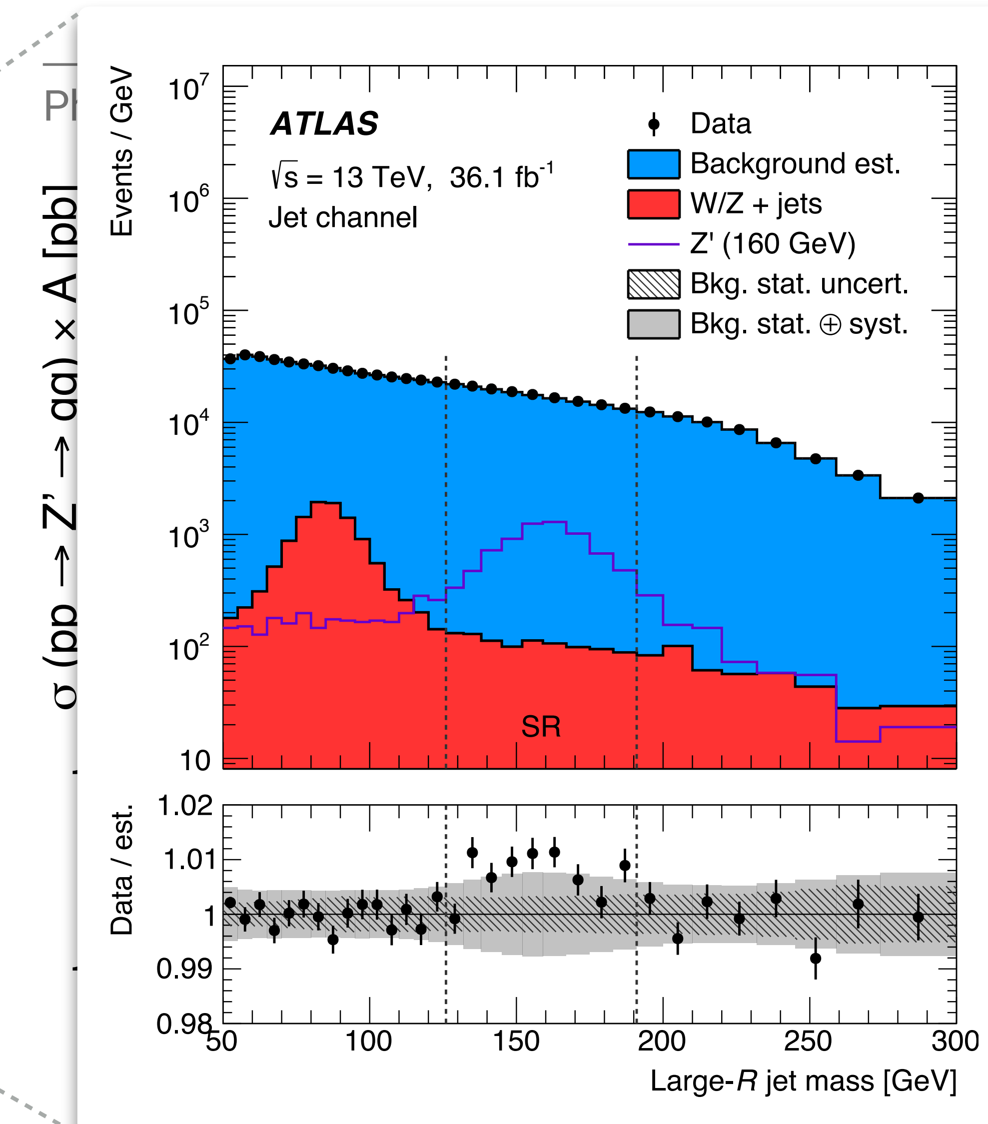
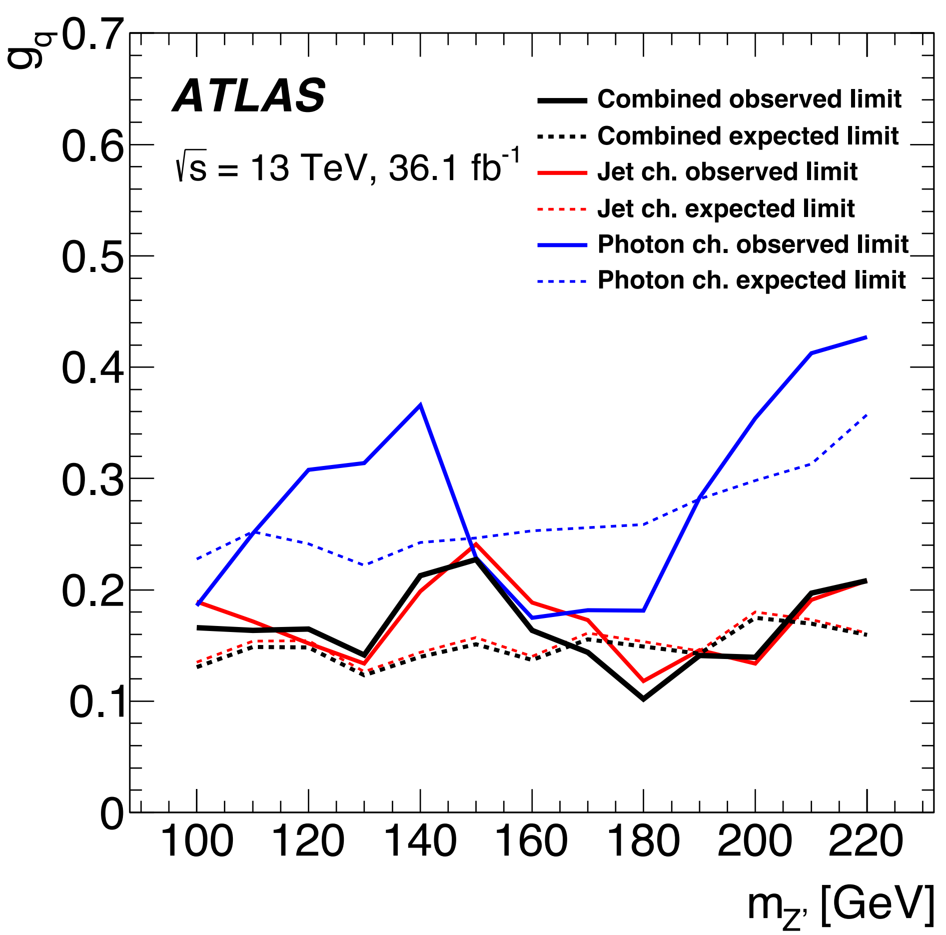




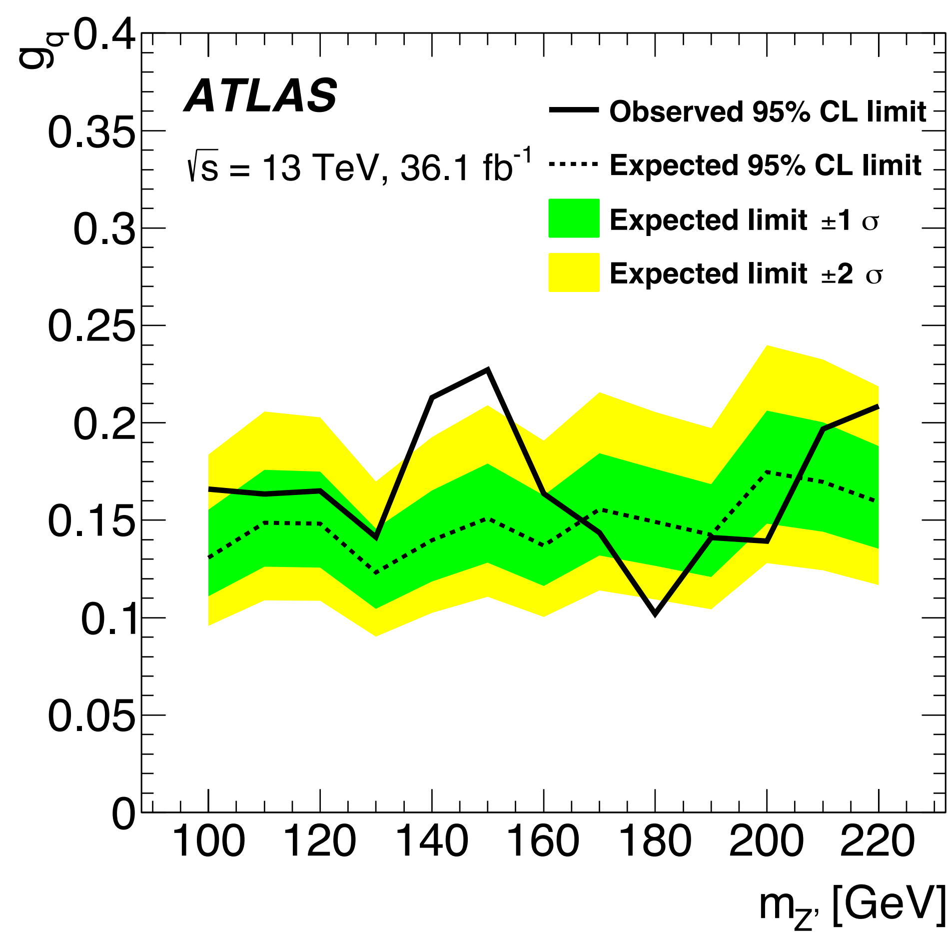
Coupling limits

- Expected, observed 95% CL exclusion limits on *Z'* coupling to SM quarks, g_q, as a function of the resonance mass $m_{Z'}$ in separate (*left*) and combined (*right*) search channels

Separate channel



Combined channel

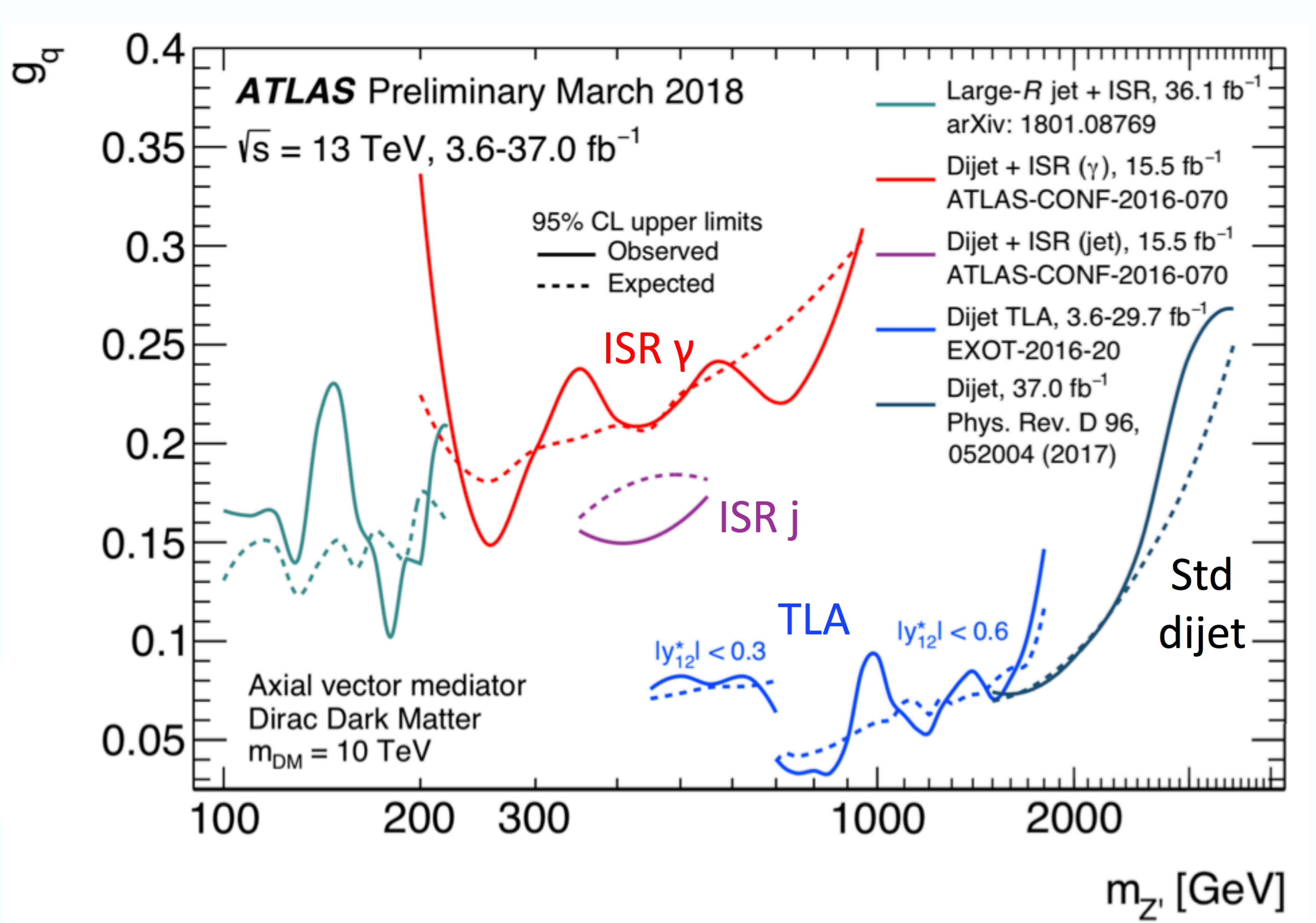


Conclusion

- **First ATLAS search** in boosted dijet + ISR final state presented
- Analysis uses **novel substructure technique** to reduce leading backgrounds, perform robust estimation in low-mass region
- Full analysis chain successfully **validated on *W/Z* peak**, result found to be consistent with SM predictions
- **Limits placed** on signal resonance production cross-section and coupling to SM quarks
- Future directions:
  - **Flavour-tagging** to reject background, probe $H(\rightarrow bb)$ + ISR
  - **Improve decorrelation** procedure and probe lower masses

Back-up

Summary plot



Event selection

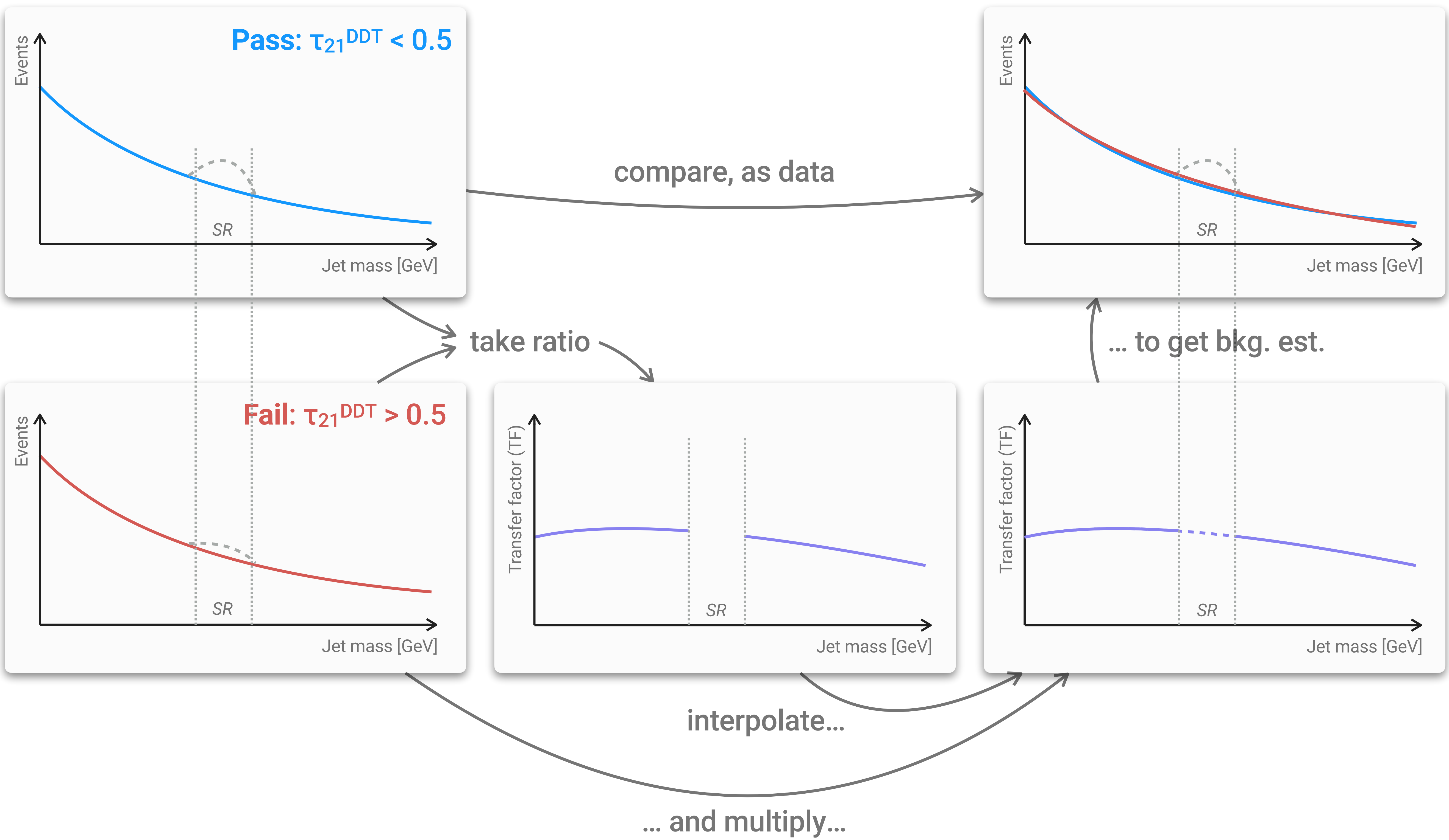
Jet channel

- **Recoil object**
  - anti-$k_t^{R=0.4}$ jet with p_T > 420 GeV
- **Signal candidate**
  - trimmed anti-$k_t^{R=1.0}$ jet with p_T > 450 GeV
  - dR(j,J) > 1.0
- **Topology**
  - $\Delta\varphi(j,J) > \pi/2$
  - $p_{T,J} > 2 \times m_J$

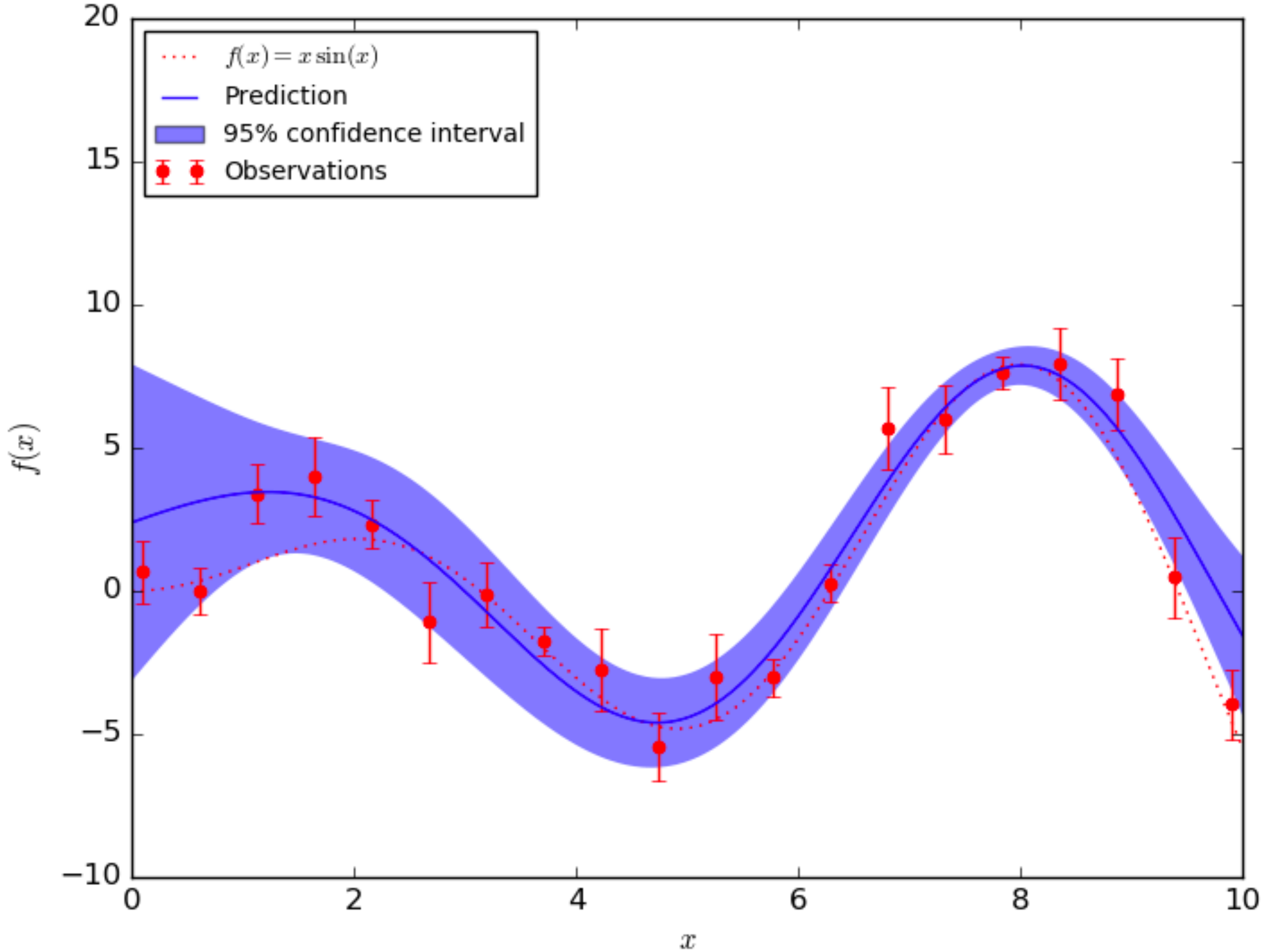
Photon channel

- **Recoil object**
  - tight, isolated photon with p_T > 155 GeV
- **Signal candidate**
  - trimmed anti-$k_t^{R=1.0}$ jet with p_T > 200 GeV
- **Topology**
  - $\Delta\varphi(\gamma,J) > \pi/2$
  - $p_{T,J} > 2 \times m_J$

Background estimation / Cartoon



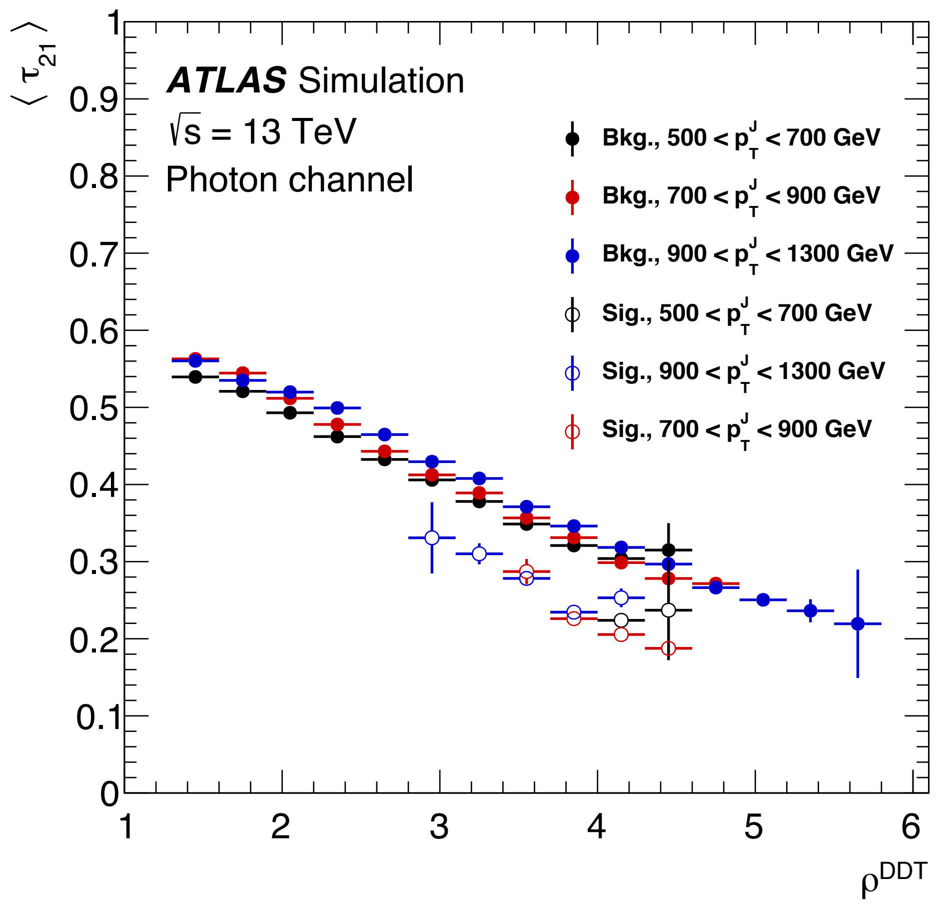
Gaussian process (GP) regression



Substructure decorrelation

- τ_{21} substructure variable decorrelation, using DDT, in the photon channel

Before decorrelation



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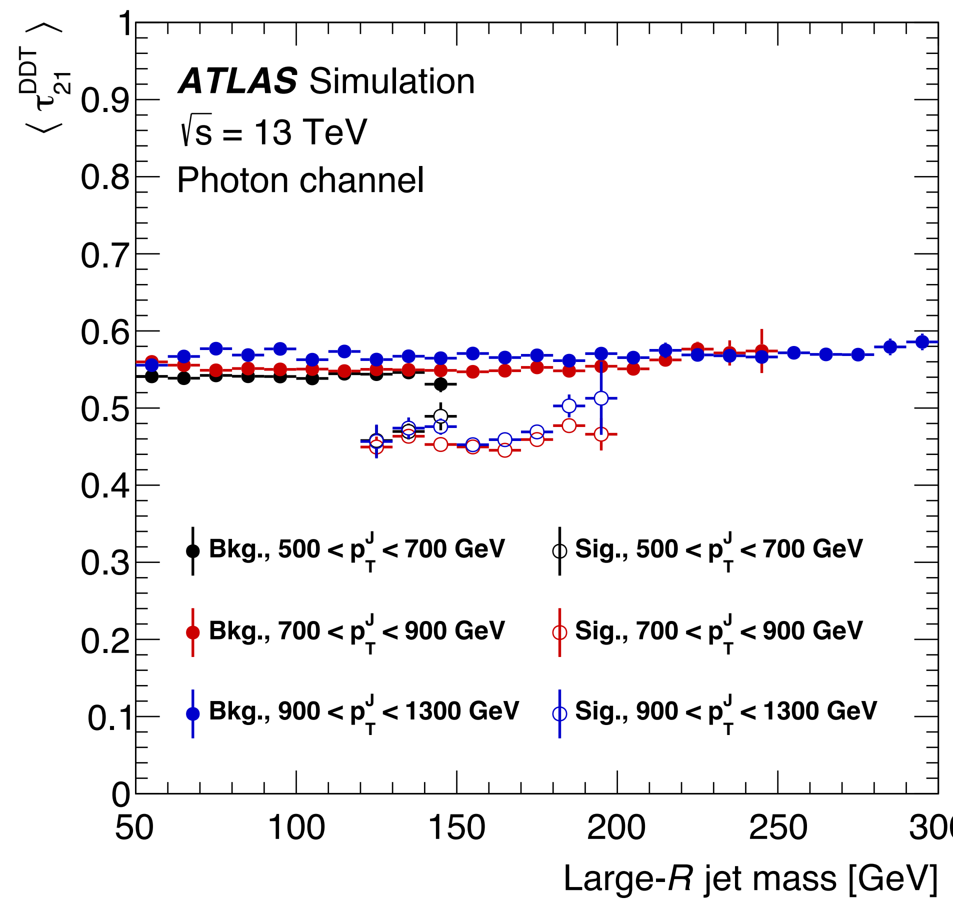

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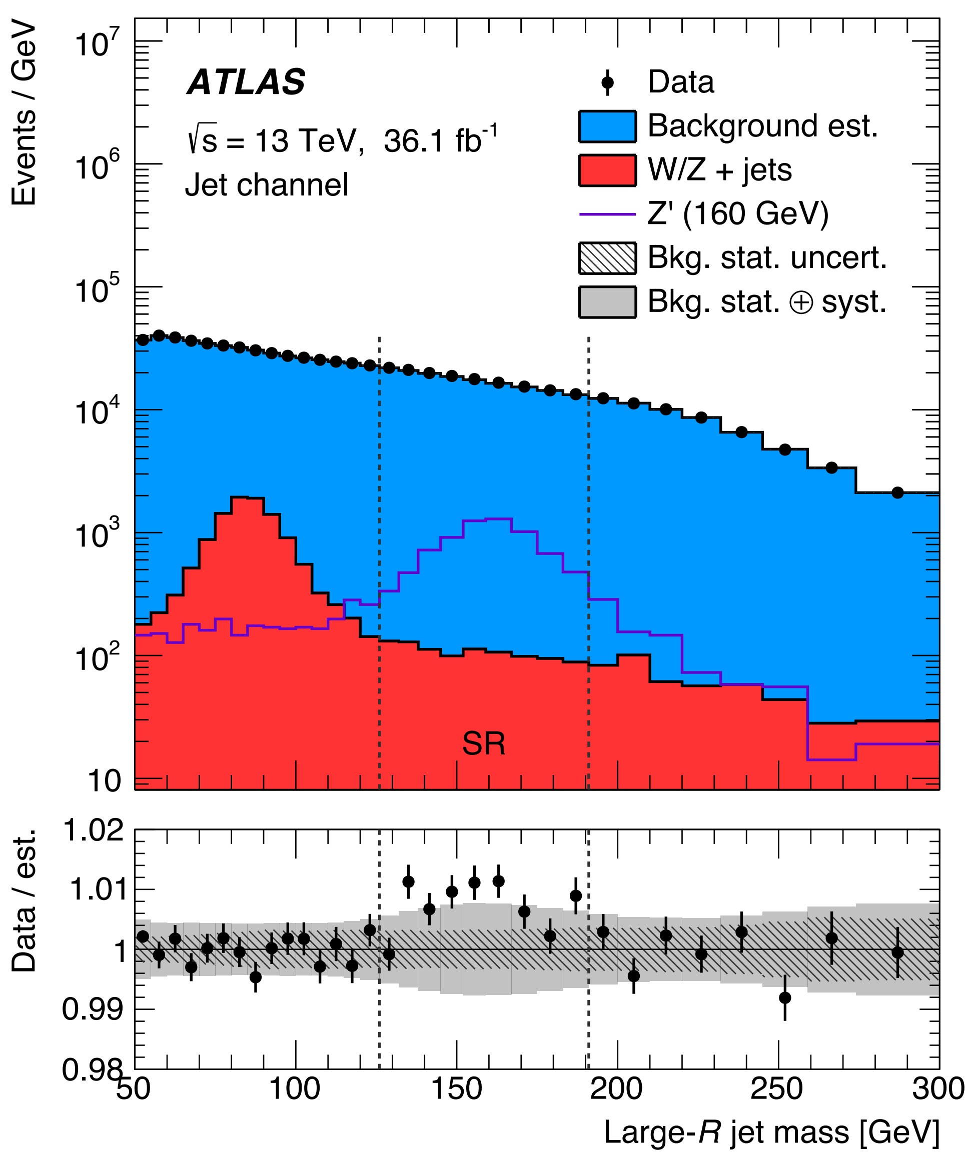
Jet channel



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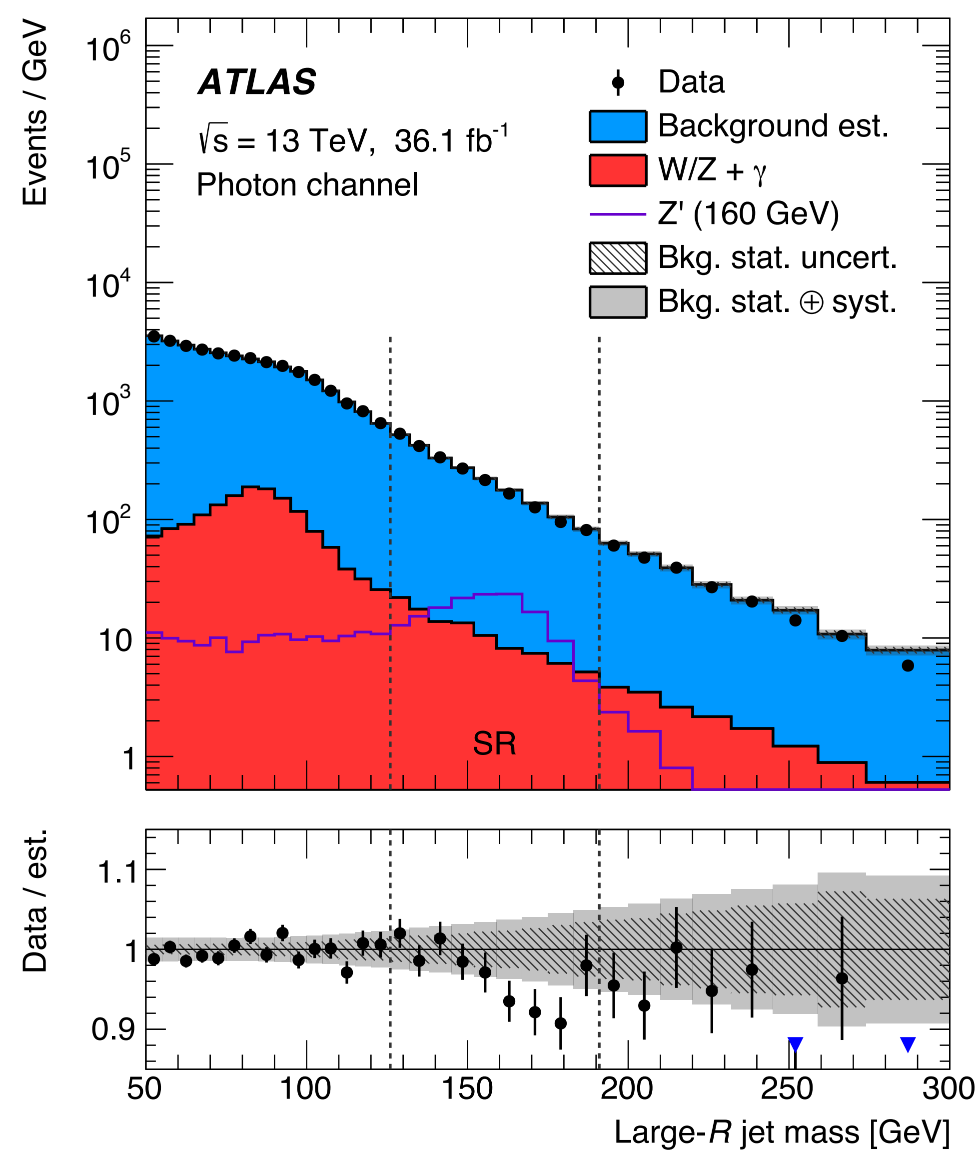
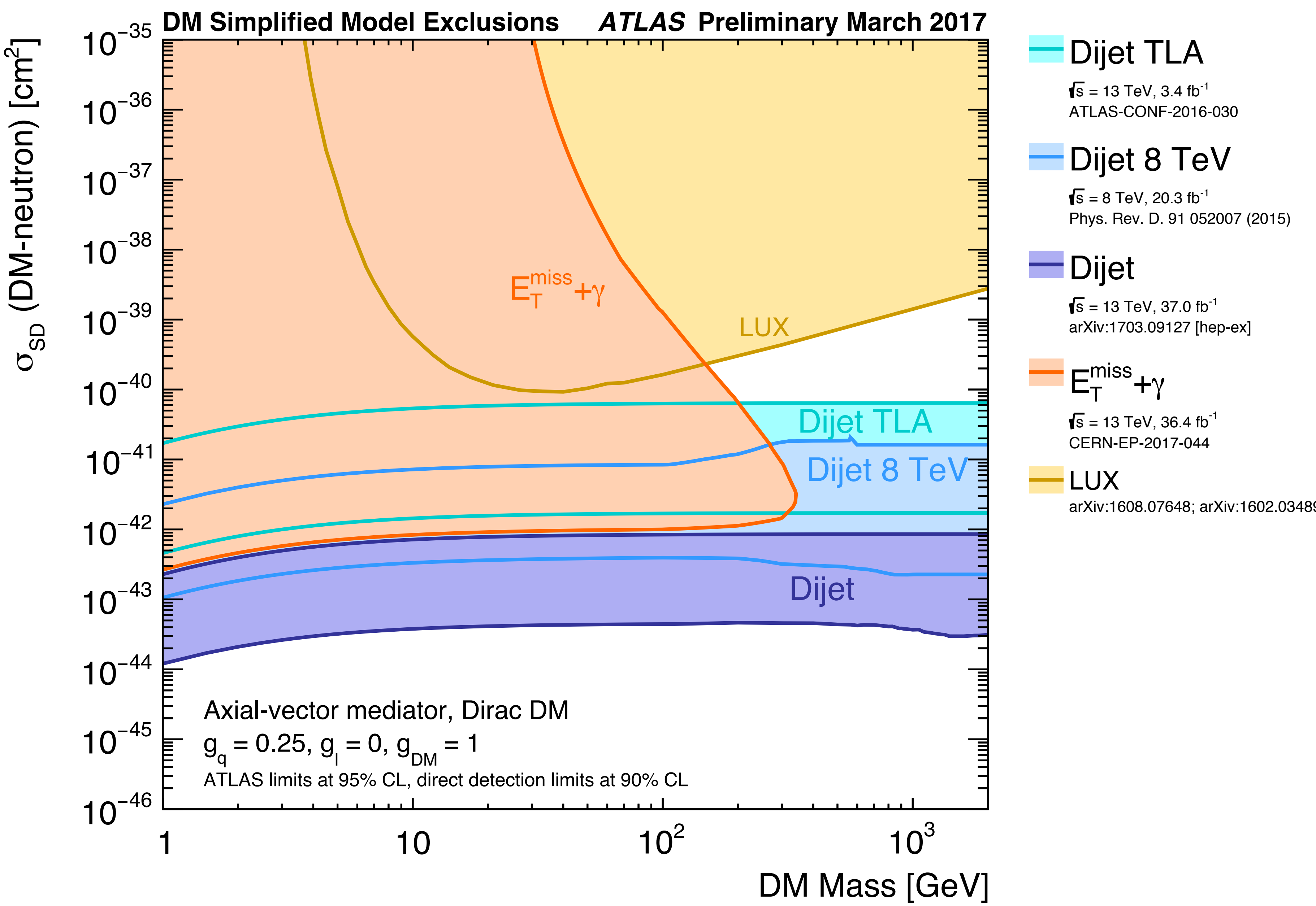


Comparison with direct detection

- 95% CL exclusion regions in (σ_{DM-n}, m_{DM})-plane in context of the Z'-like simplified model with vector-axial couplings



Comparison with direct detection

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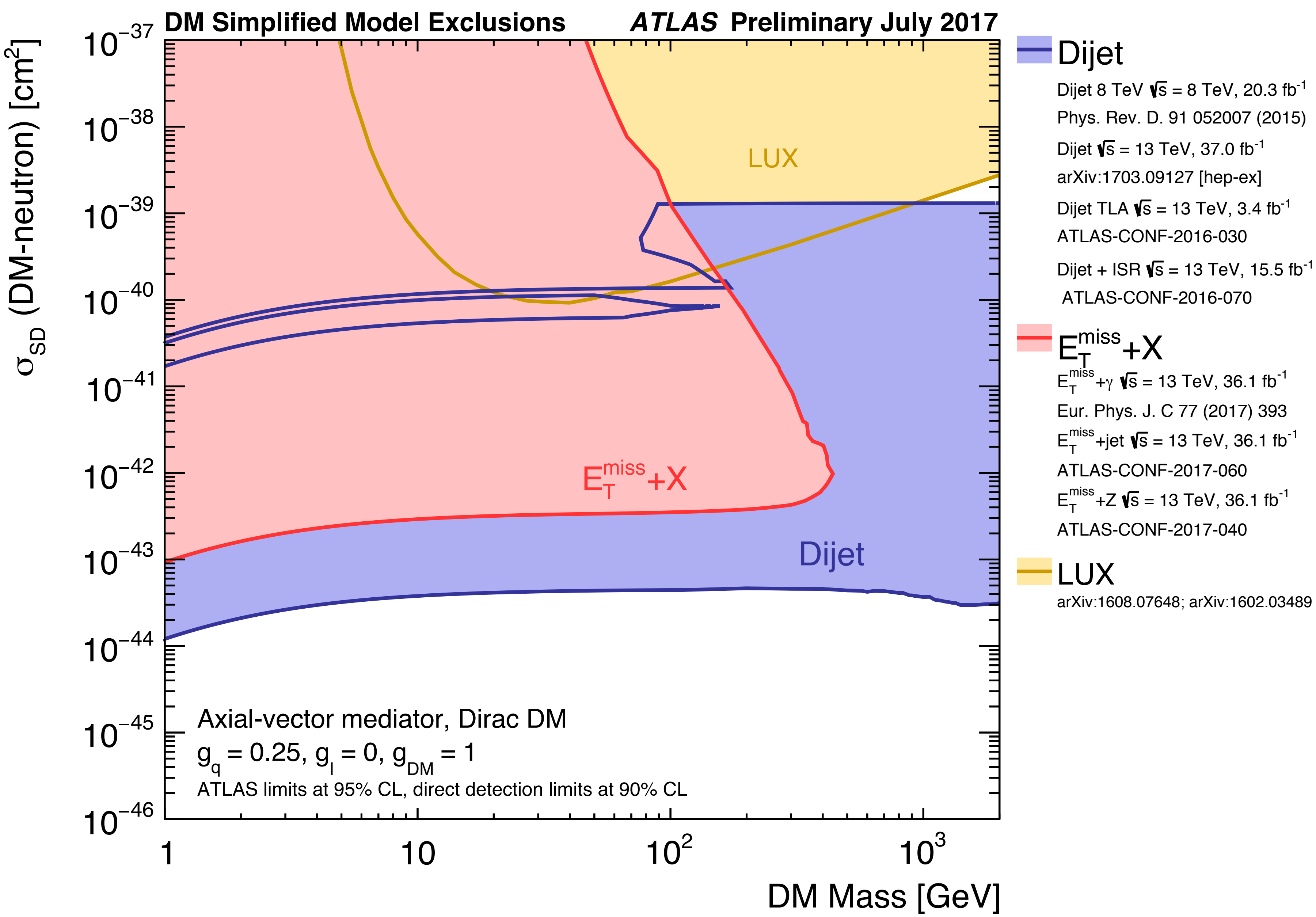

Comparison with direct detection

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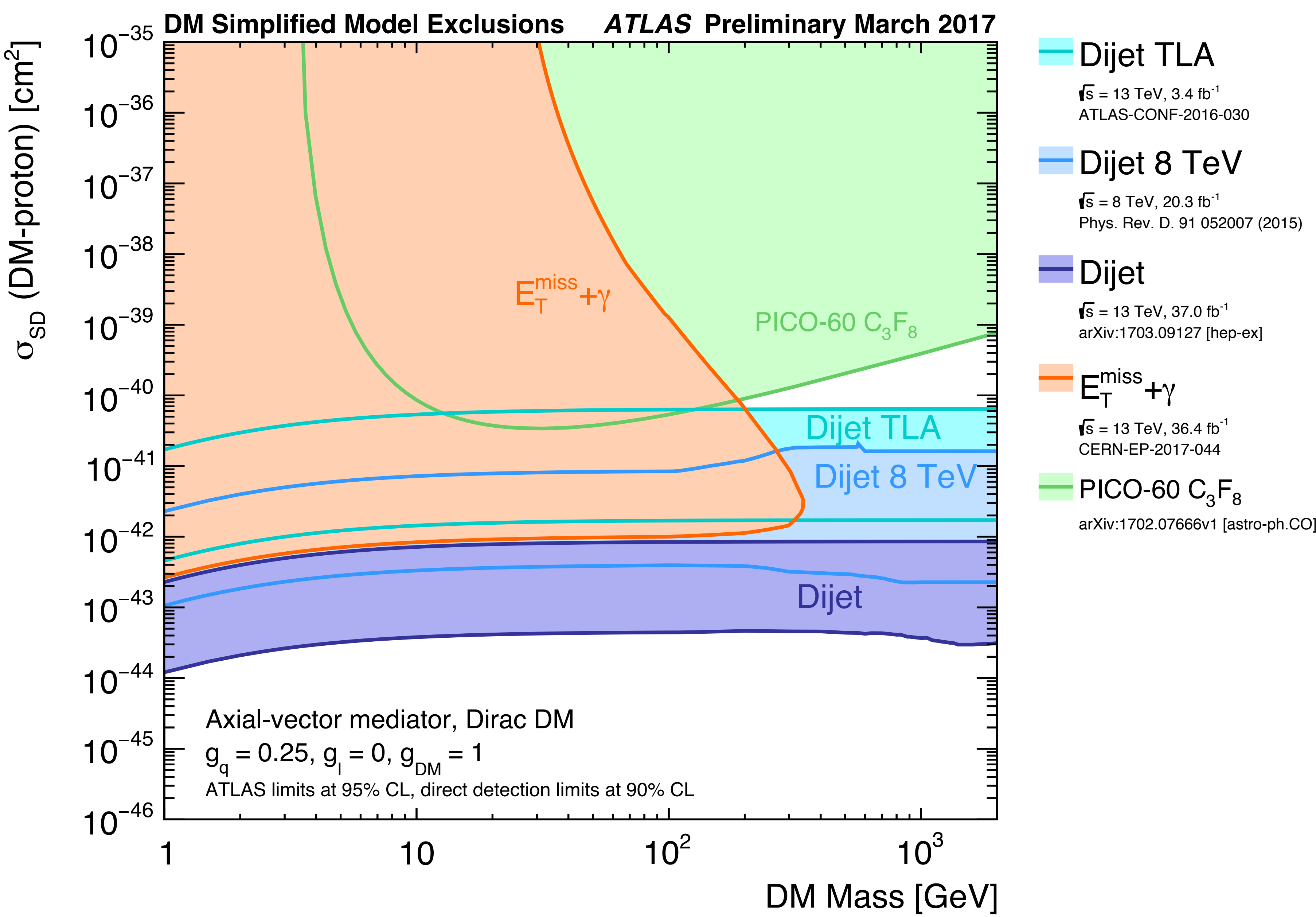

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