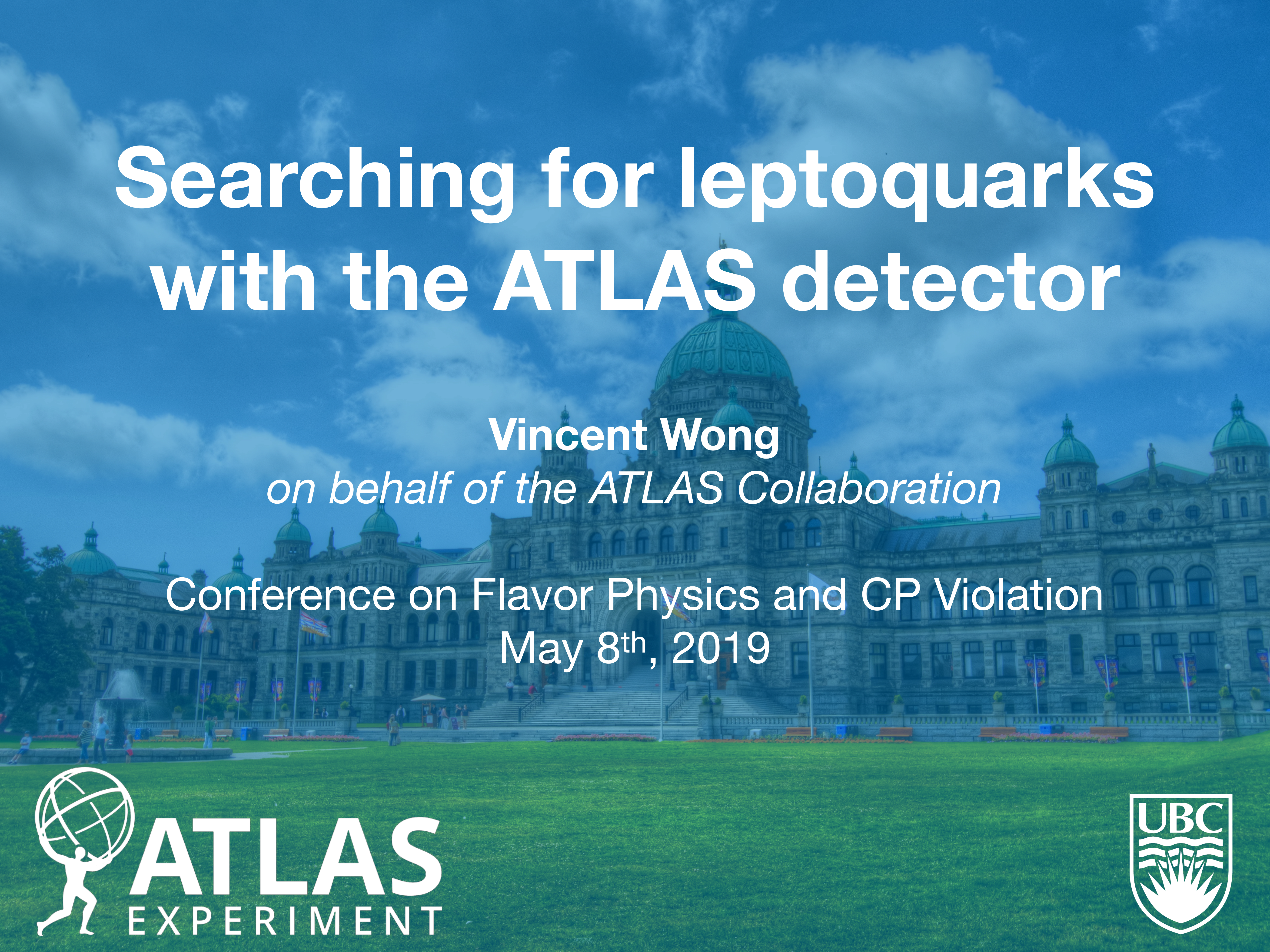


Searching for leptoquarks with the ATLAS detector

Vincent Wong

on behalf of the ATLAS Collaboration

Conference on Flavor Physics and CP Violation
May 8th, 2019

Introduction

Motivations:

- **Leptoquarks (LQ) are predicted by many GUT models, such as SU(5) unification and Pati-Salam model.**
- **Interest in leptoquarks regained due to recent hints of lepton universality violation in FCNC and semi-leptonic B-meson decays**

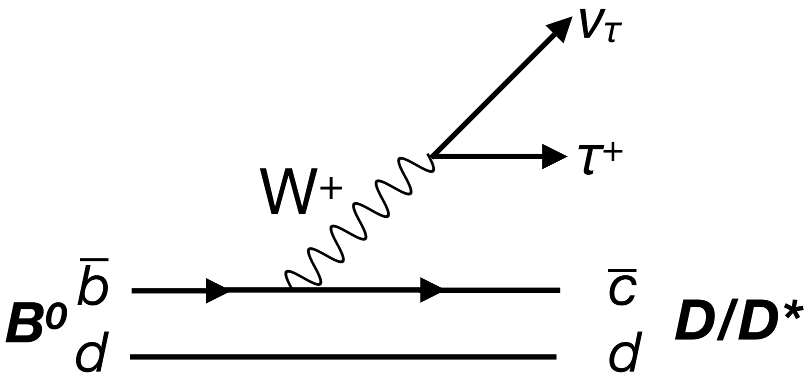
Talk by KUMAR, MALINSKÝ

$$R(D^{(*)}) = \frac{BR(B \rightarrow D^{(*)} \tau^{+} \overline{\nu})}{BR(B \rightarrow D^{(*)} \ell^{+} \overline{\nu})}$$

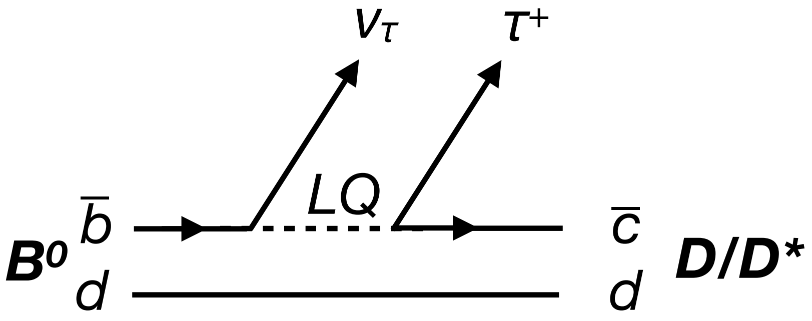
Talk by ROBINSON

3.4σ	BaBar	PhysRevD.88.072012 (2013)
1.8σ	Belle	PhysRevD.92.072014 (2015)
2.1σ	LHCb	PhysRevLett.115.159901 (2015)

SM:



LQ:

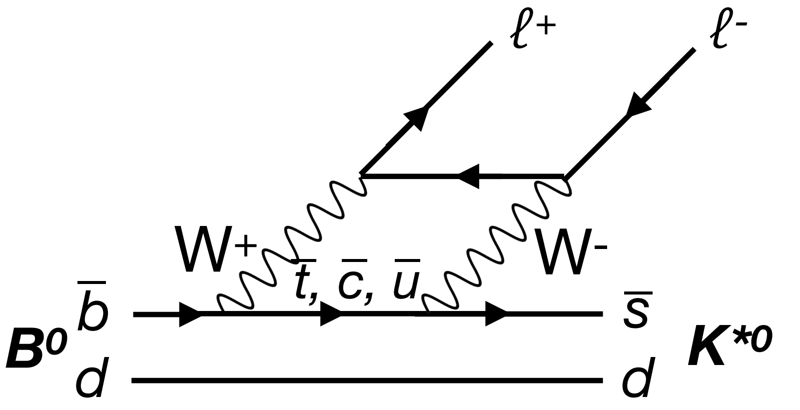


$$R(K^{(*)}) = \frac{BR(B \rightarrow K^{(*)} \mu^{+} \mu^{-})}{BR(B \rightarrow K^{(*)} e^{+} e^{-})}$$

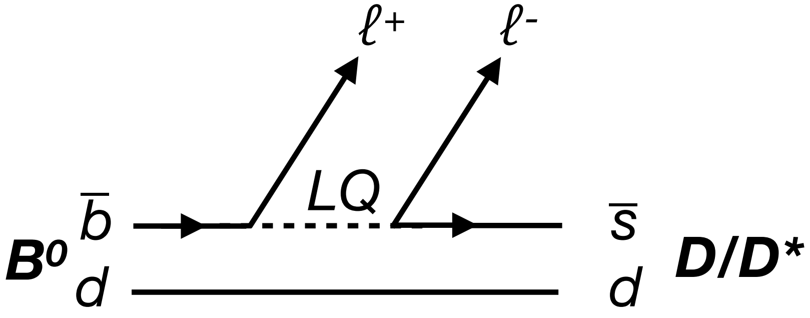
Talk by ALONSO

2.1σ (2.4σ)	LHCb	JHEP08(2017)055
2.5σ	LHCb	PhysRevLett.arXiv:1903.09252

SM:



LQ:



LQ contributes at tree-level!

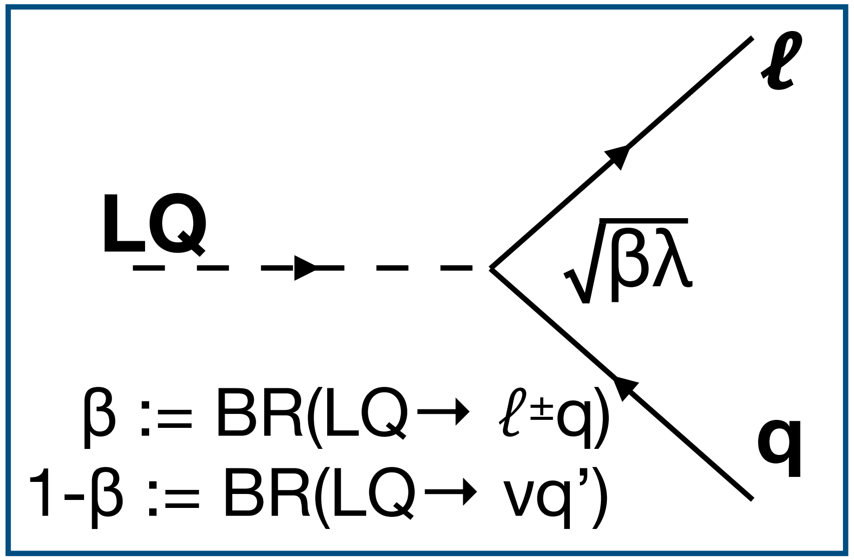
Outline

Leptoquark pair production search results with 36 fb^{-1} at 13 TeV:

- **Searches for 1st and 2nd generation leptoquarks in ATLAS [arXiv:1902.00377]**
- **Searches for up- and down-type 3rd generation leptoquarks [arXiv:1902.08103]**

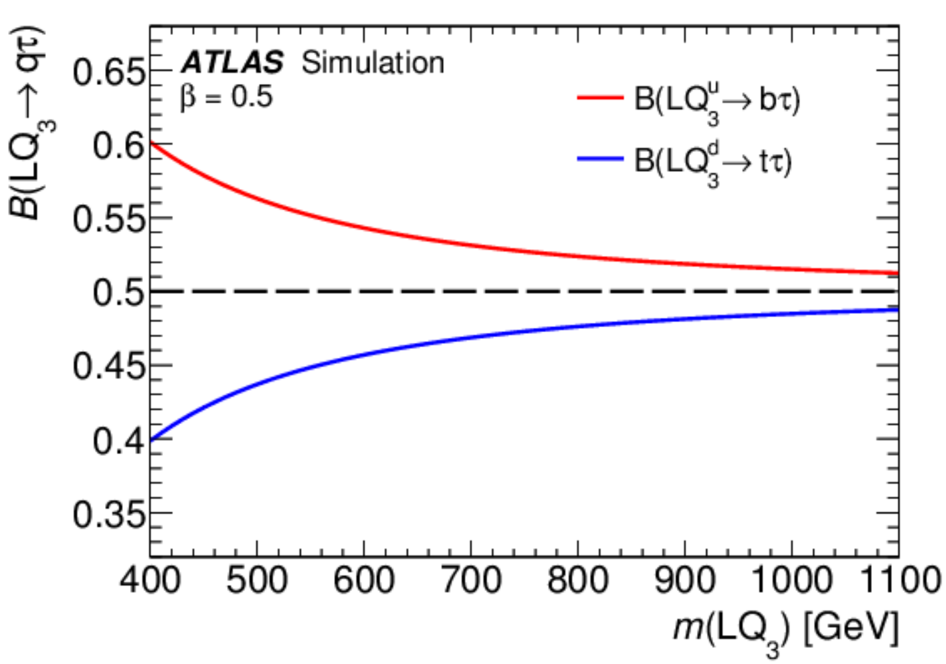
- Benchmark model (minimal Buchmüller-Rückl-Wyler model):
  - **Scalar leptoquarks couple to quarks and leptons from the same generation→LQ1, LQ2, LQ3**
  - **Model parameters:**

1. **LQ mass m_{LQ},**
2. **coupling parameter λ=0.3 (fixed),**
3. **branching ratio B for LQ→ $\ell^{\pm}$q (determined by model parameter β)**



$\beta := BR(LQ \rightarrow \ell^{\pm}q)$

$1-\beta := BR(LQ \rightarrow \nu q')$



1st & 2nd generation LQ search

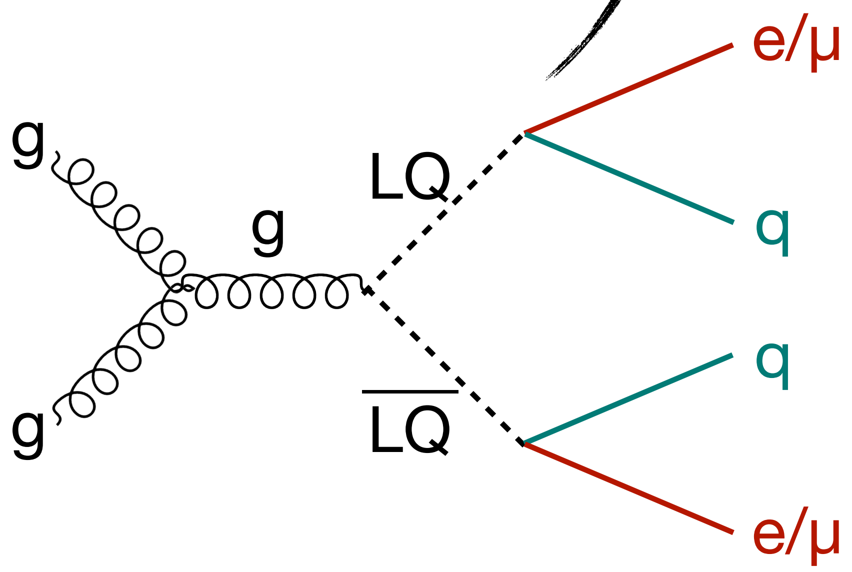
arXiv:1902.00377

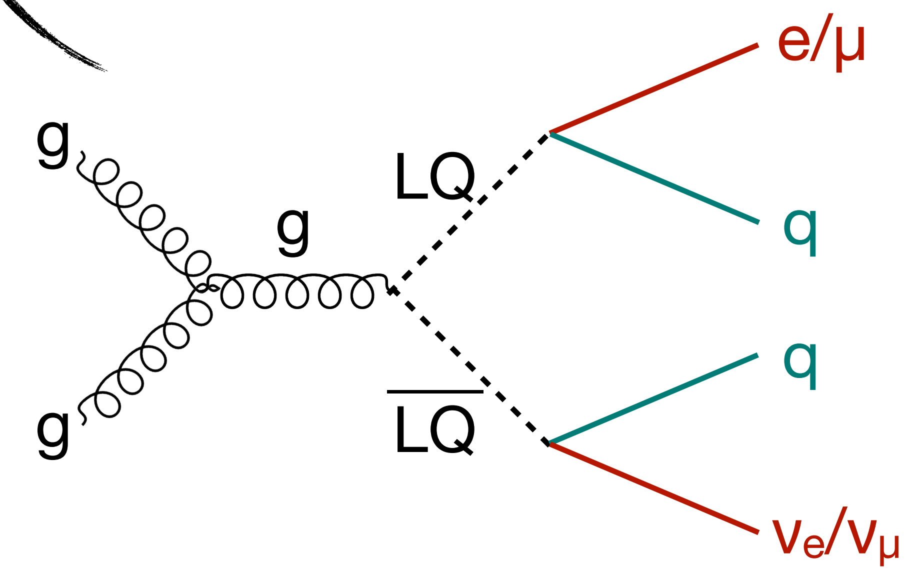
- **Searching for first and second generation LQ pair, with final states: eejj, μμjj, eνjj, μνjj**

36 fb^{-1} data; $\sqrt{s}$ = 13 TeV
Submitted to EPJC
arXiv:1902.00377

Final state	ℓℓjj	ℓνjj	ννjj
BR	β^2	$2(1-\beta)\,\beta$	$(1-\beta)^2$

$\beta := BR(LQ \rightarrow \ell\, q)$

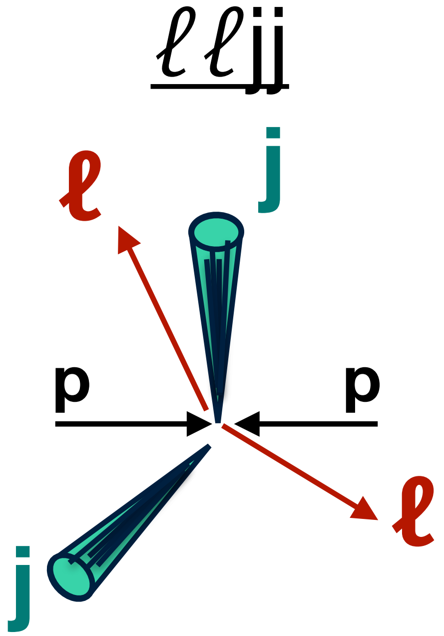




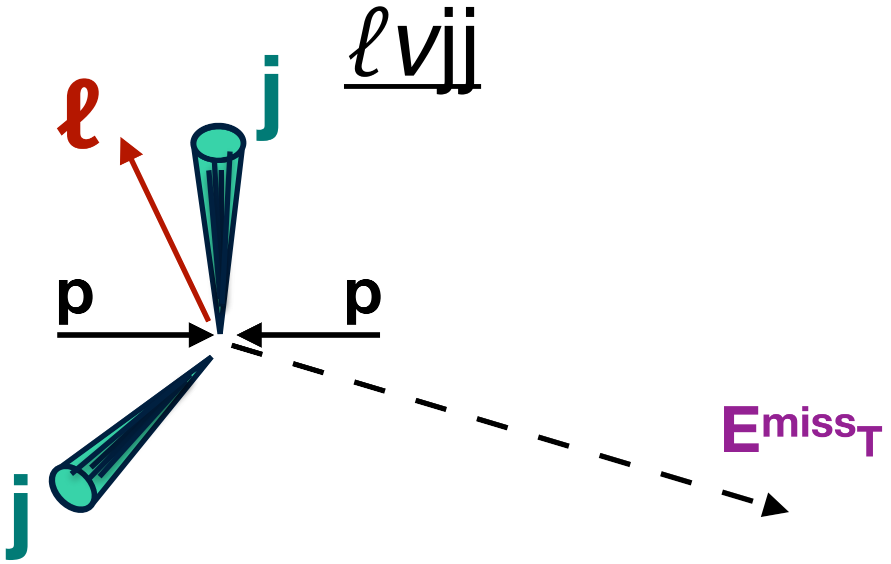
Analysis strategy

arXiv:1902.00377

Baseline selections		
Common selections	**≥ 2 jets** (p_T > 60 GeV, $\lvert\eta\rvert$ < 2.5) $\lvert\eta_{muon}\rvert < 2.5$, $\lvert\eta_{elec}\rvert < 2.47$	
Channel	$\ell\ell jj$	$\ell\nu jj$
	Exactly two e/μ **$m_{\ell\ell} > 130$ GeV**	**Exactly 1 e/μ** **$m_T(\ell, E^{miss}_T) > 130$ GeV** **$E^{miss}_T > 150$ GeV, S > 3**



- **$m_{\ell\ell} > 130$ GeV**
  → reject **$Z(\to\ell\ell)$+jets** background



- **$m_T(\ell, E^{miss}_T) > 130$ GeV**
  → reject **$t_{lep}t_{had}$, $W(\to\ell\nu)$+jets** background
- **$E^{miss}_T > 150$ GeV, S > 3**
  → reject **fakes** from **QCD** events

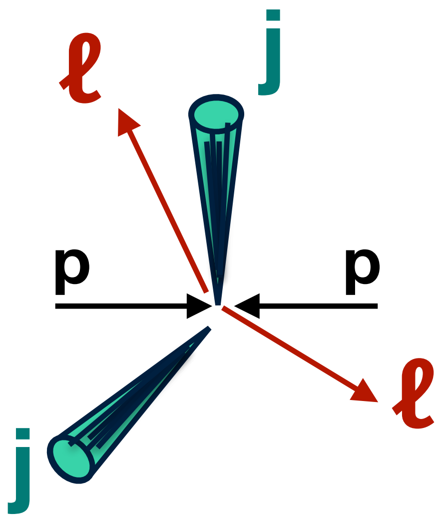
E^{miss}_T significance variable $S = E^{miss}_T / \sqrt{(p^{j1}_T + p^{j2}_T + p^{\ell}_T)}$

Analysis strategy

arXiv:1902.00377

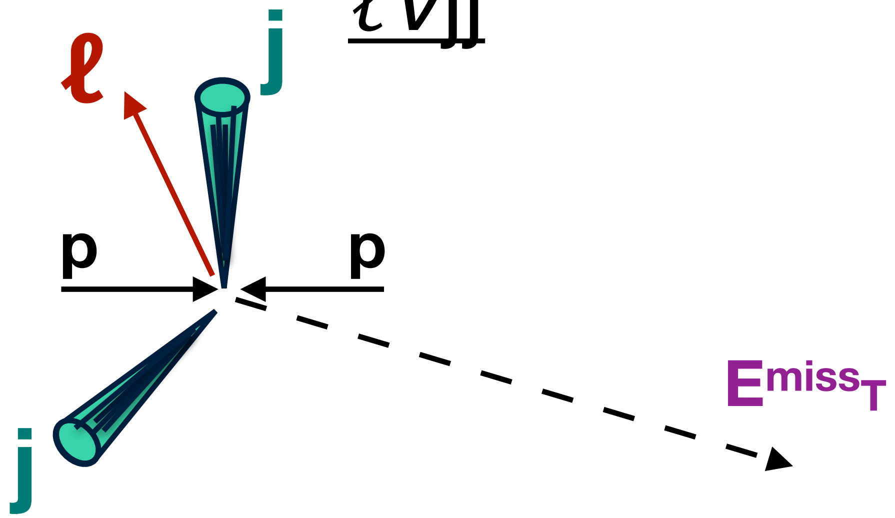
Baseline selections		
Common selections	**≥ 2 jets** ($p_T > 60$ GeV, $\lvert\eta\rvert < 2.5$) $\lvert\eta_{muon}\rvert < 2.5$, $\lvert\eta_{elec}\rvert < 2.47$	
Channel	ℓℓjj	ℓνjj
	Exactly two e/μ **$m_{\ell\ell} > 130$ GeV**	**Exactly 1 e/μ** **$m_T(\ell, E^{miss}_T) > 130$ GeV** **$E^{miss}_T > 150$ GeV, S > 3**

ℓℓjj



- **Get m^{max}_{LQ} & m^{min}_{LQ} by minimizing $|m_{\ell1,j1} - m_{\ell2,j2}|$**

ℓνjj

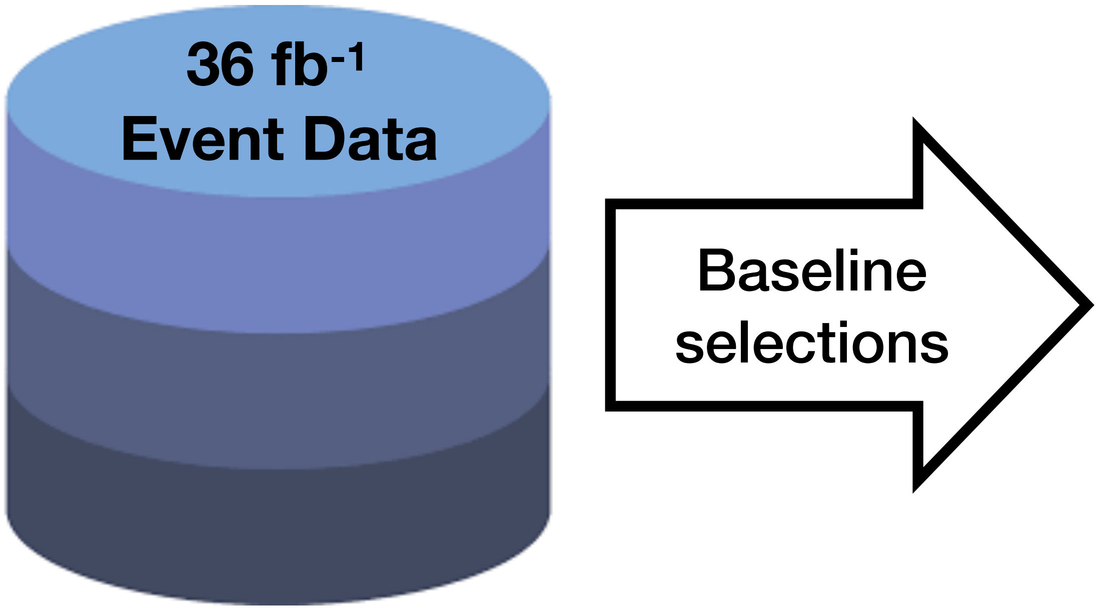


- **Get m^{max}_{LQ} & m^{min}_{LQ} by minimizing $|m_{\ell,j1} - m^T_{MET,j2}|$**

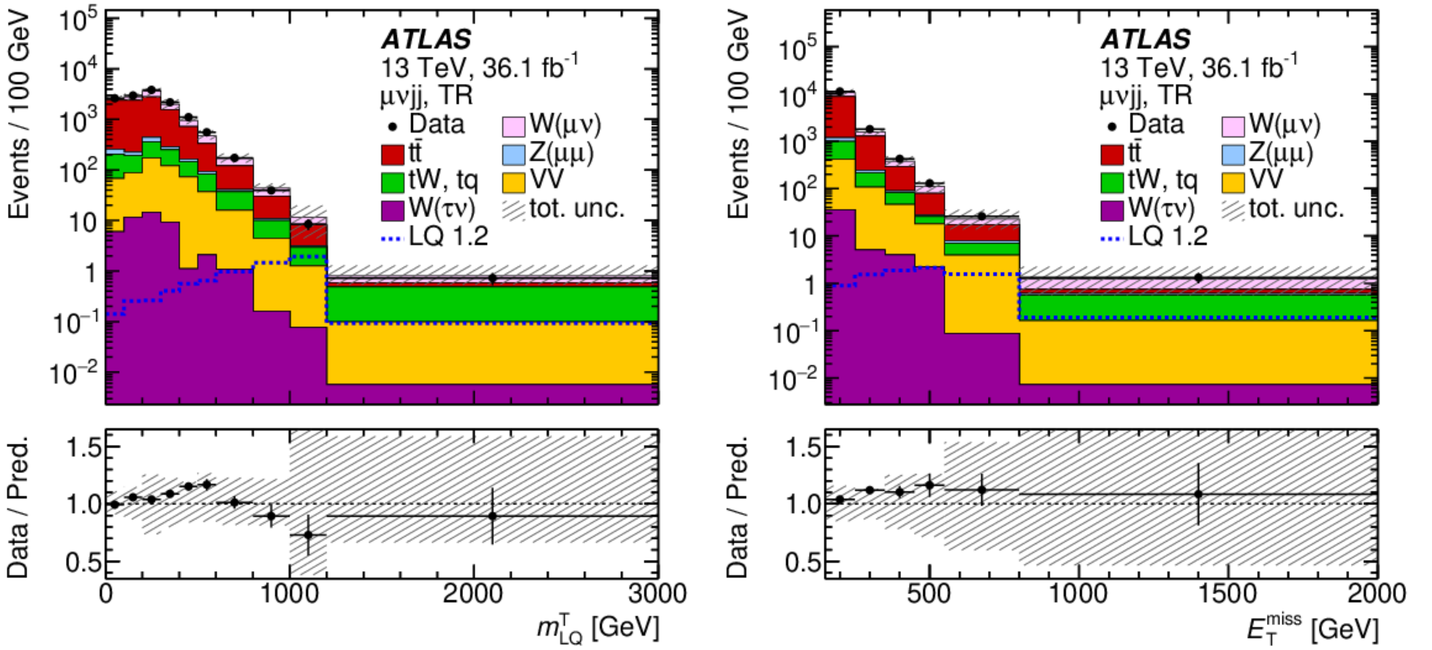
Analysis strategy

arXiv:1902.00377

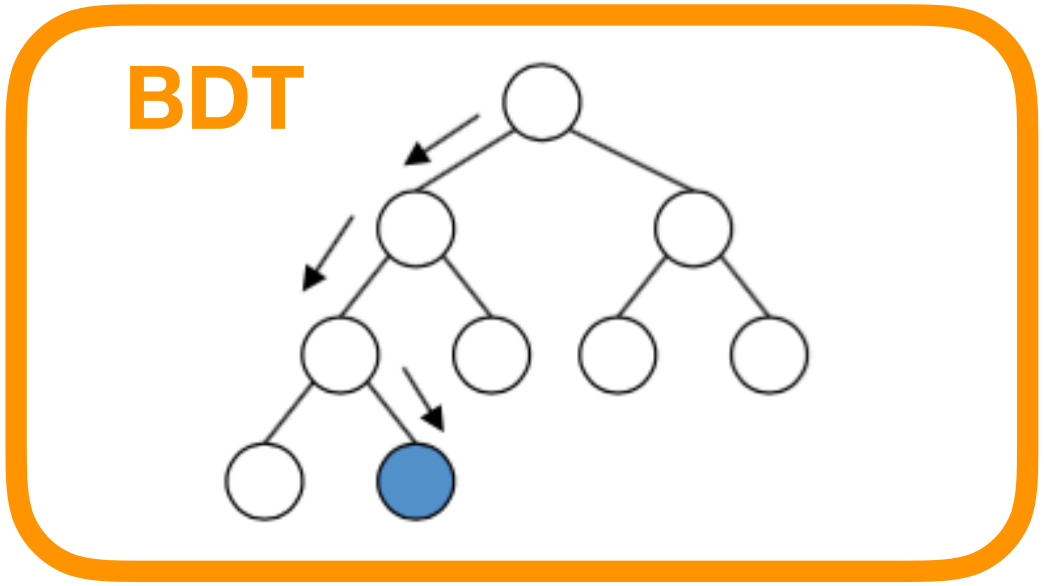
- **Use Boosted Decision Tree (BDT) to identify signal events from backgrounds.**



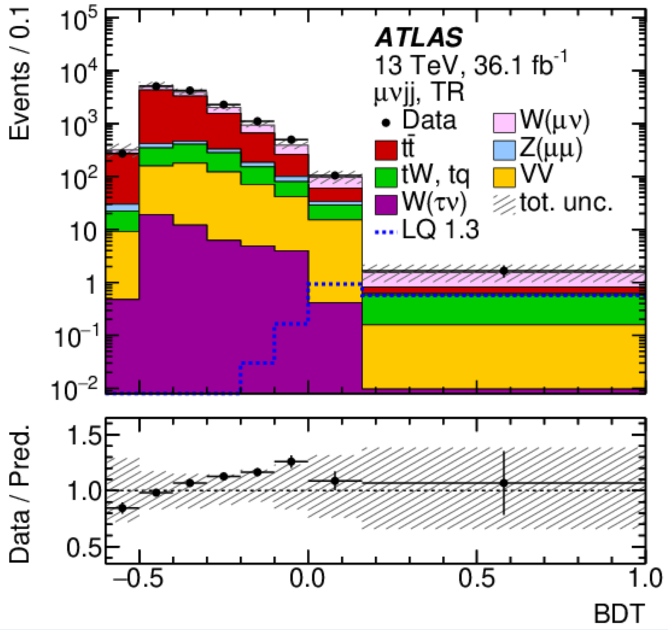
A set of discriminating variables



used as
input variables



Distribution of Classification Index



- **Signal-like events →tends to have BDT score of 1**
- **Last bin is defined as Signal Region**

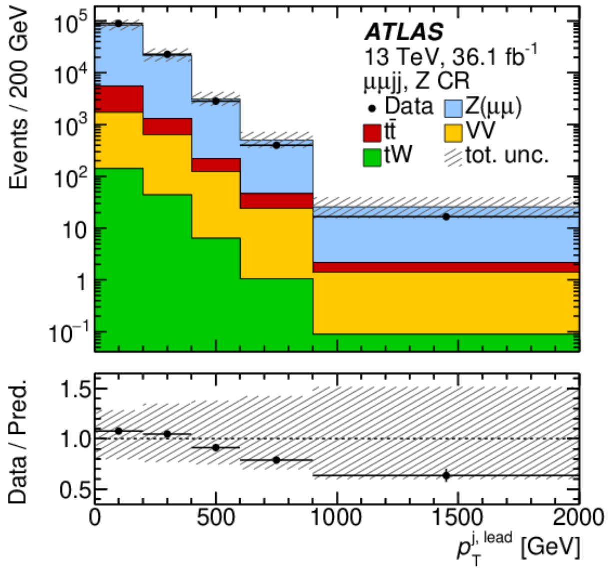
- **Train separate BDT's for each channel & each LQ mass.**

Background estimations

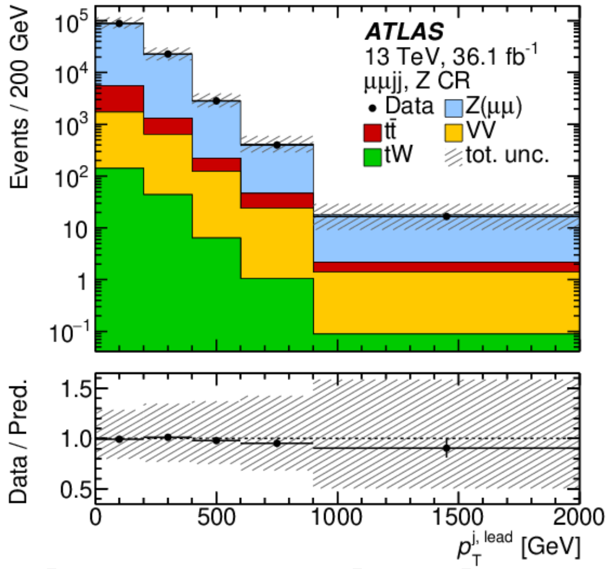
arXiv:1902.00377

- **Poor Z+jets and W+jets (Sherpa 2.2.1) modelling of data**
  →Reweighing of Z+jets and W+jets w/ weights=fcn(m_{jj}) using Z CR and W CR

Control Regions (CR) for main background process		
Z CR for ℓℓjj	$70 < m_{\ell\ell} < 110$ GeV	
W CR for ℓνjj	$40 < m_T < 130$ GeV $E^{miss}_T > 40$ GeV $S > 4$	0 b-jets
ttbar CR for ℓνjj		≥ 2 b-jets

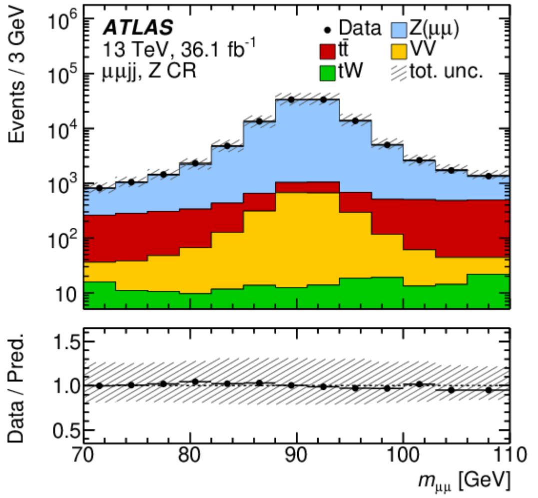


reweighing

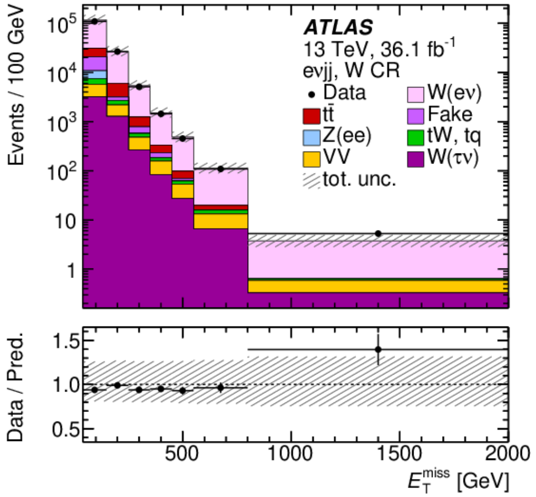


- **Simultaneous fit of 3 single-bin CRs to constraint the normalization of major backgrounds from data**

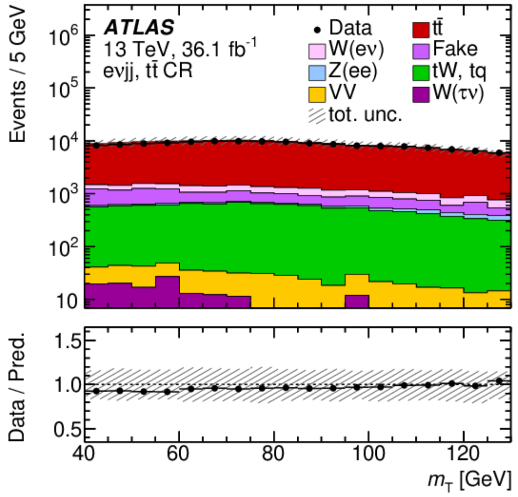
Z CR



W CR



ttbar CR

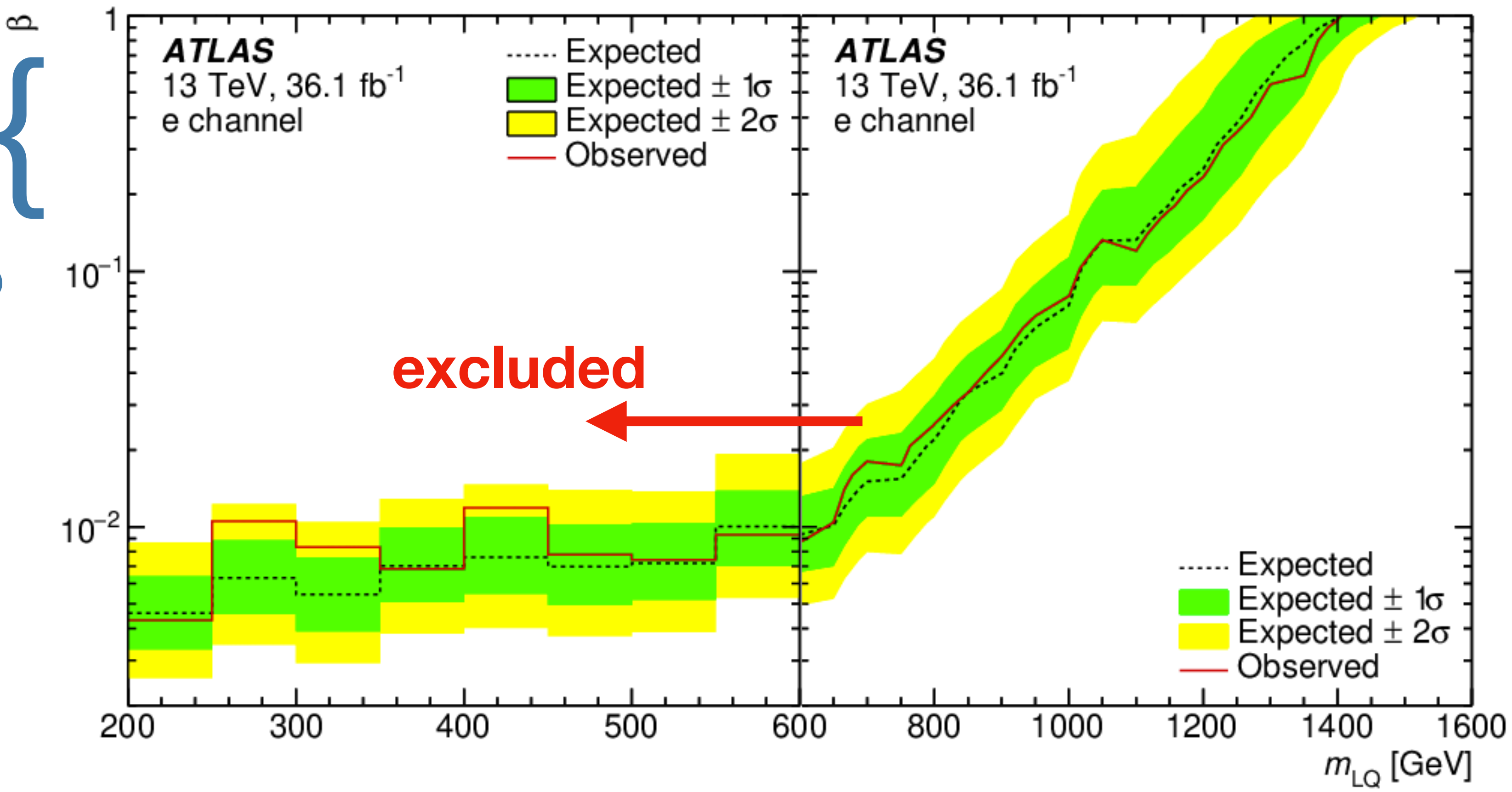


Good agreement between data and background estimation in CR's

Combined Results of ℓℓjj and ℓvjj

arXiv:1902.00377

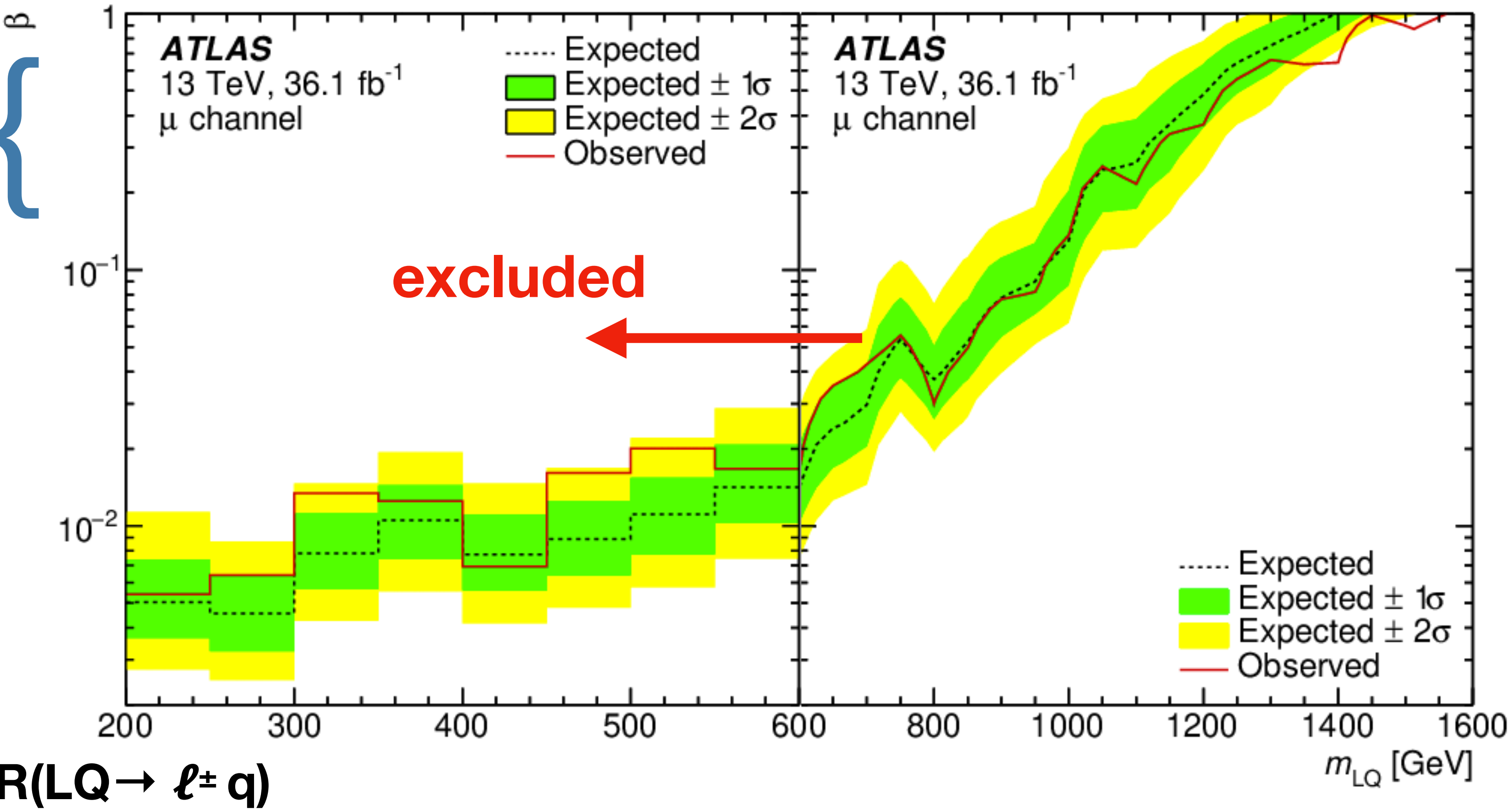
eejj best
near β=1
evjj best
near β=0.5



excluded

e channel

μμjj best
near β=1
μvjj best
near β=0.5



excluded

μ channel

Reminder: β = BR(LQ→ $\ell^{\pm}$ q)

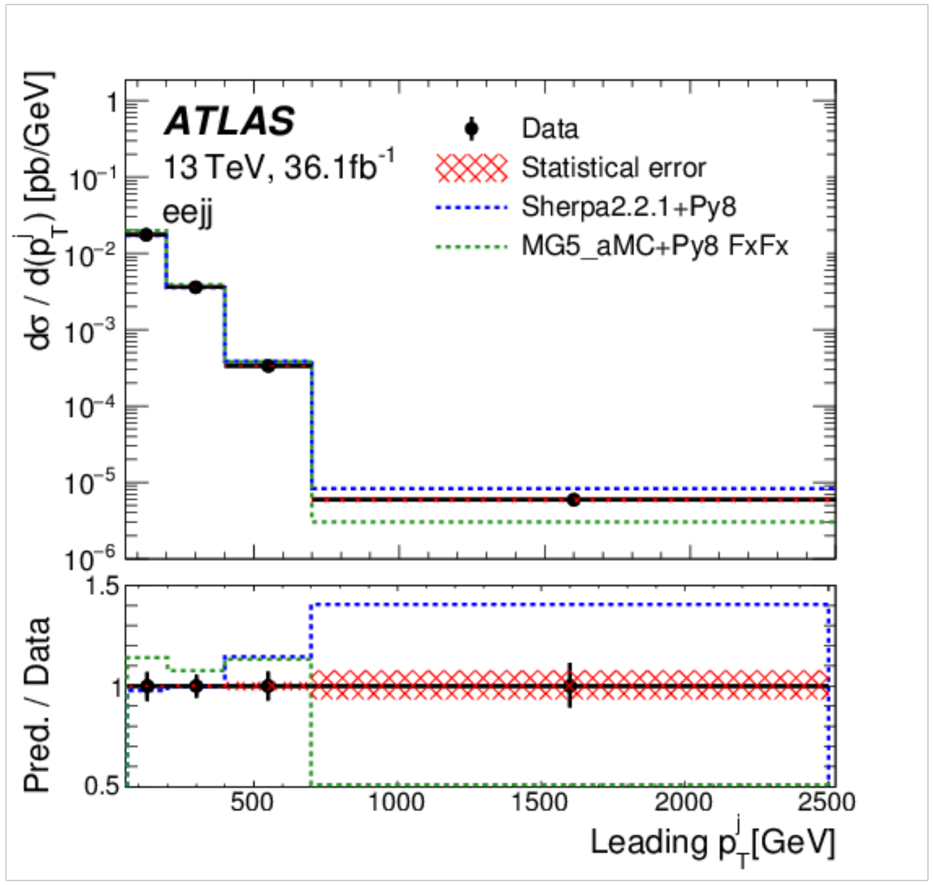
Differential-σ measurements

arXiv:1902.00377

- **Particle-level** **cross-sections measurement in some extreme measurement regions**
- **For MC development, e.g. generators tuning**

MR	Dominant process (purity)	Required leptons and jets	$m_{\ell\ell}$ selection	S_T selection	Remark
$eejj$	$Z \rightarrow ee$ (93%)	$= 2e$; $\geq$ 2jets	$70 < m_{\ell\ell} < 110$ GeV	-	Identical to Z CR
$\mu\mu jj$	$Z \rightarrow \mu\mu$ (93%)	$= 2\mu$; $\geq$ 2jets	$70 < m_{\ell\ell} < 110$ GeV	-	Identical to Z CR
$e\mu jj$	$t\bar{t} \rightarrow e\mu$ (93%)	$= 1\mu, 1e$; $\geq$ 2jets	-	-	-
Extreme $eejj$	$Z \rightarrow ee$ (94%)	$= 2e$; $\geq$ 2jets	$70 < m_{\ell\ell} < 110$ GeV	$S_T > 600$ GeV	-
Extreme $\mu\mu jj$	$Z \rightarrow \mu\mu$ (94%)	$= 2\mu$; $\geq$ 2jets	$70 < m_{\ell\ell} < 110$ GeV	$S_T > 600$ GeV	-
Extreme $e\mu jj$	$t\bar{t} \rightarrow e\mu$ (86%)	$= 1\mu, 1e$; $\geq$ 2jets	-	$S_T > 600$ GeV	-

- **Mis-modelling found in variables involving jet energies in Z measurement regions**



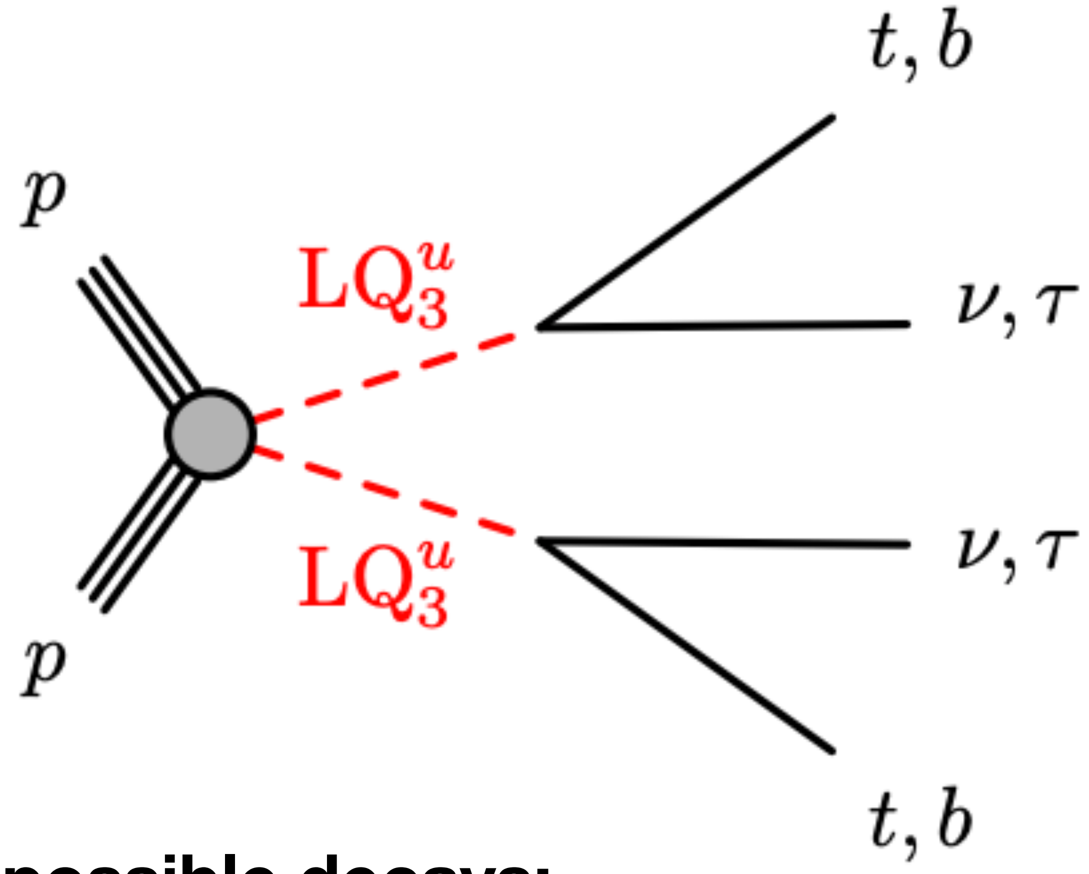
3rd generation LQ search

arXiv:1902.08103

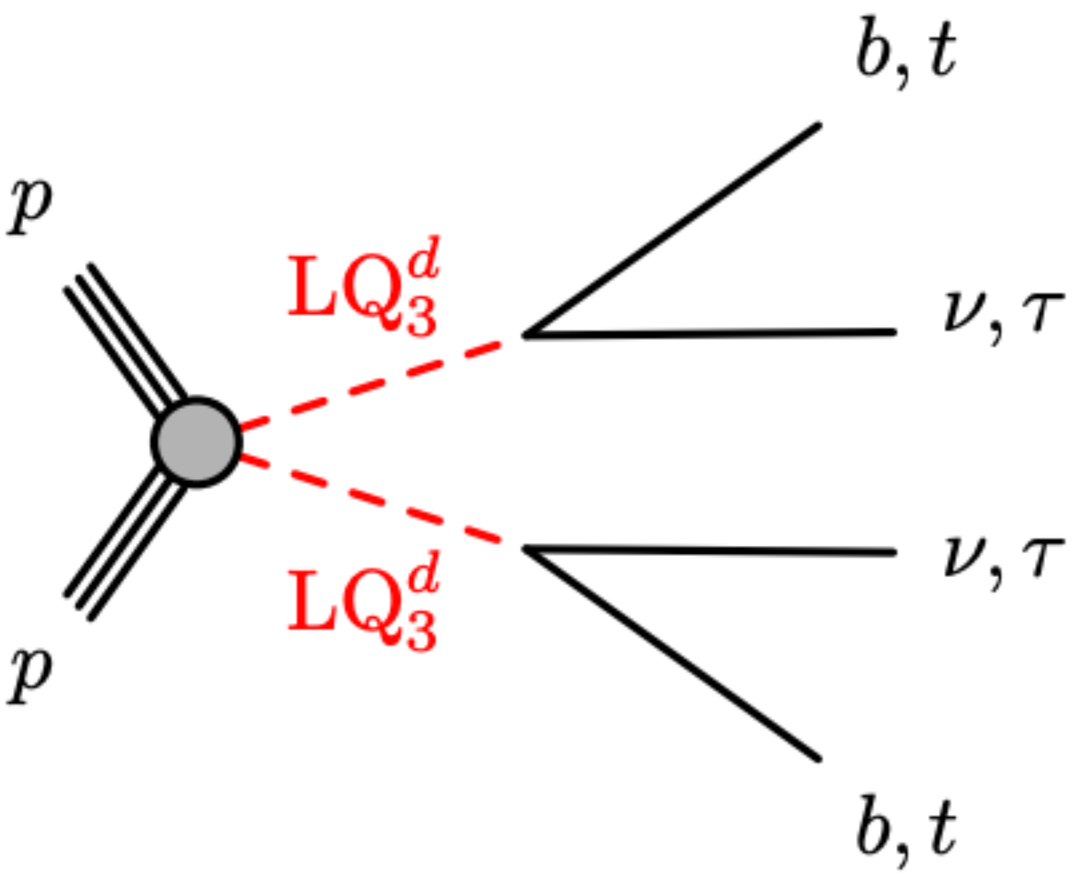
- Searching for 3rd generation LQ pair production with 36 fb-1 data at $\sqrt{s}$ = 13 TeV

36 fb^{-1} data; $\sqrt{s}$ = 13 TeV
Submitted to JHEP
arXiv:1902.08103

Up-type
LQ$_3$→bτ/tν



Down-type
LQ$_3$→tτ/bν



- possible decays:
  LQ^{u}LQ^u→bbττ / ttνν / btτν
  LQ^{d}LQ^d→bbνν / ttττ / btτν

3rd generation LQ search

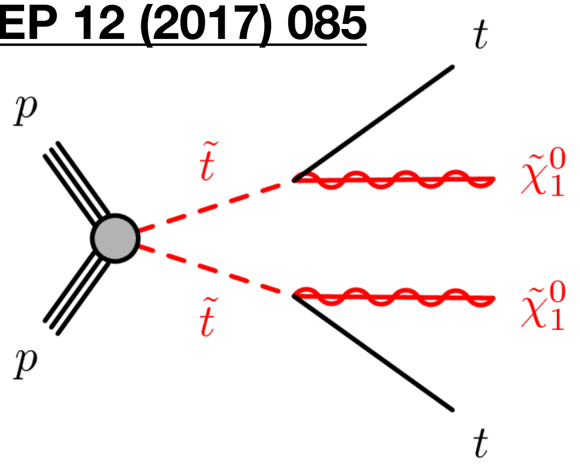
arXiv:1902.08103

- Searching for 3rd generation LQ pair production, with final states: (i) tt+E^{miss}_{T}, (ii) bb+E^{miss}_{T}, (iii) ττb+E^{miss}_{T} and (iv) bbττ

Reinterpretations of SUSY searches

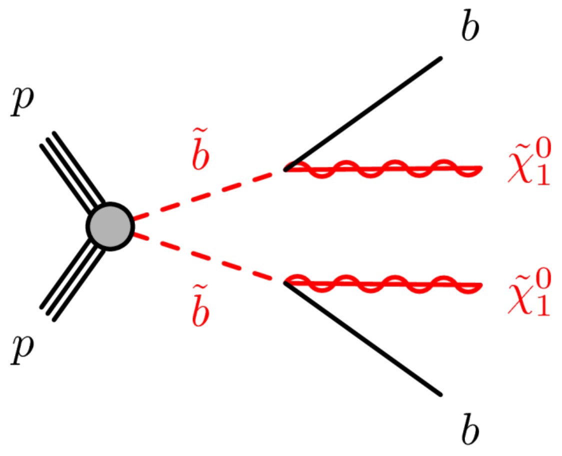
tt+E^{miss}_{T}

- Stop pair-production, with 1 lepton JHEP 06 (2018) 108
- Stop pair-production, with 0 leptons JHEP 12 (2017) 085



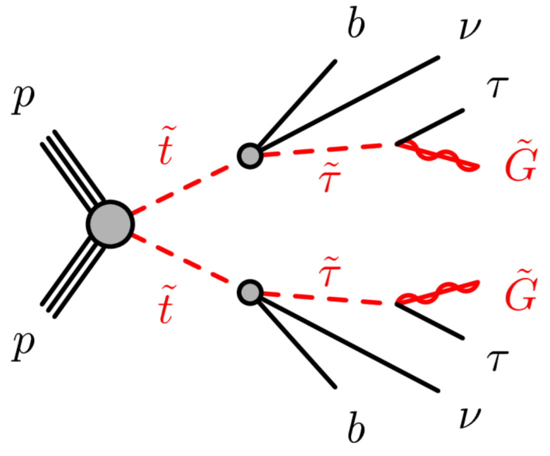
bb+E^{miss}_{T}

- Sbottom pair-production JHEP 11 (2017) 195



ττb+E^{miss}_{T}

- Stop→stau pair-production Phys. Rev. D 98 (2018) 032008



+

Dedicated analysis for LQLQ→bbττ

- Optimized based on HH→bbττ search method Phys. Rev. Lett. 121 (2018) 191801

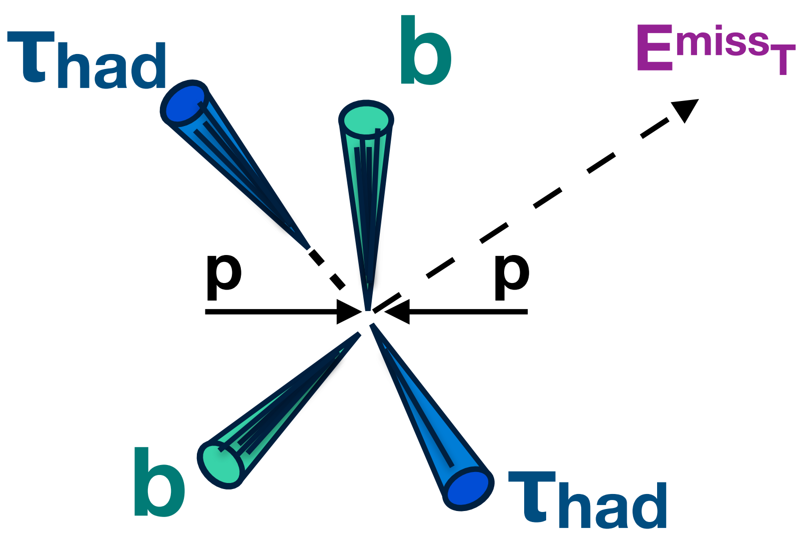
LQLQ→bb$\tau\tau$ search: Analysis strategy

arXiv:1902.08103

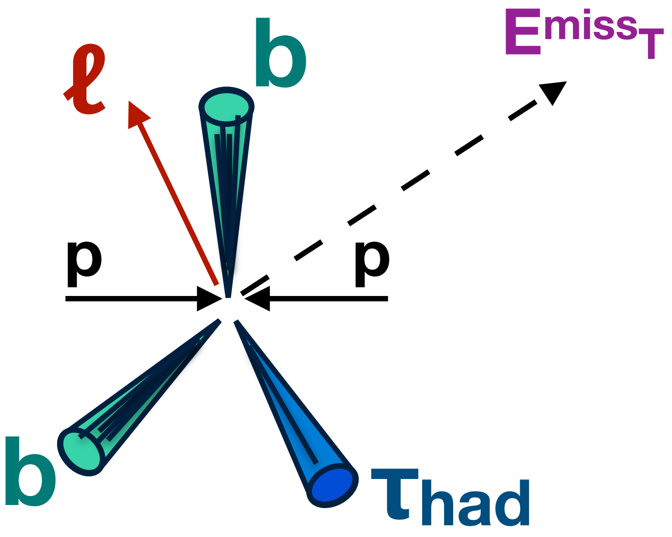
- **Four signal regions: ($\tau_{had}\tau_{had}$ and $\tau_{lep}\tau_{had}$ channels) x (1 and 2 b-tag categories)**

Channel	$\tau_{had}\tau_{had}$	$\tau_{lep}\tau_{had}$
Selections	• Single/di-tau trigger • **No e/μ** and **exactly 2 τ_{had}** (oppositely-sign charge) • **≥ 2 jets**	• Single lepton trigger • **Exactly 1 e/μ** and **1 τ_{had}** (oppositely-sign charge) • **≥ 2 jets**
Categorization	**1 and 2 b-tagged jets**	

bb$\tau_{had}\tau_{had}$



bb$\tau_{lep}\tau_{had}$



- **bτ pairing is chosen by minimizing $|m(j_1,\tau_{had,1}) - m(j_2,\tau_{had,2})|$ or $|m(j_1,\tau_{had,1}) - m(j_2,\ell)|$**

- **Major backgrounds with real taus are ttbar and Z(→$\tau\tau$) + heavy flavour jets**
- **Fake tau contribution is estimated with data-driven method**

LQLQ→bbττ search: Analysis strategy

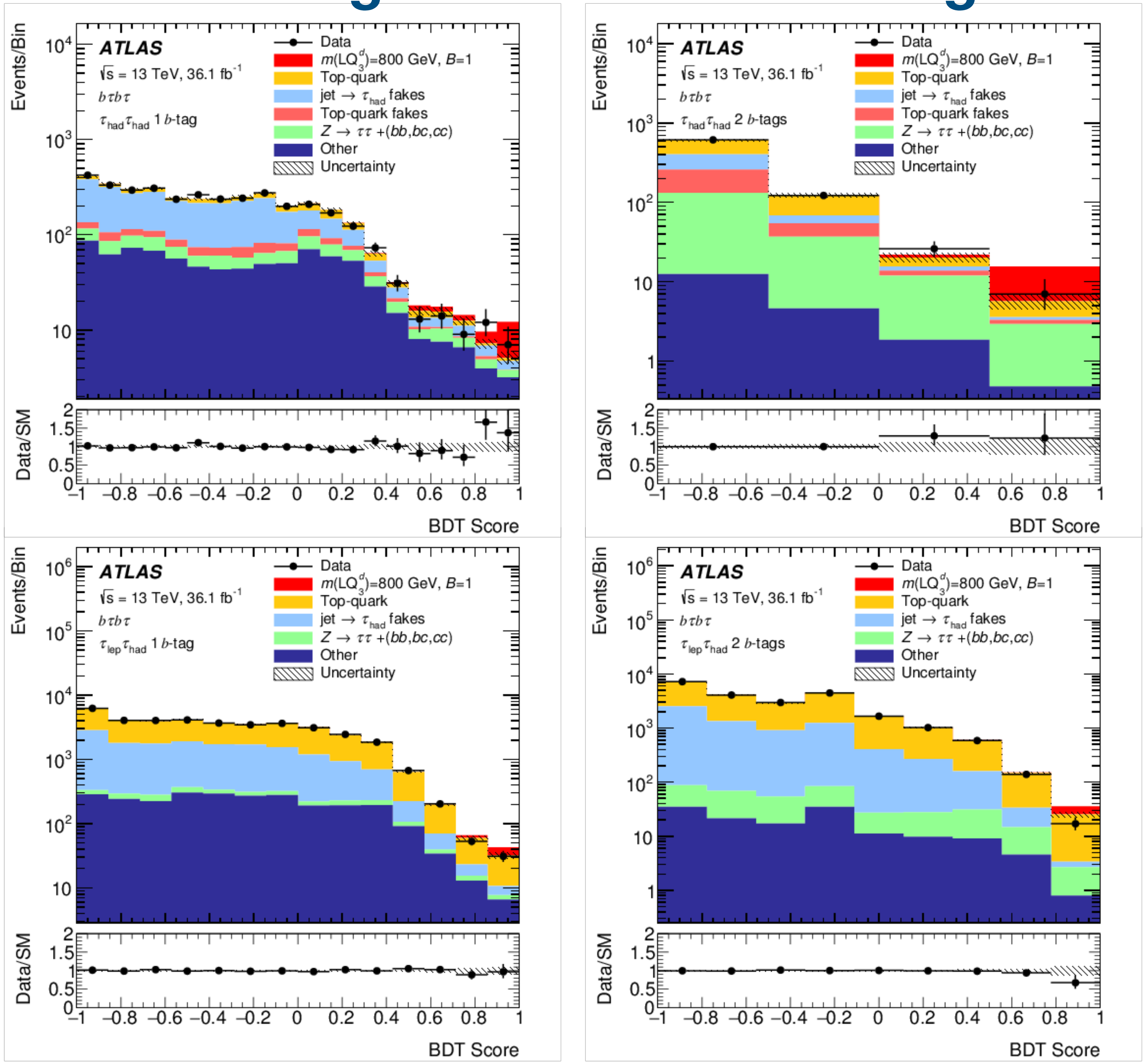
arXiv:1902.08103

- **BDT is trained for each of the four SR's & each LQ mass (for LQ^u only)**

1 b-tag **2 b-tag**

τhadτhad

τlepτhad



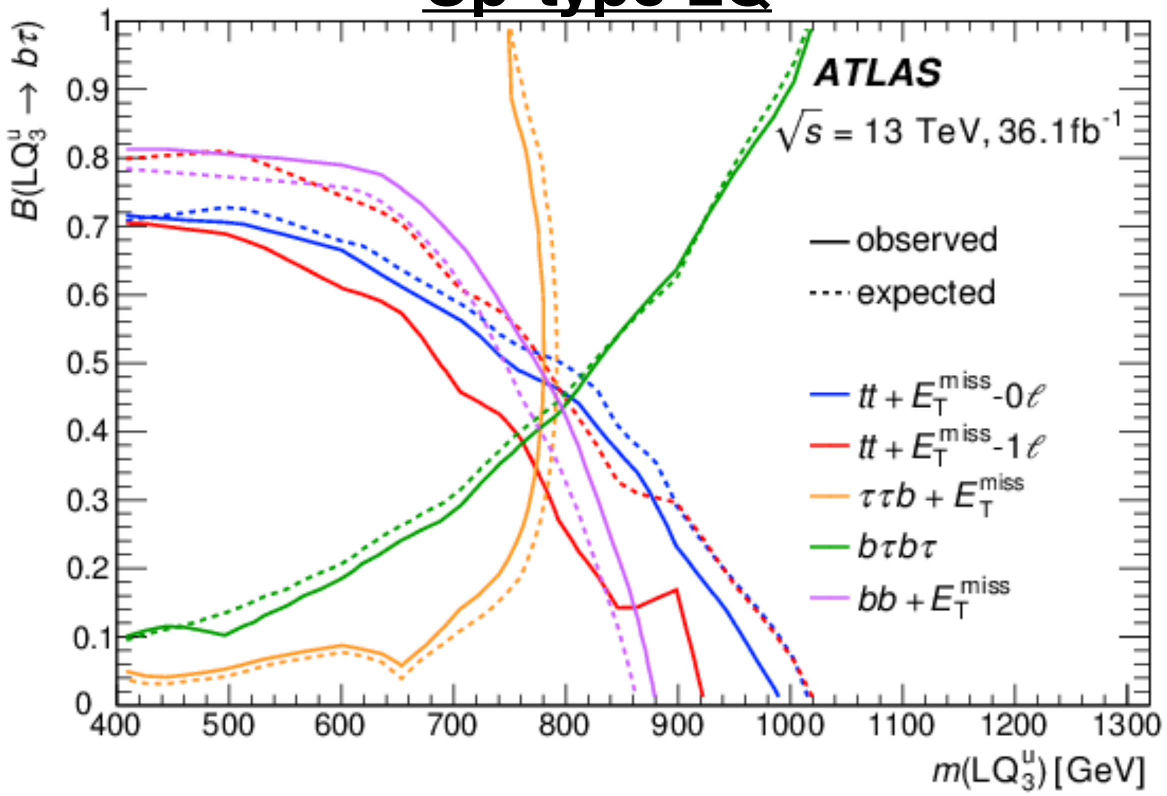
- **Single combined fit of these BDT output score profiles in all SRs and CRs**

Full Results of LQ³ search

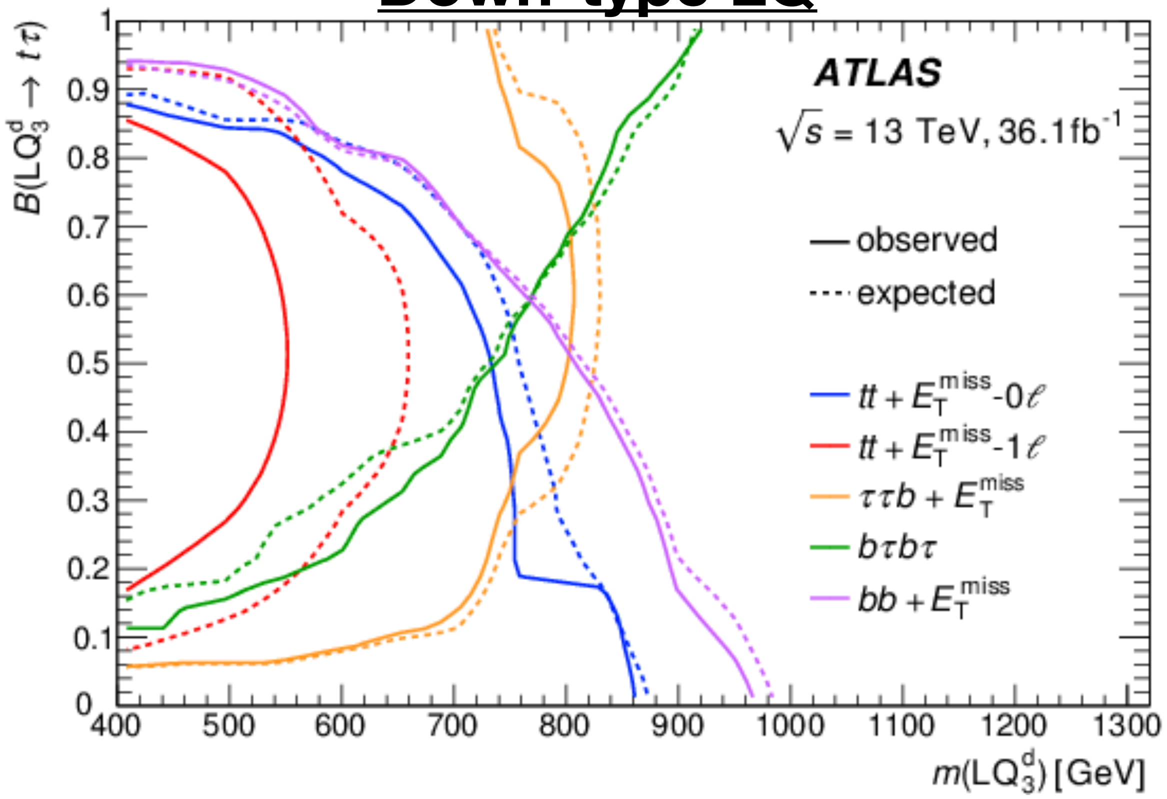
arXiv:1902.08103

Analysis	Signature	Best sensitivity
Di-Higgs reoptimization	bbττ	medium and high B
Stop Search with Zero Leptons	$tt+E_{miss}^{T}+0\ell$	low and medium B
Stop Search with One Leptons	$tt+E_{miss}^{T}+1\ell$	low and medium B (LQ^{u})
Sbottom Search with zero/one lepton	$bb+E_{miss}^{T}+0/1\ell$	low and medium B
Stop-Stau Search	$b+E_{miss}^{T}+2\tau$	all B except close to 0

Up-type LQ



Down-type LQ

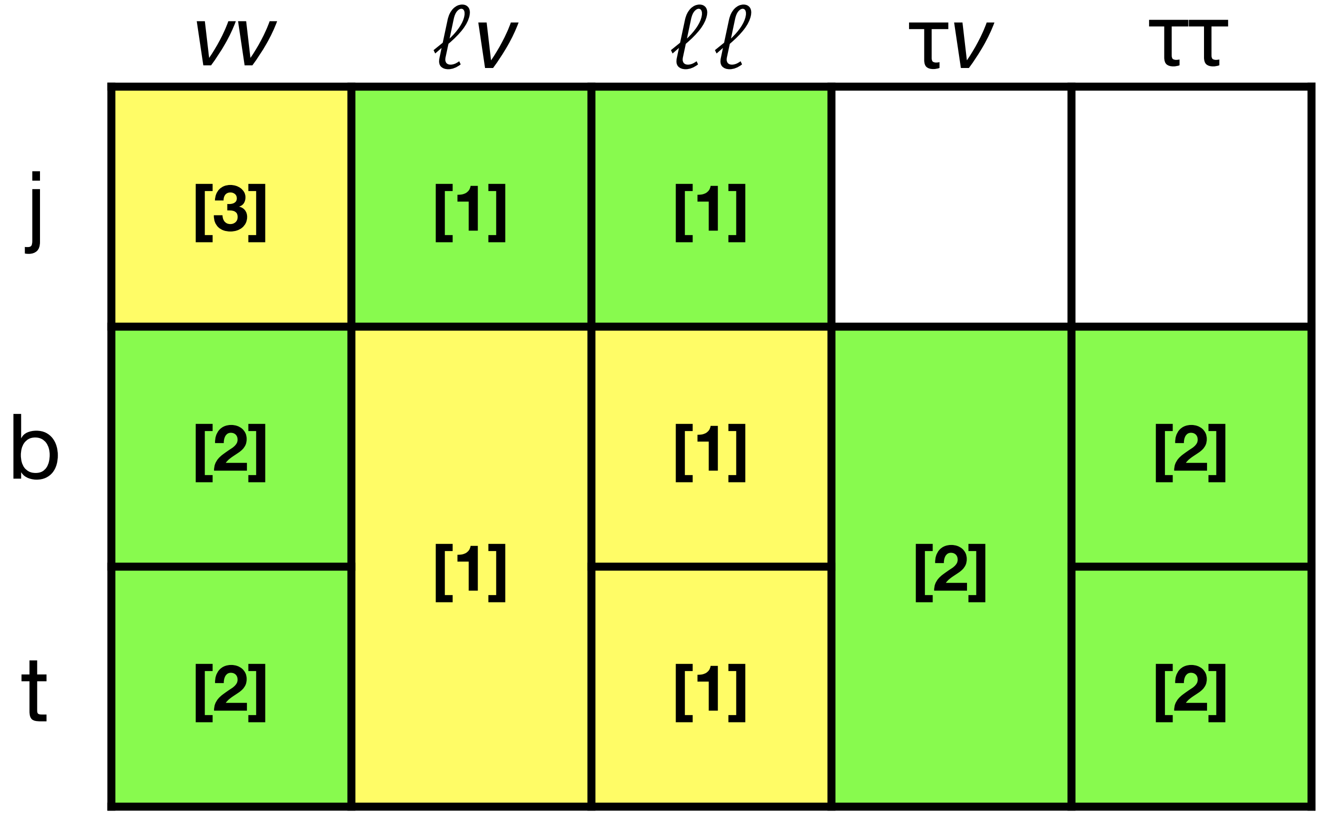


← area to the left of the curves is excluded

- **Masses below 800 GeV excluded for both up- and down-type LQs**
- **Masses below ~1 TeV excluded for BR(LQ→ℓ±q) = 0/1**

Summary

- (Scalar) LQ pair production searched with 36 fb^{-1} data
  - LQ^{1,2}: mass limits up to mLQ ≈ 1.5 TeV
  - LQ^{3}: mass limits up to mLQ ≈ 1.0 TeV



	$\nu\nu$	$\ell\nu$	$\ell\ell$	$\tau\nu$	$\tau\tau$
j	🟨 [3]	🟩 [1]	🟩 [1]	⬜	⬜
b	🟩 [2]	🟨 [1]	🟨 [1]	🟩 [2]	🟩 [2]
t	🟩 [2]		🟨 [1]		🟩 [2]

🟩 upper limit exists

🟨 possibly some sensitivity but no published results

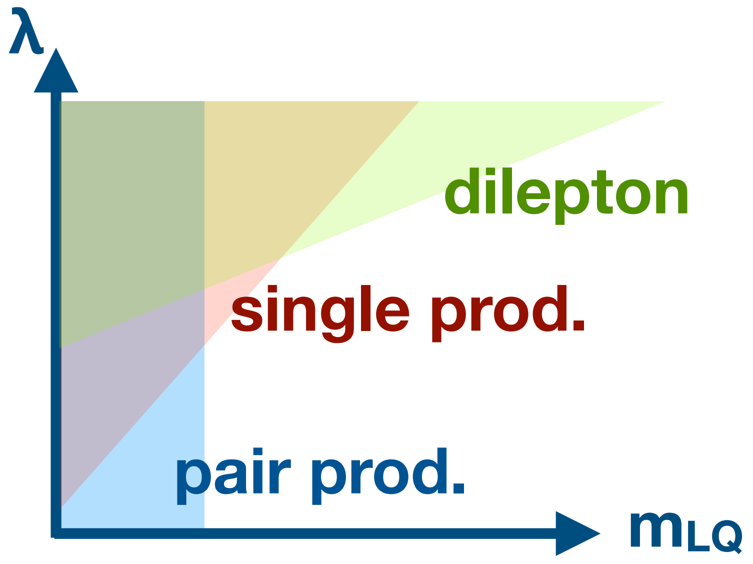
⬜ No direct search

[1] 36 fb^{-1} LQ1,2 search

[2] 36 fb^{-1} LQ3 search

[3] 36 fb^{-1} squarks pair → jets+MET search

- Let's explore the full Run 2 dataset of 139 fb^{-1}!
  - Scalar and vector LQ
  - Cross-generational LQ decays
  - Pair and single LQ production
  - Non-resonant LQ search in dilepton mass/angular spectra



Thank you for your attention

Maybe a leptoquark is also just at our front yard!

Backup Slides

Input Variables to BDT

- **1st & 2nd generation LQ:**

Channel	$\ell\ell jj$	$\ell\nu jj$
Input variable	• m_{LQ}^{min} • $m_{\ell\ell}$ • p_T^{j2} • $p_T^{\ell 2}$ • m_{LQ}^{max}	• m_{LQ} • m_{LQ}^T • m_T • E_T^{miss} • p_T^{j2} • p_T^{ℓ}

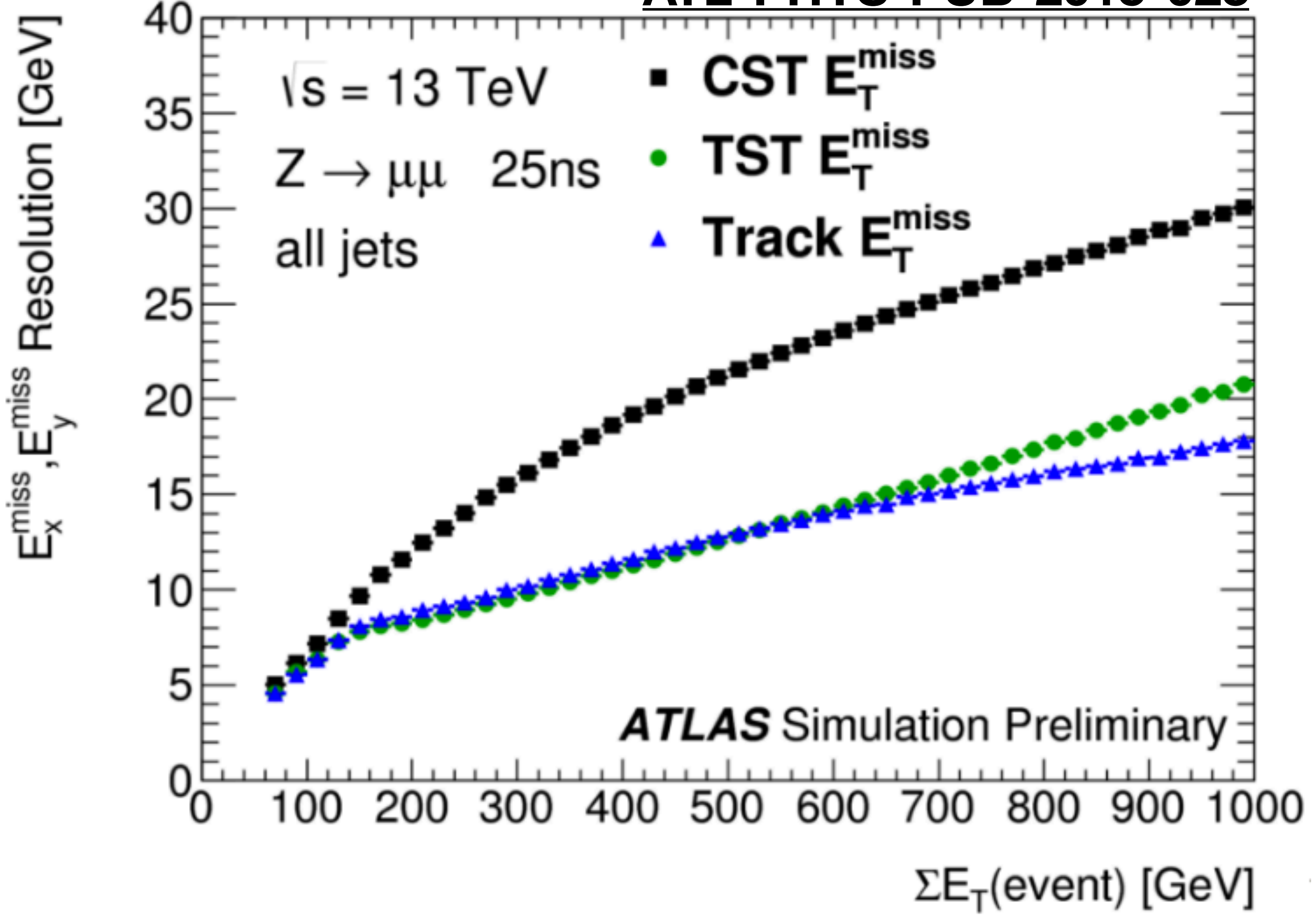
- **3rd generation LQ:**

Channel	$\tau_{had}\tau_{had}$	$\tau_{lep}\tau_{had}$
Input variable	• S_T • $m(\tau_{h1},jet)$ • $\Delta\phi(\tau_{h},jet)$ • E_T^{miss}-ϕ centrality • $p_T(\tau_{h1})$	• S_T • $m(\tau_{h},jet)$ • $m(\ell,jet)$ • $\Delta\phi(\ell,jet)$ • E_T^{miss}-ϕ centrality • $p_T(\tau_h)$ • $\Delta\phi(\ell,E_T^{miss})$

Event-based MET significance

$$\mathrm{Signif}(X) = \frac{X}{\sigma_X} \quad \Longrightarrow \quad \mathcal{S} = \frac{E_{\mathrm{T}}^{\mathrm{miss}}}{\boxed{\sqrt{\sum E_{\mathrm{T}}}}}$$

$$\sum E_{\mathrm{T}} = \sum p_{\mathrm{T}}^{e} + \sum p_{\mathrm{T}}^{\gamma} + \sum p_{\mathrm{T}}^{\tau} + \sum p_{\mathrm{T}}^{\mathrm{jets}} + \sum p_{\mathrm{T}}^{\mu} + \sum p_{\mathrm{T}}^{\mathrm{soft}}$$



ATL-PHYS-PUB-2015-023

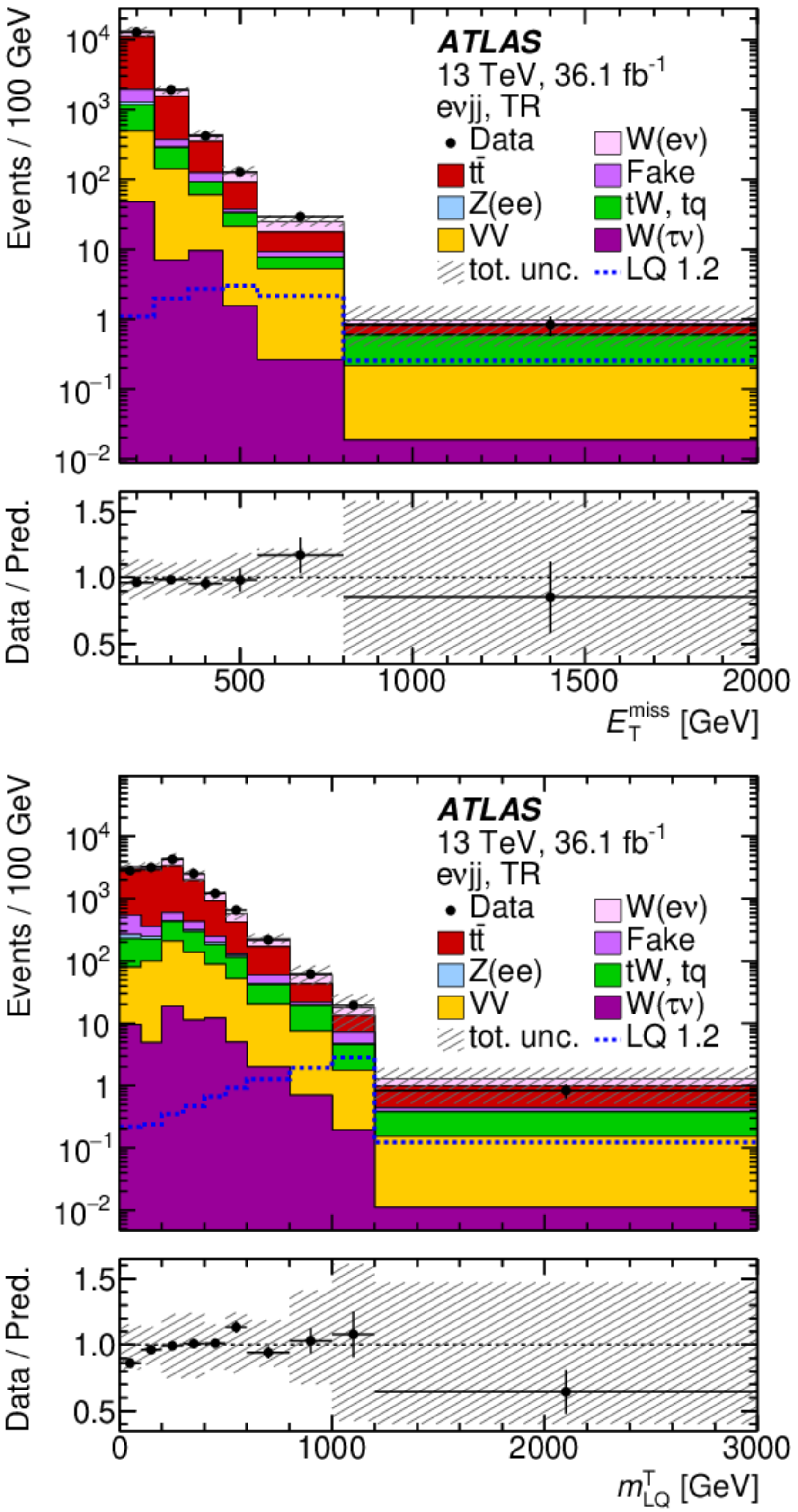
CST: calorimeter-based soft term
TST: track-based soft term

Limitations:

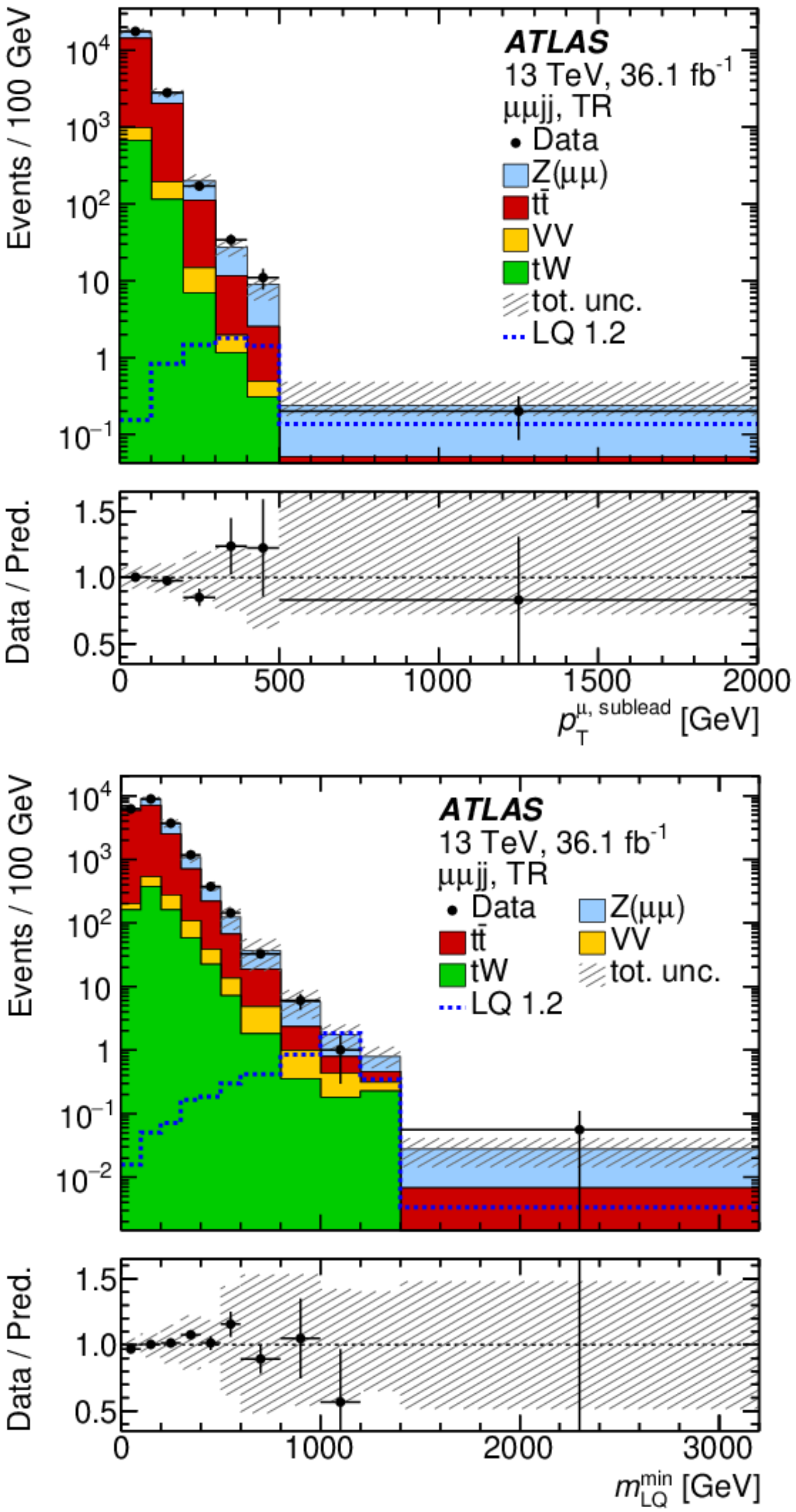
- **Proxy for the MET resolution**
- **Event based quantity, neglecting the nature of the objects.**
- **Do not take into account directional correlations**

LQ$_1$ & LQ$_2$: Input Variables to BDT

evjj



μμjj



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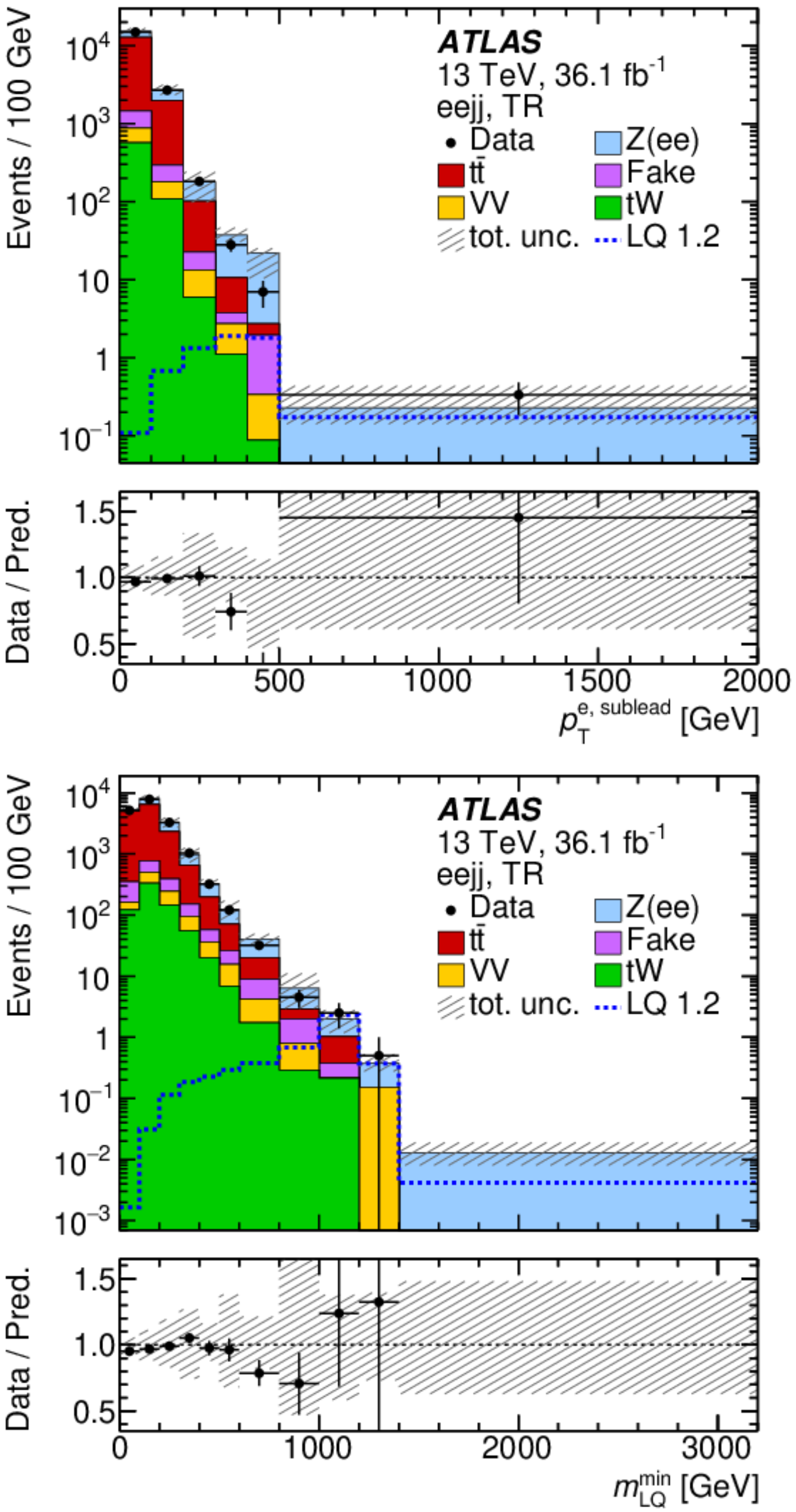
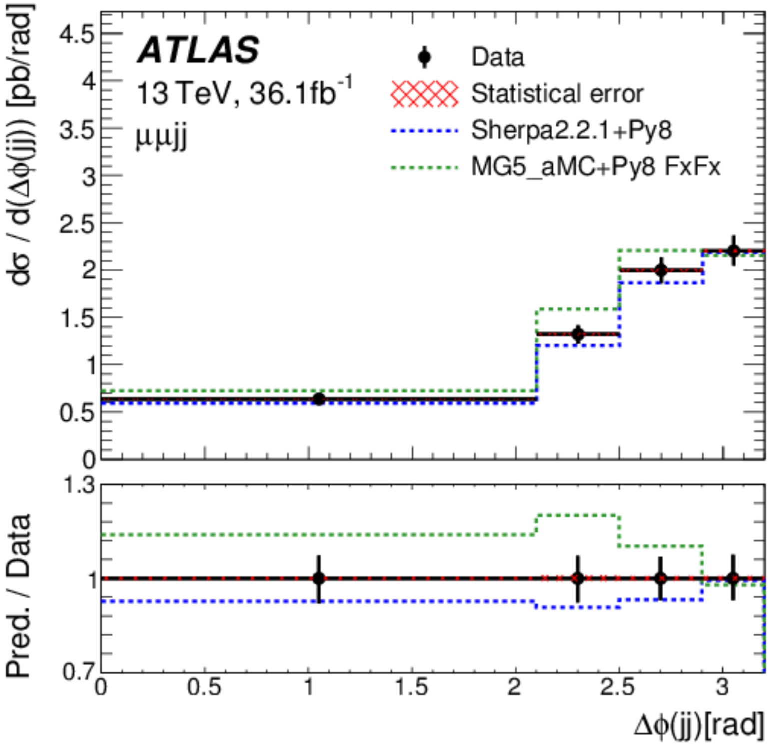
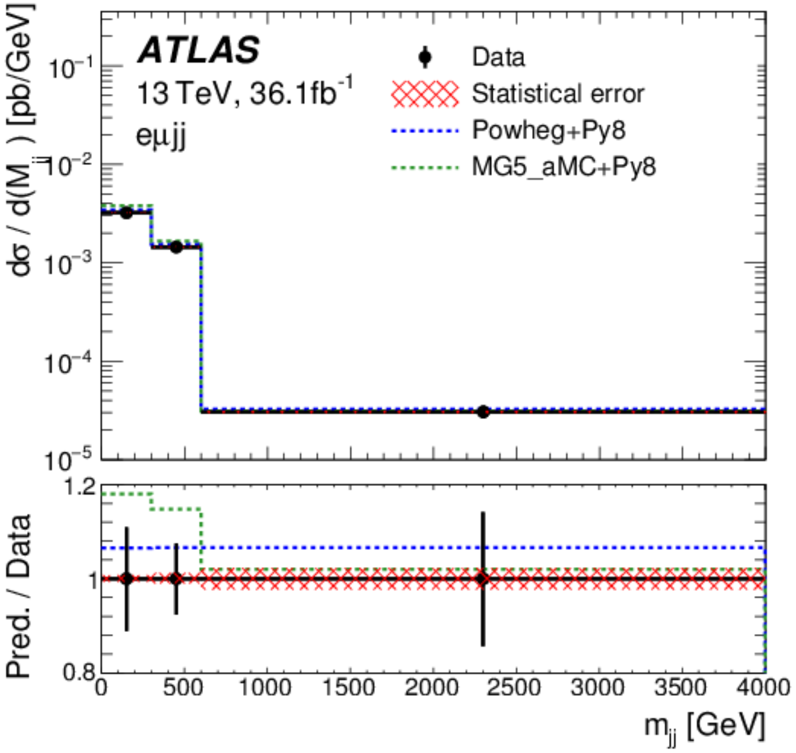
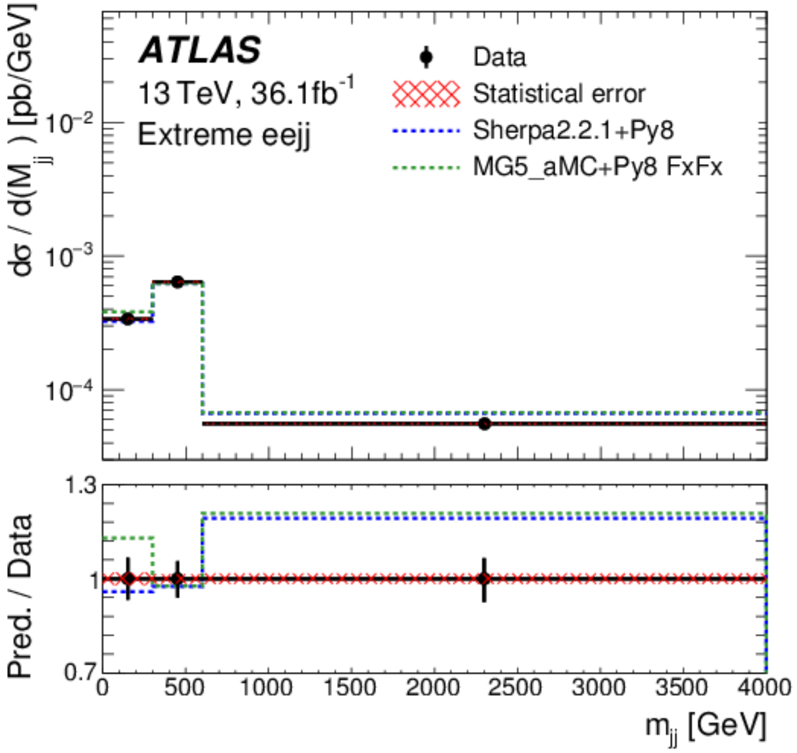


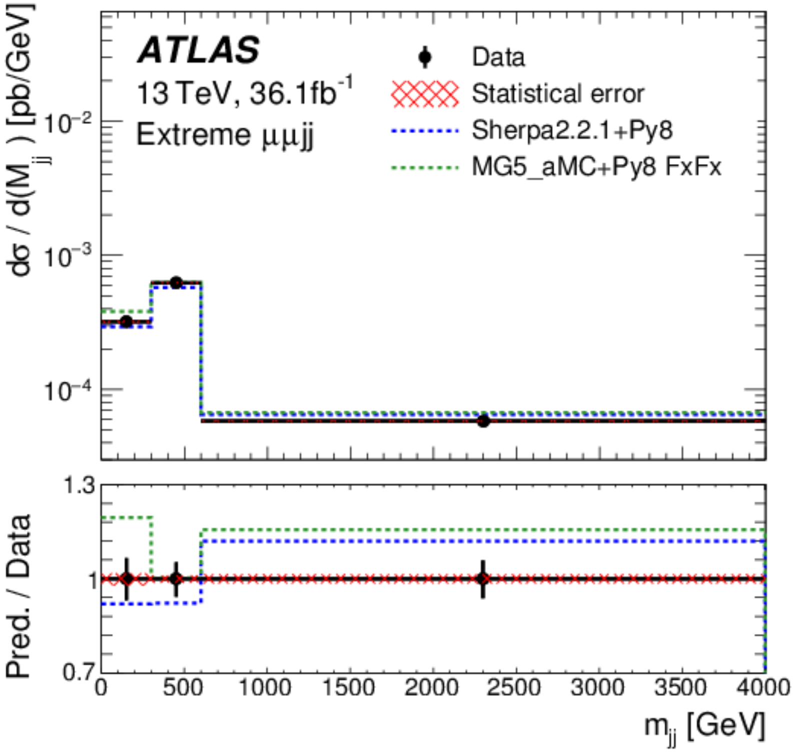
LQ$_1$ & LQ$_2$: Variables in differential-σ measurements

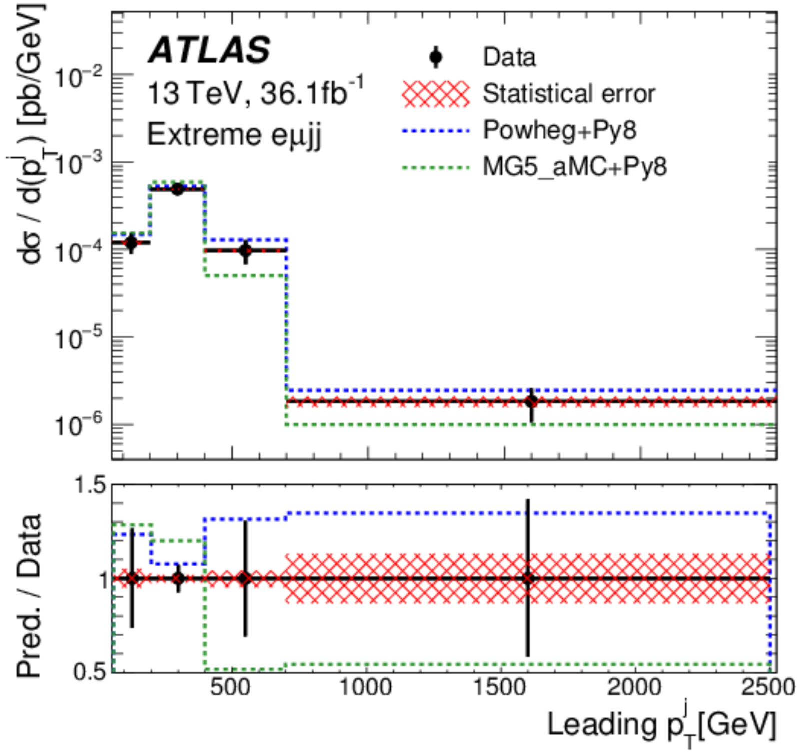
- $p_T(\ell\ell)$, $\Delta\phi(\ell\ell)$, Min $\Delta\phi(\ell,j1)$,Min $\Delta\phi(\ell,j2)$, S_T, $p_T(j1)$, $p_T(j2)$, $\Delta\phi(j1,j2)$, $\Delta\eta(j1,j2)$, $|pT(j1)| + |pT(j2)|$, $m(j1,j2)$





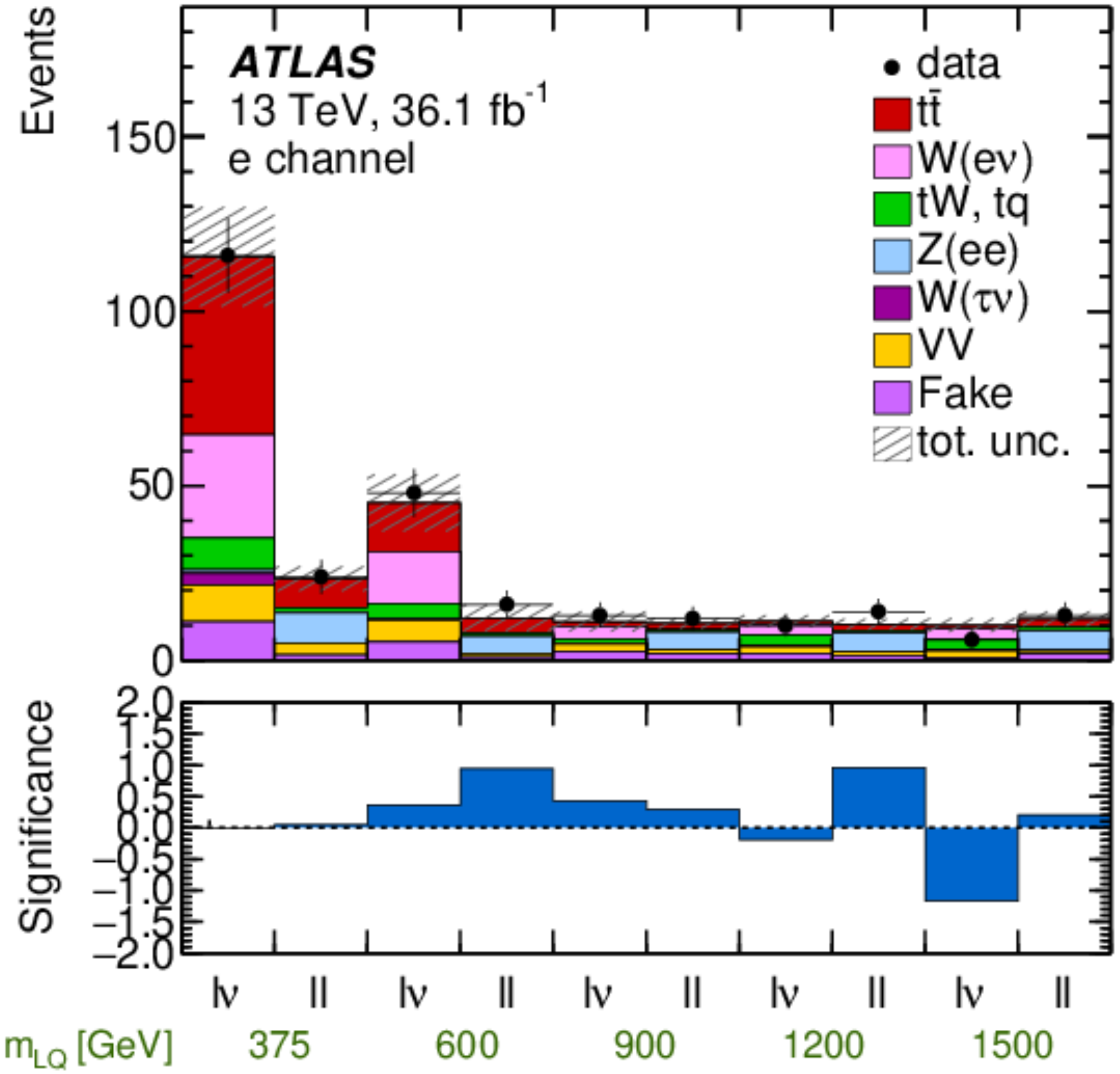




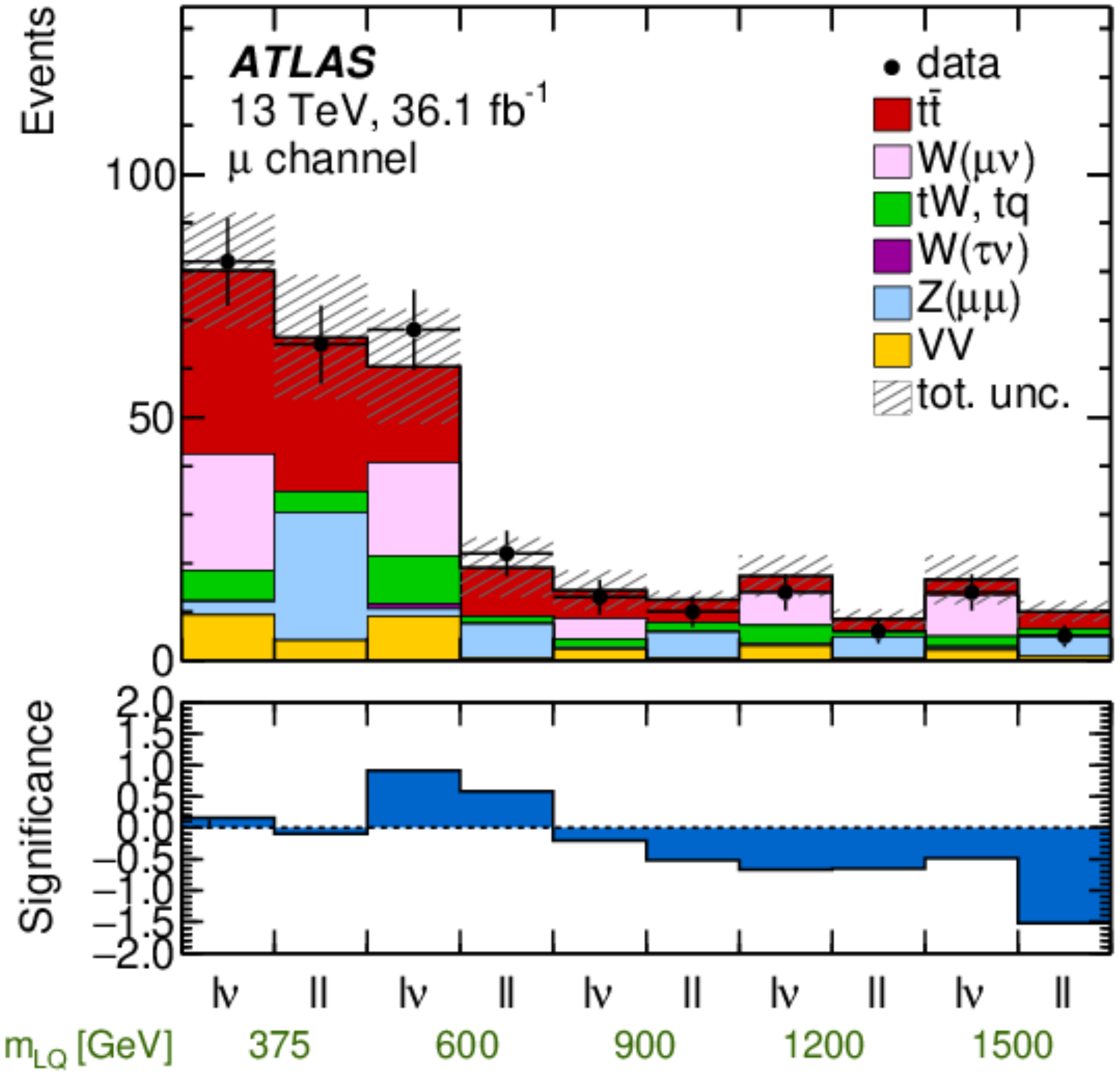


LQ_1 & LQ_2: Data vs background yields; and significance

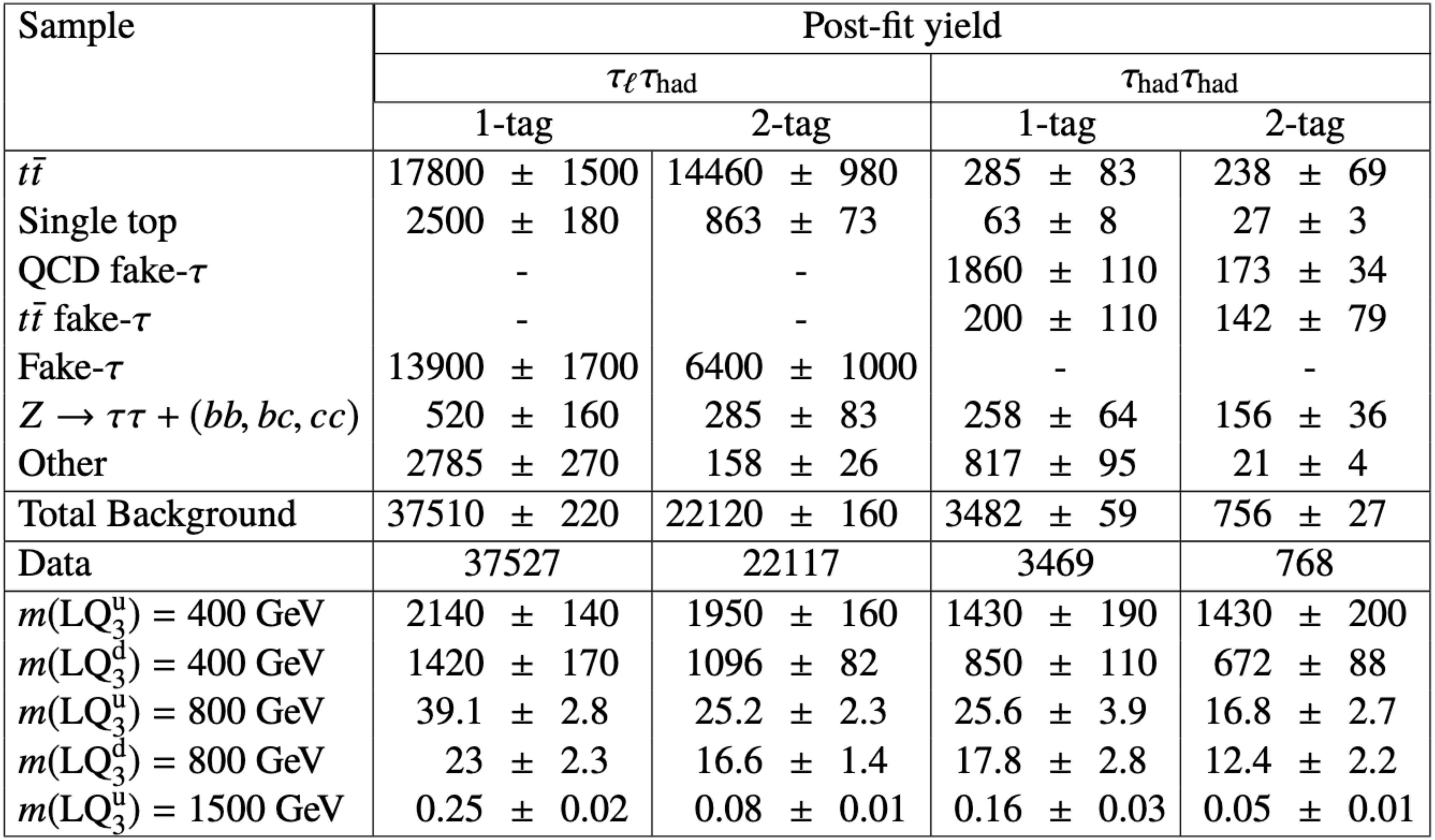
e channel



μ channel



LQ$_3$(bbττ): Yields

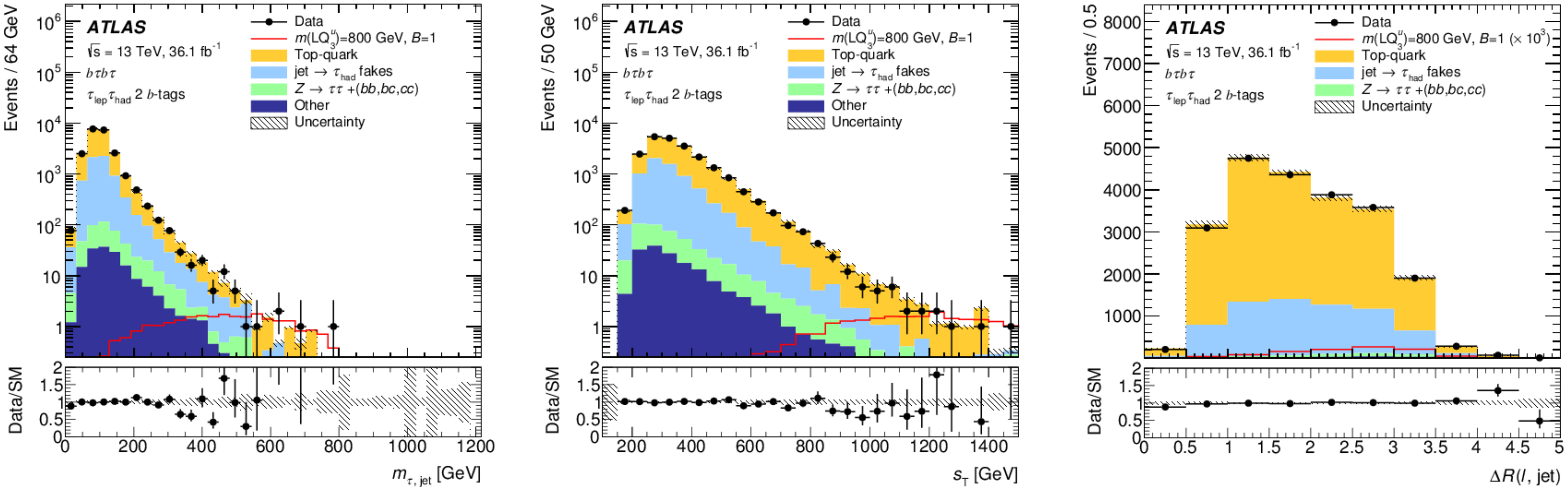


Sample	Post-fit yield			
	$\tau_\ell\tau_{\mathrm{had}}$		$\tau_{\mathrm{had}}\tau_{\mathrm{had}}$	
	1-tag	2-tag	1-tag	2-tag
$t\bar{t}$	17800 ± 1500	14460 ± 980	285 ± 83	238 ± 69
Single top	2500 ± 180	863 ± 73	63 ± 8	27 ± 3
QCD fake-τ	-	-	1860 ± 110	173 ± 34
$t\bar{t}$ fake-τ	-	-	200 ± 110	142 ± 79
Fake-τ	13900 ± 1700	6400 ± 1000	-	-
$Z \rightarrow \tau\tau + (bb, bc, cc)$	520 ± 160	285 ± 83	258 ± 64	156 ± 36
Other	2785 ± 270	158 ± 26	817 ± 95	21 ± 4
Total Background	37510 ± 220	22120 ± 160	3482 ± 59	756 ± 27
Data	37527	22117	3469	768
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 400 GeV	2140 ± 140	1950 ± 160	1430 ± 190	1430 ± 200
$m(\mathrm{LQ}_3^{\mathrm{d}})$ = 400 GeV	1420 ± 170	1096 ± 82	850 ± 110	672 ± 88
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 800 GeV	39.1 ± 2.8	25.2 ± 2.3	25.6 ± 3.9	16.8 ± 2.7
$m(\mathrm{LQ}_3^{\mathrm{d}})$ = 800 GeV	23 ± 2.3	16.6 ± 1.4	17.8 ± 2.8	12.4 ± 2.2
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 1500 GeV	0.25 ± 0.02	0.08 ± 0.01	0.16 ± 0.03	0.05 ± 0.01

LQ$_3$(bbττ): Input Variables to BDT

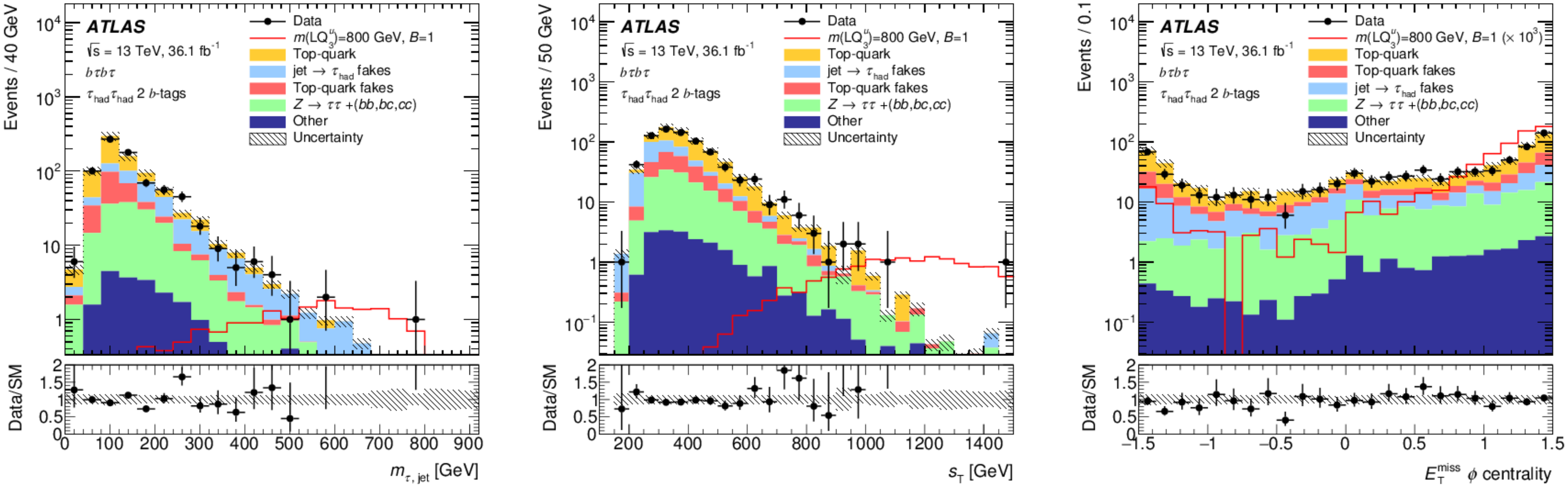
$\tau_{lep}\tau_{had}$

2 b-tags

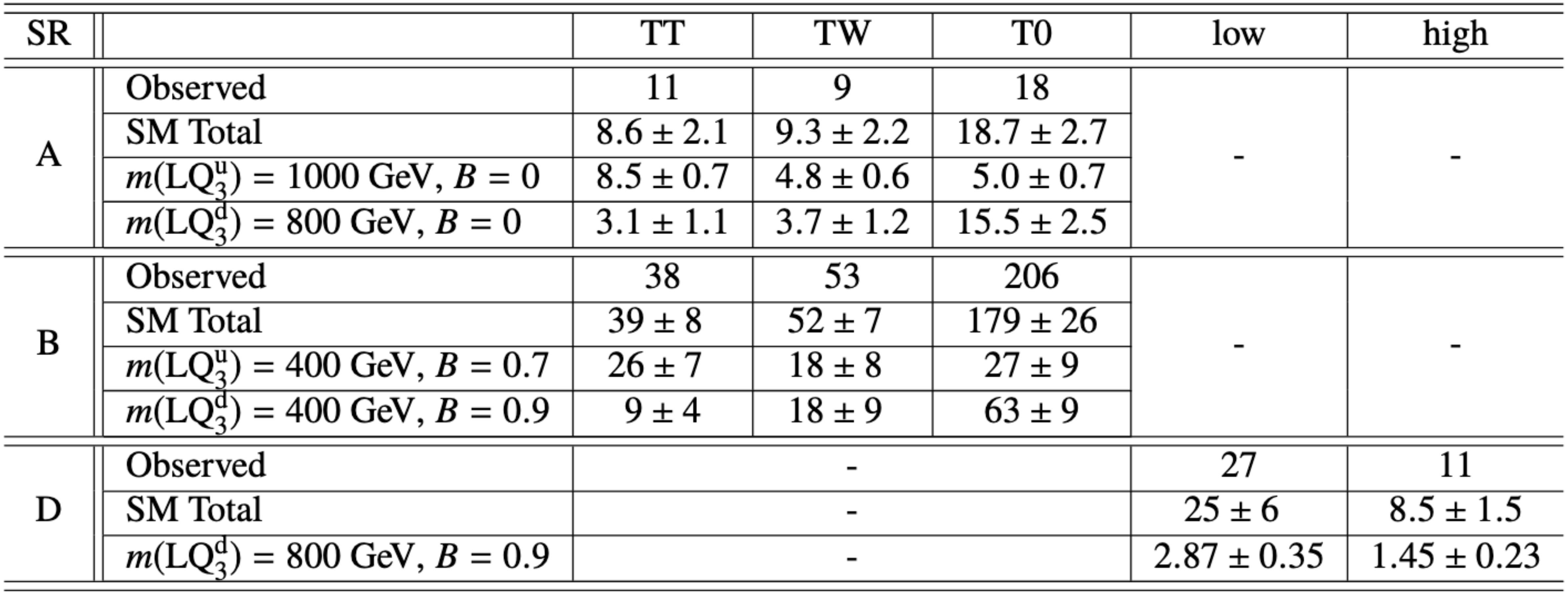


$\tau_{had}\tau_{had}$

2 b-tags



LQ3 Reinterpretation: 0-lepton Stop



SR		TT	TW	T0	low	high
A	Observed	11	9	18	-	-
	SM Total	8.6 ± 2.1	9.3 ± 2.2	18.7 ± 2.7		
	$m(\mathrm{LQ}_3^{\mathrm{u}}) = 1000$ GeV, $B = 0$	8.5 ± 0.7	4.8 ± 0.6	5.0 ± 0.7		
	$m(\mathrm{LQ}_3^{\mathrm{d}}) = 800$ GeV, $B = 0$	3.1 ± 1.1	3.7 ± 1.2	15.5 ± 2.5		
B	Observed	38	53	206	-	-
	SM Total	39 ± 8	52 ± 7	179 ± 26		
	$m(\mathrm{LQ}_3^{\mathrm{u}}) = 400$ GeV, $B = 0.7$	26 ± 7	18 ± 8	27 ± 9		
	$m(\mathrm{LQ}_3^{\mathrm{d}}) = 400$ GeV, $B = 0.9$	9 ± 4	18 ± 9	63 ± 9		
D	Observed	-			27	11
	SM Total	-			25 ± 6	8.5 ± 1.5
	$m(\mathrm{LQ}_3^{\mathrm{d}}) = 800$ GeV, $B = 0.9$	-			2.87 ± 0.35	1.45 ± 0.23

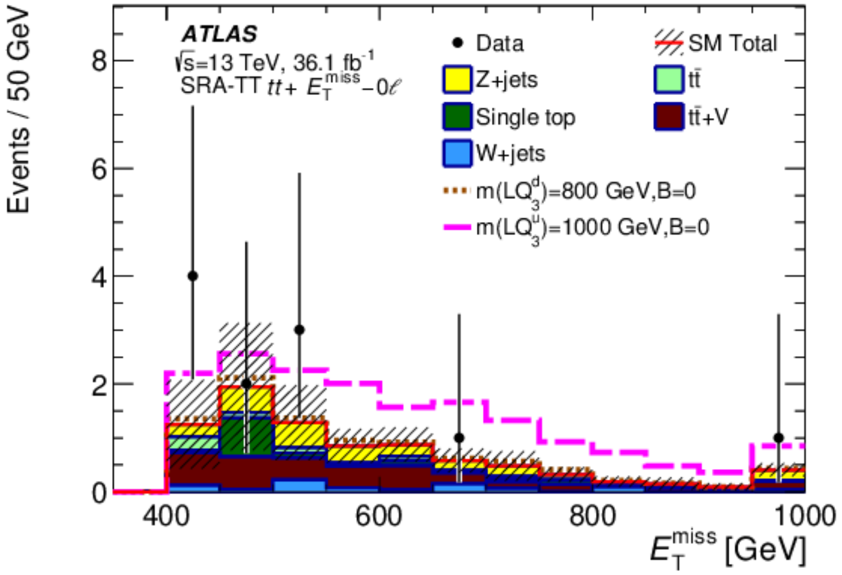
SRA & SRB: two R=1.2 jets
SRA: EmissT>600GeV
SRB: 250GeV < EmissT<600GeV

SRD: >4 jets && two b-tagged
low: 300GeV < HT(bj1,bj2) < 400GeV
high: HT(bj1,bj2) > 400GeV

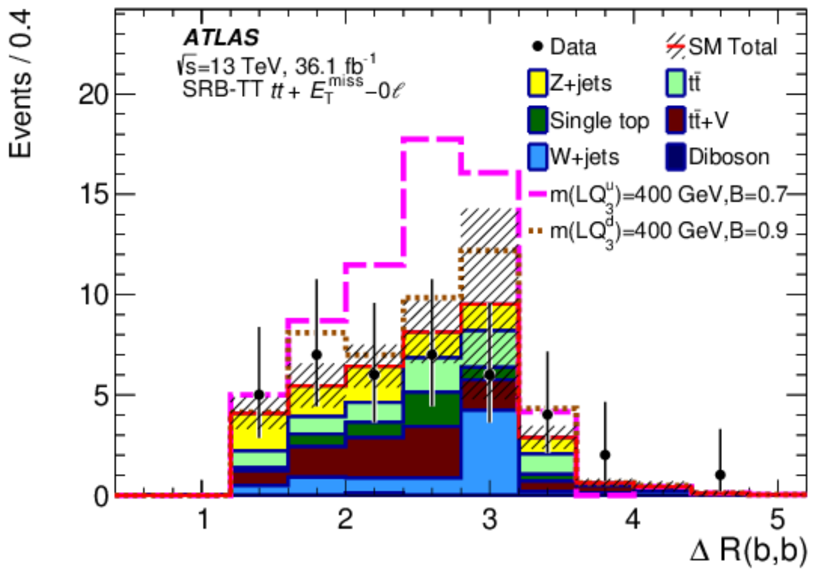
TT: m1jet,R=1.2>120GeV
TW: 60<m1jet,R=1.2<120GeV
T0: m1jet,R=1.2<60GeV

LQ3 Reinterpretation: 0-lepton Stop

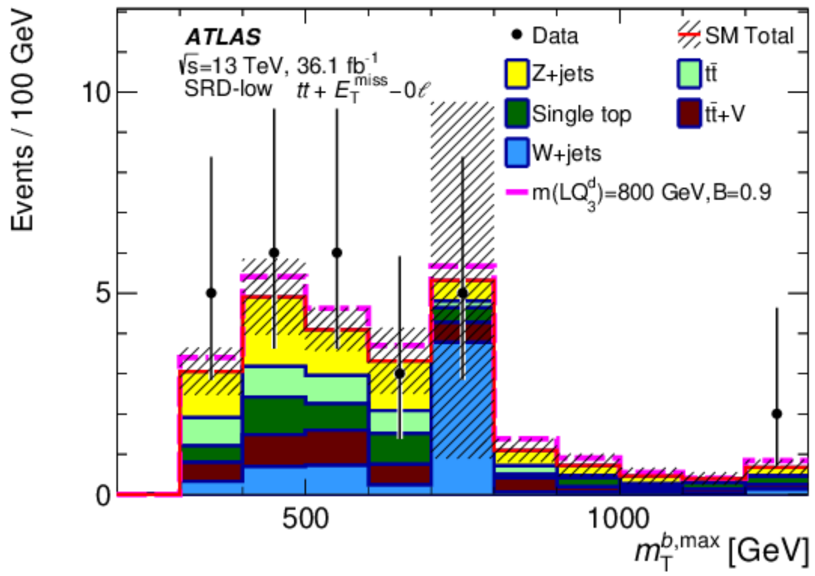
SRA-TT



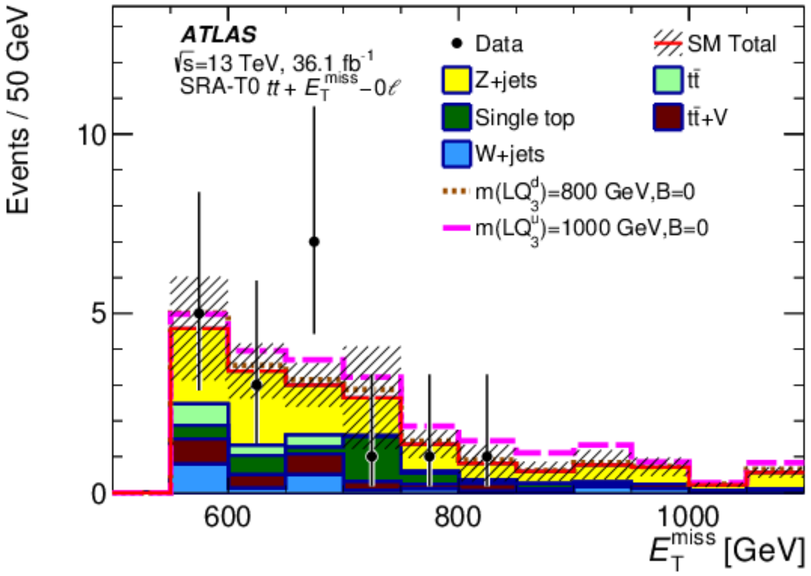
SRB-TT



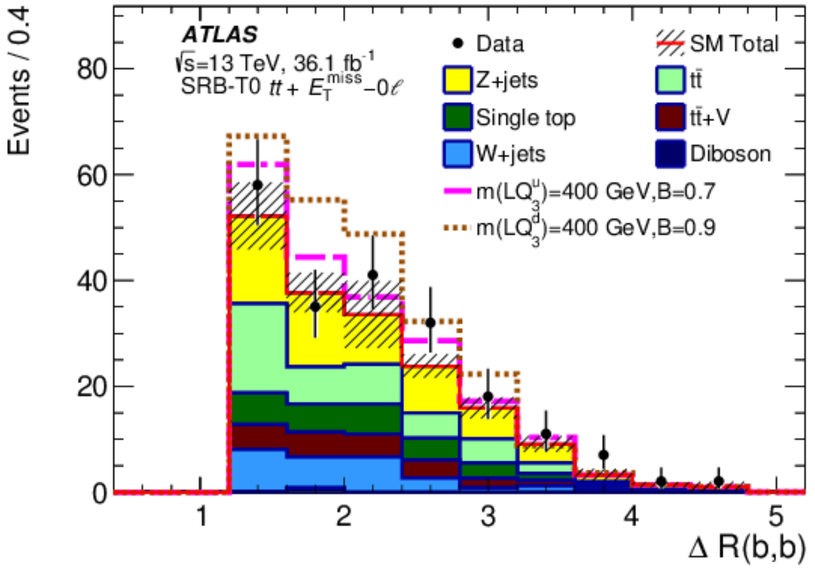
SRD-low



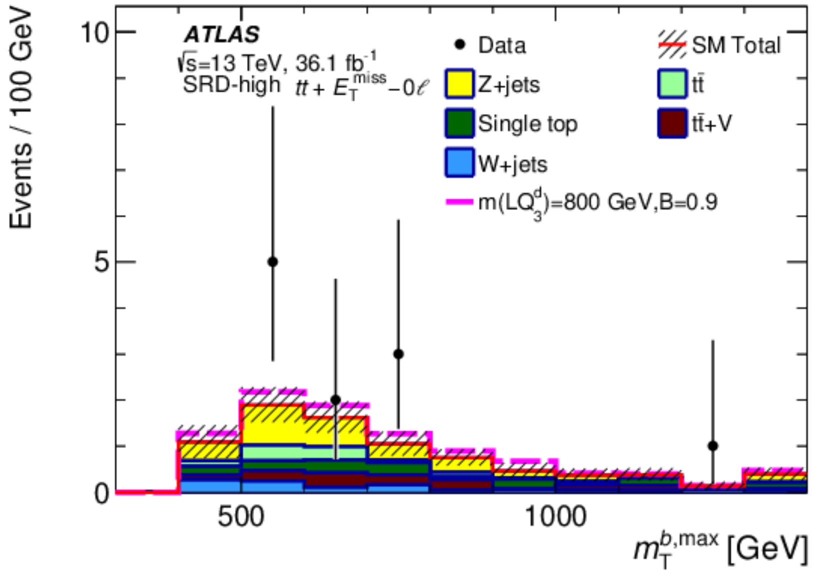
SRA-T0



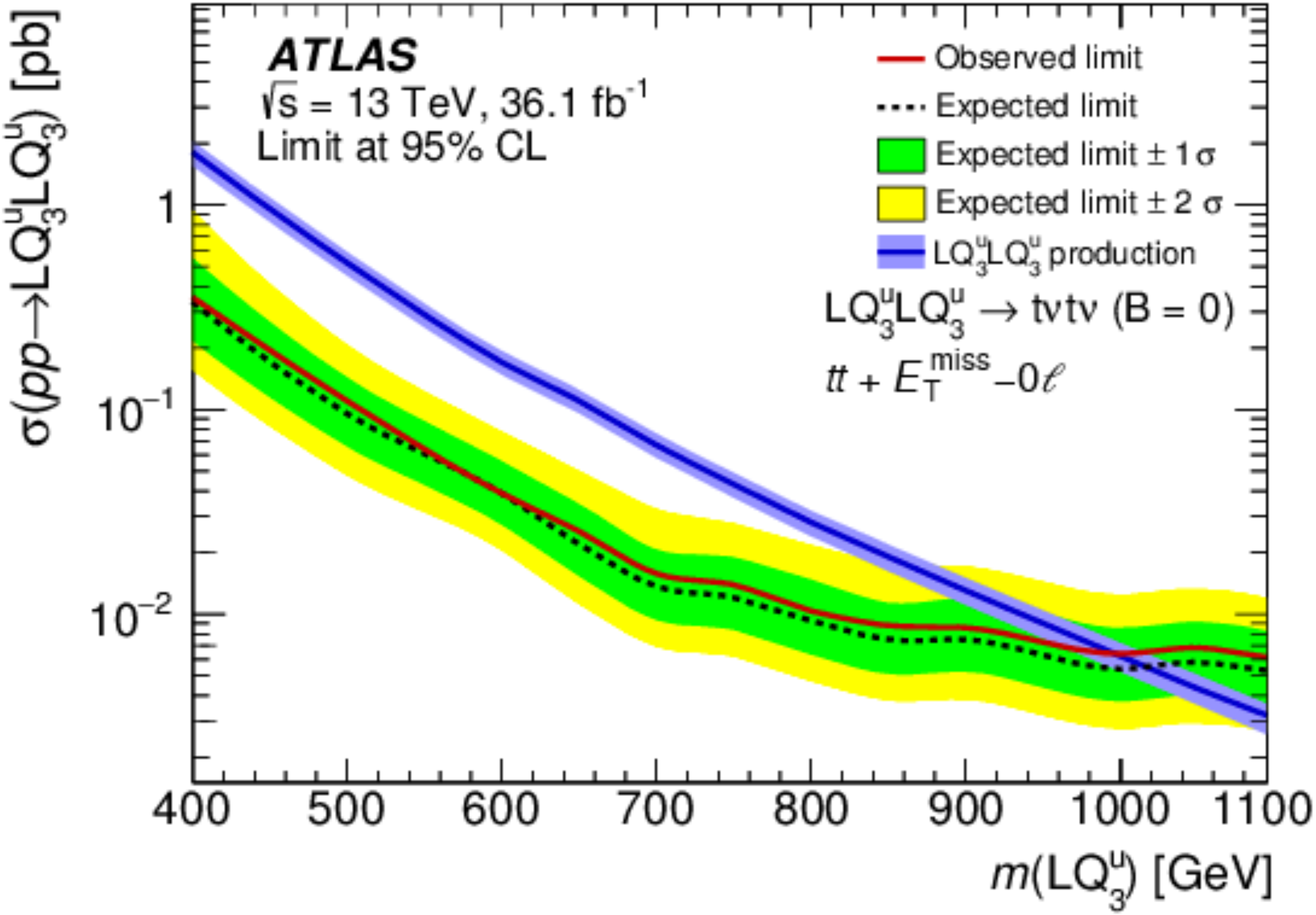
SRB-T0



SRD-high



LQ3 Reinterpretation: 0-lepton Stop



LQ3 Reinterpretation: 1-lepton Stop

Both signal regions require at least four jets, at least oneb-tagged jet, exactly one isolated electron or muon, and highEmiss
SR tN_high for >1TeV LQ

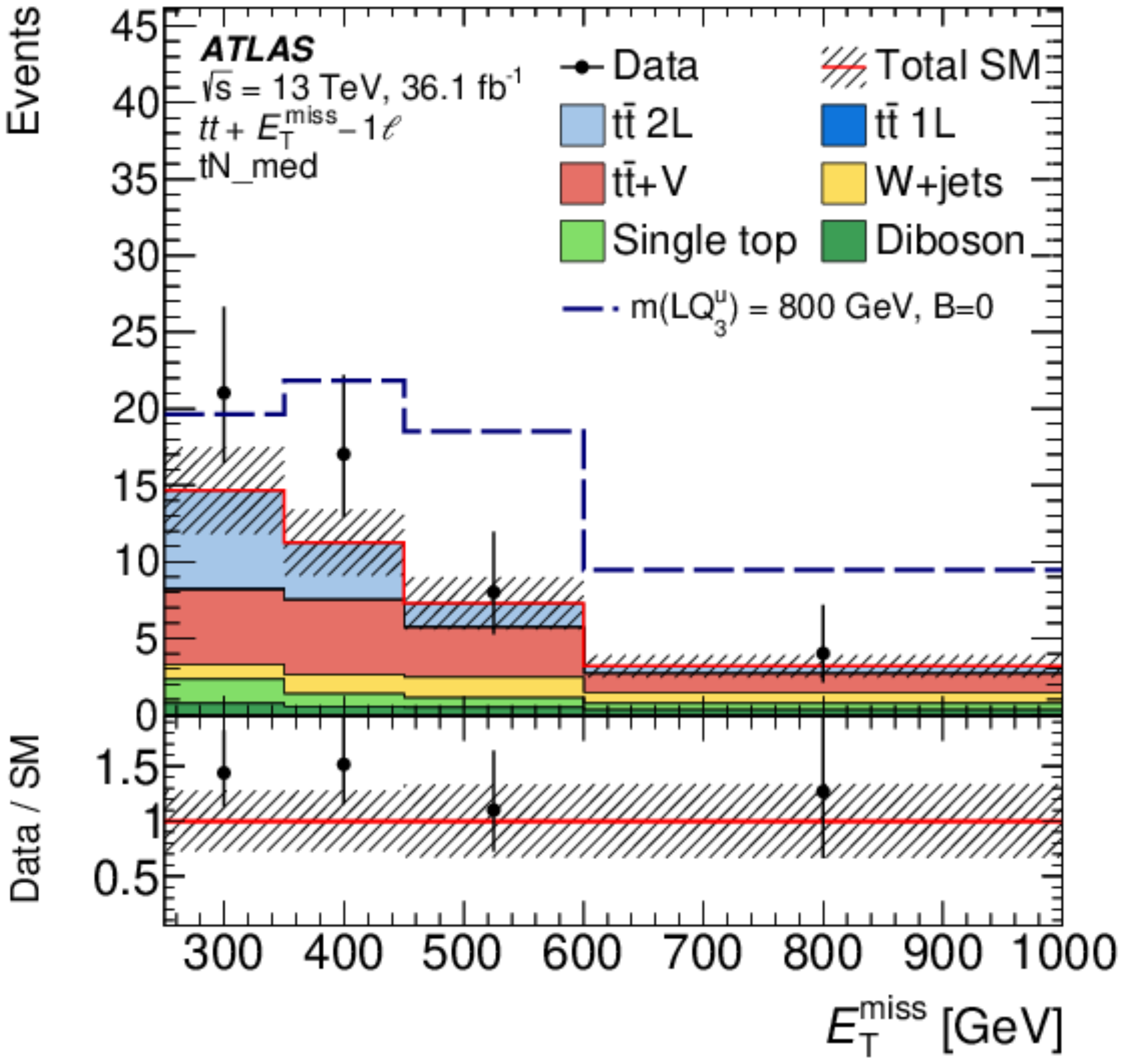
SR tN_med

$E_{\mathrm{T}}^{\mathrm{miss}}$	[250, 350] GeV	[350, 450] GeV	[450, 600] GeV	>600 GeV
Observed events	21	17	8	4
Total SM	14.6 ± 2.8	11.2 ± 2.2	7.3 ± 1.7	3.16 ± 0.74
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 400 GeV	166 ± 44	58 ± 32	11 ± 11	5.7 ± 5.7
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 600 GeV	21.0 ± 5.6	49.6 ± 8.8	31.8 ± 5.5	1.4 ± 2.1
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 800 GeV	5.0 ± 1.5	10.6 ± 1.7	11.2 ± 2.0	6.3 ± 1.4
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 1000 GeV	0.46 ± 0.14	1.18 ± 0.24	2.92 ± 0.49	4.61 ± 0.64

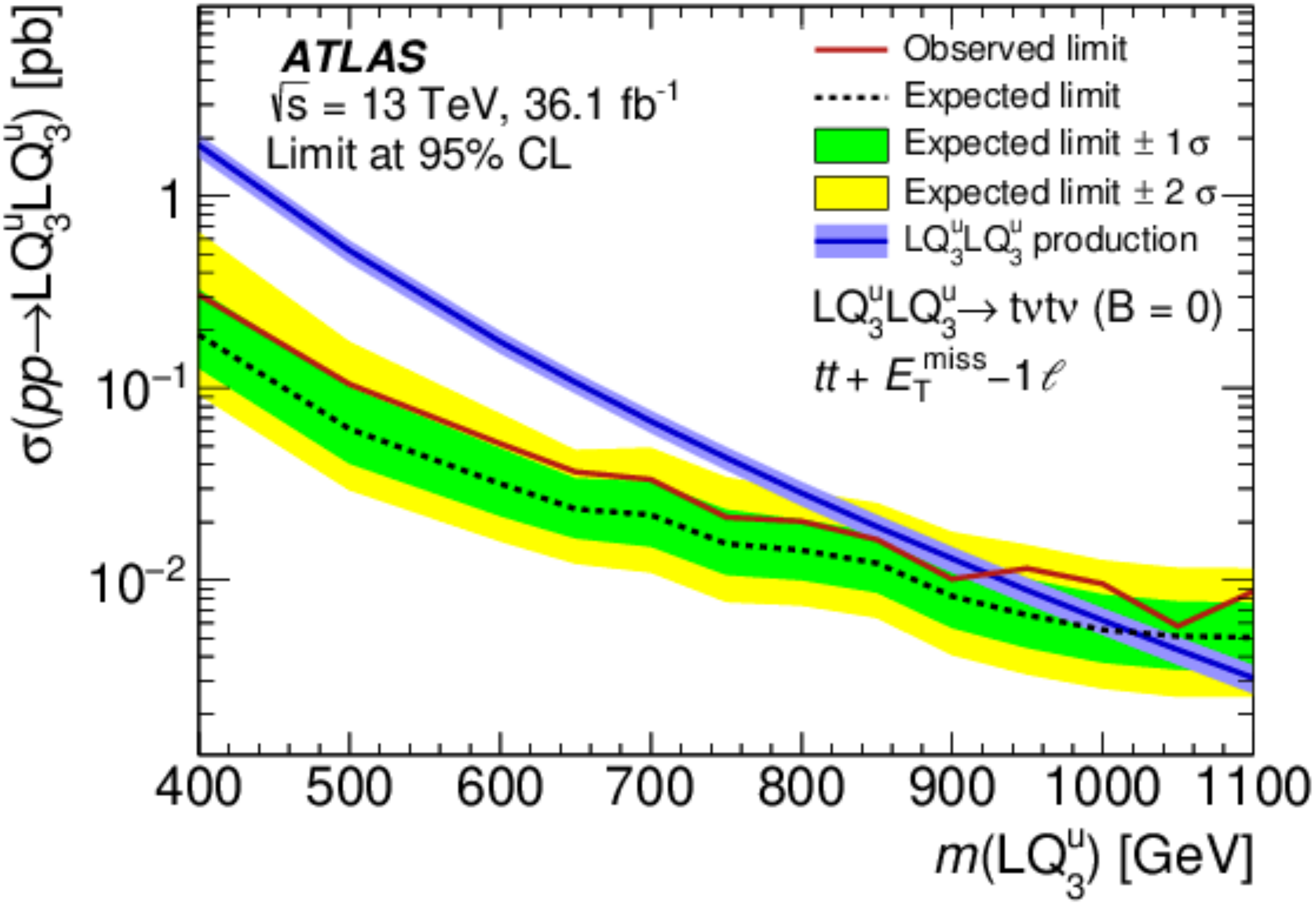
SR tN_high

Observed events	8
Total SM	3.8 ± 1.0
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 800 GeV	11.9 ± 1.8
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 900 GeV	9.5 ± 1.2
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 1000 GeV	6.7 ± 0.7
$m(\mathrm{LQ}_3^{\mathrm{u}})$ = 1100 GeV	3.7 ± 0.3

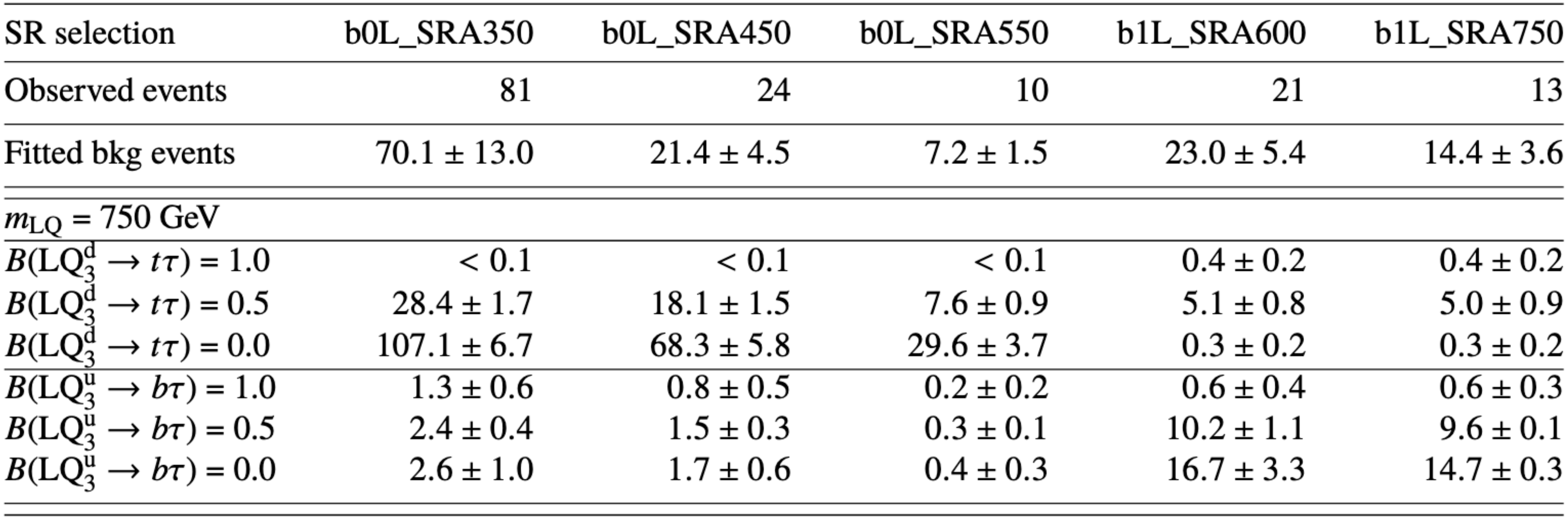
LQ3 Reinterpretation: 1-lepton Stop



LQ3 Reinterpretation: 1-lepton Stop



LQ3 Reinterpretation: Sbottom



SR selection	b0L_SRA350	b0L_SRA450	b0L_SRA550	b1L_SRA600	b1L_SRA750
Observed events	81	24	10	21	13
Fitted bkg events	70.1 ± 13.0	21.4 ± 4.5	7.2 ± 1.5	23.0 ± 5.4	14.4 ± 3.6
m_{LQ} = 750 GeV					
$B(\mathrm{LQ}_3^{\mathrm{d}} \to t\tau) = 1.0$	< 0.1	< 0.1	< 0.1	0.4 ± 0.2	0.4 ± 0.2
$B(\mathrm{LQ}_3^{\mathrm{d}} \to t\tau) = 0.5$	28.4 ± 1.7	18.1 ± 1.5	7.6 ± 0.9	5.1 ± 0.8	5.0 ± 0.9
$B(\mathrm{LQ}_3^{\mathrm{d}} \to t\tau) = 0.0$	107.1 ± 6.7	68.3 ± 5.8	29.6 ± 3.7	0.3 ± 0.2	0.3 ± 0.2
$B(\mathrm{LQ}_3^{\mathrm{u}} \to b\tau) = 1.0$	1.3 ± 0.6	0.8 ± 0.5	0.2 ± 0.2	0.6 ± 0.4	0.6 ± 0.3
$B(\mathrm{LQ}_3^{\mathrm{u}} \to b\tau) = 0.5$	2.4 ± 0.4	1.5 ± 0.3	0.3 ± 0.1	10.2 ± 1.1	9.6 ± 0.1
$B(\mathrm{LQ}_3^{\mathrm{u}} \to b\tau) = 0.0$	2.6 ± 1.0	1.7 ± 0.6	0.4 ± 0.3	16.7 ± 3.3	14.7 ± 0.3

b0L:

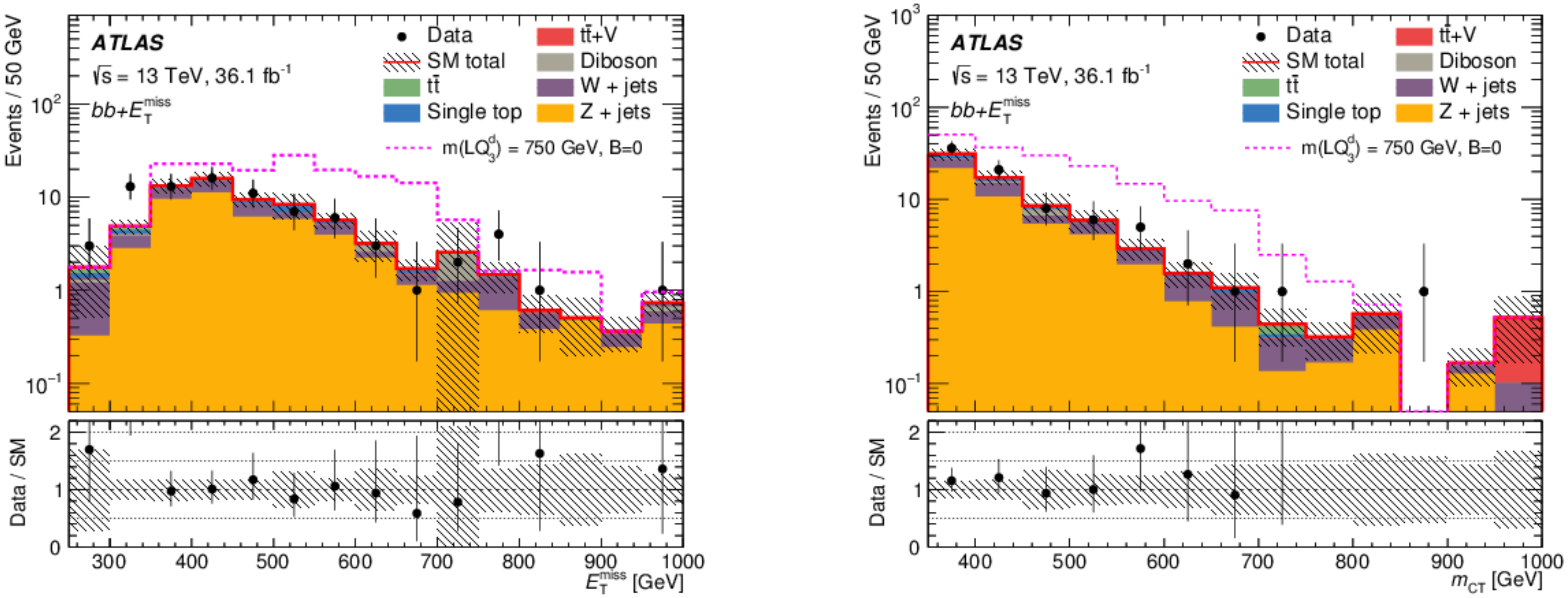
- zero-leptons, two b-tagged jets and large MET
- contransverse mass mCT>350, 450, and 550 GeV

b1L:

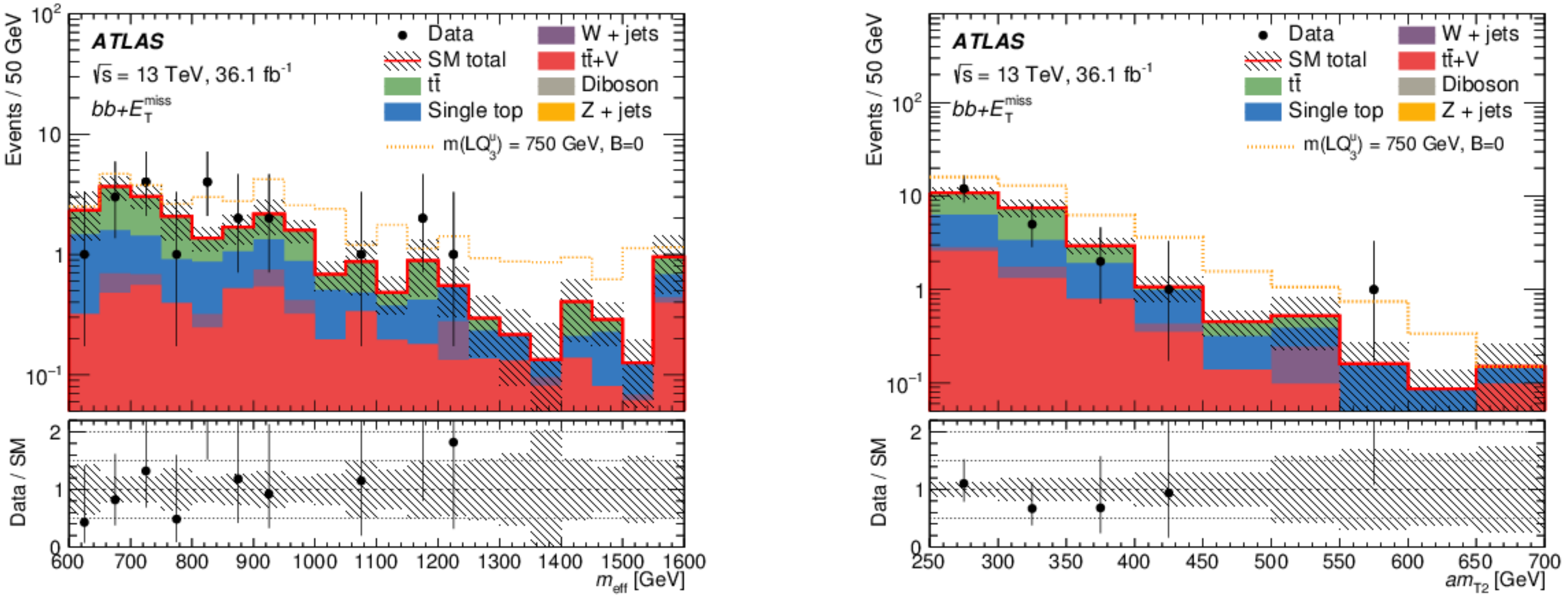
- one-lepton, two b-tagged jets and large MET
- scalar sum of the pT of the jets and EmissT>600 or 750 GeV

LQ3 Reinterpretation: Sbottom

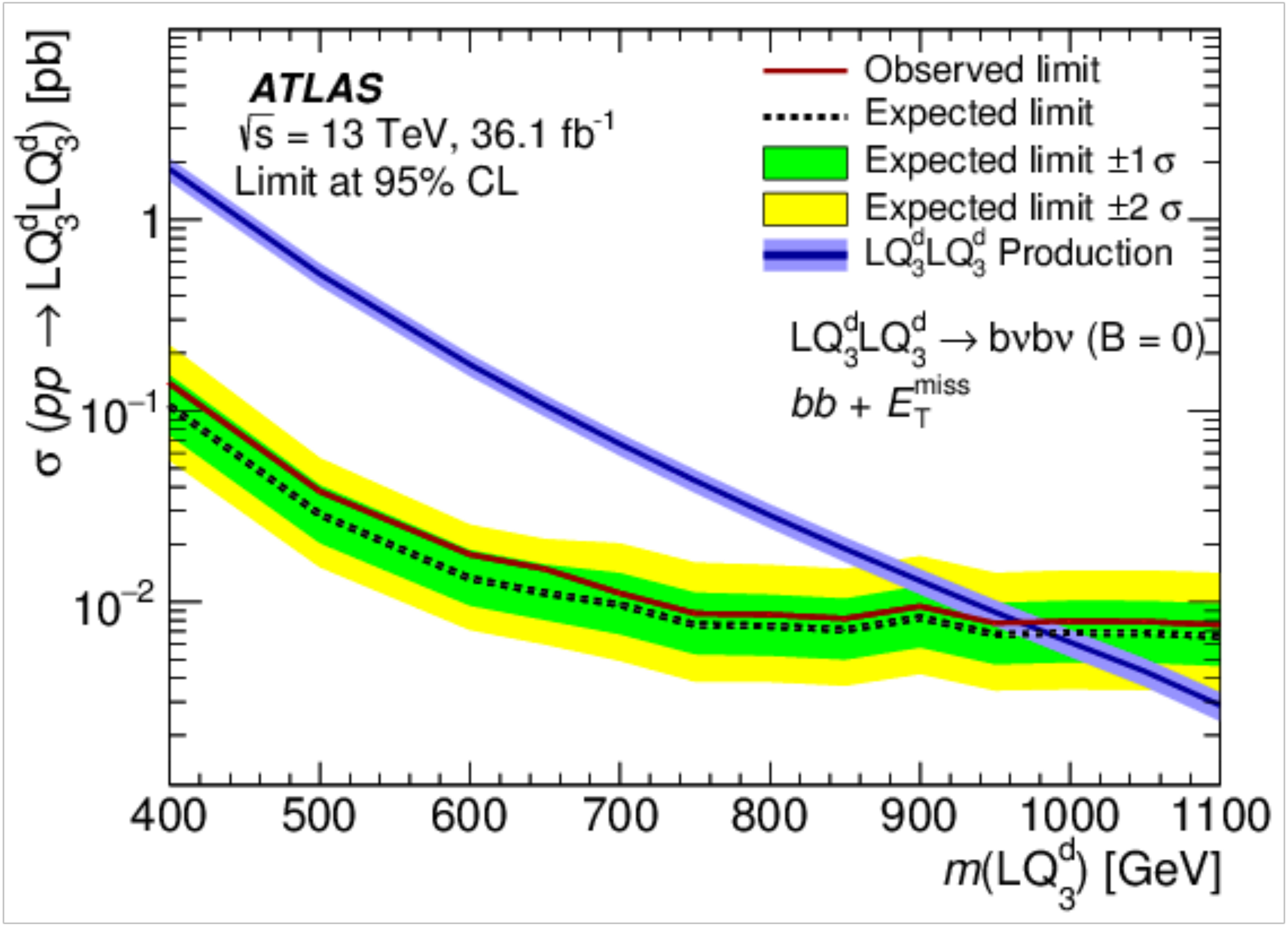
zero-lepton SR (b0L_SRA350)



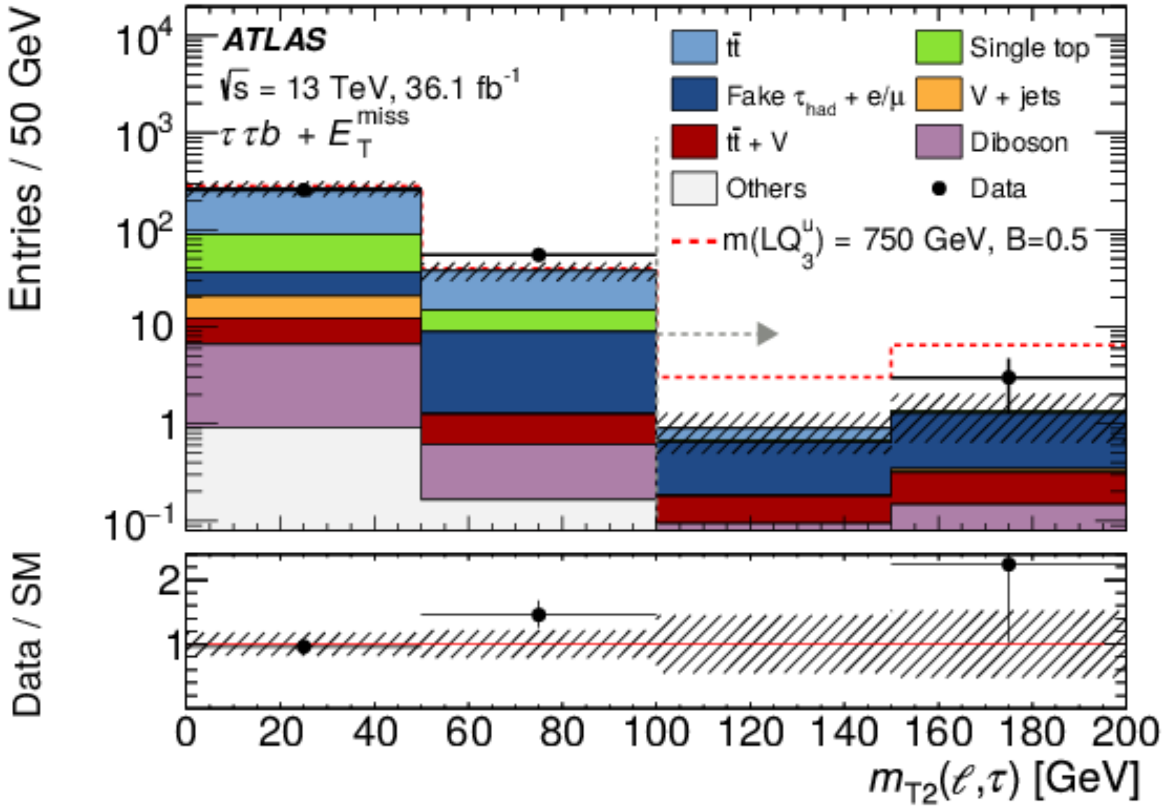
one-lepton SR (b1L_SRA600)



LQ3 Reinterpretation: Sbottom

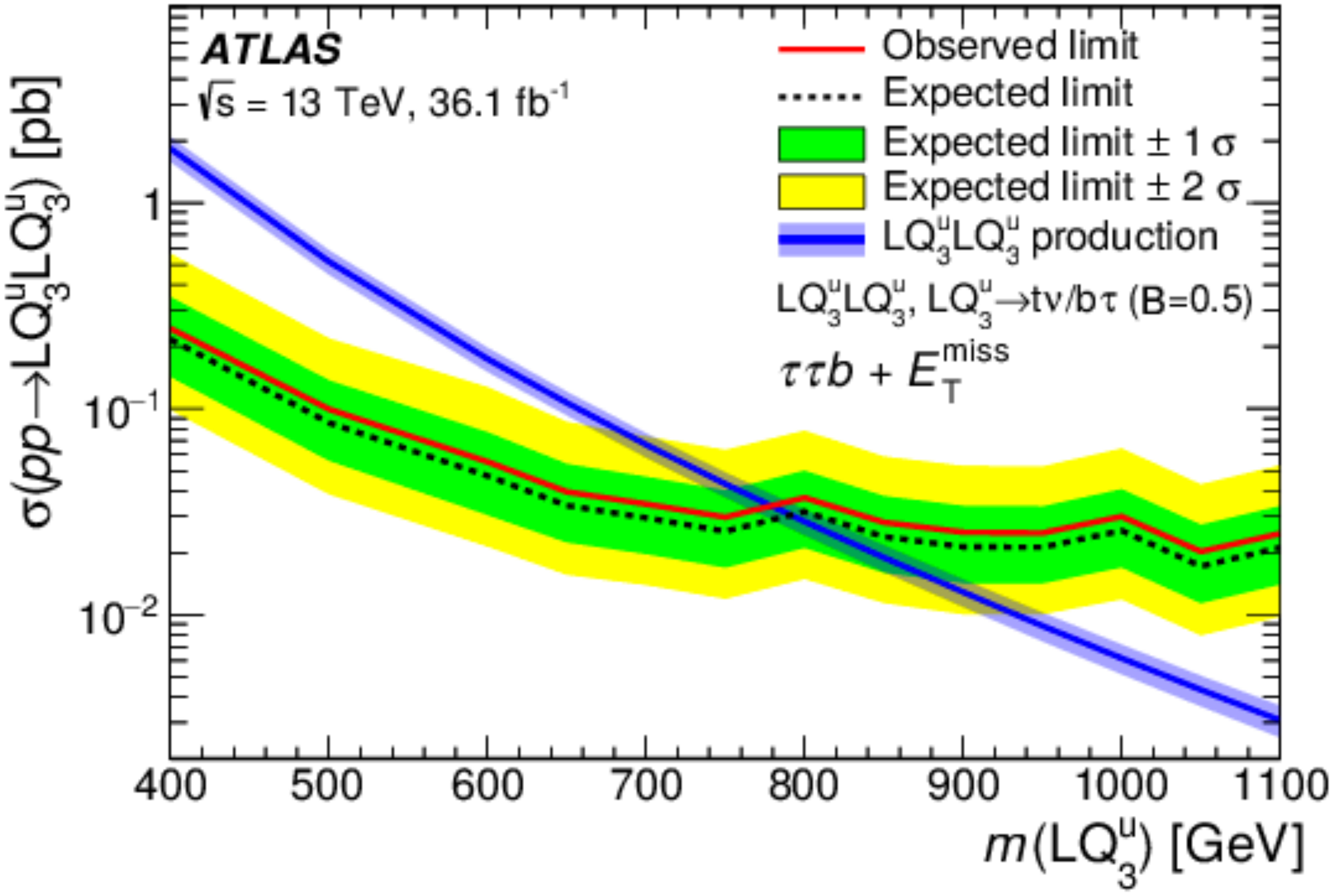


LQ3 Reinterpretation: Stop-stau


SR LH

		SR HH	SR LH
Observed events		2	3
Total SM		1.9 ± 1.0	2.2 ± 0.6
$m(\mathrm{LQ}_3^u)$ = 500 GeV	B = 0.5	10.8 ± 3.4	27 ± 7
$m(\mathrm{LQ}_3^u)$ = 750 GeV	B = 0	< 0.1	1.0 ± 0.3
$m(\mathrm{LQ}_3^u)$ = 750 GeV	B = 0.5	2.6 ± 0.8	7.3 ± 1.5
$m(\mathrm{LQ}_3^u)$ = 750 GeV	B = 1	2.6 ± 0.9	0.33 ± 0.1
$m(\mathrm{LQ}_3^u)$ = 1000 GeV	B = 0.5	0.3 ± 0.09	1.1 ± 0.3
$m(\mathrm{LQ}_3^d)$ = 500 GeV	B = 0.5	25 ± 7	49 ± 11
$m(\mathrm{LQ}_3^d)$ = 750 GeV	B = 0	< 0.1	< 0.1
$m(\mathrm{LQ}_3^d)$ = 750 GeV	B = 0.5	1.9 ± 0.5	6.2 ± 1.5
$m(\mathrm{LQ}_3^d)$ = 750 GeV	B = 1	2.4 ± 1.1	2.5 ± 1.0
$m(\mathrm{LQ}_3^d)$ = 1000 GeV	B = 0.5	0.53 ± 0.16	1.6 ± 0.4

LQ3 Reinterpretation: Stop-stau



Systematic uncertainties

Channel/Signatures	Main systematic uncertinties
LQ1 & LQ2	
electron	• top and fakes background modelling
muon	• top background modelling and muon uncertainties
LQ3	
tt+MET	• 1-lepton Stop: ttV modelling and renormalization • 0-lepton Stop: jet energy resolutiuon, ttbar modeling, Z+jet scale factor and MC statistics
bb+MET	• top (b1L) and Z(b0L) background modelling and renormalization
ττb+MET	• lep-had channel: fake estimation • had-had channel: jet- and MET-related uncertainties
bbττ	• Z+jets modelling