Searches for strong production of supersymmetric particles with the ATLAS detector

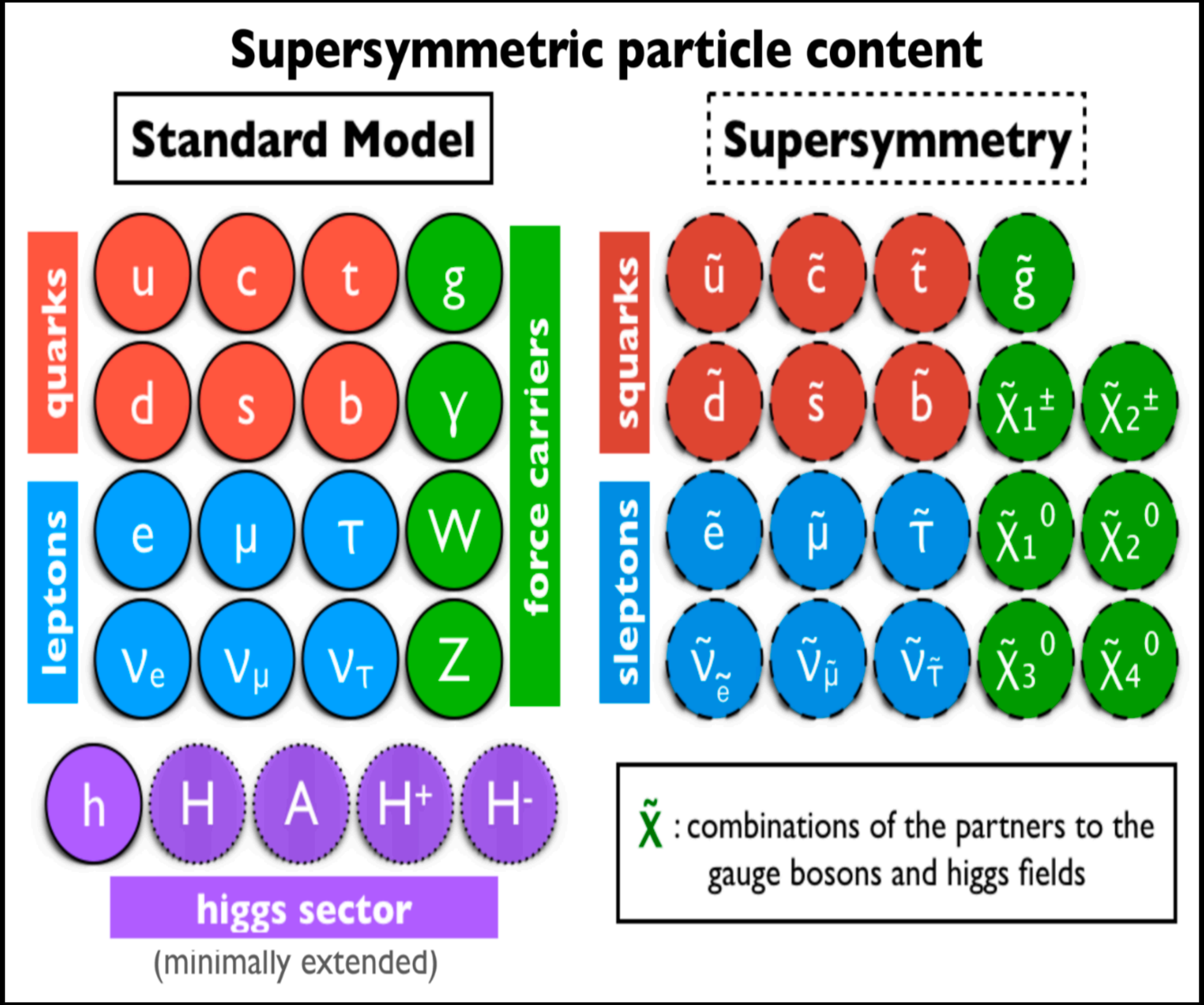
Arka Santra
on behalf of the ATLAS Collaboration
Department of Particle Physics and Astrophysics
Weizmann Institute of Science

February 21, 2022
LLWI 2022 Conference

ATLAS EXPERIMENT

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

Introduction:



★Supersymmetry (SUSY): one of the most popular Standard Model (SM) extensions.
- ★Each SM particle has its own supersymmetric partner.
  - ★Spin differing by 1/2
- ★Provides:
  - ★a dark matter candidate (for R-parity conserving theory).
  - ★the unification of fundamental forces at high energies.
  - ★a solution to the fine-tuning problem of the Higgs mass.

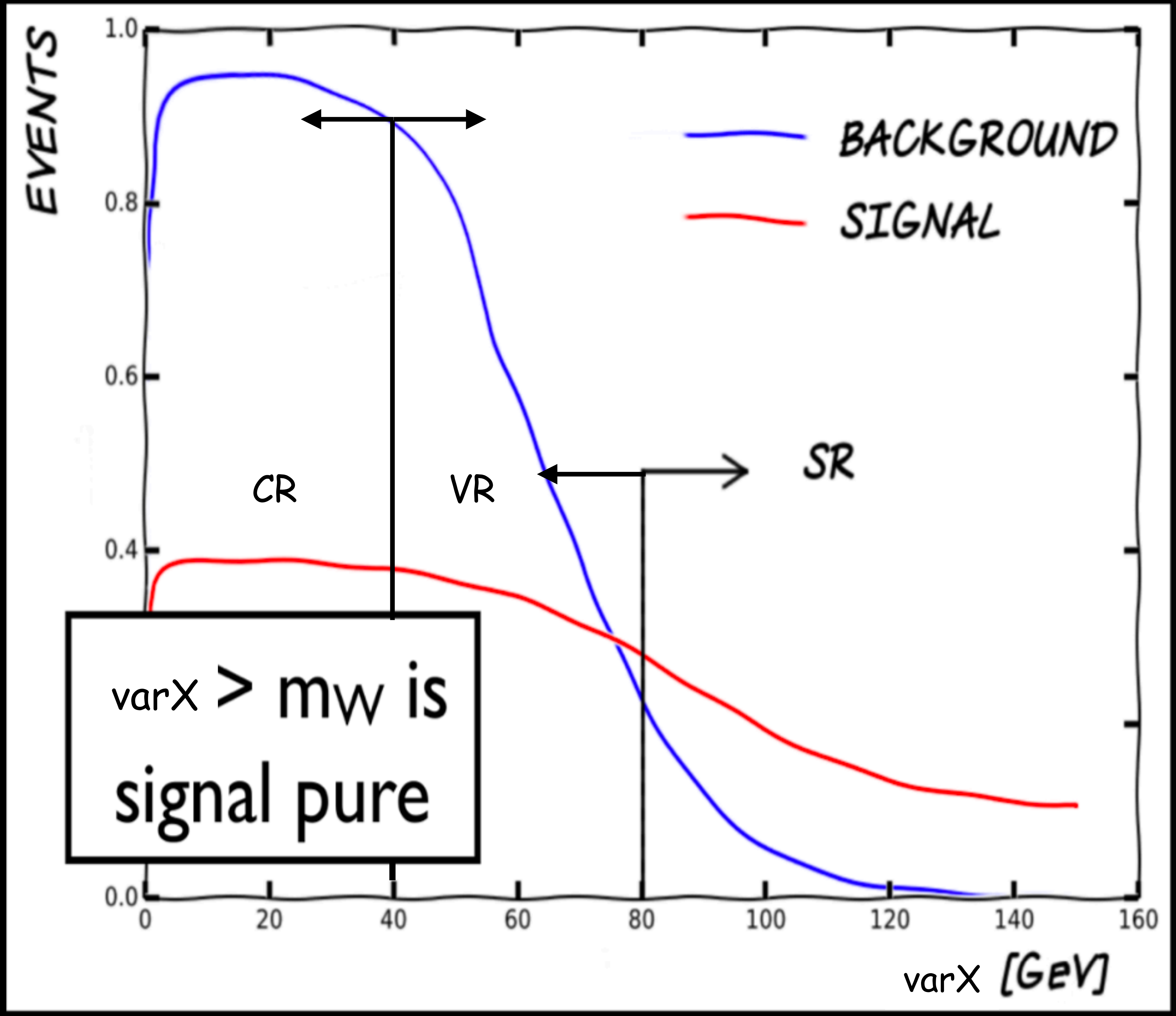
★SUSY searches at the LHC going on extensively.
- ★Strong production mechanism, as well as electroweak production.

★Strong SUSY production:
- ★Higher xsec than the electroweak production.
- ★In general, search for high p_T particles and large missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$).

SUSY searches in a nutshell

Strategy:

- ★Look for a region enriched with signal (SR)
  - ★Selection requirement on observables enhancing the signal significance.
- ★Estimate the background
  - ★May be fully data-driven
  - ★Partially data-driven where Control Regions (CR) are used to constrain the MC predictions
  - ★Validate the background estimation in the Validation Regions (VR).



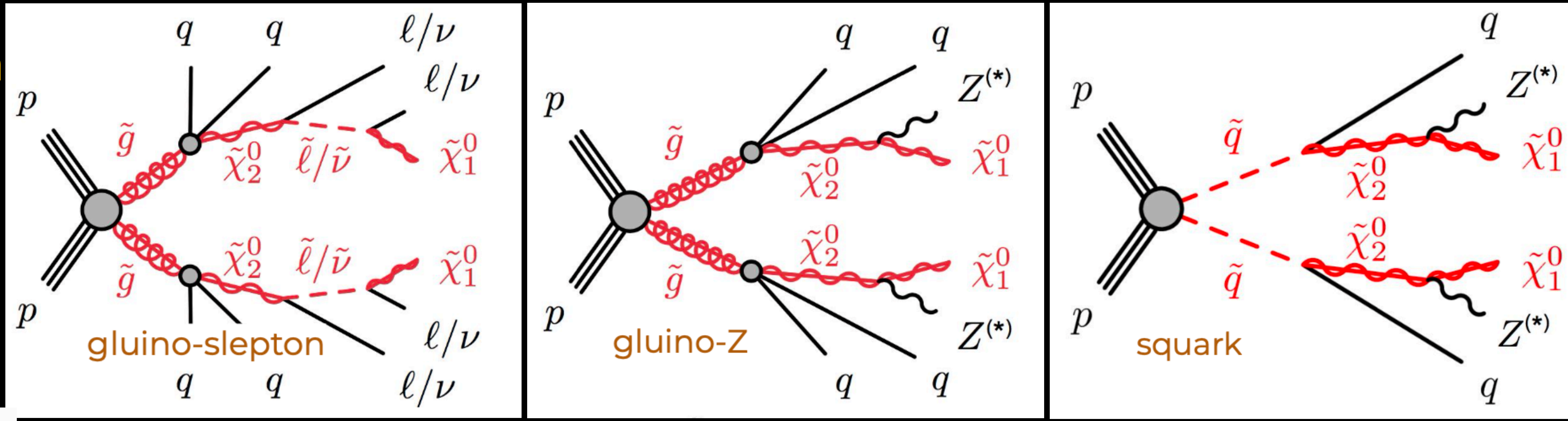
Blinding

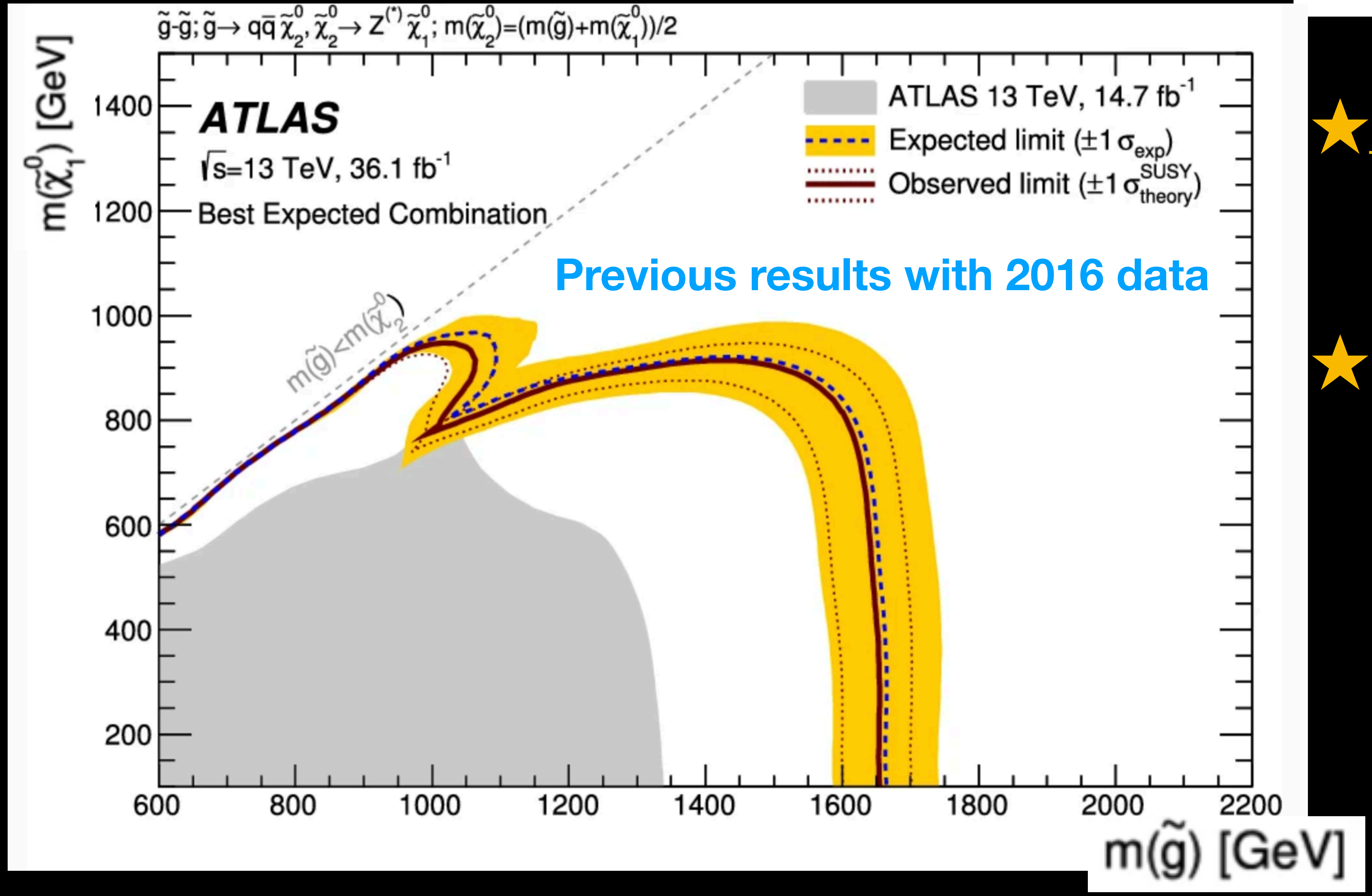
- ★The data in SR are not looked at unless the background estimations are properly understood and validated.
- ★Systematic uncertainties are understood.
- ★Once satisfied with uncertainties, data in SR are looked at.
  - ★Any significant excess of data over estimated background goes to test for discovery.
  - ★No excess in data sets upper limits in SUSY xsec and parameters.

SUSY search with two leptons and two jets

SUSY-2018-05

- ★Searches for strong production of SUSY
  - ★Gluino pair production with decay via slepton
  - ★Gluino pair production with decay via $Z^{(*)}$
  - ★Squark pair production with decay via $Z^{(*)}$
  - ★$\tilde{\chi}_1^0$ is the Lightest Supersymmetric Particle (LSP).





Previous publication with 36.1 fb^{-1}: Eur. Phys. J. C 78 (2018) 625

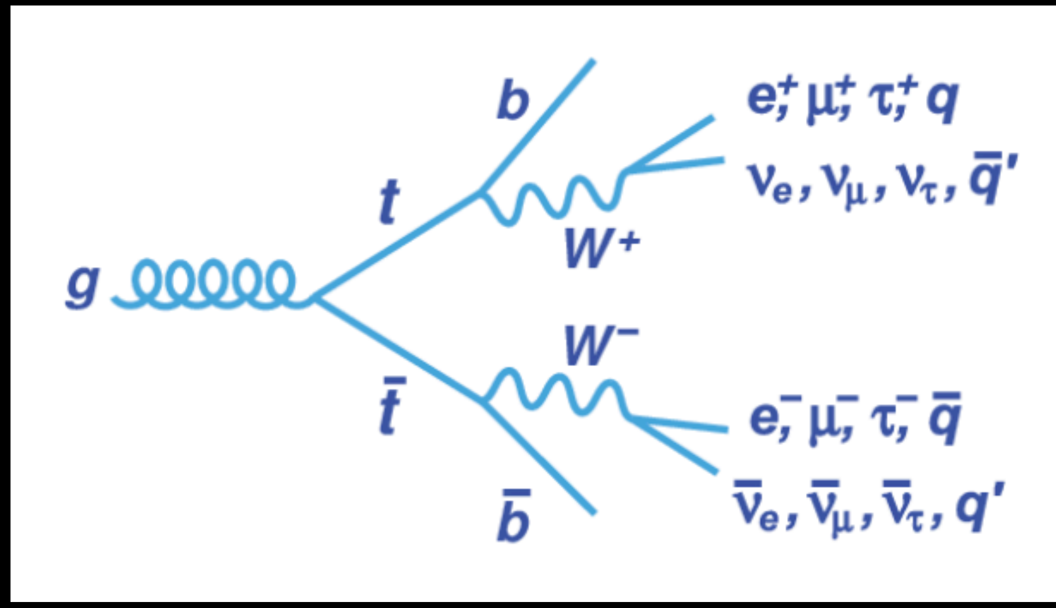
- ★Preselection:
  - ★Exactly two same flavor opposite sign electrons or muons with $p_T > 25$ GeV and two jets with $p_{\mathrm{T}} > 30$ GeV.
- ★For analysis with 139 fb^{-1}, signal regions require
  - ★High $H_{\mathrm{T}} > 250$ GeV to $H_{\mathrm{T}} > 800$ GeV, where H_{T} is the scalar sum of jet p_{T}.
  - ★High $E_{\mathrm{T}}^{\mathrm{miss}}$ (> 250 GeV to > 300 GeV)
  - ★Medium to high m_{T2} (>75 GeV to > 100 GeV), m_{T2} being the extension of the transverse mass m_{T} for the case of two missing particles.
  - ★On-shell Z regions require invariant mass within 81 GeV to 101 GeV.

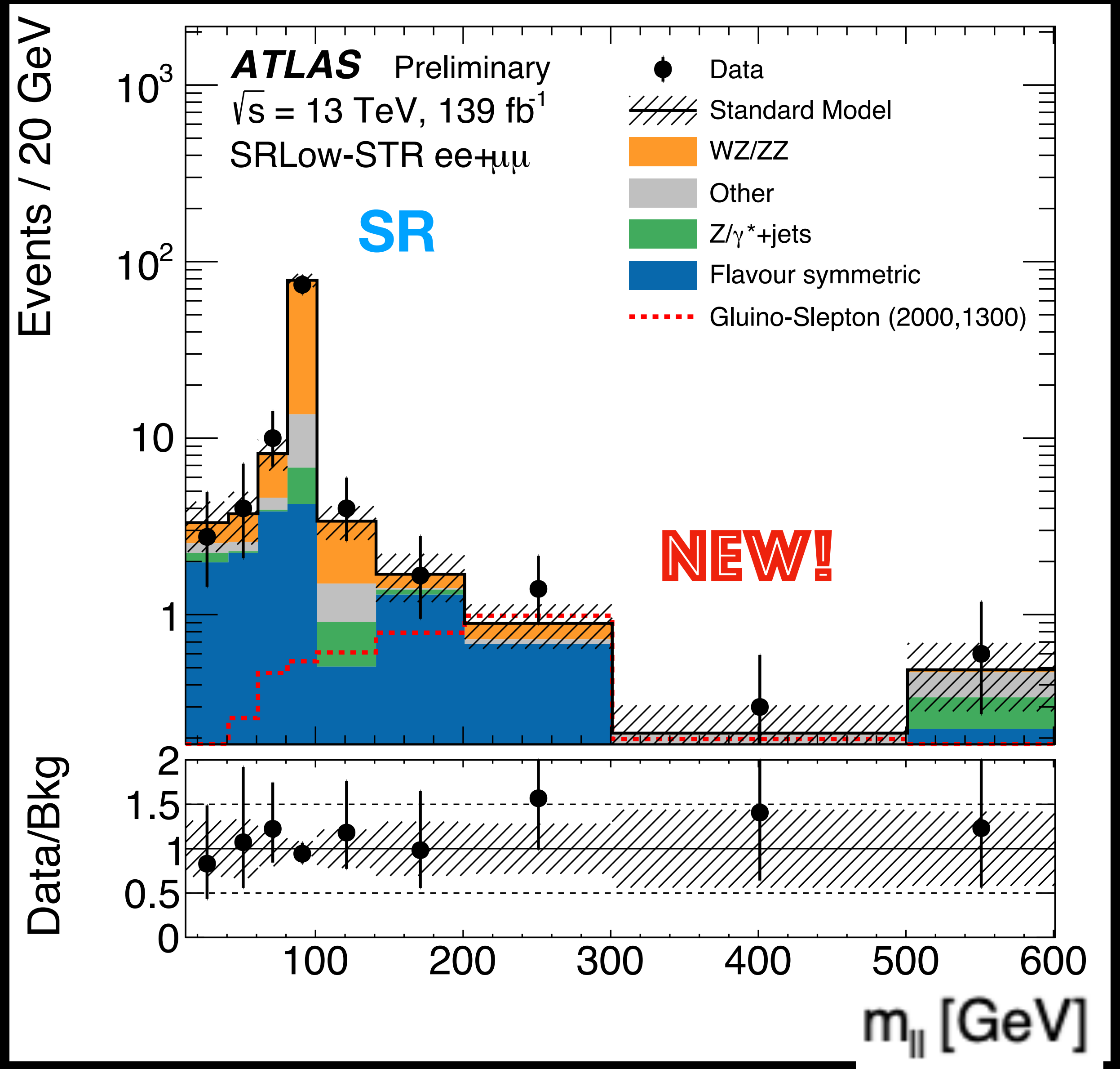
Background estimation:

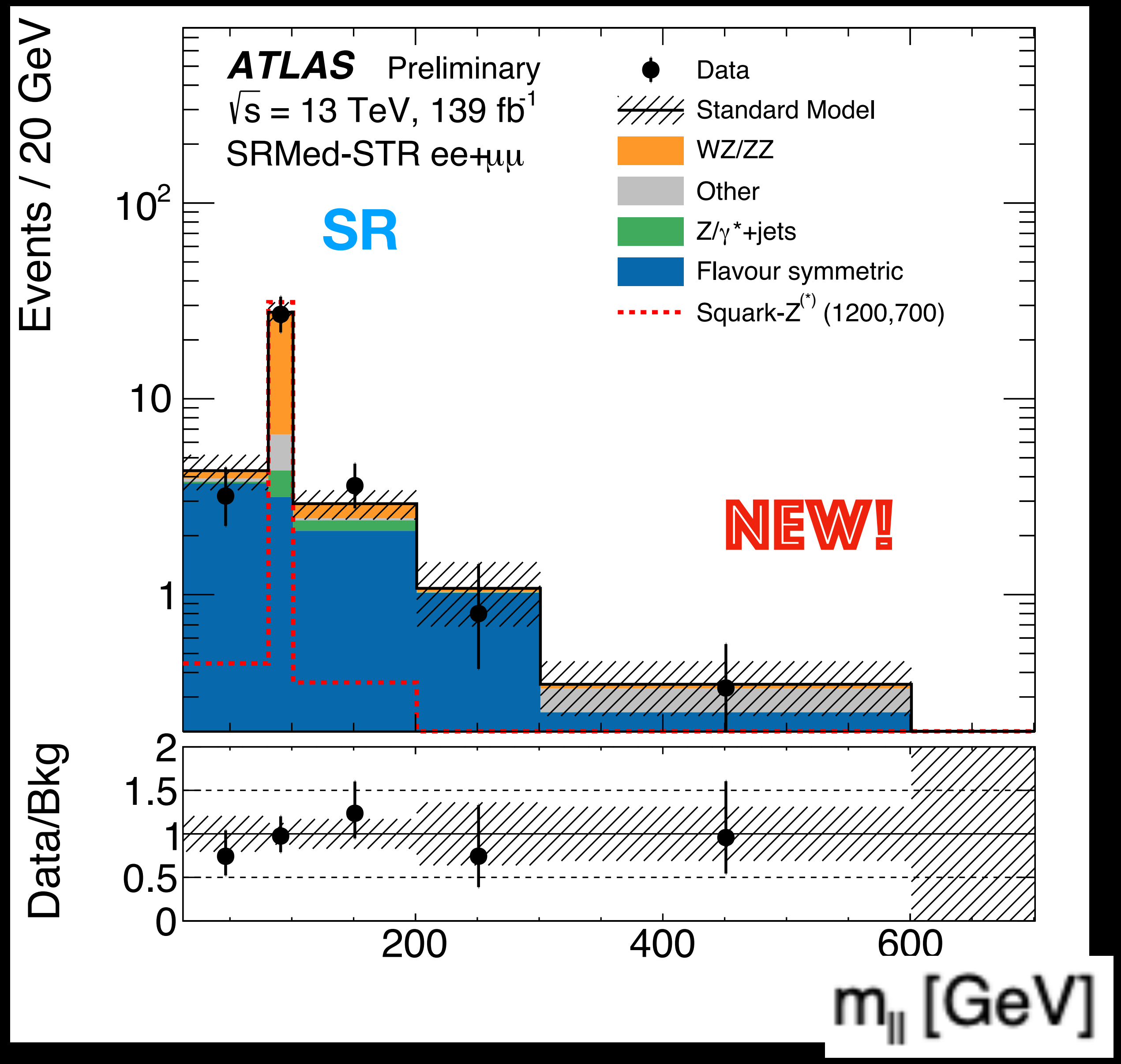
SUSY-2018-05

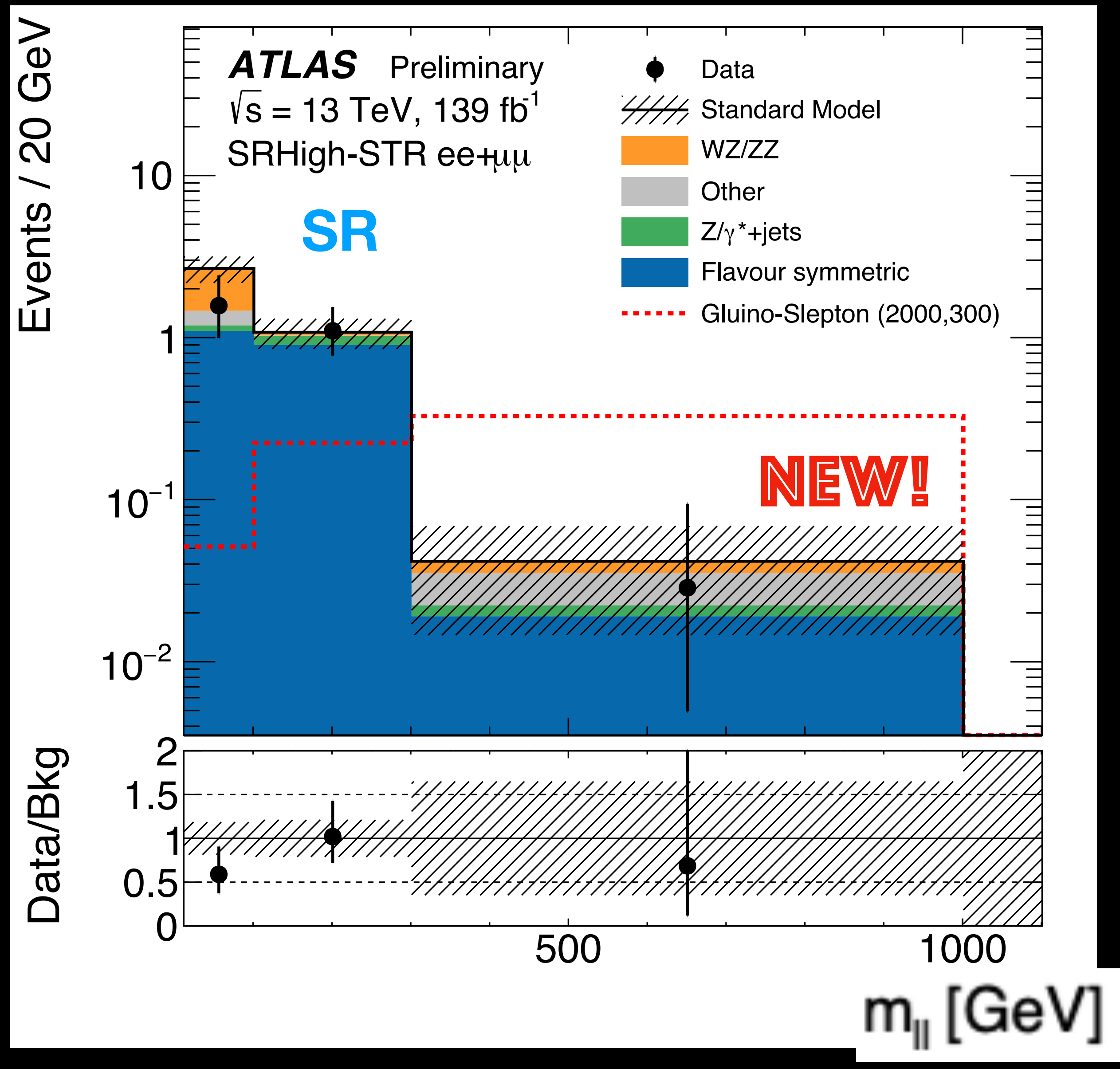
★Background for strong searches:

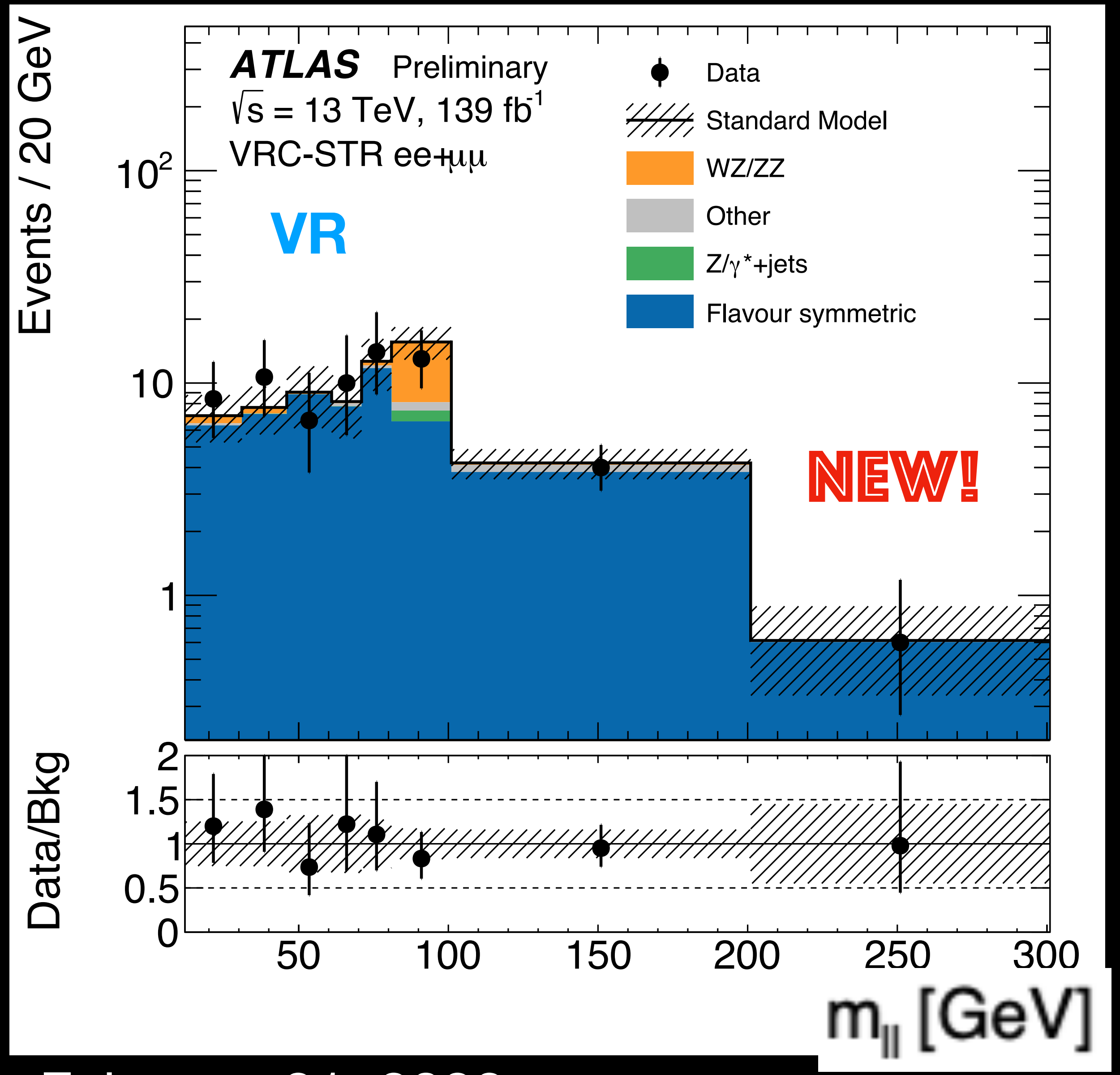
- ★$Z \rightarrow \tau\tau$, $t\bar{t}$, Wt and WW have independent leptonic decays.
  - ★ Estimated using Flavor Symmetry method from $e\mu$ events.
- ★Z+jets estimated from MC.
  - ★CR region with $\Delta\phi_m = \text{minimum}(\Delta\phi(\text{jet}_{1,2}, E_T^{\text{miss}}) < 0.4$ used to normalize the MC estimate to data.
- ★Fakes/non-prompt leptons (for $W \rightarrow l\nu$, single top etc) estimated from matrix method.
- ★Rest (WZ/ZZ) are estimated from MC.

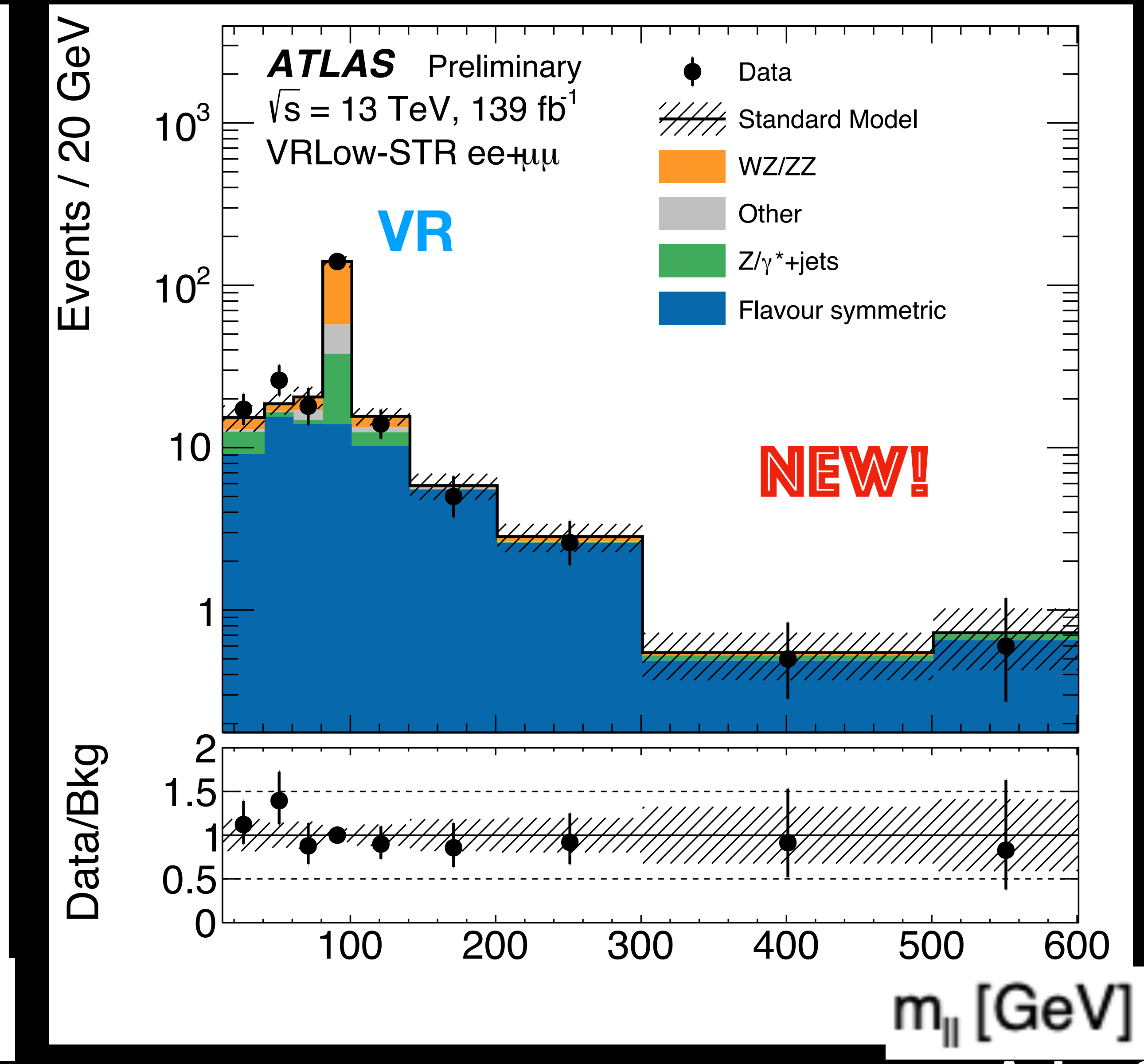








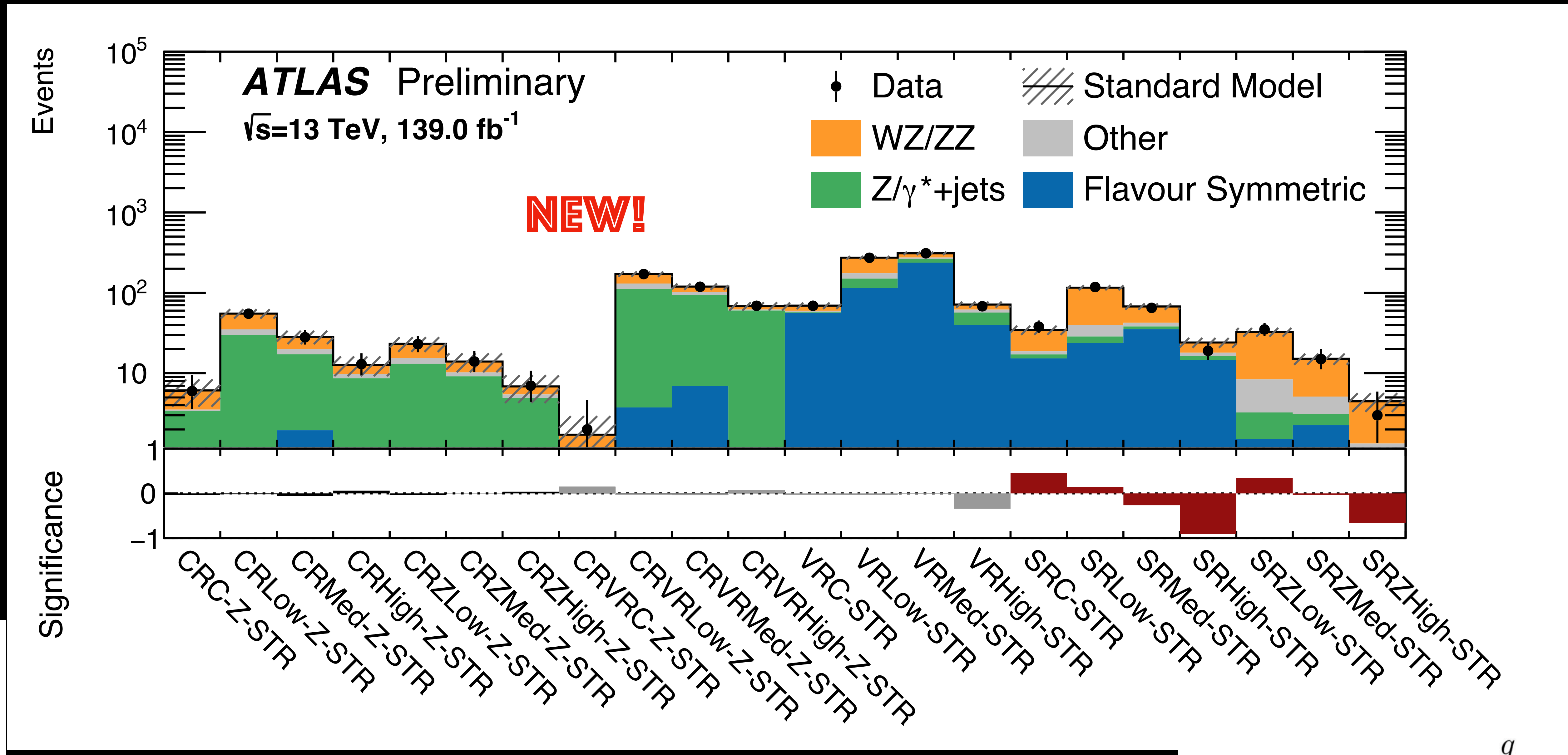


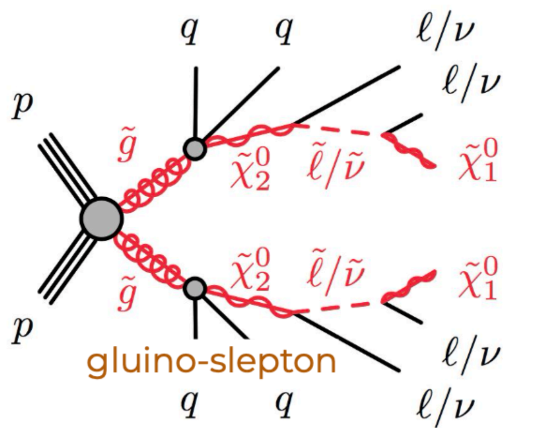


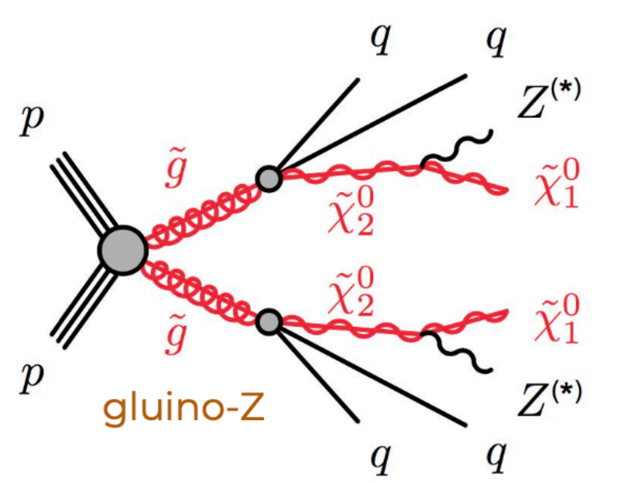
Interpretations:

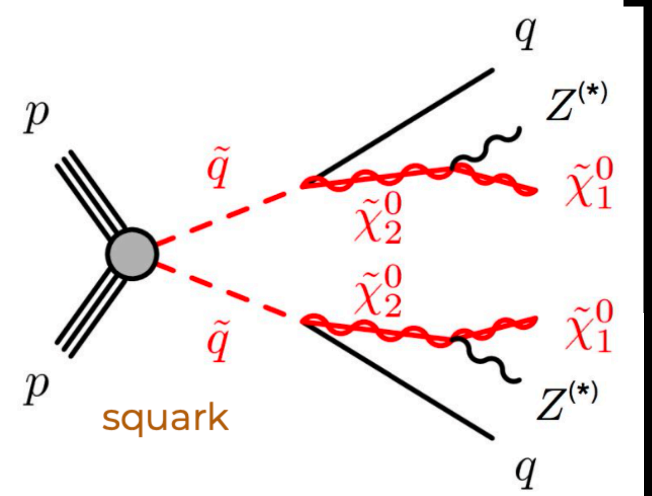
SUSY-2018-05

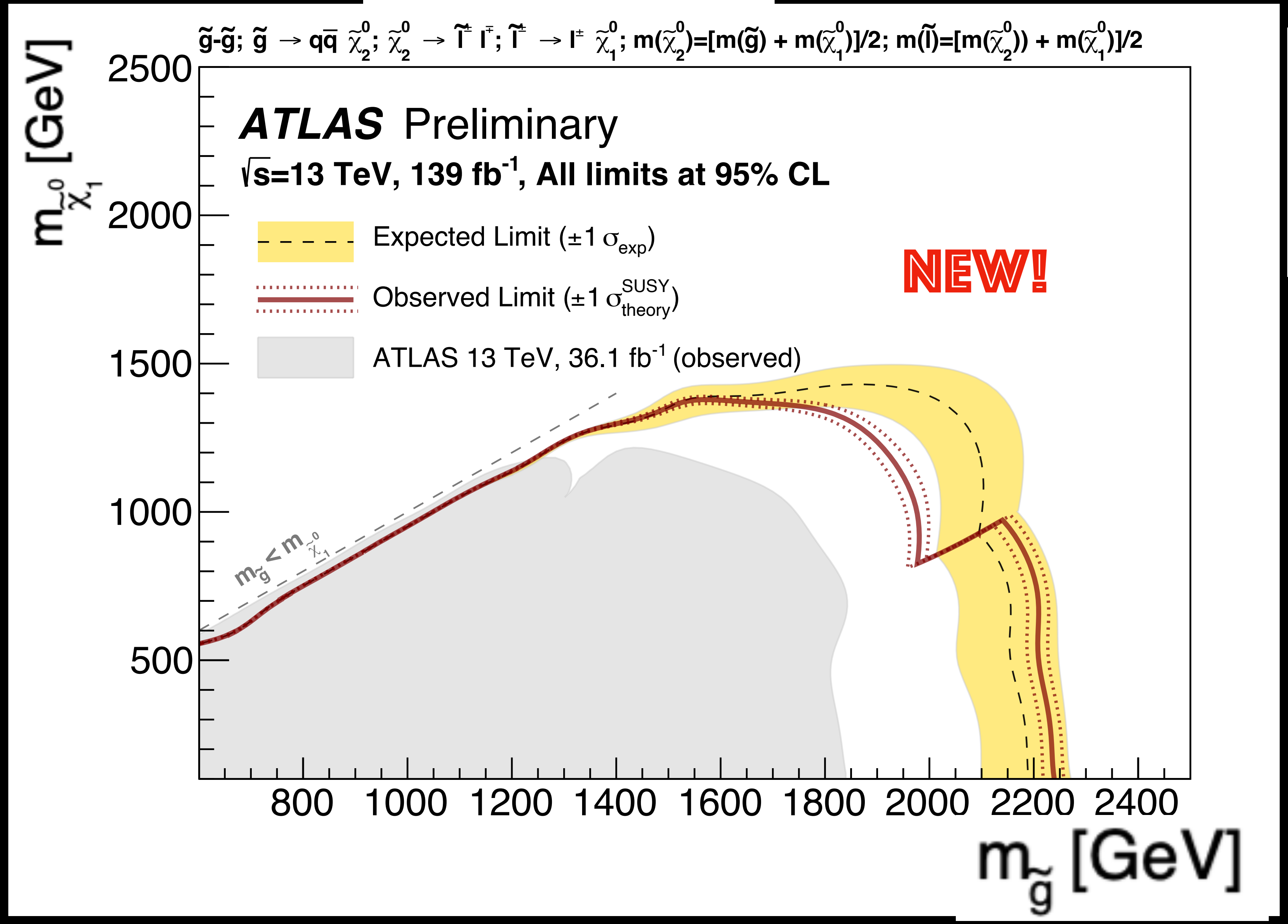
★Used best expected SR per region of phase-space.
- ★Sharp features come because of stitching of multiple SRs.
  - ★Artifact of changing between SRs

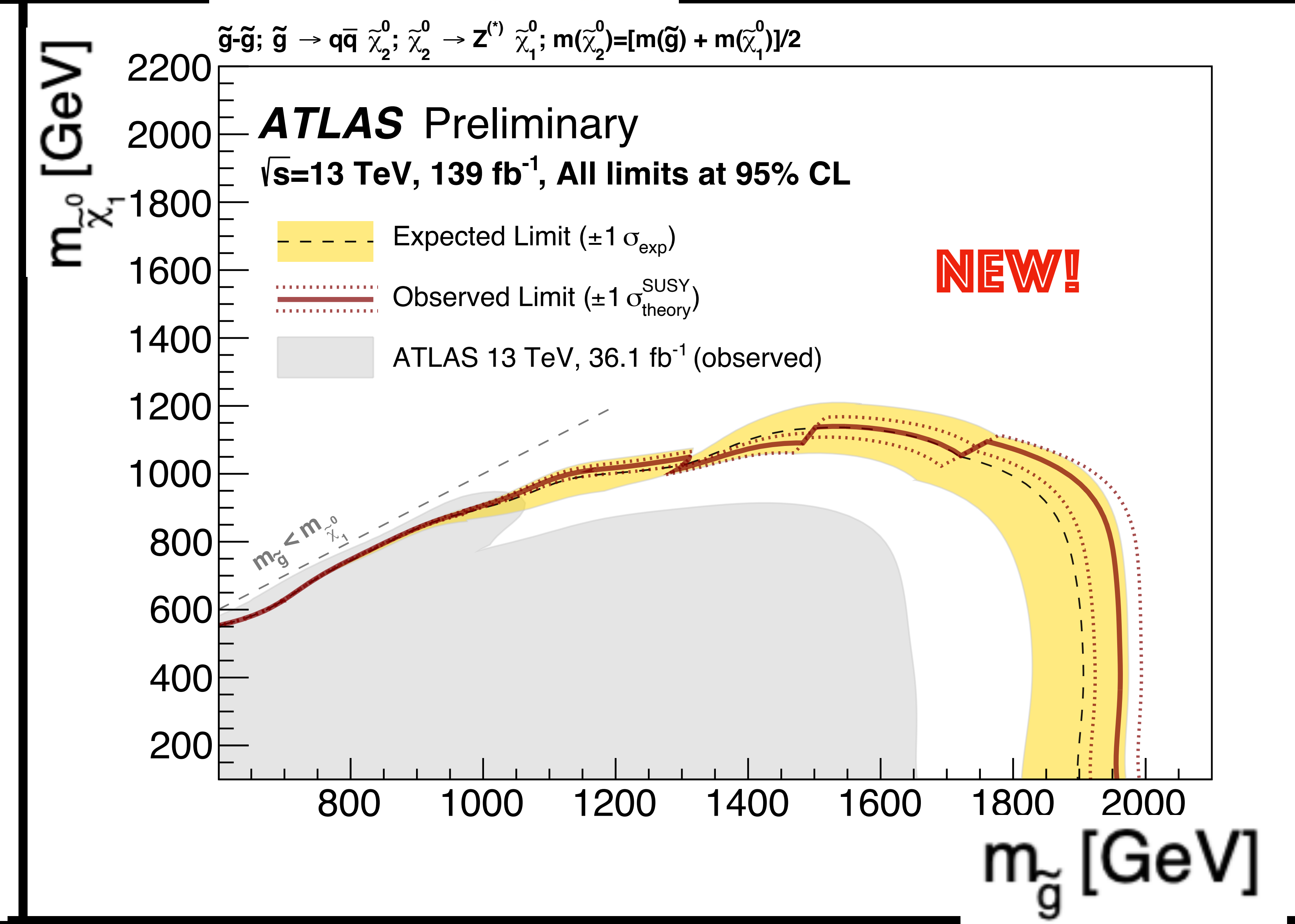


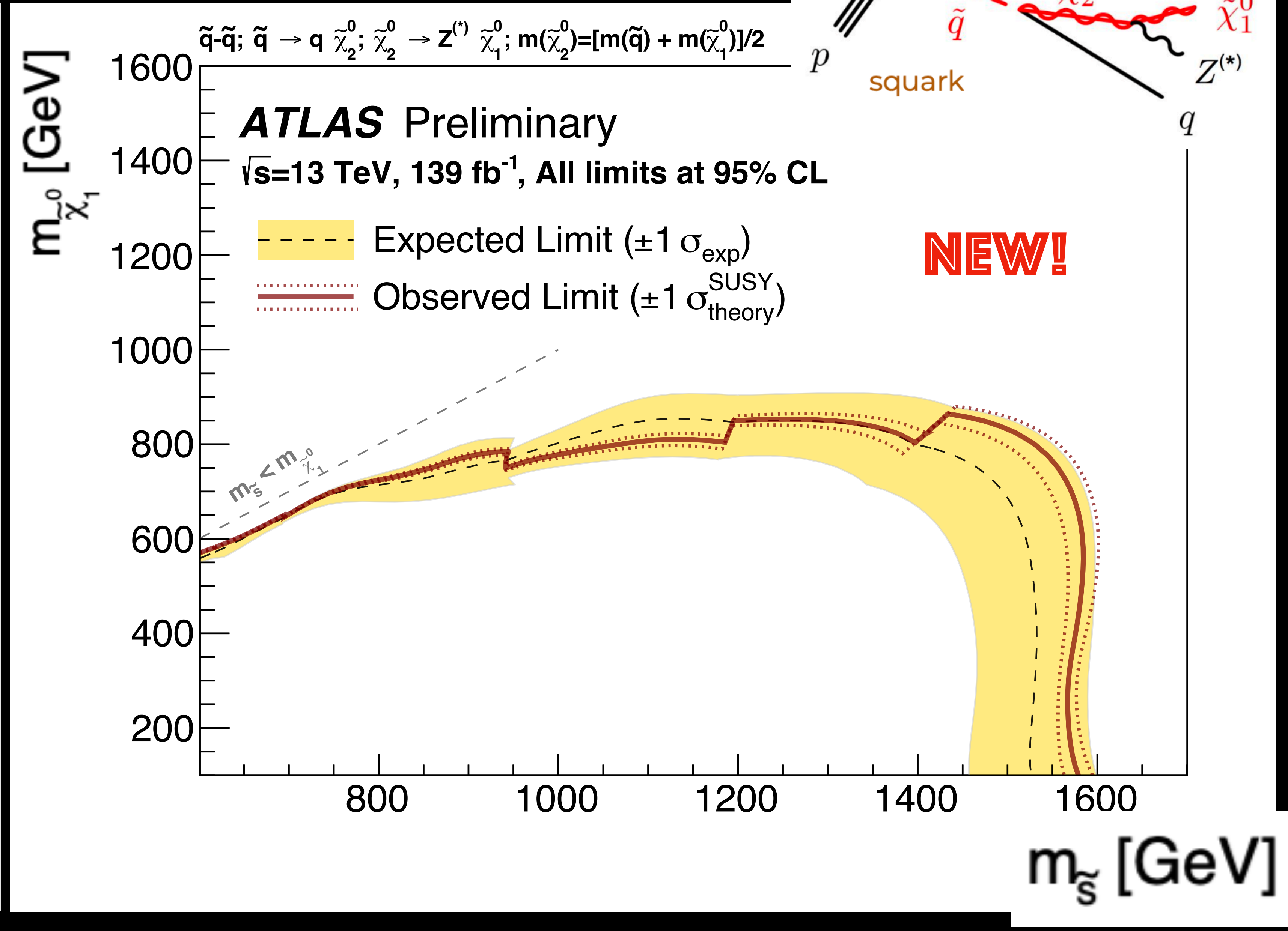








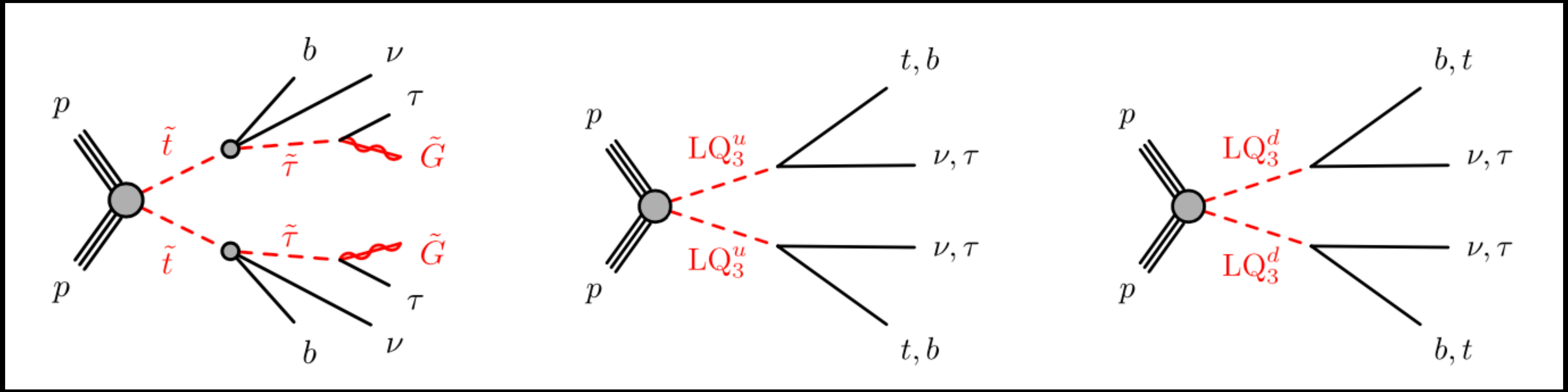




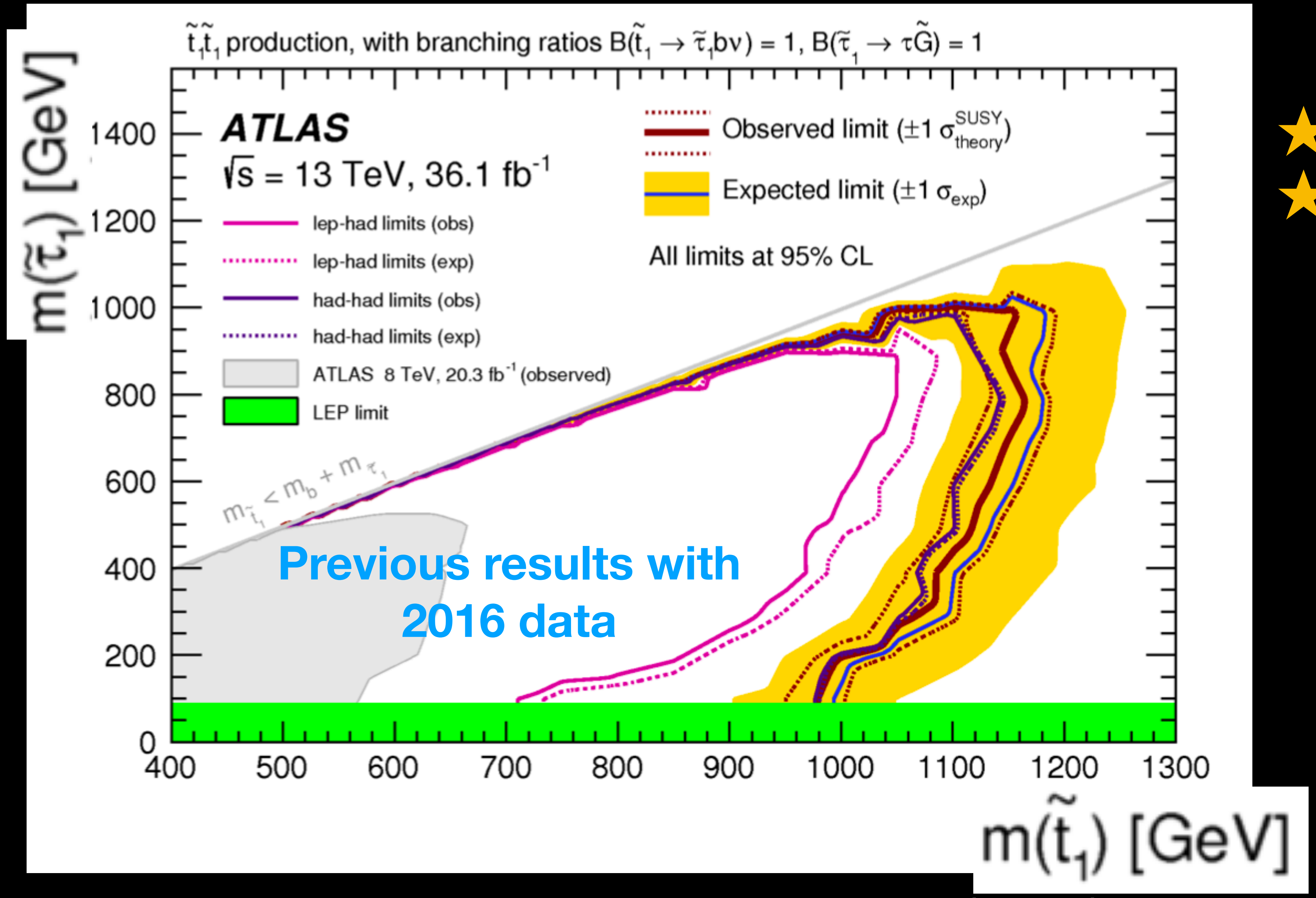
SUSY search with τ : Stop-stau signal

Phys. Rev. D 104, 112005

- ★ Direct pair production of stops
  - ★3 body decay to b-quark, neutrino and a scalar tau ($\tilde{\tau}$)
    - ★$\tilde{\tau}$ decays to τ and $\tilde{G}$ (LSP)



- ★ **Previous result with 36.1 fb^{-1}.**
  - ★Two channels
    - ★τ-s decay hadronically
    - ★One τ decay hadronically and another leptonically.
  - ★Stop mass exclusion up to 1150 GeV



Previous result (Phys. Rev. D 98, 032008 (2018))

For present search

- ★Focus on channels with hadronic τ-s
- ★Two different regions of the parameter space
  - ★Low to medium mass splitting: **2τ SR**
    - ★High p_T τ-s, high E_T^{miss} and relatively soft b-jets
  - ★High mass splitting: **1τ SR**
    - ★High p_T b-jets, relatively soft τ and high E_T^{miss}.
    - ★**1τ SR** has been optimized also for leptoquark search.

Background estimation

Phys. Rev. D 104, 112005

★Identification of τ

★Used Recurrent Neural Network (RNN) [ATLAS-PHYS-PUB-2019-033]

★Input: transverse and longitudinal impact parameters, ratio of EM energy and track momentum, mass of the track system, mass of the track+EM system etc

★Signal regions:

★2τ channel

★$E_{\mathrm{T}}^{\mathrm{miss}}$> 280 GeV, OS($\tau_1, \tau_2$)=1,$m_{T2}(\tau_1, \tau_2) > 70$ GeV

★1τ channel

★$E_{\mathrm{T}}^{\mathrm{miss}}$> 280 GeV, $\sum m_T(b_1, b_2) > 700$ GeV, $m_T(\tau) > 300$ GeV

★$S_T = p_T(\tau) + p_T(j_1) + p_T(j_2) > 800$ GeV

★Dominant background

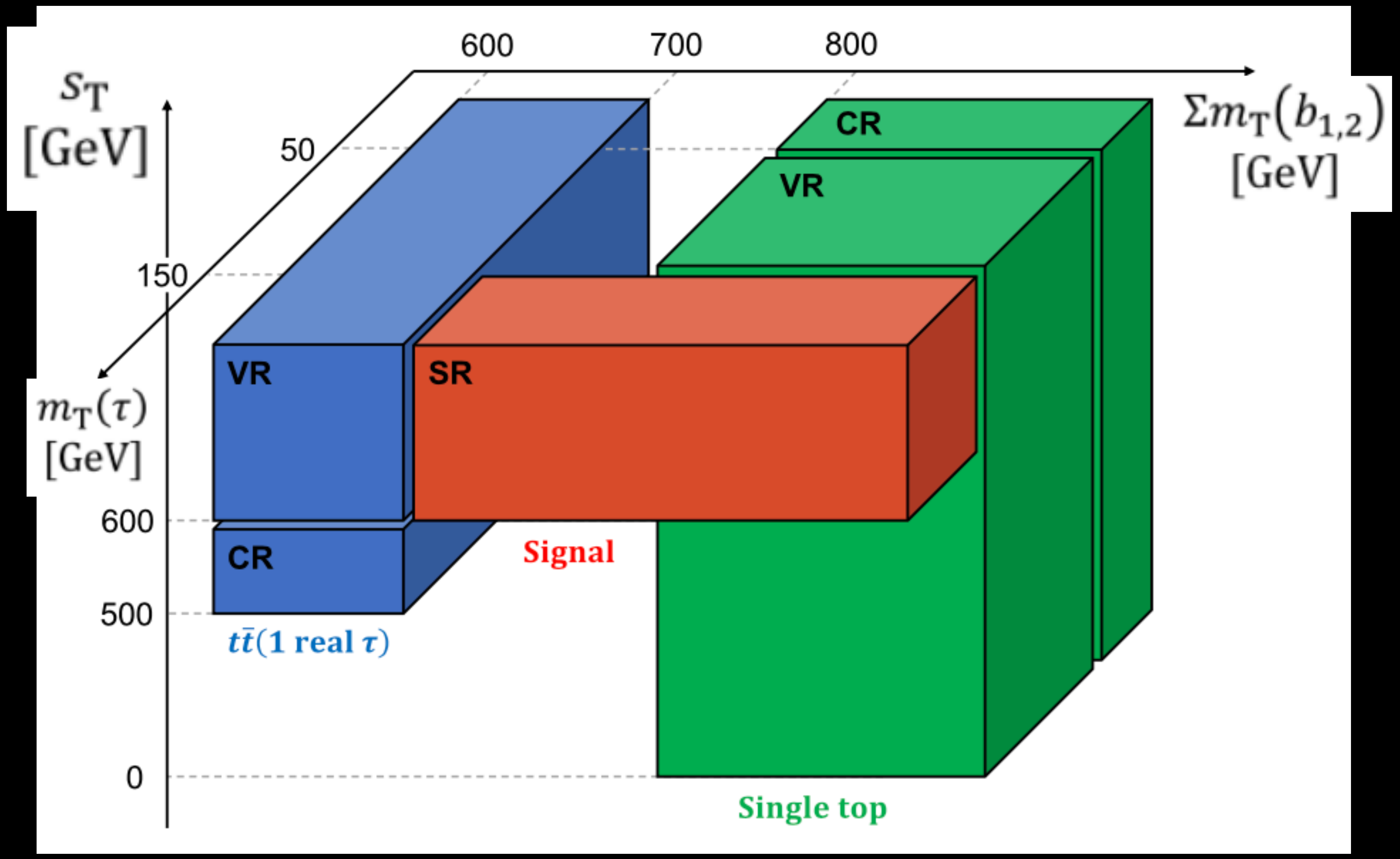
★$t\bar{t}$ (2 real τ)

★$t\bar{t}$ (1 real τ)

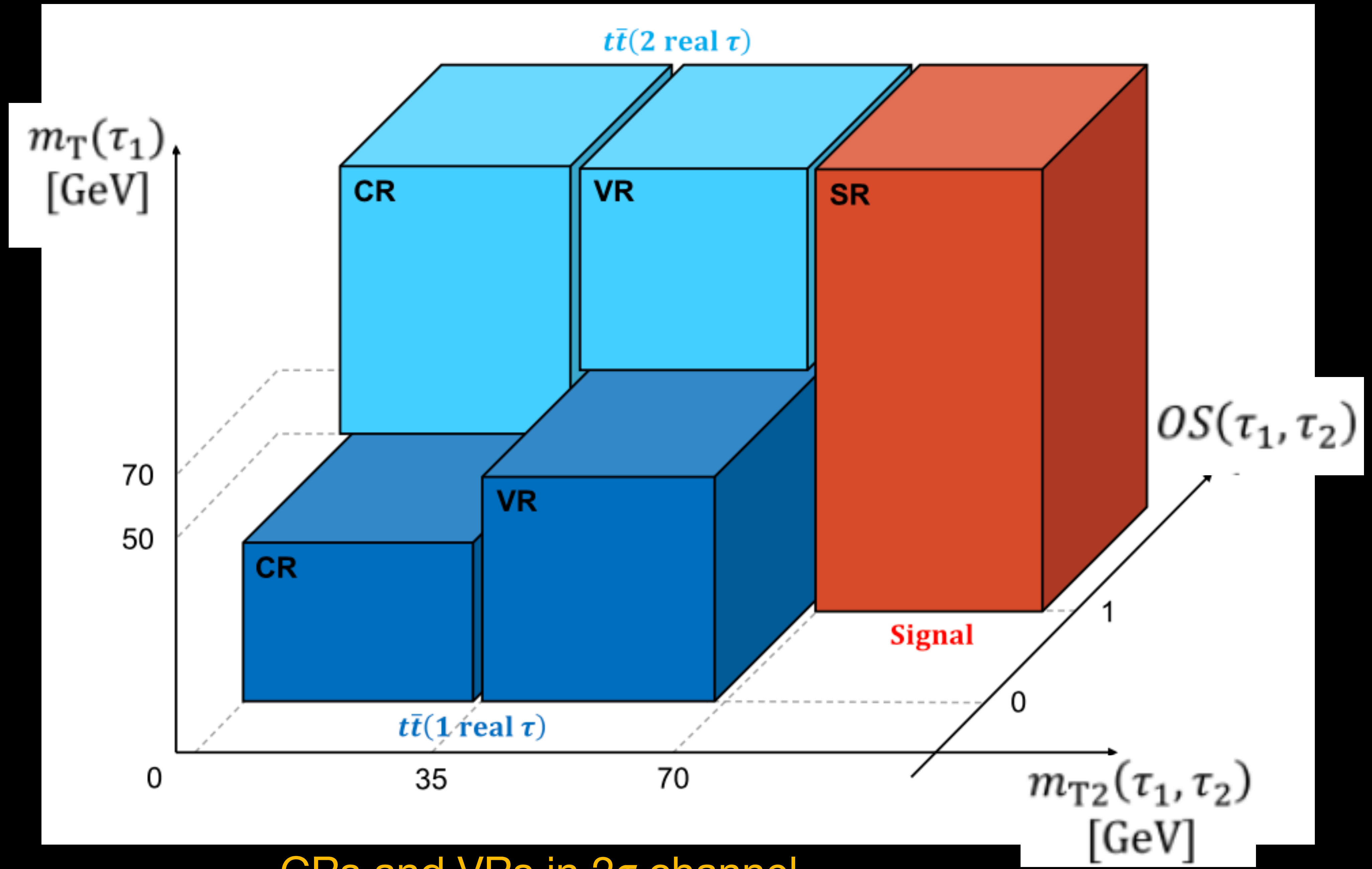
★Single top (Wt)

★Control and validation regions in both channels

★QCD is negligible because of the high $E_{\mathrm{T}}^{\mathrm{miss}}$ cut.



CRs and VRs in 1τ channel

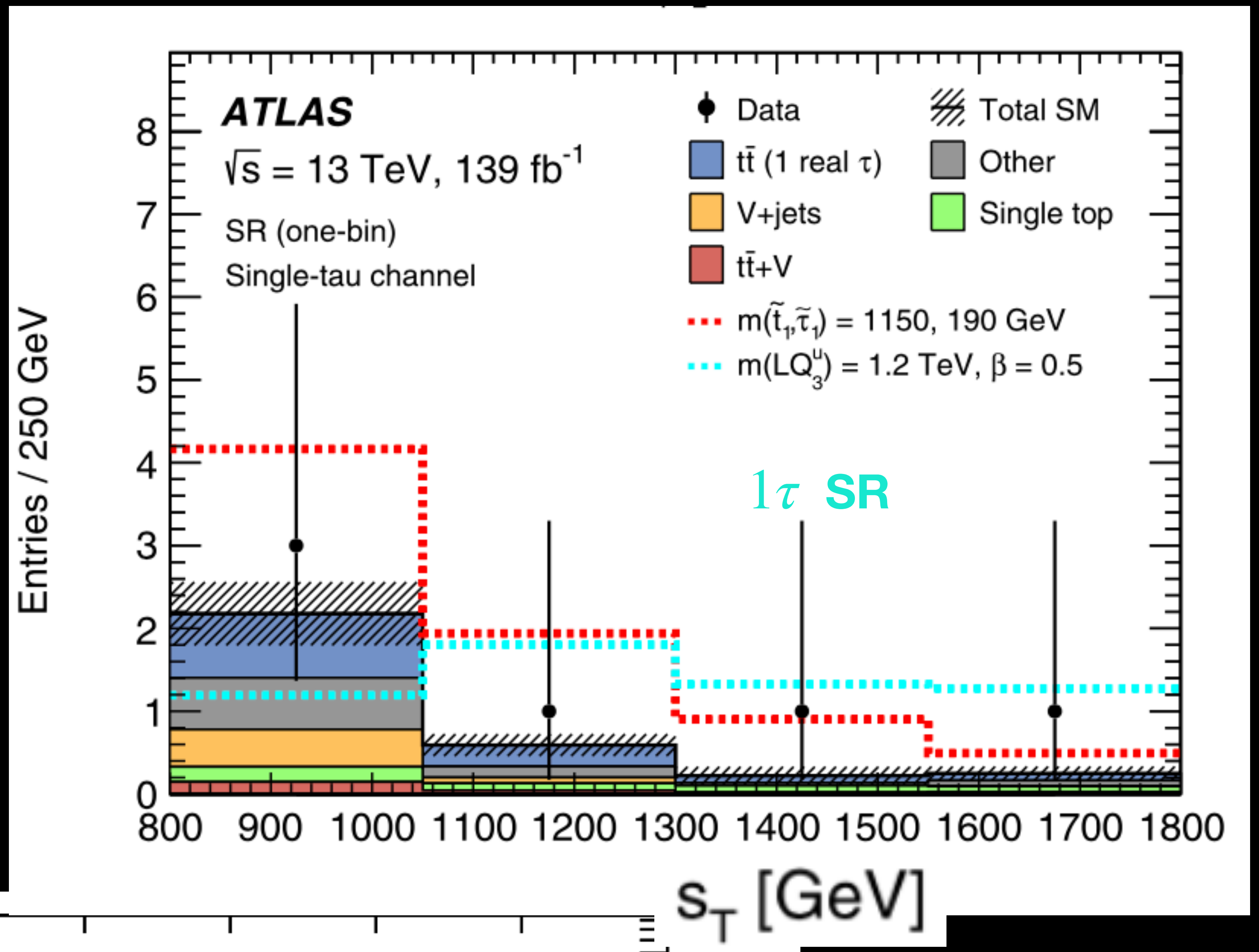


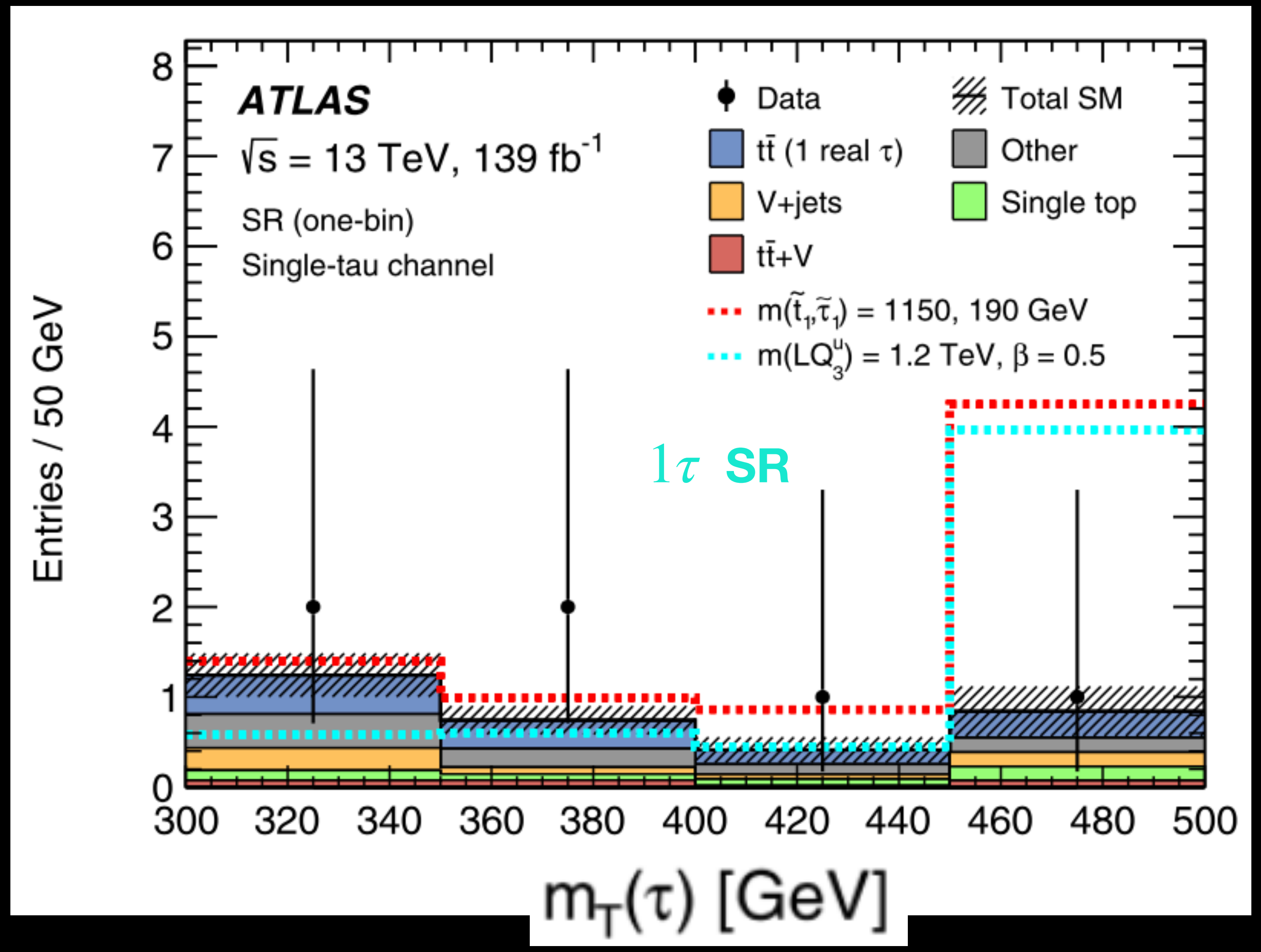
CRs and VRs in 2τ channel

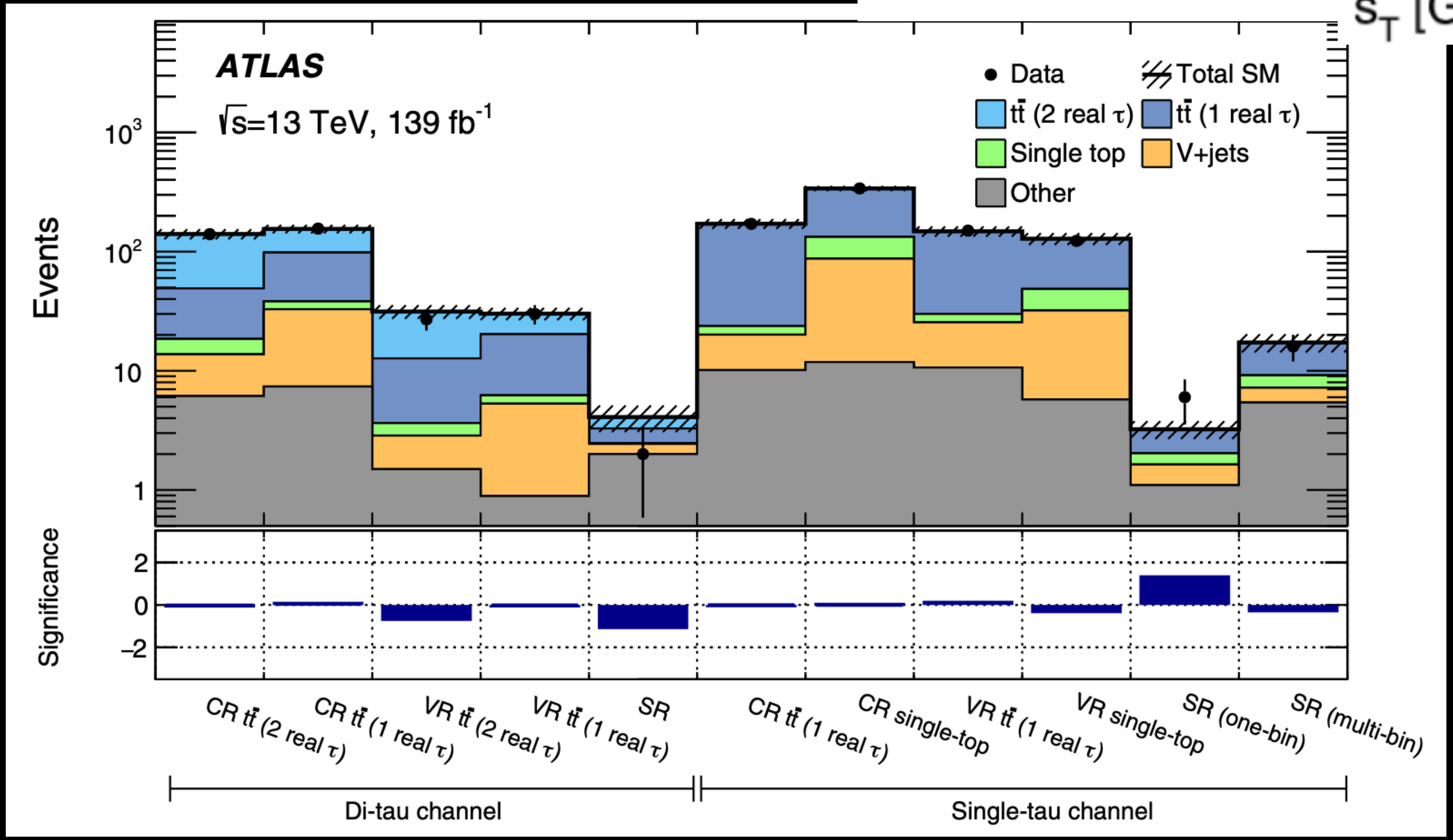
Results:

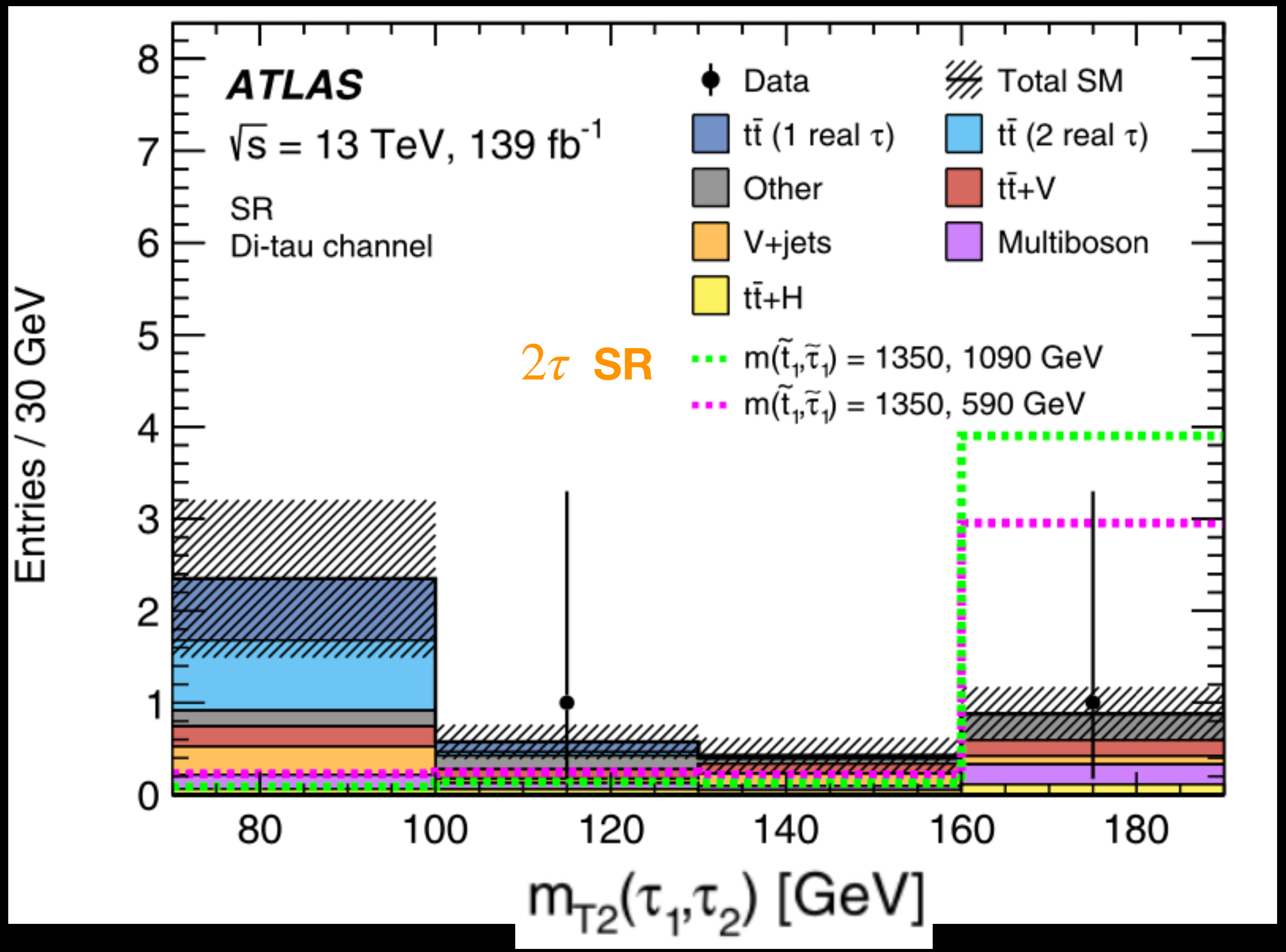
Phys. Rev. D 104, 112005

- ★ Over all good agreement for the extrapolation in
  - ★ S_T and $\sum m_T(b_1, b_2)$ (1τ channel)
  - ★ $m_{T2(\tau_1,\tau_2)}$ (2τ channel)





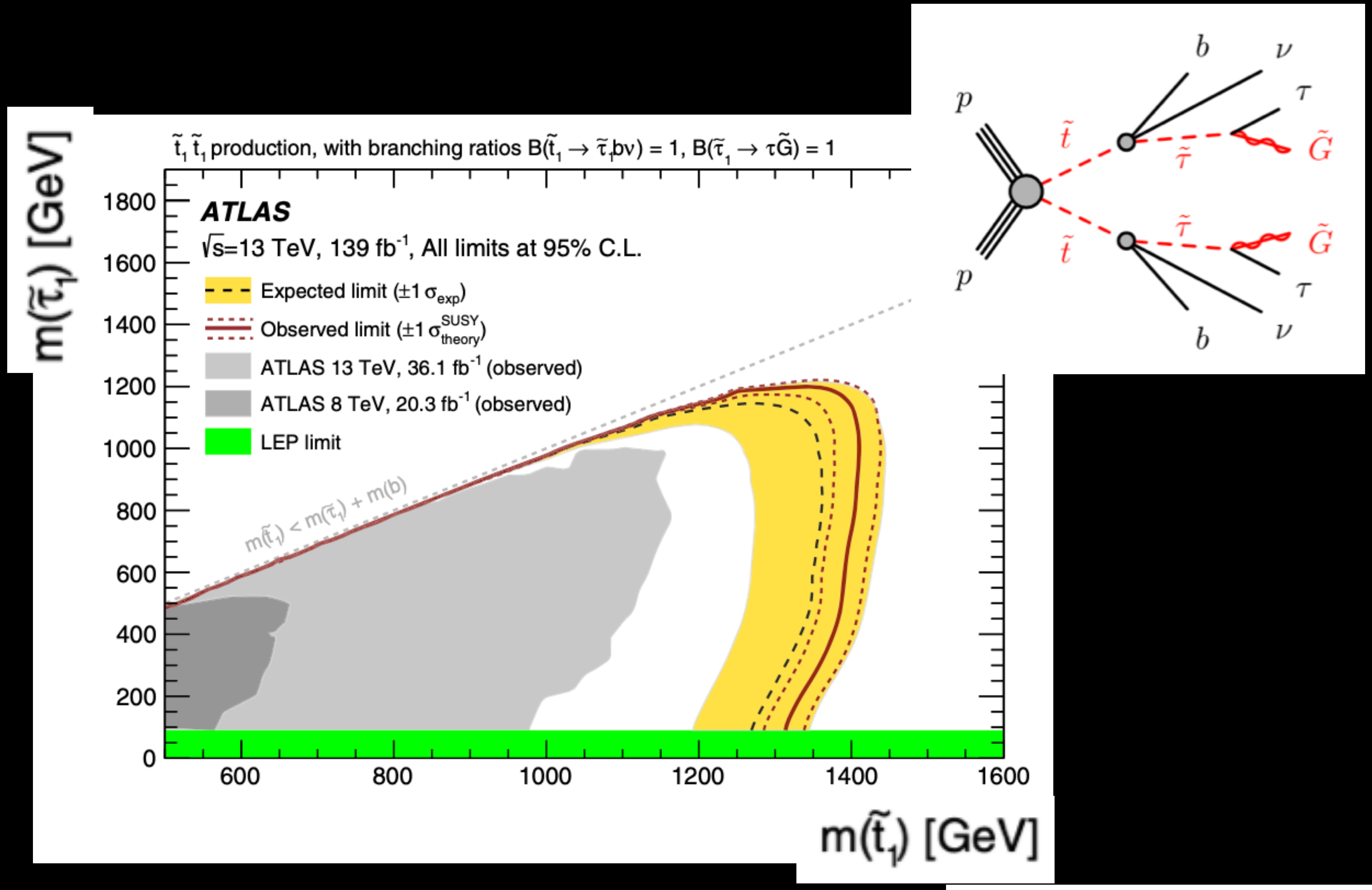


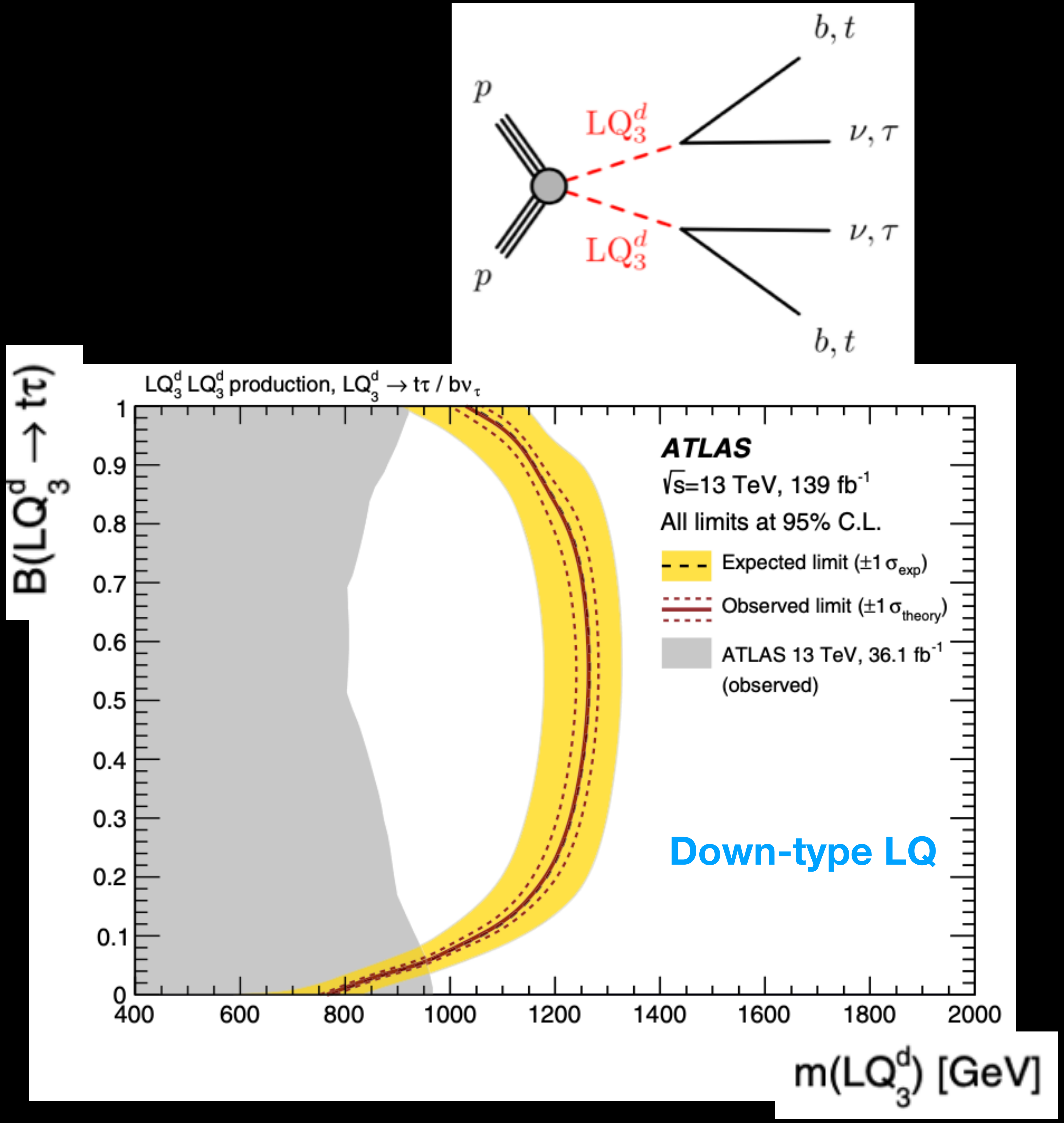


Interpretation:

Phys. Rev. D 104, 112005

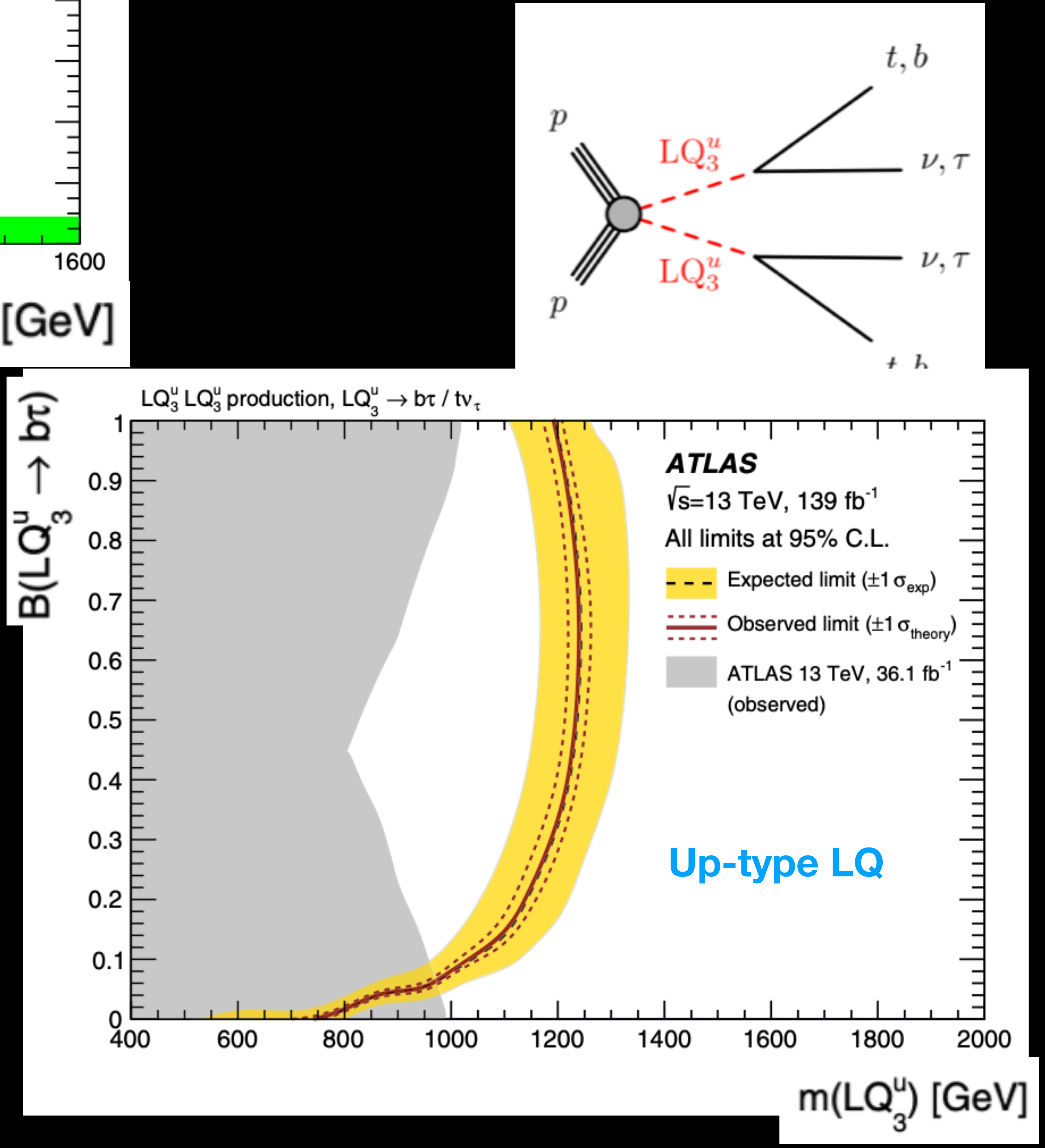
★Exclusion contours at the 95% confidence level for the stop-stau signal model





★Exclusion contours at the 95% confidence level for the third generation scalar leptoquark model

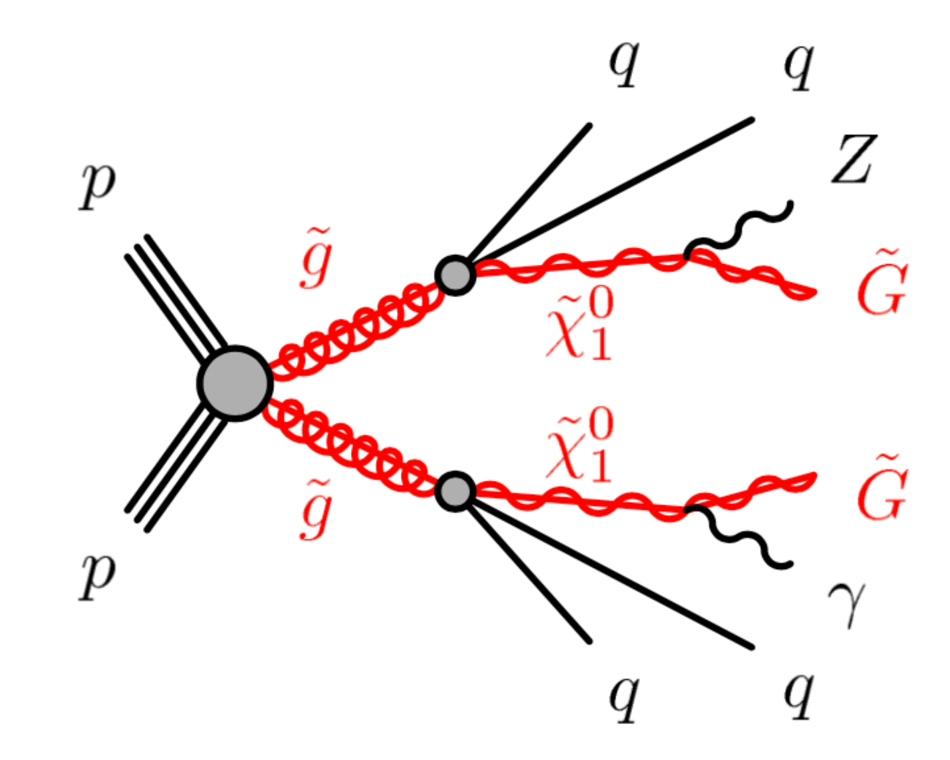
★Shown as a function of mass $m(\mathrm{LQ}_3^{\mathrm{u/d}})$ and the branching fraction $B(\mathrm{LQ}_3^{\mathrm{u/d}} \to ql)$.

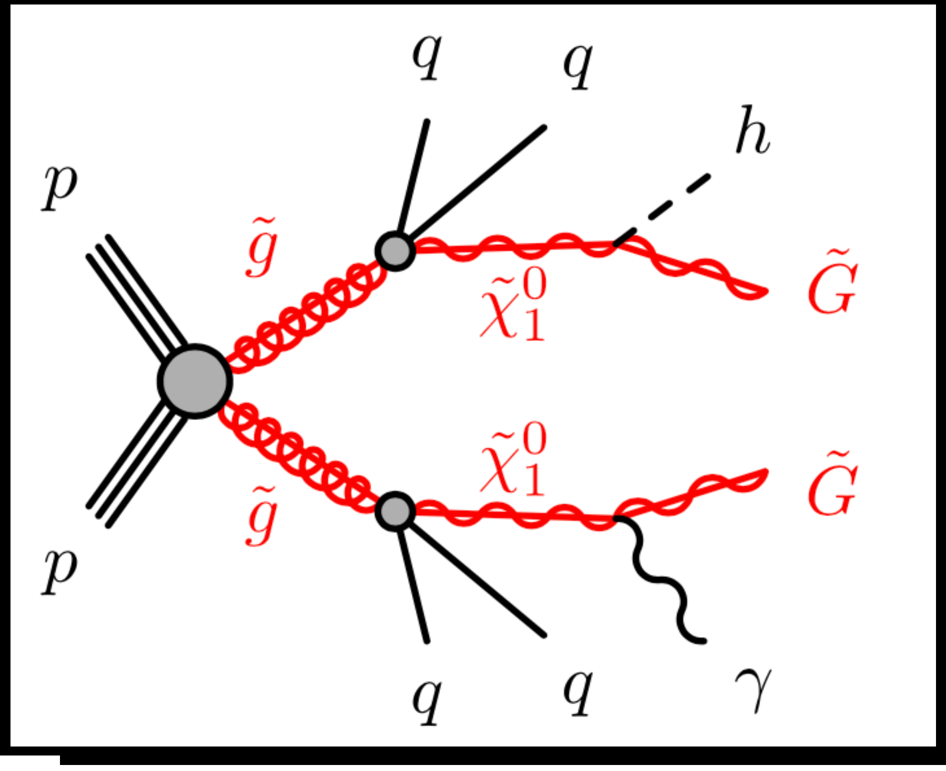


SUSY searches with photon and $E_{\mathrm{T}}^{\mathrm{miss}}$

ATLAS-CONF-2021-028

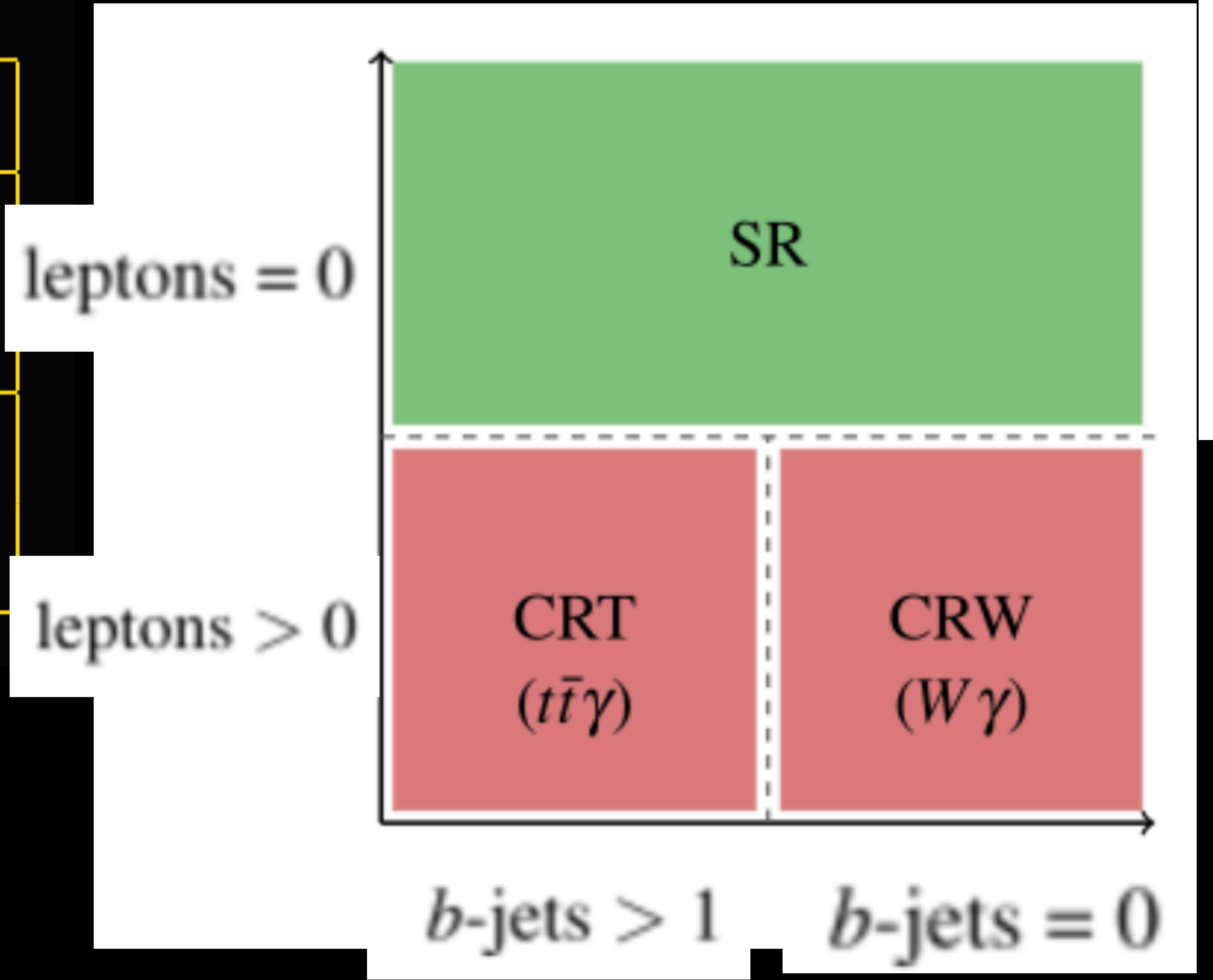
- ★Strong production of gluing pairs, decaying to photon, jets and $E_{\mathrm{T}}^{\mathrm{miss}}$.
  - ★The LSP is $\tilde{G}$, the Next to LSP is the $\tilde{\chi}_1^0$.

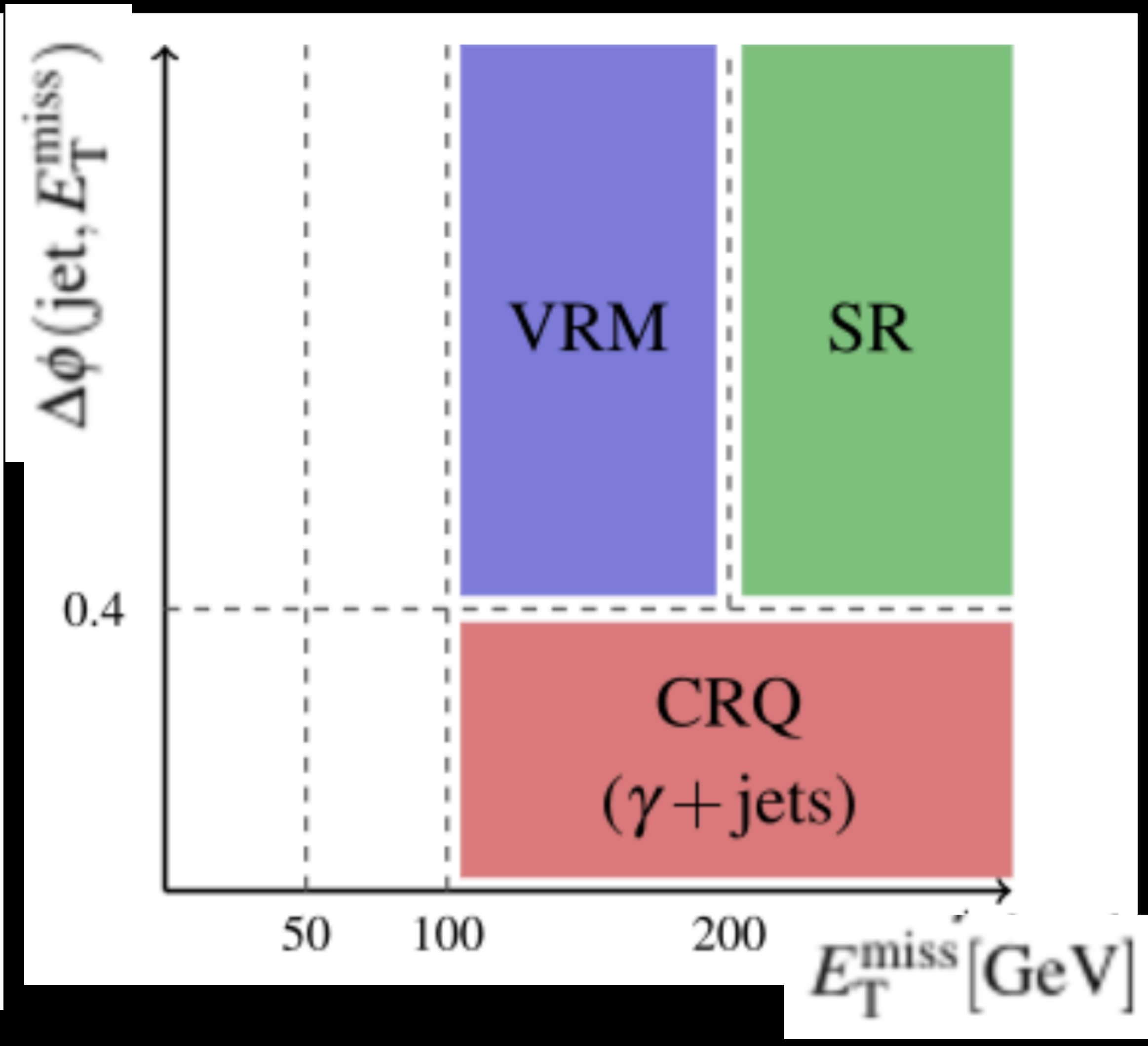




★Background for this analysis:

	Real $E_{\mathrm{T}}^{\mathrm{miss}}$	Instrumental $E_{\mathrm{T}}^{\mathrm{miss}}$
Real photon	$Z(\nu\nu)\gamma$, $W\gamma$, $Z(\nu\nu)\gamma\gamma$, $t\bar{t}\gamma$, $W\gamma\gamma$	γ+jets, $\gamma\gamma$, $Z(ll)+\gamma$, $Z(ll)+\gamma\gamma$
Fake photon	W+jets, $Z(\nu\nu)$+jets $t\bar{t}$	QCD multijets $Z(ll)$+jets

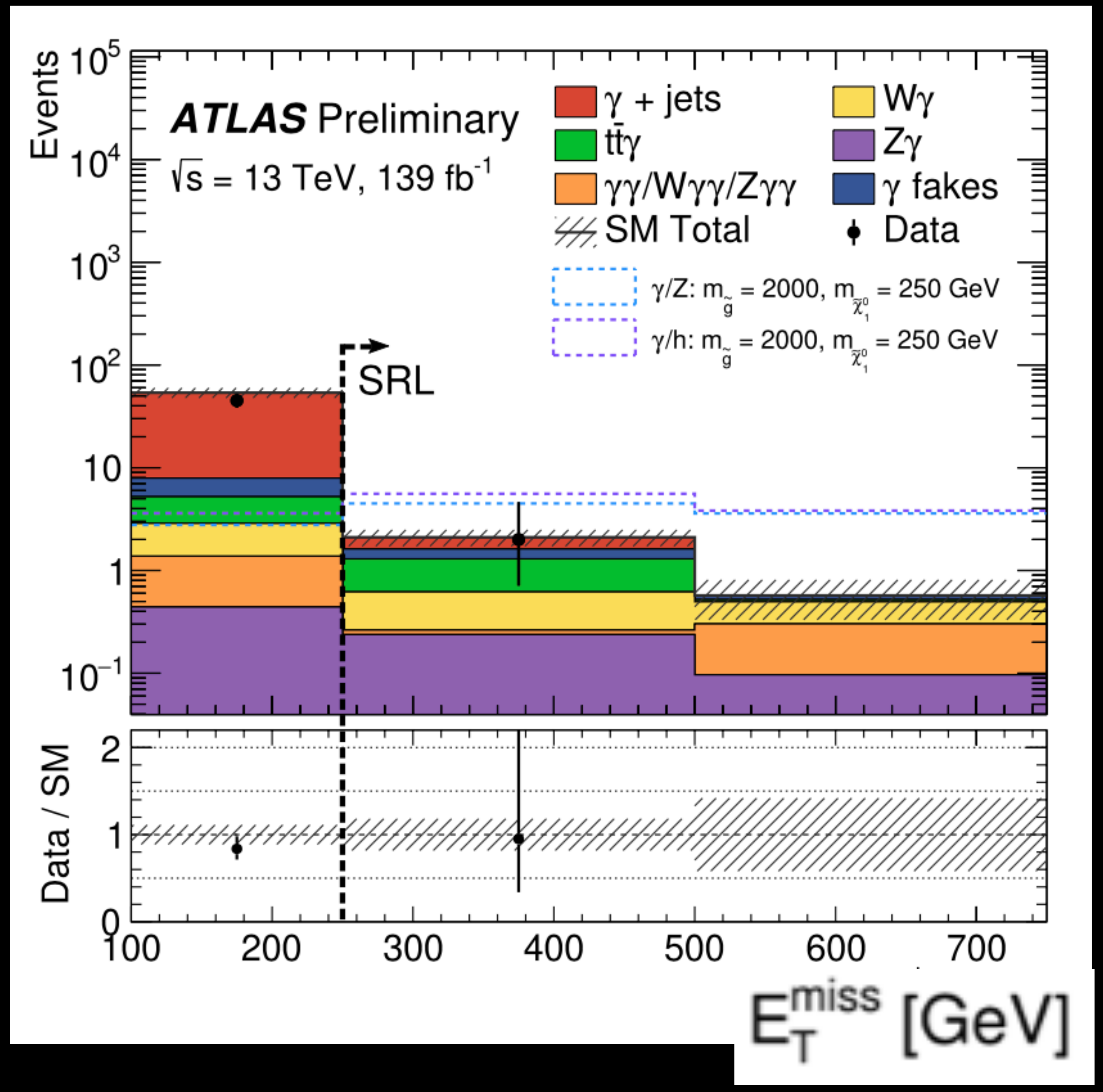


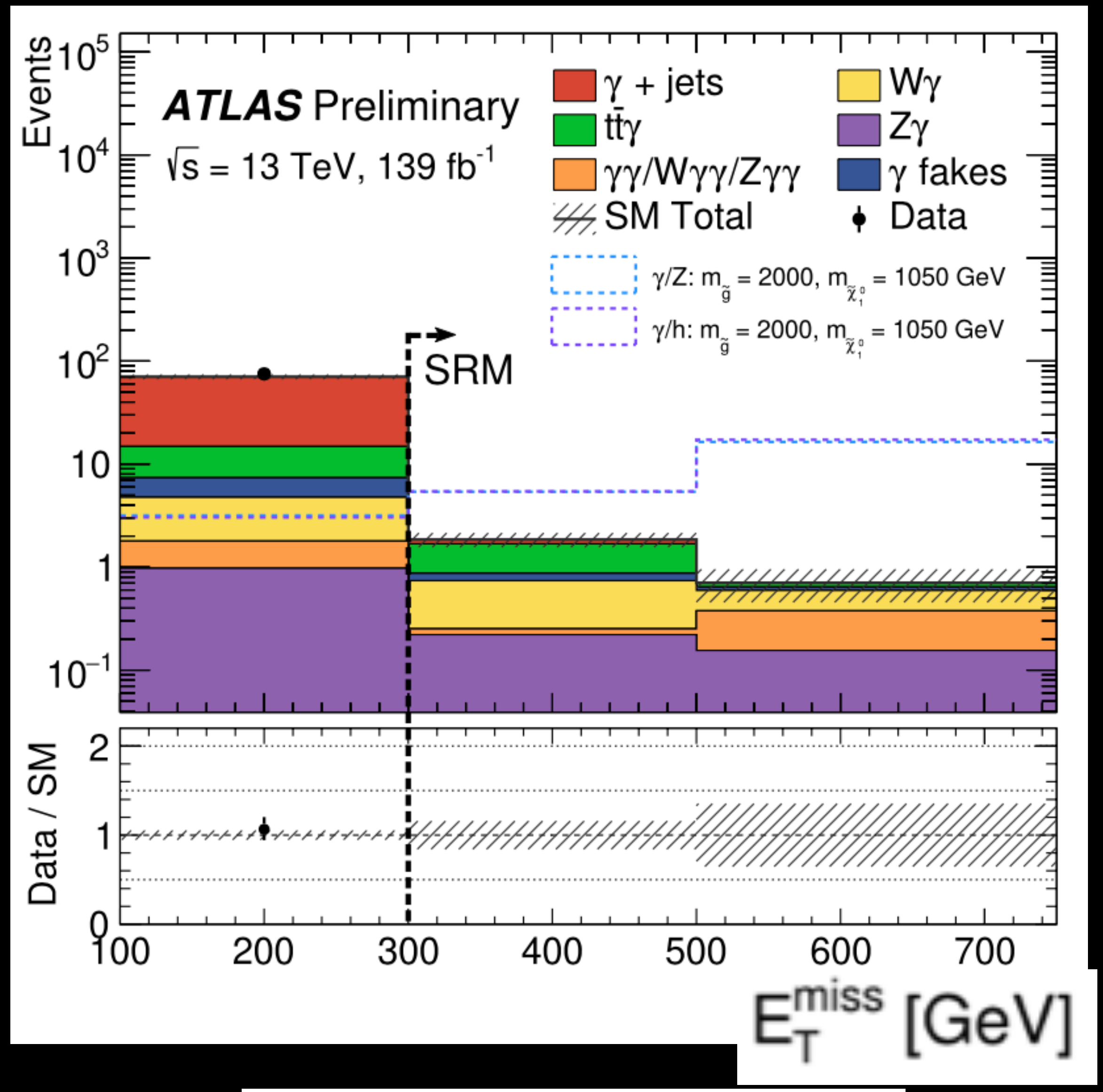


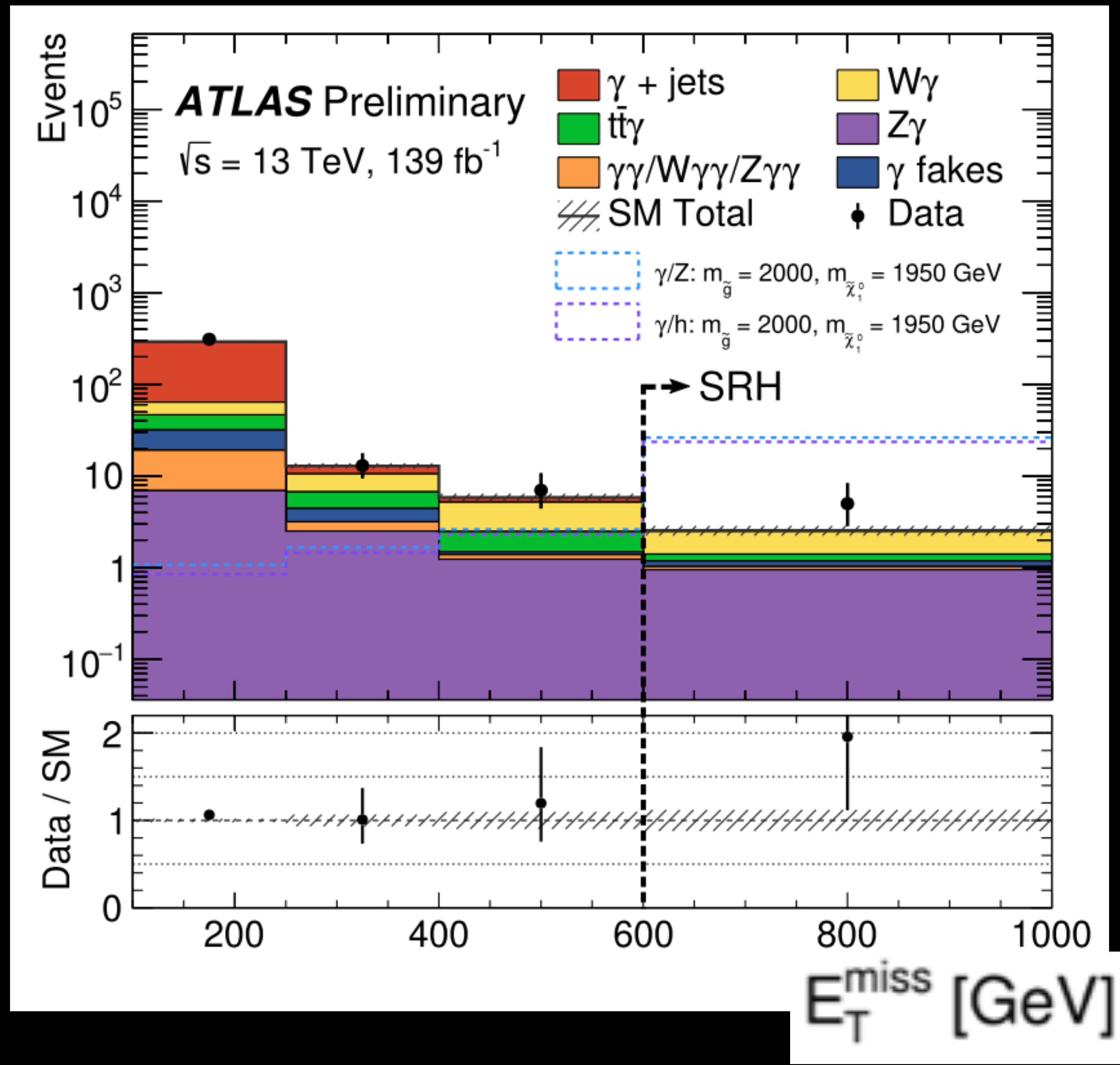
- ★Background with fake photons:
  - ★Data-driven fake rate
    - ★$e \rightarrow \gamma$ fakes
      - ★Based on data samples of $Z \rightarrow ee/e\gamma_{\mathrm{fake}}$
      - ★The fake rate is determined as a function of p_{T} and η
    - ★$j \rightarrow \gamma$ fakes
      - ★Estimated using ABCD method in the photon ID/Isolation plane

- ★Background with real photons:
  - ★Three control regions:
    - ★γ+jets constrained in CRQ
    - ★$W\gamma$ constrained in CRW
    - ★$t\bar{t}\gamma$ constrained in CRT

Results and interpretation ATLAS-CONF-2021-028

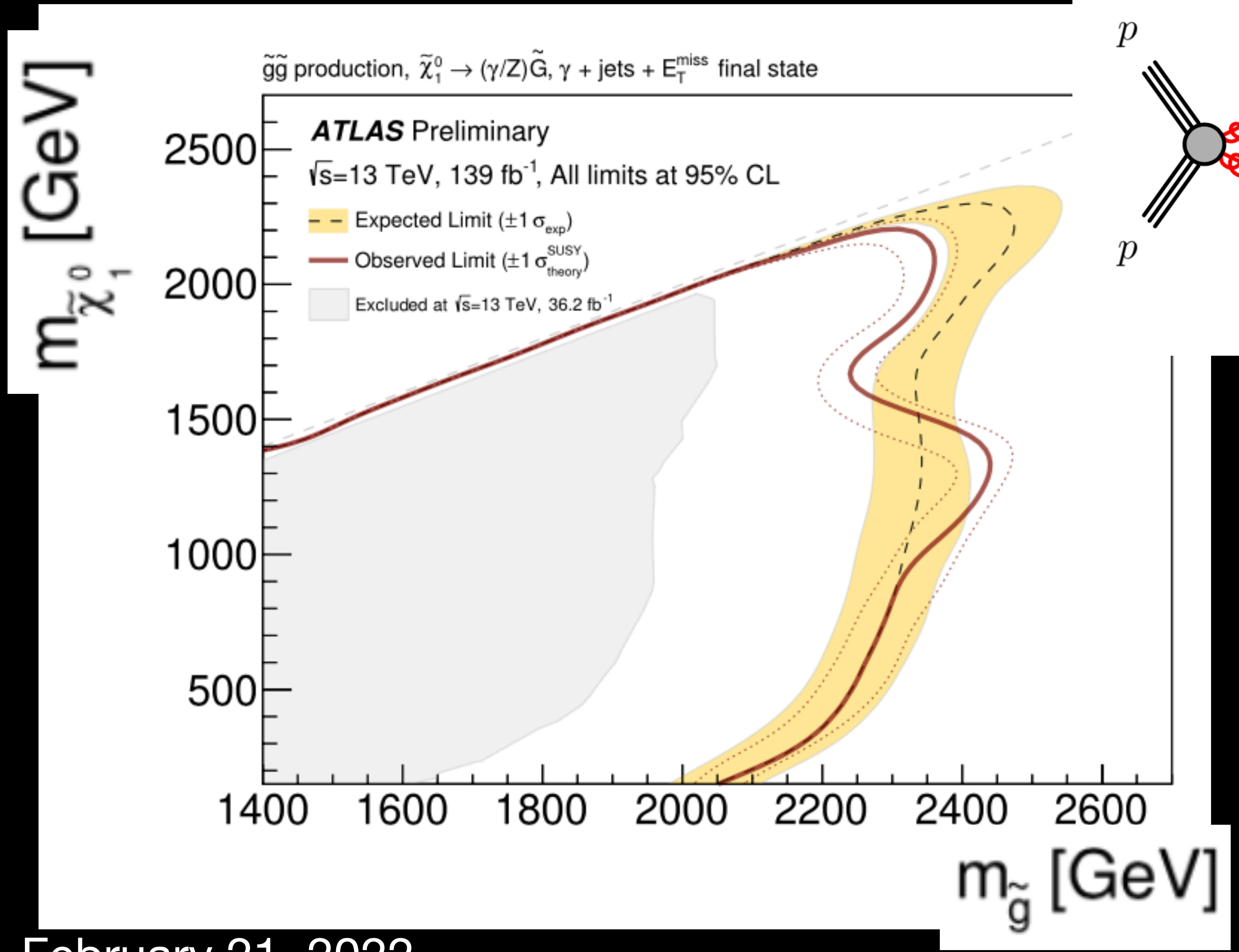


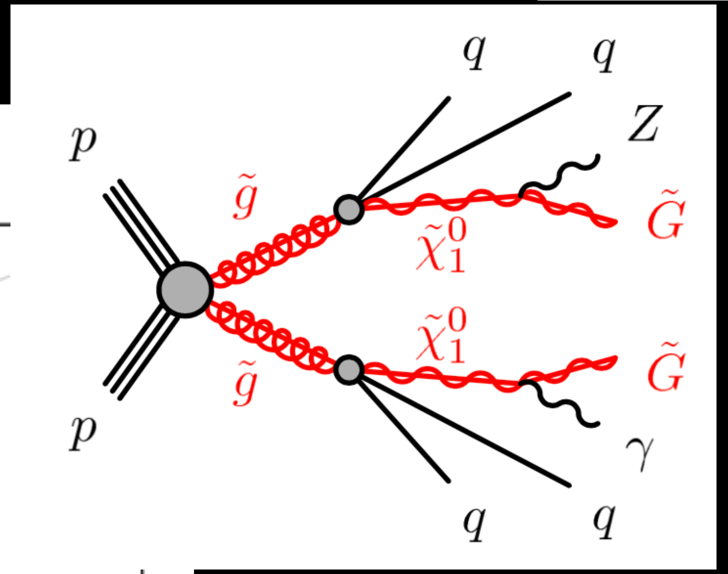


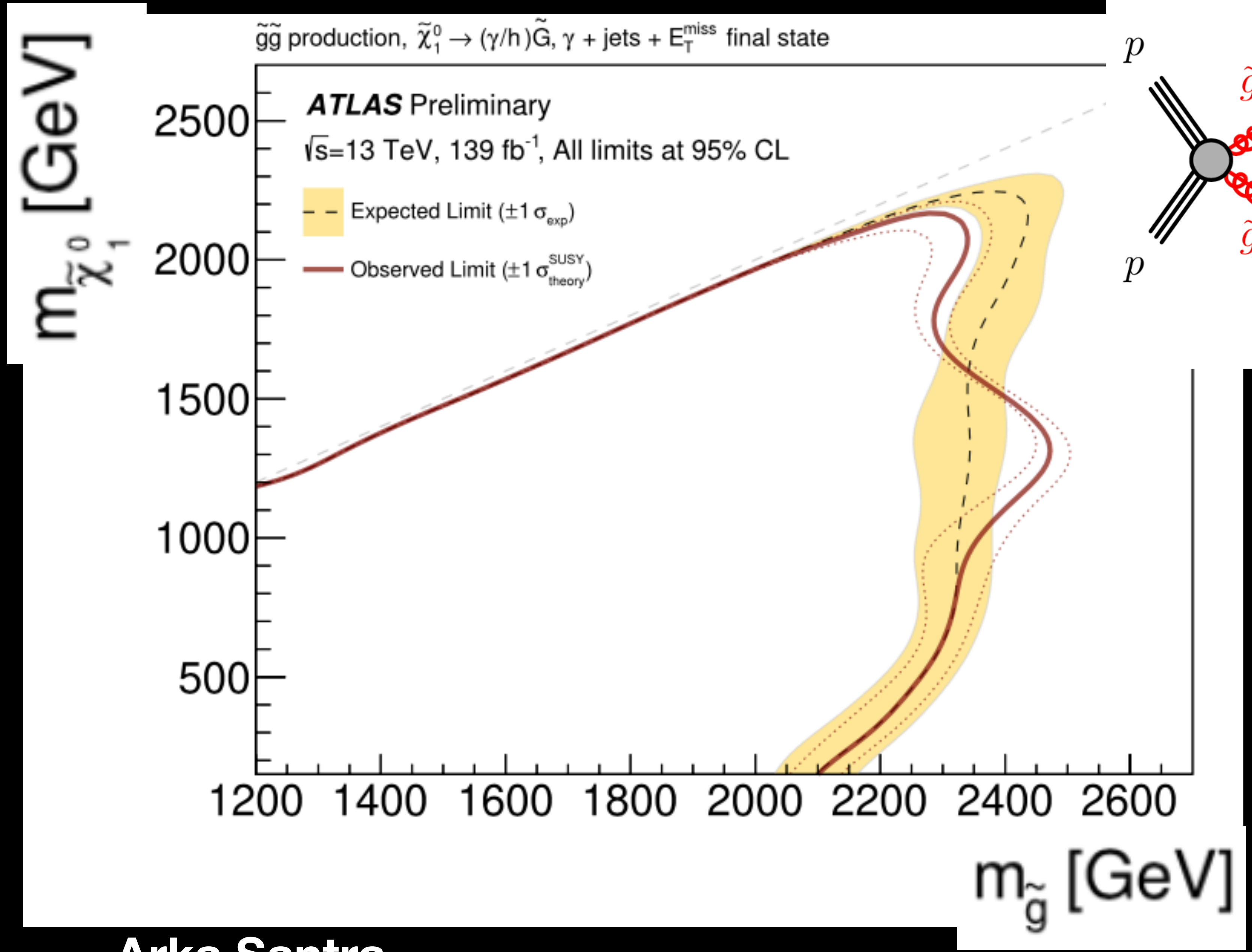


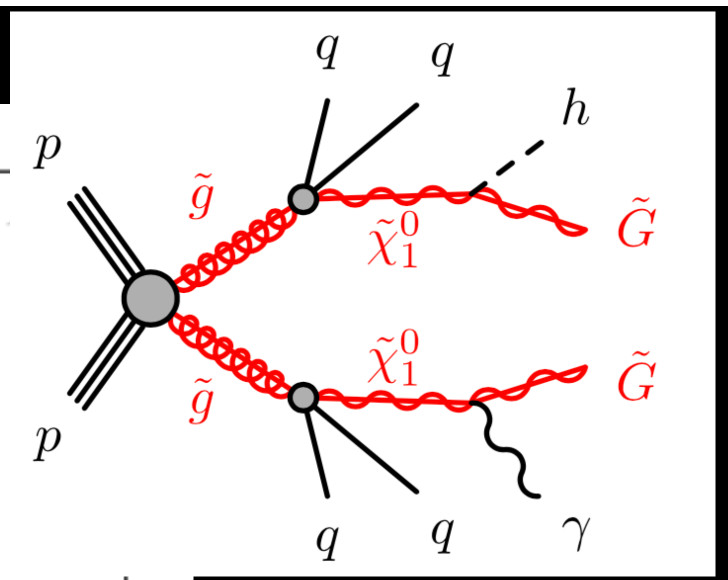
★No significant excess was observed

	SRL	SRM	SRH
Observed events	2	0	5
Expected SM events	2.67 ± 0.75	2.55 ± 0.64	2.55 ± 0.44
$t\bar{t}\gamma$	0.70 ± 0.18	0.87 ± 0.18	0.22 ± 0.05
$W\gamma$	0.55 ± 0.37	0.70 ± 0.42	1.08 ± 0.21
γ + jets	0.49 ± 0.29	0.17 ± 0.10	0.07 ± 0.01
$Z(\to \nu\nu)\gamma$	0.31 ± 0.11	0.35 ± 0.12	0.94 ± 0.28
$\gamma\gamma/W\gamma\gamma/Z\gamma\gamma$	0.23 ± 0.11	0.25 ± 0.10	0.08 ± 0.01
Fake photons from e	0.22 ± 0.08	0.04 ± 0.03	0.06 ± 0.04
Fake photons from jets	0.15 ± 0.09	0.14 ± 0.09	0.09 ± 0.07
$Z(\to \ell\ell)\gamma$	0.03 ± 0.03	0.03 ± 0.01	–









★Interpretation on γh scenario

★First limit in Run-2.

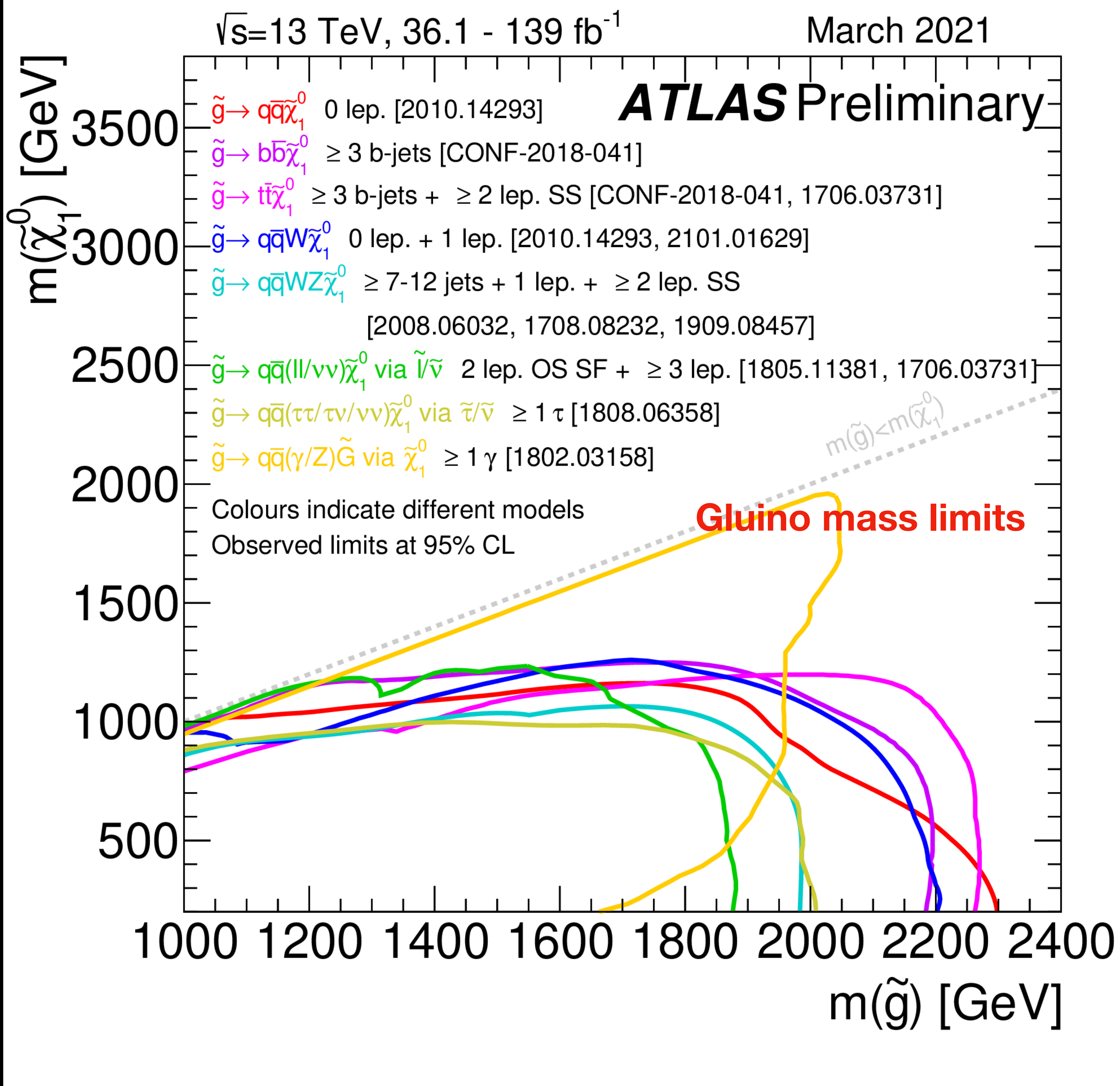
Conclusion

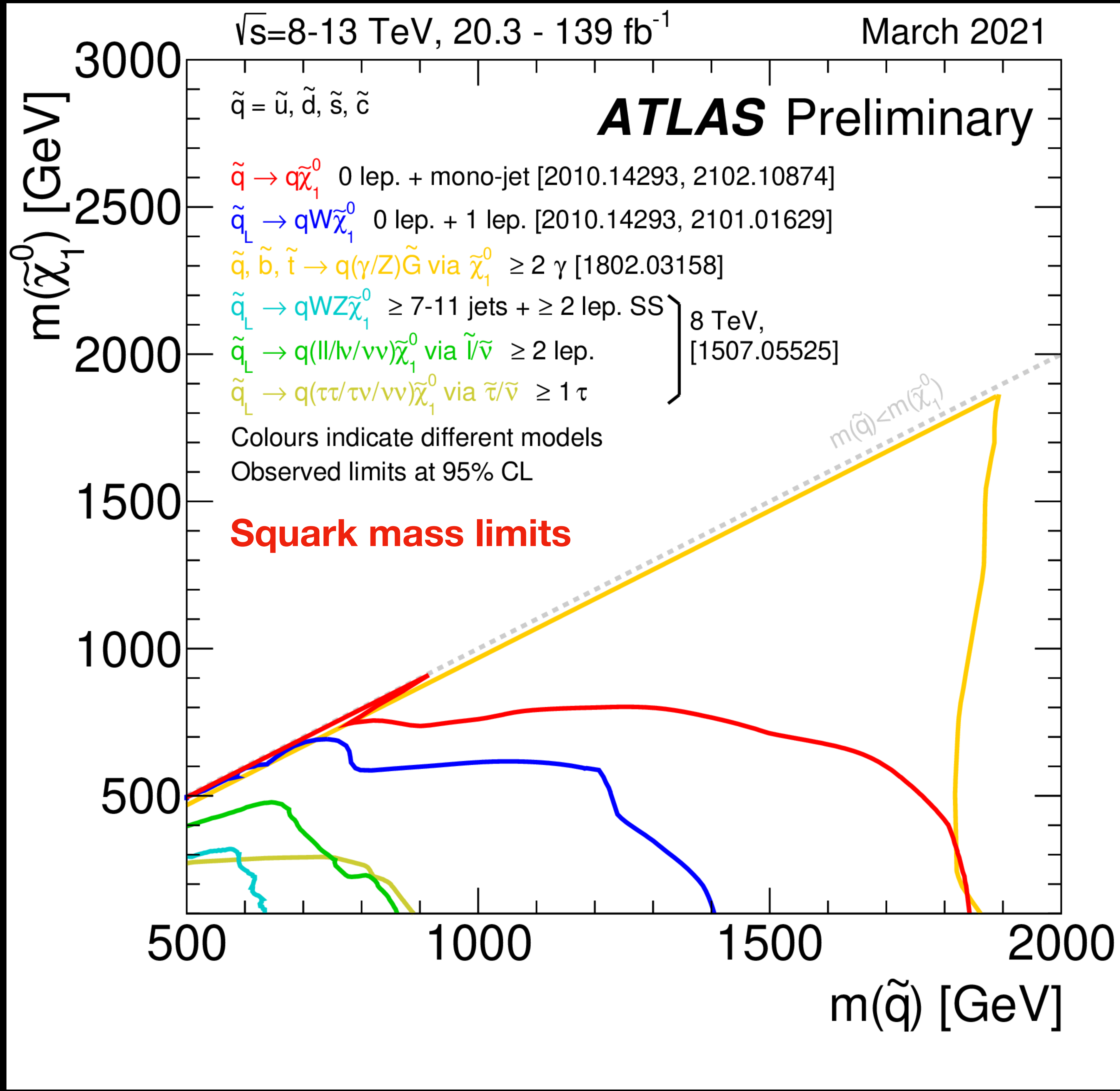
★A brief overview of present SUSY searches from ATLAS experiment in strong production is shown here.

★Very impressive and extensive search program.

★There are plenty of analyses going on right now with Run-2 dataset (139 fb^{-1}).

★Stay tuned for many interesting results.

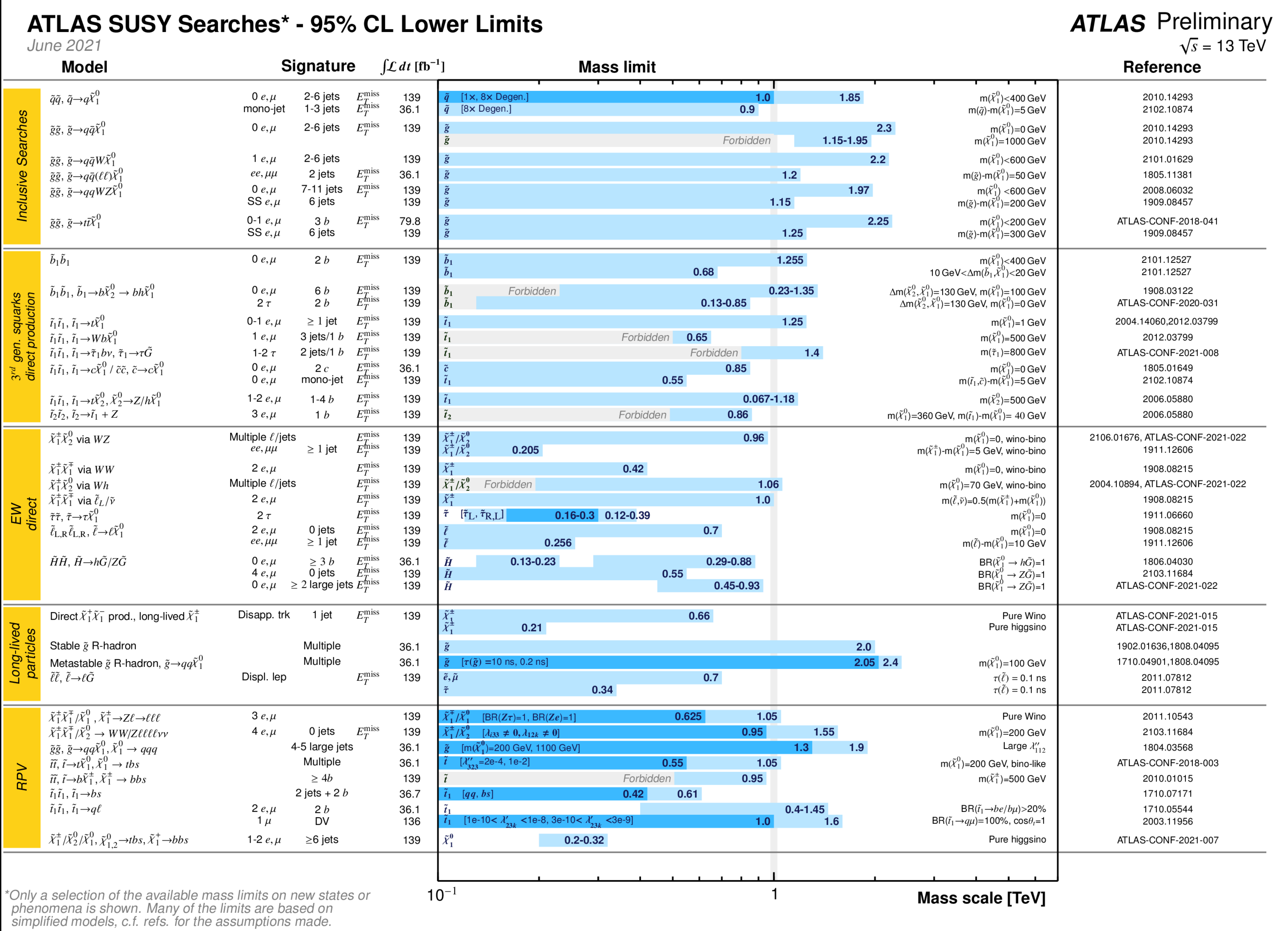




Thank You

Bonus Slides

Summary of mass limits from ATLAS for all production mode



Two leptons and two jets:

SUSY-2018-05

Year	Type	Trigger	Comment
2015	ee	HLT_2e12_lhloose_L12EM10VH	
2015	$\mu\mu$	HLT_2mu10	
2015	$\mu\mu$	HLT_mu18_mu8noL1	
2015	$e\mu$	HLT_e17_lhloose_mu14	
2015	$e\mu$	HLT_e7_lhmedium_mu24	
2016	ee	HLT_2e15_lhvloose_nod0_L12EM13VH	except run 300540
2016	ee	HLT_2e17_lhvloose_nod0	run 300540 and from period D4
2016	$\mu\mu$	HLT_2mu10	period A
2016	$\mu\mu$	HLT_2mu14	from period B
2016	$\mu\mu$	HLT_mu20_mu8noL1	periods A-D3
2016	$\mu\mu$	HLT_mu22_mu8noL1	periods from D4
2016	$e\mu$	HLT_e17_lhloose_nod0_mu14	
2016	$e\mu$	HLT_e24_lhmedium_nod0_L1EM20VHI_mu8noL1	
2016	$e\mu$	HLT_e7_lhmedium_nod0_mu24	
2017	ee	HLT_2e17_lhvloose_nod0_L12EM15VHI	except periods B5-B8
2017	ee	HLT_2e24_lhvloose_nod0	
2017	$\mu\mu$	HLT_2mu14	
2017	$\mu\mu$	HLT_mu22_mu8noL1	
2017	$e\mu$	HLT_e17_lhloose_nod0_mu14	
2017	$e\mu$	HLT_e26_lhmedium_nod0_mu8noL1	
2017	$e\mu$	HLT_e7_lhmedium_nod0_mu24	
2018	ee	HLT_2e17_lhvloose_nod0_L12EM15VHI	
2018	ee	HLT_2e24_lhvloose_nod0	
2018	$\mu\mu$	HLT_2mu14	
2018	$\mu\mu$	HLT_mu22_mu8noL1	
2018	$e\mu$	HLT_e17_lhloose_nod0_mu14	
2018	$e\mu$	HLT_e26_lhmedium_nod0_mu8noL1	
2018	$e\mu$	HLT_e7_lhmedium_nod0_mu24	

$$m_{\mathrm{T}}^2\left(\vec{p}_{\mathrm{T},a}, \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}\right) = 2 \times \left(p_{\mathrm{T},a} \times E_{\mathrm{T}}^{\mathrm{miss}} - \vec{p}_{\mathrm{T}a} \cdot \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}\right),$$

$$m_{\mathrm{T2}}^2 = \min_{\vec{x}_{\mathrm{T},1}+\vec{x}_{\mathrm{T},2}=\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}} \left[\max\{m_{\mathrm{T}}^2\left(\vec{p}_{\mathrm{T1}}, \vec{x}_{\mathrm{T},1}\right), m_{\mathrm{T}}^2\left(\vec{p}_{\mathrm{T2}}, \vec{x}_{\mathrm{T},2}\right)\}\right],$$

Preselection	Lepton triggers
Preselection	Lepton $p_{\mathrm{T}} > 25$ GeV; == 2 leptons (baseline & signal) SF-OS
Preselection	$m_{\ell\ell} > 12$ GeV
Preselection	$p_{\mathrm{T}}^{\ell\ell} > 40$ GeV
Preselection	Jet $p_{\mathrm{T}} > 30$ GeV; ≥ 2 jets
Preselection	$\Delta\phi(\mathrm{jet}_{1,2}, E_{\mathrm{T}}^{\mathrm{miss}}) > 0.4$

Region	N_{jets}	H_{T}	$E_{\mathrm{T}}^{\mathrm{miss}}$	m_{T2}	$E_{\mathrm{T}}^{\mathrm{miss,sig}}$	$p_{\mathrm{T}}^{\ell\ell}$	$m_{\ell\ell}$
SRC	–	> 250	> 250	> 90	> 10	< 100	–
SRLow	–	> 250	> 250	> 100	–	< 500	–
SRZLow	≥ 4	> 250	> 250	> 100	–	< 500	$81 < m_{\ell\ell} < 101$*
SRMed	–	> 500	> 300	> 75	–	< 800	–
SRZMed	≥ 4	> 500	> 300	> 75	–	< 800	$81 < m_{\ell\ell} < 101$*
SRHigh	–	> 800	> 300	> 75	–	–	–
SRZHigh	≥ 4	> 800	> 300	> 75	–	–	$81 < m_{\ell\ell} < 101$*

Region	n_{jets}	H_{T} [GeV]	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	m_{T2} [GeV]	$\mathcal{S}(E_{\mathrm{T}}^{\mathrm{miss}})$	$p_{\mathrm{T}}^{\ell\ell}$ [GeV]	$\Delta\phi(\mathrm{jet}_{1,2}, p_{\mathrm{T}}^{\mathrm{miss}})$	SF/DF	$m_{\ell\ell}$ [GeV]
Signal regions									
SRC	≥ 2	> 250	> 250	> 90	> 10	40–100	> 0.4	SF	> 12
SRLow	≥ 2	> 250	> 250	> 100	–	40–500	> 0.4	SF	> 12
↪SRZLow	≥ 4	> 250	> 250	> 100	–	40–500	> 0.4	SF	81–101
SRMed	≥ 2	> 500	> 300	> 75	–	40–800	> 0.4	SF	> 12
↪SRZMed	≥ 4	> 500	> 300	> 75	–	40–800	> 0.4	SF	81–101
SRHigh	≥ 2	> 800	> 300	> 75	–	> 40	> 0.4	SF	> 12
↪SRZHigh	≥ 4	> 800	> 300	> 75	–	> 40	> 0.4	SF	81–101

Two leptons and two jets: Flavor symmetry

Electron vs Muon eff

ee/mm vs em trigger eff

$$N^{\mathrm{est}} = \frac{1}{2} \cdot \left[\sum_{i}^{N_{e\mu}^{\mathrm{data}}} \left(k_e(p_{\mathrm{T}}^{i,\mu}, \eta^{i,\mu}) + k_\mu(p_{\mathrm{T}}^{i,e}, \eta^{i,e}) \right) \cdot \alpha(p_{\mathrm{T}}^{i,\ell_1}, \eta^{i,\ell_1}) - \sum_{i}^{N_{e\mu}^{\mathrm{MC}}} \left(k_e(p_{\mathrm{T}}^{i,\mu}, \eta^{i,\mu}) + k_\mu(p_{\mathrm{T}}^{i,e}, \eta^{i,e}) \right) \cdot \alpha(p_{\mathrm{T}}^{i,\ell_1}, \eta^{i,\ell_1}) \right],$$

- Corrections evaluated in a loose 2L2J region with data
- Non-FS processes subtracted off via MC

Uncertainties

- Statistics
- Non-closure tests in loose regions and SRs
    - 10% non closure syst.

Two leptons and two jets: Matrix method

- $N^{\text{FNP}}_{\text{pass}} = \dfrac{N_{\text{fail}} - (1/\epsilon_{\text{real}} - 1) \times N_{\text{pass}}}{1/\epsilon_{\text{FNP}} - 1/\epsilon_{\text{real}}}$
- Here $\epsilon_{\text{real}}$is the efficiency for a real prompt lepton to pass the single lepton requirement and ϵ_{FNP} are the same for FNP leptons.
- ϵ_{real} obtained from MC, ϵ_{FNP} obtained from data using tag-and-probe method.

The Matrix Method (MM)

For event with two leptons the following matrix is used to estimate the **fake leptons** and **leptons from non-prompt sources** (FNP background)

The predicted yields

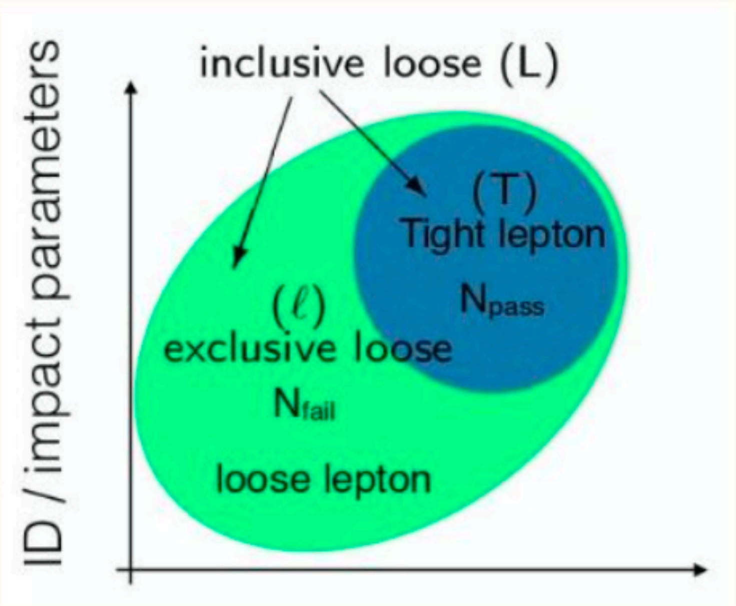
$$\begin{bmatrix} N_{TT} \\ N_{Tl} \\ N_{lT} \\ N_{ll} \end{bmatrix} = \begin{bmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r_2) & r_1(1-f_2) & f_1(1-r_2) & f_1(1-f_2) \\ (1-r_1)r_2 & (1-r_1)f_2 & (1-f_1)r_2 & (1-f_1)f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{bmatrix} \begin{bmatrix} N^{RR}_{LL} \\ N^{RF}_{LL} \\ N^{FR}_{LL} \\ N^{FF}_{LL} \end{bmatrix}$$

The measured number of events with two tight (TT), one tight and one loose (Tl, lT) and two loose (ll) leptons in the region of interest (i.e CR, VR, SR)

Notation:

The 1 and 2 subscripts refer to the two leptons (sorted after p_T)

T: lepton passes tight, **L:** lepton passes loose, **l:** lepton passes loose, but not tight



The final yields:

$$N^{RR}_{TT} = r_1 r_2 N^{RR}_{LL}$$
The real lepton background (from MC or other techniques)

$$N^{RF}_{TT} = r_1 f_2 N^{RF}_{LL}$$
$$N^{FR}_{TT} = f_1 r_2 N^{FR}_{LL}$$
$$N^{FF}_{TT} = f_1 f_2 N^{FF}_{LL}$$
The FNP background

From Rupert Tombs/Eiric Gramstad

Stop-Stau Search

SUSY-2019-018

Di-tau preselection	Single-tau preselection
E_T^{miss}-trigger fired and $E_T^{miss} > 250$ GeV	
No light leptons (e/μ)	
At least two jets	
At least two hadronic tau leptons	Exactly one hadronic tau lepton
At least one b-tagged jet	At least two b-tagged jets

Variable	CR $t\bar{t}$ (2 real τ)	CR $t\bar{t}$ (1 real τ)	VR $t\bar{t}$ (2 real τ)	VR $t\bar{t}$ (1 real τ)	SR
E_T^{miss}	—	—	—	—	> 280 GeV
$OS(\tau_1, \tau_2)$	1	—	1	—	1
$m_{T2}(\tau_1, \tau_2)$	< 35 GeV	< 35 GeV	$[35, 70]$ GeV	$[35, 70]$ GeV	> 70 GeV
$m_{vis}(\tau_1, \tau_2)$	> 50 GeV	> 50 GeV	—	—	—
$m_T(\tau_1)$	> 50 GeV	< 50 GeV	> 70 GeV	< 70 GeV	—

Stop-Stau Search

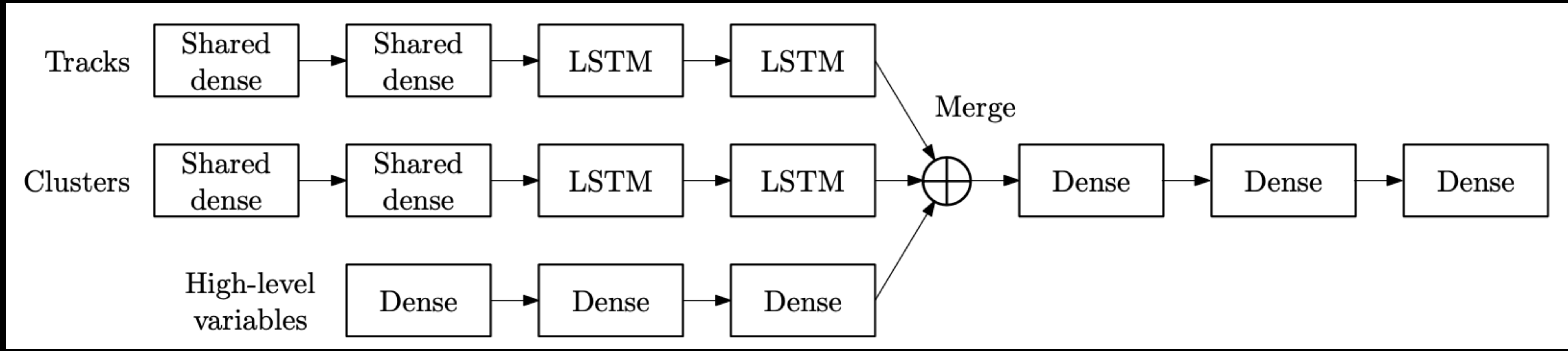
Variable	CR $t\bar{t}$ (1 real τ)	CR single top	VR $t\bar{t}$ (1 real τ)	VR single top	SR
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 280 GeV	> 280 GeV	> 280 GeV	> 280 GeV	> 280 GeV
s_{T}	[500, 600] GeV	—	> 600 GeV	—	$> 800(600)$ GeV
$\sum m_{\mathrm{T}}(b_{1,2})$	[600, 700] GeV	> 800 GeV	[600, 700] GeV	> 800 GeV	> 700 GeV
$m_{\mathrm{T}}(\tau)$	—	< 50 GeV	—	[50, 150] GeV	$> 300(150)$ GeV
$p_{\mathrm{T}}(\tau)$	—	> 80 GeV	—	> 80 GeV	— (binned)

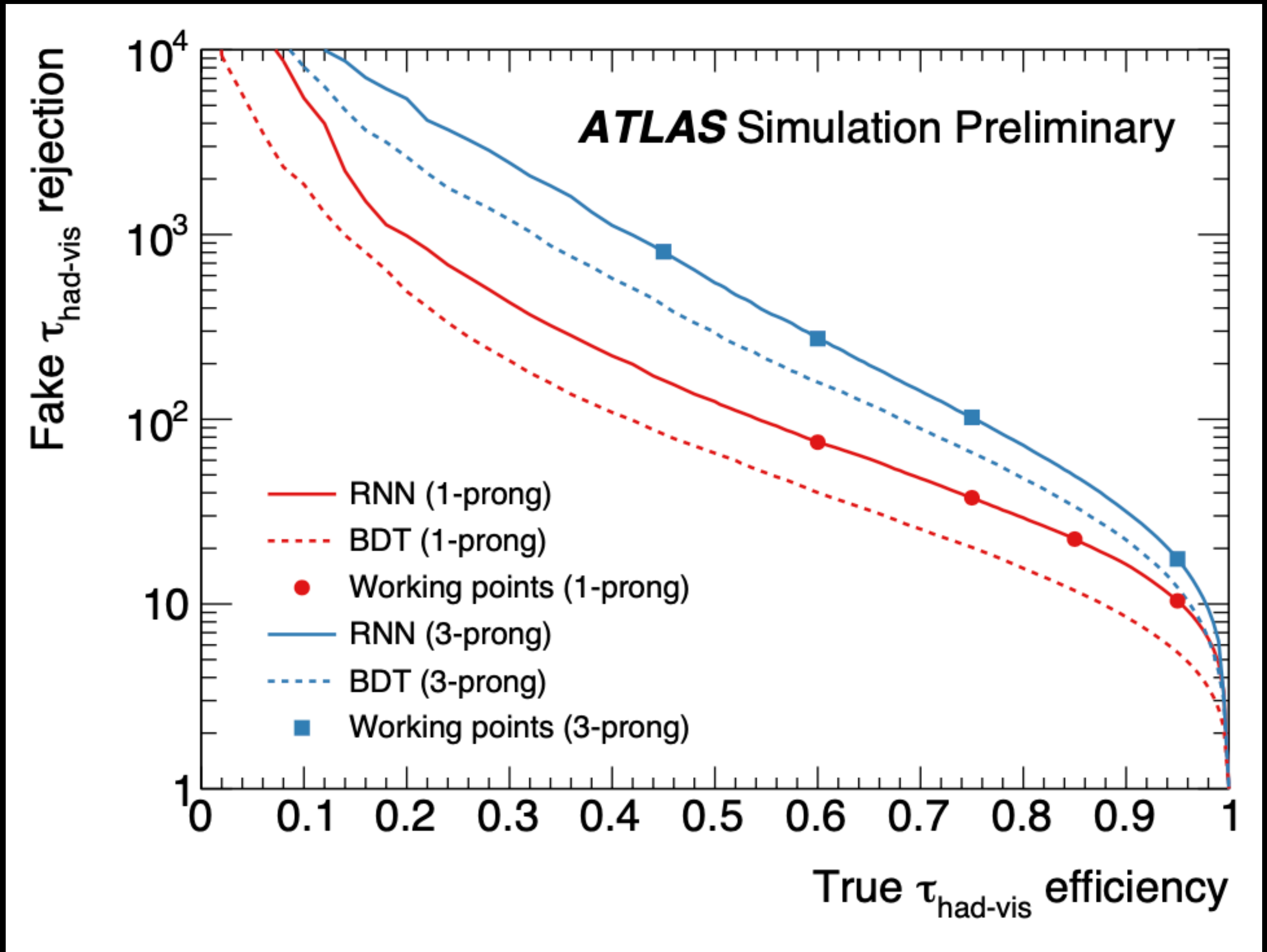
Systematic uncertainty	Di-tau SR	Single-tau one-bin SR	Single-tau multi-bin SR
Total	25%	17%	17%
Jet-related	19%	4.2%	3.9%
Tau-related	4.7%	5.5%	4.3%
Other experimental	3.7%	1.0%	0.8%
Theoretical modeling	13%	17%	19%
MC statistics	12%	7.5%	4.4%
Normalization factors	8.8%	15%	16%
Luminosity	0.8%	0.5%	0.4%

Stop-Stau: τ RNN

ATLAS-PHYS-PUB-2019-033

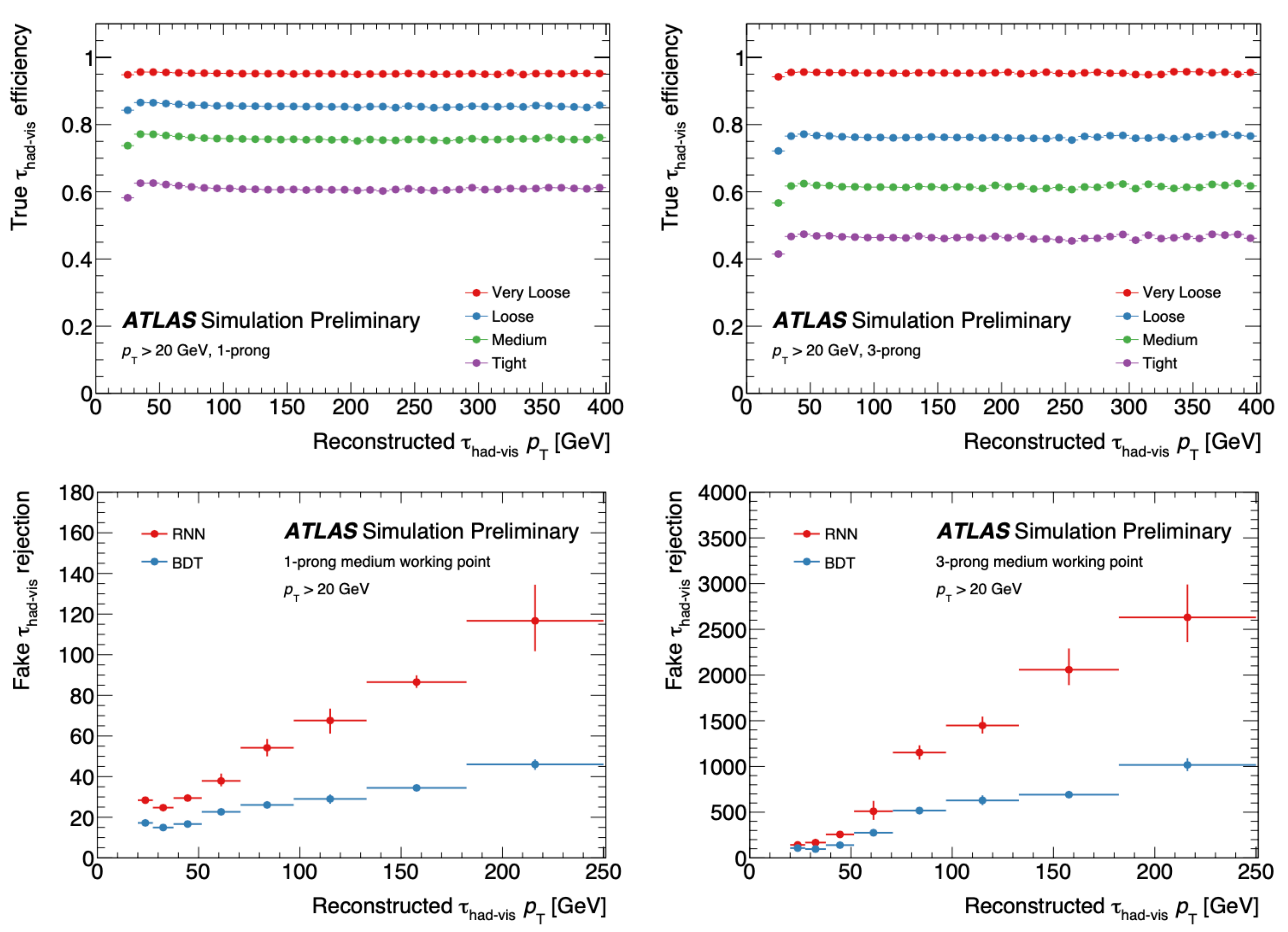
	Observable	1-prong	3-prong
Track inputs	$p_T^{\text{seed jet}}$	•	•
	p_T^{track}	•	•
	$\Delta\eta^{\text{track}}$	•	•
	$\Delta\phi^{\text{track}}$	•	•
	$\lvert d_0^{\text{track}} \rvert$	•	•
	$\lvert z_0^{\text{track}} \sin\theta \rvert$	•	•
	$N_{\text{IBL hits}}$	•	•
	$N_{\text{Pixel hits}}$	•	•
	$N_{\text{SCT hits}}$	•	•
Cluster inputs	$p_T^{\text{jet seed}}$	•	•
	E_T^{cluster}	•	•
	$\Delta\eta^{\text{cluster}}$	•	•
	$\Delta\phi^{\text{cluster}}$	•	•
	λ_{cluster}	•	•
	$\langle \lambda^2_{\text{cluster}} \rangle$	•	•
	$\langle r^2_{\text{cluster}} \rangle$	•	•
High-level inputs	$p_T^{\text{uncalibrated}}$	•	•
	f_{cent}	•	•
	$f_{\text{leadtrack}}^{-1}$	•	•
	ΔR_{max}	•	•
	$\lvert S_{\text{leadtrack}} \rvert$	•	
	S_T^{flight}		•
	$f_{\text{iso}}^{\text{track}}$	•	•
	$f_{\text{track}}^{\text{EM}}$	•	•
	$p_T^{\text{EM+track}}/p_T$	•	•
	$m^{\text{EM+track}}$	•	•
	m^{track}		•





Stop-Stau: τ RNN

ATLAS-PHYS-PUB-2019-033

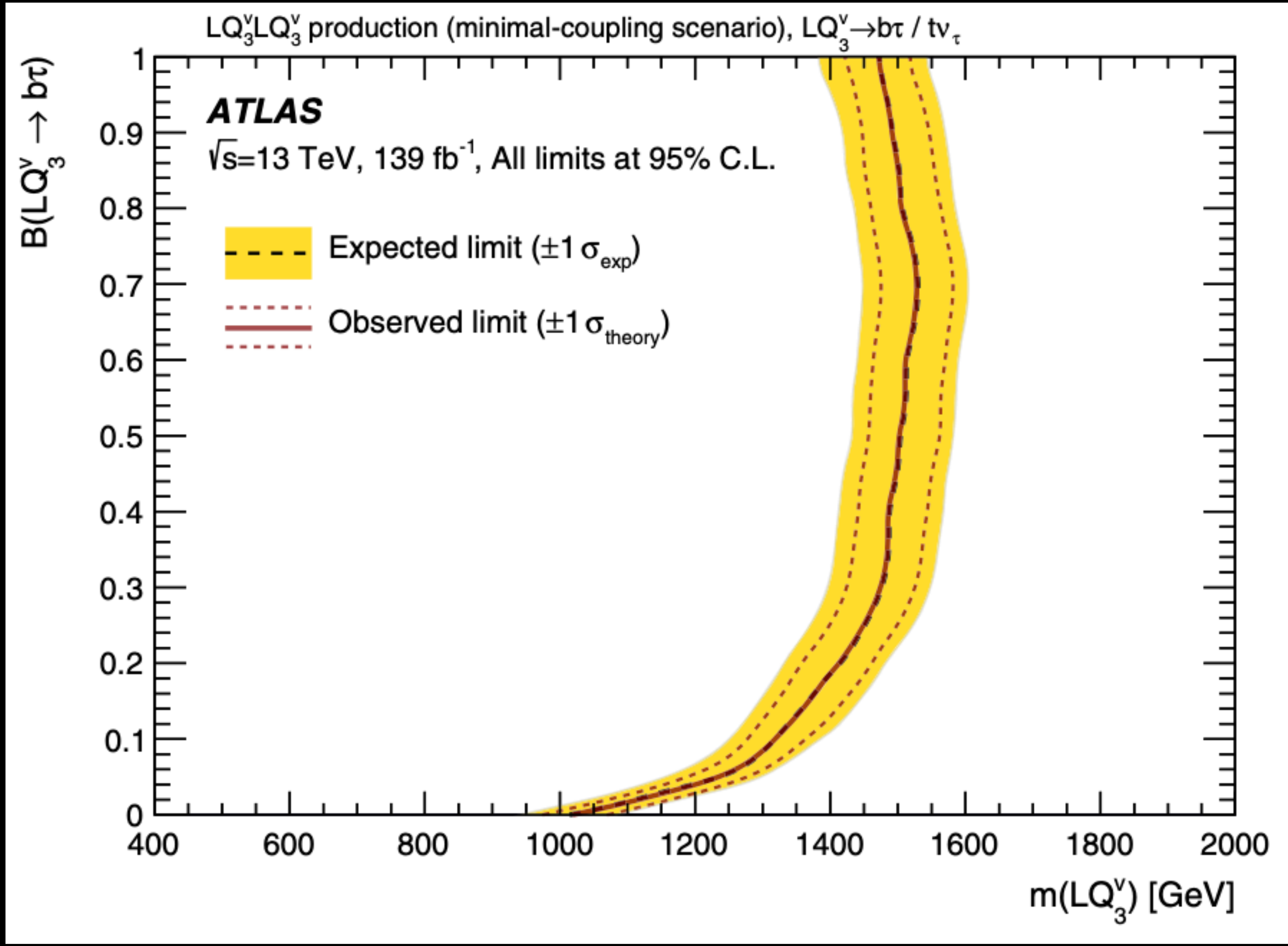


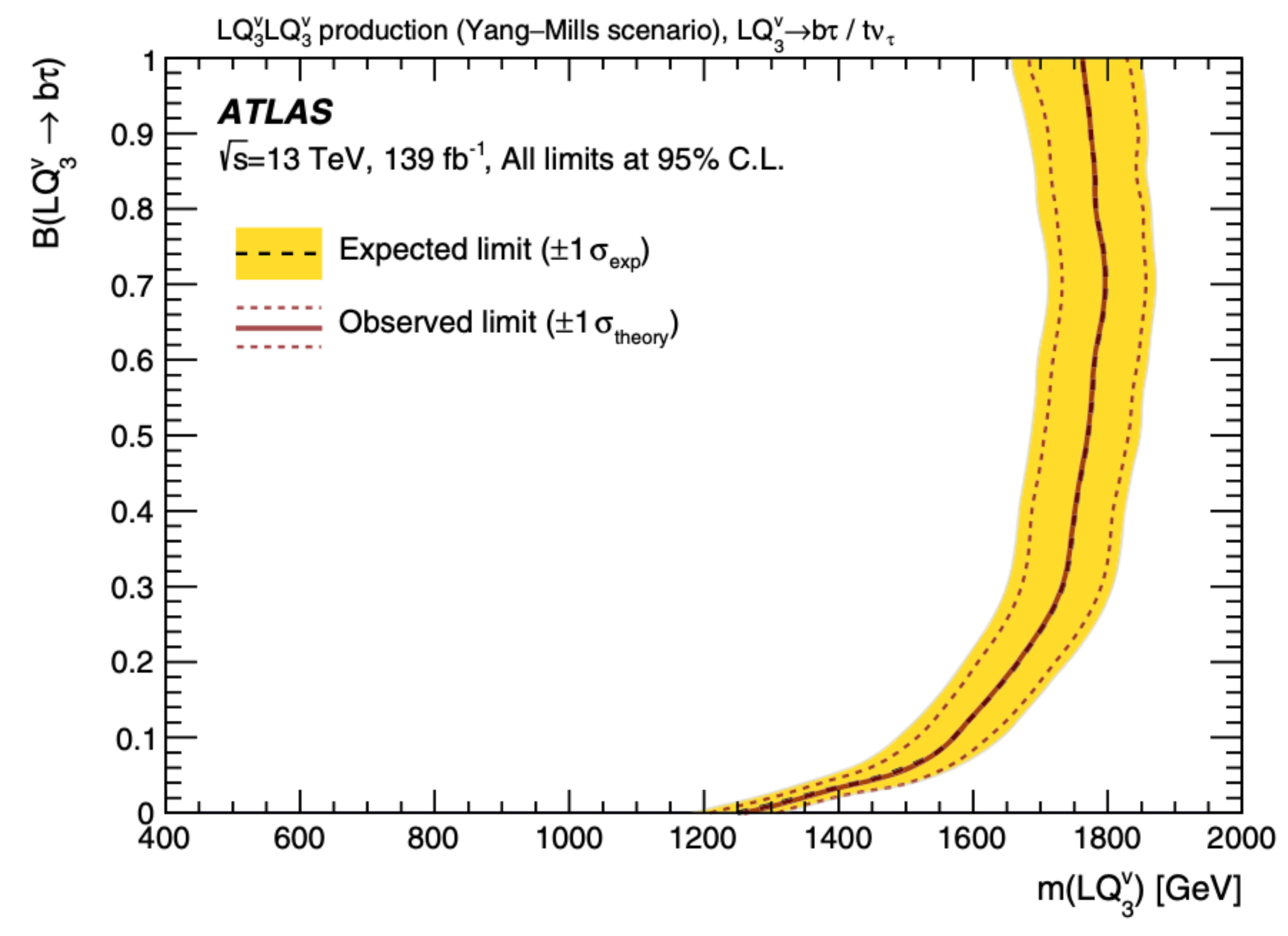
Stop-Stau

	Di-tau SR		Single-tau SR (one-bin)		Single-tau SR (binned in $p_T(\tau)$) [50, 100] GeV		[100, 200] GeV		> 200 GeV	
Observed	2		6		8		6		2	
Total bkg.	4.1	±1.0	3.23	±0.55	10.1	±1.8	5.1	±1.1	2.05	±0.64
$t\bar{t}$ (2 real τ)	0.81	±0.71	—		—		—		—	
$t\bar{t}$ (1 real τ)	0.82	±0.27	1.20	±0.30	4.8	±1.2	2.69	±0.88	0.64	±0.29
$t\bar{t}$-fake	0.51	±0.15	0.69	±0.15	2.83	±0.87	0.66	±0.17	0.185	±0.072
Single top	0.03	$^{+0.10}_{-0.03}$	0.39	$^{+0.45}_{-0.39}$	0.85	$^{+0.86}_{-0.85}$	0.54	±0.54	0.57	±0.56
W + jets	0.08	$^{+0.11}_{-0.08}$	0.35	±0.16	0.34	±0.12	0.64	±0.24	0.37	±0.12
Z + jets	0.35	±0.14	0.187	±0.054	0.275	±0.081	0.043	±0.022	0.123	±0.048
Multiboson	0.48	±0.21	0.085	±0.037	0.163	±0.037	0.111	±0.030	0.030	$^{+0.032}_{-0.030}$
$t\bar{t} + V$	0.60	±0.15	0.242	±0.064	0.65	±0.16	0.31	±0.12	0.092	±0.035
$t\bar{t} + H$	0.28	$^{+0.29}_{-0.28}$	0.039	$^{+0.040}_{-0.039}$	0.10	±0.10	0.060	$^{+0.061}_{-0.060}$	0.028	$^{+0.029}_{-0.028}$
Other top	0.122	±0.067	0.043	±0.022	0.096	±0.074	0.091	±0.049	0.0120	±0.0084

Analysis region	$\langle A\epsilon\sigma\rangle^{95}_{\text{obs}}$ [fb]	S^{95}_{obs}	S^{95}_{exp}	CL_b	$p(s = 0)$	Z
Di-tau SR	0.03	4.1	$5.3^{+2.2}_{-1.5}$	0.18	0.50	0.0
Single-tau one-bin SR	0.06	8.2	$5.1^{+2.1}_{-1.3}$	0.91	0.08	1.37

Exclusion limit (vector leptoquark)





Photon+E_T^{miss}

ATLAS-CONF-2021-028

Single photon trigger with p_T > 140 GeV

	SRL	SRM	SRH
$N_{photons}$	≥ 1	≥ 1	≥ 1
$p_T^{leading-\gamma}$	> 145 GeV	> 300 GeV	> 400 GeV
$N_{leptons}$	0	0	0
N_{jets}	≥ 5	≥ 5	≥ 3
$\Delta\phi(\text{jet}, E_T^{miss})$	> 0.4	> 0.4	> 0.4
$\Delta\phi(\gamma, E_T^{miss})$	> 0.4	> 0.4	> 0.4
E_T^{miss}	> 250 GeV	> 300 GeV	> 600 GeV
H_T	> 2000 GeV	> 1600 GeV	> 1600 GeV
R_T^4	< 0.90	< 0.90	-

Regions	$N_{photons}$	$p_T^{leading\gamma}$ (GeV)	$N_{leptons}$	N_{jets}	N_{b-jets}	$\Delta\phi(\text{jet}, E_T^{miss})$	$\Delta\phi(\gamma, E_T^{miss})$	E_T^{miss} (GeV)	H_T(GeV)	R_T^4
CRQ	≥ 1	> 145	0	≥ 3	-	< 0.4	> 0.4	> 100	> 1600	-
CRW	≥ 1	> 145	≥ 1	≥ 1	0	> 0.4	-	[100, 200]	> 400	-
CRT	≥ 1	> 145	≥ 1	≥ 2	≥ 2	> 0.4	-	[50, 200]	> 400	-
VRL1	≥ 1	> 145	≥ 1	≥ 2	-	> 0.4	-	[50, 200]	> 800	-
VRL2	≥ 1	> 145	≥ 1	≥ 2	-	> 0.4	-	[50, 200]	> 1300	-
VRL3	≥ 1	> 145	≥ 1	≥ 2	-	> 0.4	-	> 200	[600, 1600]	-
VRL4	≥ 1	> 145	≥ 1	≥ 2	-	< 0.4	-	> 200	> 1100	-
VRQ	≥ 1	> 145	0	≥ 3	-	> 0.4	> 0.4	[100, 200]	> 1600	-
VRM1L	≥ 1	> 145	0	≥ 5	-	> 0.4	> 0.4	[100, 200]	> 1600	< 0.90
VRM2L	≥ 1	> 145	0	≥ 5	-	> 0.4	> 0.4	[150, 200]	> 1600	< 0.90
VRM1H	≥ 1	> 300	0	≥ 3	-	> 0.4	> 0.4	[100, 200]	> 1600	-
VRM2H	≥ 1	> 300	0	≥ 3	-	> 0.4	> 0.4	[150, 200]	> 1600	-
VRE	≥ 1	> 145	-	≥ 1	≥ 1	> 0.4	< 0.4	> 200	[100, 1600]	-

Photon+E_T^{miss}

	SRL [%]	SRM [%]	SRH [%]
Total (stat. + syst.) uncertainty	28	25	17
Statistical uncertainty	20	15	12
Jet energy scale and resolution	18	19	4.1
b-tagging calibration	3.2	4.3	3.6
Jet fakes	2.1	2.5	2.3
MC theory	3.6	3.1	10
Electron fakes	1.4	1.9	< 1
Electron/photon energy resolution and scale	5.5	1.1	4.1
Muon reconstruction and identification	2.6	1.8	< 1
Photon ID and isolation	2.6	2.1	1.1
Pile-up reweighting	< 1	1.2	1.0
E_T^{miss} soft-term scale and resolution	< 1	< 1	< 1

Photon+$E_{\mathrm{T}}^{\mathrm{miss}}$

	SRL	SRM	SRH
Observed events	2	0	5
Expected SM events	2.67 ± 0.75	2.55 ± 0.64	2.55 ± 0.44
$t\bar{t}\gamma$	0.70 ± 0.18	0.87 ± 0.18	0.22 ± 0.05
$W\gamma$	0.55 ± 0.37	0.70 ± 0.42	1.08 ± 0.21
γ + jets	0.49 ± 0.29	0.17 ± 0.10	0.07 ± 0.01
$Z(\to \nu\nu)\gamma$	0.31 ± 0.11	0.35 ± 0.12	0.94 ± 0.28
$\gamma\gamma/W\gamma\gamma/Z\gamma\gamma$	0.23 ± 0.11	0.25 ± 0.10	0.08 ± 0.01
Fake photons from e	0.22 ± 0.08	0.04 ± 0.03	0.06 ± 0.04
Fake photons from jets	0.15 ± 0.09	0.14 ± 0.09	0.09 ± 0.07
$Z(\to \ell\ell)\gamma$	0.03 ± 0.03	0.03 ± 0.01	–

Signal Region	N_{obs}	N_{exp}	$\langle\epsilon\sigma\rangle_{\mathrm{obs}}^{95}$ [fb]	$\langle\epsilon\sigma\rangle_{\mathrm{exp}}^{95}$ [fb]	S_{obs}^{95}	S_{exp}^{95}	$p_0(Z)$
SRL	2	2.67 ± 0.75	0.030	$0.034^{+0.019}_{-0.011}$	4.12	$4.7^{+2.6}_{-1.6}$	0.50 (0.00)
SRM	0	2.55 ± 0.64	0.018	$0.032^{+0.018}_{-0.011}$	2.56	$4.4^{+2.5}_{-1.6}$	0.50 (0.00)
SRH	5	2.55 ± 0.44	0.054	$0.034^{+0.019}_{-0.011}$	7.43	$4.7^{+2.6}_{-1.6}$	0.09 (1.36)