

Searches for dark matter, supersymmetry and heavy resonances in ATLAS

Sukanya Sinha

University of Manchester

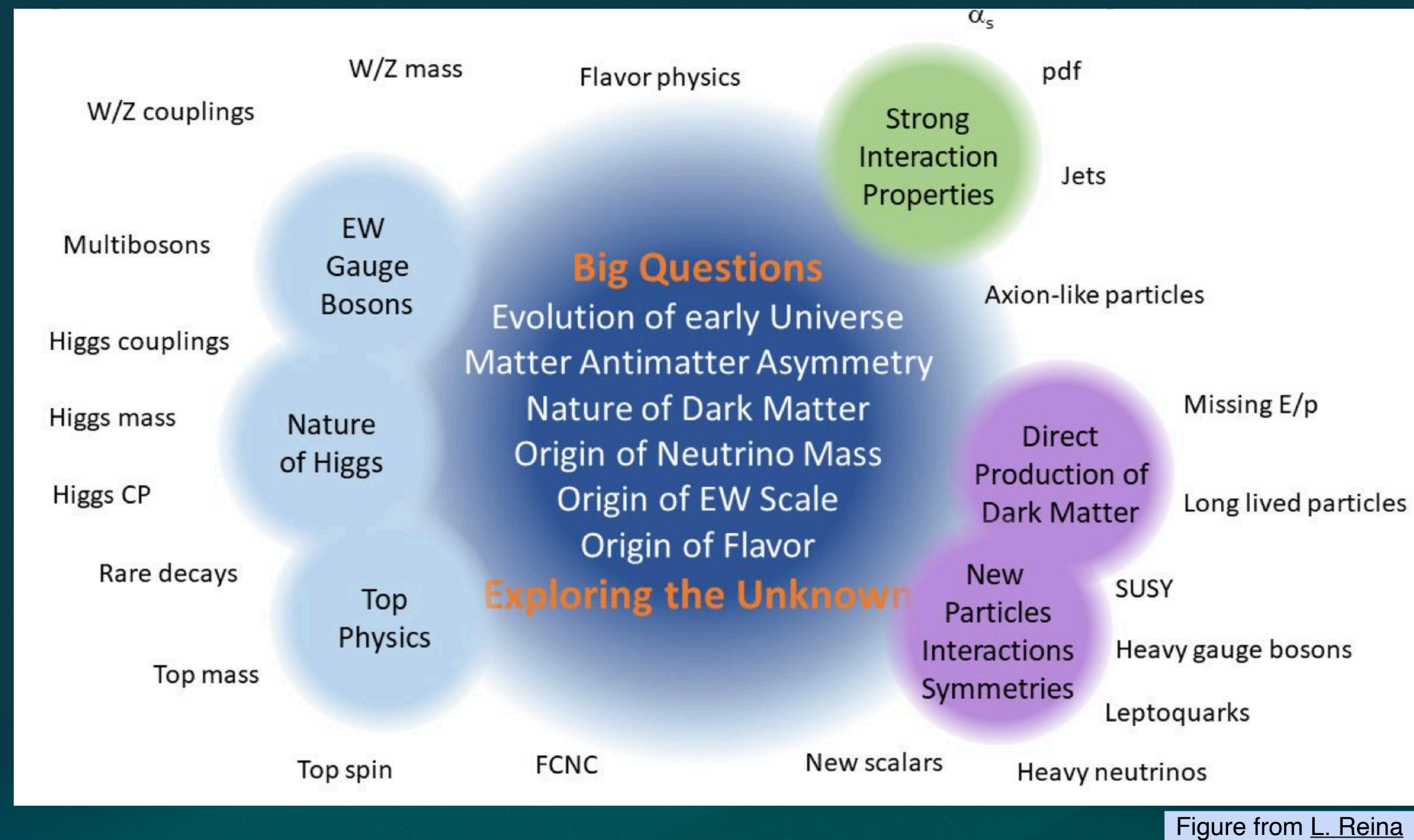
(on behalf of the ATLAS collaboration)

QCD@LHC

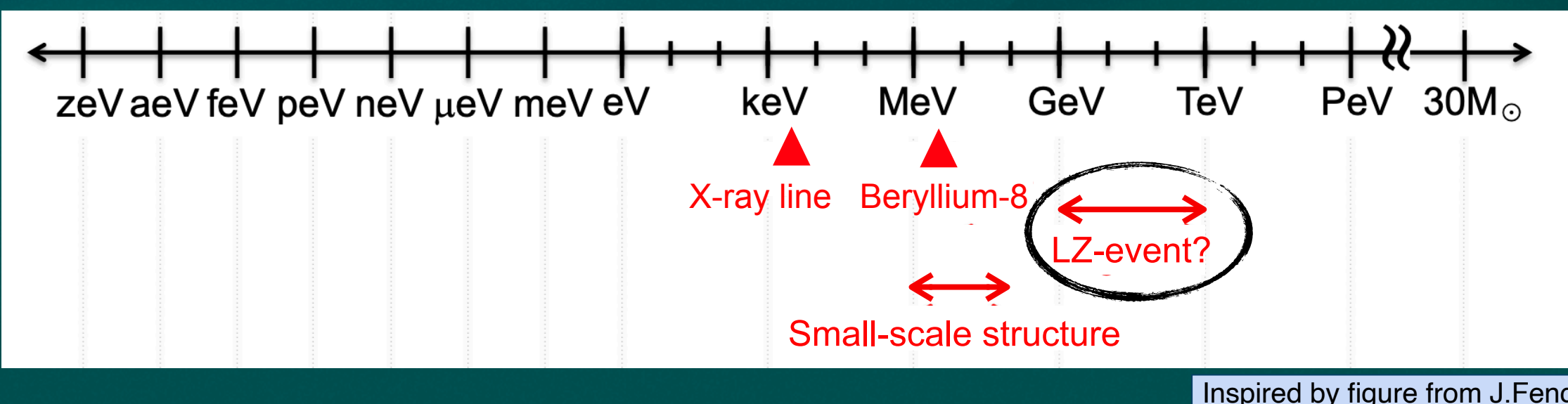
Oxford, 01/10/2026

Why BSM Physics?

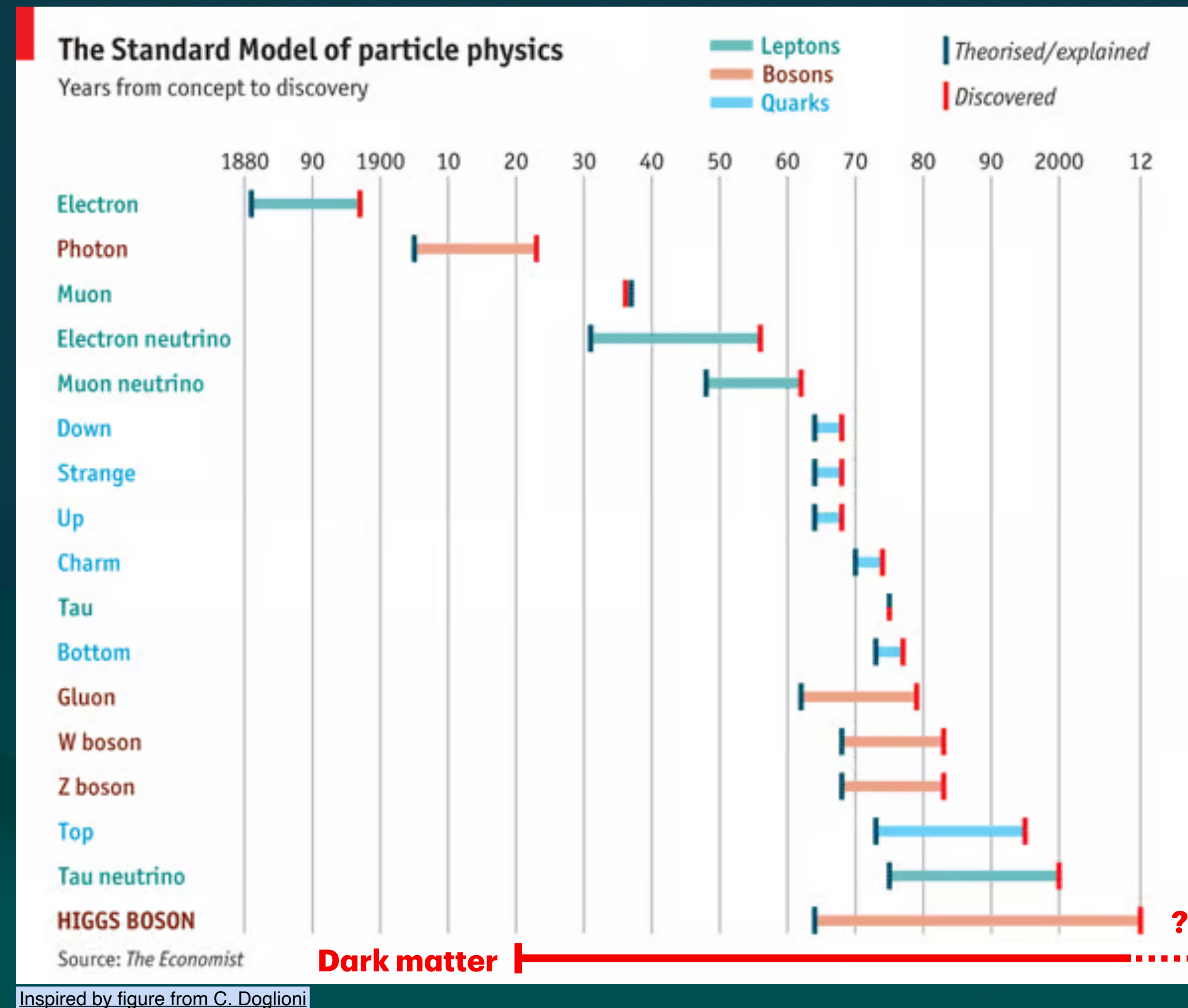
Several open questions that cannot be accommodated in the SM framework



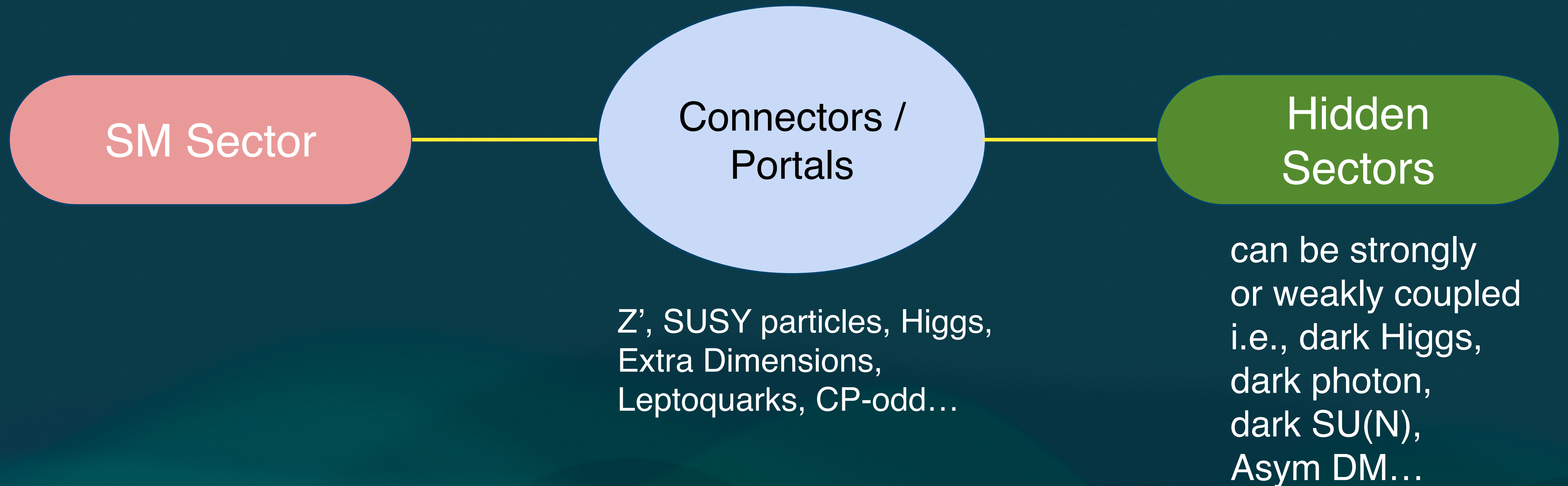
Several anomalies



Hope for unexpected discoveries!



Hidden Sectors



We have not found any concrete sign of new physics ... yet!

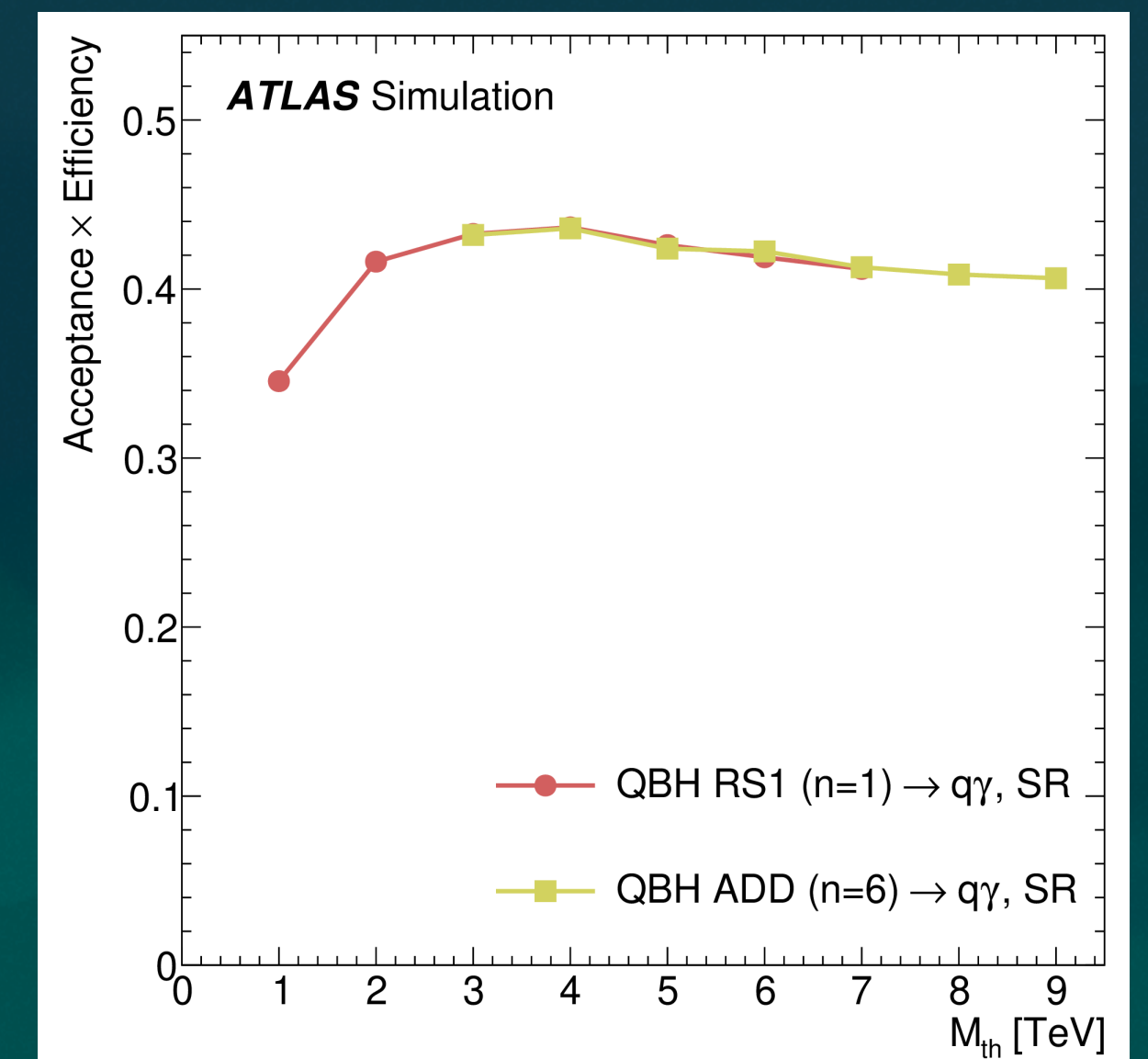
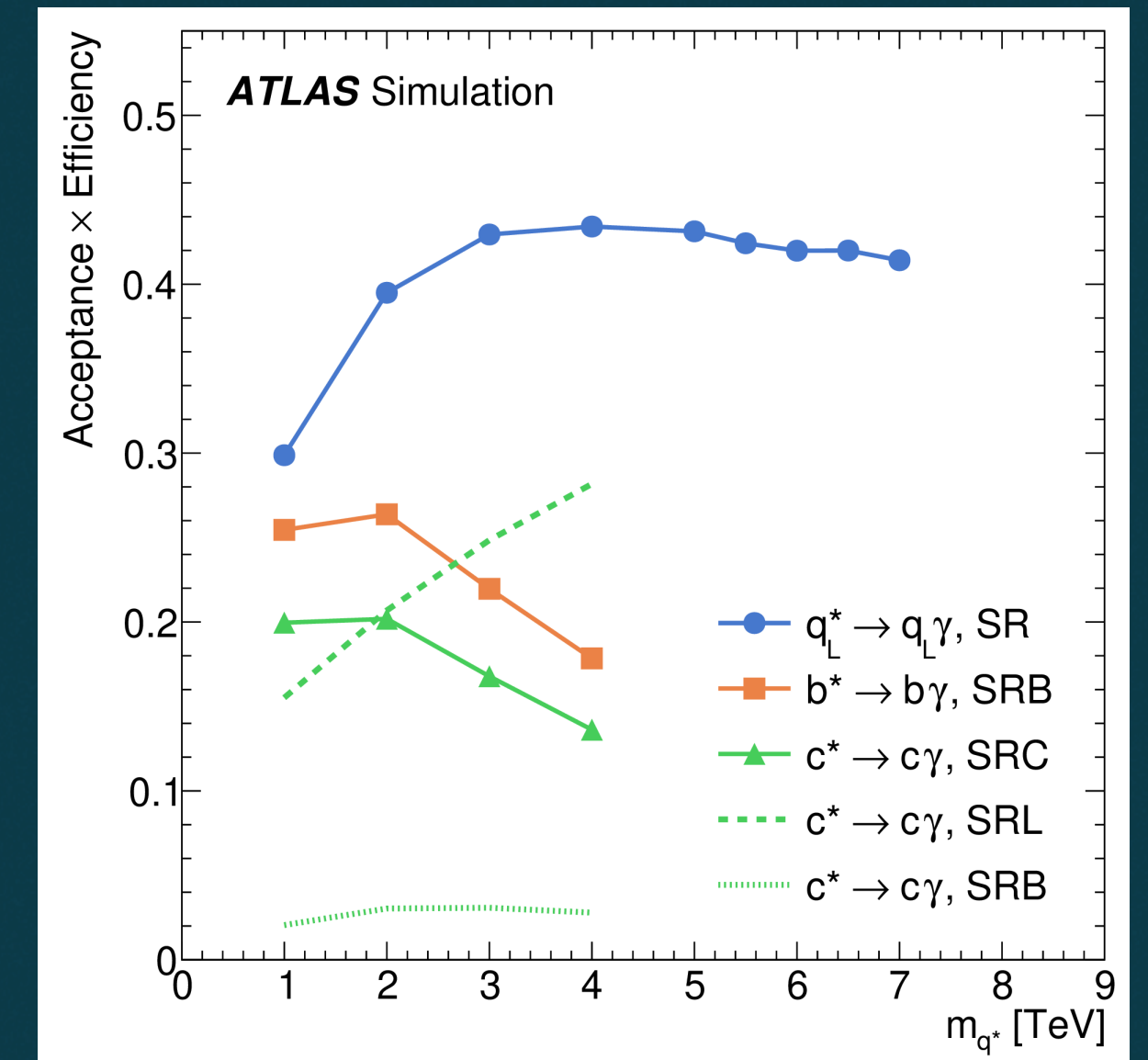
Looking at unusual topologies and hidden corners of the phase space

→ **signature based searches, using benchmark models.**

High-mass resonances in photon+jet final states (Run-2)

[arXiv:2608.26935](https://arxiv.org/abs/2608.26935)

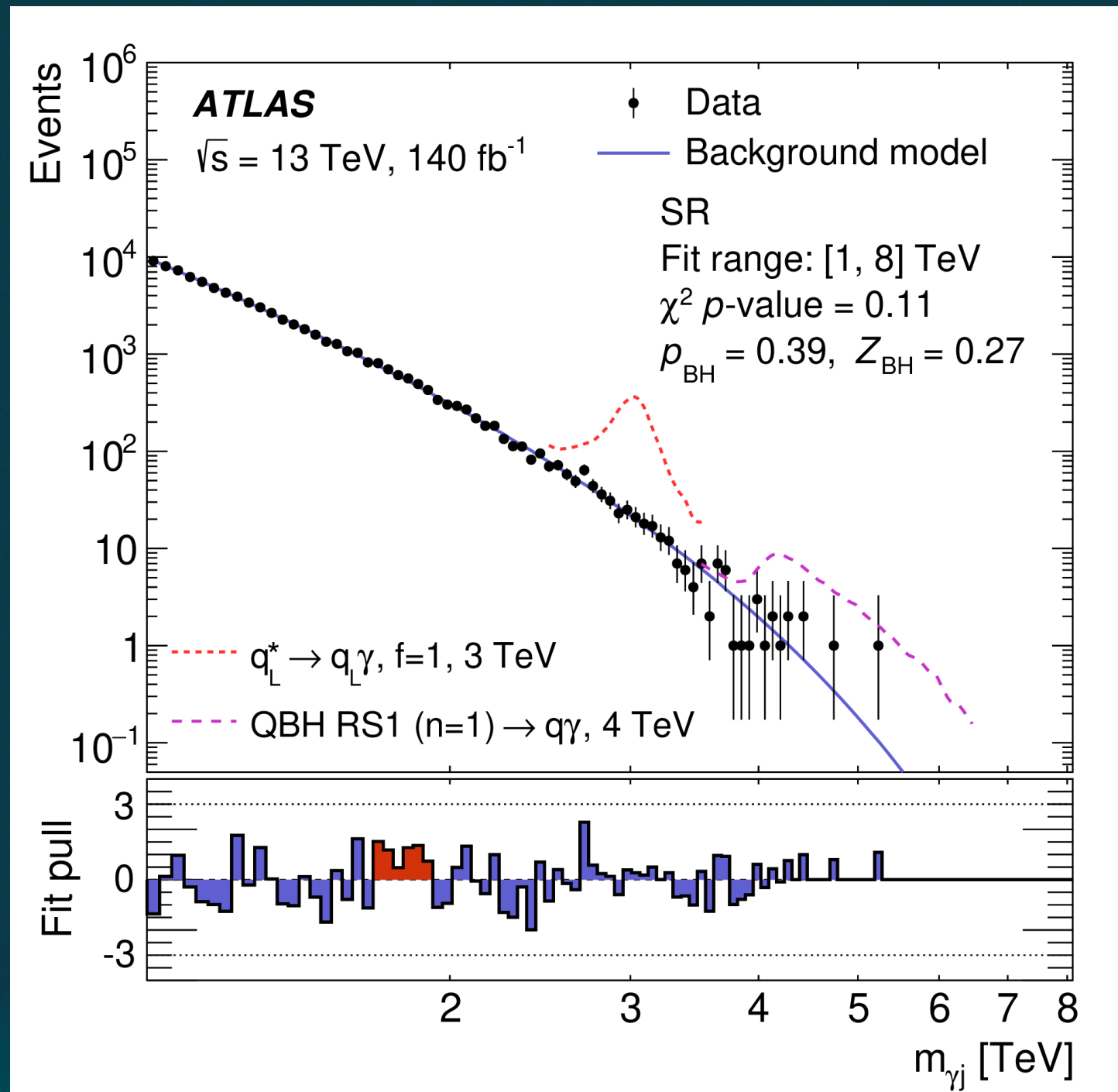
- Search for resonant excess in γ -jet system invariant mass spectrum.
- Signal interpretations on
 - excited quarks with different couplings and flavours (q_L^* , c^* , b^*)
 - non-thermal quantum black holes (QBH) in extra dimensions using RS & AHDD models (n = no.of extra spatial dimensions)
- Analysis requires $p_{T,\gamma} > 150$ GeV, $p_{T,j} > 150$ GeV, $m_{\gamma,j} > 500$ GeV with $|\Delta\eta(\gamma, j)| < 1.6$, $(p_{T,j} - p_{T,\gamma})/p_{T,\gamma} < 0.5$, and $\Delta R_{min}(\gamma, j) > 1.0$
- 4 different signal regions: inclusive SR, SRB(b-tagged), SRC(c-tagged), SRL(light flavour)
- Improved capability to distinguish between jets initiated by light quarks vs heavy quarks, using transformers.
- Distinguishing c -jets remains more challenging $\rightarrow$ signal would populate SRC, SRL and SRB - simultaneous fit approach across multiple signal regions required.



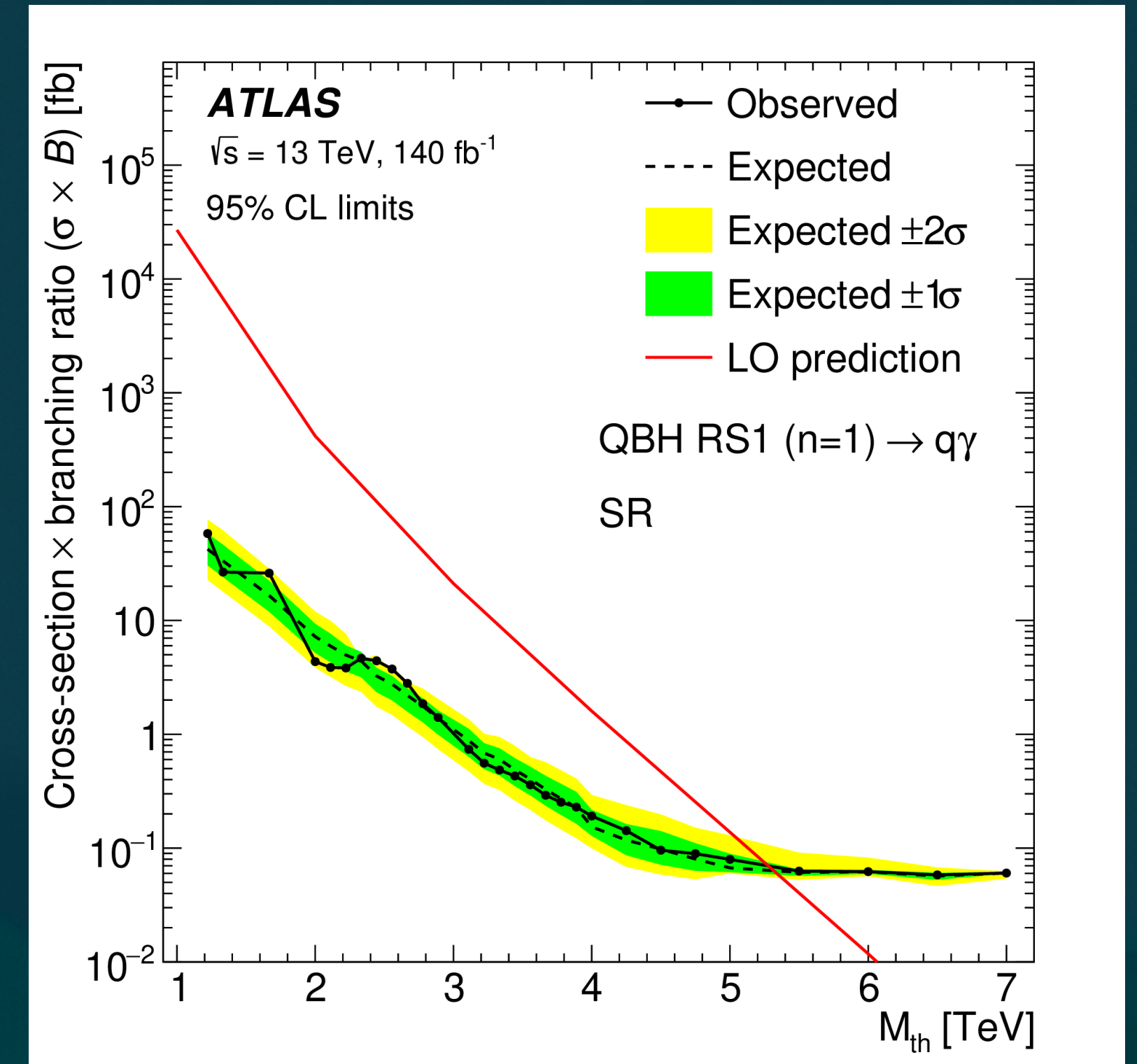
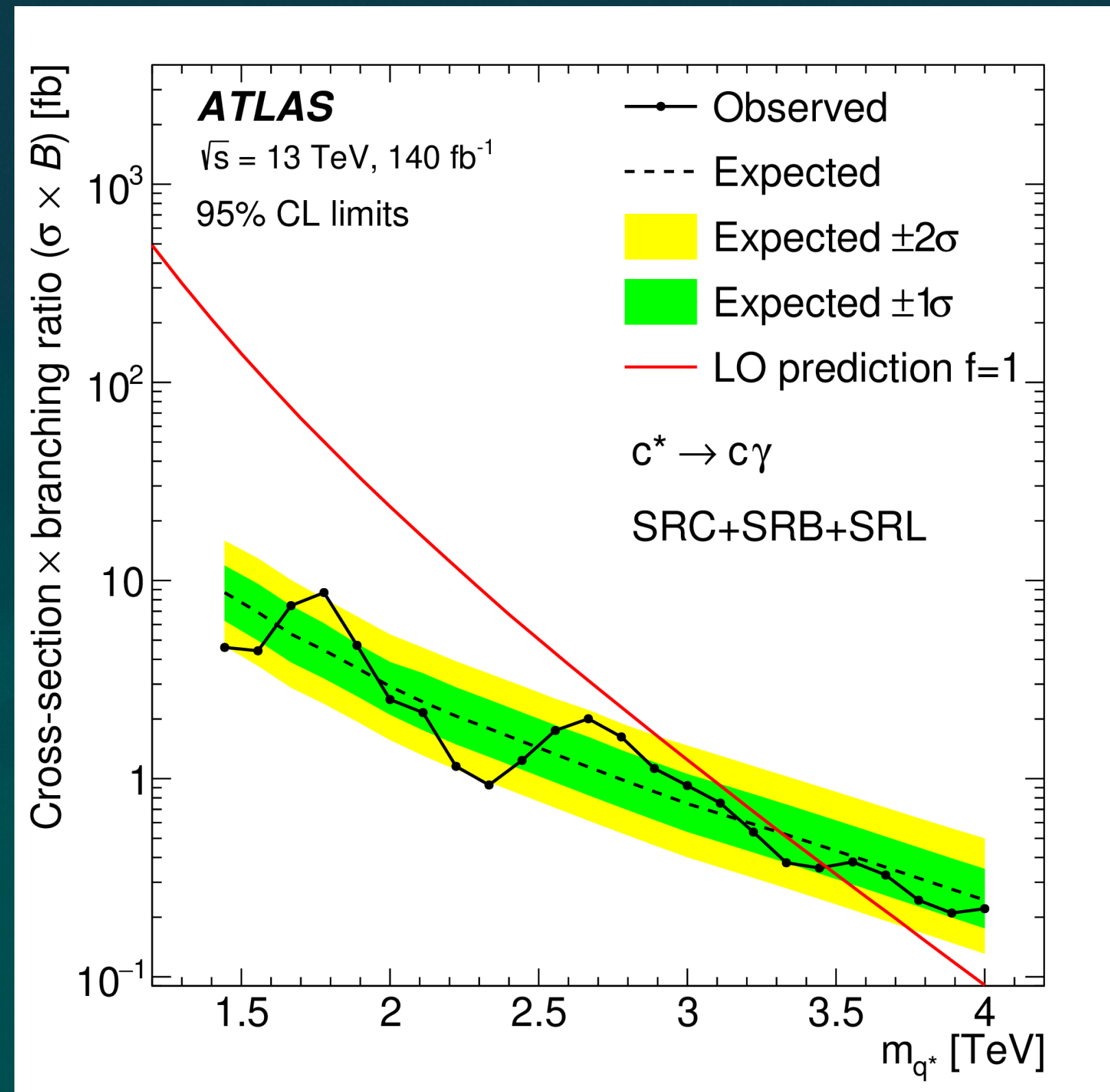
High-mass resonances in photon+jet final states (Run-2): Results

[arXiv:2608.26935](https://arxiv.org/abs/2608.26935)

No significant excess observed.



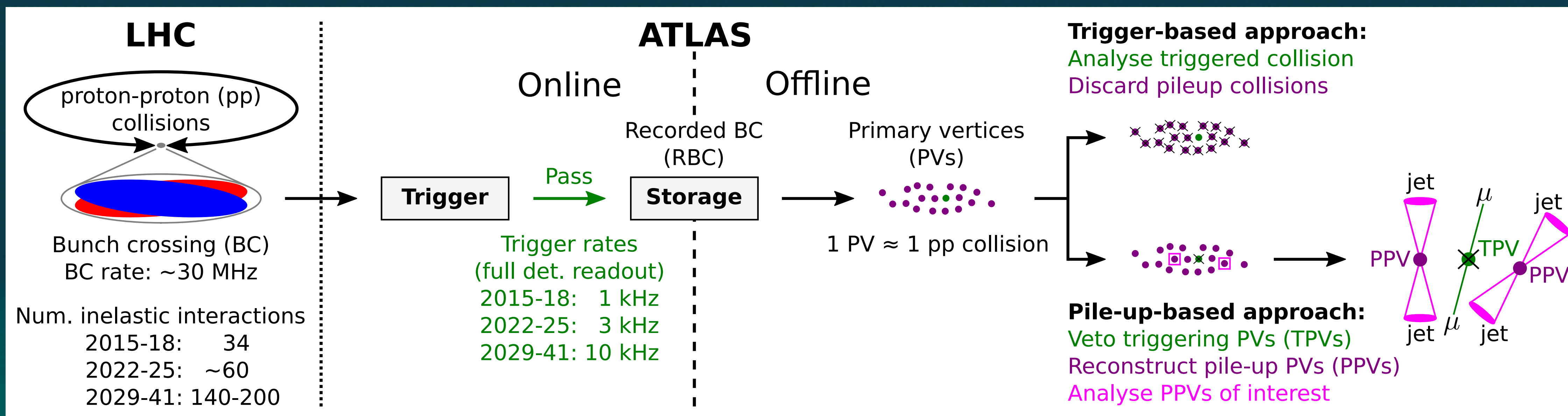
First LHC limits on c^*
in γ -jet final states!



QBH exclusion limits extended
to 5.4 TeV!

Low-mass dijet resonances in pile-up

- New technique recently developed: reconstruction of pile-up collisions to access trigger-unbiased dataset
 - First, identify and remove the collision responsible for firing the trigger
 - Reconstruct jets from all other primary vertices in the bunch crossing — focus on dijet events



[JHEP 12 \(2024\) 032](#)

Low-mass dijet resonances in pile-up (Run-2)

[arXiv:2606.03222](https://arxiv.org/abs/2606.03222)

The pile-up dataset provides large statistics for low-momentum jet topologies

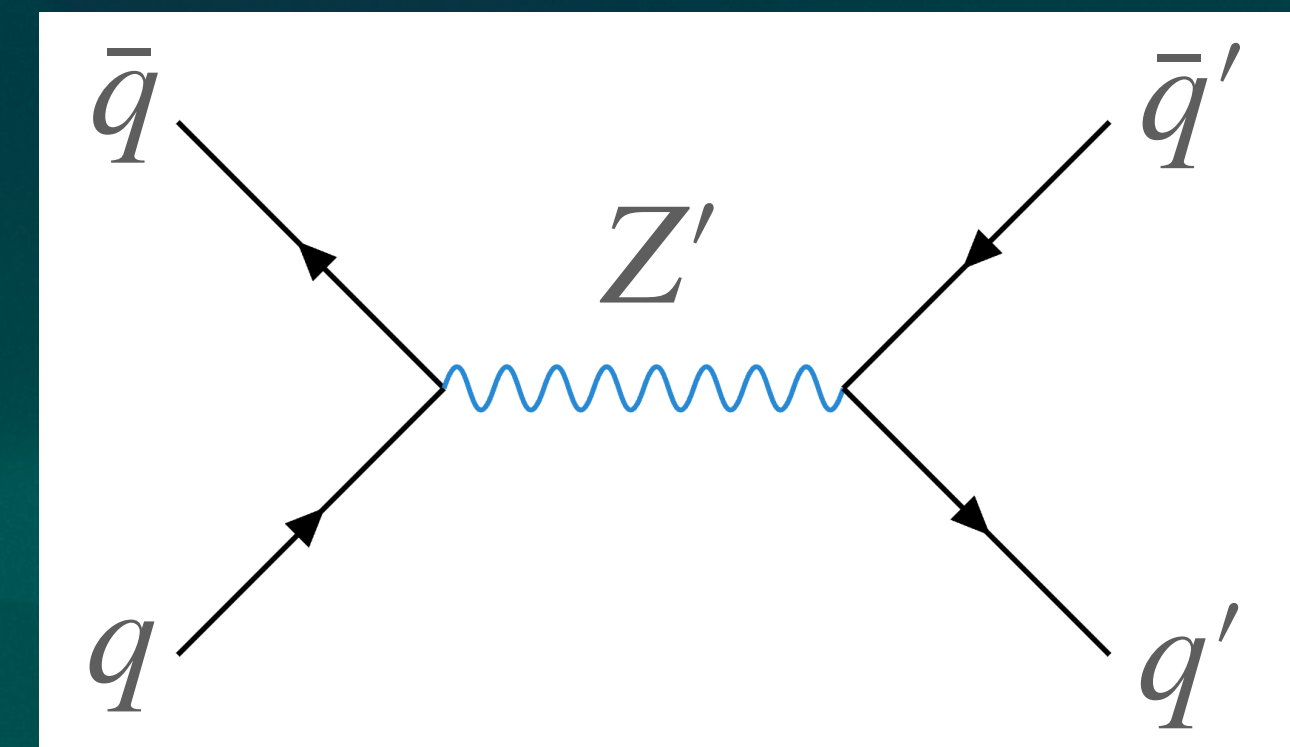
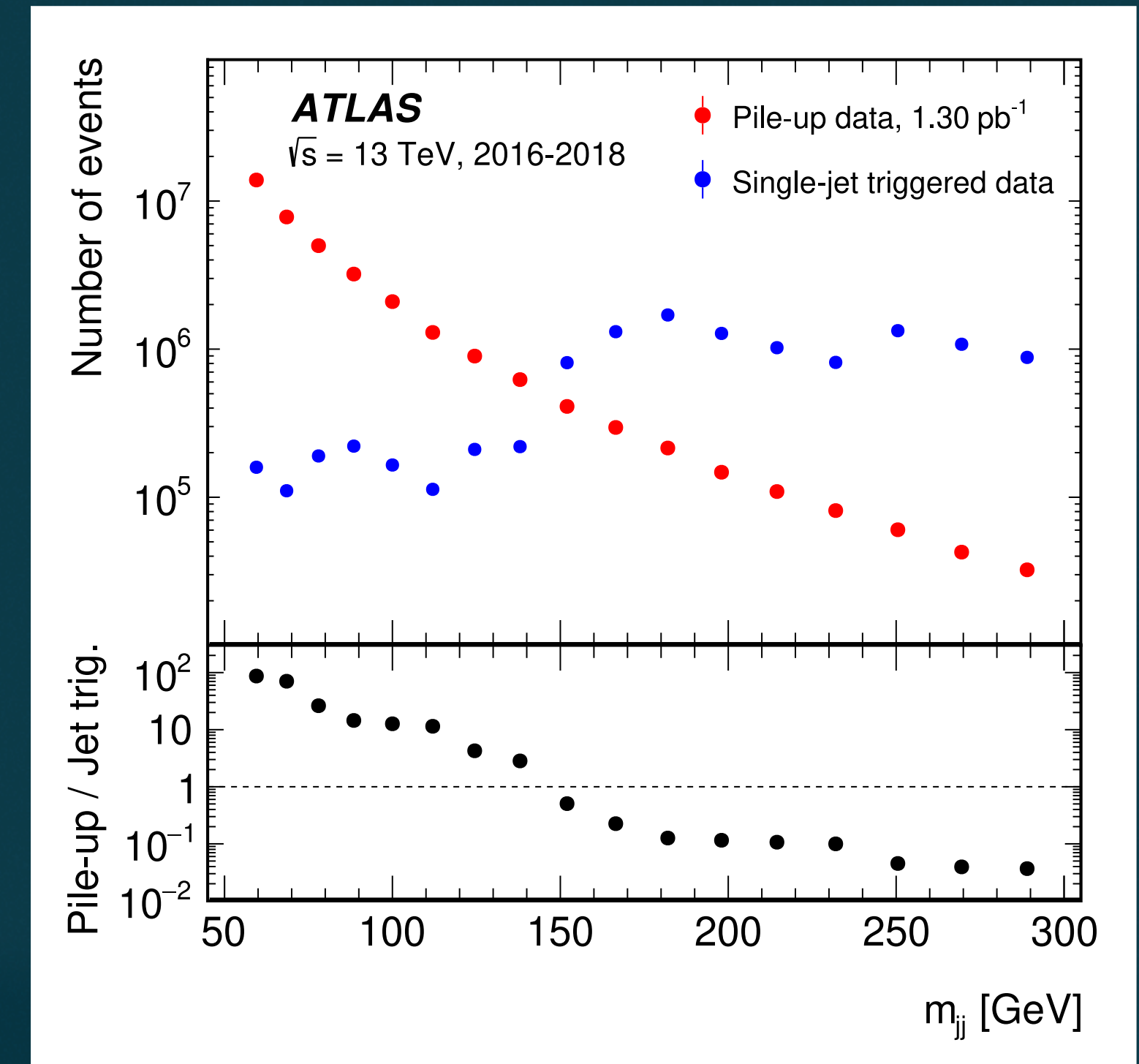
- Up to 100 times more data compared to single-jet triggers
- About 30 times more data than ZeroBias triggers

It can be used for a search for low-mass dijet resonances complementary to other techniques

- Fully generic with sensitivity to scenarios that other searches do not have
- Full object reconstruction with the inclusion of all calibrations

Search for “bump” in dijet mass spectrum in final states with ≥ 2 jets with $p_T^j > 17$ GeV and $|\eta| < 2.0$

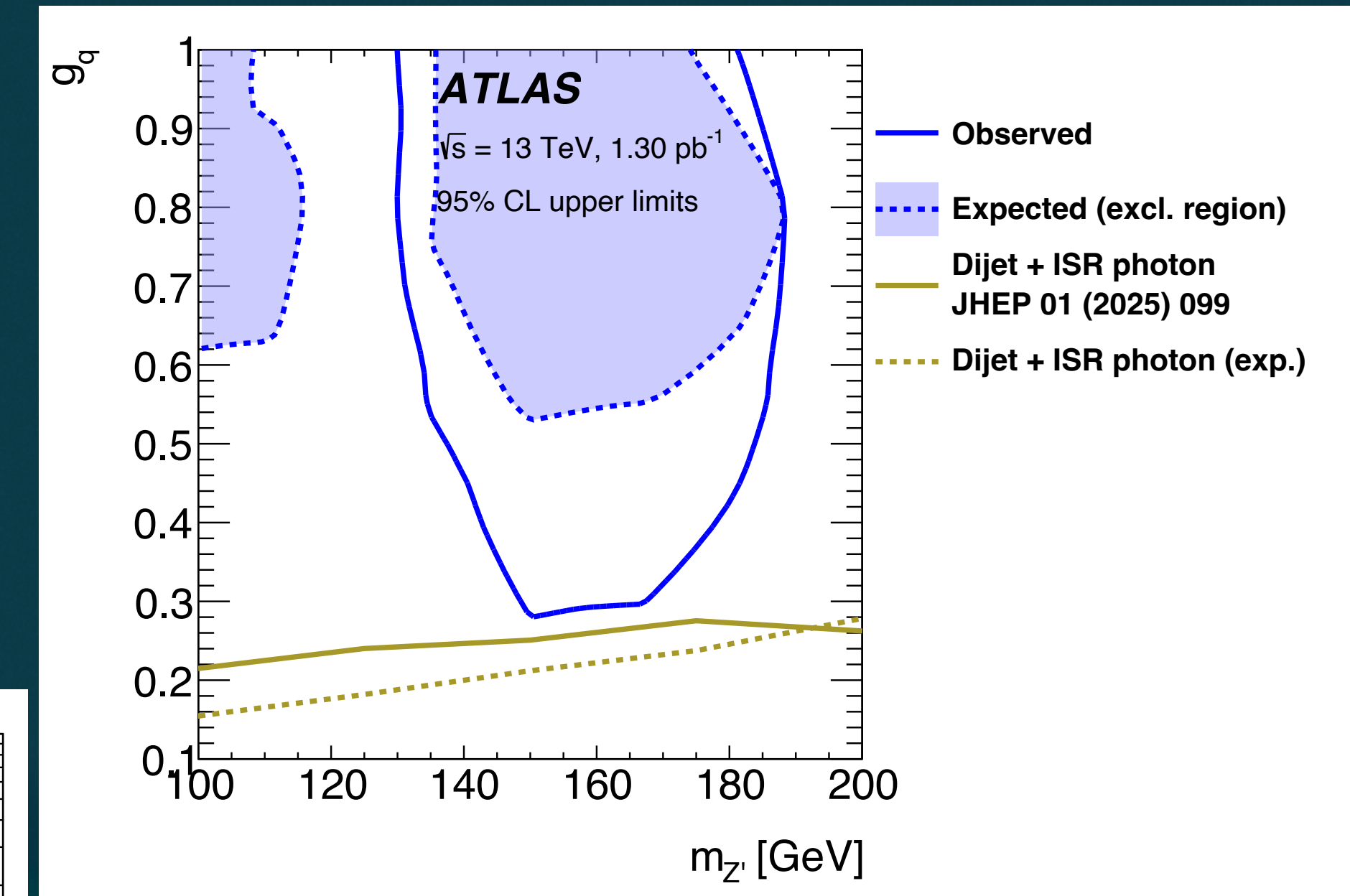
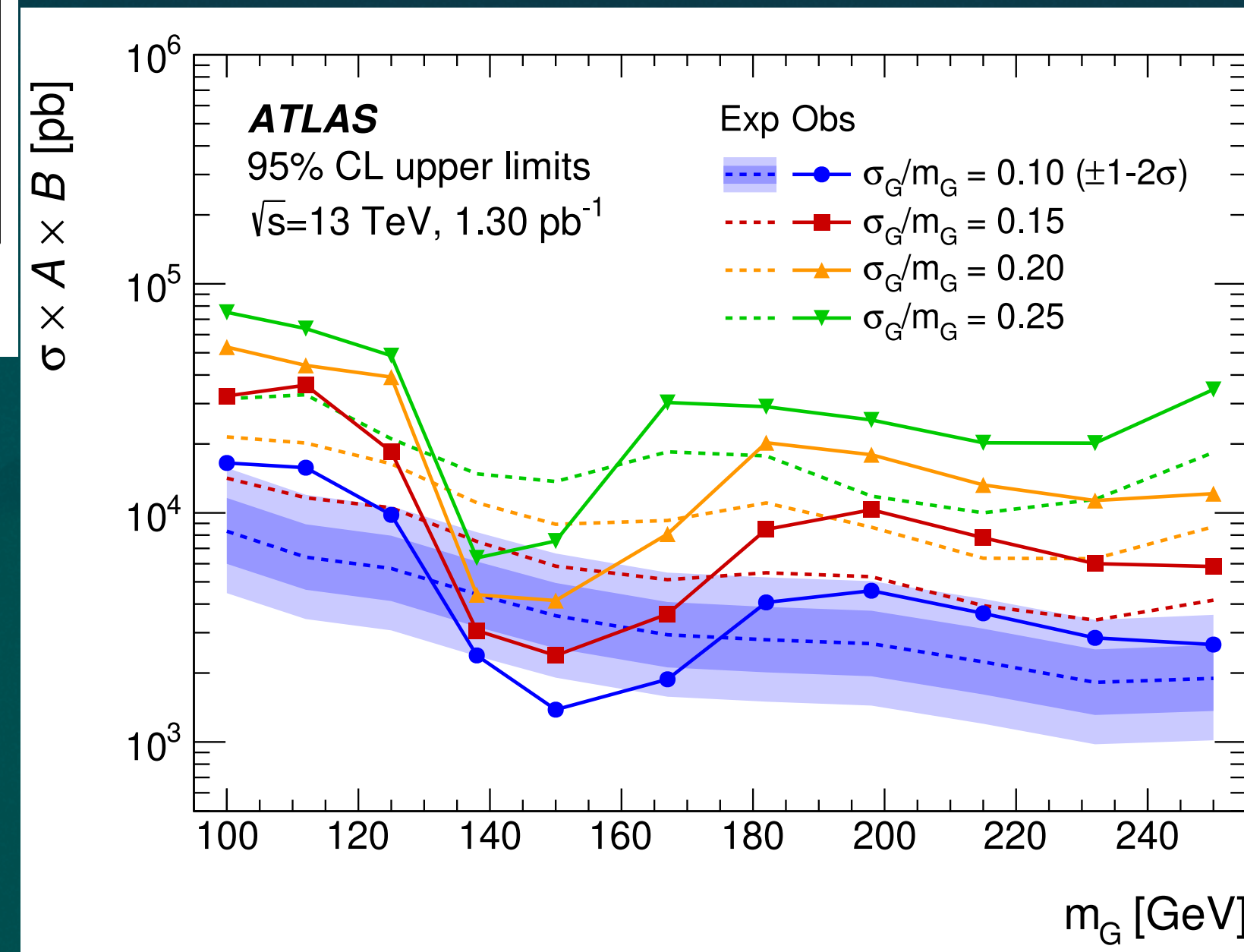
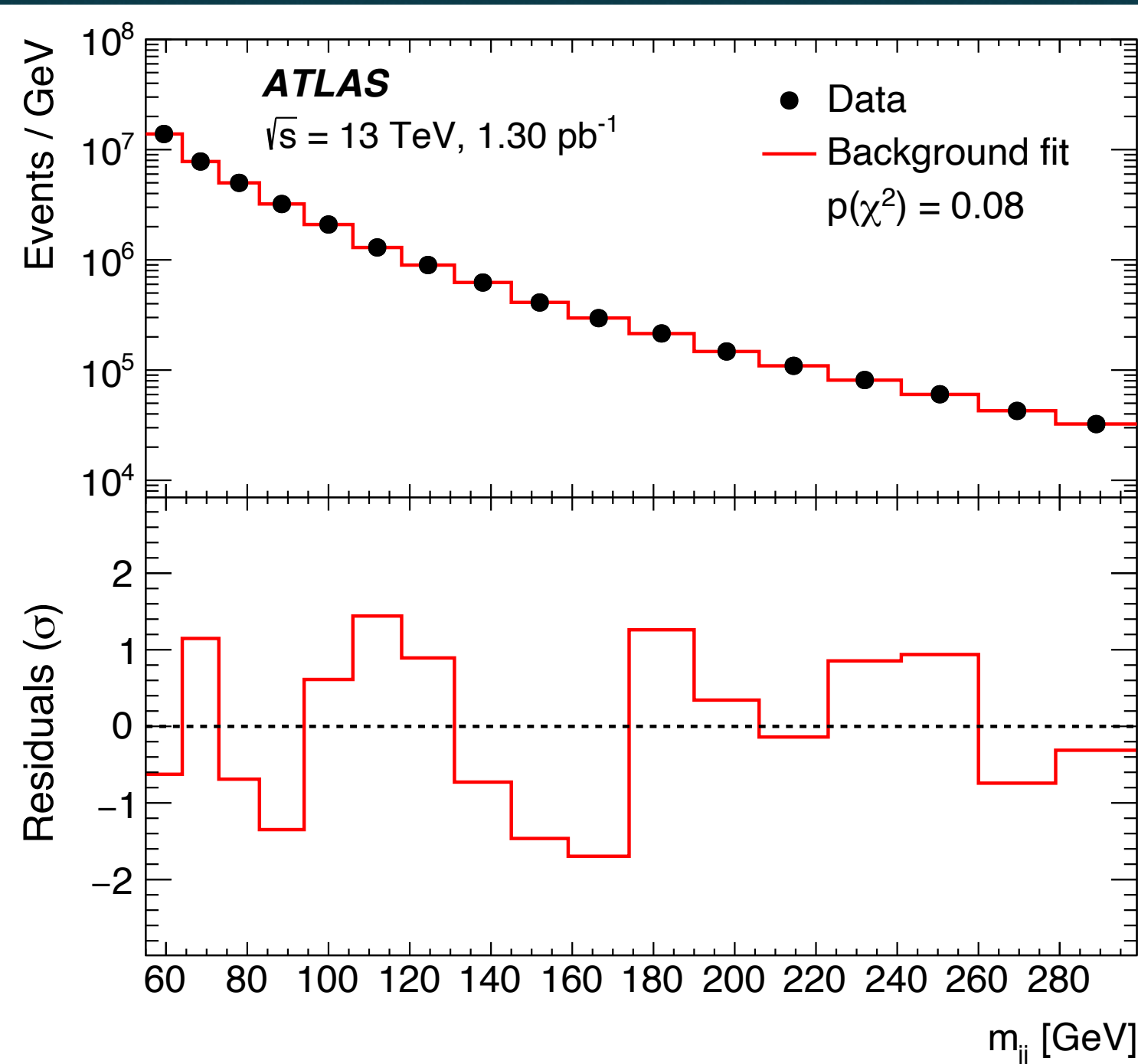
- Additional selection of $|y^*| < 0.8$ to reduce QCD multijet background
- Potentially sensitive to SM W/Z resonant decay, currently at the edge of sensitivity



Low-mass dijet resonances in pile-up (Run-2): Results

[arXiv:2606.03222](https://arxiv.org/abs/2606.03222)

No excess found $\rightarrow$ exclusion limits for Z' and generic Gaussian-like bumps



For simplified dark matter models,
 $m_{Z'} = 135 - 185 \text{ GeV}$ are excluded
for quark couplings $g = 0.6$

Lowest excluded coupling $g = 0.28$
at $m_{Z'} = 150 \text{ GeV}$

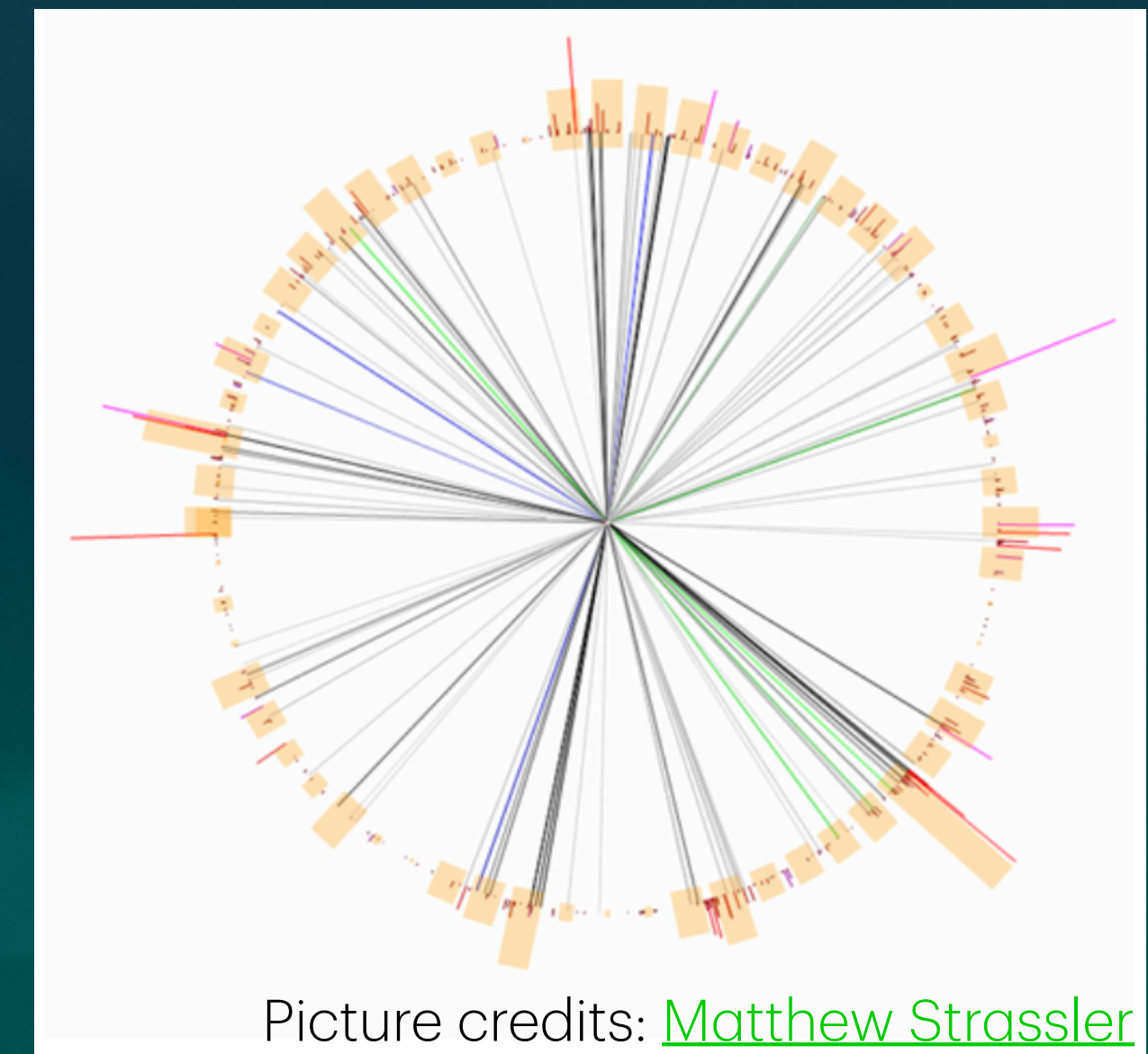
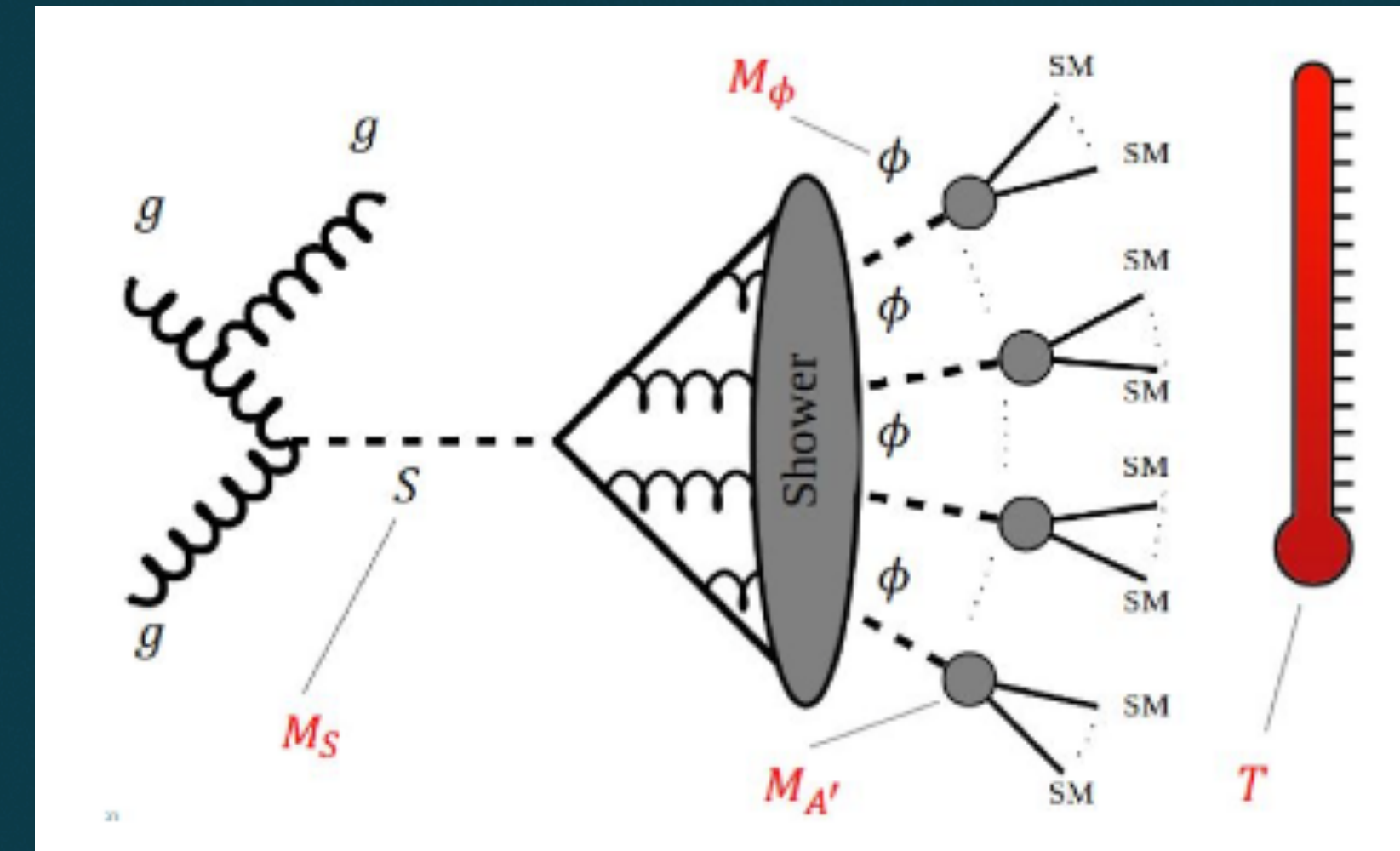
Soft Unclustered Energy Patterns

[arXiv:2605.20015](https://arxiv.org/abs/2605.20015)

Quasi-conformal dark sector with large 't Hooft coupling $\lambda \equiv g^2 N_{\text{colours}} \gg 1$

- Showering process is efficient over a larger energy range than SM QCD
- Momenta of dark mesons expected to follow approximately thermal distribution $\rightarrow$ modeled using Maxwell-Boltzmann spectrum parameterized by temperature, T .
- Other model parameters: Scalar mass (M_S), dark pseudo-scalar mesons mass (M_ϕ), dark photon mass ($M_{A'}$)
- Typical jet structures may be absent
 - $\rightarrow$ Emission of many low pt particles, i.e. signatures with isotropic distribution of soft particles
 - $\rightarrow$ Very challenging to reconstruct experimentally

Analysis targets scenarios scalar mediator produced via ggF ($S = 125, 400$ and 750 GeV) and decays into a quasi-conformal hidden sector with dark mesons ϕ decaying into pairs of dark photons A'



Soft Unclustered Energy Patterns (Run 2)

[arXiv:2605.20015](https://arxiv.org/abs/2605.20015)

Complementary searches by CMS target hadronic SUEPs produced together with high-momentum particles

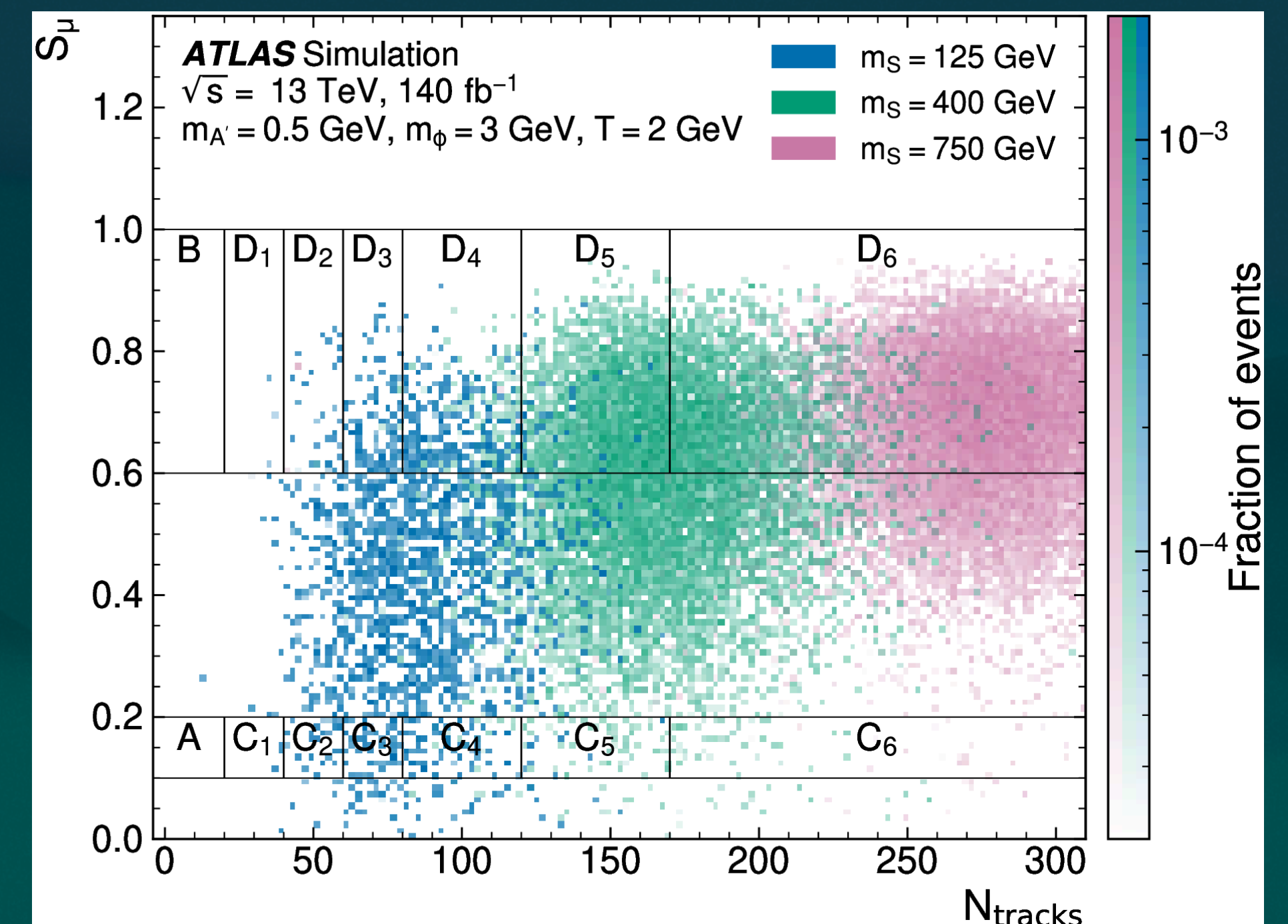
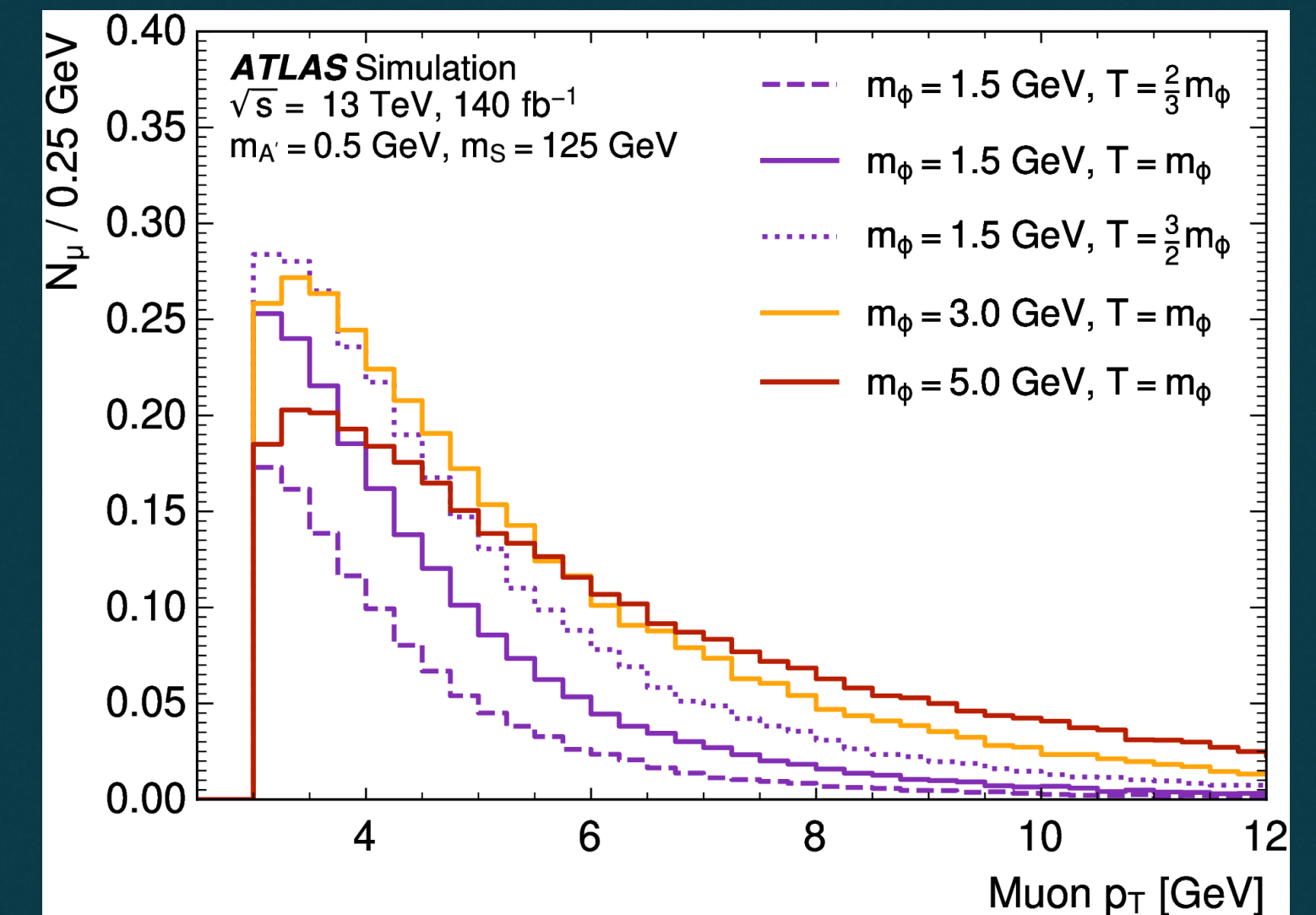
This search:

- A' decay to SM particles ($e/\mu/\pi$) with mass-dependent BRs
- Exploit $A' \rightarrow \mu^+ \mu^-$ decays for triggering and analysis

Analysis selects events with low-momentum multi-muon triggers

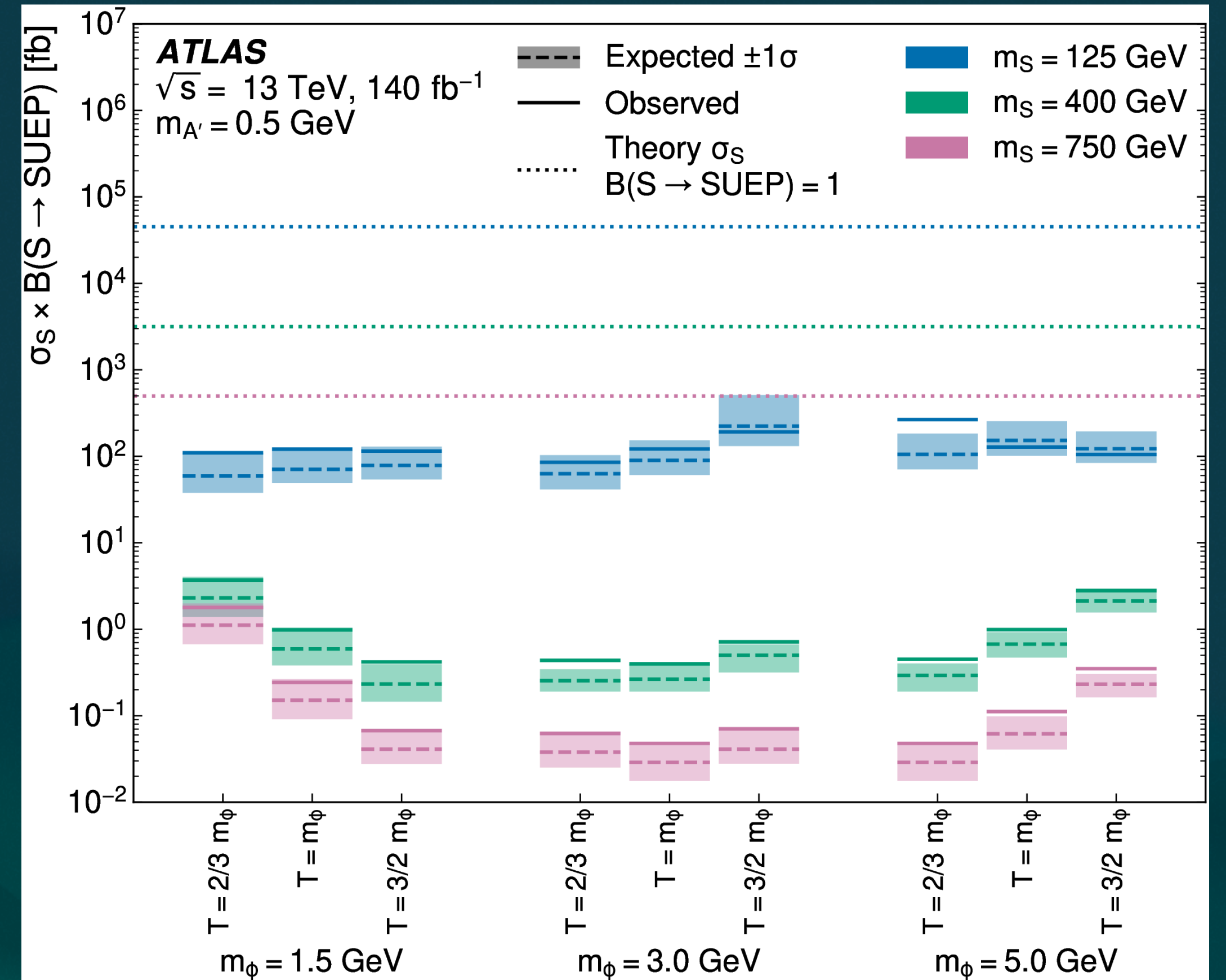
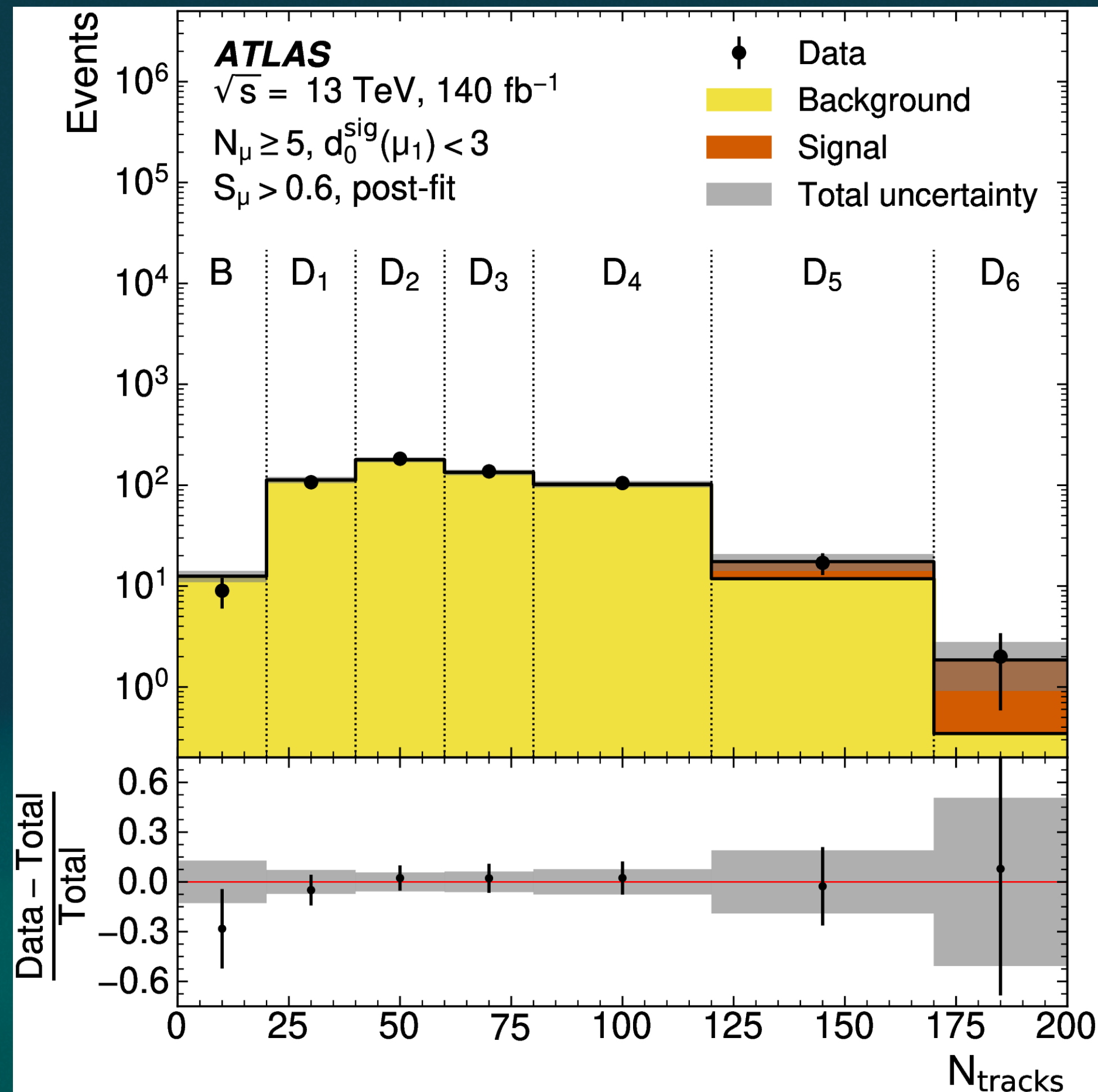
- Further require $N_\mu \geq 5$ and $\langle p_T^\mu \rangle < 10$ GeV to suppress background
- Small transverse impact-parameter significance of leading muon to suppress heavy-flavor particle displaced decays into muons

Background modelling with ABCD method parameterised in muon sphericity and number of tracks



Soft Unclustered Energy Patterns (Run 2): Results

No significant excess found. First limits on SUEPs in multi-muon final state!

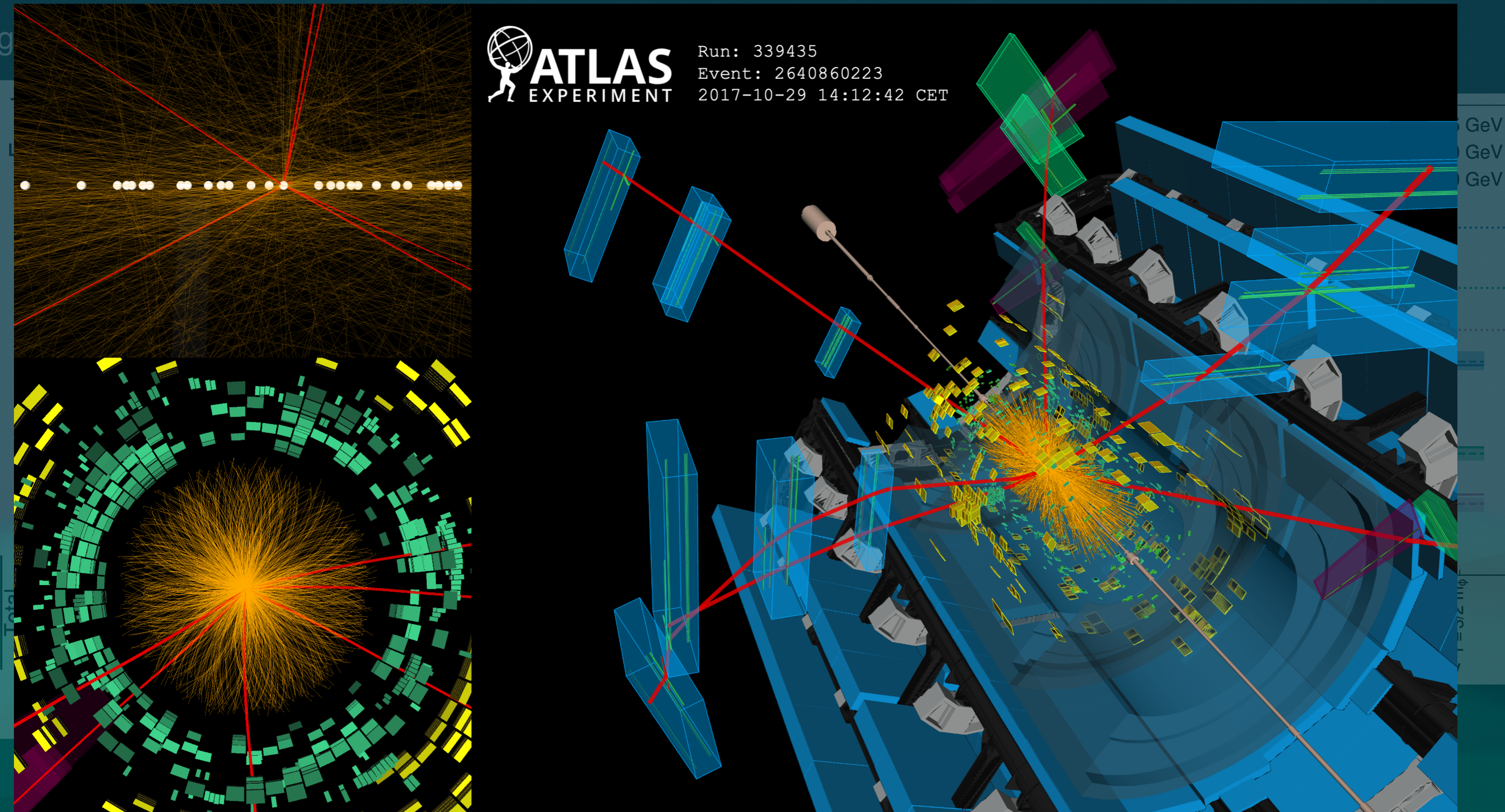


Exclusions set for 0.05 fb for a mediator mass of $m = 750 \text{ GeV}$, 0.4 fb for $m = 400 \text{ GeV}$, and 70 fb for $m = 125 \text{ GeV}$, upper limit on $\text{BR}(H \rightarrow \text{SUEP}) \sim 0.2\%$

Soft Unclustered Energy Patterns (Run 2): Results

No sig

Data - Total



R-Parity Violating SUSY (Full Run-2 + Partial Run-3)

[Phys. Rev. D 114 \(2026\) 052007](#)

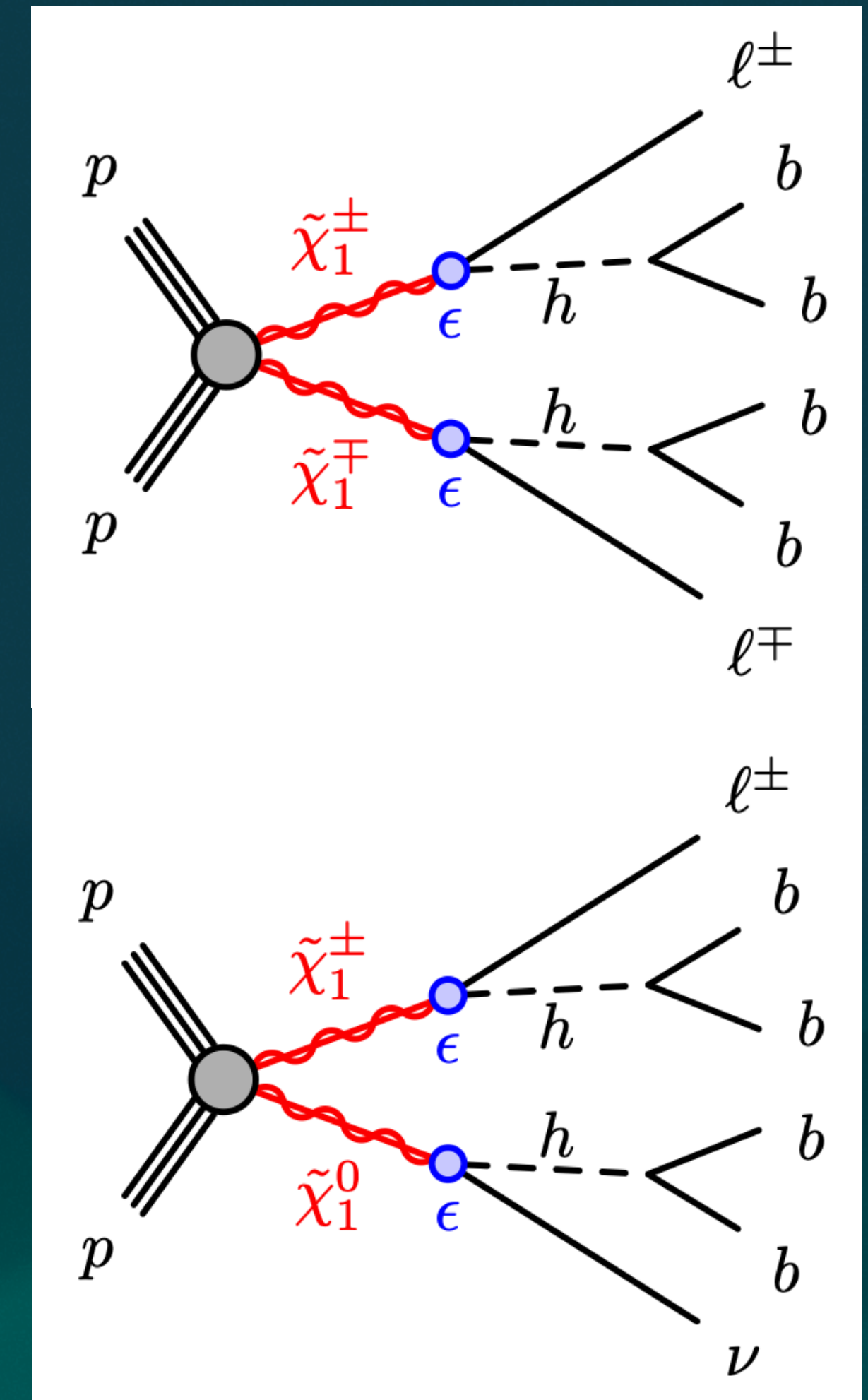
Search for charginos and neutralinos, motivated by MSSM extended with gauged $B-L$ symmetry $\rightarrow B-L$ symmetry broken by RH sneutrino acquiring VEV $\rightarrow$ spontaneously breaks R-parity (Allows for existence of single type of SUSY particles)

Analysis targets Higgs channel, with branching fractions expected above 80% in most scenarios of the model. $h \rightarrow b\bar{b}$ (58% of decays)

Chargino pair: Both Higgs-lepton assignments are tried, and one giving smaller mass asymmetry is kept.

$$A_C = \frac{|m_{C1} - m_{C2}|}{m_{C1} + m_{C2}}$$

Chargino-neutralino: Only transverse mass of neutralino ($m_{N,T}$) can be built, since neutrino's longitudinal momentum is unknown. Pairing chosen maximises ΔR between Higgs candidate and lepton.

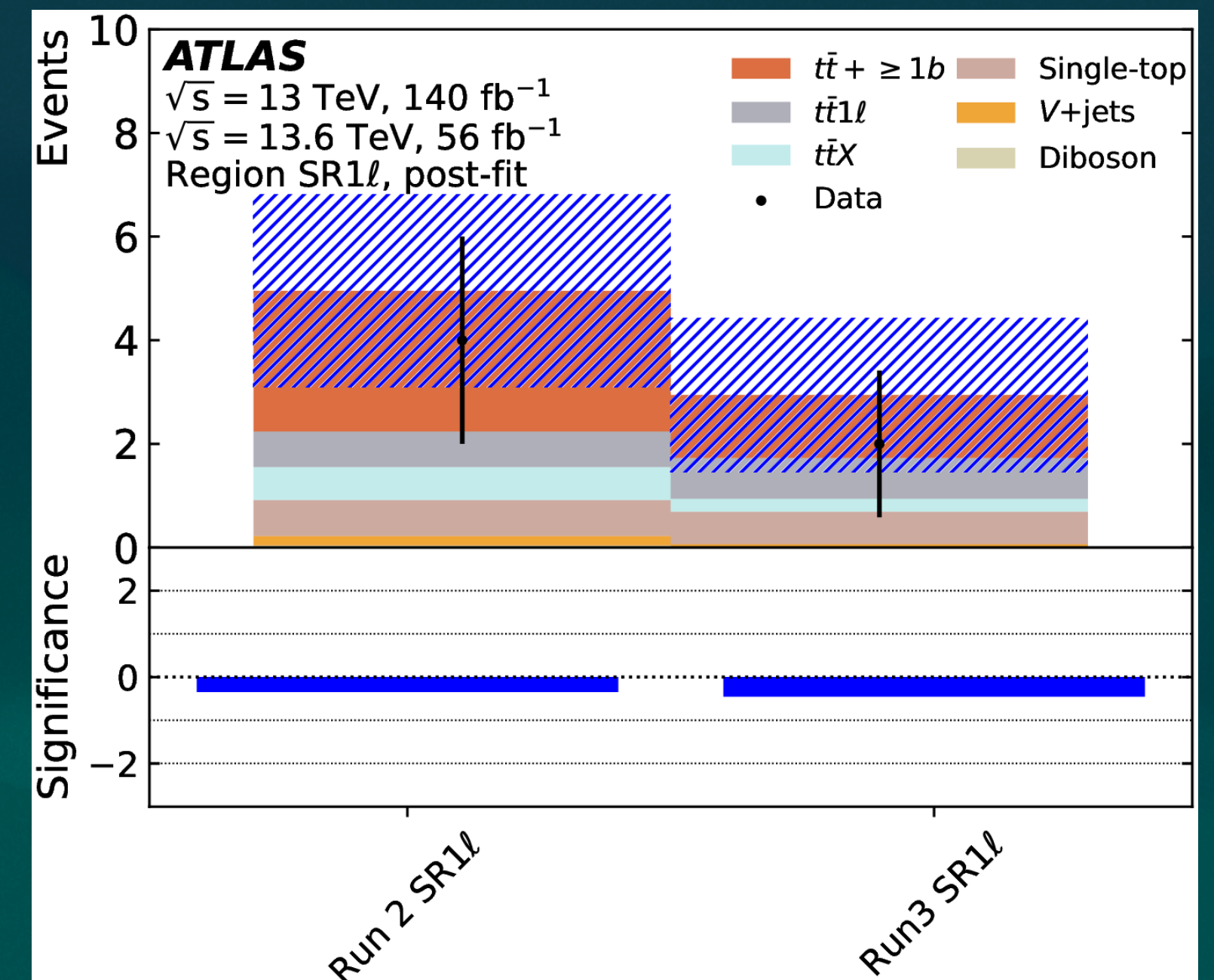
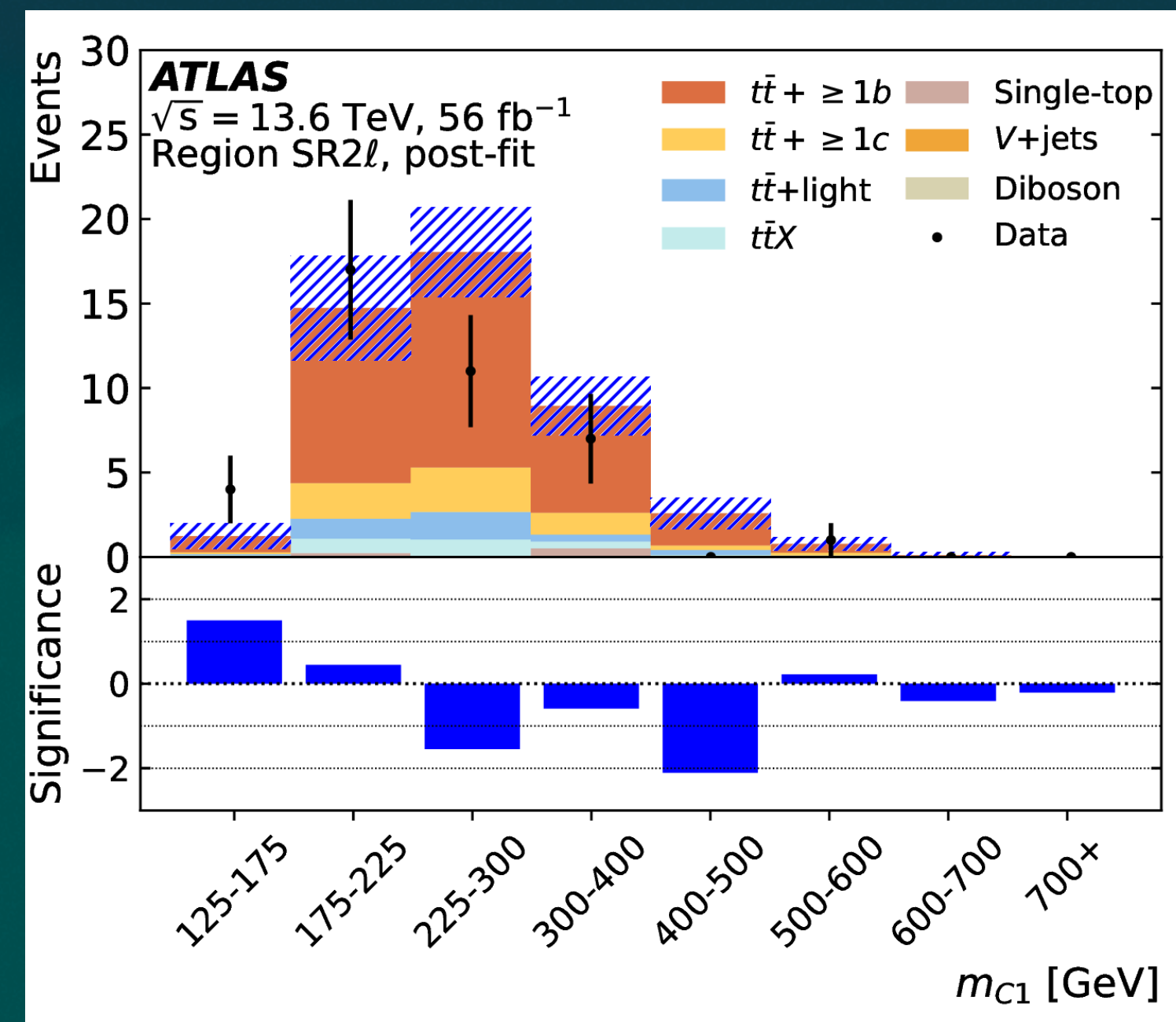
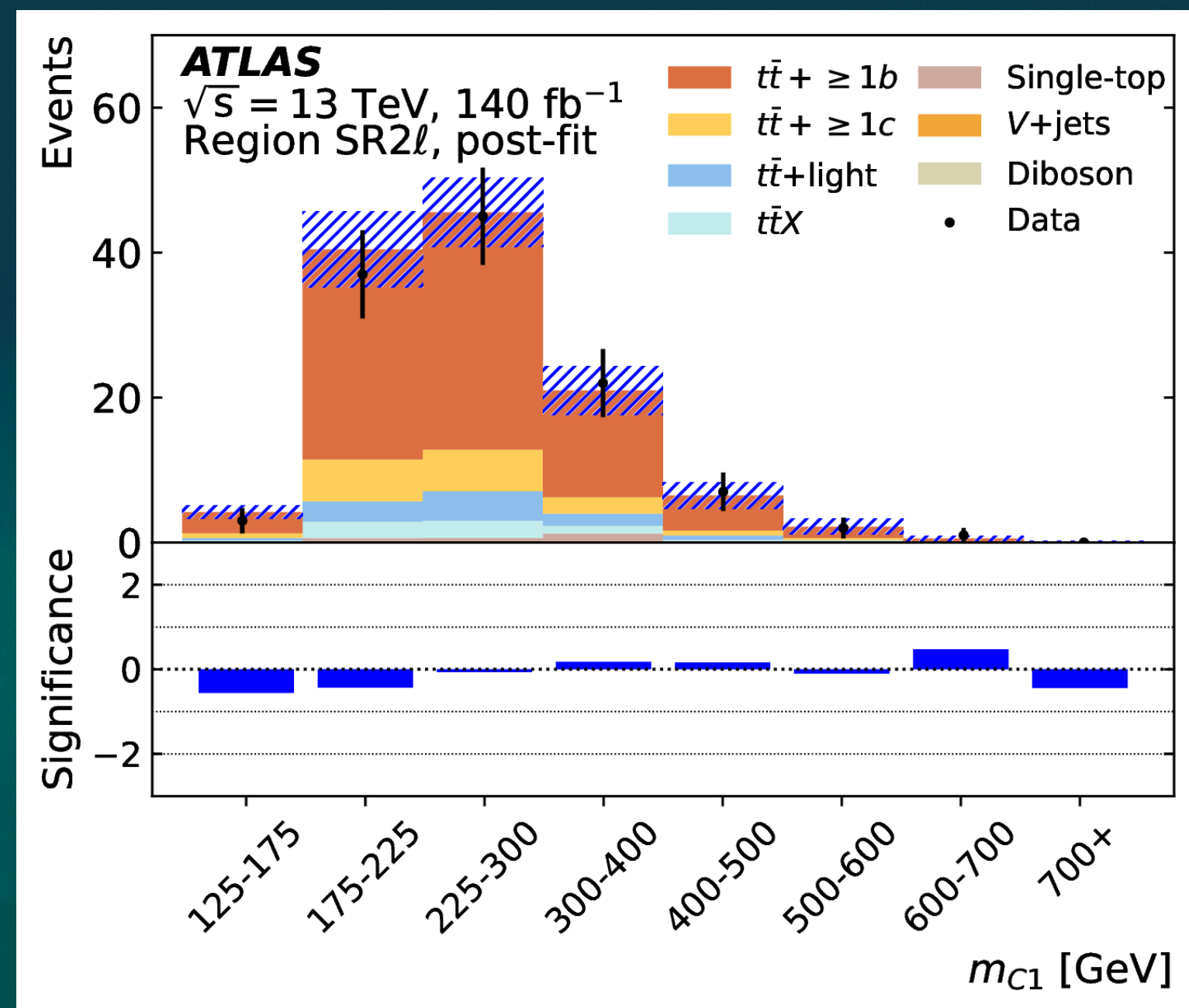
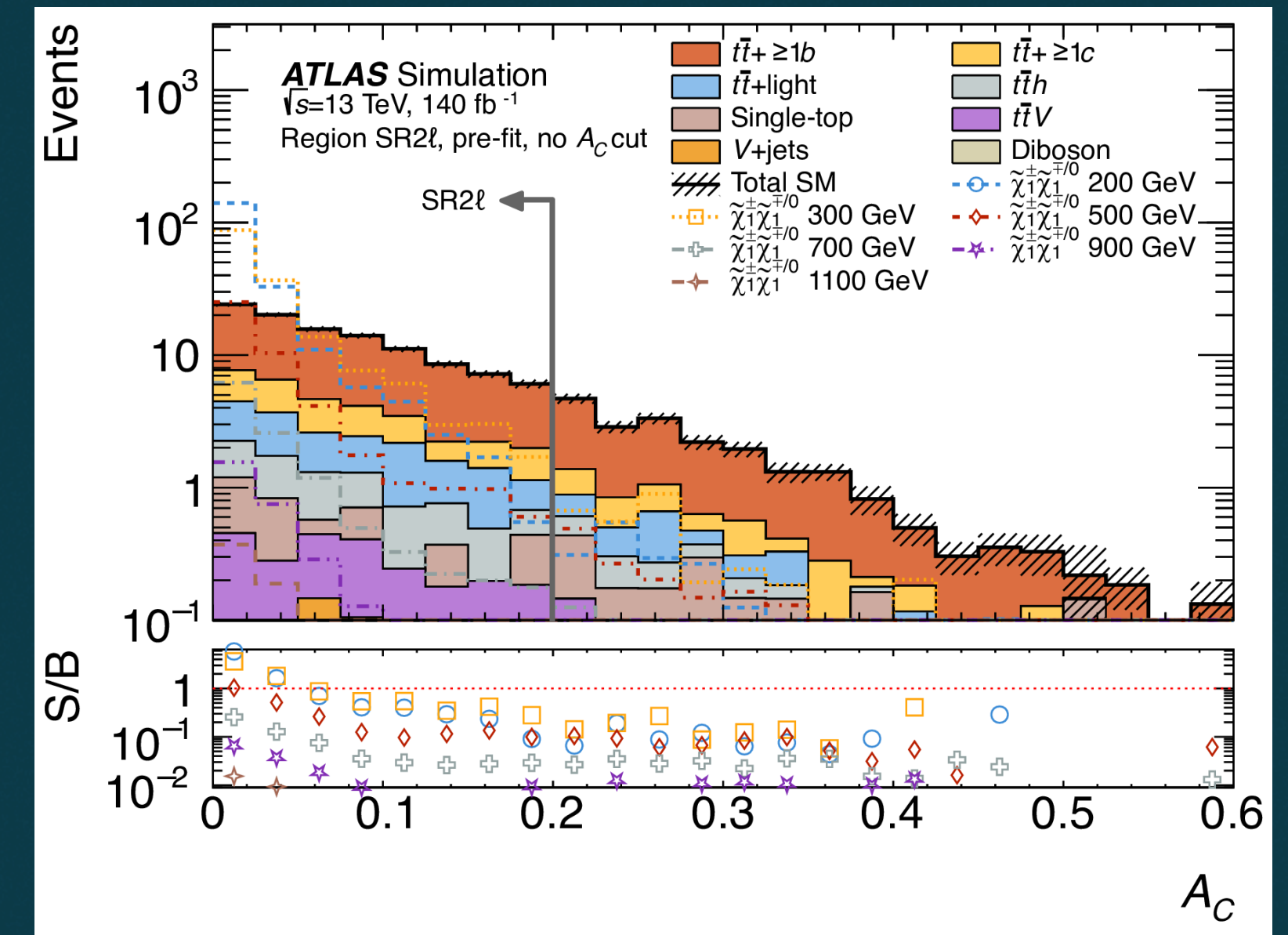


R-Parity Violating SUSY (Full Run-2 + Partial Run-3)

SR2 ℓ : ≥ 3 b-jets, both Higgs candidate masses near 125 GeV, $H_T > 400$ GeV, $m_{\ell\ell}$ well away from Z mass, $A_C < 0.2$ and $m_{C2}^{rej} > 200$ GeV

SR1 ℓ : tighter and single-binned with $H_T > 800$ GeV, $E_T^{miss} > 150$ GeV, $m_T^\ell > 100$ GeV, and min. transverse mass of any 3 leading b -jets and MET, $m_{T,min}^{b-jets} > 80$ GeV.

Several CRs and VRs defined to control backgrounds (Details in backup)

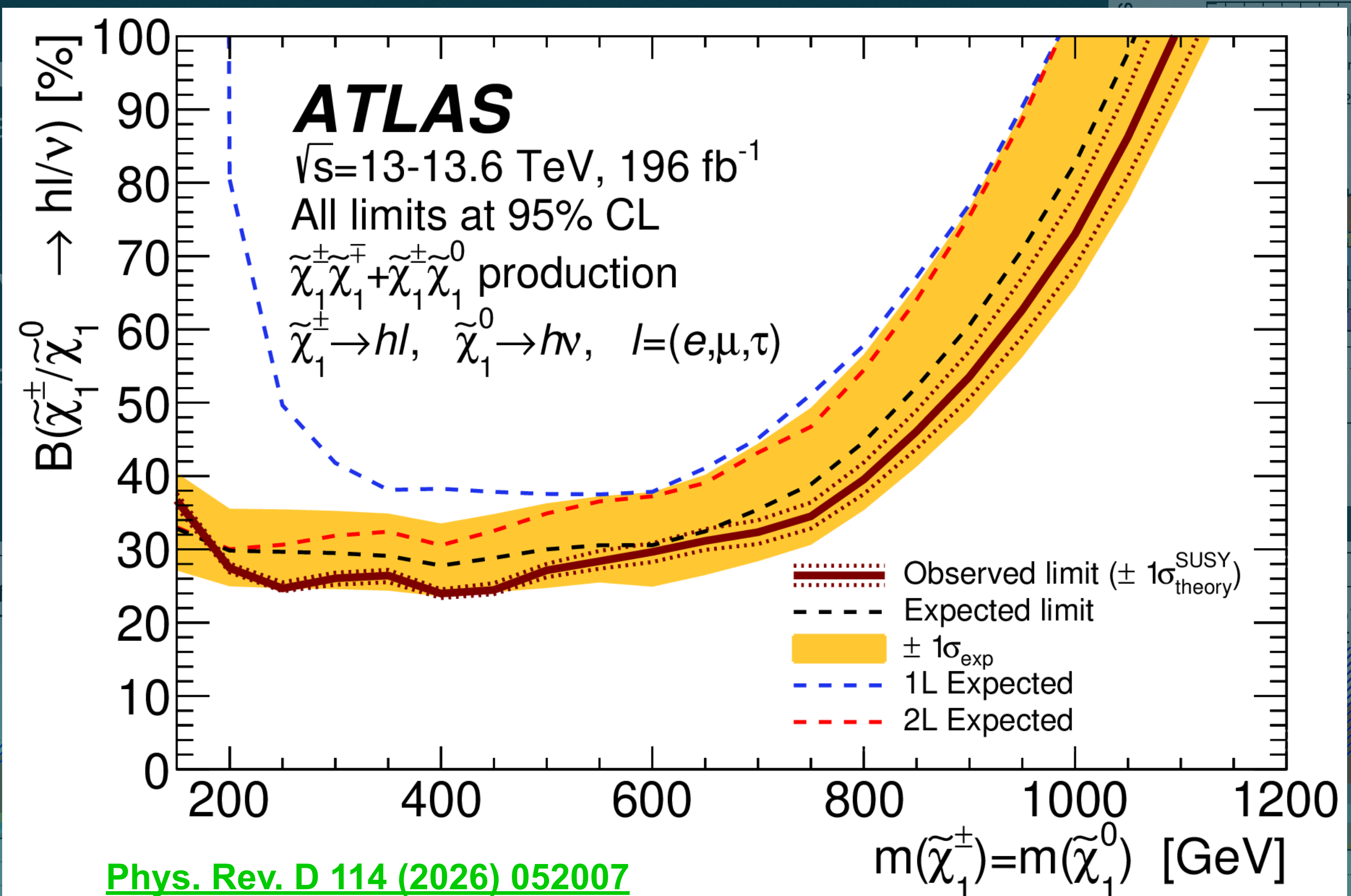


R-Parity Violating SUSY (Full Run-2 + Partial Run-3)

SR2 ℓ : ≥ 3 b-jets, both well away from Z mass

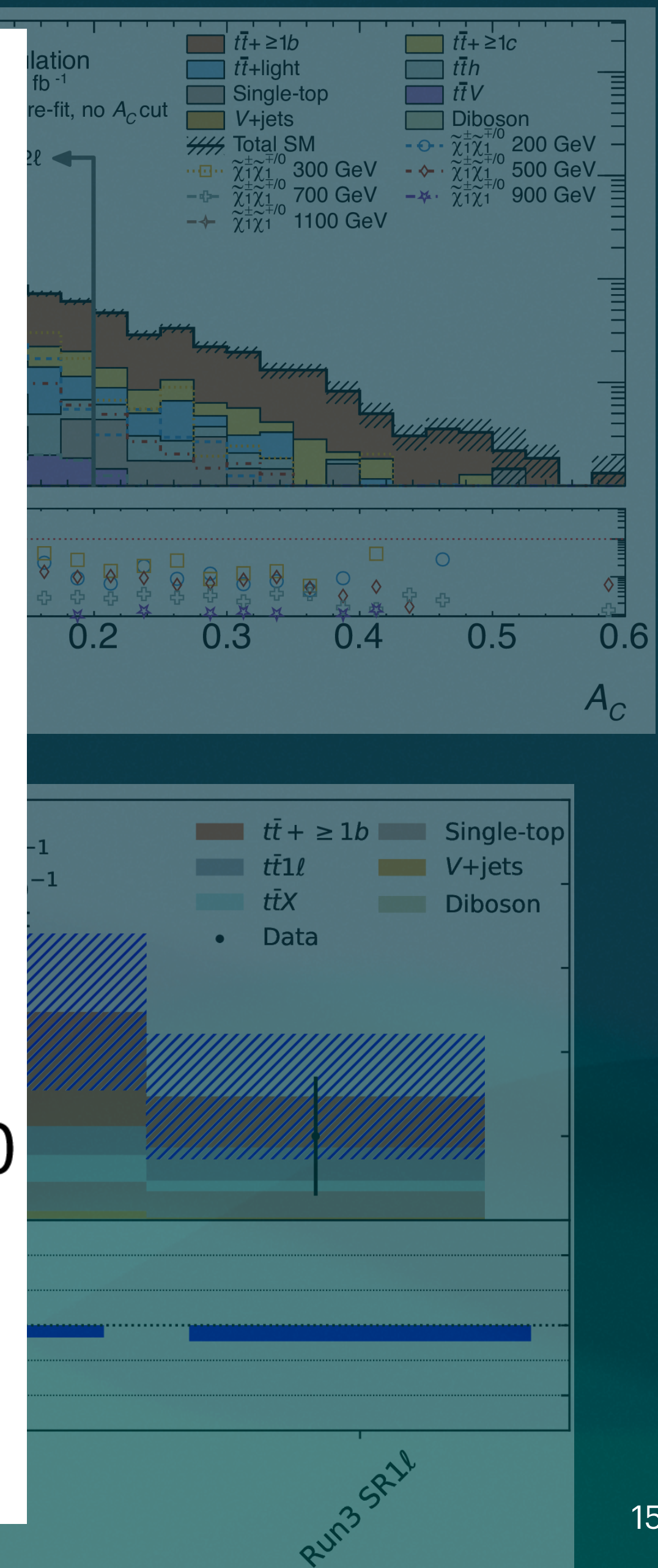
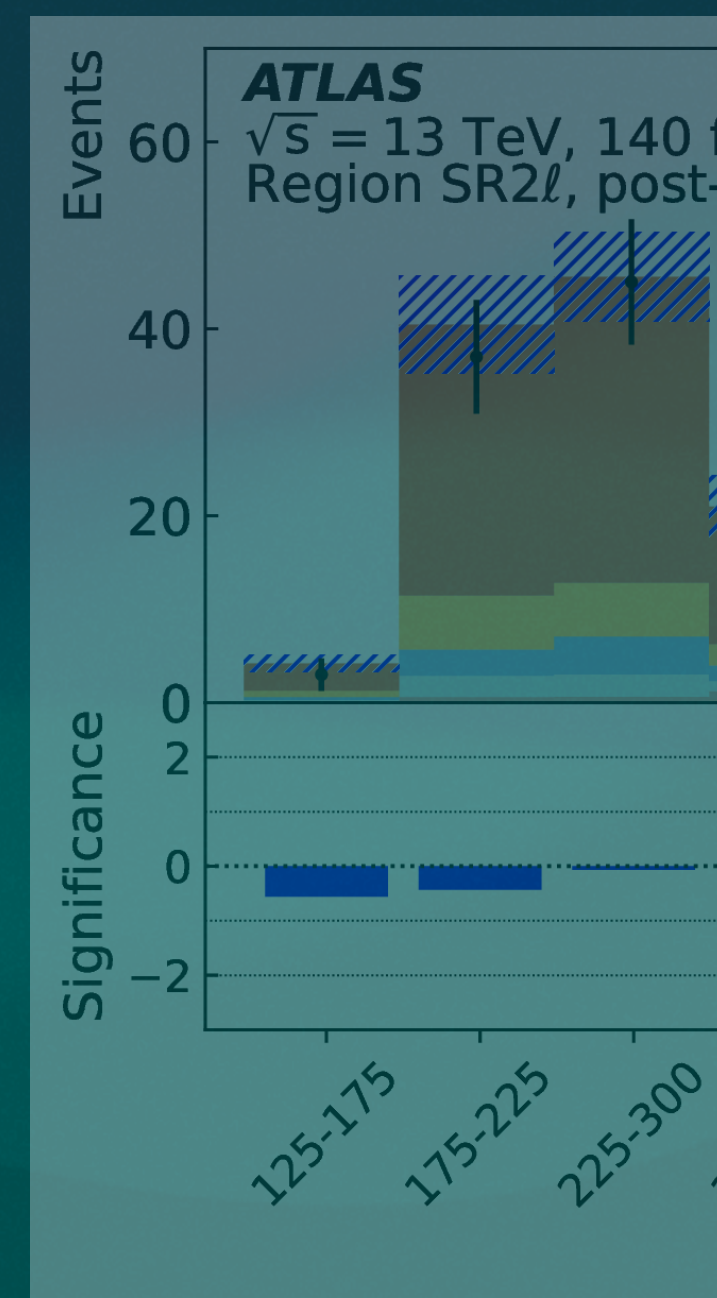
SR1 ℓ : tighter and similar to SR2 ℓ , $\sqrt{s} \geq 13$ GeV, and min. transverse energy

Several CRs and VFB



[Phys. Rev. D 114 \(2026\) 052007](#)

Charginos and neutralinos with masses between 150 GeV and 1100 GeV excluded, with BR assumed to be equal, for hypothesis where charginos are equally likely to decay into each flavour of charged lepton

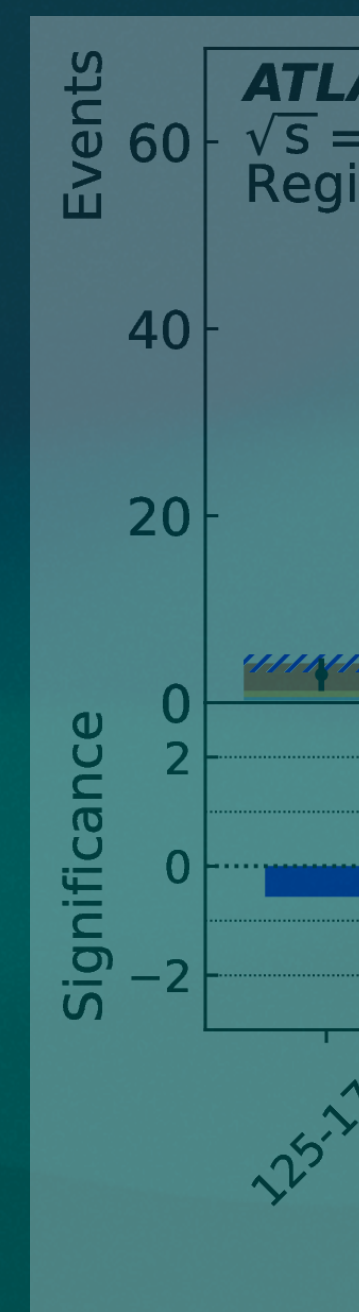


R-Parity Violating SUSY (Full Run-2 + Partial Run-3)

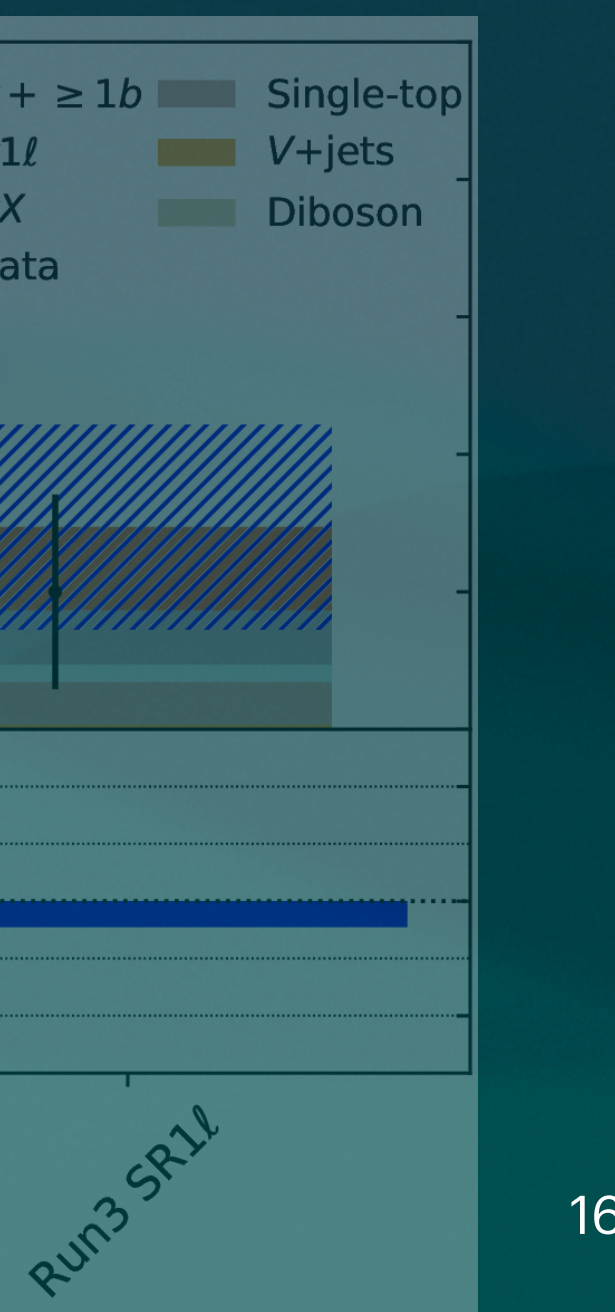
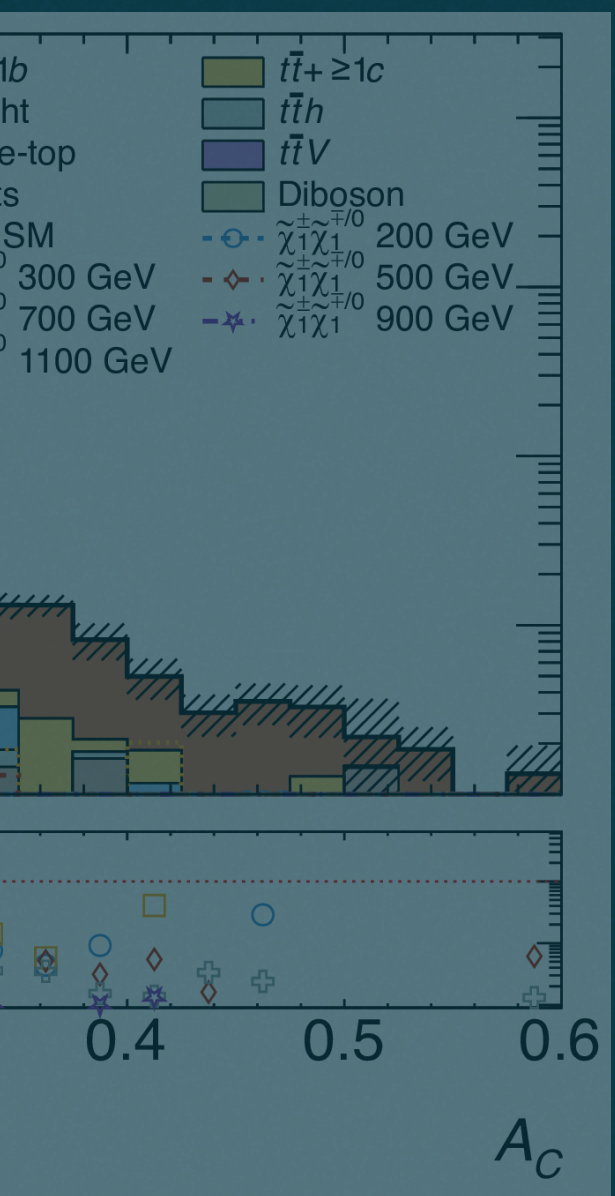
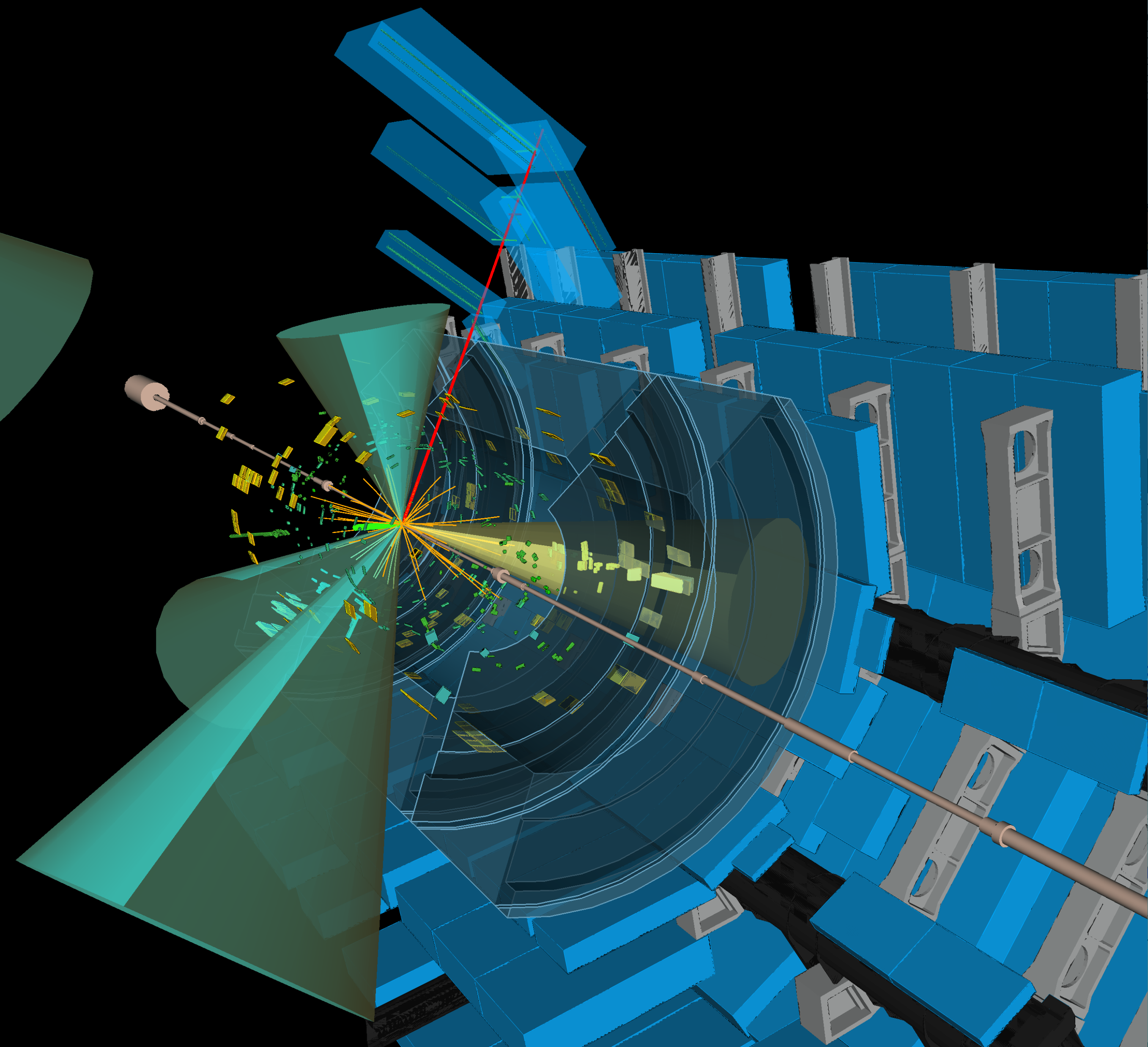
SR2 ℓ : ≥ 3
well away

SR1 ℓ : tight
GeV, and r

Several CP



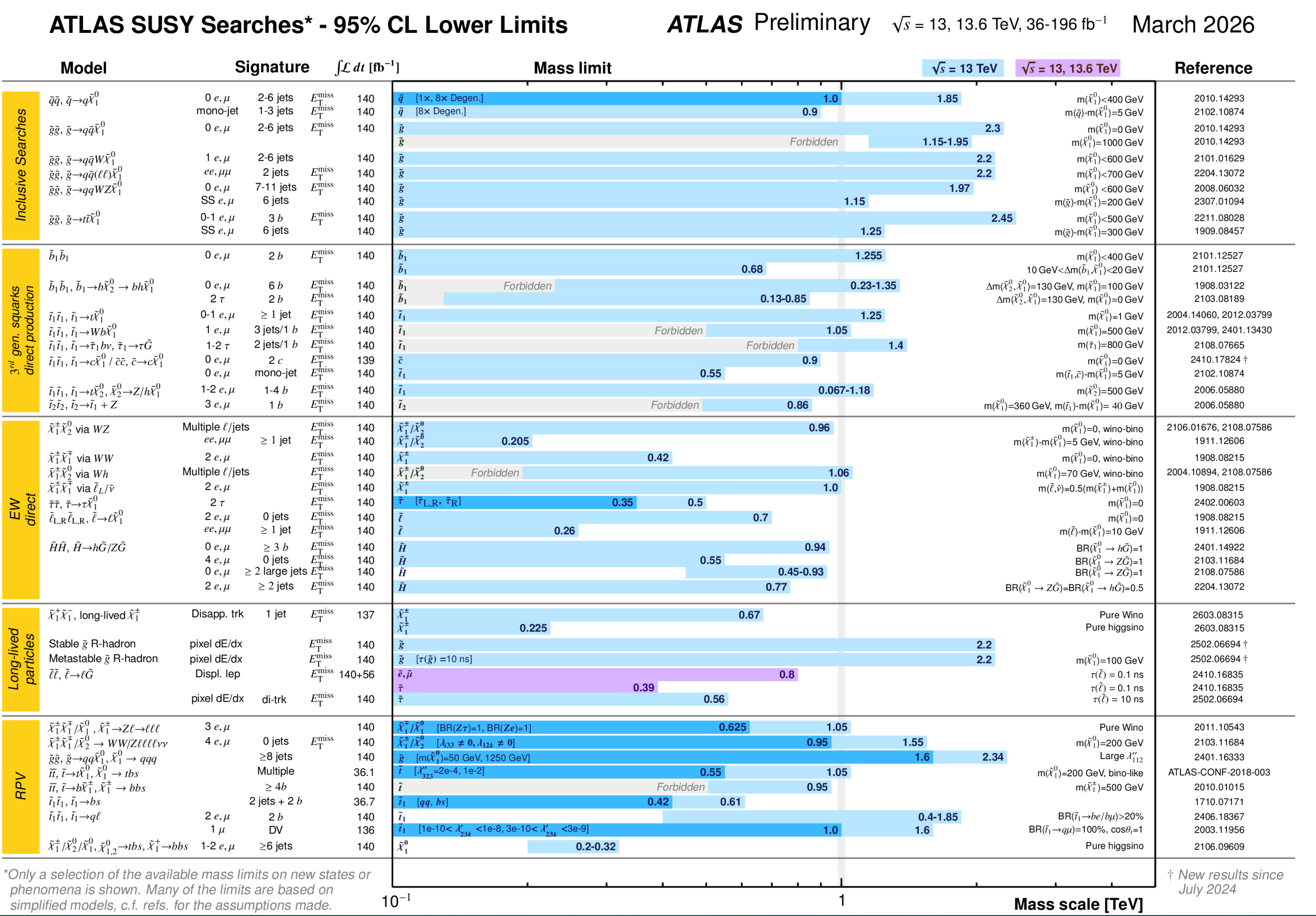
Run: 437548
Event: 2496573119
2022-10-20 10:41:52 CEST



SUSY - where we stand right now

Current collider analyses have probed a lot of the natural SUSY parameter space (bounds are subject to specific parameter choices)

- Most strongly coupled SUSY models assume existence of discrete R-parity symmetry [even parity for SM, odd parity for SUSY partners] → leads to stability of LSP (neutral & DM candidate) [gluino bounds > 2 TeV]
- R-parity violation possible (can explain flavour anomalies) → leads to highly hadronic/leptonic decays of heavy coloured SUSY particles [bounds > 1 TeV]
- Weakly interacting SUSY bounds is O(100 GeV) - 1 TeV
- Stringent limits for squarks and gluinos with large mass difference b/w relevant states



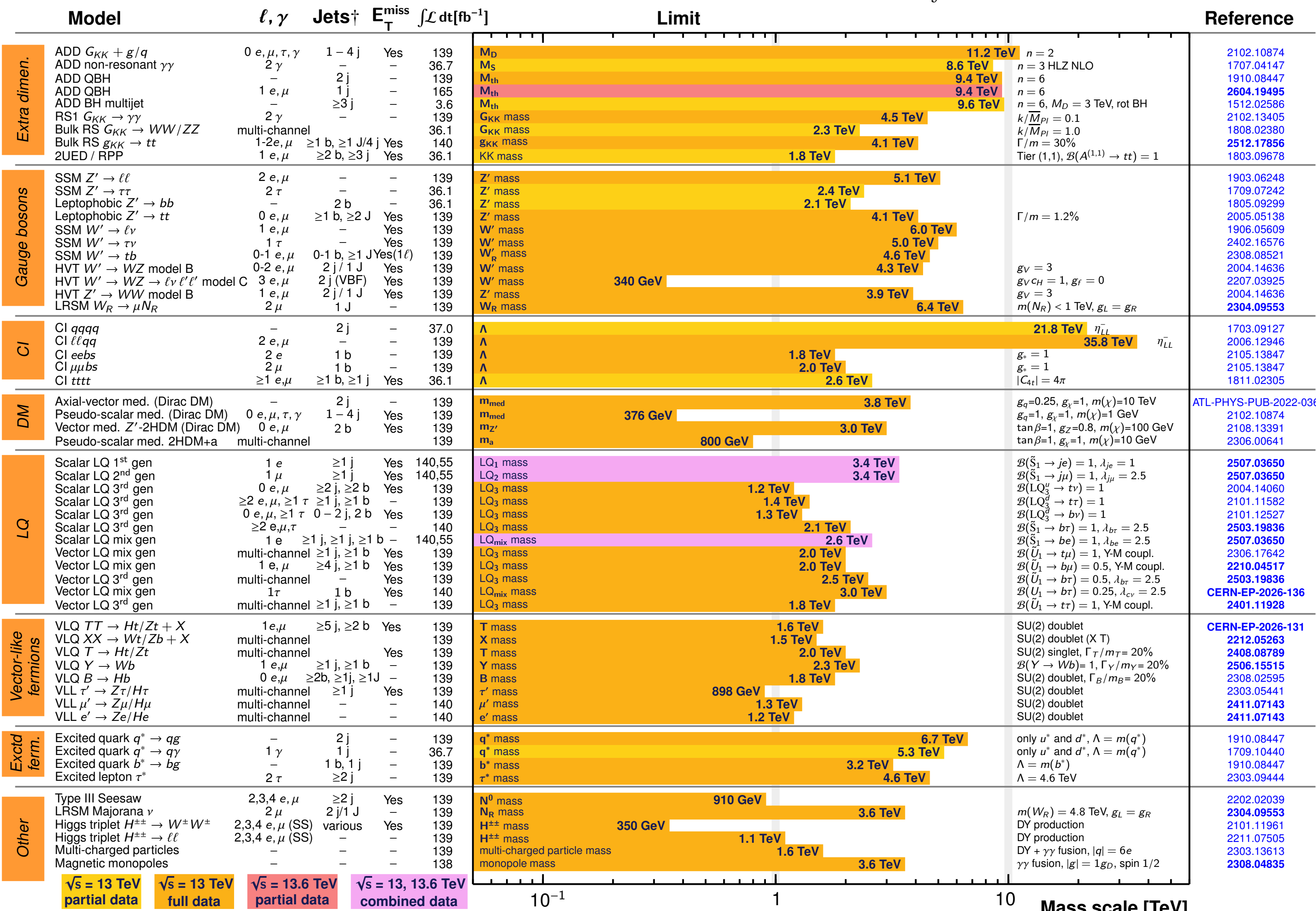
Heavy resonances - where we stand right now

ATLAS Heavy Particle Searches* - 95% CL Upper Exclusion Limits

Status: Spring 2026

ATLAS Preliminary

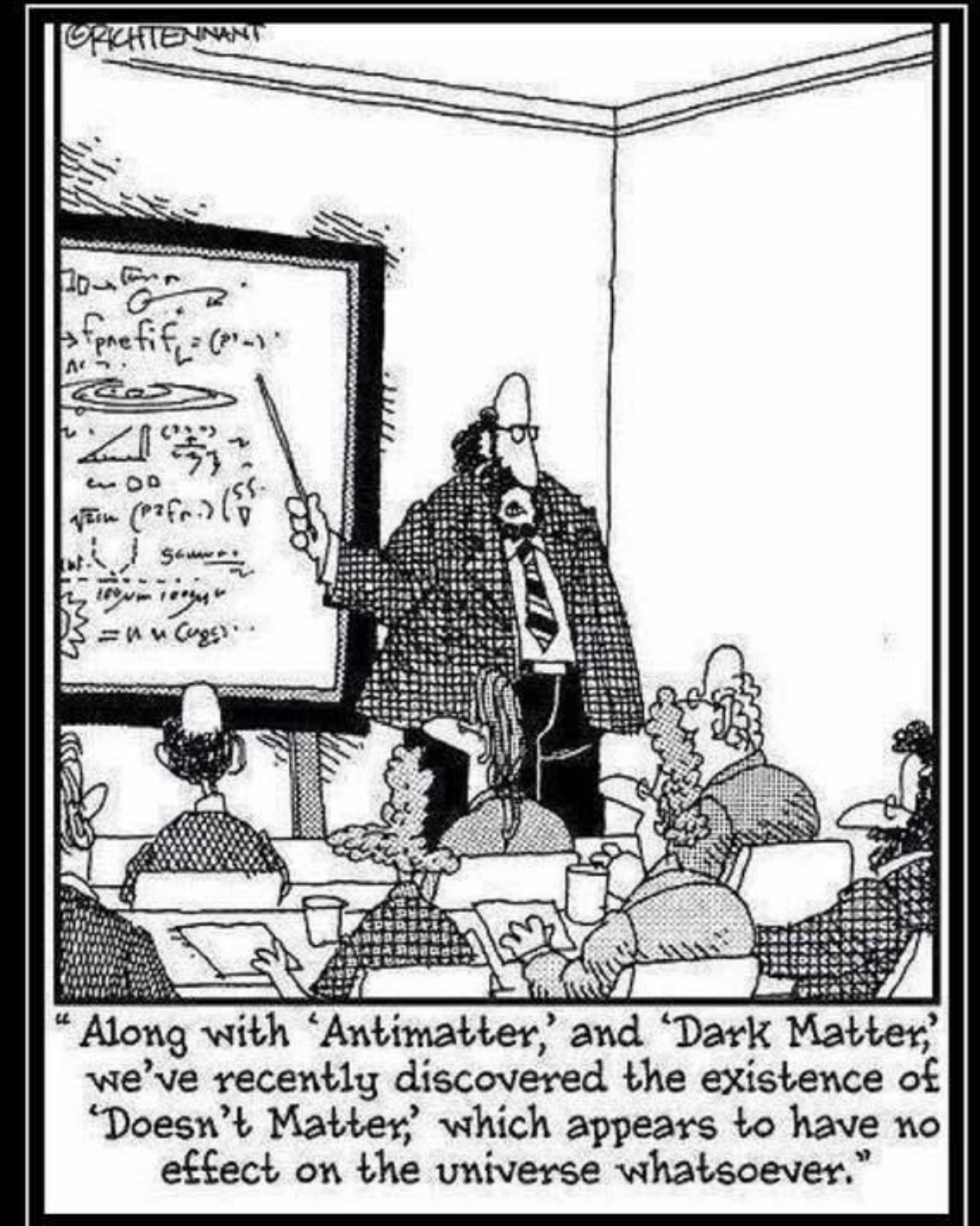
$\int \mathcal{L} dt = (3.6 - 195) \text{ fb}^{-1}$ $\sqrt{s} = 13, 13.6 \text{ TeV}$



*Only a selection of the available mass limits on new states or phenomena is shown.

Conclusions

- Several avenues of BSM sector open for exploration at the LHC!
- General effort moving towards final-state signature driven searches with some benchmark signal models
- Alternative data-sets being utilised to probe EW-scale resonances
- Challenging/unconventional signatures being probed
- None of the results discussed today have a significant excess of events over expected SM background
- Stay tuned for full Run-3 and combined Run-2+3 results!



A LECTURE AT
WHATSA MATTER U

BACKUP

RPV SUSY (Full Run-2 + Partial Run-3)

Table 3: Summary of the signal, control, and validation regions used for the 2-lepton analysis regions targeting $\tilde{\chi}_1^\pm$ $\tilde{\chi}_1^\mp$ signals. All regions require at least four jets and two oppositely charged leptons. Each region has both a Run 2 and a Run 3 version, which use the same definition.

Region	$N_{b\text{-jet}}$	m_{h1} [GeV]	m_{h2} [GeV]	H_T [GeV]	$m_{\ell\ell}$ [GeV]	A_C	m_{C2}^{rej} [GeV]	m_{C1} [GeV]
SR2 ℓ	≥ 3	$\in [100, 150]$	$\in [85, 135]$	> 400	> 106.2	< 0.2	> 200	—
CR2 ℓ 2b	2	$\in [100, 150]$	$\in [85, 135]$	—	> 106.2	< 0.2	< 200	< 500
CR2 ℓ 3b	≥ 3	$\notin [100, 150]$	$\notin [85, 135]$	> 400	> 106.2	> 0.2	—	< 700
VR2 ℓ 2b	2	$\in [100, 150]$	$\in [85, 135]$	—	> 106.2	< 0.2	> 200	< 500
VR2 ℓ 3b	≥ 3	$\notin [100, 150]$	$\in [85, 135]$	> 400	> 106.2	> 0.2	—	—

Table 4: Summary of the signal, control, and validation regions used for the 1-lepton analysis regions targeting $\tilde{\chi}_1^\pm$ $\tilde{\chi}_1^0$ signals. All regions require at least four jets and one lepton. Each region has both a Run 2 and a Run 3 version, which use the same definition.

Region	$N_{b\text{-jet}}$	m_{h1} [GeV]	m_{h2} [GeV]	H_T [GeV]	$m_{T,\min}^{b\text{-jets}}$ [GeV]	E_T^{miss} [GeV]	m_T^ℓ [GeV]
SR1 ℓ	≥ 3	$\in [100, 150]$	$\in [85, 135]$	> 800	> 80	> 150	> 100
CR1 ℓ 3b	≥ 3	$\notin [100, 150]$	$\notin [85, 135]$	> 800	> 80	> 150	≤ 100
VR1 ℓ 3b1	≥ 3	$\notin [100, 150]$	$\in [85, 135]$	> 800	> 80	> 150	≤ 100
VR1 ℓ 3b2	≥ 3	$\notin [100, 150]$	$\notin [85, 135]$	> 800	> 80	> 150	> 100