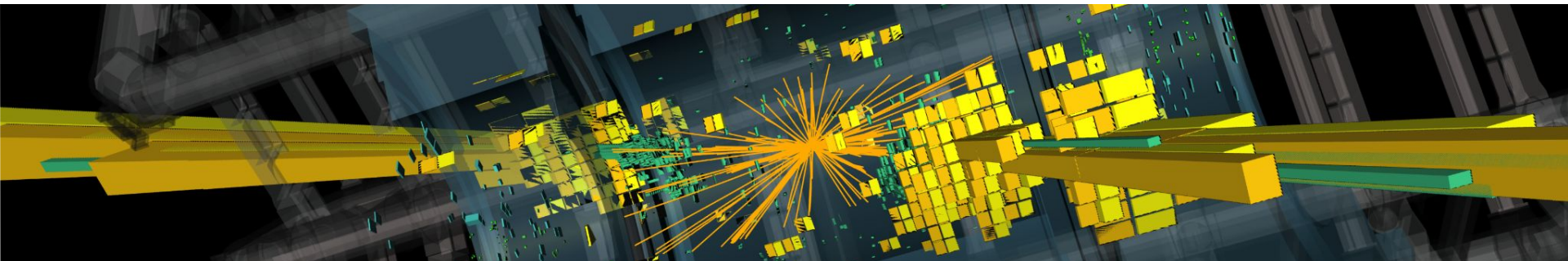


# *Searches for New Physics at the LHC*

50th Anniversary of Hadron Colliders at CERN  
14 October 2021

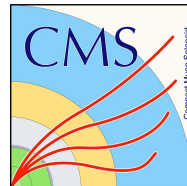


Patrick Rieck  
New York University

on behalf of the ATLAS, CMS and LHCb collaborations

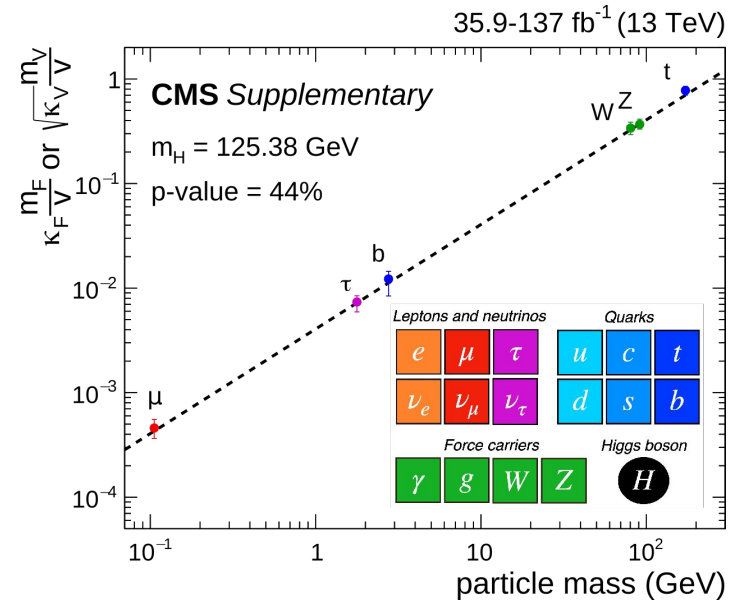


**NYU**



# After the Higgs Boson Discovery

- *New questions arise given  $m_H = 125$  GeV*
- Numerous reasons for new physics, but *no “no lose” theorem anymore*
- Hence conducting a *broad new-physics search program*, covering as many signatures as possible

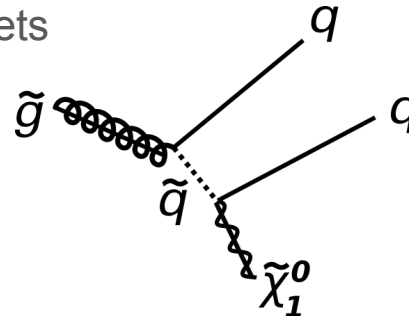
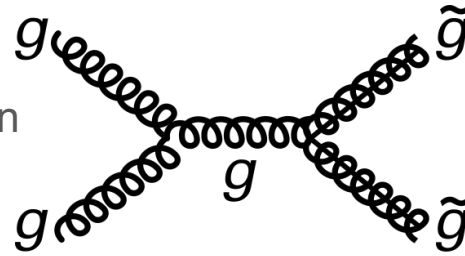


# Searching for Supersymmetry

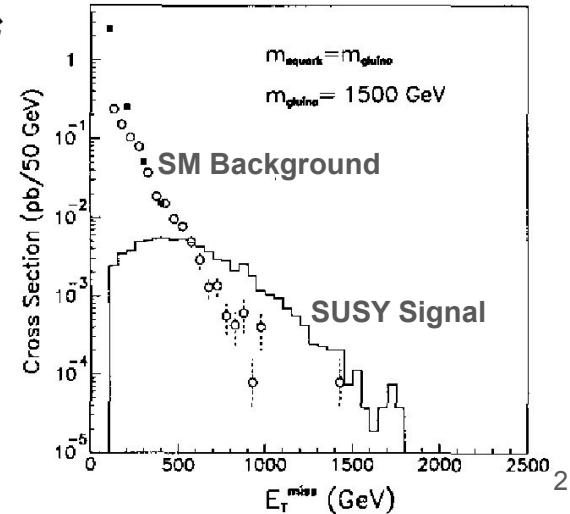
- Sparticle corrections stabilising  $m_H \approx (100 \text{ GeV})$  if  $m_{\text{SUSY}} \approx (1 \text{ TeV})$ : *Naturalness*

- Primary target: sparticle pair production via strong interactions

- Sparticle decays resulting in hadronic jets and missing transverse energy



ATLAS Letter of Intent, 1992

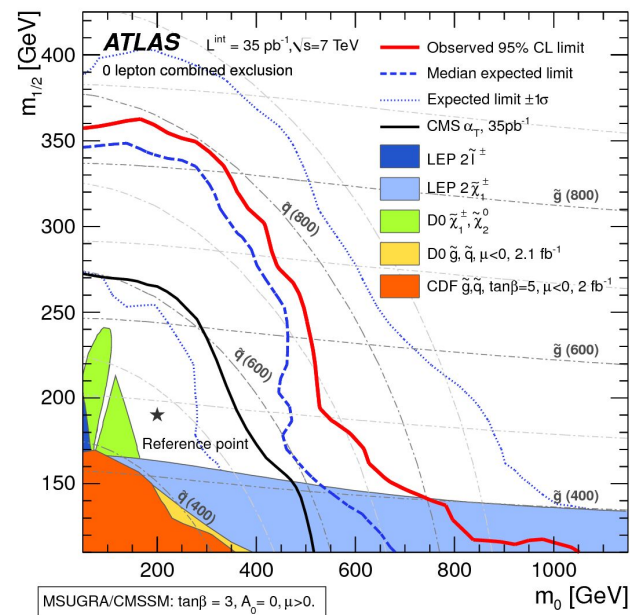
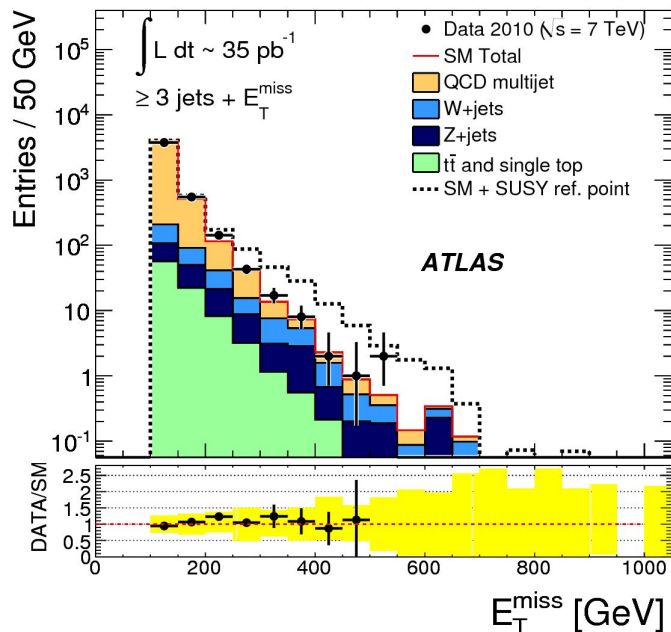


# Supersymmetry

With gluino pair production

[arXiv:2010.14293](https://arxiv.org/abs/2010.14293)

[arXiv:1909.03460](https://arxiv.org/abs/1909.03460)



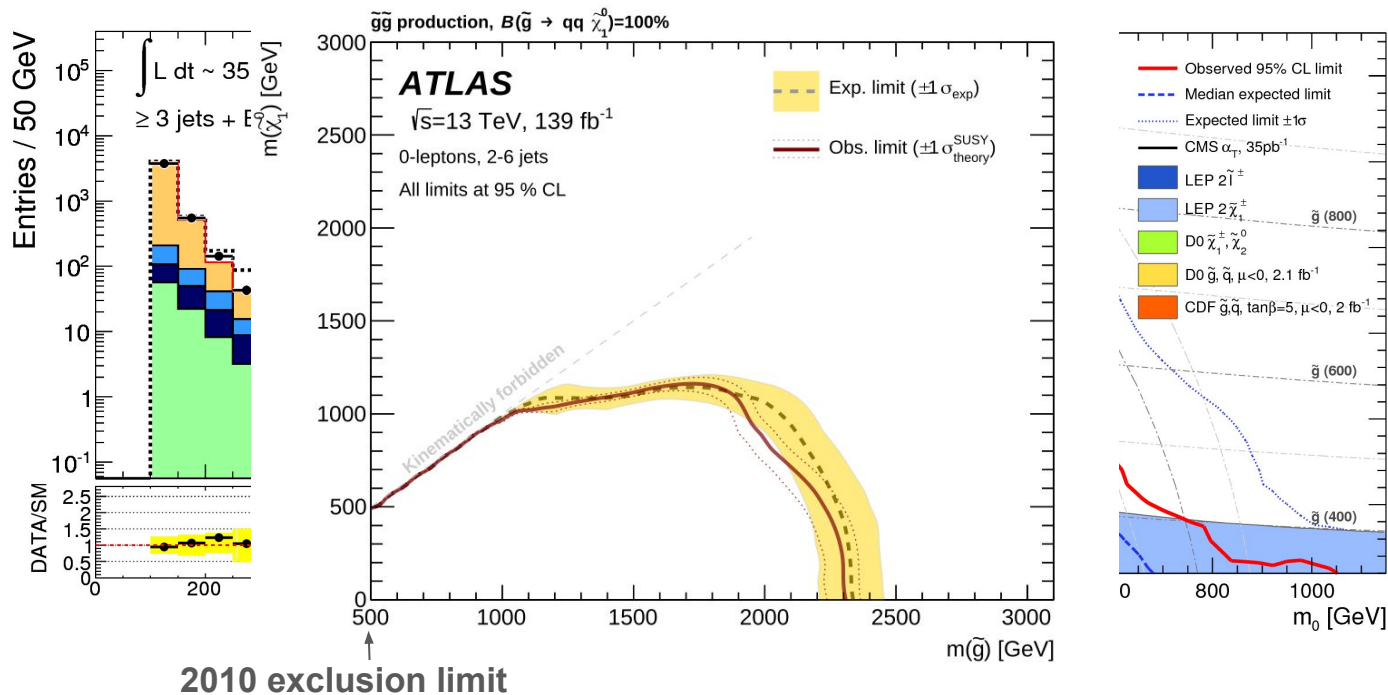
- 2010 data significantly extending LEP and Tevatron sensitivity

# Supersymmetry

With gluino pair production

[arXiv:2010.14293](https://arxiv.org/abs/2010.14293)

[arXiv:1909.03460](https://arxiv.org/abs/1909.03460)



2010 exclusion limit

- 2010 data significantly extending LEP and Tevatron sensitivity
- Run 2 data pushing exclusion limits up to  $m_{\tilde{g}} \approx 2.3$  TeV

# Supersymmetry

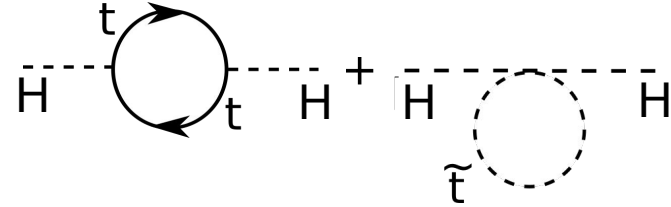
Driven by naturalness

[arXiv:2004.14060](https://arxiv.org/abs/2004.14060)

[arXiv:2107.10892](https://arxiv.org/abs/2107.10892)

[LHC Physics Working Groups](#)

- Suspecting  $m_{\text{stop}} \lesssim 1 \text{ TeV} \Rightarrow$  squark searches focus on stop



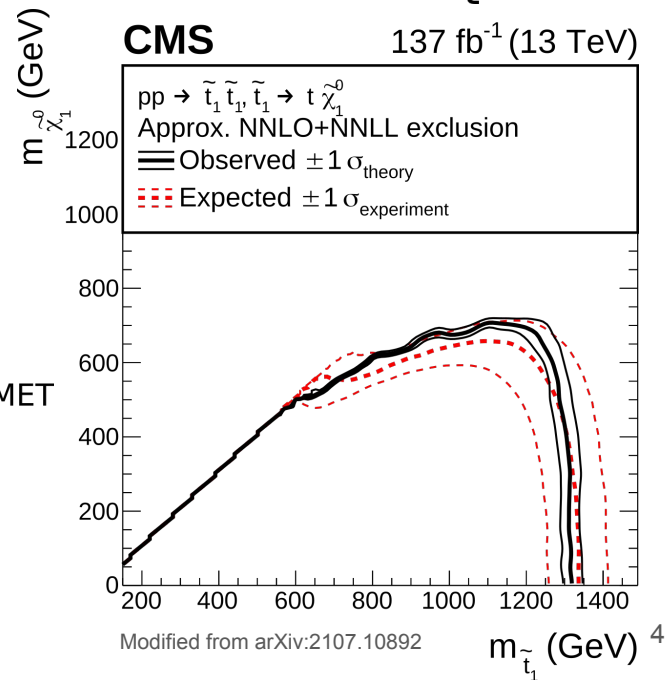
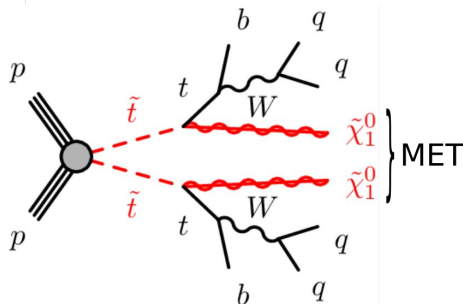
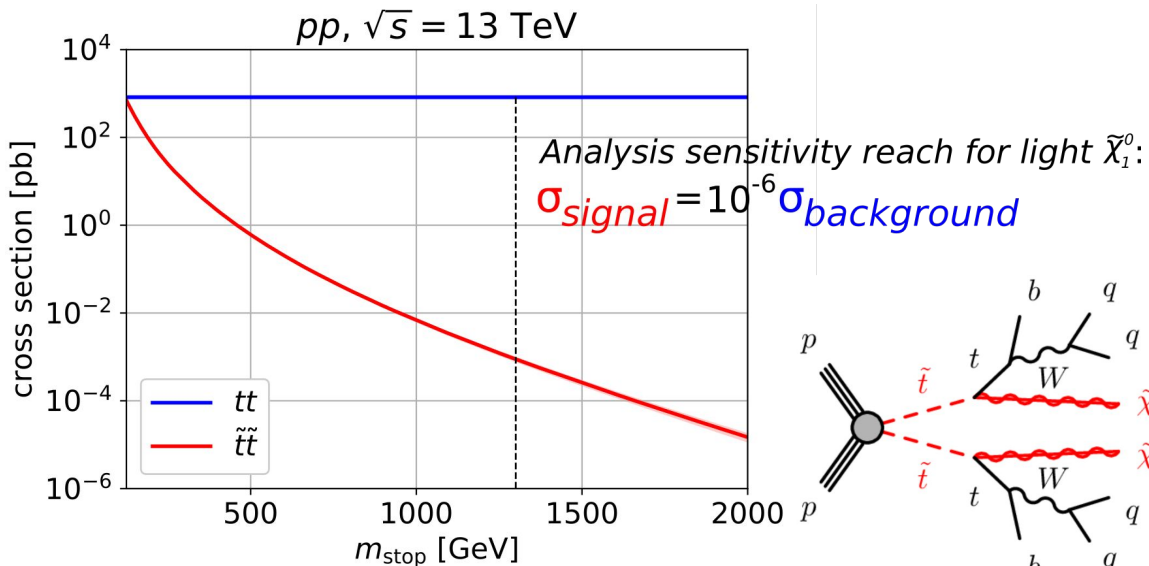
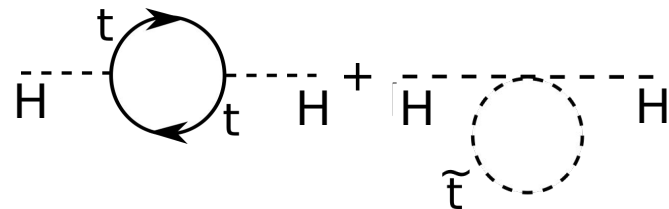


# Supersymmetry

Driven by naturalness

arXiv:2004.14060  
arXiv:2107.10892  
LHC Physics Working Groups

- Suspecting  $m_{\text{stop}} \lesssim 1 \text{ TeV} \Rightarrow$  squark searches focus on stop
  - $t\bar{t}$ +MET final state in the bulk of parameter space



- Excluding stop squarks up to  $m_{\text{stop}} = 1.3 \text{ TeV}$





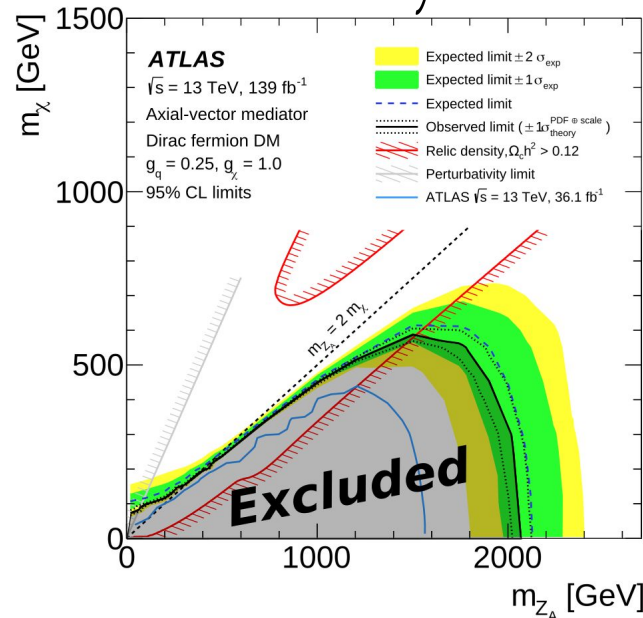
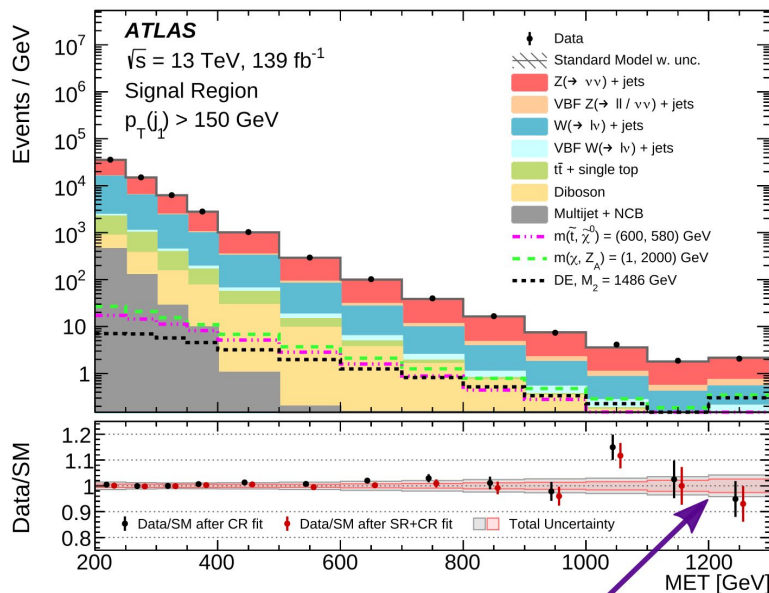
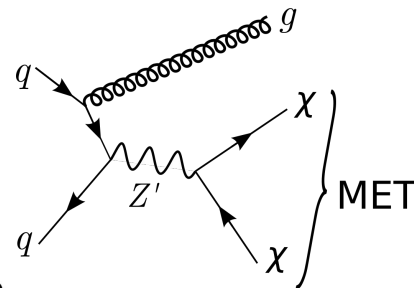
# Dark Matter

With new weak interactions

arXiv:2102.10874

arXiv:2107.13021

- Initial state radiation raising MET above the trigger threshold  
 $\Rightarrow$  *Mono-Jet selection*, searching for a high MET excess



*%-level precision search: background prediction beyond next-to-leading order in perturbation theory*

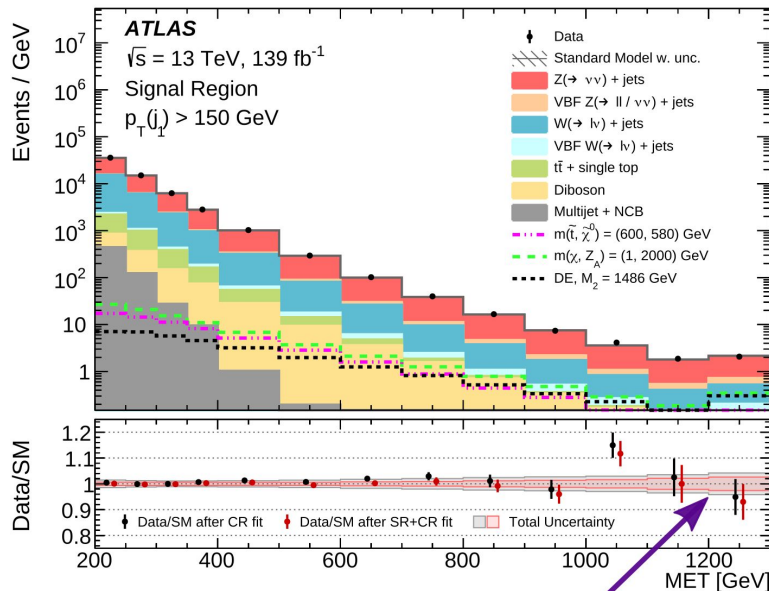
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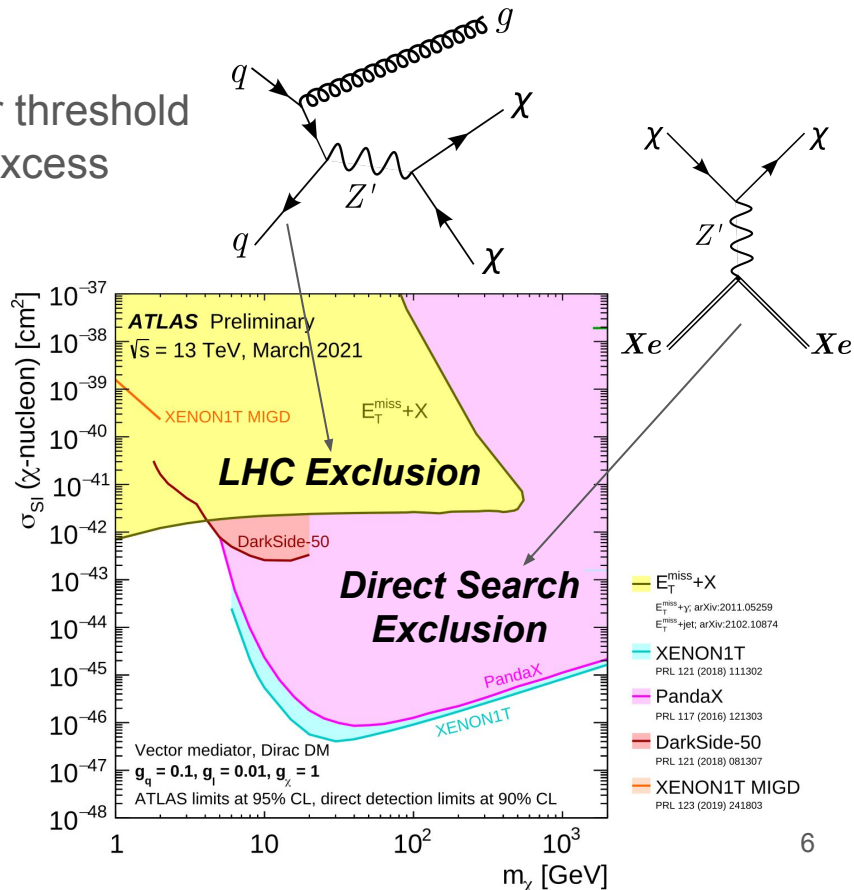
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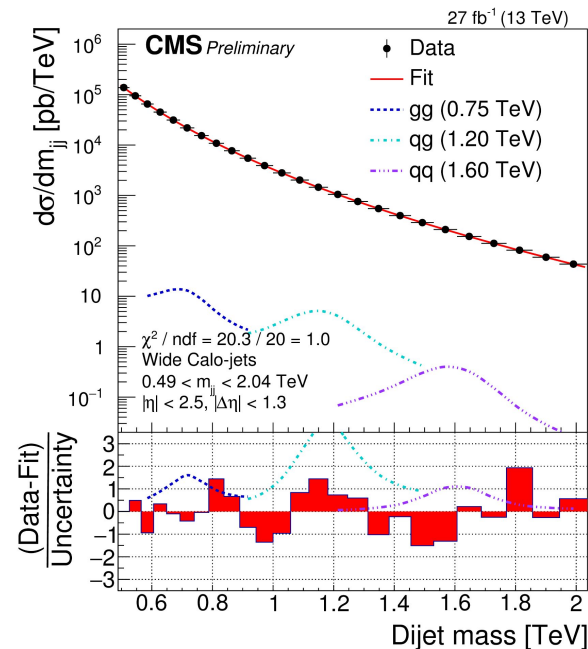
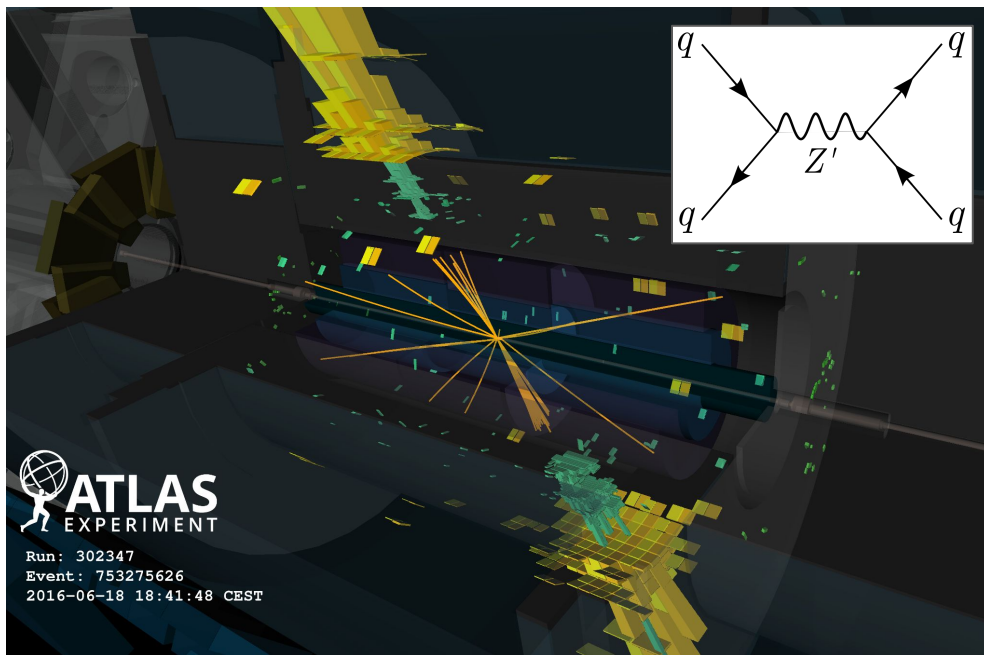


# New Weak Interactions

With dijet final states

[arXiv:1910.08447](https://arxiv.org/abs/1910.08447), [arXiv:1804.03496](https://arxiv.org/abs/1804.03496)  
[arXiv:1911.03947](https://arxiv.org/abs/1911.03947), [arXiv:1806.00843](https://arxiv.org/abs/1806.00843)

- Invariant mass spectrum of jet pairs  $\Rightarrow$  exclusion of hadronic resonances for weak couplings  $g_{Z'qq} \geq 0.1$



$$\frac{\text{Events}}{\text{sec}} \cdot \frac{\text{size}}{\text{event}} \leq 2 \frac{\text{GB}}{\text{sec}}$$

**CMS Data Scouting:** store only trigger-level calorimeter jets to reduce the event size, hence increase the recording rate  
 $\Rightarrow$  lower  $m_{jj}$  threshold

# Lepton Flavour Violation

## In Z-boson decays

[arXiv:2010.02566](#), [arXiv:2105.12491](#), [ATLAS-CONF-2021-042](#)

- Z-bosons produced per experiment:

- LHC Run 2 : 8 billions
- LEP : 4.5 millions

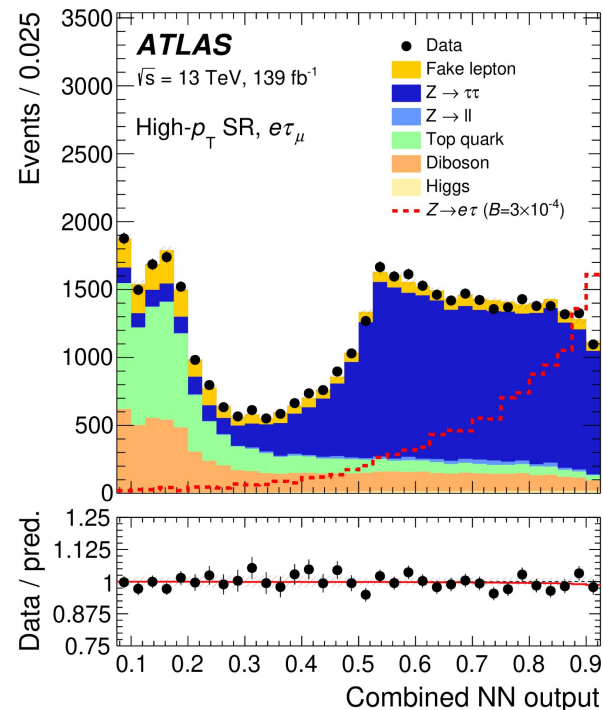
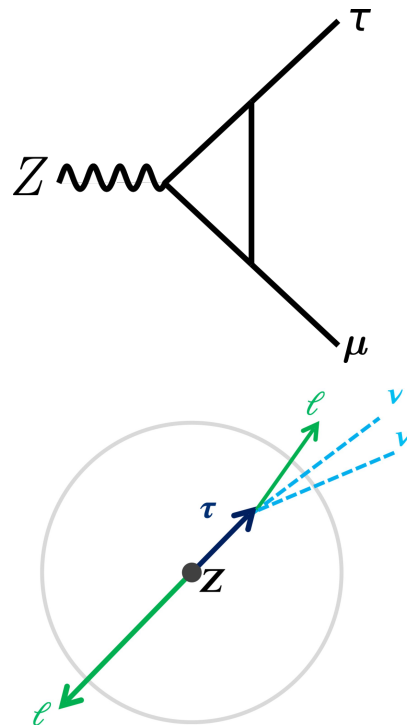
- Testing the Standard Model by searching for decays  $Z \rightarrow e\mu$ ,  $Z \rightarrow e\tau$  and  $Z \rightarrow \mu\tau$

- Branching fraction upper limits 2-5x beyond the sensitivity of LEP:

$$BR(Z \rightarrow e\mu) < 3.0 \cdot 10^{-7}$$

$$BR(Z \rightarrow e\tau) < 5.0 \cdot 10^{-6}^*$$

$$BR(Z \rightarrow \mu\tau) < 6.5 \cdot 10^{-6}^*$$



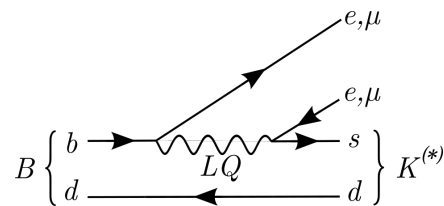
# Lepton Flavour Violation

## With Leptoquarks

[arXiv:2108.07665](https://arxiv.org/abs/2108.07665)

[arXiv:2012.04178](https://arxiv.org/abs/2012.04178)

- *Flavour physics: semileptonic B-meson decays in tension with the SM,  $3\sigma$  significances*
- Popular explanation: *leptoquarks*
  - TeV mass scale
  - Hierarchy of fermion coupling strengths



**Low  $Q^2$  precision observables**



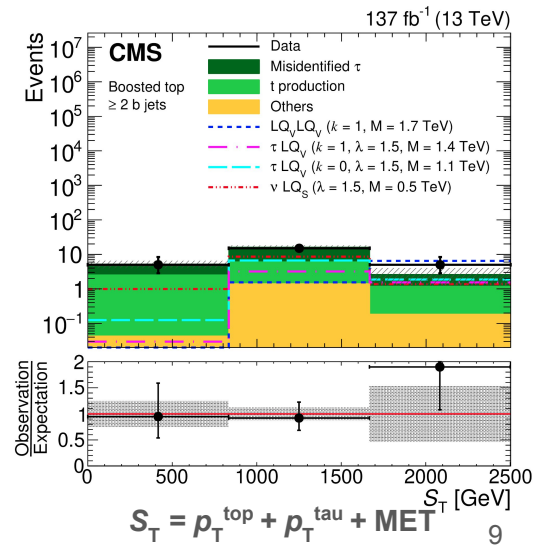
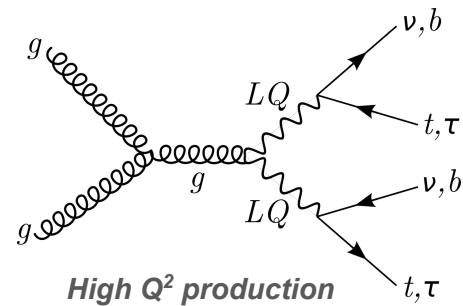
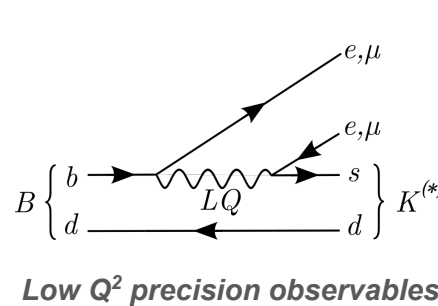
# Lepton Flavour Violation

## With Leptoquarks

[arXiv:2105.13847](https://arxiv.org/abs/2105.13847)

[arXiv:2012.04178](https://arxiv.org/abs/2012.04178)

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  - Hierarchy of fermion coupling strengths
- *Search for events with 3rd generation fermions accordingly*

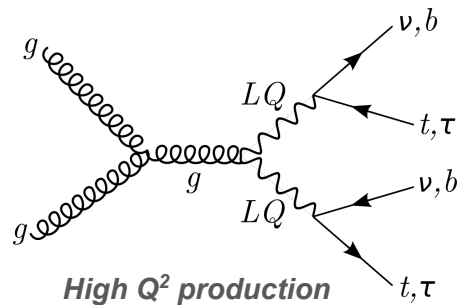
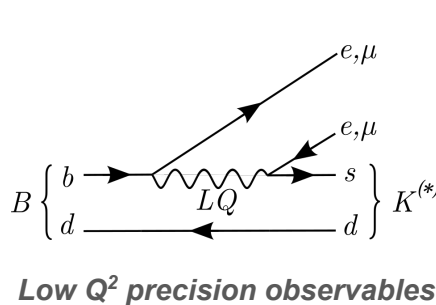


# Lepton Flavour Violation

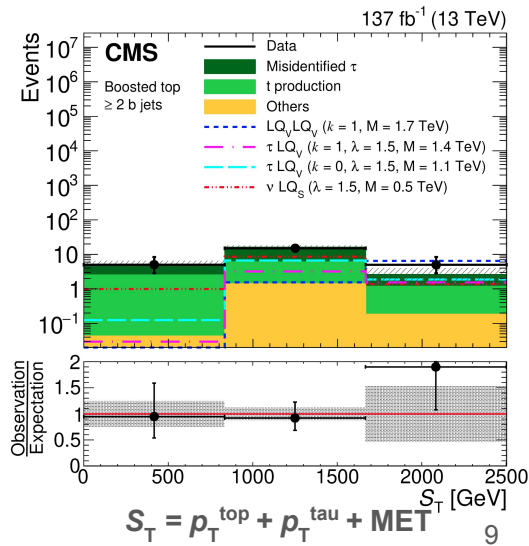
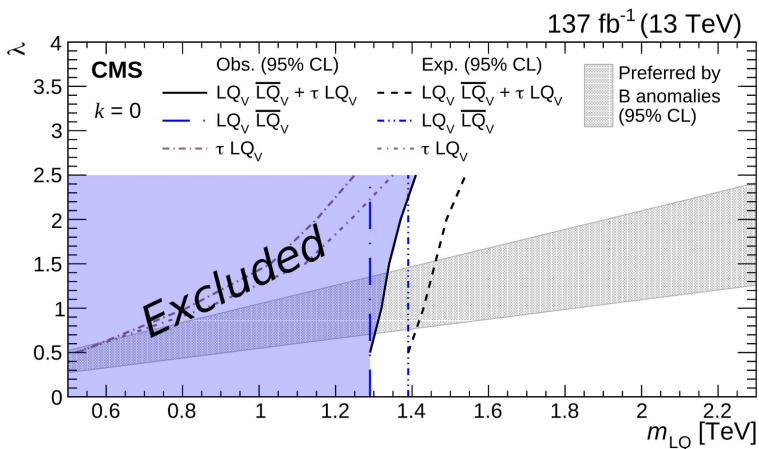
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  - Hierarchy of fermion coupling strengths
- *Search for events with 3rd generation fermions accordingly*



*Interplay of flavour physics and energy frontier searches to pin down new physics*





# Perspective

- Broad search program with distinct signatures covered
  - Great variety of searches in ATLAS and CMS as well as in LHCb which provides complementary sensitivity, way beyond the coverage of this presentation
- No discovery other than the Higgs boson so far
  - The simplest models of SUSY with TeV scale masses are not realised in nature
  - Still important new physics signatures to explore within and beyond SUSY
- 95 % of the LHC dataset still to come