Non-resonant searches at TeV Scale

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On behalf of the ATLAS and CMS collaborations

LHCP 2023 - Belgrade, Serbia
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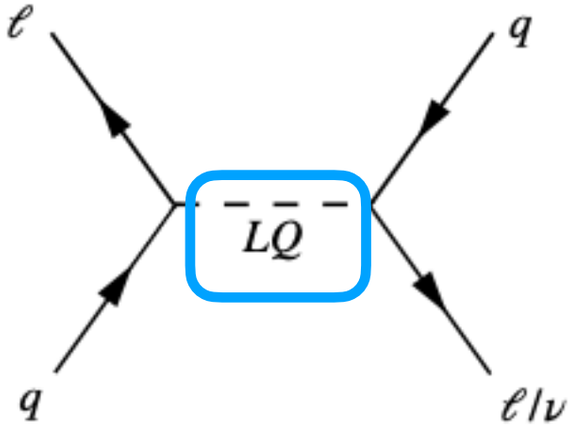
Exploring the TeV scale

- SM leaves a lot of open questions that could have hints at TeV
  - Hierarchy problem, DM, flavour anomalies, etc…
- LHC is the most direct probe of nature at the TeV scale
- Three theory paradigms to extend SM:

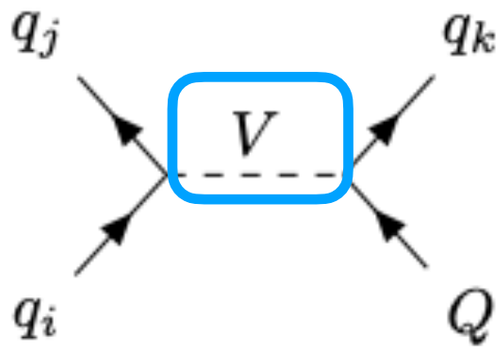
Leptoquark(LQ)

Colored states with both **baryon** and **lepton** numbers



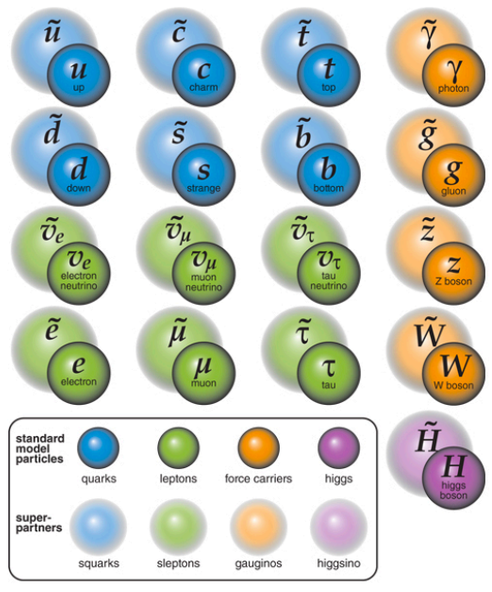
Vector-like quark(VLQ)

Colored states with **chiral** symmetry



SUSY

Spacetime symmetry that relates **boson** and **fermions** in SM



This talk will focus on recent search results from ATLAS and CMS on these topics

LQ search with lepton-quark collision

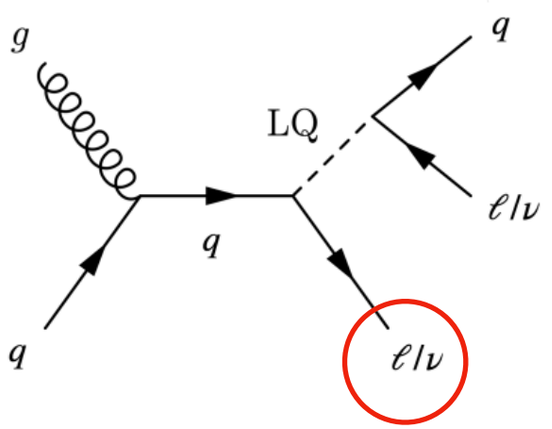
CMS-EXO-22-018

New for LHCP23!

- First search for LQ using **lepton-quark** collisions
  - Thanks to recent advances in lepton PDF calculation [PRL]
  - Precise PDF calculations show **measurable** LQ cross section at LHC

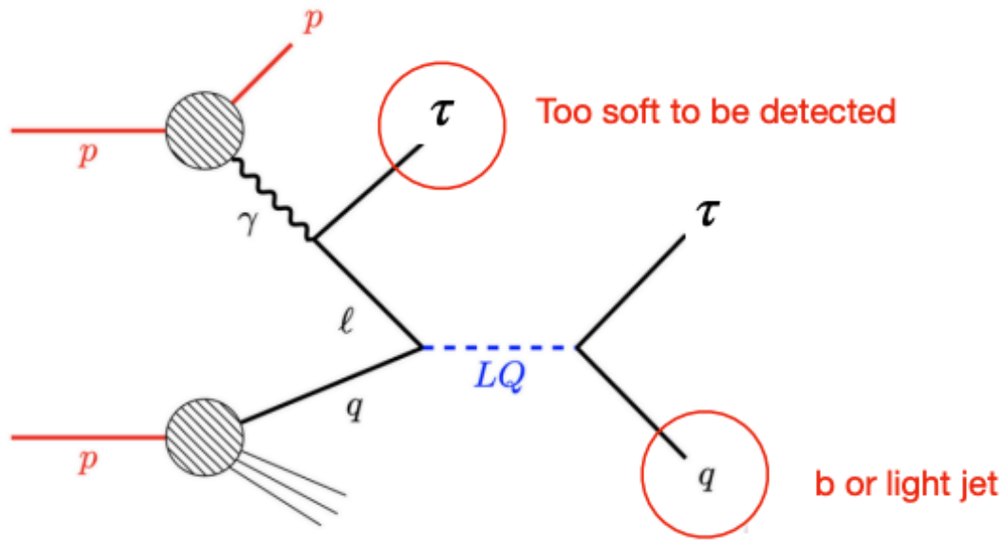
- CMS utilize this technique to probe LQ-τ-q coupling
  - Same technique can be applied to 1st and 2nd generation as well
- high p_T single τ-lepton + high p_T jet
- **No additional leptons**
  (unlike traditional single-LQ production modes)

Single-LQ production



reconstructed

Lepton-quark production

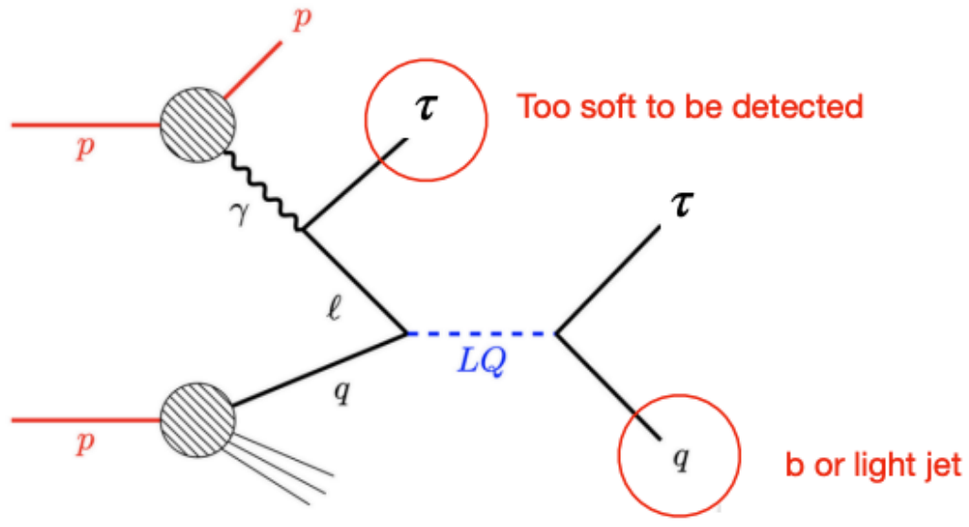


LQ search with lepton-quark collision

CMS-EXO-22-018

New for LHCP23!

- Event selections:
  - 3 τ-lepton decay cahnnels: (τ_h+jet, e+jet, μ+jet)
    - Divides into b-tag/no b-tag category
  - MET required to align with lepton
  - BDT to exploit different kinematics between W+Jet and signal
- **Collinear mass** as the final discriminant
  $m_{\text{coll}} = m_{vis}/\sqrt{x_1 x_2}$
  $x_{1(2)}$ = momentum fraction of vis. decay of τ

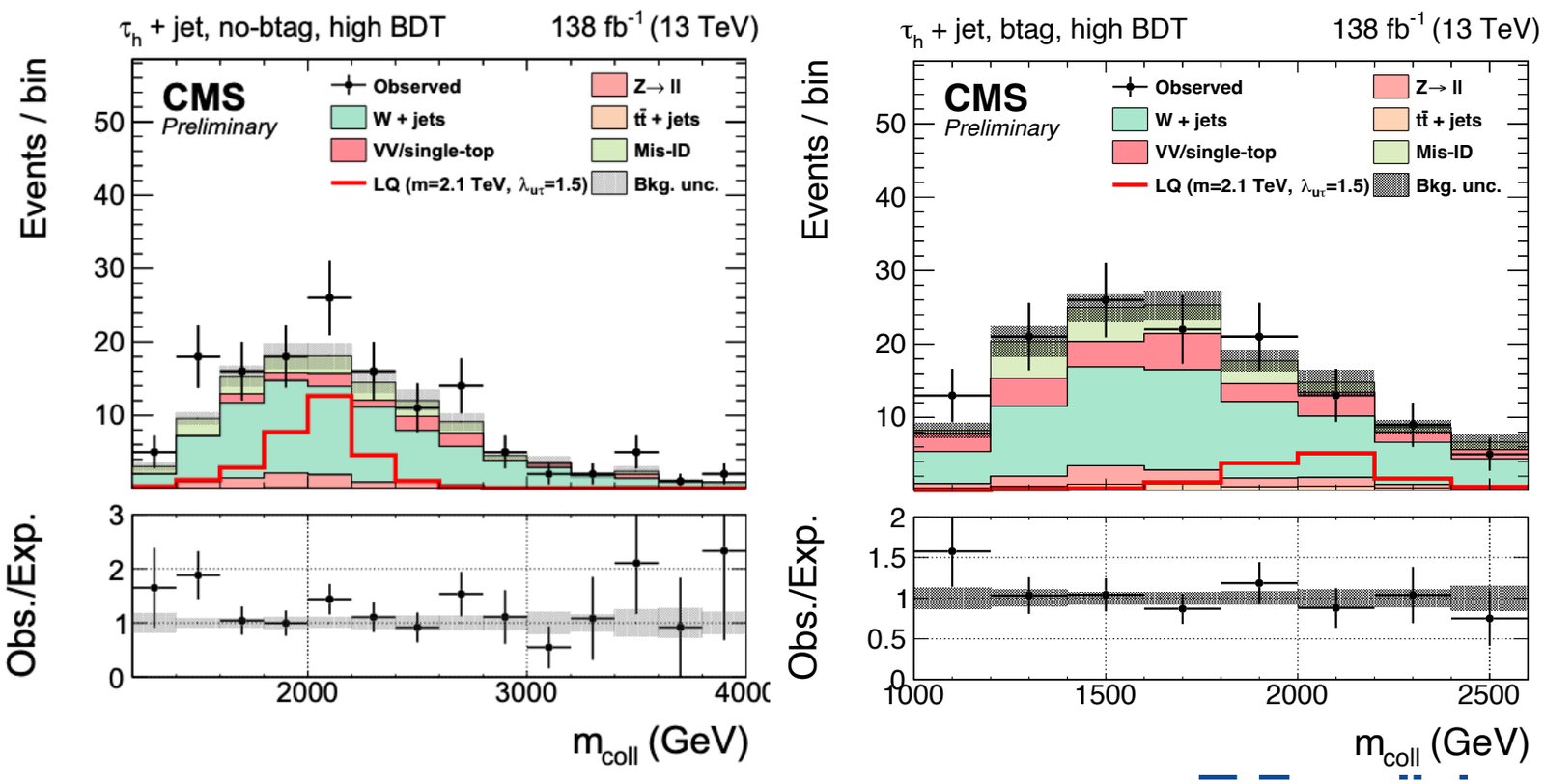


No b-tag

b-tag

No significant excess observed

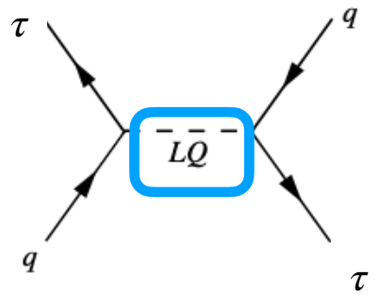
See Halil's talk for more details!



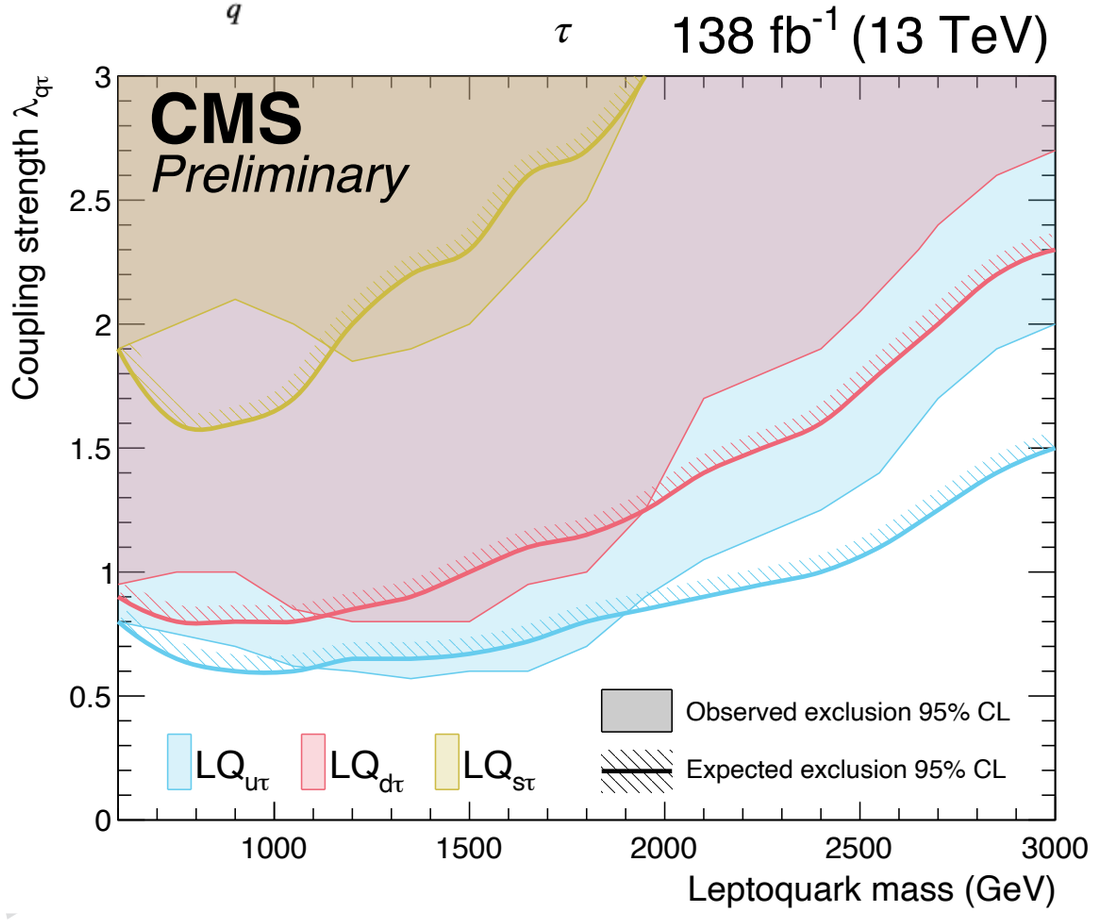
LQ search with lepton-quark collision

CMS-EXO-22-018

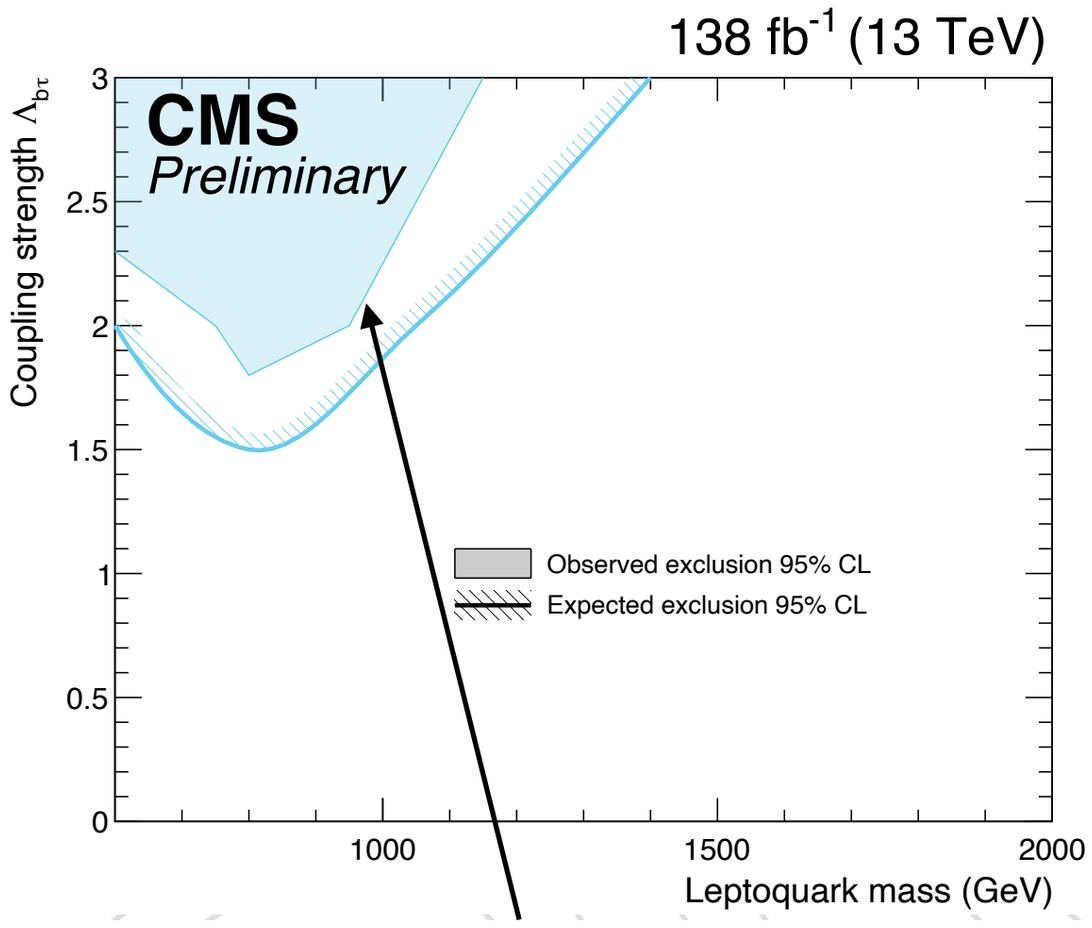
New for LHCP23!



Set constrains in the $m - \Lambda$ plane



First direct limits on leptoquark couplings to light flavored quarks and τ leptons $LQ_{s\tau}$, $LQ_{d\tau}$, $LQ_{u\tau}$

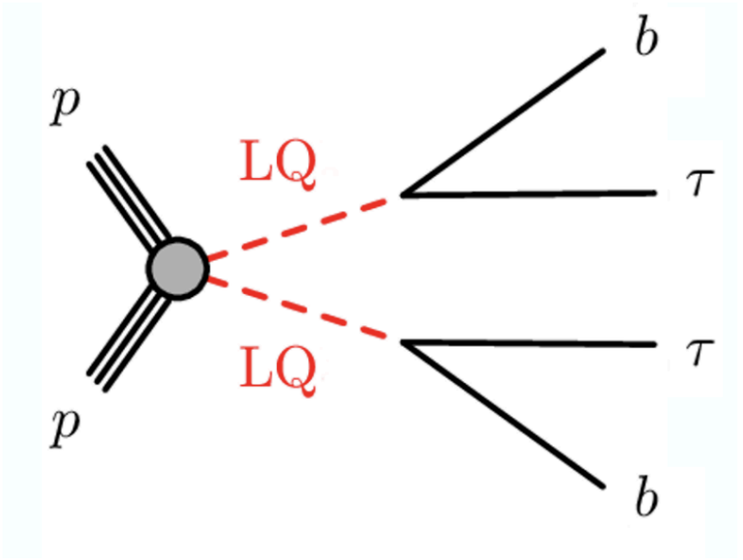


Competitive limit on $\Lambda_{\tau b}$ with those set using other production modes at high mass

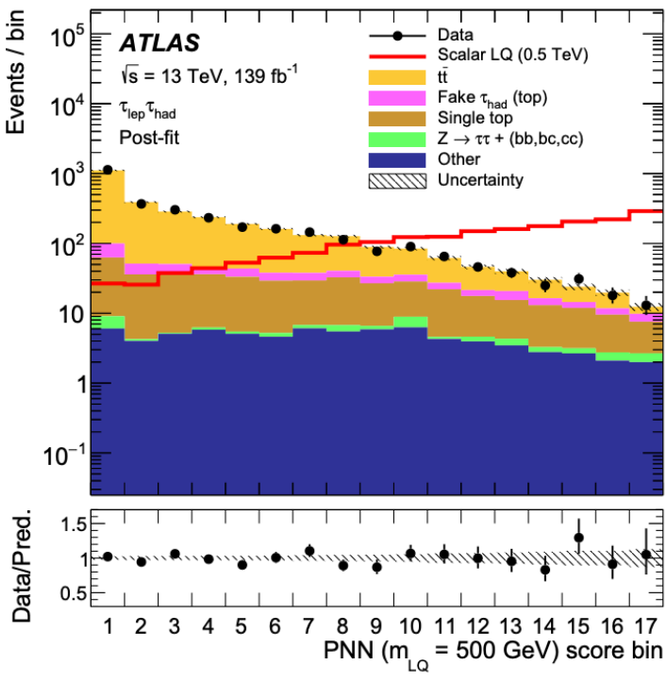
3rd generation LQ search

ATLAS EXPERIMENT **CERN-EP-2022-267**

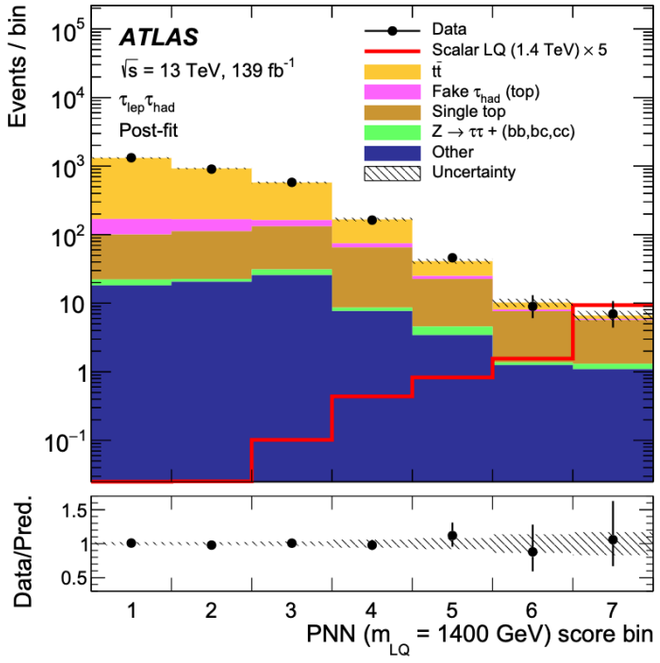
- Pair produced LQ decaying into $b\tau$ pairs
- Analysis channels:
  $\tau_h\tau_h + > 1b$ and $\tau_h\tau_{e/\mu} + > 1b$
- **Parametric Neural Network (PNN)** trained using LQ **mass** as input to distinguish from top backgrounds
  - Inputs: N_b, S_T, $m(\tau_h, \text{jet})$, $\Delta R(\tau, \text{jet})$
  - Maintain good separations for ALL LQ masses
- Improves limits by as much as 45% compared to 36fb^{-1} result

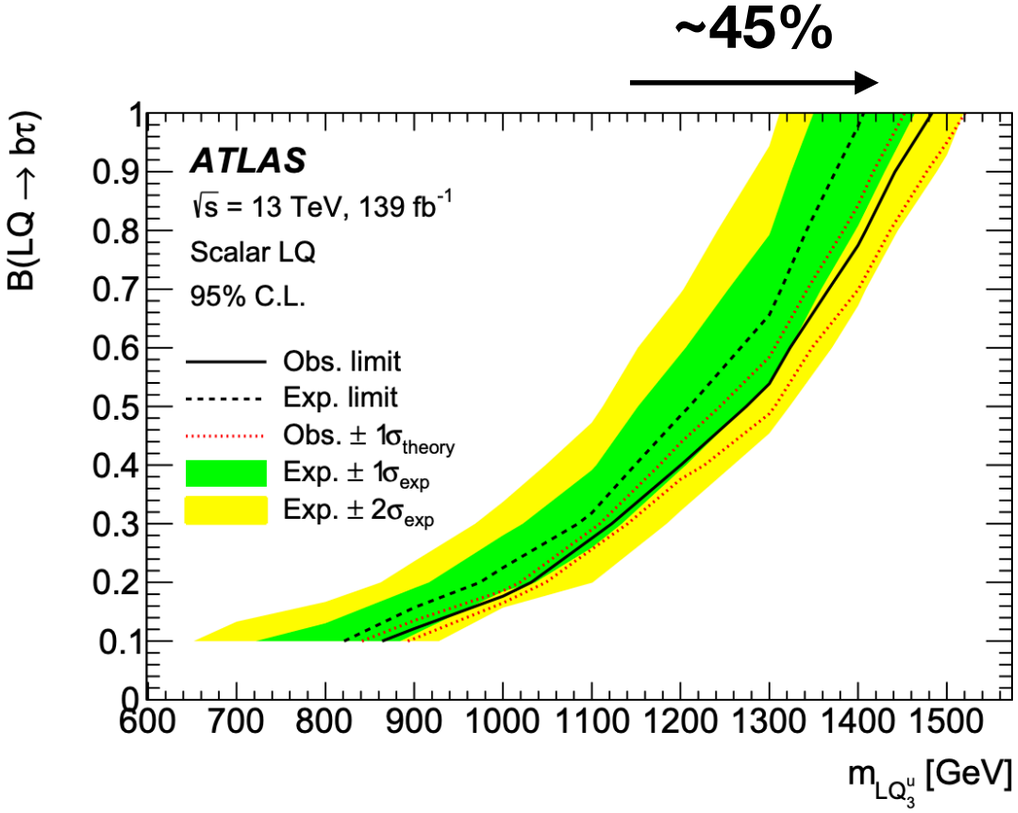


$m_{LQ} = 500$ GeV



$m_{LQ} = 1.4$ TeV





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More in Giovanni's talk

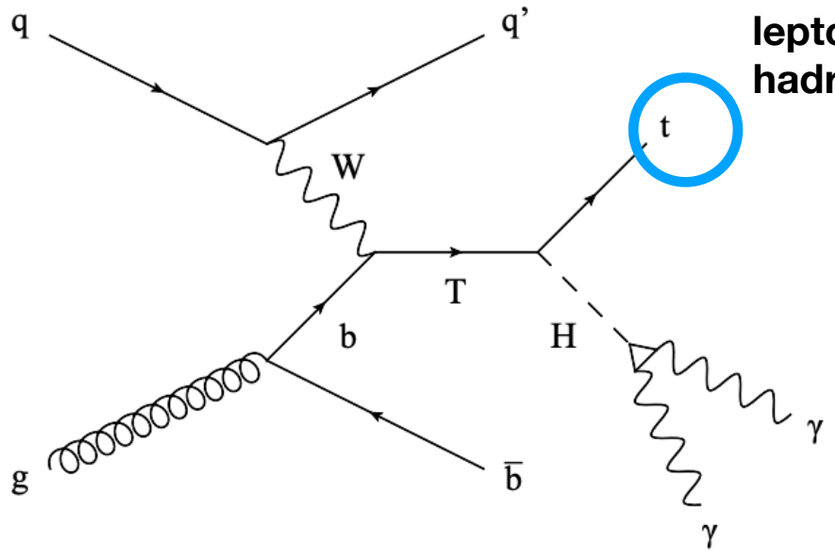
First search of T' using $H \to \gamma\gamma$

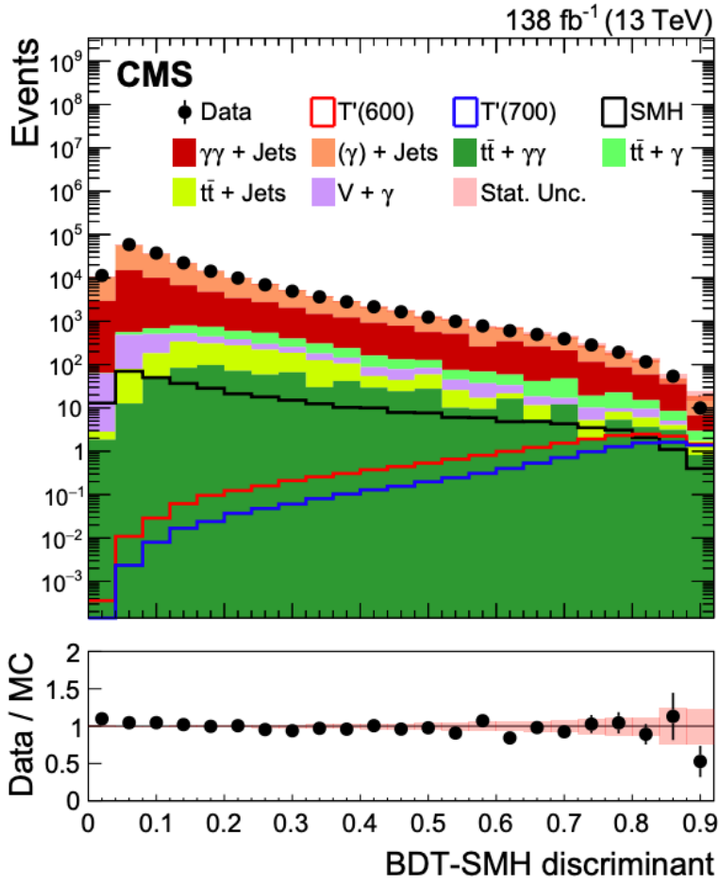
CMS-B2G-21-007

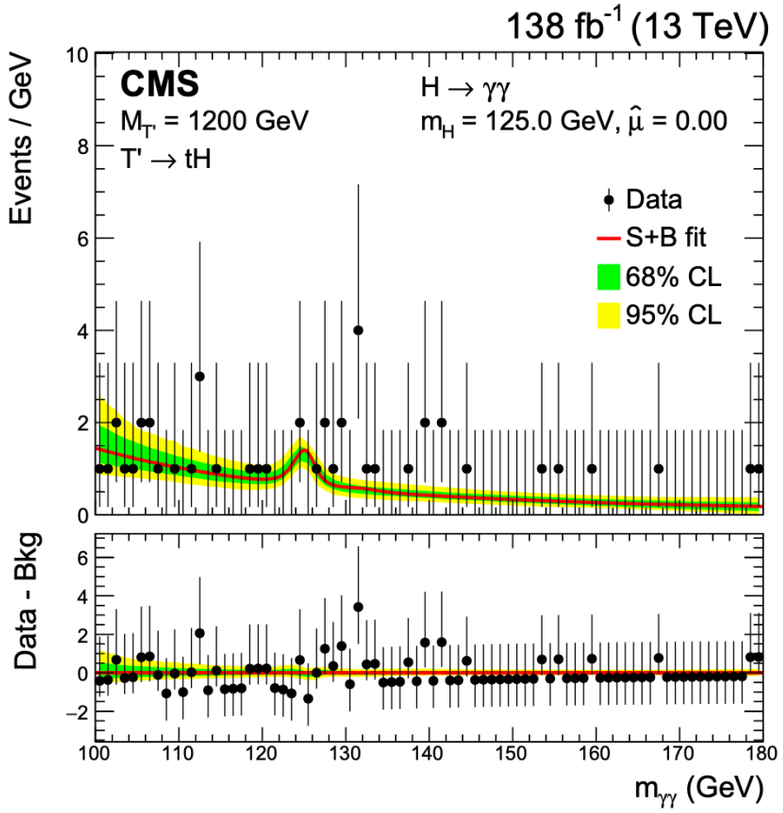
- Single production via EW interaction
  - Probes higher VLQ mass
- $T \to tH(H \to \gamma\gamma)$
  - Small Br
  - Excellent mass resolution 1-2%
- Search channel categorizes based on leptonic/hadronic top candidate

- SM ttH Higgs is the major background

- Multiple BDTs trained for low, medium, high M'_T
- Signal extraction with $m_{\gamma\gamma}$







More in Antimo's talk

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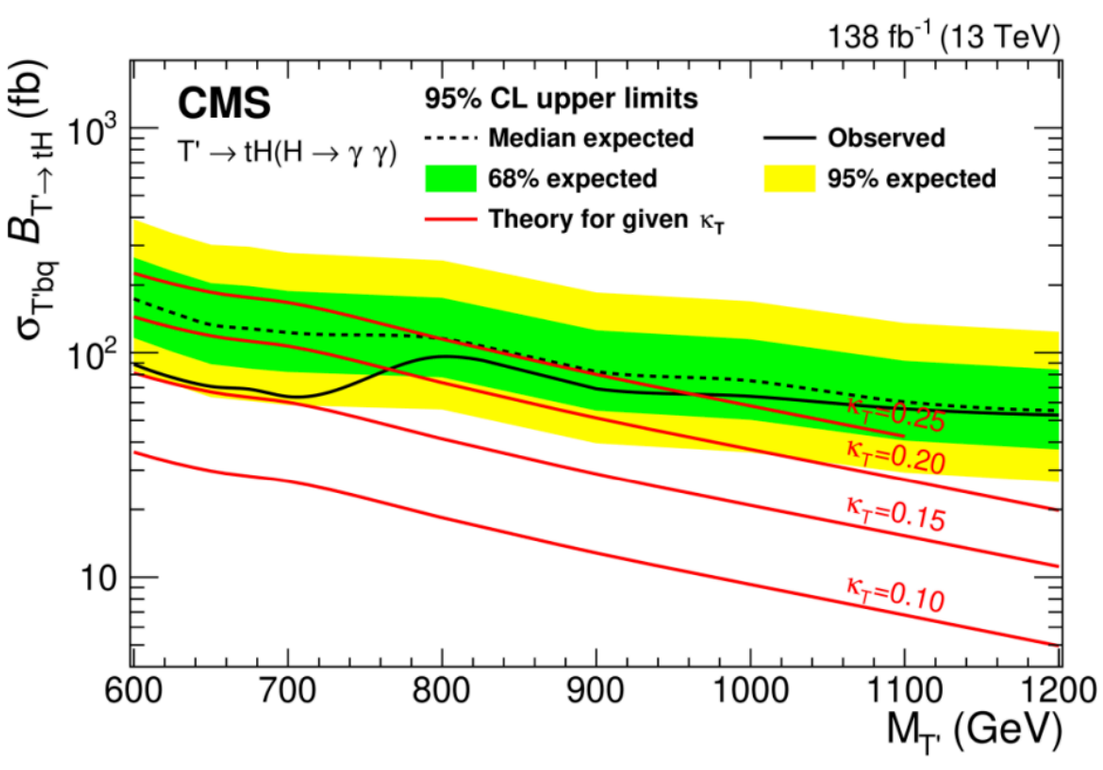
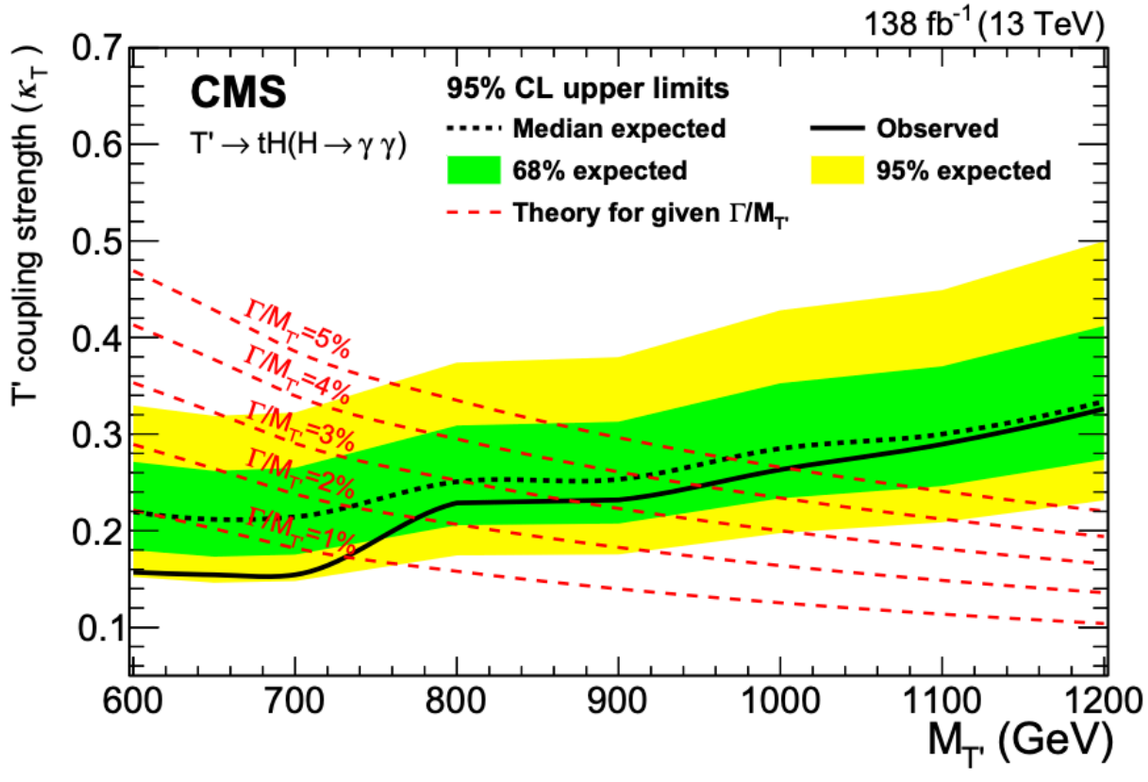
First search of T' using $H \to \gamma\gamma$

CMS-B2G-21-007

- Cross section depends on coupling strength κ_T and relative width $\Gamma/M_{T'}$
- With $\kappa_T = 0.25$, and $\Gamma/M_{T'} < 5\,\%$, the search excludes EW production of singlet T' up to a mass of 960 GeV.
- Most sensitive search to date for T masses up to 1.1 TeV within the same production mechanism exploration

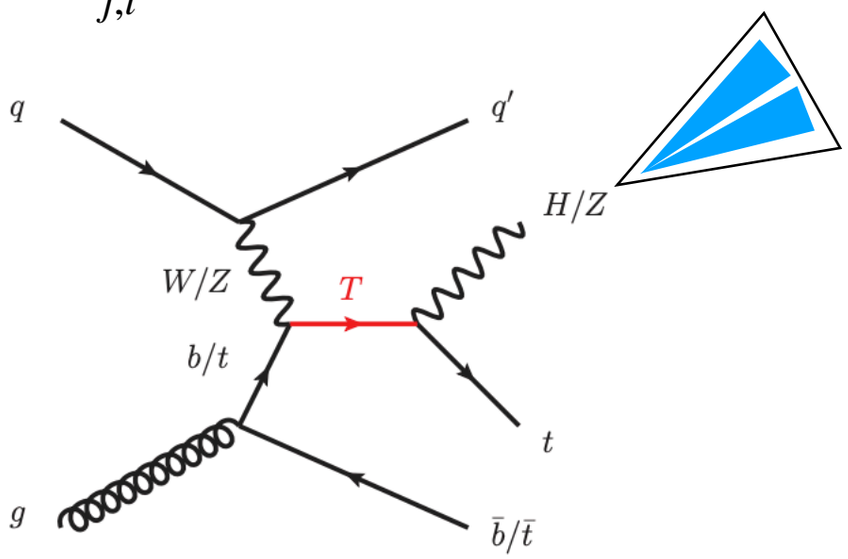




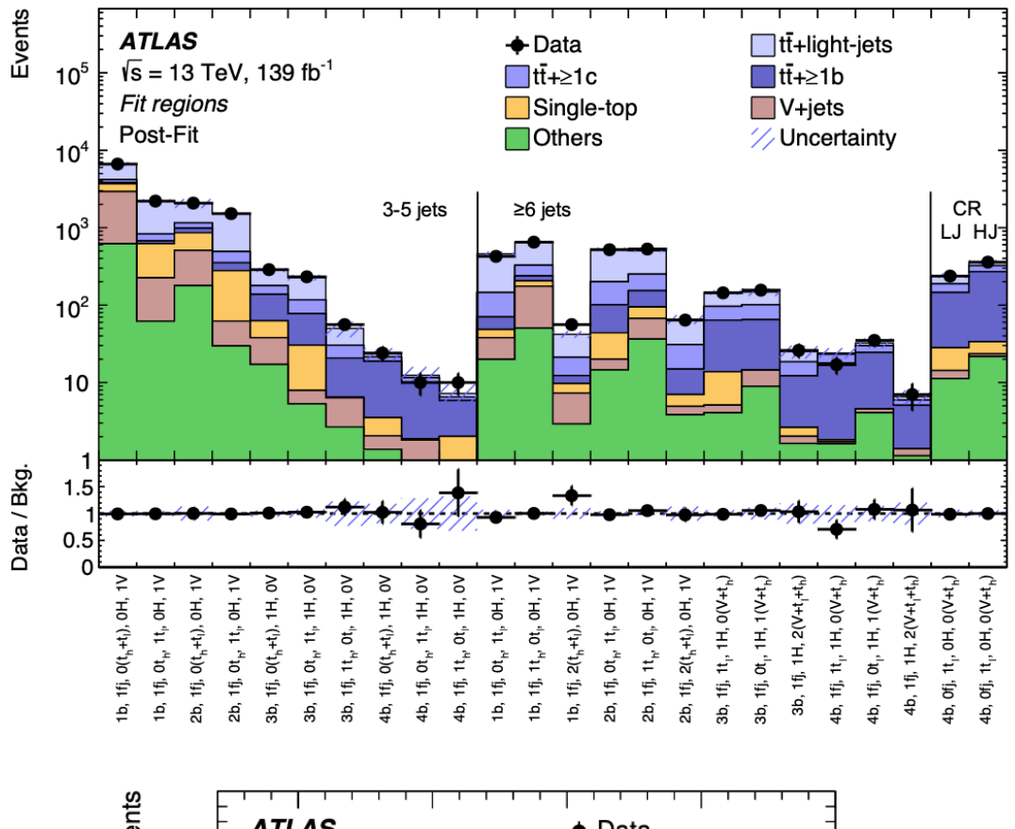
$T' \to tH(bb)/tZ(qq)$

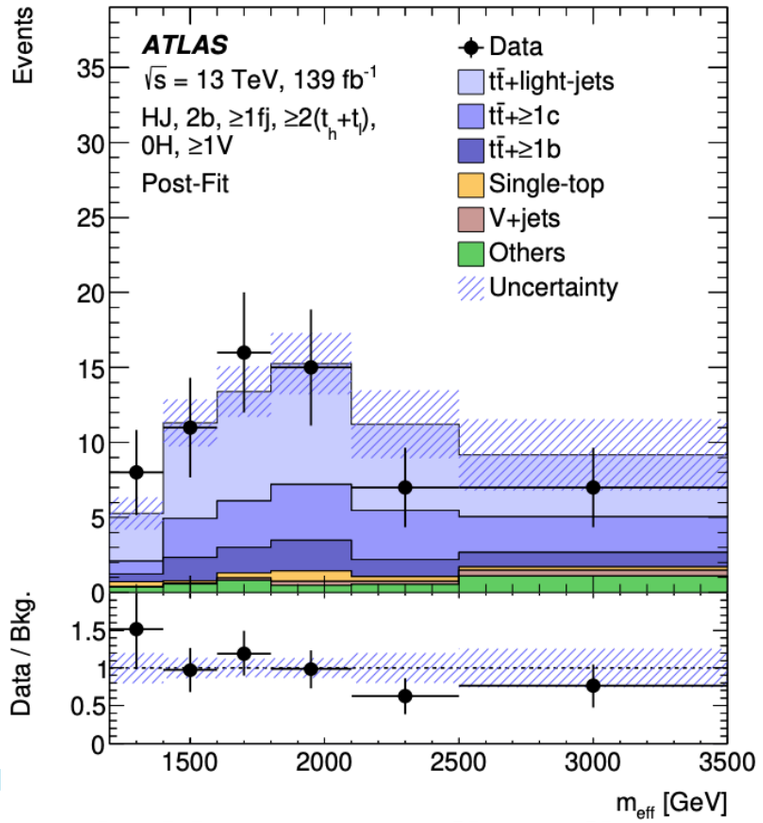
- Same model, different leverage: hadronic decays of **boosted H/Z/t**
  - Tag boosted H/Z/t jet with variable-R jet
  - Select H/Z/t based on p_T, mass and the number of sub-jets
- Comprehensive search channels:
  - 24 regions covering b and t-associated production
  - Use “effective mass” as final fit variable:

$$m_{eff} = \sum_{j,l} p_T + E_T^{miss}$$



ATLAS EXPERIMENT **CERN-EP-2023-058**



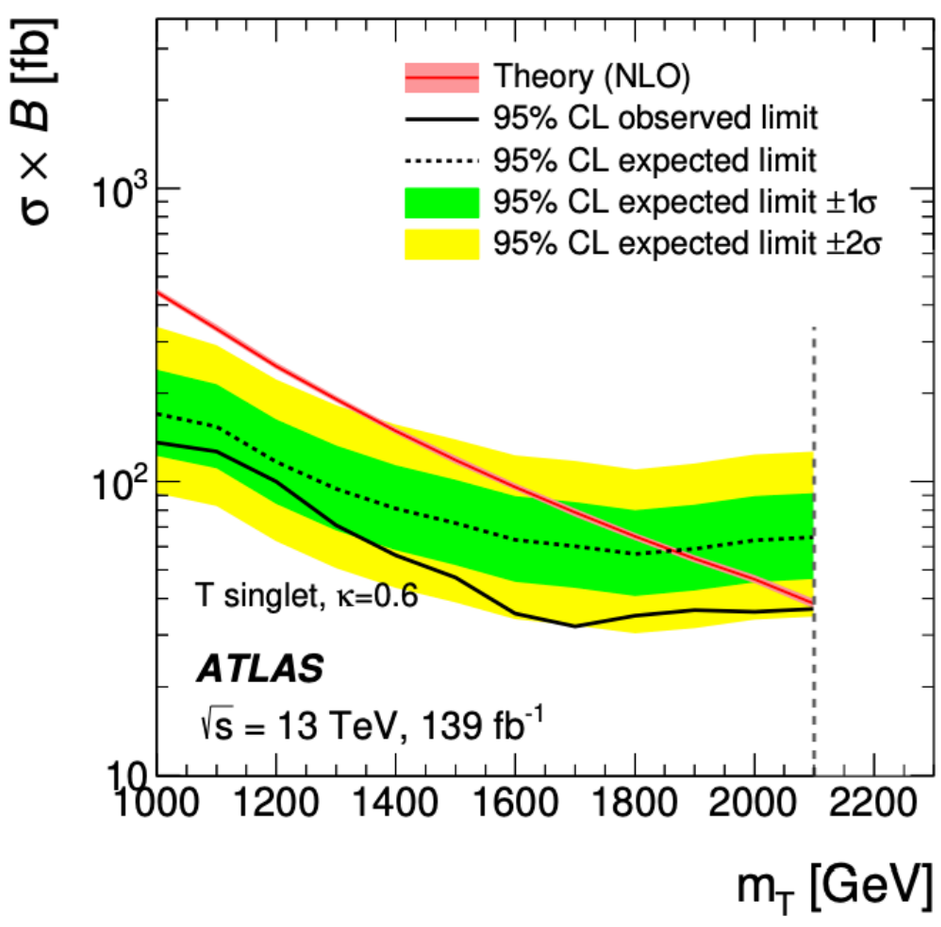


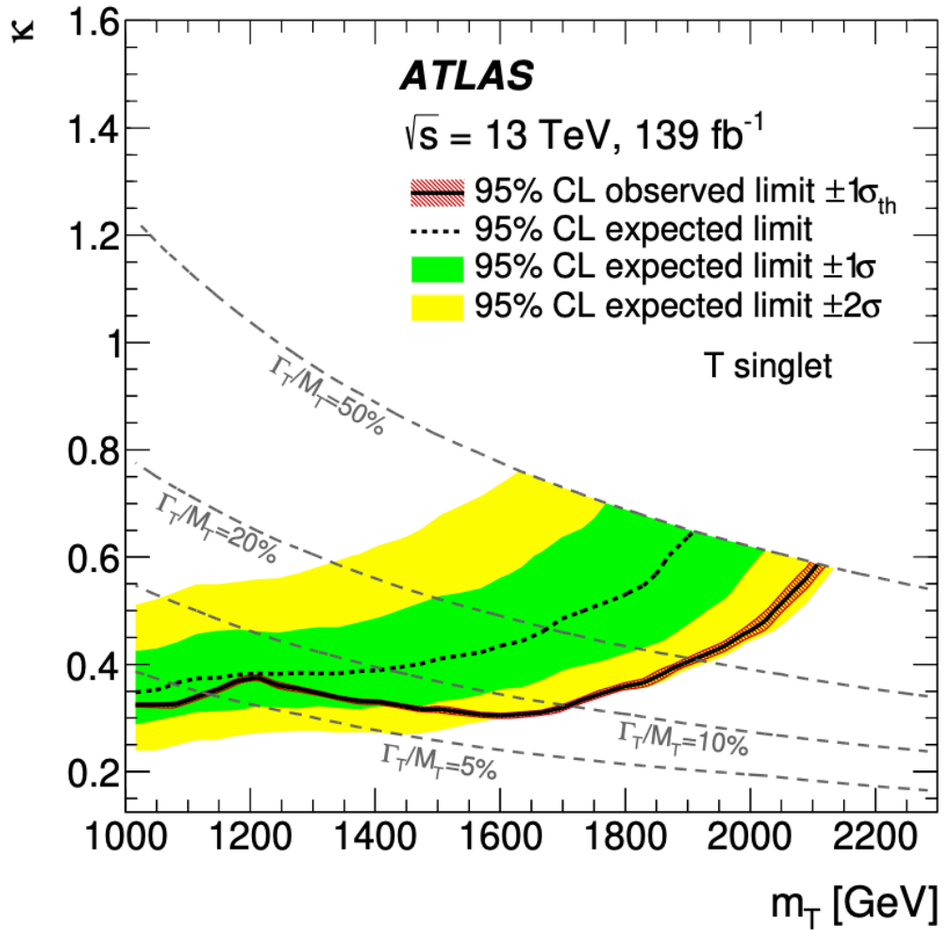
More in Venugopal’s talk

$T' \to tH(bb)/tZ(qq)$

CERN-EP-2023-058

- No significant excess observed.
- For singlet T quarks, all masses below 2.1 TeV are excluded at couplings $\kappa \geq 0.6$
- Limits extend down to $\kappa = 0.3$ for a T-quark mass of 1.6 TeV
  - ~60% improvement of limits w.r.t previous search

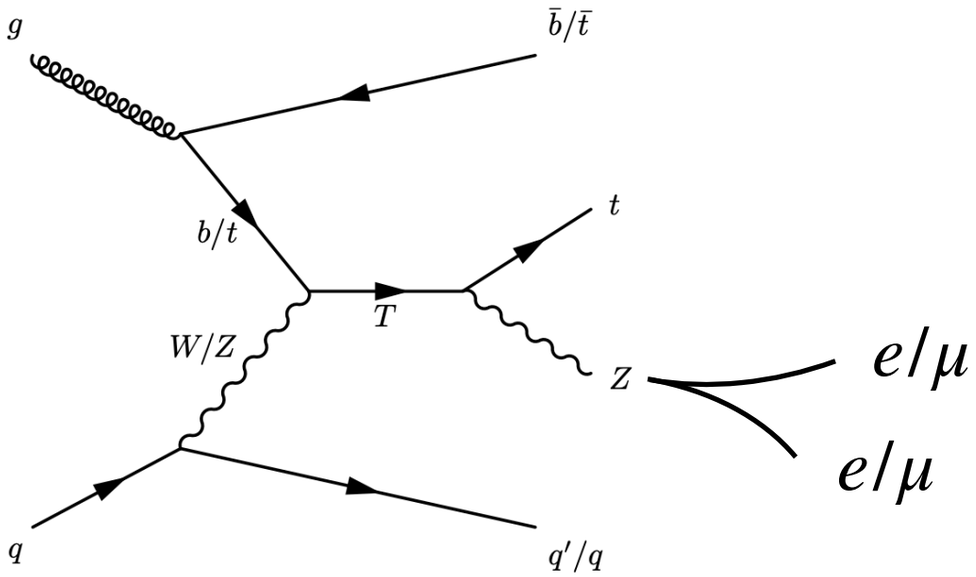


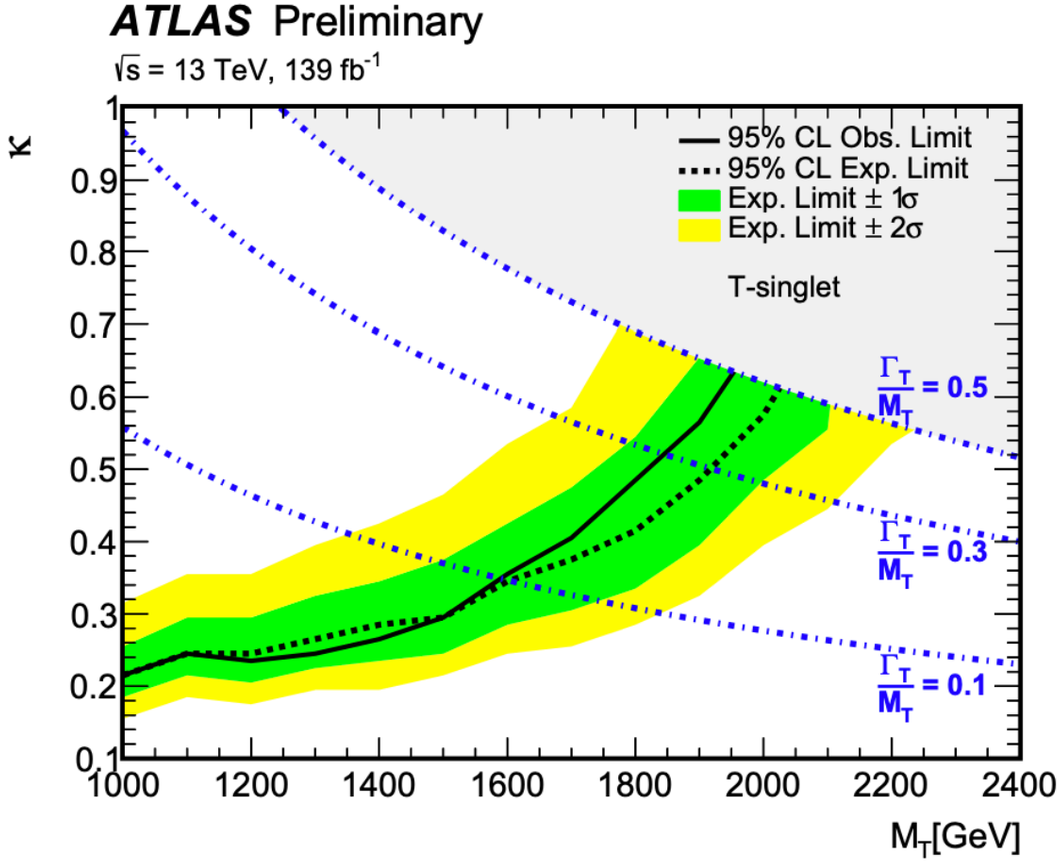


$T' \to tZ(ll)$

ATLAS EXPERIMENT **ATLAS-CONF-2023-020**

- Similar T' search, but with electron/muon pairs from Z
  - Optimized independently for 2ℓ and 3ℓ channel
- Smaller Br, but cleaner signature
- Similar exclusion limit reached compared to the hadronic search
  - Exclude up to ~2 TeV for $\kappa_T \sim 0.6$





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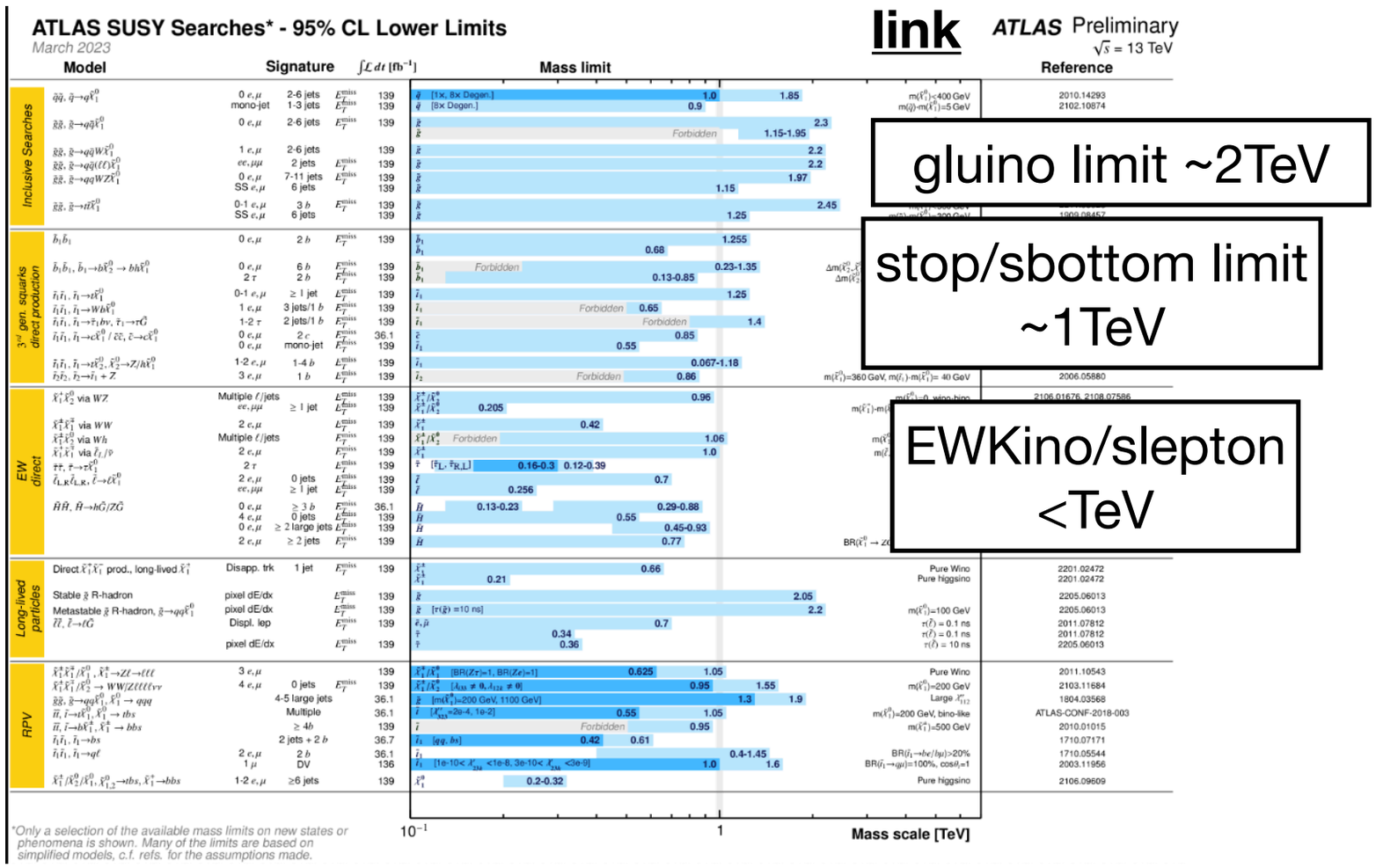
Overview of SUSY searches

- Both CMS and ATLAS have very comprehensive search program covering a wide range of SUSY signatures

- Highlight recent result with EW SUSY searches



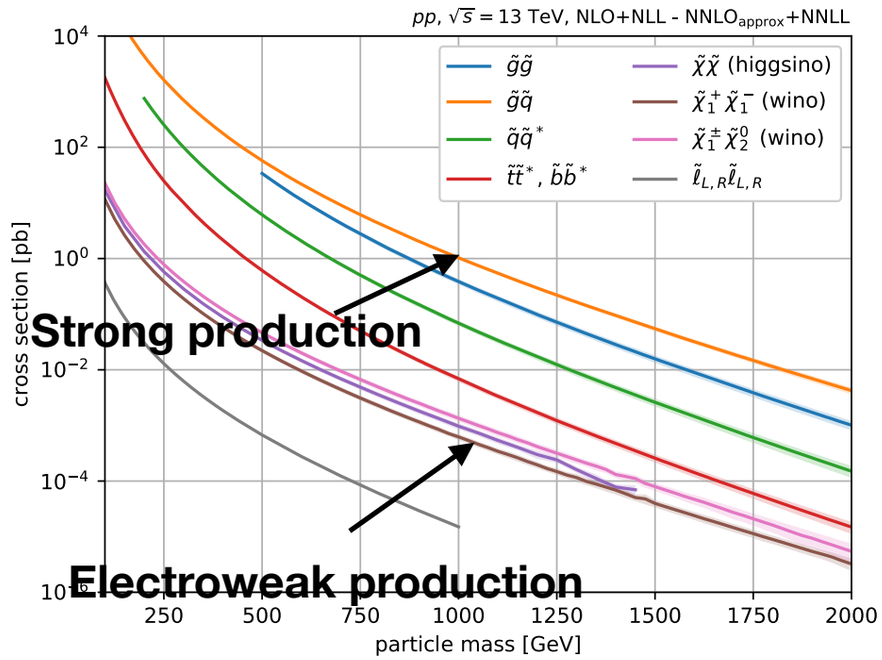
link

gluino limit ~2TeV

stop/sbottom limit ~1TeV

EWKino/slepton <TeV

LHC SUSY Working group



CMS Summary plots show similar sensitivity

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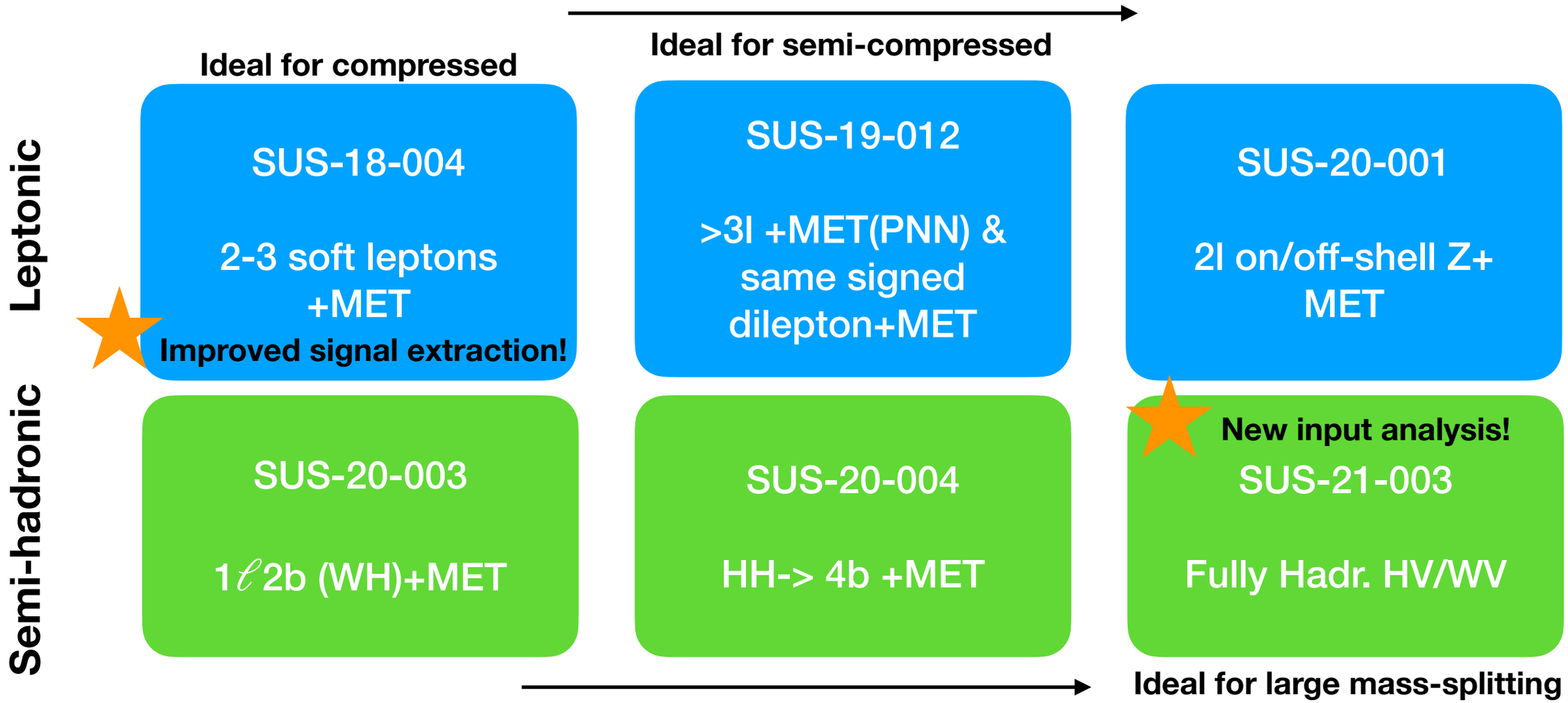
Electroweak SUSY

CMS-SUS-21-008

- EW SUSY searches phases space is very challenging
  - Generally smaller cross section
  - Compressed/split mass spectrum changes kinematics drastically
- CMS legacy run 2 combination
  - Utilize strength of different analysis
  - New interpretations & techniques



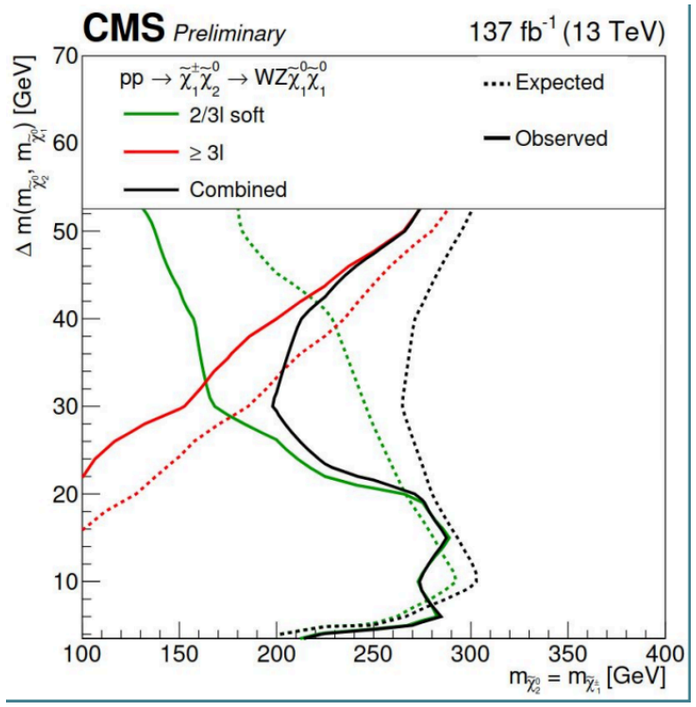
More in Sezen's talk

Electroweakino exclusion

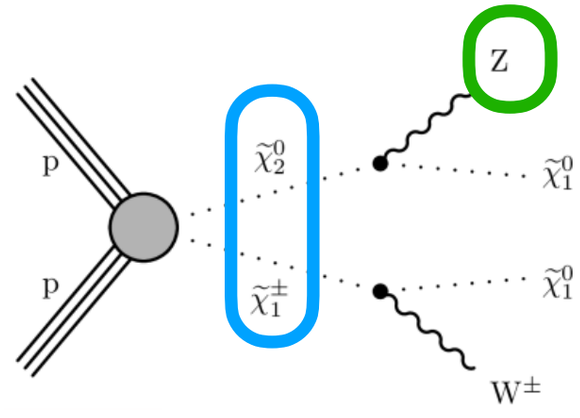
CMS-SUS-21-008

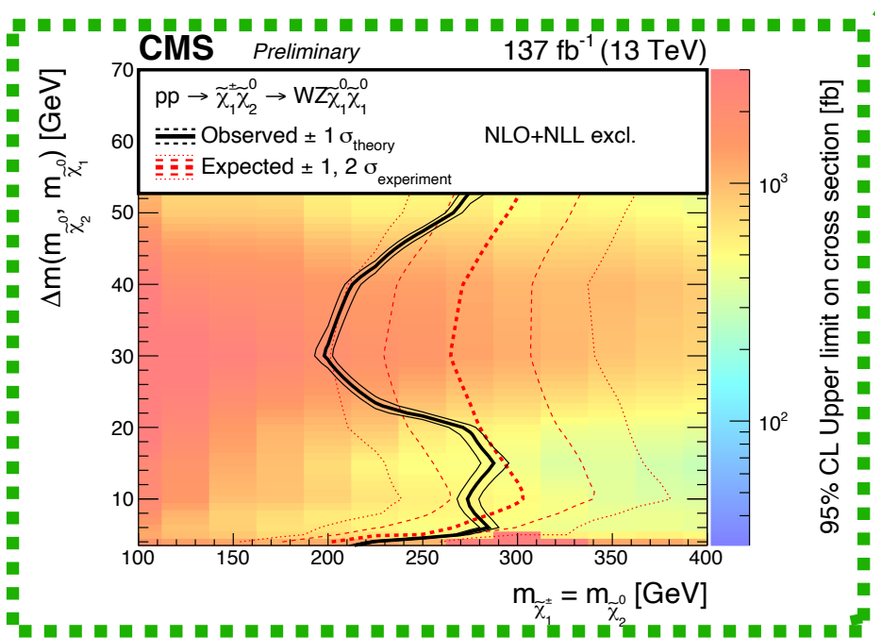
- Extend sensitivity in both compressed and uncompressed region
  - New technique and new analysis

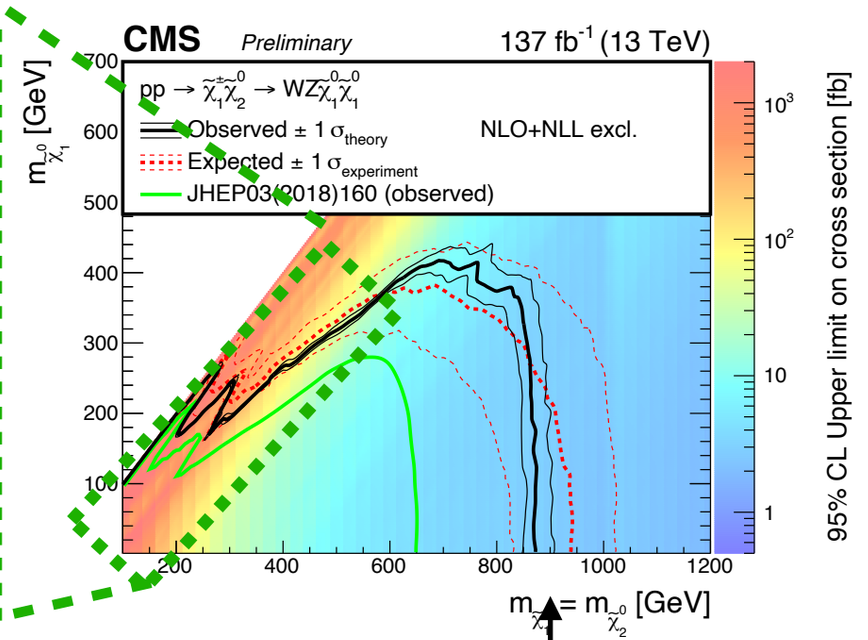
Complementarity between 2/3l soft and >3l



compressed region:
Improved signal extraction using parametric binning of Δm







uncompressed region:
New fully hadronic final state

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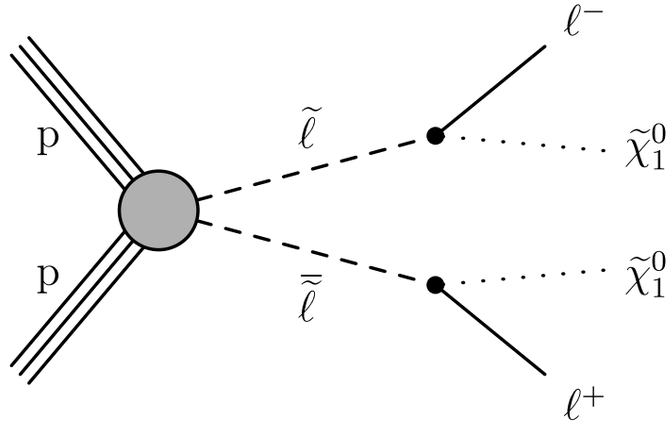
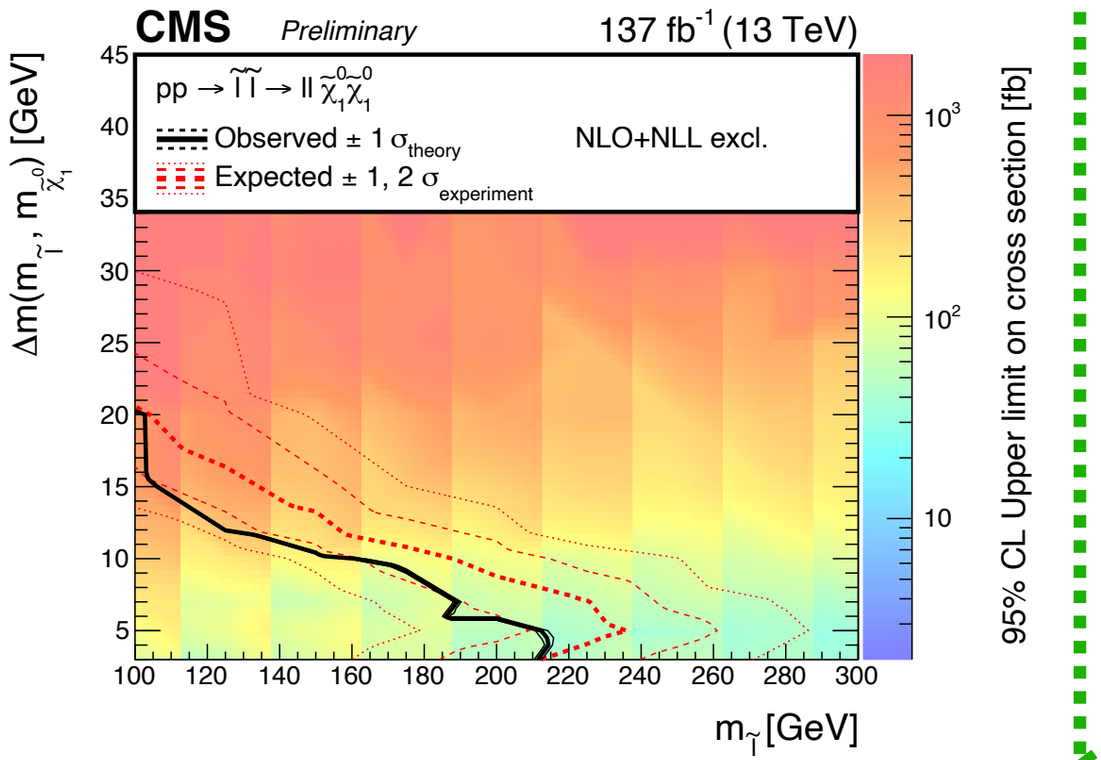
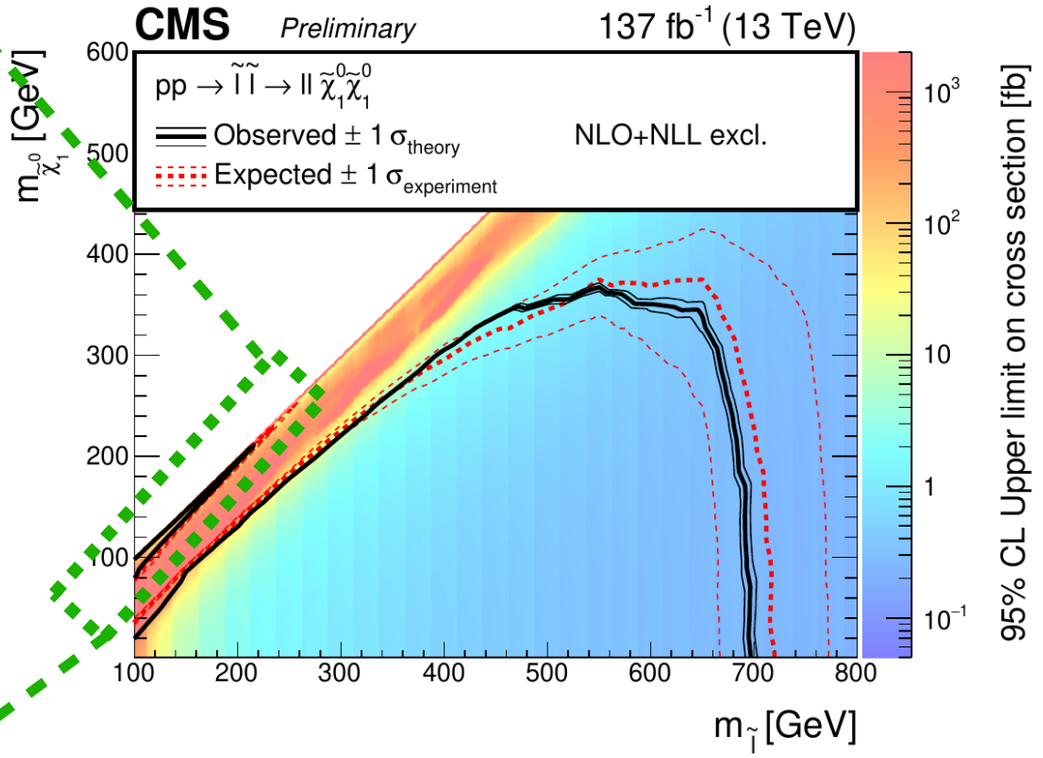
Slepton

CMS-SUS-21-008

- New interpretation w.r.t. 2016 combination
- Extremely rare:
  - One order of magnitude smaller cross section than EWKino!
- Compressed region driven by 2/3l soft lepton analysis
  - Reach slepton mass of ~200GeV at $\Delta m = 5\mathrm{GeV}$







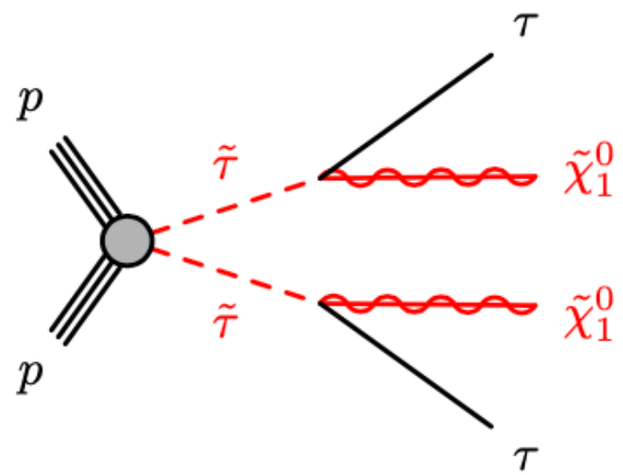
Stau pair production

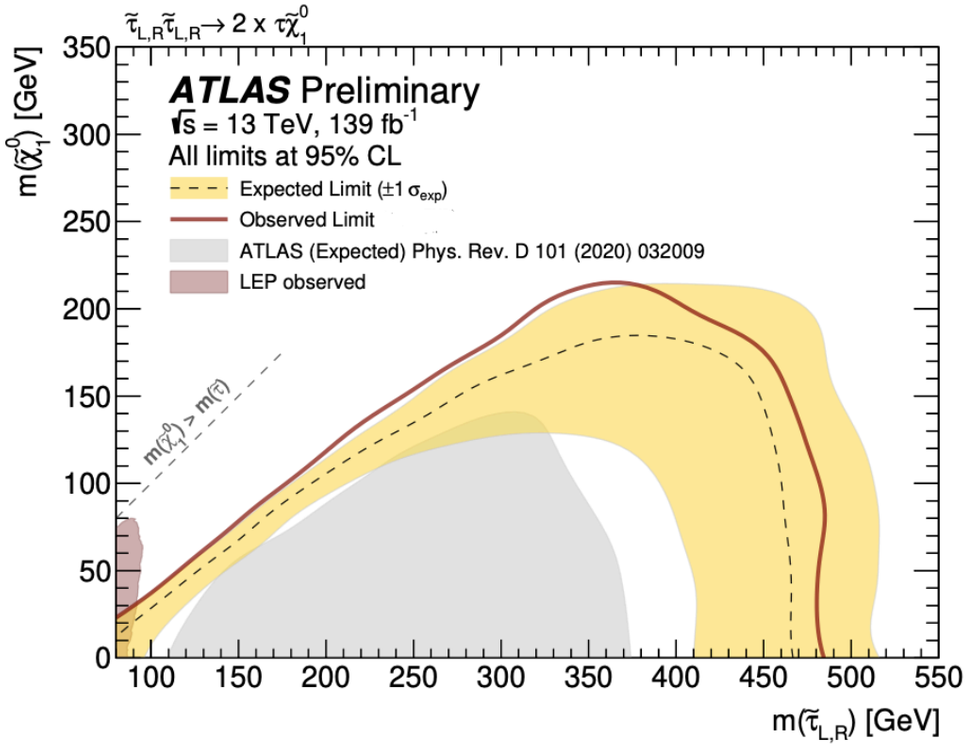
ATLAS EXPERIMENT **ATLAS-CONF-2023-029**

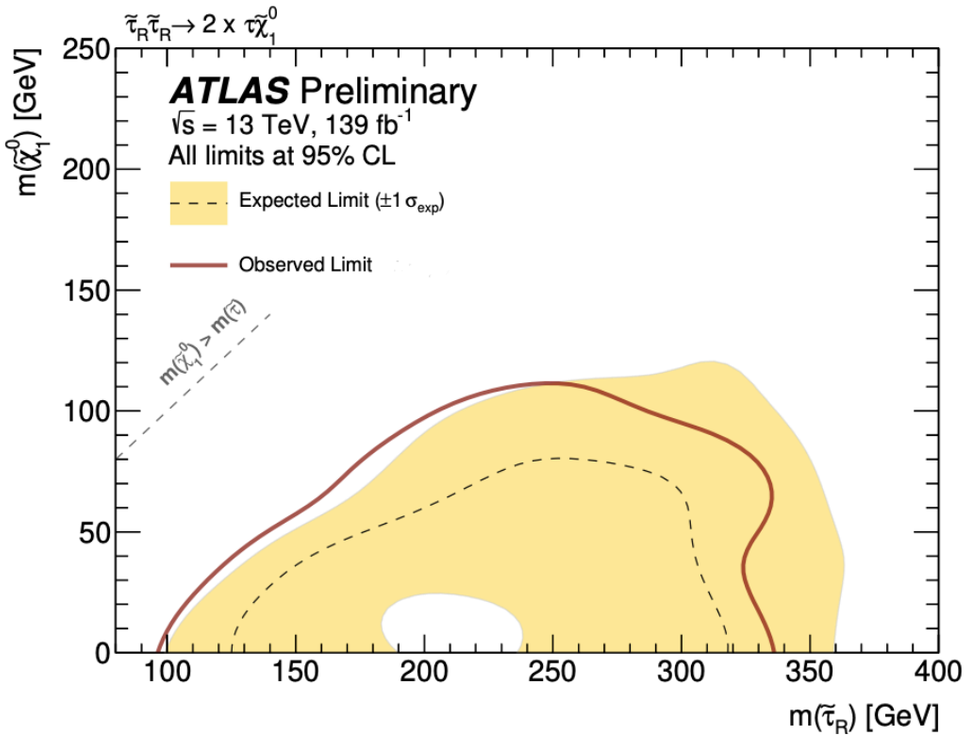
New for LHCP23!

- Search with hadronic τ_h final states which has higher BR
- Improvements comes from
  - Better tau ID with RNN[1]
  - Increased luminosity

- First sensitivity right-handed star pair production at LHC!







More in Xuanhong's talk

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Summary

- Many new results with LHC Run 2 data from ATLAS and CMS
- Seen progress made with:
  - Novel production mode (lepton-PDF)
  - Better reconstruction for physics objects (tau, boosted H/Z/t)
  - Advanced analysis techniques (PNN, BDT)
  - Comprehensive combination
- LHC Run 3 data is coming fast!
  - Apply the lessons learned in Run 2 searches