Status of Supersymmetry (SUSY) searches in CMS

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On behalf of the CMS Collaboration

BSM 2023 - Egypt

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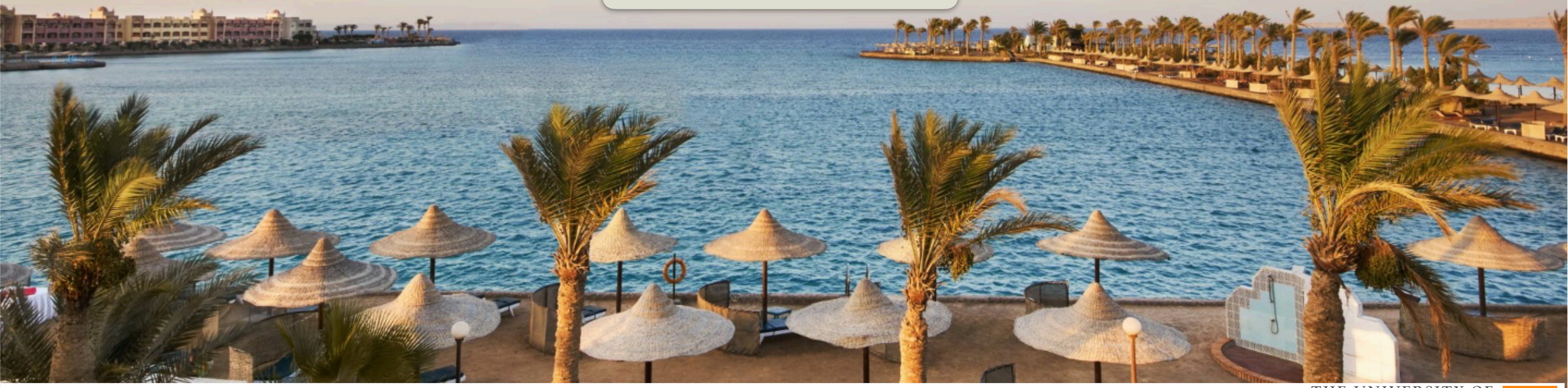


THE UNIVERSITY OF TENNESSEE KNOXVILLE

SUSY is one of many **Standard Model (SM) extensions,**
it provides solutions to several SM limitations

- *Hierarchy problem* → *SUSY stabilizes the low Higgs boson mass*
- *Dark Matter (DM) candidate* → *SUSY presents WIMP DM candidate* if R-Parity is conserved*
- *Many SUSY models*

**The lightest supersymmetric particle (LSP)*

How does CMS collaboration look for SUSY particles?

Non-exhaustive collaboration

How does CMS collaboration look for SUSY particles?

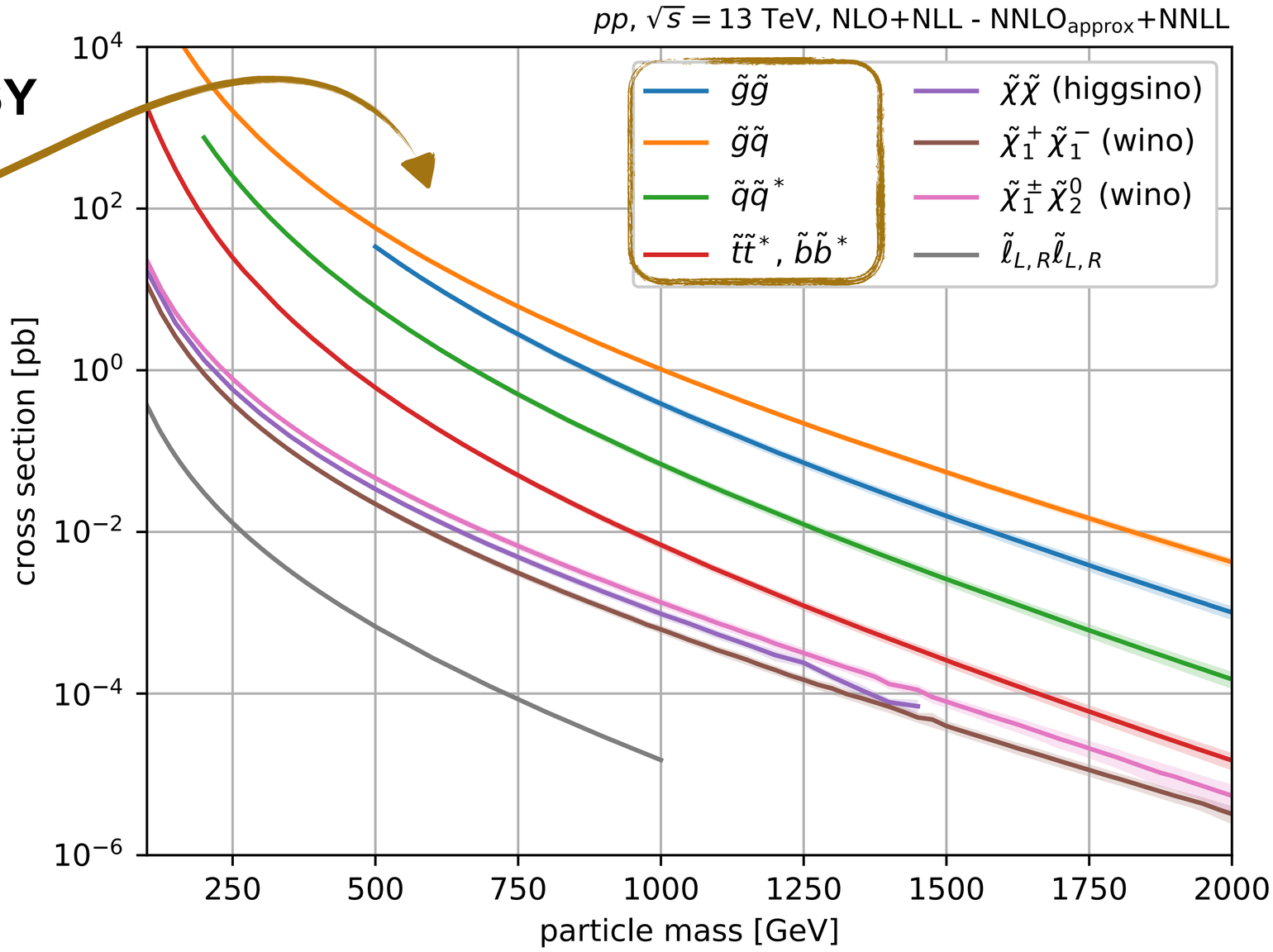
Non-exhaustive collaboration

Experimental approaches

- *High beam energy* → *explore TeV scale*
- *More data* → *probe rare processes*
- *New ideas & new search tool*

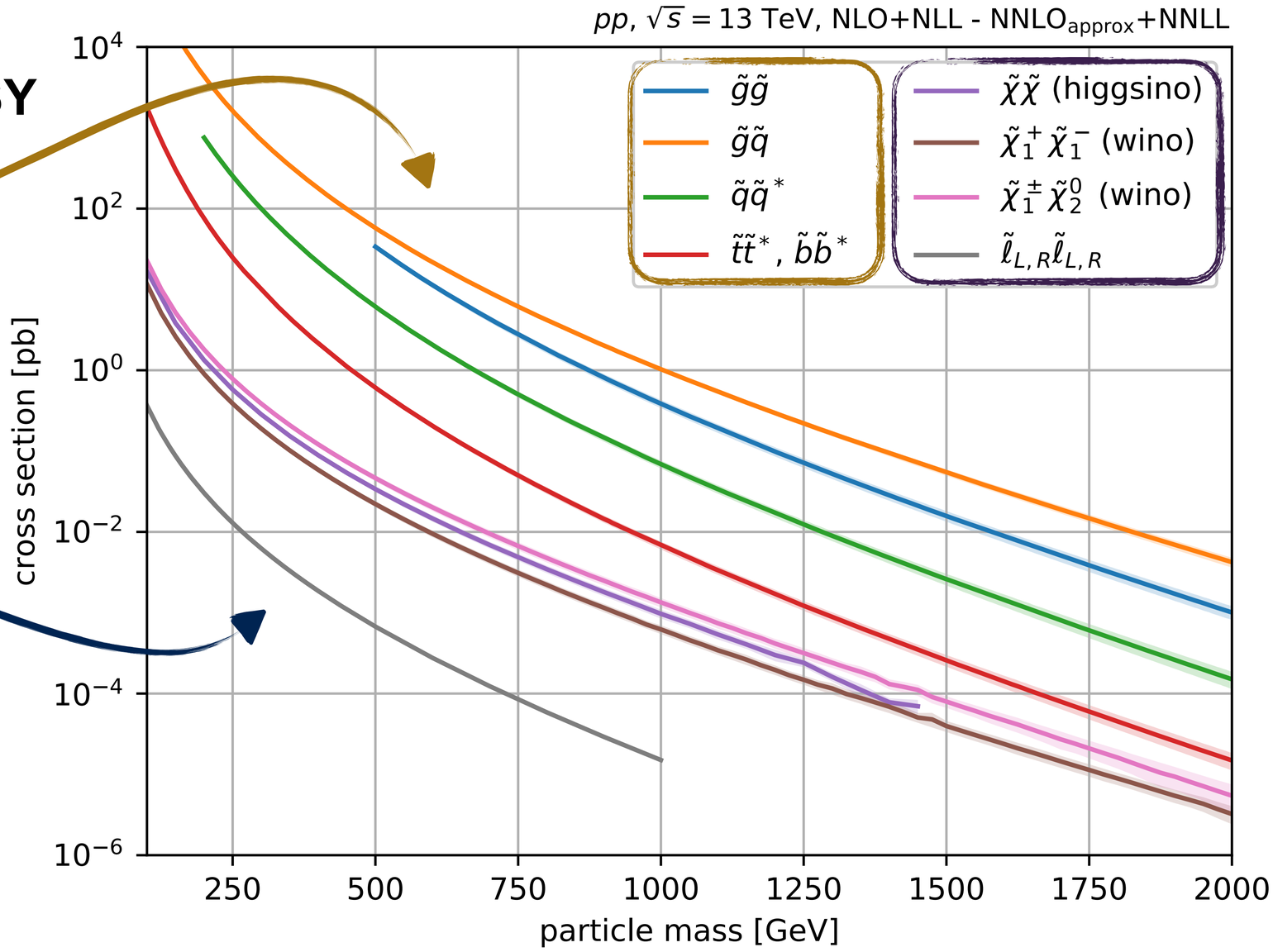
The CMS has a rich and vast SUSY search program

- *Earlier searches focused on strong productions (higher cross sections)*



The CMS has a rich and vast SUSY search program

- Earlier searches focused on strong productions (higher cross sections)
- Now expanding SUSY searches
  - Electroweak production
  - Challenging signatures, sophisticated analysis methods



⚠ **Only a handful of recent searches from CMS experiment will be shown**

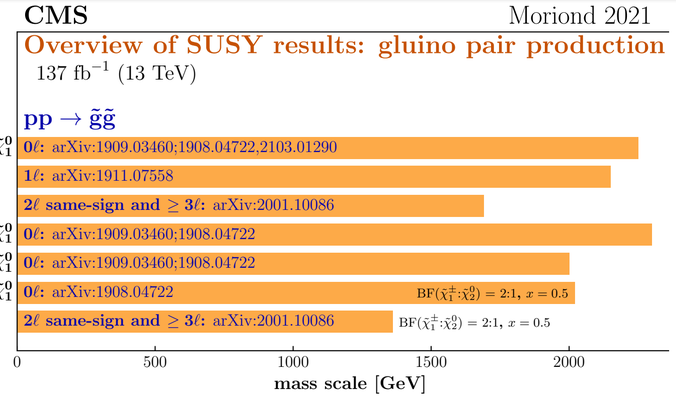
SUSY searches with CMS detector @ 13 TeV

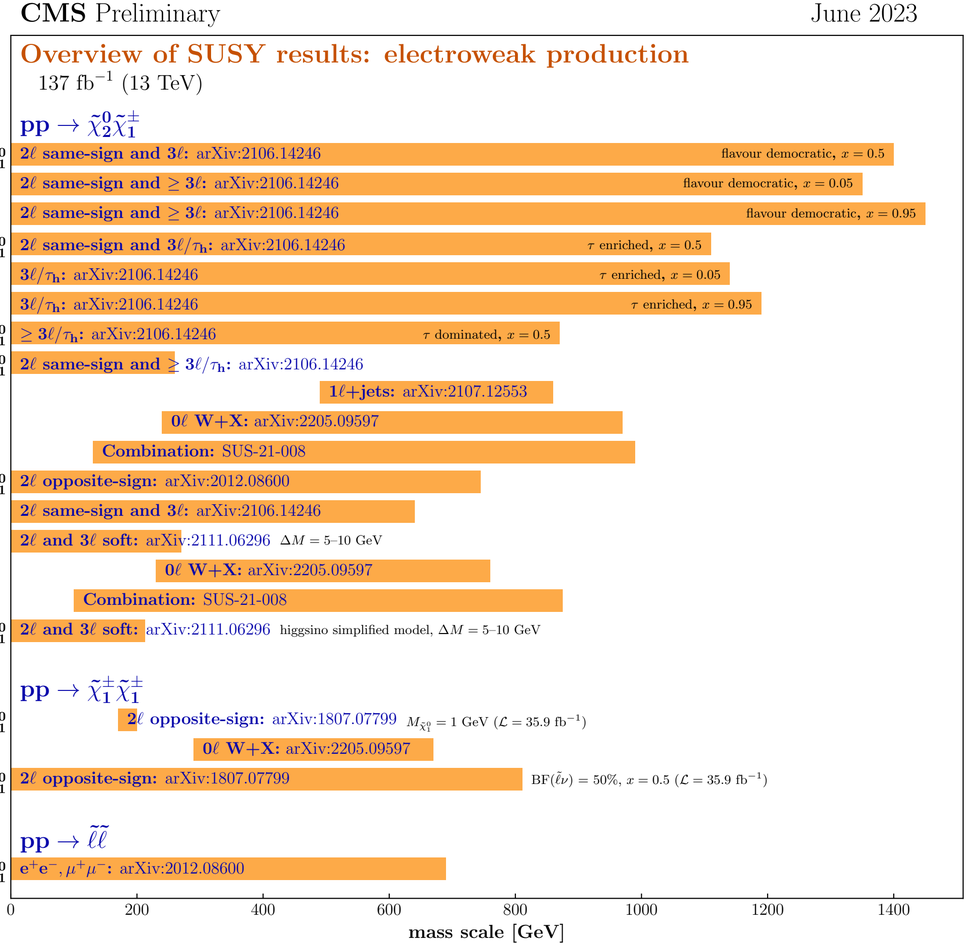
Synopsis: mass reach, per models

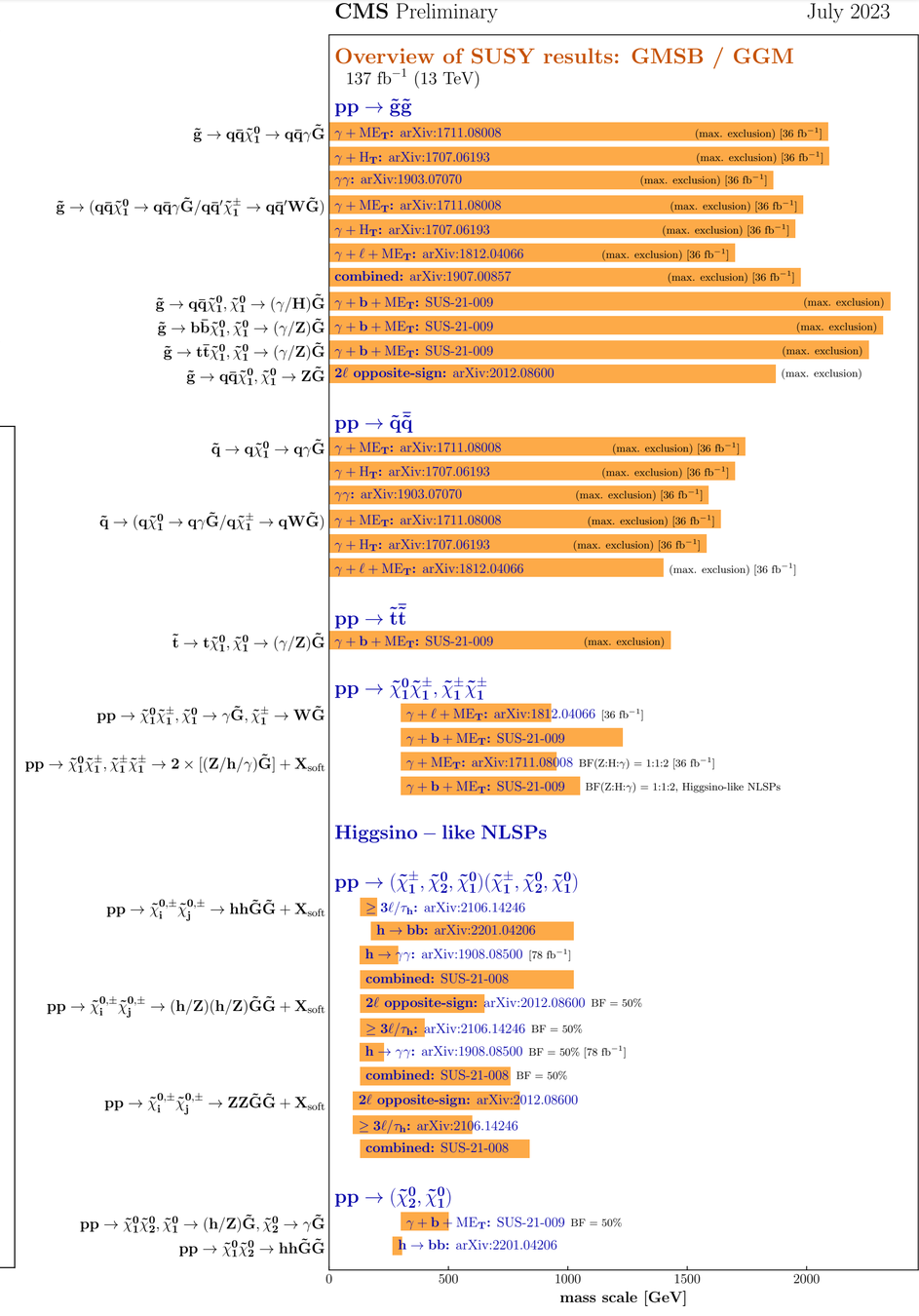
- *Despite numerous SUSY searches, no experimental evidence at LHC*
- *Mass limits have been set at 95% CL in the context of simplified models and for different final states*

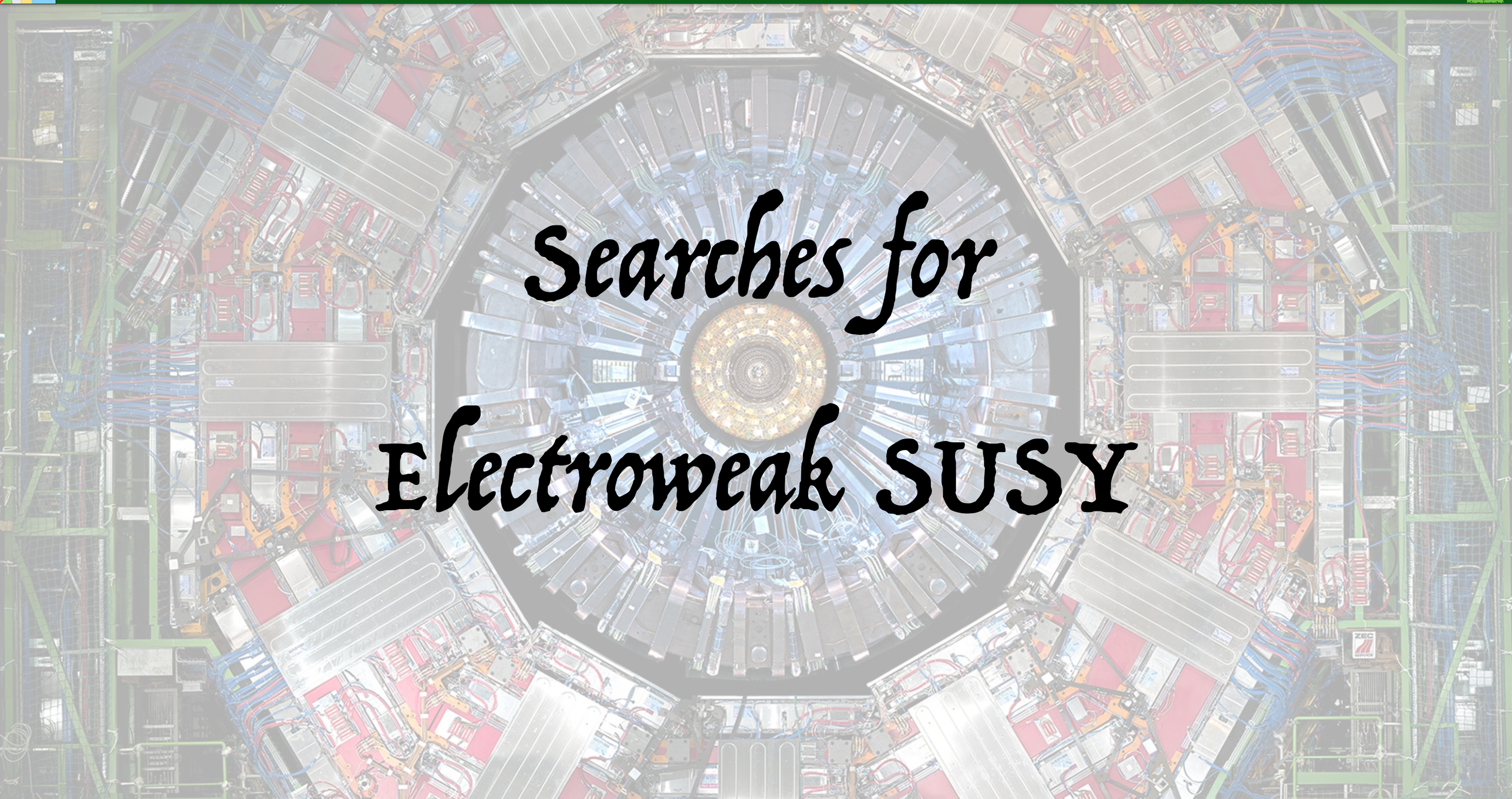
https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/index.html

Only a handful of recent searches in this talk









Searches for Electroweak SUSY

- ***Combination of 6 different SUSY searches to enhance sensitivity to a wide range of Electroweak (EW) SUSY mass hypotheses***

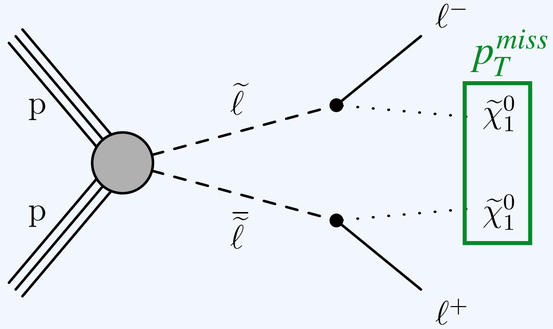
Compressed spectra

Leptonic	"$2/3\ell$ soft" 2 or 3 e/μ Opposite-sign, same flavor pair CMS-SUS-18-004	"$\geq 3\ell$" 3 or 4 ℓ Or 2 same-sign light leptons CMS-SUS-19-012	"2ℓ on-Z/non-resonant" 2 e/μ Opposite-sign, same flavor pair CMS-SUS-20-001
(Semi)Hadronic	"$1\ell 2b$" - WH 2 or 3 e/μ 1 e/μ, $H \to bb$, MET CMS-SUS-20-003	"$4b$" - HH 0ℓ $H \to bb$, MET CMS-SUS-20-004	"Hadr. WX" Fully hadronic final state ≥ 2 $jets$(AK8) & 2-6 $jets$(AK4) CMS-SUS-21-002

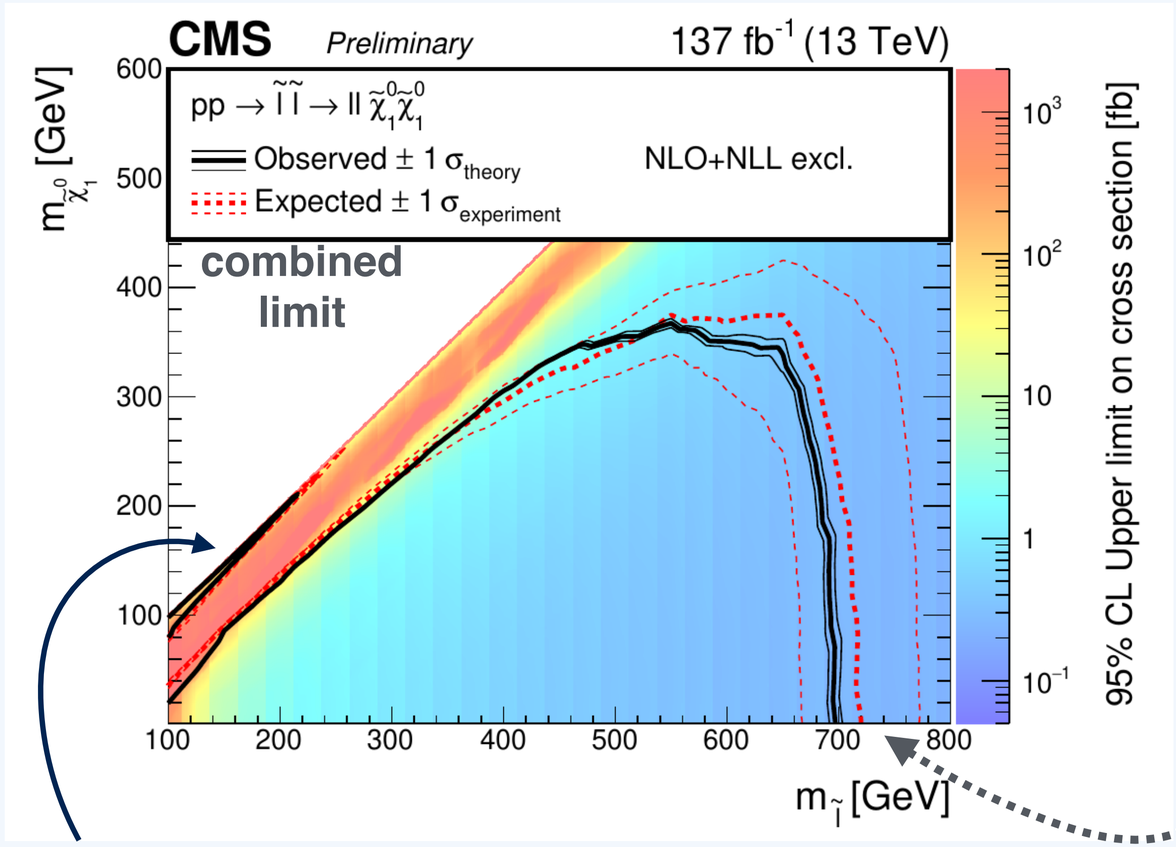
Extremely challenging searches - benefit from combinations!

CMS-PAS-SUS-21-008

Searches for Electroweak production of sleptons, charginos, neutralinos



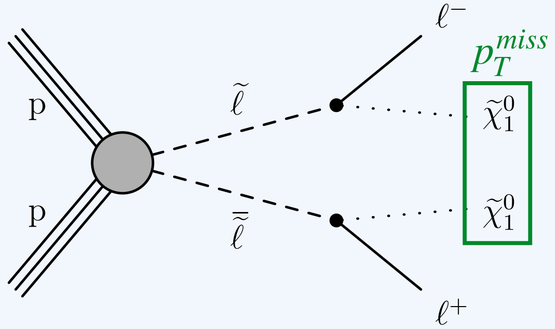
- **2/3l soft search** targets **compressed signatures**
  $\Delta m = m_{\tilde{\ell}} - m_{\tilde{\chi}_1^0} \rightarrow$ small
- **2l non resonant**: for **uncompressed scenario**



The "2/3l soft" search excludes $m_{\tilde{l}}$ of ~215 GeV at $\Delta m = 5\ GeV$

CMS-PAS-SUS-21-008

Searches for Electroweak production of sleptons, charginos, neutralinos



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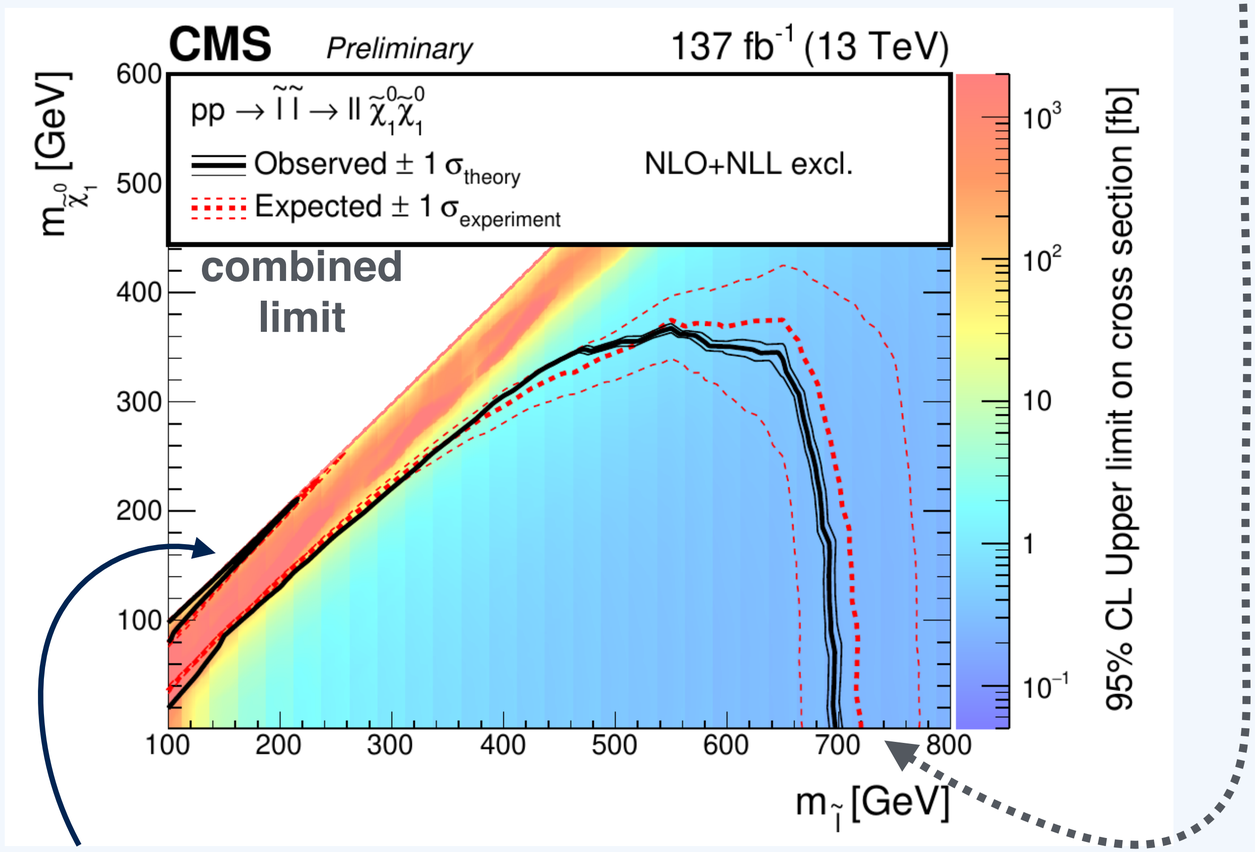

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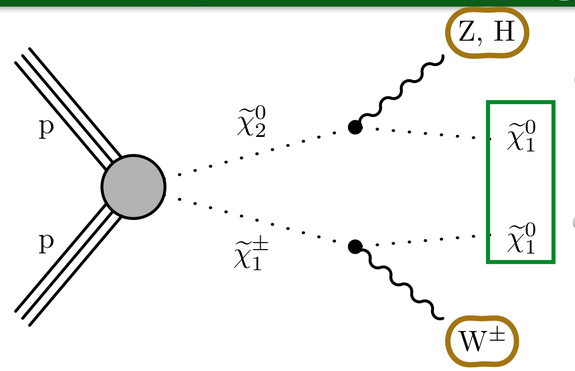
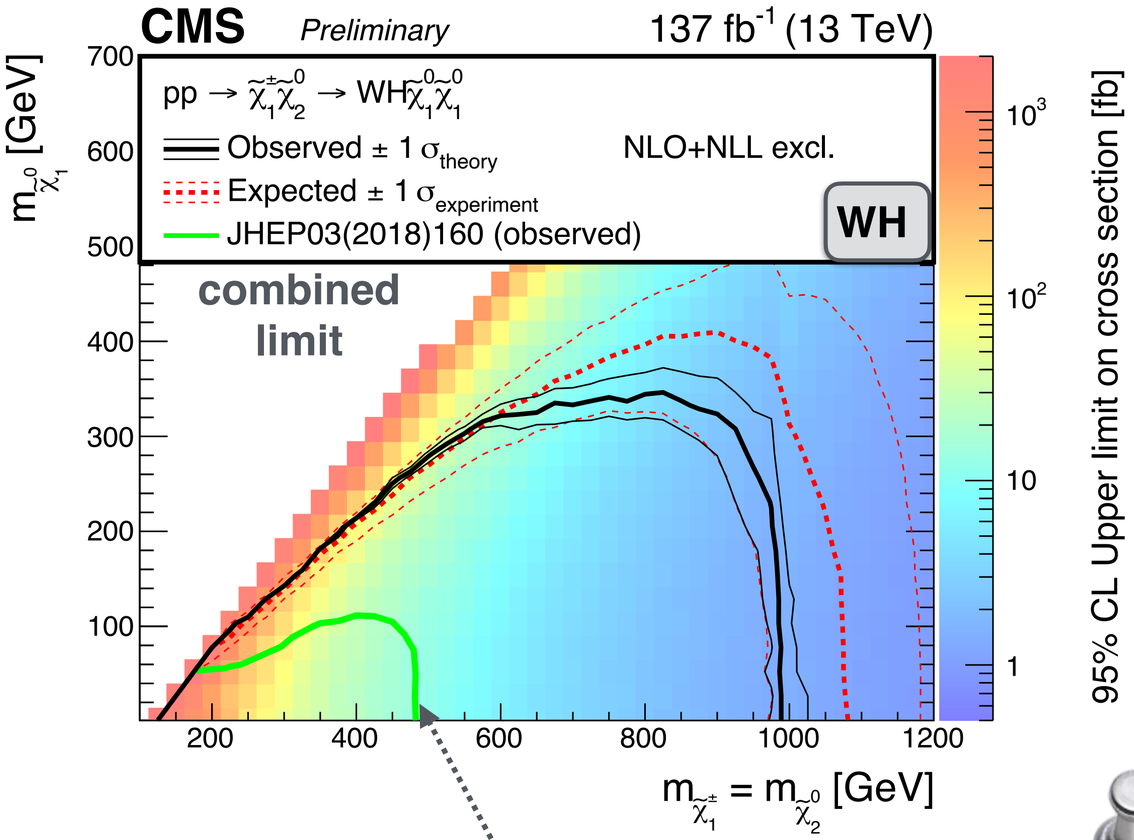


- **Uncompressed region: Hadr WX search dominates**
- **Compressed region: soft lepton search dominates**



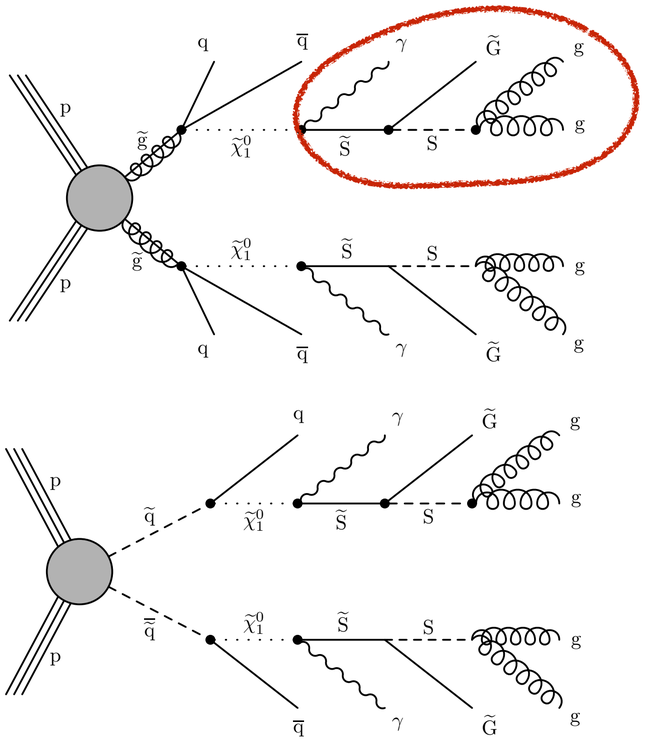
Significant improvement in terms of expected limit with respect to 2016 combination

CMS-PAS-SUS-21-008

Searches for Stealth SUSY

Search for stealth SUSY

- ***Target neutralino (LSP of visible sector), decaying into stealth sector singlino $\tilde{S}$ and photon***
  → Final state with a singlet S and low-momentum gravitino $\tilde{G}$ (LSP of hidden sector)



SUSY proposes partners for all SM particles, but any additional BSM particle would need a partner too

CMS-SUS-19-001

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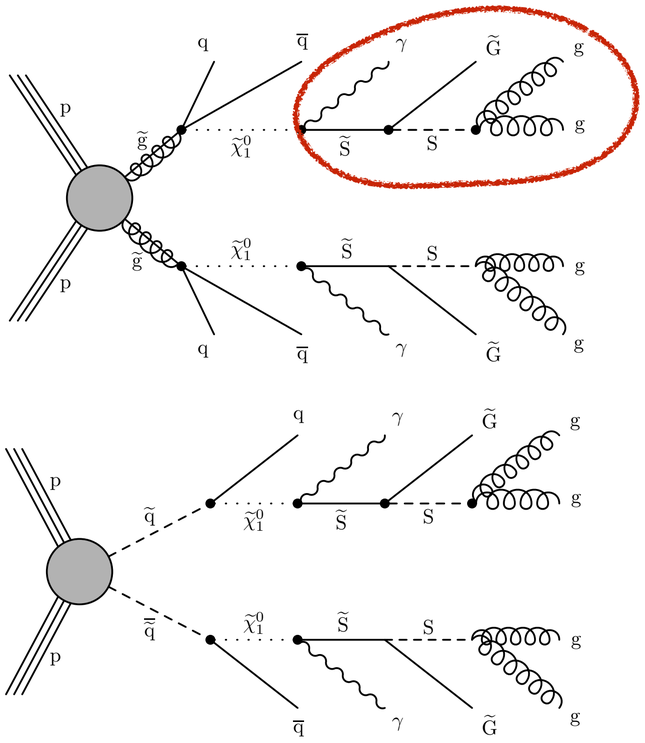
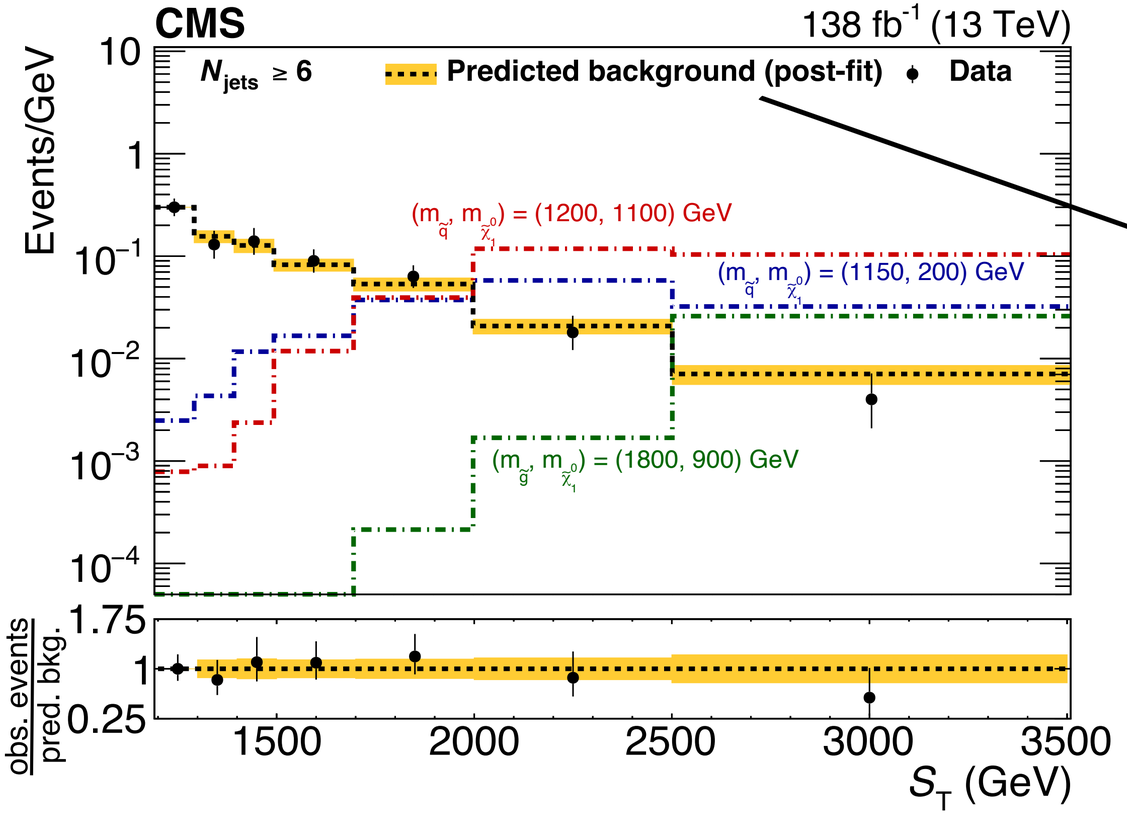
CMS-SUS-19-001



Search for strongly produced stealth SUSY:

- **2 photons** + ≥ 4 *jets* + **low p_T^{miss}**
- $S_T > 1200$ *GeV* (scalar sum of all object p_T)
- Extract signal in S_T distribution in bins of jet multiplicity (4,5, ≥ 6 *jets*)



Data-driven background estimation using S_T shape derived from low jet multiplicity

Data consistent with the prediction

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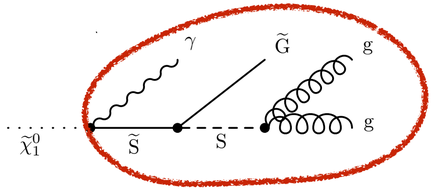
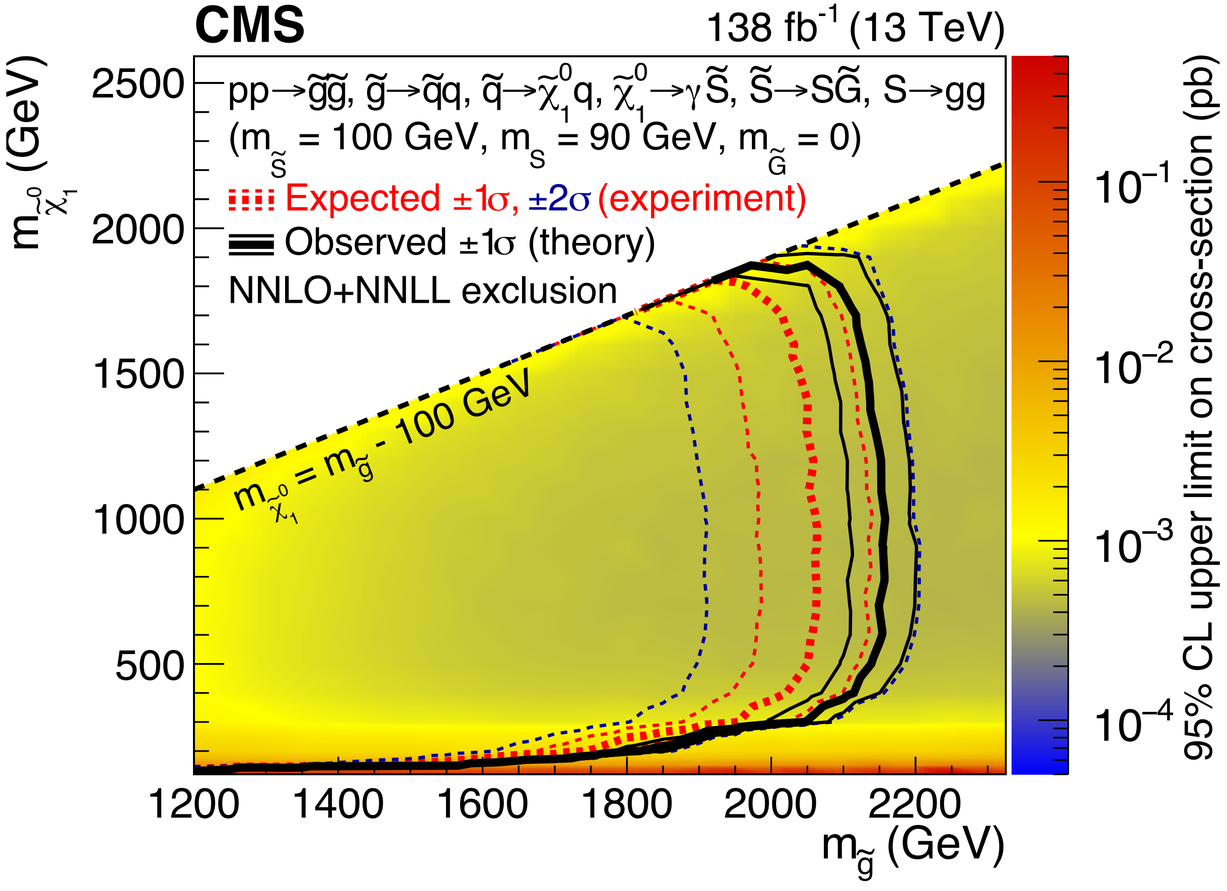
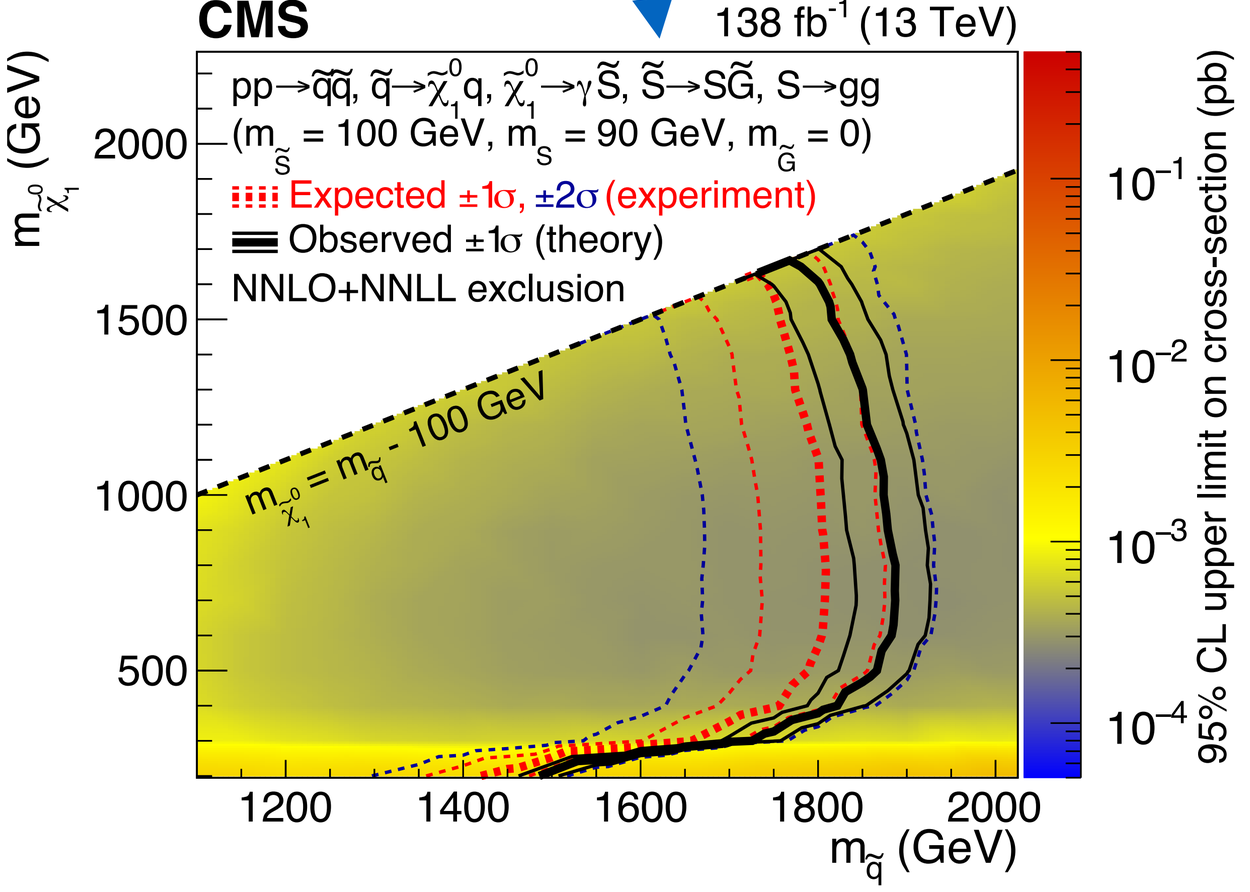
CMS-SUS-19-001



Upper limit at 95% CL for fixed singlino, singlet and gravitino masees

- **Gluino masses excluded up to 2.15 TeV**
- **Light squark masses up to 1.85 TeV**



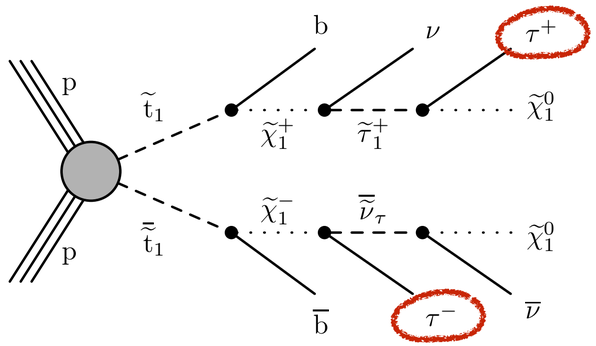


Search for top squark pair production

Search for direct top squark pair production

- ***Search for top squarks produced in pairs in the final state with two τ leptons***

CMS-SUS-21-004



- **Top squarks** play an important role in stabilizing Higgs mass
- The interaction of charginos/neutralinos with fermion-sfermion involves both gauge & Yukawa terms → **coupling to 3rd generation**

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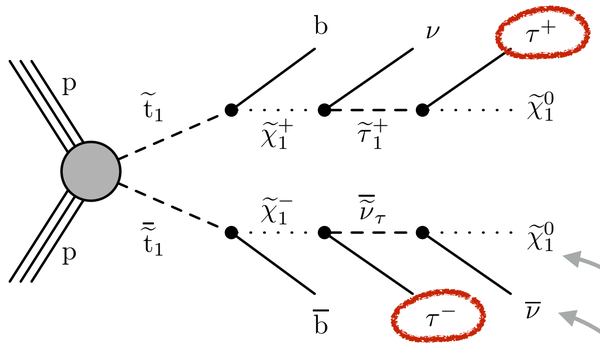

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- ***15 search regions binned in p_T^{miss}, m_{T2}, H_T***

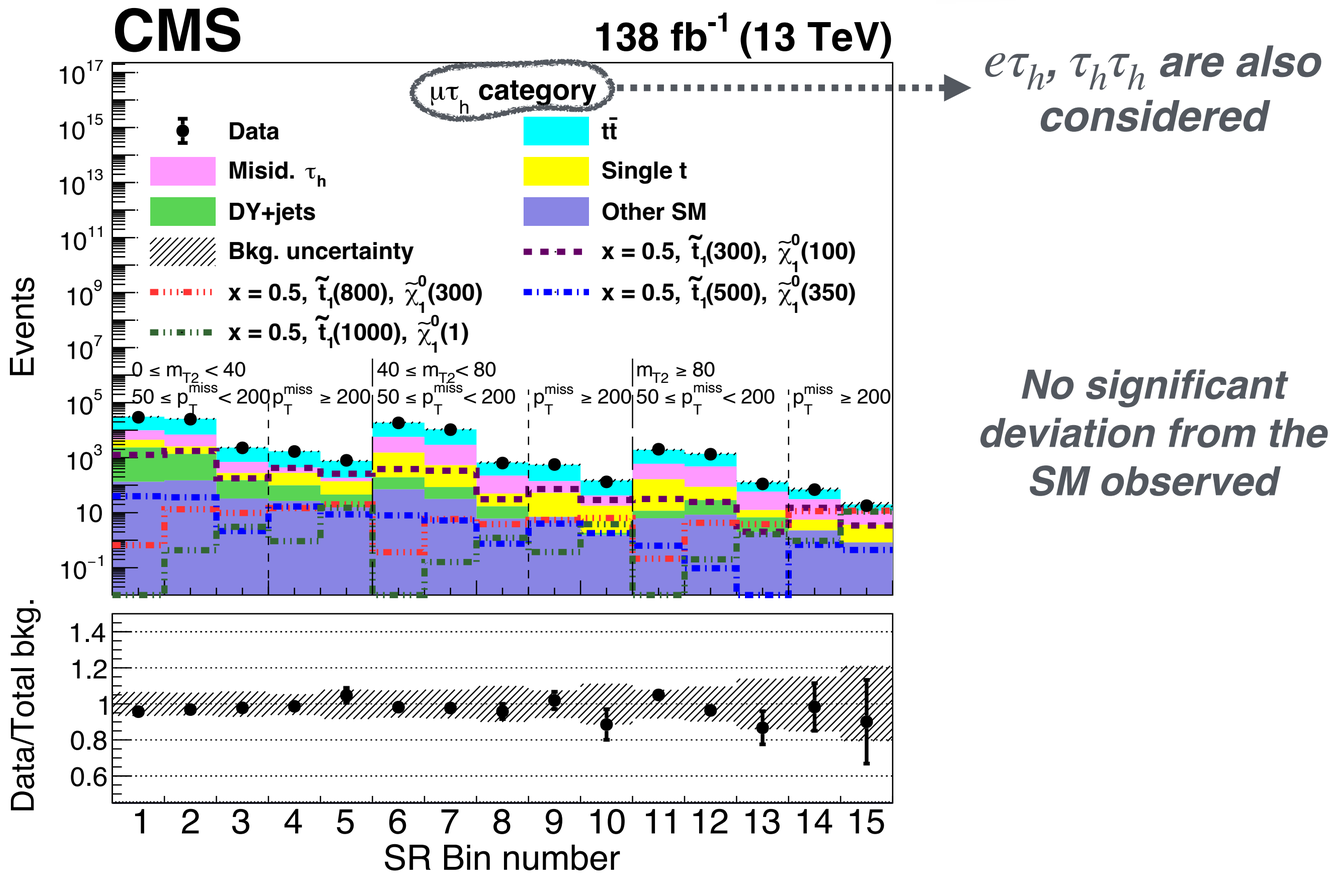
Search region binning

13 : $H_T \geq 700$ 12 : $300 \leq H_T < 700$ 11 : $100 \leq H_T < 300$	15 : $H_T \geq 700$ 14 : $100 \leq H_T < 700$
8 : $H_T \geq 700$ 7 : $300 \leq H_T < 700$ 6 : $100 \leq H_T < 300$	10 : $H_T \geq 700$ 9 : $100 \leq H_T < 700$
3 : $H_T \geq 700$ 2 : $300 \leq H_T < 700$ 1 : $100 \leq H_T < 300$	5 : $H_T \geq 700$ 4 : $100 \leq H_T < 700$

[H_T in GeV]

m_{T2} [GeV]: 0, 40, 80

p_T^{miss} [GeV]: 50, 200

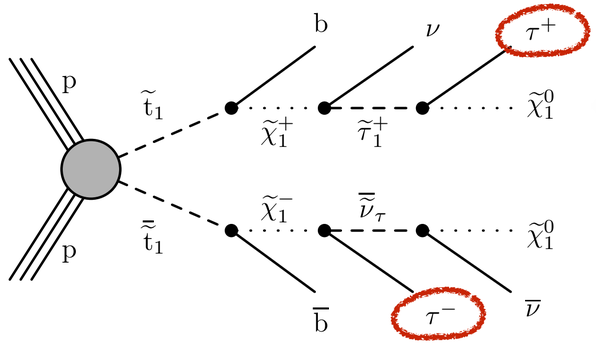


$e\tau_h$, $\tau_h\tau_h$ ***are also considered***

No significant deviation from the SM observed

Search for direct top squark pair production

- ***Search for top squarks produced in pairs in the final state with two τ leptons***



- **Top squark masses** excluded up to about 1150 GeV

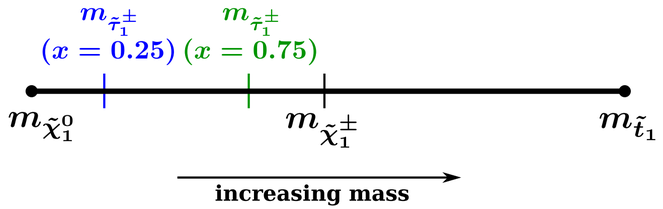
CMS-SUS-21-004

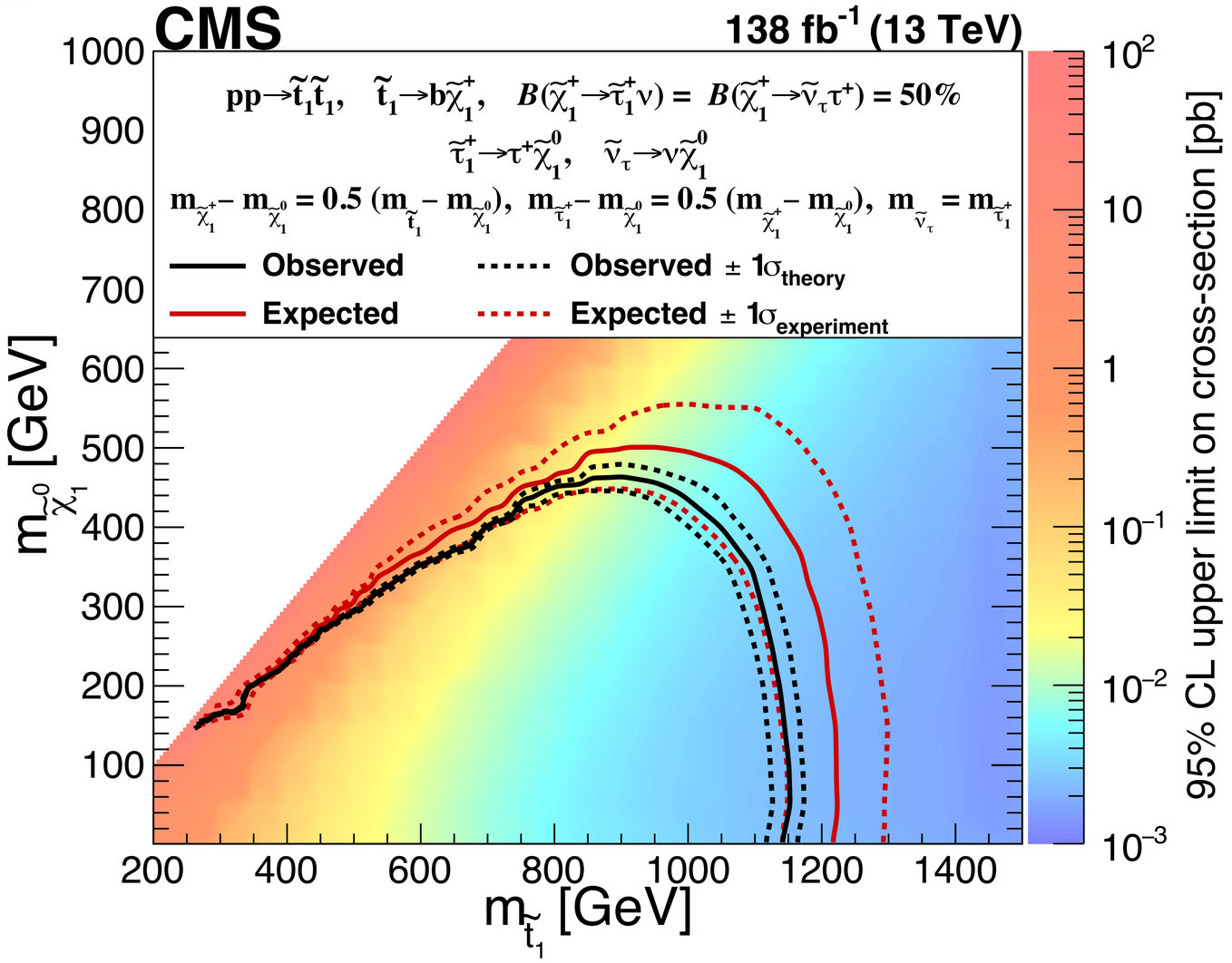
- ***Masses of SUSY particles appearing in the decay chain are parameterized as***

$$m_{\tilde{\chi}_1^-} - m_{\tilde{\chi}_1^0} = 0.5\ (m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0})$$

$$m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} = x\ (m_{\tilde{\chi}_1^-} - m_{\tilde{\chi}_1^0})$$

where $x \in [0.25, 0.5, 0.75]$, and $m_{\tilde{\nu}_\tau} = m_{\tilde{\tau}_1}$

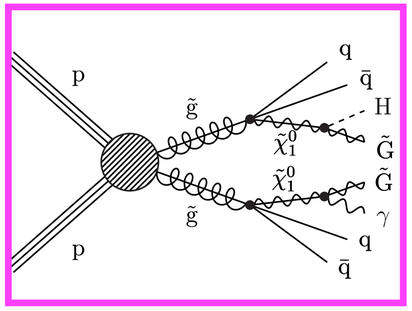


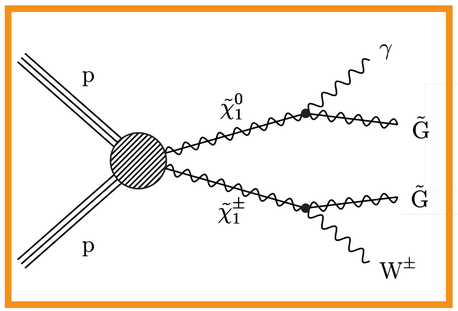


Search for SUSY in photon + jets events

Search for SUSY in photon + jets events

- ***Target events with final states consisting of ≥ 1 high p_T photon, high jet multiplicity, p_T^{miss}***
  - ***Explore both strong and electroweak productions***
    - ***Several SUSY models are considered***





CMS-SUS-21-009

Search for SUSY in photon + jets events

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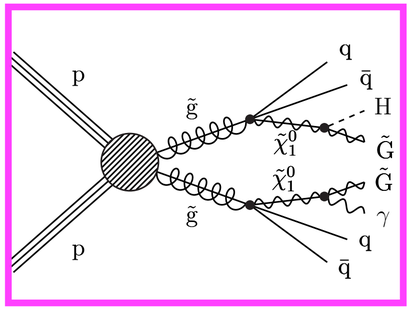
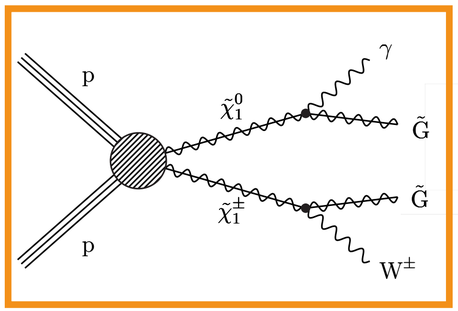


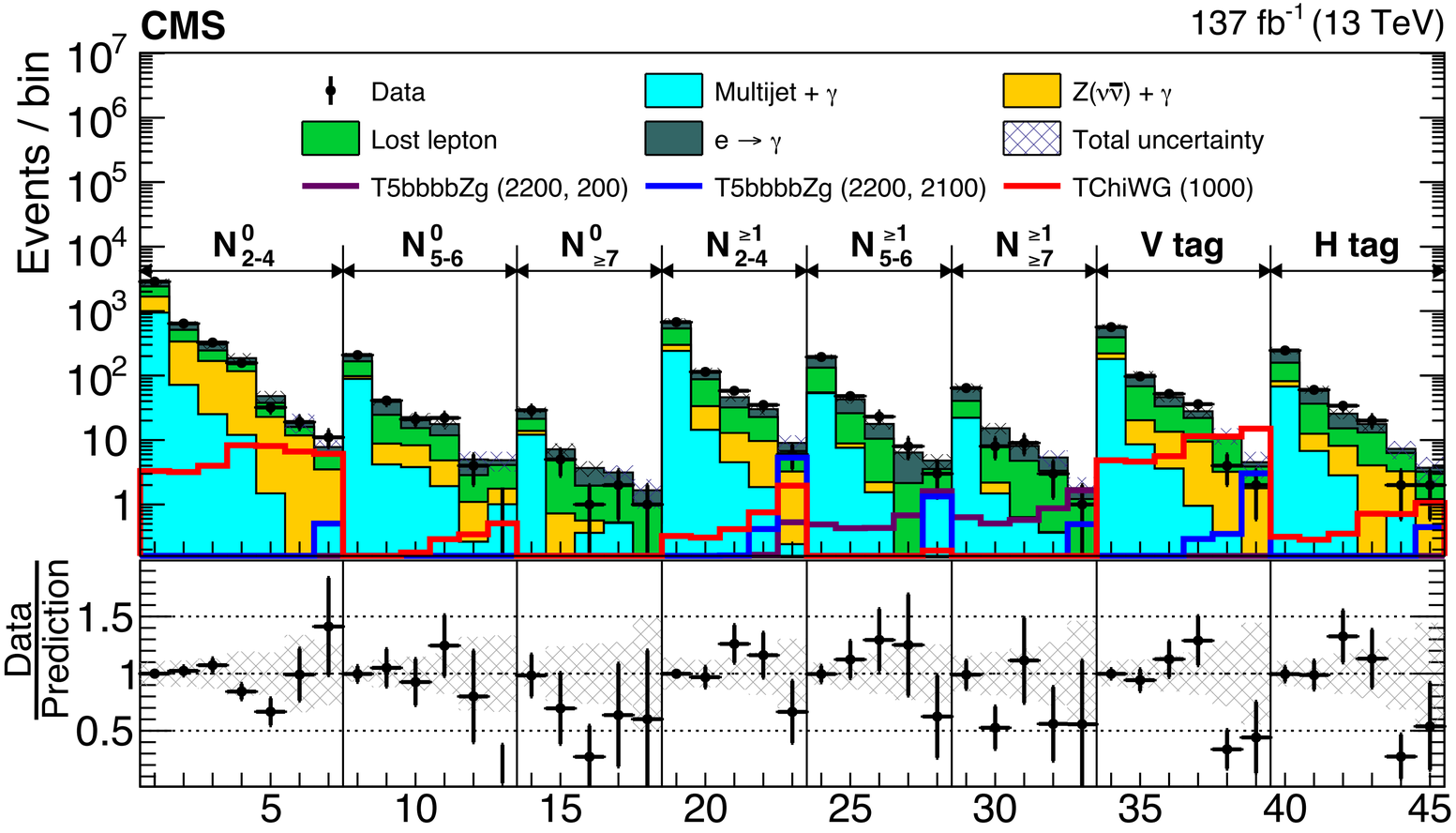


CMS-SUS-21-009

- ***45 search regions binned in:***
  - $p_T^{miss}, N_{b\text{-}jets}, V\ tag, H\ tag$

Backgrounds estimated by transfer factors applied to data control regions

Data consistent with the expectation



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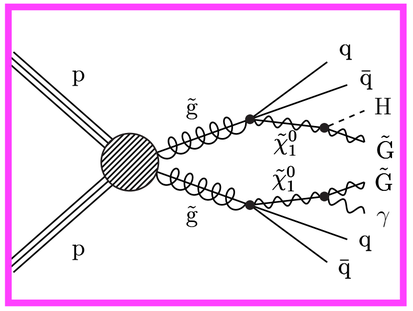

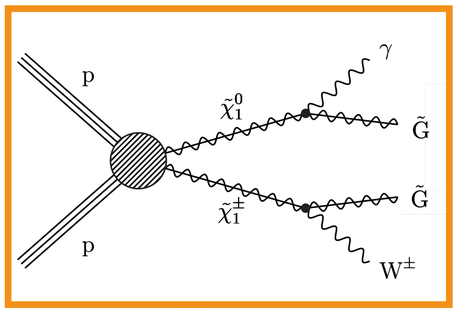

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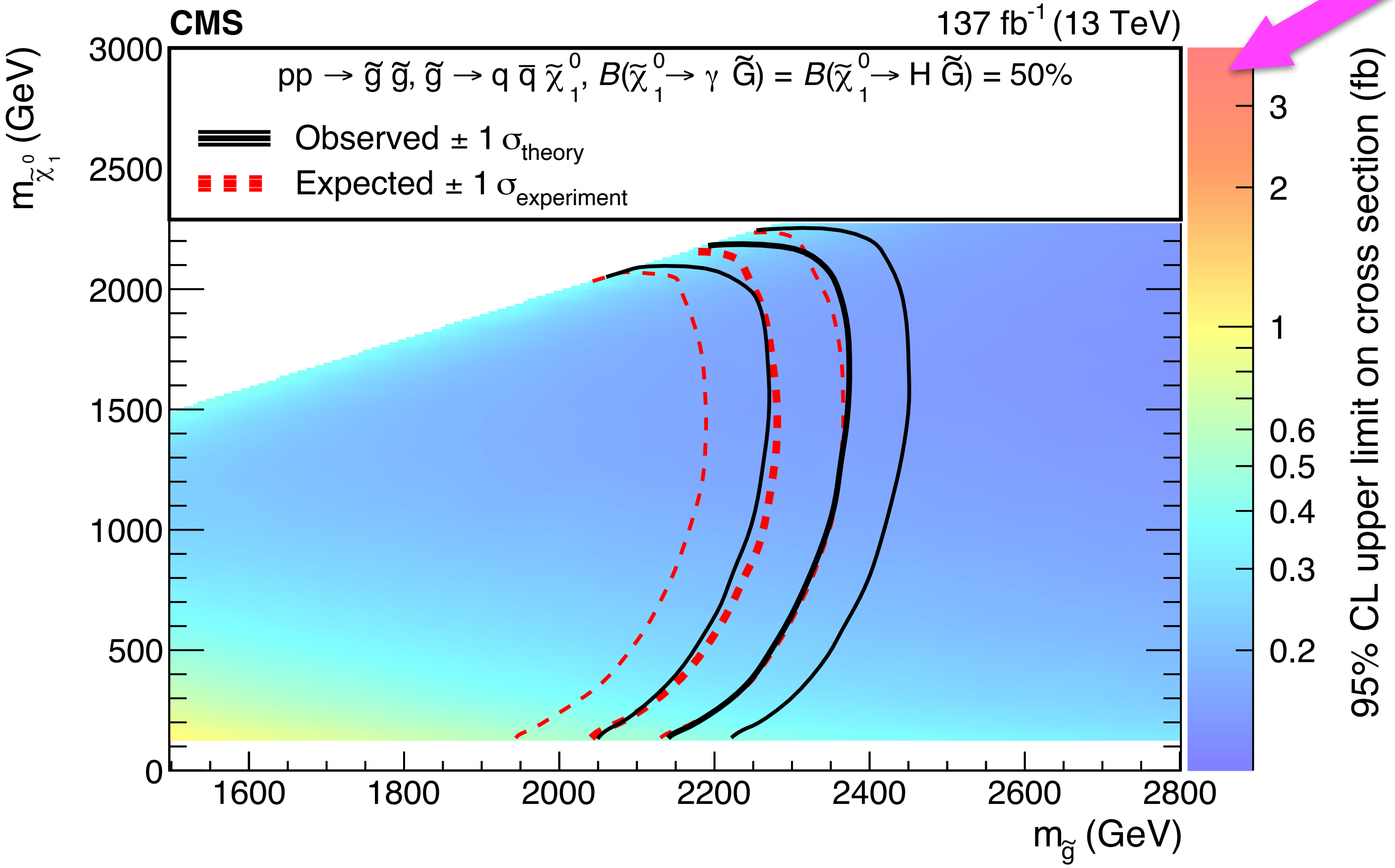
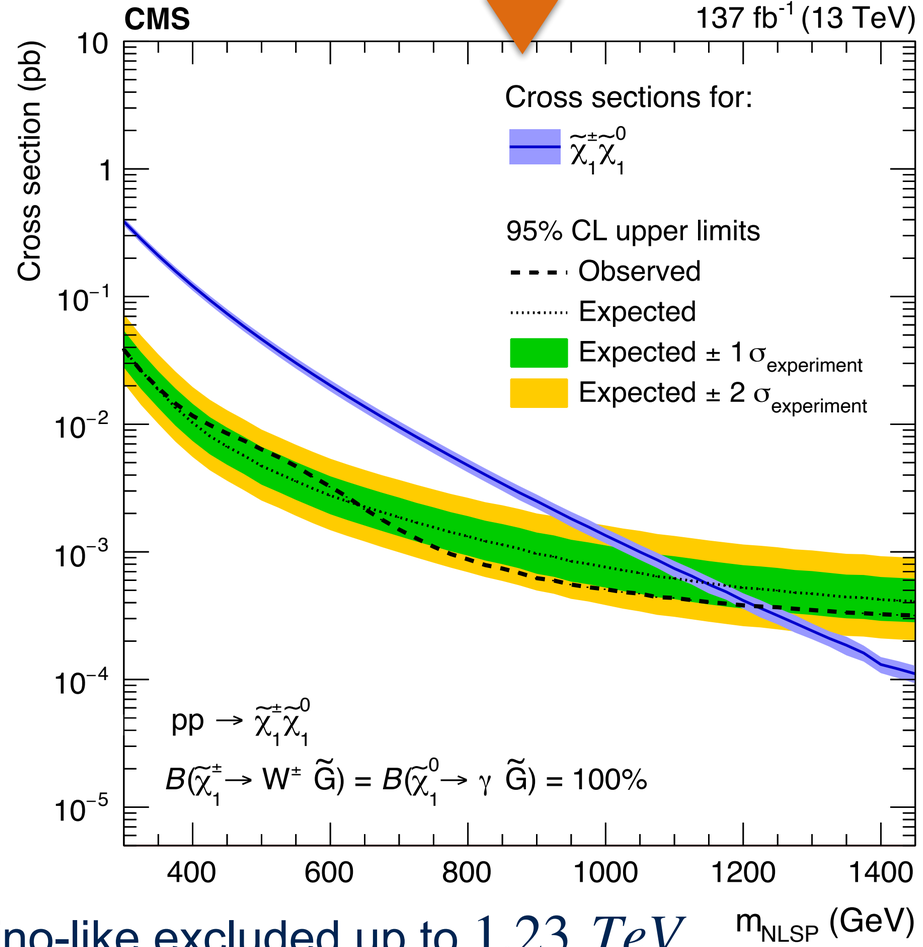


$m_{\tilde{g}}$ excluded up to $2.35\ TeV$

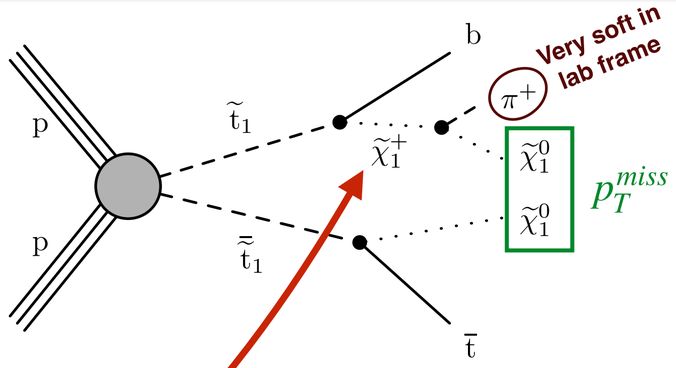


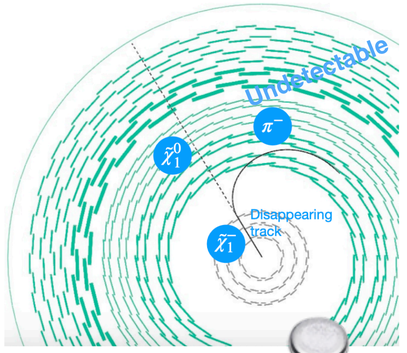
Wino-like excluded up to $1.23\ TeV$

Search for SUSY using disappearing tracks

Search for SUSY in final states with disappearing tracks (DTk)

- ***Target charged long-lived particles (LLP) in final states with ≥ 1 disappearing tracks***
  - ***If wino/higgsno is the LSP, masses of $\tilde{\chi}_1^{\pm}$ are highly degenerate → $\tilde{\chi}_1^{+}$ is a LLP***





CMS-SUS-21-006

Search for SUSY in final states with disappearing tracks (DTk)

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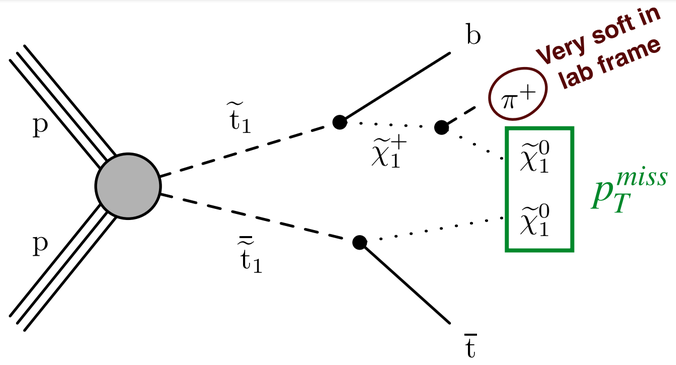
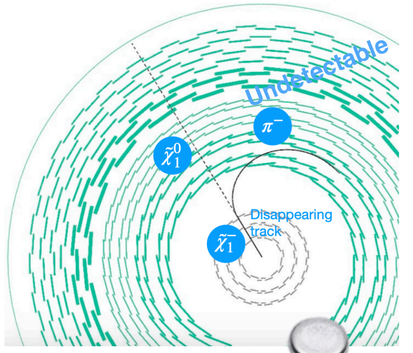
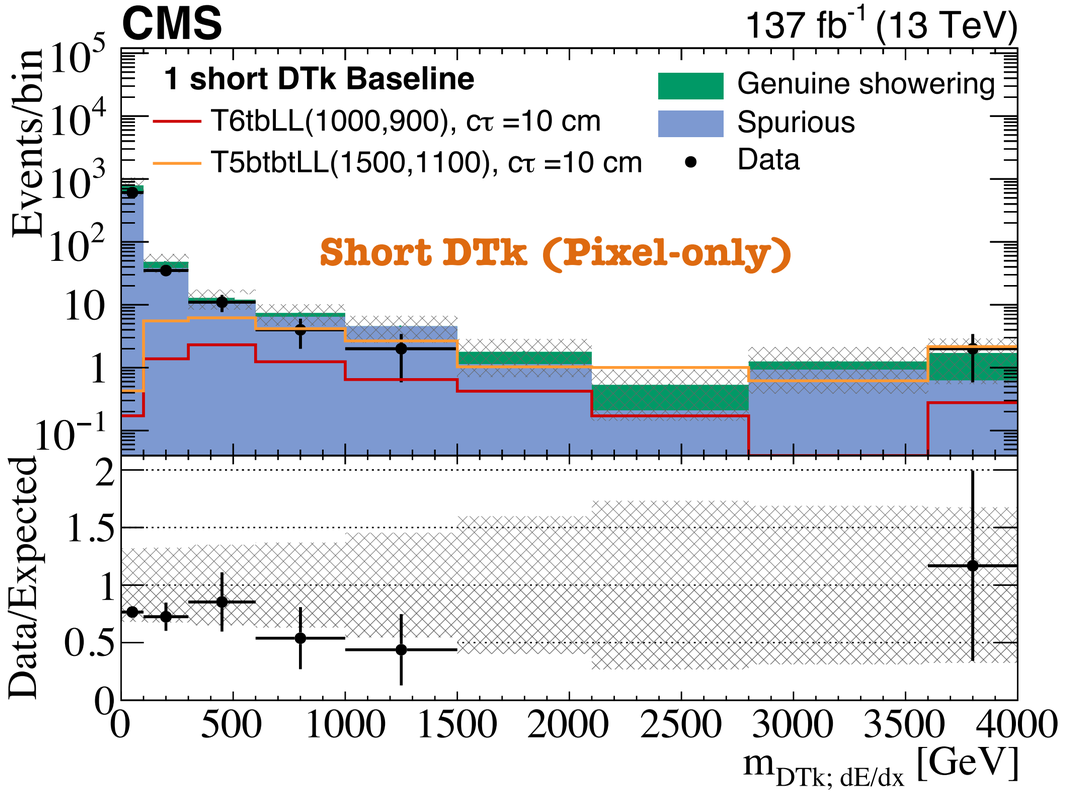
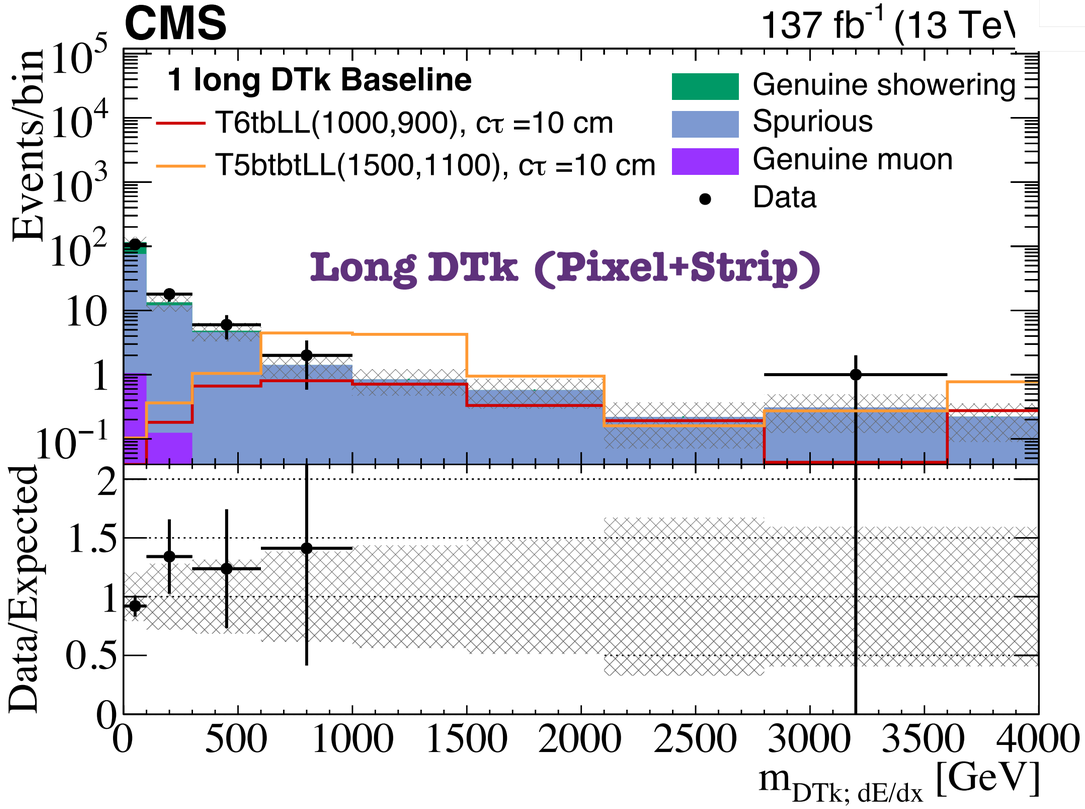




CMS-SUS-21-006

DTk are classified based on their dE/dx in the pixel detector





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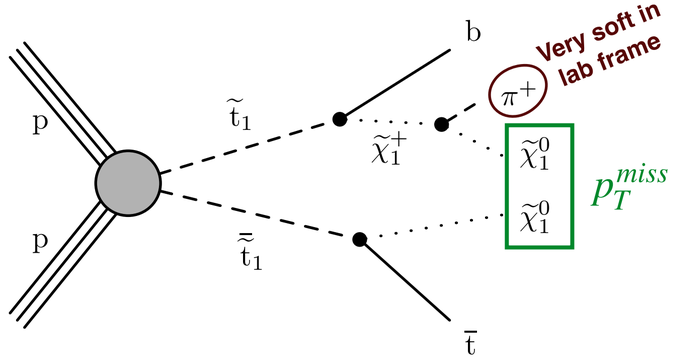
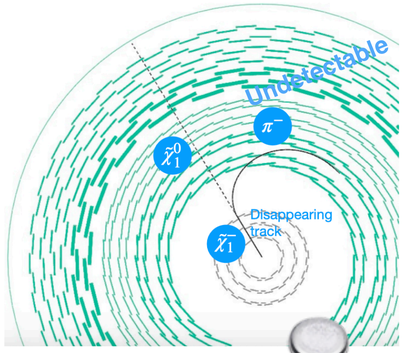
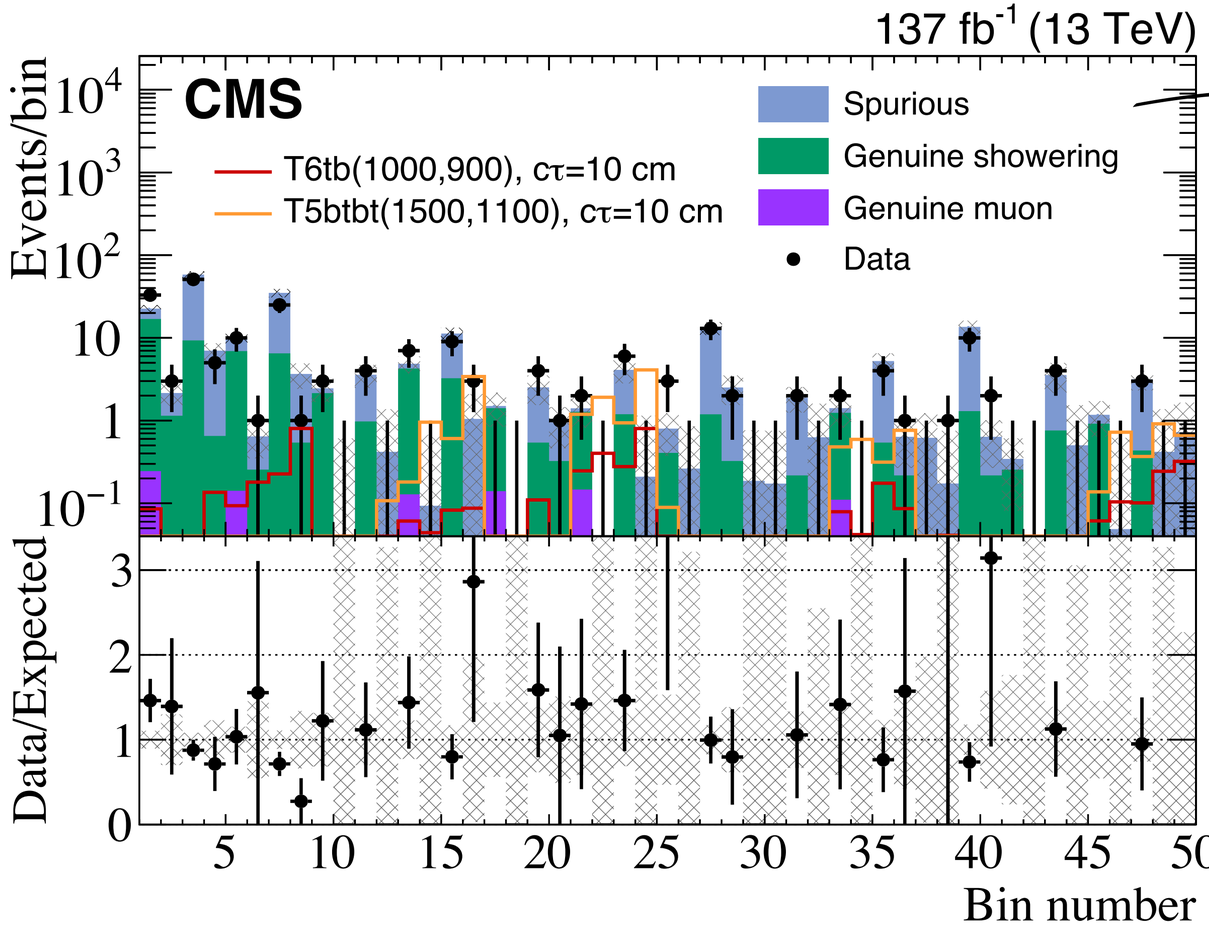




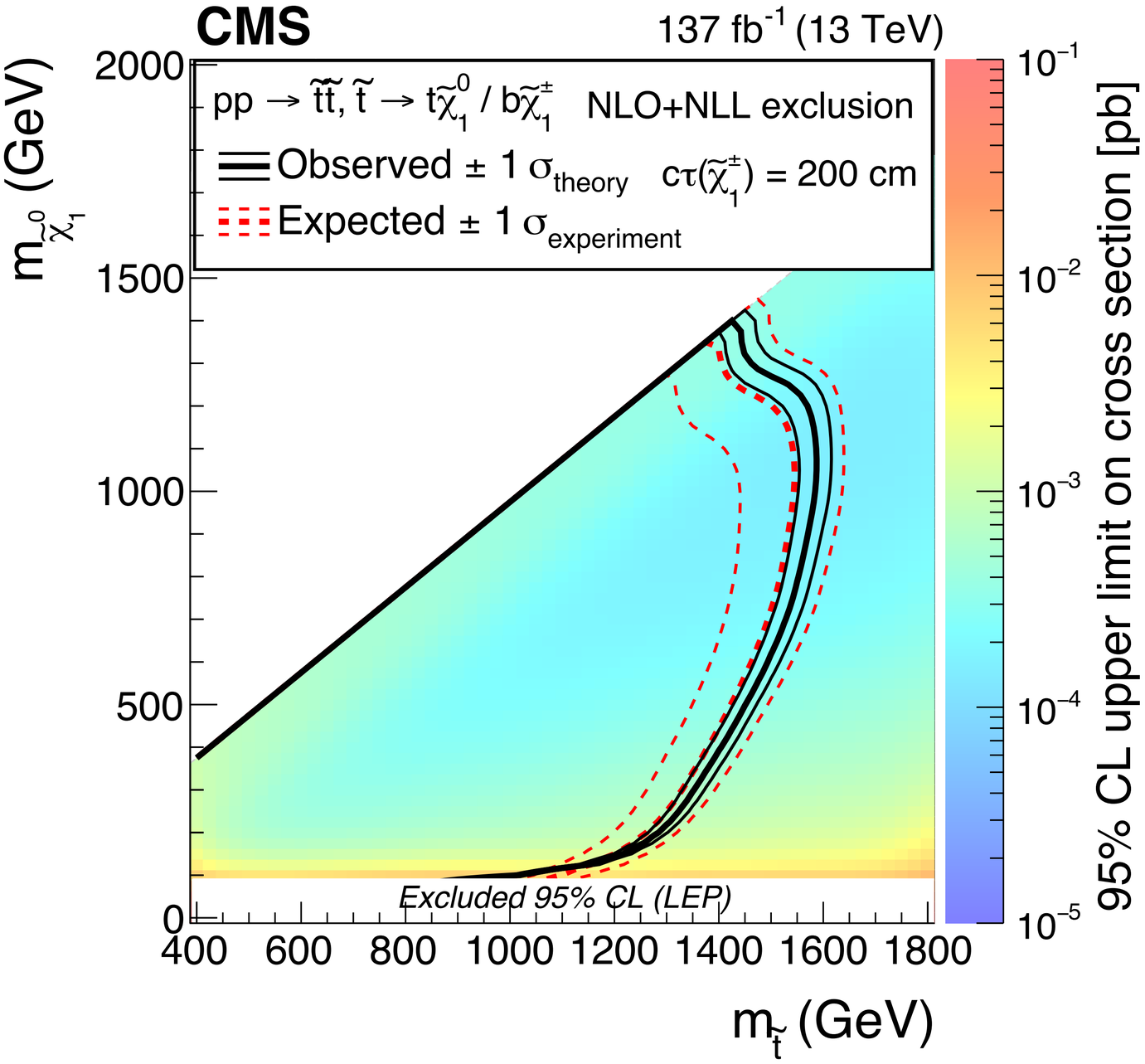
[CMS-SUS-21-006]

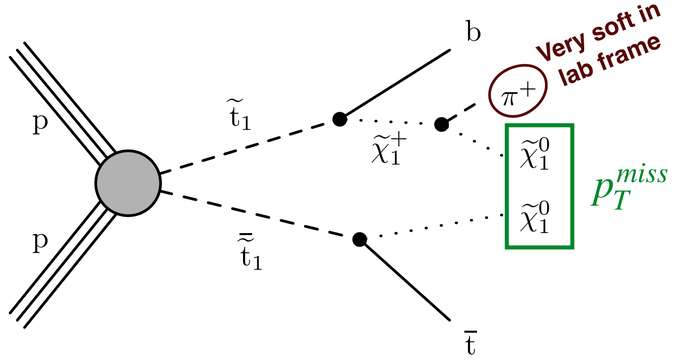


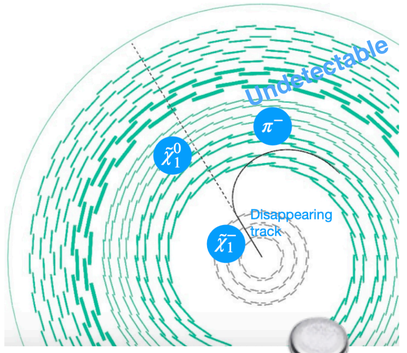
Backgrounds mostly from instrumental effects (mis-reconstruction of tracks/particles)

Data consistent with the expectation

Search for SUSY in final states with disappearing tracks (DTk)







CMS-SUS-21-006

- ***Upper limits at 95% C.L.:***
  - ***for different choices of*** $\tilde{\chi}_1^\pm$ ***proper decay length*** $c\tau$
  - $m_{\tilde{t}}$ ***excluded up to ~1.6 TeV for*** $c\tau(\tilde{\chi}_1^\pm) = 200\ cm$

- ***Upper limits also set for:***
  - $pp \to \tilde{b}\tilde{b}$***: excluding*** $m_{\tilde{b}}$ ***up to ~1.5 TeV***
  - $pp \to \tilde{g}\tilde{g}$***: excluding*** $m_{\tilde{g}}$ ***up to ~2.3 TeV***

Summary and Conclusions

- **Recent CMS SUSY searches were presented using full Run 2 data @ 13 TeV**
  - Strong/Electroweak SUSY, Stealth SUSY, unconventional signatures (disappearing tracks)

    No evidence of physics beyond the Standard Model in LHC data
- **CMS continues to enhance its search strategy**
  - Combining multiple searches, exploring challenging final states, etc
  - Small fraction of results, more SUSY searches in the backup slide
- Some Run-2 analysis have not yet released their results though
- **There is still room for improvement: LHC Run-3, HL-LHC, new detectors**

Thank you

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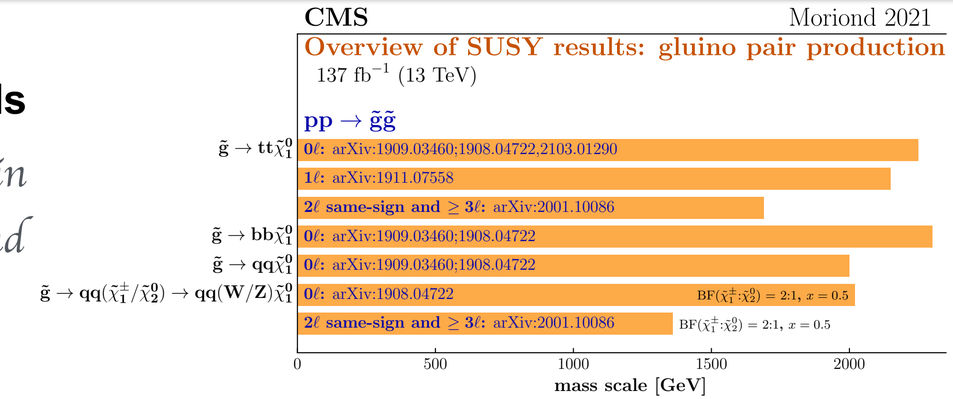
BACKUP SLIDES

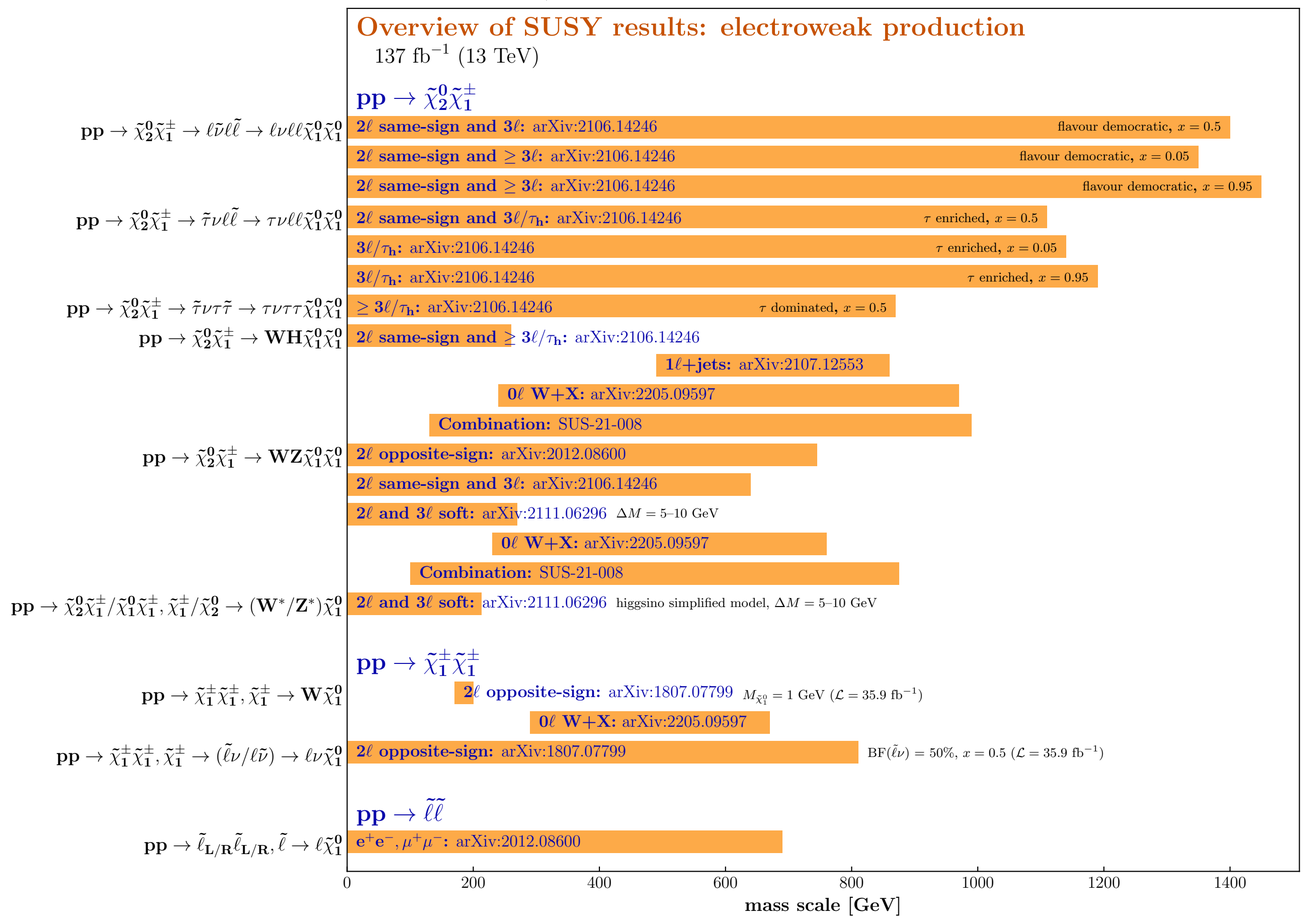
SUSY searches with CMS detector @ 13 TeV

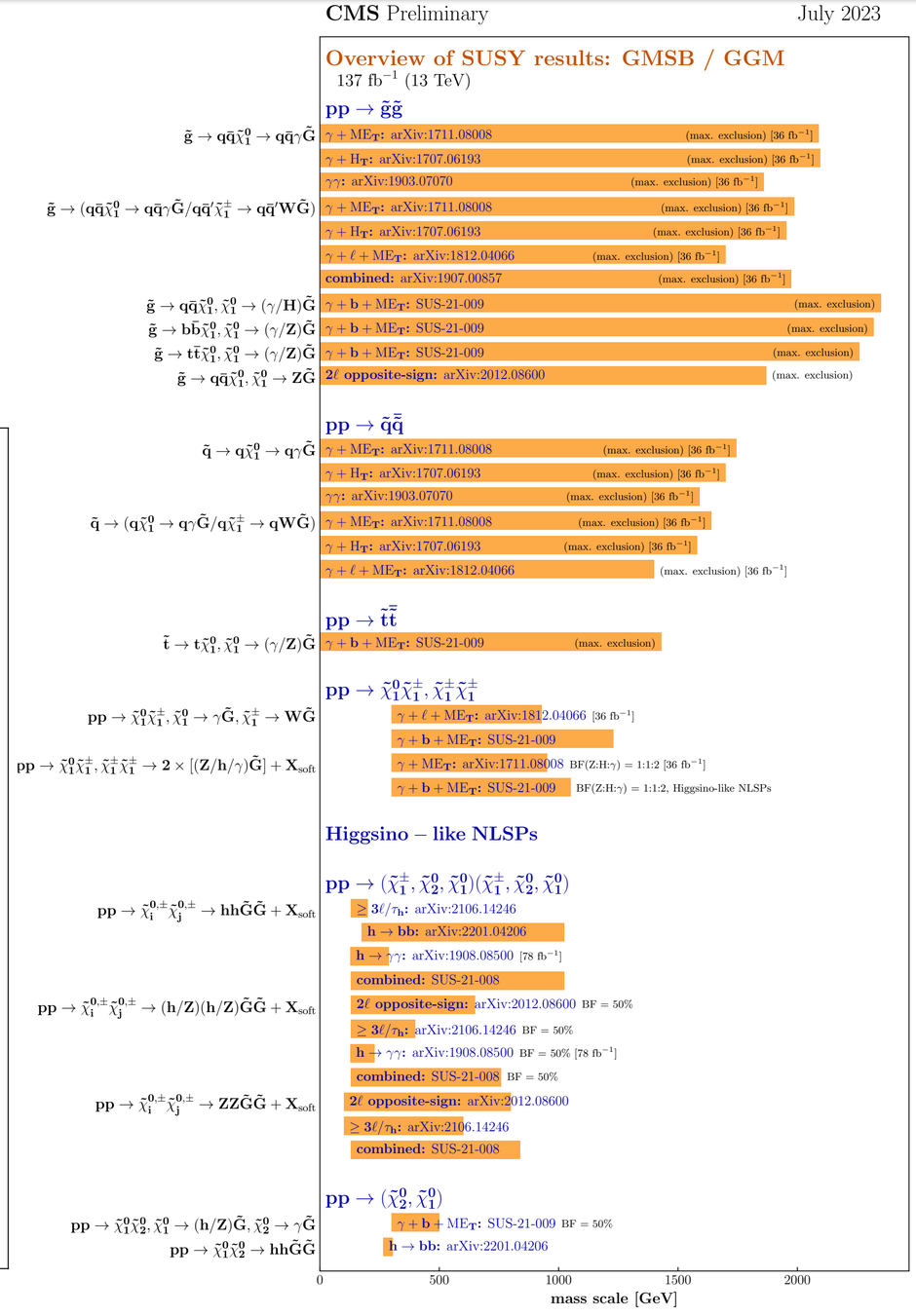
Synopsis: mass reach, per models

- *Mass limits at 95% CL obtained in the context of simplified models and for different final states*

https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/index.html







SUSY searches with CMS detector @ 13 TeV: Overview of mass limits