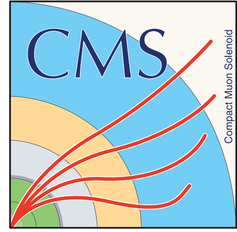


Stealth and RPV SUSY searches with CMS

Anton Stepennov (University of Cyprus) on behalf of CMS collaboration

June 13, 2024

SUSY2024

Introduction

- Multiple searches for SUSY with large missing transverse momenta (E_T^{miss}) has been performed in CMS

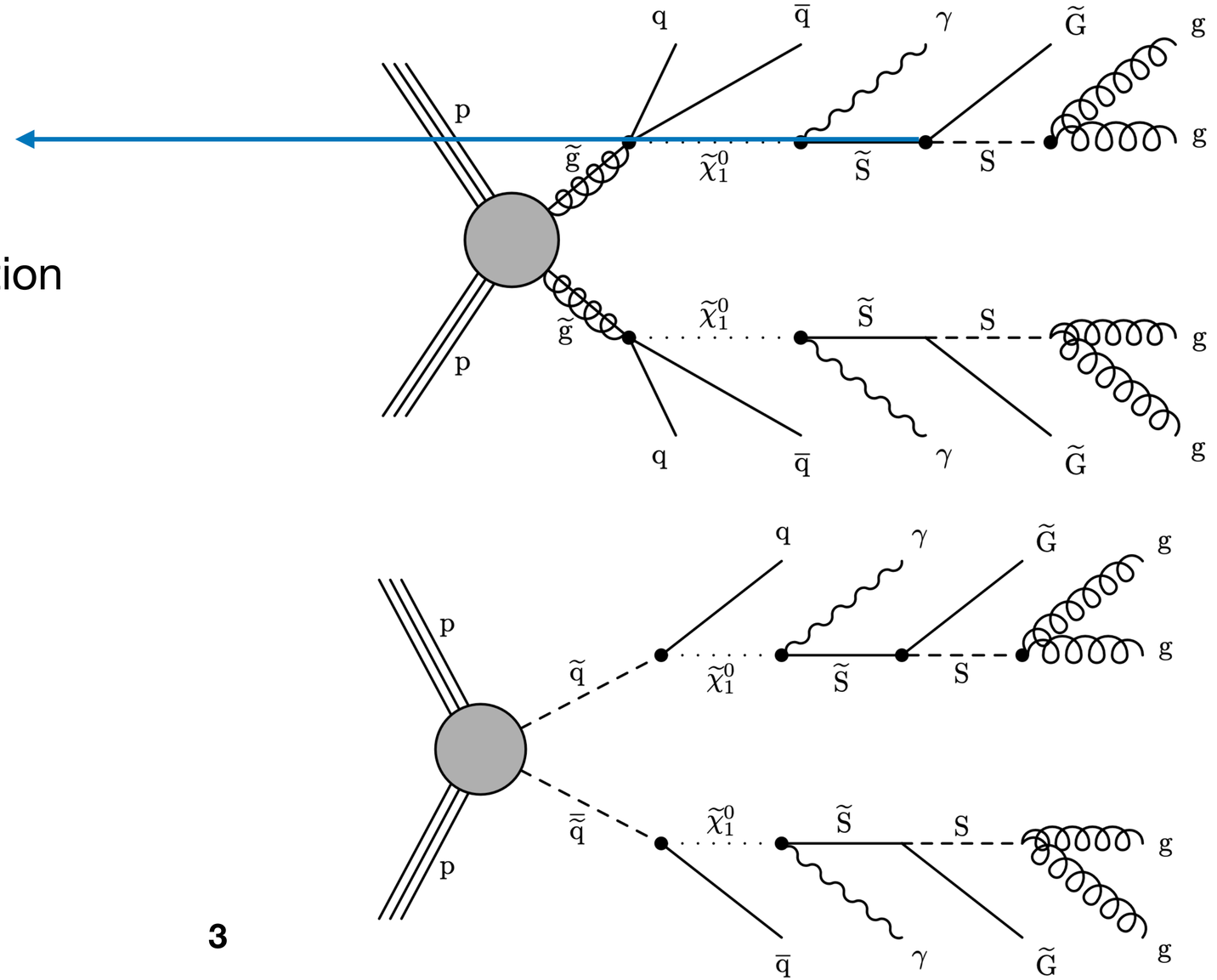
  →no evidence found so far

- Alternative strategy: looking for SUSY with small (E_T^{miss})
- Various SUSY models may manifest themselves this way:
  1. RPV
  2. Stealth SUSY
- Following searches will be presented:
  1. $2\tilde{g}/\tilde{q}\bar{\tilde{q}} \to 4q4g2\gamma2\tilde{G}/2q4g2\gamma2\tilde{G}$ SUS-19-001
  2. $\bar{\tilde{t}}\tilde{t} \to 6qt\bar{t}/6gt\bar{t}2\tilde{G}$ SUS-23-001
  3. $\bar{\tilde{t}}\tilde{t}/2\tilde{h}/2\tilde{g} \to 4/6q$ EXO-21-004
  4. $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to 6qWZ$ SUS-23-015

Stealth SUSY: multijets + diphotons

arXiv:2310.03154

- Stealth SUSY: $M_{\tilde{S}} - M_S = 10\ GeV$
  $\rightarrow$Low E_T^{miss}
- 2 scenarios: gluino or squark production
- Considered mass ranges:
  1. $1250 < M_{\tilde{g}} < 2350\ GeV$
  2. $1100 < M_{\tilde{q}} < 2000\ GeV$
- $\tilde{\chi}_1^{\ 0}$ decays to $\tilde{S}$ emitting a photon
- Multiple jets in final state



Stealth SUSY: multijets + diphotons

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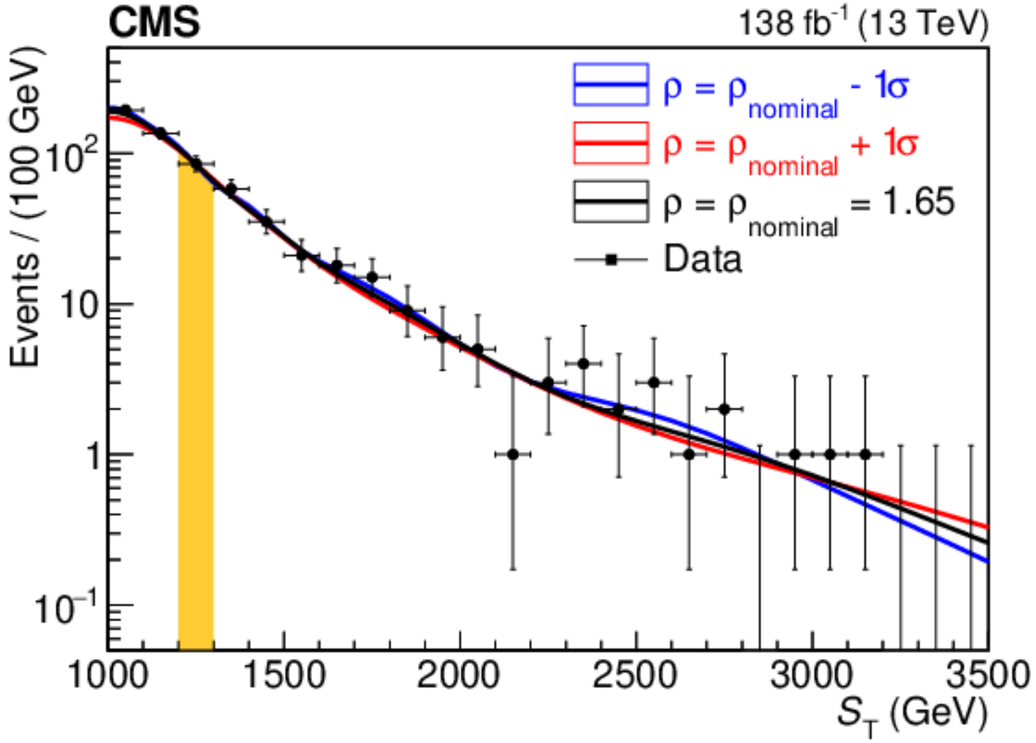
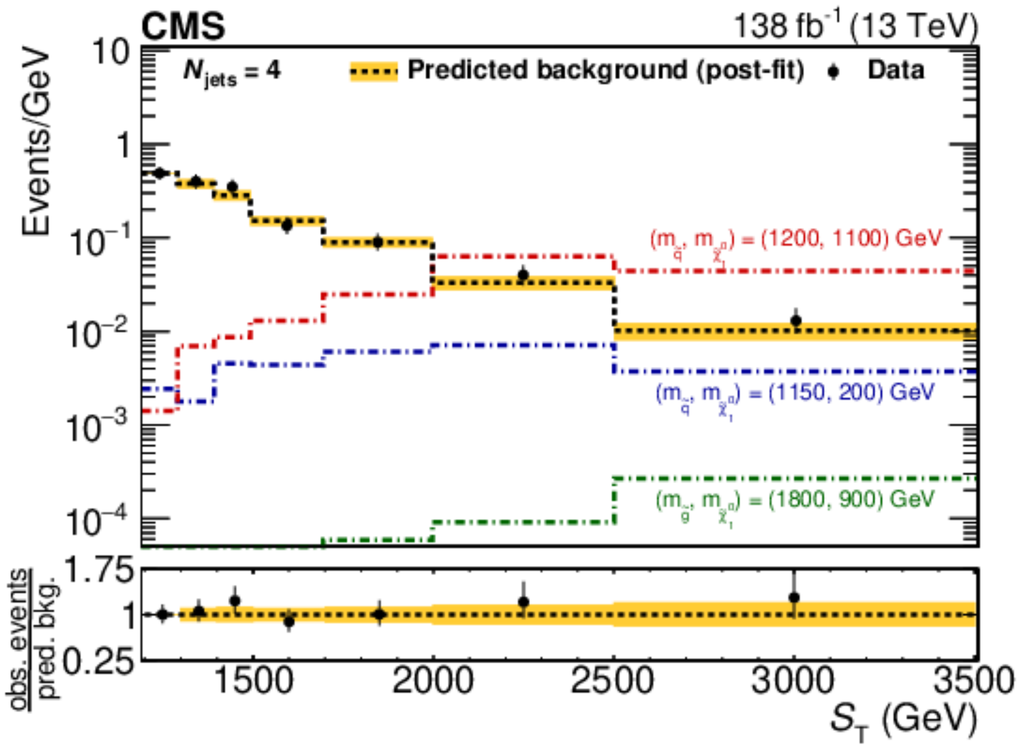




$$S_T = \sum_{i}^{objects} p_T^i$$

Event preselection:

- Two photons, $M_{\gamma\gamma} > 90\ GeV$
- N_j >= 2, S_T > 1200 GeV

Control and signal regions:

	1200 < S_T < 1300 GeV	S_T > 1300 GeV
N_j = 2	QCD bkg normalization	S_T shape template
N_j > 2	QCD bkg normalization (N_j >3)	Signal region

Data-driven background shape:

From data **MC correction**

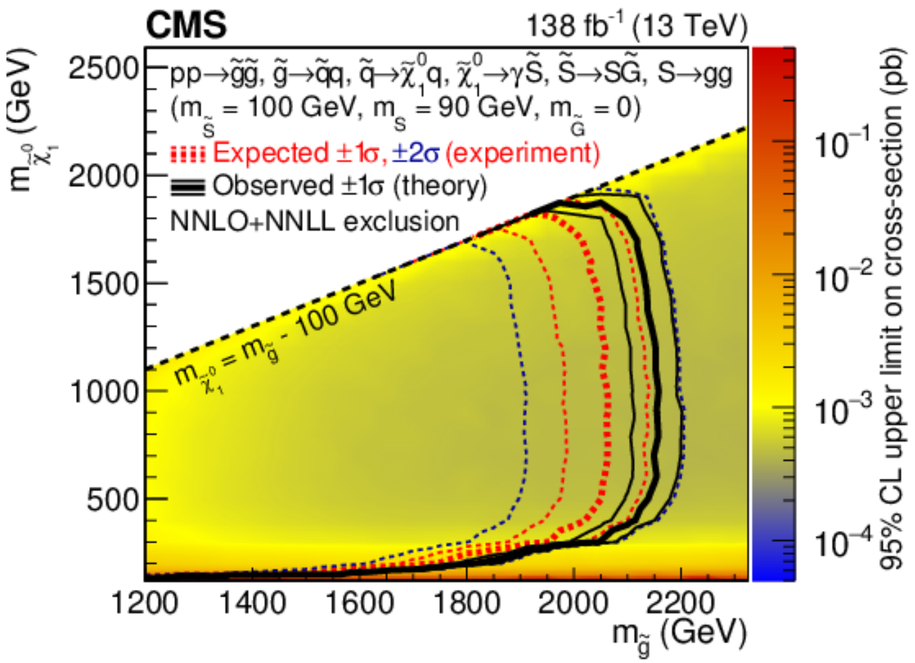
$$b(N_j, S_T\ bin) = N_{bkg}(1200 < S_T < 1300) \cdot f(S_T\ bin) \cdot r(N_j, S_T\ bin)$$

Stealth SUSY: multijets + diphotons

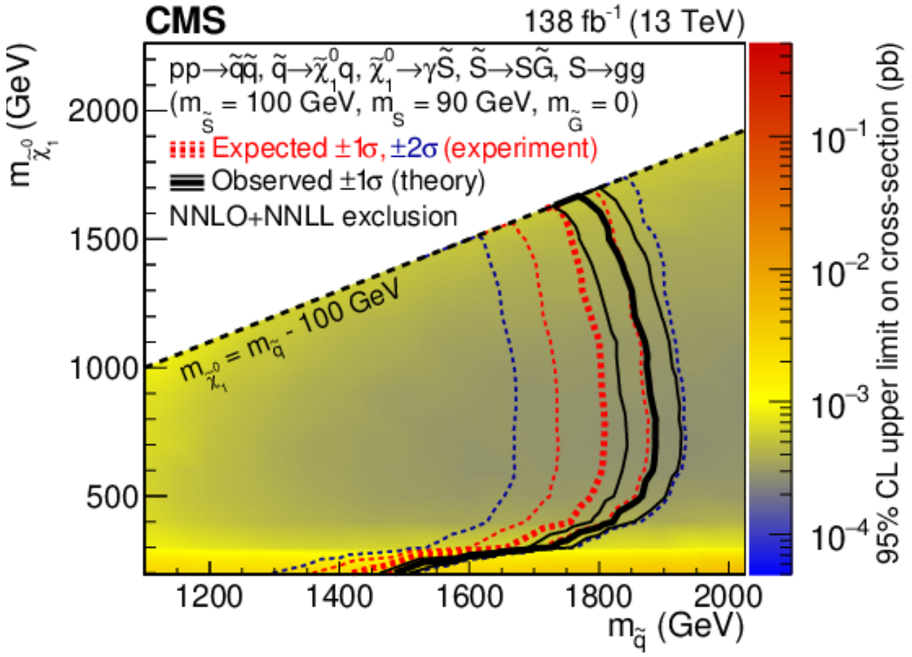
arXiv:2310.03154

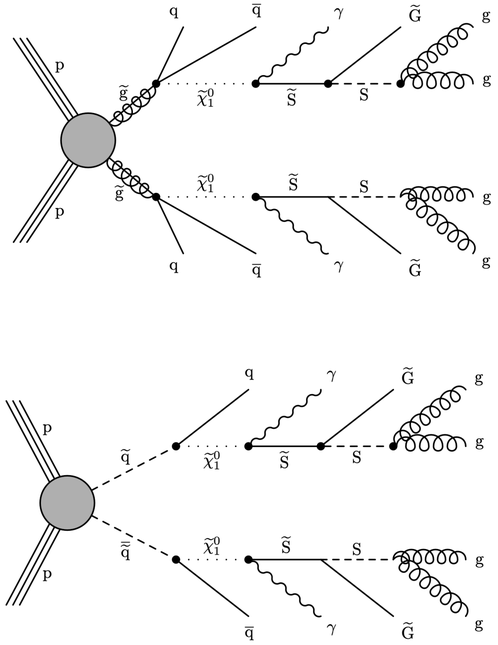
- Models with gluinos (squarks) excluded up to 2.15 TeV (1.85 TeV)
- Limits improved by 70% comparing to previous results

Gluino:



Squark:



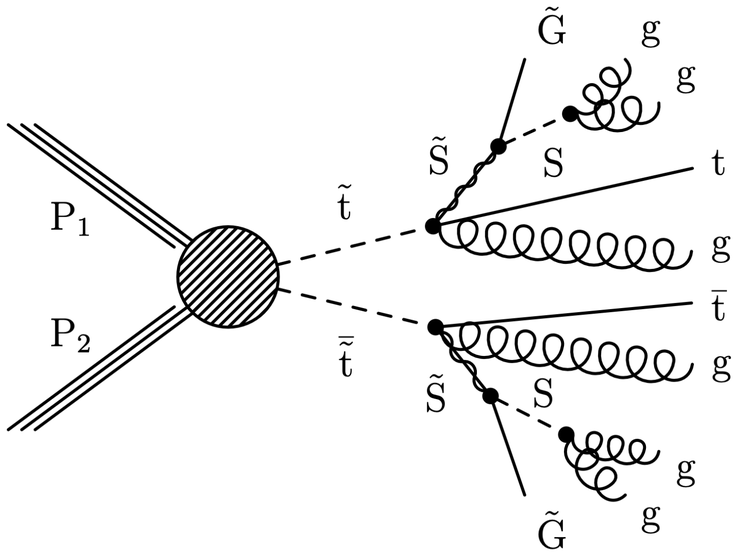


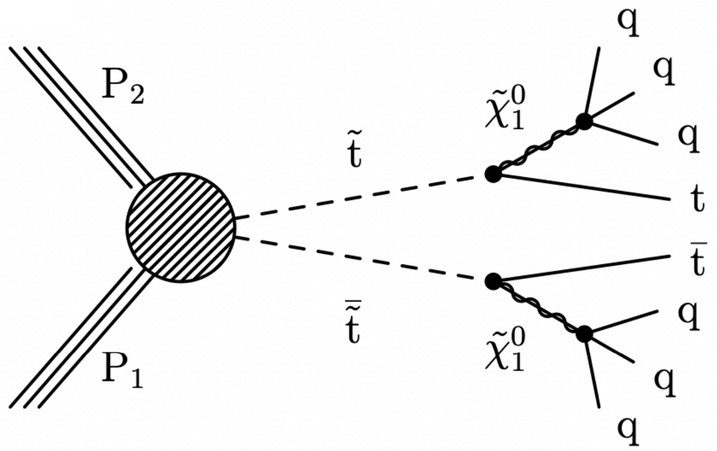
Stealth/RPV: multijets + tt

SUS-23-001

Signal characteristics:

- 2 scenarios of stops decays:
  1. RPV
  2. Stealth SUSY
- $300 < m_{\tilde{t}} < 1050\ GeV$
- Stealth SUSY: $M_{\tilde{S}} - M_S = 10\ GeV$
- Final state: $t\bar{t} + jets$ + small E_T^{miss}
- Main backgrounds: $t\bar{t} + jets$, QCD
- Previous study of this process with full Run2 data indicated a 2.8σ excess for $m_{\tilde{t}} = 400\ GeV$





Stealth/RPV: multijets + tt

SUS-23-001

Event preselection:
1. 0/1/2 leptons
2.At least 6 jets
3.At least 1 b-tagged jet
4.High H_T
5.Top-tagging

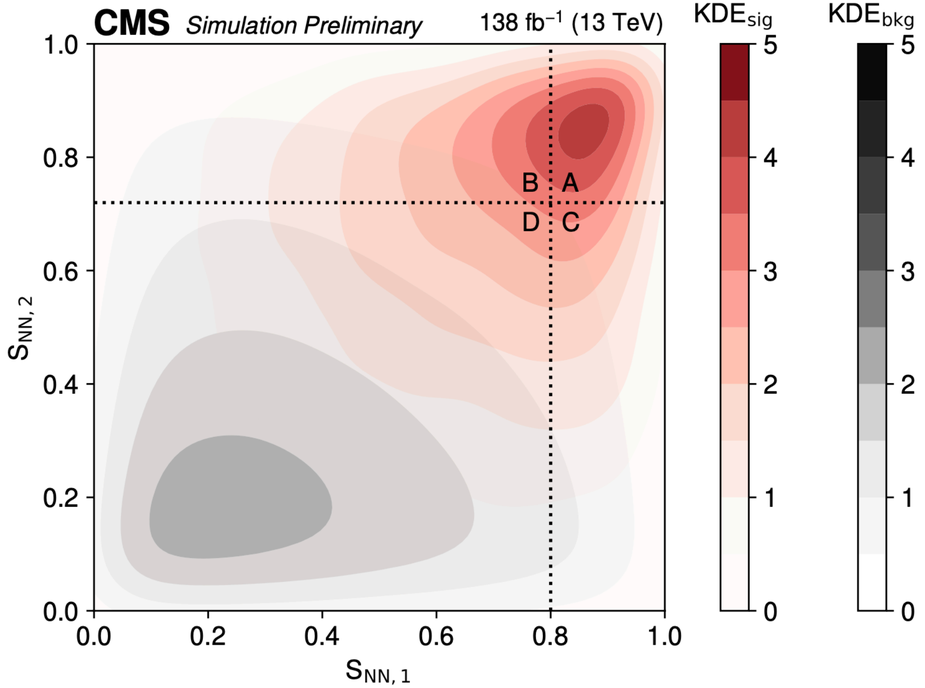
Advanced ABCD (ABCDisCoTEC) method:
- NN trained for 2 independent outputs, discriminating signal and background
- NN trained for each type of signal and 3 N_l categories
- NN output boundaries for ABCD method defined for low and hight $m_{\tilde{t}}$ regions separately
- Number of events in signal region A is corrected as

$$\kappa = \frac{N_{A,MC}}{N_{A,pred}} = \frac{N_{A,MC} \cdot N_{D,MC}}{N_{B,MC} \cdot N_{C,MC}}$$

- Inclusive in N_j

Background estimation:
- 60 analysis regions: depending on N_l and N_j
- predictions for $t\bar{t} + jets$ background obtained with ABCD method
- Prediction for QCD from data:

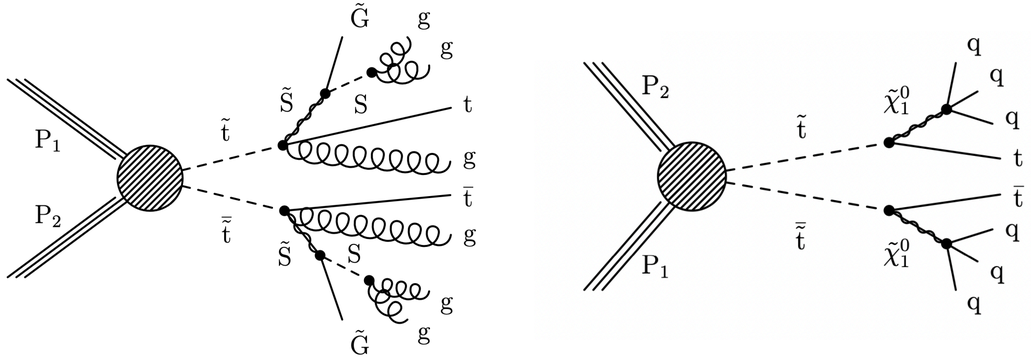
$$N_{QCD(N_j,SR\ Data)} = \frac{N_{QCD(N_j,SR\ MC)}}{N_{QCD(N_j,CR\ MC)}} \cdot N_{QCD(N_j,CR\ Data)}$$

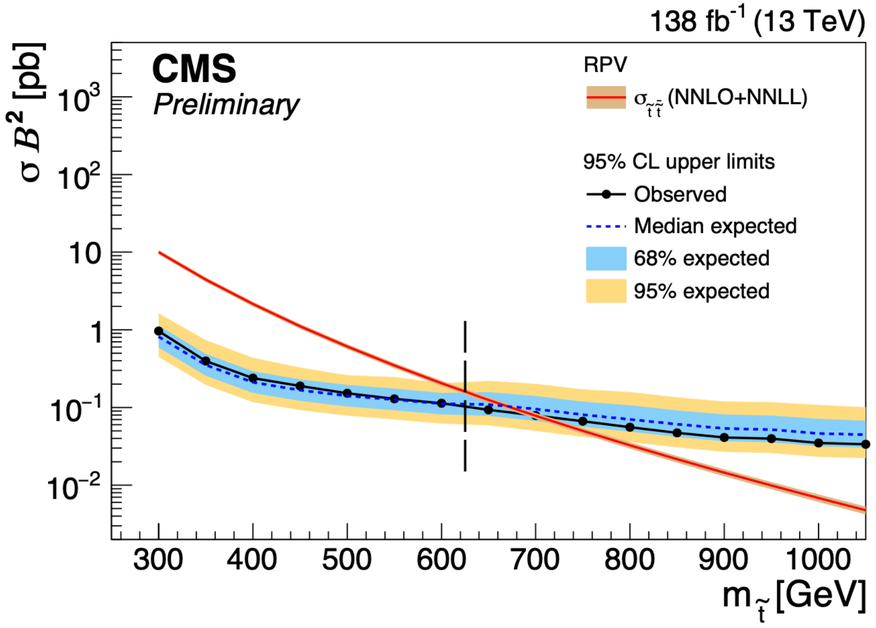


Stealth/RPV: multijets + tt

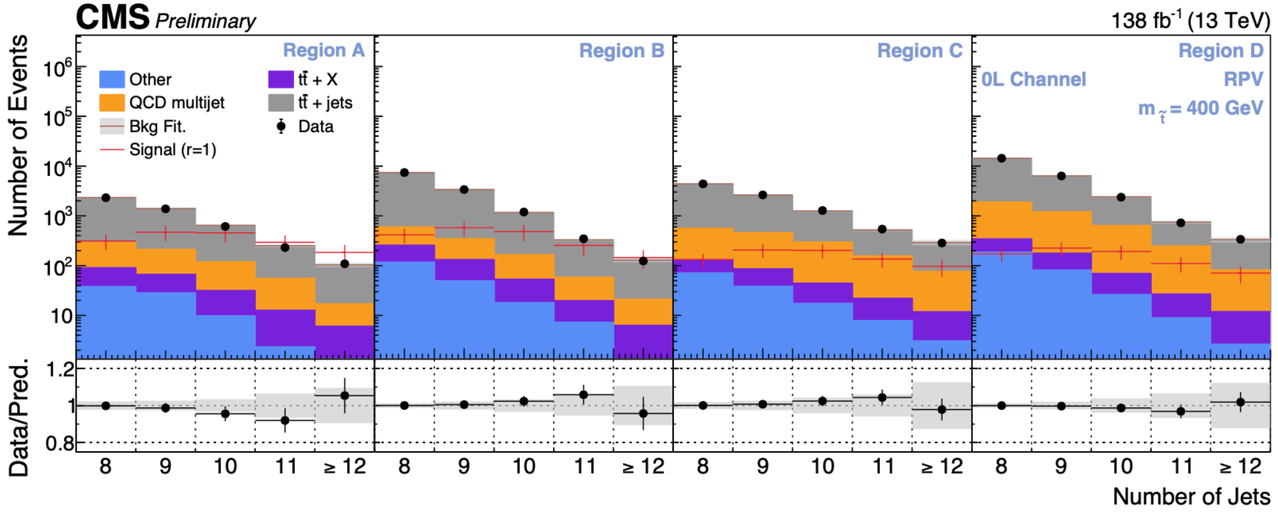
CMS-SUS-23-001

- Final results for 3 N_l channels combined
- No significant excess of events observed above the expected background for either model (previous study indicated an excess at $m_{\tilde{t}} = 400\ GeV$)
- Mass exclusion limits set at 700 GeV for the RPV model and 930 GeV for the Stealth SYY model
- Good agreement between data and background only fits





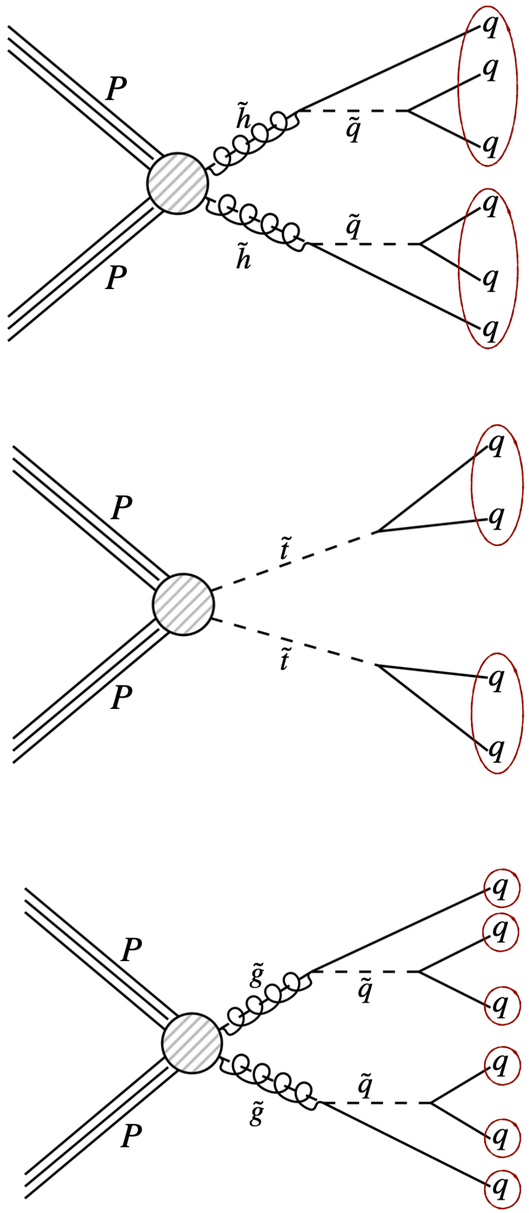
Post-fit plots example, b-only, 0L region:



RPV: multijets

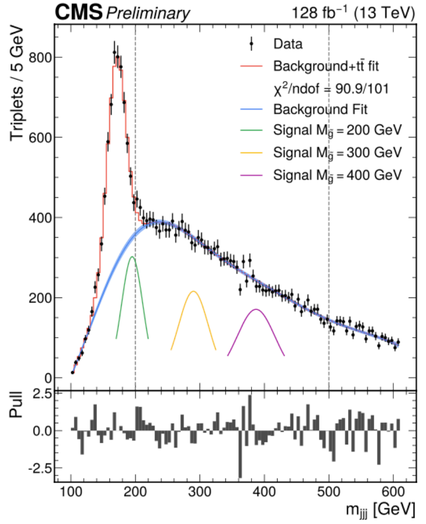
CMS-EXO-21-004

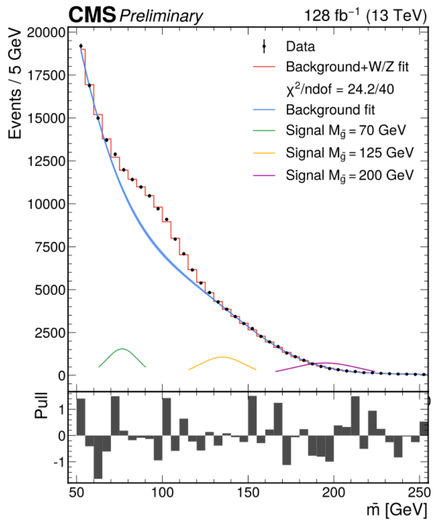
- 3 possible signals: $\tilde{h}, \tilde{t}, \tilde{g}$
- 2 categories: resolved / merged jets
- Main background: QCD



- To overcome trigger threshold limitation a special scouting dataset was used in this study, with lower H_T threshold
- Jets with cone radius dR=0.4 and 0.8 used for resolved and merged cases
- For jets with cone dR=0.8 inner structure information was used for suppressing QCD contribution
- Gaussian Process regressions was used for background estimation

SM resonances clearly seen in both categories:



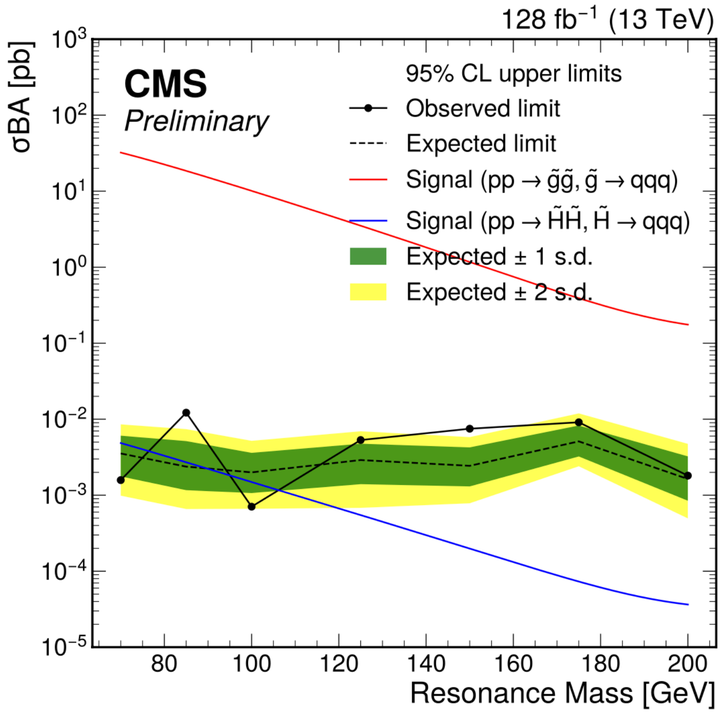


RPV: multijets

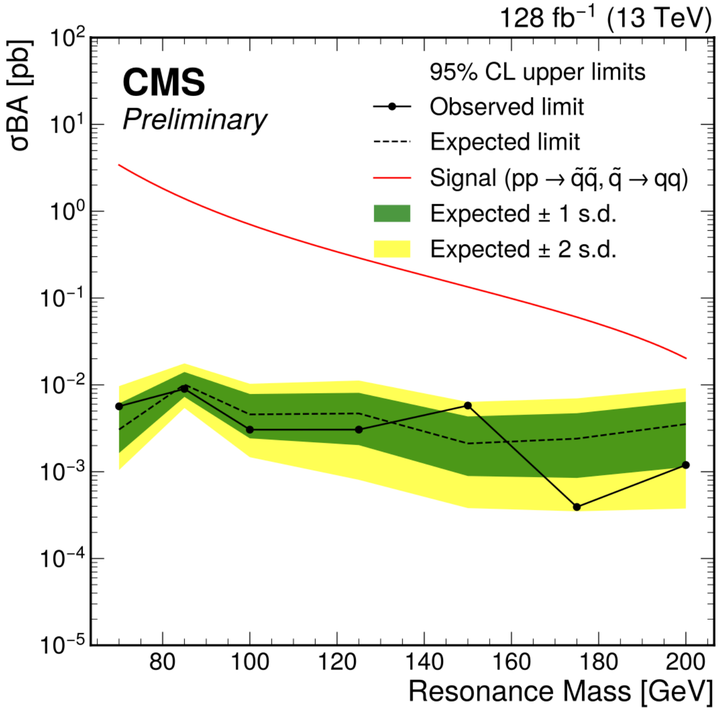
CMS-EXO-21-004

- No significant excess observed
- Most stringent limits ever set on pair produced on RPV Gluinos and RPV top squarks
- Fist ever limits on RPV Higgisnos

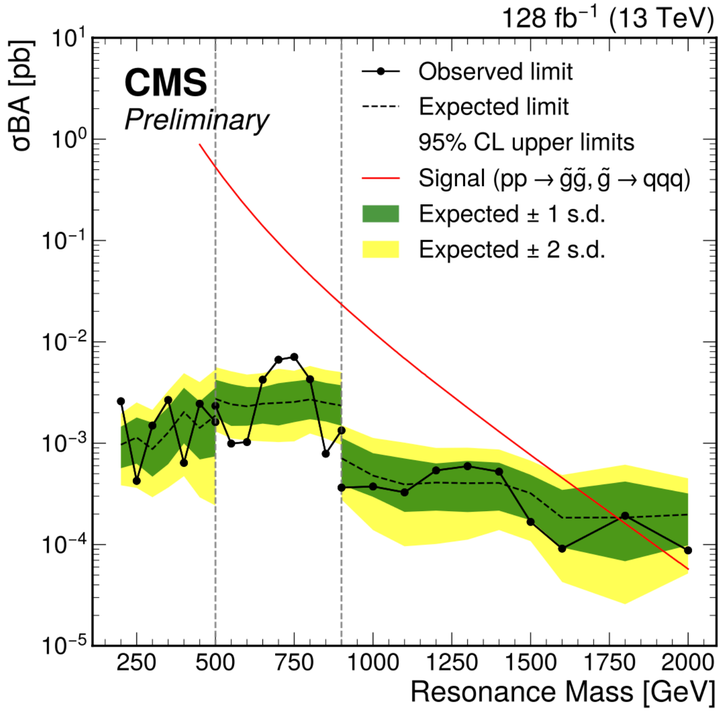
3 quark merged resonance:



2 quark merged resonance:



resolved 3 quarks resonance:

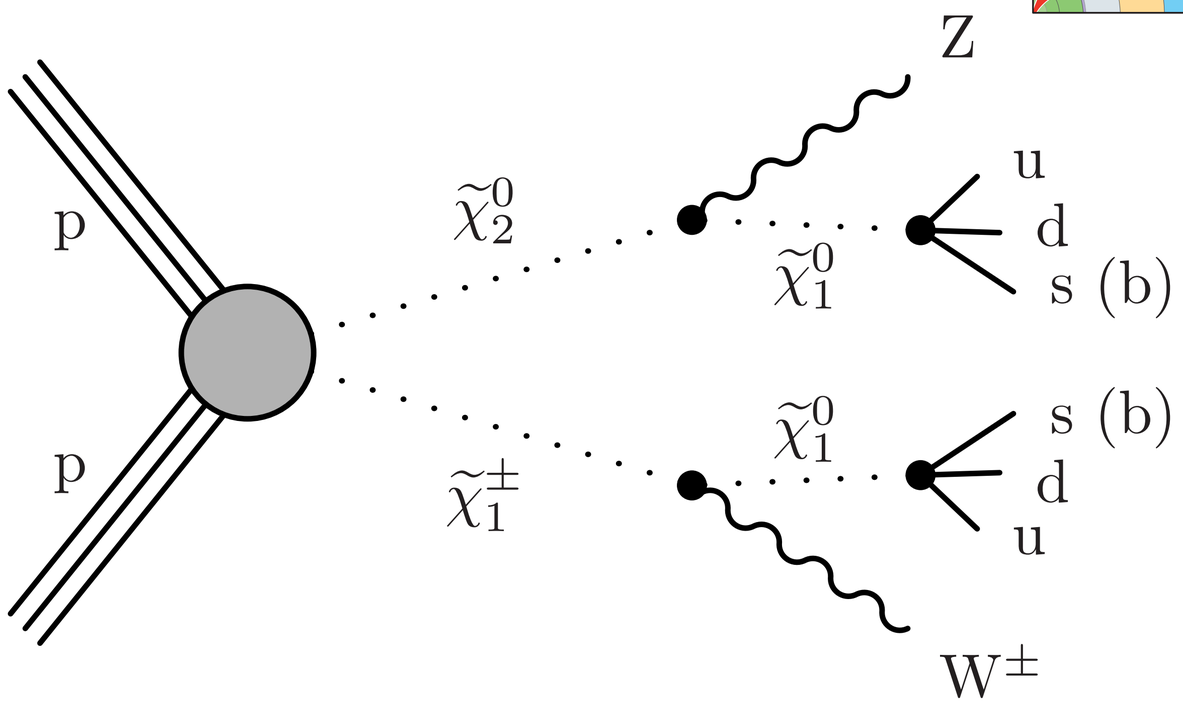


RPV: multileptons + jets

CMS-PAS-SUS-23-015

Two distinct signatures:

- W+Z + 6 light quark jets
- W+Z + 4 light, 2 b quark jets



Signal characteristics:

- Low $\tilde{\chi}_1^\pm$ mass

  => Lower number of jets
- High $\tilde{\chi}_1^\pm$ mass, low $\tilde{\chi}_1^0$ mass

  => Lower number of jets
- High $\tilde{\chi}_1^\pm$ mass, high $\tilde{\chi}_1^0$ mass

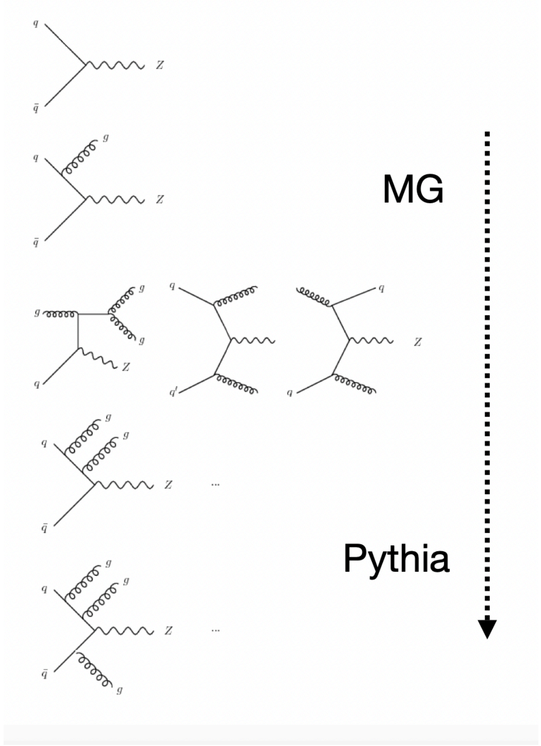
  => High number of jets
- Main backgrounds: WZ,ttZ,MisID

Event preselection:

1. 3 leptons from W/Z decays
2. At least 2 jets

RPV: multileptons + jets

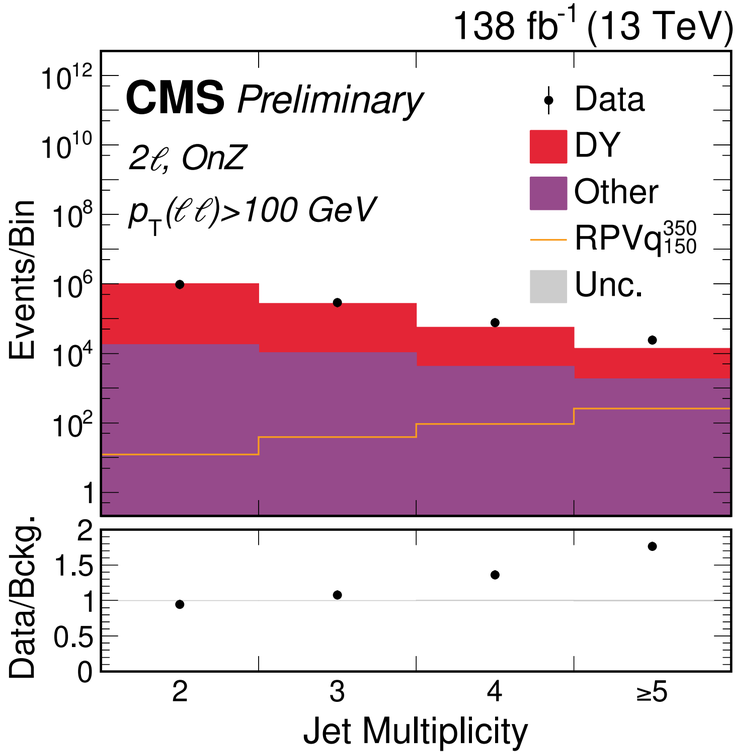
CMS-PAS-SUS-23-015



- N_j is poorly modeled in MC in many processes
- mismodeling the **probability of emitting additional jet**

  → all MC samples with similar Pythia settings in a similar way.

Data excess in control region can't be explained by signal:



Quantifying N_j mismodeling:

- R_j variable is defined as ratio of yields in pairs of neighbouring njet bins:

$$R_j(k \to k+1) = \frac{n(N_j = k+1)}{n(N_j = k)}$$

- R_j variable gives a complementary way of looking at N_j distributions

  →For large, radiative N_j, R_j approaches to an asymptotic behaviour
- R_j variable allows to derive corrections for N_j distributions in control regions

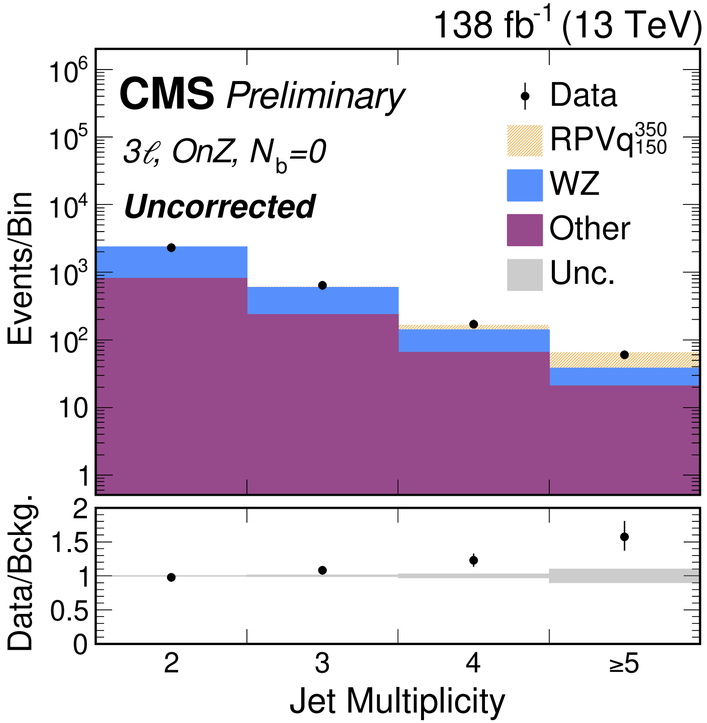
RPV: multileptons + jets

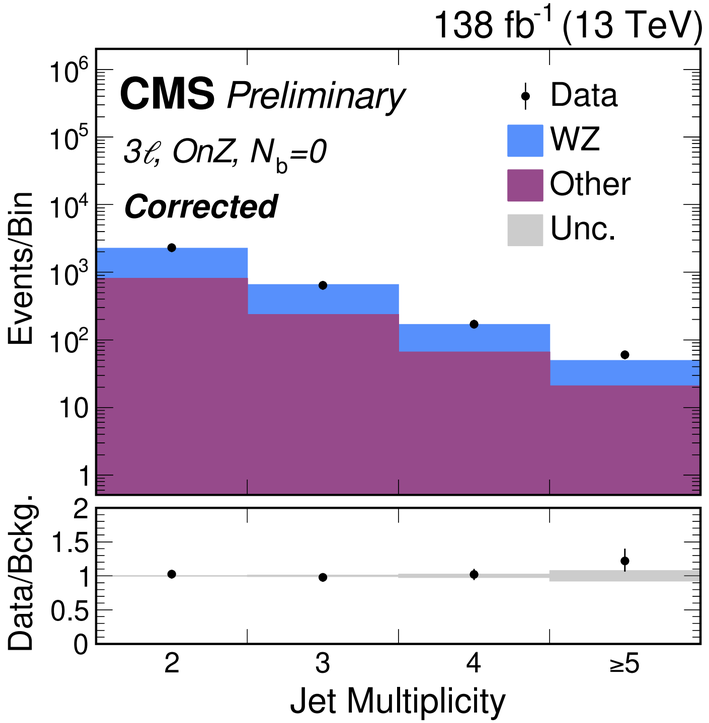
CMS-PAS-SUS-23-015

- Gap between data and uncorrected background MC can be filled with signal
- Correcting N_j distribution using proxy process control regions
- Verifying N_j corrections using W-enriched region

N_j corrections are derived in following steps:

- R_j distributions obtained for WZ, DY, ttZ and tt using MC
- R_j similarities estimated between target and proxy pairs of processes:
  - WZ (target) - DY (proxy)
  - ttZ (target) - tt (proxy)
- Corrections for N_j bins derived s.t. R_j distributions of target processes followed R_j distributions of proxy processes in Data



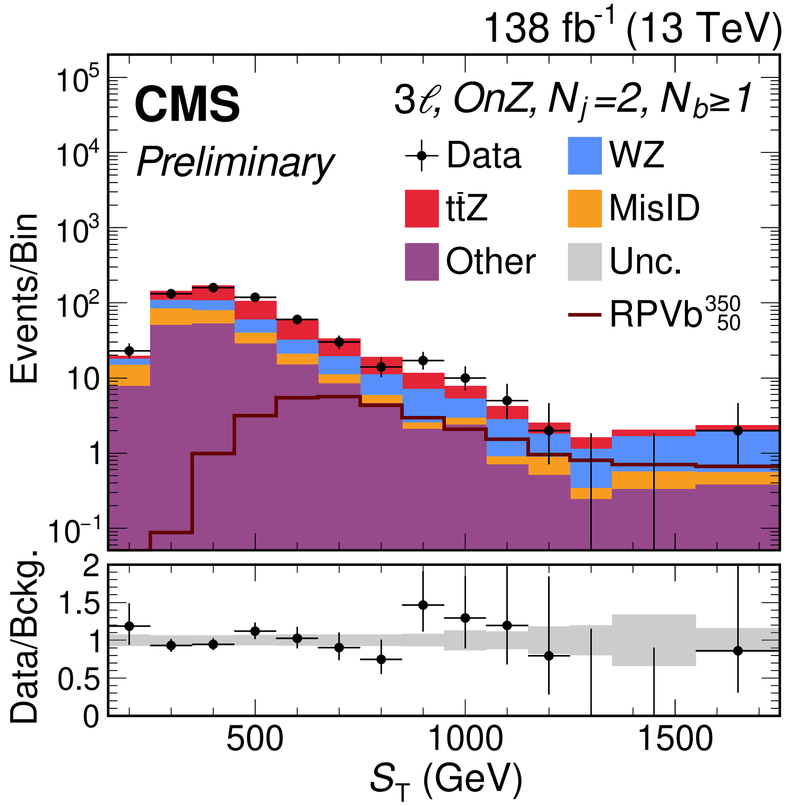


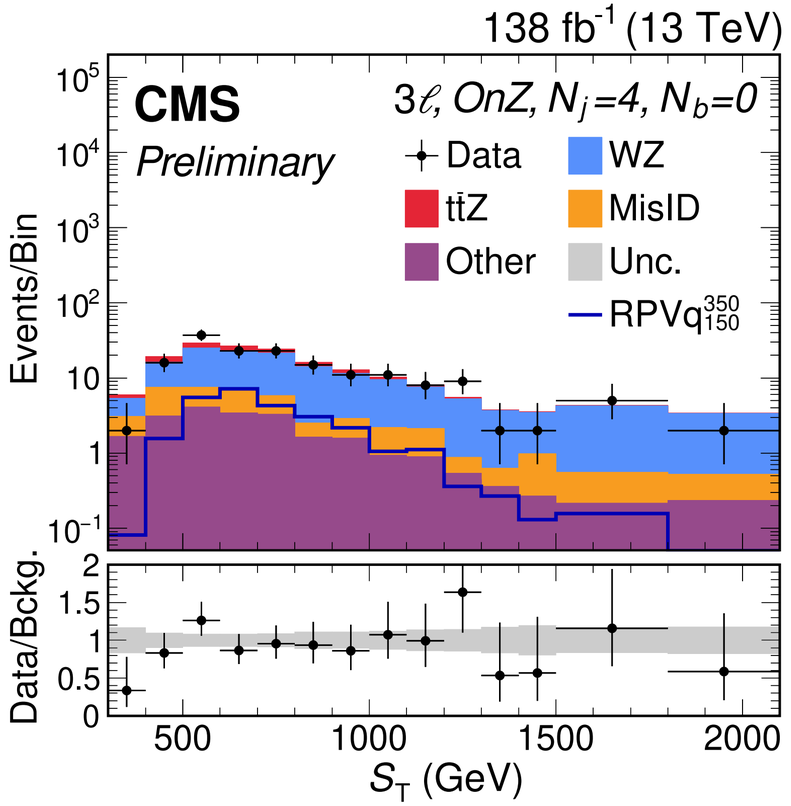
RPV: multileptons + jets

CMS-PAS-SUS-23-015

Variables used in the fit:
- S_T
- N_j
- N_b

- Depending on $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ masses, signal occupies various N_j or S_T bins
- Same bins can serve as signal region or control region depending on $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$ masses
- Simultaneous fit of all bins is done
- Events into categories:
  - 0 or >=1 b-tagged jets
  - 2 or 3 or 4 or >=5 jets

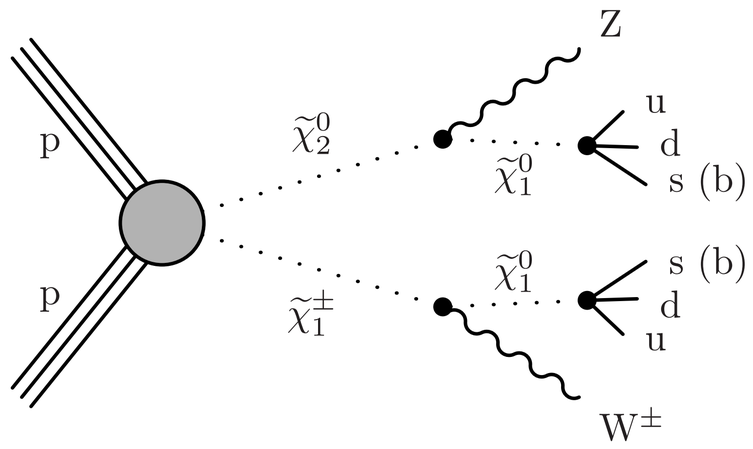


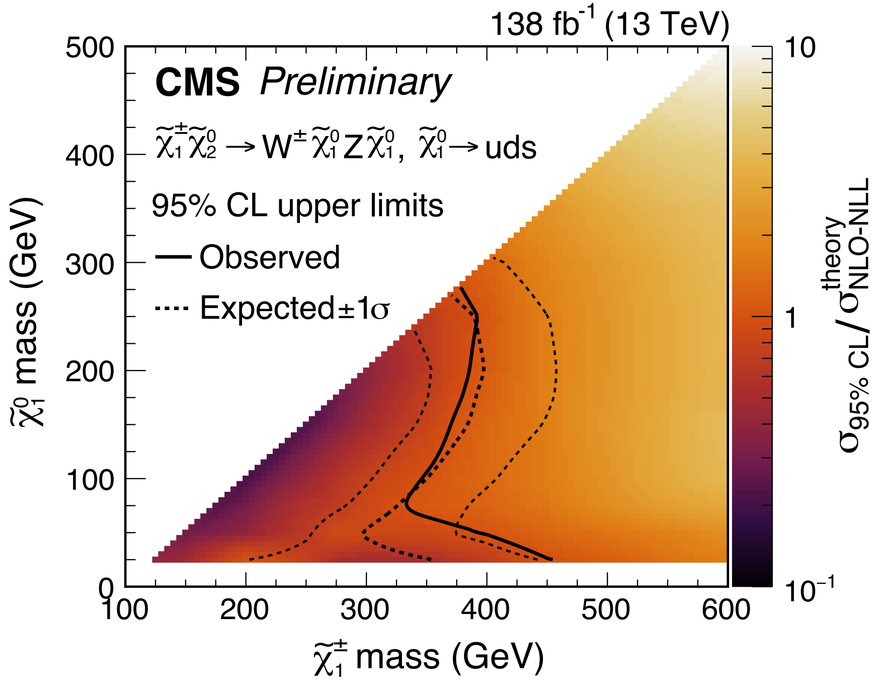


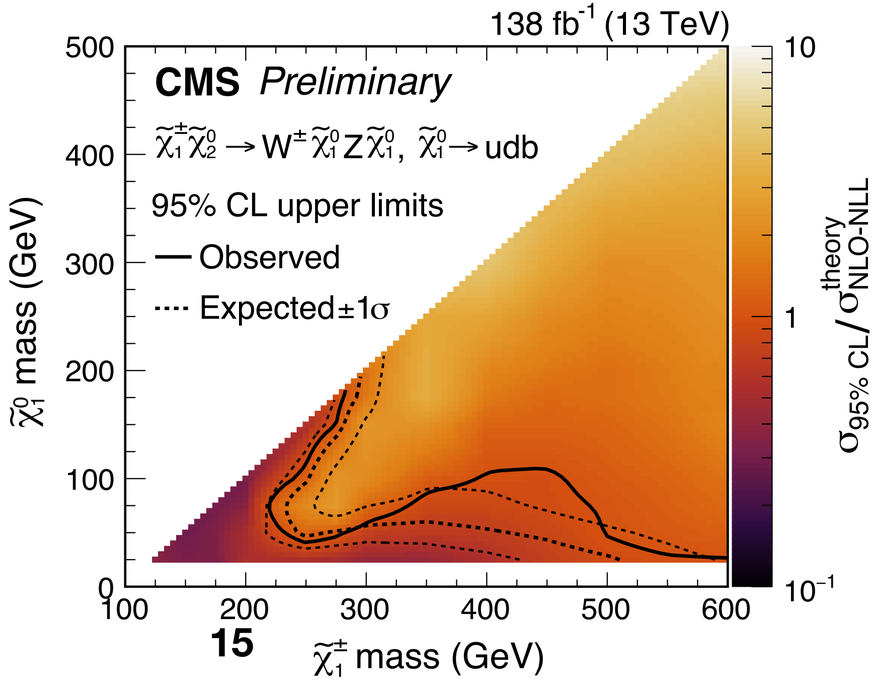
RPV: multileptons + jets

CMS-PAS-SUS-23-015

- For both models (with and without b-quarks), exclusions are of $\mathcal{O}$(100) GeV
  → still a lot of space for potential signal to hide
- Without b-quarks : N_j distribution of main background (WZ) monotonically decreases →almost flat exclusion boundary at 350 GeV
- With b-quarks: N_j distribution of main background (ttZ) peaks at ~3j
  → more complicated exclusion curve comparing to without b-quarks
- These are the first direct bounds on SUSY with weak production and "strong decay".

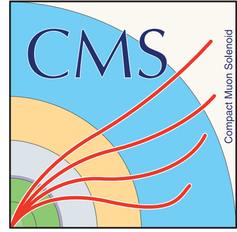






Summary

- Results of 4 different searches for RPV and Stealth SUSY presented
  - $2\tilde{g}/\tilde{q}\bar{\tilde{q}} \rightarrow 4q4g2\gamma2\tilde{G}/2q4g2\gamma2\tilde{G}$ (Stealth)
  - $\bar{\tilde{t}}\tilde{t} \rightarrow 6qt\bar{t}/6gt\bar{t}2\tilde{G}$ (RPV/Stealth)
  - $2\tilde{h}/2\tilde{t}/2\tilde{g} \rightarrow 6/4/6q$ (RPV)
  - $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow 6qWZ$ (RPV)
- No significant excess above SM background observed
- New exclusion limits set
- Starting to look at Run 3 data. Continue searches with more data and improved methods for more challenging scenarios.



Thank you