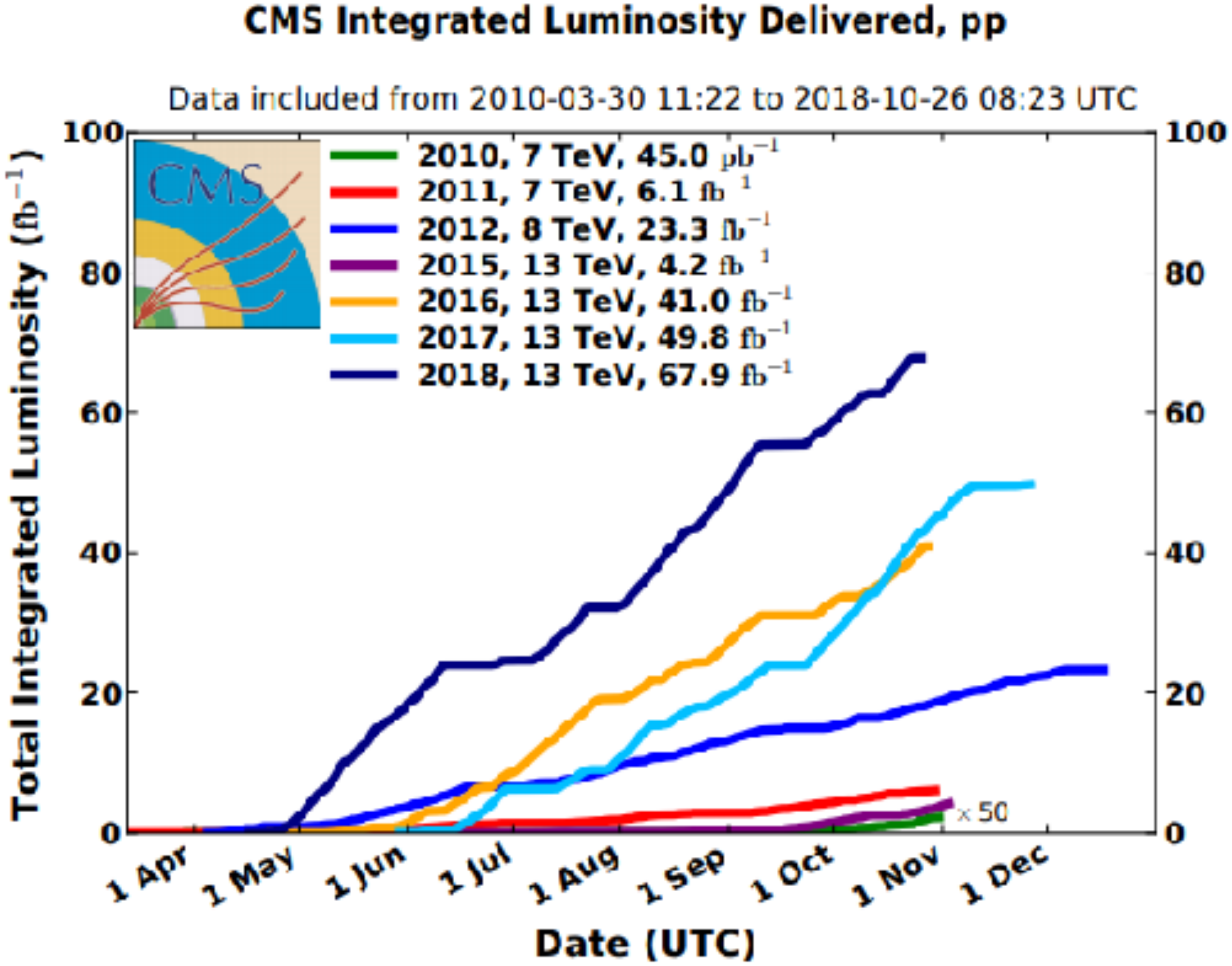
Recent results from SUSY searches in CMS

By: Scarlet Norberg
University of Puerto Rico Mayaguez(UPRM),
on behalf of the CMS collaboration

Large Hadron Collider (LHC)

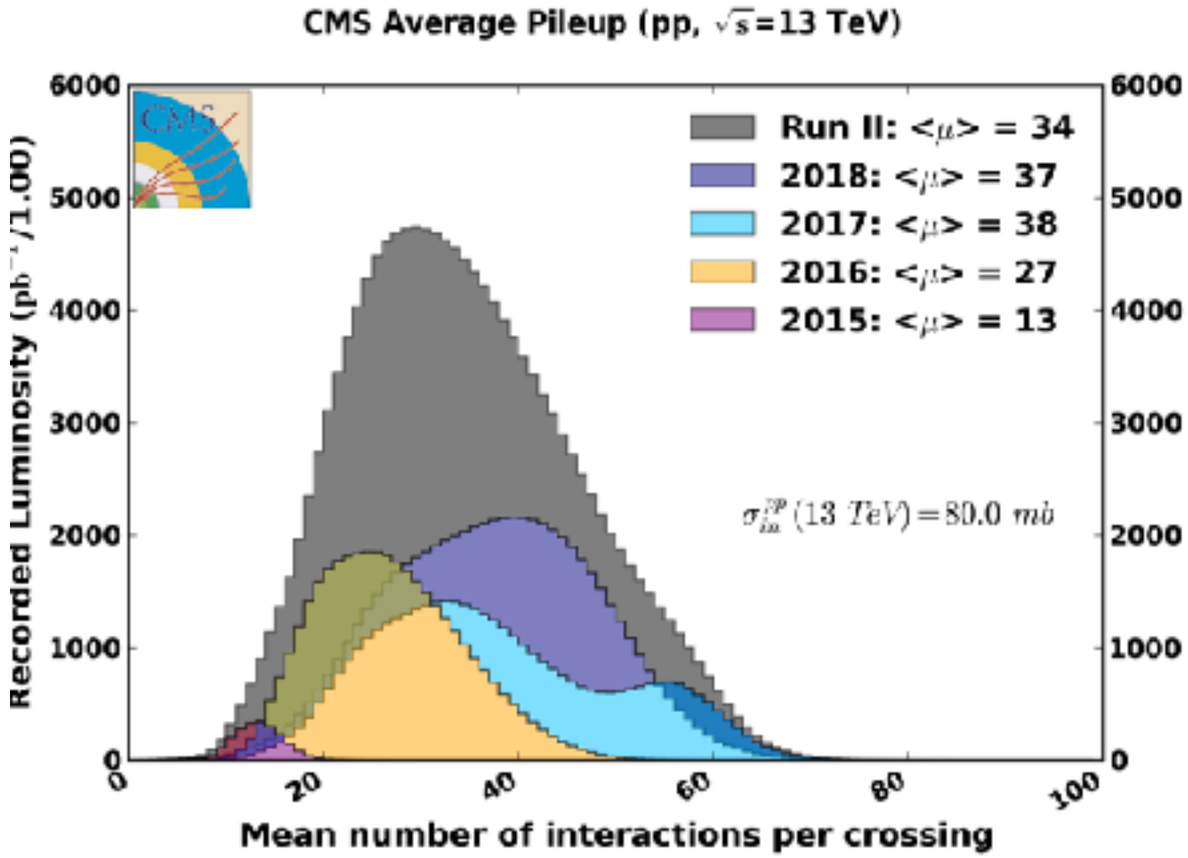


LHC performed quite well (Delivered >160 fb^{-1})

- Such an amazing performance of the LHC leads to challenges for analyses
  - Lots of information to understand quickly
  - Different PU pre year
- For the LHC and CMS Run 2 was a **huge** milestone
- Quickly need to understand the detector & physics object performance including p_T^{miss} tails, which are important for SUSY searches

Run-2 Overview

- Ran at near design center-of-mass energy (13 Tev)
- Largest dataset to date to Analyze
- 2016 36 fb^{-1} 35 Analysis+ (8 new)
- 2016+2017: 77 fb^{-1}
- 2016+2017+2018: 137 fb^{-1}



https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults

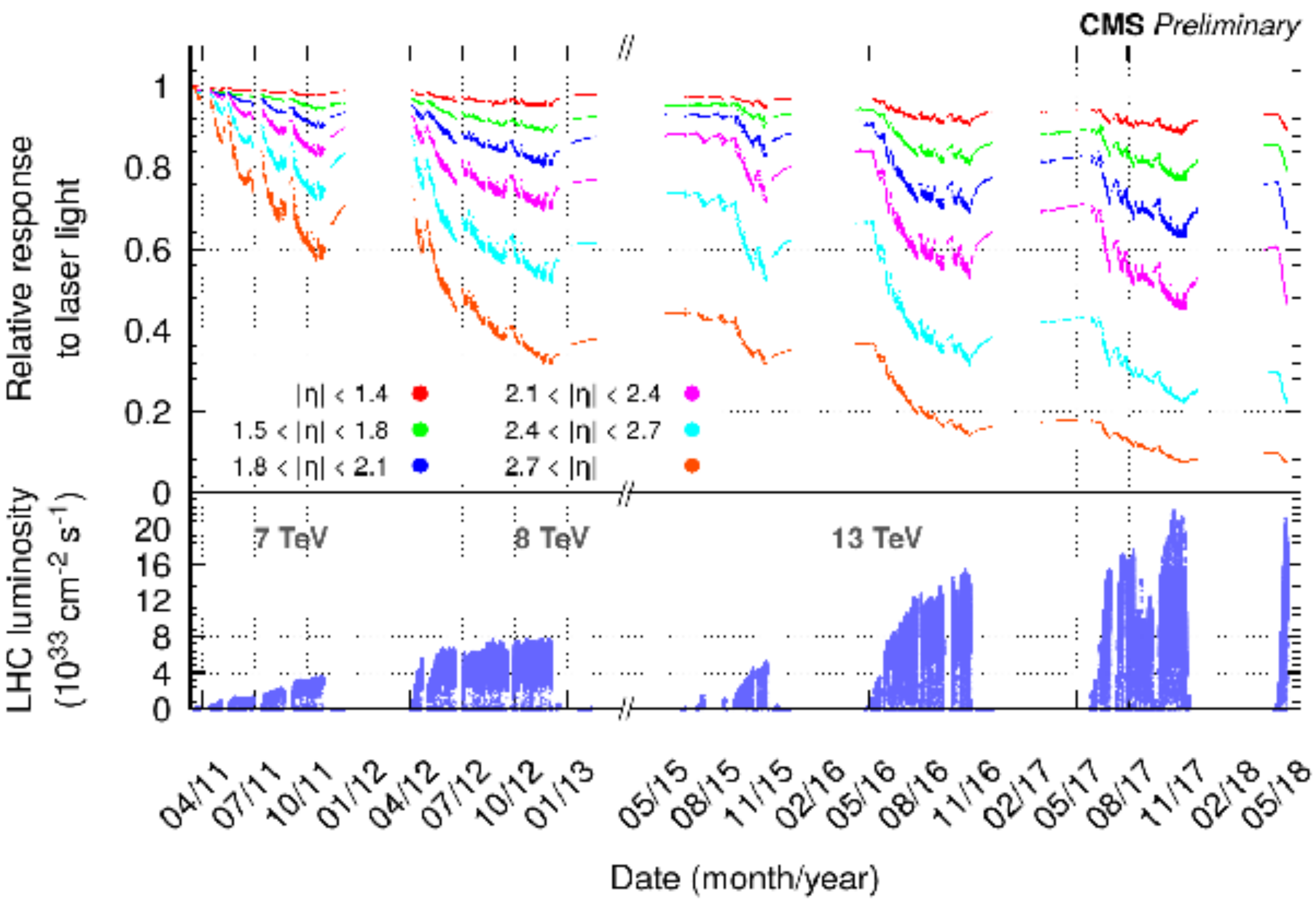
SUSY searches are expanding

- CMS has a multitude of inclusive searches as well as some targeted searches
  - Targeting as much SUSY phase space as possible
- Analysis techniques are constantly improving
- Combining analyses to push sensitivity even higher

CMS Detector

- With the challenging environment that was presented from the LHC the CMS detector proved very capable of meeting the demands
- With Higher energies and higher luminosity we have higher pileup, more radiation damage and higher occupancy which leads to life at the LHC being difficult
  - There are many examples of consequences presented by these challenges
  - e.g. loss of ECal response at high η

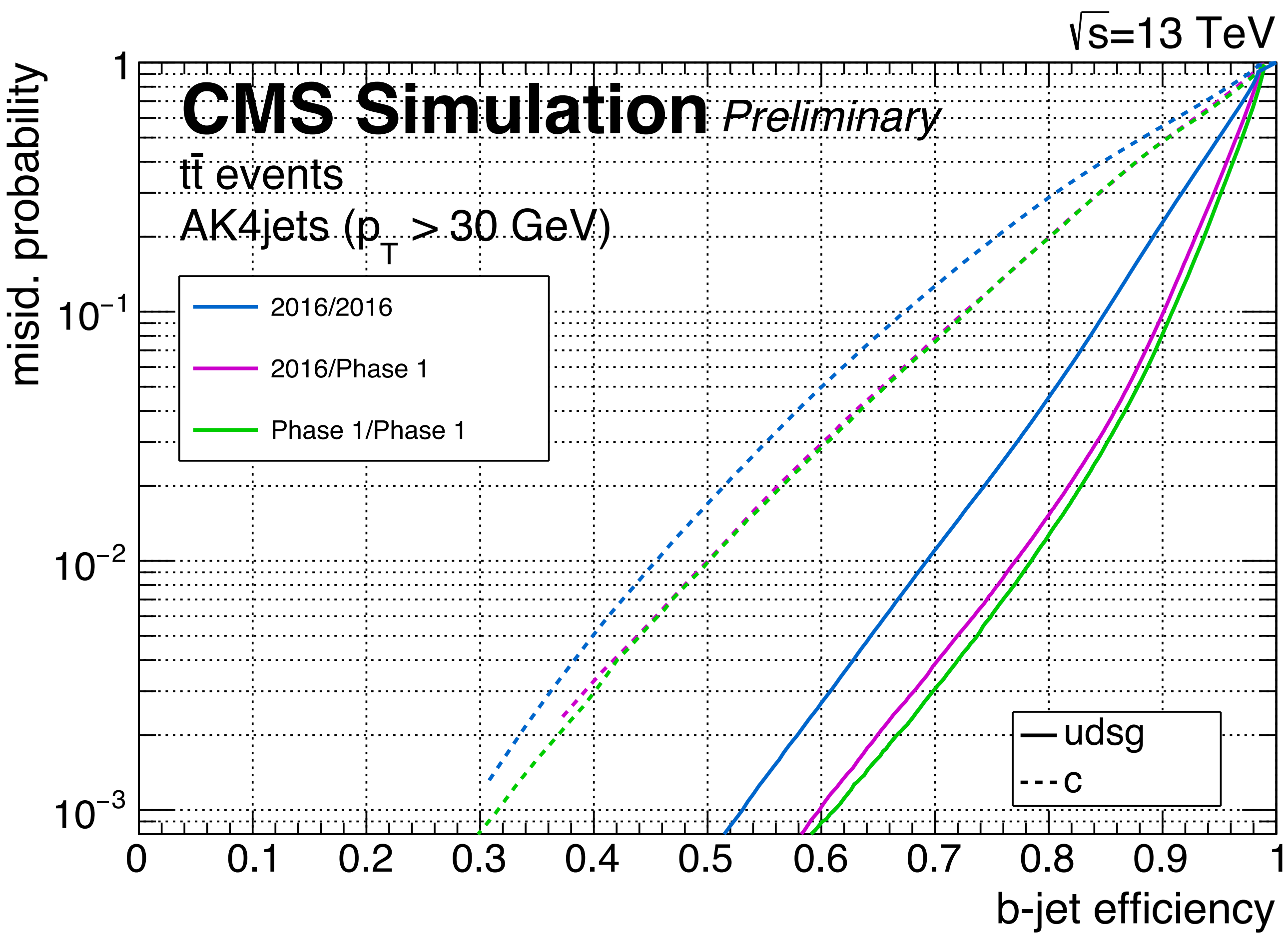
- Upgrades to the CMS detector have played a big role in ensuring that CMS remained competitive in its searches for new physics



https://twiki.cern.ch/twiki/bin/view/CMSPublic/EcalDPGResultsCMSDPS2018015

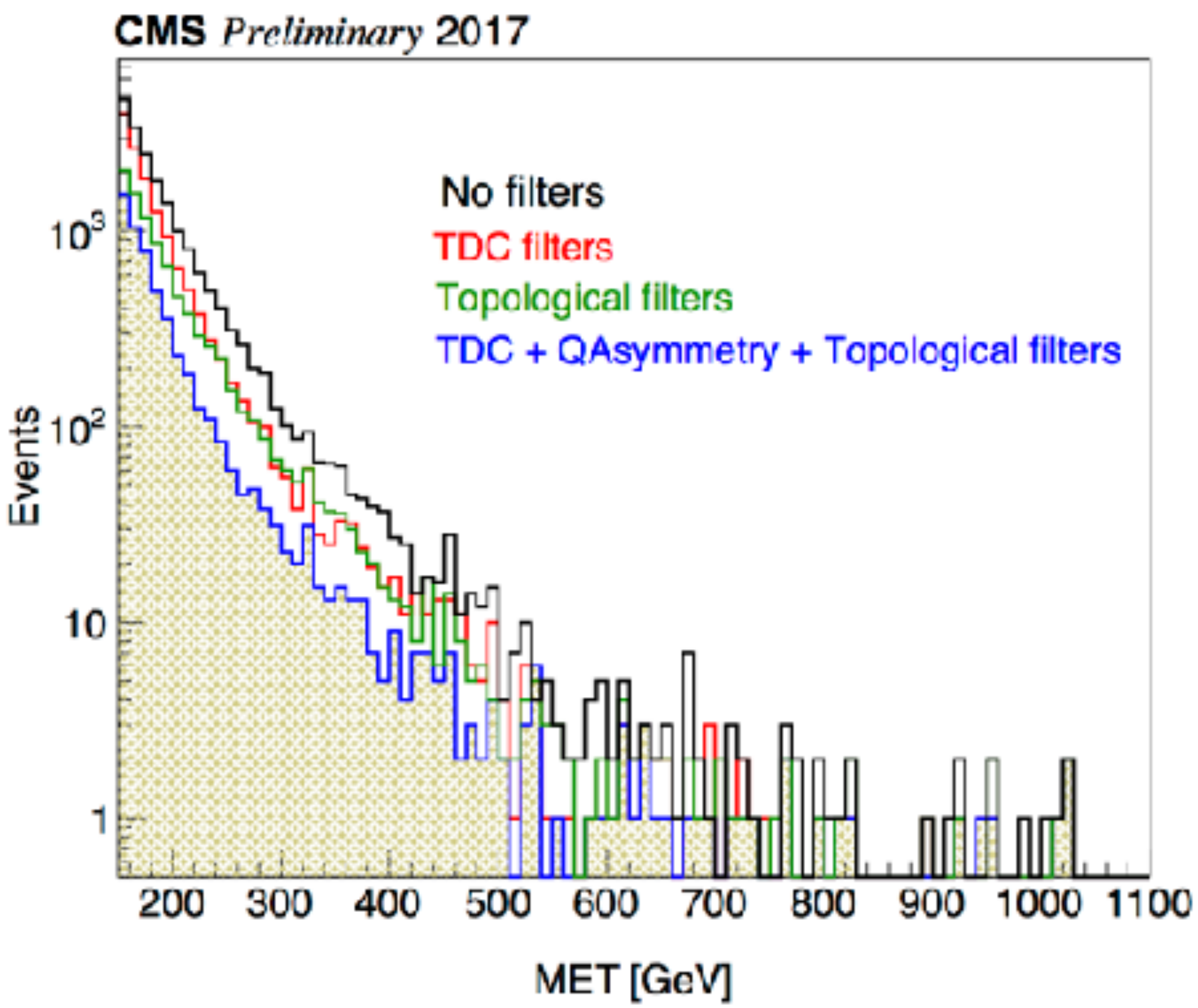
Phase-1 upgrades

Improved b-tagging performance with an upgraded pixel detector



https://twiki.cern.ch/twiki/bin/view/CMSPublic/BTVPhase1Expectations

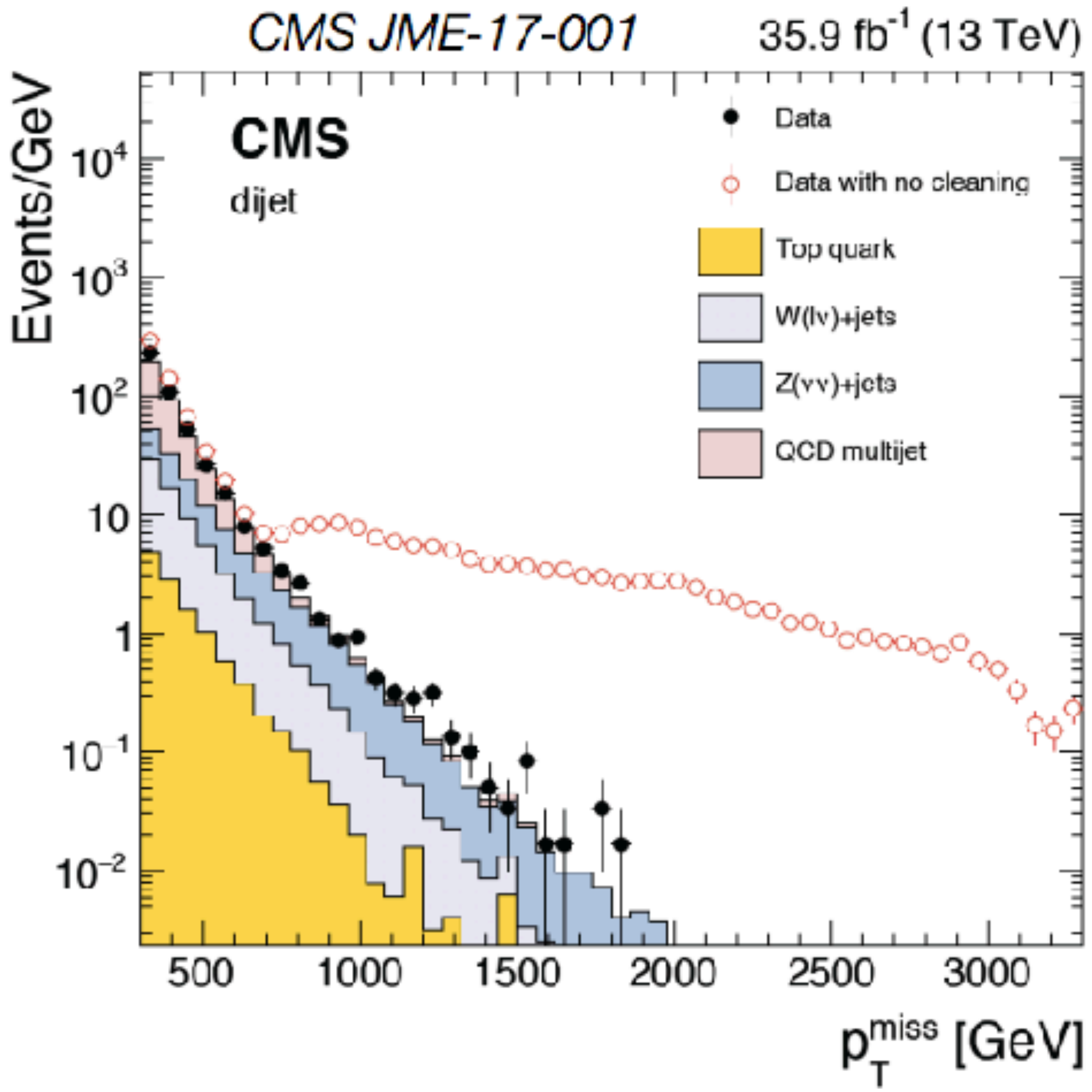
Upgrades to HCAL reduced detector noise and fake p_T^{miss}



https://twiki.cern.ch/twiki/bin/view/CMSPublic/HcalDPGResultsCMSDPS2017042

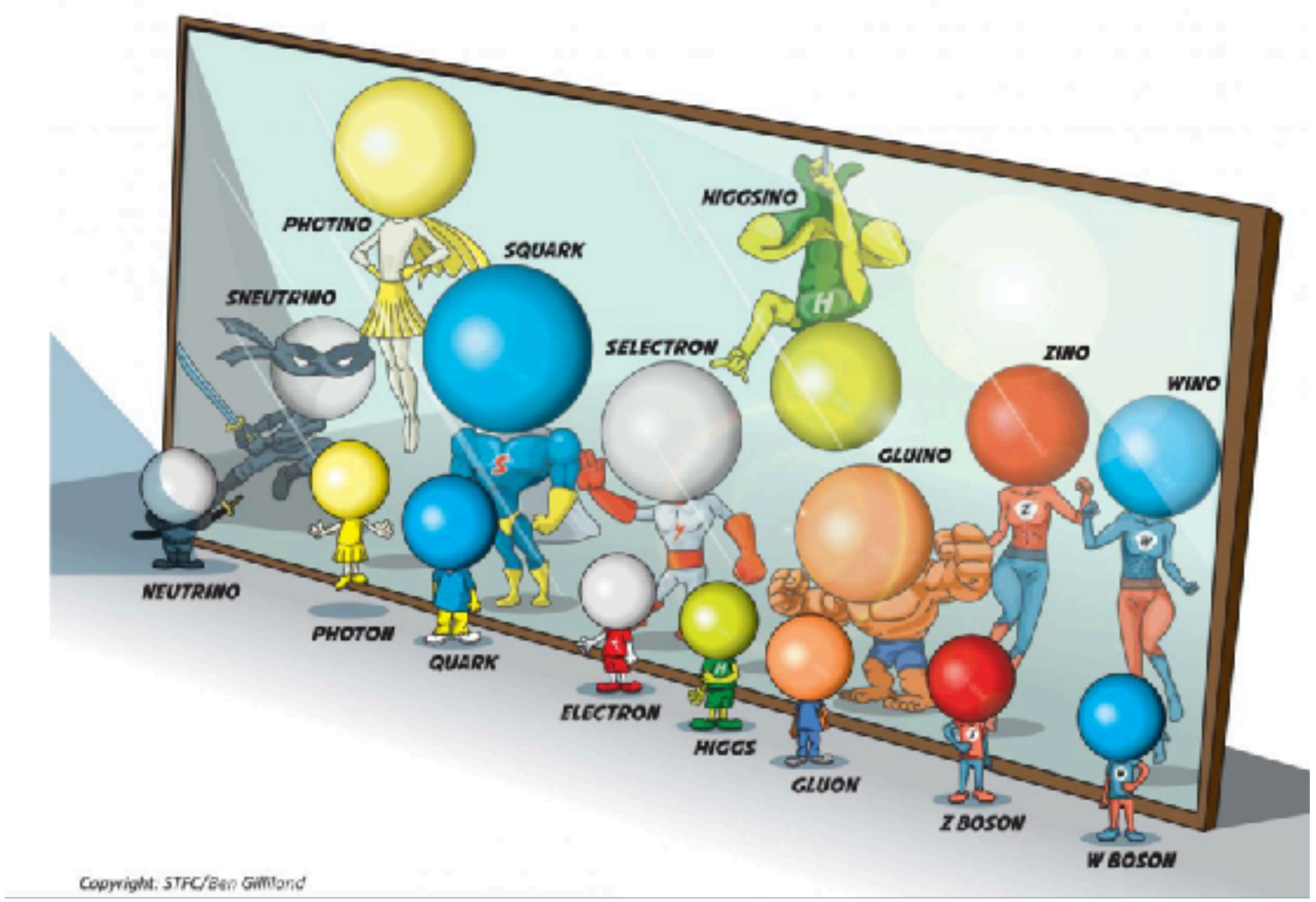
Robustness of SUSY Searches

- Commissioning of all objects has been a huge undertaking with a lot of work and effort going into it over the four years of Run-2
  - The foundation of all of our searches is our detector/object performance
- MET searches, in particular, are difficult
  - because it is sensitive to detector noise
  - It relies on strong performance of all physics objects.
  - Careful studies of anomalies in our inhomogeneous dataset have been paramount



Introduction

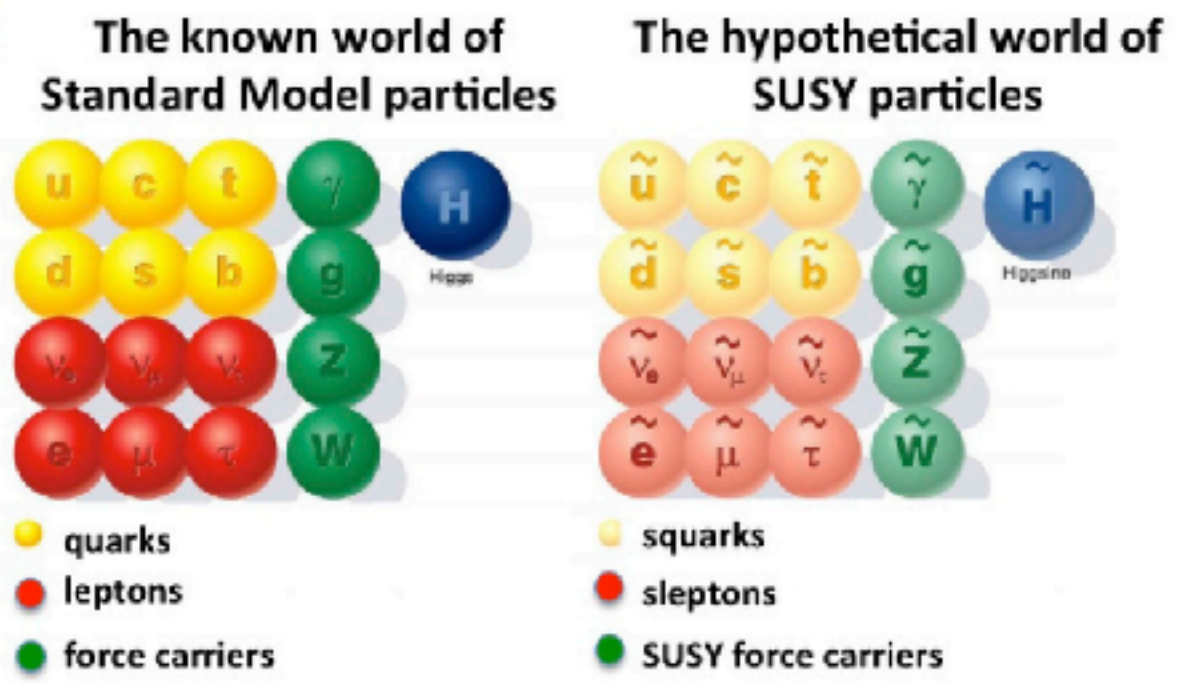
- Supersymmetry is a **very** broad topic.
- The parameter space can predict a wide range of signatures which we would like to cover as much as we can
- I will do my best to cover some highlights here
- To see all the results please look here Recent SUSY public results
- Please state tuned more to come in the coming months

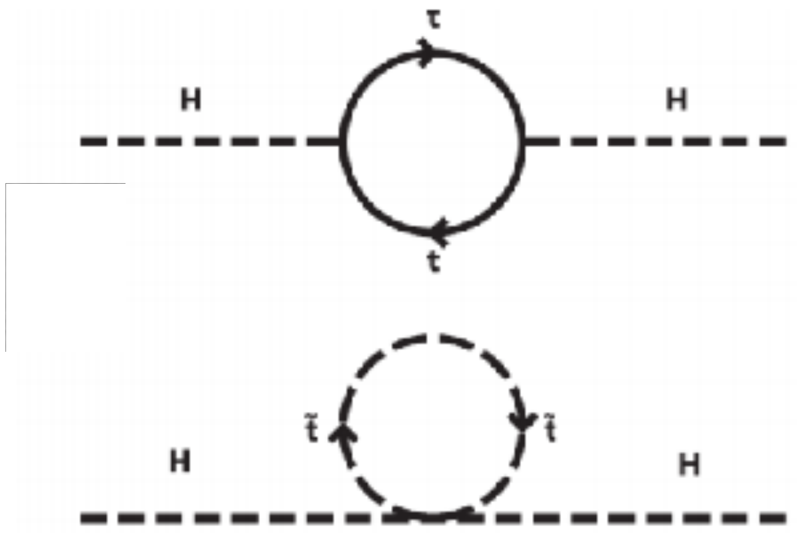


http://united-states.cern/physics/supersymmetry

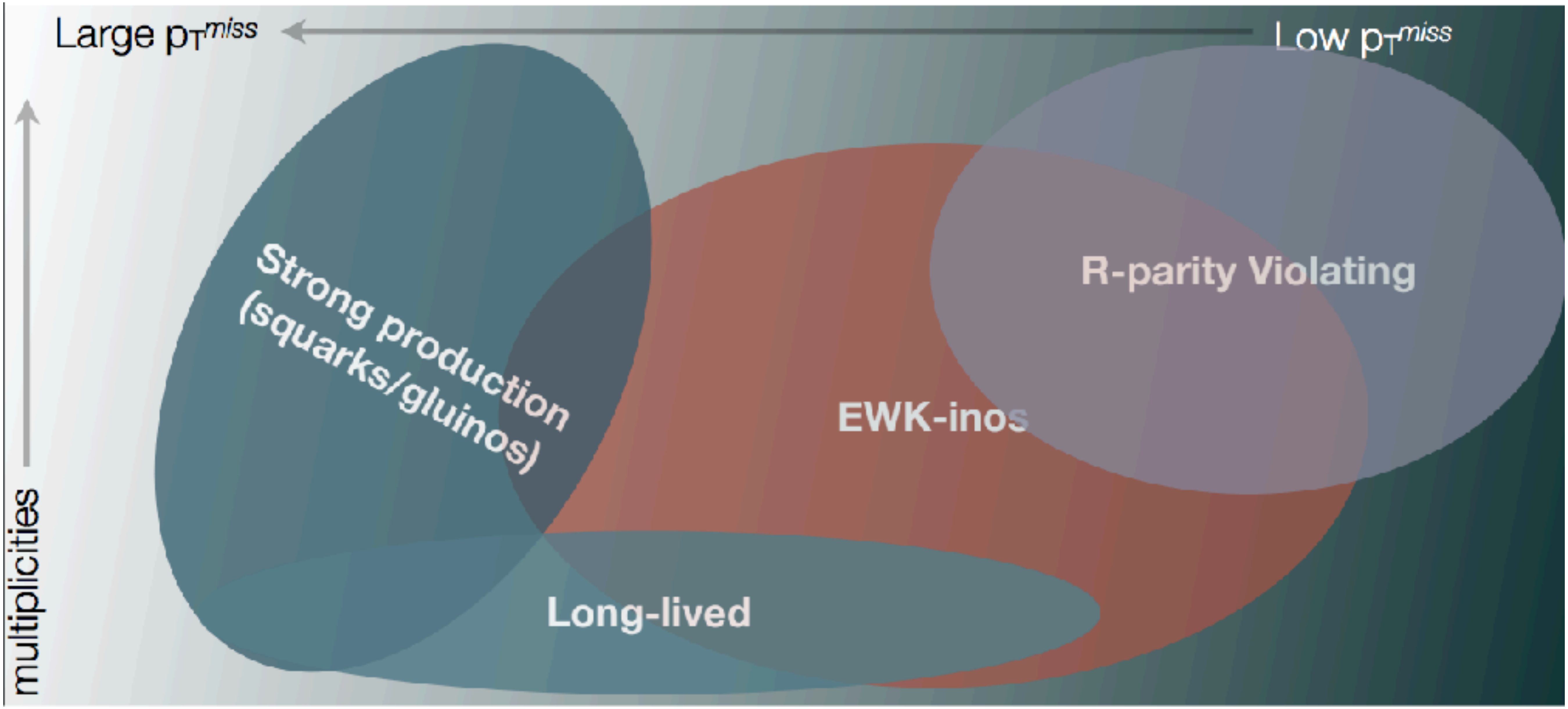
Why SUSY?

- SUSY provides the cancellation of the Higgs boson quadratic mass renormalization between top and top squark (stop)
- Naturalness arguments prefer light stop/sbottom or higgsinos, reachable by the LHC
- Supersymmetry is one of the most promising extensions of the SM
- With R-parity conservation, the lightest supersymmetric particle (LSP) is a dark matter candidate
- Use Simplified Model Spectra as guideline, consider $\tilde{\chi}_1^0$ as LSP



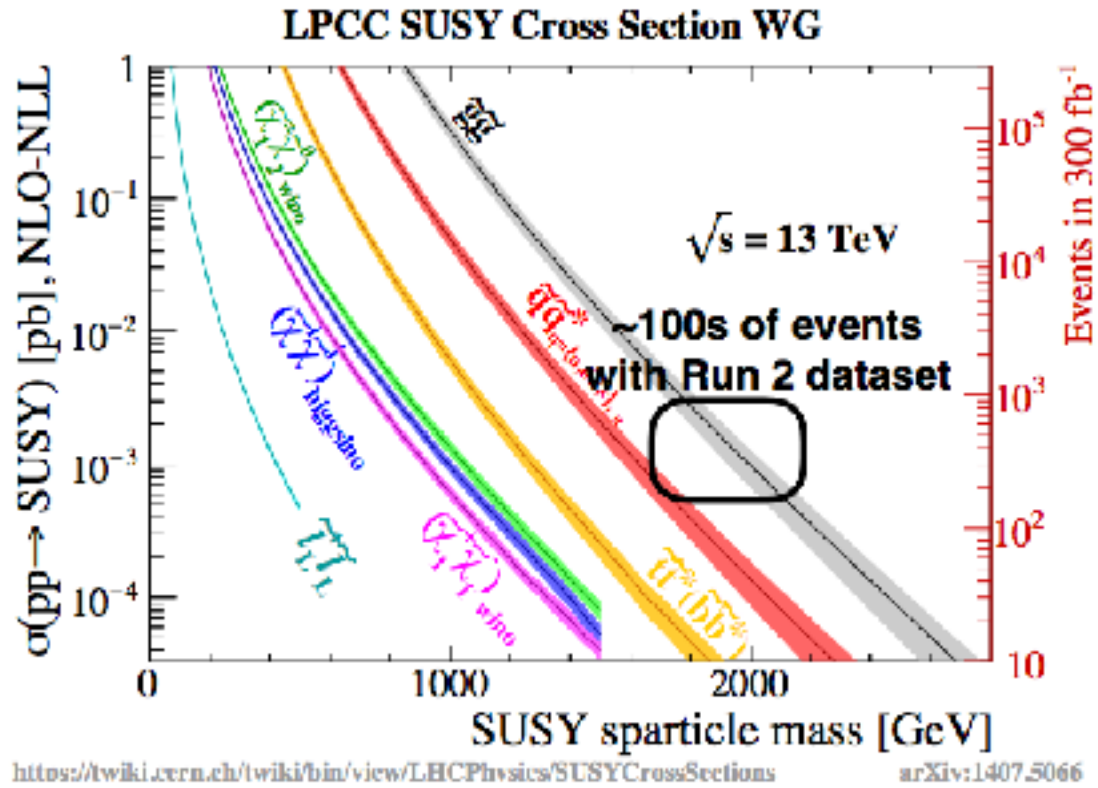


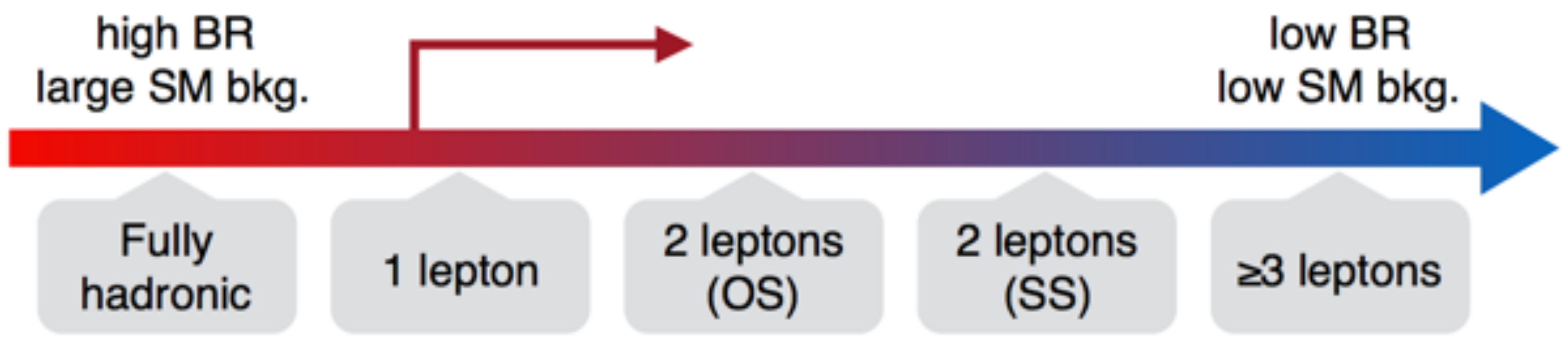
Some Topics to Cover



SUSY Search Break Down

- The largest cross-sections come from Strong production modes
  - hadronic activity/many jets
- Among the cleanest are the Leptonic final states
  - clear detector signal
  - lower branching ratio compared to hadronic analyses, but lower SM background (almost no QCD multijet)





Searches using Jets+M_{T2} Bins

- Inclusive search covering a large number of strong SUSY models
- Search variables binned in H_T, N_j, N_b, M_{T2}
  - A total of 282 signal regions
  - Binning is done this way to have an expected background count of around 1 event in the highest M_{T2} bin for every topological region in (H_T, N_j, N_b)
  - This is done to maximally exploit the additional data collected with respect to the previous version of this analysis.

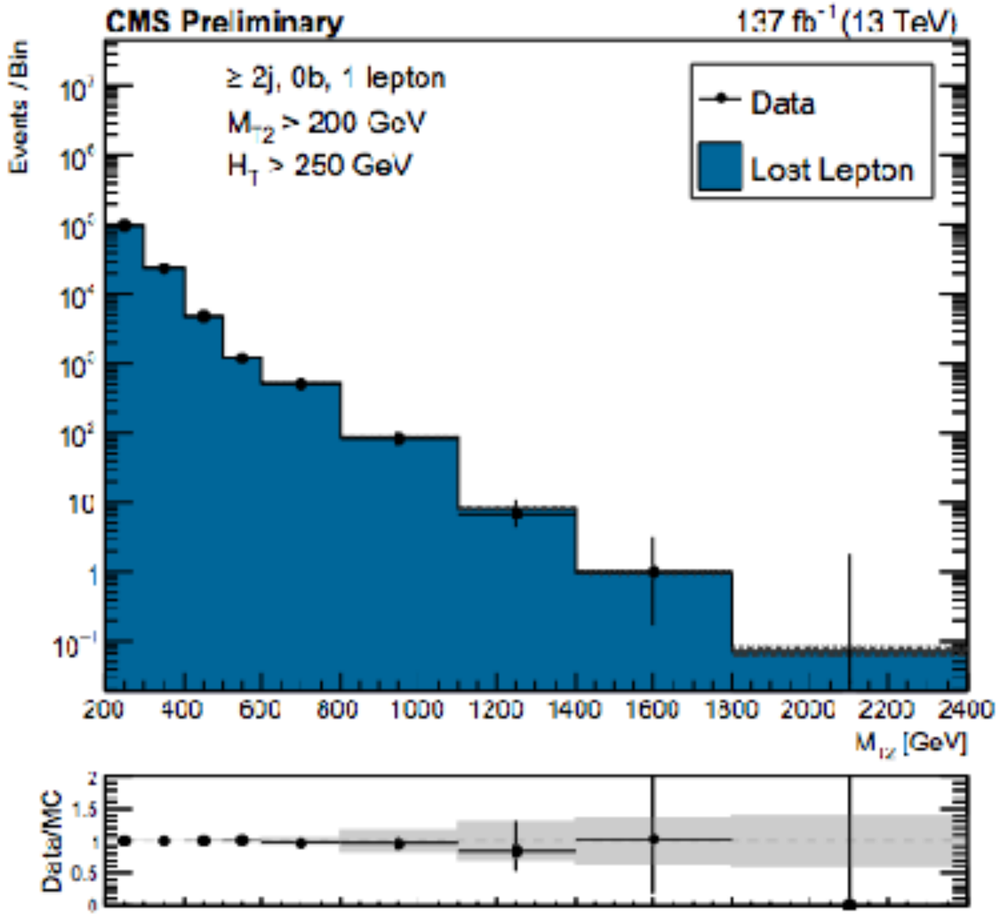
$$H_T = \sum_{jets} |\vec{p}_T|$$

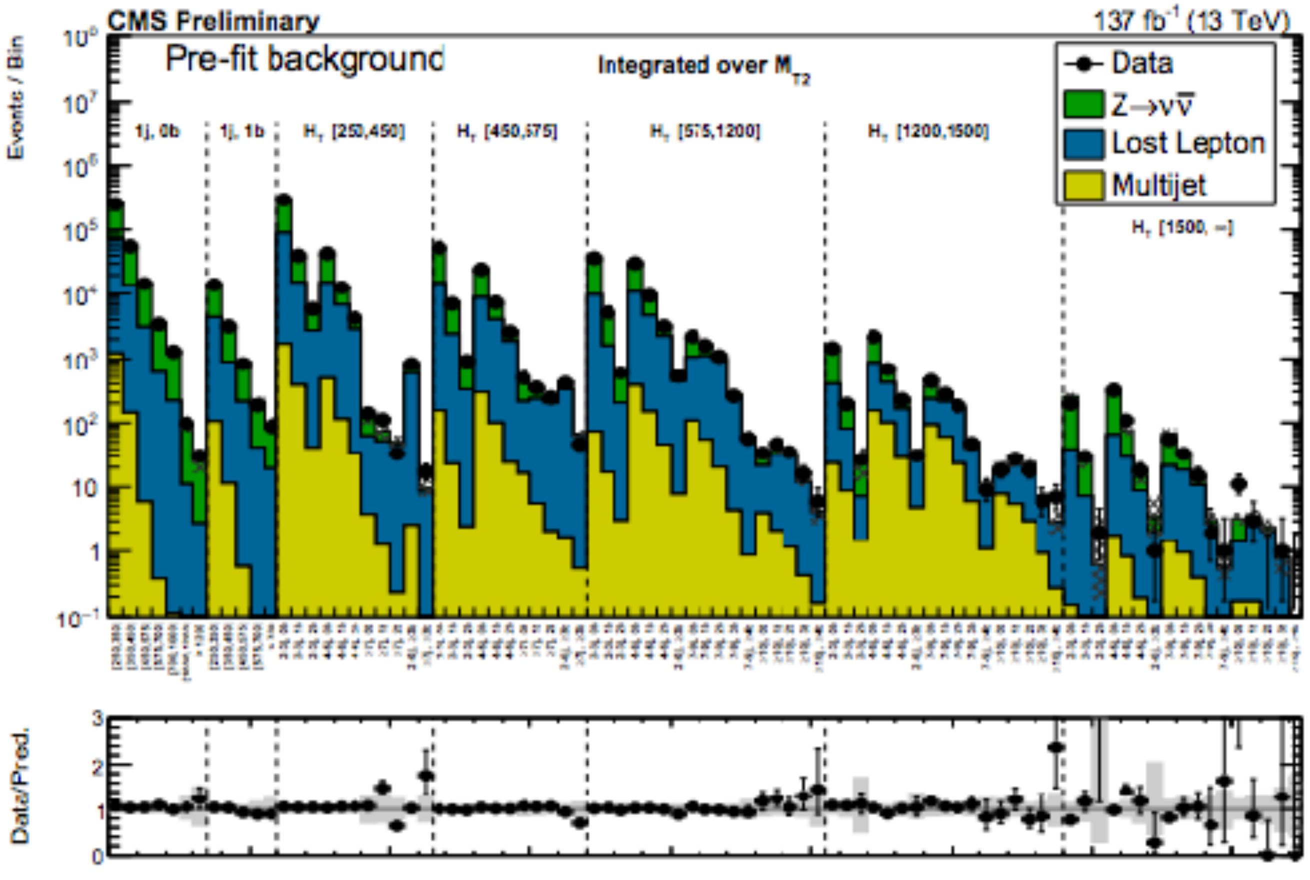
$$M_{T2}(m_X) = \min_{\vec{p}_T^{X(1)} + \vec{p}_T^{X(2)} = \vec{p}_T^{miss}} \left[\max \left(M_T^{(1)}, M_T^{(2)} \right) \right]$$

CMS-PAS-SUS-19-005

Searches using Jets+M_{T2} Overview

- Data driven SM backgrounds taken from control regions:
  - Lost lepton: p_T^{miss} from $W \to l\nu$
  - Irreducible: p_T^{miss} from $Z \to \nu\nu$
  - Multijet: p_T^{miss} from jet mismeasurements





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Seaches using Jets+M_{T2} Background

- Lost Lepton
  - Genuine MET from semi-leptonic W decay
  - Estimate with straightforward transfer factor from single-lepton (e/μ) CR
  - "Hybrid" extrapolation along M_{T2} dimension -- take M_{T2} shape from data where stats permit
- Z→Invisible
  - Irreducible background, with genuine MET from ν's
  - Estimate with transfer factor from Z→ll CR, after accounting for top contamination
  - "Hybrid" extrapolation along M_{T2} dimension
- QCD Multijet
  - Fake MET from mis-measured jets
  - Greatly suppressed with Δϕ(jet,MET) and M_{T2} cuts
  - Estimate remaining background with **Rebalance and Smear method**

Jets+M_{T2} (Results Part 1)

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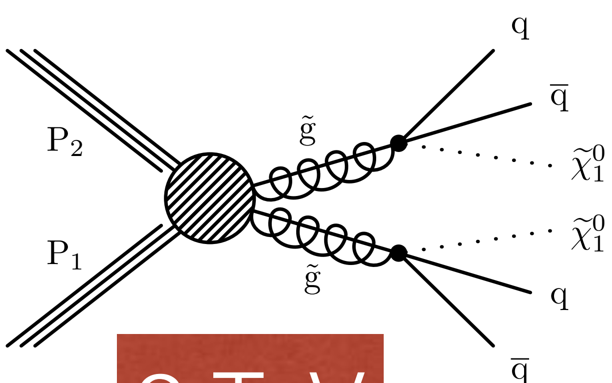
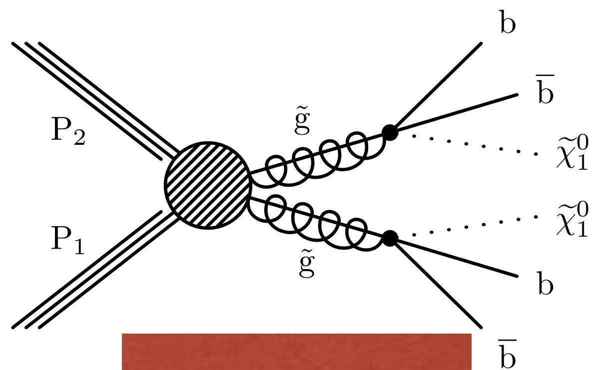
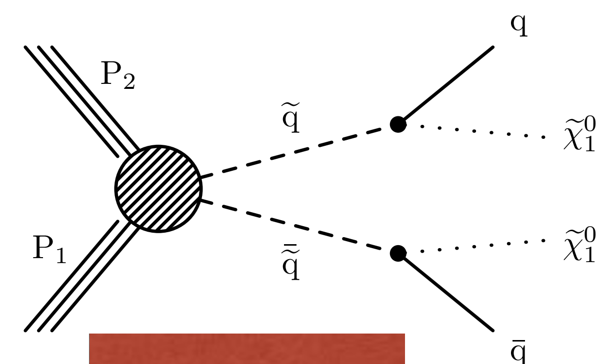
- Interpretation: simplified squark and gluino models
- Extend reach by 100-350 GeV for squarks and gluinos and by 100-250 GeV for $\tilde{\chi}_1^0$ compared to 36 fb^{-1} results



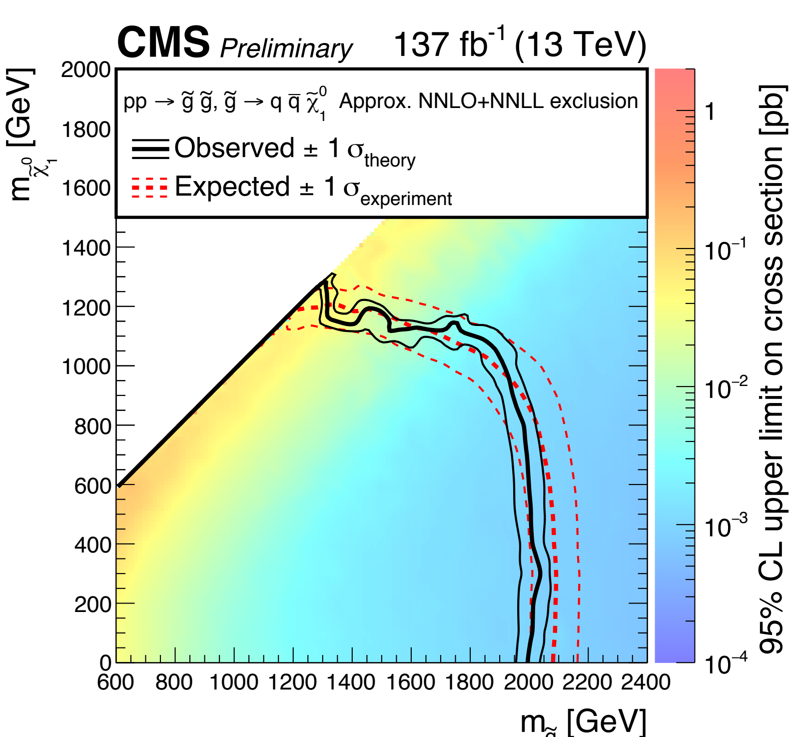
2 TeV

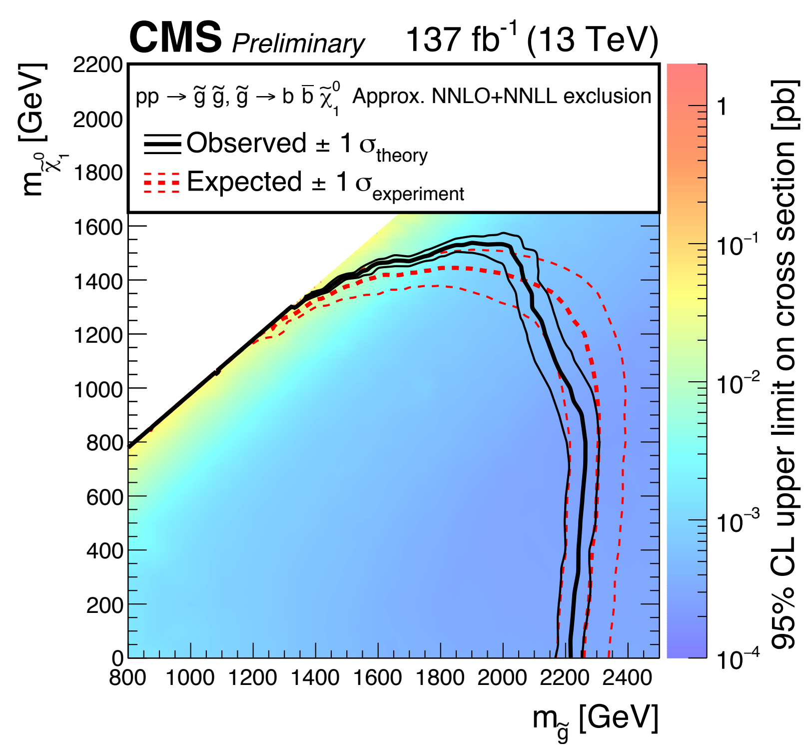


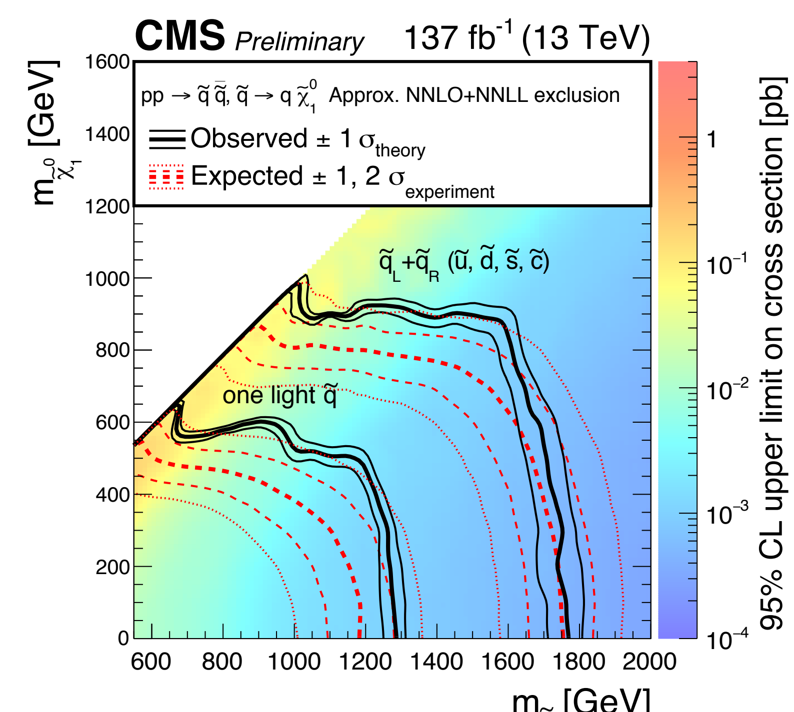
2.2 TeV



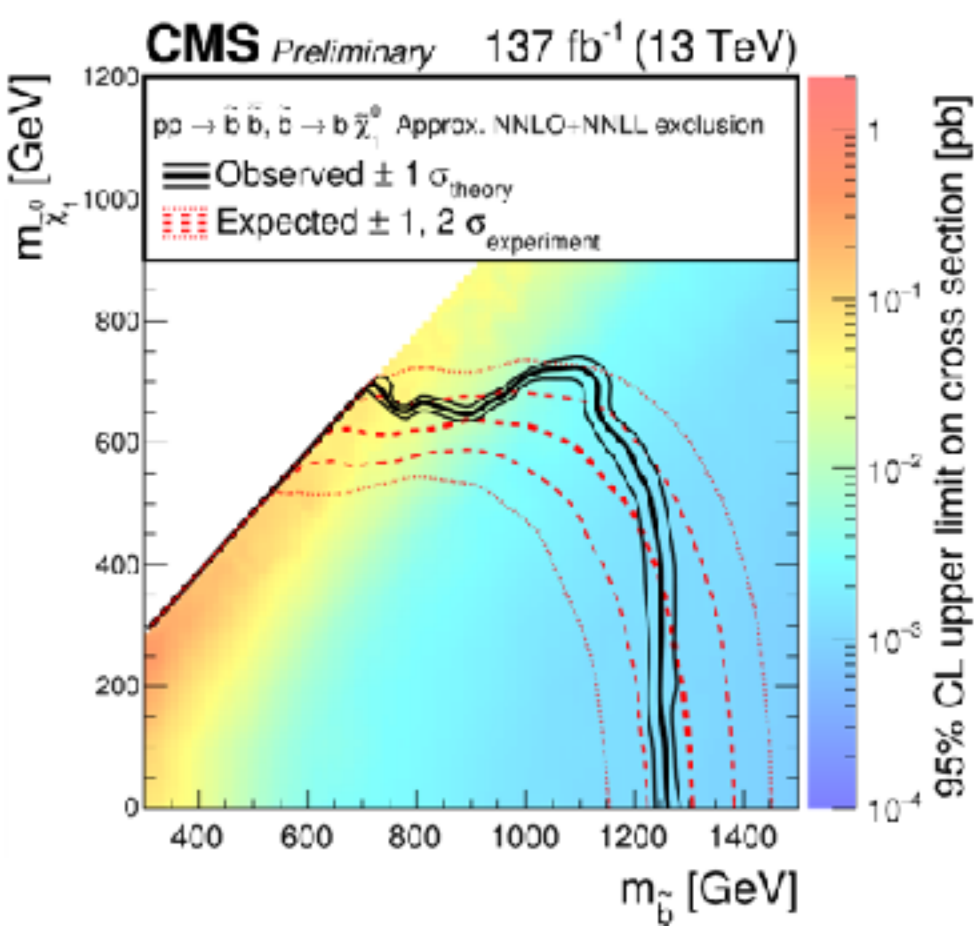
1.8 TeV

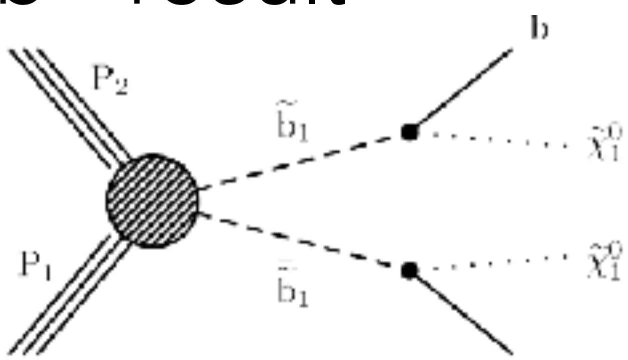


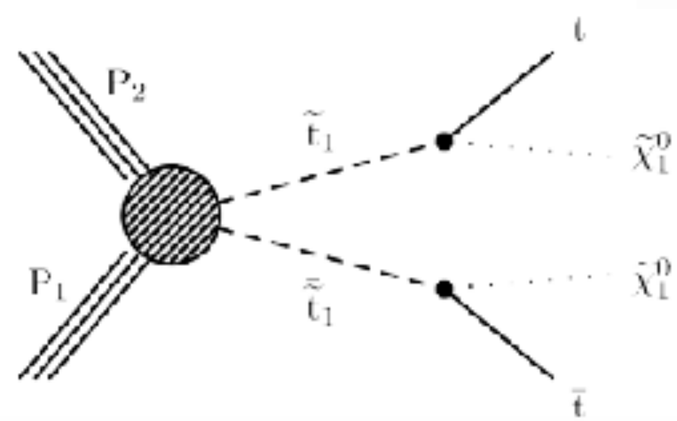


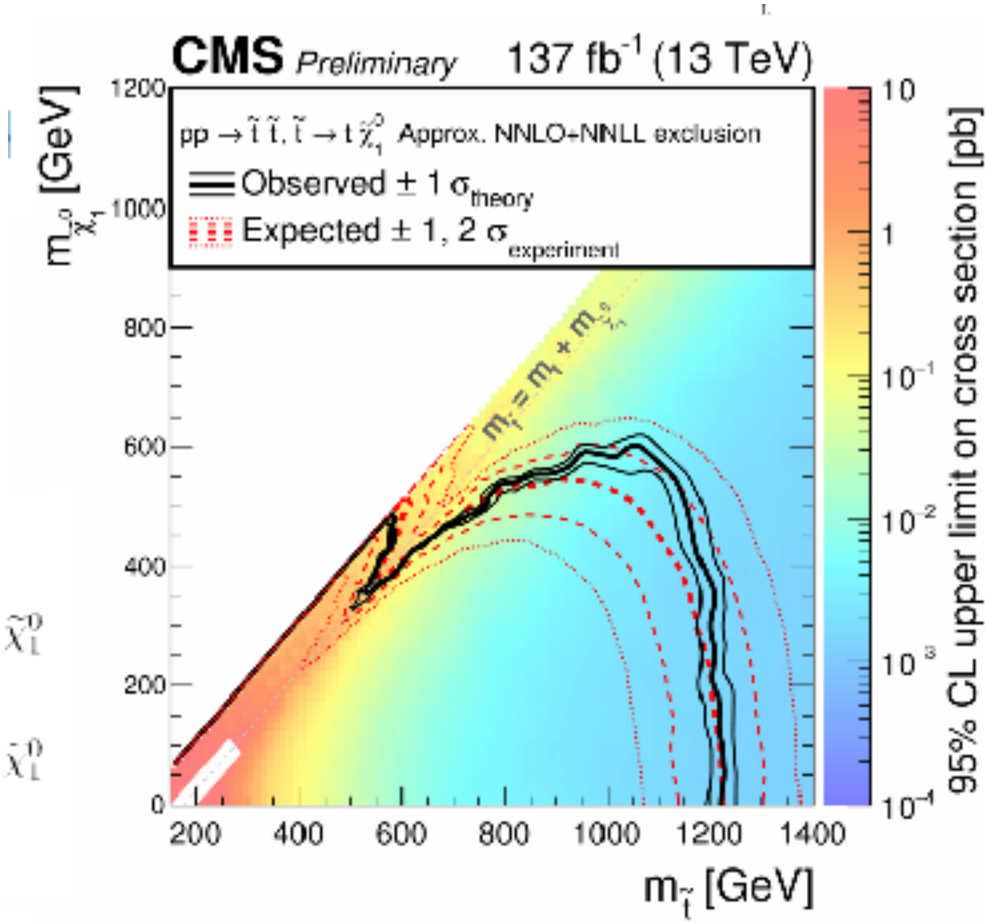


- Inclusive searches in all hadronic final state, binned in H_T, N_j , N_b, M_{T2}
- Extend reach by ~100GeV on sbottom and 130GeV on stop mass compared to 36fb^{-1} result



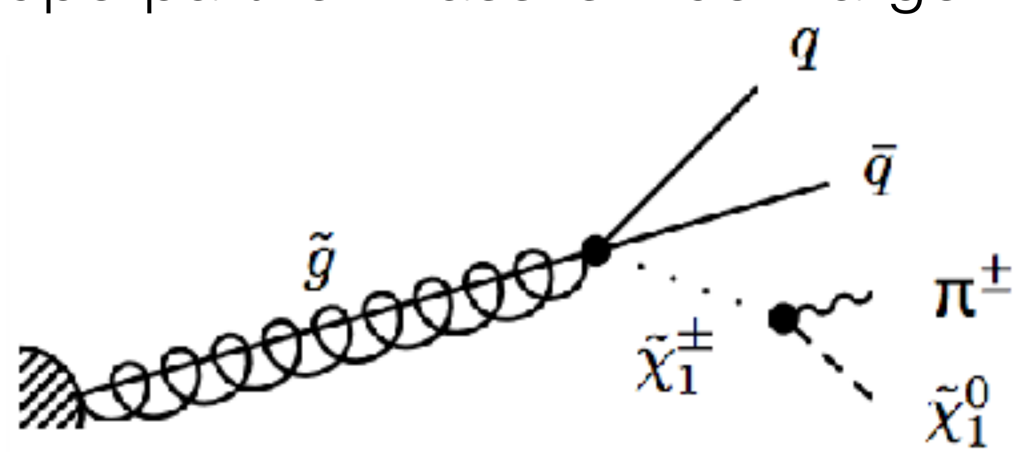






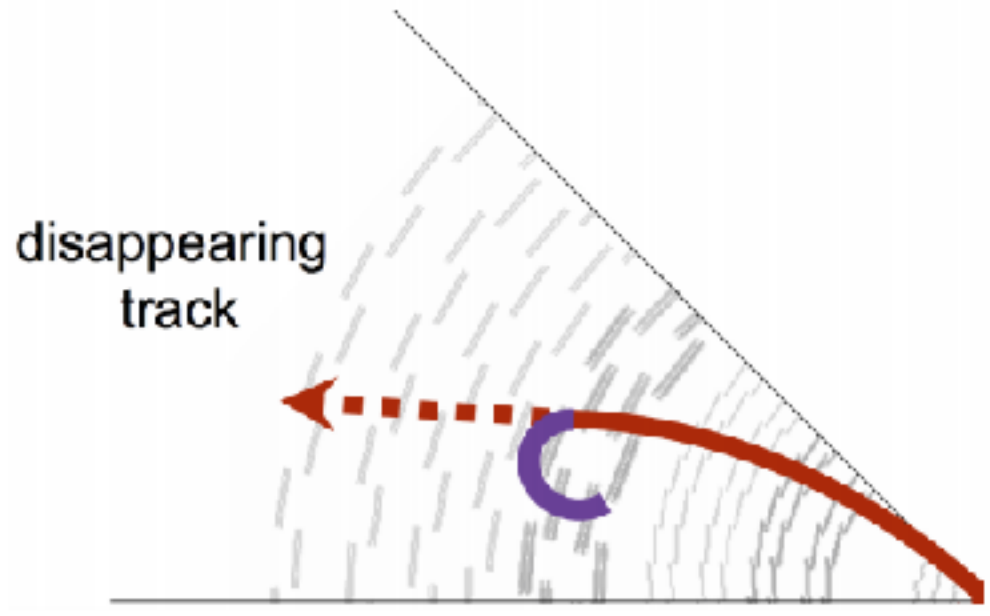
Jets + M_{T2}+ Disappearing Tracks Intro

- Inclusive M_{T2} search has limited sensitivity to compressed signal models due to worse signal acceptance and larger SM backgrounds.
- To push exclusion curves further, need to be “clever”.
- Perhaps gluinos and squarks decay first to an intermediate chargino, not directly to LSP neutralino.
- If the chargino-neutralino mass splitting is ~100’s MeV, chargino decay length of ~10’s cm is possible.
    - Chargino decays inside the tracker.
    - SM daughter is too soft to be reconstructed as a track, so the chargino track disappears.
- Disappearing track selection can suppress background by as much as 10,000x.
- Classic M_{T2} is already signal dominated if the colored superpartner mass is much larger than the LSP mass, but not in compressed scenarios



Searches Jets + M_{T2}+ Disappearing Tracks

- Long lifetimes tend to occur in compressed scenarios (near-degenerate masses)
- $\Delta m(\tilde{\chi}_1^\pm, \tilde{\chi}_1^0)$ ~ 100 MeV, $c\tau(\tilde{\chi}_1^\pm)$ ~50cm
- Backgrounds: fake tracks, misreconstructed charged pions, misreconstructed leptons
  - Fake rate applied to short track ST “candidates” (relaxed quality and isolation requirement)

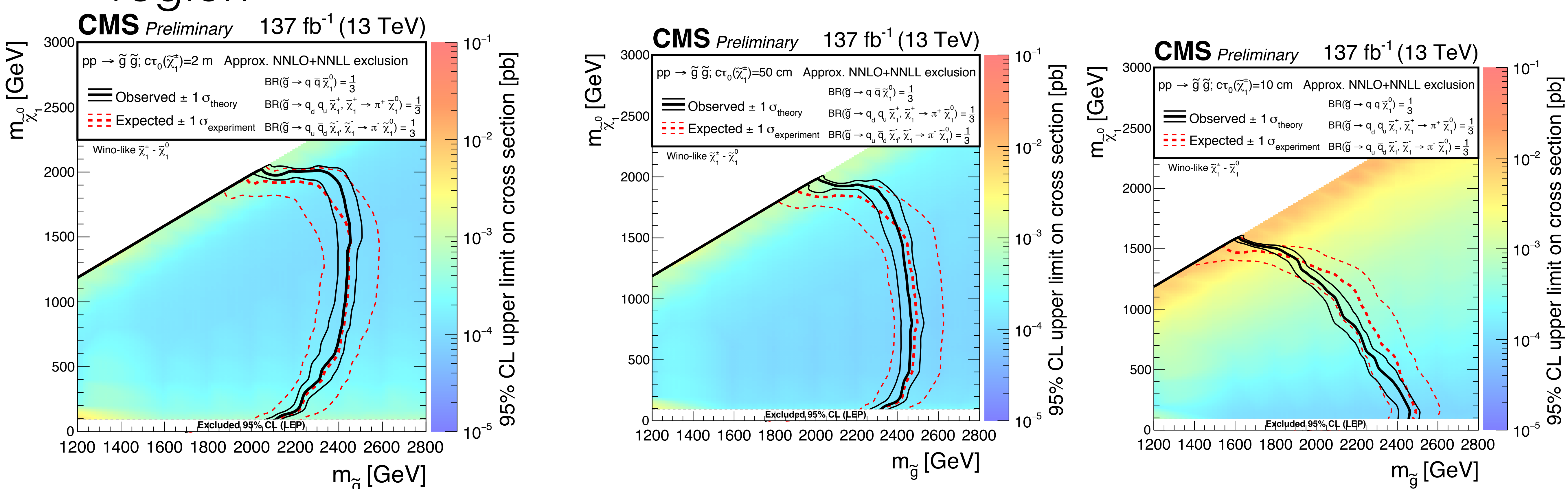


Jets + M_{T2}+ Disapp. Tracks Results

- Event Selection: ≥2 jets, M_{T2}>200 GeV ,at least one ST
- Bin in Nj, HT, ST length, p^{ST}_T
  - 68 search region

cτ [cm]	Gluino Limit	LSP Limit
10	2450	1600
50	2400	1900
200	2400	1900

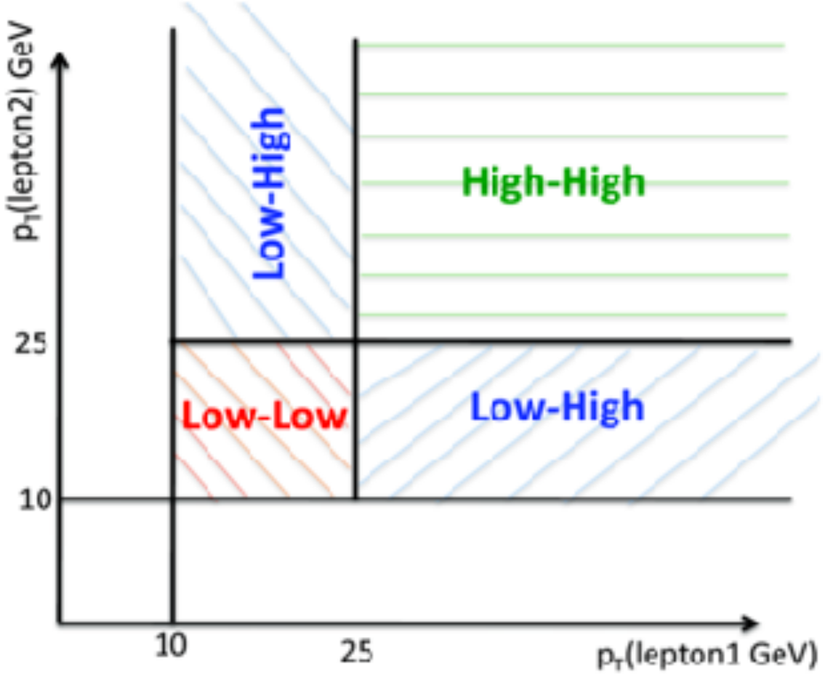
- Exclusion: $m_{\tilde{g}}$<2.46 TeV and $m_{\tilde{\chi}^0_1}$<2.0 TeV
  - Increases the exclusion by 210 GeV and 525 GeV in compressed region

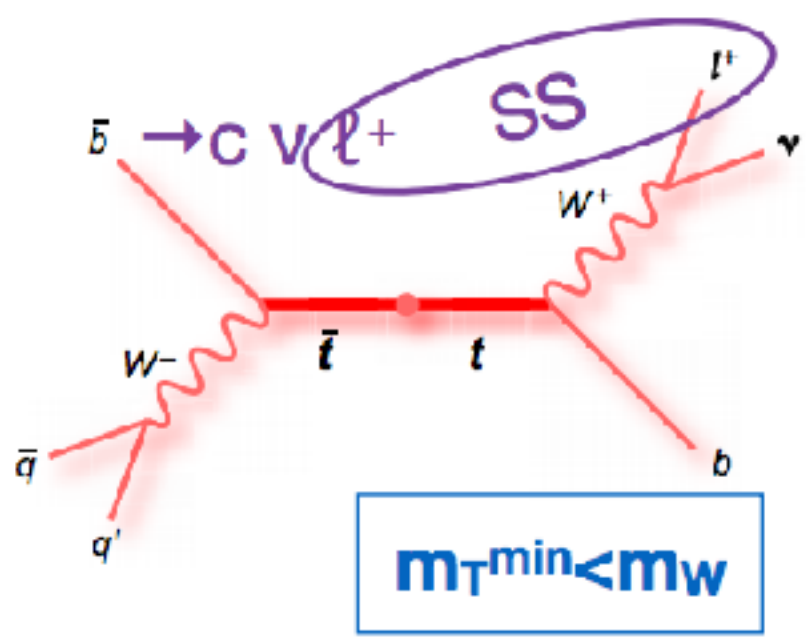


CMS-PAS-SUS-19-005

2L SS + ≥3L Search

- Preliminary full Run2 analysis based on strategies from two published 2016 analyses
- SUS-16-035/EPJC 77 (2017) 578
- SUS-16-041/JHEP 02 (2018) 067
- Baseline selection of 2 SS leptons (or 3+) and at least 2 jets
- SS signature virtually eliminates QCD, W, Z, $t\bar{t}$ processes
- Main backgrounds then come from
  - Fake/non-prompt leptons from $t\bar{t}$, W+jets (data-driven "tight-to-loose" method)
  - Also suppress with m_T^{min} variable
  - Charge misid. (data-driven)
  - Rare SM processes: WZ, ttV, X+, …
- Then perform a multidimensional binning in N(b)jets, MET, H_T, m_T^{min}, …



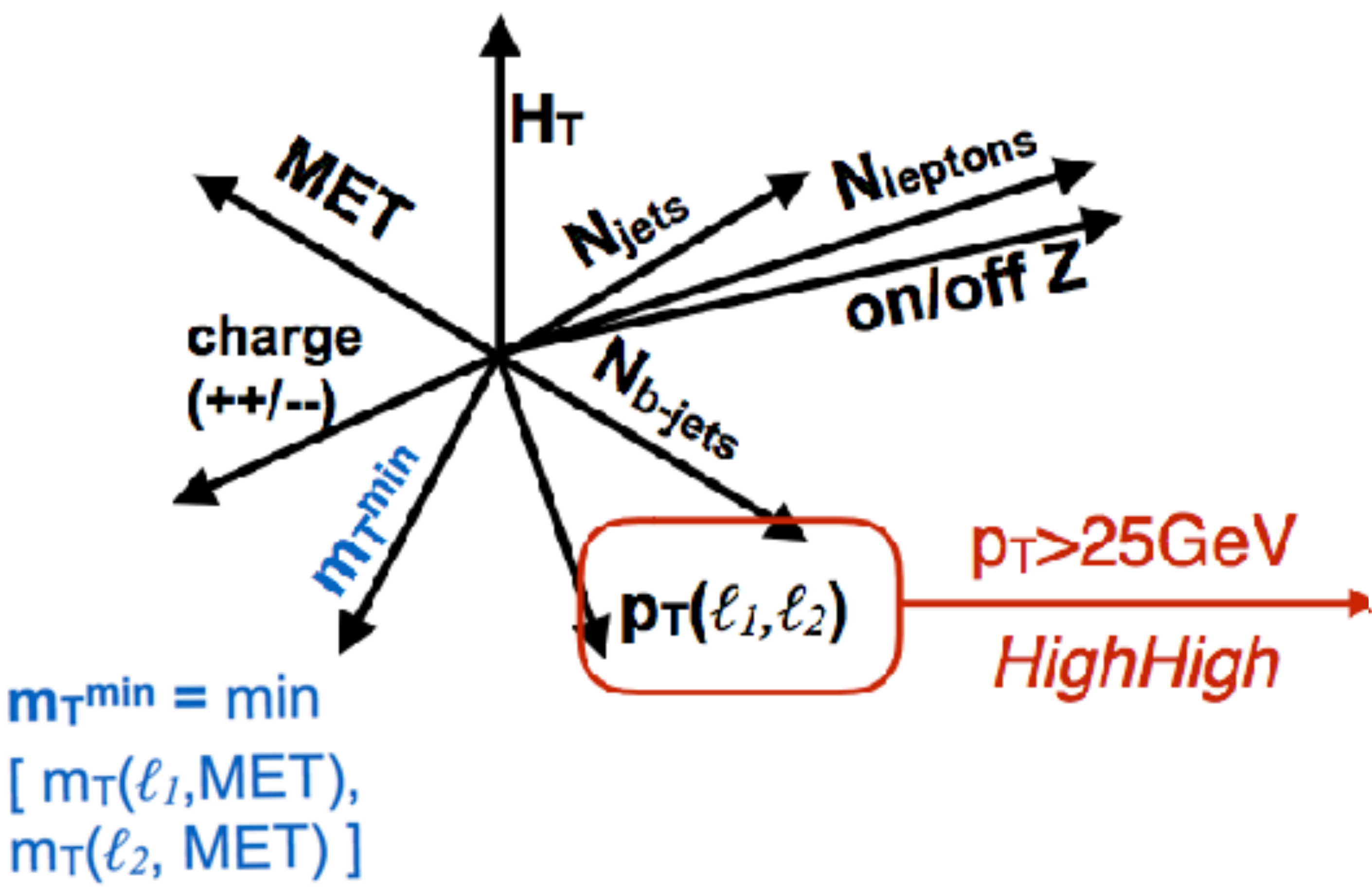


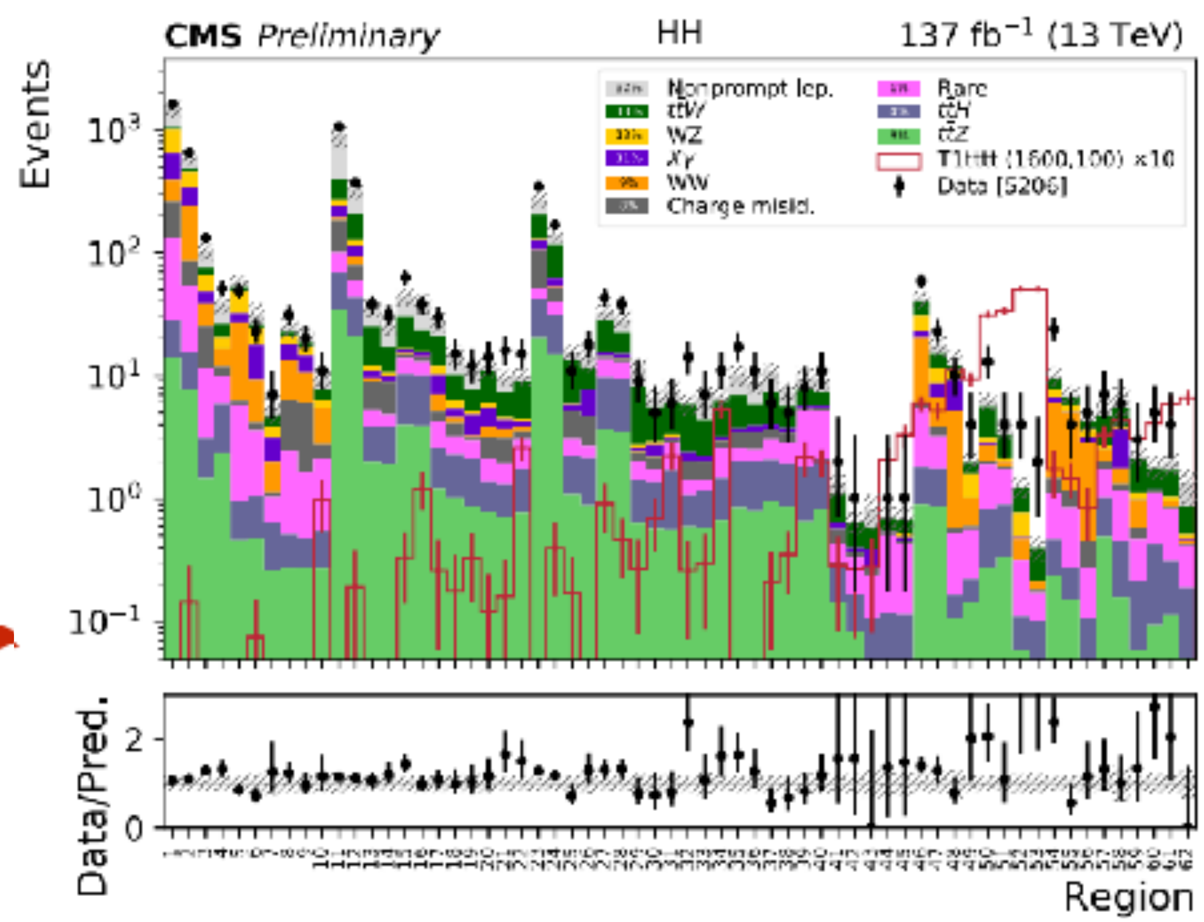
Production of same-sign (SS) and multilepton events is rare in the SM

CMS-PAS-SUS-19-008

2L SS + ≥3L

- Group 168 total signal regions into 5 categories (HighHigh, HighLow, LowLow, MultiLepton, LowMET) → sensitive to particular topologies
- Observe data/MC agreement in combined fit over all signal regions, so set upper limits on simplified models

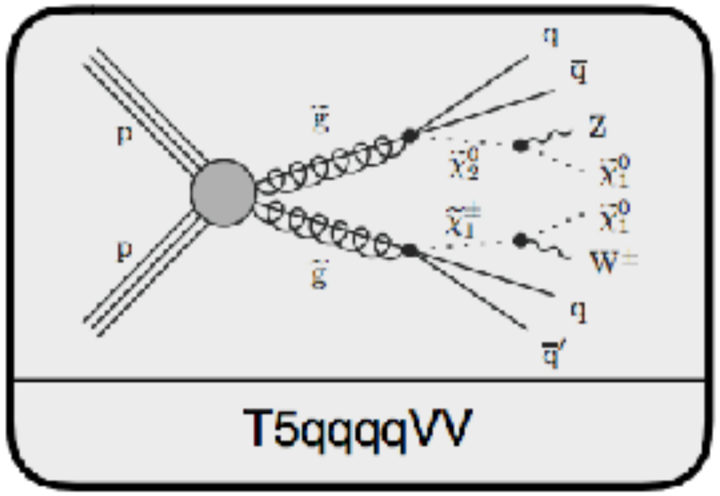


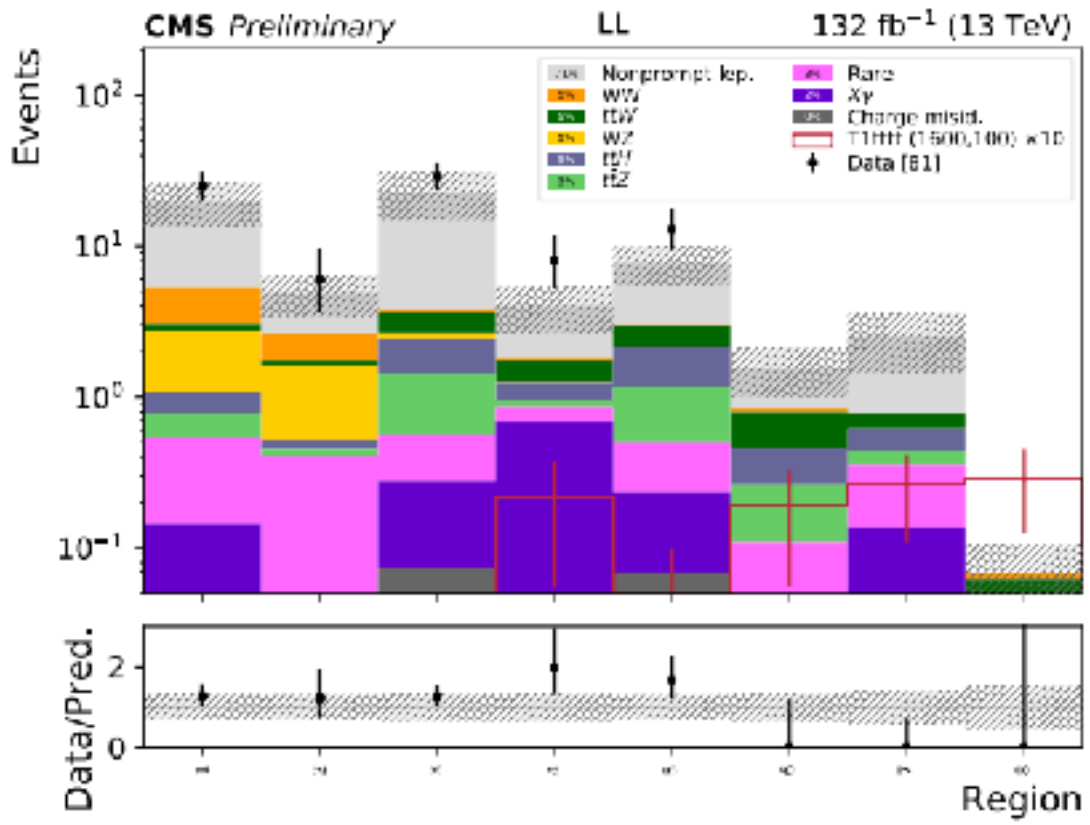


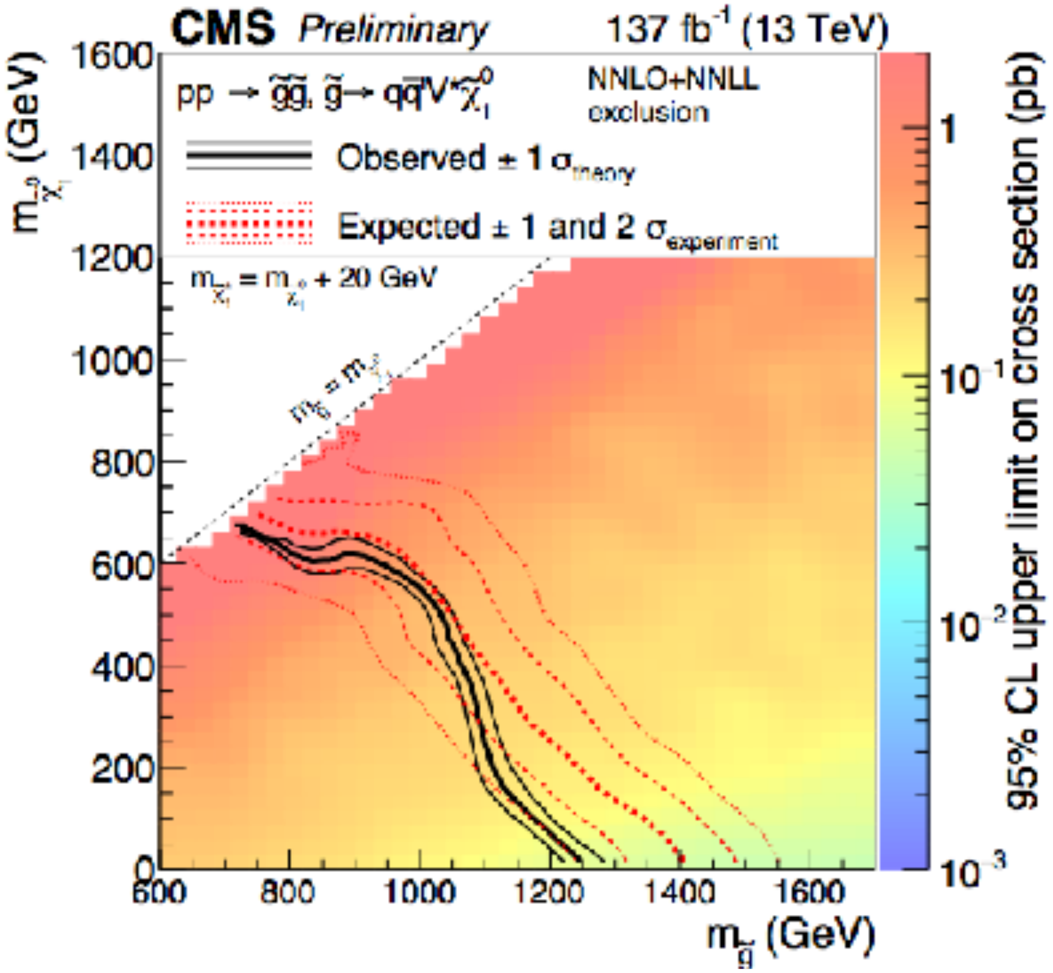
CMS-PAS-SUS-19-008

2L SS + ≥3L Results

- LowLow category for leptons with 10/15 < p_T< 25 GeV provides sensitivity to soft leptons from small mass splittings
- Exclude gluinos up to 1.25TeV in the T5qqqqVV model
- Chargino mass: halfway in between gluino and LSP mass, or here 20GeV higher than LSP mass



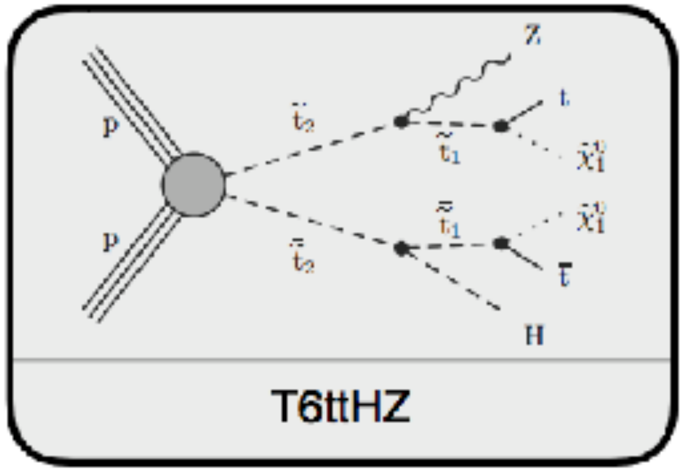


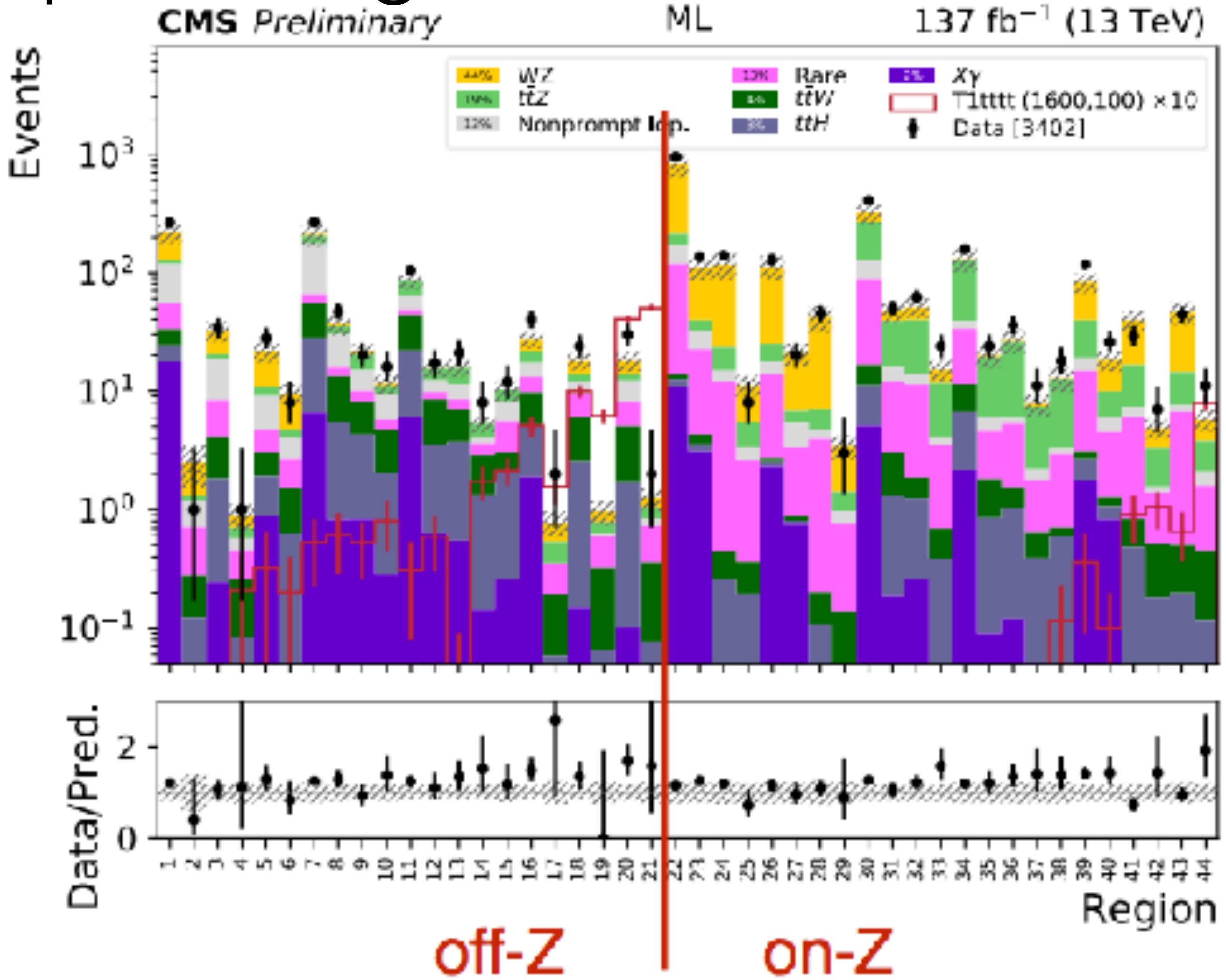


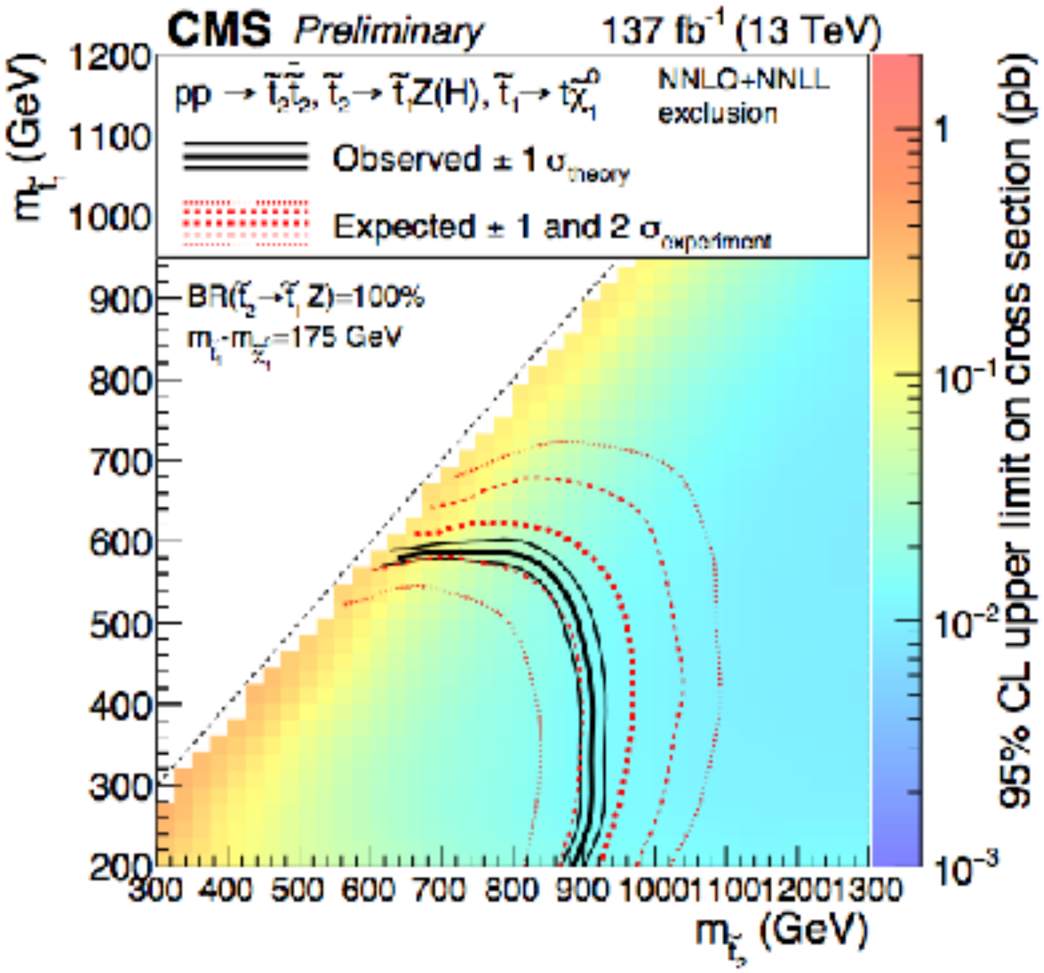
CMS-PAS-SUS-19-008

2L SS + ≥3L Results

- MultiLepton category contains both on-Z and off-Z requirements
- Exclusions reaching 900GeV for decays of second generation stop squarks providing H or Z bosons



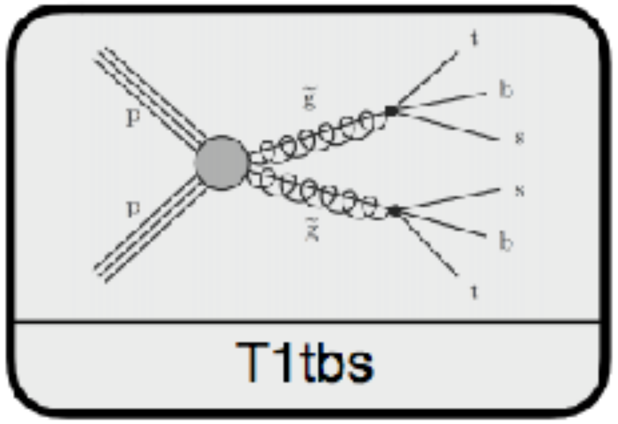


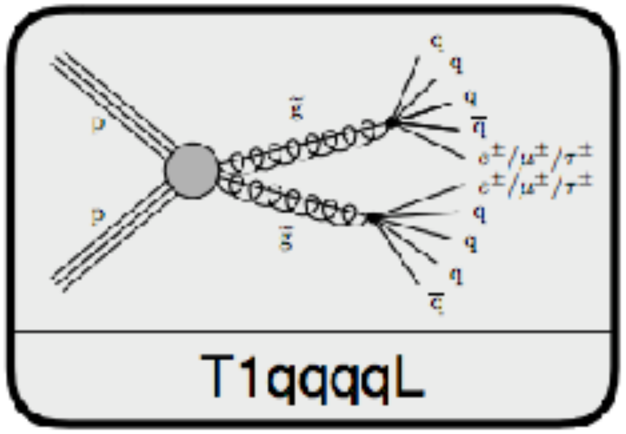


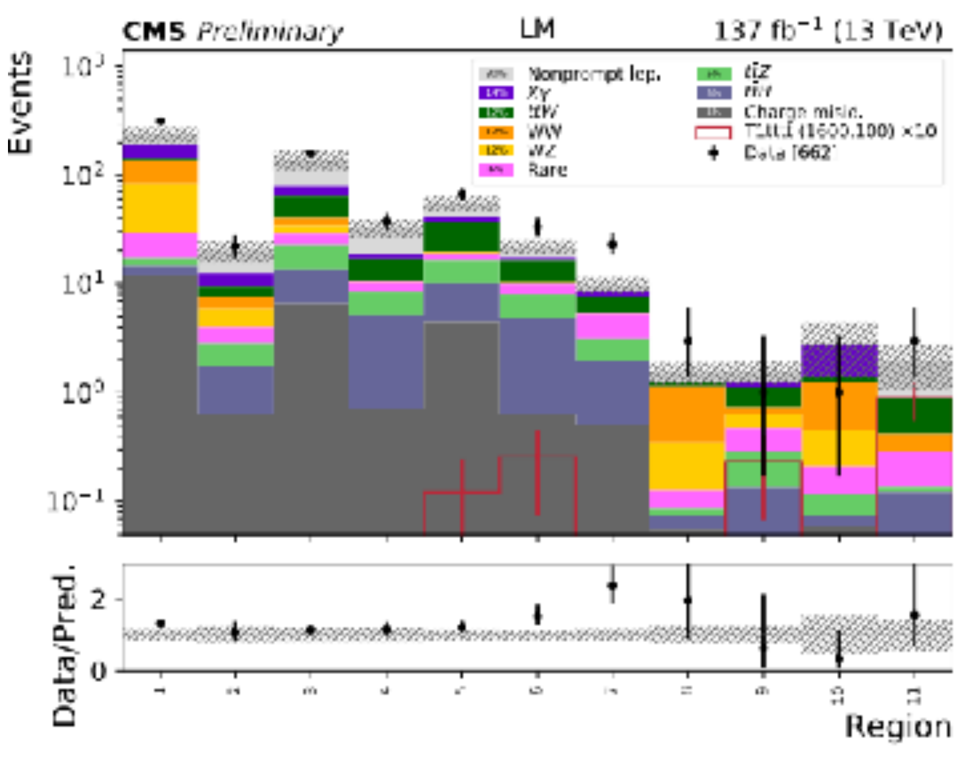
CMS-PAS-SUS-19-008

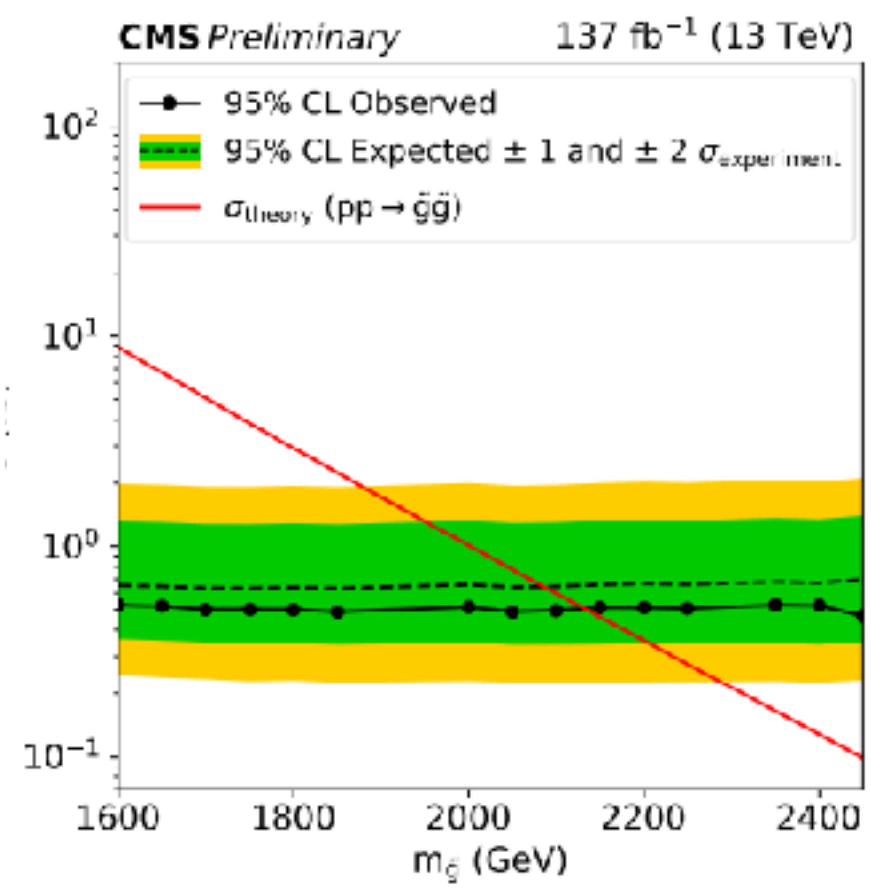
2L SS + ≥3L Results LowMET

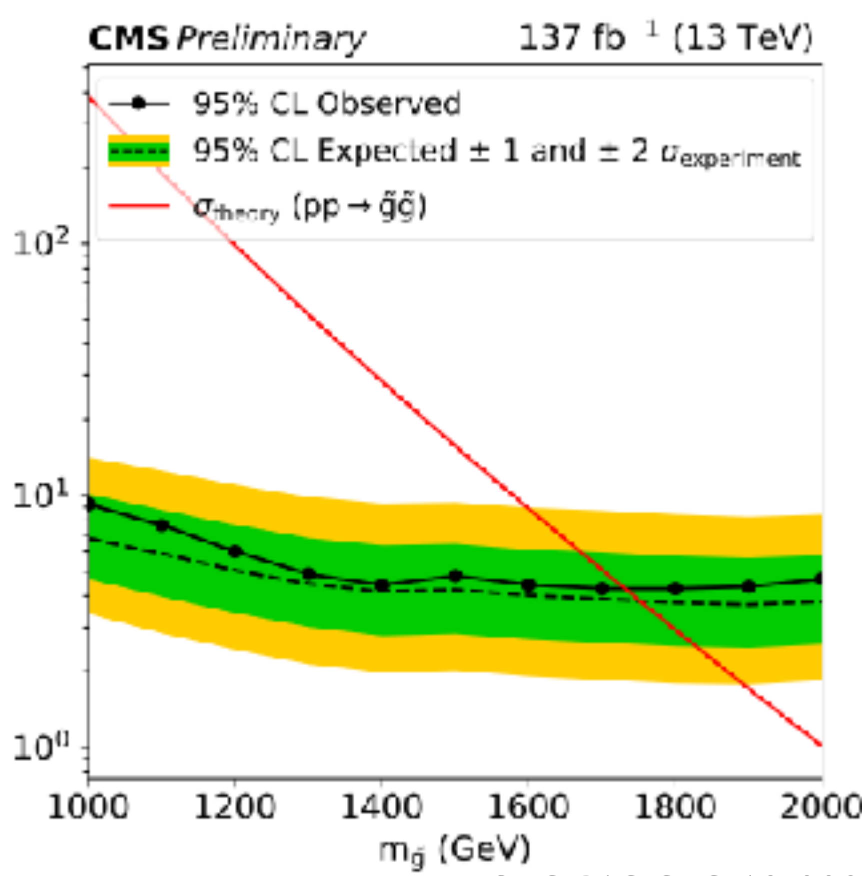
- LowMET category — relaxed MET requirements thanks to the SS signature
- Exclusions on RPV models
- T1tbs — 1.7 TeV
- T1qqqqL — 2.1TeV







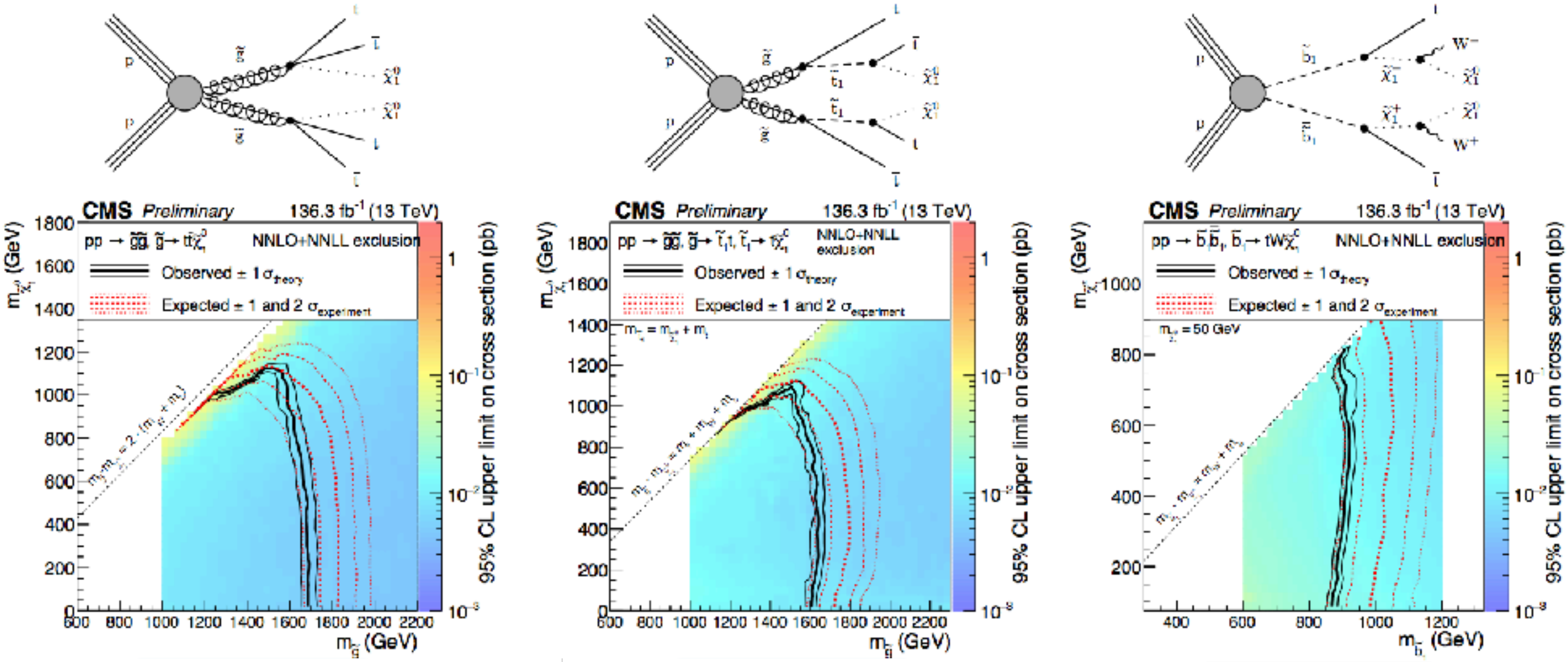




CMS-PAS-SUS-19-008

2L SS + ≥3L Results Gluino/Sbottoms

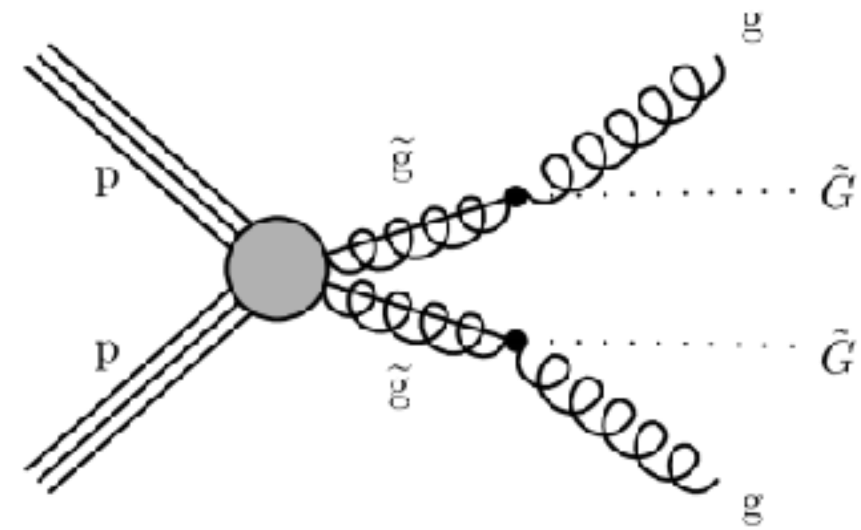
- Gluino pair production models with four top quark final states, T1tttt (left) and T5tttt (center) exclude gluinos up to ~1650 GeV
- Sbottom squark production model T6ttWW (right) excludes sbottom masses up to 900 GeV

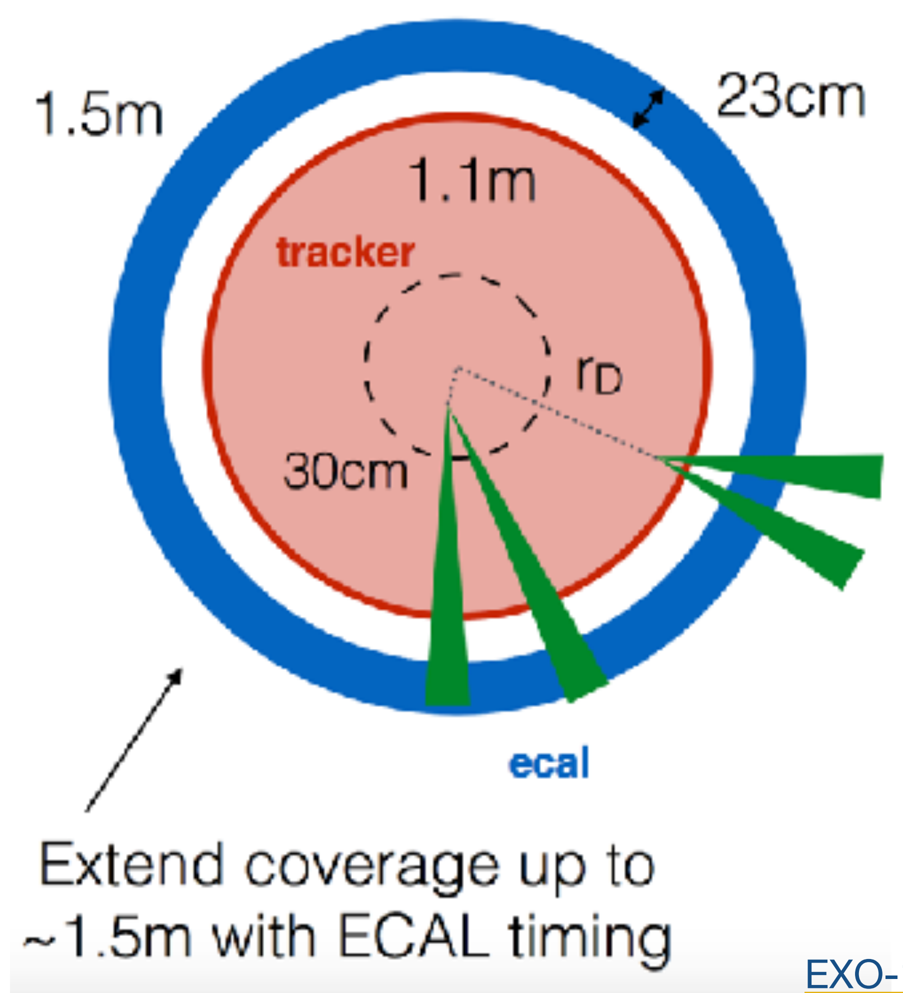


Search For Delayed Jets

- Long-lived gluinos can traverse macroscopic distances before decaying to a jet and LSP
  - Signature: p_T^{miss} and a jet with delayed ECal hits
  - Background is dominated by beam halo, comics and satellite bunches
- Selection: p_T^{miss} >300 GeV && t_{jet} > 3ns && cleaning cuts
  - Nearly background free:

Background	Prediction
Beam halo	$0.02^{+0.06}_{-0.02}$ (stat) $^{+0.05}_{-0.01}$ (syst)
Core and satellite bunches	$0.11^{+0.09}_{-0.05}$ (stat) $^{+0.02}_{-0.02}$ (syst)
Cosmics	$1.0^{+1.8}_{-1.0}$ (stat) $^{+1.8}_{-1.0}$ (syst)

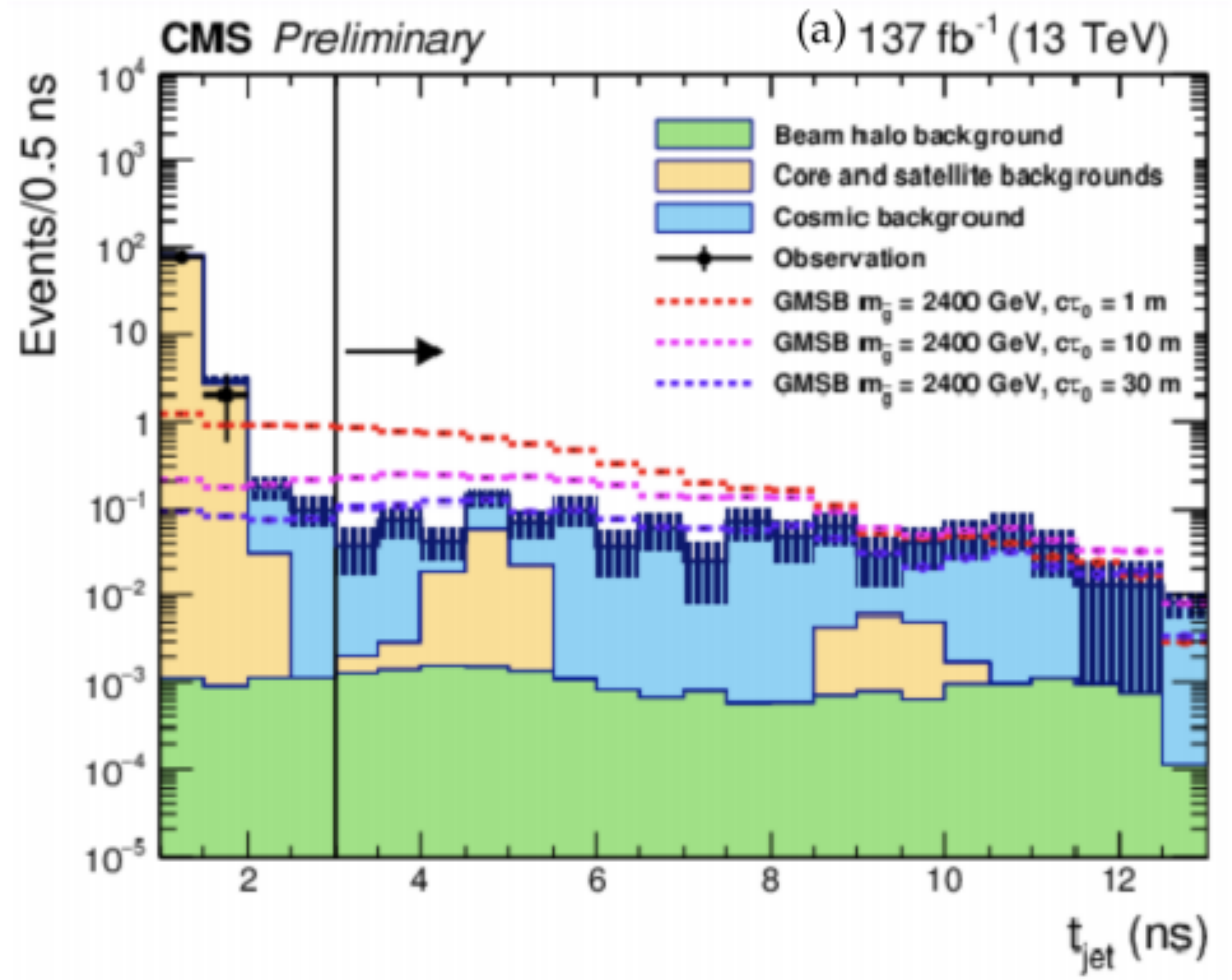




EXO-19-001

Search For Delayed Jets Background

- Three dominant background sources predicted independently
  - Beam halo, satellite bunches, cosmic muons
- Use ABCD method defined with cleaning variables targeted for each background
- Predictions tested using validation regions with closure used to define systematic uncertainty on the signal region predictions

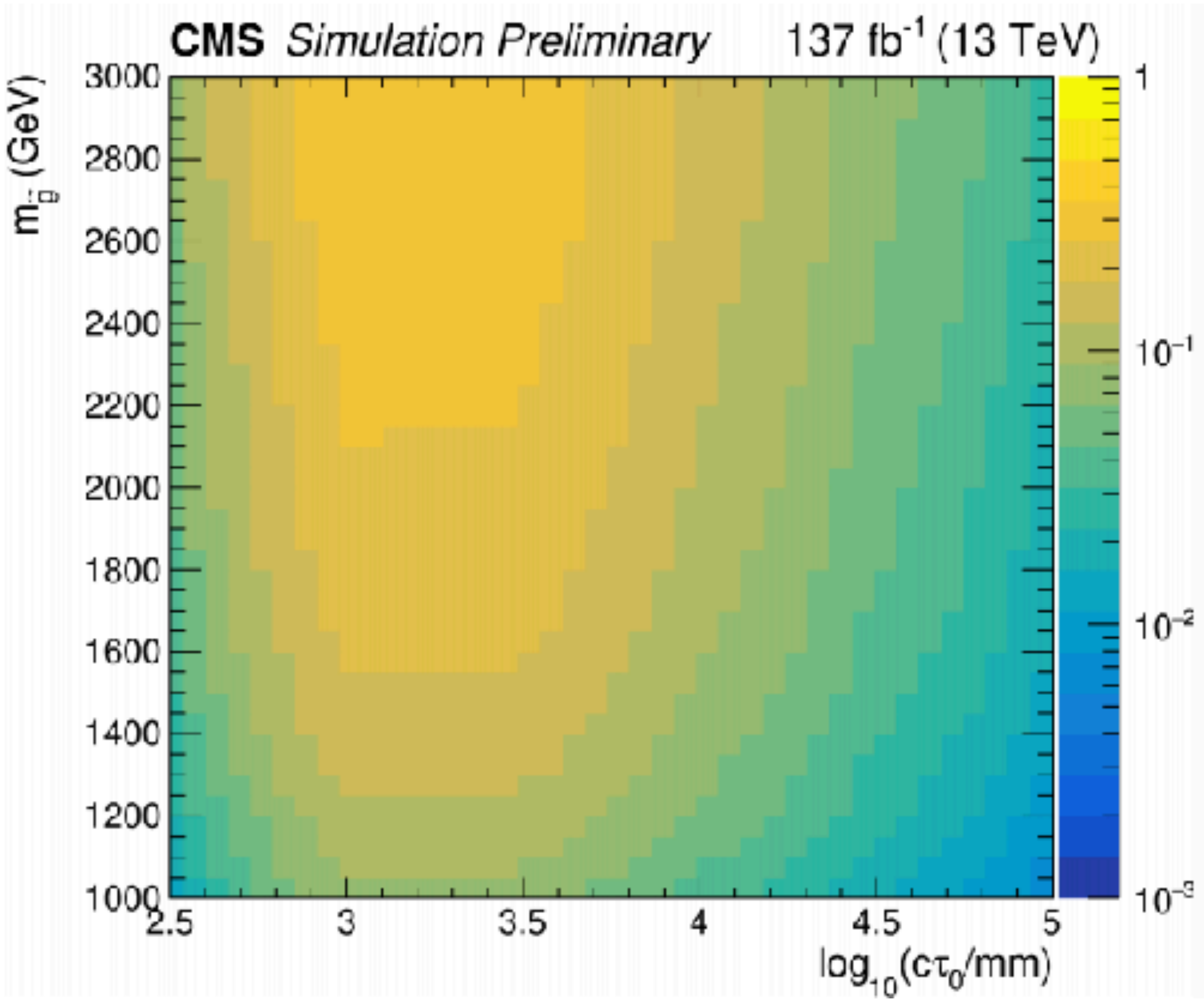


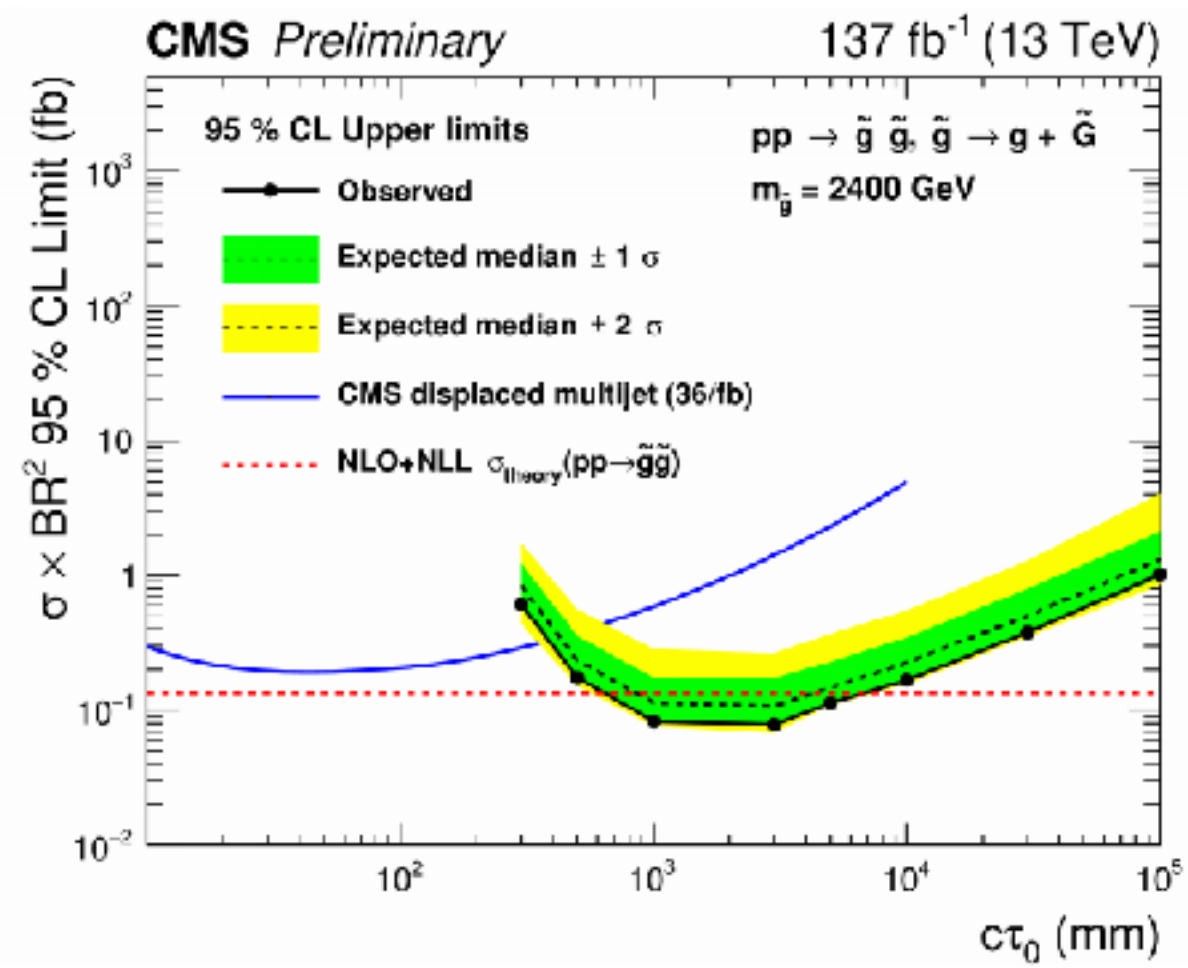
EXO-19-001

Search For Delayed Jets

Signal efficiency largest $c\tau_0$ proper decay length for $1 < c\tau_0 < 10$ m

Sensitivity complements existing displaced jet searches





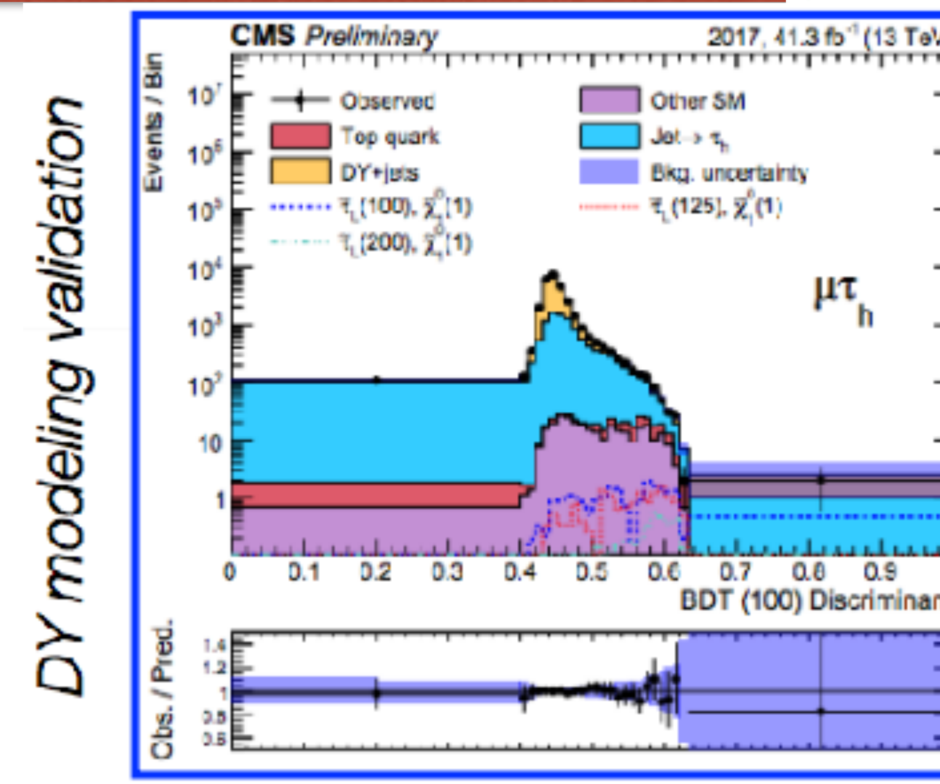
gluino masses below 2100 GeV is excluded for decay lengths of ctau between 0.3 and 30 m

EXO-19-001

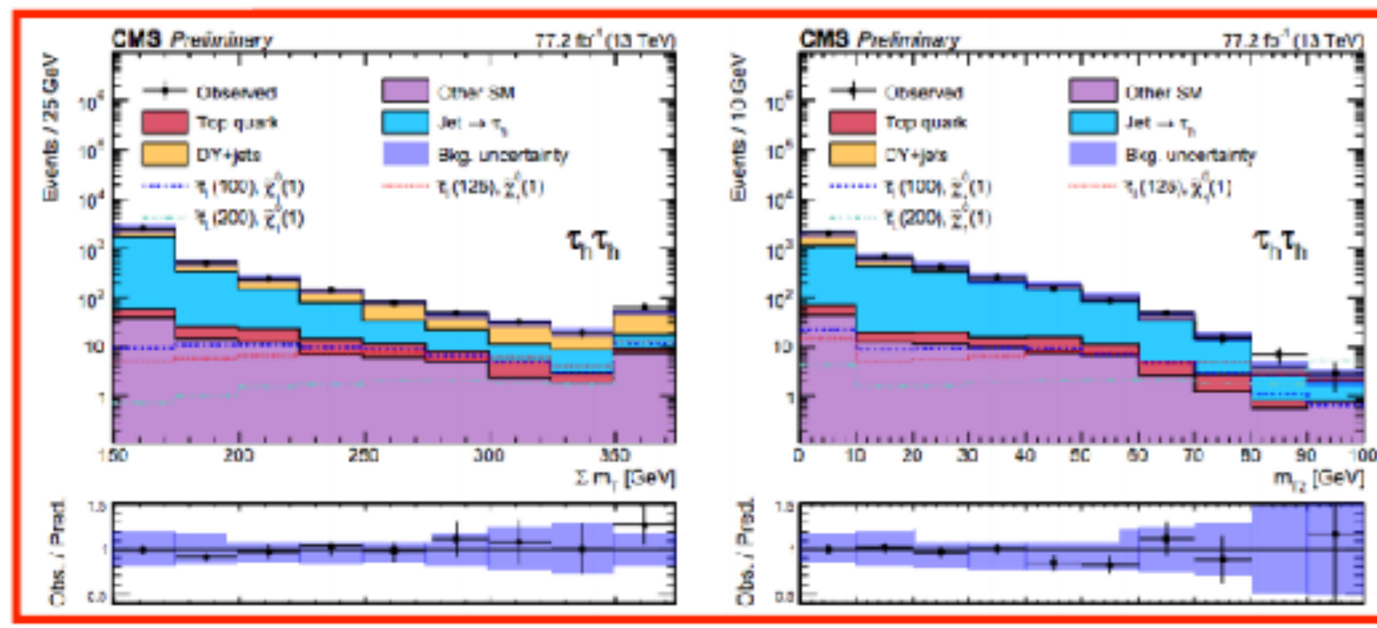
Pair production of staus

- Combination of searches for stau pair production with $l\tau_h$, and $\tau_h\tau_h$ final states (l=e,μ)
- Significant contributions from fakes
    - minimized with new deep learning-based τ reconstruction
- Events categorized by:
    - $l\,\tau_h$: custom BDT
    - $\tau_h\tau_h$: m_T (for each τ_h and p_T^{miss}) M_{T2}, and Njets

CMS-SUS-18-006

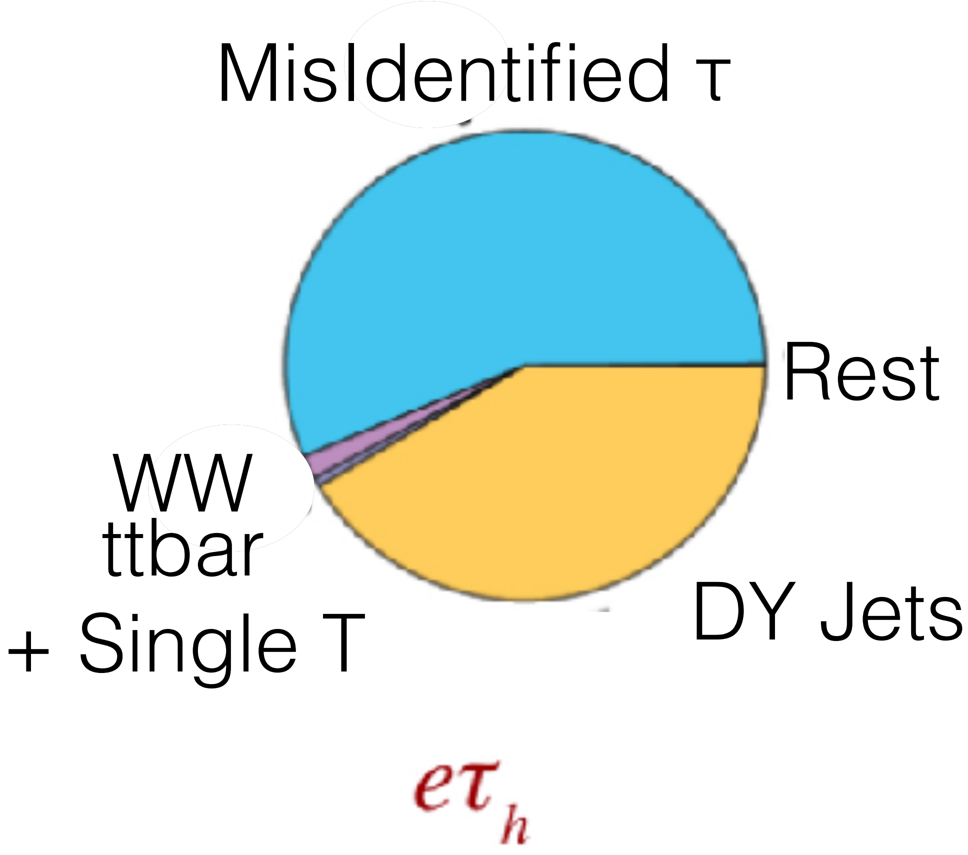


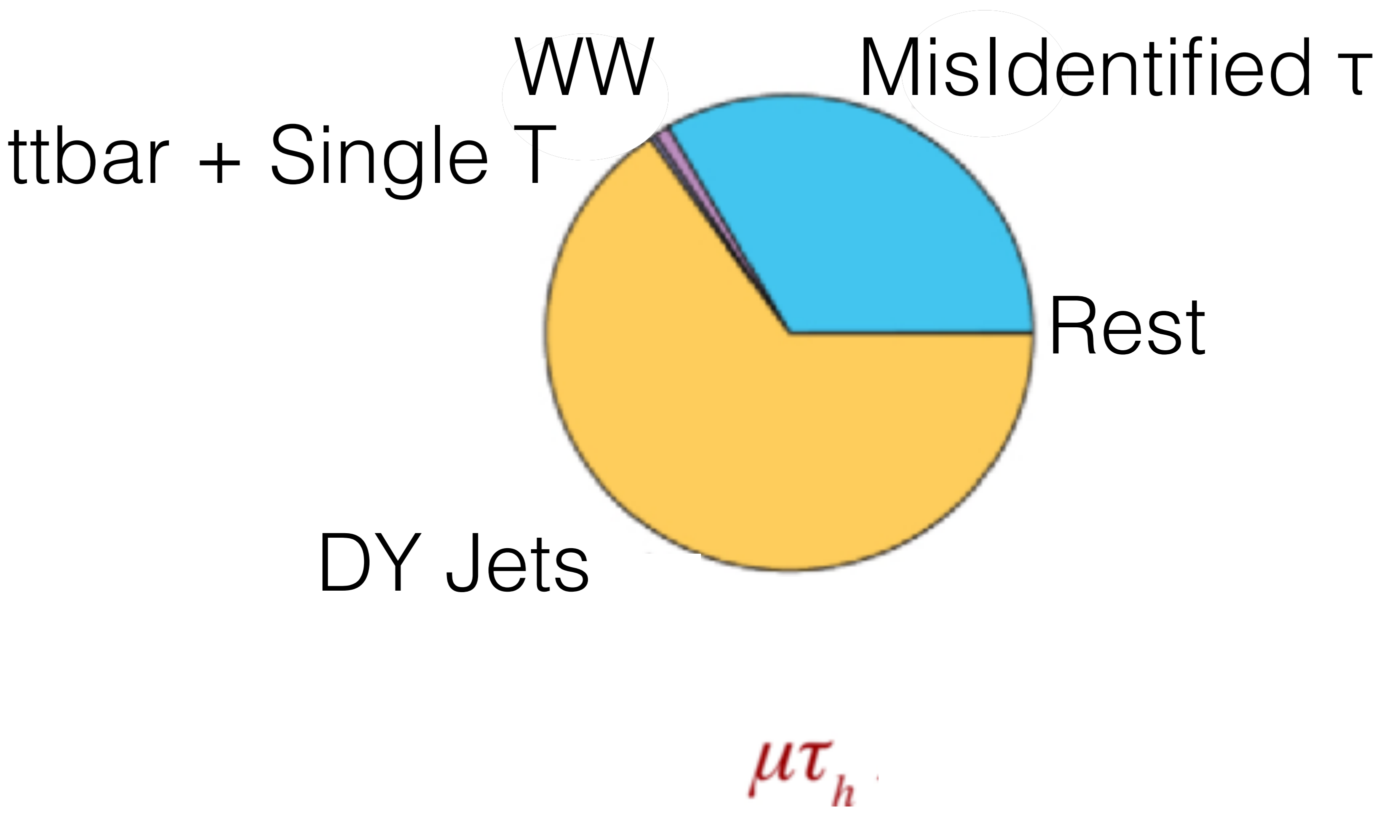
m_{T2} [GeV]	> 50						25–50					
Σm_T [GeV]	> 300		250–300		200–250		> 300		250–300		200–250	
N_j	0	≥ 1	0	≥ 1	0	≥ 1	0	≥ 1	0	≥ 1	0	≥ 1



Pair Production of Staus Backgrounds

- Z+jets, and Top related backgrounds— Shape is taken from simulation and norm. from fit to CRs
- Fakes (~W+Jets) — Shape is estimated in CR and transfer factor from orthogonal CRs gives norm.
- Rare processes are taken directly from simulation



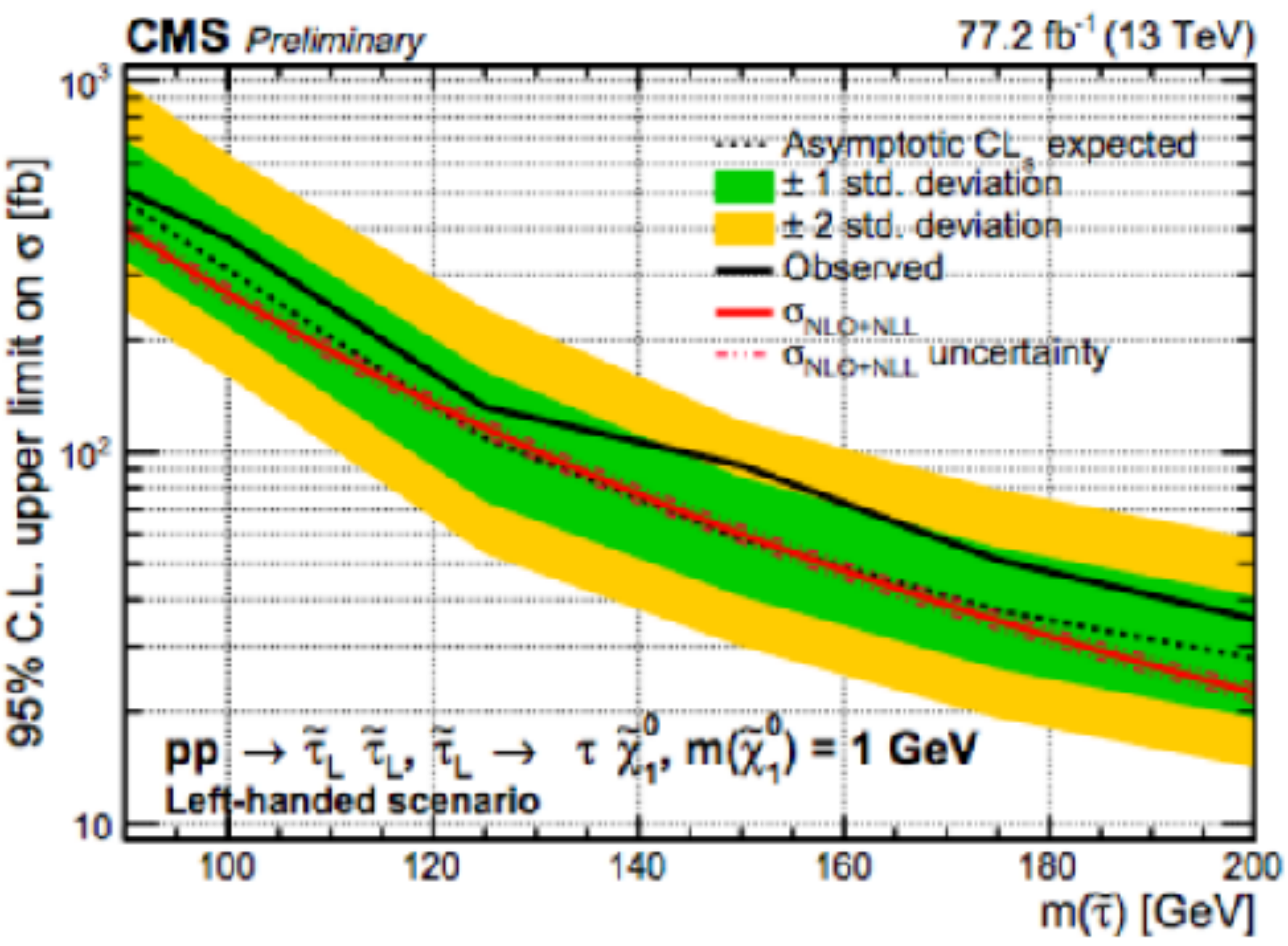


CMS-SUS-18-006

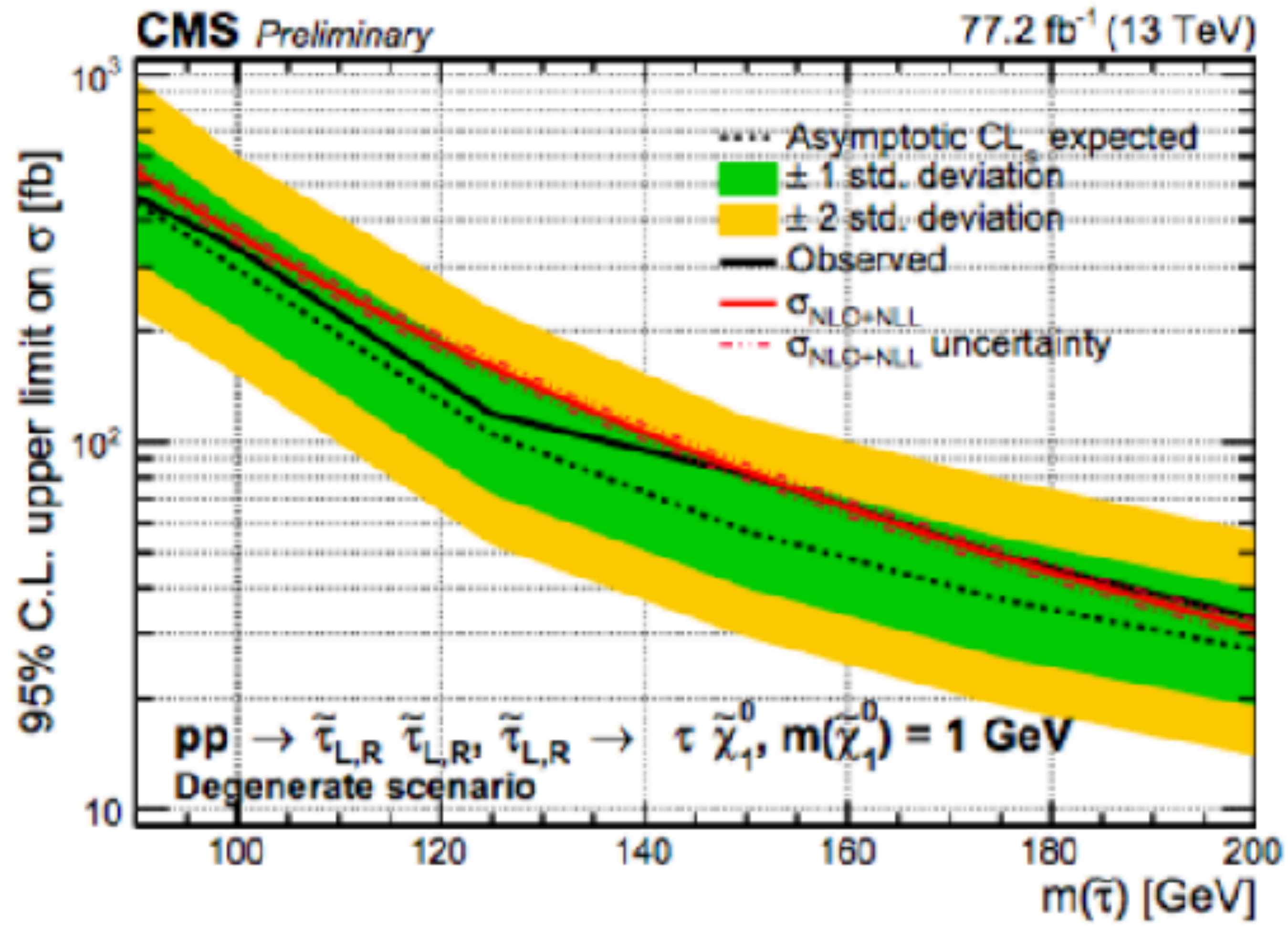
Pair production of staus

- Interpretations are done for both left-handed staus and degenerate left/right scenarios with three choices of mass $\tilde{\chi}_1^0$: 1, 10, and 20 GeV

$\sigma_{UL} < 2\sigma_{stau}$ @ 95% CL



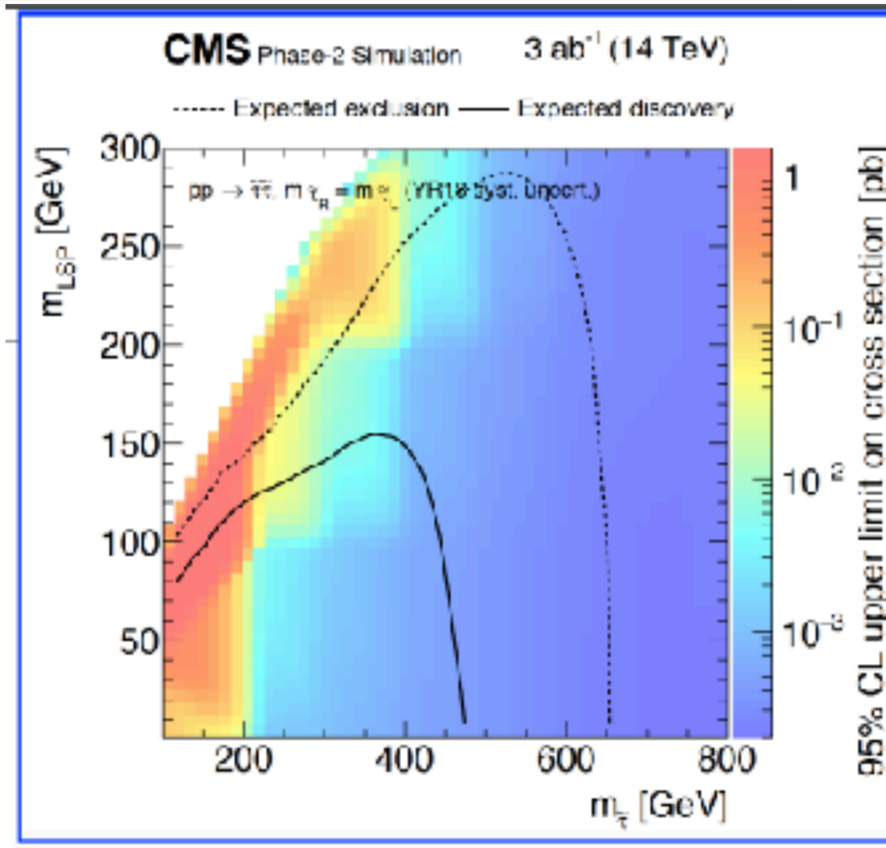
M_{stau} < 150 GeV @ 95% CL



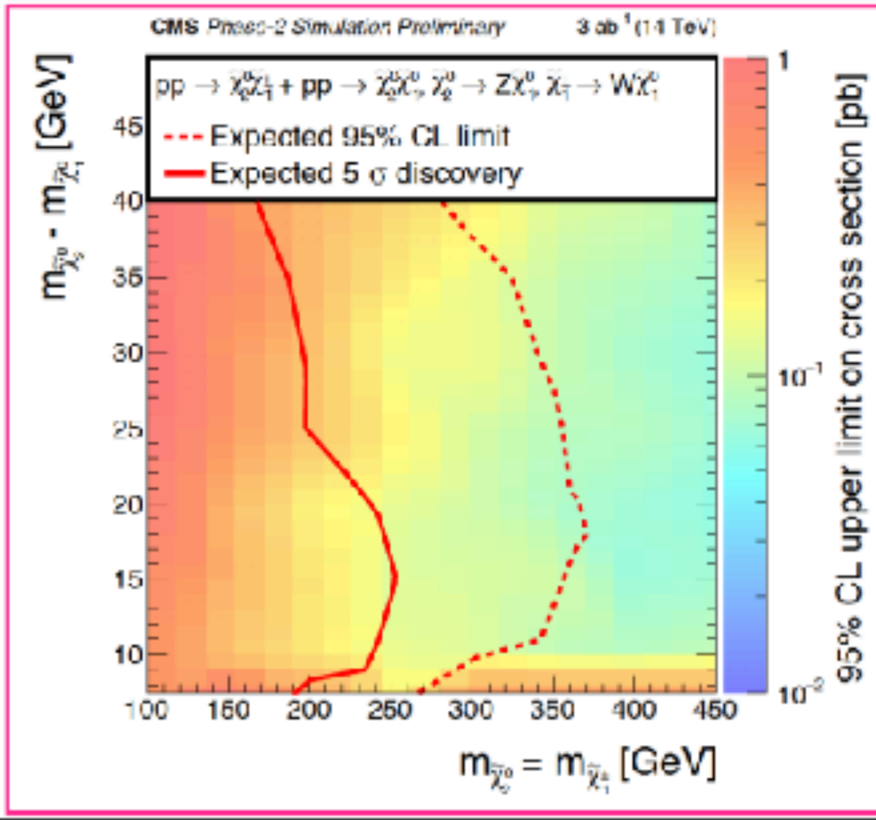
CMS-SUS-18-006

Future SUSY Searches

- Projection studies for SUSY searches with HL-LHC
- Additional luminosity will significantly improve hard to reach signatures e.g. stau pair production and compressed higgsinos with ISR & soft leptons
- See long list of HL-LHC projections here
- New detector capabilities will
  - help maintain sensitivity to signatures which are already being explored
  - Provide additional handles, e.g. calorimeter timing capabilities for constraining long lived particles



CMS-PAS-FTR-18-010



CMS-PAS-FTR-18-001

Conclusion

- The culmination of the LHC Run-2 marks the end of an era
  - Over the course of the run, CMS has seen a lot of improvement to both the detector and algorithms being employed
  - 137 fb^{-1} dataset offers a wealth of opportunities for exploration
    - Many results are not yet finalized, but in the pipeline and will become public throughout the remainder of the year
  - Existing searches show no evidence of new physics, but continue to constrain popular SUSY signatures (extensions of up to ~200 GeV are found)
- New ideas & techniques are helping to open new avenues for constraining SUSY parameter space
- Beyond Run-2, there is the potential for 14 TeV collisions in Run-3 and a new frontier in the HL-LHC!

Backup

Recap of and new results with 36 fb^{-1}

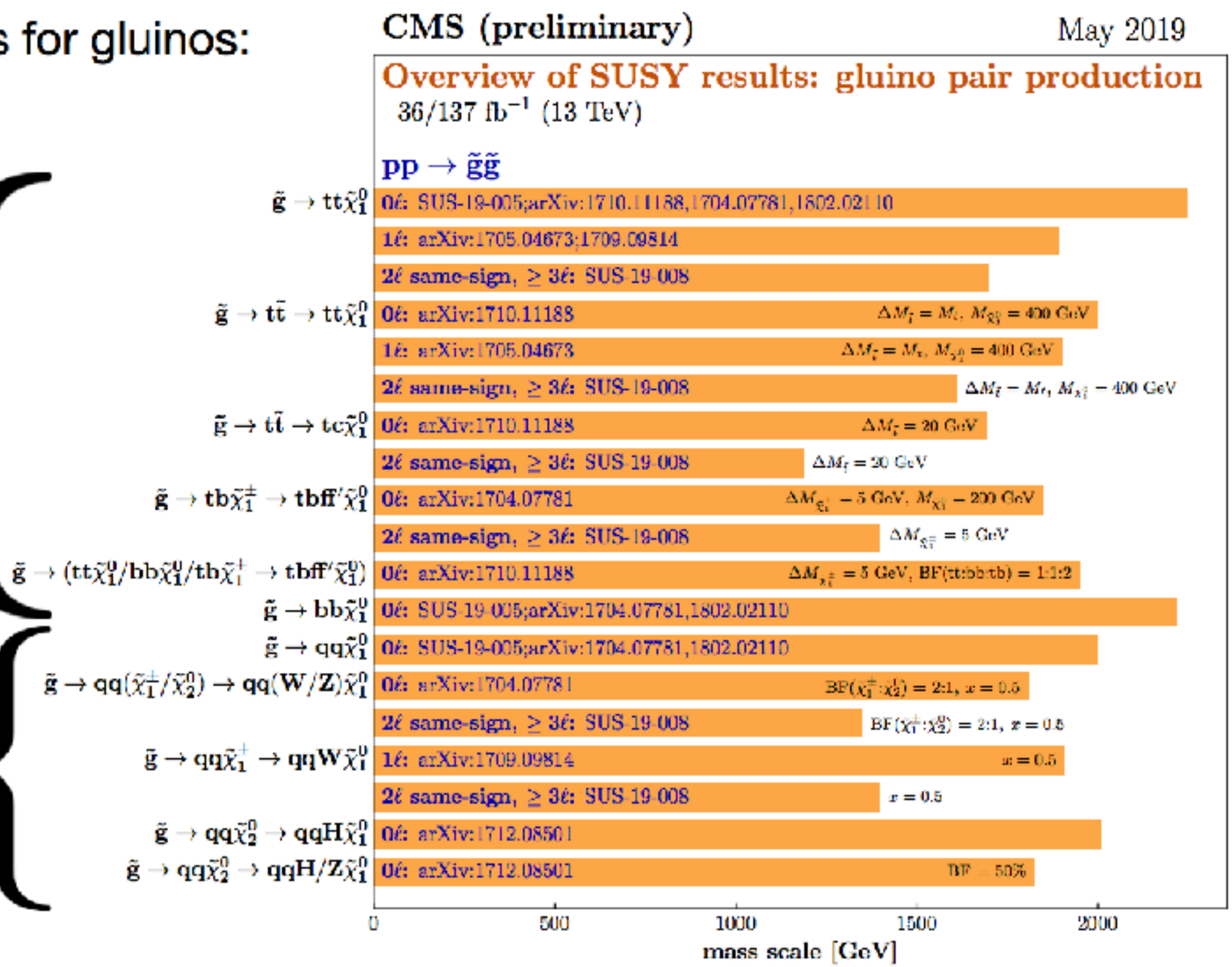
Searches for gluinos

Searches for gluinos:

Summary of results

top/bottom quark final states

light-flavor quark final states



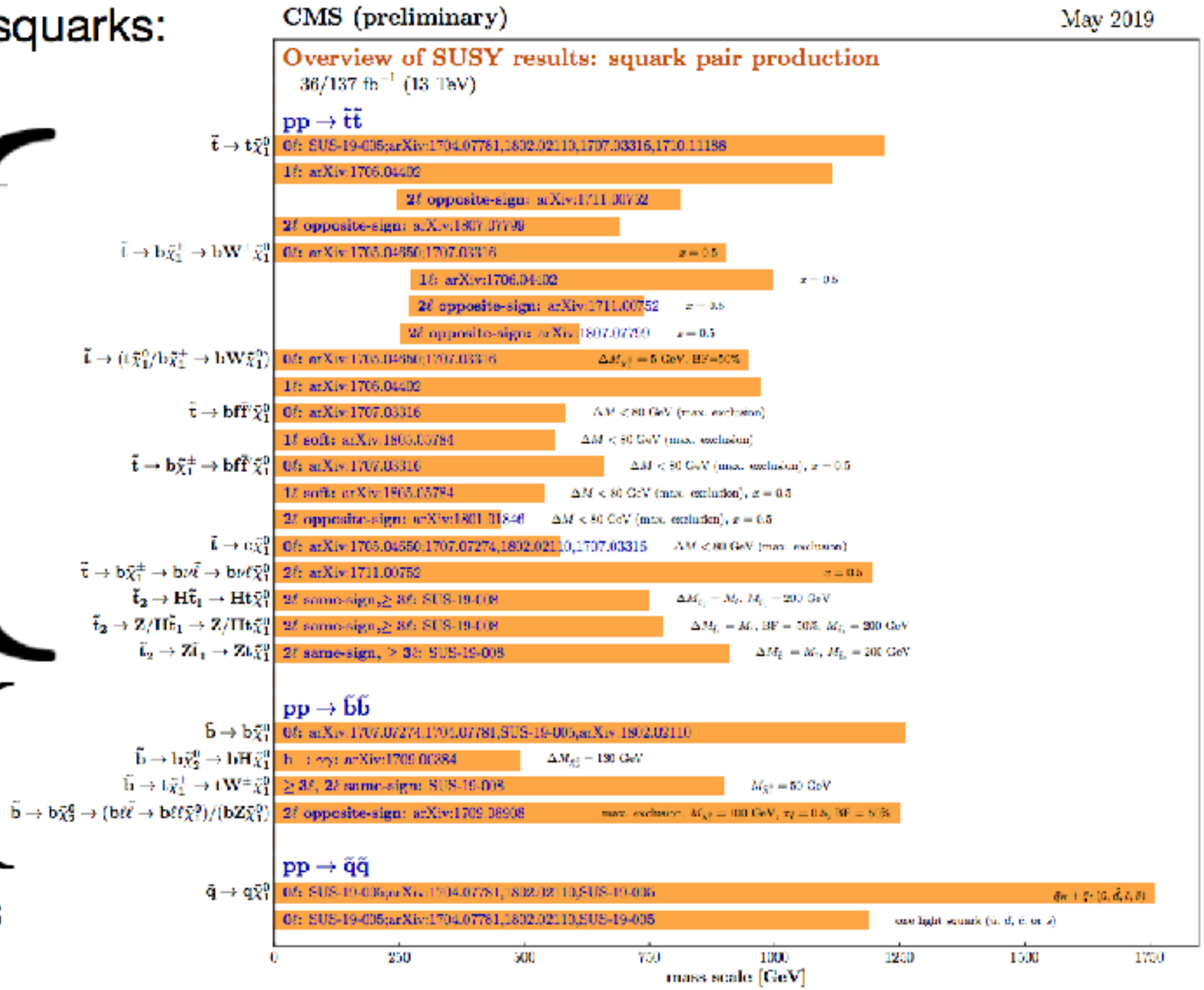
Searches for squarks:

Summary of results

stops

sbottoms

light-flavor squarks

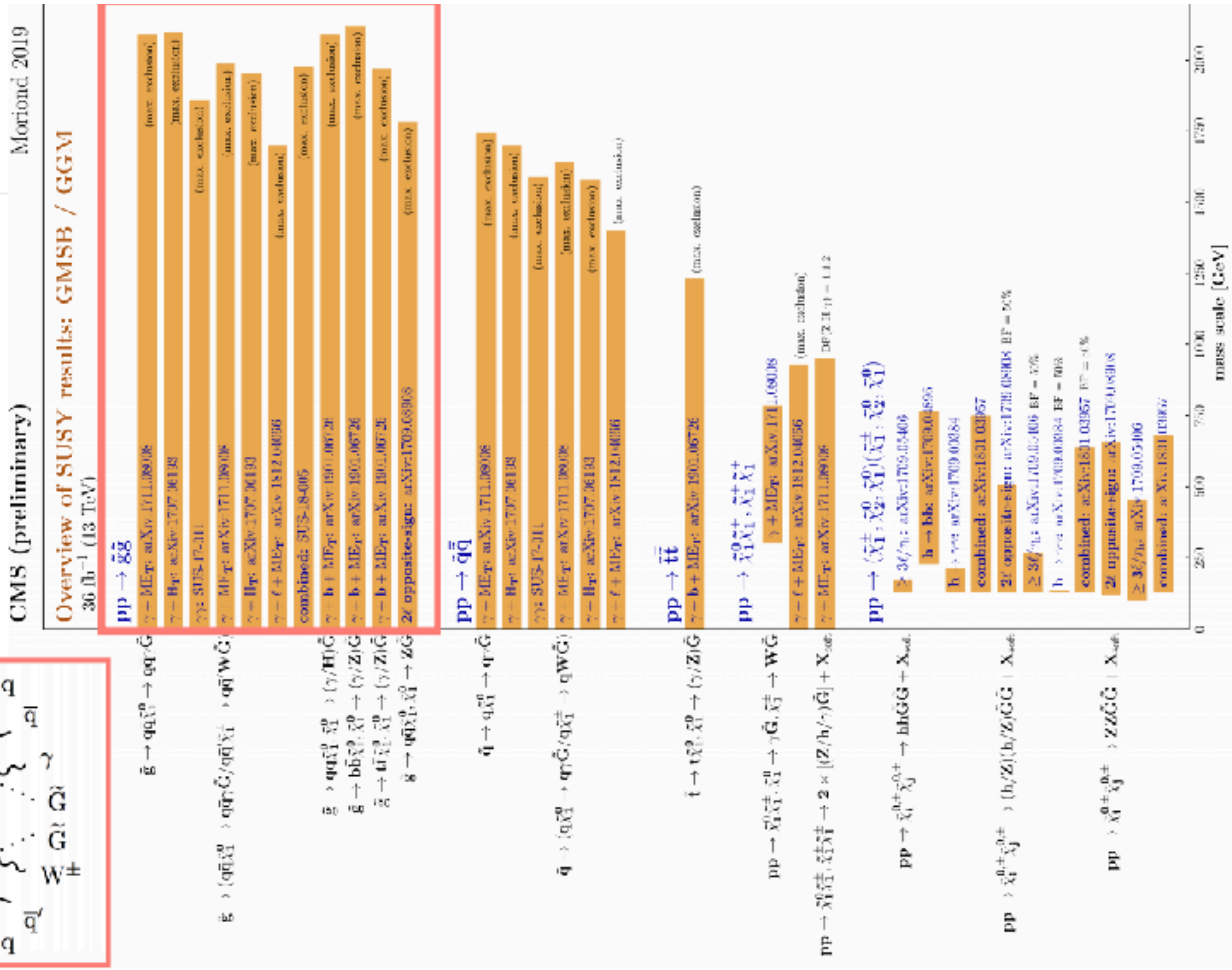


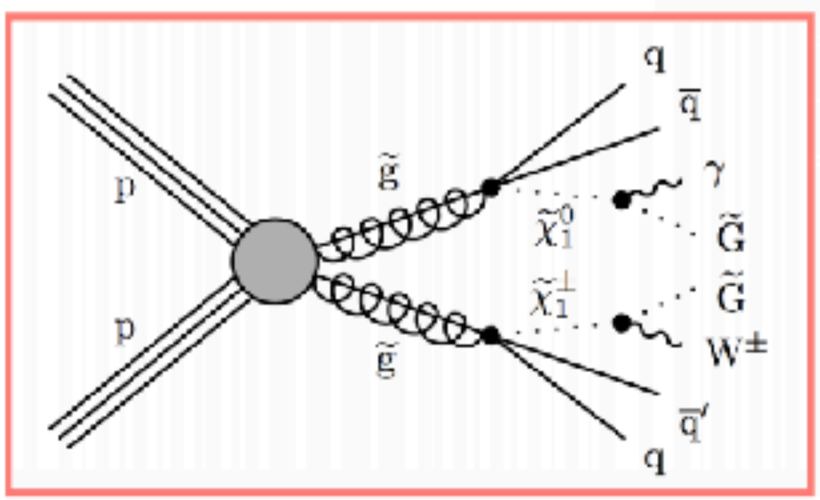
Gauge-Mediated

Review of 2016 results

Gauge-mediated

Inspired models:



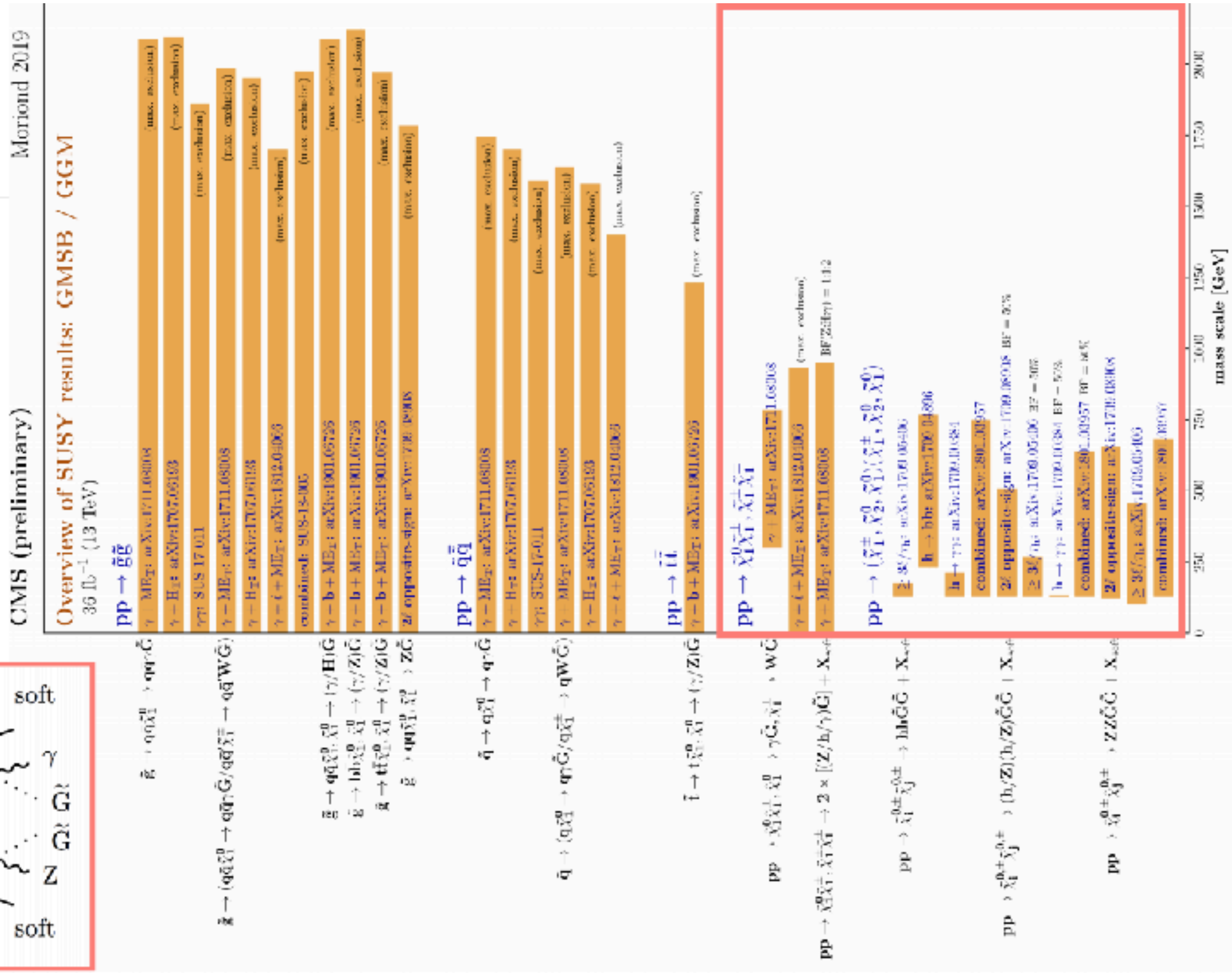


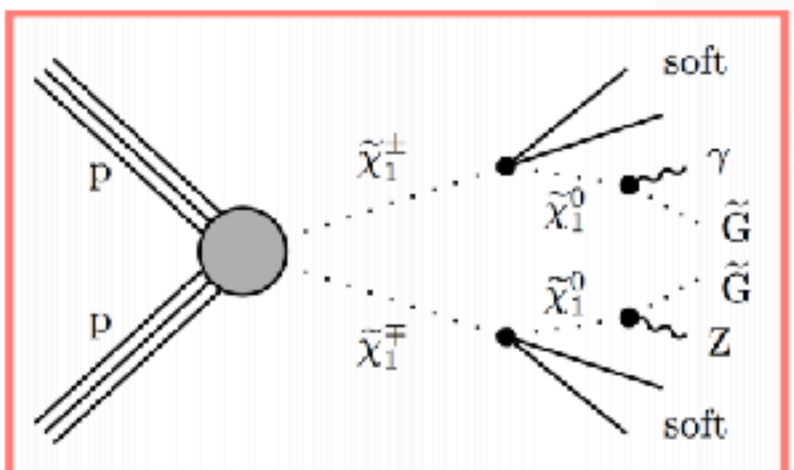
Gauge Mediated

Review of 2016 results

Gauge-mediated

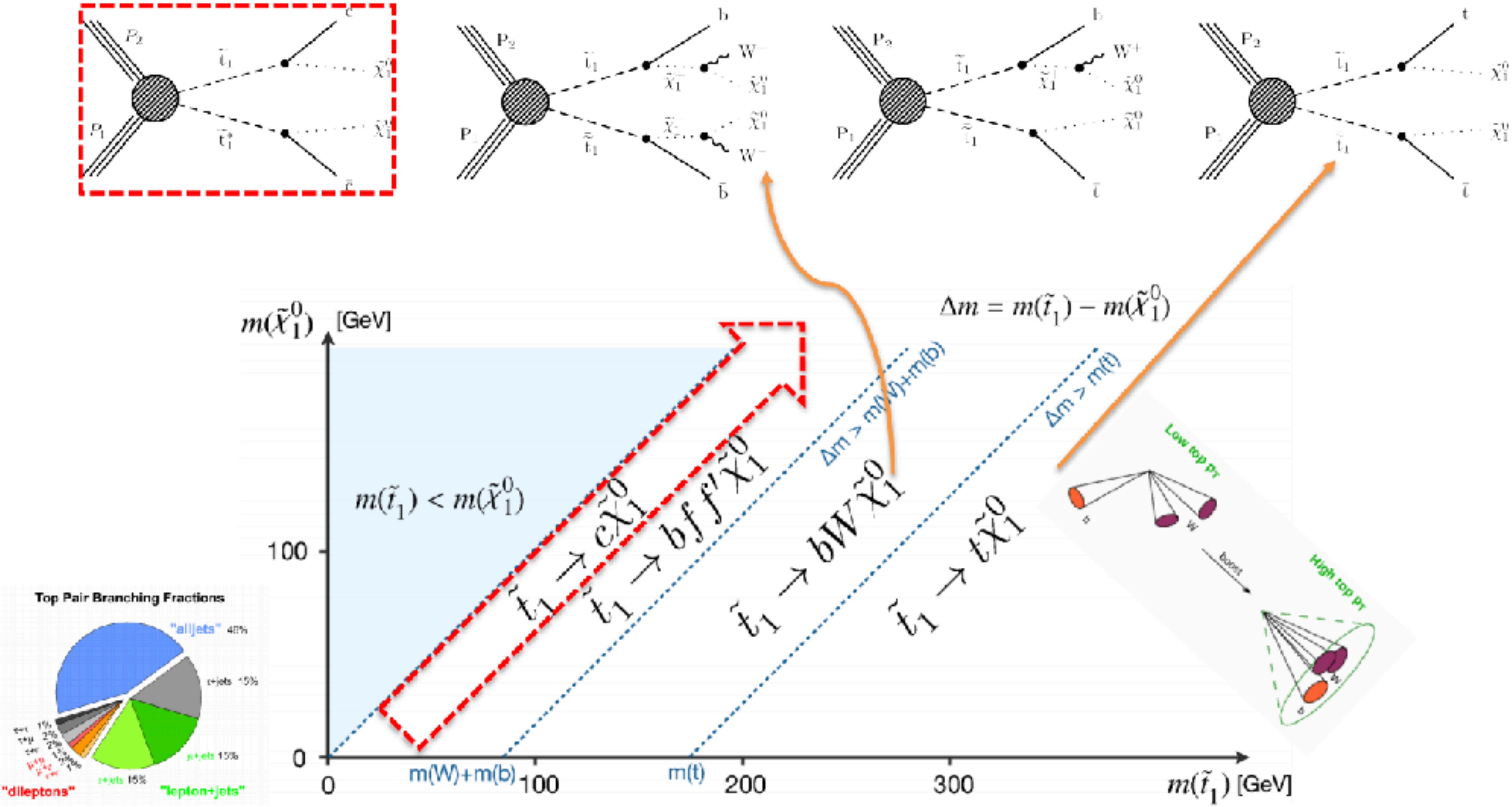
Inspired models:



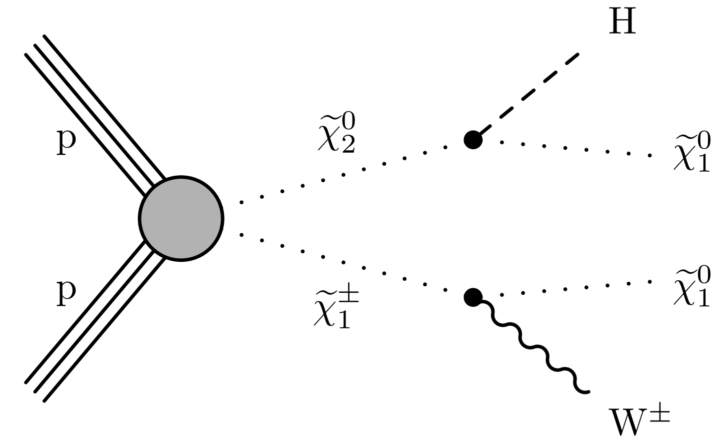


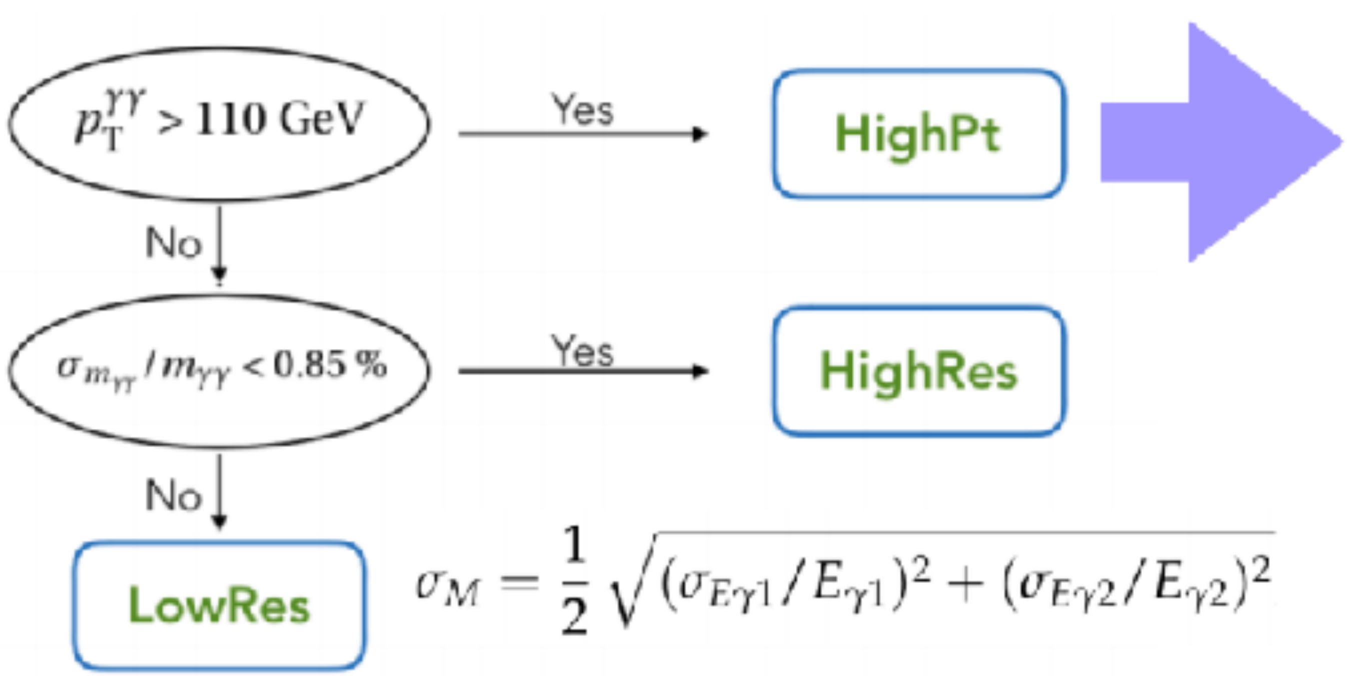
Top Squark

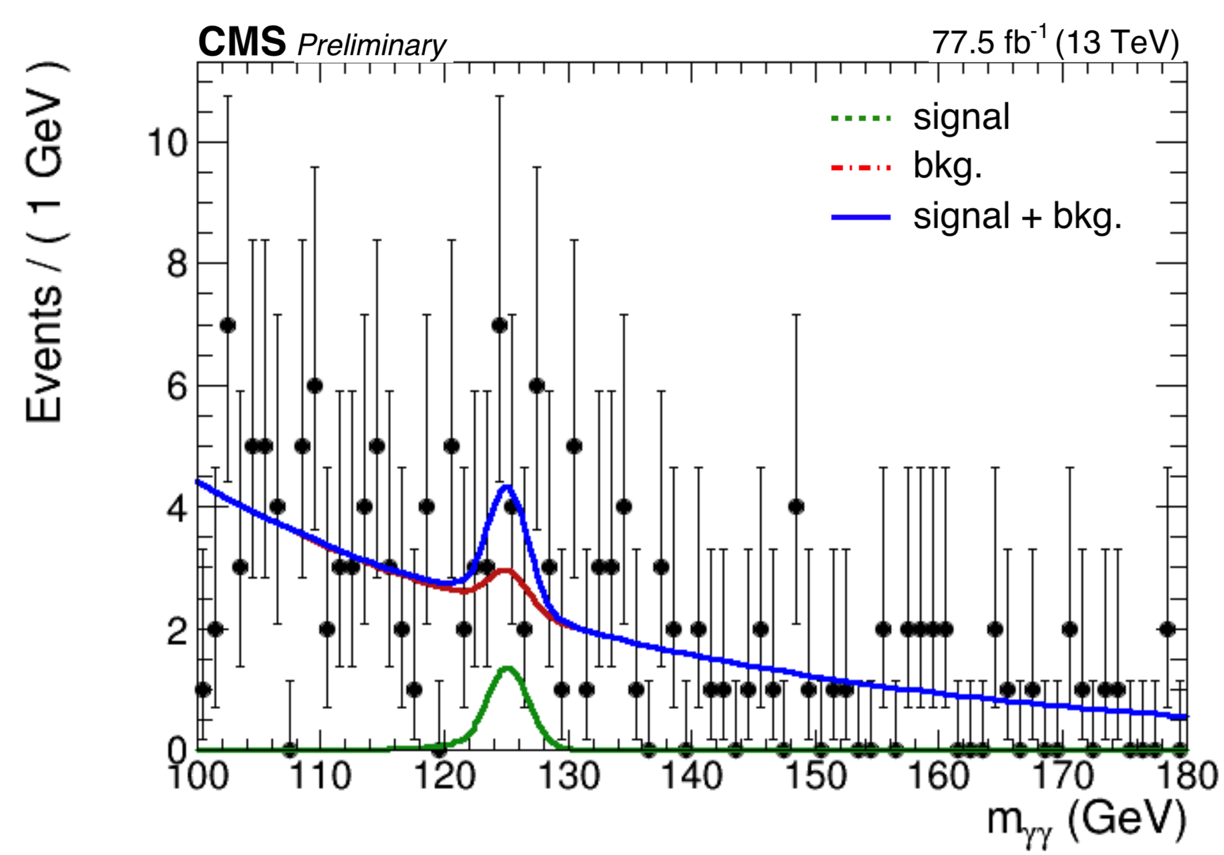
Enriched final states for top squark searches



- Data samples collected with diphoton trigger
- Require exactly 2 barrel photons with pT >40 (20) GeV for leading (sub-leading), |η| < 1.44
- m(γγ)∈[103,160] GeV
- At least one additional jet with pT>30 |η| < 3
- Selection with Razor variables and binning in terms of photon resolution







SUSY With Photons

- Models with gauge mediated SUSY breaking often produce final states with photons — 5 CMS searches with photons:
- Kinematic cuts driven by trigger requirements
- These four searches were part of a combination targeting GGM models
- New analysis: gamma+b-jets+p_T^{miss} (CMS-SUS-18–002) optimized for strong production

$\gamma\gamma + p_T^{miss}$ (SUS-17-011)

Kinematic Cuts
$p_T^\gamma > 40$ GeV, $p_T^{miss} > 100$ GeV
$m_{\gamma\gamma} > 105$ GeV, Lepton Veto for $p_T^\ell > 25$ GeV

$\gamma + p_T^{miss}$ (SUS-16-046)

Kinematic Cuts
$p_T^\gamma > 180$ GeV, $p_T^{miss} > 300$ GeV
$S_T^\gamma > 600$ GeV, $M_T\left(\gamma, p_T^{miss}\right) > 300$ GeV

$\gamma + e/\mu + p_T^{miss}$ (SUS-17-012)

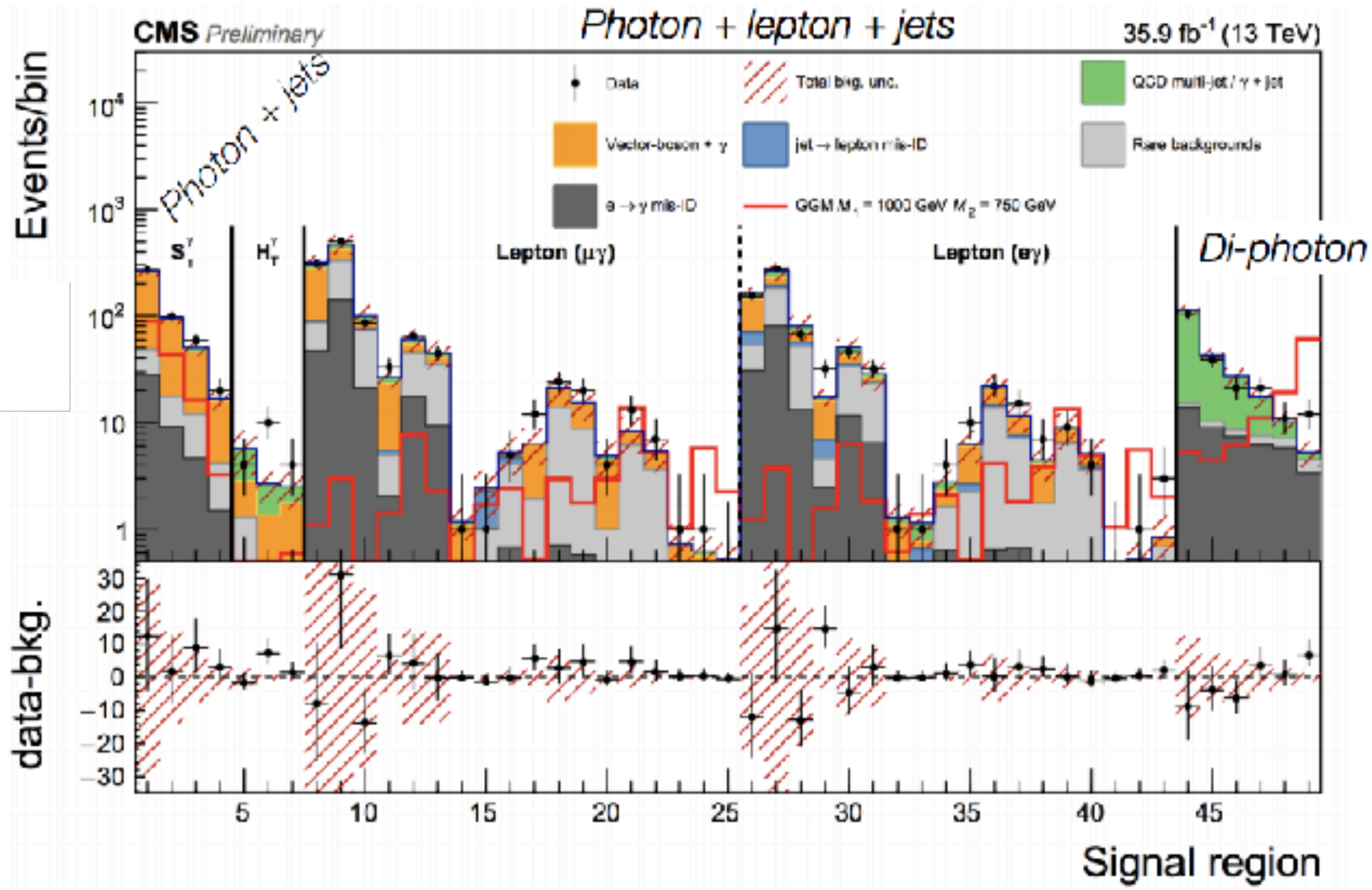
Kinematic Cuts
$p_T^\gamma > 35$ GeV, $p_T^{miss} > 120$ GeV
$p_T^\ell > 25$ GeV, $M_T\left(\ell, p_T^{miss}\right) > 100$ GeV

$\gamma + H_T$ (SUS-16-047)

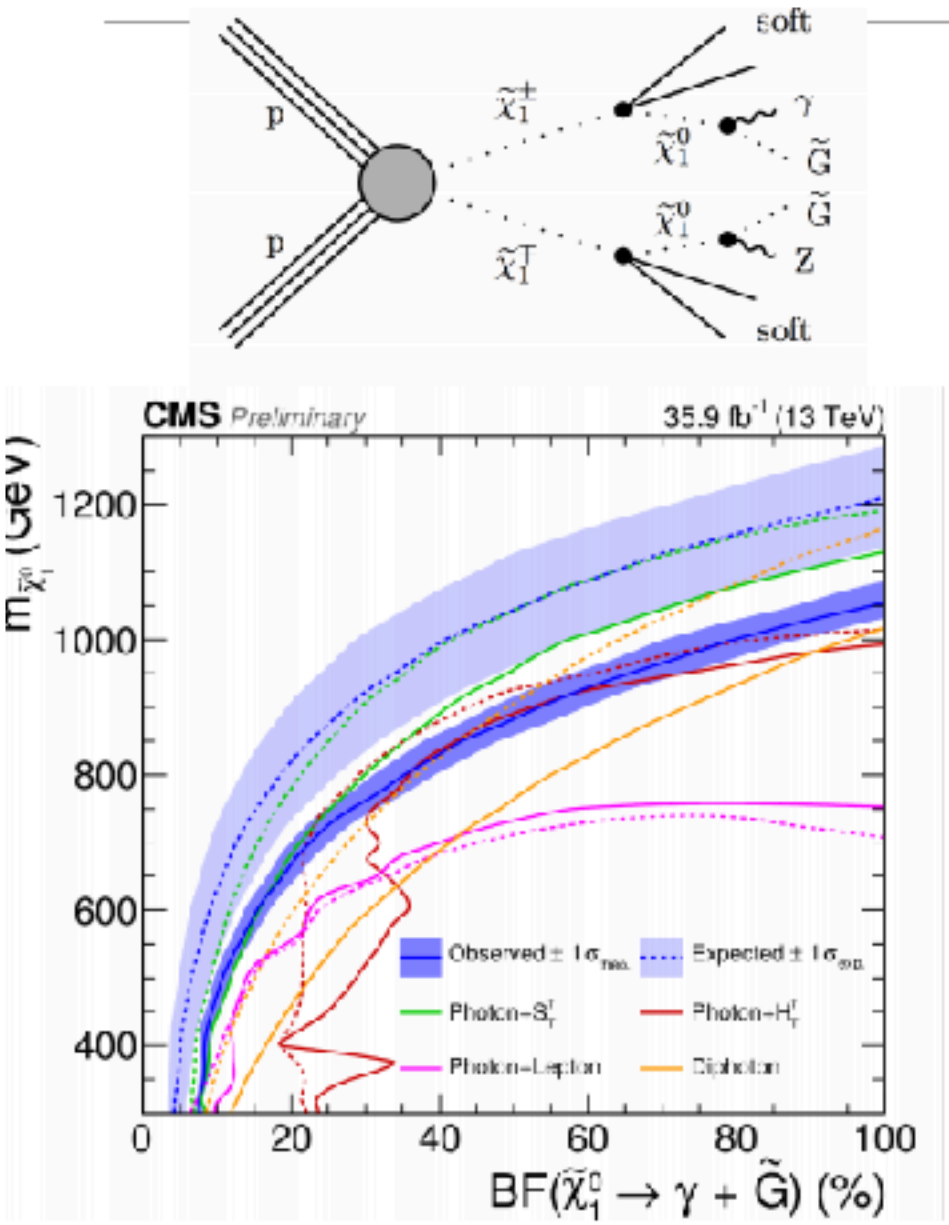
Kinematic Cuts
$p_T^\gamma > 100$ GeV, $p_T^{miss} > 350$ GeV
$H_T^\gamma > 700$ GeV, $\lvert\Delta\phi\left(\pm\vec{p}_T^{miss}, \vec{p}_T^\gamma\right)\rvert > 0.3$

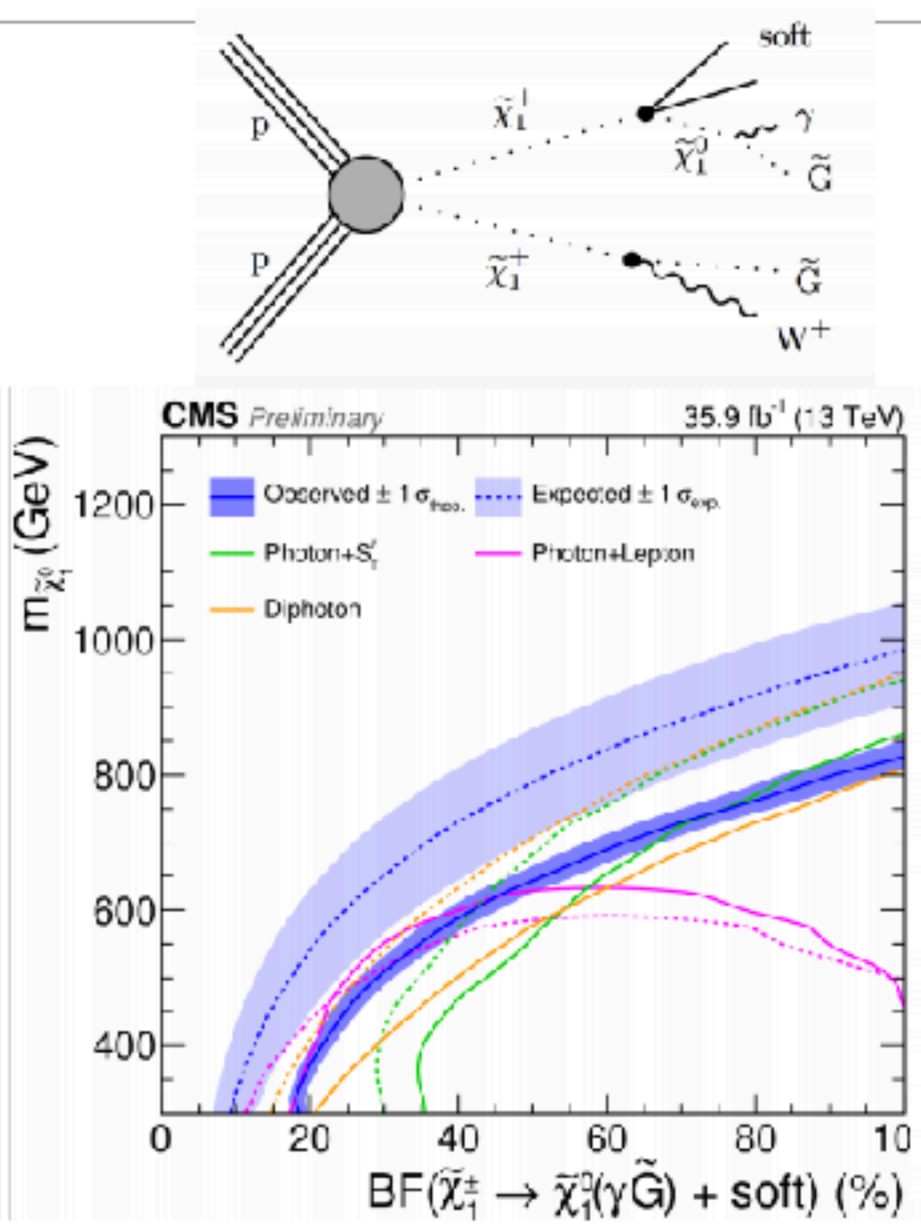
SUSY with Photons

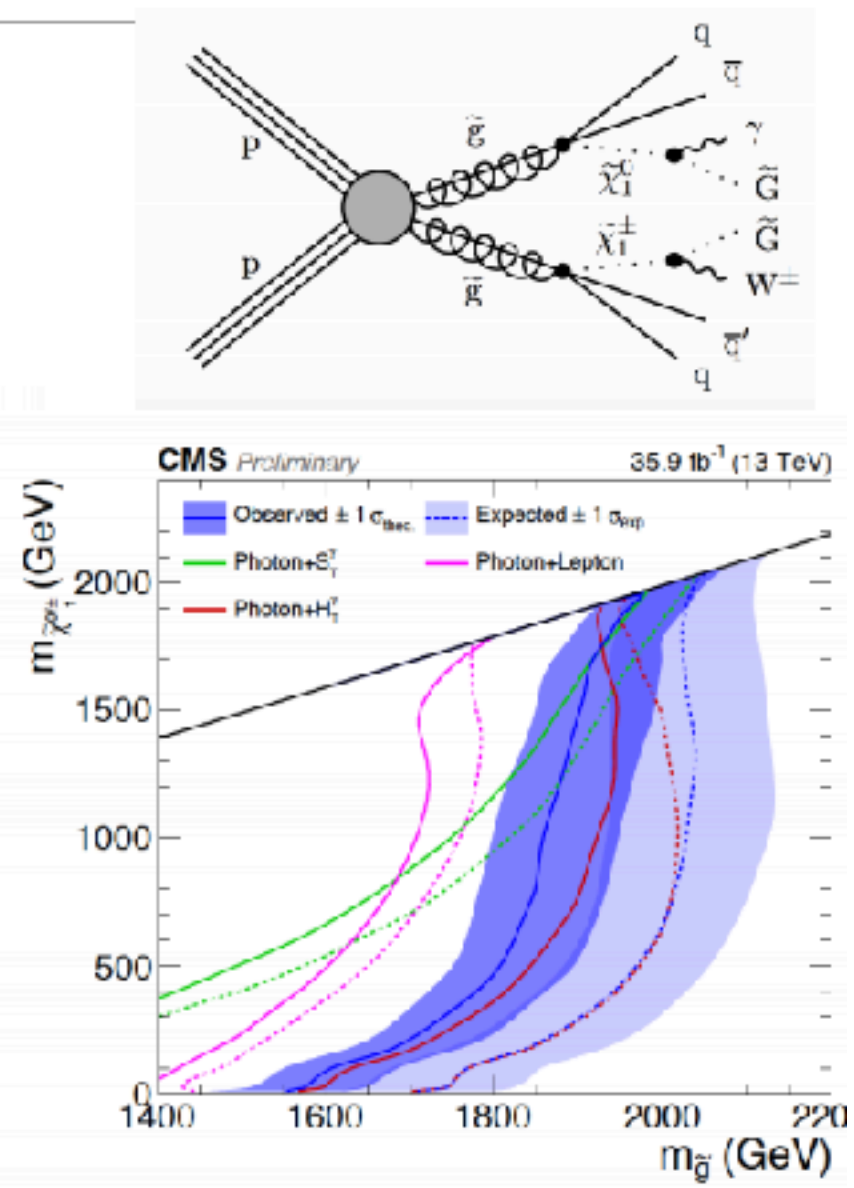
- Note: photon+jets events categories are slightly different from public results
- Under-prediction in several bins reduce observed limits
  - likely just a statistical fluctuation



Simplified Models with Photons







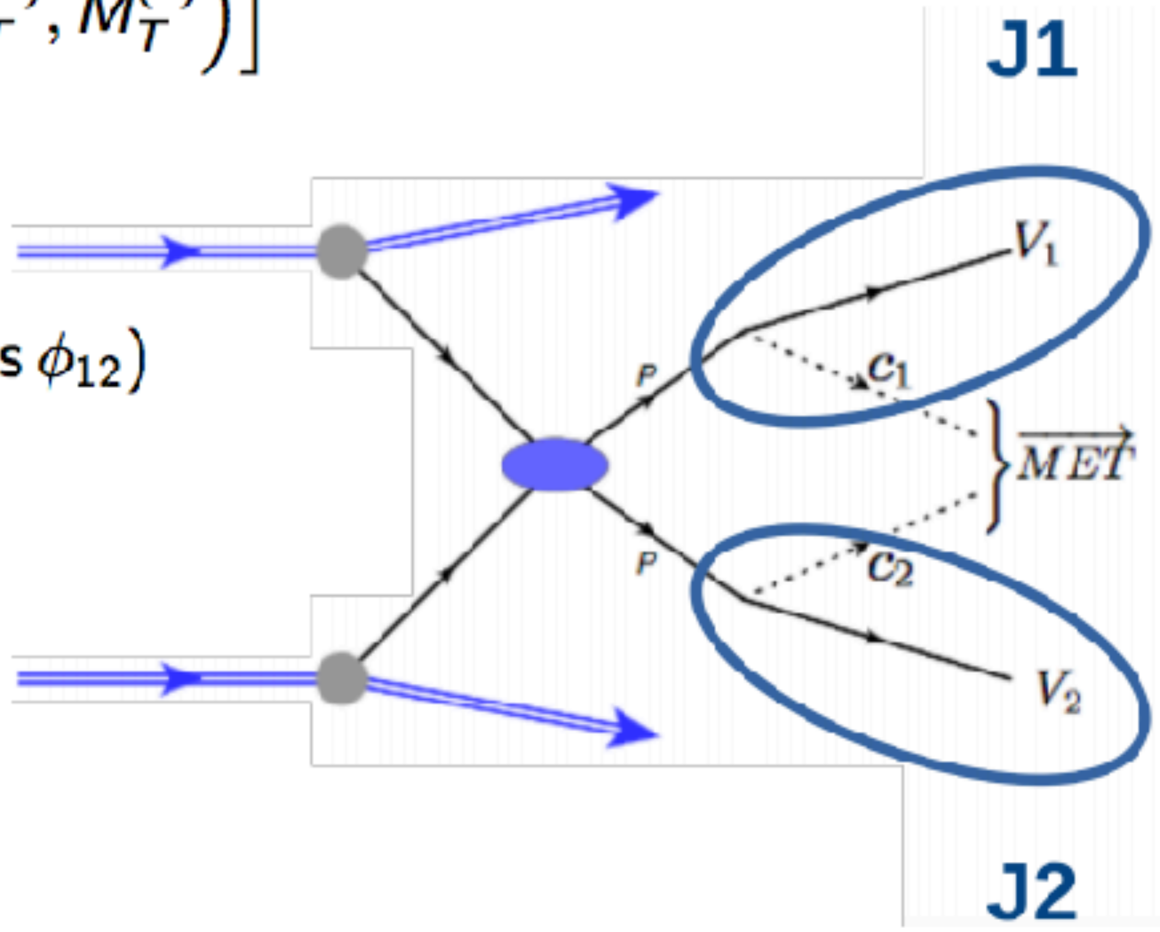
MT2

- MT2 is a generalize MET like variable for decays with two unobserved particles
- Split the visible part of the event into two hemispheres (pseudojets) for the calculation of MT2

$$M_{T2}(m_c) = \min_{\vec{p}_T^{c(1)} + \vec{p}_T^{c(2)} = \vec{p}_T^{miss}} \left[\max\left(M_T^{(1)}, M_T^{(2)} \right) \right]$$

- Approximate formula:

$$(M_{T2})^2 \sim p_T(J1) \cdot p_T(J2) \cdot (1 + \cos\phi_{12})$$



Jets+M_{T2} (Lost Lepton background)

- Estimate lost lepton background with a transfer factor from a single-lepton control region:

$$N_{LL}^{SR}(H_T, N_j, N_b, M_{T2}) = N_{1\ell}^{CR}(H_T, N_j, N_b, M_{T2}) \times R_{MC}^{0\ell/1\ell}(H_T, N_j, N_b, M_{T2}) \times k(M_{T2})$$

- **N_{1l}^{CR}**: observed 1-lepton yield in data control region. Uses same triggers as signal region
- **$R_{MC}^{0l/1l}$**: transfer factor from 1-lepton CR to 0-lepton SR. ~0.5-2.0, from MC
  - to account for lepton acceptance, ID, isolation
  - also account for τ's
- **$k(M_{T2})$** : M_{T2} extrapolation factor
  - where statistics permit, N_{CR} is taken per-M_{T2} bin and $k(M_{T2})$ = 1.
  - Otherwise, N_{CR} is integrated across M_{T2} and $k(M_{T2})$ is the M_{T2} shape from MC.

CMS-PAS-SUS-19-005

Jets+M_{T2} ($Z\rightarrow\nu\nu$ background)

CMS-PAS-SUS-19-005

- Estimate $Z\rightarrow\nu\nu$ background with a transfer factor from a dilepton control region:

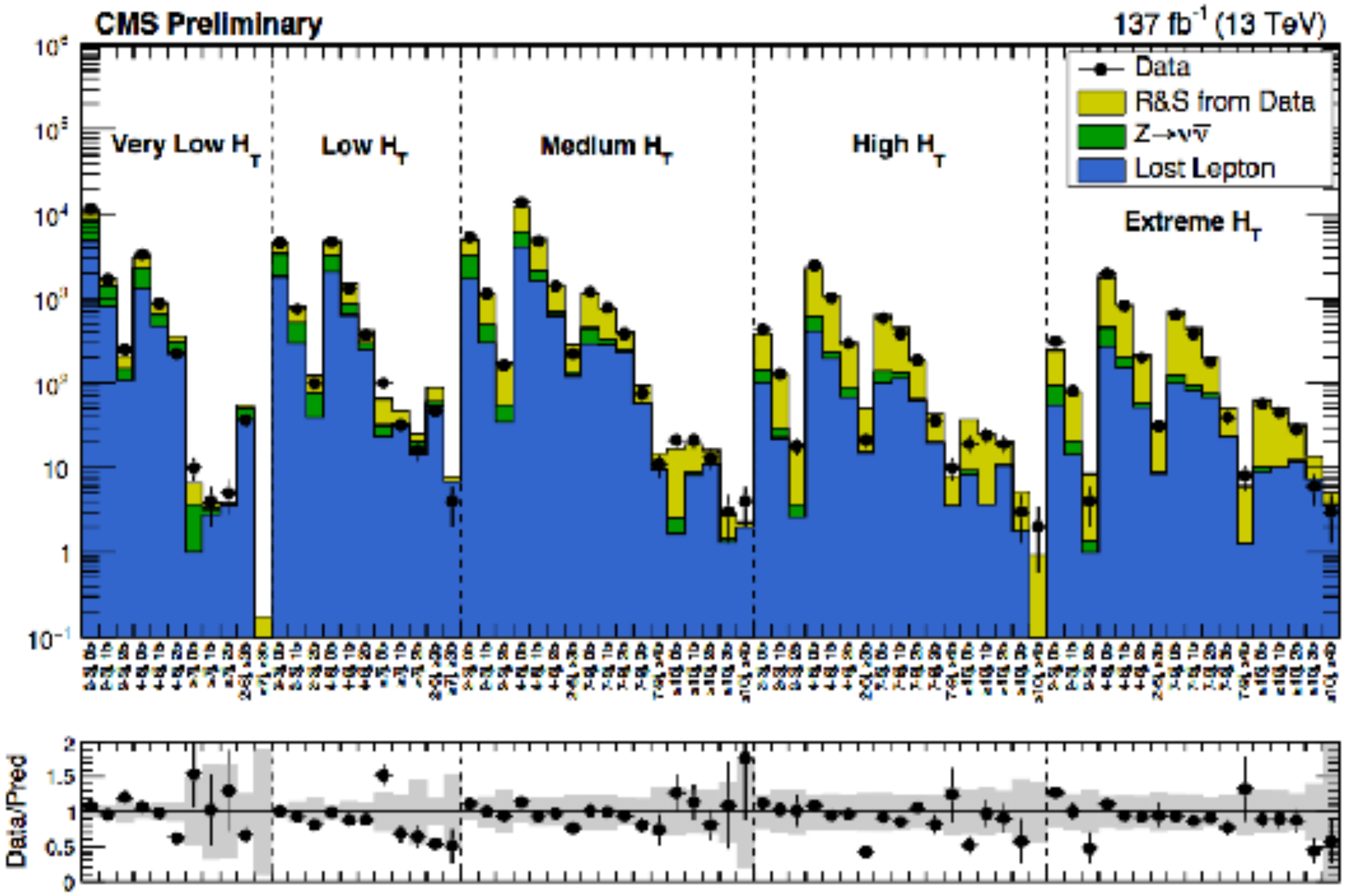
$$N^{\mathrm{SR}}_{Z\rightarrow\nu\bar{\nu}}(H_{\mathrm{T}}, N_{\mathrm{j}}, N_{\mathrm{b}}, M_{\mathrm{T2}}) = \left[N^{\mathrm{CRSF}}_{\ell\ell}(H_{\mathrm{T}}, N_{\mathrm{j}}, N_{\mathrm{b}}) - N^{\mathrm{CROF}}_{\ell\ell}(H_{\mathrm{T}}, N_{\mathrm{j}}, N_{\mathrm{b}}) \times R^{\mathrm{SF/OF}}\right] \times R^{Z\rightarrow\nu\bar{\nu}/Z\rightarrow\ell\ell}_{\mathrm{MC}}(H_{\mathrm{T}}, N_{\mathrm{j}}, N_{\mathrm{b}}) \times k(M_{\mathrm{T2}})$$

- $\mathbf{N}_{\mathrm{CRSF}}$: observed SF dilepton yield in data control region. Uses dilepton triggers
- $\mathbf{N}_{\mathrm{CROF}}$: observed OF dilepton yield OF data control region (to remove top contamination)
- $\mathbf{R}_{\mathrm{SF/OF}}$: ratio of SF/OF, measured from data in top-enriched region (**1.07 ± 0.15**)
- $\mathbf{R}_{\mathrm{MC}}^{Z\rightarrow\nu\nu/Z\rightarrow ll}$: ~5-10, to account for BR, lepton acceptance, ID, etc.
- **k(M_{T2})** : M_{T2} extrapolation factor
  - measured inclusively in N_b
  - done in a **hybrid** way, similar to the lost lepton estimate (i.e. use data when stats permit, otherwise take shape from MC)

Jets+M_{T2} (Multijet background)

CMS-PAS-SUS-19-005

- Using **Rebalance and Smear** for primary QCD estimate
  - "Rebalance" events by adjusting jet p_T's to simultaneously minimize MET and maximize a likelihood
  - Then "smear" many times according to templates of $p_T(reco)/p_T(true)$
- Derived templates using 2016, 2017, and 2018 QCD pT-binned MC
- Fit a gaussian "core", which can be widened for data to account for data/MC differences in jet resolution



Jets + M_{T2}+ Disapp. Tracks (Background)

- Estimate residual SM background using short track candidates (STCs).
- STCs pass the ST selection but with loosened isolation and quality cuts, and are not STs.
  - "Loose-not-Tight"
  - Signal-depleted
- Define f_{short} as the ratio between STs and STCs: $f_{short} = N_{ST}/N_{STC}$

$$\Longrightarrow \quad N_{ST}^{Est} = f_{short} \times N_{STC}$$

-
- **Exploit M_{T2}**: Measure f_{short} in 60 < M_{T2} < 100 GeV Measurement Region (signal-depleted).
- **Exploit M_{T2}**: Validate in 100 < M_{T2} < 200 GeV Validation Region (also signal-depleted).
- **Exploit M_{T2}**: Use to estimate background in M_{T2} > 200 GeV Signal Region.

2L SS + ≥3L (Fake/non-Prompt)

- Subtract off prompt contribution from measurement region
  - DY/W-dominated region with MET, M_T>30 is used for a template fit of DY, W, QCD to data in order to find this contribution
- Fake rate transfer factors (p_T,) are computed as ratio of tight-to-loose events after prompt subtraction
  - Define a failing lepton as passing loose criteria, but not tight
  - SR tight-tight prediction (N_{TT}) obtained from number of tight-fail (N_{TF}) and number of fail-fail (N_{FF})
  - Extra permutation terms extend this to the three lepton case

$$N_{TT,fakes} = N_{TF} \times \frac{\epsilon}{1-\epsilon} - N_{FF} \times \frac{\epsilon^2}{(1-\epsilon)^2}$$

CMS-PAS-SUS-19-008

2L SS + ≥3L Electron charge flip rate

- Electron bremsstrahlung allows indirect background from DY via $e^{\pm}e^{\pm} \rightarrow e^{\pm}e^{\pm}$ (negligible/ignored for muons)
- Opposite-sign dilepton control region used to estimate (small) charge flip background in signal region with a MCbased flip rate transfer factor (SS prediction = OS * TF)
- Summary plot (right) shows simulated flip rate and observed flip rate (ratio of same-sign to opposite-sign in Z peak)
  - MC had good modeling of data flip rate in 2016, while it under predicted starting in 2017 due to pixel issues
- A scaling factor to account for data/MC is applied per year for closure, and a 20% systematic is taken on the size of this background

CMS-PAS-SUS-19-008

2L SS + ≥3L (Rare)

- SM background processes which can give rise to prompt same sign leptons are taken from simulation
  - WZ
  - $tt\overline{W}$
  - $tt\overline{Z}$
  - $tt\overline{H}$
- W±W±
- Rares (VV, VVV, tttX, …)
- X+ ɣ
- With the large number of regions, and including the multi-lepton regions, want to let the fit constrain these processes
- Each process is assigned a 30% flat normalization uncertainty except for Rares, X+ ɣ which are assigned 50%
- Processes also have shape uncertainties from theory (QCD scale)

CMS-PAS-SUS-19-008