Search for pair-produced staus in the all-hadronic final state with the CMS experiment

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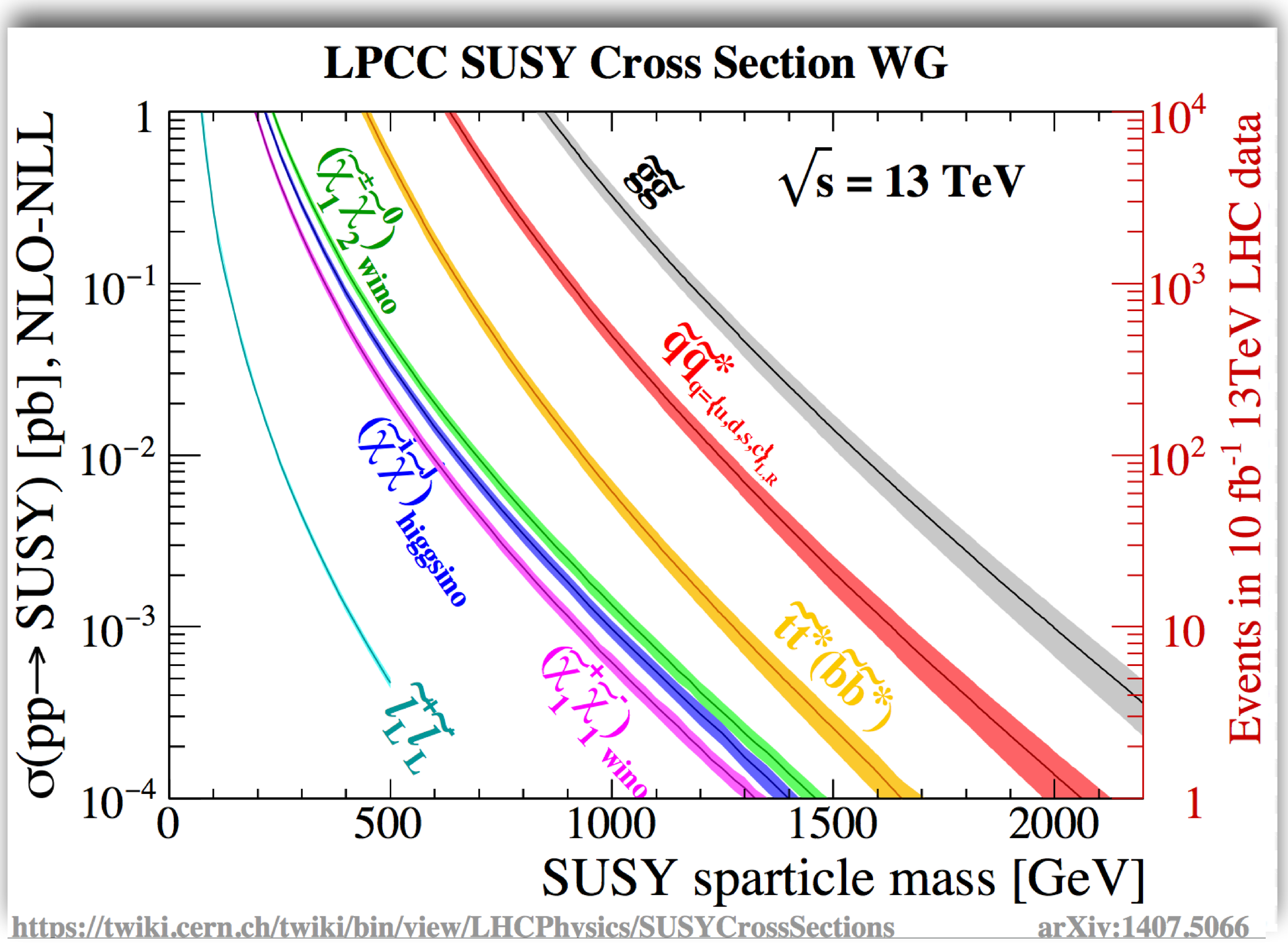
Motivating Weakly Produced SUSY

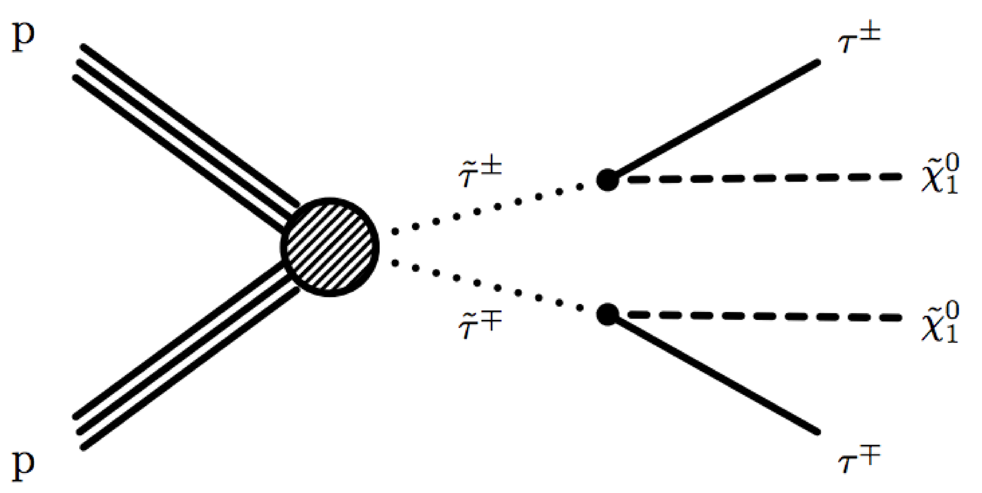
- The SM was greatly expanded with the Higgs discovery
  - ➡ For the Higgs boson to be stable at a mass of 125 GeV the SM requires fine tuning of parameters at level of~30 decimal places.
- Supersymmetry (SUSY) may provide a mechanism to protect (stabilize) the Higgs mass against radiative corrections from SM.
- No hints of SUSY production seen at the LHC after collecting ~35 fb^{-1} of data at 13 TeV
  - ➡ Large limits on strong SUSY (Gluino and Stop) production were set
  - ➡ Some weakly produced SUSY (chargino, stau) models remain largely unexcluded due to their smaller cross sections.



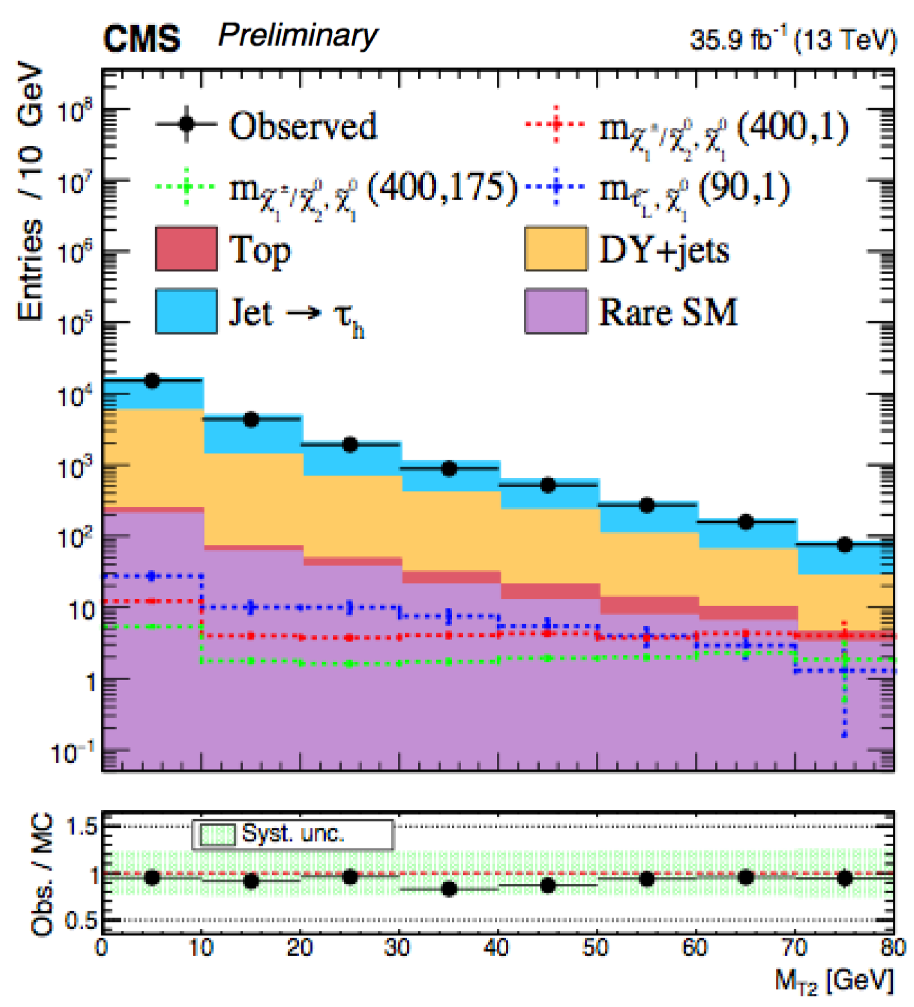
Cross sections for SUSY particle production. Direct lepton production circled above. Note these results are for 8 TeV, but general trend extends to 13 TeV.

Stau Analysis Design

- Pair production of two light stau particles leads to a challenging final state, two taus and small additional MET.
  - ➡ Analysis targets hadronic decay of both tau leptons
- Stau production at LHC has less MET than Stop/Gluino
  - ➡ Small cross section compounds difficulty
  - ➡ Simple 3 bin analysis split by kinematic variables M_{T2}, ΣM_T



$$M_{T2} = \min_{\vec{p}_T^{X(1)} + \vec{p}_T^{X(2)} = \vec{p}_T^{\text{miss}}} \left[\max\left(M_T^{(1)}, M_T^{(2)}\right)\right] \qquad \Sigma M_T = M_T(\tau_1, \vec{p}_T^{\text{miss}}) + M_T(\tau_2, \vec{p}_T^{\text{miss}})$$



M_{T2} distribution in low ΣM_T validation region

Baseline Selection :

1. Two vtight OS tau candidates
2. No b-tagged jets (loose w.p)
3. No veto electrons or muons
4. $|\Delta\varphi(\tau_1, \tau_2)| > 1.5$

SR1 (high M_{T2})

- ΣM_T >= 90 GeV

SR2 (high ΣM_T)

- 40 <= ΣM_T < 90 GeV
- ΣM_T >= 350 GeV
- MET >= 50 GeV

SR3 (moderate ΣM_T)

- 40 <= ΣM_T < 90 GeV
- ΣM_T >= 350 GeV
- MET >= 50 GeV

Background Estimation and Results

- Background split into prompt and fake (jet→τ) categories
  - ➡ Prompt tau decays are estimated in data corrected MC simulation
- Fake yields are estimated using "fake-rate" method as follows
  1. Loose-to-tight fake rate "f" measured in fake enriched data
  2. Prompt rate "p" estimated for gen-taus in MC
  3. Events are counted in loose-loose (N_{ll}), loose-tight (N_{lt}), and tight-tight (N_{tt}) regions. Count is recast as a sum of fake-fake events (N_{ff}), fake-prompt (N_{pf}), and prompt-prompt (N_{pp})

$$N = N_{pp} + N_{pf} + N_{ff} = N_{tt} + N_{tl} + N_{ll}$$

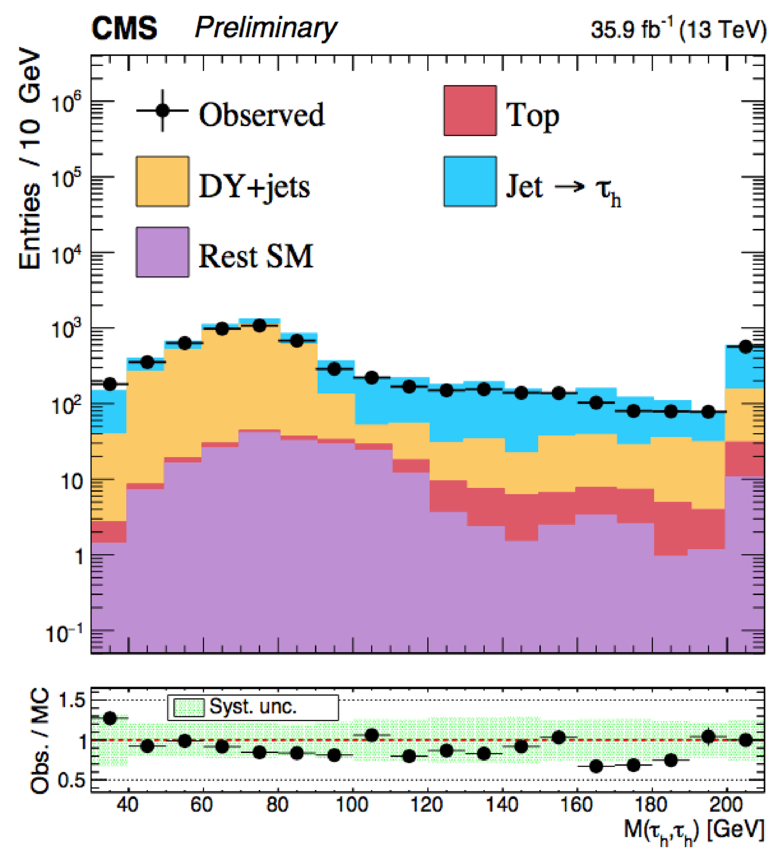
4. From the fake and prompt rates above a data driven estimate of the number of fake-fake (N_{ff}) and prompt-fake (N_{pf}) events follows

$$N_{pf} = \frac{1}{(p-f)^2}\left[-2fpN_{ll} + [f(1-p)+p(1-f)]\,N_{tl} - 2(1-p)(1-f)N_{tt}\right]$$

$$N_{ff} = \frac{1}{(p-f)^2}\left[p^2 N_{ll} - p(1-p)N_{tl} + (1-p)^2 N_{tt}\right]$$

5. The tight-tight (SR) region can then be calculated as follows :

$$N_{tt} = p^2 N_{pp} + pfN_{pf} + f^2 N_{ff}$$

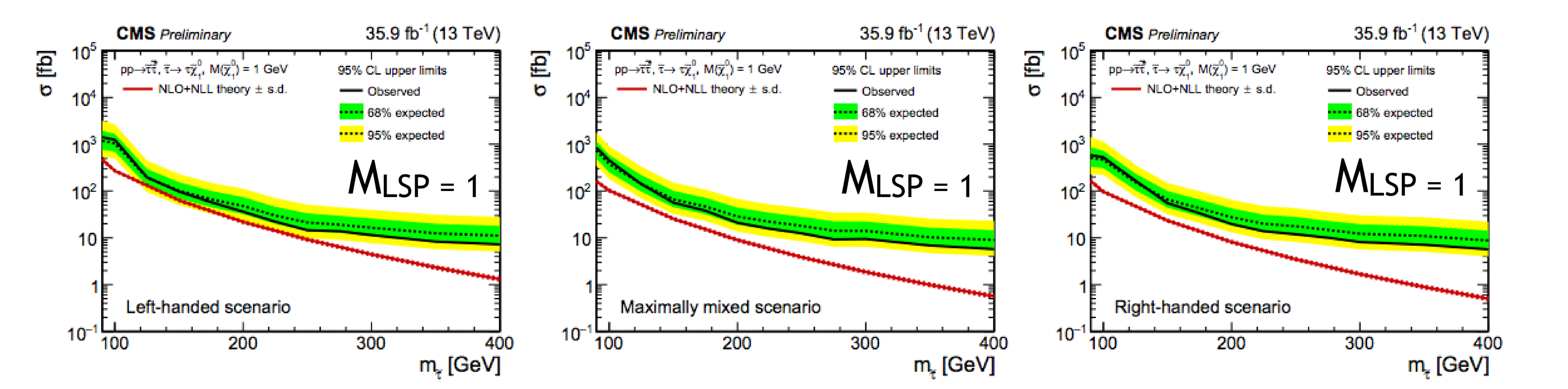


Visible mass between tau candidates in validation region

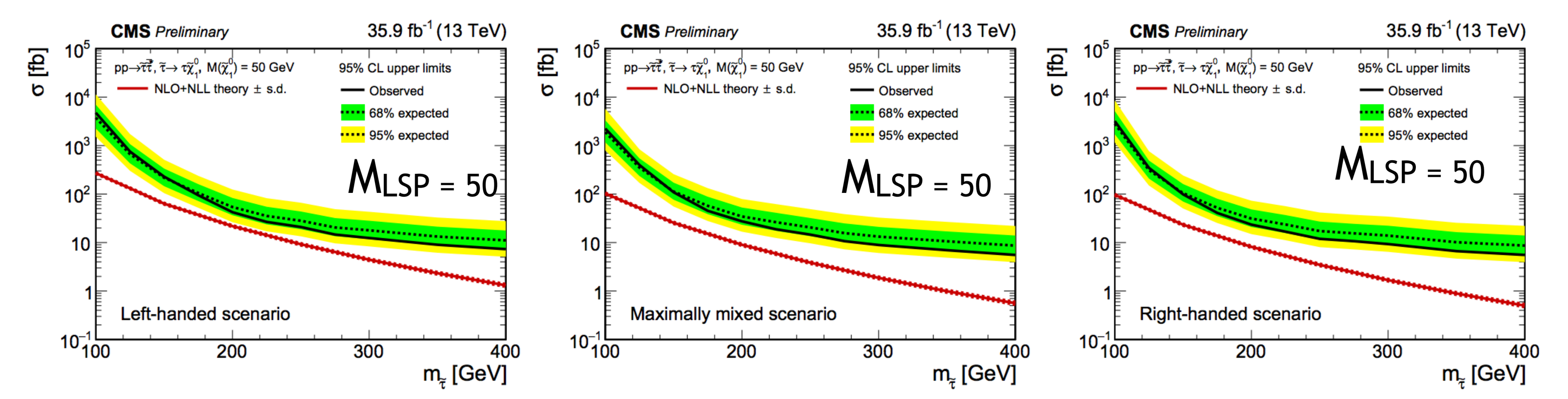
	SR1	SR2	SR3
Non-prompt and misidentified taus	$0.68^{+0.90}_{-0.68}$	2.49 ± 1.83	<1.24
Drell-Yan background	$0.80^{+0.97}_{-0.80}$	< 0.71	< 0.71
Top-quark related background	$0.02^{+0.03}_{-0.02}$	0.73 ± 0.31	1.76 ± 0.68
Rare SM processes	0.72 ± 0.38	0.20 ± 0.15	$0.20 \pm {}^{+0.25}_{-0.20}$
Total background	$\mathbf{2.22}^{+1.37}_{-1.12}$	$\mathbf{4.35}^{+1.75}_{-1.53}$	$\mathbf{3.70}^{+1.52}_{-1.08}$
Left (150,1)	1.25 ± 0.40	2.91 ± 0.59	1.53 ± 0.33
Right (150,1)	1.09 ± 0.26	1.27 ± 0.20	0.74 ± 0.17
Mixed (150,1)	1.04 ± 0.22	1.39 ± 0.27	0.92 ± 0.15
Observed	**0**	**5**	**2**

- Predicted yields for background and signal vs. Observed by SR
  - ➡ Stau polarization treated in three seperate scenarios (pure right-handed, pure-left handed, and maximally mixed production)
  - ➡ No significant deviations w.r.t. SM predictions are observed

Interpretation and Summary



- Limits set above are the strongest (M_{LSP} = 1 GeV) vs. stau mass
  - ➡ Lowest U.L. set by analysis ~1.4 for (125,1) left-handed scenario
  - ➡ Other scenarios still remain far from exclusion
- Statistical uncertainties are currently dominant source of error



- Limits become harder to set with increasing M_{LSP}
  - ➡ Much of phase space will still be uncovered by the end of Run-II
- In summary, a search for direct tau slepton pair production has been carried out by the CMS Experiment at $\sqrt{s}$ = 13 TeV
  - ➡ No signal points were excluded for the scenarios considered
  - ➡ Analysis still stands to gain from increased luminosity