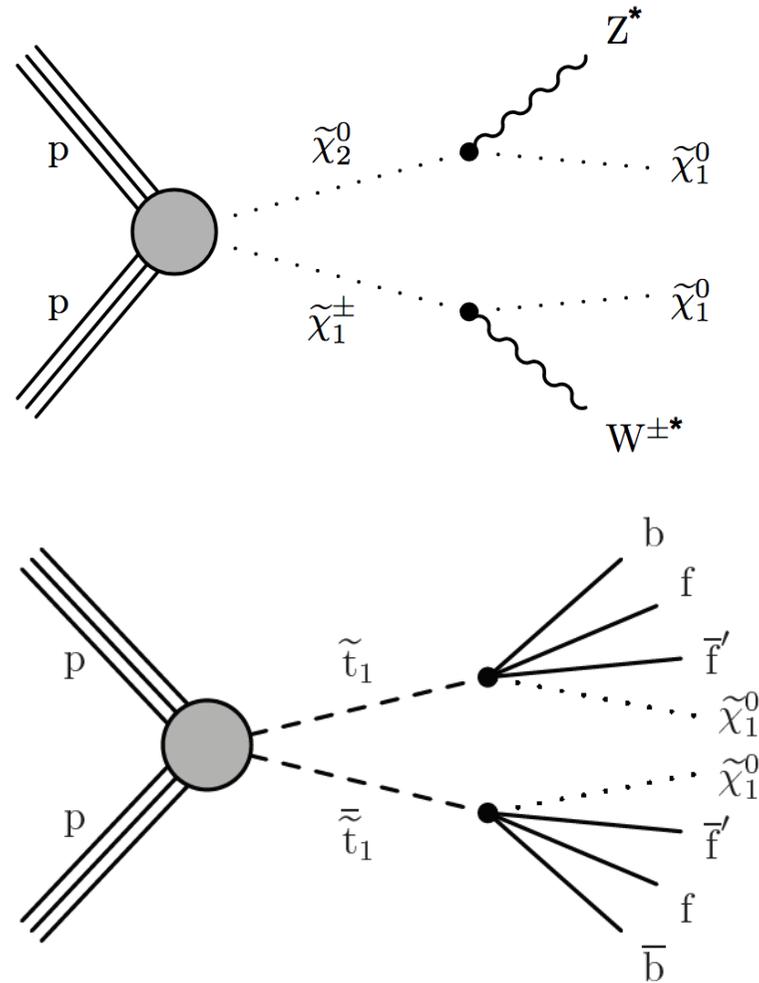


Progress in SUSY searches with final states with soft leptons in CMS



Cristina Botta
on behalf of the CMS Collaboration

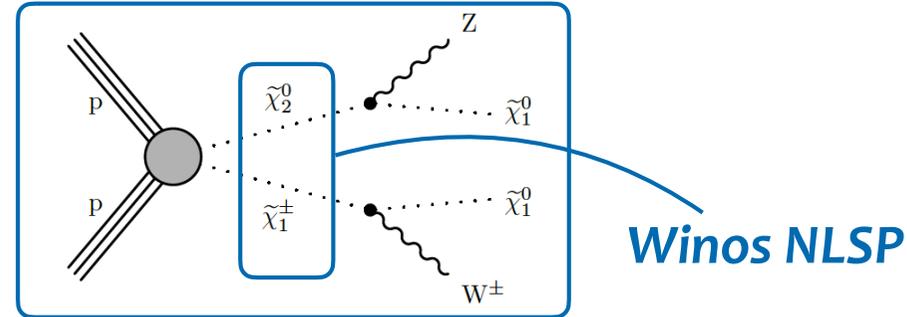
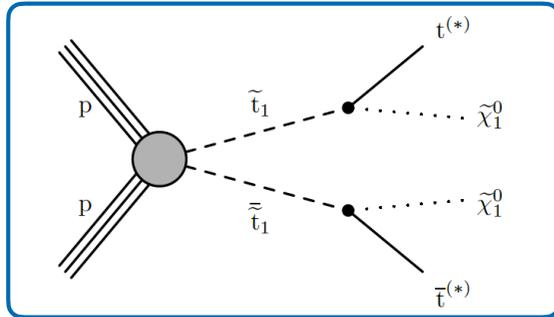
Rencontres de Moriond on “EW Interactions and Unified Theories”
10-17.03.2018, La Thuile (Italy)

Mainstream SUSY searches: leftover corners

- Absence of SUSY signals so far: **could indicate that SUSY particles have very large mass**
- **LHC RunII**: increase in production cross section extends sensitivity towards higher masses
- Many searches in events with **large E_T^{miss} and energetic final-state objects**
- But not so sensitive to scenarios with small mass splitting between the next-to-lightest SUSY particle (N-LSP) and the LSP:
COMPRESSED SPECTRA
 - visible energy and potentially E_T^{miss} relatively low: motivate searches in events with **low-momentum objects**

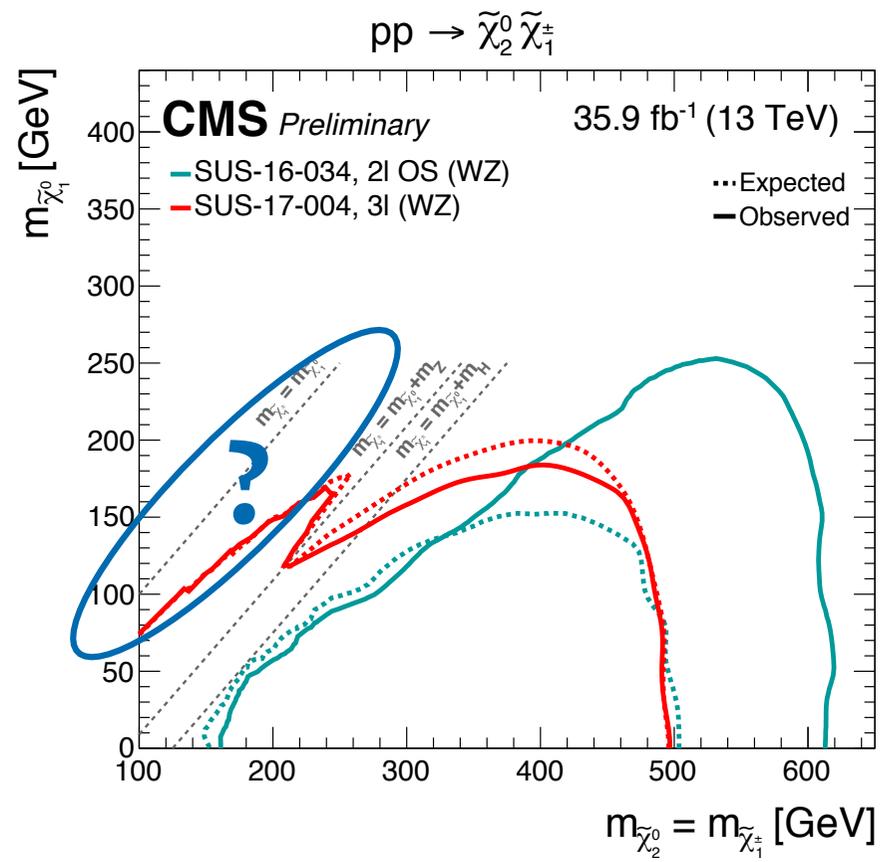
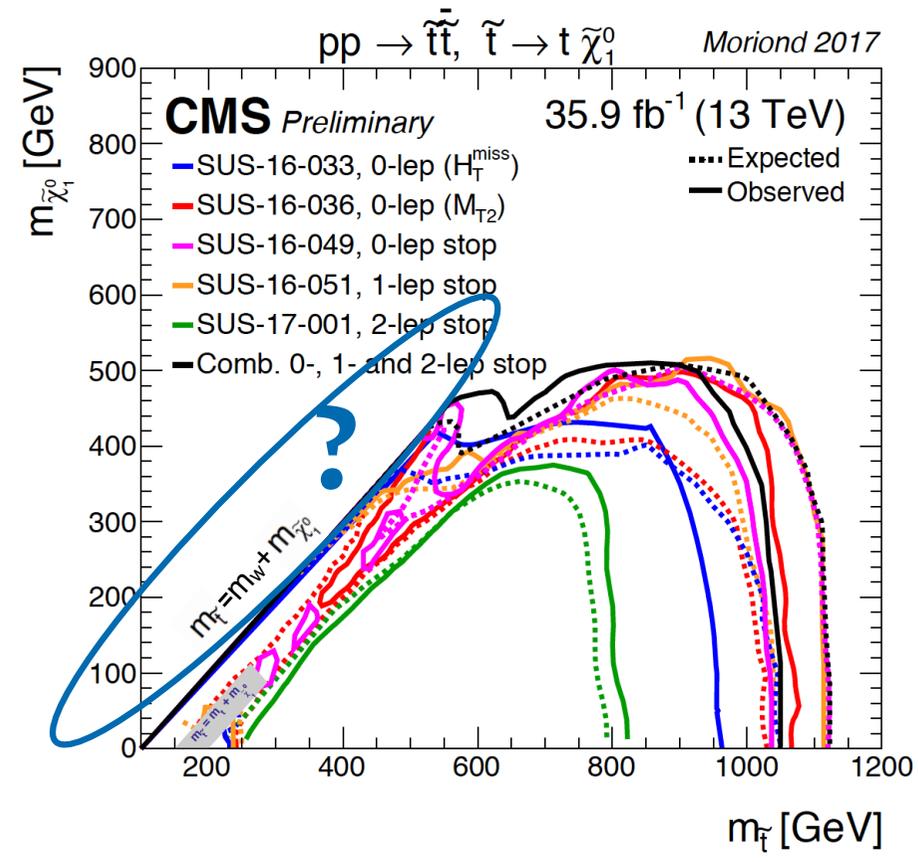
Mainstream SUSY searches:

leftover corners



Winos NLSP

Simplified models, RPV conserving SUSY, lightest neutralino LSP



The case for 'compressed' EWK SUSY

In principle, any bino/wino/higgsino mass hierarchy is allowed

$$\tilde{\chi}_3^0 \tilde{\chi}_4^0 \tilde{\chi}_2^\pm \equiv \tilde{H} \text{ (higgsino)}$$

$\Delta m \sim \text{few - tens of GeV}$

$$\tilde{\chi}_2^0 \tilde{\chi}_1^\pm \equiv \tilde{W} \text{ (wino)}$$

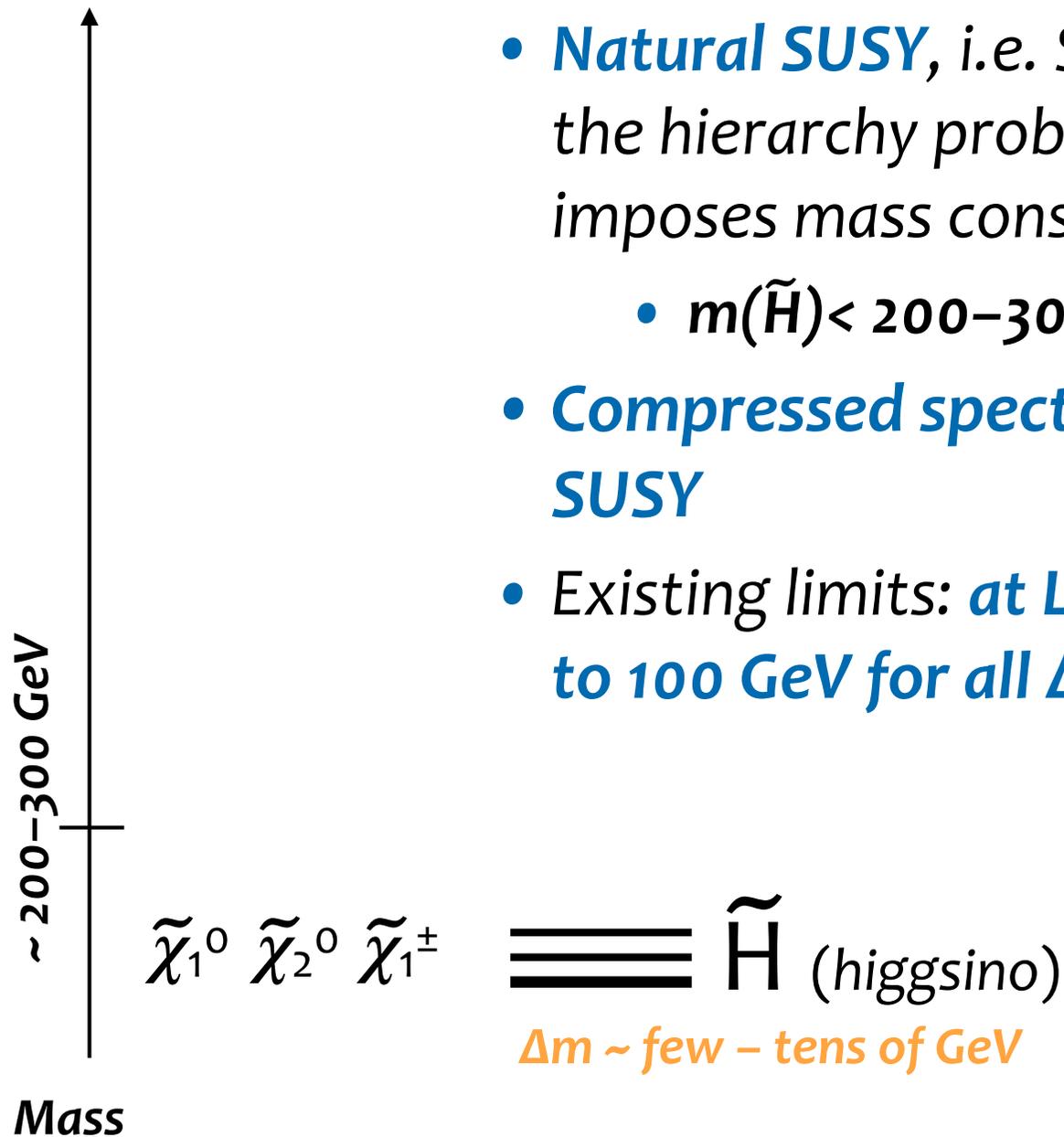
$\Delta m \sim \text{few hundreds MeV}$

(assuming heavy sfermions and higgsinos)

$$\tilde{\chi}_1^0 \text{ — } \tilde{B} \text{ (bino)}$$

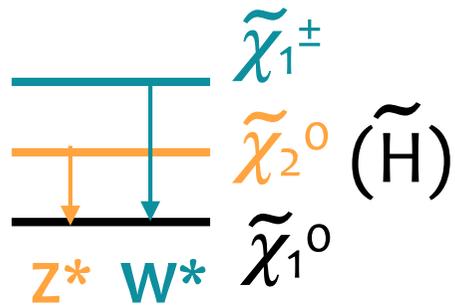
Mass

The case for ‘compressed’ EWK SUSY



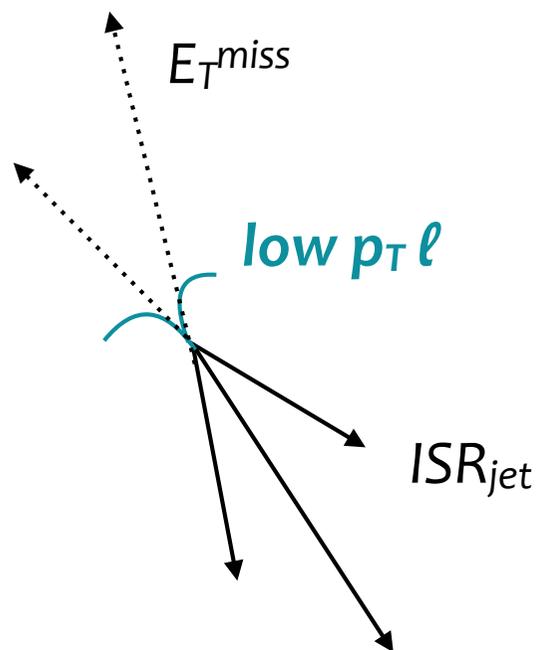
- **Natural SUSY**, i.e. SUSY models that solve the hierarchy problem with little fine tuning, imposes mass constraints
 - $m(\tilde{H}) < 200\text{--}300 \text{ GeV}$
- **Compressed spectra: ingredient of Natural SUSY**
- Existing limits: **at LEP charginos excluded up to 100 GeV for all Δm**

Search for light Higgsinos at CMS

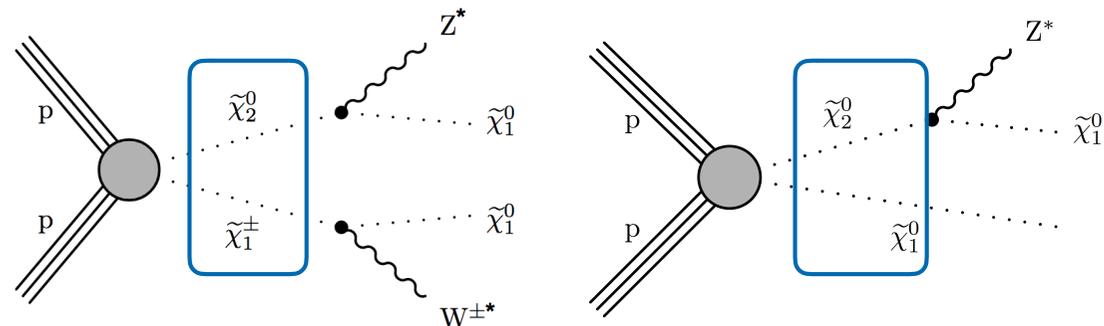


- **Need ISR jet to boost the sparticle pair system and induce E_T^{miss}**

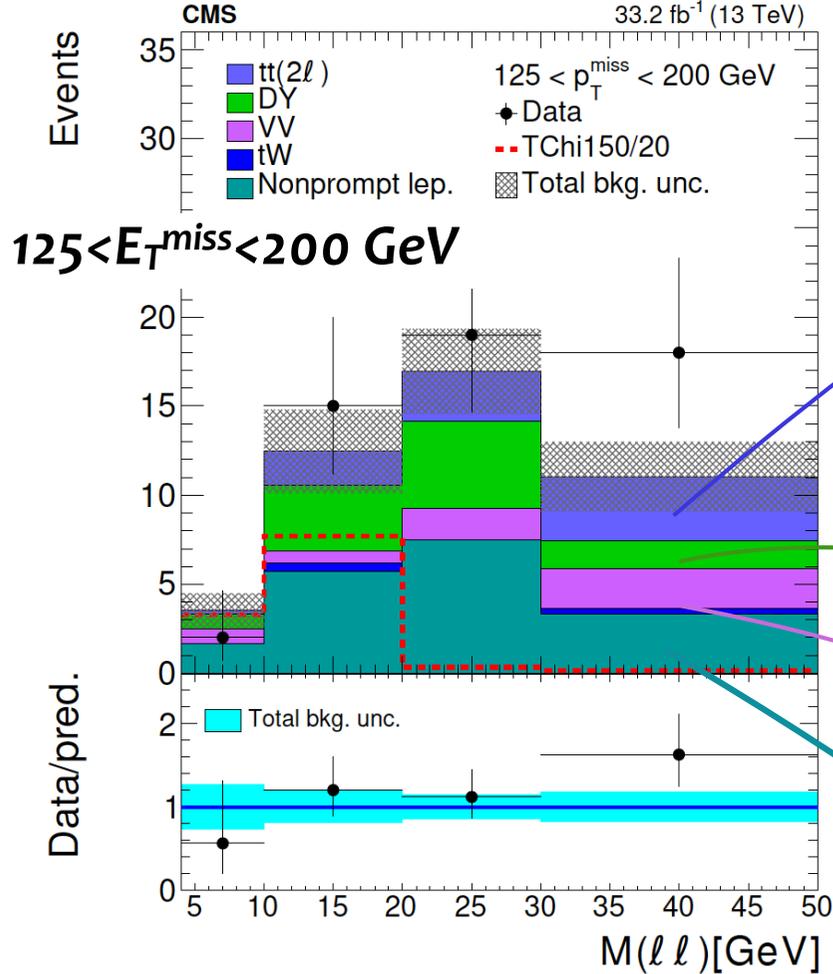
- other decay products remain soft
- if sleptons are too heavy decay happens through Z^*/W^*
- need Z^*/W^* leptonic decays to reconstruct decay product and reduce bkg



- **Signature: soft $e^\pm e^\mp / \mu^\pm \mu^\mp$ (OSSF) + E_T^{miss}**



Results

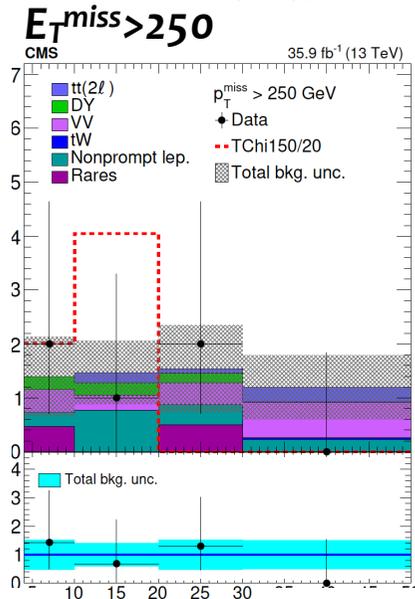
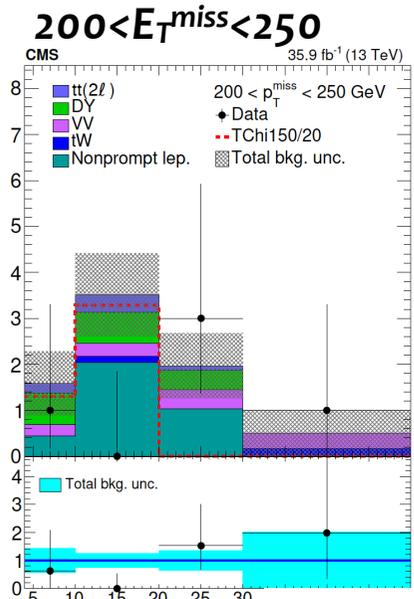


tt̄(2ℓ) : normalized to data in control region, shapes from MC

DY->ττ: normalized to data in control region, shapes from MC

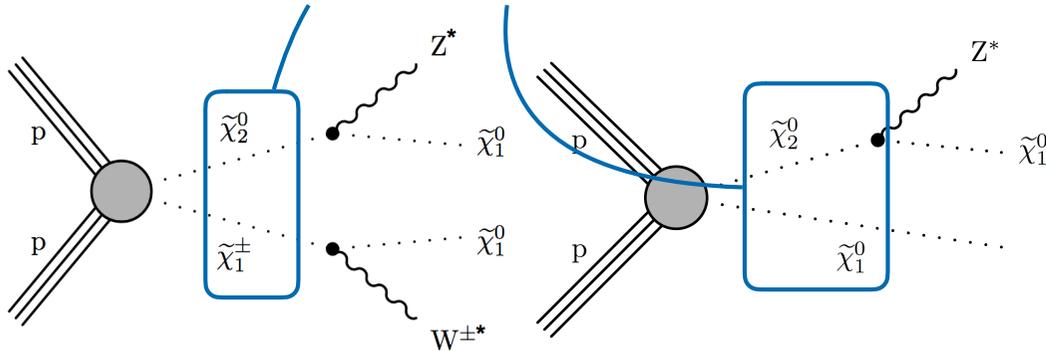
VV (mainly WW/WZ) : from MC, validated in data control region

Non-prompt prediction from tight-to-loose method, constraint in same-sign ℓ CR

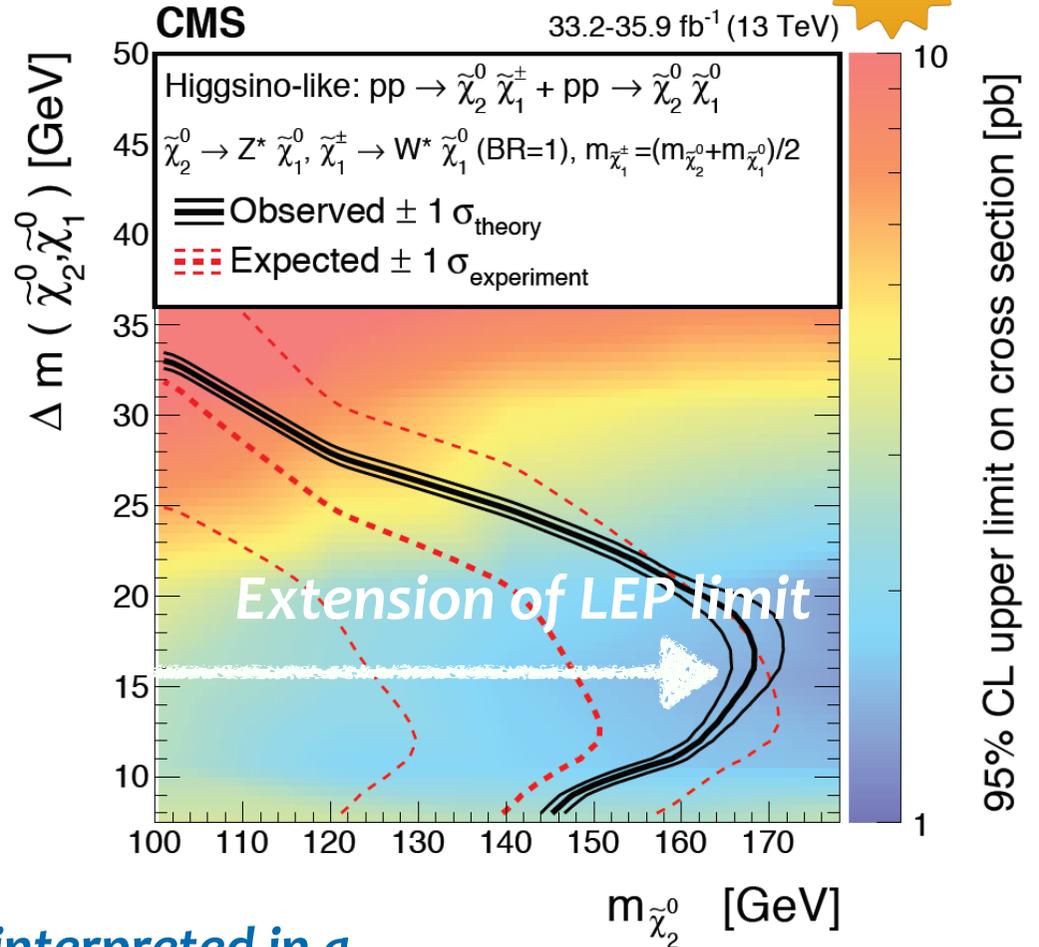
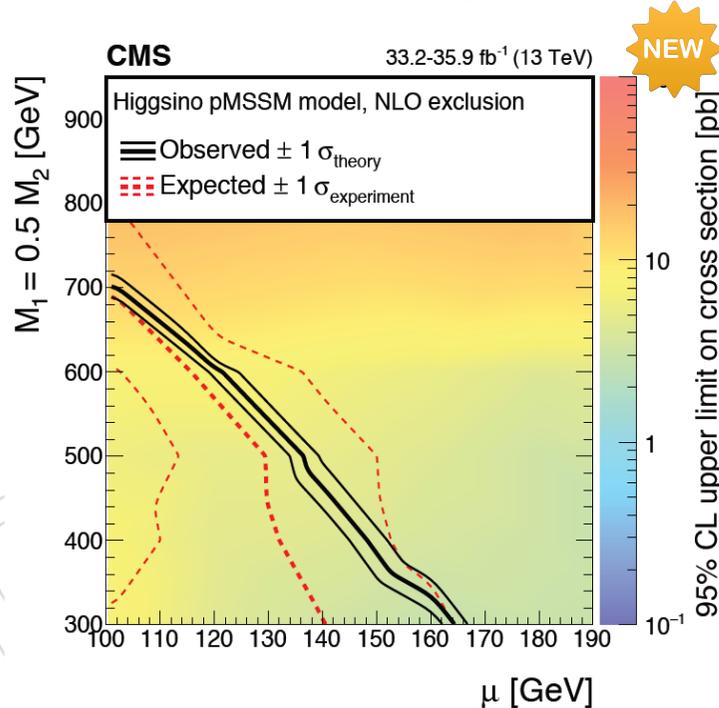


Interpretations

Higgsino-like^[1] production cross section



100% BR into Z*/W*, other SUSY particles assumed to be heavy and decoupled

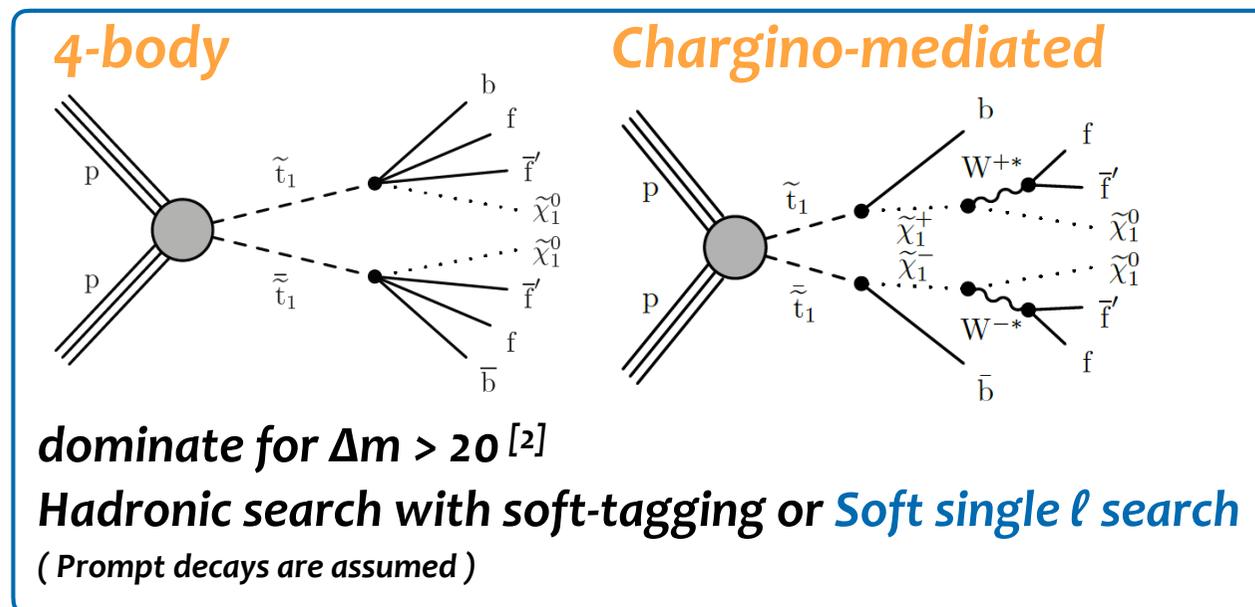


Results also interpreted in a phenomenological MSSM model:
 μ(higgsino), M1 (bino) are varied,
 M2 (wino) = 2M1

[1] B. Fuks et al. “Realistic simplified gaugino-higgsino models in the MSSM”, arXiv:1710.09941

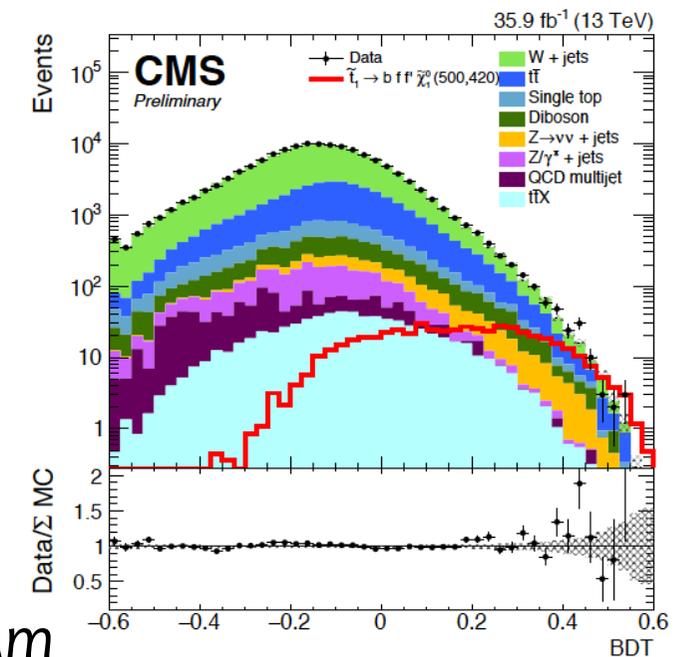
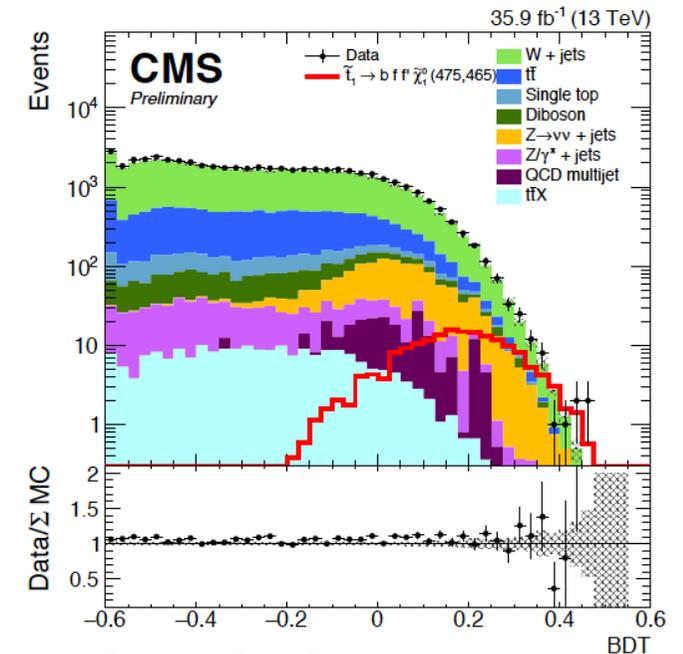
The case for ‘compressed’ stops

- **Stops expected lighter than other squarks:** mixing of the mass matrix and large Yukawa couplings
- **Cosmological observations** suggest **co-annihilation with lightest stop**^[1]
 - $\Delta m(\tilde{t}_1, \text{LSP}) \sim 15\text{-}30 \text{ GeV}$
- Search for **compressed stops:** $\Delta m < m_W$
 - **same strategy:** ISR jet to boost the sparticle pair, detect soft products



Soft single lepton search

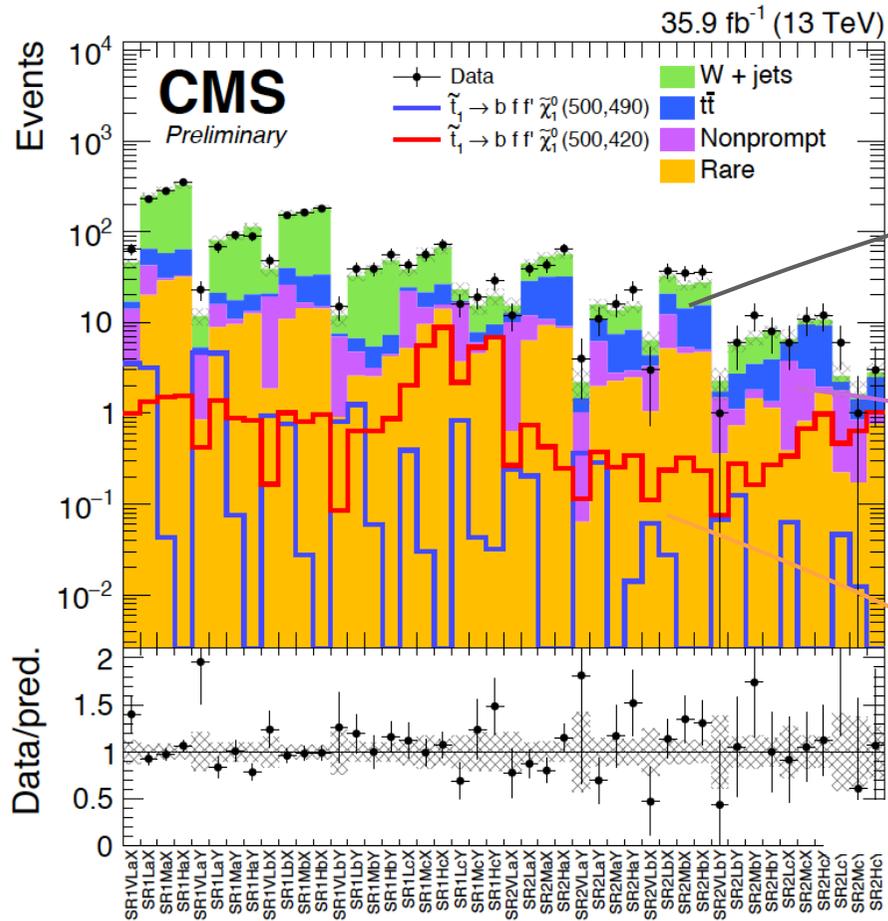
- One isolated and prompt $\mu(e)$ $p_T > 3.5(5)$ GeV, ISR jet, $E_T^{\text{miss}} > 200$ GeV
- Bkg reduction:
 - $H_T > 200$ GeV, against W+Jets
 - At most two hard jets ($p_T > 60$ GeV) against $t\bar{t}$
 - Veto second μ, e, τ $p_T > 20$ GeV
- Signal extraction based on input variables:
 - $E_T^{\text{miss}}, p_T(\ell), M_T(p_T(\ell), E_T^{\text{miss}}), N_{b\text{-loose}}, p_T(j_1), p_T(b), \eta(\ell), Q(\ell), N_{\text{jets}}, H_T, \Delta r(\ell, b), \text{Disc}(b)$
- Two approaches:
 - **Cut&Count:** SR bins to provide sensitivity for different $\Delta m(\tilde{t}_1, \text{LSP})$ and \tilde{t}_1 decays
 - **MVA:** target 4-body decay, BDT trained for different $\Delta m(\tilde{t}_1, \text{LSP})$, 8 SR from BDT $> X$ for each Δm



[CMS-SUS-PAS-17-005]

Results

Cut&Count SRs



W+jets (70%) and $t\bar{t}$ (20%)

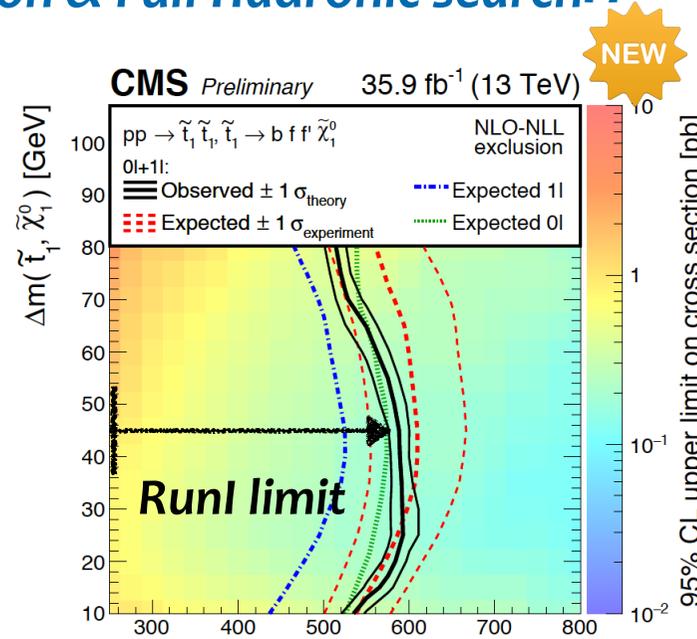
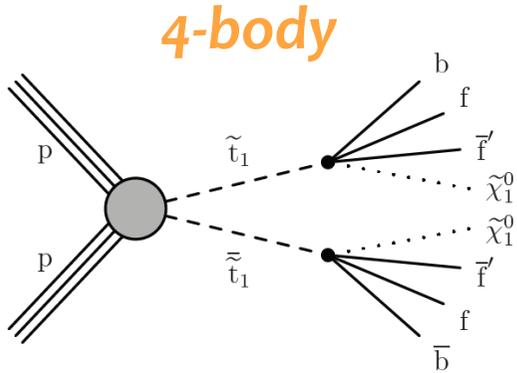
normalized to
data in high $p_T(\ell)$ region
(cut&count) or low BDT
region (MVA)

Non prompt lepton
bkg (QCD, Z->vv+jets)
from data with
tight-to-loose method

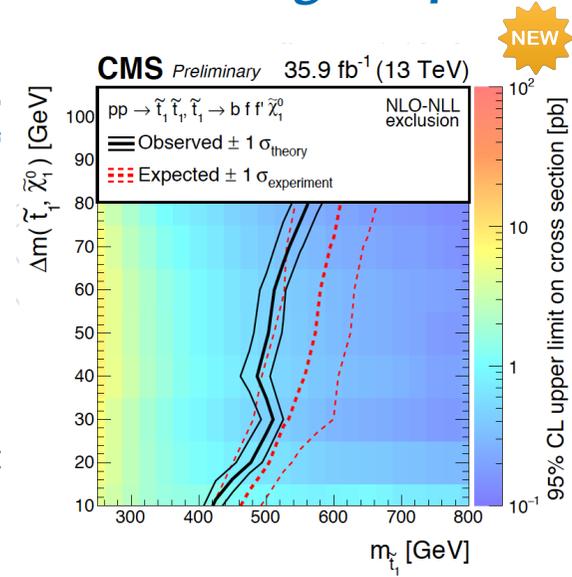
Rare processes: DY, diboson, single-top, ttX

Interpretations

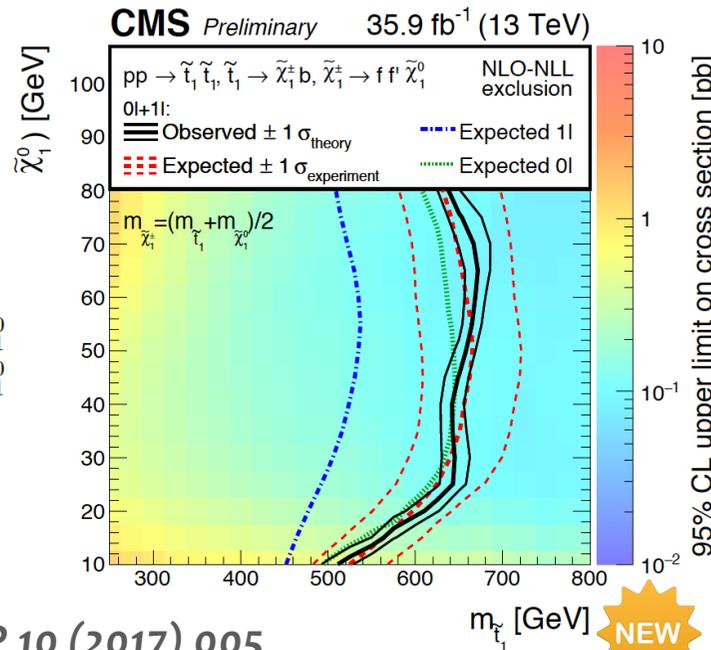
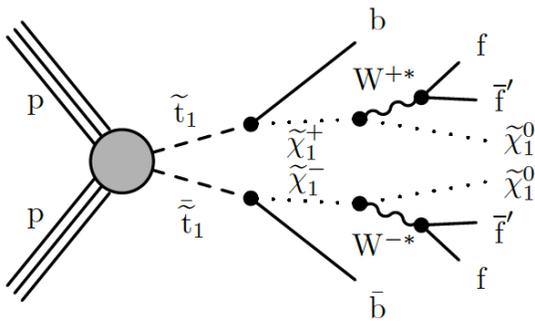
CC Single Lepton & Full Hadronic search^[1]



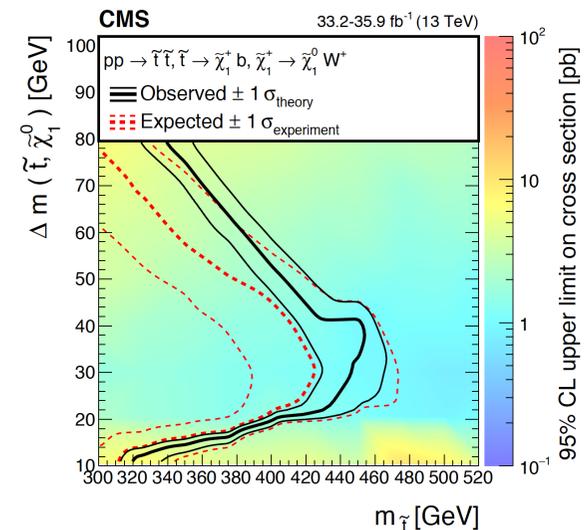
MVA Single Lepton search



Chargino-mediated



Soft opposite sign dilepton (including the eμ final state)



[1] CMS-SUS-PAS-16-049, JHEP 10 (2017) 005

Conclusions

- Several theory motivations to search for:
 - **light and compressed Higgsinos:** $m(\tilde{H}) \sim 100\text{-}300 \text{ GeV}$, $\Delta m(\tilde{\chi}_i, \tilde{\chi}_j) \sim 1\text{-}50 \text{ GeV}$
 - **light and compressed stop quarks:** $m(\tilde{t}_1) < 1 \text{ TeV}$, $\Delta m(\tilde{t}_1, \text{LSP}) < m_W$
- Challenging signatures: **low E_T^{miss} and soft decay products**
- **Using ISR boost and soft leptons reconstruction we have already explored a good portion of this phase space**
- In contrary of mainstream SUSY searches which deal with high p_T objects in the tails of the E_T^{miss} , in these corners **new approaches and ideas, such as soft-lepton triggers, have been applied and can bring further improvements.**