Search for Supersymmetry in Models with Highly Compressed Mass Spectra in the Soft Single Lepton Channel with the CMS Experiment

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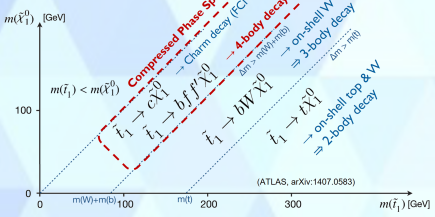
We perform a search for Supersymmetry (SUSY) with a highly compressed mass spectrum using the 2016 dataset of proton-proton collisions at $\sqrt{s}$ = 13 TeV, recorded by the CMS detector and corresponding to an integrated luminosity of 35.9 fb^{-1}.

Compressed SUSY

Even though wide regions have been excluded with recent LHC Run II results, there are several 'crevasses' of parameter space where she could still be hiding.

Natural SUSY favours relatively light top squarks (stops) and the co-annhilation of light stops and LSPs can reproduce the correct cosmological DM abundance ⇒ small mass differences Δm between the stop and LSP are well motivated:

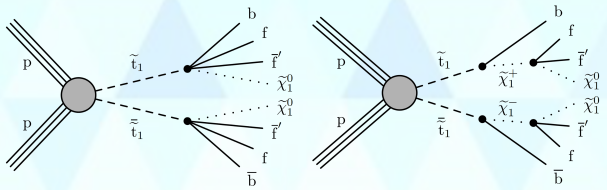
$$\Delta m \equiv m_{stop} - m_{LSP} < m_W$$



(We also consider the decay with an intermediate chargino)

Simplified Models

We interpret in a Simplified Model (SMS), decoupled from the particular multi-parameter SUSY theory with a reduced particle content. The signal models our analysis considers involve the pair-production of stops. We consider the single-lepton topology. The neutralino ($\tilde{\chi}_1^0$) is considered as the LSP. The neutralinos and the neutrino escape the detector and are detected in the form of E_T^{miss}.



Four-body stop decay *into a lepton and neutrino (quark-antiquark pair), b-quark jet and LSP*

Chargino-mediated stop decay *(chargino mass assumed halfway between stop and LSP)*

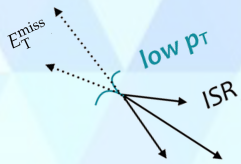
The SMS assume a 100% branching ratio to stop decays as well as prompt decays of the stops.

Analysis Strategy

Compressed regions are challenging to study, as the visible decay products have low momentum and generally do not pass detector acceptance thresholds.

This difficulty can be mitigated by the system being boosted by initial-state radiation (ISR), allowing the decay products to become detectable.

The signal events are characterised by:
- a low-momentum lepton
- a high-momentum jet (ISR)
- moderate missing transverse energy (E_T^{miss})



The analysis strategy is based on a sequential selection on discriminating variables: "Cut & Count"

Event Selection

- The **trigger** selects events with moderate E_T^{miss} > 120 GeV during data taking
- **Preselection** cuts applied: high E_T^{miss} and H_T, leading jet p_T > 100 GeV, veto on extra hard (p_T > 20 GeV) leptons and QCD-multijet rejection, to focus on relevant parameter space
- **Signal Regions** (**SRs**) chosen to enhance signal-to-background ratio

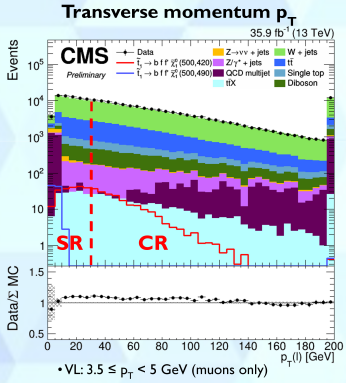
→ two sets of SRs targeted at different Δm's defined by a soft lepton with p_T < 30 GeV:

SR1 (low Δm):
- Veto b-jets (too soft to detect)
- Lepton |η| <1.5

SR2 (high Δm):
- Allow for a soft (30 < p_T < 60 GeV) b-jet

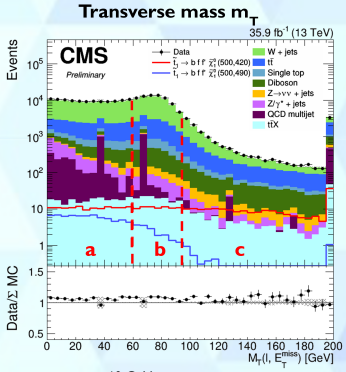
Common cuts:
- Bins in lepton p_T: VL, L, M, H
- Bins in m_T regions (a, b, c) around W-peak
- Correlation between E_T^{miss} and H_T is exploited and a simultaneous selection (C_T) is applied
- Events with only negatively charged leptons are selected in almost all SR bins, to take advantage of the charge asymmetry of W boson production

Transverse momentum p_T



- VL: 3.5 ≤ p_T < 5 GeV (muons only)
- L: 5 ≤ p_T < 12 GeV
- M: 12 ≤ p_T < 20 GeV
- H: 20 ≤ p_T < 30 GeV

Transverse mass m_T



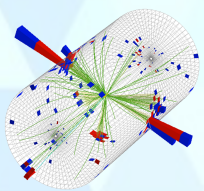
- a: m_T < 60 GeV
- b: 60 ≤ m_T < 95 GeV $M_T = \sqrt{2E_T^{miss} P_T (1 - \cos(\Delta\phi))}$
- c: m_T ≥ 95 GeV

Background Estimation

The estimation of the dominant backgrounds in the analysis is performed with a combined approach, using both data and Monte-Carlo (MC) simulation.
Control Regions (**CRs**) are chosen such that they are dominated by the relevant backgrounds, from which one can make a precise extrapolation to the SRs.

Prompt

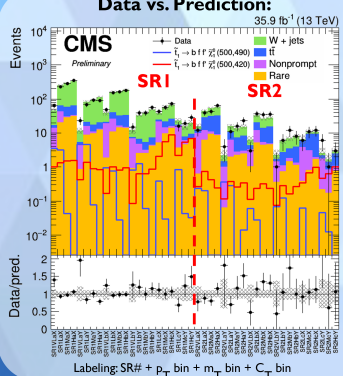
Estimation of the dominant **prompt** backgrounds, originating mainly from **W+Jets** and **tt-bar**:
- CRs defined by inverting the lepton p_T selection (p_T > 30 GeV), with one CR associated to each SR
- Data vs. simulation scale factors determined in CRs
- Scale factors applied to the simulation yields in the SRs to find the expected background contribution
- Method tested in various adjacent **Validation Regions** (**VRs**), defined in sidebands of C_T and b-jet multiplicity



Nonprompt

Estimation of the **nonprompt** backgrounds, originating mainly from **QCD-multijet** and **Z→νν**:
- Probability that a nonprompt lepton passes the analysis cuts, "Tight-to-Loose" ratio ε_{TL}, determined in a QCD-enriched **Measurement Region** (**MR**)
- "Tight" = final leptonic selection used in the analysis
- "Loose": relaxed isolation and impact parameter (d_{xy}, d_z) requirements for leptons
- "Loose-not-Tight" **Application Regions** (**ARs**) created around SRs by requiring that the lepton passes the "Loose" but fails the "Tight" criteria
- ARs reweighted using the ε_{TL} ratio to determine the expected contribution in the SRs

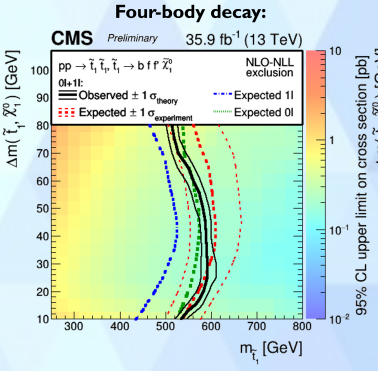
Data vs. Prediction:



Results

- Several sources of background and signal **systematic uncertainties** are taken into account, such as the MC modelling of lepton p_T and jet multiplicity distributions in W+Jets and tt-bar
- The predicted yields in the SR bins are compared to observation from 35.9 fb^{-1} of data
→ no significant deviation from the SM is observed
- Therefore, upper **limits** are set on the top squark pair-production cross section at 95% confidence level, excluding stop masses up to ≈ 500 GeV, depending on the Δm and model
- The single-lepton limits (blue) are combined (red) with the results (green) of the all-hadronic channel analysis (CMS-PAS-SUS-16-049 and JHEP10(2017)005)

Four-body decay:



Chargino-mediated decay: