Searching for supersymmetry with compressed mass spectra at CMS

Robyn Lucas, Imperial College London & RAL

IoP HEPP and APP Group Meeting, Royal Holloway

7-9 April 2014

Imperial College London

Science & Technology Facilities Council
Rutherford Appleton Laboratory

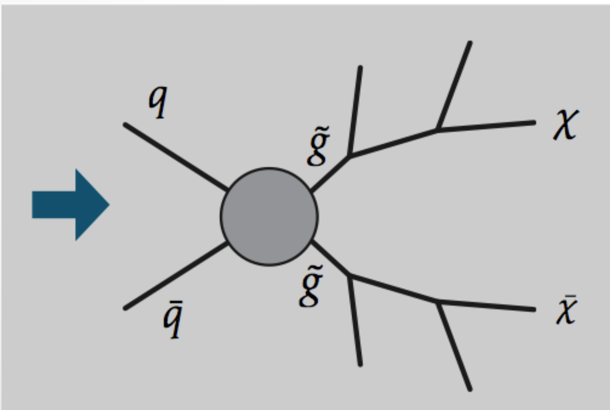
Outline

- What is compressed SUSY?
- How can we look for it?
- Stop -> charm + LSP search

Compressed SUSY

- SUSY has potential to solve many of problems in the standard model, but searches to date look distinctly SM-like

- The difficulty is, don't know what form SUSY takes, if it exists. Searches general as possible; look for a variety decay channels & final states in effort to squeeze parameter space



SUSY decay chain: final state jets, leptons, photons + large MET; Might it be 'hidden' such that traditional searches have been blind to it?

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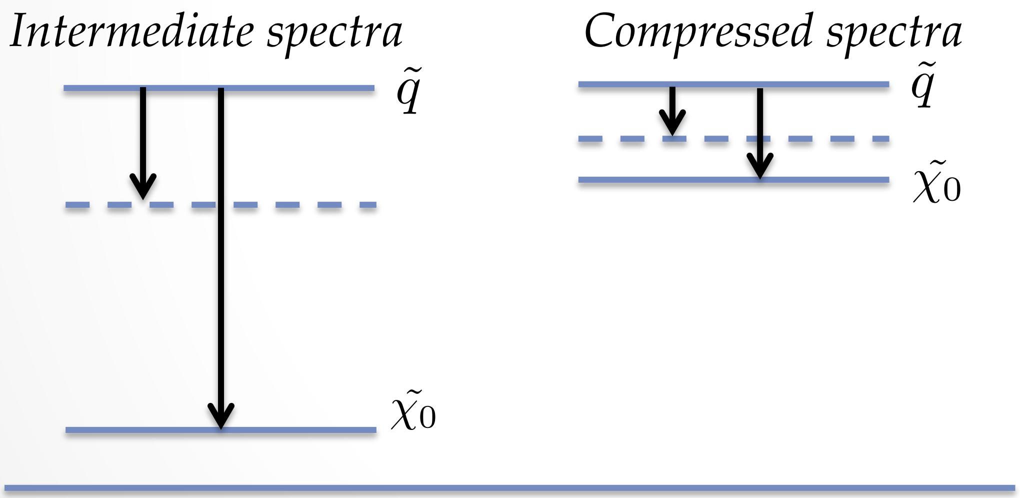
Compressed SUSY

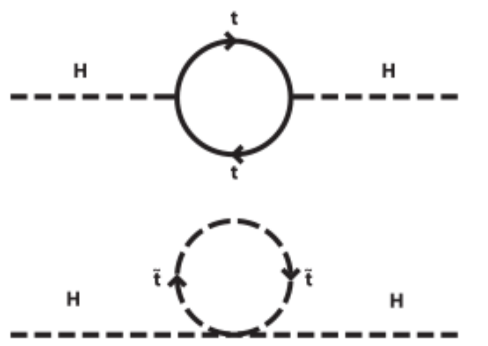
- If mass spectrum of SUSY model more compressed, i.e. parent SUSY particle close in mass to LSP, have **compressed spectra:** less visible energy in final state
  - Smaller p_T, smaller H_T, MET
  - Very hard to distinguish between signal and QCD, ttbar, electroweak backgrounds



Compressed SUSY

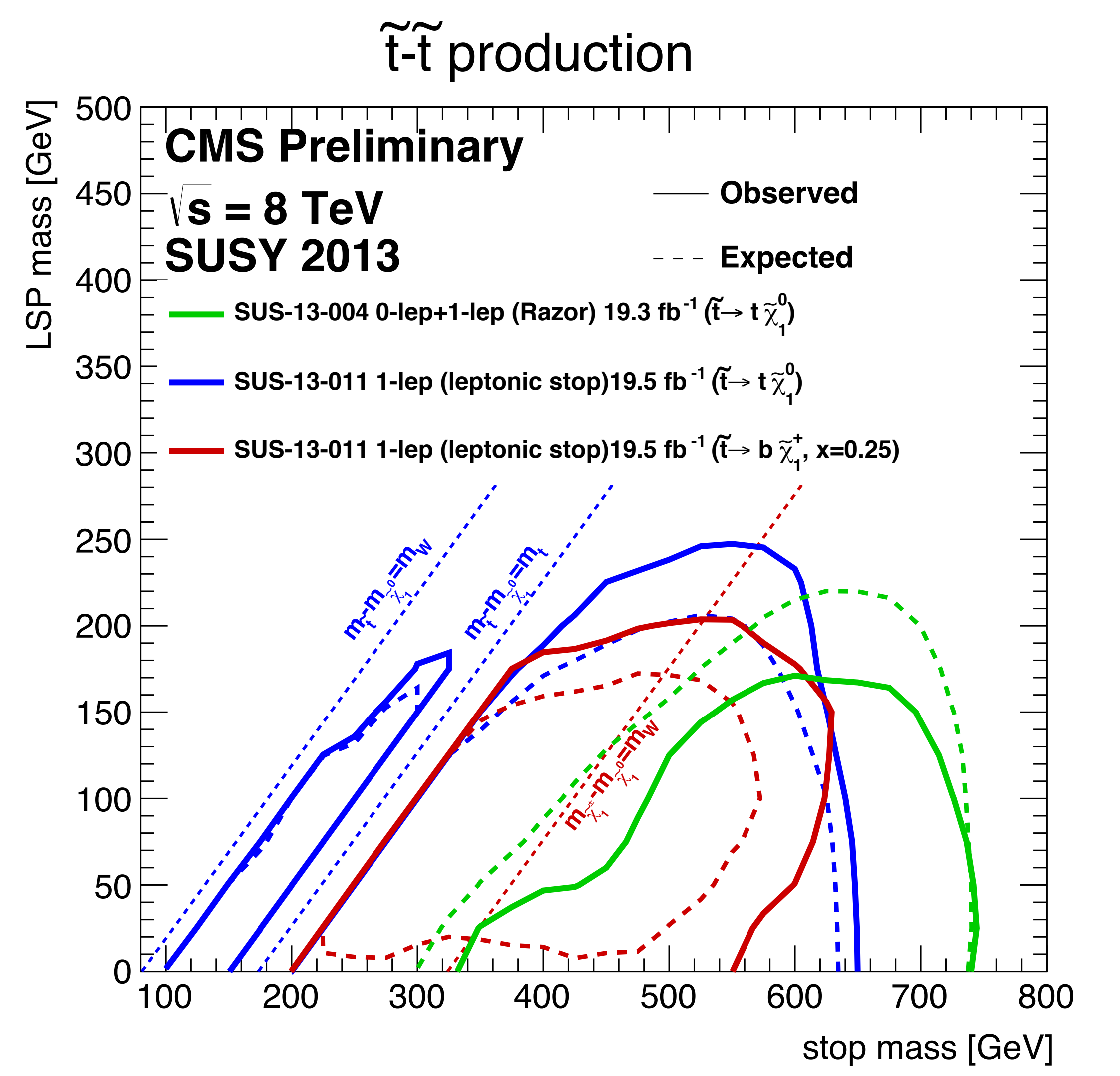
- Compressed SUSY in third generation particularly well motivated:

- Radiative corrections to Higgs mass (to one loop order) given by third generation (s)quarks: for 'natural' SUSY, stop must be close in mass to top ie. light

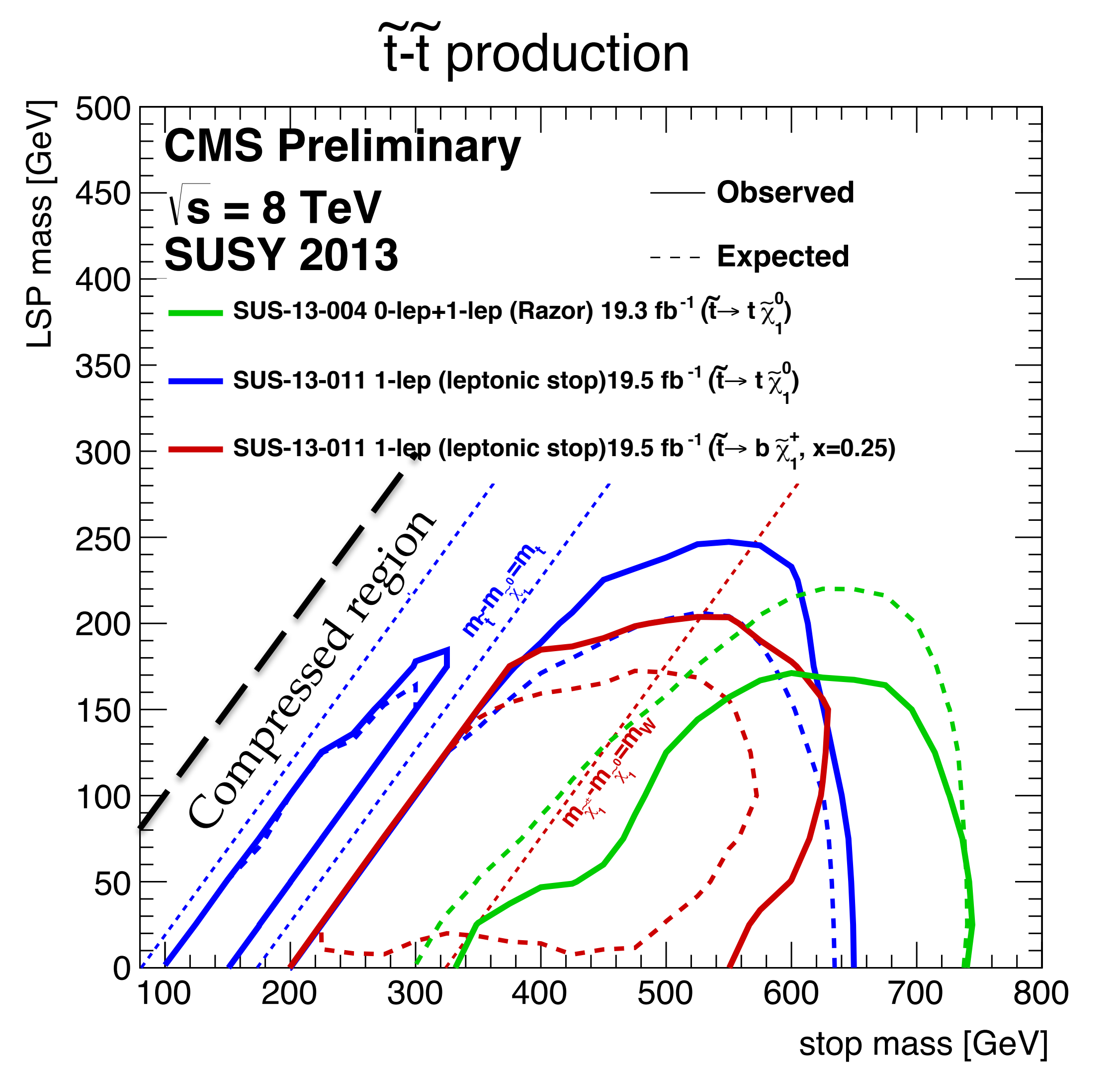


- LSP good dark matter candidate; acceptable relic density given in certain scenarios if stop close in mass to LSP
- Electroweak baryogenesis can be realized

Stop searches at CMS



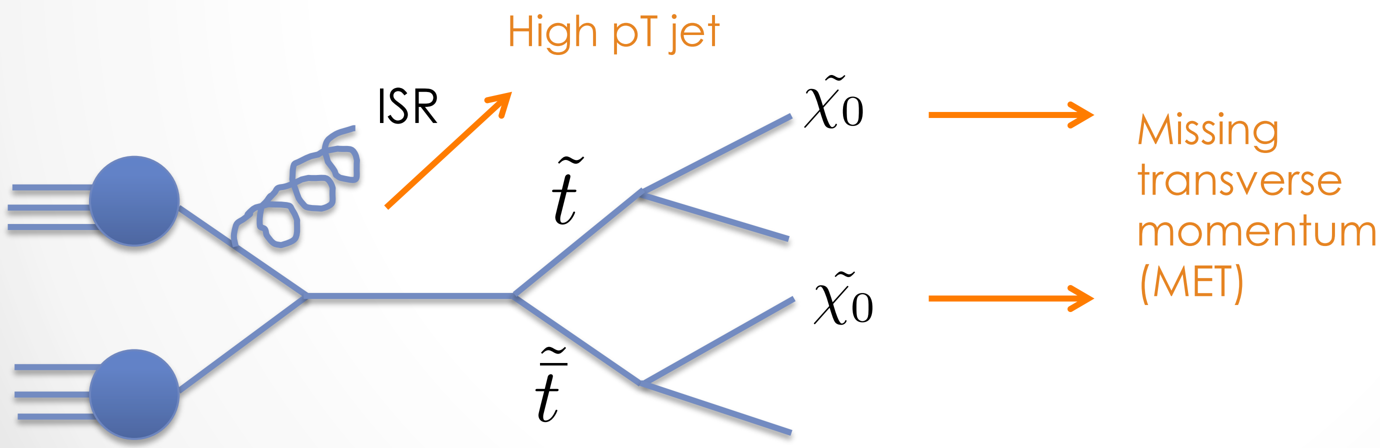
Stop searches at CMS

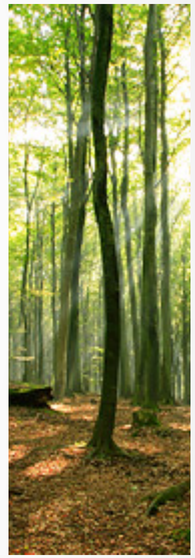


How can we search for compressed spectra at CMS?

- Traditional searches not sensitive in compressed region; soft final states indistinguishable from backgrounds

- Look for objects produced *in association* with stops: boosted events with an **initial state radiation (ISR)**





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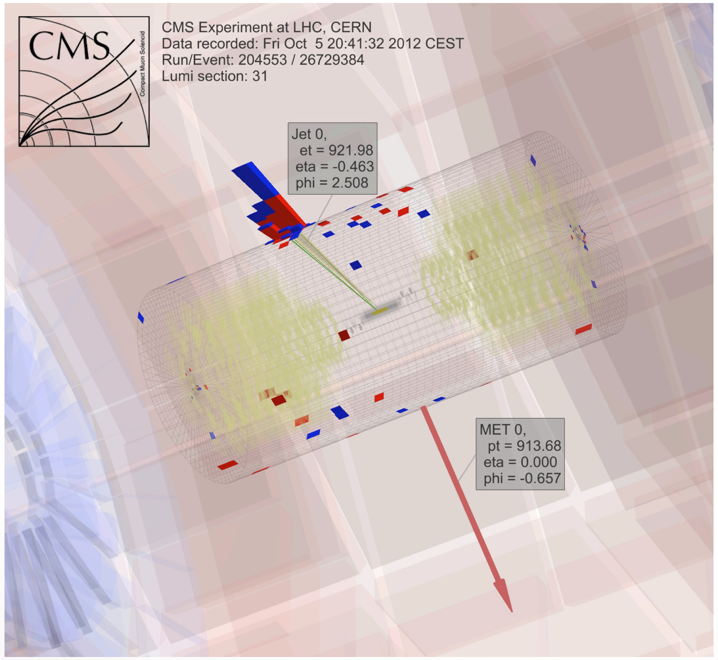
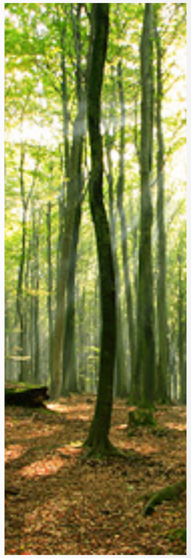




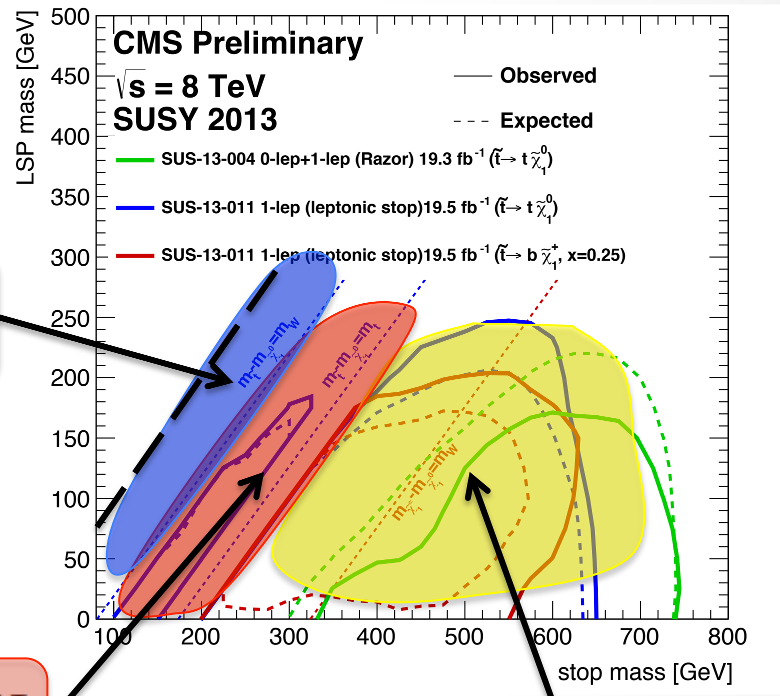
Compressed Stop Decay

- Allowed stop decays:

In compressed region
W is off shell
For light stops close in mass to LSP, dominant decay mode is FCNC loop induced decay

$$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$$

$$\tilde{t} \rightarrow c\tilde{\chi}_0$$



$$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^0 W$$

$$\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$$

Move away from the diagonal, final state decay products become more energetic and traditional searches regain sensitivity

Search for $\tilde{t} \to c\tilde{\chi}_0$

CMS-PAS-SUS-013-009, http://cds.cern.ch/record/1644584

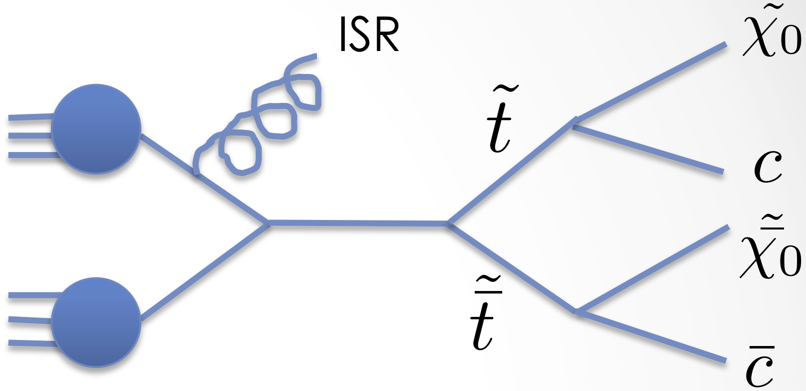
Search for top squarks decaying to a charm quark and a neutralino in events with a jet and missing transverse momentum

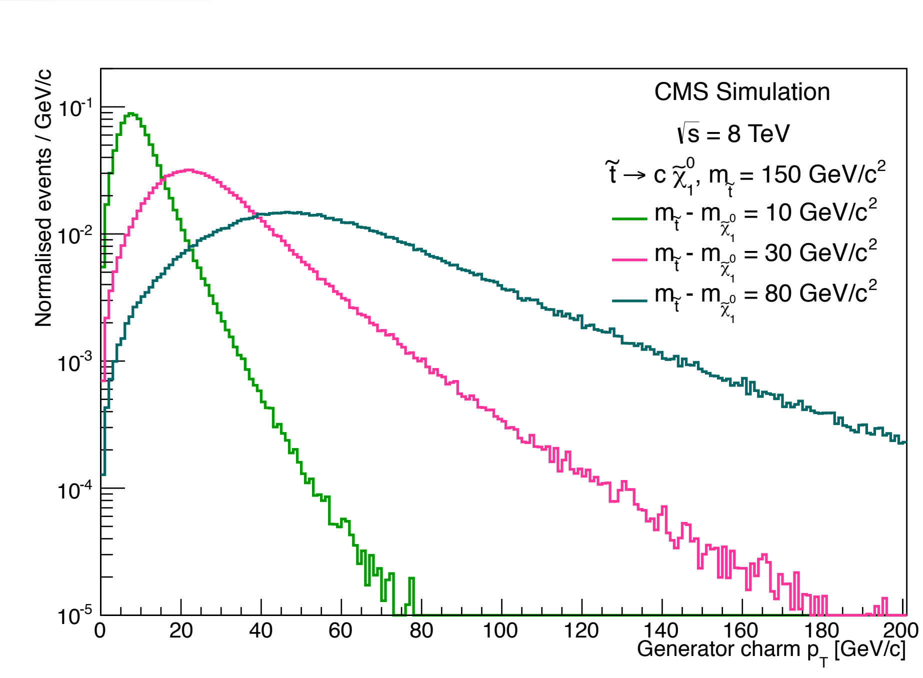
Use 19.7 fb^{-1} of pp collisions at 8 TeV to search for stop pair production, assuming 100% BF to $\tilde{t}_1 \to c\tilde{\chi}^0_1$, interpreting results using Simplified Model Spectra

- Re-optimisation of the well established CMS monojet analysis

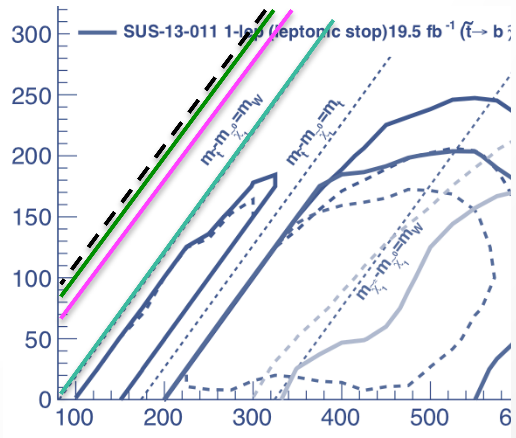
Search for $\tilde{t} \rightarrow c\tilde{\chi}_0$

- pT(j1) > 110 GeV & MET > 250 GeV
- N_{jet} < 3 & $\Delta\varphi$ (j1, j2) < 2.5
- Veto events with e, μ, hadronic τ
- Signal regions: pT(j1)>250, 300, 350, 400, 450, 500, 550 GeV





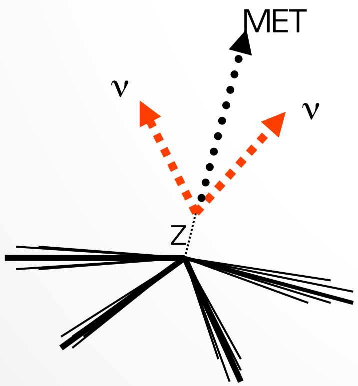
Get an invisible final state by cutting out (soft) charm jets & maintain monojet signature for range of mass differences: only count jets > 60 GeV



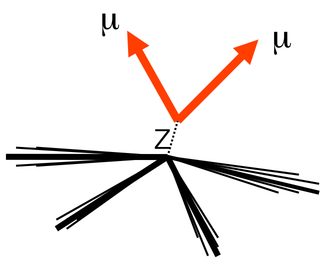
Background estimations

- Estimate main SM processes in signal regions using **data driven background estimates:**
  - Define **control region** where a SM background dominates
  - Measure number of events here & infer number of events due to SM background in signal regions
  - Exploit kinematically similar background in control region & use **replacement technique:**

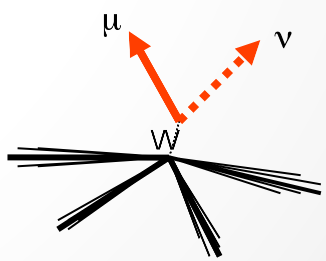
Largest irreducible background from Z(νν)+jets events:



Define control region rich in Z(μμ)+jets events & extrapolate to Z(νν)+jets events in signal region:



Use similar method of W(μν)+jets events to estimate W+jets background:

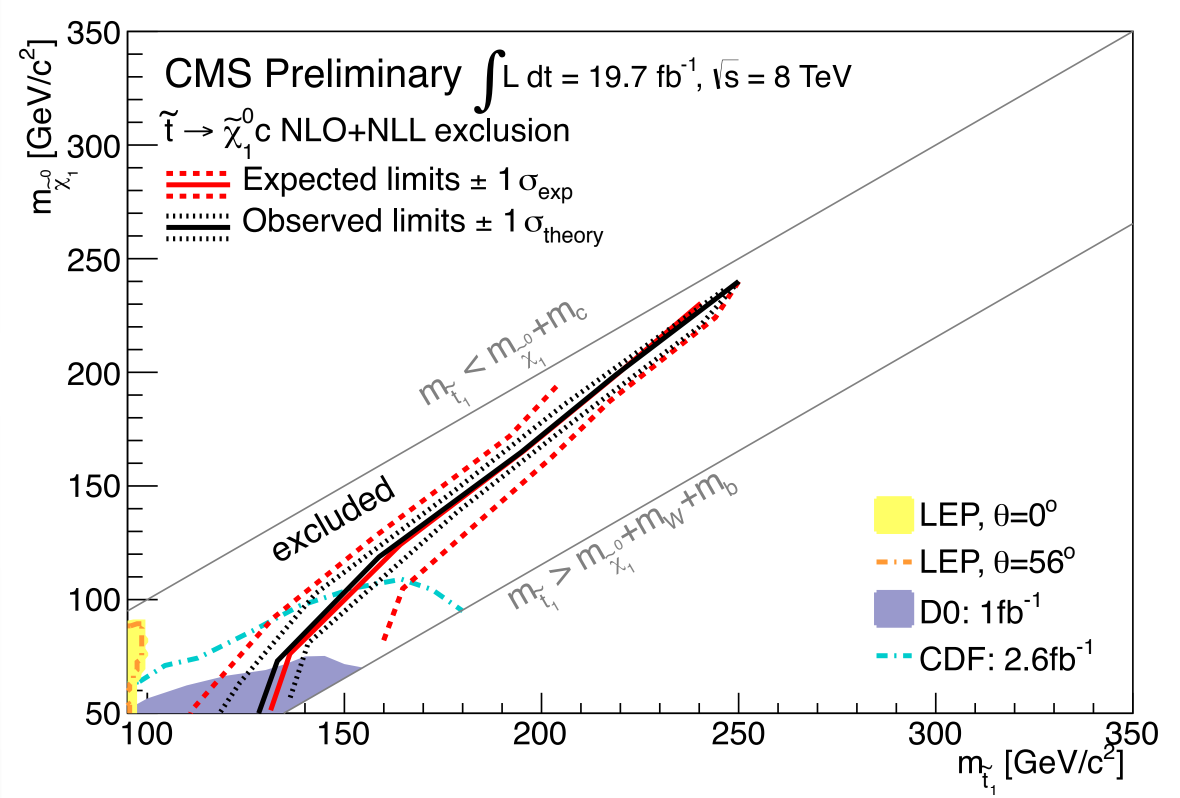


Results

$p_T(j_1)$ [GeV/c]	>250	>300	>350	>400	>450	>500	>550
Z(νν)	21209±1115	10077±592	4597±324	2250±197	1250±137	663±94	334±65
W+jets	12328±707	5939±366	2690±180	1246±92	627±52	301±29	150±18
ttbar	602±301	344±172	178±89	91±46	48±24	27±14	18±9.0
Z(ll)+jets	127±64	75±38	40±20	25±13	17±8.3	11±5.6	7.4±3.7
Single t	172±86	97±49	49±24	21±10	11±5.7	5.2±2.6	3.2±1.6
QCD	786±473	508±306	304±184	162±99	80±49	52±32	28±18
Diboson	639±320	36±184	206±103	113±56	64±32	36±18	21±10
Total SM	**35862 ± 1474**	**17409 ± 803**	**8064 ± 437**	**3907 ± 250**	**2098 ± 160**	**1096 ± 106**	**563 ± 71**
Data	**36582**	**17646**	**8119**	**3896**	**1898**	**1003**	**565**

Limit: (m_{stop}, m_{LSP})

Limits set on (m_{stop}, m_{LSP}) mass plane:



Final state is invisible:

set limits right up **to mass differences 0 GeV**, where events most 'monojet' like; advantage of this search for compressed spectra

Conclusions

- Compressed supersymmetry well motivated & a possibility for hidden SUSY
- New analysis techniques are being developed to cope with the challenges it presents

- Monojet signal a powerful tool for compressed scenarios, though (sadly) no deviation from SM observed

- Set limits for stop mass < 250 GeV for mass differences, m(stop) – m(LSP) < 10 GeV

Backup

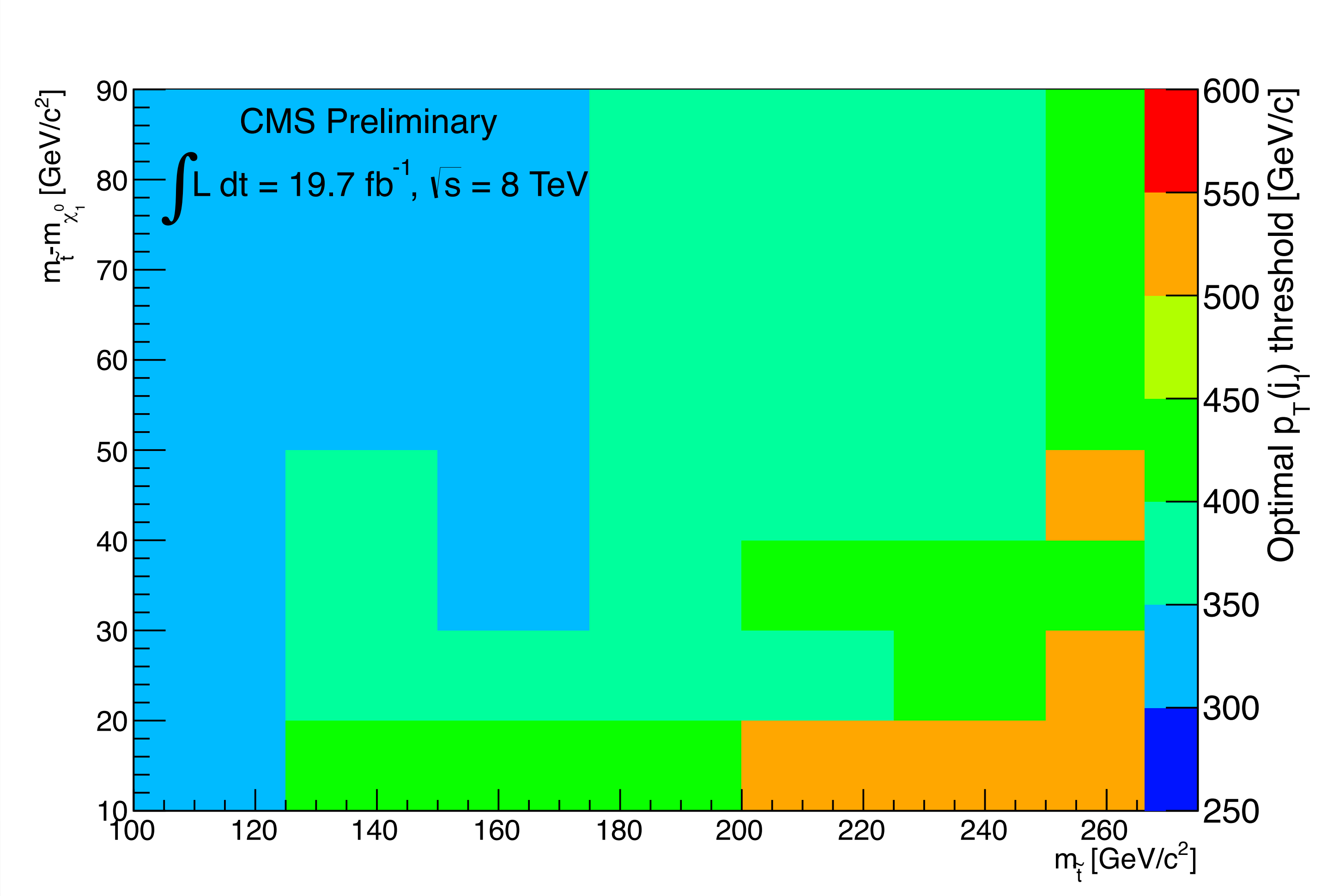
Signal

- Calculate the signal acceptance of model in each of the signal regions
- Analysis relies on accurate ISR modelling: apply 0.8 correction to acceptances as jets highly boosted; MADGRAPH overestimates highly boosted ISR jets

- Estimate 95% credible interval for a signal cross section in counting experiment
- Assign 25% systematic error to signal acceptance
  - ISR systematic 20%
  - JES ~5%, PDF <2% systematic at one SUSY point (similar to DM models)
  - Difference in acceptance for 2 & 3 parton samples; < 4% for $p_T(j_1)$<500 GeV/c
  - Conservative 25% error assigned
- 19712 pb^{-1} luminosity with 2.6% error [LUM-13-001]

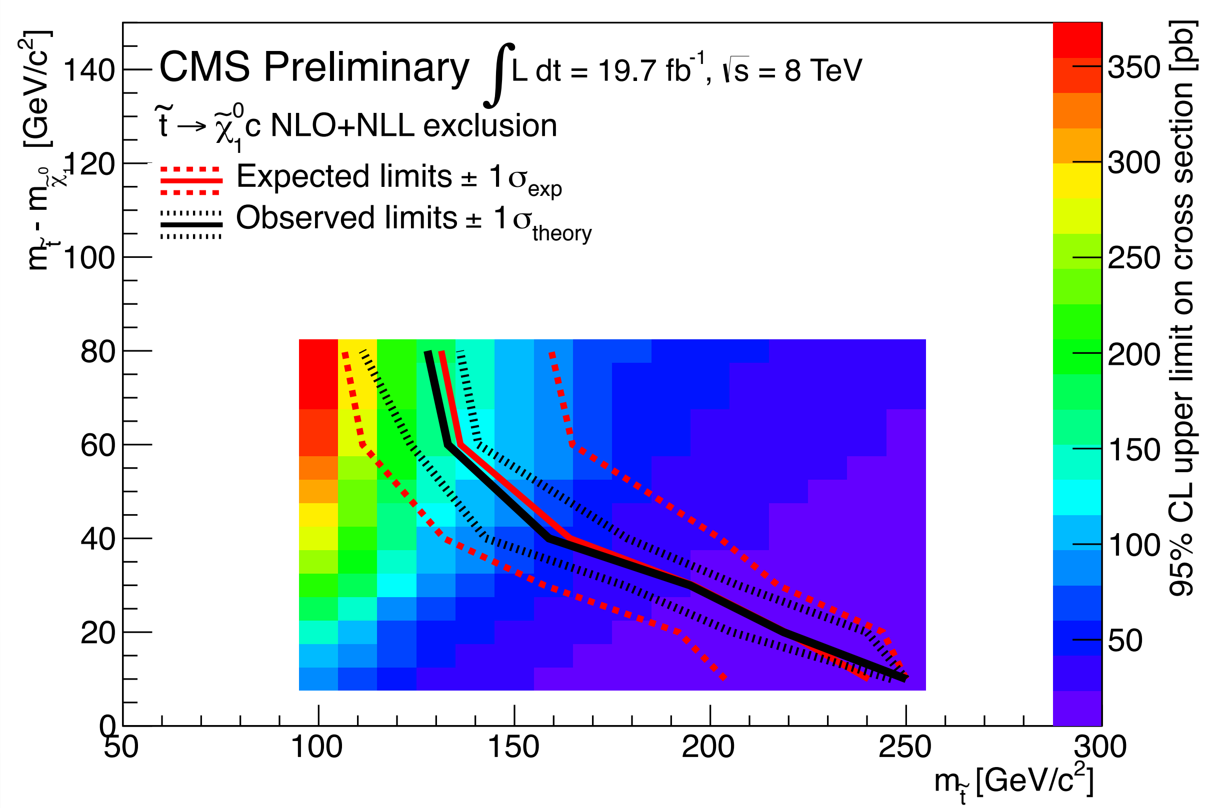
- Take search region in which get optimal expected limit for each mass point

Limit optimisation



Limit: (m_{stop}, Δm)

Limits set on (m_{stop}, m_{stop} - m_{LSP}) mass plane:



Temperature plot shows 95% CL observed limits in phase space range; lines show intersection with theory