Trilepton Signatures in the General MSSM

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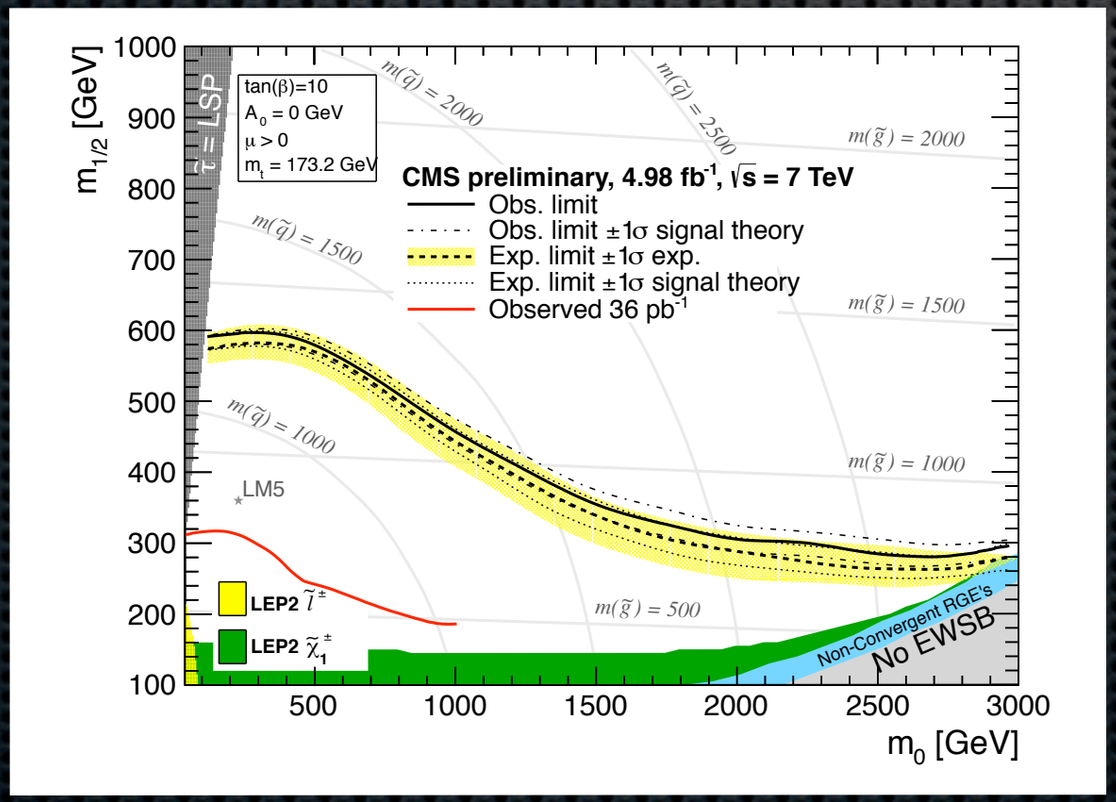
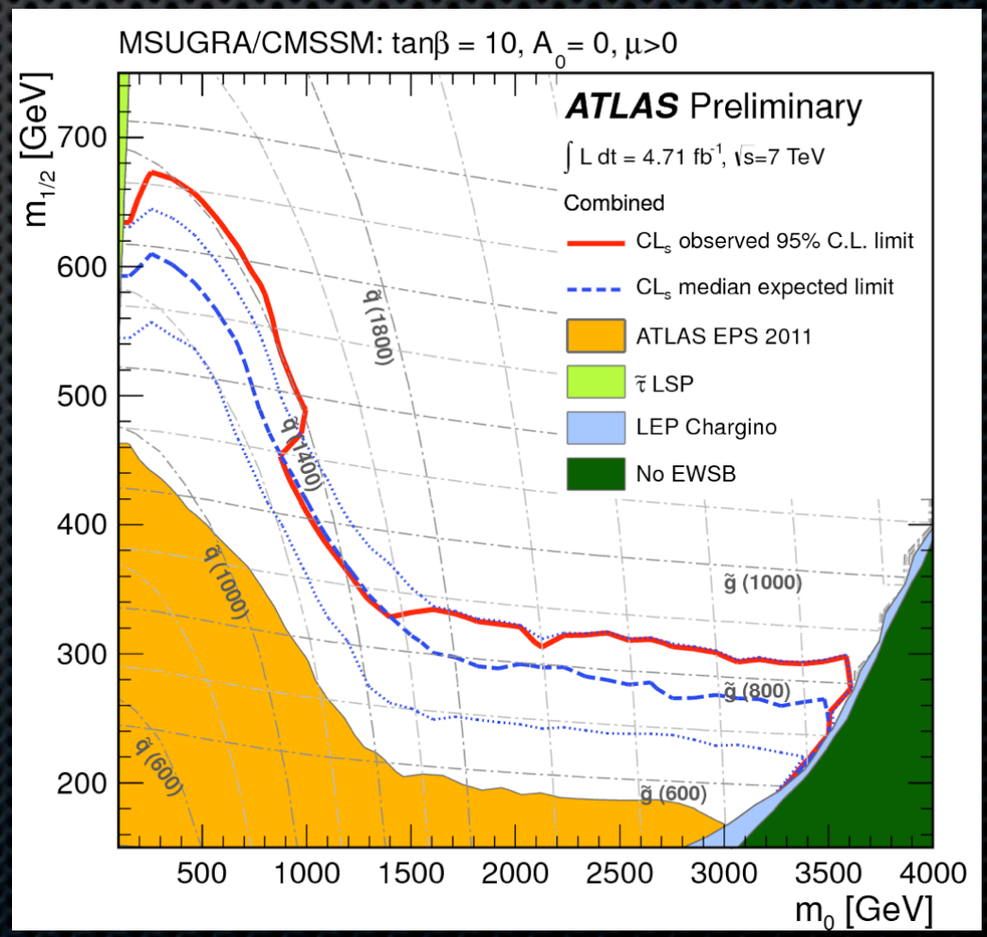
Work with Ed Berger and Zack Sullivan

SUSY Is Motivated!

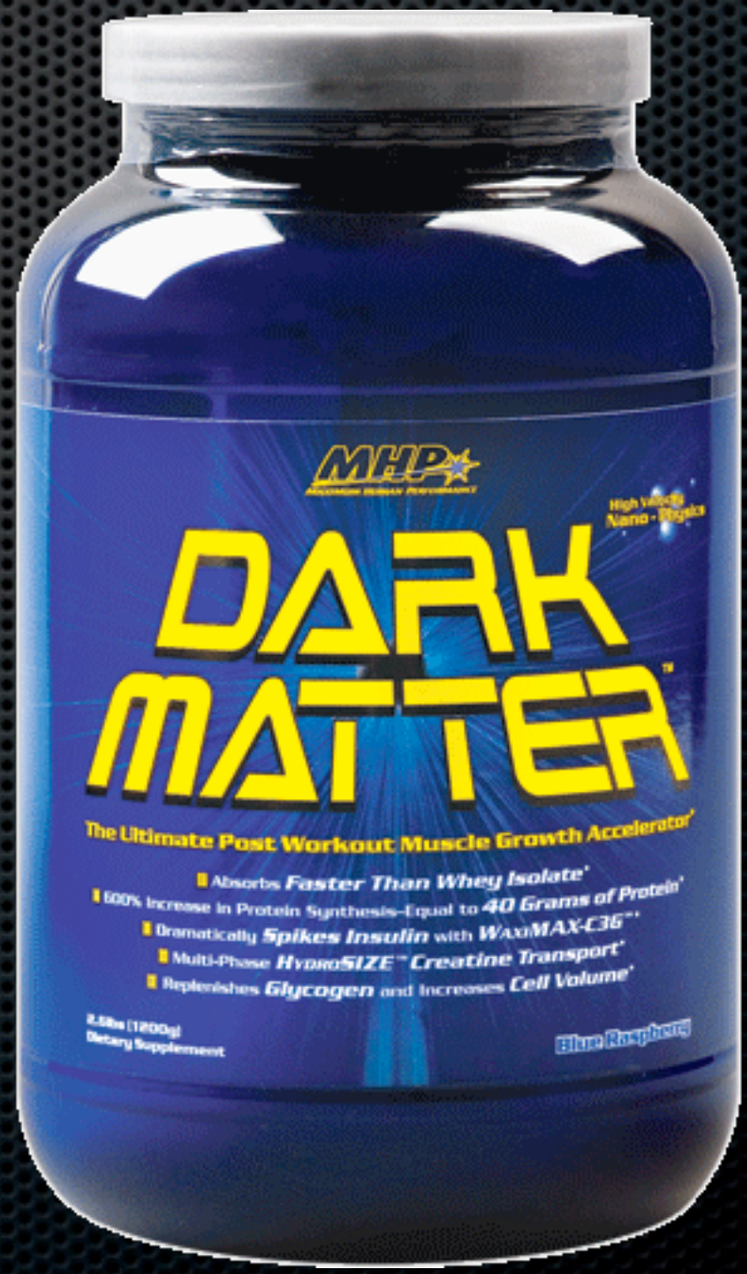
- Otherwise you wouldn't attending the "SUSY IV" session!
- But we haven't found it yet.





Focus on Electroweak

- LHC has greatest sensitivity to colored sparticles
- Limits on uncolored sparticles are much weaker
- But important- an LSP (e.g.) neutralino could be the dark matter



Scalars May Be Heavy

- Jet plus missing energy limits suggest heavy squarks
- $B_s \rightarrow \mu\,\mu$, $B \rightarrow \tau\,\nu$, $b \rightarrow s\gamma$, etc. suggest Higgses other than the lightest one are heavy
- Sleptons and staus could still be light, but inspired (?) by the apparent heaviness of squarks, we assume they are heavy as well
  - Maybe split SUSY, but really we just assume these states are heavy enough to ignore in the analyses I'll describe.

The pMSSM

- A general SUSY parameter space (not derived from a particular SUSY breaking scheme)
  - Some assumptions to keep number of parameters quasi-tractable

- Gaugino Masses: M_1, M_2, M_3
- μ, tan β
- Sfermion masses (10)
- Trilinears: A_t, A_b, A_τ
- m_A

Our pMSSM

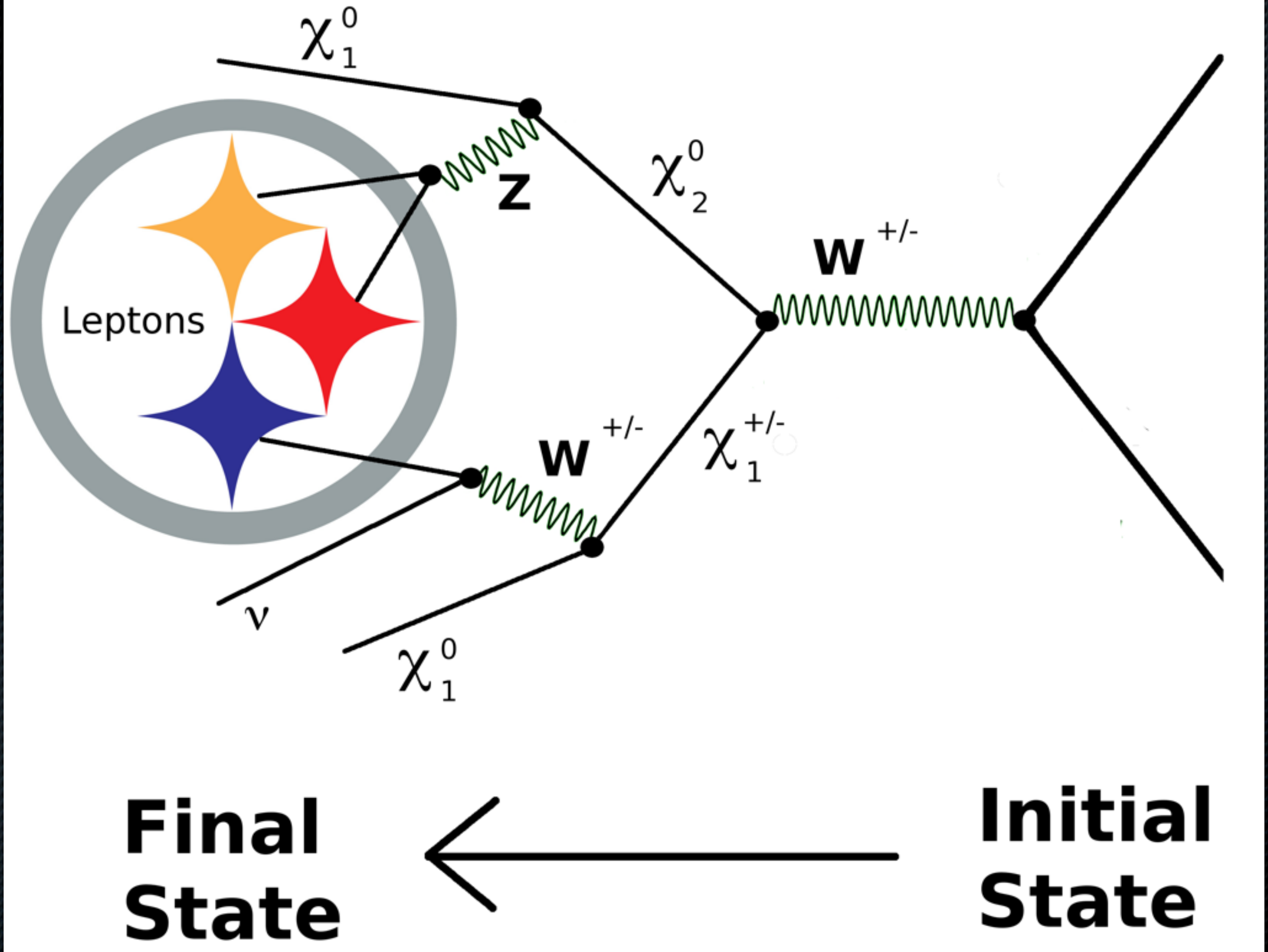
- With the assumption of heavy scalars (and gluino) the only parameters we need to describe the physics we are interested in are
  - **M_1, M_2, μ, tan β**
- We set the light Higgs mass to 125 GeV.
- Assume light Higgs is decoupled $\Rightarrow \beta - \alpha = \pi/2$

Our pMSSM

- The SUSY spectrum is (generally)
  - A Bino-like neutralino with mass |M1|
  - A Wino-like neutralino and a Wino-like chargino with masses |M2|
  - Two Higgsino-like neutralinos and a Higgsino-like chargino with masses |**μ**|

Trileptons

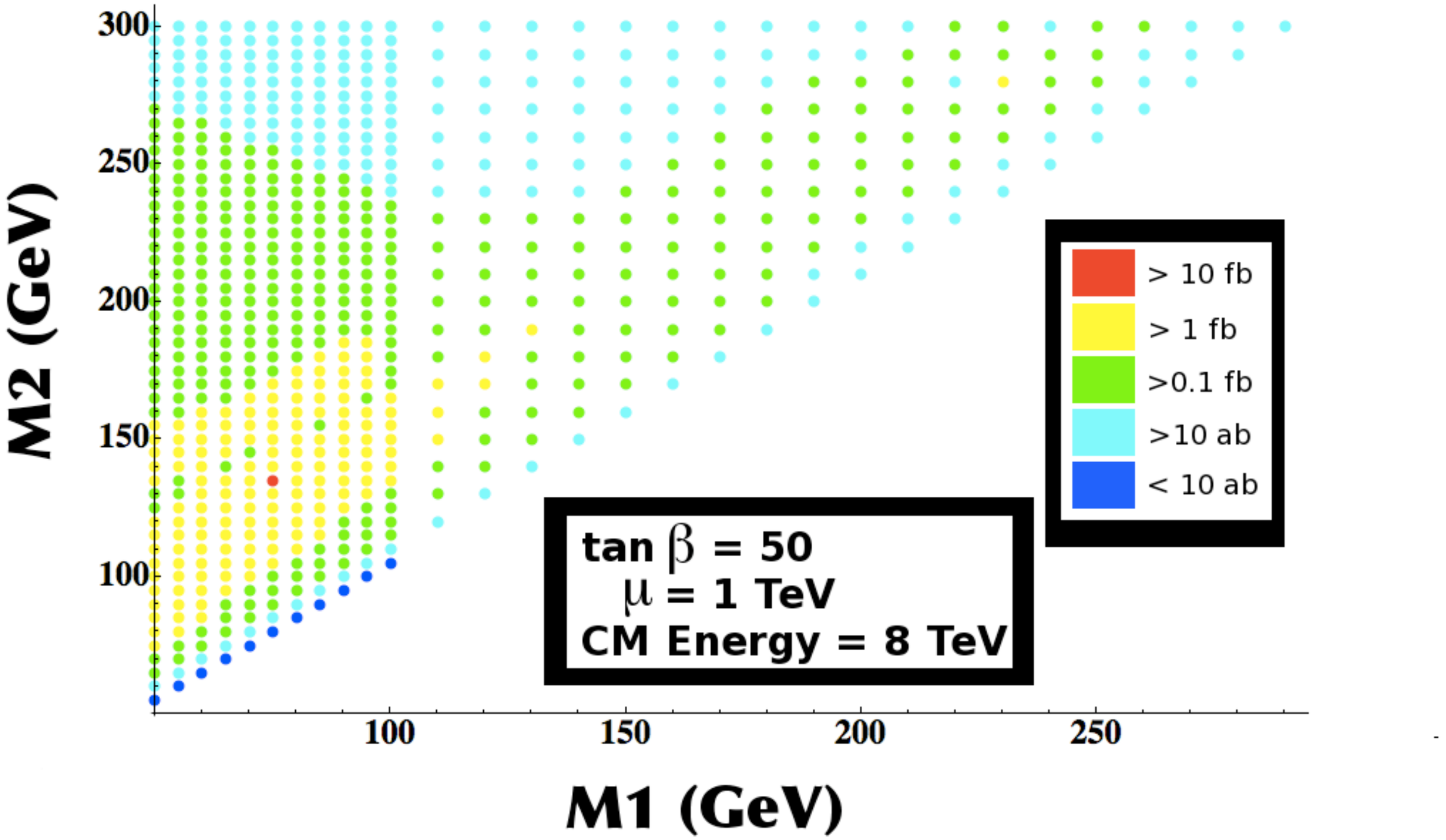
- As a start on investigating the current and future ability of the LHC to discover SUSY in or rule out the scenario of light charginos plus neutralinos **and nothing else** we consider the (well-studied- apologies for not mentioning your work in this short talk)
  trilepton channel (3l + MET)


χ_1^0
Z
χ_2^0
W +/-
Leptons
W +/-
$\chi_1^{+/-}$
ν
χ_1^0
Final State
Initial State

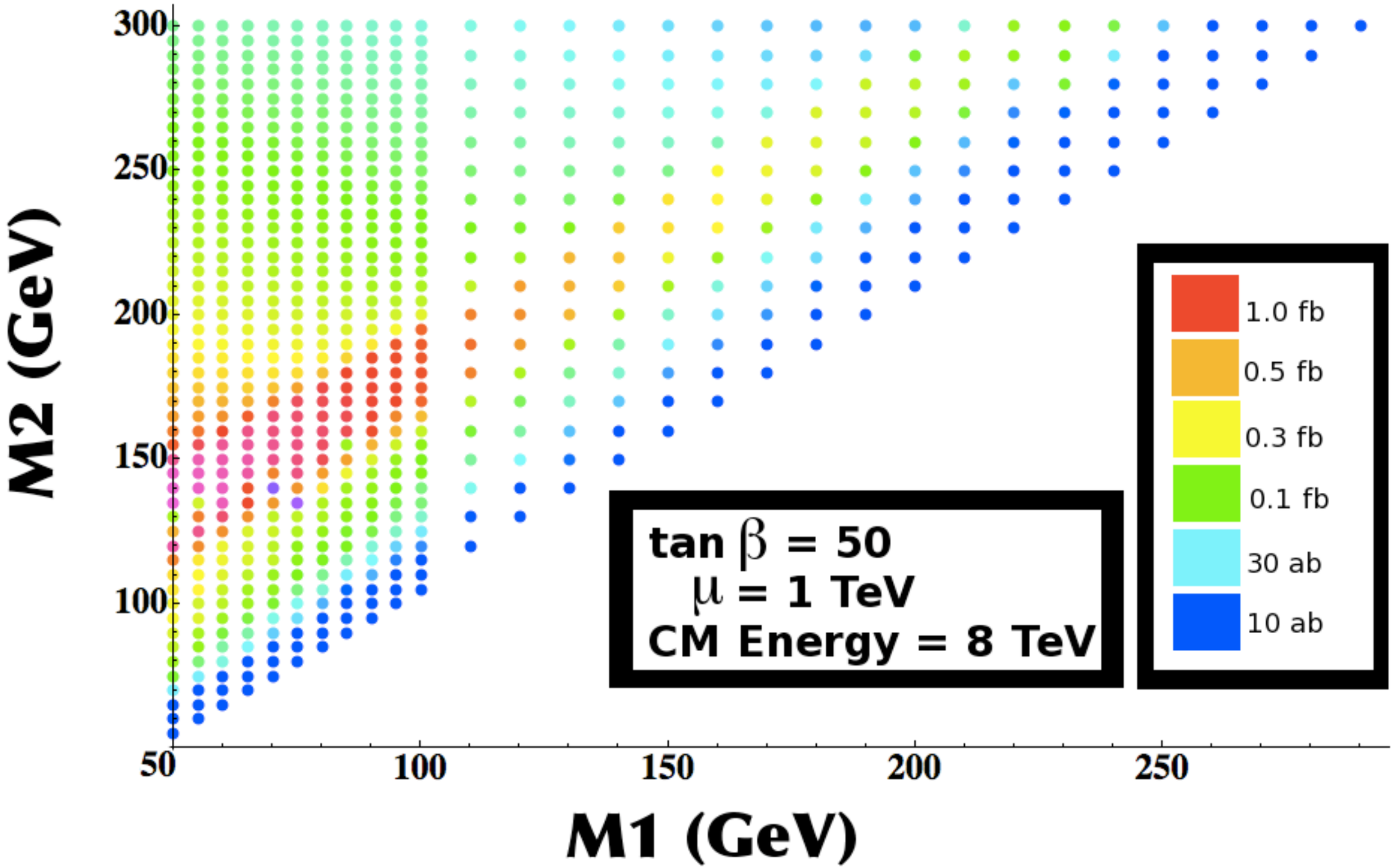
Signal

- As an example of signal cross sections, I will show signal cross sections (at 8 TeV) for events passing the "Z-depleted" and "Z-enhanced" (7 TeV) ATLAS analyses
- Only contribution from positively charged chargino

Trilepton Cross Section x BR for ATLAS Z Depleted Analysis



Trilepton Cross Section x BR for ATLAS Z Enhanced Analysis



Backgrounds

- Reducible backgrounds include:

  $t\bar{t}$
  W t
  t b
  b Z/γ*
  b $\bar{b}$ Z/γ*.
  W$b\bar{b}$
  $b\bar{b}b\bar{b}$

  where the lepton(s) come from the b(s)

TABLE I. Expected numbers of events from SM backgrounds (Bkg.) and observed numbers of events in data, for 2.06 fb^{-1}, in control regions VR1 and VR2, and in signal regions SR1 and SR2. Both statistical and systematic uncertainties are included.

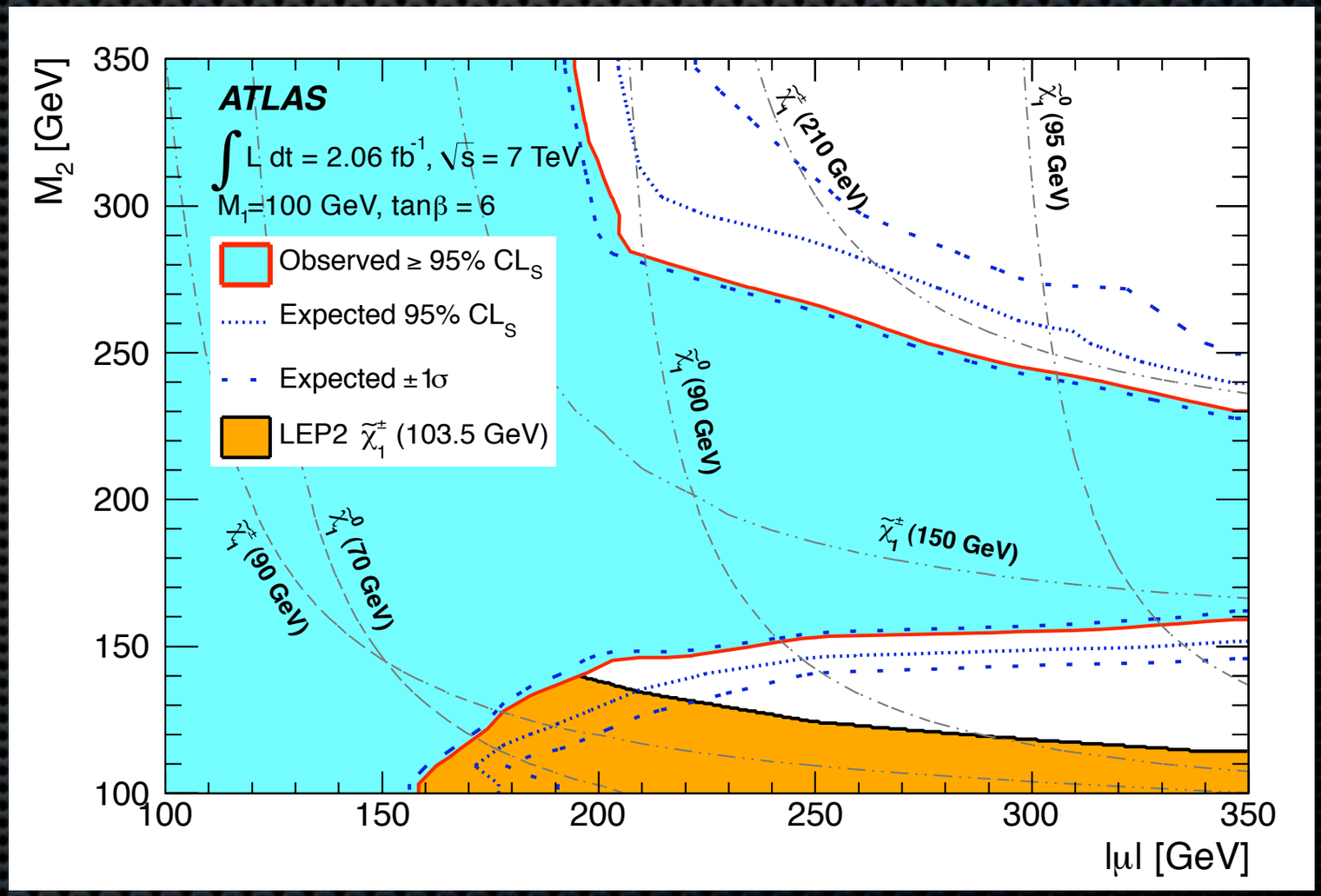
Selection	VR1	VR2	SR1	SR2
$t\bar{t}W^{(*)}/Z^{(*)}$	1.4±1.1	0.7±0.6	0.4±0.3	2.7±2.1
$ZZ^{(*)}$	6.7±1.5	0.03±0.04	0.7±0.2	3.4±0.8
$WZ^{(*)}$	61±11	0.4±0.2	11±2	58±11
Reducible Bkg.	56±35	14±9	14±4	7.5±3.9
Total Bkg.	125±37	15±9	26±5	72±12
Data	122	12	32	95

SR1: Z Depleted
SR2: Z Enhanced

ATLAS: 1204.5368 (7 TeV)

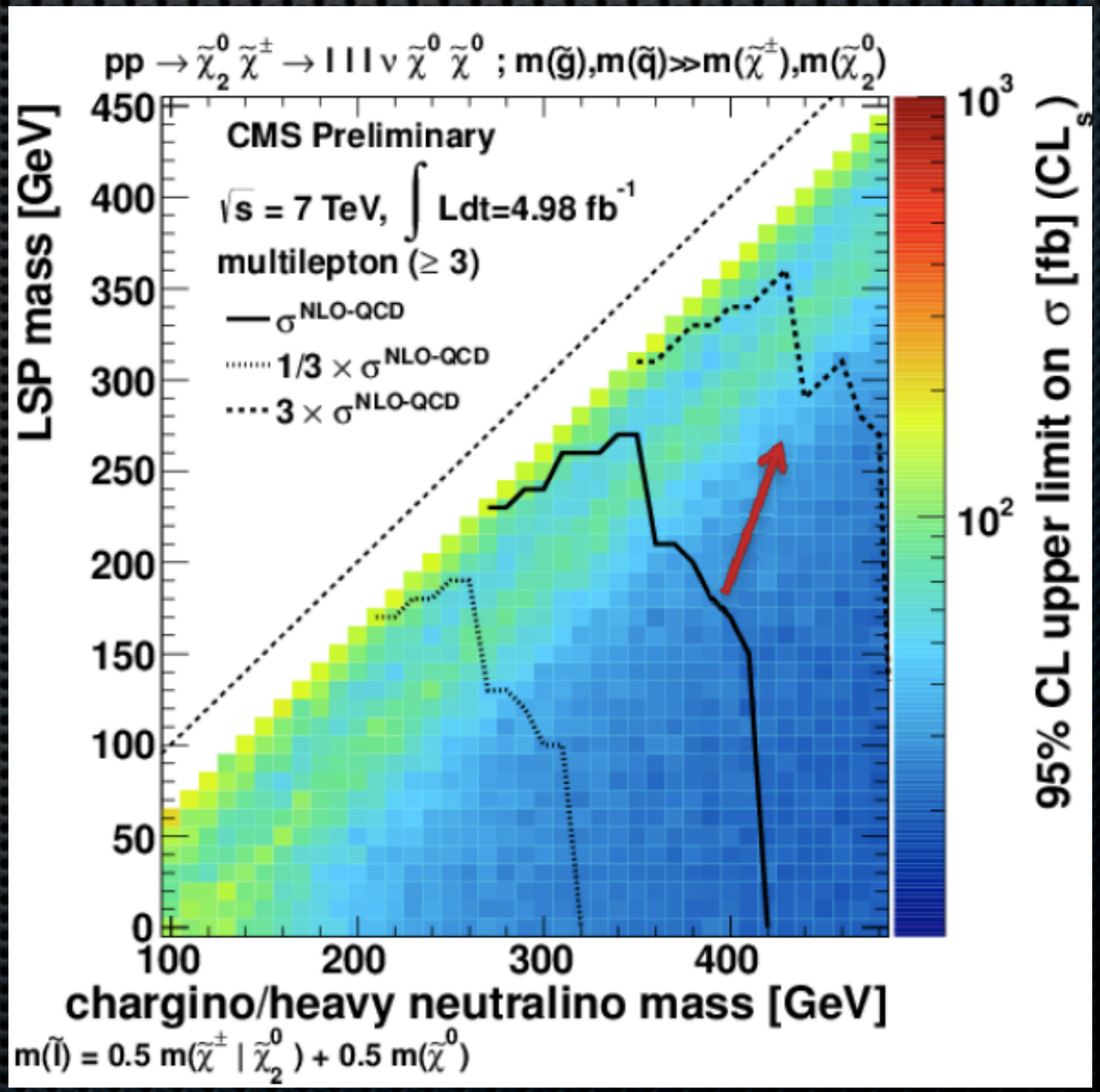
What Experiments Have Done: pMSSM

- Both ATLAS and CMS have interpreted their trilepton results in terms of limits on a pMSSM parameter space
- They set the right-handed slepton mass to be intermediate between the LSP mass and neutralino...



What Experiments Have Done: pMSSM

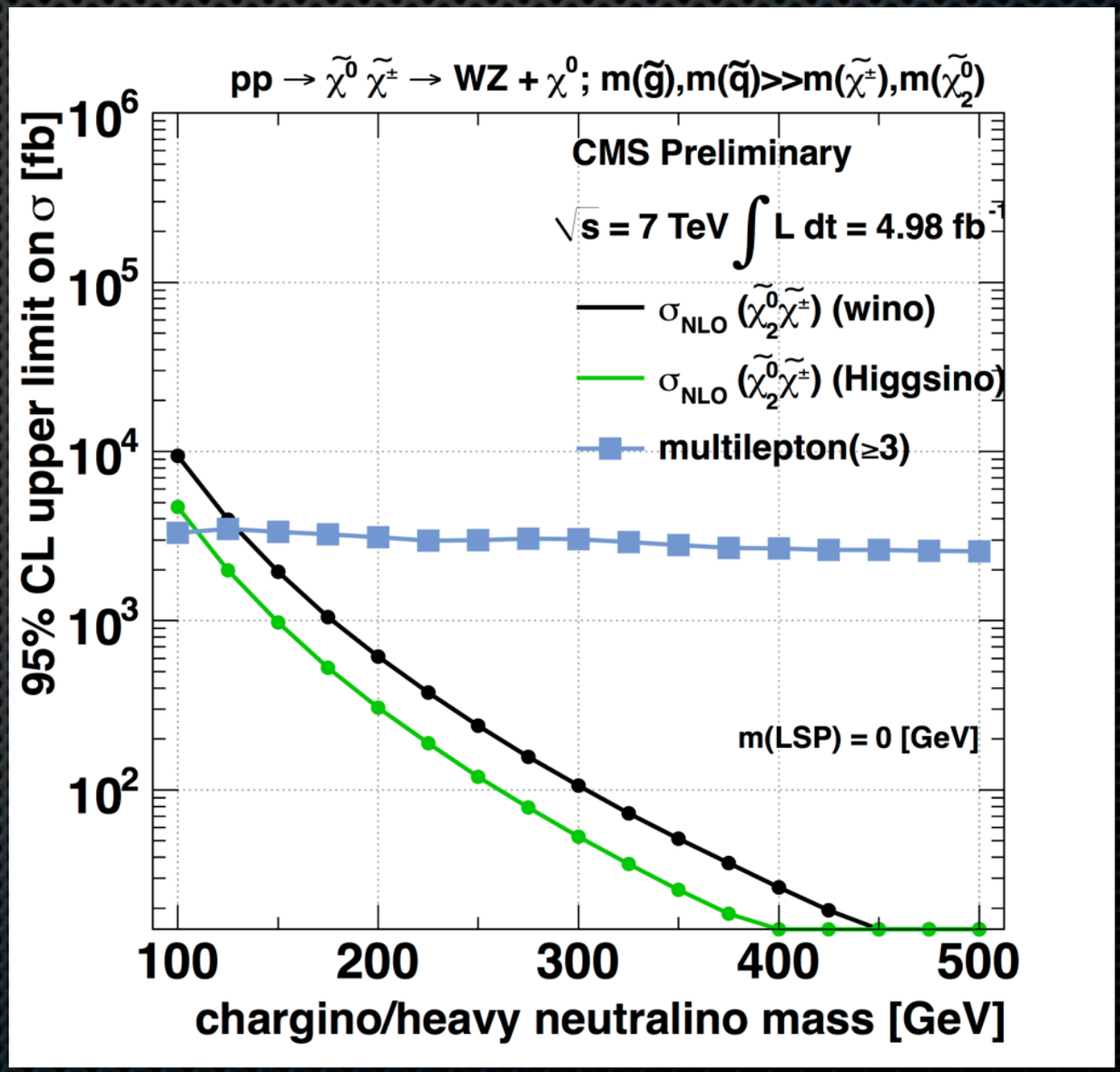
- Much higher cross section times branching ratio to trileptons due to decays to sleptons
- So this is a very different scenario- much more optimistic. Worthwhile to have an idea what can be done if sleptons are heavier.



From Sunil Somalwar's talk at U of C LHC Workshop

What Experiments Have Done: Simplified Models

- When M1 < M2 and |μ| >> |M1|, |M2|, our pMSSM space maps to the simplified model "TChiwz".



Why Do More?

- Not hard to recast these simplified models limits as limits in our pMSSM space when there is a Bino-like LSP and only Winos (or only Higgsinos) are also accessible.

Why Do More?

- However other hierarchies of M1, M2, and μ are more complicated:
  - Additional light neutralinos and charginos with different masses may be relevant.
  - If the LSP is Wino (|M2| small) or Higgsino (|μ| small), we can replace the LSP in our diagram with a nearly degenerate chargino or neutralino which may decay softly enough to avoid vetoing the event.

Why Do More?

- This particular pMSSM space is a good reflection of the MSSM without any optimistic assumptions
  - Additional e.g. sleptons make discovery in trileptons easier.
  - Light squarks would reduce the trilepton cross section, but would (hopefully!) show up in other analyses.
- A pMSSM analysis like this may be as close as one can reasonably get to obtaining limits on chargino and neutralino masses in the MSSM as a whole.
- Certainly a major step in that direction.

Conclusions

- The importance of SUSY together with its current non-observation at the LHC motivate studying scenarios where charginos and neutralinos are light, but other sparticles are heavier.
- Trilepton events provide a probe of this scenario, though for much of the parameter space other channels/ 14 TeV are definitely needed (and even then...)
- It would be good to understand the consequences of observing (or not observing) excesses in this channel (and channels in general!) for as general of an MSSM parameter space as possible.
- Both experiments have made steps in this direction; more can and should be done to increase generality.