Higgs Decays and Missing Energy Signatures

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Work in Progress

In collaboration with
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Aspen Winter Conference 2007

Introducing New Light Particles

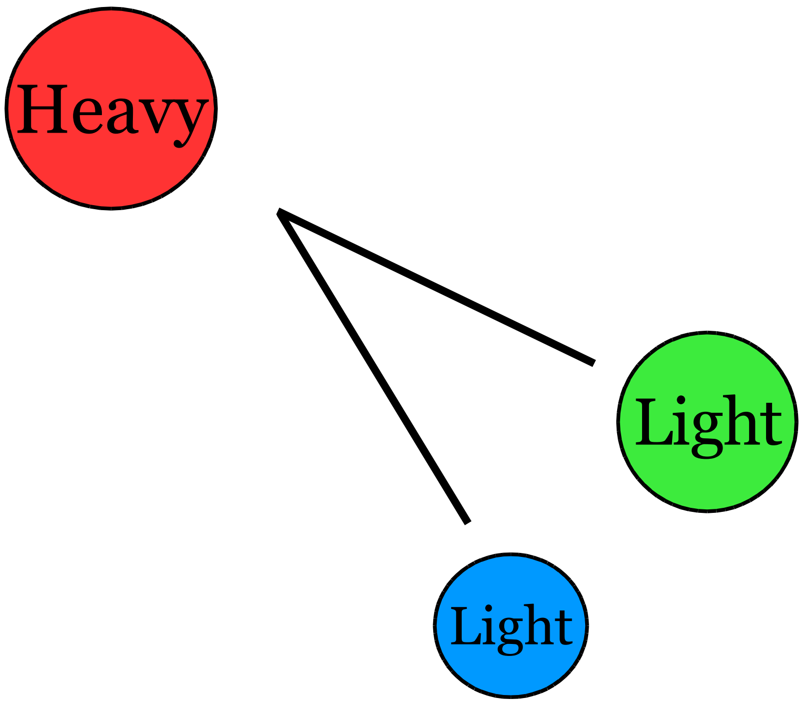
- Particle models can be extended by new light particles near bottom of spectrum
- Hints for existence suggested by both data and naturalness
- Alters decays of heavier particles – motivates adaptive collider searches

Light Particle Profile

- Constraints require
  - Neutral
  - Weakly Interacting
- Unknowns
  - Spin?
  - Couplings?
  - Stable?

Opening New Decay Channels

Most Crucial For Narrow Width Particles



Motivations (Higgs)

See Gunion talk for more details

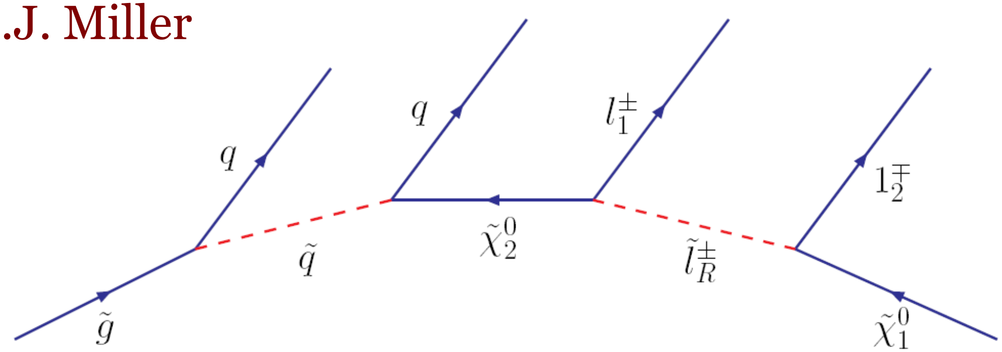
- Lighter Higgs mass (below LEP2 limit)
  - Alleviates SUSY Little Hierarchy
  - Improves Precision Electroweak Fit (esp. as top mass central value continues to decrease)
- For e.g., adding a new scalar *a* adds new dominant nonstandard Higgs decays; $h \rightarrow 2a \rightarrow 4\tau$ allows Higgs mass < 100 GeV (LEP2)

Dermisek, Gunion
Chang, Fox, Weiner
Graham, Pierce, Wacker

An Interesting Twist

- Ingredient: a parity (e.g. R-parity), where the new light particle is parity odd
- This has a drastic effect on all other parity-odd particles, this modification must alter their decays
- In this case, there are reduced limits for both Higgs searches as well as the new particles

D.J. Miller



SUSY Example

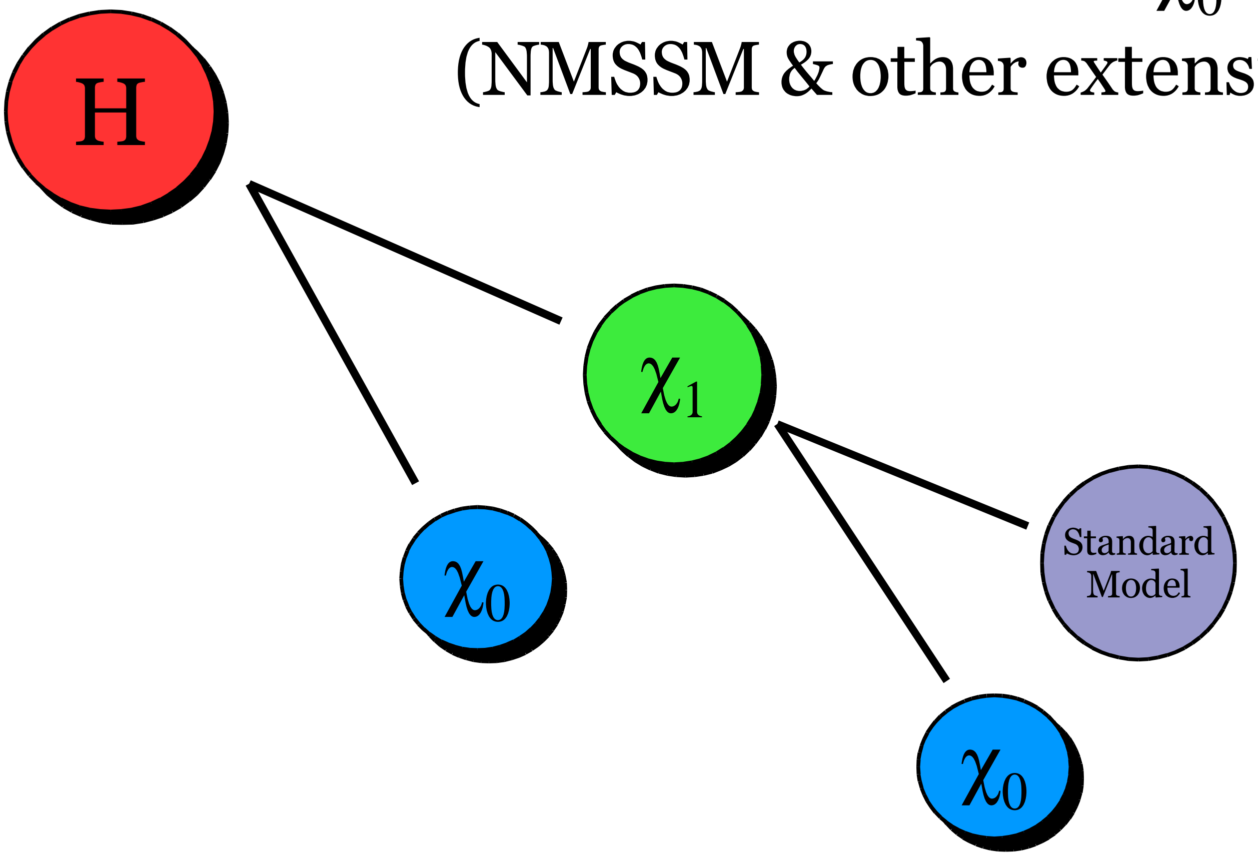
MSSM

+

new neutralino χ_0

(NMSSM & other extensions)

Barger, Langacker, Shaughnessy



Invisible $2\chi_0$ decay strongly constrained

Higgs allowed below 114.4 GeV?

However, with RPV see Kaplan et.al.

Mini-Outline

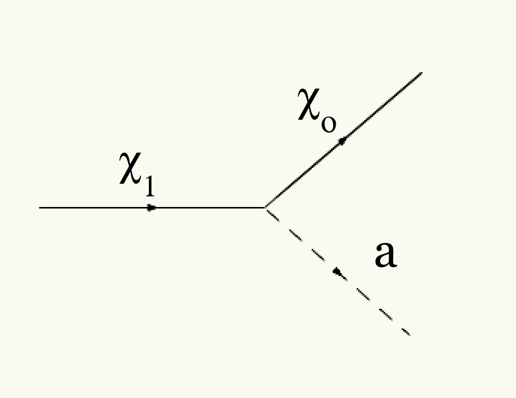
What are constraints on

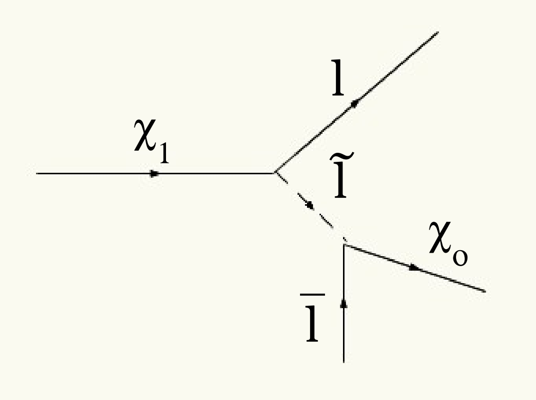
Higgs decays (LEP2)?

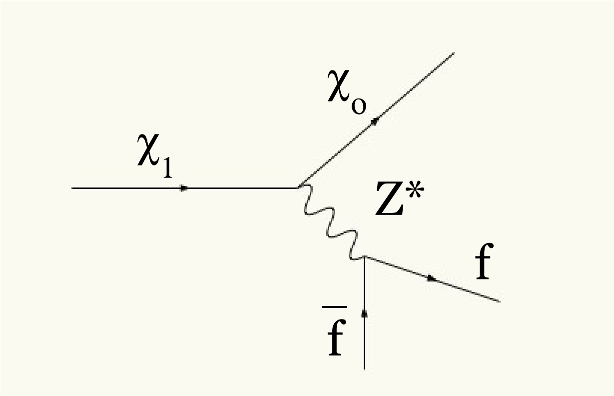
Squarks (Tevatron)?

Constraints on Higgs Mixed Neutralino Decay

- LEP2 – Higgs produced with Z
- Constraints depend on decays of χ_1

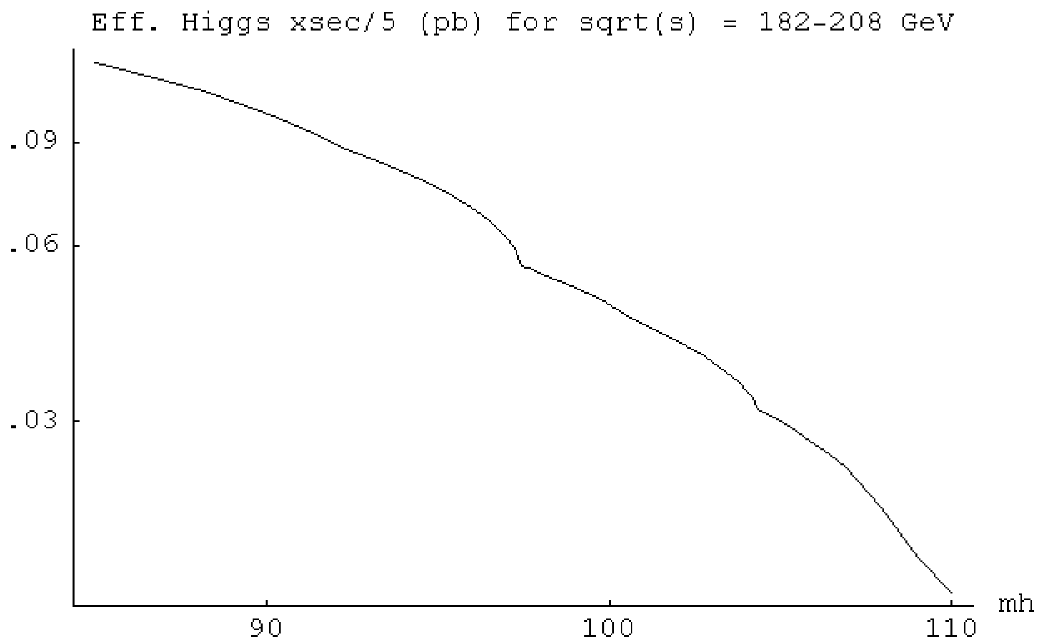






- Depends on non-Higgs searches with similar topologies, so constraints are only estimates
- Different signal assumptions: 1) optimized cuts or 2) use likelihoods based on signal

Effective Cross Sections

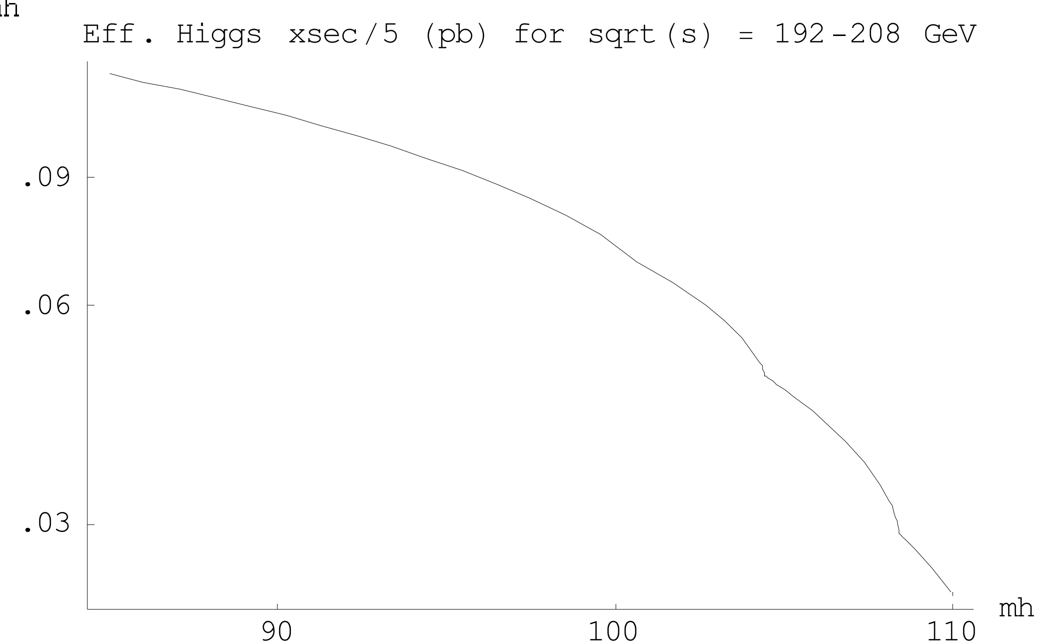


Higgs Missing Energy Constraints Strongest from LEP2 SUSY Searches

To apply constraints to Higgs, take

$Z \rightarrow$ invisible

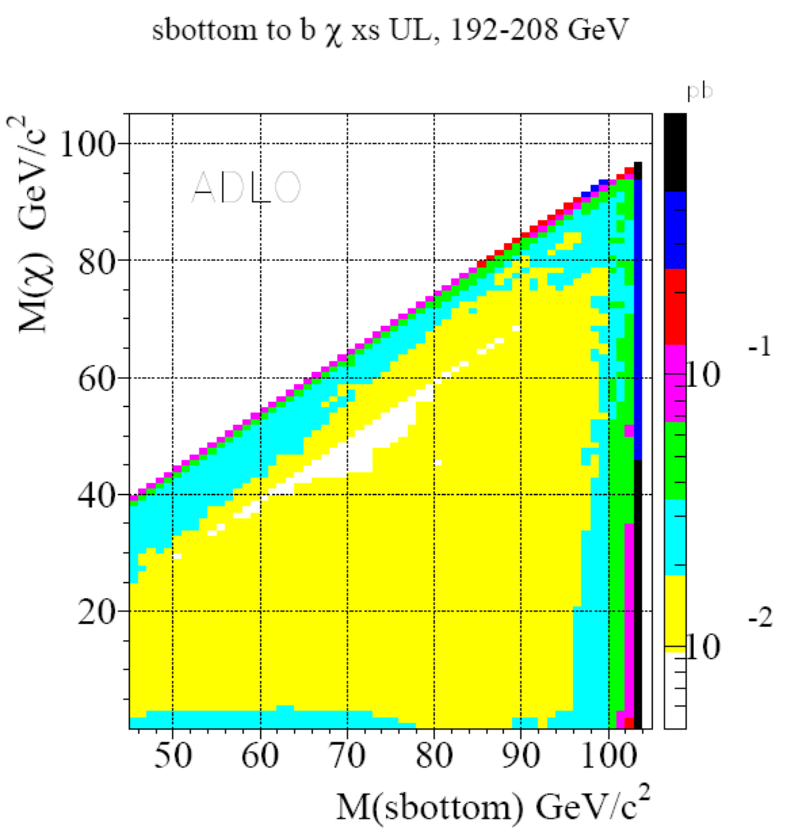
$h \rightarrow 2\chi_o f\bar{f}$



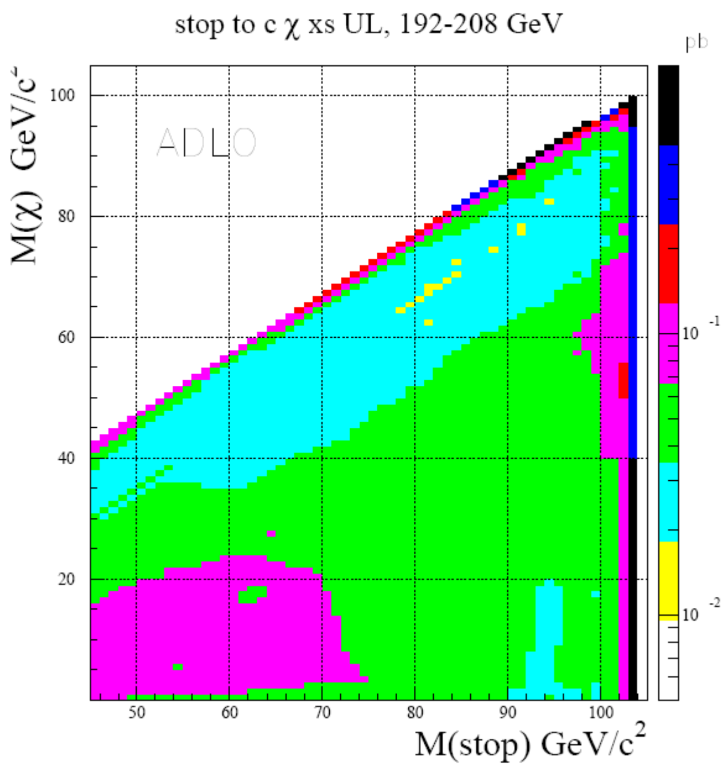
Higgstrahlung not kinematically open for all luminosity of the different analyses

SUSY Searches (jets+ME)

b decays are strong, 2 body decay into scalar allowed only if BR is not O(1)

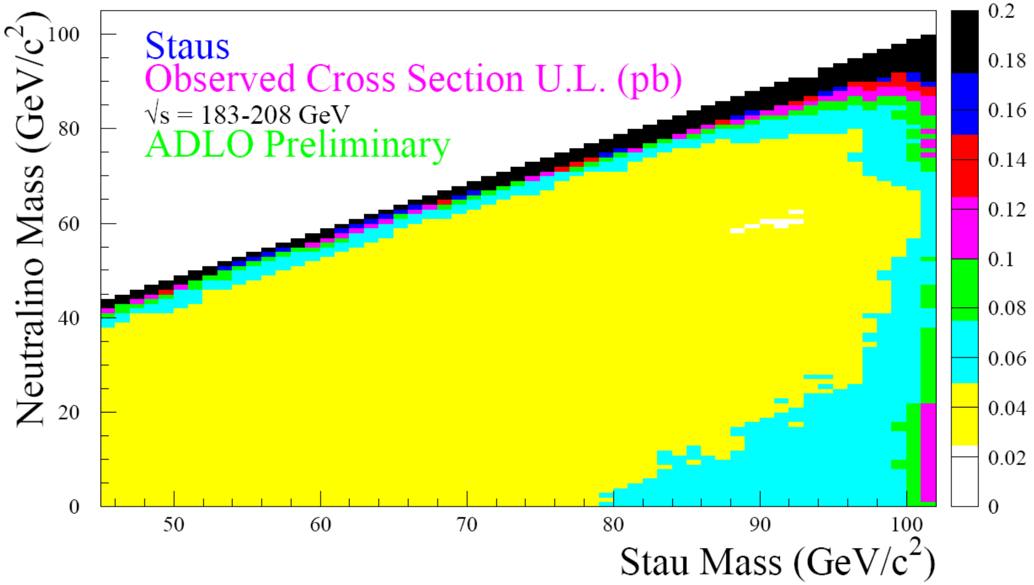


Sbottom Search
strong < .02 pb



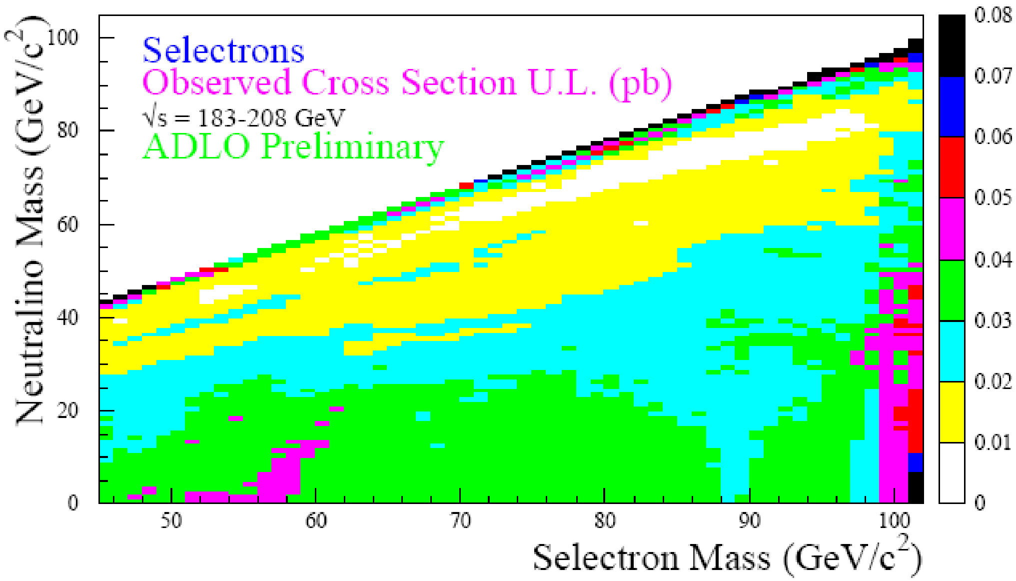
General Squark
Weaker < .06 pb

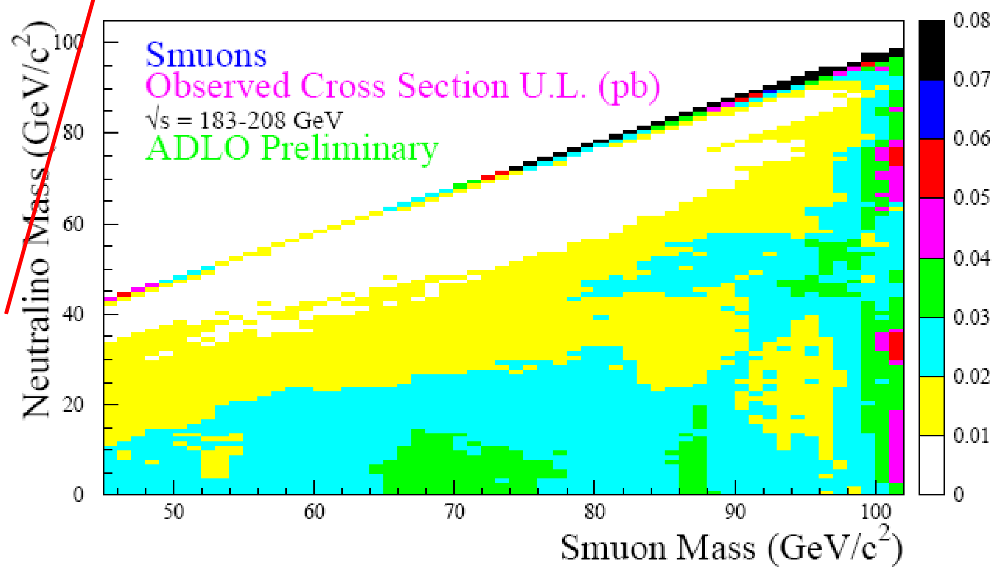
Slepton Searches (leptons + ME)



taus	< .05 pb
electrons	< .03 pb
muons	< .03 pb

Taus and off-shell Z decays allow O(1) BR to neutralinos





Higgs Limit

100 GeV Higgs seems allowed for

$BR(\chi_1 \chi_0) \sim 1$ for decays into light quarks, leptons

$BR(\chi_1 \chi_0) \sim .3$ for all modes

Neutralino Properties

h	90-110 GeV	χ_1	40-60 GeV	χ_0	1-20 GeV

- Chargino search constraint, > 100 GeV
  - Requires a new singlet Weyl Fermion (Singlino) → NMSSM?
- Z Invisible Width and Neutralino Production at LEP
  - If $\tan\beta > 1$, χ_1 is mostly bino and χ_0 is mostly singlino   Barger et.al.
- Dark Matter Abundance: No Overclosure
  - A new light scalar of mass about $2m_{\chi_0}$

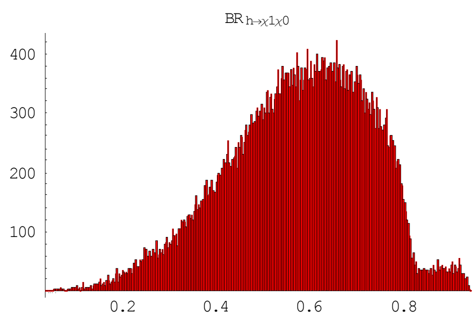
Belanger et.al.
Gunion et.al.
Barger et.al.

NMHDECAY Scan

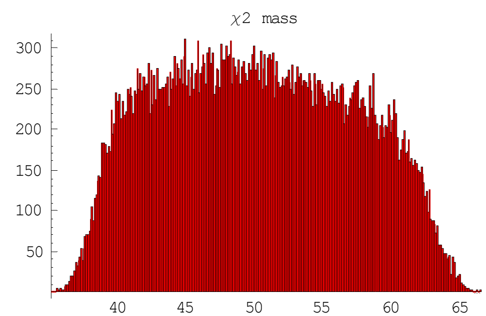
Ellwanger, Gunion, and Hugonie

Note: Before Higgs constraints Spectral Information qualitatively the same

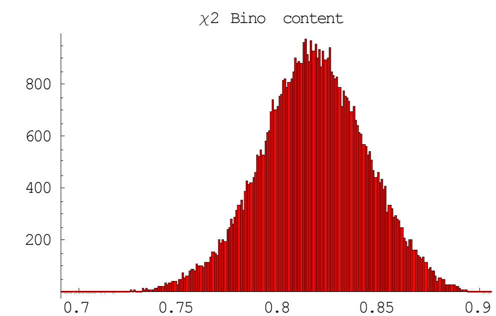
BR($h \to \chi_0 \chi_1$) [0, 1]



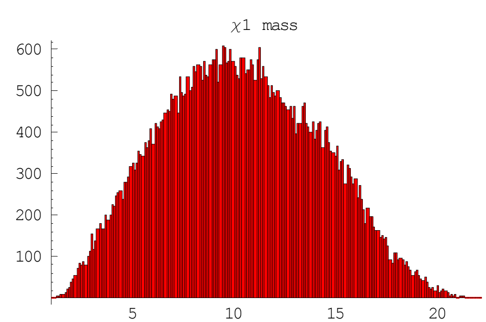
χ_1 mass [35, 65] GeV



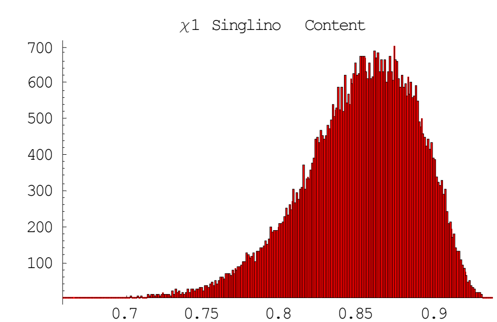
χ_1 Bino content [.7, .9]



χ_0 mass [0, 20] GeV



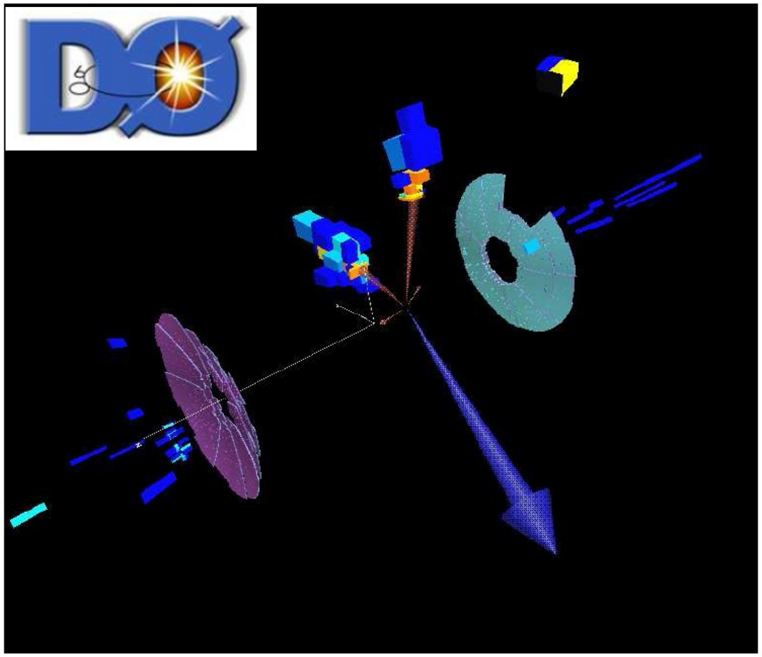
χ_0 Singlino content [.65,.95]



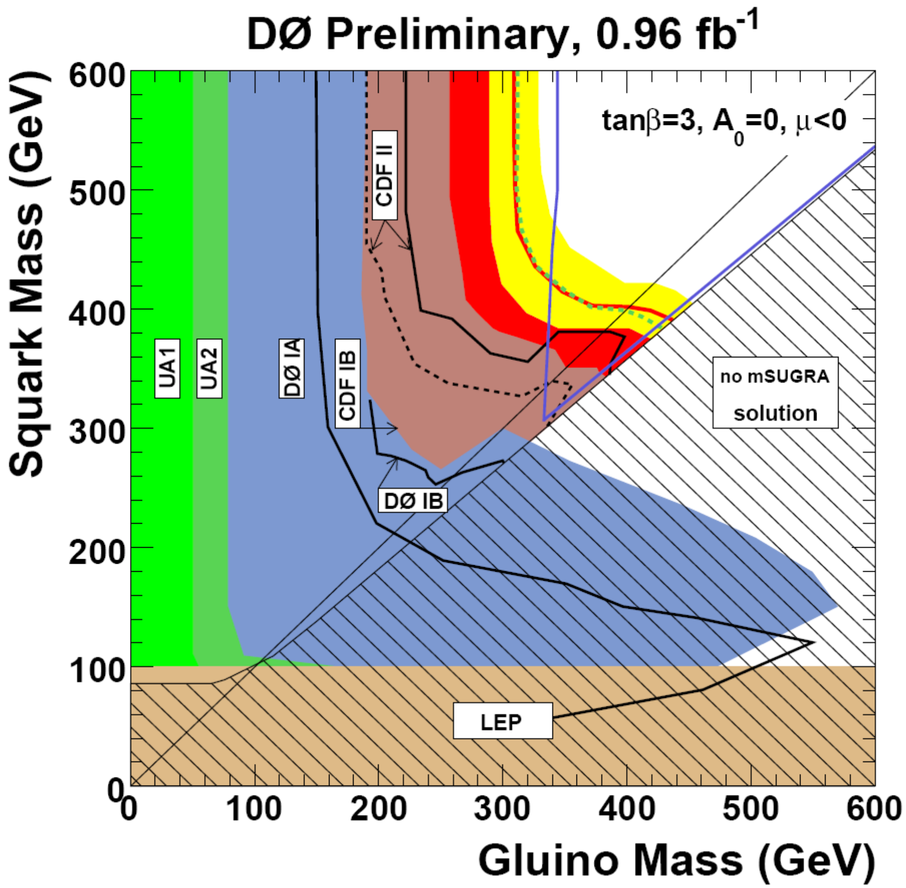
Impact on SUSY Pheno

Ellwanger,Hugonie Strassler

- Dominant singlino LSP implies longer cascades, potentially displaced vertices
- Longer cascades mean more visible energy (jets, leptons) and reduced missing energy
- Searches normally expect:
  - Squark$\rightarrow$ jet + MET
  - Gluino$\rightarrow$ 2jets + MET
- Effects degrade search esp. with optimized MET cuts

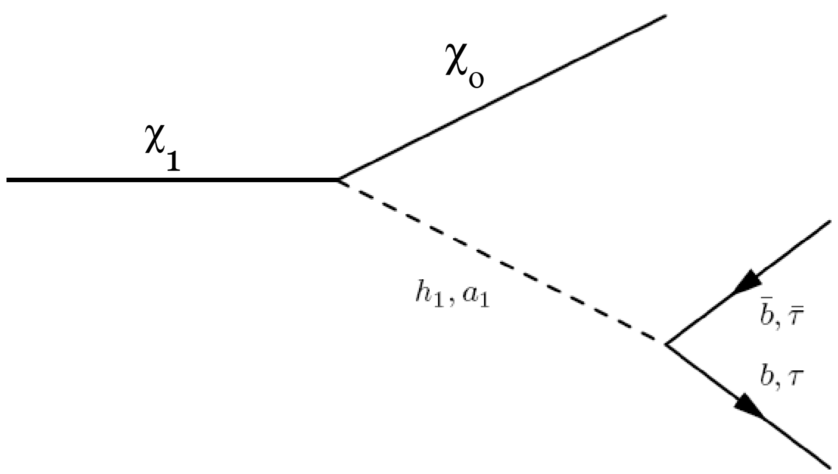


Tevatron Limits



Squark decays are actually more sensitive to dedicated gluino search

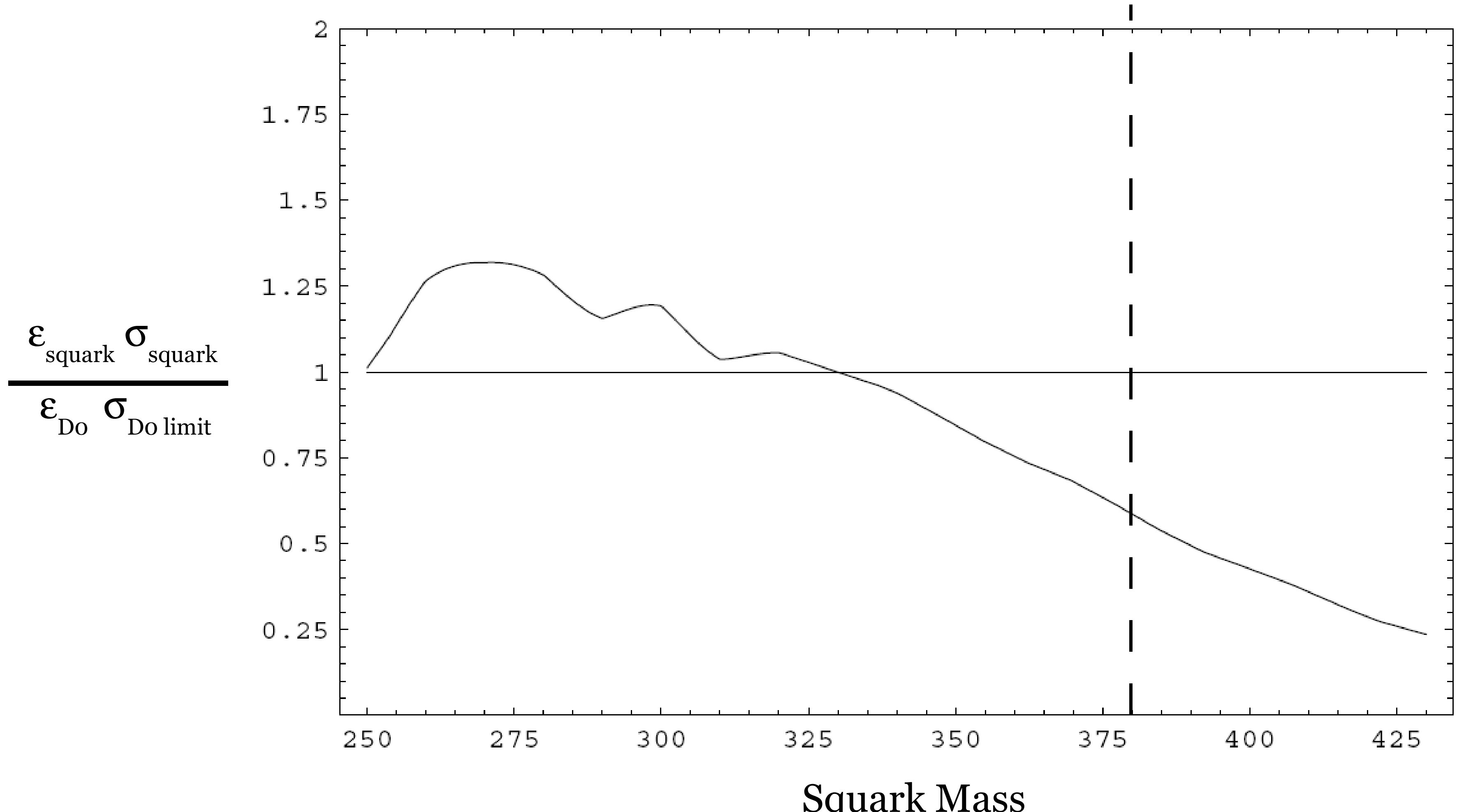
Missing Energy signature suppressed, e.g.



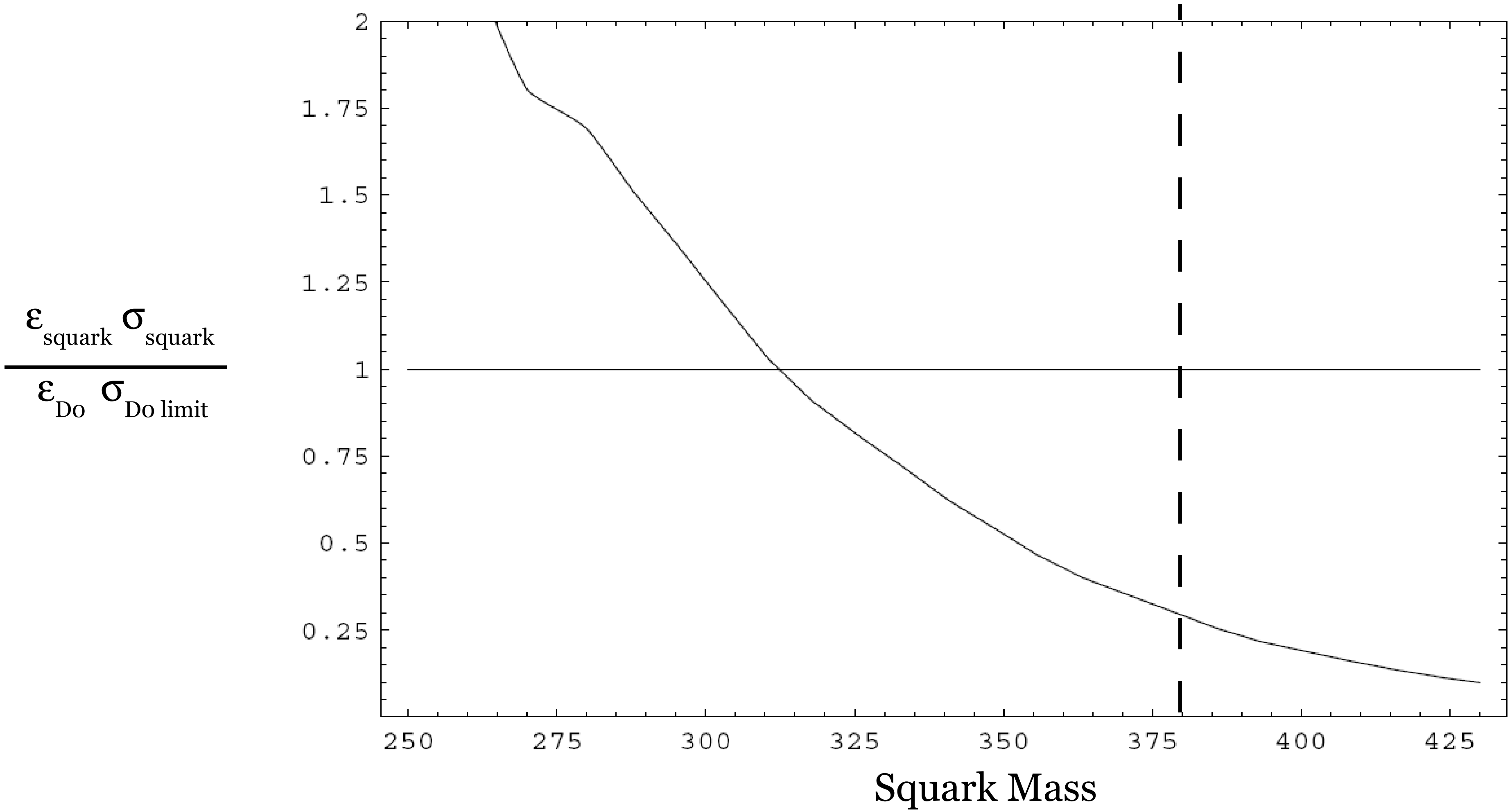
As m_a approaches m_{χ_1}, missing energy is reduced

Very Preliminary Results (DØ 2jet)

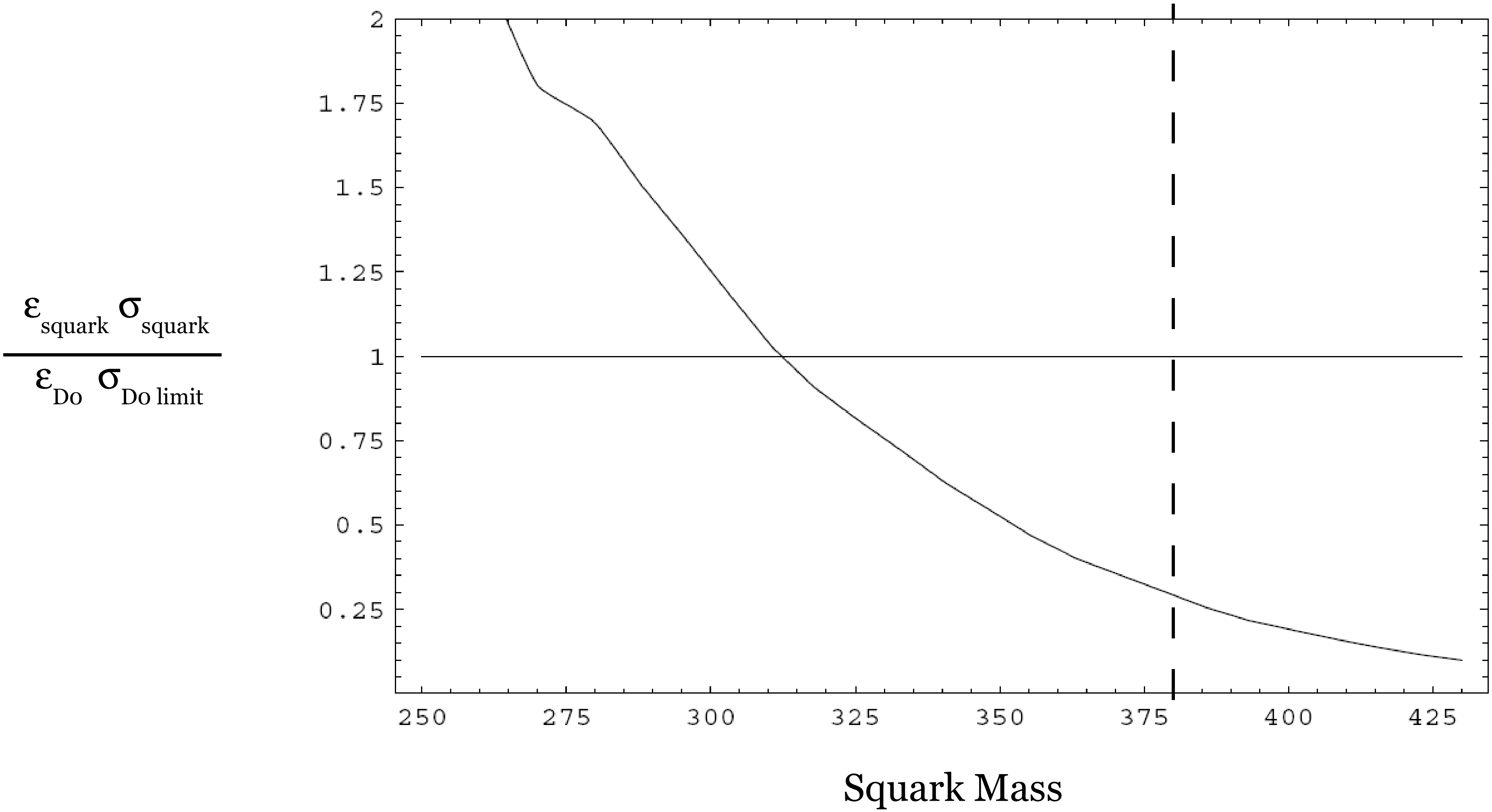
Note: All efficiencies simulated using PYTHIA, under onshell scalar assumption
VERY preliminary!!!
Only LO production xsecs, PROSPINO has alpine issues... NEAL still climatizing...
No combination of different analyses (overlapping events?)



Very Preliminary Results (DØ 3jet)



Very Preliminary Results (DØ 4jet)



Squark Handles

Higgs constraints suggest additional leptons and/or light jets, perhaps through offshell Z's
Perhaps b's at reduced rate

Left handed squarks decay into chargino which decay into onshell W's into χ_o

Analysis Goals

- Understand Tevatron search efficiencies for this type of SUSY spectra
- Prelim. ~ 50-60 GeV weakening in DØ squark limits (~80 GeV for 310 pb^{-1} analysis and offshell Z)
- Implement/Interpret CDF results
- Find distinctive features of these decays (leptons, W's likely)
- Motivates additional/adapted experimental searches that are sensitive to such “tags”

Other Scenarios

Sneutrinos

Helps with Dark Matter Abundance

Realizes off-shell Z scenario

R-parity

Neutrinos

Lepton Number is “Parity”

Off-shell Z's

Heavy particles affected are the heavy neutrinos

Conclusions

- New light particle suggested by naturalness and data in Higgs sector
- New light particle, odd under a parity, changes decays for all heavier odd parity states
- Discovery of both the heavy and light particles could require studies of such scenarios
- Finding Higgs and new Heavy States (e.g. Squarks) could require adapted searches
- For SUSY, cascades of squarks are extended, with more visible products, degraded MET

Conclusions (cont.)

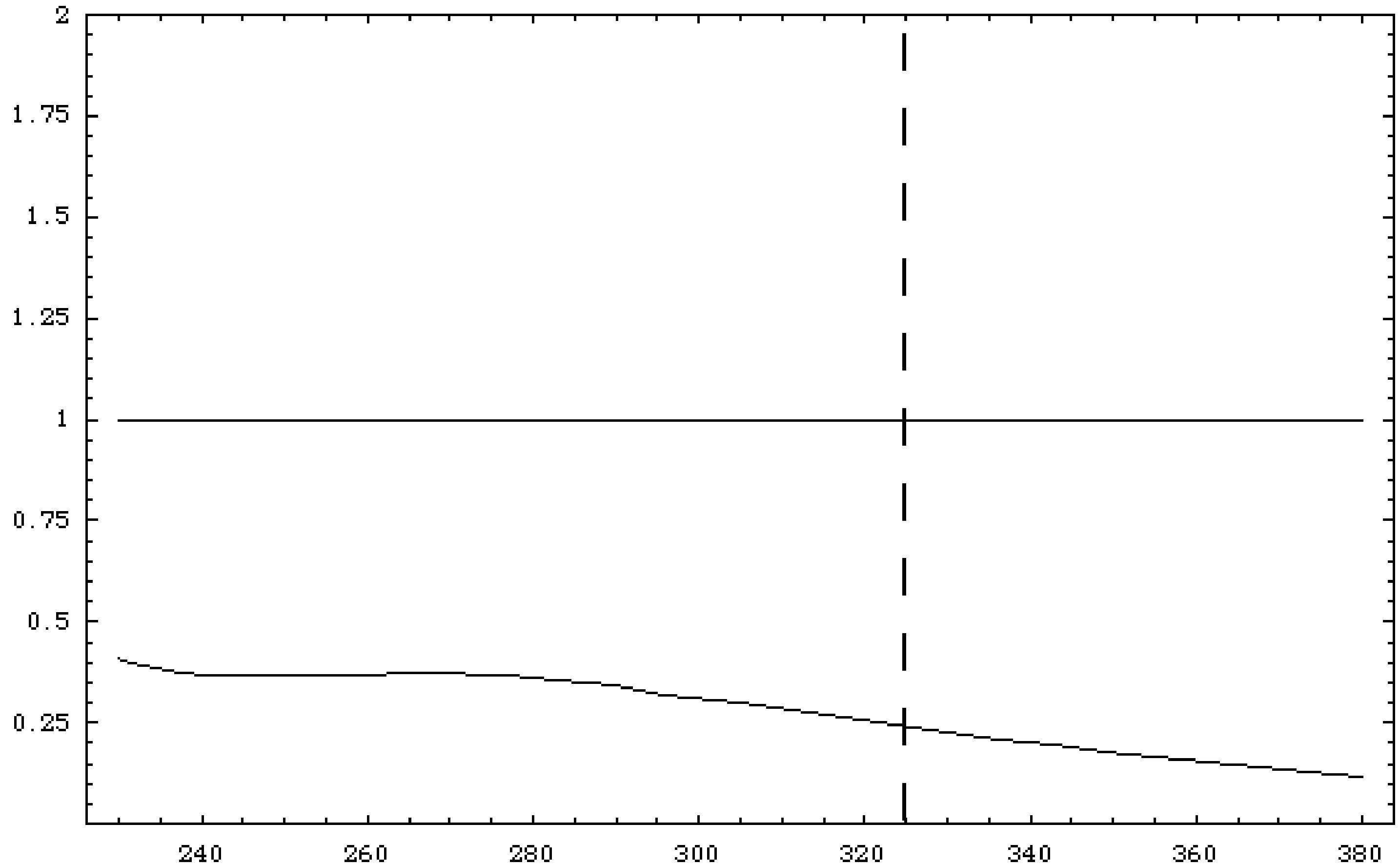
- Higgs detectable? Need ideas/studies…
- Many opportunities persist for Tevatron Squark searches
  - Lepton pairs
  - W's from charginos in cascade

You were right: There's a needle in this haystack...

Early Results (DØ 2jet)

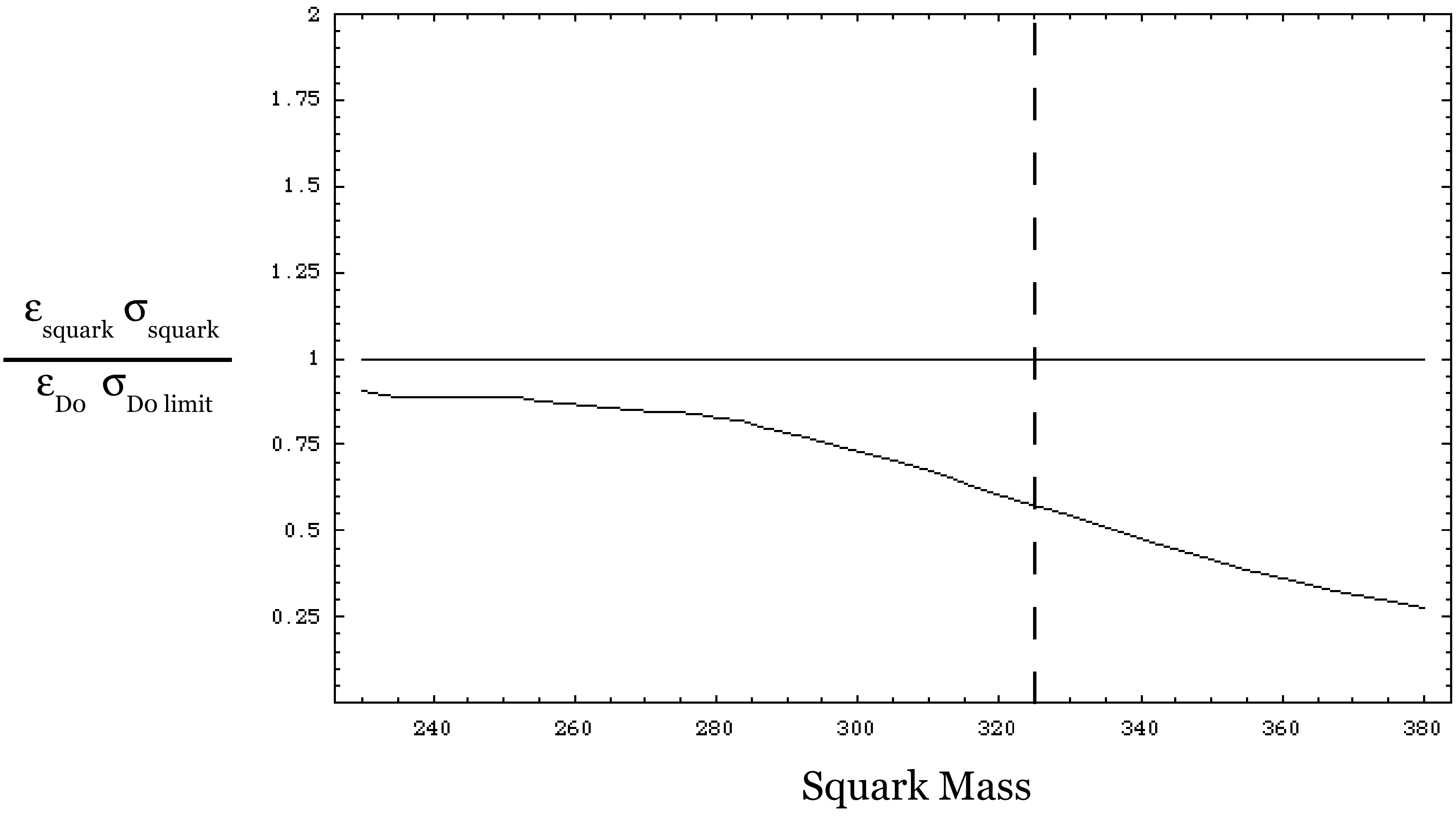
Note: All efficiencies simulated using PYTHIA, under offshell Z assumption

$$\frac{\varepsilon_{\text{squark}}\,\sigma_{\text{squark}}}{\varepsilon_{\text{Do}}\,\sigma_{\text{Do limit}}}$$



Squark Mass

Early Results (DØ 3jet)



Early Results (DØ 4jet)