SUSY Searches with Leptons at CDF

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For the CDF Collaboration

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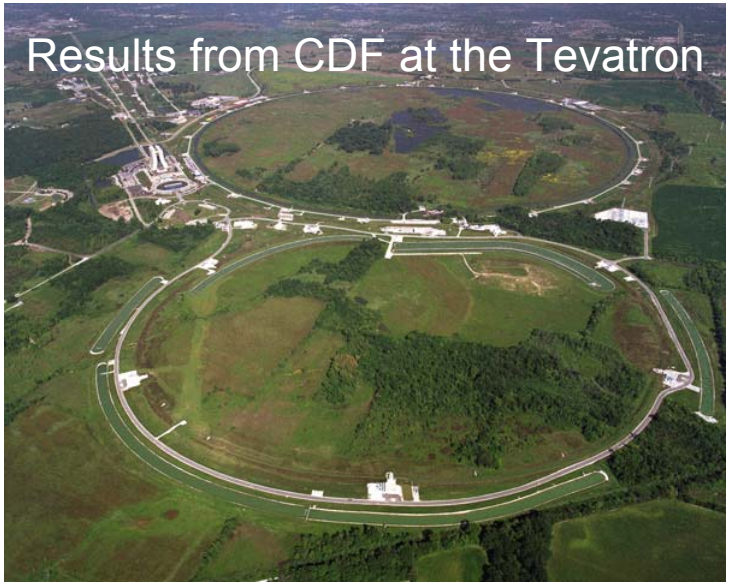
Outline



- Introduction
- RPV sneutrinos
- Trileptons
- Conclusions

Hierarchy Problem: Electron Mass

Problem:

Radius of electron $r < 10^{-19}$m

→energy to assemble the electron charge ~ $+e^2/r$ ~10,000 MeV

But electron mass is only ½ MeV

→ ½ MeV = 10,000 MeV – 9999.5 MeV ("correction")

Artificial cancellation of very large numbers.

Solution:

Posit a partner of equal and opposite charge.

→ positron (Double the particle spectrum!)

Uncertainty principle → e^+e^- pairs from vacuum

Annihilation energy for *real* e^- & *virtual* e^+ is $-e^2/r$ (Weisskopf)

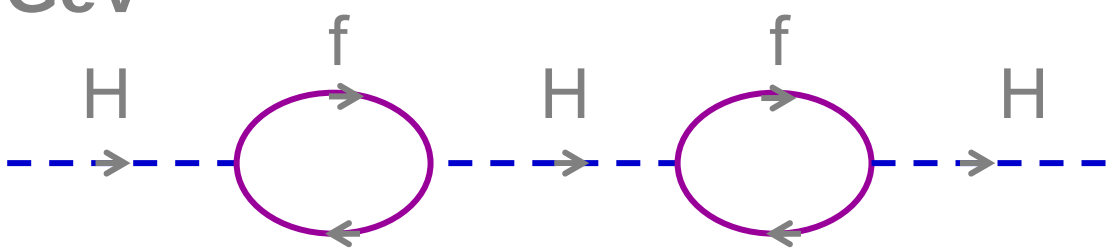
→ Natural cancellation (of Feynman Diagrams)

Lesson: New physics at 1MeV scale (positron) avoids artificial cancellation of very large numbers to get a physical quantity.

Hierarchy Problem: Higgs Mass

Radiative loops → m(Higgs) ~10^{15} GeV, but Higgs is at EW scale:

m_W,m_Z~100 GeV



Delicate 10^{15} GeV cancellation ***OR*** New physics at the TeV scale

SUSY: Double the particle spectrum by giving fermions bosonic superpartners and *vice versa. Superpartners* cancel the runaway loops, just as the positron did.

→A fundamental symmetry at par with Lorentz symmetry

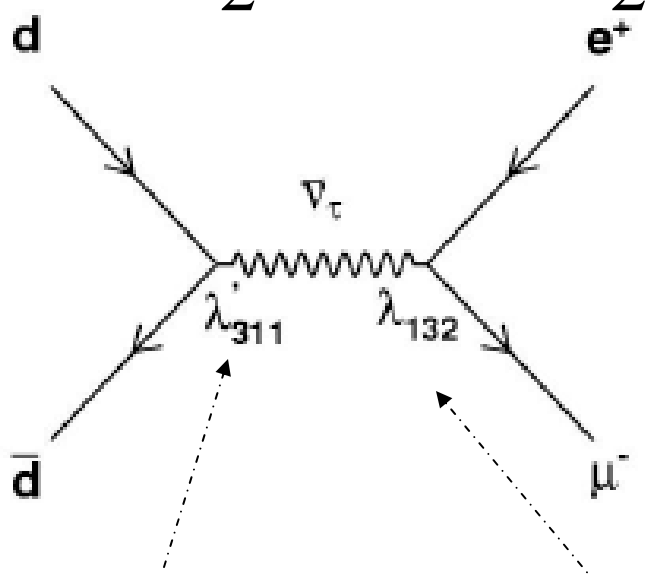
Other Wishlist Items:

- Extra CP violation for baryogenesis
- Gauge couplings unification (at high energies).
- Dark matter candidate (if R-parity).

Search 1: RPV MSSM Sneutrino

RPV (R-Parity Violating) MSSM Superpotential:

$$W_{\Delta L=1} = \frac{1}{2}\lambda^{ijk} L_i L_j \bar{e}_k + \frac{1}{2}\lambda'^{ijk} L_i Q_j \bar{d}_k + \mu'^{i} L_i H_u$$



λ'_{311} : tau-sneutrino production from d-dbar

λ_{132} : tau-sneutrino to eμ (decay BR)

Strategy: Search for high-mass unlike flavored lepton pairs $e\mu$, $e\tau_h$, $\mu\tau_h$

→Probe the λ_{ijk}-$M_{sneutrino}$ parameter space. (1 fb^{-1} data)

(Previous CDF search (2006): only eμ with 346 pb^{-1})

RPV Sneutrinos

BACKGROUNDS

- "Physics" : $Z/\gamma^* \rightarrow \tau\tau$, diboson, ttbar (Use MC)
- ``Single fake" : W/Z+jets, $Z/\gamma^* \rightarrow ee/\mu\mu$ (Use MC)
- ``Double fake" : QCD, γ+jets (Use same-sign data)

(Signal: high-mass unlike flavored lepton pairs $e\mu$, $e\tau_h$, $\mu\tau_h$)

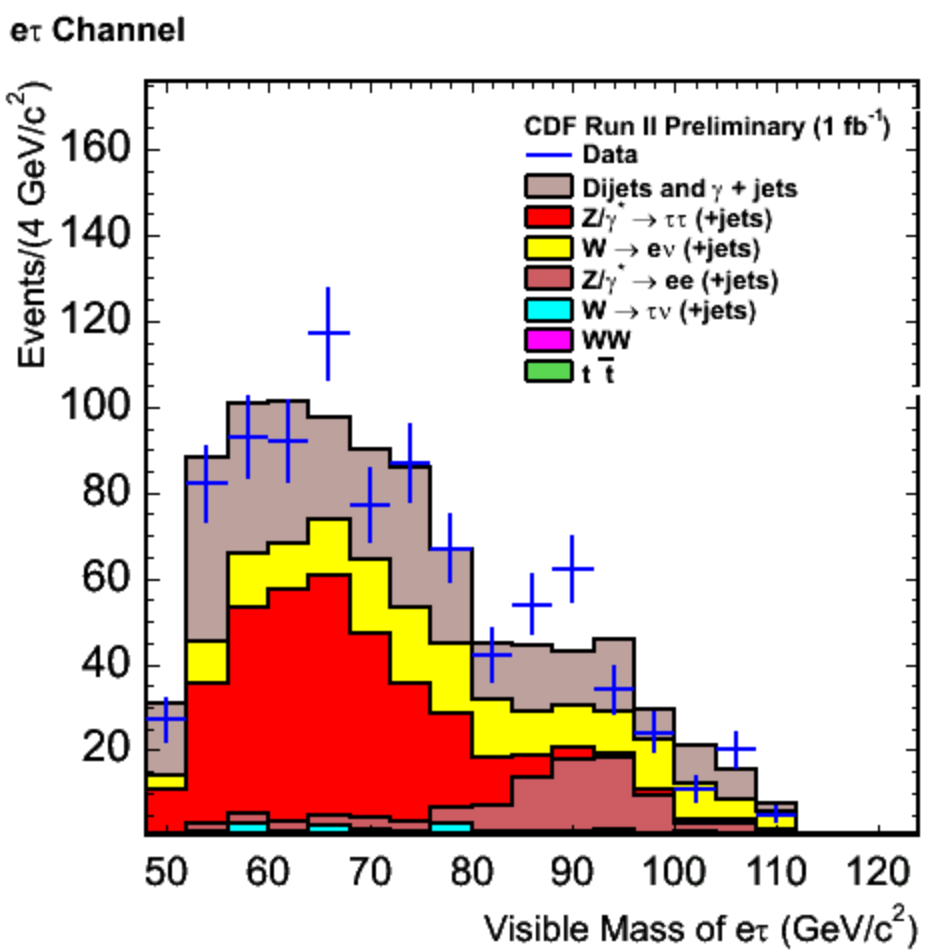
SIGNAL AND CONTROL REGIONS

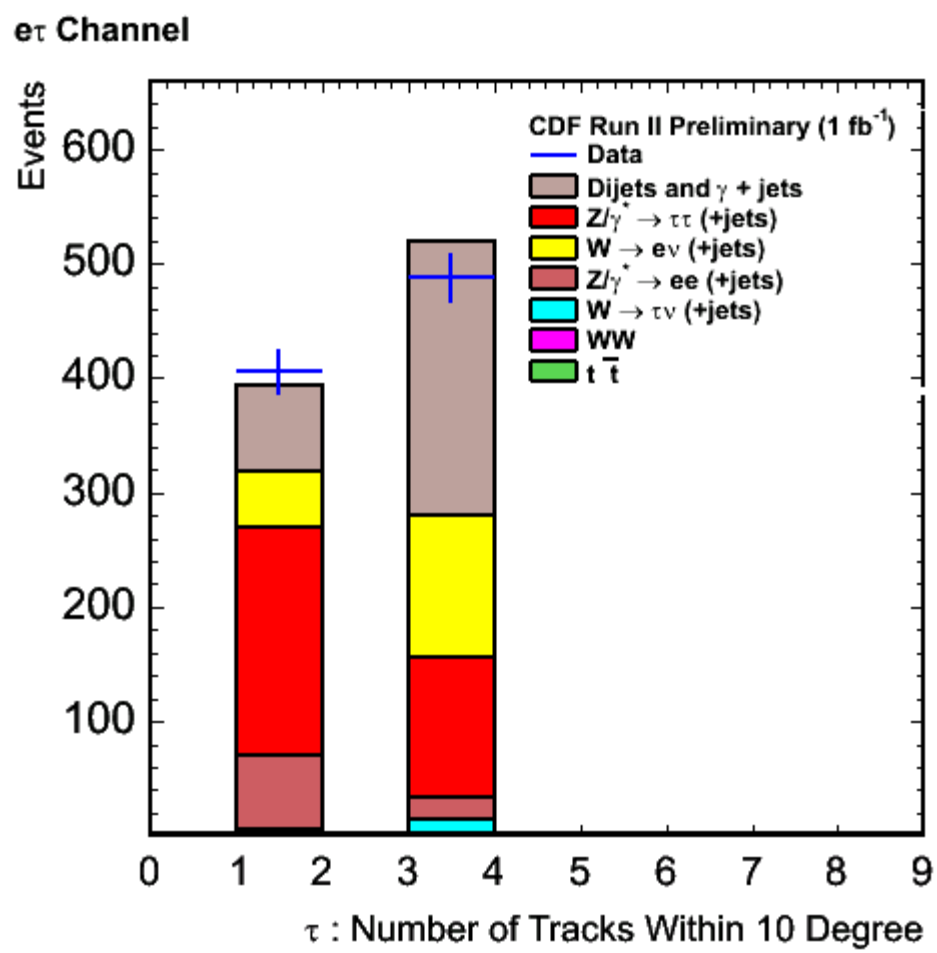
Reconstruct $e\mu$, $e\tau_h$, $\mu\tau_h$ invariant mass. (Using visible momentum for τ)

- Signal region: M_{LL} threshold from optimizing σxBR for each mass point.
- Control region: 50 GeV /c^2 < M_{LL} < 110 GeV/c^2

RPV Sneutrino Search

$e\tau$ channel control region: 50 GeV /c^2 < M_{LL} < 110 GeV/c^2

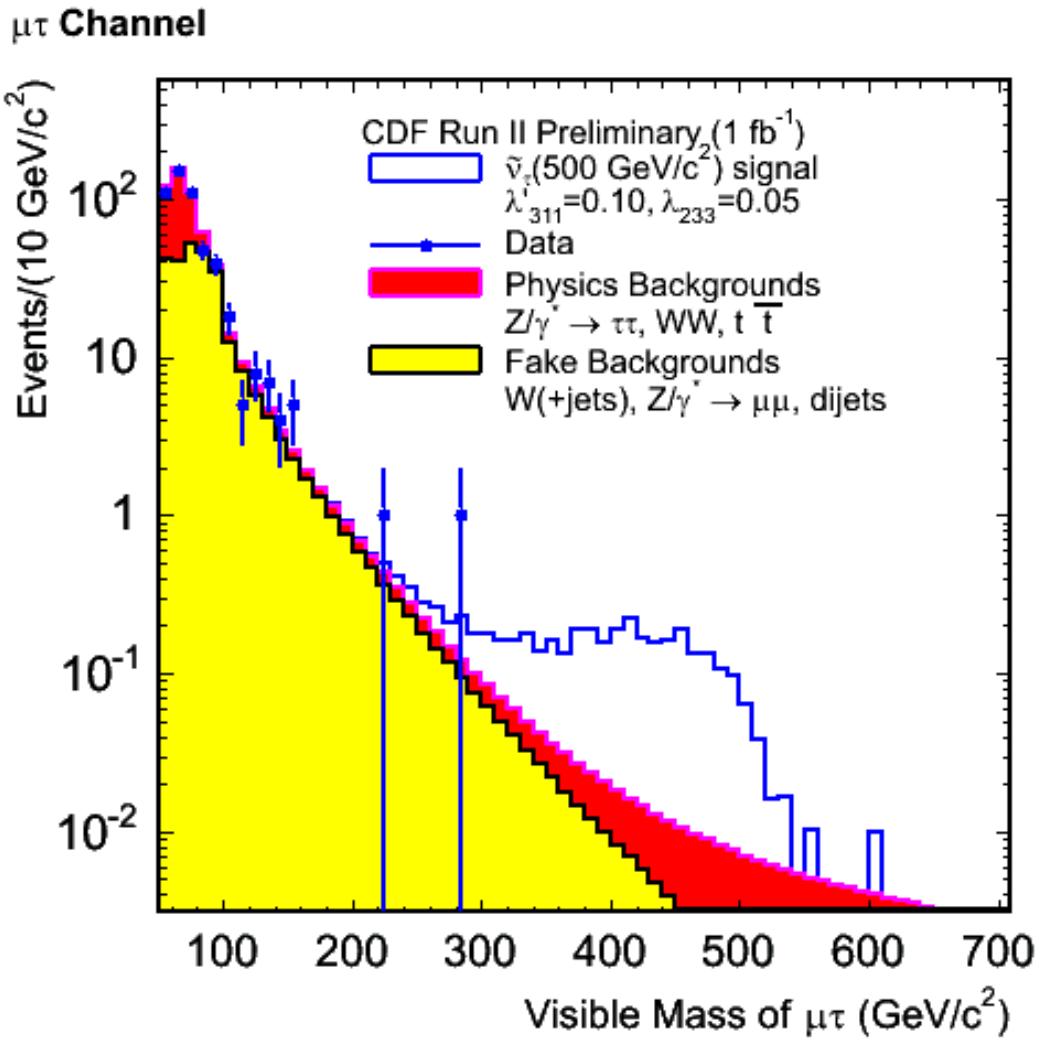




RPV Sneutrino Search

$\mu\tau$ channel result

(eμ and eτ **separately)**



Optimization for **500GeV sneutrino**

$\mu\tau$ mass > 280 GeV/c^2

SM bkgnd = 1.0+-0.3+-0.1

Expected Signal 2.8+-0.1+-0.2

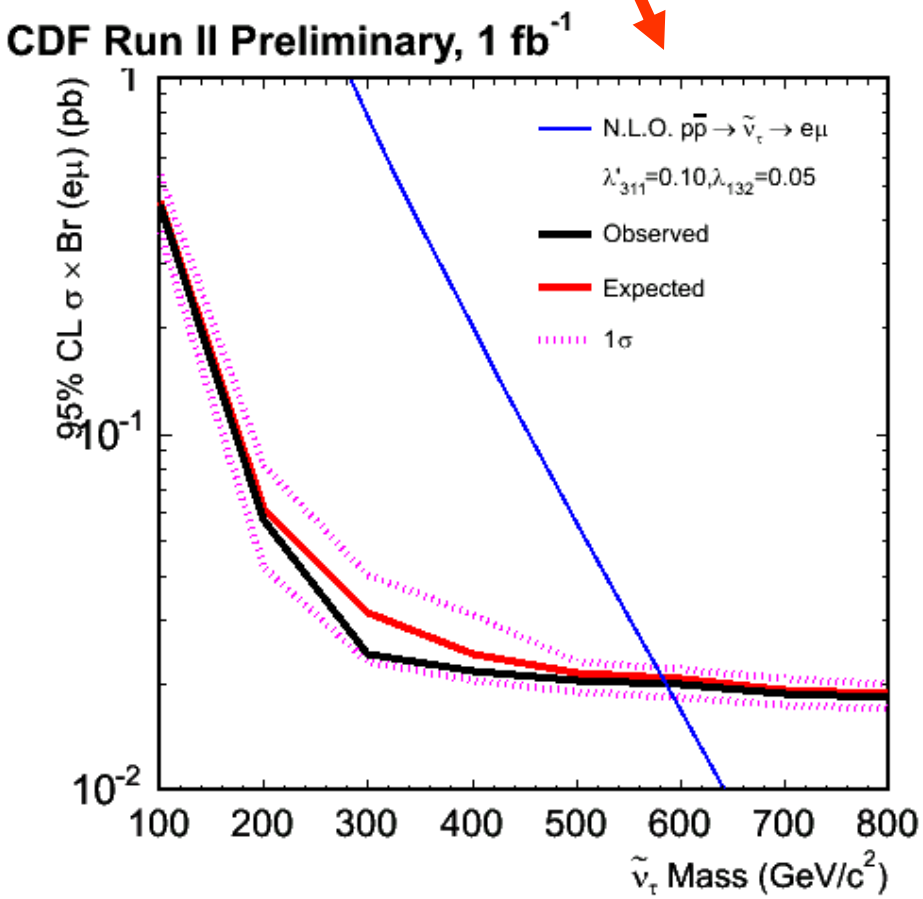
Observed events: 2

→ Set limit.

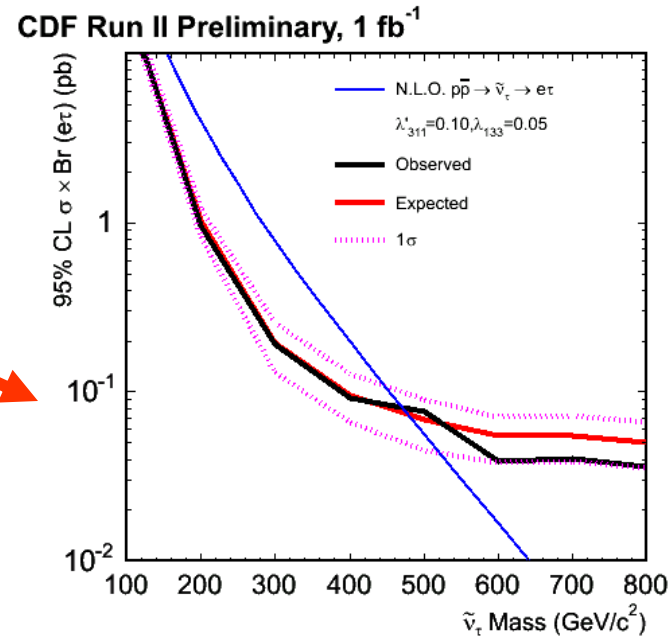
RPV Sneutrino Search: Results

For sample RPV couplings $\lambda'_{311}=0.10$ and $\lambda_{132}=0.05$, $\lambda_{133}=0.05$, $\lambda_{233}=0.05$

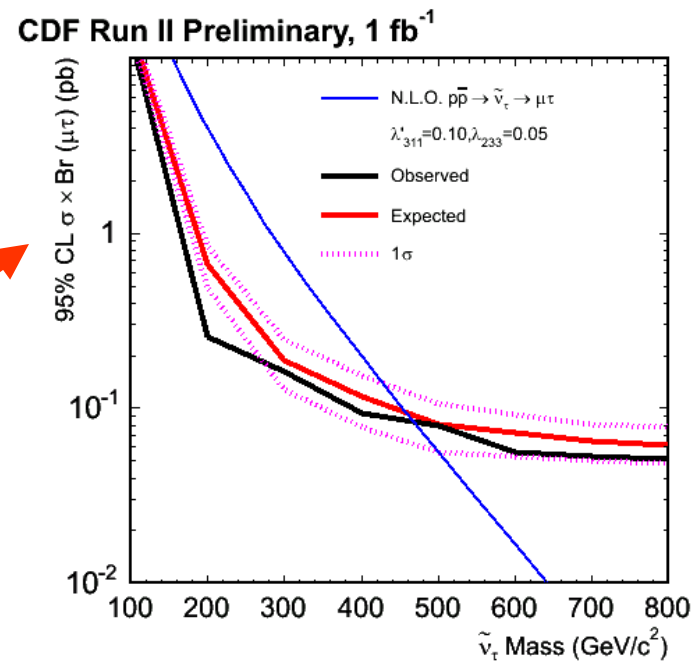
M(tau-sneutrino)>598 GeV/c^2
eμ channel



>489 GeV/c^2
eτ channel



>486 GeV/c^2
μτ channel



Search 2: SUSY Trileptons (2 fb^{-1})

Pair production of Chargino, Neutralino & subsequent decay to leptons

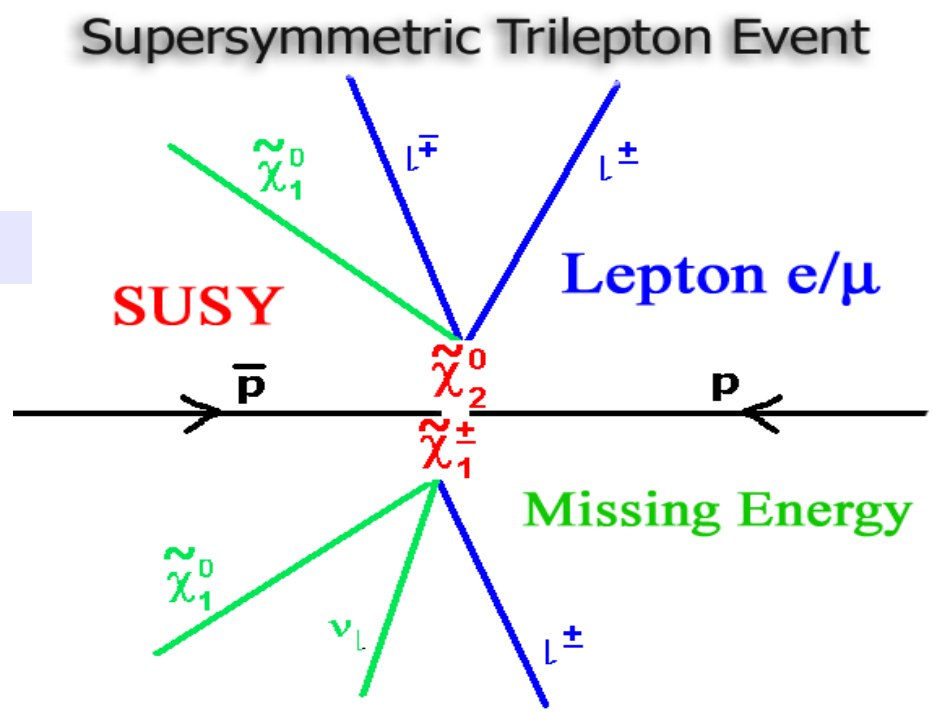
R_p is conserved

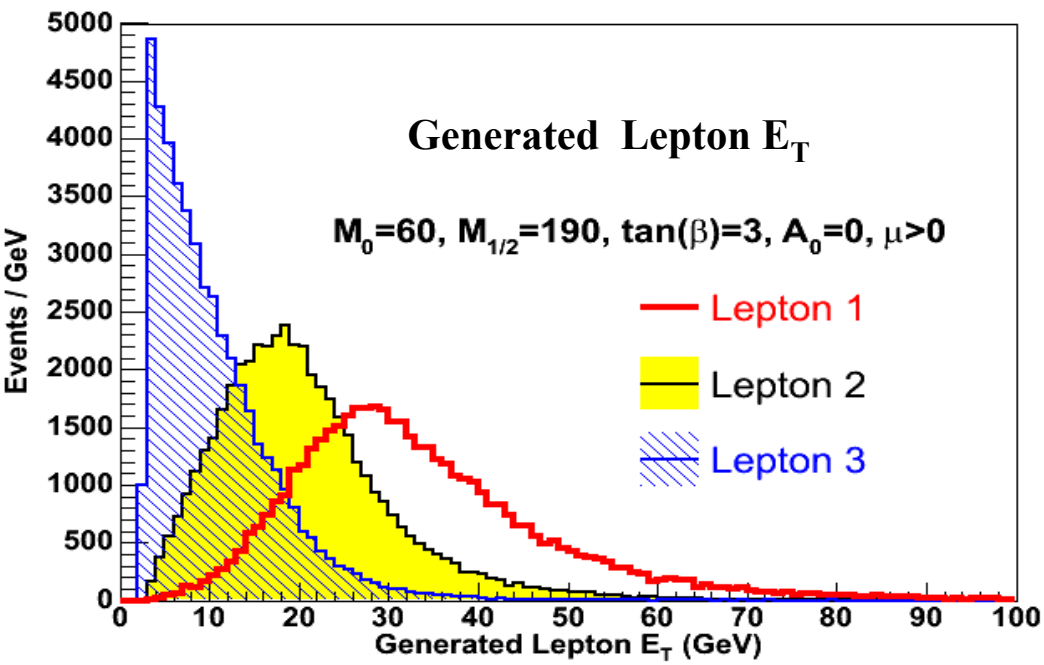
Three leptons + MET

Electrons

Muons

Isolated Tracks





Distinctive signature with

Low SM backgrounds

SUSY Trilepton Search

Signal vs Backgrounds

SIGNAL = 3 leptons + Missing Energy (MET)

σ(Signal)~0.5pb for 120 GeV/c^2 Chargino

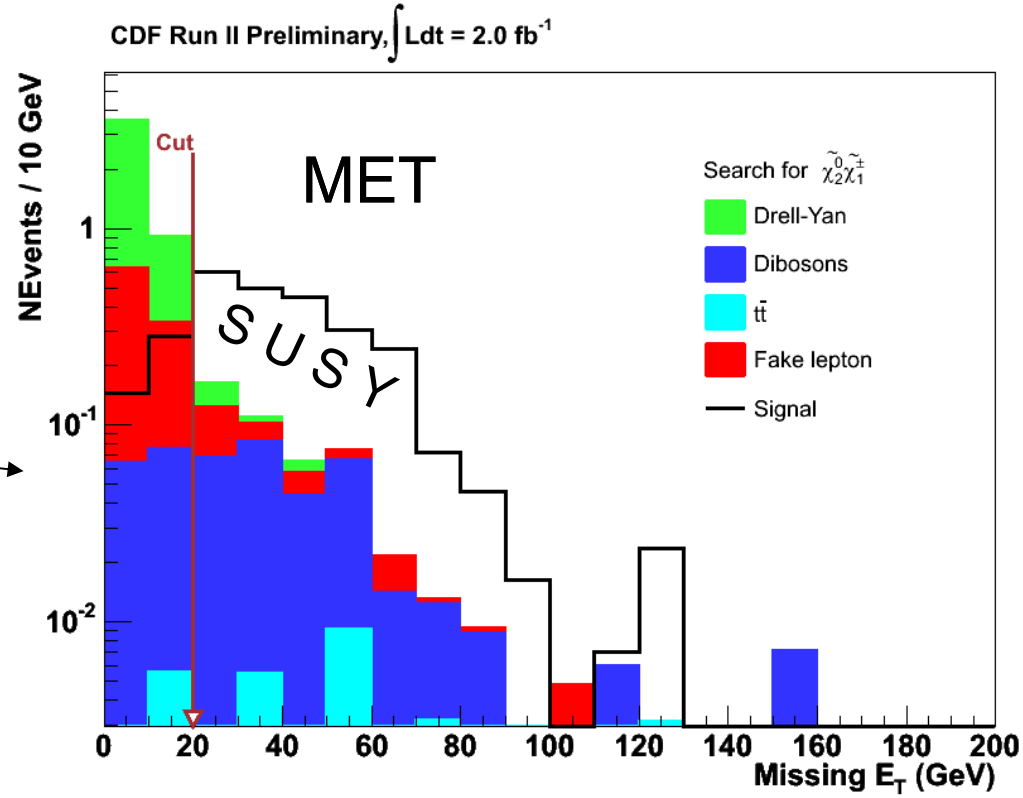
Process	σ(bkg)/σ(sig)	What it has	What it needs
$WZ \rightarrow lll\upsilon$	~ 1	3 leptons + MET	-
$ZZ \rightarrow llll$		$\geq$ 3 leptons	MET
$WW \rightarrow ll\upsilon\upsilon$		2 leptons + MET	1 lepton
Top-pair	~ 10	3 leptons + MET	-
$DY \rightarrow ll$	~ 1000	2 leptons	1 lepton + MET
$Z\gamma \rightarrow ll\gamma$	~ 30	$\geq$ 3 leptons	MET
$W \rightarrow l\upsilon$	~ 5000	1 lepton + MET	2 leptons

Trileptons:Selections

Drell- Yan Removal

MET > 20 GeV

$\Delta\varphi_{os} < 2.9$ rad



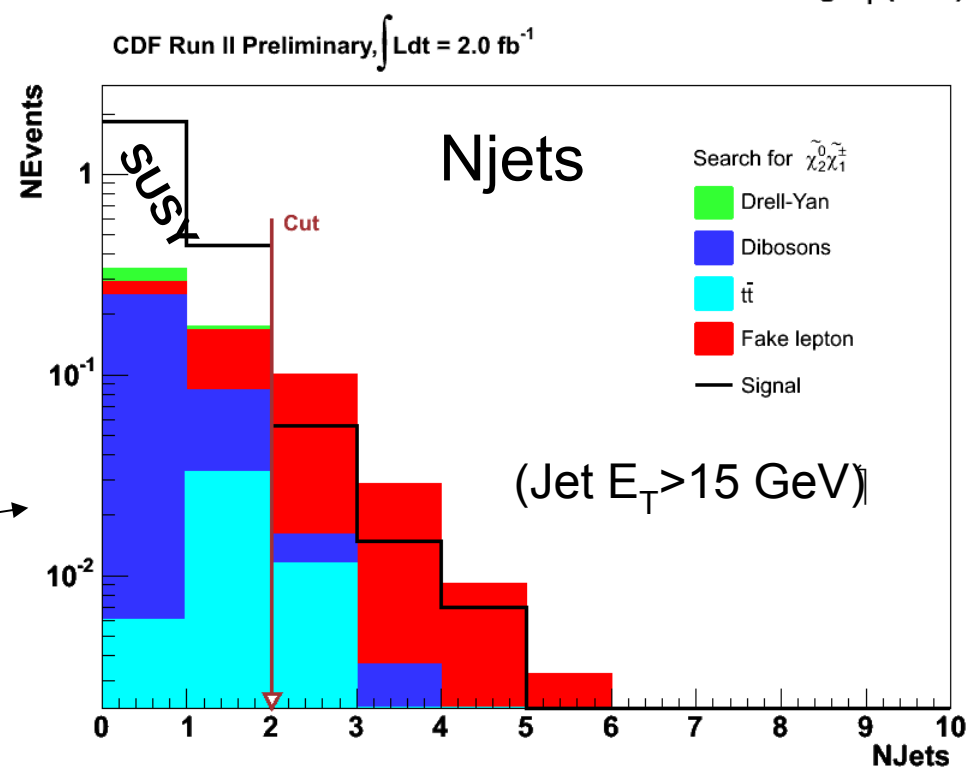
Resonance Removal

$M_{os}^1, M_{os}^2 > 20, 13$ GeV/c^2

Z-cut ($M_{os} < 76$ or > 106 GeV/c^2)

Top-pair Removal

NJets < 2



Unified Analysis Scheme

Too many overlapping trigger paths
→Five exclusive channels ordered by signal purity:

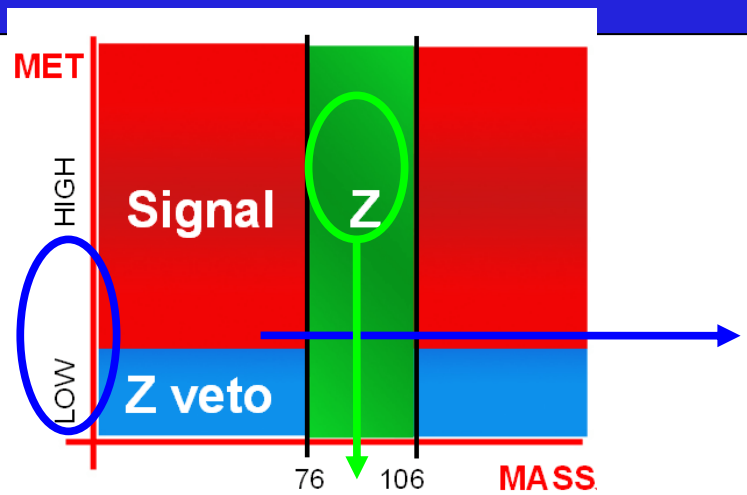
Channel	E_T (P_T) GeV
3 tight leptons OR 2 tight leptons + 1 loose electron	**15, 5, 5**
2 tight leptons + 1 loose muon	**15, 5, 10**
1 tight lepton + 2 loose leptons	**20, 8, 5 (10 if loose muon)**
2 tight leptons + 1 Track	**15, 5, 5**
1 tight lepton, 1loose lepton, 1 Track	**20, 8(10 if loose muon), 5**

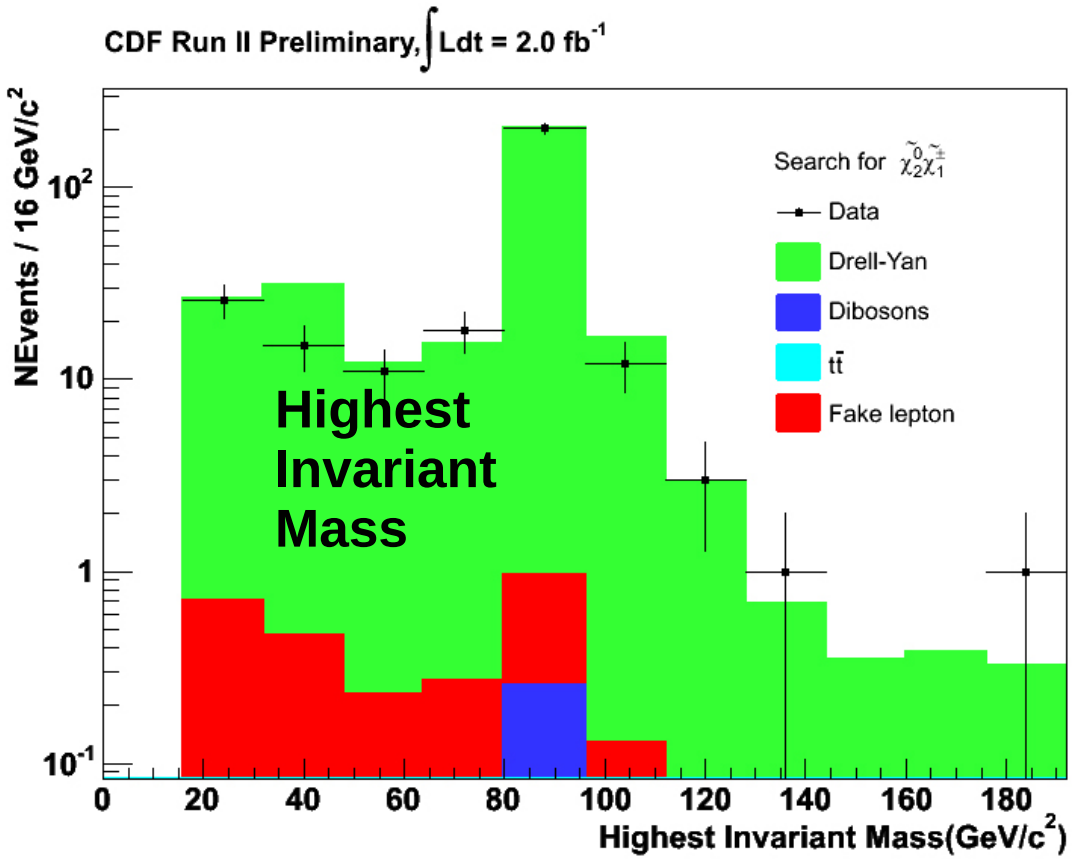
TRACK gets the single-prong tau's and remnant electrons and muons.

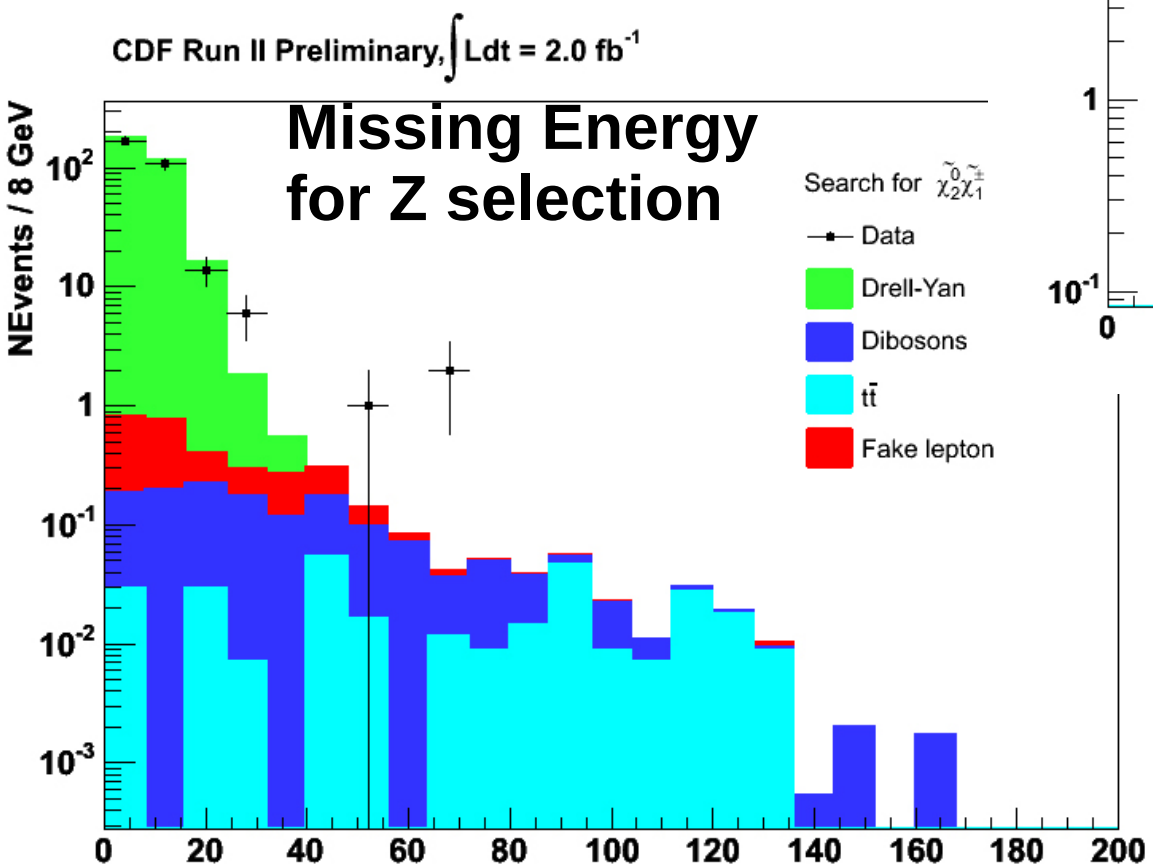
The five exclusive channels constitute

five independent experiments within CDF

Control Regions







Example Selection :
2 tight leptons + 1 Track

Final Predictions

Channel	Signal	Background	Observed
3tight	2.3±0.1±0.3	0.5±0.04±0.1	
2tight,1loose	1.6±0.1±0.2	0.3±0.03±0.03	
1tight,2loose	0.7±0.1±0.1	0.1±0.02±0.02	
Total trilepton	4.6±0.2±0.6	0.9±0.1±0.2	
2tight,1Track	4.4±0.2±0.6	3.2±0.5±0.5	
1tight,1loose,1Track	2.4±0.1±0.3	2.3±0.5±0.4	
Total dilepton+track	6.8±0.2±0.9	5.5±0.7±0.9	

TOTAL SIGNAL = 11.4 events

Signal : mSUGRA m_0=60, $m_{1/2}$=190, tan(β)=3, A_0=0, μ>0, $M(\chi_1^{\pm})$=120 GeV/c^2

Final Predictions

CDF Run II Preliminary, $\int Ldt = 2.0\ fb^{-1}$

Channel	Signal	Background	Observed
3tight	2.3±0.1±0.3	0.5±0.04±0.1	1
2tight,1loose	1.6±0.1±0.2	0.3±0.03±0.03	0
1tight,2loose	0.7±0.1±0.1	0.1±0.02±0.02	0
Total trilepton	4.6±0.2±0.6	0.9±0.1±0.2	1
2tight,1Track	4.4±0.2±0.6	3.2±0.5±0.5	
1tight,1loose,1Track	2.4±0.1±0.3	2.3±0.5±0.4	
Total dilepton+track	6.8±0.2±0.9	5.5±0.7±0.9	

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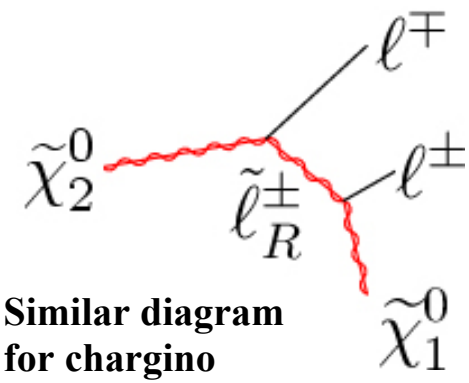
1tight,2loose	0.7±0.1±0.1	0.1±0.02±0.02	0
Total trilepton	4.6±0.2±0.6	0.9±0.1±0.2	1
2tight,1Track	4.4±0.2±0.6	3.2±0.5±0.5	4
1tight,1loose,1Track	2.4±0.1±0.3	2.3±0.5±0.4	2
Total dilepton+track	6.8±0.2±0.9	5.5±0.7±0.9	6

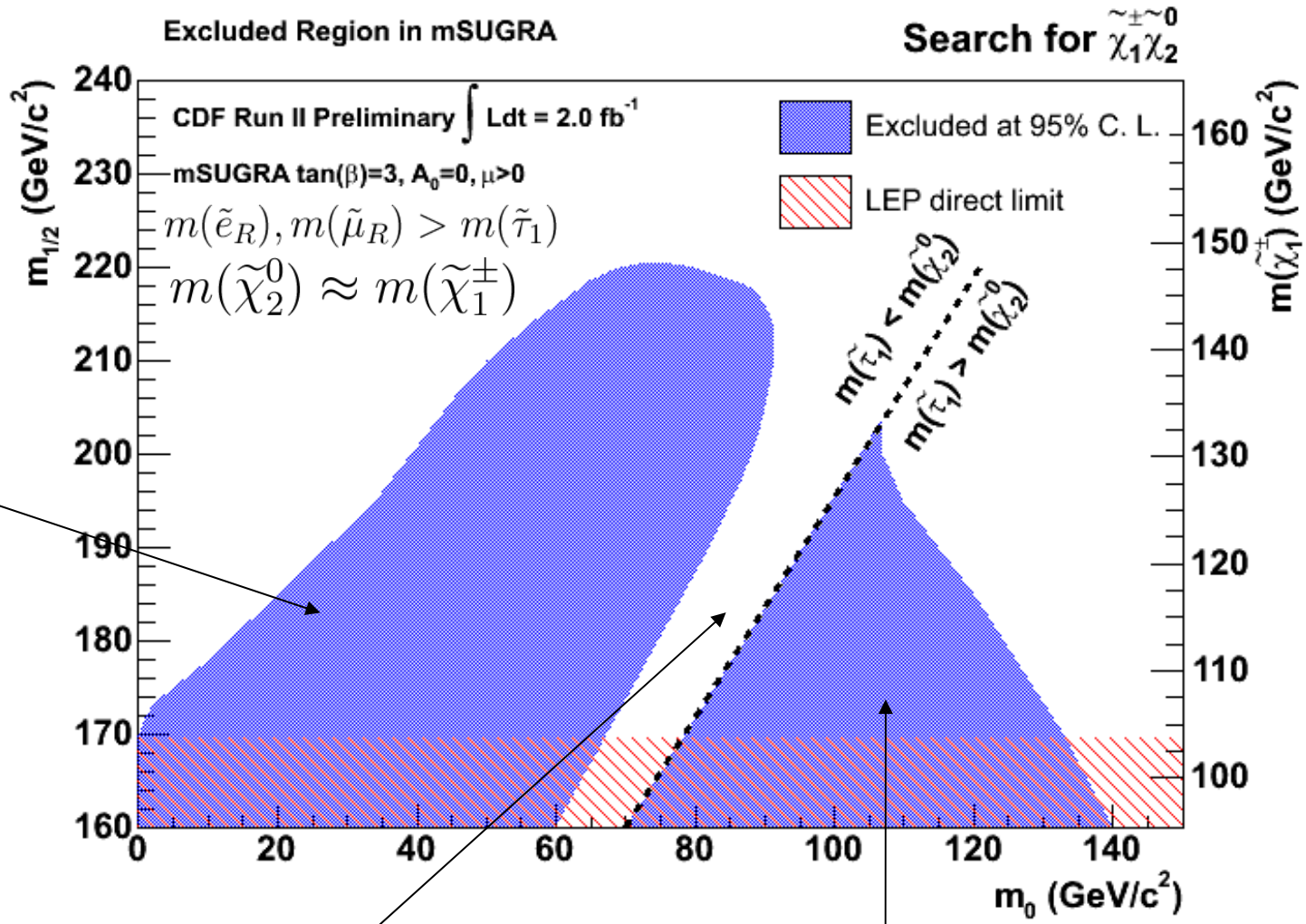
Signal : mSUGRA m_0=60, $m_{1/2}$=190, tan(β)=3, A_0=0, μ>0, $M(\chi_1^{\pm})$=120 GeV/c^2

Excluded Region in mSUGRA

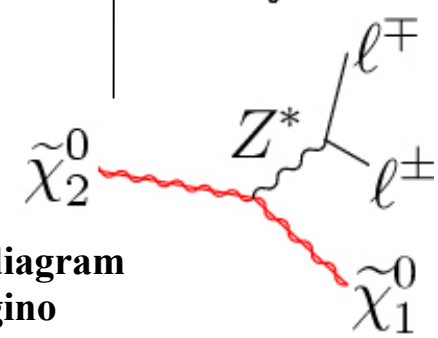
Dominated by



Similar diagram for chargino

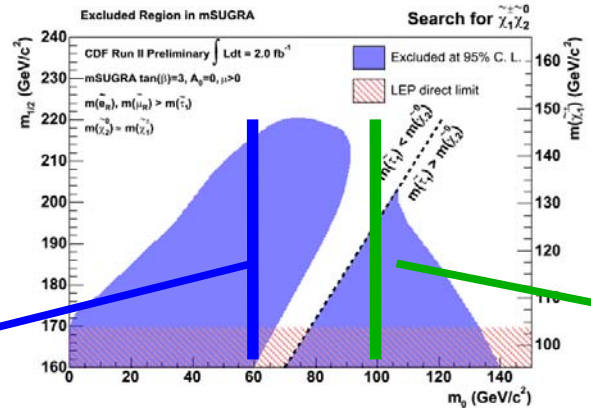


Region of no sensitivity:
M(Neutralino) – M(slepton) ≈ 0
=> soft lepton from Neutralino decay
=> loss in acceptance, no exclusion



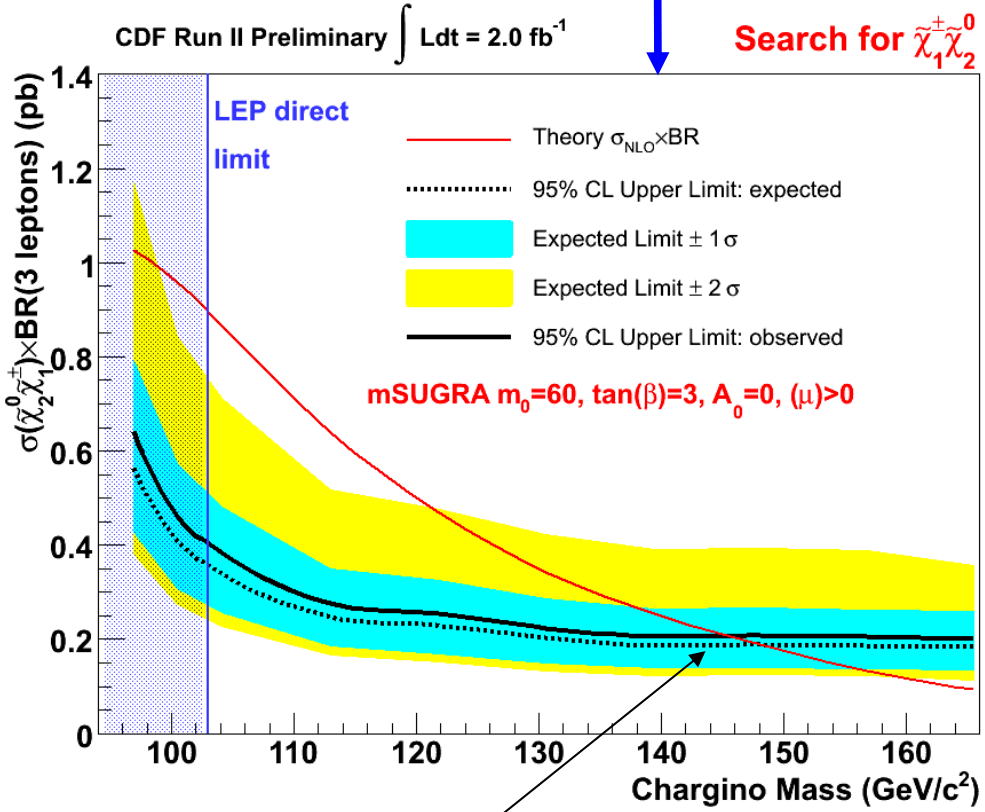
Similar diagram for chargino

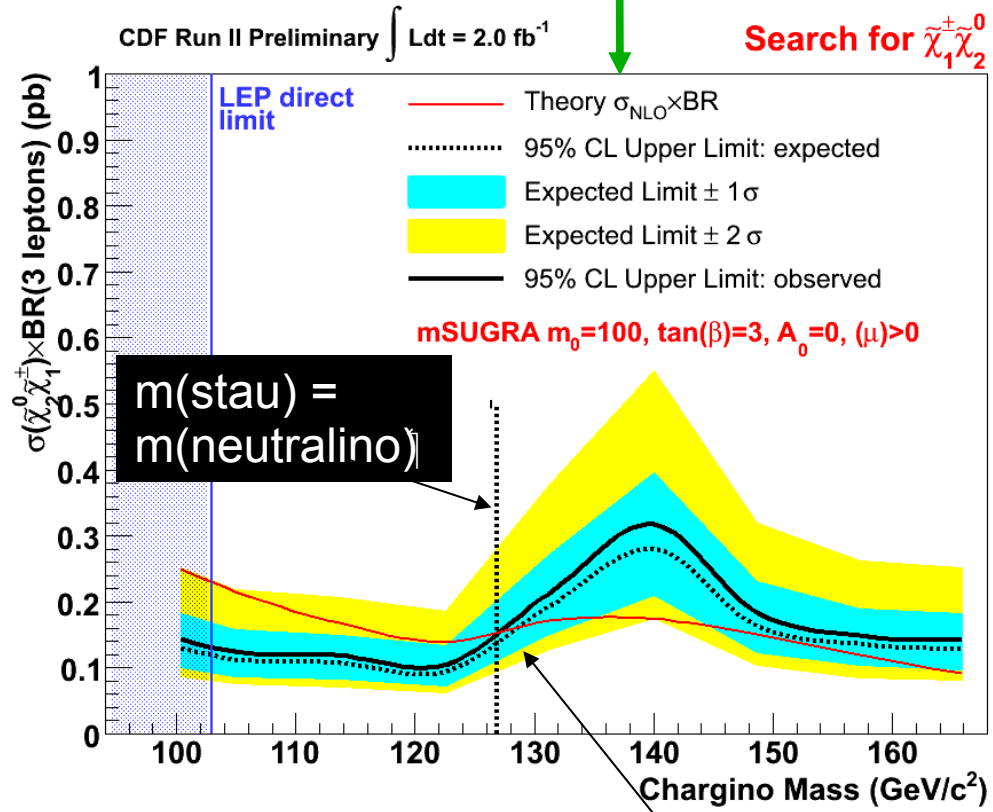
Mass limits



m_0=60 GeV/c^2

m_0=100 GeV/c^2





Exclude Chargino with Mass<145 GeV/c^2
Best direct mSUGRA limits
on Chargino mass

Exclude Chargino with Mass<127 GeV/c^2

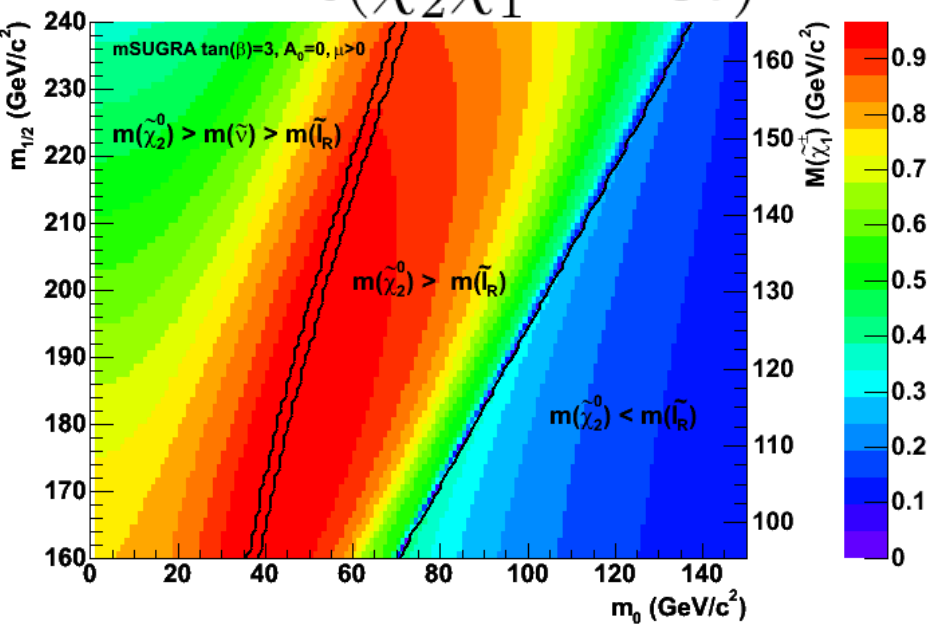
Model Independent Interpretation

- Both CDF and D0 have come up with their own under the lamp-post scenarios.

- mSUGRA is an established model, but is still only a strawman and has specific characteristics

Example:

$$BR(\tilde{\chi}_2^0\tilde{\chi}_1^{\pm} \rightarrow 3\ell)$$



How to get away from specific models?

Move away from model-specific parameters such as m0, m1/2 etc to sparticle masses (and leptonic branching ratios).

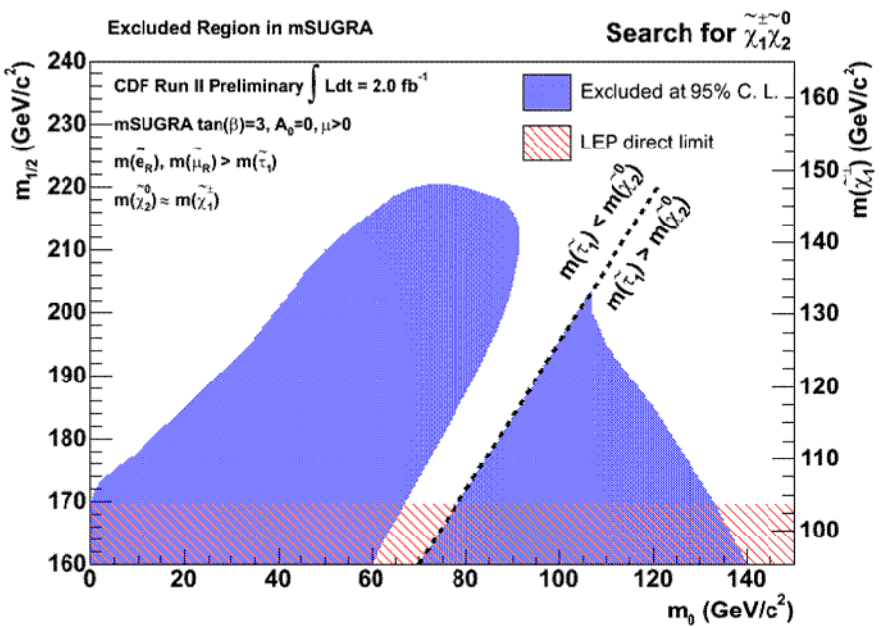
→ Experiments sensitive to the τ content
→ Break down trilepton results into four channels:
(e/μ)(e/μ)(e/μ), τ(e/μ)(e/μ), ττ(e/μ), τττ
i.e. 0-τ, 1-τ, 2-τ and 3-τ channels.

Theorist's Question:
Instead of mSUGRA results, can you give me a simple recipe for experimental sensitivity in which I can input the susy masses and trilepton branching ratios from my model?

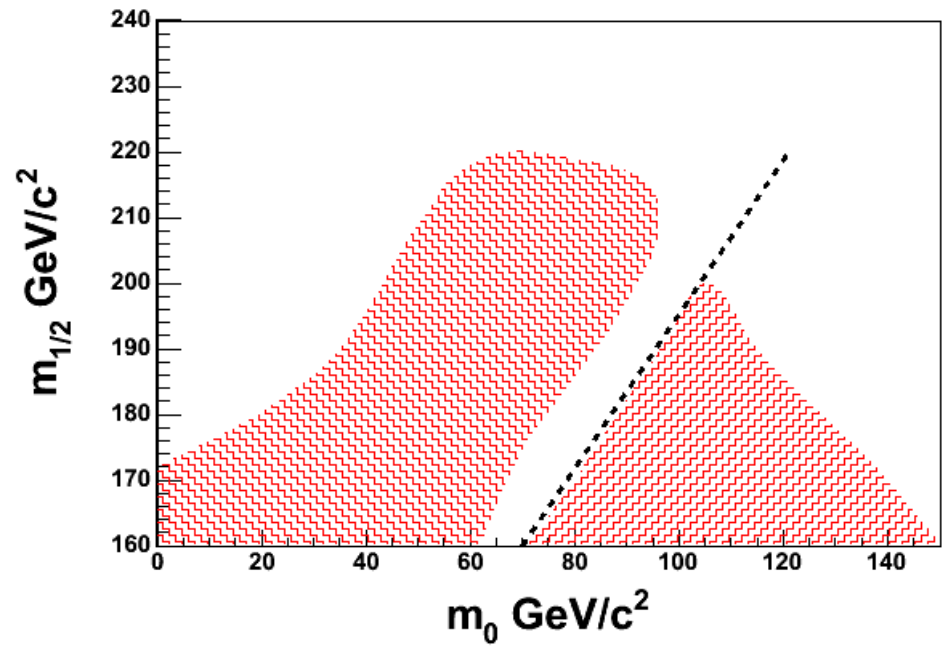
Answer:
Get sensitivity from standalone Pythia scans.
Calibrate to published Tevatron result.
Express as an analytical formula.

Trilepton Model Independent Interpretation

2 fb-1 CDF mSUGRA result
with full simulation scans



Ditto from a model-independent
formulation using Pythia. NOT CDF!



Disclaimer:
Upcoming phenomenology paper by Dube, Glatzer, Somalwar and Sood (Rutgers)
NOT a CDF result!

Summary

- New/recent results: R-parity violating MSSM sneutrino (unlike flavor leptons, 1fb^{-1}) and R-Parity conserving chargino- neutralino (trilepton+MET, 2fb^{-1}). First probe of mSUGRA since LEP with trileptons. Both searches had a good shot at seeing something.

- More data analysis (e.g. $B_s \rightarrow \mu\mu$), increased acceptance (e.g. trileptons at lower pt), improved reach (e.g. trileptons sensitive to two tau's with explicit reconstruction) in progress.

Look for more results here:

http://www-cdf.fnal.gov/physics/exotic/exotic.html