SUSY Searches with Leptons at CDF

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For the CDF Collaboration

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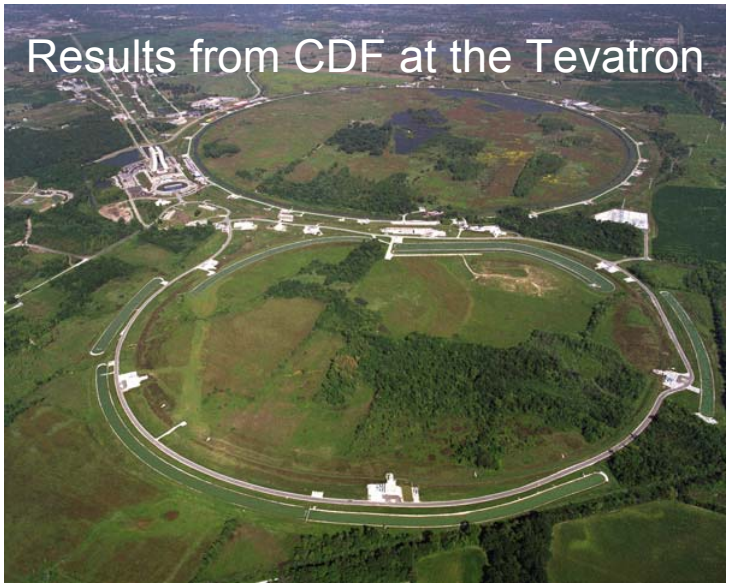
RUTGERS
UNIVERSITY

Outline



- Introduction
- RPV sneutrinos
- Trileptons
- Conclusions

Assembling an electron

$r < 10^{-19}$m → $E_{assembly} \sim e^2/r$ ~10GeV = 10,000 MeV

But m_e = ½ MeV → correction = -9999.5 MeV!

One fine cancellation!!

Give the electron a partner of equal and opposite charge, i.e. positron.

Why double the "particle spectrum"?

Uncertainty principle allows e^+e^- pair creation out of vacuum for a short duration

$$\Delta t \sim \frac{\hbar}{\Delta E} \sim \frac{\hbar}{2m_e c^2}$$

$$c\Delta t \sim \frac{\hbar c}{2m_e c^2} \sim \frac{200 MeV\, fm}{1 MeV} = 200 fm (= 2 \times 10^{-11} cm)$$

Weisskopf (1939): The annihilation energy for the real e^- and the virtual e^+ from vacuum is equal and opposite: $-e^2/r$: Cancellation!

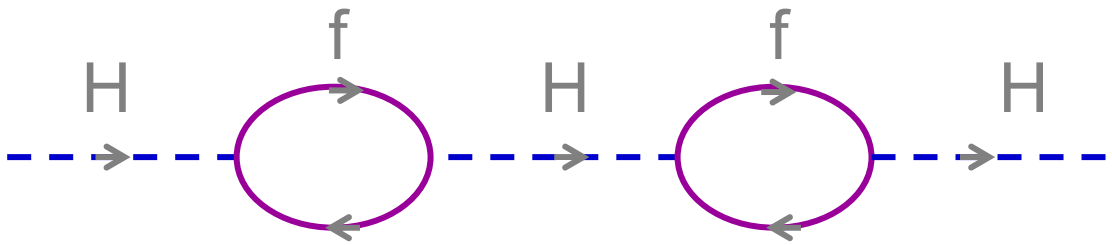
* New physics (positron) at 1MeV scale needed for a sensible theory at higher energies.

* Doubling the spectrum avoided artificial cancellation of large numbers to get a physical number.

Beyond Std Model: Hierarchy Problem

Radiative loops → Higgs mass ~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).

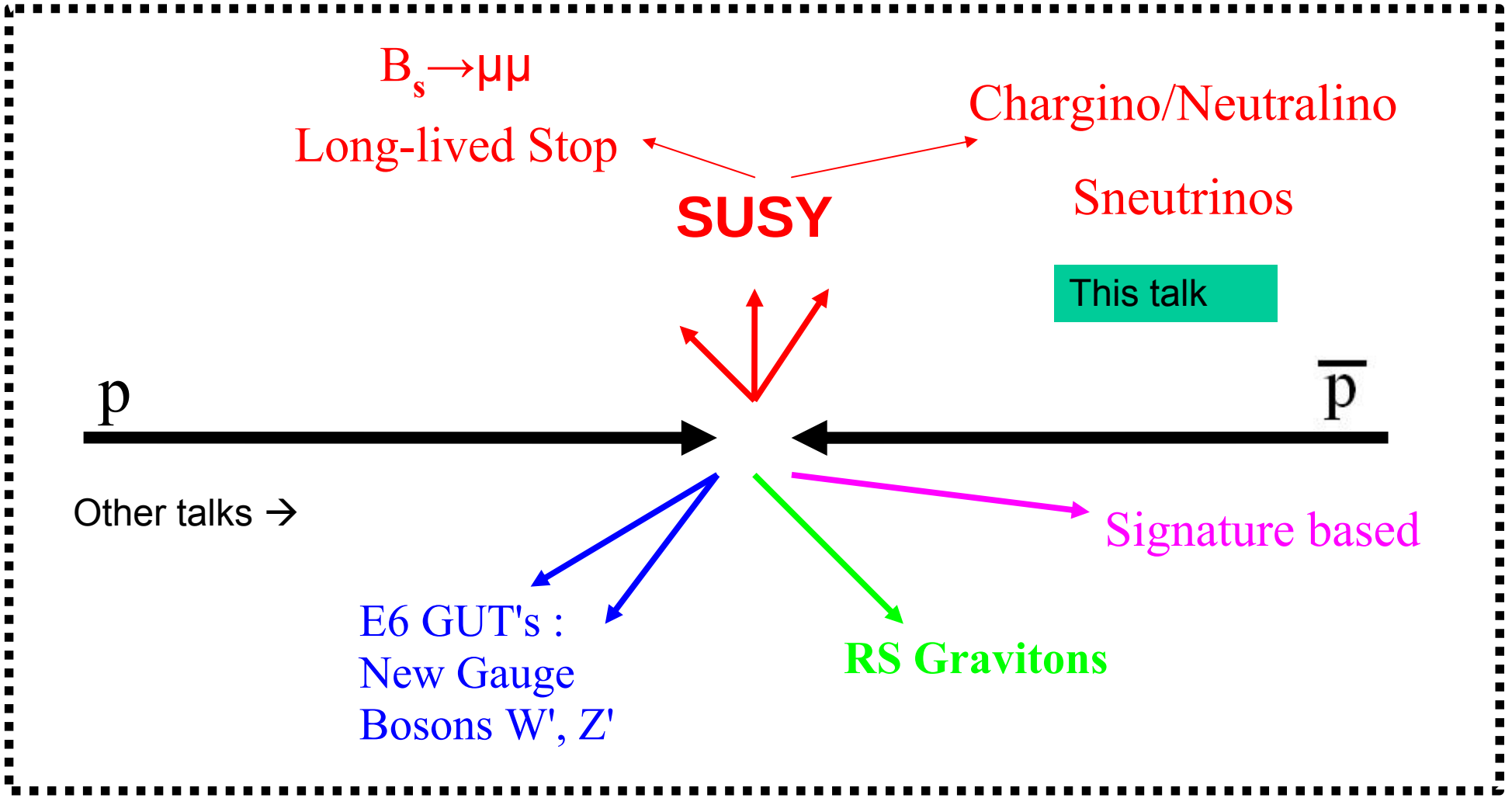
Is the Tevatron Adding to the Dark Matter Problem?

Beyond Standard Model with Leptons

Clean Signatures

Low Backgrounds

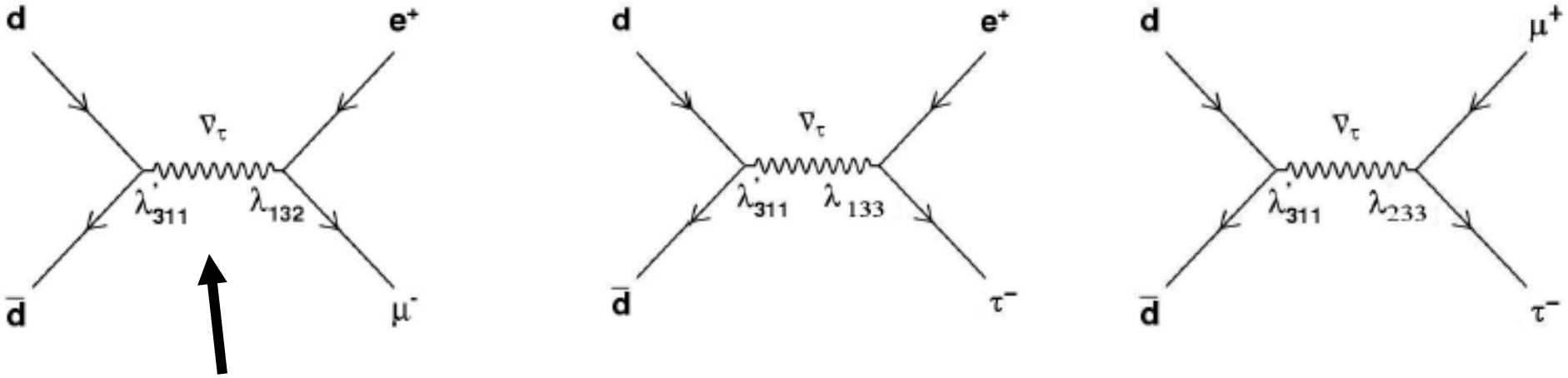
Many Models



R-Parity Violating MSSM Sneutrino Search

RPV 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} : d-dbar to tau-sneutrino (production) 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)

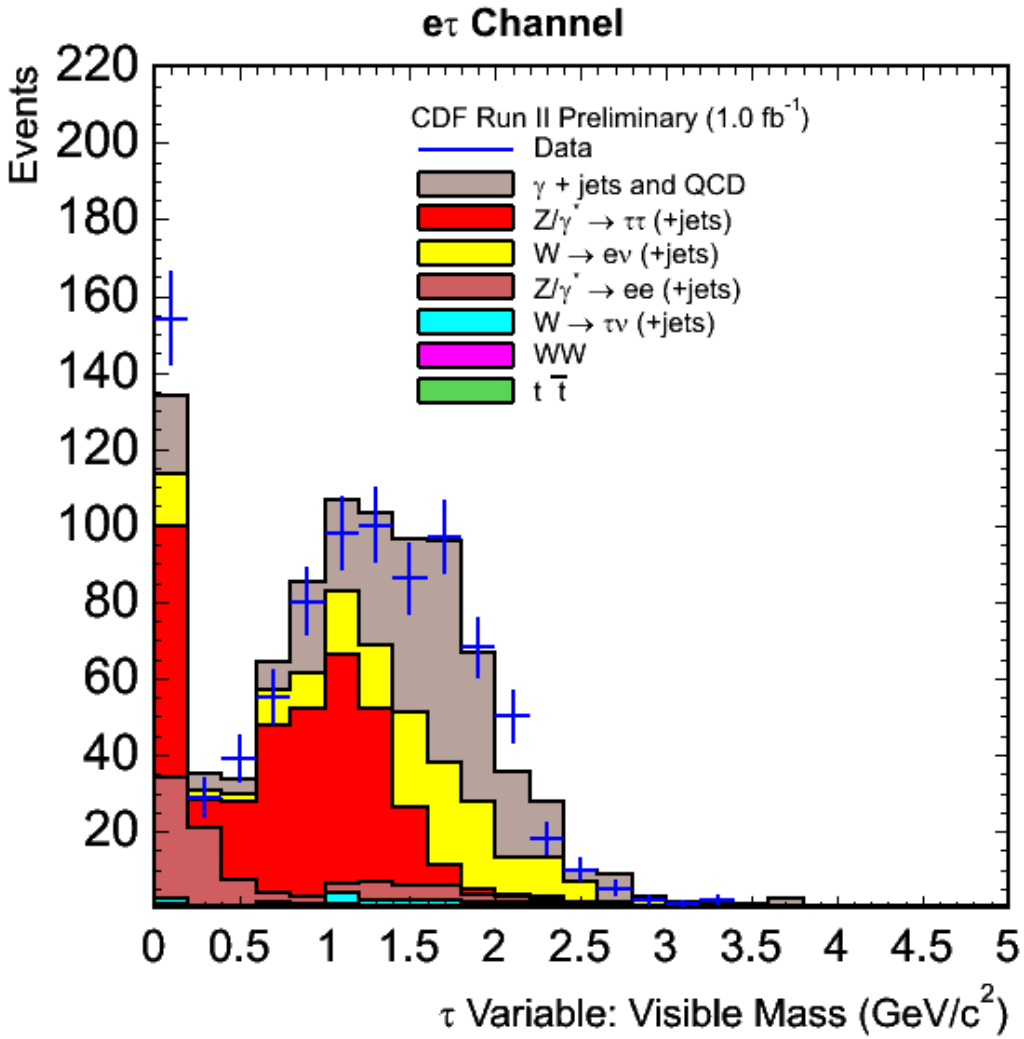
SIGNAL AND CONTROL REGIONS

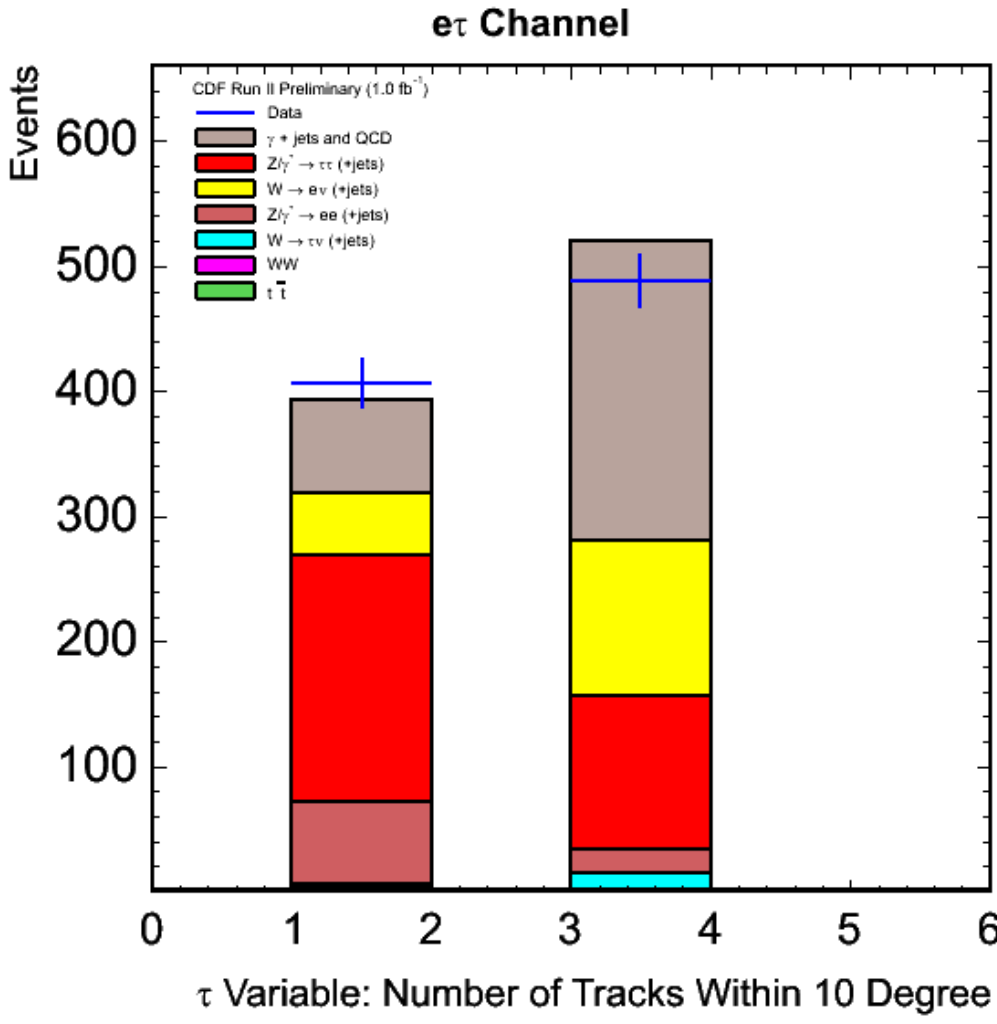
Reconstruct $e\mu$, $e\tau_h$, $\mu\tau_h$ invariant mass. (Use visible p for masses with τ)

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

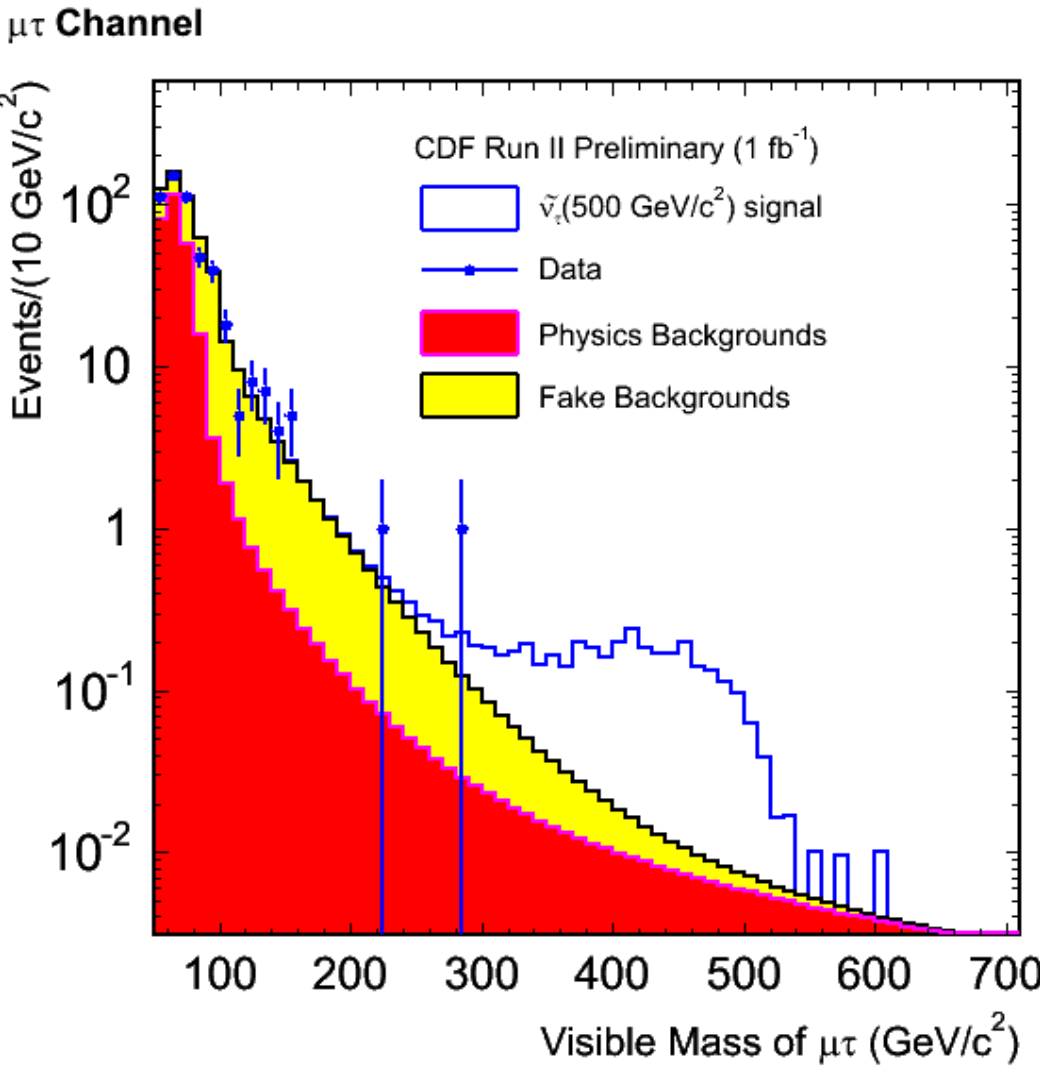
RPV Sneutrino Search

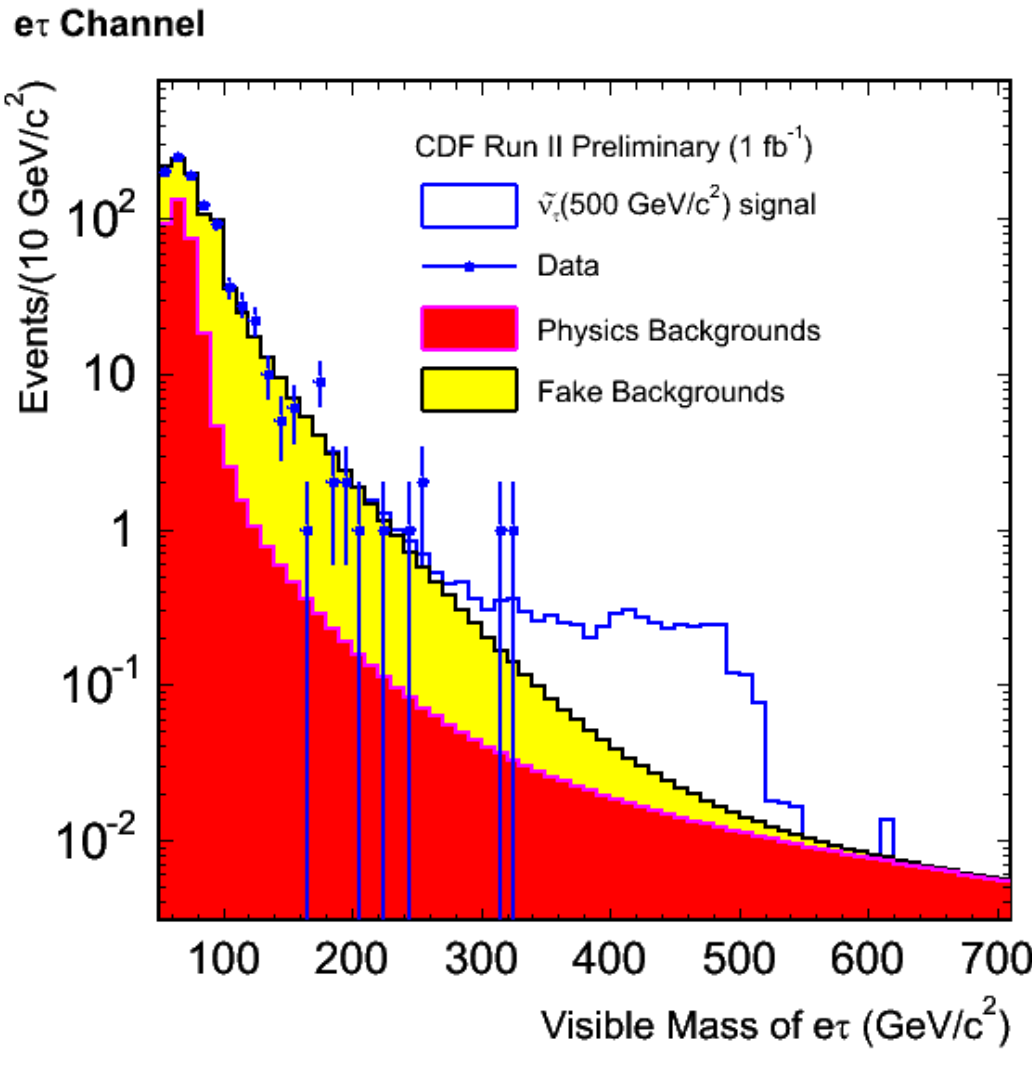
Control region: 50 GeV /c^2 < M_{LL} < 110 GeV/c^2





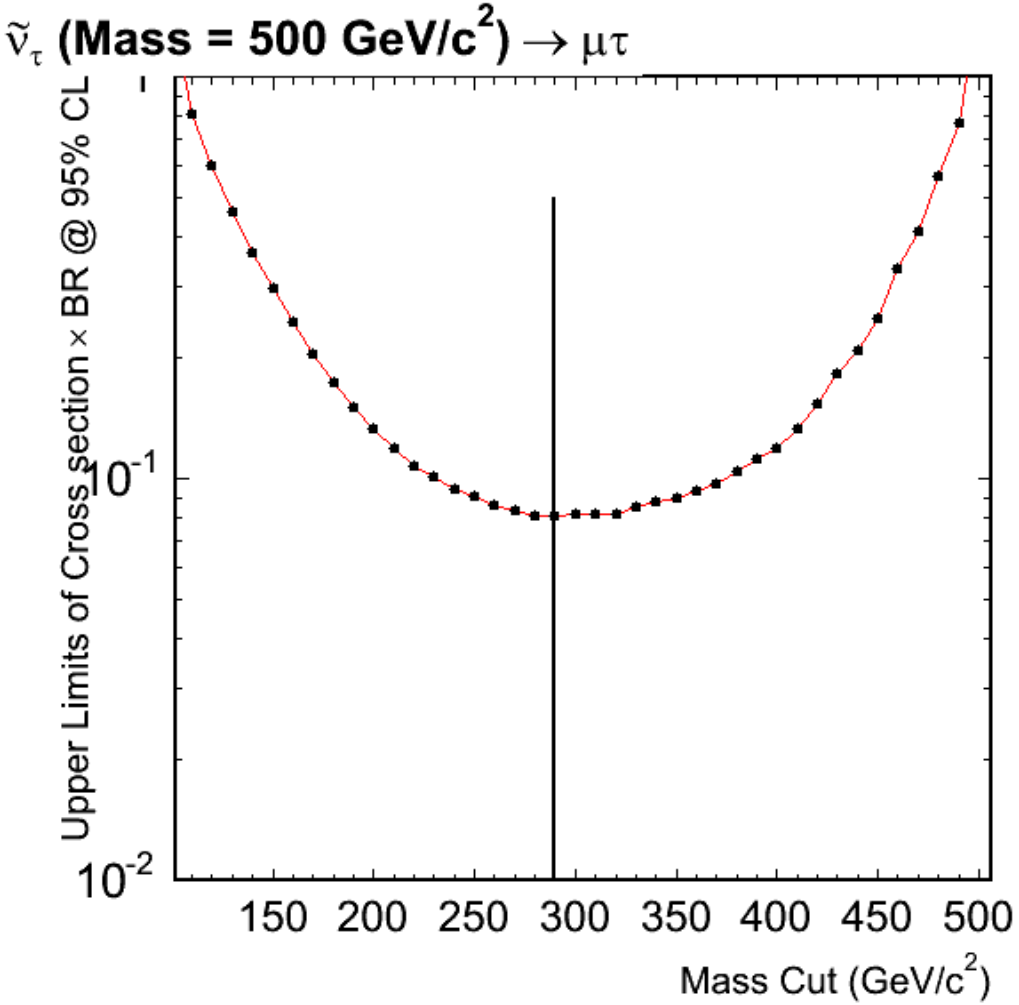
RPV Sneutrino Search





RPV Sneutrino Search

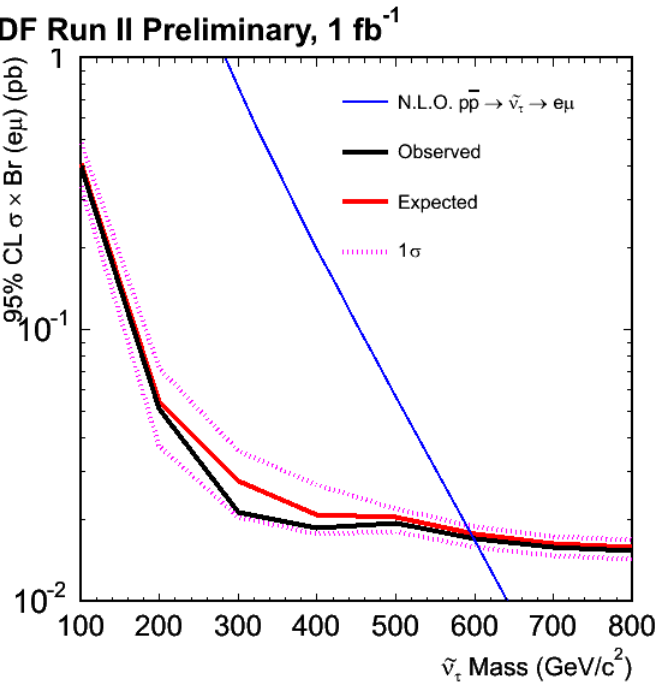
Signal Mass Cut Optimization ($\mu\tau$)

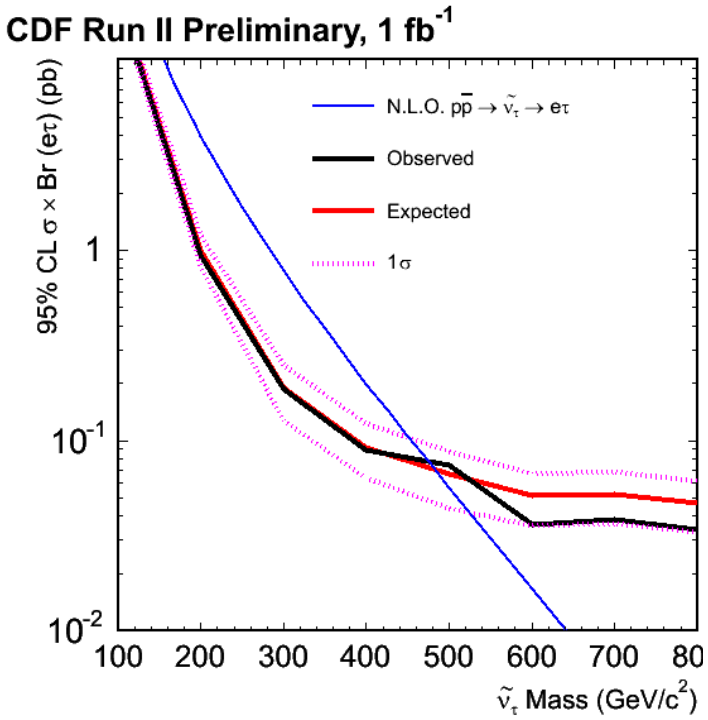


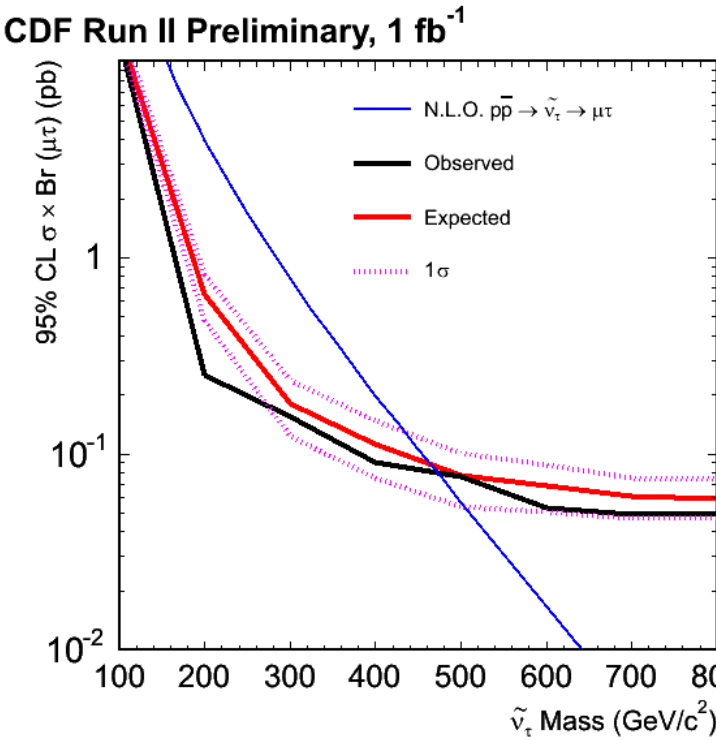
SM processes	$\mu\tau$ channel
	$M > 280 GeV/c^2$
$Z/\gamma^* \rightarrow \tau\tau$	0.4 ± 0.3
$Z/\gamma^* \rightarrow \mu\mu$	0.1 ± 0.02
$W \rightarrow \mu\nu$(+jets)	0.3 ± 0.08
$W \rightarrow \tau\nu$(+jets)	0.004 ± 0.003
WW	0.02 ± 0.004
$t\bar{t}$	0.006 ± 0.0008
QCD (γ +jets)	0.02 ± 0.005
Total SM bg →	$1.0 \pm 0.3 \pm 0.1$
Expected signal	$3.1 \pm 0.1 \pm 0.2$
Observed Events in Data	2 ↖

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

SUSY Trilepton Search

2 fb-1

Pair production of Chargino, Neutralino & subsequent decay to leptons

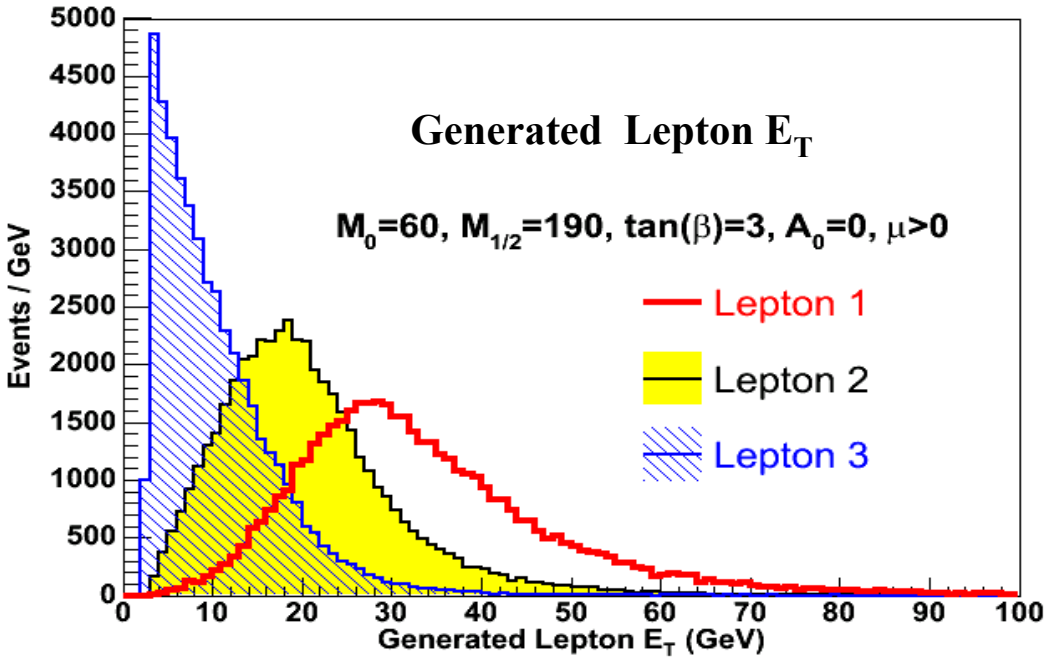
R_p is conserved

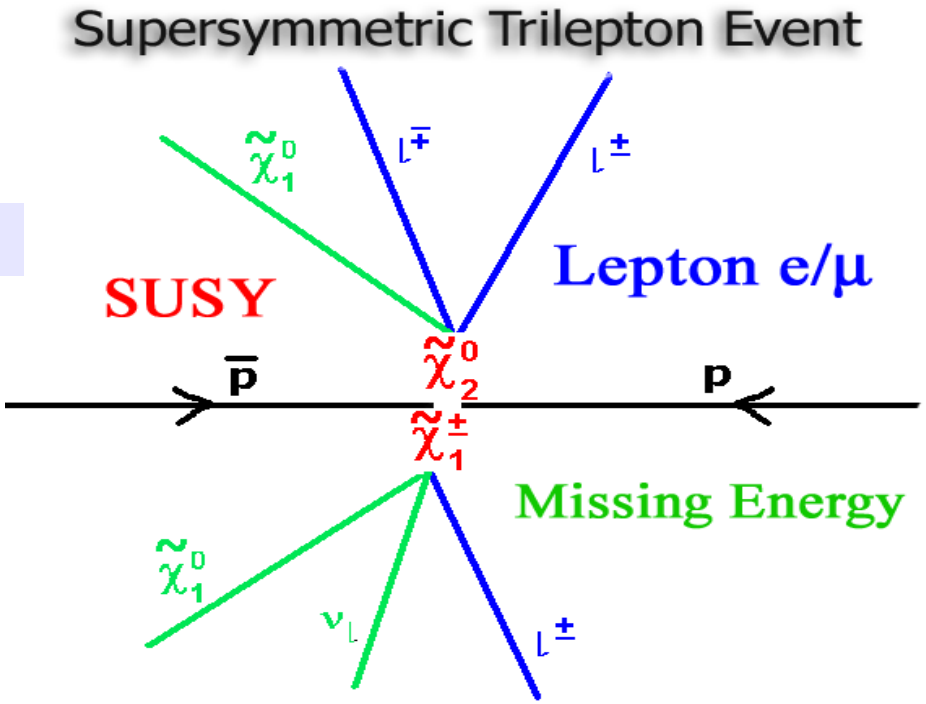
Three leptons + MET

Electrons

Muons

Isolated Tracks





Distinctive signature with

Low SM backgrounds

Trilepton E_T/p_T Selections

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

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→lllυ	~ 1	3 leptons + MET	-
ZZ→llll		≥ 3 leptons	MET
WW→llυυ		2 leptons + MET	1 lepton
Top-pair	~ 10	3 leptons + MET	-
DY→ll	~ 1000	2 leptons	1 lepton + MET
Zγ→llγ	~ 30	≥ 3 leptons	MET
W→lυ	~ 5000	1 lepton + MET	2 leptons

Selections

2 fb^{-1}

P_T > 15, 5, 5 GeV

Remove DY

MET > 20 GeV

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

< 2.8 rad for dilep+trk

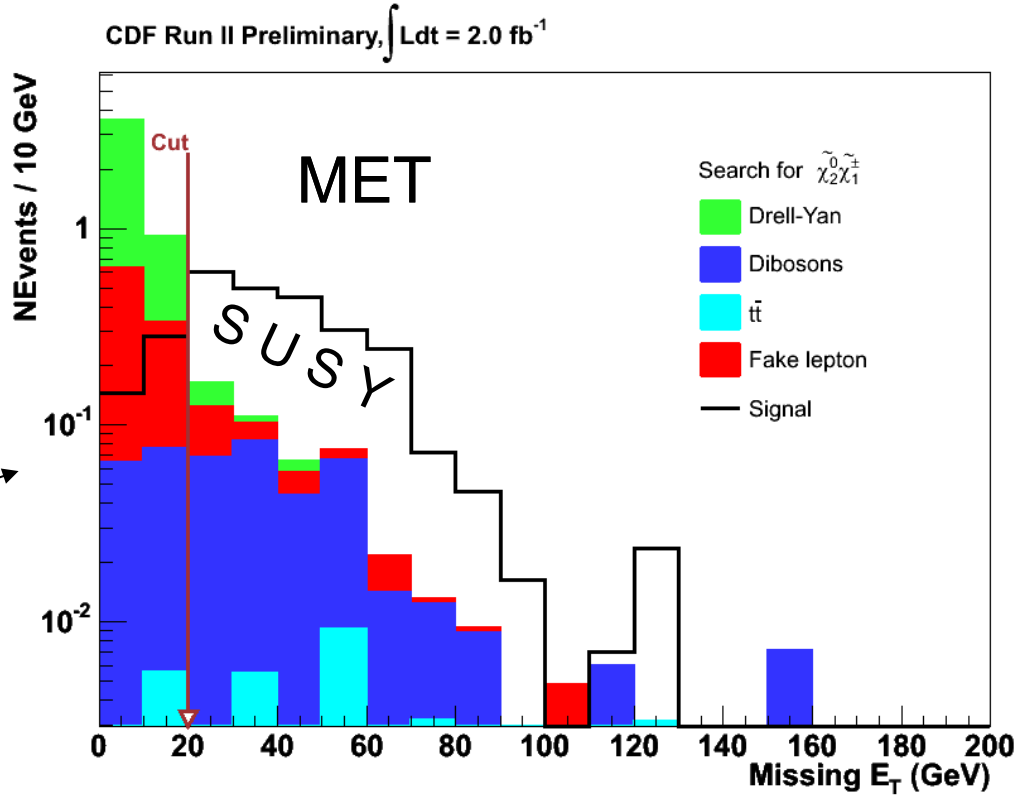
Resonance Cuts

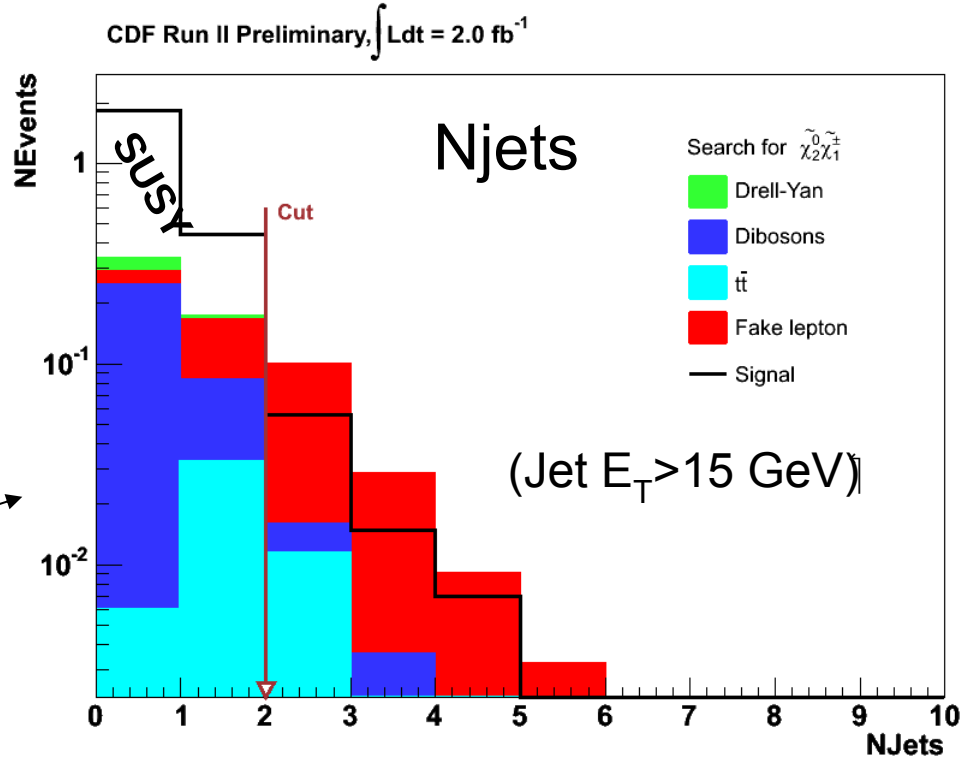
M_{os}^{1}, M_{os}^{2} > 20 , 13 GeV/c^2

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

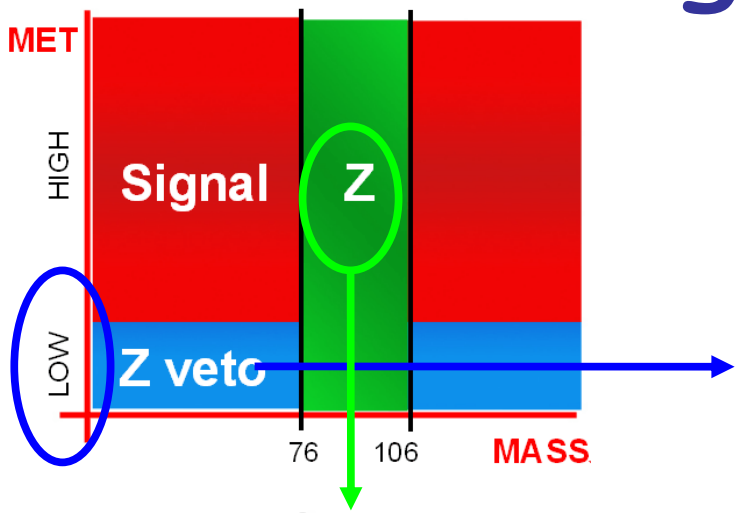
Remove top-pair

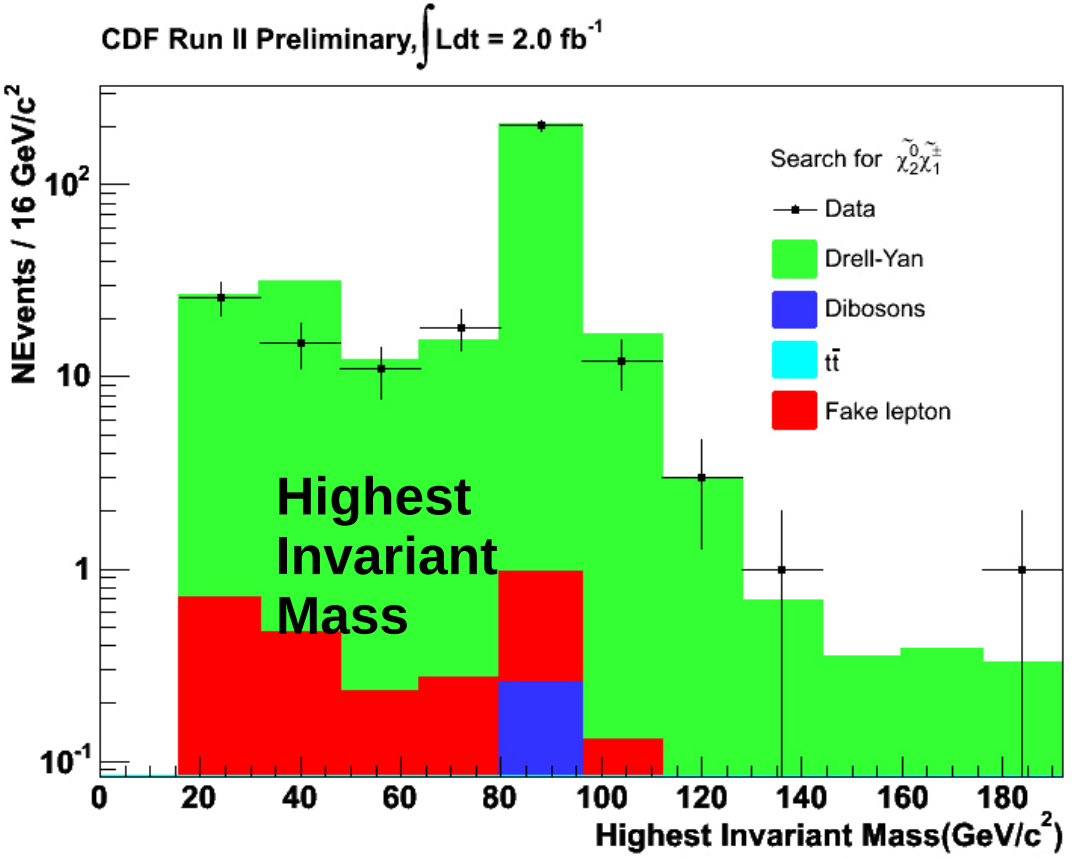
NJets < 2

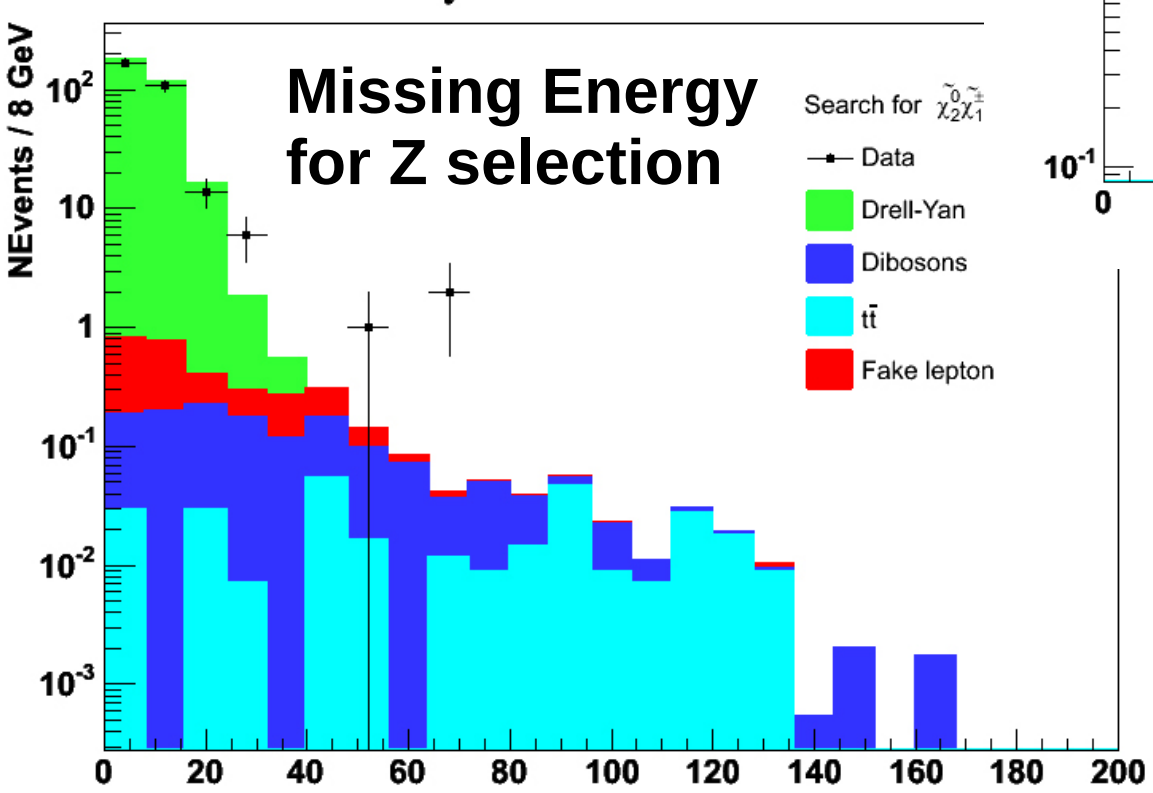




Control Regions : Trileptons







Selection :
2 tight leptons + 1 Track

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	
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

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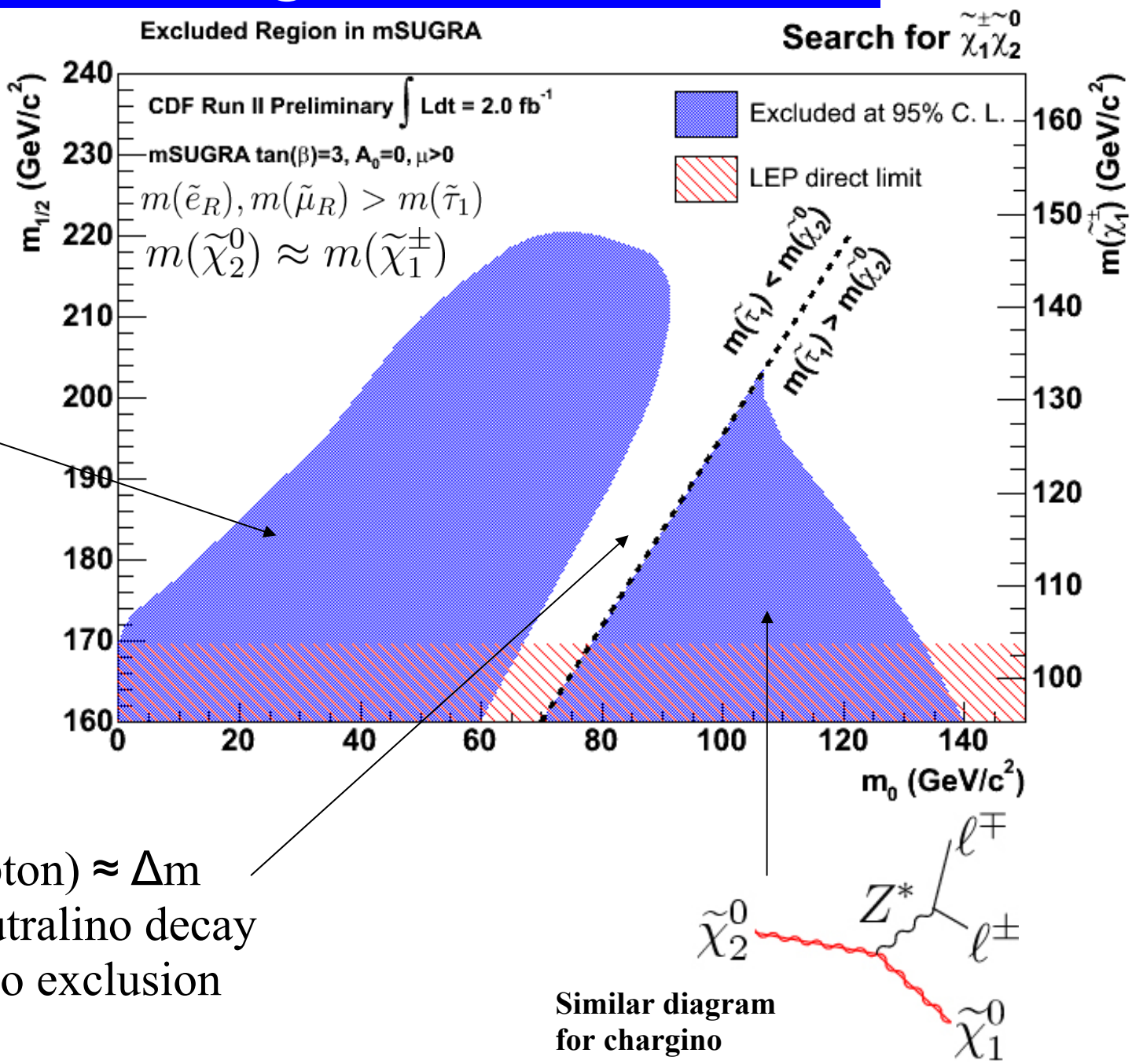
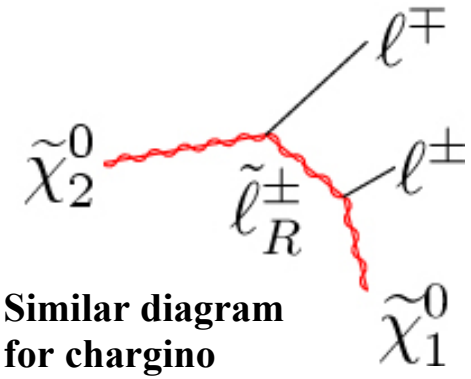
1tight,2loose	0.7±0.1±0.1	0.1±0.02±0.02	0
Total trilepton	4.6±0.2±0.6	0.9±0.1±0.2	1
2tight,1Track	4.4±0.2±0.6	3.2±0.5±0.5	4
1tight,1loose,1Track	2.4±0.1±0.3	2.3±0.5±0.4	2
Total dilepton+track	6.8±0.2±0.9	5.5±0.7±0.9	6

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

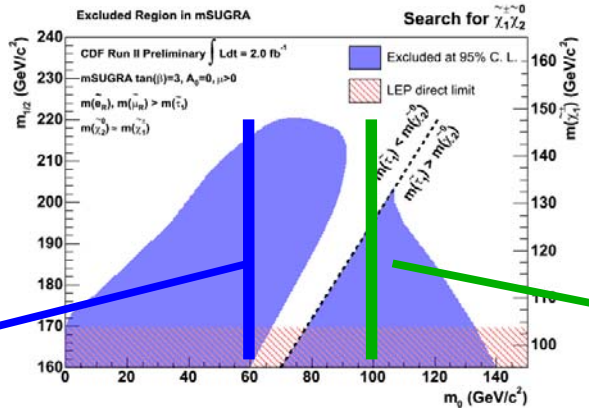


Similar diagram for chargino

Small mass difference
M(Neutralino) – M(slepton) ≈ Δm
=> soft lepton from Neutralino decay
=> loss in acceptance, no exclusion

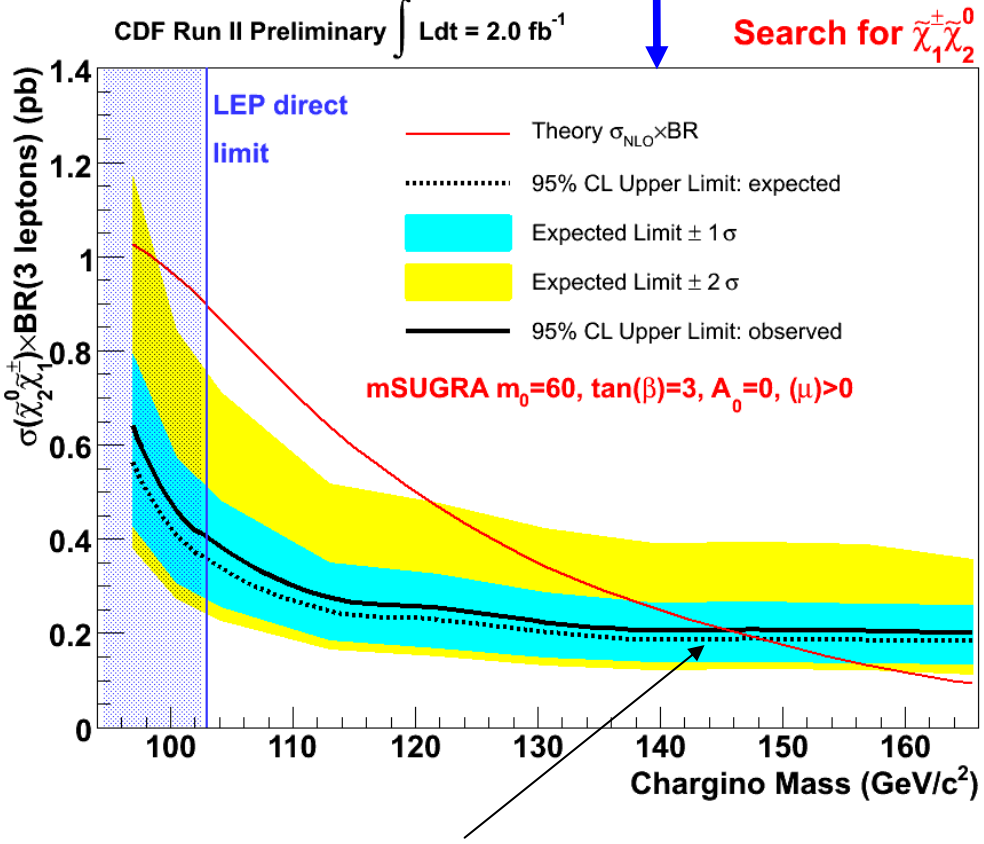
Similar diagram for chargino

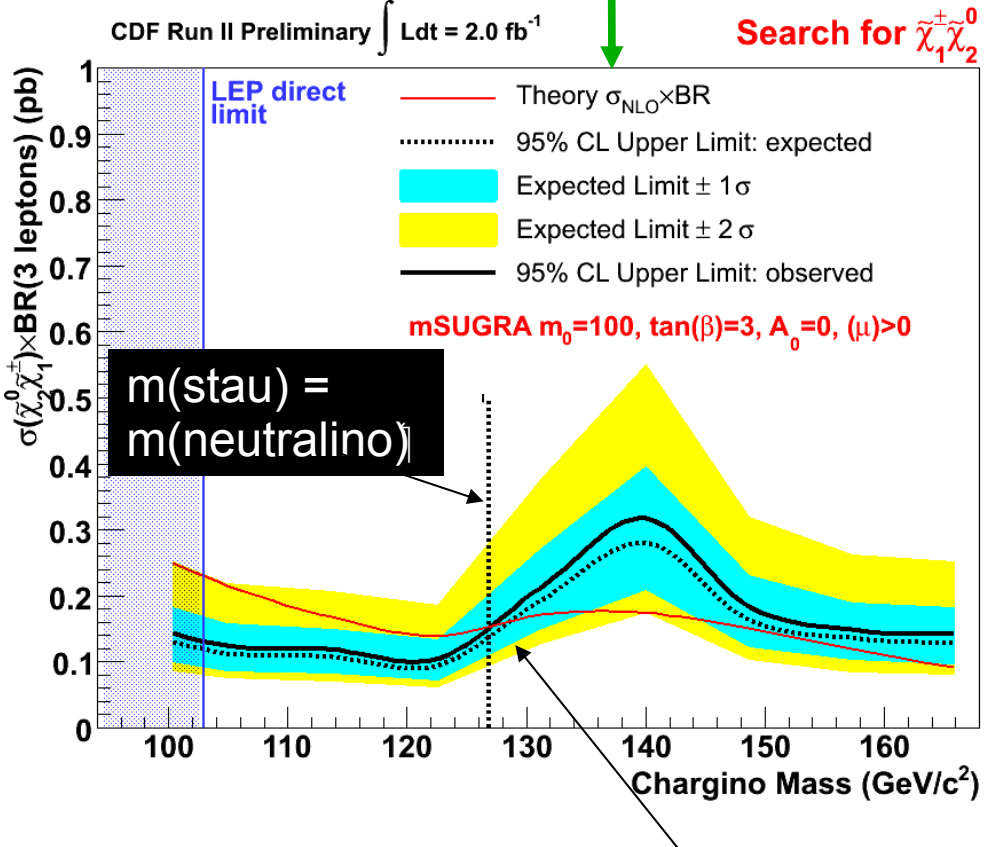
Mass limits



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

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