Chargino-Neutralino Search

$$p\bar{p} \rightarrow \widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$$

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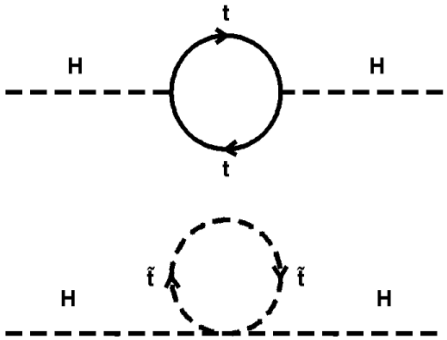
For the CDF and DØ collaborations

Supersymmetry

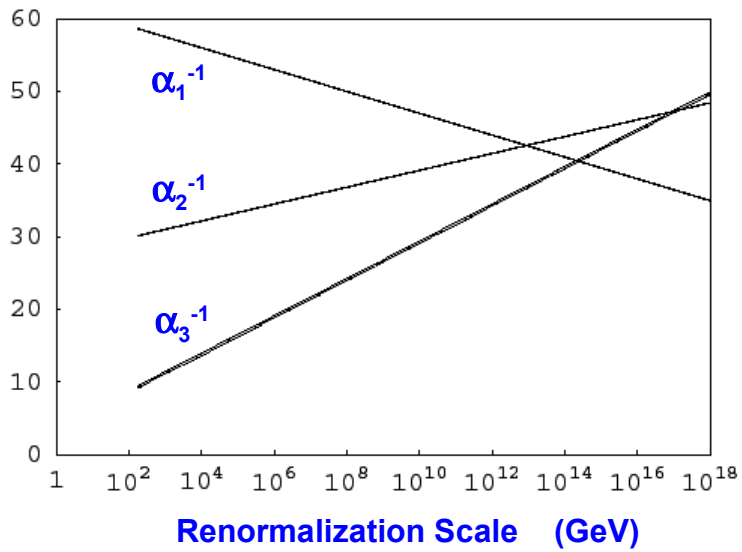
Supersymmetry solves the hierarchy problem

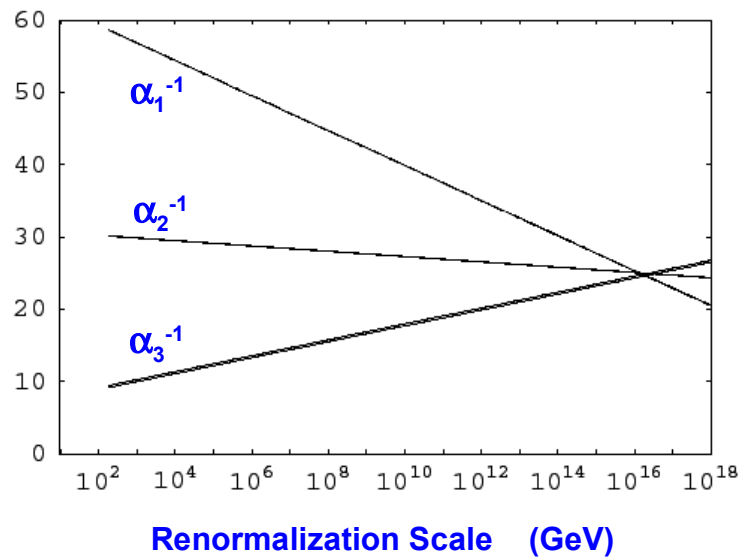
Also provides an excellent dark matter candidate (R_p conservation → LSP)

Gauge couplings are unified much better



Standard Model





mSUGRA

mSUGRA -- minimal SUper GRAvity grand unification

why? a) Widely used as a standard candle by Run I, LHC TDR's etc.

b) Manageable due to five parameters

Defined by five parameters

m_0 : common scalar mass at GUT scale

$m_{1/2}$: common gaugino mass at GUT scale

$M_1(GUT)=M_2(GUT)=M_3(GUT)= m_{1/2}$

$\tan(\beta)$: ratio of Higgs vacuum expectation values

A_0 : common trilinear scalar interaction at the GUT scale (Higgs-sfermion$_R$-sfermion$_L$)

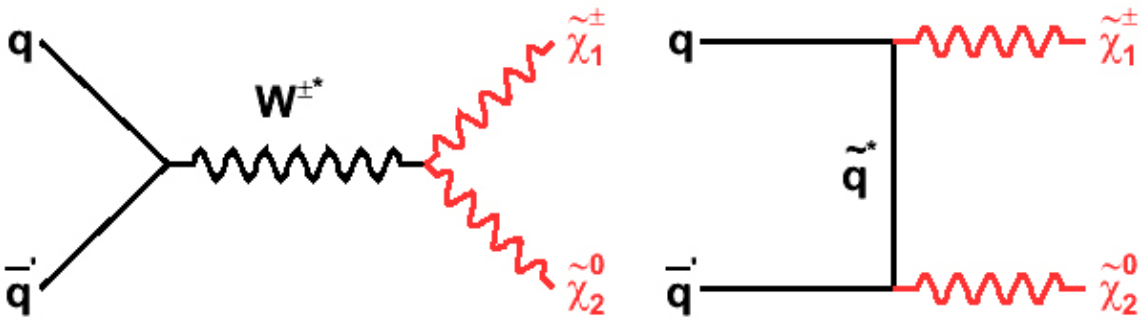
sign(μ) : μ is the Higgsino mass parameter ($|\mu^2|$ determined by EWSB)

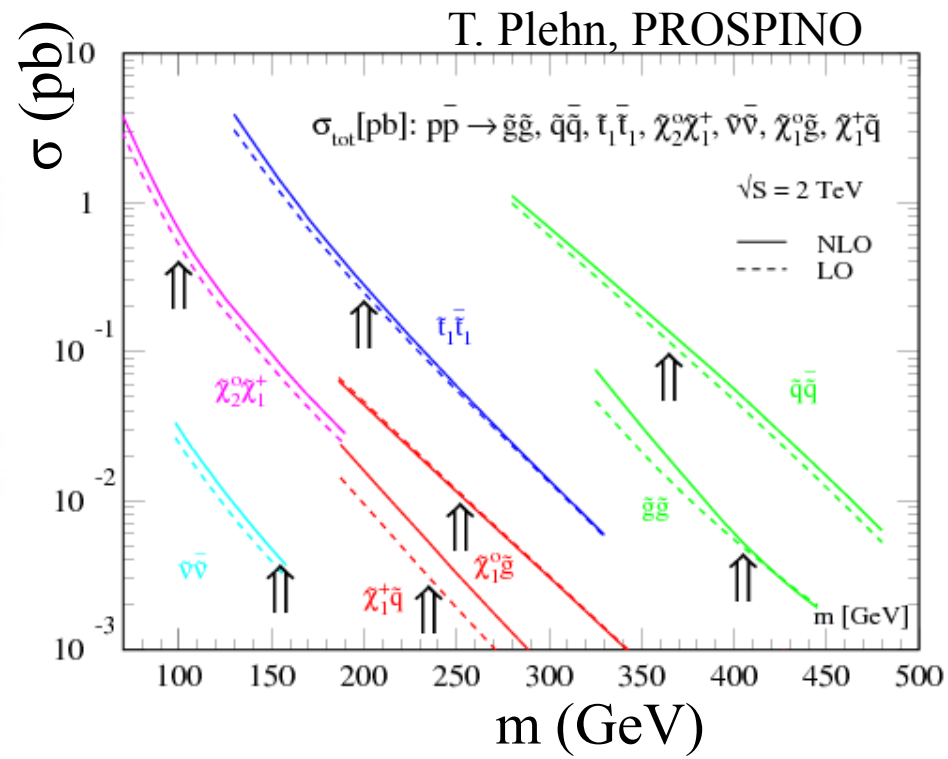
Example : CDF Signal Benchmark Point
mSUGRA m_0=60 GeV, $m_{1/2}$=190 GeV,
$\tan(\beta)$=3, A_0=0, μ>0

CDF Benchmark point
Mass Spectrum GeV

$\tilde{\chi}_2^0$	124
$\tilde{\chi}_1^\pm$	122
$\tilde{\chi}_1^0$	66
$\tilde{e}_L$	149
$\tilde{e}_R$	101
$\tilde{\tau}_1$	100
$\tilde{\tau}_2$	150
$\tilde{g}$	477
$\tilde{u}_R$	421
$\tilde{d}_L$	439

Producing Chargino-Neutralino



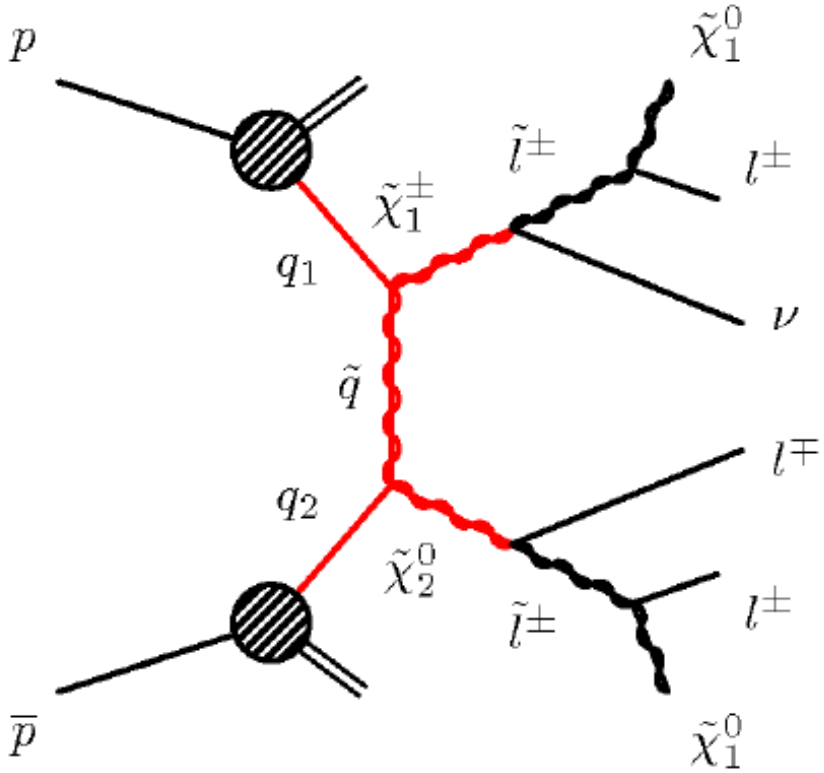


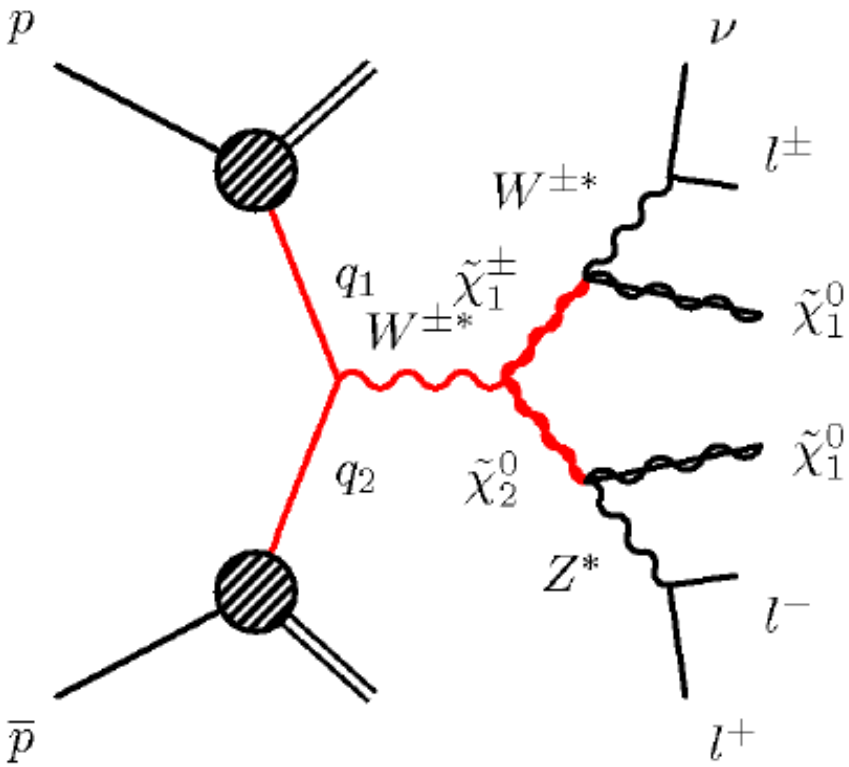
- Charginos & Neutralinos are mixtures of the higgsino, binos and winos.
- There are four neutralinos and two charginos, we look for lightest chargino and next-to-lightest neutralino.
- Produced via s-channel, destructive interference from t-channel

Decaying Chargino/Neutralino

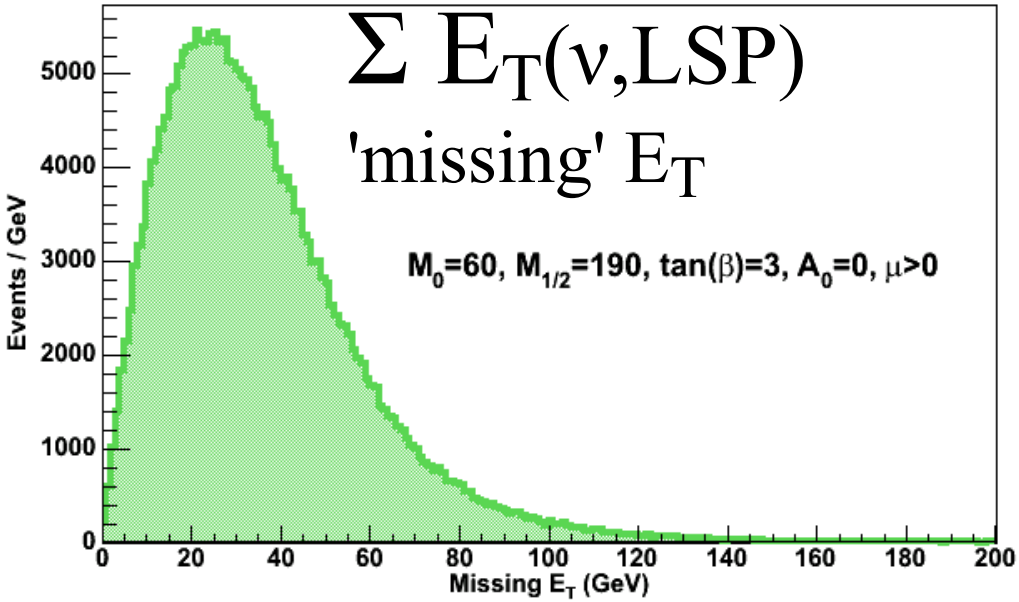
Chargino-Neutralino decays are good experimentally because they **decay to leptons** which makes identifying SUSY events easier .

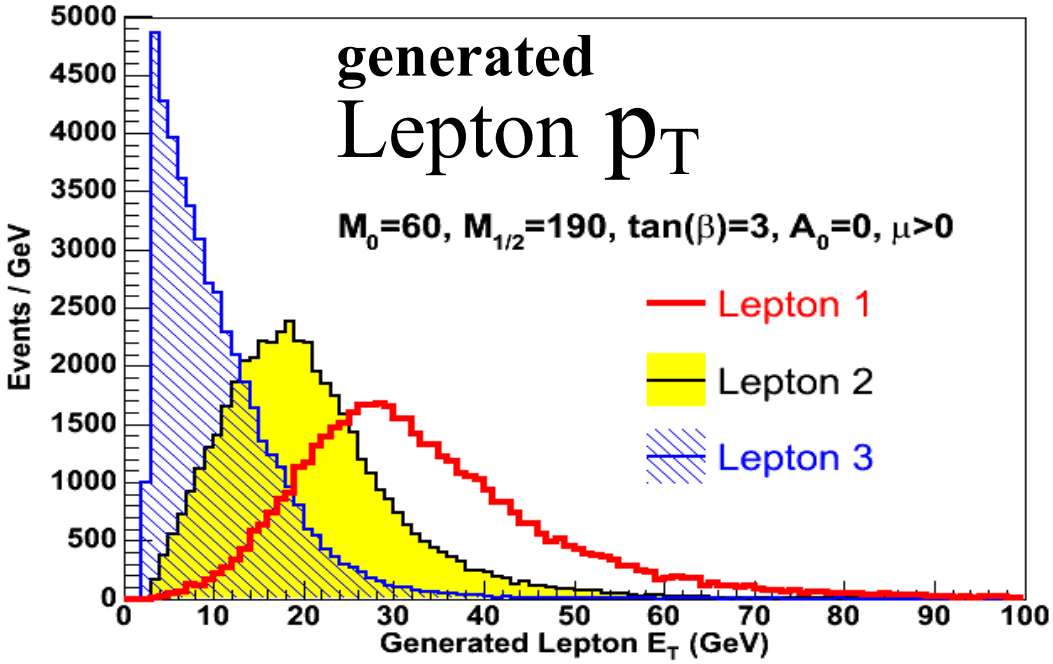
Presence of neutrino, and lightest-susy-particles (LSP's) in final state gives missing energy.

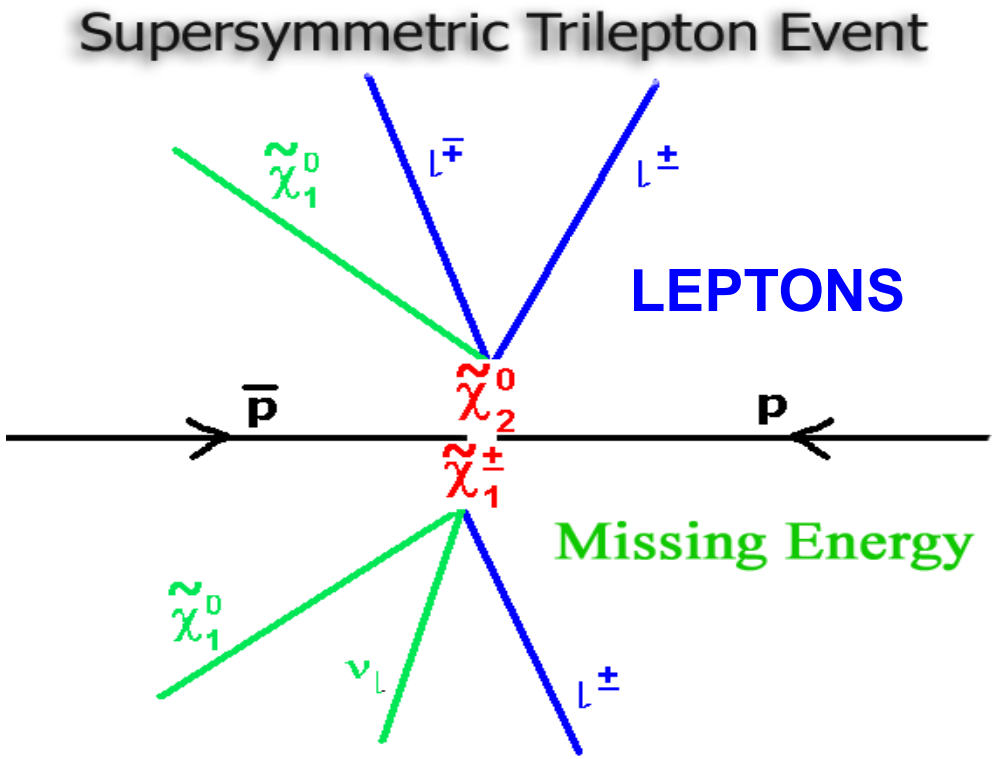




The Signature







$$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow \ell^{\pm}\ell^{\mp}\ell'^{\pm}\nu\ \tilde{\chi}_1^0\tilde{\chi}_1^0$$

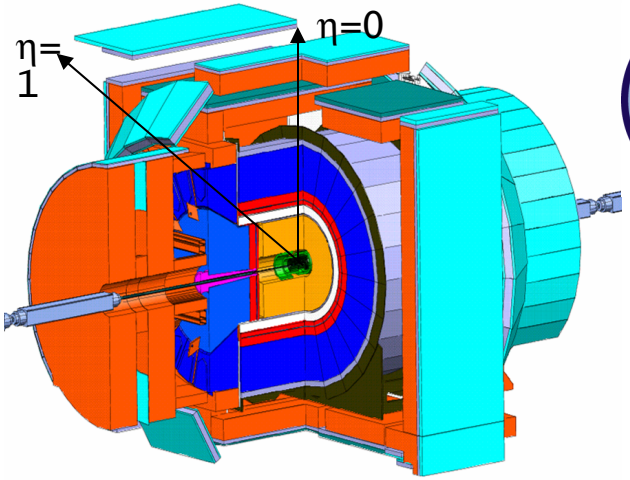
$$\ell = e, \mu, \tau$$

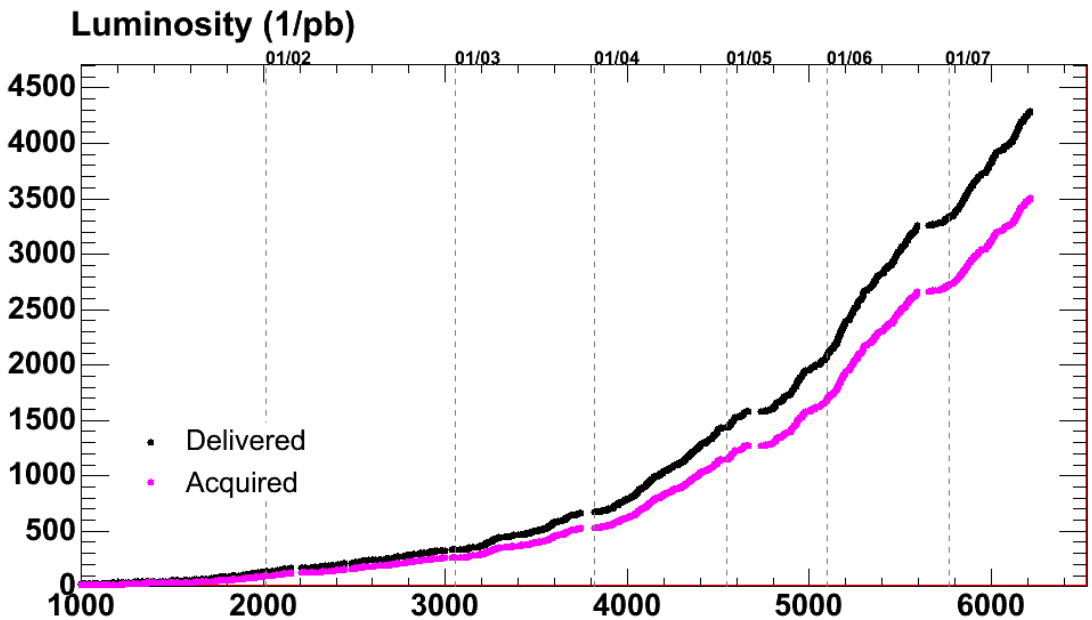
Detectors : CDF & DØ

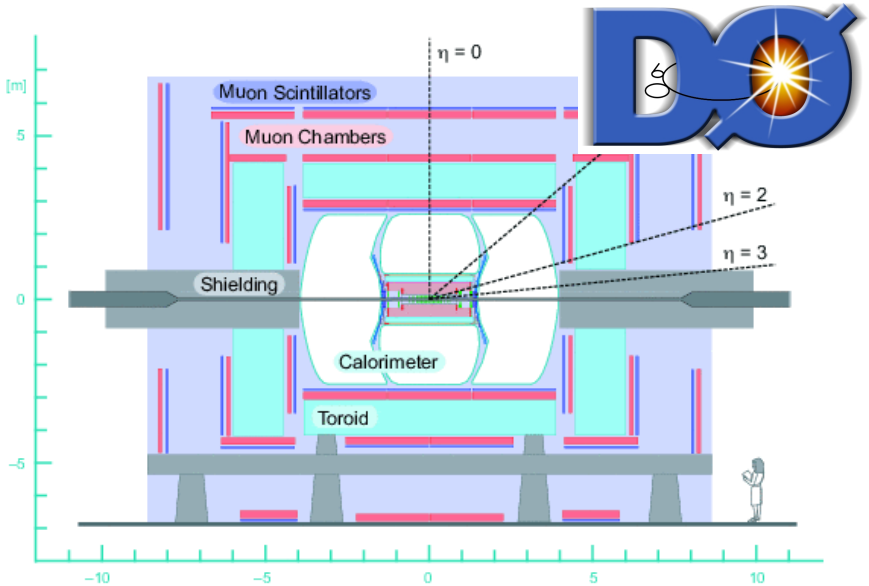
Multipurpose detectors :

- Central Tracker
- Electromagnetic (EM)

  & Hadronic (Had) Calorimeters
- Muon Systems

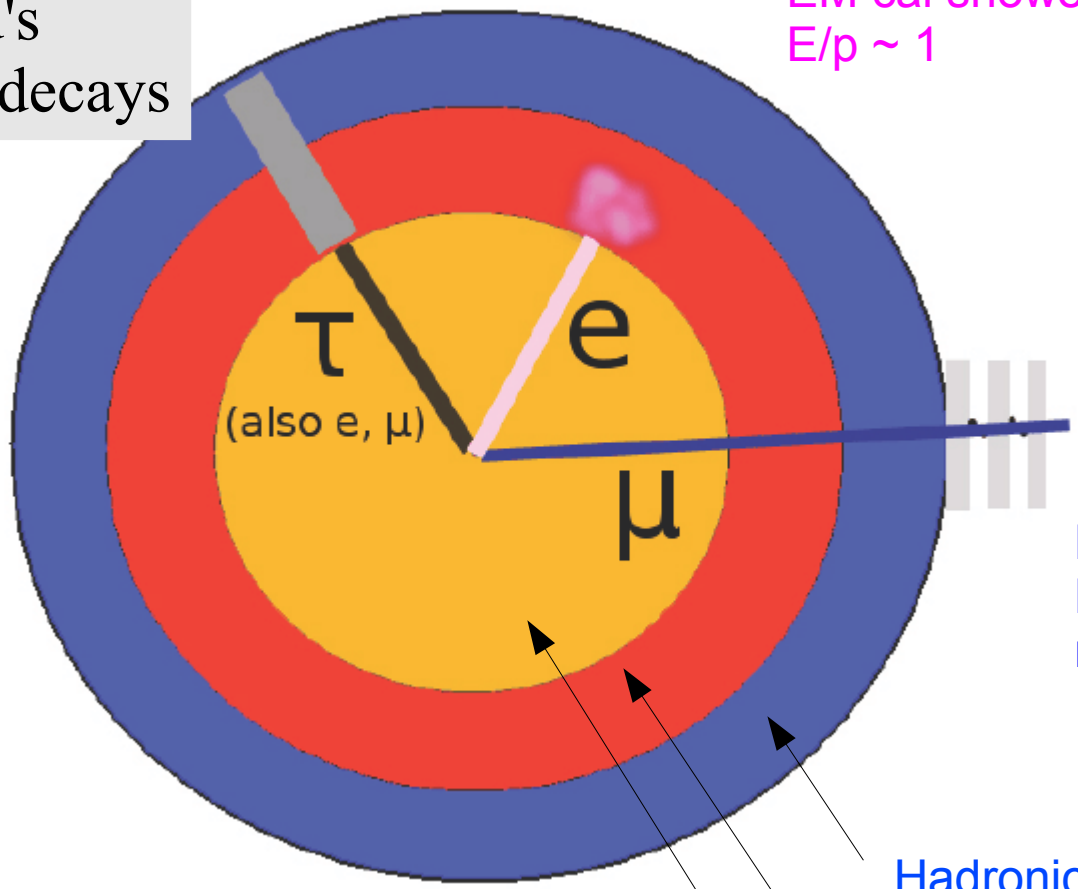






Identifying Leptons

Isolated tracks
proxy for tau's
'single-prong' tau decays



Electrons :
EM cal showers
E/p ~ 1

Muons :
MIP's , signal in
muon systems

Hadronic calorimeter

Electromagnetic calorimeter

Central Tracker

The CDF analysis

Channels & Backgrounds

2 fb^{-1}

Exclusive channels ordered by signal purity

Find three tight leptons

Else, two tight leptons(t) and a loose lepton(l).

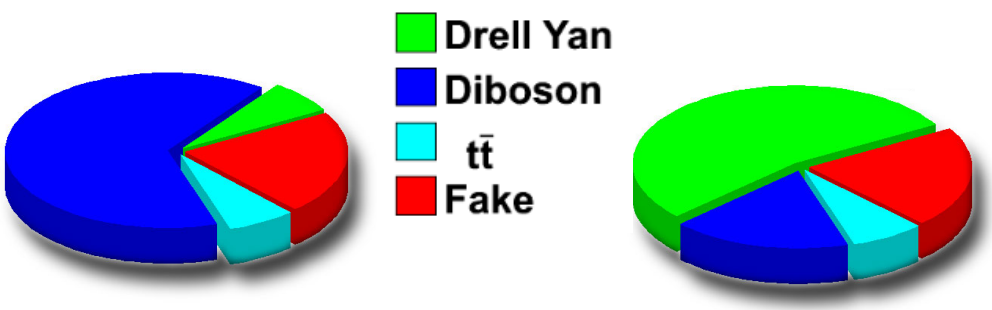
Else, one tight and two loose leptons.

Else, two tight leptons and one track(T).

Else, one tight, one loose lepton and one track.

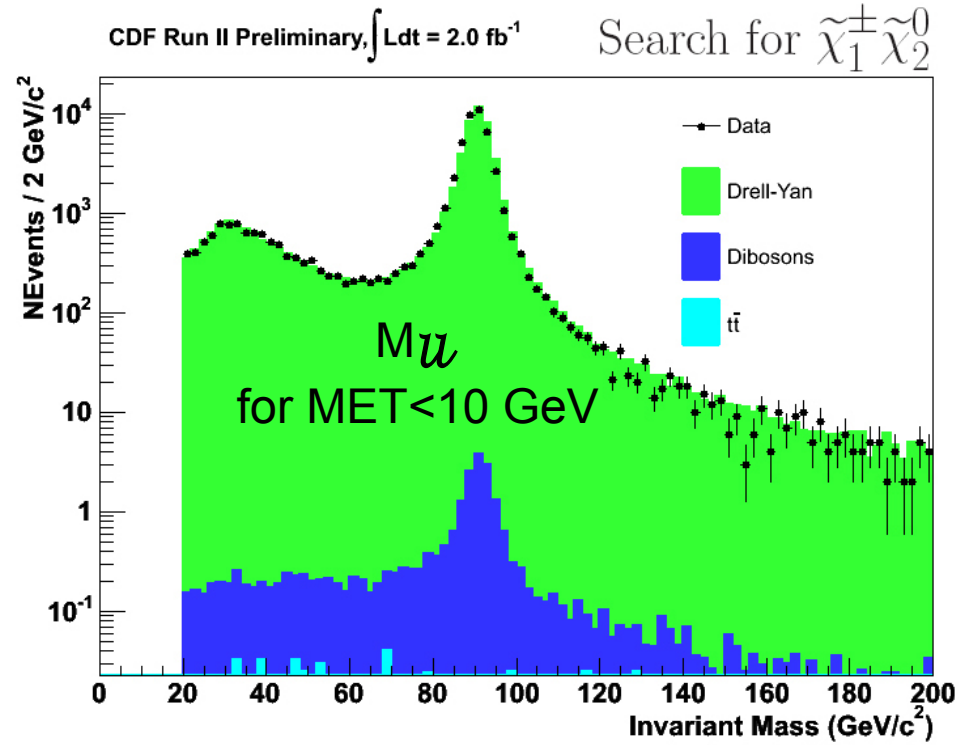
where lepton=e,μ

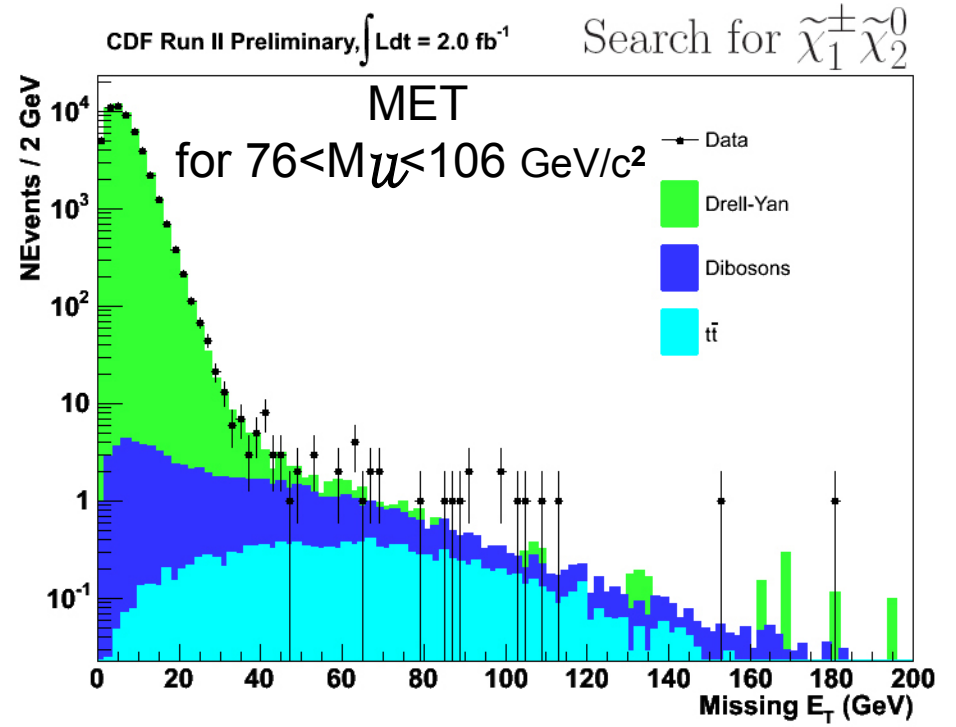
Dominant Backgrounds



Trilepton

Dilep+Trk





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

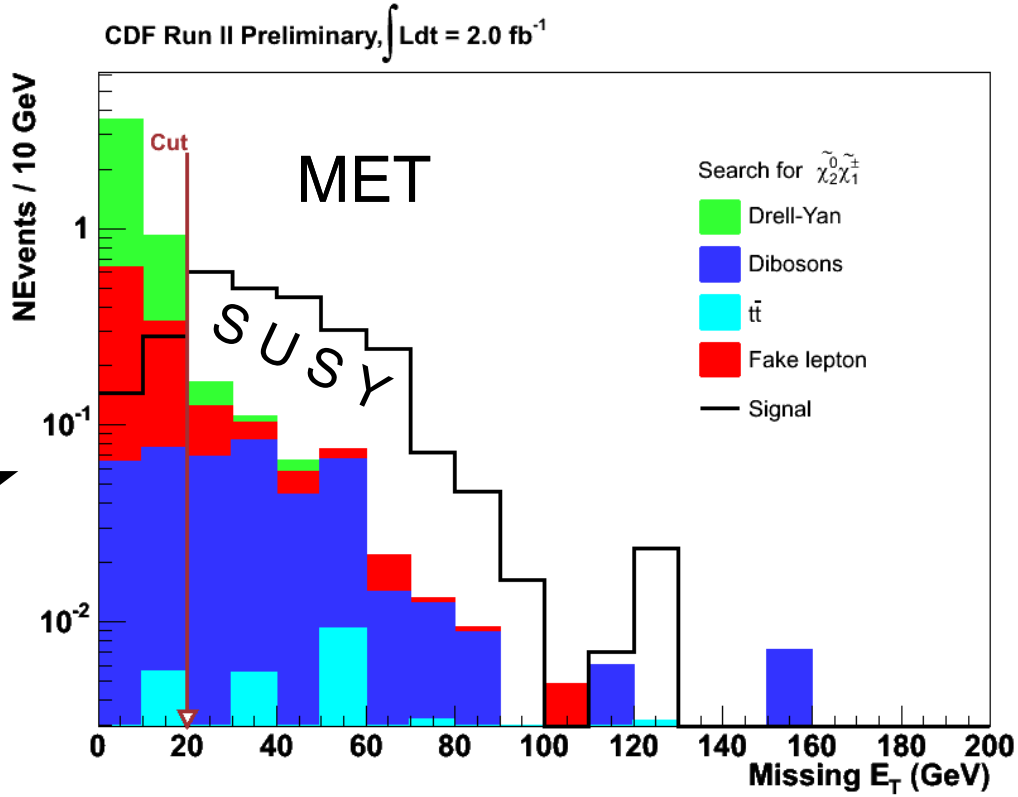
Resonance Cuts

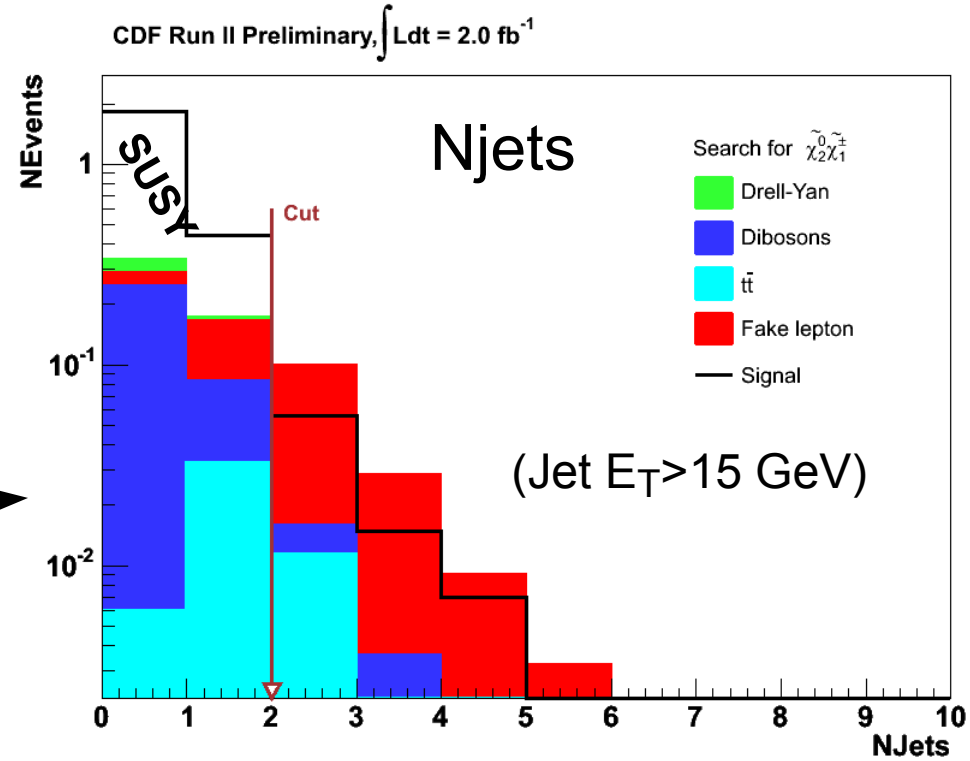
M_{os}^1, M_{os}^2 > 20 , 13 GeV/c^2

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

Remove top-pair

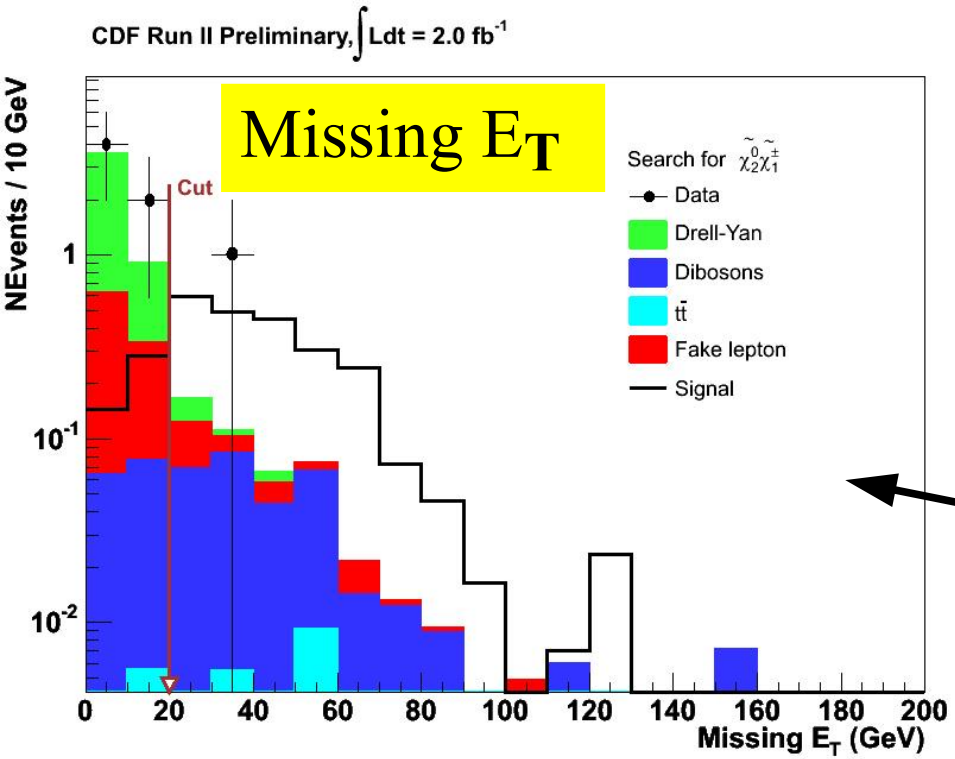
NJets < 2

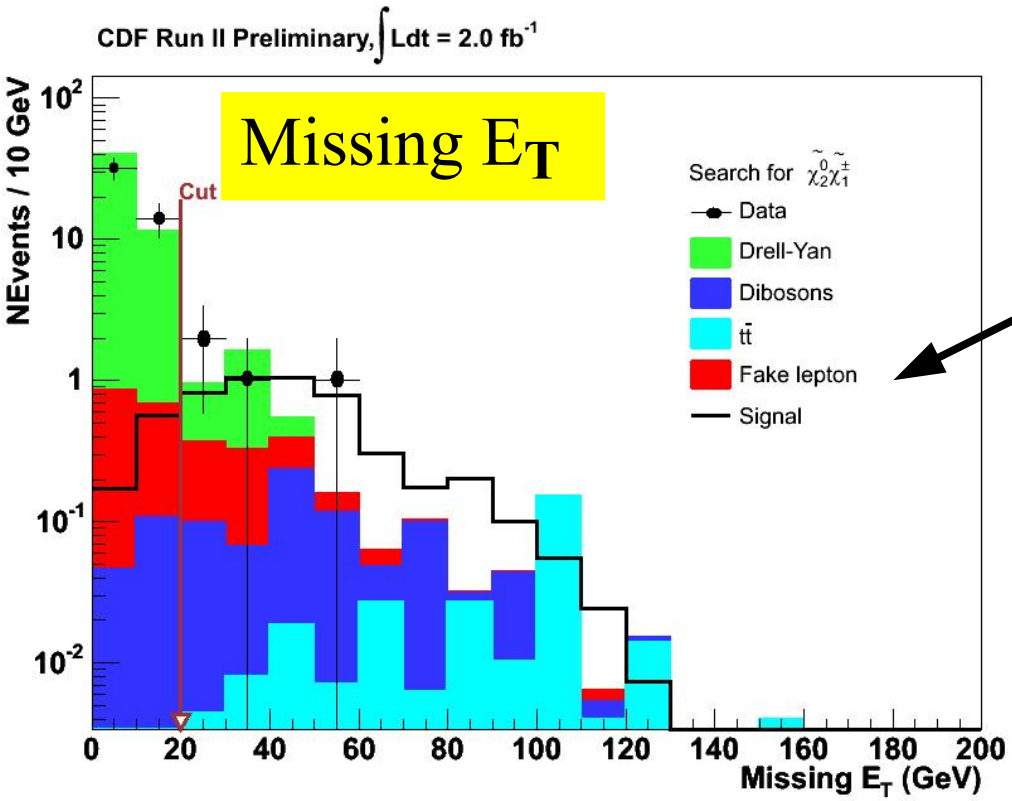




Prediction & Observation

2 fb^{-1}





Channel	Signal	Bkgd	Data
ttt	2.3±0.3	0.5±0.1	1
ttl	1.6±0.2	0.3±0.04	0
tll	0.7±0.1	0.1±0.03	0
3 leptons	4.6±0.6	0.9±0.2	1
ttT	4.4±0.6	3.2±0.7	4
tlT	2.4±0.3	2.3±0.6	2
2 leptons + Track	6.8±0.9	5.5±1.1	6

Signal mSUGRA with parameters
m_0=60, $m_{1/2}$=190, tan(β)=3, A_0=0, μ >0

No sign of SUSY!

The DØ analysis

Channels & Selections

Run IIa channels (with 1fb^{-1})

ee + Track

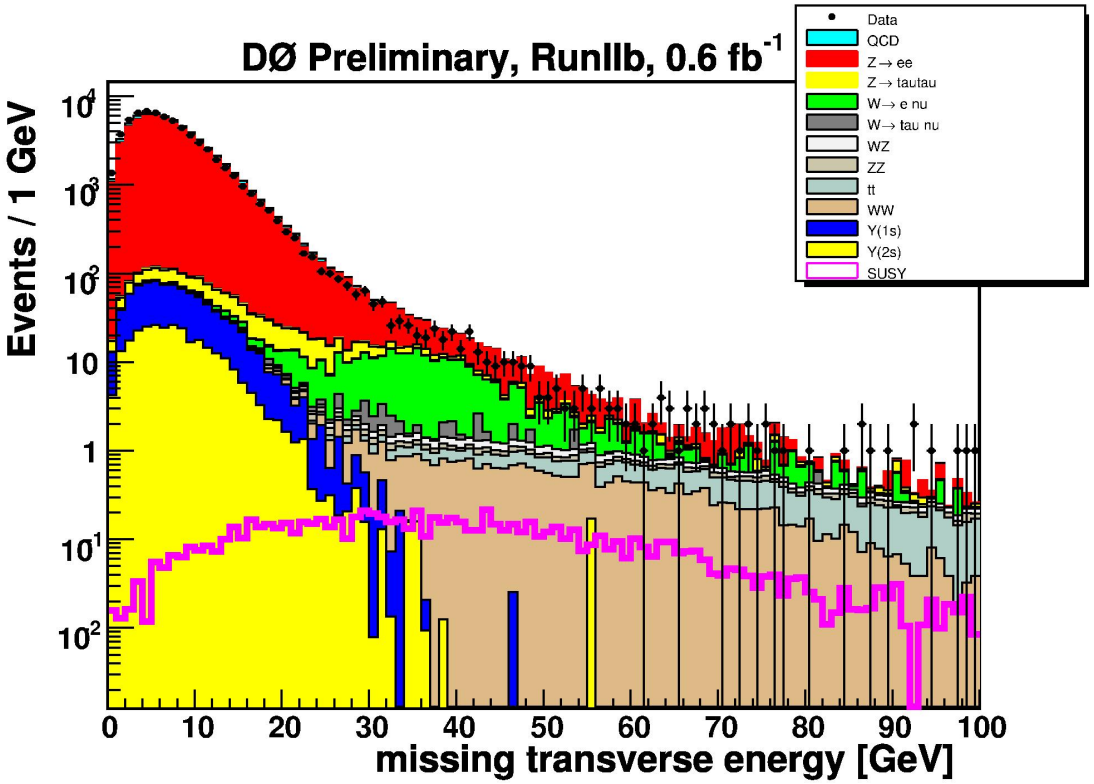
μμ + Track

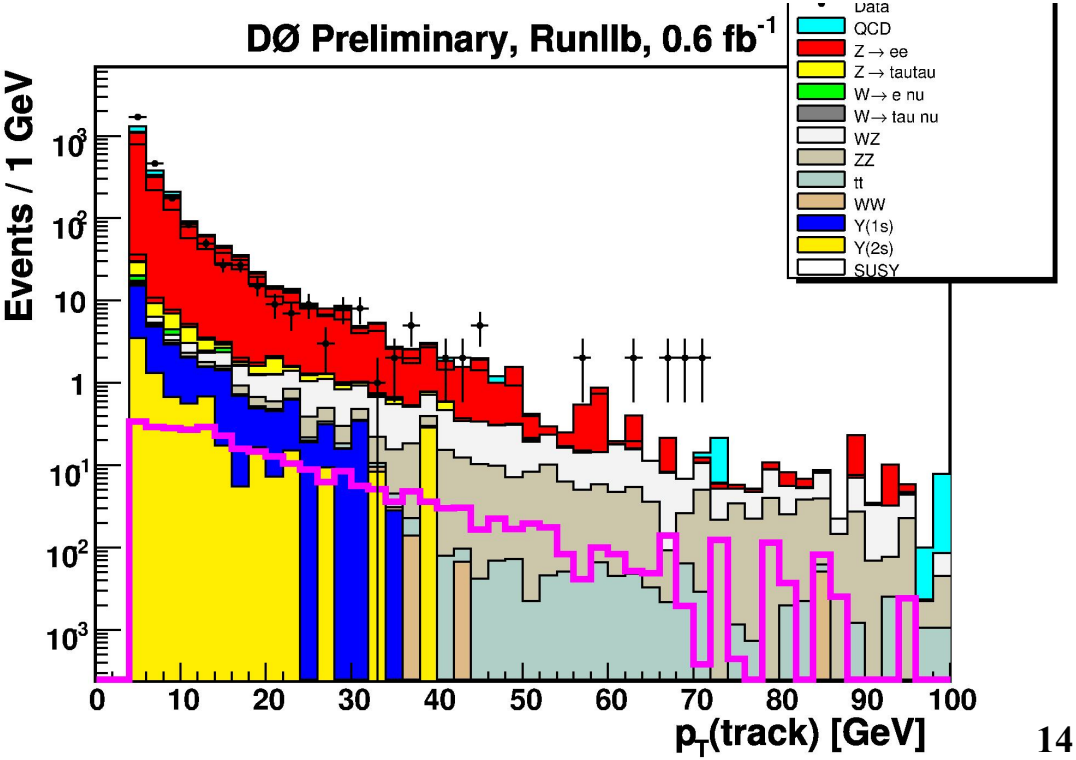
eμ + Track

Same-sign dimuons

Run IIb channel (with 0.6 fb^{-1})

ee + Track





Selections for new ee + Track :

p_T > 12, 8, 4 GeV

MET > 22 GeV

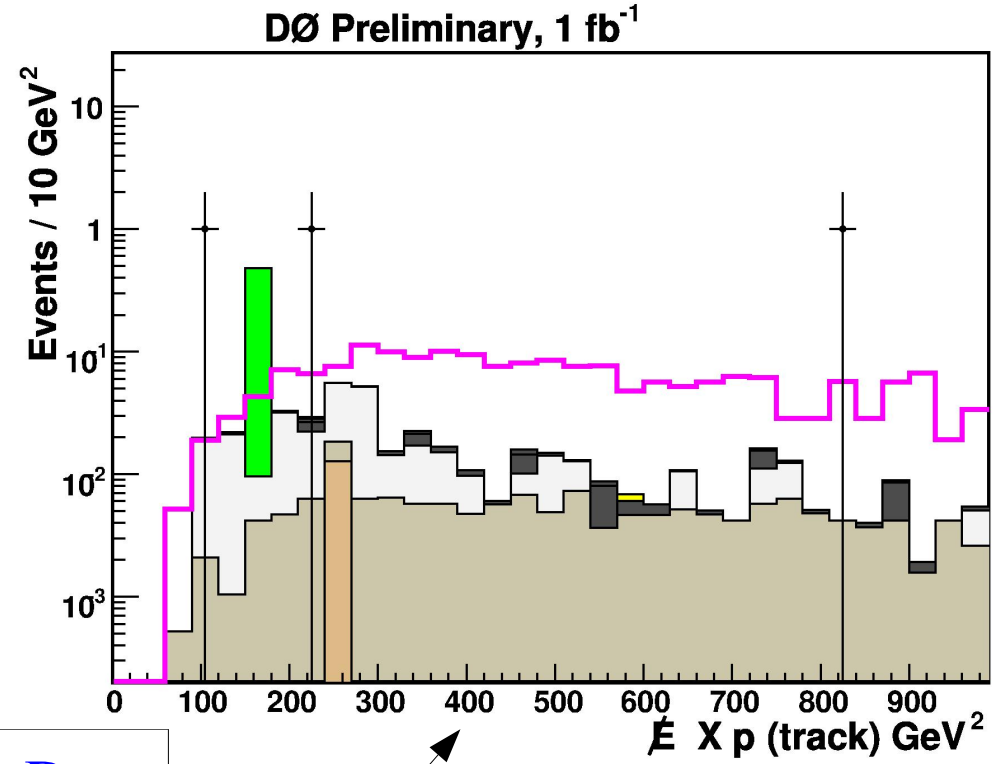
$\Delta\varphi(e,e) < 2.9$ rad

$18 < M_{ee} < 60$ GeV/c^2

$H_T < 80$ GeV

MET x Trk p_T > 220 GeV^2

Results



Channel	Lum. (fb^{-1})	Signal	Bkgd	Data
ee + T	**0.6**	0.5-2.1	1.0±0.3	0
ee + T	**1**	1.7-4.7	0.8±0.7	0
μμ + T	**1.1**	0.5-2.5	$0.3^{+1.3}_{-0.3}$	2
eμ + T	**1.1**	2.0-2.6	0.9±0.4	0
$\mu^\pm\mu^\pm$	**0.9**	0.6-3.8	1.1±0.4	1

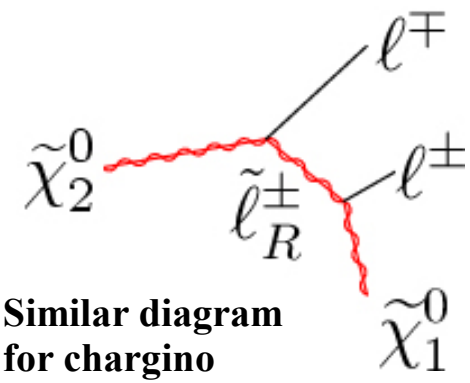
Data agrees with SM

Signal mSUGRA 'like' with no slepton mixing
m_0=88-121, $m_{1/2}$=182-221, tan(β)=3, A_0=0, μ >0

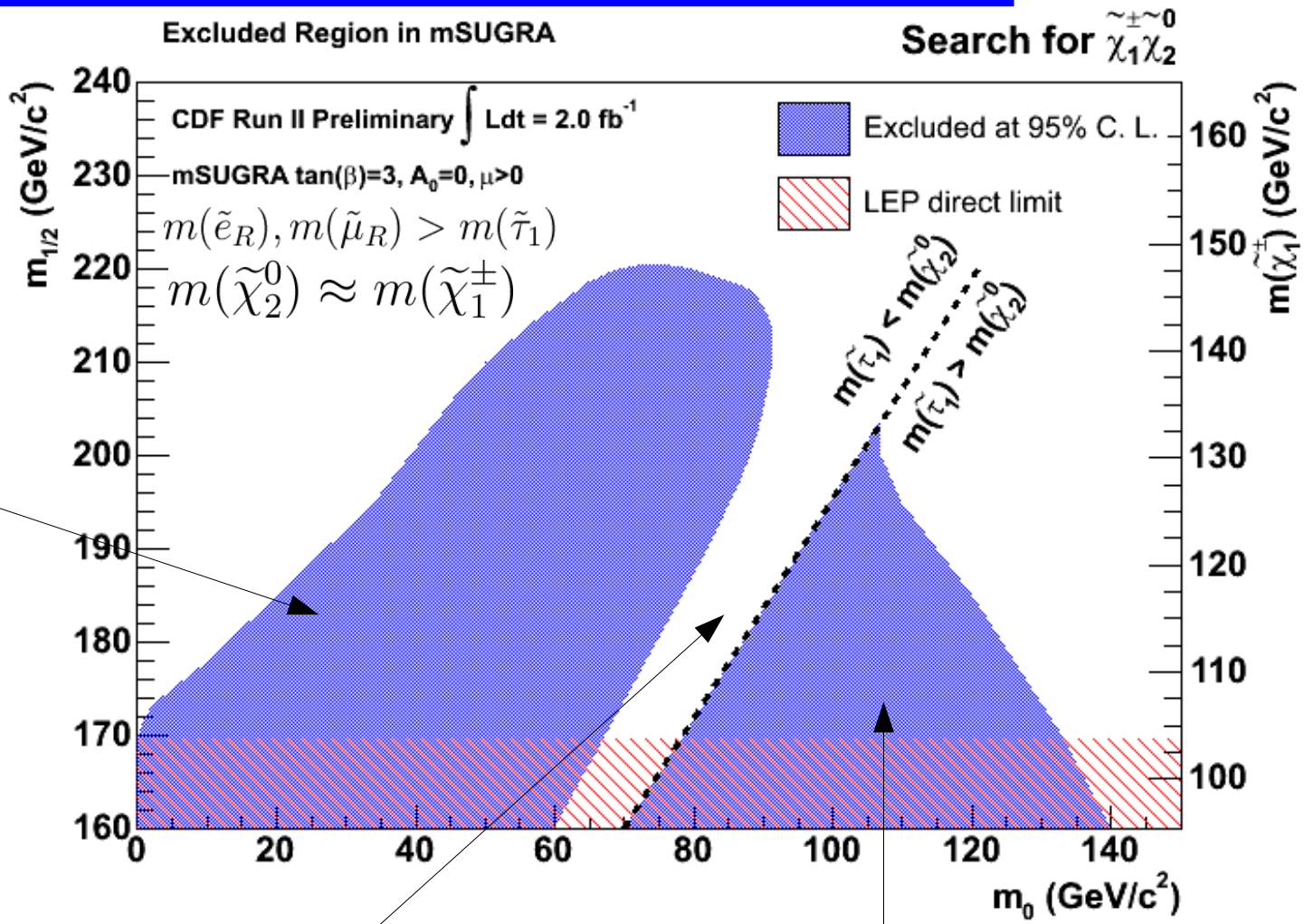
The CDF analysis RESULTS

Excluded Region in mSUGRA

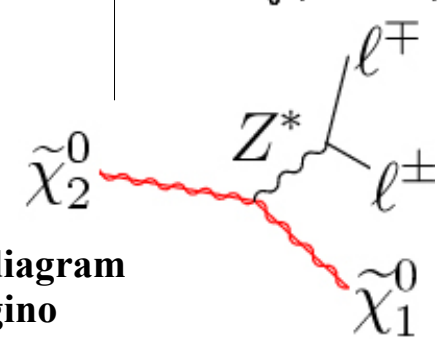
Dominated by



Similar diagram for chargino

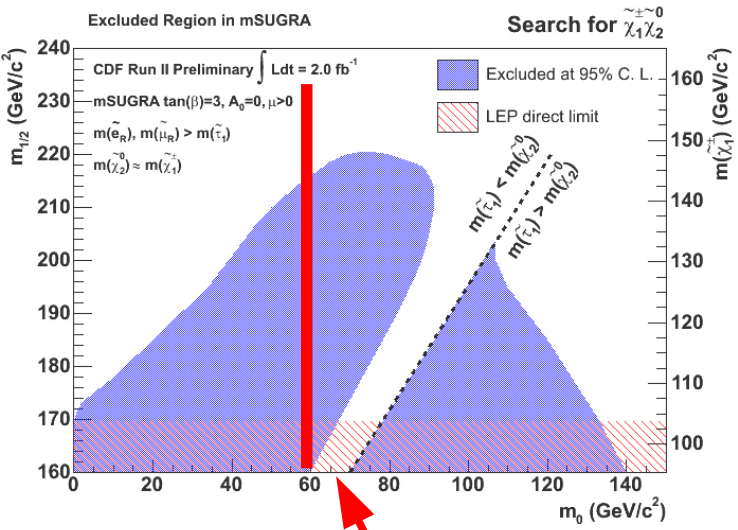


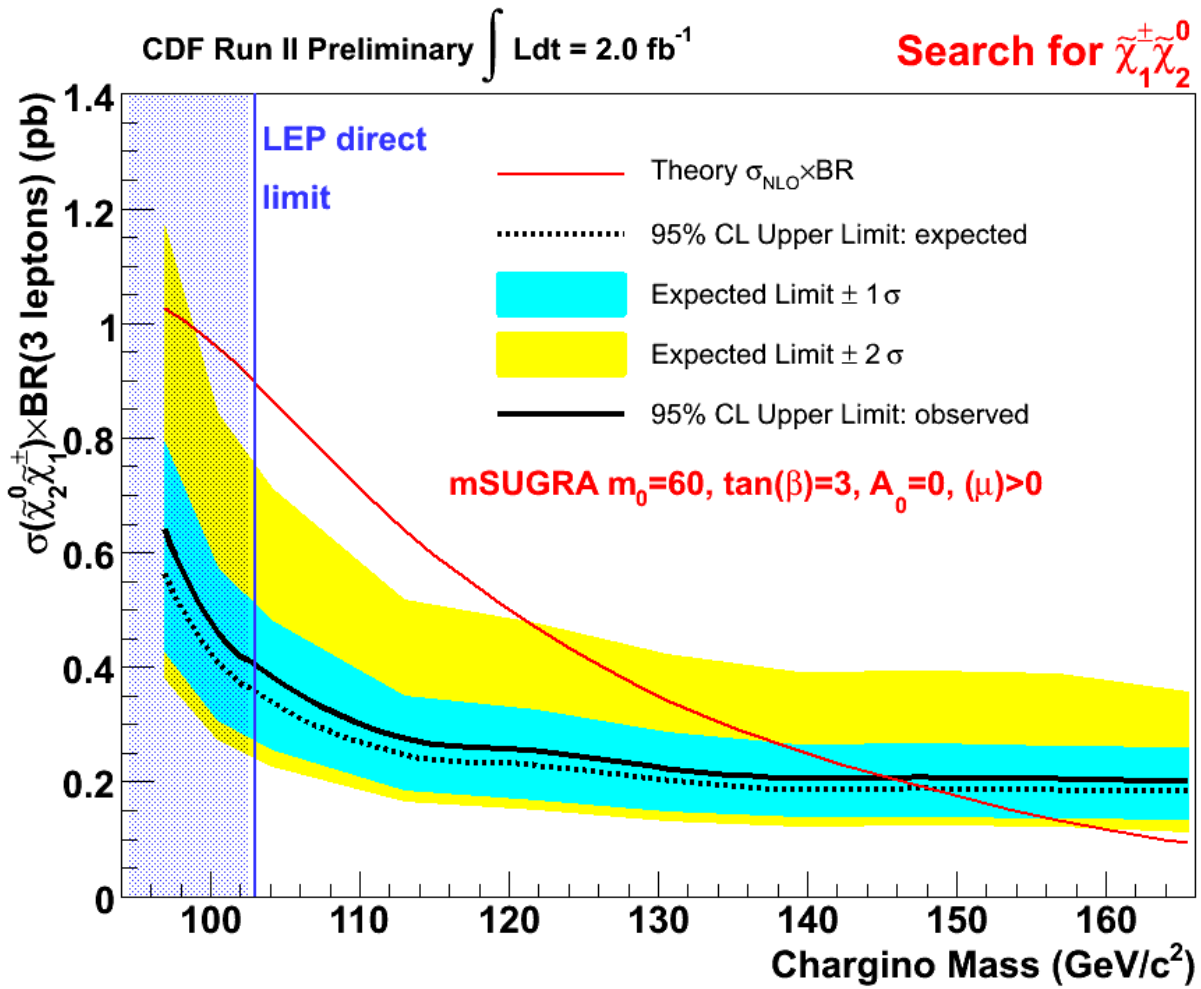
Small mass difference
M(Neutralino) – M(slepton) ≈ Δm
=> soft lepton from Neutralino decay
=> loss in acceptance, no exclusion



Similar diagram for chargino

Mass limits for m_0 = 60 GeV/c^2

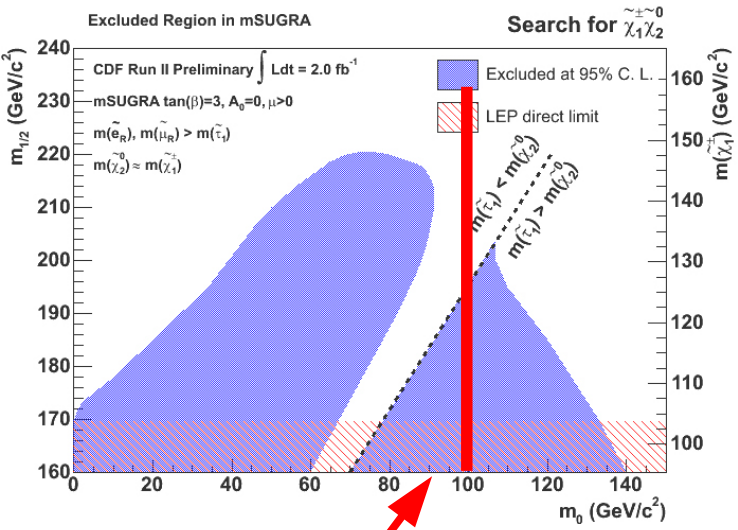


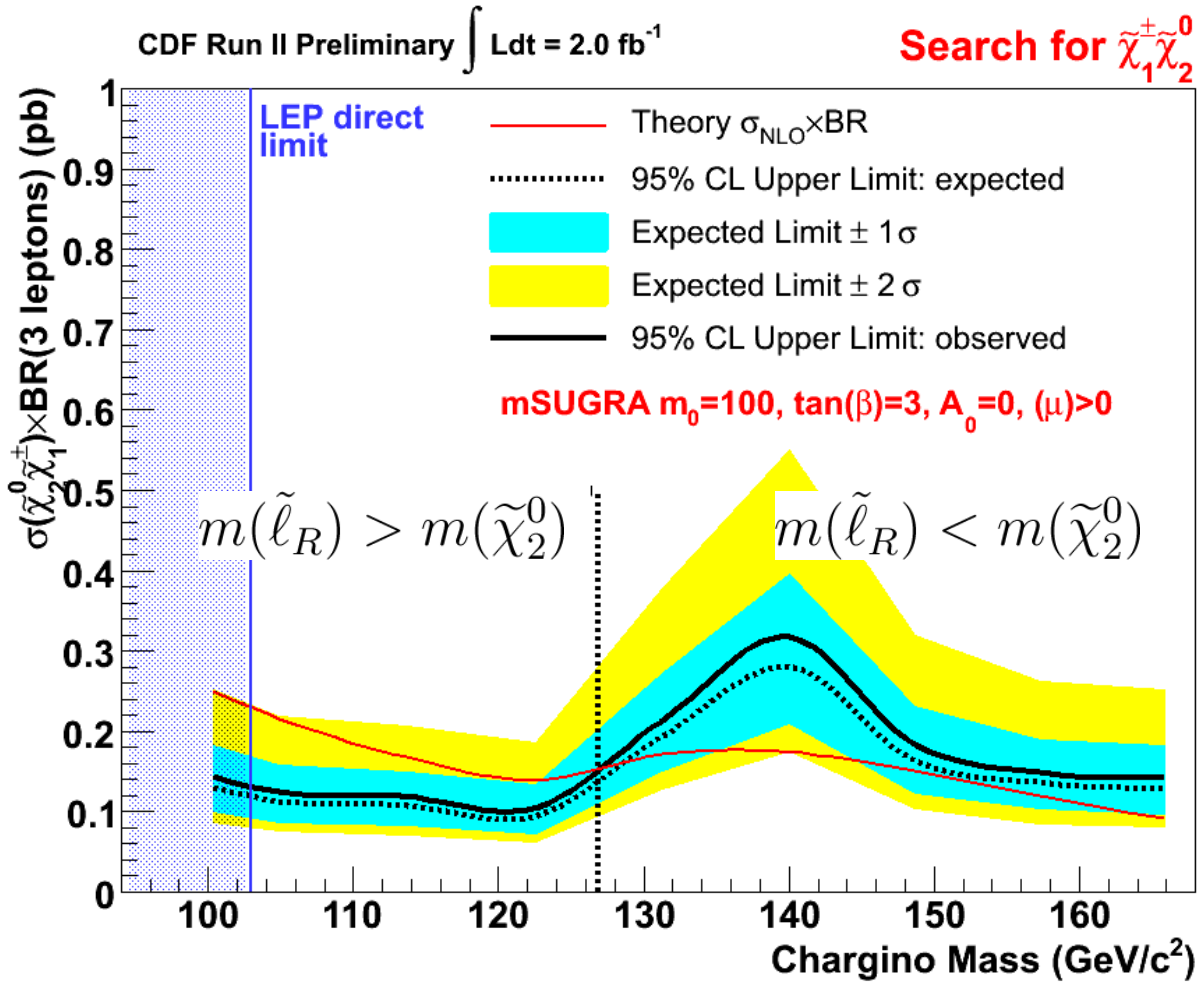


Fix m_0 = 60 GeV/c^2, vary $m_{1/2}$ along X-axis to get chargino mass.

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

Mass limits for m_0 = 100 GeV/c^2





Fix m_0 = 100 GeV/c^2, vary $m_{1/2}$ along X-axis to get chargino mass.

Exclude Chargino with Mass < 127.0 GeV/c^2

The DØ analysis
RESULTS

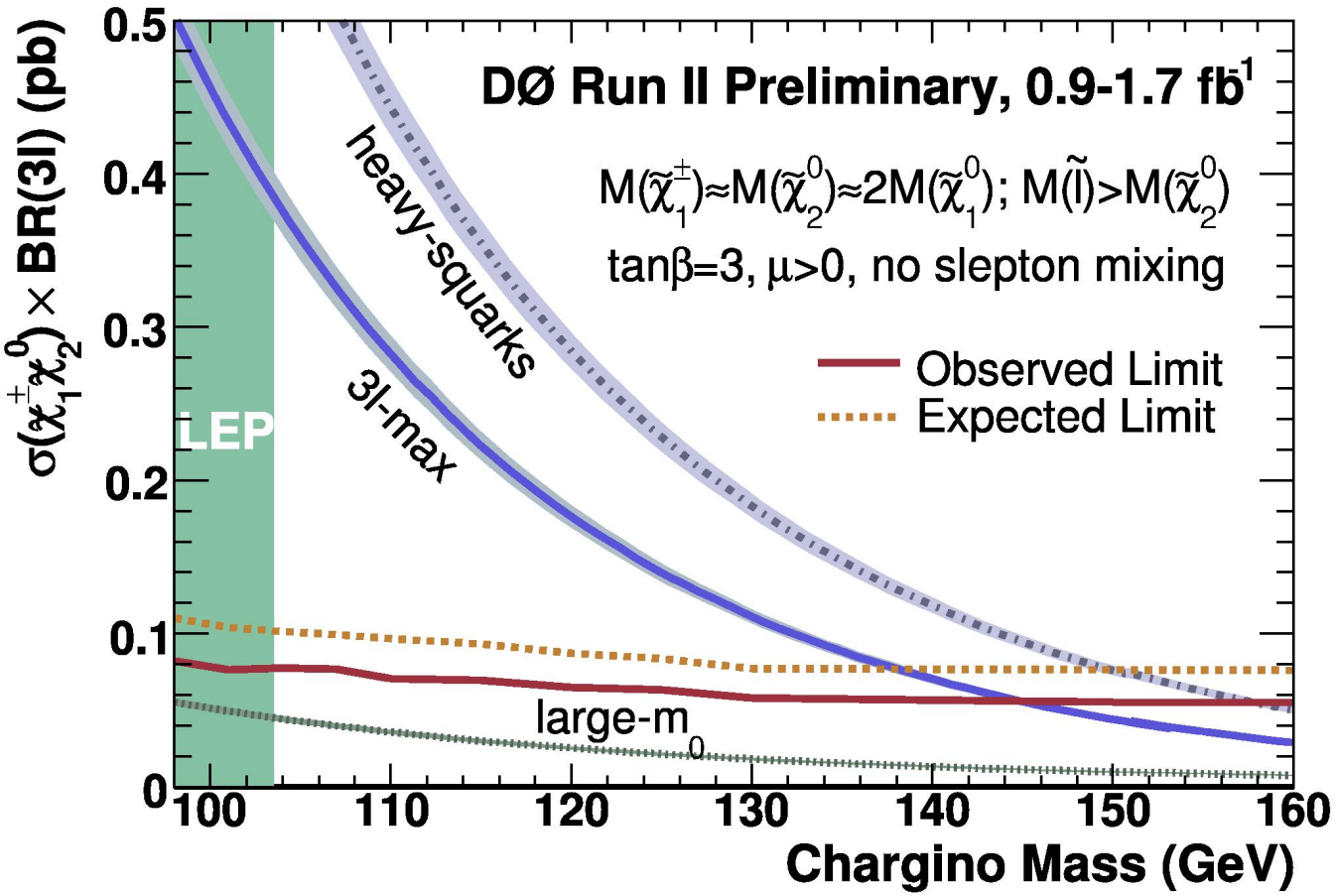
Mass limits in mSUGRA 'like' model

Three scenarios:

3l-max : Max BR to 3l

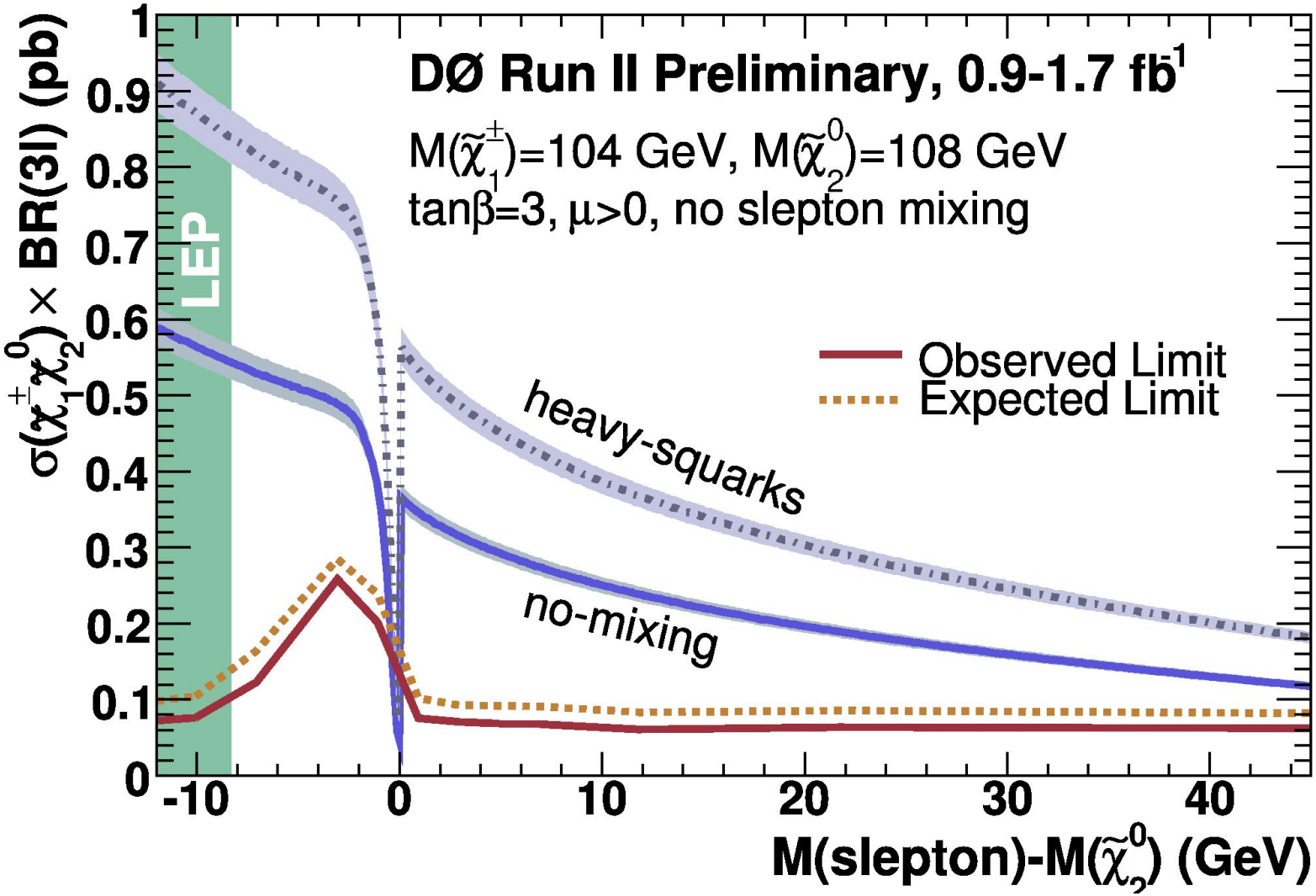
Heavy-squarks :
squarks are set to high masses to reduce t-channel production (enhancing σ)

large-m_0 : slepton,squarks both very heavy, decays mainly via virtual W,Z



Exclude Chargino with Mass < 145 GeV/c²
Best limits in no slepton mixing scenario

Mass limits in mSUGRA 'like' model



Summary

- CDF and DØ have searched for Charginos and Neutralinos with up to 2 fb^{-1} , no sign yet though!
- CDF rules out charginos up to masses of 145 GeV/c^2 in specific mSUGRA regions, and also provides an exclusion region in mSUGRA parameter space.
- DØ rules out charginos up to masses of 145 GeV/c^2 in an mSUGRA-'like' no slepton mixing scenario.
- Both results are well beyond LEP limits.

Expect more data soon

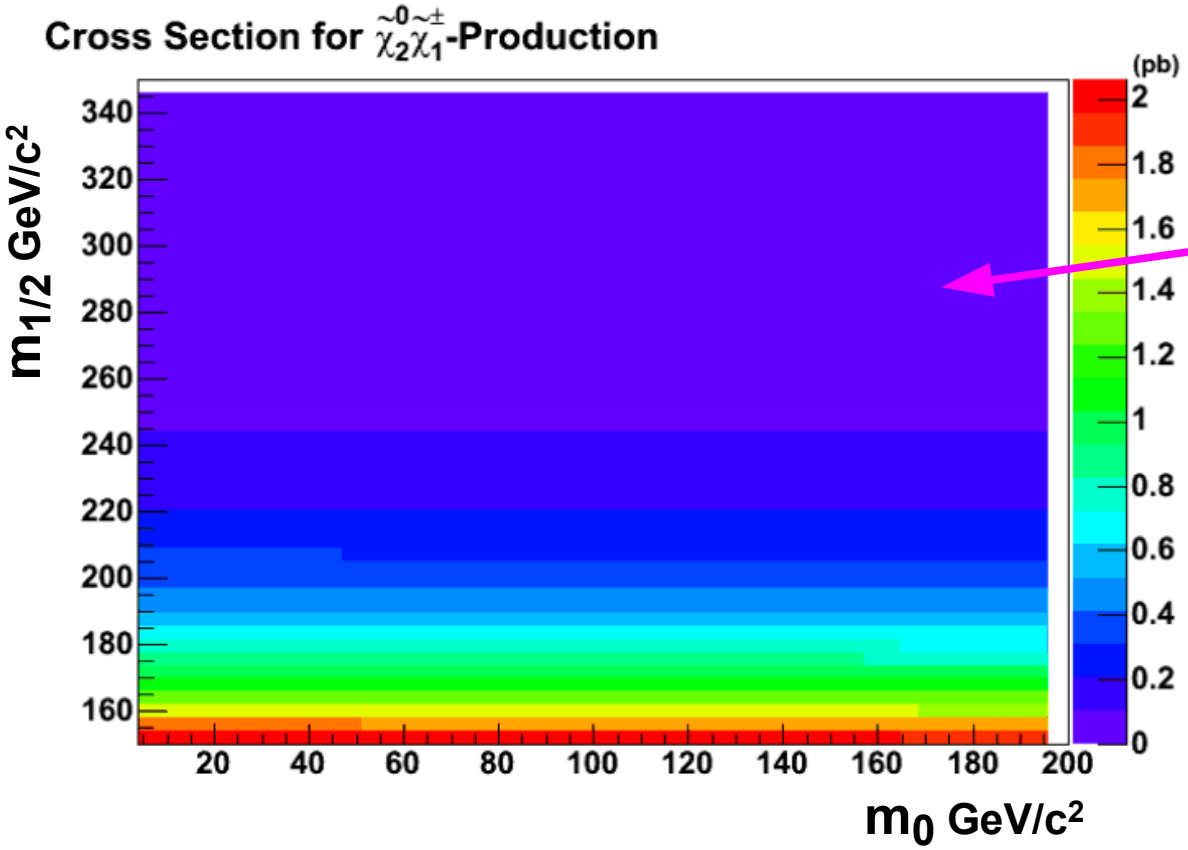
http://www-cdf.fnal.gov/physics/exotic/exotic.html

http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

BACKUP

mSUGRA Features of interest : σ

$$m(\tilde{\chi}_2^0) \approx m(\tilde{\chi}_1^\pm) \qquad m(\tilde{e}_R) = m(\tilde{\mu}_R) \approx m(\tilde{\tau}_1)$$



$$\sigma(p\bar{p} \to \tilde{\chi}_2^0\tilde{\chi}_1^\pm)$$

Cross section is a smooth function of chargino mass, hence $m_{1/2}$

mSUGRA Features of interest

$$M(\widetilde{\chi}_2^0, \widetilde{\chi}_1^\pm) > M(\tilde{\ell})$$

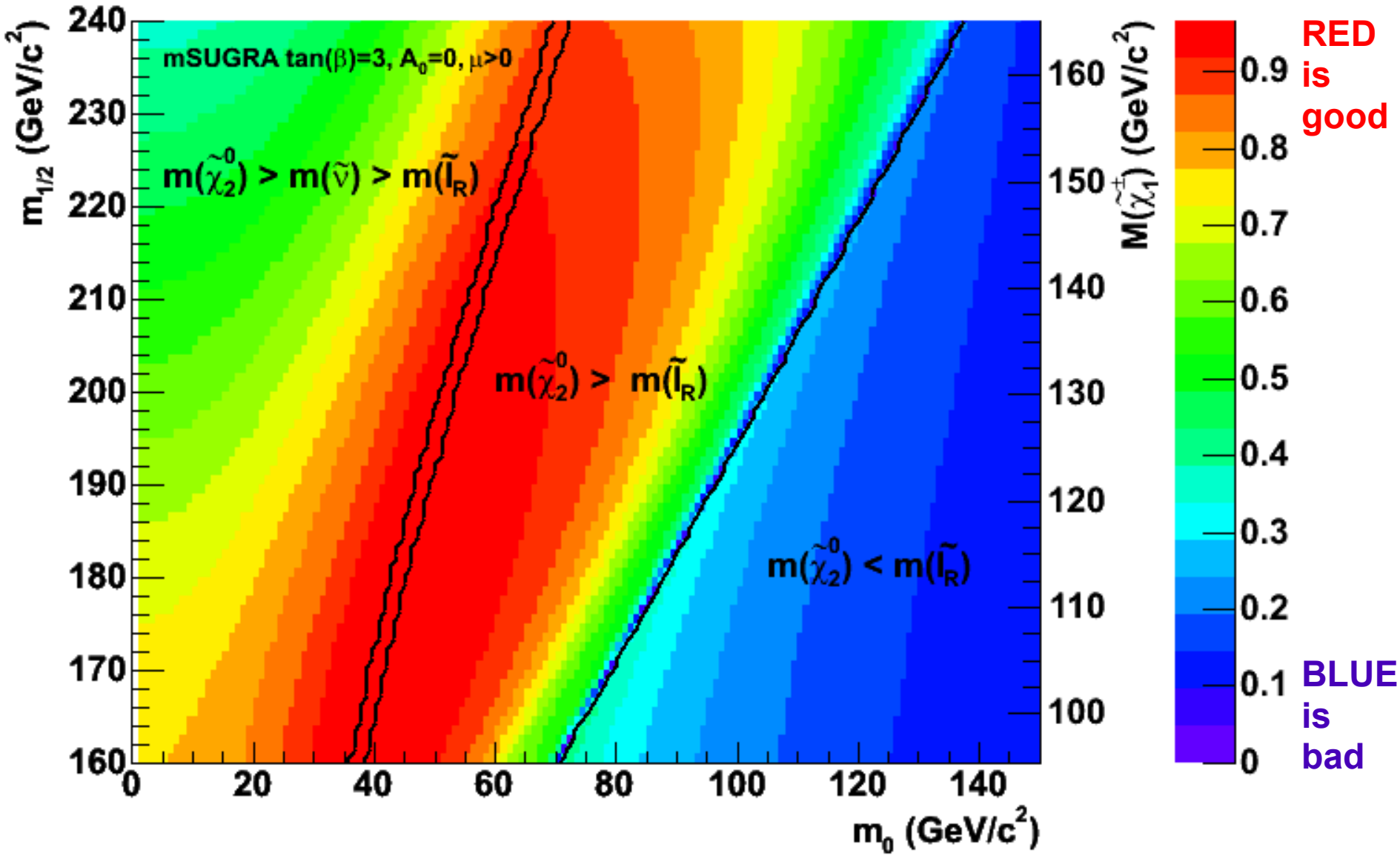
$$\widetilde{\chi}_2^0 \to \tilde{\ell}^\pm \ell^\mp, \tilde{\ell}^\pm \to \ell \widetilde{\chi}_1^0 \qquad \widetilde{\chi}_1^\pm \to \tilde{\ell}^\pm \nu, \tilde{\ell}^\pm \to \ell \widetilde{\chi}_1^0$$

$$M(\widetilde{\chi}_2^0, \widetilde{\chi}_1^\pm) < M(\tilde{\ell})$$

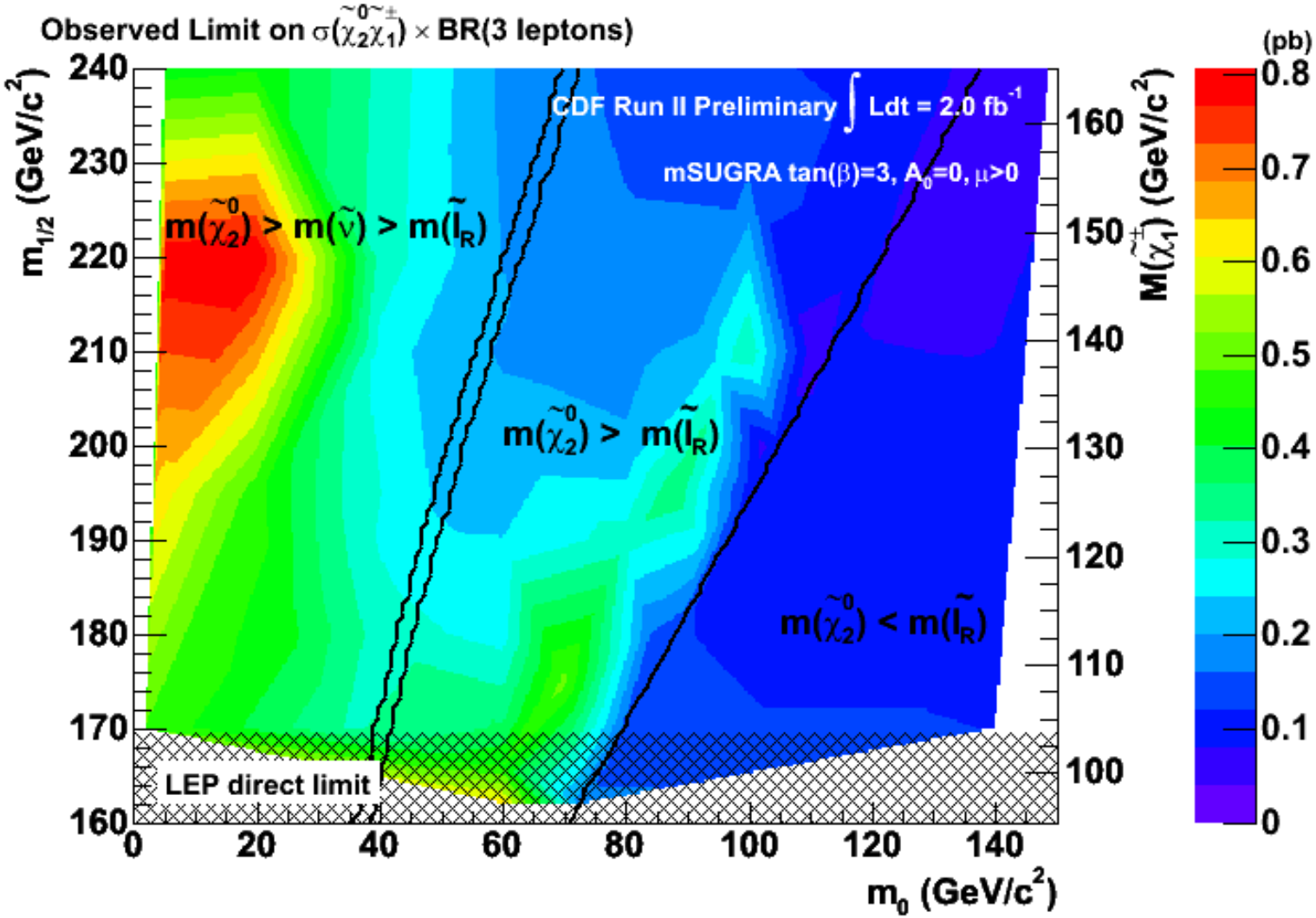
$$\widetilde{\chi}_1^\pm - - - W^* \widetilde{\chi}_1^0 - - - \ell^\pm \nu \widetilde{\chi}_1^0$$

$$\widetilde{\chi}_2^0 - - - Z^* \widetilde{\chi}_1^0 - - - \ell^\pm \ell^\mp \widetilde{\chi}_1^0$$

$BR(\widetilde{\chi}_2^0\widetilde{\chi}_1^{\pm} \to 3\ell)$



Observed Limits on σ×BR



RED is bad

BLUE is good