Search for Supersymmetry Using the Trilepton Signature of Chargino-Neutralino Production

Julian Glatzer
on behalf of the CDF collaboration

RUTGERS UNIVERSITY

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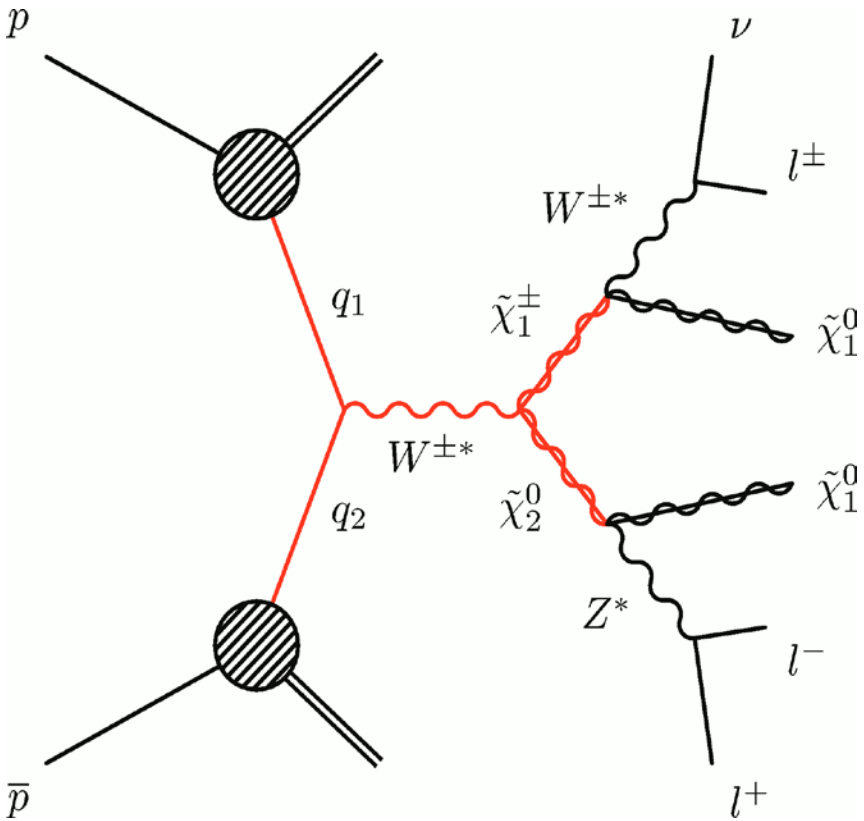
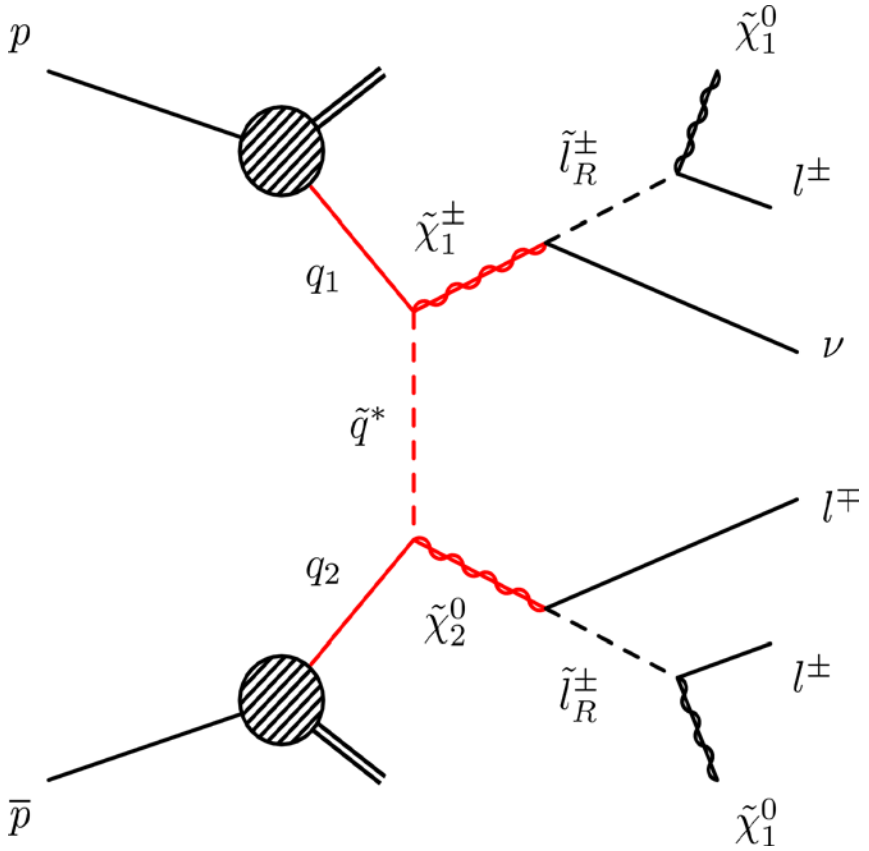
2. Analysis
3. Results
4. mSUGRA Interpretation

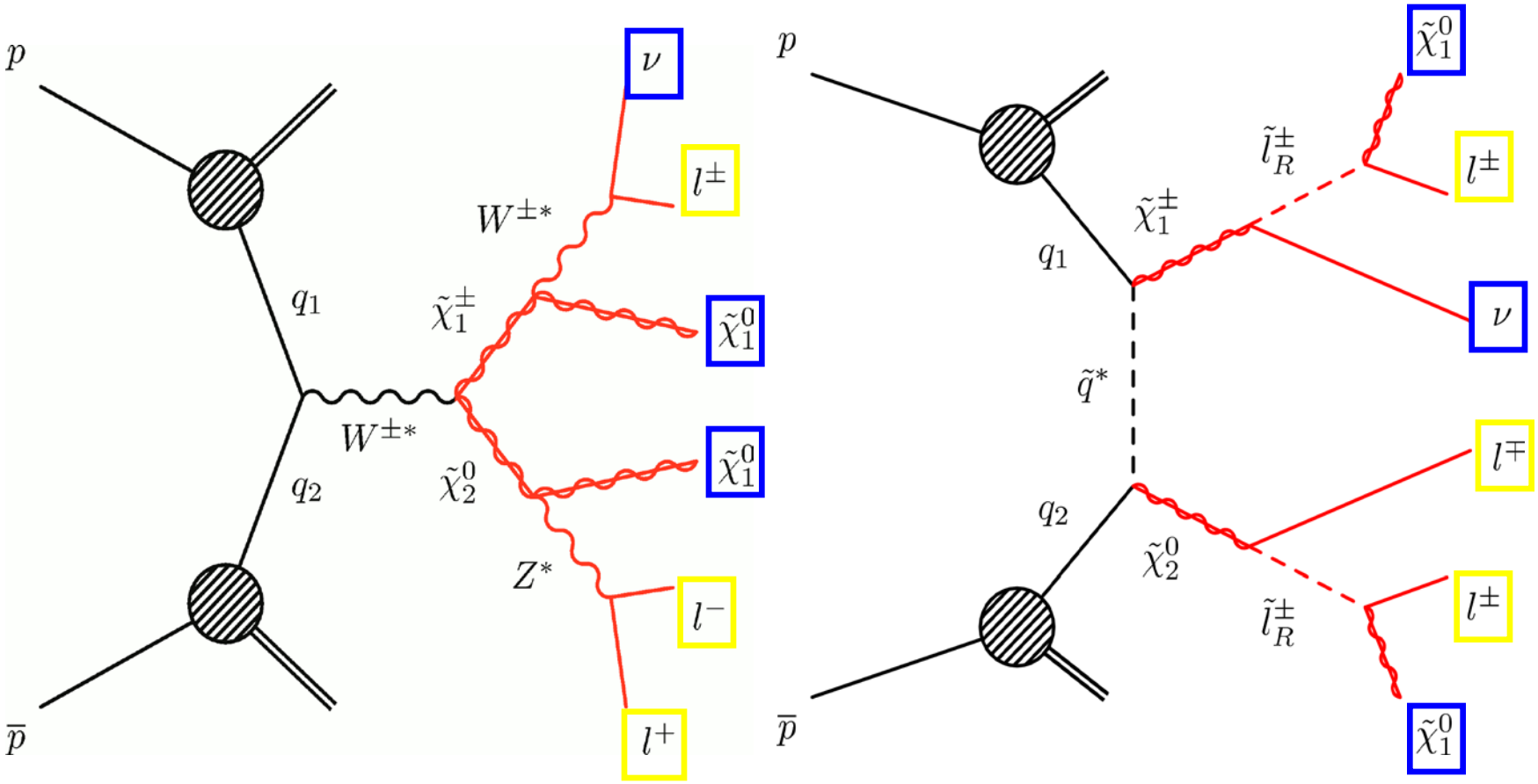
Chargino Neutralino Production





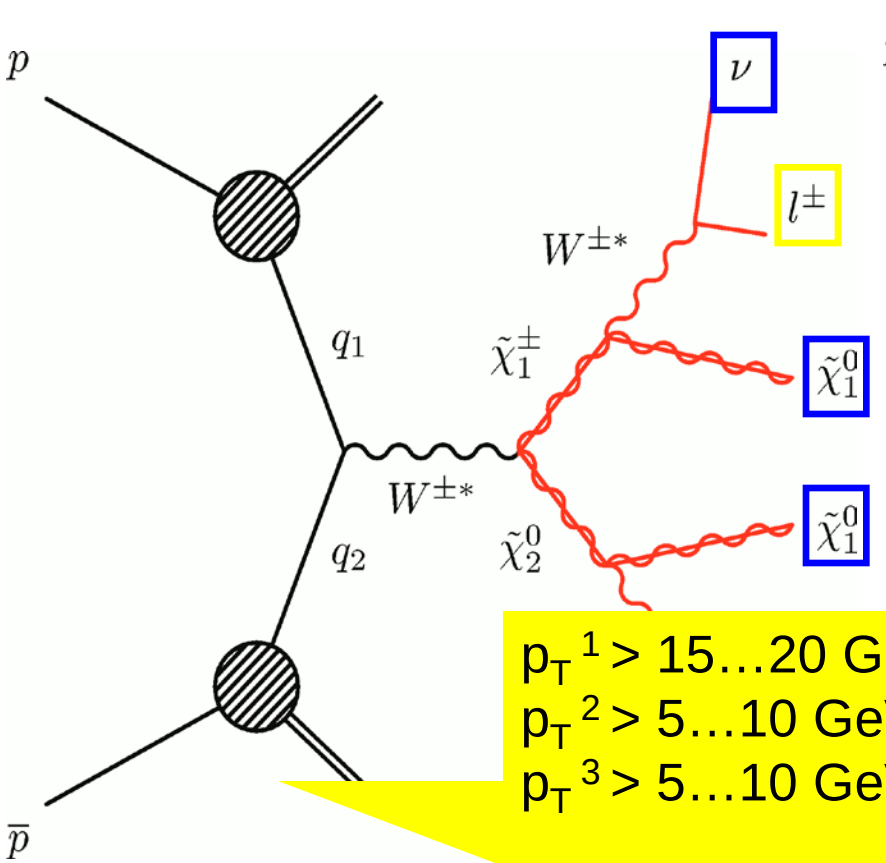
Cross section at benchmark point $\sigma = 0.5\,\mathrm{pb}$

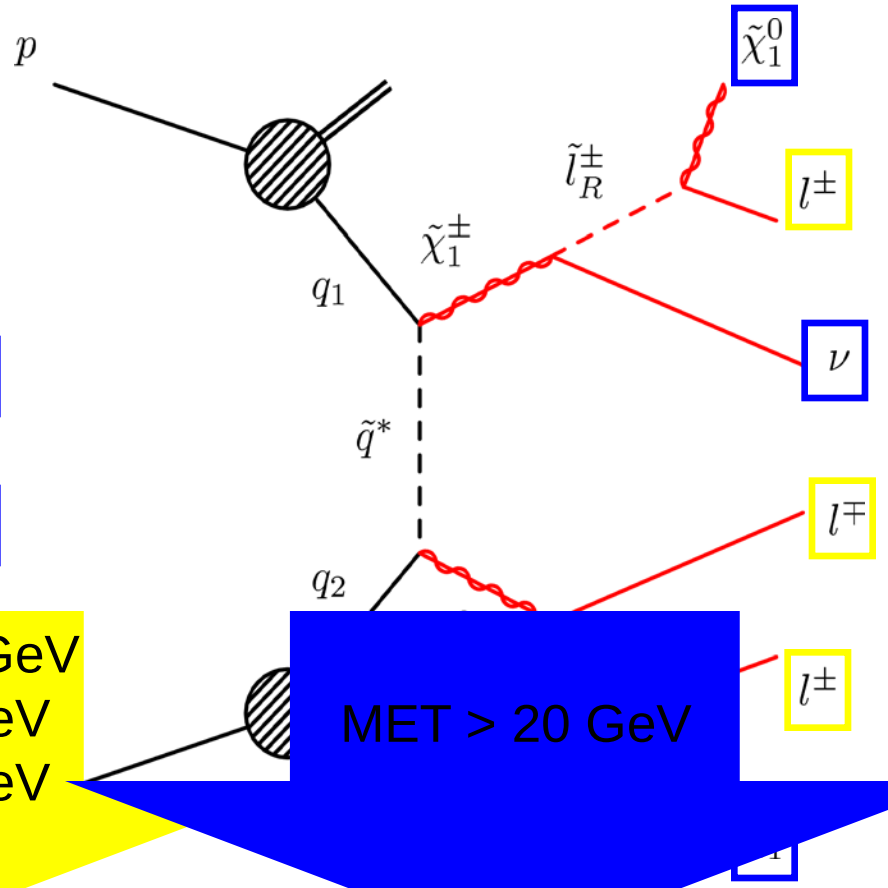
Decay of Chargino and Neutralino



Signature: 3 leptons and missing E_T

Decay of Chargino and Neutralino





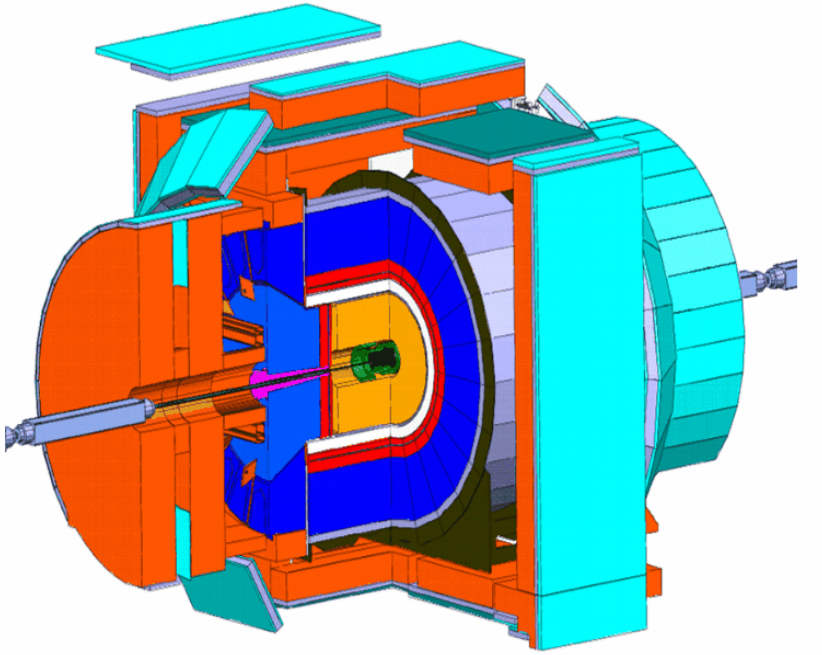
$p_T^{\,1} > 15\ldots20$ GeV
$p_T^{\,2} > 5\ldots10$ GeV
$p_T^{\,3} > 5\ldots10$ GeV

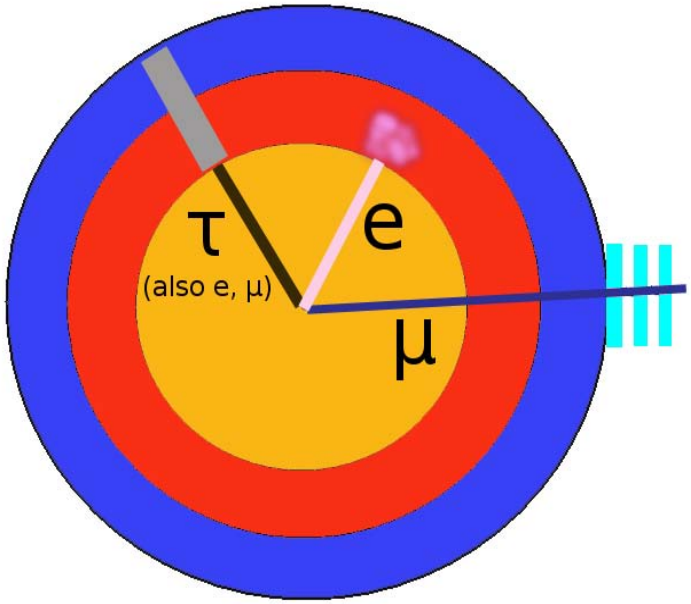
MET > 20 GeV

Signature: 3 leptons and missing E_T

The CDF Detector

Tracker | **Electromagnetic Calorimeter** | **Hadronic Calorimeter** | **Muon System**





Isolated tracks as a proxy for tau leptons.

This analysis is using $\int \mathcal{L}\, dt = 2.0\,\mathrm{fb}^{-1}$.

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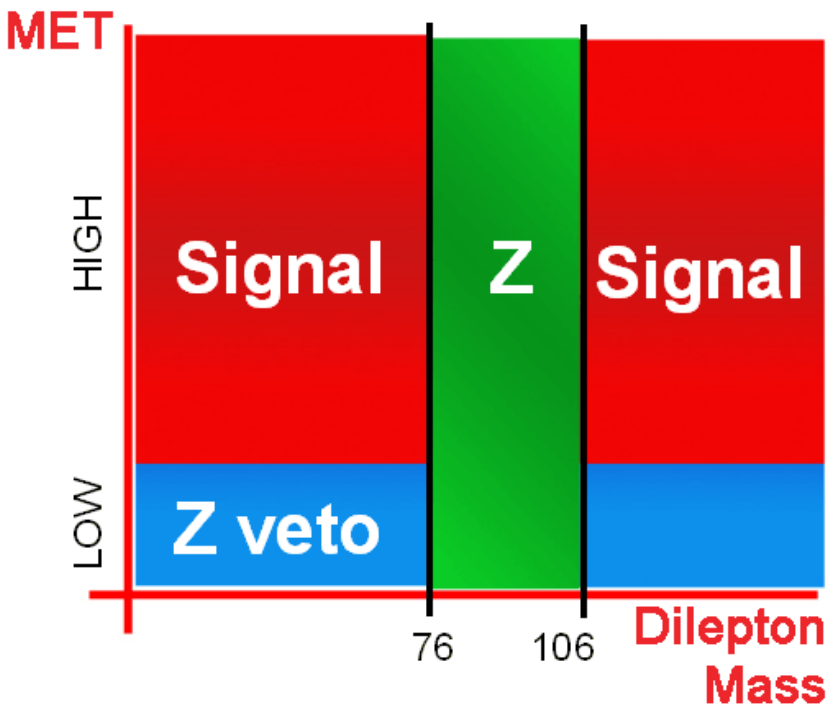
The Analysis
Unbiased counting experiment



Control Regions: also Dileptons

Find three tight leptons

Else, two tight and one loose lepton

Else, one tight and two loose leptons

Else, two tight leptons and one isolated track

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

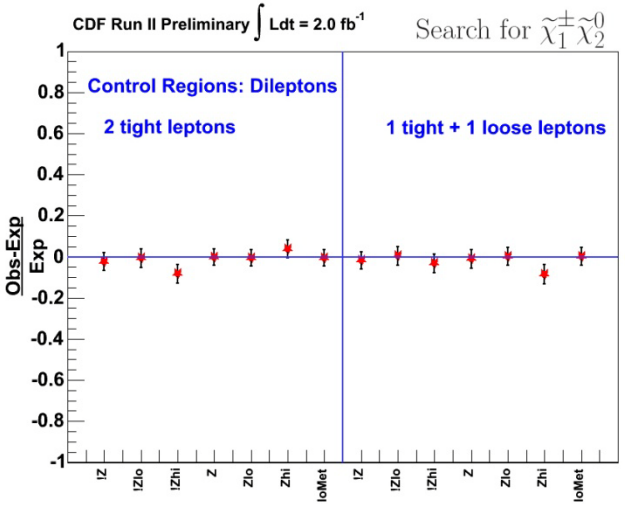
Decreasing purity

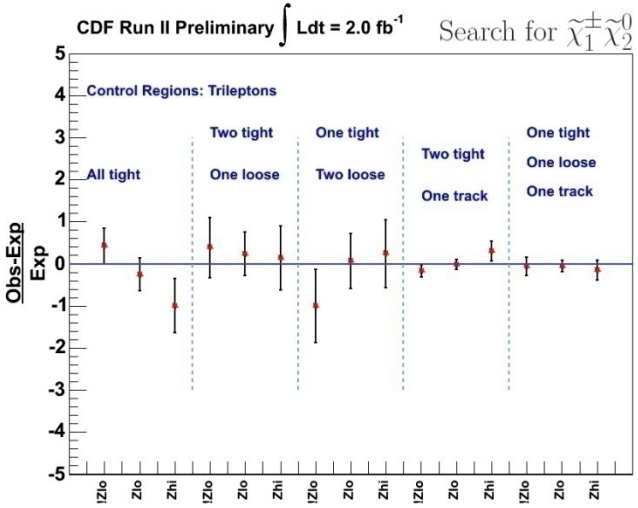
Standard Model Background

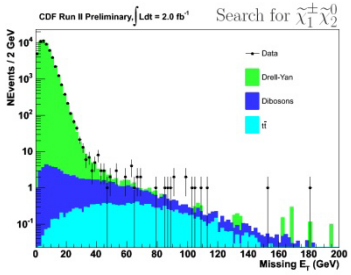
Process		Signature
Diboson		
ZZ		4 leptons
WZ		3 leptons + missing E_T
WW	$+\gamma$, T	2 leptons + missing E_T
top-pair		3 leptons + missing E_T
DY	$+\gamma$, T	2 leptons
Fake lepton		
DY	+h	2 leptons
W+jets	+h	1 lepton + missing E_T
WW	+h	2 leptons + missing E_T
top-pair	+h	2 leptons + missing E_T

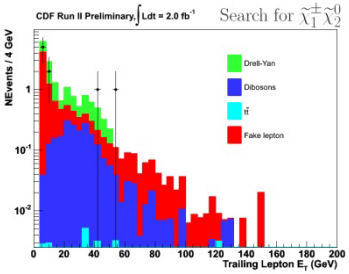
h: hadron faking a lepton, T: Track, lepton=e,μ

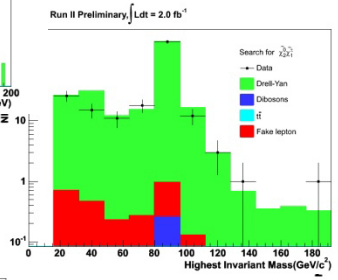
Control Regions

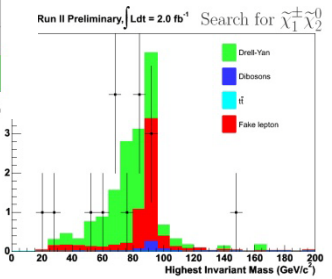


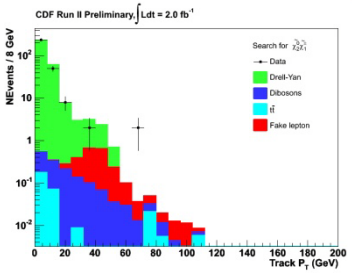


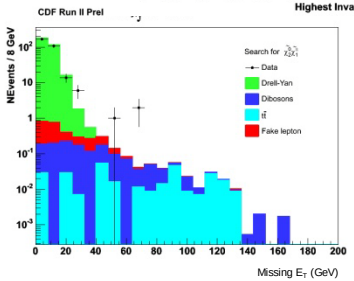


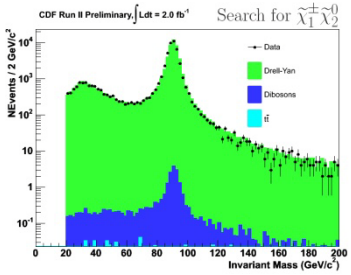












Signal Optimization

- Require missing E_T

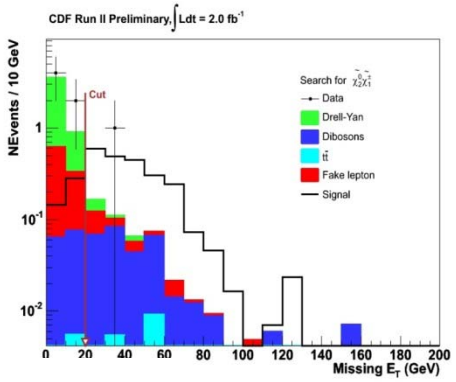
$$\not\!\!E_T > 20\,\mathrm{GeV}$$

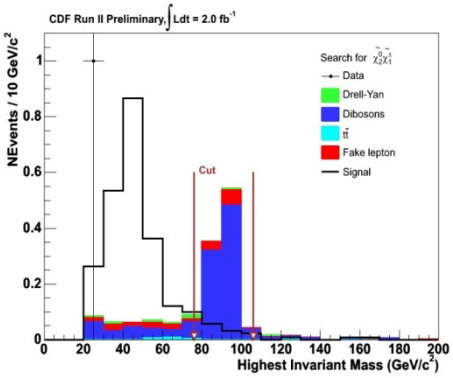
- Remove Z,J/ψ, Υ contribution by cut on dilepton invariant mass

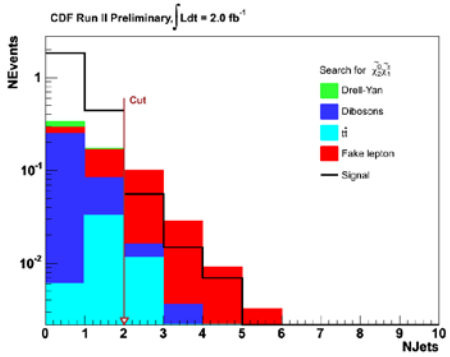
$$m_{OS}^{1,2} > 20,\ 13\,\mathrm{GeV/c^2}$$
$$m_{OS}^{1,2} \notin [76, 106]\ \mathrm{GeV/c^2}$$

- Require low hadronic activity

$$N_{Jet} < 2$$







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Final Predictions

Channel	Signal	Background	Observed
3 tight	2.25 ± 0.32	0.49 ± 0.09	
2 tight, 1 loose	1.61 ± 0.24	0.25 ± 0.04	
1 tight, 2 loose	0.68 ± 0.11	0.14 ± 0.03	
Total trilepton	4.5 ± 0.6	0.88 ± 0.14	
2 tight, 1 Track	4.44 ± 0.69	3.22 ± 0.72	
1 tight,1loose,1 Track	2.42 ± 0.35	2.28 ± 0.63	
Total Dilepton+Track	6.9 ± 0.9	5.5 ± 1.1	

Final Predictions: CDF Run II Preliminary $\int \mathcal{L} dt = 2.0\,\mathrm{fb}^{-1}$

Signal predictions for benchmark point.

Final Predictions and Results

Channel	Signal	Background	Observed
3 tight	2.25 ± 0.32	0.49 ± 0.09	1
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Total trilepton	4.5 ± 0.6	0.88 ± 0.14	1
2 tight, 1 Track	4.44 ± 0.69	3.22 ± 0.72	4
1 tight,1loose,1 Track	2.42 ± 0.35	2.28 ± 0.63	2
Total Dilepton+Track	6.9 ± 0.9	5.5 ± 1.1	6

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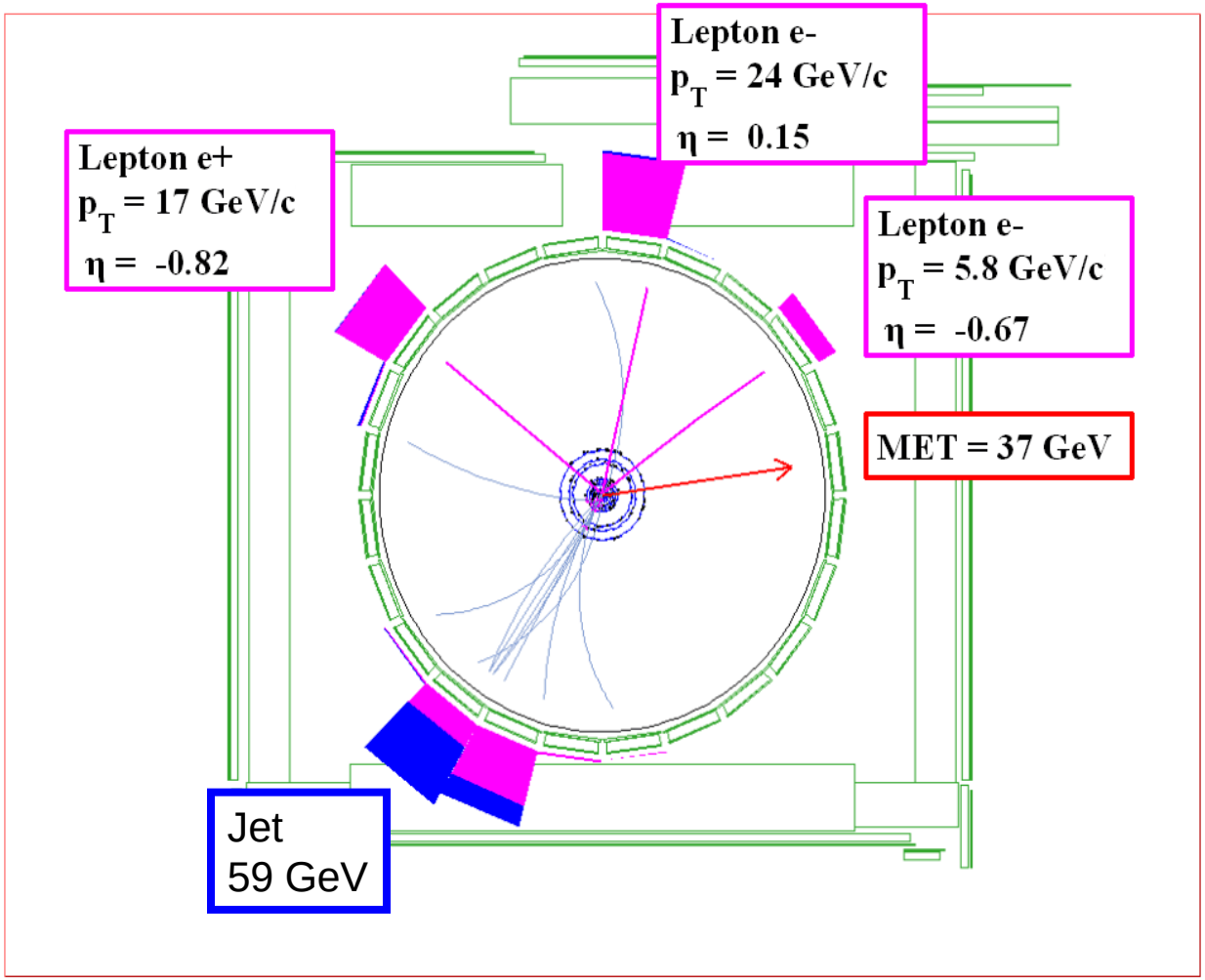
Signal predictions for benchmark point.

Display of an Event

in the three tight leptons channel



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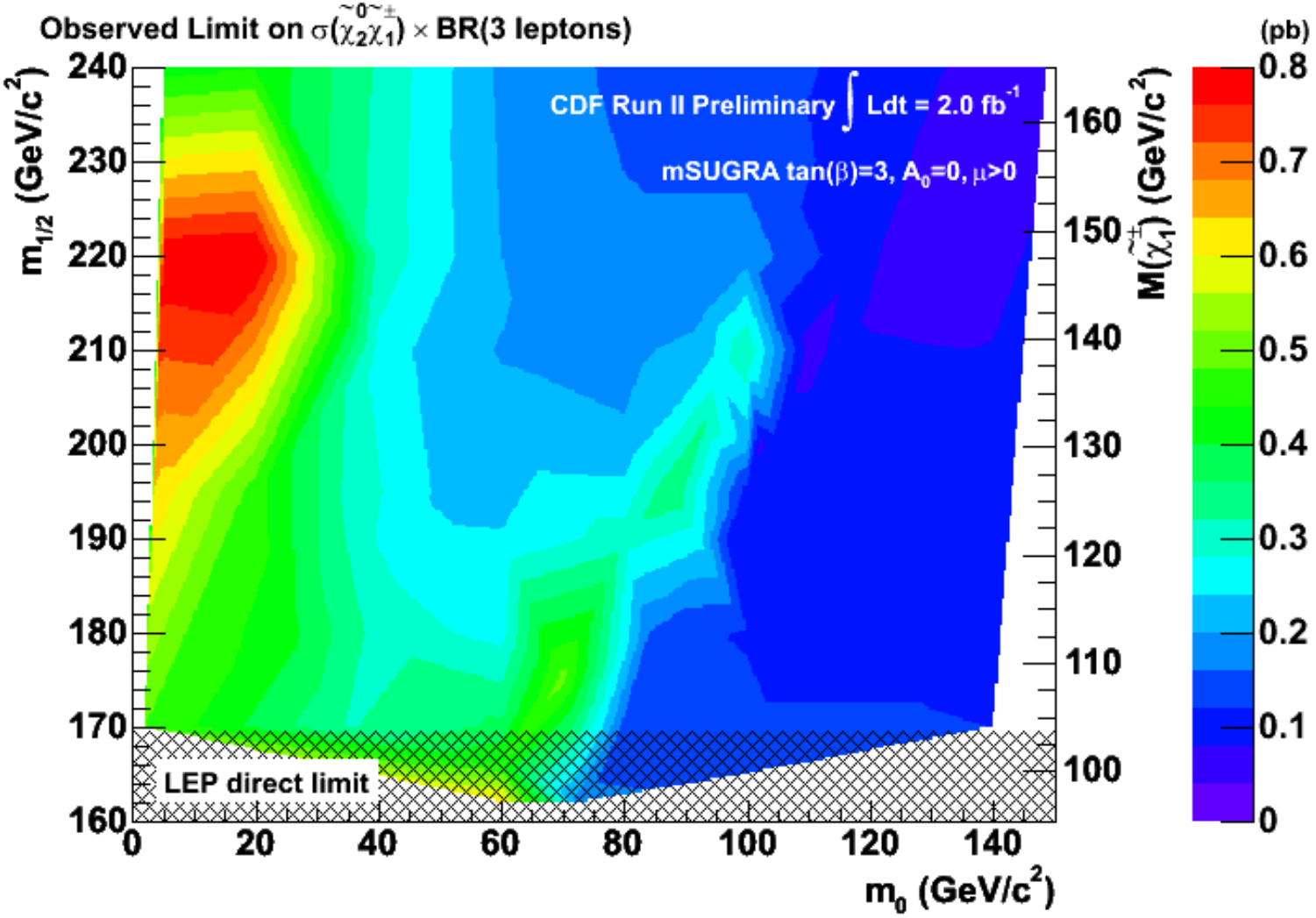
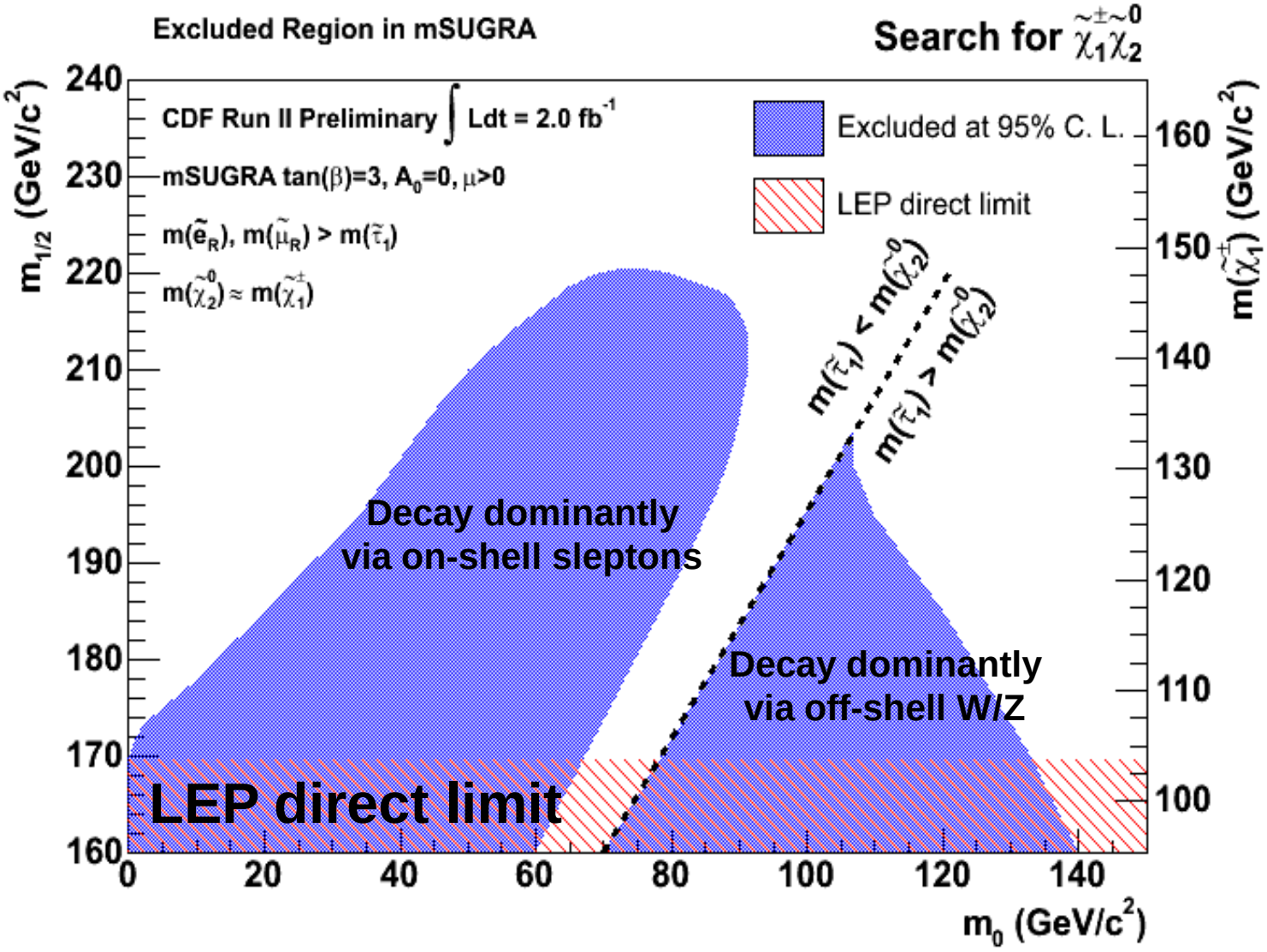
Observed Limit on σ∗BR



mSUGRA Exclusion Region



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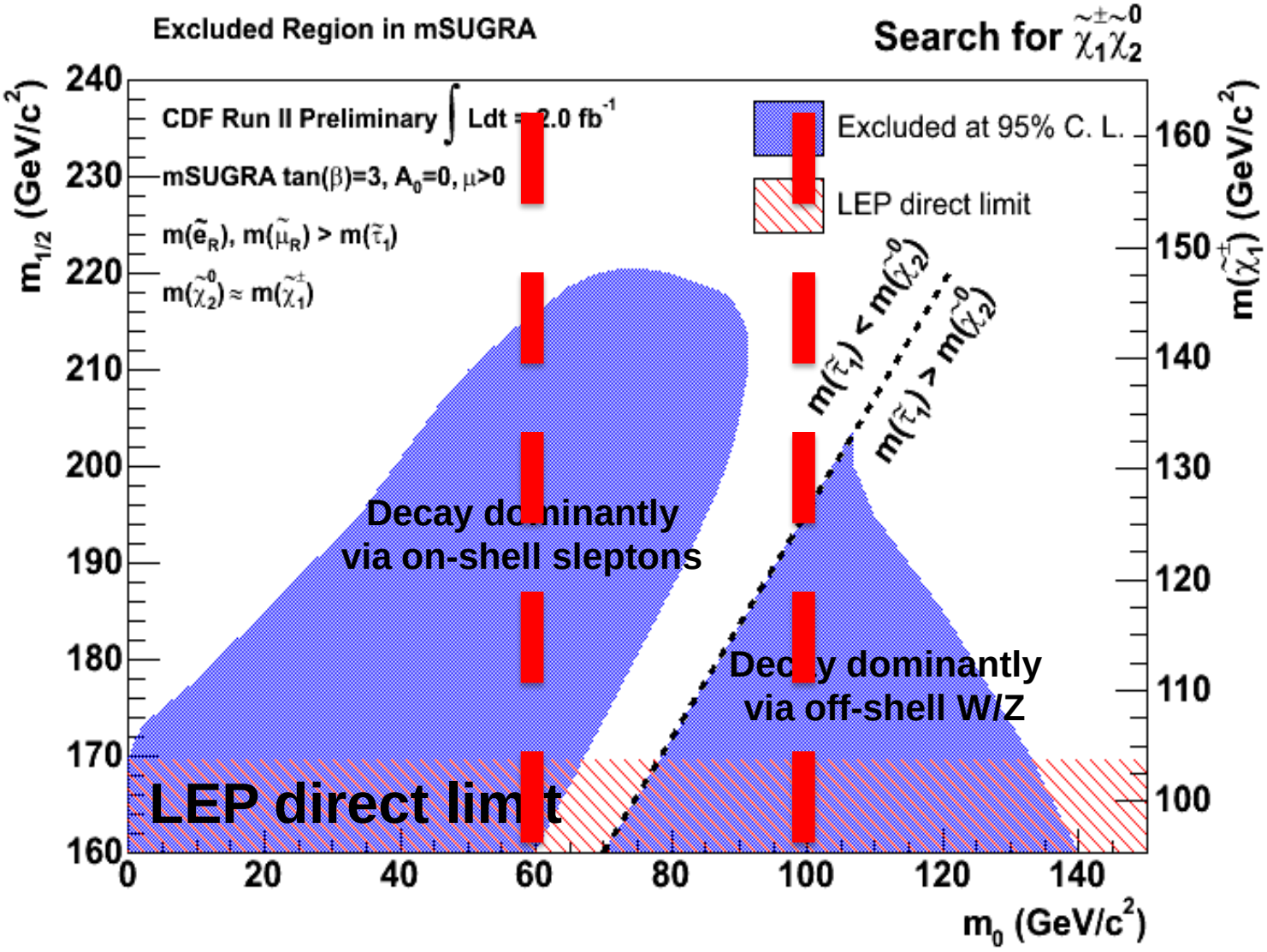
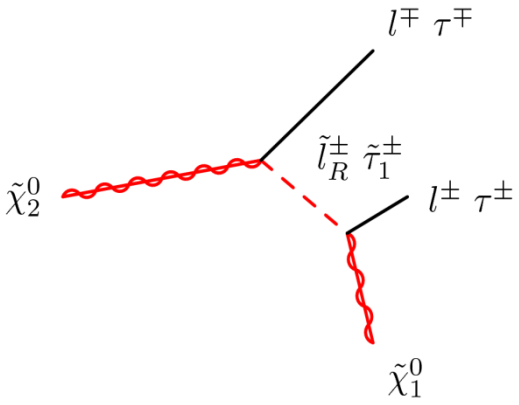
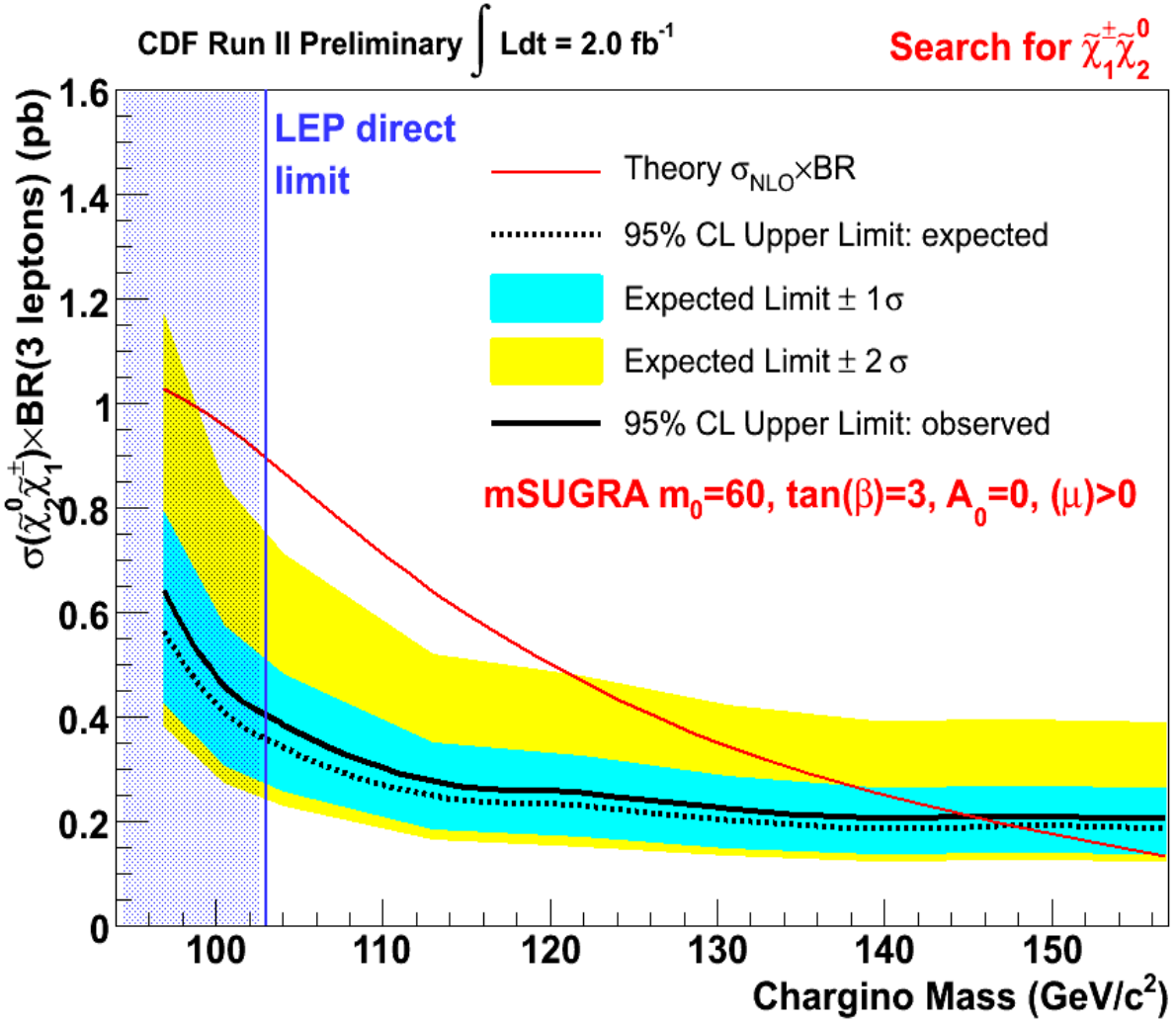


A limit on the chargino mass for m_0=60 GeV/c²





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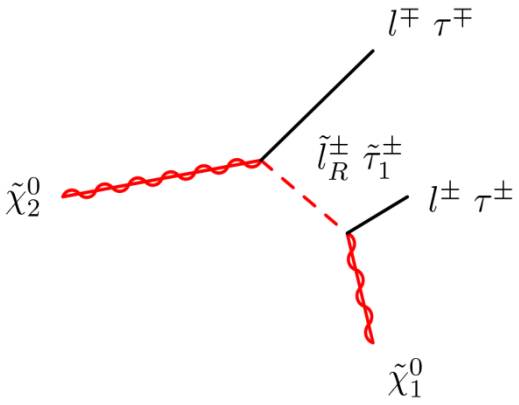

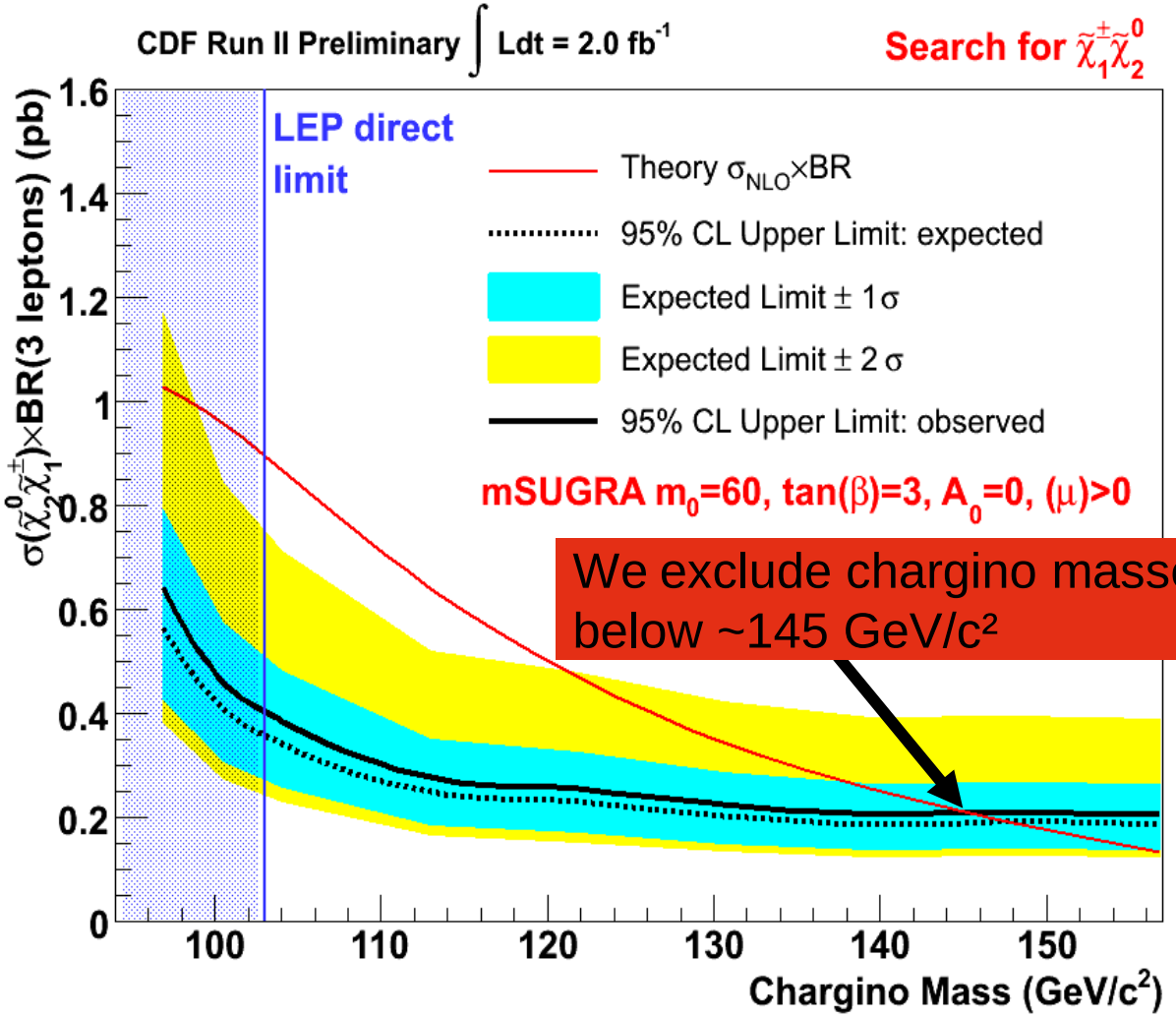

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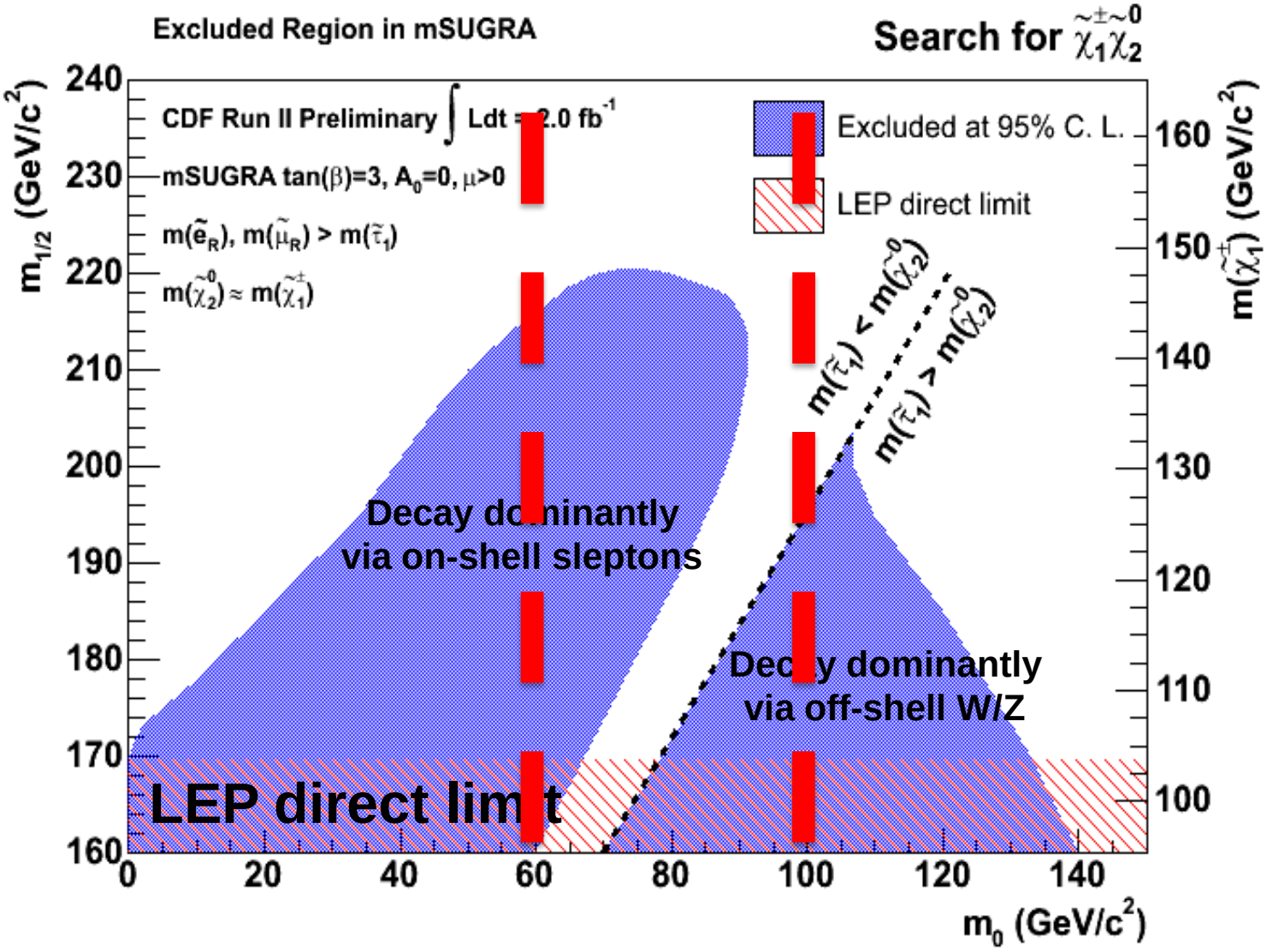
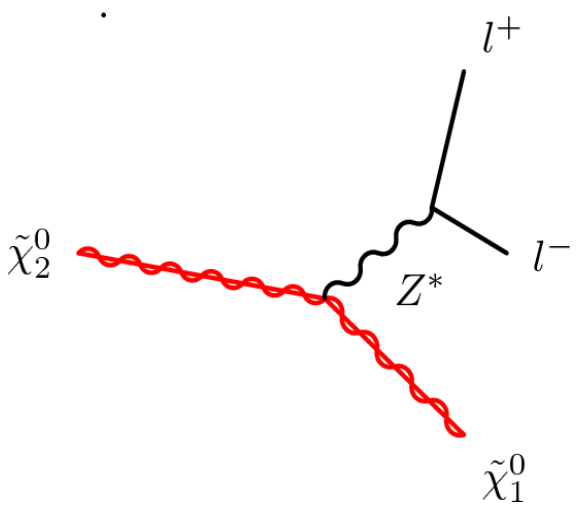
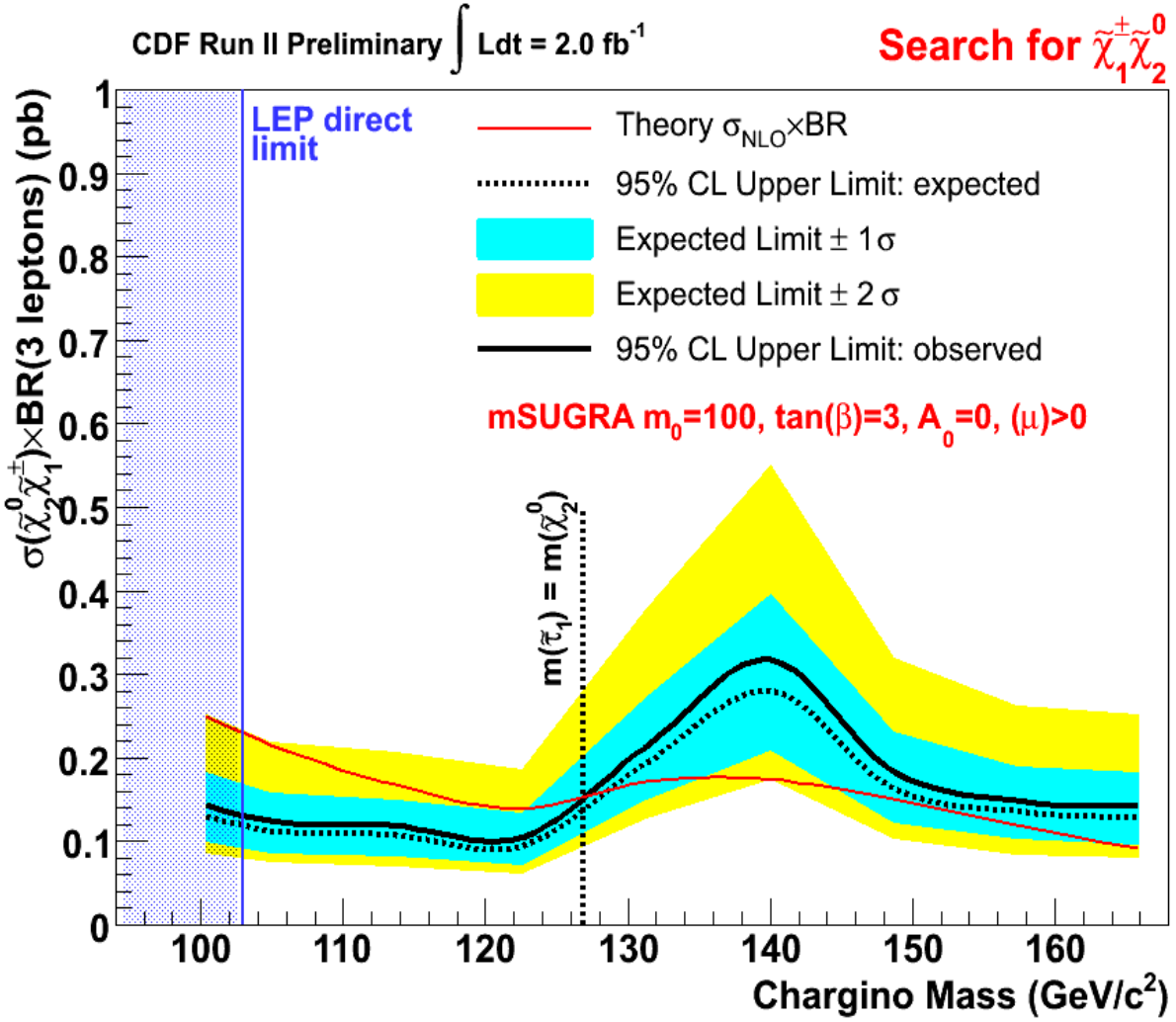


A limit on the chargino mass for m_0=100 GeV/c²





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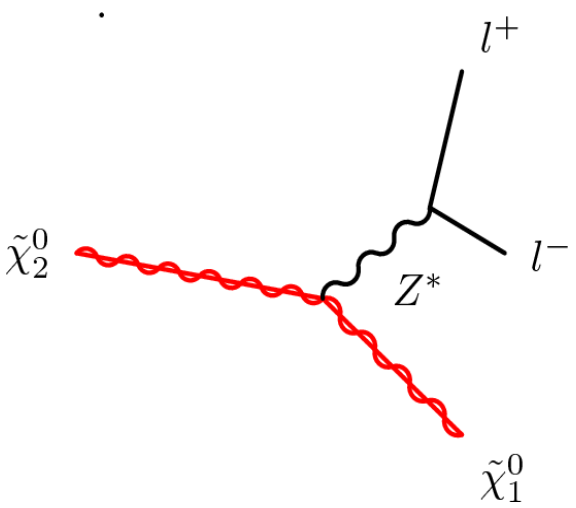
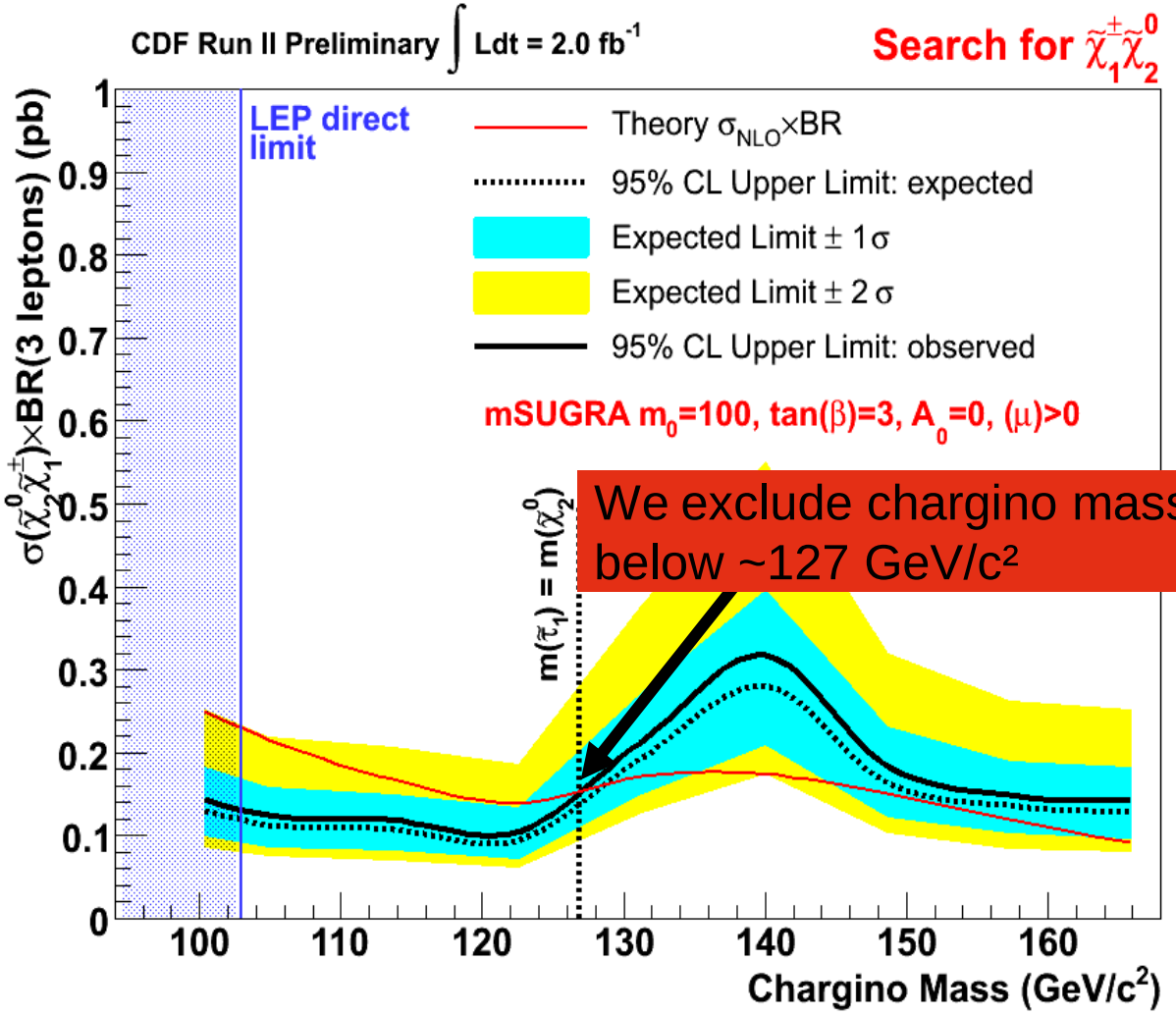
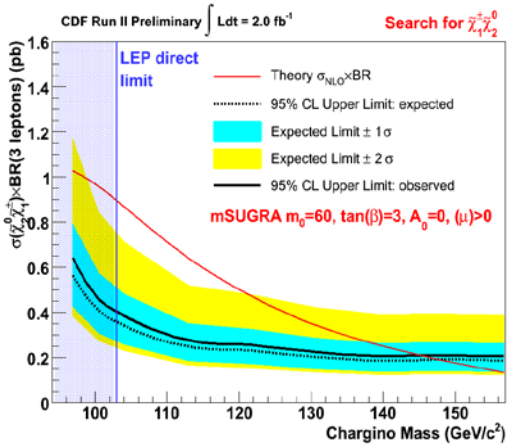
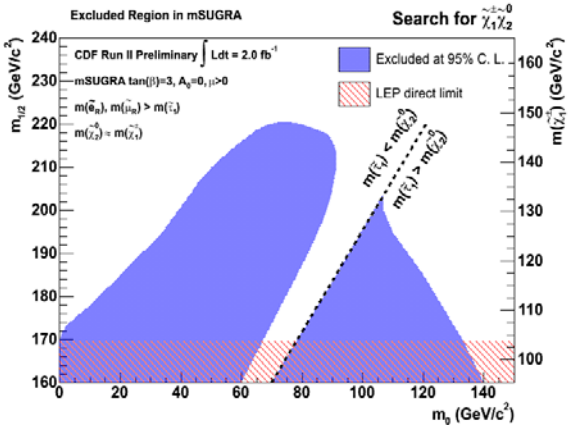




Summary

- We looked for Chargino-Neutralino production in a **trilepton + missing E_T** signature with 2.0 fb^{-1} of data
- Observations are **consistent with the standard model**
- We have set a direct **exclusion in mSugra** for chargino/neutralino





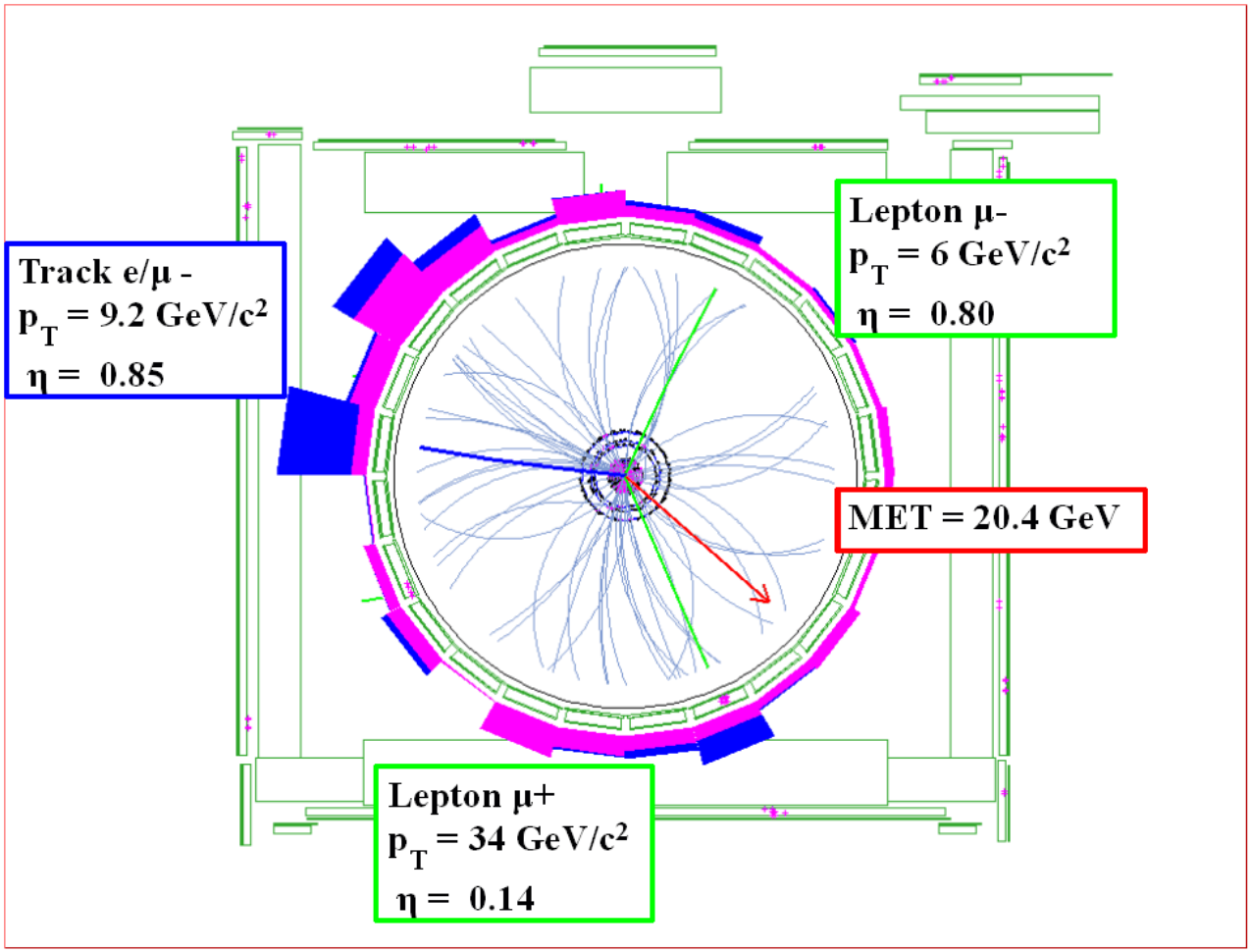
Accepted by PRL
arXiv: 0808.2446

Thank you

Backup

Display of an Event

in the two tight one track channel

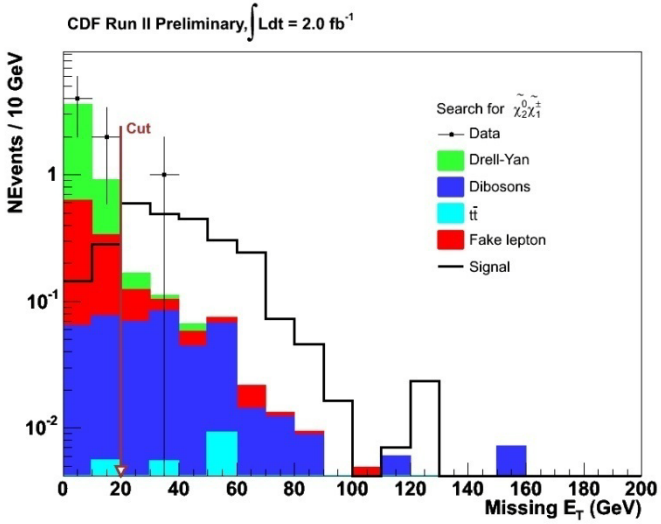


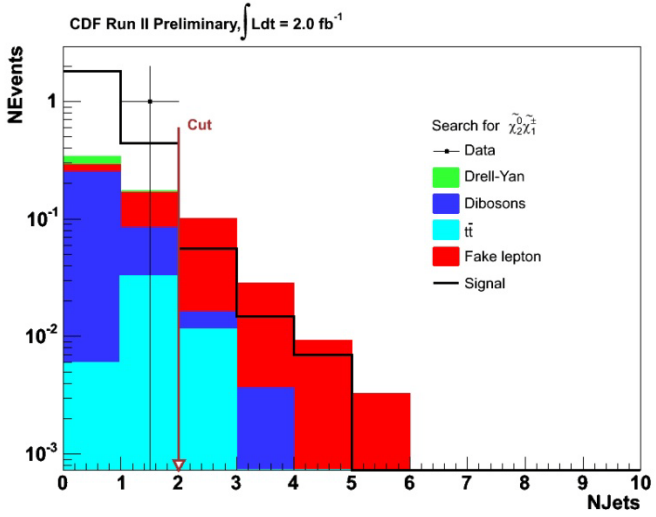
Candidate Events

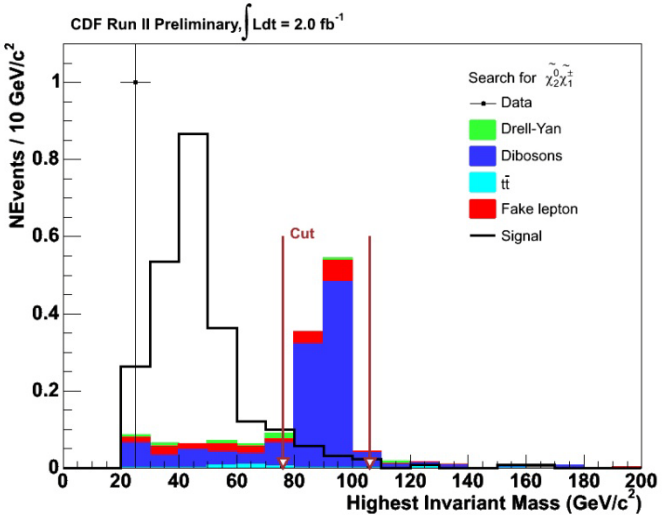
CDF RUN II Preliminary $\int \mathcal{L}dt = 2.0$ fb^{-1} : Search for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

Channel	Type	E_T^1 (GeV)	E_T^2 (GeV)	E_T^3 (GeV)	M_{OS}^1 (GeV/c^2)	M_{OS}^2 (GeV/c^2)	MET (GeV)	Jet^1E_T (GeV)
3tight	$e^-e^+e^-$	24	17	5.8	29	16	37	59
2tight,1Track	$e^-e^+T^-$	27	9.7	8.5	41	19	28	24
2tight,1Track	$e^-e^+T^+$	23	9.3	56	70	46	58	18
2tight,1Track	$\mu^+\mu^-T^-$	34	6.2	9.2	33	28	20	21
2tight,1Track	$\mu^-\mu^+T^-$	45	21	7.8	29	26	39	41
1tight,1loose,1Track	$\mu^+\mu^-T^+$	23	12.2	6.5	39	18	29	34
1tight,1loose,1Track	$\mu^+\mu^-T^-$	59	70	44	124	58	37	—

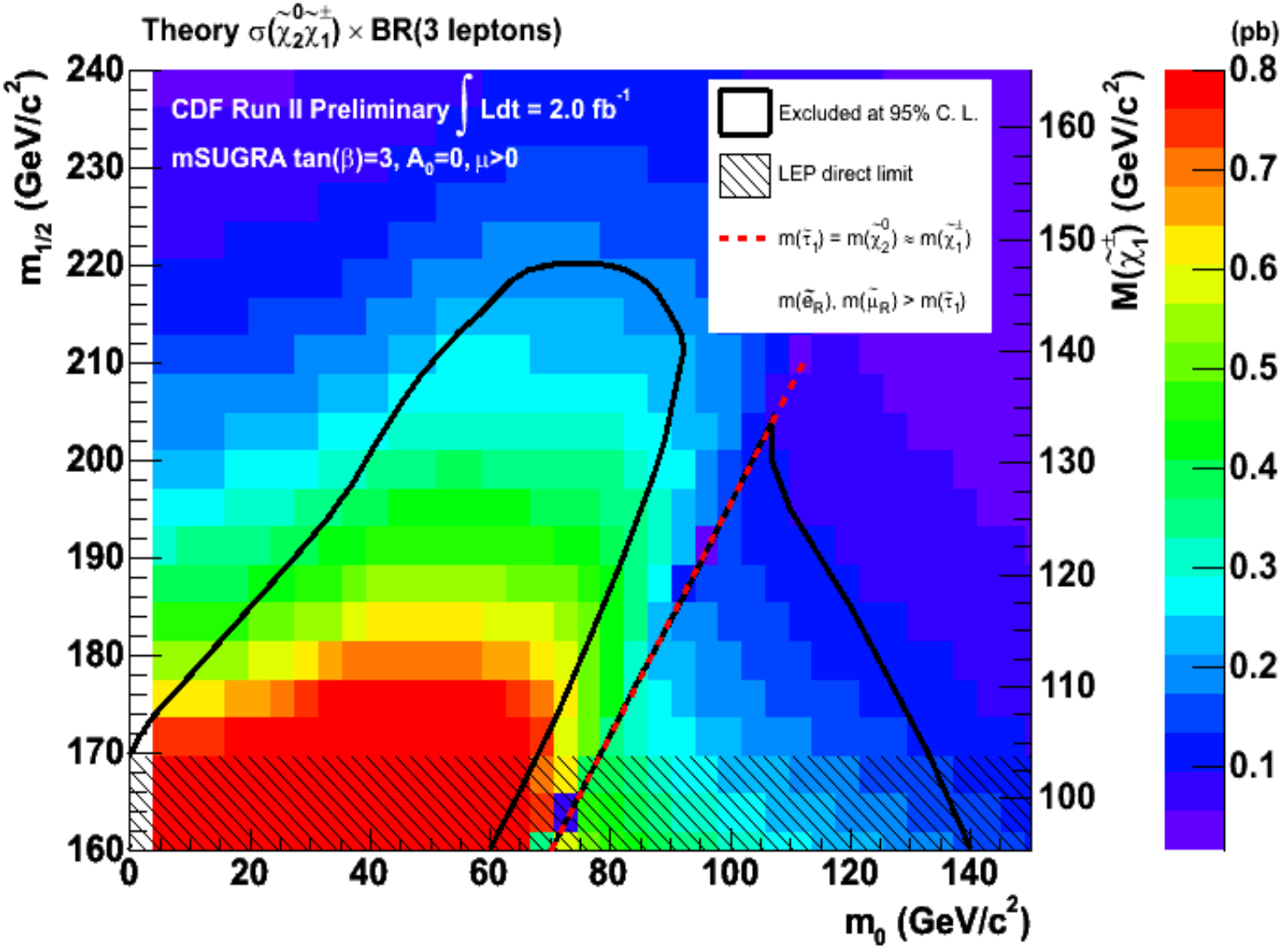
Results: 3 tight







mSUGRA Exclusion Region

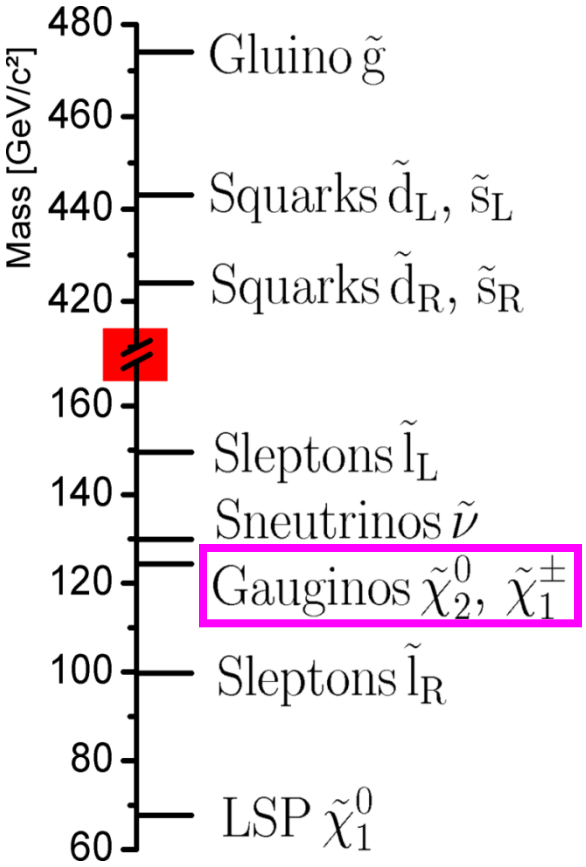


mSUGRA

minimal supergravity grand unification

5 free parameters:

- m_0: common scalar mass at GUT scale
- $m_{1/2}$: common gaugino mass at GUT scale
- tan(β): Ratio of the Higgs VEV
- A_0: common trilinear coupling at GUT scale
- sign(μ): μ is the Higgsino mass parameter



Our benchmark point: $m_0 = 60$ GeV/c², $m_{1/2} = 190$ GeV/c² , tan(β) = 3, $A_0 = 0$, μ > 0

Five different channels

are defined as five different, **mutually exclusive** experiments.

Why do we do this? Combining channels with different signal over background gives more significant results than one channel with average S/B.

Decreasing purity

	Lepton p_T
Find three tight leptons	(15,5,5)
Else, two tight and one loose lepton	(15,5,10)
Else, one tight and two loose leptons	(20,8,5/10)
Else, two tight leptons and one isolated track	(15,5,5)
Else, one tight, one loose lepton and one isolated track	(20,8/10,5)

Standard Model Background

Process		Signature
Diboson		
ZZ		4 leptons
WZ		3 leptons + missing E_T
WW	$+\gamma$, T	2 leptons + missing E_T
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h: hadron faking a lepton, T: Track, lepton=e,μ

Reducing Backgrounds

- Require missing E_T

$$\not\!\!E_T > 20\,\mathrm{GeV}$$

- Remove Z,J/ψ, Υ contribution by cut on dilepton invariant mass

$$m_{OS}^{1,2} > 20,\ 13\,\mathrm{GeV/c^2}$$
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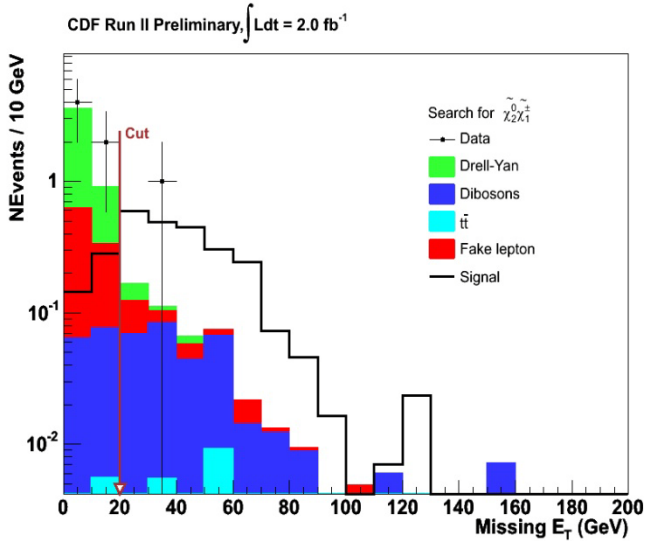
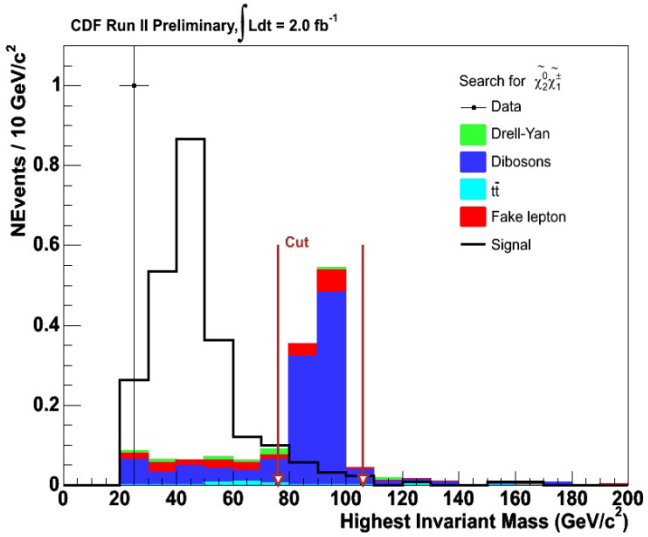
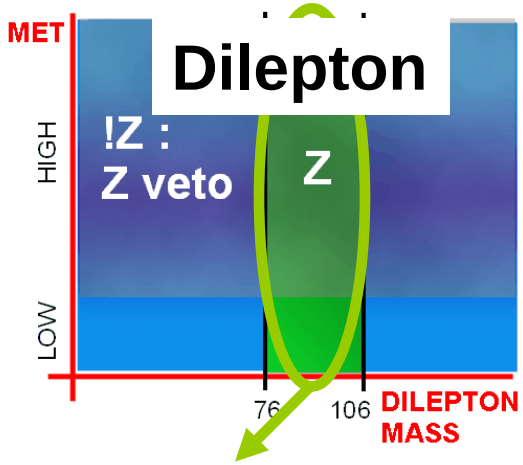
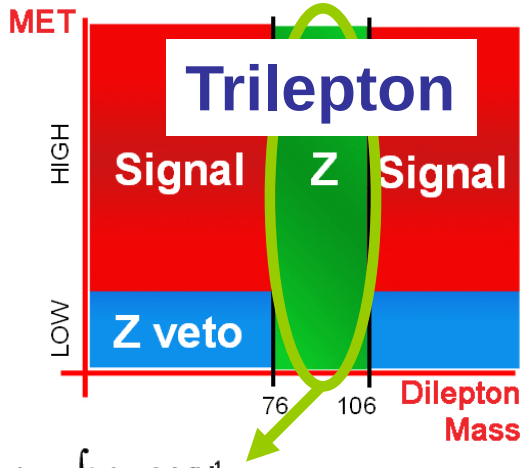
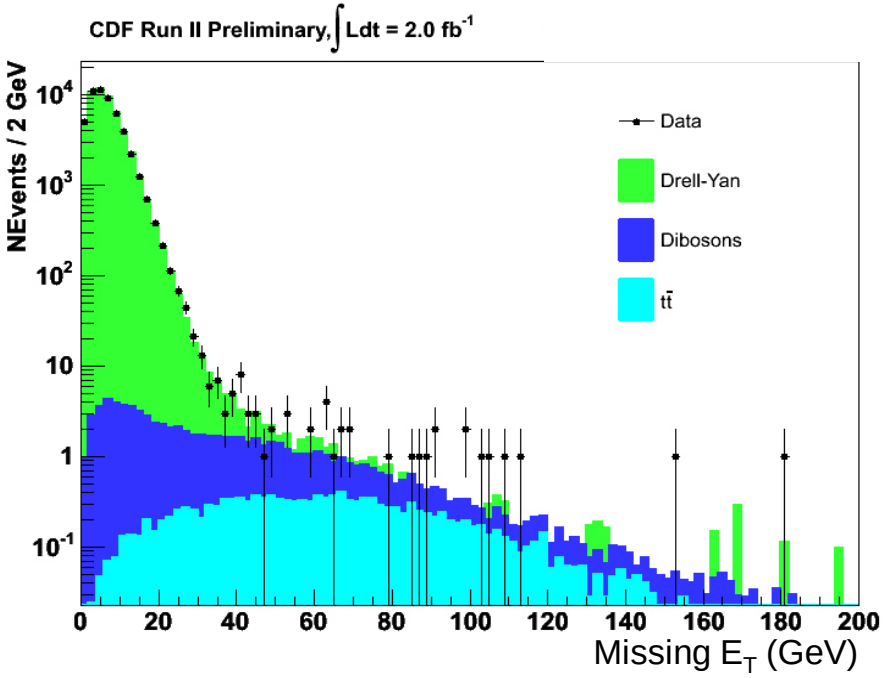


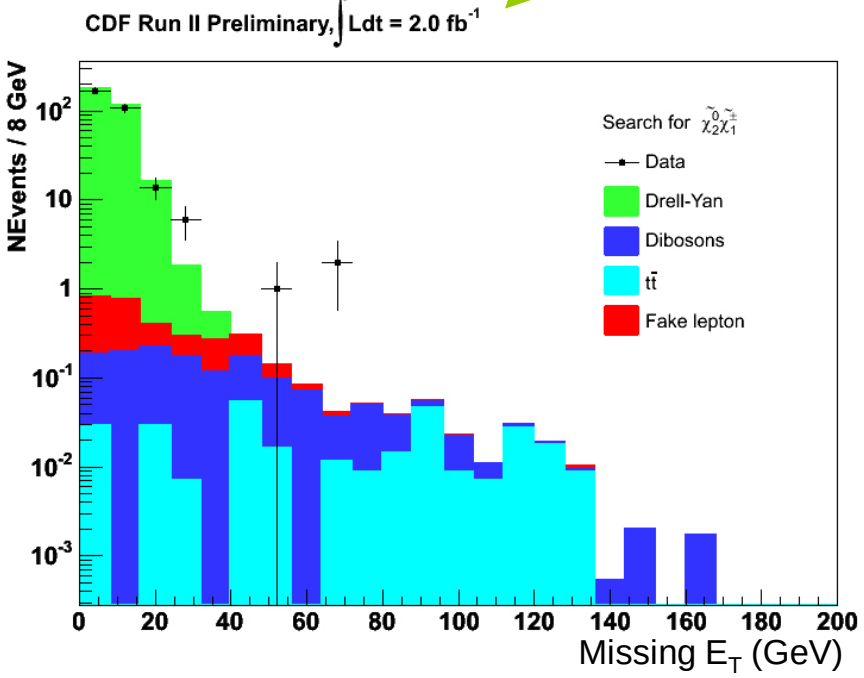


Control Regions









Methods for the Estimation of Backgrounds

Process		Estimation	Signature
Diboson			
ZZ		MC	4 leptons
WZ		MC	3 leptons + missing E_T
WW	$+\gamma$, T	MC/ITR	2 leptons + missing E_T
top-pair	(+T)	MC/ITR	3 leptons + missing E_T
DY	$+\gamma$, T	MC/ITR	2 leptons
Fake lepton			
DY	+h	FR	2 leptons
W+jets	+h	FR	1 lepton + missing E_T
WW	+h	FR	2 leptons + missing E_T
top-pair	+h	FR	2 leptons + missing E_T

h: hadron faking a lepton, T: Track, lepton=e,μ

Background Estimation:

The Isolated Track Rate

Getting the isolated track rate:

- Use data from p_T lepton lepton triggershigh
- Select $Z \rightarrow$ ee and $Z \rightarrow$ μμ by cut on invariant mass of dileptons

  $|M_{ll} - 91.2| < 15$ GeV/c^2
- Count the number of events with at least one extra isolated track as a fuction of number of „good“ tracks.

Application of the isolated track rate:

- Select event with 2 leptons and no third isolated track
- Apply isolated track rate as an event weight

The Fake Rate

A hadron is faking a lepton

- Events with more than one fake are negligible
- In „Jet-Triggered“ events the number of identified leptons per jet (electron) or isolated track (muon) as a function of the transverse energy of the denominator object is measured.
- The fake rate is applied as a weight to fakeable events in data.
- Measured and applied in data

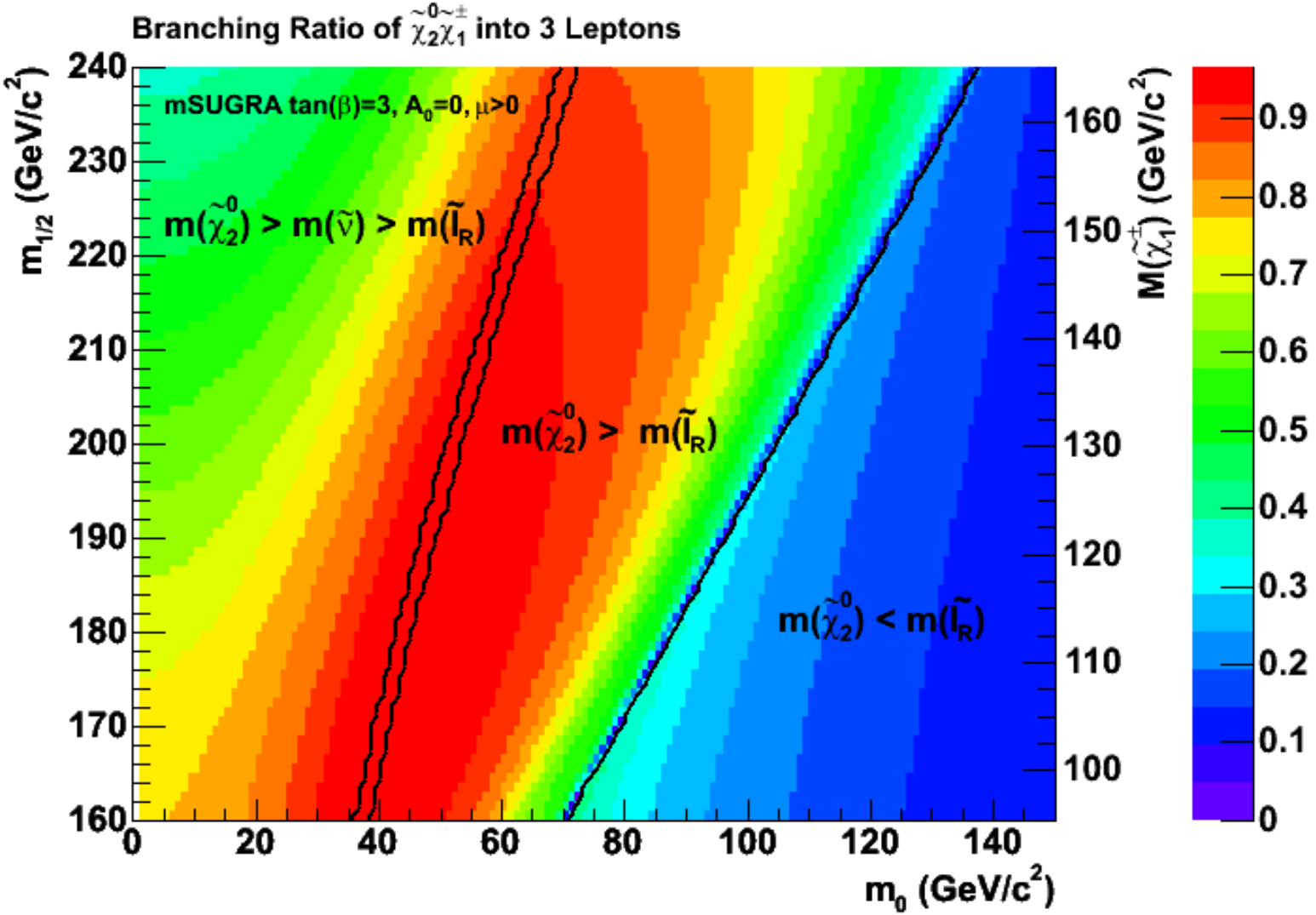
Results

Channel	$l_t l_t l_t$	$l_t l_t l_l$	$l_t l_l l_l$	$l_t l_t T$	$l_t l_l T$	$\sum$channels
Signal at BP1	2.25	1.61	0.68	4.44	2.42	11.40
Statistical Uncertainty	$\pm$0.13	$\pm$0.11	$\pm$0.07	$\pm$0.19	$\pm$0.14	$\pm$0.30
Systematic Uncertainty	$\pm$0.29	$\pm$0.21	$\pm$0.09	$\pm$0.58	$\pm$0.32	$\pm$0.76
Background	0.49	0.25	0.14	3.22	2.28	6.38
Statistical Uncertainty	$\pm$0.04	$\pm$0.03	$\pm$0.02	$\pm$0.48	$\pm$0.47	$\pm$0.67
Systematic Uncertainty	$\pm$0.08	$\pm$0.03	$\pm$0.02	$\pm$0.53	$\pm$0.42	$\pm$0.68
Observed	1	0	0	4	2	7

Table 4.10: Final number of expected signal and background events in the different analysis channels together with the observed number of events in data. The signal predictions are for benchmark point BP1.

Systematics

CDF RUN II Preliminary $\int \mathcal{L}dt = 2.0$ fb^{-1} : Search for $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$

Channel/Source	ID (%)	Trig (%)	JES (%)	X-sec (%)	PDF (%)	ISR/FSR (%)	Conv (%)	ITR(nom) (%)	ITR(alt) (%)	Fake (%)
3tight	2.3	0.3	1.5	5.0	1.4	2.3	2.2	-	-	12.2
2tight,1loose	2.5	0.3	1.7	5.9	1.6	2.5	2.1	-	-	8
1tight,2loose	2.2	0.3	3.5	5.0	1.3	2.2	1.8	-	-	10.7
2tight,1Track	1.8	0.2	3.9	2.3	1.5	1.8	-	5.8	6.0	11.6
1tight,1loose,1Track	1.8	0.2	5.2	2.4	1.5	1.8	-	8.6	10.5	9.0
Signal	4	0.5	0.5	10	2	4	-	-	-	-

mSUGRA Branching Ratio