Searches for Chargino-Neutralino Production at the Tevatron

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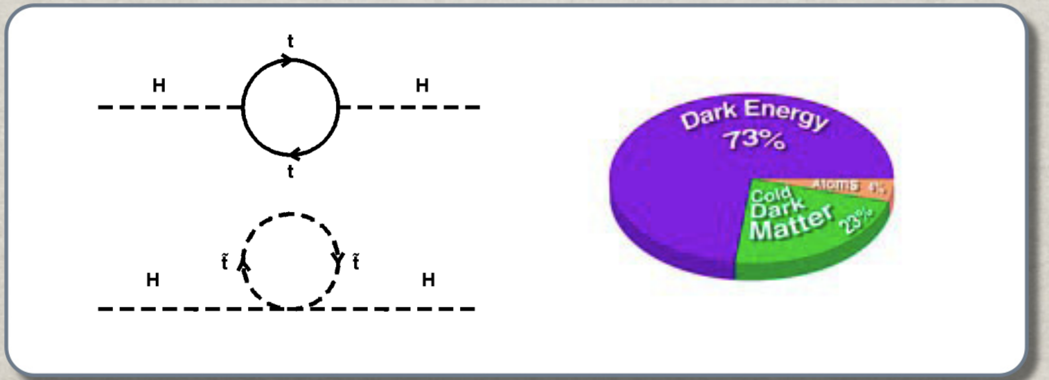
Outline

- Introduction
  - SUSY
  - Tevatron (CDF/DØ)
- Trilepton Results (Low Mass)
  - At CDF
  - At DØ
- Lepton + Jets Result (High Mass) at CDF
- Summary

Introduction: SUSY

- Standard Model (SM) is good, but seems incomplete.
  - Requires fine tuning, doesn't account for the dark energy/matter



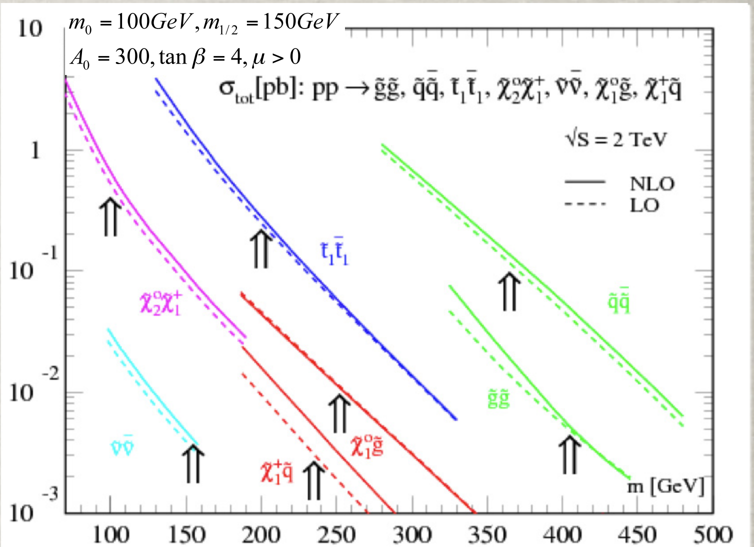
- Supersymmetry (SUSY)
  - Symmetry relating fermions and bosons
  - Solves the hierarchy problem
  - Provides an excellent dark matter candidate

mSUGRA

mSUGRA - minimal SUper GRAvity grand unification is one “flavor” of SUSY.

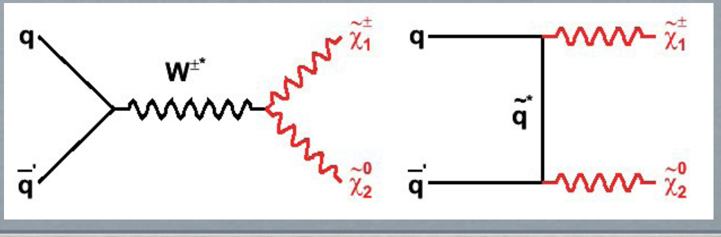
- All properties (mass, B.R., etc) determined by five parameters.
- Because of its relative simplicity it is used as a “standard candle”

- Five mSUGRA parameters
  - m_0 : common scalar mass at GUT scale
  - $m_{1/2}$: common gaugino mass at GUT scale
  - $\tan(\beta)$: ratio of Higgs vacuum expectation values
  - A_0 : common trilinear scalar interaction at the GUT scale
  - $\mathrm{sign}(\mu)$: μ is the Higgsino mass parameter
    - $|\mu^2|$ determined by EWSB



T. Plehn, PROSPINO

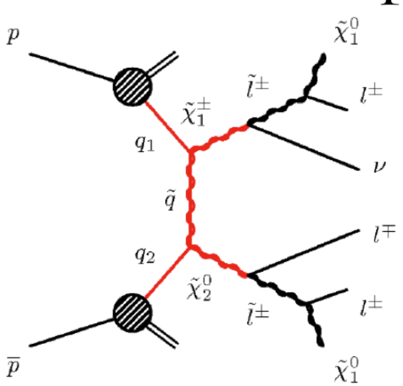
$\tilde{\chi}^{\pm}_1 \tilde{\chi}^0_2$ *Production*

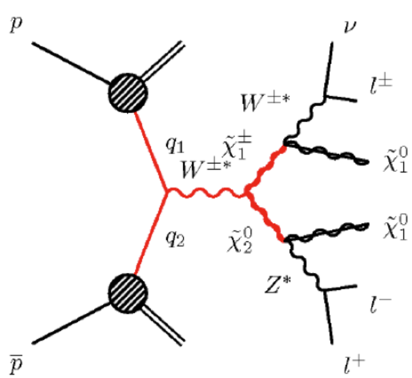


Chargino-Neutalino Decays

Why look at the trilepton channel?

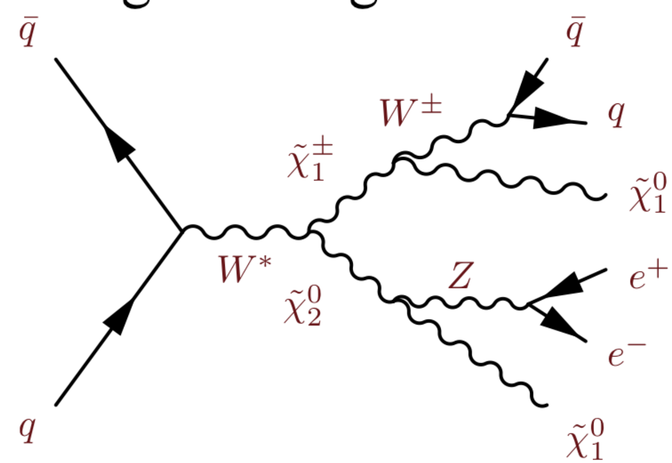
- Good
  - Three isolated leptons
  - Large E_T^{Miss}
    - Neutrino and "lightest-SUSY-Particle" (LSP) go undetected
- Bad
  - Small cross section
  - Low E_T leptons





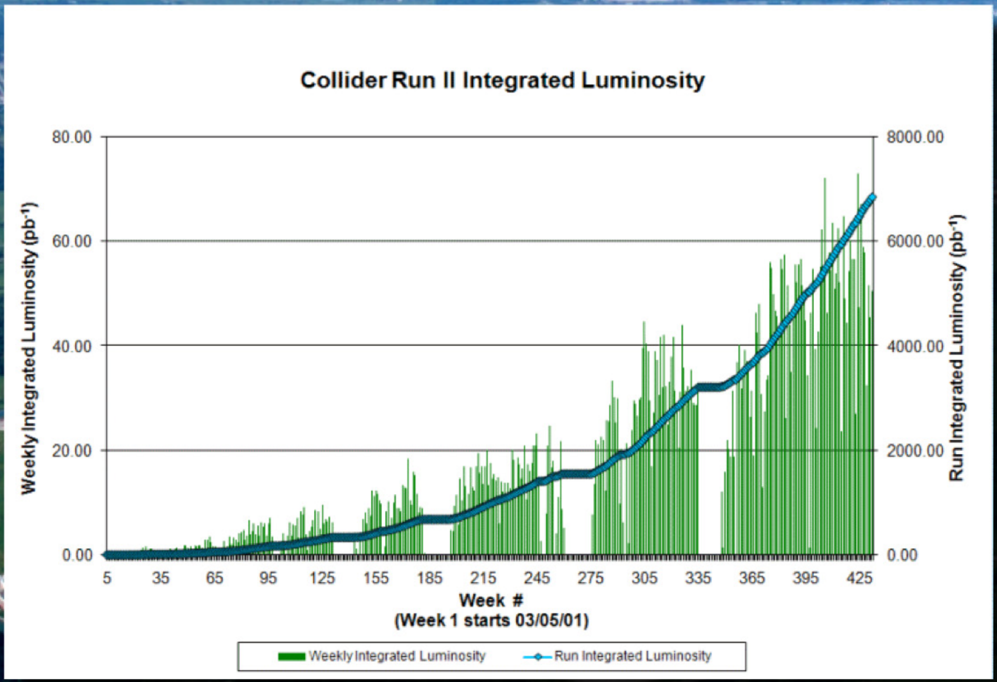
Why look at the leptons +jets channel?

- Good
  - W/Z resonances
  - Large E_T^{Miss}
    - Neutrino and "lightest-SUSY-Particle" (LSP) go undetected
- Bad
  - Larger background




Tevatron At FNAL

Tevatron At FNAL

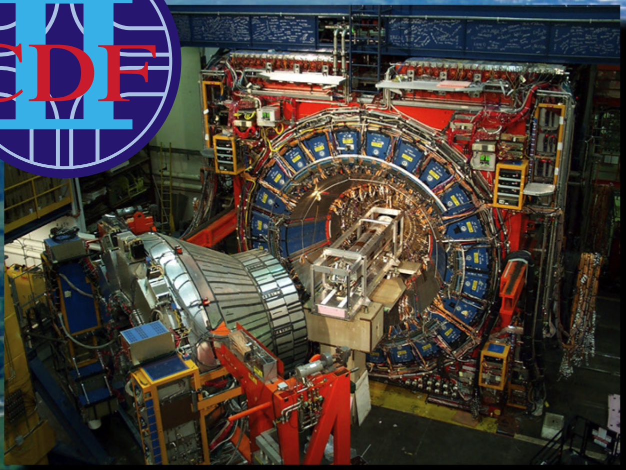


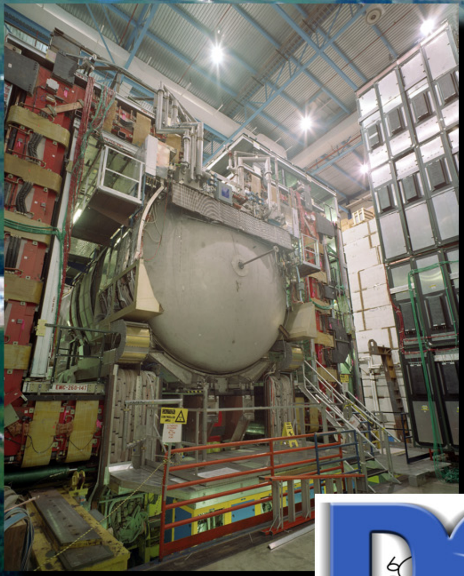
Tevatron is performing excellently

- Proton-AntiProton Collisions at $\sqrt{s}$ = 1.96 TeV
- Integrated Luminosity of 6.8 fb^{-1}
- Collecting at ~75 pb^{-1} / week

Special thanks to the Accel. Division

Tevatron At FNAL





- General Purpose Detectors
  - Central Tracker
  - Calorimetry (EM & Had)
  - Muon System

Trileptons at CDF

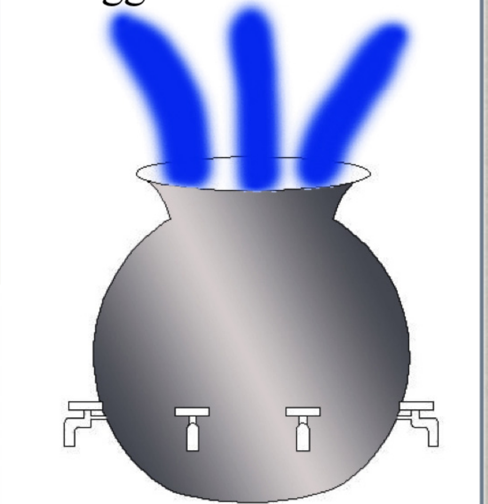
CDF Trilepton

Create mutually exclusive analysis channels, assigning events to optimize the purity.

hi
- Find three tight leptons (ttt)
  - Else two tight leptons and a loose lepton (ttl)
    - Else one tight lepton and two loose leptons (tll)
      - Else two tight leptons and one track (ttT)
        - Else one tight lepton, one loose lepton and one track (tlT)

S/B

lo



Backgrounds

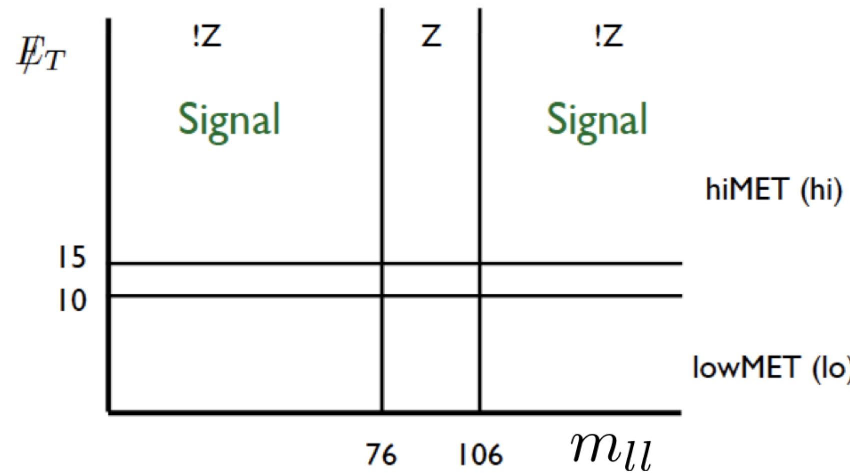
Sources with at least 3 Leptons:	Sources with 2 Leptons:	Sources with 1 Lepton:
-WZ -ZZ	-WW, Drell-Yan, ttbar -with: γ conversion *or* fake lepton *or* isolated track	-W + fake lepton + isolated track

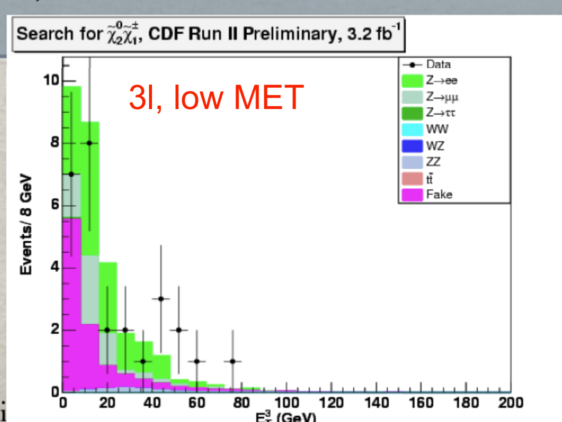
CDF Trilepton

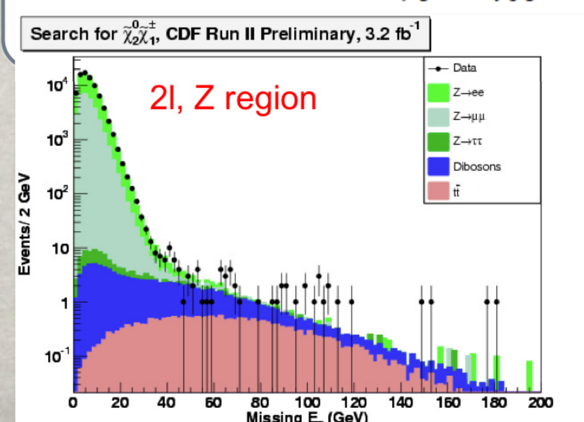
Event Selection

- 1st lepton: E_T=15-20 GeV
- 2nd & 3rd leptons: E_T=5-10 GeV
- Kinematics
  - $m_{l^-l^+}$ (Z veto)
  - N_{jets}, E^{miss}_T...

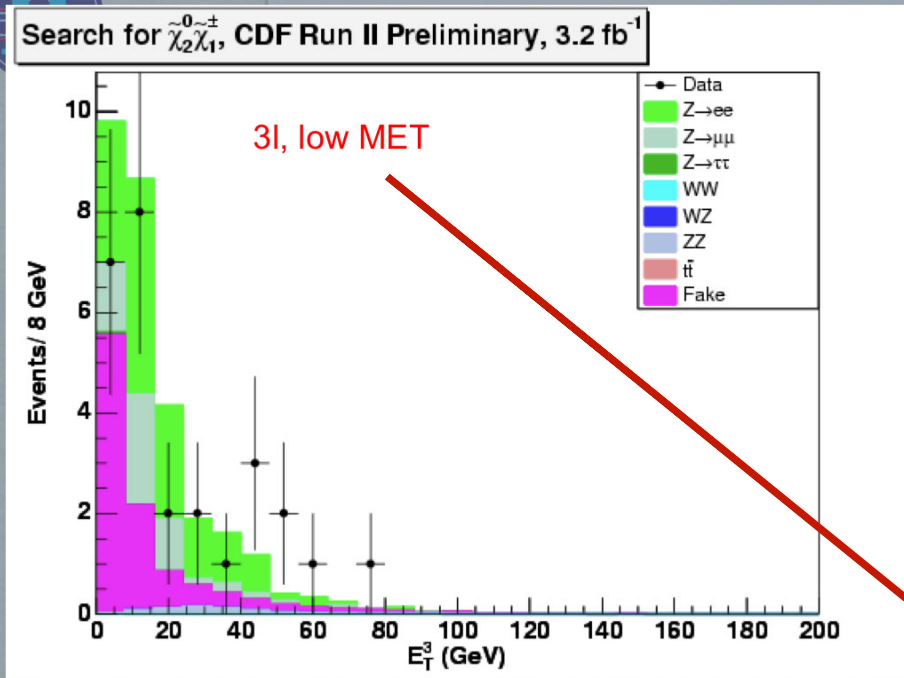
Define control regions and check the dilepton and trilepton events.

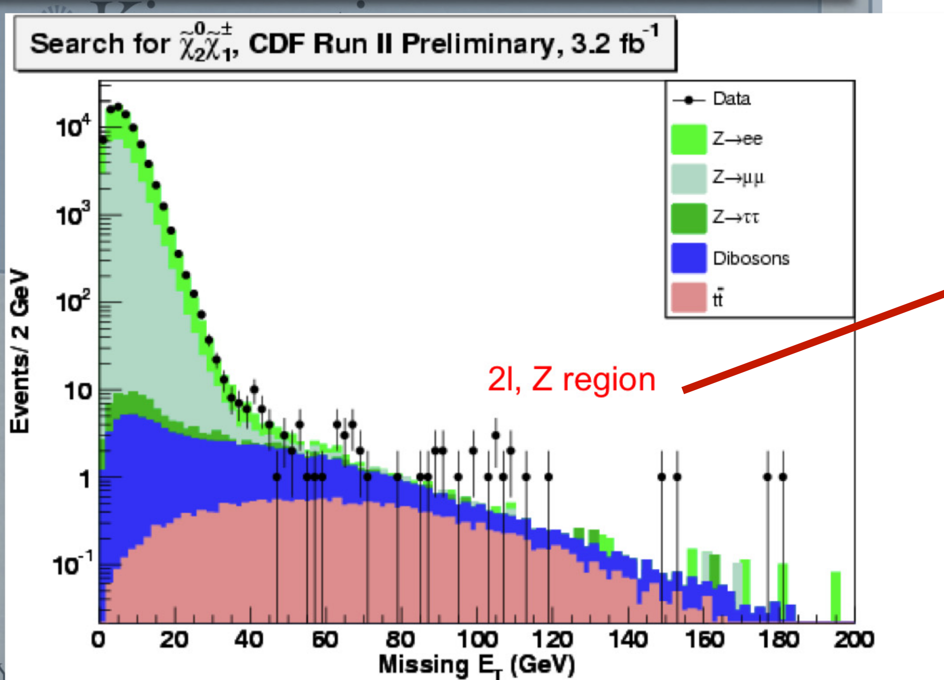




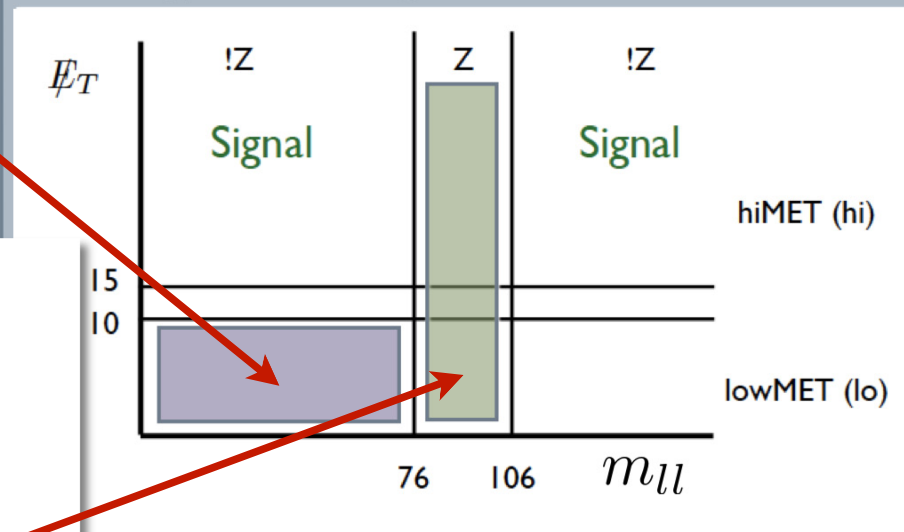


ILEPTON





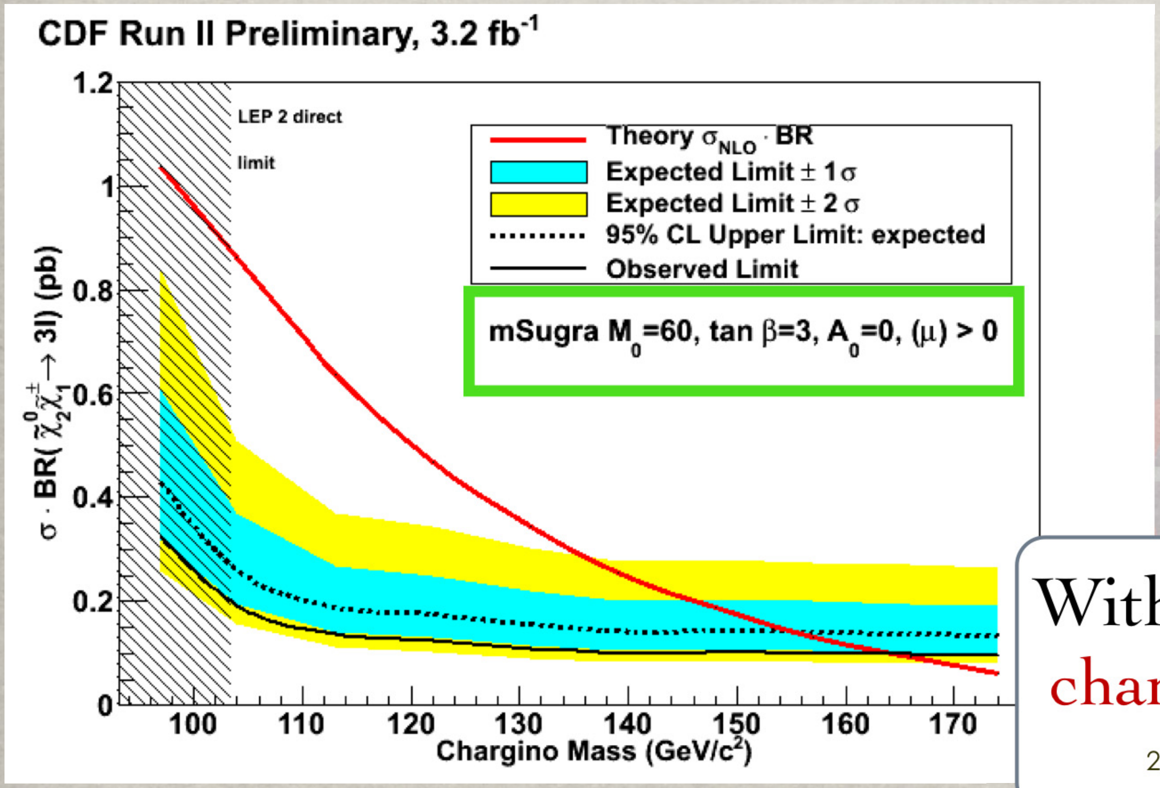
Define control Regions and check the dilepton and trilepton regions



CDF Results

Good agreement between data and SM expectation. So we calculated a limit.

Channel	SM Expectation	Data
trileptons	1.5±0.2	1
dileptons+track	9.4±1.4	6



Calculate a limit in the mSUGRA model for a particular parameter set.

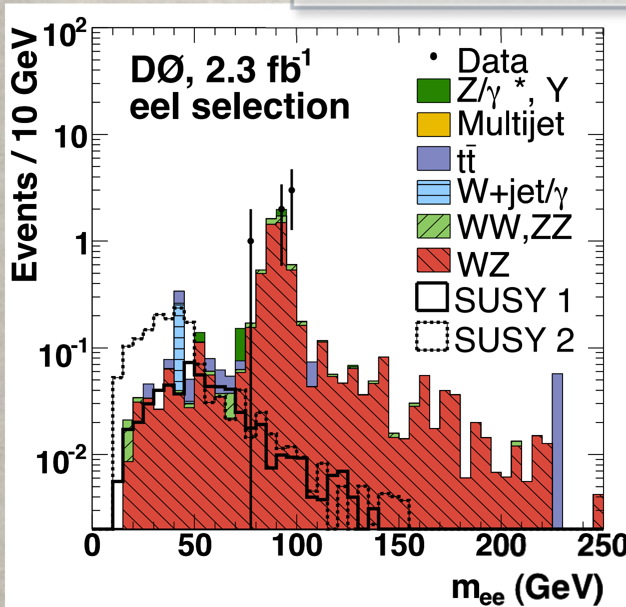
With 3.2 fb^{-1} exclude:

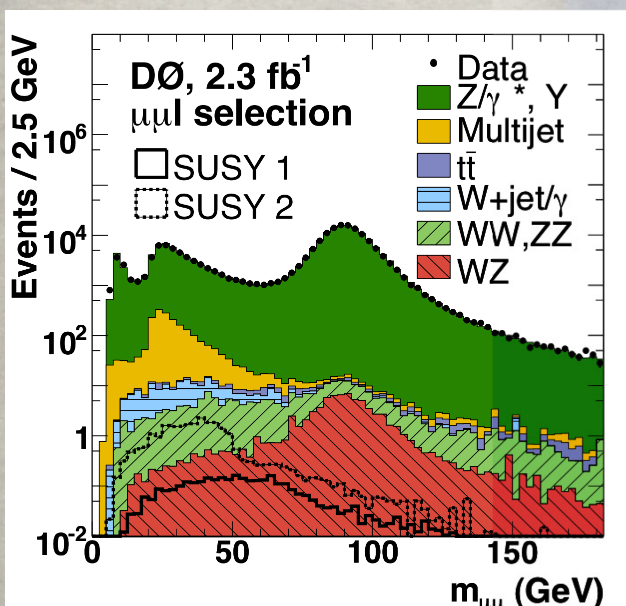
chargino mass < 164 GeV/c^2

2.0 fb^{-1} results found in ***PRL 101, 251801 (2008)***

Trileptons at DØ

DØ Trileptons





Data divided into separate channels based on lepton type.

Using 2.3 fb^{-1}

- ee+track
- μμ+track
- eμ+track

Using 1.0 fb^{-1}

- μτ+track
- μττ (hadronic decay)

Optimize the analysis for different parameter points with "low pt" and "high pt" cuts.

ee+track

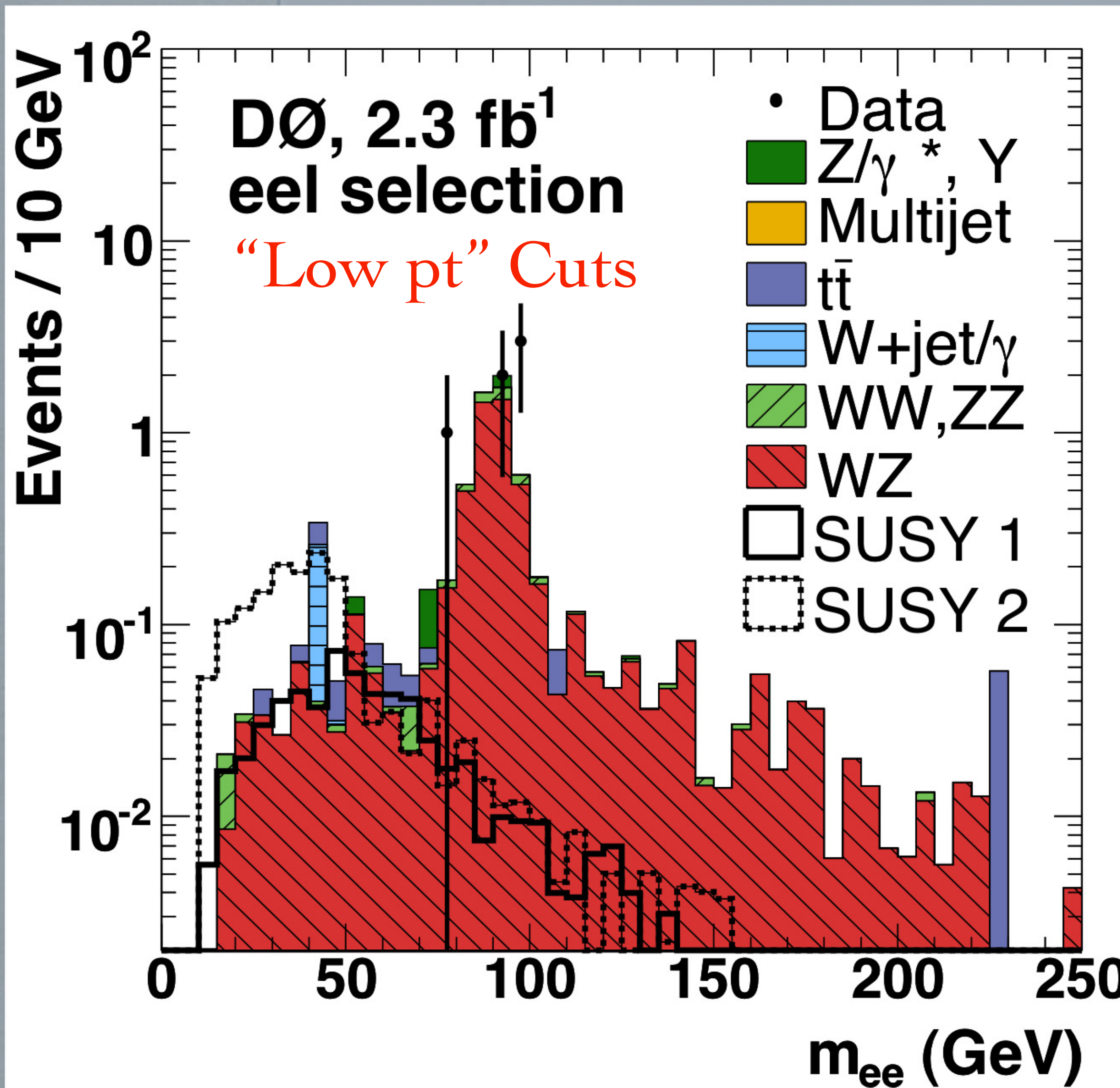
"low pt"

- $p_T^{l_1} > 12$ GeV
- $p_T^{l_2} > 8$ GeV
- $18 < m_{l^1 l^2} < 60$ GeV
- Similar for μμ+tr & eμ+tr.

"high pt"

- $p_T^{l_1} > 20$ GeV
- $p_T^{l_2} > 10$ GeV
- $0 < m_{l^1 l^2} < 75$ GeV
- Similar for μμ+tr & eμ+tr.

DØ Trileptons



SUSY1(2)
Test Points

m_0	150 GeV
$m_{1/2}$	250 (170) GeV
tan β	3
A_0	0
μ	> 0

ee+track

“high pt”

- $p_T^{l_1} > 20$ GeV
- $p_T^{l_2} > 10$ GeV
- $0 < m_{l^1 l^2} < 75$ GeV
- ...etc.

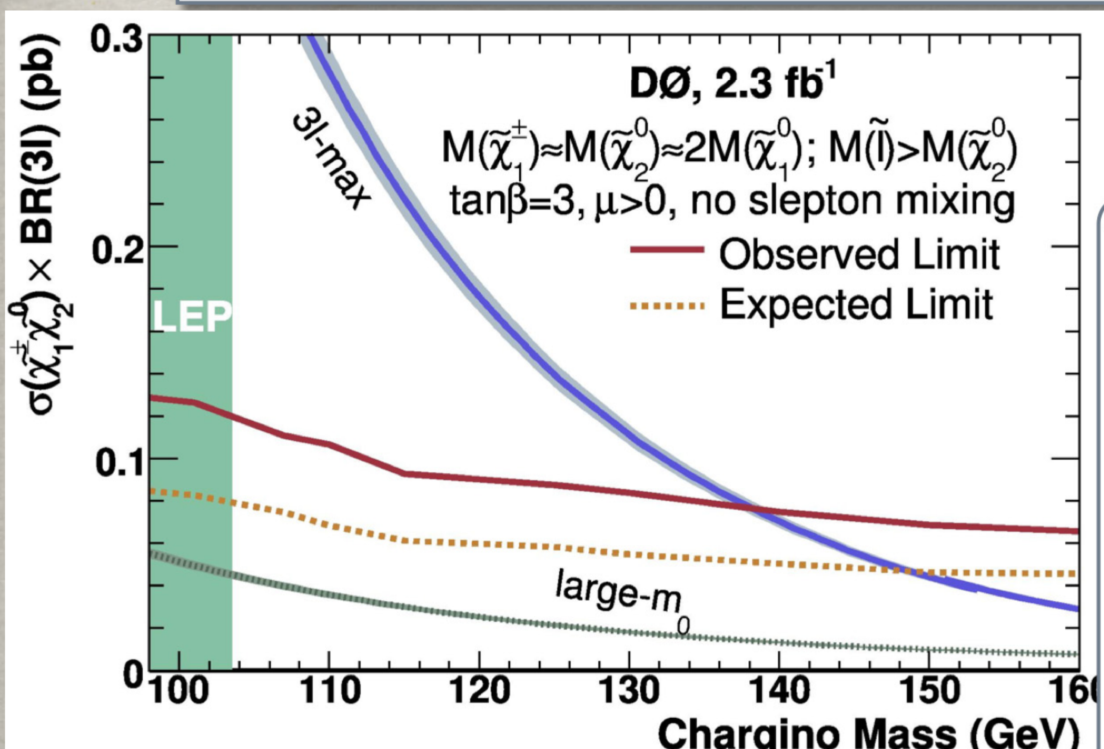
- ...etc.

DØ Results

Good agreement between data and SM expectation. So we calculated a limit.

Channel	SM Expectation	Data
Low p_T	5.4±0.6	9
High p_T	3.3±0.4	4

3l-max: Parameters that maximize B.R to 3l.



Calculate mass limits for two models.

With 2.3 fb^{-1} exclude:

3l-max, no slepton mixing:

chargino mass < 138 GeV/c^2

mSUGRA: m_0=60, tanβ=3, A_0=0, μ>0

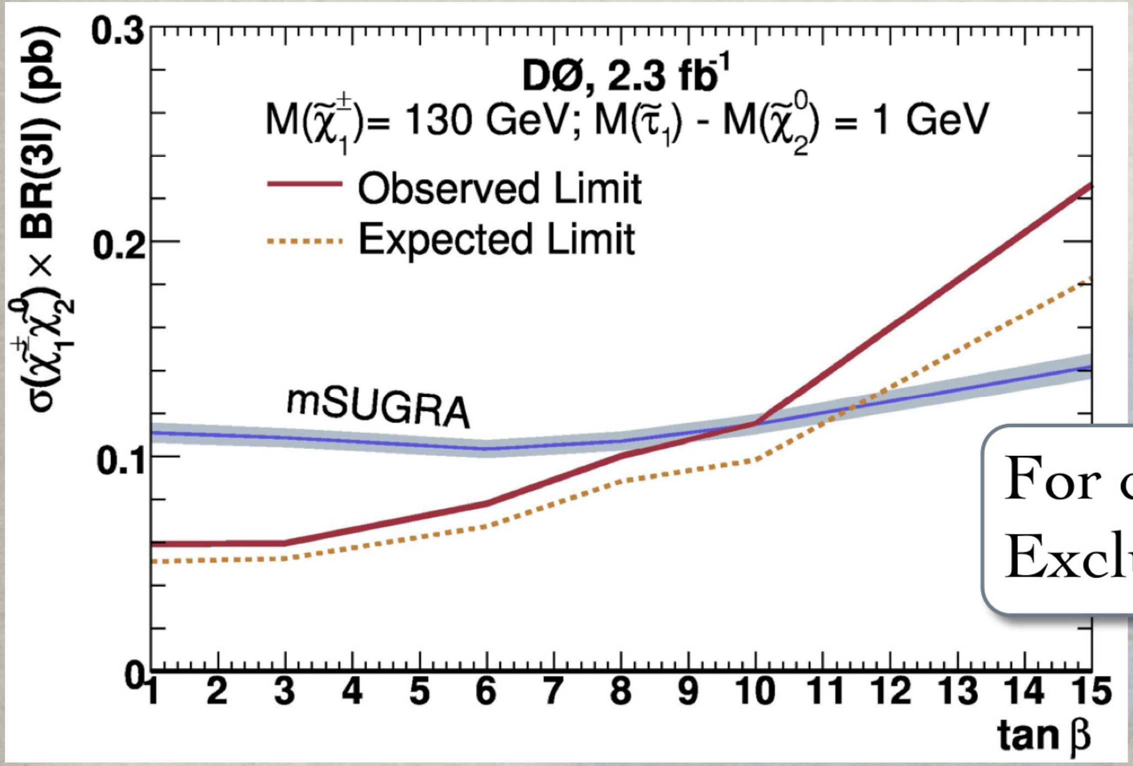
chargino mass < ~155 GeV/c^2

Preprint found at *arXiv:0901.0646 (sub.to PLB, 2009)*

DØ Results

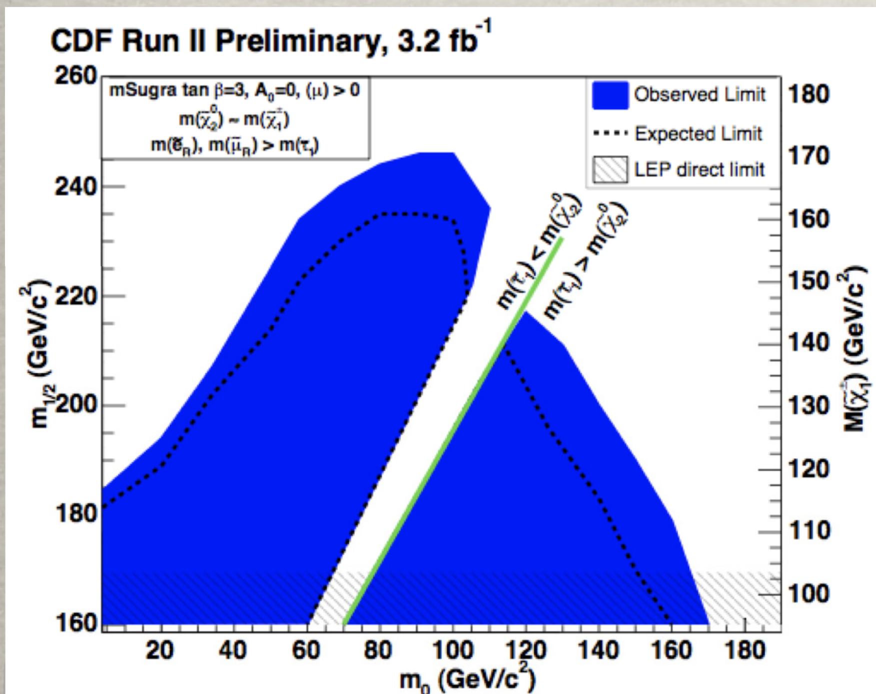
The data can be used to set limits on other parameters of mSUGRA.

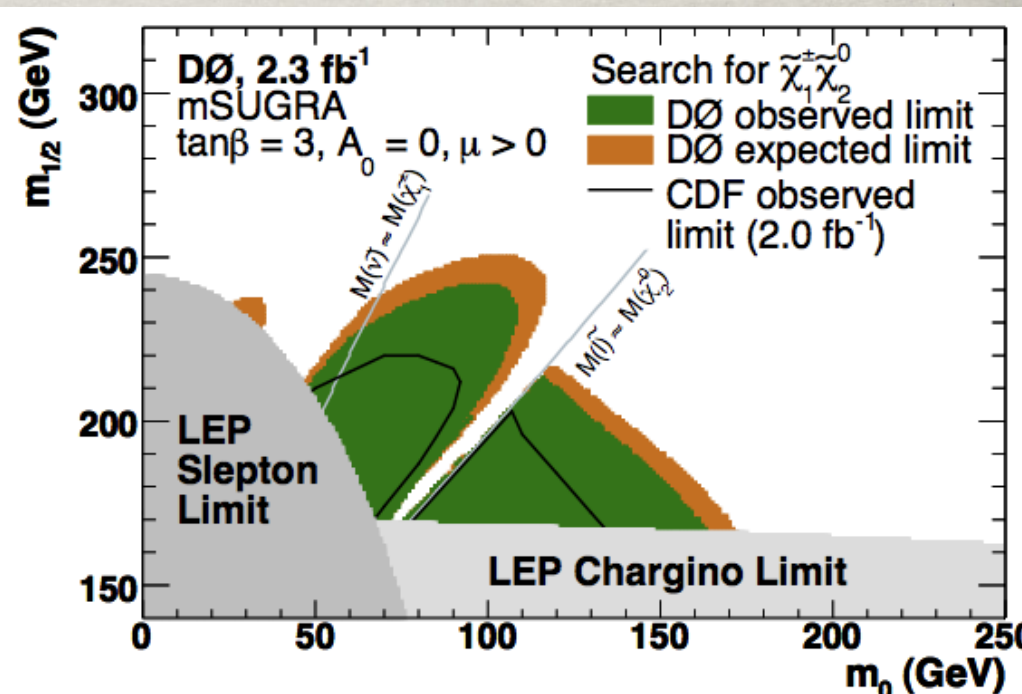
- B.R. to τ increases as a function of tan β
- $m(s\tau_1)-m(\chi^0{}_2)=1$ GeV/c^2
  - maximal leptonic BR



For chargino mass = 130 GeV/c^2
Exclude: tan $\beta < 9.6$

Trilepton Summary

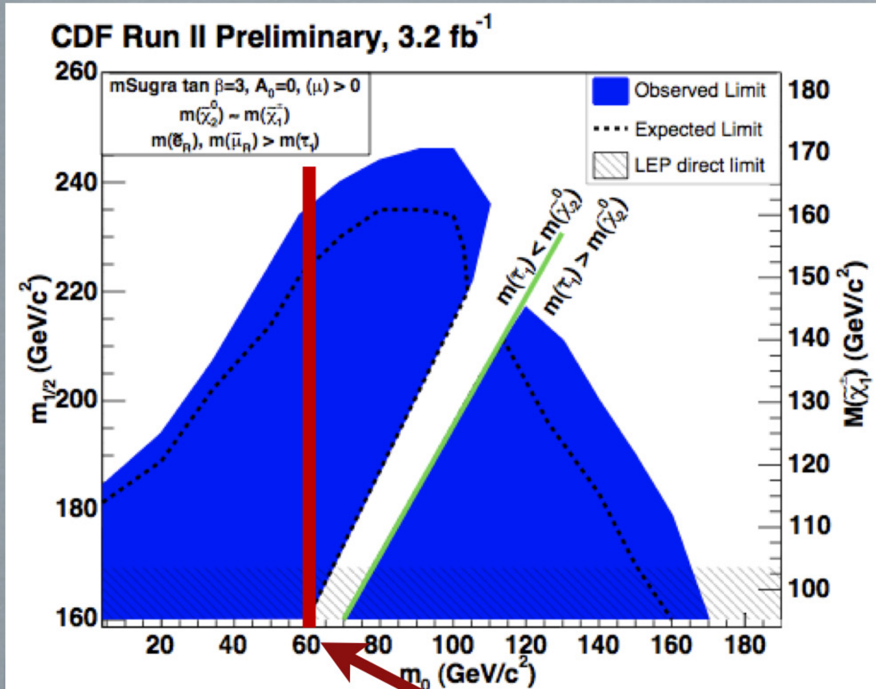


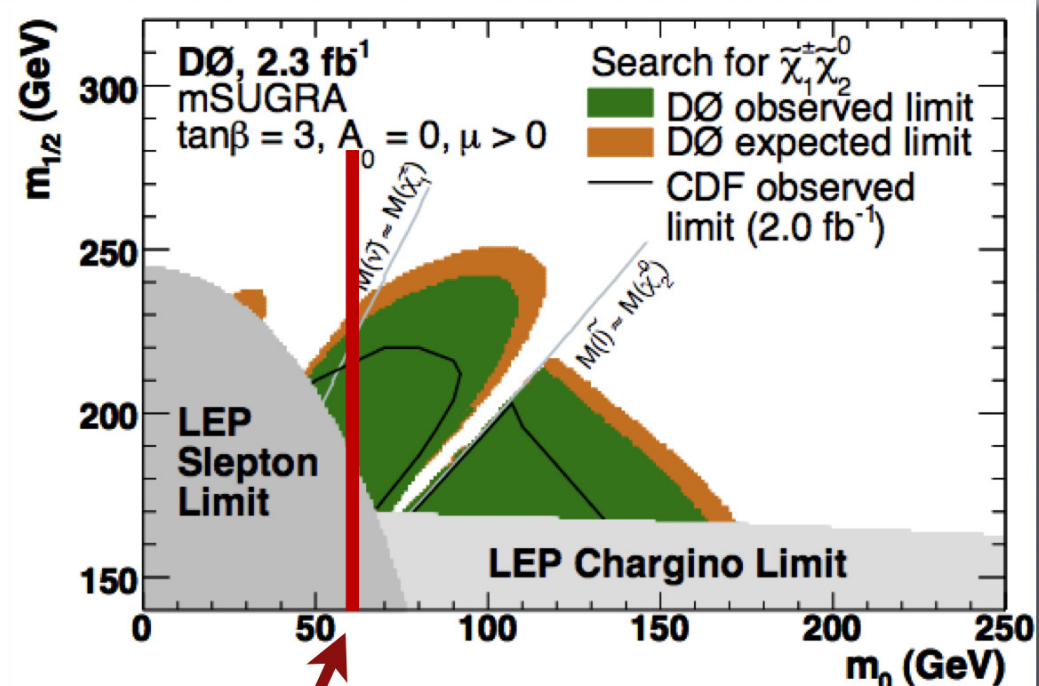


mSUGRA

- Benchmark Scenario: tan(β)=3, A_0=0, μ>0
- Above is the excluded region in $m_{1/2}$-m_0 space.
- Limits depend on neutralino-slepton mass difference.

Trilepton Summary





mSUGRA

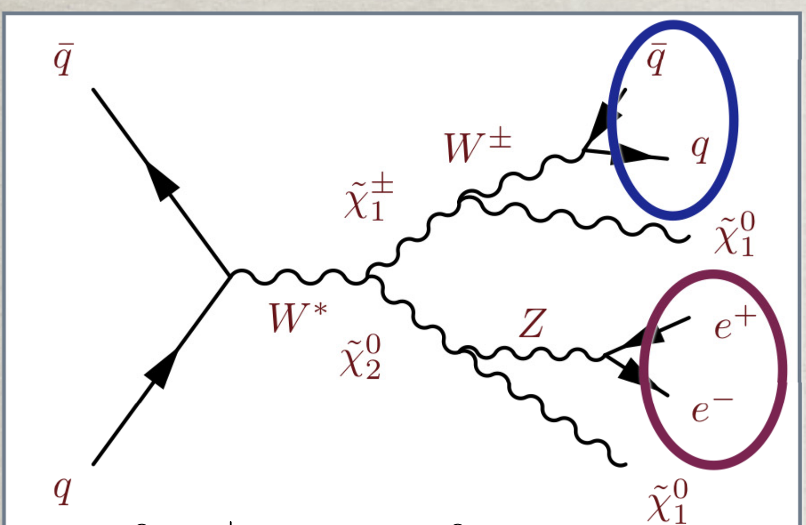
- Benchmar… >0
- Above is t… space.
- Limits dep… ass difference.

Limits at the mSUGRA test point:

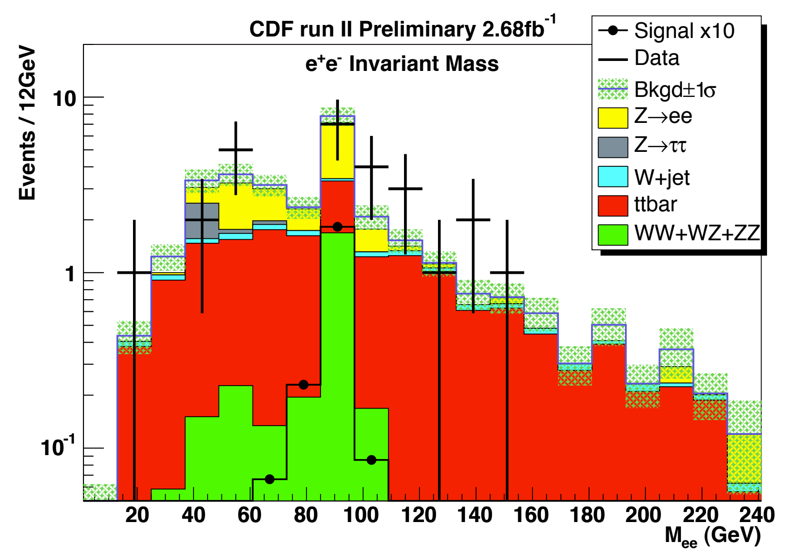
m_0=60, tanβ=3, A_0=0, μ>0

Leptons+Jets at CDF

CDF Lepton+Jets



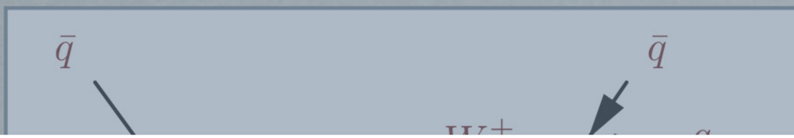
$$m(\tilde{\chi}_2^0, \tilde{\chi}_1^\pm) > m(\tilde{\chi}_1^0) + m(W, Z)$$



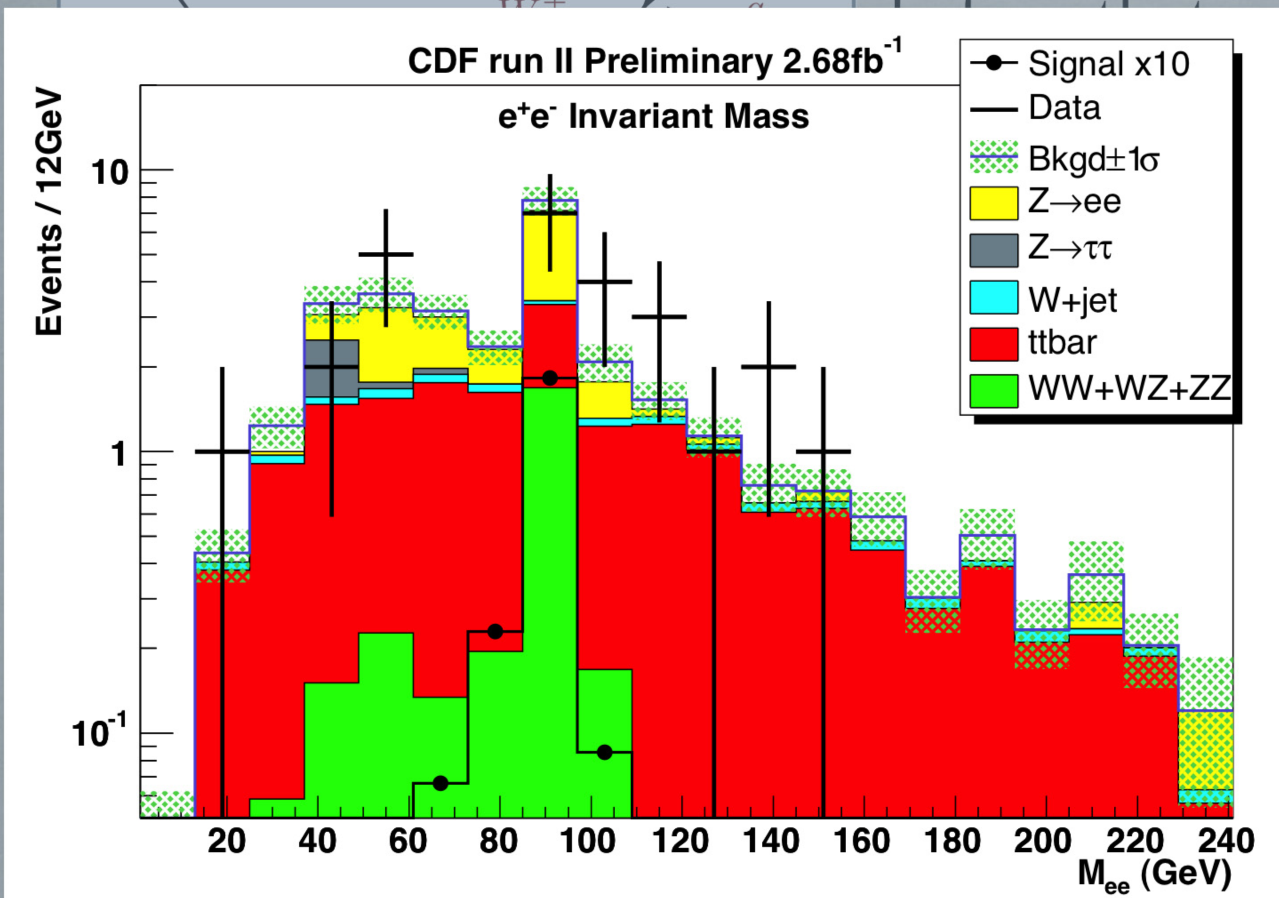
New channel not explored before that is complementary to the trileptons because it can be used to probe higher masses.

- Event Selection:
  - 2 electrons
    - $85 < m_{ee} < 97$ GeV/c^2
  - 2 jets
    - $60 < m_{jj} < 95$ GeV/c^2
  - $E^{miss}{}_T$
    - Optimized for different parameter spaces. (> 40, 50, or 60 GeV)

CDF Lepton+Jets



New channel r...



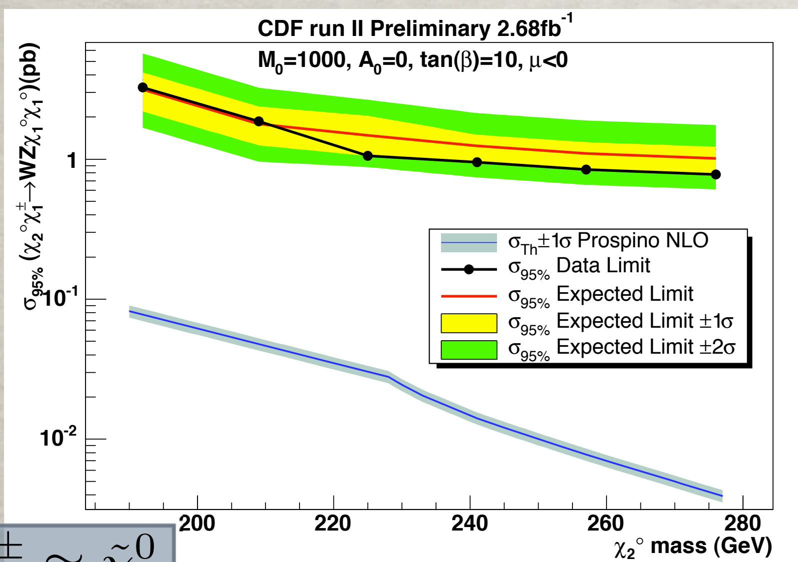
Signal Test Points

m_0	1000 GeV
$m_{1/2}$	275 GeV
tan β	10
A_0	0
μ	< 0

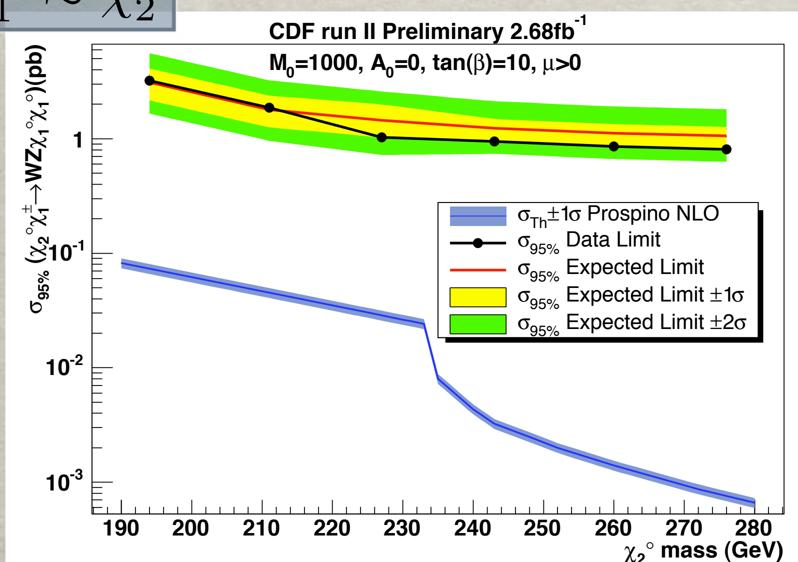
< 95 GeV/c^2

...zed for different ...ter spaces. (> 40, 50, or 60 GeV)

Results



$\tilde{\chi}_1^{\pm} \approx \tilde{\chi}_2^0$



Good agreement between data and SM expectation. So we calculated a limit.

Cut	SM Expectation	Data
$E^{miss}_T > 40$ GeV	6.41±0.92	7
$E^{miss}_T > 50$ GeV	3.76±0.58	2
$E^{miss}_T > 60$ GeV	2.02±0.33	1

- For each χ^0_2 mass we choose the E^{miss}_T cut that gives the best expected limit.
- While there is no excluded space, this channel may be interesting to search for new physics decaying to dibosons.

Summary: SUSY at the Tevatron

- CDF and DØ have searches for Chargino-Neutralino production with up to 3.2 fb^{-1} of data.
- While there is no signs of signal we are able to set limits.
- In the mSURGA model (m_0=60, tanβ=3, A_0=0, μ>0):
  - CDF has excluded chargino masses up to 164 GeV/c^2 (3.2 fb^{-1})
  - DØ has excluded chargino masses up to 155 GeV/c^2 (2.3 fb^{-1})
- CDF has added a lepton+jets analysis to probe higher masses.

The Tevatron is collecting high quality data at an unprecedented rate. Expect more results soon.

http://www-cdf.fnal.gov/physics/exotic/exotic.html
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm