Search for R-Parity Violating SUSY in the Four Lepton Final State at CDF

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Pheno ’06

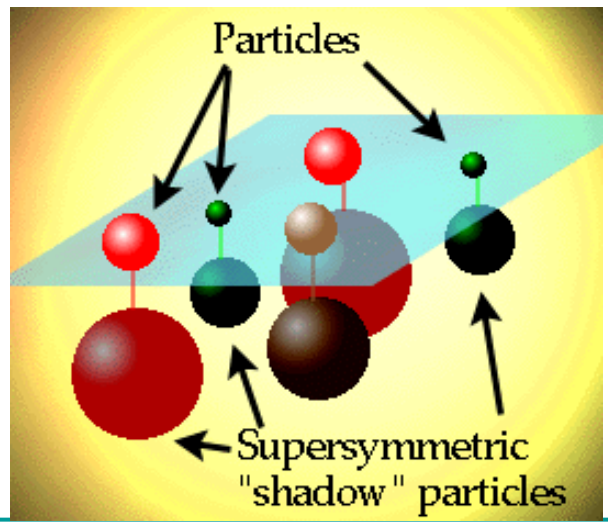
May 16, 2006

Outline

- SuperSymmetry & R-Parity Violation
- CDF Detector
- Signal & Background
- Analysis
- Results

SuperSymmetry (SUSY)

- SuperSymmetry is a proposed symmetry between fermions and bosons.
  - Possible solution to “hierarchy problem”.
  - Helps unification of SM forces.
  - Predicts double the number of known particles.
  - Broken symmetry (sparticles gain mass).
  - Introduction of Rp = $-1^{3(B-L)+2S}$
  - If Rp is conserved lightest supersymmetric particle (LSP) is stable.



R-Parity Violation (RpV)

R-parity Violation ⇨ LSP can decay!

3 additional couplings:

$$W_{RPV} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

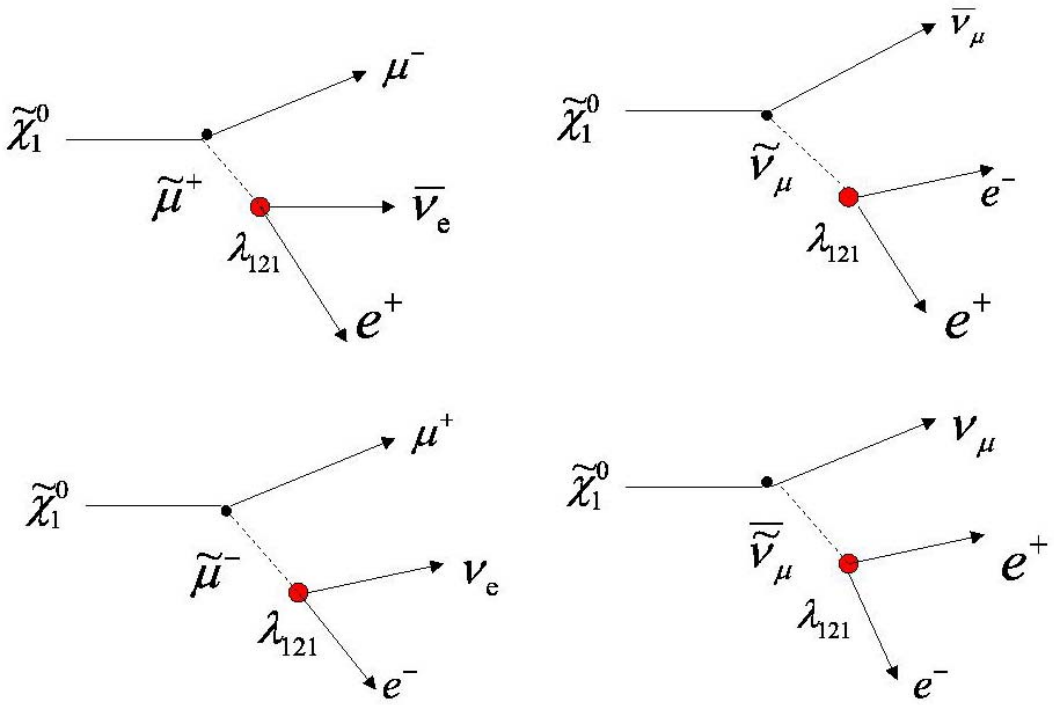
Violate lepton #

Violates baryon #

- Only consider $L_i L_j \bar{E}_k$ term, protecting proton lifetime.
- $|\lambda| < 0.1$, assume only LSP decays via RpV coupling.

Four Lepton Signature

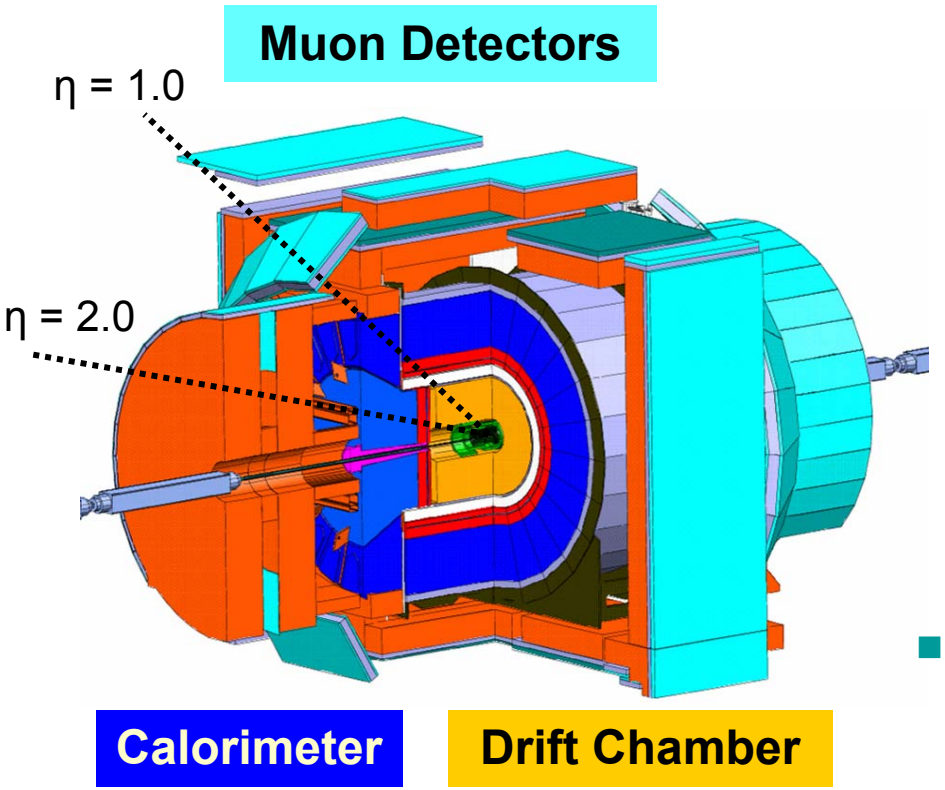
λ_{121} diagrams:



- Supersymmetric particle pair production.
- Assume only one $\lambda_{ijk} \neq 0$: λ_{121} or λ_{122}
- 2 leptons per LSP.
- Additional leptons may come from SUSY cascade decays.

⇨ 4+ leptons per event

CDF Detector & Lepton ID



- Electrons
  - Track + Calorimeter Cluster
  - 95% of energy in EM calorimeter
  - $|\eta| < 2.0$
- Muons
  - Track plus "stub" in muon detector
  - Minimum ionizing
  - $|\eta| < 1.1$
- Lepton ID crucial to analysis
  - Studied in data and MC
  - Efficient (~90%)
  - Lepton fake rate small (~0.02%)

RpV SUSY Simulation

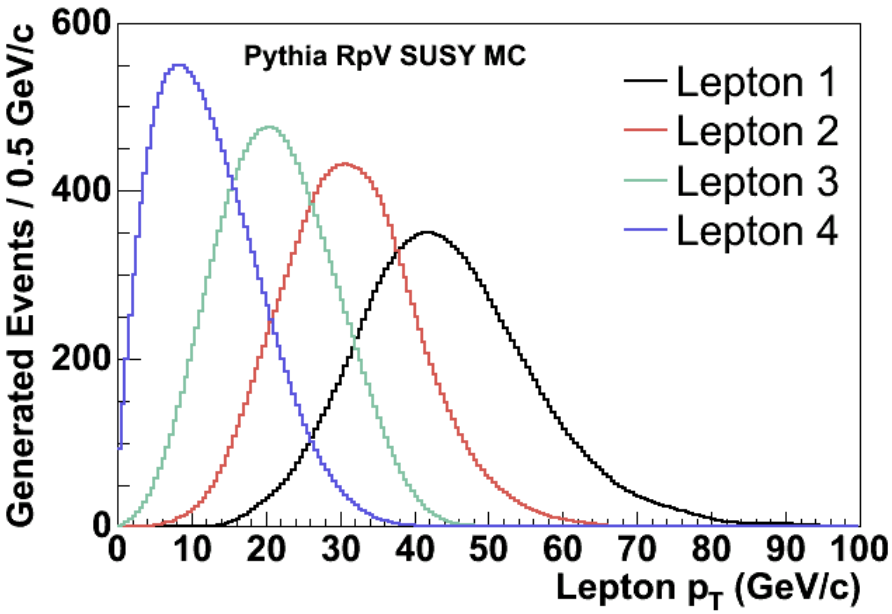
- Using mSUGRA framework.
- Sparticle masses and couplings determined by ISAJET 7.51
- MC generated using PYTHIA 6.216
- Passed through full CDF reconstruction
- NLO cross section calculated using PROSPINO2
- Signal points: Keep M_0 fixed, scan over $M_{1/2}$ and both signs of μ.

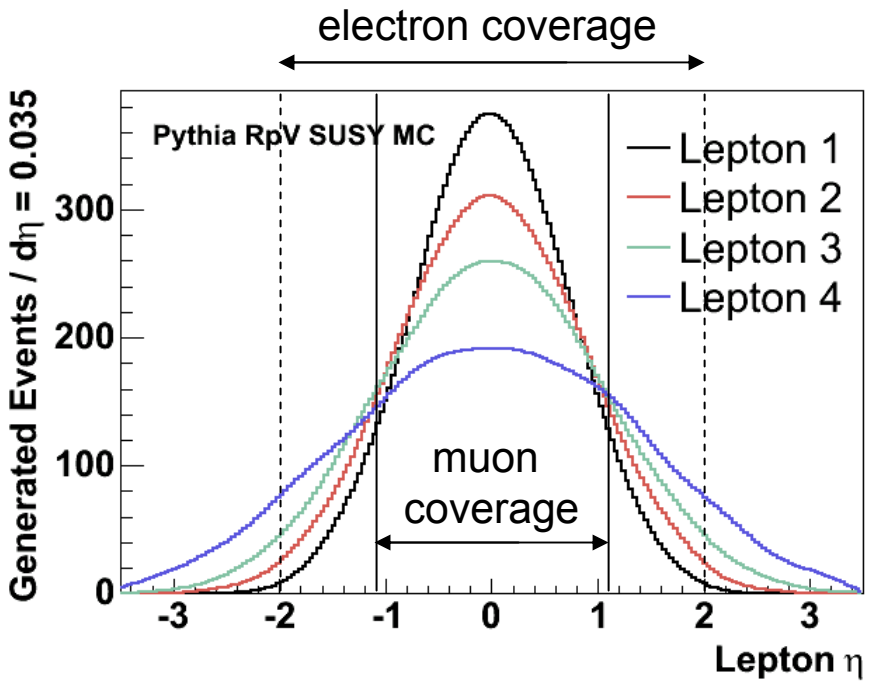
Example Point:

M_0 (GeV)	$M_{1/2}$ (GeV)	tanβ	sign μ	A_0	$M_{\tilde{\chi}_1^0}$ (GeV)	$M_{\tilde{\chi}_2^0}$ (GeV)	$M_{\tilde{\chi}_1^\pm}$ (GeV)	σ (pb)
250	260	5	+	0	99.4	182.2	181.4	0.13

Lep2 limit: $M_{\tilde{\chi}_1^0} > M_Z/2$

Signal Distributions



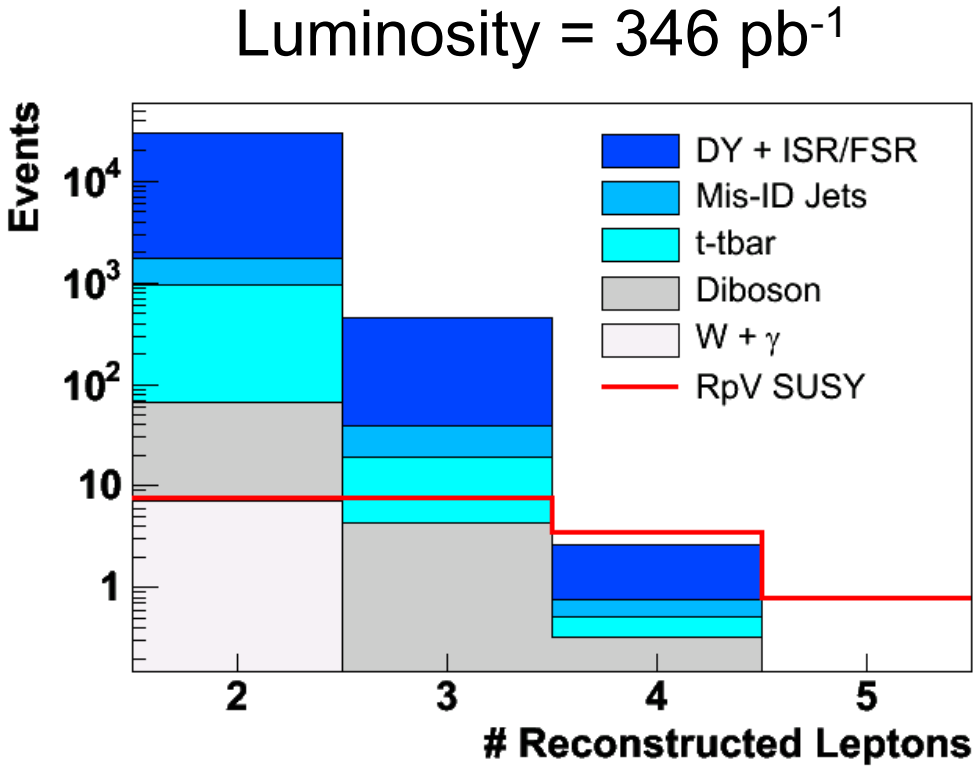


Lepton 1 Pt > 20 GeV
Lepton 2 Pt > 8 GeV

Mostly central leptons
$|\eta| < 1$

Backgrounds

- Individual processes
  - t-tbar (Pythia)
  - Diboson (Pythia/Madgraph)
- Composite backgrounds
  - W / Drell-Yan (DY) + Misidentified Jets
    - Determined from data
  - W / DY + Photon Conversions
    - Determined from MC



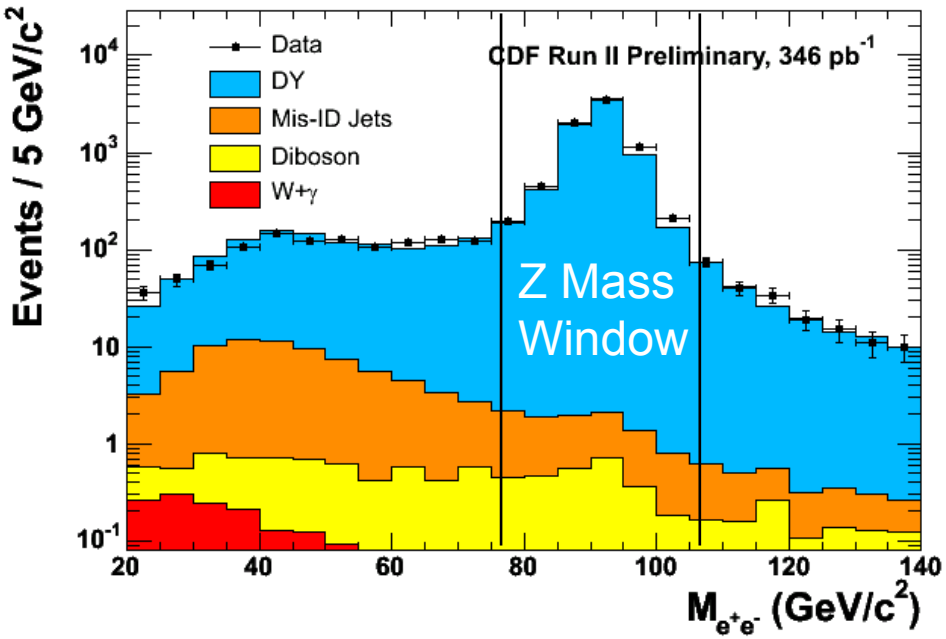
Analysis Strategy

Goal: Find heavy SUSY particles!

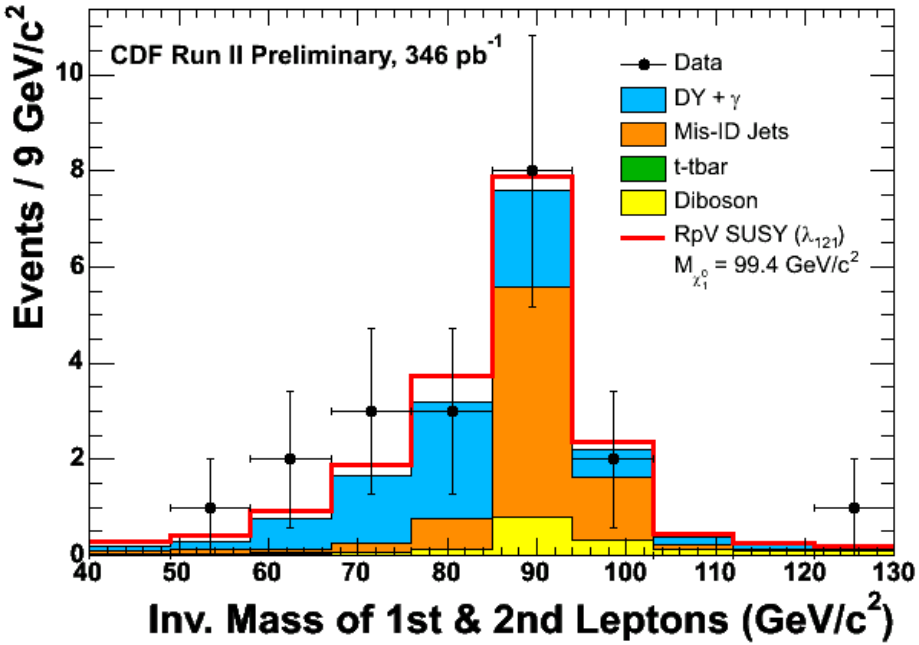
- Counting experiment with 346 pb^{-1}.
- Two signal regions "boxes" to optimize result:
  - Exactly 3 leptons
  - 4 or more leptons
- Use inclusive high-p_T lepton triggers.
- No Jet or $\not{E}_T$ cuts to stay as model independent as possible.
- Select isolated leptons.
- Additional cuts to remove DY: Inv. mass & $\Delta\phi$
- Validate with control regions.

Control Regions

Opposite sign electron pair mass

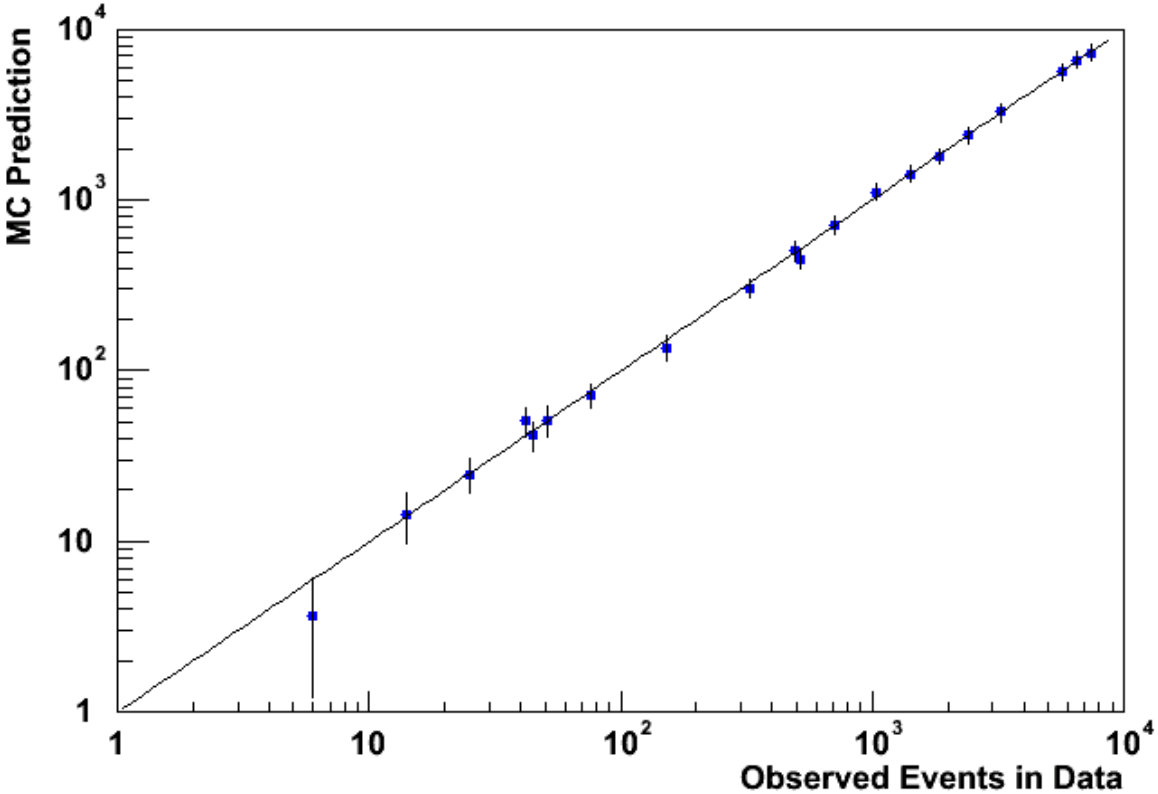


Trilepton events



- Control regions are crucial to understanding our procedure.
- Validate lepton ID efficiencies.
- Validate selection cuts.

Control Region Overview



- 26 total control regions
  - By lepton type
  - Inside & outside Z window
  - Number of leptons
  - Pass/Fail $\Delta\phi$ cut
- Plot shows relative agreement of all control regions.
  - Error bars = $\pm 1\sigma$
  - Line = perfect agreement

Opening the Box

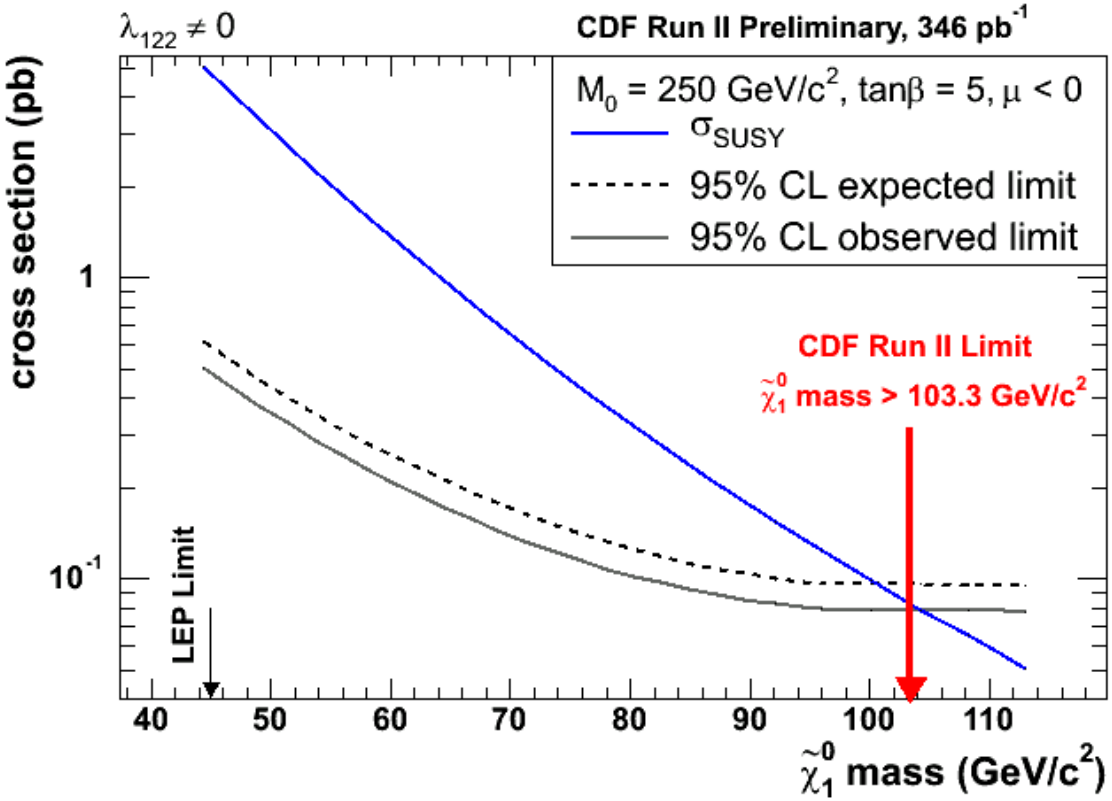
Signal Regions

Trilepton Signal Regions		
Dataset	**λ_{121}**	**λ_{122}**
$Z/\gamma^* + \gamma$	2.1 ± 0.8	1.2 ± 1.0
$W\ Z/\gamma^*$	0.2 ± 0.1	0.1 ± 0.1
Fakes	0.5 ± 0.3	0.3 ± 0.2
Total Background	2.9 ± 0.8	1.8 ± 1.0
RpV SUSY (λ_{121})	3.8 ± 0.4	-----
RpV SUSY (λ_{122})	-----	4.0 ± 0.4
Data	**5**	**1**

≥ 4 Signal Region	
Dataset	**Signal**
$Z/\gamma^* + \gamma\gamma$	0.001 ± 0.001
$Z/\gamma^* + Z/\gamma^*$	0.004 ± 0.002
Fakes	0.004 ± 0.003
Total Background	0.008 ± 0.004
RpV SUSY (λ_{121})	1.5 ± 0.2
RpV SUSY (λ_{122})	1.5 ± 0.3
Data	**0**

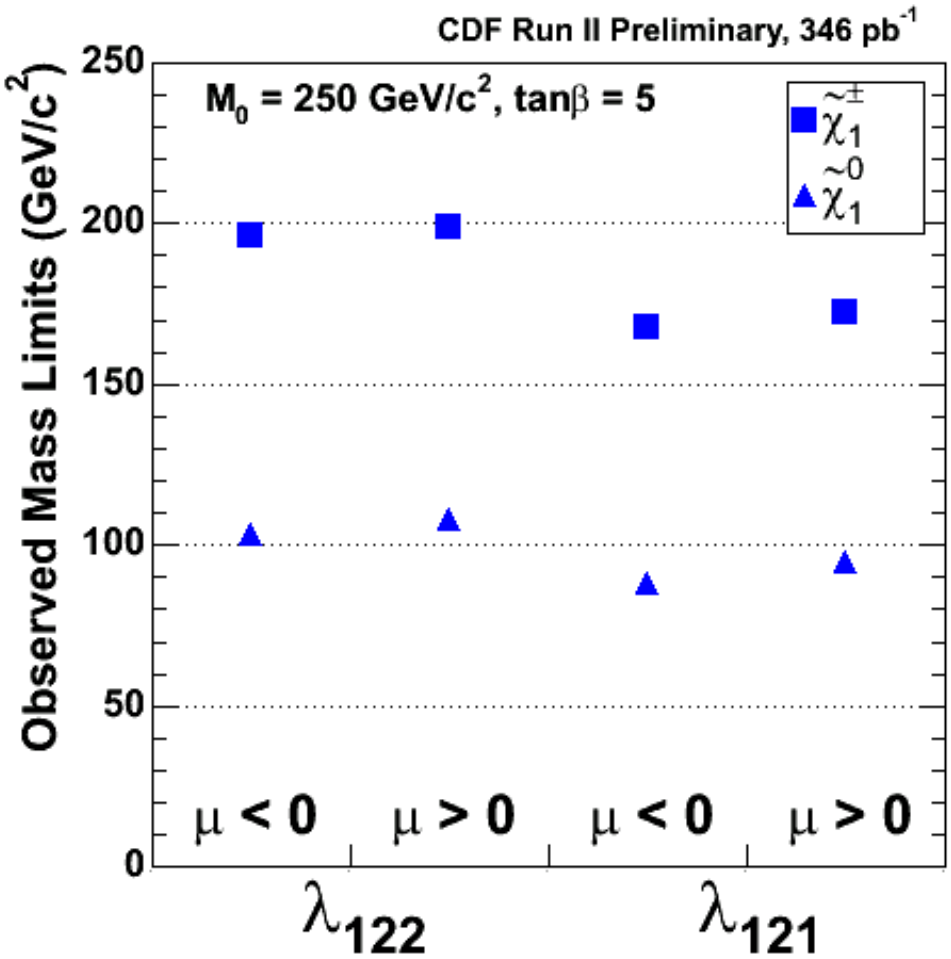
- Probability of observing ≥ 5 events with 2.9 expected = 17%.
- Signal regions consistent with background and no signal.

Setting Limits



- Use Bayesian method to find σ_{obs}, combining 3 and ≥4 lepton signal regions.
- Set limits for $\lambda_{121} \neq 0$ and $\lambda_{122} \neq 0$ and both signs of μ.

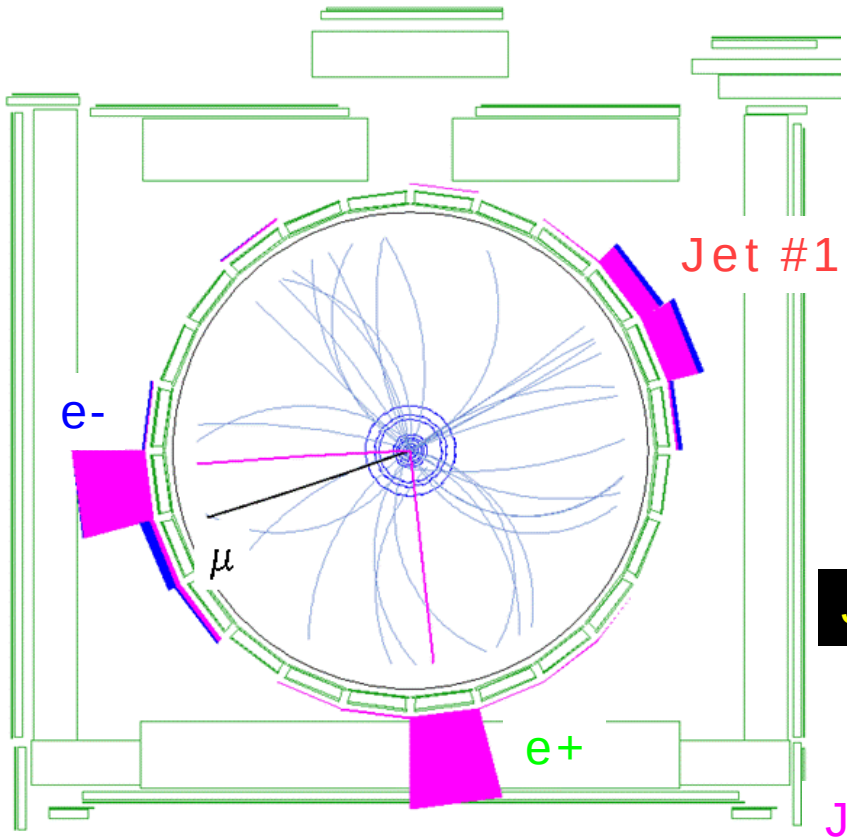
Results



- Set limits on chargino and neutralino masses.

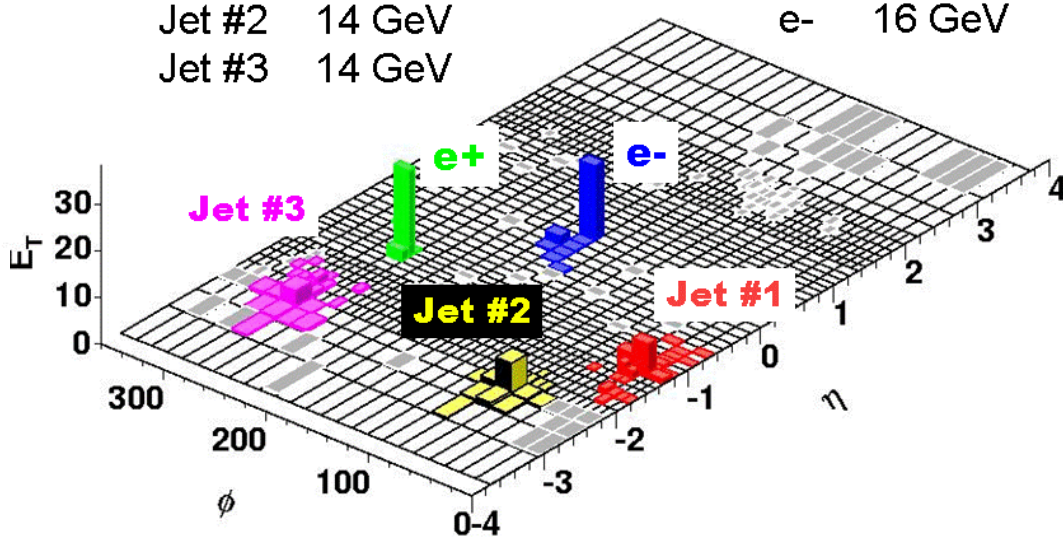
DØ Limits		
SUSY Scenario	$M\tilde{\chi}_1^0$ (GeV/c^2)	$M\tilde{\chi}_1^{\pm}$ (GeV/c^2)
λ_{122}, $\mu > 0$	118	229
λ_{122}, $\mu < 0$	115	230
λ_{121}, $\mu > 0$	119	231
λ_{121}, $\mu < 0$	117	234

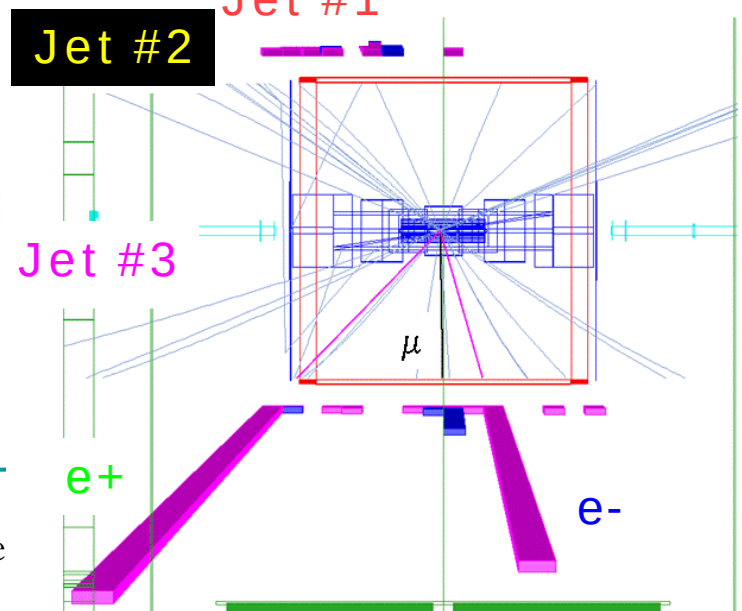
Event Display



Jet #1 23 GeV
Jet #2 14 GeV
Jet #3 14 GeV

e+ 21 GeV
e- 16 GeV





e+ 21 GeV
e- 16 GeV
μ 10 GeV/c
Jet #1 23 GeV
Jet #2 14 GeV
Jet #3 14 GeV

Conclusions

- Completed a search for R-parity Violating SuperSymmetry for $\lambda_{121} \neq 0$ and $\lambda_{122} \neq 0$ scenarios.
- No significant evidence of physics beyond the Standard Model detected.
- We set mass limits on the lightest neutralino and chargino.
- We are working on a publication.

Backup

Limits

Limits				
SUSY Scenario	$M_{\tilde{\chi}_1^0}$ (GeV/c^2)		$M_{\tilde{\chi}_1^\pm}$ (GeV/c^2)	
	expected	observed	expected	observed
λ_{122}, $\mu > 0$	103.6	108.4	189.2	198.7
λ_{122}, $\mu < 0$	100.2	103.3	190.4	196.5
λ_{121}, $\mu > 0$	99.8	94.8	182.1	172.6
λ_{121}, $\mu < 0$	95.5	88.4	181.3	167.4