Search for Anomalous Production of Multi-lepton Events at CDF

Alon Attal

for the CDF collaboration

Joint Meeting of Pacific Region Particle Physics Communities

(APS-DPF2006 + JPS2006 ...)

October 29 - November 03, 2006

Sheraton Waikiki Hotel, Honolulu, Hawaii

Outline

- Motivation
- R_pV SUSY
- CDF & lepton detection
- Analysis
- Results

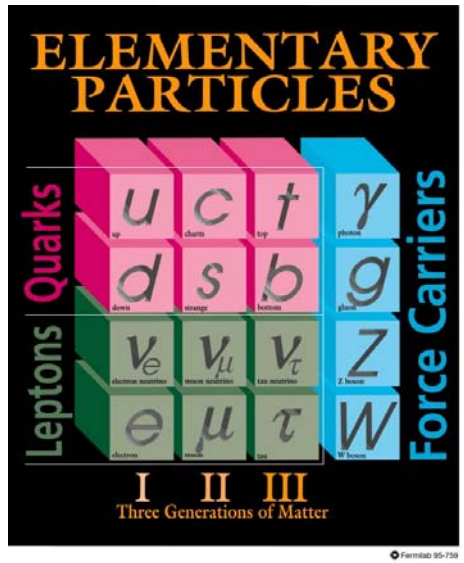
Standard Model & Beyond

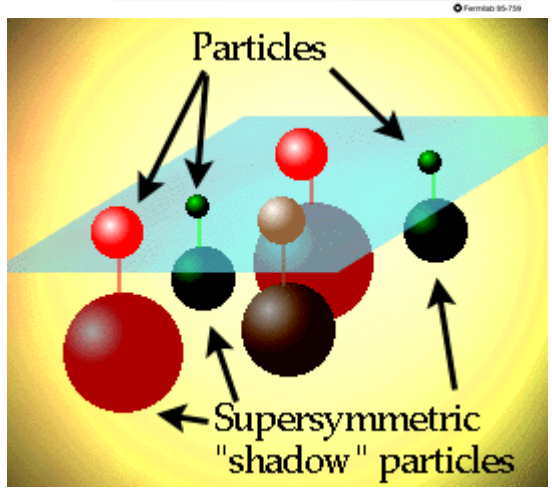
The SM agrees extraordinarily well with detector measurements, but is there more?

Many new physics models predict new particles at the electroweak scale (~100 GeV/c^2).

For example, in Supersymmetry a new particle is predicted for every one in the SM with different mass and spin.

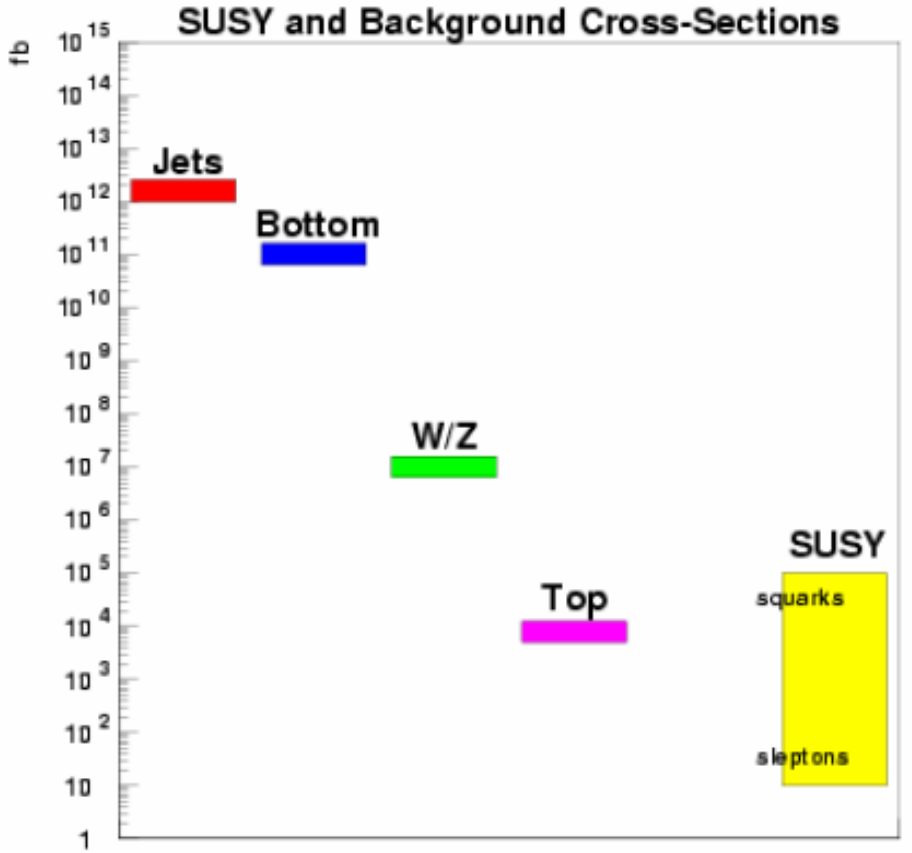
Fermions ⟷ Bosons





Analysis Strategy

- Require a method to reduce backgrounds while preserving new physics signal.
- At the Tevatron, jet production rate >> lepton production rate.
- Search for events with ≥ 3 charged leptons.
- Complements searches for leptons + $\not\!\!E_T$.
- Attempt to be as model independent as possible.
- Sensitive to R_pV SUSY, and other new physics models.



R-Parity (R_p)

New quantum Number:

$R_p = (-1)^{[3(B-L) + 2S]}$

+1 for SM particles

-1 for  particles

B = baryon #, L = lepton #, S = spin

If R_p is conserved:

Lightest SUSY particle (LSP) is stable, dark matter candidate.
SUSY particles are pair produced.

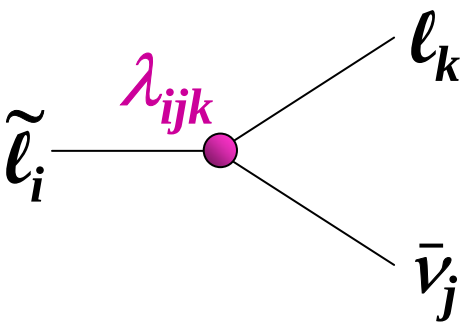
R-Parity Violation ($R_p V$)

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 #



- Choose only $L_i L_j \bar{E}_k$ term ≠ 0, protecting proton lifetime.
- $|\lambda| < 0.1$, only LSP decays via RpV coupling.

$R_p V$ Decays

Most sensitive to λ_{121} and λ_{122}.

$p\bar{p}$

$q\bar{q} \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^\pm$
$q\bar{q} \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$

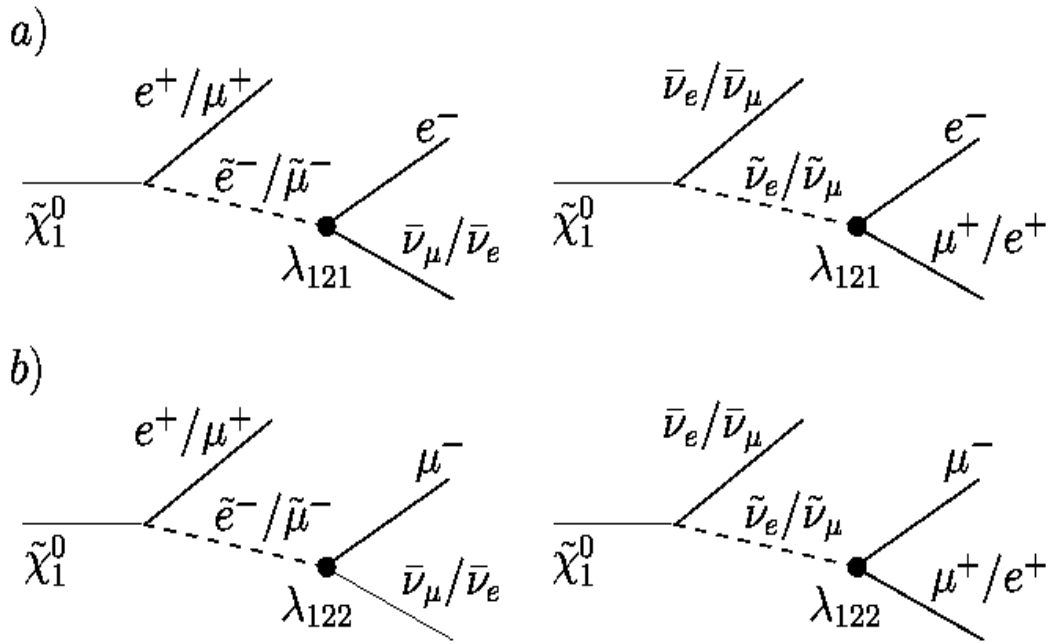
2 particles

cascade decay

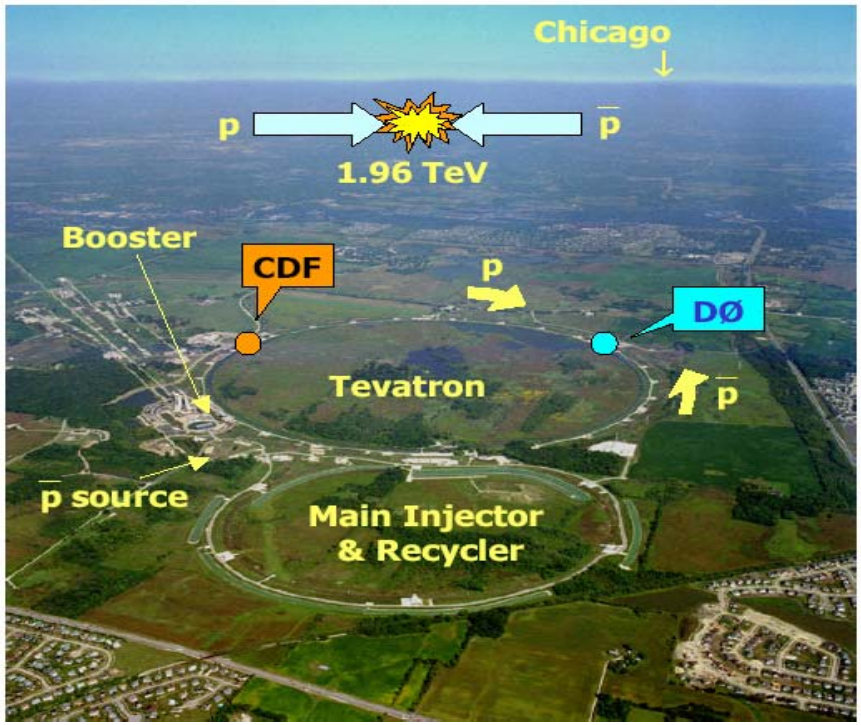
2 LSPs ($\tilde{\chi}_1^0$)

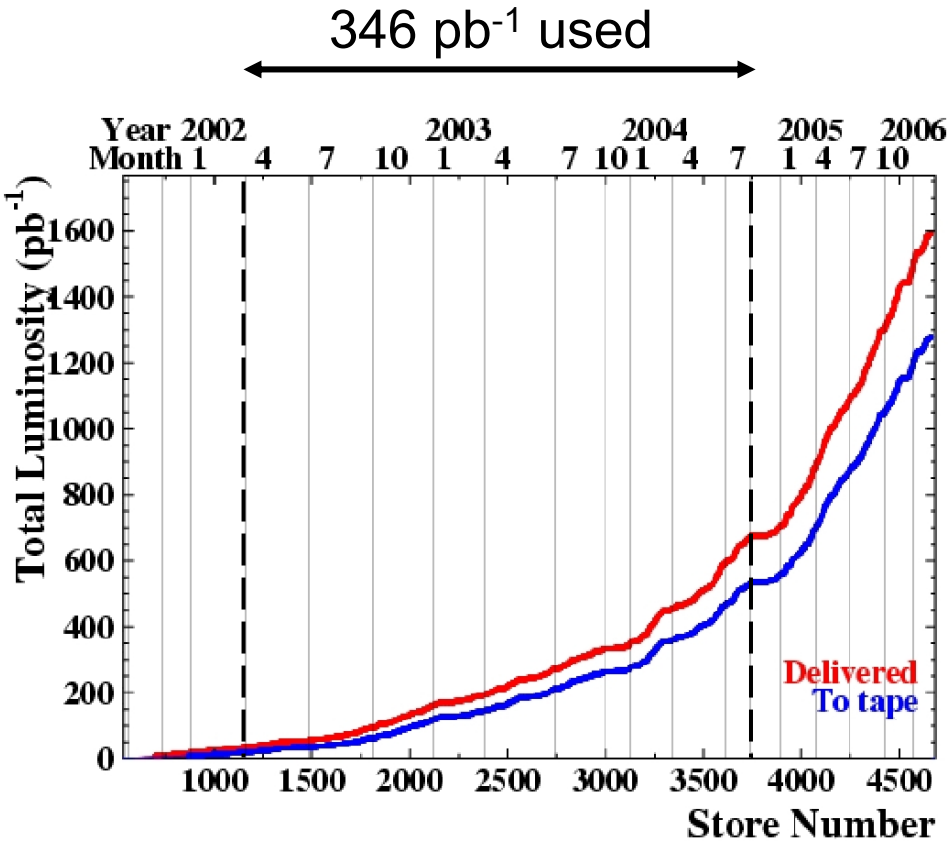
$R_p V$ decay

≥ 4 Charged Leptons



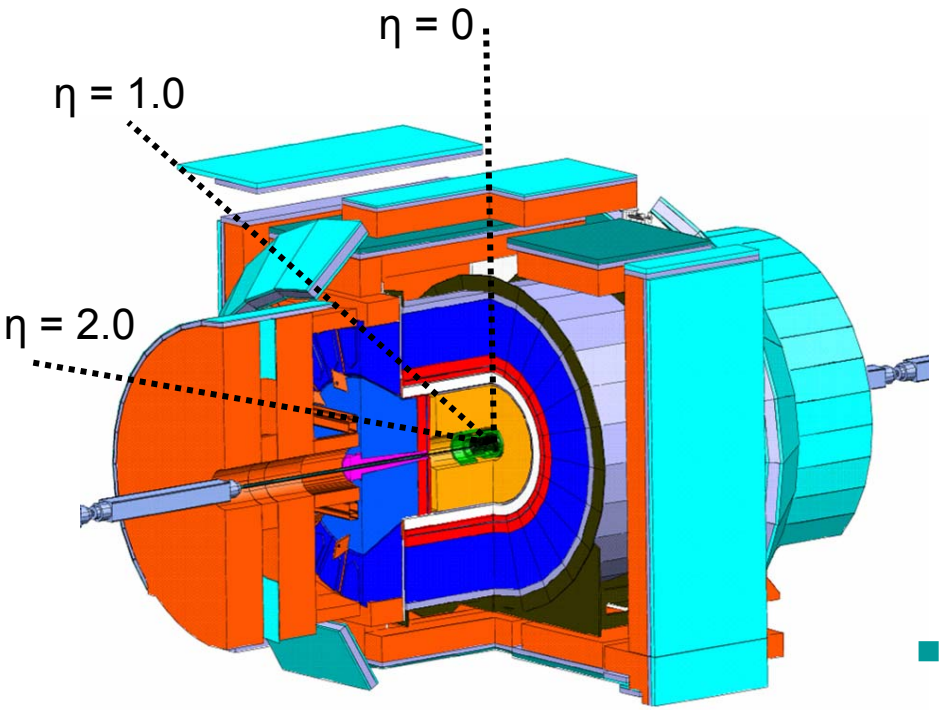
Tevatron & Luminosity





Data taken from March 2002 – August 2004

CDF Detector & Lepton ID



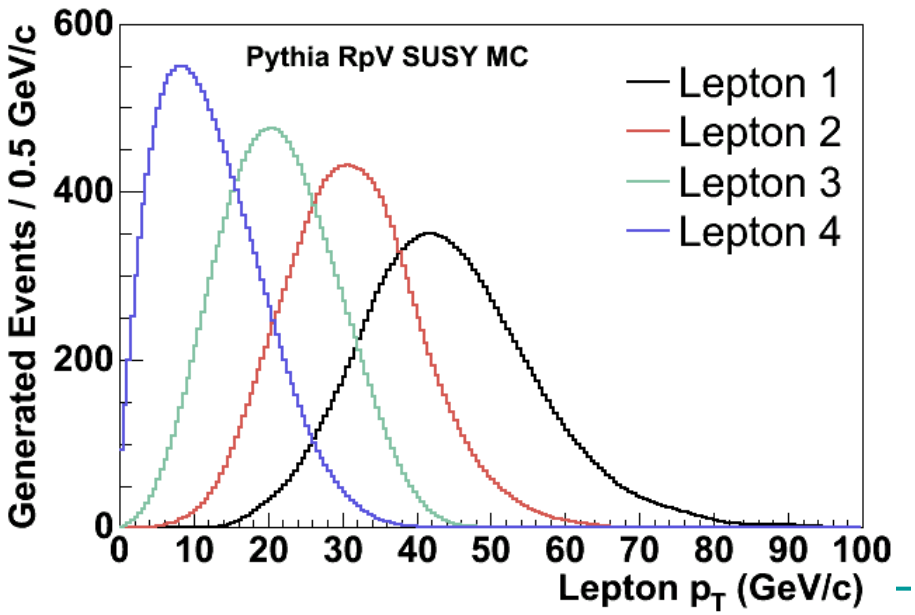
- Electrons
  - Track + Calorimeter Cluster
  - 95% of energy in EM calorimeter
  - $|\eta| < 2.0$
- Muons
  - Track plus "stub" in muon detector
  - Minimum ionizing
  - $|\eta| < 1.0$
- Lepton ID important to analysis
  - Studied in data and MC
  - Efficient (~90%)
  - Probability that jets are misidentified as leptons is small ($\lesssim 0.02\%$)

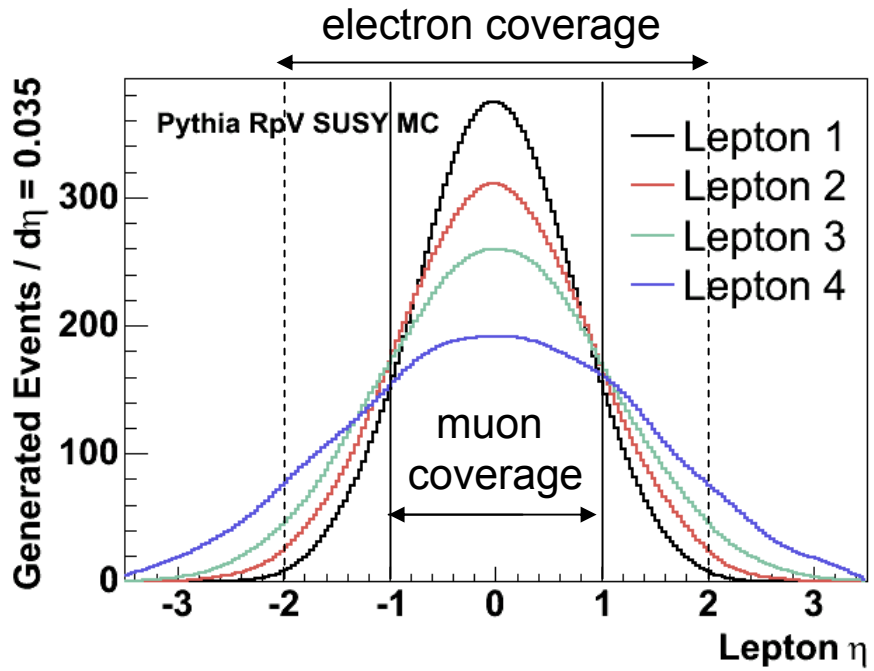
MC Signal Distributions

Using mSUGRA framework

Analysis Reference 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



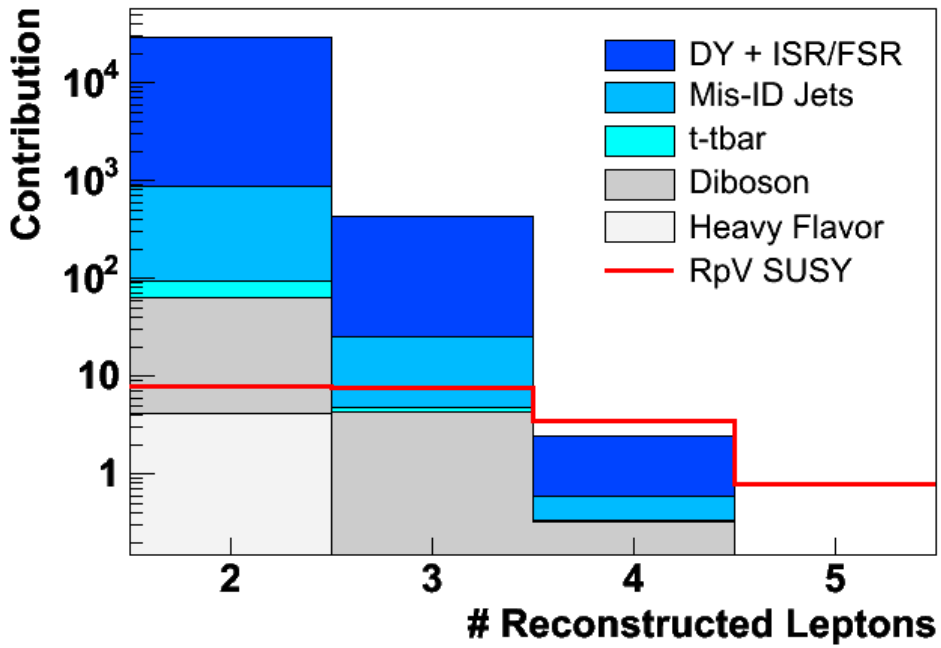


Basic Event Selection

- Use high-p_T lepton triggers (p_T > 18 GeV/c).
- Lepton p_Ts: 20, 8, 5, 5 GeV/c.
- Dominant background from DY, impose following cuts on opposite sign leptons:
  - Impose Z veto cut (76-106 GeV/c^2)
  - $|\Delta\phi| < 160°$ cut.
- Require isolated leptons to reduce jet backgrounds.
- Low mass cut (> 15 GeV/c^2) to reduce heavy flavor, and low mass resonances.

Before Event Selection

Luminosity = 346 pb^{-1}

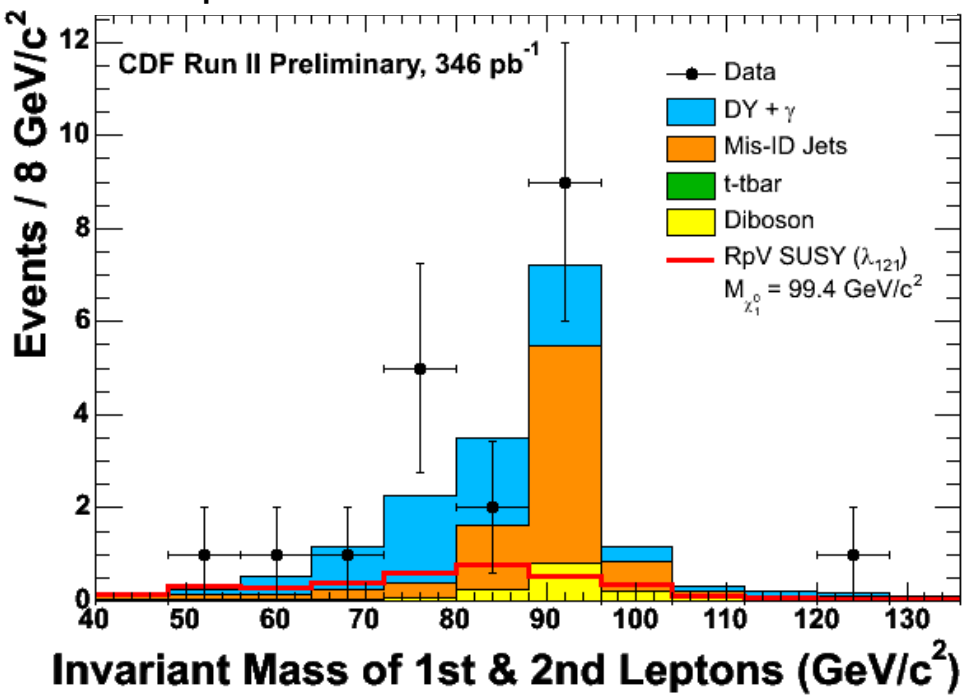


Events with > 3 leptons very clean!

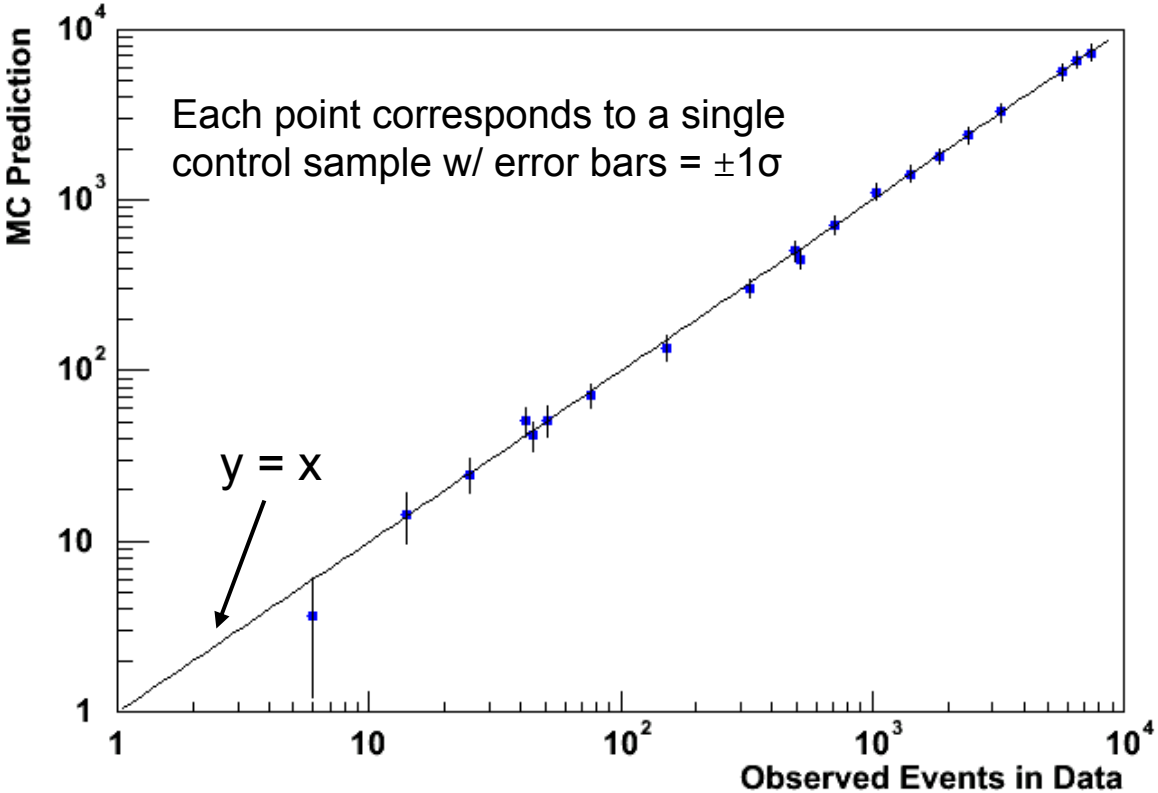
Validation

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

Trilepton events that fail 1 or more cuts



Control Sample Overview



- 26 total control samples (summary on left)
  - By lepton type
  - Inside & outside Z window
  - Number of leptons
  - Pass/Fail $\Delta\phi$ cut
- Analysis procedure is validated through agreement between data and MC prediction

Signal Samples

Trilepton Signal Samples		
Process	**λ_{121} (e$\ell\ell$)**	**λ_{122} ($\mu\ell\ell$)**
$Z/\gamma^* + \gamma$	2.1 ± 0.8	1.2 ± 1.0
$Z/\gamma^* + W$	0.2 ± 0.1	0.1 ± 0.1
Fakes	0.7 ± 0.4	0.5 ± 0.3
Total Background	3.1 ± 0.9	1.9 ± 1.0
RpV SUSY (λ_{121})	3.8 ± 0.4	-----
RpV SUSY (λ_{122})	-----	4.0 ± 0.4
Data		

≥ 4 Lepton Signal Sample	
Process	**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

Very Clean Signature

Signal Samples

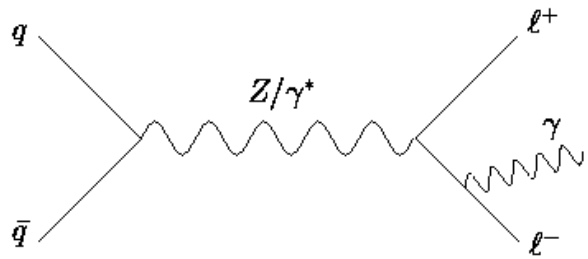
Trilepton Signal Samples		
Process	**λ_{121} (e$\ell\ell$)**	**λ_{122} ($\mu\ell\ell$)**
$Z/\gamma^* + \gamma$	2.1 ± 0.8	1.2 ± 1.0
$Z/\gamma^* + W$	0.2 ± 0.1	0.1 ± 0.1
Fakes	0.7 ± 0.4	0.5 ± 0.3
Total Background	3.1 ± 0.9	1.9 ± 1.0
RpV SUSY (λ_{121})	3.8 ± 0.4	-----
RpV SUSY (λ_{122})	-----	4.0 ± 0.4
Data	**5**	**1**

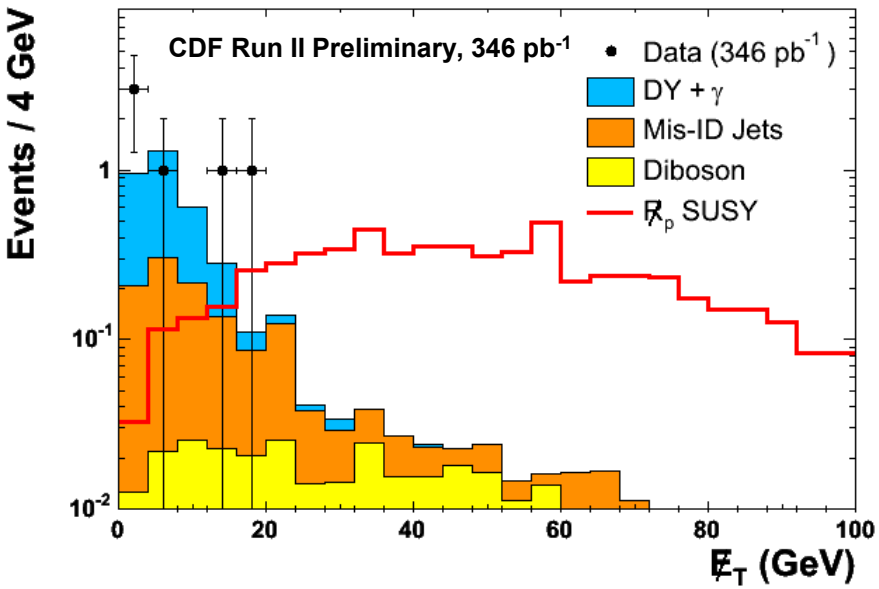
≥ 4 Lepton Signal Sample	
Process	**Signal**
$Z/\gamma^* + \gamma\gamma$	0.001 ± 0.001
$Z/\gamma^* + Z/\gamma^*$	0.004 ± 0.002
Fakes	0.004 ± 0.003
Total Background	0.008 ± 0.004
RpV SUSY (λ_{121})	1.5 ± 0.2
RpV SUSY (λ_{122})	1.5 ± 0.3
Data	**0**

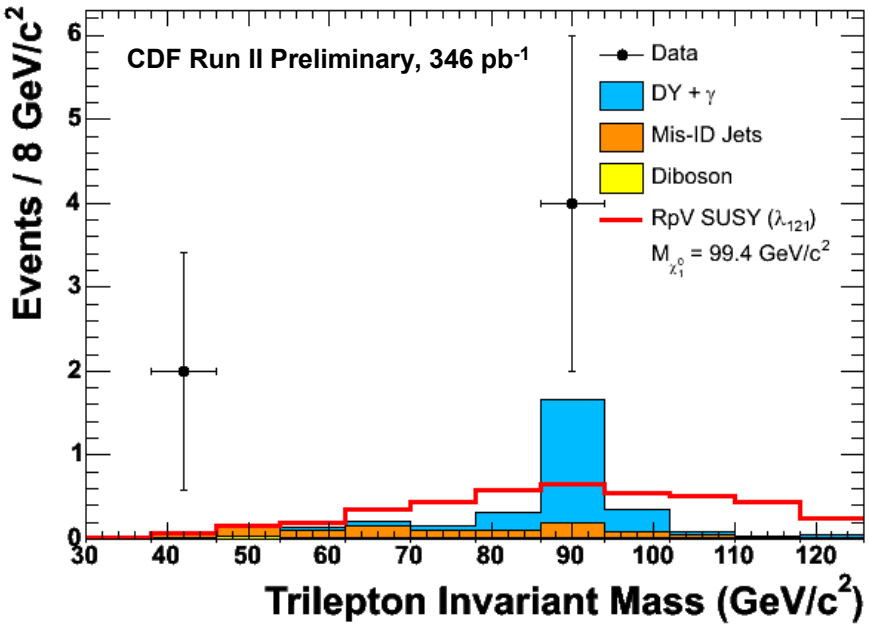
- Signal events: 4 eee, 1eeμ, 1 $\mu\mu$e
- Probability of observing ≥ 5 events with 3.1 expected = 17%

Event Distributions

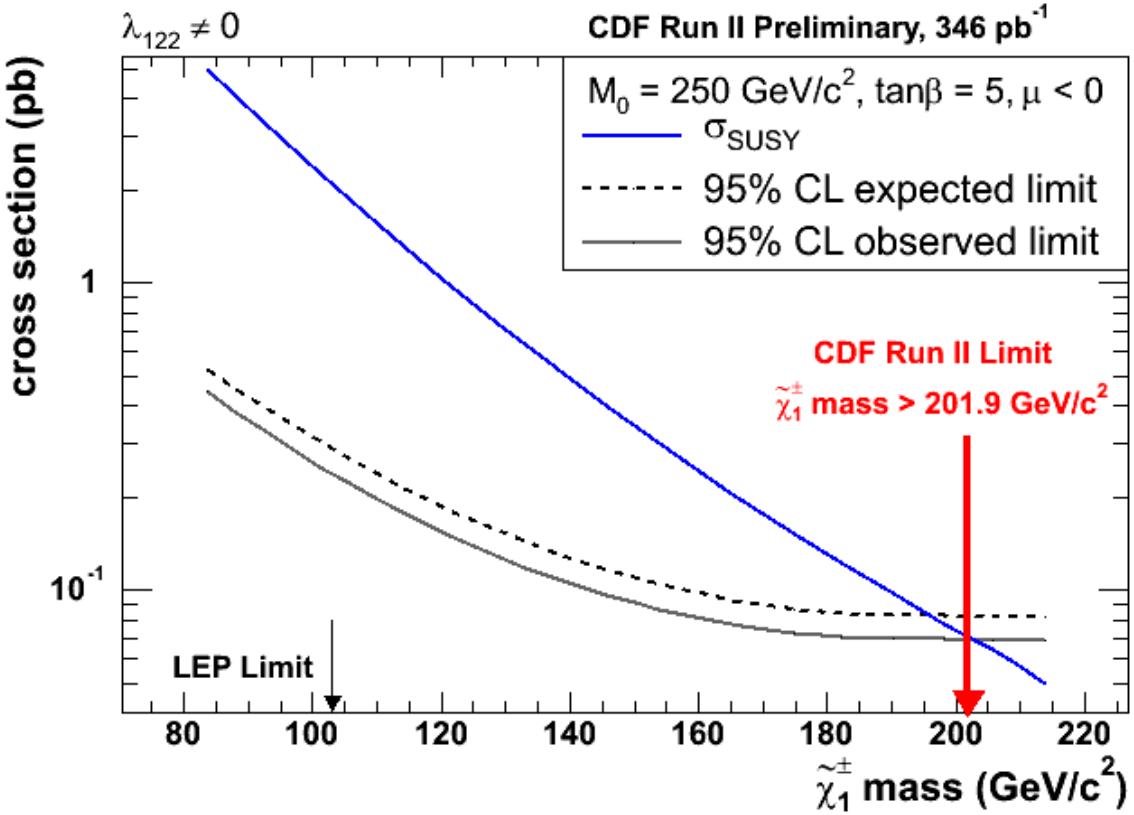
- 4 of the 6 events appear to be Z + γ events.
- 2 of the 6 events appear to have mis-ID jets.
- Consistent with background prediction.





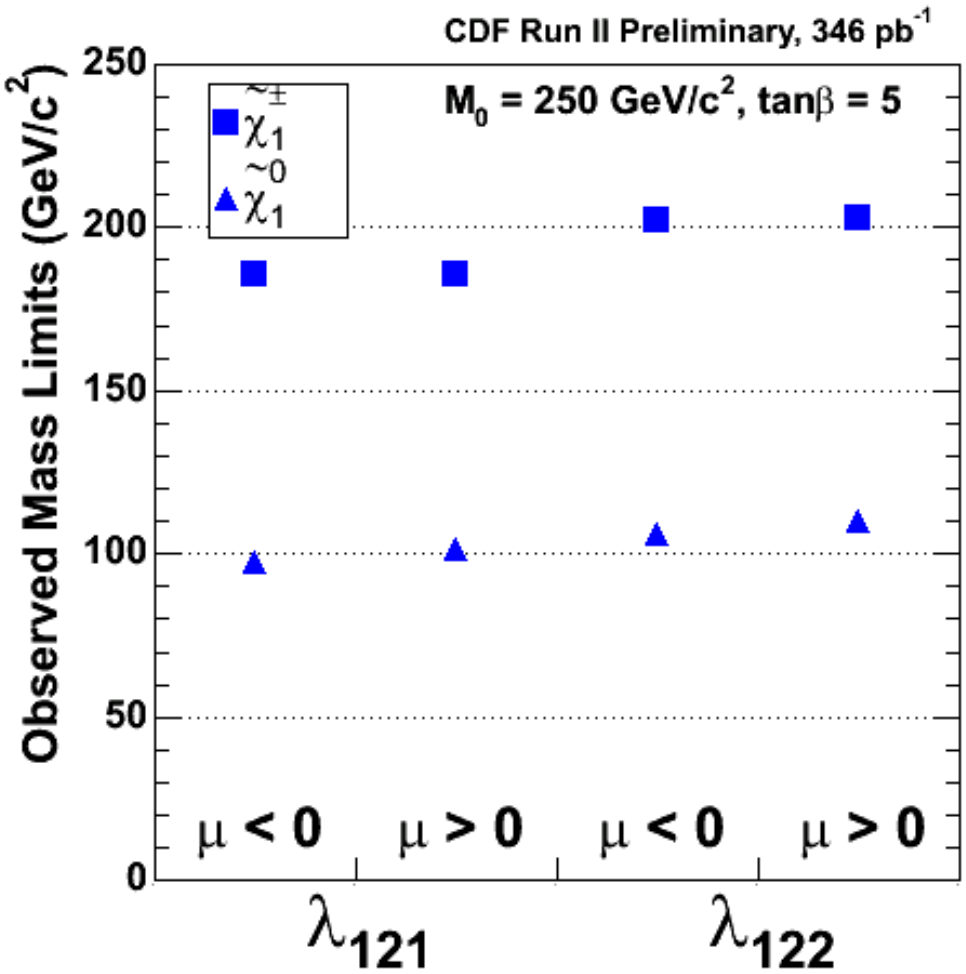


Setting Limits



- Use Bayesian method to find σ_{obs}, combining 3 and ≥4 lepton signal samples.
- Set limits for both signs of μ, λ_{121}, and λ_{122}.

Results



- Set limits on chargino and neutralino masses.

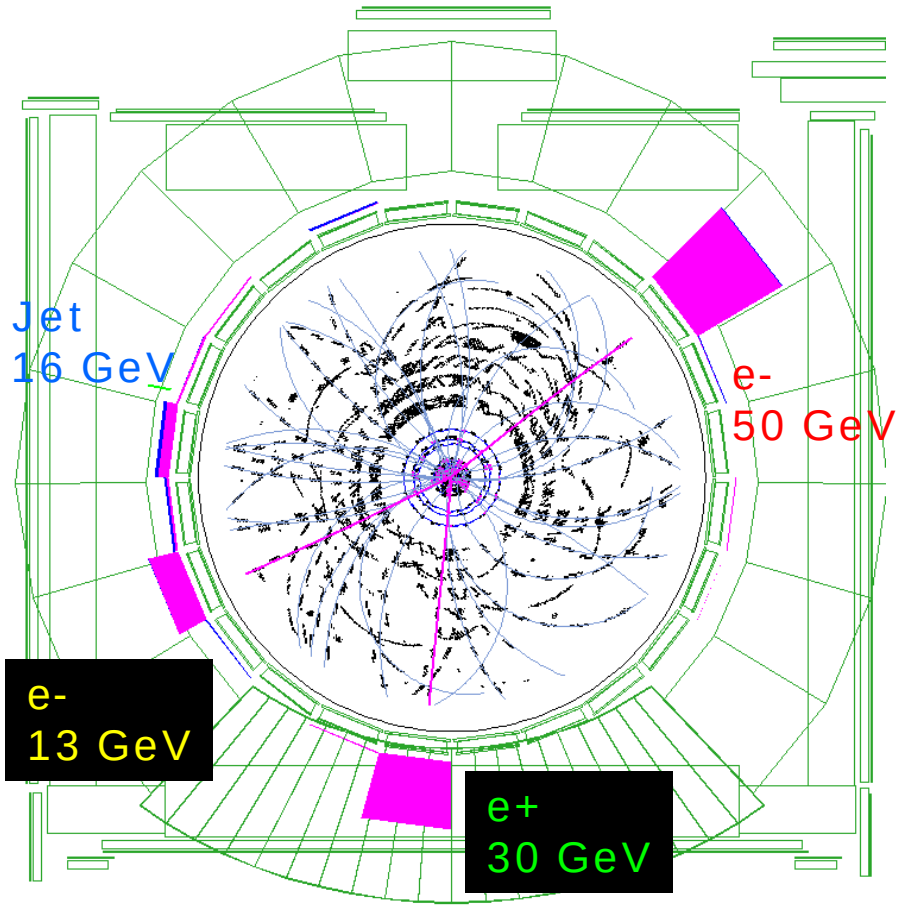
CDF Limits		
SUSY Scenario	$M\tilde{\chi}_1^0$ (GeV/c^2)	$M\tilde{\chi}_1^{\pm}$ (GeV/c^2)
λ_{121}, $\mu < 0$	98	186
λ_{121}, $\mu > 0$	102	185
λ_{122}, $\mu < 0$	106	202
λ_{122}, $\mu > 0$	110	203

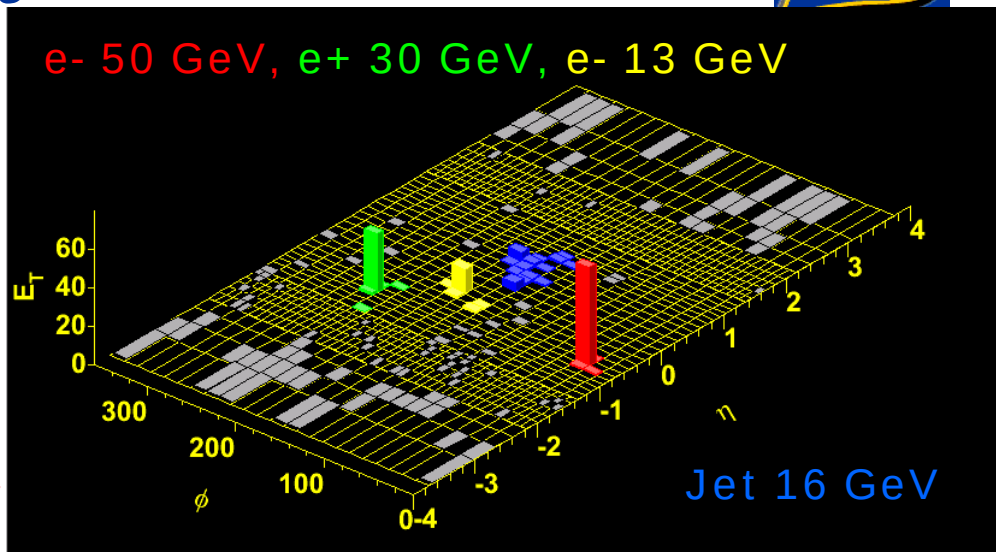
Conclusions

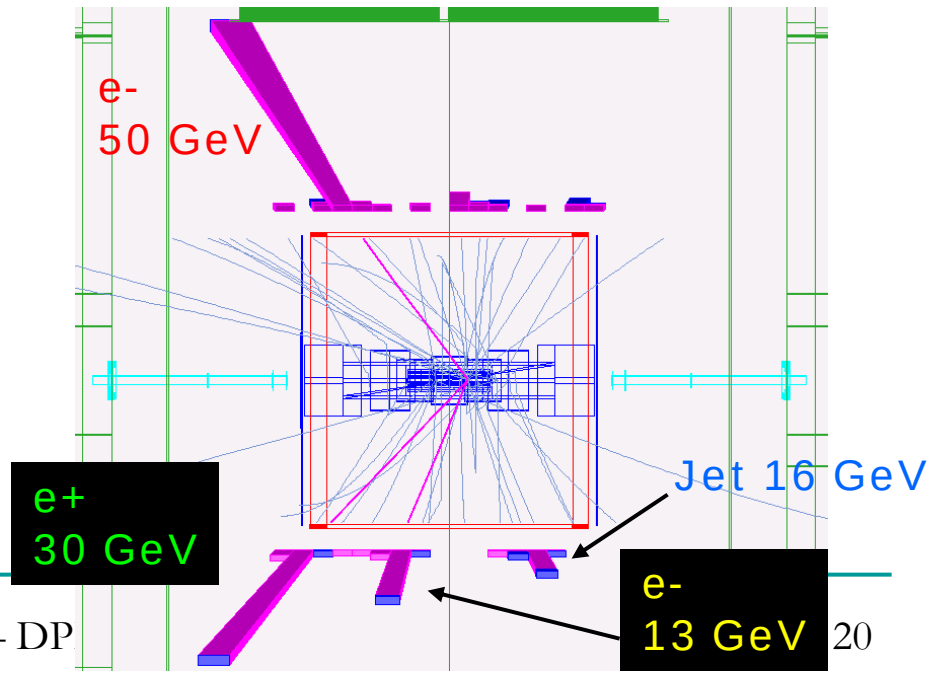
- We completed a search for new physics in the multilepton channel.
- We used a minimal amount of cuts to try and limit model dependence.
- No significant evidence of physics beyond the SM was detected.
- Limits on the lightest neutralino and chargino masses were set using an $R_p V$ SUSY framework.
- The ≥ 4 lepton sample provides a promising new method to search for new physics with the higher luminosity currently being delivered to the Tevatron.

Backup

Trilepton Event







Leading M_{ee} = 70 GeV/c^2

$\not\!\!E_T$ = 1.5 GeV

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_{121}, $\mu > 0$	105.0	101.5	191.9	185.3
λ_{121}, $\mu < 0$	101.1	97.7	192.2	185.6
λ_{122}, $\mu > 0$	107.7	110.4	197.5	202.7
λ_{122}, $\mu < 0$	102.7	106.3	195.3	201.9

DØ Limits on R_pV SUSY

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