

HEP2005 International Europhysics Conference on High Energy Physics

# Search for R-Parity Violating Scalar Leptons and Gauginos at TeVatron

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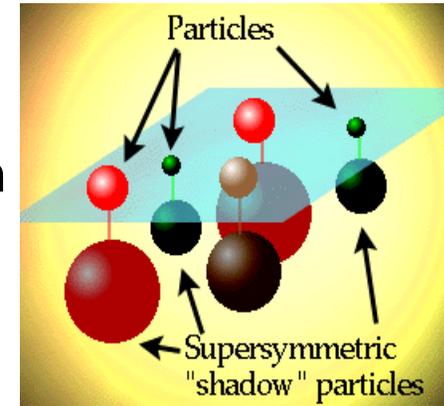
University of Wisconsin



On behalf of the CDF and DØ Collaboration  
Lisbon Portugal, July 21<sup>st</sup> – 27<sup>th</sup> 2005

# Introduction

- R parity  $\equiv (-1)^{2J+3B+L}$ ;  $R = \pm 1$  for  $\begin{cases} \text{Standard Model} \\ \text{SuperSymmetry} \end{cases}$
- No compelling reason for R-parity conservation in SUSY.



- Minimal RPV SUSY model  $\equiv$  MSSM + these Yukawa couplings in the Lagrangian:  

$$\mathbf{L}_{RPV} \equiv [\lambda_{ijk} \mathbf{L}_i \mathbf{L}_j \bar{\mathbf{E}}_k + \lambda'_{ijk} \mathbf{L}_i \mathbf{Q}_j \bar{\mathbf{D}}_k + \lambda''_{ijk} \bar{\mathbf{D}}_i \bar{\mathbf{D}}_j \bar{\mathbf{U}}_k]$$
 where  $(\bar{\mathbf{F}})$  are for (anti-)fermion doublet(singlet).

Ex:  $\begin{pmatrix} \nu \\ \mu \end{pmatrix} \begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} d \end{pmatrix} \quad \begin{pmatrix} \nu \\ e \end{pmatrix} \begin{pmatrix} \nu \\ \tau \end{pmatrix} \begin{pmatrix} \mu \end{pmatrix}$

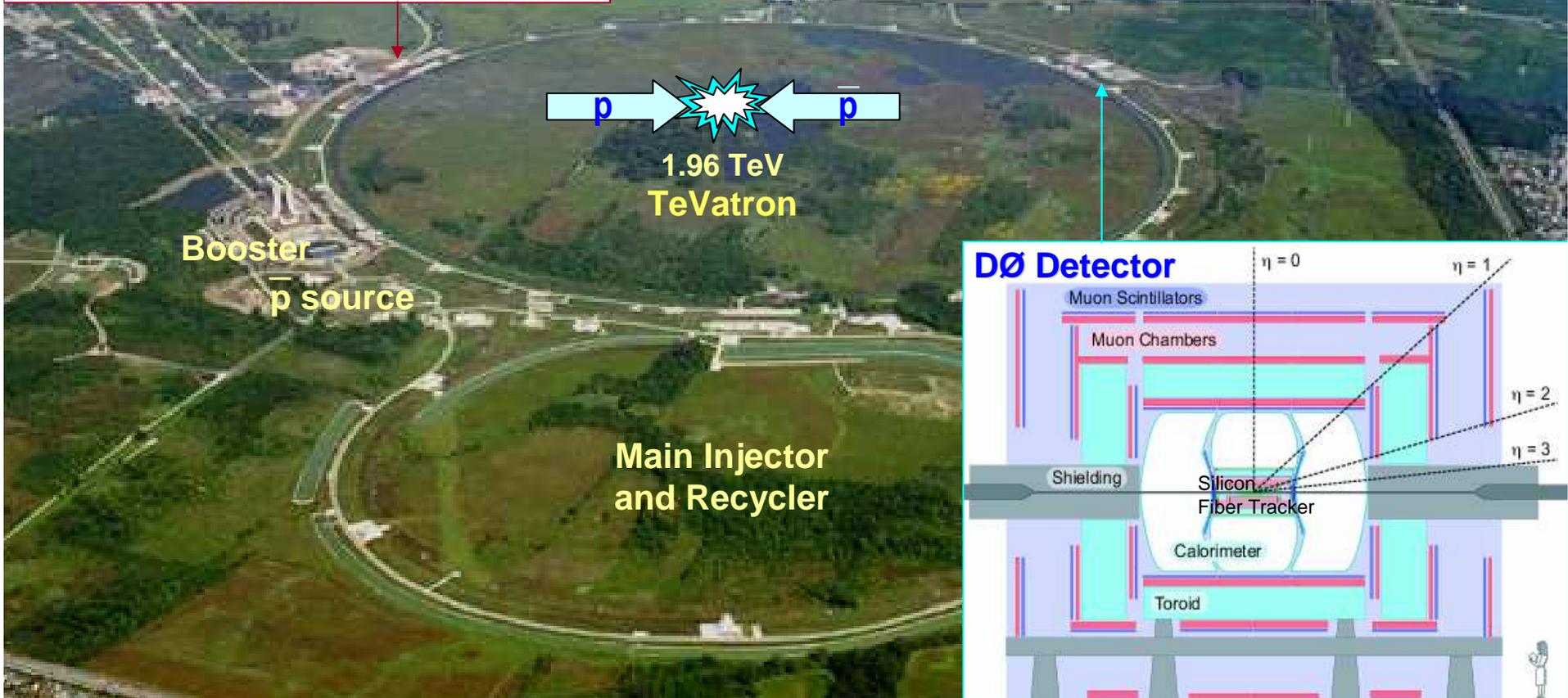
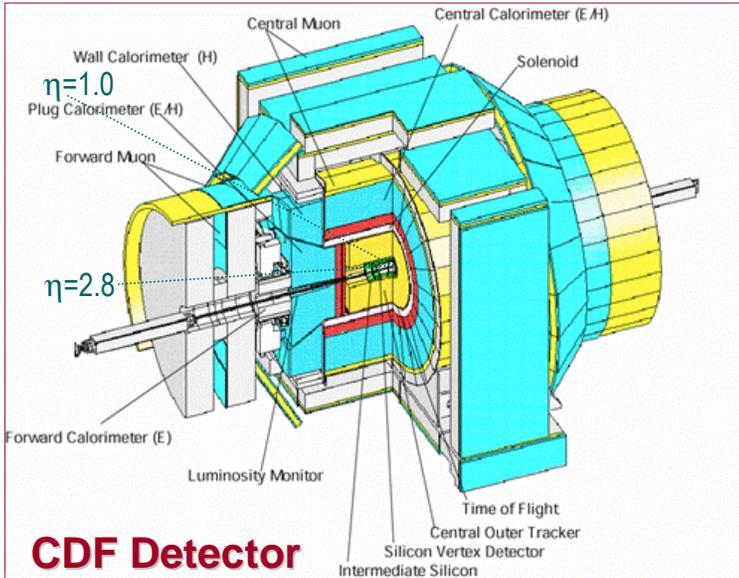
Expect lightest super particles (LSP) to decay dominantly to one of the 45 independent coupling terms but who knows which one?!

- $\lambda^{(l)}$  : lepton number violation (LNV)
- $\lambda^{(b)}$  : baryon number violation (BNV)

- Proton lifetime forbids the coexistence of LNV and BNV but not either one.

# Apparatus

- TeVatron is energy frontier till LHC's turn-ON
- Both detectors are well-understood by now
  - mature particle ID, coverage, tracking and trigger systems
- 800/pb physics quality data on tape each site
- Run II goal is to cumulate 4.4~8.5 fb<sup>-1</sup> by 2009



# RPV Searches at TeVatron

## RPV sneutrino decay searches:

- $\tilde{\nu} \rightarrow ee/\mu\mu$  from CDF

- $\tilde{\nu} \rightarrow e\mu$  **recent results** from CDF

## RPV smuon search from DØ

## RPV decay of neutralino into multiple lepton final state

- via  $\lambda_{121}$  – from DØ

- via  $\lambda_{122}$  – from DØ

- via  $\lambda_{133}$  – from DØ

- via  $\lambda_{121}$  and  $\lambda_{122}$  – results soon from CDF

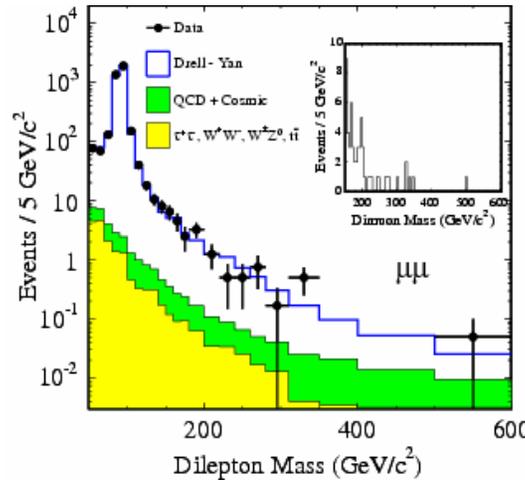
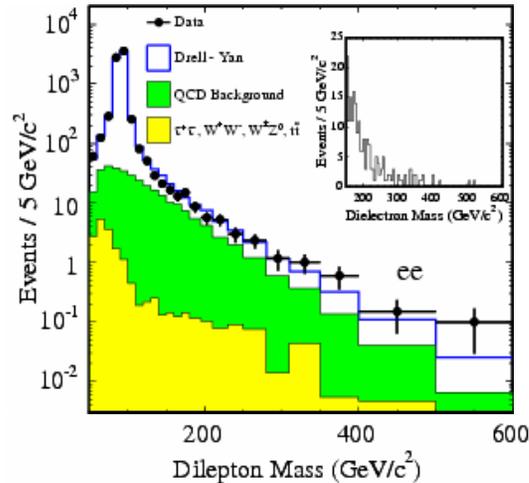


Search for the pair production of  $\tilde{t}$   $\xrightarrow{\text{RpV}}$   $\tau, b$

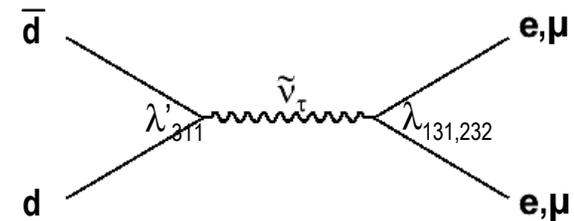
– to be presented in next talk by T. Munar



# High Mass RPV $\tilde{\nu} \rightarrow ee/\mu\mu$ Search

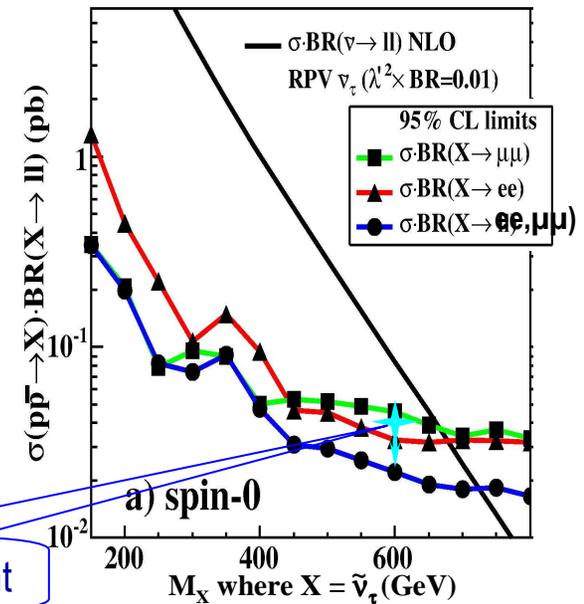


submitted to hep-ex/0506034



- RPV  $\tilde{\nu}$  cross-section and coupling limits as part of the spin-0 new physics search results
- selected  $ee$  or  $\mu\mu$  with  $M_{ll} > 150$  GeV
  - Electrons  $E_t > 25$  GeV,  $|\eta_{e2}| < 2.8$   
– higher acceptance; more QCD background
  - Muon (track)  $pt > 20$  GeV,  $|\eta_{\mu 2}| < 1.5$
- took Z as a control region
- used 200/pb CDF Run II data
- improved CDF Run I results owing majorly to the increased lepton acceptance.

CDF Run I  $ee, \mu\mu$  ref point





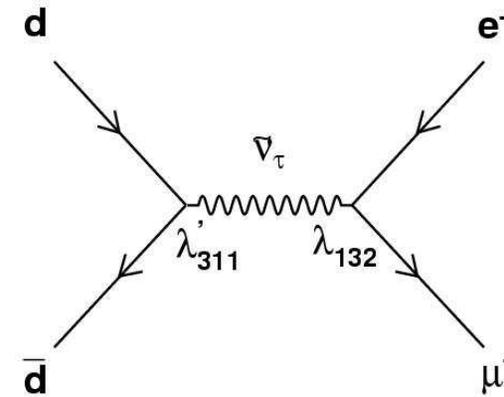
# RPV $\tilde{\nu} \rightarrow e\mu$ Search

Search for high mass resonance decaying directly to electron and muon with opposite charge signs.

Lack of competing Standard Model background!

Models that predict such decays include

- Lepton flavor violation (LFV)  $Z'$
- R-parity violation sneutrinos



Analysis makes conventional assumptions:

- ❖ All the RPV couplings zero except those in question,  $\lambda'_{311}$  and  $\lambda_{132}$ ;
- ❖ Branching ratio  $BR(d\bar{d} \rightarrow \tilde{\nu}_\tau \rightarrow e\mu) = 100\%$

Select events with  $>1$  electron and  $>1$  muon,

- each with  $p_t > 20$  GeV
- each within  $|\eta| < 1.1$
- with opposite charge signs
- $|\Delta Z_{0e\mu}| < 5$  cm

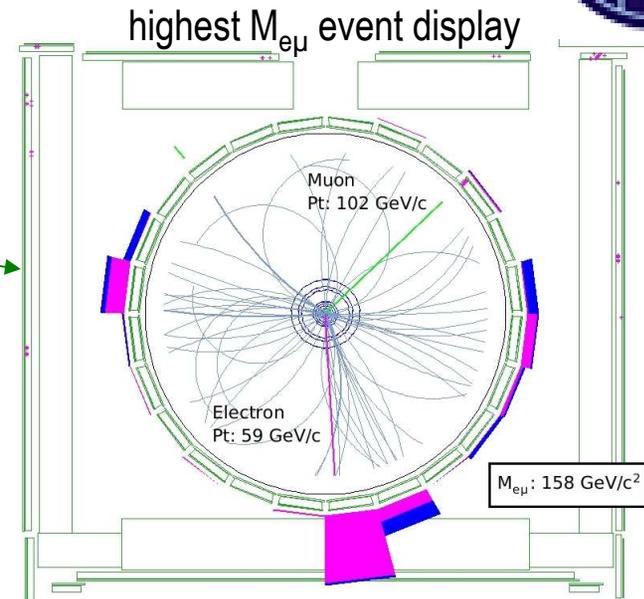
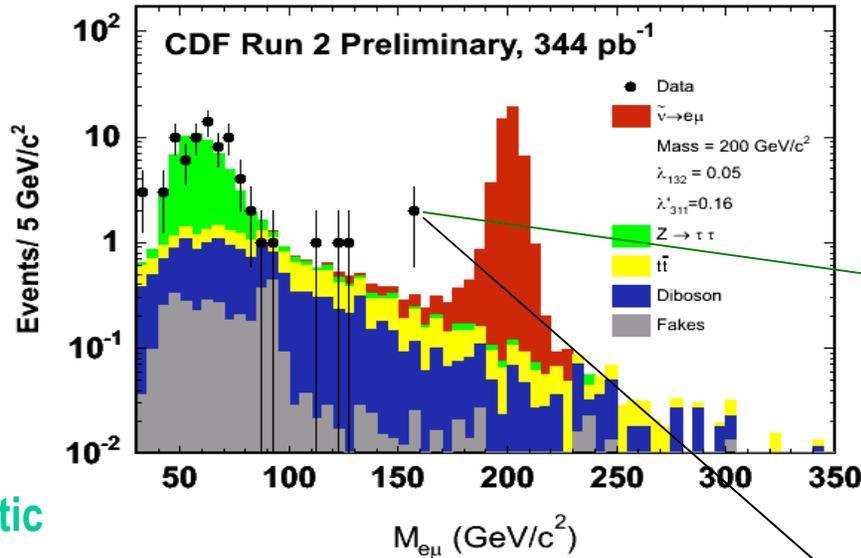
No met cut. No jet cut.

**recent results**

# RPV $\tilde{\nu} \rightarrow e\mu$ Search

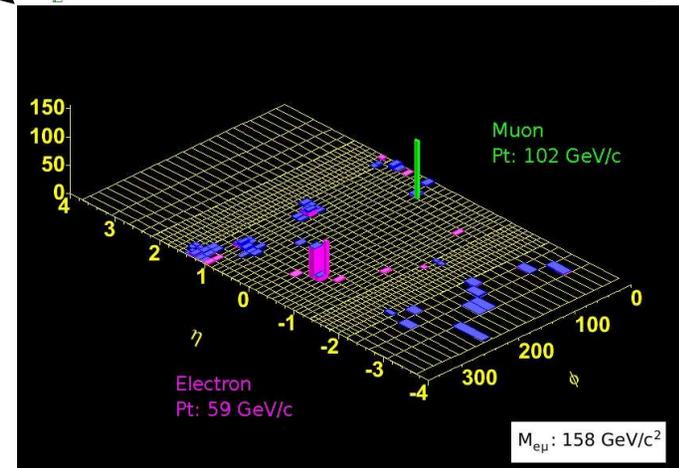


Good agreement between data and MC; small systematic errors.

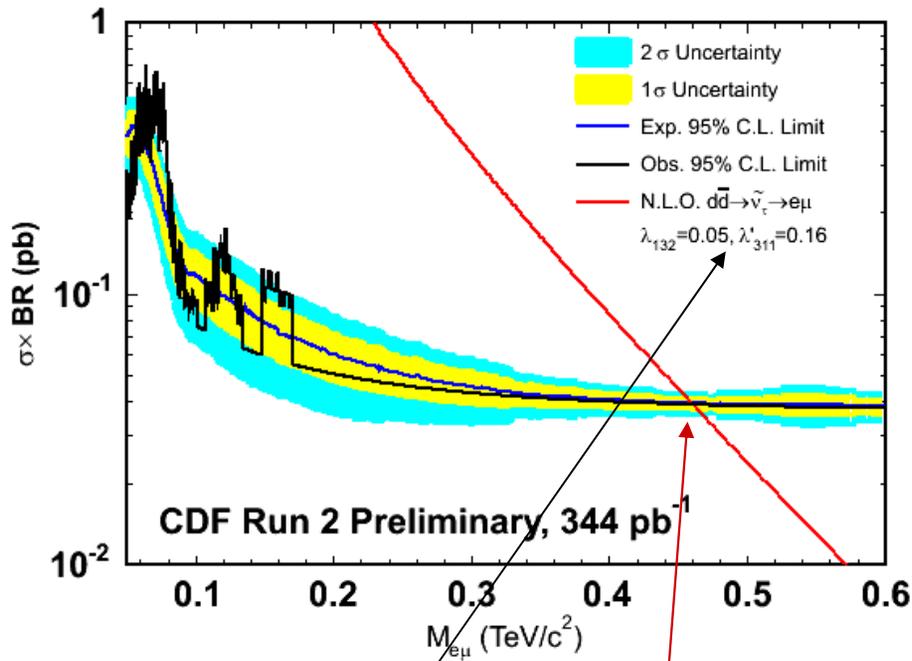


CDF Run II Preliminary, 344 pb<sup>-1</sup>

Process	CR: 50 < M <sub>ll</sub> < 100	100 < M <sub>ll</sub> < 800 (GeV)
Z → ττ	38.77 ± 6.68	0.57 <sup>+0.76</sup> <sub>-0.57</sub>
diboson	6.63 ± 2.61	3.48 ± 1.88
tt̄	3.57 ± 1.90	3.16 ± 1.79
QCD	2.90 ± 2.42	0.44 <sup>+0.87</sup> <sub>-0.44</sub>
total BG	51.87 ± 7.80	7.66 ± 2.84
observed	56	5

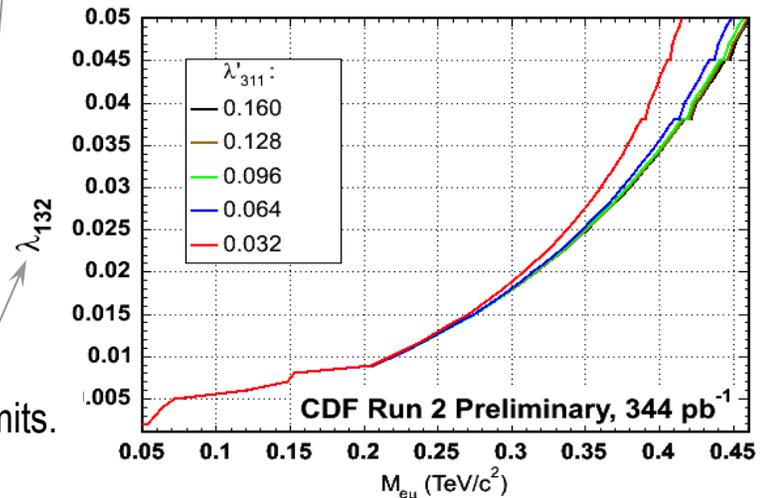
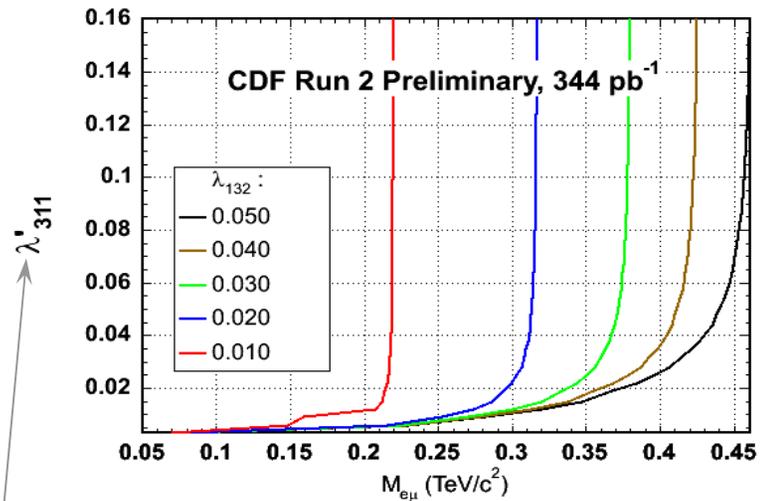


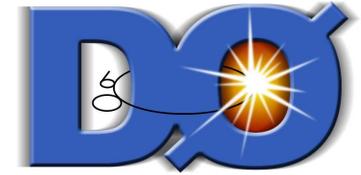
# RPV $\tilde{\nu} \rightarrow e\mu$ Search



For the existing best limits from hep-ph/0406029  
 $\lambda_{132} < 0.05$  and  $\lambda'_{311} < 0.16$ , set  $M_{\tilde{\nu}} > 430$  GeV.

Also pushed down  $\lambda'_{311}$  and  $\lambda_{132}$  from the existing best limits.

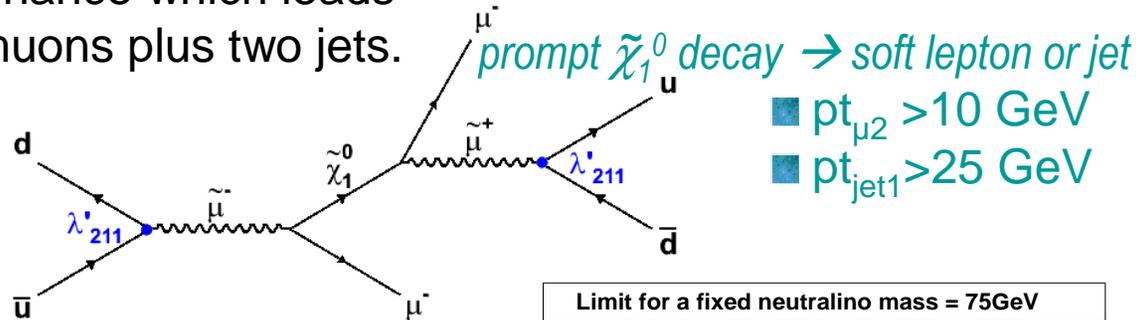




# Slepton Production via $\lambda'_{211}$

Search for smuon resonance which leads to a final state of two muons plus two jets.

smuon and neutralino mass reconstructable – useful in background suppression.

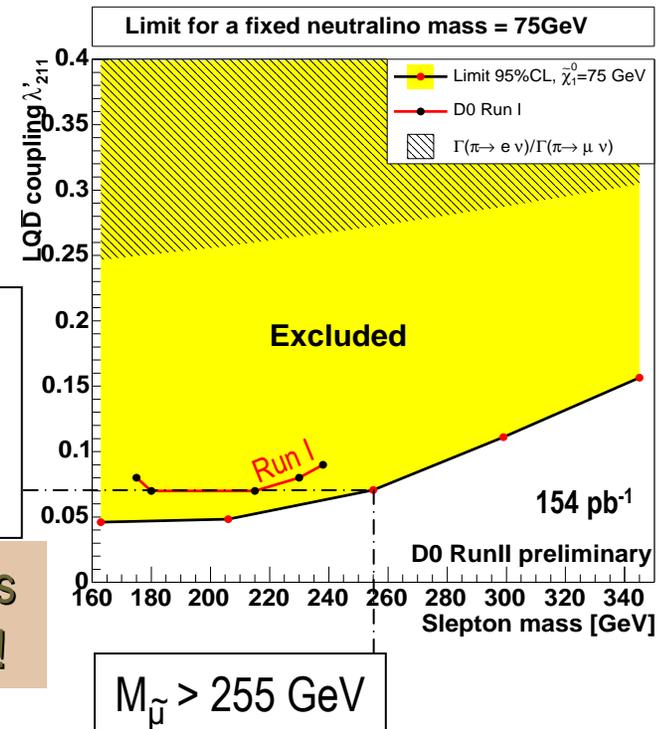
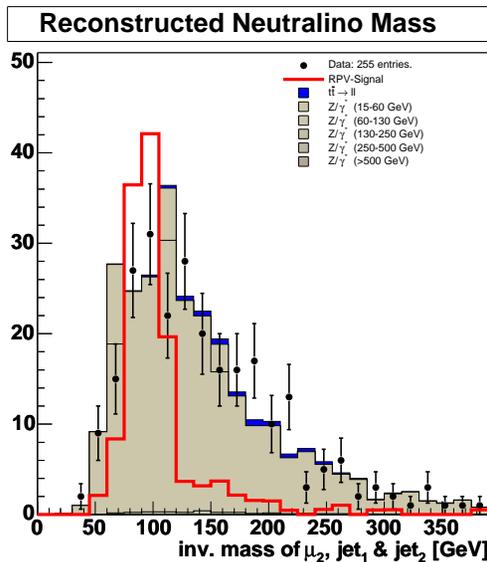


expected  $1.1 \pm 0.4$   
observed 2 events

probing along axis of  $M_{\tilde{\mu}}, M_{\tilde{\chi}_1^0} \sim \lambda'_{211}$

$A_0=0$   
 $\tan\beta=2$   
 $\mu<0$   
 $\lambda'_{211}=0.07$

Excluded area grows with increasing  $\lambda'_{211}$ !



# RPV Search in $\geq 3$ Lepton Final State

■ Within existing limits set by experiments, the  $\lambda$  couplings are typically too small in comparison to gauge couplings to make RPV to compete with the RPC decays.

- most processes are still R-parity conserving and sparticles (SP) can only be pair produced in  $\overline{pp}$  collisions at TeVatron;
- only LSP can decay to SM particles;
- (heavy) SP decay to LSP prior to any RPV decay to SM particles.

■ Considering events in such a RPV framework:

$\overline{pp} \rightarrow \text{SP-pair} + X \rightarrow \text{LSP-pair} + XYZ \xrightarrow{\text{RPV}} \text{lllv} + XYZ \Rightarrow$  **at least 4 leptons in the end!**

Searches generally assume

$\text{BR}(\text{LSP} \rightarrow \text{llv}) = 100\%$  and

all  $\lambda_{ijk} = 0$  but the one in question.

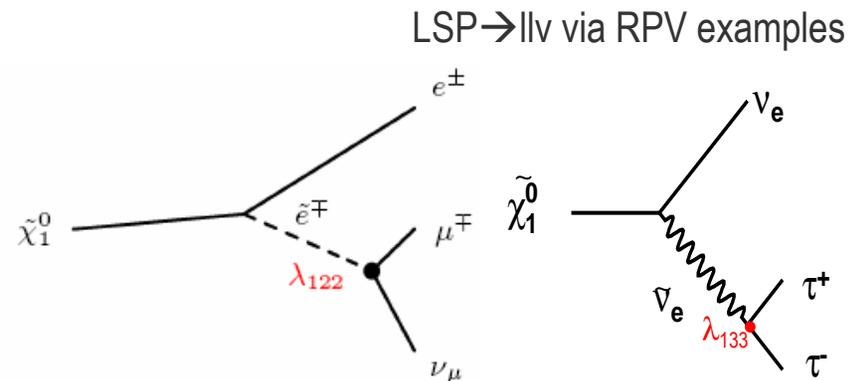


searched channels:

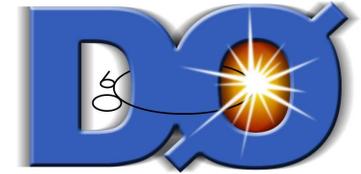
$\lambda_{121} - eee\nu\nu, e\mu ee\nu\nu, \mu\mu ee\nu\nu$

$\lambda_{122} - \mu\mu\mu\nu\nu, e\mu\mu\nu\nu, ee\mu\nu\nu$

$\lambda_{133} - ee\tau\nu\nu$



# RPV Search in $\geq 3$ Lepton Final State



## Analysis Algorithm:

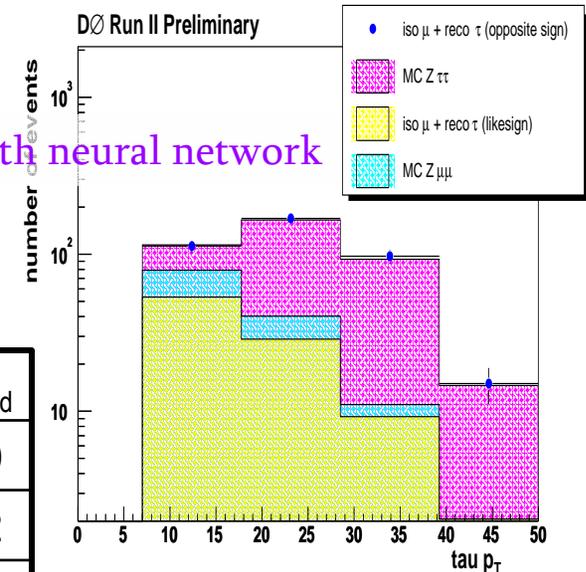
### Select

- Medium pt ee or  $\mu\mu$  with mass outside B & Z regions
- Additional low pt lepton, including tauon!
- Significant missing  $E_t$
- 4<sup>th</sup> lepton NOT required for acceptance

Effective  $\tau$ -ID with neural network

### Scan over $M_{1/2}$ with fixed $A_0$ , $\tan\beta$ and $M_0$ :

final state	$L_{\text{int}}$ ( $\text{pb}^{-1}$ )	$\lambda$ constraint	$A_0$	$\tan\beta$	$M_0$ (GeV)	$N_{\text{expect}} : N_{\text{observed}}$
ee{e,u}	238	$\lambda_{121}=0.010$	0	5	250	$0.45\pm 0.43 : 0$
uu{e,u}	160	$\lambda_{122}=0.001$	0	5	250	$0.63\pm 1.93 : 2$
ee $\tau_{had}$	199	$\lambda_{133}=0.003$	0	10	80.0	$1.04\pm 1.42 : 0$



### Extract cross-section and gaugino mass limits:

final state	$M_{\tilde{\chi}^0}; M_{\tilde{\chi}^\pm}$ for $\mu < 0$	$M_{\tilde{\chi}^0}; M_{\tilde{\chi}^\pm}$ for $\mu > 0$
ee{e,u}	$M > 95; 181$ GeV	$M > 97; 183$ GeV
uu{e,u}	$M > 84; 160$ GeV	$M > 90; 165$ GeV
ee $\tau_{had}$	--,---	$M > 66; 118$ GeV

## All Improved Run I Results!



Reference to CDF:

- Run I  $M_{\tilde{\chi}^0} > 65$  GeV via  $\lambda_{121}$ ,  $\mu < 0$ ,  $\tan\beta=2$
- Run II results coming soon!

# RPV 4-Lepton Search



## Analysis Direction:

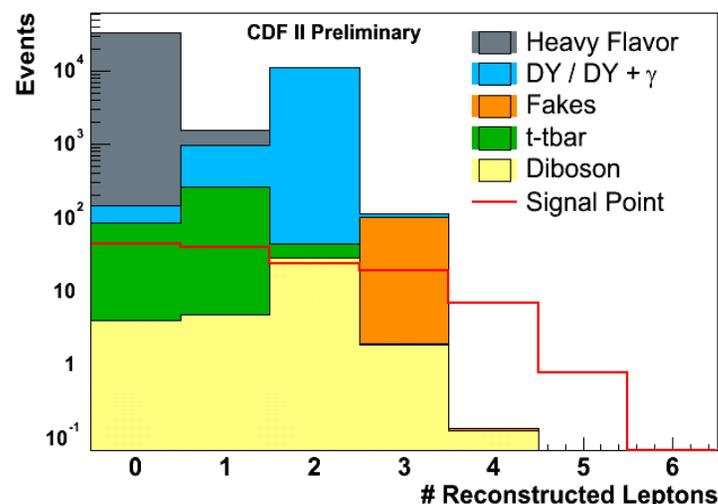
- SUSY model independent
  - ❑ LEP2 used MSSM
  - ❑ TeVatron uses mSugra
- Sensitive to entire SUSY parameter space

Planning to probe  $\mu > 0$   
and  $\mu < 0$  and high  $\tan\beta$   
space starting from

$A_0$	$\tan\beta$	$M_0$ (GeV)
0	5	250

## Event Selection:

- 1<sup>st</sup> lepton with  $E_t > 20$  GeV
- 2<sup>nd</sup> lepton with  $E_t > 8$  GeV
- $15 < M_{ee/\mu\mu} < 76$  ||  $M_{ee/\mu\mu} > 106$  GeV
- 3<sup>rd</sup> lepton with  $E_t > 5$  GeV
- 4<sup>th</sup> lepton with  $E_t > 5$  GeV



- Addition of 4<sup>th</sup> lepton reduces  
signal by 76%  
background by 98%

1<sup>st</sup> and 2<sup>nd</sup> leptons  $\in$  {electron, muon}  
– analysis is sensitive to  $\lambda_{121}$  and  $\lambda_{122}$

analysis in progress; results soon!

# Conclusion

- ❑ No R-parity violation SUSY evidence has been found in  $350 \text{ pb}^{-1}$   $\overline{pp}$  collision data at TeVatron so far.
- ❑ The hunting for R-parity violation SUSY is still, as it needs to be, going on...

