Search for R-parity violating Supersymmetry

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- Introduction to R-parity violating SUSY
- Three DØ searches via non-zero LLE (short and long lived LSP) and LQD couplings
- Perspectives for RPV SUSY at the LHC
R-Parity Violation Supersymmetry

R-parity: \( R_P = (-1)^{3B+L+2S} \)

\[
W = W_{MSSM} + W_{R_P}
\]

\[
W_{R_P} = \frac{1}{2} \lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k
\]

S is the particle spin, B is the baryon number, L is the lepton number

R-parity violating extension of the MSSM

- R-parity conserving production
- associated/pair production of gauginos
- decay via \( \lambda_{ijk} \) into 4 charged leptons

- **Resonant** production via \( \lambda'_{211} \) of smuon or sneutrino
- Cascade decay to LSP (neutralino)
- decay via \( \lambda'_{211} \) into 2 jets & 1 lepton
- \( \sigma \propto (\lambda'_{211})^2 \)

Chiral superfields:

- L: lepton doublet superfield
- E: lepton singlet superfield
- Q: quark doublet superfield
- D: down-like quark singlet superfield
- \( \lambda, \lambda', \lambda'' \): Yukawa couplings
Sparticle Production

- R-parity violating production
- s-channel: enhanced cross section
- $\sigma \propto \lambda'^2$
- Only one gaugino
- $\chi^0_1 \rightarrow 1$ lepton + 2 jets

- pair/associated gaugino production
- production is R-parity conserving
- Each $\chi^0_1 \rightarrow 3$ leptons
Pair/associated production (LLE)

- Two gauginos, possible cascade decay to $\chi_1^0 \chi_1^0$
- $\chi_1^0$ is assumed to be the LSP
- Require prompt decay of $\chi_1^0 \rightarrow \lambda > \sim 0.01$
- Final state: 4 charged leptons & 2 neutrinos
- Analyses require 3 leptons and missing transverse energy (eee or ee\(\mu\) or e\(\mu\)\(\mu\) or \(\mu\)\(\mu\)\(\mu\) or eee\(\tau\)) and $\text{ME}_T$

\[
\chi_1^0 \rightarrow l l v
\]
Pair/associated production (LLE)

Three LLE couplings $\lambda_{121}, \lambda_{122}, \lambda_{133}$

leading to final states

- $\text{eee or eem} \ (\lambda_{121})$
- $\text{e\mu\mu or \mu\mu\mu} \ (\lambda_{122})$
- $\text{ee\tau} \ (\lambda_{133})$

![Graph showing data and signal events](image)

DØ, 360 pb$^{-1}$

Work in progress
Pair/associated production (LLE)

Lower limits on $\chi_1^0$ ($\chi_1^\pm$) up to 119 GeV (234 GeV)

Interpretation within the $\chi_1^0 - \chi_1^\pm$ mass plane

To be submitted to Physics Letters B
LHC reach for non-zero LLE couplings

Reach for 10 fb$^{-1}$
\[ \lambda_{123} = 10^{-3} \]
\[ \tan \beta = 2 \]

\[ q\bar{q} \rightarrow \chi \chi \rightarrow 4l + 2\nu + X \]
Search for neutral long lived particles

Selection criteria

- **Two muons** with $p_T > 10$ GeV
- **Require long lifetime** of the neutralino
  \[ 5 \text{ cm} < (\text{muon vertex} - \text{primary vertex}) < 20 \text{ cm} \]
  \((\chi_1^0 \text{ lifetime determined by } \lambda_{122})\)

![Diagram of neutralinos and muons](image)

Require two muons from a displaced vertex

0 data events found

0.75 ± 1.1 ± 1.1 events expected
Search for neutral long lived particles

http://www-d0.fnal.gov/Run2Physics/WWW/results,np.htm
Resonant Slepton Production via LQD

Final state: 2-muon & 2-jet
Three dominant signal channels:

1. $\tilde{\mu} \rightarrow \tilde{\chi}_1^0 \mu$
2. $\tilde{\mu} \rightarrow \tilde{\chi}_2^0 \mu$
3. $\tilde{\nu}_\mu \rightarrow \tilde{\chi}_1^\pm \mu$

- Analyze each channel separately
- Possible to reconstruct neutralino & slepton mass
- Cross section limits for every channel
- Combination within mSUGRA
Resonant Slepton Production via LQD

- possible to reconstruct neutralino and slepton mass

Reconstructed $\chi_1^0$ mass

Signal reference point:

$m(\tilde{\tau}) = 260$ GeV

$m(\tilde{\chi}) = 100$ GeV

$\tilde{\mu} \rightarrow \chi_1^0 \mu$

$\tilde{\mu} \rightarrow \chi_2^0, 3^0, 4^0 \mu$

$\tilde{\nu}_\mu \rightarrow \tilde{\chi}_{1,2}^\pm \mu$

Work in progress

DØ, 380 pb$^{-1}$
Resonant Slepton Production via LQD

Cross section limit

Interpretation within mSUGRA ($\tan\beta=5$, $\mu<0$, $A_0=0$)

To be submitted to Physical Review Letters
Perspectives for the LHC

Resonant slepton production

5σ reach

\[ \tan \beta = 2 \]
\[ \mu < 0 \]

LHC @ 30 fb\(^{-1}\)

Moreau, Perez, Polesello, Deliot
Conclusion

- Presented searches for R-parity violating SUSY
  - Pair/associated gaugino production (LLE)
  - Neutral long lived particles (LLE)
  - Resonant slepton production (LQD)
- No excess found in the data
- Very stringent limits were set

- Tevatron suffers from small cross sections and/or is constrained to a “small” parameter space

- At the LHC backgrounds will be challenging, especially for low (s)particle masses
LHC reach for non-zero LLE couplings

Reach for 10 fb⁻¹
\( \lambda_{123} = 10^{-3} \)
\( \tan \beta = 2 \)

Neutralino \( c\tau \) (mm)

\[ \tilde{\chi}^0 \rightarrow e^+ \bar{\nu}_\mu e^- + \mu^+ \bar{\nu}_e e^- + c.c. \]

\( \lambda_{121} = 0.05 \)

\( \lambda_{121} = 0.05, \tan \beta = 2, \mu < 0, A_0 = 0 \)
mSUGRA parameter space

\[ \tan \beta = 5, \mu < 0 \]