



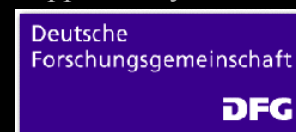
Search for R-parity violating Supersymmetry with the DØ Detector

Christian Autermann

on behalf of the DØ Collaboration

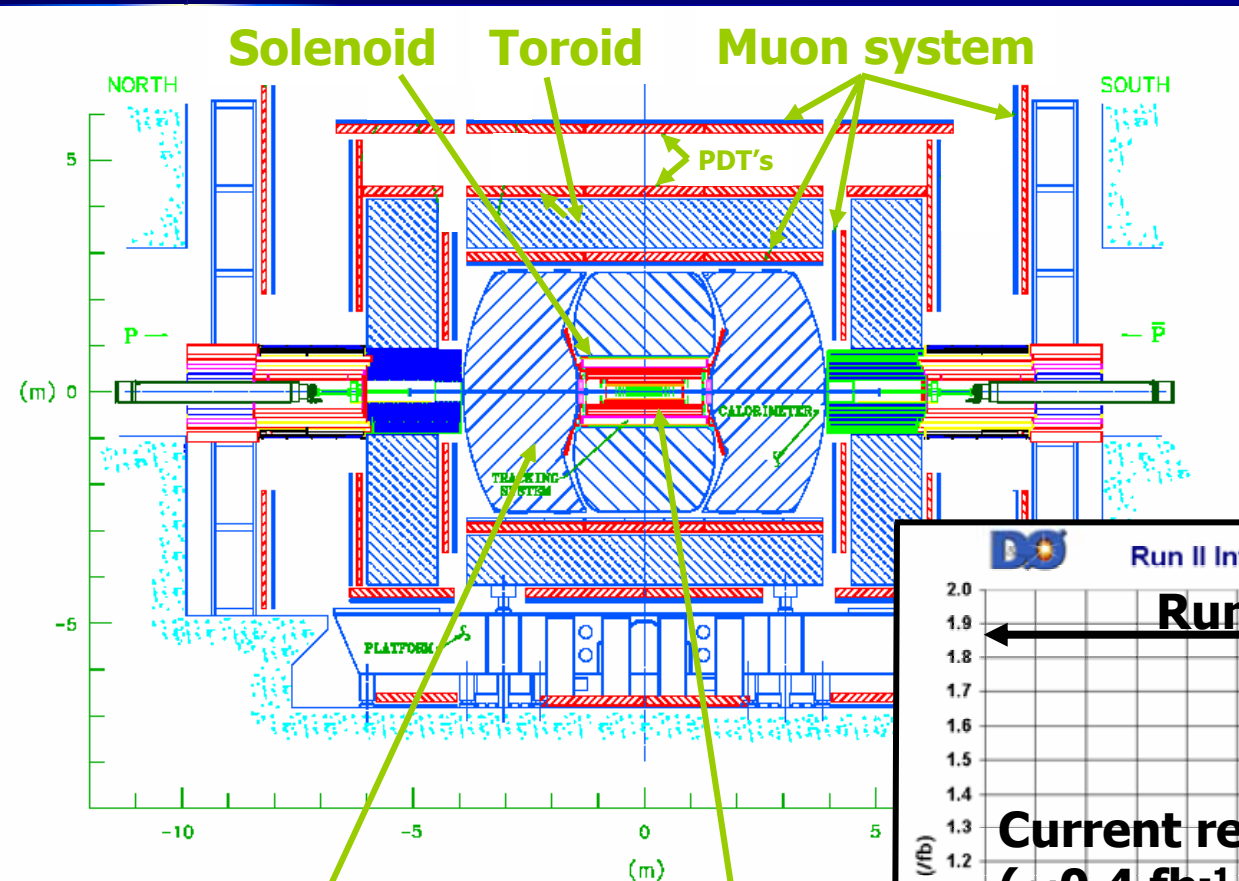
- Introduction to R-parity violating SUSY
- Three DØ searches for \mathcal{R}_p Supersymmetry:
 1. Short lived LSP in three-lepton final states
 2. Long lived LSP in di-muon final states
 3. Resonant second generation slepton production

Supported by:



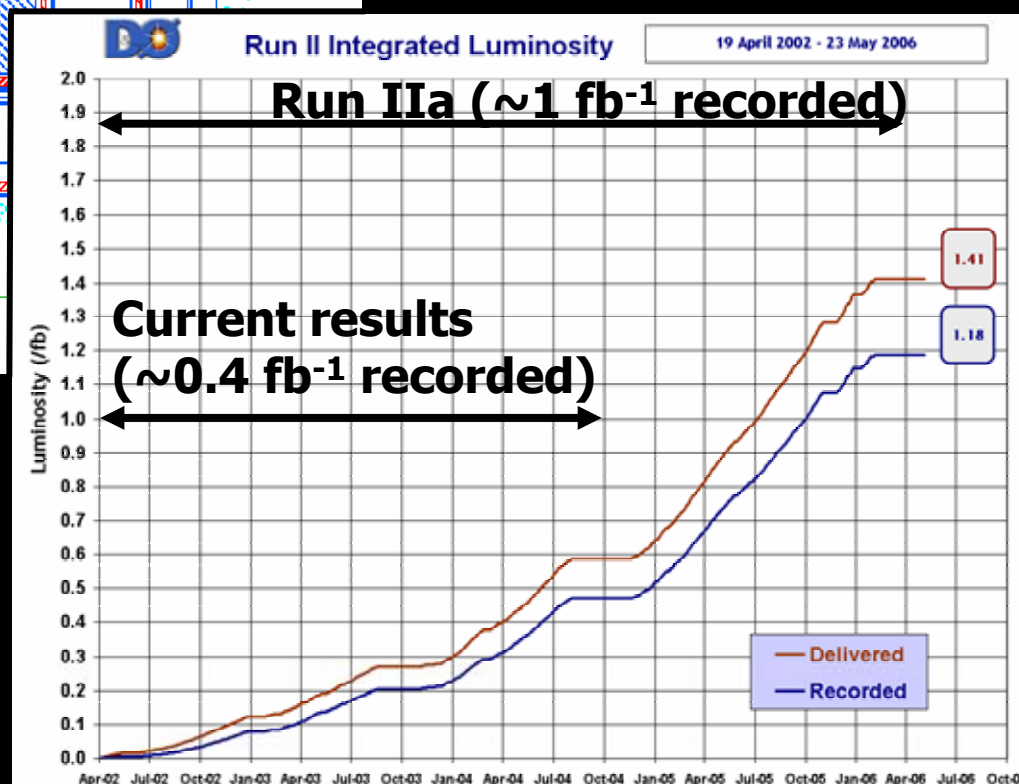


The DØ Experiment at the Tevatron Collider



$p\bar{p}$ -collider
 $\sqrt{s} = 1.96 \text{ TeV}$

Liquid Argon Calorimeter
Silicon and Scintillating Fiber Tracker





R-Parity Violation Supersymmetry

3

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

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

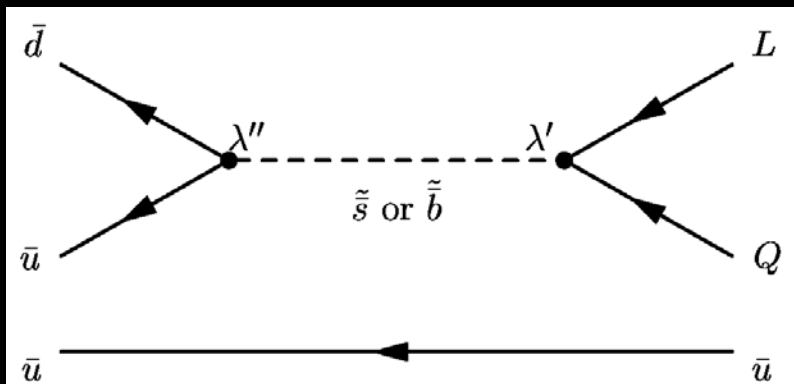
$$W = W_{MSSM} + W_{R_P}$$
$$W_{R_P} = \frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

R-parity violating
extension of the MSSM
 $i, j, k = 1, 2, 3$ generation indices

- Lepton number violation, $\Delta L=1$
- Gauge symmetry enforces $\lambda_{ijk} = -\lambda_{jik}$
→ 9 λ couplings

- Lepton number violation, $\Delta L=1$
- 27 λ' couplings

Only one coupling is assumed to be non-zero at a time!
(Stringent limits, i.e. from proton decay)



Chiral superfields:

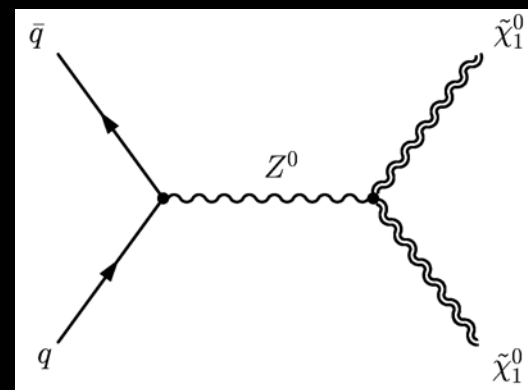
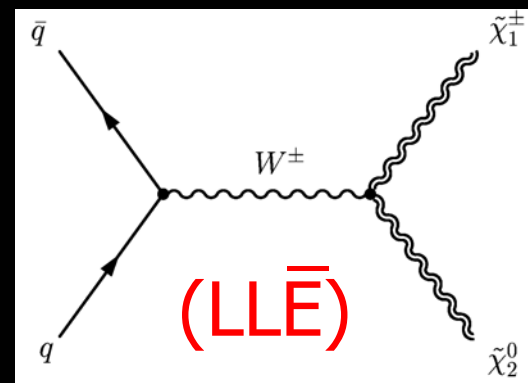
L: lepton doublet superfield
E: lepton singlet superfield
Q: quark doublet superfield
D: down-like quark singlet
 $\lambda, \lambda', \lambda''$: Yukawa couplings

LSP no candidate for dark
matter in RPV models

Sparticle Production at the Tevatron

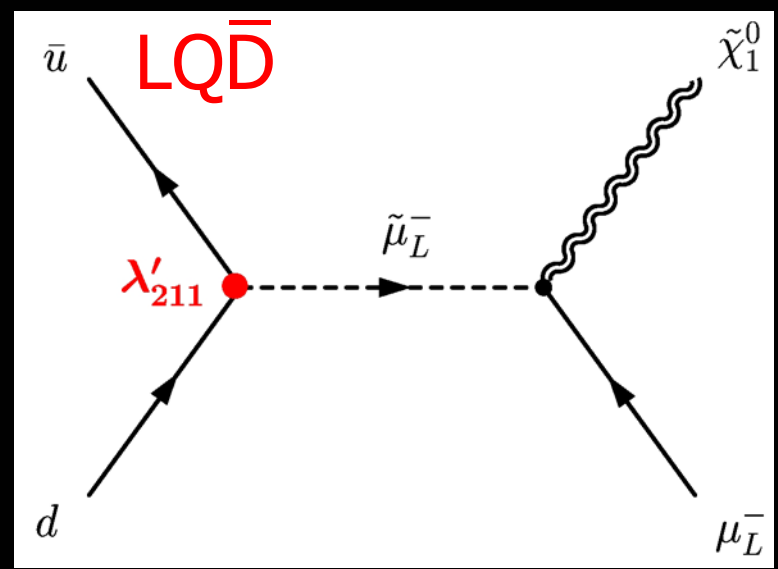
Search for LLE couplings

- pair/associated gaugino production
- production is R-parity conserving
- Each $\chi_1^0 \rightarrow 3$ leptons (2 charged & 1 neutrino) via RPV



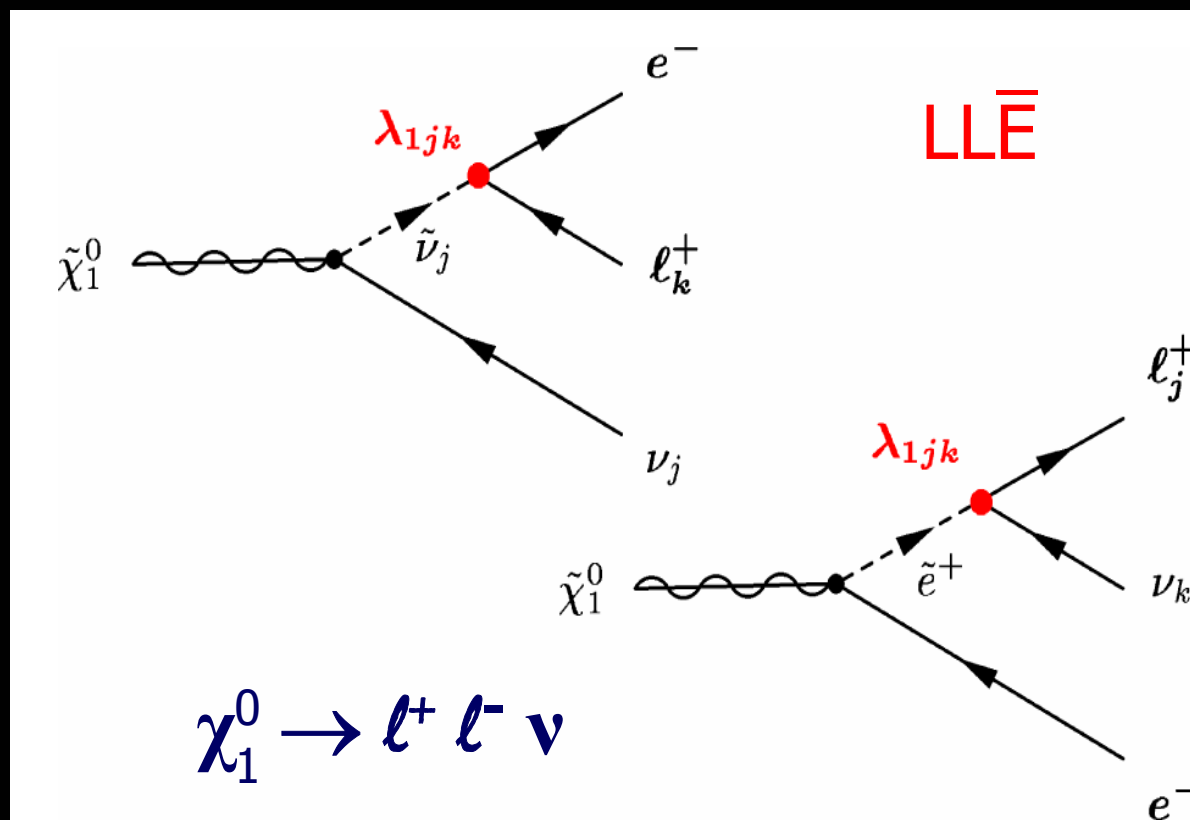
Search for LQD coupling

- R-parity violating production
- s-channel: **enhanced cross section**
- cross section $\sigma \propto (\lambda')^2$
- Only one gaugino
- $\chi_1^0 \rightarrow 1$ lepton + 2 jets via RPV



Pair/associated production (LLE, prompt decay)

- Require prompt decay of $\tilde{\chi}_1^0 \rightarrow \lambda > \sim 0.01$
- $\tilde{\chi}_1^0$ is assumed to be the LSP

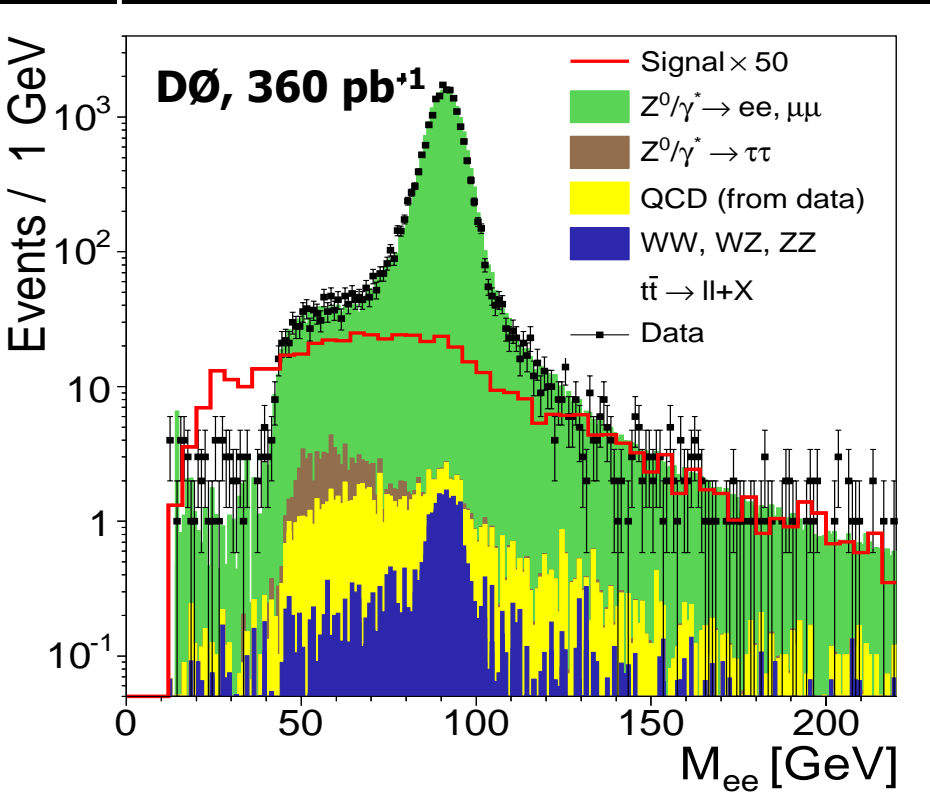


- Final state: 4 charged leptons & 2 neutrinos from one vertex
- Analyses require 3 leptons and missing transverse energy
- Three different LLE couplings are probed: $\lambda_{121}, \lambda_{122}, \lambda_{133}$



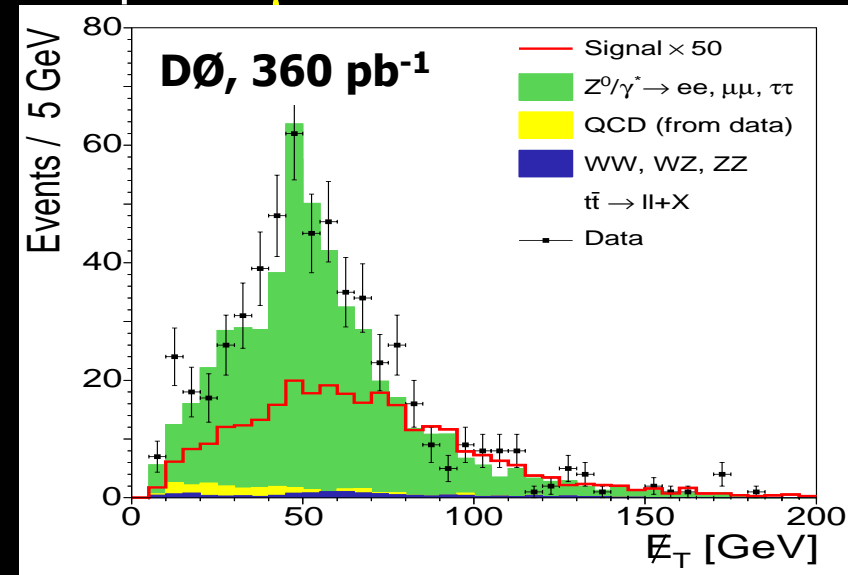
Pair/associated production (LLE, prompt decay)

Sample: $2 e$

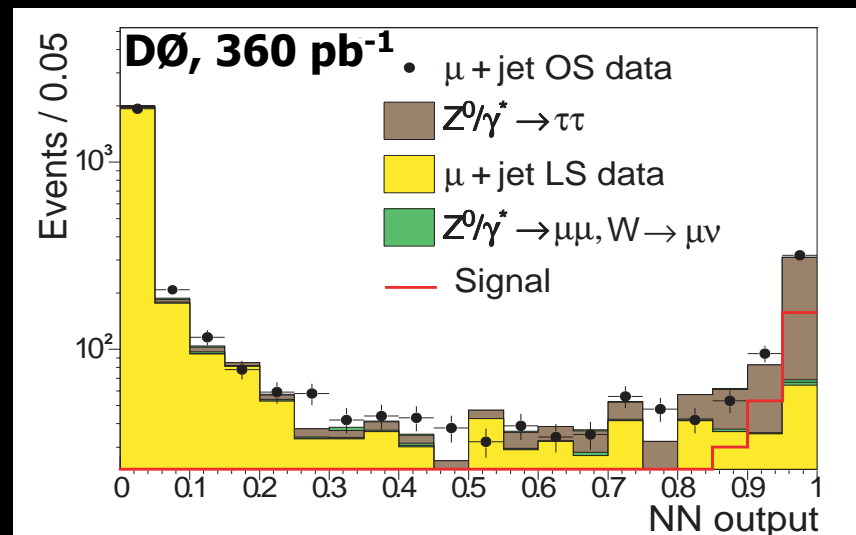


Signal scaled by factor 50
mSUGRA point:
 $m_0=1$ TeV, $m_{1/2}=280$ GeV
 $\tan\beta=5$, $\mu>0$, $A_0=0$

Sample: 2μ with Z^0 -veto



τ Identification: Neural Net





Pair/associated production (LLE, prompt decay)

1st analysis

eee or eeμ

electron $p_T > 20$ GeV
 electron $p_T > 20$ GeV
 electron or muon
 $p_T > 10$ GeV

missing $E_T > 15$ GeV

found events 0
 expected SM $0.9^{+0.4}_{-0.1} \pm 0.1$

2nd analysis

μμμ or μμε

muon $p_T > 15$ GeV
 muon $p_T > 8$ GeV
 muon or electron
 $p_T > 4$ GeV $p_T > 5$ GeV

missing $E_T > 10$ GeV

sum lepton $p_T > 50$ GeV
 additional 2D cut ($M_{\mu\mu}, \cancel{E}_T$)

found events 0
 expected SM $0.4 \pm 0.1 \pm 0.1$

3rd analysis

eet

electron $p_T > 10$ GeV
 electron $p_T > 10$ GeV
 tau neural net identification
 $p_T > 10$ GeV

remove Z-peak $M_{\mu\mu} > 80$ GeV
 $\cancel{E}_T / \sqrt{S_T} > 1.5$ GeV^{1/2}

found events 0
 expected SM $1.3 \pm 1.7 \pm 0.5$

Combination of all three analyses into limits on the three channels

λ_{121}

λ_{122}

λ_{133}

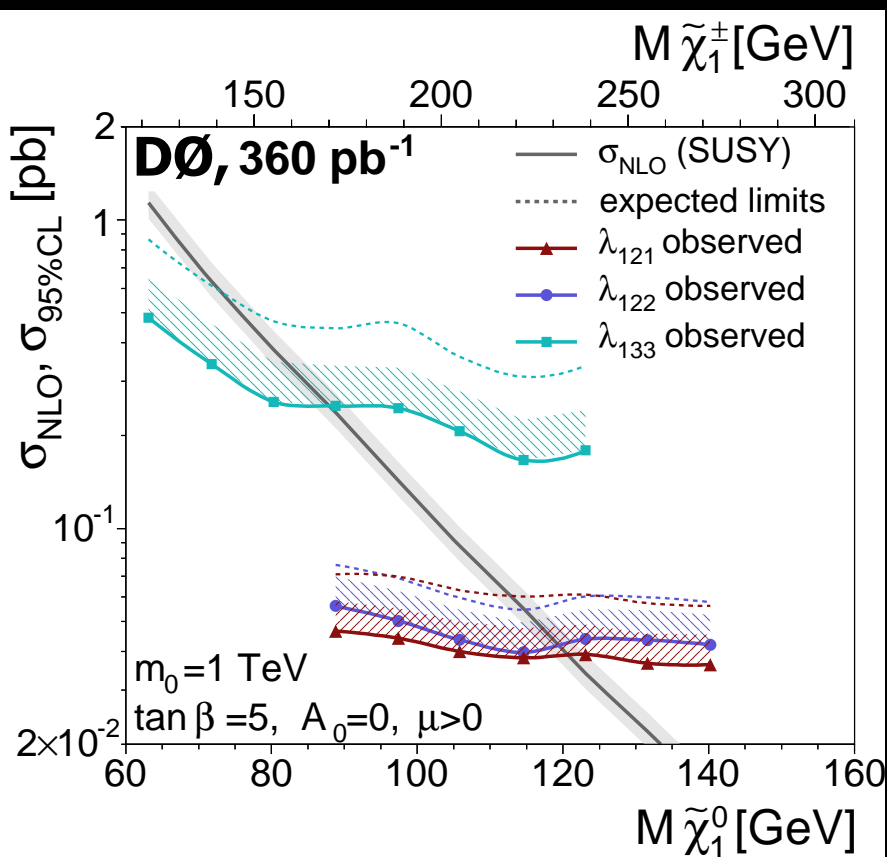


Pair/associated production (LLE, prompt decay)

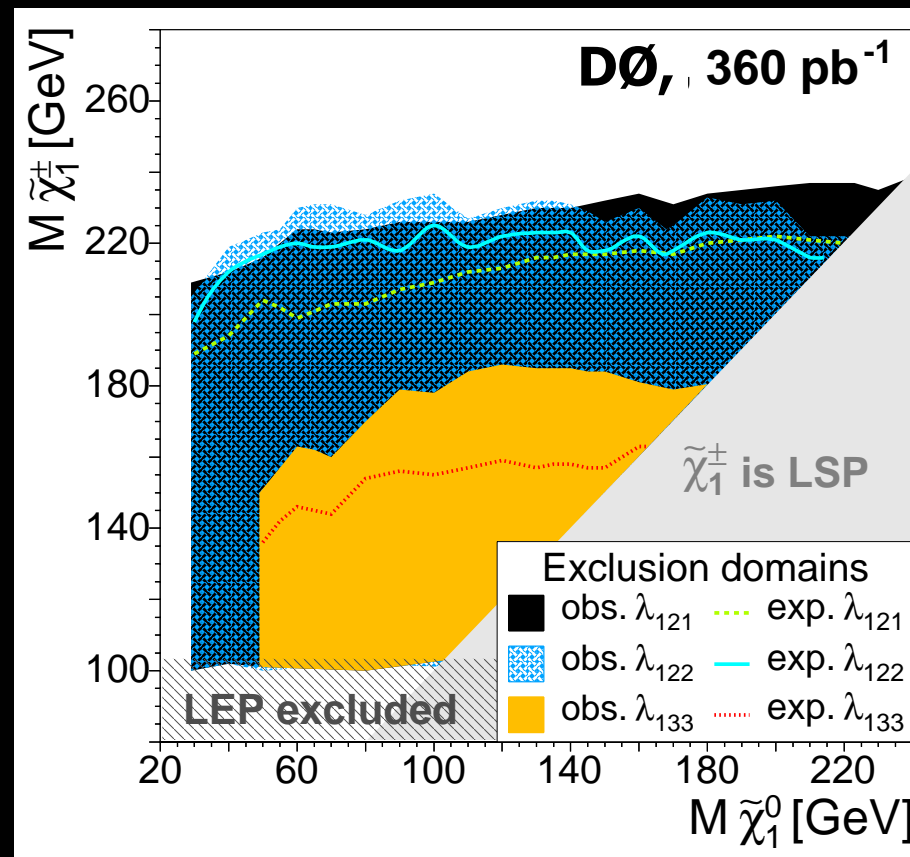
Accepted by Physics Letters B

Lower limits on χ_1^0 (χ_1^\pm)
up to **119 GeV** (**234 GeV**)

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



mSUGRA



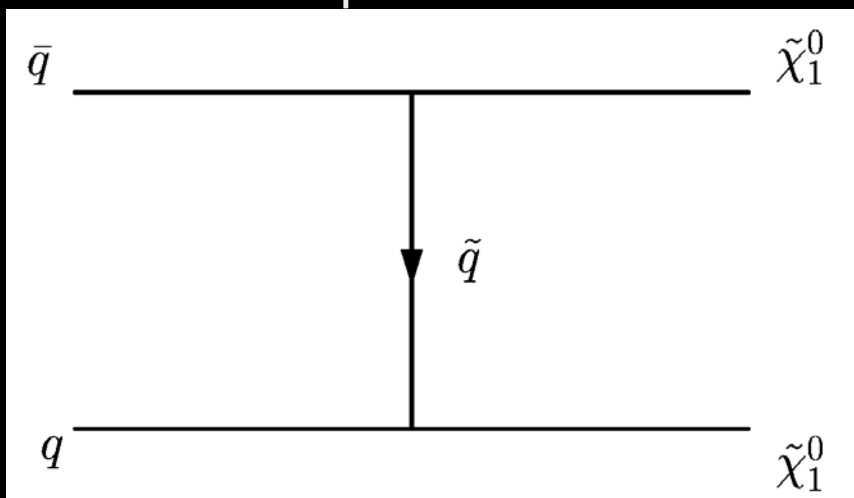
no GUT MSSM

(no relation between M1 and M2)

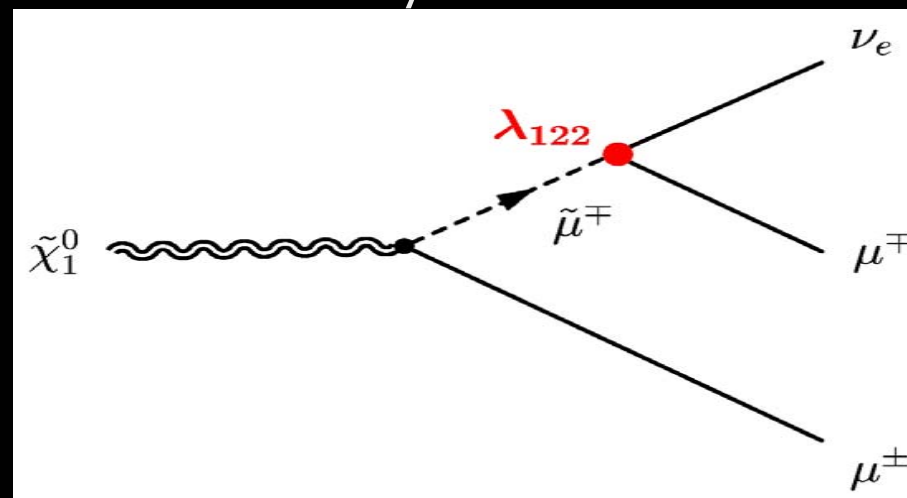
Specific analysis for very small λ_{122} coupling:

→ **Long lifetime** of the neutralino, $c \cdot \tau = \mathcal{O}(\text{cm})$, mass = $\mathcal{O}(\text{GeV})$

Pair production



Decay

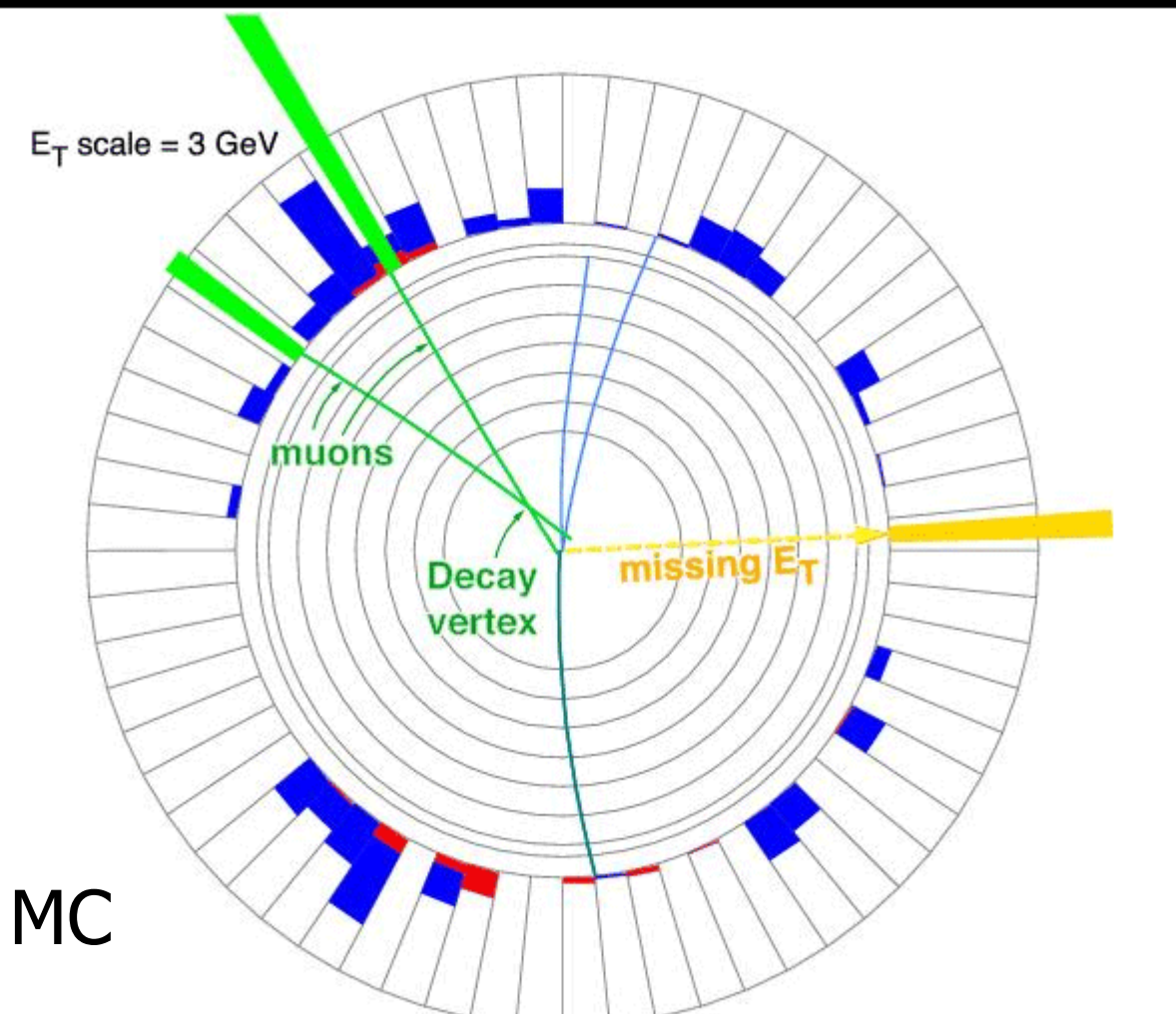


Require only observation of **one neutralino decay**.

Selection criteria: **Two muons** with $p_T > 10 \text{ GeV}$

$M_1 = 3, 5, 8, 10 \text{ GeV}$, $M_2 = 200 \text{ GeV}$, $M_3 = 400 \text{ GeV}$
 $\tan\beta = 10$, $\mu = -5000$, $\lambda_{122} < 1.0$
 $M_{\tilde{b}_1} = 1.5 \text{ TeV}$, $M_{\tilde{q}} = 300 \text{ GeV}$

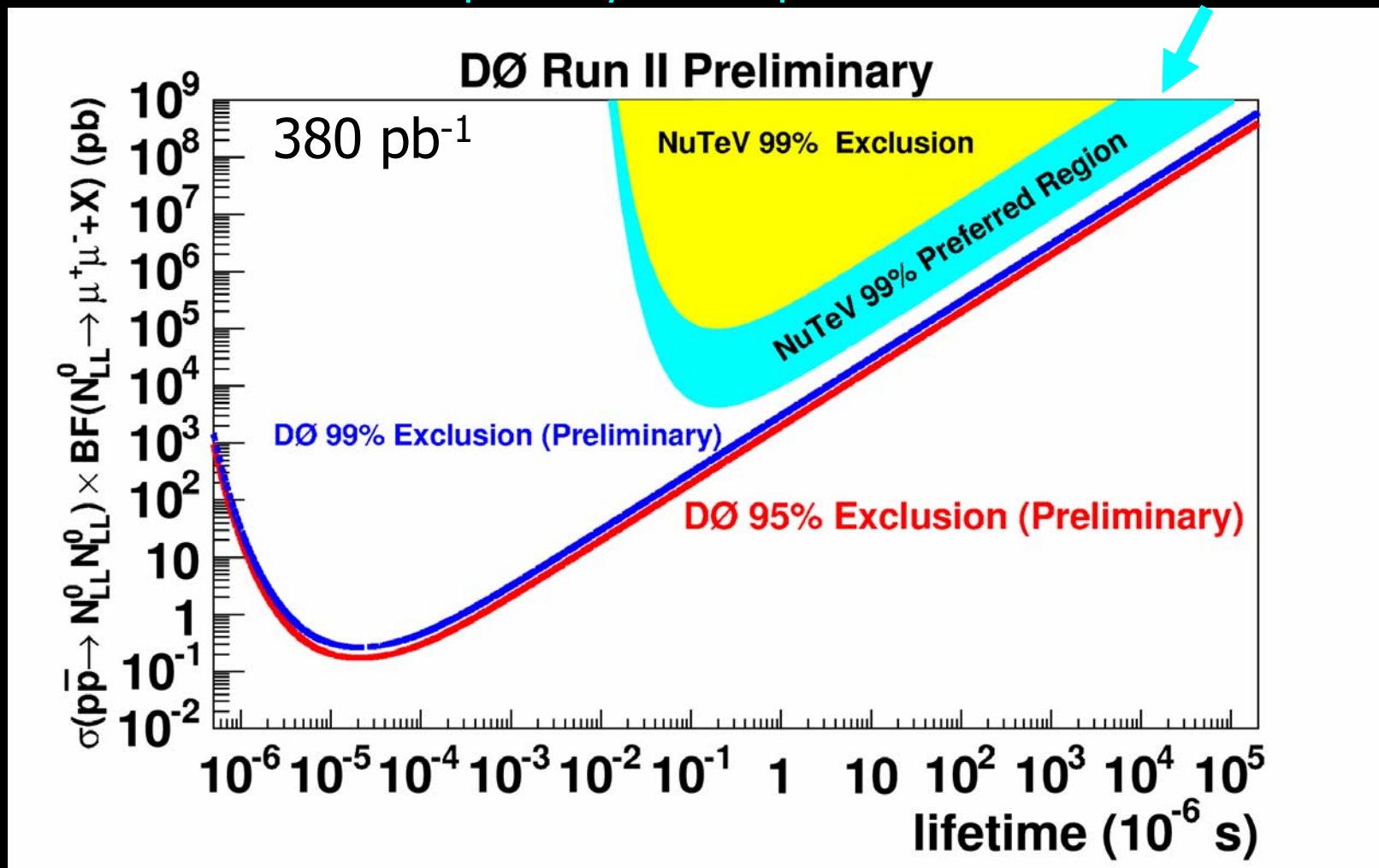
Long lifetime of the neutralino leads to displaced vertex
 $5 \text{ cm} < (\text{decay radius}) < 20 \text{ cm}$
 (χ_1^0 lifetime determined by λ_{122})



Result

0 data events found
 $0.8 \pm 1.1 \pm 1.1$ SM
 events expected

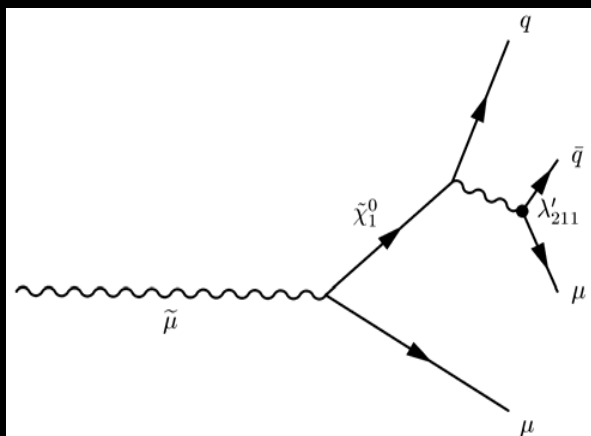
Inspired by 3 unexpected NuTeV di-muon events



Final state: **2-muon & 2-jet**

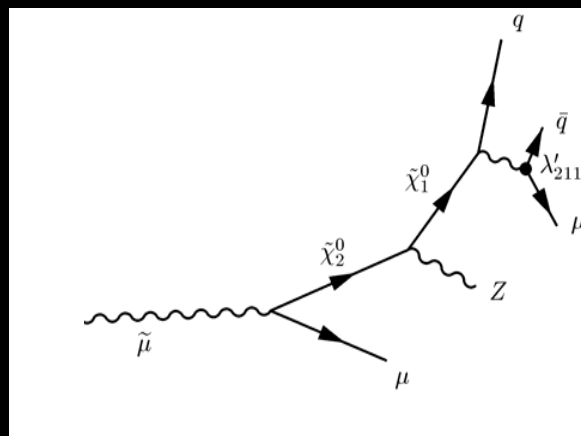
Three dominant signal channels:

1.



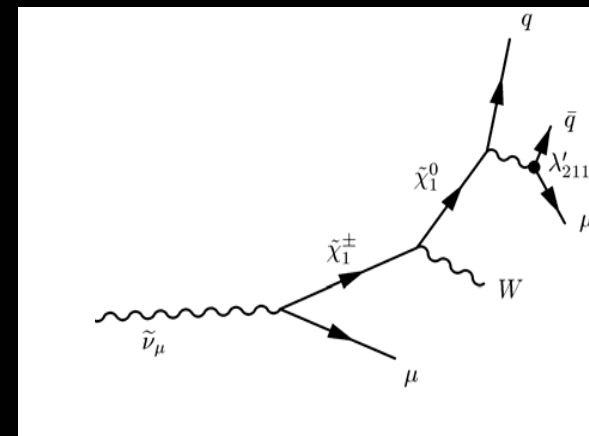
$$\tilde{\mu} \rightarrow \tilde{\chi}_1^0 \mu$$

2.



$$\tilde{\mu} \rightarrow \tilde{\chi}_2^0 \mu$$

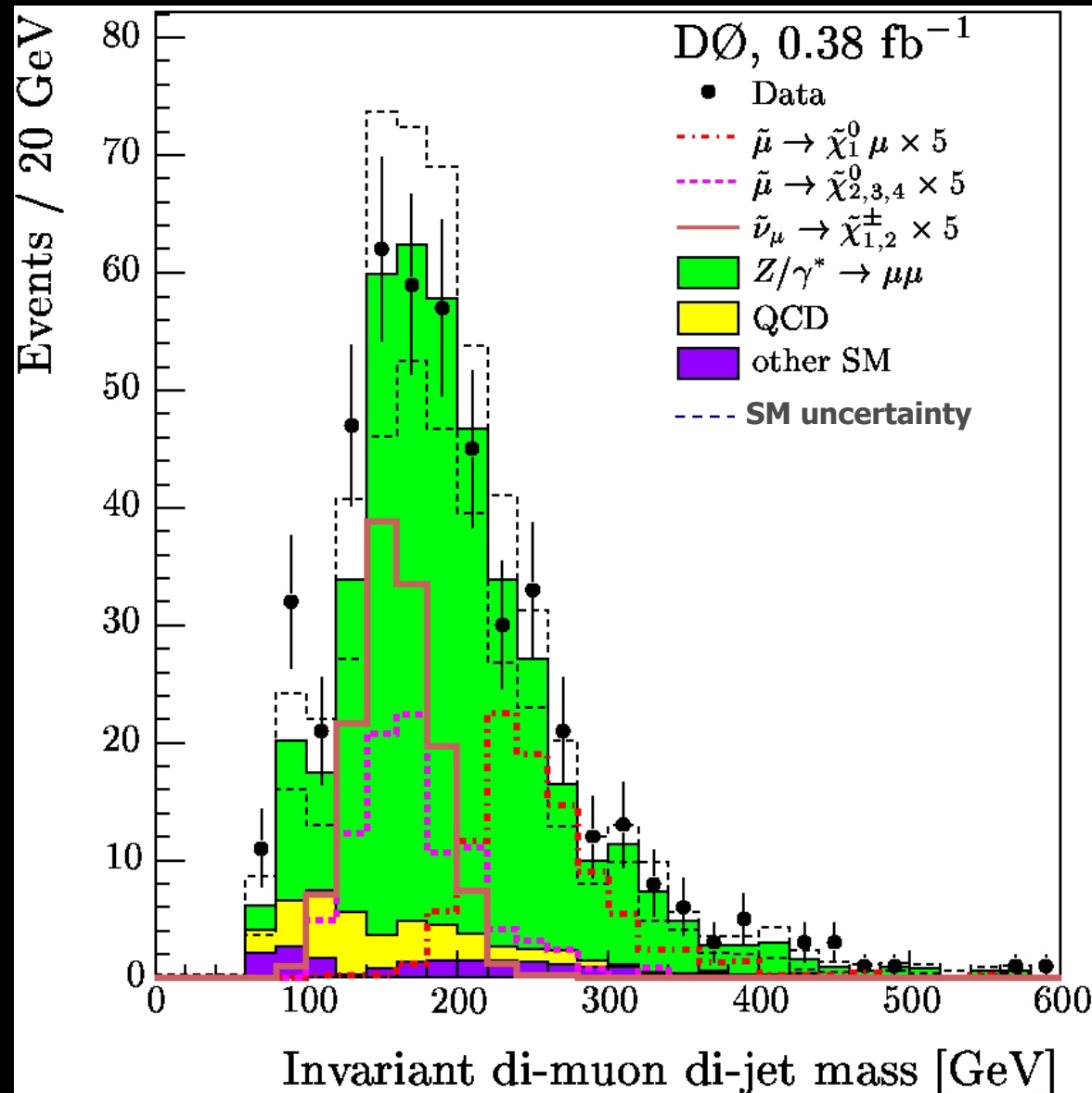
3.



$$\tilde{\nu}_\mu \rightarrow \tilde{\chi}_1^\pm \mu$$

- Each channel analyzed separately
- Possible to **reconstruct neutralino & slepton** mass
- **Cross section limits** for every channel
- **Combination** within mSUGRA

Reconstructed slepton candidate mass:



Signal reference point :

$$m(\tilde{l}) = 260 \text{ GeV}$$

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

Results for this point:

data SM expectation

| | | |
|--|----|------------------------|
| $\tilde{\mu} \rightarrow \tilde{\chi}_1^0 \mu$ | 14 | $11.9 \pm 2.1 \pm 1.6$ |
| $\tilde{\mu} \rightarrow \tilde{\chi}_{2,3,4}^0 \mu$ | 28 | $25.4 \pm 3.2 \pm 5.4$ |
| $\tilde{\nu}_\mu \rightarrow \tilde{\chi}_{1,2}^\pm \mu$ | 8 | $6.5 \pm 1.6 \pm 1.6$ |

The final selection and the results for each point depend on the neutralino and slepton masses of the point under study.

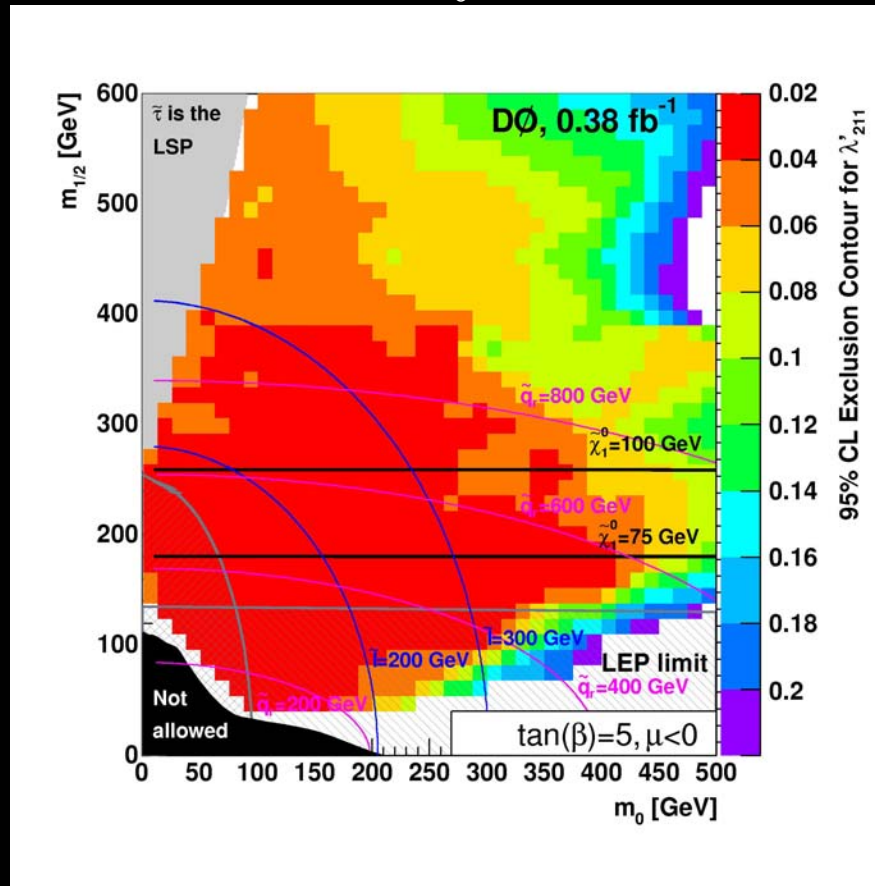
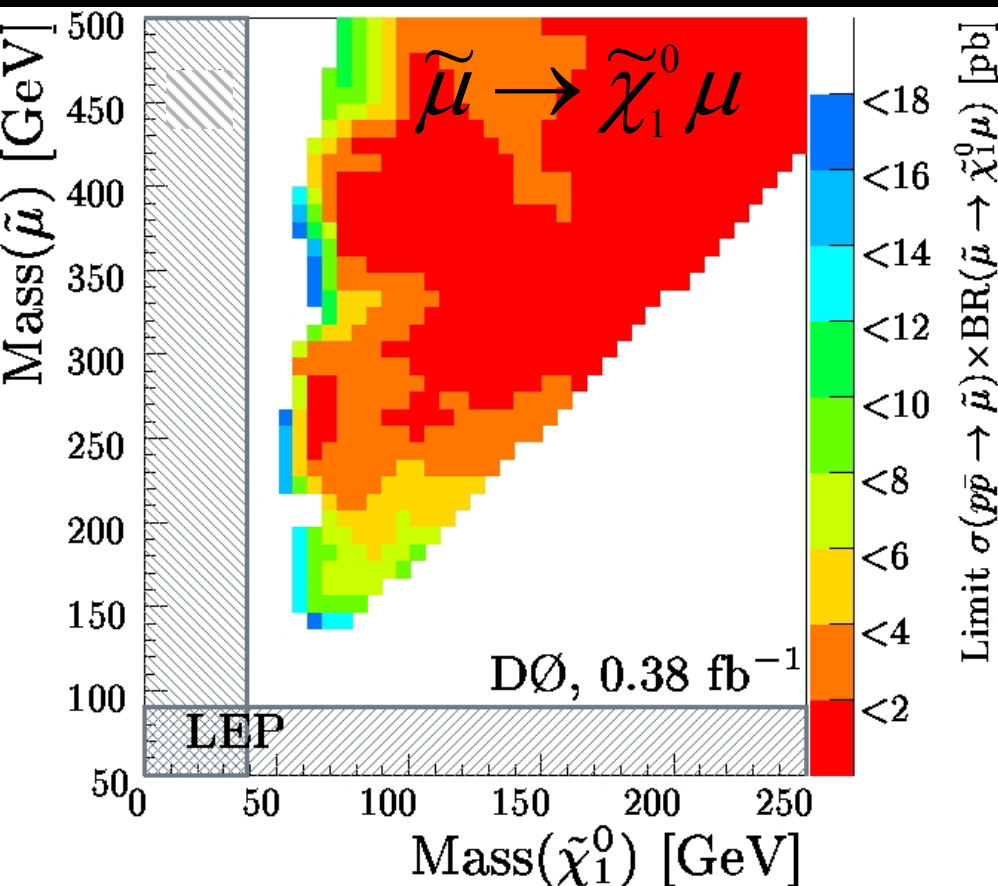


Resonant Slepton Production via LQD

Submitted to Physical Review Letters

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

Cross section limit



e.g.: Exclude $m(\tilde{\tau}) < 358 \text{ GeV}$ for $\lambda'_{211}=0.09$

$D\phi$ Run I excluded $m(\tilde{\tau}) < 280 \text{ GeV}$ for $\lambda'_{211}=0.09$ and $m(\tilde{\chi}_1^0)=200 \text{ GeV}$



Conclusion

Search for
RPV SUSY

- DØ searches for R-parity violating SUSY:
 - **LLE**: Pair/associated gaugino production in tri-lepton final states (arxiv:hep-ex/0605005)
 - **LLE**: Neutral long lived particles in di-muon final states
 - **LQD**: Resonant slepton production in di-muon di-jet final states (arxiv:hep-ex/0605010)
- No excess found in the data
- Very stringent limits were set
- More than twice as much data is already recorded, new data will come in