Search for R-parity Violation at the Tevatron

On behalf of the CDF and DØ Collaborations

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- s-particle resonant production: resonant production of smuon and muon sneutrino, run I results and run II prospects (DØ)

R-parity

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

- $R = +1$ for SM particles, and -1 for SUSY particles
- Conserved R-parity: allows to suppress processes violating lepton L and baryon B numbers
- R-parity violation: Cannot be excluded
  $W_{RPV} = \lambda_{ijk} L_i L_j E_k^C + \lambda'_{ijk} Q_i L_j D_k^C + \lambda''_{ijk} U_i^c D_j^c D_k^C + \epsilon_i L_i H_2$
  45 new Yukawa couplings

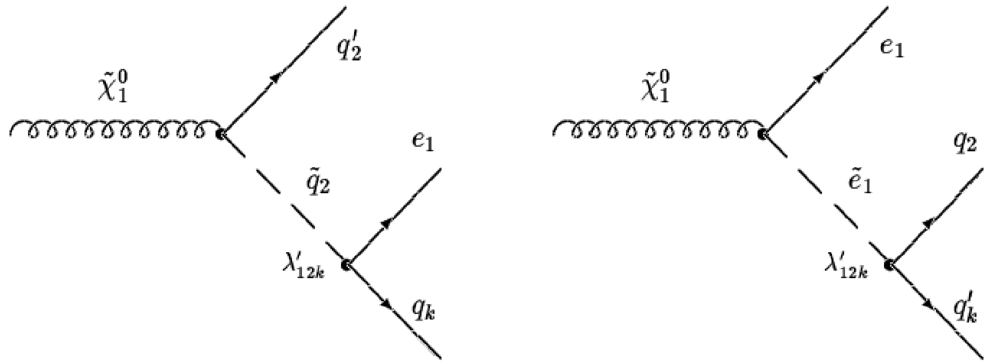
Experimental consequences of R-parity violation

- LSP is unstable: Production with R-parity conserved, Decay with R-parity violated, Cross section proportional to coupling
  - Without displaced vertex: sensitivity $\lambda, \lambda', \lambda'' > 10^{-4}$, Couplings difficult to determine, disappearance of missing E_T signal due to decay of LSP, increase the number of jets (baryon number violation) or the number of leptons (lepton number violation)
  - With displaced vertex: sensitivity $10^{-9} < \lambda, \lambda', \lambda'' < 10^{-4}$, coupling can be measured
- Single production of $R = -1$ scalars: Production with R-parity violated, decay to the LSP ($\tilde{\chi}$) with R-parity conserved, decay of the LSP with R-parity violated, cross section proportional to the coupling squared, sensitivity $\lambda', \lambda'' > 10^{-2} - 10^{-3}$, coupling and sparticle masses can be measured

R-parity violation at Tevatron

Process	DØ	CDF
$\tilde{\chi}^0$ pair production, decay with R parity violated (λ')	yes	yes
$\tilde{\chi}^0$ pair production, decay with R parity violated (λ)		yes
Stop production (R-parity conserved), decay with R parity violated (λ')		yes
Resonant production of $\tilde{\nu}, \tilde{\mu}$ production with R parity violated (λ'), decay to LSP (R parity conserved) (λ') decay of LSP (R parity violated) (λ')	yes	

λ' coupling: $\tilde{\chi}^0$ pair production (DØ)



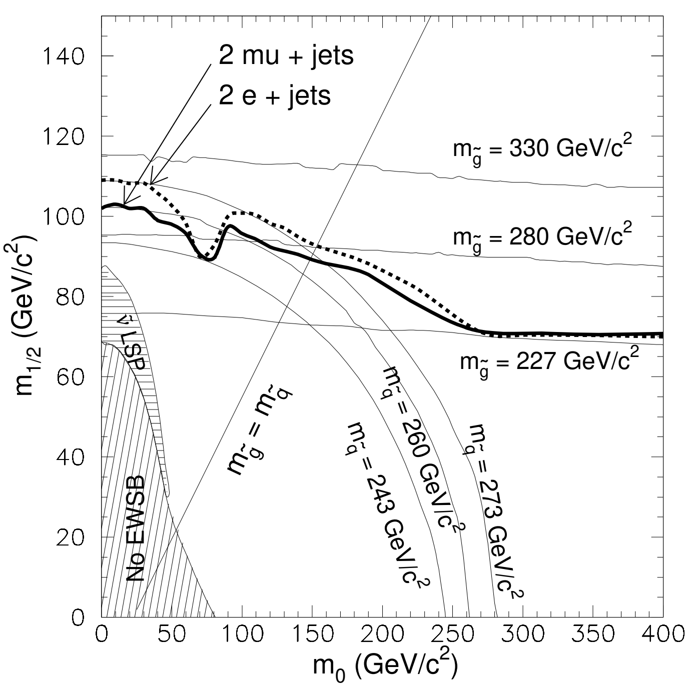
- All pair production processes considered
- One dominant coupling: one of the six λ'_{1jk} (electron) and λ'_{2jk} (muon) with j=1,2, k=1,2,3. LSP decays to 1 electron/muon and 2 jets
- Channel: $\geq$ 2 electrons, muons + $\geq$ 4 jets (offline cuts: $E_T^{el} \geq 15$, 10 GeV, $E_T^{jets} \geq 15$ GeV, M_{ee} not in the 76-106 mass range
- Background: Drell Yan, $t\bar{t}$, $Z \to \tau\tau \to ee + ...$, $Z \to \mu\mu + jets$, $WW \to \mu\mu$, misidentication of jets as electrons

λ' coupling: $\tilde{\chi}^0$ pair production (DØ)

- Results in e channel: $\mathcal{L} = 99 \pm 4.4$ pb^{-1}, 2 events observed, exp. background: $1.8 \pm 0.2 \pm 0.3$
- Results in μ channel: $\mathcal{L} = 78 \pm 4$ pb^{-1}, 0 event observed, exp. background: $0.18 \pm 0.031 \pm 0.02$

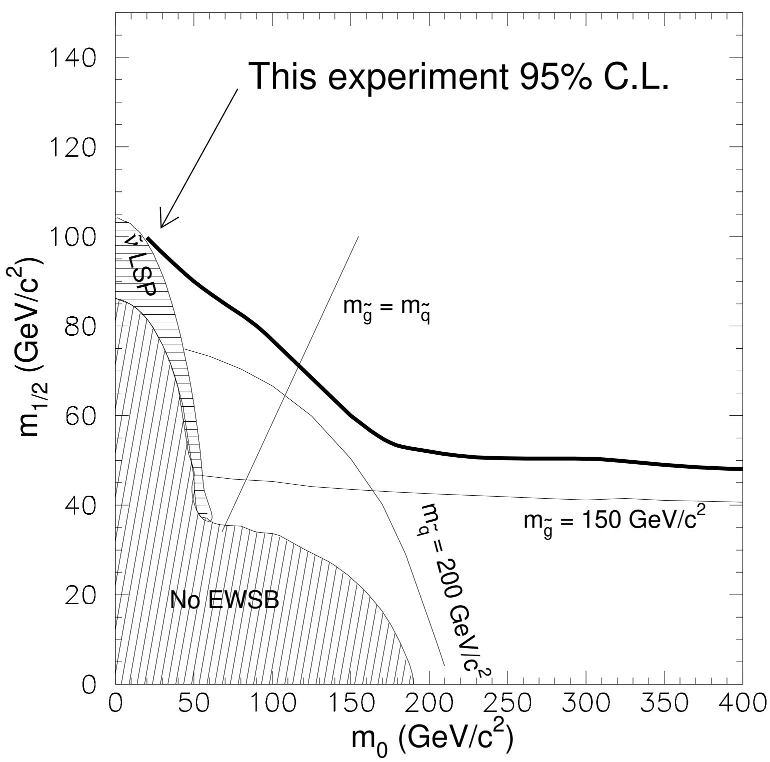
Exclusion contours for $\tan\beta = 2$, $A_0 = 0$, $\mu < 0$

Electron channel: PRL 83 (1999) 4476,
Muon channel: preliminary



λ' coupling: $\tilde{\chi}^0$ pair production (DØ)

Exclusion contours for $\tan\beta = 6$, $A_0 = 0$, $\mu < 0$
in the muon channel



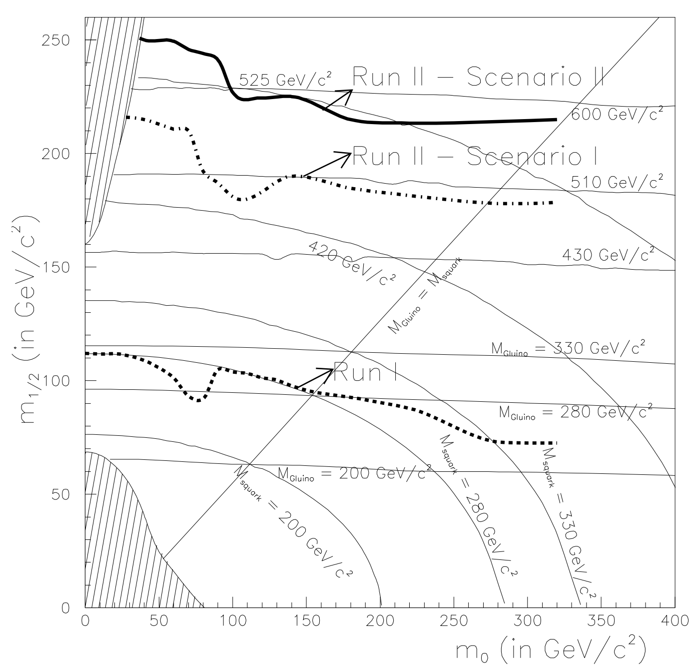
DØ preliminary

λ' coupling: $\tilde{\chi}^0$ pair production (DØ)

Prospects for Run II a in the dielectron channel,
$\mathcal{L} = 2\ \mathrm{fb}^{-1}$, $A_0 = 0$, $\mu < 0$, $\tan\beta = 2$

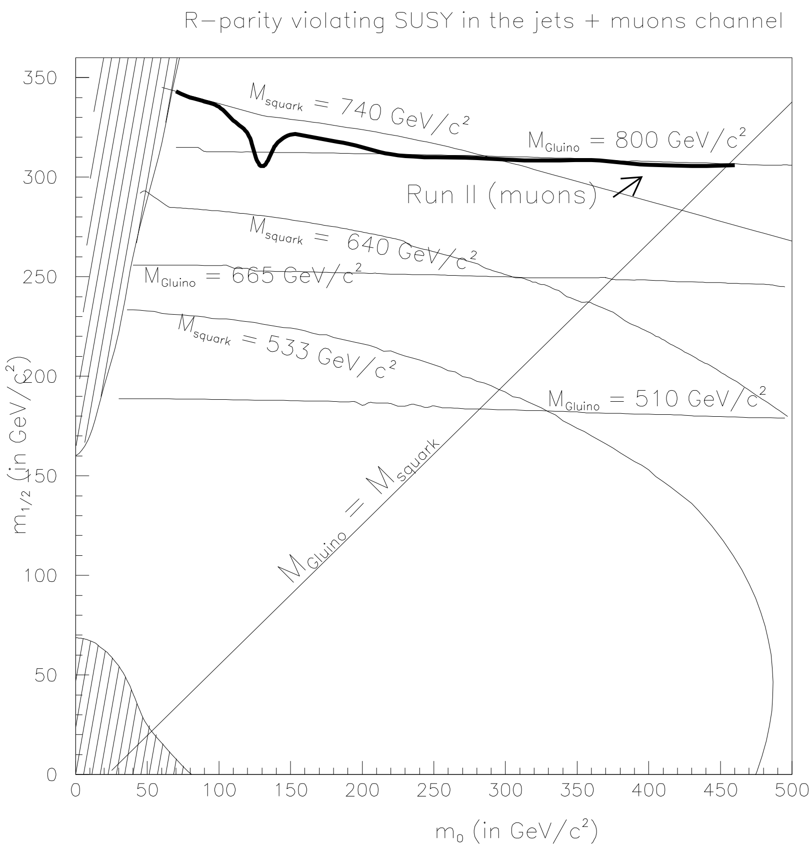
- Scenario I: Improvement due to luminosity increase only
- Scenario II: In addition, electron misidentification reduced by a factor 2 due to magnetic field, and improved detector

$M_{\tilde{g}} \to 500$ GeV, $M_{\tilde{q}} \to 400$ GeV



λ' coupling: $\tilde{\chi}^0$ pair production (DØ)

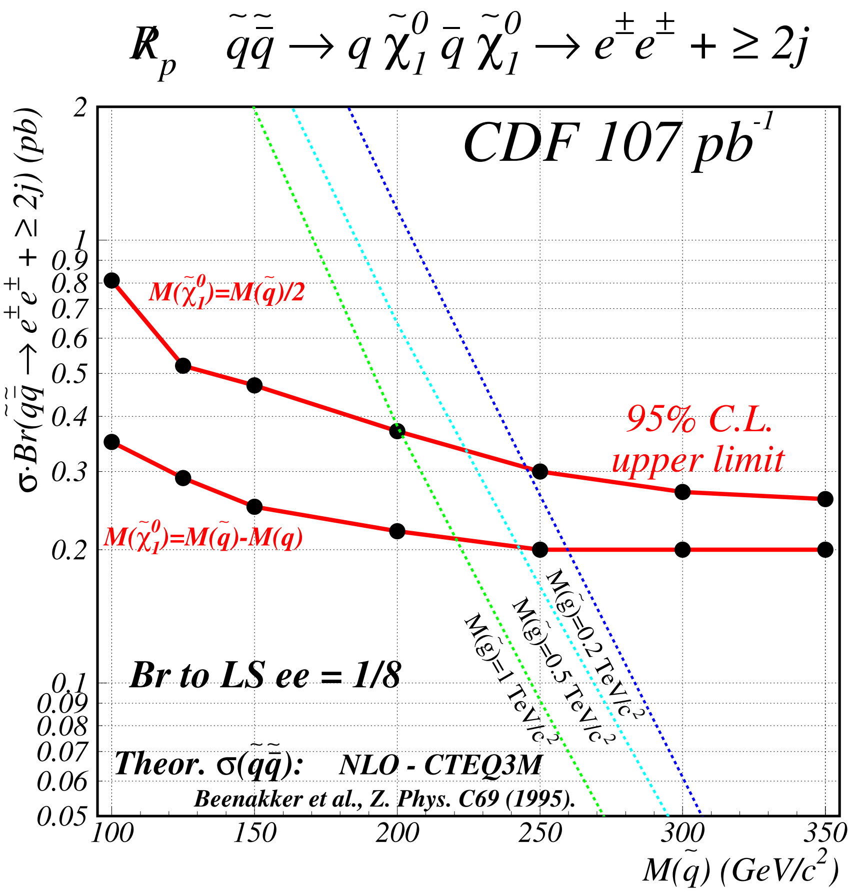
Prospects for Run II a in the dimuon channel, $\mathcal{L} = 2\ \mathrm{fb}^{-1}$, $A_0 = 0$, $\mu < 0$, $\tan\beta = 2$, valid for $\lambda'_{2jk} \geq 10^{-3}$



λ' coupling: $\tilde{\chi}^0$ pair production (CDF)

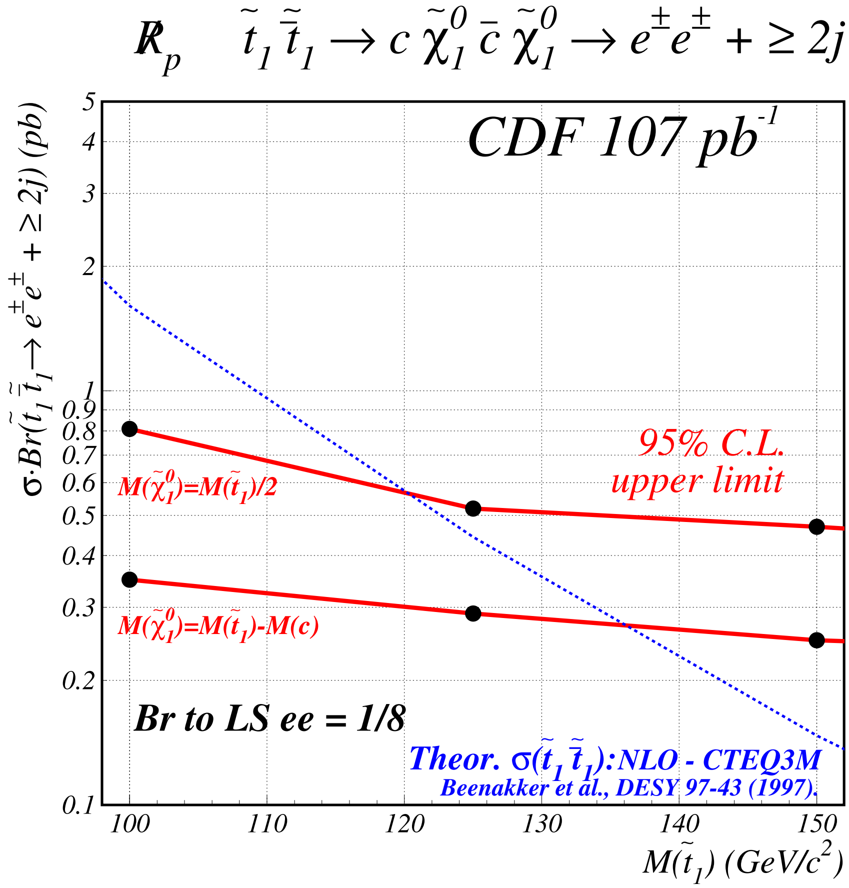
$$\tilde{q}\bar{\tilde{q}} \to (q\tilde{\chi}_1^0)(\bar{q}\tilde{\chi}_1^0) \to (qqde^\pm)(qqde^\pm) + HC$$
$$\tilde{t}\bar{\tilde{t}} \to (c\tilde{\chi}_1^0)(\bar{c}\tilde{\chi}_1^0) \to (cqde^\pm)(\bar{c}qde^\pm) + HC$$

Exclusion for $M_{\tilde{q}},\ M_{\tilde{t}}$



PRL 83 (1999) 2133

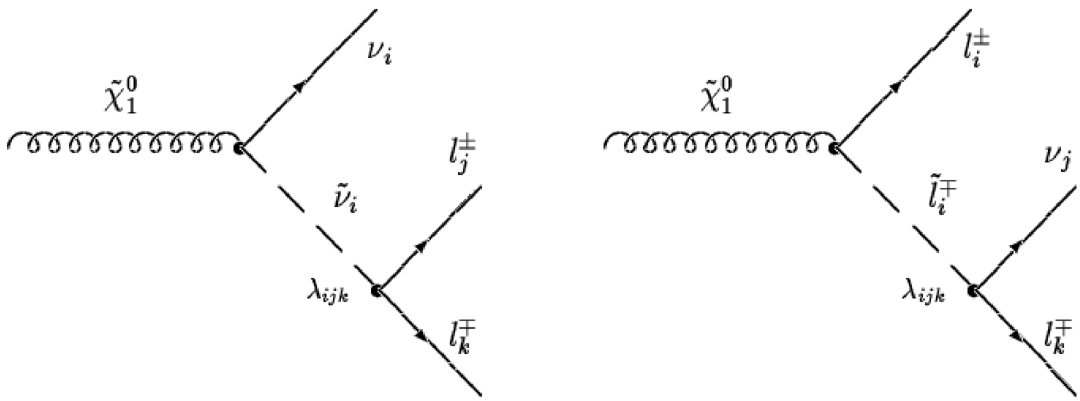
λ' coupling: $\tilde{\chi}^0$ pair production (CDF)



PRL 83 (1999) 2133

λ coupling: $\tilde{\chi}^0$ decay (CDF)

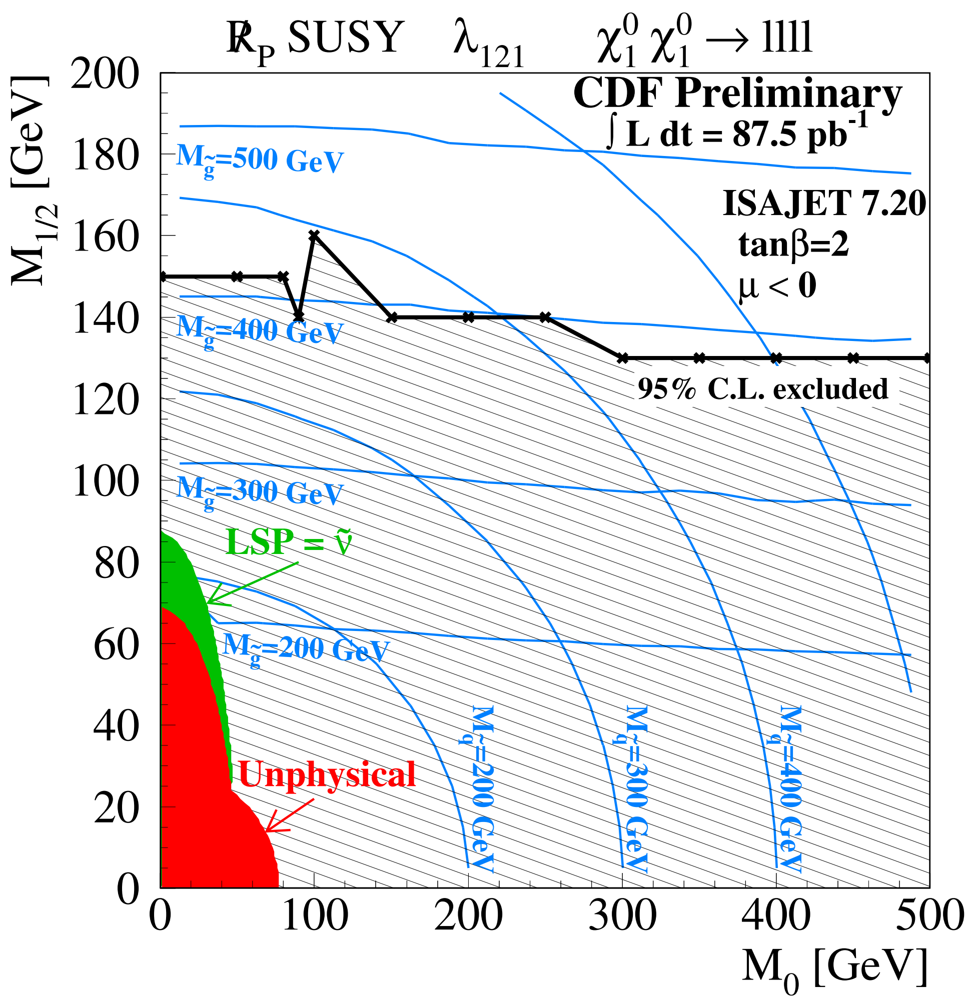
Decay of $\tilde{\chi}_1^0$ assuming λ_{121} is dominant



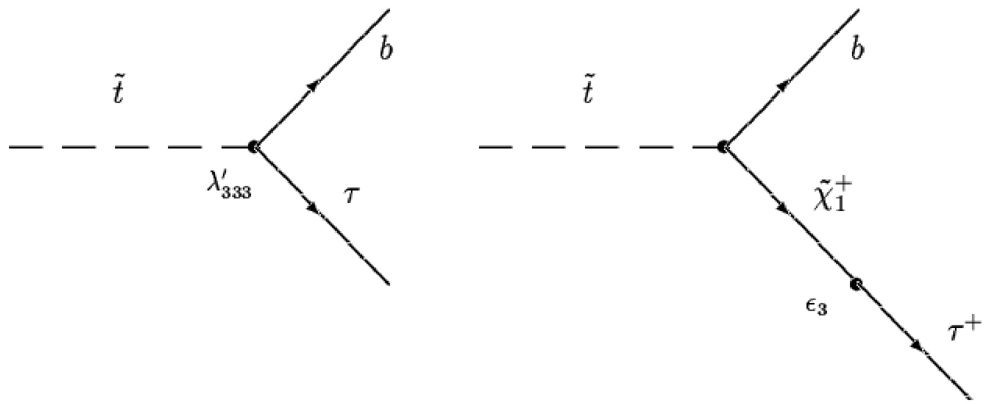
$$p\bar{p} \to SUSY \to \tilde{\chi}^0\tilde{\chi}^0 \to llll + X$$

- Require 4 leptons (electrons or muons): E_T of at least 12, 5, 5, 5, GeV
- Leptons should be isolated: $\Delta R^{ll} > 0.4$
- Result: One signal event $ee\mu\mu$, muons are not isolated (suggestive of a heavy flavour event)
- Expected background: 1.2 ± 0.2 event

λ coupling: $\tilde{\chi}^0$ decay (CDF)



Case of λ': RPV stop decay (CDF)



- Only λ'_{333} and ϵ_3 are non zero
  $\tilde{t}\bar{\tilde{t}} \to (b\tau^+)(b\tau^-) + X$

- τ_1 decays leptonically: isolated l ($E_T > 10$ GeV), missing E_T

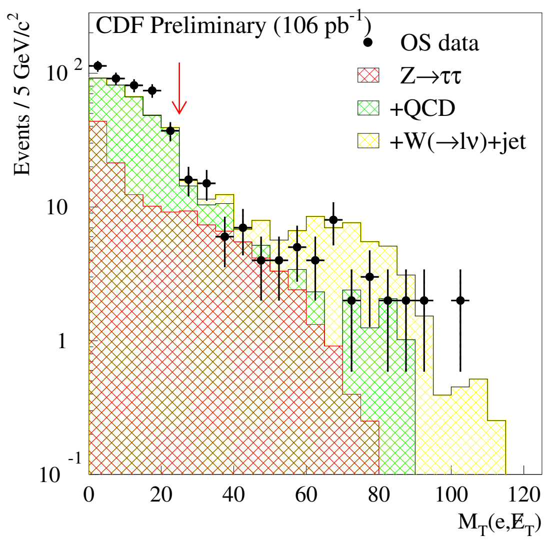
- τ_2 decays hadronically: in R <0.4:
  1 or 3 prong ($|\Sigma Q| = 1$), $N_{\pi^0} < 3$,
  $p_T^\tau = p_T^{\pi^0+trk} > 15$ GeV, $M_{\pi^0+trk} < 1.8$ GeV

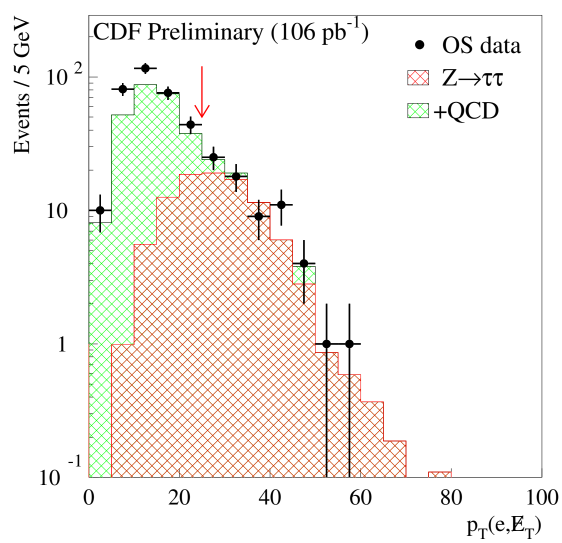
- Estimate $\sigma_{\tilde{t}\bar{\tilde{t}}}$ relative to $\sigma_{Z\to\tau\tau}$

Case of λ': RPV stop decay (CDF)

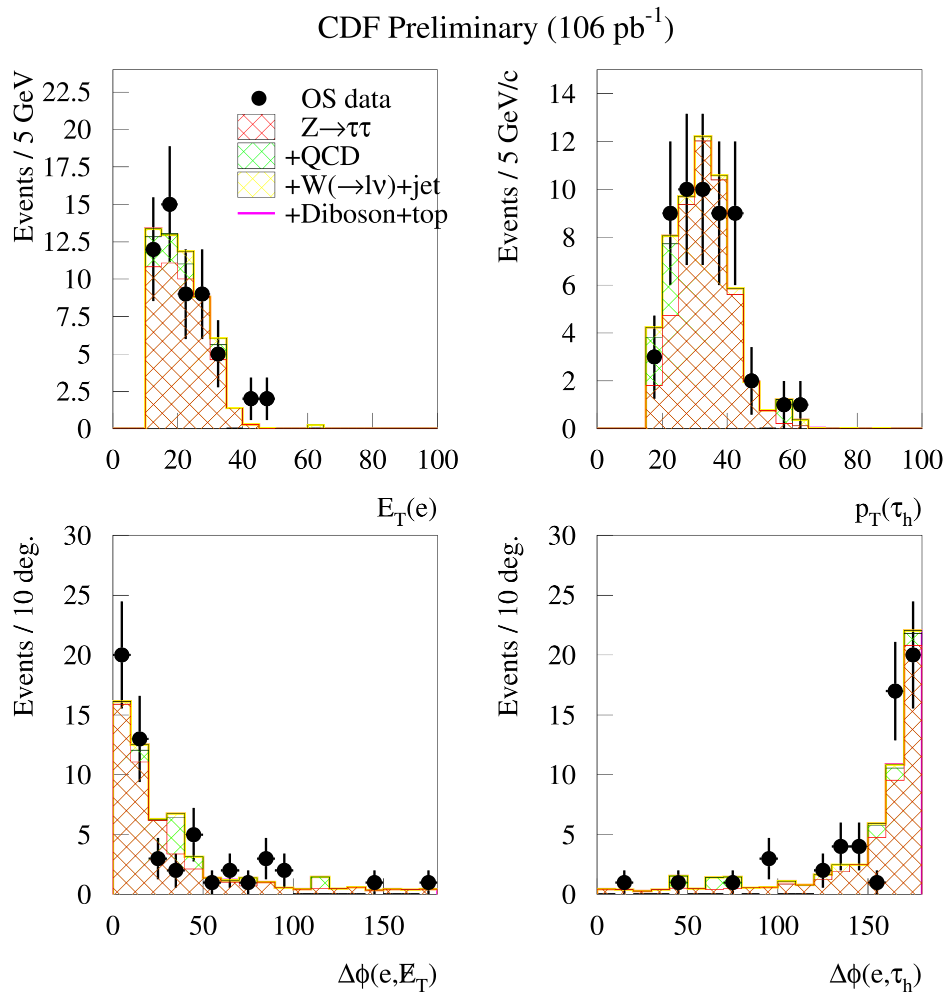
1st step: Select $Z \to \tau^+\tau^-$:

Remove $Z \to ll$ (e or μ) around M_Z, no jets,
$M_T(l, MET) < 25$ GeV ($W + jets$),
$p_T(l, MET) > 25$ GeV (QCD)





Case of λ': RPV stop decay (CDF)



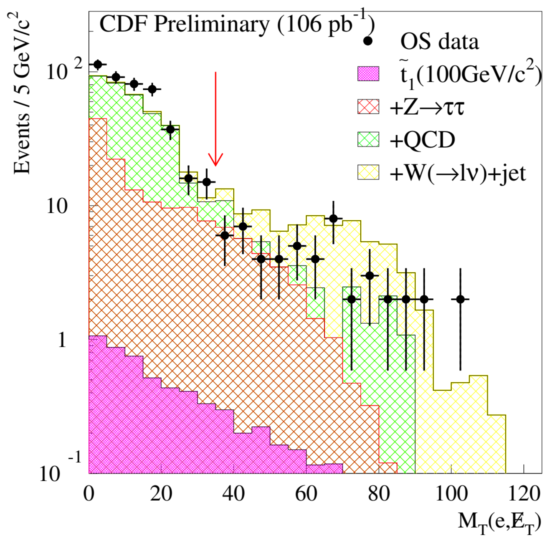
- Expect: $N(Z \to \tau\tau = 47.2 \pm 0.6 \pm 2.8$ events
- Observe: $N(Z \to \tau\tau = 45.6 \pm 7.8 \pm 0.2$ events

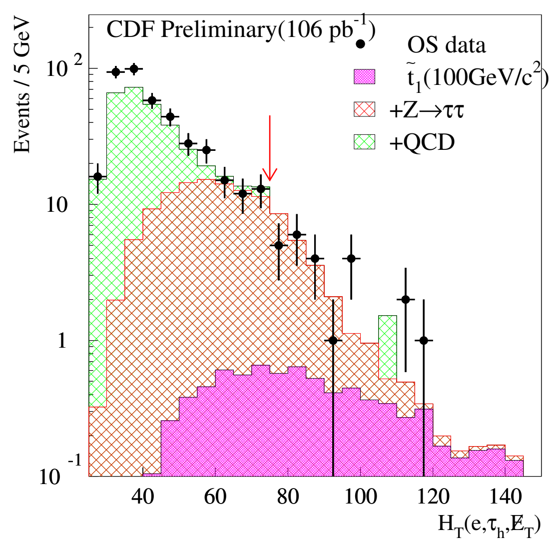
Case of λ': RPV stop decay (CDF)

2nd step: Select $\tilde{t}\bar{\tilde{t}}$: Require two or more jets,

$M_T(l, MET) < 35$ GeV (W+jets),

$H_T = |E_T^l + MET + p_T^\tau| > 75$ GeV (QCD)



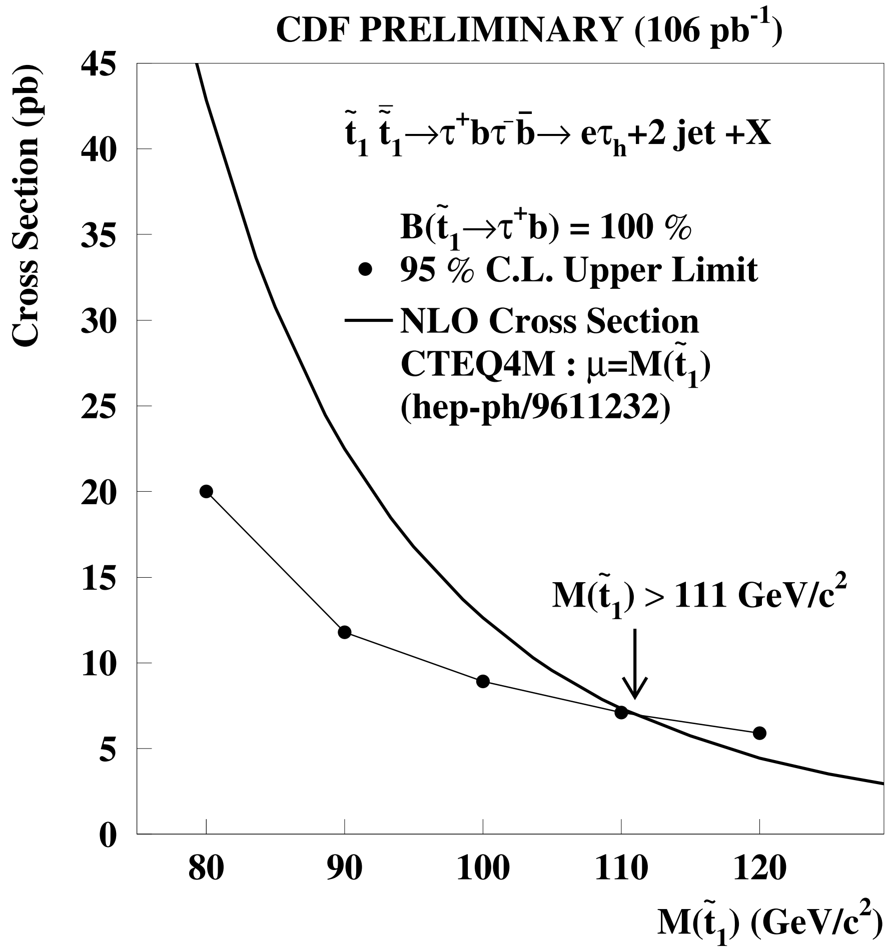


Case of λ': RPV stop decay (CDF)

Results: 0 events observed

SM background: $1.92 \pm 0.11 \pm 0.15$ events

Assume $Br(\tilde{t} \to b\tau) = 100\%$



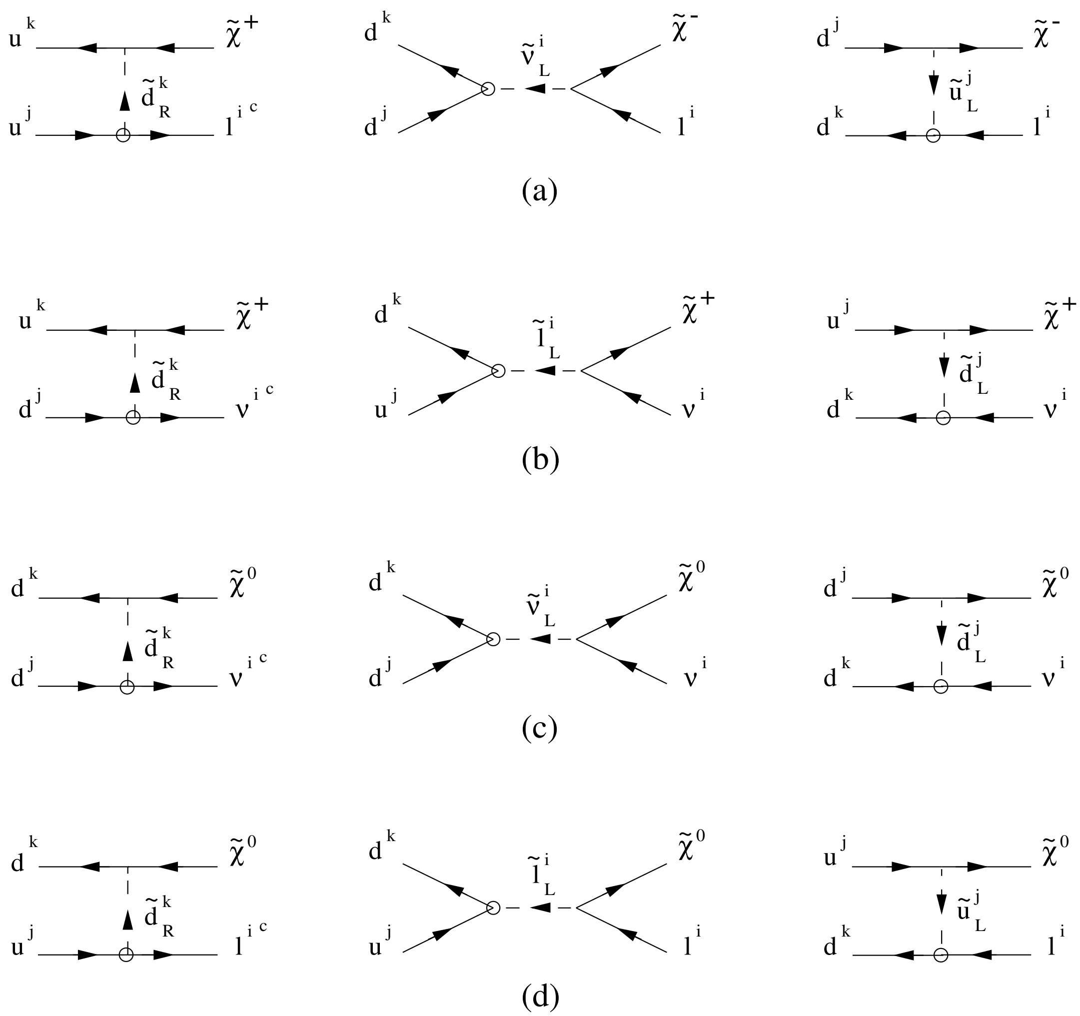
Resonant production

- Resonant production via λ' or λ''
  - via λ': resonant slepton production ($\tilde{\mu}\ \tilde{\nu}$)
  - via λ'': resonant squark production ($\tilde{t}$)
- Decay of these sparticles: generally via R-parity conserved couplings
- Cascade to LSP: the LSP decays inside or outside the detector depending on the value of the dominant coupling considered

Resonant slepton production

Dominant coupling λ':

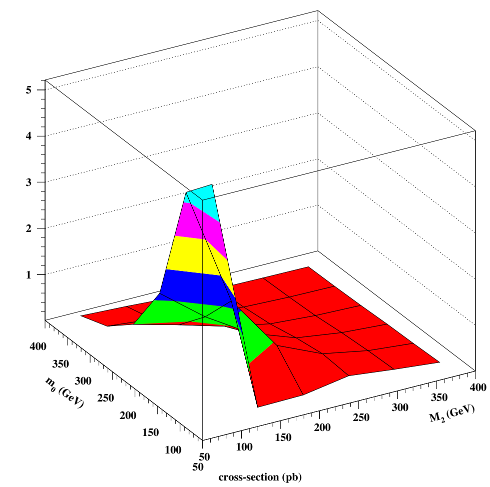
- Chargino or neutralino singly produced
- 4 possible channels:

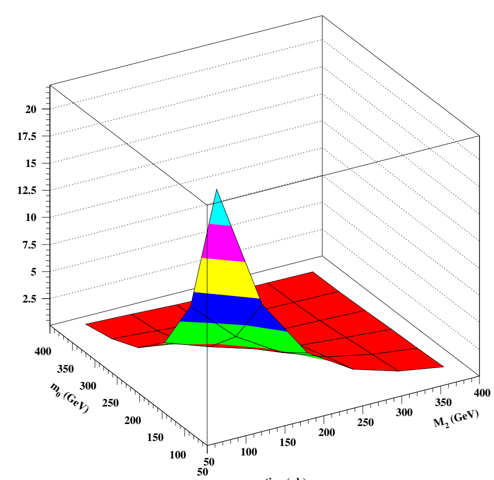


Ref: F.Déliot, G.Moreau, C.Royon, EPJ C 19 (2001) 155

Resonant $\tilde{\mu}$ and $\tilde{\nu}_\mu$ production (DØ)

- Cross section decreases as a function of m_0: sneutrino or smuon heavier
- Cross section decreases as a function of $m_{1/2}$: Chargino or neutralino mass increases





Resonant slepton production (DØ)

- Dominant coupling: λ'_{211}, resonant $\tilde{\mu}$ or $\tilde{\nu}_\mu$ production

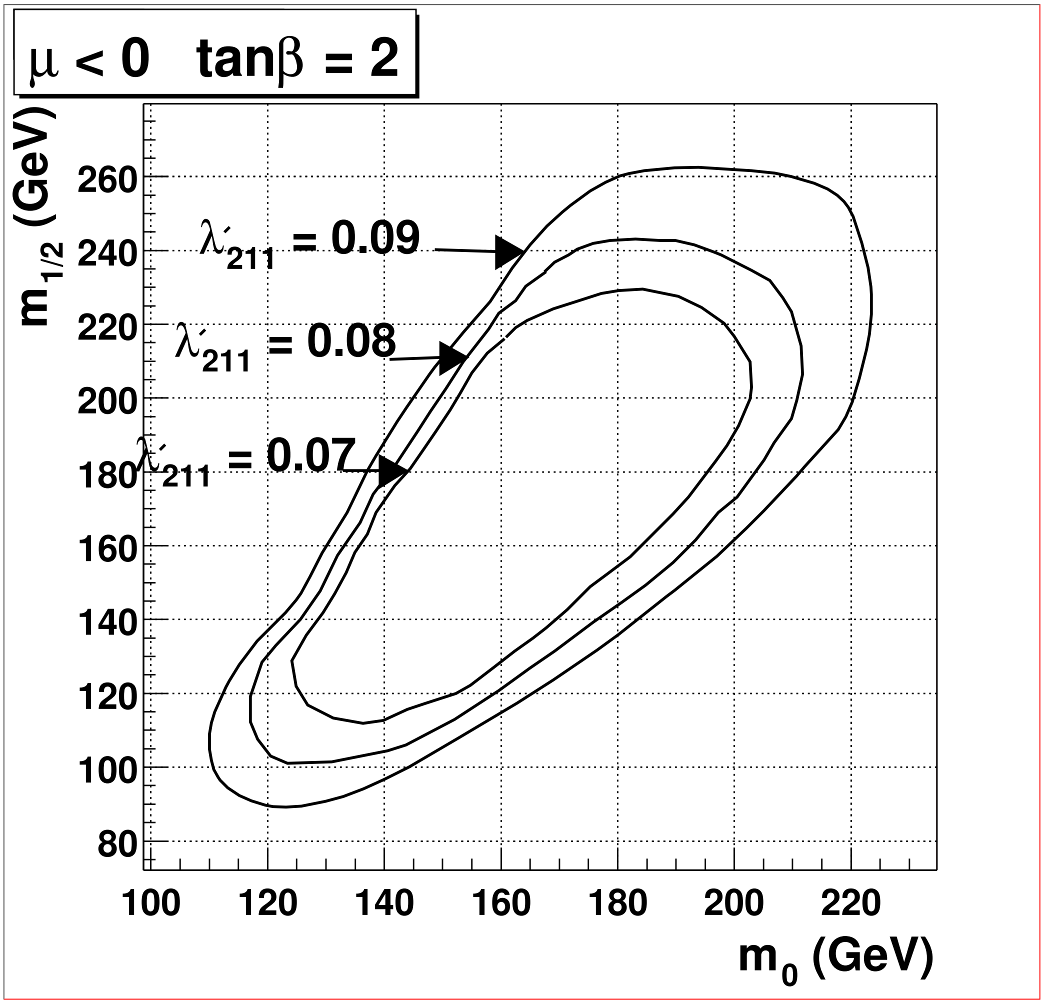
- Decays:
  $\tilde{\nu}_\mu \to \tilde{\chi}\mu \to \mu + \chi^0 + W \to \mu + \mu + W$+2 jets,
  $\tilde{\mu} \to \tilde{\chi}^0\mu \to \mu + \mu +$ 2 jets

- Channel: ≥ 2 muons $+ \geq 2$ jets, Offline cuts: p_T^μ >20 GeV, $E_T^{jets} > 20$ GeV, $H_t > 50$ GeV, $\Delta R_{\mu j} > 0.5$

- Background: $t\bar{t}$, $Z+$ 2 jets, $WW+$ jets

- Run I results: $\mathcal{L}= 94 \pm 5$ pb^{-1}, 5 events observed, expected background: 5.34 ± 0.07

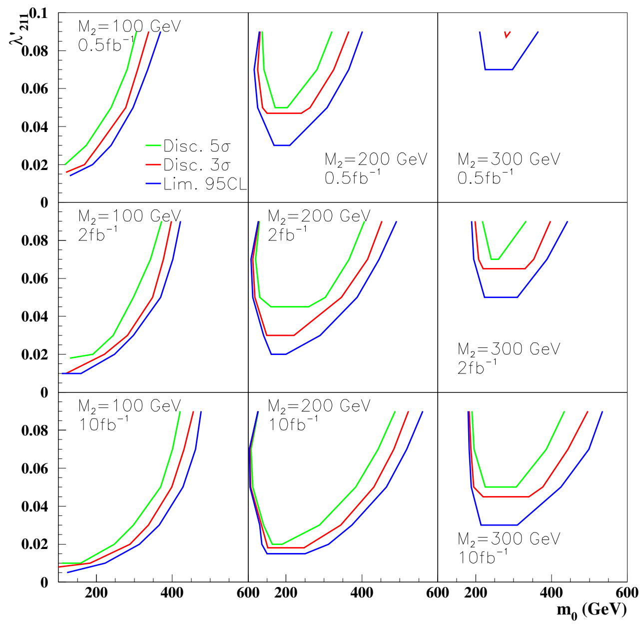
Resonant slepton production (DØ)

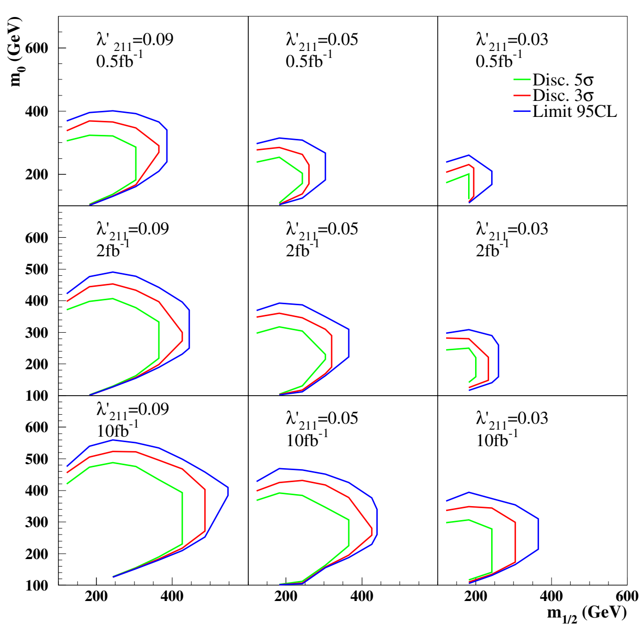


DØ Preliminary

Resonant slepton production: Run II prospects

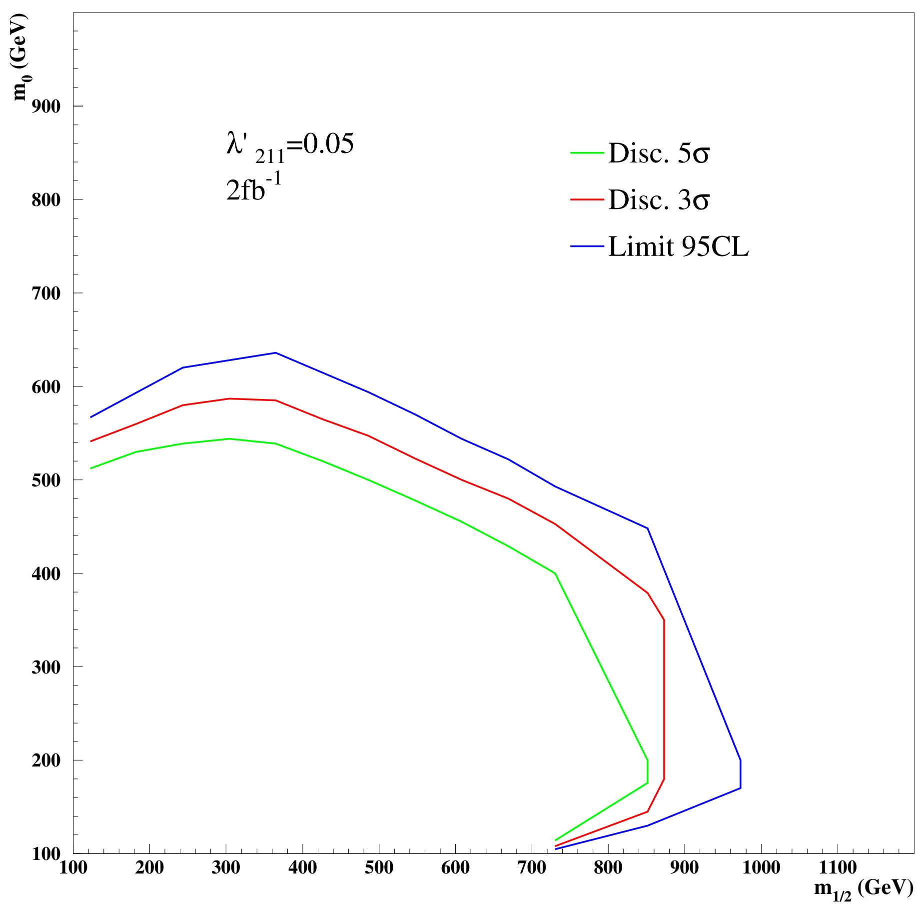
Search for trilepton channel via resonant sneutrino production ($A_0 = 0$, $\mu < 0$, $\tan\beta = 1.5$)





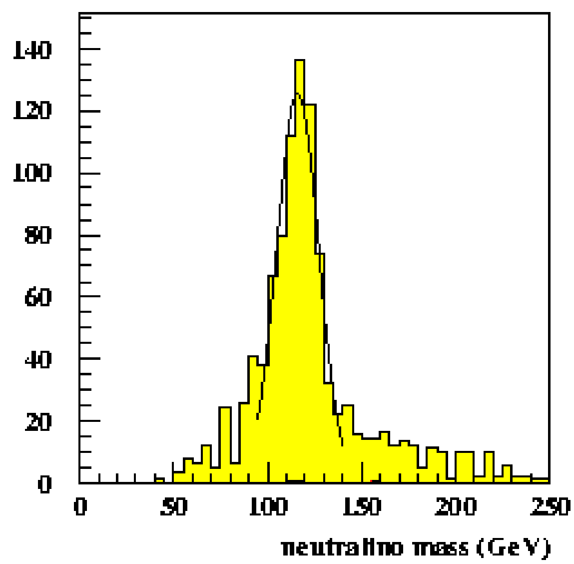
Resonant slepton production: Run II prospects

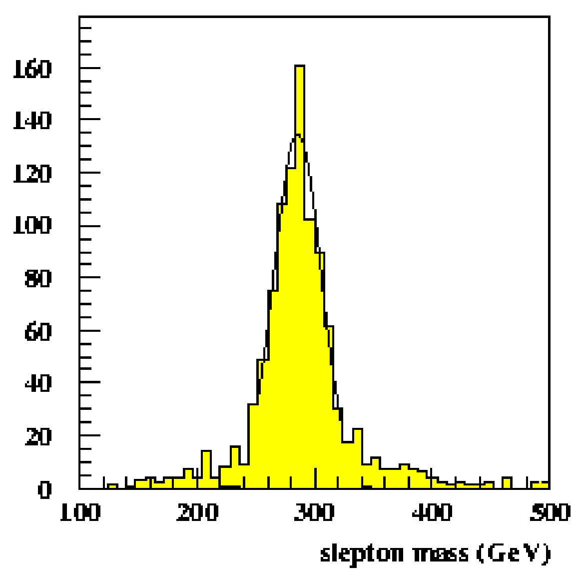
Search for like sign dileptons via resonant smuon or muon sneutrino production ($A_0 = 0$, $\mu < 0$, $\tan\beta = 1.5$)



Resonant slepton production: Run II prospects

Mass reconstruction: example, $\mu\mu$, $M_{\tilde{\chi}_1^0} = 116$ GeV, $M_{\tilde{\mu}}$ =285 GeV, $\tilde{\chi}_1^0 \to jj$(leading) + softer μ





Conclusion

- DØ and CDF searches for R-parity violation in Run I: No sign of R-parity violated SUSY found
- DØ and CDF run II will provide a great discovery potential:
  - 20 times more luminosity before 2004, another additional factor 7 before 2008
  - 10% more energy
  - improved detectors

  Large increase in sensitivity on R-parity violated coupling and mass