Searches for New Physics at DØ

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on behalf of the DØ Collaboration

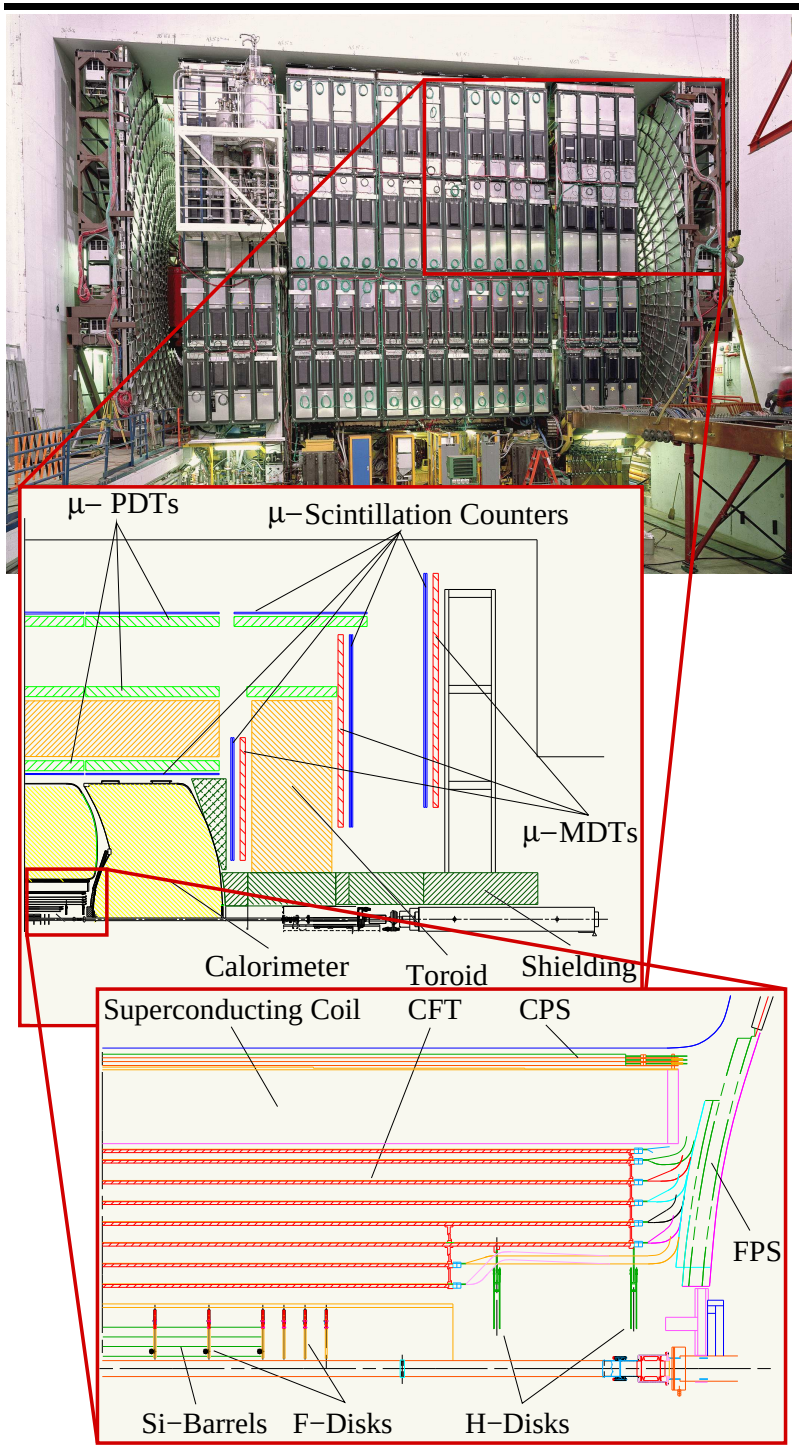
Searches for Extra Dimensions
- ADD, RS

Searches for Supersymmetry
- Squarks/Gluinos
- Charginos/Neutralinos
- $B_s \longrightarrow \mu\mu$
- R-parity Violation
- GMSB

Conference notes and plots for full set of results available at

http://www-d0.fnal.gov/Run2Physics/WWW/results/NP/np.htm

DØ Detector and Run II Dataset



Excellent Acceptance:

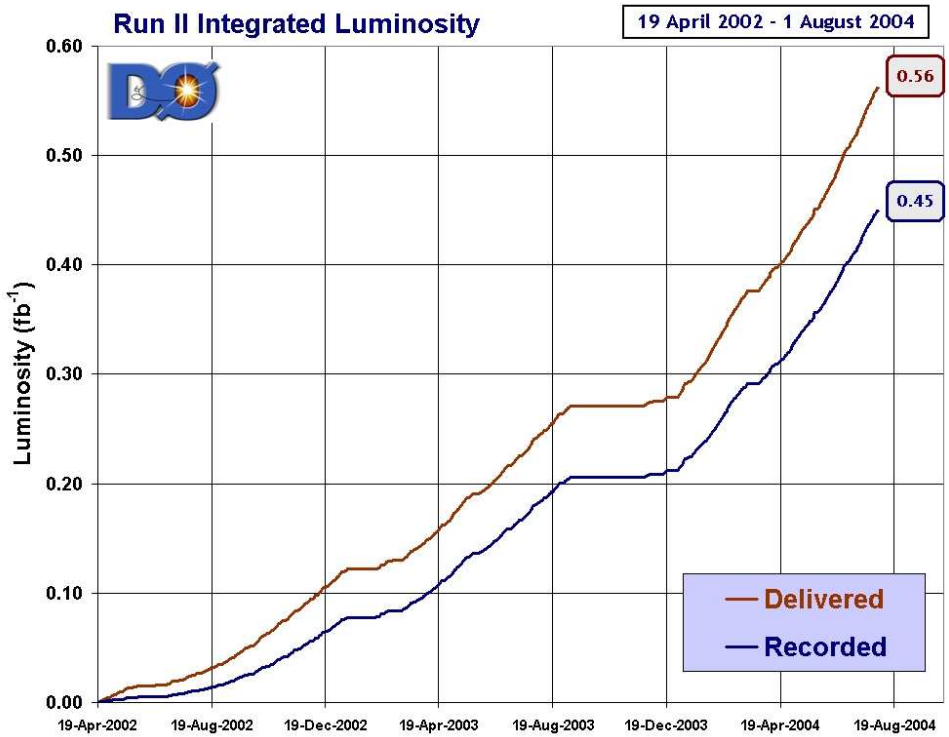
Electron Acceptance	$\lvert\eta\rvert < 3.0$
Muon Acceptance	$\lvert\eta\rvert < 2.0$
Precision Tracking (Silicon)	$\lvert\eta\rvert < 3.0$

Hermetic LAr Calorimeter:

$\rightarrow$ good jet energy and $\not\!\!E_t$ resolution

Run II Dataset:

- 0.45 fb^{-1} collected
- ICHEP analyses based on up to 260 pb^{-1}



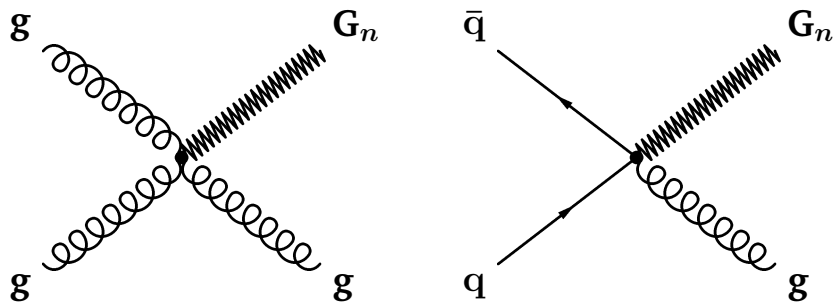
Search for Extra Dimensions – Graviton Production

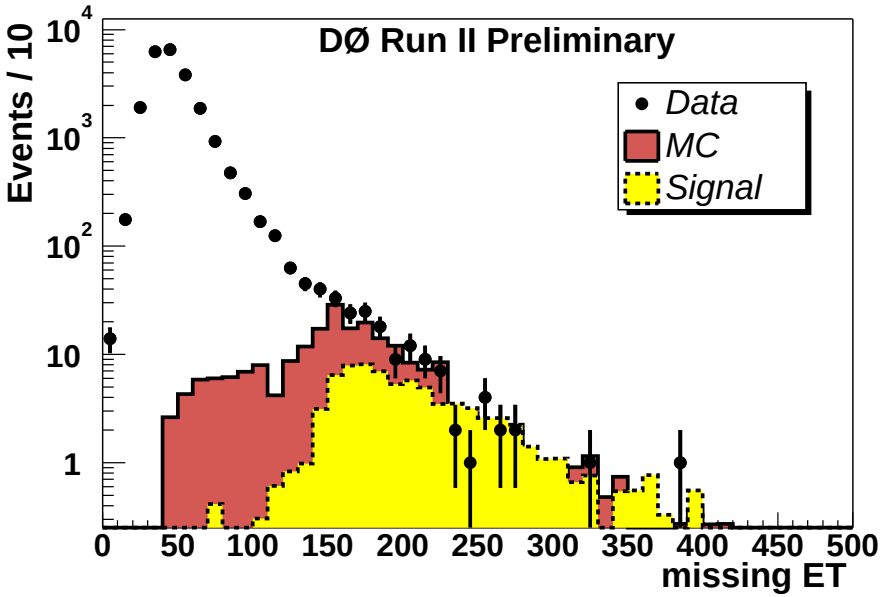
- Graviton produced recoiling against quark/gluon
- Large Extra Dimension (ADD):

  Kaluza-Klein tower of many gravitons

  $\longrightarrow$ sizeable cross-sections
- Gravitons escape detection

  $\longrightarrow$ monojet signature





Analyzed 85 pb^{-1} collected by Jets+$\not\!\!E_t$ trigger:

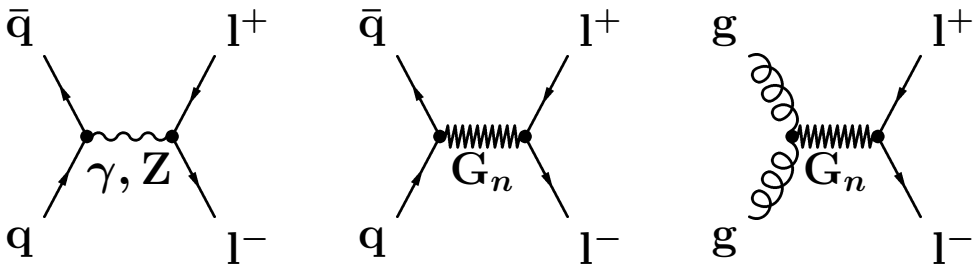
- Jet $p_\perp$>150 GeV, $\not\!\!E_t$>150 GeV
- 100^{+50}_{-30} events expected (mainly Z$\longrightarrow \nu\bar{\nu}$)
- 63 events observed

$\longrightarrow$ limit on M_D: >680 GeV

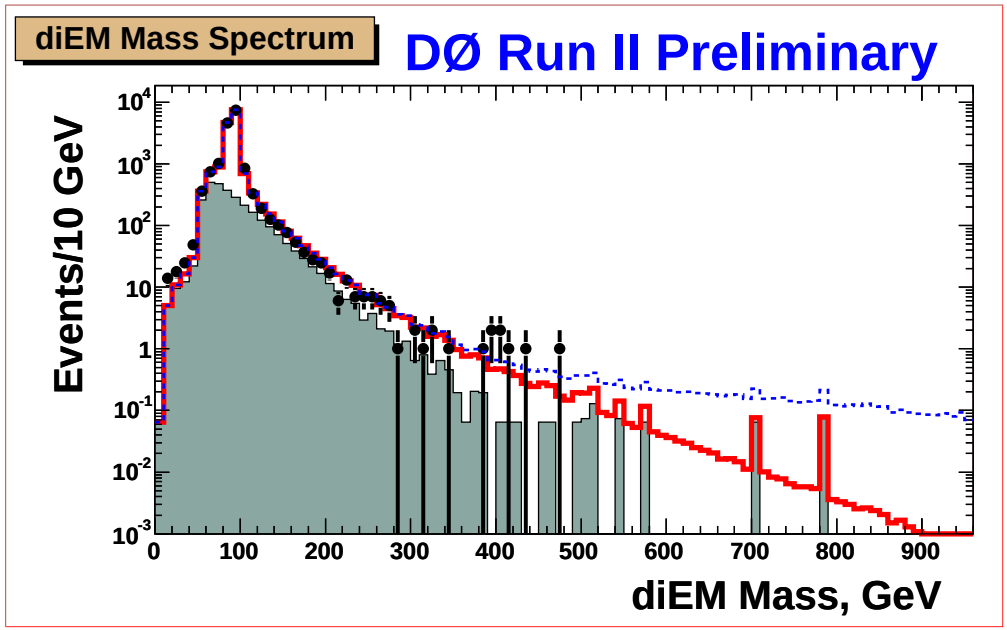
Update with more data and improved JES in progress

Search for Extra Dimensions – Diphoton/Dilepton Production

Corrections to diphoton/dilepton cross-sections via graviton-exchange:



Analyzed 200 pb^{-1} of diem-data:



No excess of events at high invariant masses

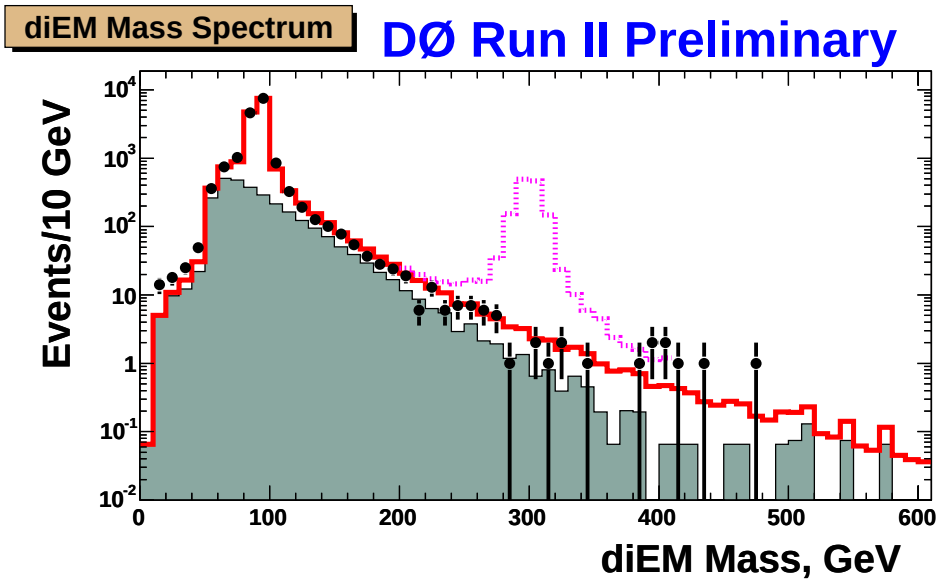
→ World's best limit on fundamental Planck scale M>1.43 TeV (GRW convention)

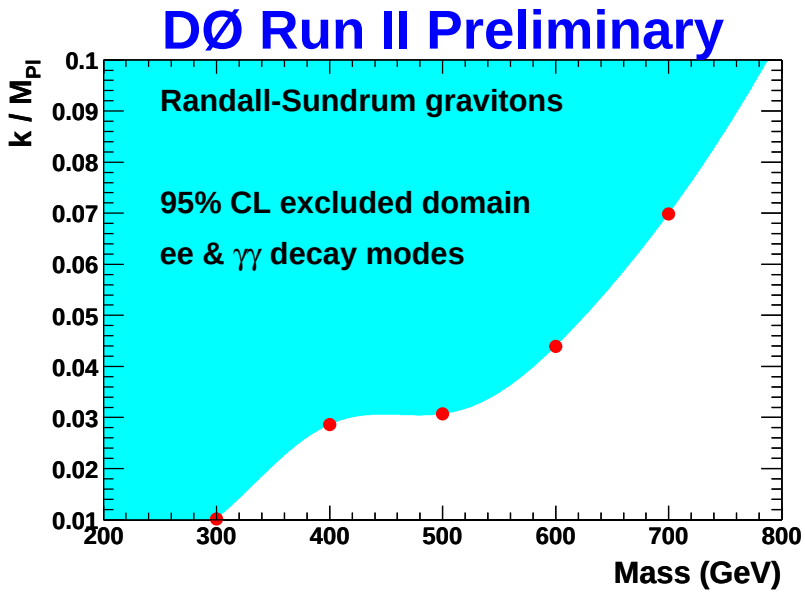
Search for Extra Dimensions – Graviton Production

Randall-Sundrum Model:

- First Kaluza-Klein excitation with mass of order 1 TeV
- Free parameters: coupling parameter k/M_{Pl} and mass of first excitation

Search for resonant Graviton production in diphotons and dielectrons (200 pb^{-1}):





No evidence for heavy resonance

→ Limits on RS-Graviton couplings as a function of mass

→ For k/M_{Pl}=0.1: M_G >785 GeV

Search for Supersymmetry – Introduction

Direct searches for SUSY partners at the Tevatron:

- **Squarks/Gluinos**
  - strong production $\longrightarrow$ high cross-sections
  - some (model-dependent) prejudice that masses are relatively high
- **Charginos/Neutralinos**
  - relatively small cross-sections
  - chargino mass limit from direct searches at LEP: "only" 103 GeV
  - cascade decays can provide clean signatures

Signatures vary with model assumptions:

- MSSM with R-parity conserved: Missing Et (Jets+$\not{E}_t$, Trileptons+$\not{E}_t$)
- MSSM with R-parity violation: Multileptons, Leptons plus Jets
- GMSB (with Neutralino NLSP): Diphotons

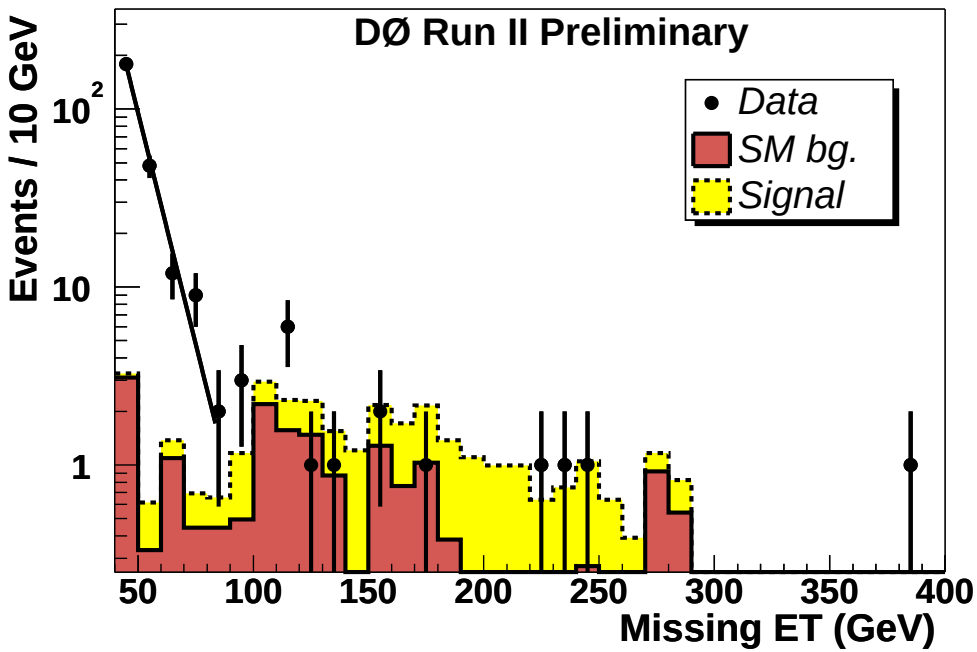
Search for Supersymmetry – Squarks/Gluinos

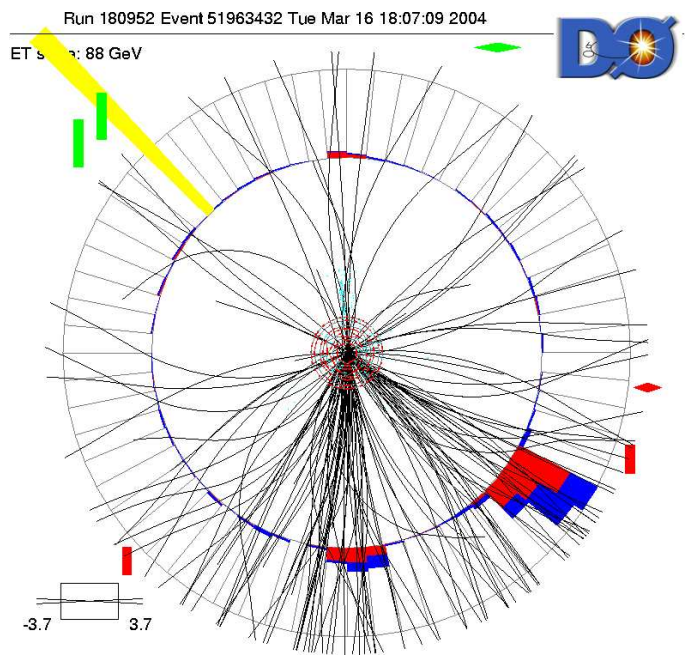
- Signature: $\tilde{q}\tilde{q} \rightarrow q\tilde{\chi}_1^0 q\tilde{\chi}_1^0$ (2 jets + $\not{E}_t$)
- Massive background from multijet production, Z+jets (with $Z \rightarrow \nu\bar{\nu}$)

$\rightarrow$ Tight cuts:

  - $\not{E}_t > 175$ GeV, $\Sigma\, p_t^{jet} > 275$ GeV
  - Lepton veto (removes $W \rightarrow l\nu$+jets)

- So far analyzed 85 pb^{-1} of data collected by Jets+$\not{E}_t$ trigger:
- Efficiencies about 7% for squark masses around 300 GeV
- 4 events observed (2.7$\pm$1.0 expected)

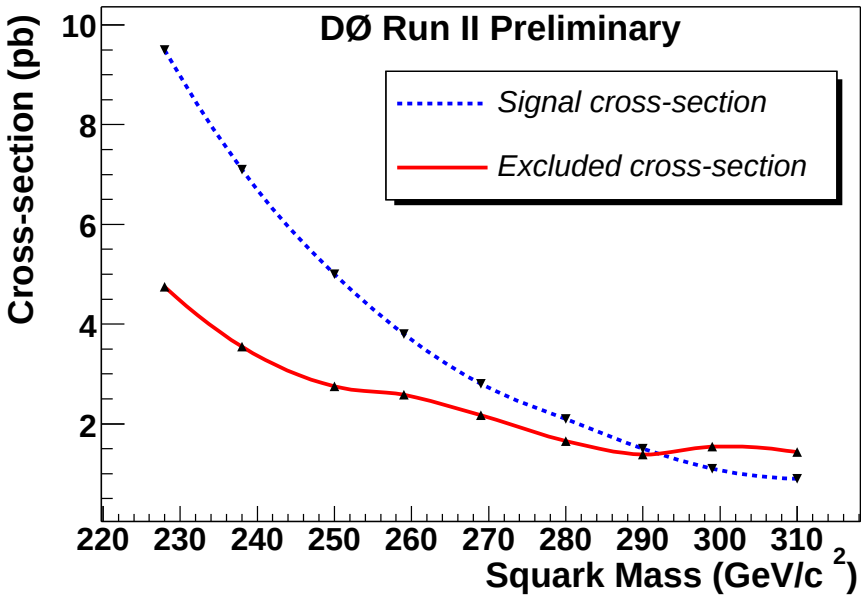


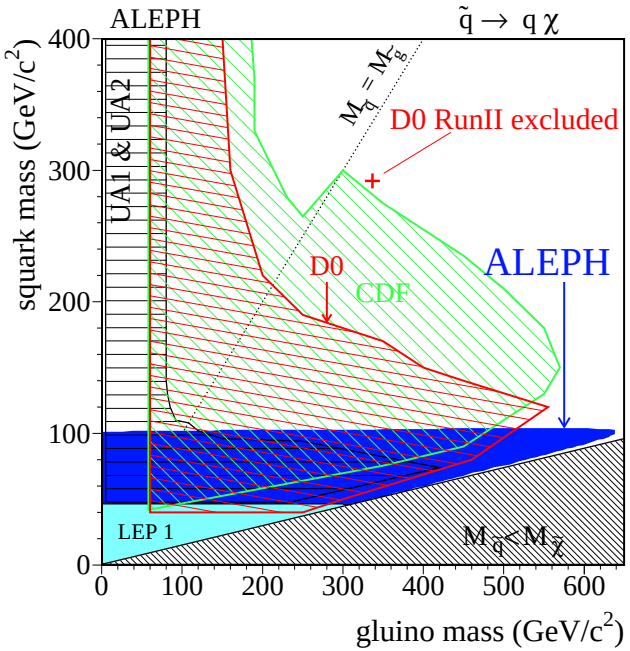


Search for Supersymmetry – Squarks/Gluinos

Interpretation of the result:

- line in mSUGRA with $m_{\tilde{q}} < m_{\tilde{g}}$:
  scanning $m_{1/2}$ for m_0=25 GeV, $\tan\beta$=3, A_0=0, μ <0





Comments:

- more realistic model (e.g. not excluded by LEP) would have larger chargino and slepton masses (relaxing mass unification)
- limits in ($m_{\tilde{q}}$,$m_{\tilde{g}}$)-plane would still apply (cascade decays via gauginos/sleptons reduce efficiency)

Outlook:

- working on full scan of ($m_{\tilde{q}}$,$m_{\tilde{g}}$)-plane
- next update will include dedicated multijet-analysis ($m_{\tilde{q}} > m_{\tilde{g}}$), more data, improved JES systematics

Search for Supersymmetry – Charginos/Neutralinos

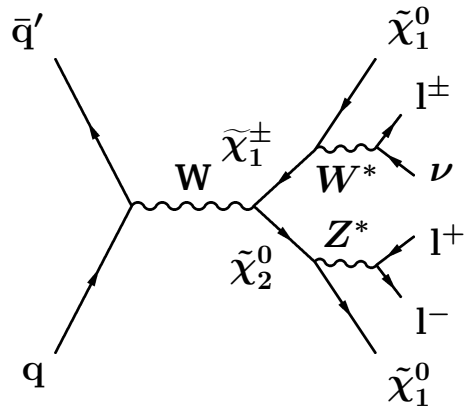
Golden Channel: leptonic cascade decays → 3 leptons plus $\not{E}_t$

Challenges:

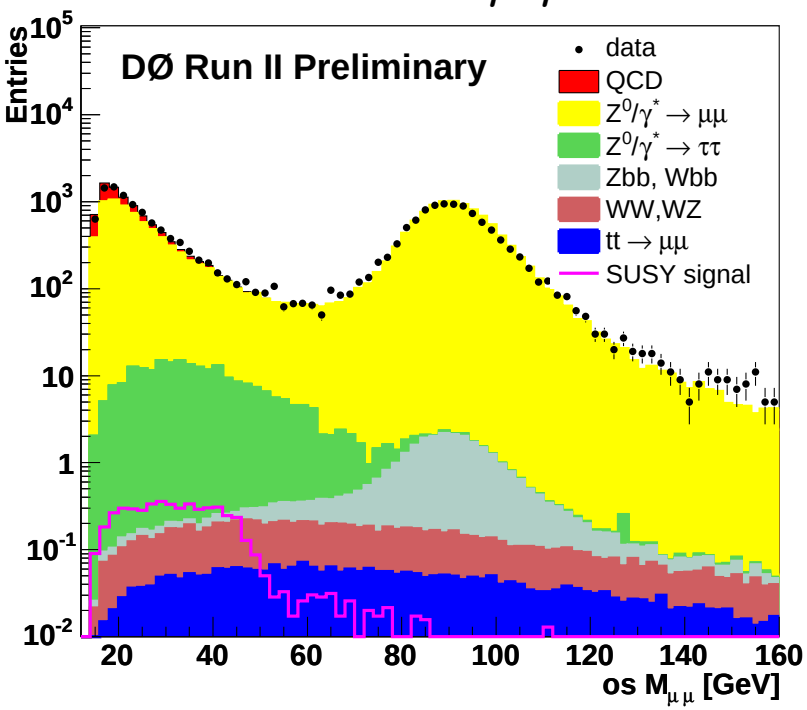
- small event rates ($\sigma \times$BR$<$0.5 pb)
- leptons with low transverse momenta

Four selections:

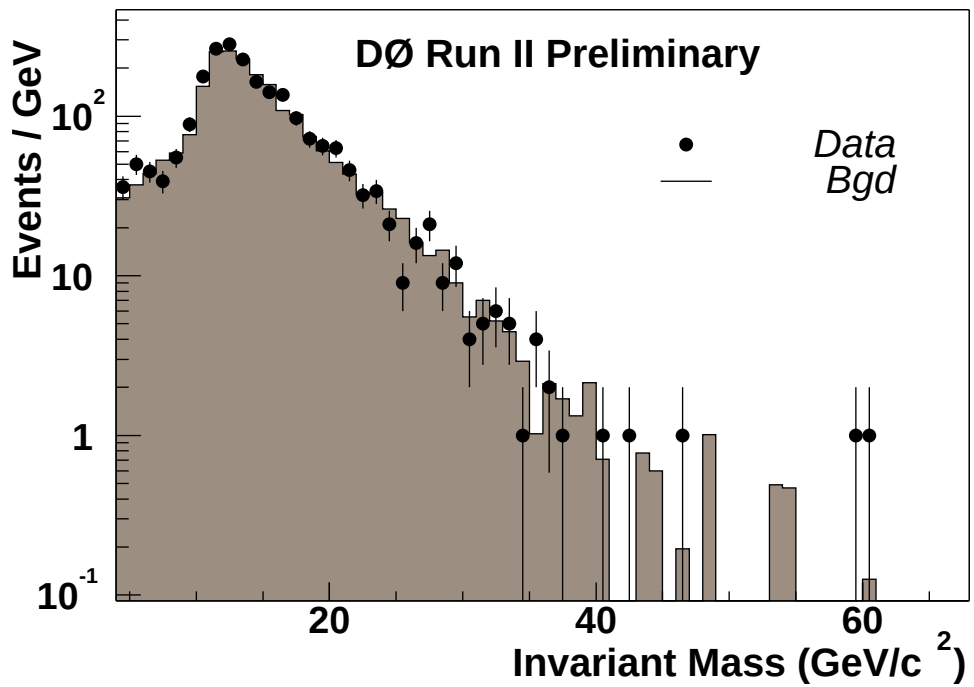
- ll+track (ll=ee,eμ,$\mu\mu$): 220-250 pb^{-1}
- like-sign dimuons: 150 pb^{-1}



Invariant Mass $\mu^+\mu^-$



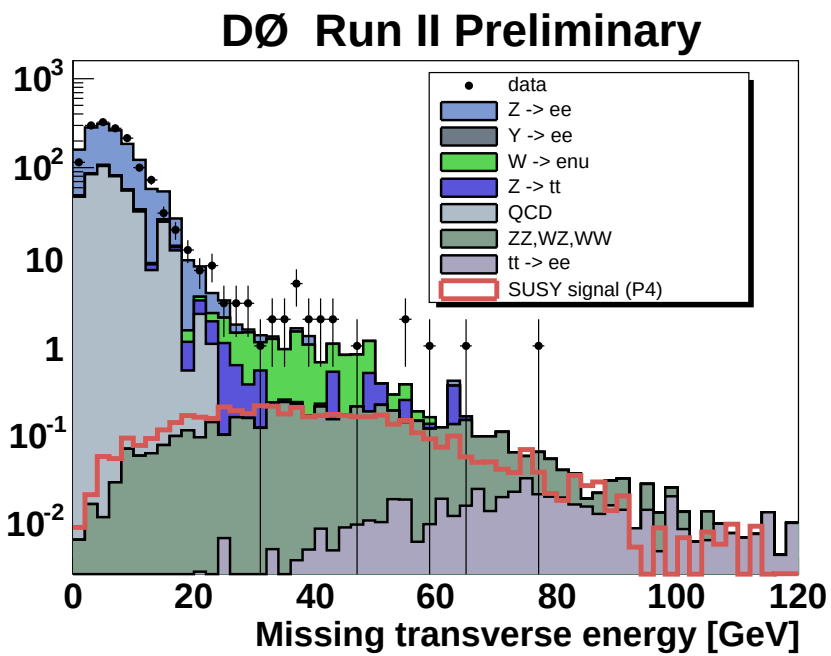
Invariant Mass $\mu^+\mu^+$

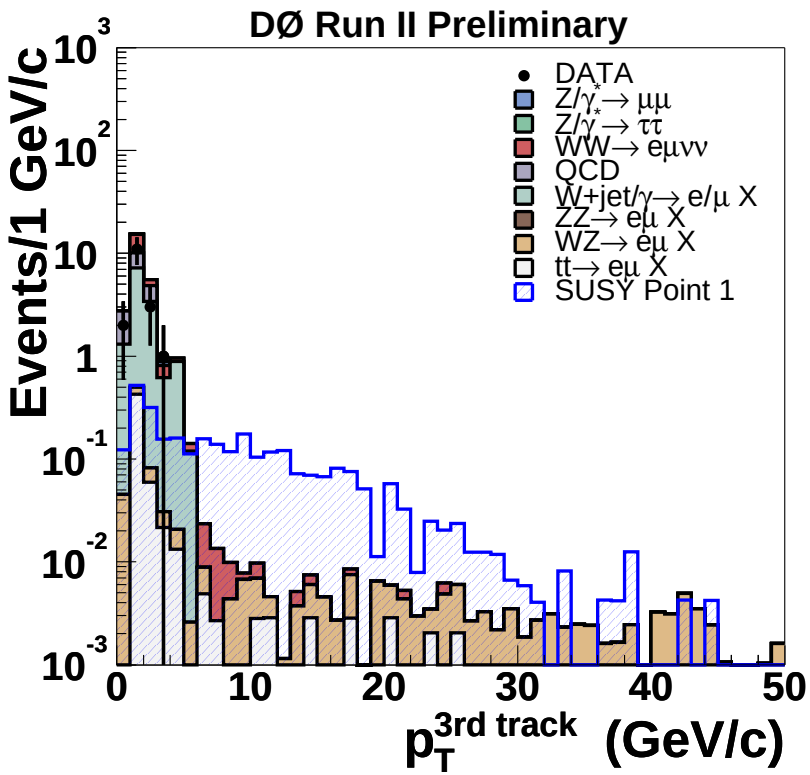


Search for Supersymmetry – Charginos/Neutralinos

Selection: Two identified leptons plus

- significant missing transverse energy
- additional isolated track (except for ls-$\mu\mu$ selection)
  - very low cut on track pt (3 or 5 GeV)
  - efficient for e,μ and hadronic τ-decays

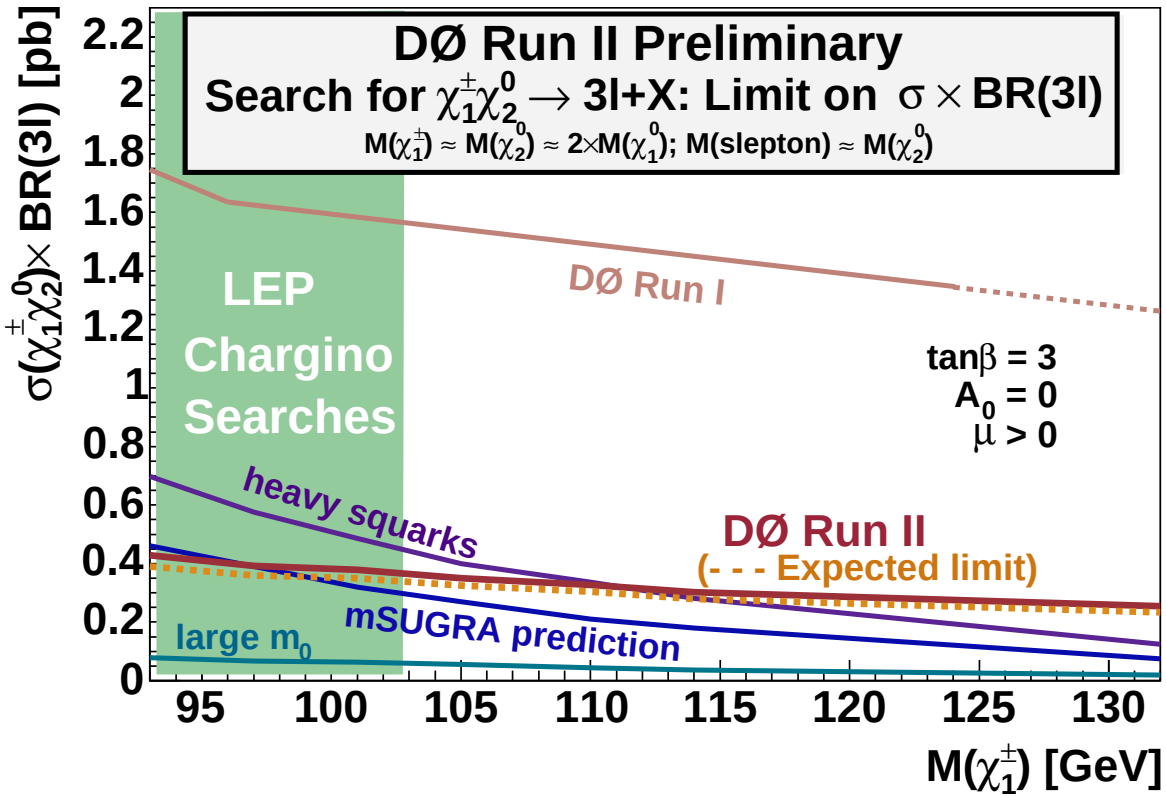




Backgrounds mainly dominated by WW, WZ, Wγ:

Selection	Expected Background	Observed	Signal ($m_{\tilde{\chi}^{\pm}}$=100 GeV)
eel	0.68±0.40±0.32	1	1.83±0.08±0.08
eμl	0.29±0.33±0.02	0	1.25±0.06±0.07
$\mu\mu$l	1.83±0.40±0.21	1	1.12±0.04±0.12
ls-$\mu\mu$	0.13±0.06±0.02	1	0.36±0.03±0.03

Search for Supersymmetry – Charginos/Neutralinos



Note: Limit on $\sigma \times$BR applicable to general SUSY with similar mass hierarchy

Interpretation in 3 reference scenarios (all: $\tan\beta$=3, A_0=0, μ >0):

- "mSUGRA"
  Parameter choices maximize leptonic BR ($m_{\tilde{\ell}} \approx m_{\tilde{\chi}_2^0} \to$ sfermion decays dominate)
- "Large m_0"
  Decays via W^*/Z^* dominate $\to$ leptonic BR is low
- "Heavy squarks" (relaxing scalar mass unification)
  Enhanced cross-section (destructive interference with squark-exchange suppressed)

Search for Supersymmetry: $B_s \to \mu^+\mu^-$

- SM prediction: $BR(B_s \to \mu^+\mu^-) = 3.8 \times 10^{-9}$
- can be enhanced by non-SM graphs:

  SUGRA: $\sim (\tan\beta)^6$

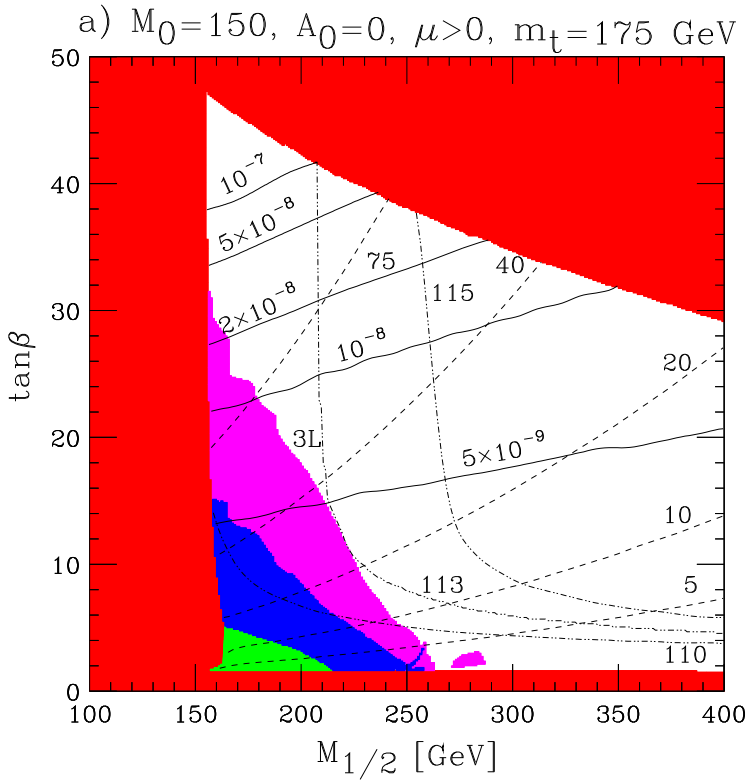
  $\to$ significant at high $\tan\beta$

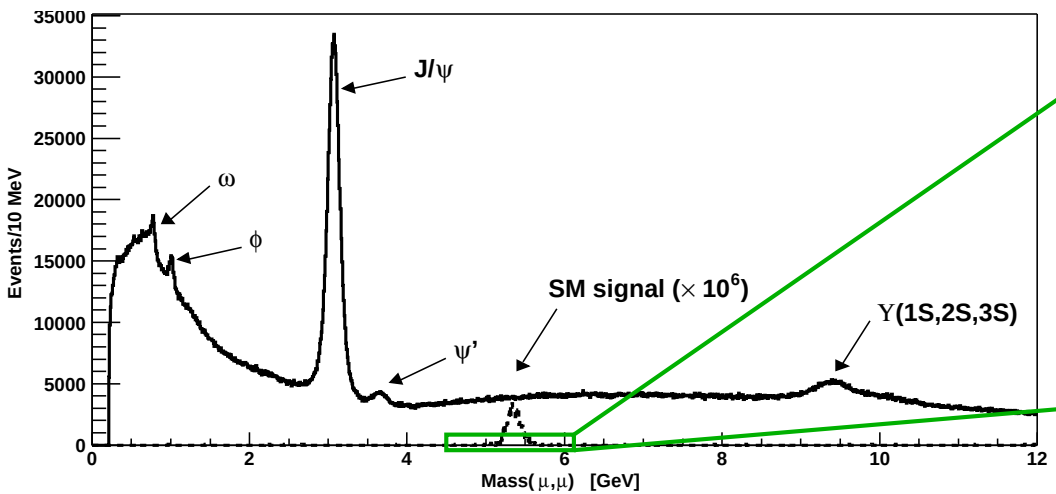
  $\to$ complementary to trilepton search
- Tevatron: large production rate for B_s
- Selection: two isolated muons, displaced vertex
- Results based on 240 pb^{-1}:

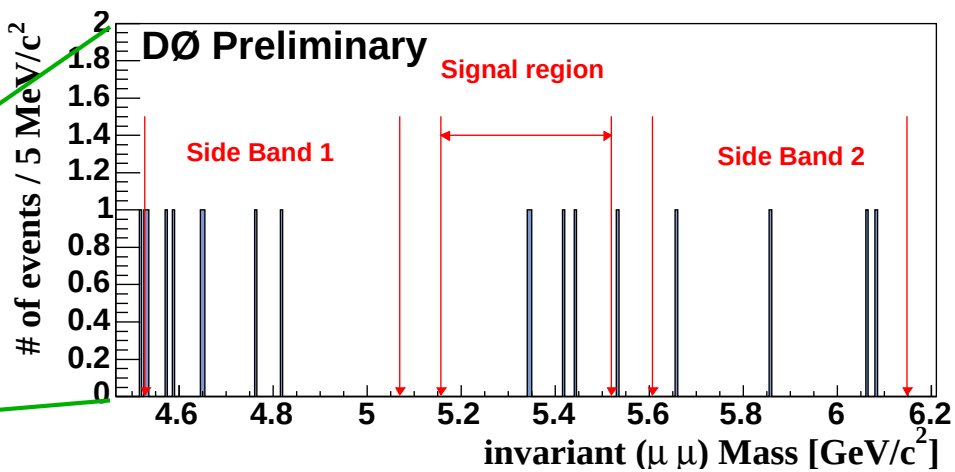
  4 events observed, 3.7 ± 1.1 events expected

  $BR(B_s \to \mu^+\mu^-) < 4.6 \times 10^{-7}$ (at 95% C.L.)

(Dedes et al., hep-ph/0207026)





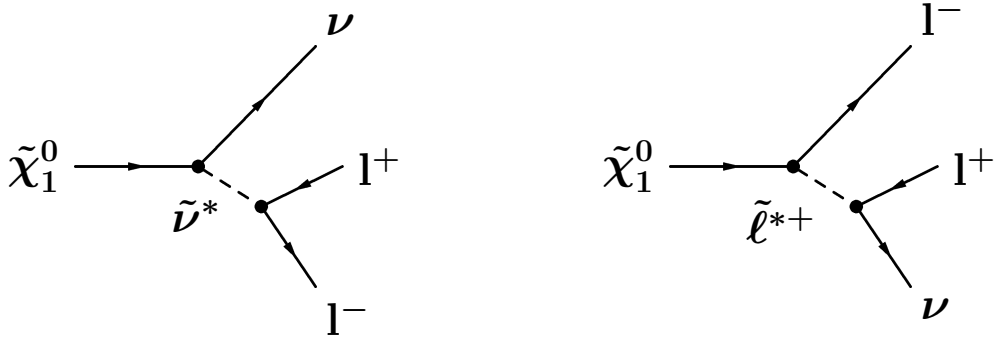


Search for Supersymmetry: R-Parity Violation

Most general Superpotential contains 45 R-parity violating Yukawa terms:

$$W_{RPV} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

→ LSP can decay into SM fermions. For $L_i L_j \bar{E}_k$-coupling:



→ Chargino/Neutralino production leads to final states with 4l+$\not{E}_t$+X

Analyzed up to 240 pb^{-1} with 4 trilepton selections:

– eee+$\not{E}_t$+X, eeμ+$\not{E}_t$+X, e$\mu\mu$+$\not{E}_t$+X, $\mu\mu\mu$+$\not{E}_t$+X

Search for Supersymmetry: RPV

Selection

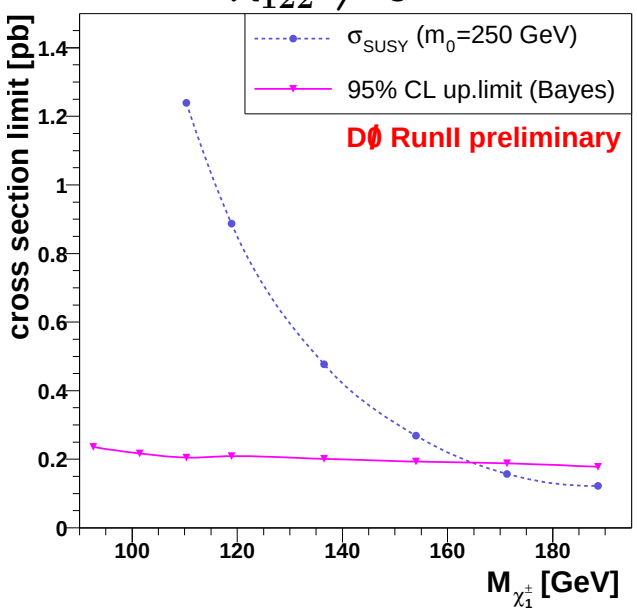
- requiring 3 (out of 4) identified leptons
- very low pt cuts on third lepton (down to 3 GeV)
- loose $\not{E}_t$ requirement

Backgrounds dominated by DY with fake 3rd lepton, WW/WZ:

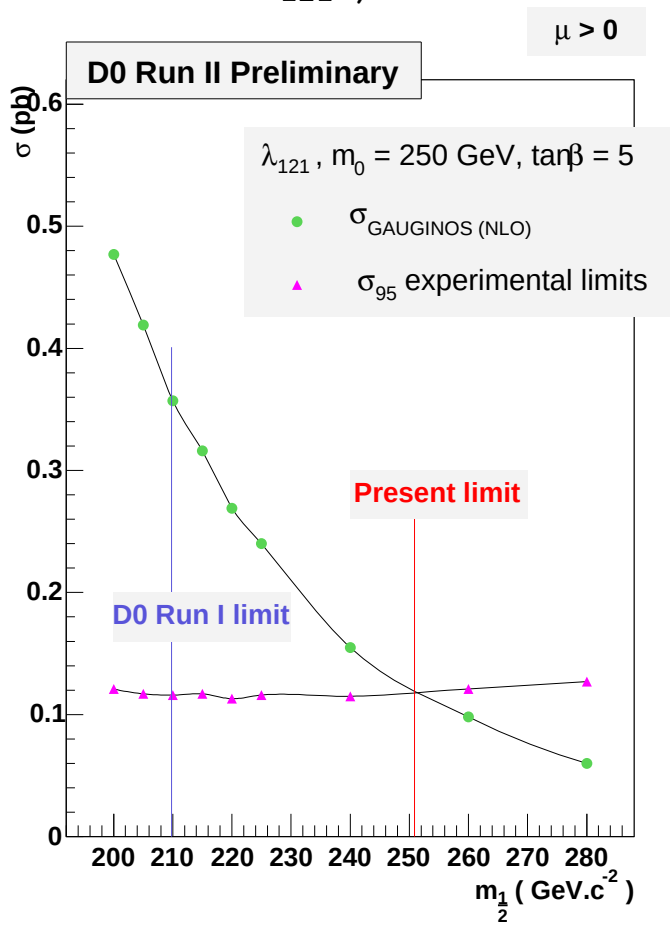
Selection	Background	Observed
$\mu\mu\mu$	0.56 ± 1.40	1
$e\mu\mu$	0.07 ± 1.33	1
eel	0.45 ± 0.43	0

Interpretation within two reference scenarios:

$\lambda_{122} \neq 0$



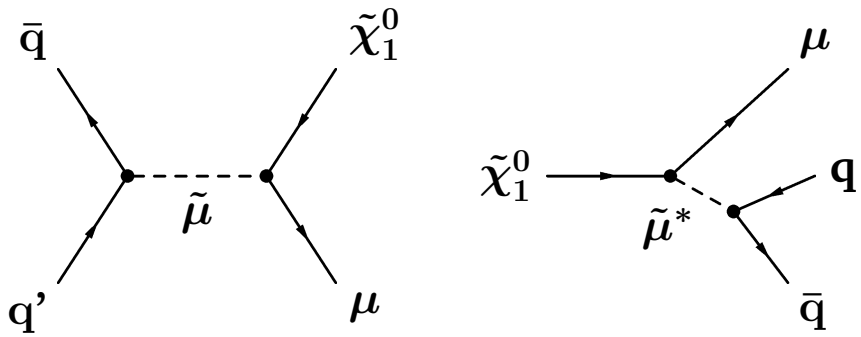
$\lambda_{121} \neq 0$



Search for Supersymmetry: RPV

R-parity violation allows production of single SUSY particles

New Analysis: Search for resonant production of smuons via λ'_{211} (154 pb^{-1})



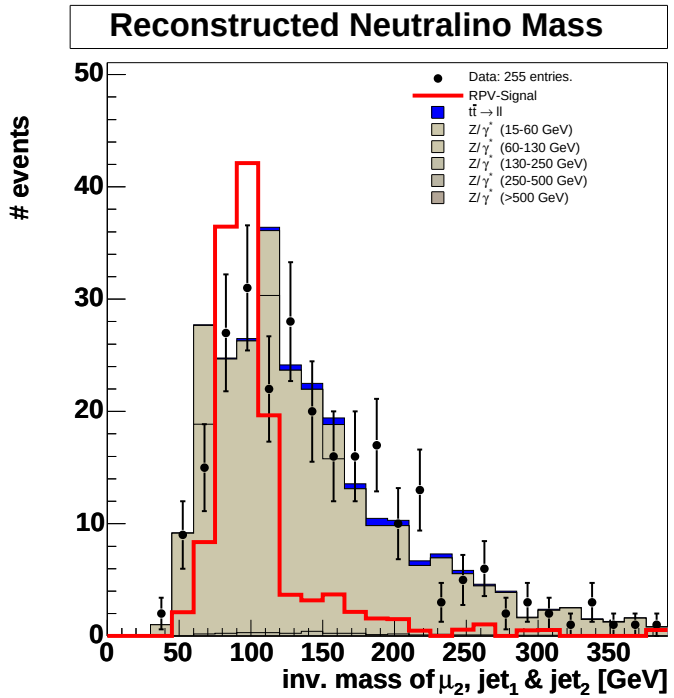
Selection

- Two muons (pt>8,20 GeV), two jets (pt>15 GeV)
- Topological cuts to reduce Z+jets background
- Reconstruction of Neutralino and Smuon invariant masses

Background Expectation:

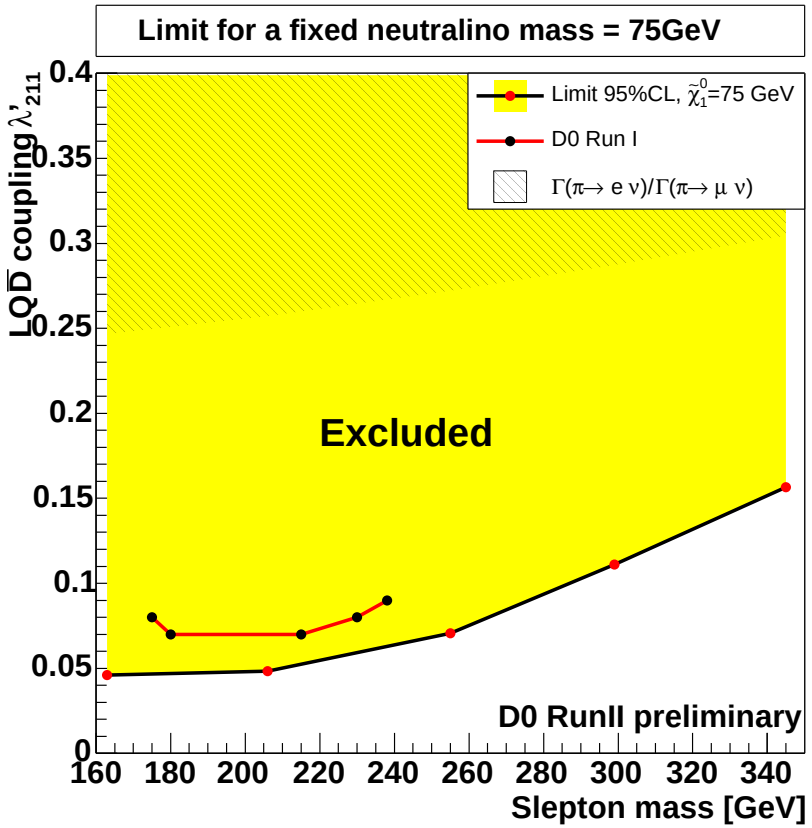
0.1 up to 1.6 events (dep. on mass hypotheses)

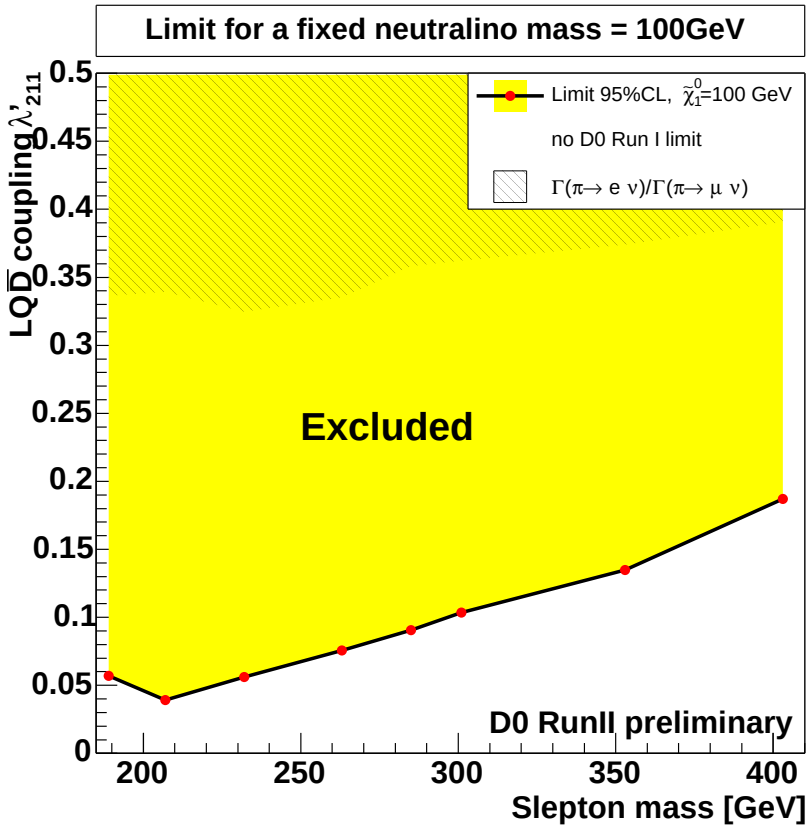
No excess observed ($\leq$2 events found in data)



Search for Supersymmetry: RPV

Interpretation: Limits on λ'_{211} as a function of Smuon and Neutralino mass





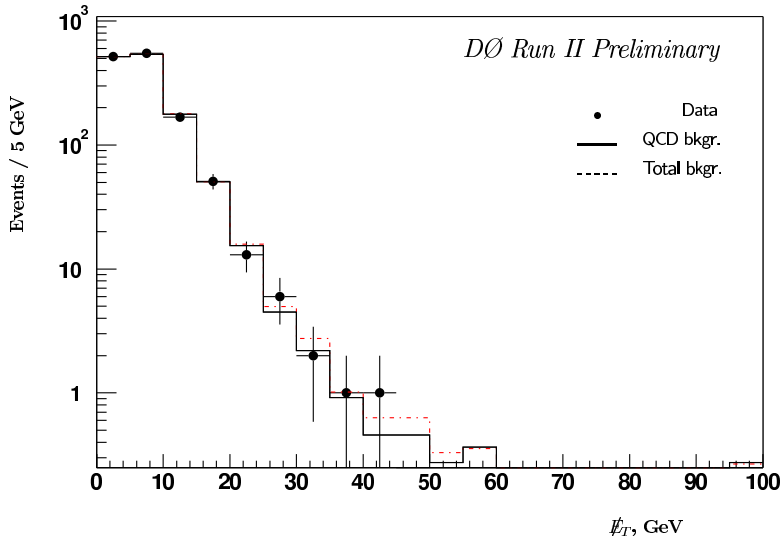
Search for Supersymmetry: GMSB

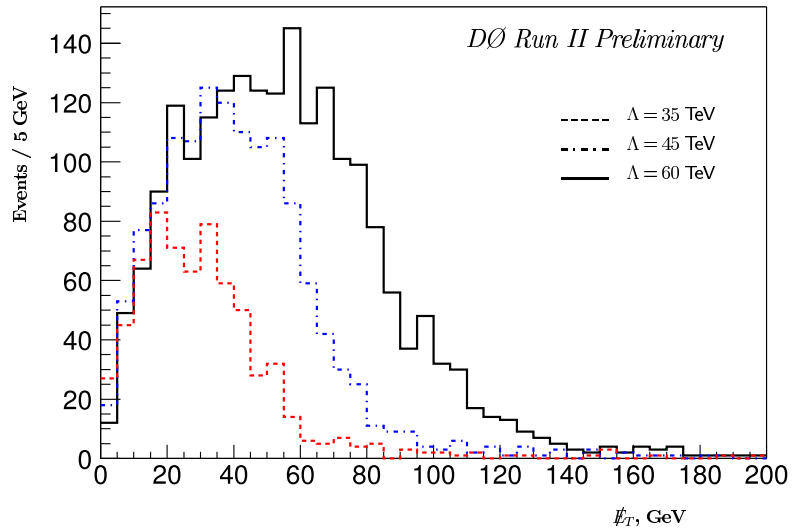
Gauge Mediated SUSY Breaking: Gravitino $\tilde{G}$ is LSP

Assuming Neutralino NLSP: $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$

$\rightarrow$ **Chargino/Neutralino production leads to final states containing $\gamma\gamma + \not{E}_t$**

$\rightarrow$ **Inclusive search for 2 photons plus $\not{E}_t$ (185 pb^{-1})**





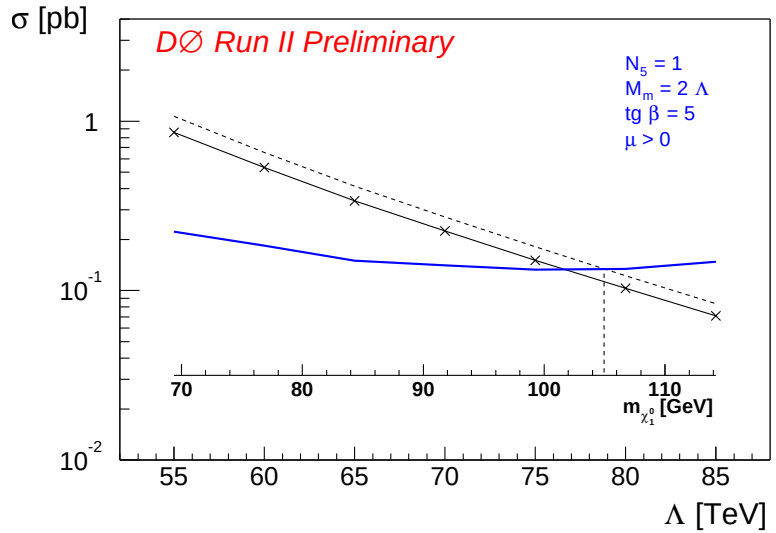
Optimized Cut: $\not{E}_t$>40 GeV

$\rightarrow$ **1 event observed (2.5±0.5 expected from fakes)**

$\rightarrow$ **improved cross-section limits**

For N_5=1, M_m=2Λ, $\tan\beta$=5, μ >0:

$m_{\tilde{\chi}_1^0}$ >105 GeV, $m_{\tilde{\chi}^\pm}$ >192 GeV



Conclusions

- DØ is probing new physics beyond existing limits
- Broad range of signatures and models under study
- Many more results available, even more in progress
- Always open to new ideas $\longrightarrow$ please contact us!