Search for Hidden Dimensions in Run I Tevatron Data

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Hidden Dimensions
Outline

Searches for the Effects of SUSY

Search for Resonant Slepton Prod.

Search for Stop Pairs $\rightarrow \tau\, b\, \tau\, b$

Searches for the Effects of Large Extra Dimensions

Search in monojet $+\not{E}_T$

Search in $\gamma + \not{E}_T$

(also gravitino and gen. limit)

Supersymmetry

- New symmetry between fermions and bosons
- Predicts superpartners for all known particles
- R-parity $\equiv (-1)^{3B+L+2S}$

  +1 for SM, –1 for SUSY particles

  in models where R-parity is conserved
- R-parity violation in production or decay

$\lambda_{ijk} L_i L_j E_k$, $\lambda'_{ijk} L_i Q_j D_k$ Lepton number violating

- Lightest SUSY particle

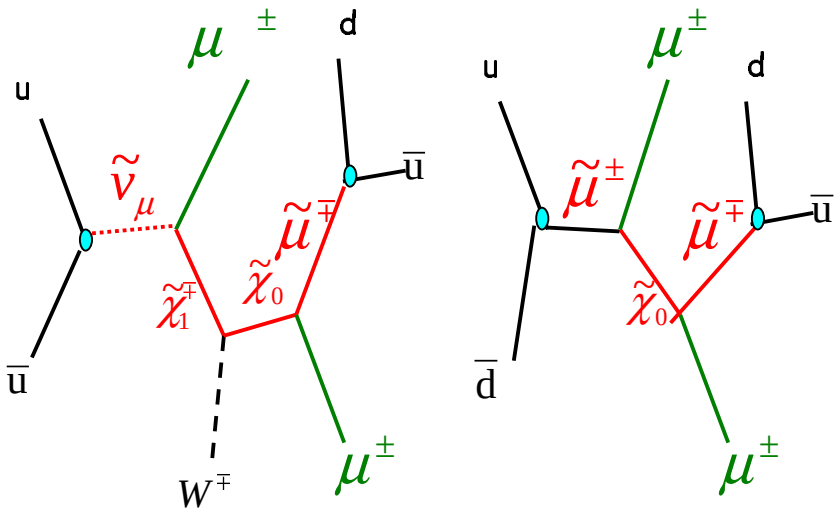
  $\tilde{\chi}^0_1$ in gravity mediated models

  $\tilde{G}$ in gauge mediated models - $\tilde{\chi}^0_1 \rightarrow \tilde{G}\gamma$
- mSUGRA -MSSM with assumptions about physics at the GUT scale
- Five parameters

Parameter	Description
$\tan\beta$	Ratio of higgs vacuum expectation values
sign(μ)	Sign of Higgs mixing parameter
m_0	common scalar mass
$m_{1/2}$	common gaugino mass
A_0	common trilinear coupling

M_{top} also required

DØ Search for Resonant Slepton Production in RPV mSUGRA (λ'_{211})



- Assuming dominant λ'_{211} $LQ\bar{D}$ coupling
- Search for 2 μ and 2 jet final state (94 pb^{-1})

Initial Selection:

two central jets
two central muons

$E_T^{j1,j1} > 20$ GeV
$p_T^{\mu1,\mu2} > 20$ GeV
$H_T(\text{jets}) > 50$ GeV

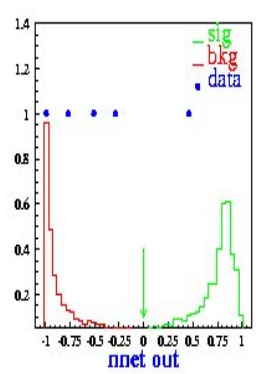
7-5-3-1 NN variables:

$E_T^{j_1} + E_T^{j_2}$, $p_T^{\mu_1} + p_T^{\mu_2}$, $M_{inv}^{\mu_1,\mu_2}$
$\Delta R^{\mu_1,\mu_2}$, $\Delta R^{\mu_1,j_{nn}}$, Sph., Aplan.

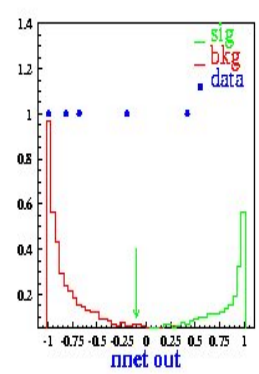
Background:

Z+2jets	$t\bar{t}$	WW	Total	Obs.
4.8	0.53	0.01	5.34±0.07	5

sneutino

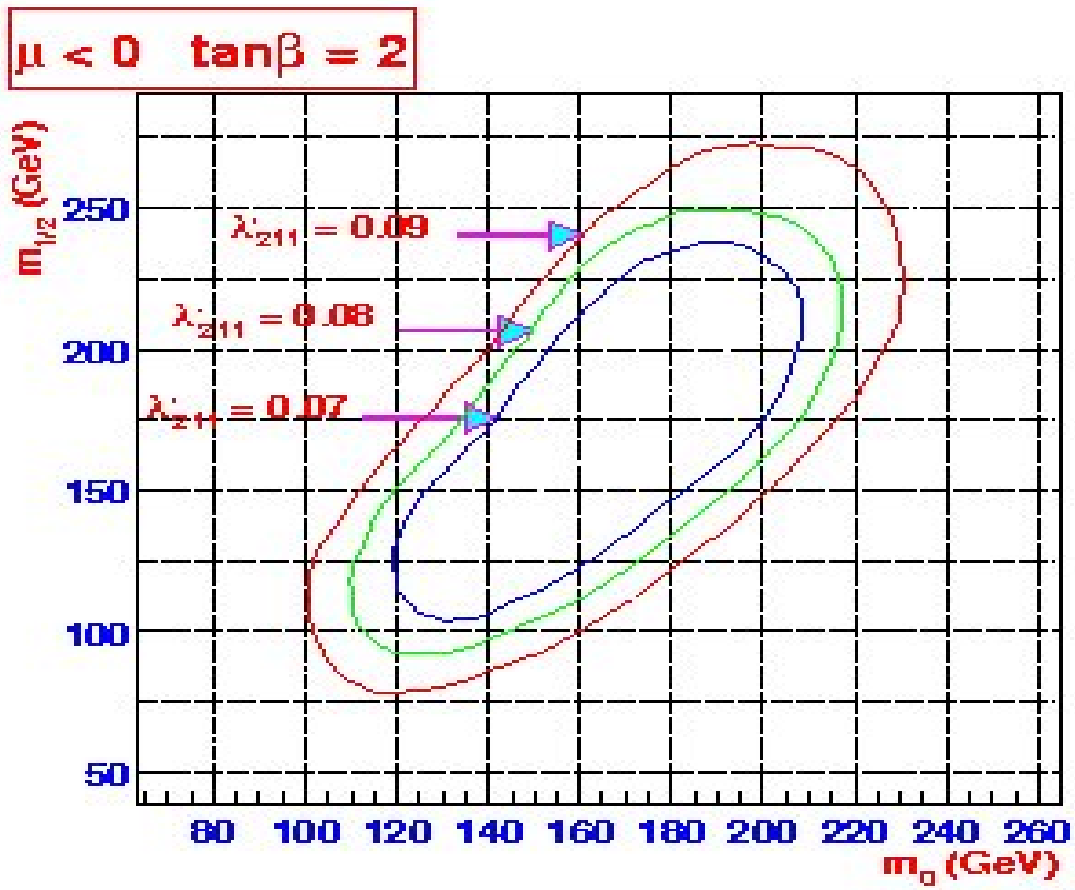


smuon



DØ Search for Resonant Slepton production in RPV mSUGRA (λ'_{211})

95% CL limit contour



After NN selection, expect

1.01±0.02 SM events.

Observed: 2 events

Signal: ~ 6 at contour

CDF RPV SUSY Search for Stop Pairs decaying into τ b τ b

- Stop pairs are produced thru RPC
- Assuming RPV only in the 3rd generation: $\tilde{t}\bar{\tilde{t}} + X \rightarrow \tau_l + b + \tau_h + \bar{b} + X$

  λ'_{333} in $\lambda'_{ijk} L^i Q^j \bar{D}^k$ in the superpotential
- Use $Z \rightarrow \tau_l \tau_h$ with no jet as a calibration to cancel systematic errors:

$$\sigma_{\tilde{t}\bar{\tilde{t}}} = \sigma_Z \cdot Br(Z \rightarrow \tau\tau) \cdot \frac{(N^{obs}_{\tilde{t}\bar{\tilde{t}}} - N^{b}_{\tilde{t}\bar{\tilde{t}}}) / a_{\tilde{t}\bar{\tilde{t}}}}{(N^{obs}_{Z} - N^{b}_{Z}) / a_Z}$$

Major SM Backgrounds:

- Z, γ^* (ττ) + jets
- W (eν,μυ) + jets
- W (τυ) + jets
- Diboson
- Multijet

CDF RPV SUSY Search for Stop Pairs Decaying into τ b τ b

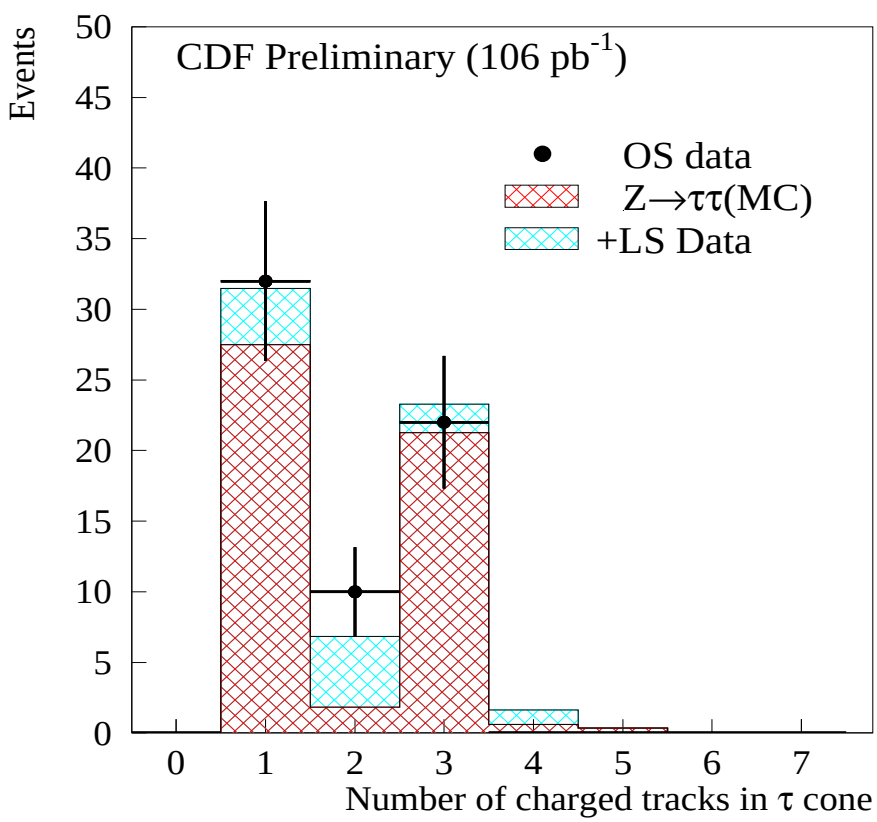
Selections (106 pb^{-1}):

e: E_T>10 GeV, P_T^{trk}> 8 GeV/c, $|\eta|$<1.0

μ: P_T>10 GeV/c, $|\eta|$<0.6

τ_h: P_T>15 GeV/c, $|\eta|$<1.0

τ_h ID: number of tracks and π^o in a narrow cone, isolation energy, etc

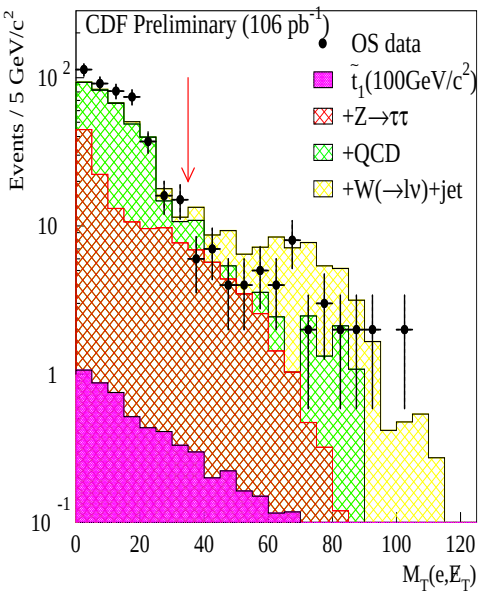


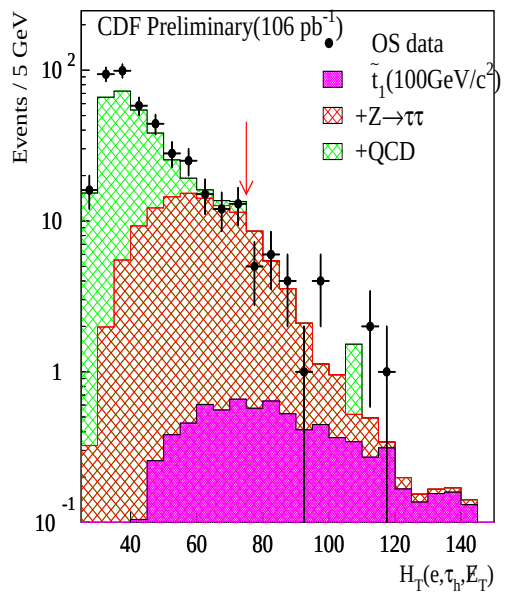
CDF RPV SUSY Search for Stop Pairs Decaying into τ b τ b

Additional Selections:

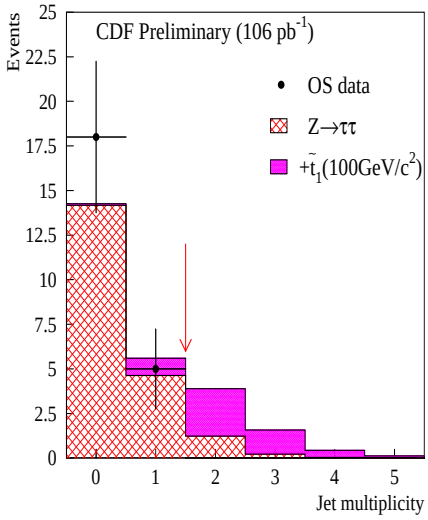
$M_T(\text{lepton}, \not{E}_T) < 35$ GeV/c^2

$H_T(\text{lepton}, \tau_h, \not{E}_T) > 70$ GeV



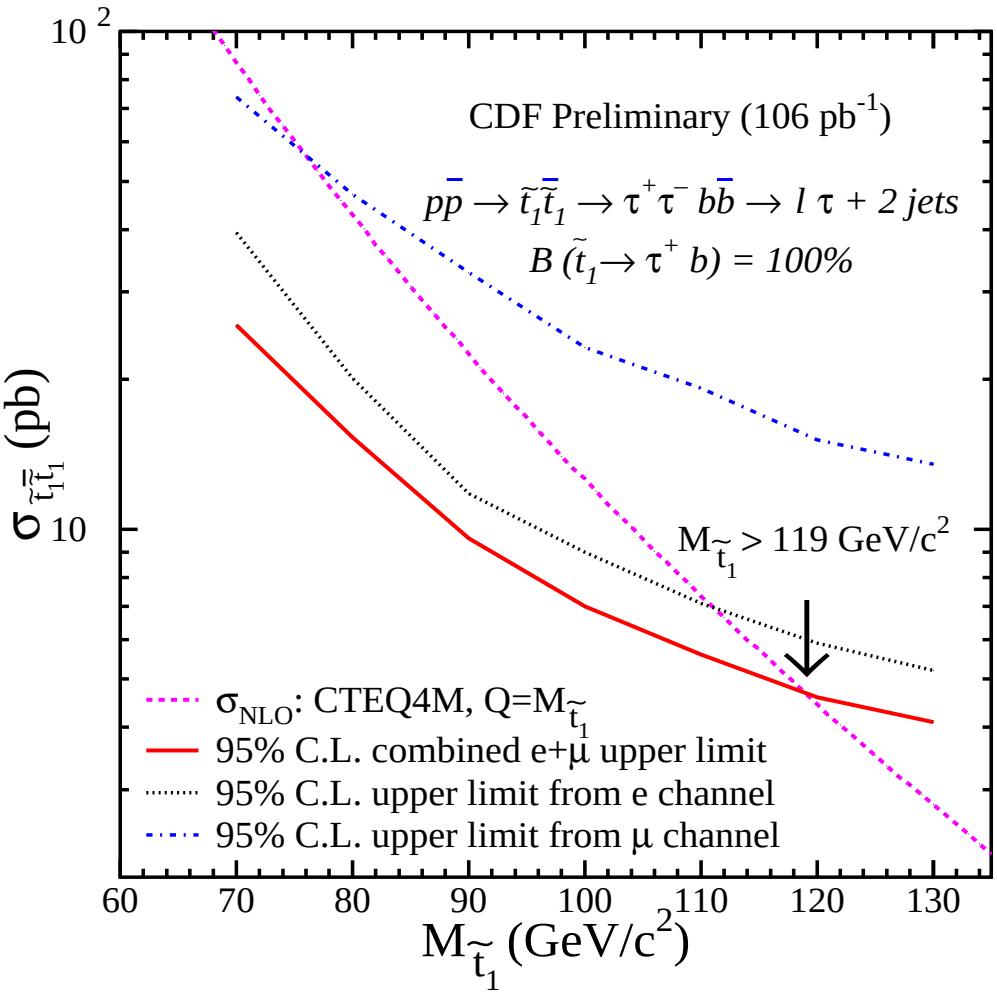


≥ 2 jets: $E_T > 15$ GeV



channel	bkgd	obs	acc.% at $m_{\tilde{t}} = 120$GeV
e	1.92±0.18	0	3.18
μ	1.13±0.13	0	1.79

CDF RPV SUSY Search for Stop Pairs Decaying into τ b τ b



Conclusion:

No signal found; limit is set.

(ALEPH: $m_{\tilde{t}} > 93\,\mathrm{GeV/c^2}$)

Large Extra Dimensions

Large Extra Dimensions resolve the hierarchy problem by reducing the quantum-gravity scale to ~TeV

SM – 3+1 dimensional brane

Gravitons can propagate in extra dimensions

$G_N^{-1} = M_{pl}^2$ replaced by $G_N^{-1} = 8\pi R^n M_d^{2+n}$

The radius of the compactified space (assumed to be a torus) is

$$R = \frac{1}{\sqrt[n]{8\pi} M_d} (M_{Pl} / M_d)^{2/n}.$$

For M_d ~ 1TeV, we have

$$R = \begin{cases} 1.2\times10^{12}\,\text{m} & n=1, \\ 0.48\,\text{mm} & n=2, \\ 3.6\,\text{nm} & n=3, \\ 9.7\times10^{-12}\,\text{m} & n=4. \end{cases}$$

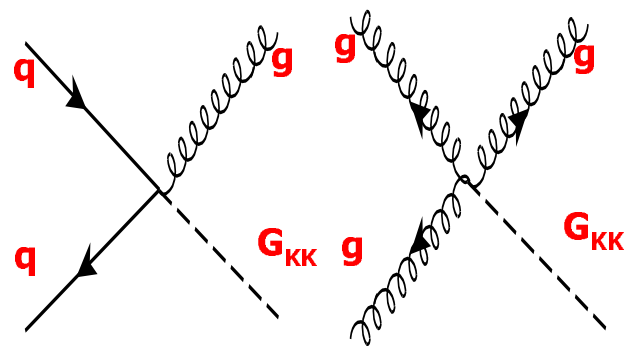
Ref. Giudice, Rattazzi, Wells Phys. B544, 3(1999) hep- ph/9811291

Signatures for Large Extra Dimensions at the Tevatron

Real Gravitons

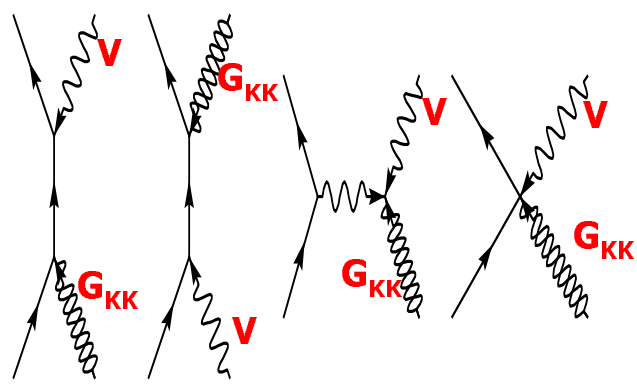
Monojets at hadron colliders

- Kaluza-Klein gravitons couple to the energy-momentum tensor, and therefore contribute to most SM processes



Single VB at hadron or e^+e^- colliders

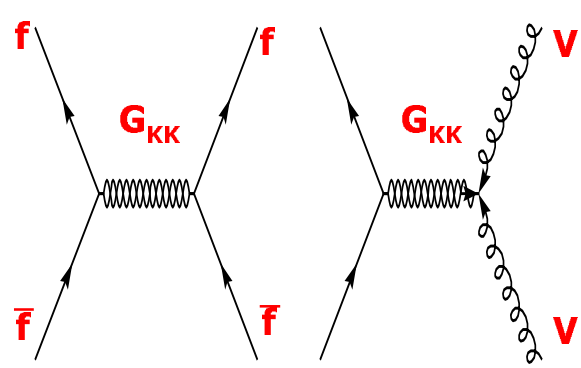
- Since gravitons can propagate in the bulk, from our perspective in (3+1) space-time, energy and momentum will appear not to be conserved in G_{KK} emission



Virtual Gravitons

Fermion or VB pairs at hadron or e^+e^- colliders

- Depending on whether the G_{KK} leaves our brane or remains virtual, collider signatures can include single photons/Zs/jets with missing E_T, or pair produced objects



DØ Search for Monojet Production by Real Graviton Emission

Selection Cuts

- Number of jets ≥ 1
- E_T of the leading jet >150 GeV
- E_T of the other jets < 50 GeV
- Leading jet central, with good jet quality
- $\not{E}_T$ > 150 GeV
- Reject events with isolated muons
- Reject cosmic rays

D0 Analysis

Luminosity 78.8 pb^{-1}

WZ background = 30.2 ± 4.0

QCD/cosmics = 7.8 ± 7.1

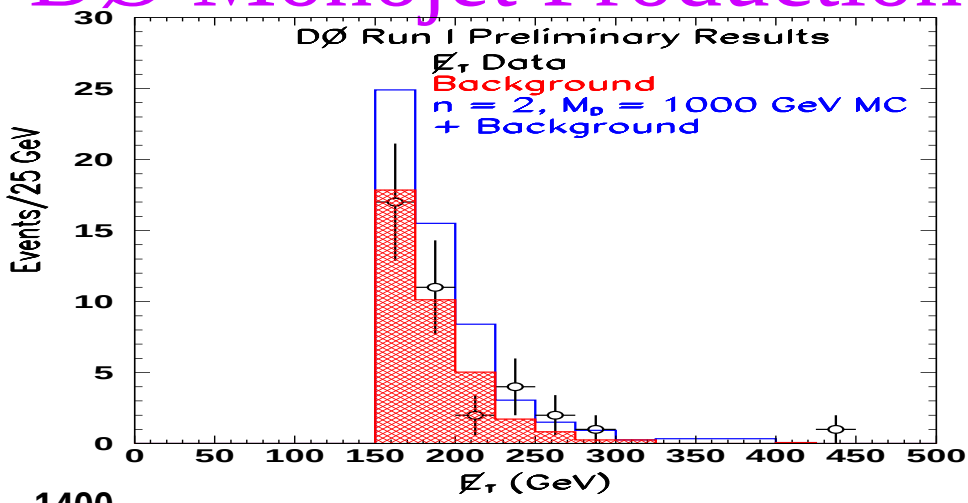
total background = 38.0 ±8.2

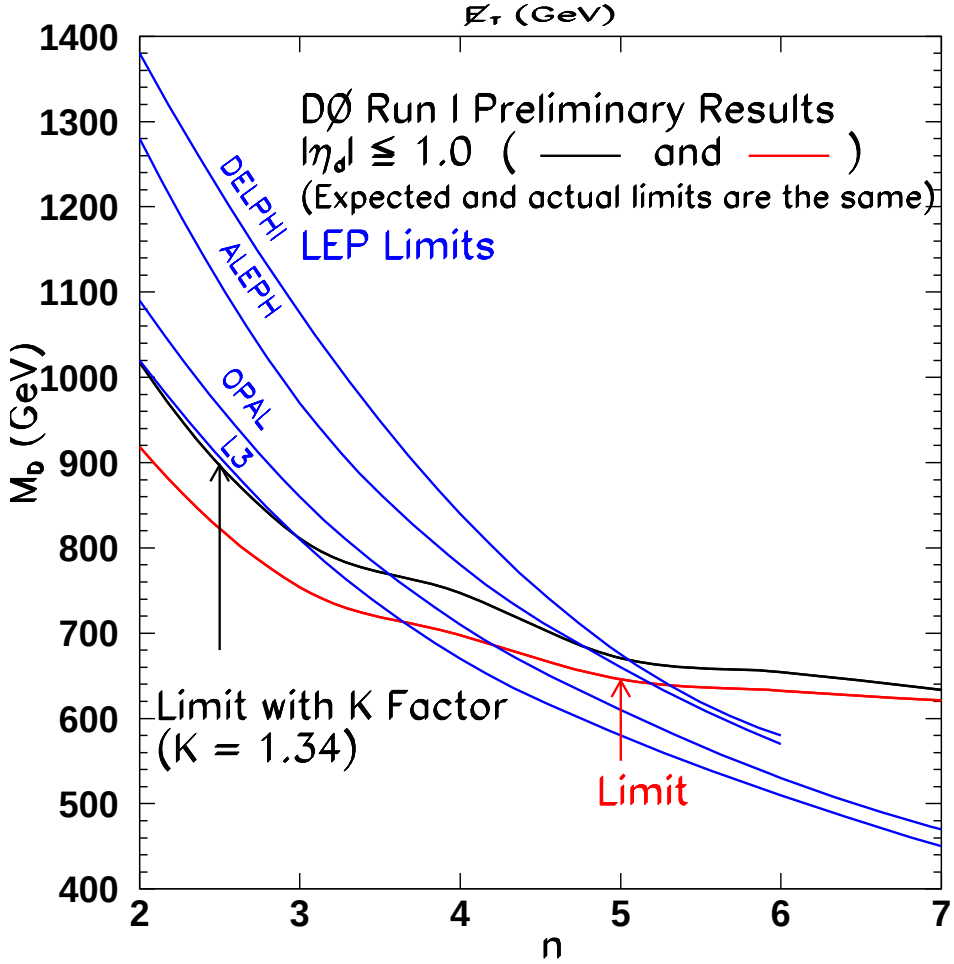
Data: # events = 38

Ref. Giudice, Rattazzi, Wells

Phys. B544, 3(1999) hep- ph/9811291

DØ Monojet Production





N = 4, M_D > 698 GeV (840 GeV, DELPHI)

N = 6, M_D > 632 GeV (580 GeV, DELPHI)

CDF $\gamma + \not{E}_T$

Motivation: Photons can tag invisible particles such as gravitino in SUSY and graviton in LED

One high energy central $\gamma + \not{E}_T$

Selections:

- $E_T^\gamma > 55$ GeV and $|\eta^\gamma| < 1.0$
- $\not{E}_T > 45$ GeV .
- No jets with $E_T > 15$ GeV
- No tracks with $P_T > 5$ GeV/c
- Reject cosmic ray events

11 events observed in 87 pb^{-1} of data

Backgrounds:

- Cosmic Rays: 6.3 ± 2.0
- $Z\gamma \to \nu\nu\gamma$: 3.2 ± 1.0
- $W \to e\nu$: 0.9 ± 0.1
- prompt diphoton: 0.4 ± 0.1
- $W\gamma$: 0.3 ± 0.1
- QCD (not used): 0.9
- Total: 11.0 ± 2.2

CDF $\gamma+\not{E}_T$

- **Search for superlight gravitino**

  Model: hep-ph/9801329, Brignole, etc.

  derive an absolute lower limit on the gravitino mass $m_{3/2}$ and scale $F=\sqrt{3}m_{3/2}M_{planck}$ of SUSY breaking

  Process: $q\bar{q} \rightarrow \tilde{G}\tilde{G}\gamma$

  Result: $\sqrt{F} > 221$ GeV

  Past best limit: 217 GeV $M_{3/2}>1.17*10^{-5}$eV

  (CDF jet + $\not{E}_T$, DELPHI $\gamma+\not{E}_T$)

- Search for Large Extra Dimensions

  Model: Arkani-Hamed, Dimopoulos, Dvali, PLB 429

  Process: $q\bar{q} \rightarrow G_{kk}\gamma$

  Result:
  - N = 4, M_D > 549 GeV (840 GeV, DELPHI)
  - N = 6, M_D > 581 GeV (580 GeV, DELPHI)
  - N = 8, M_D > 602 GeV (411 GeV, L3)

Gen. cross section limit: 112 fb ≥ acc. x ε x $\sigma_{NP\text{->}\gamma+MET}$

Hidden Dimensions
Tevatron Outlook

Other New Run I SUSY and LED Results

Search for new physics in lepton + γ

Search for RPV in $\mu\mu$+4 jets

mSUGRA search in e + jets

Search for RPV resonant sleptons in $e\mu$

Search for stop in like sign $t\,\bar{t}$

Search for stop in $e\mu$

Search for stop in jets +$\not{E}_T$

Extra Dimensions search in ee, $\gamma\gamma$

More good physics to come from Run I data while we look forward to Run 2 results!