

Search for
Hidden Dimensions
in Run I Tevatron Data

Sharon Hagopian
Florida State University

for the DØ and CDF Collaborations

37th Rencontres de Moriond
Electroweak Interactions and Unified Theories
Les Arcs, Savoie, France March 9-16, 2002

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 + \cancel{E}_T

Search in $g + \cancel{E}_T$

(also gravitino and gen. limit)

Supersymmetry

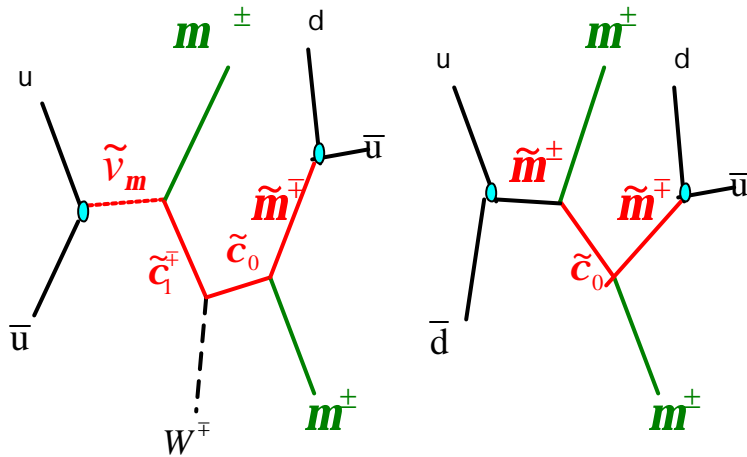
- New symmetry between fermions and bosons
- Predicts superpartners for all known particles
- R-parity $\equiv (-1)^{3B+L+2S}$
 +1 for SM, -1 for SUSY particles
 in models where R-parity is conserved
- R-parity violation in production or decay
 $?_{ijk} L_i L_j E_k, ?'_{ijk} L_i Q_j D_k$ Lepton number 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 |
| $\text{sign}(\mu)$ | 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 (l'_{211})



- Assuming dominant l'_{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

$$E_T^{j1,j1} > 20 \text{ GeV}$$

$$p_T^{\mu1,\mu2} > 20 \text{ GeV}$$

$$H_T(\text{jets}) > 50 \text{ GeV}$$

Background:

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

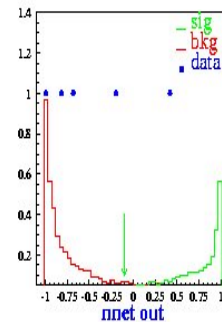
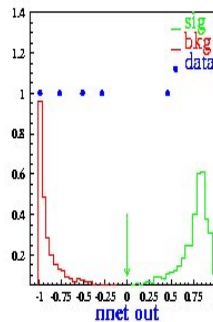
7-5-3-1 NN variables:

$$E_T^{j1} + E_T^{j2}, p_T^{m1} + p_T^{m2}, M_{inv}^{m1,m2}$$

$$\Delta R^{m1,m2}, \Delta R^{m1,jm}, \text{Sph.}, \text{Aplan.}$$

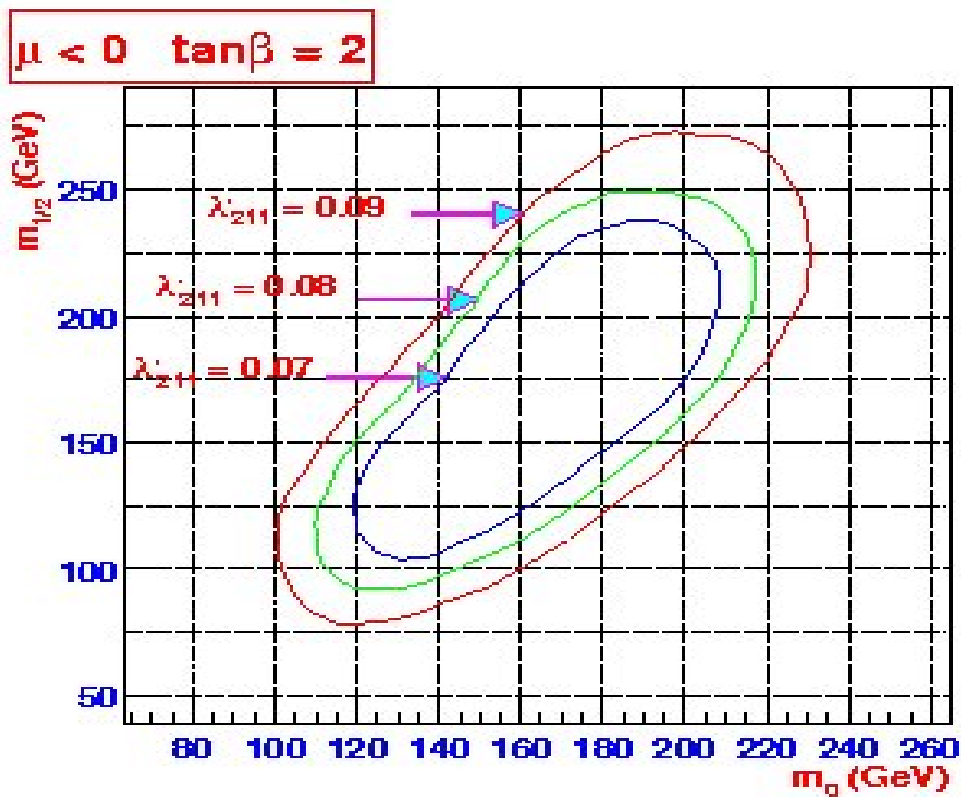
sneutino

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 $\tau b \tau b$

- Stop pairs are produced thru RPC
- Assuming RPV only in the 3rd generation: $\tilde{t}\tilde{t} + X \rightarrow t_l + b + t_h + \bar{b} + X$
 I'_{333} in $I'_{ijk} L^i Q^j \bar{D}^k$ in the superpotential
- Use $Z \rightarrow t_l t_h$ with no jet as a calibration to cancel systematic errors:

$$s_{\tilde{t}\tilde{t}} = s_Z \cdot Br(Z \rightarrow tt) \cdot \frac{(N_{\tilde{t}\tilde{t}}^{obs} - N_{\tilde{t}\tilde{t}}^b) / a_{\tilde{t}\tilde{t}}}{(N_Z^{obs} - N_Z^b) / a_Z}$$

Major SM Backgrounds:

- Z, γ^* ($\tau\tau$) + jets
- W ($e\nu, \mu\nu$) + jets
- W ($\tau\nu$) + jets
- Diboson
- Multijet

CDF RPV SUSY Search for Stop Pairs Decaying into $\tau b \tau b$

Selections (106 pb^{-1}):

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

μ : $P_T > 10 \text{ GeV}/c$, $|\eta| < 0.6$

τ_h : $P_T > 15 \text{ GeV}/c$, $|\eta| < 1.0$

τ_h ID: number of tracks and π^0 in a narrow cone, isolation energy, etc

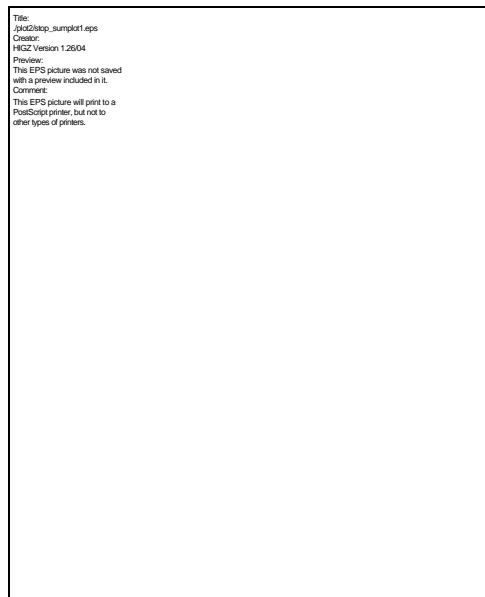
Title:
/plot/tautrack.eps
Creator:
HIGZ Version 1.26/04
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

CDF RPV SUSY Search for Stop Pairs Decaying into $\tau b \tau b$

Additional Selections:

$$M_T(\text{lepton}, \cancel{E}_T) < 35 \text{ GeV}/c^2$$

$$H_T(\text{lepton}, \tau_h, \cancel{E}_T) > 70 \text{ GeV}$$



$$\geq 2 \text{ jets: } E_T > 15 \text{ GeV}$$



| channel | bkgd | obs | acc.% at $m_{\tilde{\tau}} = 120 \text{ GeV}$ |
|---------|-----------|-----|---|
| 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 $\tau b \tau b$

Title:
stop_comb_limit_color.eps
Creator:
HIGZ Version 1.23/07
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Conclusion:

No signal found; limit is set.

(ALEPH: $m_{\tilde{\tau}} > 93 \text{ GeV}/c^2$)

Large Extra Dimensions

Large Extra Dimensions resolve the hierarchy problem by reducing the quantum-gravity scale to $\sim \text{TeV}$

SM – 3+1 dimensional brane

Gravitons can propagate in extra dimensions

$G_N^{-1} = M_{\text{pl}}^2$ 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

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

For $M_d \sim 1\text{TeV}$, we have

$$R = \begin{cases} 1.2 \times 10^{12} \text{ m} & n = 1, \\ 0.48 \text{ mm} & n = 2, \\ 3.6 \text{ nm} & n = 3, \\ 9.7 \times 10^{-12} \text{ m} & n = 4. \end{cases}$$

Ref. Giudice, Rattazzi, Wells

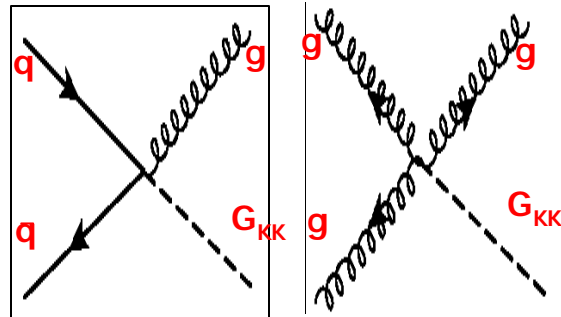
Phys. B544, 3(1999) hep-ph/9811291

Signatures for Large Extra Dimensions at the Tevatron

Real Gravitons

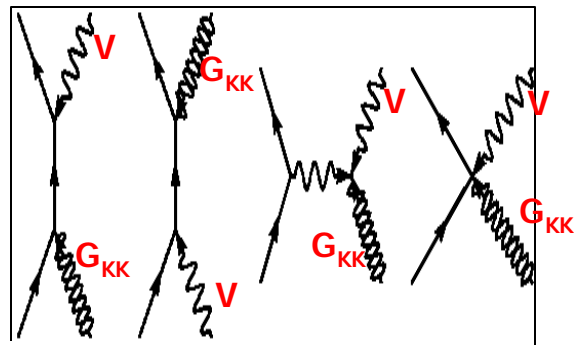
Monojets at hadron colliders

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



- 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

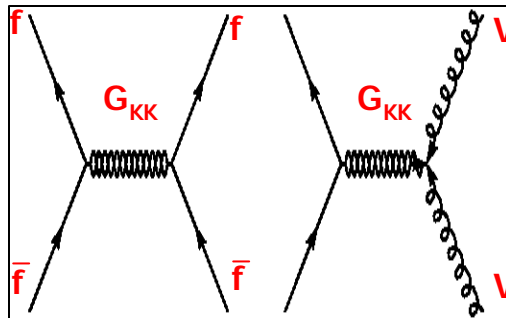
Single VB at hadron or e^+e^- colliders



Virtual Gravitons

- 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

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



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
- $\cancel{E}_T > 150$ 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

Title:
data_wzod_ed1501c_n_j125qph2h_noem_nc25a.ps (Portrait A 4)
Creator:
HIGZ Version 1.23/07
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Title:
contour1501c_m.ps (Portrait A 4)
Creator:
HIGZ Version 1.23/07
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

CDF $\gamma + \cancel{E}_T$

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

One high energy central $g + \cancel{E}_T$

Selections:

- $E_T^\gamma > 55 \text{ GeV}$ and $|\eta^\gamma| < 1.0$
- $\cancel{E}_T > 45 \text{ GeV}$.
- No jets with $E_T > 15 \text{ GeV}$
- No tracks with $P_T > 5 \text{ GeV}/c$
- Reject cosmic ray events

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

Backgrounds:

- Cosmic Rays: 6.3 ± 2.0
- $Z\gamma \rightarrow \nu\nu\gamma$: 3.2 ± 1.0
- $W \rightarrow e\nu$: 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 $\gamma + E_T$

• Search for superlight gravitino

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

derive an absolute lower limit on the gravitino mass $m_{3/2}$ and scale

$F = \sqrt{3} m_{3/2} M_{\text{plank}}$ of SUSY breaking

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

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

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

(CDF jet + E_T , DELPHI $g + E_T$)

• Search for Large Extra Dimensions

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

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

$N = 4, M_D > 549 \text{ GeV}$ (840 GeV, DELPHI)

$N = 6, M_D > 581 \text{ GeV}$ (580 GeV, DELPHI)

Result: $N = 8, M_D > 602 \text{ GeV}$ (411 GeV, L3)

Gen. cross section limit: $112 \text{ fb} \geq \text{acc.} \times \epsilon \times \sigma_{\text{NP} \rightarrow \gamma + \text{MET}}$

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 + 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!