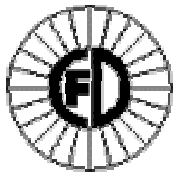


Recent Results in Search for New Physics at Tevatron (Run I)



John Zhou
Rutgers University
on behalf of
CDF and DØ collaborations

- SUSY
 - RPV mSUGRA stop search in tau channels (CDF)
 - RPV mSUGRA search in muon channels (DØ)
 - mSUGRA in single electron channel (DØ)
- Large Extra Dimensions
 - Diphoton channel (CDF)
 - Jets + \cancel{E}_T channel (DØ)
- Leptoquark (DØ)
- Model Independent searches
 - $\gamma + \cancel{E}_T$ (CDF)
 - Quaero (DØ)



Tevatron (Run I) Introduction

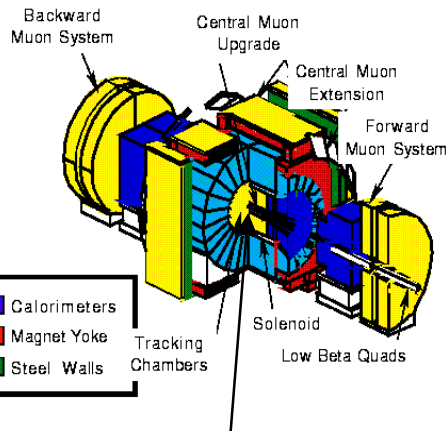


Tevatron

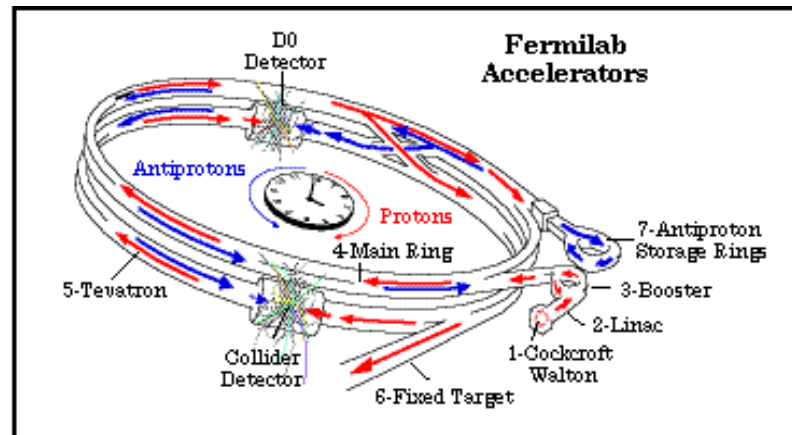
proton-antiproton collision @ $\sqrt{s} = 1.8$ TeV

CDF

CDF Detector



Silicon Vertex Detector

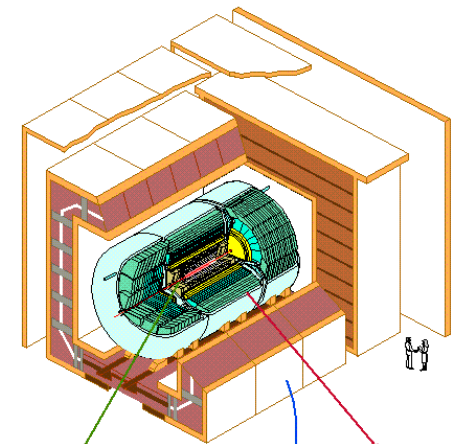


Run I (Oct. 92 → Feb. 96)

total integrated luminosity
~ 120^{-1} pb / detector

Expected ~ 2 fb $^{-1}$ in Run II a !

D0



D0 Detector

<p>TRACKING</p> <p>$\sigma(\text{vertex}) = 6$ mm $\sigma(\text{r0}) = 60$ μm (VTX) $= 180$ μm (CDC) $= 200$ μm (FDC)</p>	<p>MUON</p> <p>$\eta < 3.3$</p> <p>$\frac{\delta P}{P} = 0.2 \oplus .003 P$</p>	<p>CALORIMETRY</p> <p>$\eta < 4$ $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$ $\sigma(\text{EM}) = 15\% / \sqrt{E}$ $\sigma(\text{HAD}) = 50\% / \sqrt{E}$</p>
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CDF RPV mSUGRA Search in Decays of Stop Pair (I)



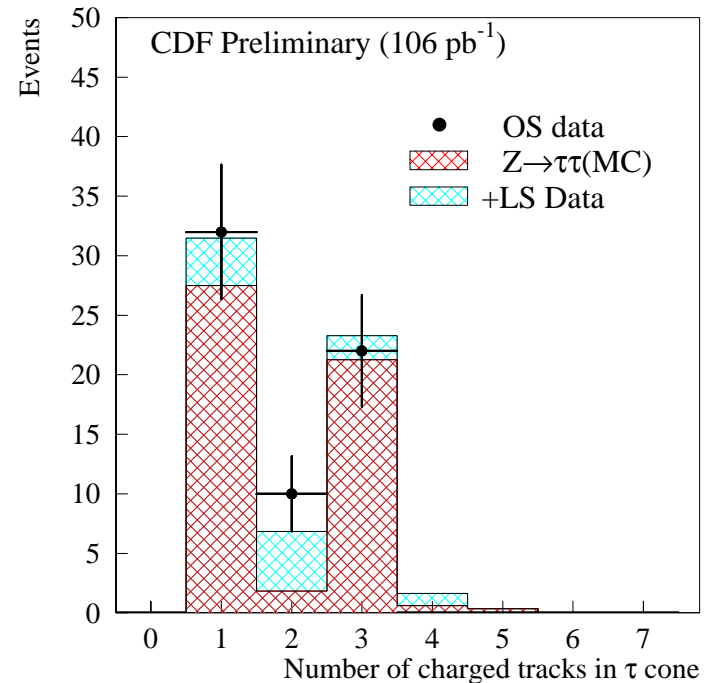
- Stop pair are produced thru RPC
- Assuming RPV only in the 3rd generation: $\tilde{t}\tilde{t} + X \rightarrow \tau_l + b + \tau_h + \bar{b} + X$
 λ'_{333} in $\lambda'_{ijk} L^i Q^j \bar{D}^k$ in the superpotential

τ_h selection (106 pb^{-1}):

- τ_h : cluster $P_T > 15 \text{ GeV}/c$, $|\eta| < 1.0$
- τ_h ID: number of tracks and π^0 in a narrow cone, isolation energy, etc.

Major SM Backgrounds:

- $Z, \gamma^* (\tau\tau) + \text{jets}$
- $W (e\nu, \mu\nu) + \text{jets}$
- $W (\tau\nu) + \text{jets}$
- Diboson
- Multijet





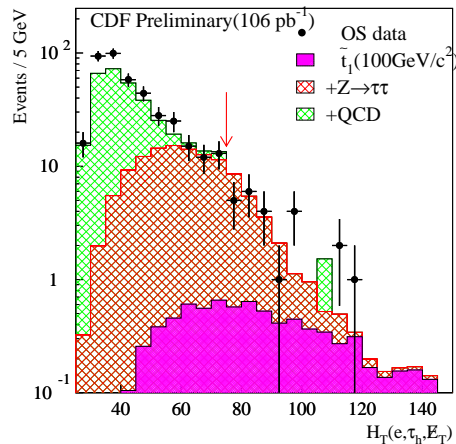
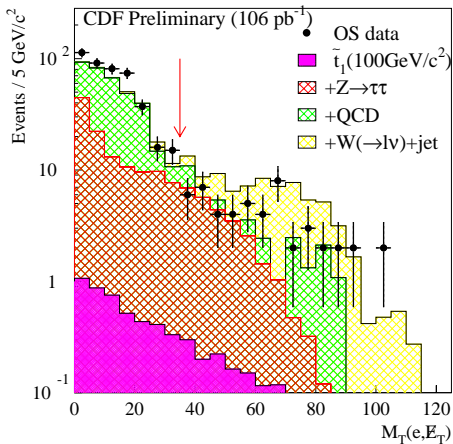
CDF RPV mSUGRA Search in Decays of Stop Pair (II)



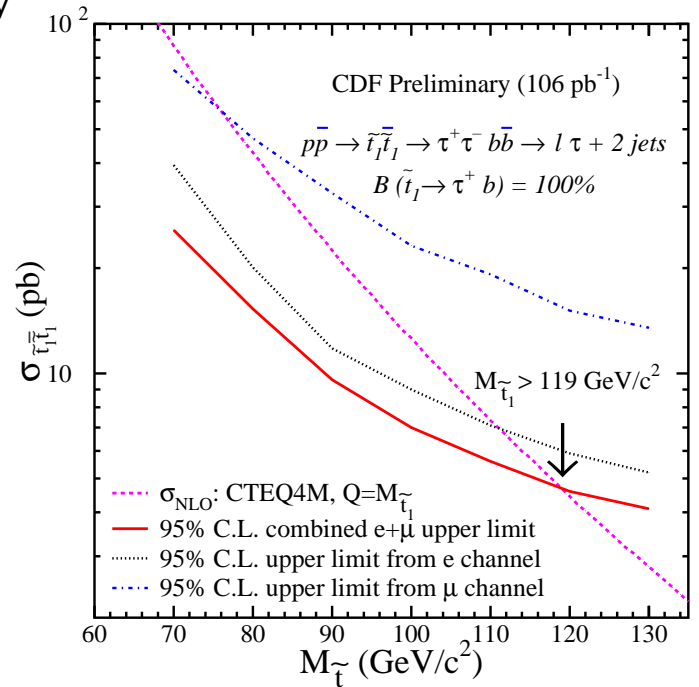
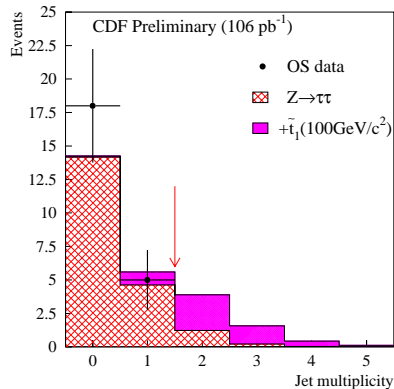
Additional Selections:

$$M_T(\text{lepton}, \cancel{E}_T) < 35 \text{ GeV}/c^2 \quad H_T(\text{lepton}, \tau_h, \cancel{E}_T) > 70 \text{ GeV}$$

limit



≥ 2 jets: $E_T > 15 \text{ GeV}$



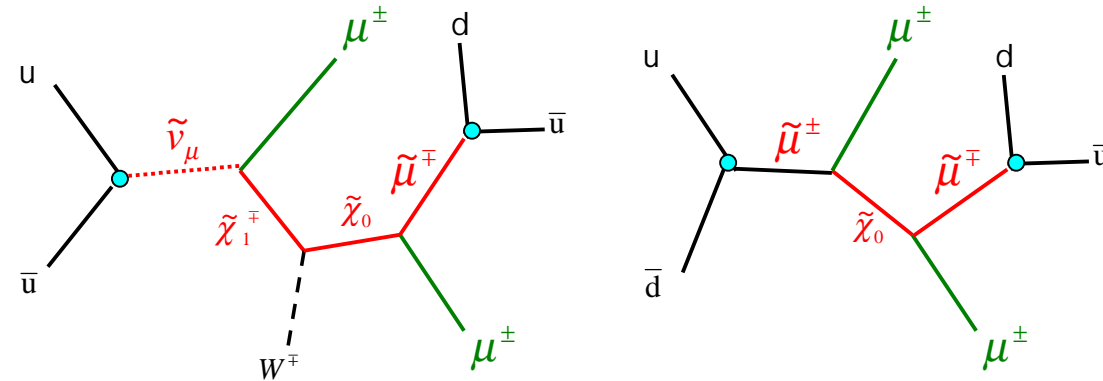
channel	bkgd	obs	eff% at $m_{\tilde{t}_1} = 120\text{GeV}$
e	1.92±0.18	0	3.18
μ	1.13±0.13	0	1.79

Conclusion:

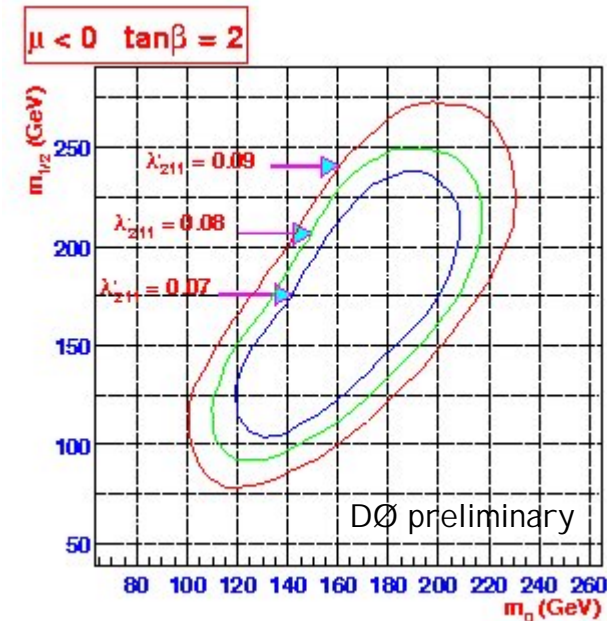
No signal found; limit is set.
 (ALEPH: $m_{\tilde{t}_1} > 93 \text{ GeV}/c^2$)



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



95% CL limit contour



- Assuming dominant λ'_{211} coupling
- Search for 2 μ 's and 2 jets final state

Initial selections (94 pb^{-1}):

$$E_T^j > 20 \text{ GeV (2 jets)}, p_T^\mu > 20 \text{ GeV}/c$$

$$|\eta^j| < 2.5, |\eta^{\mu_1, \mu_2}| < 1.0, 1.7$$

$$H_T > 50 \text{ GeV}$$

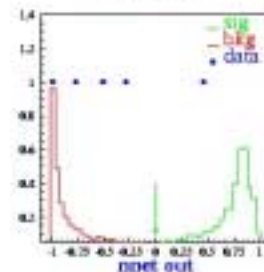
cosmic ray rejection

NN variables:

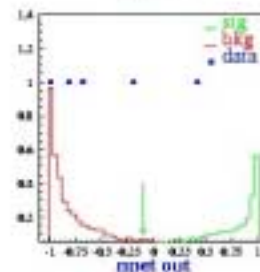
$$E_T^{j_1} + E_T^{j_2}, p_T^{\mu_1} + p_T^{\mu_2}, M_{inv}^{\mu_1, \mu_2}$$

$$\Delta R^{\mu_1, \mu_2}, \Delta R^{\mu_1, j_m}, \text{Sph.}, \text{Aplan.}$$

sneutino

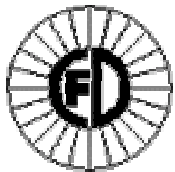


smuon



After NN selection,
expect 1.01 ± 0.02 SM
events. Observed: 2.
Signal: ~ 6 at contour

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

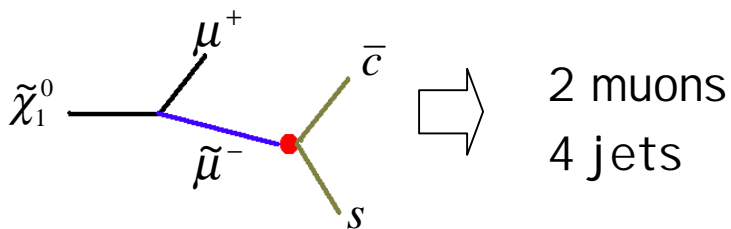


DØ Search for RPV mSUGRA in Dimuon and Four-jets channel



Assumptions:

- SUSY particles pair produced
- only one coupling dominates, e.g. λ'_{222}
- only the LSP ($\tilde{\chi}_1^0$) goes RPV decay



Selections:

$$E_T^j > 15 \text{ GeV (4 jets)}$$

$$p_T^{\mu_1, \mu_2} > 15, 10 \text{ GeV/c}$$

$$|\eta^j| < 2.5, |\eta^{\mu_1, \mu_2}| < 1.0, 1.7$$

$$H_T^{\mu, j} > 150 \text{ GeV}$$

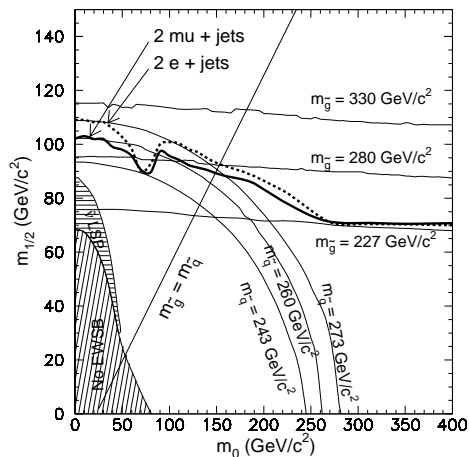
$$\text{Aplanarity} > 0.03$$

$$M_{\mu_1, \mu_2} > 5 \text{ GeV}$$

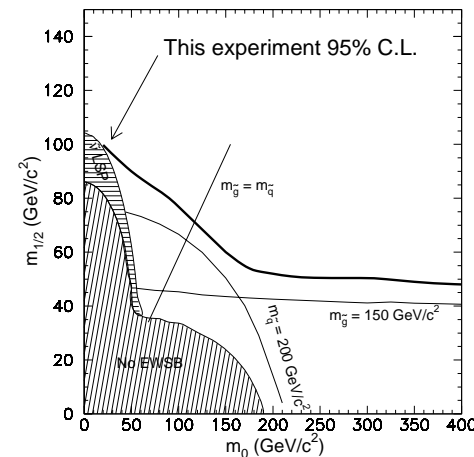
77.5 pb⁻¹

Z+jets	0.14±0.03
t \bar{t}	0.04±0.01
Total bg	0.18±0.04
Obs.	0

Limits



$\tan\beta=2, \mu<0, A_0=0$



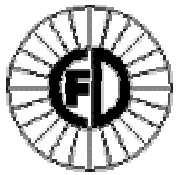
$\tan\beta=2, \mu<0, A_0=0$

$\tan\beta=2, \mu<0, A_0=0$		
m_0	$M_{1/2}$	Nsig
80	90	2.7
190	90	2.1
260	70	2.7
400	90	0.8

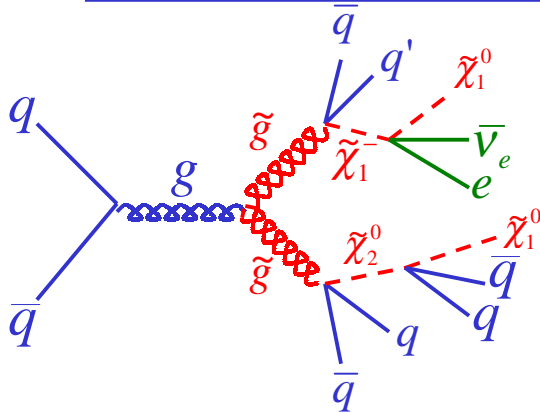
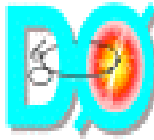
Conclusions
($\tan\beta=2$):

$$m_{\tilde{q}} > 240 \text{ GeV}$$

$$m_{\tilde{g}} > 224 \text{ GeV}$$



DØ Search for RPC mSUGRA in Single Electron Channel (I)



- Sensitive to moderate m_0 region; complements dilepton, jets+ \cancel{E}_T searches.

- Selections (92.7 pb^{-1}):

$$E_T^e > 20 \text{ GeV}$$

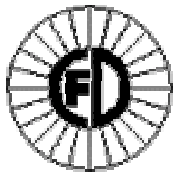
$$E_T^j > 15 \text{ GeV (4 jets)}$$

$$\cancel{E}_T > 25 \text{ GeV}$$

- $t \bar{t} : 16.8 \pm 5.2$
 - $WW + \geq 2 \text{ jets} : 1.4 \pm 0.3$
 - Multijet: 19.1 ± 4.7
 - $W + \geq 4 \text{ jets} : 43.0 \pm 7.6$
- Total background: 80 ± 10

Observed:
72 events

We use Neural Network to further optimize signal significance

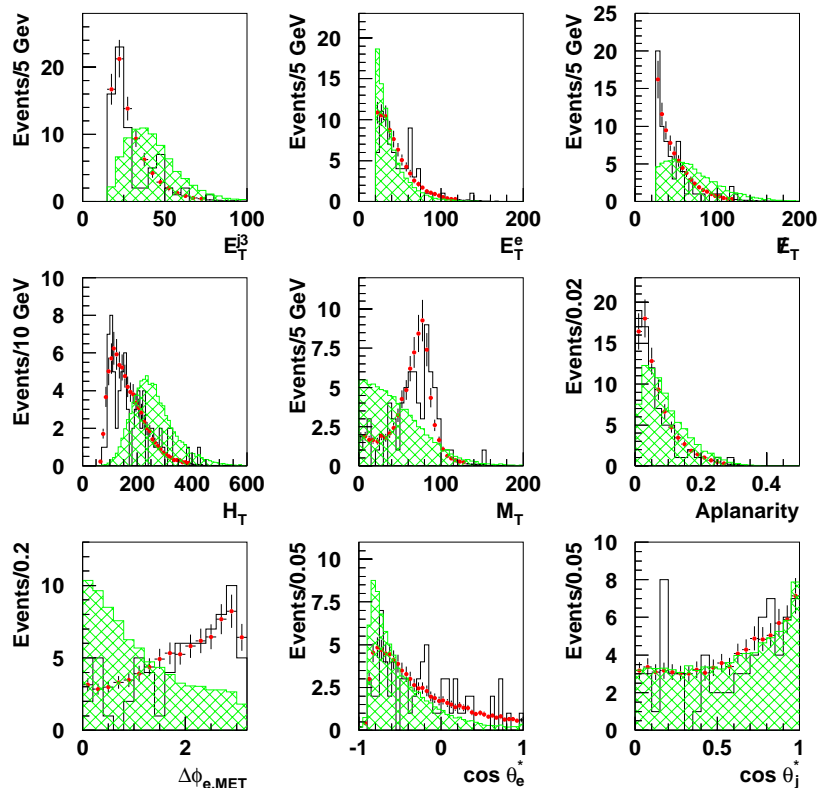


DØ Search for RPC mSUGRA in Single Electron Channel (II)



- NN variable to optimize

DØ preliminary



NN training:

$$m_0=170 \text{ GeV}/c^2$$

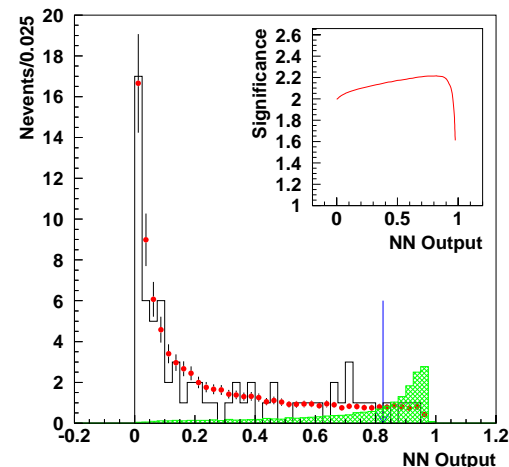
$$m_{1/2}=58 \text{ GeV}/c^2$$

$$N_{\text{signal}}=10.4$$

$$N_{\text{bkgd}}=4.4$$

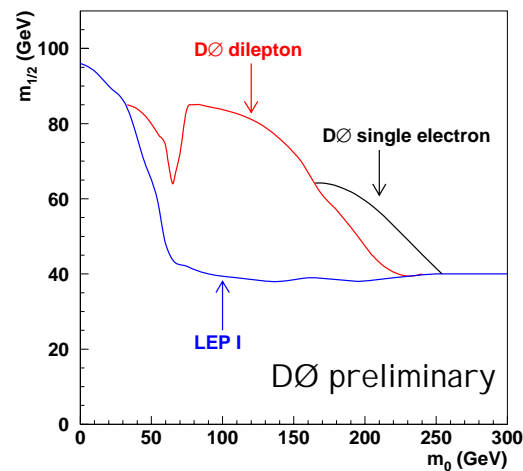
$$N_{\text{obs}}=4$$

DØ preliminary



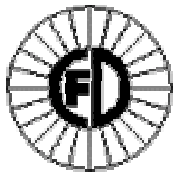
$$\tan\beta=3, \mu<0, A_0=0$$

Limit contour



Best limit: LEP, www.cern.ch/LEPSUSY

Best Tevatron limit: CDF jets+ E_T , PRL 88, 041801



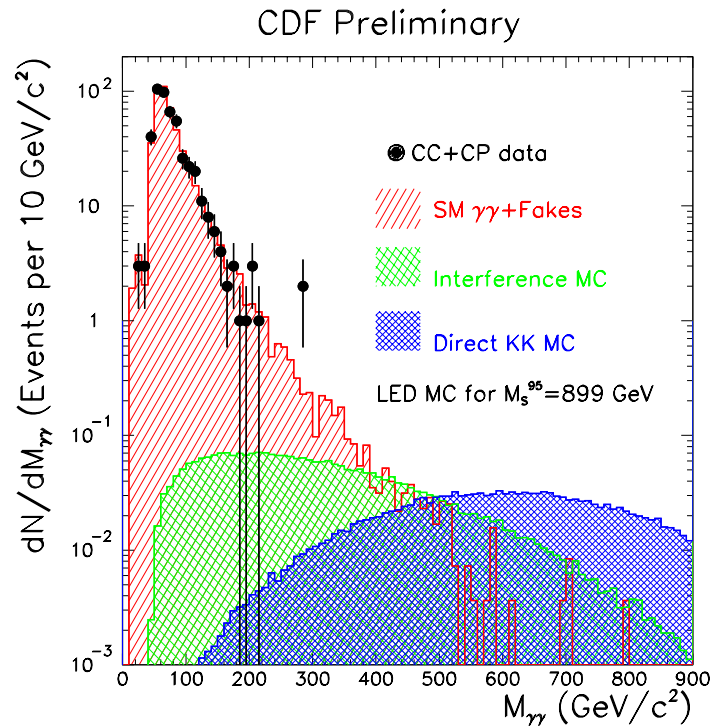
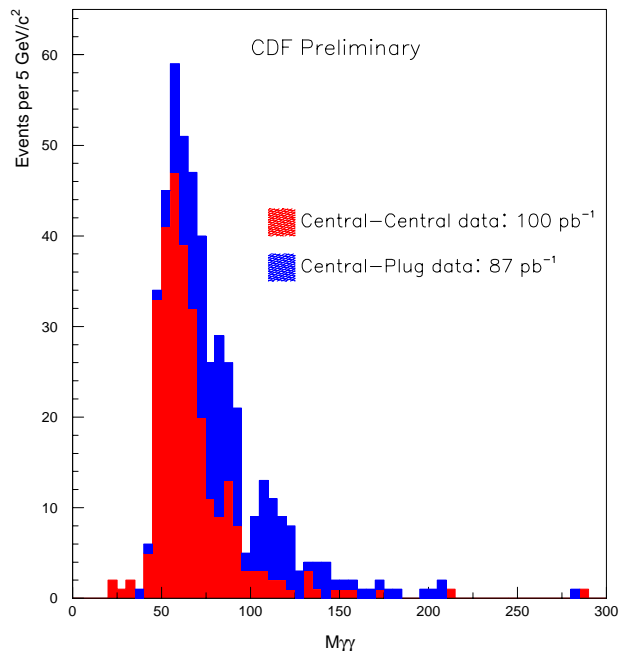
CDF Search for Large Extra Dimension in Diphoton Events



Cross section of $p\bar{p} \rightarrow \gamma\gamma + X$:

$$\frac{d\sigma}{dM_{\gamma\gamma}} = \frac{d\sigma}{dM_{\gamma\gamma}} \Big|_{SM} + \eta \frac{d\sigma}{dM_{\gamma\gamma}} \Big|_{INT} + \eta^2 \frac{d\sigma}{dM_{\gamma\gamma}} \Big|_{KK}$$

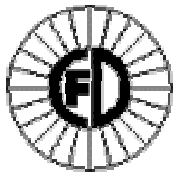
$\eta = \frac{\lambda}{M_S^4}$ is the variable to fit



Cuts: $E_T^\gamma > 22 \text{ GeV}$, $|\eta| < 1.0$
 Observed: CC: 287, CP: 192
 SM: CC: 96 ± 31 , CP: 76 ± 31
 fake: CC: 184 ± 63 , CP: 132 ± 28

$M_S > 1.01 \text{ TeV}$
 in GRW
 convention
 (100 pb^{-1})

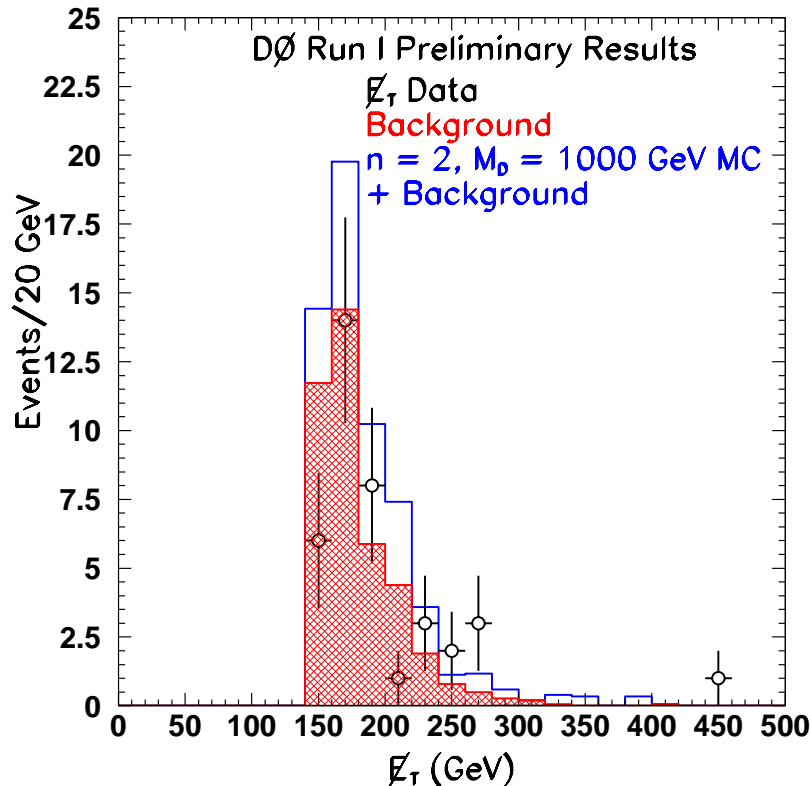
DØ, adding $\cos\theta^*$ in the fit, and with an extended data set (incl. elects), obtained $M_S > 1.21 \text{ TeV}$ (GRW, 127 pb^{-1}) PRL 86(1156)



DØ Search for Large Extra Dimension in Jet(s) + \cancel{E}_T Channel

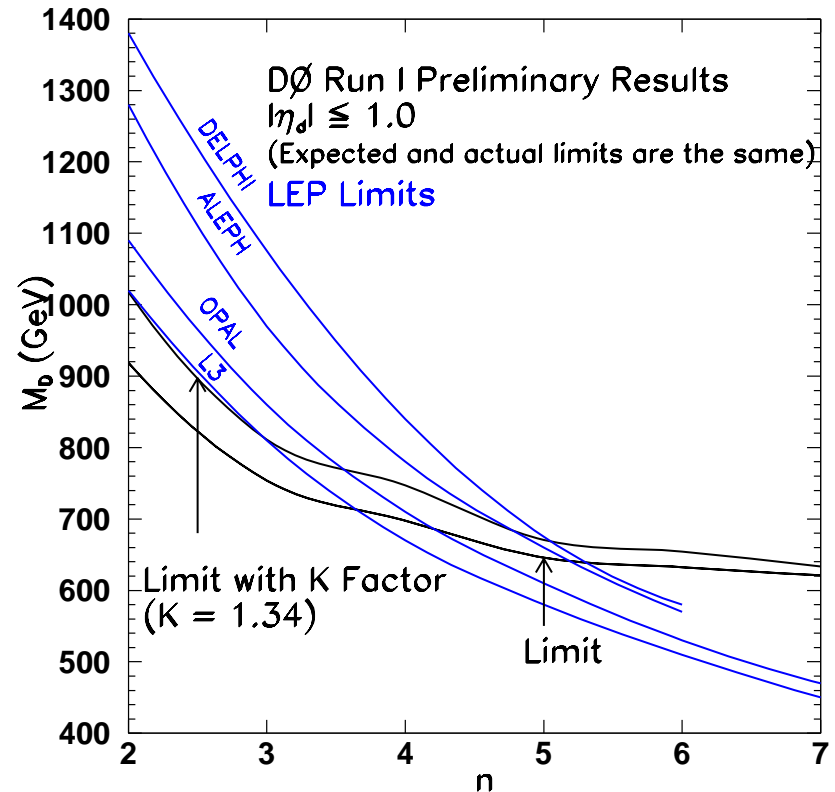


jet $E_T(1)/MET > 150\text{GeV}$ in central calorimeter
jet $E_T(2) < 50\text{ GeV}$



- Luminosity: 78.8 pb^{-1}
- W/Z background: 38.0 ± 8.2
(including $N_{\text{QCD/Cosmics}}$ events: 7.8 ± 7.1)
- Observed: 38

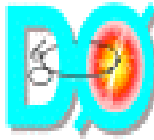
Limit



- **DØ Run I preliminary Limits Complement LEP results at high n**

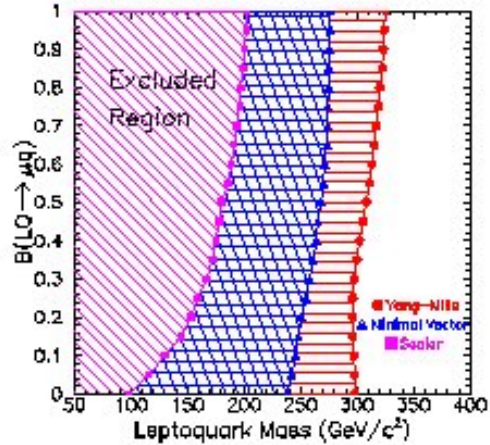
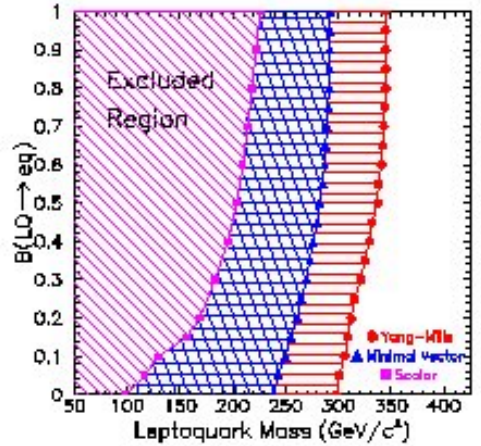
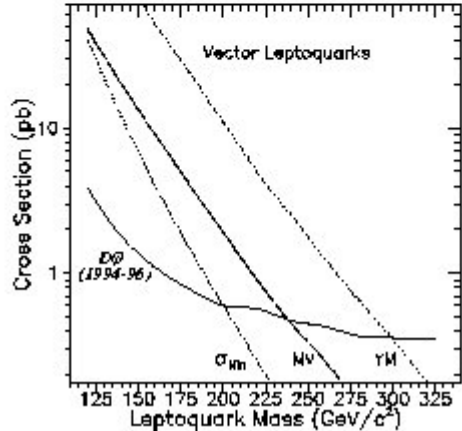
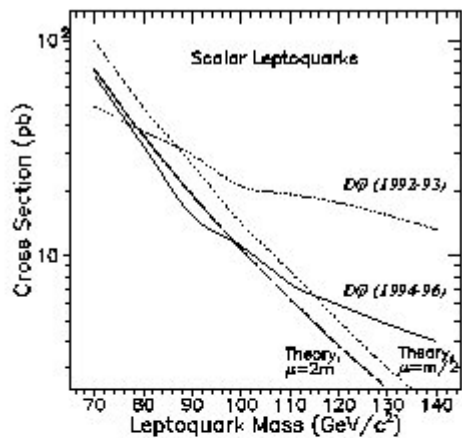


DØ Search for Leptoquark in 2 jets + \cancel{E}_T Channel



- Sensitive to exclusive $LQ \rightarrow vq$ decay; involves all three generations
- Dominant Backgrounds:
 - W +jets, Z +jets, $t\bar{t}$
 - multijet
- NN optimization on:
 - $\cancel{E}_T, \Delta\phi(j_1, j_2), E_T(j_2)$
- Result:

NN signal	bkgd	Obs.	signal
SLQ (100 GeV)	56.0 ± 8.1	58	25.1 ± 2.7
VLQ (200 GeV)	13.3 ± 2.8	10	15.8 ± 1.3



$m_{SLQ} > 98 \text{ GeV}$
 $m_{VLQ} > 200, 238, 298 \text{ GeV}$ for σ_{min} , MV, and YM couplings



CDF $\gamma + \cancel{E}_T$ Analysis (I)



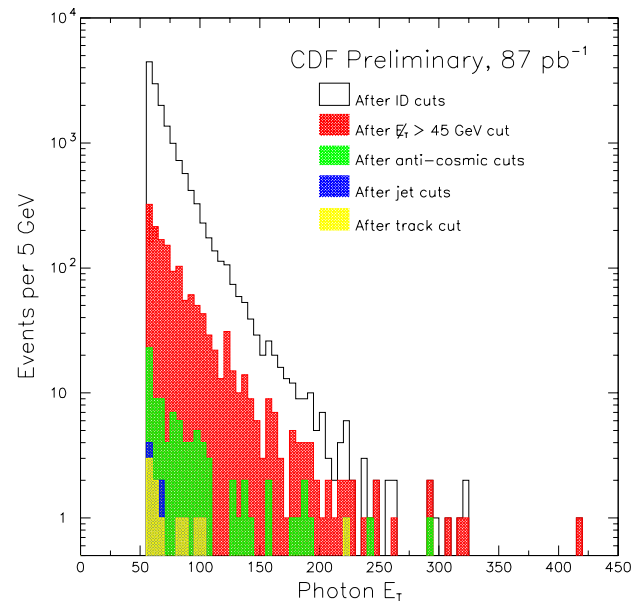
Motivation:

Photon tagging invisible particles such as gravitino in SUSY and graviton in LED

Selections:

- $E_T^\gamma > 55 \text{ GeV}$ and $|\eta^\gamma| < 1.1$.
- $\cancel{E}_T > 45 \text{ GeV}$.
- Reject cosmic ray events
- No jets with $E_T > 15 \text{ GeV}$
- No tracks with $P_T > 5 \text{ GeV}/c$

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
- Total: 11.0 ± 2.2



CDF $\gamma + \cancel{E}_T$ Analysis (II)



- Search for superlight gravitino

Model: hep-ph/9801329, Brignole, etc.
derive an absolute lower limit on the gravitino mass $m_{3/2}$ and scale

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

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

Result: $\sqrt{F} > 221 \text{ GeV}, m_{3/2} > 1.17 \times 10^{-5} \text{ eV}$

Past best limit: 217 GeV (CDF jet + \cancel{E}_T , DELPHI $\gamma + \cancel{E}_T$)

- Search for Large Extra Dimension

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

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

Result:

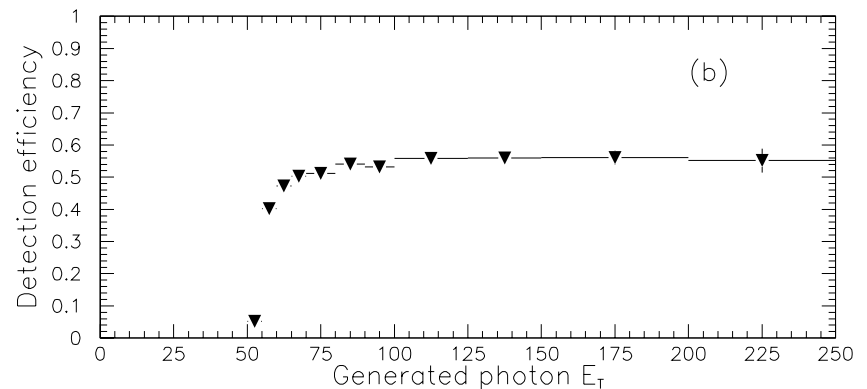
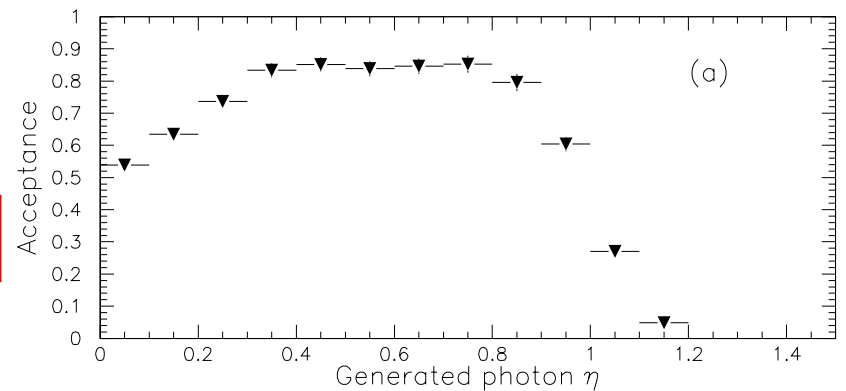
$N = 4, M_D > 549 \text{ GeV}$ (680 GeV, DELPHI)

$N = 6, M_D > 581 \text{ GeV}$ (510 GeV, DELPHI)

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

- Generalized acc. And eff. To allow new models to be tested:

CDF Preliminary





Quaero - DØ Makes its Data Public!

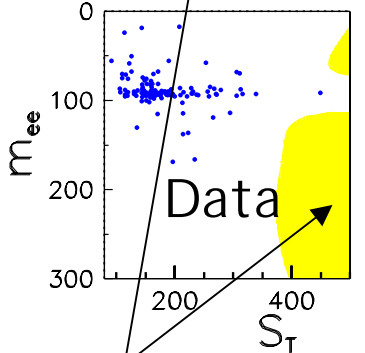
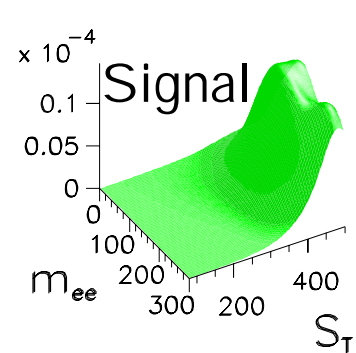
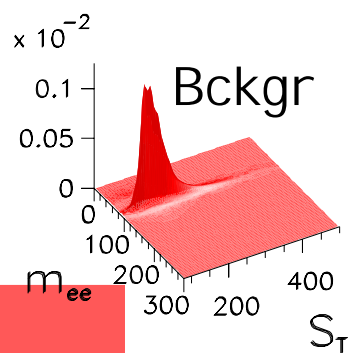
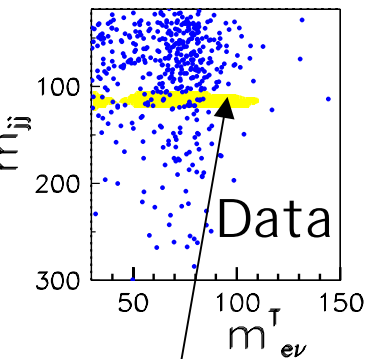
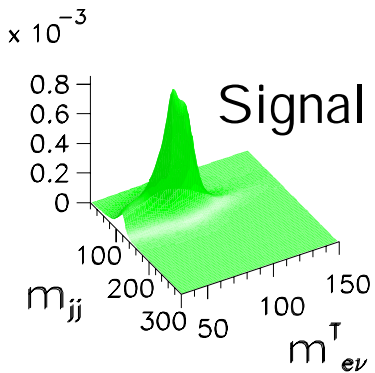
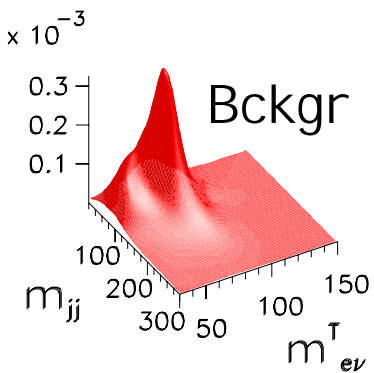


QUAERO automatically optimizes an analysis for a particular signature provided by the user, using DØ data sets and SM backgrounds. QUAERO was demonstrated in eleven separate searches: SM WW, ZZ, and $t\bar{t}$ production; resonant $h \rightarrow WW, ZZ$; $W' \rightarrow WZ$, and $Z' \rightarrow t\bar{t}$ production; associated Higgs production; and pair production of first generation scalar leptoquarks. Search for $W' \rightarrow WZ$ is the first of its kind.

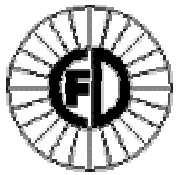
$Wh \rightarrow evjj$, w/
kinematic fit to W

Quaero: Latin for "to seek"

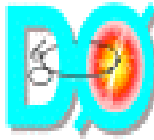
$LQLQ \rightarrow eejj$



Region of max sensitivity



Conclusions



- Searches for New Physics in Run I data are still actively being pursued. During the past years, better limits have been achieved in
 - RPV, RPC mSUGRA parameters
 - Large Extra Dimensions
 - Leptoquark masses
- New tools and techniques have been developed, e.g. model independent search strategies.
- With these new tools, better detectors, and higher luminosity, Run 2 will be an exciting period for New Physics searches and discoveries.