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

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Rutgers University
on behalf of
CDF and DØ collaborations

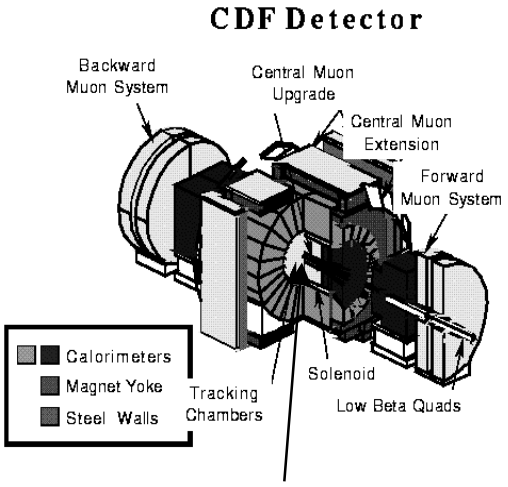
- SUSY
  - RPV mSUGRA stop search in tau channels (CDF)
  - RPV mSUGRA search in muon channels (DØ)
  - mSUGRA in single electron channel (DØ)
- Large Extra Dimensions
  - Diphoton channel (CDF)
  - Jets + $\not\!\!E_T$ channel (DØ)
- Leptoquark (DØ)
- Model Independent searches
  - $\gamma + \not\!\!E_T$ (CDF)
  - Quaero (DØ)

Tevatron (Run I) Introduction

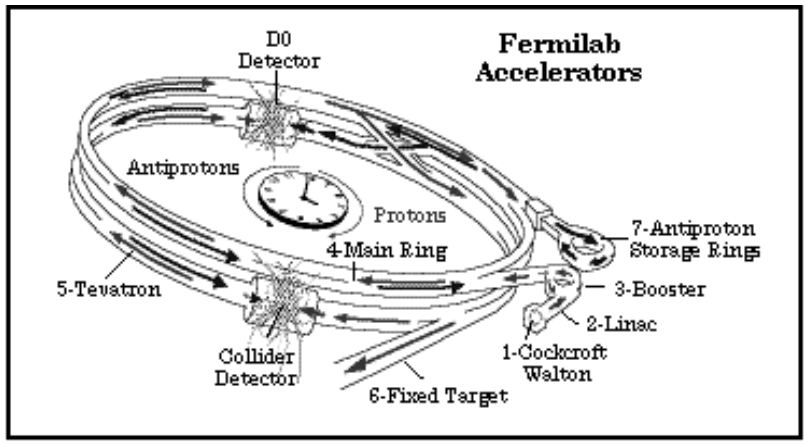
Tevatron

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

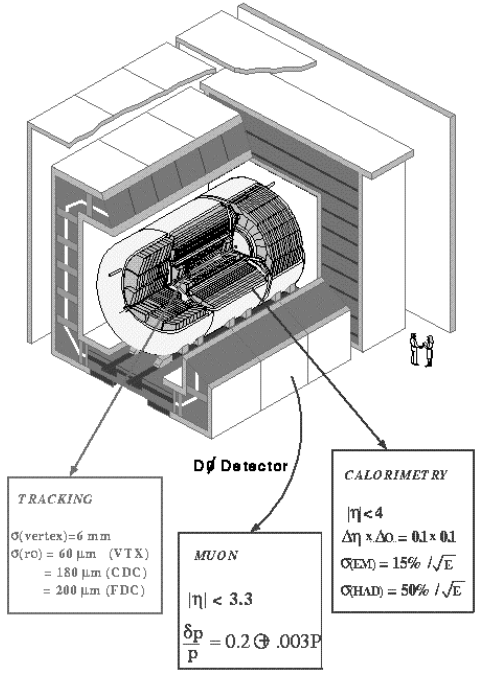
CDF



Silicon Vertex Detector



DØ



Run I (Oct. 92 → Feb. 96)

total integrated luminosity

~ 120^{-1} pb / detector

Expected ~ 2 fb^{-1} in Run IIa !

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

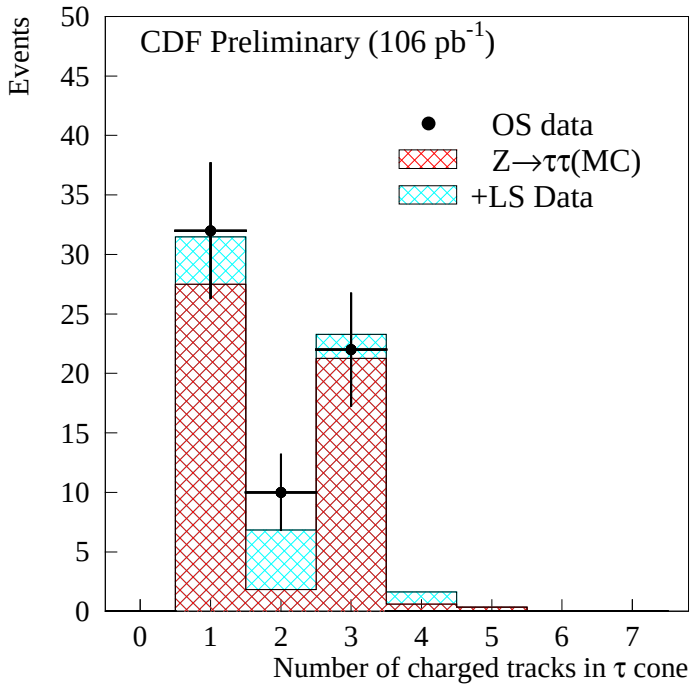
- Stop pair are produced thru RPC
- Assuming RPV only in the 3rd generation: $\tilde{t}\bar{\tilde{t}} + X \rightarrow \tau_l + b + \tau_h + \bar{b} + X$ λ'_{333} in $\lambda'_{ijk} L^i Q^j \bar{D}^k$ in the superpotential

τ_h selection (106 pb^{-1}):

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

Major SM Backgrounds:

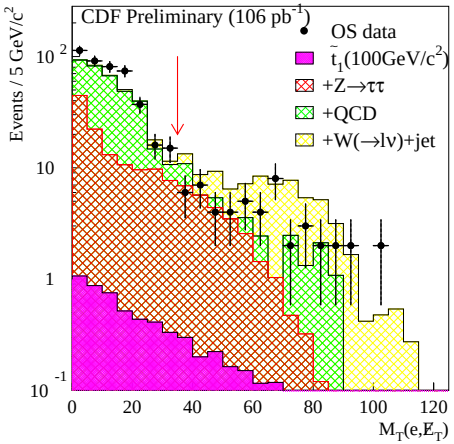
- Z, γ^* ($\tau\tau$) + jets
- W ($e\nu$,$\mu\upsilon$) + jets
- W ($\tau\upsilon$) + jets
- Diboson
- Multijet

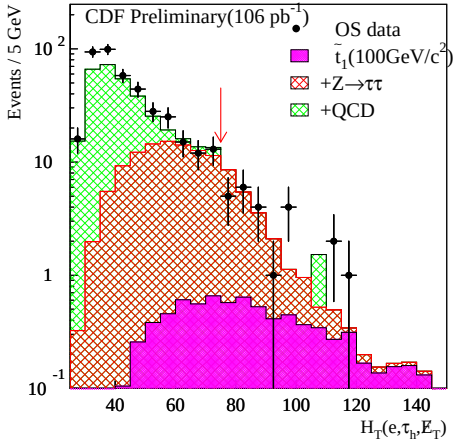


CDF RPV mSUGRA Search in Decays of Stop Pair (II)

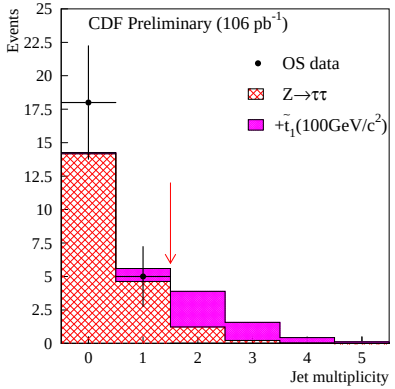
Additional Selections:

$M_T(\text{lepton}, \not{E}_T) < 35$ GeV/c^2 $H_T(\text{lepton}, \tau_h, \not{E}_T) > 70$ GeV



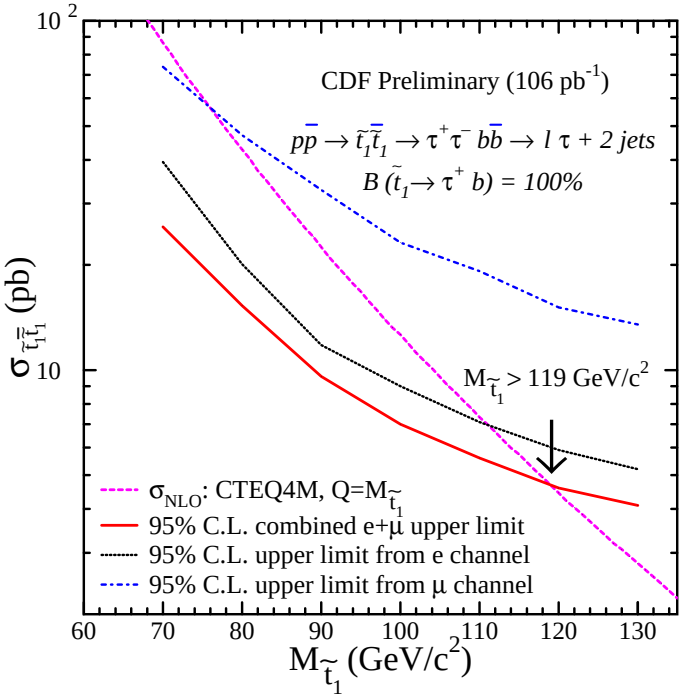


≥ 2 jets: $E_T > 15$ GeV



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

limit

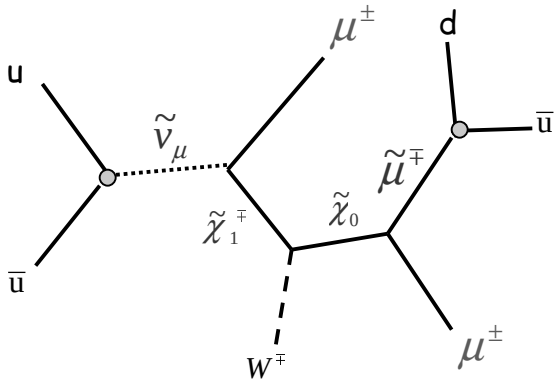


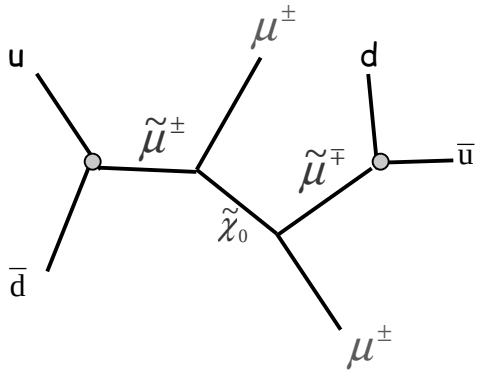
Conclusion:

No signal found; limit is set.

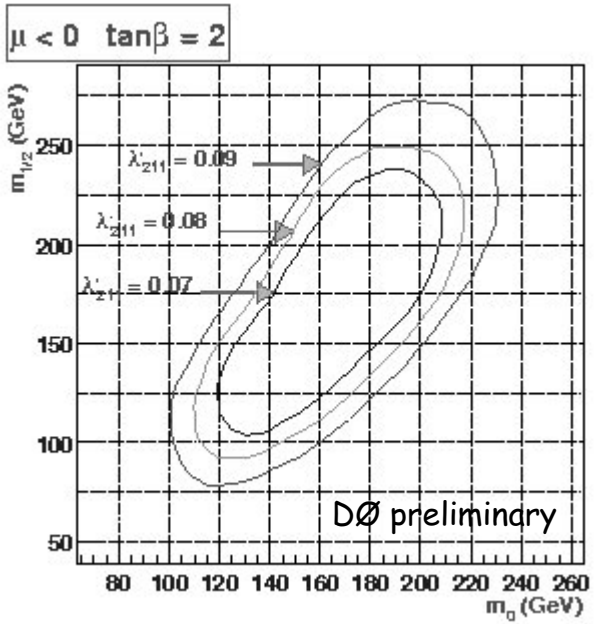
(ALEPH: $m_{\tilde{t}} > 93\,\text{GeV/c}^2$)

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

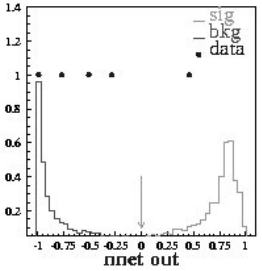
Z+2jets	$t\bar{t}$	WW	Total	Obs.
4.8	0.53	0.01	5.34±0.07	5

NN variables:

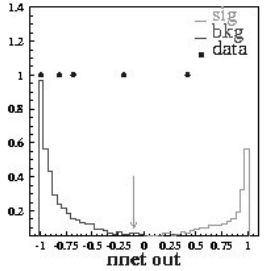
$E_T^{j_1} + E_T^{j_2}$, $p_T^{\mu_1} + p_T^{\mu_2}$, $M_{inv}^{\mu_1,\mu_2}$

$\Delta R^{\mu_1,\mu_2}$, $\Delta R^{\mu_1,j_{nn}}$, Sph., Aplan.

sneutino



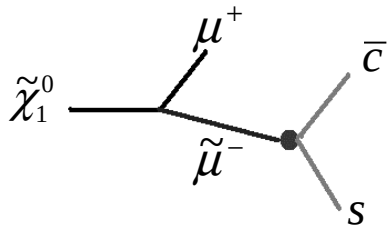
smuon



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

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



2 muons
4 jets

- Selections:

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

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

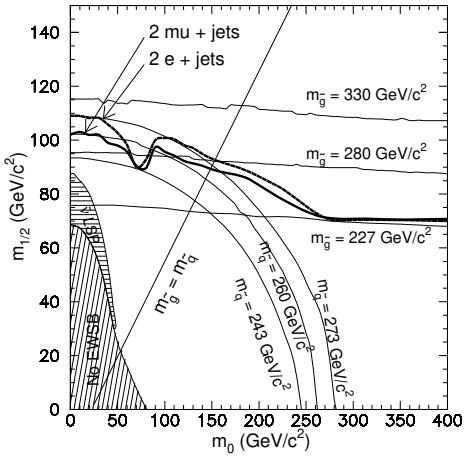
$|\eta^j| < 2.5, |\eta^{\mu_1,\mu_2}| < 1.0, 1.7$

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

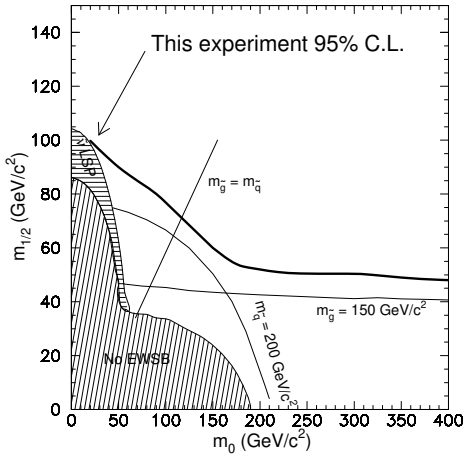
$\text{Aplanarity} > 0.03$

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

Limits



tanβ=2, μ<0, A_0=0



tanβ=2, μ<0, A_0=0

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

tanβ=2, μ<0, A_0=0

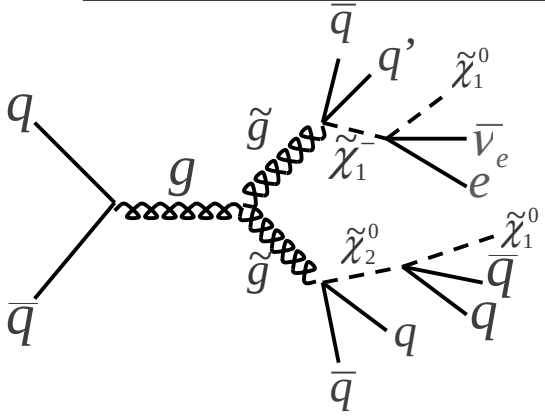
m_0	$M_{1/2}$	Nsig
80	90	2.7
190	90	2.1
260	70	2.7
400	90	0.8

Conclusions (tanβ=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+$\not\!\!E_T$ searches.
- Selections (92.7 pb^{-1}):

$E_T^e > 20\,\mathrm{GeV}$

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

$\not\!\!E_T > 25\,\mathrm{GeV}$

- $t\bar{t}$: 16.8 ± 5.2
- WW + ≥ 2 jets : 1.4 ± 0.3
- Multijet: 19.1 ± 4.7
- W + ≥ 4 jets : 43.0 ± 7.6

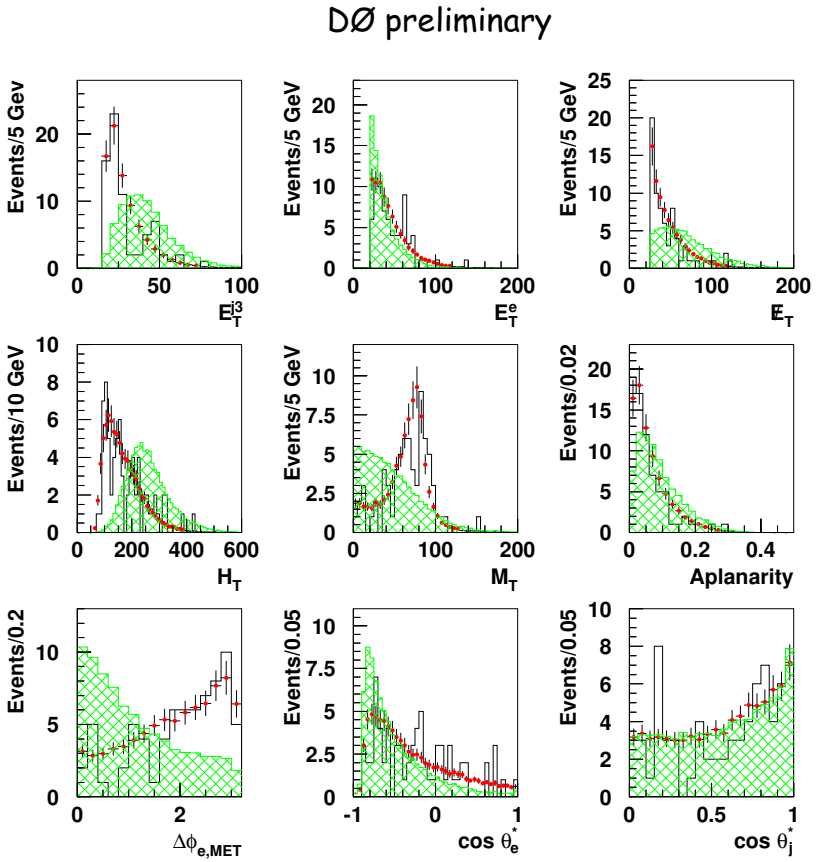
Total background: 80 ± 10

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



NN training:

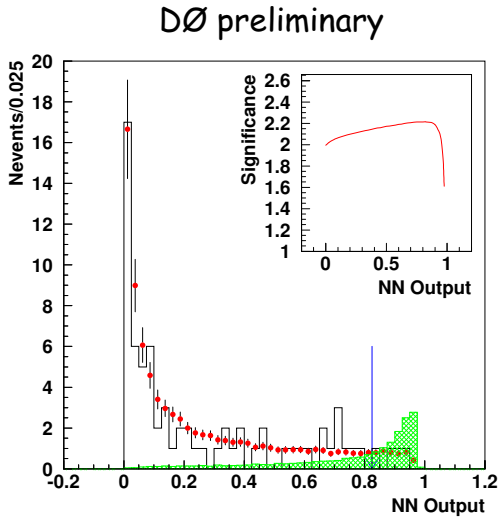
m_0=170 GeV/c^2

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

N_{signal}=10.4

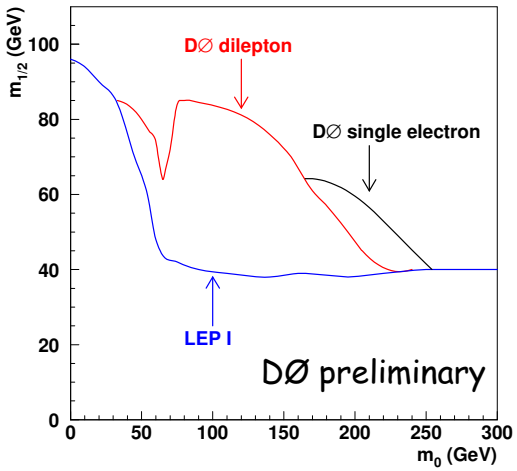
N_{bkgd}=4.4

N_{obs}=4



tanβ=3, μ<0, A_0=0

Limit contour



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

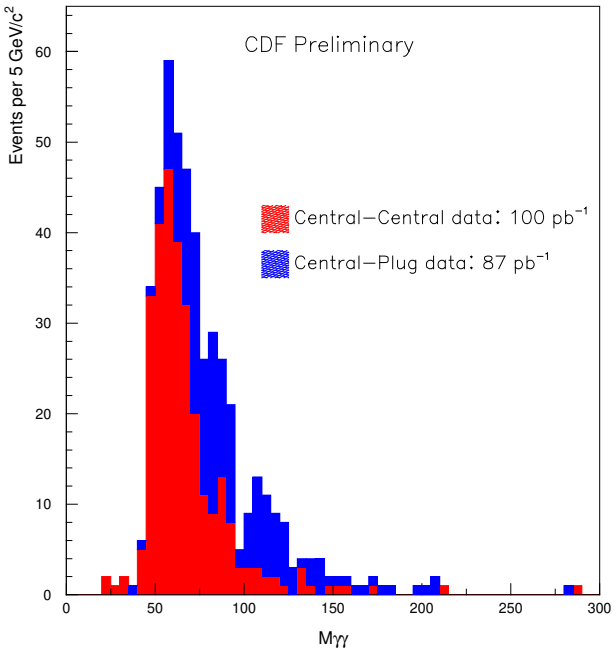
Best Tevatron limit: CDF jets+$\not\!\!E_T$, PRL 88, 041801

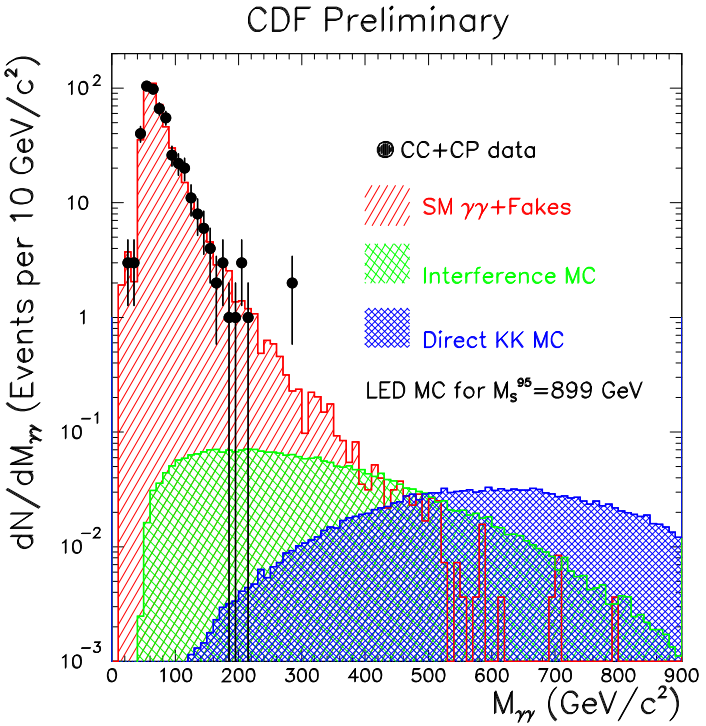
CDF Search for Large Extra Dimension in Diphoton Events

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

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

- $\eta = \frac{\lambda}{M_S^4}$ 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

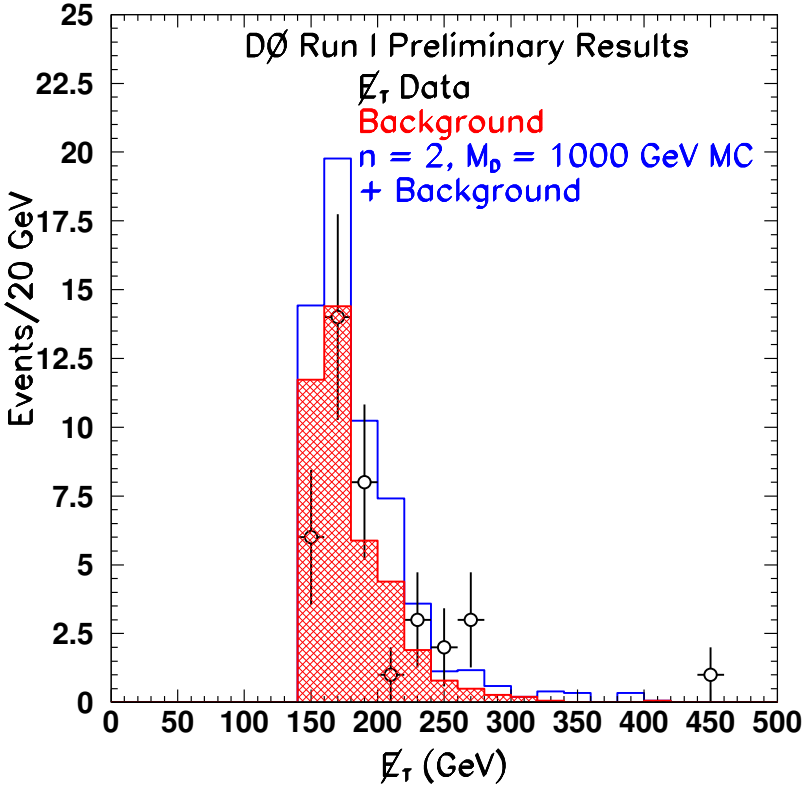
fake: CC: 184±63, CP: 132±28

M_s>1.01 TeV in GRW convention (100 pb^{-1})

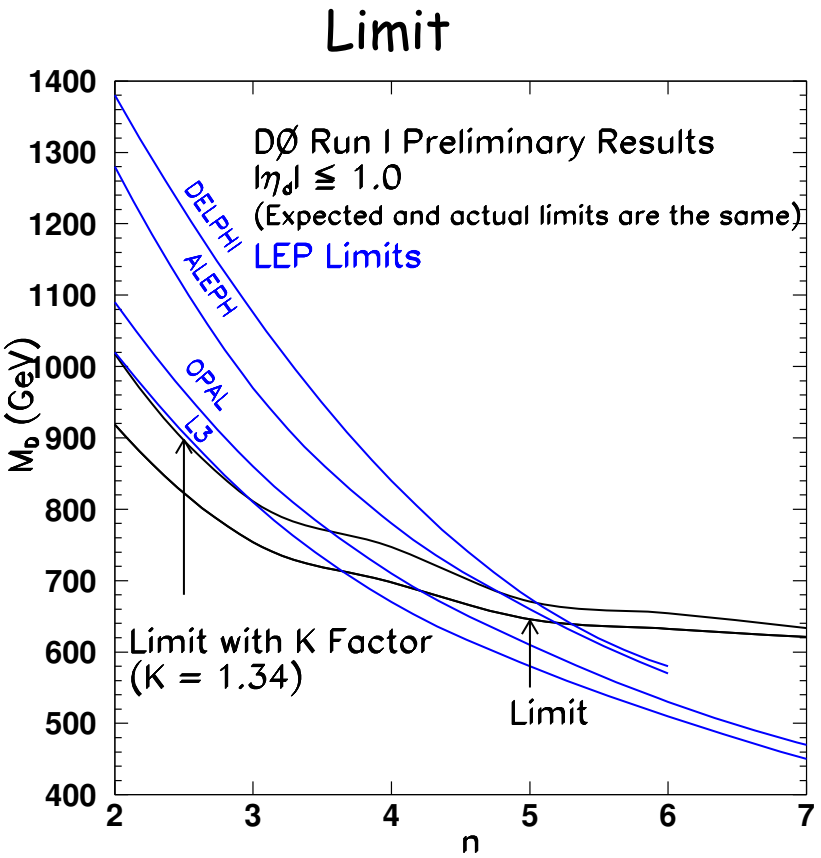
DØ, adding cosθ* in the fit, and with an extended data set (incl. elecs), obtained M_s>1.21 TeV (GRW,127 pb^{-1}) PRL 86(1156)

DØ Search for Large Extra Dimension in Jet(s)+$\not\!\!E_T$ Channel

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



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

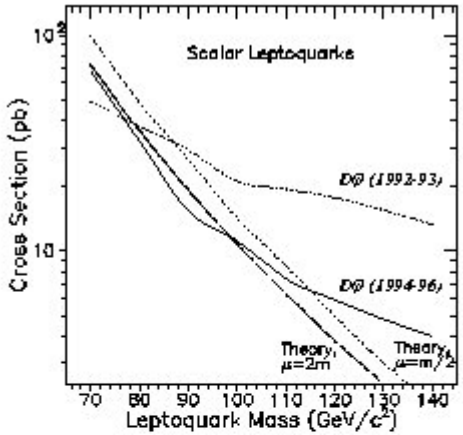


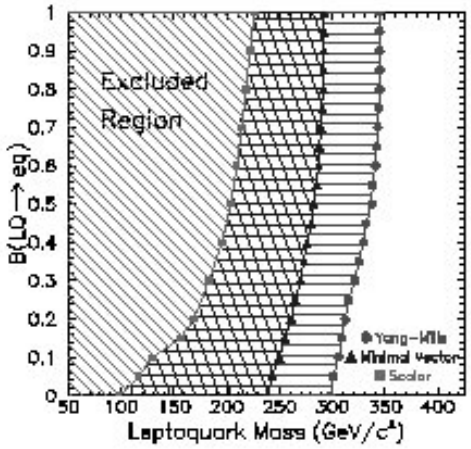
- DØ Run I preliminary Limits Complement LEP results at high n

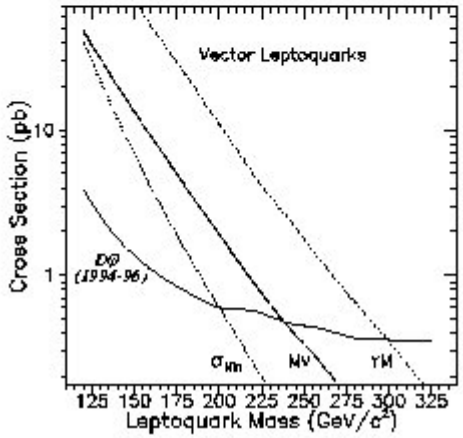
DØ Search for Leptoquark in 2 jets+$\not\!\!E_T$ Channel

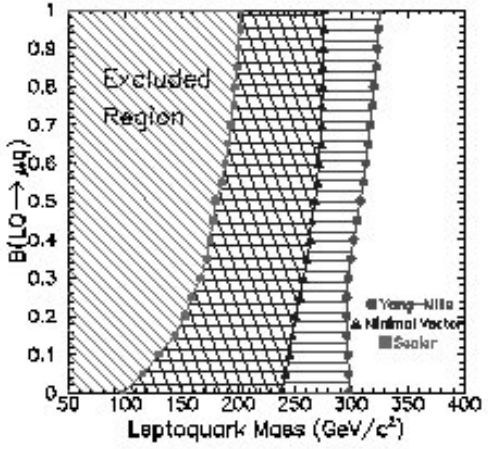
- Sensitive to exclusive $LQ \rightarrow \nu q$ decay; involves all three generations
- Dominant Backgrounds:
  - W+jets, Z+jets, $t\bar{t}$
  - multijet
- NN optimization on:
  $\not\!\!E_T$, $\Delta\varphi(j_1,j_2)$, $E_T(j_2)$
- Result:

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 GeV

m_{VLQ}>200, 238, 298 GeV for σ_{min}, MV, and YM couplings

CDF γ+$\not\!\!E_T$ Analysis (I)

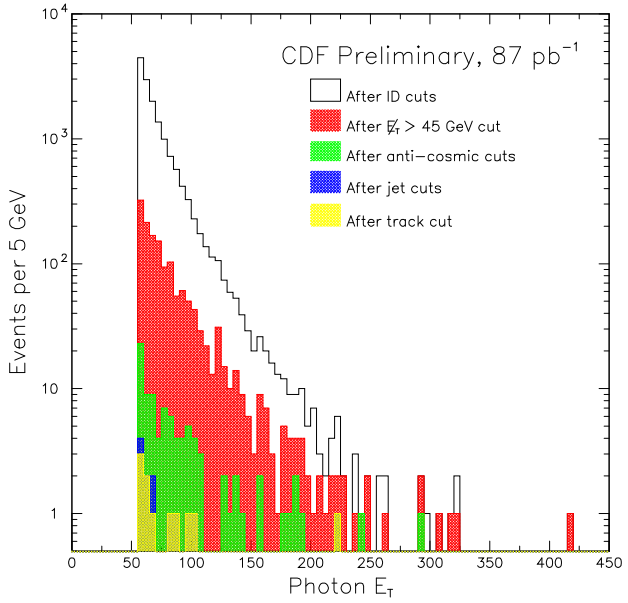
Motivation:

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

Selections:

- $E_T^\gamma > 55\,\mathrm{GeV}$ and $|\eta^\gamma| < 1.1$.
- $\not\!\!E_T > 45\,\mathrm{GeV}$.
- Reject cosmic ray events
- No jets with E_T > 15 GeV
- No tracks with P_T > 5 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 γ+$\not\!\!E_T$ 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 $F=\sqrt{3}m_{3/2}M_{planck}$ of SUSY breaking

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

  Result: $\sqrt{F} > 221\,\mathrm{GeV}, m_{3/2} > 1.17\times10^{-5}\,\mathrm{eV}$

  Past best limit: 217 GeV (CDF jet +$\not\!\!E_T$, DELPHI γ+$\not\!\!E_T$)

- Search for Large Extra Dimention

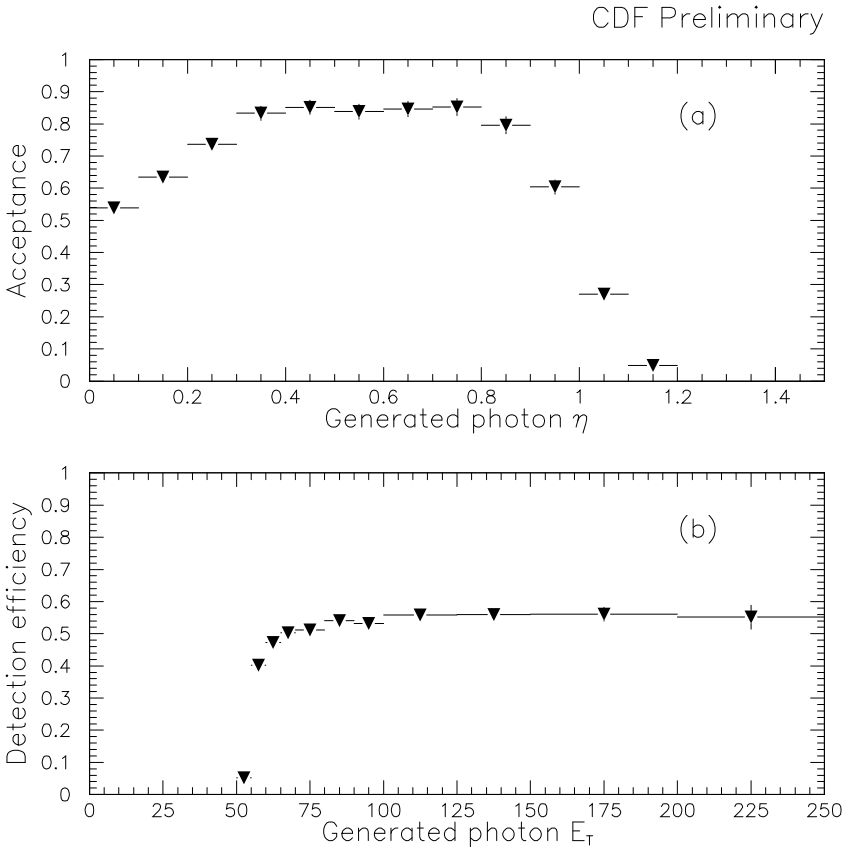
  Model: Arkani-Hamed, Dimopoulos, Dvali, PLB 429

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

  Result:

  N = 4, M_D > 549 GeV (680 GeV, DELPHI)
  N = 6, M_D > 581 GeV (510 GeV, DELPHI)
  N = 8, M_D > 602 GeV (411 GeV, L3)

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



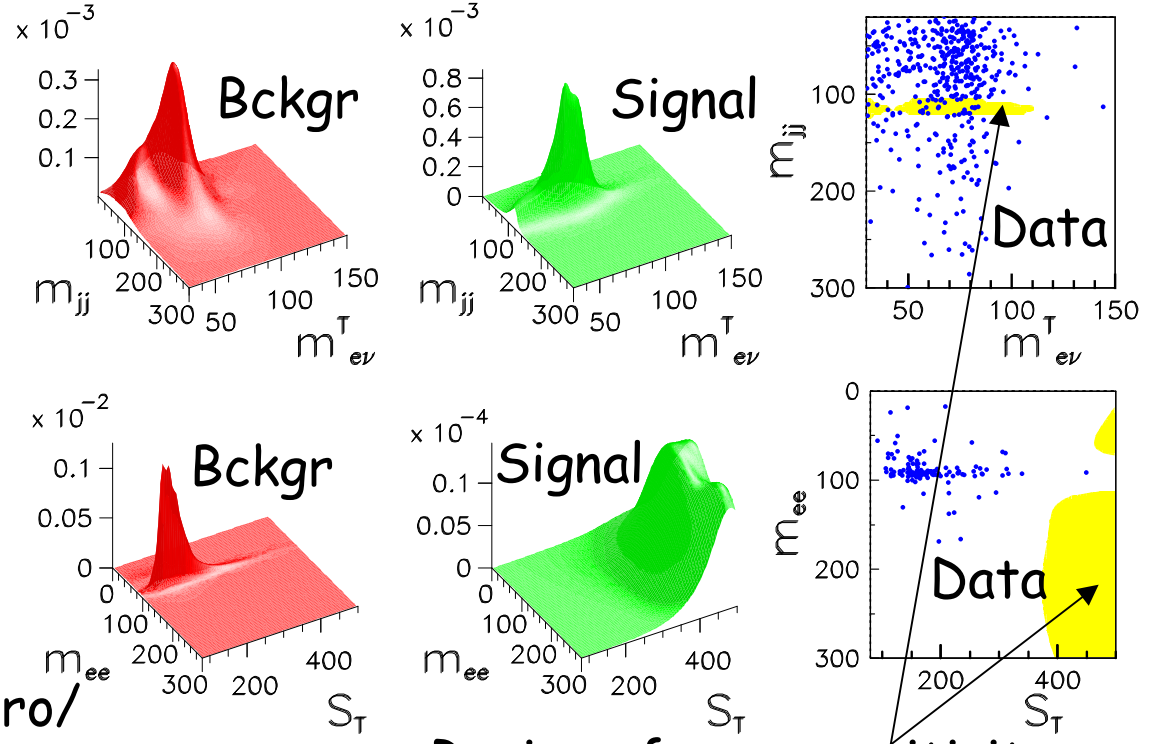
Quaero – DØ Makes its Data Public!

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 $\rightarrow e\nu jj$, w/ kinematic fit to W

Quaero: Latin for "to seek"

LQLQ $\rightarrow eejj$



Region of max sensitivity

http://quaero.fnal.gov/quaero/

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.