Searches for Physics beyond the Standard Model at the Tevatron

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Les Recontre de Physique de la Vallée d'Aoste
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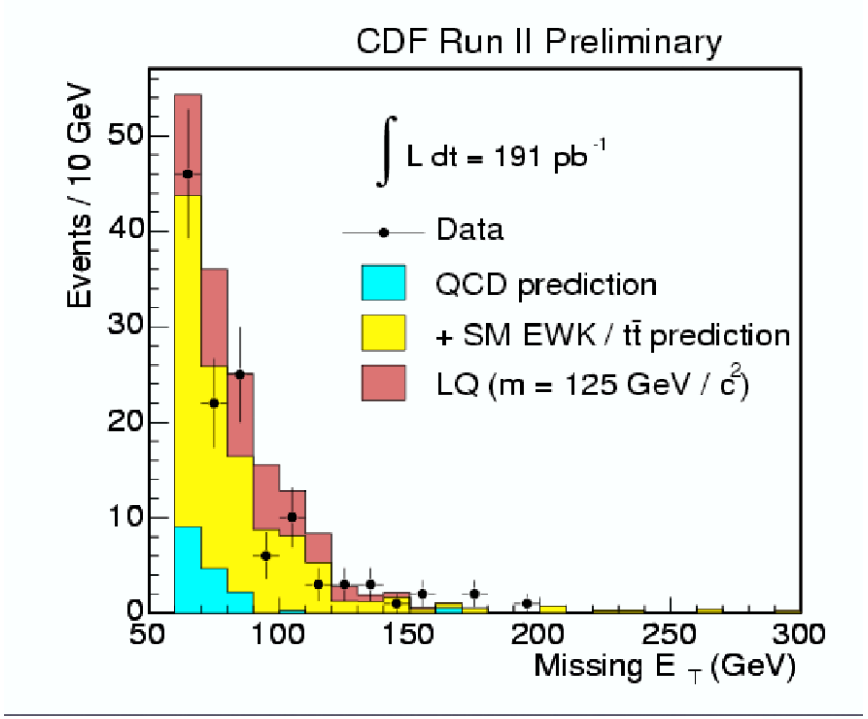
Overview

- Leptoquarks
- SUSY
- Excited electrons
- Heavy gauge bosons
- Model independent searches
- Extra dimensions

Leptoquarks

- Carry lepton and baryon number
- Fractional charge
- Included in many SM extensions (GUT, technicolor, composite models,...)
- Pair produced at Tevatron
  - $LQ_N \rightarrow q_N + l_N, q_N + \nu_N$
- Assume intra-generational coupling
    - 1^{st} generation (LQ_1 -> $eq, \nu_e q$)
    - 2^{nd} generation (LQ_2 -> $\mu q, \nu_\mu q$)
- Parameter $\beta = BR(l^{\pm}q)$

Leptoquarks: Jets + MET

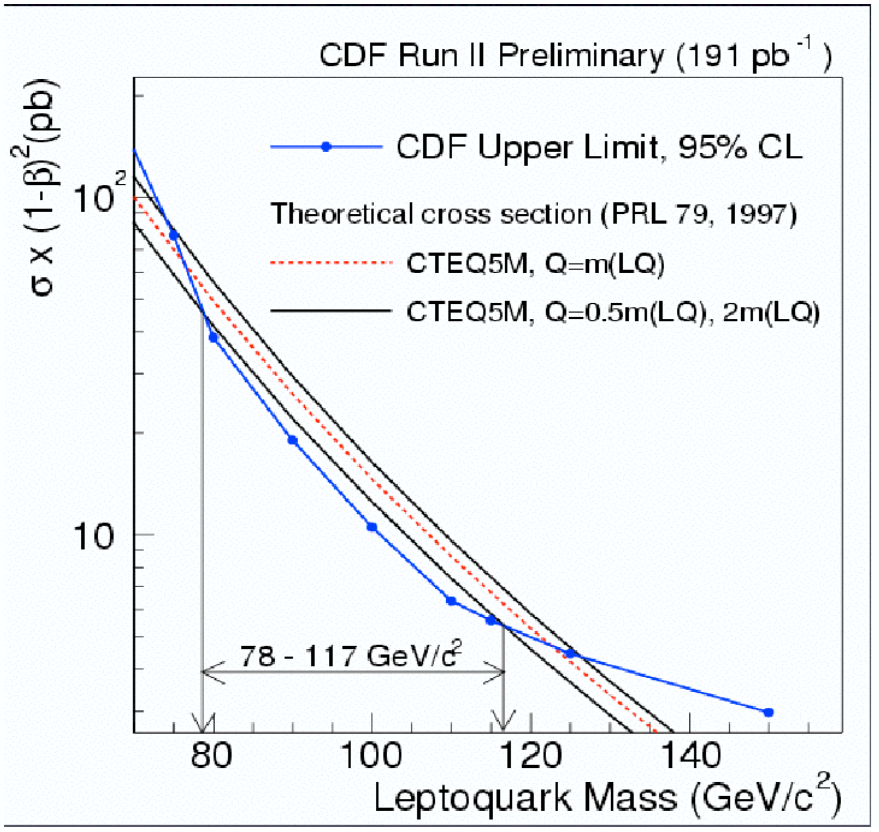


$L = 191\ pb^{-1}$

MET > 60 GeV

2 high E_T jets

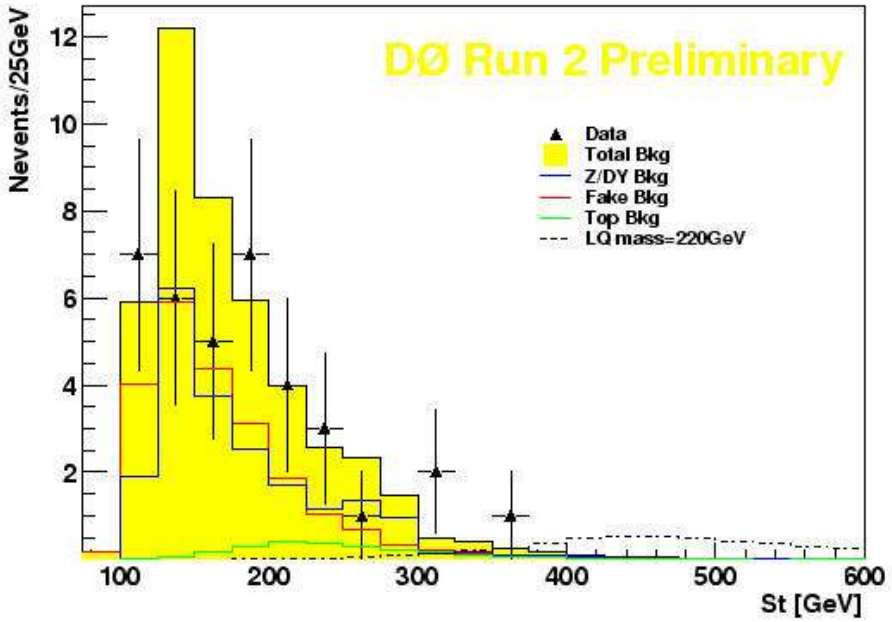
$80 < \Delta\phi(j,j) < 165$



Background: 118 ±14

Data: 124

1st Generation LQ in eejj Channel



L = 135 pb^{-1}

2 electrons, E_T > 25 GeV

>= 2 jets, E_T > 20 GeV

Exclude Z → ee region

S_T > 375 GeV

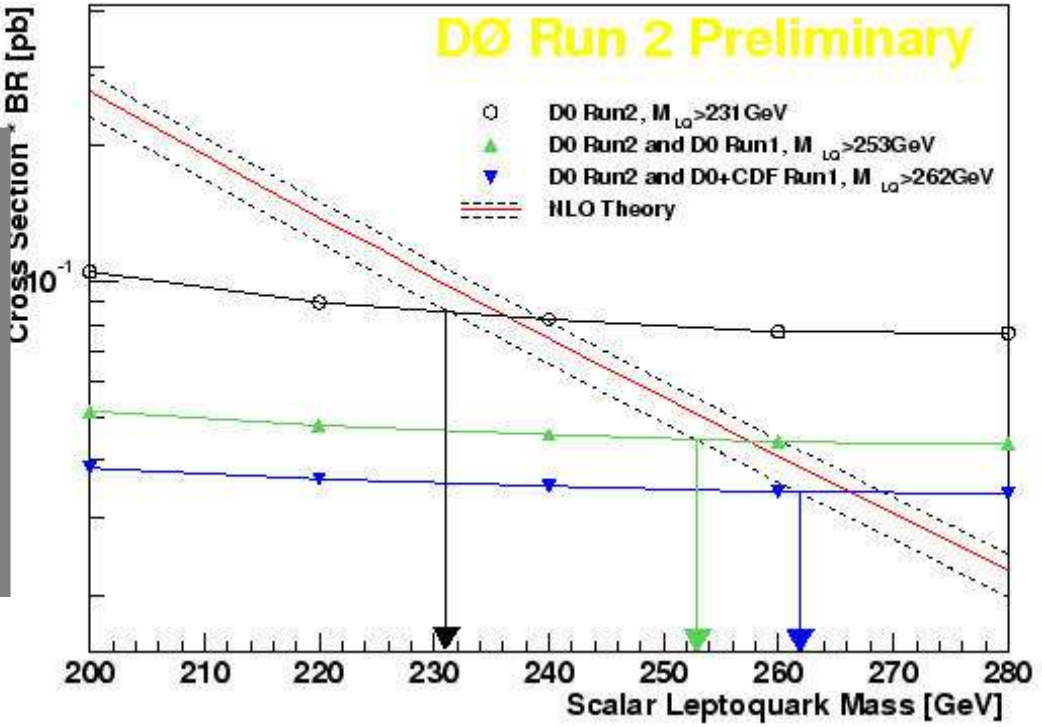
Background: 0.9 ±0.25

Data: 0

M(LQ1) > 231 GeV for β= 1

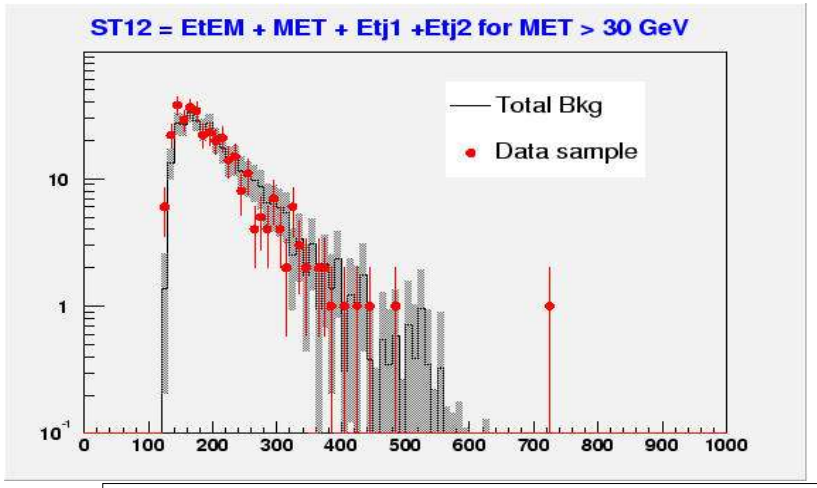
M(LQ1) > 253 GeV w D0 Run 1

M(LQ1) > 262 GeV w D0+CDF Run I



$S_T = \Sigma$ (E_T of electrons and jets)

1st Generation LQ in eνjj Channel



L = 121 pb^{-1}

1 electron, E_T > 35 GeV

>= 2 jets, E_T > 25 GeV

missing ET > 30 GeV

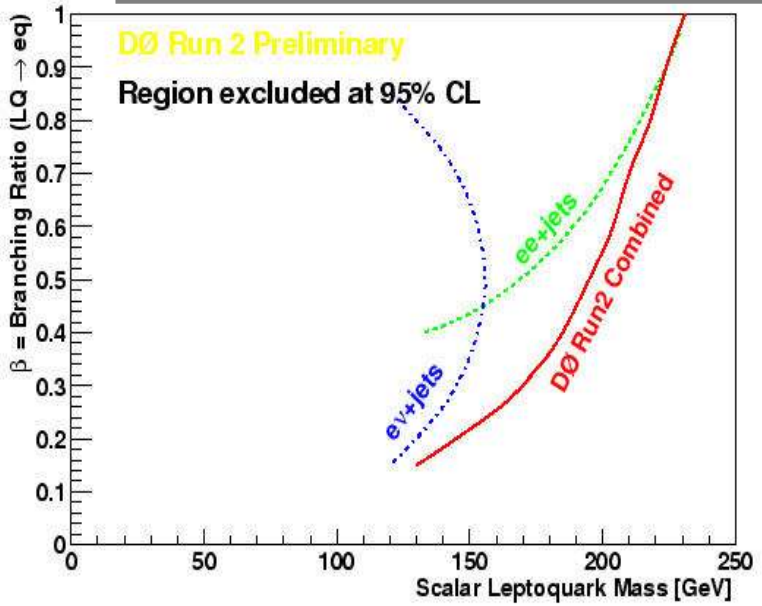
S_{T12} > 330 GeV

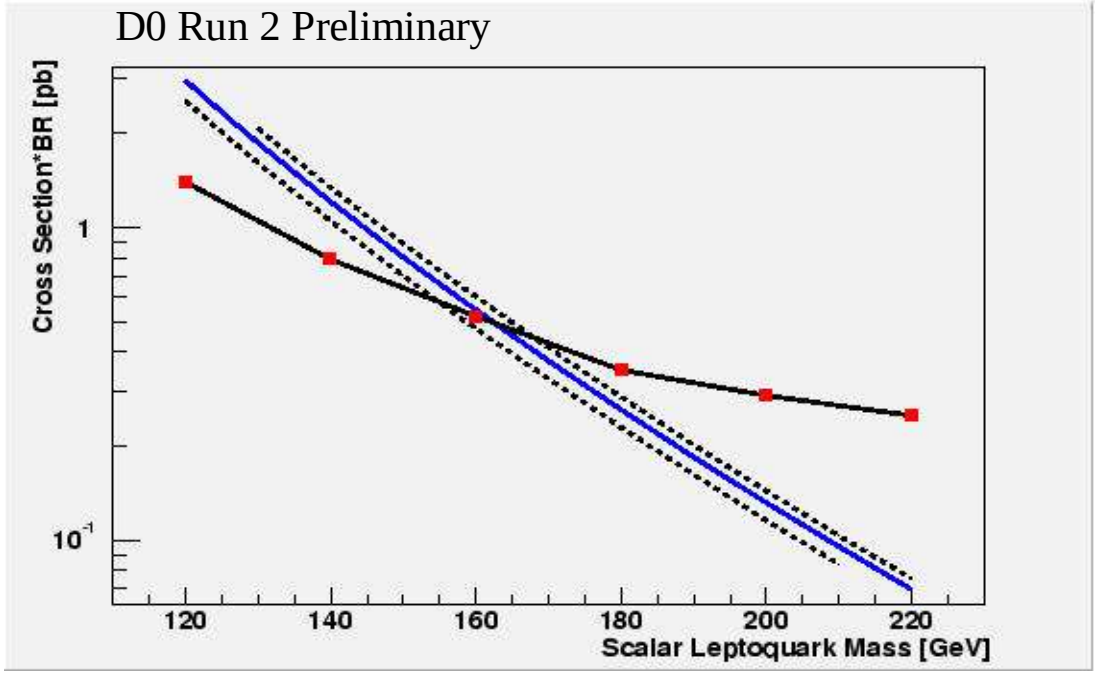
M_T^{ev} > 110 GeV

Background: 4.19 ±1.0

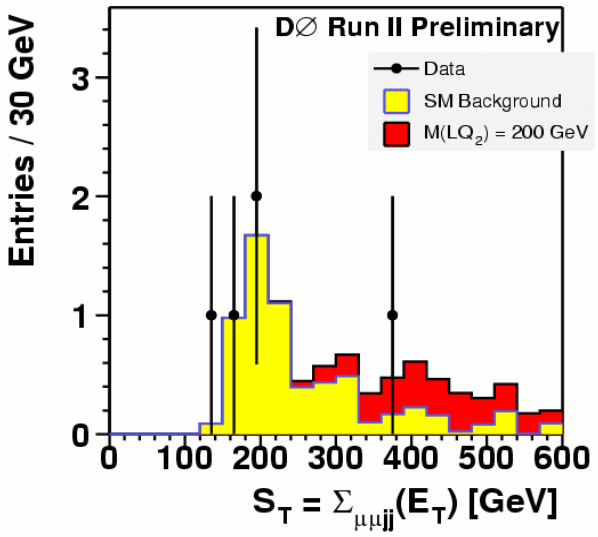
Data: 3

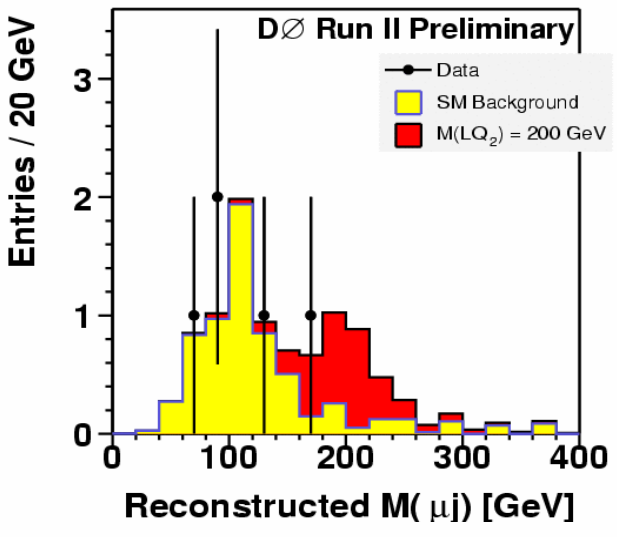
M(LQ1) > 156 GeV for β= 0.5





2nd Generation Leptoquarks in μμjj





L = 104 pb^{-1}

2 μ, E_T > 15 GeV

>= 2 jets, E_T > 25 GeV

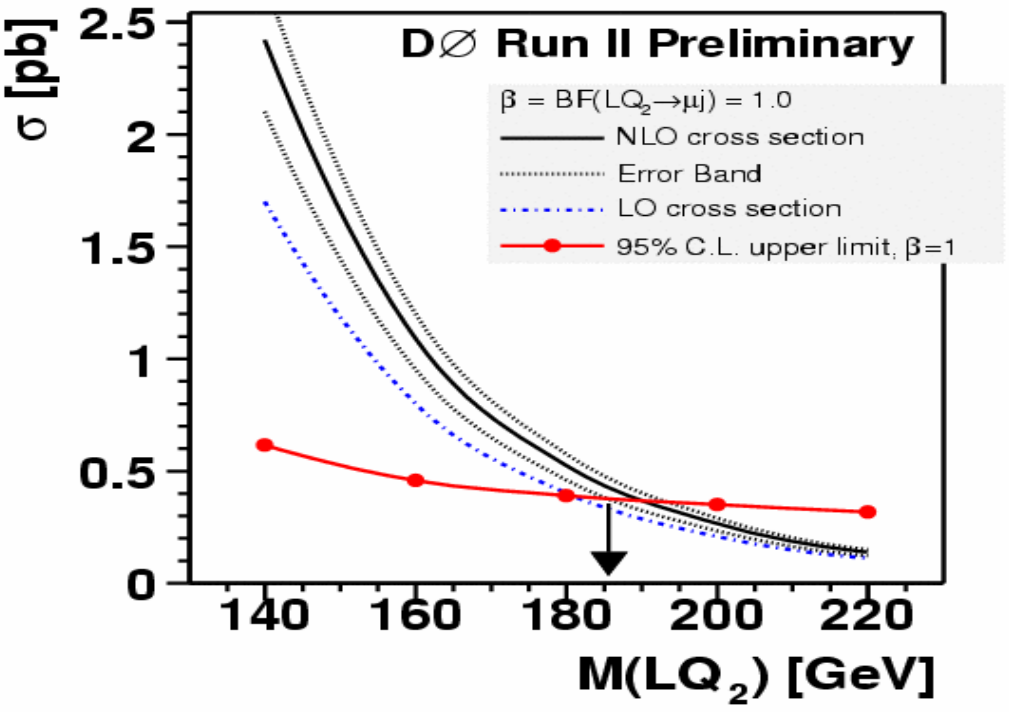
M(μμ) > 110 GeV

S_T > 280 GeV

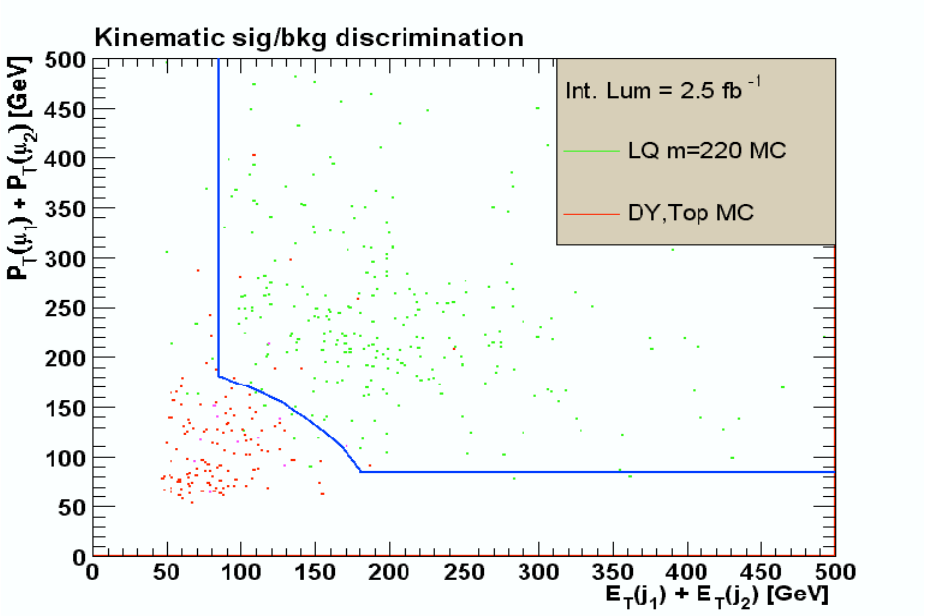
Background: 1.59 ±0.49

Data: 1

M(LQ2) > 186 GeV for β= 1



2nd Generation Leptoquarks in μμjj



$L = 198\ pb^{-1}$

$2\ \mu,\ P_T > 25$ GeV

2 jets, $P_T > 15$ GeV, 30 GeV

15 GeV < M(μμ)

exclude 76 < M(μμ) < 106 GeV

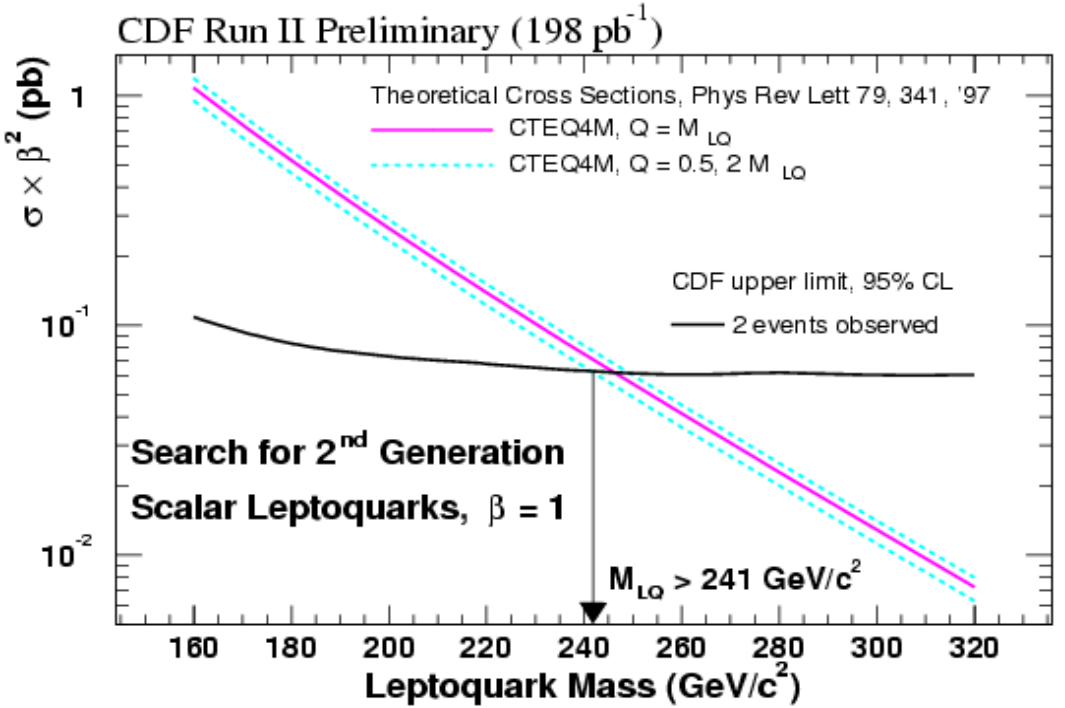
$\sum P_T(j_i) > 85$ GeV, $\sum P_T(\mu_i) > 85$ GeV

$\sqrt{(Sum(j)^2 + Sum(\mu)^2)} >$ 200 GeV

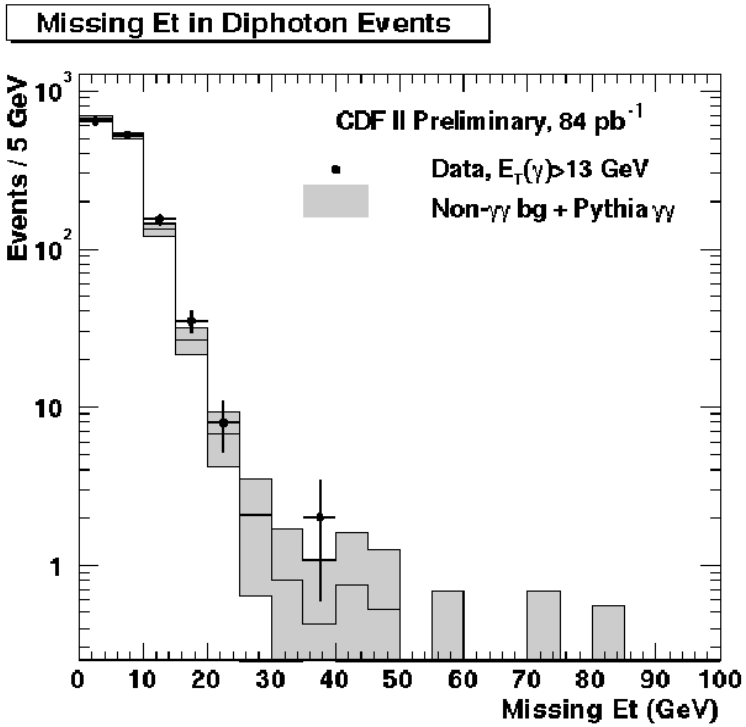
Background: 3.15 ±1.17

Data: 2

M(LQ2) > 241 GeV for β= 1



SUSY GMSB γγ+MET



L = 84 pb^{-1}

2 isolated photons, E_T > 13 GeV

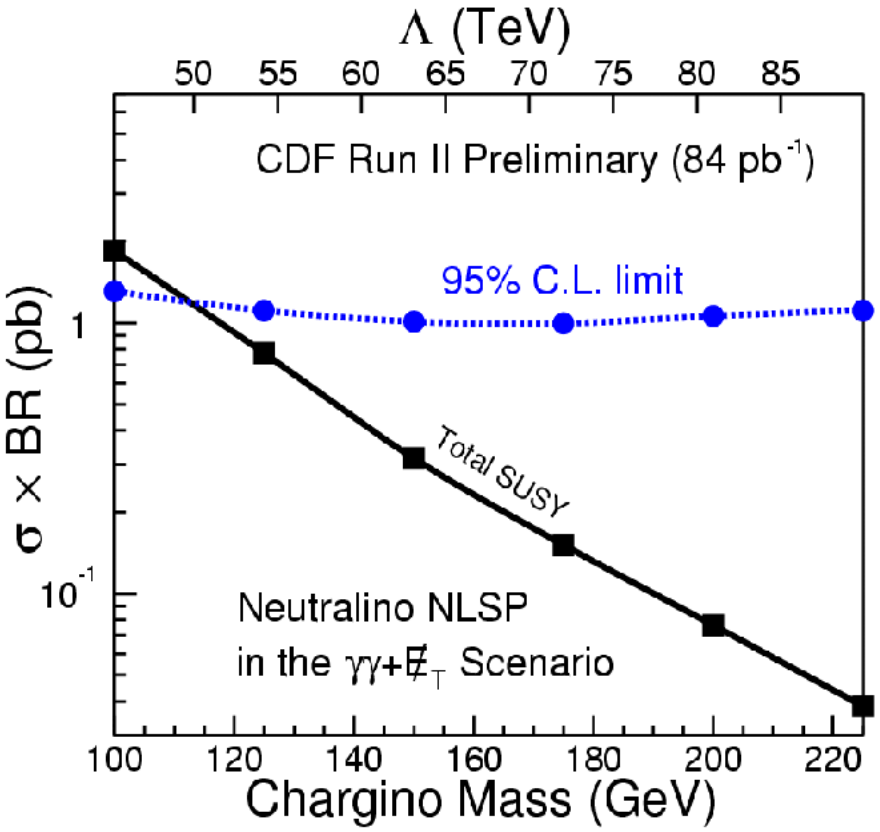
missing E_T > 25 GeV

missing E_T separated from γ and jets

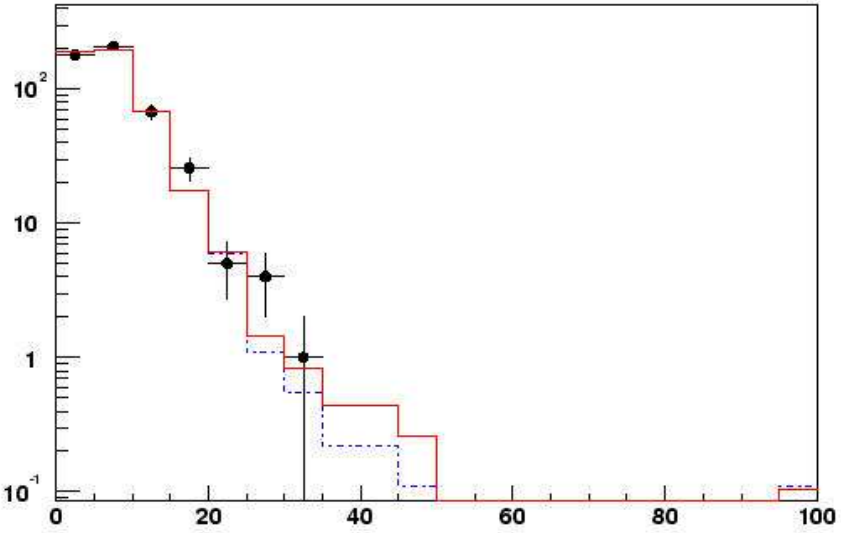
Background: 2 ±2

Data: 2

$M(\chi^{\pm}_1)$ > 113 GeV



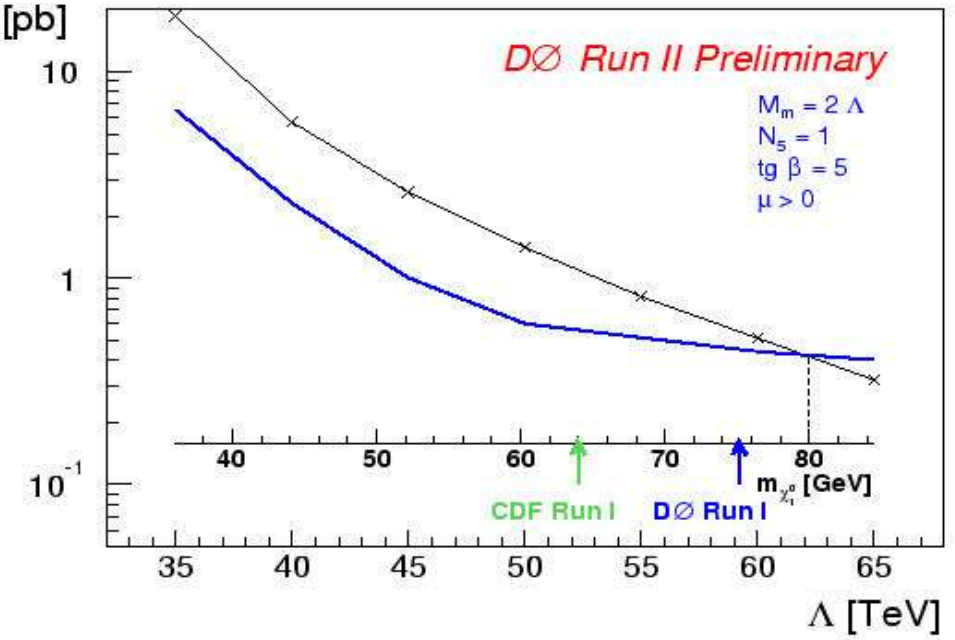
SUSY GMSB searches in γγ+MET



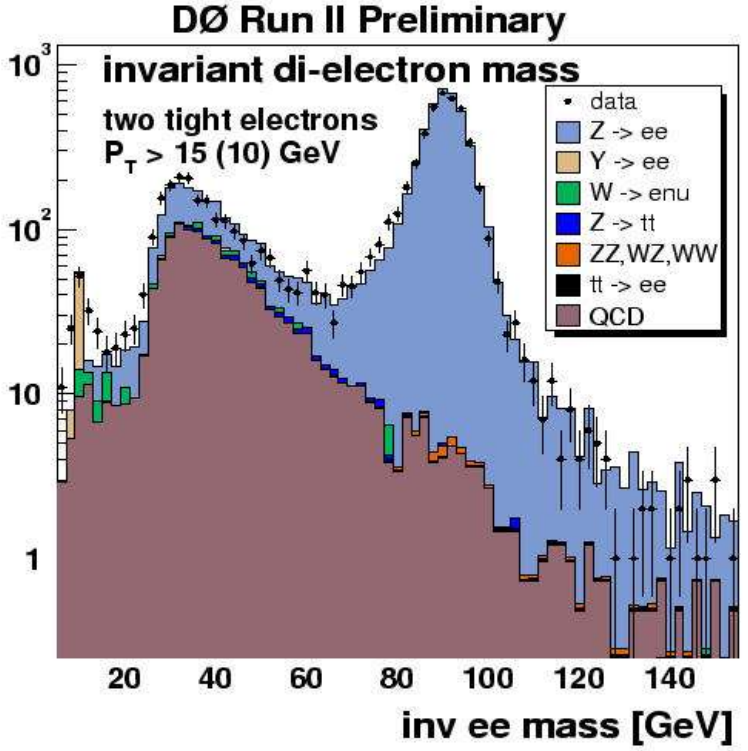
L = 128 pb^{-1}
2 photons, E_T > 20 GeV
missing E_T >35 GeV
remove events with mismeasured jets or electrons

Background: 1.38 ±0.30
Data: 0

$M(\chi^0_1)$ > 80.8 GeV
$M(\chi^\pm_1)$ > 144 GeV
for M_{top} = 174.3 GeV
tan β= 5, Λ= 62.5



SUSY Tri-Lepton Channel: e+e+l



L = 132 pb^{-1}

2 electrons, E_T > 15, 10 GeV

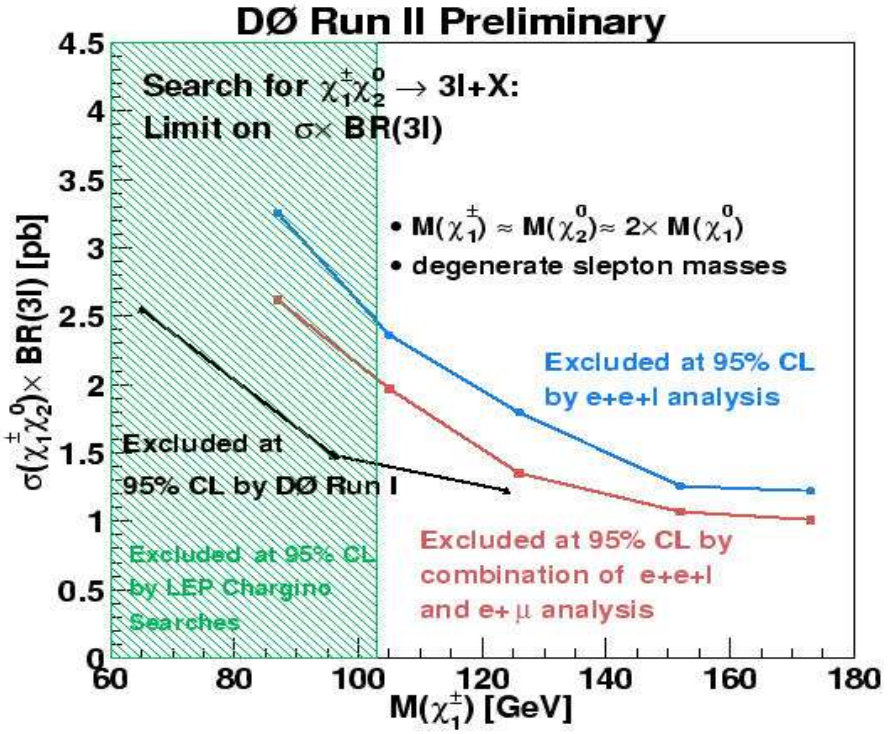
20 < M(e,e) < 75 GeV

missing E_T > 20 GeV

isolated track P_T > 5 GeV

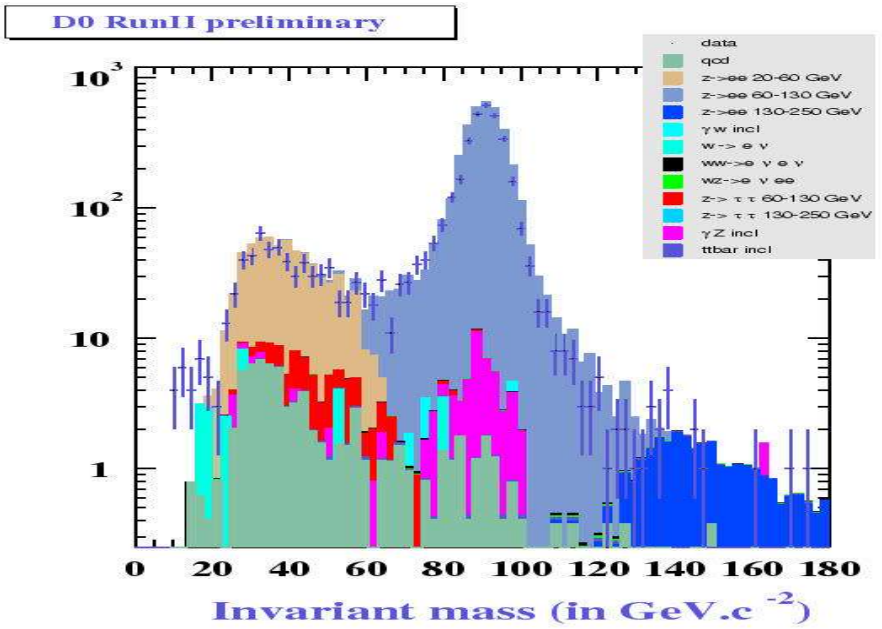
Background: 2.6 ± 2.2

Data: 1



Combined with eμ analysis:

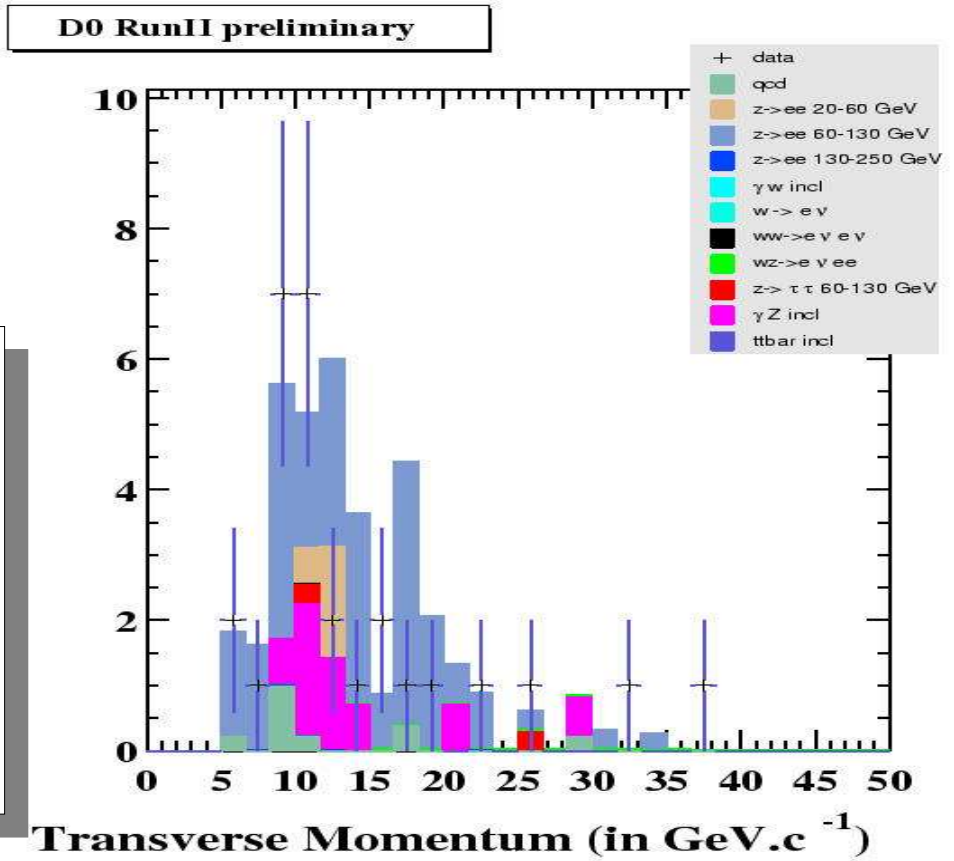
Searches for RPV SUSY



L = 117 pb^{-1}

3 electrons, E_T > 15, 10, 5 GeV

$\Delta R(e,jet) > 0.7$



Background: 3.0 ±1.5

Data: 3

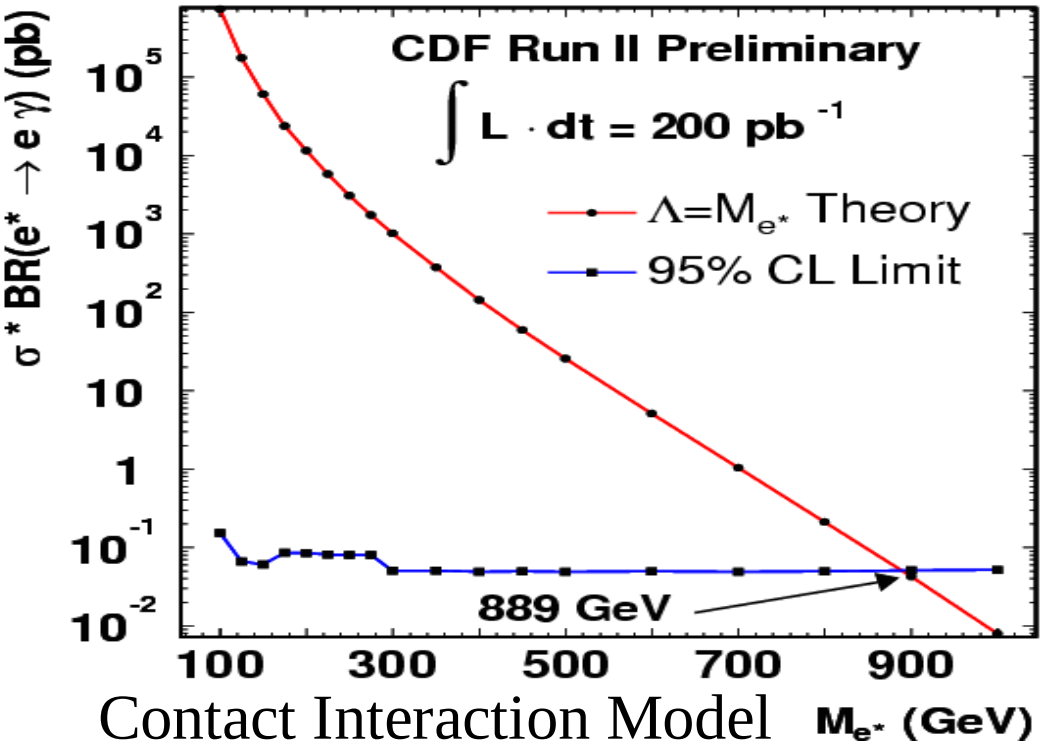
For m_0 > 500 GeV, $m_{1/2}$ = 150 GeV

σ > 1.3 pb for μ < 0 excluded

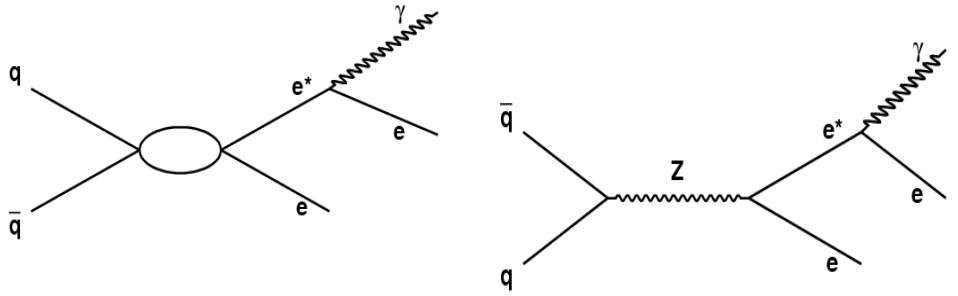
σ > 1.4 pb for μ > 0 excluded

Excited Electrons: eeγ

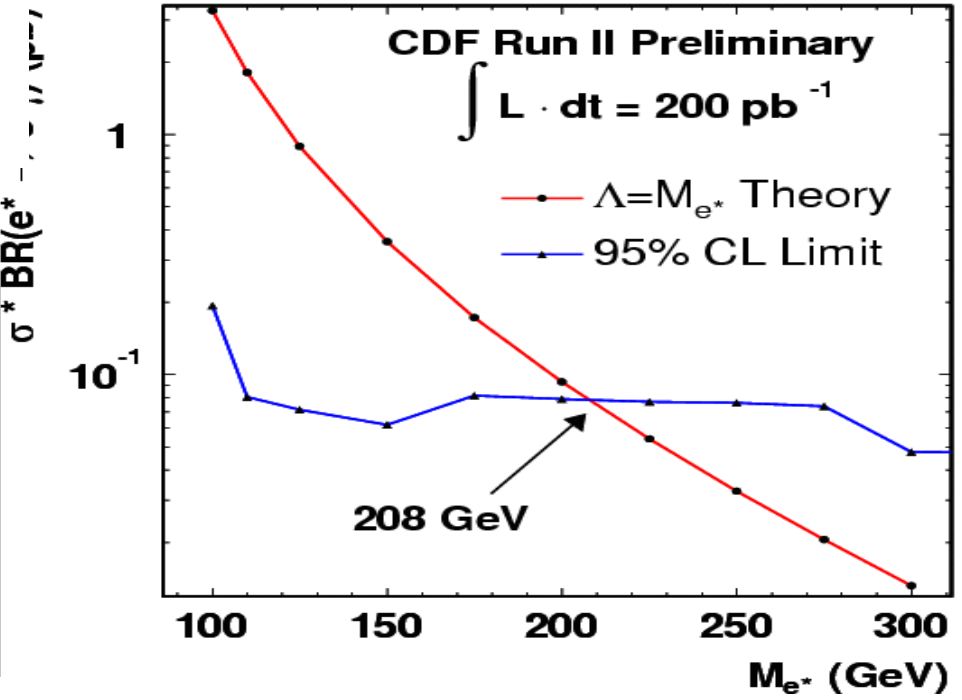
L = 200 pb^{-1}
Look for resonance in eγ channel



Contact Interaction Model



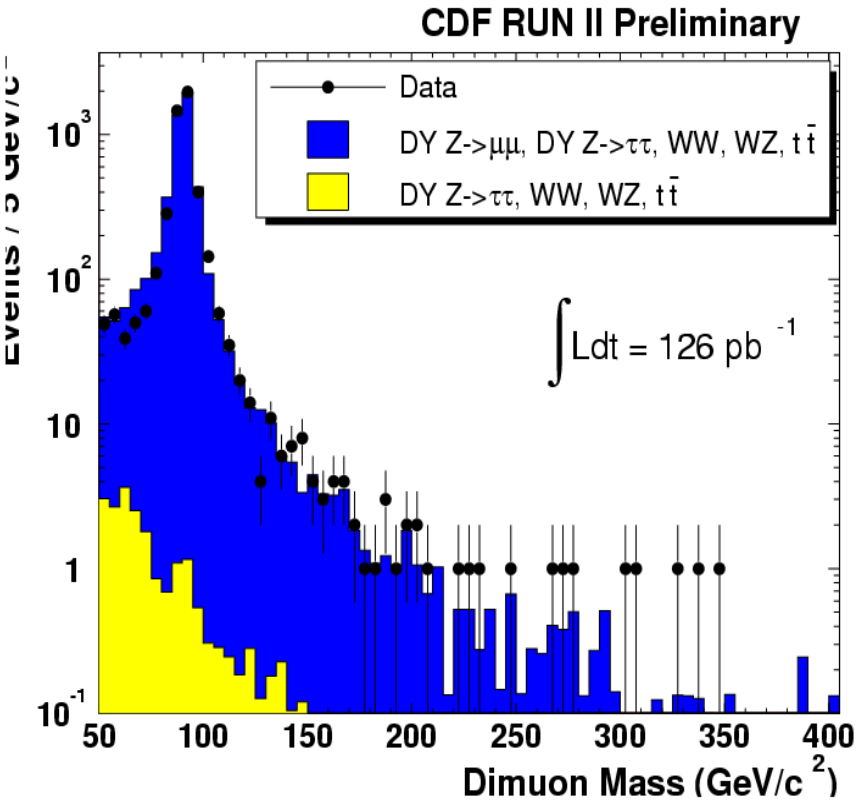
Gauge mediated Model



Background: 3 events
Data: 3

M(e*) > 889 GeV (Contact Interaction)
M(e*) > 208 GeV (Gauge Mediated)

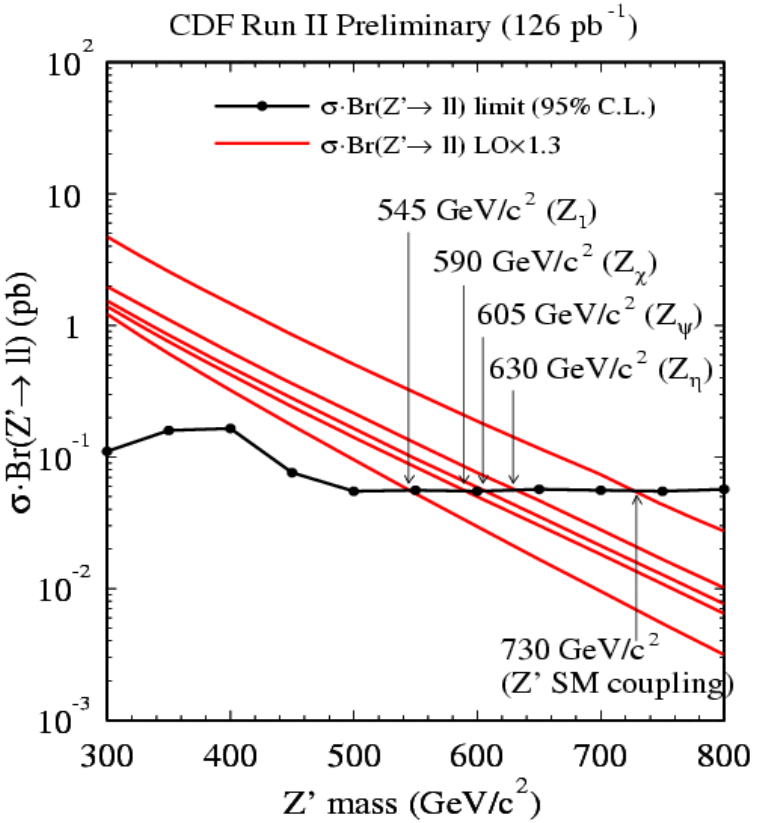
Heavy Gauge Bosons Z' → ee/μμ



L = 126 pb^{-1}

2 electrons, E_T > 25 GeV

2 μ, M(μμ) > 250 GeV

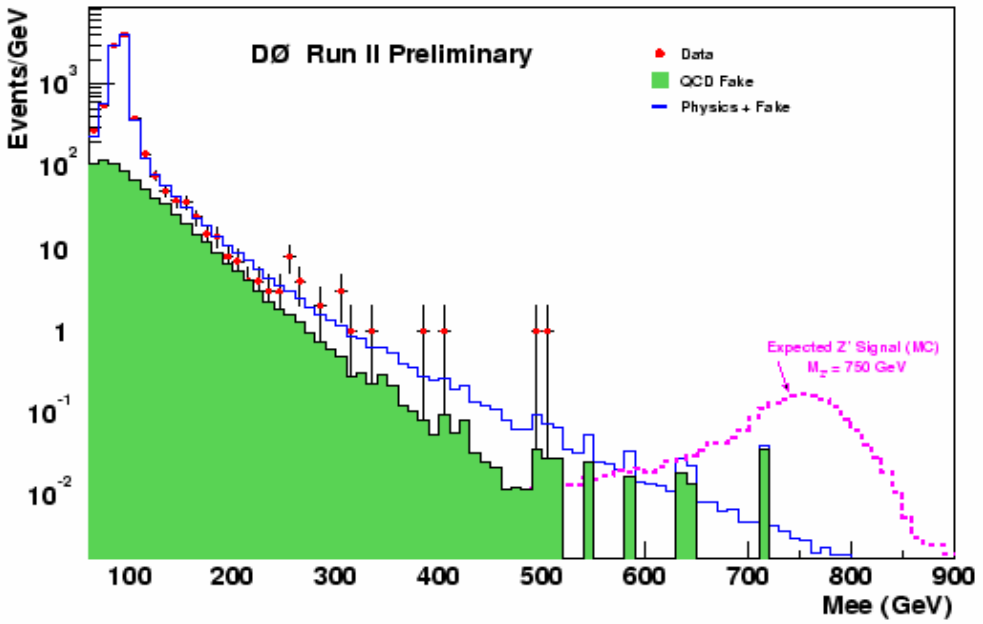


No excess observed.

Combine results from e and μ.

M(Z') > 730 GeV

Heavy Gauge Bosons Z' → ee



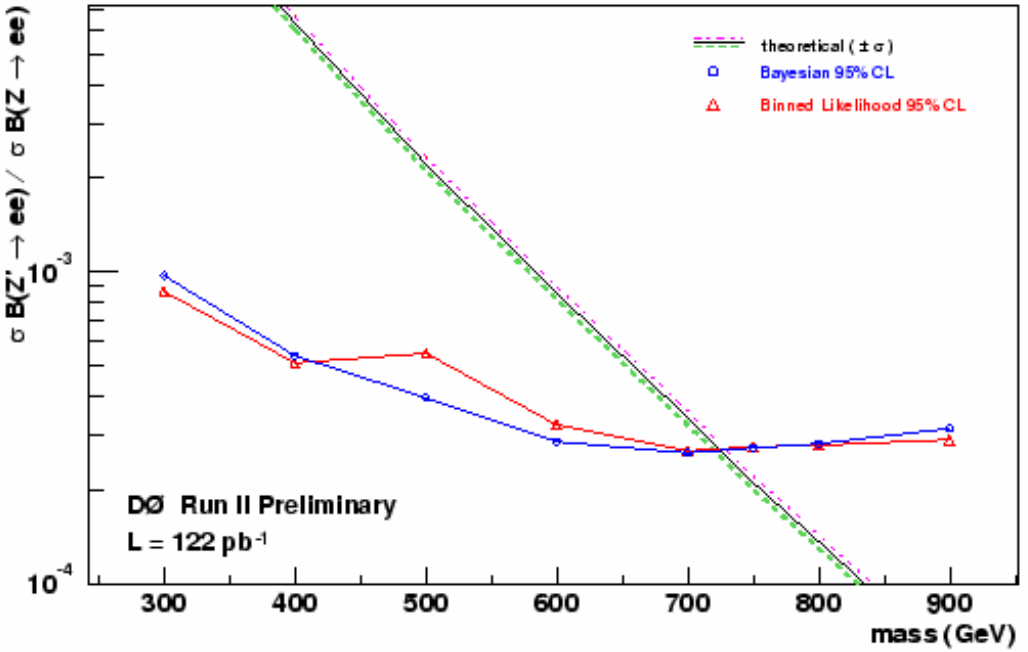
$L = 122\ pb^{-1}$

2 electron candidates, $E_T > 25$ GeV

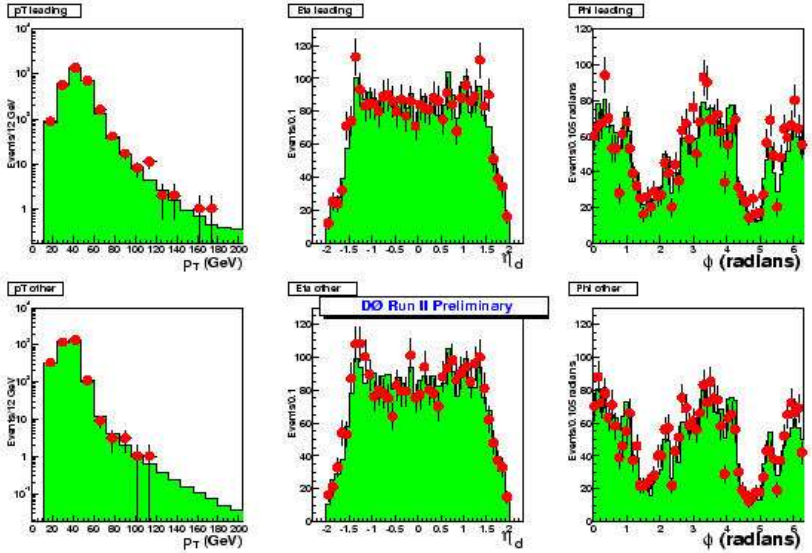
At least one electron central, track matched

No excess observed in 150 – 1000 GeV mass bins.

M(Z') > 719 GeV



Heavy Gauge Bosons $Z' \rightarrow \mu\mu$



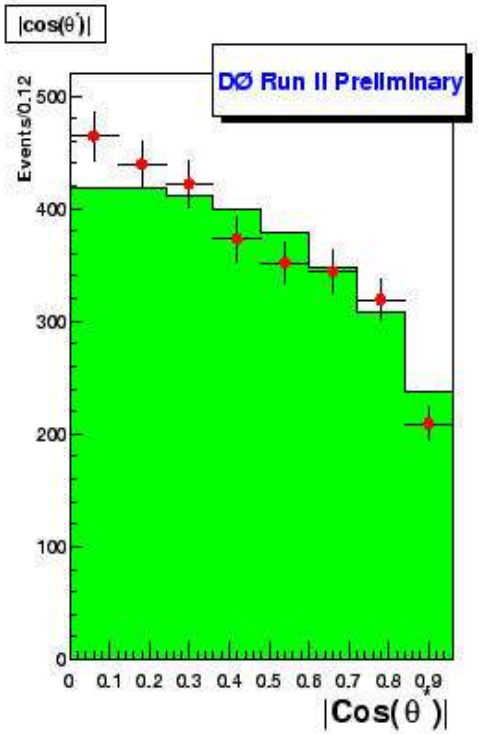
$L = 100\ pb^{-1}$

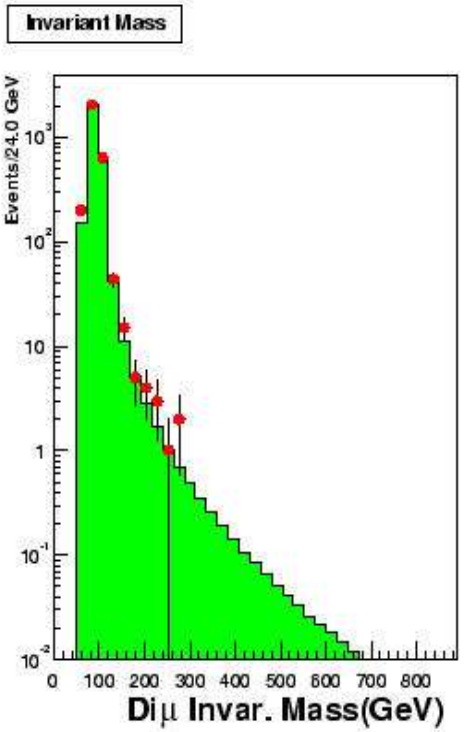
$>= 2\ \mu$, $P_T > 25$ GeV

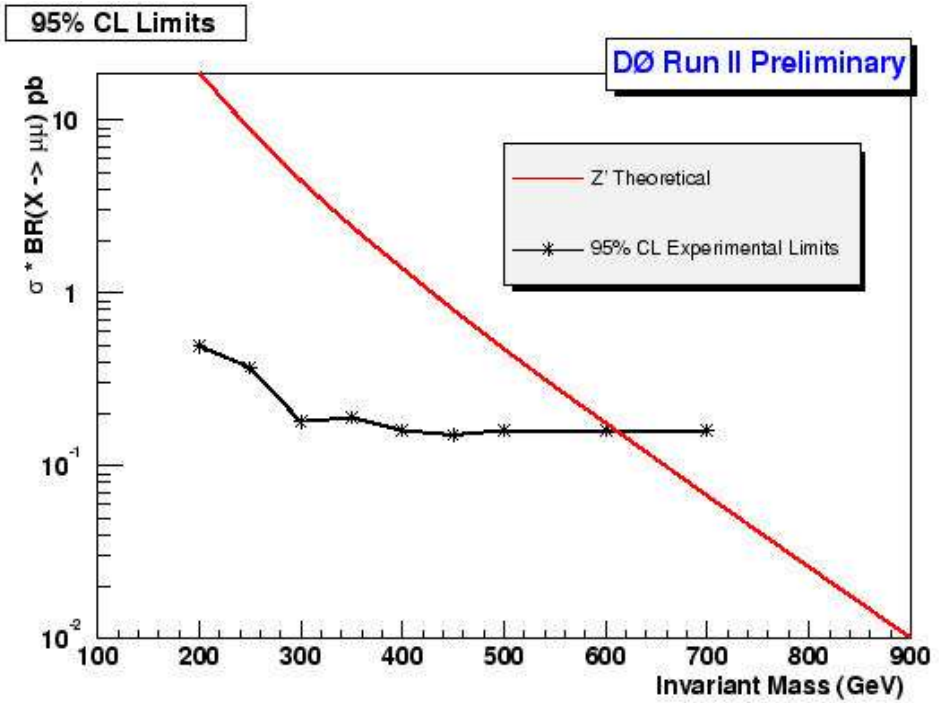
$M(\mu\mu) > 50$ GeV

No excess of events

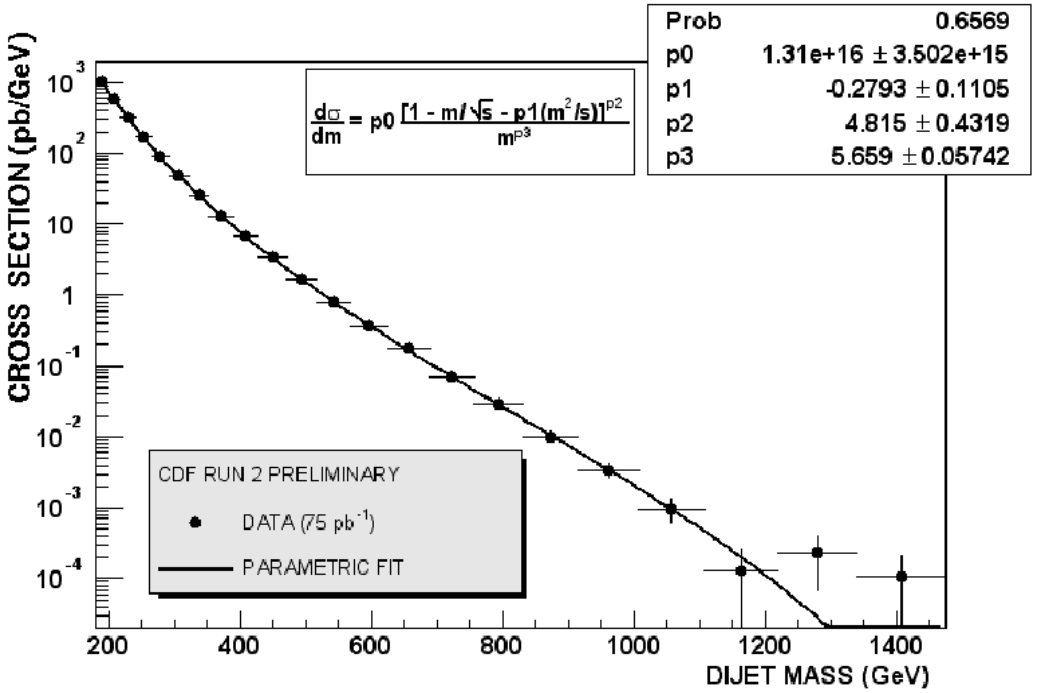
M(Z') > 610 GeV





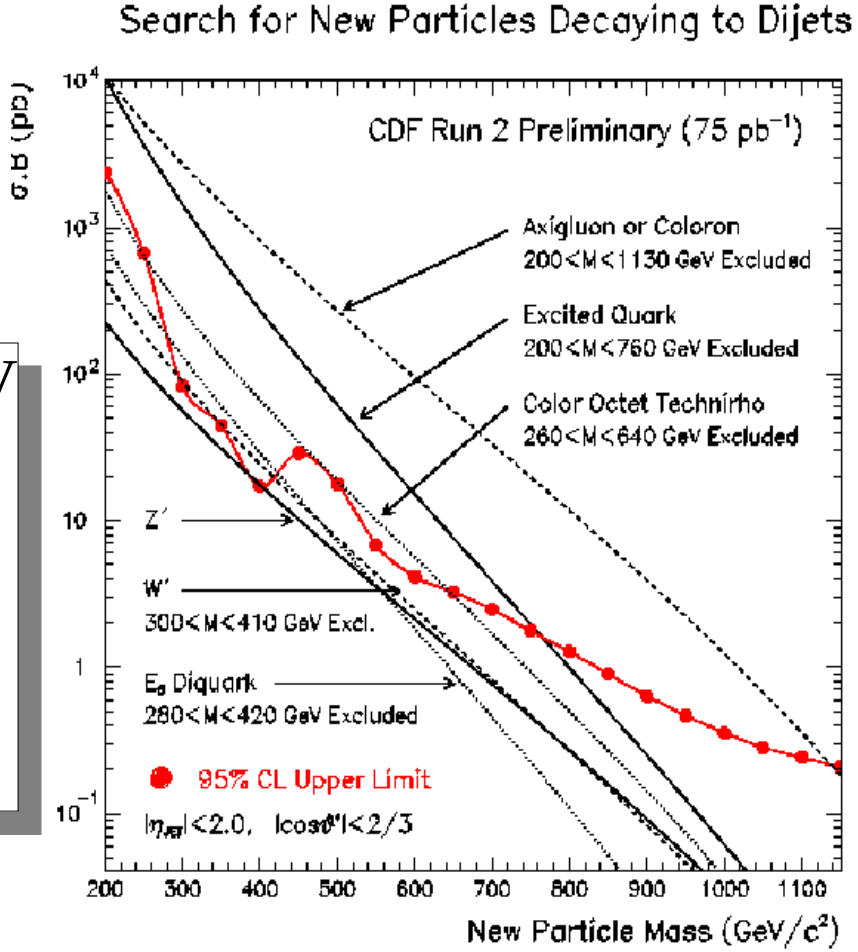


Model independent Searches: Dijets



L = 75 pb^{-1}

Search for resonances in di-jet spectrum. Sensitive to many new physics processes.



Axigluon/Coloron: 200 < M < 1130 GeV
Excited Quark: 200 < M < 760 GeV
Technirho: 260 < M < 640 GeV
E6 Diquark: 280 < M < 420 GeV

Also: RS Extra dimensions (see later).

Extra Dimensions

- SM particles confined to 3+1 dimensions
- Gravitons can propagate in extra dimensions
- Solution to hierarchy problem and "weakness" of gravitational force

Arkani-Hamed, Dimopoulos, Dvali (ADD)

N "large" extra dimensions

$M^2_{Pl} = (M_{Pl}^{[3+N]})^{N+2} R^N \equiv M_S^{N+2} R^N$

M_S fundamental Planck scale (possibly O(TeV))

N = 1 excluded (R ~ 108 km)

N = 2, R ~ 1 mm (precision experiments)

N >= 3 Can be only tested at colliders

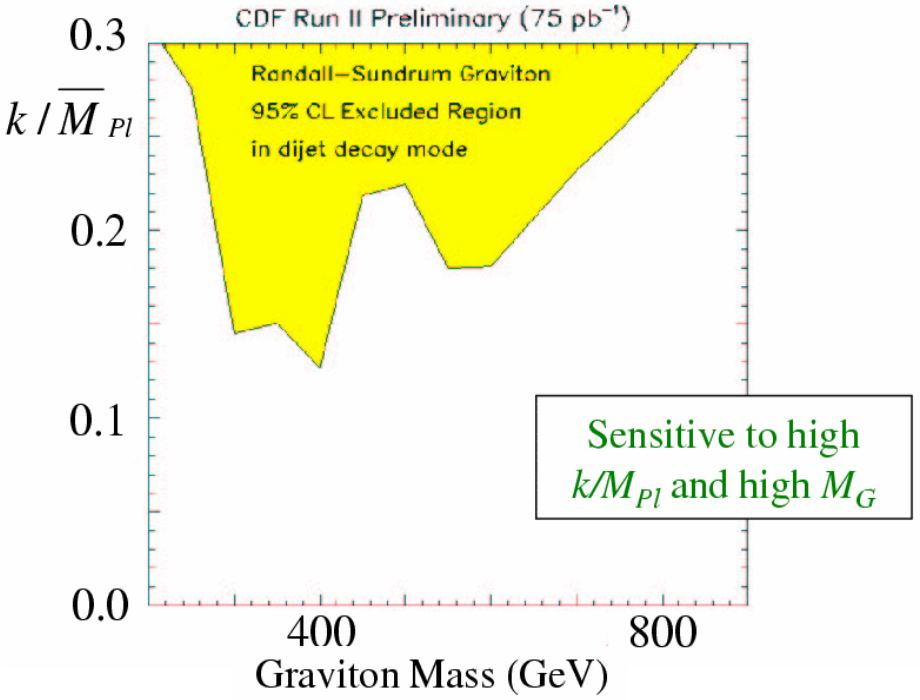
Randall Sundrum

- Extra dimension which is highly curved

$\Lambda_\pi = M_{pl} e^{-kR\pi} \sim$ TeV

Coupling k/M_{Pl}

RS Extra Dimensions: Di-jets

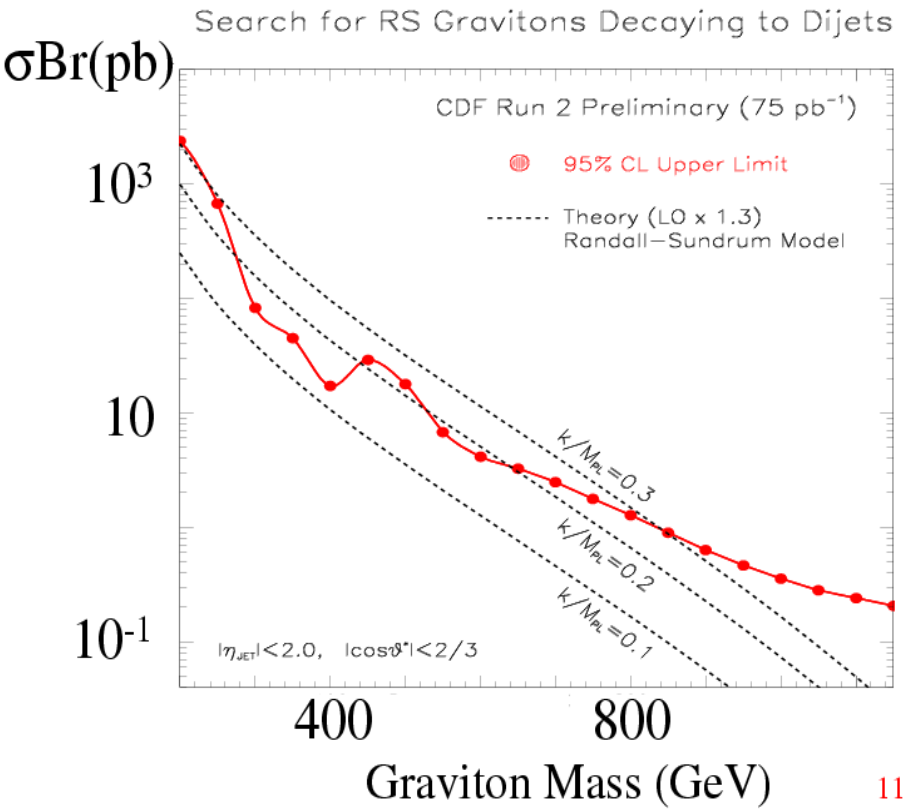


Sensitive to high k/M_{Pl} and high M_G

L = 75 pb^{-1}

2 highest E_T jets, $|\eta| < 2$

Search for resonances at high Mass

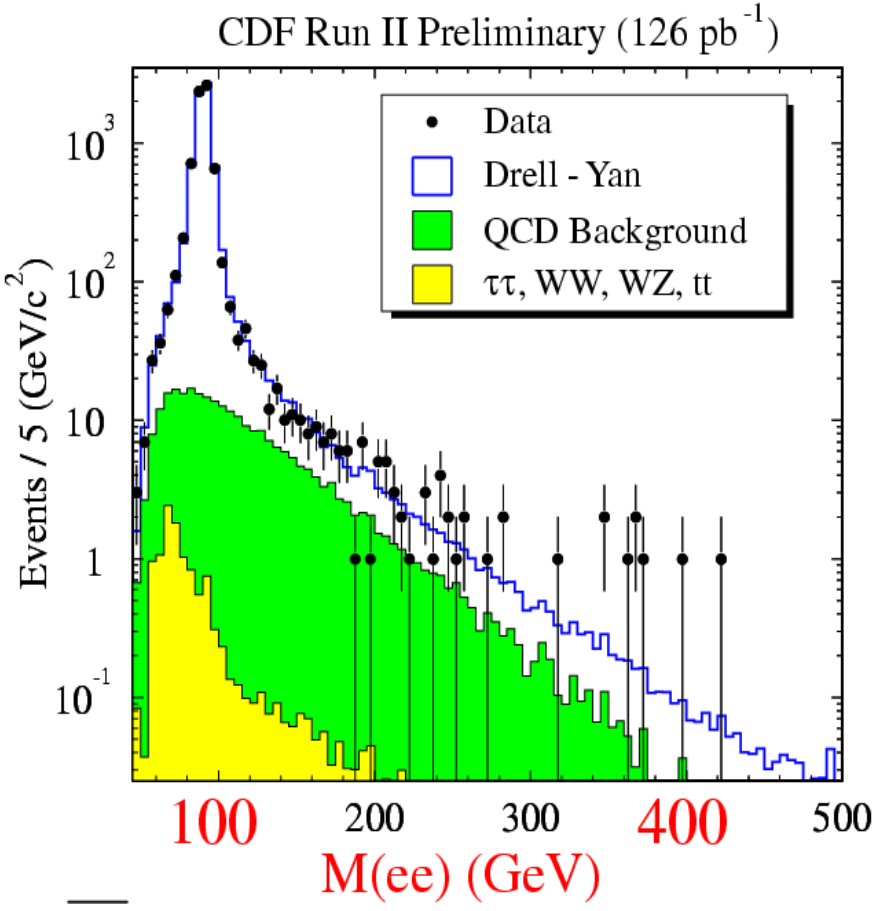


No excess observed.

Exclude

$220 < M_G < 840$ GeV (k/M_{Pl}=0.3)

Randall-Sundrum ED: Di-Leptons

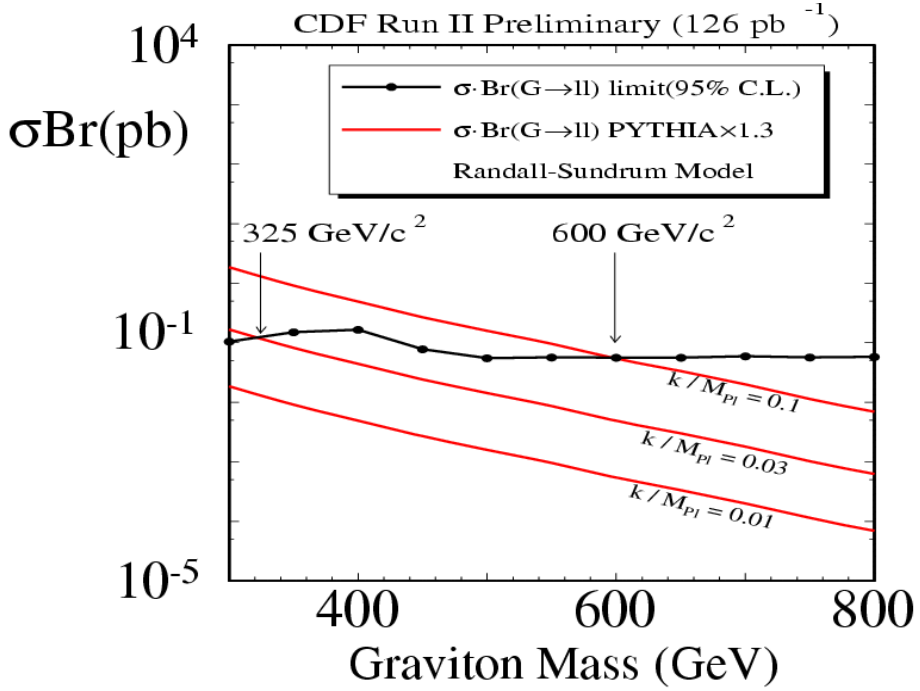


L = 126 pb^{-1}

a) 2 μ, P_T > 20 GeV

b) 2 electrons, E_T > 25 GeV

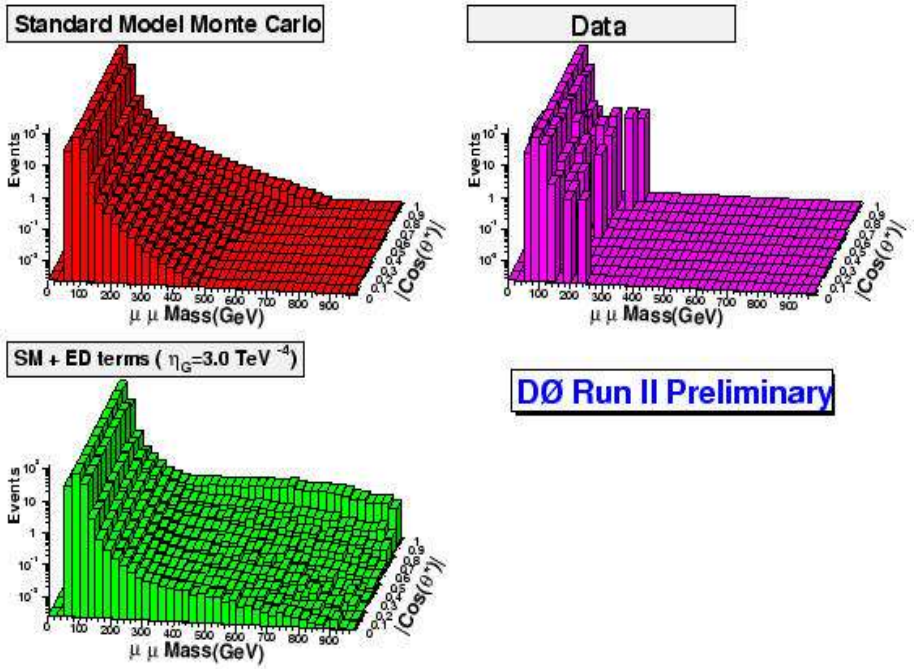
Search for resonances at high Mass



No excess observed. Results combined to set limits.

M_G > 600 GeV (k/M_{Pl} = 0.1)

Large Extra Dimensions: μμ



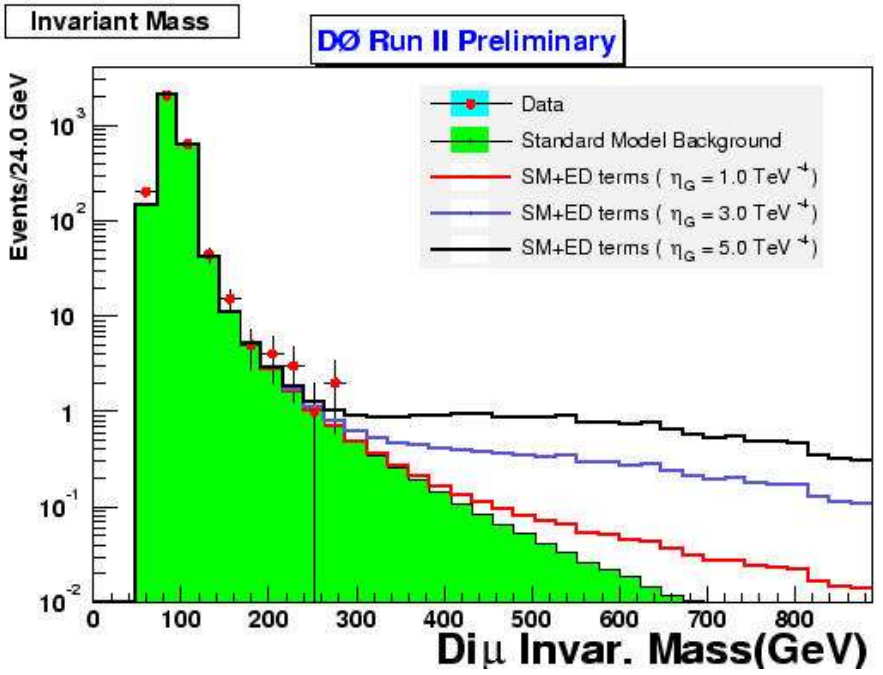
L = 100 pb^{-1}

>= 2 μ, P_T > 25 GeV

M(μμ) > 50 GeV

Compare M(μμ) and cos(θ*) to SM distributions.

M_S > 880 GeV

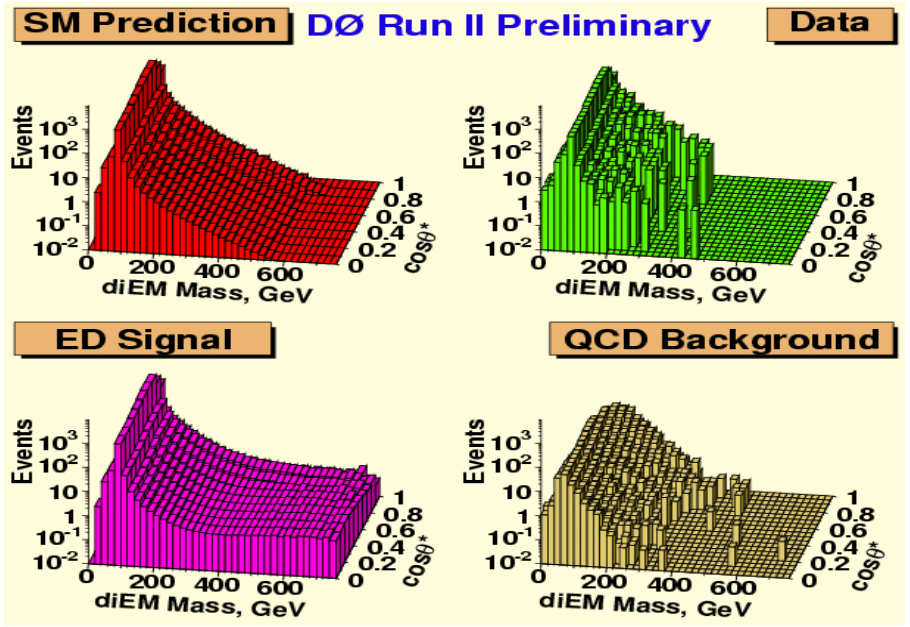


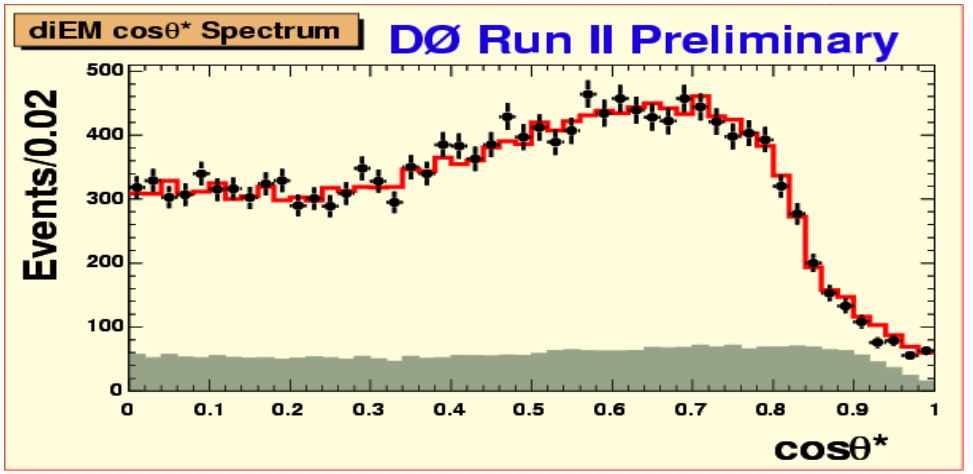
Large Extra Dimensions: ee and γγ

L = 194 pb^{-1}

2 electrons/γ, E_T > 25 GeV

track isolation

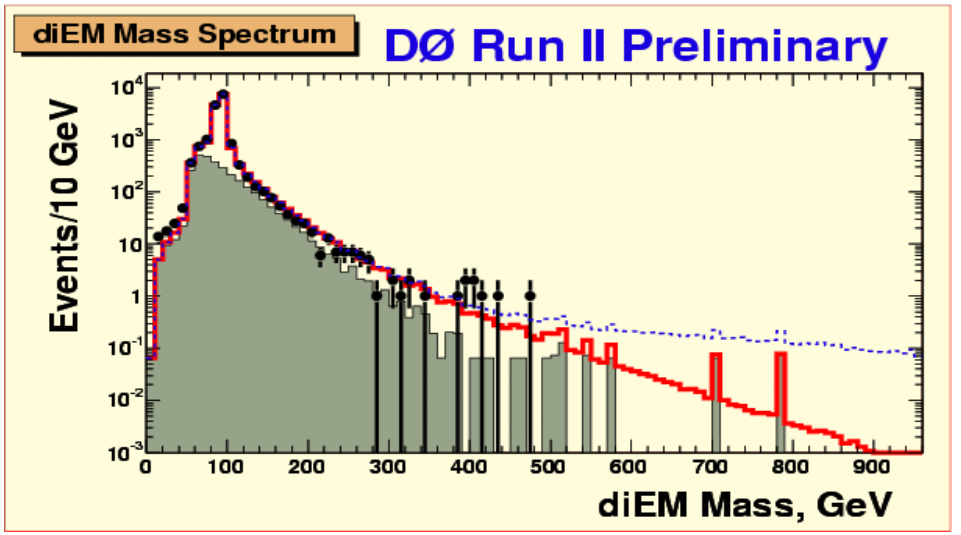




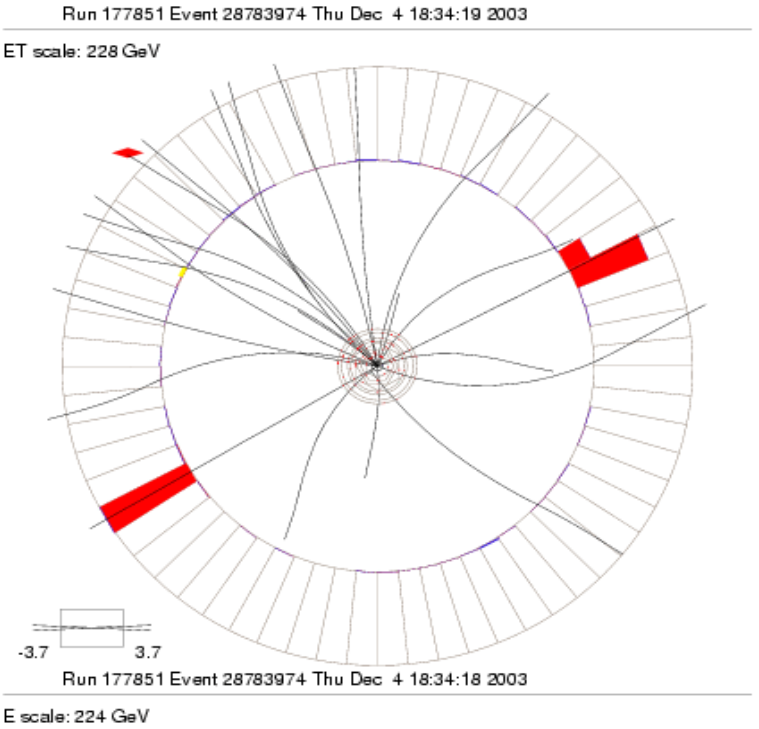
Compare to SM distributions

M_S > 1.36 TeV (GRW)

M_S > 1.43 TeV when combined with Run I results



Highest Mass Event



Invariant Mass: 475 GeV

$\cos \theta^* = 0.01$

Conclusions

- Large number of searches beyond the Standard Model have been performed by CDF and D0.
- Various results have been presented including new limits for 2^{nd} generation Leptoquarks, excited electrons and large extra dimensions.
- Many more new results are forthcoming in the next months.
- Aiming for publications in spring.

Some Tevatron Limits for New Physics

LQ1	eejj	M(LQ1) > 231 GeV
LQ2	eν jj	M(LQ2) > 156 GeV
LQ2	μ μ jj	M(LQ2) > 241 GeV
GMSB $\gamma\gamma$ + MET	$\gamma\gamma$ + MET	M($\chi^{\pm}_1$) > 144 GeV
RPV SUSY	eee	σ < 1.3 (1.4) pb-1
e*	e + γ	M_{CI} > 889 GeV, M_{GM} > 208 GeV
Z'	Z' → ll	M(Z') > 730 GeV
Z'	Z' → ee	M(Z') > 719 GeV
Z'	Z' → μ μ	M(Z') > 610 GeV
RS ED	jj	M_G > 840 GeV
RS ED	ll	M_G > 600 GeV
LED	μ μ	M_S > 880 GeV
LED	ee/$\gamma\gamma$	M_S > 1.36 GeV (1.43 GeV)