New Particle Searches at CDF

Koji Ikado
Waseda University
for the CDF Collaboration

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Outline

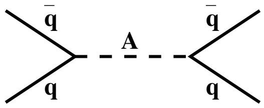
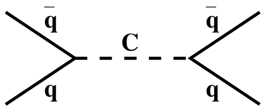
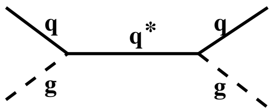
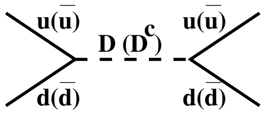
1. Introduction
2. Recent Results from Run II
3. Prospects for Run II SUSY searches
4. Summary

Introduction

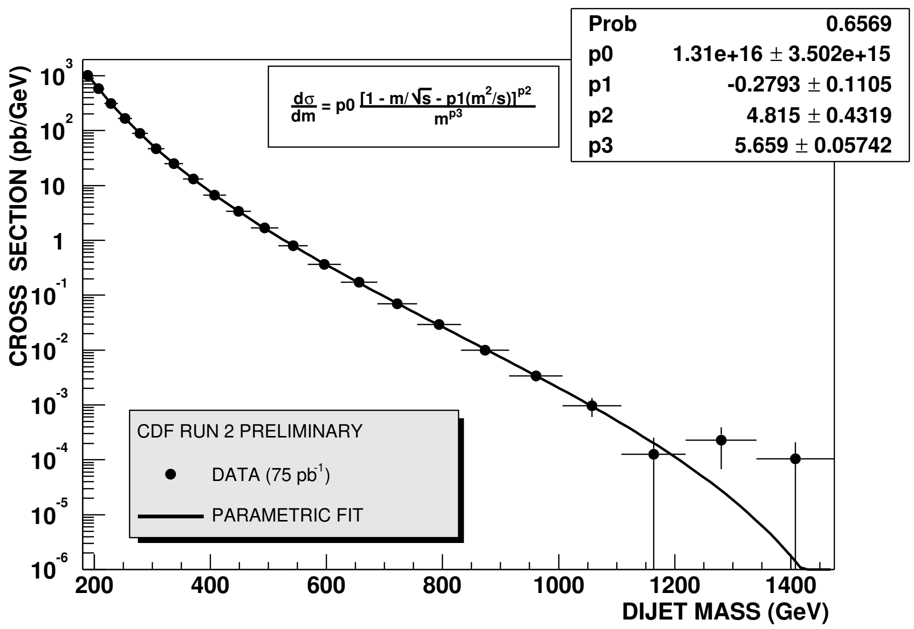
- In the roughly $70 \sim 80$ pb^{-1} Tevatron Run II, CDF has conducted a wide variety of searches for exotic particles
- While no new physics has been discovered, the searches have yielded strong constraints on theoretical models
- Review recent Run II results according to signatures
  - ◇ Dijet
  - ◇ Diphoton
  - ◇ Dilepton
  - ◇ Leptoquark
  - ◇ CHAMP (CHArged Massive stable Particle)
  - † All results are preliminary
- Review prospects for Run II SUSY searches
  - ◇ Squark & Gluino
  - ◇ Chargino & Neutralino
  - ◇ Stop
  - ◇ GMSB
  - † Selected topics

Dijet Based Searches

New Particles That Decay to Dijets

Model	Particle	Production/Decay	J^{P}(color) & $\Gamma/2$
Chiral Color SU(3)L x SU(3)R	Axigluon A		$1^{+}(8)$ .05 M
Extended Technicolor	Coloron C		$1^{-}(8)$ .05 M
Composite Fermions	Excited Quark q*		$1/2^{+}(3)$ .02 M
Superstring Inspired E6 Models	Diquarks D, D^{C}		$0^{+}(\bar{3})$ .004 M

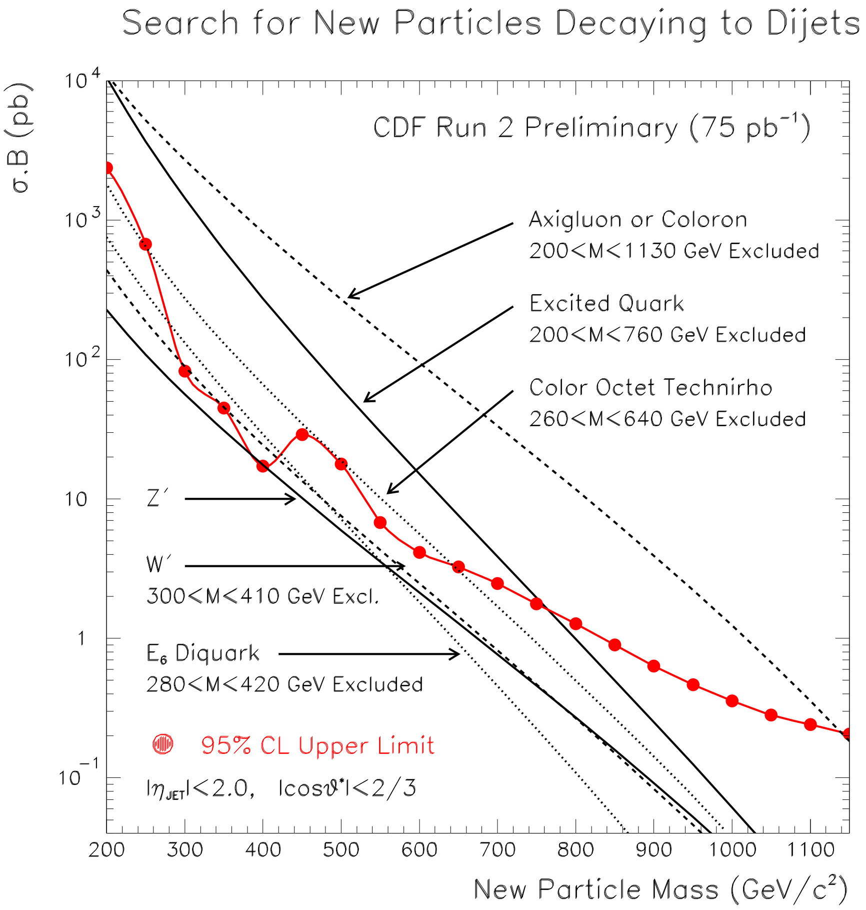
- **Event Selection**
  - $\frac{\not{E}_T}{\sqrt{\sum E_T}} < 6$ and $\sum E_T < 2.2$TeV
  - Two highest E_T jets
- **Dijet invariant mass distribution (with a background parameterization fit)**



No significant evidence for new particles

Dijet Based Searches

- **Cross section limit (95% C.L.)**



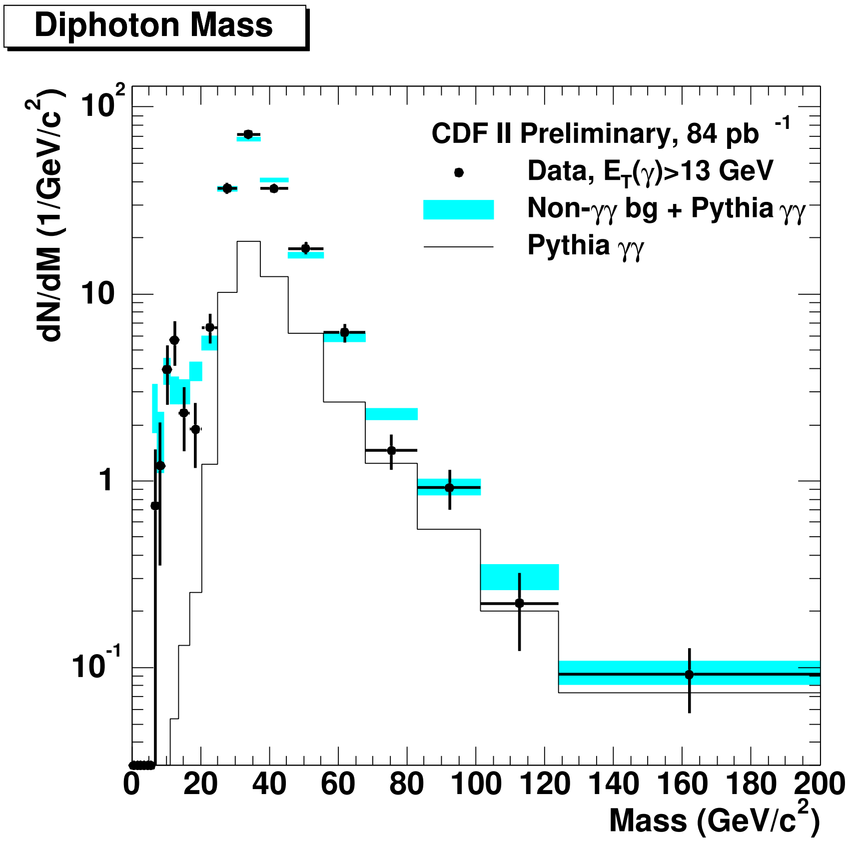
- **Mass limits for new particles**

New Particles	Run 2 limit (GeV$/c^2$)
Axigulon	$200 < M < 1130$
Excited Quarks	$200 < M < 760$
E6 Diquark	$280 < M < 420$
W'	$300 < M < 410$
Technirho	$260 < M < 640$

Better results than Run I results (106 pb^{-1})

Diphoton Based Searches

- Events selection
  - ◇ Two photon $E_T > 13$ GeV
  - ◇ cosmic ray and beam halo rejection
- Diphoton invariant mass distribution



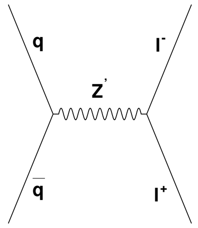
- Diphoton + Lepton search

Signature	Data	Predicted $E_T^\gamma > 13$ GeV	Predicted $E_T^\gamma > 25$ GeV
$e\gamma\gamma$	0	$0.27 \pm 0.10 \pm 0.14$	$0.04 \pm 0.03 \pm 0.02$
$\mu\gamma\gamma$	0	$0.04 \pm 0.007 \pm 0.02$	$0.007 \pm 0.005 \pm 0.004$

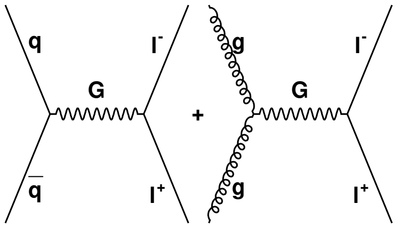
Consistent with SM background prediction

Dilepton Based Searches

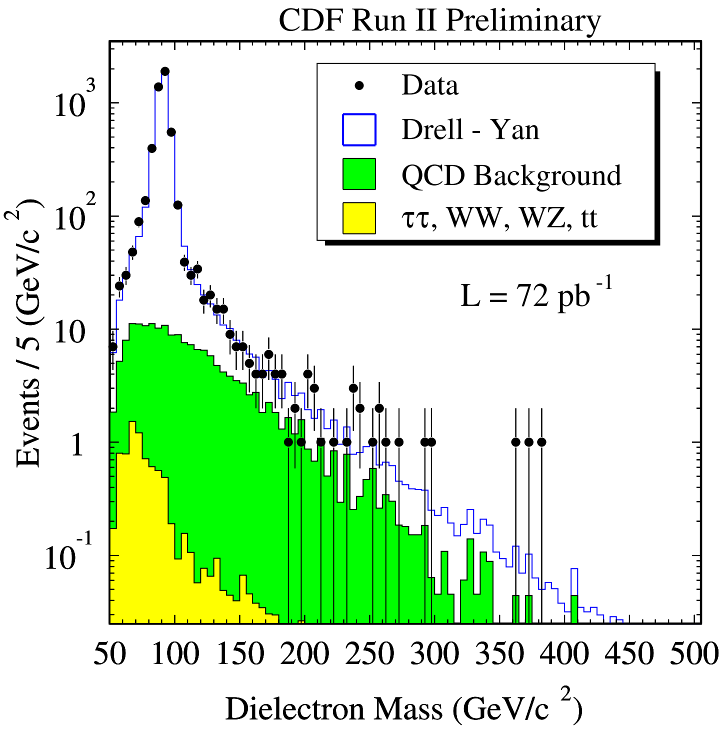
- Search for new particles in high mass dileptons
  - ◇ New neutral gauge boson Z' (spin 1)
    Additional gauge boson to the Standard Model Z

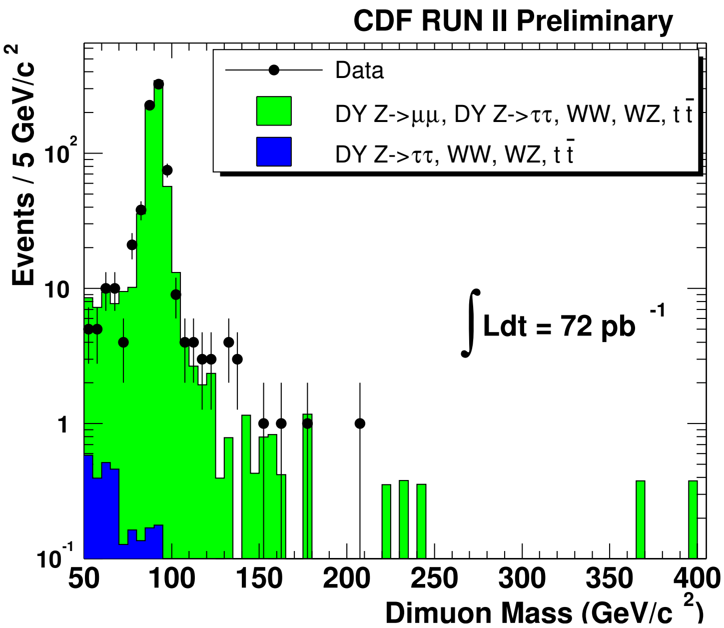


  - ◇ Randall-Sundrum graviton (spin 2)
    Excited graviton in 5 dimensions



- Dilepton invariant mass distribution

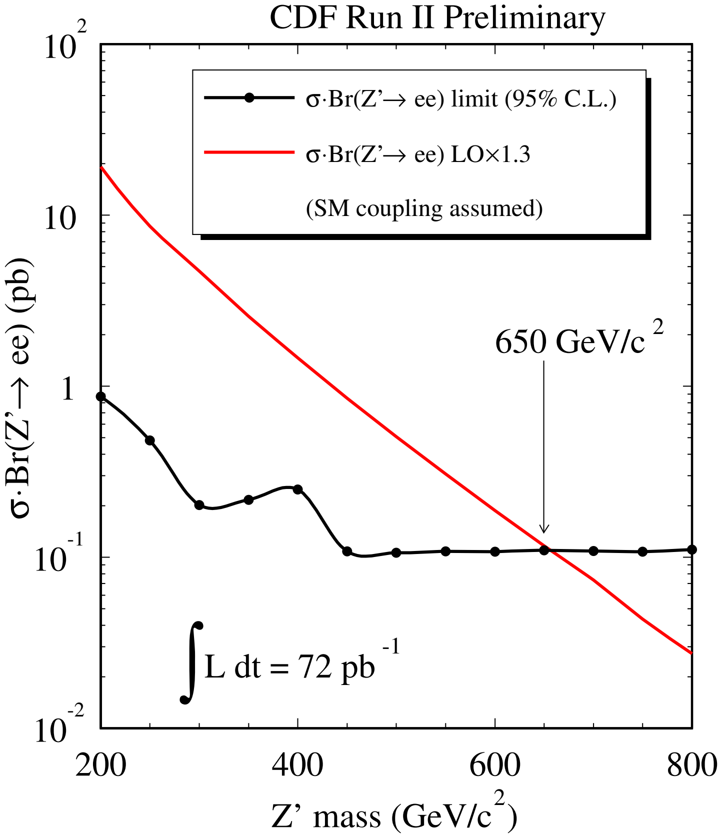


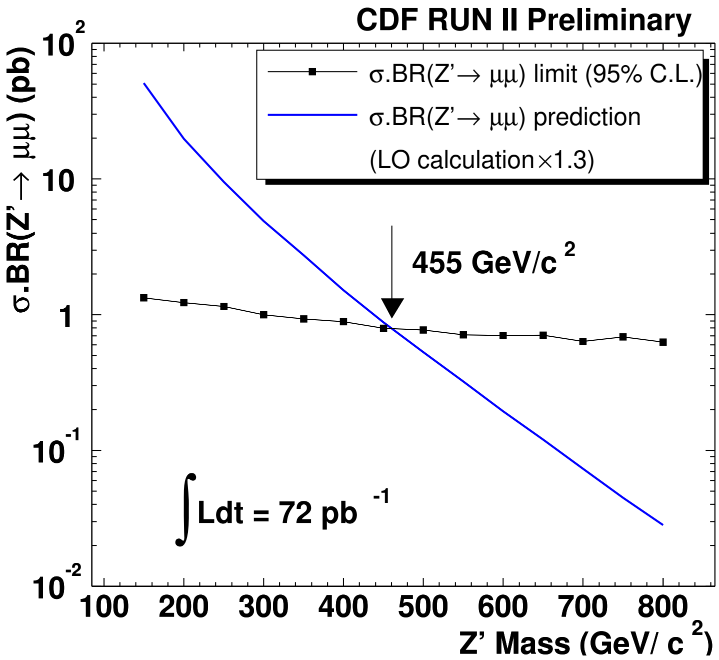


No excess observed

Dilepton Based Searches

- Z' cross section limits





- Z' search history (e^+e^- mode)

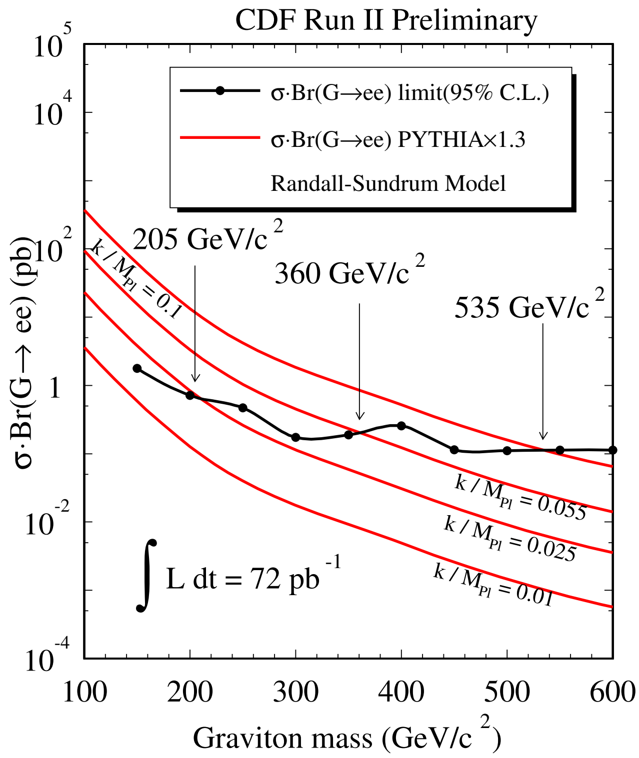
run	Luminosity (pb^{-1})	Mass limit (95% C.L.) (GeV$/c^2$)
1988 - 1989 (Run0)	4	387
1992 - 1993 (RunIa)	20	505
1994 - 1995 (RunIb)	90	640
2002 - 2003 (RunIIa)	72	650

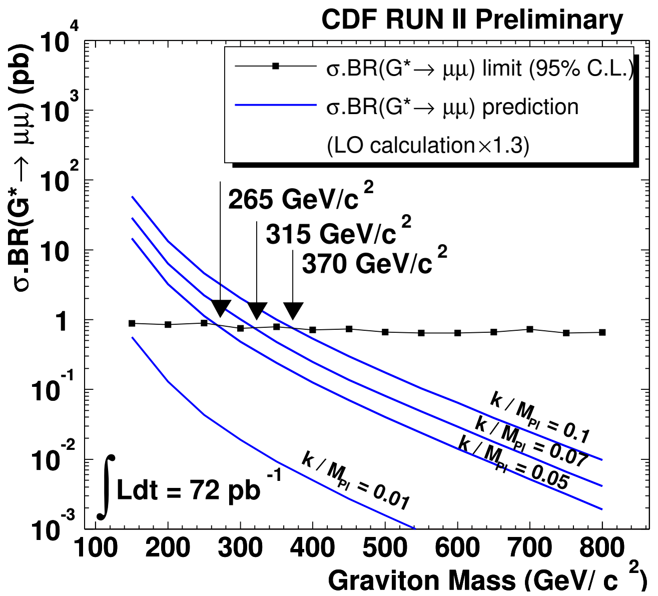
Comparable results to Run I results

$\dagger$ **Combine ee and $\mu\mu$ channels in progress**

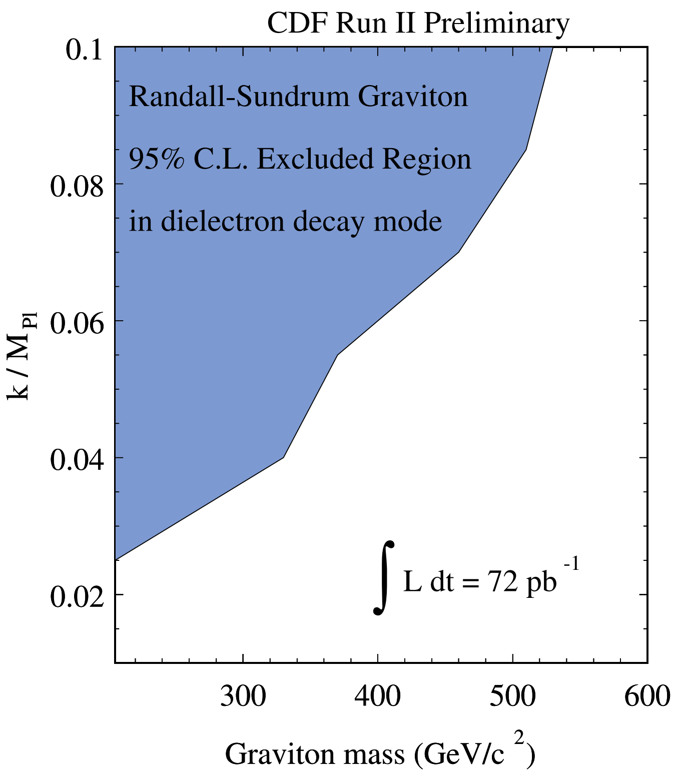
Dilepton Based Searches

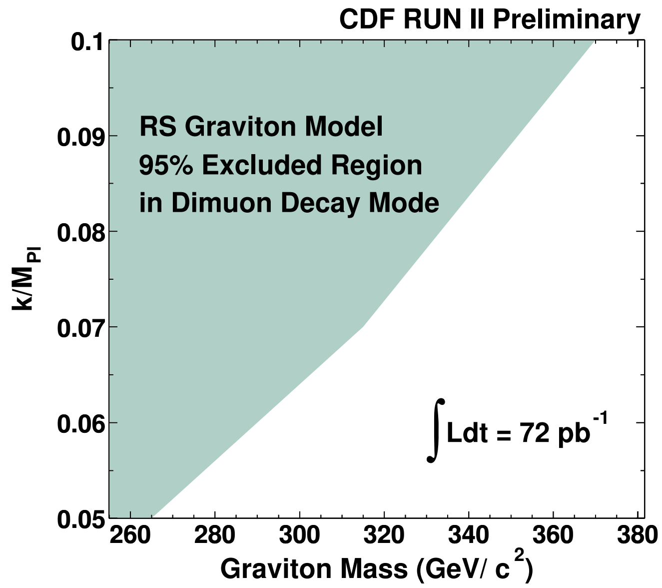
- **Randall-Sundrum graviton cross section limits**





- **Randall-Sundrum graviton cross section limits**





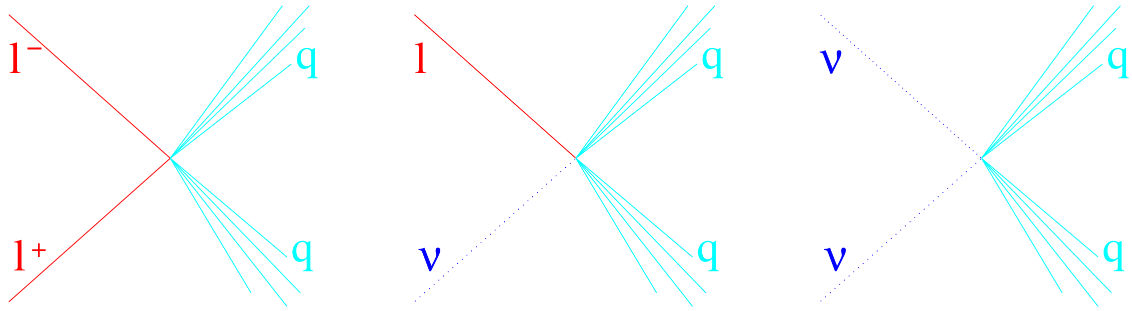
First limits from collider experiments

Leptoquark Search

- Colored objects that carry both B and L numbers and interact with SM fermions

- Decay modes

  - $LQLQ \to \ell^+\ell^- qq$
  - $LQLQ \to \ell^\pm \nu qq$
  - $LQLQ \to \nu\nu qq$

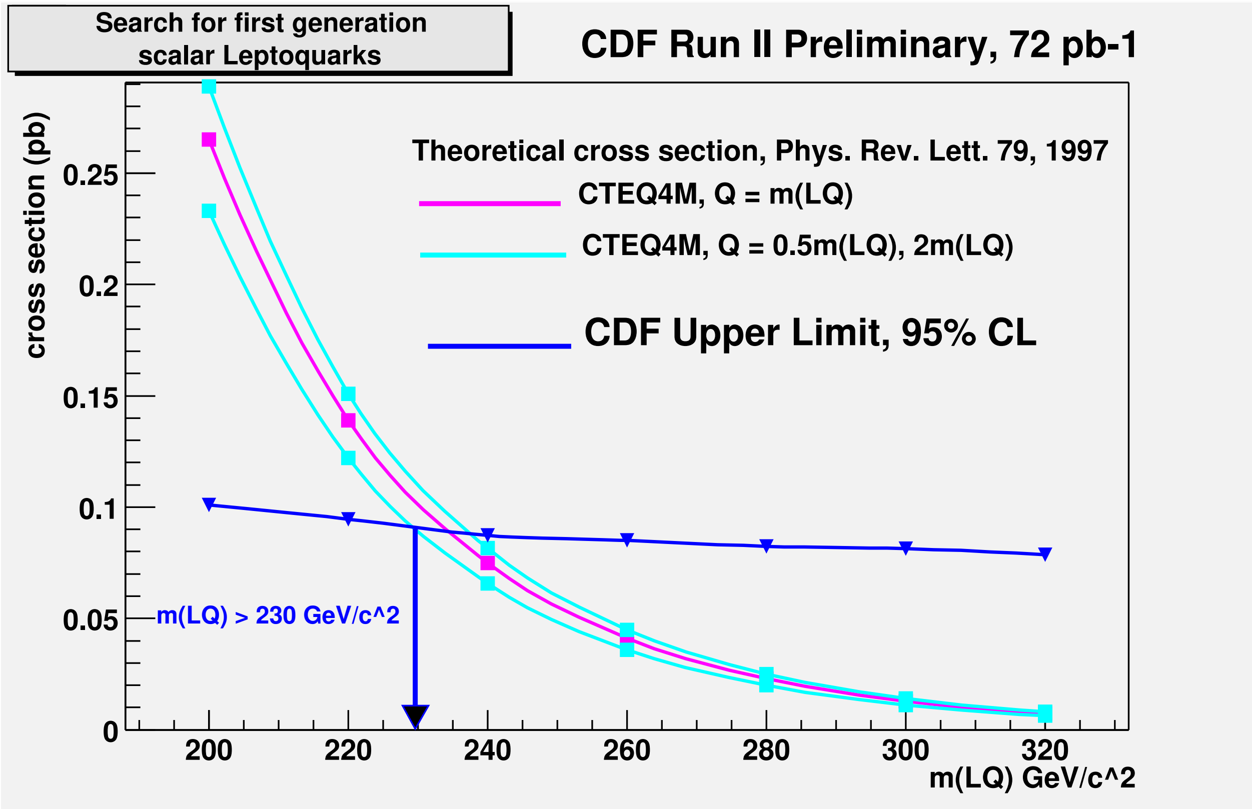


- Event selection for first leptoquark search

  - Two electrons with $E_T > 25$ GeV
  - $Z \to e^+e^-$ veto
  - Two jets with $E_T^{j1} > 30$ GeV, $E_T^{j2} > 15$ GeV
  - $E_T^{j1} + E_T^{j2} > 85$ GeV, $E_T^{e1} + E_T^{e2} > 85$ GeV
  - $\sqrt{E_T^{e1} + E_T^{e1} + E_T^{j1} + E_T^{j2}} > 200$ GeV

Leptoquark Search

- Cross section limit



† 0 events observed

- Mass limit (95% C. L.)

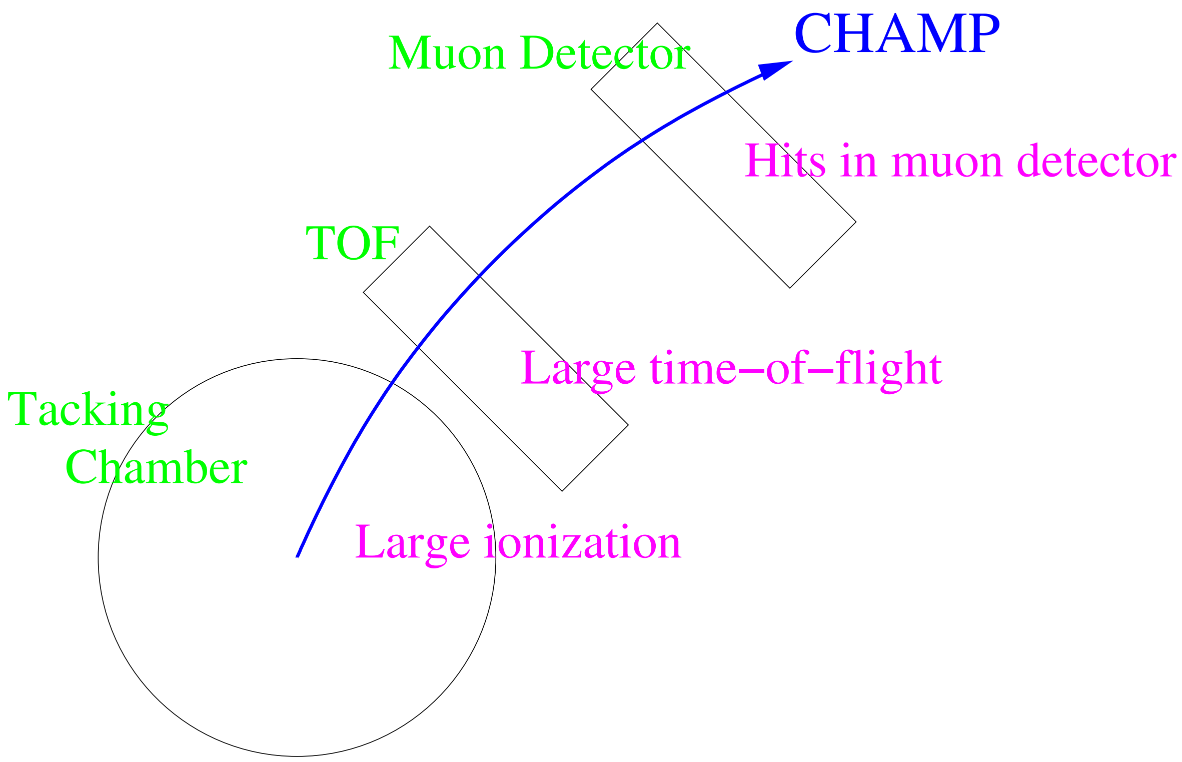
◇ Run II : 230 GeV$/c^2$
(Run I : 220 GeV$/c^2$)

Comparable results to Run I results

† Leptoquark search in $\not{E}_T$ + jets in progress

CHAMP Search (CHArged Massive Particle)

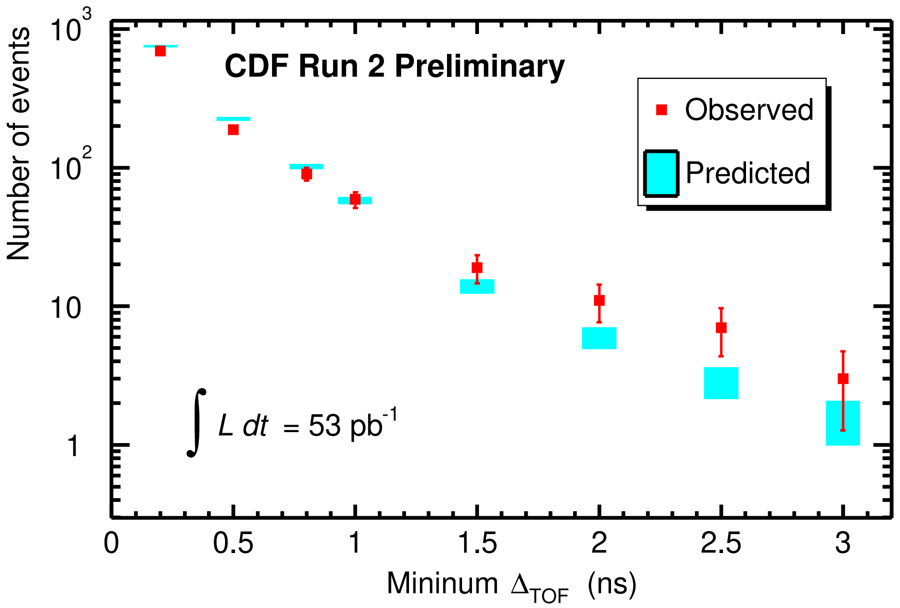
- Long lived particles escaping a detector
- Distinctive signature
  - ◇ Slow moving and high transverse momentum
    - Large ionization energy loss
    - Long time-of-flight
  - ◇ Isolated



- Event selection
  - ◇ $\Delta_{TOF} =$ (Measured TOF) $-$ (TOF for particle at c) > 2.5 ns
  - ◇ Cosmic ray veto

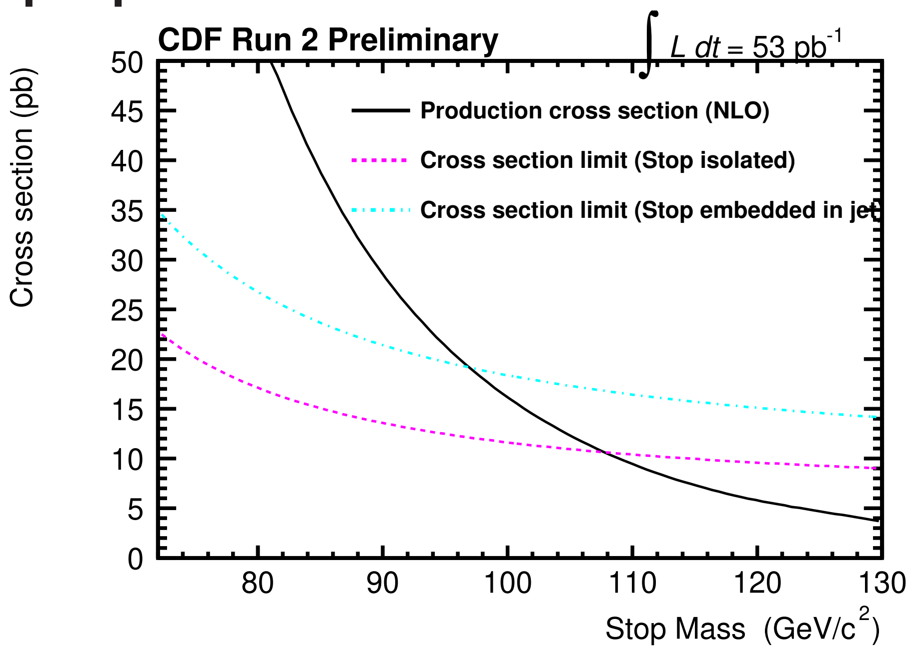
CHAMP Search (CHArged Massive Particle)

- **Predicted and observed events**



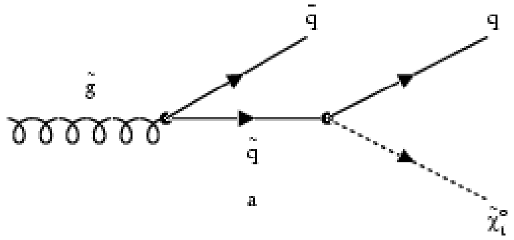
  - ◇ **Expect : 2.9 ± 0.7(stat) $\pm$ 3.1(sys) events**
  - ◇ **Observe : 7 events**

- **Stable stop squark cross section limit**

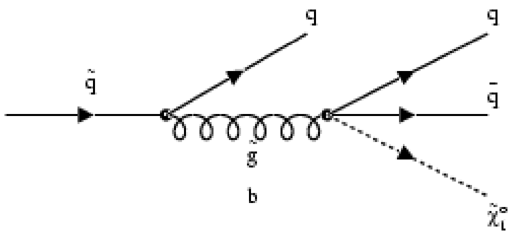


  - ◇ **$M_{\tilde{t}} > 108$ GeV (isolated stop)**
  - † **LEP limit : $M_{\tilde{t}} > 95$ GeV**

Squark & Gluino

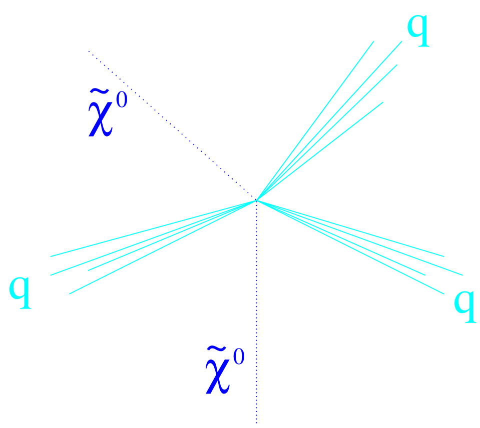


- **Production :**
  - ◇ $p\bar{p} \rightarrow \widetilde{q}\widetilde{q}, \widetilde{q}\widetilde{g}, \widetilde{g}\widetilde{g}$



- **Decays :**
  - ◇ $\widetilde{q} \rightarrow q\widetilde{\chi}^0$
  - ◇ $\widetilde{g} \rightarrow \widetilde{q}q \rightarrow qq\widetilde{\chi}^0$

- **Experimental signature for squark and gluino**
  - ◇ $\not{E}_T + \geq 3$ **Jets**



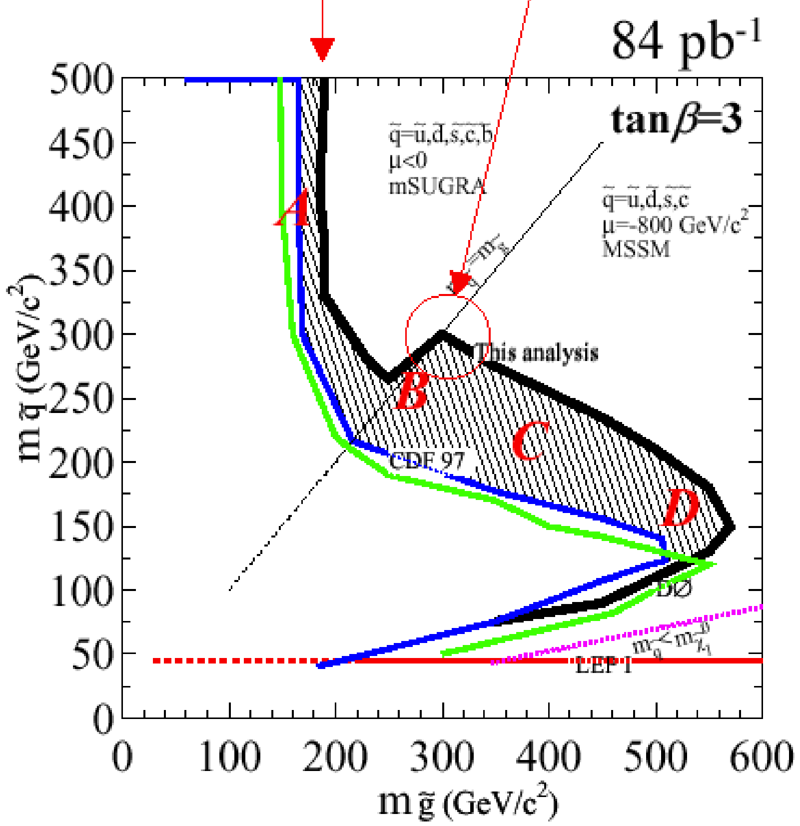
- **Squark and gluino couple strongly to quark and gluon**
  - **Tevatron is the proper machine to search for squarks and gluinos (large production cross section)**

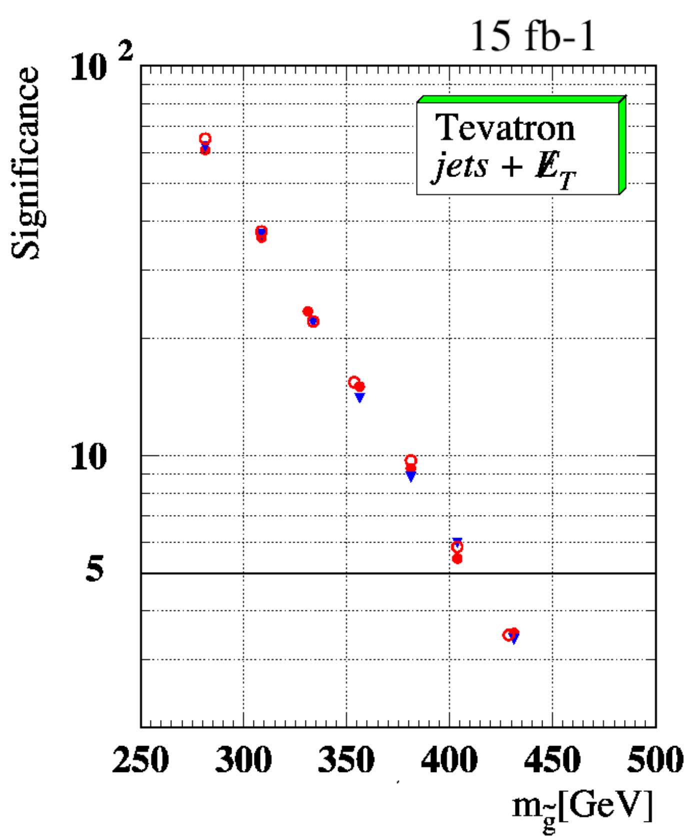
Squark & Gluino

- Run I limit and Run II prospect

$M_{\tilde{g}} > 300\ \mathrm{GeV/c^2}\quad M_{\tilde{q}} \approx M_{\tilde{g}}$

$M_{\tilde{g}} > 195\ \mathrm{GeV/c^2}$





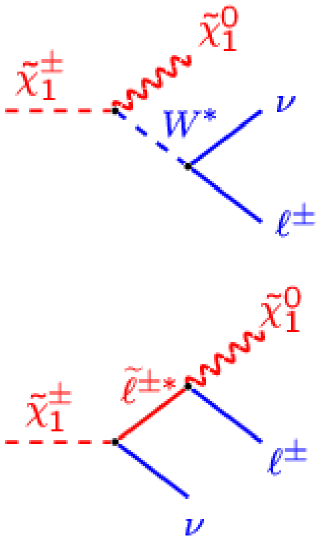
CDF, PRL 88 (2002) 041801
$N_{j15} \geq 3$, $\Delta\phi^{min}(j,\not{E}_T) > 0.5$ rad (28.6^o)
$N_{trk10}^{iso} = 0$, $E_T^{j1} > 70$, $E_T^{j2} > 30$ GeV
$\not{E}_T > 70$, $H_T = \not{E}_T + E_T^{j2} + E_T^{j3} > 150$ GeV

V. Krutelyov *et al.*, PLB 505 (2001) 161
$N_{j15} \geq 4$, $\Delta\phi^{min}(j,\not{E}_T) > 30^o$
$N_{l15} = 0$
$\not{E}_T > 100$, $\not{E}_T + E_T^{j1} + E_T^{j2} > 350$ GeV

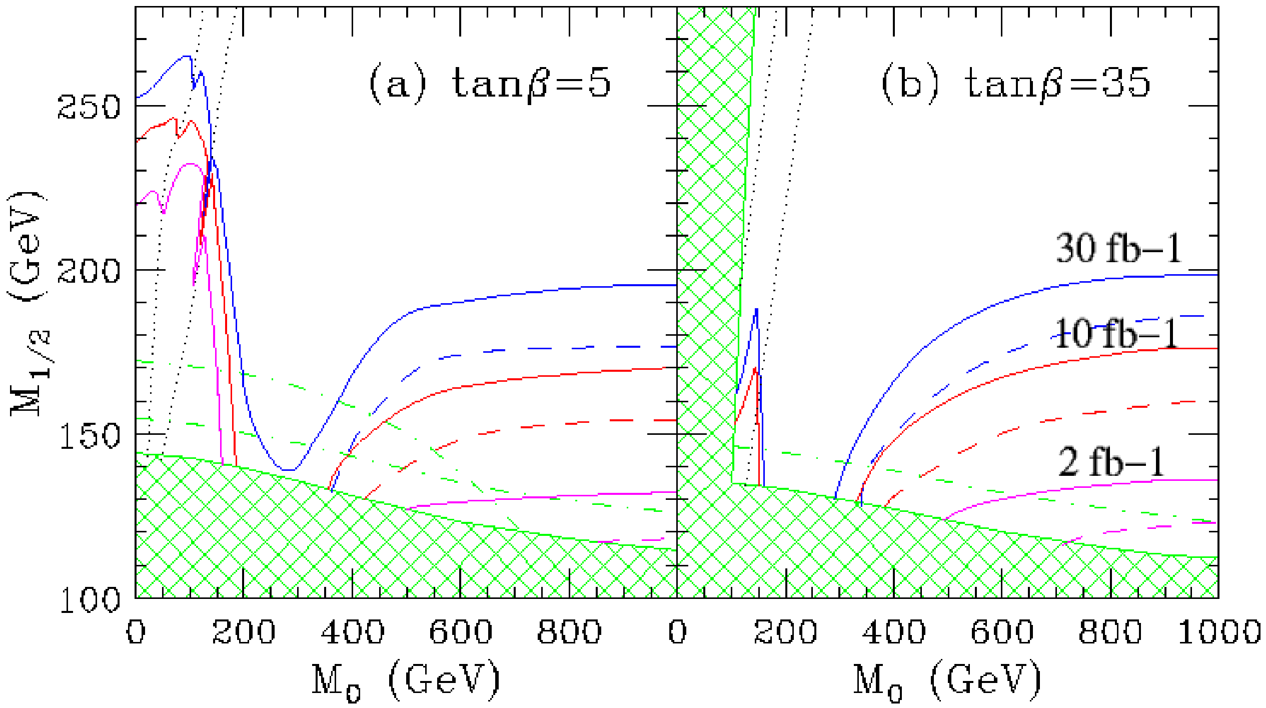
- Run II 5σ reach (15 fb^{-1}) : 410 GeV ($M_{\tilde{g}} = M_{\tilde{q}}$)

Chargino & Neutralino

- Trilepton plus $\not{E}_T$ from chargino-neutralino production is one of the cleanest signatures



- 3σ reach
  - ◇ Event selection
    - $P_T(\ell_1, \ell_2, \ell_3) > 11, 7, 5$ GeV
    - $\not{E}_T > 25$ GeV and $M_{\ell^+\ell^-}$ cut

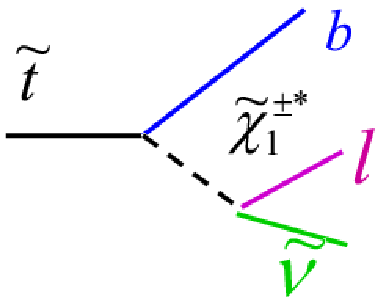


Phys. Rev. D 60 (1999) 075004

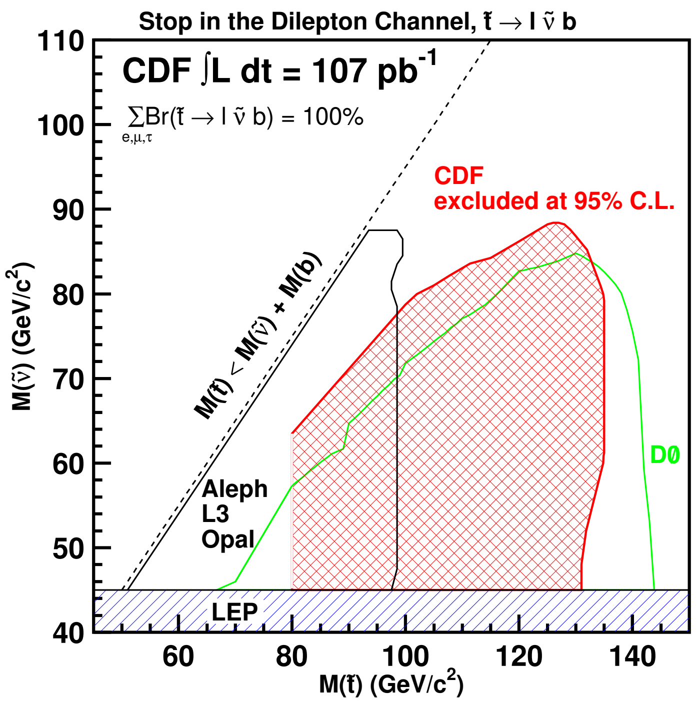
Stop

- Lightest stop ($\tilde{t}_1$) is a very good candidate for studying at Tevatron
  - Larger cross section compared to that for sleptons
- Decay for $M_{\tilde{\nu}} < M_{\tilde{t}} < M_{\tilde{\chi}_1^{\pm}}$

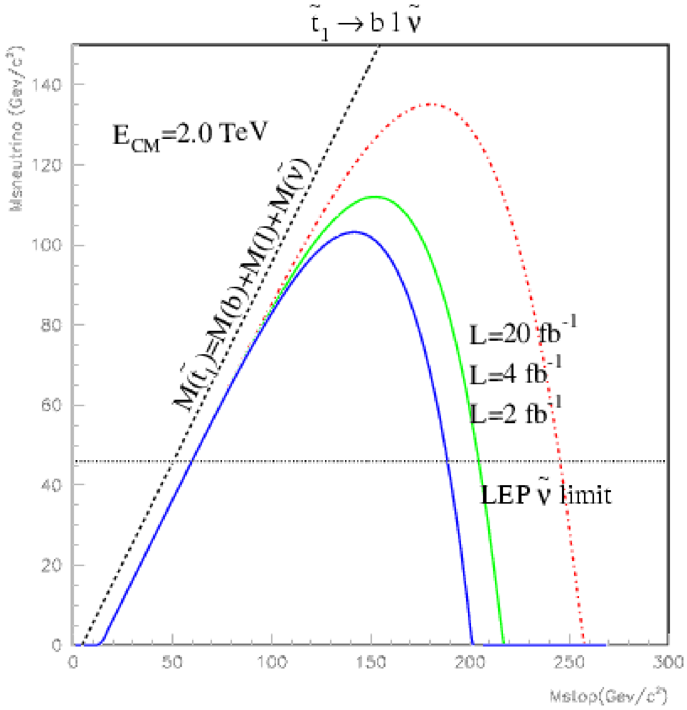
◇ $\tilde{t} \to b\ell^+\tilde{\nu}_\ell$



- Run I limit and Run II prospect for stop



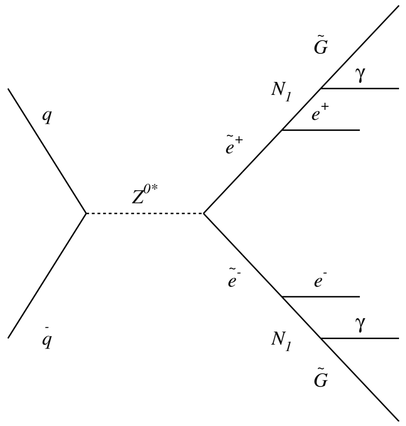
(To be published)



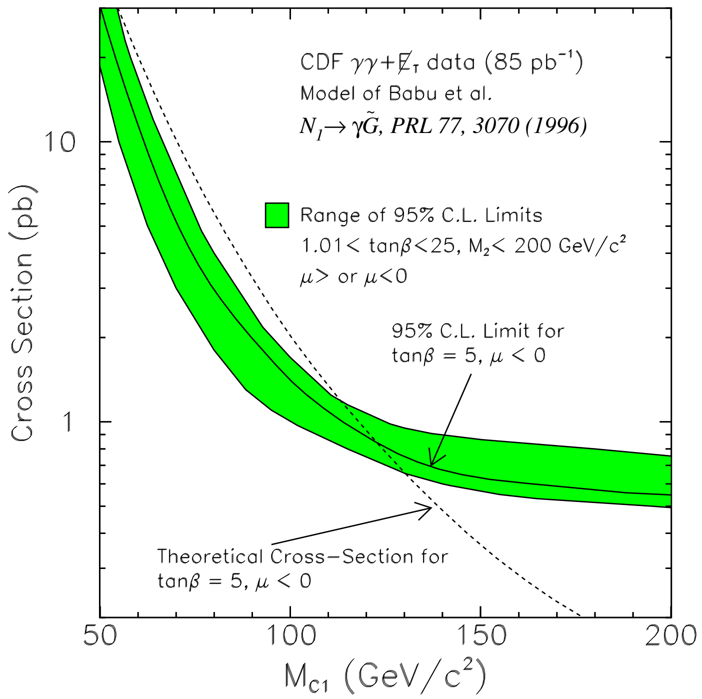
Phys. Rev. D62 (2000) 035011

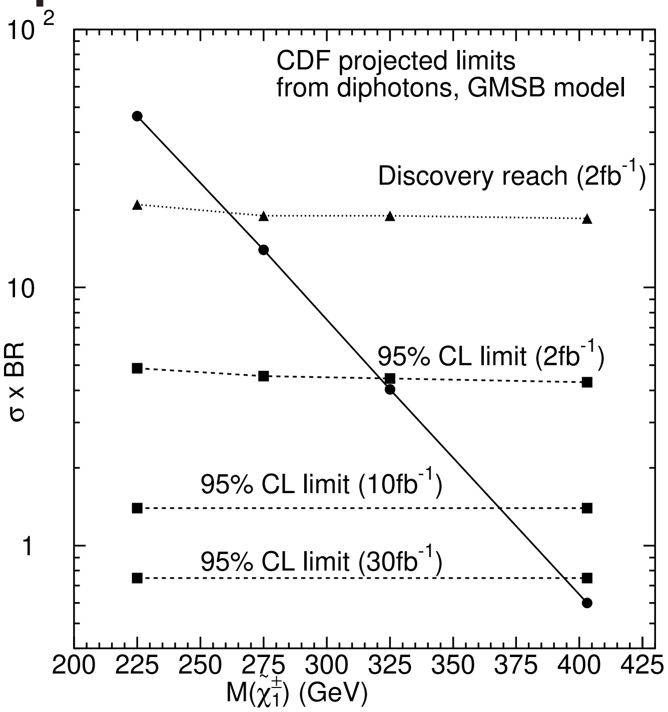
GMSB

- NLSP = $\tilde{\chi}_1^0 \rightarrow$ NLSP decays to the Gravitino with emission of a photon : $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$
- Experimental signature
  - ◇ $\gamma\gamma + \not{E}_T + X$ (X = leptons and jets)



- Run I limit and Run II prospect





Phys. Rev. D59 (1999) 092002 hep-ph/0008070

- ◇ Run I limit (85 pb^{-1}) : $M_{\tilde{\chi}^\pm} > 120$ GeV
- ◇ Run II prospect (2 fb^{-1}) : $M_{\tilde{\chi}^\pm} > 325$ GeV

Summary

- CDF is taking data actively and producing first results on searches for new physics
- Some of the results are already better than Run I results
- Some of the results are obtained using new features of the new detector