Searches for New Phenomena in CDF

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Outline

Accelerator and Detector Upgrades

Model Based Searches

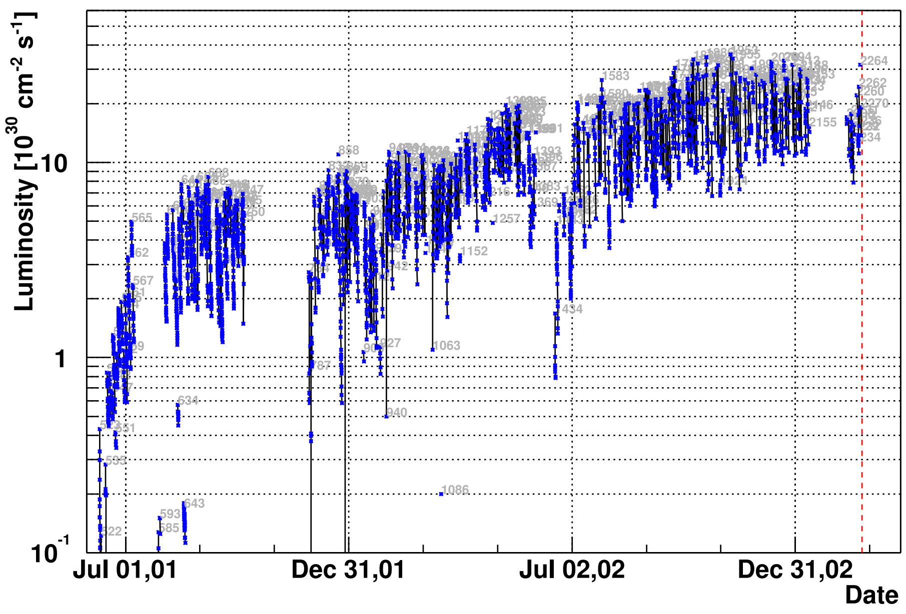
- ◇ New Gauge Bosons
- ◇ Extra Dimensions
- ◇ Leptoquarks
- ◇ Higgs
- ◇ Susy

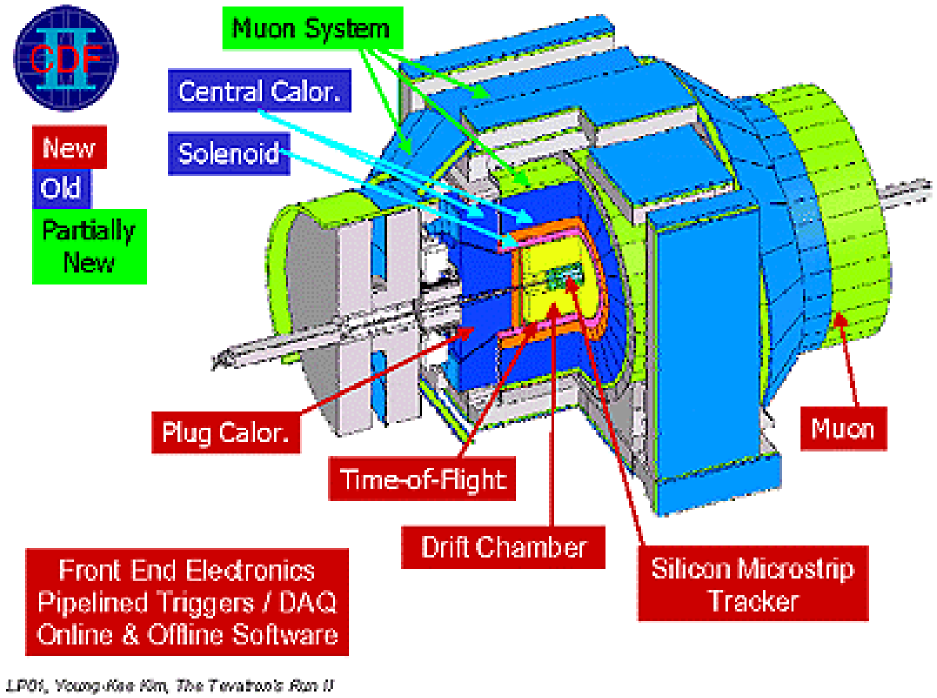
Signature Based Searches

- ◇ CHAMPs
- ◇ Dijet Mass Bump
- ◇ Missing E_T
- ◇ Photons
- ◇ Tau Leptons

Accelerator Status

- $\diamond$ $\sqrt{s} = 1.96\ TeV$
- $\diamond$ $\mathcal{L} \sim 2 \div 3\ \times 10^{31}\ cm^{-2}s^{-1}$
- $\diamond$ $\mathcal{L}^{int} = 180\ pb^{-1}$





Detector Upgrades

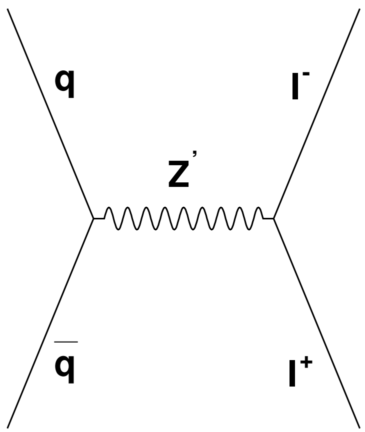
- $\diamond$ New plug calorimeter and tracking chamber to faster response
- $\diamond$ New silicon detectors:
  - $\circ$ 3-D reconstruction
  - $\circ$ tracking extended to $|\eta| = 2$
- $\diamond$ Time-Of-Flight (TOF System)
- $\diamond$ Extended Muon coverage ($|\eta| = 1. \rightarrow 1.5$)
- $\diamond$ Renewed trigger and DAQ systems

Drell-Yan Dilepton Production

High Mass Dileptons allow to search for new particle production:

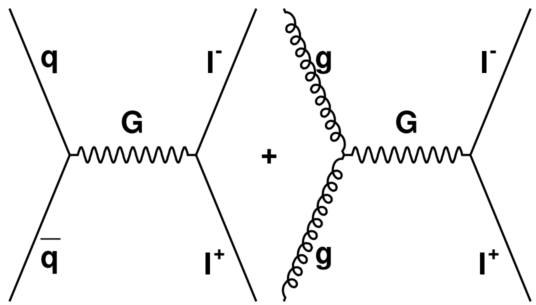
New Neutral Gauge Boson Z'

- SM coupling assumed;



Randall-Sundrum Graviton

- small extra-dimension solution to the hierarchy problem by means of a non-factorizable geometry;
- Excited graviton in 5 dimensions;
- Free parameters: mass M_G and coupling k/M_{PL};

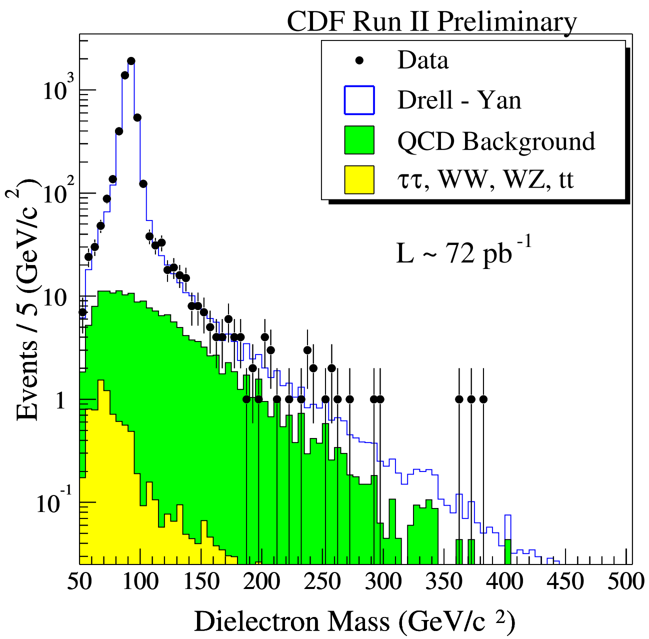


Search for New Neutral Gauge Boson Z' in Dielectron Channel

Selection

- Drell-Yan production $q\bar{q} \to Z' \to e^+e^-$;
- one good central electron $E_T > 25\ GeV$;
- a second good central electron OR one good plug electron $E_T > 25\ GeV$;
- $\not{E}_T/\sqrt{\Sigma E_T} < 2.5$.

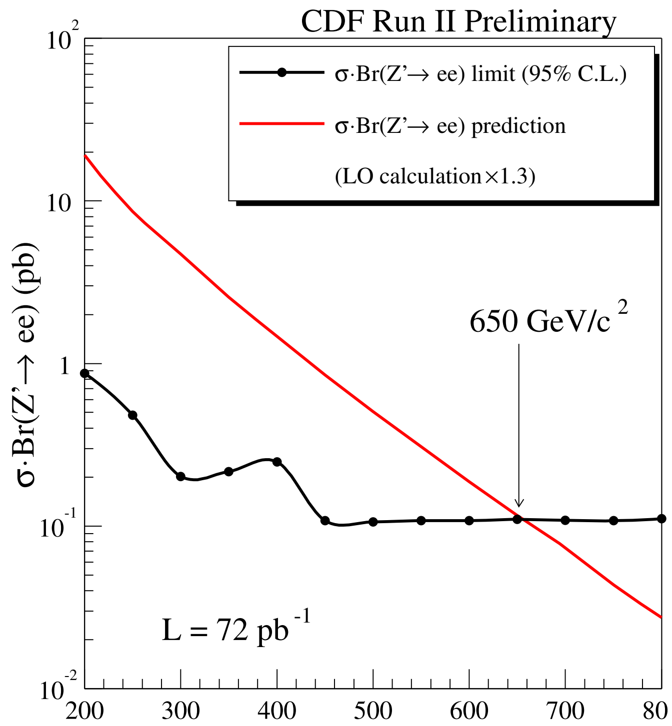
Results ($72\ pb^{-1}$)



No Excess Observed

Limit

(SM coupling assumed)

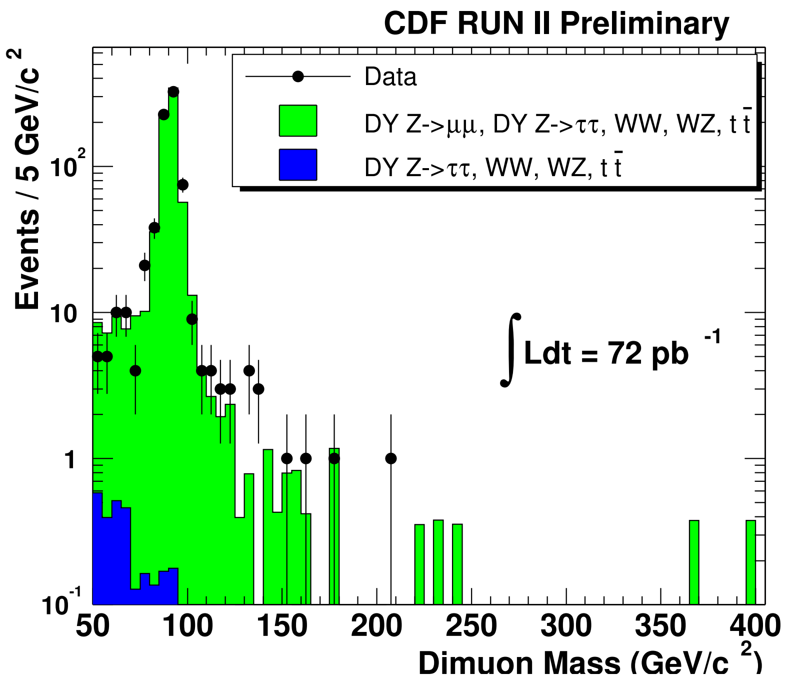


Search for New Neutral Gauge Boson Z' in Dimuon Channel

Selection

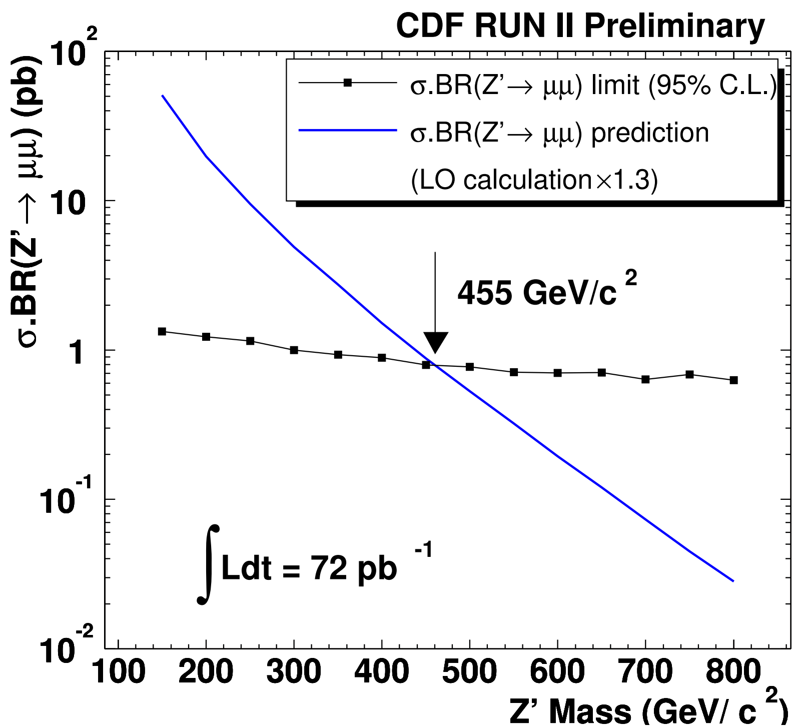
- two good muons $P_T > 20\ GeV/c$;
- cosmic ray rejection by vertex, impact parameter and timing cuts;
- QCD rejection: $\Sigma^{0.4}_{cal.\ tow.} E_T < 0.1 \cdot P_T$.

Results ($72\ pb^{-1}$)



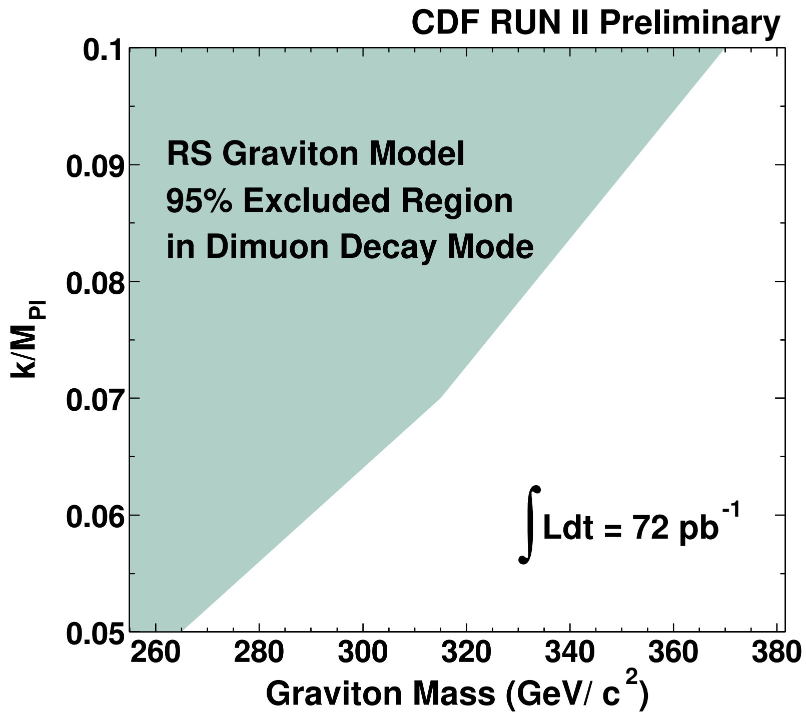
No Excess Observed

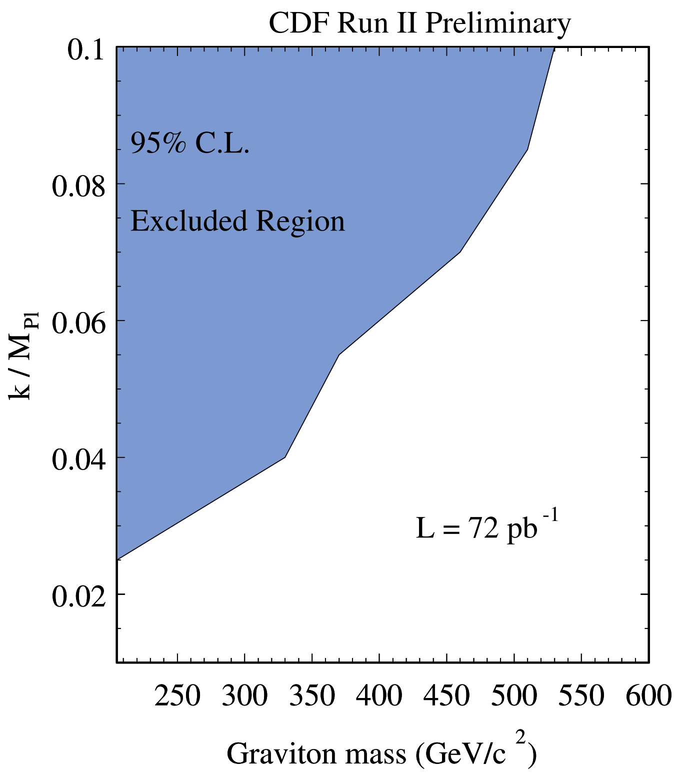
Limit



Results for Graviton Searches

Results for resonance searches in high mass dilepton used to set limits on Randall-Sundrum graviton too:





Leptoquark Searches in Run II

Leptoquarks generally pair produced and decaying to $(lq)(lq)$, $(lq)(\nu q)$ or $(\nu q)(\nu q)$.

No generation mixing expected from FCNC constraints.

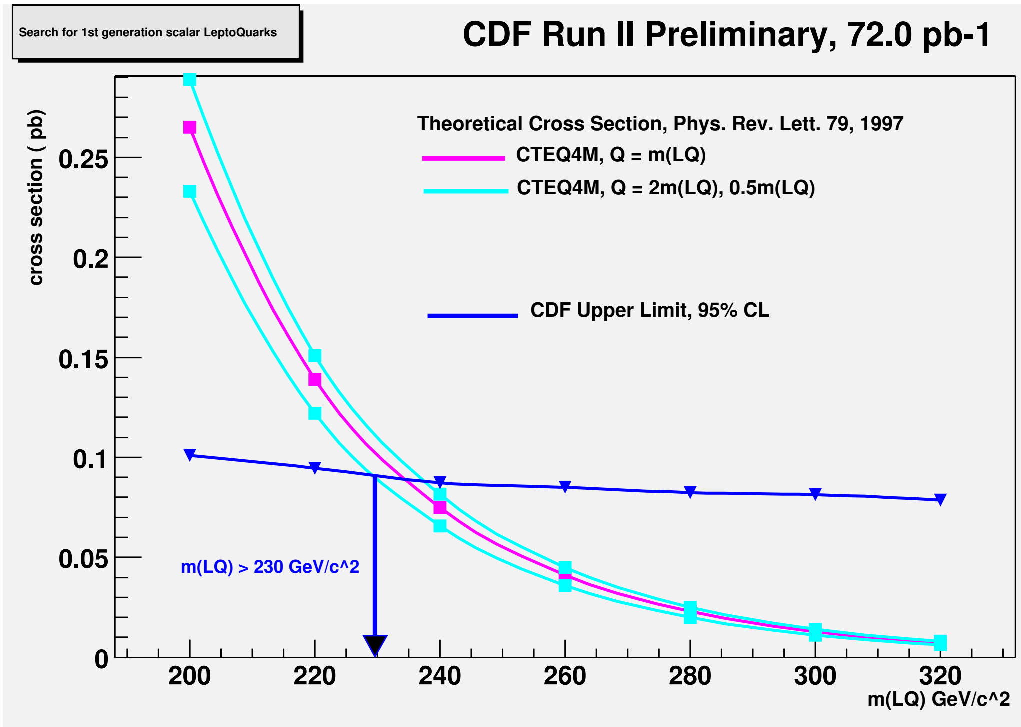
$\beta(LQ- > lq)$ model dependent.

A search for first generation leptoquark has been performed in dielectron+jets channel

Selection

- inclusive electron triggers used ($72\ pb^{-1}$)
- Two central electron w/ $E_T > 25\ GeV$
- Two jets ($E_T^{j1} > 30\ GeV$,$E_T^{j2} > 15\ GeV$)
- events w/ $76 < M_{ee} < 110\ GeV/c^2$ removed for $Z \rightarrow e^+e^-$ rejection
- $E_T^{j1} + E_T^{j2} > 85\ GeV$
- $E_T^{e1} + E_T^{e2} > 85\ GeV$
- $\sqrt{((E_T^{j1} + E_T^{j2})^2 + (E_T^{e1} + E_T^{e2})^2)} > 200\ GeV$
- 0 events observed

Limits



$M_{LQ} < 230\ GeV/c^2$ excluded (95% CL)

CHArged Massive Particles

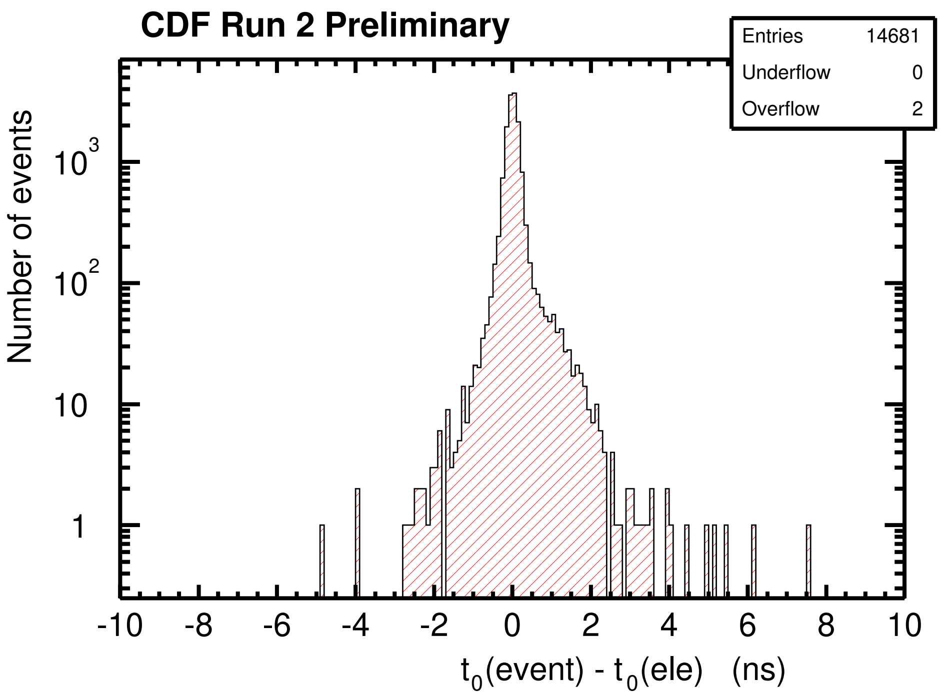
Signature and Selection

- Long-lived particles escaping CDF detector $\Rightarrow$ look at high-P_T muon triggers

- Isolated, slow moving $\Rightarrow \begin{cases} P_T > 40\ GeV/c \text{ to have full tracking efficiency for} \\ 100\ GeV/c^2 \text{ CHAMPs} \\ \text{long time} - \text{of} - \text{flight through the detector} \end{cases}$

Time Of Flight Measurements

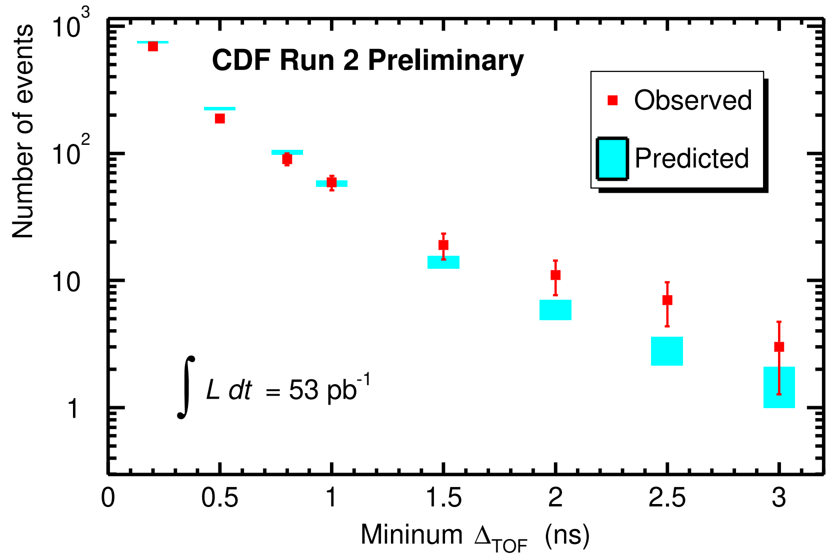
- Run II TOF system provides sensitivity to higher $\beta\gamma$ values than dE/dx
- Event t_0 from tracks w/ $P_T < 20\ GeV/c$
- Event t_0 tested with $W \to e\nu$ sample
- Look for track with high $TOF_{track} - t_0$

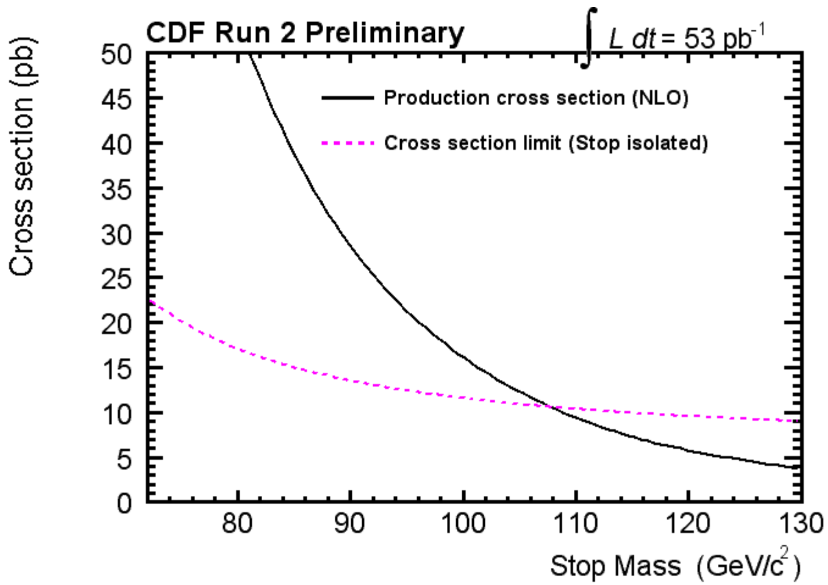


CHArged Massive Particles

Results

- Maximize probability of discovery: $TOF_{track} - t_0 > 2.5\ ns$;
- Background predictions from tracks with $20 < P_T < 40\ GeV/c$;
- Exp. 2.9 ± 0.7 (stat) ± 3.1 (sys) events
- Observed 7 events





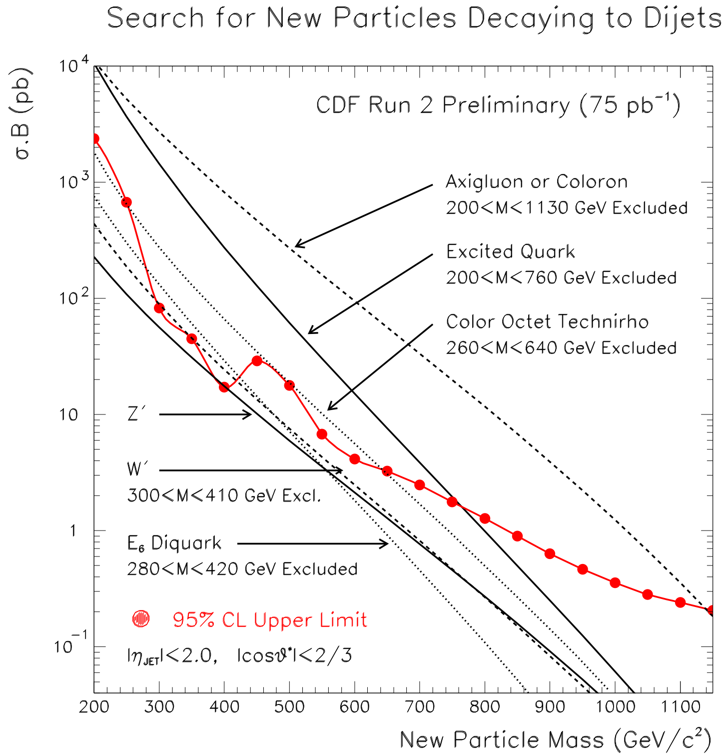
Limits ($53\ pb^{-1}$)

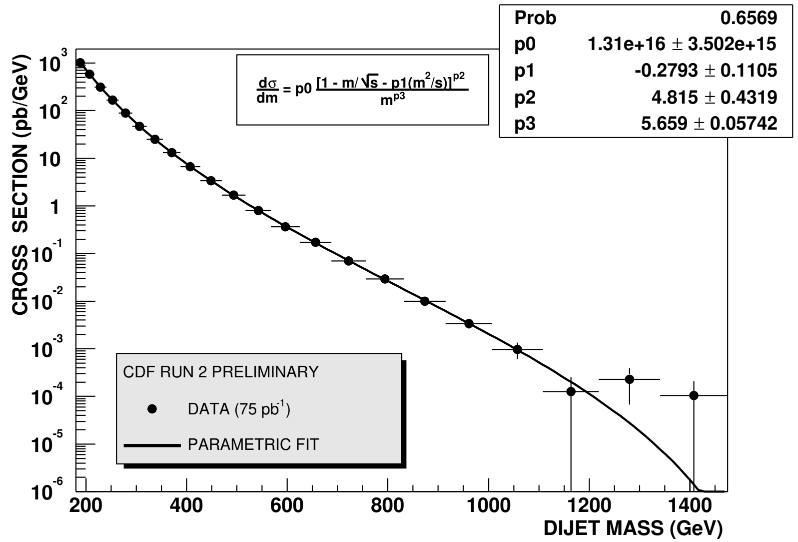
- stable stop model considered;
- NLO cross section ($\mu = M(t_1)$);
- $m_{\tilde{t}} < 107\ GeV/c^2$ excluded (95% CL);

Dijet Mass Bumps

Event Selection

- Inclusive jet samples (75 pb^{-1})
- Get two highest E_T jets w/ $|\eta| < 2$ & $|tanh((\Delta\eta)/2)| < 2/3$
- No evidence for new particles





Limits

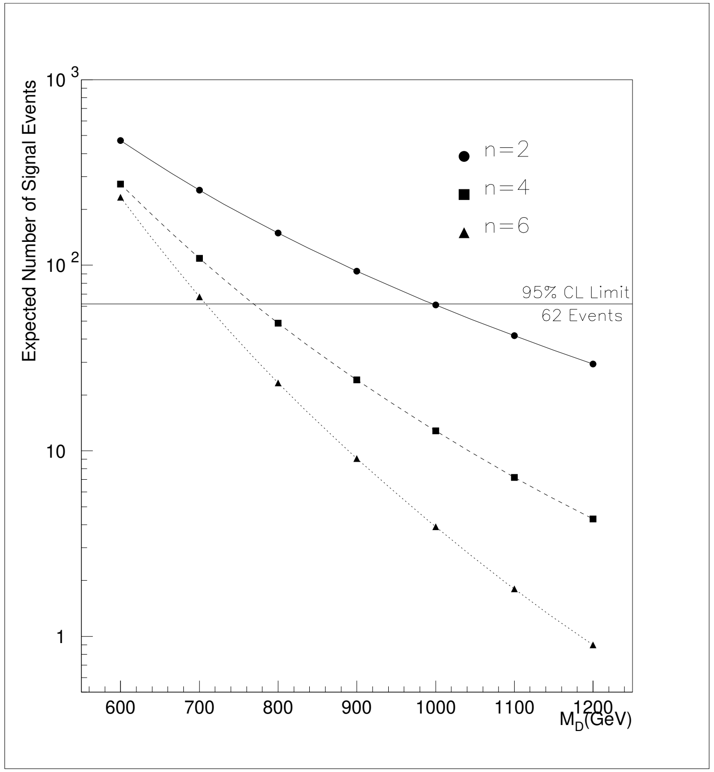
95% CL excuded mass regions:

- Axigluon or Coloron: $200 < M < 1130\ GeV/c^2$
- Excited Quarks: $200 < M < 760\ GeV/c^2$
- E6 Diquark: $280 < M < 420\ GeV/c^2$
- Color Octet Technirho: $260 < M < 640\ GeV/c^2$
- Extra Gauge Boson W': $300 < M < 410\ GeV/c^2$

Exclusive $\not\!\!E_T$+ Jet in Run I

Model

- Extra dimensions provide solution to the hierarchy problem;
- Graviton propagates in $4 + n$ dimensions;
- New effective Plank scale M_D: $M^2_{PL} \sim R^n M_D^{2+n}$.



Signature and Selection

- Graviton emission: $q\bar{q} \rightarrow gG$, $qg \rightarrow qG$, $gg \rightarrow gG$;
- Graviton escaping detector: $\not\!\!E_T > 80\ GeV$;
- Additional jet $\Delta\phi(jet - \not\!\!E_T) > 0.3$.
- Expected 274 ± 16 events (main from $Z \rightarrow \nu\bar{\nu}$)
- Observed 284 events.

95% CL Limits	$n = 2$	$n = 4$	$n = 6$
M_D	995 GeV	768 GeV	707 GeV

Inclusive Missing E_T and Photon Searches in Run II

Several triggers implemented to study weakly interacting particle production...

- MET35+2JETS
  $\not{E}_T > 35\ GeV$ & 2 jets w/ $E_T > 10\ GeV$
- MET45
  $\not{E}_T > 45\ GeV$
- MET_BJET
  $\not{E}_T > 20\ GeV$ & 2 disp. tracks ($|d_0| > 100\ \mu m$)
- MET_L3PS100
  $\not{E}_T > 25\ GeV$ & prescale 100

...and new phenomena leading to photons in the final states

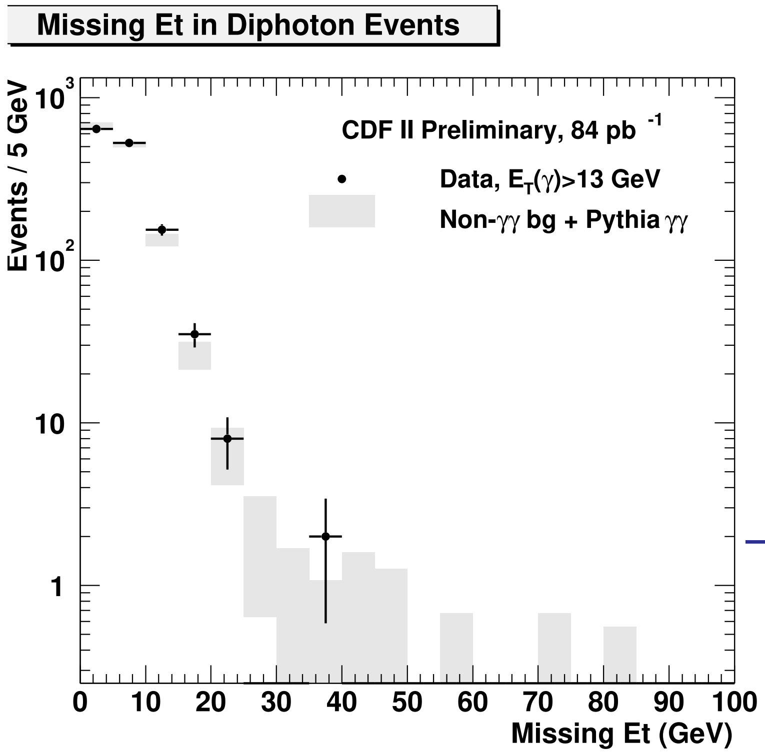
- INCLUSIVE PHOTON
  $E_T^\gamma > 25$ or 50 or 70 GeV
- PHOTON+B JET
  $E_T^\gamma > 10\ GeV$ & disp. track ($|d_0| > 120\ \mu m$)
- DIPHOTON
  $E_T^\gamma > 12$ or 18 GeV
- PHOTON+ MUON
  $E_T^\gamma > 16\ GeV$ & $P_T^\mu > 4\ GeV$
- TRIPHOTON
  $E_T^\gamma > 10\ GeV$
- PHOTON+ DIJET
  $E_T^\gamma > 18\ GeV$ & $E_T^{jet1} > 18,\ E_T^{jet2} > 10\ GeV$

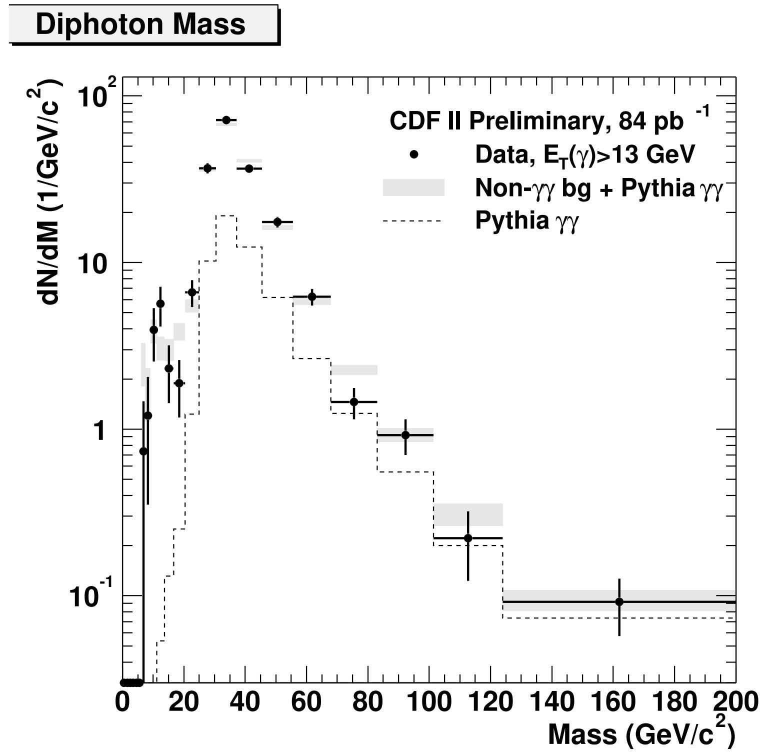
Large samples are being collected and tested

Inclusive Diphoton Searches in Run II

Sample Selection ($84\ pb^{-1}$)

- Two central photon $E_T > 13\ GeV$;
- cosmic ray and beam halo rejection cuts
- Observed 1365 events
- Observed 95 events w/ $E_T^{\gamma} > 25\ GeV$

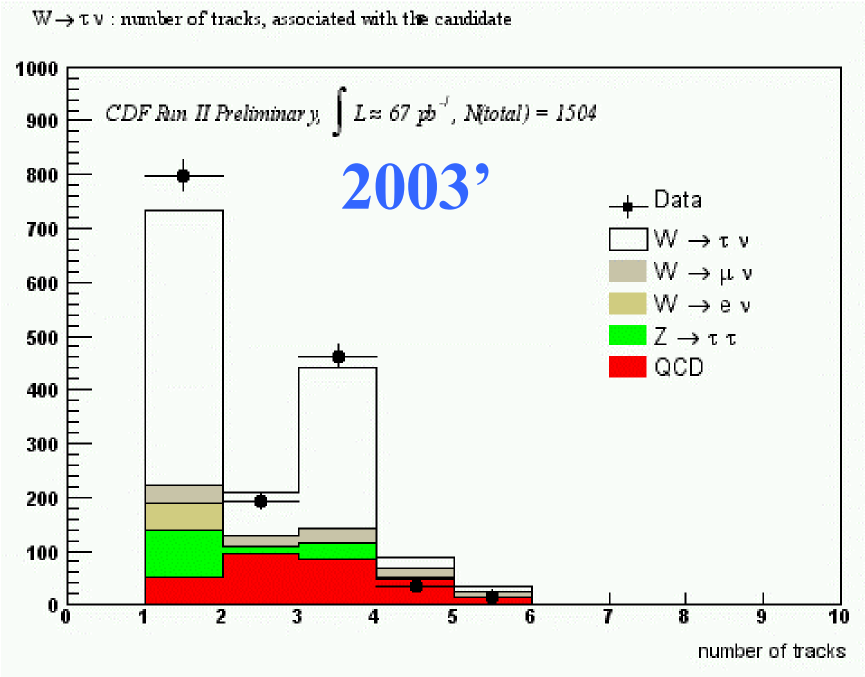




Diphoton + Lepton Events

	Obs.	Exp. $E_T^{\gamma} > 13\ GeV$	Exp. $E_T^{\gamma} > 25\ GeV$
$e\gamma\gamma$	0	$0.27 \pm 0.10 \pm 0.14$	$0.04 \pm 0.03 \pm 0.02$
$\mu\gamma\gamma$	0	$0.04 \pm 0.007 \pm 0.02$	$0.007 \pm 0.005 \pm 0.004$

Tau Lepton Based Searches



Detection of τ leptons

- Large cross sections into final states with τ for SUSY Higgs production ($tan\beta >> 1$)
- Implemented single tau and ditau triggers:
  - $\tau + \not{E}_T$ ($H^{\pm}$ searches)
  - $\tau_h + \tau_l$ $(l = e, \mu)$ (h^0, H^0, A^0)
  - $\tau_h \tau_h$ (h^0, H^0, A^0)
- clear $W \to \tau\nu$ signal visible

Improved τ detection and reconstruction also offers interesting perspectives for SUSY searches like for example:

- R-parity violating stop decays $p\bar{p} \to \tilde{t}\tilde{\bar{t}} + X \to (b\tau^+)(\bar{b}\tau^-) + X$.
- Chargino-Neutralino searches $p\bar{p} \to W^{\pm} \to \tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to (\tau^{\pm}\nu\tilde{\chi}_1^0)(\tau^{\pm}\tau \mp \tilde{\chi}_1^0)$.

Results for these analyses expected for APS

R-parity Violating Scalar Top Quarks (Run I Data)

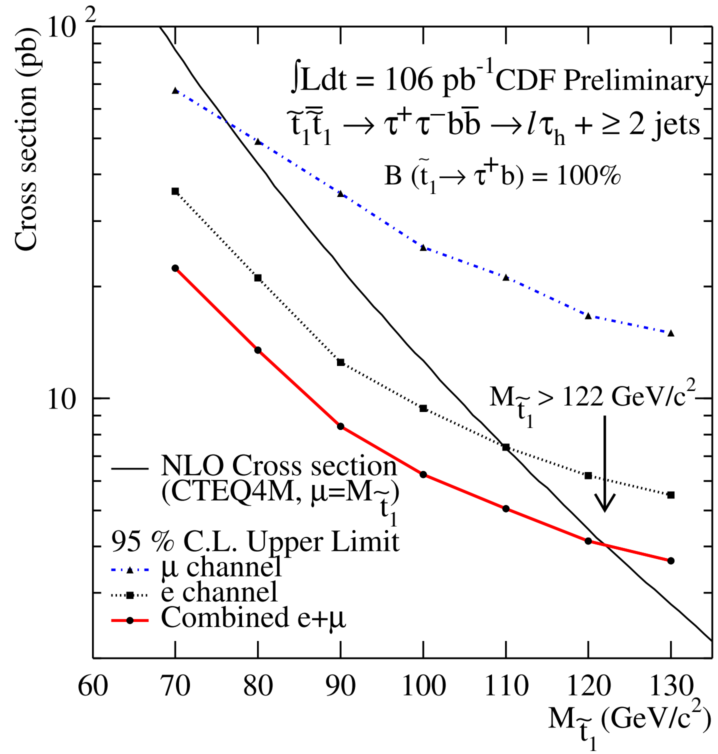
Model

- R-parity conserving scalar top pair production;
- Stop decay via $\not{R}_P$ Yukawa interaction to τb;
- Look for the signatures $\tilde{t}\bar{\tilde{t}} \to \tau^+\tau^- b\bar{b} \to l\tau_h + \geq 2$ jets;

Selection

- Opposite sign $l\tau$;
- $l\tau + \geq 2$ jets;
- $M_T(l, \not{E}_T) < 35\ GeV/c^2$;
- $\Sigma|P_T(l, \tau, \not{E}_T)| > 75\ GeV/c$;
- Expected $3.2^{+1.4}_{-0.3}$ events;
- Observed 0 events;
- Limit for $\beta(\tilde{t} \to b\tau) = 1$;

Limits



$\not R$-parity Violating Sneutrinos (Run I Data)

Model

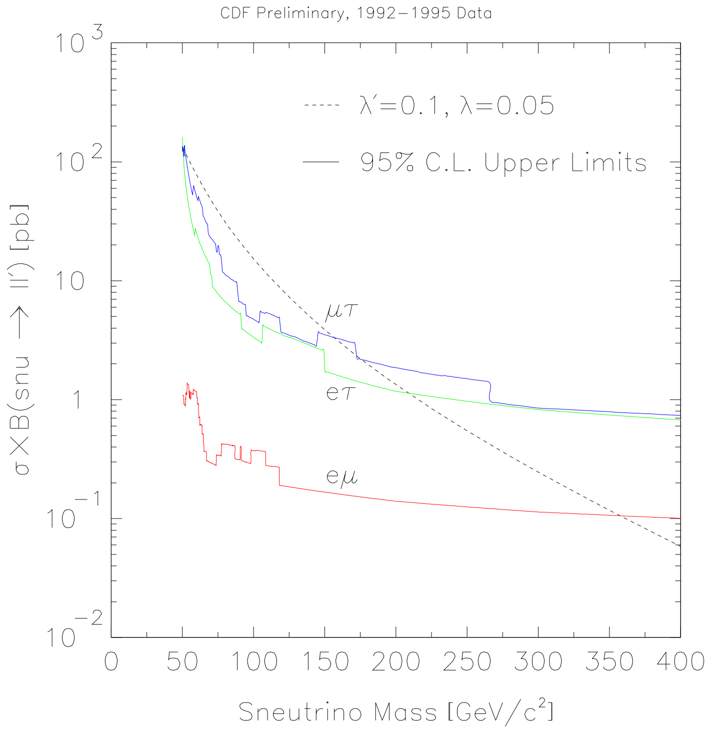
- Single $\tilde{\nu}$ production from $d\bar{d}$ annihilation via $\not R_P$ Yukawa interaction;
- Decay via separate $\not R_P$ Yukawa interaction to opposite sign leptons;
- Look for the signatures $\tilde{\nu} \to e\mu$, $\tilde{\nu} \to \tau\mu \to e\mu\nu\nu$, $\tilde{\nu} \to \tau e \to e\mu\nu\nu$;

Selection

- $|z_{vertex}| < 60\ cm$;
- ≥ 1 good μ w/ $P_T > 15\ GeV/c$;
- ≥ 1 good e with $E_T > 20\ GeV$;
- opposite sign & $\Delta\phi(e,\mu) > 120^o$;
- for τ channels : $\Delta\phi(l,\tau) < 60^o$;

	$e\mu$	$e\tau$	$\mu\tau$
Data	19	4	12
Bkg.	20 ± 1	6.0 ± 0.5	9.6 ± 0.8

Limits



Search for Doubly-Charged Higgs

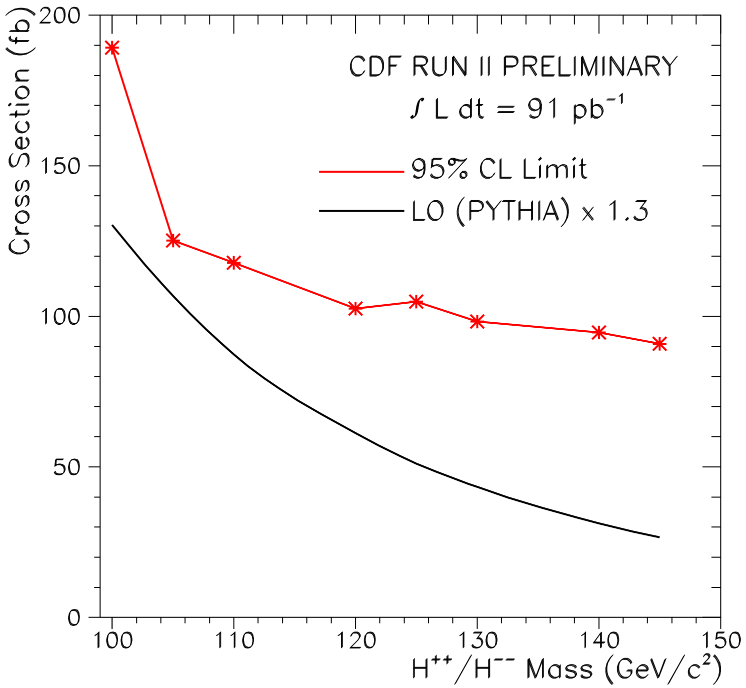
- Left-Right Symmetry breaking: $SU(2)_L \otimes SU(2)_L \otimes U(1)_{B-L} \rightarrow SU(2)_L \otimes U(1)_L$
- Higgs fields are a left-right doublet $\phi(1/2,1/2,0)$ and two triplets:

$$\Delta_{L,R} = \begin{pmatrix} \frac{1}{\sqrt{2}} H^{+}_{L,R} & H^{++}_{L,R} \\ H^{0}_{L,R} & \frac{-1}{\sqrt{2}} H^{+}_{L,R} \end{pmatrix}$$

- Light neutrino masses successfully predicted via see-saw mechanism!
- Supersymmetric models suggest low mass doubly charged Higgs

H^{++} Properties and Selection

- Pair (Z exchange) or singly (WW fusion) produced in $p\bar{p}$ collisions
- Same-sign leptons decay mode providing strong experimental signature
- Inclusive electron trigger used (91 pb^{-1})
- Two central same-sign electrons required
- $M_H \pm 10\%$ dielectron mass windows explored



Conclusions

- CDF detector is collecting data from March 2001
- Run II searches for new phenomena have started
- First limits using dileptons and dijet mass spectra have been already set for various phenomena
- Specific theories beyond the Standard Model have been tested
- New Time-Of-Flight system has been exploited to search for CHAMPs
- Results are already improving Run I ones
- Larger samples are being collected and tested for searches based on τ lepton, Missing E_T and photon signature
- High integrated luminosity will provide the best opportunity for new physics discoveries until LHC starts to run.