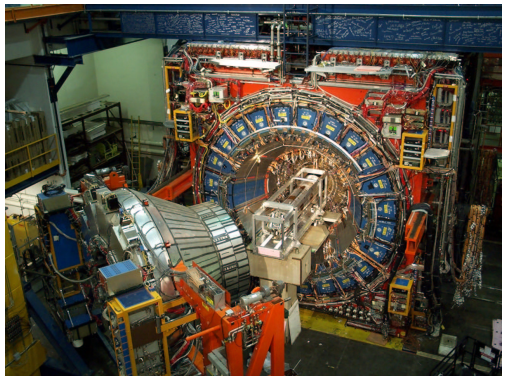
Search for New Physics with CDF



Antoni Munar
University of Pennsylvania

On behalf of the CDF Collaboration

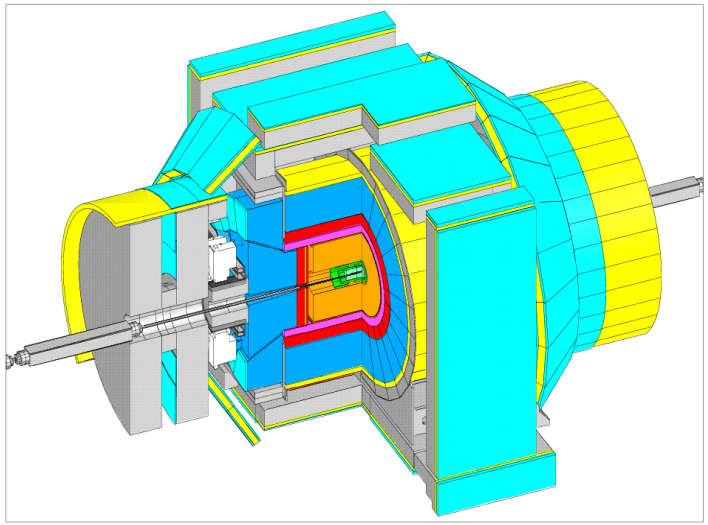
DIS-2003

Outline

- ***CDF Run-II***
  - Detector Upgrades
  - Accelerator Status and Luminosity goals
- ***New Run-II Results***
  - *Searches at the high-end of the energy spectra*
    - Z'
    - Randall-Sundrum Graviton
    - Excited Leptons
  - *Follow-up on Run-I anomalies*
    - Di-Photon based searches
  - *Searches for resonances in the dijet spectrum*
  - *Lepto-quarks Searches*
  - *Exploiting New Detector Capabilities*
    - Search for Charge Massive Particles (TOF)
    - Improved Tau Identification (new Lepton-Track Trigger)
  - *First Higgs Boson Searches*

The CDF-II Detector

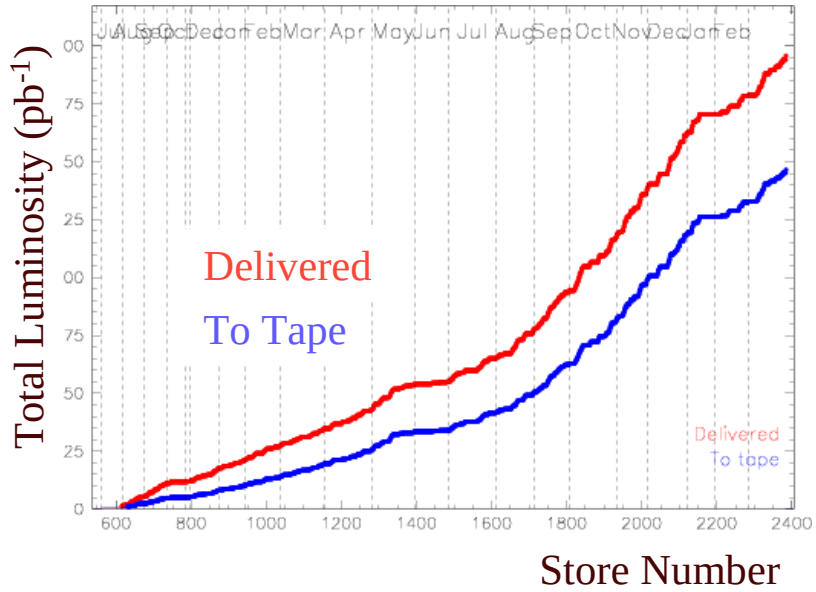
- **Detector Upgrades**
  - *New Silicon Tracking*
    - Extended coverage $|\eta|<2$, interaction region
    - 3-D reconstruction
  - *Replaced Central Drift Chamber*
    - Faster response (designed for 132 ns bunch crossing operation)
    - 96 layers, *dE/dx* samples/track
  - *New Plug Calorimeter*
    - $1.3< |\eta|<3.5$, same technology as central
  - *Added Time-Of-Flight*
    - ~ 100 ps time resolution
  - *Extended muon coverage*
    - $|\eta|<1$ to $|\eta|<1.5$
  - *New Full Digital Trigger*
    - Tracks at L1 ($p_T>1.5$ GeV/c)
    - Silicon Tracks at L2 with ~ offline resolution ($p_T>2.0$ GeV/c)



- Silicon Tracking Detectors
- Central Drift Chambers
- Solenoid Coil /TOF
- EM Calorimeter
- Hadronic Calorimeter
- Muon Drift Chambers
- Muon Scintillator Counters

Accelerator Status

- *Collisions at $\sqrt{s}$=1.96 TeV*
- Stable data-taking since June shutdown~ 155 pb^{-1} on tape
- > 90% of silicon integrated
- ~ 5-7 pb^{-1}/wk @ > 90% efficiency
- Record instantaneous luminosity after January shutdown ~4-$10^{31}cm^{-2}s^{-1}$



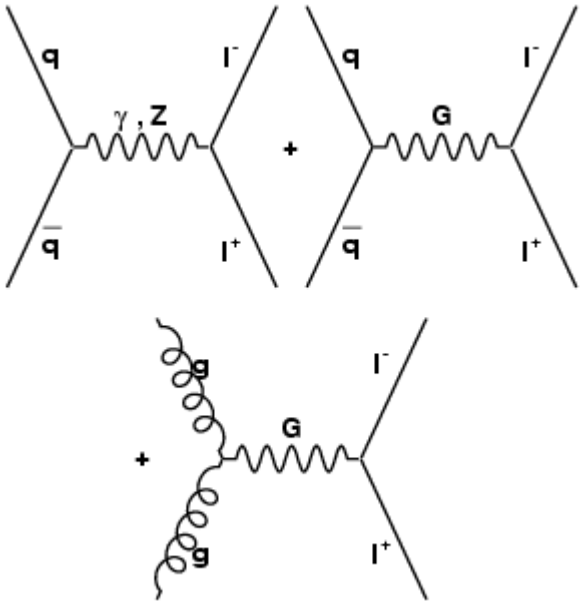
Most of the Analyses :
53 - 91 pb^{-1}
(March 02 – January 03)

Luminosity Goals Autumn 2003:

Base Line: 200 pb^{-1} / 5.0 $10^{31}cm^{-2}s^{-1}$/10 pb^{-1} week
Goal: 320 pb^{-1} / 8.0 $10^{31}cm^{-2}s^{-1}$/15 pb^{-1} week

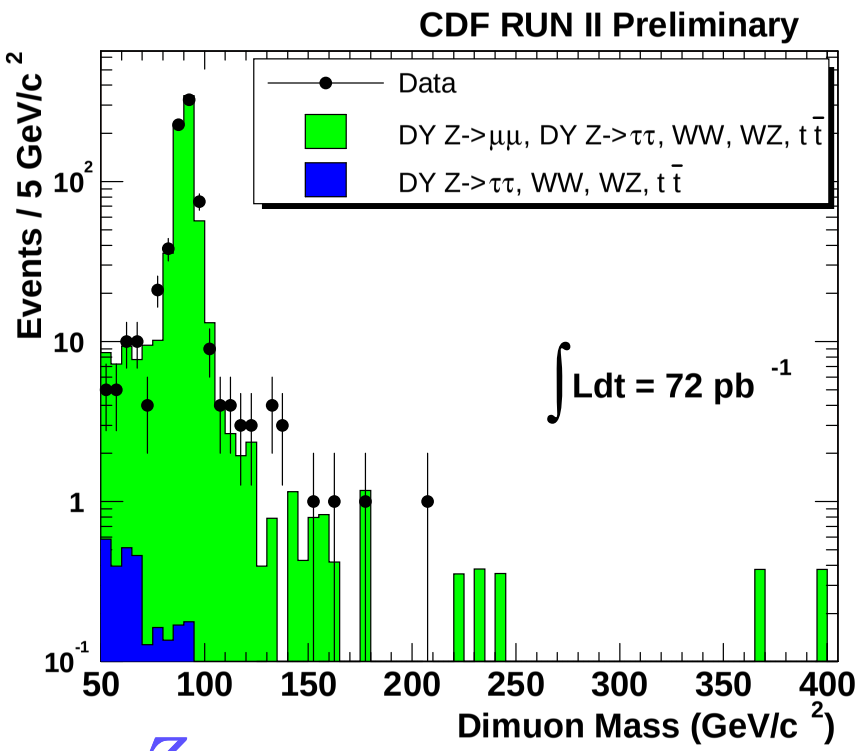
New Resonances in Drell-Yan Dilepton

- ***Many Extensions of the SM***
  - *New gauge bosons (spin 1) above EW scale*
  - *Couplings but not mass predicted by the theory*
  - *High Mass resonances in Dilepton channel*
- ***Extra-Dimensions Models (Randall-Sundrum)***
  - *4 space-time dimensions + 1 extra dimension*
  - *Kaluza-Klein Modes lead to observable spin 2 resonances*

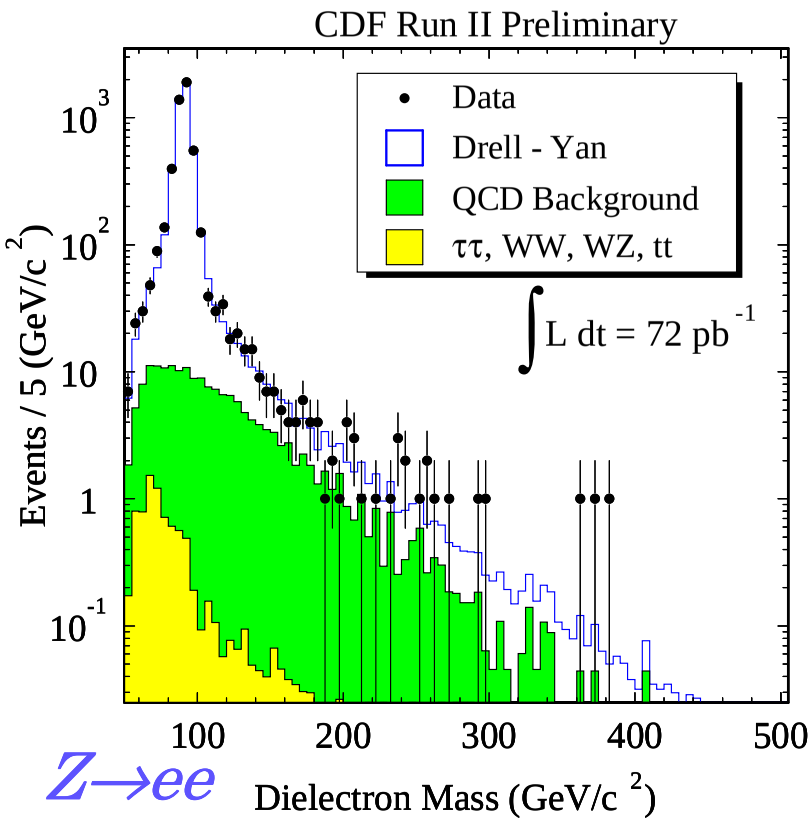


New Resonances in Drell-Yan Dilepton

- *Search in lepton-lepton invariant mass spectra*
  - *2 Electrons (Central-Central, Central-Plug)*
    - *E_T>25 GeV , P_T>13 GeV/c (Central), 2 Muons P_T> 20 GeV/c*
- *Backgrounds Drell-Yan, QCD misidentified electrons, WW, WZ, tt*



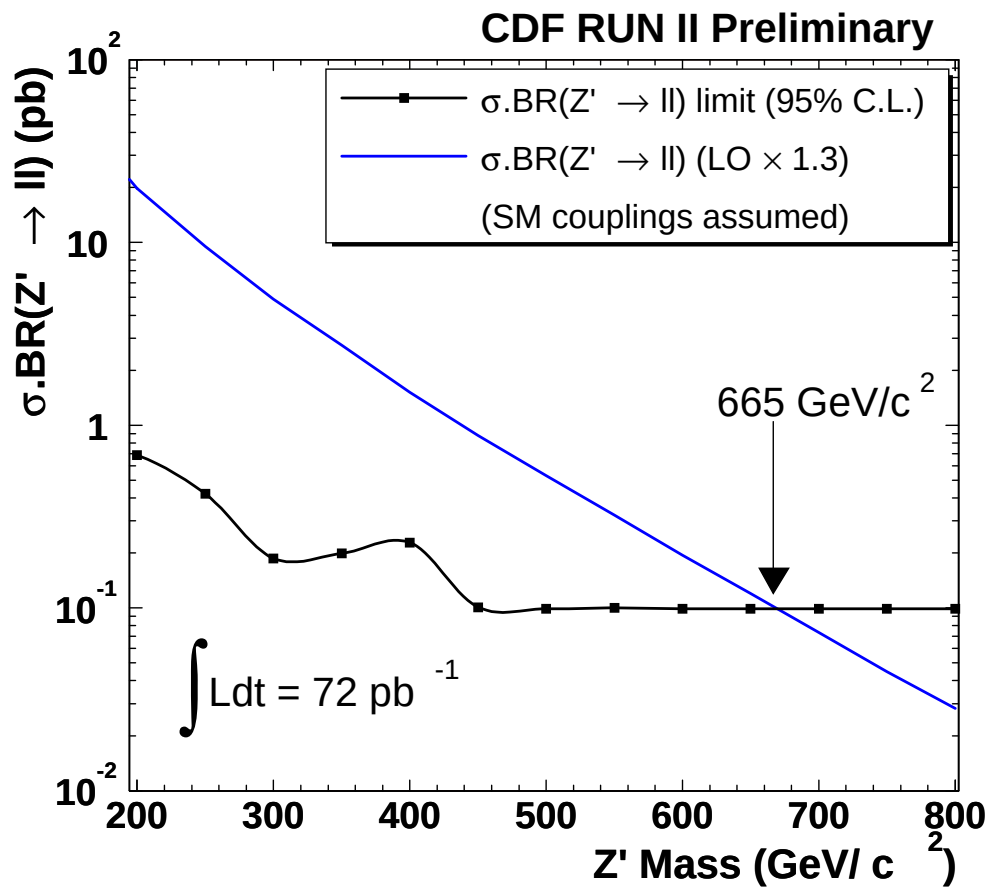
$Z \rightarrow \mu\mu$



$Z \rightarrow ee$

New Resonances in Drell-Yan Dilepton

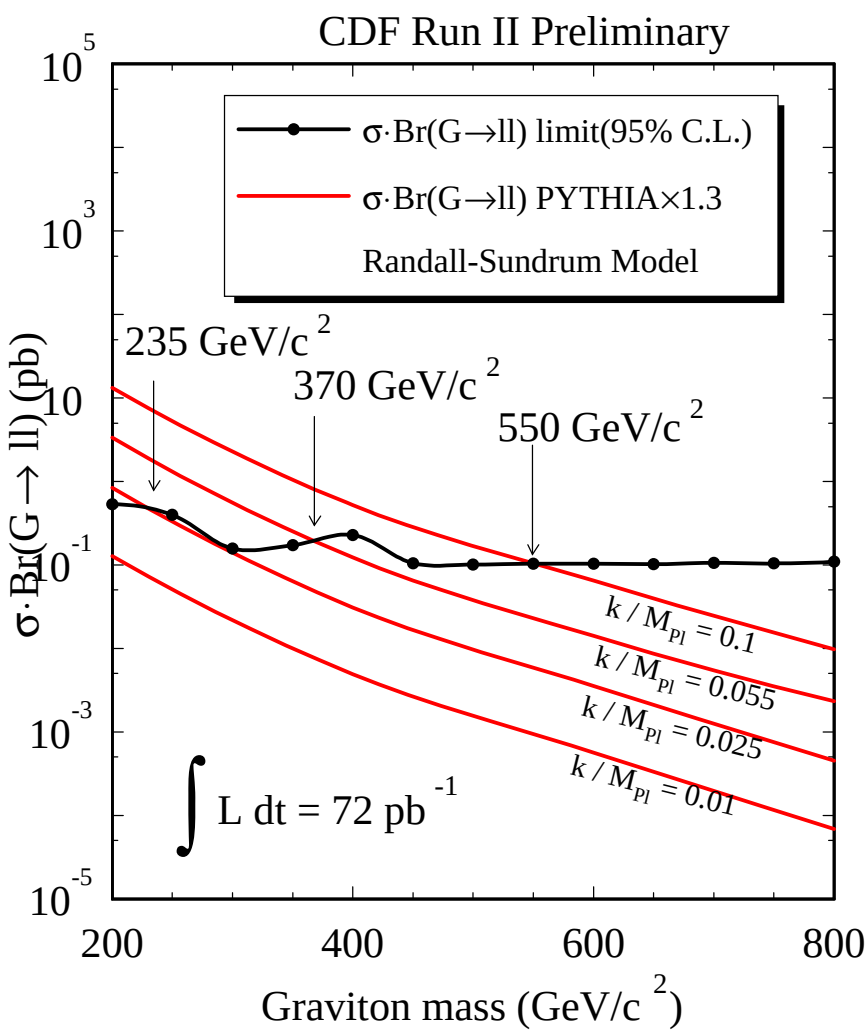
- *Z' Limits*
  - *Dielectron: $M_{Z'}$>650 GeV/c^2 (Run-I 640 GeV/c^2 90 pb^{-1})*
  - *Dimuon: $M_{Z'}$>455 GeV/c^2 (Run-I 575 GeV/c^2 90 pb^{-1})*
  - *Combined*
    - ***665 GeV/c^2***



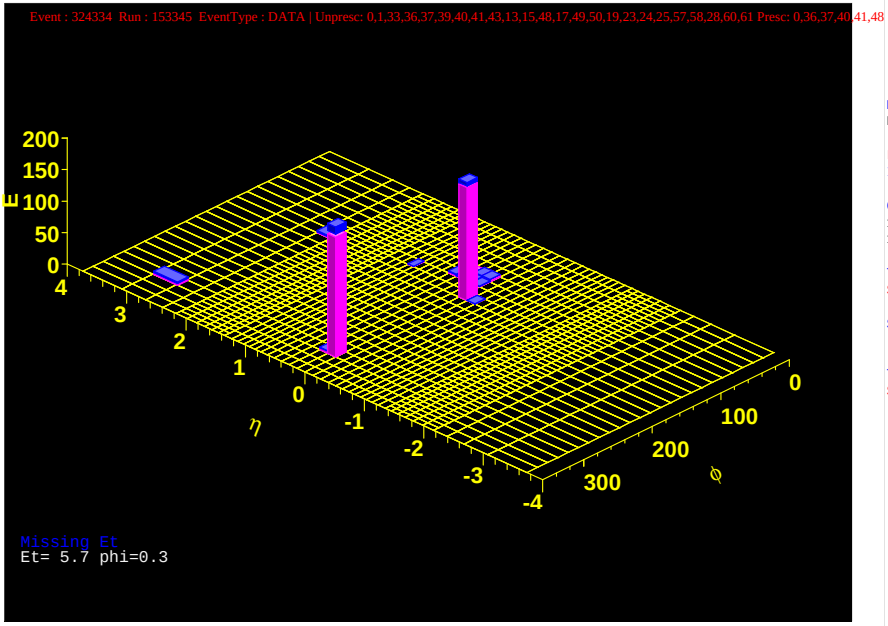
Systematics ~9%
- *Acceptance 4.6%(PDF)*
  +1.4%(fiducial)
  Efficiency 6%
  Luminosity 6%

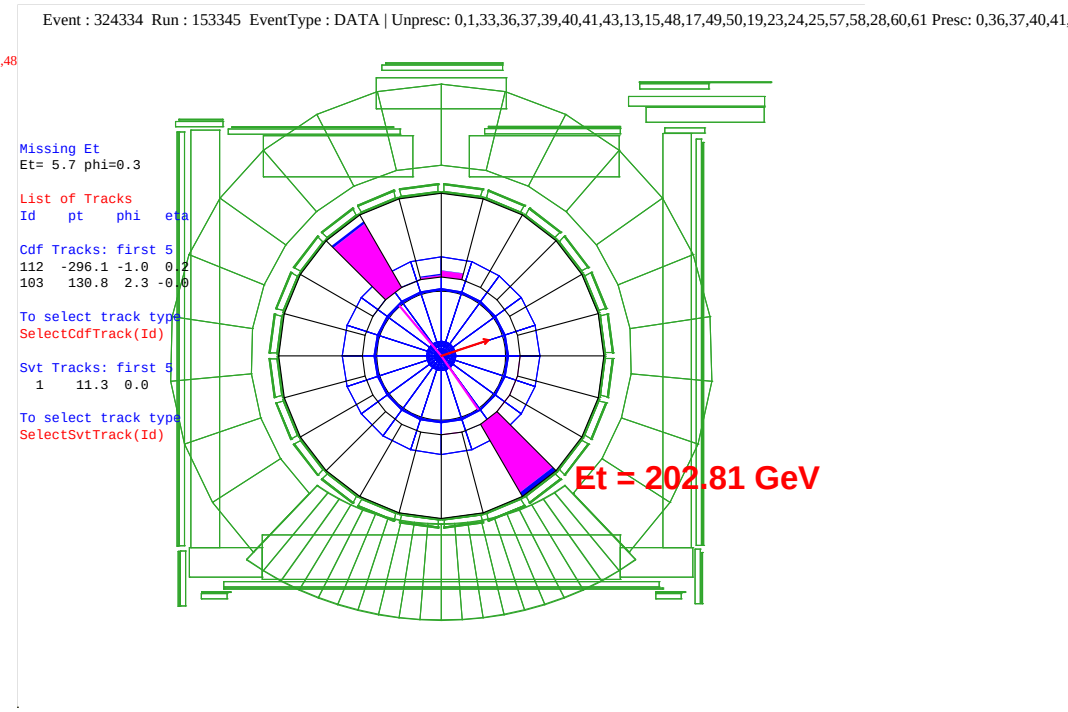
New Resonances in Drell-Yan Dilepton

- ***Gravitino Limits***
  - *Dielectron:*
    - $M_{G'} > 535\ GeV/c^2$
  - *Dimuon:*
    - $M_{G'} > 370\ GeV/c^2$
  - *Combined*
    - ***550 GeV/c²***



Highest M_{ee} Event (371 GeV/c^2)





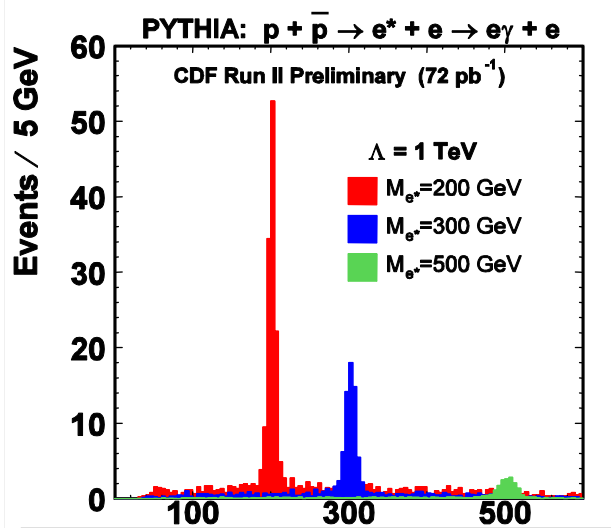
Excited Leptons

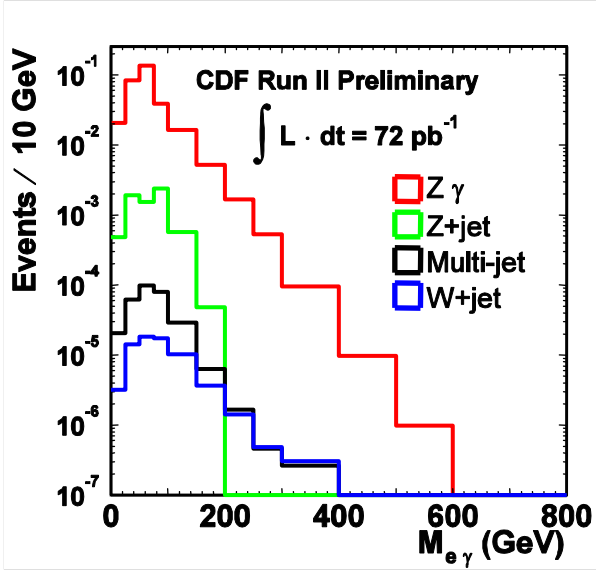
- *Search for excited or exotic electrons*

$$p + \bar{p} \rightarrow e^* + e \rightarrow e\gamma + e$$

- Final state with resonance in the $e\gamma$ channel
- Limit on $\sigma \cdot BR(e^* \rightarrow e\gamma)$ for contact interaction model

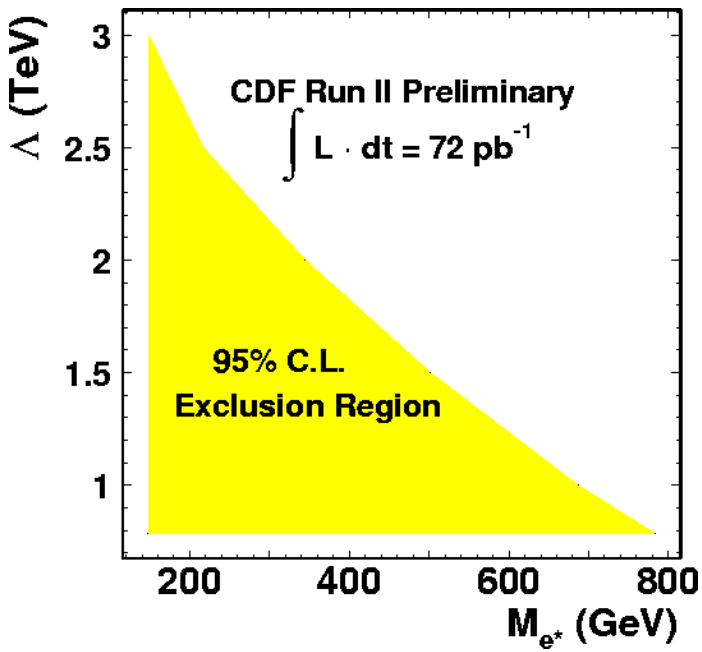
  Baur U. Phys. Rev. D42, 3 1990
- σ dependent on e^* mass and compositeness scale Λ
- *Selection*
  - Two electrons E_T>25 GeV, photon E_T>25 GeV
  - Reject events with dielectron mass within Z mass window (80-100 GeV/c^2)
- *Backgrounds*
  - *$Z\gamma$, Z+jet, W+jets, Multijet*
  - *$Z\gamma$ dominant contribution*
  - *11% systematic uncertainty*

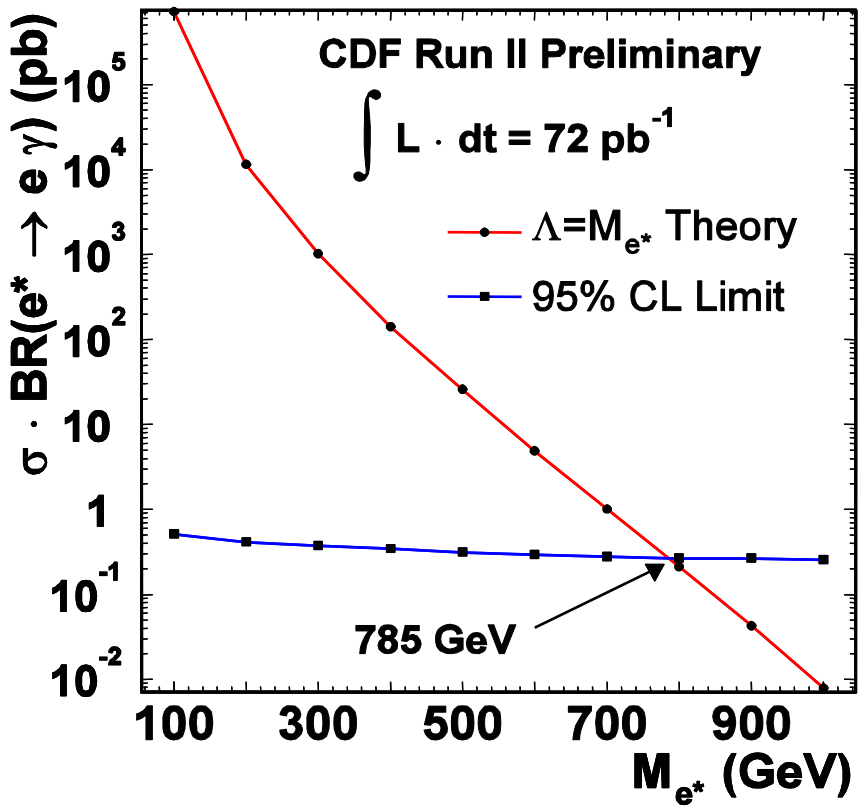




Excited Leptons

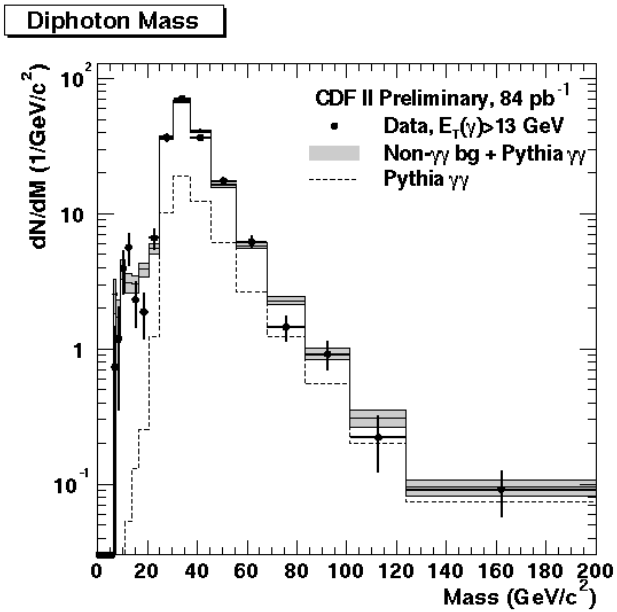
- 0 events observed
- *Limits on $M_{e\gamma}$ and* $\sigma \cdot BR(e^* \rightarrow e\gamma)$
  - *$M_{e\gamma} = \Lambda$, $M_{e\gamma} < 785$ GeV/c²*
- *Current Limit (H1)*
  - *$M_{e\gamma} = \Lambda$ $M_{e\gamma} < 223$ GeV/c²*

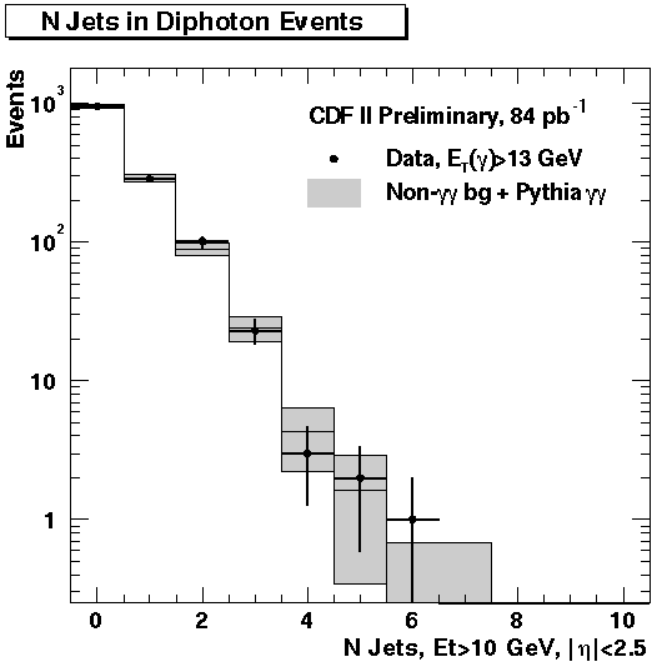




Inclusive Searches in DiPhoton Signature

- *Sample (84 pb^{-1})*
  - Two central photons E_T>13 GeV/c^2
  - After cosmic and beam halo clean-up
    - Observed 1365 events, 95 with E_T>25 GeV/c^2





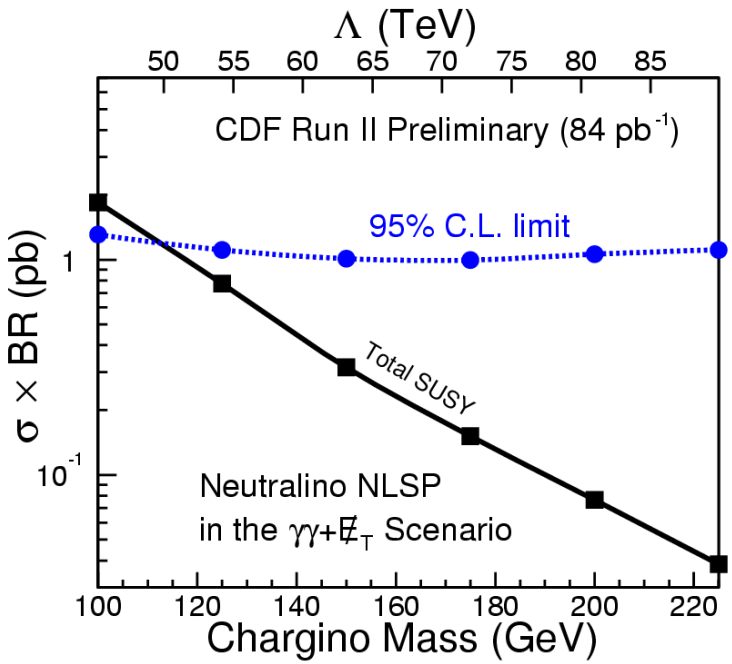
- *Search for Diphoton + extra leptons*
  - Bkg: Wγγ, Z γγ, e- (e)fake γ,Zγ,eγ+jet,μγ+jet

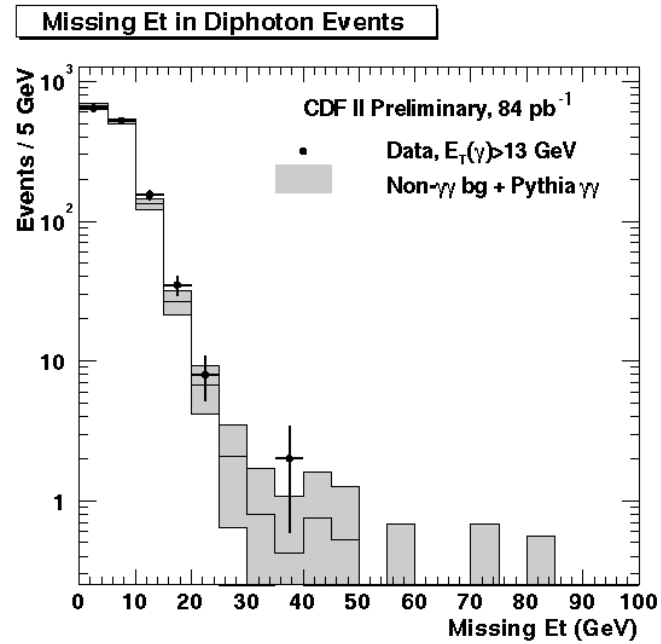
CDF II Preliminary $\gamma\gamma\ell$ Search, 84 pb^{-1}		
Selection	Observed	Predicted
$\gamma\gamma$ (E_t > 13 GeV), $e^{\pm}$ (E_t > 20 GeV)	0	$0.27 \pm 0.10 \pm 0.14$
$\gamma\gamma$ (E_t > 25 GeV), $e^{\pm}$ (E_t > 20 GeV)	0	$0.04 \pm 0.03 \pm 0.02$
$\gamma\gamma$ (E_t > 13 GeV), $\mu^{\pm}$ (P_t > 20 GeV)	0	$0.04 \pm 0.007 \pm 0.02$
$\gamma\gamma$ (E_t > 25 GeV), $\mu^{\pm}$ (P_t > 20 GeV)	0	$0.007 \pm 0.005 \pm 0.004$

Inclusive Searches in DiPhoton Signature

- *Limits on Gauge Mediated Supersymmetry*
  - *Gravitino: the LSP particle*
  - *NLSP: Neutralino or Slepton $N_1 \rightarrow \gamma G$*
  - *Final State: $\gamma\gamma$ + MET*

$$(p\bar{p} \rightarrow \chi\chi \rightarrow N_1 N_1 + X \rightarrow \gamma\gamma GG + X)$$





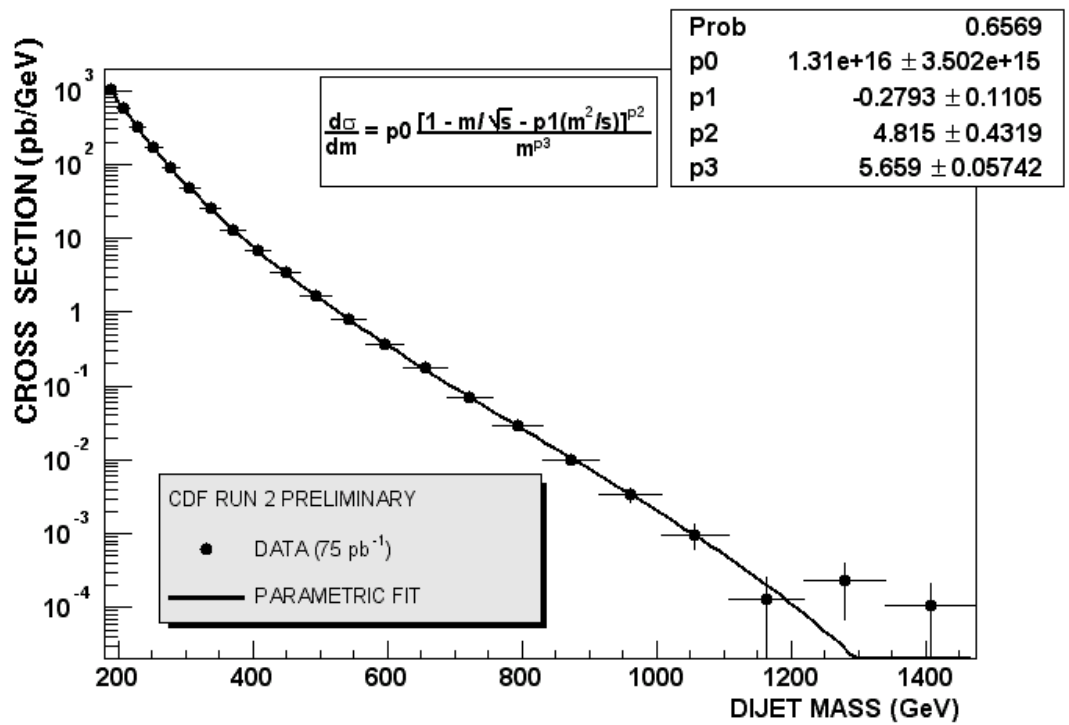
- *Expected Events: 2 ± 2*
- *Observed: 2*

M_C > 113 GeV/c^2 @ 95% C.L.

Resonances in Dijet Spectrum

- *Event Selection*
  - Inclusive Jet Sample (75 pb^{-1}) (JET-20, JET-50, JET-100)
  - Two Highest E_T jets
    - Cone 0.7, $|\eta|<2$ $|\cos\theta^*|<2/3$, $M_{jj}>188$ GeV/c^2
- Fit the Mass Spectrum with a smooth background

No evidence of resonances

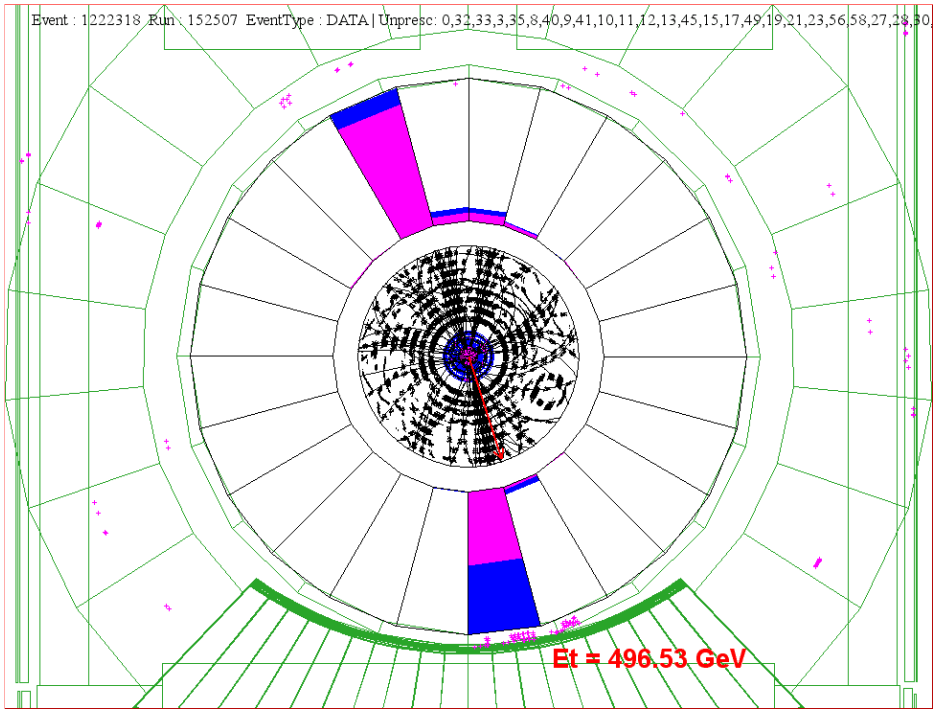


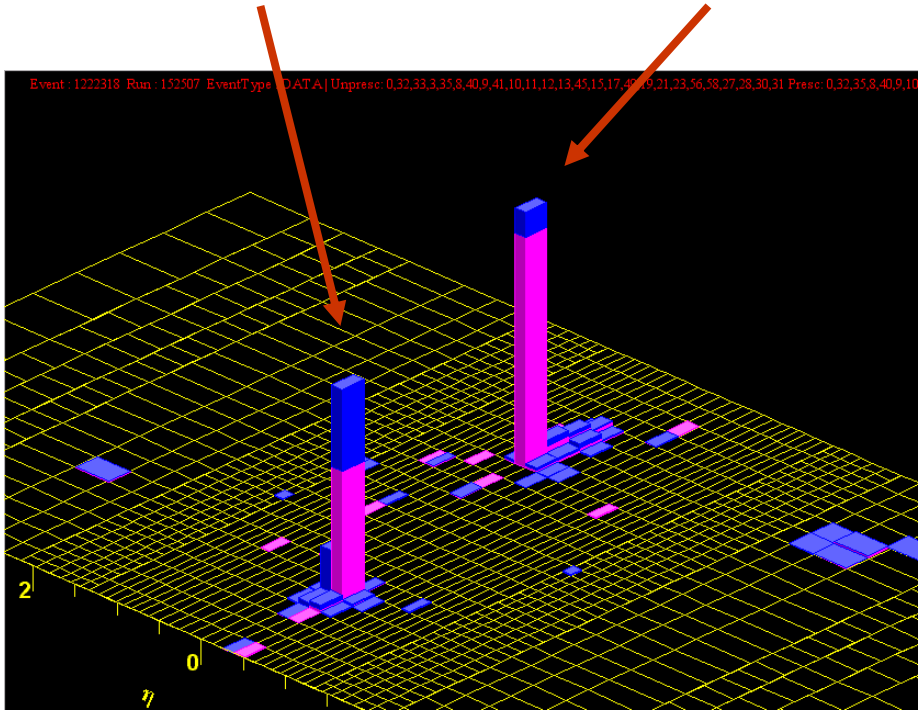
Highest M_{jj} Event

- Run 152507 event 1222318
- Dijet Mass = 1364 GeV (corr)
- cos θ* = 0.30
- z vertex = -25 cm

J2 E_T = 633 GeV (corr)
546 GeV (raw)

J1 E_T = 666 GeV (corr)
583 GeV (raw)



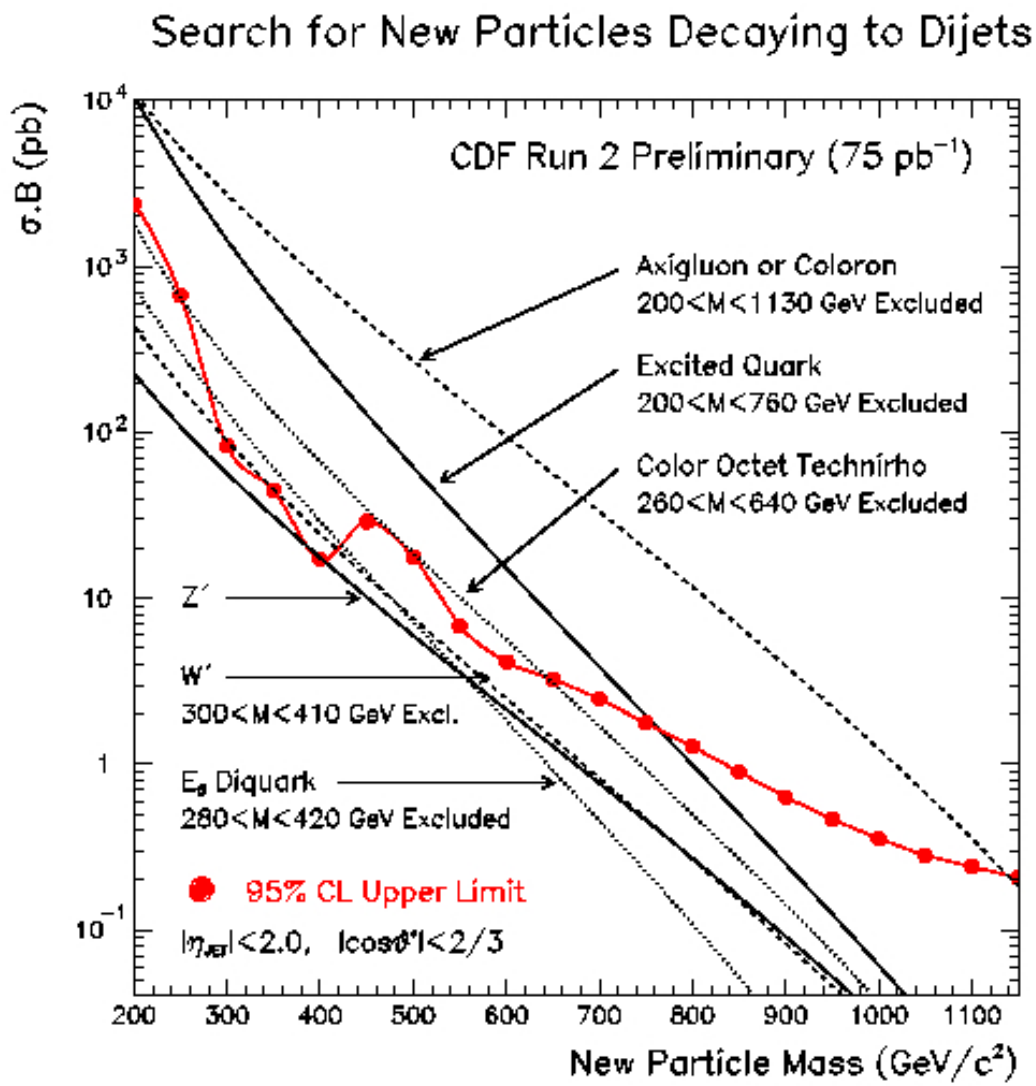


Resonances in Dijet Spectrum

Excluded:

- Axigluons,
- Excited Quarks,
- Octet Technirhos ,
- E6 Diquarks,
- W'

Limits already improved with respect RUN-I



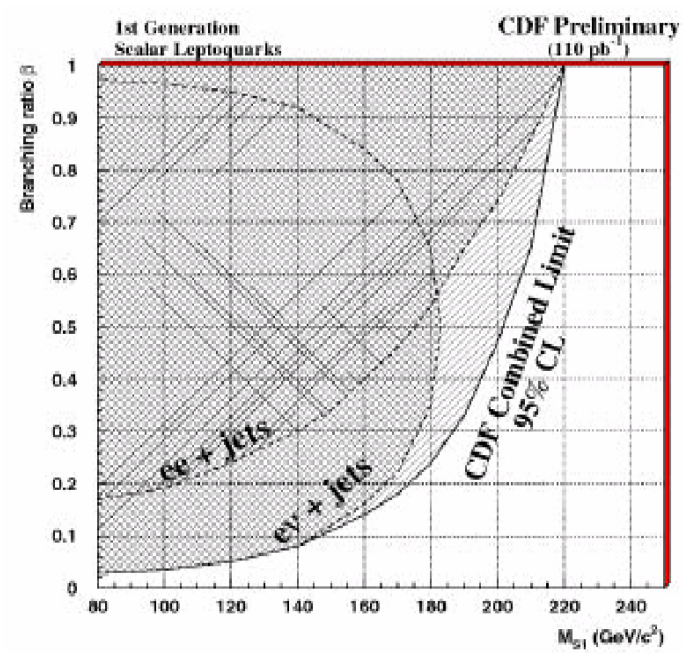
Leptoquark Searches

Existing Tevatron LQ Searches

$pp \to gg \to LQ$, $LQ \to l^+l^-$, $l^\pm\nu qq$, $\nu\nu qq$

- *Limits depend on **type** of LQ (scalar/vector, generation), LQ-quark-lepton **couplings** and $\beta = BR(LQ \to l^\pm q)$*

1st Gen.	β	Scalar (GeV/c)	Vector Minimal Coupling (GeV/c)	Vector Yang-Mills Coupling (GeV/c)
DZero	1	225(242)	292	345
	0.5	204	282	337
	0	98	238	298
CDF	1	220(242)	280	330
	0.5	202	265	310

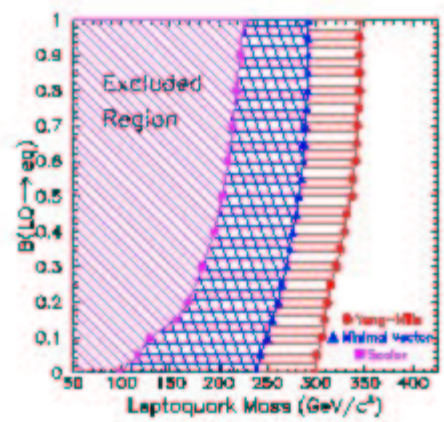


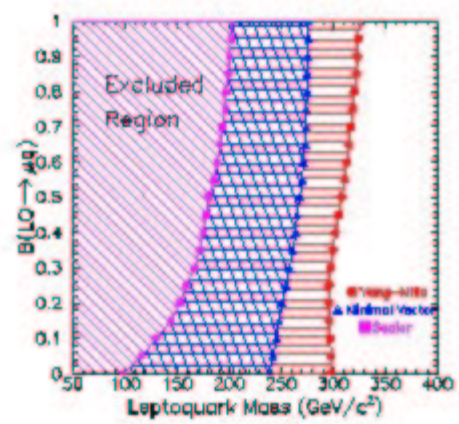
Leptoquark Searches

➢ *Existing Tevatron LQ Limits*

2nd Gen	β	Scalar (GeV/c)	Vector Minimal Coupling (GeV/c)	Vector Yang-Mills Coupling (GeV/c)
DZero	1 0.5 0	200 180 98	275 260 238	325 310 298
CDF	1 0	202 123	171	222

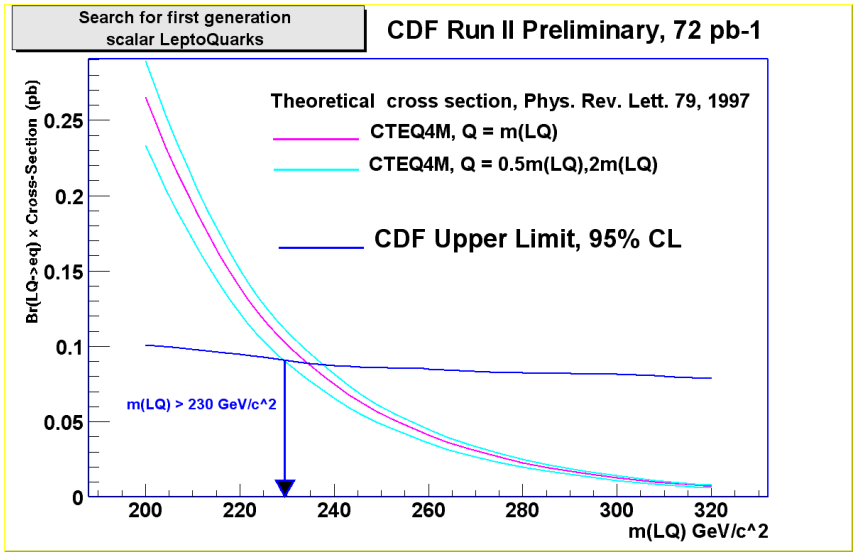
3rd Gen	β	Scalar (GeV/c)	Vector Minimal Coupling (GeV/c)	Vector Yang-Mills Coupling (GeV/c)
DZero	0.5 0	98	238	209 298
CDF	1 0	99 148	170 199	225 250





Run-II update: 1st generation LQ

- *2 high E_T electrons and 2 jets*

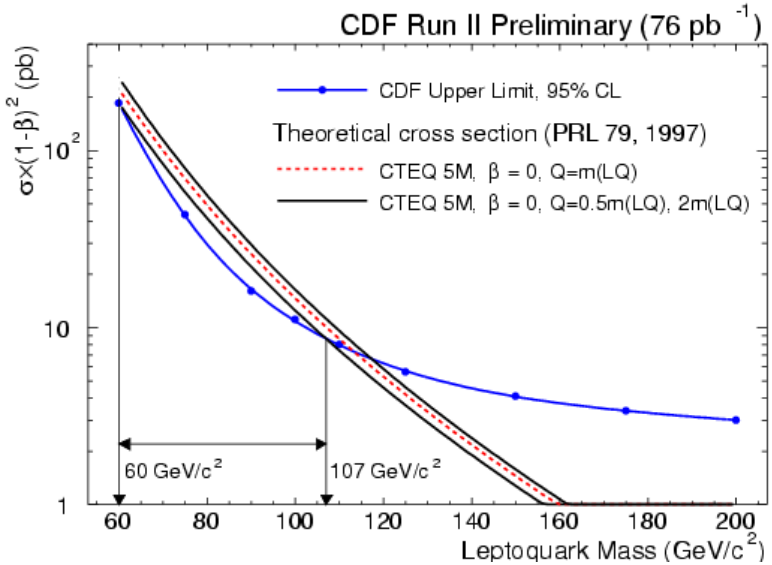


M(LQ) > 230 GeV/c² @ 95% CL
(Run I 220 GeV/c²)

Limit already better than Run I

- 25% increase in the cross section
- ~factor 1/3 less luminosity
- acceptances slightly higher

- *Missing Energy and 2 jets*



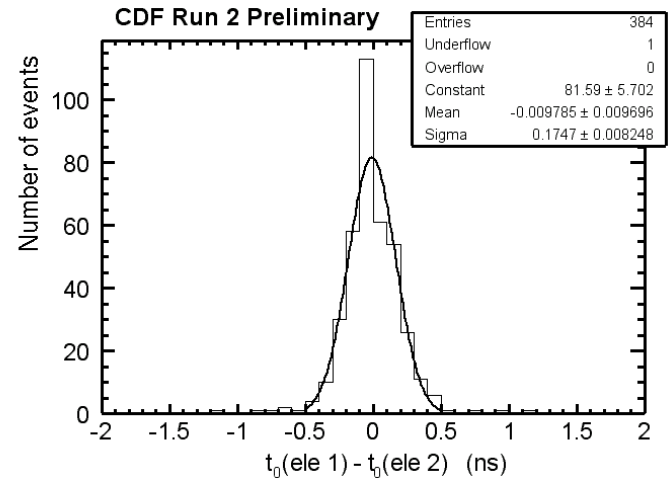
M(LQ) < 60 GeV/c² or
M(LQ) > 107 GeV/c² @ 95% CL

- This decay channel was not searched in Run I by CDF
- Limit from D0 (Run I, similar luminosity) M(LQ) > 98 GeV/c² @ 95 % CL

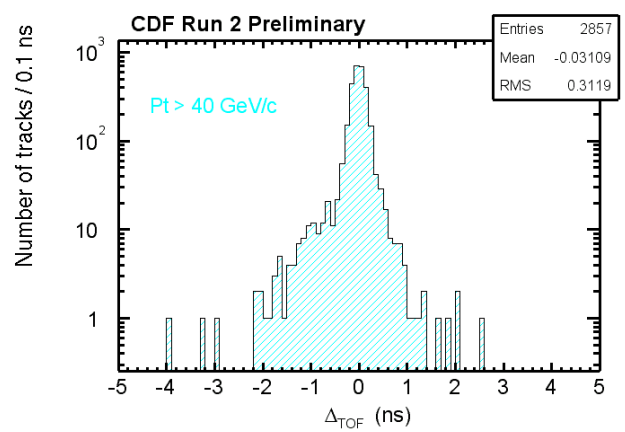
Combination of channels in progress

Charged Massive Particles

- *Arise in different models*
  - *Heavy quarks (*small couplings)
  - *SUSY scenarios with stable particles*
- *Distinctive Signature*
  - *Isolated slow-moving high P_T particle*
    - *Large dE/dx, long time-of-flight, escapes from detector*
- *Data Selection:*
  - *High P_T muons (>18 GeV/c)* ***53 pb^{-1}***
  - *Tracks with P_T>40 GeV /c (full tracking efficiency)*
  - *TOF_{track}-t_0 > 2.5 ns*
- ***Backgrounds:***
  - *Cosmic Rays (Removed Δ t>2.5 ns)*
  - *t_0 anomalous early*
    - *Control Samples P_T<40 GeV/c*



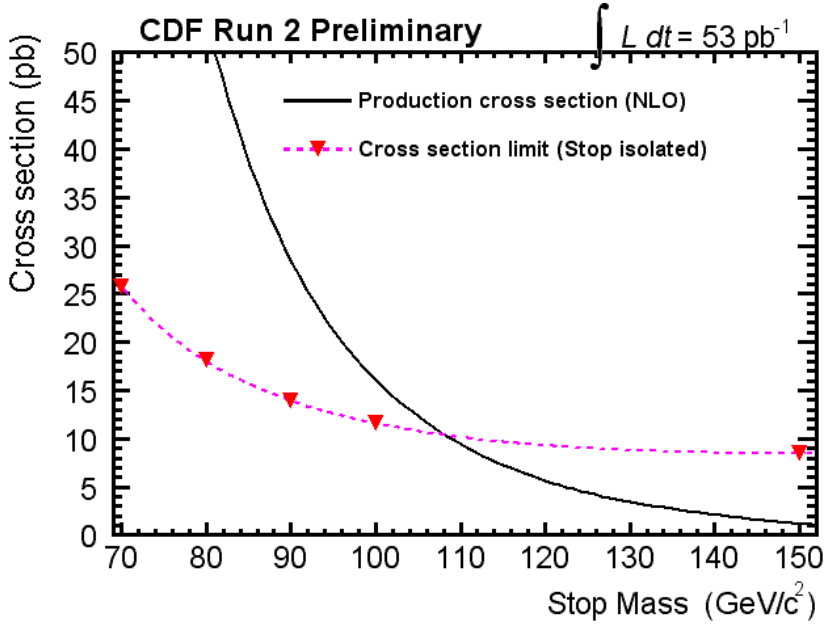
Δt resolution form tight Z sample

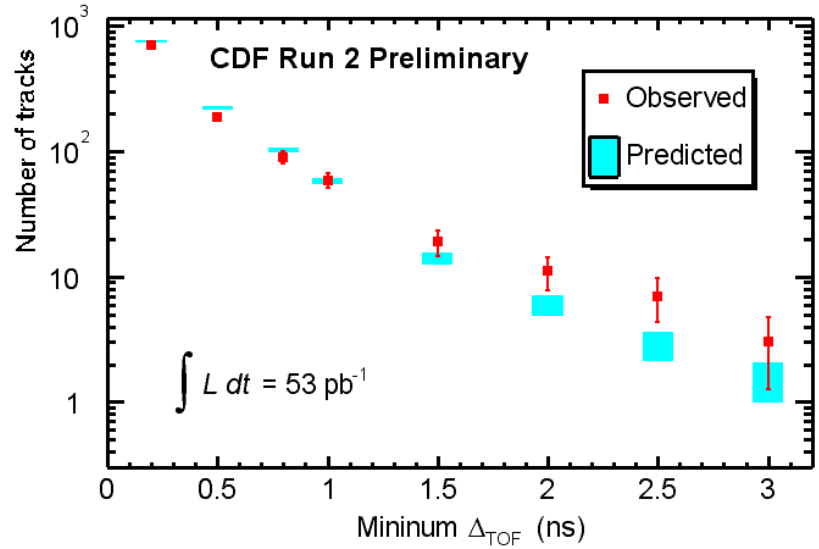


$TOF_{track} - t_0$ (t_0 fitted with all TOF tracks)

Charged Massive Particles

- *Searches for stop particles*
  - *GMSB models, NLSP stable particle*
- *Signal region:*
  - *Δt > 2.5 ns, track P_t>40 GeV/c*
- *Systematics*
  - *Background prediction W-tight and top multijet samples (track density)*





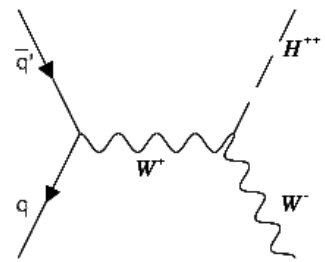
Predicted: 2.9 ±0.7 (stat) ±3.1 (sys)

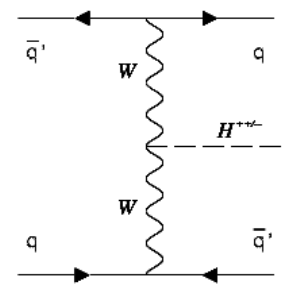
Observed: 7

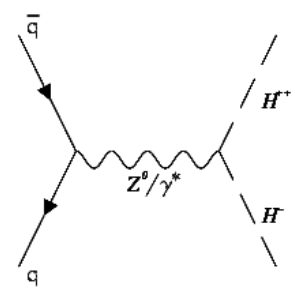
- Exclusion Limits
  - *M_{stop}> 108 GeV/c^2 at 95 % C.L.*
  - *LEP M_{stop}> 95 GeV/c^2*

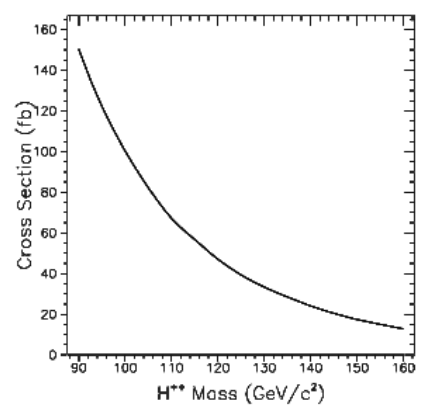
Doubly Charged Higgs

- *Any model with Higgs triplets predicts double charged Higgs*
- *Left-Right Symmetry breaking Models*
  - *It predicts low neutrino masses*
  - *The supersymmetric extension suggests low mass doubly charged Higgs*
- *At Tevatron energies pair production of doubly charged Higgs is dominant*



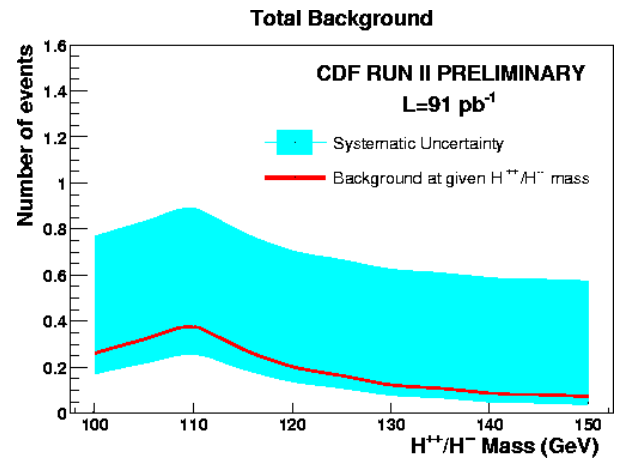


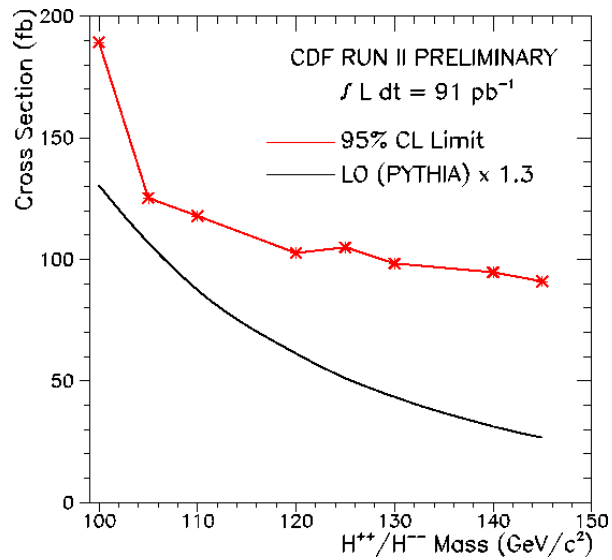




Doubly Charged Higgs

- *Same sign dielectron data (~91 pb^{-1})*
  - *Sensitive to single and pair production*
- *Selection: High E_T inclusive electron trigger*
  - *Eff: ~ 90.7%*
- *Search in M_{ee}> 100 GeV in mass windows of 10 % M_H (3σ)*
- ***Backgrounds:***
  - ***Instrumental: electron misidentified***
    - *$Z \rightarrow e^- e^+$,QCD jet/photon,$W \rightarrow e\nu$, $Z \rightarrow ee$ + jet/photon*
- ***Limits:***
  - *Control Region Z_{mass} (80<M_{ee}<100 GeV/c^2)*
    - *$0.6^{+0.5}_{-0.1}$ predicted, 0 observed*
  - ***Signal: 0 observed***

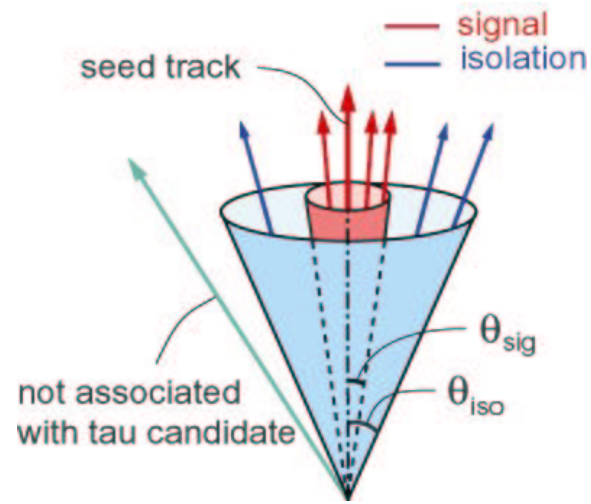




Reach sensitivity up to 125 GeV/ c ^{2} by Summer

τ *lepton* Identification

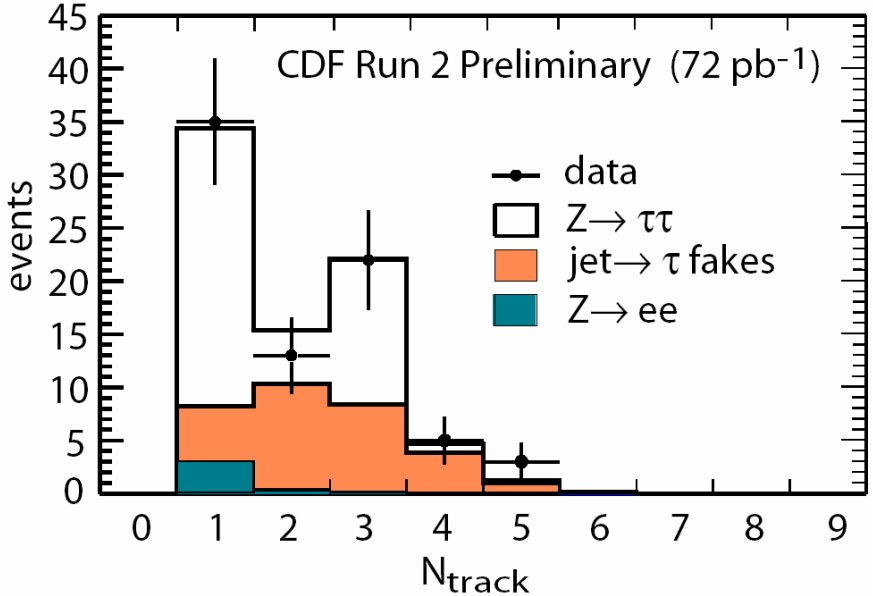
- ***τ - Signatures***
  - *Large cross sections for τ signatures in SUSY Higgs production (tan β >> 1)*
  - *R-parity violating decays*
  - *Chargino-Neutralino Searches*
- *Traditionally considered "difficult"*
- ***New (Jan-2002) CDF Lepton+Track Trigger***
  - *Lepton P_T>8 GeV/c (Level 1 eXtremely Fast Tracker)*
  - *Isolated track at Level 2*

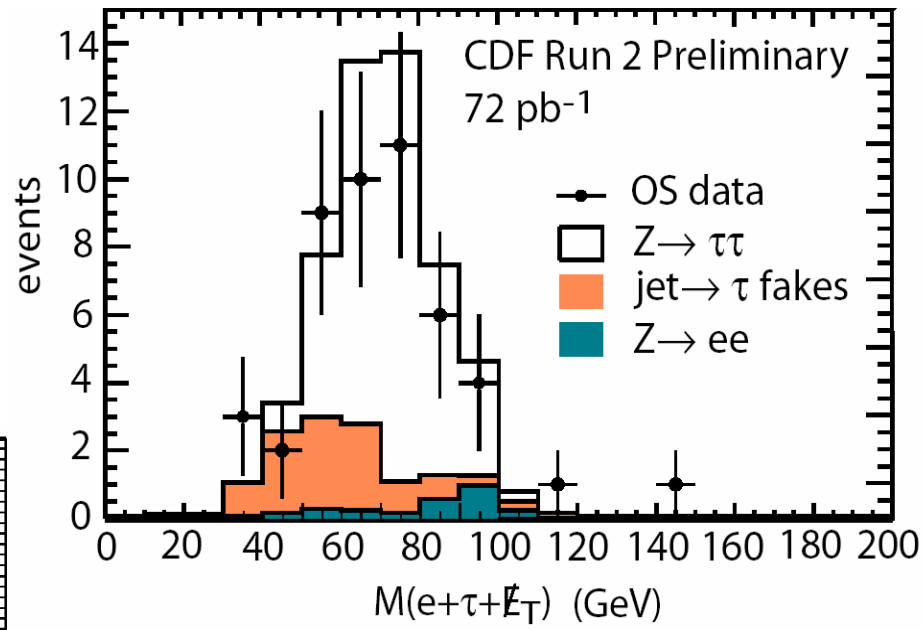


- ***Signature***
  - Narrow, isolated jet.
  - Low track multiplicity (1 or 3).
  - Low π^0 multiplicity (0-3).

τ *lepton* Identification

- ***$Z \rightarrow \tau\tau$ signal identified***
  - ***τ-had, τ-leptonic***





Fake rate x 3 reduced compared with Run-I

Conclusions

- *CDF actively taking data and producing first physics results*
- *Aggressive Program in Search for New Physics*
  - *Broad Signature Based Approach*
  - *Taking Advantage of New Detector Features*
    - *Time-Of-Flight Detector*
    - *Powerful Track Trigger at Level 1 and Level 2*
- *More results to come…*
  - *Heavy flavor + Missing Energy…*
    - *sbottom, stop quarks searches…*