Searches for New Particles at CDF

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(on behalf of the CDF collaboration)

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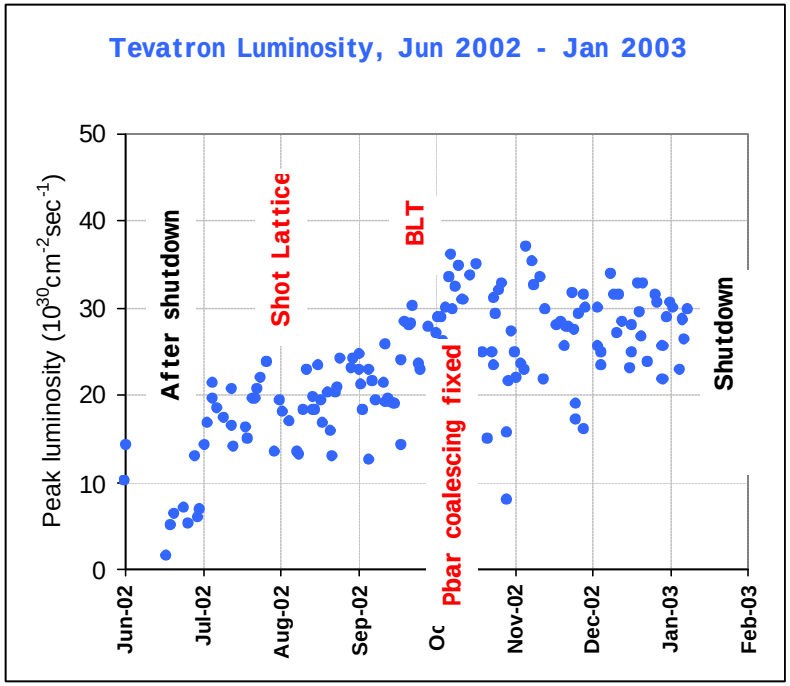
Outline of the Talk

- Status of the machine and the CDF detector
- Analysis strategies at CDF II
- First Run II results
  - Searches for new particles in DY spectrum
    - Z' and Randall-Sundrum Graviton
  - Searches for new resonances in the dijet spectrum
  - New limits on LeptoQuarks in the dielectrons + jets channel
  - Search for doubly charged Higgs
  - Searches for CHArged Massive ParticleS
  - searches for new physics involving photons
- SUSY
  - Run II status
  - latest results from Run I

Machine Status

Accelerator Status

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

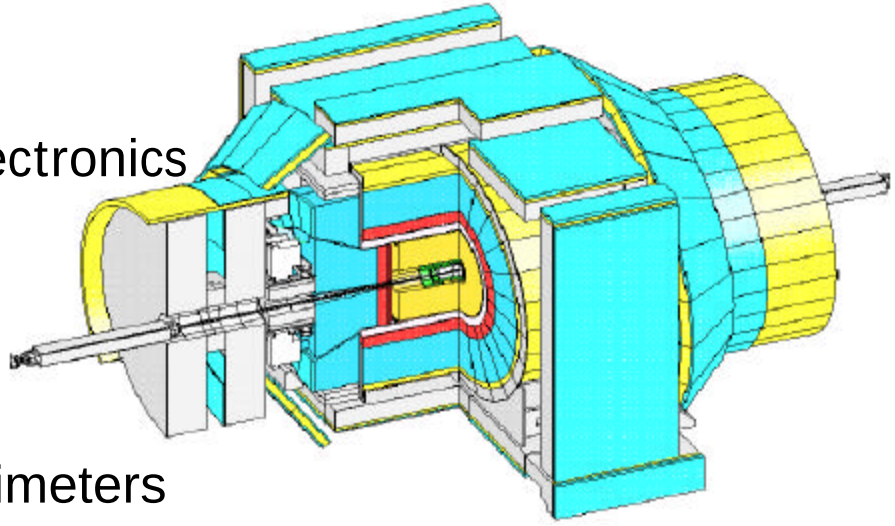


Parameter	Current Performance	FY03 Goal	Run II Goal	
Typical Luminosity	3.2e31	6.6e31	33e31	$cm^{-2}sec^{-1}$
Integrated Luminosity	6.0	12.0	70.0	pb^{-1}/week

Improvements from Run I

Taking physics quality data since Feb 2002

- New central tracker drift chamber
  - **$N_{axial}=N_{stereo}=48$,**
  - **$Dp_t/p_t<0.001p_t$**
- New silicon vertex detector
  - **7 layer, 3-D reconstruction, $|h|<2$**
- New front-end, DAQ and trigger electronics
  - Fully digital trigger
  - L1 tracking trigger
  - L2 secondary vertex trigger



- New Scintillating tile end-plug calorimeters
- Increased $\eta\phi$ coverage for muon detectors
- New scintillator based Time of Flight system

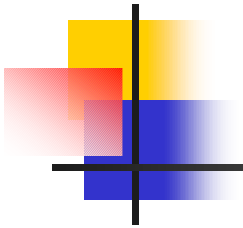
Analysis Strategies

- Two different approaches will be actively pursued in Run II in a complementary way:
- A) Traditional model driven analyses
  - pick a favorite theoretical model/ pick a process, choose the best signature(s): optimize selection acceptances based on signal MC
  - calculate the expected background
  - evaluate the limit or discover a new signal
- B) Signature-based approach
  - pick a specific signature (i.e. diphoton+X)
  - define the sample in terms of known processes
  - publish estimates of acceptances & cross section information useful for theorists
  - see an excess? Inconsistency with SM? Test one or more models later

☺ **best optimization!**

☹ **model might become soon outdated!**

☹ **not best optimization but...☺ open to a whole lot of models!**
An unbiased study is fundamental for data understanding



Model Based Results

- Searches for new particles in DY spectrum
  - additional neutral gauge bosons
  - ExtraDimensions
- Search for 1st generation Leptoquarks in dielectrons + jets
- Search for doubly charged Higgs
- SUSY

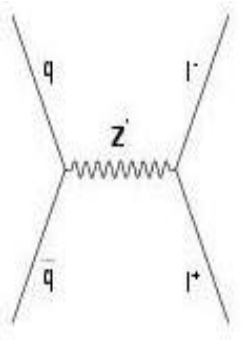
Search for New Resonances in High Mass Dileptons

- New neutral gauge bosons

  various extensions of the SM

  parameter M(Z')

  resonance in dileptons channel



- ExtraDimensions

Hierarchy problem : $M_{Pl} = \frac{1}{\sqrt{G_N}} \approx 10^{19}\,GeV >> M_W$

- Arkani-Hamed, Dimopoulos, Dvali (ADD) models:
  - Gravity can propagate in large extra dimensions

$$\Rightarrow M_{Pl}^2 \sim R^n M_D^{n+2}$$

  - *n : number of extra dimensions*
  - *R : size of those compactified extra dimensions*
- M_D of the order of the TeV is possible

- Randall-Sundrum graviton model

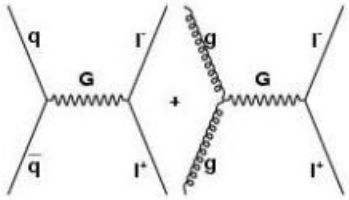
  4-dimensional metric multiplied by *warp* factor

  exponentially changing with the additional dimension

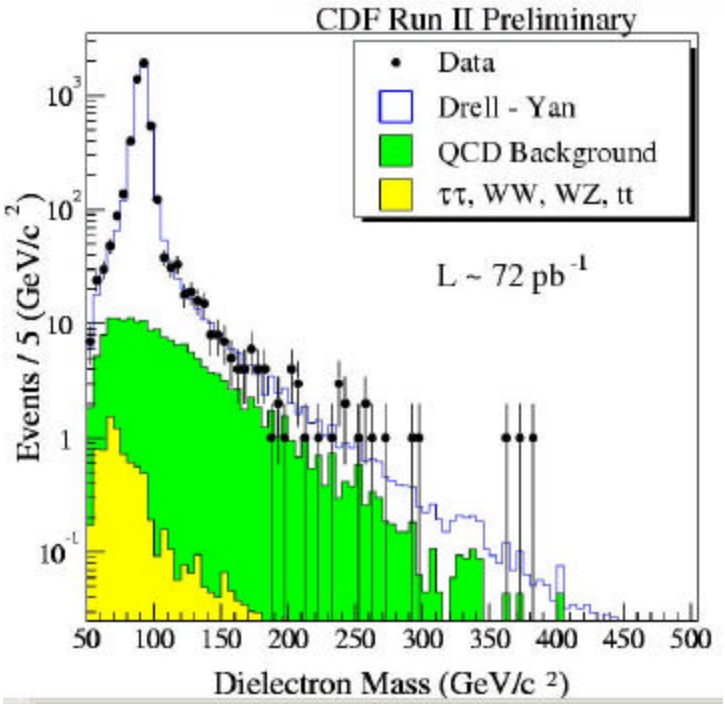
  ⇒ Generating a large hierarchy does not require a large r_c

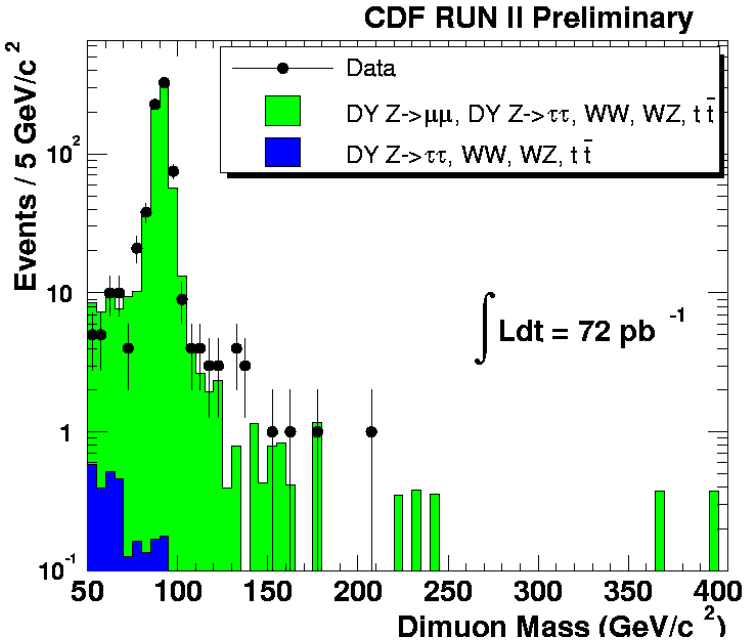
The coupling of individual KK states to matter is set by the weak scale (parameters : M_G and $k/M_{P\ lanck}$)

KK states can be observed as spin 2 resonances



Drell Yan Spectra

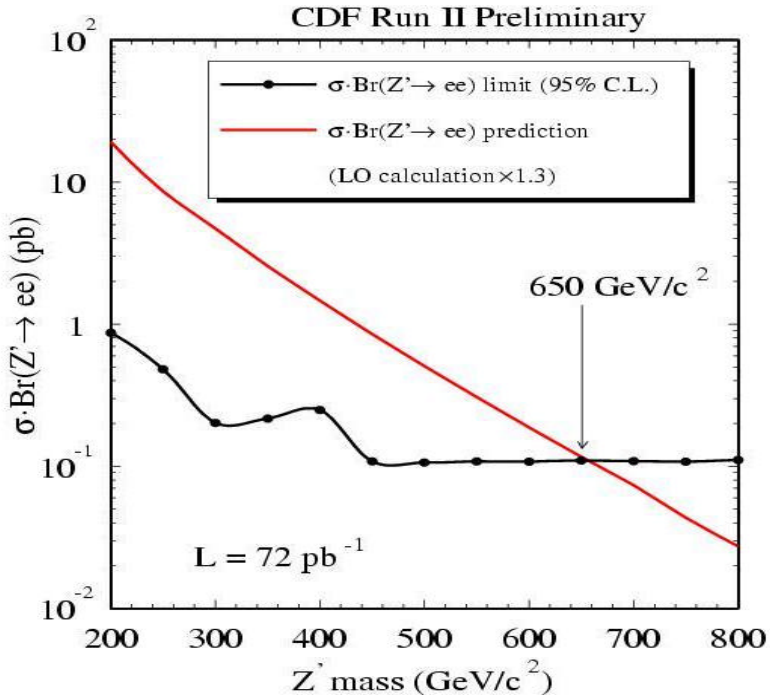


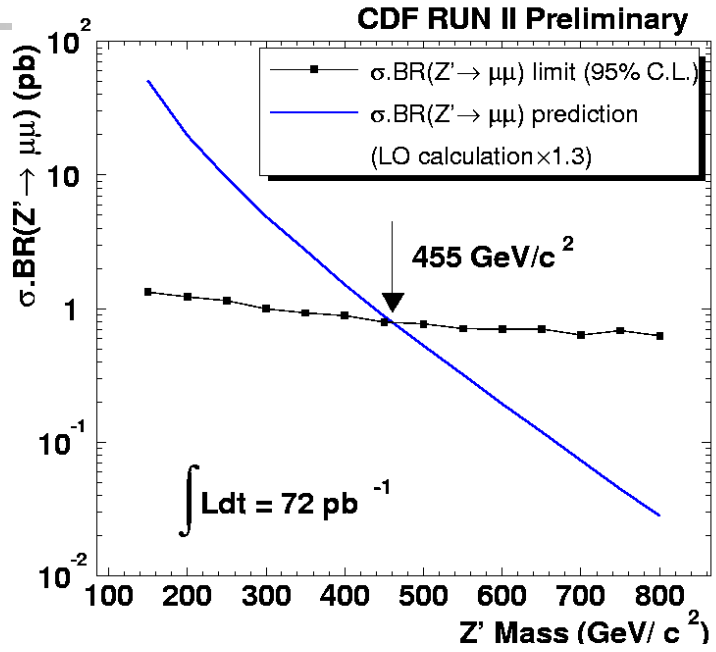


Background sources:
- DY events
- QCD misidentified events
- Electroweak dileptons events (WW,WZ,tt ..)
- Cosmic rays (dimuons) negligible at high mass

Data consistent with SM background

Z' Limits





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

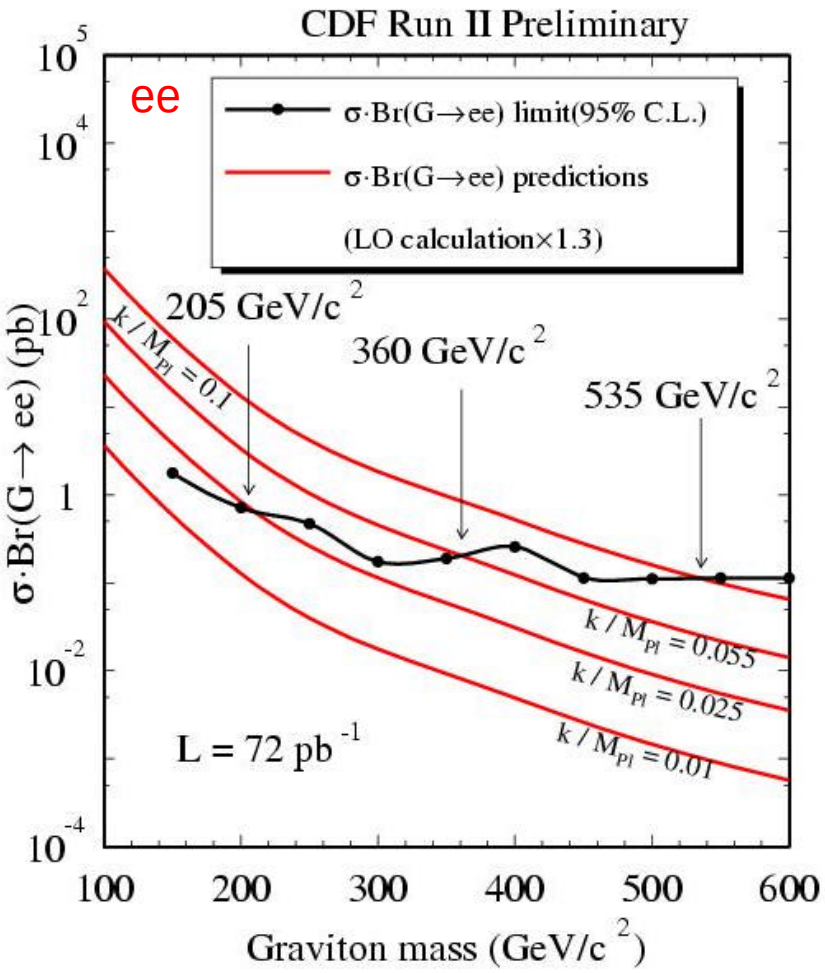
run	Luminosity (pb^{-1})	Mass limit (95% C.L.) (GeV/c^2)
1988 - 1989 (Run0)	4.05	387
1992 - 1993 (RunIa)	19.7	505
1994 - 1995 (RunIb)	90	640
141544 - 145654 (RunIIa)	10.4	460
141544 - 154799 (RunIIa)	51.2	630

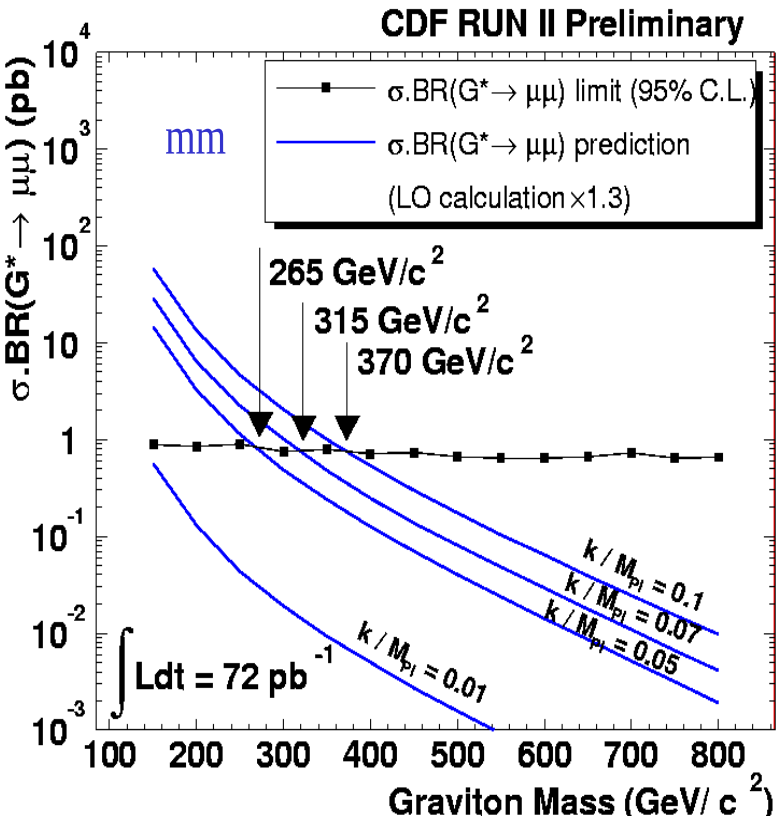
Table 1: History of CDF neutral boson searches in dimuon channel.

CDF Run II Preliminary

CDF run	Luminosity (pb^{-1})	$M_{Z',95\%C.L.}$ (GeV/c^2)
Run IA	18.8	440
Run IB	88.6	575
Run IIA (summer '02)	16	275
Run IIA (winter '03)	72.0	455

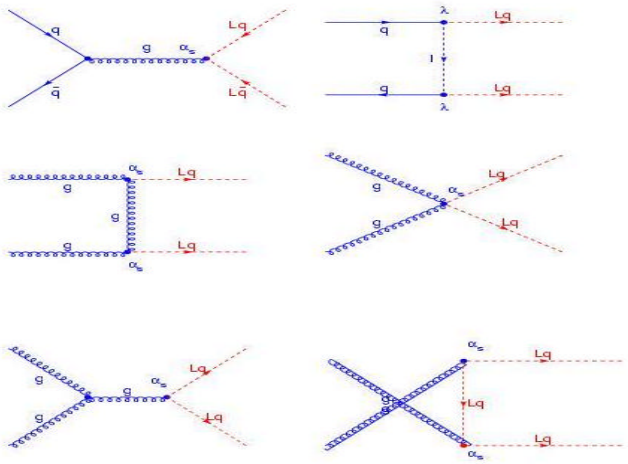
Limits : R-S Graviton



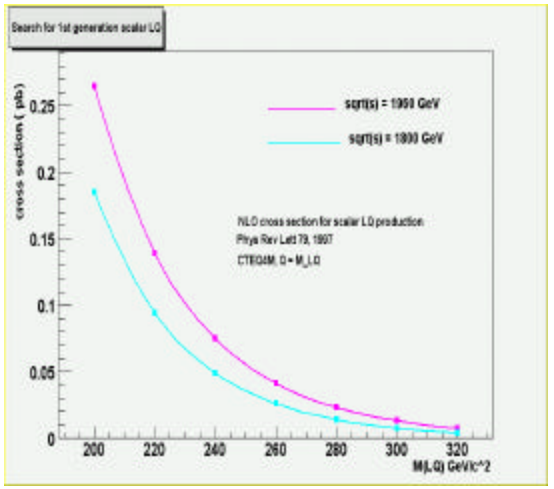


Search for 1st Generation scalar LeptoQuarks

- Production
  - qg → LQ + LQbar
  - gg → LQ + LQbar
  - qqbar → LQ + Lqbar
- Decay
  - LQLQ → l^+l^-qq,
  - LQLQ → $l^{\pm}nqq$,
  - LQLQ → $nnqq$
- Experimental signature:
  - 2 high pt isolated leptons + jets
  - MET + jets
  - one isolated lepton + MET + jets



β = Br(LQ->eq)

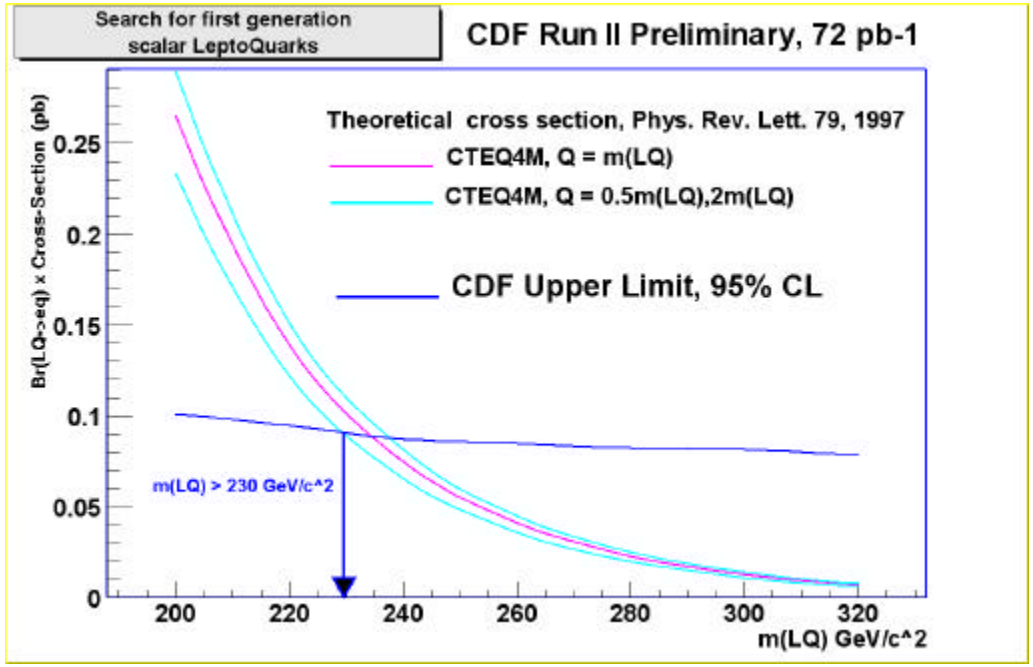


Search for First Generation scalar LQ

- 2 central electrons with E_T > 25 GeV
- 2 jets with $E_T(j1)$ > 30 and $E_T(j1)$ > 15 GeV
- removal of events with 76 < M_{ee} < 110 GeV/c^2
- $E_T(j1) + E_T(j2) > 85$ GeV && $E_T(e1) + E_T(e2) > 85$ GeV
- Ö(($E_T(j1) + E_T(j2)$)^2 + ($E_T(e1) + E_T(e2)$)^2) > 200 GeV

0 events observed

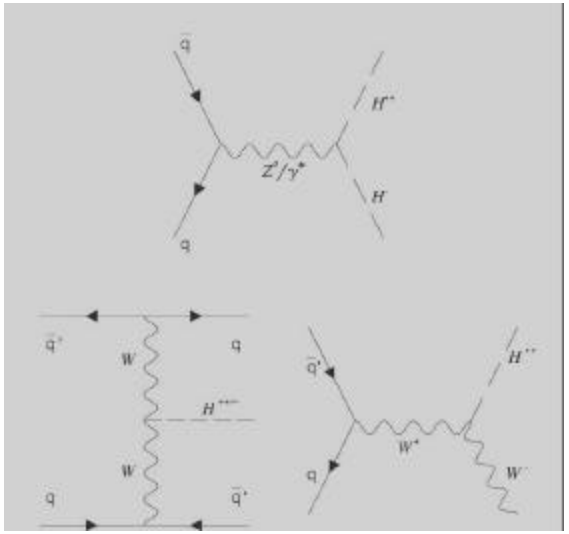
25% increase in the cross section
~factor 1/3 less luminosity
acceptances slightly higher



M(LQ) > 230 GeV/c^2 @ 95% CL
(Run I 220 GeV/c^2)

Search for doubly charged Higgs

- Doubly charged Higgs are members of Higgs triplets occurring in several types of models:
  - extensions of the Higgs sector of the SM
  - left-right symmetric models
  - SUSY left-right symmetric models
- responsible for symmetry breaking of $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ down to $SU(2) \times U(1)_{EM}$
- Light neutrino masses naturally predicted (via seesaw mechanism)
- masses in the range of 1 TeV
  - LEP limit up to 100 GeV/c^2 (prompt and long lived)

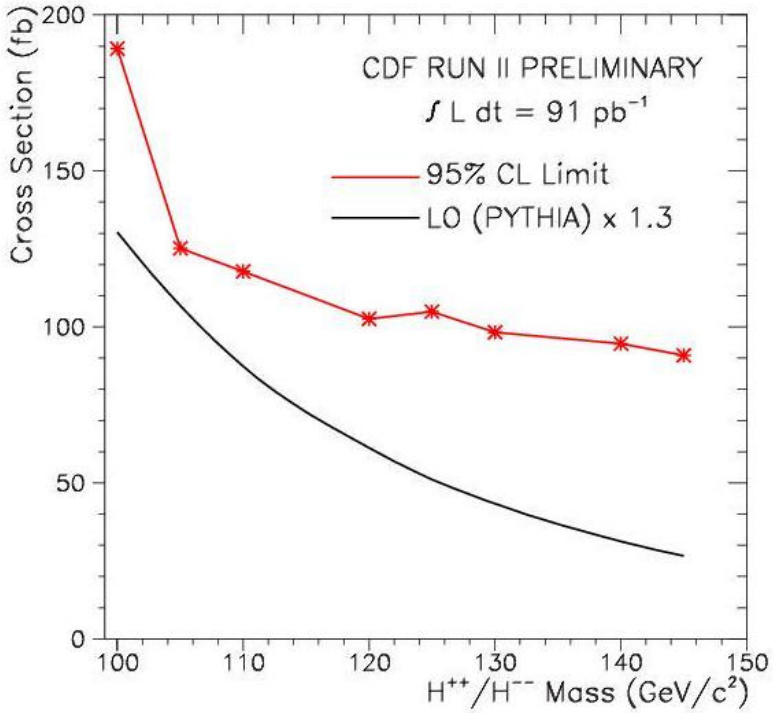


At the TeVatron doubly charged Higgs can be
paired-produced (Z exchange) or singly produced (WW fusion)
x-section ~ O(fb)
signature:
same sign leptons

Search for doubly charged Higgs

- Same sign dielectron mass distribution is used to search for doubly charged Higgs of a given mass
  - search region defined as of ± 10% of Higgs mass
  - signal region above the Z mass
  - low mass region as control region
- Very low background
  - W/Z + misidentified jet
  - WZ production
  - opposite signed mis-measured electron

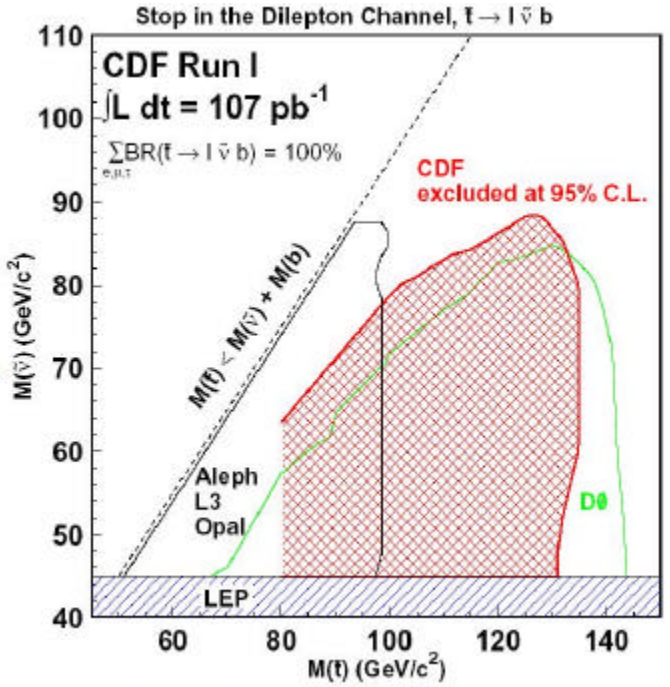
0 events observed

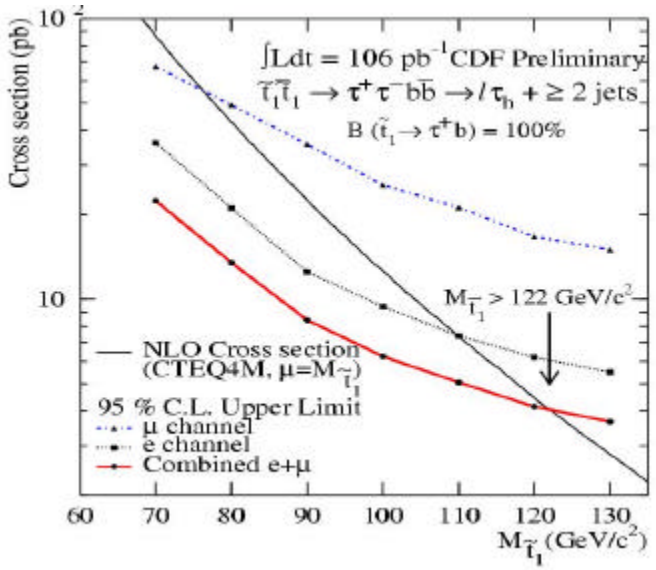


SUSY

- Run II statistics still too low to allow for extraction of signal from background
  - understanding of the main datasets is still in progress - results expected for APS
- Latest Run I results
  - Direct production of stop
    - assumes Br(stop ® lb sneutrino) = 100%
    - 2 l^+l^- isolated pair
    - ≥ 1 jet and significant MET
    - main background:
      - tt, bb, VV, DY
  - RPV stop
    - assumes Br(stop ® t b) = 100%
    - consider τ-lepton (μ,e) final state

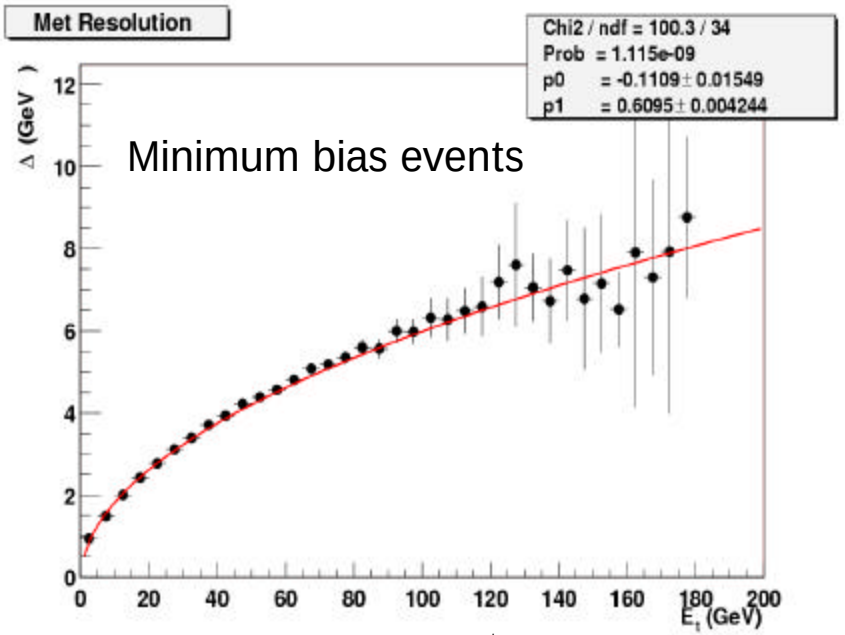
3rd generation



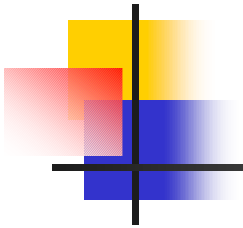


Exotic Triggers

- Several new triggers have been implemented and are currently used and/or validated
  - Missing E_T
  - Missing E_T + heavy flavors
    - trigger for Higgs
  - Several Photons triggers
    - Inclusive photons, di-photons,
    - photon + leptons
    - photon + dijet
    - photon + heavy flavor
  - SUSY dileptons (low p_t threshold)



Run 1: 0.53/√Σ Et with forward cal. Use |η|<4.2
Run II: 0.60/√Σ Et with plug only |η|<3.6
With miniplug |η|<5.5

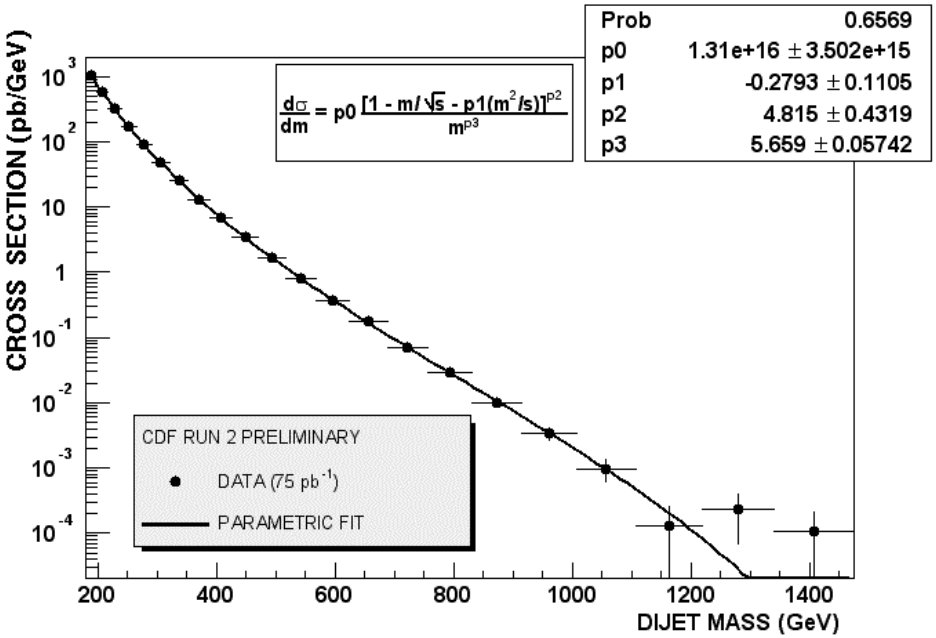


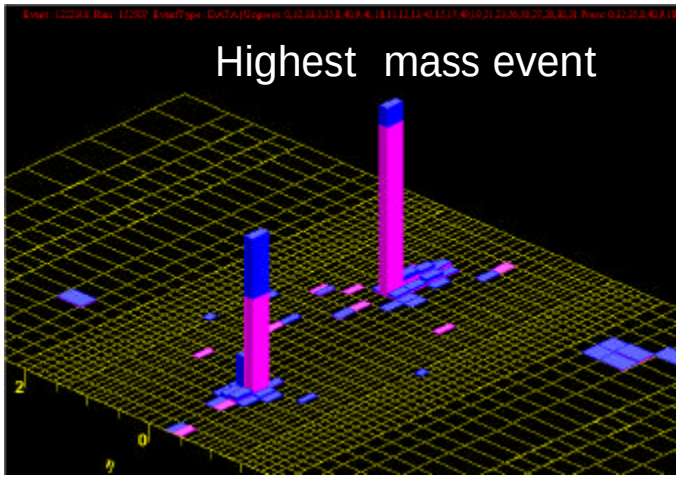
Signature-Based Searches

- Searches for mass bumps in the dijet spectrum
- Searches for CHArged Massive ParticleS
- Search for new physics involving photons

Search for Mass Bumps in Dijets

- Inclusive jet samples
- MET/$\sqrt{\Sigma E_T}$ < 6 and ΣE < 2.2 TeV
- 2 highest E_T jets selected
- fit of the mass spectrum with a simple background parameterization and search for bumps comparable with the mass resolution.



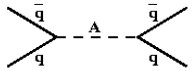
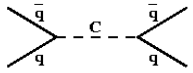
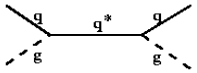
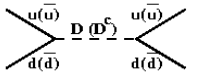


no significant evidence for a new particle signal

Run 152507 event 1222318
Dijet Mass = 1364 GeV/c^2
cos θ* = 0.30
z vertex = -25 cm

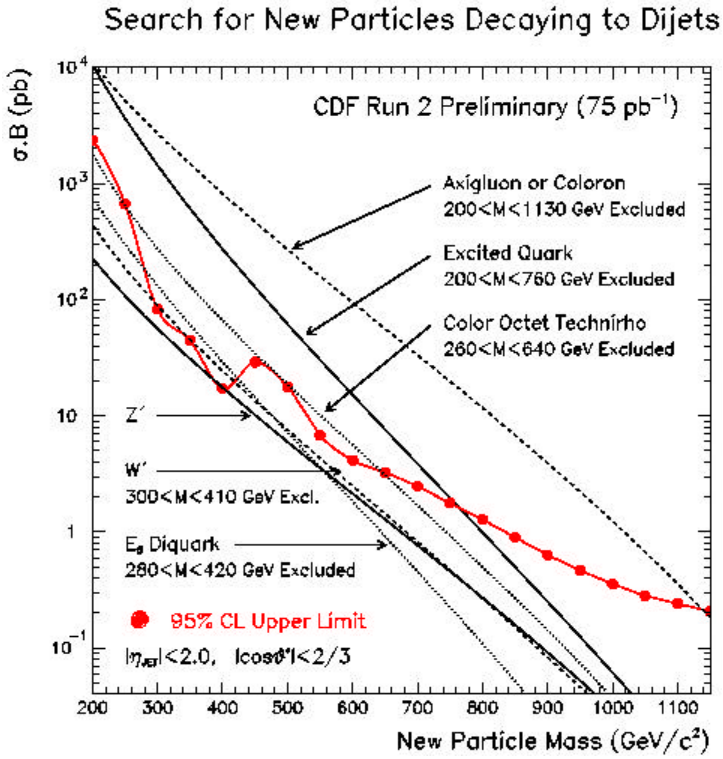
Calibration still in progress

Search for Mass Bumps in 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

Excluded

- Axigluons or flavor universal colorons
  - 200 < m < 1130 GeV/c^2
- Excited quarks
  - 200 < m < and 760 GeV/c^2
- Color octet technirhos
  - 260 < m < 640 GeV/c^2
- E6 diquarks 280 < m < 420 GeV/c^2
- W' 300 < m < 410 GeV/c^2

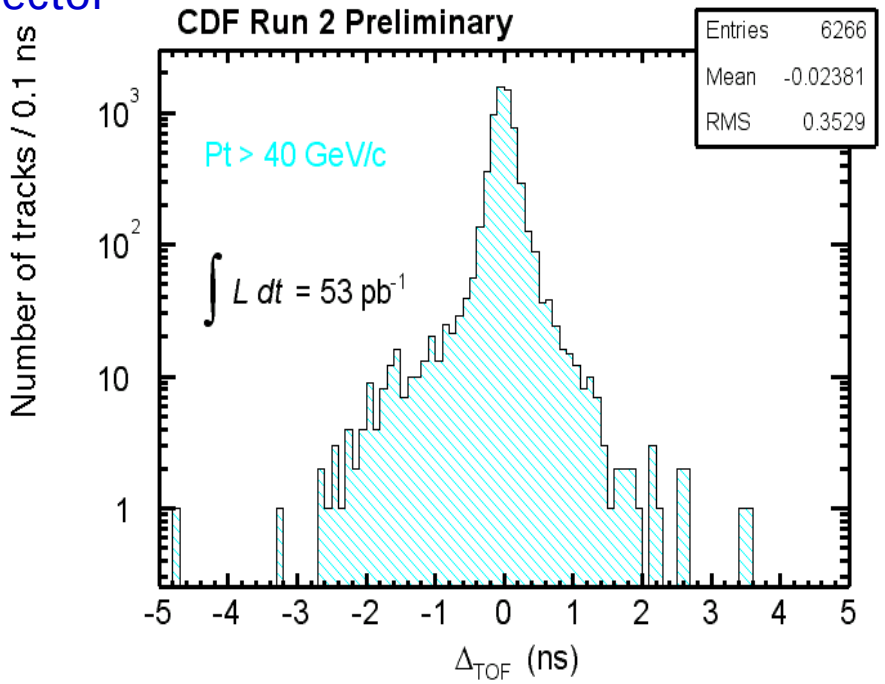


Results improved in respect to CDF Run I

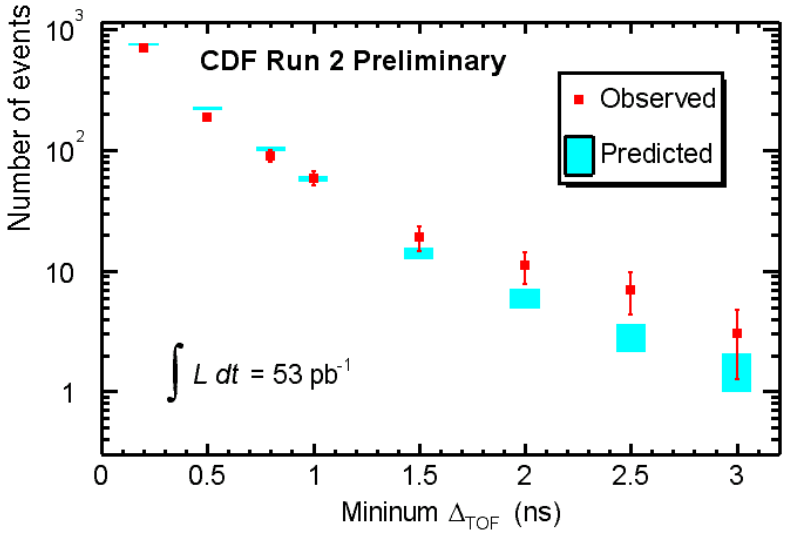
CHArged Massive ParticleS

- Long lived particles escaping the CDF detector
  - looking at high pt muon trigger
- Isolated, slow moving
  - p_t > 40 GeV/c to have full tracking efficiency
  - long time of flight through the detector

- TOF measurement
  - RunII TOF system provides sensitivity to higher $\beta\gamma$ than dE/dx (LEP searches)
  - event t_0 from tracks with P_T > 20 GeV/c
    - tested with W electron sample
  - Looking for tracks with high TOF_{tracks} - t_0



CHArged Massive ParticleS



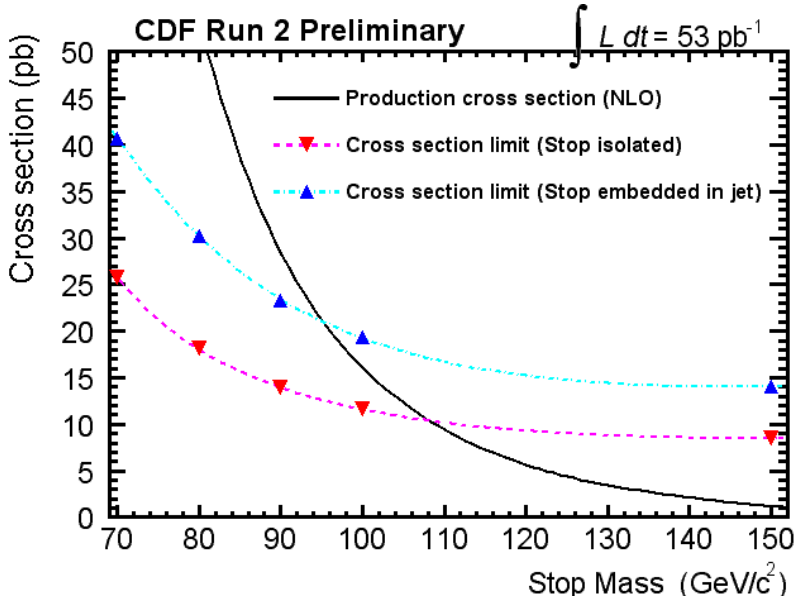
Predicted/observed events in the signal region (statistical uncertainties only).

The counting experiment required Δ(TOF) > 2.5 ns.
This point has a background prediction of

2.9 +/- 0.7 (stat) +/- 3.1 (sys), with 7 observed.

Backgrounds:
- instrumental
- cosmic rays (negligible for Δ(TOF) > 2.5)

Interesting NLSP cases in GMSB
- stop or stau as the lightest SM partners
- stop - strongly interacting
- stau - weakly interacting



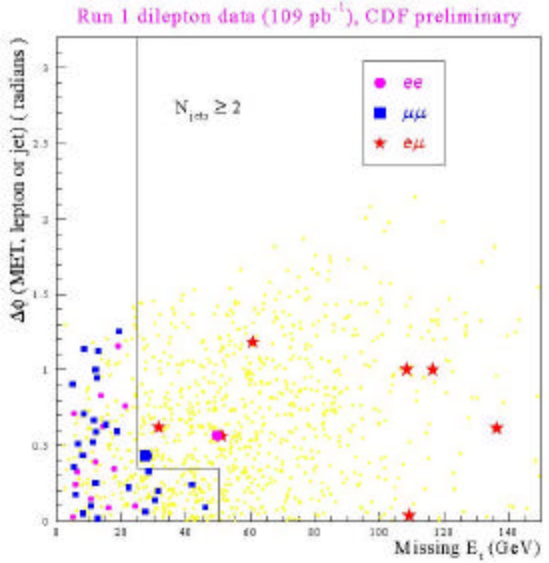
M(stop) > 108 GeV at 95% CL. (isolated stop)
M(stop) > 95 GeV at 95% CL. (non isolated stop)

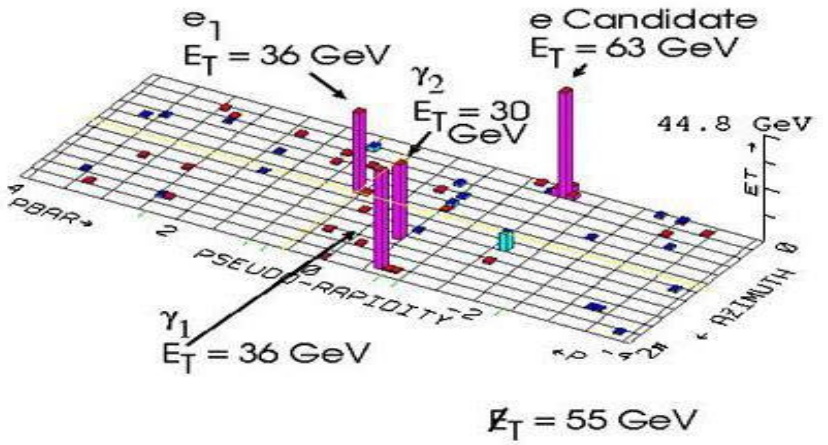
LEP m(stop) > 95 GeV/c^2

Follow Up on Run I Anomalies

See P. Kohen's talk

- Top sample:
  - Excess of eμ candidates with large MET in dileptons
  - Kinematical distributions of tt system
- Excess of soft leptons tags in W + 2/3 jets events
- Photons-leptons anomalies:
  - eeγγ Met candidate event



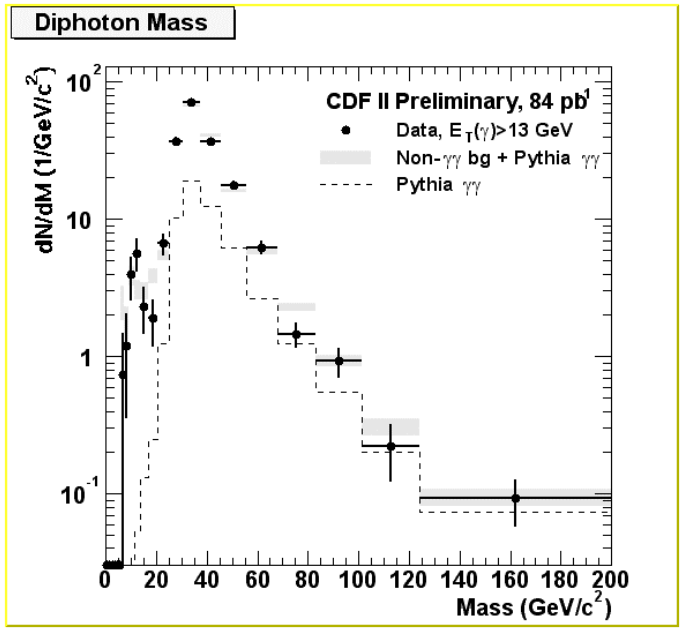


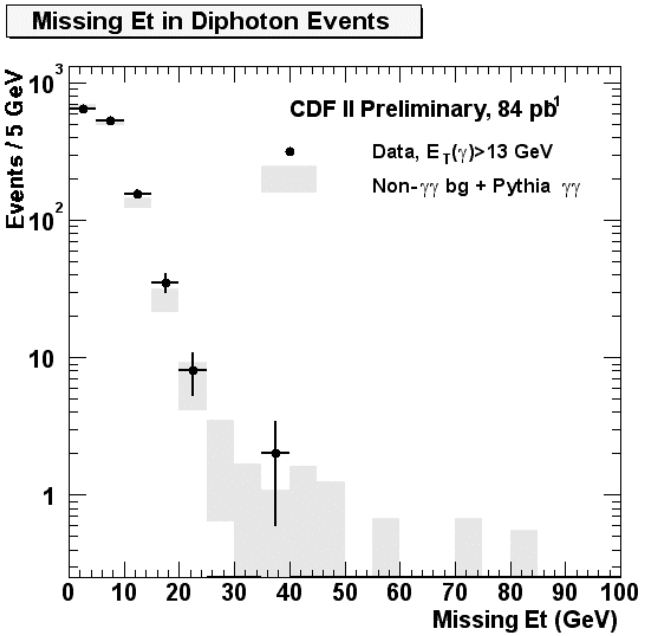
Follow Up on Run I Anomalies

Searches for new physics in the diphoton sample

Sample selection (84 pb^{-1})

- 2 central photons E_T > 13 GeV
- cosmic rays and beam halo rejection
- Observed 1365 events (95 events with E_T > 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	$0.04 \pm 0.007 \pm 0.02$	$0.007 \pm 0.005 \pm 0.004$

Conclusions

- CDF is taking data actively and it is producing its first results on searches for ~~n~~ew physics
  - signature based approach
  - model based results

- Some of the results are already better than Run I, due to the increase in the $\sqrt{s}$
  - Z'
  - Leptoquarks
  - Dijets mass bumps

- Some of the results have been obtained using new features of the CDF II detector
  - CHAMPS