



New Phenomena Searches at CDF

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For the CDF Collaboration

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Lake Louise Winter Institute

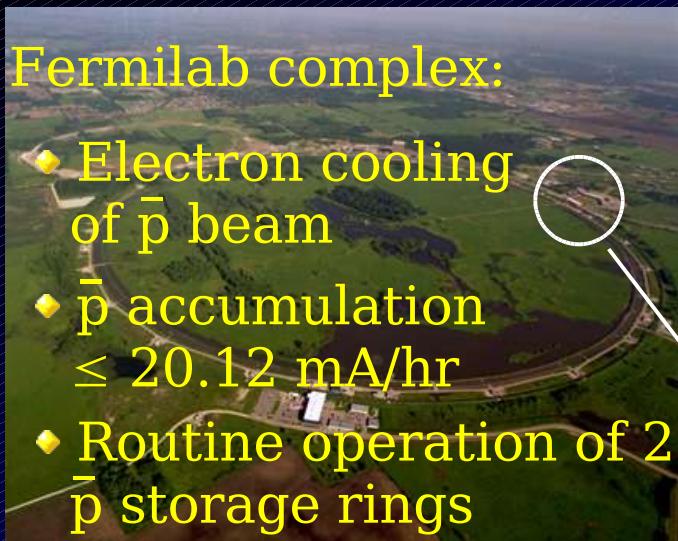


Introduction

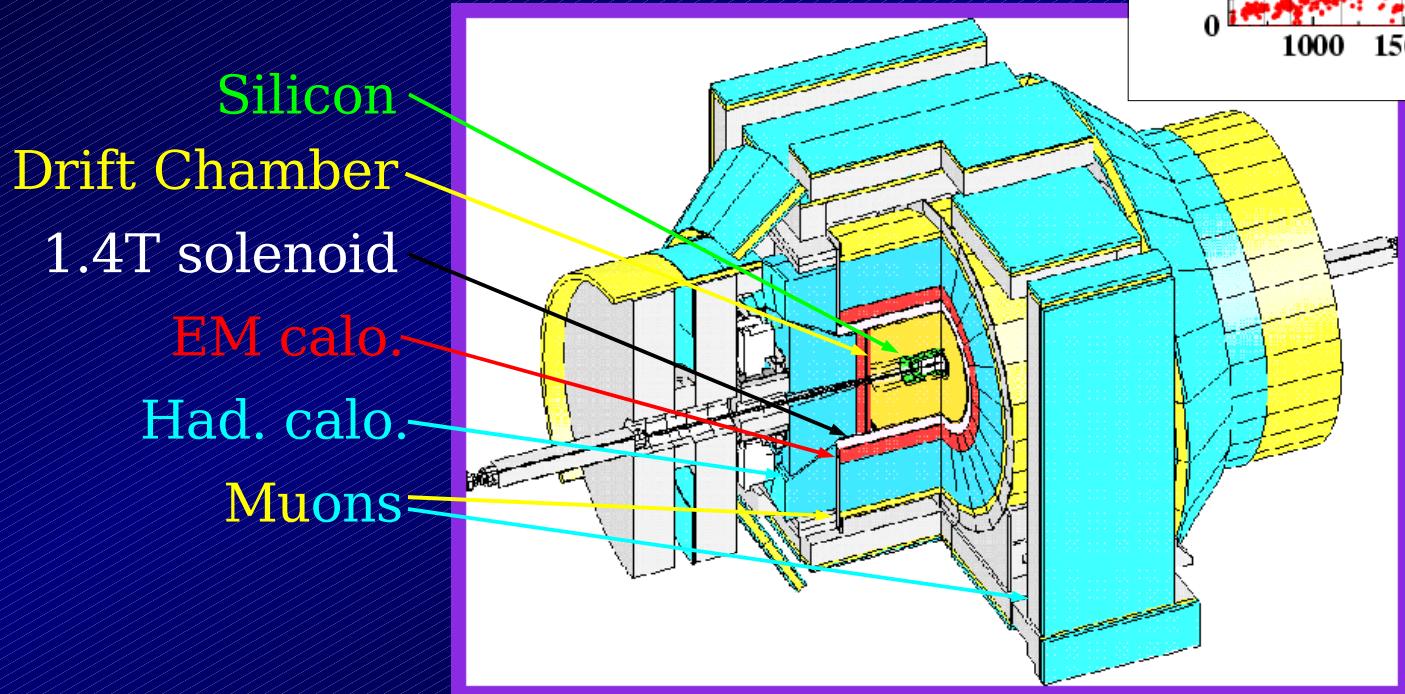
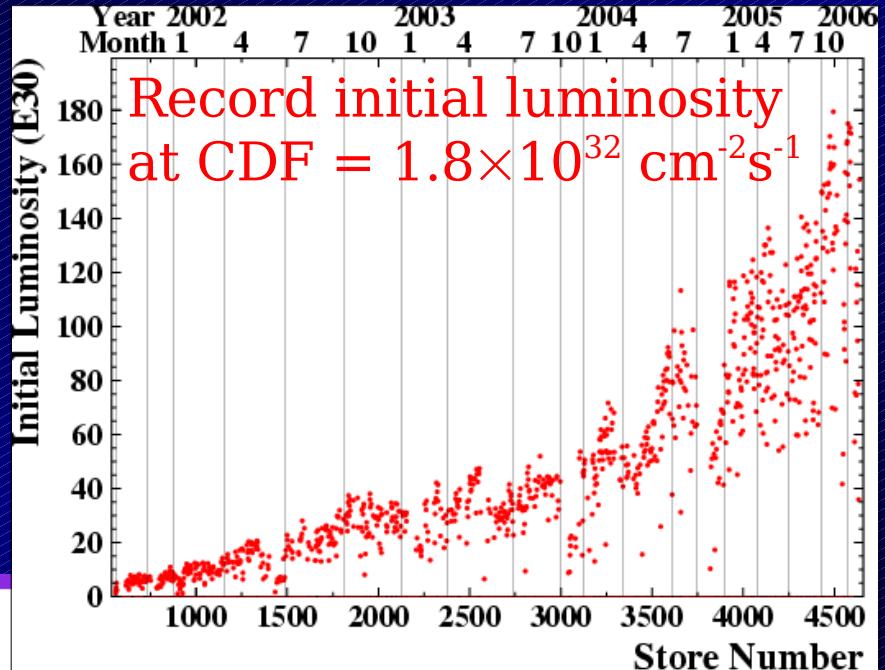
- The Standard Model falls short on several key questions:
 - Do the forces unite?
 - What is dark matter? How about dark energy?
 - What is the true nature of gravity?
 - Do particles get mass from a SM Higgs field, or something more?
- Answers may come through new phenomena:



CDF at the Tevatron

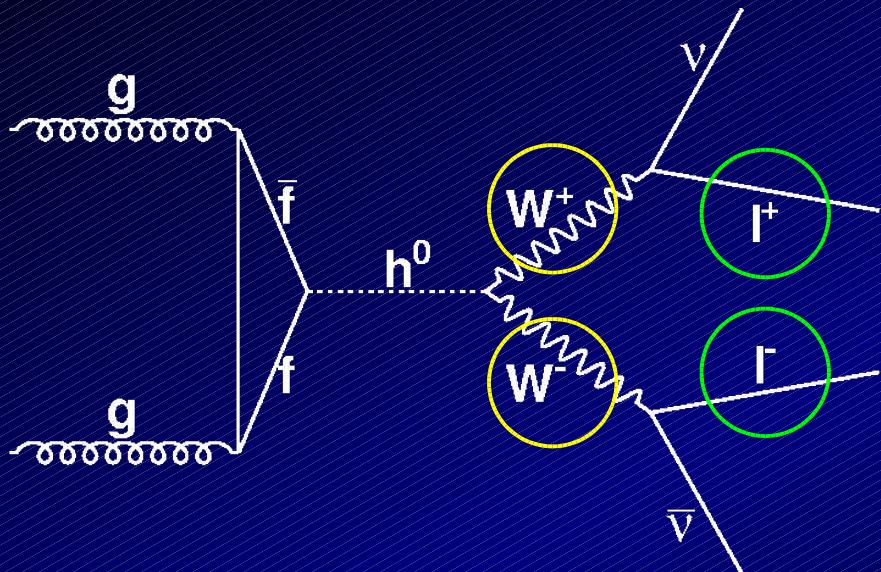


CDF



SM Higgs in $h^0 \rightarrow WW^{(*)}$

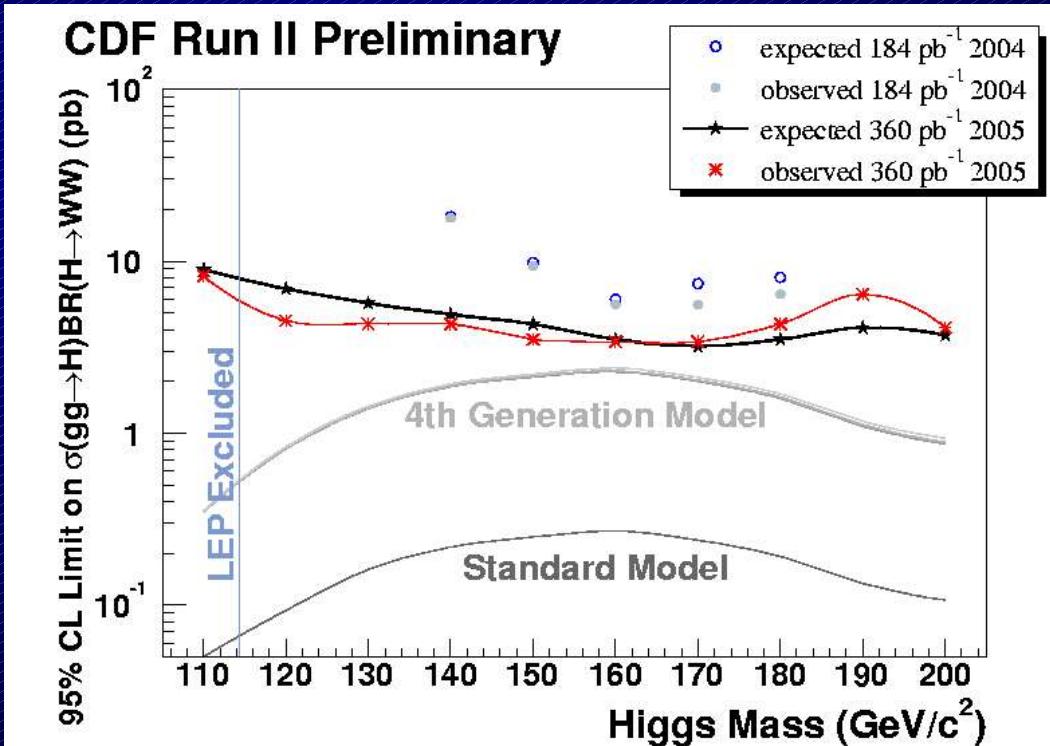
- At Tevatron, single neutral h^0 is dominant Higgs production
- $h^0 \rightarrow WW$ is dominant decay for $M_{\text{Higgs}} > 135 \text{ GeV}/c^2$



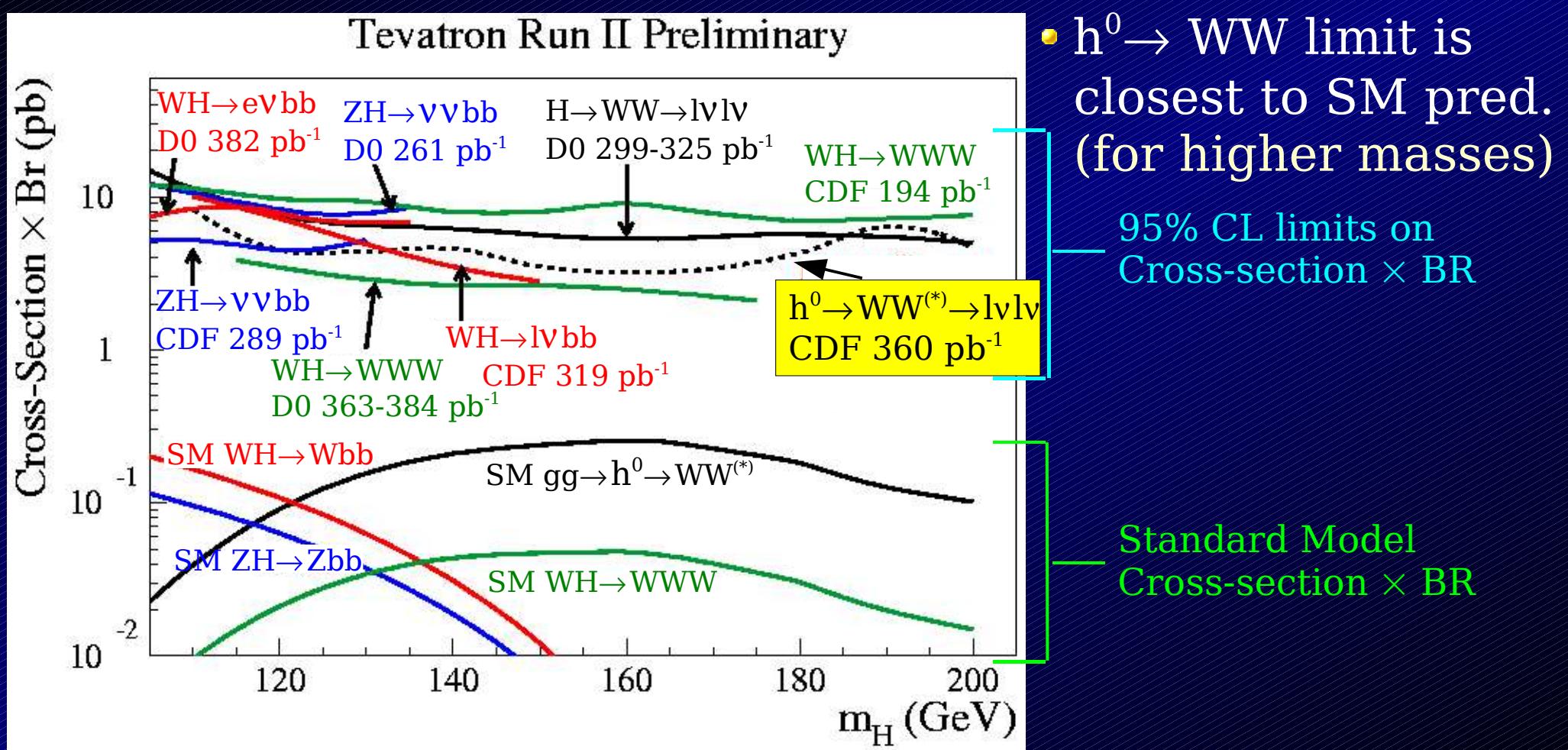
Use $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ decay modes

Use azimuthal angle between 2 leptons
to separate $h^0 \rightarrow WW$ from dominant SM
background of WW production

New result with 360 pb^{-1}



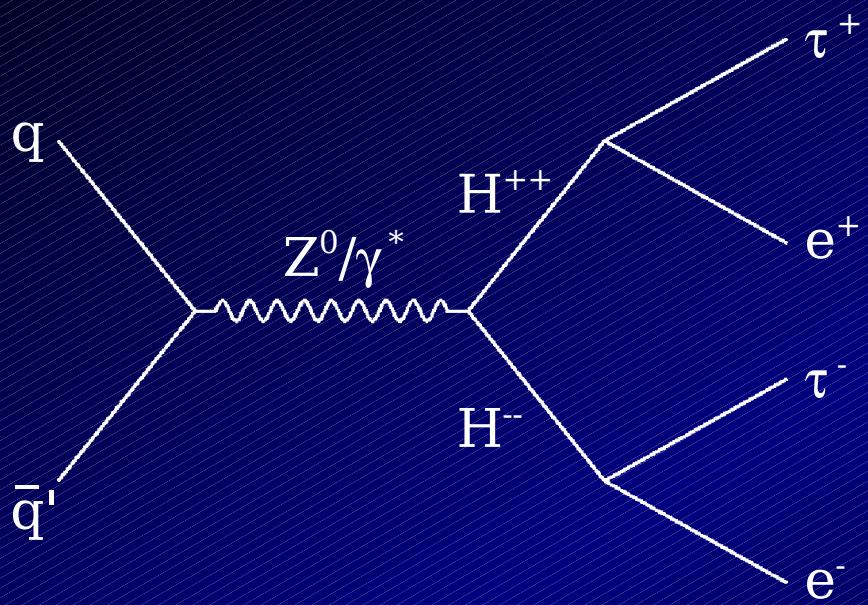
SM Higgs in $h^0 \rightarrow WW^{(*)}$



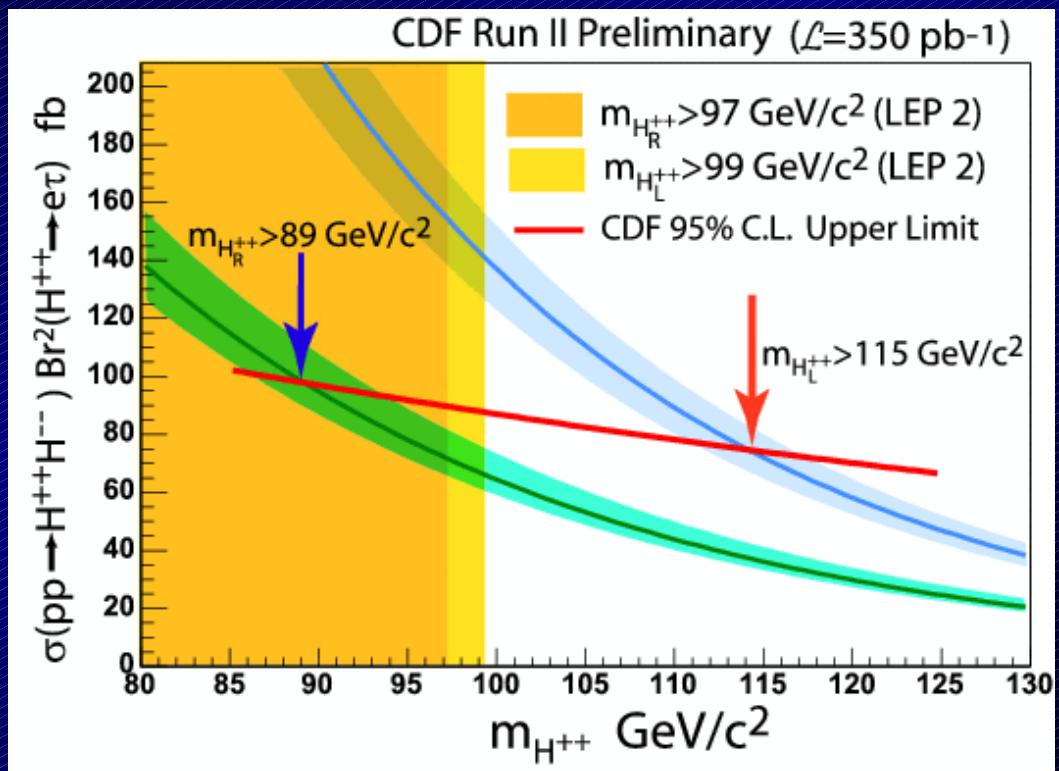
- New channels on the way: ZH production, with $Z \rightarrow ll$ and $W \rightarrow bb$
- Tool improvements: better b-tagging, neural nets for sig. vs. bkg.

Search For $H^{++} H^{-}$

- Doubly charged, pair production
- Lepton-flavor violating decay



Reconstruct 3 or 4 isolated leptons
 Fights hadronic (QCD) backgrounds
 $E_T + \sum p_T(\text{leptons}) > 190 \text{ GeV}$ and Z veto
 Reduces remaining electroweak bkg.



Expected background: 0.25 events
 Observed in 350 pb^{-1} : 0 events

$$\sigma(pp \rightarrow H^{++}H^-) \times \text{Br}^2(H^{++} \rightarrow e\tau) < 73.5 \text{ fb}$$

$$m_{H^{++}_L} > 115 \text{ GeV}/c^2$$

Large Extra Dimensions (I)

- Proposal for gravitons populating 4+n dimensional Bulk
(Arkani-Hamed, Dimopoulos, Dvali, Phys Lett B429 1998)
- Direct production of graviton: $q\bar{q} \rightarrow gG$, $qg \rightarrow qG$, $gg \rightarrow gG$
- Interpretation for energetic jet + missing E_T
 $E_T > 150 \text{ GeV}$ $\cancel{E}_T > 120 \text{ GeV}$

Standard Model Backgrounds:

265 ± 30 events

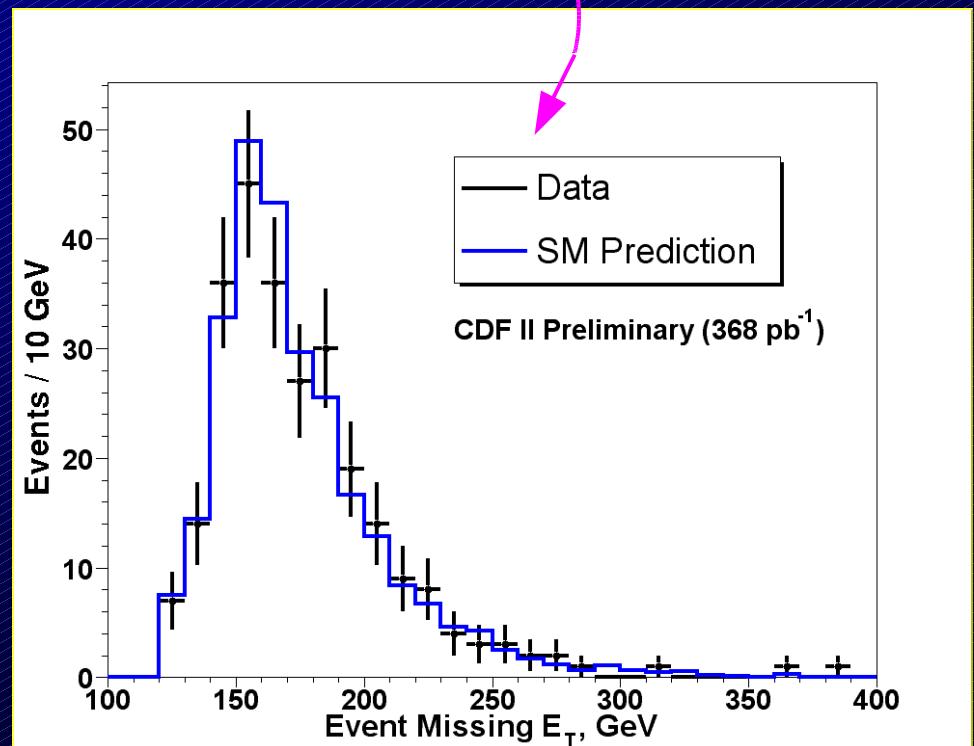
$Z \rightarrow \nu\nu$ + jets (real \cancel{E}_T , irreducible)

$W \rightarrow \ell\nu$ + jets (\cancel{E}_T from ν or lost lepton)

QCD (\cancel{E}_T from mis-measured jets)

Observed in 368 pb^{-1} of data:

263 events



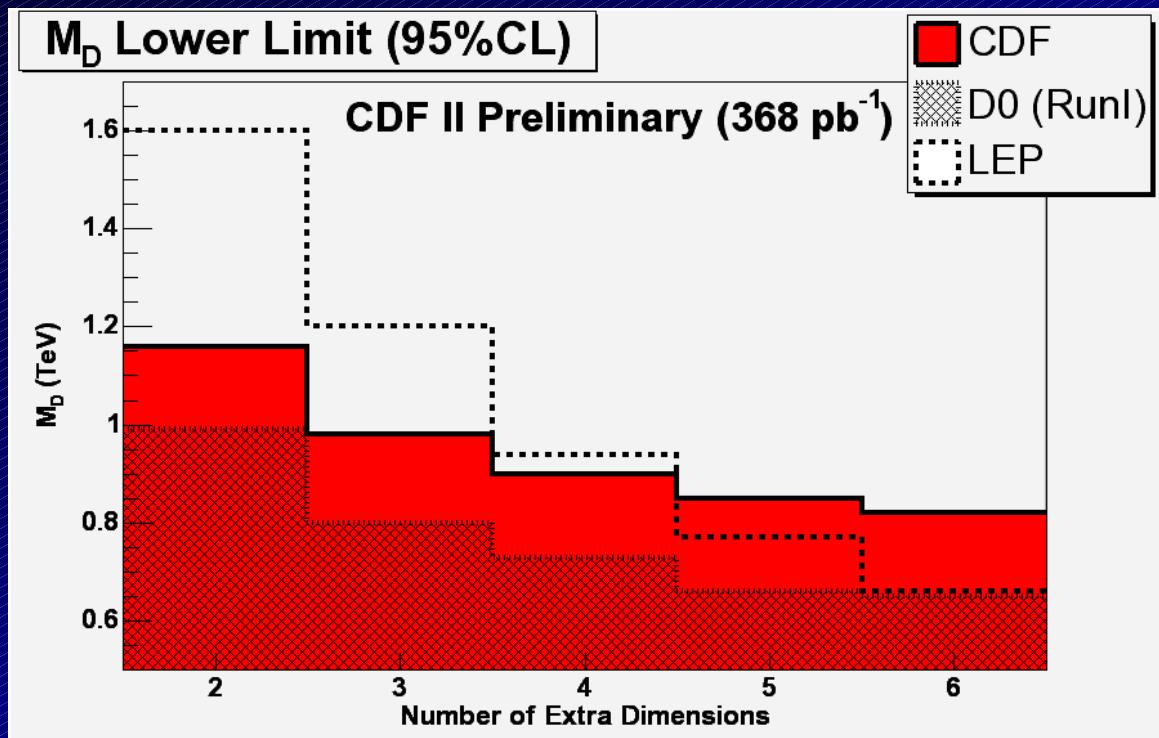
Large Extra Dimensions (II)

- Place lower limit on effective scale and upper limit on size

Effective Planck scale M_D :

$$M_{\text{Planck}}^2 \sim R^n M_D^{2+n}$$

95% CL limits



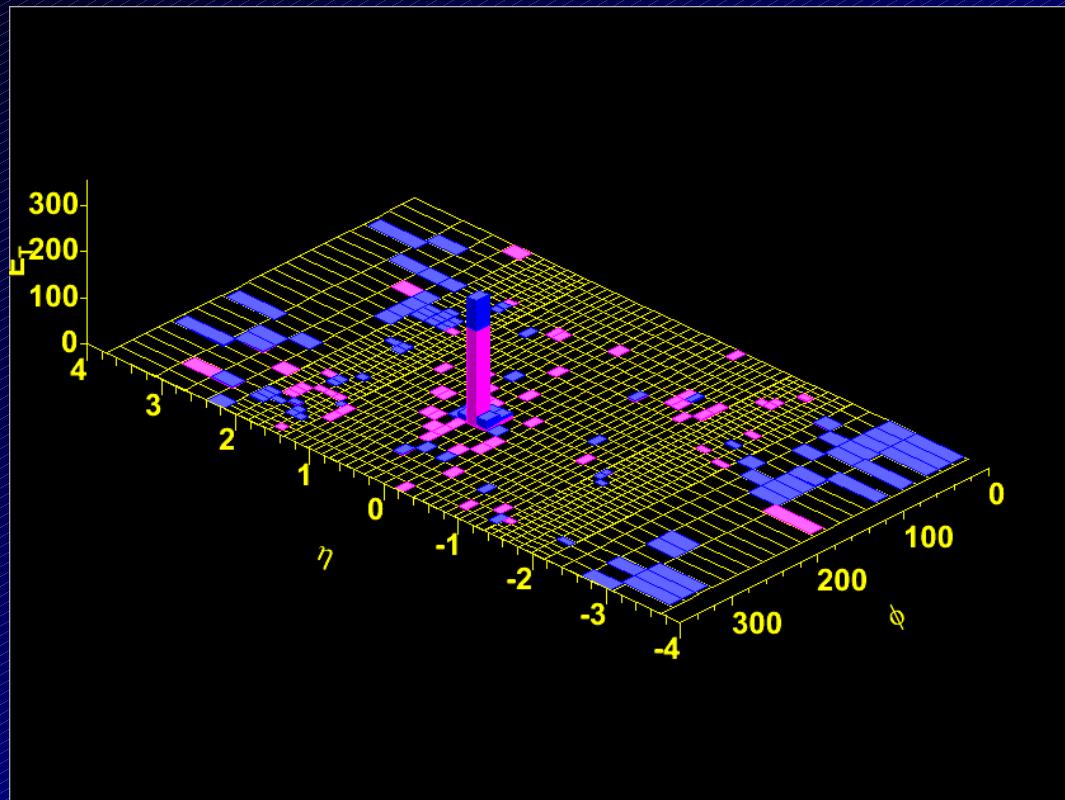
n	M_D (TeV)	R (mm)
2	>1.16	<0.36
3	>0.98	$<3.7 \times 10^{-6}$
4	>0.90	$<1.1 \times 10^{-8}$
5	>0.85	$<3.5 \times 10^{-10}$
6	>0.83	$<3.4 \times 10^{-11}$

(For $K = \sigma_{\text{NLO}}/\sigma_{\text{LO}} = 1.3$)

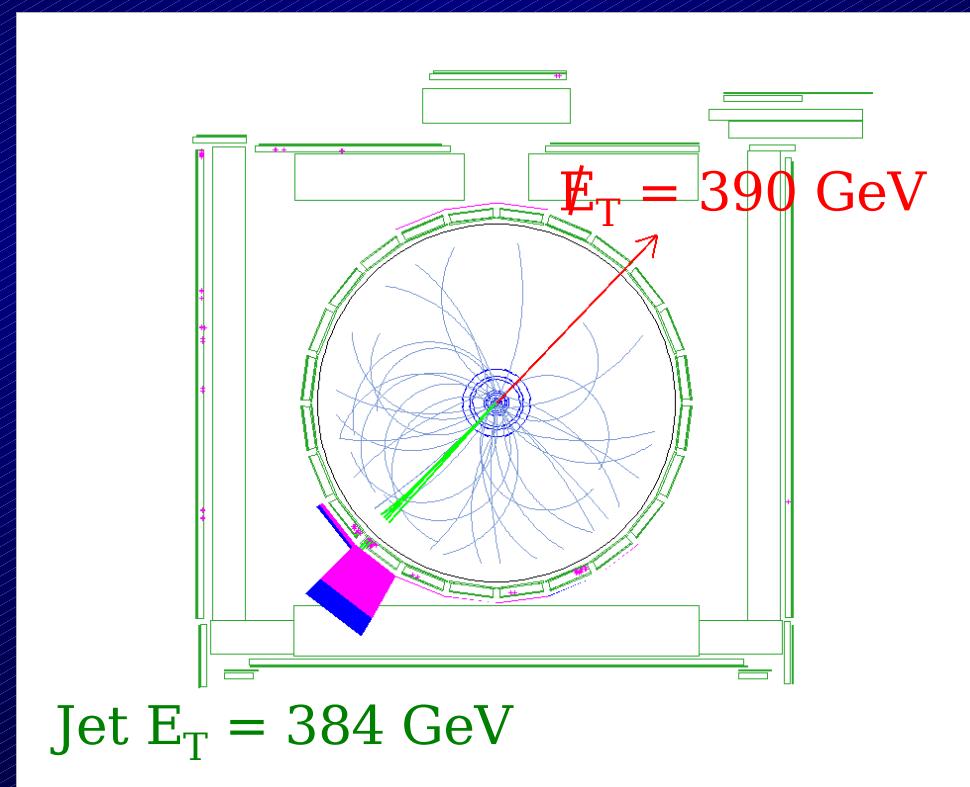
Event Displays for L.E.D.

Highest E_T event: $E_T = 390 \text{ GeV}$
Jet $E_T = 384 \text{ GeV}$

Unrolled calorimeter view:



r- ϕ view:



Shows EM calorimeter energy (purple)
Hadronic calorimeter energy (blue)

Heavy Objects: Z'

- Search for new physics in di-electron mass and $\cos(\theta^*)$
 - Look for a peak in M_{ee} and look for a distortion in $\cos(\theta^*)$
 - Z' would interfere with the Z/γ^* (just as Z and γ^* interfere in SM)

Drell Yan background dominates

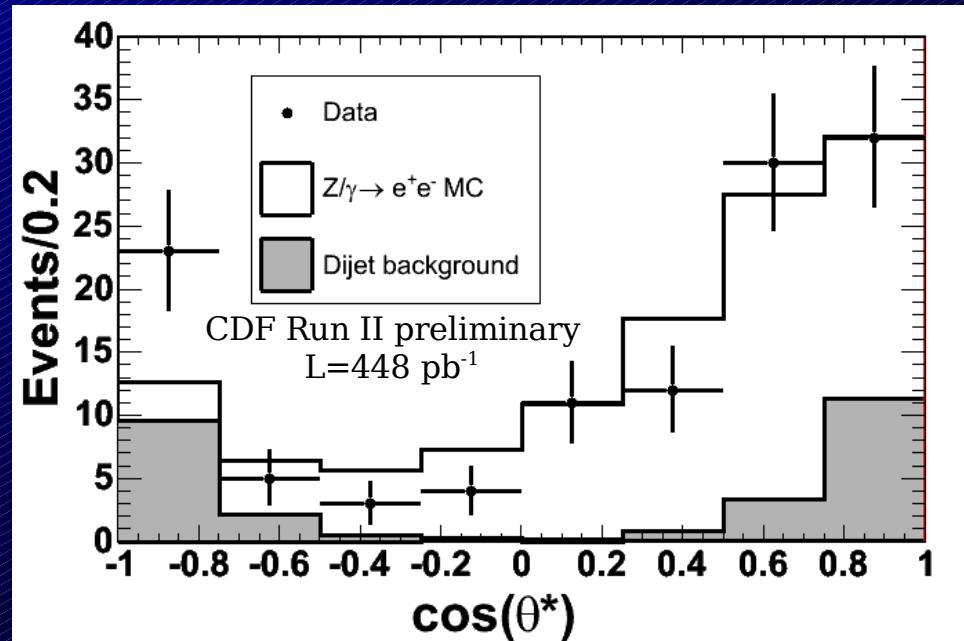
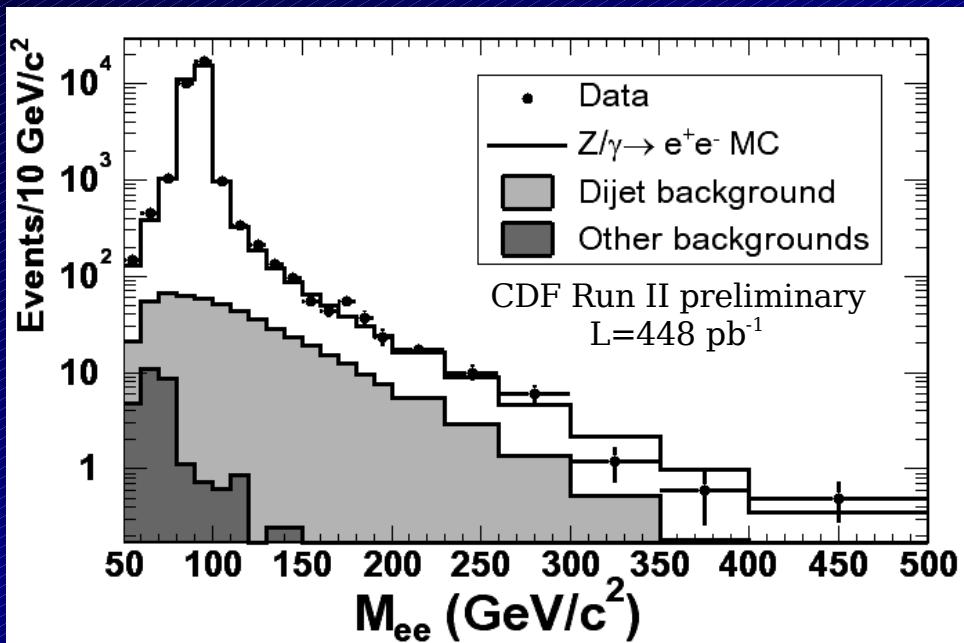
MC is normalized to luminosity

Data more consistent with $Z/\gamma^* + \text{bkgs}$
than with $Z/\gamma^*/Z' + \text{bkgs}$ for many models

For $M_{ee} > 200 \text{ GeV}/c^2$:

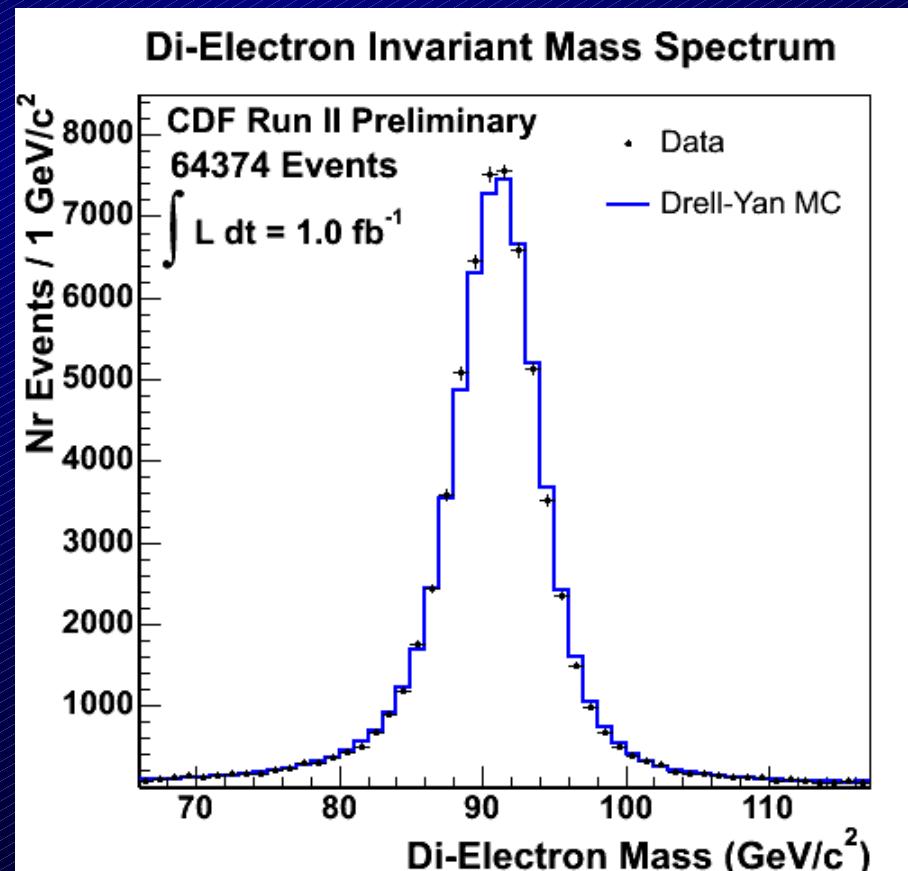
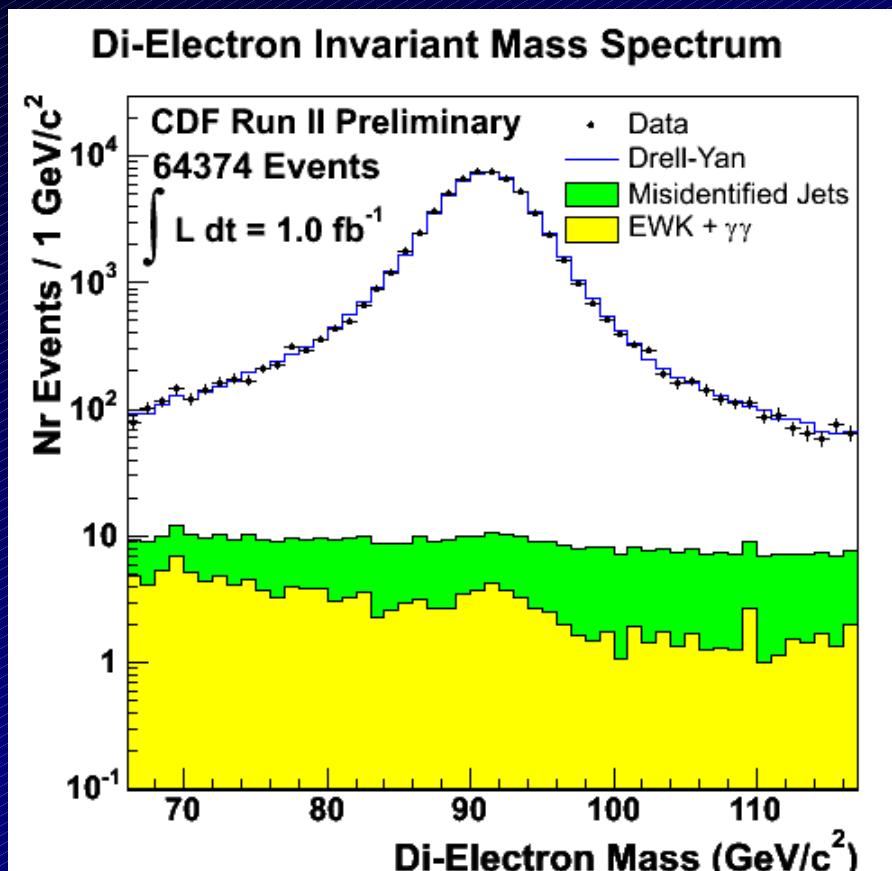
Total Standard Model: 115^{+16}_{-19} events
Observed in 448 pb^{-1} : 120 events

$M_{Z'}^{(\text{seq})} > 855 \text{ GeV}/c^2$ at 95% CL



Di-electron Sample

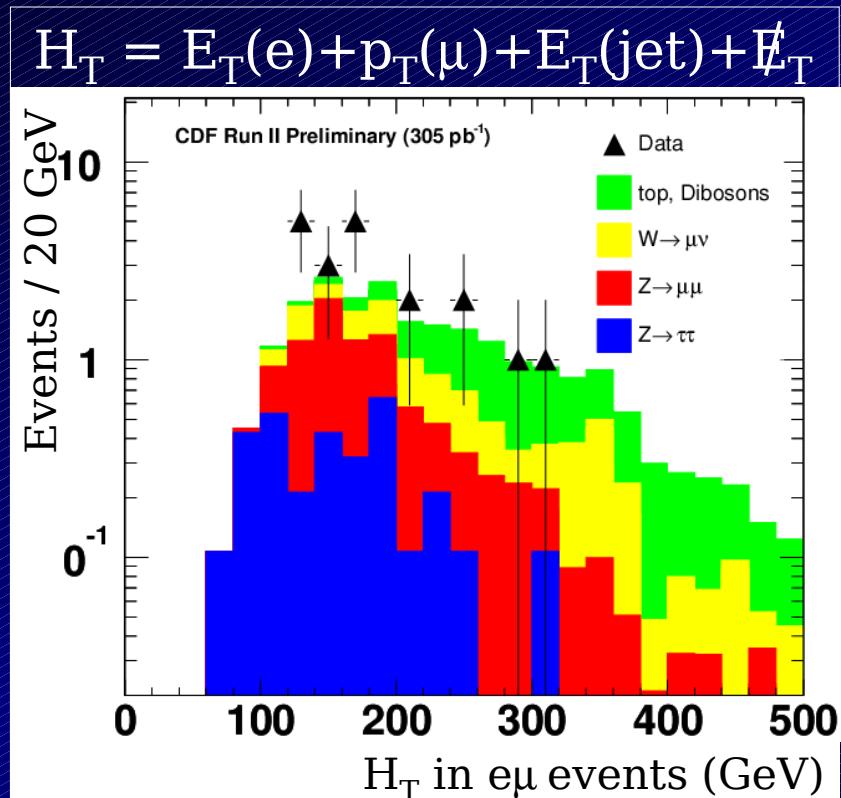
- Will use for di-electron new physics searches at high M_{ee}
 - central/central or central/plug, two electrons with $E_T > 25 \text{ GeV}$
- Plots show range: $66 < M_{ee} < 116 \text{ GeV}/c^2$
- Drell Yan MC normalized to Z peak region
 - Using 1.01 fb^{-1}



Same, but linear scale

Heavy Objects in Dilepton+X

- Signature based search for anomalous dilepton+X events
 $X \in \{ \text{large event } H_T, \text{large } E_T \text{ jets, b-quark jets, 3}^{\text{rd}} \text{ lepton, large } \cancel{E}_T, \dots \}$
- Open to heavy quarks, b' , t' , extra dimensions, SUSY
(Apply first to Bjorken, Pakvasa, Tuan heavy quark model, hep-ph/0206116)
CKM matrix structure \rightarrow 3 down-type iso-singlet right-handed quarks:



$Q_R \bar{Q}_R$ production, with $Q_R \rightarrow W/Z/H + u/d$

- Dilepton($e\mu$) + ≥ 2 jets($E_T > 50$ GeV)
- Control region: $H_T < 200$ GeV
- Signal region: $H_T > 400$ GeV
- No events seen in 305 pb⁻¹ of data
Expect: 0.802 ± 0.440 SM
 0.526 ± 0.058 QQ

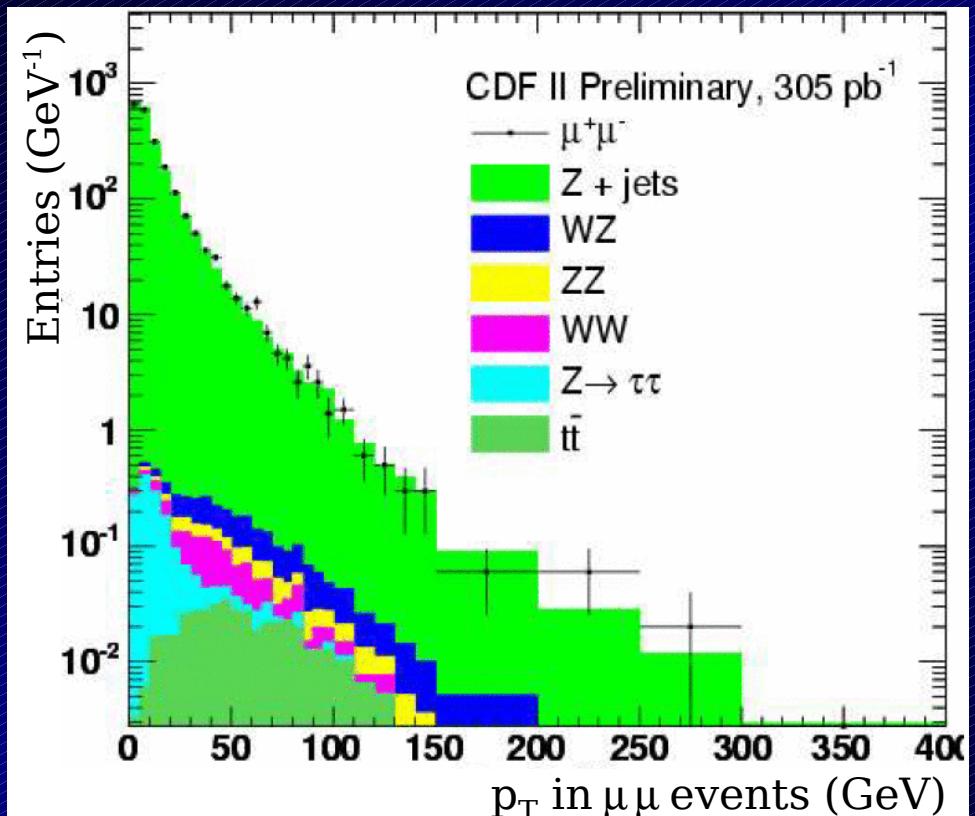
$4.49 \times \sigma_Q = 90\% \text{ CL limit}$

$\sigma_Q = 0.289 \text{ pb}$ for 300 GeV quark

Will soon update to > 700 pb⁻¹

... or in High p_T Z Bosons

- Looking for heavy objects decaying to Z bosons
Could be heavy quarks, Z', sparticle, ...
- High p_T Z \rightarrow ee and Z \rightarrow $\mu\mu$; Will include W decays later
Will also later add requirements such as E_T , photon, or b-quark jets



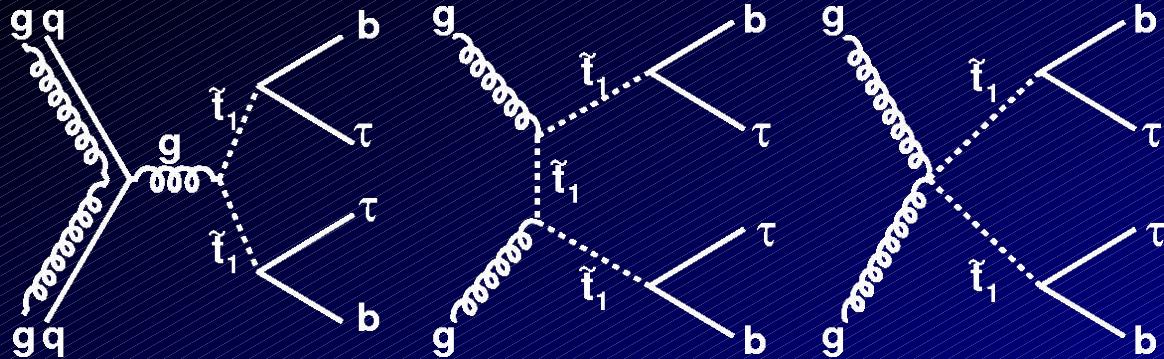
- Z mass cut: $66 < M_{ll} < 116$ GeV/c²
- Z p_T agrees between data and SM background (Monte Carlo)
- Limits obtained on differential cross section of extra Z production as function of p_T
Example, using signature of heavy quark model: Q_R $\bar{Q}_R \rightarrow u d W Z$

$$\sigma < 0.170 \pm 0.005 \text{ pb}$$

95% CL limit, for 300 GeV quark

SUSY: R-Parity Violating Stop

- Supersymmetric top (stop) quark pair production



Production:

Same diagrams exist for scalar
3rd generation leptoquarks (LQ3)

Decay:

R-parity violating

Look for $\tau_{e/\mu}$, τ_h , and 2 jets

Backgrounds:

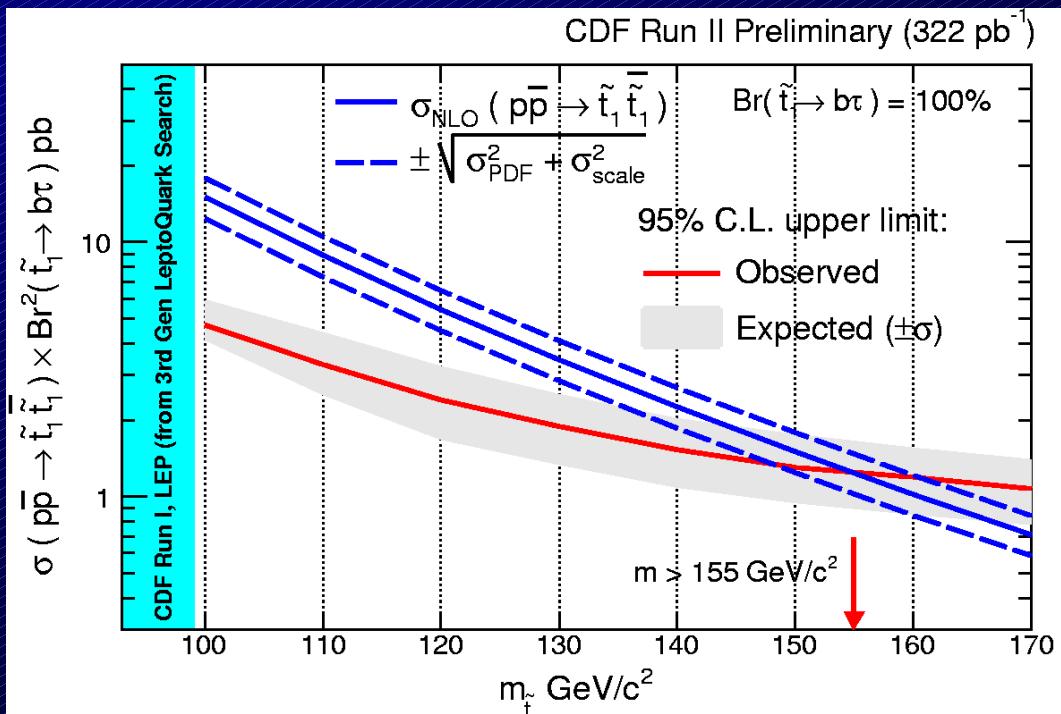
Z+jets and QCD reduced using
 $p_T(\text{lepton}) + p_T(\tau_h) + \cancel{E}_T > 85 \text{ GeV}$

W+jets (jet fakes tau) reduced
using transverse mass of (lepton, \cancel{E}_T)

Expected SM: $2.26^{+0.46}_{-0.22}$ events
Observed in 322 pb^{-1} : 2 events

$m_{\text{stop}} > 155 \text{ GeV}/c^2$

(Same limit applies to LQ3)



Conclusions

- Some of the latest new phenomena results from CDF:
Higgs

Higgs in $h^0 \rightarrow WW^{(*)}$ (most sensitive channel for higher masses)
Search For $H^{++} H^-$ (setting limits)

Large Extra Dimensions

Setting limits on effective mass scale and radii

Heavy Objects

Z' (setting mass limit)
Dilepton+X and high $p_T Z$ (broad searches for anomalous events)

SUSY

R-parity violating stop (setting mass limit)

- Numerous other results are headed your way this Winter!