New Phenomena Searches at CDF

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For the CDF Collaboration

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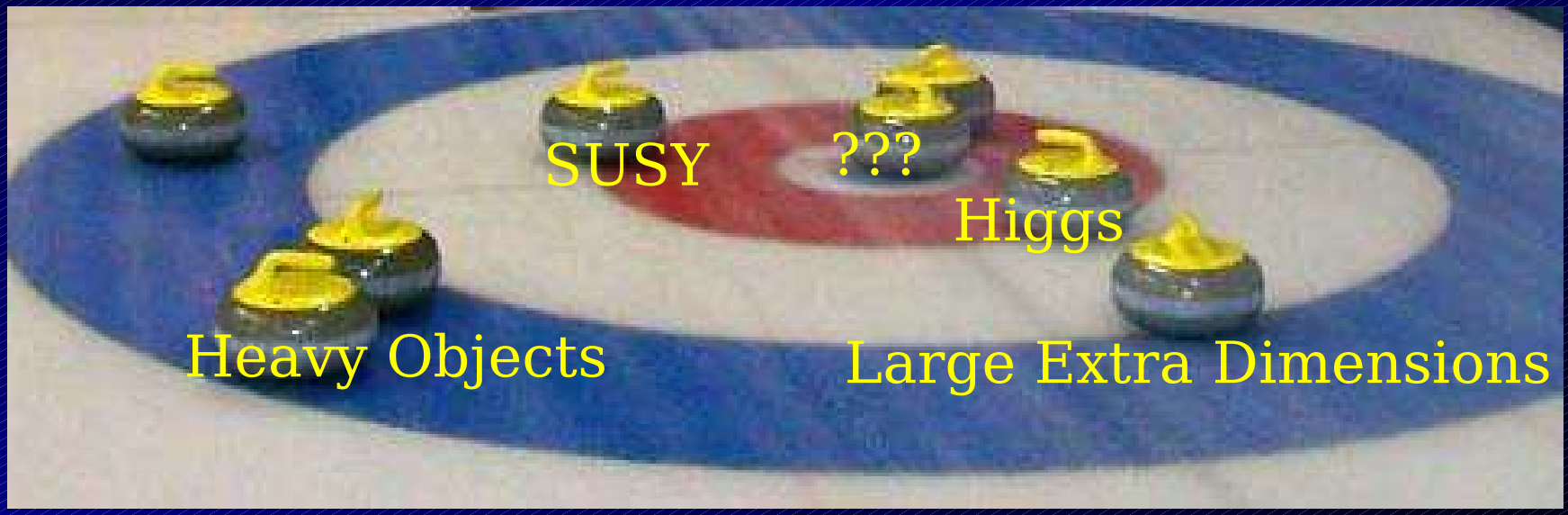
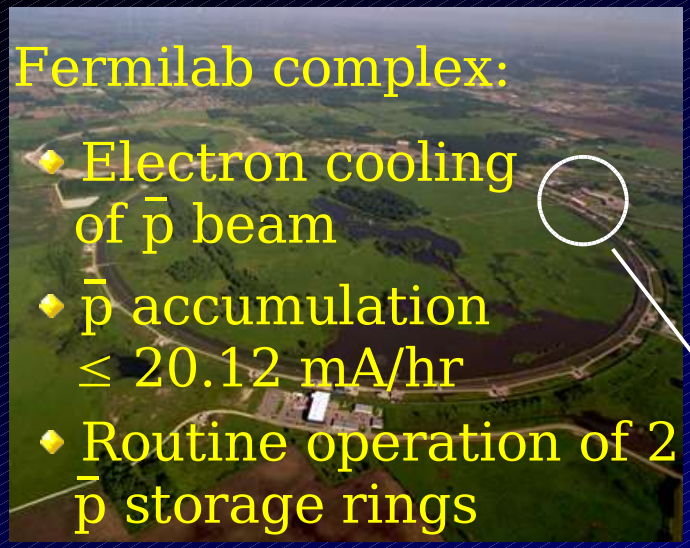
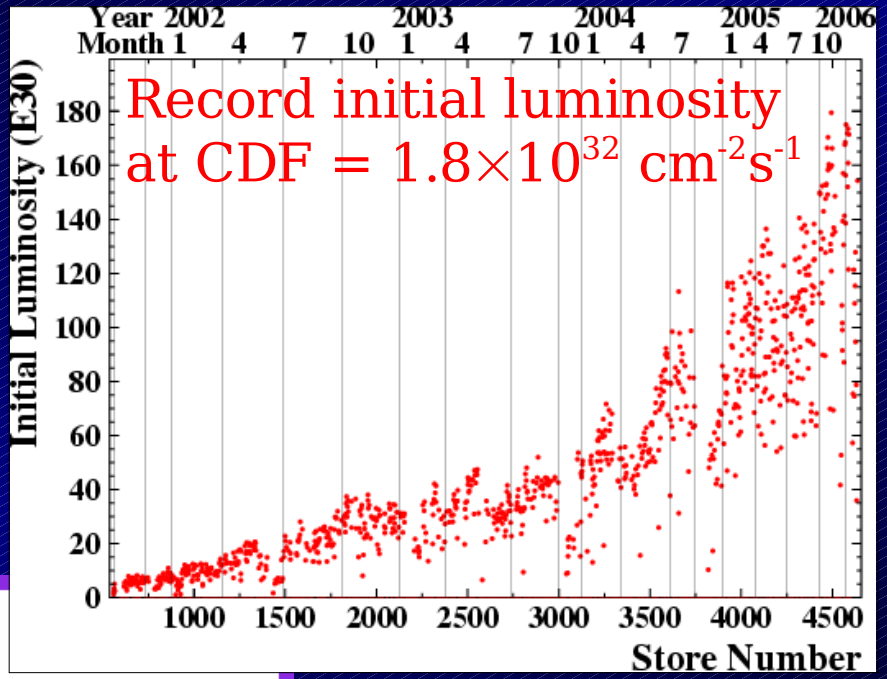
Introduction

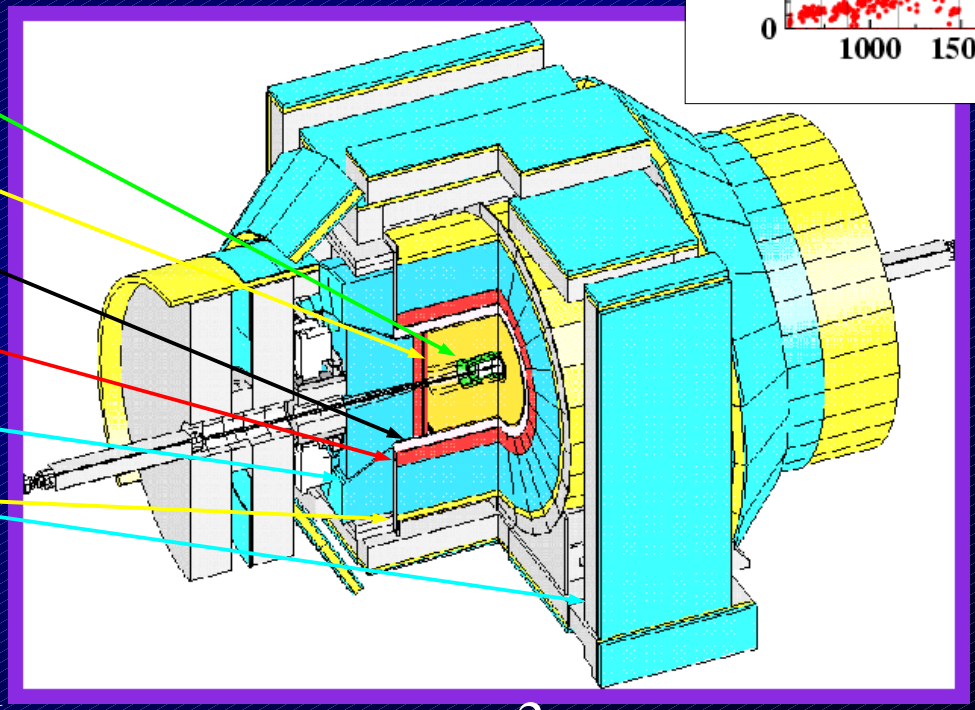
- The Standard Model falls short on several key questions:
  - Do the forces unite?
  - What is dark matter? How about dark energy?
  - What is the true nature of gravity?
  - Do particles get mass from a SM Higgs field, or something more?
- Answers may come through new phenomena:



CDF at the Tevatron

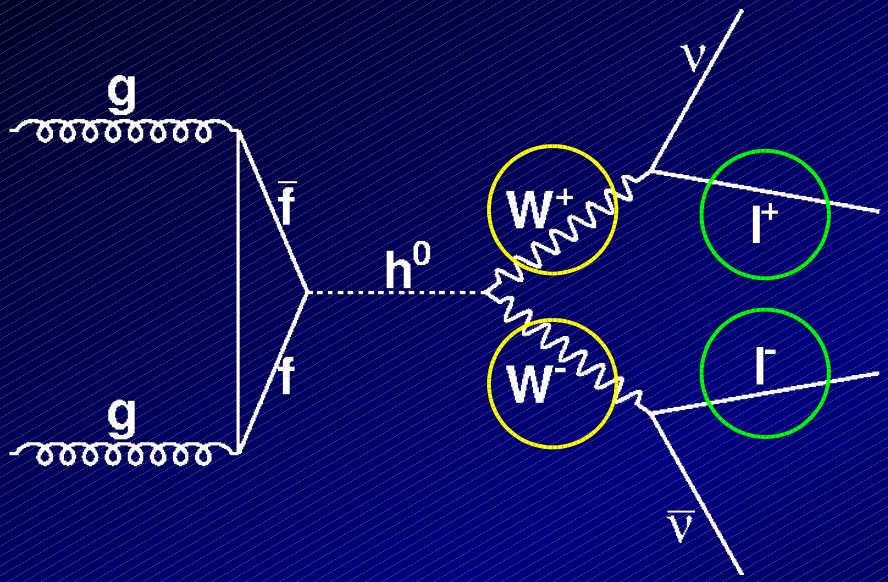






SM Higgs in $h^0 \rightarrow WW^{(*)}$

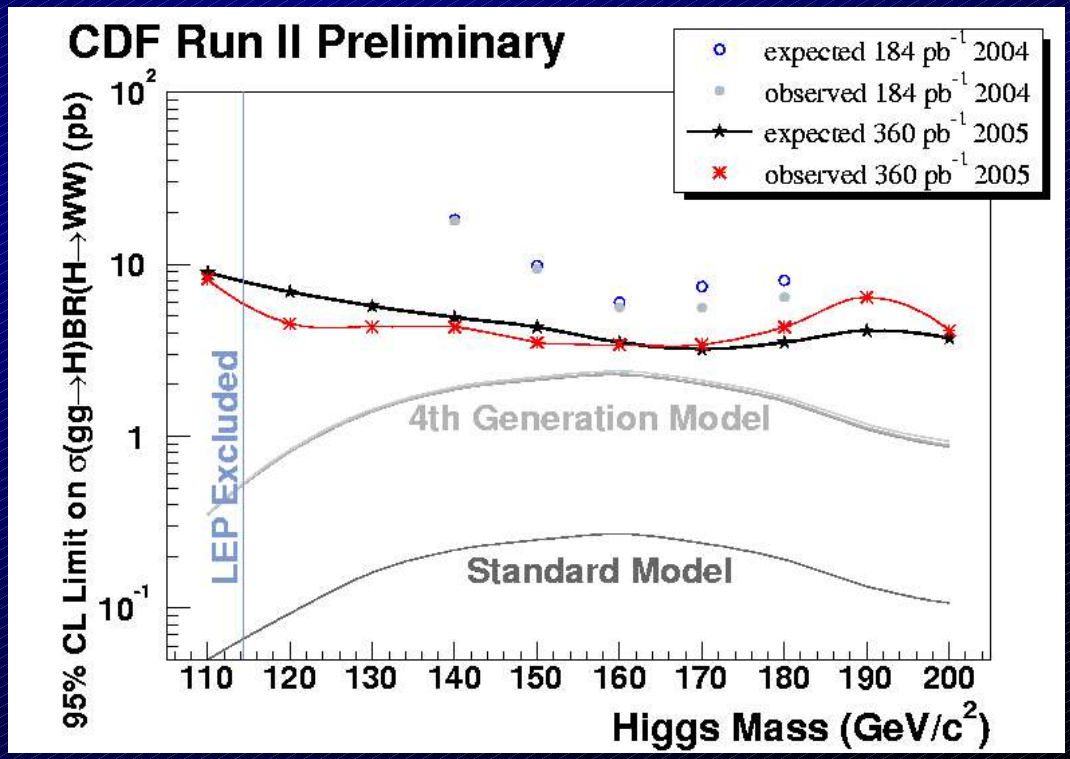
- At Tevatron, single neutral h^0 is dominant Higgs production
- $h^0 \rightarrow$ WW is dominant decay for $M_{Higgs} > 135$ GeV/c^2



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}



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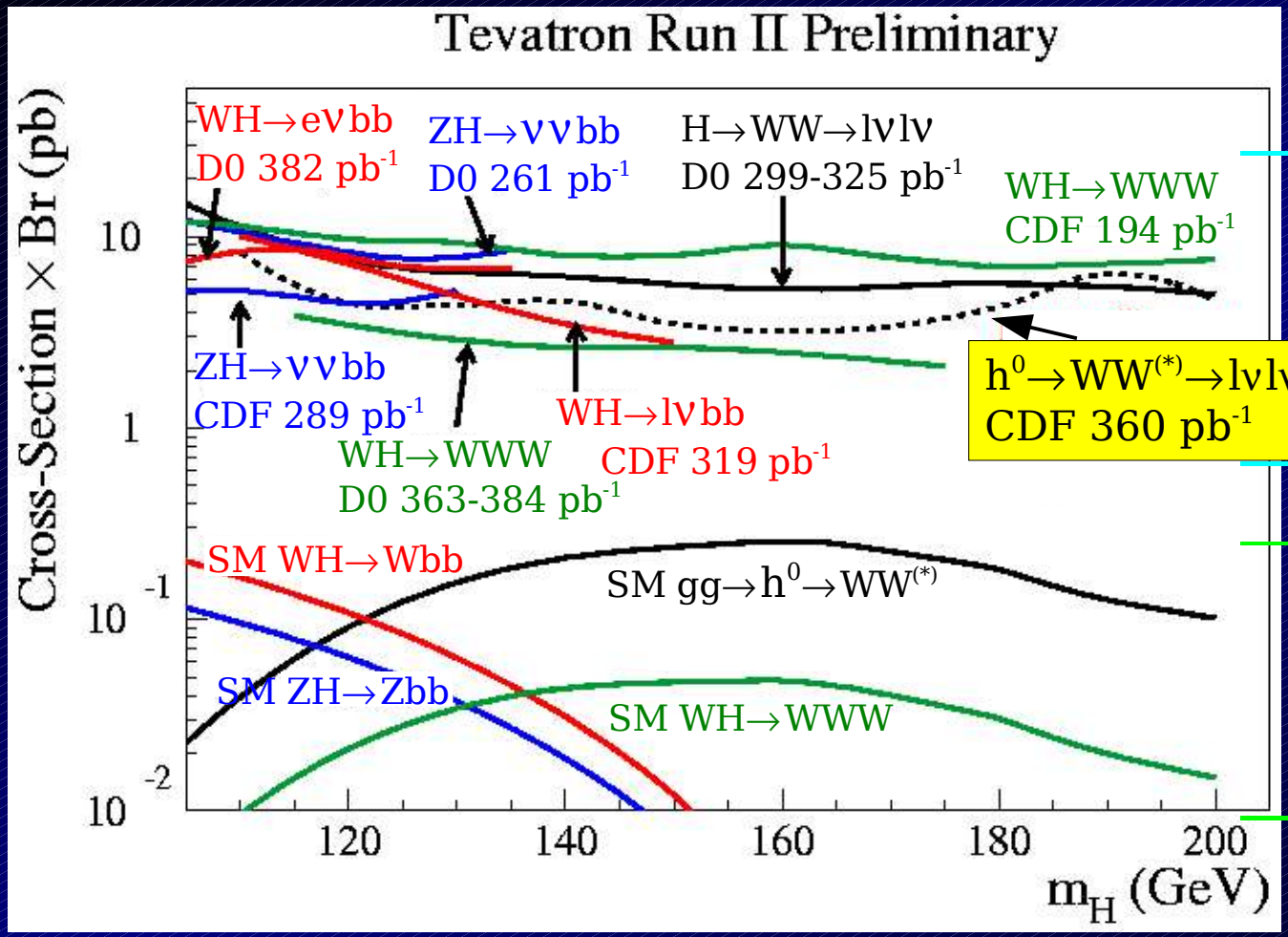


- $h^0 \rightarrow$ WW limit is closest to SM pred. (for higher masses)

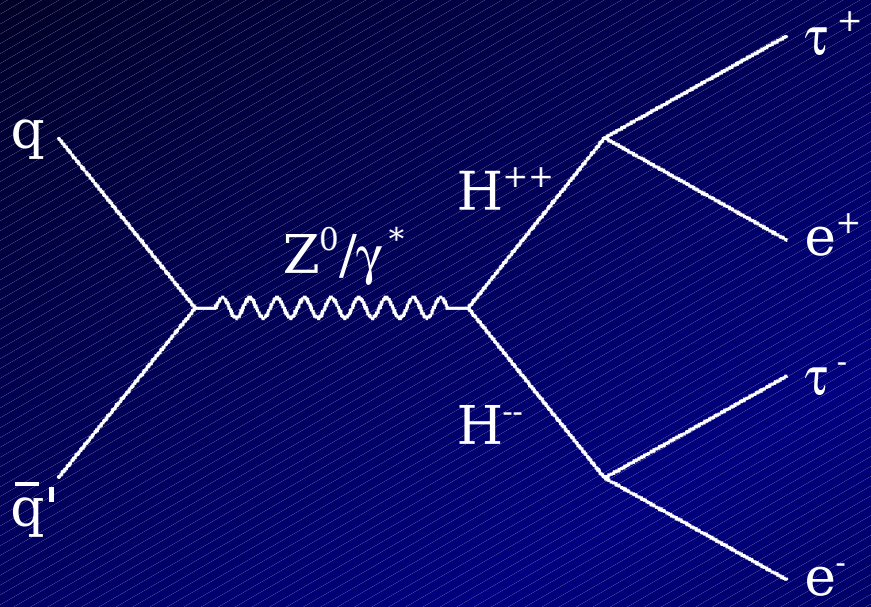
95% CL limits on Cross-section × BR

Standard Model Cross-section × BR

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

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

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

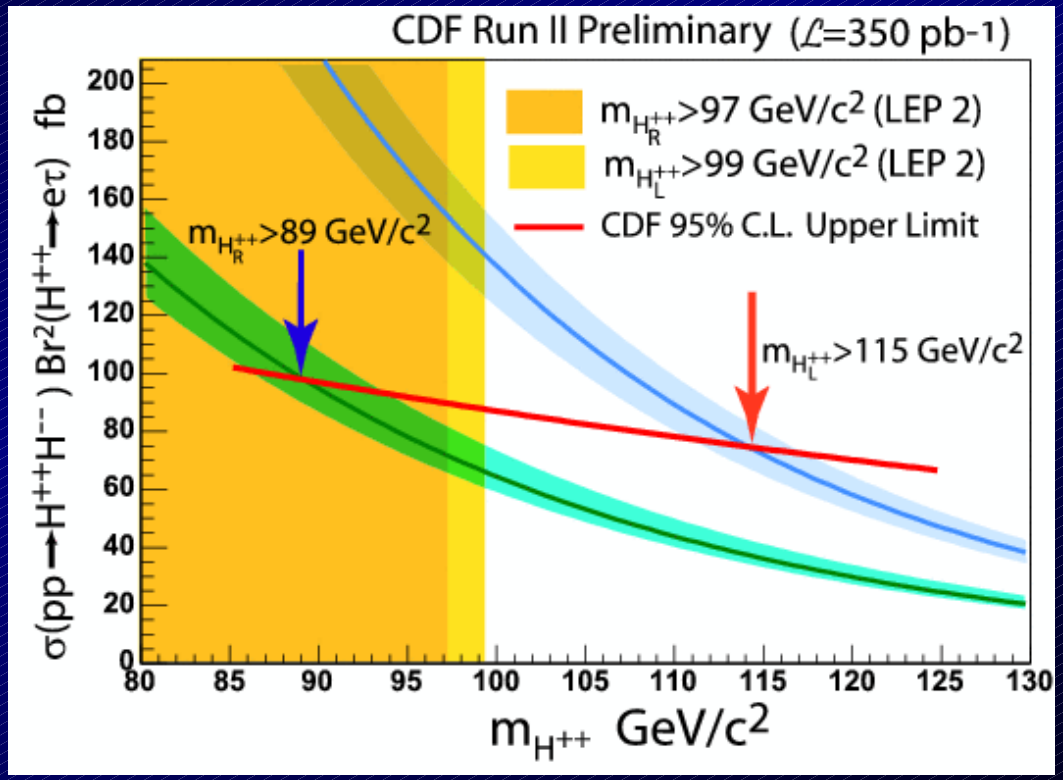


Reconstruct 3 or 4 isolated leptons

Fights hadronic (QCD) backgrounds

$\not{E}_T + \Sigma p_T(\text{leptons}) > 190$ GeV and Z veto

Reduces remaining electroweak bkgs.



Expected background: 0.25 events

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

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

$m_{H_L^{++}} > 115$ 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: $qq \rightarrow gG$, $qg \rightarrow qG$, $gg \rightarrow gG$
- Interpretation for energetic jet + missing E_T
  $E_T > 150$ GeV $\not\!\!E_T > 120$ GeV

Standard Model Backgrounds:

265 ± 30 events

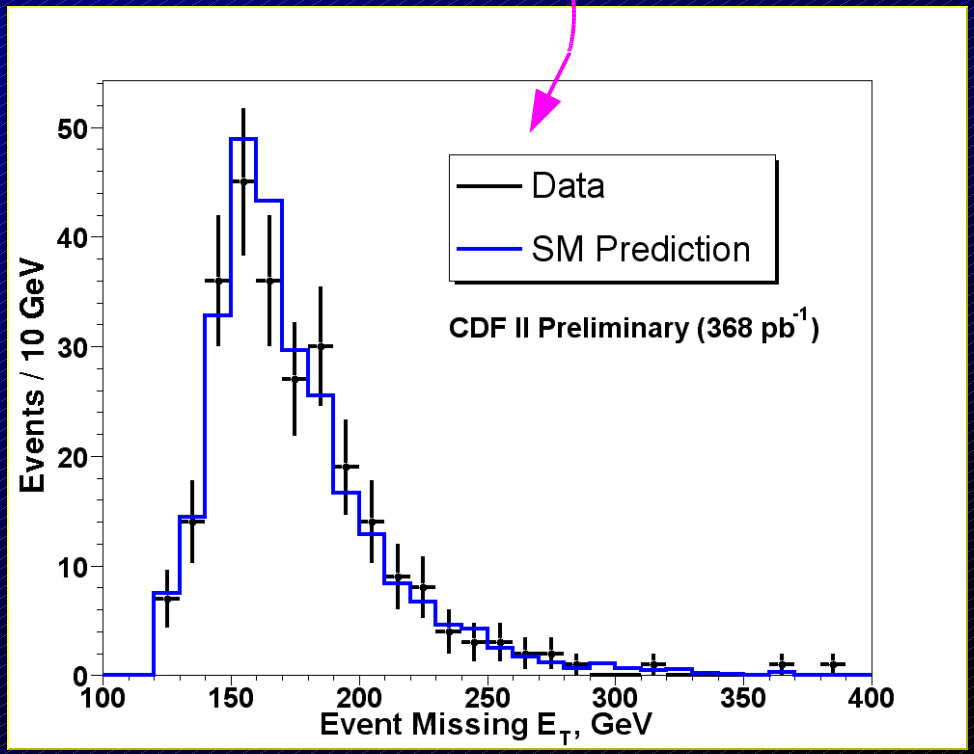
$Z \rightarrow \nu\nu$ +jets (real $\not\!\!E_T$, irreducible)

$W \rightarrow \ell\nu$ +jets ($\not\!\!E_T$ from ν or lost lepton)

QCD ($\not\!\!E_T$ from mis-measured jets)

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

263 events

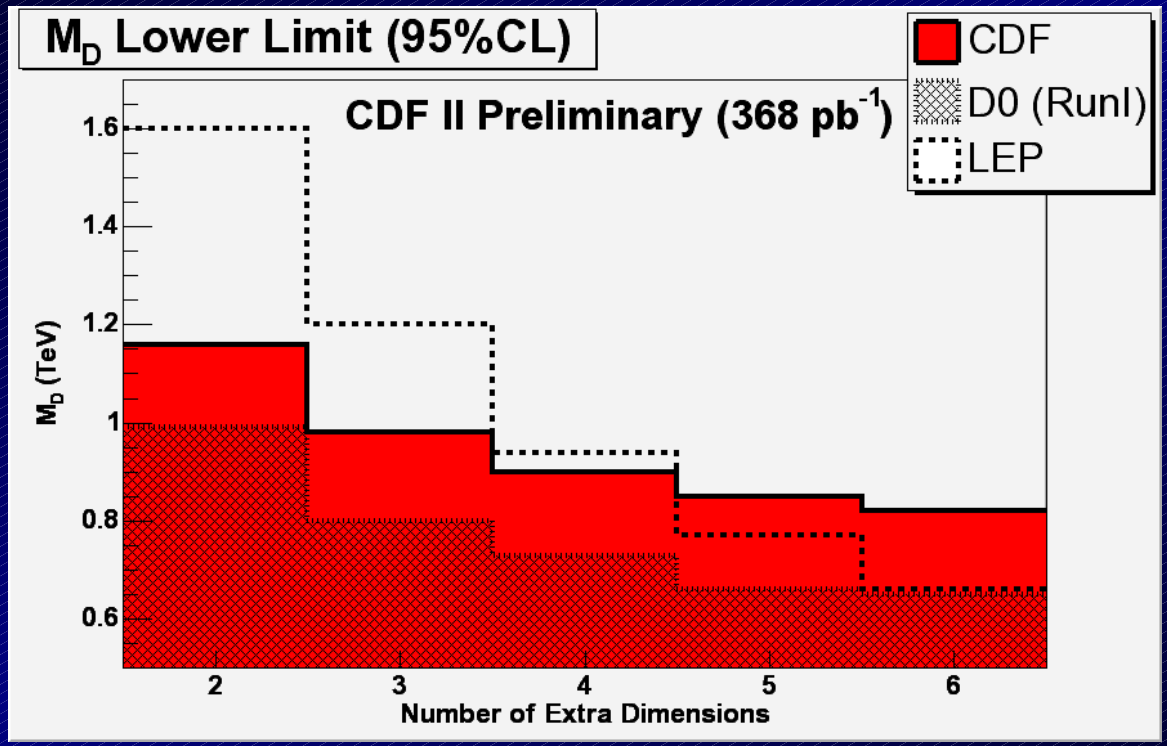


Large Extra Dimensions (II)

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

Effective Planck scale M_D:

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



95% CL limits

n	M_D (TeV)	R (mm)
2	>1.16	<0.36
3	>0.98	$<3.7\times10^{-6}$
4	>0.90	$<1.1\times10^{-8}$
5	>0.85	$<3.5\times10^{-10}$
6	>0.83	$<3.4\times10^{-11}$

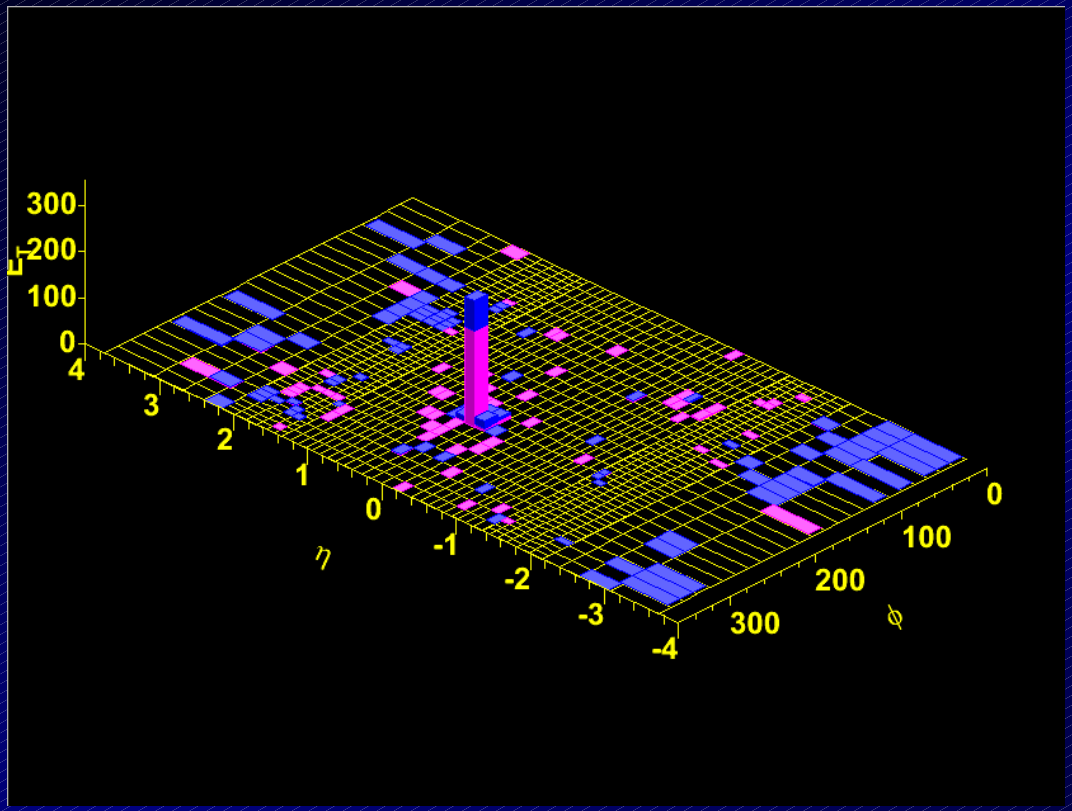
(For $K = \sigma_{NLO}/\sigma_{LO} = 1.3$)

Event Displays for L.E.D.

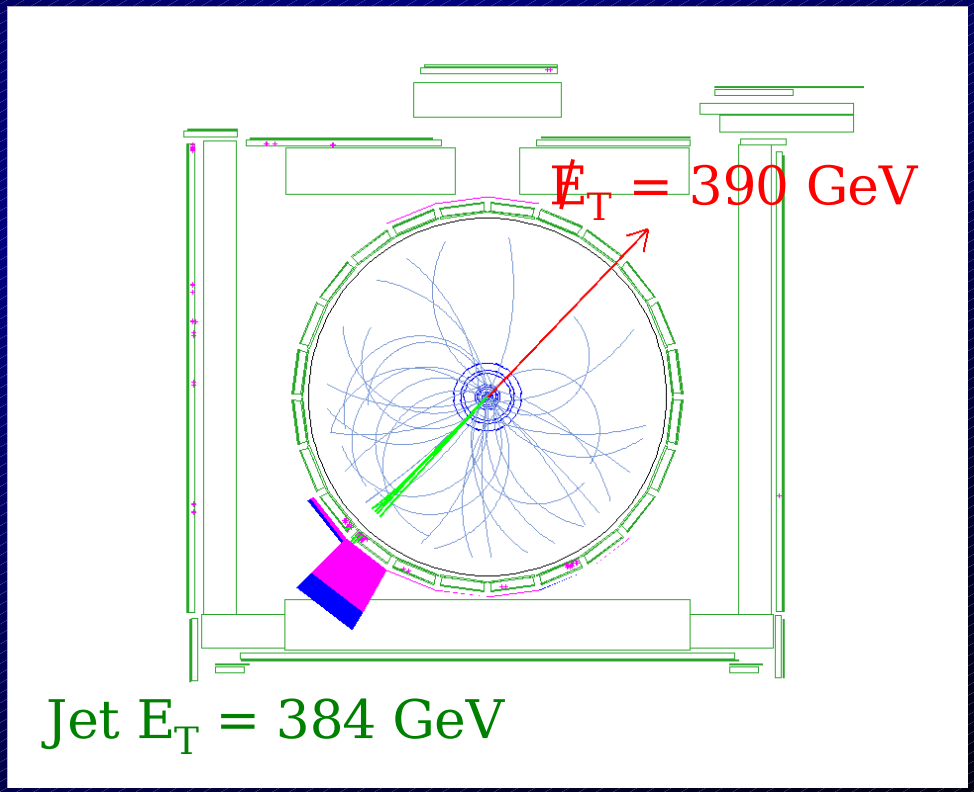
Highest $\not\!\!E_T$ event: $\not\!\!E_T$ = 390 GeV

Jet E_T = 384 GeV

Unrolled calorimeter view:



r-ϕ view:



Shows EM calorimeter energy (purple)

Hadronic calorimeter energy (blue)

Heavy Objects: Z'

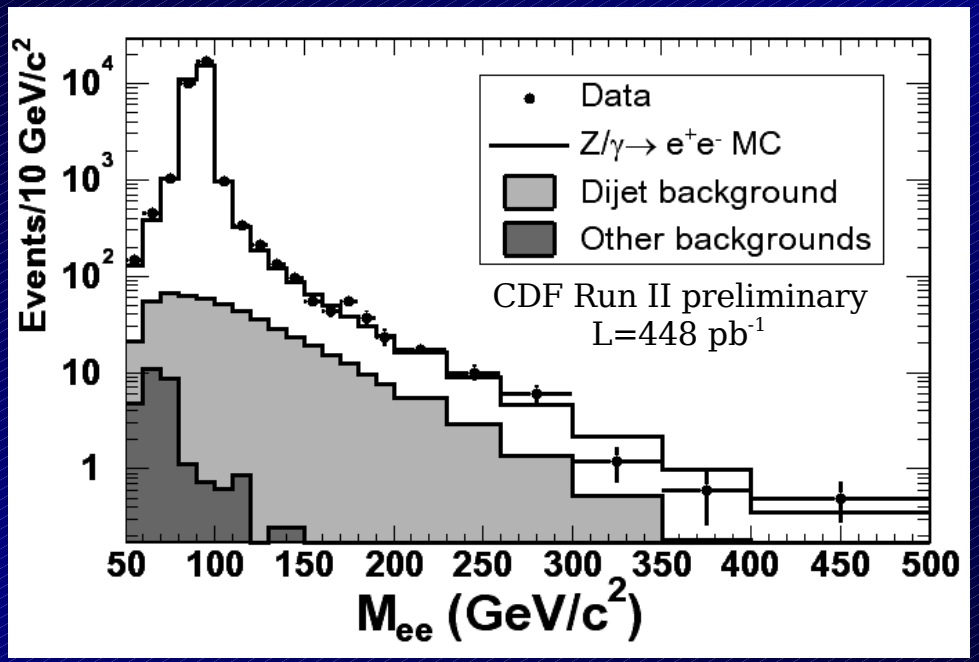
- Search for new physics in di-electron mass and $\cos(\theta^*)$
  - Look for a peak in M_{ee} and look for a distortion in $\cos(\theta^*)$
  - Z' would interfere with the Z/γ^* (just as Z and γ^* interfere in SM)

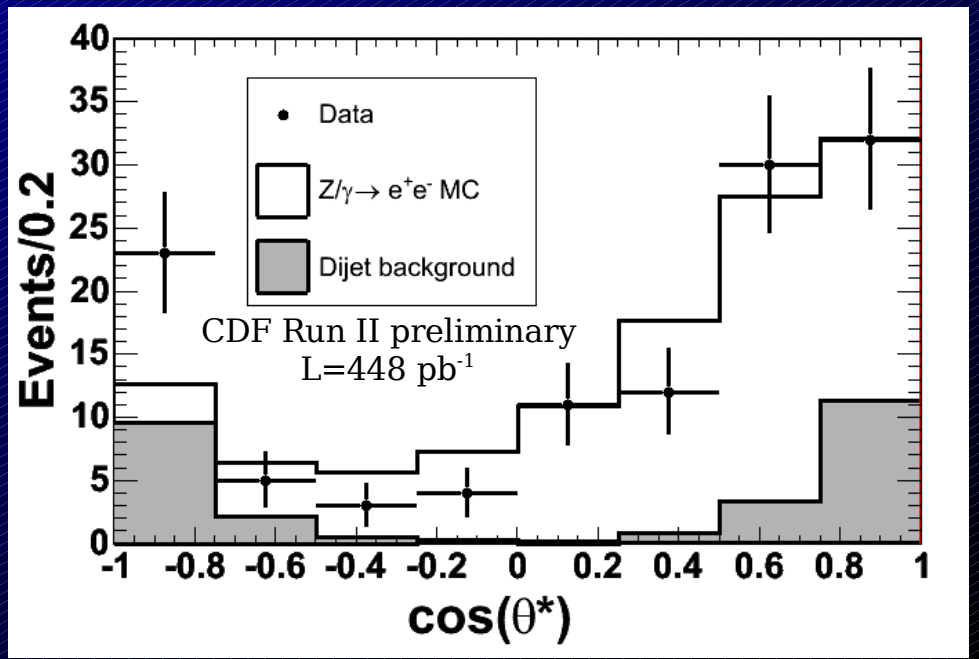
Drell Yan background dominates
MC is normalized to luminosity

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

For $M_{ee} > 200$ GeV/c^2:
Total Standard Model: 115^{+16}_{-19} events
Observed in 448 pb^{-1}: 120 events

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



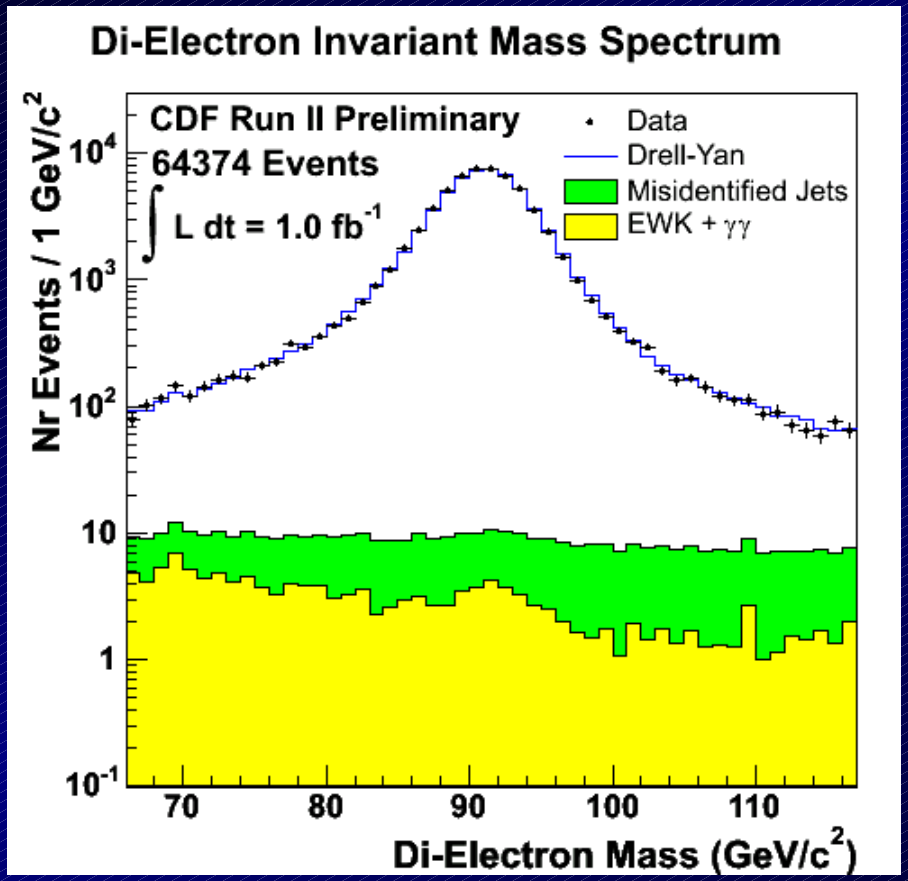


Di-electron Sample

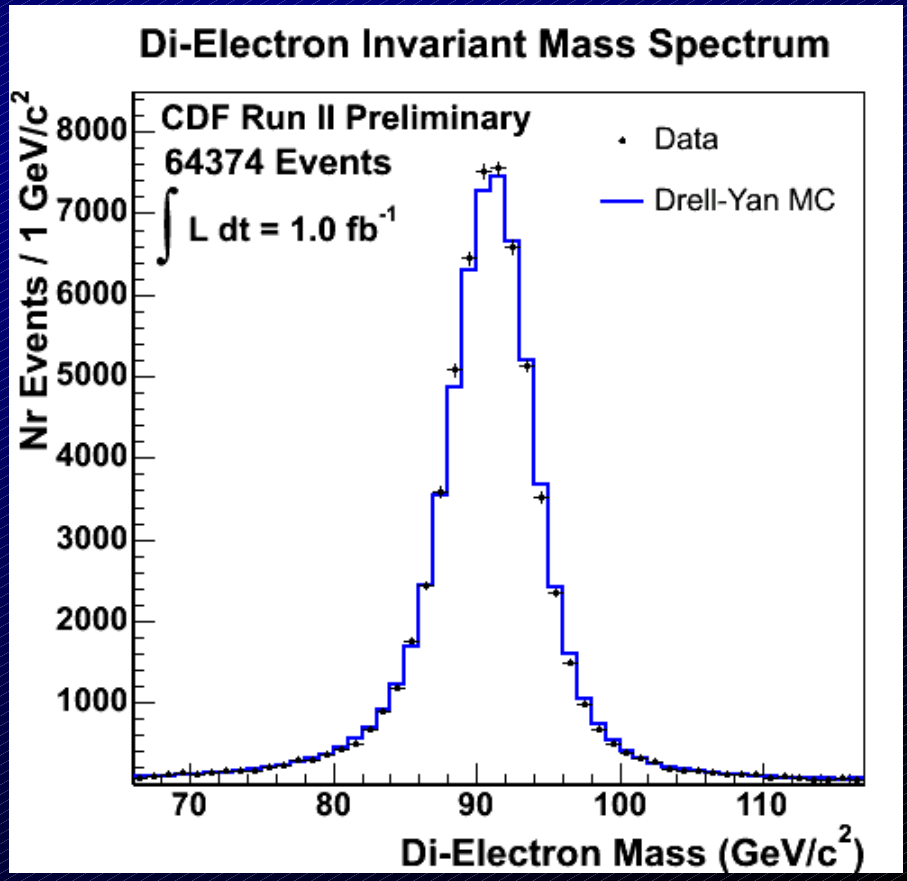
- Will use for di-electron new physics searches at high M_{ee}
  - central/central or central/plug, two electrons with $E_T > 25$ GeV

Plots show range: $66 < M_{ee} < 116$ GeV/c^2

- Drell Yan MC normalized to Z peak region
- Using 1.01 fb^{-1}



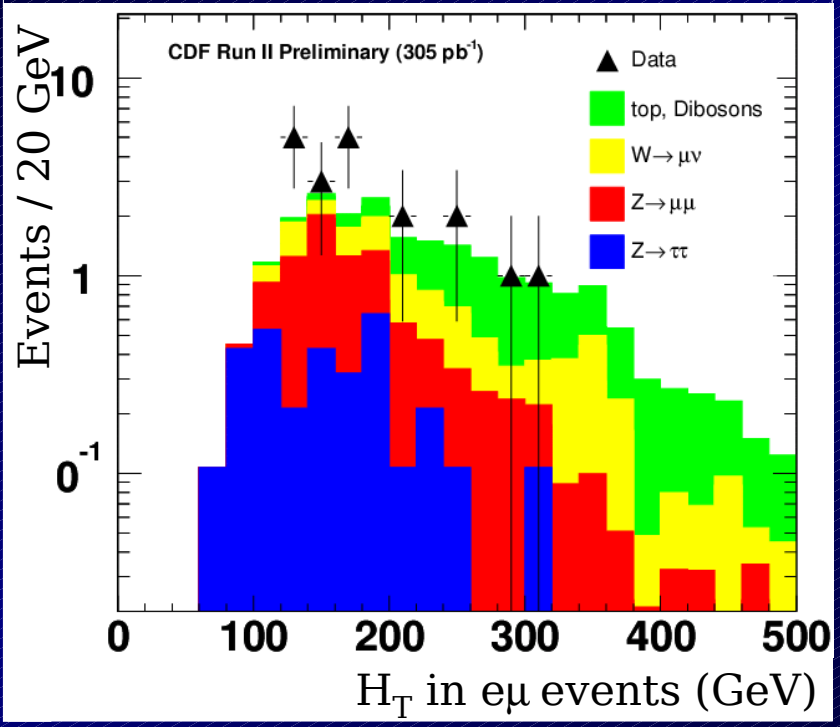
Same, but linear scale



Heavy Objects in Dilepton+X

- Signature based search for anomalous dilepton+X events
  X ∈ { large event H_T, large E_T jets, b-quark jets, 3rd lepton, large $\not\!\!E_T$, ... }
- Open to heavy quarks, b', t', extra dimensions, SUSY
  (Apply first to Bjorken, Pakvasa, Tuan heavy quark model, hep-ph/0206116)
  CKM matrix structure → 3 down-type iso-singlet right-handed quarks:
  $Q_R\overline{Q}_R$ production, with $Q_R \rightarrow$ W/Z/H + u/d

$H_T = E_T(e)+p_T(\mu)+E_T(jet)+\not\!\!E_T$



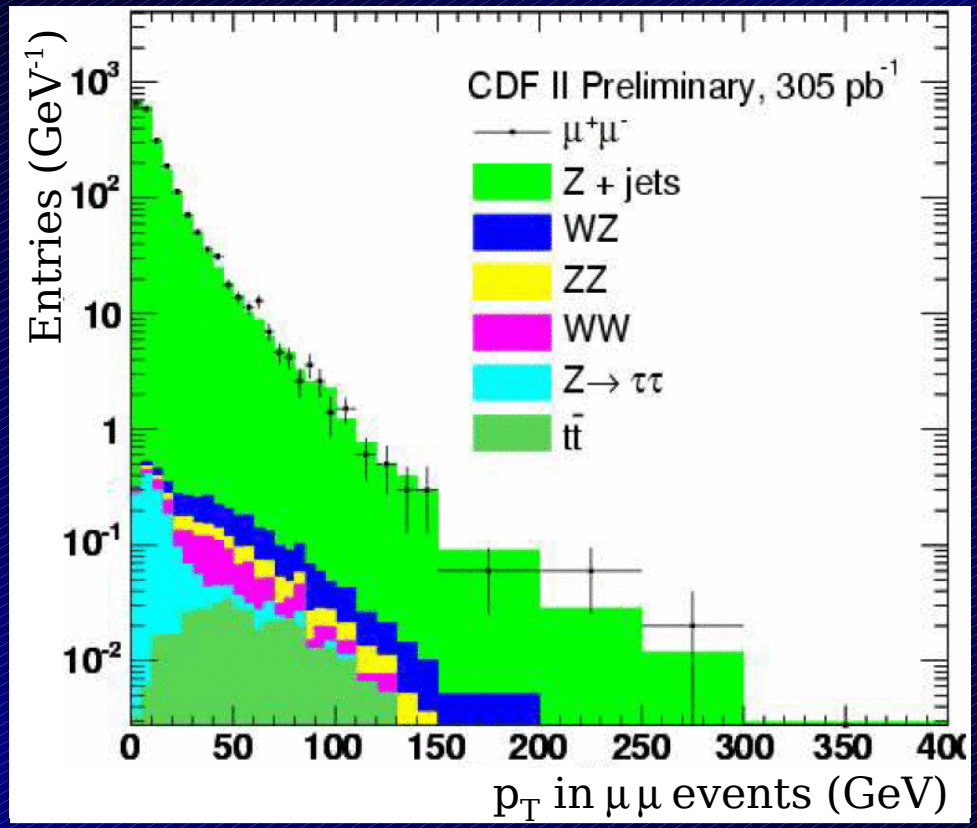
- Dilepton(eμ) + ≥2 jets(E_T>50 GeV)
  Control region: H_T < 200 GeV
  Signal region: H_T > 400 GeV
- No events seen in 305 pb^{-1} of data
  Expect: 0.802 ± 0.440 SM
  0.526 ± 0.058 QQ

$4.49\times\sigma_Q$ = 90% CL limit
σ_Q= 0.289 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 $\not\!\!E_T$, photon, or b-quark jets

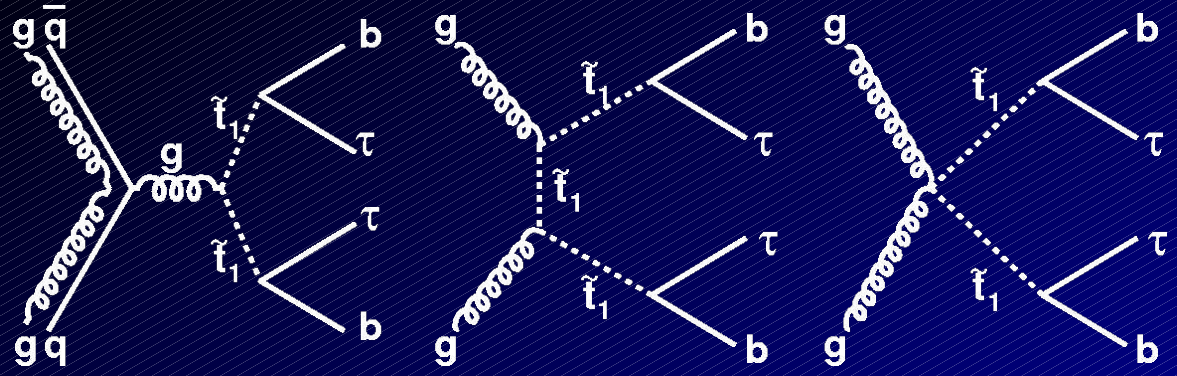


- Z mass cut: $66 < M_{ll} < 116$ GeV/c^2
- Z p_T agrees between data and SM background (Monte Carlo)
- Limits obtained on differential cross section of extra Z production as function of p_T
  Example, using signature of heavy quark model: $Q_R\overline{Q}_R \rightarrow udWZ$

$\sigma < 0.170 \pm 0.005$ 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 $p_T(\text{lepton}) + p_T(\tau_h) + \not{E}_T > 85$ GeV

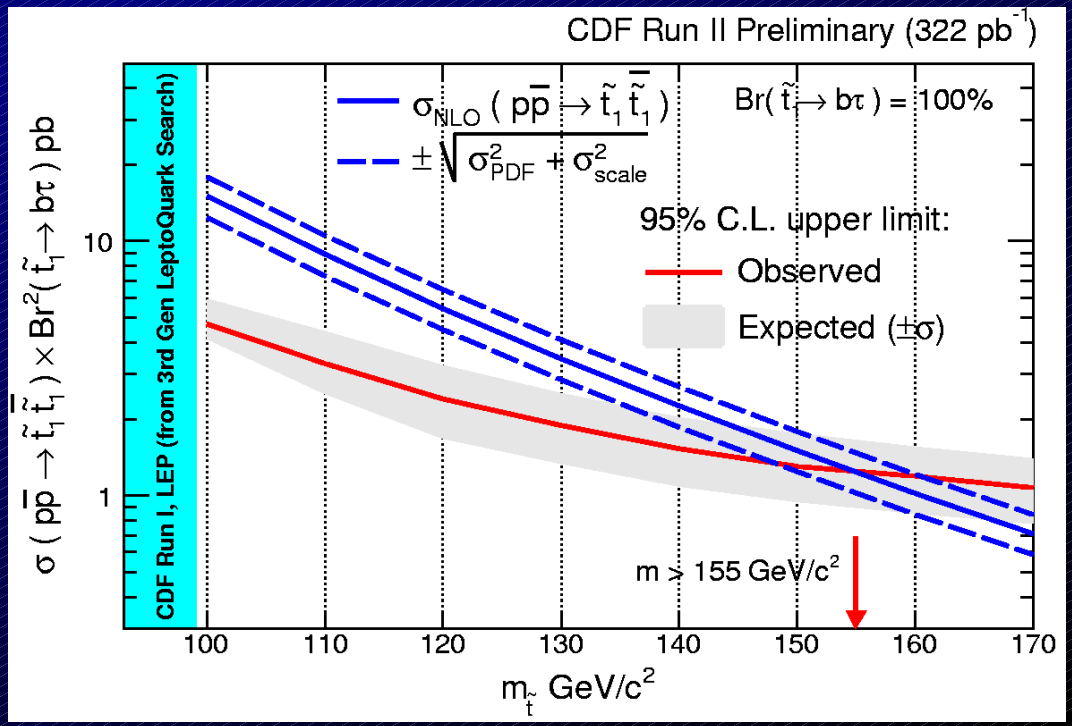
W+jets (jet fakes tau) reduced using transverse mass of (lepton, $\not{E}_T$)

Expected SM: $2.26\ ^{+0.46}_{-0.22}$ events

Observed in 322 pb^{-1}: 2 events

$m_{stop} > 155$ 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!