



New Phenomena Searches at CDF

Aron Soha

(University of California at Davis)

For the CDF Collaboration

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Lake Louise Winter Institute

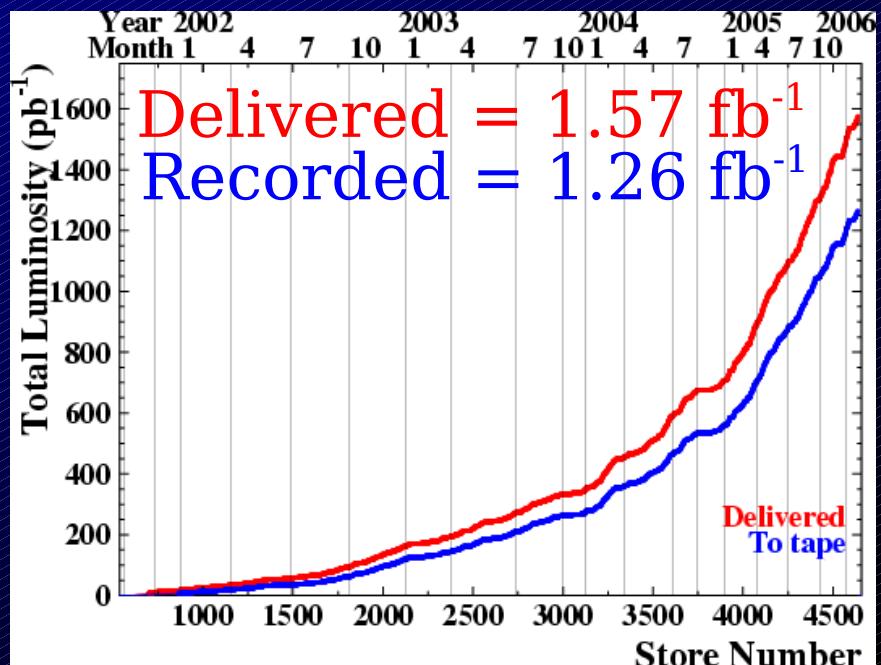
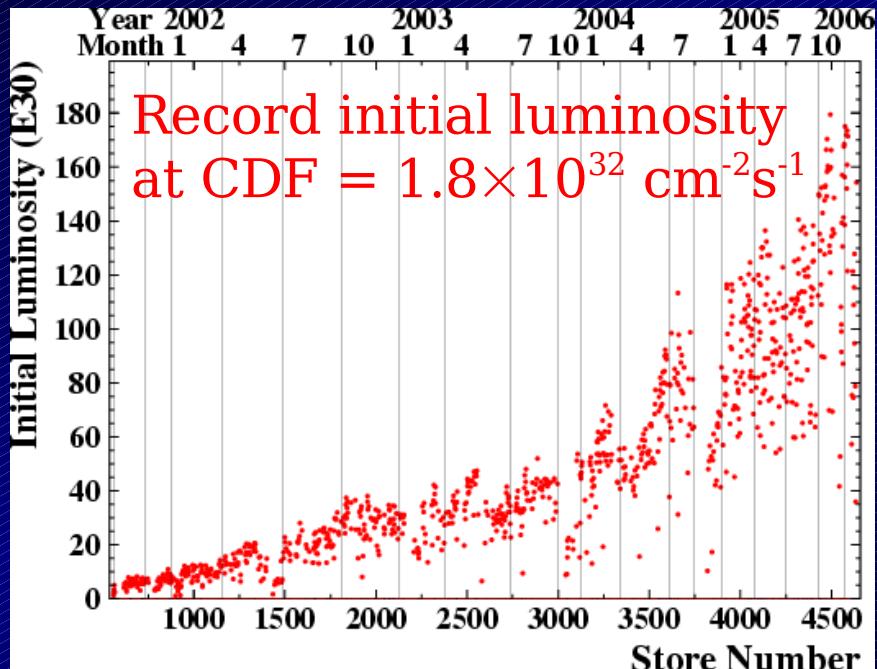
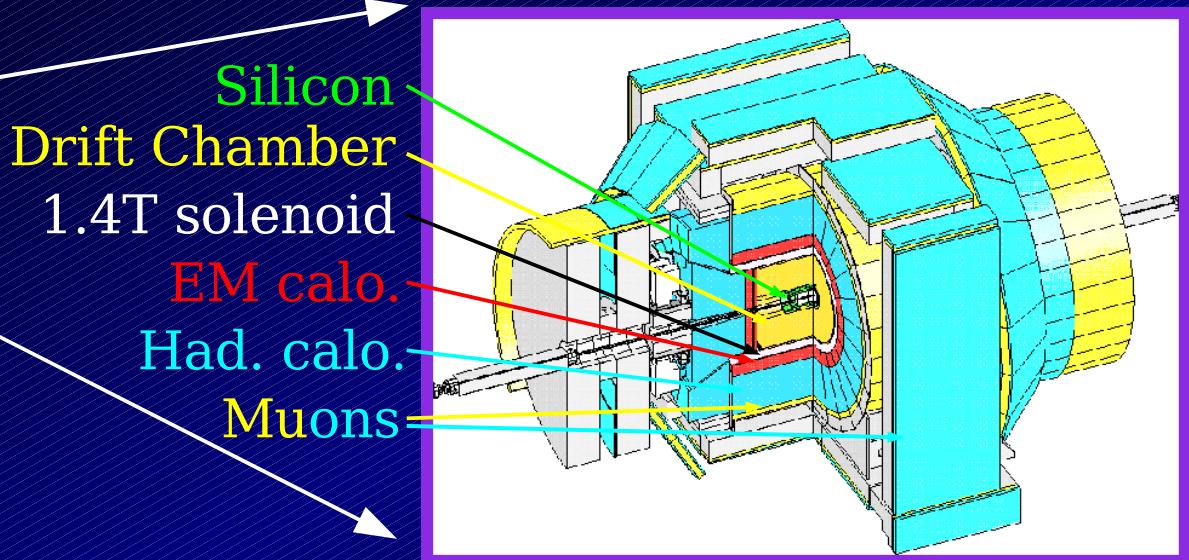
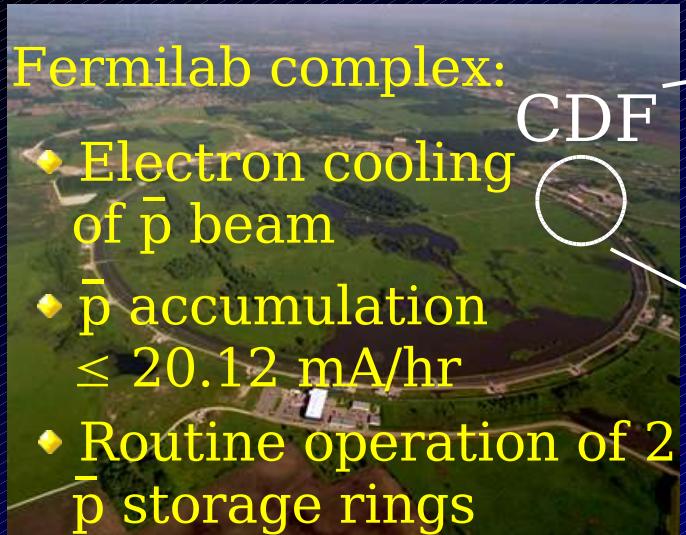


Introduction

- 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:

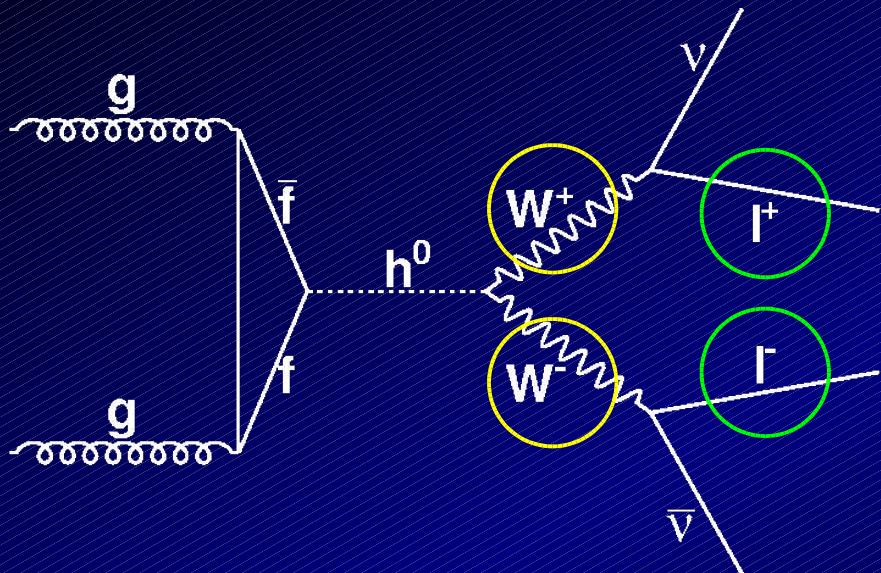


CDF at the Tevatron



Higgs in $H \rightarrow WW^{(*)}$

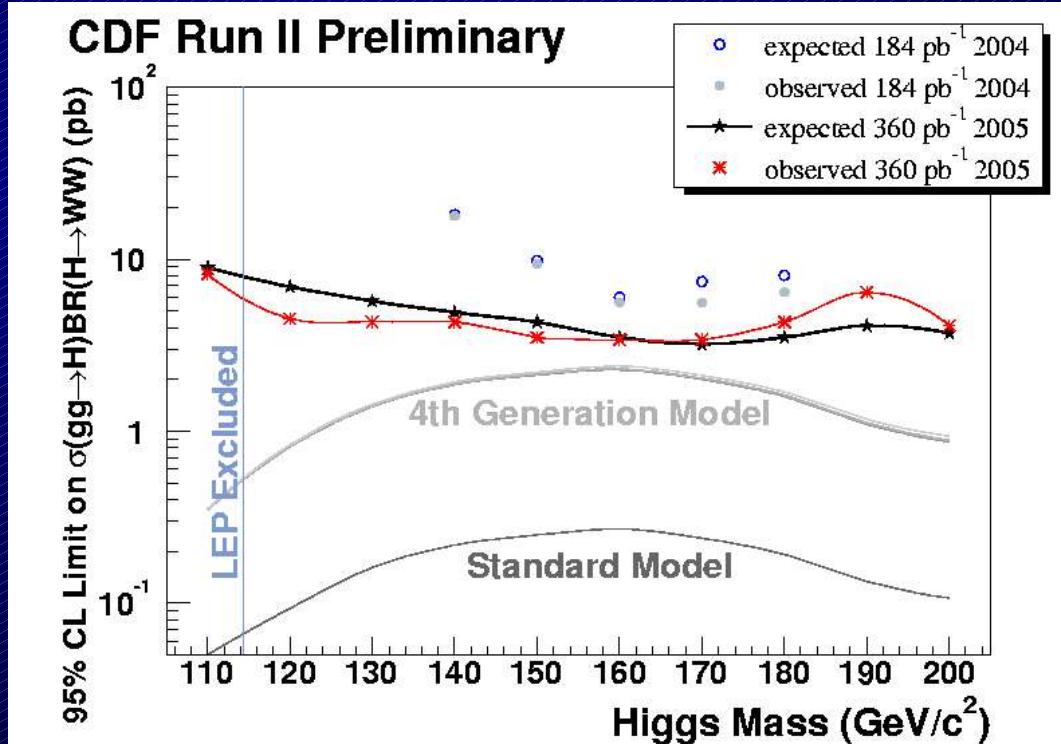
- At Tevatron, single neutral h^0 is dominant Higgs production
- $H \rightarrow WW$ is dominant decay for $M_{Higgs} > 135 \text{ GeV}/c^2$



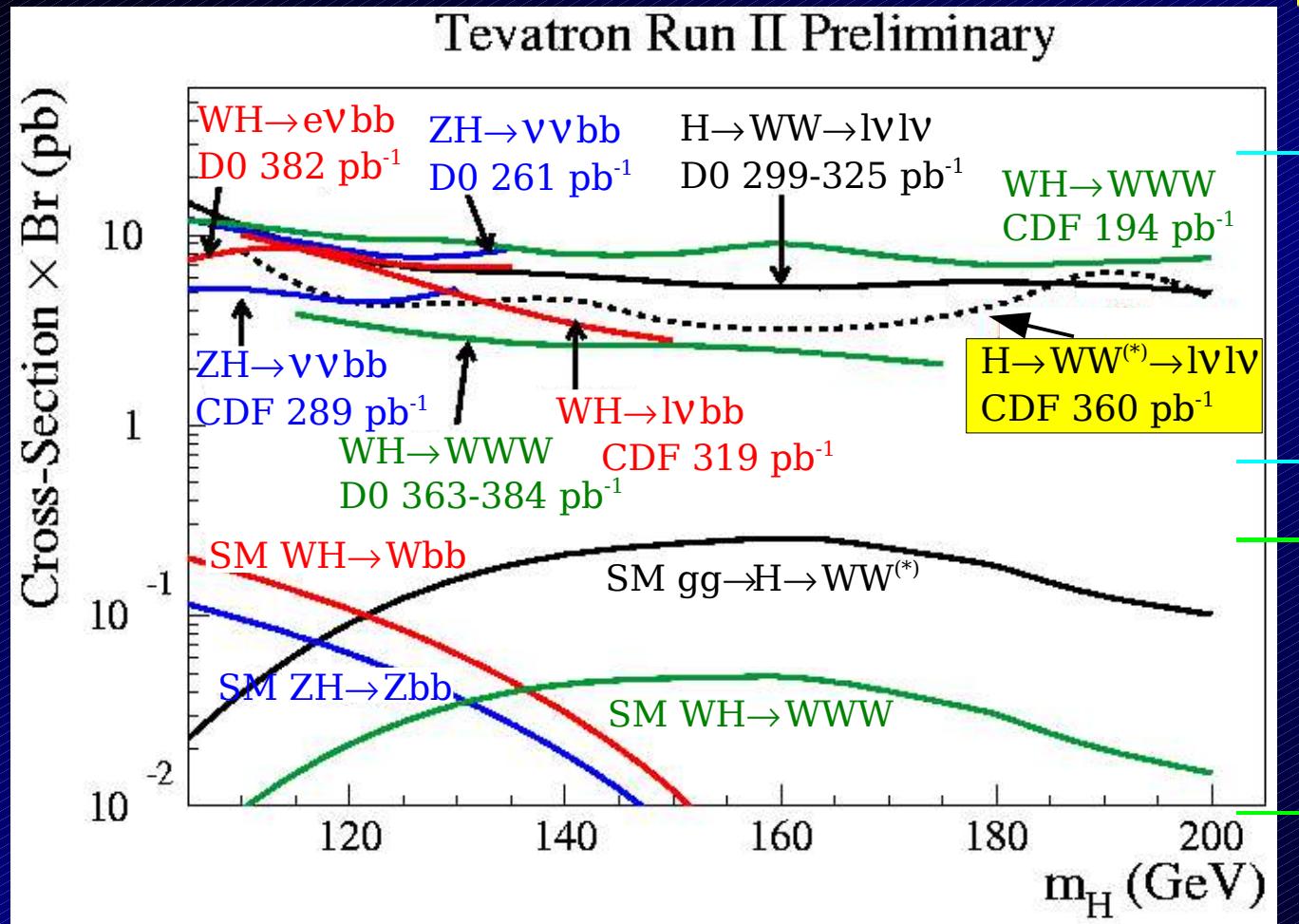
Use $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$ decay modes

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

Updated to 360 pb^{-1}



Higgs in $H \rightarrow WW^{(*)}$



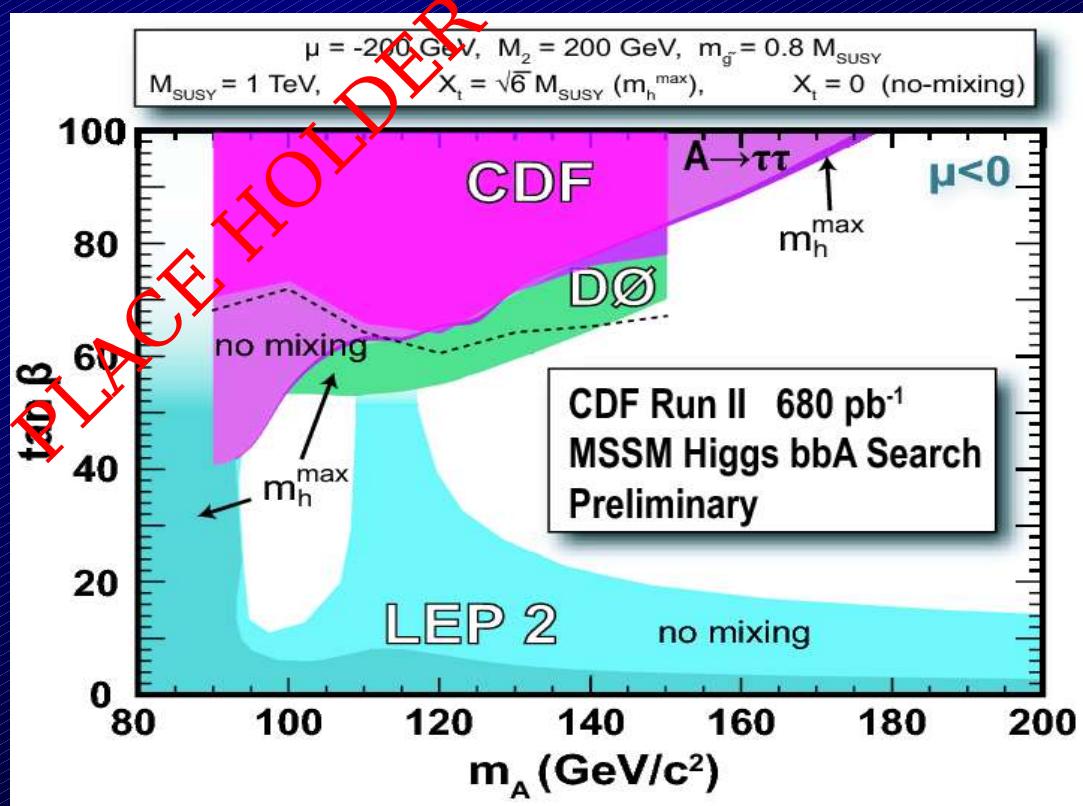
- $H \rightarrow WW$ limit is closest to SM pred. (for higher masses)

95% CL limits on Cross-section × BR

Standard Model Cross-section × BR

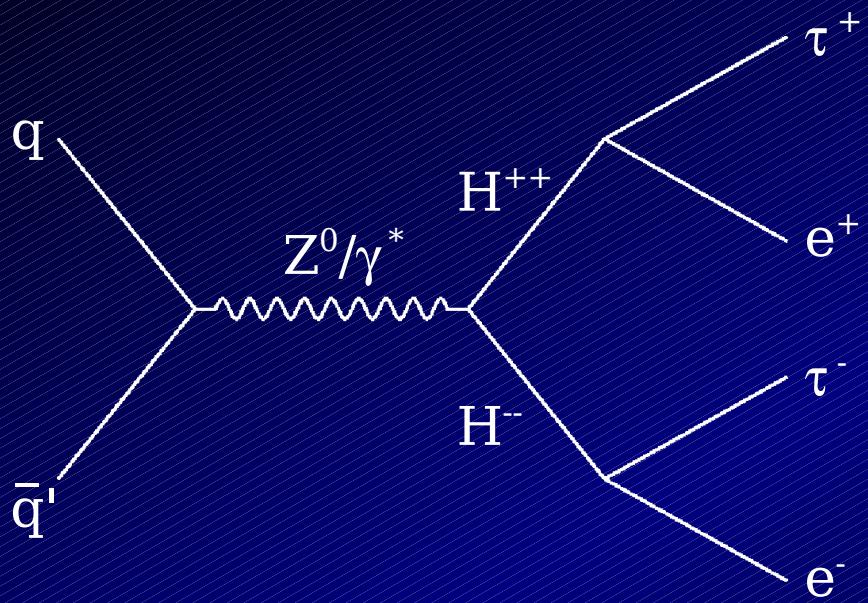
Higgs in $p\bar{p} \rightarrow (b)bH \rightarrow (b)bbb$

- Featured in MSSM scenarios with high $\tan\beta$
 bbH coupling $\sim \tan^2\beta$, cross-section is $O(10 \text{ pb})$
- Require ≥ 3 jets with $E_T > 20 \text{ GeV}$, with 3 that are b-tagged
QCD background mimics signal, so:
 - Require 3 b-tagged jets
 - Use di-jet mass of leading 2 jets
 - Shape depends on 3rd jet flavor
 - Ratio of correct b-tags to mis-tags determined in fit to data
- No evidence found, so limit set using 680 pb^{-1}

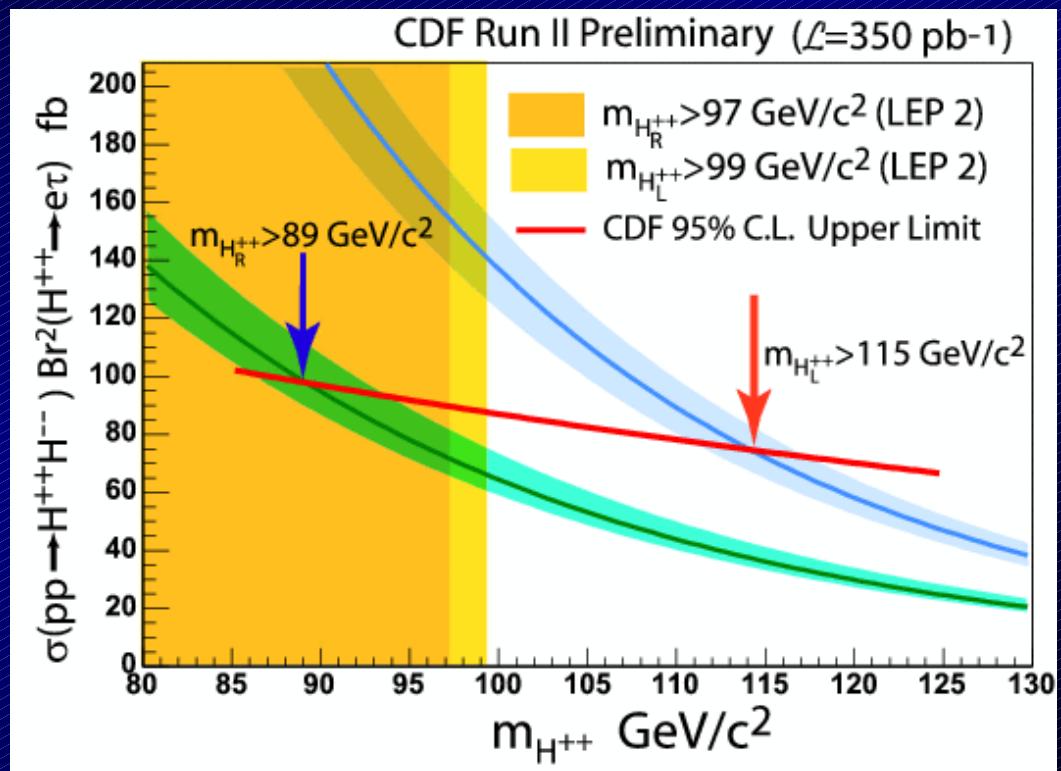


Search For $H^{++} H^{-}$

- 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: $q\bar{q} \rightarrow gG$, $g\bar{g} \rightarrow q\bar{G}$, $g\bar{g} \rightarrow g\bar{G}$
- Interpretation for energetic jet + missing E_T
 $E_T > 150 \text{ GeV}$ $\cancel{E}_T > 120 \text{ GeV}$

Standard Model Backgrounds:

265 ± 30 events

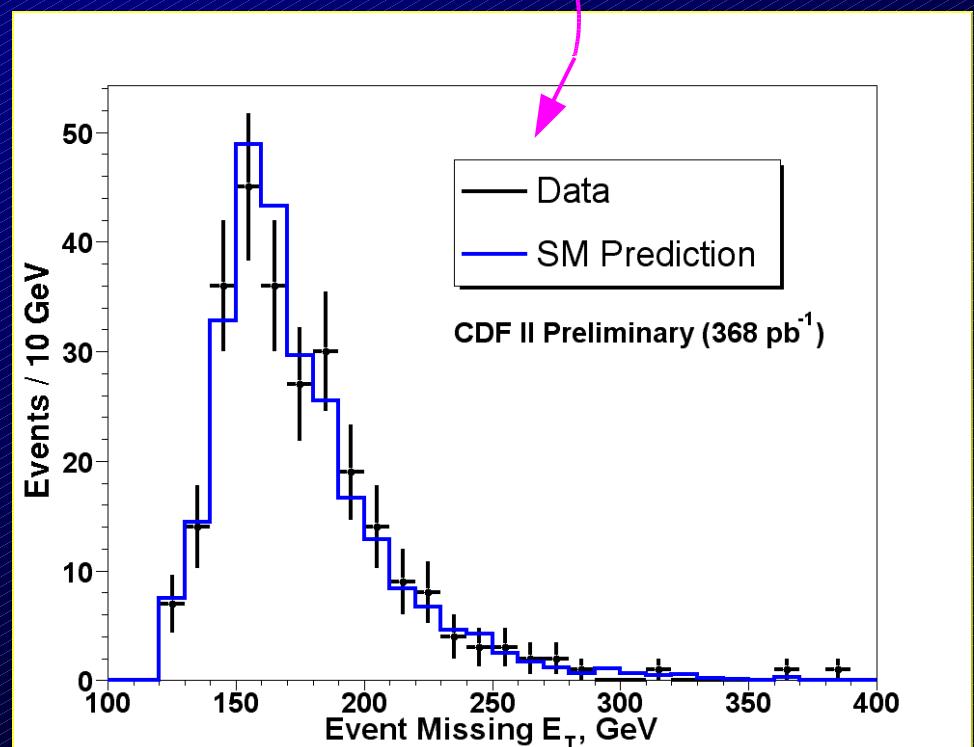
$Z \rightarrow vv + \text{jets}$ (real \cancel{E}_T , irreducible)

$W \rightarrow \ell v + \text{jets}$ (fake \cancel{E}_T from lost lepton)

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

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

263 events



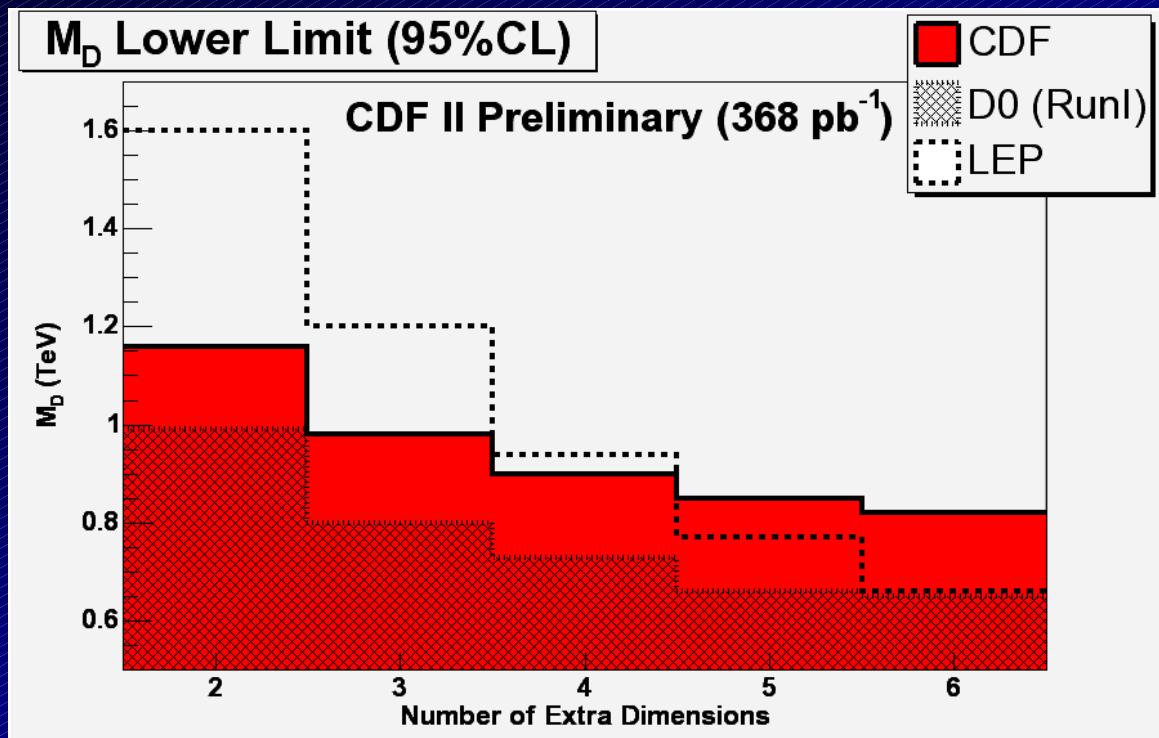
Large Extra Dimensions (II)

- 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

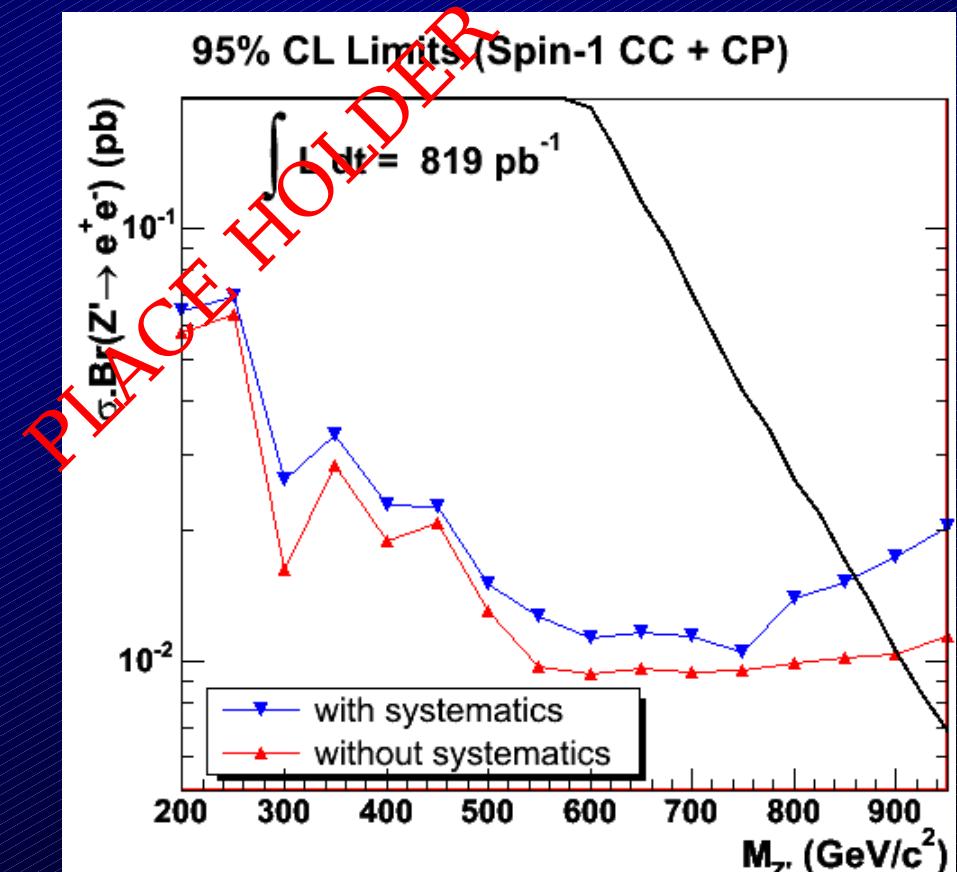
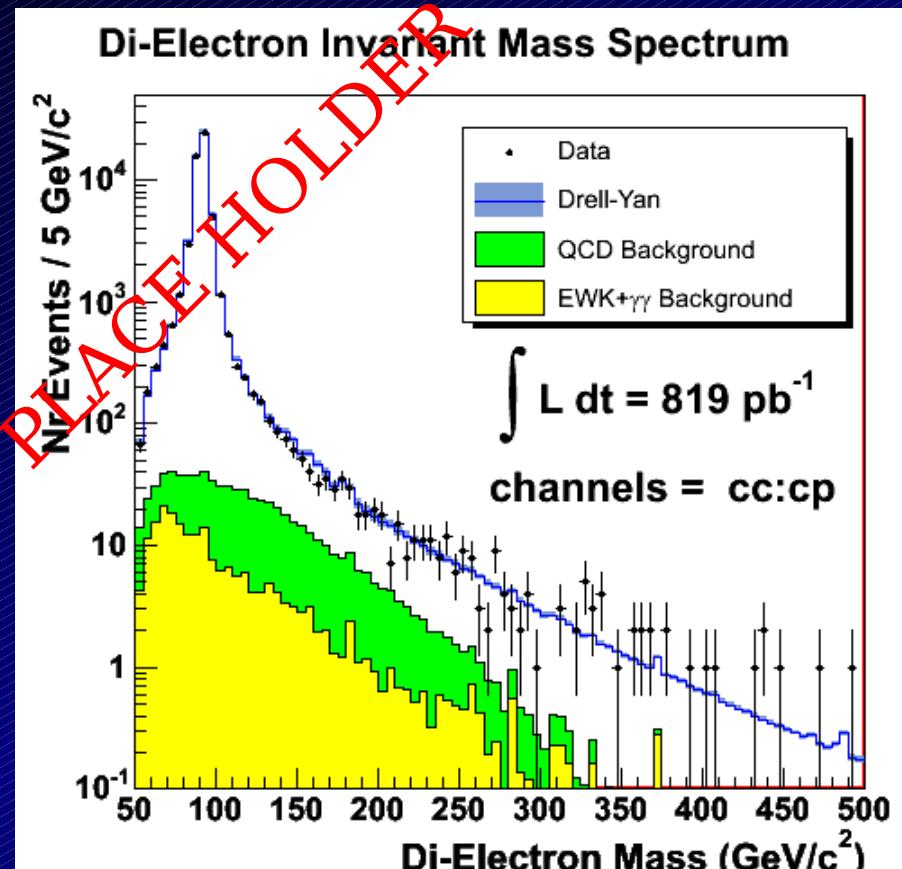


n	M_D (TeV)	R (mm)
2	>1.16	<0.36
3	>0.98	$<3.7 \times 10^{-6}$
4	>0.90	$<1.1 \times 10^{-8}$
5	>0.85	$<3.5 \times 10^{-10}$
6	>0.83	$<3.4 \times 10^{-11}$

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

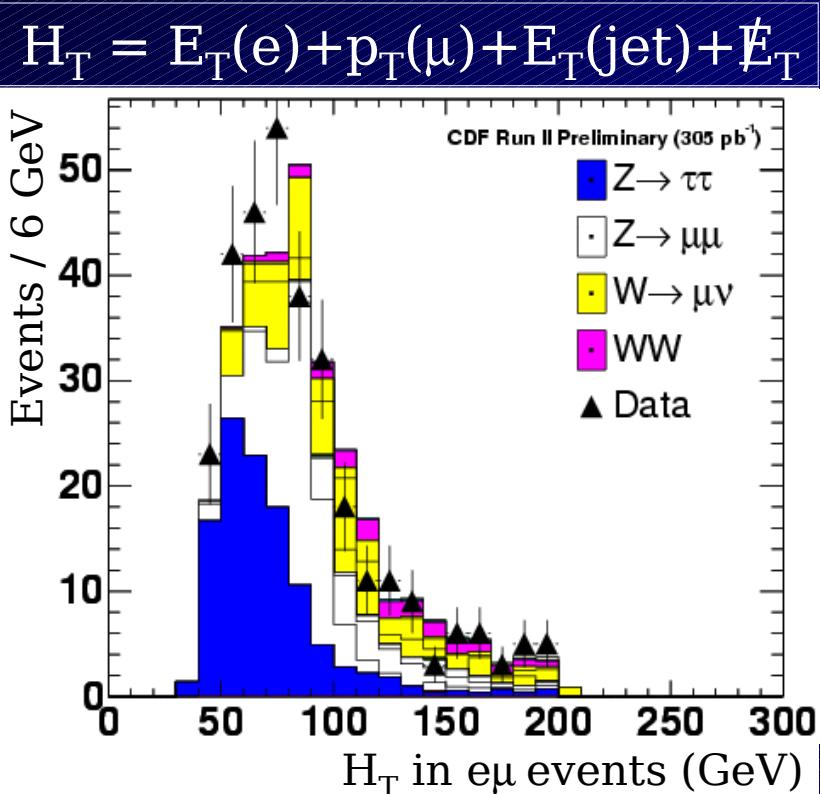
Heavy Objects: Z'

- Search for new physics in di-electron high mass spectrum
Two central/central or central/plug electrons, each with $E_T > 25$ GeV
Drell Yan background dominates
Estimated by normalizing simulation to data in region of Z peak



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 $Q_R \rightarrow W/Z/H + u/d$

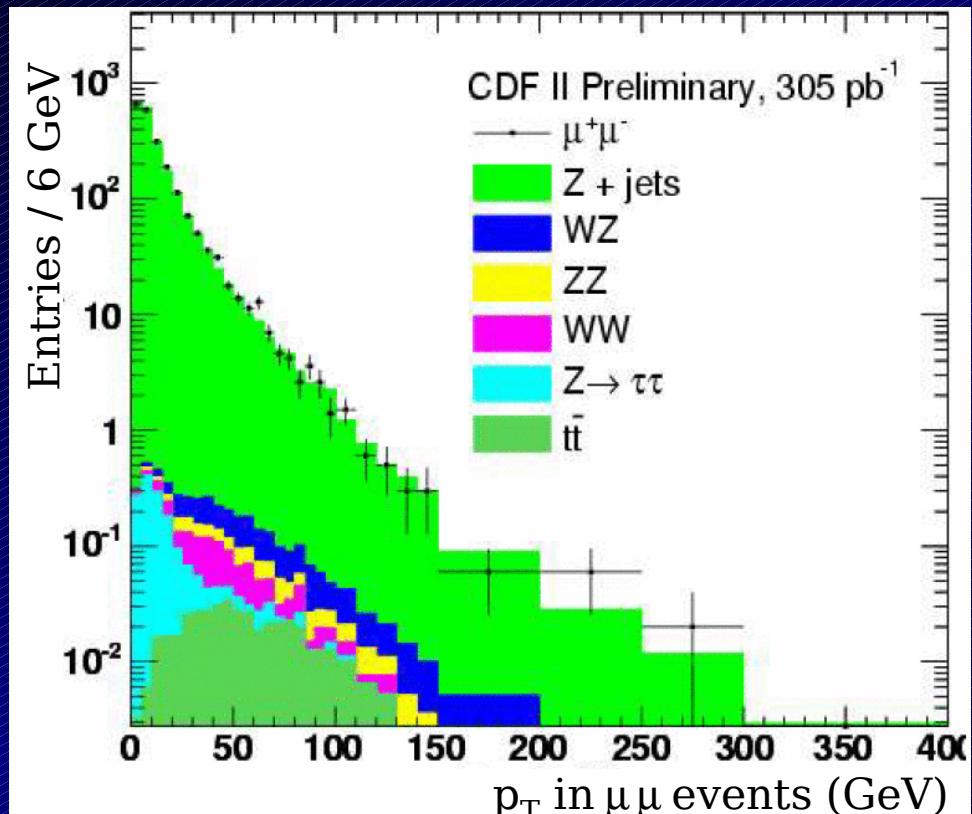
- Dilepton($e\mu$) + ≥ 2 jets($E_T > 50$ GeV)
- Control region: $H_T < 200$ GeV
- Signal region: $H_T > 400$ GeV
- No events seen in 305 pb⁻¹ of data
Expect: 0.802 ± 0.440 SM
 0.526 ± 0.058 QQ

$4.49 \times \sigma_Q = 90\% \text{ CL limit}$
 $\sigma_Q = 0.289 \text{ pb for } 300 \text{ GeV quark}$

Will soon update to $> 700 \text{ pb}^{-1}$

... 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: $66 < M_{ll} < 116 \text{ GeV}/c^2$
- 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: $Q_R\bar{Q}_R \rightarrow udWZ$

$\sigma < 0.170 \pm 0.005 \text{ pb}$
95% CL limit, for 300 GeV quark

SUSY: Squarks & Gluinos

- mSUGRA scenarios with R-parity conservation

Production:

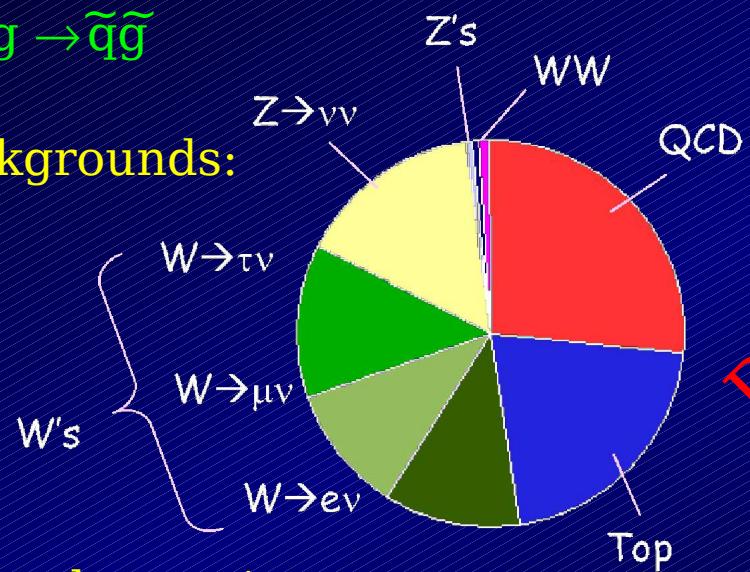
$$q\bar{q} \rightarrow \tilde{q}\tilde{\bar{q}}, \tilde{g}\tilde{g}$$

$$gg \rightarrow \tilde{q}\tilde{\bar{q}}, \tilde{g}\tilde{g}$$

$$qq \rightarrow \tilde{q}\tilde{\bar{q}}$$

$$qg \rightarrow \tilde{q}\tilde{g}$$

Backgrounds:



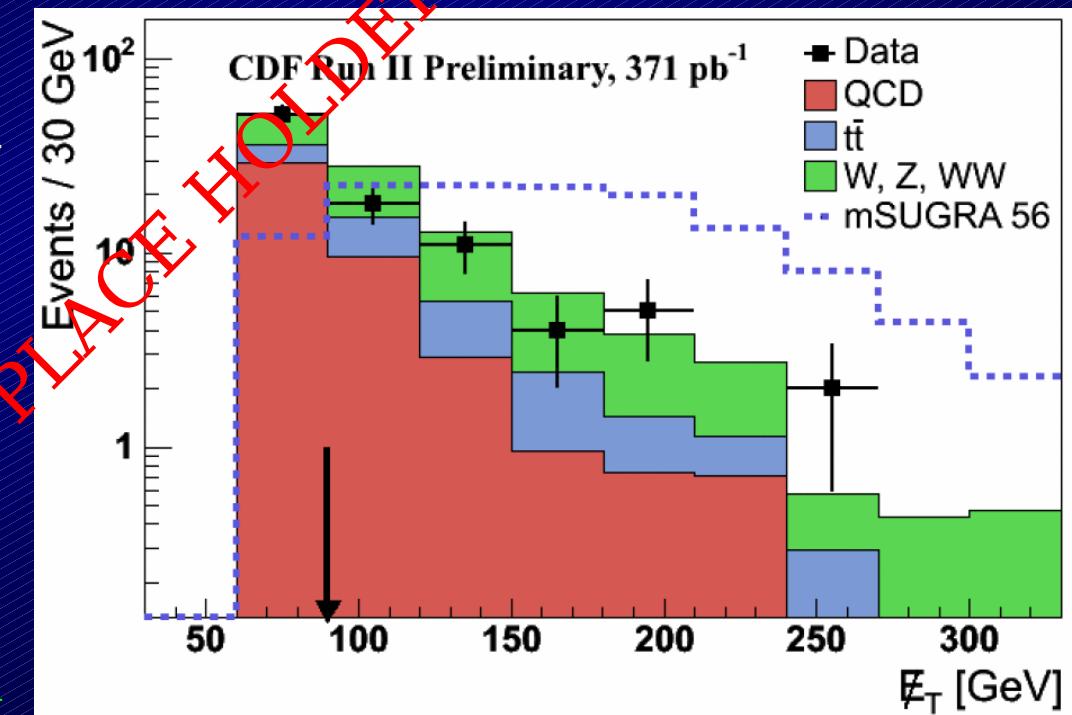
Example requirements:

$$E_T > 100 \text{ GeV}, H_T > 330 \text{ GeV},$$

$$E_T(\text{jet } 1, 2, 3) > 150, 80, 25 \text{ GeV}$$

Decay:

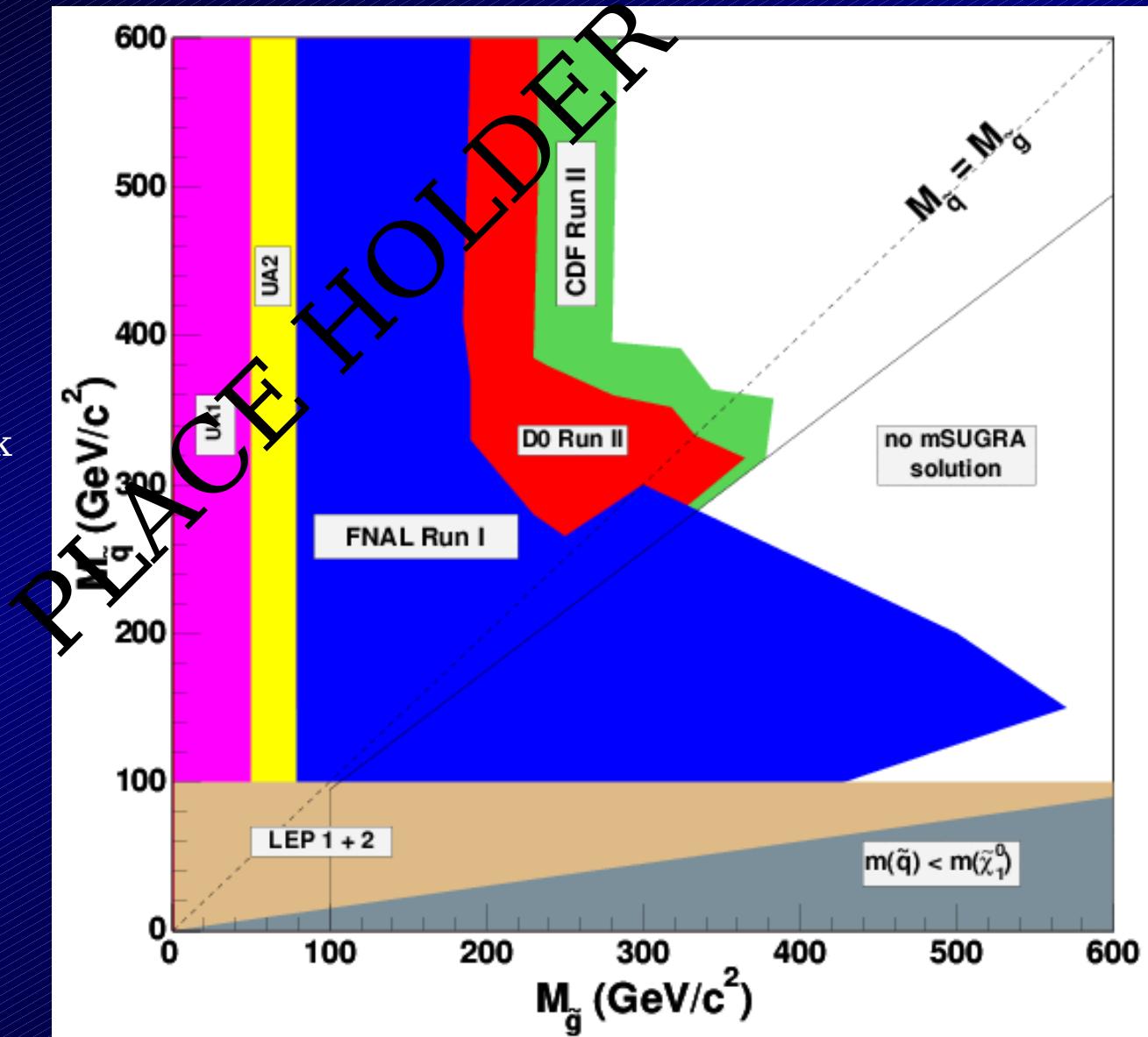
Cascade decays of squarks and gluinos to SM counterparts (\rightarrow multiple jets) and lightest neutralinos which are undetected (\rightarrow missing E_T)



- No excess of signal seen over Standard Model backgrounds

Squarks & Gluinos (II)

- Excluded regions in $M_{\text{squark}} - M_{\text{gluino}}$ plane, at 95% CL
- Region below $M_{\text{gluino}} = 284 \text{ GeV}/c^2$ excluded for all M_{squark}
- For $M_{\text{gluino}} \approx M_{\text{squark}}$ M_{gluino} excluded below $383 \text{ GeV}/c^2$



Conclusions

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

Higgs in $H \rightarrow WW^{(*)}$ (most sensitive channel for higher masses)

Higgs in $pp \rightarrow (b)bH \rightarrow (b)bbb$ (exploring MSSM with high $\tan\beta$)

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

Squarks & Gluinos (constraining masses in mSUGRA scenario)

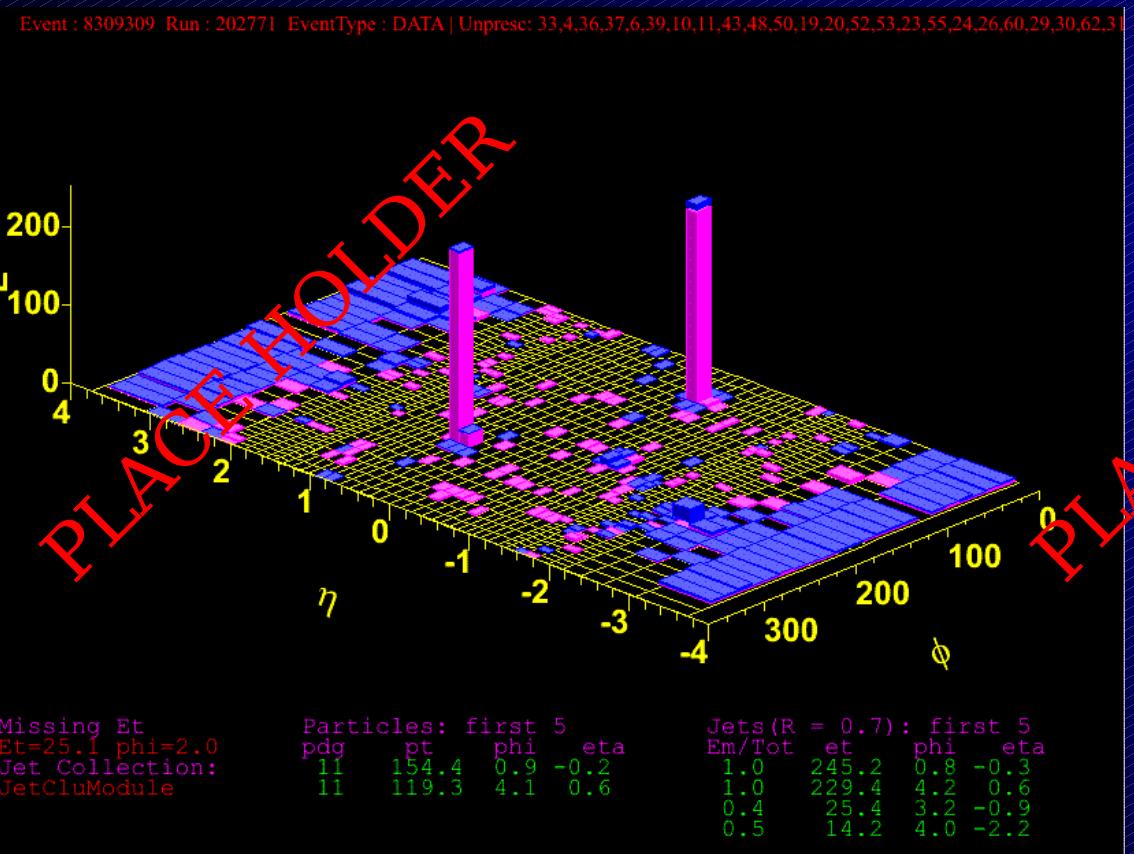
- Numerous other results are headed your way this Winter!

Backup →

Z' Search Event Displays

High M_{ee} event: $M_{ee} = 491 \text{ GeV}/c^2$

Unrolled calorimeter view:

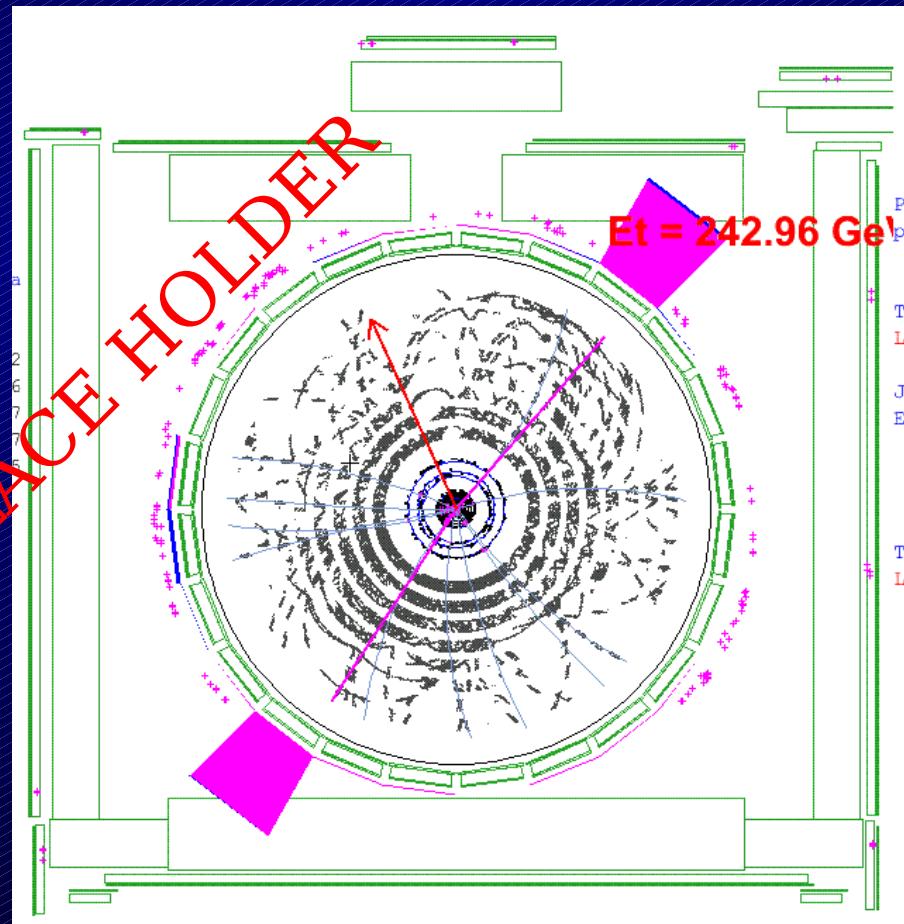


Shows EM calorimeter energy (purple)
Hadronic calorimeter energy (blue)

Lake Louise, Feb. 19, 2006

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r- ϕ view:



Shows all tracks with $p_T > 1 \text{ GeV}/c$

Aron Soha, UC Davis