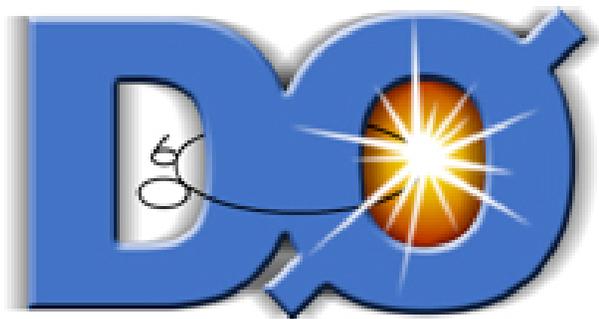


**Tevatron Non-SUSY BSM:
Searches for Physics Beyond the SM and MSSM**

**David Stuart
University of California, Santa Barbara**

**DIS 2007, Munich
April 2007**



Outline

There are two categories of searches:

1. Model driven

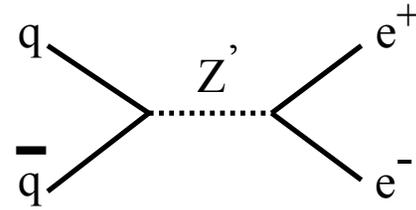
- New Dimensions, New Interactions, or New Particles
- Specifically optimized

2. Signature driven

- Look for deviations from SM in specific final states
- Broadly optimized

Most recent results use ≈ 1 inverse femtobarn.

New Gauge Boson: $Z' \rightarrow ee$

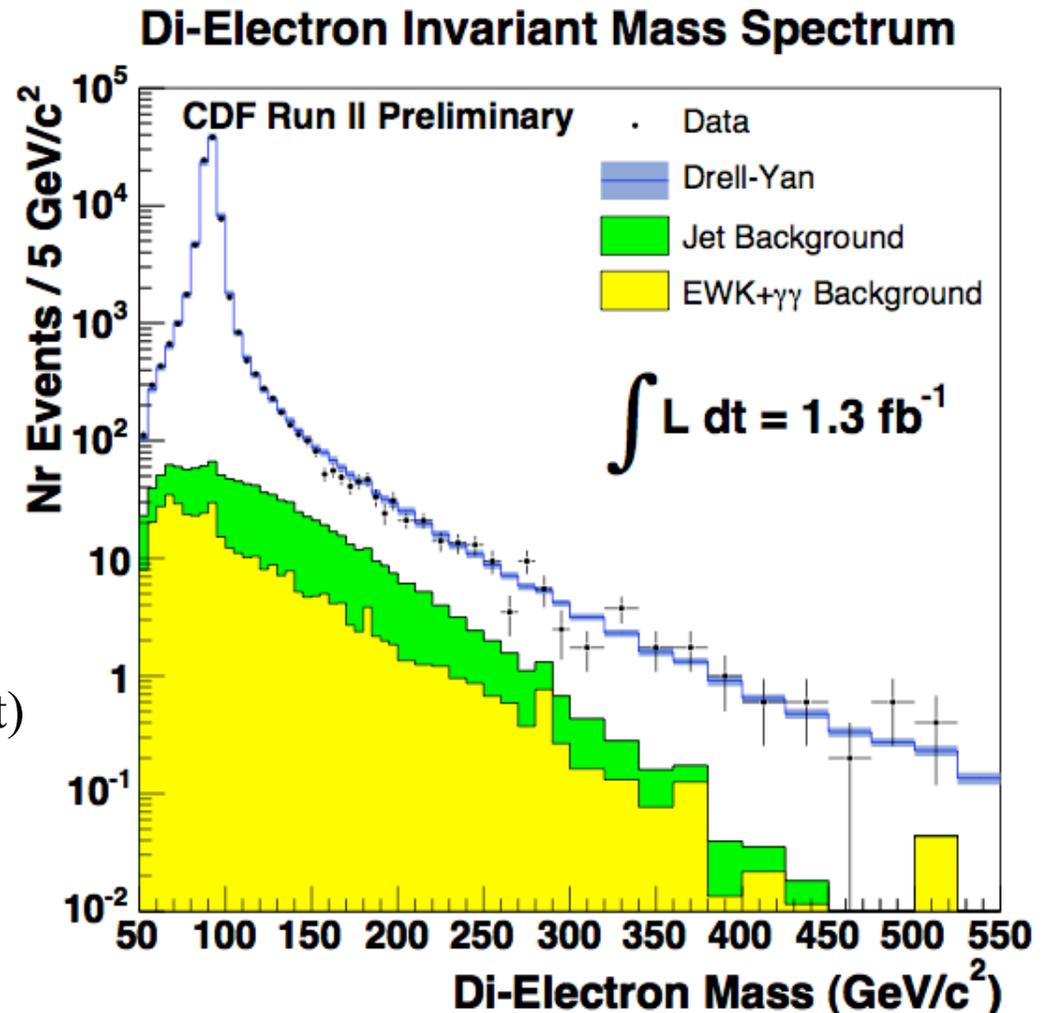


Model: Many unification models

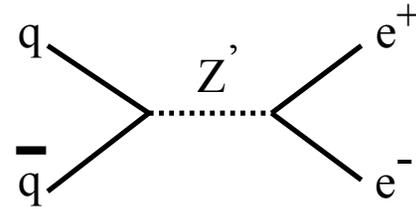
Signature: Di-electron mass peak

Backgrounds:

- Drell-Yan (Irreducible & dominant)
- QCD fakes
- Diboson and top



New Gauge Boson: $Z' \rightarrow ee$

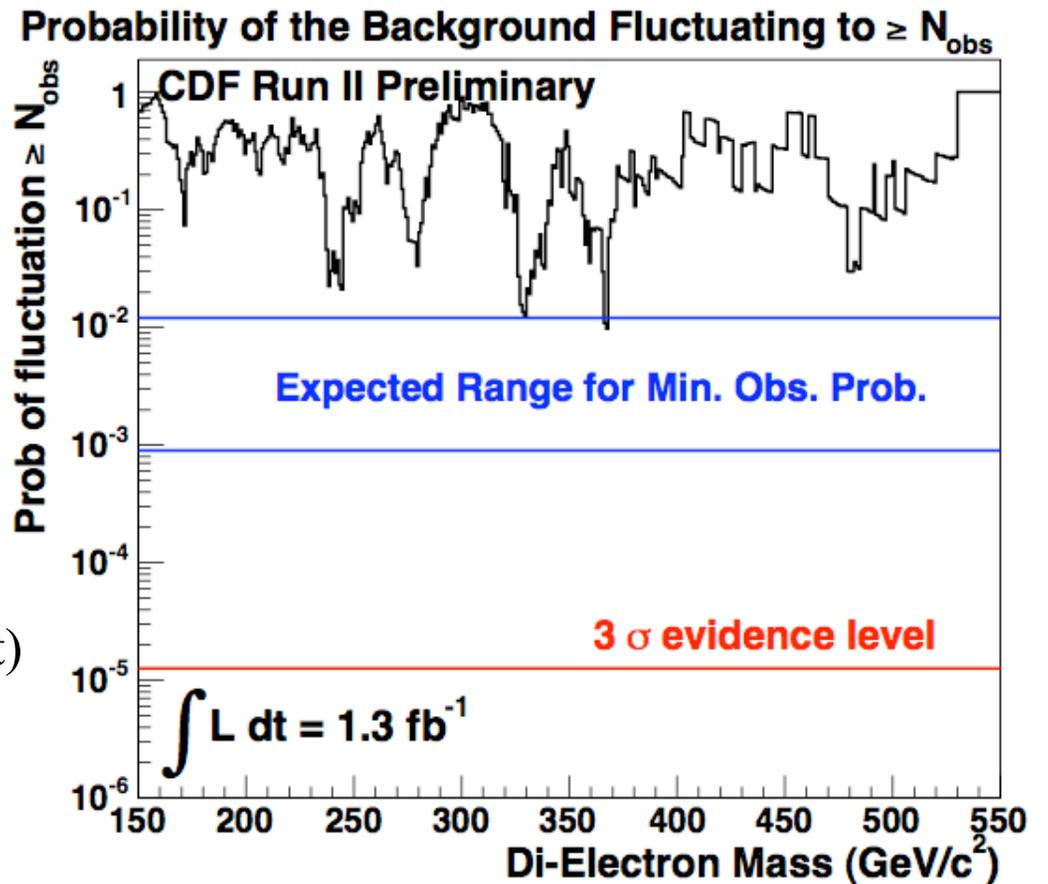


Model: Many unification models

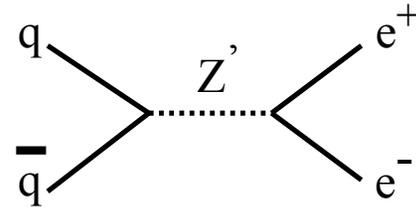
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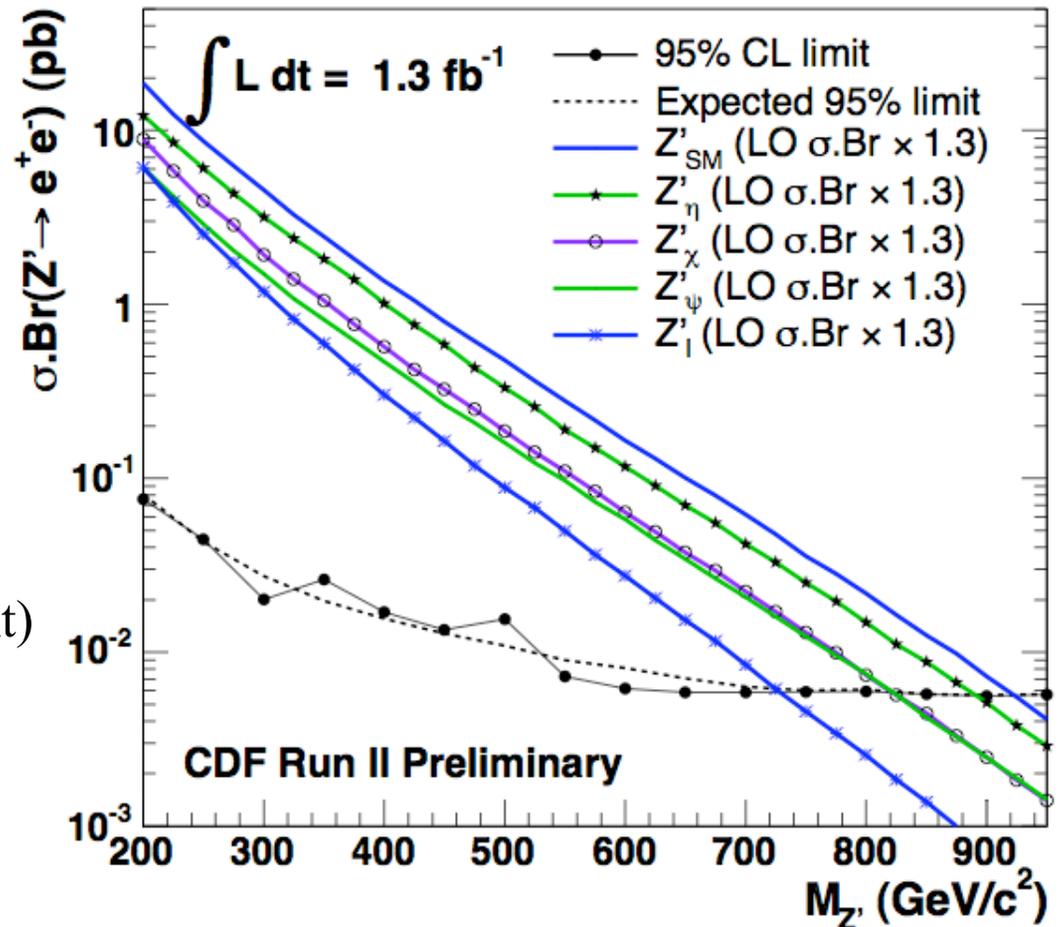
Model: Many unification models

Signature: Di-electron mass peak

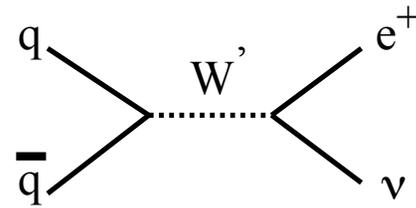
Backgrounds:

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- QCD fakes
- Diboson and top

95% CL Limits (Spin-1, e^+e^-)



New Gauge Boson: $W' \rightarrow e\nu$



Model: Many unification models

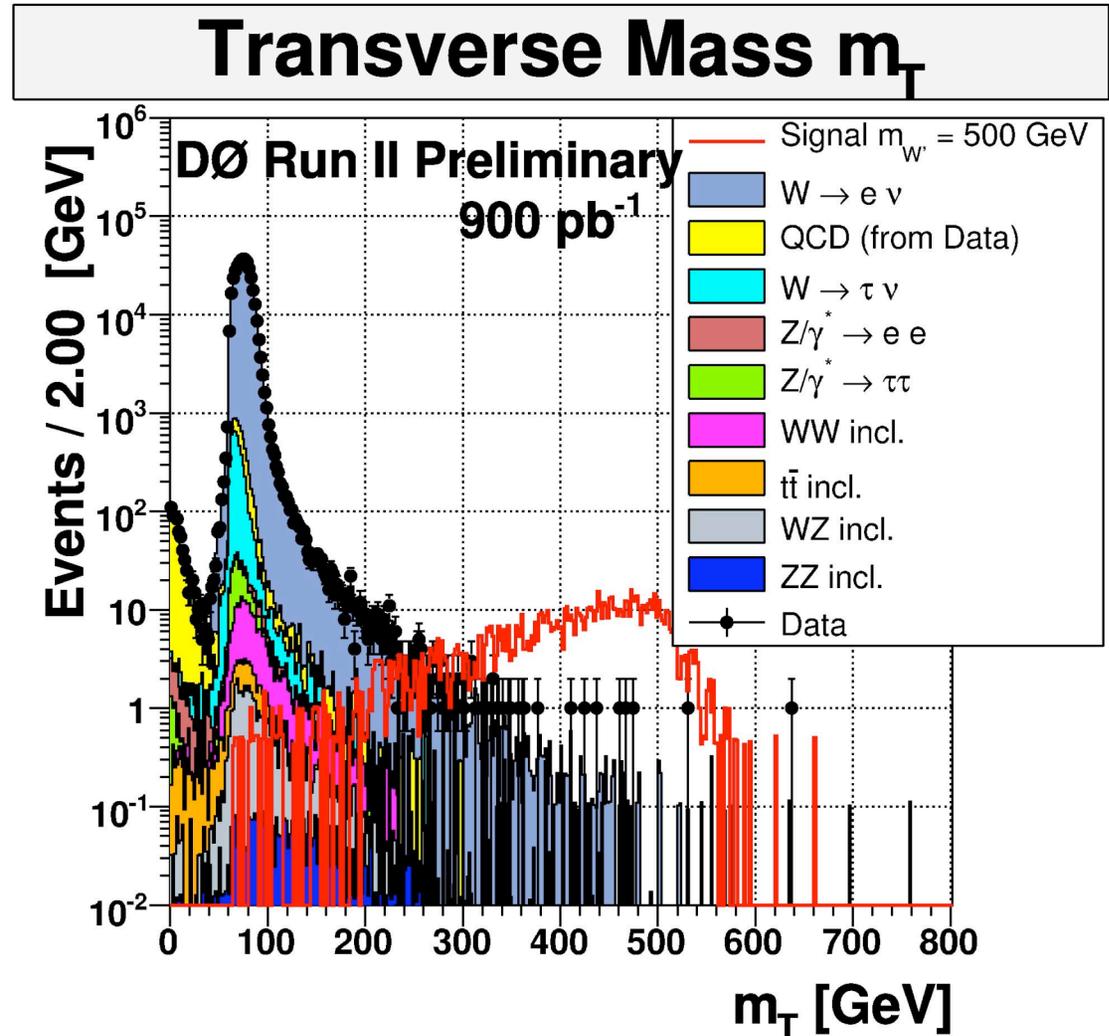
Signature:

High transverse mass peak

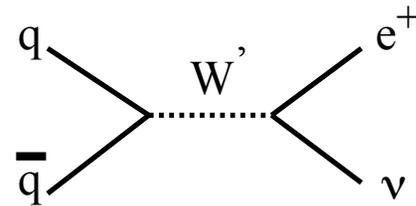
Backgrounds:

Tail of W

QCD (suppressed w/ $\Delta\phi$ cuts on jets w/ $E_T > 15$)



New Gauge Boson: $W' \rightarrow e\nu$



Model: Many unification models

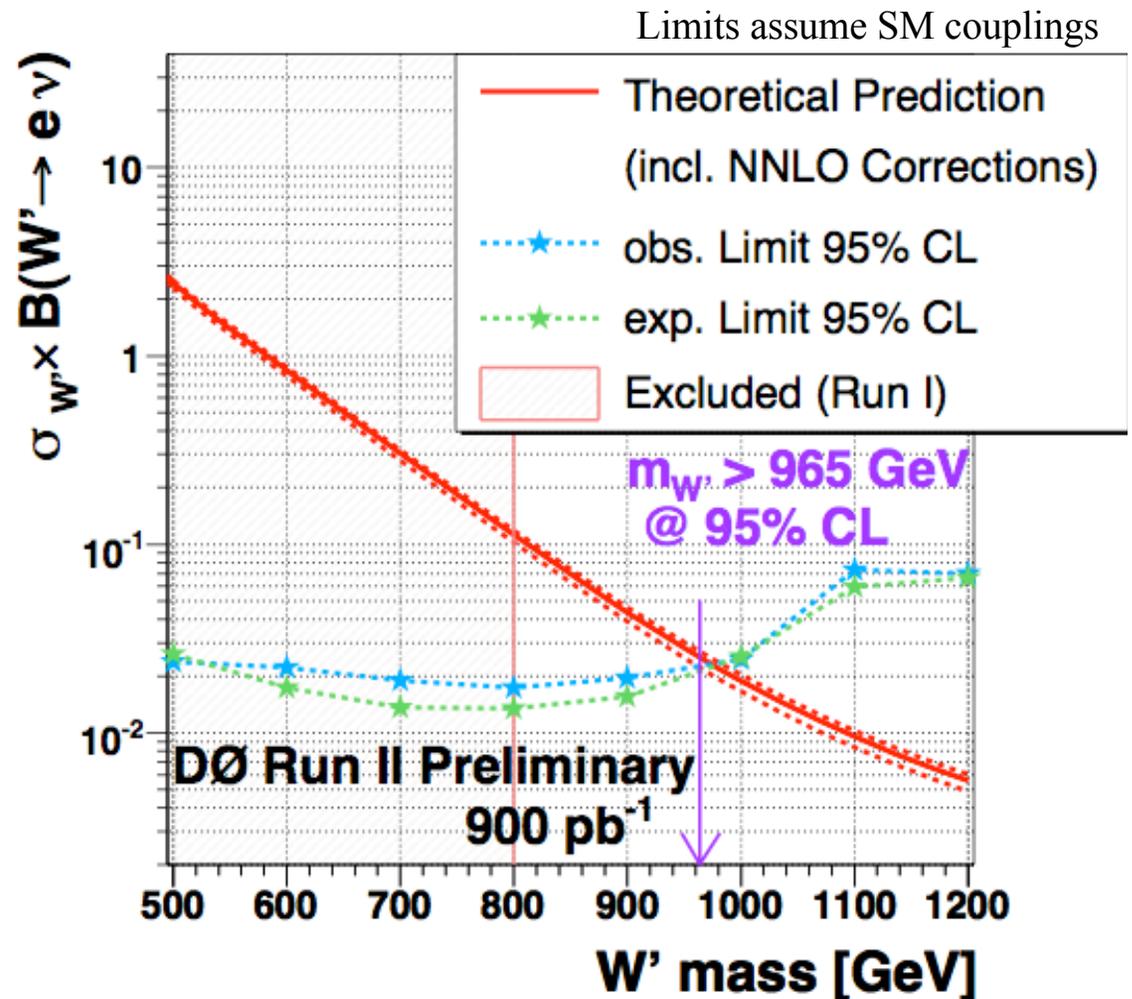
Signature:

High transverse mass peak

Backgrounds:

Tail of W

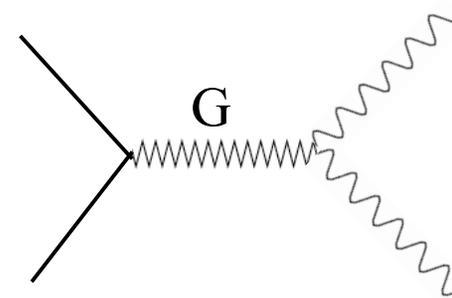
QCD (suppressed w/ $\Delta\phi$ cuts on jets w/ $E_T > 15$)



RS Extra Dimensions: $G \rightarrow \gamma\gamma$



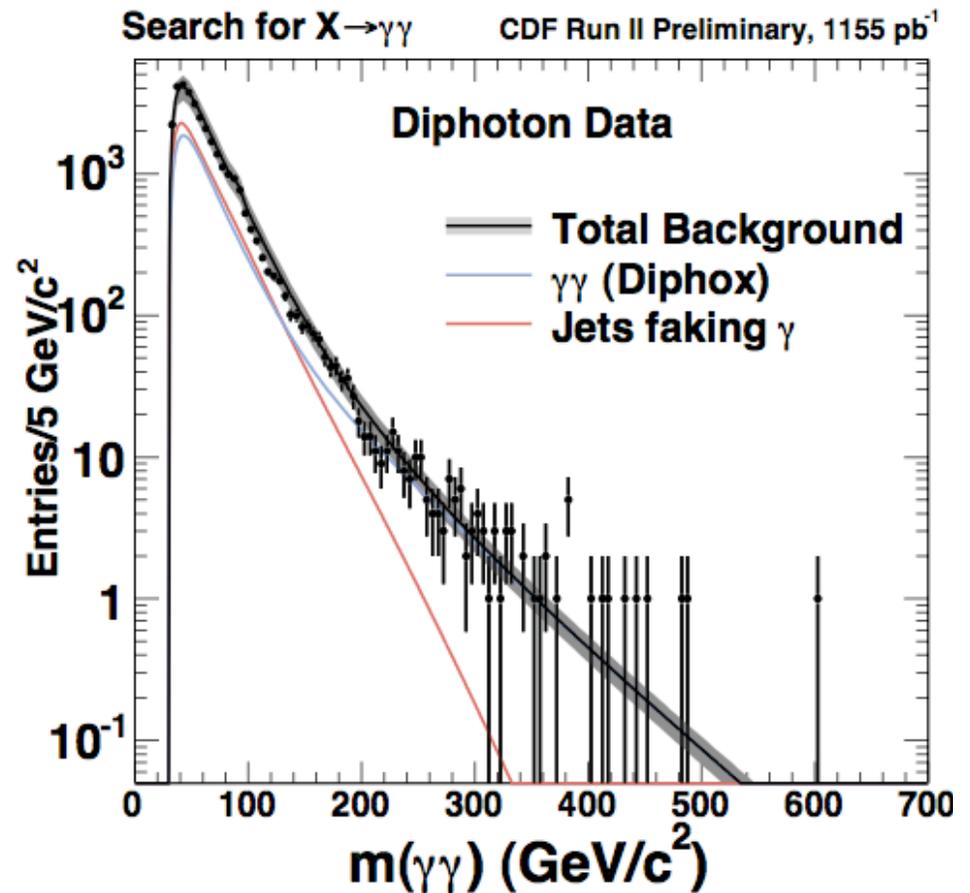
Model: Strongly coupled graviton in Randall-Sundrum warped extra dimension



Signature: Di-photon mass peak

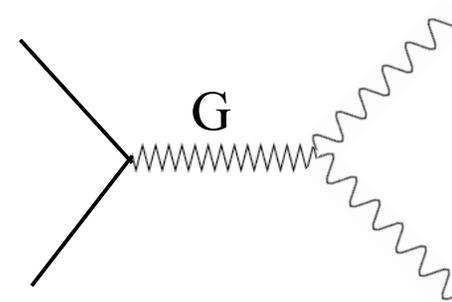
Backgrounds:

- QCD jets faking photons
- SM di-photon production (dominant at high mass)





RS Extra Dimensions: $G \rightarrow \gamma\gamma$



Model: Strongly coupled graviton in Randall-Sundrum warped extra dimension

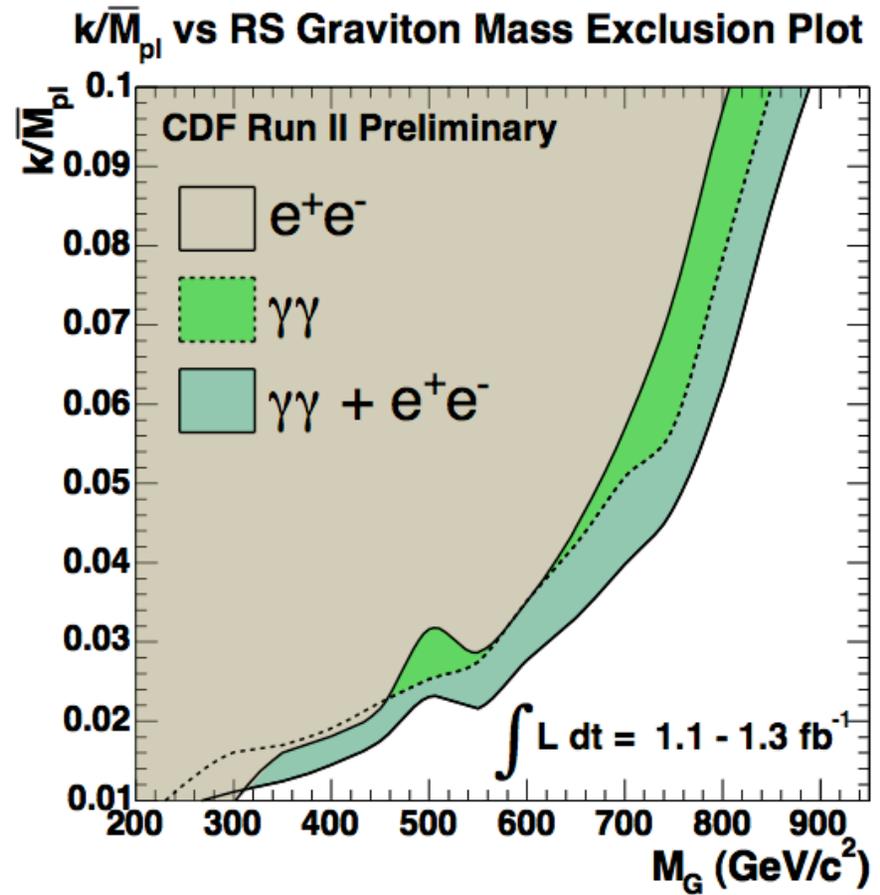
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Limits:

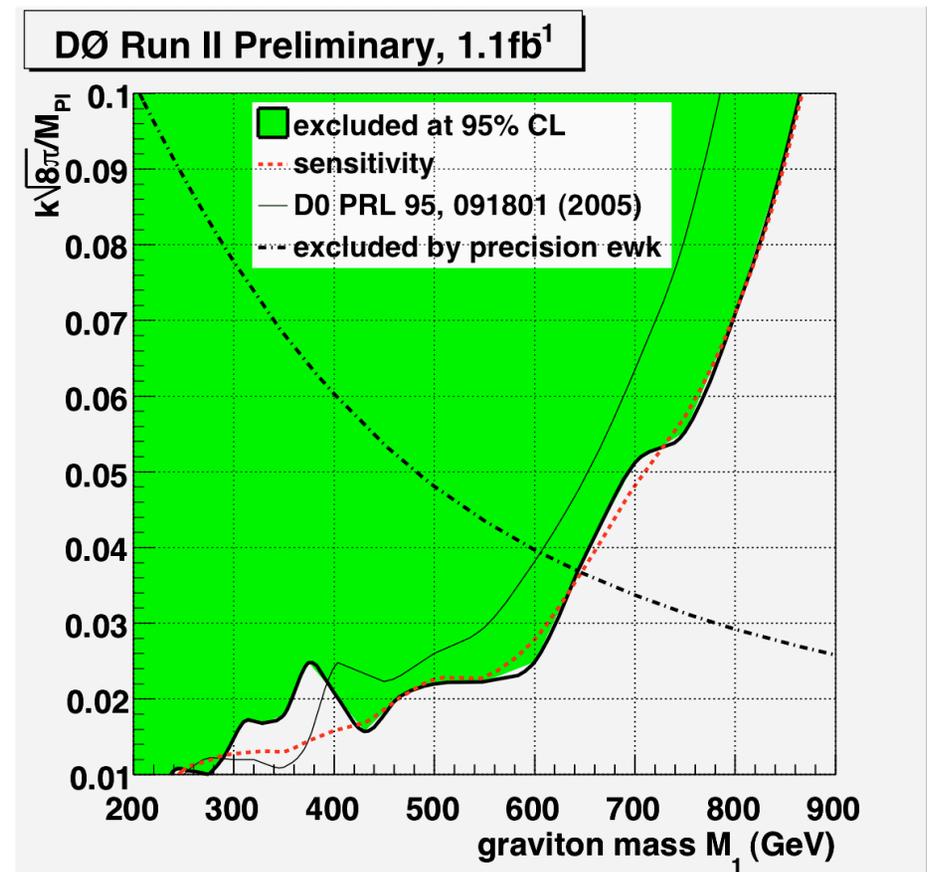
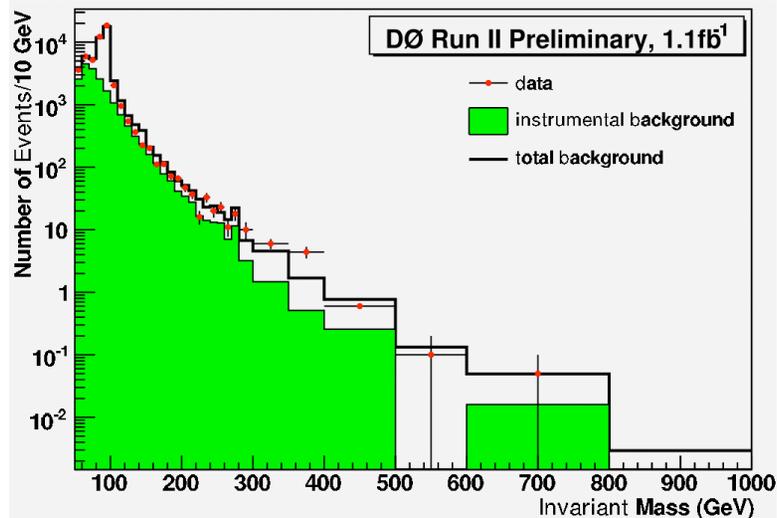
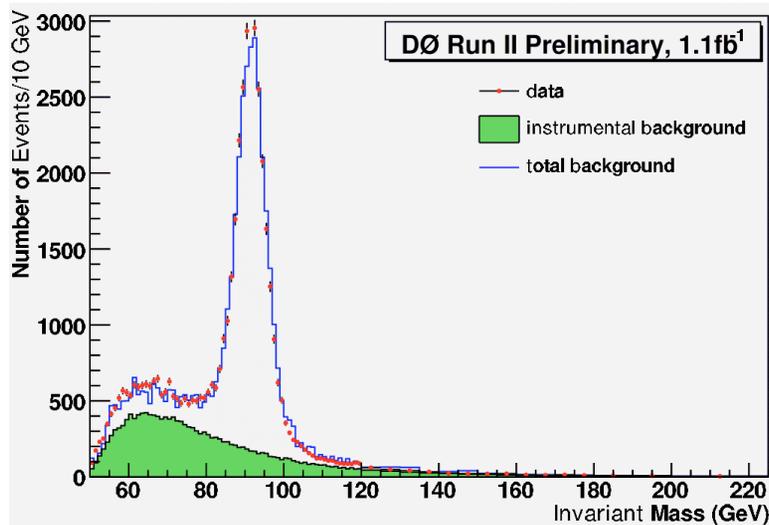
- Comparable to di-leptons
- Mass limits to 850 GeV when $\gamma\gamma$ and ee combined





RS Extra Dimensions: $G \rightarrow \gamma\gamma$ or ee

A similar search at DØ combines ee and $\gamma\gamma$ at the analysis stage as di-EM.

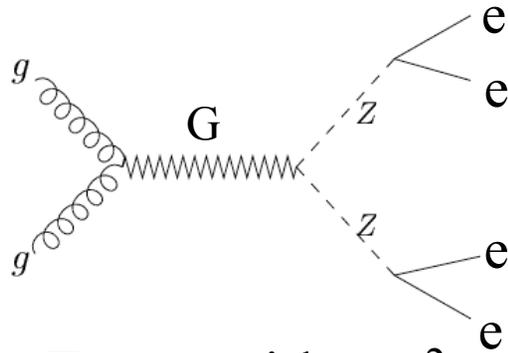




RS Extra Dimensions: $G \rightarrow ZZ \rightarrow eeee$

Model: Strongly coupled graviton in Randall-Sundrum warped extra dimension

Signature: Four electron mass peak



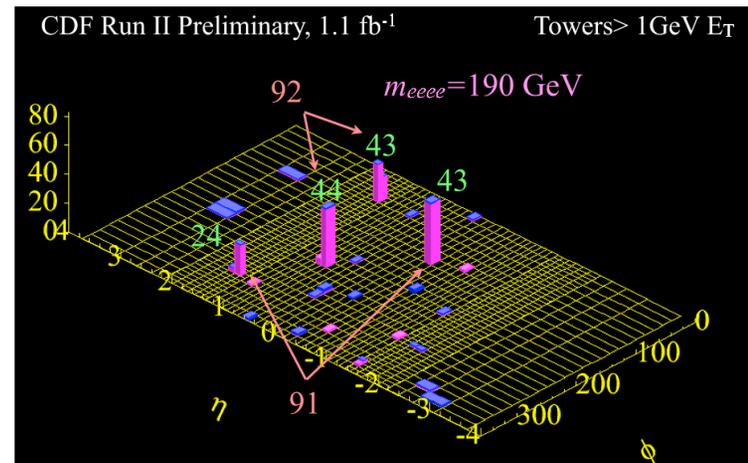
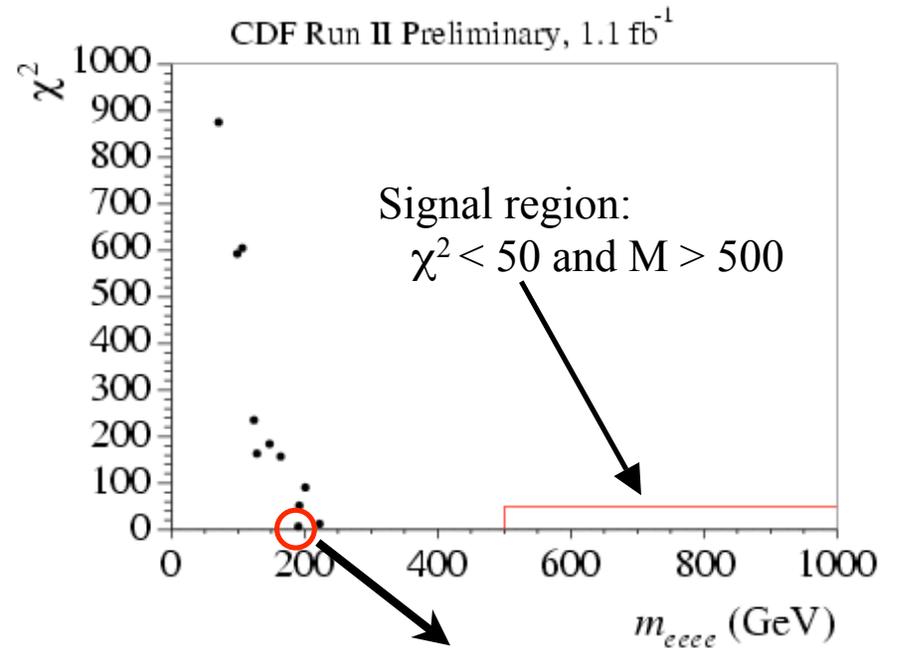
Select $Z \rightarrow ee$ with a χ^2 .

$$\chi^2 = \sum \left(\frac{m_{ee} - m_{Z^0}}{\sigma} \right)^2$$

~3 GeV

Backgrounds:

Very low backgrounds (0.02 ± 0.02 events) so use very loose electron selection.



Large Extra Dimensions: Monojet + Missing E_T

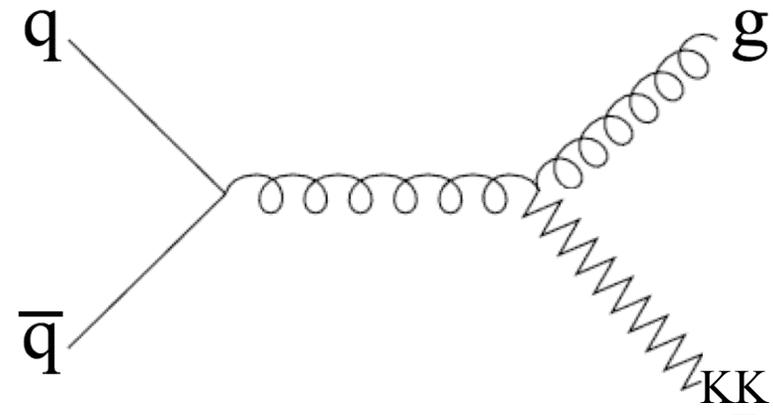


Model: ADD large extra dimensions

Signature: 1 or 2 jets + MET

Backgrounds:

QCD with fake MET	39 ± 14
$Z \rightarrow \nu\nu + \text{jet}$	398 ± 30
$W \rightarrow \tau\nu$	192 ± 30
$W \rightarrow l\nu$	157 ± 13





Large Extra Dimensions: Monojet + Missing E_T

Model: ADD large extra dimensions

Signature: 1 or 2 jets + MET

Backgrounds:

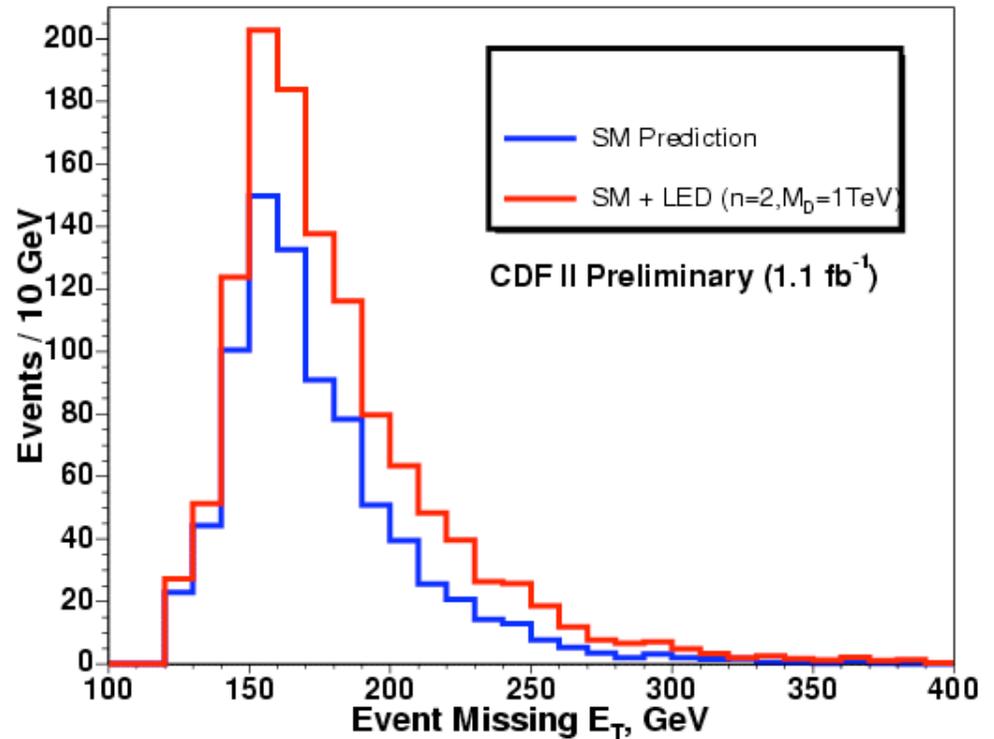
QCD with fake MET 39 ± 14

$Z \rightarrow \nu\nu + \text{jet}$ 398 ± 30

$W \rightarrow \tau\nu$ 192 ± 30

$W \rightarrow l\nu$ 157 ± 13

No shape difference,
so predicted from data.





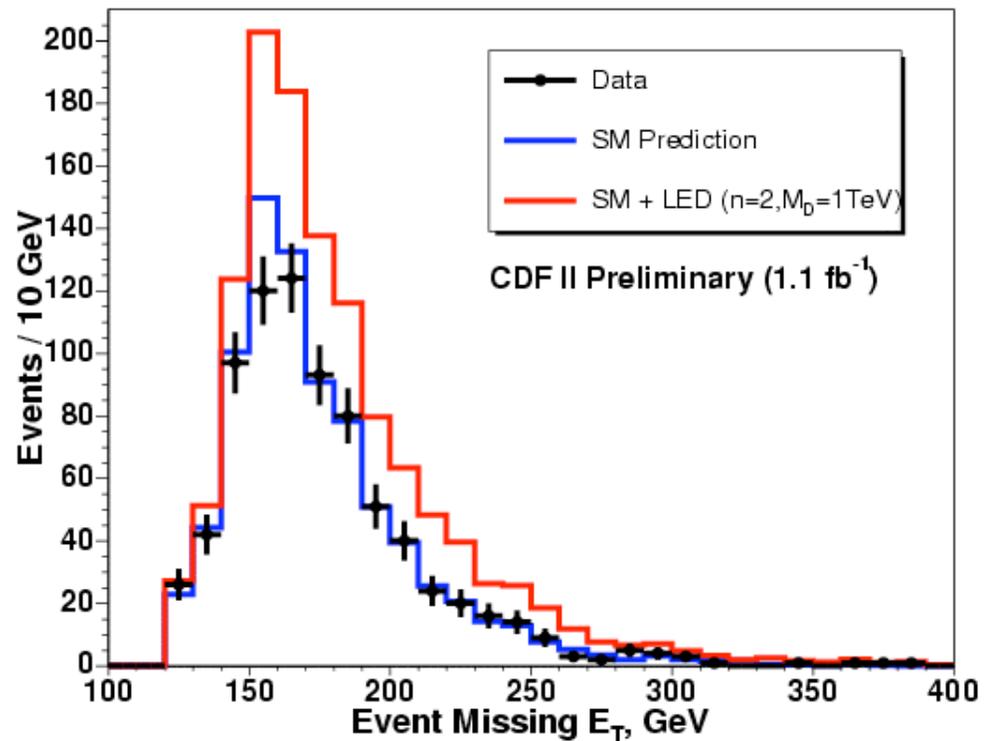
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Excited electron: $e^* \rightarrow e\gamma$

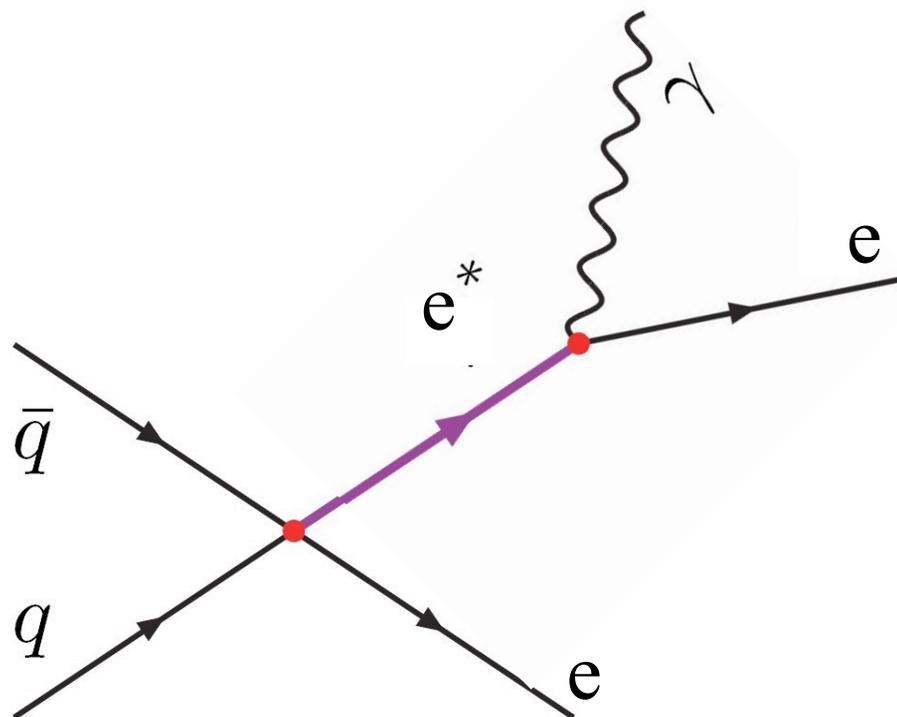
Model: Compositeness

Signature: $e\gamma$ mass peak

Backgrounds:

$DY+\gamma$

$Z \rightarrow ee$ with brem





Excited electron: $e^* \rightarrow e\gamma$

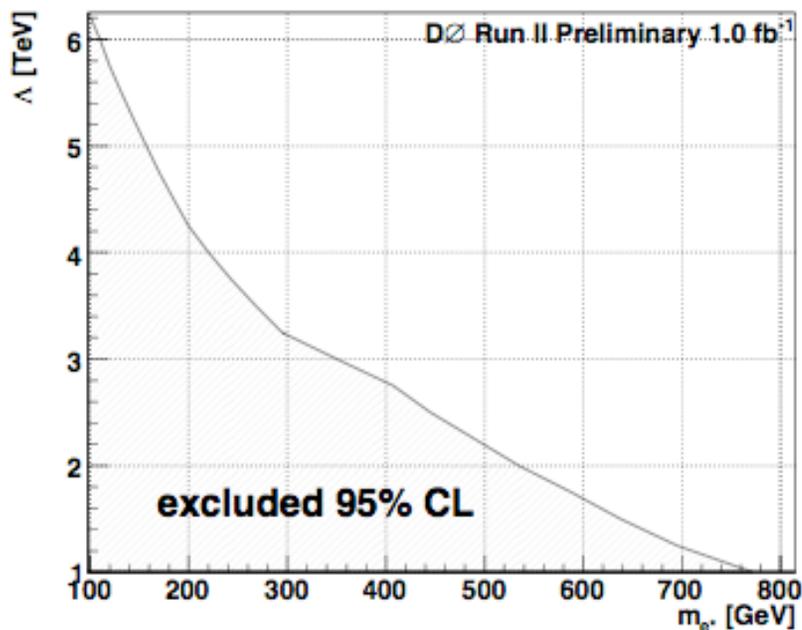
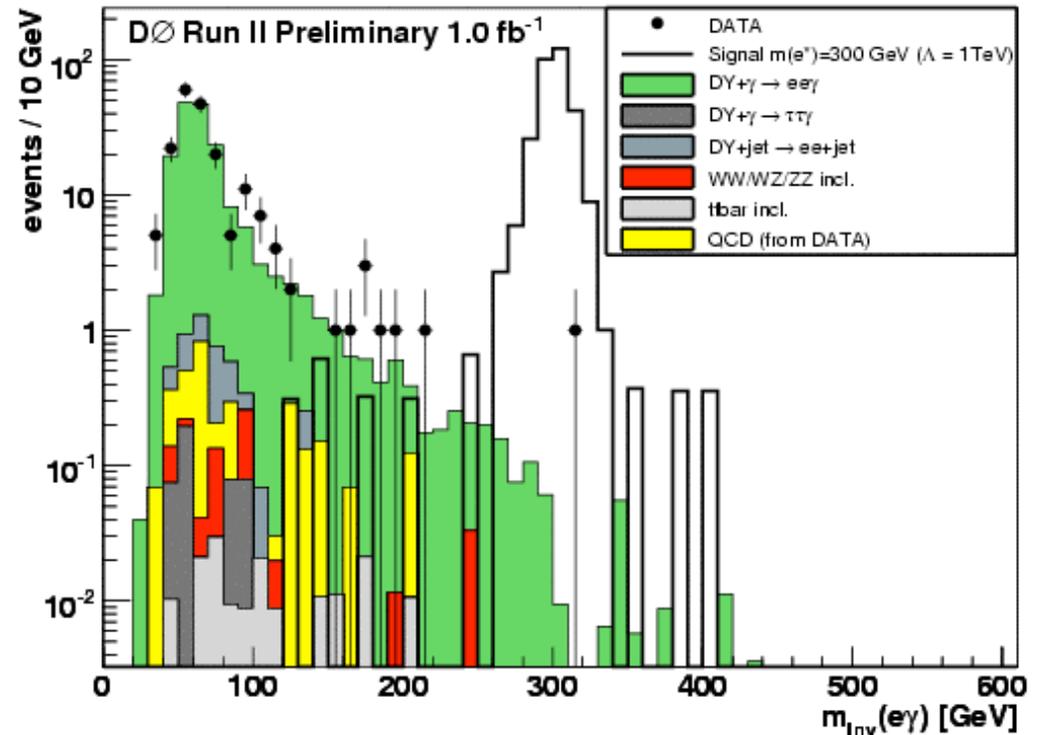
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Backgrounds:

$DY+\gamma$

$Z \rightarrow ee$ with brem





2nd generation Leptoquark:

Model: LQ carries both color and lepton #

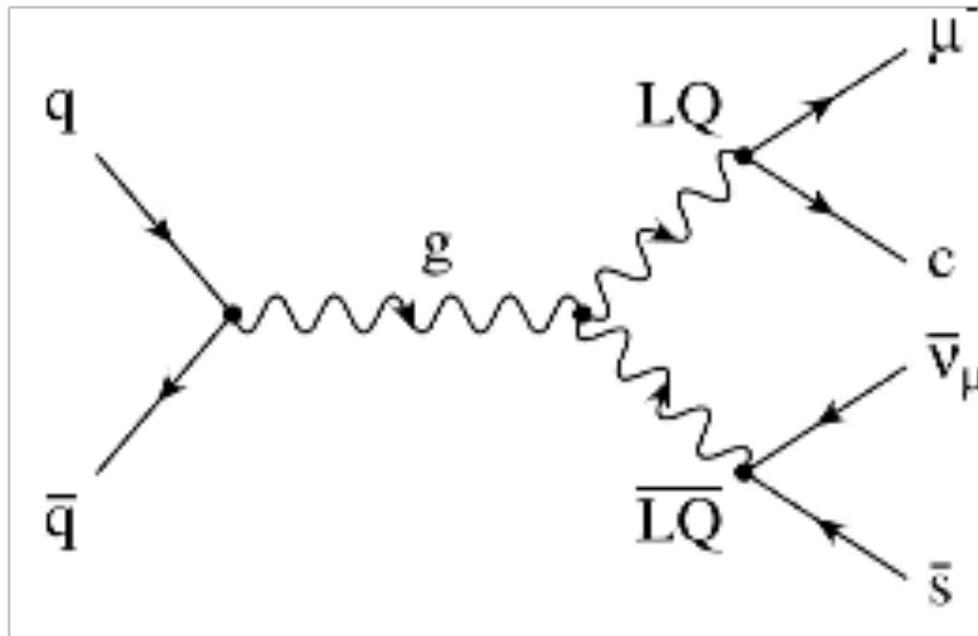
Signature:

$\mu + 2 \text{ jets} + \text{MET}$

μj mass peak

Backgrounds:

W+jets & top





2nd generation Leptoquark:

Model: LQ carries both color and lepton #

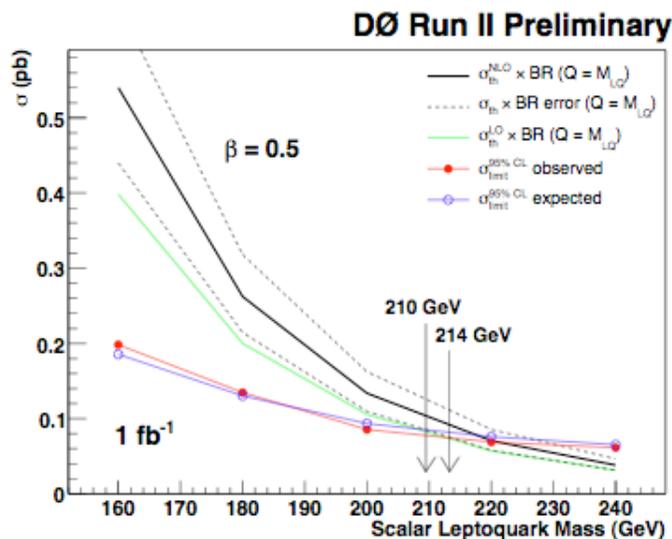
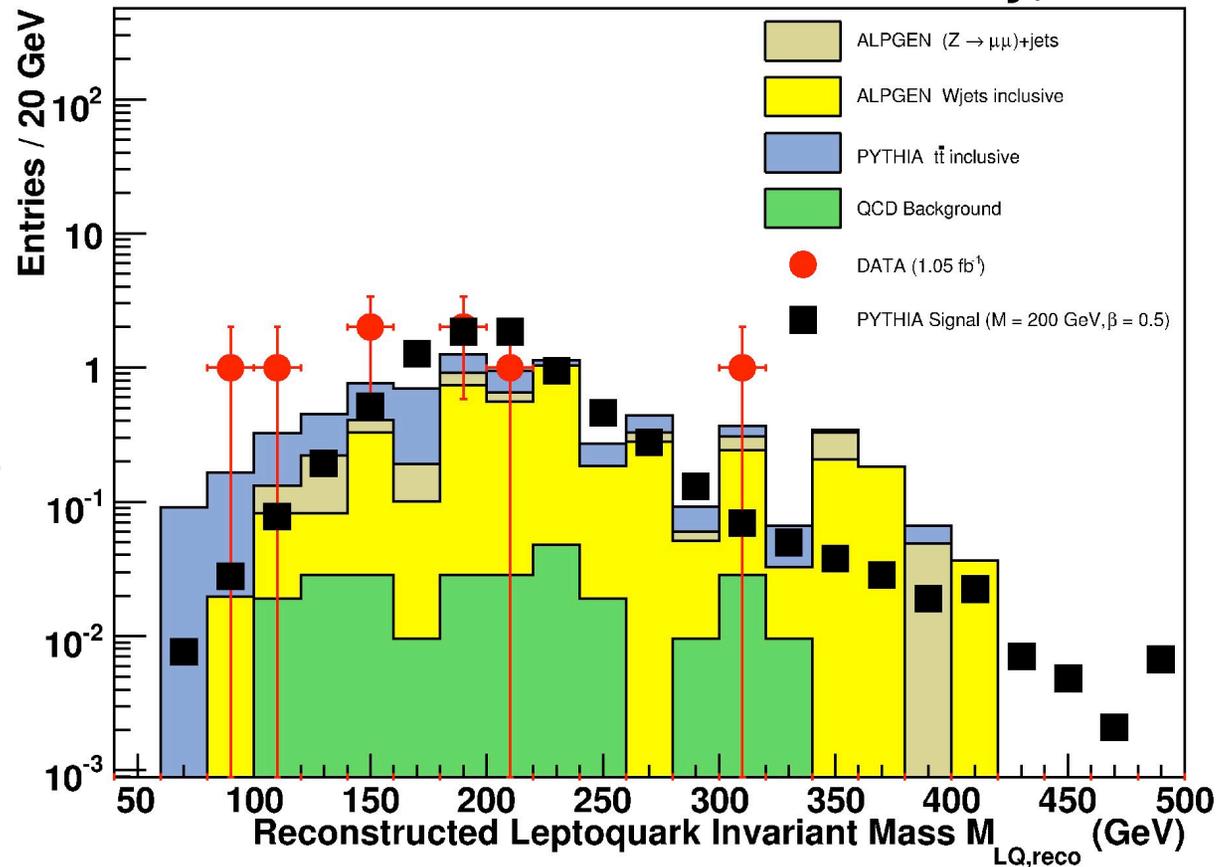
Signature:

$\mu + 2 \text{ jets} + \text{MET}$
 μj mass peak

Backgrounds:

$W + \text{jets}$ & top

DØ Run II Preliminary, 1 fb^{-1}





4th generation quark: $b' \rightarrow bZ$

Model: 4th gen quark w/ small couplings to 1st three generations.

Signature: Z+ jets

At least 3 jets, $E_T > 30$ GeV

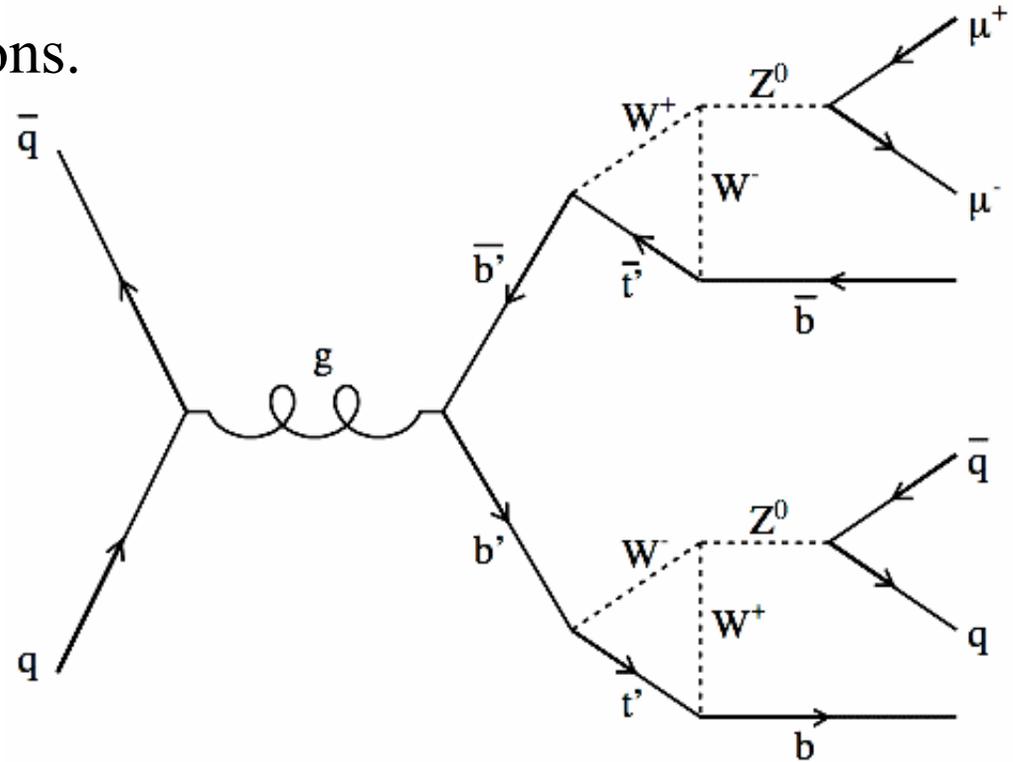
Large total jet energy, J_T

Background: Z+ jets

Predicted from the data

by fitting E_T spectrum

and modeling J_T





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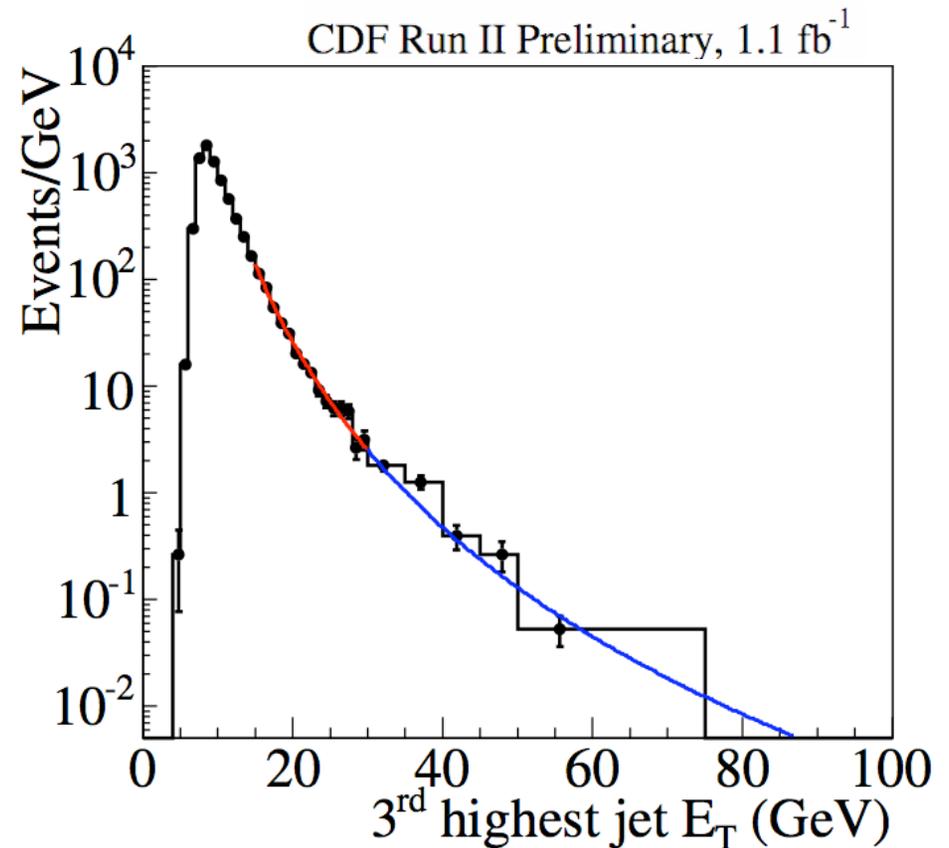
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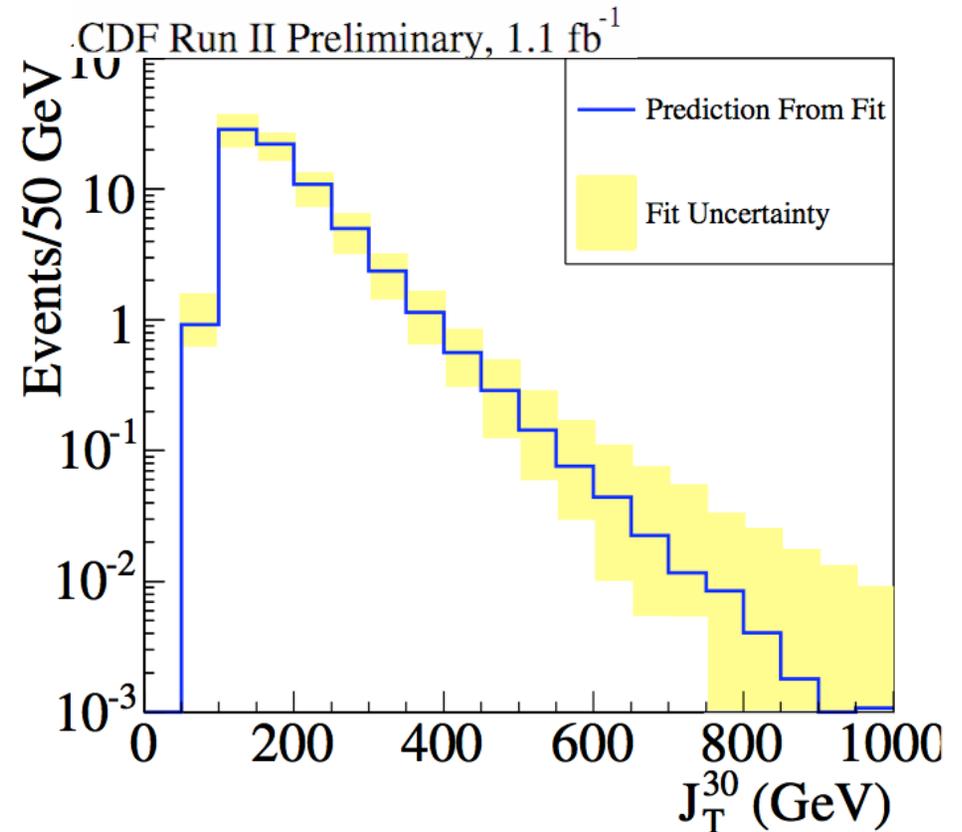
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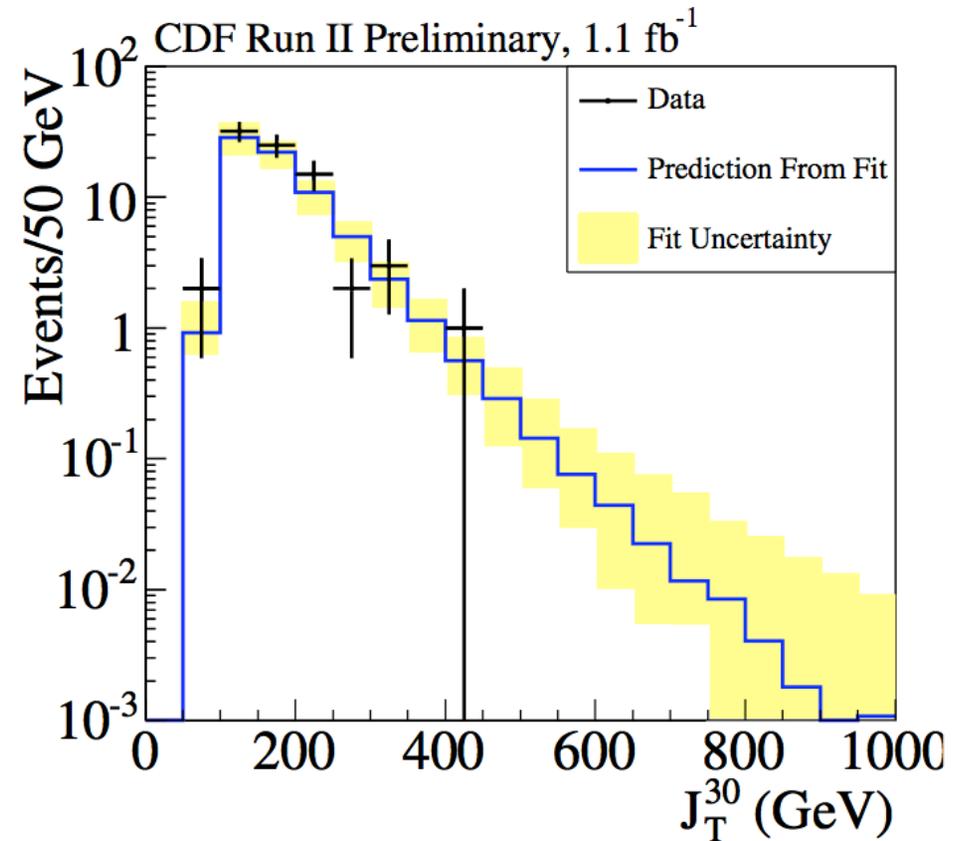
Background: Z+ jets

Predicted from the data

by fitting E_T spectrum

and modeling J_T

Data consistent with prediction,
limits obtained at 0.5 pb and 270 GeV.





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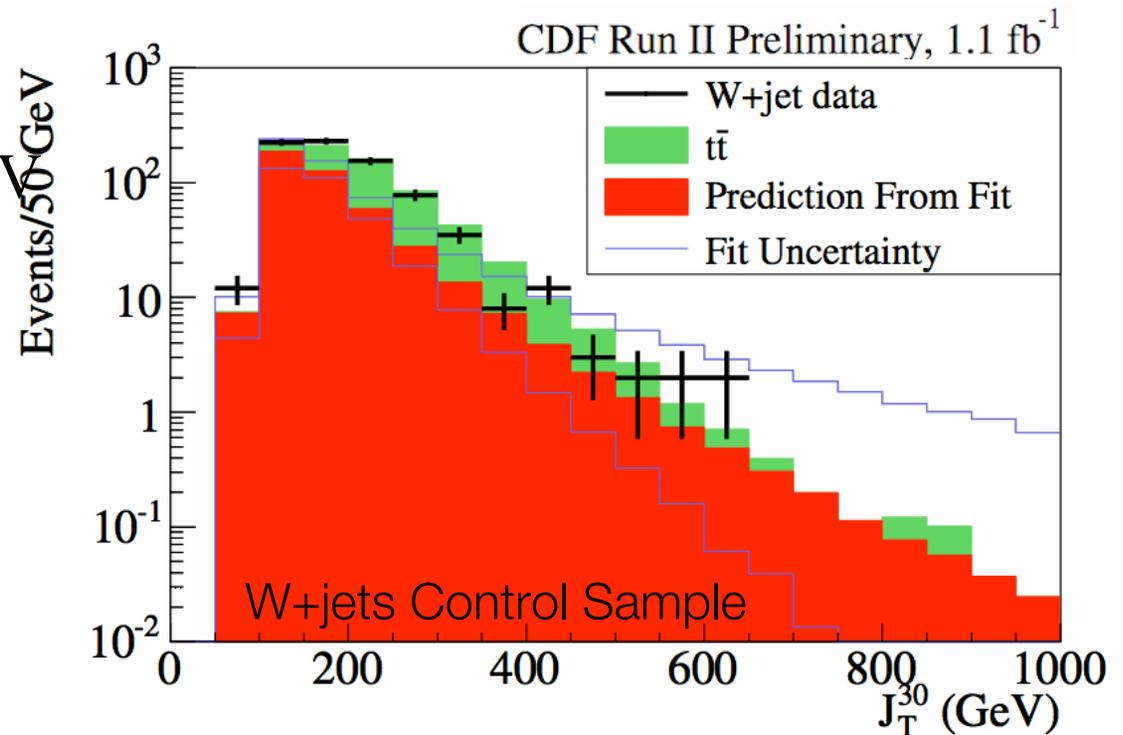
Signature: Z+ jets

At least 3 jets, $E_T > 30$ GeV

Large total jet energy, J_T

Background: Z+ jets

Predicted from the data by fitting E_T spectrum and modeling J_T



Top in W+jets is used as a cross-check of the MC-less method

Model Independent Searches

Making a search model-specific increases its sensitivity at the cost of breadth.

Making a search less specific increases its breadth at the cost of sensitivity.

There are several model-independent search results from the Tevatron...

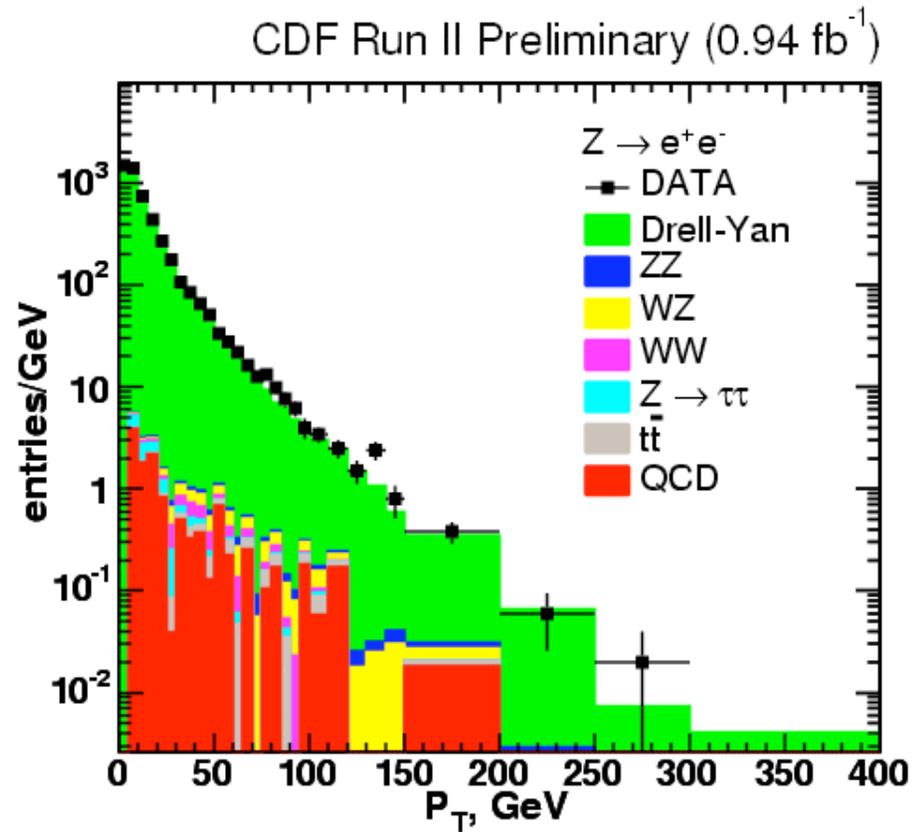


Search for high p_T Z

Background: Z+ jets

QCD from same-sign data

Others predicted with MC



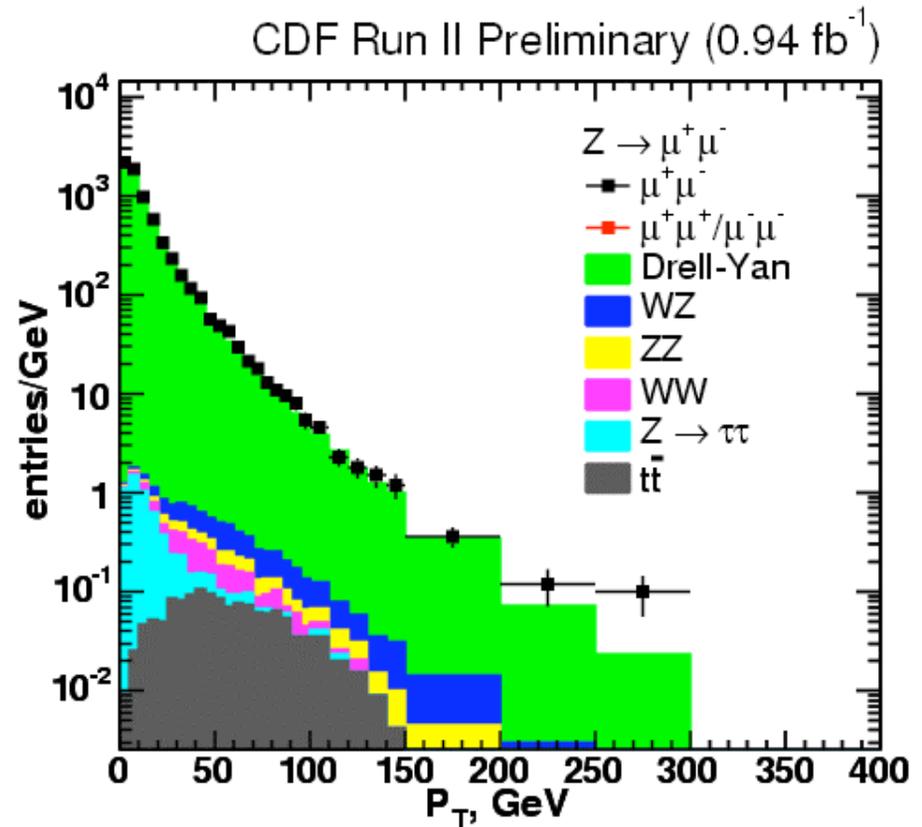


Search for high p_T Z

Background: Z+ jets

QCD from same-sign data

Others predicted with MC



Search for $Z + X$



CDF Run II Preliminary (0.94 fb⁻¹)

X	Expected e^+e^-	Observed e^+e^-	Expected $\mu^+\mu^-$	Observed $\mu^+\mu^-$
Leptons	1.6 ± 0.3	3	2.4 ± 0.4	2
Photons	12.4 ± 1.5	14	15.0 ± 1.8	14
H_T	$36.4^{+4.9}_{-5.8}$	45	$41.3^{+5.0}_{-5.2}$	53
MET	85.4 ± 12.3	97	$55.9^{+9.7}_{-5.8}$	74



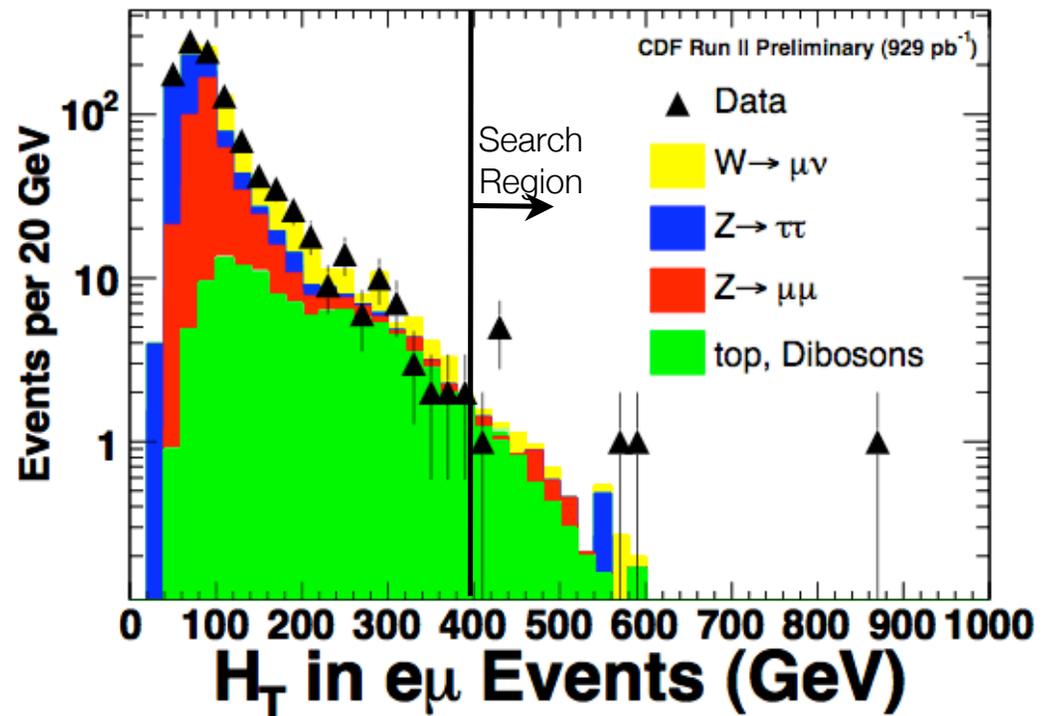
Search for Dilepton + X

where $X = \gamma, H_T, \text{MET}, \text{high } E_T \text{ jets}, \text{b-jets}, \text{leptons}$

Background: Z+jets, Z+ γ , Diboson, top, QCD

“Unusual” dileptons + 2j + $H_T > 400$

≥ 2 jets	$e\mu$	Same sign $ee/\mu\mu$
SM	2.9 ± 1.5	1.5 ± 0.8
Data	2	0

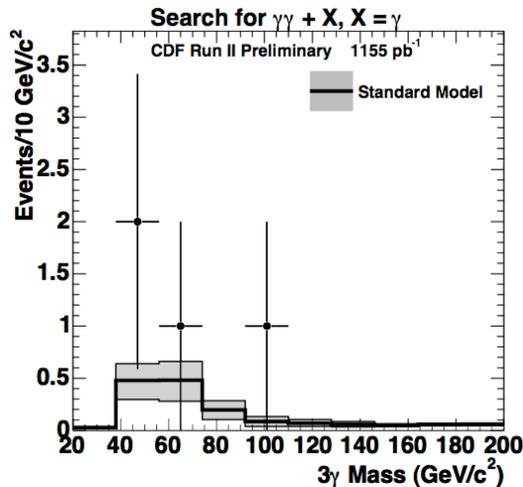
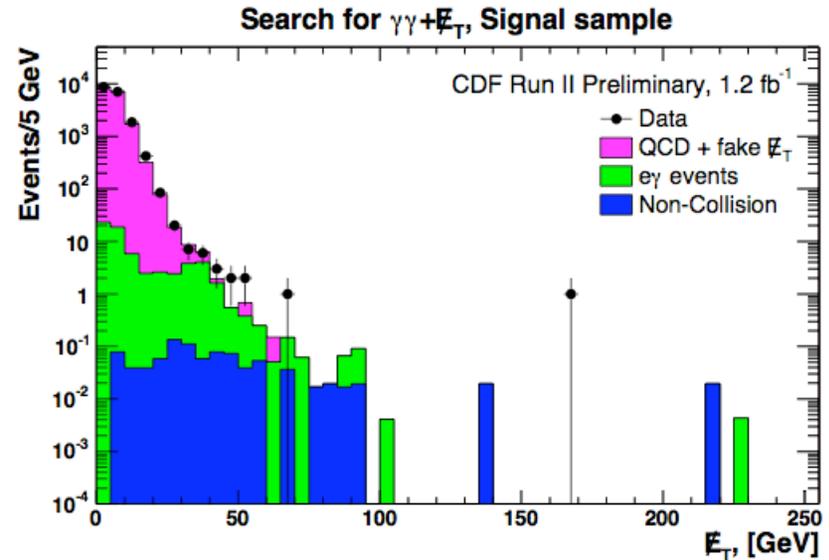
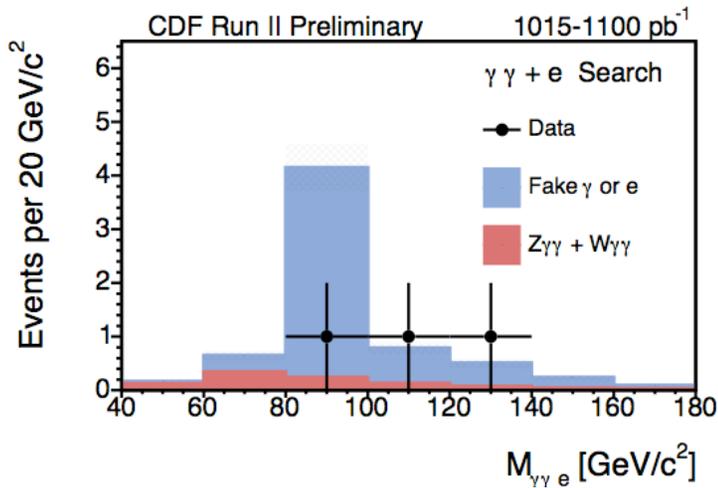


Highest H_T event looks top-like, with a b-tag and 3 jets.



Search for $\gamma\gamma + X$, where $X = e/\mu/\gamma/\text{MET}$

- Partially motivated by Run I $ee+\gamma\gamma+\text{MET}$ candidate event

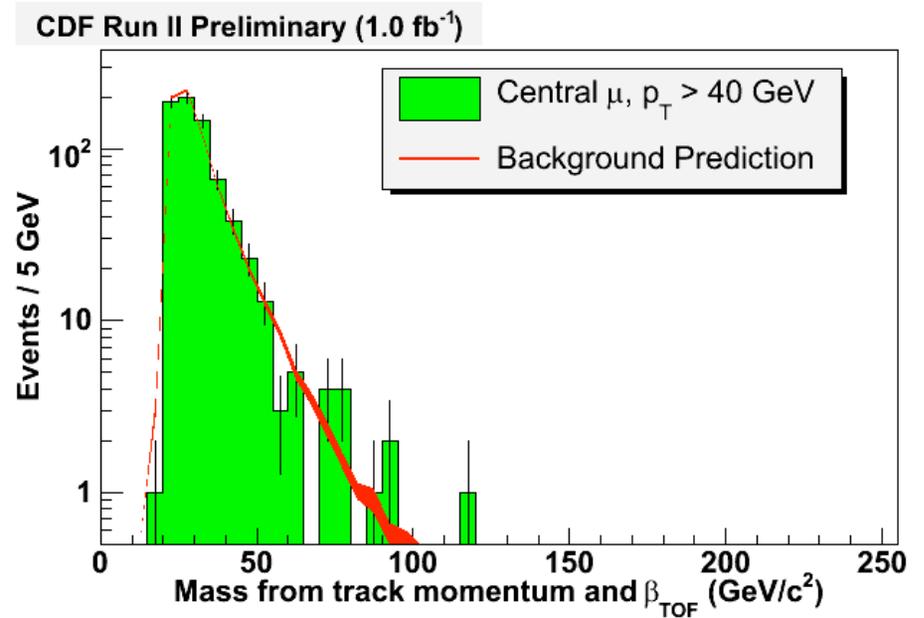
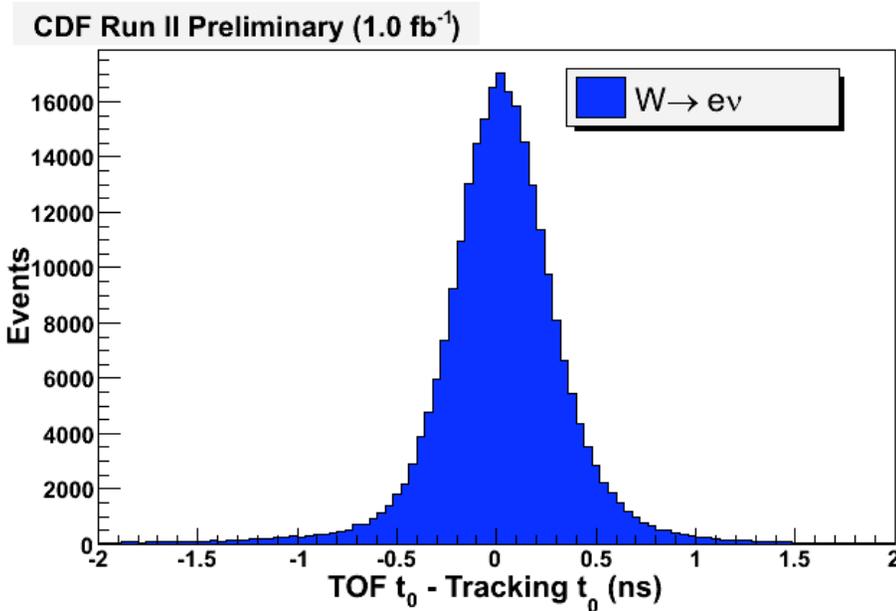


	$\gamma\gamma e$	$\gamma\gamma\mu$	$\gamma\gamma\gamma$	$\gamma\gamma + \text{MET}$ MET > 75
SM	6.8 ± 0.8	0.8 ± 0.1	2.2 ± 0.7	0.24 ± 0.22
Data	3	0	4	1

Search for Stable CHArged Massive Particles (CHAMPs)



If heavy, a CHAMP would penetrate like a muon, but it would be slow.
D0 searched with muon chamber scintillator timing, and
CDF searched with its TOF counters.



Limits on $\sigma \cdot A$ of 10 fb if weakly interacting and 48 fb if strongly interacting.



Summary

- CDF and D0 have varied searches, both model specific and model independent.
- Some fluctuations seen, as one would expect in a large ensemble of measurements.

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- But, we are not done hammering away at it:
 - The Tevatron expts will collect about 4x more data.



Summary

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- Some fluctuations seen, as one would expect in a large ensemble of measurements.
- The Standard Model wins again.
- But, we are not done hammering away at it:
 - The Tevatron expts will collect about 4x more data.
 - There is a Larger Hammer Coming.