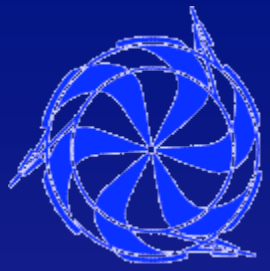


Searches for Extra Dimensions and New Electroweak Bosons at the Tevatron

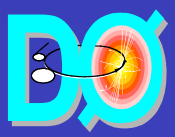
Pierre Savard

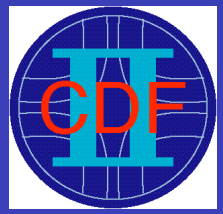
University of Toronto and TRIUMF

International Conference on High Energy Physics

Moscow

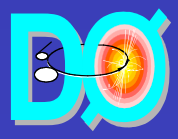
July 29th 2006

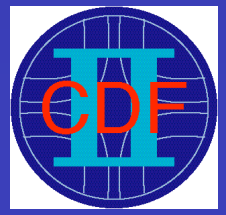




Outline

- Review of Extra Dimension Models
- New Heavy Gauge Bosons
- Latest Experimental Results with ~ 1 fb^{-1}
  - CDF Monojet Analysis (ADD Gravitons)
  - DØ and CDF Randall Sundrum Graviton Search
  - CDF Z′
  - DØ W′
- Conclusions





New Gauge Bosons: Motivation

- Many new physics models that address the shortcomings of the SM predict the existence of new massive gauge bosons:
  - Neutral Z', for example:
    - Superstring-inspired E6 model
    - Little, littlest Higgs
  - Charged W', for example:
    - Left-right symmetric models ($SU(2)_L$ X $SU(2)_R$)
    - Little Higgs

Extra Dimensions: Motivation

- Extra dimensions have been invoked in the context of quantum theories of gravity (String Theory)
- Large Extra Dimensions (LED) were proposed in the late 90's as a solution to the hierarchy problem
  - Electroweak energy scale ~ energy scale of gravity
- Since then, new extra dimension models have been developed and been used to solve other problems: Dark Matter, Dark Energy, SUSY Breaking, etc.
- Some of these models can be experimentally tested at high energy colliders

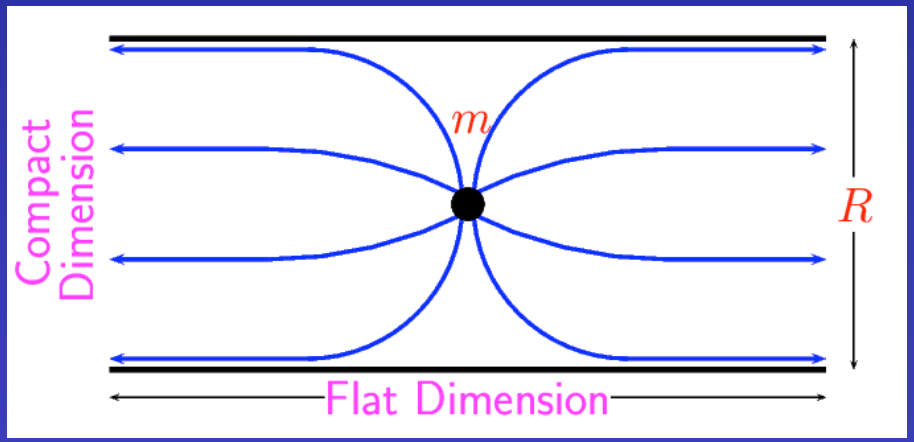
Gravity in Large Extra Dimensions

- Gravitational Potential in 4 Dimensions (Newton)

$$V(r) = G_N \frac{m_1 m_2}{r} = \frac{1}{(M_{Pl})^2} \frac{m_1 m_2}{r}$$

- n extra dimensions, compactified at radius R

r<<R $V(r) \sim \frac{1}{(M_D)^{n+2}} \frac{m_1 m_2}{r^{n+1}}$ ⇒ $V(r) \sim \frac{1}{(M_D)^{n+2}} \frac{m_1 m_2}{R^n} \frac{1}{r}$ r>R

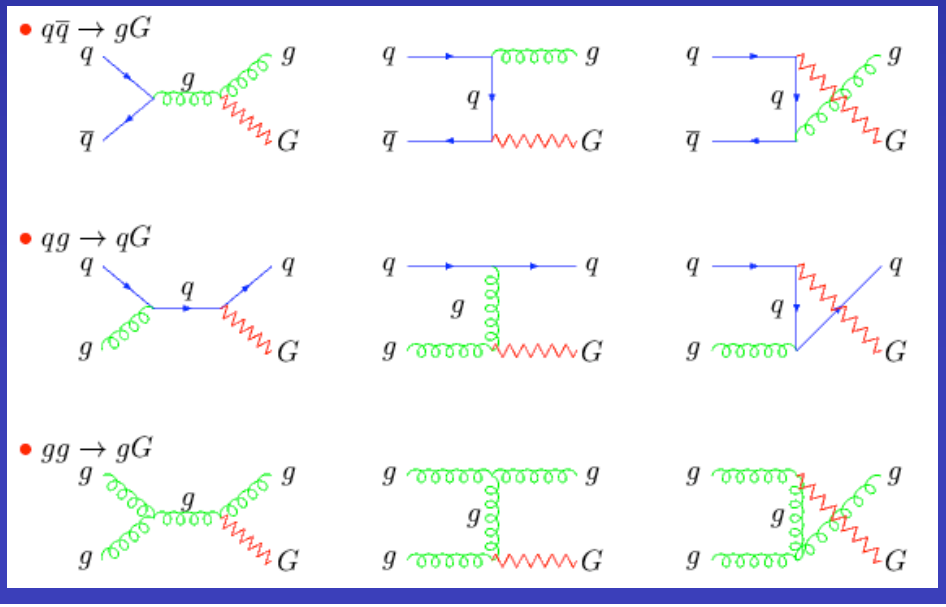


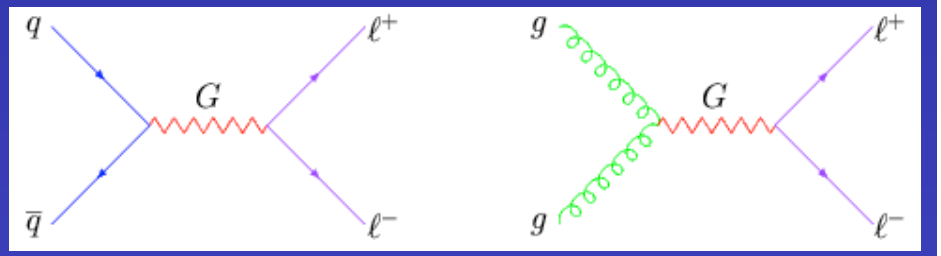
At large distances, must return to original potential

$(M_{PL})^2 \sim R^n (M_D)^{2+n}$

Extra Dimension Models

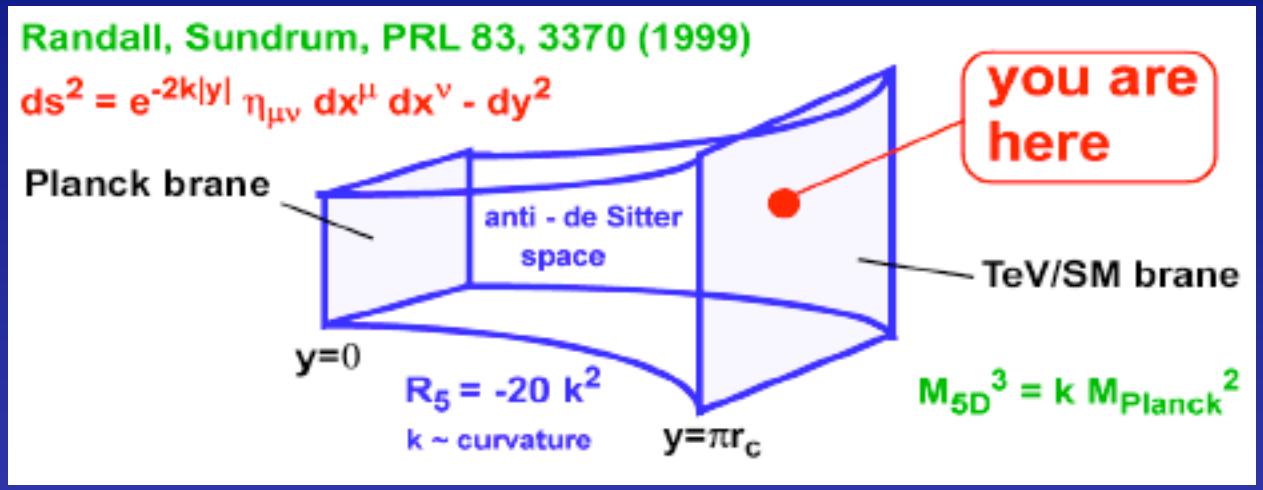
- Arkani-Hamed, Dimopoulos, and Dvali (ADD)
  - Phys.Lett. B429(1998), Nuc.Phys.B544(1999)
  - *n* extra dimensions, compactified at radius *R*
  - SM is confined to brane in a higher dimensional space
  - Only gravity can access extra dimensions
  - Signatures: Jet+Missing E_T, γ+Missing E_T, lepton pairs, γ pairs





Extra Dimension Models

- Randall-Sundrum Model:



- One warped extra dimension (from J. Lykken)
- Two branes, gravity localized on one, SM localized on second
- Fundamental graviton coupling: $\Lambda_\pi^{-1} = M_{pl}^{-1} e^{kr\pi}$
- Kaluza-Klein spacing: $m_n = k\pi\Lambda_\pi / M_{pl}$, $\sim 0.01 < k/M_{pl} < 0.1$
- Signature: narrow, high mass resonances

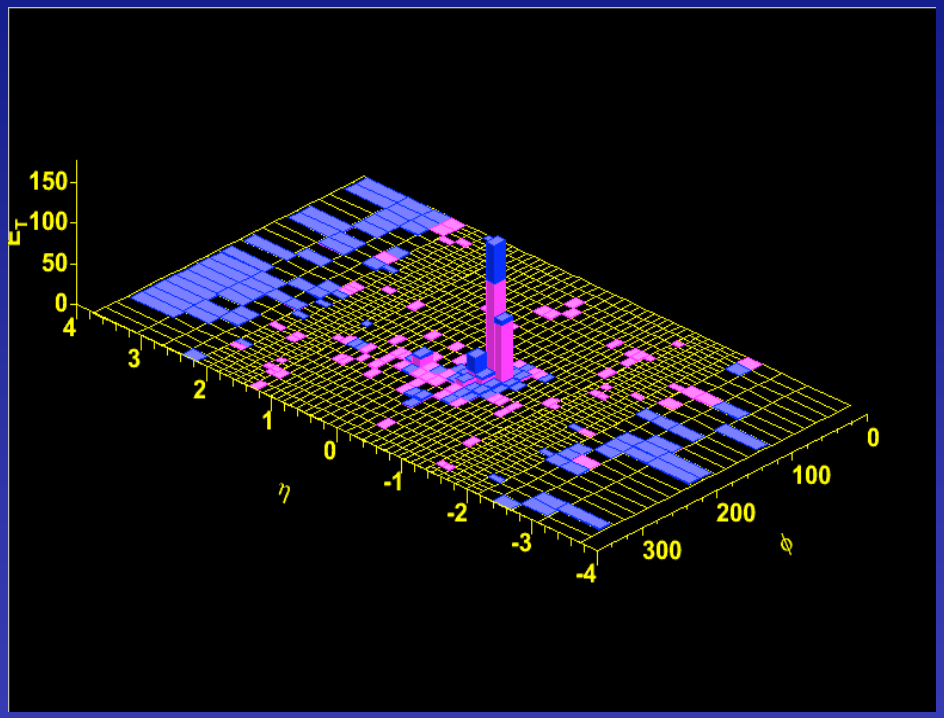
Monojet + missing Et Search

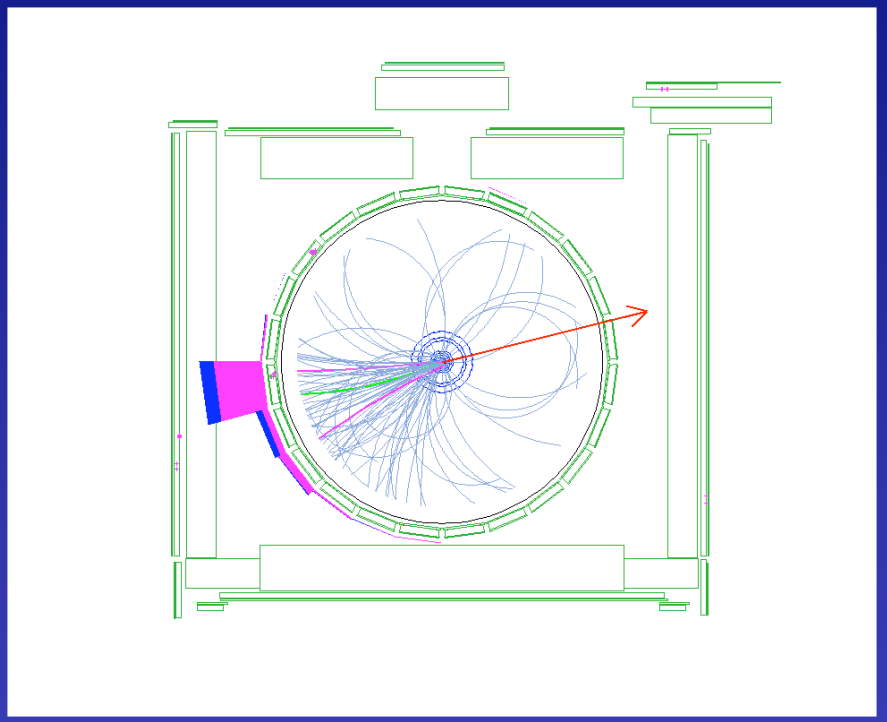
- Data sample of ~1.1 fb^{-1} collected using a jet trigger with a threshold of 100 GeV E_T
- Have enough data to be able to make data-driven estimates of the major backgrounds.
- The most important backgrounds are:
  - Electroweak (1-jet + $Z \rightarrow \nu\nu$ and $W \rightarrow \ell\nu$: ℓ not identified)
  - QCD (mismeasured jets) → small (~6% of total bkg), estimated using data

Monojet event selections

- The leading jet must have E_T(corr) > 150 GeV to ensure that the trigger is fully efficient;
- Large missing energy is expected from the escaping particle (missing transverse energy > 120 GeV);
- A 2nd jet of lower energy (E_T(2) < 60 GeV) is tolerated to increase the acceptance (ISR/FSR)
- To remove the charged lepton of W + jets events, we require no isolated tracks with P_T > 10 GeV/c and an Em fraction < 0.9
- To reduce QCD bkg, the MET must not be in the same azimuthal direction (ϕ) as any jets.

Example of Signature (most energetic event)

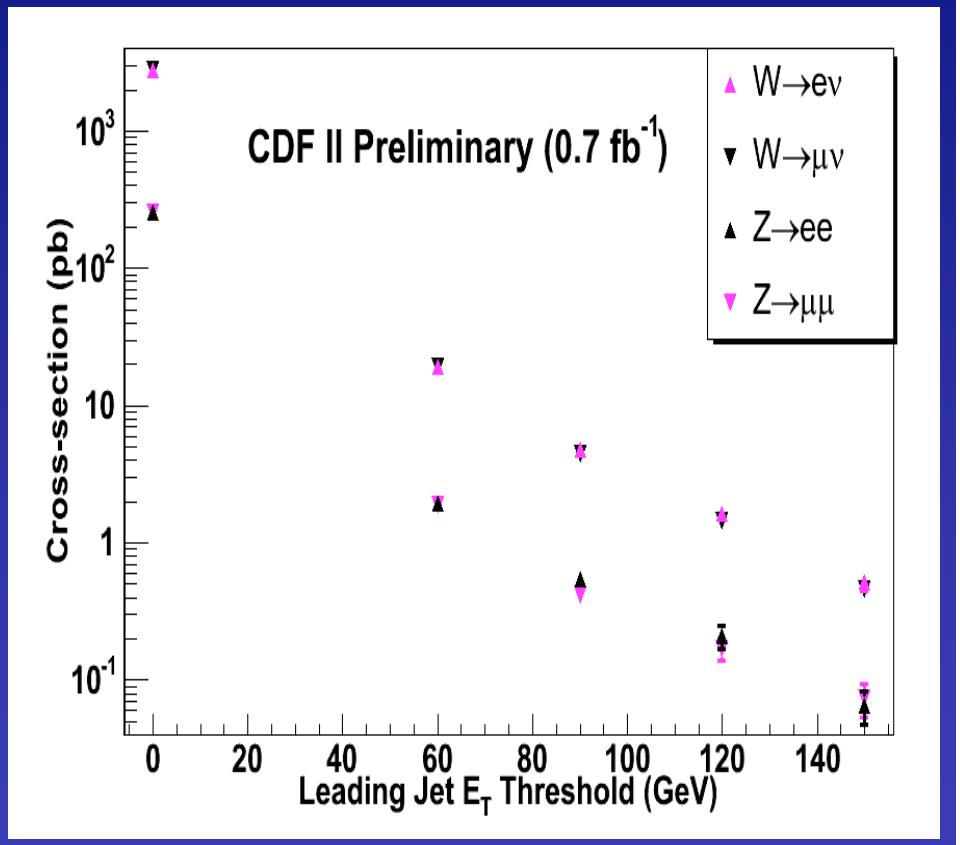




Jet E_T = 419 GeV, Missing E_T = 417 GeV

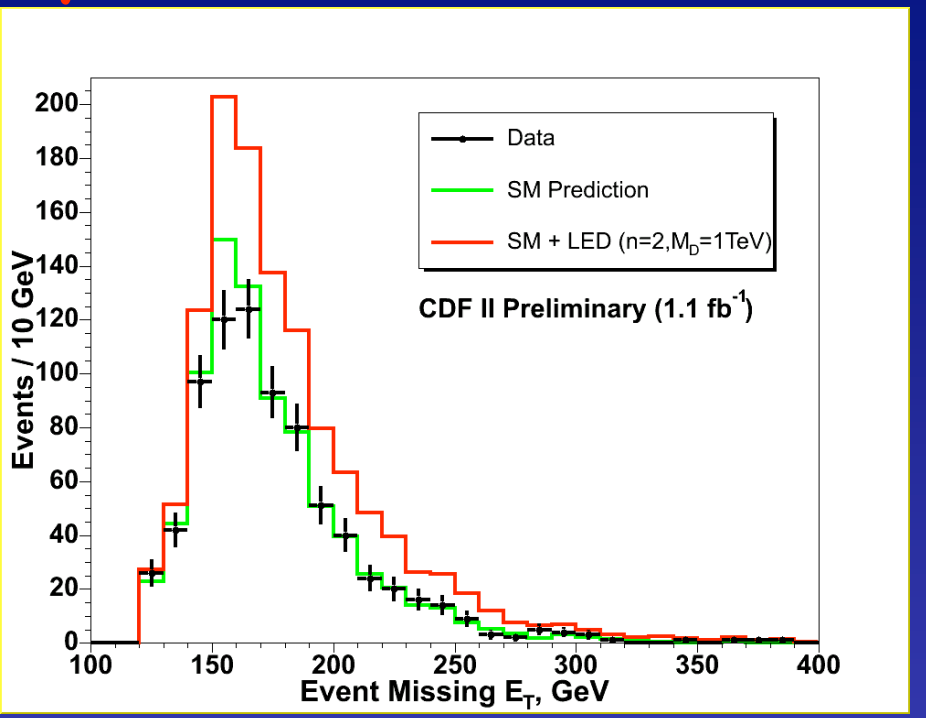
Electroweak Background Calculation

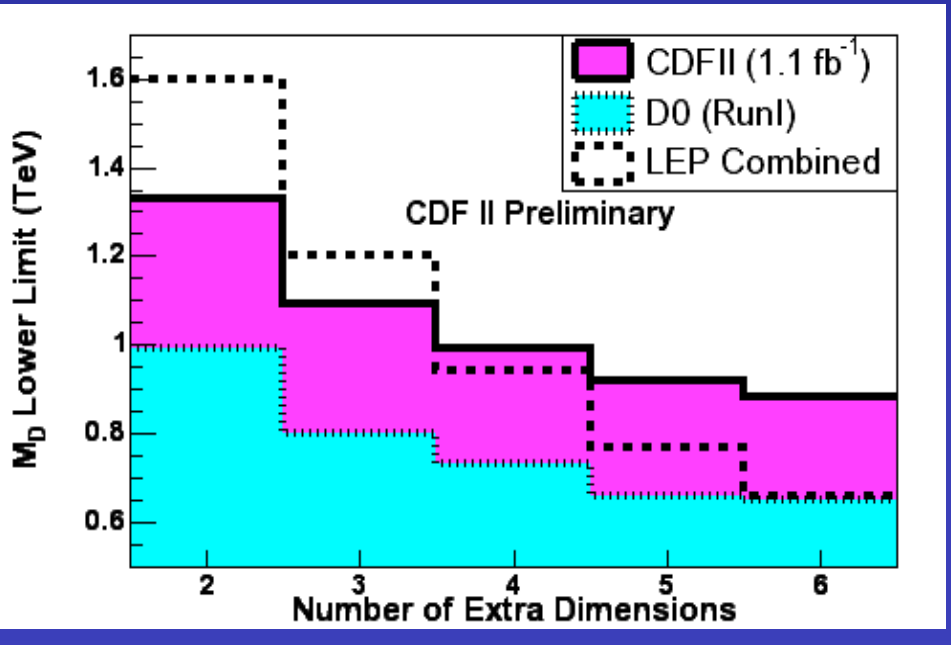
- To make a data-driven estimate of $Z \rightarrow \nu\nu$, $W \rightarrow \ell\nu$:
  - 1-jet+W/Z ($Z \rightarrow \ell\ell$, $W \rightarrow \ell\nu$, ℓ = e, μ) cross sections are measured with sample of identified leptons
  - W cross sections normalized to Z cross sections using theoretically robust ratio between $W \rightarrow \ell\nu$ and $Z \rightarrow \ell\ell$ cross sections.
  - Correct using measured branching ratios
  - Use simulation to estimate acceptance of missed lepton in $W \rightarrow \ell\nu$ (ℓ = e, μ, τ)



Monojet Results, ADD Limits

Background	Expected Events
$Z \rightarrow \nu\nu$	398 ± 30
$W \rightarrow \tau\nu$	192 ± 20
$W \rightarrow \mu\nu$	119 ± 12
$W \rightarrow e\nu$	58 ± 6
$Z \rightarrow ll$	7 ± 1
QCD	39 ± 14
Non-Collision	6 ± 6
Total Predicted	819 ± 71
Data Observed	779

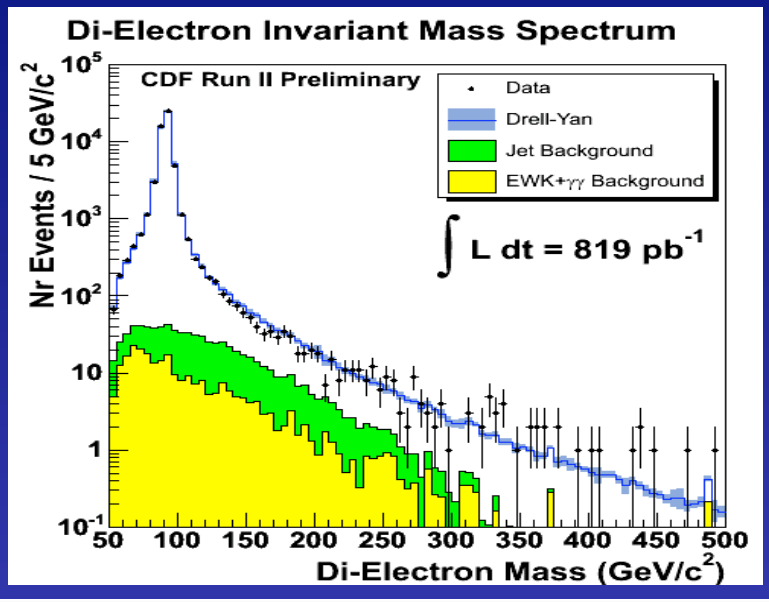


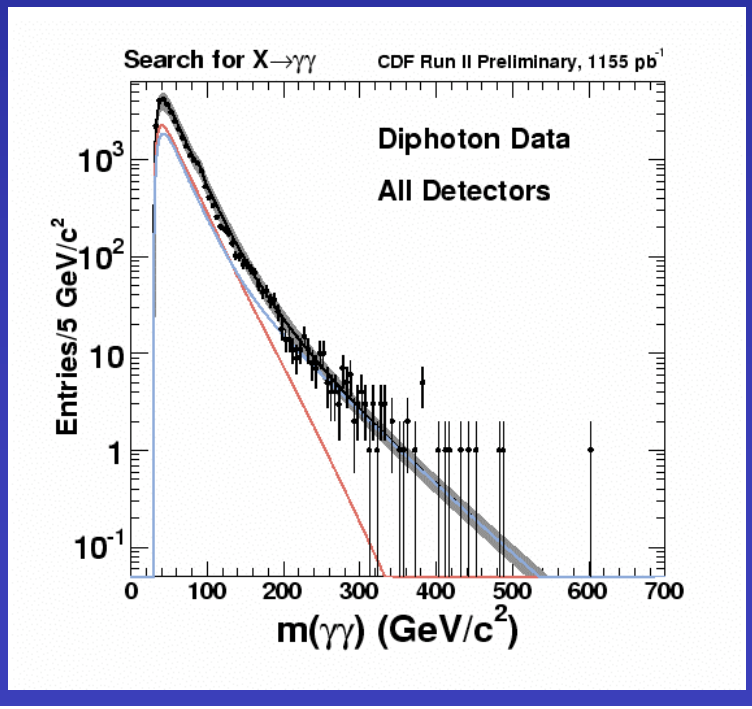


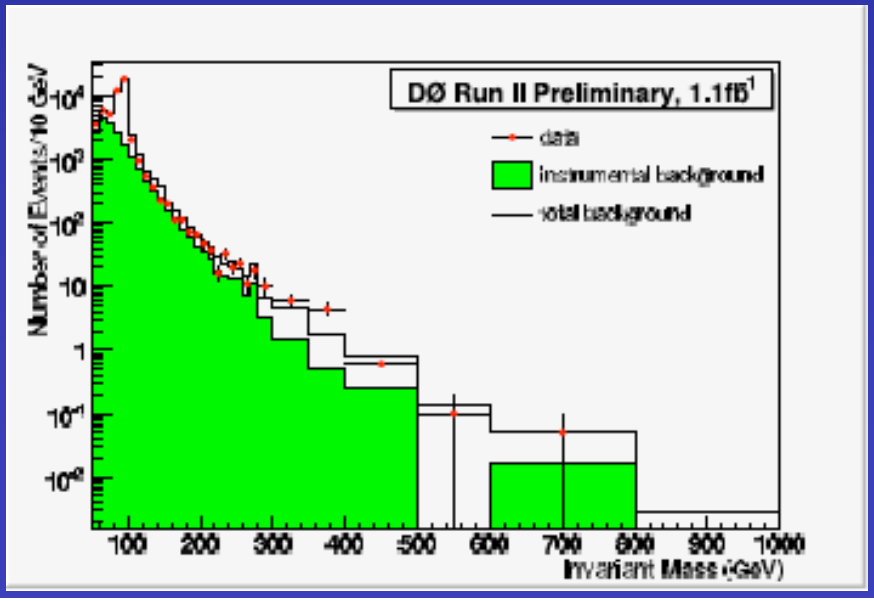
n	M_D (TeV/c^2) (K=1.3)	R(mm)
2	> 1.33	< 0.27
3	> 1.09	$< 3.1 \times 10^{-6}$
4	> 0.99	$< 9.9 \times 10^{-9}$
5	> 0.92	$< 3.2 \times 10^{-10}$
6	> 0.88	$< 3.1 \times 10^{-11}$

RS Search in e^+e^- and $\gamma\gamma$ Channels

- Backgrounds to dielectron, diphotons signals come:
  - SM Drell-Yan ($Z^0/\gamma^* \rightarrow e^+e^-$)
  - Direct $\gamma\gamma$ production
  - QCD and W+jets
  - Other Electroweak processes

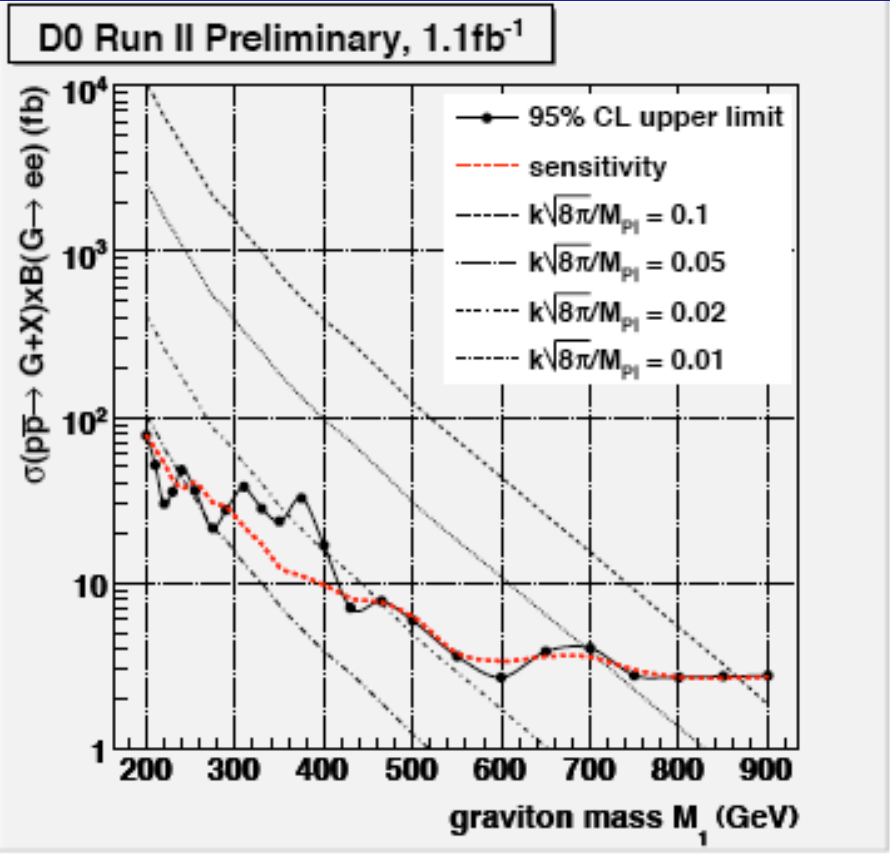


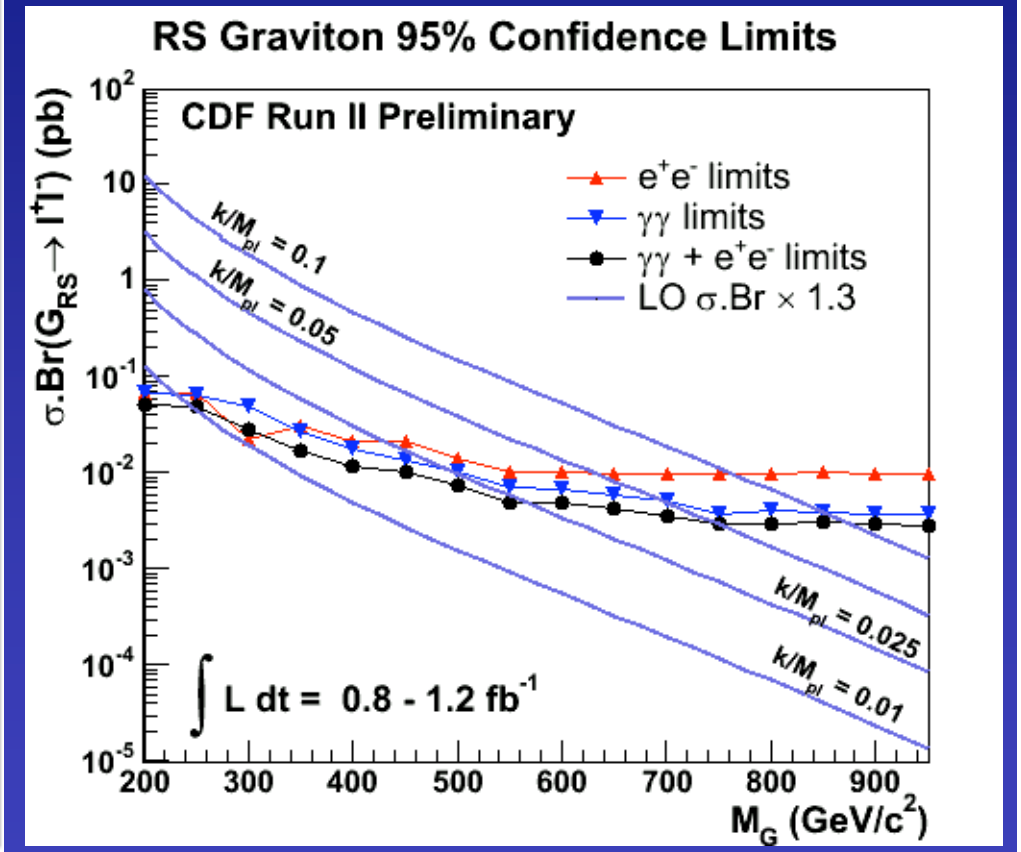




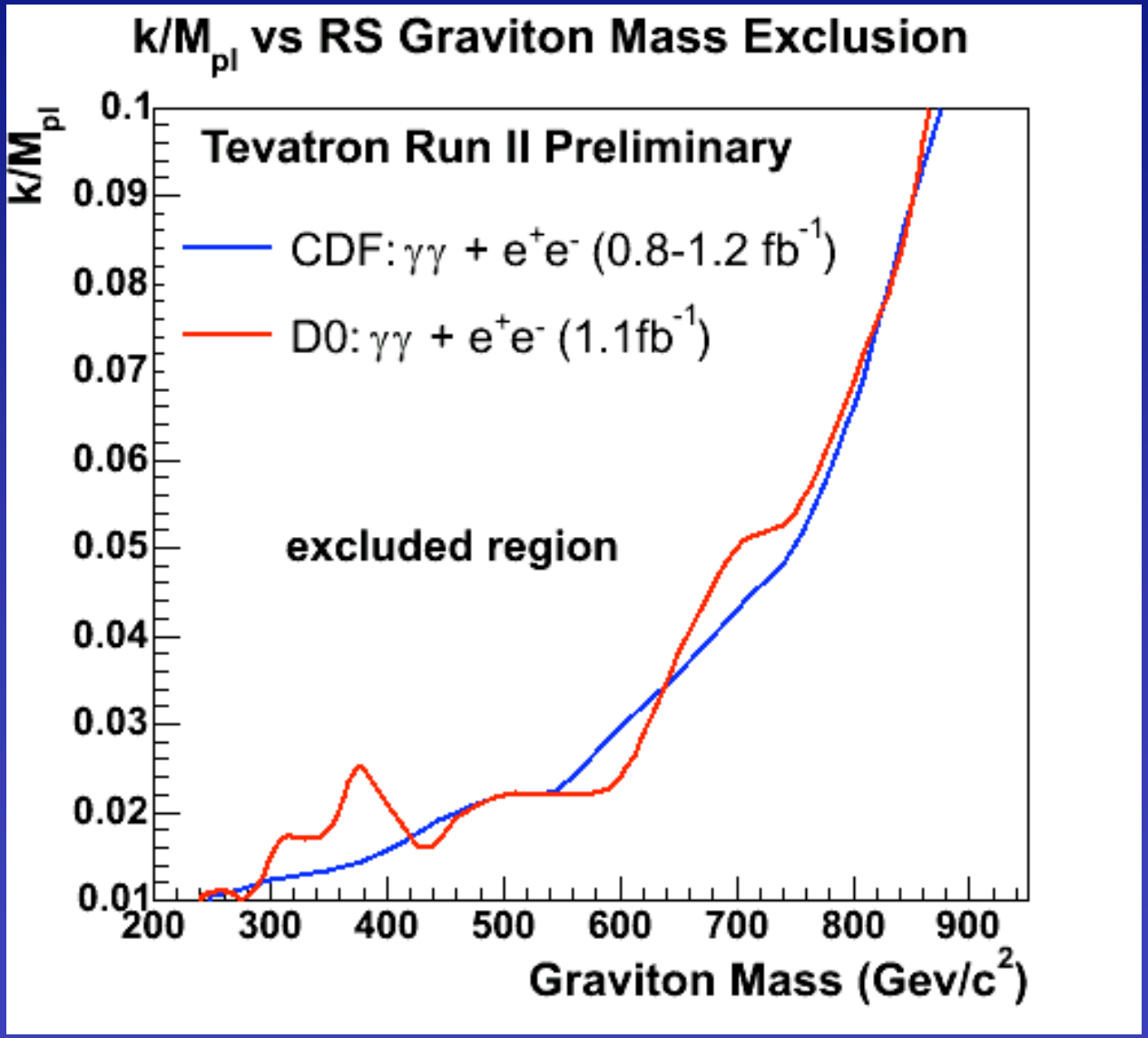
RS Limits: Cross Section vs M_G

- Systematic uncertainties on limits include mass dependent efficiency and acceptance, Z cross section, backgrounds



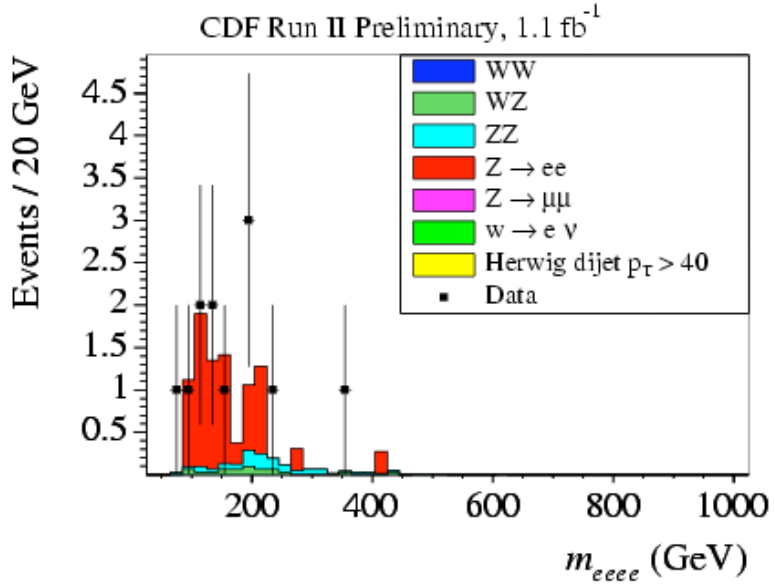


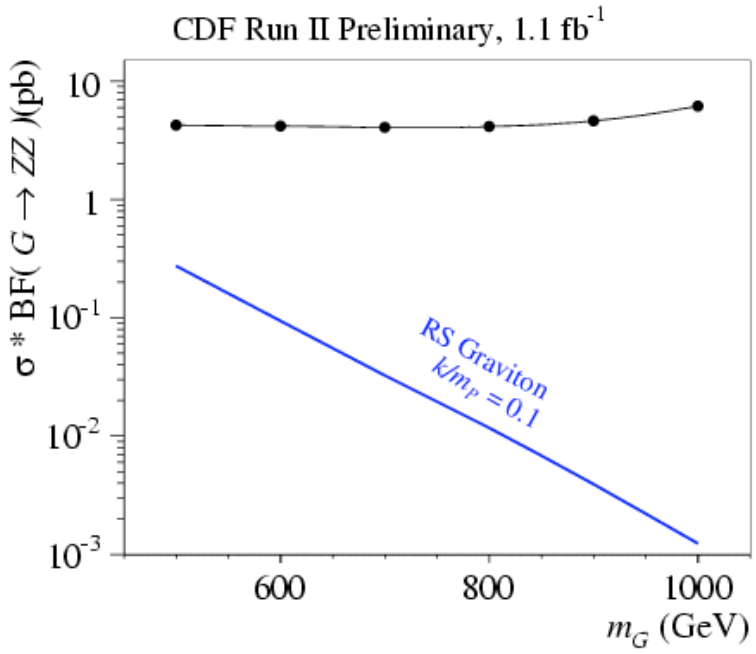
RS Limits: k/M_{pl} vs M_G



CDF RS ZZ→$e^+e^-e^+e^-$ Search

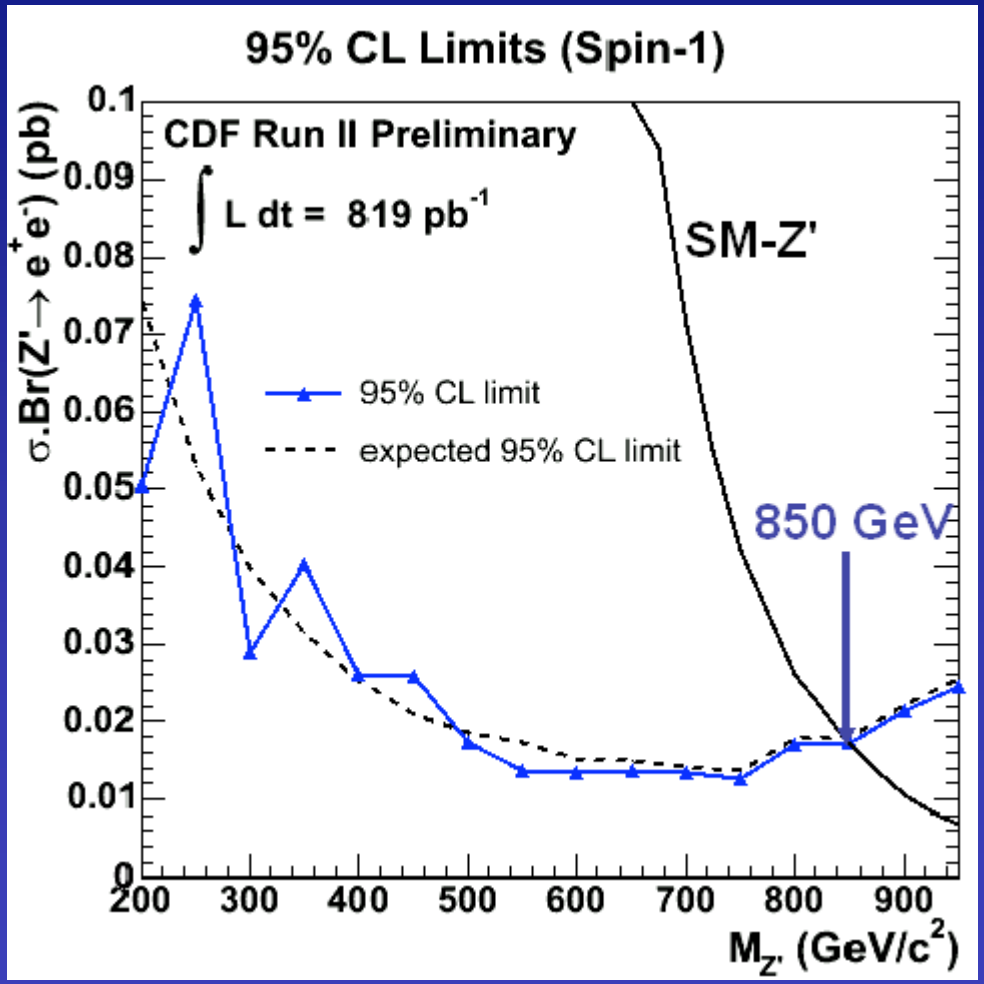
- Very clean signature (low backgrounds)
- low cross section X branching ratio
- Low acceptance X efficiency





CDF SM-like Z' Limit

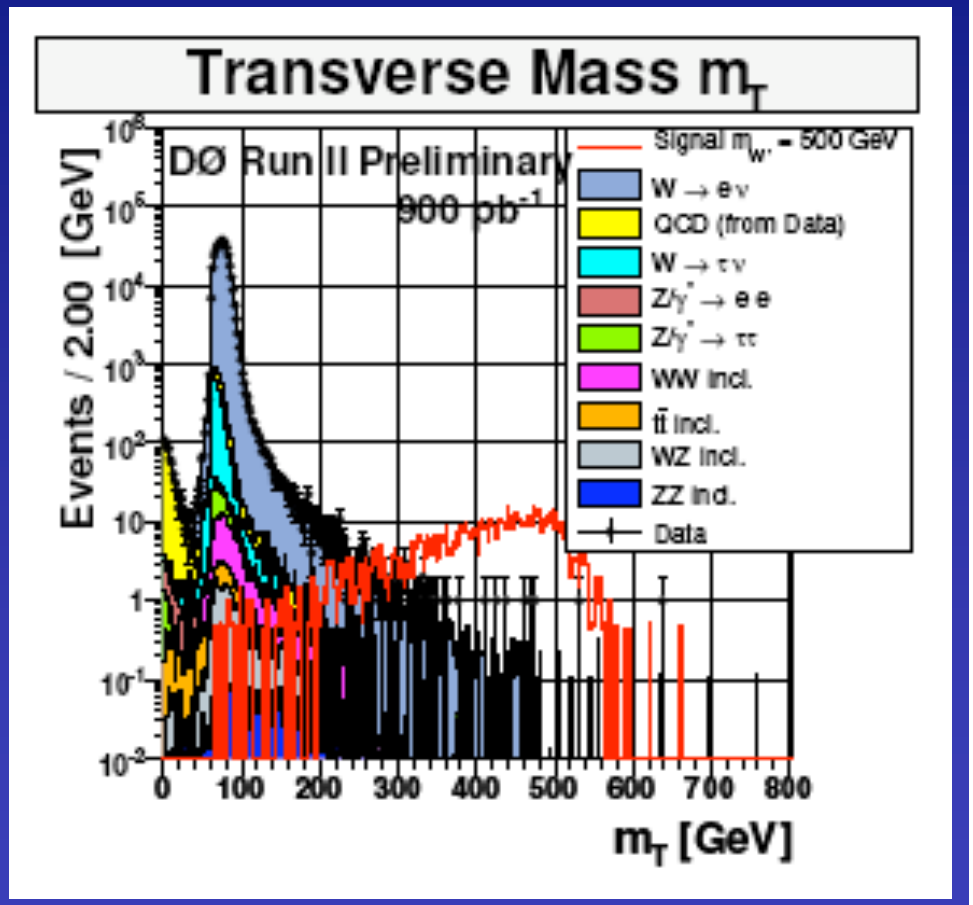
- Re-interpret CDF results in terms of a limit on a Z' boson with SM-like couplings
- 95% CL lower limit on Z' mass: 850 GeV



DØ W′ →eν Search

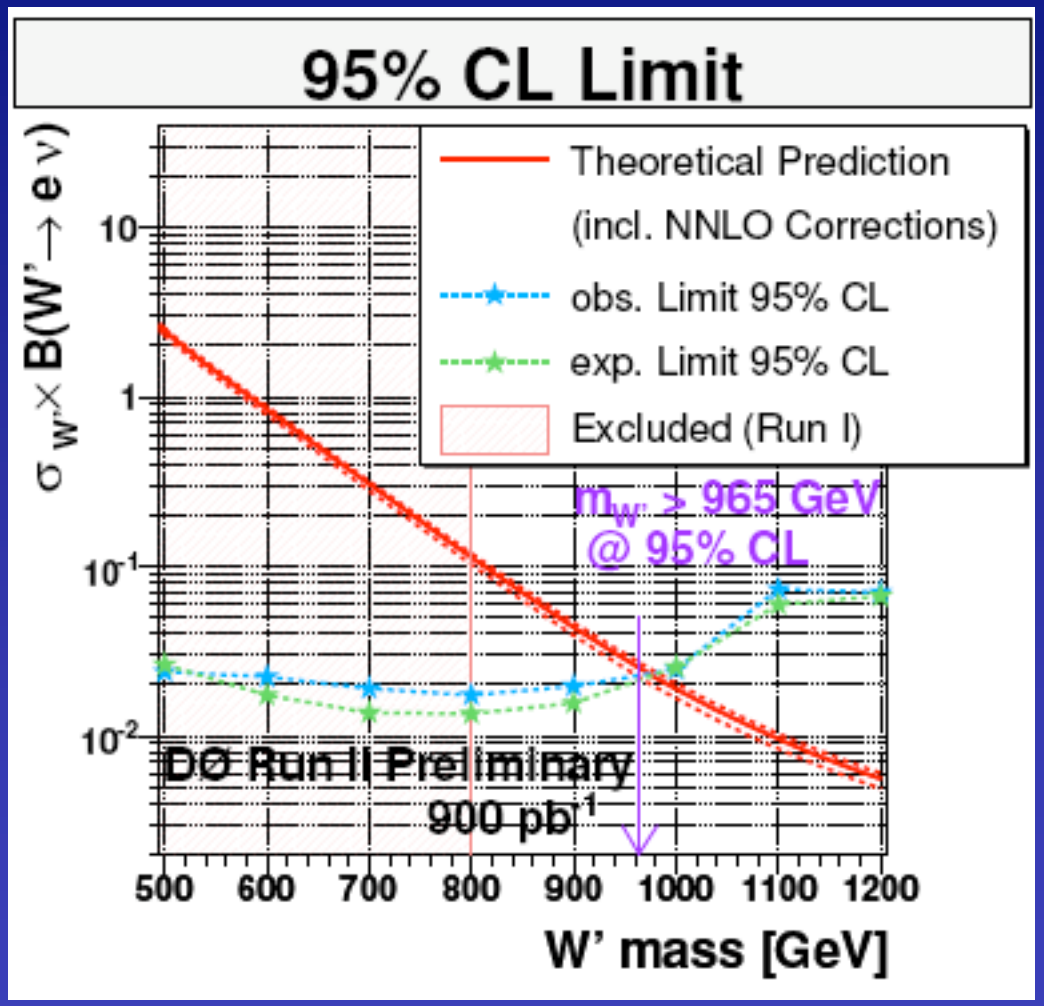
- Search uses 900 pb-1 of data

- Backgrounds to W′ signal:
  - Main background: SM W*
  - QCD multijet background (calculated from data)
  - Drell-Yan ($Z^0/\gamma^* \rightarrow e^+e^-$, one electron lost)
  - Other Electroweak processes (e.g. WW, ZZ, WZ)



DØ W'→eν Mass Limits

- Limits assume:
  - No mixing between gauge groups
  - g' (new coupling to fermions) equal to SM
  - CKM matrix equivalent (U') equal to SM CKM matrix
  - New decay channels like WZ are suppressed
  - W' width assumed to scale with its mass
- 95% CL lower limit on W' mass: 965 GeV



Conclusions

- We presented the latest Tevatron results on searches for extra dimensions and new gauge bosons using ~1 fb^{-1} of data

- No significant excess above Standard Model expectations was observed in the following search channels:
  - Monojet + Missing Et
  - High mass resonance with dielectrons
  - High mass resonance with diphotons
  - $G \rightarrow ZZ$
  - $W' \rightarrow e\nu$

- Both Tevatron collaborations are looking at other search channels. Results available soon.

RS Limits: k/M_{pl} vs M_G