Searches for physics beyond the Standard Model in final states with two leptons and jets with the DØ detector

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For the DØ Collaboration

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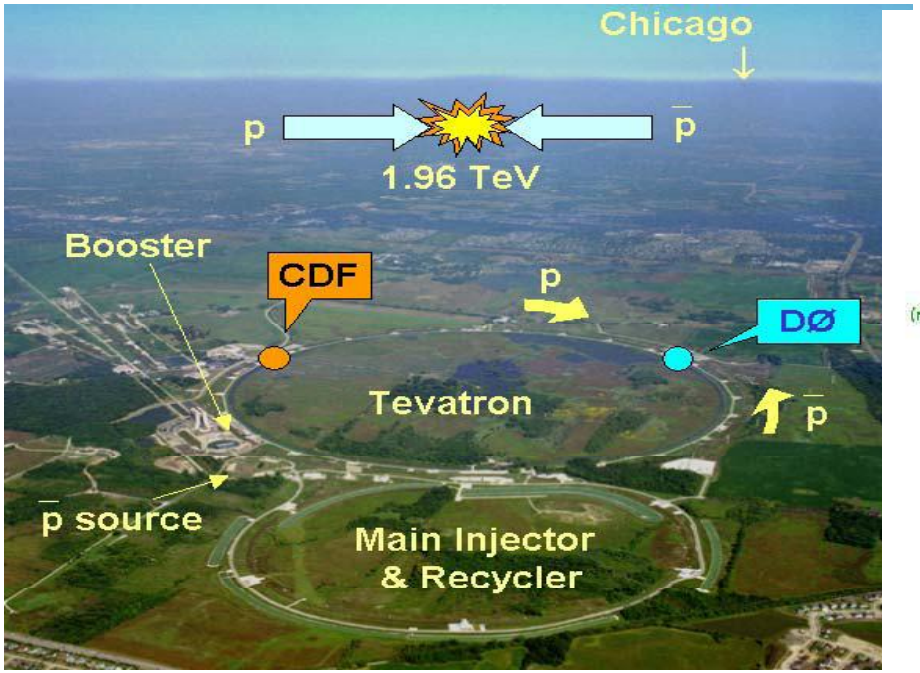
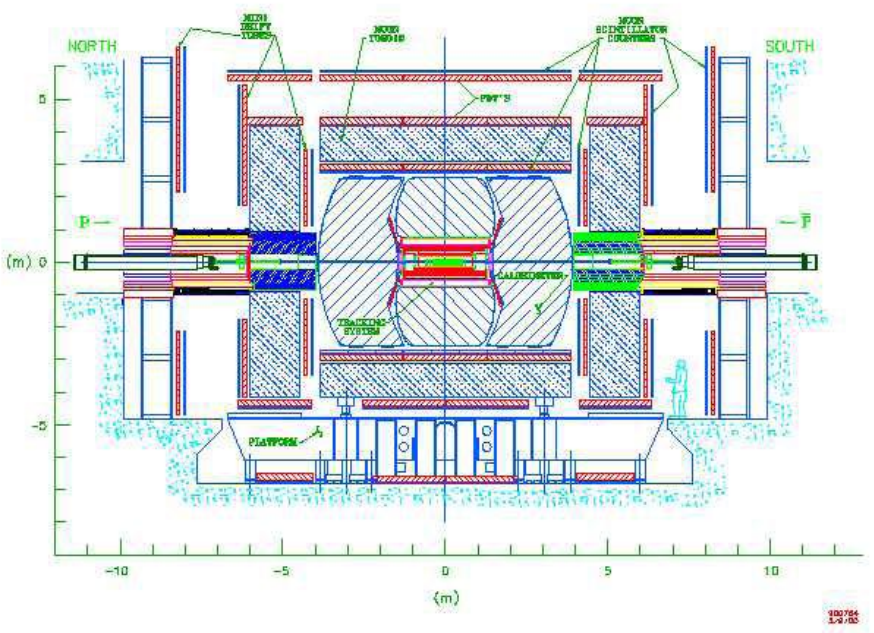
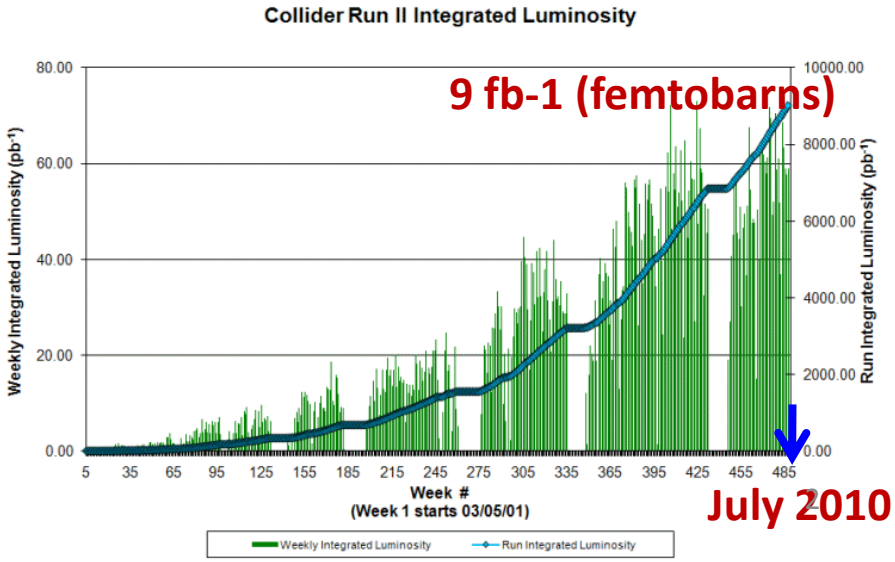
The DØ Detector





- Tevatron is performing extremely well
- Instantaneous luminosity > 3.5 X 10^{32} cm^{-2} s^{-1}
- Delivered 9 fb^{-1} integrated luminosity upto July
- DØ has collected 8 fb^{-1} of data up to July 2010
- More to come



Introduction

- The Standard Model (SM) offers an accurate description of current experimental data in high energy physics.
- However, it is believed to be embedded in a more general theory.
- Extensions of the SM to higher mass scales have been proposed.
- The new particles and phenomena predicted by these theories can be searched for at the Tevatron.

This talk will focus on lepton + 0 jets searches :

- New Gauge Bosons,
  1. $Z' \rightarrow ee$
  2. $W' \rightarrow WZ \rightarrow lll\nu$
- Extra Dimensions, Randall Sundrum gravitons

High Mass narrow resonances in the di-electron channel

- Many models of Grand Unified Theories (GUT) symmetry breaking predict neutral gauge bosons, Z'.
- The Z' bosons couple to Standard Model fermions via the electroweak interaction (Sequential Standard Model (SSM), string compactification models.
- They can be observed at Hadron Colliders as narrow resonances, $q\bar{q} \rightarrow Z' \rightarrow ee$

Trigger: 2 clusters of energy deposits in the electromagnetic (EM) calorimeter

Event Selection:

- Two isolated EM clusters, $|\eta|<1.1$, $E_T>25$ GeV
- EM energy deposit should resemble EM shower
- EM shower should match with a track
- No requirement on charges of the two candidates (avoid losses due to charge mis-id)

Invariant Mass

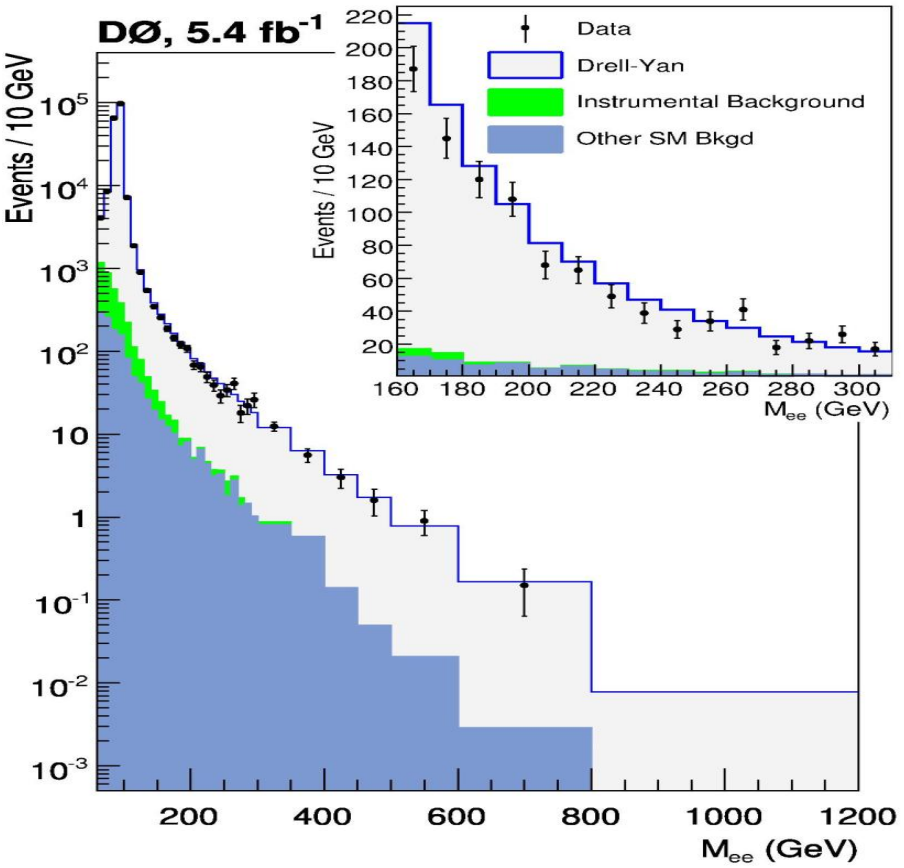
Backgrounds

Physics:

- Drell-Yan (main)
- $Z/\gamma^* \rightarrow \tau^+\tau^-$
- $W+X \rightarrow e\nu + X$,
  X is a jet/γ misidentified as e
- $W^+W^- \rightarrow e^+e^-\nu\nu$
- $W^\pm Z, Z \rightarrow e^+e^-$
- $t\bar{t} \rightarrow W^+b \rightarrow W^-b \rightarrow e^+\nu_e b + e^-\nu_e \bar{b}$

Instrumental:

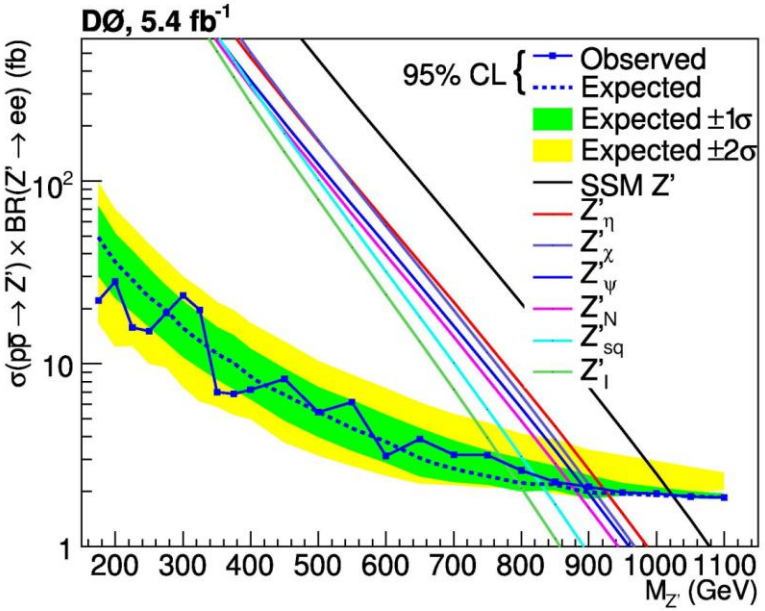
QCD multijet events
(both jets misidentified as electrons)



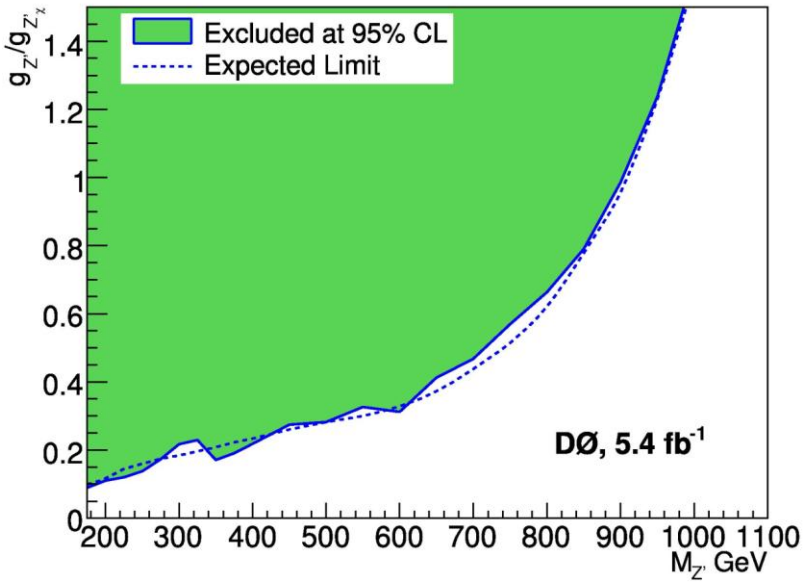
Invariant mass spectrum of ee pairs for data with expected total background and the contributions from instrumental and other SM background superimposed, search for a bump in the higher mass region

Mass Limits

No excess is observed in the entire mass range studied
limits are set on Z' mass in various models
e.g. Z' is excluded below 1023 GeV in the SSM model



Mass limits for SSM , and superstring inspired E6 models.



Exclusion in the $M_{Z'}$ vs. ratio of coupling strengths plane

arXiv: 1008.2023
Submitted to PLB

$W' \rightarrow WZ \rightarrow lll\nu$

As we know, Standard Model could be a low energy approximation of a more fundamental theory.

A of the many possible extensions are:

- Sequential Standard Model (SSM) ($W' \rightarrow WZ$ decay is suppressed)
- Little Higgs
- Technicolor

The extensions predict new heavy W' resonances decaying to a pair of W and Z bosons

Alternate mechanism of electroweak symmetry breaking

Observation of WZ resonances is important

- Evidence of new physics
- Insight into origin of mass

Technicolor:

ρ_T (narrow widths) $\rightarrow$ WZ

Experimental signature similar to that of W'

W' → WZ→ lllν

Event Selection:

- Leptonic decays, Trigger: single EM, single muon
- 3 charged leptons, p_T>20 GeV
- MET > 30 GeV (neutrino)

Background: genuine leptons from Standard Model WZ, ZZ decays

WZ Candidate selection:

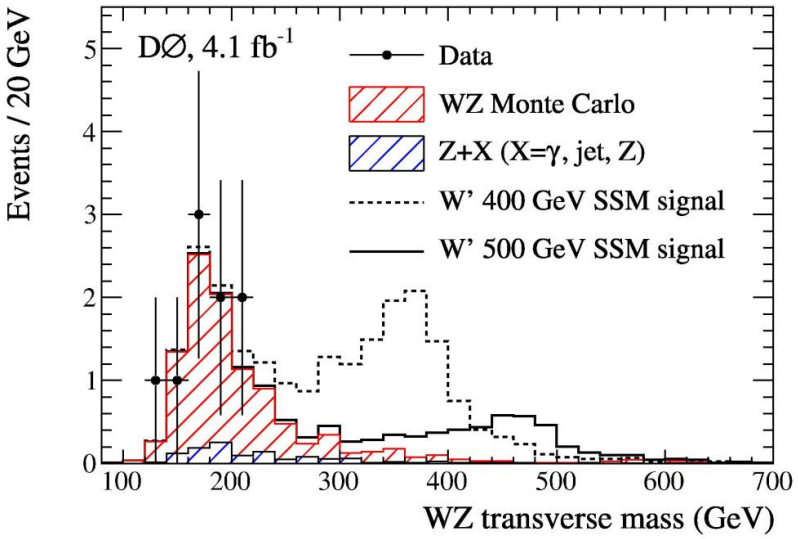
Select Z :

- opposite charged e or μ pair
- invariant mass within 70 GeV to 110 GeV

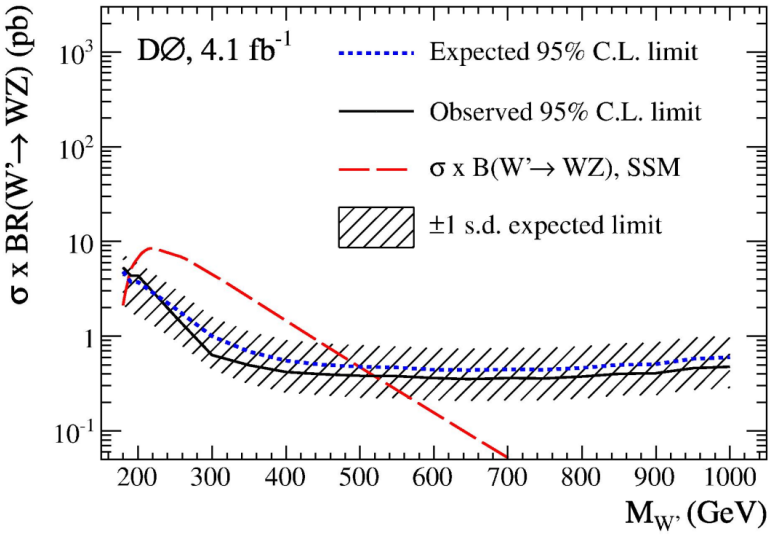
Select W: the highest p_T remaining lepton

Lepton from W decay seprated from leptons From Z decay by ΔR > 1.2

$\Delta R=\sqrt{(\Delta\eta)^2 + (\Delta\Phi^2)}$



Transverse mass distribution of the WZ system in data with the major SM backgrounds.

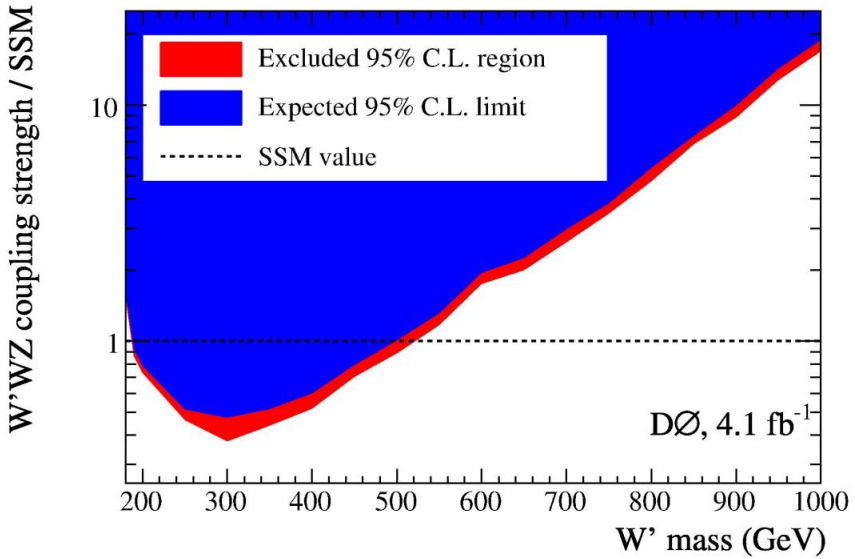


Expected and excluded area of the W'WZ coupling strength normalized to the SSM value as a function of the W' mass.

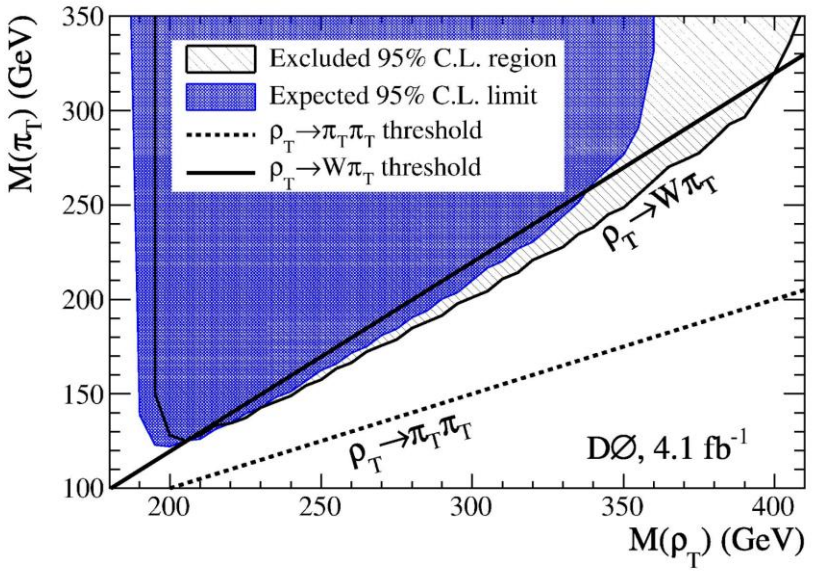
Limit on W'WZ coupling, σ x Br. Fraction of W'

9 data events observed after all the selection criteria
In good agreement with the background prediction (10.2± 1.6 events)

Results are interpreted within the low-scale technicolor model (LSTC) –
$M(\rho_T) < 400$ GeV (well within Tevatron's reach)
LSTC region explored - $M(\rho_T) \leq M(\pi_T)$



Observed and expected 95% C.L. upper limits and 1 s.d. band around the expected limits on the σ x B(W' → WZ) with the SSM prediction overlaid.



Expected and excluded areas of the $M(\pi_T)$ vs. $M(\rho_T)$ are given with the thresholds of the $\rho_T \rightarrow W\pi_T$ and $\rho_T \rightarrow \pi_T\pi_T$ overlaid.

Phys. Rev. Lett. 104, 061801 (2010)

Randall-Sundrum (RS) Gravitons

Large disparity between the Planck scale, M_{Pl}~ 10^{16} TeV and the electroweak scale~ 1 TeV is the hierarchy problem in Standard Model

The RS model proposes the existence of a 5th dimension with a warped space time metric bounded by two 3D branes
The SM fields are localised on one, and gravity originates on the other

Then, TeV scales are naturally generated from Planck scale

Two parameters of the theory are,
K = curvature radius
r_c = compactification of the extra dimension

Gravitons are the only particles that propagate in the fifth dimension, and appear as a Kaluza-Klein series of massive excitations (kk gravitons, G)
They have spin 2, mass splitting ~ 1 TeV and a universal coupling to the SM fields (UED)

K and r_c are expressed as M_1, mass of the first excited state, k/M_{Pl}, the dimensionless coupling to the Standard Model
To address the hierarchy prblem, M_1 ~ TeV, $0.01 \leq k/M_{Pl} \leq 0.1$

Randall-Sundrum Gravitons

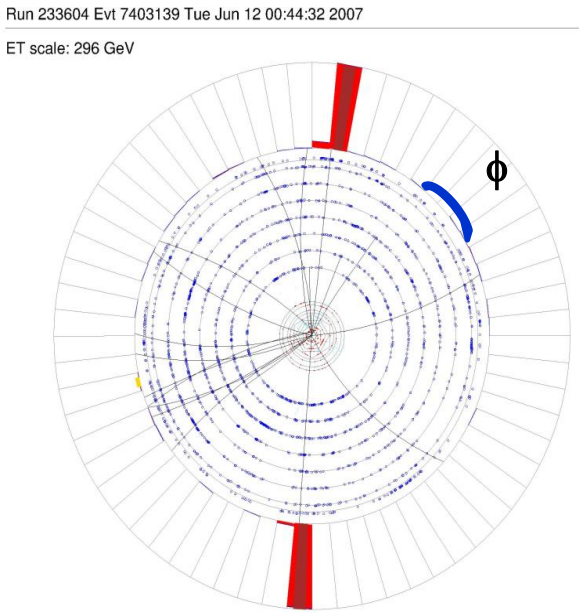
RS Gravitons could be produced in $p\bar{p}$ collisions and decay to SM fermion or boson pairs

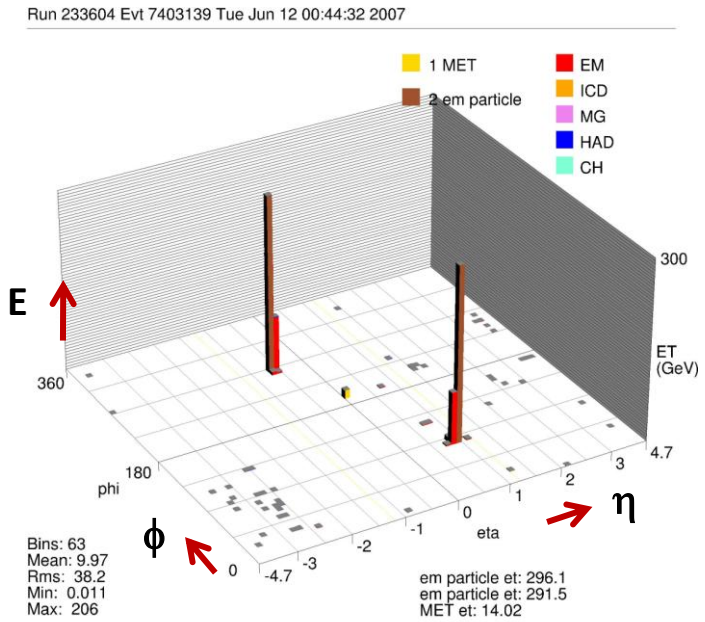
$$q\bar{q}\ (gg) \rightarrow G \rightarrow ee\ (\gamma\gamma)$$

DØ looks for KK gravitons as narrow resonances of two electrons or photons

Trigger & Event Selectio
Similar to the Z' search
Two isolated di-EM clust
E_T > 25 GeV

Event Display

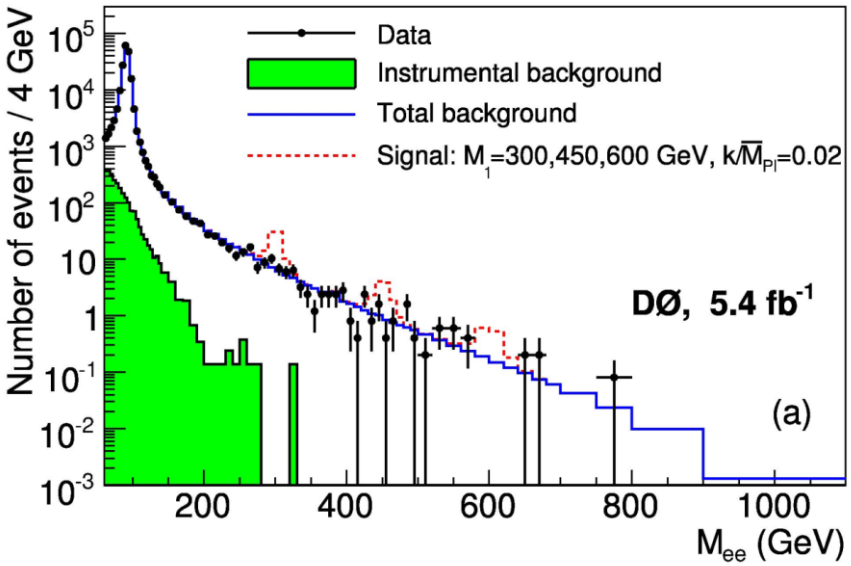


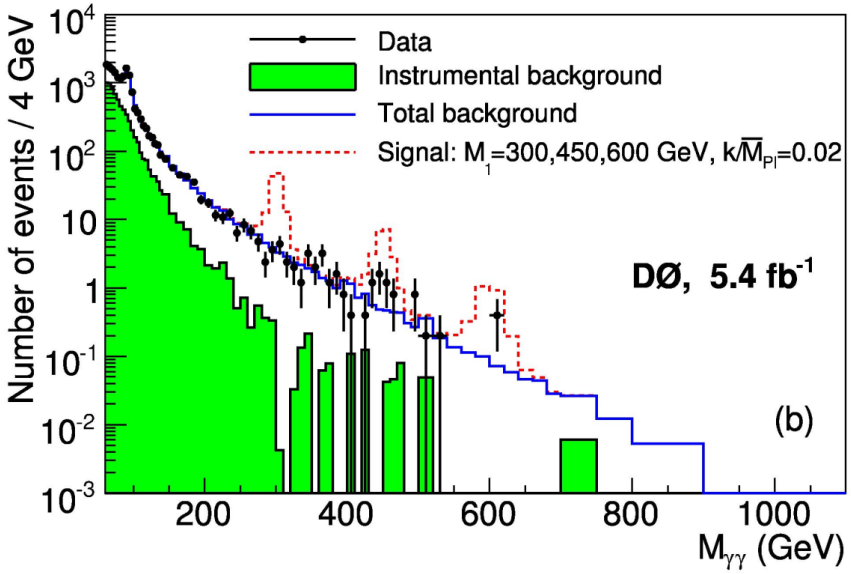


Most Energetic Event – Invariant Mass = 766 GeV

Two clean EM clusters

Invariant Mass of ee or γγ



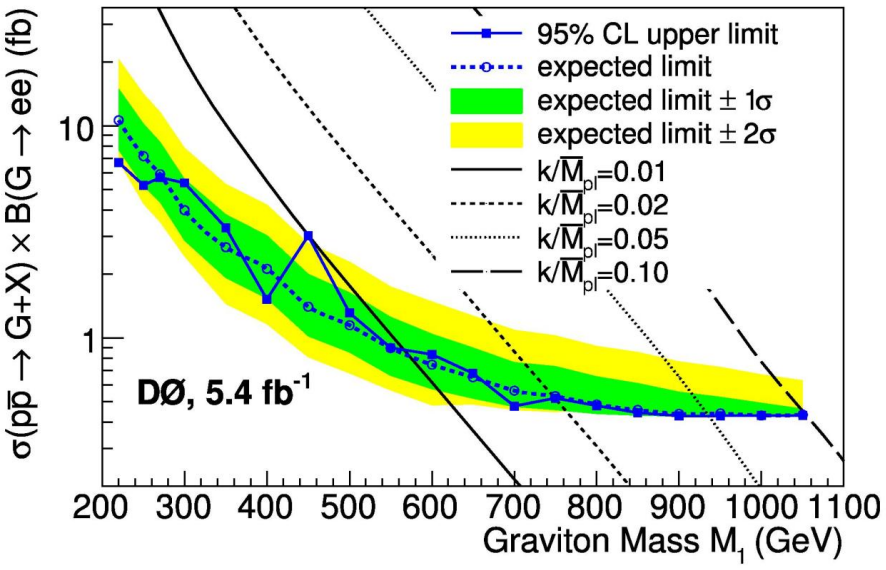


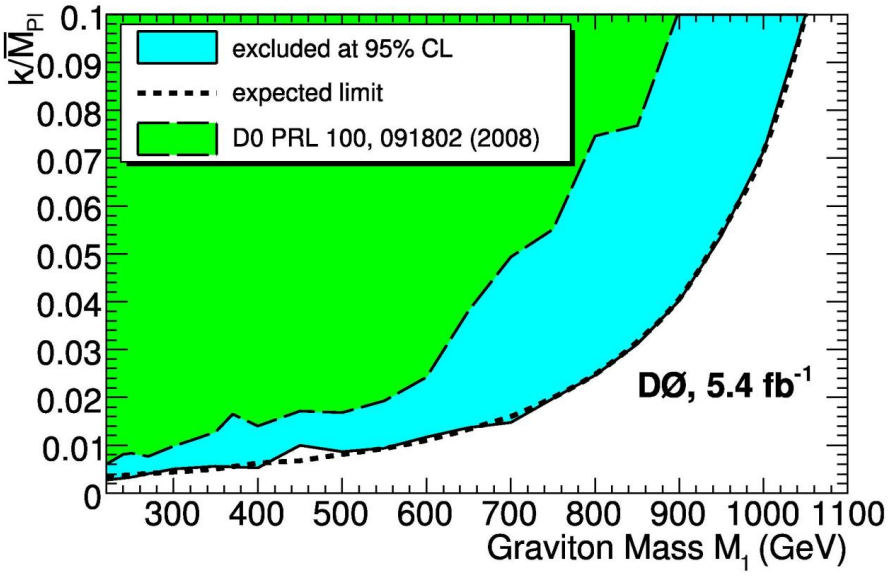
Look for excess events in different mass ranges depending on the values of the parameters of the RS model

Limits on model parameters

Experimental data matches well with background events

Limits are set on graviton mass and RS model parameters

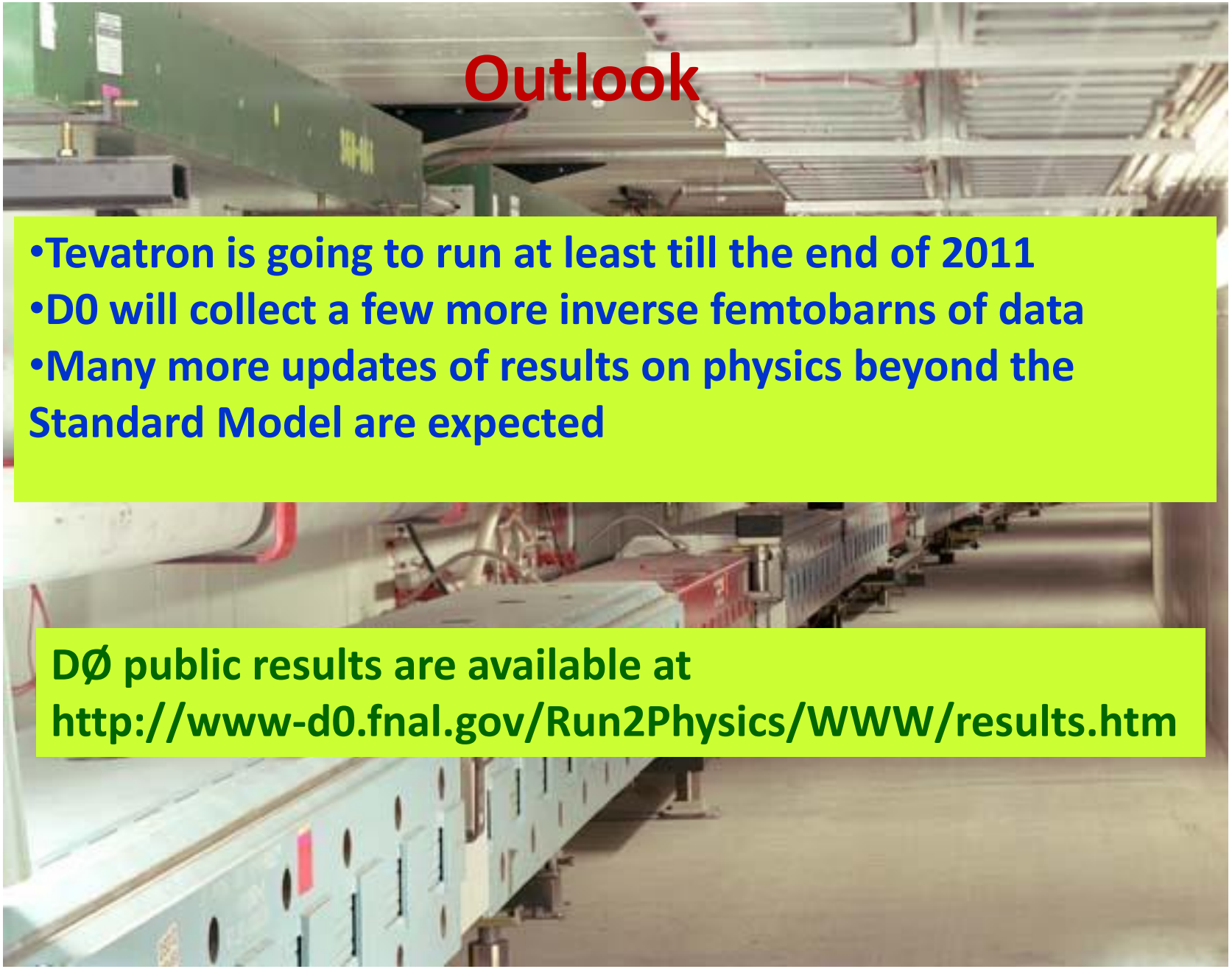




Gravitons are excluded for mass < 1050 GeV
for $k/M_{pl} = 0.1$

Phys. Rev. Lett. 104, 241802 (2010)

Outlook



- Tevatron is going to run at least till the end of 2011
- D0 will collect a few more inverse femtobarns of data
- Many more updates of results on physics beyond the Standard Model are expected

DØ public results are available at
http://www-d0.fnal.gov/Run2Physics/WWW/results.htm