Searches for new Gauge Particles in Dilepton and Diphoton Final States at the Tevatron

Jedong Lee
University of Rochester

For the CDF and D0 Collaborations

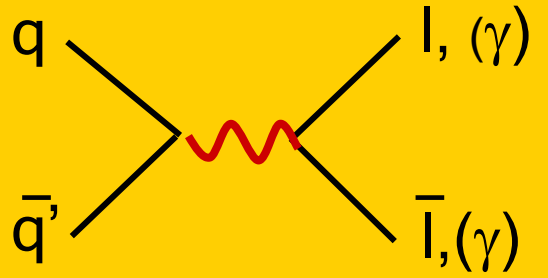
PANIC05
Oct 27, 2005

Introduction

- Gauge Particle : Force carriers.
  - Many theories (beyond SM) expect more than what we know.
  - Heavier ones may be discovered at CDF/D0. (Tevatron is the high energy frontier.)
  - Generated from $q\bar{q}$ annihilation from $p\bar{p}$ collision at 1.96 TeV.
- Dilepton/Diphoton channel
  - Signal is very clean.
  - Low SM background (mainly Drell-Yan) at high mass.
  - Better chance to find new particles.

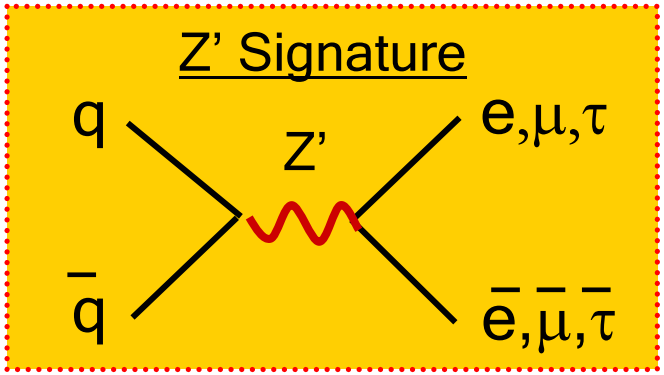
Force	Gauge Boson
Electromagnetic	γ
Weak	W^+, W^-, Z
Strong	gluon
Gravity	Graviton

Gauge Boson production/decay at Tevatron



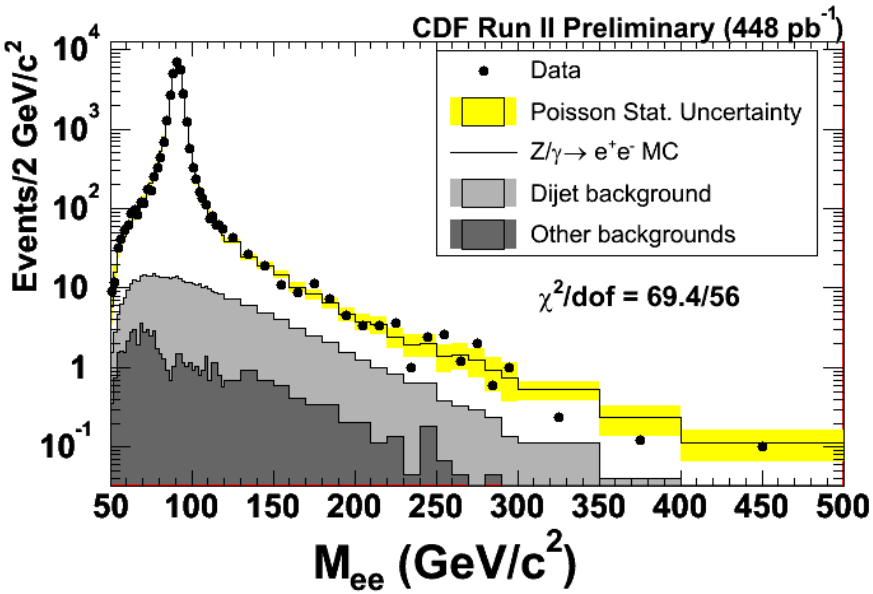
Z' Searches

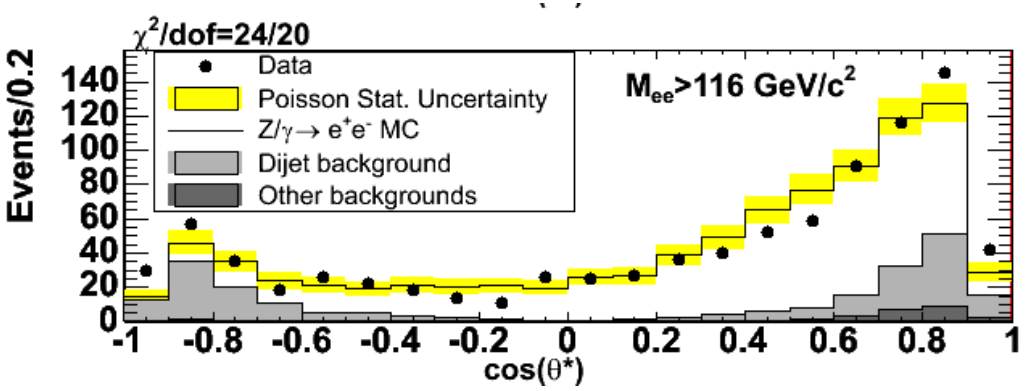
- Z' : Extra neutral gauge boson
  - Most extensions to SM predict at least one.
- Popular models
  - E6 GUT
  - Little Higgs
- Generic Z' model
  - Describes any effective U(1) gauge boson.
  - Carena, Daleo, Dobrescu and Tait (FNAL).
    - Phys.Rev.D70:093009,2004
  - Use theory constraints to reduce the number of parameters.
    - Suppressed FCNC, no exotic fermions, anomaly cancellations.
    - Four scenarios with three parameters each.
    - $M_{Z'}$ Z' mass, $g_{Z'}$ strength, x coupling parameter



Generic Z' Search at CDF (ee)

- Integrated Luminosity 448 pb^{-1}.
- Selection
  - Two high P_T isolated electrons
  - Require opposite charge
- Dijet background estimated using jet fake rate.
- Systematic uncertainty dominated by background estimation.
- Very good agreement between data and prediction.



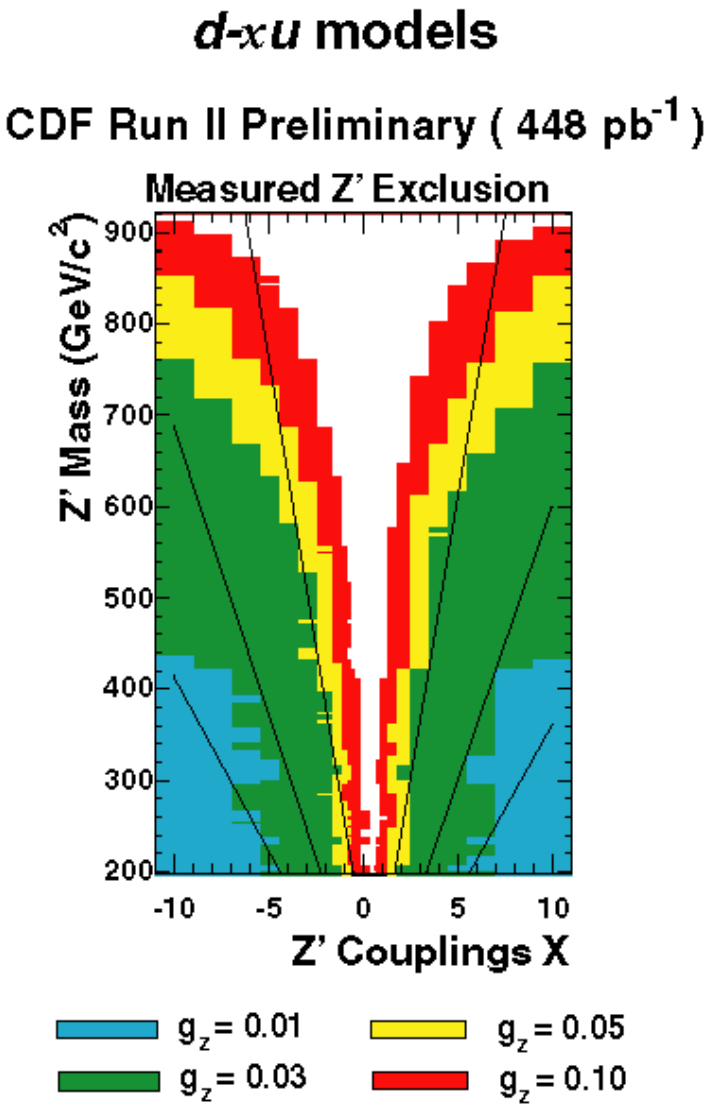


- θ* : Electron scattering angle off the proton direction.

Generic Z' Search at CDF (ee)

- CLs method for setting limits.
- Line : LEP exclusion.
- Colored : CDF Run II exclusion.
- Limits for the E6 Z's

	95% CL Limit
Seq.Z'	845 GeV/c^2
Z_I	625 GeV/c^2
$Z\eta$	715 GeV/c^2
$Z\psi$	690 GeV/c^2
$Z\chi$	720 GeV/c^2

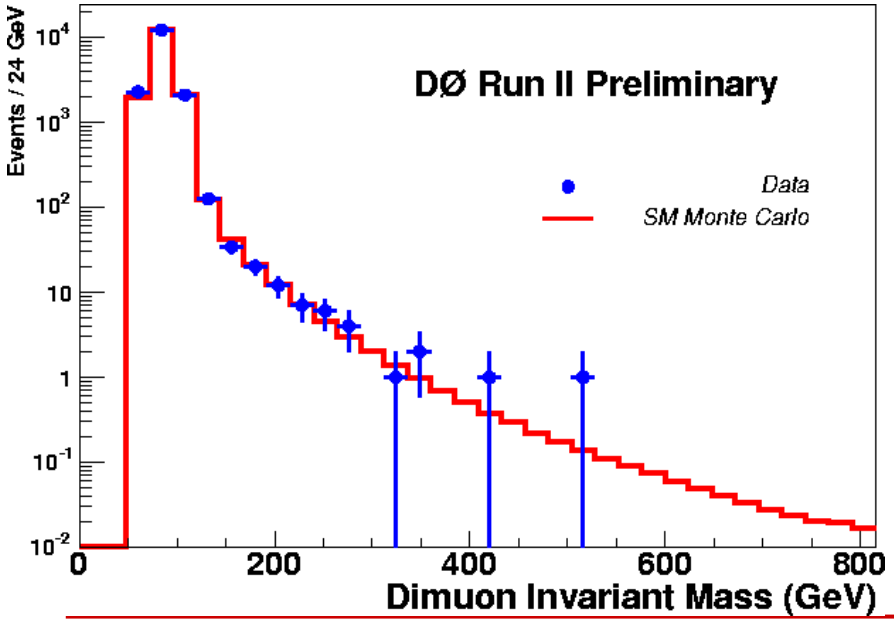


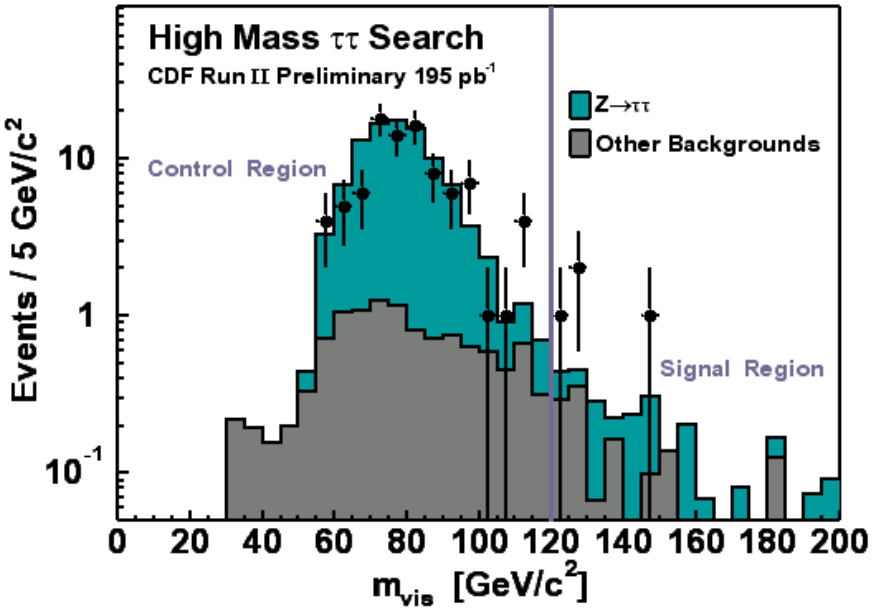
More Channels

- Bayesian binned likelihood fitting set the limits.
  - 95% CL one-sided lower limits.

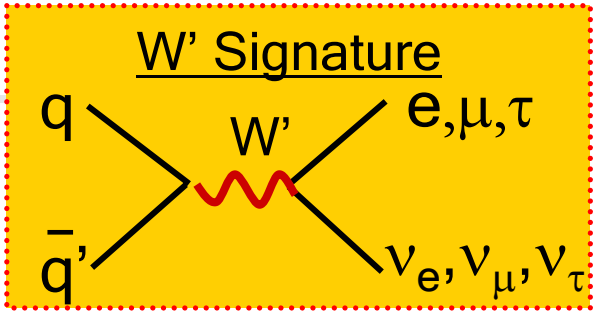
- $Z' \rightarrow \mu\mu$ at D0:
  - 250 pb-1
  - Sequntial Z' limit : 680 GeV/c^2

- $Z' \rightarrow \tau\tau$ at CDF:
  - 195 pb-1
  - Sequential Z' limit : 394 GeV/c^2

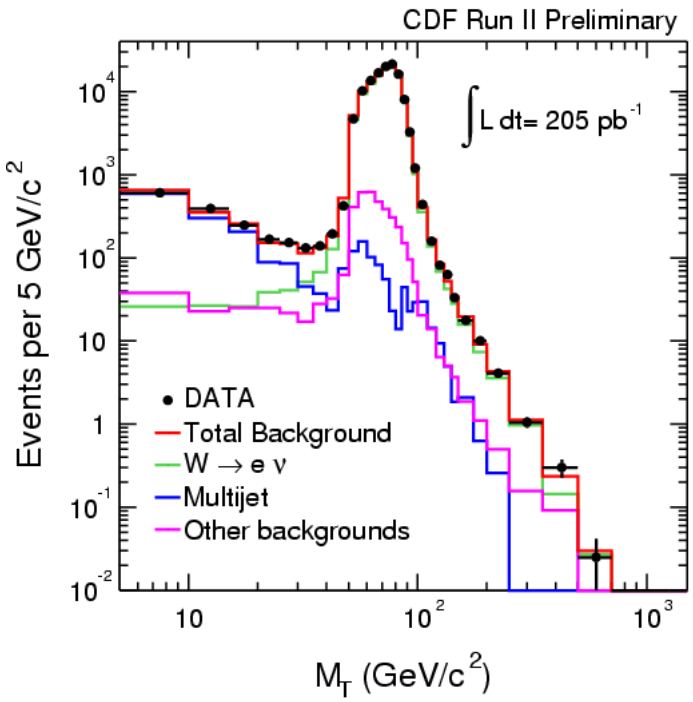


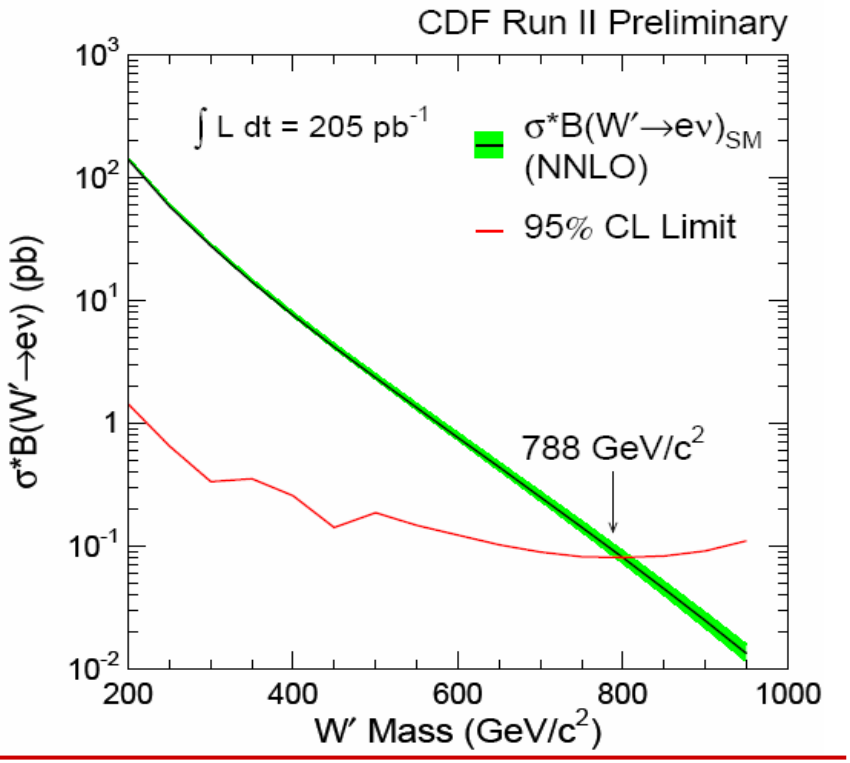


W' → eν Search at CDF



- W' : Extra massive charged gauge boson.
  - Predicted by left-right symmetric models.
- Look for excess in transverse mass (M_T) 205 pb^{-1}
  - Very good agreement over many orders of magnitude in M_T.
- Bayesian binned likelihood fitting; no evidence for W'
  - 95 % CL limit is set 788 GeV/c^2.

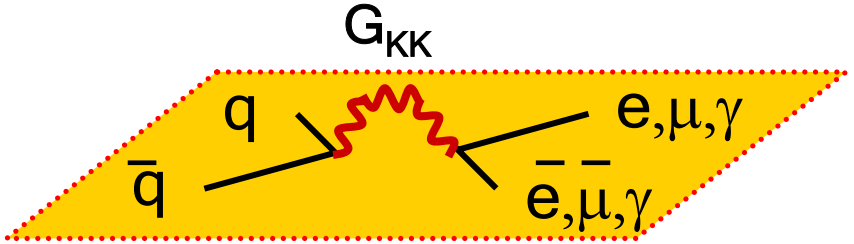




Extra Dimension and Graviton

- If extra dimensions are not small…
  - Fundamental Planck scale (M_S) can be within reach.
  - Graviton and/or other gauge bosons can escape our brane.
  - Particles get excited in the extra dimension (KK, Kaluza-Klein).

Virtual Graviton Effect

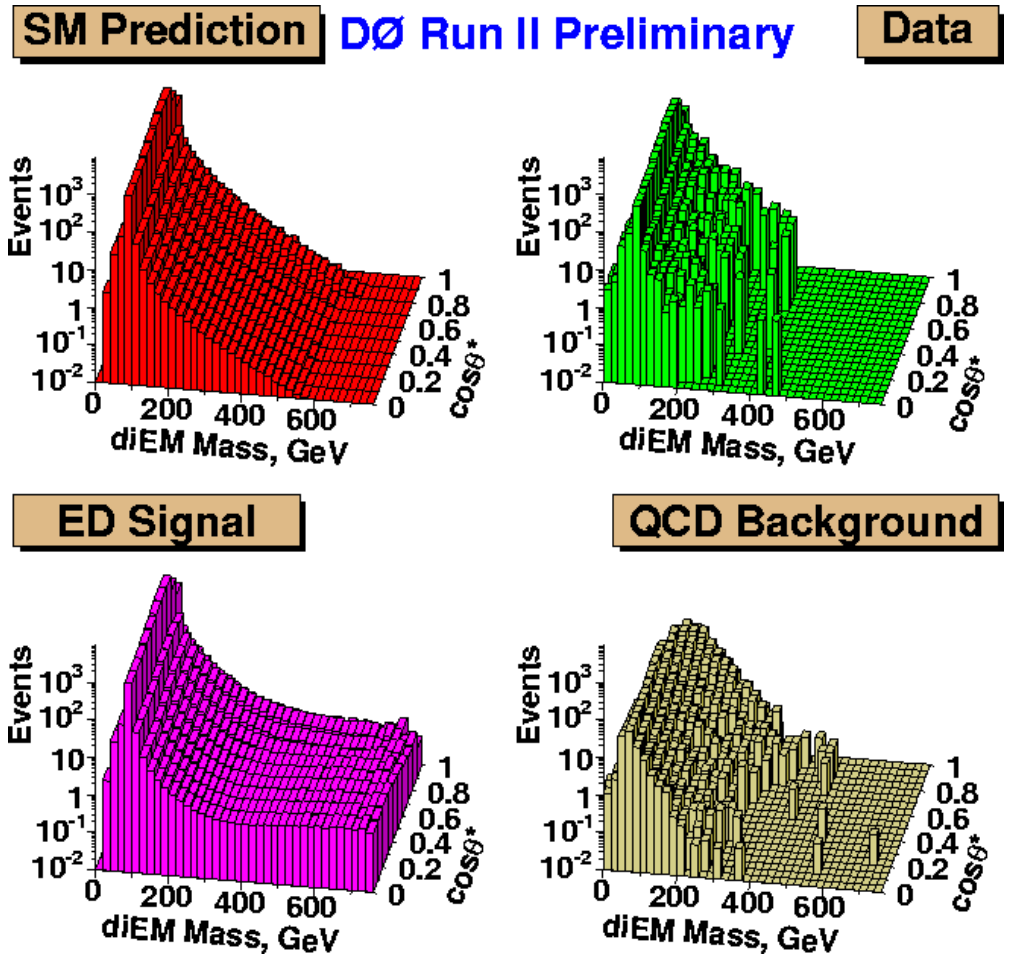


- Three scenarios: (there are many more)
  - ADD (Arkani-Hamed, Dimopoulos, and Dvali, Phys. Lett. **B429**, 263, (1998))
    - n (>2) extra dimensions with size R (between ~1nm and ~10fm).
    - Only graviton lives in the bulk… $M^2_{Planck} = M_s^{n+2} R^n$
    - Three ways of formulizing effective ADD (GRW, Hewett, HLZ)
  - DDG (Dienes, Dudas, and Gherghetta. Aka TeV^{-1} , Nucl. Phys. **B537**, 47 (1999))
    - Only g/γ/W/Z propagate into extra dimension of ~1 TeV^{-1} or 10^{-19}m.
  - RS (Randall-Sundrum, Phys. Rev. Lett. **83**, 3370 (1999))
    - Gravitons propagate into a single extra dimension of ~$1/M_{pl}$ or 10^{-35}m.

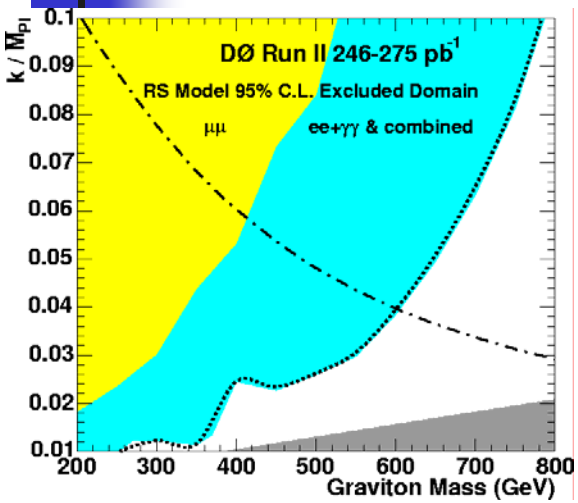
ADD Model at D0 (ee, $\gamma\gamma$)

- Data agrees well with the SM background.
- Bayesian 95% CL limits for M_S.

GRW		1.36 TeV/c^2
Hewett	λ=+1	1.22 TeV/c^2
	λ=-1	1.10 TeV/c^2
HLZ	n=2	1.56 TeV/c2
	n=3	1.61 TeV/c2
	n=4	1.36 TeV/c2
	n=5	1.23 TeV/c2
	n=6	1.14 TeV/c2
	n=7	1.08 TeV/c2

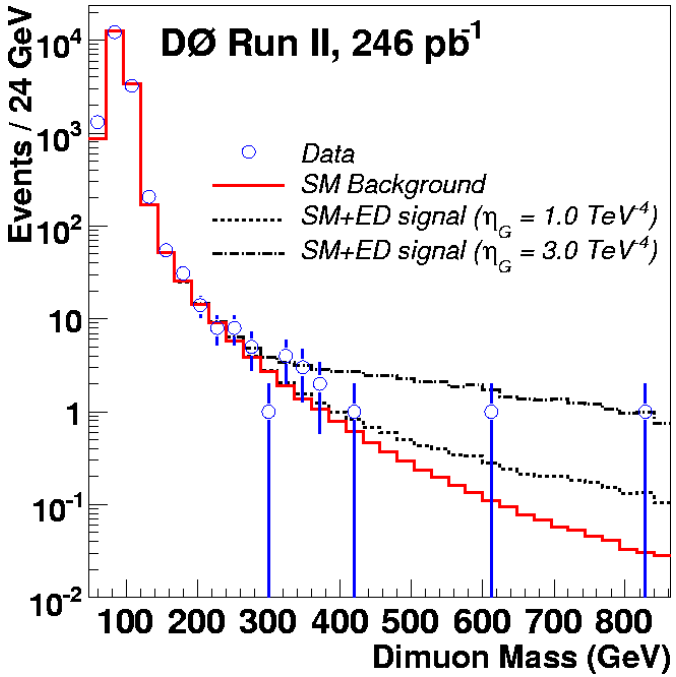


More Models, More Channels

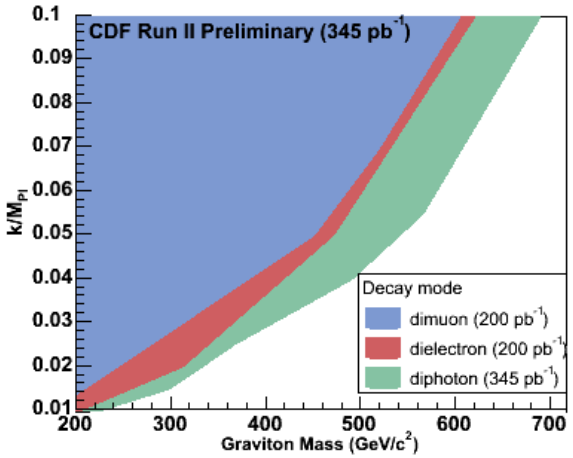


RS Graviton at D0 (275 pb^{-1}), ee, μμ, γγ
- $M_{GKK} > 785$ GeV/c^2 ($k/M_{Pl} = 0.1$)
- $M_{GKK} > 250$ GeV/c^2 ($k/M_{Pl} = 0.01$)

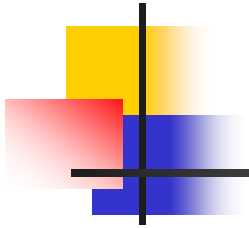
TeV^{-1} ED Search at D0 (200 pb-1), ee
Compactification scale $M_C > 1.12$ TeV/c^2



RS Graviton Searches, 95% C.L. Exclusion Regions



RS Graviton at CDF (345 pb^{-1}), ee, μμ, γγ



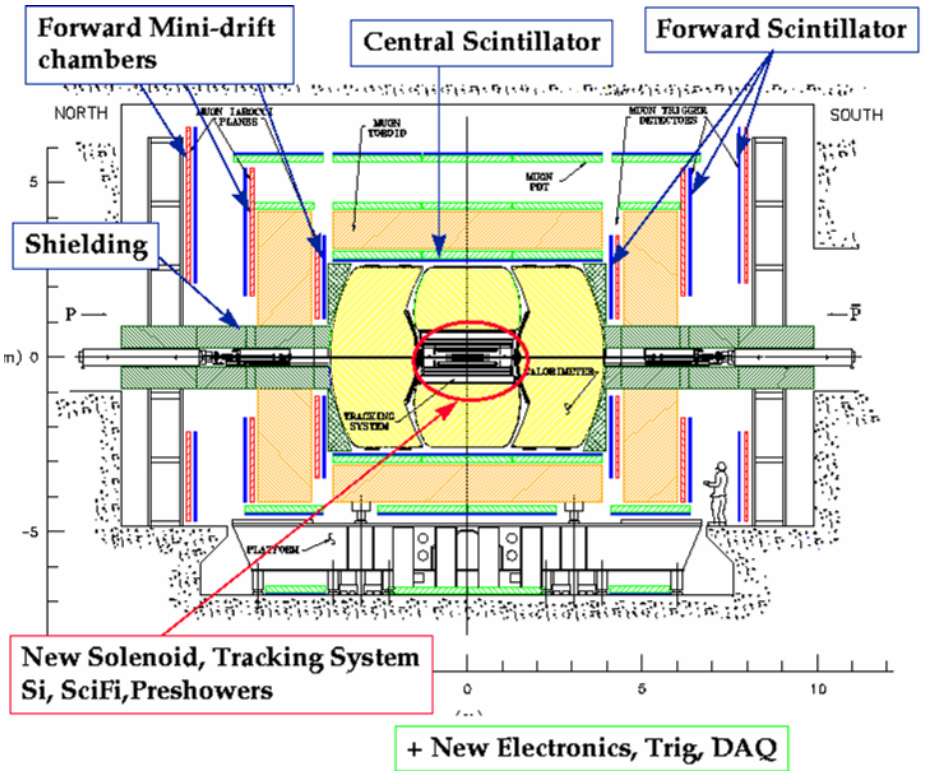
Conclusion

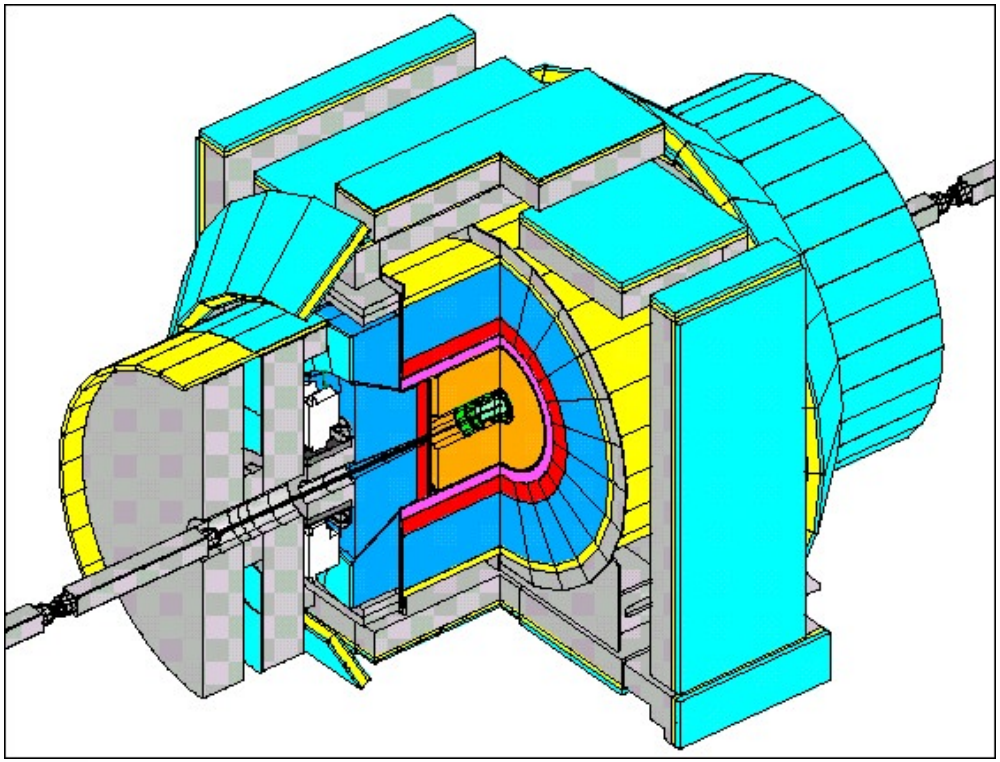
- Tevatron is the high energy frontier.
  - Best place to search for massive extra gauge bosons and extra spatial dimensions.
- Dilepton/Diphoton channels provide clean signal and low background.
- CDF and D0 has been pioneering the searches.
  - No evidence for new physics yet.
  - Data consistent with Standard Model.
- Many searches with more data are underway.
  - We have 1 fb-1 on the tape!
  - http://www-cdf.fnal.gov/physics/exotic/exotic.html
  - http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

BACKUP

CDF and D0 Detector

- General Purpose 4π detectors.
- Central solenoid and silicon vertex tracker.





Generic Z' Model

- Four classes of solutions satisfy the constraints.
  - Within a class, Z' is specified by three parameters.
    - $M_{Z'}$ (Z' mass)
    - g_Z (strength)
    - x (coupling)

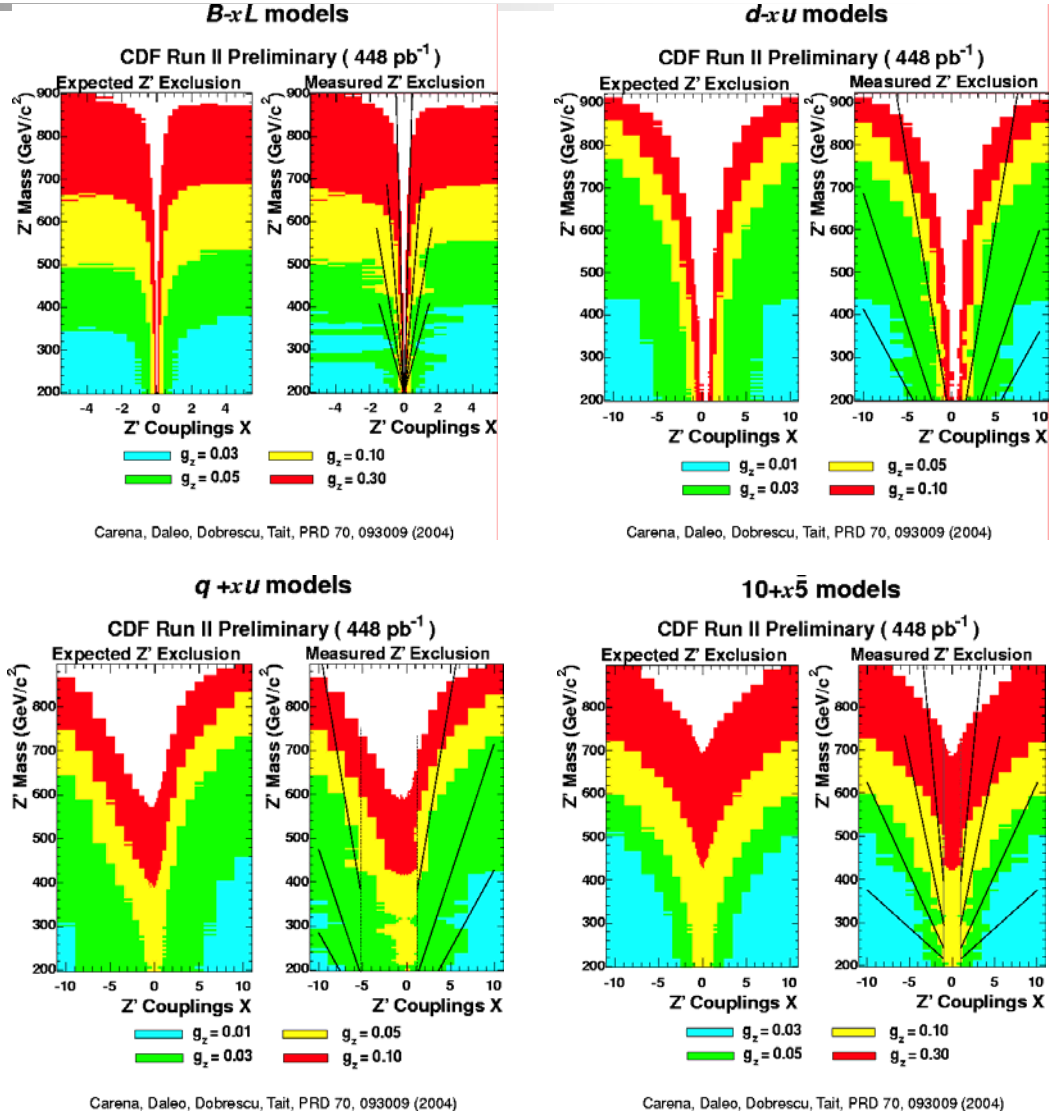
	b-xL	q+xu	10+x5	d-xu
$q_L=(u_L,d_L)$	+1/3	+1/3	+1/3	0
u_R	+1/3	+x/3	-1/3	-x/3
d_R	+1/3	(2-x)/3	-x/3	+1/3
$l_L=(e_L,v_L)$	-x	-1	+x/3	(x-1)/3
e_R	-x	-(2+x)/3	-1/3	+x/3

- E6 motivated models can be obtained.
  - d-xu gives Z_I with x=0
  - 10+x5 gives $Z\eta$ (x=-0.5), $Z\psi$ (x=1), $Z\chi$ (x=-3).

Generic Z' Search at CDF (ee)

- CLs method for setting limits.
- Line : LEP exclusion.
- Colored : CDF Run II exclusion.
- Limits for the E6 Z's

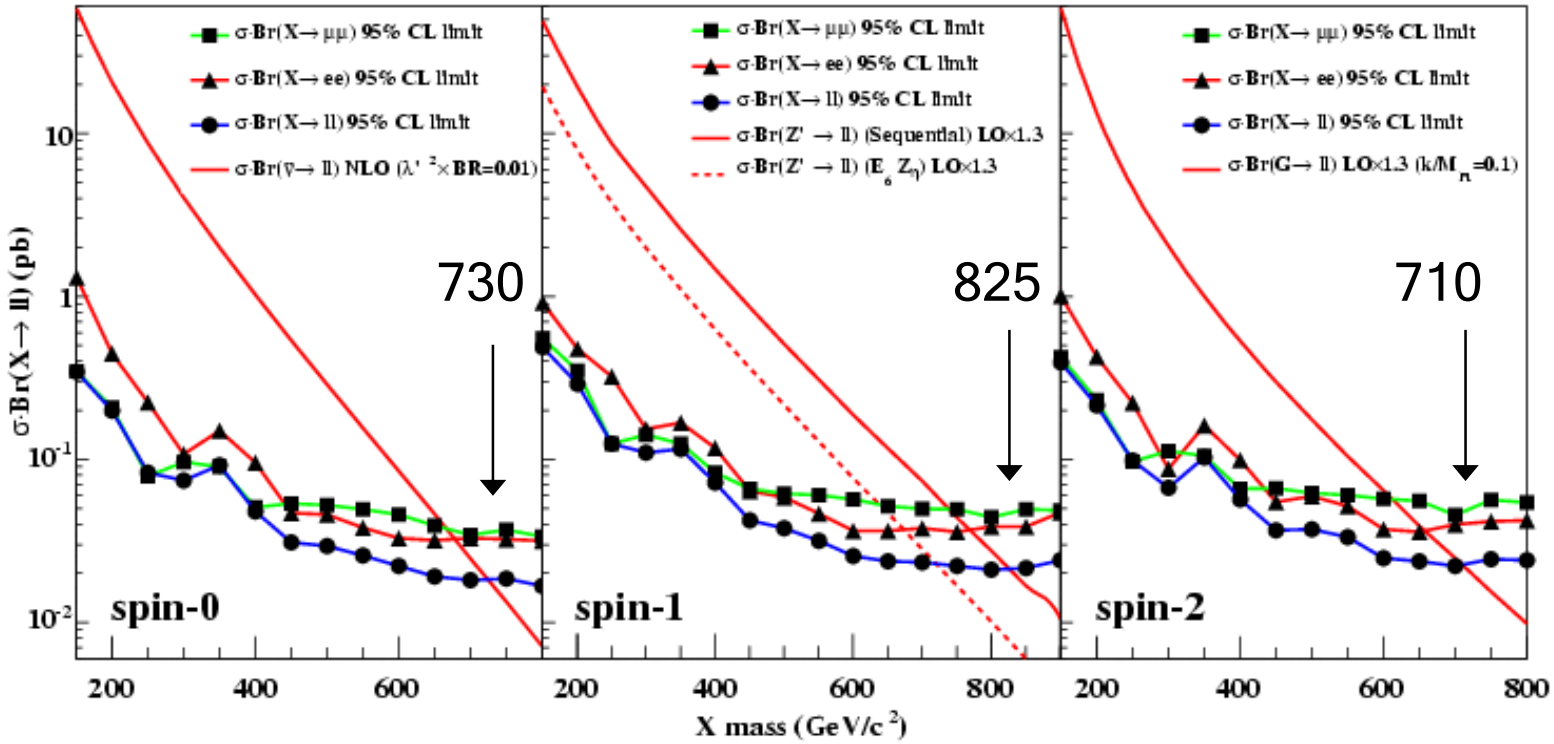
	95% CL Limit
Z_I	625 GeV/c^2
$Z\eta$	720 GeV/c^2
$Z\psi$	690 GeV/c^2
$Z\chi$	715 GeV/c^2



ee and μμ channels at CDF

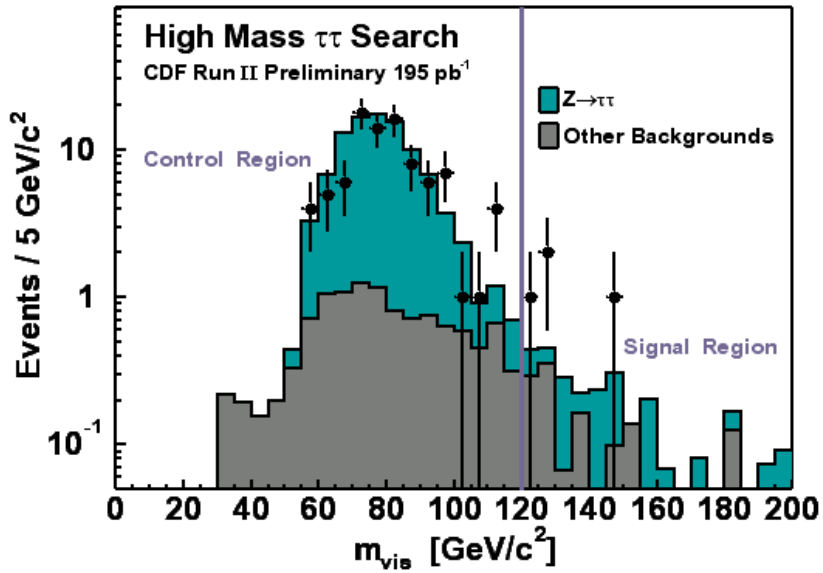
- Integrated luminosity 200 pb-1.
- Search based upon the acceptances for general spin-0,1,2 particles.

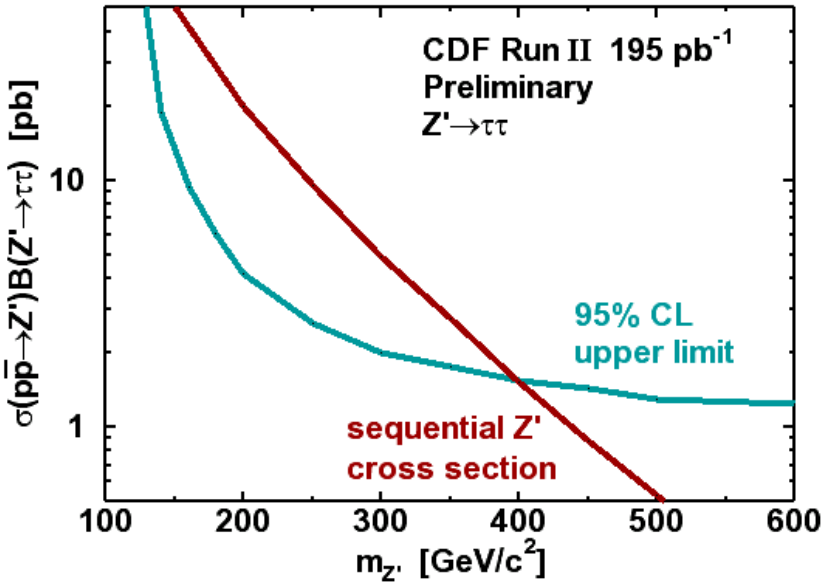
σ*Br(X→μμ) 95% CL limit
σ*Br(X→ee) 95% CL limit
ee, μμ combined limit



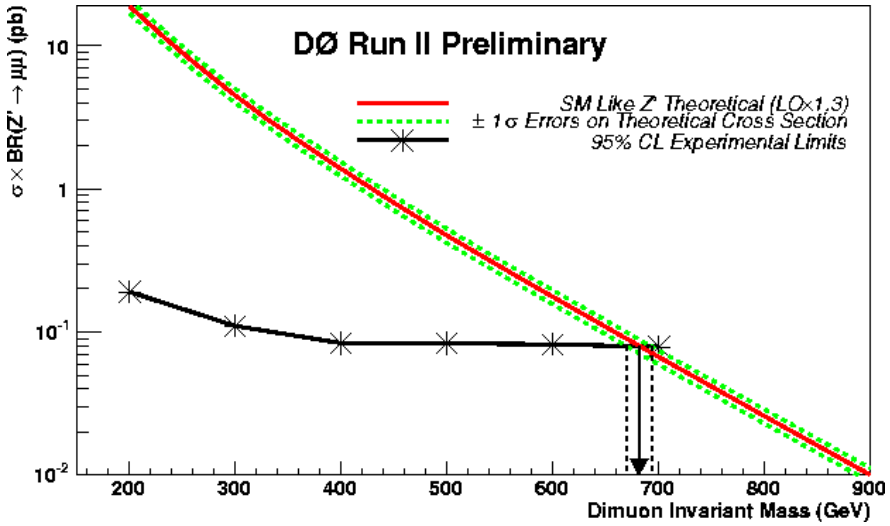
Z' → ττ at CDF

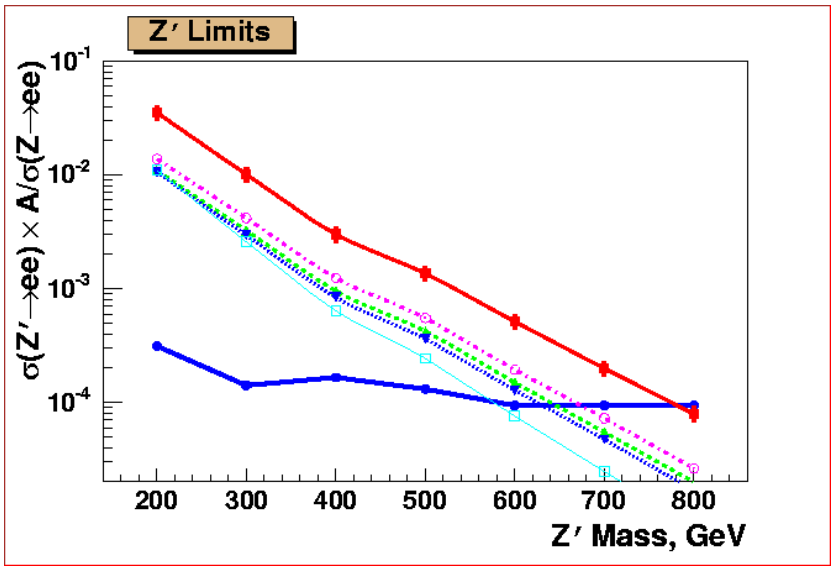
- Integrated luminosity 195 pb-1.
- Selection
  - Two central τ pairs.
  - At least one hadronic and leptonic decays.
- Consistent with Background.
- 95% CL limit 394 GeV.





Z' Searches at D0 (ee and μμ)





Effective ADD Models

- Three ways to formulize ADD model.
  - GRW
    - No dependence on the sign of interference or the number of extra demensions (n).
  - Hewett
    - Distinguishes constructive/destructive interferences.
  - HLZ
    - Sign of interference fixed, n-dependence is accounted for.

- Dilepton production cross section:

$$\frac{d^2\sigma}{dMd\cos\theta^*} = f_{\mathrm{SM}} + f_{\mathrm{int}}\eta_{\mathrm{G}} + f_{\mathrm{KK}}\eta_{\mathrm{G}}^{\ 2}$$

- Extra dimension effect:

$$\eta_{\mathrm{G}} = F / M_{\mathrm{S}}^4$$

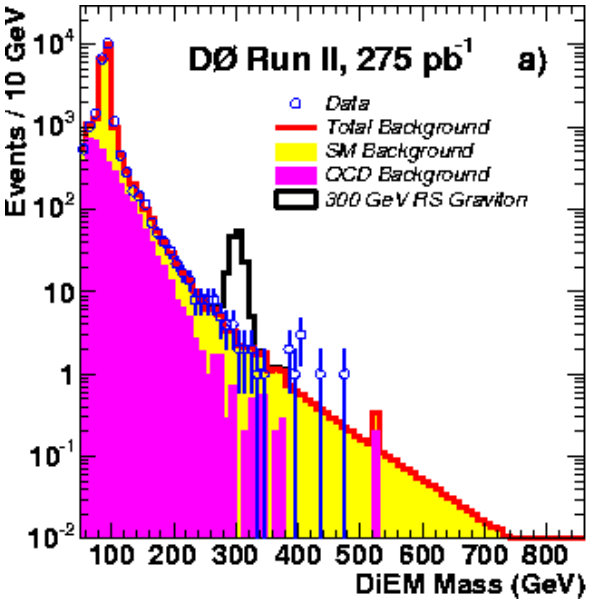
- Different formalisms for F:

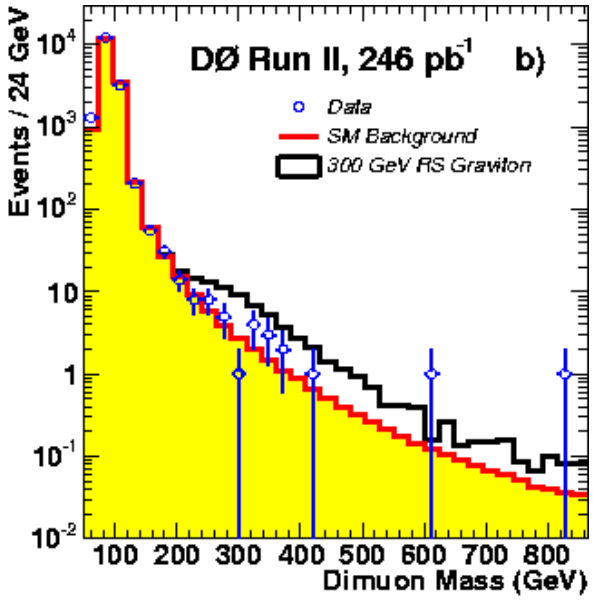
$$F = 1(\mathrm{GRW})$$

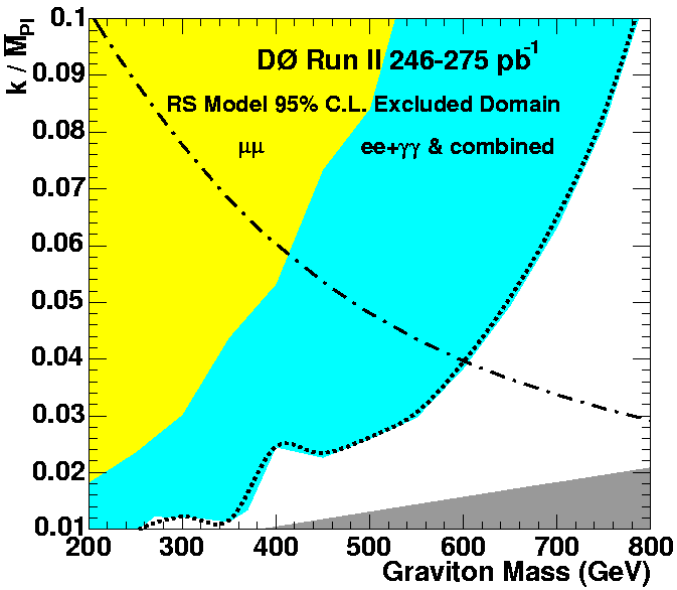
$$F = \pm\frac{2}{\pi}(\mathrm{Hewett})$$

$$F = \left\{ \begin{array}{c} \log\left(\frac{M_{\mathrm{S}}^4}{M^2}\right), n = 2 \\ \frac{2}{n-2}, n > 2 \end{array} \right\}(\mathrm{HLZ})$$

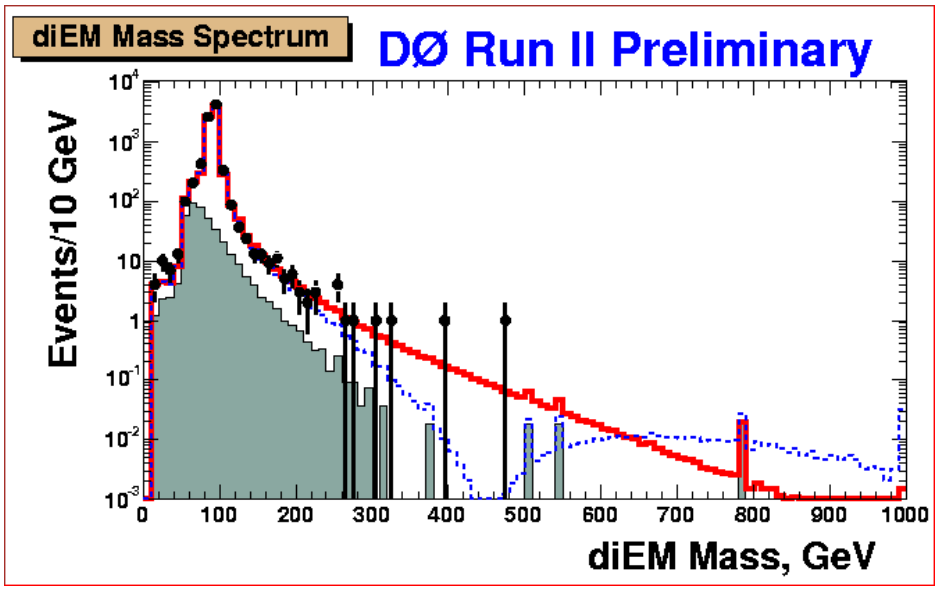
RS at D0 (ee and $\gamma\gamma$)

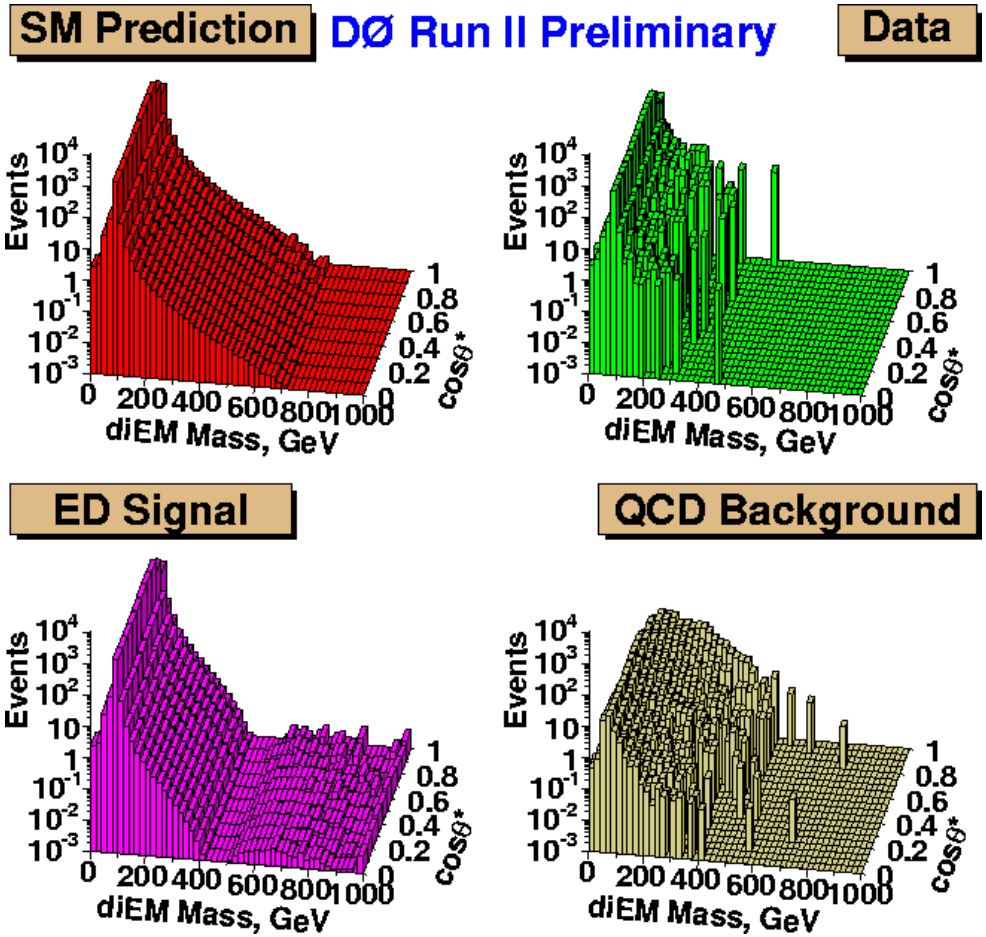






TeV^{-1} at D0 (ee)


diEM Mass Spectrum
DØ Run II Preliminary
Events/10 GeV
diEM Mass, GeV


SM Prediction
DØ Run II Preliminary
Data
ED Signal
QCD Background
Events
diEM Mass, GeV
cosθ*

RS at CDF ($\gamma\gamma$)