Search for extra spatial dimensions in dilepton, diphoton and Jets+MeT final states

Lisa Berntzon, CPPM/D0
berntzon@cppm.in2p3.fr
for the D0 collaboration

Outline

- Extra Dimension (ED) Models and Signatures studied at D0 Run II
- Results on Large EDs search (LEDs):

  -virtual graviton exchange in ee, $\gamma\gamma$, $\mu\mu$ channels.
- Preliminary results on LEDs search:

  -direct graviton emission, jets + MeT channel.
- Results from first dedicated search for Randall-Sundrum Gravitons, ee, $\gamma\gamma$, $\mu\mu$
- Summary and Conclusions

Extra Dimensions: Models, 1

n extra dims in models where SM particles live on a D3-brane:

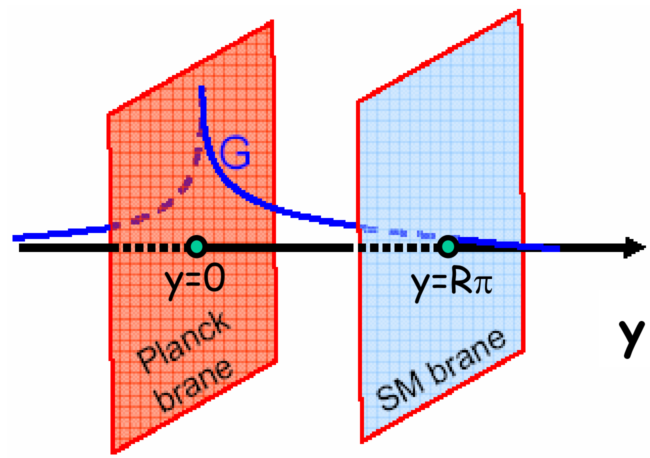
1. Large Extra Dimensions (LED) Arkani-Hamed,Dimopoulos,Dvali Phys Lett B429 (98)
   - Hierarchy problem explained: gravity appears weak ($M_{EW} \ll M_{Pl}$) because it propagates in LEDs.
   - LEDs are compactified, R=compactification radius
   - M_S is the fundamental scale, not M_{PL} :
     $M^2_{PL} \sim M_S^{n+2} R^n$ => M_S can be lowered to TeV scale
   - gravitons propagate in the bulk => Kaluza-Klein tower $G^{(k)}$

   ⇒ expect: virtual exchange of graviton KK modes,
   real graviton emission

Extra Dimensions: Models, 2

2. Warped Extra Dimension (RS) Randull,Sundrum Phys Rev Lett 83 (99)
   - One extra dimension of size R, and a special metric with curvature-scale k.
   - Solution of hierarchy problem via localization of gravity.
   - Zero mode graviton $G^{(0)}$ localized at the Planck-brane (y = 0).
   - SM fields localized on TeV-brane (y = $R\pi$).
   - M_{Pl} -size operators yield low-energy effects on SM brane with scale $\Lambda_\pi = M_{Pl}\exp(-k\pi R)$, $\Lambda_\pi \sim 1$ TeV solves hierarchy problem
   - Gravitons propagate in the bulk => Predicts low mass graviton resonances $G^{(k)}$

   $\Rightarrow$ Search for first graviton resonance. in Mass(ff or diboson)



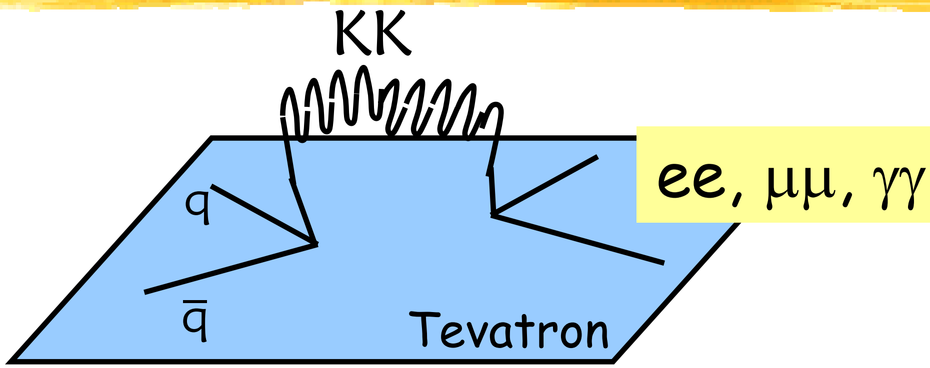
Parameters R and k can be expressed in :

M_1 = mass of first resonance

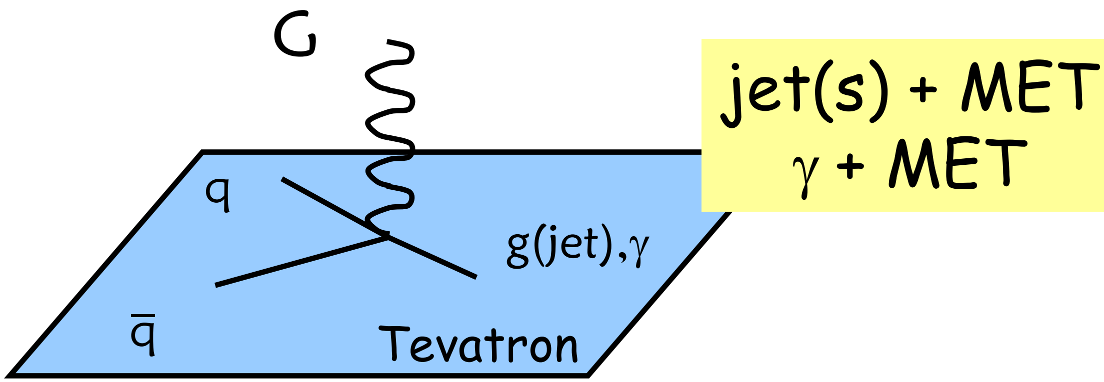
k/M_{Pl} – coupling: governs prod. cross section and width of resonance

Extra Dimensions: Topologies

Exchange Virtual Gravitons (LED,TeV^{-1},RS)



Emission of Real Gravitons (LED)



Graviton escapes out of the 3D brane => E, p appear to be not conserved

Large Extra Dimensions: Virtual Graviton Exchange

Gravity effects interfer with SM => prod. Cross section has 3 terms: SM, interference, direct gravity effects:

$$\sigma = \sigma_{SM} + \eta_G \sigma_{int} + \eta_G^2 \sigma_{KK}$$

- Effect of ED parameterized by a single variable:

$$\eta_G = F / M_S^4$$

- 3 conventions on writing the effective Lagrangian:
  - Hewett: (Hewett, Phys Rev Lett 82, 4765 (99)) $F = 2\lambda/\pi$ with $\lambda = \pm 1$
  - GRW: (Giudice, Rattazzi, Wells, hep-ph/9811291 $F = 1$
  - HLZ: (Han, Lykken, Zhang, hep-ph/9811350) $F = \log(M_S^2/s)$ for $n = 2$, $F = 2/(n-2)$ for $n > 2$

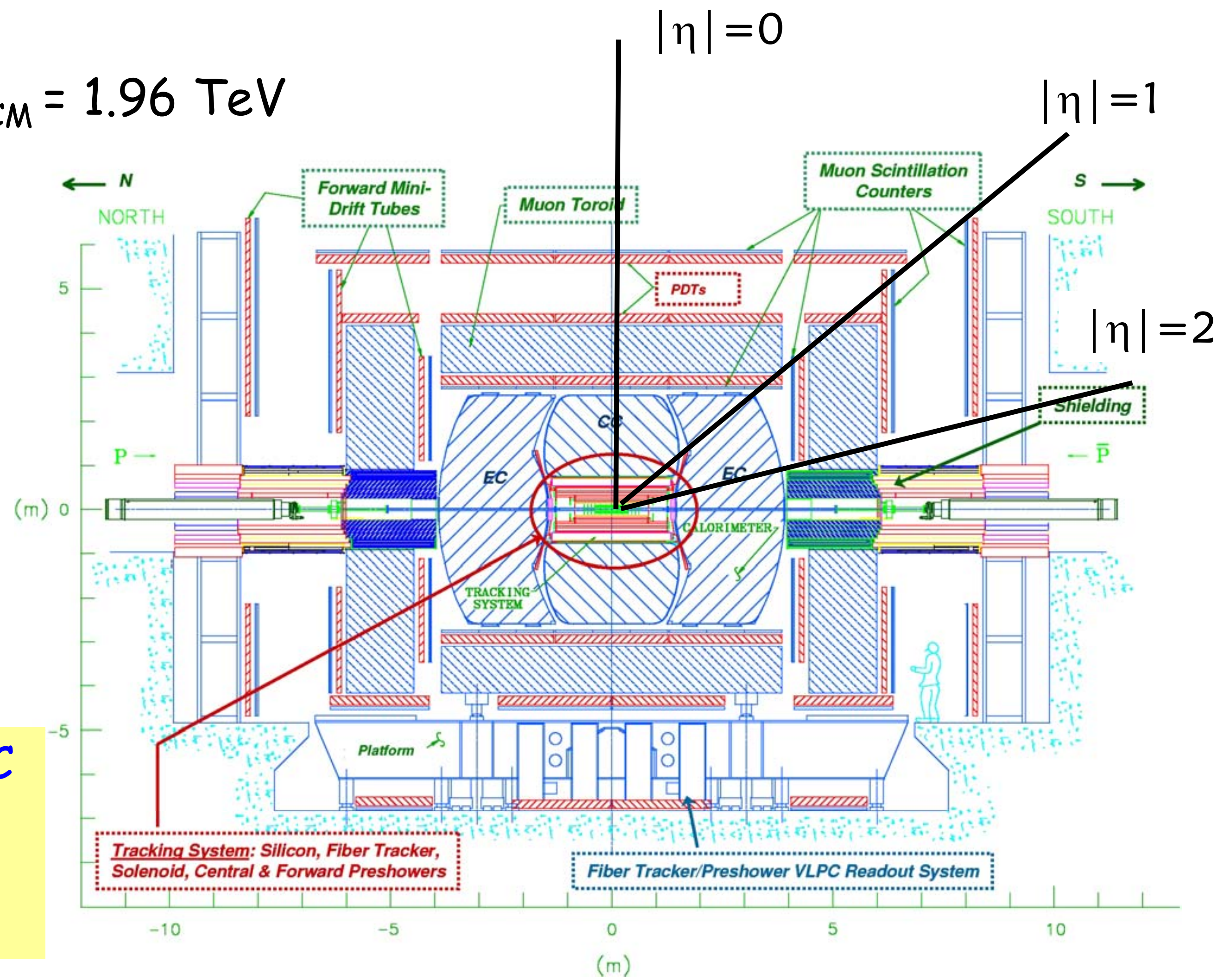
All 3 are equivalent, only the definitions of M_S differ.

The Dzero Detector

Tevatron Collider:

$p\bar{p}$-collisions, E_{CM} = 1.96 TeV

D0 RunII detector:



Central Calorimeter: CC
End Calorimeters: EC
CC : $|\eta|<1.1$
EC : $1.5<|\eta|<2.4$

LEDs: Virtual Graviton Exchange ee, $\gamma\gamma$, $\mu\mu$

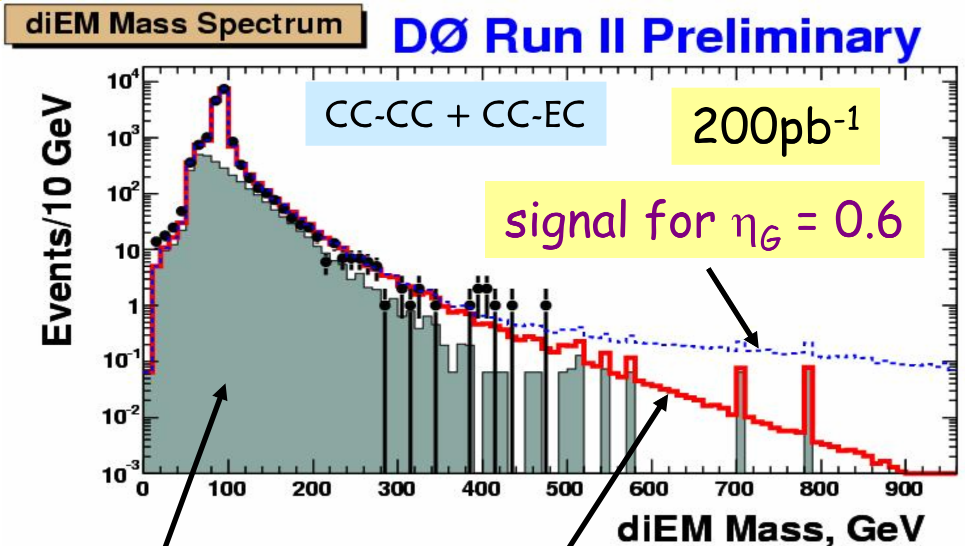
diEM = combine ee and $\gamma\gamma$, to maximise efficiency

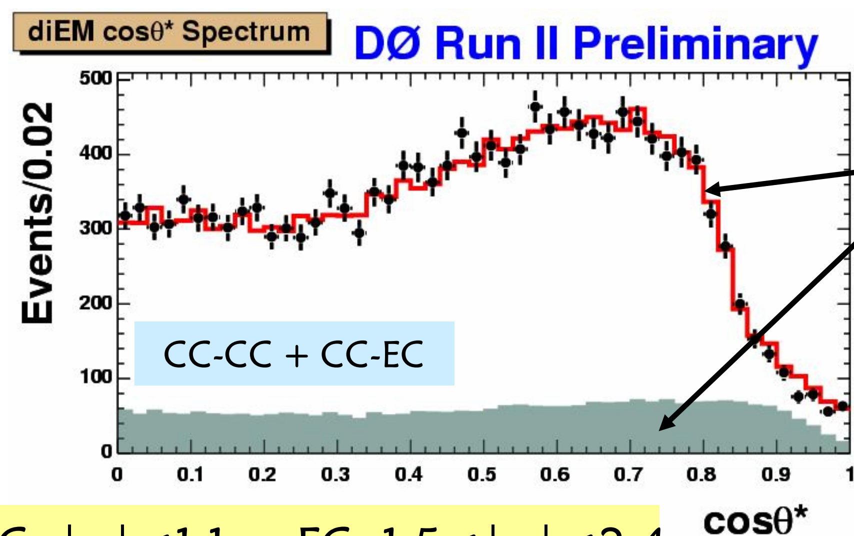
- 2 EM objects, no track req. on e
- track isolation, E_T > 25 GeV
- overall EMID efficiency: 85 ± 1 %

backgrounds:

- Drell-Yan and direct $\gamma\gamma$,
- QCD= misidentified jets,

Sum fitted to low mass diEM data





QCD

D-Y + direct $\gamma\gamma$ + QCD

Signal: High-mass, low |cosθ*| tail

for M_{diEM} > 350 GeV:

N_{exp} = 9.7 (1.6 QCD), N_{obs} = 8

Systematics: 7-20% dominated by stat + sys of QCD bkg

CC: $|\eta|<1.1$ EC: $1.5<|\eta|<2.4$

LEDs: Virtual Graviton Exchange ee, γγ, μμ

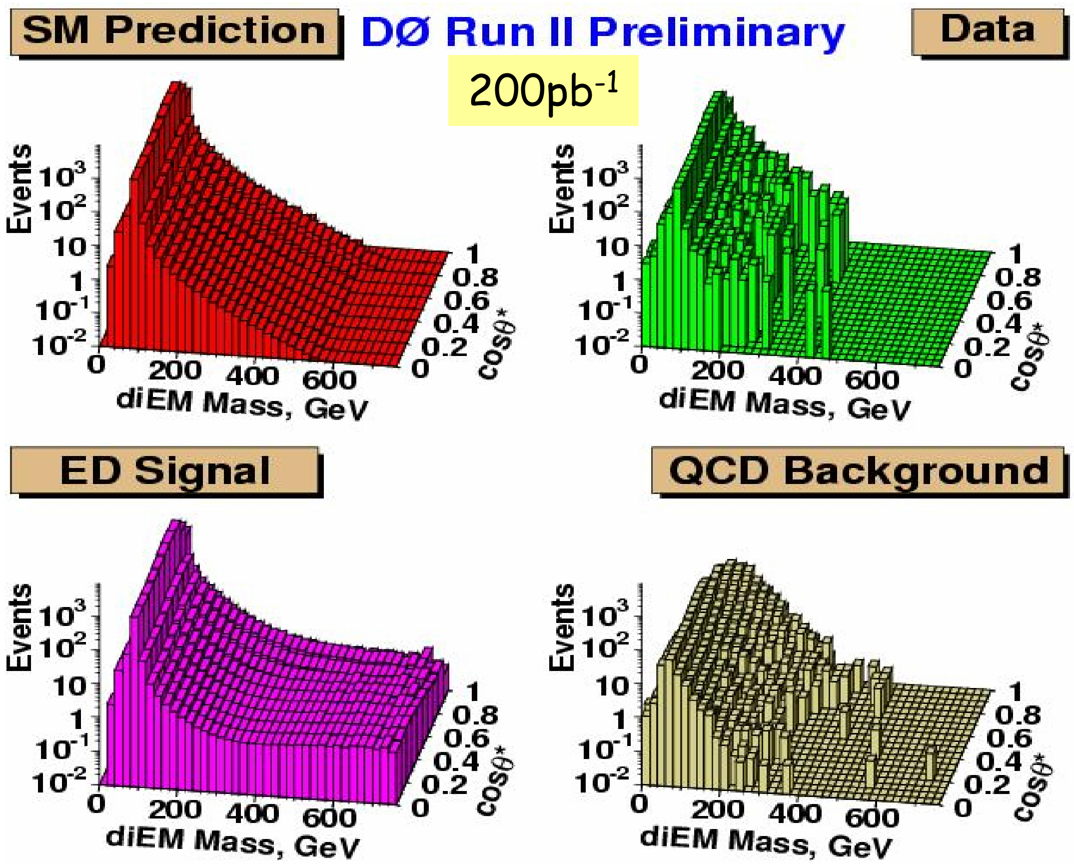
diEM:

Data agree well with SM predictions =>

2 D Binned Likelihood fit of M_{diEM} vs $|\cos\theta^*|$ as a function of η_G

=>Set limits on η_G alone or in combination with Run I results

=> give 95% CL limits on M_S



LEDs: Virtual Graviton Exchange ee, γγ, μμ

μμ

First search for LED in μμ at a hadron collider.

2 μ's with $P_T > 15$ GeV:

- isolated, $|\eta|<2$.
- cosmic veto
- $M_{\mu\mu} > 50$ GeV

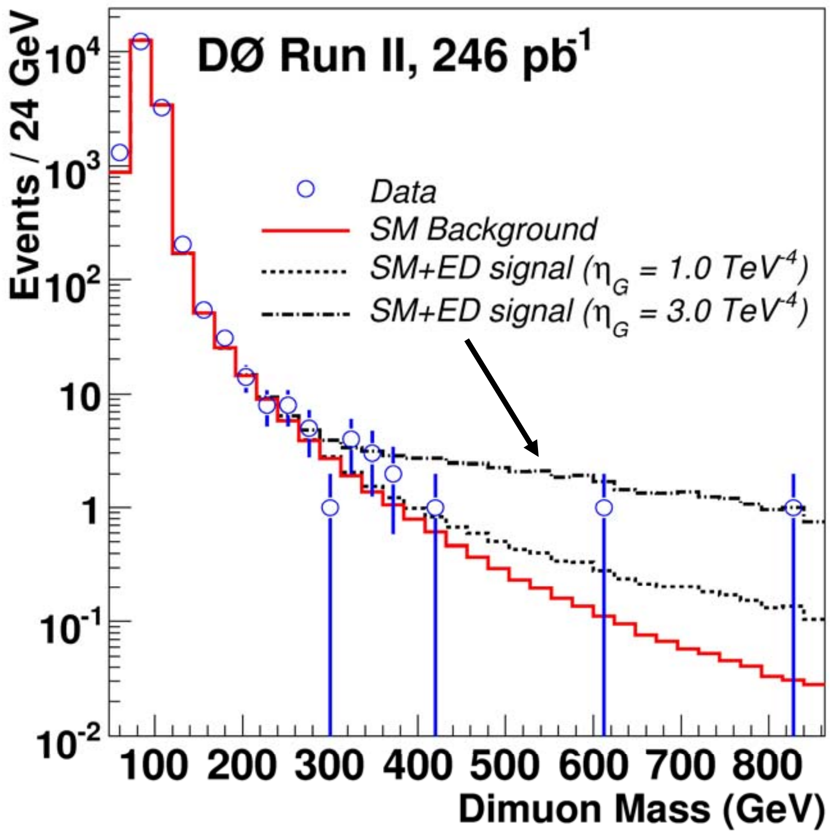
Background:

SM D-Y production.

for $M_{\mu\mu} > 400$ GeV:

$N_{exp} = 4$ and $N_{obs} = 3$

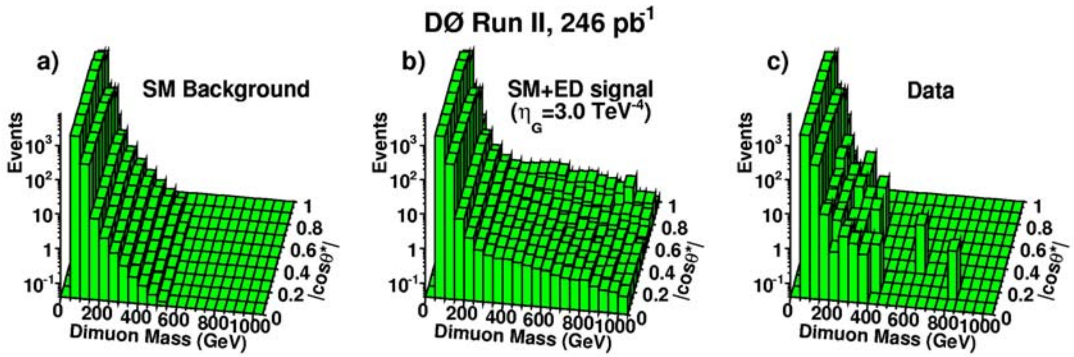
FERMILAB-PUB-05/250-E

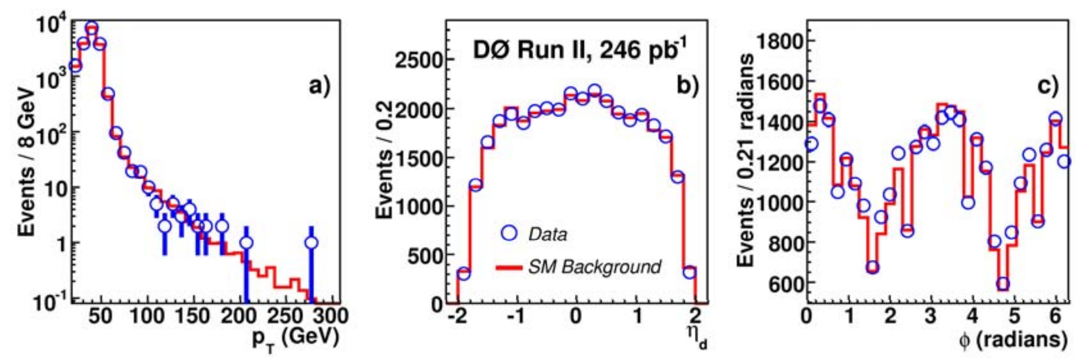


LEDs: Virtual Graviton Exchange ee, γγ, μμ

μμ

Data agrees with SM Prediction =>
$M_{\mu\mu}$ vs $|\cos\theta^*|$ distr. used in 2D fit, as a function of η_G
=> Limit on η_G
=> 95% CL limits on M_S





Data/SM-MC comparison

LEDs: Virtual Graviton Exchange ee, γγ, μμ

μμ : M_S in TeV @ 95% CL. :

FERMILAB-PUB-05/250-E

GRW	HLZ						Hewett	
	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$	$\lambda=+1$	$\lambda=-1$
1.07	1.09	1.27	1.07	0.97	0.90	0.85	0.96	0.93

diEM : M_S in TeV @ 95% CL, Preliminary results:

	Hewett		GRW	HLZ (TeV, @95% CL)					
	$\lambda=+1$	$\lambda=-1$		$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
Run II	1.22	1.10	1.36	1.56	1.61	1.36	1.23	1.14	1.08
Run I+II	1.28	1.16	1.43	1.67	1.70	1.43	1.29	1.20	1.14

Most stringent constraints on LED to date among all experiments.

LEDs: Direct Graviton Emission

jet(s)+MET

Mono-jet like topology with high MET,

Challenge: large instrumental background from MET mismeasurement and cosmics

Final selection:

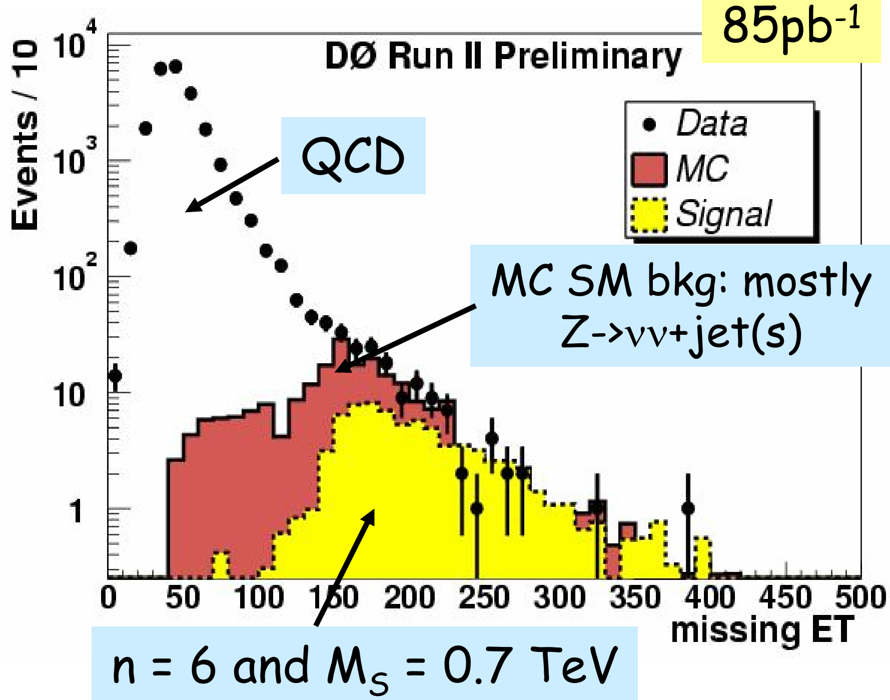
- PT(jet1) > 150 GeV, $|\eta| < 1$
- MET > 150 GeV
- PT(jet2) < 50 GeV
- $\Delta\phi$ (MET,jet1) > 30°

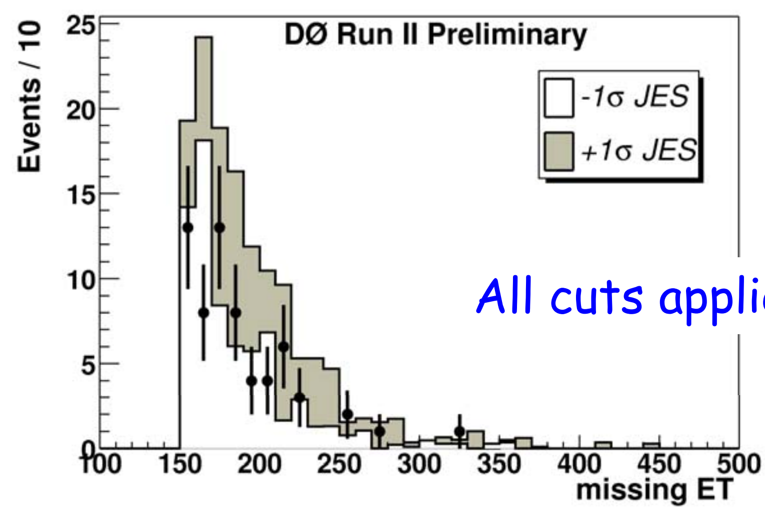
N_{exp} = 100.2 ± 6.2 (stat) ± 7.5 (theo) + 50 - 30 (JES)

N_{obs} = 63 (~ 5% efficiency)

Prel. limits on M_S ~ 660-680 GeV

85pb^{-1}





All cuts applied

updated analysis with more luminosity and new JES in process ...

RS Gravitons search

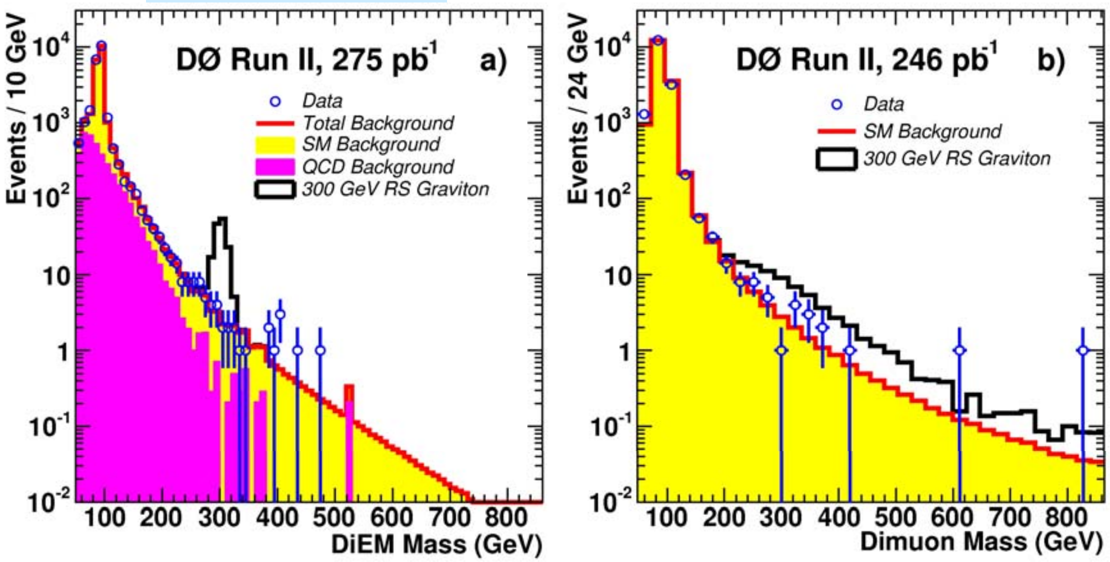
ee, γγ, μμ

First dedicated search for RS gravitons to date.

ee, γγ : combined in diEM data set:
2 EM objects, no track req. on e,
track isolation, $E_T > 25$ GeV

μμ: 2 μ's with:
$P_T > 15$ GeV, isolated,
$|\eta|<2$, cosmic veto

CC-CC + CC-EC



Signal: M_1=300 GeV
k/M_{Pl}=0.05
Background: D-Y (ee, μμ),
direct γγ (γγ), QCD (diEM)

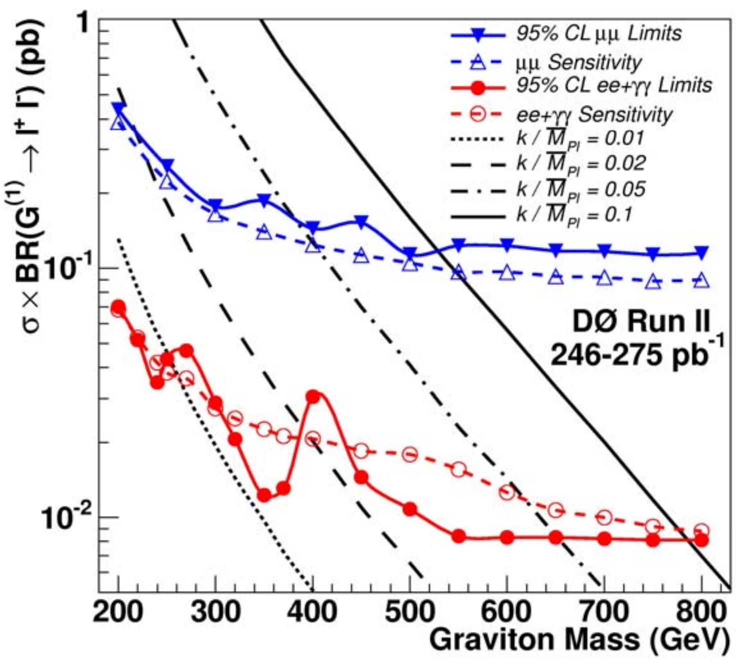
data agree with expected SM background => set limits with mass window method

CC: $|\eta|<1.1$ EC: $1.5<|\eta|<2.4$

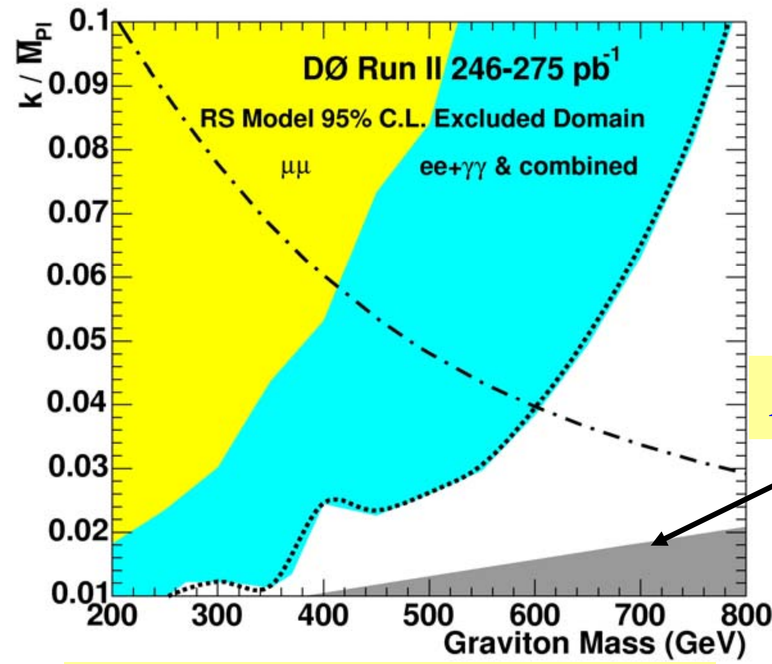
RS Gravitons search

ee, μμ, γγ

95% C.L. upper limits on graviton production cross section:



95% C.L. exclusion limits on the RS model parameters M_1 and k/M_{Pl}



$\Lambda_\pi > 10$TeV

M_1 up to 785 (250) GeV excluded for k/M_{Pl} = 0.1 (0.01)

Combined limit, dotted line

Precision EW data excludes below dashed-dotted line

Accepted by PRL, FERMILAB-PUB-05/126-E

Summary and Conclusions

- LEDs, ee, $\gamma\gamma$, $\mu\mu$: - best limits in the world on LED using 200, 246 pb^{-1} Ms >1.07, 1.43 TeV ($\mu\mu$,diEM, GRW) 95%C.L
- LEDs, Jets+MET: The only RunII monojet search so far, limit better than D0 RunI using less data (only 85 pb^{-1}), thanks to superior detector, higher energy.
- First dedicated RS graviton search. Results in ee+$\gamma\gamma$, $\mu\mu$ using 275, 246 pb^{-1} M_1 up to785 (250) GeV, excluded for k/M_{Pl} = 0.1 (0.01) 95%C.L
- Now more than 800 pb^{-1} recorded on tape, more results to come !

Backup slides

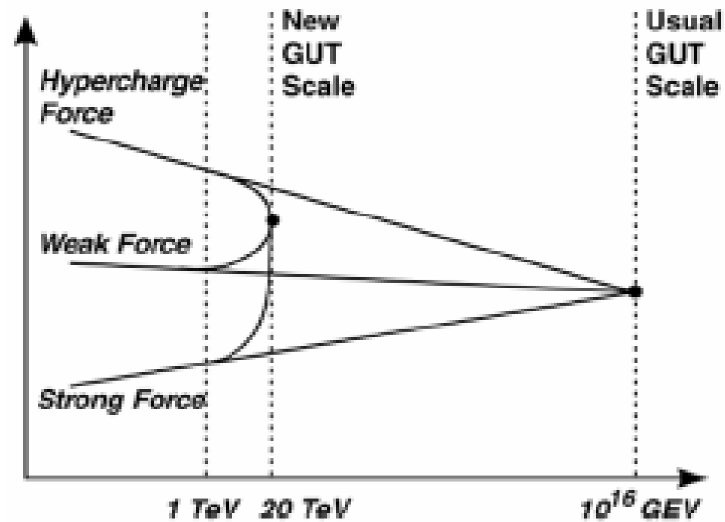
TeV^{-1} Extra Dimensions: Model

2. TeV^{-1} Extra Dimension (TeV^{-1}) Dienes,Dudas,Gherghetta Nucl Phys B537 (99)

- Intermediate size EDs, $R \sim TeV^{-1}$
- M_C : compactification scale (~ TeV)
- SM gauge fields can propagate in the bulk => mixing and interference among SM bosons and their higher order KK modes
- lower GUT scale by changing running of the couplings

=> expect:

- resonances at high energies (LHC ...)
- virtual exchange (Tevatron)



TeV^{-1} Extra Dimension: Virtual Exchange of Z/γ KK states

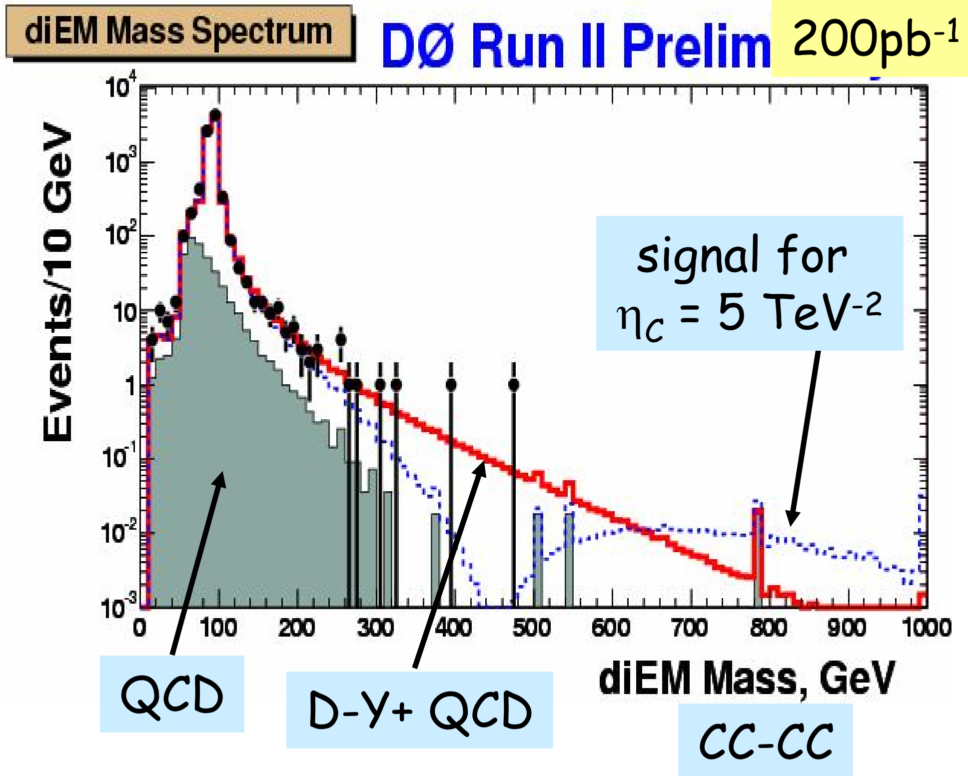
ee

ee (> 1 EM w/ track match)

- same procedure as for LED analysis but with virtual Z/γ KK states effects parameterized by: $\eta_C = \pi^2/3M_C^2$
- N_{exp} = 12.1 (4.3 QCD), N_{obs} = 9 for M(diEM)>350 GeV and EC-EC included

=> Limit set as done for LED: η_C < 2.63 TeV^{-2} =>

M_C > 1.12 TeV @ 95% CL



LEP

from combined precision EW measurements:

M_C > 6.6 TeV

Run II Integrated Luminosity

19 April 2002 - 17 July 2005