CDF Searches for New Physics at High Diphoton and Dilepton Masses

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- Motivation - Alternatives to SUSY
- Introduction to the Tevatron and CDF
- Dilepton (*ee*, $\mu\mu^*$) and $\gamma\gamma$ Event Selection
- Comparison of Background Expectation to Data
- Spin Dependent Acceptances
- Preliminary Results
- Summary and Conclusions

*$\tau\tau$ searches presented by A. Anastassov

Alternatives to SUSY to Solving the Hierachy Problem

(M_{EW} << M_{Planck}?)

Extra dimensional (ED) solutions

ADD

Taking compact space to be very large

Gravity freely propagates in the many large extra dimensions (n=2-7)

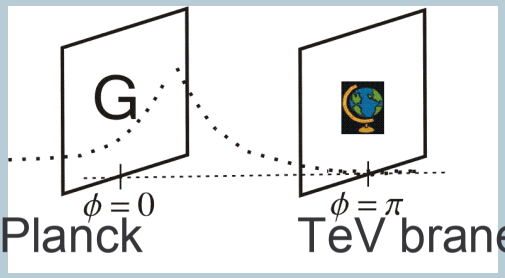
$$M_{Pl}^2 = V_n M_{Pl(4+n)}^{(2+n)}$$

To solve hierarchy: $M_{Pl(4+n)} \sim 1$ TeV

hep-ph 9803315

RS

Curvature of the extra dimension



1 highly curved extra dimension
Gravity localised in the ED

Scale of physical phenomena on the TeV-brane is specified by the exponential warp factor:

$$\Lambda_\pi = \bar{M}_{Pl} e^{-kR_c\pi}$$

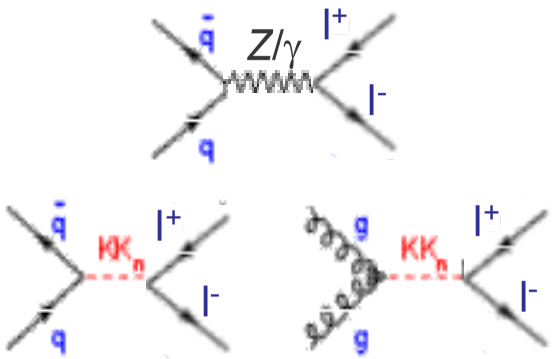
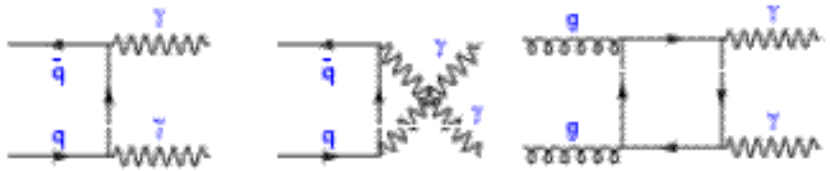
$\Lambda_\pi \sim$ TeV if $kR_c \sim 11$-12.

hep-ph 9905221

Search for ED?

- Deviations in cross sections (σ) and angular distributions from SM processes caused by graviton exchange

Resonance in RS model and broad change in σ in ADD model

Dilepton Channel		Diphoton Channel
	Standard Model	
	Extra Dimensions	

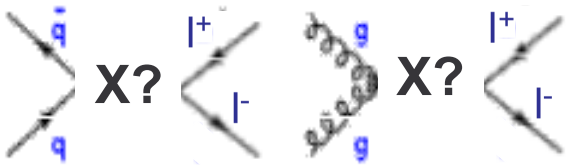
✓Clean experimental signature ✓Low backgrounds

✓**Also search for other physics models**

Other New Physics Searches in Dilepton Channels

Also set limits on new physics

- Z' (E6 and Little Higgs) (Spin-1)
- RPV sneutrinos (Spin 0)

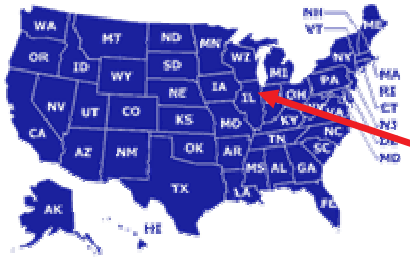


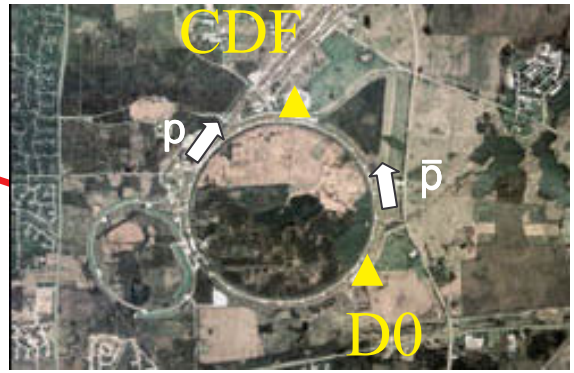
Search Strategy

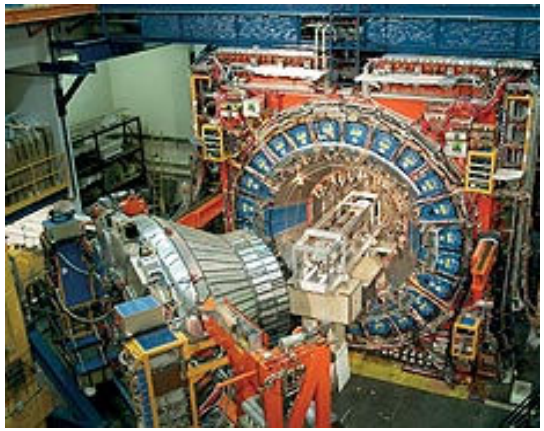
- Perform general searches comparing data to expectation
- Determine spin dependent acceptance and σ.BR
- Interpret data according to many new models!

CDF @ Tevatron $p\bar{p}$ Collider

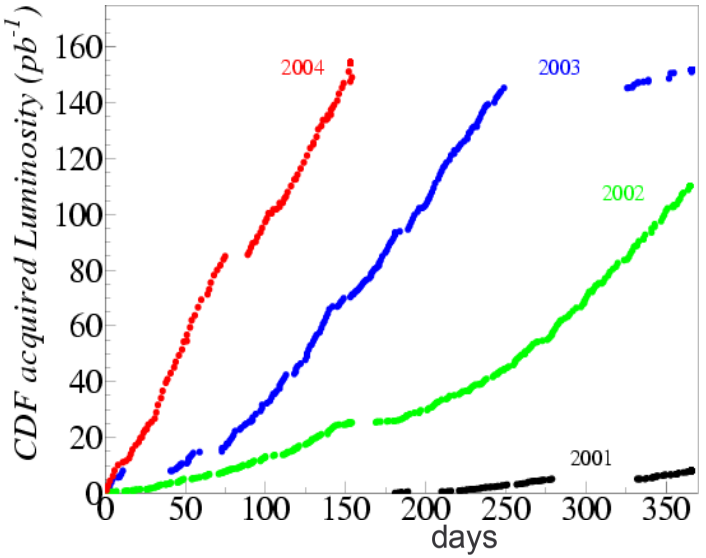
Highest energy collider operating in the world!







Run I (1992-1996)
$\sqrt{s} \approx 1.8$ TeV, 110/pb
Run II (2001-2009)
$\sqrt{s} \approx 1.96$ TeV
Physics Analyses use ~ 200/pb
collected between 03/02 and 09/03



Search Selection

μμ

2 isolated μ P_T>20 GeV

$|\eta_{\mu 1}|<1$, $|\eta_{\mu 2}|<1.5$

Cosmic ray rejection cuts

ee

2 two isolated e, E_T > 25 GeV

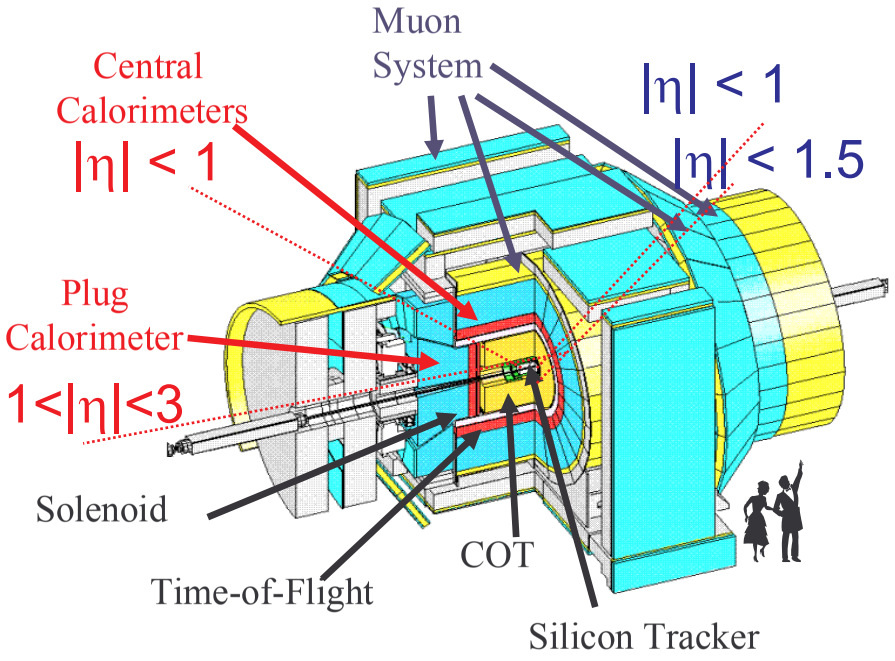
2 central e (CC)

or 1 central and 1 forward e (CP)

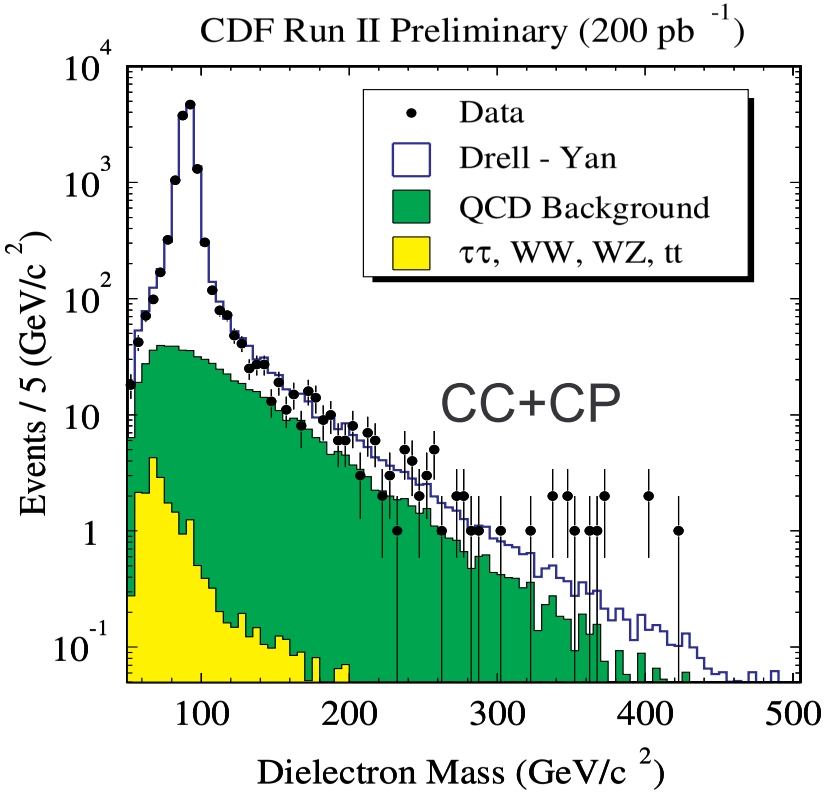
γγ

2 isolated γ E_T>15 GeV

2 central γ (CC)

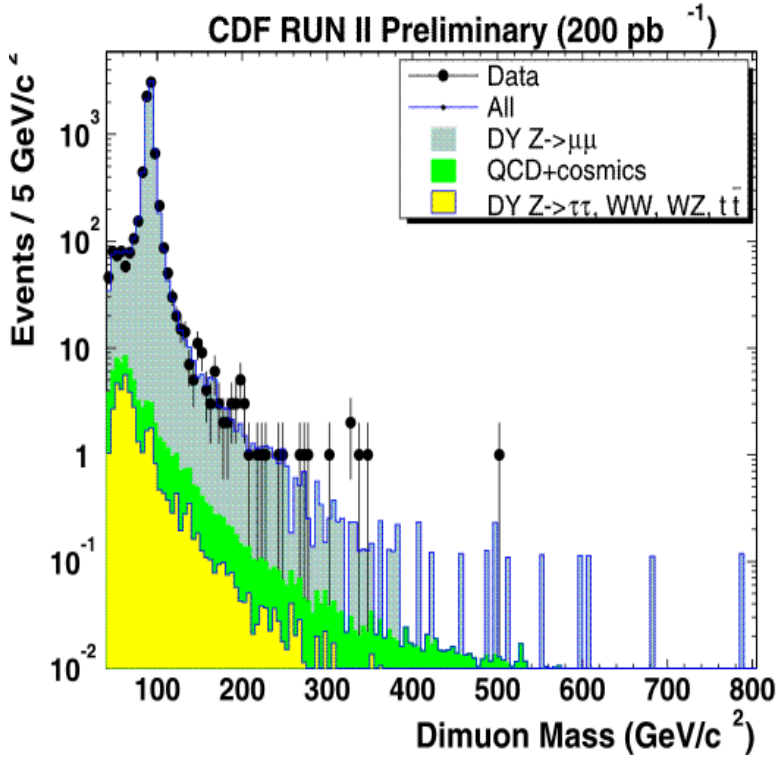


High Mass Dielectrons



Mass (GeV/c^2)	N_{exp}	N_{obs}
200	70.5	71
250	26.7	30
300	11.1	14
350	4.6	9
400	2.0	2
450	0.9	0

High Mass Dimuons

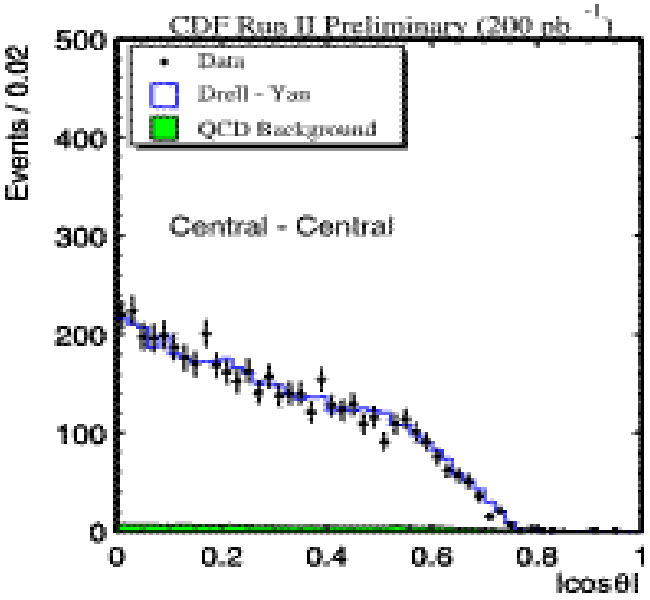


Mass (GeV/c^2)	N_{exp}	N_{obs}
150	55.25 ± 2.50	58
200	20.88 ± 0.97	18
250	9.44 ± 0.49	9
300	5.22 ± 0.32	6
350	3.23 ± 0.24	1
400	2.28 ± 0.19	1
450	1.79 ± 0.16	1
500	1.24 ± 0.13	1
550	1.03 ± 0.11	0

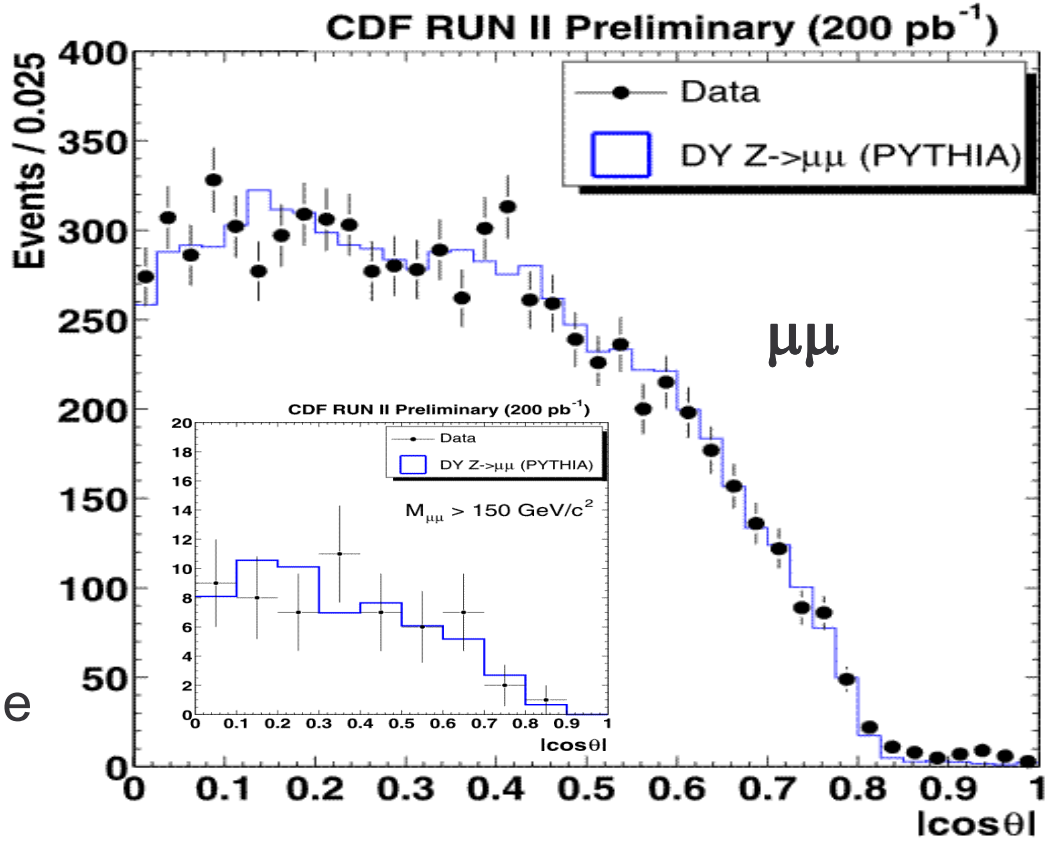
Total of ~ 7500 dimuon candidates in 200 pb^{-1} data

High mass dilepton spectra is consistent with background prediction

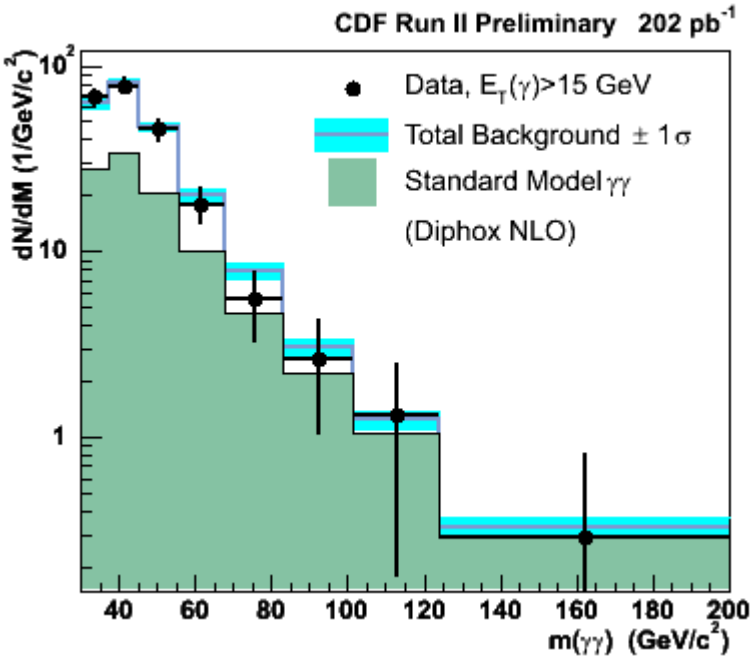
Dilepton Angular Distributions



cosθ* in Collins-Soper frame

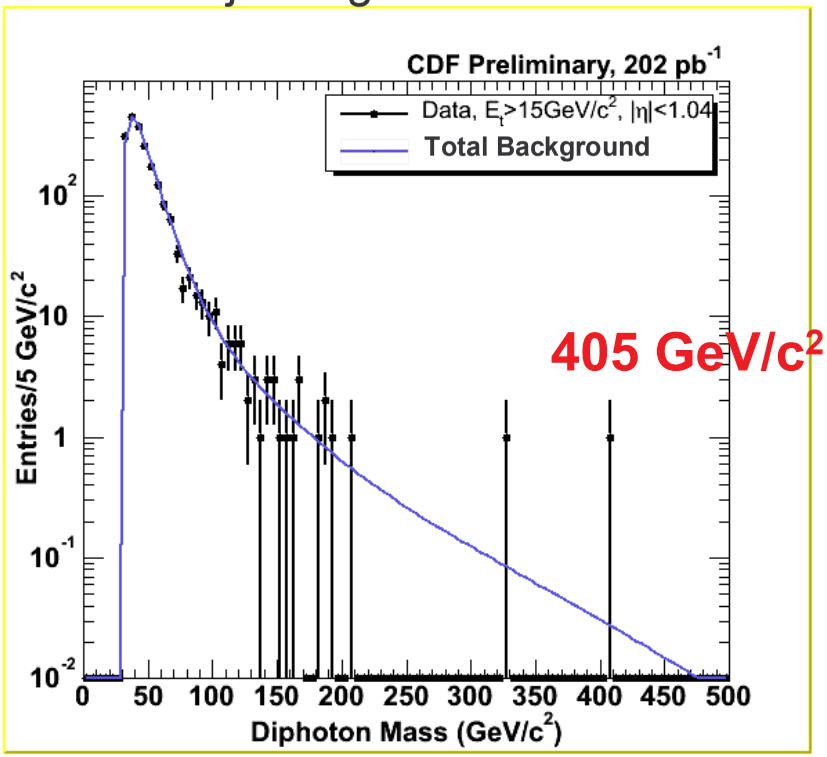


High Mass Diphotons

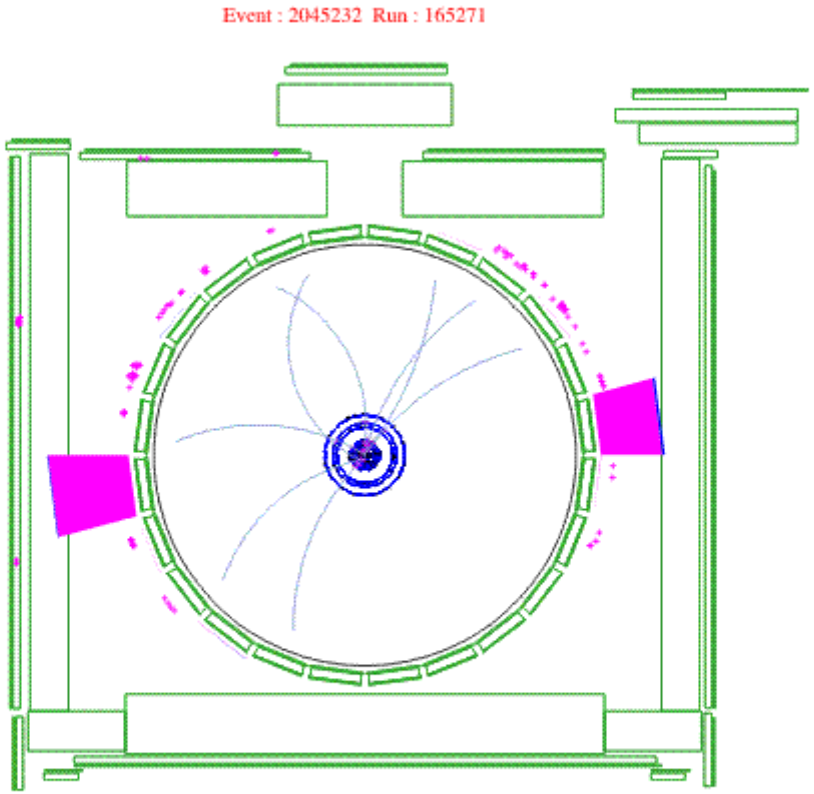


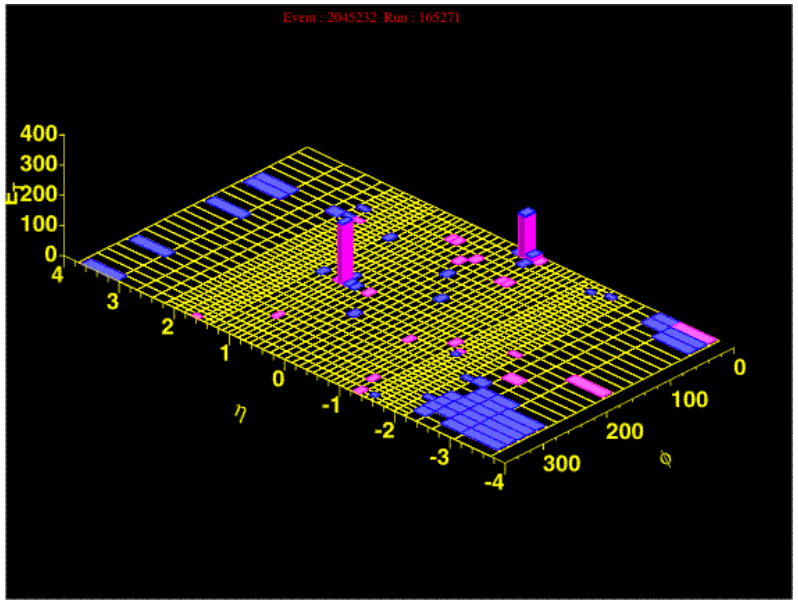
Backgrounds

- Standard Model diphoton production
- Fakes: γ-jet and jet-jet,
  where jet fragments into a hard π^0



$\gamma\gamma$ Highest Mass Event



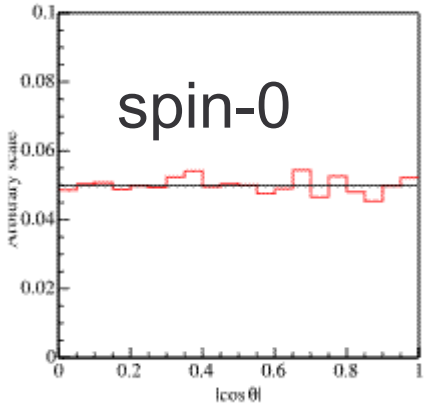


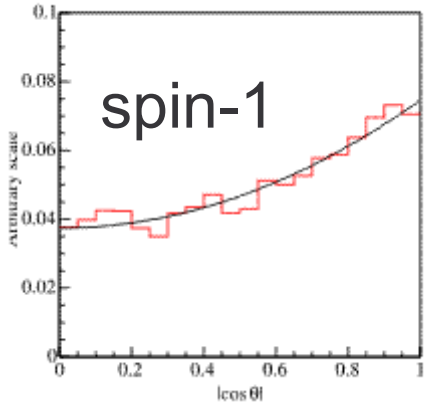
Diphoton Mass = 405 GeV

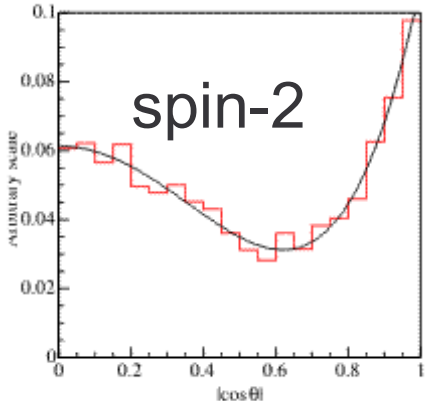
Photon Et = 172, 175 GeV

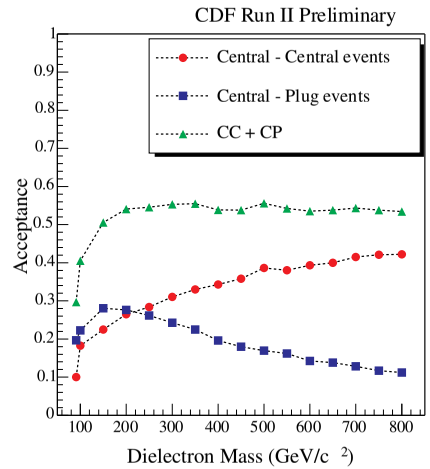
Spin-dependent Acceptance

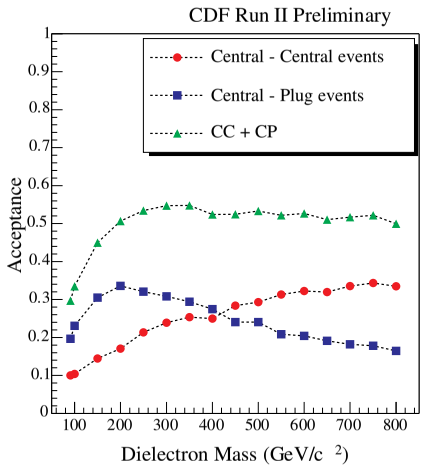
Angular distribution and therefore acceptance of decay products depends on the spin of the decaying particle.

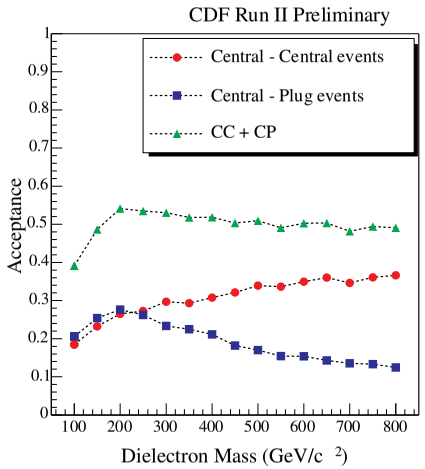












New Physics Limits

95 % C.L. upper limits on σ.BR($G \rightarrow \gamma\gamma$) are placed using $\pm 3\sigma$ search windows around M_G

95 % C.L. upper limits on σ.BR($X \rightarrow ll$) for spin-0,1,2 and lower limits on string scale are placed using binned likelihood method

$$L(\alpha/\eta)=\Pi_i \frac{\mu_i^{n_i} e^{\mu_i}}{n_i!}$$

n_i : observed events

$\mu_i = \alpha\, N_i^{sig} + N_i^{bkg}$ (Resonant particles)

$\mu_i = N_i^{sig}(\eta) + N_i^{bkg}$ (LED spectrum)

Likelihoods are integrated to give the final limits, taking into account the signal and background systematic uncertainties

Sources of systematic uncertainties:

Luminosity (6%)

Acceptance (PDF, MC statistics..)

Energy/Momentum scale resolution

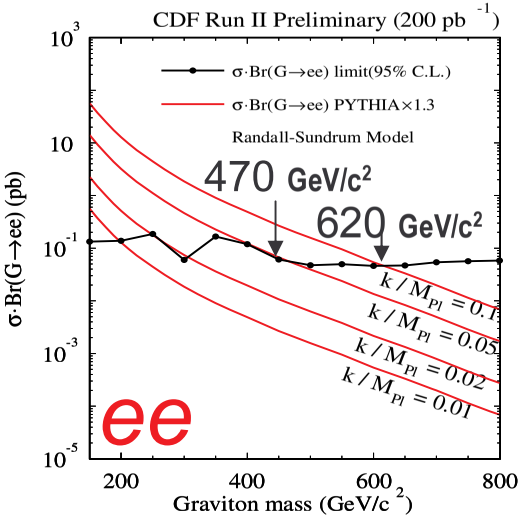
Selection Efficiencies

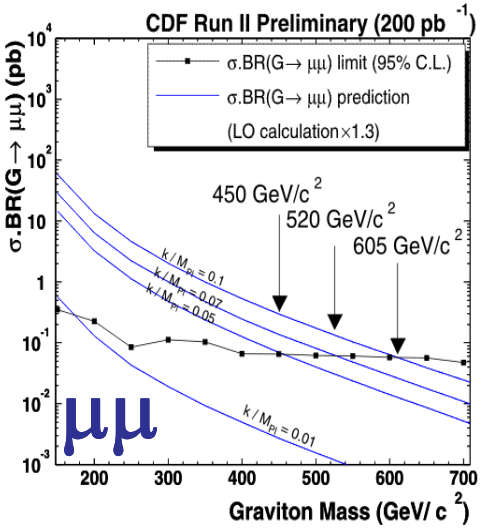
Background statistics and normalisation

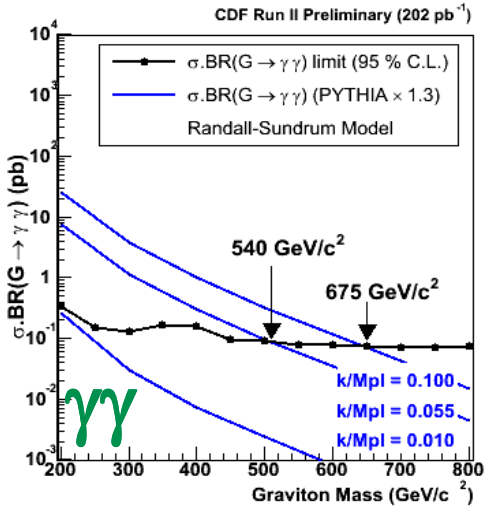
$$N_{95\%} = \alpha_{95\%} N_{sig}$$

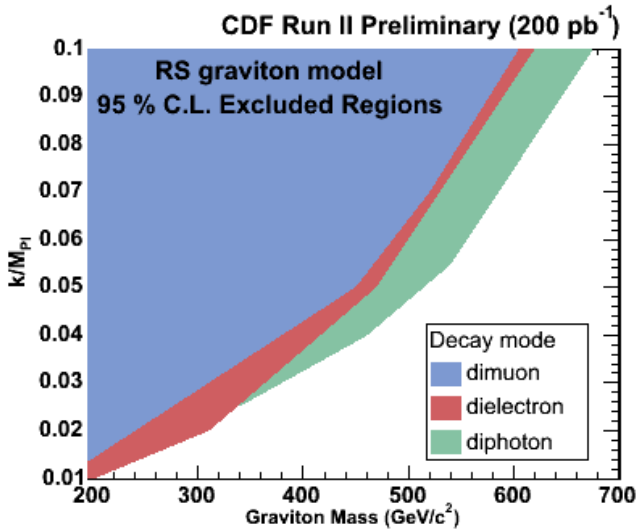
$$\sigma_{95\%} = \frac{N_{95\%}}{\varepsilon A \mathcal{L}}$$

Randall-Sundrum Graviton









ee has largest acceptance at low mass

γγ has largest acceptance at high mass

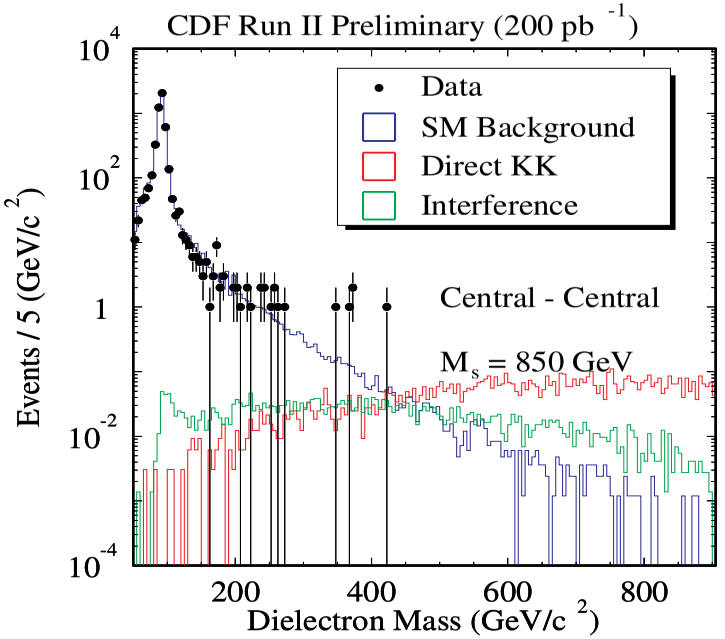
BR(**G→γγ**) = 2 * BR(**G→ee**)

Large Extra Dimensions

Set a limit on the effective Planck scale (M_s^4) in ADD model

Parameterise the cross section in terms of $\eta = \lambda/M_s^4$ (*λ=±1)

$$\sigma = \sigma_{SM} + \eta\,\sigma_{INT} + \eta^2\,\sigma_{KK}$$



CDF Run II Preliminary (200 pb^{-1})

η_{95} (10^{-12}GeV^{-4})		* Hewett (GeV)		HLZ (GeV)					GRW (GeV)
$\lambda<0$	$\lambda>0$	$\lambda<0$	$\lambda>0$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$	
1.05	1.18	**987**	**959**	1315	1105	999	929	879	1105

CDF Run I: 780 768

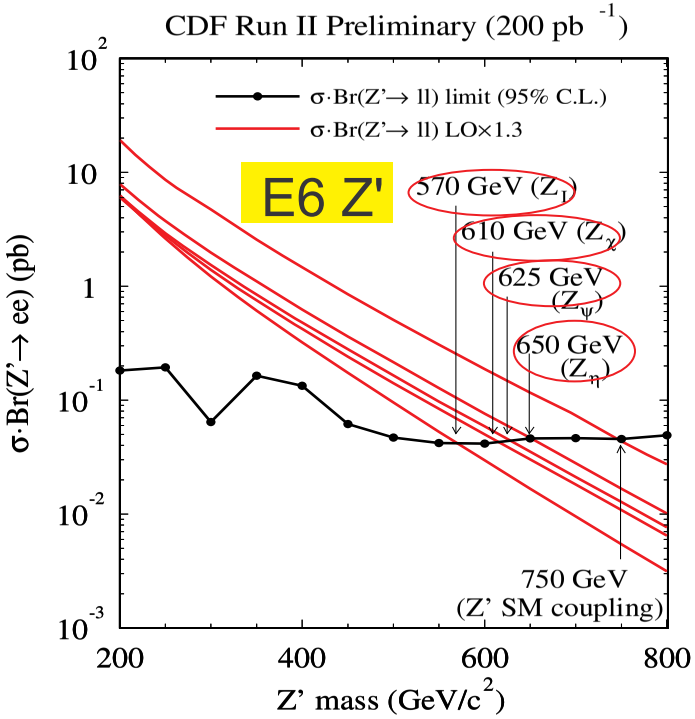
Spin-1 Dilepton Limits

Z' bosons

Sequential Z`: Reference model with SM-like couplings to fermions
Free parameter M(Z`)

CDF Run	L(pb^{-1})	Mass Limit @ 95 %	
Z' SM		**ee**	**μμ**
Run IA(92-93)	20	505	
Run IB(94-94)	90	640	590
IIA (winter 04)	200	**750**	**735**

Run I limits exceeded!



E6 Model Z`: del Aguilia et al., Nuc Phys B287 (87)
Unification of strong and EWK forces at GUT

$E6 \rightarrow (SO(10) \rightarrow SU(5) \times U(1)_\chi) \times U(1)_\psi$

$Z' = Z_\psi \sin\theta_{E6} + Z_\chi \cos\theta_{E6}$

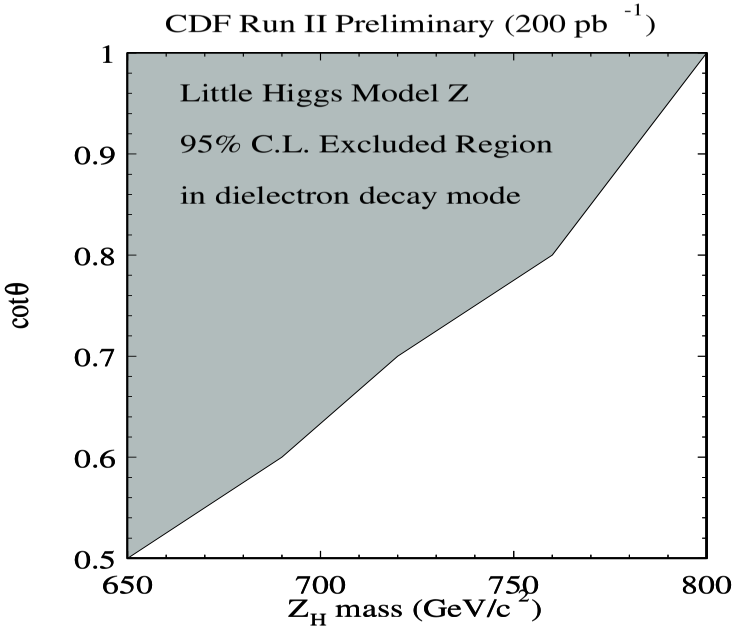
$Z_\eta, Z_I \Leftrightarrow \theta_{E6} = \sin^{-1}\sqrt{3/8}, \sin^{-1}\sqrt{5/8}$

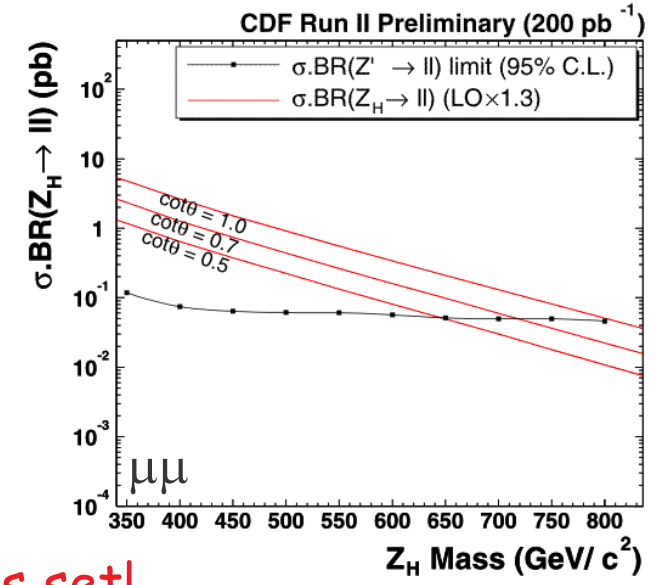
Spin-1 Dilepton Limits

Little Higgs Z'

Solve fine-tuning and hierarchy by canceling divergences of Higgs mass

SU(2) Z_H coupling parameter cotθ





First limits set!

Littlest Higgs Z_H ($\rightarrow ee$)

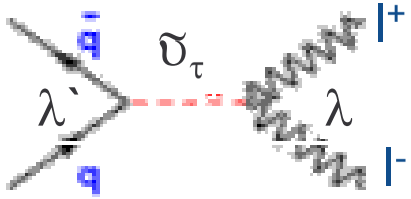
$M(Z_H)>800$ GeV/c^2 for cotθ=1.0

$M(Z_H)>755$ GeV/c2 for cotθ=0.9

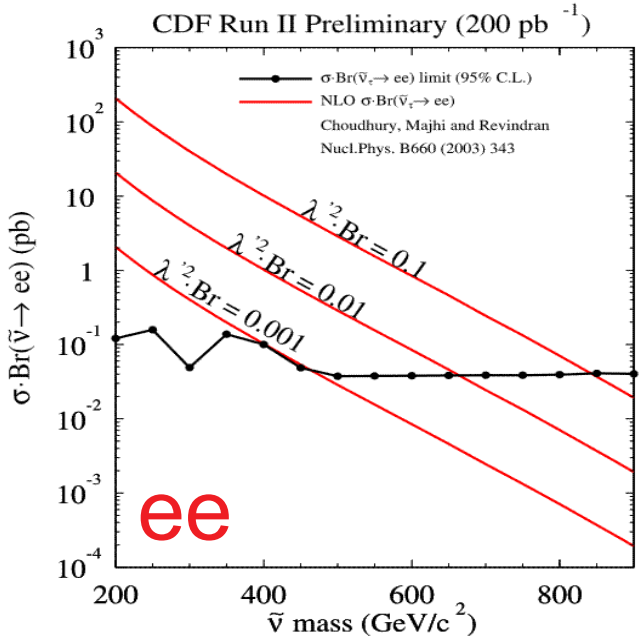
Arkani-Hamed, Cohen, Georgi, Phys. Lett. B 513, 232, 2001
Han, Logan, McElrath, Wang, Phys. Rev. D 67, 095004, 2003

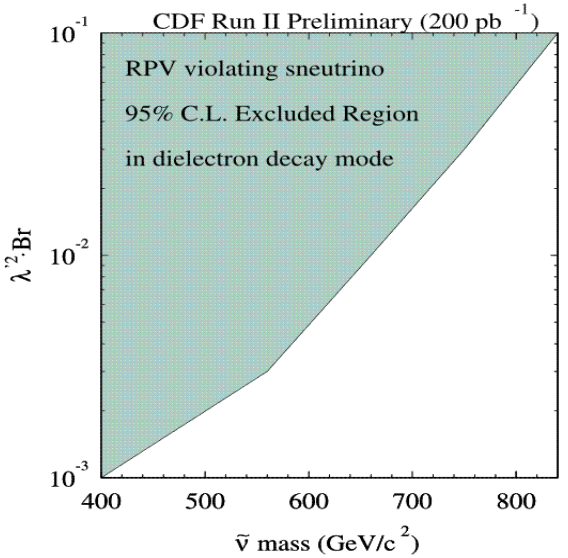
Spin-0 new physics limits

$\not{R}_P$ sneutrino



λ'^2.Br	CC (GeV)	CP (GeV)	CC+CP (GeV)
0.1	830	710	840
0.01	650	550	660
0.001	400	340	400





Summary and Conclusions

- Many searches for new physics at CDF are underway
- Presented: preliminary results in high mass ee+$\mu\mu$+$\gamma\gamma$ (200 pb^{-1})
  - ✓ **Surpassed the sensitivity and results of Run I high mass dilepton searches**
  - ✓ **Limits shown either exceed any published results of direct searches or are the first limits ever!**
- Lots more CDF data to analyse
- Combined results and publications are on the way

Many new exciting results from CDF
and more coming soon!