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Search for Extra Dimensions in the Diphoton Channel at CDF

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Outline

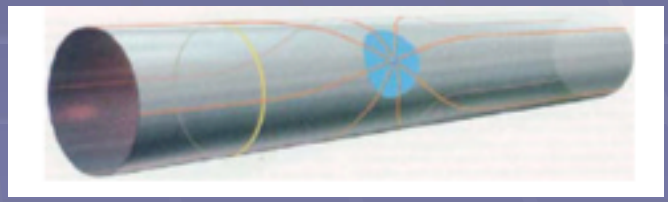
- Extra Dimensions
- Randall-Sundrum warped dimensions
- Collider signatures
- Increasing search sensitivity at CDF
- Diphoton candidate selection
- Efficiencies
- Backgrounds
- Systematics
- Limit setting
- Current limits
- Summary and plans

Extra Dimensions

Why EDs?
Come 'naturally' with string theory
Resolves hierarchy problem
($M_{Pl} / M_{EW} \sim 10^{16}$)
…

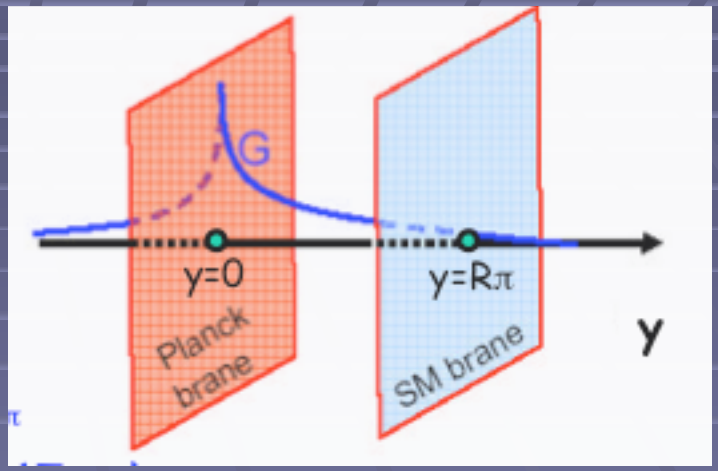
Many models:
ADD large extra dimensions
RS warped extra dimension
TeV^{-1} with modes of ~ TeV spacing
…

Restrictions on ED topologies:
EDs must be compactified
for inverse square law to hold.
If size smaller the ED: lines spread out equally in all directions.
If larger can only spread in infinite direction



RS Model

Warped 5D spacetime bound by positive (Planck) and negative (Weak) energy branes.
SM particles open strings confined to weak brane
Closed graviton string propagates in bulk



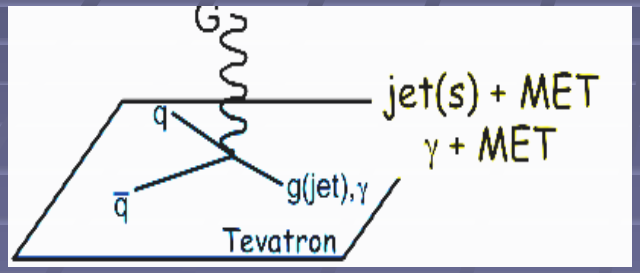
$$\Lambda_\pi = M_{Pl} e^{-kRc\pi}$$
for $kRc \sim 11\text{-}12$ $\Lambda_\pi \sim$ TeV
$0.01 < k/M_{Pl} < 0.1$

Probability function of graviton decreases exponentially

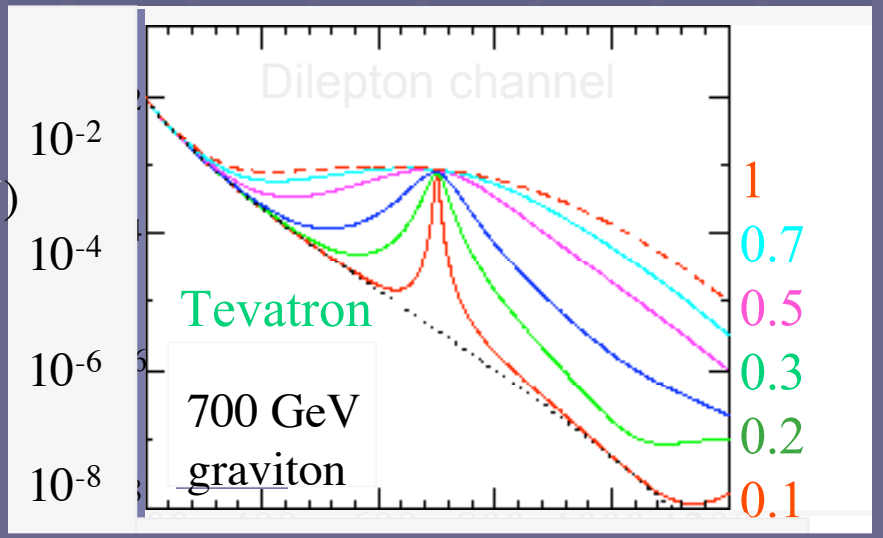
KK tower $G^{(n)}$ of modes of mass $M_n = x_n k e^{-kR\pi}$
(x_n first Bessel function ; well separated modes)
→ look for first graviton resonance.

RS Model: collider signatures

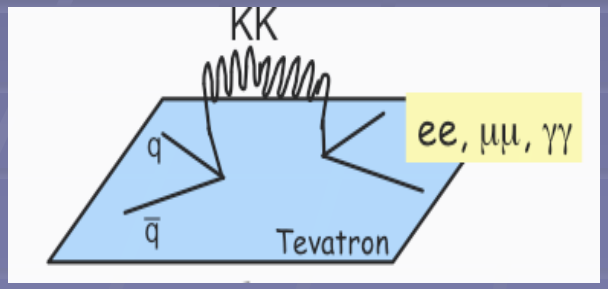
Real graviton emission



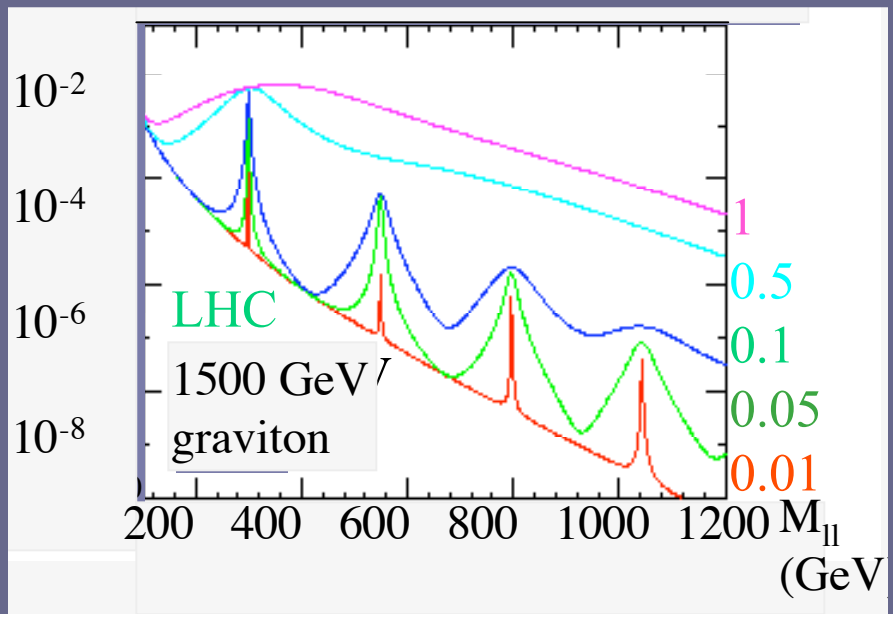
dσ/dM (pb/GeV)



Virtual graviton emission



BR(G→γγ) =
2 * BR(G→ee)



Increasing Sensitivity

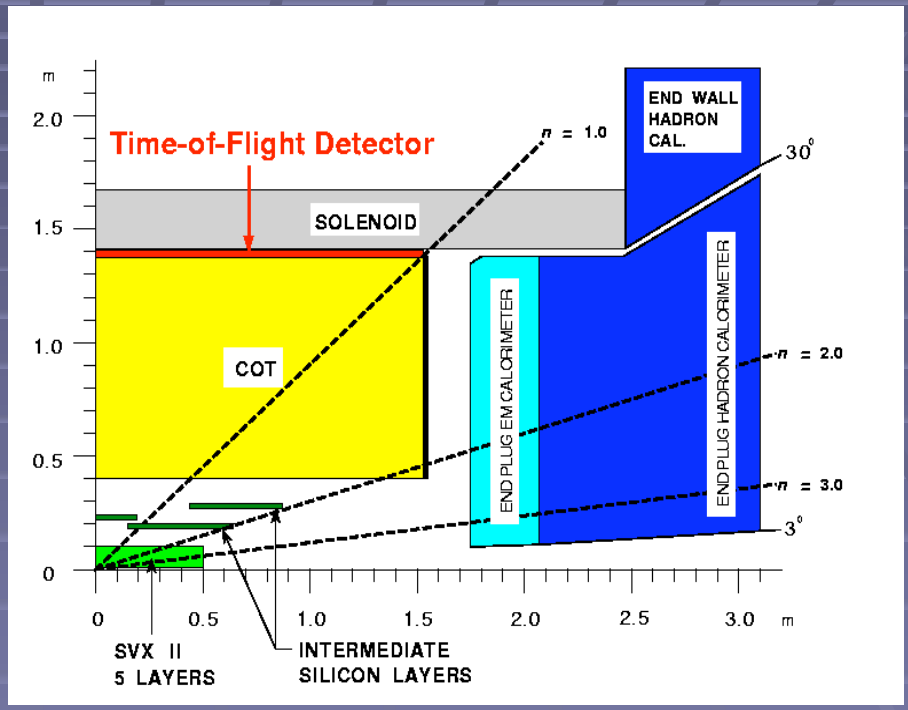
Significant increase in integrated luminosity from previous analysis of 202 pb^{-1}.

Central region:

$\int Ldt = 886\ pb^{-1}$

Plug region (also requires good Si):

$\int Ldt = 812\ pb^{-1}$



Increase η range to include $1.2 < |\eta| < 2.8$ where $\eta = -\log(\tan(\theta/2))$ by including upgraded plug. First for Run II $\gamma\gamma$ channel.

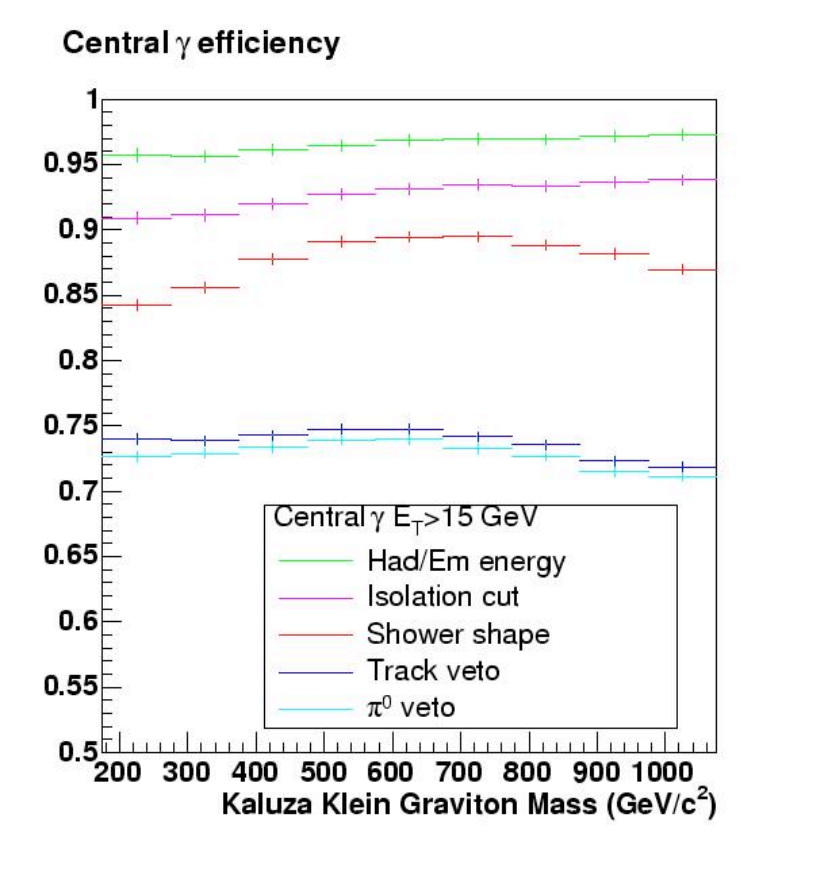
Photon Selection

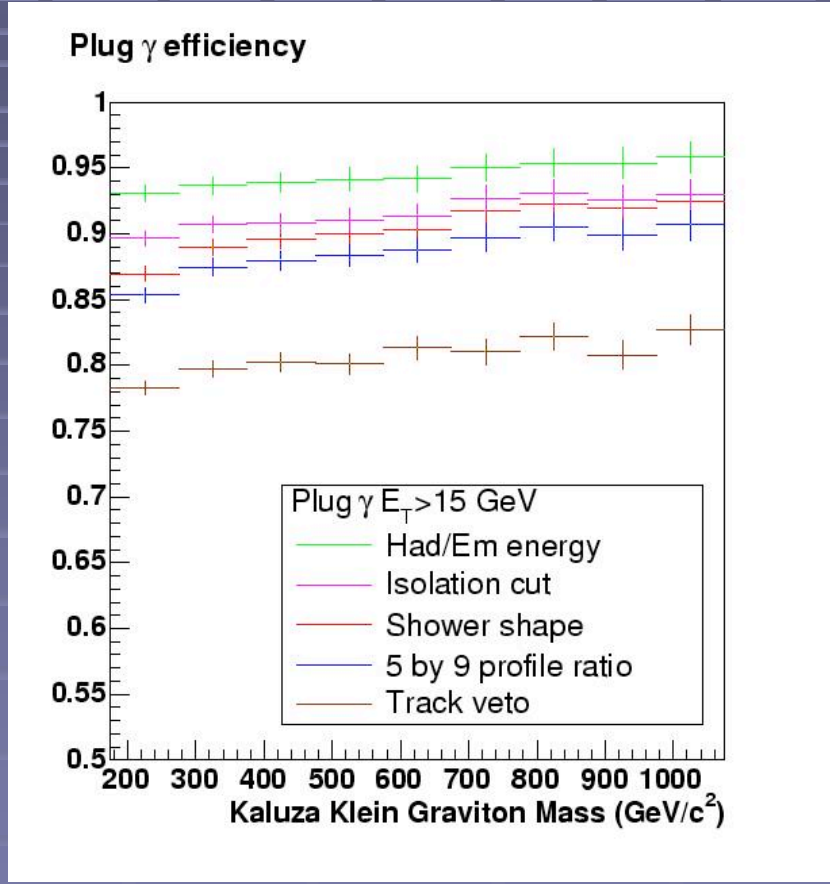
Photons required to have passed DIPHOTON or SUPERPHOTON triggers

Photon pair candidates are constrained to be:

- in standard central or plug region of detector.
- have $E_T > 15$ GeV and $M_{\gamma\gamma} > 30$ GeV.
- have shower shape consistent with EM shower through strip and wire hits in shower maximum detectors.
- Low ratio of energy deposited in hadronic calorimeter to EM calorimeter.
- track veto (zero or one track with low P_t).
- Remove π^0s by asking for low energy in second cluster in strip detector.

Photon Efficiencies



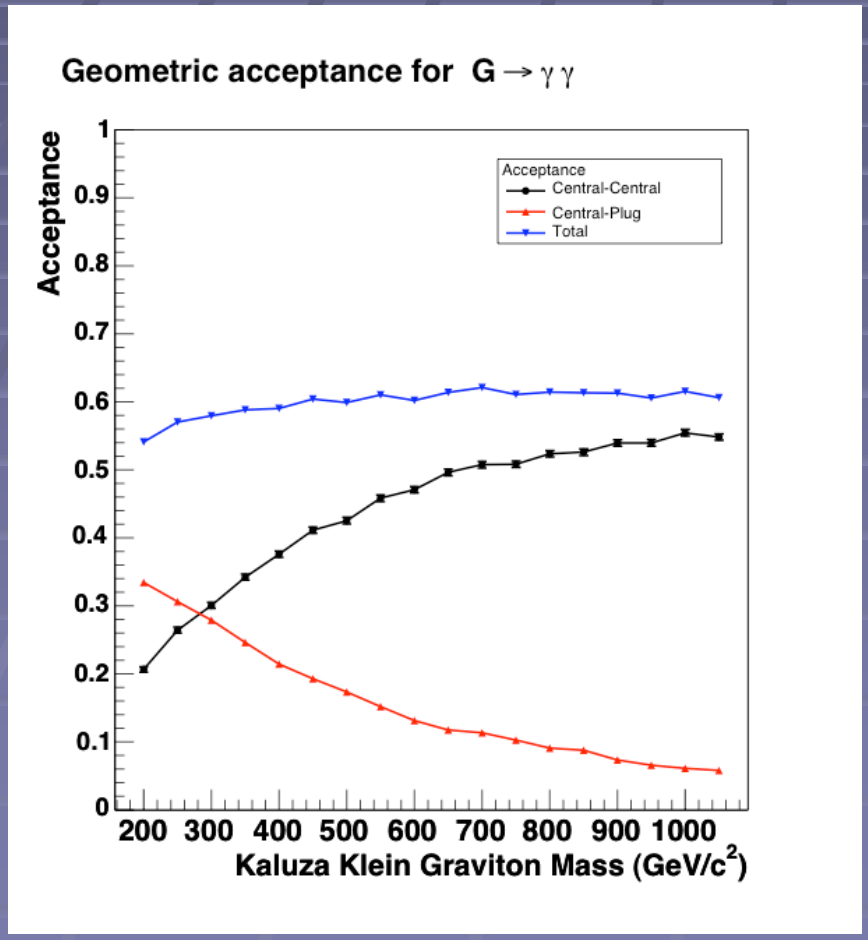


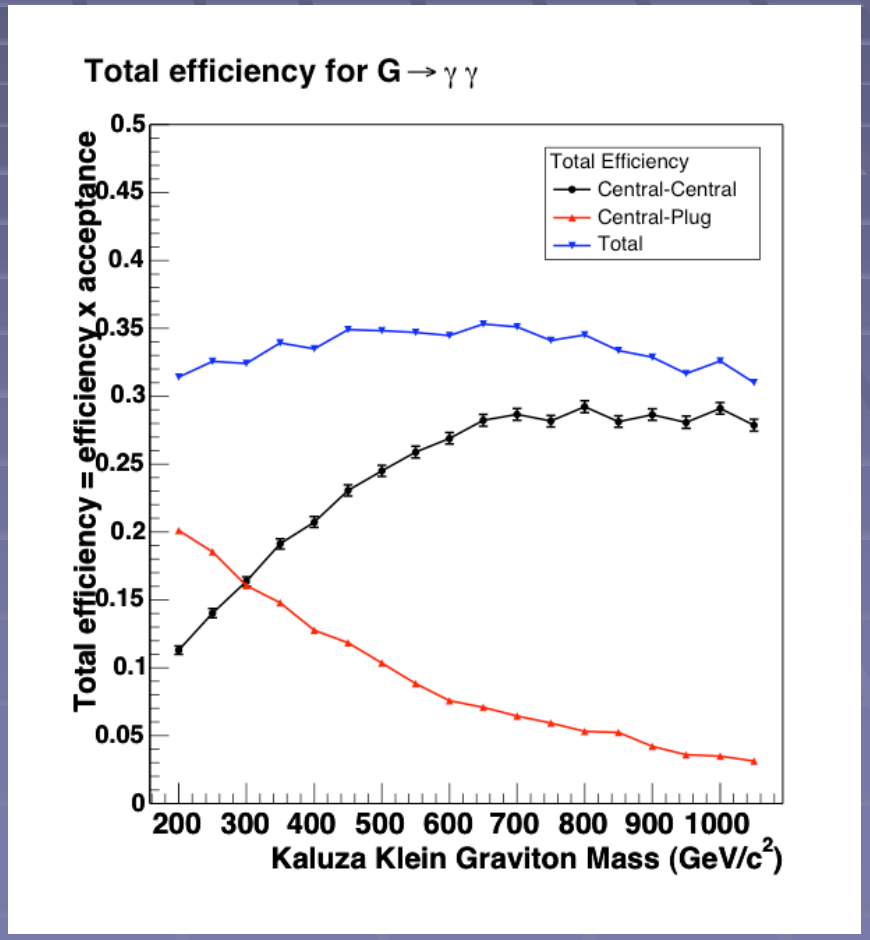
Generated using HERWIG RS MC for
200 GeV < MG < 1050 GeV in 50 GeV
Increments with $k/M_{Pl} = 0.01$

CDF Run II Preliminary

Increase in Total Efficiency

CDF Run II Preliminary





Background Estimation

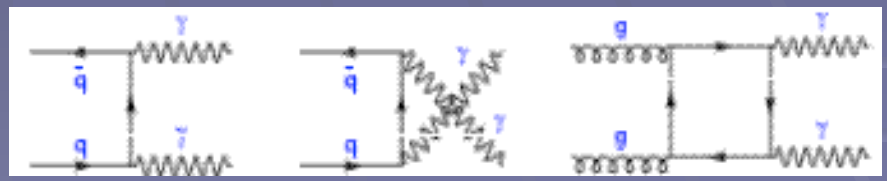
Diphoton fake events:

γ-jet and jet-jet

estimated using sidebands:
-loosen $\gamma\gamma$ selection criteria
- exclude tight $\gamma\gamma$ events
- apply various tighter cuts for systematics
- fit to the spectrum

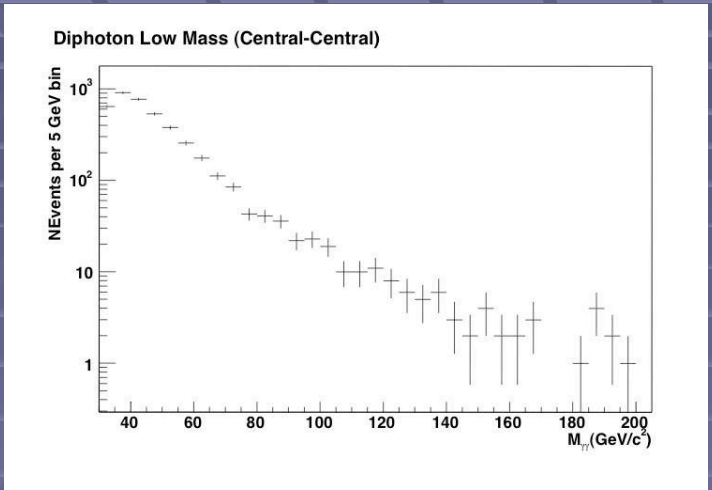
Standard Model diphoton production estimated using Diphox (NLO), absolutely normalised

mass spectrum corrected for efficiency from Pythia SM $\gamma\gamma$ prod.



Sample	$\gamma\gamma$ candidates	Sideband
CC	4142	8226
CP	7836	29578

Background Estimation

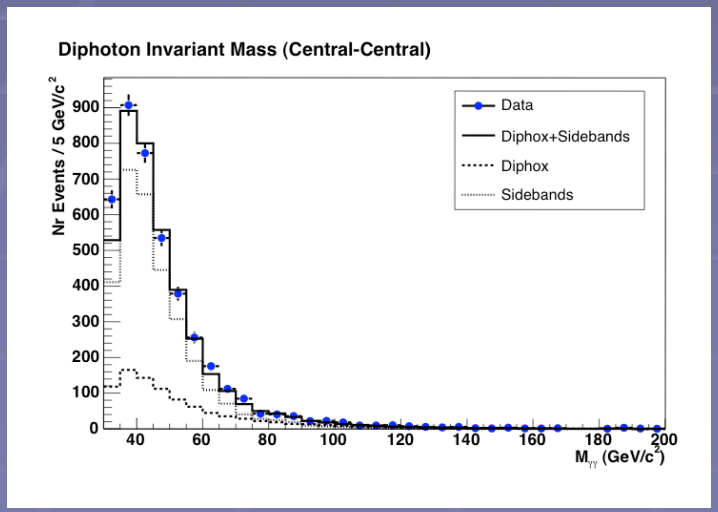


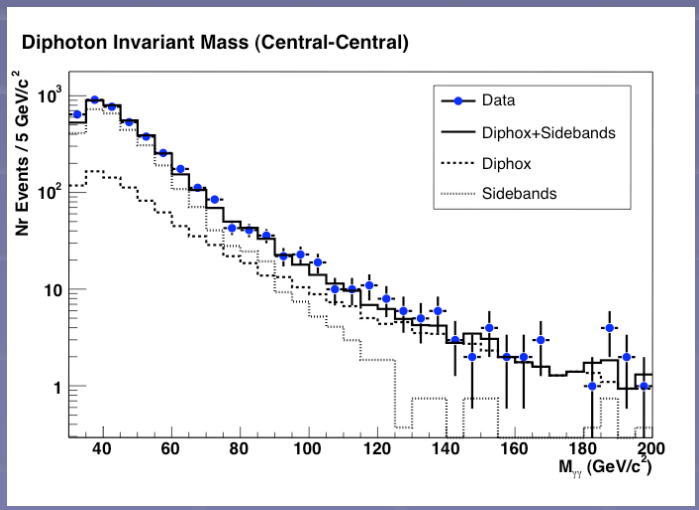
Normalised in the low mass region

$$\int_{40}^{100} N_{data} = \int_{40}^{100} N_{diphox} + \int_{40}^{100} N_{SB}$$

where $N_{diphox} = \sigma_{diphox} \varepsilon L$

CDF Run II Preliminary





Systematic errors

Acceptance:
Vary E_T by +/- 1% for Z mass difference in data and MC
PDFs
ISR/FSR
Luminosity
Energy resolution

Efficiency:
Scaling from Z study
Trigger
Z vertex
γ conversions

Background:
Diphox
QCD fakes (from sidebands)

Setting Limits

Likelihood that binned diphoton data (Nd_i) is described by a predicted background and hypothetical signal (Ns_i):

$$L(\sigma) = \prod_{i=1}^{Nbins} \frac{\mu(\sigma)^{Nd_i} e^{-\mu(\sigma)_i}}{d_i!}$$

Where $\mu(\sigma) = A\varepsilon L Ns_i / Ns_{tot} + Nb_i$

Ns_i: number of signal events

Nb_i: number of background events

Nd_i: number of data events

Ns_{tot}: number of signal events passing selection in *ith* bin

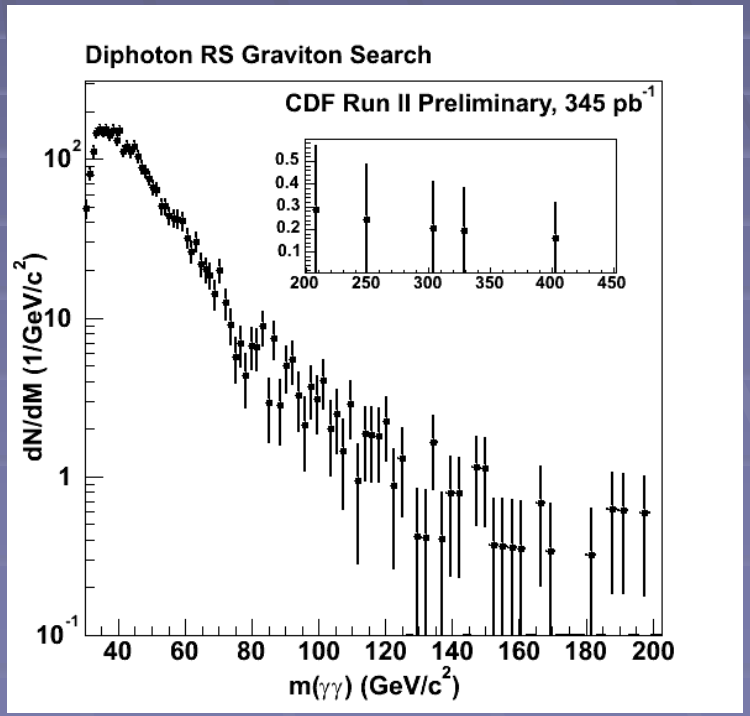
Limits

95 % confidence level obtained by integrating likelihood wrt σ such that

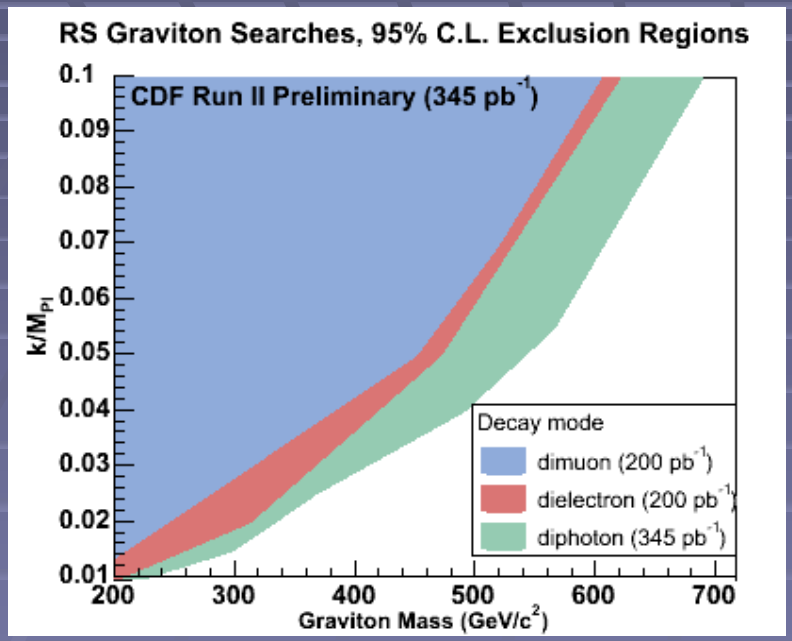
$$\frac{\int_{\sigma=0}^{\sigma^{95}} L(\sigma)}{\int_{\sigma=0}^{\infty} L(\sigma)} = 0.95$$

CC and CP channels combined by multiplying individual likelihoods.

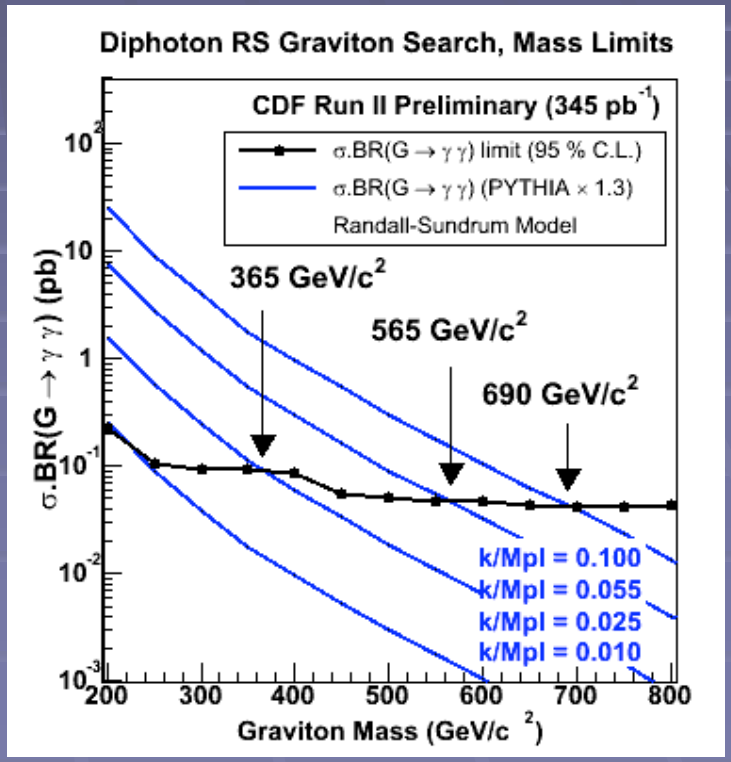
Compare observed limit to that expected if only background was present:
5 000 pseudo-experiments generated for each mass point and limit calculated.
Median then taken as expected limit.



Current Limits from CDF



Compare to RS cross section for different values of the k/M_{Pl} parameter.



ee has greatest sensitivity at low mass but γγ predominates at high mass.

Summary and Plans

- EDs provide natural solution to hierarchy problem and come ‘naturally’ with string theory.
- Provide visible signatures at high energy colliders such as CDF.
- New diphoton search increases sensitivity through increasing the geometric acceptance and using higher integrated luminosities.

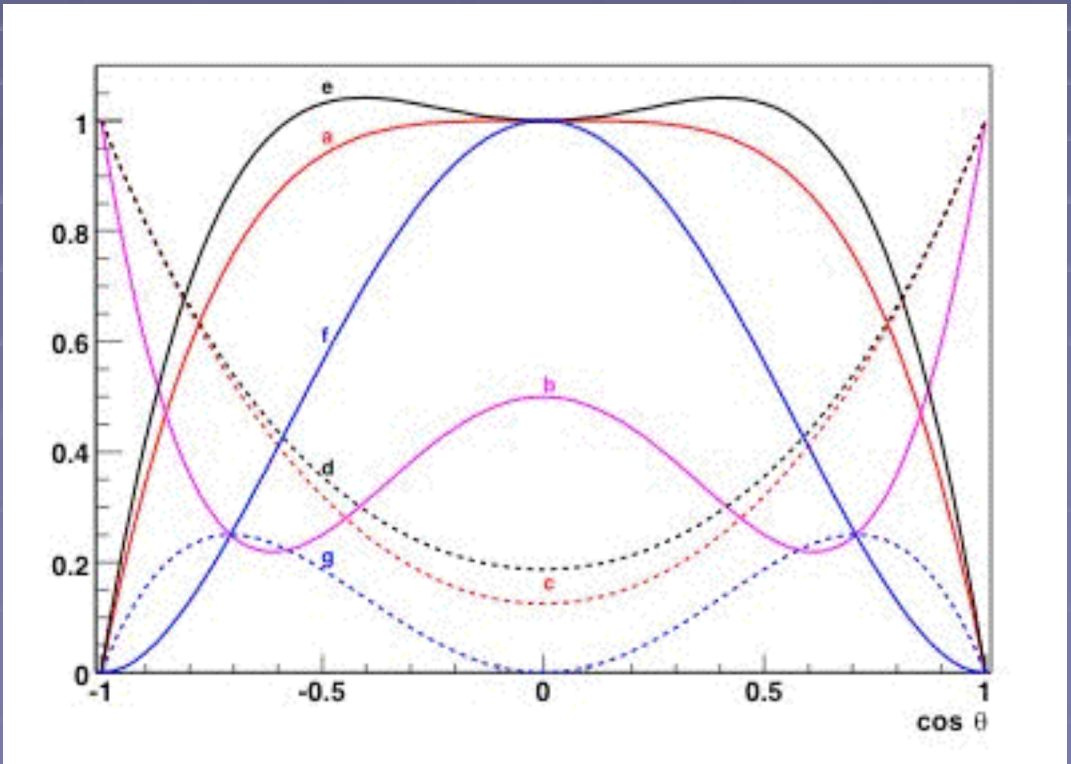
- Future plans to present limit for full ~800 pb^{-1} dataset.

Backup Slides

Acceptance Distribution

- gg-> G-> $\gamma\gamma$ predominates but qq-> G -> $\gamma\gamma$ flattens angular distribution

β represents velocity of decay products, shown in limit of negligible mass (β = 1)



c shows gg and a shows qq (others are for ff, ZZ, WW, HH decay products)

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