Search for Randall-Sundrum Gravitons at CDF

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On behalf of the CDF collaboration

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Randall-Sundrum Extra Dimension Model

- Hierarchy problem: large disparity between the Planck scale (10^{16}TeV) and electroweak scale (~1TeV).
- Randall-Sundrum extra dimension model
  - 5-dimensional warped geometry
  - Weak brane $\phi=\pi$ and Planck brane $\phi=0$
- Hierarchy is generated by a warp factor $\exp(-kr_c\pi)$
  - k: curvature of extra dimension
  - r_c: compactification radius of extra dimension
- Kaluza-Klein tower of graviton states
  - Mass of first excitation: m_1
  - Width parameter: k/M_{Pl}
- Decay products of RS graviton can be probed at hadron collider
  - G->$\gamma\gamma$, G->ll, etc.
  - Spin-2: Γ (G->$\gamma\gamma$) = 2Γ(G->ll)
- We performed a search for RS gravitons in the diphoton channel at CDF using 5.4fb^{-1} of Run II data.

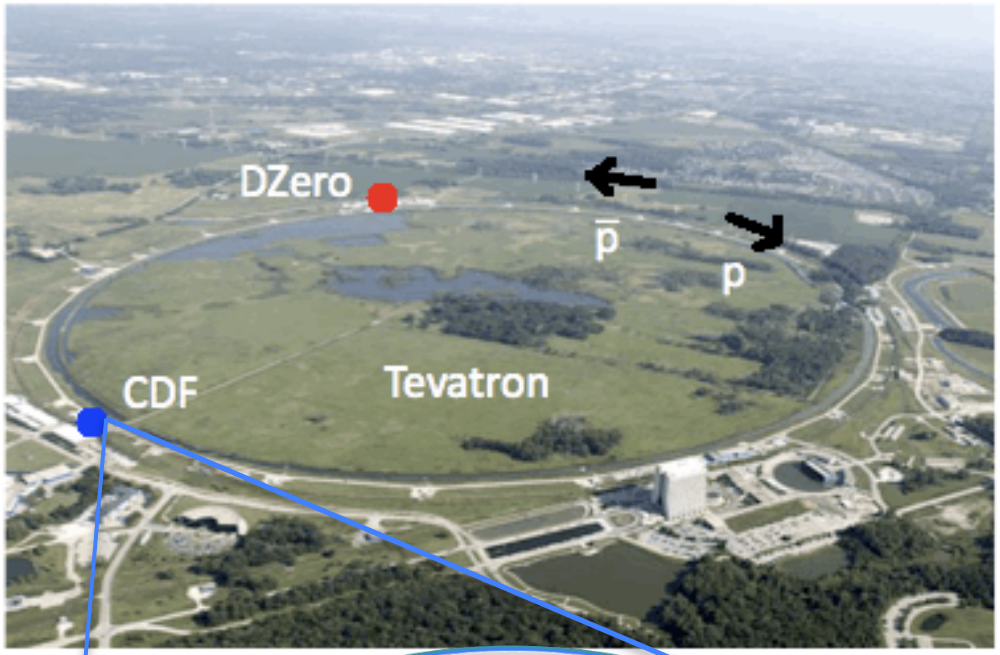
The Tevatron and CDF

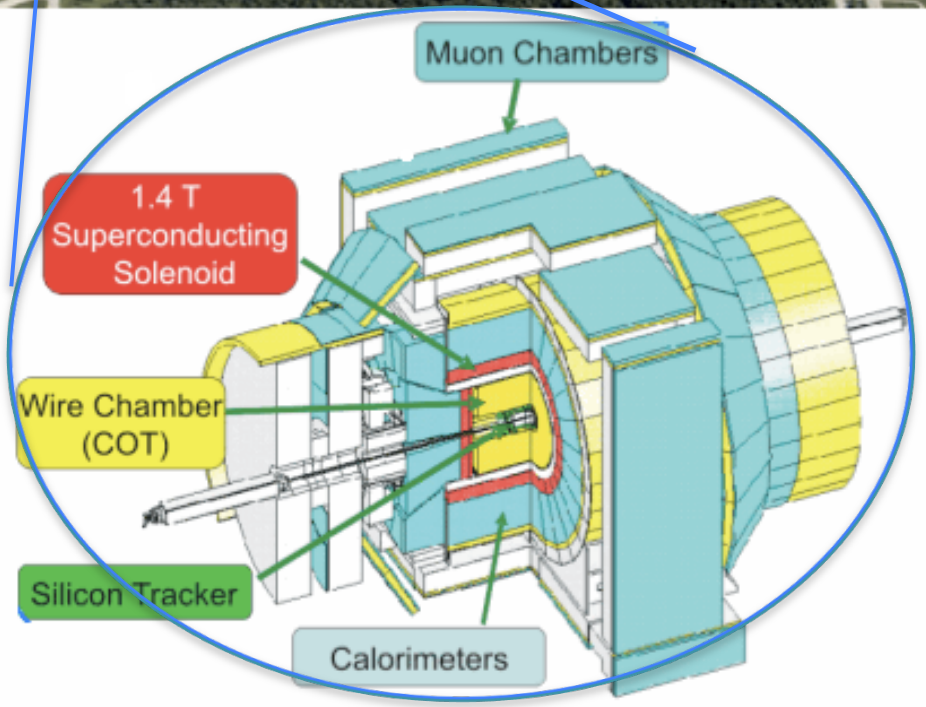
Tevatron:

- Proton-antiproton accelerator
- $\sqrt{s}$ = 1.96 TeV
- Delivered 8.6 fb^{-1}
- Recorded 7.1 fb^{-1}

CDF

- Collider Detector at Fermilab
- Tracking (large *B* field):
  - Silicon tracking
  - Wire Chamber
- Calorimetry:
  - Electromagnetic (EM)
  - Hadronic
- Muon system



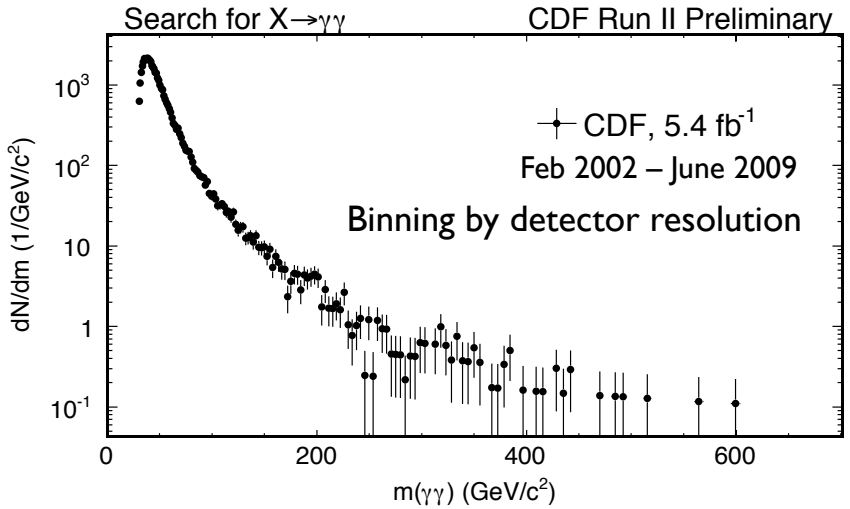


Analysis Overview

- Event selection
- Signal efficiency: Pythia MC
- Background estimation
  - SM diphoton background
  - Jets faking photons
- Upper limits on $\sigma \times Br(G->\gamma\gamma)$ as a function of mass
- Lower limits on graviton mass as a function of k/M_{Pl}

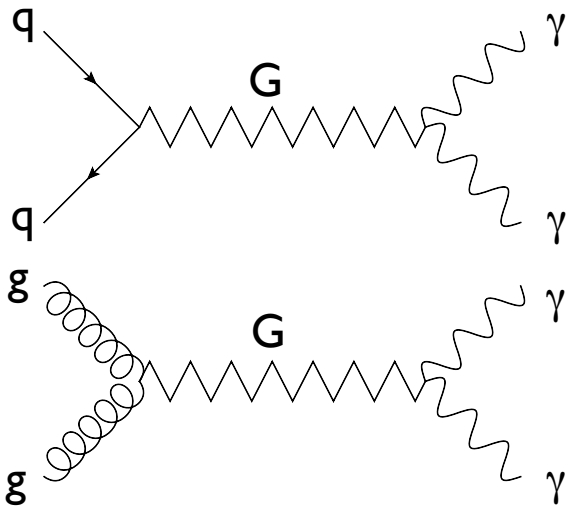
Diphoton Event Selection

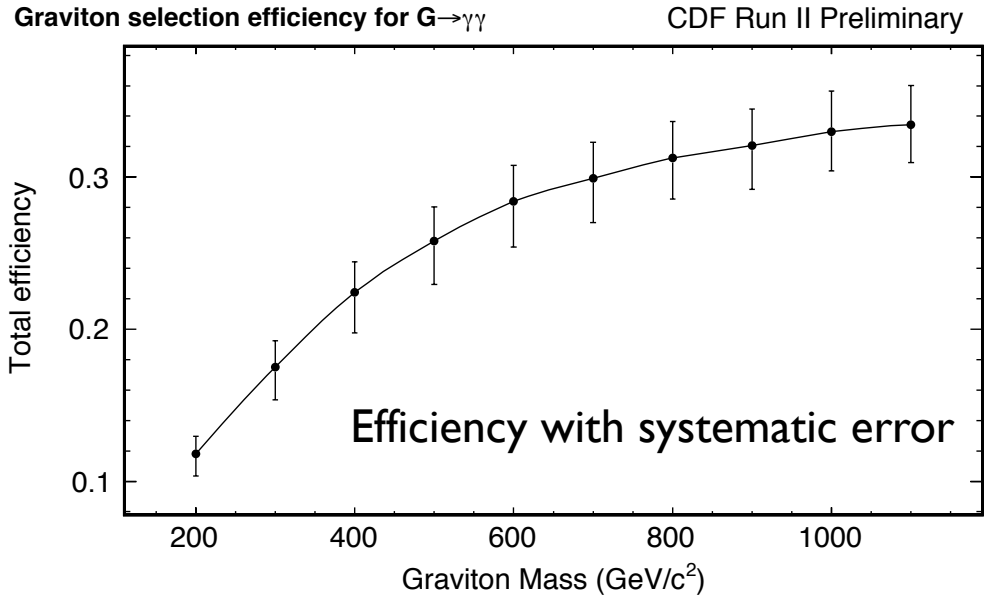
- Used a combination of 4 triggers to select di-photon events
  - 100% efficient for m(γγ)>50GeV
- Interaction vertex in the fiducial region
- Standard CDF photon ID
  - Transverse shower profiles consistent with a single-photon
  - Photon candidate is isolated
- Both photons in the central calorimeter (| η |<1)
- E_t>15GeV for each photon, m(γγ)>30GeV
- Correct Photon selection efficiency and EM energy scale based on Z->ee events



Signal Efficiency and Event Yield

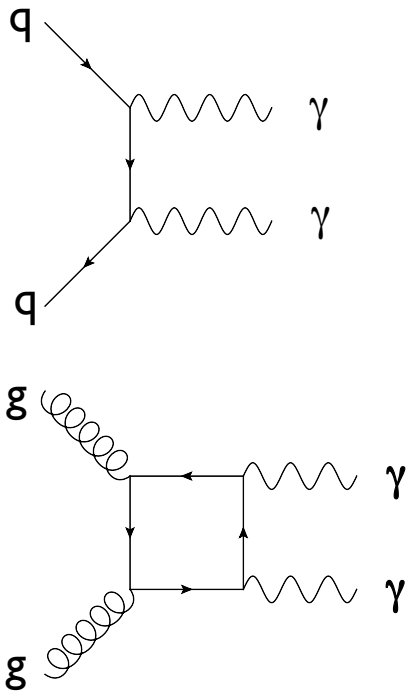
- Generate signal MC using Pythia
  - Masses from 200 GeV to 1.1 TeV at 100 GeV intervals
  - k/M_{Pl}=0.01: decay width much smaller than detector resolution
- Rising shape caused by detector acceptance
- Systematic uncertainty on expected signal events:
  - ~10%: luminosity and ISR/FSR

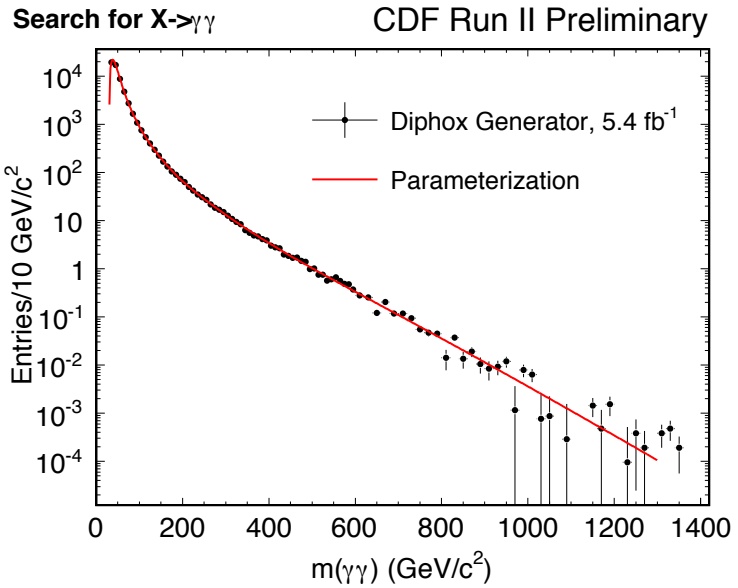




SM Background: QCD diphotons

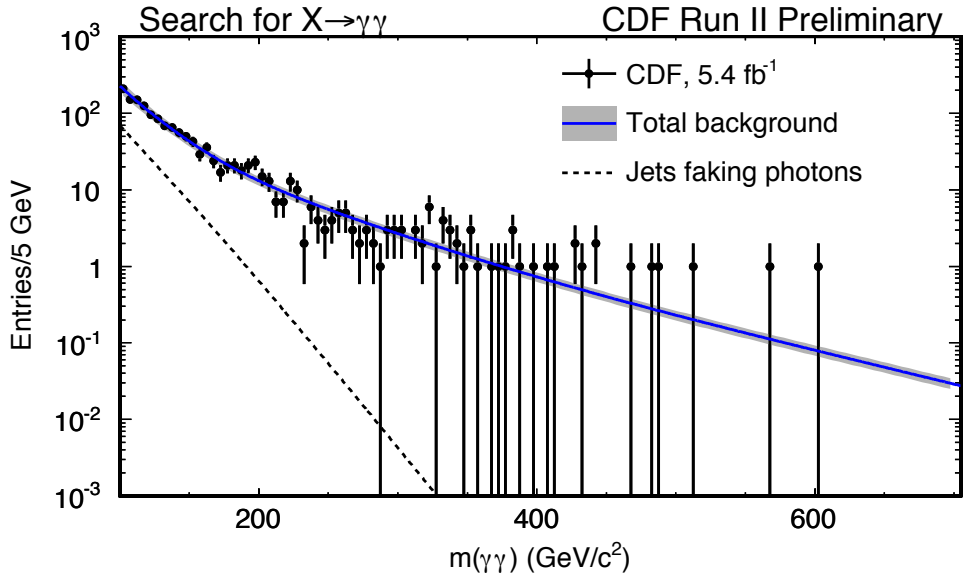
- Shape evaluated with Diphox NLO cross section MC
- Shape corrected by selection efficiency evaluated with Pythia diphoton MC
- Systematic uncertainty:
  - ~20%: PDFs and Q^2 scales (μ_F, μ_f, μ_R)





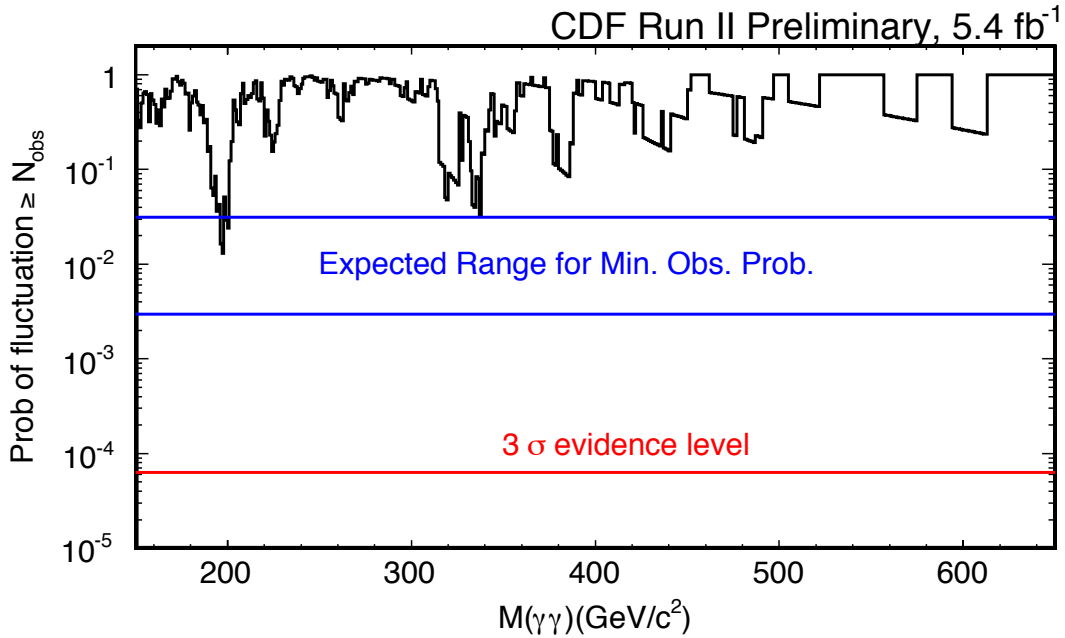
Background Fit

- Fit data diphoton mass spectrum with Diphox + a function form of 2 exponentials (jets faking photons).
- Allow normalization of Diphox to float, the best fit normalization is 1.016.
- Contribution of jets faking photons is negligible for mass > 200 GeV.
- Largest excess at 200 GeV.

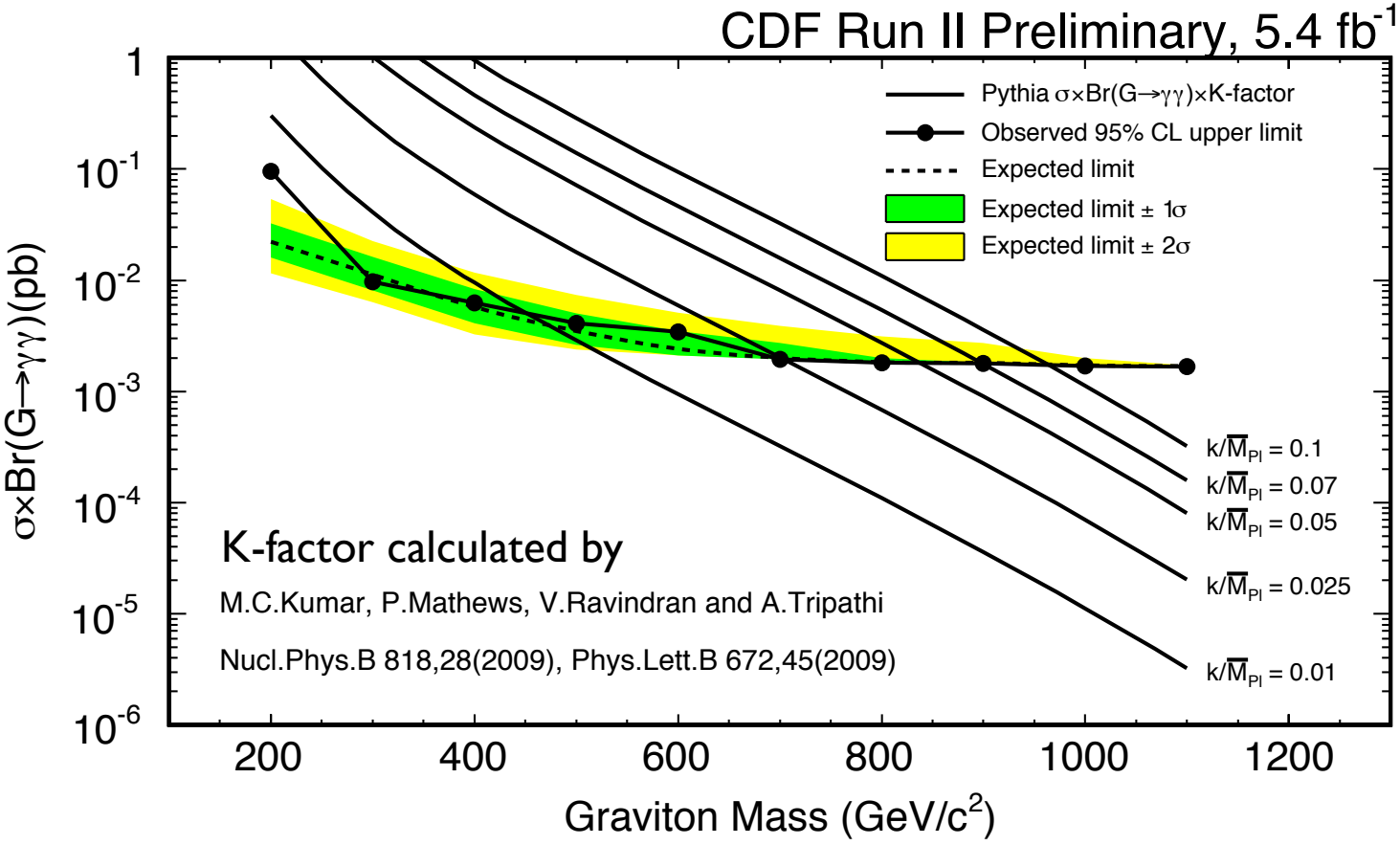


Bump Search

- Performed a frequentist model independent search for excess.
- Calculated the probability for the background to fluctuate to the level of the data or higher for every point in the mass spectrum.
- Background uncertainty is integrated out assuming it is Gaussian distributed.
- The expected range and 3 σ level are determined through pseudo-experiments.

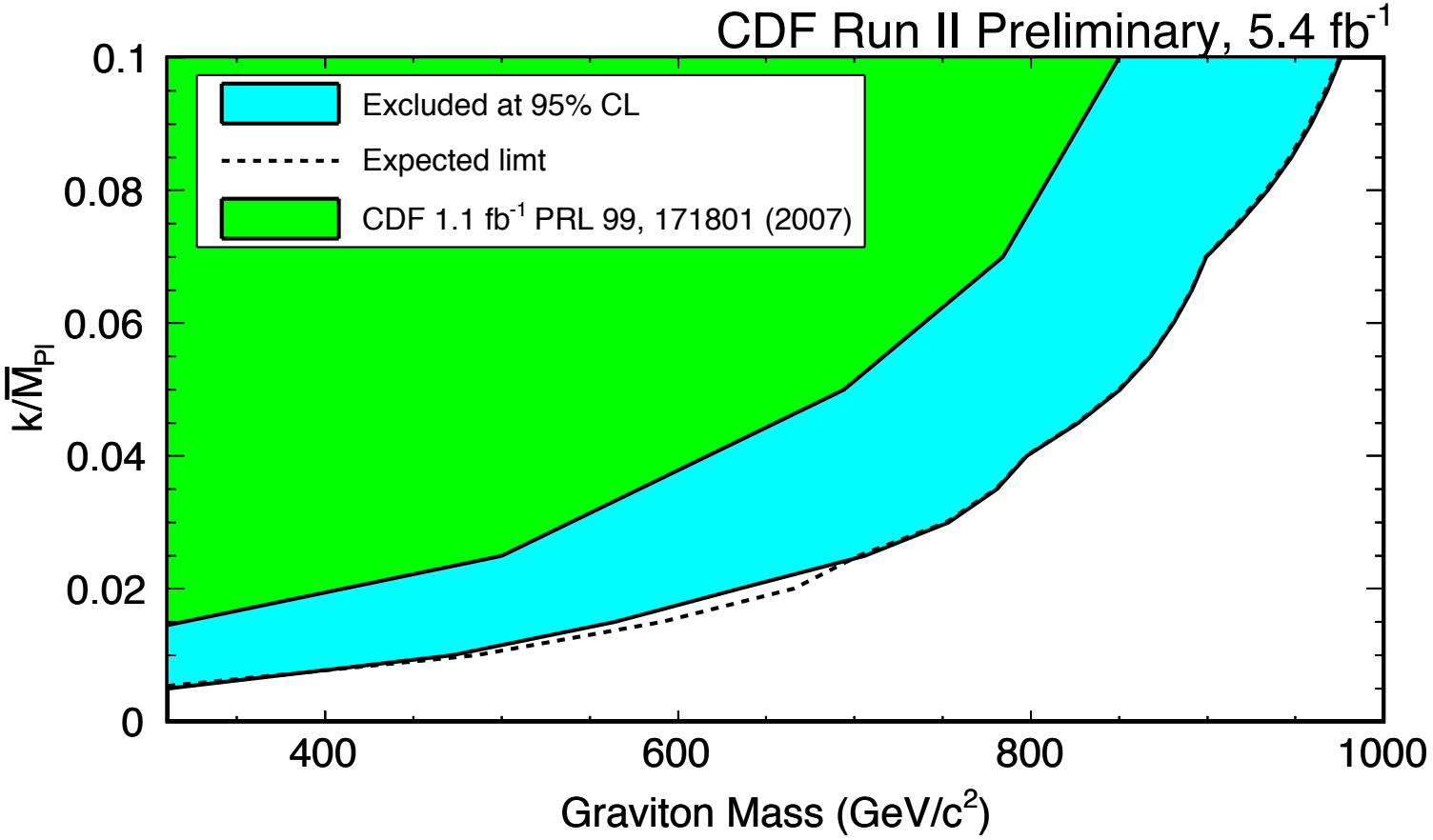


Cross Section Limits



Pythia LO cross section calculation is corrected by K-factor (1.54 at 200 GeV decreasing to 0.98 at 1 TeV).

Limit on RS Model



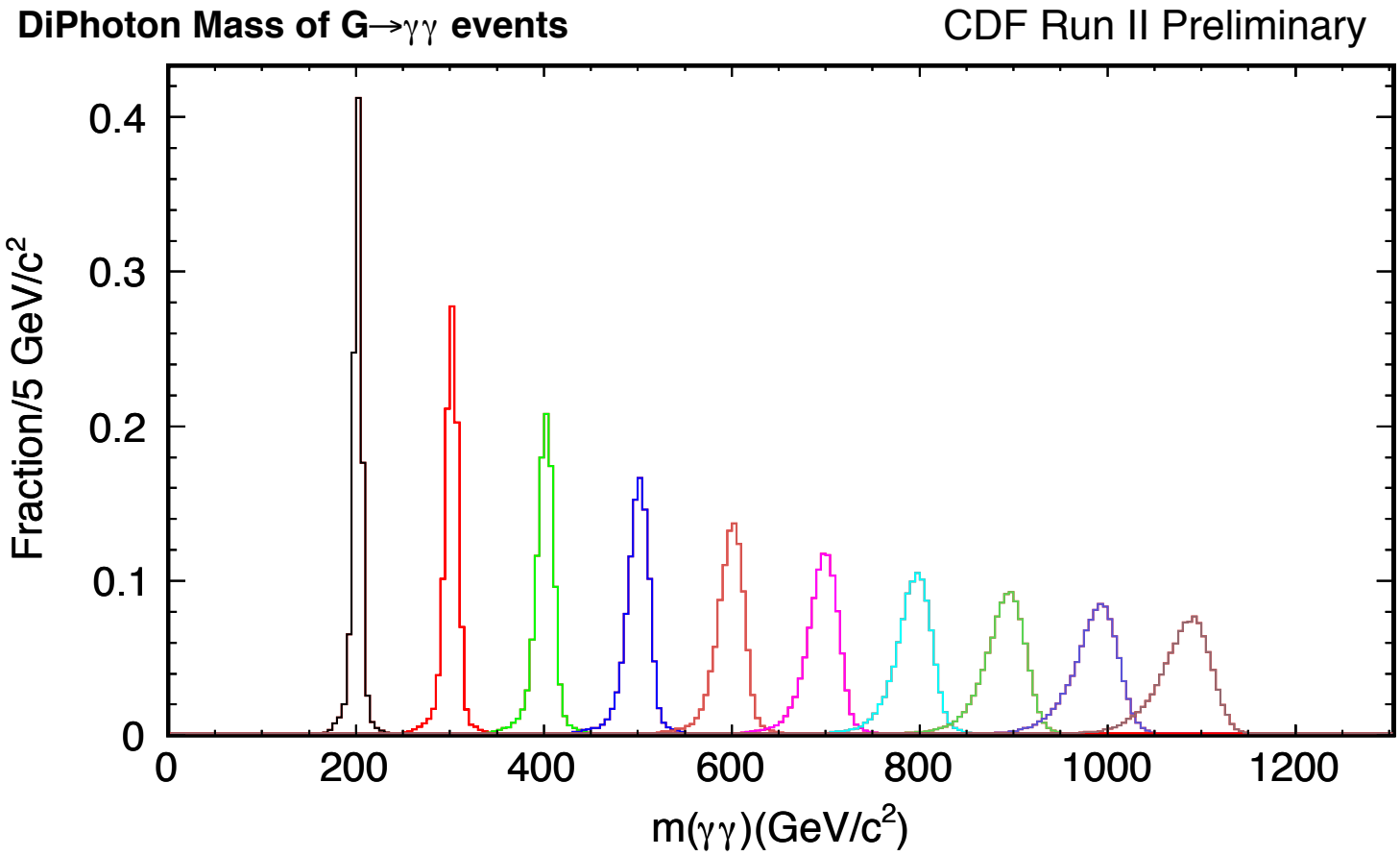
- Limit greatly improved over previously CDF published results.
- M_G>472 GeV for k/M_{Pl} = 0.01 and M_G>976 GeV for k/M_{Pl} = 0.1

Summary

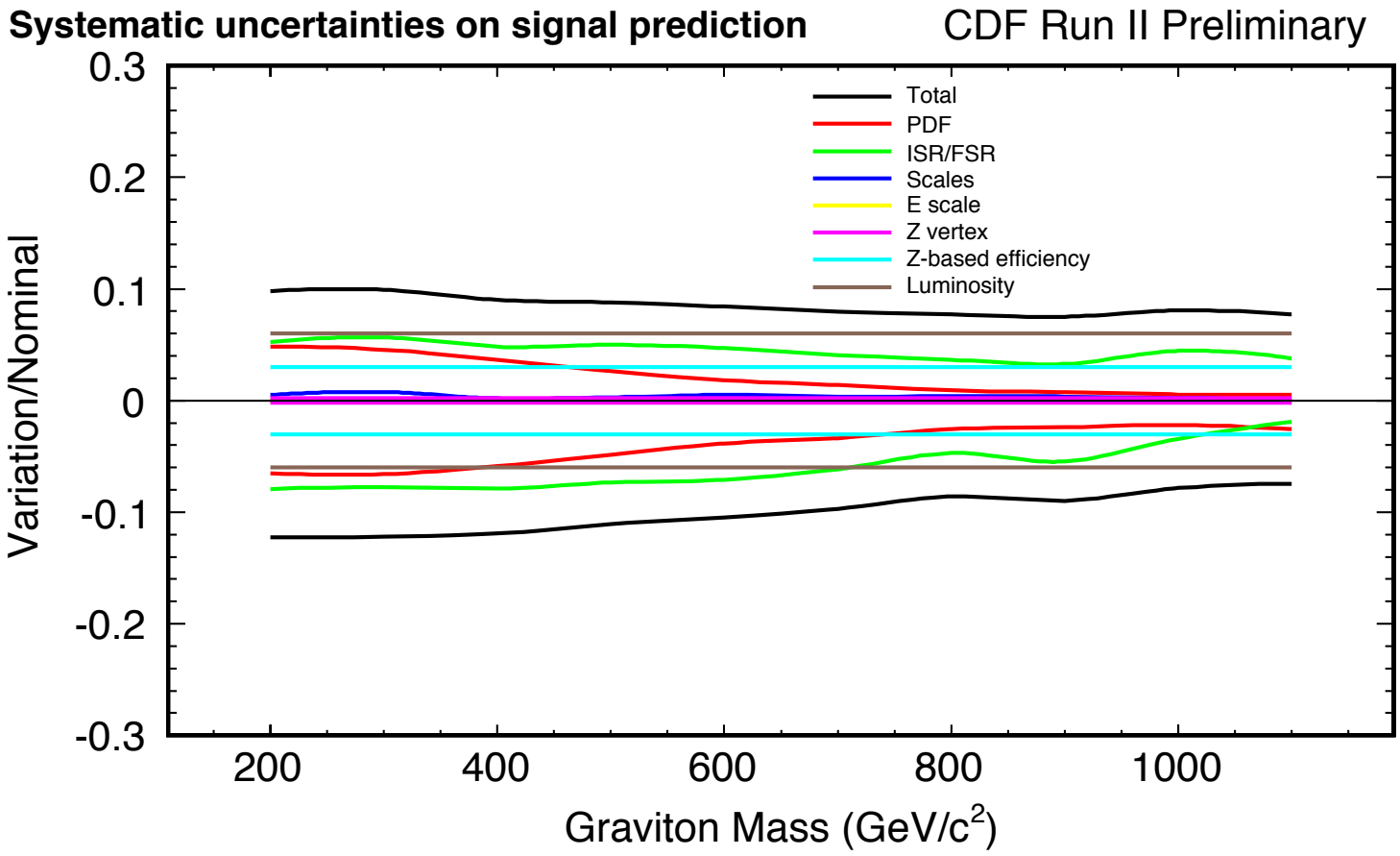
- We have performed a search for RS gravitons in the diphoton decay channel using 5.4 fb^{-1} of data collected at CDF.
- Our data mass spectrum is consistent with the SM expectation.
- We have improved the limits on the RS mass:
  - M_G>472 GeV for k/M_{Pl} = 0.01 and M_G>976 GeV for k/M_{Pl} = 0.1

Backup Slides

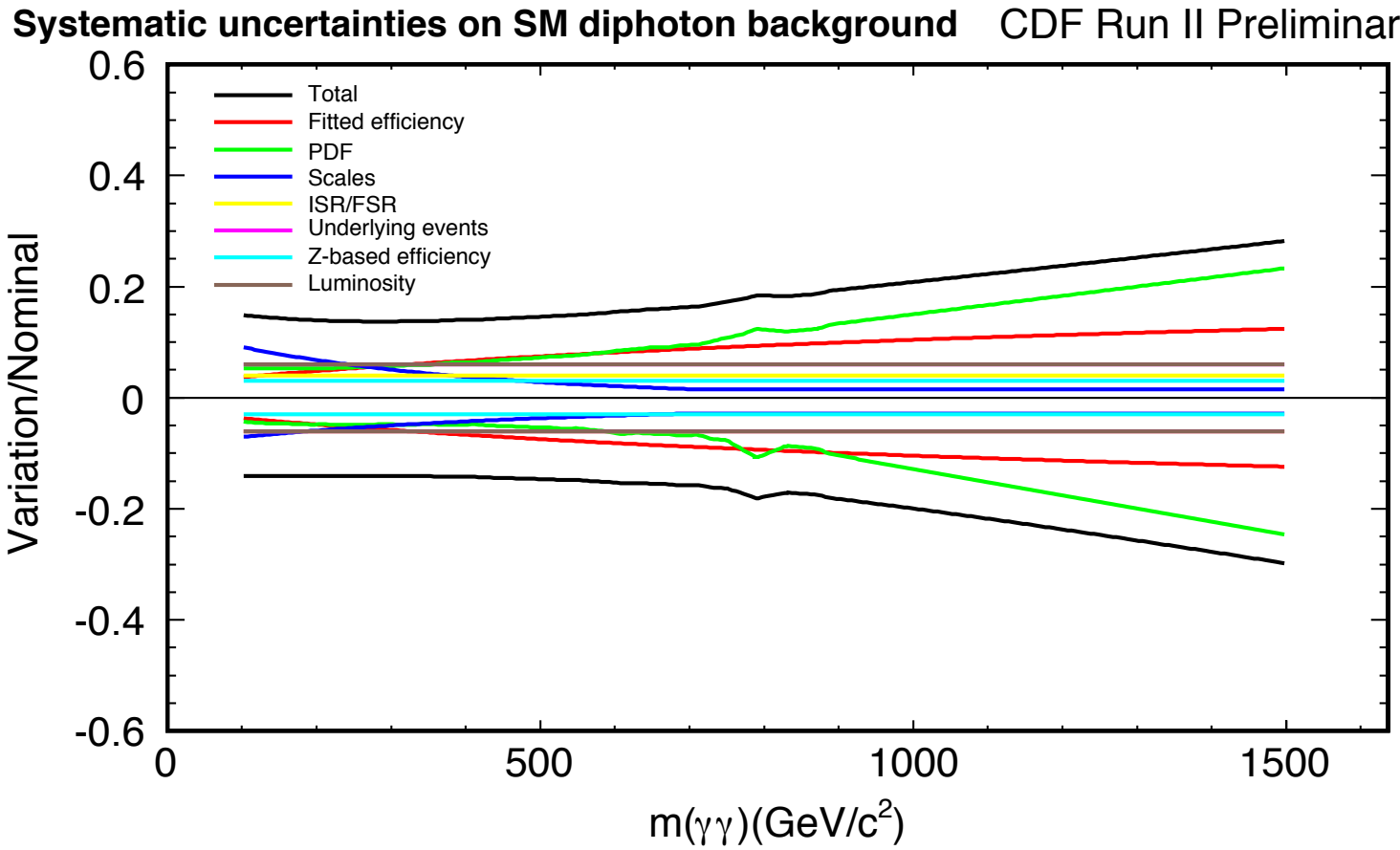
Signal Shape



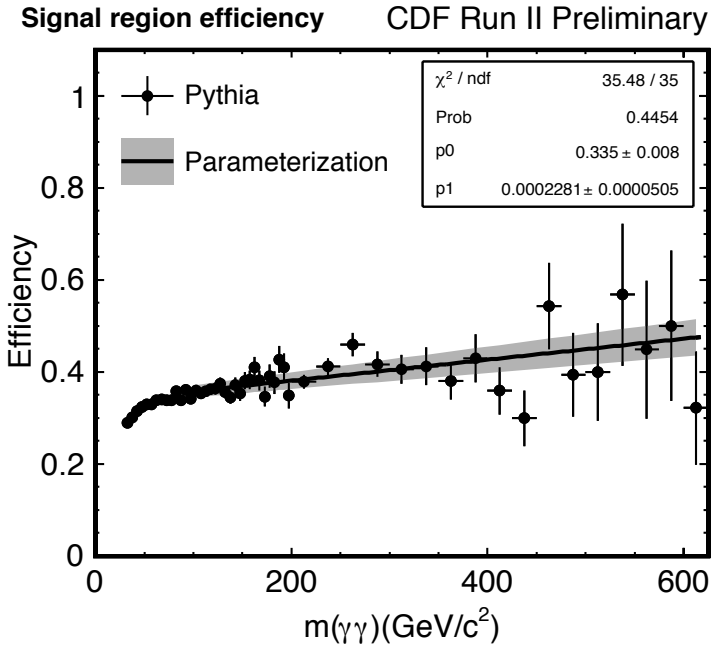
Signal Systematics

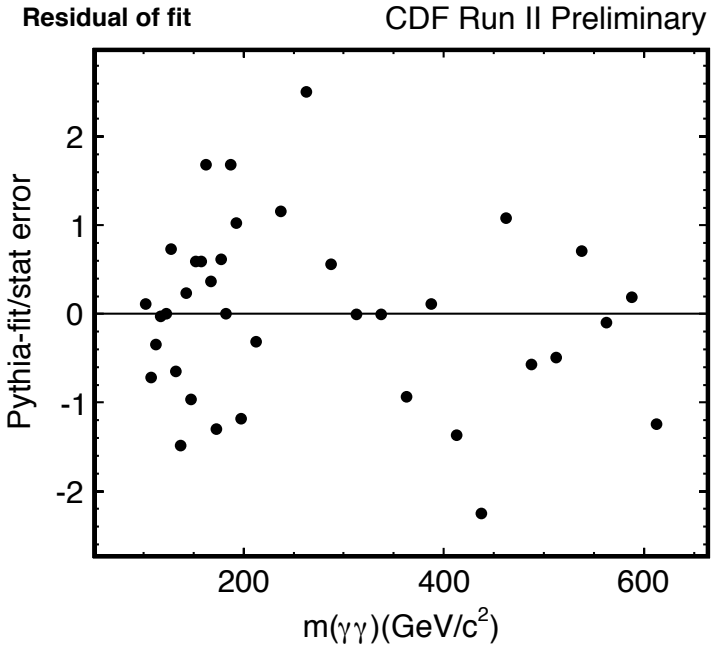


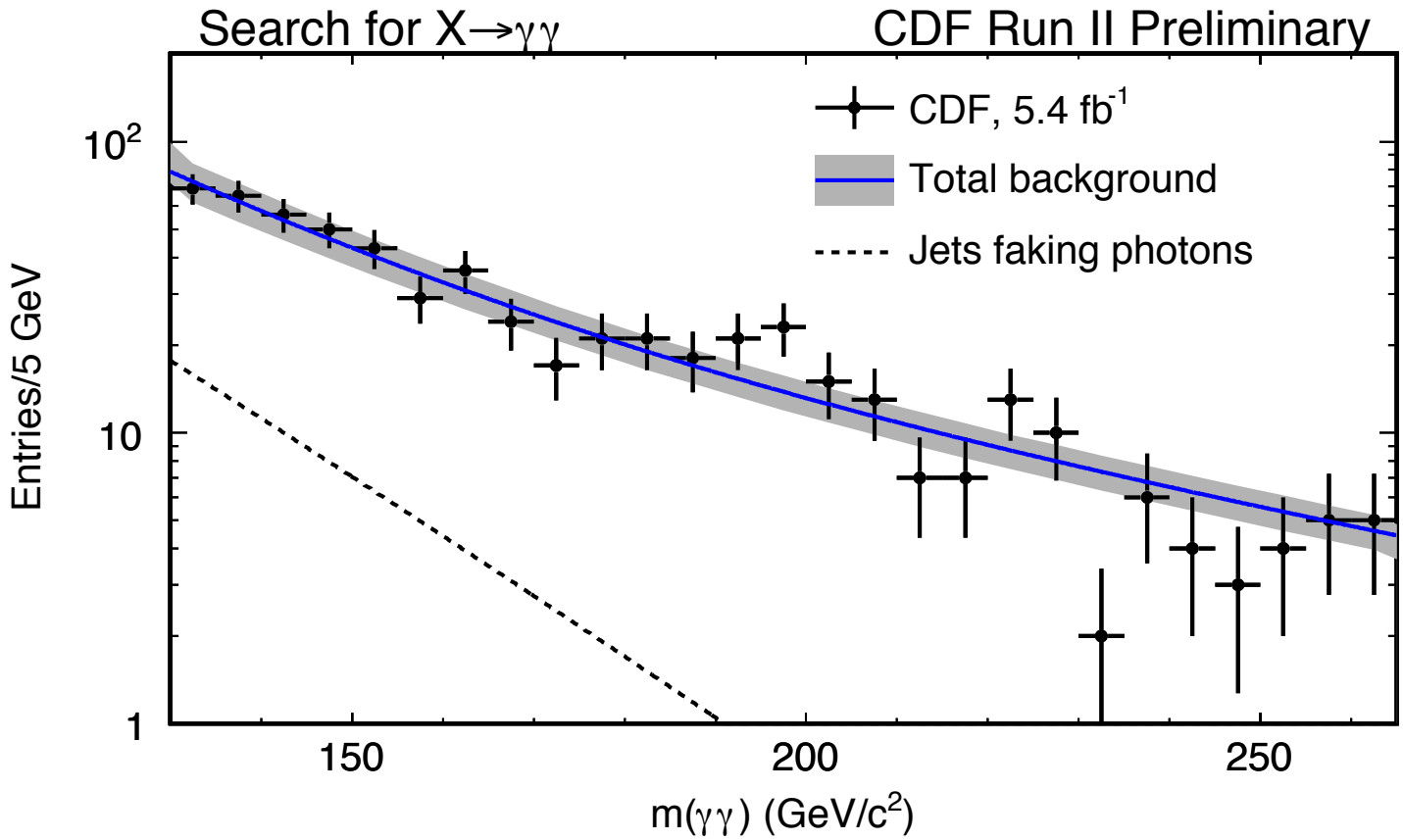
Background Systematics

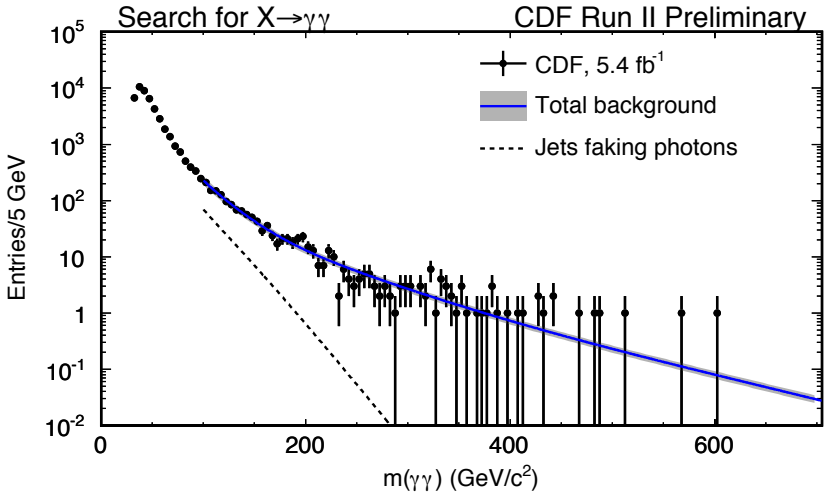


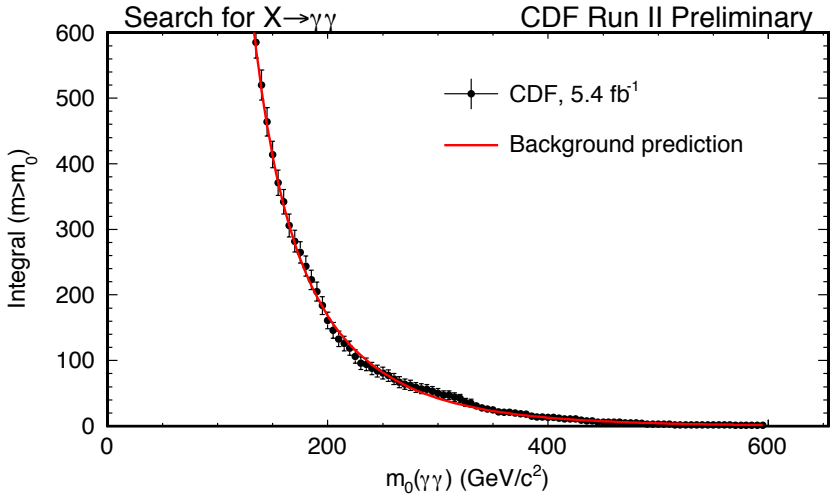
Diphoton Selection Efficiency

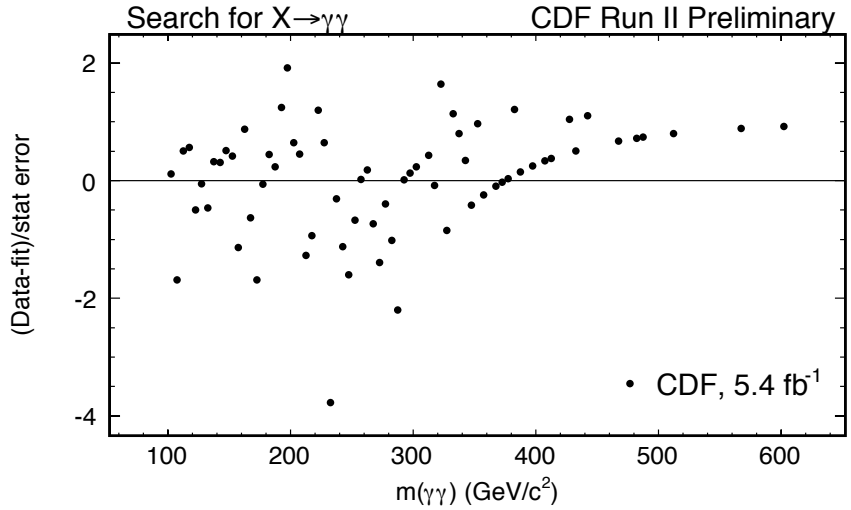


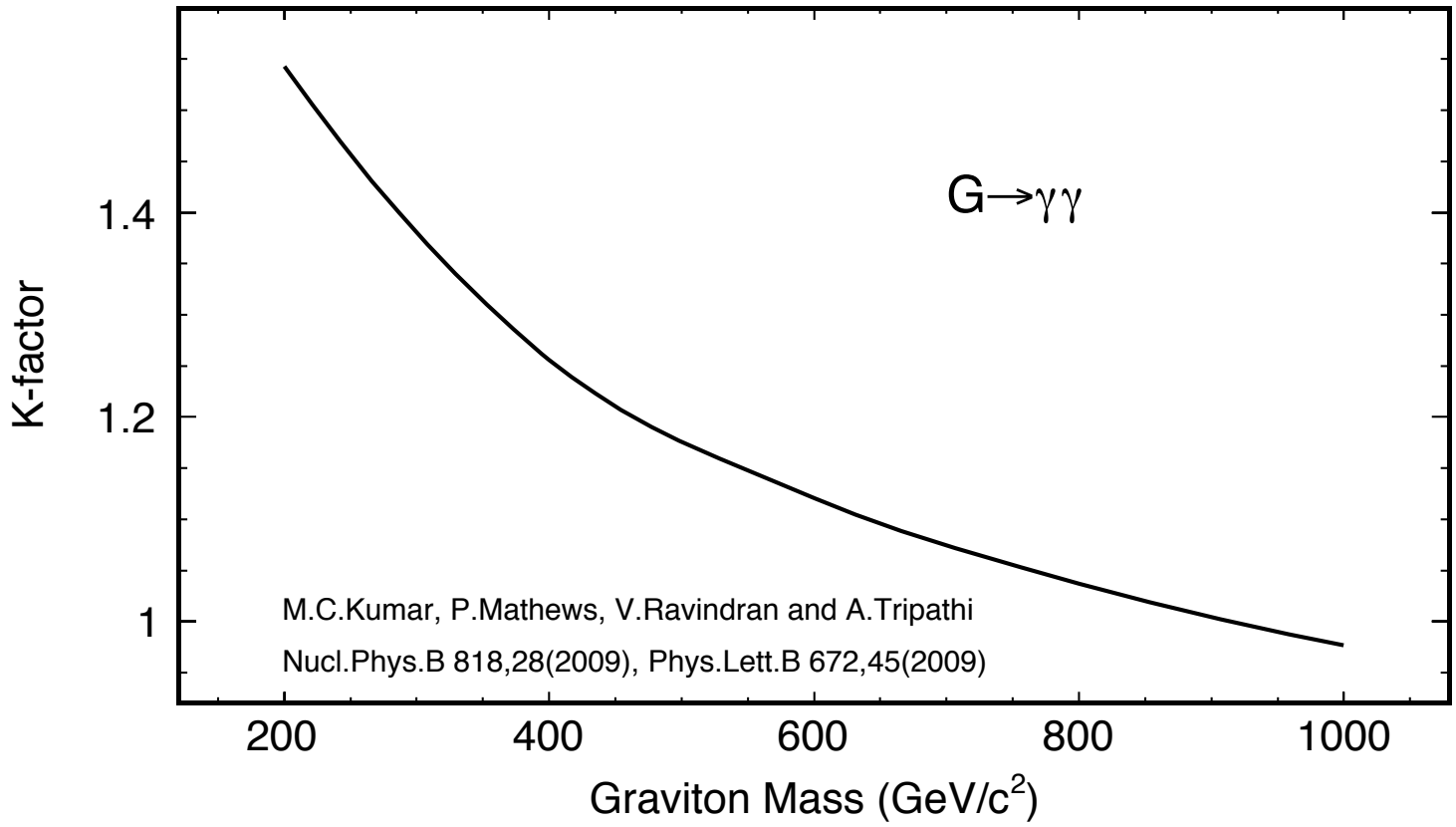



Search for X→γγ
CDF Run II Preliminary
CDF, 5.4 fb-1
Total background
Jets faking photons
Entries/5 GeV
10²
10
1
150
200
250
m(γγ) (GeV/c²)


Search for X→γγ
CDF Run II Preliminary
CDF, 5.4 fb-1
Total background
Jets faking photons
Entries/5 GeV
m(γγ) (GeV/c2)


Search for X→γγ
CDF Run II Preliminary
CDF, 5.4 fb-1
Background prediction
Integral (m>m0)
m0(γγ) (GeV/c2)


Search for X→γγ
CDF Run II Preliminary
CDF, 5.4 fb-1
(Data-fit)/stat error
m(γγ) (GeV/c2)


K-factor
1.4
1.2
1
G→γγ
M.C.Kumar, P.Mathews, V.Ravindran and A.Tripathi
Nucl.Phys.B 818,28(2009), Phys.Lett.B 672,45(2009)
200
400
600
800
1000
Graviton Mass (GeV/c²)