Diphoton Analysis: RS Graviton Search
Status and Future Plans

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17th March 2004
Photon meeting

Overview

- Dataset and Signal Sample Selection
- Signal Data Sample
- SM NLO diphoton spectrum
- Background Sample
  - photon + fake photon
  - Sideband method
- Background Estimate Plans
- Trigger Efficiency
- Future plans

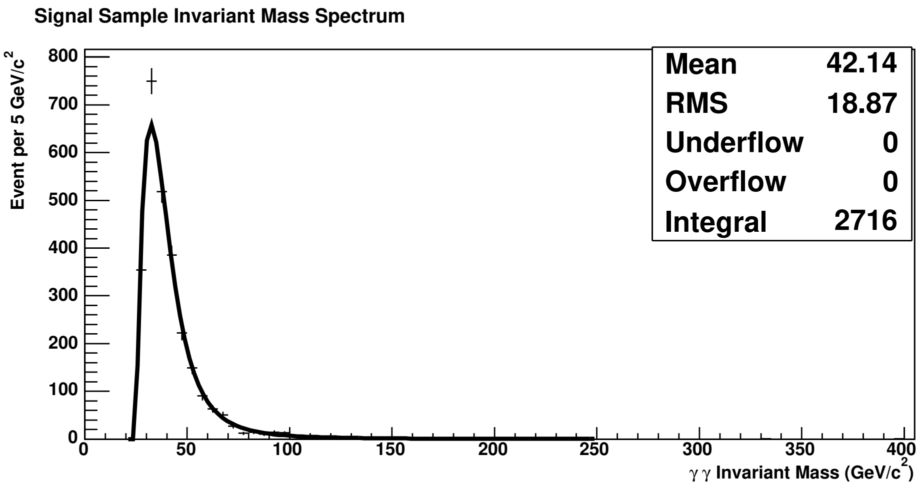
Dataset and Signal Sample Selection Criteria

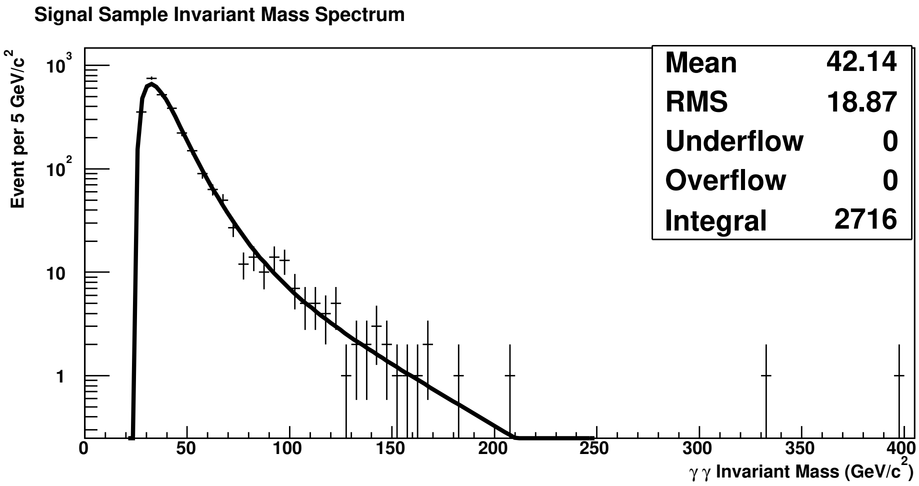
- Data used has 5.1.1 processing
- Stntuplised in version 5.2.0 dev 241
- Stripped 12 and 18 GeV diphoton triggers from the cph20c datasets
- Entered in stntuple catalog: "stntuple/dev_241:cph20c_diphoton"
- Good runs were required: Same as for gg+met, based on DQM v4
  http://www-cdf.fnal.gov/internal/dqm/goodrun/v4/goodv4.html
  Good runs from 138819 to 168889
  Luminosity: 198 pb^{-1}
- Standard Photon cuts V2.1 applied to both photons

Event Cuts
trigger path: DIPHOTON 12 or DIPHOTON 18 ZVertex exists, $\lvert z\rvert < 60$ cm GOODRUN
Photon Cuts for both photons
Central CES strip and wire clusters present CES $\lvert x\rvert < 21.0$ cm CES $9.0 < \lvert z\rvert < 230.0$ cm
Had/EM$< 0.055 + 0.00045 * E$ CalIso(cone 0.4) $< 2.0 + 0.02 * (Et - 20$ GeV$)$ or $< 0.1Et$ if $Et < 20.0$ avg, scaled CES $\chi^2 < 20$ N3D$= 0$ || N3D$= 1$ and Pt$< 1.0 + 0.005 * Et$ SumPt (cone 0.4) $< 2.0 + 0.005Et$ Second CES cluster $E < 2.4 + 0.01 * Et$ or $E < 0.14 * Et$ if $Et < 18.0$

Signal Data Sample

After application of selection cuts and
Et $>$ 13 GeV : 2716 diphoton events (plot below)
Et $>$ 15 GeV and $M_{\gamma\gamma} > 30$ GeV : 1589 diphoton events





Three events above 200 GeV/c^2
run: event: 165271 : 2045232 Mass :397 GeV/c^2
Cosmic? some out of time Energy, but event is well-balanced
run: event: 165435 : 446579 Mass : 332 GeV/c^2
run: event: 166007 : 2285035 Mass : 208 GeV/c^2

We find no CR events in our signal sample, according to our criteria
We plan to study the individual events in more detail

Comparison with expectation from SM and background

Need to know number of expected background events in the search region
Background = SM diphoton production + QCD background

- SM : use Diphox NLO MC

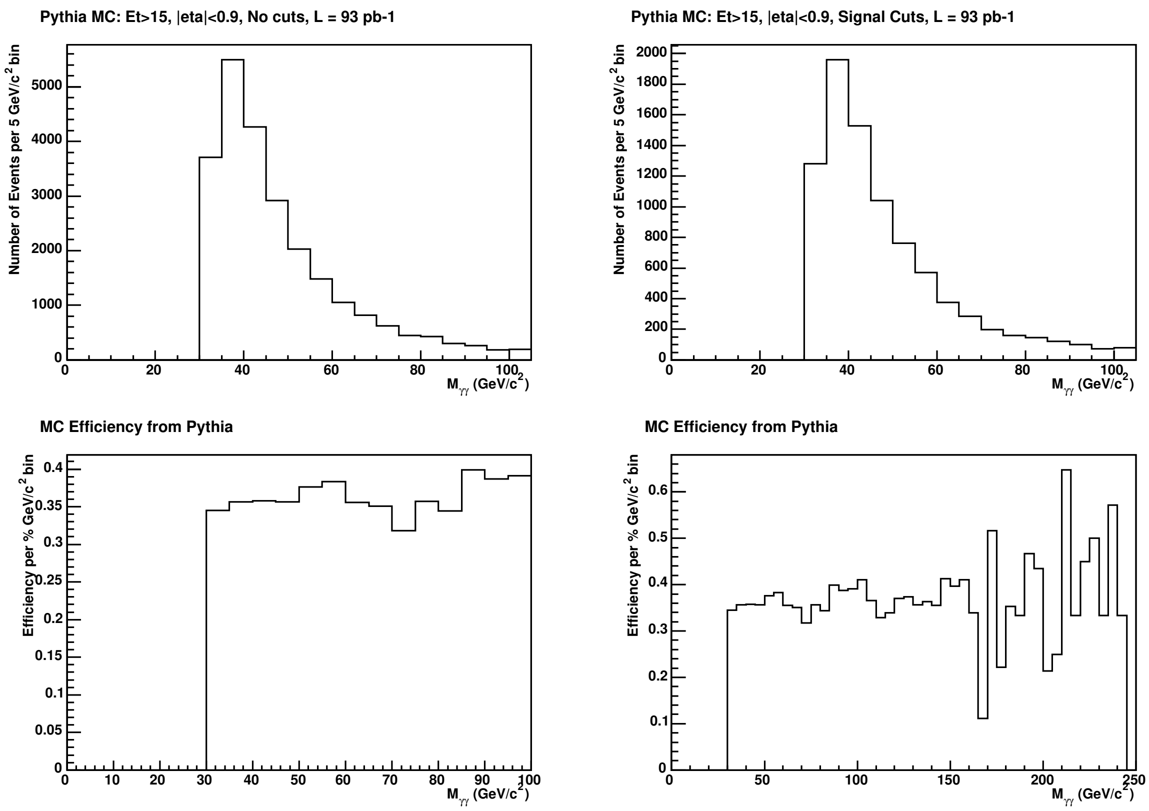
  Pythia gives a LO estimate of diphoton cross-section
  This would underestimate the expected number of events
  Diphox gives a NLO estimate of cross-section

  Obtain efficiency of MC from Pythia:
  by comparing $\mathrm{N}_{Generated}$ to the $\mathrm{N}_{Pass-Selection-Cuts}$
  then apply this efficiency to Diphox NLO generator level cross-section

- QCD background :
  1. sideband spectrum
  2. photon + fake photon spectrum

Efficiency from Pythia

(Top Left:) Looping through Genp banks: select Et>15 and $|\eta| < 0.9$ (as in diphox) for both photons Mgg>30.
Plot GENP invariant mass
(Top right:) Looping through Genp banks: select Et>15 for both photons match GENP photons with reconstructed photons (within 5 degrees)
Apply photon cuts.
Plot GENP invariant mass
(Lower, two ranges): Efficiency (divide above plots)



Investigating the change in efficiency if the Isolation cut is loosened from 1 GeV to 4 GeV.
Since there is a 4 GeV cut placed in Diphox

Sideband Data Sample

The events are required to be in good runs, have a good vertex and pass the diphoton 12 or 18 trigger
Both photons must pass the loose photon cuts:

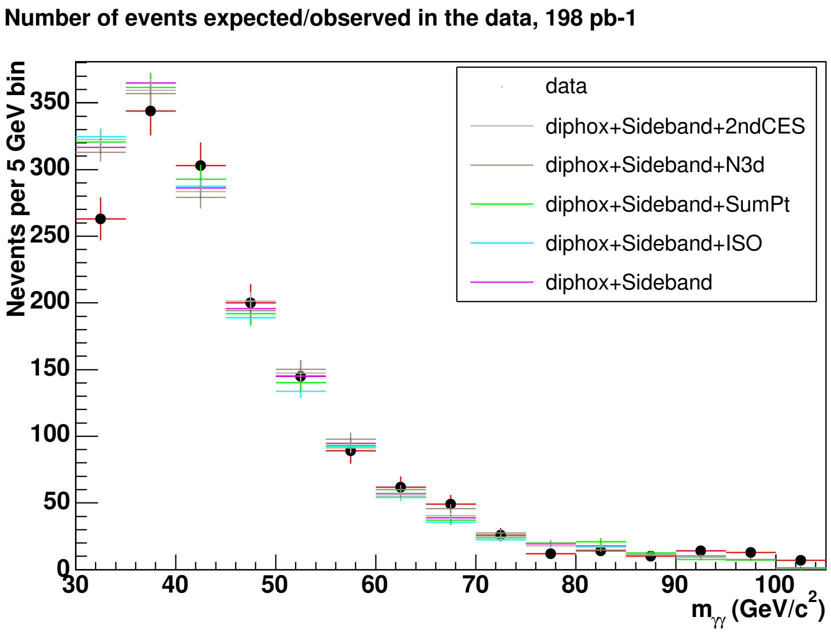
- central detector
- looser iso cut of:
  float iso3 = IsoCorr(photon); // V2.1 cuts
  (etc<20.0 ? iso3<0.15*etc : iso3<3.0 + 0.02*(etc-20.0));
  rather than
  (etc<20.0 ? iso3<0.1*etc : iso3<2.0 + 0.02*(etc-20.0));
- Pt()<0.25*etc
- SumPt4()<5.0
- HadEm()<0.125

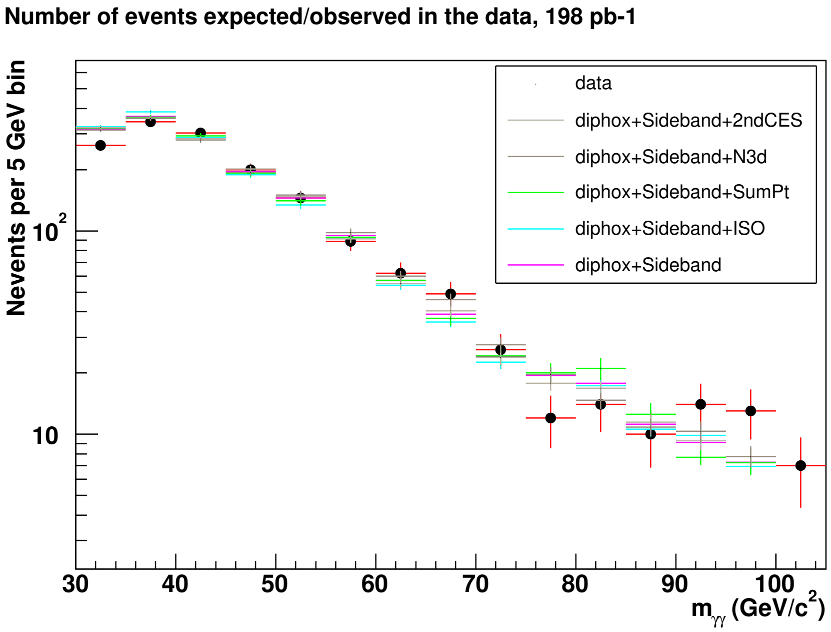
and have Et>15 GeV, and Mgg > 30 GeV
but the events which contain 2 or more gold photons are excluded
So this sample does not contain any of our signal events

Signal : 1589 events
Sideband: 3357 (none above 220 GeV)
Sideband + iso (tighter cut applied to signal) : 2171
Sideband + N3d (applied to signal) : 2064
Sideband + Sumpt4 (applied to signal) : 1137
Sideband + 2nd CES (applied to signal) : 1630

Comparison of Expected/Observed Number of Events

Sideband shapes are normalised such that in the range from 25 to 100 GeV
$\int_{25}^{100} N_{data} = \int_{25}^{100} N_{diphox-198pb-1} + \int_{25}^{100} N_{sideband}$
Errors are the statistical errors from the sidebands, scaled due to scale factor (different looser cuts applied)
MC selection efficiency applied to diphox (to be updated with Et>15 cut), Et>13, Et>14 at present - hence discrepancy at low $M_{\gamma\gamma}$





Comparison of Expected/Observed Number of Events
Using photon fake-rate

Investigate using 10iso triggered
sample (in catalogue "dev_241/cph20c_10iso"), 198 pb^{-1}
same good run list as for signal sample
+ have at least 1 good photon with Et>15 GeV
+ have a good vertex in the event

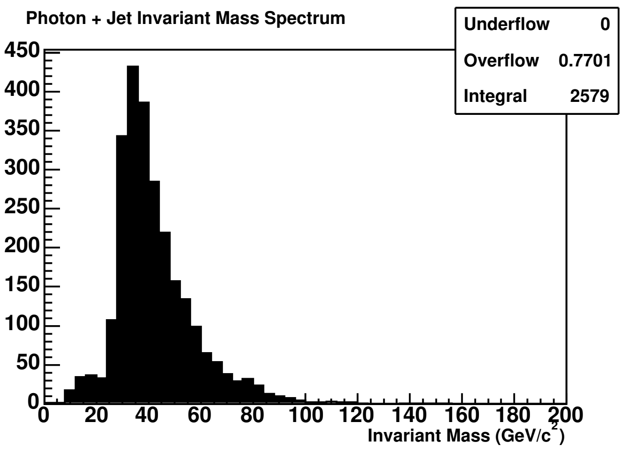
(1) The loop over jets (with $|eta| < 1.04$)

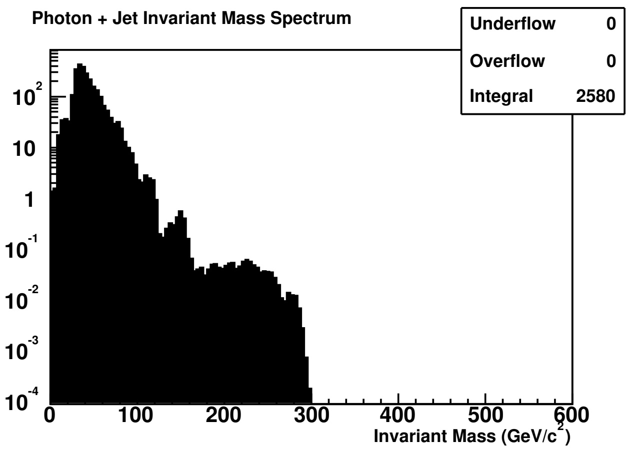
(2) Weight each jet by appropriate weighting:
Use Fake rate: $(e^{(a*Et+b)} + c) \times 10^{-3}$ (CDF 6838)

(3) Fake photons from jets have a different energy than the orginal jet
So smear the jet E by a gaussian (mean of 0.934, width of 0.0428)

(4) Apply Jet Et > 15 GeV Et cut
Calculate invariant mass spectrum of photon+jet

(5) Scale up by Trigger prescale of 1600





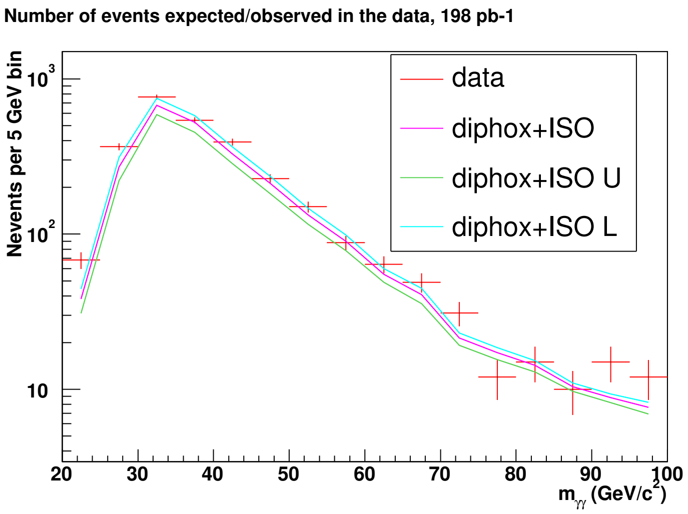
Comparison of Expected/Observed Number of Events Using Fake Photon + Photon Method

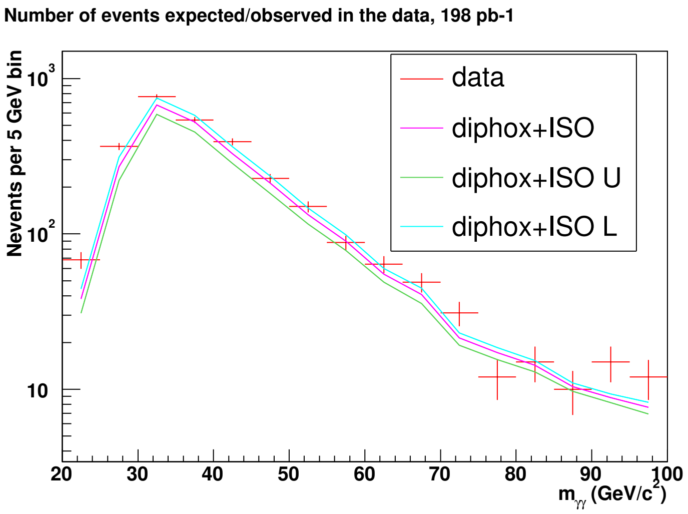
Fake Photon + photon background is scaled from ISO10 trigger (1600) to the data luminosity

Diphox is absolutely normalised to 198 pb^{-1}

Band from fake pho+photon from Systematics of Helen's method: upper and lower bound

MC selection efficiency applied to diphox (to be updated with Et>15 cut), Et>13, Et>14 at present

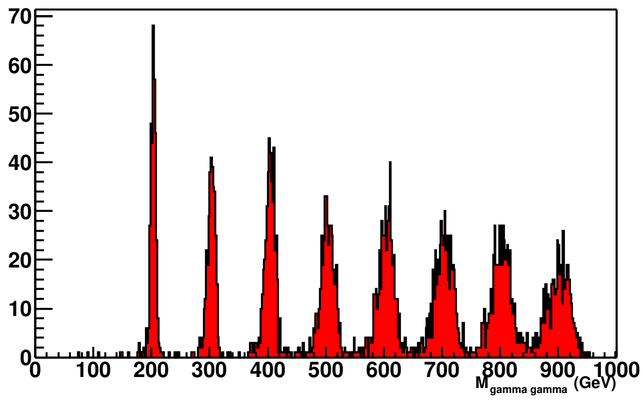




Search Regions

Initially plan to set limits on the Randall-Sundrum Graviton Model
Signal is in the high invariant mass region

Initially plan to take the signal region as 3 σ around the reconstructed invariant mass for each M_G
(CDF Note 6560)



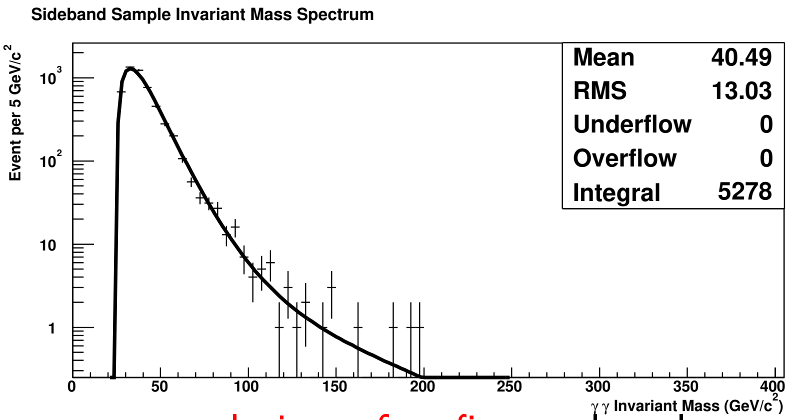
M_G	Mean	Sigma (σ_M)	$3\times\sigma_M$
200	202	5.4	16
250	252	7	21
300	301	11	32
350	352	11	32
400	400	12	36
450	454	13	38
500	499	17	52
550	551	18	55
600	600	19	57
650	645	20	59
700	697	21	64
750	751	22	66
800	797	25	76
850	843	27	80

Need to know background in search region: i.e. at high invariant mass

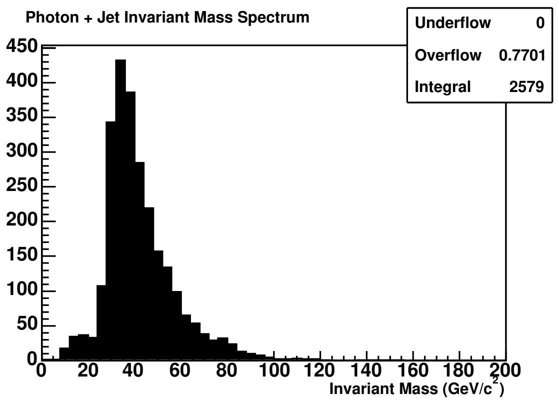
Background in Signal Region at High Mass - To do

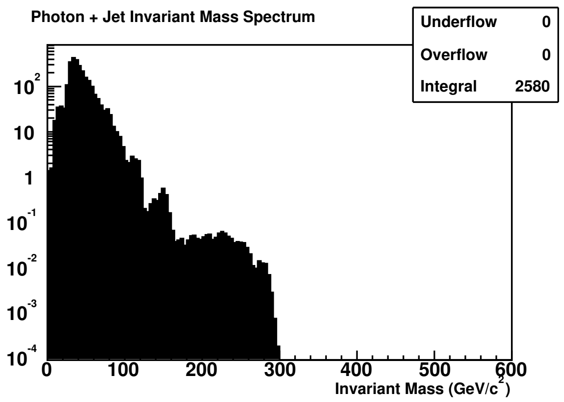
Need to know number of expected background events in each signal window
Background = SM diphoton + QCD background

- QCD background :
  1. estimate from an extrapolation of a fit to the sideband spectrum (here fit is a double exponential)



  2. or from an extrapolation of a fit to the photon + fake photon spectrum





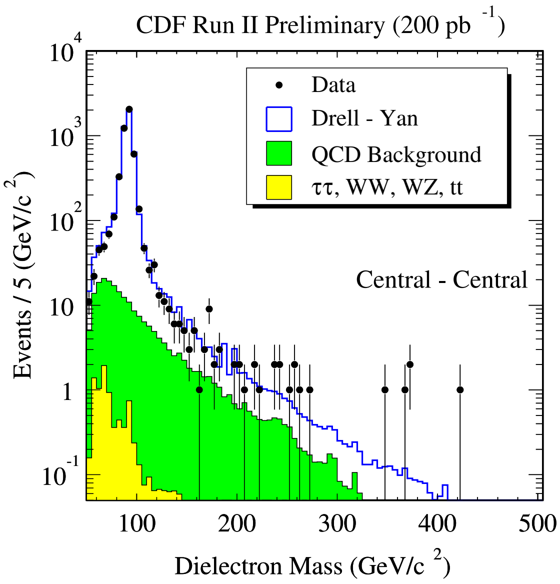
Almost negligible for very high invariant mass.
The probability of a jet faking a photon is 4×10^{-5} above E_t>100 GeV/c^2
Fake rate for 10iso above 200 GeV/c^2 : 0.3
Fake rate for 10iso above 300 GeV/c^2 : 0

So less than this expected in a signal window (max width < 100 GeV/c^2)

....Background in Signal Region at High Mass - To do

- SM diphoton production: from extrapolating diphox above 300 GeV/c or generating events using Resbos

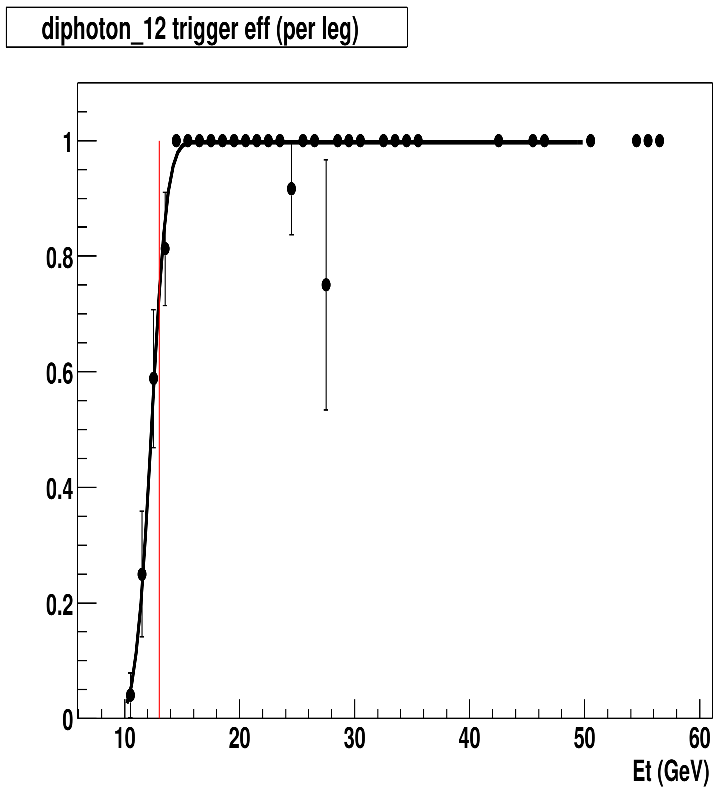
- Other SM background contributions
  - Drell-Yan where an electron fakes a photon
    (from CDF 6879 DY $\rightarrow \mu\mu$)
    DY for $M_{\gamma\gamma} > 250$ from $M_{\mu\mu} > 250$
    5.17*(198pb^{-1}/126pb^{-1})*(0.15%)*(0.15%)$= 1 \times 10^{-5}$



  - estimate W γ where the electron fakes a photon

Trigger efficiencies for Diphoton 12 and 18

Diphoton 12 Trigger Efficiency is ≈ 100 % for Et>15 GeV, $M_{\gamma\gamma}$>30 GeV. Details in CDF note 6312.



The combination of the diphoton 12 and diphoton 18 triggers are assumed to be 100 % efficient for Et>15 GeV $M_{\gamma\gamma} > 30$ GeV

- Plan to investigate adding PHOTON 50 and 70 triggers to ensure trigger is 100 % efficient at high invariant mass

Future Plans

- Make SM diphox plot for Et $>$ 15 GeV photon cuts
- Plot SM diphoton invariant mass spectrum to high invariant mass (using diphox or Resbos)
- Extrapolate fits of sidebands and photon+fake photon to higher invariant mass
- Estimate other background contributions
- Update MC in version 5.3.1 (generating now!)
- Calculate efficiencies and acceptance with the new code version
- Initially set limits on the RS model
- Look at more generic searches in the diphoton channel

Cosmic Cuts Applied to both photons

No events in the sidebands or the signal region are tagged as CRs

Photon is tagged as a Cosmic if it satisfies one of these criteria:

- absolute difference in metPhi and photon Phi < 2.9
- ((MEt/photon Etc) - 1.0)$>$ 0.2
- Photon is out of time ($>$-200.0 AND $<$ 300.0) AND ($<$-23.0 OR $>$41.0)
- If Number of Cosmic Stubs $>$ 0 (NCosStubPho())
- If photon is tagged as a Halo: (if(p0->HaloWest()+p0->HaloEast()>1))
- if(p0->Sidewedges()<=2)
if((p0->Seedwedge() - 1.5*p0->Sidewedges())>=6) CR
else if(p0->Sidewedges()<=12)
if((p0->Seedwedge() - 0.5*p0->Sidewedges())>=8) CR
else
if(p0->Seedwedge()>=14) CR