Isolating a light Higgs boson from the di-photon background at the LHC

(In collaboration with
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Light Higgs at LHC

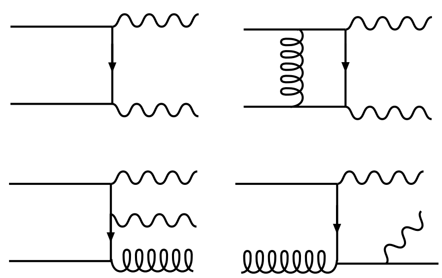
- Indirect limits from electroweak measurements:
  m_H< 196-230 GeV at 95% CL

- Lightest MSSM Higgs has m_H <135 GeV, with properties similar to SM Higgs over most of parameter space

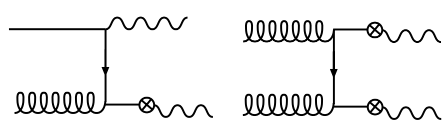
- For light Higgs at LHC (m_H<140 GeV), "golden mode" is $gg \to H \to \gamma\gamma$; good experimental resolution allows for best mass measurement

Di-photon Production at LHC

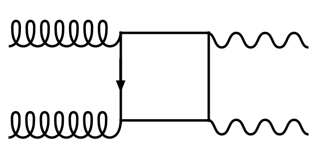
- Direct $q\bar{q} \rightarrow \gamma\gamma$ at NLO



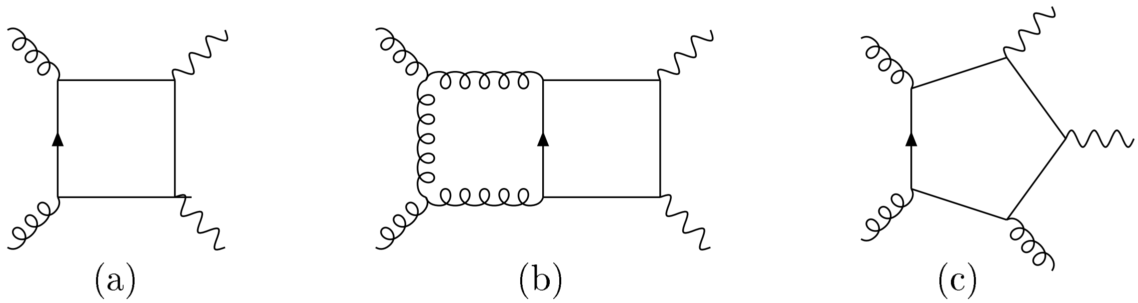
- Fragmentation



- gg box (NNLO)



NLO corrections to $gg \rightarrow \gamma\gamma$



- Singularity structure same as typical 1-loop NLO.

- Collinear/soft singularities handled by subtraction method.

$$d\sigma^{\mathrm{NLO}} = (d\sigma^{\mathrm{LO}} + d\sigma^{\mathrm{V}} + d\sigma^{\mathrm{S}}) + (d\sigma^{\mathrm{R}} - d\sigma^{\mathrm{S}})$$

- Monte Carlo program allows general kinematic cuts.

Kinematic Cuts

$p_T(\gamma_1) > 40 \qquad p_T(\gamma_2) > 25 \qquad |y(\gamma_{1,2})| < 2.5$

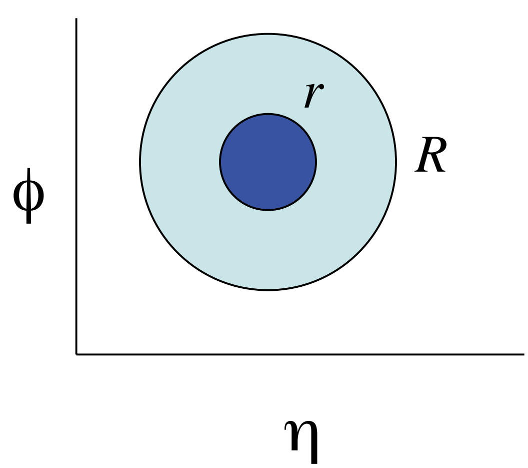
Photon Isolation

Standard: Require hadronic $E_T < E_{T\,max}$ in cone radius R.

Smooth: Require hadronic $E_T < E_{T\,max}(r)$ in all cones $r < R$ with

$$E_{T\,max}(r) \equiv p_T(\gamma)\varepsilon\left(\frac{1-\cos r}{1-\cos R}\right)$$

(removes all fragmentation contributions)



Numerical details

•Standard cuts:
Use DIPHOX* (thanks to Thomas Binoth)
for all but gg contribution.

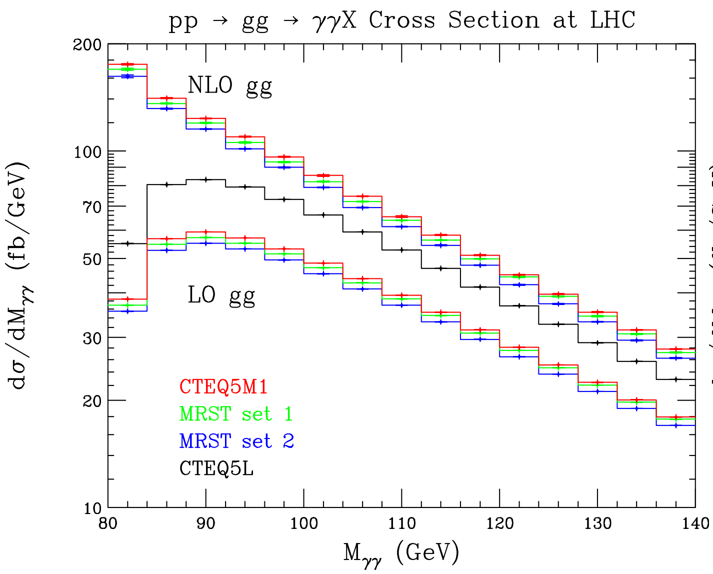
•Smooth cuts:
We implemented NLO $q\bar{q} \to \gamma\gamma$ also.

•We implemented $gg \to H \to \gamma\gamma$ at NLO
in large m_t limit.

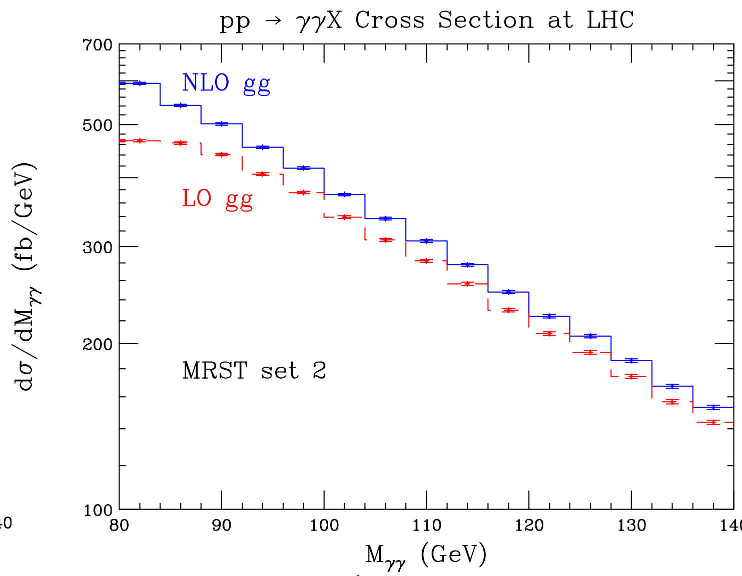
•Defaults:
-$\mu_R = \mu_F = 0.5\, M_{\gamma\gamma}$
-Use MRST99 set 2.

*Binoth et al, Eur. Phys. J.C **16**, 311 (2000)

NLO vs. LO Cross Sections



gluon fusion only



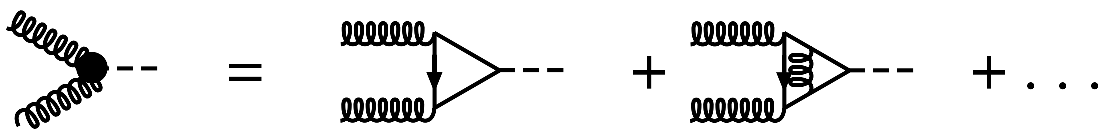
total

Standard Cone (R=0.4, $E_{T\,max}$=15 GeV)

NLO K factors

$M_{\gamma\gamma}$ (GeV)	K_{Higgs}	K_{gg}
98	2.92	1.82
118	2.54	1.61
138	2.39	1.55

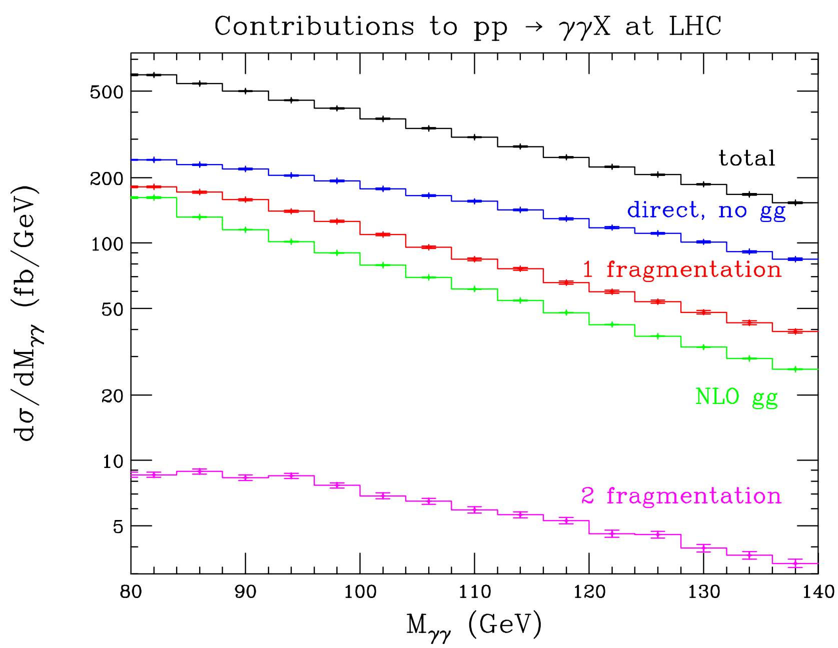
Short-Distance Contribution for $m_t \to \infty$



$$\propto 1 + \frac{11\alpha_s}{2\pi} \approx 1.2$$

- Not large enough to explain difference in K-factors

Contributions to $pp \to \gamma\gamma X$ at LHC



Standard Cone (R=0.4, $E_{T\,max}$=15 GeV)

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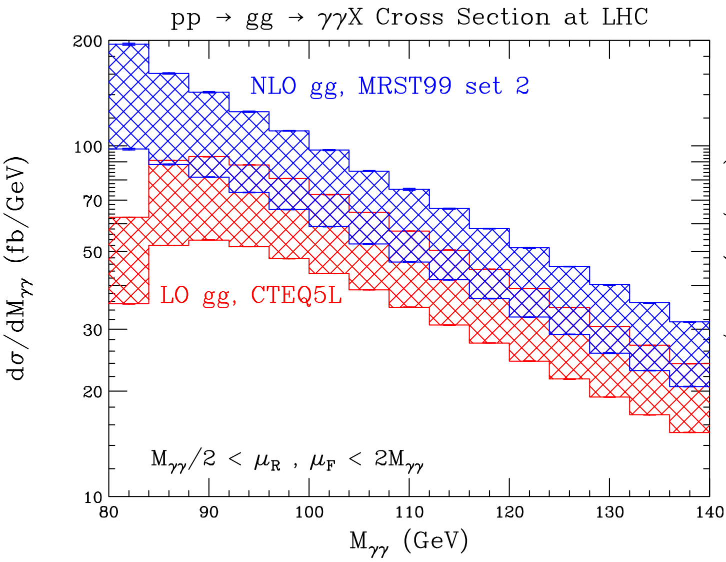
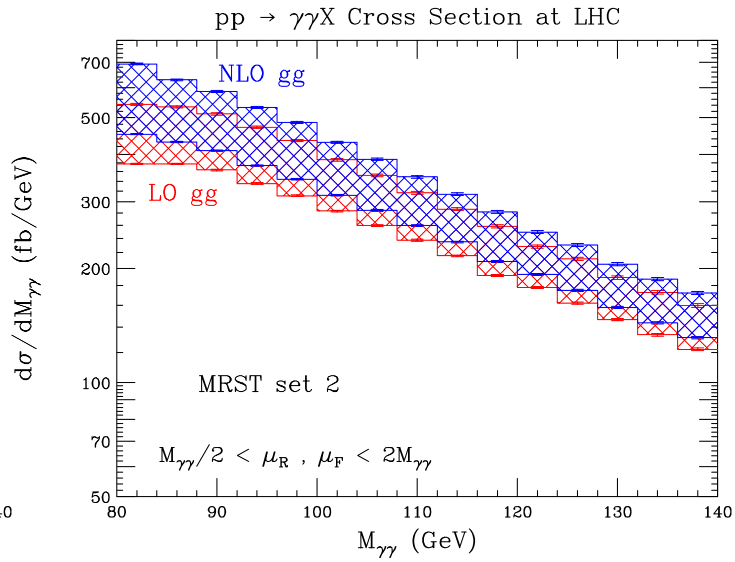
Scale Dependence (independent variation)



gluon fusion only

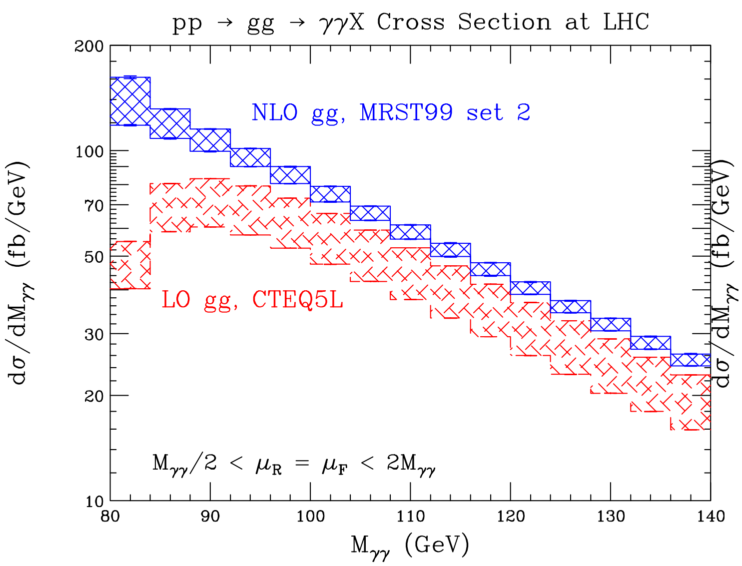


total

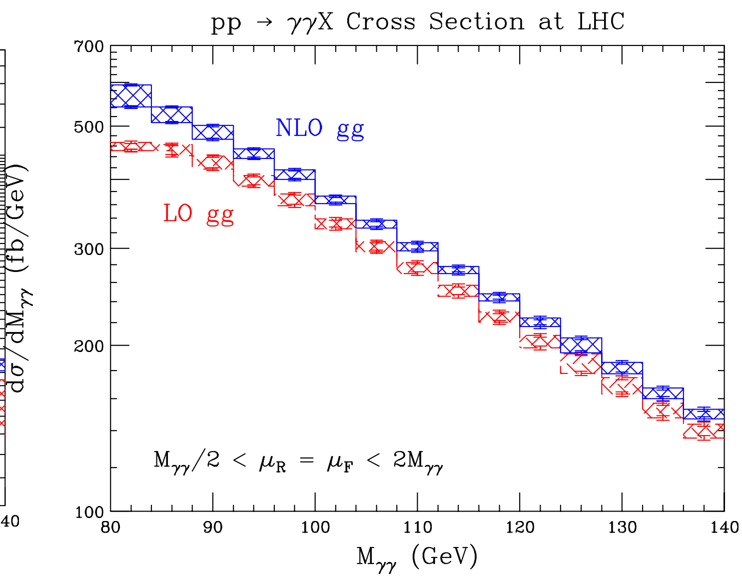
Standard Cone (R=0.4, $E_{T\,max}$=15 GeV)

μ_R and μ_F varied independently.

Scale Dependence (diagonal variation)



gluon fusion only

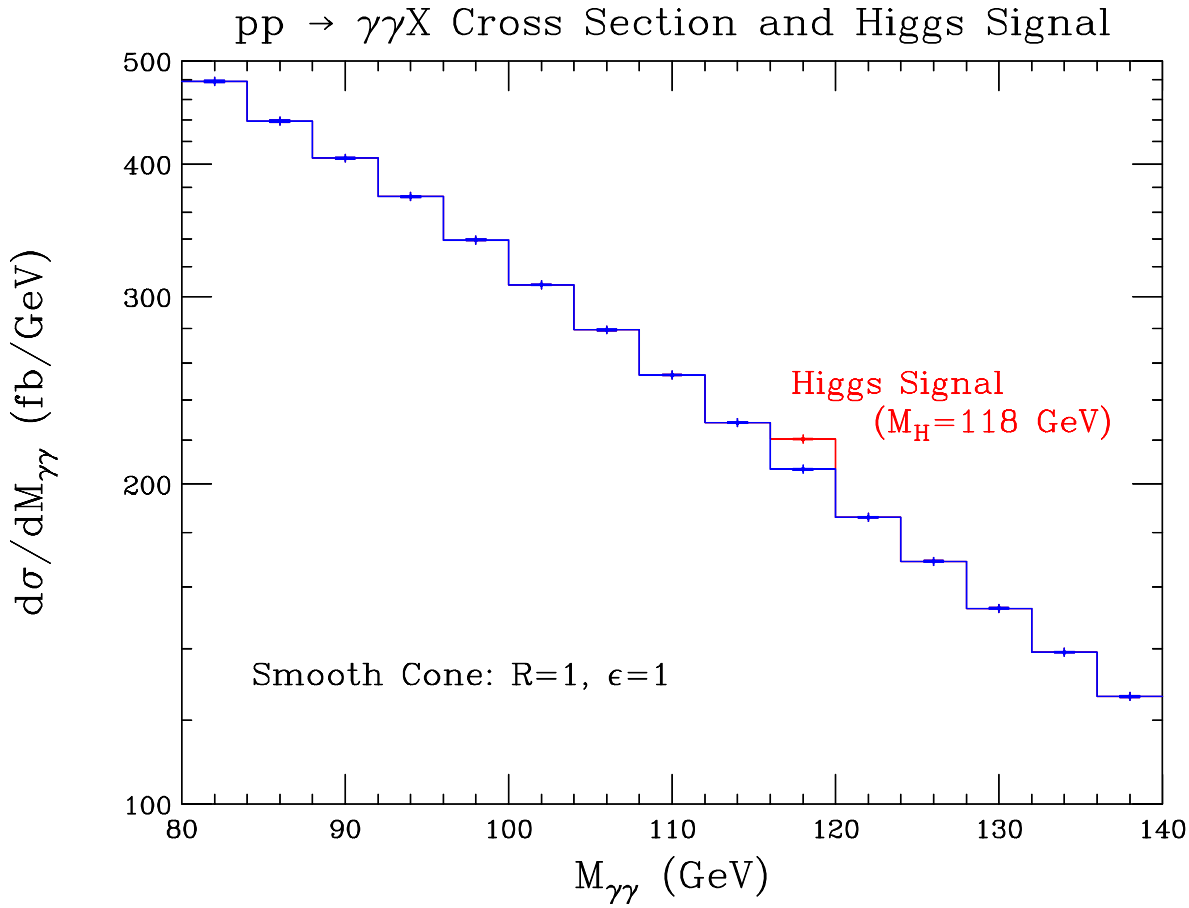


total

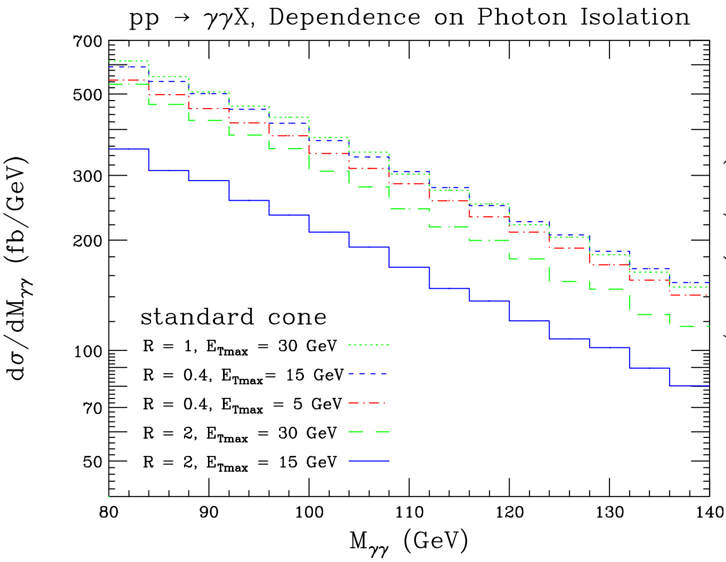
Standard Cone (R=0.4, $E_{T\,max}$=15 GeV)

μ_R and μ_F varied together ($\mu_R = \mu_F$).

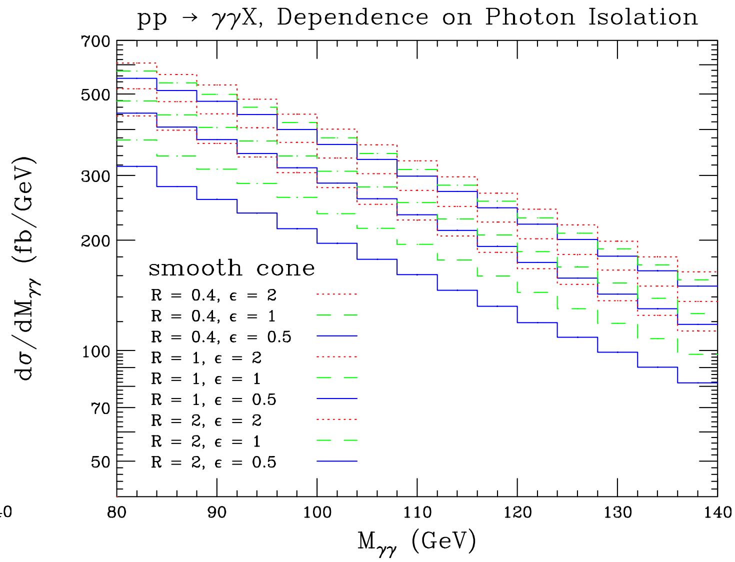
Higgs Signal at LHC



Dependence on Photon Isolation Cuts

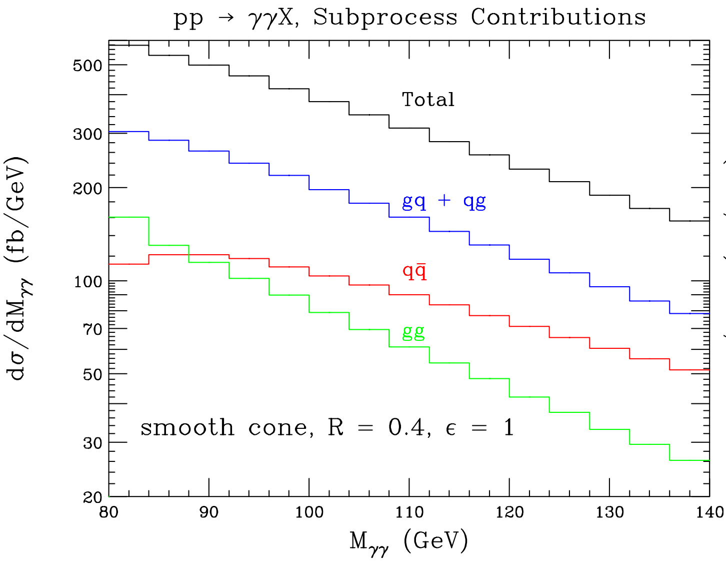


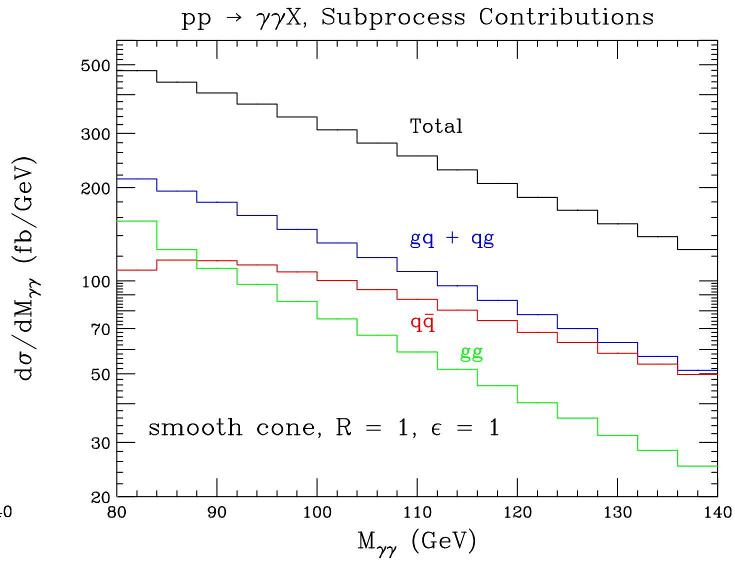
Standard Cone



Smooth Cone

Subprocess Contributions





Smooth cone

Number of Signal and Background Events (Smooth Cone)

R, ε	S	B	$S/\sqrt{B}$
0.4, 2	993	22,000	6.7
0.4, 1	995	21,000	6.9
0.4, 0.5	987	20,100	7.0
1, 2	973	18,400	7.2
1, 1	950	17,000	7.3
1, 0.5	917	15,800	7.3
2, 2	899	15,200	7.3
2, 1	822	13,100	7.2
2, 0.5	718	10,800	6.9

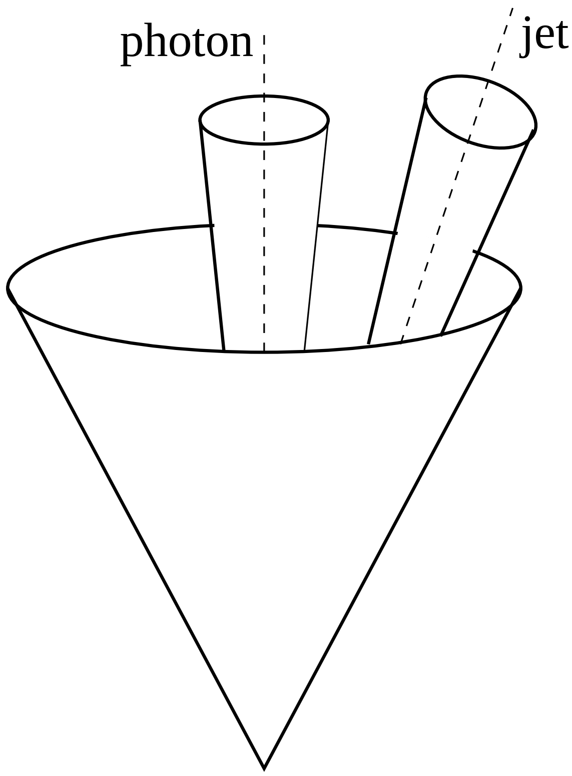
- Assume Higgs mass 118 GeV
- 30 fb^{-1} Luminosity
- Mass Bin $116<M_{\gamma\gamma}<120$ GeV
- Assume efficiency factor of 0.57 for both**S** and **B.**
  (0.81 per γ for ID, 0.87 for fiducial cuts)
- Assume additional 20% reducible background.

Number of Signal and Background Events (Standard Cone)

R, $E_{T\,max}$	**S**	**B**	**S/$\sqrt{B}$**
1, 30	981	20,600	6.8
0.4, 15	994	20,400	7.0
0.4, 5	980	19,000	7.1
1, 15	953	16,900	7.3
2, 30	913	16,400	7.1
2, 15	818	11,200	7.7

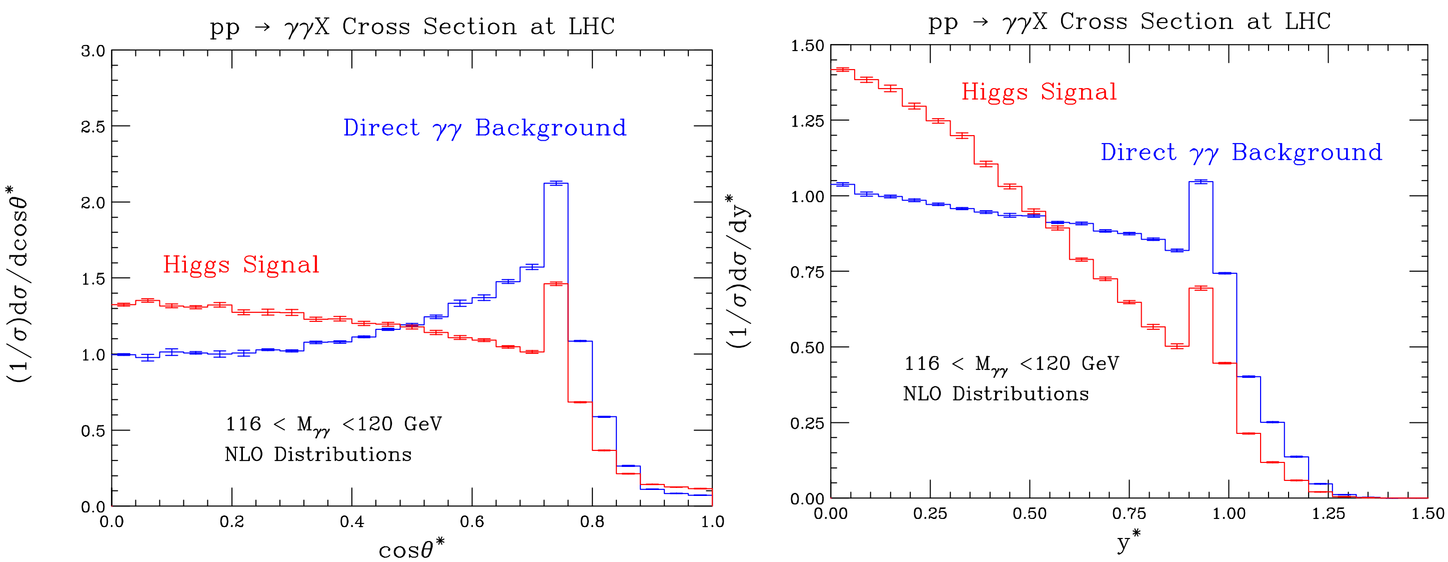
- Assume Higgs mass 118 GeV
- 30 fb^{-1} Luminosity
- Mass Bin $116<M_{\gamma\gamma}<120$ GeV
- Assume efficiency factor of 0.57 for both **S** and **B.**
  (0.81 per γ for ID, 0.87 for fiducial cuts)
- Assume additional 20% reducible background.

Jet Veto



- Standard isolation in cone R_1
  plus jet veto in cone R_2
- Better behaved, both theoretically
  and experimentally, than
  standard isolation with large cone

Angular Distributions

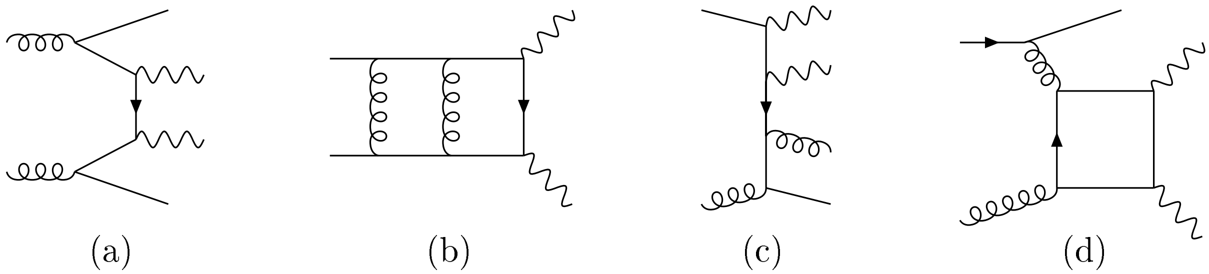


- increases significance from 7.3 to 7.6

$$y^* = (y(\gamma_1) - y(\gamma_2))/2$$

At LO: $\cos(\theta^*) = \tanh(y^*)$

Other NNLO Contributions not Included



•Similar study of $gg \rightarrow W\gamma\bar{q}q$ and
$gg \rightarrow WZ\bar{q}q$ found to be small.
(Adamson,d Florian, Signer)

•qg-intiated process may be most serious..

Summary and Conclusions*

•NLO corrections to $gg \to \gamma\gamma$ computed.

•K factor substantially smaller than for $gg \to H \to \gamma\gamma$

•Effect on total irreducible di-photon background is modest.

•More severe isolation reduces background more than signal. (but effect on reducible background must also be included.) Jet veto may be preferable.

•y^* (or $\cos\theta^*$) is a good discriminator of signal and background.

*(The numbers and plots in this talk are preliminary.)