2γNNLO

NNLO computation for diphoton direct contribution at hadronic colliders

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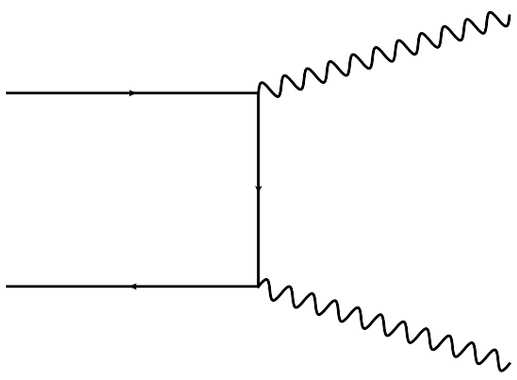
In collaboration with S.Catani, L.Cieri, G.Ferrera, M.Grazzini

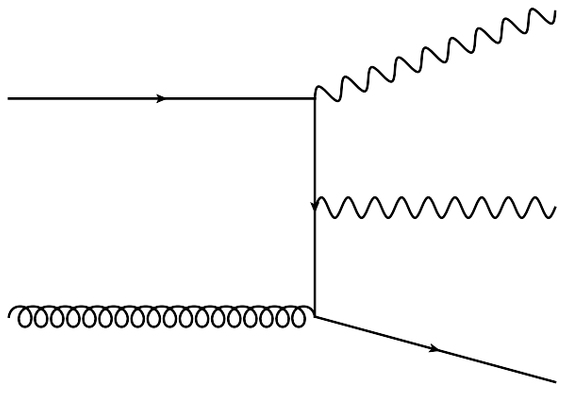
Workshop on Photon Physics and Simulation at Hadron Colliders
Paris, March 30 2012

◉ Direct Contribution

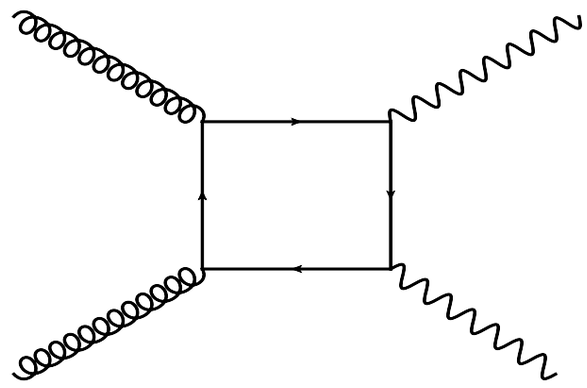
We know higher order corrections are needed



$\mathcal{O}(\alpha_s^0)$ but $q\bar{q}$ Luminosity



$\mathcal{O}(\alpha_s)$ but qg Luminosity



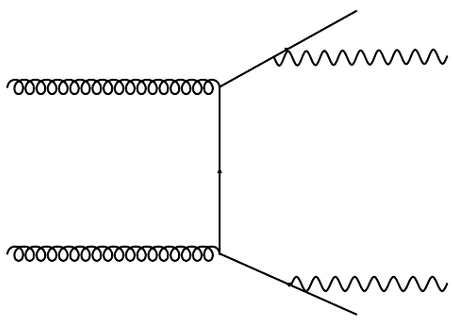
$\mathcal{O}(\alpha_s^2)$ but gg Luminosity

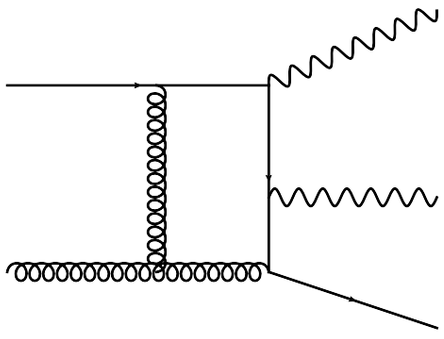
included in all calculations

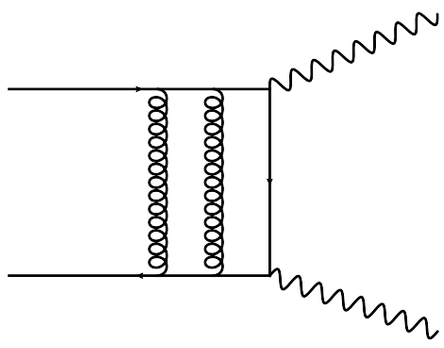
$\gamma\gamma$ production ➡ Box (subset of NNLO) known to be as large as Born!

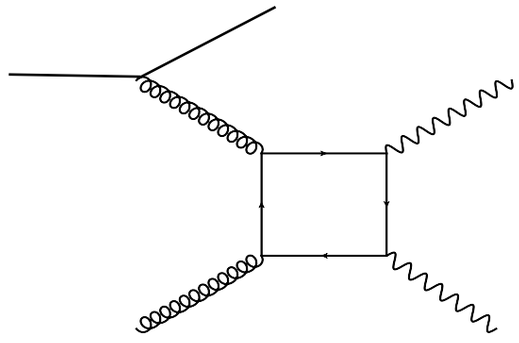
Dicus, Willenbrock

◉ Full NNLO control of Diphoton production









+ ....

NNLO using q_T-Subtraction

S.Catani, M.Grazzini

- Originally used for Higgs and Drell-Yan
- Generalized to any process with final state colorless system ***F***

S.Catani, L.Cieri, DdeF, G.Ferrera, M.Grazzini

Fully exclusive NNLO code for $pp \to F$

2γNNLO

First exclusive NNLO in pp collisions with two final state particles

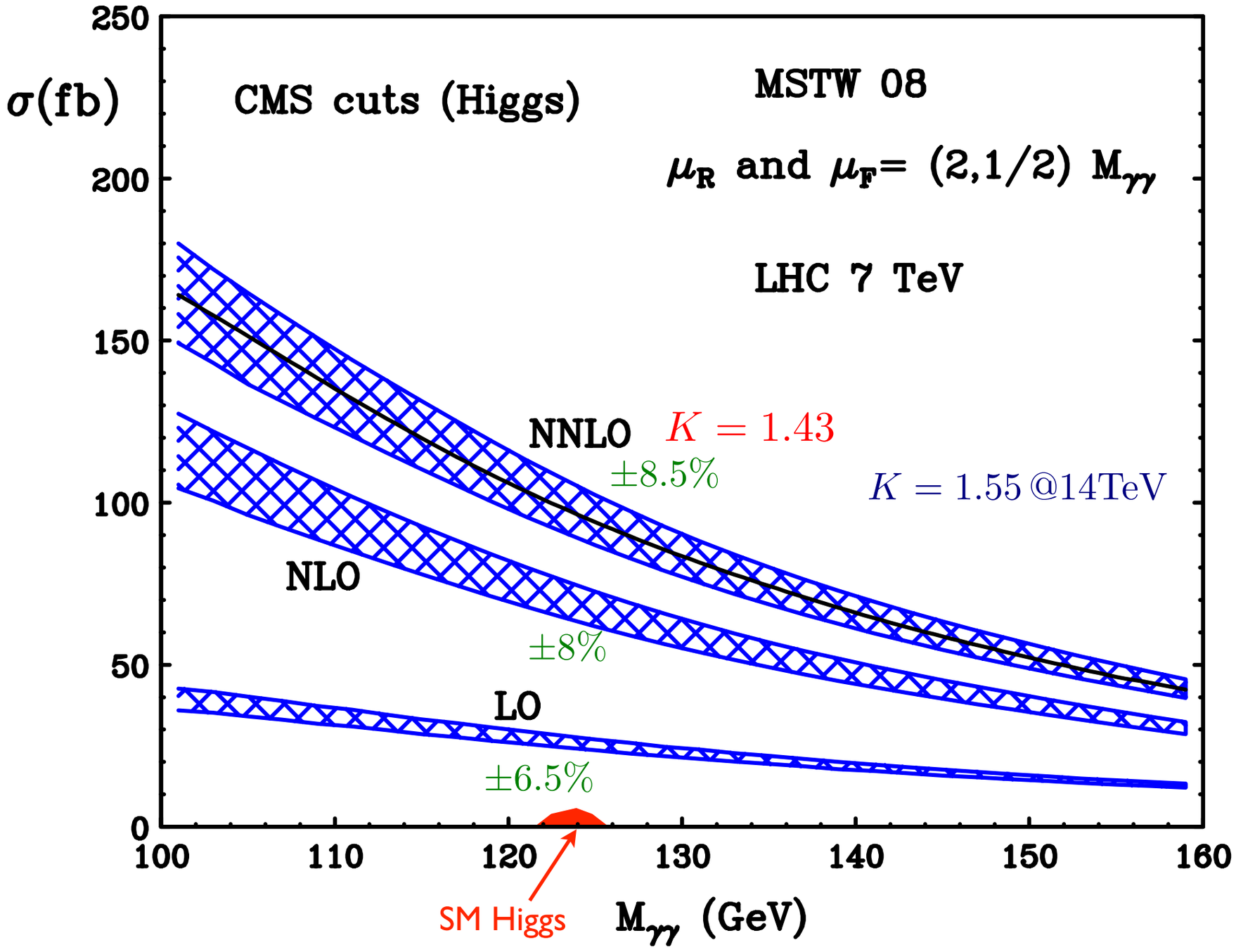
S.Catani, L.Cieri, DdeF, G.Ferrera, M.Grazzini

Two-loop amplitudes available C.Anastasiou, E.W.N.Glover, M.E.Tejeda-Yeomans

Diphoton + jet at NLO V.Del Duca, F.Maltoni, Z.Nagy, Z.Trocsanyi

Separation between direct and resolved component NOT physical in general (beyond LO)

Higgs search at 7 TeV : scale dependence



$$p_T^{\gamma\, hard} \geq 40\,\mathrm{GeV}$$

$$p_T^{\gamma\, soft} \geq 30\,\mathrm{GeV}$$

$$100\,\mathrm{GeV} \leq M_{\gamma\gamma} \leq 160\,\mathrm{GeV}$$

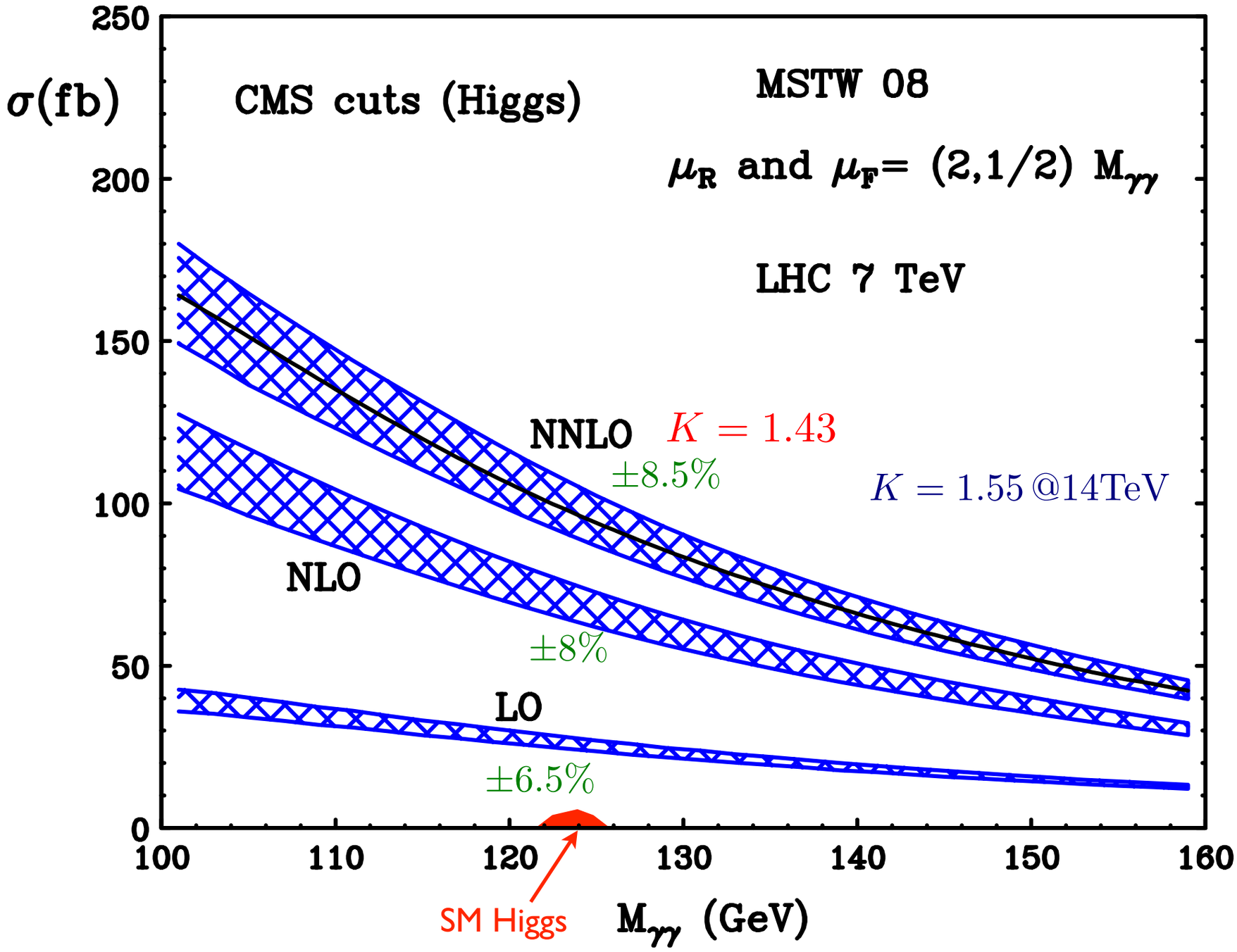
$$|\eta^\gamma| \leq 2.5$$

excluding $1.4442 \leq |\eta^\gamma| \leq 1.566$

$$\epsilon = 0.05$$

- Scale does not represent TH uncertainties at LO and NLO ➡ new channels
- All channels open at NNLO ➡ estimate of TH uncertainties

Higgs search at 7 TeV : scale dependence



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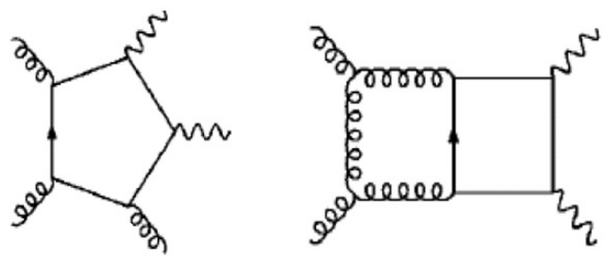
α_s^3 Bern, Dixon, Schmidt (2002)



Some N³LO terms known to contribute ~5%

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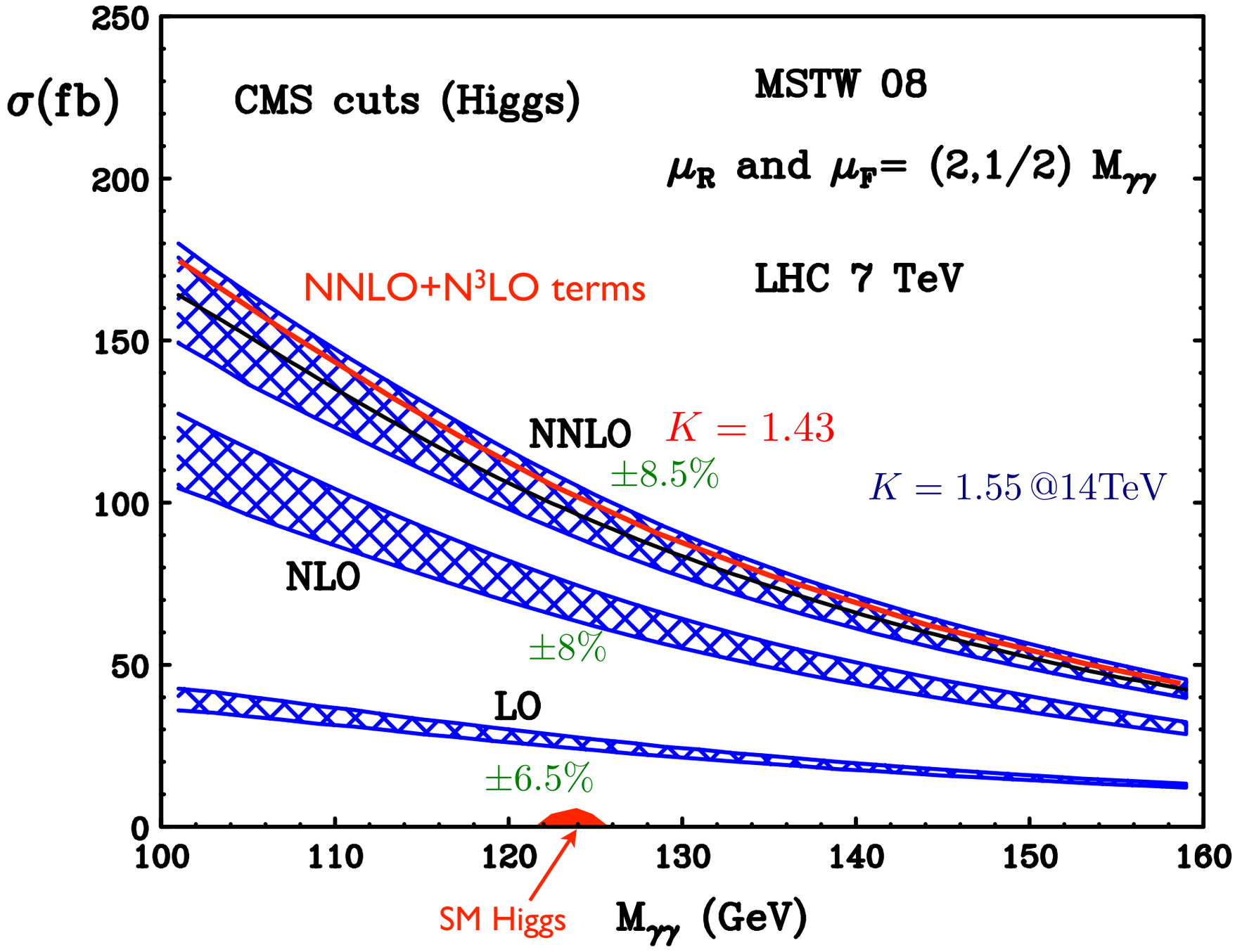

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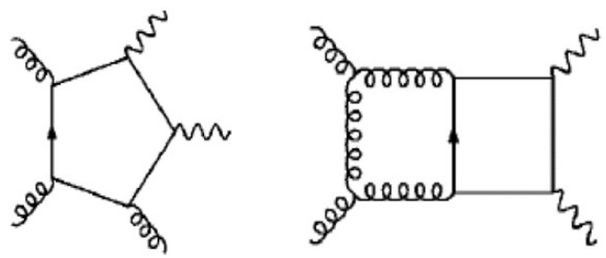

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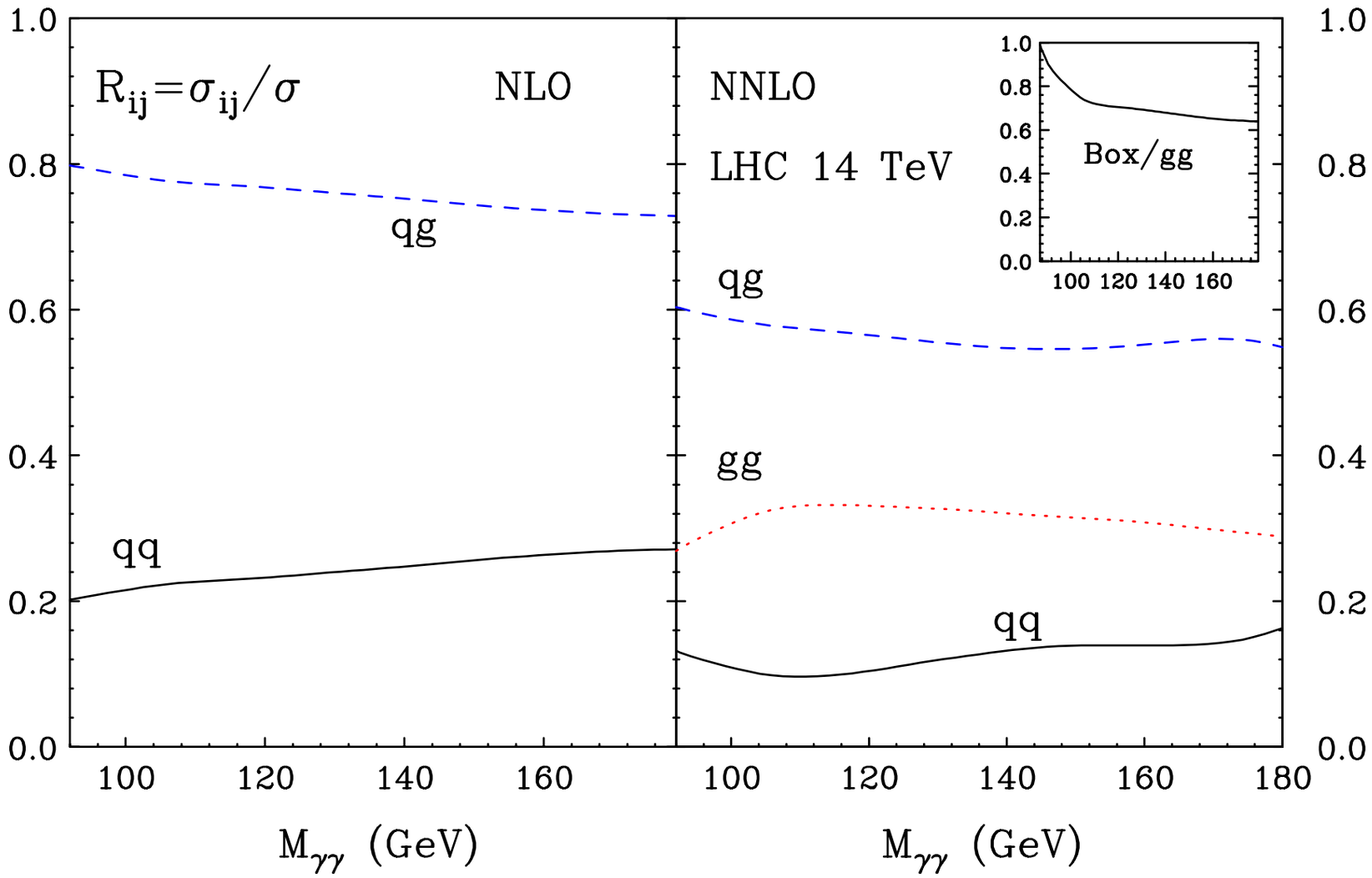
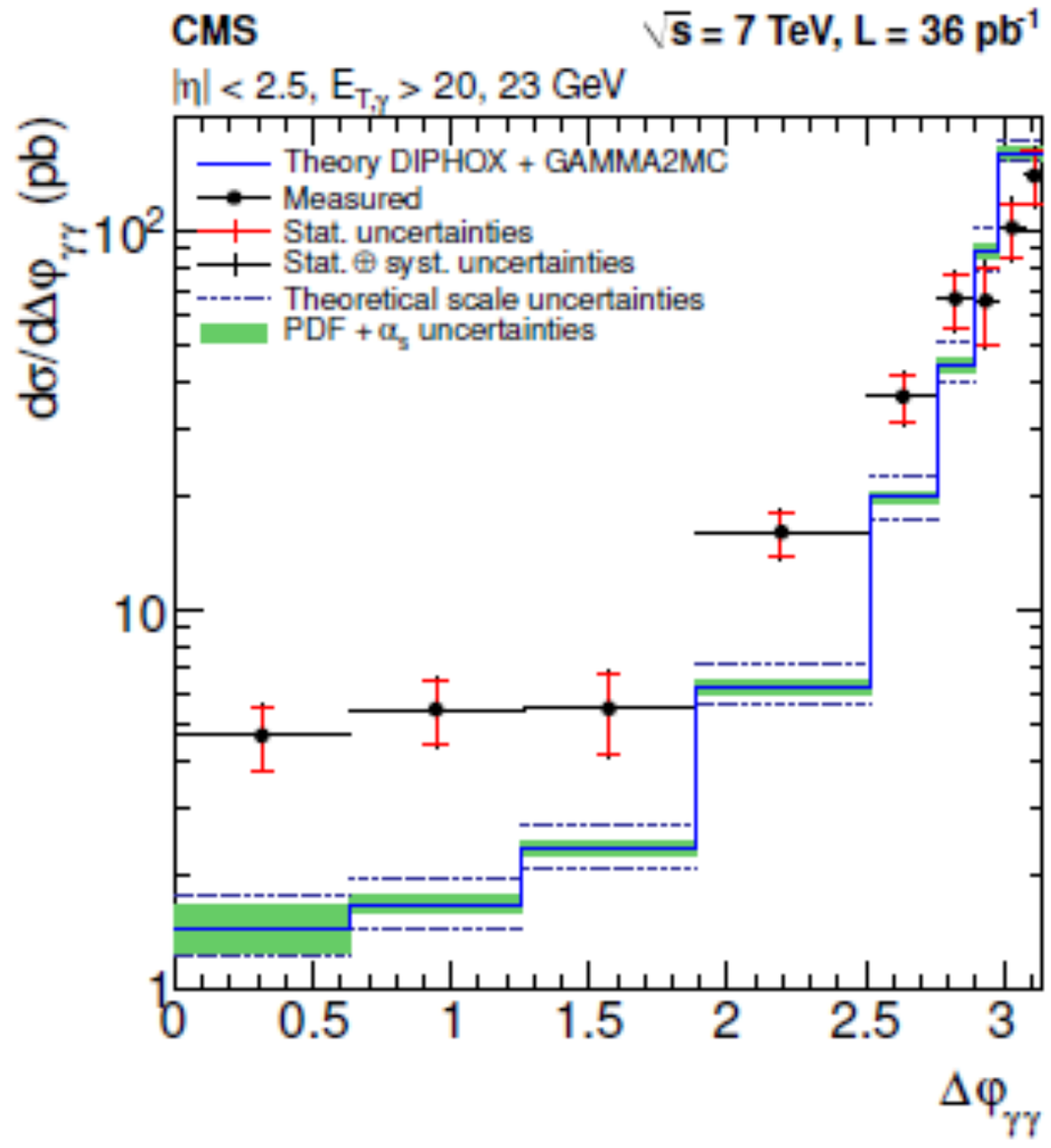
Channels @ 14 TeV



Box only ~22% of NNLO correction

Main contribution from qg channel
(corrections to NLO dominant channel)

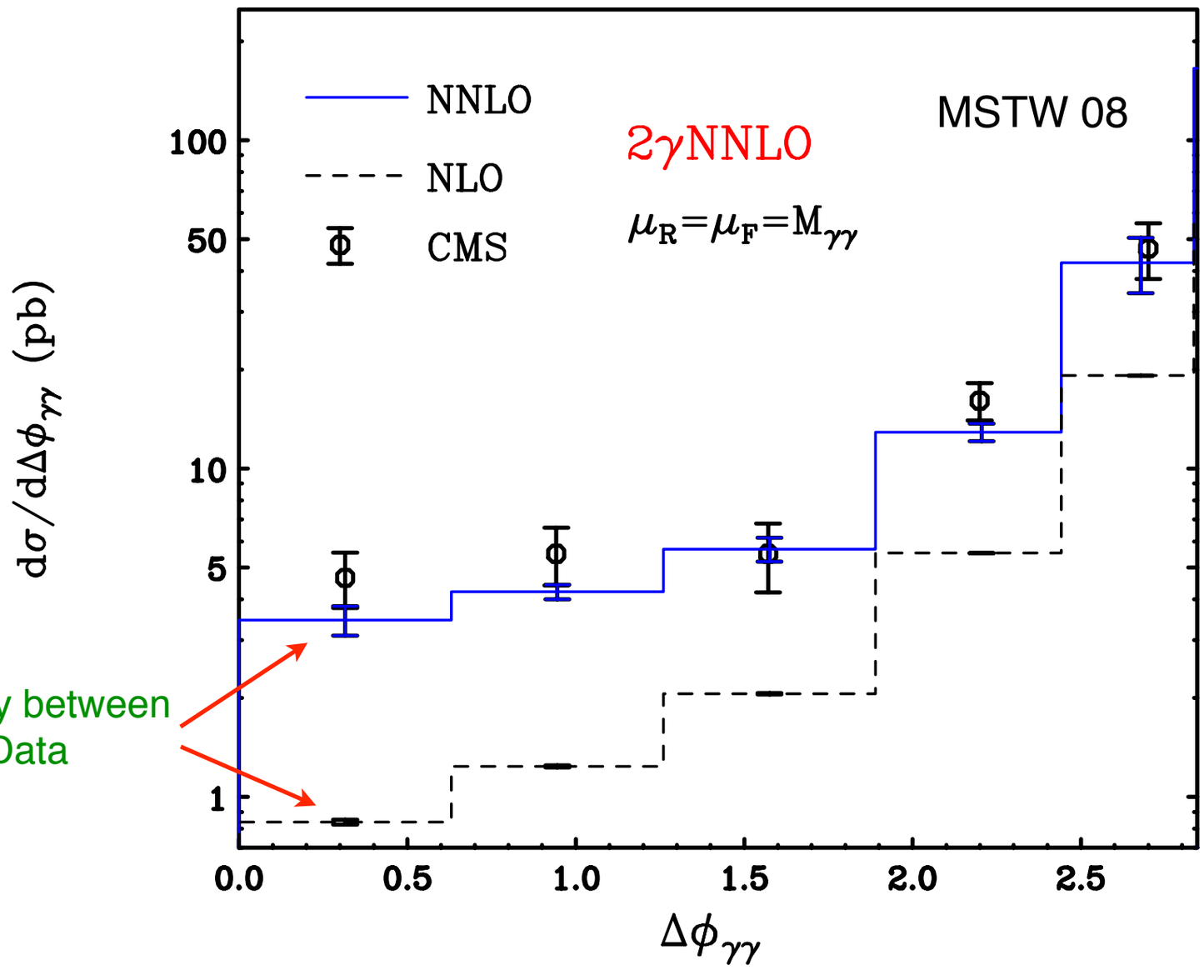
Discrepancy found between NLO and Experimental data at low $\Delta\phi_{\gamma\gamma}$



NNLO Corrections much larger in some kinematical regions

"away from back-to-back configuration"

NLO effectively lowest order



large discrepancy between NLO and Data

$\sqrt{S} = 7\,\mathrm{TeV}$

CMS diphoton cuts

$p_T^{\gamma\,hard} \geq 23\,\mathrm{GeV}$

$p_T^{\gamma\,soft} \geq 20\,\mathrm{GeV}$

$|\eta^\gamma| \leq 2.5$

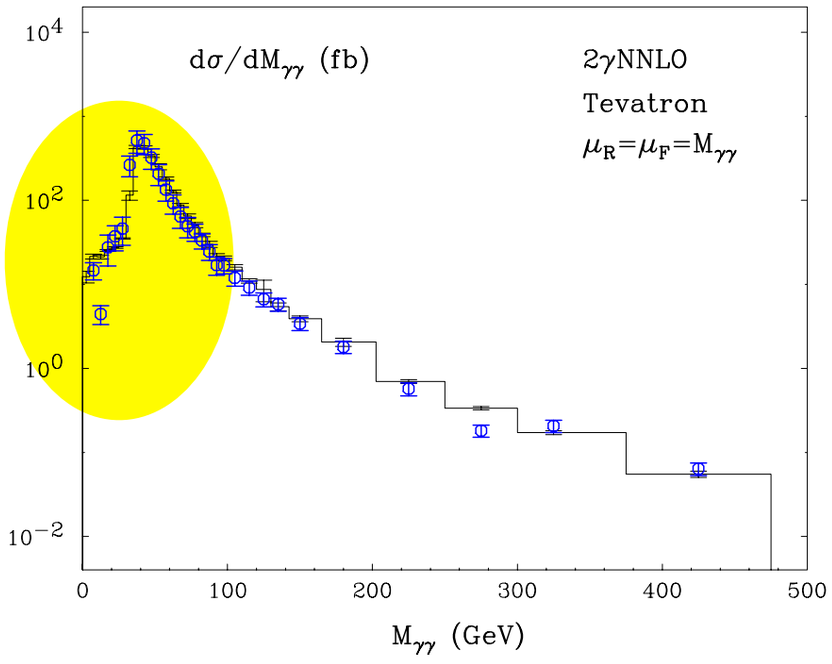
$R_{\gamma\gamma} > 0.45$

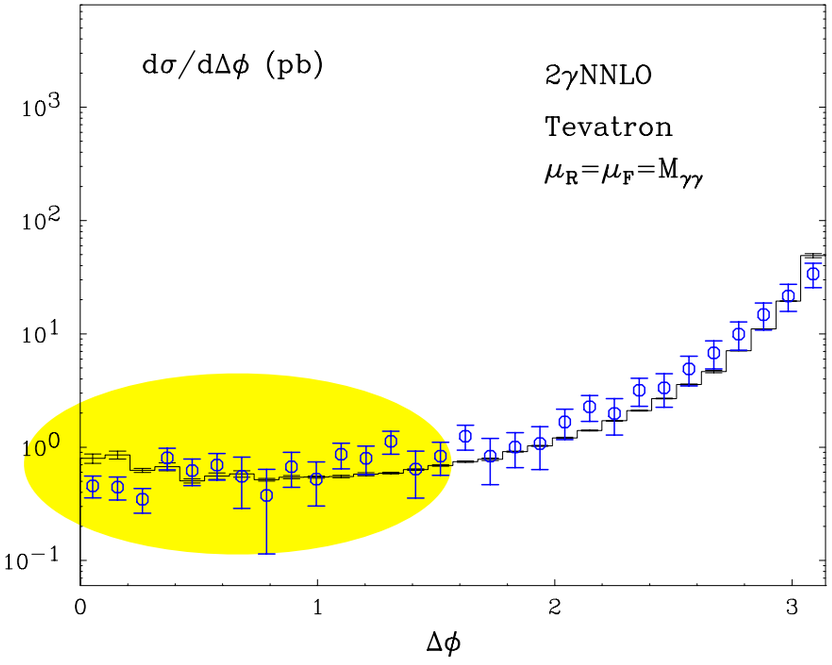
smooth cone isolation

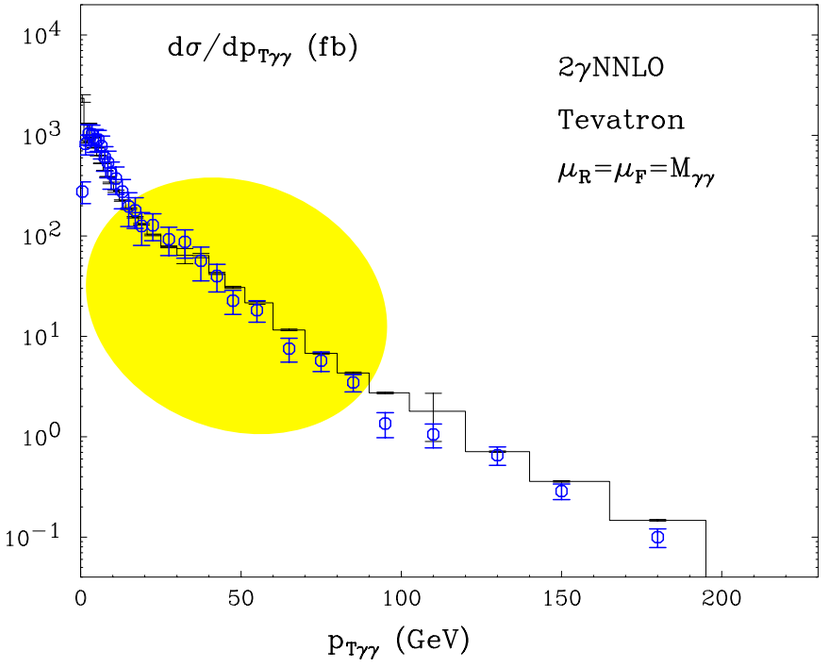
NNLO corrections essential to understand the data

In general, extra radiation at NNLO accuracy (hard and soft)

- Sizable corrections where effectively NNLO (40-55 %)
- Fills in the gaps where NLO is effectively Born (huge K factor)
- Extends kinematical range coverage
- First order with all channels included
- First (reliable) estimate of TH uncertainties



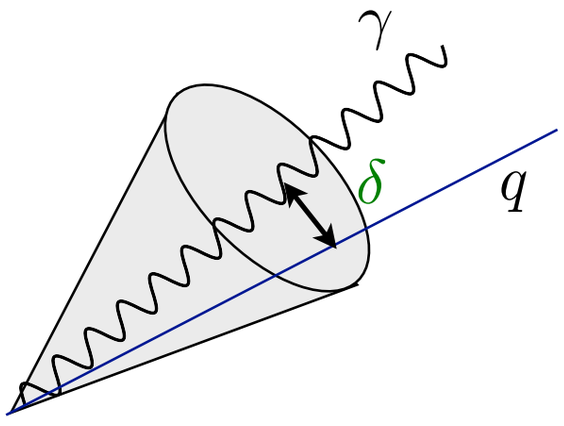




Future 2γNNLO

User-friendly version and release code

(Later) Implement subtraction terms → standard cone



Standard Photon Isolation

$$E_T^{had}(\delta) \leq E_{T\,max}^{had}$$

Smooth Photon Isolation

S.Frixione

$$E_T^{had}(\delta) \leq E_{T\,max}^{had}\ \chi(\delta)$$

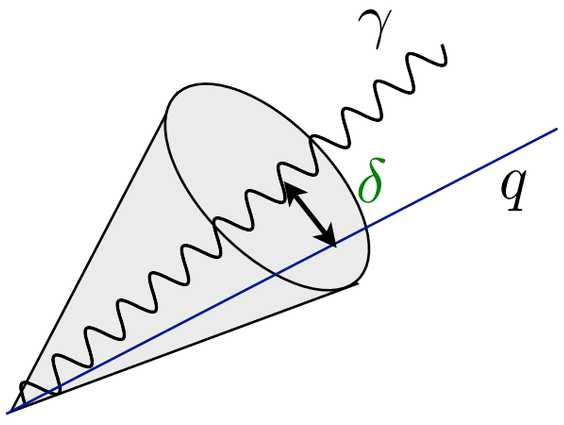
$$\chi(\delta) = \left(\frac{1-\cos(\delta)}{1-\cos(R_0)}\right)^n \leq 1$$

only soft emission allowed if collinear to photon

- no quark-photon collinear divergences
- no fragmentation component (only direct)
- Direct contribution well defined

More restrictive than usual cone : lower limit on cross section

In real (TH)life... how much different? NLO comparison $R_0 = 0.4 \quad n = 1$



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CMS Higgs cuts at 7 TeV

Standard: direct+fragmentation (Diphox)

$E_{T\,max}^{had}$	standard/smooth	Frag. comp. (cone)
2 GeV	< 1%	6%
3 GeV	< 1%	10%
4 GeV	1%	13%
5 GeV	3%	16%
0.05 p_T	< 1%	8%
0.5 p_T	11%	52%

if isolation tight enough, hardly any difference between standard and smooth cone

Backup Slides

Asymmetric cuts and pQCD

$$\sqrt{S} = 7\,\mathrm{TeV}$$

$$|\eta^{\gamma}| \leq 2.5$$

$$R_{\gamma\gamma} > 0.45$$

$$\mu_R = \mu_F = M_{\gamma\gamma}$$

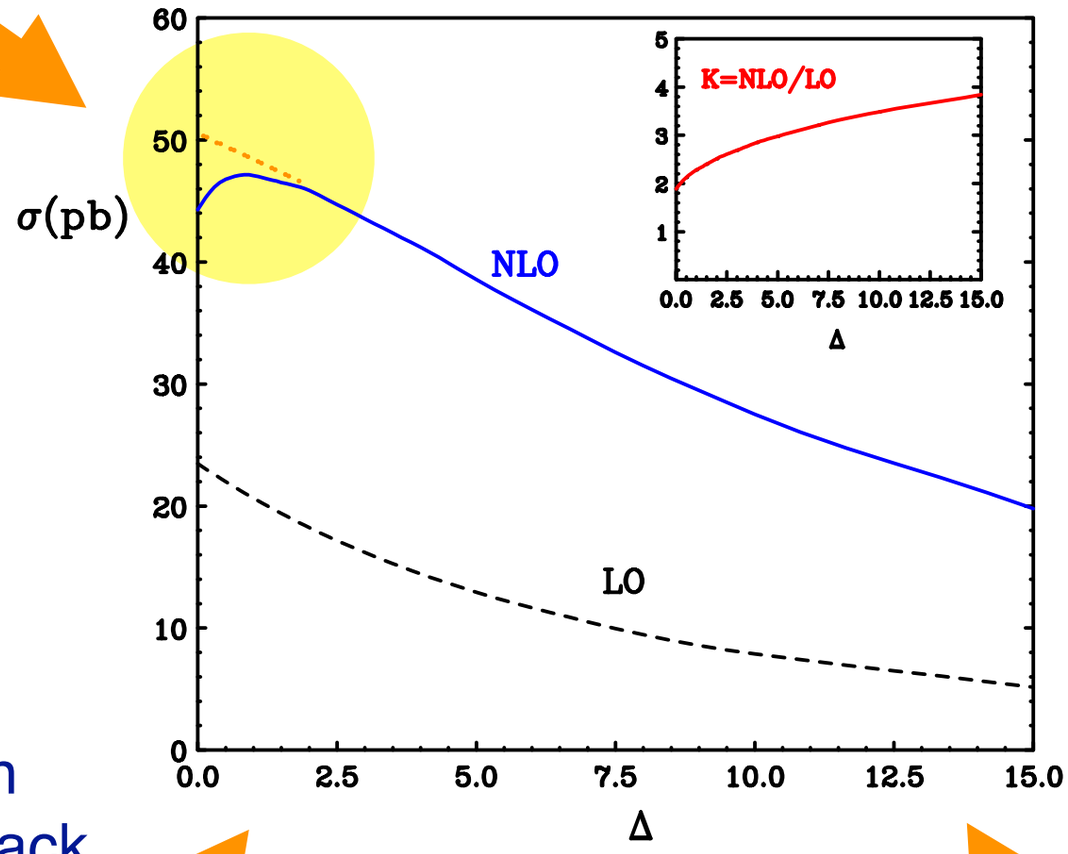
CTEQ6 NLO pdfs

$$p_T^{\gamma\, harder} \geq (20 + \Delta)\,\mathrm{GeV}$$

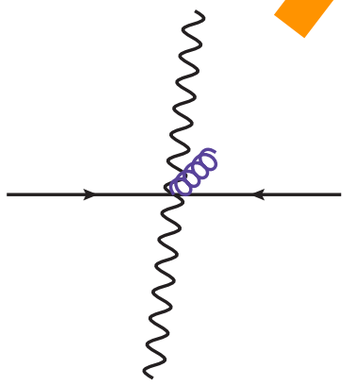
$$p_T^{\gamma\, softer} \geq 20\,\mathrm{GeV}$$

for jets: Frixione, Ridolfi (1997)

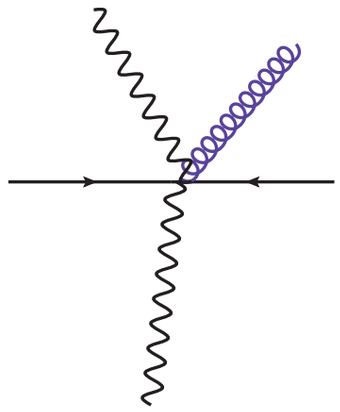
Fixed order calculation not reliable at small Δ



Sensitive to soft gluon emission (dominant in back to back configuration)



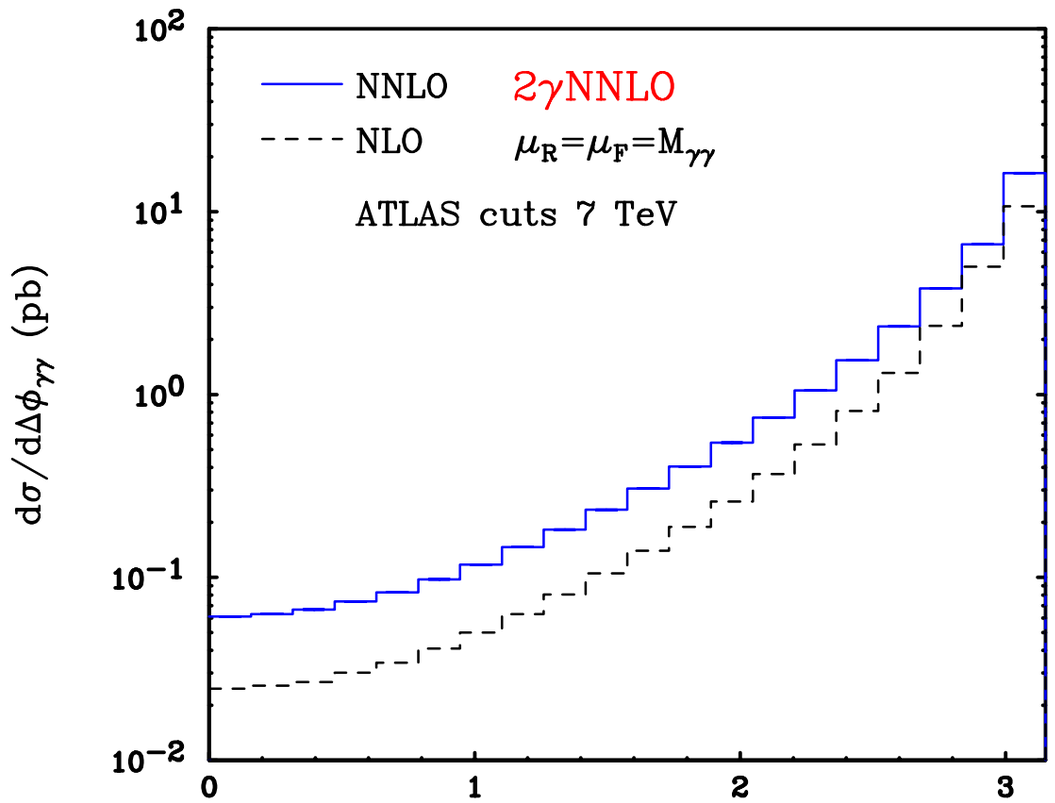
"Affected" by opening of phase space for "hard" radiation (not allowed at LO)



effectively LO away from back to back

damned if you do, damned if you don't

With Higgs search cuts at 7 TeV



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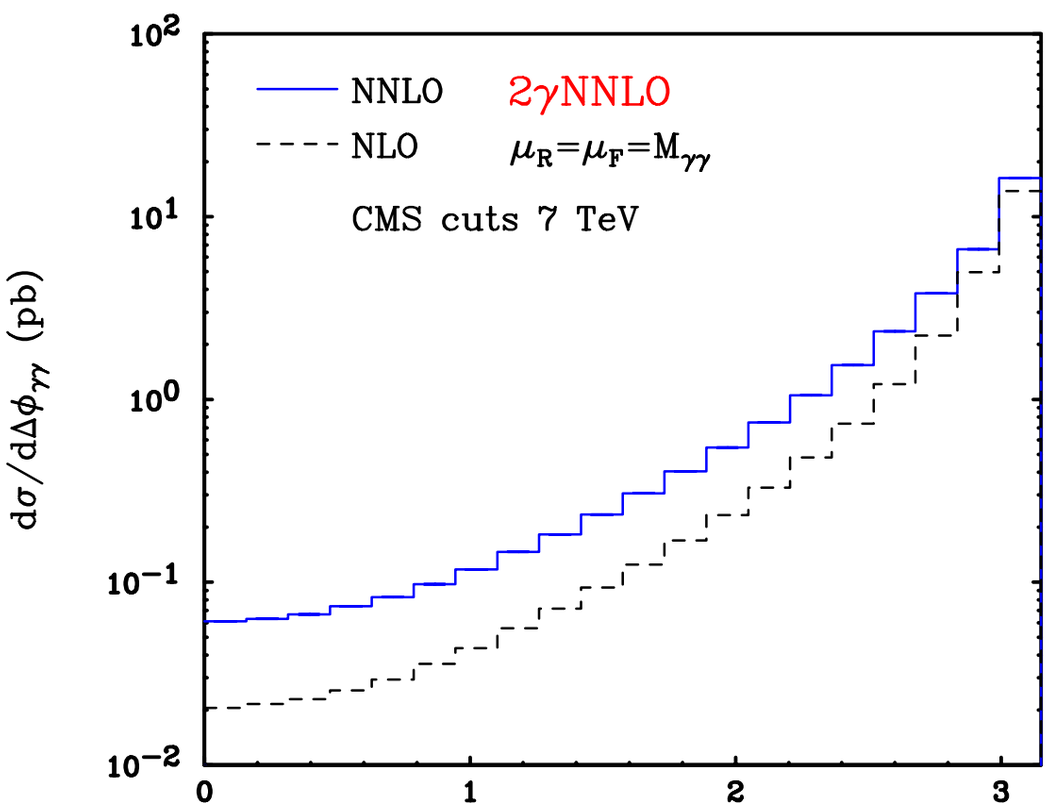

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