Single and double diffractive prompt photon production at the LHC

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Outline

- Motivation
- Diffractive physics
- Prompt photon production
- Diffractive production of photons considering the Resolved Pomeron Model
  - single diffractive processes
  - double diffractive (central diffractive) processes
- Present some results for $\gamma + X$ and $\gamma\gamma$ production in single and double diffractive processes
- Conclusions

Introduction

- The production of prompt photons provides an important probe of the proton's gluon distribution due to dominance of the LO Compton-like subprocess $qg \to \gamma q$.
- Diffractive processes $\Longrightarrow$ rapidity gaps in the hadronic final state
- Exchange of a Pomeron with vacuum quantum numbers
- $p\mathbb{P}$ and $\mathbb{P}\mathbb{P}$ interactions
- What is a Pomeron actually?
- If Pomeron has substructure $\Longrightarrow$ DPDFs
- Diffractive distributions of quarks and gluons in the Pomeron
- Tested in several processes like dijets, dileptons, heavy quarks, quarkonium + photon...
- In this contribution, we study photon production as a complementary test of diffractive processes and pomeron structure.

Photon production in pp collisions

- Contributing LO diagrams:
  - $qg \to q\gamma$ (Compton), $q\bar{q} \to g\gamma$ (annihilation)
  - $q\bar{q} \to \gamma\gamma$ (pure EM), $gg \to \gamma\gamma$, $gg \to g\gamma$
- Inclusive prompt photon production cross section

$$\frac{d\sigma}{dy dp_T^2} = \sum_{abcd} \int_{x_{a\,min}}^{1} dx_a f_a(x_a, Q^2) f_b(x_b, Q^2) \frac{x_a x_b}{2x_a - x_T e^y} \frac{d\sigma}{d\hat{t}}(ab \to cd)$$

$$x_{a\,min} = \frac{x_T e^y}{2 - x_T e^{-y}} \;, x_b = \frac{x_a x_T e^{-y}}{2x_a - x_T e^y} \;, x_T = 2p_T/\sqrt{s}$$

  - $f_{a,b/p}$: CTEQ6L parton distributions
  - $\frac{d\hat{\sigma}}{d\hat{t}}$: LO partonic cross sections
  - Higher order contributions (not considered here) can be taken into account effectively with a K factor

Diffractive parton distributions

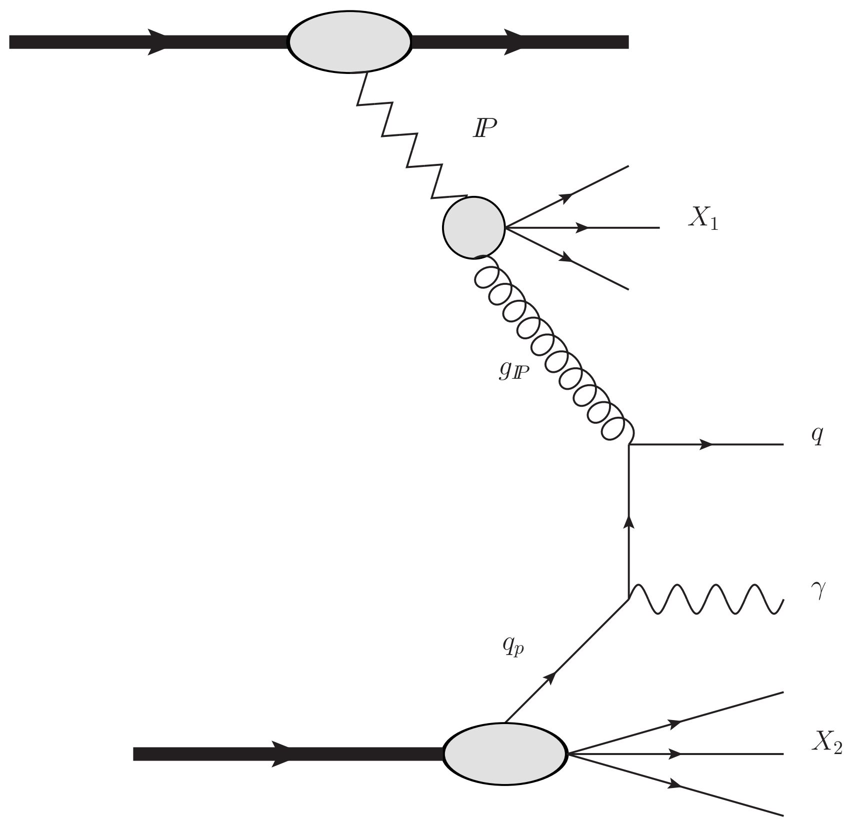
- Resolved Pomeron Model
- Diffractive parton distributions in the proton: Convolution of
  - flux of Pomerons $\Rightarrow f_{I\!P}(x_{I\!P}) = \int_{t_{min}}^{t_{max}} dt f_{I\!P}(x_{I\!P}, t)$
    - $x_{I\!P}$: momentum fraction of the proton carried by the Pomeron
    - t_{min}, t_{max}: kinematic boundaries
    - H1 Collaboration: flux factor motivated by Regge theory $\Rightarrow$ $f_{I\!P/p}(x_{I\!P}, t) = A_{I\!P} \cdot \frac{e^{B_{I\!P} t}}{x_{I\!P}^{2\alpha_{I\!P}(t)-1}}$
    - Pomeron trajectory assumed linear: $\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$
  - parton distributions in the Pomeron $\Rightarrow g_{I\!P}(\beta, \mu^2)$, $q_{I\!P}(\beta, \mu^2)$
    - β: momentum fraction carried by the parton inside the Pomeron
- Diffractive quark and gluon distributions:

$$q^D(x, \mu^2) = \int dx_{I\!P} d\beta \delta(x - x_{I\!P}\beta) f_{I\!P}(\beta, \mu^2) q_{I\!P}(x_{I\!P}) = \int_x^1 \frac{dx_{I\!P}}{x_{I\!P}} f_{I\!P}(x_{I\!P}) q_{I\!P}(\beta, \mu^2)$$

$$g^D(x, \mu^2) = \int dx_{I\!P} d\beta \delta(x - x_{I\!P}\beta) f_{I\!P}(\beta, \mu^2) g_{I\!P}(x_{I\!P}) = \int_x^1 \frac{dx_{I\!P}}{x_{I\!P}} f_{I\!P}(x_{I\!P}) g_{I\!P}(\beta, \mu^2)$$

Single Diffractive photon production

- γX production, X is a jet or a unobserved photon



- Pomeron emitted from one of the two protons: include both $pI\!P$ and $I\!Pp$ interactions

Single Diffractive Photon production

- Contributing LO diagrams:
  - $qg \to q\gamma$ (Compton), $q\bar{q} \to g\gamma$ (annihilation)
  - $q\bar{q} \to \gamma\gamma$ (pure EM), $gg \to \gamma\gamma$, $gg \to g\gamma$
- Single Diffractive prompt photon production cross section

$$\frac{d\sigma}{dy dp_T^2} = \sum_{abcd} \int_{x_{a\,min}}^{1} dx_a f_a^D(x_a, Q^2) f_b(x_b, Q^2) \frac{x_a x_b}{2x_a - x_T e^y} \frac{d\sigma}{d\hat{t}}(ab \to cd)$$

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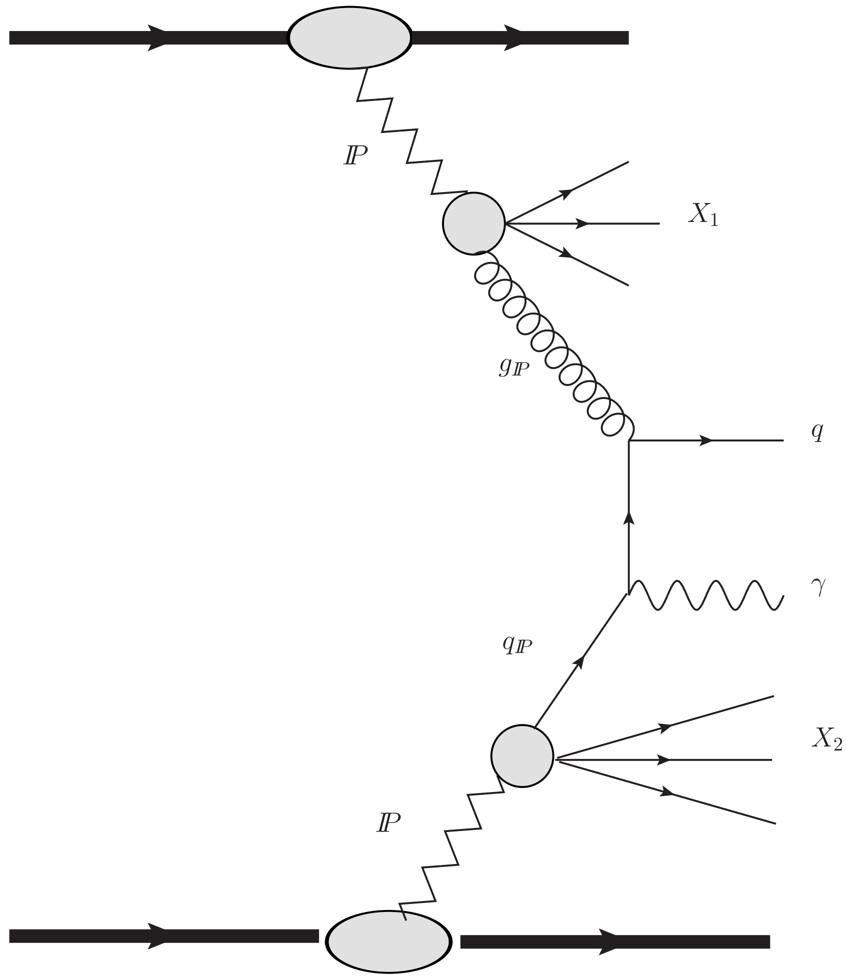
  - $f_a^D \; f_{b/p} + f_{a/p} \; f_b^D$
  - $\frac{d\hat{\sigma}}{d\hat{t}}$: LO partonic cross sections
- $p\mathbb{P}$ and $\mathbb{P}p$ interactions

Double Diffractive photon production

- Central diffractive: $I\!P I\!P$ interactions



- events with two rapidity gaps and γ+jet or $\gamma + \gamma$ at central region
- amplified sensitivity to test the DPDF's

Double Diffractive Photon production

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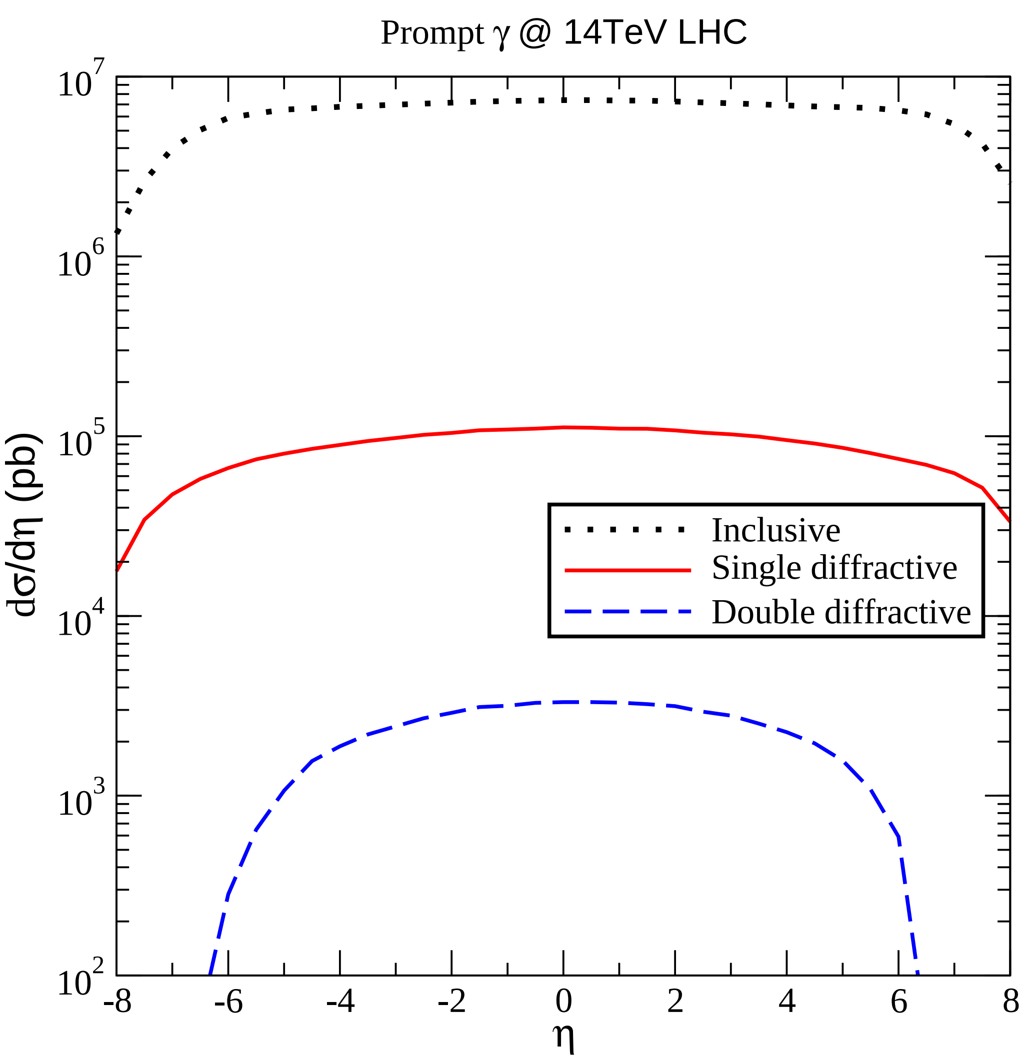
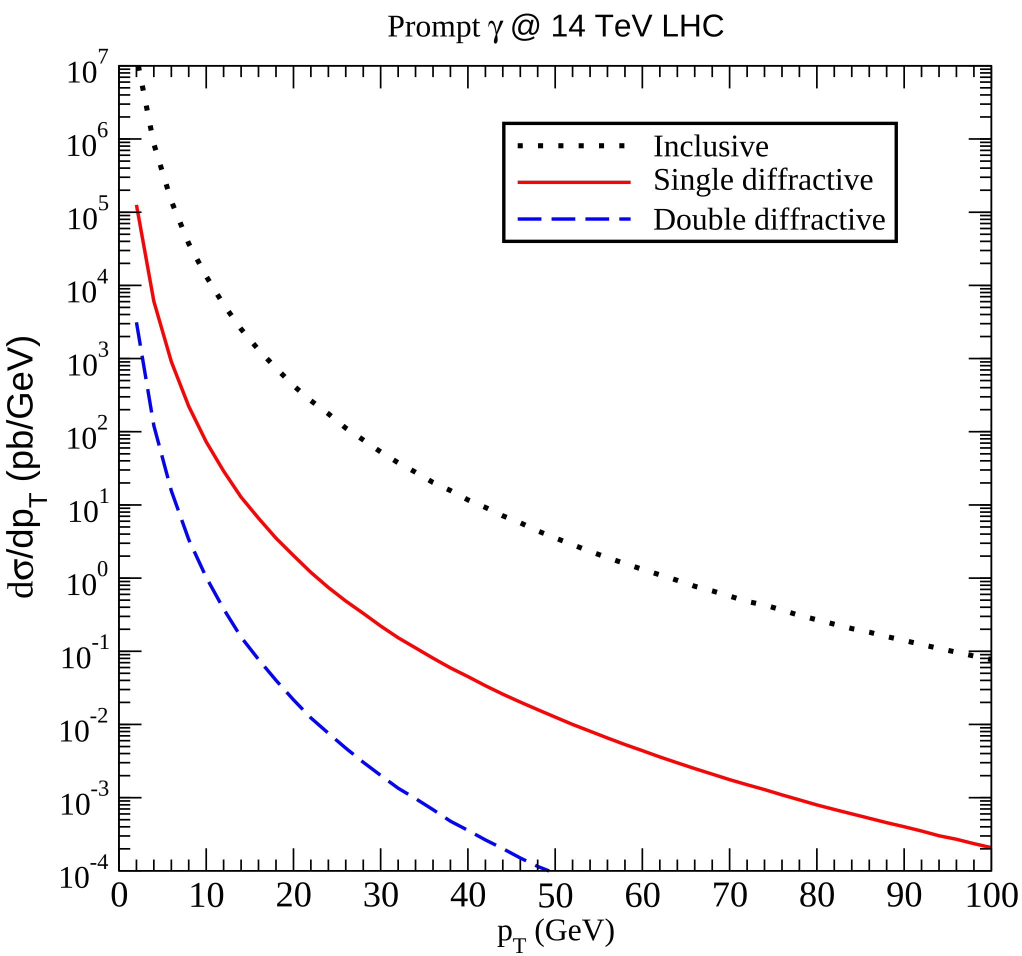
  - $f_a^D(x_a, Q^2)$, $f_b^D(x_b, Q^2)$: diffractive PDF's in both protons
  - $\frac{d\hat{\sigma}}{d\hat{t}}$: LO partonic cross sections
- $I\!P I\!P$ interactions

SD and DD prompt photon production @ LHC



- η distribution of identified photon
- Inclusive, single diffractive and double diffractive channels
- Gap survival factors included (*KMR*)
  - $S_G(SD) = 0.05$
  - $S_G(DD) = 0.02$
- reduction of two orders of magnitude
  - inclusive to single diffractive
  - single to double diffractive
- This could be measured at the LHC

SD and DD prompt photon production @ LHC



- p_T distribution of identified photon
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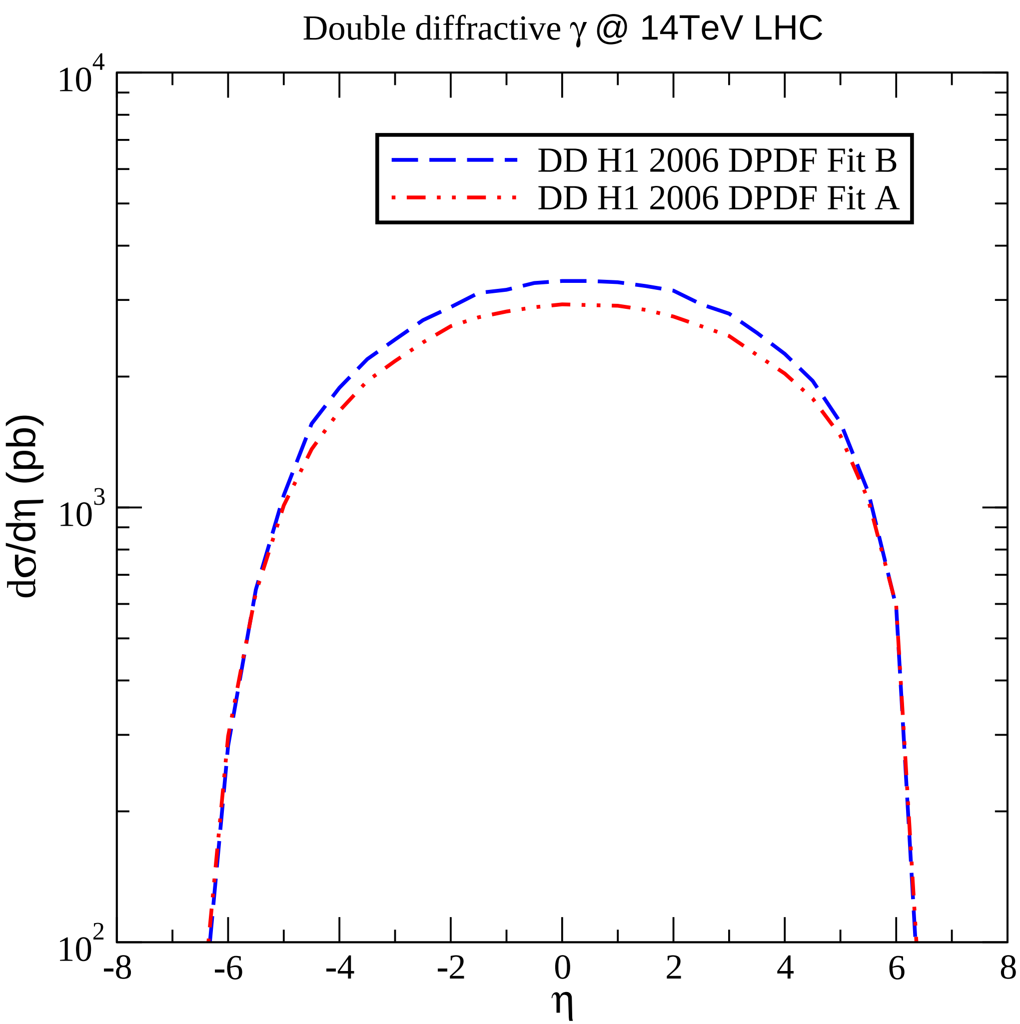
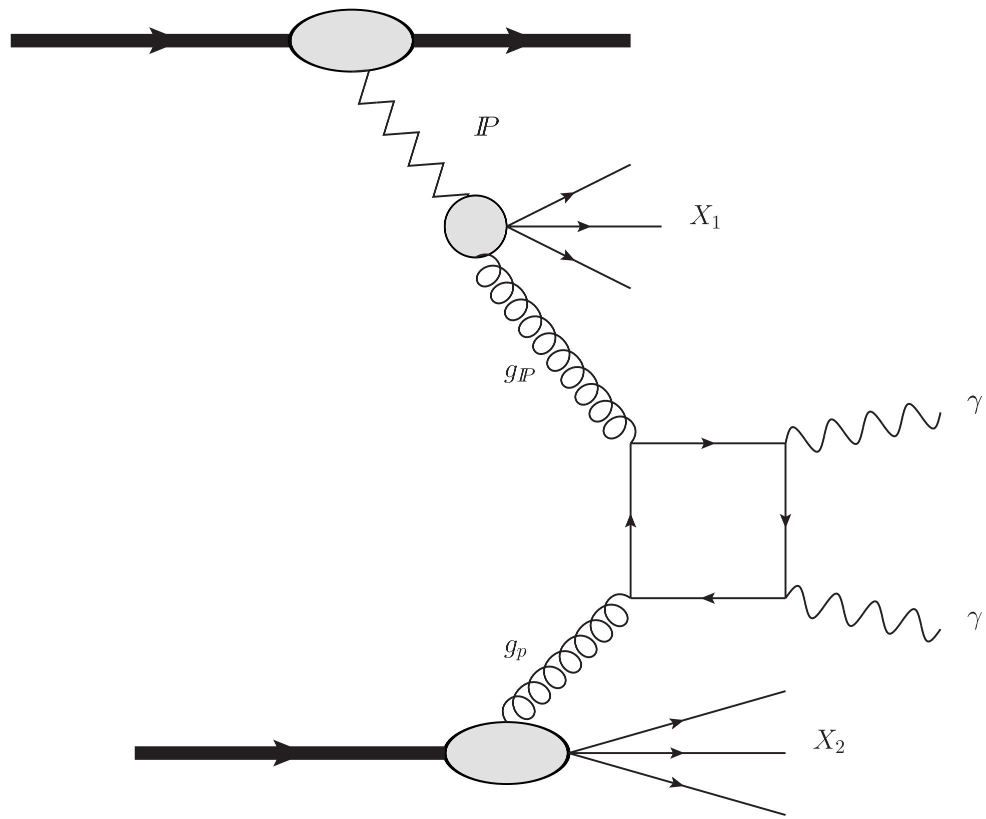
Sensitivity against HERA fits for the Pomeron



- Two H1 2006 fits [*EPJC 48, 715 (2006)*]
- $\neq$ gluon densities at starting scale for QCD evolution
- $\neq$ effective pomeron intercept and other parameters...
  - fit A: $\alpha_{\mathbb{P}}(0) = 1.118 \pm 0.008$, ...
  - fit B: $\alpha_{\mathbb{P}}(0) = 1.111 \pm 0.007$, ...
- Small differences, mainly in $|\eta| < 4$ region
- $\Rightarrow$ *fit B used in all other results*

Single Diffractive $\gamma\gamma$ production

- $\gamma\gamma$ production (subdominant terms of single γ production)
- $q\bar{q} \to \gamma\gamma$ (pure EM), $gg \to \gamma\gamma$ (quark box)



- $pI\!P$ and $I\!Pp$ interactions

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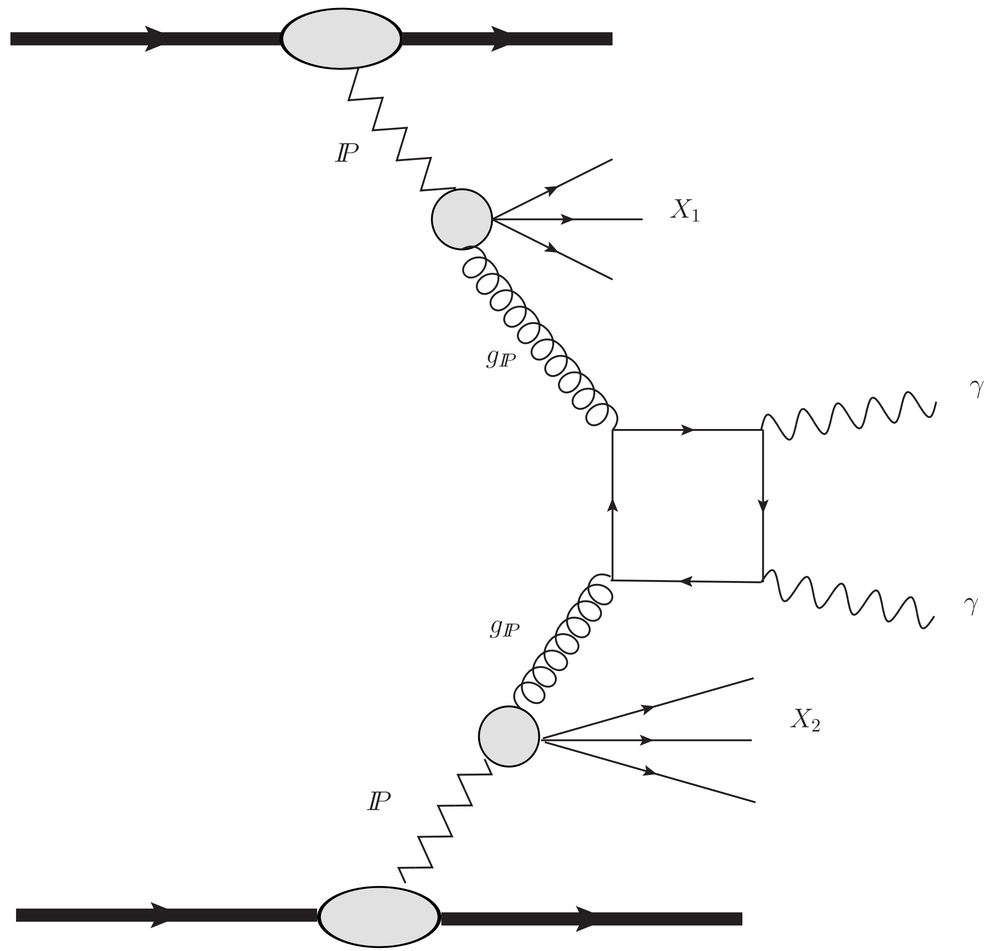
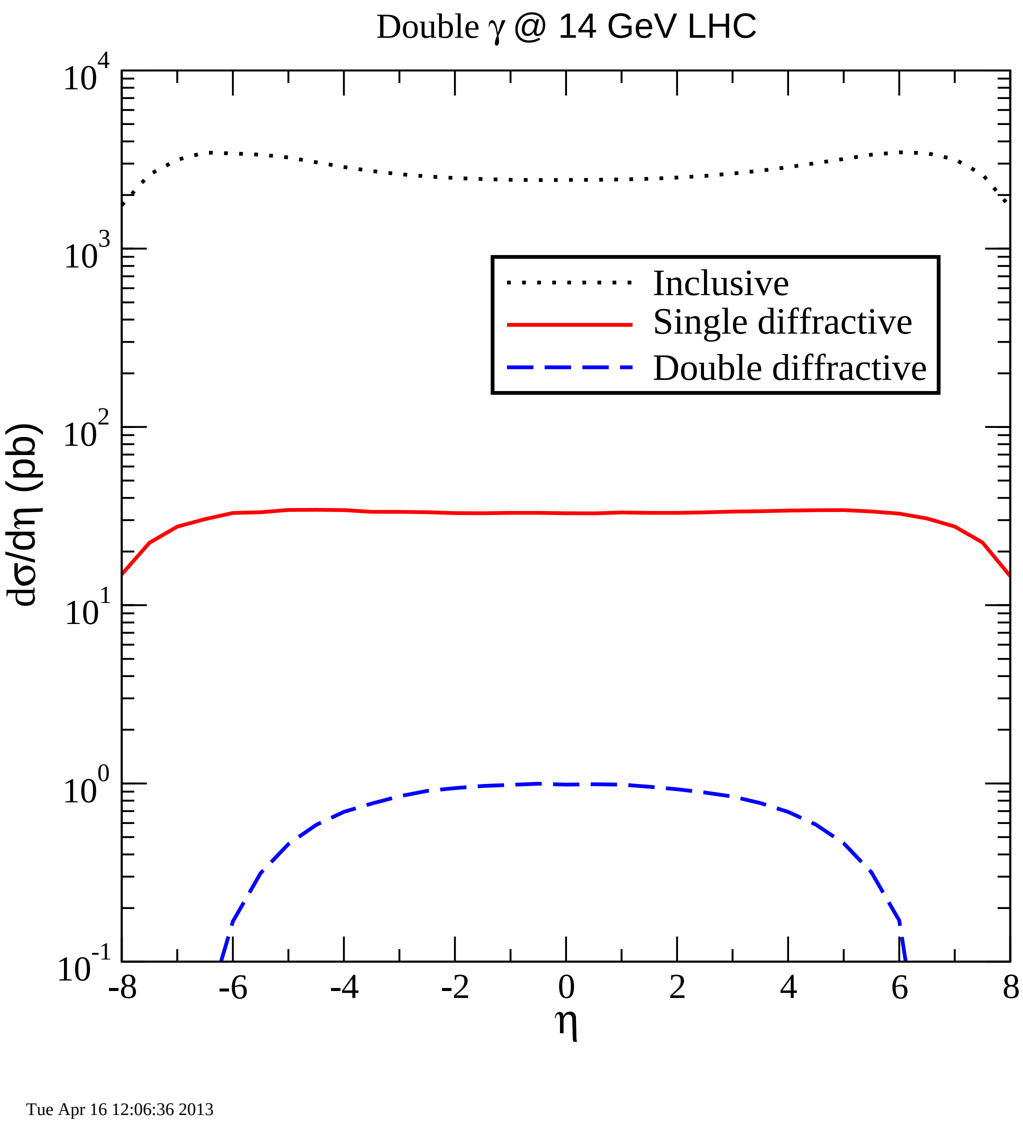


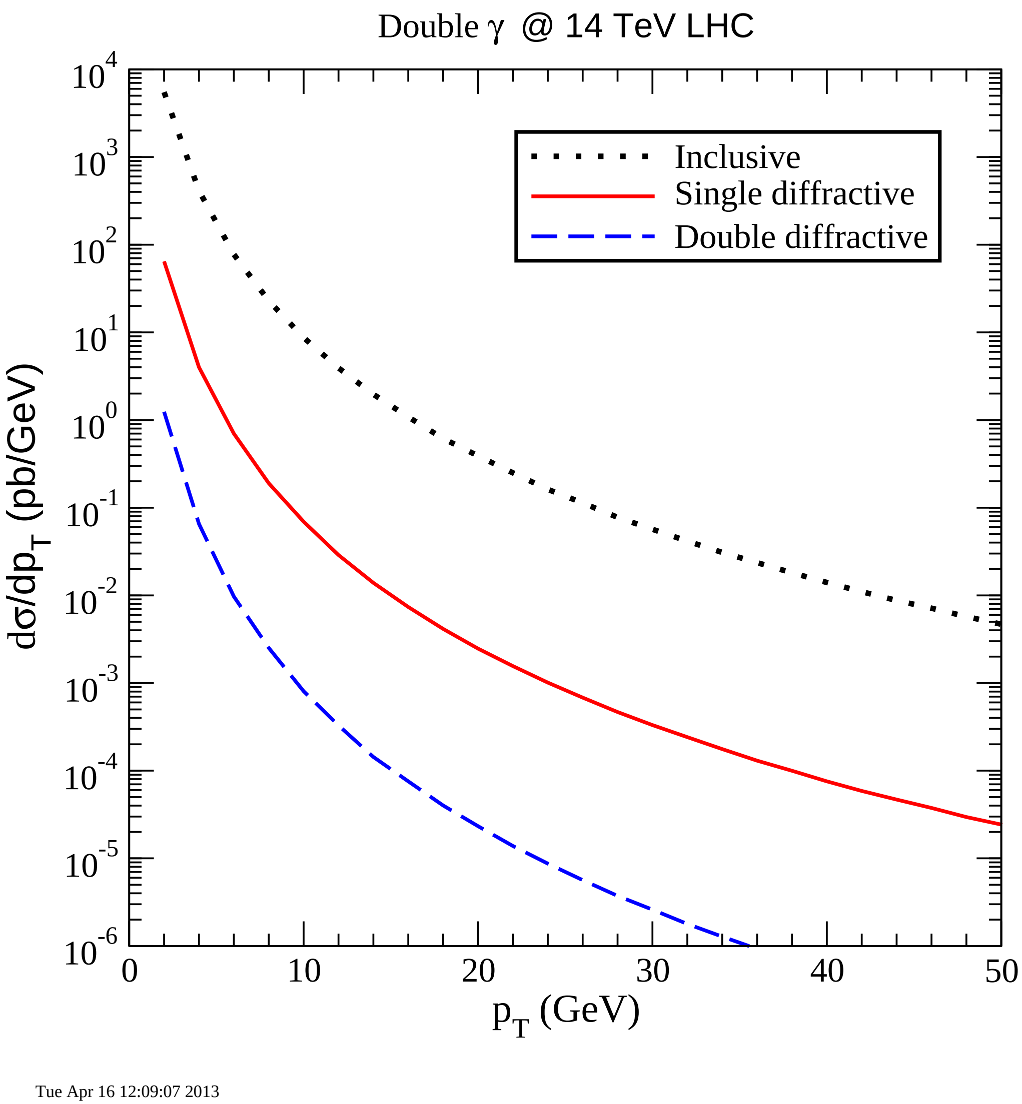
- $I\!P I\!P$ interactions

SD and DD $\gamma\gamma$ production @ LHC



- much smaller cross section than in single γ case: $\approx$ 3 orders of magnitude
- cleaner process than in single γ case (γ + jet)

SD and DD $\gamma\gamma$ production @ LHC



- much smaller cross section than in single γ case: $\approx$ 3 orders of magnitude
- cleaner process than in single γ case (γ + jet)
- To be compared with KMRS approach applied to exclusive $\gamma\gamma$ production (*Khoze, EPJC 38 (2005) 475*) $\rightarrow p_T$ distributions considering certain kinematic cuts
- There are Tevatron data for this process (exclusive), how about LHC?
  - *strictly speaking, not the same processes* (central diffractive X exclusive)

Estimates for the total cross section

- including gap survival probabilities

final state	inclusive	single diffractive	central diffractive
γ jet	1×10^8 pb	1.37$\times 10^6$ pb	2.86$\times 10^4$ pb
$\gamma\gamma$	4.5×10^4 pb	504 pb	9.14 pb

- diffractive PDF's and resolved pomeron model can be tested @ LHC
- diffractive PDF's can be improved by combining different observables

Conclusions and discussion

- γ scattering - the oldest experiment for diffraction (photons as waves)
- Now photons as particles, including both QED and QCD interactions
- Predictions for diffractive production of photons in pp collisions at the LHC
  - both single and central diffractive to probe $p\mathbb{P}$ and $\mathbb{P}\mathbb{P}$ interactions
  - both prompt photon and $\gamma\gamma$ production
- Complementary processes to dileptons, dijets, heavy quarks, quarkonium $+$ photon

  See works by A. Szczurek, C. Marquet, C. Royon, V.P Goncalves, M.M. Machado, M.V.T. Machado...
- Resolved Pomeron model based on the diffractive factorization formalism
- Pomeron with partonic substructure (describes HERA data very well)
- Feasible values at LHC energies ($\gamma+$ jet)
- *These are simple (LO) estimates. For more robust results, go to higher order and compare with BFKL approach...*
- Constrain the underlying model for the Pomeron and diffractive parton distributions
- Expecting this observables to be measured at LHC