Photons as probes of gluon saturation in forward dilute+dense collisions

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Motivation

- Photons produced in collision experiments (RHIC, LHC) are powerful probes, sensitive to strongly correlated and highly occupied gluon states.
- At high $\sqrt{s}$ (and low-x), dynamics of these states is described by the Color Glass Condensate (CGC) [1]. Contributions in this framework are listed in Fig.1.
- LO is parametrically dominant. However, the NLO terms are kinematically enhanced at low-x by high gluon occupancy.

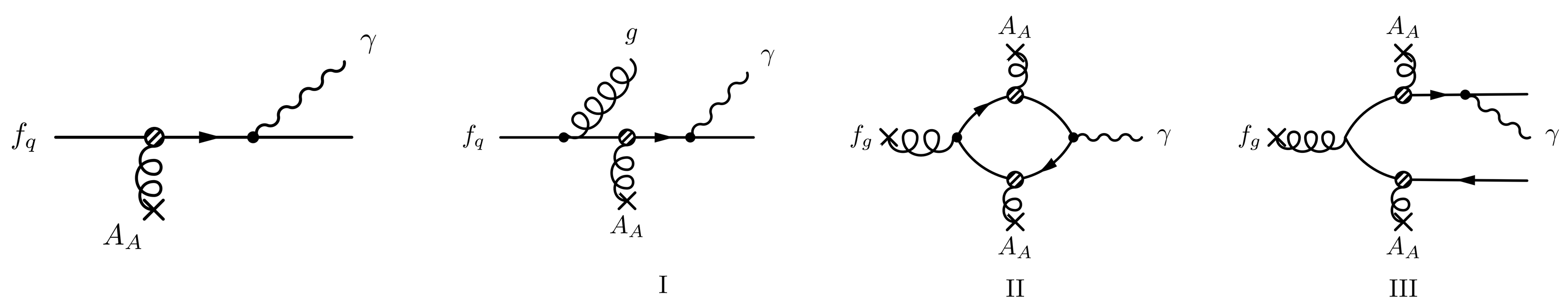

Figure 1: Leading order and next-to-leading order processes for prompt photon production in proton-nucleus collisions.

NLO cross-section

Amplitude is perturbative in the quark and photon [2, 4] sectors, while glue is calculated using the CGC. Contributions can be put into four different diagram classes (Fig. 2).

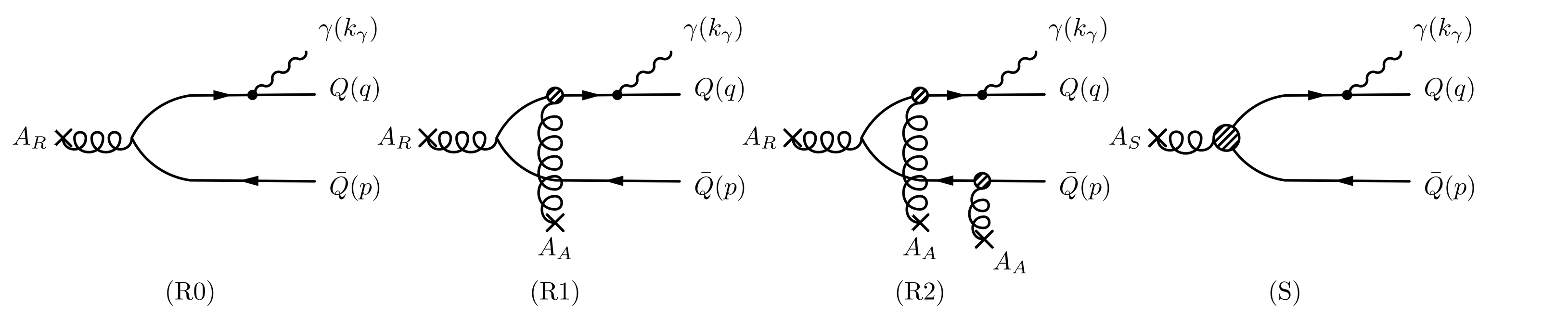

Figure 2: Contribution classes for process III.

Our main result is the inclusive-photon cross-section, represented as

$$\frac{\mathrm{d}\sigma^{\gamma}}{\mathrm{d}^2\boldsymbol{k}_{\gamma\perp}\mathrm{d}\eta_{k_\gamma}} = \frac{\alpha_e\alpha_S^2 q_f^2}{C_F}\varphi_p \otimes \left\{\tau_{g,g}\phi_A^{g,g} + \tau_{g,q\bar{q}}\,\phi_A^{q\bar{q},g} + \tau_{q\bar{q},q\bar{q}}\,\phi_A^{q\bar{q},q\bar{q}}\right\} \quad (1)$$

- Full (CGC) cross section is non-$\boldsymbol{k}$ factorizable.
- Higher order correlator information is encoded in the $\phi_A^{q\bar{q},q\bar{q}}$, $\phi_A^{q\bar{q},g}$, $\phi_A^{g,g}$ functions.
- In the dilute-dilute ($Q_{S,A}^2/\boldsymbol{k}_\perp \sim 1$) limit, $k_\perp$ factorization is recovered and agrees with fully perturbative amplitude [3].

LO vs NLO: η dependence

- $x_p = k_{\gamma,\perp}\, e^{\eta_\gamma}/\sqrt{s}$, $\quad x_A = k_{\gamma,\perp}\, e^{-\eta_\gamma}/\sqrt{s}$
- Low rapidities, η_γ, and low photon transverse momenta, $k_\perp$, imply low-x, and gluon high occupancies, which enhance the NLO diagrams relative to LO.

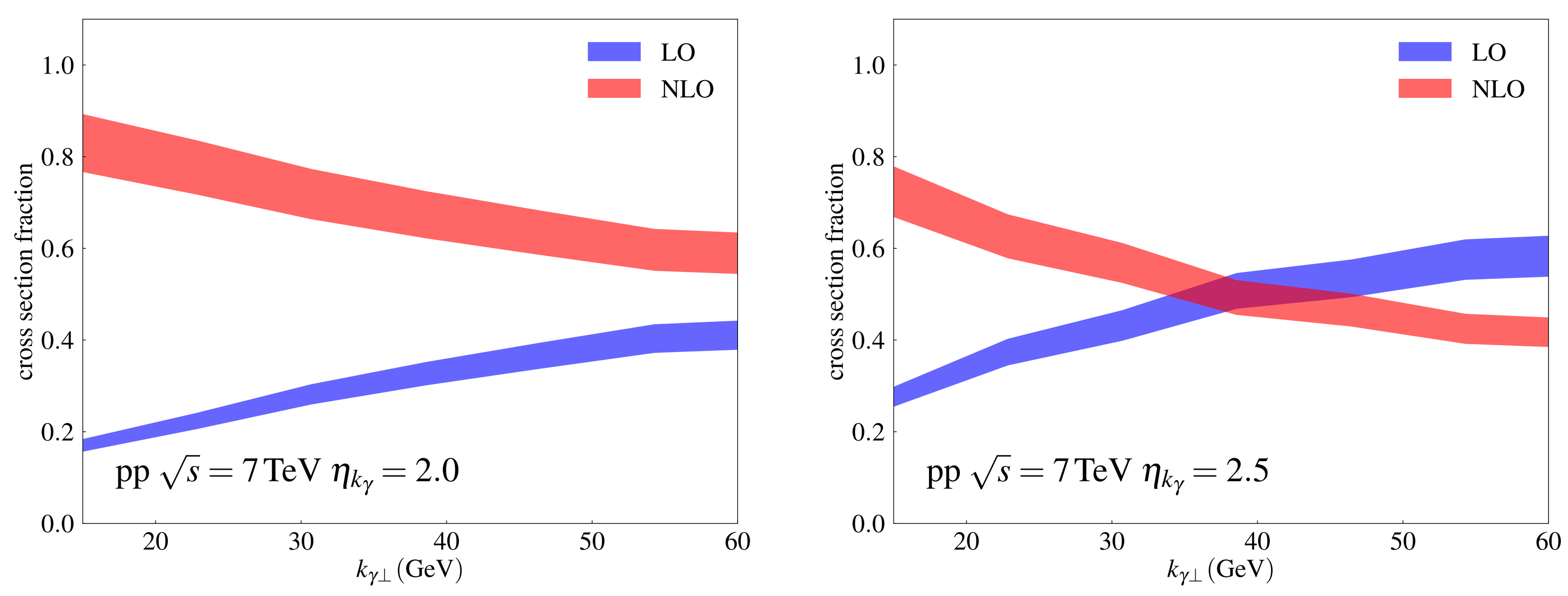

Figure 3: Relative size of LO and NLO contributions for increasing rapidity of the photon , η_γ. NLO becomes dominant at low-x regimes.

LO vs NLO: $\sqrt{s}$ dependence

- $x_p = k_{\gamma,\perp}\, e^{\eta_\gamma}/\sqrt{s}$, $\quad x_A = k_{\gamma,\perp}\, e^{-\eta_\gamma}/\sqrt{s}$
- High center of mass energies, $\sqrt{s}$, and low photon transverse momenta, $k_\perp$, imply low-x, and gluon high occupancies, which enhance the NLO diagrams relative to LO.

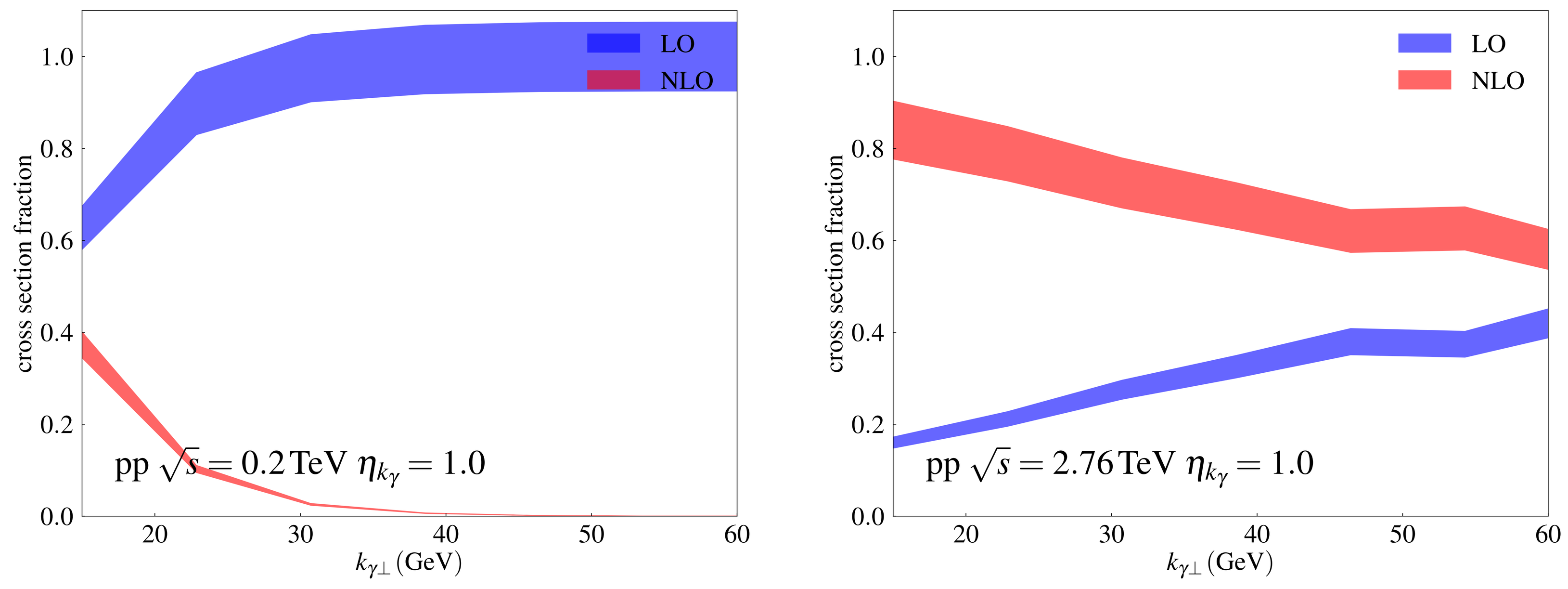

Figure 4: Relative size of LO and NLO contributions for increasing center of mass energy, $\sqrt{s}$. NLO becomes dominant at low-x regimes.

Forward p+p at ATLAS and CMS

Isolated LO+NLO cross-section for u, d, s, c quarks.

Hadronic activity suppressed for $\sqrt{(\phi_q-\phi_\gamma)^2+(\eta_q-\eta_\gamma)^2} < R$.

K-factor: $K = 0.4$.

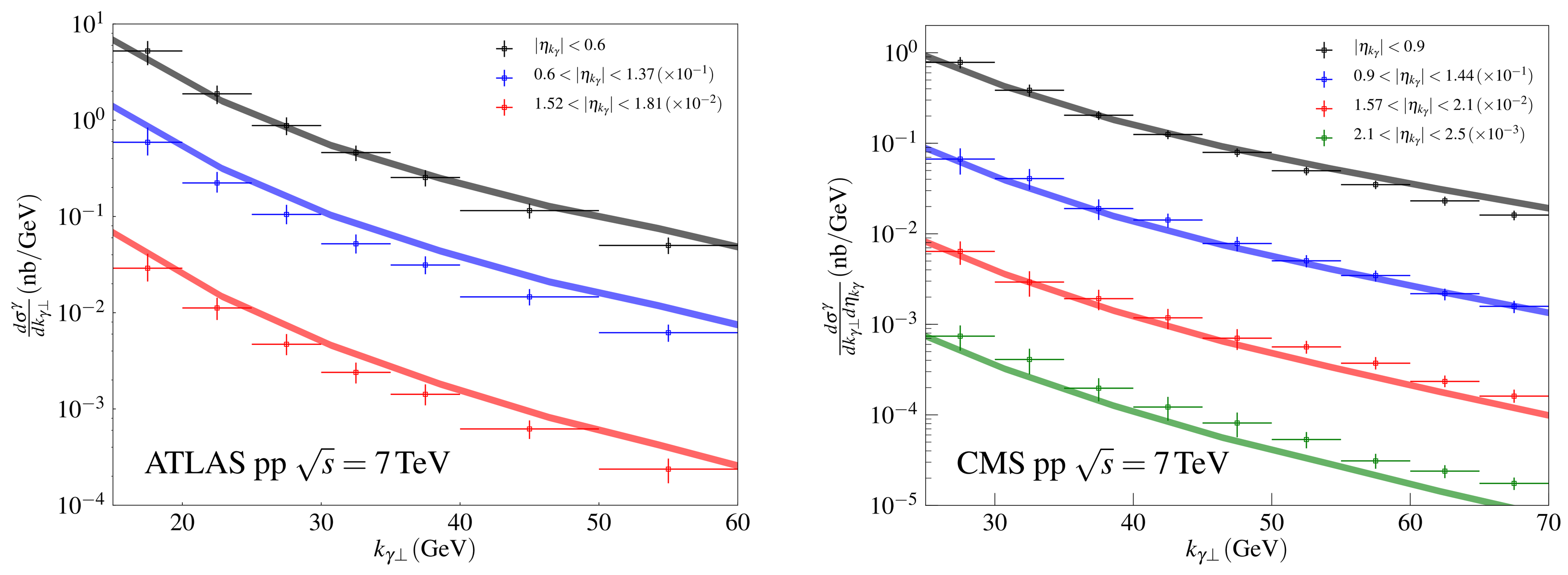

Figure 5: Data comparison for isolated photons with the total (LO + NLO) cross-section for the ATLAS [6] and CMS [5] experiments.

Summary and Outlook

- Full analytic description of dilute-dense systems at NLO.
- NLO dominates over LO at LHC energies.
- Fair description of CMS and ATLAS data at 2.76 and 7 TeV.
- Prediction for low-$k_\perp$ photons in p+A is already achievable and is our near future objective.
- Jet-photon and quarkonia-photon correlations can be calculated using this formalism.

References

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