Implementing the Exact Kinematic Constraint in the Saturation Formalism

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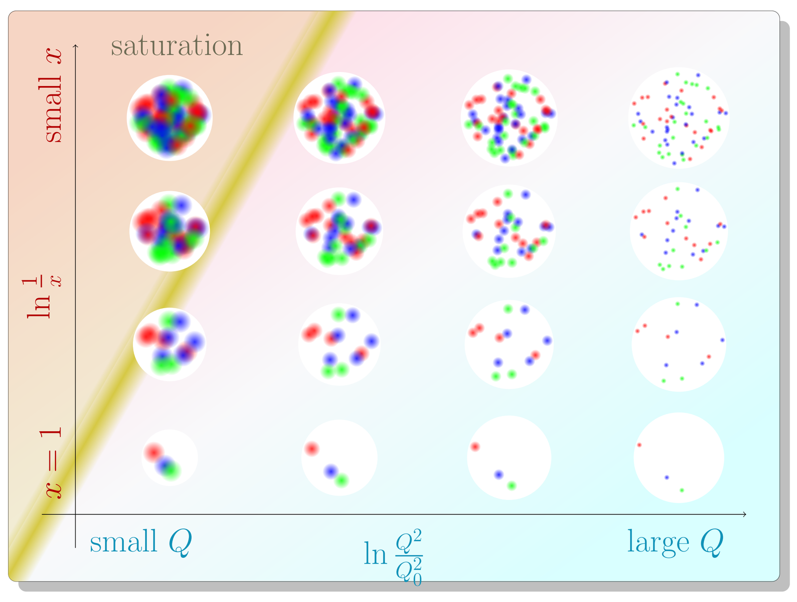
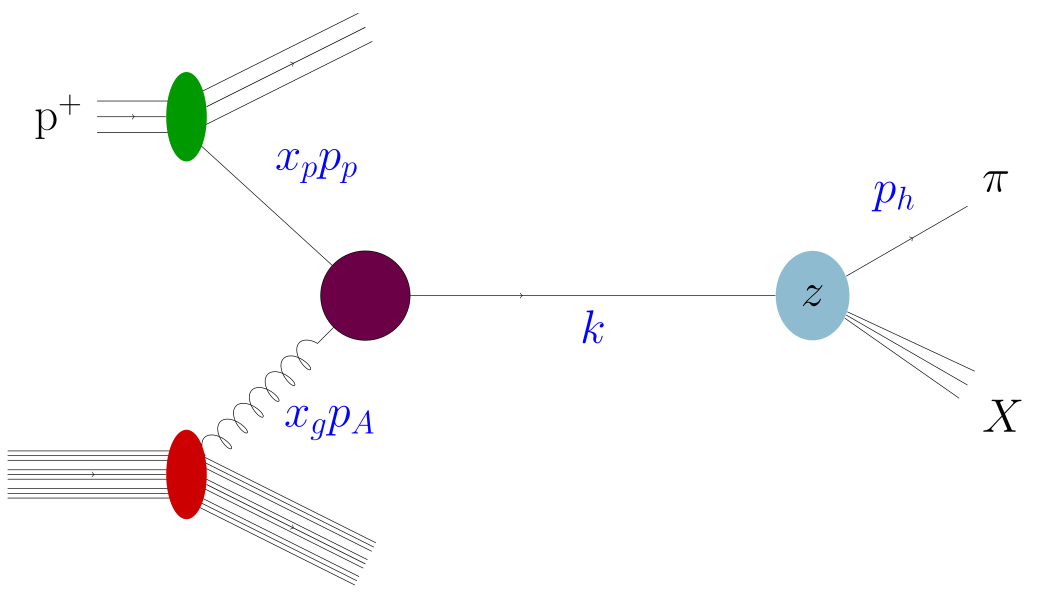
Inclusive hadron production in pA collisions is a modern hot topic in high-energy QCD. It's well suited to probe the nuclear unintegrated gluon distribution in the saturation regime and possibly provide the first distinct experimental signature of gluon saturation.



The current streak of activity began with the derivation of the primary next-to-leading order terms in 2012 (Chirilli et al. 2012). After three years of analysis, we now have symbolic and numerical results, complete up to next-to-leading order, for the hadron production cross section, with comparisons to data at both the RHIC and the LHC.

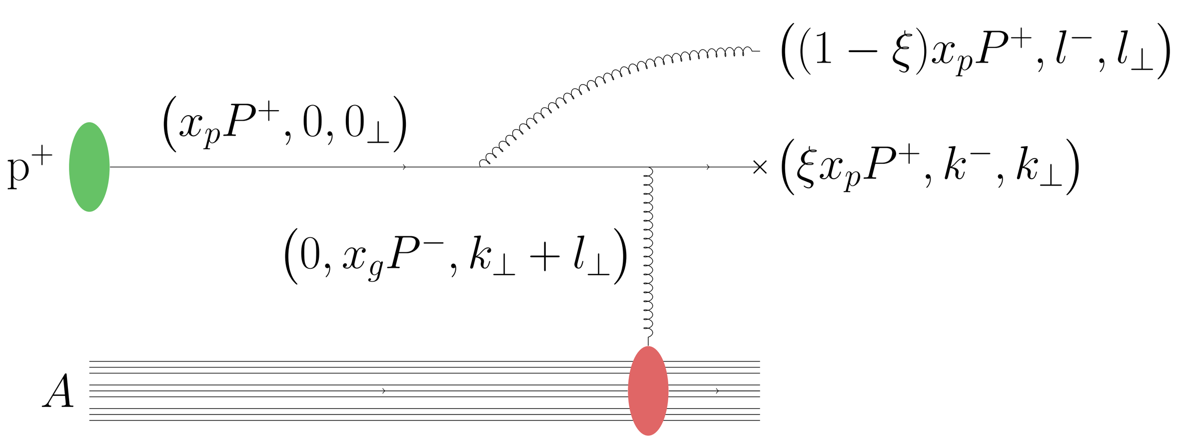
Cross section in the hybrid formalism



The hybrid factorization scheme, also called dilute-dense factorization, expresses a cross section in terms of an integrated parton distribution, representing the structure of the projectile proton, and an unintegrated dipole distribution, representing the structure of the target nucleus.

$$\frac{\mathrm{d}^3\sigma}{\mathrm{d}Y\,\mathrm{d}^2\vec{p}_\perp} = \sum_{i,j\in q,g}\sum_{k\in\{0,1\}}\int_\tau^1 \frac{\mathrm{d}z}{z^2}\int_{\tau/z}^1 \mathrm{d}\xi\, x f_i(x,Q^2) D_{h/j}(z,Q^2)\int \mathrm{d}^2\vec{x}_\perp \mathrm{d}^2\vec{y}_\perp\, \mathcal{H}_{ij}^{(k)}(z,\xi,\vec{x}_\perp,\vec{y}_\perp) S(z,\vec{x}_\perp,\vec{y}_\perp)$$

Kinematical Constraint



The emitted gluon is subject to a kinematical constraint that restricts it to a minimum amount of plus-component momentum.

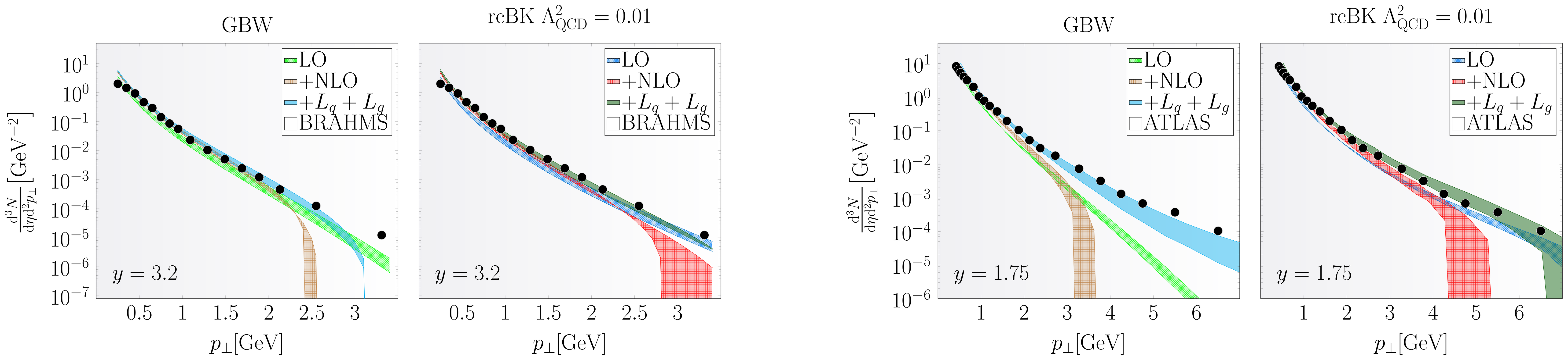
$$x_g P^- = \frac{l_\perp^2}{2(1-\xi)x_pP^+} + \frac{k_\perp^2}{2\xi x_pP^+} \le P^-$$

$$x_g \le 1 \qquad \Longrightarrow \qquad \xi \le 1 - \frac{l_\perp^2}{x_p s}$$

This modifies the dipole splitting functions, leading to new terms in the cross section contributing at next-to-leading order. Earlier work (Chirilli et al. 2012) omitted this modification, but we have now derived it and calculated the effect numerically.

Results for RHIC and LHC

Previous results (Staśto, Xiao, and Zaslavsky 2014) exposed the problem of negative NLO contributions at high $p_\perp$. Now, we see that the new terms arising from the kinematical constraint help offset the negativity. We are able to describe the data at forward rapidity from both RHIC and LHC experiments, up to high enough $p_\perp$ that the collinear factorization takes over (Staśto, Xiao, Yuan, et al. 2014).



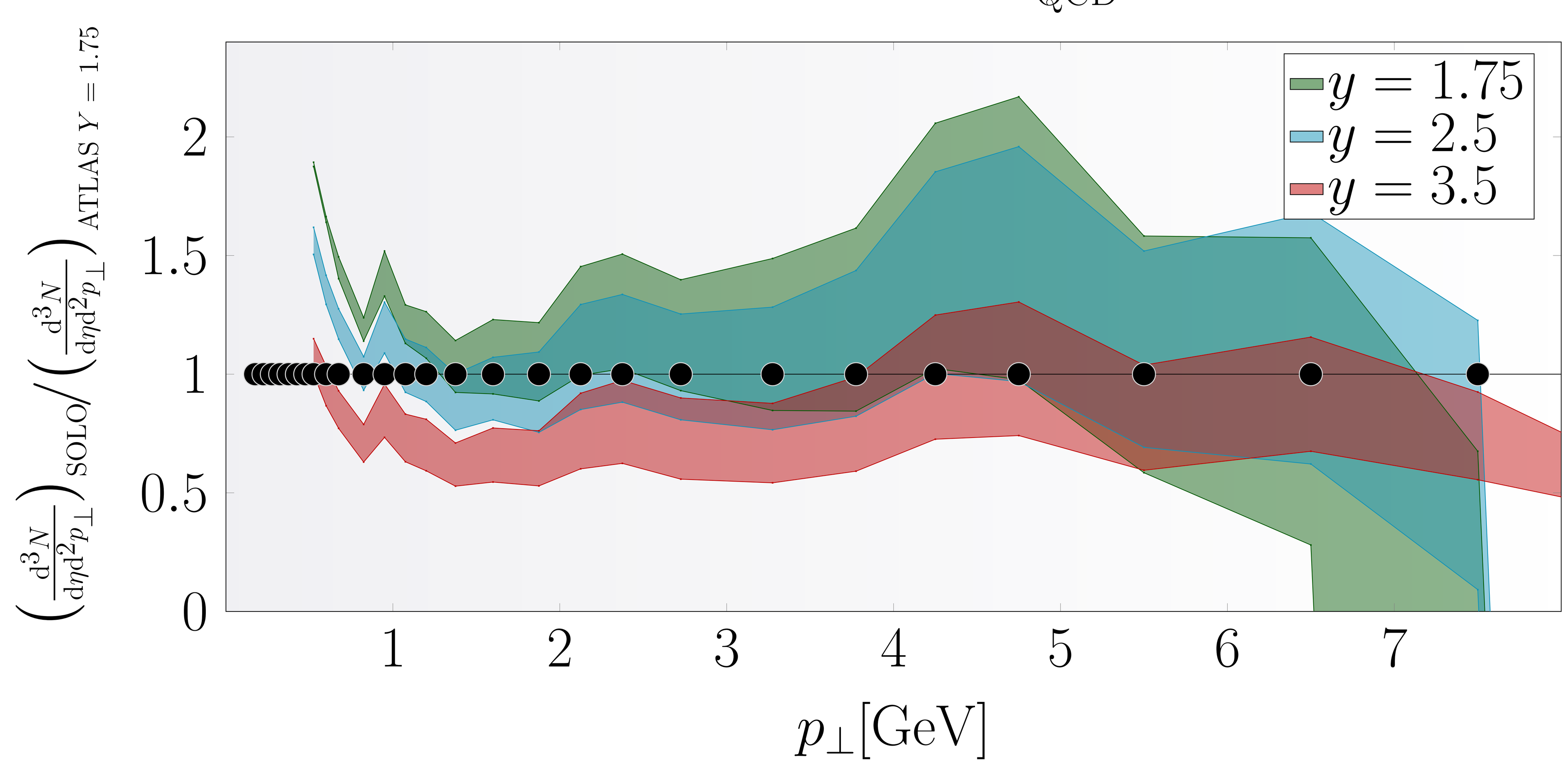
Confirming Saturation?

Wanted: data from LHC experiments (perhaps LHCb) at more distinct forward rapidities

This result has the potential to be a strong confirmation of saturation physics, but more comparisons with experimental data are needed; in particular, it should be able to correctly predict the variation of the cross section with rapidity.

The figure of interest is the ratio of the yield computed by our numerical program SOLO, at various forward rapidities, to the ATLAS data at rapidity $y = 1.75$. On the right are results for this ratio using the rcBK solution with GBW initial condition as the gluon distribution, with all leading and next-to-leading order terms (including the kinematic corrections) incorporated in the calculation. At moderate $p_\perp$ of roughly 1 GeV to 3 GeV, the theoretical uncertainty becomes small and the results for different rapidities can be distinguished, making this ideal for testing the saturation model's predictions!

Ratio to Data: rcBK $\Lambda^2_{\mathrm{QCD}} = 0.01$



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