Studying dense gluonic matter at LHCb

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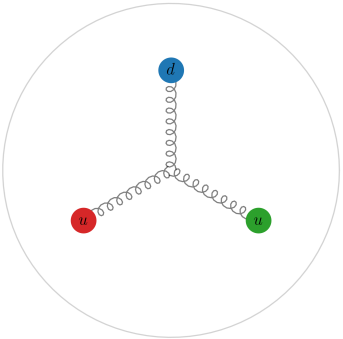
Zooming in on the proton

Energy scale $Q \sim 1/\lambda$

$\lambda > r_p \sim 10^{-15}$ m

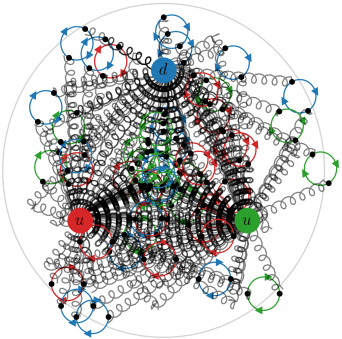
Can't resolve internal structure



$\lambda < r_p$

Quarks and gluons (partons)

QCD!

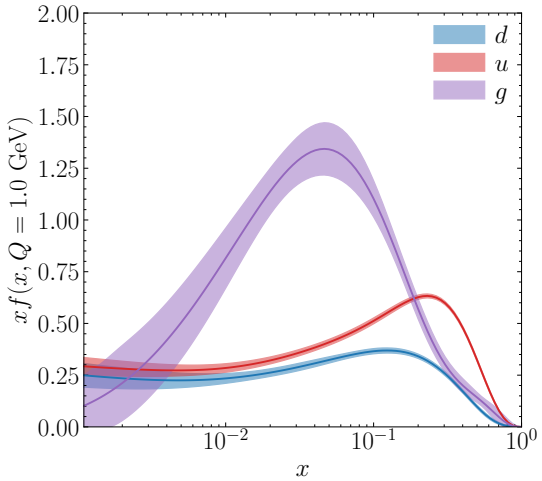


$\lambda \ll r_p$

Parton sea emerges

Parton Distribution Functions (PDFs)

PRD 103 (2021) 1, 014013

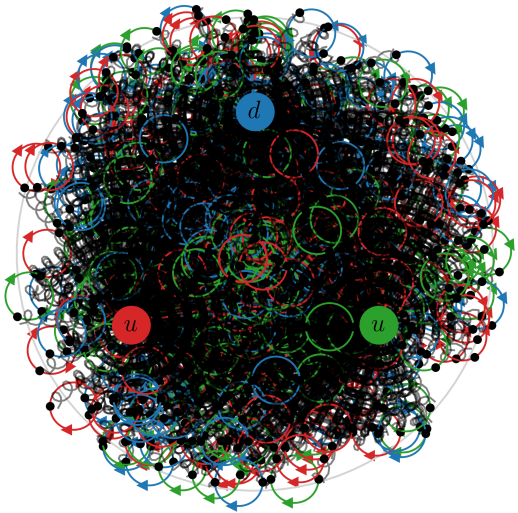


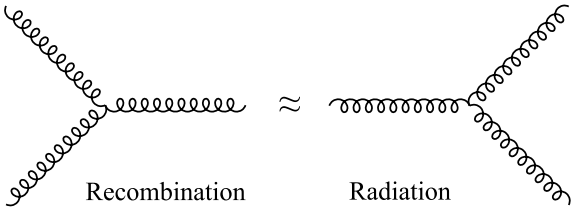
DGLAP equation

$$\frac{d}{\ln Q^2}\begin{pmatrix} q \\ g \end{pmatrix} = \left(\quad \right) \begin{pmatrix} q \\ g \end{pmatrix}$$

- $\boldsymbol{x}$: momentum fraction carried by parton
- Nonperturbative initial conditions determined from global fits to data
- QCD radiation produces the parton sea

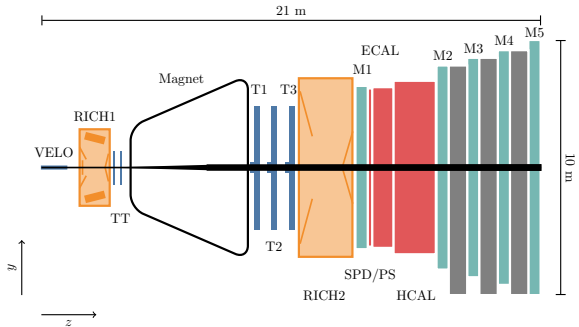
Gluon saturation



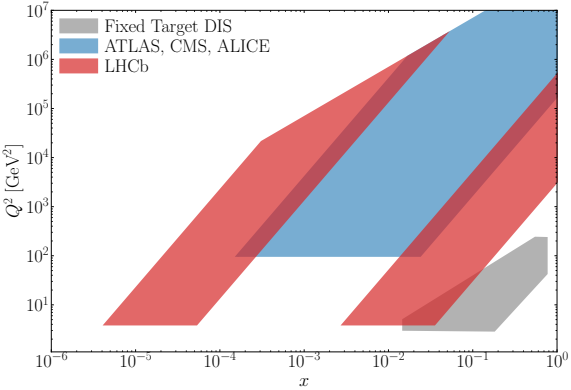


- At high densities, the proton will saturate, resulting in nonlinear (non-DGLAP) parton density evolution.
- Gluon density is highest at low x and is enhanced in heavy nuclei by $A^{1/3}$.

LHCb detector and coverage [Int. J. Mod. Phys. A 30 (2015) 07, 1530022]



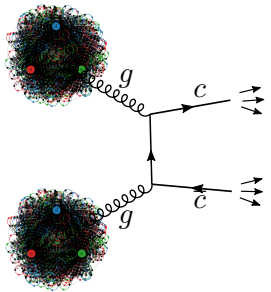
- Forward acceptance: $2 < \eta < 5$
- **tracking**, **calorimetry**, **RICH**, **muon**
- Excellent vertex resolution ($10 - 50$ μm in x and y)

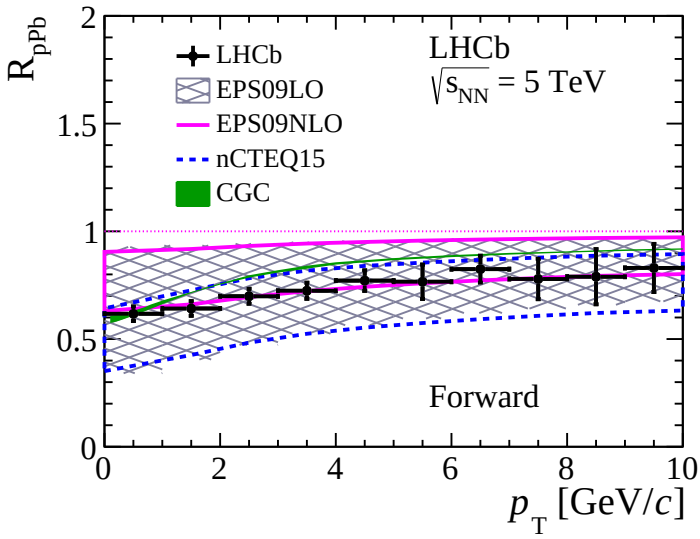


Collect data in the p-going (low-x) and Pb-going (high-x) configurations

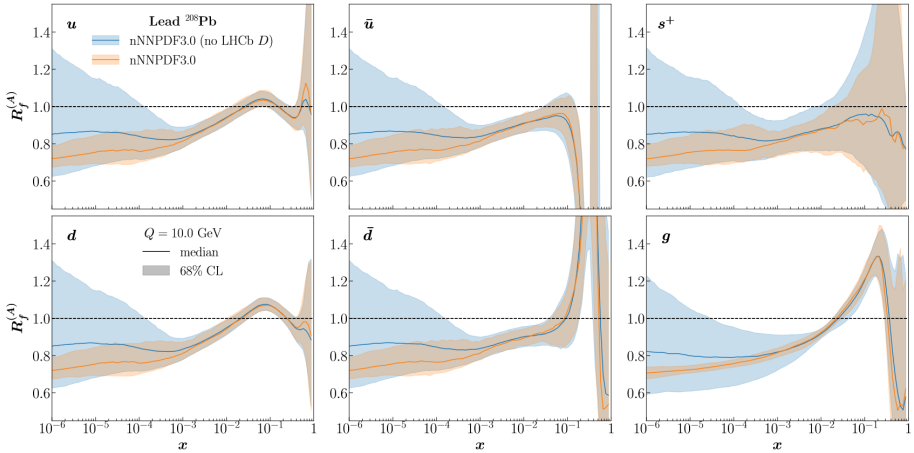
Charm hadron production [JHEP 10 (2017) 090]

$$R_{p\mathrm{Pb}} = \frac{1}{208}\frac{\sigma_{p\mathrm{Pb}}}{\sigma_{pp}}$$





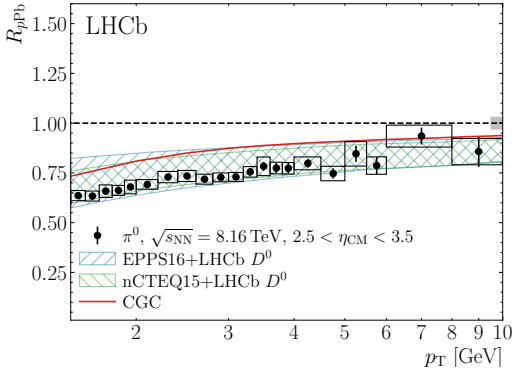
The impact of LHCb data [EPJC 82 (2022) 6, 507]

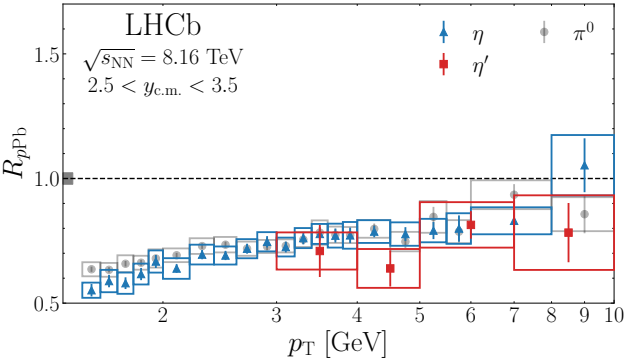


Low-x nPDF are now constrained! $\rightarrow$ **Overconstrain** to look for nonlinear evolution.

π^0, η, and η' production [PRL 131 (2023) 042302, arXiv:2310.17326]

$$m(\pi^0) < m(\eta) < m(\eta') < m(D^0)$$





Precise and consistent description of the nucleus at low x across multiple observables.

LHCb is studying matter at unprecedented gluon densities!