Constraining the low-x structure of nuclei with LHCb

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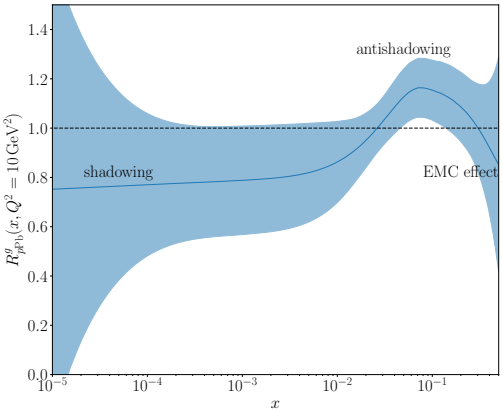
on behalf of the LHCb collaboration

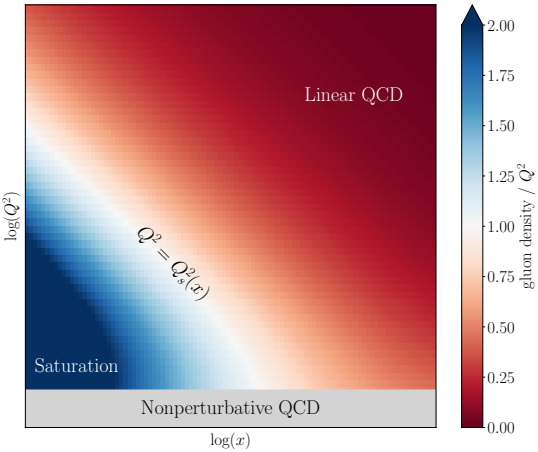
Quark Matter 2023
September 5, 2023

The goals of low-x physics

Describe nucleon structure at low x

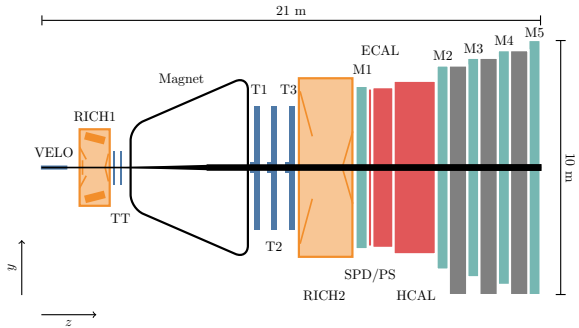


Understand QCD at high gluon densities

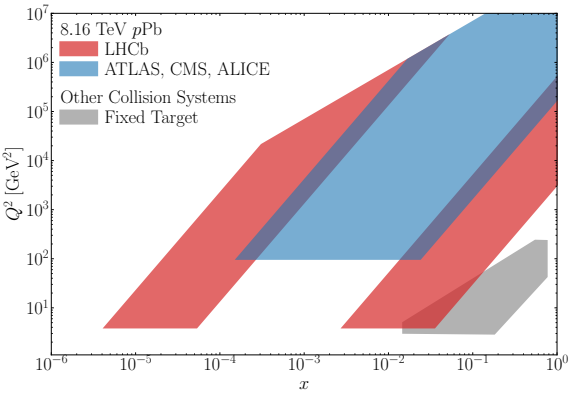


EPPS16, EPJC 77 (2017) 3, 163

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

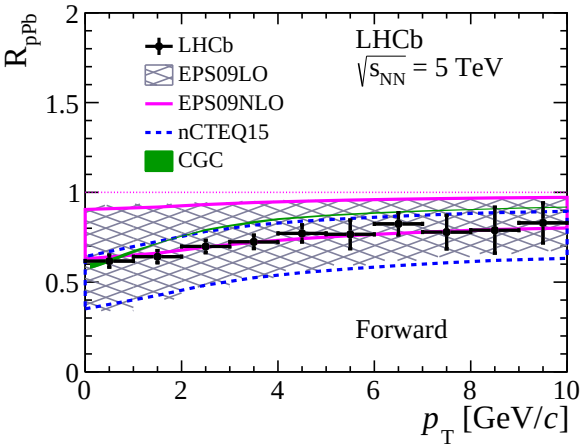


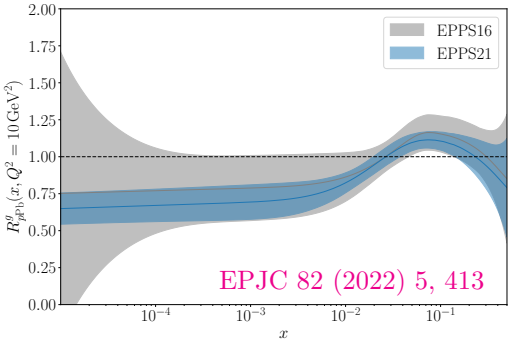
- Forward acceptance: $2 < \eta < 5$
- **tracking**, **calorimetry**, **RICH**, **muon**
- Excellent vertex resolution ($10 - 50$ μm in x and y)



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

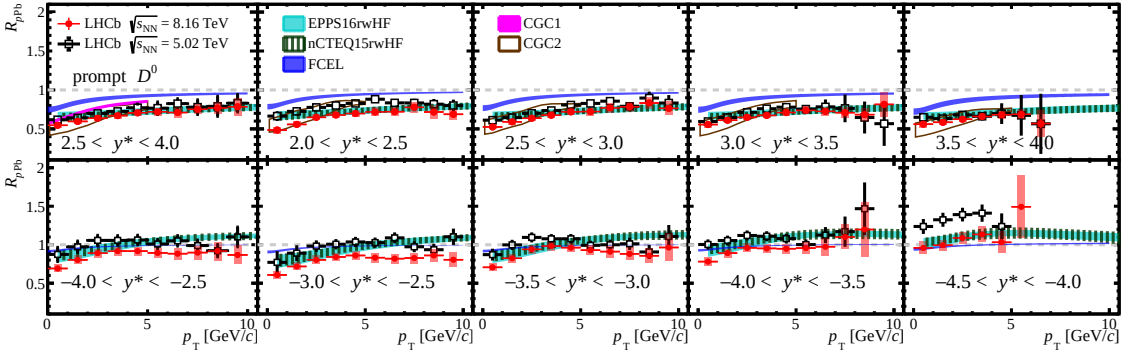
Open charm: D^0 at 5.02 TeV (JHEP 10 (2017) 090)





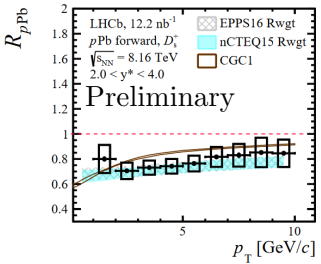
LHCb D^0 data now tightly constrains the gluon nPDF at low x. New data will overconstrain and could reveal non-linear QCD, breakdown of collinear factorization, etc.

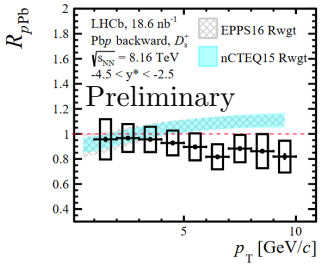
Open charm: D^0 at 8.16 TeV (arXiv:2205.03936, accepted by PRL)

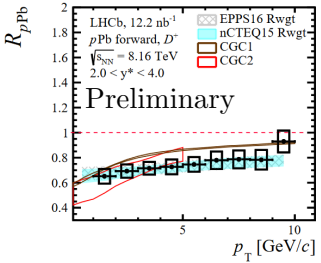


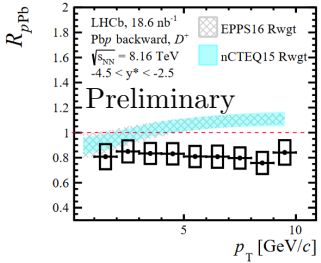
Larger 8.16 TeV dataset allows for higher precision and higher energy provides access to lower x. Good agreement with predictions and 5.02 TeV data at forward rapidity, but tension at backward rapidity.

Open charm: $D^{\pm}_{(s)}$ at 8.16 TeV (LHCb-PAPER-2023-021, **NEW!**)







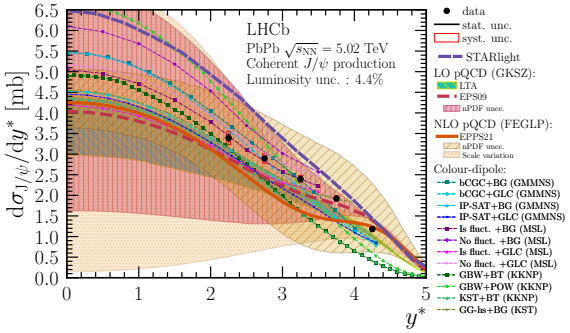


- Similar pattern to D^0 production: good agreement at forward rapidity with unexpected suppression at backward rapidity.
- See Chenxi Gu's talk for discussion of implications for hadronization modification

Where do we go from here?

Ultraperipheral Collisions

See Xiaolin Wang's talk tomorrow



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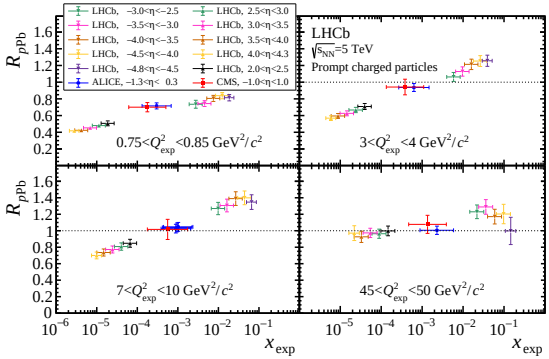
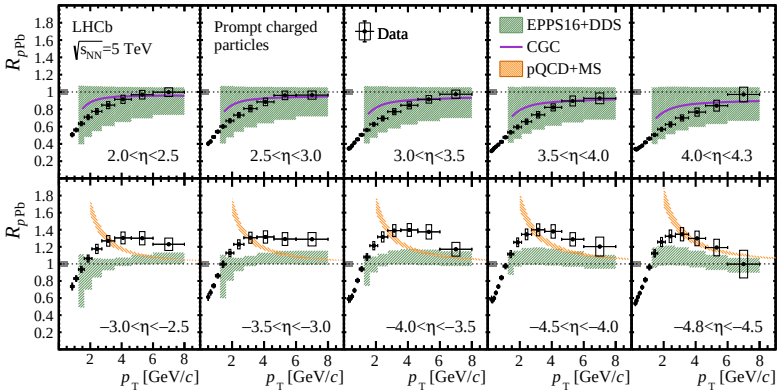
Light Hadron Production



PRL 128 (2022), 142004

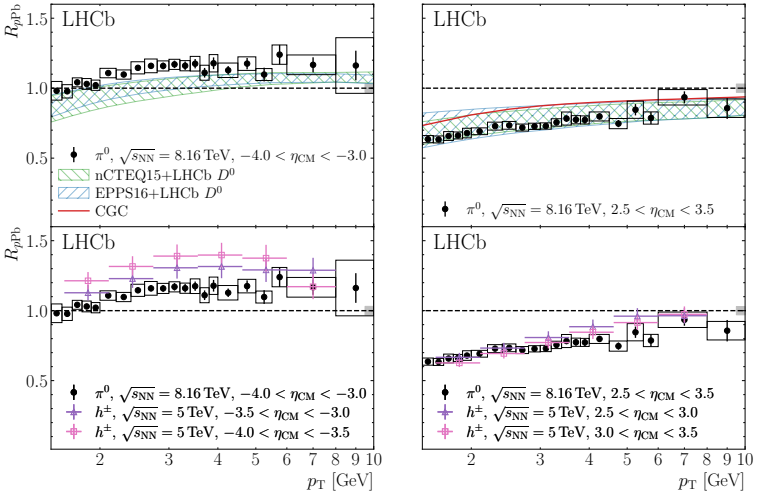
Charged particle production (PRL 128 (2022), 142004)



EPPS16+DDS, CGC, pQCD+MS

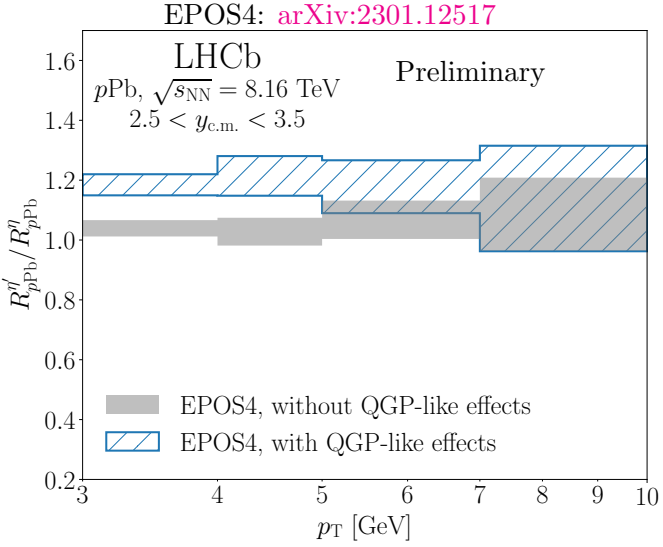
LHCb charged particle data probes gluon densities for $10^{-6} < x < 10^{-1}$ over a wide range in Q^2. Need to understand high-x enhancement in order to make sense of low-x data.

π^0 production (PRL 131 (2023) 042302)



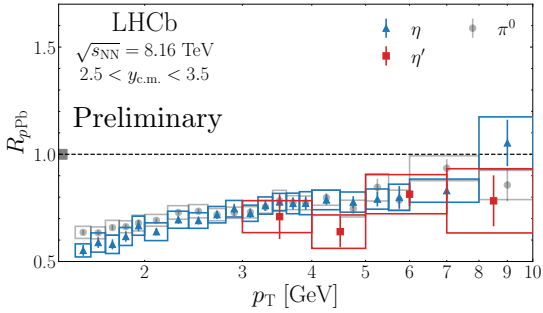
- Excellent agreement with nPDF predictions and charged-particle data at low x
- Small excess at high x
- Possible explanations
  - Radial flow leading to a mass-dependent enhancement
  - Quark coalescence leading to a larger baryon enhancement

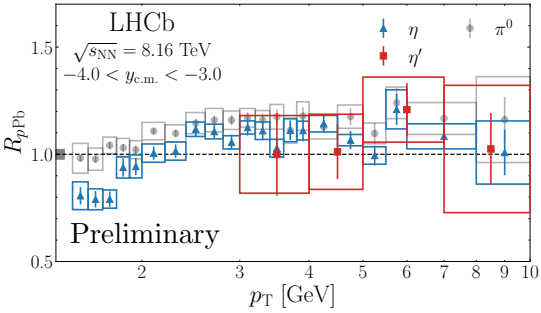
η and η' production (LHCb-PAPER-2023-030, **NEW!**)



- Studying the mass dependence of nuclear effects can help reveal their origin.
- Can help disentangle hot and cold QCD effects.
- Studying the η and the η' allows us to isolate the mass dependence.
- Necessary for future studies of direct photons

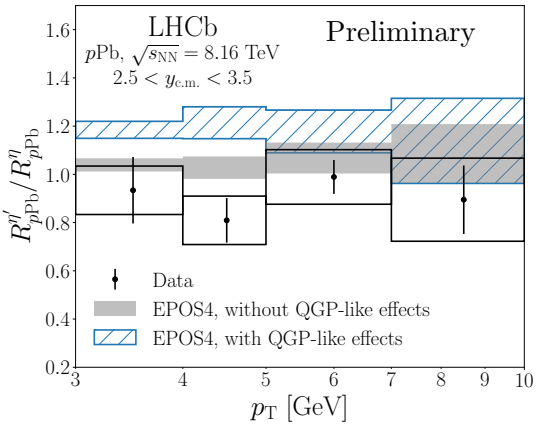
η and η' production (LHCb-PAPER-2023-030, **NEW!**)

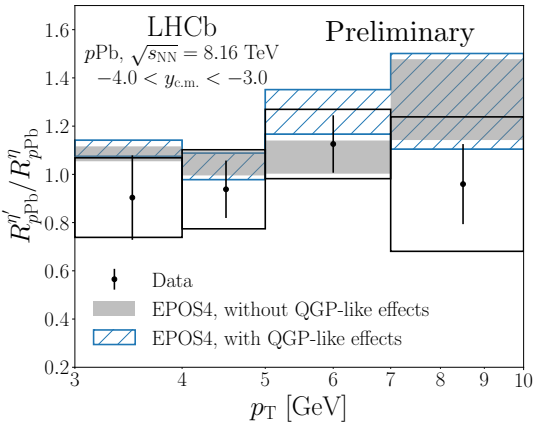




- Study $\eta \to \gamma\gamma$ and $\eta' \to \pi^+\pi^-\eta$.
- π^0, η, and η' nuclear modification factors all agree where they overlap.
- No evidence of mass-dependent effects!

η and η' production (LHCb-PAPER-2023-030, **NEW!**)





No evidence for mass-dependence of the nuclear modification of light neutral hadrons!
Data can constrain models of hot QCD effects in small collision systems.

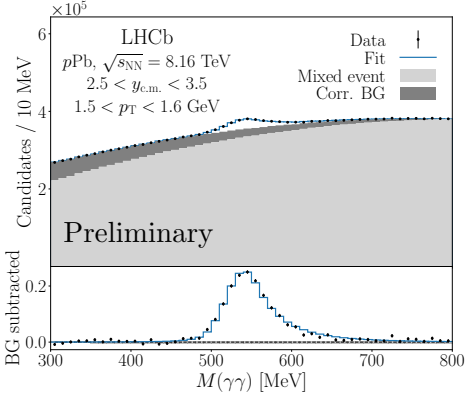
Final thoughts

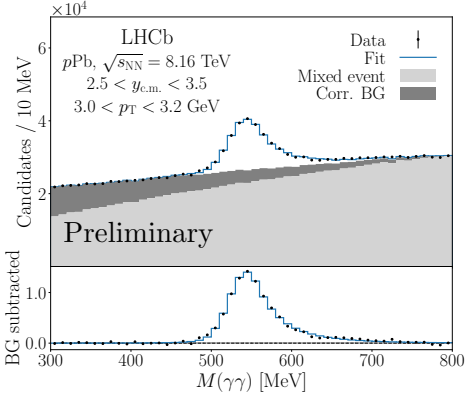
- LHCb data has helped provide a successful description of the nucleon at low x, but understanding the underlying physics is much harder.
- New LHCb open charm production measurements push to lower x with better precision than previous LHCb measurements.
- New LHCb light hadron production measurements will help disentangle low-x effects from hot QCD effects in small collision systems.
- LHCb has a lot of work to do...
  - Identified hadron production measurements ($\pi^{\pm}$, $K^{\pm}$, p, K^0_S, Λ, etc.)
  - Additional photoproduction measurements in UPCs (Xiaolin Wang's talk tomorrow)
  - Direct photon production and photon-hadron correlations

Thank you!

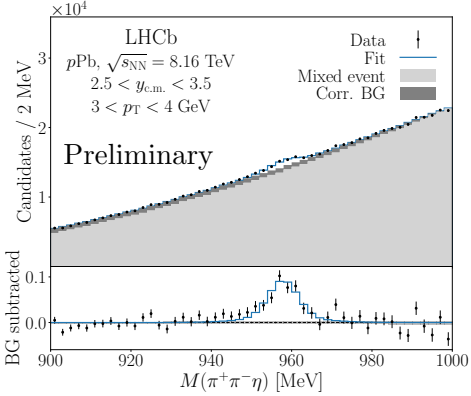
Backup

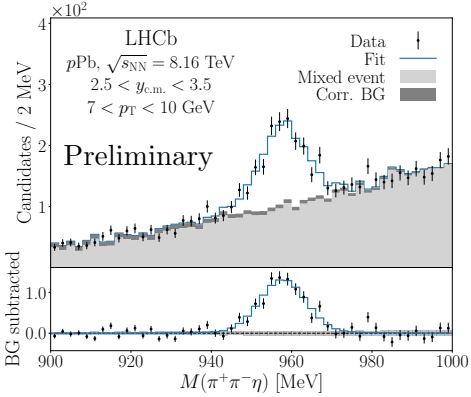
η mass fits (LHCb-PAPER-2023-030, **NEW!**)



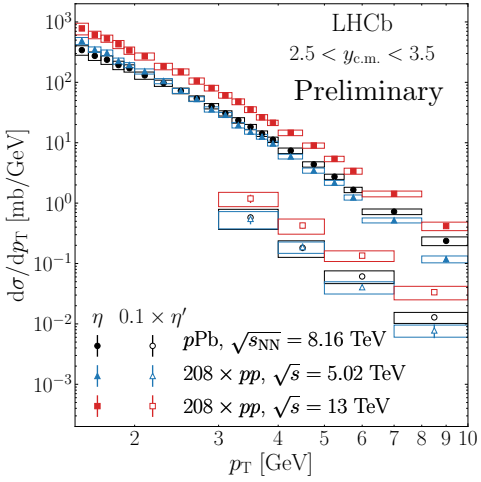


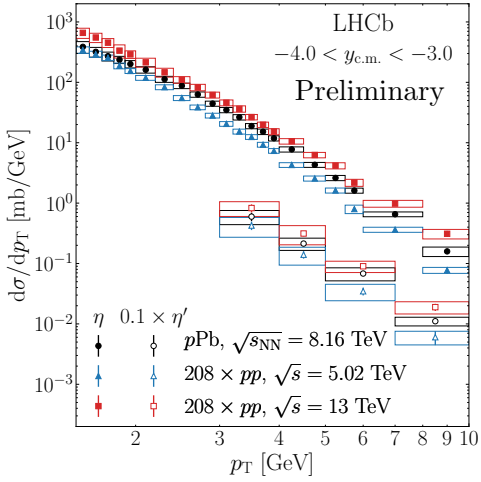
η' mass fits (LHCb-PAPER-2023-030, **NEW!**)





η and η' differential cross sections (LHCb-PAPER-2023-030, **NEW!**)





η/π^0 ratios (LHCb-PAPER-2023-030, **NEW!**)

	$-4.0 < y_{\text{c.m.}} < -3.0$	$2.5 < y_{\text{c.m.}} < 3.5$
5.02 TeV pp	$0.344 \pm 0.006 \pm 0.040$	$0.371 \pm 0.006 \pm 0.045$
13 TeV pp	$0.385 \pm 0.006 \pm 0.050$	$0.407 \pm 0.006 \pm 0.052$
8.16 TeV pPb	$0.346 \pm 0.004 \pm 0.043$	$0.386 \pm 0.004 \pm 0.047$