Light hadron and photon production in pPb collisions at LHCb

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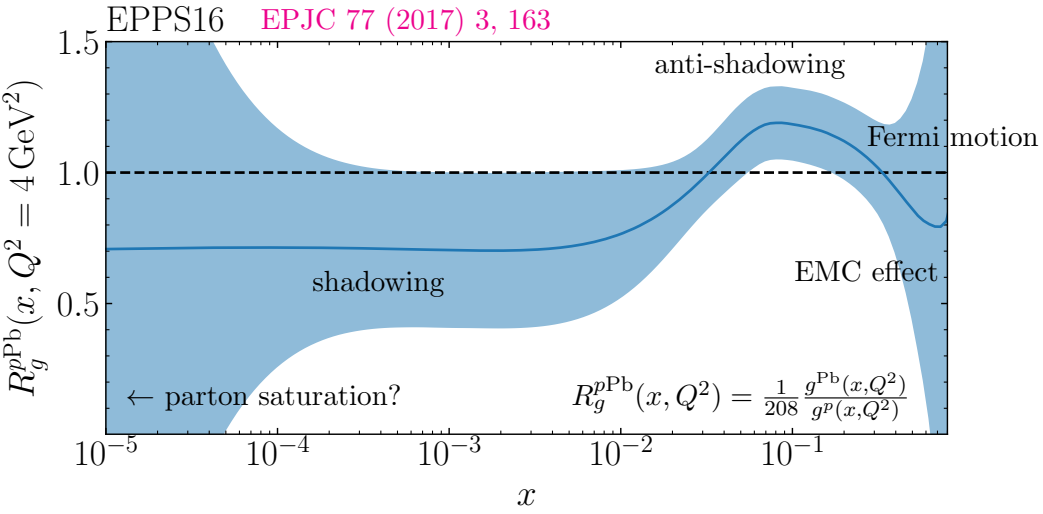
on behalf of the LHCb Collaboration

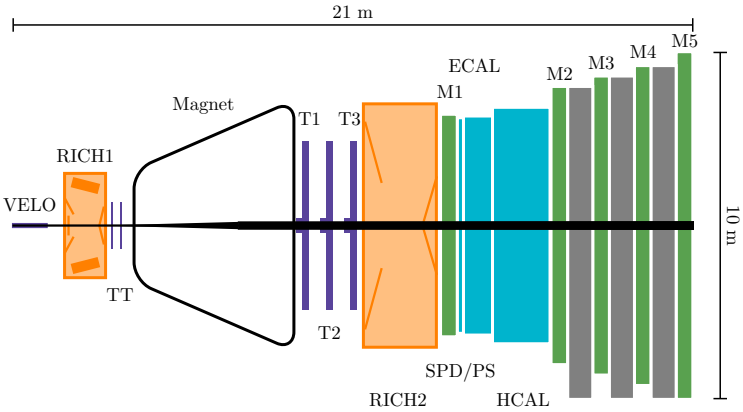
Low-x Workshop
September 30, 2021

Nuclear PDFs

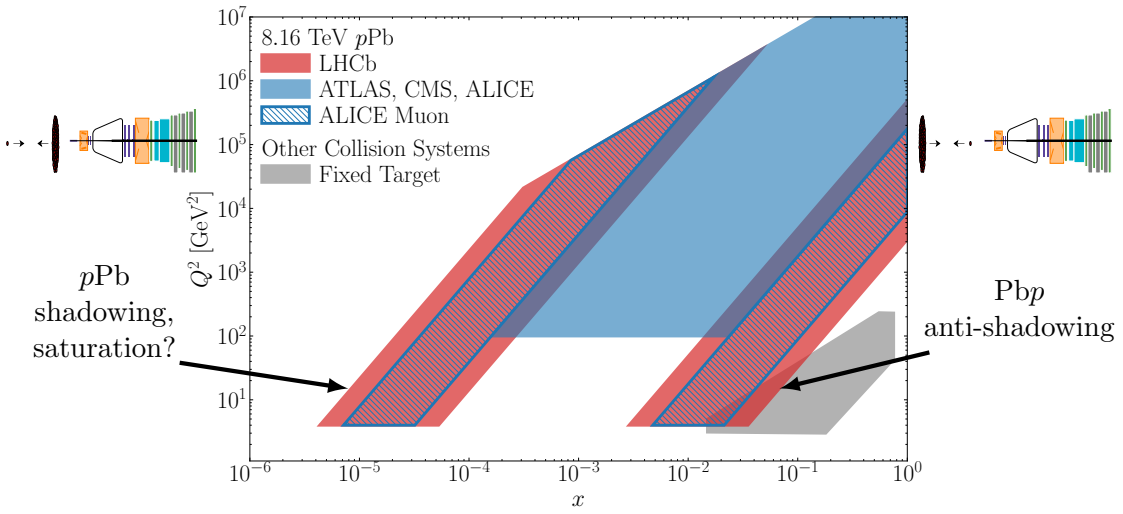


The LHCb detector (Int. J. Mod. Phys. A 30, 1530022 (2015))

- Forward spectrometer: $2 < \eta < 5$
- **tracking**, **calorimetry**, **RICH**, **muon** systems
- Excellent vertex resolution ($10 - 50$ μm in x and y)
- Track $\sigma(p)/p \sim 0.5 - 1.0\%$
- Fixed-target mode with the SMOG system

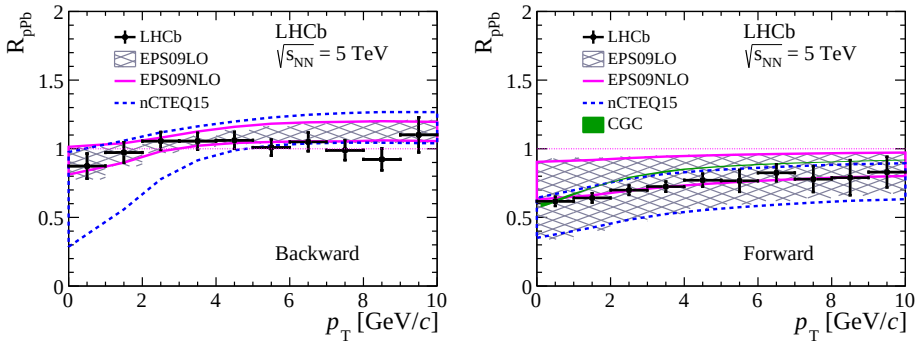


LHCb kinematic coverage



LHCb's impact: D-meson production (JHEP **10**, 090 (2017))

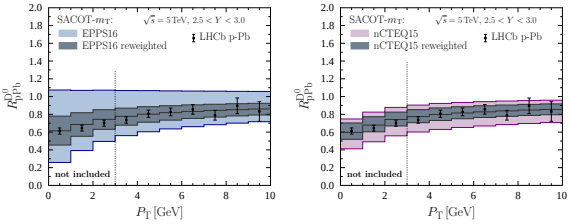
$2.5 < |y_{\rm CM}| < 4.0$ for $p_{\rm T} < 6\,{\rm GeV}$
$2.5 < |y_{\rm CM}| < 3.5$ for $6 < p_{\rm T} < 10\,{\rm GeV}$



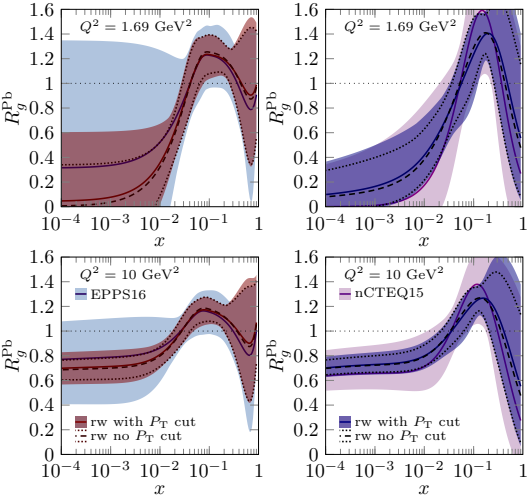
EPS09: JHEP **04**, 065 (2009), nCTEQ15: PRD **93**, no.8, 085037 (2016), CGC: PRD **91**, no.11, 114005 (2015)

- Measured D-meson production in pp and pPb down to $p_{\rm T} = 0$
- Backward measurement probes the high(ish)-x antishadowing region
- Forward measurement probes the low-x shadowing region

LHCb's impact: D-meson production (JHEP **05**, 037 (2020))



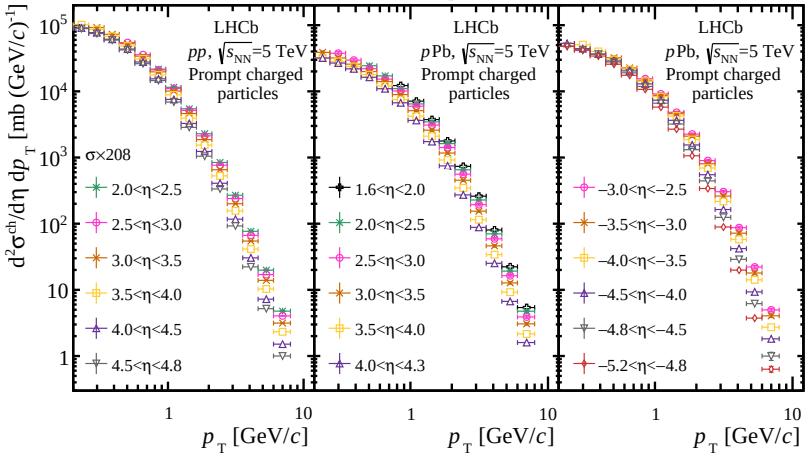
- First studied in PRL **121**, no.5, 052004 (2018)
- LHCb D production data incorporated using Hessian reweighting (EPJC **79**, no.6, 511 (2019))
- LHCb data provide strong constraints on gluon nPDFs, especially at low-x



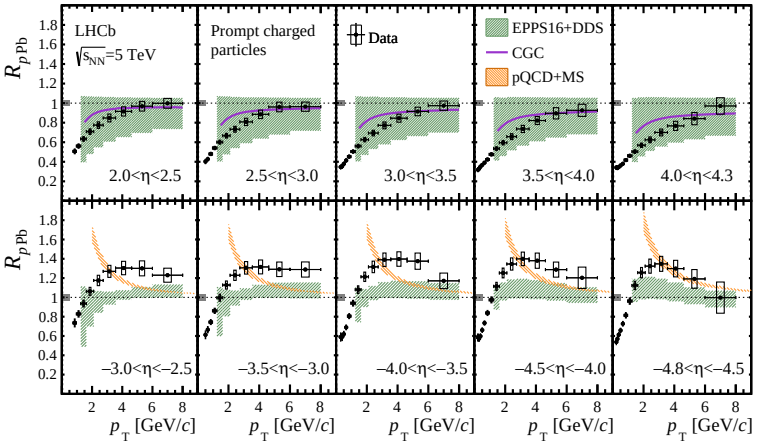
"rw" = Reweighted with LHCb D production data

Prompt charged particle production (arXiv:2108.13115)

- Forward measurement probes unexplored x: $10^{-6} \lesssim x \lesssim 10^{-4}$
- Potentially probes the saturation region at low p_{T}
- Measurement is very precise: $\mathrm{d}^2\sigma/\mathrm{d}p_{\mathrm{T}}\mathrm{d}\eta$ ($R_{p\mathrm{Pb}}$) uncertainties as small as 3% (4%)



Prompt charged particle production (arXiv:2108.13115)

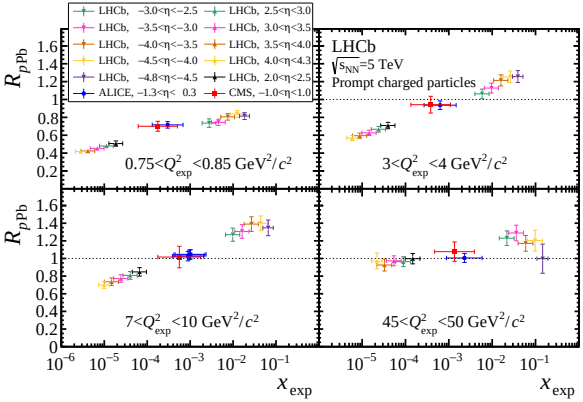


Theory predictions

- EPPS16+DDS
  JHEP **09**, 138 (2014)
- CGC
  PRD **88**, 114020 (2013)
- pQCD+MS
  PRD **88**, 054010 (2013)

- Strong suppression at forward rapidities
- Large enhancement at backward rapidities not explained by nPDF calculations

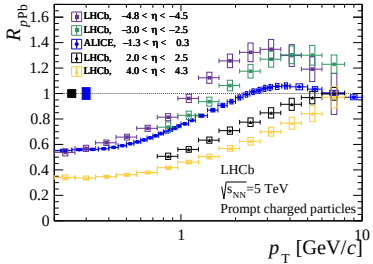
Prompt charged particle production (arXiv:2108.13115)

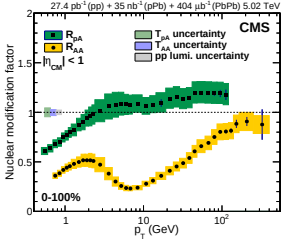


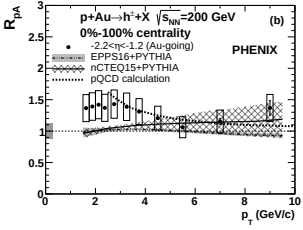
ALICE: JHEP **11**, 013 (2018)
CMS: JHEP **04**, 039 (2017)

- Study the evolution of $R_{p\mathrm{Pb}}$ using experimental proxies for x and Q^2
- $Q^2_{\mathrm{exp}} = m^2 + p^2_{\mathrm{T}}$,
  $x_{\mathrm{exp}} = \frac{Q_{\mathrm{exp}}}{\sqrt{s_{\mathrm{NN}}}} e^{-\eta_{\mathrm{CM}}}$
- Continuous evolution in x_{exp} at various Q^2_{exp} across multiple experiments

Prompt charged particle production (arXiv:2108.13115)







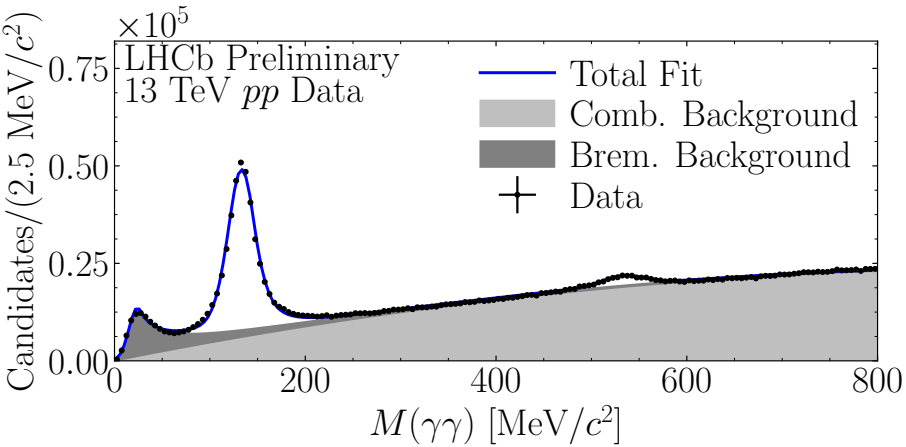
The big picture

- At forward rapidities, LHCb is probing unexplored territory
- Large excess at backward rapidities
- CMS sees a large enhancement in pPb at high p_T (JHEP **04**, 039 (2017))
- PHENIX sees a large enhancement at low p_T PRC **101**, no.3, 034910 (2020)
- All three enhancements occur at similar x and no theory calculation successfully describes all of them

Neutral pion production (work in progress)

- Charged particles and π^0s share similar production processes and kinematic regimes
- For π^0s, the particle species is known, so measurements are easier to interpret
- Systematic uncertainties are mostly independent
- π^0 production measurements will further constrain PDFs and will provide information that can help explain large charged particle excesses at high x
- Neutral meson spectra are needed for direct photon searches

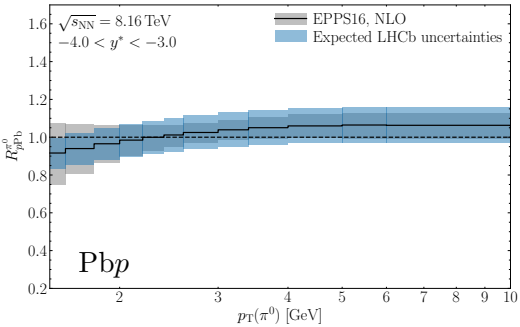
Neutral pion production (work in progress)

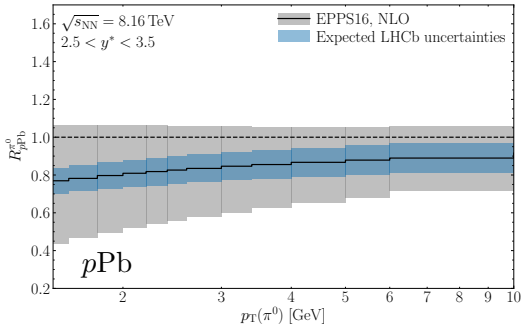


- Reconstruct photons that convert in the detector material
- Combine converted photons with ECAL photons to reconstruct π^0 candidates
- Extract yields using fits to the diphoton mass spectra

Neutral pion production (work in progress)

$$R^{\pi^0}_{p\mathrm{Pb}}(p_\mathrm{T}) = \frac{1}{208}\frac{\mathrm{d}\sigma^{\pi^0}_{p\mathrm{Pb}}/\mathrm{d}p_\mathrm{T}}{\mathrm{d}\sigma^{\pi^0}_{pp}/\mathrm{d}p_\mathrm{T}}$$

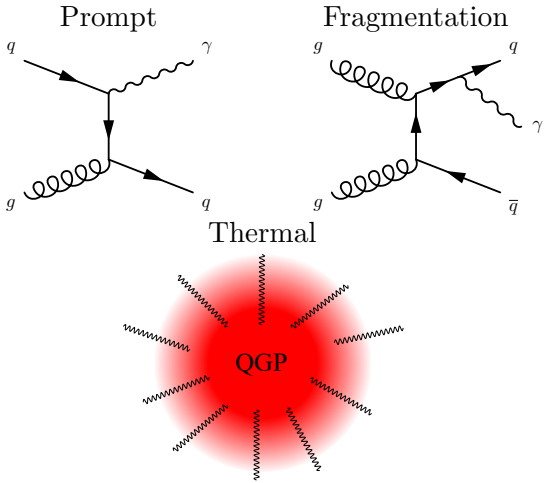




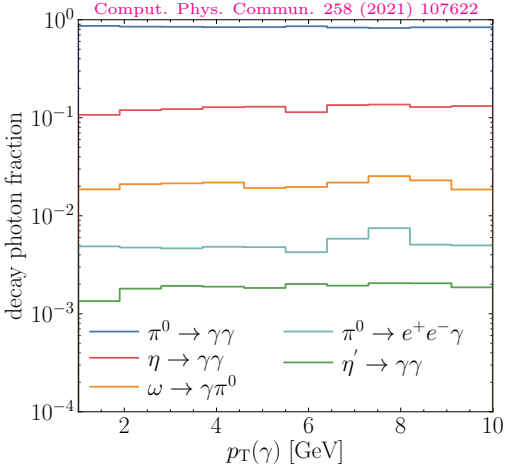
- Theory predictions from JHEP 09 (2014) 138
- Expected LHCb uncertainties dominated by photon reconstruction efficiency

Direct photon production (work in progress)

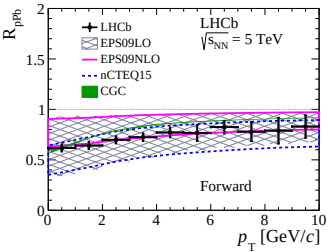
Direct Photons

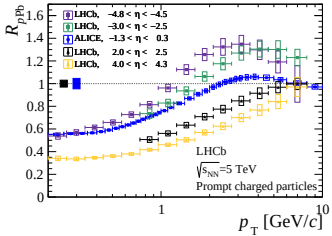


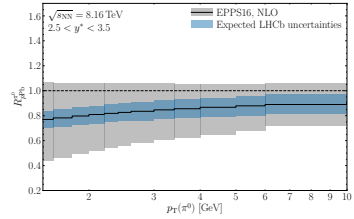
Decay Photons



Conclusion







- LHCb data has already had a large impact on low-x nPDFs
- Measurements of charged particle, π^0, and direct photon production at LHCb will provide complementary strong constraints
- Entering an era of precision measurements in the shadowing regime

Thank You!