Prompt Photon Production at LHCb

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on behalf of the LHCb collaboration

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Quark Matter
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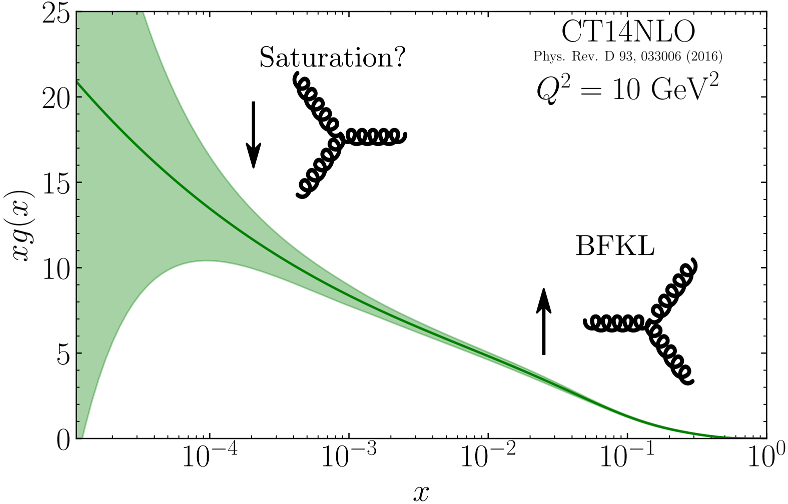
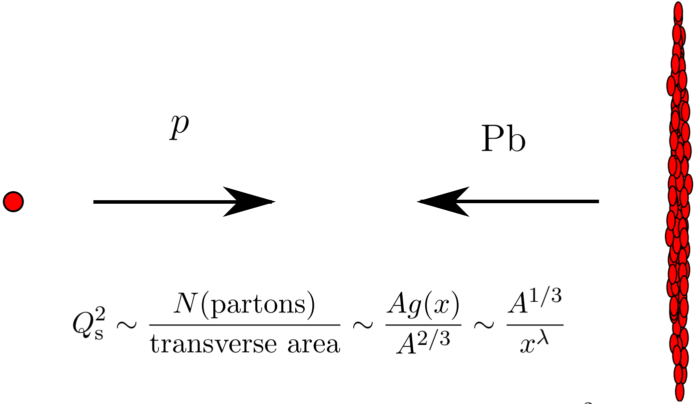
Gluon Saturation

At high number density, expect gluon recombination to compete with gluon splitting, leading to saturation of the gluon PDF



Saturation Scale

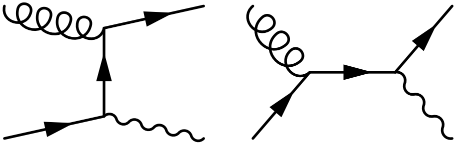
- Saturation effects are important when $1/Q \gtrsim$ distance between partons
- Characterized by the saturation scale Q_s^2
- Probe sees a Lorentz-contracted disk of area $\sim \pi A^{2/3}$



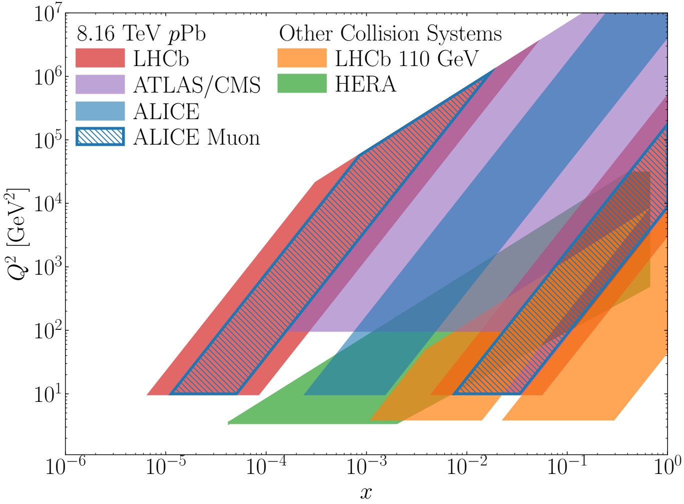
$$Q_\mathrm{s}^2 \sim \frac{N(\text{partons})}{\text{transverse area}} \sim \frac{A g(x)}{A^{2/3}} \sim \frac{A^{1/3}}{x^\lambda}$$

- Ideal observables will be sensitive to low-x gluons at low Q^2 in heavy nuclei

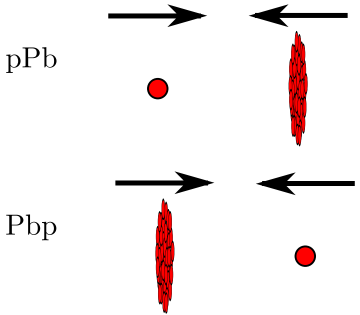
Direct Photons



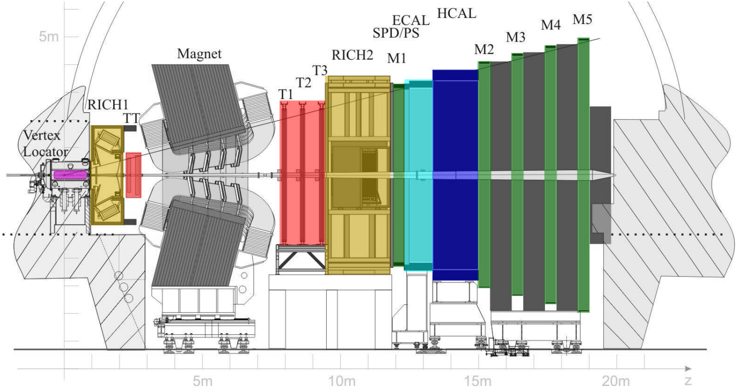
- Direct photons sensitive to gluon PDF
- LHCb has access to direct photon production at low x in unexplored kinematic territory
- Low-p_{T} ($\lesssim 5$ GeV) direct photons are most sensitive



The LHCb Detector



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



- Designed to study B decays in pp collisions
- Participated in 2013 and 2016 pPb runs
- Began participating in AA runs in 2015

- Fully instrumented for $2 < \eta < 5$
- Tracker, ECAL, HCAL, Muon
- High precision vertex locator (VELO)
- Ring imaging Cherenkov (RICH)

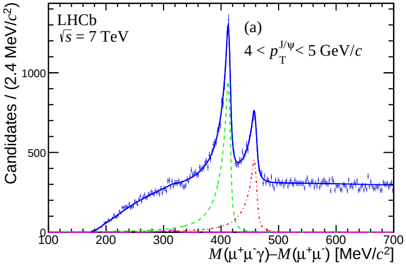
Strategy

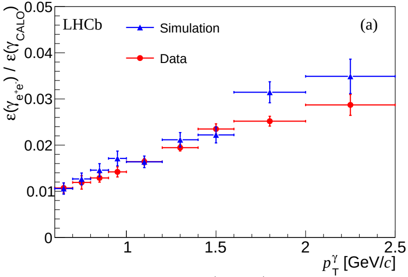
Converted photons

- Better energy resolution than ECAL photons at low-p_{T}
- No backgrounds from merged π^0s

Isolation

- Define a cone of $\Delta R \coloneqq \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.5$ around each converted photon
- Combine with converted photons with ECAL photons in cone to find contribution from π^0 decays
- Cut on $\sum_{\mathrm{cone}} p_{\mathrm{T}}$ to enhance direct photon signal
- Use unisolated pp data as a control





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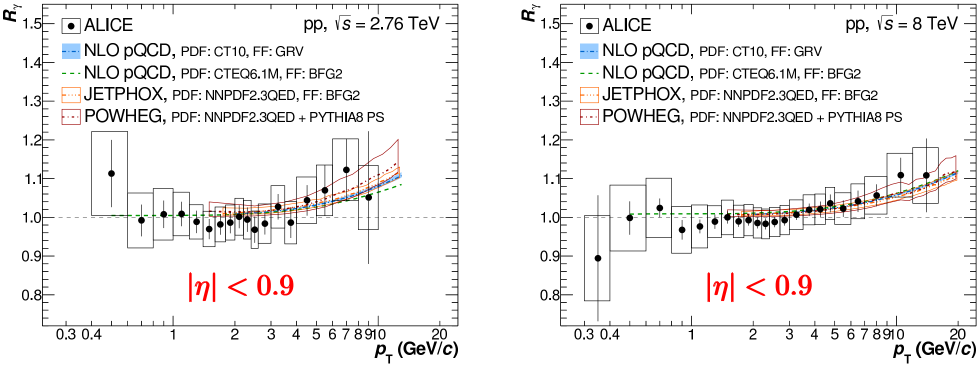
Report results in terms of the double ratio R_γ

$$R_\gamma = \frac{(\gamma^{\text{inc}}/\gamma^{\pi^0})_{\text{Data}}}{(\gamma^{\text{dec}}/\gamma^{\pi^0})_{\text{MC}}}$$

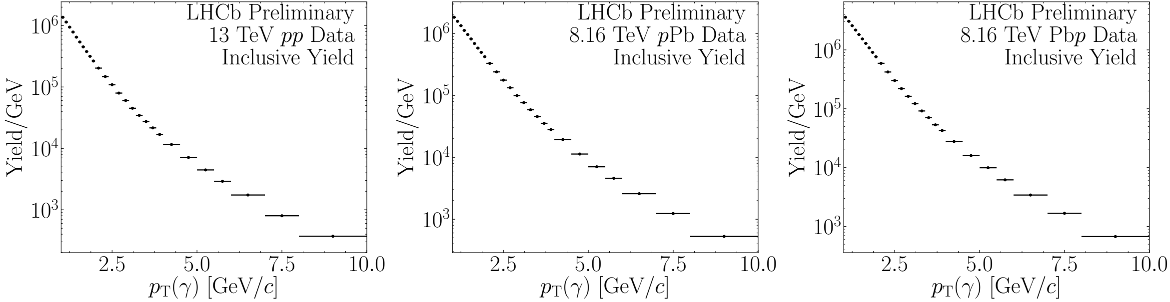
Similar to the strategy used in ALICE direct photon studies



ALICE, arXiv:1803.09857

Photon Reconstruction

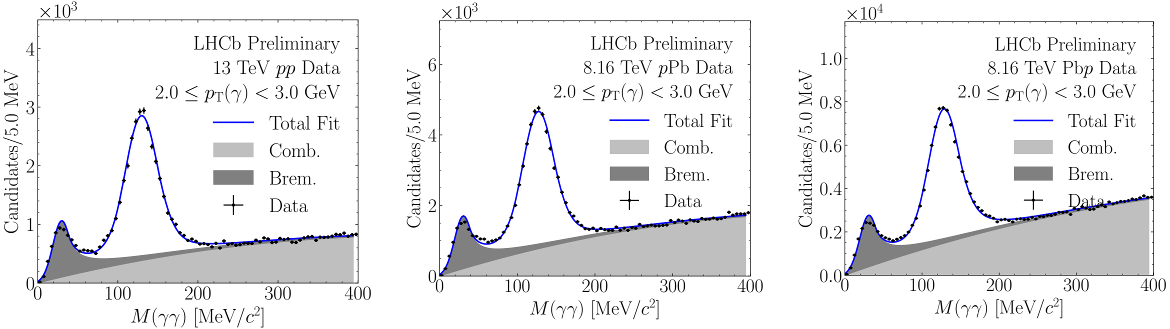
$$R_\gamma = (\gamma^{\text{inc}}/\gamma^{\pi^0})_{\text{Data}} \Big/ (\gamma^{\text{dec}}/\gamma^{\pi^0})_{\text{MC}}$$



- Study photons with $1 < p_{\mathrm{T}} < 5$ GeV and $2.5 < \eta < 4.0$
- Use only electrons without associated VELO hits to improve resolution

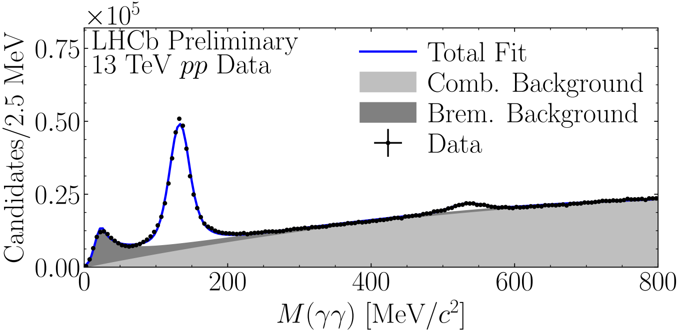
π^0 yield extraction

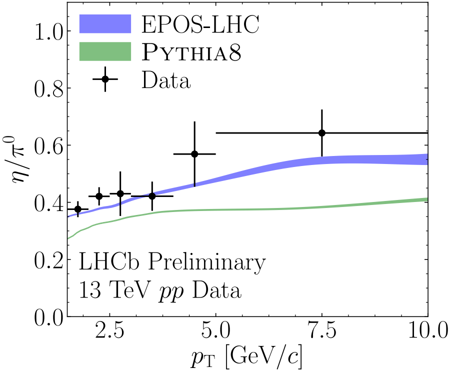
$$R_\gamma = (\gamma^{\text{inc}} / \gamma^{\pi^0})_{\text{Data}} \Big/ (\gamma^{\text{dec}} / \gamma^{\pi^0})_{\text{MC}}$$



- Extract π^0 component by fitting the $\gamma^{\text{conv}} + \gamma^{\text{ECAL}}$ mass spectrum
- Must be corrected for ECAL photon efficiency
- Data-driven study using $(B^+ \to \chi_{c1}(\to \gamma J\psi)K^+) \Big/ (B^+ \to J/\psi K^+)$ in progress
- Consistent with MC to within 6% (BR uncertainty)

η/π^0

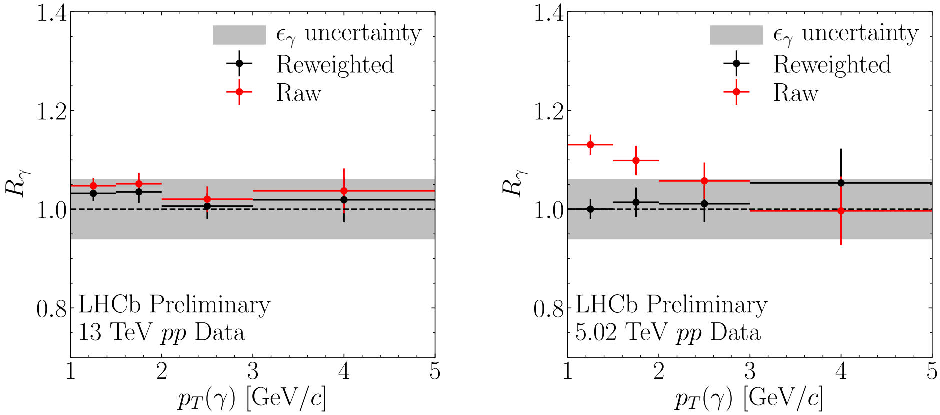




- Need to know the fraction of decay photons originating from π^0 decays
- Can check by measuring η/π^0
- Only $\sim 15\%$ of decay photons are from η decays, so this leads to percent level effects on R_γ

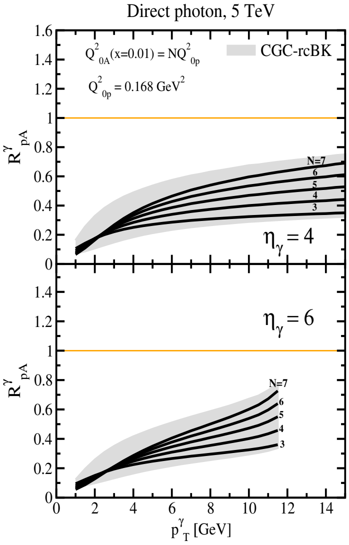
Control Results

- Use 13 TeV pp MC for the denominator in each double ratio
- Reweight to correct for differences in multiplicity and underlying π^0 p_{T} spectrum
- Consistency between 13 TeV and 5 TeV means we can use control studies to drive down uncertainties in photon efficiency



Observables

Phys. Lett. B718 (2013) 1058



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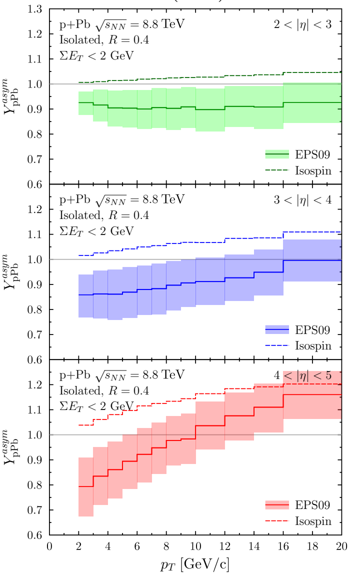
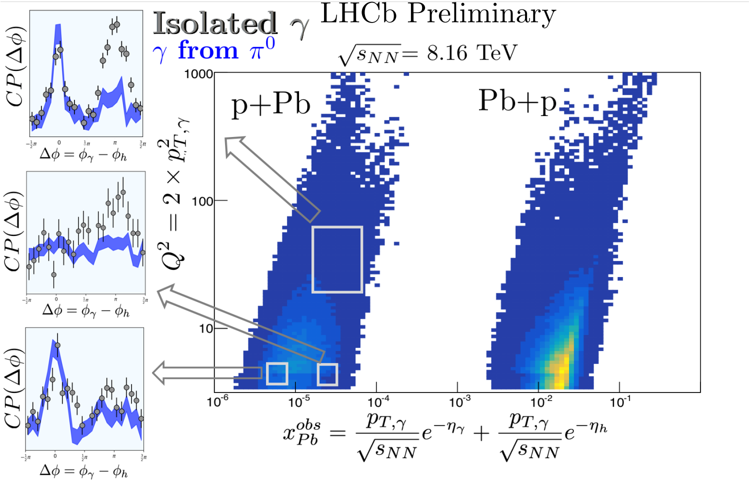


- Saturation causes large suppression in $R_{p\text{Pb}}$, but the direct photon contribution in inclusive pp is small and will require additional work to drive down systematics
- Observables such as $R_{\text{FB}} := Y^{asym}_{p\text{Pb}}$ and $R^{p\text{Pb}}_\gamma / R^{\text{Pb}p}_\gamma$ can be measured more precisely and are possibly just as interesting

Other LHCb Studies

- LHCb also studying direct $\gamma + h$ correlations
- See poster by Cesar Luiz da Silva for more details



Summary

- Making progress towards measurements of direct photon production at LHCb
- Control studies show that we have a good understanding of systematic effects
- Observables such as R_{FB} and $R_\gamma^{p\mathrm{Pb}}/R_\gamma^{\mathrm{Pb}p}$ allow for more precise but potentially interesting measurements. Theory input welcome!
- LHCb has enormous potential to study saturation physics, and this is just the beginning!