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Forward Physics of D^0 meson: A Study of Production and Angular Correlations in pp and p-Pb Collisions

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Introduction

The impact of cold nuclear matter (CNM) on heavy flavor production and dynamics can be understood by measuring nuclear modification factor and azimuthal angular correlations of open heavy flavors. At forward rapidities (y), these results carry information on gluon saturation effects and the role of parton distribution functions in nuclear environments. Experimental measurements from LHCb on nuclear modification factor R_{pPb} and azimuthal angular correlations of D^0–$\bar{\mathrm{D}}^0$ [1–3] provide numerous testing grounds to investigate the effects of nuclear PDFs, contribution of next-to-leading-order processes and color glass condensate (CGC) formalisms.

Methodology

In this work,we compute the R_{pPb} of D^0 meson and azimuthal angular correlations of D^0–$\bar{\mathrm{D}}^0$ at forward rapidities for different beam remnant treatments with nuclear PDFs [4]. The results are compared to the respective LHCb measurements in pp collisions at = 7 TeV [3] and pPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV [1] and $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV [2]. The pp and pPb collisions in different center of mass energies are modeled with PYTHIA8, with LHAPDF6 to integrate NNPDF4 and nNNPDF3 as the free-proton and nuclear PDF, respectively. PYTHIA8 is deployed with default Monash, and two forward tunes, namely Monash forward, and QCDCR forward [5]. The forward tunes were recently developed in the perspective of forward physics at the LHC and achieve better description of π^0, n and direct photon data at very foward rapidities than default tunes. The default Monash and QCDCR tune differ at the color reconnection level during hadronization, while the Monash forward and QCDCR forward have optimized parameters related to beam remnant physics. Our study allows us to see the effects of PDFs, nPDFs, and different forward beam remnant descriptions within PYTHIA8 on heavy quark production, and azimuthal angular correlation of D^0–$\bar{\mathrm{D}}^0$. It can shed light on the gluon saturation and modification of charm meson kinematics in a nuclear environment.

The nuclear modification factor is calculated as

$$R_{\mathrm{pPb}} = \frac{1}{\langle T_{\mathrm{pPb}} \rangle} \frac{\mathrm{d}^2 N_{\mathrm{pPb}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}{\mathrm{d}^2 \sigma_{\mathrm{pp}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}} \qquad (1)$$

where, $\mathrm{d}^2 N_{\mathrm{pPb}}(\mathrm{d}^2\sigma_{\mathrm{pp}})/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}$ are the p_{T}-differential cross sections in pPb (pp) collisions for a corresponding center of mass energy, and $\langle T_{\mathrm{pPb}} \rangle$ is the thickness factor for Pb. The azimuthal angular correlation of D^0–$\bar{\mathrm{D}}^0$ pairs is calculated with the difference in azimuthal angle of a prompt D^0 meson acting as the trigger (trig), and its associated (assoc) anti-particle in the manner $\Delta\varphi = \varphi_{\mathrm{trig}} - \varphi_{\mathrm{assoc}}$, having kinematic selections $3 < p_{\mathrm{T}} < 12$ GeV/c and $2 < y < 4$.

Results & Discussions

FIG. 1 shows the R_{pPb} predictions from PYTHIA8 with nNNPDF3 for three tunes, compared with LHCb data at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV. At 5.02 TeV, QCDCR underestimates the data at high

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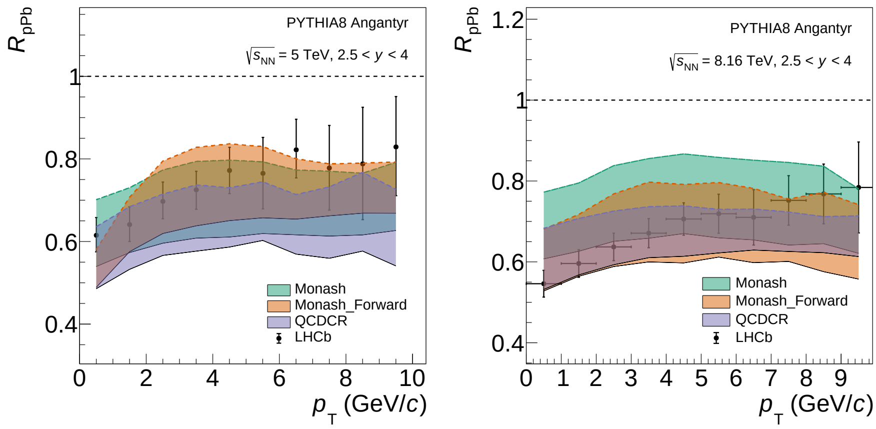

FIG. 1: Comparison of nuclear modification factor of prompt D^0 computed using PYTHIA8 simulation with LHCb measurement at $\sqrt{s_{NN}} = 5.02$ TeV (left) and $\sqrt{s_{NN}} = 8.16$ TeV(right).

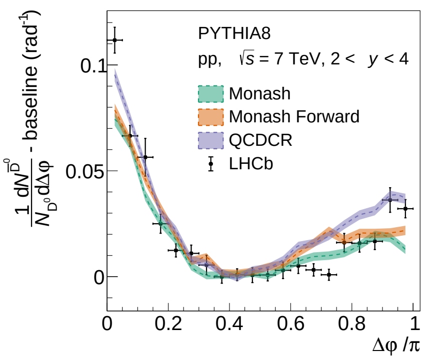

FIG. 2: The comparison of azimuthal angular correlation of D^0–$\bar{D}^0$ obtained for pp collisions at $\sqrt{s} = 7$ TeV with different PYTHIA8 tunes.

p_T, contrary to default and forward Monash tunes. For 8.16 TeV, QCDCR underestimates the forward rapidity data but gives better agreement at low p_T compared to default Monash.

In FIG. 2, the QCDCR forward tune accurately describes near and away side peaks of the D^0–$\bar{D}^0$ azimuthal angular correlations. Even though Monash and Monash forward result are similar, forward tunes perform better. This means that precise beam remnant modeling at forward rapidities is crucial for understanding CNM effects. Future qualitative and quantitative azimuthal correlation comparisons in pp and pPb systems will show the impacts of cold nuclear medium.

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