Hadronic resonance production in asymmetric collisions with ALICE at the LHC

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1 Motivation

- In asymmetric collisions, the produced particle yields are different in forward and backward rapidity directions [1]. One of the important observables to probe cold nuclear matter effects (multiple scattering, nuclear shadowing etc.) is rapidity asymmetry in particle yield or forward-backward asymmetry ($Y_{\rm asym}$), defind as

$$Y_{\rm asym}(p_T) = \frac{\text{Yield}_{\rm Forward}(p_T)}{\text{Yield}_{\rm Backward}(p_T)}.$$

- It is interesting to study ratios of particle yields between a given rapidity window to its corresponding negative window [2].
- The rapidity dependent study of K^{*0} and ϕ vector mesons in p–Pb collisions can help to understand cold nuclear matter effects from hot dense matter produced in heavy ion collisions. Measurements also serve as a reference for heavy-ion (Pb–Pb, Xe–Xe) collisions.

2 Experimental setup and Analysis details

Data collected by the ALICE experiment in the 2016 p–Pb run at an energy of 5.02 TeV have been analysed. Time Projection Chamber (TPC) and Time Of Flight (TOF) detectors are used for particle identification whereas multiplicity selection is done using forward V0A detector.

K^{*0} and ϕ are reconstructed via their hadronic decay channels using invariant mass method.

Data	p-Pb (2016)
$\sqrt{s_{\rm NN}}$	5.02 TeV
MC	DPMJET (2017)
Multiplicity estimator	V0A ($2.8 < \eta < 5.1$)
PID	TPC & TOF

$$(K^{*0})(\bar{K}^{*0}) \rightarrow (K^+\pi^-)(K^-\pi^+)$$
$$\phi \rightarrow K^+ + K^-$$

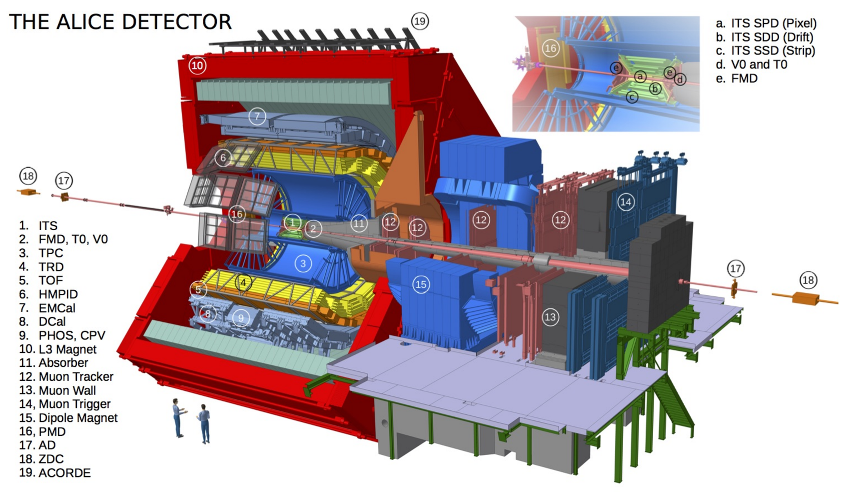

Figure 1: ALICE detector setup [3]

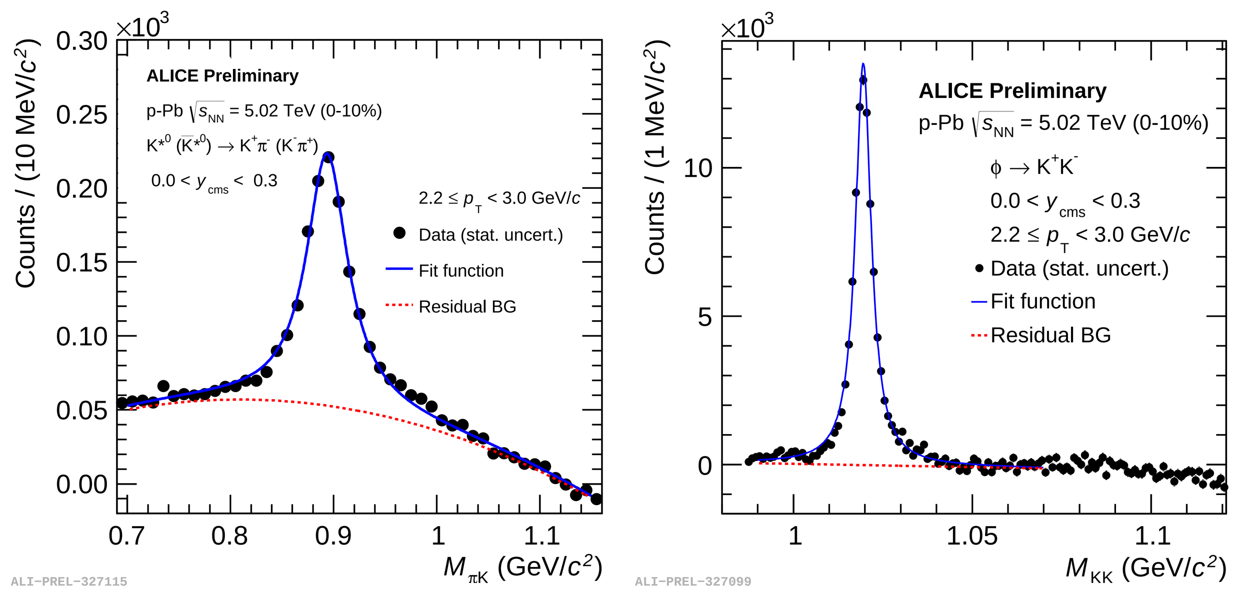

Figure 2: Invariant mass distribution of unlike sign πK and (KK) pairs (black marker) after subtraction of normalized mixed event background at $2.2 < p_{\rm T}$ (GeV/c) < 3.0 in the rapidity ranges $0.0 < y_{\rm cms} < 0.3$ for 0-10 % p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$.

- **Invariant mass method**: For each event, the invariant mass $M_{\pi K}$ (M_{KK}) distributions are constructed using all unlike charge combinations of πK (KK) for K^{*0} (ϕ).

$$M_{\pi K} = \sqrt{(E_{\pi^\pm} + E_{K^\mp})^2 - (\vec{p}_{\pi^\pm} + \vec{p}_{K^\mp})^2}$$
$$M_{KK} = \sqrt{(E_{K^+} + E_{K^-})^2 - (\vec{p}_{K^+} + \vec{p}_{K^-})^2}$$

- **Combinatorial background reconstruction**: Event mixing technique is used to estimate the combinatorial background.
- **Fit function**: K^{*0} - Breit-Wigner for signal + 2nd order polynomial for residual background.
  ϕ - Voigtian for signal + 1st order polynomial for residual background.
- **Corrected $p_{\rm T}$ spectra**:

$$\frac{1}{N_{\rm evt}}\frac{{\rm d}^2 N_{corrected}}{{\rm d}y {\rm d}p_{\rm T}} = \frac{1}{N^{acc}_{\rm evt}} \times \frac{N_{raw}}{{\rm d}y{\rm d}p_{\rm T} \times BR} \times \frac{f_{norm} \times f_{sl} \times f_{vtx}}{\varepsilon_{rec}} \quad (1)$$

$N_{\rm raw}$ = Number of raw counts (area under the signal peak), BR, $\varepsilon_{\rm rec}$, $f_{\rm norm}$, $f_{\rm sl}$ and $f_{\rm vtx}$ are branching ratio, reconstruction efficiency × acceptance, signal loss and vertex correction factors, respectively.

3 Results

3.1 Transverse momentum ($p_{\rm T}$) spectra

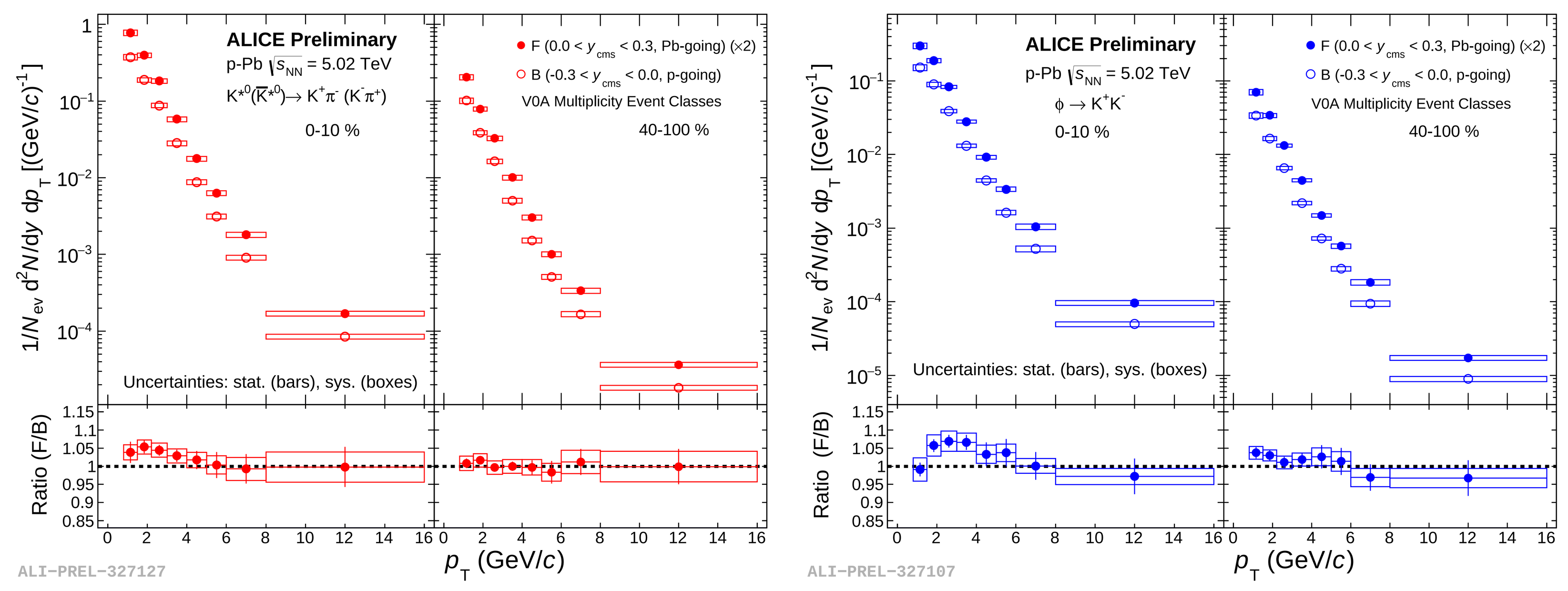

Figure 3: $p_{\rm T}$ spectra of K^{*0} and ϕ for multiplicity classes 0-10 %, 40-100 % in the rapidity range $0.0 < y_{\rm cms} < 0.3$ (forward) and $-0.3 < y_{\rm cms} < 0.0$ (backward) in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV.

Lower panels show the ratio of the transverse momentum ($p_{\rm T}$) spectra in the forward to backward rapidities which defines $Y_{\rm asym}$.

3.2 Rapidity asymmetry (Y_{asym})

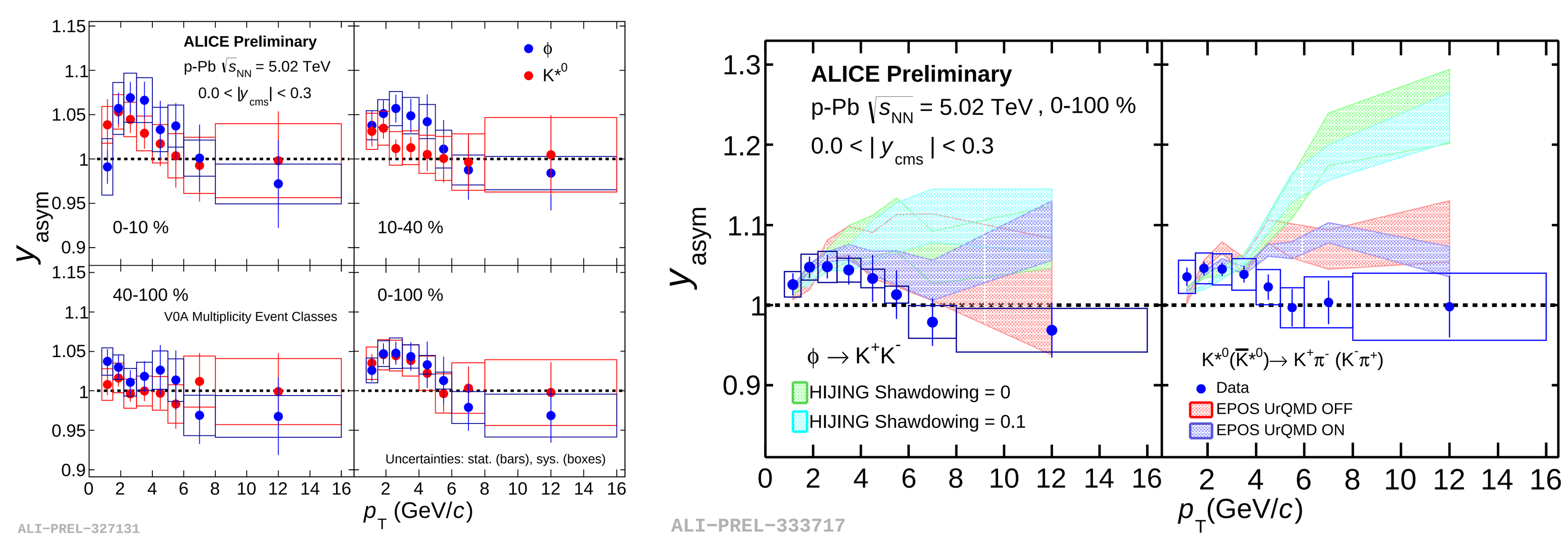

Figure 4: Left: Rapidity asymmetry (Y_{asym}) of K^{*0} (red marker) and ϕ (blue marker) as a function of $p_{\rm T}$ for various multiplicity classes in the rapidity ranges $0.0 < |y_{\rm cms}| < 0.3$ in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV. Right: Comparison of model predictions from EPOS (with and without UrQMD) and HIJING (with and without shadowing) to the measurements (Y_{asym}) for 0-100 % multiplicity class.

- Rapidity asymmetry is observed at low $p_{\rm T}$ for high multiplicity classes (0-10 %), whereas no significant asymmetry is measured at high $p_{\rm T}$ for all multiplicity classes. These asymmetries decreases from high to low multiplicity.
- The asymmetry at low $p_{\rm T}$ for high multiplicities indicates the presence of nuclear effects.
- No species dependence of Y_{asym} is observed for K^{*0} and ϕ vector mesons. Results for two particles are consistent with each other within uncertainties.
- No significant difference of Y_{asym} are observed in EPOS (with without UrQMD) and HIJING (with and without shadowing parameter) for K^{*0} and ϕ.
- At low $p_{\rm T}$ results from EPOS and HIJING are close to the measurement for both mesons whereas at high $p_{\rm T}$, results of K^{*0} from HIJING show higher asymmetry than ϕ.

4 Conclusions

- Rapidity asymmetry in K^{*0} and ϕ production observed at low $p_{\rm T}$ in high multiplicity collisions, whereas no significant difference at high $p_{\rm T}$ and low multiplicity in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV.
- Results indicate presence of potential nuclear effects.
- No species (K^{*0} and ϕ) dependence of $Y_{\rm asym}$ is observed.
- Model results form EPOS and HIJING closer to the mesutements at low $p_{\rm T}$. Results from EPOS (with and without UrQMD) and HIJING (with and without shadowing) show similar behaviour for K^{*0} and ϕ.

References

[1] B. I. Abelev et al. (STAR Collaboration) Phys. Rev. C 76, 054903.

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[3] ALICE Collaboration, Int. J. Mod. Phys. A29 (2014) 1430044.

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