φ meson production in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV with ALICE at the LHC

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Abstract

Strangeness production is a key tool to understand the properties of the medium formed in heavy-ion collisions: an enhanced production of strange particles was early proposed as one of the signatures of the Quark-Gluon Plasma. The φ meson, due to its $s\bar{s}$ valence quark content, provides insight into strangeness production.

The ALICE experiment has measured φ meson production in the dimuon channel in the forward rapidity region $2.5 < y < 4$ in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV.

The preliminary φ meson p_{T} spectra for different centrality classes and the yield as a function of the collision centrality in the transverse momentum range $2 < p_{\mathrm{T}} < 7$ GeV/c are presented. These results are also compared with the ones previously obtained in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV.

Keywords:
Quark Gluon Plasma, heavy ions, dimuons, vector mesons, low mass region

1. Introduction

Quantum Chromodynamics predicts the occurrence of a phase transition from the hadronic matter to a plasma of deconfined quarks and gluons (Quark-Gluon Plasma) when extreme conditions of temperature and energy density are reached. These conditions can be recreated in laboratory through ultrarelativistic heavy-ion collisions.

Strangeness production provides key information on the hot and dense state of strongly interacting matter produced in high-energy heavy-ion collisions: in fact, an enhanced production of strange particles was early proposed as one of the signatures of the Quark-Gluon Plasma (QGP) [1]. The φ meson, due to its $s\bar{s}$ valence quark content, is an excellent probe of strangeness production in heavy-ion collisions. The observables considered in this analysis are the transverse momentum (p_{T}) spectra as a function of the collision centrality and the central-over-peripheral ratio R_{CP}.

Vector mesons are reconstructed with the ALICE muon spectrometer [2] in the rapidity range $2.5 < y < 4$ through their decay into muon pairs. Dileptons are not affected by strong final-state interactions in the QGP, differently from the products of the hadronic decay channels, which are unlikely to escape the medium without reacting further.

The ALICE muon spectrometer is composed of a front hadron absorber, a set of cathode pad chambers (five stations, each one composed of two chambers) for the track reconstruction in a dipole field, an iron wall

acting as a muon filter and two stations, each one made of two resistive plate chambers (RPC) for the muon trigger. The analyzed data were collected requiring the coincidence of an unlike-sign dimuon trigger and a minimum bias trigger. The dimuon trigger requires two opposite sign tracklets in the muon trigger system. The single muon p_T threshold was set at ~ 1 GeV/c. The minimum bias trigger, independent from the muon trigger, was based on a set of forward scintillators (V0) and on a silicon pixel detector (SPD) placed in the vertex region.
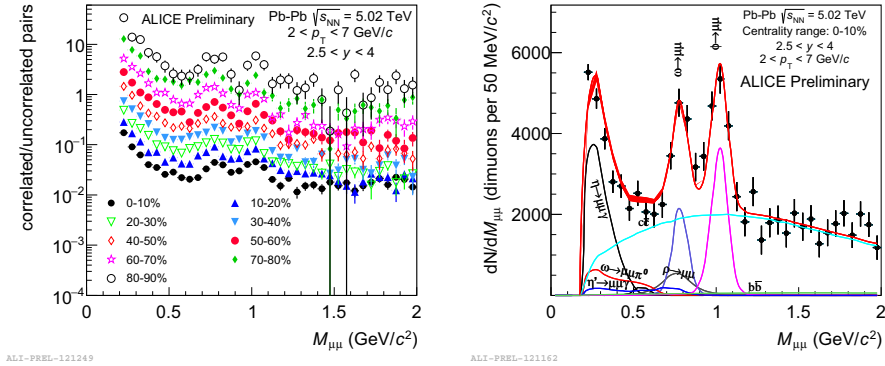
2. Analysis

Fig. 1. Left: opposite-sign/combinatorial background ratio for $2 < p_T < 7$ GeV/c. Right: Invariant mass distribution for $2 < p_T < 7$ GeV/c, for the most central collisions (0-10%).

The data from Pb–Pb collisions were collected in 2015 at $\sqrt{s_{NN}} = 5.02$ TeV and amount to an integrated luminosity of ~225 μb^{-1}. Muon tracks were selected requiring that the tracks reconstructed in the tracking stations matched the ones in the trigger chambers and that their pseudorapidity was in the range $-4 < \eta_\mu < -2.5$. Here and in the following, the sign of η_μ is determined by the choice of the LHC reference system. A cut on the single muon $p_T > 0.85$ GeV/c was also applied. Muon pairs were selected inside the dimuon rapidity interval $2.5 < y_{\mu\mu} < 4$. Due to the fact that the acceptance for low mass dimuons is close to zero for $p_T < 2$ GeV/c, only dimuons with $p_T > 2$ GeV/c were selected.

The combinatorial background was evaluated through the event mixing technique; like-sign pairs were used to normalize the background. The ratio between the opposite-sign spectra and the combinatorial background, shown in Fig. 1 (left panel) for $2 < p_T < 7$ GeV/c, grows from central to peripheral collisions. In particular, at the ϕ peak, this ratio grows from ~0.05 in the most central bin (0-10%) to ~5 in the most peripheral one (80-90%).

An example of invariant mass distribution, after the combinatorial background subtraction, is shown in Fig. 1 (right) for $2 < p_T < 7$ GeV/c, for the most central bin (0-10%). The invariant mass distribution is described as a superposition of light meson decays into muon pairs, with an additional contribution coming from charm and beauty semi-muonic decays. Low-mass resonance shapes come from a Monte Carlo simulation with a parametric generator [3], while open charm and beauty have been generated using a parametrization of PYTHIA [4]. In order to extract the signal, the mass spectrum has been fitted with these contibutions, leaving as free parameters the normalizations of $\eta \rightarrow \mu^+\mu^-\gamma$, $\omega \rightarrow \mu^+\mu^-$, $\phi \rightarrow \mu^+\mu^-$ and open charm. The other processes were fixed according to the relative branching ratios or cross sections (σ), as done in [3]. In particular, the normalization of the ρ relative to the ω meson was fixed requiring that $\sigma_\rho = \sigma_\omega$ [5, 6, 7].
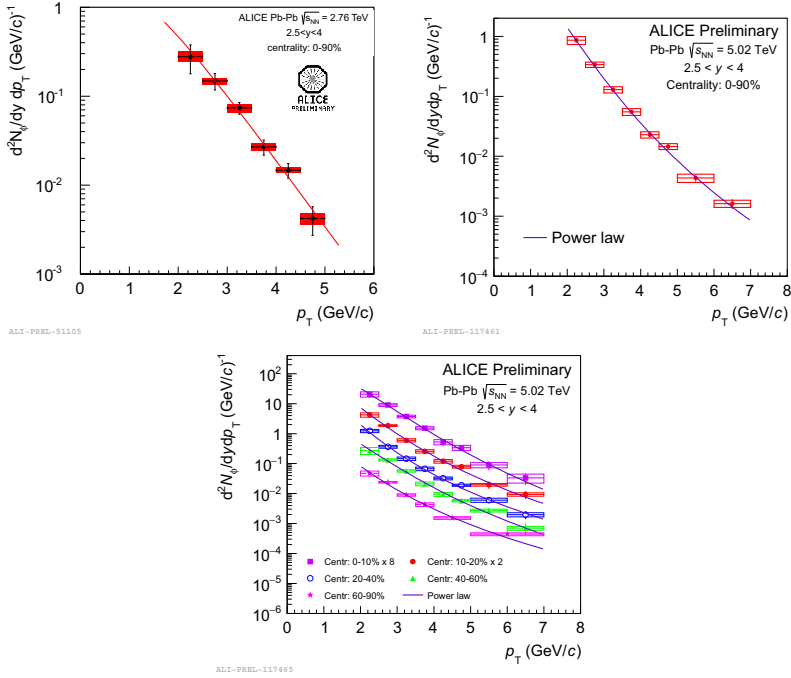
Fig. 2. Top, left: p_T spectrum, integrated over centrality, in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. Top, right: p_T spectrum, integrated over centrality, in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Bottom: p_T spectrum for several centrality classes in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

3. Results

Figure 2 (top, left and right panels) shows the comparison between the p_T spectra, integrated over centrality, in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and at $\sqrt{s_{NN}} = 5.02$ TeV respectively. The $\sqrt{s_{NN}} = 2.76$ TeV spectrum covers the p_T range $2 < p_T < 5$ GeV/c and can be fitted with the exponential function of the form $dN/dp_T \propto p_T e^{-m_T/T}$.

For the spectrum measured at $\sqrt{s_{NN}} = 5.02$ TeV, the p_T range has been extended up to 7 GeV/c, and a power-law function

$$dN/dp_T \propto \frac{p_T}{\left[1 + (p_T/p_0)^2\right]^n} \tag{1}$$

is needed to include the high p_T tail.

The comparison of the ϕ p_T spectra for different centralities is shown in Fig. 2 (bottom), for 0-10%, 10-20%, 20-40%, 40-60% and 60-90% centrality classes. All centralities are well described by a power-law function. Peripheral collisions are characterized by a slightly harder p_T tail than the central collisions.

The ϕ central-over-peripheral ratio R_{CP} has been calculated, for each centrality bin, as

$$R_{CP} = \frac{\left(dN_\phi/dy\right)^{central}/\langle T_{AA}\rangle^{central}}{\left(dN_\phi/dy\right)^{peripheral}/\langle T_{AA}\rangle^{peripheral}}, \tag{2}$$

where dN_ϕ/dy is the ϕ yield and $\langle T_{AA}\rangle$ is the average nuclear overlap function [8] in that centrality bin.

The ϕ R_{CP} as a function of $\langle N_{part}\rangle$, for $2 < p_T < 7$ Gev/c, is shown in Fig. 3 (left). The peripheral reference bin corresponds to 60-90% centrality. The R_{CP} decreases from peripheral to central collisions, implying a suppressed ϕ production in central collisions with respect to peripheral.
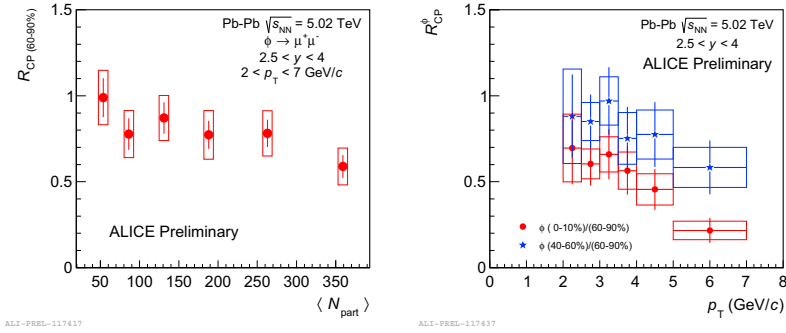
Fig. 3. $\phi\,R_{CP}$ in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Left: $\phi\,R_{CP}$ as a function of $\langle N_{part}\rangle$, for $2 < p_T < 7$ GeV/c. Right: $\phi\,R_{CP}$ as a function of p_T, for central to peripheral and semi-peripheral to peripheral collisions.

The R_{CP} as a function of p_T was calculated similarly as the R_{CP} as a function of $\langle N_{part}\rangle$. The p_T dependence of the R_{CP} for central to peripheral and semi-peripheral to peripheral collisions is shown in Fig. 3, right side. The R_{CP} is significantly smaller than 1 for $p_T \gtrsim 4$ GeV/c in the case of central to peripheral collisions. In the semi-peripheral to peripheral case, the decrease is much less pronounced, meaning that the ϕ production in the intermediate/high p_T region is more suppressed in central collisions.

4. Summary

The production of ϕ meson was measured via its dimuon decay channel in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV at forward rapidity, in the p_T region $2 < p_T < 7$ GeV/c.
The comparison between the ϕ p_T spectrum integrated over centrality at $\sqrt{s_{NN}} = 2.76$ TeV and at $\sqrt{s_{NN}} = 5.02$ TeV shows that the former, which covers the $2 < p_T < 5$ GeV/c range, can be fitted with an exponential function, while for the latter a power-law function is needed to describe the higher p_T tail up to 7 GeV/c. The p_T spectra are well fitted with a power-law function also in the case of 0-10%, 10-20%, 20-40%, 40-60% and 60-90% centralities, although the peripheral collisions are characterized by a harder slope with respect to central collisions.
The ϕ R_{CP} as a function of $\langle N_{part}\rangle$ decreases from peripheral to central collisions, implying a suppressed ϕ production in central collisions. The R_{CP} as a function of p_T decreases for $p_T \gtrsim 4$ GeV/c, implying a suppressed ϕ production in the intermediate/high p_T region in central collisions with respect to peripheral collisions.

References

[1] J. Rafelski, B. Müller, Strangeness Production in the Quark - Gluon Plasma, Phys. Rev. Lett. 48 (1982) 1066, [Erratum: Phys. Rev. Lett.56,2334(1986)]. doi:10.1103/PhysRevLett.48.1066.
[2] K. Aamodt, et al., The ALICE experiment at the CERN LHC, JINST 3 (2008) S08002. doi:10.1088/1748-0221/3/08/S08002.
[3] B. Abelev, et al., Light vector meson production in *pp* collisions at $\sqrt{s}$ = 7 TeV, Phys. Lett. B710 (2012) 557–568. arXiv:1112.2222, doi:10.1016/j.physletb.2012.03.038.
[4] T. Sjöstrand et al., J. High Energy Phys. 0605 (2006) 026. arXiv:hep-ph/0603175, doi:10.1088/1126-6708/2006/05/026.
[5] Aguilar-Benitez, M. et al., Inclusive particle production in 400 GeV/c pp-interactions, Z. Phys. C 50 (3) 405–426. doi:10.1007/BF01551452.
[6] G. Agakichiev et al., Neutral meson production in p-Be and p-Au collisions at 450GeV beam energydoi:10.1007/s100529800804.
[7] A. Uras for the NA60 Collaboration, Low mass dimuon production in pA collisions at $\sqrt{s}$ = 27.5 GeV with NA60, Journal of Physics G: Nuclear and Particle Physics 38 (12) 124180.
[8] Abelev, B. et al., Centrality determination of pb-pb collisions at $\sqrt{s_{NN}}$ = 2.76 tev with alice, Phys. Rev. C 88 (2013) 044909. doi:10.1103/PhysRevC.88.044909.