Recent resonance results in p+p collisions at LHC energies from the ALICE detector

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Abstract

Short lived hadronic resonances are sensitive to the medium properties of a heavy-ion collision, in particular to the temperature, density and expansion velocity. Resonances decaying into hadrons are used to estimate the time span and hadronic interaction cross section in the hadronic phase between chemical and kinetic freeze-out. The detection of early decoupled resonances aims at studying chiral symmetry restoration via their mass shift and width broadening. These proceedings will summarize the RHIC results and show the first resonance measurements from the ALICE detector of p+p collisions at LHC energies.

Key words: Resonances, hadronic and partonic lifetime, medium modification
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1. Introduction

Yields of resonances measured via their hadronic decays are sensitive to the hadronic lifetime of the nuclear medium in a heavy-ion reaction. At RHIC energies of 200 GeV the partonic lifetime has been extracted via the pion HBT lifetime measurement ($\Delta \tau = 5 - 12 \text{ fm/c}$) [1], which determines the time from the beginning of the collision to kinetic freeze-out and the hadronic lifetime (of $\Delta \tau > 4 \text{ fm/c}$) from resonance measurements under the assumption that the chemical freeze-out occurs at hadronization [2,3]. Initially resonances were suggested to study chiral symmetry restoration due to their mass shifts and width broadening close to the phase transition from partonic matter into hadronic matter. The leptonic decay channel was suggested as a clean probe with nearly no interaction of the decay particles with the later hadronic medium. However, regenerated resonances from the late hadronic phase feed into this signal. According to UrQMD calculations, the re-scattering and regeneration processes change the measured resonance yield predominantly in the low momentum region ($p_T = 0-2 \text{ GeV/c}$) [4]. Therefore high momentum resonances and their decay particles are less likely to be affected by the hadronic
medium. In order to investigate the impact of the partonic medium and the mixed phase around the phase transition on resonance properties one needs to reconstruct high momentum resonances which are produced rather early. This might be possible through the selection of resonances from the away-side distribution of a triggered di-jet event [5]. This newly suggested analysis requires a large jet production cross section and profits from a larger partonic lifetime (expected to be $\sim 10$ fm/c at LHC) to enrich the sample. ALICE is the optimal detector for it since it provides an excellent particle identification capability for decay particles and provides jet identification via leading particle selection or full jet reconstruction using the Electromagnetic Calorimeter (EMCal).

2. Resonance Reconstruction

The main ALICE detector components used to identify the decay daughters and reconstruct the resonance particle are the Time Projection Chamber (TPC) and Inner Tracking System (ITS) which measure the momenta of charged particles. The charged particle identification is done via dE/dx (low pt) and the Time of Flight detector (TOF) (above $p_T = 0.7$ GeV/c) [6]. For p+p collisions the two VZERO counters are used to reject most of the beam-gas interactions, in order to select the minimum bias events. All events with longitudinal primary vertex position $z_{vertex} > 10$ cm are rejected in order to avoid biases due to the detector acceptance.

The direct measurement of resonances in the detectors is not possible due to their short lifetimes ($c\tau_{\phi(1020)} = 45$ fm, $c\tau_{\Xi(1530)} = 20$ fm, $c\tau_{\Sigma(1385)} = 6$ fm and $c\tau_{K(892)} = 4$ fm) resulting from their strong decay. Instead, they are identified by reconstructing the invariant mass from the decay daughter candidates. Charged particles are identified by the energy loss per unit length, dE/dx, and the momentum measured with the TPC [7]. To identify the neutral $\Lambda$ and $\Xi$ their decay vertex topology information is used. A large source of background comes from uncorrelated pairs. A fit of the background is performed to extract the resonance signal. Mixed event background and like-sign pair background are studied for different resonances.

![Graphs showing resonance invariant mass spectra](image)

Fig. 1. (Left) $K^+K^-$ invariant mass spectrum between $p_T = 1-1.5$ GeV/c in p+p 900 GeV collisions. The curve is the combined fit of square-root function + Gaussian to the points. (Right) $K+\pi$ invariant mass spectrum in p+p 7 TeV collisions (blue) and the mixed event background (red)[7].
3. Invariant mass signals in p+p collisions

The invariant mass signals for the different resonances are shown in figure 1 and figure 2. The $\phi(1020)$ is reconstructed via its $K^+ + K^-$ decay in p+p 900 GeV collisions (figure 1 left) and K(892) is reconstructed via is $K + \pi$ decay in p+p 7 GeV collisions (figure 1 right). Figure 2 shows the invariant mass distribution from weak decaying decay daughters Λ and Ξ, which are first identified via topological decay vertex. The Σ(1385) is reconstructed via Λ + π (figure 2 left) and the Ξ(1530) via Ξ+π (figure 2 right) decay in pp collisions at the c.m.s. energy of 7 TeV. The measured masses and width of the resonance signals are in agreement with the PDG values.

![Image of invariant mass spectra for Λ + π and Ξ+π](image1.png)

Fig. 2. (Left) Λ + π invariant mass spectrum for the extraction of the Σ(1385) resonance in pp collisions at the CMS energy of 7 TeV (pt-integrated). (Right) Ξ+π invariant mass spectrum for the extraction of the Ξ(1530) resonance in pp collisions at the CMS energy of 7 TeV (pt-integrated).

4. Results

In heavy-ion collisions we see a suppression of short lived resonances using the K(892)/K and Λ(1520)/Λ with respect to p+p collisions at RHIC energies due to the extended hadronic lifetime. Since the $\phi$’s lifetime (44 fm/c) is large compared to the source lifetime (5-10 fm/c) a suppression of $\phi$/K is not expected which is also confirmed by the data. Figure 3 shows the $\phi$/K ratio for different collision energies and collision systems (p+p, e+e, A+A). Within their large errors they are compatible with a value of 0.12. The new data from ALICE of the $\phi$/K in p+p is in agreement with the ratio at the lower energies from RHIC and SPS.

![Image of $\phi$/K ratio for different collision energies and systems](image2.png)

Fig. 3. $\phi$/K ratio for different collision energies and collision systems (p+p, e+e, A+A).
The charged hadron-\(\phi(1020)\) resonance and charged hadron-K(892) resonance angular correlations are shown in figure 4 (left) with Hadron trigger \(p_T > 3\) GeV/c and associated \(\phi(1020)\) \(p_T > 1.5\) GeV/c and Fig 5 with Hadron trigger \(p_T > 2\) GeV/c and associated K(892) with no \(p_T\) cut. The angular correlation \((\Delta\phi)\) shows clearly a same- and away-side distribution of the correlated resonance with respect to a higher momentum trigger particle. The integrated yield of the same-and away-side distributed resonances shows that about 25% of the selected resonances are coming from a jet (figure 5). The mass and width of the \(\phi(1020)\) versus the angle with respect to the trigger particle (figure 4 middle and left) is constant and in agreement with the PDG values and the contribution from momentum resolution. The agreement with the PDG value on the away-side is expected in minimum bias p+p collisions where no extended medium is present.

Fig. 4. (Left) Angular correlation of hadron-\(\phi(1020)\) resonance from p+p 7 TeV collisions. Hadron trigger \(p_T > 3\) GeV/c and associated \(\phi(1020)\) \(p_T > 1.5\) GeV/c. Mass (middle) and width (right) of the phi(1020) signal versus the angular distribution with respect to the trigger particle, which are in agreement with the PDG values and the expected small contribution to the width from the momentum resolution.

Fig. 5. Angular correlation of hadron- K(892) resonance from p+p 7 TeV collisions. Hadron trigger \(p_T > 2\) GeV/c and associated K(892) without a momentum cut.

References