Insights into the internal structure of exotic resonances with ALICE

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Introduction

Understanding the quark composition of hadrons has been a central goal in non-perturbative quantum chromodynamics for decades. Standard hadrons are traditionally classified based on the quark model, with baryons consisting of three quarks (qqq) and mesons formed from a quark–antiquark pair ($q\bar{q}$) [1]. While many established states align with this quark model, there are certain hadrons, including observed resonances, whose properties suggest an exotic structure, featuring unconventional configurations. In the case of light scalar mesons, their conventional quark content remains a subject of ongoing investigation, with many theoretical interpretations concerning whether their internal structure conforms to compact multi-quark states or exhibits a more molecular-like configuration.

Hadronic resonances are particles with relatively short lifetimes, comparable to or shorter than the lifespan of the hadronic gas created in heavy-ion collisions and possibly in high-multiplicity p–A and pp collisions at collider energies. Exotic resonances exhibit masses typically falling in the range between 1 and 2 GeV/c^2. The quark composition of scalar mesons, such as $f_0(980)$ and $f_1(1285)$, continues to be a subject of active research. In addition, Lattice QCD predicts the possible existence of glueballs, unique particles composed solely of gluons [2, 3]. Some proposed candidates for glueball searches include $f_0(1370)$, $f_0(1500)$, and $f_0(1710)$.

The ALICE detector at the Large Hadron Collider (LHC) is specifically designed for heavy-ion collisions and the study of the quark–gluon plasma. Within ALICE, numerous sub-detectors are used in the analysis of resonances. Notably, the Inner Tracking System (ITS) and the Time Projection Chamber (TPC) are instrumental in determining the primary vertex, tracking particles, and enabling particle identification (PID) through specific energy loss measurements. The Time-Of-Flight (TOF) detector specializes in PID by precisely measuring particle time of flight. Additionally, the V0A ($2.8 < \eta < 5.1$) and V0C ($-3.7 < \eta < -1.7$) detectors are used for event triggering and event selection based on charged-particle multiplicity at forward rapidities [4].

Potential structures of exotic resonances

The latest ALICE results on $f_0(980)$ and pion yield ratios in pp collisions have been compared to the γ-CSM model predictions in two scenarios [5]. When considering no net strangeness content for the $f_0(980)$ ($|S| = 0$), the model predicts higher yield ratios for low values of multiplicity ($\langle dN_{ch}/d\eta \rangle$) compared to when assuming $|S| = 2$. Interestingly, these predictions converge and match closely once $\langle dN_{ch}/d\eta \rangle$ exceeds 100 [6]. A multiplicity-dependent double ratio, defined as the ratio of $f_0(980)$ to K^{*0} yields in multiplicity intervals divided by the one in low-multiplicity events for p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, is shown in Fig. 1. Predictions assuming either $|S| = 0$ or $|S| = 2$ strangeness content of $f_0(980)$ reveal distinct trends. In the presence of strangeness $|S| = 2$, there's a noticeable increasing trend for the $f_0(980)/K^{*0}$ yield ratio, consistent with expectations since particles like kaons possess strangeness $|S| = 1$. Notably, the measured trend qualitatively aligns

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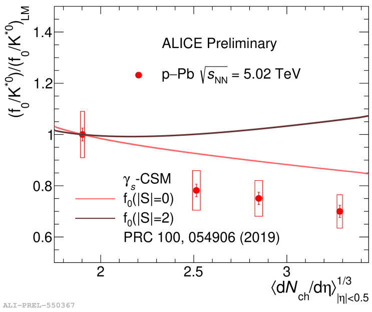

FIG. 1: Multiplicity dependence of double ratio of $f_0(980)$ to K^{*0} yields

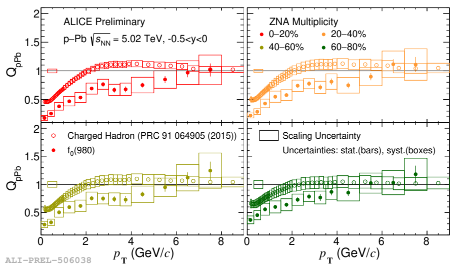

FIG. 2: Nuclear modification factor of $f_0(980)$ in p–Pb collisions at 5.02 TeV

with the $|S| = 0$ scenario in which the $f_0(980)$ has no strangeness content.

Recently, the ALICE experiment has conducted estimations of the nuclear modification factor for the $f_0(980)$ in p–Pb collisions. The results are shown in Fig. 2 and reveal a significant $f_0(980)$ yield suppression at low p_T, which is stronger than that measured for charged hadrons and is more pronounced for more central collisions. This suppression may be attributed to the presence of rescattering effects. Interestingly, there is no Cronin peak observed in the intermediate p_T region, which might suggest that the $f_0(980)$ meson possesses an ordinary meson structure.

Glueball search

Glueballs are composed solely of gluons. Experimental investigations conducted by WA102 [7] have shown clear $f_1(1285)$ and $f_1(1420)$ signals in the $KK\pi$ invariant mass distributions in the range 1-2 GeV/c^2. In Fig. 3, a signal peak for $f_0(1710)$ is visible in the $K^0_S K^0_S$ invariant mass distribution and fitted with a Breit-Wigner function, along with $f_0(1270)$ and $f_2(1525)$. It provides promising insights into the search for glueballs.

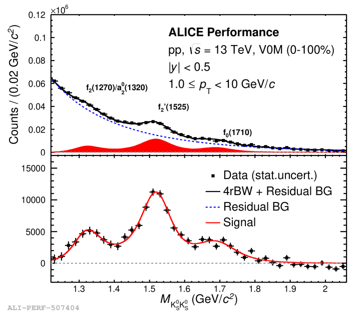

FIG. 3: Invariant mass distributions of $K^0_S K^0_S$ pairs

Acknowledgments

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