An insight into strangeness with $\phi(1020)$ production from small to large collision systems with ALICE at the LHC

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Outline

- Introduction
- Signal Extraction
- Transverse momentum ($p_T$) spectra and mean-$p_T$
- $\phi$ vs. other resonances
- Strangeness enhancement
- Effective strangeness of $\phi$
- Conclusion
Resonances are sensitive to evolution dynamics and are important to probe the hadronic phase due to their short lifetimes.

Re-scattering of decay daughters results in signal loss and regeneration of resonance results in signal gain.

More on Resonances

Stay tuned for S. Dudi’s talk at 15:15 today
Introduction

Resonances are sensitive to evolution dynamics and are important to probe the hadronic phase due to their short lifetimes.

Re-scattering of decay daughters results in signal loss and regeneration of resonance results in signal gain.

As $\phi$ consists of strange valence quarks, it can shed light into strangeness production.

Effective strangeness of $\phi$?

- Mass = 1.019 GeV/c$^2$
- Width = 4.25 MeV/c$^2$
- Lifetime = 46.4 fm/c
ALICE Detector

1. ACORDE | ALICE Cosmic Rays Detector
2. AD | ALICE Diffractive Detector
3. DCal | Di-jet Calorimeter
4. EMCal | Electromagnetic Calorimeter
5. HMPID | High Momentum Particle Identification Detector
6. ITS-IB | Inner Tracking System - Inner Barrel
7. ITS-OB | Inner Tracking System - Outer Barrel
8. MCH | Muon Tracking Chambers
9. MFT | Muon Forward Tracker
10. MID | Muon Identifier
11. PHOS / CPV | Photon Spectrometer
12. TOF | Time Of Flight
13. T0+A | Tzero + A
14. T0+C | Tzero + C
15. TPC | Time Projection Chamber
16. TRD | Transition Radiation Detector
17. V0+ | Vzero + Detector
18. ZDC | Zero Degree Calorimeter
Signal Extraction

- **φ(1020) is reconstructed via invariant mass technique**

- **The uncorrelated background is estimated using event-mixing and like-sign technique.**

- **In different $p_T$ intervals, raw yields are obtained from the combinatorial background subtracted signal distributions**

- **φ(1020) peak is fitted with a Voigtian function and residual background is fitted with 2nd order polynomial**

$$\frac{dN}{dm_{KK}} = \frac{A\Gamma}{(2\pi)^{3/2}\sigma} \int_{-\infty}^{\infty} \exp \left[ -\frac{(m_{KK} - m')^2}{2\sigma^2} \right] \frac{1}{(m' - M)^2 + \Gamma^2/4} dm'$$

- **A Voigtian function is used due to the fact that the mass resolution and width of $\phi$ have similar magnitudes**
Transverse momentum ($p_T$) Spectra

- $p_T$-spectra measured in fine multiplicity bins at three collision energies in pp
- Ratio to INEL>0 increases at low $p_T \rightarrow$ hardens with increasing multiplicity
- For $p_T > 4$ GeV/c, spectral shape is independent of multiplicity
- Similar behavior observed for other light flavored particles
$p_T$-differential yield Ratio and Integrated yields

- **High-$p_T$ yields increase as a function of collision energy**
- **Bulk production at low-$p_T$ is independent of collision energy**

Event multiplicity drives the particle production, irrespective of collision energy
Mean Transverse Momentum

- Similar $<p_T>$ for $K^{*0}$, $p$ and $\phi$ in central Pb-Pb collisions $\rightarrow$ expected from hydrodynamical models (similar mass)

- $pp$ and $p$-Pb follow same trend as a function of multiplicity while the trend is different for Pb-Pb collisions

- Exceed central Pb-Pb values in high multiplicity $pp$ and $p$-Pb collisions
Particle Ratios

\( \rho/\phi \) ratio is almost flat at low-\( p_T \) for central Pb-Pb and Xe-Xe collisions → expected from hydrodynamical (similar mass) but can be described with latest recombination models.

\( \rho/\phi \) ratio drops at high-\( p_T \) and becomes similar to peripheral Pb-Pb and inelastic pp collisions.
Short-lived resonances are suppressed in large collision systems with respect to thermal model prediction and with respect to pp and peripheral Pb-Pb collisions.

EPOS (with UrQMD) seems to describe the resonance suppression qualitatively while without modeling the hadronic phase via UrQMD, does not describe the suppression.
φ vs other Resonances

- Short-lived resonances are suppressed in large collision systems with respect to thermal model prediction and with respect to pp and peripheral Pb-Pb collisions.
- EPOS (with UrQMD) seems to describe the resonance suppression qualitatively while without modeling the hadronic phase via UrQMD, does not describe the suppression.
- The modelling of hadronic phase via UrQMD doesn’t affect φ production.
- φ is not suppressed due to its long lifetime compared to the lifetime of fireball.

Small fraction of φ decays in the hadronic phase
ALICE for the first time observed the strange particle enhancement in high multiplicity collisions of small system, pp and p-Pb.

The strangeness enhancement increases with particle strangeness content.
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The strangeness enhancement increases with particle strangeness content.

$\phi/\pi$ shows the same trend as $K/\pi$.

Possible stronger increase for $\Lambda/\pi$ compared to $K/\pi$ and $\phi/\pi$ in very low multiplicity pp collisions.

What is the effective strangeness of $\phi$?
Effective strangeness of $\phi$

- $\phi(\text{S}=0)$ yield in agreement with thermal model expectation in central Pb-Pb collisions
Effective strangeness of $\phi$

- $\Phi(S=0)$ yield in agreement with thermal model expectation in central Pb-Pb collisions
- But decreases towards smaller multiplicity in contrast to the expectation from strangeness canonical suppression
- Favors non-equilibrium production ($\gamma_s<1$) of $\phi$ or all strange particles.
Effective strangeness of $\phi$

- $\phi(S=0)/K(S=1)$ fairly flat as a function of multiplicity → The $\phi$ has effective strangeness of 1-2 units
Effective strangeness of $\phi$

- $\phi(S=0)/K(S=1)$ fairly flat as a function of multiplicity → The $\phi$ has effective strangeness of 1-2 units
- $\Xi(S=2)/\phi(S=0)$ fairly flat as a function of multiplicity →
  - The $\phi$ has effective strangeness of 1-2 units
  - Hint of different evolution $\Xi$ and $\phi$ in very low multiplicity pp collisions.
  - In contrast to expectation from non-equilibrium production as quantified with strangeness suppression factor.

$\phi(S=0)$ production in small systems remains to be understood!
Conclusions

- At low $p_T$, transverse momentum spectra harden with increasing multiplicity.
- For $p_T > 4$ GeV/c, spectral shape is independent of multiplicity.
- Bulk production at low-$p_T$ is independent of collision energy for minimum bias pp collisions.
- Event multiplicity drives the particle production, irrespective of collision energy for pp collisions.
- Small fraction of $\phi$ decays in the hadronic phase and not affected by re-scattering and/or regeneration.
- Thermal production of $\phi$ in Pb-Pb collisions.
- Effective strangeness of $\phi$ and production in small systems is still a puzzle.
Conclusions

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- Effective strangeness of $\phi$ and production in small systems is still a puzzle.