Hadronic resonance production measured by ALICE detector at the LHC energies

Angela Badalà
INFN Sezione di Catania
for the ALICE Collaboration

ALICE dataset

<table>
<thead>
<tr>
<th>Dataset</th>
<th>$\sqrt{s_{\text{NN}}} \ (\text{TeV})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010 pp</td>
<td>7</td>
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<tr>
<td>2011 pp</td>
<td>2.76</td>
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<tr>
<td>2010 Pb-Pb</td>
<td>2.76</td>
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<td>2.76</td>
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<tr>
<td>2013 p-Pb</td>
<td>5.02</td>
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</tbody>
</table>

- Motivations
- Resonance reconstruction in ALICE
- Results on $K^*(892)^0$ and $\phi(1020)$ production:
  - Mean transverse momentum
  - Ratios of resonances to stable hadrons
  - Resonance nuclear modification factors
- Summary
Resonances in heavy-ion collisions

Resonances have lifetimes of about few fm/c \( \rightarrow \tau_{\text{resonance}} \sim \tau_{\text{fireball}} \)

- Resonances may give information on the nuclear matter dynamics and chiral properties

Modification of yield, \( \langle p_T \rangle \) and particle ratios as hints of regeneration/rescattering effect \( \rightarrow \) Timescale chemical-kinetic freeze-out

Modification of width, mass and branching ratio
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- Comparison with particles that differ by mass, baryon number, strangeness content → particle production mechanisms

A. Badalà - ICNFP2014 - 28 July - 6 August 2014 - Kolymbari, Crete (Greece)
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- Comparison with particles that differ by mass, baryon number, strangeness content → particle production mechanisms
- Resonance nuclear modification factor → study in-medium energy loss
- Resonance measurements in pp and p-Pb system are useful as reference and to test the system size dependence and the role of cold nuclear matter effects.
ALICE- Particle identification

Particle identification ($\pi$, K from resonance decay) by:
- dE/dx in gas (Time Projection Chamber)
- Time-of-flight measurements (Time-Of-Flight)

VZERO scintillator detectors:
- centrality definition in Pb-Pb (V0A and VOC)
- multiplicity event classes in p-Pb (V0A)
**K*0 and φ invariant mass**

**Pb-Pb**

- Data (stat. uncert.)
  - Breit-Wigner Peak Fit
  - Residual BG
- 0.8 < \(p_T\) < 1.2 GeV/c
- Cent. 0-20%

**K*0 → πK**

Fit: Rel. Breit-Wigner (K*) or Voigtian(φ) + polynomial

Extracted mass and width consistent with PDG values

**p-Pb**

- Data, event-mix bigk subtracted
- Breit-Wigner peak fit
- Residual background
- Statistical uncertainties

Combinational background: event-mixing or like-sign techniques

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**K*(892)⁰ and φ(1020) p_T spectra in Pb-Pb**

2010 Pb-Pb data analysis: \( p_T \leq 5 \) GeV/c

New analysis of Pb-Pb 2011 data extends measured \( p_T \) up to 10 GeV/c for K*⁰ and up to 21 GeV/c for φ.
$K^*(892)^0$ and $\phi(1020)$ $p_T$ spectra in p-Pb

New analysis 2013 p-Pb data
$K^{*0}$ and $\phi$ $p_T$ spectra measured in various multiplicity bins

Range $K^{*0}$: $0 < p_T < 15$ GeV/c
Range $\phi$: $0.2 < p_T < 16$ GeV/c
Resonance $\langle p_T \rangle$ - energy dependence

$\langle p_T \rangle_{LHC}$ higher than $\langle p_T \rangle_{RHIC}$ ($\sim 20\%(30\%)$ for $K^*(\phi)$) → Consistent with a stronger radial flow at LHC than RHIC. Global Blast-wave fit on $\pi$, $K$, $p$ shows $\sim 10\%$ increase in $\langle \beta_T \rangle$ over RHIC (ALICE Phys. Rev. Lett. 109, 252301 (2012))
In central Pb-Pb collisions particles with similar mass \((K^*, p\) and \(\phi)\) have similar \(<p_T>\). → consistent with hydrodynamical picture, i.e. \(p_T\) distribution determined by particle mass.
The mean $p_T$ of particles ($\pi$, $K$, $p$, $\Lambda$) increases with multiplicity with a rate stronger for heavier particles.
Mean $p_T$ of $K^{*0}$ and $\phi$ increases with multiplicity, as well.
\[ \langle p_T \rangle \text{ in } p-Pb: \text{ mass ordering?} \]

- ALICE preliminary, p-Pb \( s_{NN} = 5.02 \text{ TeV} \)
- V0A Multiplicity classes (Pb side)
  - \( \phi \)
  - \( K^{*0} \)
  - ALICE pp 7 TeV
  - \( p \)
  - \( K^{\pm}K_S^0 \)
  - \( \pi^\pm \)

\[ \langle dN_{ch} / d\eta \rangle_{\text{lab}}^{\text{V0A}} |_{|\eta_{\text{lab}}| < 0.5} \]

\[ \langle p_T \rangle \text{ (GeV/c)} \]

- Preliminary p-Pb: \( K^{*0}, \phi \)

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$<p_T>$ in $p$-$Pb$: mass ordering?

- ALICE preliminary, $p$-$Pb$ $s_{NN} = 5.02$ TeV
- V0A Multiplicity classes (Pb side)
- $\phi$, $K^{*0}$
- ALICE $pp$ 7 TeV
- $\Lambda$, $p$, $K^{\pm}$, $K^0_S$, $\pi^{\pm}$

$<p_T>$ (GeV/c)

$\langle dN_{ch}/d\eta \rangle_{\text{V0A}}^{\text{absol}} |_{|\eta| < 0.5}$

Mass (MeV)

- $\pi^{\pm}$, $K^{\pm}$, $K^0_S$, $K^{*0}$, $\phi$, $\Lambda$

- $<p_T>$ for $p$ and $\Lambda$ follow mass ordering
\(<p_T>\) in p-Pb: mass ordering?

- Meson resonances \(<p_T>\) is larger than \(p\) and \(\Lambda\)
- \(p\) and \(\Lambda\) follow mass ordering
\[ \langle p_T \rangle \text{ in } p-Pb: \text{ mass ordering?} \]

- \(\langle p_T \rangle\) for \(p\) and \(\Lambda\) follow mass ordering.
- Meson resonances \(\langle p_T \rangle\) is larger than \(p\) and \(\Lambda\) one.

Do resonances not follow mass ordering or do protons deviate?
Similar deviation from mass ordering observed also in pp, then likely due to production mechanisms.

- \( \langle p_T \rangle \) for p and \( \Lambda \) follow mass ordering.
- Meson resonances \( \langle p_T \rangle \) is larger than p and \( \Lambda \) one.

Do resonances not follow mass ordering or do protons deviate?
**$K^*/K$, $\phi/K$ system size dependence**

- $\phi/K$ in central Pb-Pb collisions consistent with the value measured in pp collisions and with thermal model prediction (Andronic et al., J. Phys. G38(2011)124081)

- $K^*/K$ exhibits a strong suppression going from peripheral to most central Pb-Pb collisions (i.e. increasing system size) → consistent with $K^*$ rescattering as the dominant effect

In p-Pb collisions
- $\phi/K$ rather independent from event multiplicity class
- $K^*/K$ sits along the extrapolation from pp to peripheral Pb-Pb collisions
$K^*$ and $\phi$ spectra predicted using blast-wave model parameters ($T_{\text{kin}}, n, \text{and } \beta_s$) measured in global BW fits of $\pi$, K and p in Pb-Pb collisions (ALICE coll. Phys. Rev. C88(2013)044910).

Normalization

\[
\begin{align*}
-K^* \text{ Integral} &= \text{Yield}(K^\pm, \text{Pb-Pb}) \times \text{Ratio}(K^*/K, \text{th.fit}) \\
-\phi \text{ Integral} &= \text{Yield}(K^\pm, \text{Pb-Pb}) \times \text{Ratio}(\phi/K, \text{th.fit})
\end{align*}
\]


- $\phi$ not suppressed in either central or peripheral collisions
- $K^0$ suppressed for $p_T < 2$ GeV/c in central collisions. No suppression in peripheral collisions. → As expected from dominating rescattering effects
Using the Torrieri-Rafelski model it is possible to estimate the lower limit of the hadronic lifetime $\tau_{\text{kin}} - \tau_{\text{chem}} (\tau > 2 \text{ fm/c})$.
• $p/\phi$ ratio is flat for $p_T < 3-4$ GeV/c in central Pb-Pb collisions → similar spectra shapes of $p$ and $\phi$ → low-$p_T$ spectral shape determined by particle mass, i.e. consistent with hydrodynamic description

• $p/\phi$ ratio in $p$-Pb collisions for all event multiplicity class similar to peripheral Pb-Pb and pp collisions

• Indication of flattening of the $p/\phi$ ratio below 1.5 GeV/c in most central $p$-Pb collisions → hint of the onset of a collective behaviour?
High-$p_T$: in most central Pb-Pb collisions, a strong suppression is observed with respect to pp collisions, both for resonances as well as stable hadrons.

Intermediate $p_T$: $R_{AA}(\phi)$ lower $R_{AA}(p)$. Since $p/\phi$ ratio in Pb-Pb is flat $\rightarrow$ differences due to pp reference spectra.

Low $p_T$: below 2 GeV/c larger suppression of $K^*0$ production with respect to charged hadrons $\rightarrow$ can be explained in terms of rescattering effects.
In p-Pb no suppression with respect to pp, only a moderate Cronin peak at intermediate momentum.
Summary

K*(892)⁰ and ϕ(1020) resonance production has been measured in a wide momentum range in p-Pb and Pb-Pb collisions at the LHC, as a function of multiplicity (centrality)

- In pp and in p-Pb resonances <p_T> does not follow the same mass ordering as in central Pb-Pb, where it is compatible to that of stable hadrons with similar mass.

- K*/K exhibits a strong suppression going from peripheral to most central Pb-Pb collisions (i.e. increasing system size) → K* yield affected by rescattering in the hadronic phase, while ϕ behaves as a long-lived particle.

- In central p-Pb, at low p_T ϕ/p ratio seems flat as in central Pb-Pb collisions → hints of the onset of a collective behaviour?

- In central Pb-Pb collisions, similarly to other hadrons, high-p_T resonances are strongly suppressed.
Ευχαριστώ
Backup slides
For $K^* (892)^0$ and $\phi(1020)$ no mass shift or width broadening in Pb-Pb collisions