Strangeness and light flavor production as a function of multiplicity in proton-proton collisions measured with ALICE

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Introduction

Hyperon-to-pion ratio as a function of the average charged multiplicity density $\langle dN_{ch}/d\eta \rangle$ at midrapidity ($|\eta| < 0.5$)

**Strangeness production:** historically related to the formation of a QGP
Hyperon-to-pion ratio as a function of the average charged multiplicity density \( \langle dN_{ch} / d\eta \rangle \) at midrapidity (\( |\eta| < 0.5 \))

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- **p-Pb results:**


  - Consistent with *pp* at low multiplicities and with *central Pb-Pb* at high multiplicities
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The ALICE Experiment at the LHC

**Specificity:** low-momentum tracking and particle identification in a high-multiplicity environment
The ALICE Experiment at the LHC

**ITS** ($|\eta|<0.9$)
- 6 Layers of silicon detectors
- Trigger, tracking, vertex, PID ($dE/dx$)

![ITS standalone tracks](chart)

ALICE has at its disposal practically all known particle identification techniques in a broad $p_T$ range!

![Decay Topology](chart)
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+ relativistic rise

**ALICE**
pp, $\sqrt{s} = 7$ TeV

$\frac{dE}{dx}$ in TPC (arb.units)

$\frac{dE}{dx}$

$10^{-1}$  $1$  $10$  $10^2$

$p_T$ (GeV/c)

$10^1$  $10^2$

$K$  $p$  $d$  $\pi$  $\rho$
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\[
\Xi^- \rightarrow \Lambda + \pi^-
\]
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**V0** [V0A (2.8<\eta<5.1) & V0C (-3.7<\eta<-1.7)]
- Forward arrays of scintillators
- Trigger, beam gas rejection
- Multiplicity estimator:
  - Event selection based on total charge deposited in the V0A and V0C detectors ("V0M")
  - $\langle dN_{ch}/d\eta \rangle$ estimated as the average number of primary charged tracks in $|\eta| < 0.5$
Transverse Momentum Spectra

- V0M Multiplicity Classes:
  \[ \langle dN_{\text{ch}}/d\eta \rangle^{\text{INEL}>0} \approx 6.0 \]

\[
\begin{align*}
I \to \langle dN_{\text{ch}}/d\eta \rangle &\approx 3.5 \times \langle dN_{\text{ch}}/d\eta \rangle^{\text{INEL}>0} \\
\vdots \\
X \to \langle dN_{\text{ch}}/d\eta \rangle &\approx 0.4 \times \langle dN_{\text{ch}}/d\eta \rangle^{\text{INEL}>0}
\end{align*}
\]

ALICE Preliminary
pp at \( \sqrt{s}=7 \) TeV
V0M Mult. Evt. Classes

ALI–PRL–111017

D.D. Chinellato – 38th International Conference on High Energy Physics
Relative Strangeness Production

- Quantified via strange to non-strange integrated particle ratios vs $\langle dN_{ch}/d\eta \rangle$
- Significant enhancement of strange and multi-strange particle production
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\[ \text{ALICE, arXiv:1606.07424} \]

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- Follows the trend observed in $p$-Pb, despite differences in initial state
- Particle ratios reach values that are similar to those observed in central Pb-Pb collisions

Summary

• An enhanced production of strange and multi-strange particles has been observed in high-multiplicity pp collisions (arXiv:1606.07424)

• The multiplicity dependence of strangeness production is strikingly similar in pp and p-Pb, and approaches values similar to those in central Pb-Pb

• None of the current MC models are successful at fully describing these observations.

• Open questions (stay tuned!):
  • Will the relative strangeness production in smaller systems eventually saturate?
  • Higher energy pp (13 TeV): how do charged-particle multiplicities and collision energy relate?
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Thank you!
Backup
Modification of Transverse Momentum Spectra

- Spectra become harder at higher multiplicities
- The hardening is more pronounced for baryons than for mesons

\[
\langle dN_{ch}/d\eta \rangle_{\text{INEL}>0} \approx 6.0
\]
Baryon to Meson Ratios

ALICE Preliminary pp $\sqrt{s} = 7$ TeV
- V0M Class I, $\langle dN_{ch}/d\eta \rangle = 21.3$
- V0M Class X, $\langle dN_{ch}/d\eta \rangle = 2.3$
(V0M Multiplicity Classes)

ALICE p-Pb $\sqrt{s_{NN}} = 5.02$ TeV
- 0-5%, $\langle dN_{ch}/d\eta \rangle = 45.1$
- 60-80%, $\langle dN_{ch}/d\eta \rangle = 9.8$
(V0A Mult. Classes - Pb side)

ALICE Pb-Pb $\sqrt{s_{NN}} = 2.76$ TeV
- 0-5%, $\langle dN_{ch}/d\eta \rangle = 1601.0$
- 60-80%, $\langle dN_{ch}/d\eta \rangle = 55.5$

Dependence with the event multiplicity in pp qualitatively similar to p-Pb and Pb-Pb
Baryon to Meson Ratios

\[
\frac{(p + \bar{p})}{(\pi^+ + \pi^-)}
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ALI-PREL-110279
Multiplicity dependence of baryon to meson ratios in momentum intervals

Remarkable consistency across systems as a function of multiplicity
Radial flow? Color reconnection?...
Particle Ratios Across Colliding Systems

- Small systems:
  - Strangeness enhancement
  - Relative decrease of $K^*$
  - No multiplicity dependence of baryon/meson ratio

- Towards central Pb-Pb:
  - Strangeness abundance constant
  - $K^*$ abundance decreases further
  - Baryon/meson decreases

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**ALICE Preliminary**

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- Observed increase is more pronounced for baryons with higher strangeness content