Strangeness production with ALICE at the LHC

Maria Vasileiou on behalf of the ALICE Collaboration
National and Kapodistrian University of Athens
Physics Department

ICNFP2019
Outline

- Introduction
- ALICE Detector and PID
- Strange particle detection
- Strangeness production in pp, p-Pb, Xe-Xe and Pb-Pb collisions:
  - transverse momentum spectra
  - baryon-to-meson ratios
  - strangeness enhancement
- Conclusions
ALICE is designed to study the physics of strongly interacting matter under extremely high temperature and energy density conditions to investigate the properties of the quark-gluon plasma (QGP). The Experiment has collected data from:

- **pp collisions at** $\sqrt{s} = 0.9, 2.76, 5.02, 7, 8, 13$ TeV
  - Test QCD inspired models
  - Search for collective effects in small systems
  - Provide reference for p-Pb and Pb-Pb data

- **p-Pb collisions at** $\sqrt{s_{NN}} = 5.02, 8.16$ TeV
  - Discriminate between initial (cold nuclear matter) and final state (QGP) effects
  - Search for collective effects in small systems
  - Provide reference for Pb-Pb data

- **Xe-Xe collisions at** $\sqrt{s_{NN}} = 5.44$ TeV
  - Study the colliding system size dependence

- **Pb-Pb collisions at** $\sqrt{s_{NN}} = 2.76, 5.02$ TeV
  - Study QGP properties and its evolution
THE ALICE DETECTOR

1. ITS
2. FMD, T0, V0
3. TPC
4. TRD
5. TOF
6. HMPID
7. EMCal
8. DCal
9. PHOS, CPV
10. L3 Magnet
11. Absorber
12. Muon Tracker
13. Muon Wall
14. Muon Trigger
15. Dipole Magnet
16. PMD
17. AD
18. ZDC
19. ACORDE

a. ITS SPD (Pixel)
b. ITS SDD (Drift)
c. ITS SSD (Strip)
d. V0 and T0
e. FMD
**ITS**

- **Inner Tracking System:**
  - 2 layers of Silicon Pixel Detector (SPD)
  - 2 layers of Silicon Drift Detector (SDD)
  - 2 layers of Silicon Strip Detector (SSD)

- Drift and Strip Detectors provide a measurement of the ionization energy loss

- PID to very low $p_T$:
  - pions down to 100 MeV/c with stand-alone tracking
TPC

- PID via $dE/dx$ in gas – Ar/CO$_2$ (90:10) – up to 159 samples

- Truncated mean $dE/dx$ calculated and used for particle identification (PID) in a wide momentum range

- Largest $\pi/K$ and $K/p$ separation achieved at low $p$ ($< 2.0$ GeV/$c$)
At high $p_T$: particles separated on a statistical basis via multi-Gaussian fits
**TOF**

- **Time - Of - Flight:**
  Multigap Resistive Plate Chambers (MRPC)
  PID at intermediate momenta

- Resolution $\sim 80$ ps
Centrality Selection in Pb-Pb Collisions

- Event centrality classes are defined based on the amplitude measured in the V0 scintillators placed at:
  - $2.8<\eta<5.1$ (V0A)
  - $-3.7<\eta<-1.7$ (V0C)
- Curve: Glauber model fit to the measurement


ICNFP2019 - International Conference on New Frontiers in Physics

M. Vasileiou
Strange particle detection

- Topological decay reconstruction
- Geometrical and kinematical selections
- Invariant mass analysis

\[
\begin{align*}
K_S^0 &\rightarrow \pi^+ + \pi^- \text{ (B.R. 69.2\%)} \\
\Lambda &\rightarrow p + \pi^- \text{ (B.R. 63.9\%)} \\
\bar{\Lambda} &\rightarrow \bar{p} + \pi^+ \text{ (B.R. 63.9\%)} \\
\Xi^- &\rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^- \text{ (B.R. 63.9\%)} \\
\bar{\Xi}^+ &\rightarrow \bar{\Lambda} + \pi^+ \rightarrow \bar{p} + \pi^+ + \pi^+ \text{ (B.R. 63.9\%)} \\
\Omega^- &\rightarrow \Lambda + K^- \rightarrow p + \pi^- + K^- \text{ (B.R. 43.3\%)} \\
\bar{\Omega}^+ &\rightarrow \bar{\Lambda} + K^+ \rightarrow \bar{p} + \pi^+ + K^+ \text{ (B.R. 43.3\%)}
\end{align*}
\]
Pb-Pb Collisions
Strangeness enhancement

- Enhanced production of strange particles in A-A collisions w.r.t. pp
- Enhancement increases with the strangeness content of the particle
- Decreasing trend with increasing energy, as a result of (canonical) suppression in pp collisions

Strangeness enhancement

- In pp collisions the production of strangeness relative to pions is larger at the LHC
- Increase of strangeness production measured in Pb-Pb w.r.t. pp collisions
- Saturation of the ratios for large number of participants
- Values consistent with statistical hadronization models
Transverse momentum spectra

- Hardening of the spectra with increasing centrality
- More pronounced for heavier particles (radial flow)
Transverse momentum spectra

Same pattern for multi-strange hadrons
Baryon to meson ratios

- Same features in Pb-Pb collisions at both energies
- We observe a depletion at low $p_T$ and an enhancement at intermediate $p_T$
- Recombination model approximately reproduces the shape but overestimates the baryon enhancement by about 15%
- EPOS describes the dependence over the entire $p_T$ range
Baryon to meson ratios

- **Similarities** in the evolution across different systems
- **We observe a depletion at low** $p_T$ **and an enhancement at intermediate** $p_T$
pp Collisions
Transverse momentum spectra

- Shape evolution similar to Pb-Pb
- Hardening of $p_T$ spectra with increasing multiplicity
- Hardening more pronounced for higher-mass particles
- In Pb-Pb collisions such behavior explained by hydrodynamical models
Transverse momentum spectra

- Same pattern as observed in pp@7Tev
Transverse momentum spectra

➢ Same pattern as observed in pp@7Tev
Strange particle yields

- Yields of strange hadrons increase linearly with the charged particle multiplicity
- Same trend in pp@7 TeV and pp@13 TeV
- The abundance of strange hadrons seems to be invariant with the collision energy
Strange-to-pion yields

- **Enhancement** of strange to non-strange hadron production from pp to most central Pb-Pb collisions
- **Steeper** slope with more strange content
- **Almost saturated** trend in most central Pb-Pb collisions for all particles
- **Origin** of strangeness production in Pb-Pb collisions driven by the final state rather than by the collision system or energy
- **QCD inspired models** fail to describe the data
Baryon-to-meson ratio

- Yield ratios do not change significantly with multiplicity → the observed enhanced production rates of strange hadrons w.r.t. pions is not due to the difference in the hadron masses

- None of the MC models can describe all particle ratios simultaneously

ALICE, Nature Physics 13 (2017) 535
Strangeness enhancement

- Yield ratios to pions divided by the values measured in the inclusive pp sample
- The observed multiplicity dependent enhancement follows a hierarchy determined by the hadron strangeness

ALICE, Nature Physics 13 (2017) 535
pp, p-Pb, Xe-Xe, Pb-Pb Collisions
Strangeness enhancement

- Results from Xe-Xe@5.44 TeV collisions follow the trend observed in Pb-Pb collisions
- Strange particle production is collision energy independent at similar multiplicity
Strange resonance production

For the small collision systems the ratio of baryonic resonance to stable particle with same strangeness content has no multiplicity dependence

Increasing pattern depends only on strangeness content and not on particle mass: enhancement of higher mass resonances is the same as for the lower mass ground-state particle with the same strangeness content.

Conclusions

- ALICE has measured strangeness production in pp, p-Pb, Xe-Xe and Pb-Pb collisions.

- In Pb-Pb collisions a hardening of strange hadron transverse momentum spectra is observed, with increasing centrality (radial flow).

- Similar effect measured in pp@7, 13 TeV collisions, with increasing multiplicity.
Conclusions

- Strangeness enhancement is observed in high multiplicity pp collisions.

- Strange-to-pion ratios evolve smoothly with charged particle multiplicity, regardless collisions system and energy.

- Strangeness enhancement has been studied with resonances. In small systems the enhancement as a function of multiplicity, is found to be driven by strangeness content.
Thank you!