Multi-Strange Particle Production in p-Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV with ALICE at the LHC

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Outline

- Strangeness Enhancement
- Detecting Strange Particles with ALICE
- Results in Small Systems
- New Results from p-Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV
- Outlook and Summary
Strangeness Enhancement

- The enhanced yield of strange particles was one of the earliest proposed signatures of the formation of a deconfined Quark-Gluon Plasma (QGP)
  J. Rafelski and B. Müller, PRL 48, 1066 (1982)

- In ALICE, strange particle yields in AA collisions with respect to non-strange particles are higher than in pp

Detecting Strange Particles with ALICE
A Large Ion Collider Experiment

Detectors used in this analysis are:
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  - Inner Tracking System (ITS) (|\eta|<0.9)
    - 6 layers of silicon detectors
    - Used for trigger, tracking, vertexing
A Large Ion Collider Experiment

Detectors used in this analysis are:

1. **Inner Tracking System (ITS) ($|\eta|<0.9$)**
   - 6 layers of silicon detectors
   - Used for trigger, tracking, vertexing

2. **TPC ($|\eta|<0.9$)**
   - Gas-filled ionisation chamber
   - Used for tracking, vertexing, PID ($dE/dx$)
- A Large Ion Collider Experiment
- Detectors used in this analysis are:
  - Inner Tracking System (ITS) ($|\eta|<0.9$)
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    - Used for trigger, tracking, vertexing
  - TPC ($|\eta|<0.9$)
    - Gas-filled ionisation chamber
    - Used for tracking, vertexing, PID ($dE/dx$)
  - V0A ($2.8<\eta<5.1$ Pb-going direction)
    - Forward scintillator arrays
    - Used for trigger and multiplicity estimation
Multiplicity Estimation

- Multiplicity can be defined as the number of charged particles per event.

- Event activity is measured by ALICE at forward rapidity by the V0A detector.

- Multiplicity classes are defined as percentile intervals of cross-section.
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\[
\langle dN_{\text{ch}}/d\eta \rangle_{\eta<0.5} = \begin{array}{cccccc}
4.47 & 10.97 & 18.39 & 26.89 & 35.49 & 42.40 \\
\pm 0.14 & \pm 0.29 & \pm 0.48 & \pm 0.7 & \pm 0.92 & \pm 1.1 \\
\end{array},
\]

Signal Extraction

Detect strange particles from the topology of their weak decays
Plot invariant mass in $p_T$ and multiplicity bins and extract yields

- $\Xi^+ \Xi^-$, $-0.5 < y < 0$
  - $2.1 < p_T < 2.3$ (GeV/c)
- $\Omega^+ \Omega^-$, $-0.5 < y < 0$
  - $2.4 < p_T < 2.9$ (GeV/c)

$\Xi^+ \Xi^-$ BR: $99.887 \pm 0.035\%$
$\Omega^+ \Omega^-$ BR: $67.8 \pm 0.7\%$
$\Lambda \rightarrow p \pi^-$ BR: $63.9 \pm 0.5\%$

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ALICE | INPC 2019, Glasgow, UK | Emily Willsher
Results in Small Systems
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- Enhancement of ratio of strange particle yields to pions observed in small collision systems (pp + p-Pb)

- Significant enhancement in pp with $dN_{ch}/d\eta$

- pp and p-Pb in strong agreement at same $dN_{ch}/d\eta$

- Smooth evolution from low $dN_{ch}$ pp to high $dN_{ch}$ p-Pb which reaches levels in Pb-Pb
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- Results for strange to non-strange yield ratios are not reproduced well by microscopic models
Results in Small Systems

- Plot Baryon to Meson ratio
- Observed enhancement is related to strangeness not mass
- Plot $(h/\pi)/(h/\pi)^{pp}_{\text{INEL}>0}$
- Hierarchy - strength of enhancement depends on strangeness content of baryon

Results in Small Systems

- Charged particle multiplicity is biggest driver of strangeness enhancement.

- Results consistent for different colliding energies and collision systems measured by ALICE (pp, p-Pb, Pb-Pb, Xe-Xe).

- Strangeness production increases until saturation levels are reached.
New Results from p-Pb Collisions at $\sqrt{s_{NN}} = 8.16$ TeV
New Results in p-Pb at 8.16 TeV

Spectra fitted with a Lévy-Tsallis function
Particle Yields

New Results in p-Pb at 8.16 TeV

Same $dN_{ch}/d\eta$ dependence is observed as in p-Pb at 5.02 TeV

Trend continues at higher values of $dN_{ch}/d\eta$
Cascade to Pion Ratios

- **New Results** in p-Pb at 8.16 TeV
- New higher energy results are in agreement with lower energy measurements
- New measurements extend multiplicity reach of p-Pb data
Cascade to Pion Ratios

- **New Results** in p-Pb at 8.16 TeV now included

- New p-Pb results are consistent with the smooth evolution between collision systems
Outlook and Summary
Outlook

- Future studies of p-Pb will be extended to higher $dN_{ch}/d\eta$ using a dedicated high-multiplicity trigger \( \Rightarrow \) explore the p-Pb/Pb-Pb overlap region

- Run 3+4 measurements will extend pp data into the Pb-Pb region as well \( \Rightarrow \) will ratios saturate or continue to rise?
Summary

- Ongoing studies of strangeness enhancement will contribute to the understanding of particle production mechanisms in small systems.

- New results from p-Pb collisions at $\sqrt{s_{\text{NN}}} = 8.16$ TeV have been presented.

- Cascade to pion ratios show an increase as a function of $dN_{\text{ch}}/d\eta$ across collision systems and initial colliding energies.

- Future studies will provide more insight into behaviour in small systems at multiplicities as high as those reached in heavy-ion collisions.
Thank you!
Results in Small Systems

- pp data can be compared to different event generators
  - PYTHIA8 (Lund String model) – poor reproduction with/without colour reconnection
  - DIPSY (colour ropes) – qualitatively describes increase
  - EPOS-LHC (core-corona) – ok qualitative description of trend
Results in Small Systems

- In macroscopic statistical hadronisation models, strange hadron production in small systems is suppressed due to conservation of strangeness quantum number (Canonical Supression)

- Magnitude of suppression dependent on strangeness content

- Model describes data well except $\phi$ meson

Results in Small Systems

- $\phi$ does not behave liked hadron with strangeness quantum number 0

- $\phi$ shows enhancement with $dN_{ch}/d\eta$

- $\Xi(S=2)/\phi(S=0)$ ratio is constant within uncertainties for $dN_{ch}/d\eta > 10$

- $\phi$ meson behaves like particle with two strange quarks $S=2$
Results in Small Systems

- Same scaling for strangeness production with $dN_{ch}/d\eta$ observed in pp collisions
- Hadrochemistry driven by event activity not collision energy
Mean $\langle p_T \rangle$

- New Results in p-Pb at 8.16 TeV included
- Rising trend of $\langle p_T \rangle$ for all particles