Recent measurements of identified hadron spectra and multiplicities in Be+Be and Ar+Sc collisions at SPS energies

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Preliminary results on $\pi^+, \pi^-, K^+, K^-$ and $p$ on:

- Transverse momentum distributions.
- Rapidity distributions.
- Mean multiplicities.

Produced in strong and electromagnetic processes in primary interactions:

- **Be+Be** – 20% most central collisions (NA61/SHINE preliminary).
- **Ar+Sc** – 5% most central collisions (NA61/SHINE preliminary).

Will be compared to available World data on $p+p$, $Au+Au$ and $Pb+Pb$:

Particle identification — \textit{tof} and $dE/dx$
Event selection in Ar+Sc collisions

Centrality classes – Projectile Spectator Detector

- The PSD is located most downstream on the beam line and measures the projectile spectator energy $E_F$ of the non-interacting nucleons of the beam nucleus.
- The energy measured by the PSD is used to select events classes corresponding to the collision centrality.
Section 1

Identified hadrons spectra
Spectra in $y$ and $p_T$ – Be+Be @ 30A GeV/c

Preliminary results from "dEdx" analysis for 0-20% centrality

- $\pi^-$
- $\pi^+$
- $p$

- $K^-$
- $K^+$

NA61/SHINE preliminary
Spectra in $y$ and $p_T$ – Be+Be @ 150A GeV/c

Preliminary results from "dEdx" analysis for 0-20% centrality
Section 2

Inverse slope parameter
$m_T$ distributions

Kaon spectra measured in mid-rapidity ($0 < y < 0.2$) are fitted with exponential function in order to extract the inverse slope parameter $T$.

No systematic deviation from the exponent is observed in measured $m_T$ region at all collision energies.
Inverse slope parameter $T$ in $\text{Be}+\text{Be}$ collisions (NA61/SHINE preliminary) is close to $\text{p}+\text{p}$ measurements.
Inverse slope parameter $T$

Extrapolation of Ar+Sc points to $T(y \approx 0)$ falls close to Pb+Pb, while smaller systems are placed significantly lower.

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**NA61/SHINE**

- **Ar+Sc**
  - $K^+$
  - $K^-$

- **Be+Be**
  - $K^+$
  - $K^-$

- **p+p**
  - $K^+$
  - $K^-$

**NA49**

- **Pb+Pb**
  - $K^+$
  - $K^-$

- **C+C**
  - $K^+$
  - $K^-$

- **Si+Si**
  - $K^+$
  - $K^-$

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Preliminary data from NA61/SHINE and NA49 experiments.
Section 3

Rapidity distributions
Extrapolation in $p_T$

- In order to obtain $dn/dy$ yields, the data is extrapolated in $p_T$ to account for unmeasured regions.

- Exponential dependence in $p_T$ is assumed:

$$\frac{1}{p_T} \frac{d^2n}{dp_T dy} = \frac{dn/dy}{T \cdot (m_K + T)} \cdot e^{-(m_T - m_K)/T}$$

- The function integral outside the acceptance region is added to the measured data points (typically of the order of 1%).
Rapidity distributions of kaons from Be+Be collisions
0-20% centrality, tof-dEdx and dEdx methods combined

NA61/SHINE preliminary
Obtaining "4\pi" acceptance: extrapolation in $y$

Two symmetrically placed gaussians are used to construct the fitting function:

$$f_{\text{fit}}(y) = A \times \left( \frac{1}{\sigma_0 \sqrt{2\pi}} \exp \left( - \frac{(y - y_0)^2}{2\sigma_0^2} \right) + \frac{1}{\sigma_0 \sqrt{2\pi}} \exp \left( - \frac{(y + y_0)^2}{2\sigma_0^2} \right) \right)$$

$\leftarrow \text{Be+Be @150A GeV/c}$

Symmetry with respect to $y=0$ is assumed at all beam energies.
Kaon rapidity distributions from Ar+Sc collisions

0-5% centrality, dEdx analysis method only

Shape parameters: $y_0$ and $\sigma$ are fixed to values obtained in NA49’s Pb+Pb. Measurements of $tof$ will add data in $y \approx 0$ region in the near future.
Proton rapidity distribution

Comparison with Pb+Pb

Proton rapidity distribution measured in:
- p+p (preliminary)
- Be+Be (0-20% centrality)

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Proton rapidity distribution

Comparison of Be+Be and p+p collisions

Pronounced qualitative difference of proton rapidity spectrum between light systems (p+p, Be+Be) and Pb+Pb in 40A GeV/c.
Section 4

Mean multiplicities with comparison to other systems
\[ \langle K^+ \rangle / \langle \pi^+ \rangle \]

\[ \langle K^+ \rangle / \langle \pi^+ \rangle \text{ for } \text{Be}+\text{Be} \text{ close to } \text{p}+\text{p}. \]
\[ \text{Ar}+\text{Sc} \text{ placed in between } \text{p}+\text{p} \text{ and } \text{Pb}+\text{Pb}. \]
$K^+ / \pi^+$ at $y \approx 0$

$K^+ / \pi^+$ at $y \approx 0$ is similar for \textbf{Be+Be} and \textbf{p+p} and largely different for \textbf{Pb+Pb}.
\[ \langle K^- \rangle / \langle \pi^- \rangle \]

\[ \langle K^- \rangle / \langle \pi^- \rangle \] for Be+Be close to \( p+p \).
Ar+Sc placed in between \( p+p \) and Pb+Pb.
$K^-/\pi^-$ at $y \approx 0$

$K^+/\pi^+$ at $y \approx 0$ for $\text{Be}+\text{Be}$ is lower than results for $\text{p}+\text{p}$ collisions.
Energy dependence of $K^+/\pi^+$

"the horn" plot

No "horn"-like structures visible in intermediate size systems: Be+Be and Ar+Sc.
Conclusions

Preliminary results on:
- 20% most central Be+Be collisions were presented.
- 5% most central Ar+Sc collisions were presented.

- Spectra in $y$ and $p_T$ of $\pi^+$, $\pi^-$, $K^+$, $K^-$ and $p$ were discussed.

- Inverse slope parameter $T$ measured in Be+Be collisions is close to p+p, while $T$ obtained for Ar+Sc closer resembles results from Pb+Pb.

- The measurements of $K^+/\pi^+$ and $K^-/\pi^-$ ratios show similar trend in system size dependence – data on Be+Be is usually closer to p+p, while results on Ar+Sc are placed in between p+p and Pb+Pb.

- No "horn"-like structures seen in energy dependence of $K^+/\pi^+$ ratios measured in intermediate size systems: Be+Be and Ar+Sc.

More results on the subject will follow in the near future!
Thank you for your attention!

Event of Ar+Sc collision recorded by NA61/SHINE
Backup slides