Strangeness flow in Au+Au collisions at 1.23 AGeV measured with HADES collaboration

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Why is it interesting to study strangeness flow?

Kaon flow is very sensitive on KN potential

Kaons are good probe of EOS

Kaons might exist inside neutron stars


Kaon propagation and production in nuclear medium is affected by kaon-nucleon potential

Kaon flow is important test for models like HSD, IQMD, BUU...
**High Acceptance Di-Electron Spectrometer**

Fixed target experiment
Toroidal magnetic field
=> Six sector design provides
Full azimuthal coverage
18°-85° polar coverage

Very precise time and position measurement
=> Great hadron detector
(as well as lepton - new ECAL)

Superfast DAQ (above 10kHz HIC)
HADES strangeness program

At low energy HIC rise of $K/\Phi$ - ratio
Universal $<A_{\text{part}}>$ dependence of
strangeness production (different thresholds)
Suppression of $K^-$ w.r.t $K^+$ in n+A
More details in presentation
M. Lorenz on Monday 10.6.

$\pi^- + C$ resp. $W$ @ 1.7 GeV/c

$\alpha = 1.45 \pm 0.06$
$\chi^2/\text{NDF} = 5.90/10 = 0.59$

arXiv:1812.03728
(accepted by PRL)
Au+Au at 1.23 AGeV

Centrality Determination:

Selected 0-40% most central collisions

After additional event quality cuts => 2.1 billion Events

Excellent particle identification

This opens possibilities for very challenging analysis
Event Plane reconstruction and resolution

Event Plane is reconstructed from hits of charged projectile spectators registered in Forward Wall (big rapidity gap between FW and rest of HADES)

Resolution of EP reconstruction based on method described in arxiv:nucl-ex/9711003 (2 subevent method)
Kaon identification

Charged pions identification

Topological cuts (secondary vertex reconstruction)

Background subtraction (mixed event technique)

Energy losses in MDC and TOF

$K^0_s \rightarrow \pi^- + \pi^+$

$K^0_s$

$K^+$

$K^0$ and $K^+$ transitions.
Two methods of flow analysis

Get number of kaons

Fit azimuthal distribution and fit with Fourier expansion

Use event plane resolution correction

Based on work: Phys. Rev. C 88, 014902

Fit invariant mass spectra

$$\langle \cos(n\Delta \phi) \rangle^{\text{obs}} = \frac{S}{S + B} \langle M_{\text{inv}} \rangle \langle \cos(n\Delta \phi) \rangle^{\text{sig}} \quad \text{and} \quad \langle \cos(n\Delta \phi) \rangle^{\text{bkg}} = c_0 + c_1 M_{\text{inv}} + c_2 M_{\text{inv}}^2 + c_3 M_{\text{inv}}^3$$
$K^0_s$ directed and elliptic flow

$v_1$ is slowly rising with rapidity (towards forward rap.)
No strong dependency of $v_1$ with centrality
Slope of $v_1$ at midrapidity is positive (big errors)

$v_2$ is negative (out-of-plane) similar to pions
$K^+$ directed and elliptic flow

$v_1$ is slowly rising with rapidity (towards forward rap.)
No strong dependency of $v_1$ with centrality
Slope of $v_1$ at midrapidity is positive (big errors)

$v_2$ is negative (out-of-plane) similar to pions
$v_2$ independent of rapidity and decreases with transverse momentum
Comparison to world results and models

KaoS (J. Phys. G 31 (2005) no. 6, S693-700)
Au+Au @ 1.5 AGeV

FOPI (Phys. Rev. C 90, 025210, 2014)
Ni+Ni @ 1.91 AGeV

HADES preliminary
Au+Au @ 1.23 AGeV

\[ v_1 = 0.090 \pm 0.002 \]
\[ v_2 = -0.077 \pm 0.002 \]
only statistical errors
centrality 20-40 %
\[ 0.3 < y_{_T} < 0.7 \]
\[ p_T \in (200-500) \text{ MeV/c} \]
Summary and Outlook

Differential analysis of kaon flow was presented
Comparison with FOPI and KaoS data shows a good agreement
Comparison between $K^0_s$ and $K^+$ shows good agreement

Study systematic uncertainty
Detailed comparison with different models

NEW data from Ag+Ag @ 1.58 AGeV (FAIR-0 phase)
BACKUP
Acceptance and Reconstruction corrected phase-space distribution of kaons

We obtained similar number of both kaons (similar threshold)
However the correction factors for neutral kaons are >100
and for positive kaons ~4