Highlights from the NA61/SHINE experiment

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SHINE = SPS Heavy Ion and Neutrino Experiment

\[ \sqrt{s_{NN}} = 5.1–17.3(27.4) \text{ GeV} \]

Strong interactions (this talk)

- study the onset of deconfinement
- search for the critical point

Cosmic rays and neutrinos

Antoni Marcinek (IFJ PAN)
NA61/SHINE detector — unique multi-purpose facility

- large acceptance: full forward hemisphere, down to $p_T = 0$
- particle identification: dE/dx in Time Projection Chambers, Time of Flight
- ion (Be, Ar, Xe, Pb) and hadron ($\pi$, $K$, p) beams, various targets including liquid H$_2$

Central Ar+Sc collision at 150A GeV/c
NA61/SHINE in virtual reality: http://shine3d.web.cern.ch/shine3d
New results on identified hadron spectra in Be+Be and Ar+Sc collisions

see more in the talk by Maciej Lewicki on Wednesday
New results on identified hadron spectra in Be+Be and Ar+Sc collisions

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Multiplicity and net-charge fluctuations in p+p, Be+Be and Ar+Sc collisions

\[ \kappa_1 = \langle N \rangle \]
\[ \kappa_2 = \langle (\delta N)^2 \rangle = \sigma^2 \]
\[ \kappa_3 = \langle (\delta N)^3 \rangle = S\sigma^3 \]
\[ \kappa_4 = \langle (\delta N)^4 \rangle - 3\langle (\delta N)^2 \rangle^2 = K\sigma^4 \]

where:
- \( N \) – multiplicity; \( \delta N = N - \langle N \rangle \)
- \( \sigma \) – standard deviation
- \( S \) – skewness; \( K \) – kurtosis

- No structure indicating critical point
- Multiplicity \( \kappa_2 / \kappa_1 \): increasing difference between small systems (p+p and Be+Be) and a heavier system (Ar+Sc) with collision energy
- Net-charge \( \kappa_3 / \kappa_1 \): increasing difference between Be+Be and other systems (p+p and Ar+Sc) with collision energy
- \( \kappa_4 / \kappa_2 \): consistent values for all measured systems at given collision energy
Proton and charge hadron intermittency in Ar+Sc and Pb+Pb collisions

see posters by Nikolaos Davis, Tobiasz Czopowicz and Haradhan Adhikary

\[ F_r(M) = \frac{\left\langle \frac{1}{M} \sum_{m=1}^{M} n_m(n_m - 1)\ldots(n_m - r + 1) \right\rangle}{\left\langle \frac{1}{M} \sum_{m=1}^{M} n_m \right\rangle^r} \]

where \( \langle \ldots \rangle \) denotes averaging over events, \( M \) the number of cells

\( \bullet \) Statistically independent points, cumulative variables

\( \bullet \) No indication of critical point in these analyses (power-law scaling \( F_r(M) \sim M^{\Phi_r} \))

\( \bullet \) Work on more advanced methodology ongoing

→ poster by N. Davis
The Levy stability parameter $\alpha$ describes shape of the source.

3D Ising model with random external field predicts $\alpha = 0.5 \pm 0.05$ at critical point.
Spectator-induced electromagnetic effects in Ar+Sc collisions

First time ever observation of the spectator-induced electromagnetic effects in peripheral small systems: Ar+Sc at 40\,A\,GeV/c

This effect provides information on the space-time evolution of the system


New data on hadron spectra in p+p reactions

see the talk by Maciej Lewicki on Wednesday
Detector upgrade and 2022+ data taking

Main goal: first ever open charm measurements at SPS

- What is the mechanism of open charm production?
- How does the onset of deconfinement impact open charm production?
- How does the formation of quark-gluon plasma impact $J/\psi$ production?
Summary

- 2D scan in system size and energy is completed revealing unexpected dependencies (onset of fireball), delivering new exciting results
- So far no convincing indication of the critical point
- Detector upgrade almost done, open charm measurements starting this year
- NA61/SHINE contributions:
  - Talk on Wednesday: News on strangeness production from NA61/SHINE, Maciej Lewicki
  - Poster: Intermittency analysis in NA61/SHINE: hunting for critical point signatures in proton fluctuations, Nikolaos Davis
  - Poster: Intermittency of charged hadrons in NA61/SHINE, Tobiasz Czopowicz
  - Poster: New approach to study intermittency by NA61/SHINE, Haradhan Adhikary
  - Poster: Symmetric Levy HBT measurements at NA61/SHINE, Barnabás Pórfy
  - Poster: Feasibility studies of Lambda transverse polarization in p+p interactions within NA61/SHINE at the CERN SPS, Yehor Bondar
Heavy ion physics (this talk)

- 2D scan in collision energy and system size
- spectra, correlations, fluctuations
- search for the critical point
- study the onset of deconfinement

Cosmic rays and neutrinos

- precision measurements of spectra
- cosmic rays: Pierre Auger Observatory, KASCADE
- neutrinos: T2K, Minerva, MINOS, NOνA, LBNE
NA61/SHINE detector — unique multi-purpose facility

- fixed target experiment
  various targets including liquid H₂
- beams:
  ion (Be, Ar, Xe, Pb), hadron (∇, K, p)
- large acceptance:
  full forward hemisphere, down to $p_T = 0$
- directly only charged hadrons
- identification:
  dE/dx in Time Projection Chambers, Time of Flight
- centrality:
  forward energy in Projectile Spectator Detector

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NA61/SHINE two-dimensional scan

NA61/SHINE explores the phase diagram of strongly interacting matter by performing a 2D scan in collision energy and system size.
Directed and elliptic flow in Pb+Pb

- Significant mass dependence of the directed flow and its midrapidity slope
- Some mass dependence also for elliptic flow
- Significant energy dependence for pion directed flow
- Insignificant energy dependence for elliptic flow