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RECENT RESULTS AND THE FUTURE OF THE NA61/SHINE STRONG INTERACTIONS PROGRAM*

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NA61/SHINE is a fixed target experiment at the CERN Super-Proton-Synchrotron. The main goals of the experiment are to discover the critical point of strongly interacting matter and to study the properties of the onset of deconfinement. In order to reach these goals, the collaboration studies hadron production properties in nucleus–nucleus, proton–proton and proton–nucleus interactions. In this paper, recent results on particle production in p+p interactions, as well as Be+Be and Ar+Sc collisions in the SPS energy range, are reviewed. The results are compared with available world data. The future of the NA61/SHINE scientific program is also presented.

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1. Introduction

The NA61/SHINE experiment performs a unique two-dimensional scan of the phase diagram of strongly interacting matter. The main goals are the study of the properties of the onset of deconfinement by measurements of hadron production and the search for the critical point of strongly interacting matter by measuring event-by-event fluctuations. Measurements are performed in a wide beam momentum range (from 13 up to 150/158A GeV/c) and for various systems (p+p, p+Pb, Be+Be, Ar+Sc, Xe+La and Pb+Pb). The program is motivated by the discovery of the onset of deconfinement in Pb+Pb collisions at 30A GeV/c by the NA49 experiment [1, 2].

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NA61/SHINE is a fixed target experiment at the CERN SPS [3]. The detection system is based on eight Time Projection Chambers (TPC) providing acceptance in the full forward hemisphere, down to $p_{\mathrm{T}} = 0$. The TPCs allow for tracking, momentum and charge reconstruction as well as the measurement of mean energy loss per unit path length. Time-of-Flight (ToF) walls provide additional particle identification by measuring particles mass. The Projectile Spectator Detector (PSD), a zero-degree calorimeter, allows selecting collision centrality based on the measurement of forward energy. The full detector system of the NA61/SHINE experiment is presented in Fig. 1.

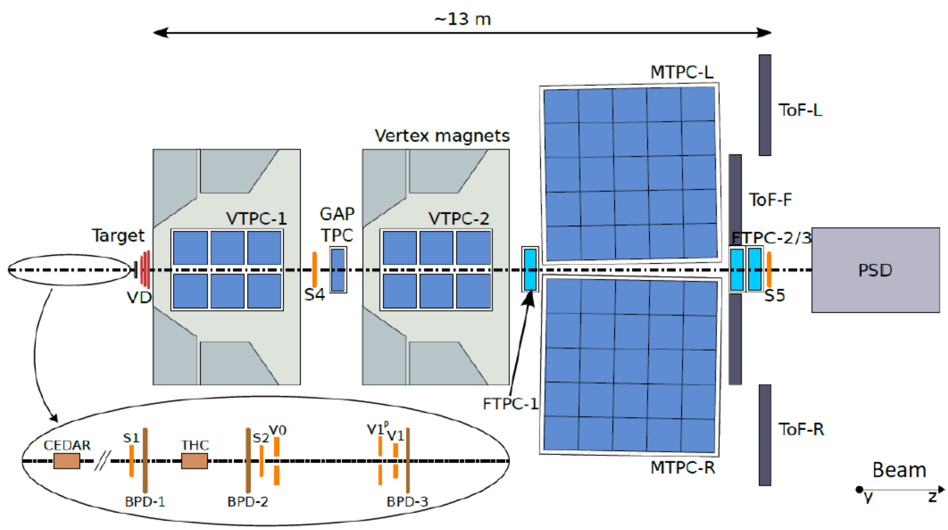

Fig. 1. NA61/SHINE detector system.

2. Onset of deconfinement

One of the main purposes of NA61/SHINE is to study the phase transition between hadron gas (HG) and quark–gluon plasma (QGP). The measurements concentrate on observables for which the Statistical Model of the Early Stage (SMES) predicts characteristic signals [4].

Mean multiplicities of all pions, $\langle\pi\rangle$, normalized to the average number of wounded nucleons, $\langle W\rangle$, are shown in Fig. 2. The results were compared with world data from other experiments [5–7]. At higher SPS energies, the slope of the energy dependence is larger for the heavy systems (Pb+Pb, Ar+Sc) than for the light ones (p+p, Be+Be). SMES predicts an increase of the slope in the quark–gluon plasma due to a larger number of degrees of freedom. All A+A data come from central collisions.

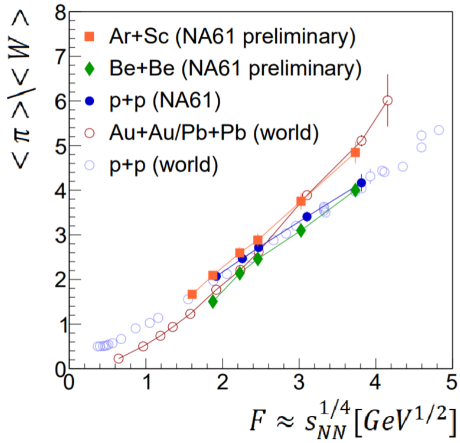

Fig. 2. Energy dependence of the ratio $\langle\pi\rangle/\langle W\rangle$ of pion multiplicity to the number of wounded nucleons.

Figure 3 presents the multiplicity ratio of charged kaons to pions at mid-rapidity. Figure 4 shows the energy dependence of the inverse slope parameter of transverse mass spectra of charged kaons. NA61/SHINE results on $p+p$ interactions [8] and Be+Be collisions were compared with results from central Pb+Pb collisions from NA49 [1, 2] and other experiments [9–14].

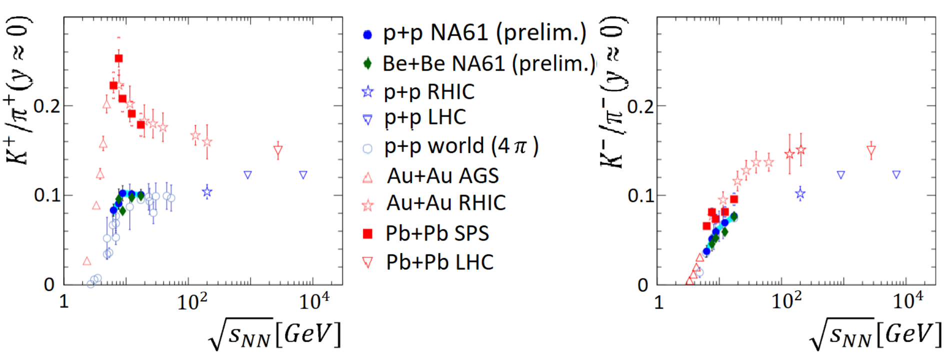

Fig. 3. Energy dependence of the K^+ (left) and K^- (right) multiplicity divided by the corresponding charged π multiplicity at mid-rapidity.

A plateau visible in the energy dependence of the inverse slope parameter in Fig. 4 and peaks seen in Fig. 3 (left panel) for Pb+Pb and Au+Au collisions in the SPS energy range were predicted by the SMES model as signatures of the onset of deconfinement. In the SPS energy range, the NA61/SHINE results on $p+p$ interactions exhibit a qualitatively similar energy dependence (step) for the inverse slope parameter, and a step instead of a peak in the kaon-to-pion ratio. Thus, some properties of hadron production previously attributed to the onset of deconfinement in heavy-ion collisions are present also in p+p interactions. Surprisingly, while the inverse slope parameter in Be+Be collisions lies slightly above that in p+p interactions, the values of the charged-kaon-to-pion ratio are very close in Be+Be and p+p reactions.

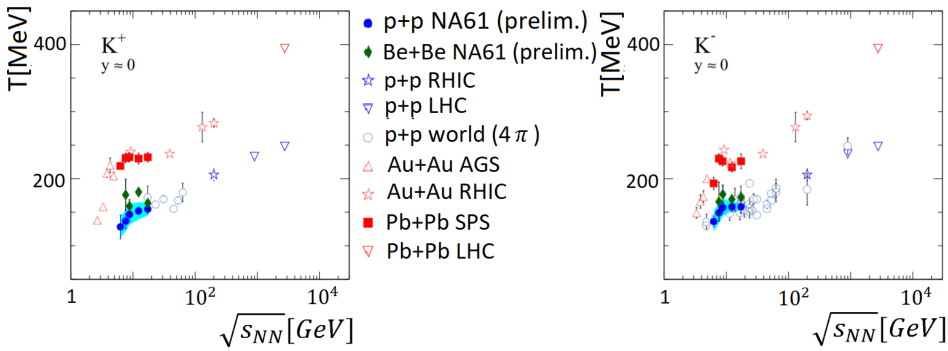

Fig. 4. Energy dependence of the inverse slope parameter of the transverse mass spectra of K^+ (left) and K^- (right).

3. Search for the critical point

NA61/SHINE uses the strongly intensive measures $\Sigma[P_{\mathrm{T}}, N]$ and $\Delta[P_{\mathrm{T}}, N]$ to study transverse momentum and multiplicity fluctuations [15]. Within the Wounded Nucleon Model, they depend neither on the number of wounded nucleons (W) nor on fluctuations of W. Moreover, in the Grand Canonical Ensemble, they do not depend on volume and volume fluctuations. $\Sigma[P_{\mathrm{T}}, N]$ and $\Delta[P_{\mathrm{T}}, N]$ have two reference values, namely, they are equal to zero in the case of no fluctuations and one in the case of independent particle production. Figure 5 shows deviations of $\Sigma[P_{\mathrm{T}}, N]$ and $\Delta[P_{\mathrm{T}}, N]$ from unity (independent particle model) that are smoothly growing with energy, which may be due to the increasing azimuthal acceptance. So far, there are no prominent structures in the NA61/SHINE data which could be related to the critical point (see the expected signal from the critical point in Fig. 5, upper panel).

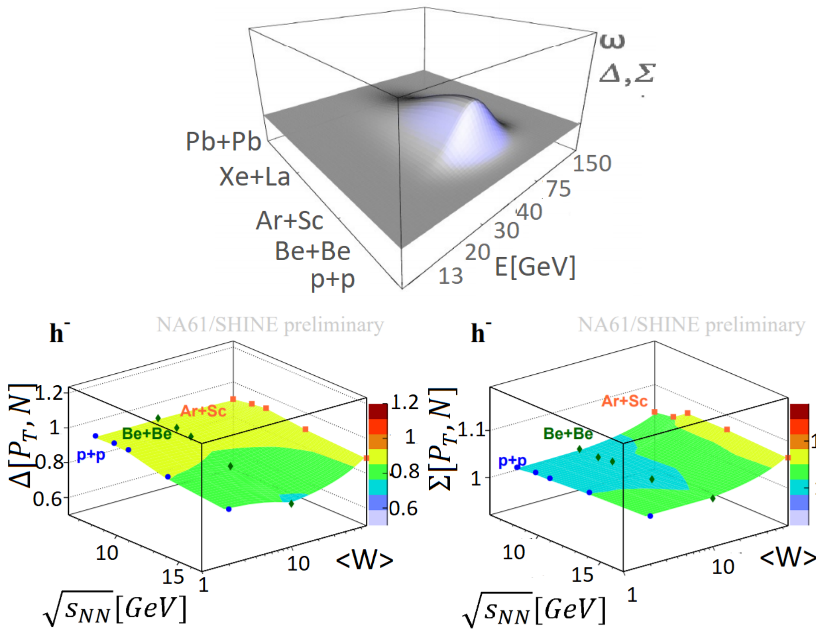

Fig. 5. Upper panel: a hill expected in an energy and system size scan for a fluctuation observable. Lower left panel: $\Delta[P_{\mathrm{T}}, N]$. Lower right panel: $\Sigma[P_{\mathrm{T}}, N]$. Both lower panels are for negatively charged hadrons for 5% of the most central collisions.

4. NA61/SHINE detector upgrade

This year NA61/SHINE started a pilot program of open charm measurements with the new Small Acceptance Vertex Detector (SAVD).

The construction of a high-resolution vertex detector was mostly motivated by the importance and the possibility of the first direct measurements of open charm meson production in heavy-ion collisions at SPS energies. In the first step, a limited-acceptance version of the detector, named SAVD, was built. This device covers 35% of the acceptance of the final version, and is foreseen to operate beyond 2020. The constructed SAVD is based on MIMOSA-26AHR sensors developed in IPHC Strasbourg.

A detector upgrade is planned during the long shutdown LS2 at CERN during the years 2019–2020: the readout speed will be increased to 1 kHz and the Large Acceptance Vertex Detector will be constructed.

The upgraded detector will allow a high-statistics beam momentum scan with Pb+Pb collisions for precise measurements of D-meson production and multi-strange hyperon production in 2021–2024.

5. Summary

This contribution briefly discusses recent results from the NA61/SHINE energy and system size scan performed to study the onset of deconfinement and search for the critical point of strongly interacting matter. Results on produced particle multiplicity and fluctuations were presented.

The measured fluctuations show no indication of a critical point. Still, such features may be revealed in future results on Xe+La and Pb+Pb collisions.

In addition, the extension of the NA61/SHINE program, such as the detector system upgrade and plans to measure precisely open charm in 2021–2024, were discussed in this contribution.

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REFERENCES

[1] C. Alt *et al.*, *Phys. Rev. C* **77**, 024903 (2008).
[2] S. Afanasiev *et al.*, *Phys. Rev. C* **66**, 054902 (2002).
[3] N. Abgrall *et al.*, *JINST* **9**, P06005 (2014).
[4] M. Gaździcki, M.I. Gorenstein, *Acta Phys. Pol. B* **30**, 2705 (1999).
[5] L. Ahle *et al.*, *Phys. Rev. C* **57**, 466 (1998).
[6] V. Blobel *et al.*, *Nucl. Phys. B* **103**, 221 (1976).
[7] A. Golokhvastov, *Phys. Atom. Nuclei* **64**, 84 (2001).
[8] S. Puławski, *PoS* **CPOD2014**, 010 (2015).
[9] M. Gaździcki, D. Roehrich, *Z. Phys. C* **65**, 215 (1995).
[10] M. Gaździcki, D. Roehrich, *Z. Phys. C* **71**, 55 (1996).
[11] M. Kliemant, B. Lungwitz, M. Gaździcki, *Phys. Rev. C* **69**, 044903 (2004).
[12] I. Arsene *et al.*, *Phys. Rev. C* **72**, 014908 (2005).
[13] K. Aamodt *et al.*, *Eur. Phys. J. C* **71**, 1655 (2011).
[14] B.B. Abelev *et al.*, *Phys. Lett. B* **736**, 196 (2014).
[15] A. Aduszkiewicz *et al.* [NA61/SHINE Collaboration], *Eur. Phys. J. C* **76**, 635 (2016).