PARTICLE PRODUCTION PROPERTIES AT SPS ENERGY RANGE — RECENT RESULTS FROM THE NA61/SHINE EXPERIMENT*

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One of the main physics goals of the NA61/SHINE programme on strong interactions is the study of the properties of the onset of deconfinement. This goal is pursued by performing an energy- (beam momentum 13A–158A GeV/c) and system-size ($p+p$, $p+$Pb, Be+Be, Ar+Sc, Xe+La) scan. In particular, recent inclusive spectra of identified hadrons in inelastic $p+p$ and centrality selected Be+Be and Ar+Sc interactions at the SPS energies. The energy dependence of quantities inspired by the Statistical Model of the Early Stage (kink, horn and step) are shown.

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1. The NA61/SHINE facility

The NA61/SHINE detector [1] is a large acceptance hadron spectrometer with excellent capabilities in charged particle momentum measurements and identification by a set of eight Time Projection Chambers as well as Time-of-Flight detectors. The high-resolution forward calorimeter, the Projectile Spectator Detector (PSD), measures energy flow around the beam direction, which in nucleus–nucleus reactions is primarily a measure of the number of projectile spectator (non-interacted) nucleons and is thus related to the violence (centrality) of the collision. A set of beam detectors identifies beam particles and measures precisely their trajectories.

NA61/SHINE performed a two-dimensional scan in collision energy (13A–150A GeV/c) and system size ($p+p$, Be+Be, Ar+Sc, Xe+La, Pb+Pb) to study the phase diagram of strongly interacting matter. The main goals of NA61/SHINE are the search for the critical point and a study of the onset of deconfinemnet.

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2. Study of the onset of deconfinement

The Statistical Model of the Early Stage (SMES) [2] predicts a 1st order phase transition from the QGP to a hadron matter phase between top AGS and top SPS energies. In the transition region, constant temperature and pressure in the mixed phase and an increase of the number of internal degrees of freedom are expected.

A plateau ("step") in the energy dependence of the inverse slope parameter T was observed by the NA49 experiment in Pb+Pb collisions for m_{T} spectra of $K^{\pm}$. It was expected for the onset of deconfinement due to the presence of a mixed phase of hadron gas (HRG) and quark–gluon plasma (QGP). In $p+p$ interactions at SPS energies, the inverse slope parameter T of m_{T} spectra shows qualitatively similar energy dependence as in central Pb+Pb collisions ("step") and such a behaviour seems to emerge also in Be+Be reactions, as visible in Fig. 1. The values of the T parameter in Be+Be collisions are slightly above those in $p+p$ interactions. The T parameter in Ar+Sc reactions is found between those in $p+p$/Be+Be and Pb+Pb collisions [3–5].

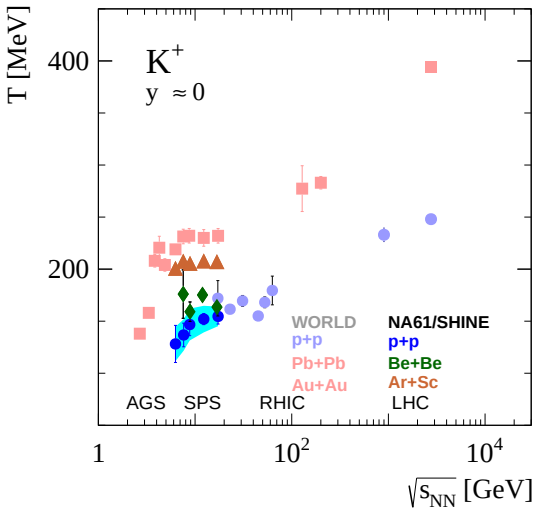

Fig. 1. Inverse slope parameter T of m_{T} spectra of K^+ at mid-rapidity as a function of collision energy. Most results are shown with statistical uncertainties only. For the $p+p$ data, the shaded band indicates systematic uncertainties.

Finally, rapid changes of the ratios K^+/π^+ at mid-rapidity and $\langle K^+\rangle/\langle\pi^+\rangle$ as a function of collision energy ("horn") were observed in Pb+Pb collisions by the NA49 experiment. These were predicted by the SMES model as a signature of the onset of deconfinement. These two ratios together with new NA61/SHINE results from Be+Be and Ar+Sc collisions are shown in Fig. 2.

A plateau-like structure is visible in $p+p$ interactions. The ratio K^+/π^+ at mid-rapidity as well as the ratio of total yields from Be+Be collisions is close to the $p+p$ measurements. For the five analysed energies of Ar+Sc collisions, the ratio K^+/π^+ at mid-rapidity and $\langle K^+\rangle / \langle \pi^+\rangle$ is higher than in $p+p$ collisions but shows a qualitatively similar energy dependence — no horn structure visible.

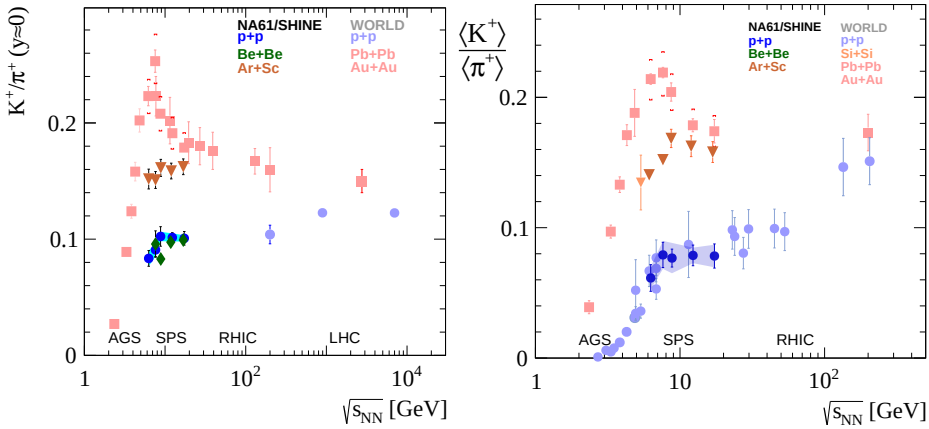

Fig. 2. Ratio of yields K^+/π^+ at mid-rapidity and the ratio of total yields $\langle K^+\rangle / \langle \pi^+\rangle$ produced in $p+p$, Be+Be, Ar+Sc and Pb+Pb collisions as a function of collision energy.

3. Ξ^- and $\bar{\Xi}^+$ production in $p+p$ interactions at 158 GeV/c

Hyperons are excellent probes of the dynamics of proton–proton interactions as constituent strange quarks are not present in the initial state of this process. Therefore, hyperon production has been studied in a long series of experiments in elementary hadron+hadron interactions. However, the experimental situation in this field remains inconclusive.

New data from $p+p$ collisions on Ξ^- and $\bar{\Xi}^+$ hyperon production are presented [5]. The event sample consists of 53 million registered interaction trigger events obtained at 158 GeV/c beam momentum corresponding to $\sqrt{s_{NN}} = 17.3$ GeV. The results refer to primary Ξ^- and $\bar{\Xi}^+$ produced in strong and electromagnetic processes and are corrected for detector geometrical acceptance and reconstruction efficiency.

To find the Ξ candidates, all Λ candidates are combined with pion tracks of appropriate charge (daughter track). A fitting procedure is applied, using as parameters the decay position of the V^0 candidate, the momenta of both the V^0 decay tracks, the momentum of the daughter track and finally, the z position of the Ξ decay point. The x and y position of the Ξ decay

position are not subject to the minimization, as they are determined from the parameters using momentum conservation. This procedure yields the decay position and the momentum of the Ξ candidate.

Preliminary results derived from two-dimensional spectra (y *versus* p_{T}) are presented as transverse momentum distributions in bins of rapidity in Fig. 3. Statistical uncertainties are shown as vertical bars and preliminary estimates of systematic uncertainty are indicated by grey bands. The lines (blue) show results of exponential fits to the measurements binned in m_{T}.

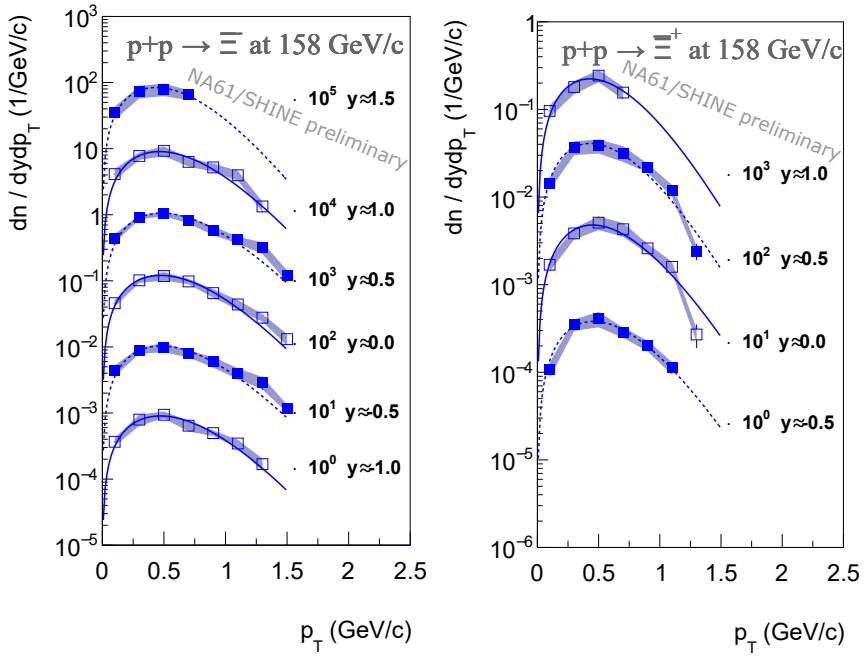

Fig. 3. (Colour on-line) Preliminary results on transverse momentum spectra of Ξ^- (left) and $\bar{\Xi}^+$ (right) hyperons produced in inelastic p+p interactions at 158 GeV/c in consecutive rapidity bins. Results are scaled for better separation, grey bands indicate systematic uncertainty, lines (blue) exponential fits.

4. Measurement of open charm (D^0 and $\bar{D}^0$ meson) production as extension of the strong interaction program

NA61/SHINE proposes to measure open charm (D^0 and $\bar{D}^0$ meson) production in central Pb+Pb collisions [6] with an upgraded detector system at the CERN SPS. This will be the first precision measurements of open charm production in heavy-ion collision in the CERN SPS energy domain.

The proposed measurements of D^0 and $\bar{D}^0$ production in central Pb+Pb collisions at the SPS will be possible after upgrading the NA61/SHINE experimental set-up by:

— Construction of a Vertex Detector (VD), which will provide precise tracking downstream of the target and thus reduce by many orders of magnitude the background below the D^0 and $\bar{D}^0$ peaks.

— Replacement of the TPC electronics which will increase the read-out rate by a factor of about 10 (up to 1 kHz).

— Upgrade of the trigger and data acquisition systems (TDAQ) as required by the VD and TPC upgrades.

— Upgrade of the particle spectator detector (PSD) used for centrality determination.

— Construction of a new ToF detector (MRPC) for particle identification.

The upgrade of TPC read-out, TDAQ, PSD, DCS, MRPC and VD is progressing according to schedule and required funding is available.

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