Comment on "Strangeness enhancement in $p+A$ and S+A interactions at energies near 200 A GeV"

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We argue that the recent analysis of strangeness production in nuclear collisions at 200 A GeV/c performed by Topor Pop *et al.* [1] is flawed. The conclusions are based on an erroneous interpretation of the data and the numerical model results. The term "strangeness enhancement" is used in a misleading way.

In a recent publication Topor Pop and collaborators ("TP*") [1] discuss the production of strange particles in nuclear collisions at CERN SPS energies within microscopic models. Their analysis and conclusions are mainly based on the comparison of the data from the NA35 experiment [2] with the HIJING model [3].

In this Comment we wish to point out that the analysis procedure used by TP* is problematic, both with respect to the interpretation of the data and to the way these are compared to the model. The results presented in TP* do not support the conclusions drawn by the authors.

We wish to first comment on problems with the procedure of TP* and afterwards on inconsistencies in the interpretation of their results.

I. In the abstract of Ref. [1] one reads: "The HIJING model is used to perform a *linear* extrapolation from pp to AA". In order to justify this procedure a comparison between p+p data [4] and the HIJING model is done in Section III A of Ref. [1]. From this comparison TP* conclude: "We note that the *integrated* multiplicities for neutral strange particles $\langle\Lambda\rangle$, $\langle\overline{\Lambda}\rangle$ and $\langle K^0_S\rangle$ are reproduced at the level of three standard deviations for pp interactions at 200 GeV. However, the values for $\langle\overline{p}\rangle$ and $\langle\overline{\Lambda}\rangle$ are significantly over predicted by the model". This, together with Figs. 1a, 2a of Ref. [1], is taken as evidence that the HIJING model is sufficiently accurate in its reproduction of Λ and kaon production in p+p collisions to allow for a meaningful extrapolation to $p+A$ and $A+A$ data.

An inspection of Table I in Ref. [1] leads, however, to the opposite conclusion: The yields of $\langle\Lambda\rangle$ and $\langle K^0_S\rangle$ are significantly overpredicted by HIJING (6–7 standard deviations [5] for Λ and 9–10 standard deviations for K^0_S). The yields of $\overline{p}$ and $\overline{\Lambda}$ seem also to be overpredicted by HIJING but they agree with the model within 3 standard deviations.

Furthermore, Fig. 1a of Ref. [1] shows that HIJING also fails to reproduce the Λ rapidity spectrum in p+p

collisions. In fact it was shown previously by one of the authors of TP* that the HIJING model underpredicts the stopping of baryons in nuclear collisions [6]. This biases the form of the Λ rapidity distribution producing characteristic forward–backward peaks (see Figs. 1a–d in Ref. [1]) which are not observed or (in the case of p+p collisions) are significantly lower in the data.

We therefore conclude that the HIJING model has severe shortcomings in its reproduction of the p+p data which eliminate it as a candidate for "a *linear* extrapolation from pp to AA". A detailed discussion of the effect of strangeness enhancement in AA cannot be reliably based on the comparison with this model.

II. In Sec. III C of Ref. [1] the rapidity and the transverse mass (momentum) spectra of strange particles are compared with the HIJING and VENUS models. This analysis is misleading and the ensuing discussion of the transverse mass spectra is meaningless since the authors do not restrict the calculated spectra to the rapidity acceptance of the experimental data. The failure to properly account for experimental acceptances is also reflected in the following misleading statement in the introduction of Ref. [1]: "In addition, there have been substantial changes in the final published data [2] relative to earlier comparisons to preliminary data [7,8]". In fact the experimental data published in [7,8] are consistent with the recently published results [2]; the differences are due to an enlarged acceptance and statistics of strange particles in S+S collisions [9] following modifications of the NA35 set–up [2] which then also allowed for an analysis of strangeness production in S+Ag and S+Au collisions [2].

We expect that taking into account the experimental acceptances will result in lowering the model points by a factor of up to about 3. One should also note that different data sets have significantly different acceptances. These acceptance cuts can not be neglected in the analysis of the transverse mass spectra, as done by TP*, since they influence both the spectral shapes and the local yields of strange particles.

Let us now comment on the conclusions drawn by TP* from their results. They write [1]: "Our main conclusion therefore is that strangeness enhancement is a nonequilibrium effect clearly revealed in the lightest ion interactions". This conclusion is based on the following TP* observation: "The strangeness enhancement in the minimum bias p+S is striking because the number of target nucleons struck by the incident proton is on the average only 2." The conclusion and its justification do NOT follow from the TP* analysis. Its origin can be traced as follows: TP* compare the Λ rapidity distribution for p+S interactions with the HIJING model (Fig. 1b in Ref. [1]). They observe that HIJING underpredicts the Λ yield at midrapidity. This disagreement is called by TP* the observation of a strangeness enhancement in p+S interactions. However, as argued above, the underprediction of midrapidity Λ's by HIJING is a direct consequence of its weak baryon stopping. Fig. 1b of Ref. [1]

shows very clearly that the *under*prediction of midrapidity Λ's in p+S collisions by HIJING is accompanied by an *over*prediction of Λ's in the proton fragmentation region. This reflects the incorrect description of baryon stopping in p+A collisions by the model. As such it has nothing to do with an enhanced production of strange particles.

Since the discovery of anomalously high production of strangeness in central nucleus–nucleus collisions at AGS and SPS energies [10,11] "strangeness enhancement" has been defined in a model independent way as an increase of the ratio between the *total* multiplicity of strange quarks (particles) and that of non-strange quarks (particles) when going from nucleon–nucleon interactions to nuclear collisions. It can be quantified [12,13] by studying the change of the strangeness suppression factor λ_S which is commonly used in the elementary particle physics, or by analysing the factor E_S introduced in [2] in order to avoid experimental problems in the evaluation of λ_S for nuclear collisions. The compiled data on strangeness production in p+p [4] and p+A [13,2] interactions lead to the conclusion that *there is no strangeness enhancement in* p+A *interactions at 200 GeV/c*. This statement is based on 8 independent measurements of strange and non-strange particle production in p+A interactions, with A ranging from Mg to Au. The NA35 data from p+S collisions alone lead also to the same conclusion.

On the other hand, *strangeness enhancement is observed in central nucleus–nucleus collisions* at all studied collision energies [14] (e.g. for central S+S and S+Ag collisions at 200 A GeV/c). Due to the model deficiencies discussed in this Comment, the analysis of TP* does not allow to trace the mechanism for this enhancement. The statement of TP* that it is "clearly a nonequilibrium effect" which prohibits the use of "simplistic fireball models" for its interpretation has not been proven. None of the known microscopic and kinetic models based on hadronic and string dynamics (including HIJING and VENUS) is able to reproduce the strangeness enhancement effect observed at CERN SPS energies [15].

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