POSSIBLE TEST OF THE MULTIPLE SCATTERING NATURE OF HADRON-NUCLEUS INTERACTIONS

By K. Zalewski

Institute of Nuclear Physics, Cracow*

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It is pointed out that Bose–Einstein symmetrization effects should be enhanced on nuclei, if the scattering process consists of separate elementary interactions. The enhancement is estimated and found large.

High energy hadron-nucleus scattering has been a field of active research for many years (cf. e. g. Ref. [1]). Many basic questions, however, still remain unanswered. One of them is: does it make sense to analyse hadron-nucleus collisions into hadron-constituent nucleon collisions. Both multiple scattering models [2–4] and models, where scattering is single on an unresolved object [5] claim success. The purpose of this note is to point out that, under plausible assumptions about hadron-nucleon scattering, the ambiguity may be resolved by a study of Bose-Einstein symmetrization effects for pairs of produced pions.

Ideally, after correction for combinatorial factors, the probability of finding two like pions (pions of equal charge) and momenta $\boldsymbol{p}_1, \boldsymbol{p}_2$ should for $\boldsymbol{p}_1 \approx \boldsymbol{p}_2$ be twice bigger than the corresponding probability for a pair of unlike pions [6–8]. This picture assumes no short range, rapidly varying, dynamical correlations between pions. It has recently been stressed [9] that for like charged pions originating from a single jet, short range repulsion is expected, because configurations where pairs of neighbouring particles have exotic quantum numbers should be dynamically suppressed. According to a crude estimate from Ref. [9], the negative dynamical correlations for like charged pions from a single jet roughly compensate the positive correlations due to Bose-Einstein symmetrization. Thus the visible symmetrization effect is due mainly to pairs of like particles originating from different jets. Consequently, the ratio of probabilities (denoted further $2-\varepsilon$), which ideally should have been equal two, will be suppressed. These ideas have support in experimental data [9].

* Address: Instytut Fizyki Jądrowej, Kawiory 26a, 30-055 Kraków, Poland.

Consider now n-fold scattering in a hadron-nucleus (hA) collision. If the particles produced in different hN collisions have no dynamical short range correlations in momentum space, the expected value of the parameter ε is

$$\varepsilon = \frac{\varepsilon_N}{n}, \tag{1}$$

where ε_N corresponds to hN collisions. Experimentally $\varepsilon_N \approx 0.5$ [9]. This value should be interpreted with caution, because there are purely experimental reasons (e. g. misidentification of particles), which make the effective ε_N greater. Nevertheless, we shall assume as an experimental fact that ε_N is significantly greater than zero. In order to find ε_A corresponding to hA scattering it is necessary to average relation (1) over n. According to single scattering models $n = 1$. Therefore

$$\varepsilon_A = \varepsilon_N. \tag{2}$$

In multiple scattering models, on the other hand, the average number of collisions is given by the formula

$$\bar{\nu} = \frac{A\sigma_{in}^{hN}}{\sigma_{in}^{hA}}. \tag{3}$$

Numerical values of $\bar{\nu}$ for various nuclear mass numbers A can be found e. g. in Ref. [10]. Assuming for simplicity that the distribution in numbers of collisions is a truncated Poissonian

$$P(n) = \frac{\nu^n}{n!}\,\frac{1}{1-e^{-\nu}} \quad \text{for } n > 0;\ P(0) = 0, \tag{4}$$

one finds

$$\nu = \frac{\nu}{1-e^{-\nu}} \tag{5}$$

and

$$\varepsilon_A = \varepsilon_N \sum_{n=1}^{\infty} \frac{\nu^n}{nn!}\,\frac{1}{1-e^{-\nu}}. \tag{6}$$

The predictions (2) and (6) are compared in Fig. 1. It is seen that even a crude estimate of ε_A can eliminate one of the two mechanisms. This is our main result. We conclude with a few remarks.

1. Formulae (2) and (6) have to be modified, if ε_N has a significant energy dependence. The energy independence of ε_N is plausible at high energies for the models considered in Ref. [9], but has not yet been checked experimentally. It is of course easy to find models of hN interactions, where ε_N decreases with increasing energy. A simple example is the independent cluster emission model with energy independent clusters and a rising plateau.

For such models ε_A will decrease with increasing A (i. e. $\bar{\nu}$) for the single scattering approach as well. The energy dependence of ε_N is in itself a very interesting problem.

2. In order to test the model proposed in Ref. [9] it would be instructive to look at pairs different from pairs of charged pions. Thus $\pi^0\pi^0$ pairs are nonexotic and according

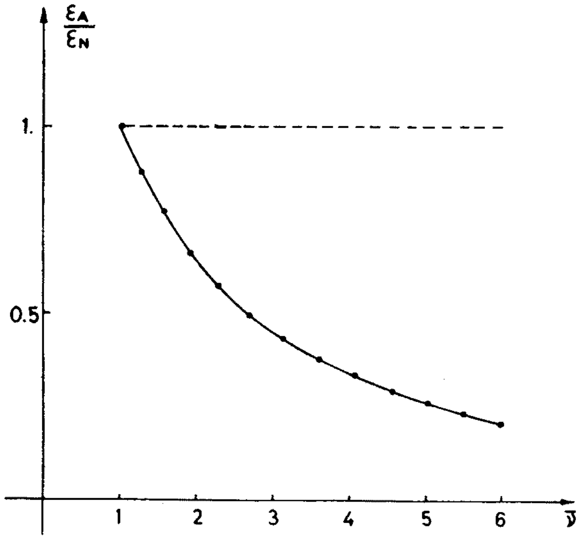

Fig. 1. Dependence of the ratio $\varepsilon_A/\varepsilon_N$ (see text) on the number of collisions defined by formula (3). ------- single scattering models, ——— multiple scattering models

to the model their parameter ε_N should be close to zero. Pairs $K^+\pi^+$, on the other hand, are exotic and do not involve symmetrization. Thus negative correlations should dominate for them.

3. For the cancellation predicted in Ref. [9] to work, the extension in momentum space for the dynamical and the symmetrization correlations should be similar. When pions are produced in a bigger region (in configuration space), the correlation peak (in momentum space) due to symmetrization is believed to become narrower [6–8]. This is another factor, which may upset the cancellation and consequently enhance the symmetrization effect in nuclei. If, as expected for scattering on a heavy nucleus, the production region is a long thin tube, the nuclear size effect should be, however, strongly directional and thus possible to separate from the effect discussed in this paper.

4. Formula (3) yields the number od collisions expected to contribute in the central region of the rapidity distribution. At low rapidities additional rescattering of particles slow in the laboratory system occurs. At high rapidities the density in rapidity has almost no A-dependence [10] and looks as if only one collision were contributing. Thus outside the central region our calculations are not applicable. One might guess that in the high rapidity region $\varepsilon_A = \varepsilon_N$, but an experimental study would be very interesting.

5. The multiple scattering and single scattering models discussed here are particularly simple cases, where the strength of the nuclear effect can be easily calculated without

making specific assumptions. Data on the symmetrization effect, however, are relevant for the evaluation of other models as well. For instance, incoherent production models (statistical, hydrodynamical etc.) are likely to differ markedly in symmetrization effects from coherent (e. g. Bremsstrahlung type) models.

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