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PROPOSAL OF EXPERIMENTAL TESTS FOR THE MULTIPLE SCATTERING NATURE OF HADRON-NUCLEUS SCATTERING

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It is pointed out that experimental data on the A-dependence of the average multiplicity of produced particles in $\bar{p}$-nucleus collisions and/or on the number of leading protons in p-nucleus collisions, could be used to eliminate some of the competing models of hadron-nucleus scattering.

Present data on high-energy hadron-nucleus scattering are being explained by an amazing variety of competing models (cf. e. g. [1]). It has been stressed that measurements of the inelasticity coefficient as function of the nuclear mass number A [2], [3], or measurements of the A-dependence of second order Bose-Einstein interference (BE) effects [4] could resolve some ambiguities. In particular, for an important class of models (non-interacting fire-ball model, leading particle cascade (LPC) model etc., for a review and references see [3]) the collision of a hadron with a nucleus consists of a sequence of incoherent and almost independent collisions with single target nucleons. At first the incident hadron collides with a nucleon, then the leading particle emerging from this first collision (which is a way of talking about some much more complicated object) may hit another target nucleon, and so the process continues until the n-th generation leading particle leaves the nucleus. For such models the inelasticity coefficient and the BE effects should increase with A. For models, where the final leading particle takes part in one collision only [3], [5], at least the inelasticity coefficient should exhibit little or no A-dependence. Intermediate results are predicted e. g. by models, where scattering is multiple, but coherent [2], or by models, where the leading particle takes part in some, but not all collisions [6]. In this note we describe two effects, which could exhibit clearly the multiple scattering of the leading particle as predicted by the LPC type models, if this exists.

As is well known (cf. e. g. [7]) the difference between the $\bar{p}N$ and pN cross-sections is positive and decreases rapidly with increasing energy (it drops from about 12 mb at

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10 GeV to about 3 mb at 200 GeV [7]). This is due mainly to annihilation channels in $\bar{p}N$ scattering, which have no counterpart in pN scattering. According to LPC models, the leading particle loses energy (typically 50 per cent) at each collision. This increases the chances for annihilation in latter collisions and consequently increases the average multiplicity of produced particles. Even if only part of the cross-section difference were due to annihilation, the remaining increase of the cross-section, when energy is degraded, would result in an increase of the average number of collisions and again lead to an increase in the average multiplicity. To summarize: LPC type models predict that the ratio of average multiplicities

$$R = \frac{n(\bar{p}A)}{n(pA)} \tag{1}$$

should increase with A because of the enhancement due to degradation of energy in successive collisions with the target nucleons when the incident particle is $\bar{p}$. The effect should be particularly spectacular for scattering on heavy nuclei at energies so high that $n(\bar{p}N) \approx n(pN)$. No such effect is expected in models [3], [5], where the leading particle takes part in one elementary collision only.

Another effect is the A-dependence of the number of leading protons in pA scattering. Let us denote by P the average number of forward leading protons in pN collisions. Then $1-P$ is the probability that the incident proton gets converted into another particle (not decaying into pX). Experimentally, $P = 0.75$ and within the experimental errors, which are 10–15 per cent, does not change with energy in the range from $s = 12\ \mathrm{GeV}^2$ to $s = 2810\ \mathrm{GeV}^2$ [8]. Assuming that the leading non-proton behaves as if it could be only a neutron i.e. that it has again probability P for remaining non-proton at the next collision (if any) and probability $1-P$ to convert back into a proton, we find in LPC type models that the probability of having a leading proton after n collisions is

$$P(n) = \tfrac{1}{2}[1+(2P-1)^n]. \tag{2}$$

Averaging this probability over a truncated Poissonian distribution

$$p(n) = \frac{\nu^n}{n!} e^{-\nu}(1-\delta_{n,0})/(1-e^{-\nu}), \tag{3}$$

where ν can be calculated from standard formulae for the average number of collisions

$$\nu/(1-e^{-\nu}) = n(A) = A\sigma^{\mathrm{in}}(pN)/\sigma^{\mathrm{in}}(pA), \tag{4}$$

we find for scattering on a nucleus with mass number A

$$P(A) = \tfrac{1}{2}[1+(n(A)/\nu)(e^{(2p-1)\nu}-1)/(e^{\nu}-1)]. \tag{5}$$

Thus, with increasing A the probability of finding a leading proton (in the sense of LPC models: as the continuation of the incident proton, not necessarily as e.g. the fastest particle) decreases from 0.75 at $A = 1$ to 0.5. It is possible to introduce a number of refinements into this discussion (e.g. using a probability distribution more realistic than (3)), but the qualitative result remains unchanged: Due to multiple independent scattering, the probability that a leading proton is found in a pA collision decreases with increasing A. For many models [3], [5], no such dependence is expected.

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