MOMENTUM DEPENDENCE OF NUCLEAR ATTENUATION OF FAST HADRONS AND THE STRING MODEL

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The EMC and SLAC data on momentum dependence of nuclear attenuation of fast hadrons produced by leptons from nuclear targets are interpreted in terms of the string model of particle production. It is shown that the colour string formed in a collision interacts strongly in nuclear matter before the final hadron is formed. A prediction for behaviour of nuclear attenuation in the region of large momentum of the hadron is given.

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It is now well established that high-energy hadrons are not produced at the moment of collision, but after some formation time. The formation time was discussed lately [1] in terms of the string model of particle production [2]. The ambiguity in the very concept of formation time was shown, due to the fact that hadrons are composite objects and their various constituents can be produced at different times. Two extreme definitions for formation time was chosen. The first is the yo-yo time (or length) which corresponds to the point where both constituents of the hadron meet for the first time to form a yo-yo mode representing the hadron. The second, the constituent time, represents the point where the first constituent of the hadron is created.

A comparison with the data on p and $\bar{p}$ production by 30 GeV pions from various nuclei [3] indicated [1] that the constituent length is preferred — instead of the yo-yo length which seemed to be more natural candidate for the production point of the hadron [2]. A recent analysis of the EMC data [4] confirmed this result [5]. The data of the Ref. [4] concerned the leptoproduction of hadrons from nuclear targets:

$$l+A \to l'+h+\text{anything}. \qquad (1)$$

The measured quantity was the nuclear attenuation ratio:

$$R_A(x_F, \nu, Q^2) = \frac{dN_A(x_F, \nu, Q^2)\varrho_D}{dN_D(x_F, \nu, Q^2)\varrho_A}, \qquad (2)$$

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where dN_A is the number of hadrons observed in collisions with nuclear target A and dN_D is the appropriate number from collisions with deuterium; ϱ_A and ϱ_D are the targets' surface densities. ν and Q^2 denote the energy and momentum squared of the virtual photon, $x_F = p_L/\nu$ where p_L is the longitudinal momentum of the hadron h. The kinematical range of 10 GeV $< \nu <$ 230 GeV and $0.1 < x_F < 1.0$ was covered. However, in the Ref. [5] only the ν-dependence of R_{Cu} was discussed.

In the present paper we analize the data on the x_F-dependence of R_A. We compare also the model with the SLAC data [6] from 1978. We show that all these data are consistent with the earlier results i.e. that the constituent length describes the data much better then the yo-yo length. We show also a characteristic prediction for the behaviour of R_A in the large x_F region.

As it was shown in [1] the attenuation ratio R_A can be approximated by:

$$R_A = \int d^2b \int_{-\infty}^{\infty} dz\varrho(z, b) \int_{z}^{\infty} dz' D(x_F, z'-z) W_0(z, z'), \tag{3}$$

where in case of leptoproduction:

$$W_0(z, z') = \left(1 - \int_{z}^{z'} dz'' \sigma_q \varrho(z'', b) - \int_{z'}^{\infty} dz'' \sigma_h \varrho(z'', b)\right)^{A-1}, \tag{4}$$

σ_q and σ_h are the initial current quark and final hadron cross-sections, respectively. $D(x_F, l)$ is the distribution of the formation length l i.e. the probability that the hadron h is created at the point $z' = z+l$ after the interaction of the lepton in the nuclear matter at the depth z. ϱ is the nuclear density normalized to unity.

As discussed in [1] the distribution of the constituent length l_C is given by:

$$D(x_F, l_C) = x_F \delta(L - x_F L - l_C) + \theta(l_C)\theta(L - x_F L - l_C) x_F L(1+C) \frac{(l_C)^C}{(l_C + x_F L)^{C+2}(1-x_F)^C}, \tag{5}$$

where

$$L = \nu/\kappa \tag{6}$$

is the total length of the coloured string, κ is the string tension. Distribution of the yo-yo length can be obtained from (5) using the relation:

$$l_Y = l_C + x_F L. \tag{7}$$

The string tension was taken 0.8 GeV/fm [7] and the parameter $C = 0.3$ [2]. We used the nuclear density in the Woods-Saxon form:

$$\varrho(r) = \frac{\varrho_0}{1+\exp((r-R)/a)} \tag{8}$$

with the surface parameter $a = 0.54$ fm and the nuclear radius $R = 1.19\,A^{1/3} - 1.61\,A^{-1/3}$. For σ_h we used the mean of the absorptive parts of π^+p and π^-p cross sections using the formula [1]:

$$\sigma_{abs} = \sigma_{tot} - 3/2\sigma_{el}. \tag{9}$$

Knowing that σ_q should be small ($\lesssim 1$ mb) [5] we took $\sigma_q = 0$ in our calculations.

In Fig. 1 we show R_A calculated according to (3)–(5) compared to the EMC data for Cu target. One sees good agreement with the data for both energies $\nu = 35$ GeV and $\nu = 145$ GeV. The smooth growth of R_A for $\nu = 35$ GeV in the medium range of x_F is reflected also in the model result. In the region of small x_F the approximation of no rescattering [1] in the Eqs. (3) and (4) is no longer sufficient: slow hadrons appearing in this region can be products of secondary interactions occurring in the nuclear matter and they can cause the growth of R_A. What seems to be interesting, is the rapid fall of predicted value of R_A for $x_F \gtrsim 0.8$. It is a result of the fact that the constituent length $l_C \to 0$ when $x_F \to 1$, and of the characteristic shape of the distribution (5) with a delta contribution at $l_C = (1-x_F)L$ proportional to x_F. More precise data would be needed, however, to verify this prediction.

In the same figure the prediction for the yo-yo length is plotted. It does not agree with the data for $\nu = 35$ GeV. This confirms the result of the Refs. [3, 5], indicating that the coloured strings formed in the collision can interact in nuclear matter before the hadron is finally formed.

In Fig. 2 we plot a similar comparison as in Fig. 1, but for the Sn-target. The data are not so accurate as for Cu but the agreement with the model for the constituent length is also good. Especially the last point of the data catches our attention indicating perhaps the decrease of R_A in the region of large x_F. But these data, averaged in very wide range of ν (10 GeV $< \nu <$ 230 GeV), are not precise enough to make firm conclusion. The prediction for the yo-yo length is similar as for the Cu-target ($R_A \cong 1$) and does not agree with the data.

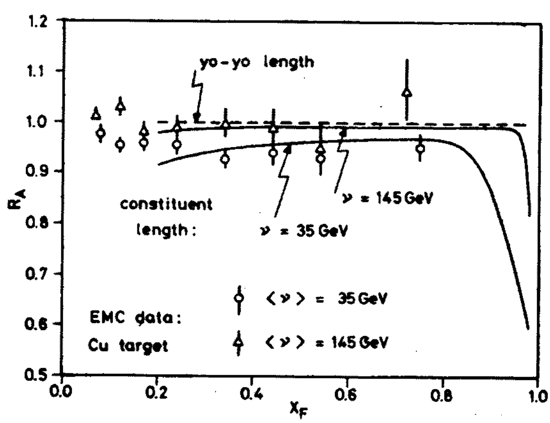

Fig. 1. Nuclear attenuation ratio R_A calculated for the constituent length (full line) and the yo-yo length (dashed line) for two energies: $\langle\nu\rangle = 35$ GeV and $\langle\nu\rangle = 145$ GeV. The curves concerning the yo-yo length lie on one another indicating lack of attenuation ($R_A \cong 1$). The curves for the constituent length fit the EMC data [4] very well. Used target is Cu

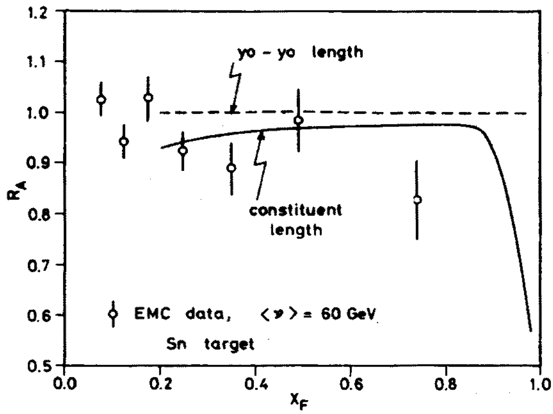

Fig. 2. R_A calculated for Sn target. Data as in Fig. 1, but averaged over whole range of ν (10 GeV $< \nu$ $<$ 230 GeV, $\langle\nu\rangle = 60$ GeV). The curve predicted for the constituent length (full line) fits the data better than the one for the yo-yo length (dashed line). The last point of the data catches attention indicating the decrease of R_A

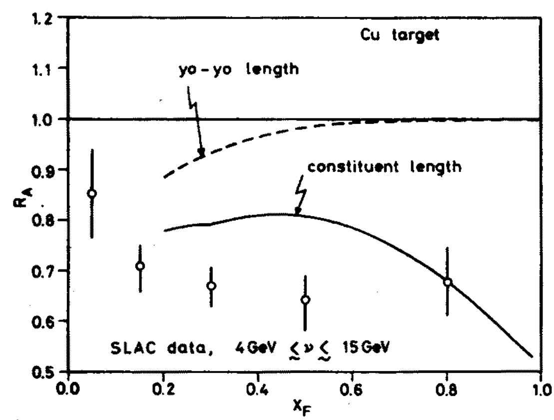

Fig. 3. Model calculations of R_A compared to the SLAC data [6] for the Cu target. The curve for the constituent length does not fit the data very well, but the yo-yo length can be surely excluded

Finally in Figs. 3 and 4 we plot the result obtained for Cu and Sn targets compared with the SLAC data [6]. Here one sees also that the constituent length is preferred, although the curve calculated for the constituent length for the Cu target does not fit the experimental points very well. However, the SLAC data are averaged in wide range of ν (4 GeV $\lesssim \nu$ $\lesssim$ 15 GeV). In this range the model output varies rather strongly. We chose for calculations $\langle\nu\rangle = 8$ GeV, but it may be not the representative value. In both figures the disagreement of the yo-yo length predictions with the data is clearly seen.

To summarize, it was shown that the constituent length is preferred by the data on x_F dependence of nuclear attenuation. It means that the coloured strings created in the collision can interact in nuclear matter before the hadron is finally formed. It confirms

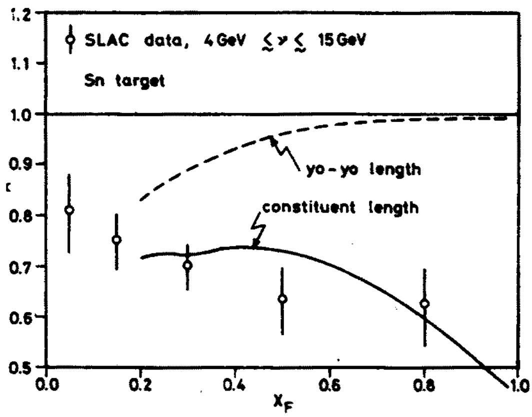

Fig. 4. Comparison to the SLAC data as in Fig. 3, but for the Sn target. The result is similar — the line for the constituent length is in good agreement with the data, the yo-yo length gives too large value of R_A

the earlier results obtained in [1] and [5]. More precise data would be needed, however, to verify the characteristic prediction for behaviour of R_A in the very-large-x_F region.

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