ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

E2 - 11837

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1978

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Submitted to "Письма в ЖЭТФ"

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Кварк-партонная модель взаимодействия адронов с ядрами

Предложен метод собственных состояний (МСС) для вычислений поперечных сечений адрон-ядерных взаимодействий. Показано, что МСС эквивалентен модели многократного рассеяния, в которой учитываются наряду с упругим и неупругое экранирование. Показано, что МСС приводит к корректной пространственно-временной картине адрон-ядерных взаимодействий. Анализ экспериментальных данных показывает, что в кварк-партонной модели валентные кварки в адроне около половины времени проводят в пассивном состоянии, т.е. в состоянии без медленных партонов.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

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Quark-Parton Model for Hadron-Nucleus Interactions

An eigenstate method (ESM) for hadron-nucleus cross section calculations is proposed. It is shown that ESM is equivalent to the multiple scattering model, including the inelastic screening. It is shown by the quark-parton model that valence quarks in a hadron are about half the time in the passive state, i.e., they have no wee-parton.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1978

1. Atomic nuclei are a useful tool for investigating the space-time pattern of hadronic interactions. The well-known phenomenon of increasing longitudinal distances has been investigated intensively recently in the multiparticle production reactions on nuclei [1,2,3]. Some consequences of this effect for elastic hadron-nucleus scattering have been analysed here.

Let us consider a fast hadron with the momentum P satisfying the condition:

$$P/\mu^2 \gg R_A. \qquad (1)$$

Here P/μ^2 is the longitudinal distance of interaction, μ is some hadronic mass, R_A is the radius of the target nucleus. If the dimension of the interaction area is larger than the R_A value, one cannot divide the intermediate states of the hadron in the nucleus into the elastic and inelastic ones, as is generally done in the multiple scattering model (MSM).

2. Consider the method of the decomposition of the wave function $|\Psi\rangle$ into the eigenstates $|\Psi_k\rangle$ of the interaction Hamiltonian (ESM is the eigenstate method) [4,5]

$$|\Psi\rangle = \sum_k c_k |\Psi_k\rangle, \qquad (2)$$

where

$$\langle\Psi_i|\Psi_k\rangle = \delta_{ik}, \qquad (3)$$

$$\sum_k c_k^2 = 1, \qquad (4)$$

$$\hat{f}|\Psi_k\rangle = f_k|\Psi_k\rangle. \qquad (5)$$

Here $i\hat{f}$ is a scattering amplitude operator. The amplitudes f_k are supposed to be real. The elastic scattering amplitude f^{hA} due to eqs. (2)-(5) is equal to

$$f^{hA} = \langle\Psi|\hat{f}|\Psi\rangle = \sum_k c_k^2 f_k^{hA} \quad . \tag{6}$$

It is assumed here that condition (1) is satisfied, so the states $|\Psi_k\rangle$ are not mixed during the interaction. To calculate the amplitudes f_k^{hA} one can use the ordinary Glauber model /6/. At the same time the whole amplitude (6) differs drastically from the Glauber one. It is shown below that this distinction for quark scattering on a "black" nucleus is about 100%.

3. Now let us show that ESM is identical to MSM which includes all elastic and inelastic screening corrections. The screening correction to the elastic $h-d$ scattering amplitide in ESM has the following form

$$(\Delta f^{hd}) = \sum_k c_k^2 (f_k^{hN})^2 \quad . \tag{7}$$

The corresponding Glauber correction is equal to

$$(\Delta f^{hd})_{GL} = (\sum_k c_k^2 f_k^{hN})^2 \quad . \tag{8}$$

The inelastic screening correction /7/ can be written as follows:

$$(\Delta f^{hd})_{in} = \sum_k \langle\Psi_k|\hat{f}|\Psi\rangle^2 - \langle\Psi|\hat{f}|\Psi\rangle^2 =$$

$$= \sum_k c_k^2 (f_k^{hN})^2 - (\sum_k c_k^2 f_k^{hN})^2 \quad . \tag{9}$$

It is seen that the sum of expressions (8) and (9) is equal to expression (7). It is easy to generalize the above proof to any nucleus.

4. Consider the quark-parton model where a hadron is assumed to consist of the valence quarks, each carrying the parton sea. The eigenstates $|\Psi_k\rangle$ should be treated in this model as the states $|k\rangle$ with the definite number of wee-partons /8,9/ $(k = 0,1,2,\dots)$, because only the wee-partons can interact with a target /10/. The wee-parton number means the number of parton combs containing partons with $P \approx m$. As the passive component $(k = 0)$ weight c_0^2 cannot decrease with energy /8/, one can assume the c_0^2 value to be large at high energies, and the passive state of the hadron plays an outstanding role, in some phenomena.

5. Consider the diffraction dissociation of the quark q (u and d quarks) on the proton target

$$\sigma_{diff}^{qp} = (1-P_q)(\sigma_{e\ell}^{qp} + \sigma_{diff}^{qp}) + \\ + P_q^2 \int d^2b(\langle f^2\rangle_{act} - \langle f\rangle_{act}^2) . \tag{10}$$

Here $P_q = \sum_{k=1} c_k^2$ is an active component weight for the q-quark, b is an impact parameter. $\langle f\rangle_{act} = \sum_{k=1} c_k^2 f_k$.

If one neglects the dispersion of the amplitude f_k in the active state, i.e., the second term in expression (10), one finds after the calculations of $\sigma_{e\ell}^{qp}$ and σ_{diff}^{qp} the value $P_q \gtrsim 0.5$. We have estimated also the contribution to σ_{diff}^{qp} of the second term in expression (10) and find it to be very small, about 8%. This gives $P_q \lesssim 0.55$. So the main contribution to the diffraction dissociation comes from the passive component of the quark.

6. The proton-nucleus total cross section has the following form:

$$\sigma_{tot}^{pA} = 3P_q(1-P_q)^2 I_1 + 3P_q^2(1-P_q) I_2 + P_q^3 I_3 \, , \tag{11}$$

where

$$I_n = 2\int d^2b[\,1 - \exp\{-n\sigma_{tot}^{qN} T_A(b)/2P_q\}]. \tag{12}$$

Here $\sigma_{tot}^{qN} \approx 17$ *mb*, $T_A(b)$ is the profile function of the nucleus. From comparison of (11) and (12) with the experimental data for σ_{tot}^{pA} at 240 *GeV* /11/ one obtains the values of P_q shown in the *Table*.

Table

A	^{12}C	^{27}Al	^{64}Cu	^{207}Pb
P_q	0.4	0.45	0.5	0.67

The growth of P_q with the A-value may be connected with the smallness of an energy of 240 *GeV* for large nuclei, from the point of view of condition (1). This is justified by the fact that the σ_{tot}^{pA} value for the ^{207}Pb nucleus decreases with energy /11/.

7. So ESM gives the correct space-time interpretation of hadron-nucleus interactions and permits one to extract some interesting information about hadron structure. We have stated above that the fast quark spends about half the time in the passive, i.e., noninteractive, state. For this reason no universal hadronic cross section will emerge in the asymptotics and there are no absolutely "black" objects in nature.

The detailed calculations of the hadron-nucleus cross sections, the hadron-hadron interaction analysis in ESM and strange quark properties investigations will be published elsewhere.

The authors are very indebted to I.Mandjavidze, N.N.Nikolaev, M.G.Ryskin, and Yu.M.Shabelsky for useful discussions.

REFERENCES

1. *Kancheli O.V. JETP Lett., 1973, 18, p.465.*
2. *Nikolaev N.N. Proc. Triest Topical Meeting on Multiple Production on Nuclei, Trieste, June, 1976.*
3. *Anisovich V.V., Shabelsky Yu.M., Shechter V.M. Nucl. Phys., 1978, B133, p.477.*
4. *Feinberg E.L., Pomeranchuk I.Ya. Suppl. Nuovo Cim., 1956, III, p.652.*
5. *Good M.L., Walker W.D. Phys.Rev., 1960, 120, p.1857.*
6. *Glauber R.J. High Energy Physics and Nuclear Structure, Amsterdam, 1967.*
7. *Gribov V.N. JETP, 1969, 56, p.892; JETP, 1969, 57, p.1306.*
8. *Grassberger P. Nucl.Phys., 1977, B125, p.84.*
9. *Miettinen H., Pumplin G. Fermilab-Pub-78/21-THY (1978).*
10. *Gribov V.N. VIII Winter School of Physics LNPI, Leningrad, 1973, 42, p.5.*
11. *Murthy P.V.R. et al. Nucl.Phys., 1975, B92, p.269.*

Received by Publishing Department on August 17 1978.