ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ
ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

ԳԻՏԱԿԱՆ ՀԱՂՈՐԴՈՒՄ НАУЧНОЕ СООБЩЕНИЕ

ЕФИ-183(29)76

L.A. Grigoryan, V.A. Shakhbazyan

THE ELASTIC SCATTERING OF K-MESONS ON THE ^{4}He NUCLEUS IN THE COMPLEX MOMENTA THEORY FOR THE ENERGY REGION (20÷100) GeV

АРУС

ԵՐԵՎԱՆ 1976 ЕРЕВАН

YEREVAN PHYSICS INSTITUTE

Scientific Report ЕФИ-183(29)76

L.A.GRIGORYAN,V.A.SHAKHBAZYAN

THE ELASTIC SCATTERING OF K-MESONS ON THE ^{4}He NUCLEUS IN THE COMPLEX MOMENTA THEORY FOR THE ENERGY REGION (20 ÷ 100) GeV

Yerevan, 1976

Научное сообщение ЕФИ-183(29)76

Л.А.ГРИГОРЯН, В.А.ШАХБАЗЯН

УПРУГОЕ РАССЕЯНИЕ К-МЕЗОНОВ НА ЯДРЕ ^4He В ТЕОРИИ КОМПЛЕКСНЫХ МОМЕНТОВ В ОБЛАСТИ ЭНЕРГИЙ 20 ÷ 100 ГЭВ.

Получены дифференциальные сечения процессов упругого рассеяния К-мезонов на ядре ^4He для энергий налетающей частицы в 30 и 50 Гэв, полное сечение в интервале от 10 до 10^3 Гэв и дифференциальное сечение при фиксированной передаче $|t| = 0{,}21(\text{Гэв/c})^2$ в зависимости от энергии в интервале 10÷100 Гэв. Расчет выполнен в эйкональной и квазиэйкональной моделях теории комплексных моментов. Показано, что эффекты неупругой экранировки очень существенны.

Ереванский физический институт
Ереван 1976

Scientific Report ЕФИ-I83(29)76

L.A.GRIGORYAN, V.A.SHAKHBAZYAN

THE ELASTIC SCATTERING OF K-MESONS ON THE ^{4}He NUCLEUS IN THE COMPLEX MOMENTA THEORY FOR THE ENERGY REGION (20 ÷ 100) GeV

The differential cross-sections of the $K^{\pm}$-mesons elastic scattering on the ^{4}He nucleus for energies of incident particle 30 and 50 GeV, total cross section in the energy region($10 \div 10^3$) GeV and the differential cross-section at the fixed transfer momentum $/t/ = 0{,}21(GeV/c)^2$ depending of energy in the region (10 ÷ 100)GeV are obtained. The calculation is made in eikonal and quasieikonal models of the complex momenta theory. It is shown, that the inelastic screening effects are very important.

Yerevan Physics Institute
Yerevan, 1976

The use of the ^{4}He nucleus instead of the nucleon as a target in the complex angular momenta theory has a number of advantages. The first one is that quantum numbers of the ^{4}He nucleus ($J^P = 0^+, I^G = 0^+$) allow us reduce the number of types of Regge-pole trajectories which must be used for the correct description of the collision process. For example, in the process of π°-meson photoproduction on the ^{4}He nucleus only the ω -trajectory contributes to the pole approximation [1], and for the correct description of rescatterings on the same nucleon [2] and on the different nucleons [3] it is erough to take into account also only the P-trajectory; the processes of the elastic scattering of the π -meson and of the photoproduction of the ρ^0-meson on the ^{4}He nucleus may be descibed by use of only P-and P'-trajectories [4] .

The second advantage is that differential cross-sections in the region of rather small transfer momenta ($/t/\sim 0 \div 0,3$ $(\frac{GeV}{c})^2$) change much more rapidly than in the case, when the target is a nucleon. For example, in the case of π -meson elastic scattering on the ^4He nucleus[4] the differential cross section changes in the above mentioned region of transfer momenta by six orders. This circumstance opens the possibility of the much more precise determination of parameters of different models of the complex angular momenta theory because the differential cross-sections become very sensitive to their values.

The third advantage is that the investigation of high energy collisions with the ^4He nucleus makes it possible to determine the value of the so-called inelastic screening[5] . As was shown in the preceeding paper[4] the comparison of eikonal and quasieikonal[7] models of the complex angular momenta theory gives strongly different behaviours of differential cross-sections for the π -meson elastic scattering on the ^4He nucleus.

In this paper we present the results of the calculation of differential and total cross-sections in the framework of both above mentioned models for the elastic scattering of charged K-mesons on the ^4He nucleus in the energy region(20 ÷ 100) GeV (in the laboratory system).

2. Main Assumptions and Formulae for the Calculation

We shall calculate amplitudes of processes

$$K^{\pm} + {}^4He \longrightarrow K^{\pm} + {}^4He \qquad (*)$$

in the framework of Glauber expansion taking into account coefficients of the inelastic screening (or, speaking otherwise, "shower enhancement" coefficients). In general, this coefficients may be weakly dependent on s and t, but we shall neglect these dependences, because we confine ourselves to the region

$$20\,GeV \le E_{lab} \le 100\,GeV\ , \qquad 0 \le |t| \lesssim 0.3\left(\frac{GeV}{c}\right)^2 \qquad (**)$$

Our main aim is to obtain the value of the inelastic screening effect and therefore we make simplest assumptions about the nuclear formfactor and spin structure of the K - meson-nucleon scattering amplitude:

i) the nuclear formfactor is described by the simple exponental function of $- t R^2$, where R is the radius of ^4He nucleus;

ii) Spin-flip terms in the K-meson-nucleon amplitude are neglected, because in the elastic scattering on the nucleus double spin-flip terms contribute. Both of these assumptions are fully applicable in the region (**).

Amplitudes of processes (*) are of the form

$$M_{K^\pm\, ^4He} = \sum_{K=1}^{4} \widetilde{M}_K \qquad (1)$$

where

$$\widetilde{M}_1 = 4 \exp\left(-\frac{3q^2R^2}{16}\right) M_{K^\pm N}(q, c, c')\ , \qquad (2)$$

$$\tilde{M}_2 = i\,6\exp\left(\frac{q^2R^2}{16}\right)\int\frac{d^2q'}{\pi}\exp\left\{-\frac{R^2}{4}\left[q'^2+(\vec{q}-\vec{q}\,')^2\right]\right\}\times$$

$$\times\left\{C^{-1}C'^2 M^{(P)}_{K^\pm N}(q',C,C')\,M^{(P)}_{K^\pm N}(q-q',C,C')\,+\right.$$

$$+\,2M^{(P)}_{K^\pm N}(q',C,C')\,M^{(R)}_{K^\pm N}(q-q',1,1)\,+ \qquad (3)$$

$$\left.+\,M^{(R)}_{K^\pm N}(q',1,1)\,M^{(R)}_{K^\pm N}(q-q',1,1)\right\}.$$

$$\tilde{M}_3 = -4\exp\left(\frac{q^2R^2}{16}\right)\iint\frac{d^2q'd^2q''}{\pi^2}\exp\left\{-\frac{R^2}{4}\left[q'^2+q''^2+(q-q'-q'')^2\right]\right\}\times$$

$$\times\left\{C^{-2}C'^4 M^{(P)}_{K^\pm N}(q',C,C')\,M^{(P)}_{K^\pm N}(q'',C,C')\,M^{(P)}(q-q'-q'',C,C')\,+\right.$$

$$+\,3C^{-1}C'^2 M^{(P)}_{K^\pm N}(q',C,C')\,M^{(P)}_{K^\pm N}(q'',C,C')\,M^{(R)}_{K^\pm N}(q-q'-q'',1,1)\,+$$

$$+\,3M^{(P)}_{K^\pm N}(q',C,C')\,M^{(R)}_{K^\pm N}(q'',1,1)\,M^{(R)}_{K^\pm N}(q-q'-q'',1,1)\,+$$

$$\left.+\,M^{(R)}_{K^\pm N}(q',1,1)\,M^{(R)}_{K^\pm N}(q'',1,1)\,M^{(R)}_{K^\pm N}(q-q'-q'',1,1)\right\}, \qquad (4)$$

$$\tilde{M}_4 = -i\exp\left(\frac{q^2R^2}{16}\right)\iint\frac{d^2q'd^2q''d^2q'''}{\pi^3}\exp\left\{-\frac{R^2}{4}\left[q'^2+q''^2+q'''^2+(q-q'-q''-q''')^2\right]\right\}\times$$

$$\times\left\{C^{-3}C'^6 M^{(P)}_{K^\pm N}(q',C,C')\,M^{(P)}_{K^\pm N}(q'',C,C')\,M^{(P)}_{K^\pm N}(q''',C,C')\,M^{(P)}_{K^\pm N}(q-q'-q''-q''',C,C')\,+\right.$$

$$+\,4C^{-2}C'^2 M^{(P)}_{K^\pm M}(q',C,C')\,M^{(P)}_{K^\pm N}(q'',C,C')\,M^{(P)}_{K^\pm N}(q''',C,C')\,M^{(R)}_{K^\pm N}(q-q'-q''-q''',1,1)\,+$$

$$+\,6C^{-1}C'^2 M^{(P)}_{K^\pm N}(q',C,C')\,M^{(P)}_{K^\pm N}(q'',C,C')\,M^{(R)}_{K^\pm N}(q''',1,1)\,M^{(R)}_{K^\pm N}(q-q'-q''-q''',1,1)\,+ \qquad (5)$$

$$+\,4M^{(P)}_{K^\pm N}(q',C,C')\,M^{(R)}_{K^\pm N}(q'',1,1)\,M^{(R)}_{K^\pm N}(q''',1,1)\,M^{(R)}_{K^\pm N}(q-q'-q''-q''',1,1)$$

$$\left.+\,M^{(R)}_{K^\pm N}(q',1,1)\,M^{(R)}_{K^\pm N}(q'',1,1)\,M^{(R)}_{K^\pm N}(q''',1,1)\,M^{(R)}_{K^\pm N}(q-q'-q''-q''',1,1)\right\}.$$

Here $M_{K^\pm N}(q, C, C')$ are amplitudes of the elastic scattering of $K^\pm$ - mesons on a nucleon, $M_{K^\pm N}(q,C,C') = M^{(P)}_{K^\pm N}(q,C,C') + M^{(R)}_{K^\pm N}(q,1,1)$, $M^{(P)}_{K^\pm N}(q,C,C')$ is that part of the amplitude, which is described only by all the possible pomeron exchanges, and $M^{(R)}_{K^\pm N}(q,1,1)$ is the remainder of the amplitude, to which contribute the resonance trajectories; C, C' are "shower enhancement" coefficients, $R \approx 1{,}31$ f [8] is the radius of ^{4}He nucleus. According to the assumptions of Ref./7/ we neglect in the "resonance" part of the amplitude the contribution of showers. In eqs (1) - (5) it is assumed the normalization of amplitudes used in Ref./7/. If showers are absent at all and we deal only with elastic re - scatterings both on the same nucleon and on the different nucleons, then C = C' = 1 everywhere, and we obtain the eikonal model of the complex angular momenta theory. If we want to take into account the existence of showers with comparatively small masses, then following the Ref./7/ consideration we assume that C and C' are different constants nonequal to the unity. So we obtain the quasieikonal model of the complex angular momenta theory, applied to processes (*). Here we have assumed, that inelastic screening effects in nuclei, predicted by V.N. Gribov [5], may be described by "shower enhancement" coefficients of the quasieikonal model [7]. In general, this assumption needs in the experimental verification. But for the elastic scat - tering of K-mesons on the nucleus this assumption is plausible, because as it follows from the calculation made in the paper

/9/, the main part of the shower coefficient is determined by the shower in the vertex of the K-meson-pomeron interaction. As is well known, the elastic scattering of the K-meson on the nucleon in Regge-pole theory is described by means of P - P'-, ω -, ρ and A_2 - trajectories. But if we want to describe the elastic scattering of the K - meson on the ^4He nucleus in the pole approximation, we take into account only P - P' - and ω -trajectories. This follows from the properties of ^4He nucleus $(J^P = 0^+, I^G = 0^+)$. A_2 - and ρ - trajectories might contribute only to terms including even number of resonance exchanges, But in the energy region (20 ÷ 100) GeV the contribution of such terms is small. Therefore, we are allowed to assume, that A_2 - and ρ -trajectories do not contribute to the processes (*) at all. Now we can write down the expressions for $M^{(P)}_{K^\pm N}(q, C, C')$ and $M^{(R)}_{K^\pm N}(q,1,1)$.

They are of the form

$$M^{(P)}_{K^\pm N}(q, C, C') = i\eta_p \exp(-\lambda_p q^2) + i\sum_{K=2}^{\infty} \frac{(-1)^{K-1}\eta_p^K C C'^{K-2} \exp\left(-\frac{q^2\lambda_p}{K}\right)}{K!\cdot K\cdot \lambda_p^{K-1}} \tag{6}$$

$$M^{(P')}_{K^\pm N}(q,1,1) = i\sum_{K=1}^{\infty}\sum_{b_K=1}^{2}\left\{\frac{(-1)^{K-1}(i^{-1}\eta_{p'})^{b_K}\varepsilon_{p'}^{b_K}\cdot \eta_p^{K-b_K}\cdot \eta_{p'}^{b_K}}{(K-b_K)!\,b_K!\,\lambda_p^{K-b_K}\cdot\lambda_{p'}^{b_K}} \times \right.$$

$$\left.\times\frac{\exp\left\{-q^2/\left[\frac{K-b_K}{\lambda_p}+\frac{b_K}{\lambda_{p'}}\right]\right\}}{\left(\frac{K-b_K}{\lambda_p}+\frac{b_K}{\lambda_p}\right)}\right\}, \tag{7}$$

$$M^{(\omega)}_{K^{\pm}N}(q,1,1) = \pm i \sum_{k=1}^{\infty} \Big\{ (-1)^{k-1} (i^{-1}\eta_{\omega}) \varepsilon_{\omega} \times \frac{\gamma_P^{k-1}\gamma_{\omega}}{(k-1)!\,\lambda_P^{k-1}} \times \frac{\exp\{-q^2/[\frac{k-1}{\lambda_P} + \frac{1}{\lambda_{\omega}}]\}}{\left(\frac{k-1}{\lambda_P} + \frac{1}{\lambda_{\omega}}\right)} \Big\} \qquad (8)$$

$\gamma_P, \gamma_{P'}, \gamma_{\omega}$ are residues of P - P' - and ω - trajectories respectively. Substituting eqs. (6) - (8) into eqs. (1)-(5) and integrating them over q',q'',q''' we obtain final formulae, which were used in the numerical calculations and are not presented here, because they are too cumbersome.

3. Results of the Numerical Calculations

Now we present and discuss results of the numerical calculations. There were calculated differential cross-sections for two energies E_{lab}=30 and 50 GeV, total cross-sections in the energy region $(10 \div 10^3)$ GeV and differential cross-sections at fixed $/t/ \equiv \tau = 0{,}21(\frac{GeV}{c})^2$ in the energy range $(10 \div 100)$ GeV. The calculations were made both for eikonal and quasieikonal models of the Regge-Pole theory. Parameters of the quasieikonal model are taken from paper [7]. Parameters of the eikonal model are taken from paper [10]. Differential cross-sections for both energies show considerable difference between eikonal (dashed lines) and quasieikonal (solid lines) models (Figs.1,2). Dips of differential cross-sections are at 0,33 $(\frac{GeV}{c})^2$ for eikonal model and at 0,27 $(\frac{GeV}{c})^2$ for quasieikonal model. To make the value of descripancy between the models more visual, we have calculated and plotted total cross-sections and differential cross-sections at fixed t(Figs.3,4). Total cross-sections differ only about 5 $\div$ 10%. The differential cross-sections at τ = 0,21(GeV/c)^2 differ much more, being in the quasieikonal model nearly two times less than those in the eikonal model. At larger transfer momenta the difference becomes still more. Summing up the results we can say, that the inelastic screening may be very big and its experimental study already at Serpukhov energies will be of great interest.

Figure Captions

Fig. 1. Differential cross-sections of the (a) K^- - and (b) K^+- meson elastic scatterings on the ^4He nucleus at the energy E_{lab} = 30 GeV in the eikonal (dashed line) and quasieikonal (solid line) models.

Fig. 2. Differential cross-sections of the (a) K^-- and (b) K^+-meson elastic scatterings on the ^4He nucleus at the energy E_{lab} = 50 GeV in the eikonal (dashed line) and quasieikonal (solid line) models.

Fig. 3. Total cross-sections of (a) $K^{-4}He$ and (b) $K^{+4}He$ in the eikonal (dashed line) and quasieikonal (solid line) models.

Fig.4. Differential cross-sections of the (a) K^-- and (b) K^+-meson elastic scatterings at fixed $\tau \equiv |t| = 0{,}21(GeV/c)^2$ as a function of the energy in eikonal (dashed line) and quasieikonal (solid line) models.

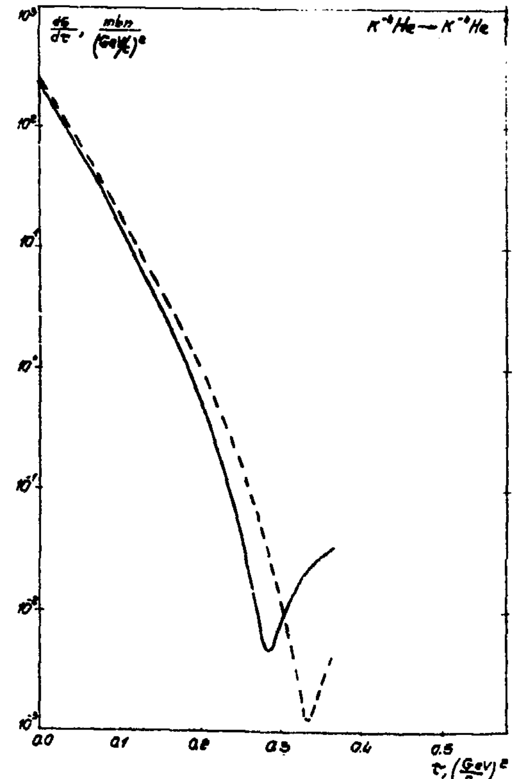

dσ/dt , mbn/(GeV/c)²
He → He
0.0
0.1
0.2
0.3
0.4
0.5
t, (GeV/c)²

Fig 1a

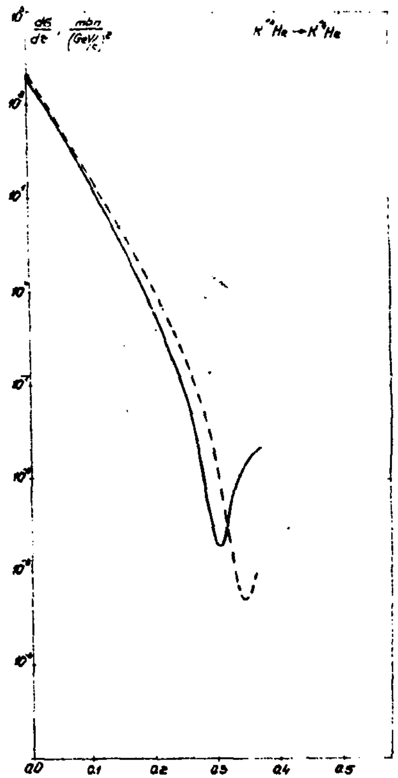
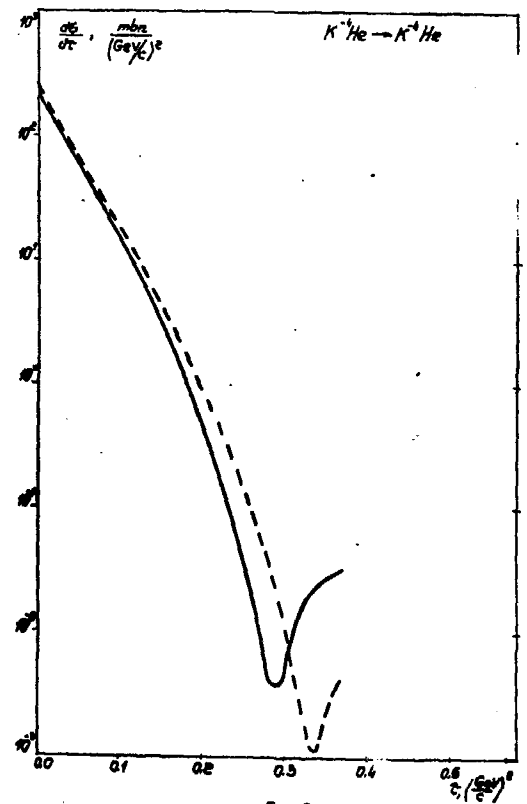
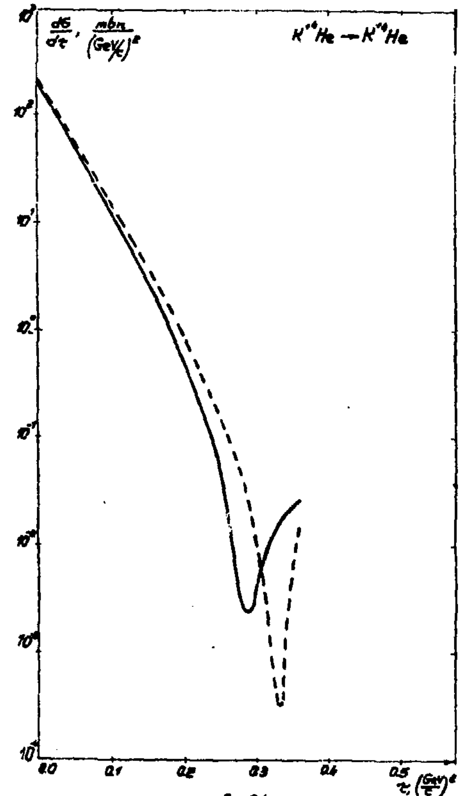

dσ/dt , mbn/(GeV/c)²
0.0
0.1
0.2
0.3
0.4
0.5

Fig 1b



$\frac{d\sigma}{dt}$, $\frac{mbn}{(GeV/c)^2}$
$K^- {}^4He \rightarrow K^- {}^4He$
0.0
0.1
0.2
0.3
0.4
0.5
$t, (\frac{GeV}{c})^2$

Fig 2a.



$\frac{d\sigma}{dt}$, $\frac{mbn}{(GeV/c)^2}$
$K^- {}^4He \rightarrow K^- {}^4He$
0.0
0.1
0.2
0.3
0.4
0.5
$t, (\frac{GeV}{c})^2$

Fig 2b.

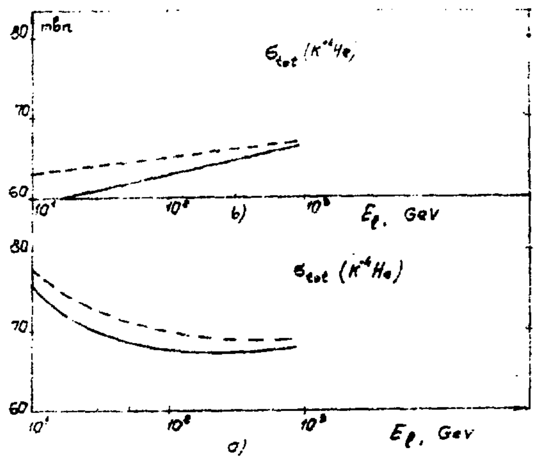

mbn
$\sigma_{tot}(K^{+4}He)$
b)
E_ℓ, GeV
$\sigma_{tot}(K^{-4}He)$
a)
E_ℓ, Gev

Fig 3.

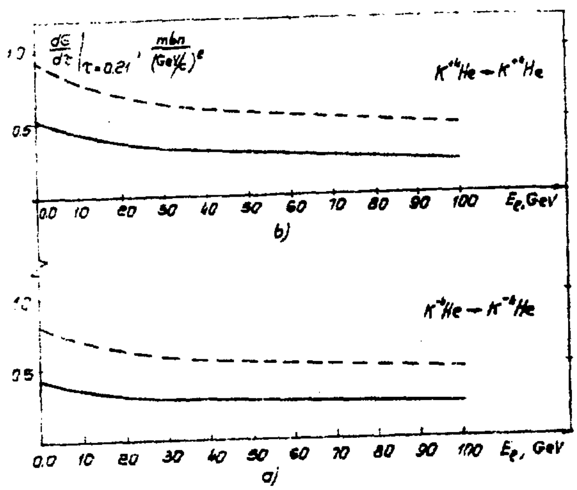

$\frac{d\sigma}{dt}\Big|_{t=0.21}$, $\frac{mbn}{(GeV/c)^2}$
$K^{+4}He \to K^{+4}He$
b)
E_ℓ,GeV
$K^{-4}He \to K^{-4}He$
a)
E_ℓ, GeV

Fig 4.

References

1. V.A.Tsarev, Sov.J.Nucl.Phys., 10, 367 (1969).
2. L.A.Grigoryan, V.A.Shakhbazyan, Scient.Rep. of Yerevan Physics Institute, N.63 (1974).
3. L.A.Grigoryan, V.A.Shakhbazyan, Scien.Rep. of Yerevan Physics Institute, N.101 (1974).
4. L.A.Grigoryan, V.A.Shakhbazyan, Sov. J.Nucl. Physics (in press, the preceeding communication).
5. V.N.Gribov, JETR, 56, 892 (1969).
6. K.A.Ter-Martirosyan, Sov. J.Nucl.Phys. 10, 1047, (1969).
7. K.G.Boreskov, A.M.Lapidus, C.T.Sukhorukov, K.A.Ter-Martirosyan, Sov. J.Nucl.Phys. 14, 814 (1971).
8. G.I.Lykasov, A.V.Tarasov, Sov. J.Nucl.Phys. 17, 301 (1973).
9. A.B.Kaidalov, Sov. J.Nucl.Phys., 13, 401 (1971).
10. S.T.Sukhorukov Sov.J.Nucl.Phys. 12, 154 (1970).

The manuscript was received on the 15th of April 1976

Л.А.ГРИГОРЯН, В.А.ШАХБАЗЯН

УПРУГОЕ РАССЕЯНИЕ К-МЕЗОНОВ НА ЯДРЕ ^{4}Не В ТЕОРИИ КОМПЛЕКСНЫХ МОМЕНТОВ В ОБЛАСТИ ЭНЕРГИЙ 20 ÷ 100 ГЭВ.

(на английском языке)
Ереванский физический институт

Тех.редактор А.С.Абрамян

Заказ 599 ВФ-03872 Тираж 299

Подписано к печати 29/VI-76 г. Формат издания 30 х 40

I,0 уч.изд.л.Ц.7 к.

Отпечатано на ротапринте
Ереванского физического института, Ереван 36, пер. Маркаряна 2