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ABSTRACT

The elastic scattering of 40.9 MeV ^{3}He-particles from ^{12}C were investigated in the framework of the simple one-channel optical model. An overall good fit could be obtained. The ambiguities of the real central potential are discussed.

АННОТАЦИЯ

Упругое рассеяние частиц ^{3}He с энергией 40,9 Мэв на ^{12}C было изучено в рамках оптической модели. Экспериментальное и теоретическое угловые распределения хорошо согласуются. Многозначность реального центрального потенциала дискутируется.

KIVONAT

40.9 MeV energiáju ^{3}He részecskék ^{12}C-nen való rugalmas szóródását vizsgáltuk az egy-csatornás optikai modell keretében. Szögeloszlás analizisében jó egyezést értünk el. A real central potenciál többértelmüségét diszkutáljuk.

1. Introduction

Elastic scattering of ^{3}He-particles has been investigated in the region of light and medium mass nuclei [1], /and see references of [1]/, however, owing to the experimental difficulties up to now there are only few results on ^{3}He elastic and inelastic scattering, usually in a limited angular range, in comparison with p,d and α data. This fact explains that there is no comprehensive information on ^{3}He optical potential parameters in a wide range of energy and a large variety of nuclei.

These data are useful in order to have entrance -channel optical model parameters for the study of /^{3}He,t/, /^{3}He, pick up/ and /^{3}He, stripping/ reactions using the DWBA and CCBA analysis. Also the charge-exchange reaction /^{3}He, t/ has widely been employed nowadays to investigate the isovector giant resonances.

Many optical model analysis of data for helion scattering from nuclei have been succesfull in providing good fits, but they have generally failed to produce unique descriptions of the potentials involved a number of ambiguities - caused by strong absorption of composite particles - these include discrete families of potential depths and an unclear choice between volume and surface absorption.

The concept of volume integral for the real potential per particle pair, J_R, may be used to classify discrete families of potentials [2].

Thus it seemed interesting to study the elastic scattering of helions by ^{12}C nucleus to investigate the problem of ambiguities in the optical potential of helions at least with the hope to reduce the number of discrete potential ambiguities. The investigated families are that with $J_R \approx 430$ and 620 MeV·fm^3. With this aspect the work complements previous systematic studies of scattering by ^{12}C [1].

2. Experimental

The measurements were carried out with the momentum analysed ^3He-beam of the Hamburg Isochronous Cyclotron. The energy was set to E =40.9 MeV; with a FWHM energy spread of about 30 keV the maximum current was 900 nA. The beam was focused onto the target to form a spot 2 mm wide by 5 mm high in a 80-cm-diam. scattering chamber. The targets, prepared for other Sm-scattering, experiments, were produced by evaporating Sm and depositing it on thin carbon foil about 20 $\mu g/cm^2$. The total target thickness was about 60 $\mu g/cm^2$. The scattered particles were detected either by an E-ΔE-surface-barrier-detector-telescope or two Si/Li/-detectors. The surface barrier detectors were cooled to -30^{o}C, the Si/Li/-detectors to -55^{o}C. The overall resolution was 40 to 80 keV FWHM. The usual ORTEC-particle -identifier technique was used to extract the ^3He-events from the E-ΔE-telescope signals. The differential cross section data concerning ^{12}C could be extracted from the total ^3He spectrum /SmO_2+^{12}C/. More detailed description of the experiment can be found in ref. [3].

3. Optical model analysis

The optical model potentials used was of the form

$$V(r) = -V_R f(r, R_R, a_R) - i W_V f(r, R_i, a_i) - i 4 a_i W_D \times$$

$$\frac{d}{dr} f(r, R_i, a_i) + V_C(r), \qquad /1/$$

where f/r, R, a/ is the well khown Saxon-Woods form factor, $R=r_o \cdot A^{1/3}$ and V_c/r/ the Coulomb potential due to a uniformly charged sphere of radius $1.3 \cdot A^{1/3}$ fm. Earlier analyses [4,5] extend into the backward hamisphere, show a slight preference for a surface peaked Saxon-Woods derivative form factor of the imaginary part of the potential.

The computer code MAGALI [6] used for the analysis minimizes the function

$$N\chi^2 = \sum_{i=1}^{N} \left(\frac{\sigma_{th}(\Theta_i) - \sigma_{exp}(\Theta_i)}{\Delta\sigma_{exp}(\Theta_i)} \right)^2 \qquad /2/$$

N being the number of experimental data points, $\sigma_{th}(\Theta_i)$ the predicted theoretical cross section and $\sigma_{exp}(\Theta_i)$ the experimental value at the scattering angle Θ_i, and $\sigma_{exp}(\Theta_i)$ the associated experimental error.

Extensive calculations have been done by taking into account the different terms of the potential expression (1).

The spin-orbit potential is expected to be small [8]. Our first systematic calculations have shown that the spin-orbit term for 40 MeV helion scattering from ^{12}C produces observable effects in the angular distributions at scattering angles greater than 140 degrees only.

For different potential families, namely for the probably most physical, the shallower and deeper ones - with $J_R \approx 430$ and 620 MeV.fm^3, respectively - the best fits are shown in fig. 1. and compared with the experimental cross section data. In the investigated angular range there are differences in the shape of the angular distribution; for angels larger than $\Theta \sim 100^o$; consequently there is some evidence that the potential family of $J_R \approx 430$ MeV.fm^3 with surface absorption is the preferred one.

With regard to the best fitt parameters /table 1./ we make the following remarks: from our experimental results we found r_{oi} to be greater r_{or} in agreement with earlier analysis of α-particles [9] and He-3-particles [7] : the diffuseness parameters are larger than that for other light nuclei, however, as it is known, the diffuseness parameters for static deformed nuclei increase due to the effect of collective channels.

It is known that the elastic scattering of strongly absorbed composite particles is sensitive to the tail region of the optical potential as was shown in α - and helion - scattering [9,10,11]. Only a few partial waves contribute mainly to the scattering process: a phenomenological description is obtained through the parametrization of the reflection coefficient in the analysis of elastic scattering from the relation of the strong absorption radius R_s to that partial wave ℓ, where the real part of the reflection coefficient is 0.5 /see definition in ref. 12/. Furthermore the discrete optical potentials giving equally good fits to the data are similar in their shape and magnitude in the region of the strong absorption radius, the quality of fit is virtually independent of the magnitude of the potential in the nuclear interior. - These expectations were also proved in the present analysis: for ^{12}C nucleus we found - investigating the actual fits - a point R_x at a large distance where the various real potentials have the same magnitude: this point is near to the strong absorption radius $R_{1/2}$. This is demonstrated in fig. 2 and in table 2. which contains R_x and $R_{1/2}$ with the associated partial wave /ℓ/. It is to be noted, since other equivalent potentials with different shapes and magnitudes in the nuclear interior, but the correct form in the nuclear surface yield equally good fit to the data, it is clear, that the volume integral of the central potential cannot have the same physical significance as in case of nucleon nucleus potentials. Thus the volume integrals are suitable only to classify the discrete potential families having the same form factors, however, without physical meaning.

4. Conclusion

The simple optical model with surface absorption term and without spin-orbit potential gives a satisfactory description of the elastic scattering of 40.9 MeV-helions from ^{12}C nucleus in the measured angular range. It turns out that the sets of discrete potentials giving "equivalent" fits to the data have similar shape and the same magnitude at a large radius R_x /$\approx$ 4.44 fm/, which is near to the strong absorption radius.

The present experimental data seem to resolve the problem of discrete ambiguities in the real optical potential, showing a preference for the potenfial family with J_R=430 MeVfm^3.

5. Acknowledgements

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Table 1. Optical model parameter sets, deep and shallow potentials respectively

Potential family	set	MeV V_R	fm a_R	fm r_{OR}	MeV W_V	MeV W_D	fm a_i	fm r_{oi}	MeV.fm^3 J_R	$^2/N$
2	A	119.08	0.78	1.11	12.75	0.0	0.72	1.83	436	21.4
	B	118.64	0.762	1.11	0.0	14.07	0.82	1.32	421	9.7
3	A	202.3	0.62	1.11	17.20	0.0	0.81	1.50	612	16.8
	B	204	0.61	1.11	0.0	16.25	0.83	1.28	628	19.2

Table 2. Comparison of the strong absorption radius $R_{1/2}$ and R_x

Potential family	$\ell_{1/2}$	$R^{fm}_{1/2}$	R^{fm}_{x}
$J_R^{MeV\cdot fm^3} = 430$	10	4.4	4.44
$J_R^{MeV\cdot fm^3} = 620$	10	4.4	

Figure captions

1/A The experimental differential cross section data displayed as ratio to Rutherford cross section. The solid and dashed curves represent the optical model fits using surface absorption in the potentials with normalized volume integral of the real potential 430 and 620 MeV·fm^3, respectively.

1/B As for Fig. 1/A for volume absorption in the optical potential.

2 The real potentials for the families used to fit the data.

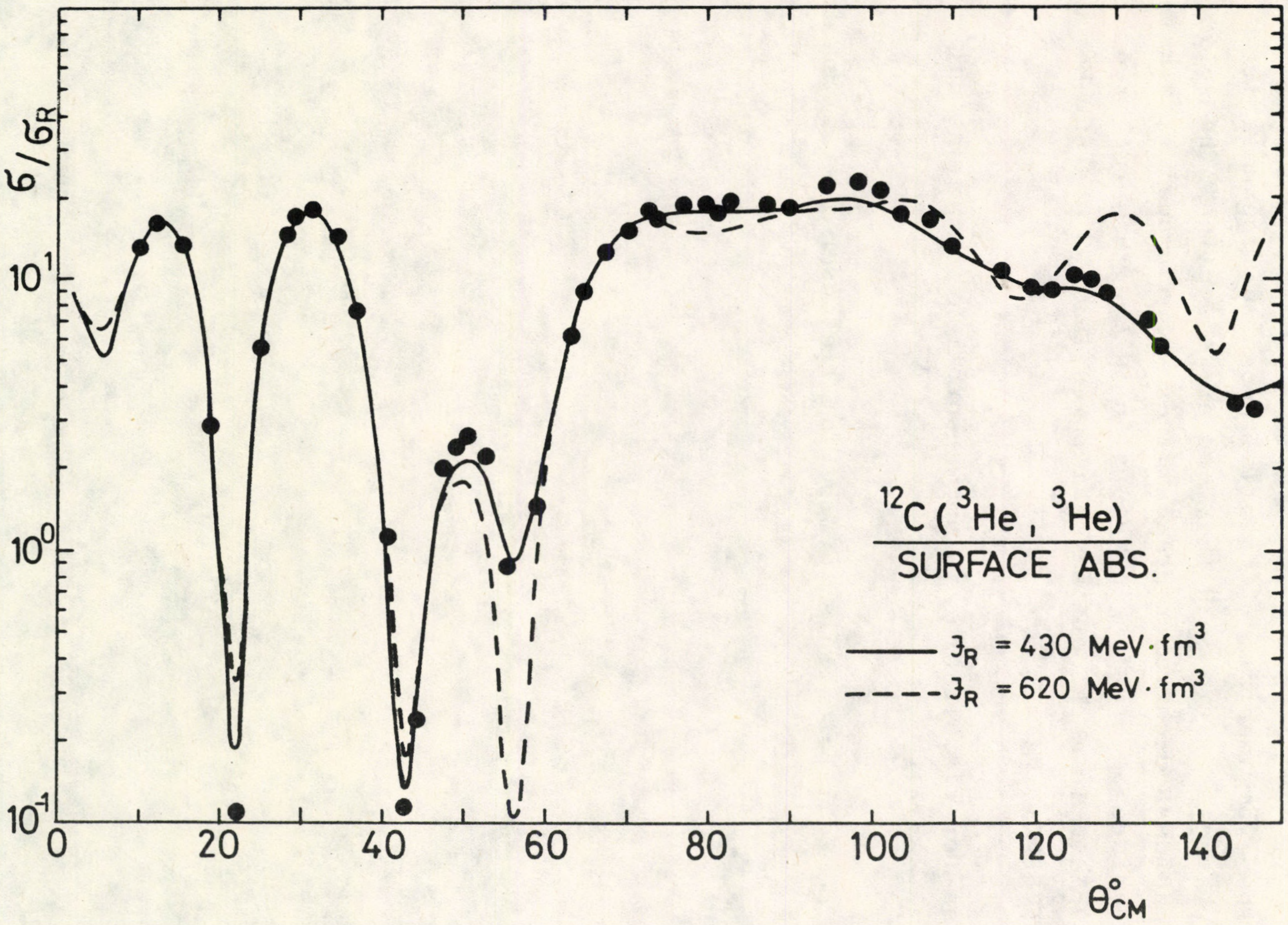
σ/σ_R
10^1
10^0
10^{-1}
0
20
40
60
80
100
120
140
θ°_{CM}
$^{12}C(^3He, ^3He)$
SURFACE ABS.
$J_R = 430$ MeV·fm^3
$J_R = 620$ MeV·fm^3

Fig. 1/A

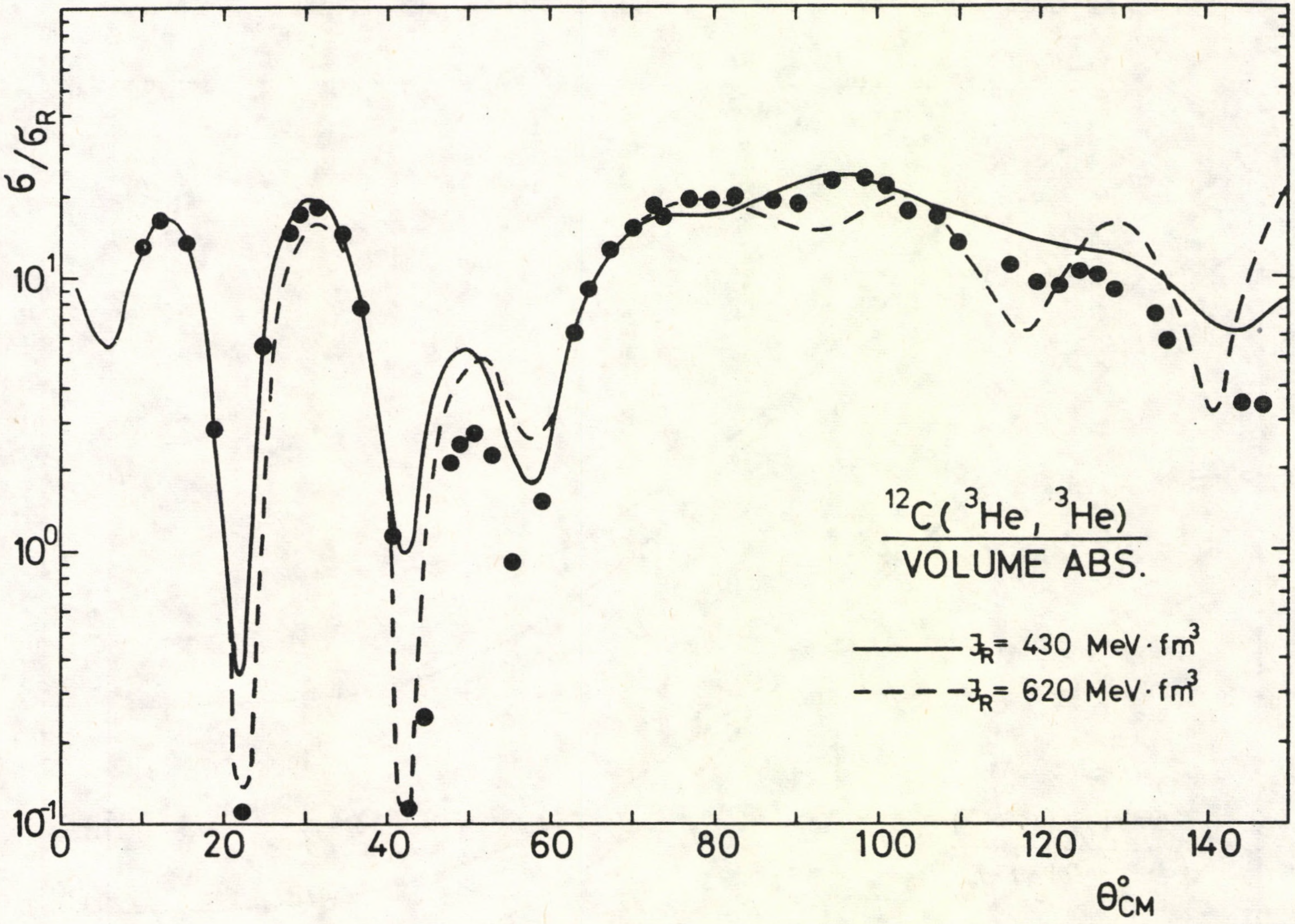
σ/σ_R
10^1
10^0
10^{-1}
0
20
40
60
80
100
120
140
θ°_{CM}
$^{12}C(^3He,\ ^3He)$
VOLUME ABS.
J_R = 430 MeV · fm^3
J_R = 620 MeV · fm^3

Fig. 1/B

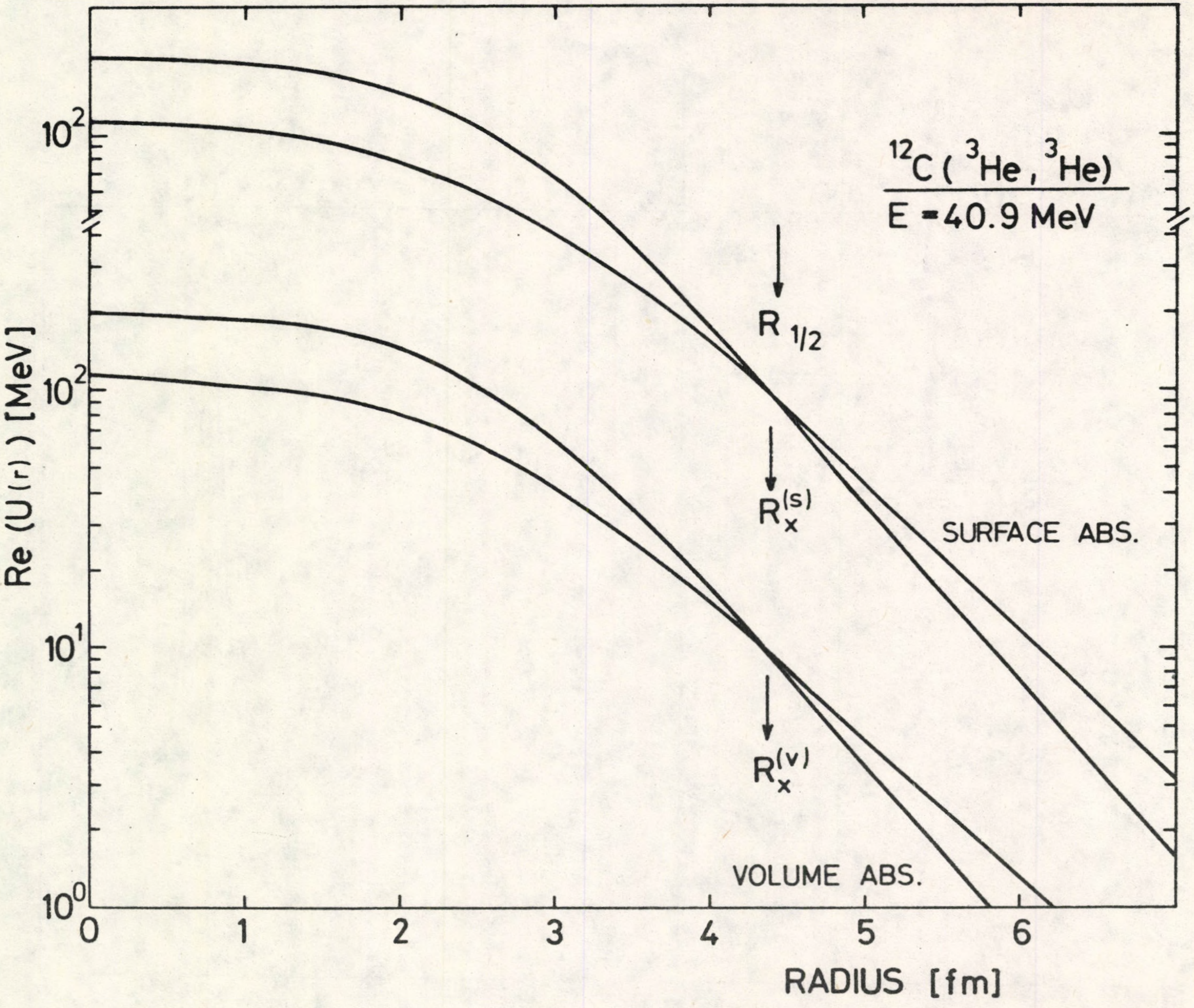
10^2
10^2
10^1
10^0
Re (U(r)) [MeV]
$^{12}C(^3He, ^3He)$
E = 40.9 MeV
$R_{1/2}$
$R_x^{(s)}$
$R_x^{(v)}$
SURFACE ABS.
VOLUME ABS.
0
1
2
3
4
5
6
RADIUS [fm]

Fig. 2

Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Szegő Károly
Szakmai lektor: Sziklai János
Nyelvi lektor: Kluge Gyula
Példányszám: 390 Törzsszám: 81-234
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