Preprint YerPhI-1431(1)-95

ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ
ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ
YEREVAN PHYSICS INSTITUTE

SOURCE OF INTERMEDIATE-MASS FRAGMENT EMISSION, $4 \leq Z_f \leq 10$, IN THE INTERACTIONS OF 3GeV ELECTRONS WITH ^{197}Au NUCLEI

G.E. MARKARYAN, G.M. AIVAZYAN, H.V. BADALYAN,
D.M. BEGLARYAN, H.G. ŻOHRABYAN

Ереван

Препринт ЕрФИ-1431(1)-95

ИСТОЧНИК ИСПУСКАНИЯ ФРАГМЕНТОВ ПРОМЕЖУТОЧНЫХ МАСС, $4 \leq Z_f \leq 10$, ПРИ ВЗАИМОДЕЙСТВИИ ЭЛЕКТРОНОВ С ЭНЕРГИЕЙ 3 ГэВ С ЯДРАМИ ^{197}Au

Г. Е. Маркарян, Г. М. Айвазян, Г. В. Бадалян,
Д. М. Бегларян, Г. Г. Заграбян

Представляются и анализируются энергетические спектры фрагментов промежуточных масс, $4 \leq Z_f \leq 10$, испущенных под углами 50, 90, 120° в реакции $e+{}^{197}Au+fr+x$, вызванной электронами с энергией 3ГэВ. Измерения проводились на внутреннем пучке Ереванского синхротрона с использованием методики полупроводниковых телескопов. Диапазон измеренных кинетических энергий фрагментов составлял ~ 2÷7МэВ/нуклон.

Проведенный кинематический анализ энергетических спектров и их анализ на основе модифицированных Максвелл-Больцмановских распределений, учитывающих тепловой и нетепловой вклады в спектры фрагментов, указывает на изотропное испускание фрагментов из некоторого общего горячего движущегося источника, который существенно меньше, ~ 50-60 нукл. массы ядра-мишени. Были получены следующие значения для скорости и температуры источника: $\beta_s = 0.01 \pm 0.001$, $T \approx 5$МэВ. Полученное значение для параметра наклона спектров, ~ 13МэВ ("кажущаяся температура"), согласуется с предсавлением о доминирующем нетепловом вкладе в высокоэнергетические части спектров.

Ереванский физический институт

Introduction

Recent years it is observed an increasing interest to the problem of intermediate-mass fragment (IMF) production in collisions of energetic bombarding particles with nuclei [1-23] This interest, in particular, has been stimulated by the works [1-3, 7, 10], where some of the observed IMF production characteristics, such, for example, as power-law dependence of the fragment mass or charge yeilds ($\sigma \sim A(Z)^{-\tau}$) and others are related to possible creation in nuclear matter instabilities and critical phenomena at excitation energies in Gev region. Based on analysis of available and new obtained experimental data (mainly from proton and heavy ion induced reactions), novel conceptions and models for IMF production have been put forward in these years. Among the advanced models, one can, for example, single out the liquid gas phase transition model [3-9] the cold nuclear breakup model [10], the nuclear lattice model [11], variety of the statistical multifragmentation models [12-13], and so on. Special attention has also been paid to determination source (or sources) of IMF emission. There are both the works suggesting on IMF emission from a fully equilibrated remnant [3,25-27] and those -on essential contribution of non-equilibrium sources [14-17]. In spite of many works devoted to this problem there is not, at present, clear understanding of the processes, leading to IMF formation and emission. Thus, for elucidation of the above problem, additional experimental and theoretical efforts should be made, including study of IMF production in reactions unduced by energetic electrons and photons, which is, unfortunately, almost absent [18-22]. In this work we present experimental data and their analysis on IMF ($4 \le Z_i \le 10$) emission, at angles of $50^\circ, 90^\circ$ and 120° in $e + {}^{197}Au \to fr + x$ reaction induced by 3 GeV electrons.

2. Experimental technique

The measurements were performed on internal beam of Yerevan synchrotron using experimental set-up "e-A" [23], schematically shown in fig. 1. A thin ($\sim 1 \mu m$) gold film, providing multiple electron beam traversals, was used as the target. Fragments emitted from the target were detected (in solid angles of $\sim 5 \cdot 10^{-4}$ sr) by ΔE-E-V telescopes, each consisting of three silicon semiconductor detectors of thickness 20-50, 1000 and 1000 μm, respectively. The telescopes were located in the vacuum chamber of the set-up, at angles of 50°, 90° and 120° to the direction of the electron beam. The measured range of the fragment kinetic energy was within $\sim$ 2-7 MeV/nucl. The accuracy of the energy determination was $\sim$ 5%. The fragments were identified by charge with the resolution of $\sim$ 10%, mainly dependent on ΔE detector thickness non-uniformity. Extraction, accumulation and preliminary processing of the data were performed by means of electronic system operating on-line with microcomputer "Electronica 60" [24]. Electrons traversed through the target were monitored by means of Gauss-quantometer accepting bremstrahlung emitted from the target. The accuracy of the monitoring was $\sim$ 15%.

3. General features of the fragment energy spectra

After performing data handling operations and acounting for needed corrections such, for example, as the fragment ionisation losses in the target, detection efficiency, and others, we have obtained the fragment energy spectra, used in subsequent analysis. Fig.2 shows, for example, the fragment energy spectra at 90°. As can be seen from the figure, the spectra have Maxwell-Boltzman-type form with exponentially decreasing tails; absolute differencial cross sections ~ 10^{-4} times less than corresponding ones obtained on proton beams, at bombarding energies close to ours [14-15]; the most probable fragment kinetic energy is shifted to higher energies with the fragment charge. The typical dependence of the fragment spectra on measured angle is shown, for B and N fragments, in fig.3. As can be seen from the figure, the fragment differential cross sections decrease with the detection angle. It should be noted, that low energy cut-off of the fragment energy spectra, obtained at 50° and 120°, is due to both larger thicknesses of ΔE detectors used at these angles and some apparatus disturbances in these parts of the spectra.

4. Analysis and description of the fragment energy spectra

a) Analysis of the invariant differential cross sections.

For all of the measured fragments we have determined the fragment invariant differential cross sections $\frac{1}{p}\frac{d2\sigma}{d\Omega dE}$ and plotted the corresponding energy spectra. Typical dependence of these spectra on measured angles is shown in fig.4 for B and O fragments, respectively. Such dependence suggests a possibility of the isotropic fragment emission from a common source (system), moving with some translate velocity with respect to laboratory system. To check the validity of this concept for the fragments emitted in the measured reaction and estimate the source velocity (β_s), we have plotted the known $\frac{1}{p}\frac{d2\sigma}{d\Omega dE} = f(V_{\parallel}\ V_{\perp})$ diagrams for longitudinal and transverse fragment velocity components, at several values of constant invariant cross sections. Fig. 5 shows, for example, these diagrams for B and O fragments, at 3 values of constant invariant cross sections, denoted on the figure by numbers 1.2.3. As can be seen from the figures, the dots with equal numbers lie on semi-circles drawn from the same center, shifted along $V_{\parallel}$ axis on some value $\beta_s = 0.01$. Similar pictures have been observed for all measured fragments and, moreover, the value for β_s has turned out to be the same and equal to 0.01. Thus, the results of performed analysis are in agreement with the concept of isotropic emission of the measured fragments from a common moving source.

b) "Angle joined" fit of exponentally decreasing parts ("tails") of the fragment energy spectra.

For additional verification of applicability of the above concept for the fragment emission in the measured reaction and determination of the source velocity, it has been proposed and performed join fit of the exponentially decreasing parts ("tails") of each fragment energy spectra (at angles of 50°, 90°, 120°) with equation (1)

$$\frac{d^2\sigma}{d\Omega dE} = N\left(\frac{E}{E^*}\right)^{1/2} \exp\left(-\frac{E^*}{T'_1}\right), \qquad (1)$$

where N- common (50, 90, 120°) normalization constant,

E- fragment kinetic energy in laboratory system

$E^* = E + \frac{M_f \beta_s^2}{2} - 2\sqrt{E\,\frac{M_f \beta_s^2}{2}}\cos\theta$ -fragment kinetic energy in source rest frame,

β_s - translate source velocity in laboratory system,

M_f-**fragment mass number** (mass number of the most intensively producing isotope of each element [3, 26]),

$\theta(50^\circ, 90^\circ, 120^\circ)$-fragment emission angle in laboratory system,

T'_1 - common $(50^\circ, 90^\circ, 120^\circ)$ slope parameter of the fragment spectra in source frame, where index 1 is used to denote "tails" of the spectra, and prime (') - no accounting for source recoil (see also: c) d)).

The values for β_s and T'_1 obtained from this "angle joined" fit of each measured fragment, are presented in Table 1.

Table 1

The values for β_s and T'_1 obtained from the "angle joined" fit of exponentially decreasing parts of the fragment spectra.

Fragments	β_s	T'_1 (MeV)	χ^2/n
Be	0.0106 ± 0,0008	10.5 ± 0.53	0.63/10
B	0.0102 ± 0.0005	10.1 ± 0.37	3.6/17
C	0.0099 ± 0.0006	9.4 ± 0.5	2.7/15
N	0.01 ± 0.0009	9.6 ± 0.9	2.9/12
O	0.014 ± 0.0012	8.5 ± 1.5	0.16/9
F	0.01 ± 0.0016	7.4 ± 1.6	1.1/7
Ne	0.0092 ± 0.0037	7.5 ± 3.7	0.2/4

n- number of experimental points used in the fit.

As can be seen from Table 1, it is observed:

- Rather good fit of the joined (50°, 90°, 120°) exponentially decreaing parts of each fragment spectra, by eq.(1).
- Constancy of source velocity value, $\beta_s = 0.01$, obtained from this fit of each measured fragment spectra.

Thus, the results of this fit are also consistent (at least, for the fragment kinetic energies above the "Coulomb peak") with the isotropic emission of the measured fragments from a common moving source. Using the obtained value for the source velocity (β_S=0.01), we have transformed the laboratory energy spectra of each fragment, measured at 50°,90°,120°, into the source rest frame. Examples of such transformation, for Be, B, N, O fragments are shown in figs. 6-7. As can be seen from the figures, the fragment energy spectra in the source rest frame nearly coincide with each other, what additionally illustrates the isotropic fragment emission from a common moving source in the measured reaction.

c) Analysis of the fragment spectra slope parameter (T'_1).

The values for the fragment spectra slope parameter, obtained from the described "angle joined " fit, are also presented in Table 1. As can be seen from Table I, it is observed some decrease of this parameter with the fragment charge number. In the earlier work [25] on IMF production ($3\le z_f\le14$) in $P + Xe \to fr + X$ and $P+Kr\to fr + X$ reactions, unduced by high energy protons, it was observed a linear decrease of the fragment spectrum slope parameter (T') with the fragment mass number for fragments heavier than carbon (fig.8) which was interpreted there as the emission of these fragments through a mechanism of quasi-two-body desintegration of a remnant, having some quantity T (apparent temperature), related to the slope parameter T by

$$T' = T(1-\frac{A_f}{A_R}), \qquad (2)$$

where A_f -fragment mass number,

A_R -remnant mass number.

The values for, T, obtained there had turned out to be, apparent temperatures (~ 14-15MeV) for the measured reactions, and values of A_R close to (~ 20 nucleon mass less) the target nucleus mass number. Emission of the lighter measured fragments ($4 \le Z_f < 7$), however, could not be interpreted there in such a manner.

In fig. [illegible] we have also plotted the relationship between T'_1 (see Table [illegible]) and A_f, obtained from the "angle joined" fit of our energy spectra. Mass number of the most intensively producing isotope of each element [3,26] was used for A_f. As can be seen from the figure the nearly linear decrease of the slope parameter T'_1 with the fragment mass number A_f is also observed for our data and, moreover, including the lighter measured fragments ($4 \le Z_f < 7$). Based on the approach suggested in [25] we have assumed that this decrease of T'_1 is due to two-body kinematics and approximated it with equation similar to (2)

$$T'_1 = T_1 \left(1 - \frac{Af}{As}\right) \qquad (3)$$

where As - source mass number,

T_1 - appparent temperature.

The values for apparent temperature, T_1, and a source mass number, As, obtained from such approximation, are shown in Table 2.

Table 2

The values for "T_1" and "As" obtained from approximation with eq. (3).

Fitted fragments	T_1 (MeV)	As	χ^2/n
Be - Ne	12.7 ± 1.2	52 ± 17	0.36/7
Be - F	12.8 ± 1.3	52 ± 17	0.35/6
B - Ne	12.8 ± 1.6	51 ±19	0.35/6
B - F	12.9 ± 1.7	51 ±20	0.35/5

n -number of the fitted fragments.

As can be seen from the Table 2, the obtained value for "T_1"

(13MeV) is close to the ones, obtained from proton induced reactions [14-15, 25-27], but the value for "As" - essentially less than the target-nucleus mass number (~ 200).

d) Description of the fragment energy spectra obtained at 90°

The fragment energy spectra measured at 90° (fig 2) in some extent, include low-energy part of kinetic energies (before "Coulomb peak") and as can be seen from the fig.2 have Maxwell-Boltzmann-type form, typical for IMF energy spectra from proton-nucleus and nucleus-nucleus induced reactions. For approximation of these spectra at 90°, we have followed to the concept [3] of thermal and nonthermal contributions to IMF energy spectra and have used the expression (4), basically similar to the one proposed in the cited work [3]

$$\frac{d^2\delta}{d\Omega dE}=N\left(\frac{E}{E^*}\right)^{1/2}\int_0^{E^*-KB}\varepsilon^{1/2}(E^*-KB-\varepsilon)^{1/2}\exp\left\{-[\varepsilon/T_1+(E^*-KB-\varepsilon)/T_2]\nu\right\}d\varepsilon, \qquad (4)$$

where N - normalization constant,

$B = \dfrac{e^2 Z_f(Z_t-Z_f)}{r_0[A_f^{1/3}+(A_t-A_f)^{1/3}]}$ - nominal Coulomb barrier,

A_t, Z_t, A_f, Z_f - mass number and charge of target-nucleus and fragment respectively,

K - nominal barrier fraction,

r_0 = 1.44 fermi,

$\nu = \dfrac{As}{As-A_f}$ - factor accounting for source recoil,

As - source mass number,

T_1 - slope parameter (apparent temperature),

T_2 - temperature of fragment emitting system (source),

ε - fragment energy variable related to Fermi motion of nucleons in nuclear system.

The expression (4) is a convolution of two Maxwell-Boltzmann-type distributions, one of those with parameter T_1, attributed to "tails" of the energy spectra, accounts for nonthermal contribution, while the other one - heating of the fragment emitting system (source) to temperature T_2. The choice of such approximation is also supported by the obtained high value for T_1 (~ 13MeV), close to those (~ 12-15MeV) for IMF spectra from proton induced reactions [14-15, 25-27]. As it was noted in a number of works [3-5, 25], it is problematic to consider such high value as a nuclear temperature, and in some works [3-5,28] this parameter is related to mean square momentum of nucleons in cold nuclear system, what is also consistent with the observed nearly independence of this parameter on bombarding energy and target used in IMF production reactions [3, 8, 25].

Below, we briefly describe the fit of the fragment energy spectra at 90°, by using eq. (4). At first, we have performed individual fits of each fragment spectra to obtain values for normalization constant, N, and nominal Coulomb barrier fraction, K. These fits were performed at $\nu=1$, and fixed values for the fragment spectra slope parameter, T'_1, and the source velocity, β_s (see Table 1). The values for K obtained from these fits have turned out to be nearly independent on fragment charge and equal to 0,5 close to those for IMF from proton-induced reactions [26-27]. Then, at fixed values of, N, and, K, (obtained from the individual fits), β_s, and T_1 (see Table 2), we have performed, using eq.(4), simultaneous fit of all measured fragment energy spectra and determined the values for mass number, A_s, and temperature, T_2 of the fragment emitting source.

The results obtained from this simultaneous fits are **presented** in Table 3.

Table 3

The values for, As and T_2 obtained from simultaneous fit of the fragment energy spectra at 90°

Fragments fitted simultaneously	T_2 (MeV)	A_s (nucleon mass)	χ^2/n
Be - Ne	4.8 ± 0.2	60 ± 4.5	71/64
Be - F	4.9 ± 0.3	56 ± 4	64/57
B - Ne	4.8 ± 0.3	60 ± 5.2	55/54
B - F	5 ± 0.3	56 ± 5	48/47

n-number of the fitted points.

As can be seen from the Table 3, the obtained values for As, are in agreement with those obtained from the fit of the slope parameters, T'_1 (see Table 2) and the value for the source temperature, T_2, is ~ 5MeV.

Concluding remarks

The results obtained from performed analysis, apparently, evidence that in the measured $e + {}^{197}Au \rightarrow fr + x$ reaction, induced by 3GeV electrons, the fragments ($4 \leq Z_f \leq 10$) are isotropically emitted from some hot ($T_2 \sim 5$MeV) source, moving relative to the laboratory system with the velocity $\beta_s = 0.01$ and having the size (~50-60 nucl.mass) essentially less than target-nucleus one (~200). Consistency of the obtained values for the size, velocity and temperature of the source can be seen from the following estimations:

1. Using the obtained values for the size and velocity of the source, one can estimate its momentum to be of ~ 500-600 MeV/c

i, e ~15-20% of the incident electron momentum (Pe=3 GeV/c). Having in view, that considerable part of the incident momentum is taken away by scattered electron in this inclusive reaction, such estimation for the average momentum, acquired by the source, seems quite reasonable. If the measured fragments were emitted from a remnant having mass number close to target nucleus one, as is apparently the case for proton-induced IMF production reactions [3, 25-27], then its momentum, at the determined velocity (β_s =0.01), would amount to ~ 70% of the incident electron momentum, what seemed not probable.

2. The obtained value for the source temperature is ~ 5MeV. Using the thermodynamical relationship between excitation energy U^* and temperature T,

$$U^* = aAT^2, \qquad (5)$$

where a- level dencity parameter (1/10),

A- mass number of nuclear system,

one can estimate, that at the obtained values for the mass number (~ 50-60 nucl.mass) and temperature (~ 5MeV) of the source, its excitation energy is ~ 125-150MeV, which is in agreement with the one (~ 130MeV) resulting from our cascade calculations of the reaction, by using the program presented in [29]. It should be also noted, that at present we complete analysis of our data obtained in the study of the same reaction induced by 2 and 4,5 GeV electrons. The results of this analysis, which will be published, also support the ones described here.

The authors wish to thank V. N. Arutunyan, M. A. Mikaelyan, Y. D. Nersesyan, S. A. Shatyan, T. A. Vardanyan and T. G. Galstyan for their help in the measurements, and the operating crew of Yerevan synchrotron for stable work of the accelerator during the runs.

Figure captions

Fig. 1. Schematic view of the experimental set-up "e-A".

Fig. 2. Laboratory energy spectra for Li through Mg fragments emitted at angle of 90° in $e+{}^{197}Au \rightarrow fr+x$ reaction induced by 3GeV electrons. Cross sections have been multiplied by factors indicated on figure. In this and subsequent figures only statistical errors of the differential cross sections are given. The dashed curves represent the described fits (see 4d)) of the spectra by modified Maxwell-Boltzmann distribution accounting for thermal and nonthermal contribution to the fragment energy spectra.

Fig. 3. Laboratory energy spectra for B and N fragments at angles 50°, 90°, and 120°.

Fig. 4. Spectra of the invariant differential cross sections for B and O fragments at angles of 50°, 90° and 120° in laboratory system.

Fig. 5. Plot of the invariant cross-sections for B and O fragments in the $(V_{\parallel}\ V_{\perp})$ plane. Three values of the cross sections differing from each other by a factor of 2 are presented. Center of semicircles passing through the dots with equal numbers is shifted along $V_{\parallel}$ axis on the same value $\beta c=0.01$.

Fig.6. Energy spectra for B and N fragments at angles of 50°, 90°, and 120° (in laboratory system) transformed to the source rest frame by using determined value of the source velocity $\beta s=0.01$.

Fig.7. Energy spectra for Be and O fragments at angles 50°, 90° and 120° (in laboratory system) transformed to the source rest frame by using determined value of the source velocity $\beta_S = 0.01$.

Fig.8. The dependence of the fragment spectra slope parameter T'_1 on fragment mass number A_f obtained from the analysis of our data with dashed line representing the fit of T'_1 by eq. $T'_1 = T_1(1- A_F/A_S)$. For comparison, similar dependences obtained in the work [5] are also shown (dashed lines are drawn to guide the eyes).

References

[1] *J.E.Finn, S.Agarwal, A.Bujak, et al., Phys. Rev. Lett. 49(1982).*

[2] *A.I.Warwick, H.H.Wieman, H.H.Gutbrod, et.al, Phys. Rev. C27(1983)1083*

[3] *A.S.Hirsch, A.Bujak, J.E.Finn, et.al, Phys. Rev. C29 (1984)508*

[4] *J.Hufner, Phys. Rep. 125(1985)129*

[5] *W.G.Lynch, Ann.Rev.Nucl.Part.Sci.,37(1987)493*

[6] *L.P.Csernai, J.I.Kapusta, Phys.Rep. 131(1986)223*

[7] *A.D.Panagiotou, M.W.Curtin, D.K.Scott, Phys.Rev.C36 (1985)53*

[8] *N.T.Porile,A.T.Bujak, D.D.Carmony, et.al, Nucl.Phys.A 471(1987)149*

[9] *M.E.Fisher, Physics (N.Y.)3,255(1967)*

[10] *J.Aichelin and J.Hufner, Phys.Lett.B 136(1984)15*

[11] *W.Bauer, O.Post, D.R.Dean and U.Mosli, Nucl.Phys.A 452(1986)699*

[12] *D.H.E Gross and H.Massmann, Nucl.Phys.A471(1987)339*

[13] *H.W.Barz, J.P.Bondorf and H.Schulz, Nucl.Phys.A462 (1987)742*

[14] *V.V.Avdeichikov, A.I.Bogdanov, V.A.Budilov, et.al, JINRP1- 872 D4648(1987)*

[15] *V.V.Avdeichikov, A.I.Bogdanov, V.A.Budilov, et.al, Yad Fiz.48(1988)1736 [Sov.J.Nucl.Phys.48,1043(1988)]*

[16] *R.Kwiatkowski, J.Boshkin, H.Karwowski, et.al, Phys.Lett. 171B(1986)41*

[17] *P.E.Fields, K.Kwiatkowski, D.Bonser, et.al,Phys.Lett. 220B (1989)356*

[18] S.Liberto, F.Meddi, G.Romano, et.al, Nucl.Phys. A298(1978) 519

[19] G.M.Aivazian, V.N.Arutunian, H.V.Badalian, et.al, preprint EFI-857(8)-86,1986, preprint EFI 859(10)-86,1986(Yerevan)

[20] E.A.Akhverdian, G.M.Aivazian, V.N.Arutunian, et.al., Abstract Book II,PANIC 87,Kyoto, April,1987

[21] G.M.Aivazian, V.N.Arutunian, H.V.Badalian, et.al.,Sov.J. VANT, 2(27)1984

[22] R.A.Astabatian, N.A.Demechina, R.L.Kavalov, et.al.,Sov.J. VANT 5(23)1991

[23] V.N.Arutunian, H.V.Badalian, D.M.Beglarian et.al.,"Izvestia",serie "Fizika" 14,N3,1979(journal of Armenian Academi of sciences)

[24] H.G.Zohrabian, Preprint EFI-1295(81)-99,1990(Yerevan)

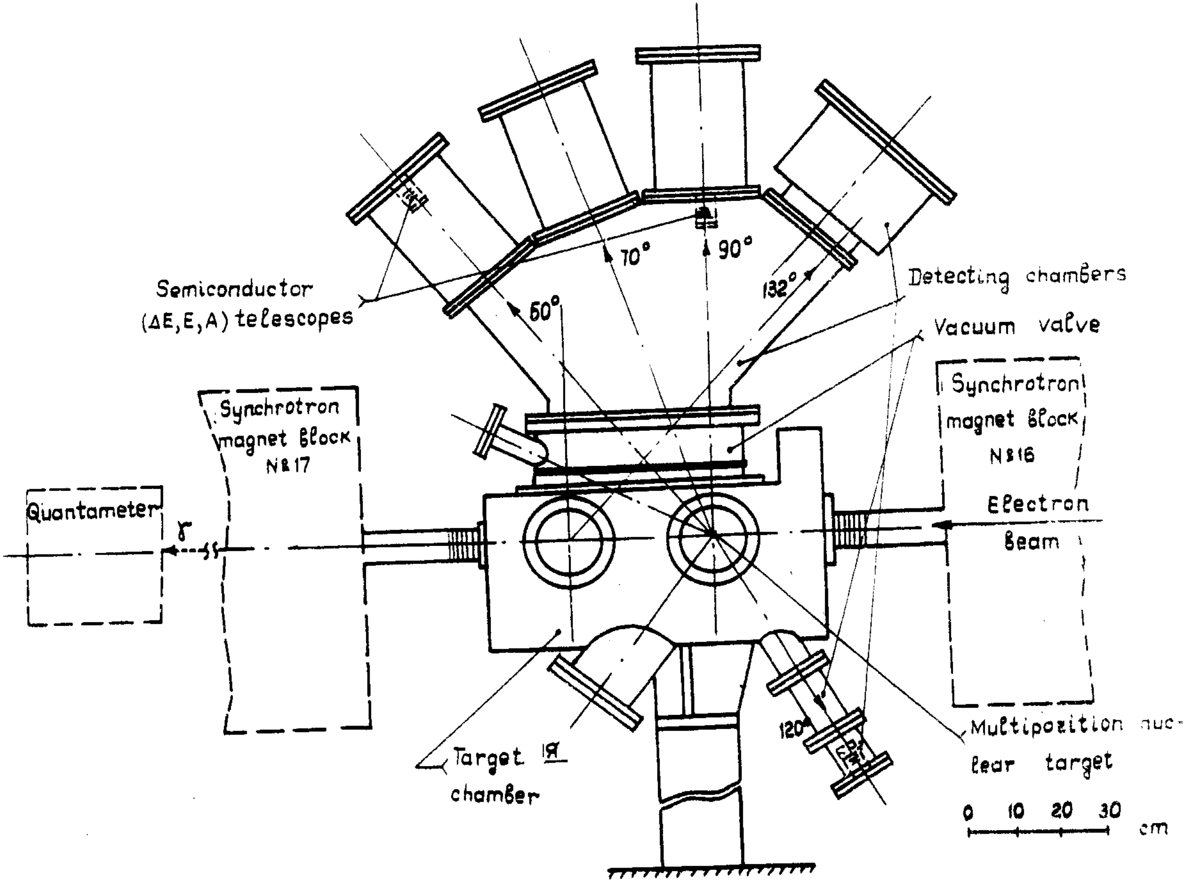
[25] F.A.Gaidos, L.J.Cutay, A.S.Hirsch, et.al.,Phys.Rev.Lett. 49(1982)1321

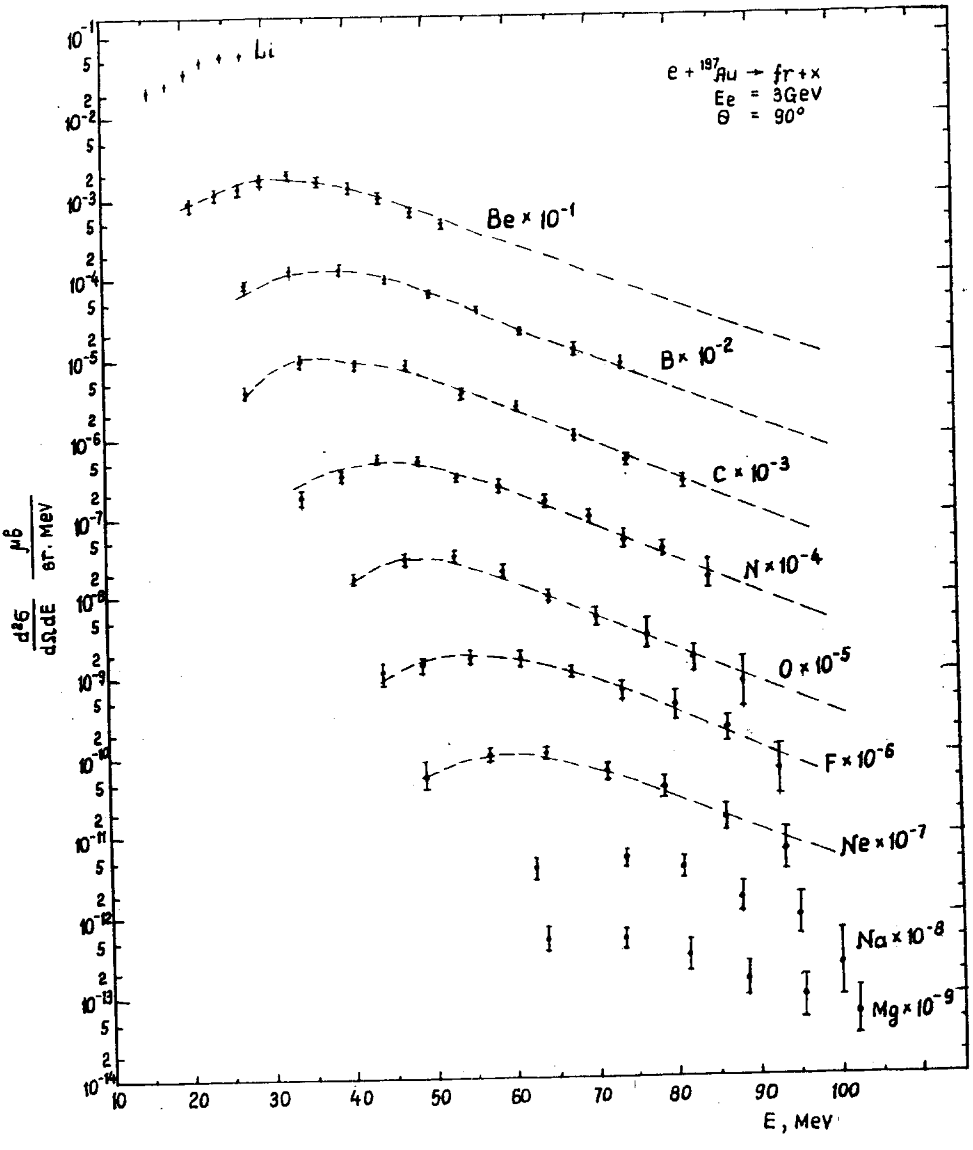
[26] A.M.Poskazer, G.W.Butler and E.K.Hyde, Phys.Rev.C3(1971) 882

[27] G.D.Westfall, R.G.Sextro, A.M.Poskanzer, et.al.,Phys.Rev.C 17(1978)1368

[28] A.S.Goldhaber, Phys.Rev.C17,2243(1978)

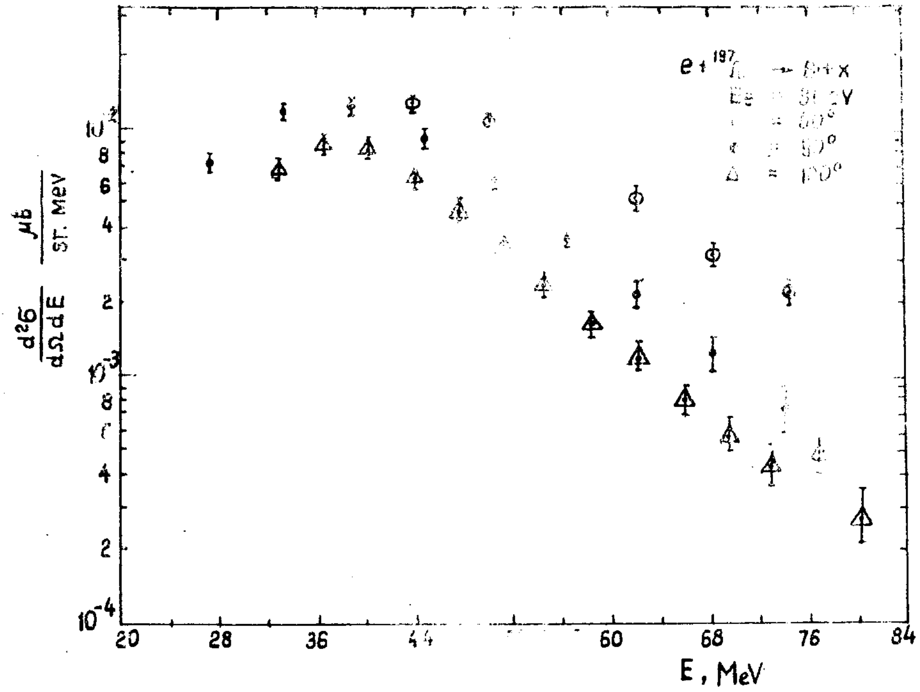
[29] K.Hanssgen and J.Rauft CPC,39(1986)37

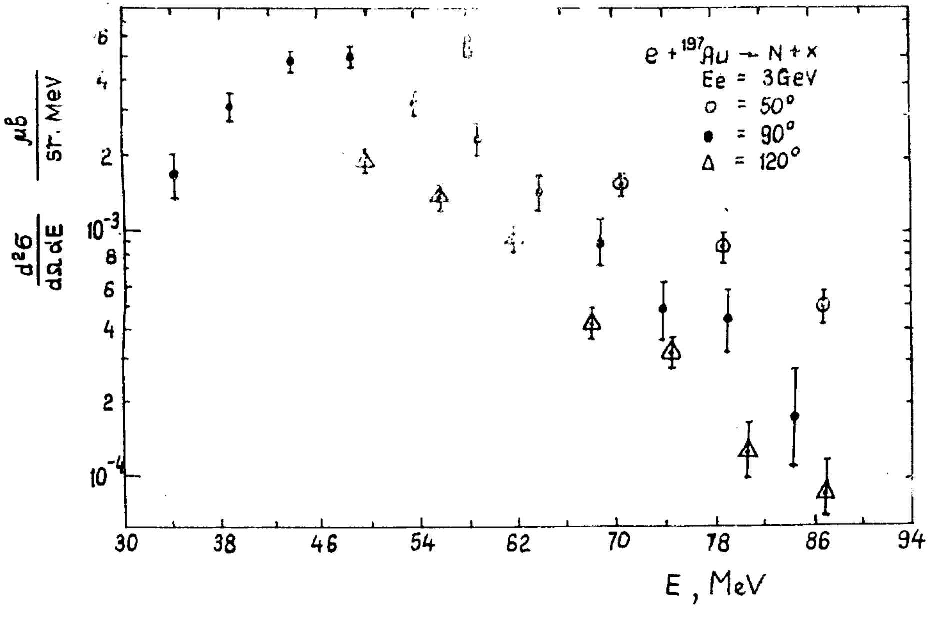

Semiconductor
(ΔE,E,A) telescopes
Detecting chambers
Vacuum valve
60°
70°
90°
132°
120°
Synchrotron
magnet block
N≗17
Quantameter
γ
Synchrotron
magnet block
N≗16
Electron
beam
Target IЯ
chamber
Multiposition nuc-
lear target
0 10 20 30
cm

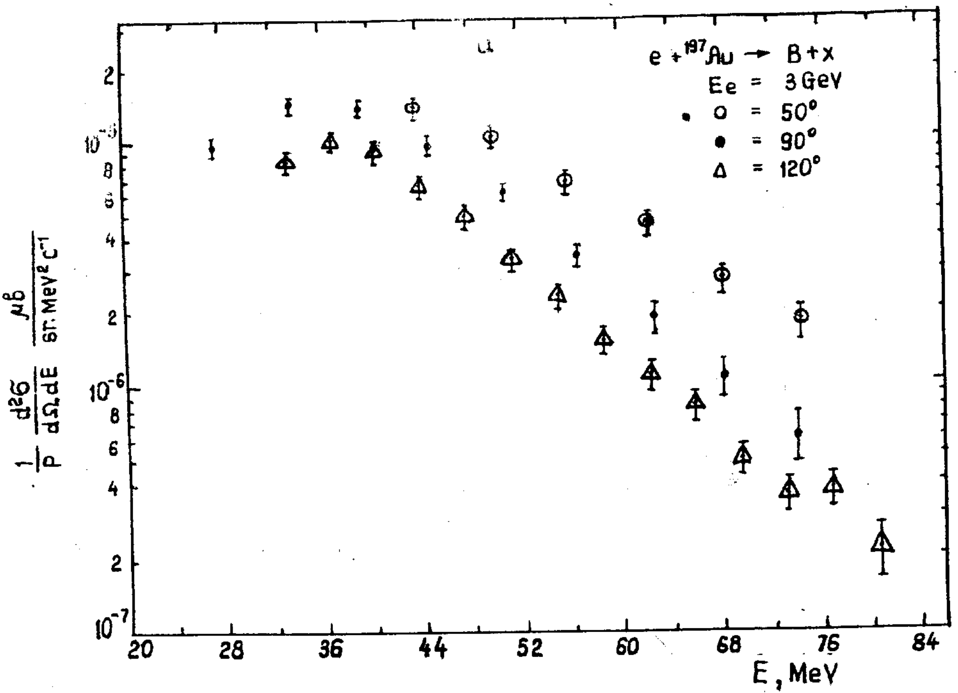


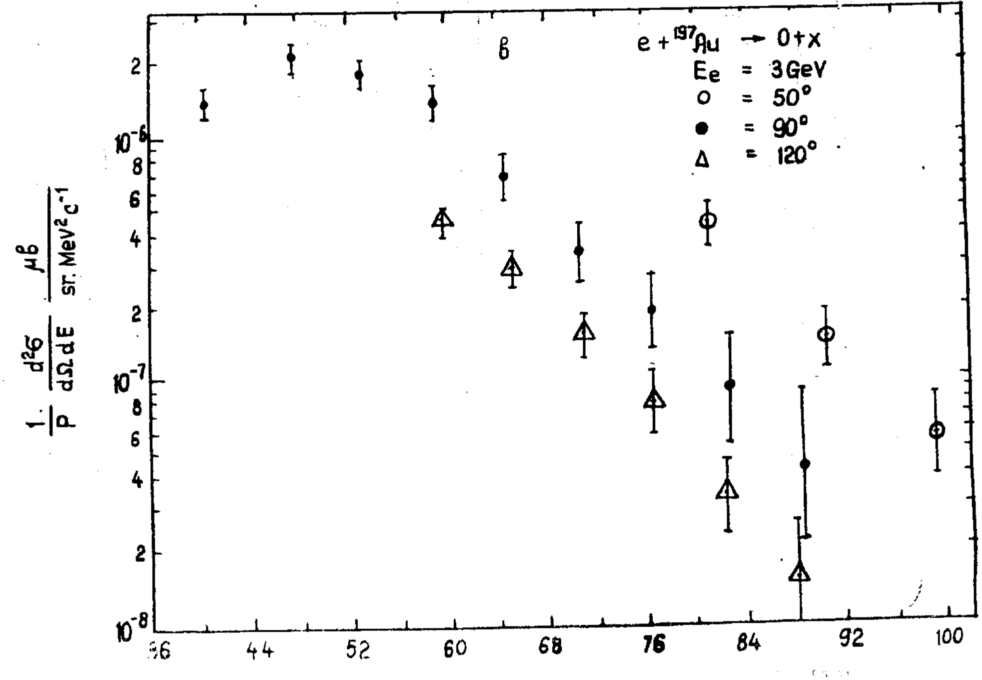
$e + {}^{197}Au \rightarrow fr + x$
$E_e = 3GeV$
$\Theta = 90°$
Li
Be × 10^-1
B × 10^-2
C × 10^-3
N × 10^-4
O × 10^-5
F × 10^-6
Ne × 10^-7
Na × 10^-8
Mg × 10^-9
d²σ/dΩ dE μb/sr. MeV
E, MeV
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10
20
30
40
50
60
70
80
90
100

Fig.2


$e + {}^{197}Au \rightarrow N + x$
Ee = 3GeV
○ = 60°
● = 90°
Δ = 120°
$\frac{d^2\sigma}{d\Omega dE}$
$\frac{\mu b}{st.\ MeV}$
10^{-2}
8
6
4
2
10^{-3}
8
6
4
2
10^{-4}
20
28
36
44
60
68
76
84
E, MeV


$e + {}^{197}Au \rightarrow N + x$
Ee = 3GeV
○ = 50°
● = 90°
Δ = 120°
$\frac{d^2\sigma}{d\Omega dE}$
$\frac{\mu b}{st.\ MeV}$
6
4
2
10^{-3}
8
6
4
2
10^{-4}
30
38
46
54
62
70
78
86
94
E, MeV


a
e + ¹⁹⁷Au → B + x
Ee = 3 GeV
○ = 50°
● = 90°
Δ = 120°
1/P d²σ/dΩ dE μb/(sr. MeV² c⁻¹)
2
10⁻⁵
8
6
4
2
10⁻⁶
8
6
4
2
10⁻⁷
20
28
36
44
52
60
68
76
84
E, MeV


б
e + ¹⁹⁷Au → O + x
Ee = 3 GeV
○ = 50°
● = 90°
Δ = 120°
1/P d²σ/dΩ dE μb/(sr. MeV² c⁻¹)
2
10⁻⁶
8
6
4
2
10⁻⁷
8
6
4
2
10⁻⁸
36
44
52
60
68
76
84
92
100

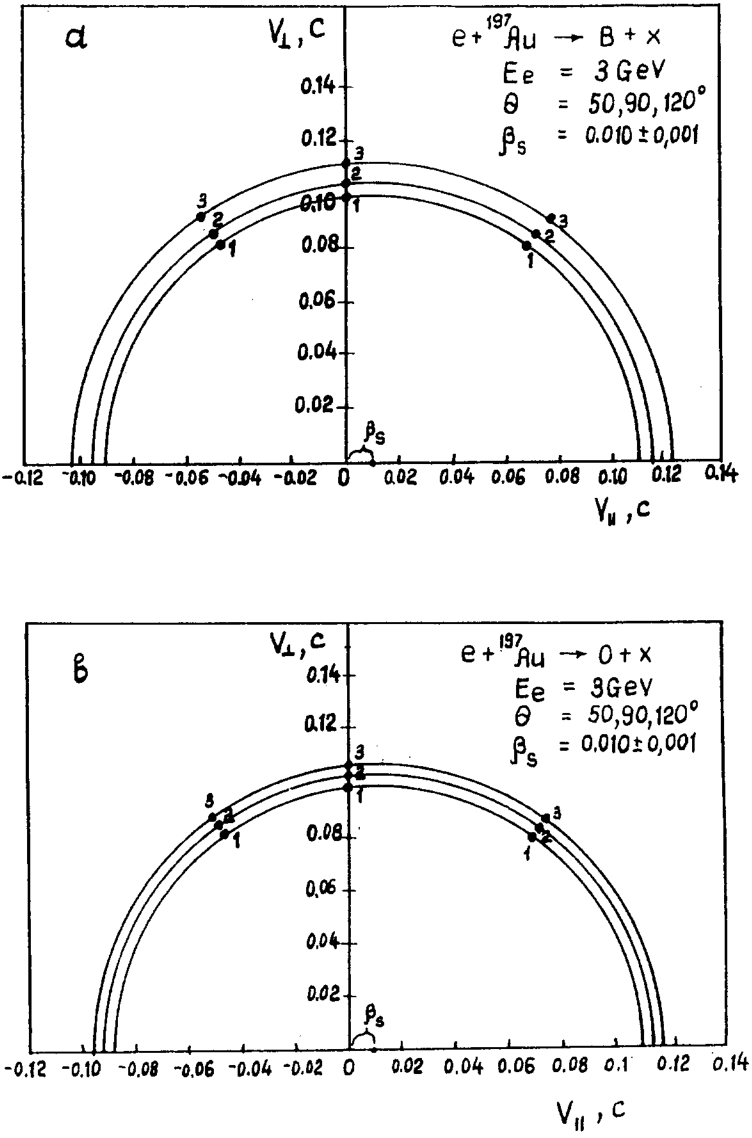

a
V⊥ , c
e + 197Au → B + x
Ee = 3 GeV
θ = 50,90,120°
βs = 0.010 ± 0,001
0.14
0.12
0.10
0.08
0.06
0.04
0.02
1
2
3
βs
-0.12
-0.10
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
V∥ , c
б
V⊥ , c
e + 197Au → O + x
Ee = 3GeV
θ = 50,90,120°
βs = 0.010 ± 0,001
0.14
0.12
0.08
0.06
0.04
0.02
1
2
3
βs
-0.12
-0.10
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
V∥ , c

Fig. 5

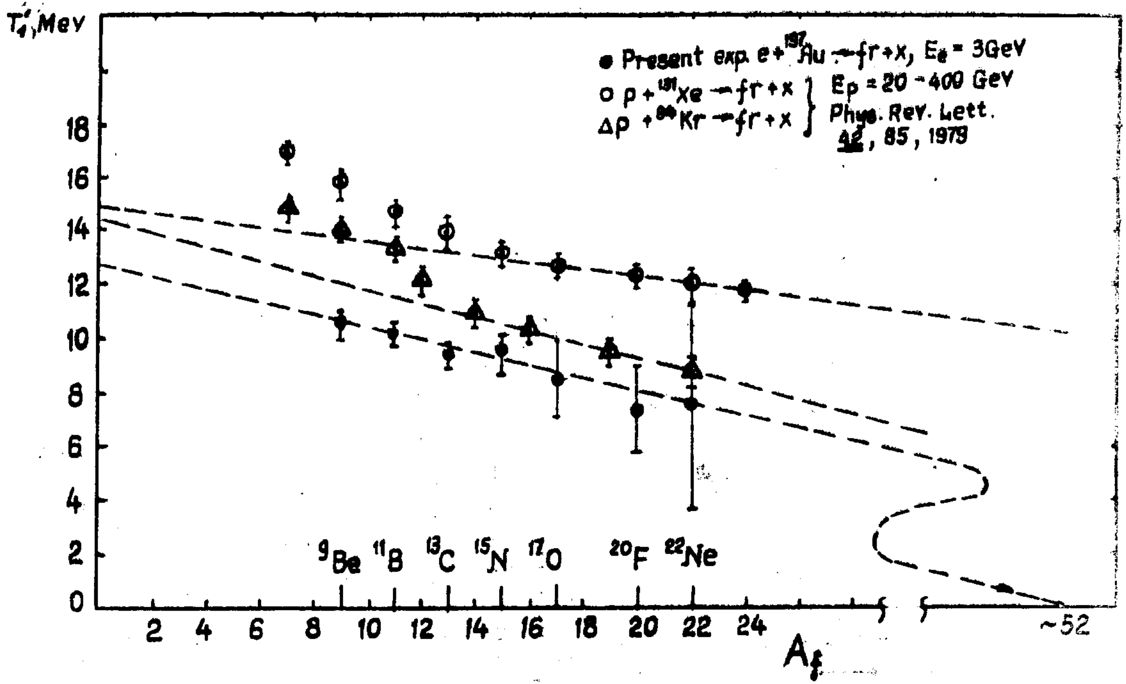

T'_4, Mev
18
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20
22
24
~52
A_f
● Present exp. e+ 197Au → fr+x, Ee = 3GeV
○ p + 131Xe → fr+x
Δp + 84Kr → fr+x
Ep = 20 - 400 GeV
Phys. Rev. Lett. 42, 85, 1979
9Be
11B
13C
15N
17O
20F
22Ne

Fig.6

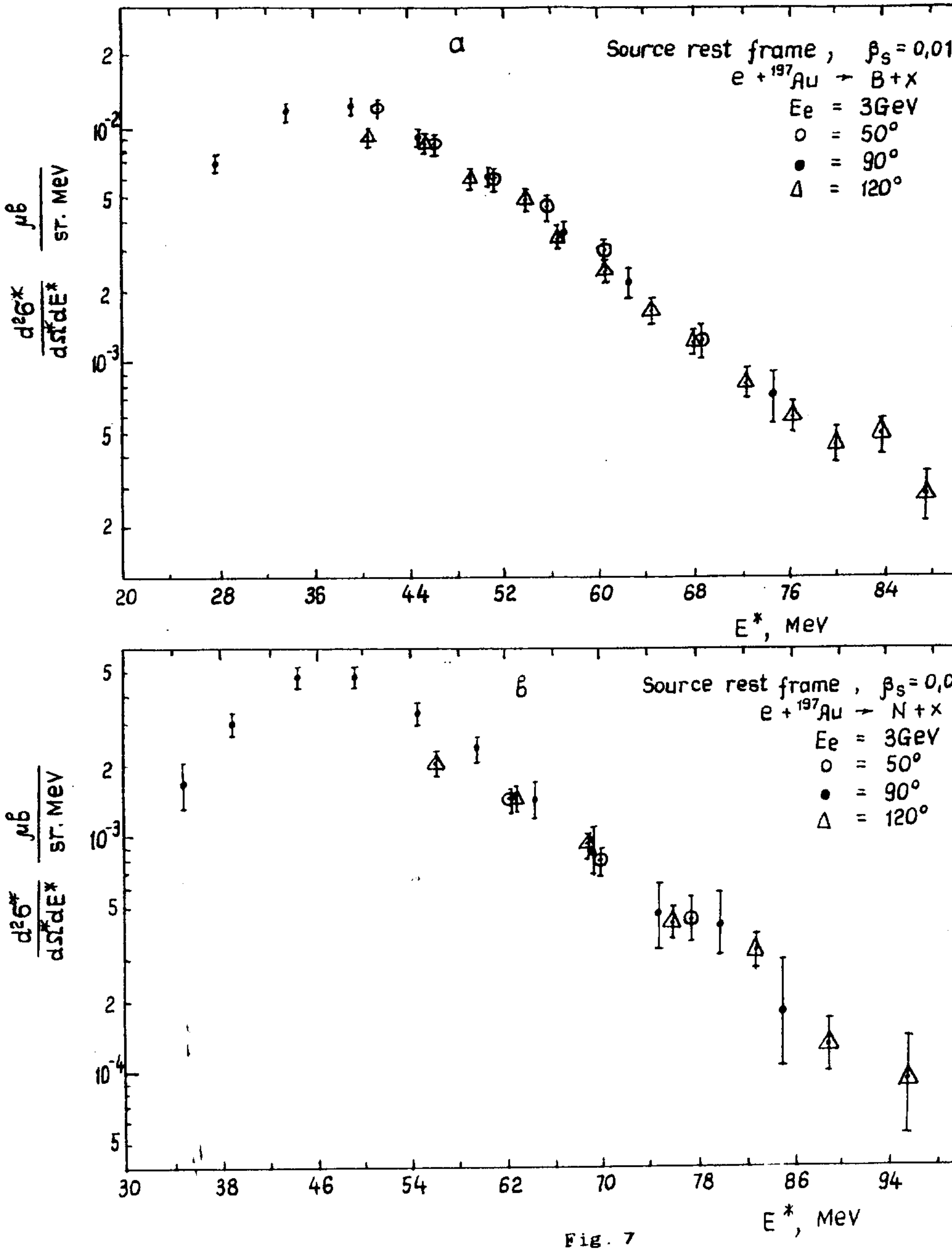

a
Source rest frame , βs = 0,01
e + 197Au → B + X
Ee = 3GeV
o = 50°
• = 90°
Δ = 120°
dσ²* / dΩ*dE* μb / sr. MeV
2
10-2
5
2
10-3
5
2
20
28
36
44
52
60
68
76
84
E*, MeV
б
Source rest frame , βs = 0,0
e + 197Au → N + X
Ee = 3GeV
o = 50°
• = 90°
Δ = 120°
dσ²* / dΩ*dE* μb / sr. MeV
5
2
10-3
5
2
10-4
5
30
38
46
54
62
70
78
86
94
E*, MeV

Fig. 7

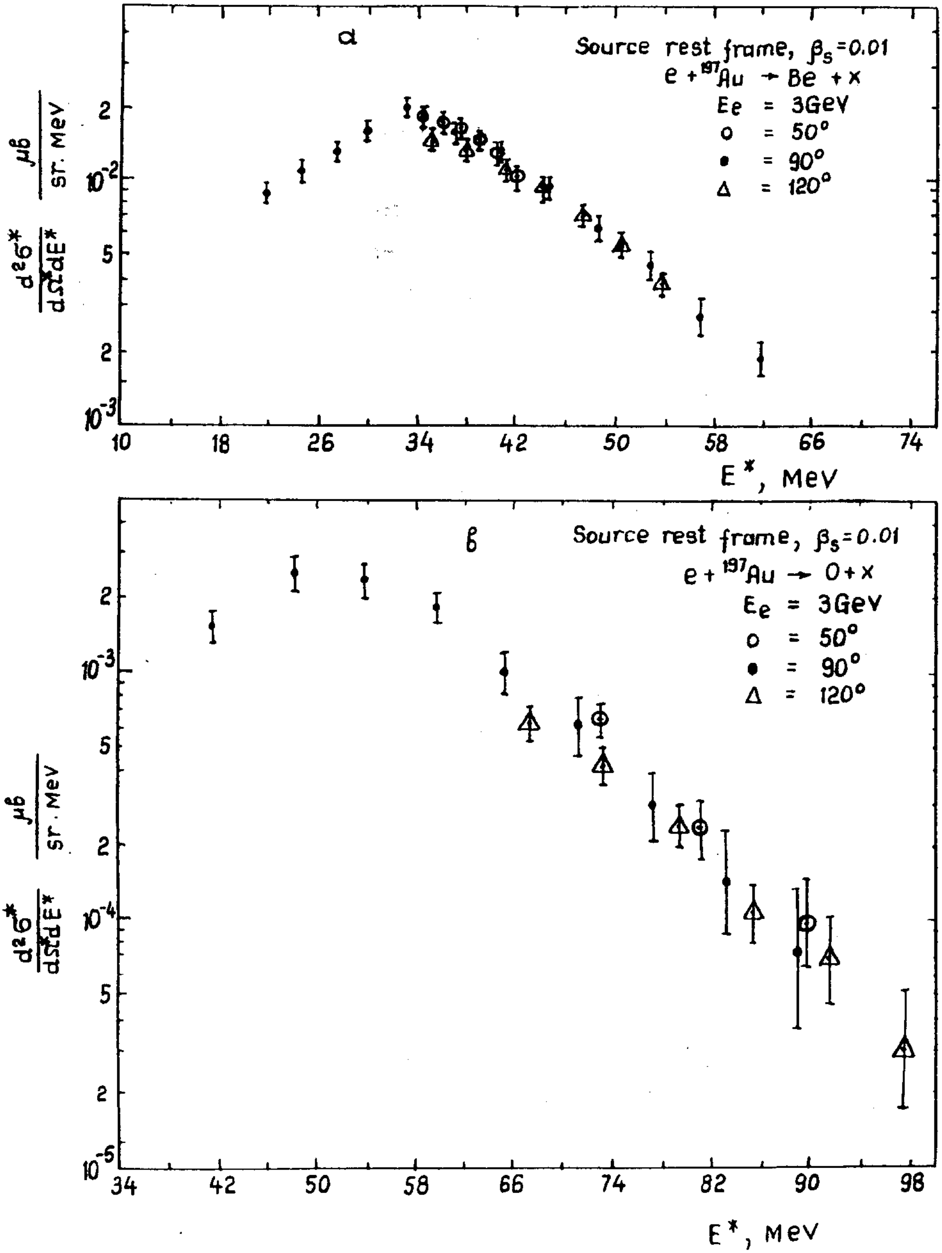

a
Source rest frame, β_s=0.01
e + ^{197}Au → Be + x
E_e = 3GeV
○ = 50°
● = 90°
Δ = 120°
$\frac{d^2\sigma^*}{d\Omega^* dE^*}$ $\frac{\mu b}{sr. MeV}$
2
10^{-2}
5
2
10^{-3}
10
18
26
34
42
50
58
66
74
E*, MeV
б
Source rest frame, β_s=0.01
e + ^{197}Au → O + x
E_e = 3GeV
○ = 50°
● = 90°
Δ = 120°
$\frac{d^2\sigma^*}{d\Omega^* dE^*}$ $\frac{\mu b}{sr. MeV}$
2
10^{-3}
5
2
10^{-4}
5
2
10^{-5}
34
42
50
58
66
74
82
90
98
E*, MeV

Fig 8.

Նախնատիպ ԵրՖԻ- 1431(1)-95

3 ԳէՎ ԷՆԵՐԳԻԱՅԻ ԷԼԵԿՏՐՈՆՆԵՐԻ ^{197}Au ՄԻՋՈՒԿՆԵՐԻ ՀԵՏ ՓՈԽԱԶԴԵՑՈՒԹՅԱՆ ԺԱՄԱՆԱԿ ՄԻՋԱՆԿՅԱԼ ԶԱՆԳՎԱԾԻ՝ $4\le Z_f\le 10$ ՖՐԱԳՄԵՆՏՆԵՐԻ ԱՐՁԱԿՄԱՆ ԱՂԲՅՈՒՐԸ

Գ.Ե.Սարգարյան, Գ.Մ.Այվազյան, Հ.Վ.Բաղալյան,
Զ.Մ.Բեգլարյան, Հ.Գ.Զոհրաբյան

Աշխատանքում ներկայացված և վերլուծված են 3Գէվ էներգիայի էլեկտրոններով հարուցված $e+{}^{197}Au\rightarrow f+x$ ռեակցիայում 50, 90, 120° անկյունների տակ արձակված միջանկյալ զանգվածով $4\le Z_f\le 10$ ֆրագմենտների էներգետիկ սպեկտրները։

Չափումները կատարվել են Երևանյան սինքրոտրոնի ներքին փնջի վրա՝ օգտագործելով կիսահաղորդիչային դետեկտորներից բաղկացած տելեսկոպների մեթոդը։ Ֆրագմենտների չափված կինետիկ էներգիաների տիրույթը կազմում է ~ 2-7Մէվ/նուկլոն։ Էներգետիկ սպեկտրների կինեմատիկական վերլուծությունը, ինչպես նաև այդ սպեկտրների վերլուծությունը Մակսվել-Բոլցմանյան ձևափոխված բաշխումների հիման վրա, որոնք հաշվի են առնում ջերմային և ոչ ջերմային ներդրումները ֆրագմենտների սպեկտրներում, ցուցադրում են ֆրագմենտների իզոտրոպ արձակումը ինչ-որ ընդհանուր, տաք շարժվող աղբյուրից, որը էապես փոքր է, ~50-60 նուկլոնային զանգված, թիրախային միջուկից։ Աղբյուրի արագության և ջերմաստիճանի համար ստացվել են հետևյալ մեծությունները՝ $\beta_c=0.01\pm0.001$, T ~5Մէվ։ Սպեկտրների թեքության պարամետրի ստացված արժեքը, ~ 13Մէվ (թվացող ջերմաստիճան T), համաձայնվում է սպեկտրների առավել էներգետիկ մասում գերակշիռ ոչ ջերմային ներդրման պատկերացման հետ։

Երևանի ֆիզիկայի ինստիտուտ

Preprint YerPhI-1431(1)-95

SOURCE OF INTERMEDIATE-MASS FRAGMENT EMISSION, $4 \le Z_f \le 10$, IN THE INTERACTIONS OF 3GeV ELECTRONS WITH ^{197}Au NUCLEI

G.E. Markaryan, G.M. Aivazyan, H.V. Badalyan,
D.M. Beglaryan, H.G. Zohrabyan

The energy spectra of intermediate - mass fragments, $4 \le Z_f \le 10$, emitted at angles of 50, 90, 120° in the $e + {}^{197}Au \to fr + x$ reaction induced by 3GeV electrons are presented and analyzed. The measurements were carried out on internal beam of Yerevan synchrotron by using semiconductor telescope technique. The range of the measered fragment kinetic energies was within ~ 2--7 MeV/nucleon. The performed kinematical analysis of the fragment energy spectra and their analysis based on modified Maxwell-Boltzmann distributions accounting for thermal and nonthermal contributions to the spectra suggest an isotropic emission of the fragments from a common hot moving source which is essentially less, ~ 50-60 nucleon mass, than the target-nucleus used. The values for the velocity and temperature of the source obtained from the analysis are: $\beta s = 0.01 \pm 0.001$, $T \sim 5$MeV. The obtained value for the fragment spectra slope parameter (apparent temperature) ~ 13MeV is consistent with dominanting nonthermal contribution to the high energy parts of the spectra.

Yerevan Physics Institute

ТЕХНИЧЕСКИЙ РЕДАКТОР А. С. АБРАМЯН

Формат 60x84/16
Офсетная печать Уч. изд. л. 0,5
Тираж 100 экз.
Зак. тип. N 175
Индекс 3649

Отпечатано в Ереванском Физическом Институте
Ереван 36, ул. Братьев Алиханян, 2