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K.V.ALANAKYAN, M.J.AMARYAN, G.A.ASRYAN, R.A.DEMIRCHYAN,
K.Sh.EGIYAN, Zh.L.KOCHAROVA, E.M.MATEVOSYAN, M.S.OHANJANYAN,
M.M.SARGSYAN, Yu.G.SHARABYAN, S.G.STEPANYAN

SPECTRA OF CUMULATIVE PROTONS IN $e+^{12}C \to e'+p+X$ REACTION

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Կ.Վ.ԱԼԱՆԱԿՅԱՆ, Մ.Զ.ՄԱՐՏԱՆ, Գ.Ա.ՄՈՐՏԱՆ, Ռ.Ա.ԴԵՄԻՐՃՅԱՆ,
Կ.Ե.ԵԼԻՑՅԱՆ, Է.Մ.ՄԱԹԵՎՈՍՅԱՆ, Յու.Գ.ՇԱՐԱԲՅԱՆ, Մ.Մ.ՍԱՐԳՍՅԱՆ,
Ս.Գ.ՍՏԵՓԱՆՅԱՆ, Ժ.Լ.ՔՈՉԱՐՈՎ, Մ.Մ.ՀԱՆԶԱՆՅԱՆ

ԿՈՒՄՈՒԼՅԱՏԻՎ ՊՐՈՏՈՆՆԵՐԻ ՍՊԵԿՏՐՆԵՐԸ $e+^{12}C \to e'+p+X$ ՌԵԱԿՑԻԱՅՈՒՄ

Ներկայացված են և հետազոտվում են $^{12}C(e,e'p)$ ռեակցիայում $Q^2=(0.1-0.25)(ԳԷՎ/c)^2$ տիրույթում ստացված կումուլյատիվ պրոտոնների սպեկտրներին վերաբերվող առաջին փորձարարական տվյալները:

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Երևան 1991

Up to now the spectra of cumulative protons (CP) produced in electromagnetic interactions on nuclei have been investigated only in real photon beam, i.e. with four momentum transfer $Q^2=0$ [1,2,3,4,5]. The obtained data together with those on primary hadrons [6,7,8,9,10] show, that CP spectra are asymptotically invariant to the type and energy of primary particles and also to target nuclei and have an exponential form with slope parameter $T_{oc}=50$MeV. This means that cumulative protons are produced in processes at much higher temperatures than in typical nuclear ones, where $T_{onucl}\cong 10$MeV.

Certainly, the invariance of spectra (especially to target nuclei) is an argument in favour of the locality of cumulative particles production, but not an evidence. For example, the calculations show, that two-step processes also provide the exponential form of spectra with close values of slope parameter. Note that CP electroproduction at different four-momentum transfer are classical.

Recently we have started new investigations of CP production in (e,e'p) reaction. The first physical results have been obtained in [11]. It was shown that in energy spectra of electrons scattered in coincidence with protons accepted in the wide range of kinetic energy (80-200)MeV the effects predicted by the spectator model of two-body correlation are observed. However, the cumulative protons spectra are not studied in [11]. Note, that it is very important, because up to now such data at Q^2 are absent, and according to the spectator model the form of these spectra does not depend on Q^2. In this work the first data obtained are presented and CP spectra in (e,e'p) reaction on ^{12}C at $Q^2=(0.1-0.25)GeV^2/c^2$ are analyzed.

2. Experiment

The reaction

$$e + {}^{12}C \rightarrow e' + p + X \qquad (1)$$

has been investigated on the "Deuteron-2" experimental setup under the following kinematical conditions: $E_e=1.94$GeV; $E_{e'}=(0.8-1.94)$GeV; $\theta_{e'}=15\pm2^o$; $T_p=(90\pm7.5;\ 104\pm6.5;\ 123\pm10;$

149±12.5; 181±17.5)MeV, ϑ_{ep}=(66±8^{o}; 90±8^{o}; 120±8^{o}; 140±8^{o}). Electrons were detected by a magnetic spectrometer [12] with a π/e rejection system consisting of a gaseous threshold Cerenkov counter [13] and a lead-scintillator "sandwich" shower counter [14]. Protons were detected by the range telescope (RT) [15] measuring dE/dx at a fixed range or fixed energy loss. Primary electron beam characteristics are described in [16]. So far as the main goal of this work is the investigation of the proton spectra in the reaction (1), it is important to be sure that these spectra are measured without distortion. With this aim two spectra from Ref.[17] are presented in Fig.1: the one obtained with the present RT (points) and that obtained on another experimental setup as a result of irradiation of the target by bremsstrahlung γ-quanta (solid line). Fig.2 shows the typical energy distribution of protons at fixed ν=E_e-$E_{e'}$=(160±20)MeV. The solid line is a calculation by CELEG [18].

3. Experimental results

The energy spectra (invariant cross section f=(1/p)d$^2\sigma$/dΩ_pdE_p) of protons from (1) integrated over ν=(0-0.6)GeV are presented in Fig.3. The spectra for the wide angular range of (112$^{o}\leq\vartheta_{ep}\leq$148^{o}) ( ) as well as for different angles ϑ_{ep}=120^{o} ( ) and ϑ_{ep} =140^{o} ( ) are shown accordingly. The spectra are well described by exponential parameterization

$$f_p(T_p,\vartheta_{ep}) = C(\vartheta_{ep})\ \exp(-T_p/\ T_o(\vartheta_{ep})) \qquad (2)$$

with slope parameters $T_{op}\cong$42MeV at ϑ_{ep}=120^{o} and $T_{op}\cong$33MeV at ϑ_{ep}=140^{o}, i.e. the spectra fall faster with increasing registration angles, as it was found in primary real photon [19] and hadron [20] beams. However, the absolute values of T_o in case of the reaction (1) are slightly different than in photo- and hadroproduction. This is apparently due to the integration in a wide range of ν. To check this, the ν dependence of T_o is presented in Fig.4. As can be seen, the parameter T_o grows with increasing ν and at ϑ_{ep}=140^{o} (see

Fig.4a), beginning with $\nu \cong 350$ 400MeV, it lies on the plateau with $T_o \cong 40$MeV. In [21] it has been noted, that spectra of cumulative protons at a fixed angle of registration become invariant (the T_o is independent of energy of γ-quanta) starting from $E_\gamma = 0.4-0.5$GeV (see Fig.5 of Ref.[22], where instead of T_o the energy dependence of the parameter $B=2M_p/T_o$ is shown). The results presented in Fig.4 at $\vartheta_{ep}=140^o$ confirm this conclusion for virtual γ-quanta. However, in this case one should be careful, because the Q^2 are changed with increasing ν at a fixed electron scattering angle, whereas in case of primary real photons the four-momentum transfer $Q^2=0$ is a constant. Fig.5 illustrates how strong is Q^2 dependence of T_o. As can be seen, a slow Q^2 dependence of T_o is observed, and in the investigated region of ν the contribution of this effect can be less than $\cong 5\%$. Therefore, making conclusions seems to be correct. Note that, generally, the ν dependence of T_o should be studied at constant Q^2.

Although the uncertainties of T_o at $\vartheta_{ep}=120^o$ are large, nevertheless one can conclude that in this case the increase of T_o could be connected with the effect observed in [11], where it is seen that at $\vartheta_{ep}=120^o$ there are two peaks in the spectra of electrons scattered within $\nu=(0-0.3)$GeV and $\nu=(0.3-0.6)$GeV, which, apparently, is to be interpreted as an influence of two different processes. As in the case of $\vartheta_{ep}=140^o$ there is only one peak for $\nu=(0.3-0.6)$GeV, which means a contribution of only one mechanism, and therefore ν dependence of T_o has a "normal" character.

As is predicted by the two-body correlation spectator model, a shift of electron spectra towards low energies should be observed. The calculations show that the quasielastic peak, after scattering on nucleons with momentum within $P_p=(0.4-0.6)$GeV/c will be just in the region of $\nu=(0-0.3)$GeV at $\vartheta_{ep}=120^o$ and $\nu=(0.3-0.6)$GeV at $\vartheta_{ep}=140^o$. Therefore, the spectra of protons from these regions of ν have to be similar. Fig.6 presents both of them and, as is seen, the slope parameters are the same. Indeed, the observed similarity of spectra is a serious argument in favour of the two-body correlation mechanism of CP production. However, for more evidences it is

necessary to investigate these spectra after choosing the (e',p) events according to the kinematics of electrons scattering on two-body correlation at rest. The same spectra shown in Fig.6 after such a choice of the events are presented in Fig.7. As is seen, the spectra also are similar and besides, the slope is slightly less.

It is interesting to investigate the spectra of protons at $\vartheta_{ep}=120^{o}$, but in the range of ν=(0.3-0.6)GeV, where a second peak in the electron spectra was observed [11]. In Fig.8 two spectra of protons are presented: before and after the above-mentioned choosing of events. As one can see, in this case the spectra of protons are strongly distorted, i.e. the events with low energies of protons are cut off. Note, that the data presented are preliminary and we plan to repeat this experiment with an essentially higher statistics. The comparison of experimental data with theoretical predictions will be done in our forthcoming works.

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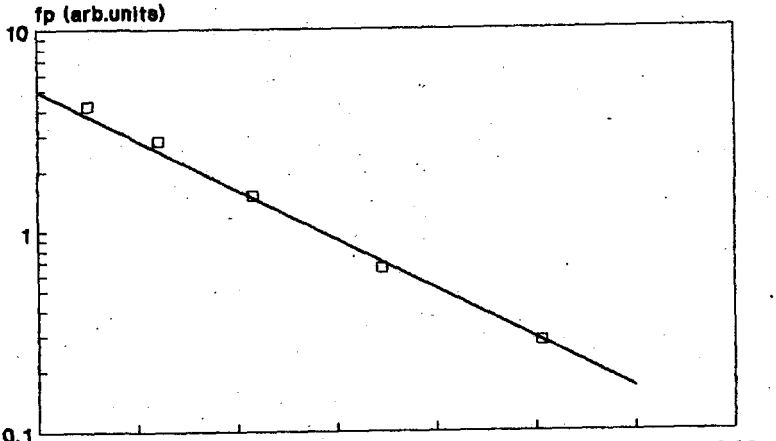
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0.1
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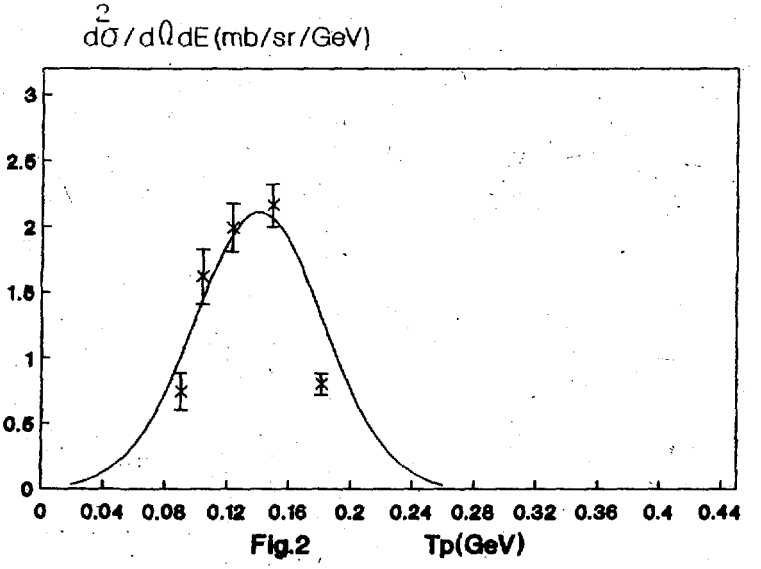
0.14
0.16
0.18
0.2
0.22
Tp (GeV)

Fig.1


d²σ/dΩdE (mb/sr/GeV)
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2
1.5
1
0.5
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.4
0.44
Tp(GeV)

Fig.2

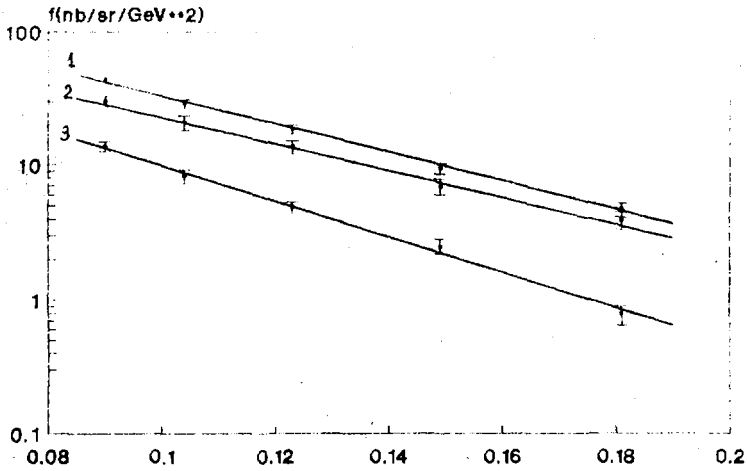
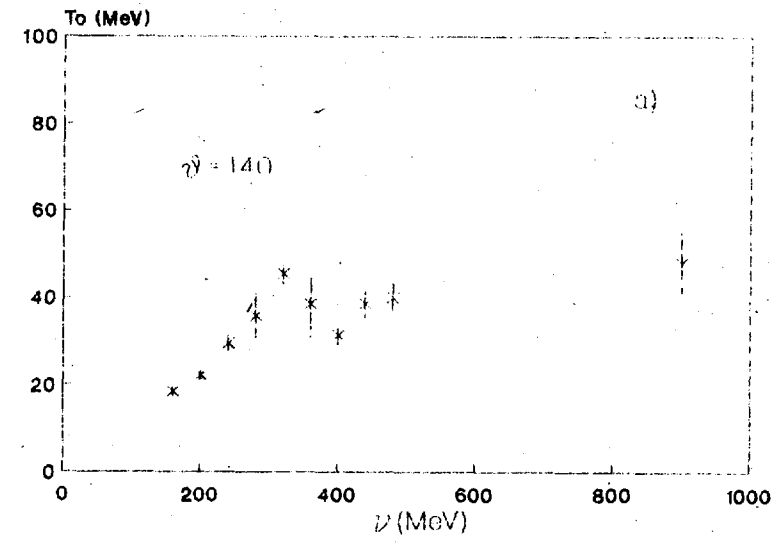


Fig.3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60
40
20
0
a)
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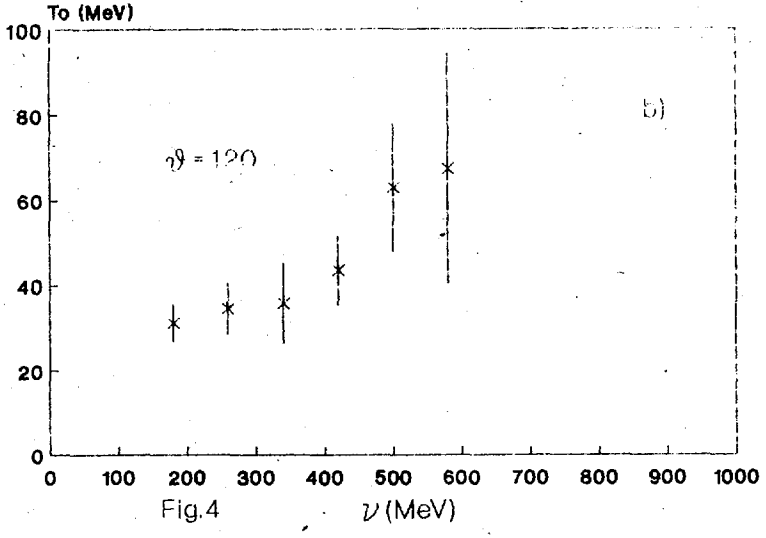
0
200
400
600
800
1000
ν (MeV)


To (MeV)
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60
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20
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b)
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100
200
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500
600
700
800
900
1000
ν (MeV)

Fig.4

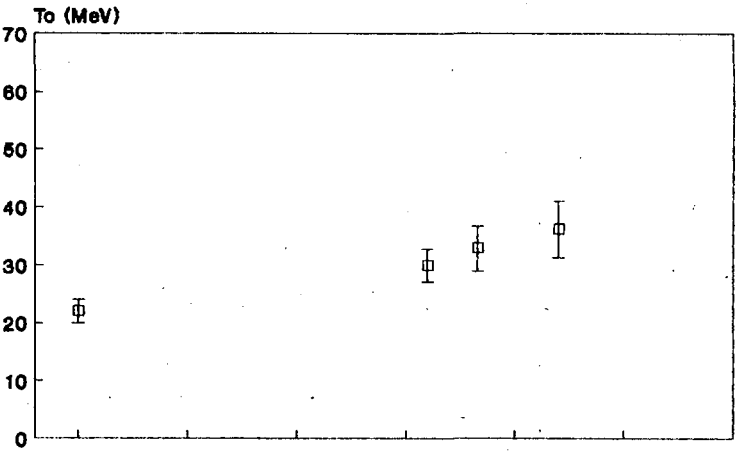


Fig.5 Q**2 (GeV/c)**2

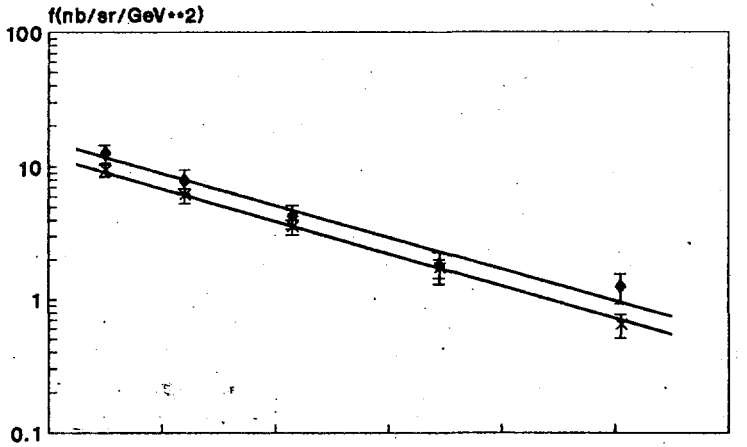
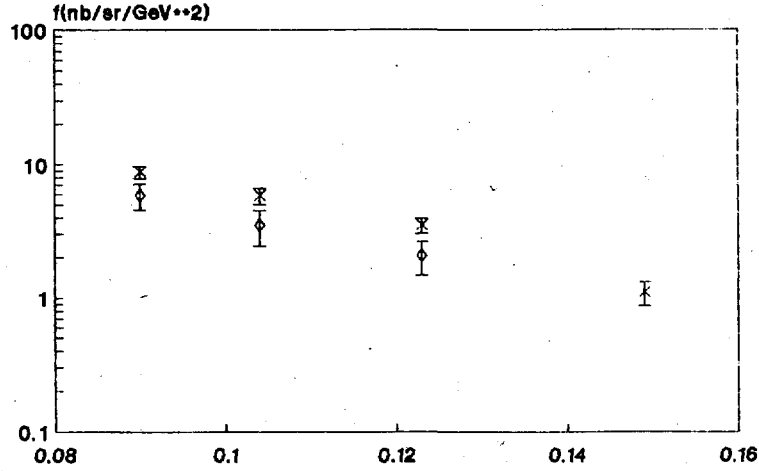


Fig.6 Tp(GeV)


f(nb/sr/GeV**2)
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10
1
0.1
0.08
0.1
0.12
0.14
0.16
Tp(GeV)

Fig.7

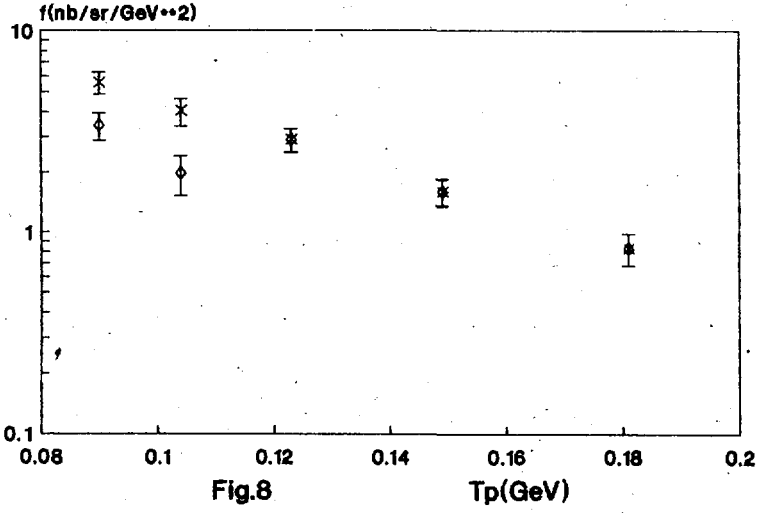
f(nb/sr/GeV**2)
10
1
0.1
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Tp(GeV)

Fig.8

Figure captions

Fig.1 Energy spectra of protons produced on ^{12}C at $\vartheta_{ep}=140^{o}$ (□) – this experiment, solid line – photoproduction at $E_{\gamma}^{max}=4.5$ GeV [17].

Fig.2 Energy distribution of protons in quasielastic region at fix $\nu=(160\pm20)$MeV. The solid line is calculation by CELEG [18] using standart Fermi distribution.

Fig.3 Invariant cross section dependence of protons from reaction (1) integrated over the $\nu=(0-0.6)$GeV at $112^{o}\leq\vartheta_{ep}\leq148^{o}$(1), $\vartheta_{ep}=120\pm8^{o}$, $\vartheta_{ep}=140\pm8^{o}$.

Fig.4 The slope parameter T_o as a function of ν at $\vartheta_{ep}=140^{o}$ (a) and $\vartheta_{ep}=120^{o}$ (b).

Fig.5 Q^2 of T_o for $\nu=(0.3-0.6)$GeV range at $\vartheta_{ep}=140^{o}$.

Fig.6 Energy spectra of protons for $\nu=(0-0.3)$GeV range at $\vartheta_{ep}=120^{o}$(■) and $\nu=(0.3-0.6)$GeV range at $\vartheta_{ep}=140^{o}$(X).

Fig.7 The same as in fig.6 after choosing the data by pair kinematics. (x) – $\vartheta_{ep}=140^{\circ}$, (◊) – $\vartheta_{ep}=120^{\circ}$

Fig.8 Spectra of protons from reaction (1) in the $\nu=(0.3-0.6)$GeV range at $\vartheta_{ep}=120^{o}$ before (X) and after choosing the data by pair kinematics.

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К.В.АЛАНАКЯН, М.Дж.АМАРЯН, Г.А.АСРЯН, Р.А.ДЕМИРЧЯН,
К.Ш.ЕГИЯН, Ж.Л.КОЧАРОВА, Э.М.МАТЕВОСЯН, М.С.ОГАНДЖАНЯН,
М.М.САРГСЯН, С.Г.СТЕПАНЯН, Ю.Г.ШАРАБЯН
СПЕКТРЫ КУМУЛЯТИВНЫХ ПРОТОНОВ В РЕАКЦИИ $e+{}^{12}C \to e'+p+X$
(на английском языке, перевод авторов)
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The address for requests:
Information Department
Yerevan Physics Institute
Alikhanian Brothers 2,
Yrevan, 375036
Armenia, USSR

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