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A. TITLE: Study of Short-Range Properties of Nuclear Matter in Electron-Nucleus and Photon-Nucleus Interactions With Backward Particle Production Using the CLAS Detector

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C. THIS PROPOSAL IS BASED ON A PREVIOUSLY SUBMITTED LETTER OF INTENT

/X/ YES
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IF YES, TITLE OF PREVIOUSLY SUBMITTED LETTER OF INTENT

Study of Short-range Correlations in Light Nuclei in Processes of Electron scattering in coincidence With Backward Nucleons and Δ-isobars

D. ATTACH A SEPARATE PAGE LISTING ALL COLLABORATION MEMBERS AND THEIR INSTITUTIONS

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Study of Short-Range Properties of Nuclear Matter in Electron-Nucleus and Photon-Nucleus Interactions With Backward Particle Production Using the CLAS Detector

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Summary

We propose to study few-nucleon short-range correlations in nuclei using eA and γA scattering.We intend to use the signature of fast backward nucleon and Δ-isobar production to suppress the more common processes of scattering on bound nucleons with low momenta. The proposed studies includes correlations between fast backward baryons and the quasi-elastic scattering peak position, reactions with backward nucleons detected in coincidence with the scattered electrons and recoil nucleons near the quasielastic peak, and three-nucleon correlations with production of two backward nucleons. We also propose to investigate the quark-gluon structure of short-range correlations by measuring backward Δ- isobar electroproduction on light nuclei. The proposed research work using CLAS at high Q^2 will be more effective than that carried out in Yerevan at low Q^2. In addition it will add to the knowledge gained throuth analogous hadronic scattering experiments, as well as exciting electro- and photo-production experiments, all of which indicate the importance of few-nucleon correlations in nuclei.

1. Introduction

One of the most important problems of modern high energy nuclear physics is the investigation of nuclear matter properties at short ranges, where the quark-parton degrees of freedom are expected to be evident. The use of high-energy leptons, in particular high-energy electrons, is well suited for such a studies since it is then possible to resolve short range distance effects (at high momentum transfer), without creating essential distortions of the object under study i. e. nuclear matter through strong interactions.

In the investigation of the short-range behavior of nuclear matter, the study of intranuclear few-nucleon short-range correlations (SRC) [1] is of special importance since the presence of high momenta in a nucleus, i.e. the high momentum component of nuclear wave functions is due to such correlations [2]. Since the high momentum component of nuclear wave functions is small (i. e. the probability of SRC is small), it is convenient to choose kinematics, where the contributions of more common processes associated with uncorrelated nucleons (nucleons in nuclei with low momenta) will be small. The study of SRC in backward (cumulative) particle production is one such possibility. Indeed, analysis of backward (cumulative) hadron production in reactions like $\gamma(\pi,p) + A \to h + X$ [3,4,5] indicate the presence of significant short-range two (three) nucleon correlations of ground-state wave functions of nuclei (see [1,2] and references for review). However, it is not possible to use these data to analyze the structure of short-range correlations, and, in particular, to search for non-nucleon degrees of freedom in the correlations. For example non-nucleon degrees of freedom, like 6q - configurations, Δ- isobars, etc., are likely to be enhanced in the correlations.

The main purposes of the proposed experiments is the study of the short-range properties (short-range correlations) of nuclei in electron-nucleus scattering, when at least one secondary particle is detected at a backward angle. Such experiments in the $Q^2 < 1(\mathrm{GeV/c})^2$ range have been started in Yerevan. However, to reliably resolve short-range correlations, high values of Q^2 (> 1 $(\mathrm{GeV/c})^2$) are necessary.

2. The Processes to be Investigated

Reactions:

- A(e,e'p)X	- p-backward
- A(e,e'p,N)X	- p-backward, N-forward or N-backward, p-backward
- A(e,e'p_1,$\Delta(N^*)$)X	- p_1 -backward, resonance-forward
- A(e,e'p_1,p_2,p_3)X	- all "backward - forward" combinations
- A(e,e'π)X	- π-backward
- A(e,e'Δ)X	- Δ-backward
- A(e,e'Δ,p)X	- Δ-backward, p-forward
- A(γ,p)X	- p-backward
- A(γ,p_1,p_2)	- p_1-backward, p_2-forward
- A(γ,p,π)	- p-backward, π-forward
- A(γ,d)	- d-backward

Nuclei:

D, He, C, Al, Cu, Pb

Kinematical Regions:

- Primary (electron or photon) energy
  - from 1 to 4 GeV.
- Transverse:
  - energy - from 0 to 3.5 GeV
  - Q^2 - from 0 to 4.0 (GeV/c).

- Momenta of secondary hadrons:

protons	- from 400 to 1500	MeV/c
pions	- from 100 to 1200	MeV/c
deuterons	- from 500 to 2000	MeV/c
neutrons	- from 400 to 1000	MeV/c

- Polar angles of secondary hadrons:

  - from 20 to 135 degr.

Polarization:

- beam and target - unpolarized.

3. Physical Motivations

The investigations of the processes mentioned above (see section 2) are part of a large experimental program, the complete development of which will require additional work. At present, the theoretical calculations have not been done for all proposed processes. For cases, when such calculations are not yet reliable, only physical motivations will be considered. These calculations, should however be completed before the beginning of the proposed experiments. For instance, the calculations on (e , e' Δ_{backw}) reactions have recently been begun [6] (for deuteron yet) and soon it will be possible to obtain detailed information and reasonable predictions for this proposed reaction.

For some reactions there are reasonable theoretical developments (such as for (e , e' N_{backw}),(e , e' N_{backw},N_{forw}) processes) [2] which allows one to make useful predictions.

3.1 Electroproduction of Fast Backward (FB) Protons

$$e + A = e' + p_{backw} + X \qquad (1)$$

By "backword" one means that $\theta_{pq} \geq 90°$, while "fast"- means that the nucleon has a momentum of $p_{FB} >> p_f$(were p_f is a Fermi momenta in nuclei), or roughly $p_{FB} > 0.4$ GeV/c. Such definitions restrict one to a region where short-range correlations are thought to be dominant in the ground-state nuclear wave functions. In such reactions one studies how a residual nucleus decays after instantaneous removal of one nucleon. This information is complementary to the measurements of the spectral function in the conventional reaction $e + A \rightarrow e' +$ leading forward nucleon $+ X$.

The cross section of the reaction (1) is formally expressed via the so-called decay function $D(\mathbf{p}_i, E_i, \mathbf{p})$ - a product of the probability to find a nucleon in the nucleus with given momentum $\mathbf{p}_i$ (on which electron scattering takes place) and to have a residual system (A-1) with excitation energy E_i (this probability is proportional to the spectral function $S(\mathbf{p}_i, E)$), times the probability that the system (A-1) contains a nucleon with momentum $\mathbf{p}$, which is detected in the final state (in the spectator model).

According to the few-nucleon short range correlation model both nucleons belong to one and the same correlation and momenta $\mathbf{p}_i$ and $\mathbf{p}$ are correlated (for two-nucleon correlation $\mathbf{p}_i = - \mathbf{p}$).

At present, the decay function $D(\mathbf{p}_i, E_i, \mathbf{p})$ is determined only for pair correlations.It is obvious that in this case (neglecting motion of a pair as a whole) [2]

$$D(\mathbf{p}_i, E_i, \mathbf{p}) = S(\mathbf{p}_i, E)\delta(\mathbf{p}_i + \mathbf{p}) \qquad (2)$$

and is valid at $p_i \simeq p < 0.8$ GeV/c.

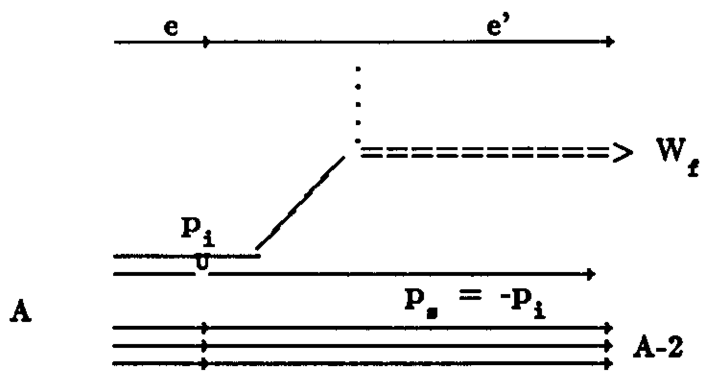

Diagram 1

The kinematics of the Spectator Model (SM) for pair correlation are as follows:

$$W^2 = (\nu - T_s + M_N)^2 - (q - p_s)^2 \qquad (3)$$

were T_s ($= E_i$) and p_s ($= p$) are the kinetic energy and momentum of the spectator nucleon respectively (see Diagram 1), $\nu = E_e - E'_e$, $q = p_e - p_{e'}$. Choosing W, one can study any region of excitation (in the quasielastic region $W = M_N$, in the Δ- resonance region $W_\Delta = M$, etc).

The cross section of reaction (1) using the SM and impulse approximation (IA) has the form

$$d^4\sigma/d\Omega_e dE_e d\Omega_s dE_s = E_s p_s \sigma_{eN} D(p_i, T_s, p_s) \qquad (4)$$

where σ_{eN} is the cross section for scattering of electrons on nucleons with momentum p_i,in correlated pair.

According to the relation (4) two different types of information can be obtain by studying reaction (1) : first, the characteristics of strongly bound nucleon in correlations can be determined by studying σ_{eN} at a given value of $D(p_i, T_s, p_i)$ and secondly the characteristics of correlations can be determined by studying of $D(p_i, T_s, p_s)$ at given value of σ_{eN}.

Experiments of the first type for uncorrelated (low momentum) nucleons in nuclei were carried out at NIKHEF [7]. Results show that the influence of the usual off-shell effects on a nucleon is small, while the influence of the remaining nuclear medium amounts to 10-15 %. In backward proton production with $p_s > 0.4$ GeV/c the binding energy of nucleons in pairs is high enough (>100 MeV) such that off-shell effects can be large. To verify of these effects one can measure the dependence of the ratio $R = d^4\sigma(E_{e1})/d^4\sigma(E_{e2})$ [7] (at the same values of q,ν,p_s,T_s)on the kinematic variables of the backward nucleon. In this ratio the uncertainties of the decay function $D(p_i,T_s,p_s)$ and the SRC nucleon formfactor are divided out. In Fig. 1,2 the such dependences are shown. The calculations were made according to models [2,8,9], which account for off-shell effects in different ways. As can be seen, a significant influence of off-shell effects at large momenta and angles of backward nucleons is expected. Moreover the predictions of various models are significantly different.

Additional very interesting information can be obtained by measuring R at two values of Q^2 and the same values of E_e,p_s,T_s. It is possible to find the kinematic conditions such that the ratio R is sensitive to the form-factor effects of short-range correlated nucleons, and not to the uncertainties connected with off-shell effects and $D(p_i,T_s,p_s)$. Note, that in [7] such kinematics were achieved by restricting the momenta of the internuclear nucleon to less than 0.1- 0.15 GeV/c, where results of all IA models coincide within 1%. In Fig.3 the results of R calculations with two models [8,9] at $Q^2 = 0.7$, $Q^2 = 1.0$ $(GeV/c)^2$ as a function of p_s are shown. The off-shell uncertainties for these models differ less than 3%. This allows one to observe the formfactor effects connected with the slowing of the SRC nucleon (the nucleon slowing was taken into account by $r \simeq r_o + \lambda p_i^2$ relations where λ was obtained by assuming of average nucleon slowing in nuclei ≃3% [10]). Thus, the experimental investigations of R, allow one to define the real σ_{eN}.

The knowledge of σ_{eN} makes it possible to get very important information about the $D(p_i,T_s,p_s)$ function, i. e. about both the wave functions and probability of SRC. In the nonrelativistic Impulse Approximation for the Spectator Model:

$$D(p_i,T_s,p_s) = a_2(A)\frac{n_{pair}(p_i)}{(M_{pair} - E_s)/M_{pair}}\delta(E)\delta^3(p) \qquad (5)$$

where, $a_2(A)$ is a SRC pair probability in nuclei and $n_{pair}(p_i)$is a momentum distribution of SRC nucleons. Note, that in (5) pair motion as a whole is neglected (see below).

In Fig.4 and 5 the spectra of scattered electrons in reaction (1) at various angles and momenta of backward protons are shown. For these calculations the de Forest off-shell approximation for σ_{eN} [8] and deuteron wave functions with a Paris Potential in n_{pair} were used. It can be seen,for chosen kinematical conditions there are significant shifts which depend on the angles and momentum of backward protons. Moreover, with increasing proton momentum the cross section in the quasielastic region strongly decreases. Note, that in preliminary experimental results from Yerevan on FB proton electroproduction, shifts in E' dependences of the cross section at small Q^2 were observed. In Fig.6 and 7 these dependences for pair correlation kinematics and at two values of angle (120° and 140°) are shown.

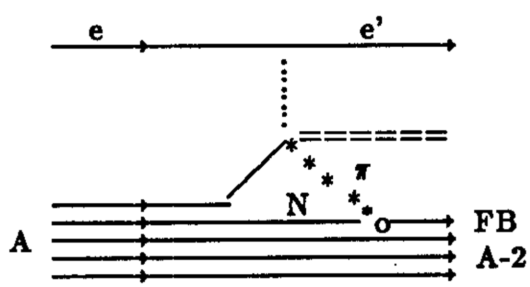

Diagram 2a

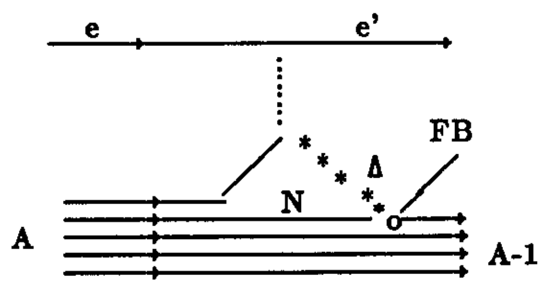

Diagram 2b

It is clear that, the experimental signature discussed above can be significantly masked by final state interactions. Indeed, the FB proton can be produced in two-step processes shown in Diagrams 2a and 2b. To suppress the contributions of these processes both measurments at high value of Q^2 and with light nuclei are needed. For example,the process represented in Diagram. 2b can produce FB nucleons at $\theta = 180^\circ$ with momenta $p = 0.4$, 0.3, 0.2 GeV/c at $Q^2 = 0.$, 0.5 and $1(\mathrm{GeV/c})^2$, respectively. Studies with heavier nuclei will also allow one to better understand the processes shown in Diagram.2, especially those in Diagram.2b, the detailed analysis of which is planned for the above mentioned Yerevan experiment.

3.2 Coincident Electroproduction of Fast Backward and Forward Nucleons

$$e + A \to e' + N_{backw} + N_{forw} + X \qquad (6)$$

In contrast to the measuremeant (1) just discussed, averaging is not performed over the momentum p_i and the excitation energy E_i. The process (6) essentially complements the measurements of the reaction (e,e'2N) with two forward nucleons in the quasideuteron kinematics. Note, that these reactions may be used for direct identification of the processes of quasielastic scattering on one nucleon in two-body short-range correlations. Measurment of the various combinations of nucleons $((p_{backw},p_{forw}),(n_{backw},p_{forw})$, etc) allows one to study contributions of pp, pn, nn pairs and investigate the isotopic dependences of backward nucleon production. The possibility of studying the intranuclear motion of pairs is another feature of these reactions. Theoretical investigations [11] predict very interesting corrections to pair wave functions due to pair center of mass motion:

$$S_{pair}(k,\epsilon) = n_{pair}(k) \frac{\exp(-\beta((\sqrt{\epsilon}-\sqrt{\epsilon^*})/\sqrt{\epsilon})^2)}{\epsilon^*} C \qquad (7)$$

where ϵ is a kinetic energy of pair, $\epsilon^* = k^2/ 2M$, n_{pair} is the square of SRC wave functions, without center of mass motion, and β is a free parameter. The coefficient C is obtained from the normalization:

$$\int S_{pair}(k,\epsilon)d\epsilon = n_{pair}(k) \qquad (8)$$

The experimental study of relation (7) may be performed by detecting secondary nucleons in reactions (6) with different relative momenta, which provide different values of SRC center mass momenta.

3.3 Search for Three-Nucleon Correlations in Electroproduction of Two Fast Backward or Two Fast Backward and One Forward Nucleons

For such correlations we consider the nuclear wave functions where the fast nucleon momentum is balanced by two nucleons (Fig.8). The existence of such correlations is indicated, in particular, by the regularities of the (e,e') cross section at $x > 2$ and $Q^2 \geq 1$ (GeV/c) observed in SLAC experiments (see ref.[12]). In the search for these correlations one must study the relations

$$e + A \rightarrow e' + N_{backw} + N_{backw} + X \qquad (9)$$

$$e + A \rightarrow e' + N_{backw} + N_{backw} + N_{forw} \qquad (10)$$

Using light nuclei, with $Q^2 \geq 1$ $(GeV/c)^2$ and $\nu > 0.5$ GeV the energy transferred to the struck nucleon is high enough to destroy the correlation, hence the final state interaction between the struck nucleon and other ones of the correlation is weak.

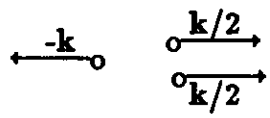

Fig. 8

Experience in the analysis of similar reactions with hadron projectiles h + A --> p + p + X [13] indicates , that for $A \leq 6$, two-step processes constitute a small correction. As a result, it will be possible to study the shift of the position of the quasielastic peak, as a function of such a correlation, which provides information about the momentum of the balancing nucleon in the region of momenta larger than in the case of (1). By measuring forward protons and neutrons, one will be able to determine the relative importance of the ppp and ppn correlations.

The study of the production of two FB nucleons with similar momenta, $p_1 \simeq p_2$ over a wide range of nuclei, is of interest. Using the analysis widely used for similar hadronic reactions (see, e.g., ref.[13], it will be possible to investigate the difference between the space-time picture for $(\gamma^* A)$ and (hA) inelastic interactions.

3.4 Search for Non-Nucleon Baryonic Components of Nuclear Wave Functions in Electroproduction of Fast Backward Δ- Isobars

Backward Δ- isobar production in reactions such as

$$e + A \rightarrow e' + \Delta^{++}_{backw} + X \qquad (11)$$

$$e + A \rightarrow e' + \Delta^{o}_{backw} + X \qquad (12)$$

$$e + A \rightarrow e' + \Delta_{backw} + p_{forw} + X \qquad (13)$$

may provide an important key to the presence of multiquark configurations and Δ- isobar admixtures in nuclei. Indeed, the specific properties of 6q, 9q ...admixtures widely discussed in literature, are the significant overlap with ΔN, ΔΔ configurations.

Consequently, one may expect copious production of Δ's and N^* in the decay of these configurations after absorption of γ^*. It is natural to search for Δ's from the decays in the backward direction, since in this case the Δ-production does not contribute to the γ^*N scattering. In addition, one can choose kinematics, where no fast backward pions can be produced in the scattering from a quasifree nucleon (e.g., for $Q^2 = 1(Gev/c)^2$, $x = 0.5$, $p_{max} = 0.1 Gev/c$ for $\theta = 180°$), leading to suppression of two-step processes like that shown in Diagram 3. Production of backward Δ-isobars is also expected within the meson-field-theory models of nuclei, where Δ's are present in the nuclear wave function on the level of a few per cent.

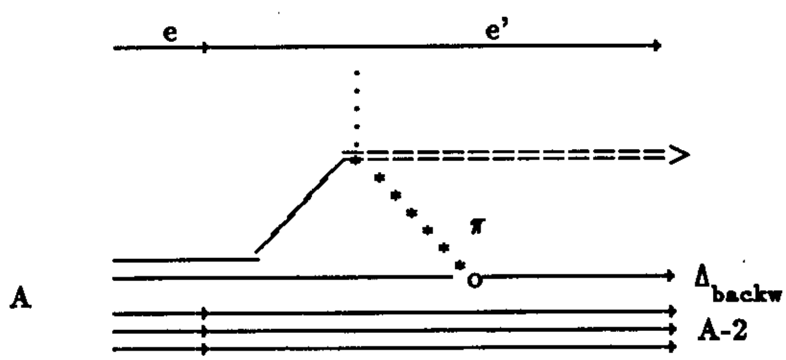

Diagram 3

The momentum distribution of Δ-isobars will be broader then that of nucleons, because the energy denominator for the NN --> NΔ, ΔΔ transitions over a wide momentum range is mainly determined by the Δ-N mass difference and not by the kinetic energies of Δ and N (see, e.g., Ref [1]). The experimental situation with backward Δ-isobar production is somewhat controversial. In the ν + Ne --> μ^{+} + Δ^{++} experiment [14] no signals associated with Δ's were detected,while in the experiment p + Ne --> Δ + X at 300 GeV/c signals were claimed [15]. The reactions (11,12) can be qualitatively studied using CLAS. One must choose the lightest nuclei as targets to suppress rescattering effects and vary kinematics in a wide range of Q^2 and X to study the role of two-step processes. In such a reconnaissance experiment we will be able to obtain significant limits on the backward Δ-isobar production and hopefully be able to detect a signal from non-nucleon baryonic degrees of freedom in nuclei.

4. Inclusive Photoproduction of FB Protons

$$\gamma + A \to p_{backw} + X \qquad (14)$$

where γ is both real and virtual photons. For real photons these processes were investigated in detail at Yerevan [3,16]. The main conclusions which can be drawn are:

i) spectra of FB photoprotons have a universal character(independent of target-nucleus and primary energy, for $E_\gamma \geq 0.5$ GeV). The universality of these spectra on nuclei supports the contention that the interaction of γ-quanta in nuclear matter has a local character. This conclusion was also made earlier in the analyses of hadron data[4,17].

ii) in the range of E_γ = 2. - 4.5 GeV the cross section of FB ($p_{FB} \geq$ 0.5 GeV/c) protons does not decrease with increasing energy. This behaviour is the same for all nuclei from ^{12}C to ^{208}Pb. The idential behaviour of cross sections, independent of target nuclei suggest the following: first, the interaction is local, and secondly, final state interaction does not make a essential contribution. Moreover,these data indicates that in FB photoproduction, incident γ-quanta interact in nuclei only once. It must be pointed out that measurements of the photon energy dependence of FB proton production have been made for only one value of momenta and proton angle and with large errors. Hence both more detailed and improved accuracy measurements are needed. Moreover such measurements must be done for virtual photons over a range of Q^2 values.

5. The Counting Rates

Complete calculations of expected counting rates can be carried out after studying of all characteristics of CLAS, and after developing theoretical calculations for all reactions proposed in sec.2. At present, we can estimates rates only for the processes of $e + A \to p_{backw} + X$ and for $\gamma + A \to p_{backw} + X$ (see sections 3.1 and 4. respectively) using experimental data on these processes taken in Yerevan and theoretical calculations.

5.1 The Counting Rates of Reaction (1)

The complete investigation of the reaction (1)requries a stastistical accuracy better than 3% for each 4 parameter bin coresponding to $\Delta E_e = 0.01\text{GeV}$, $\Delta E_p = 0.01\text{GeV}$, $\Delta\theta_e = 0.017\text{rad}$, $\Delta\theta_p = 0.085\text{rad}$. The cross section of the reaction (1) processes determined from our experimental data at $Q^2 \simeq 0.25\ (\text{GeV/c})^2$ is about $5.\mu\text{b sr}^{-2}\text{GeV}^{-2}$.

The counting rate is determined using the relation:

$$N_{ep} = \frac{d^4\sigma}{d\Omega_e dE_e d\Omega_p dE_p} (\Delta\Omega_e \Delta E_e \Delta\Omega_p \Delta E_p) L \qquad (15)$$

where $\Delta\Omega_e$ and $\Delta\Omega_p$ - are solid angles of secondary electrons and protons respectively, ΔE_e and ΔE_p are energy acceptances and L is the luminosity.

To calculate data rates we assume $L = 10^{33} cm^{-2} sec^{-1}$, $\Delta\Omega_p = 0.4sr$ (proton polar angle interval $90° \lesssim \theta_p \lesssim 135°$), $\Delta\Omega_e = 1.8\ 10^{-2} sr$(electron polar angle interval $10° \lesssim \theta_e \lesssim 25°$). These assumptions correspond to the design parameters of the CLAS detector [21]. Under these conditions ($Q^2 \simeq 0.2(GeV/c)^2$) $N_{ep} \simeq 7\ 10^{-3}\ sec^{-1}$. However, primary measurements will be done at $Q^2 \simeq 1(GeV/c)^2$. In this case $N_{ep} \simeq 4.5\ 10^{-4} sec^{-1}$ because the cross section decreases approximately as $1/Q^4$. For 10^3 events (~3% statistic accuracy) ~600h of total beam time is needed. For this proposed experiment a $10^3 sec^{-1}$ (e,e') trigger rate is needed, because the cross section of (e.e') at $Q^2 \simeq 1(GeV/c)^2$ is approximately $30\mu b\ st^{-1} GeV^{-1}$.

5.2 The counting Rates of Reaction (14)

To estimate counting rates for reaction (14) the experimental data obtained in Yerevan [3,16] were used, according to which the cross section of reaction (14) at $E = 3GeV$, $\theta_p = 120°$, $p_p = 0.5GeV/c$ is about $1.0 \cdot mb \cdot sr^{-1} \cdot GeV^{-1}$. For the photoproduction case the counting rates are estimated by

$$N_p = \frac{d^2\sigma}{d\Omega_p\, dE_p} (\Delta\Omega_p\ \Delta E_p)\ L \qquad (16)$$

where $\Delta\Omega_p$ and ΔE_p are solid angle and energy acceptance of secondary protons. The following values of quantities in (16) were used: $L = 10^{29} cm^{-2} sec^{-1}$ (tagged photons intensity $10^7 sec^{-1}$), $\Delta\Omega_p = 0.4sr$ (angular interval $90° \lesssim \theta_p \lesssim 135°$), $\Delta E_p = 0.2GeV$ ($T_p = 100 - 300MeV$). The counting rates in this case are about $\sim 6 sec^{-1}$ and for 10^6 events (as in electroproduction case, see sec. 5.1) ~50h of beam time is needed.

6. Conclusion

We propose a series of measurements of high Q^2 inelastic eA- scattering with detection of backward secondary nucleons and Δ-isobars , aimed at the investigation of short-range correlations in nuclei. This will be the next step in investigations carried out at low Q^2 in Yerevan, those on the bubble chamber neutrino experiments at FNAL [18] and CERN [19] , as well as the investigations of the related hadronic processes of cumulative particle production more completely studied in Moscow [4,13] and Dubna [20]. The results will be analyzed using the few-nucleon correlation model developed in Leningrad [1,2], which allows one to calculate the cross section of the processes discussed accounting for relativistic effects based on the light cone dynamics.

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Figure Captions

Fig.1 The relation $R = d\Sigma(E_e = 2GeV)/d\Sigma(E_e = 4GeV)$ as a function of the angle θ_{pq} at $Q^2 = 0.2(GeV/c)$ and $p_s = 0.5$ GeV/c calculate by [2,8,9] models of off-shell approximation and curve "Free" for on-shell one.

Fig.2 The ratio R as a function of p_s at $\theta_{pq} = 180°$.

Fig.3 The ratio R for different values Q^2 as a function of p_s at $\theta = 180°$.

Fig.4 Spectra of scattered electrons at different values of spectator angles θ_{pe}:a-90°,b-120°,c-140°.

Fig.5 The cross section of electron scattering on anucleon include in a pair correlation with spectator momenta 0.4 GeV/c (a) and 0.6 GeV/c (b).

Fig.6 Comparison of experimental electron spectrum and theoretical calculations in relativistic (solid curve) and nonrelativistic (dashed curve)approximations at $\theta_{pe} = 120°$.

Fig.7 The same as in Fig.6, for $\theta_{pe} = 140°$.

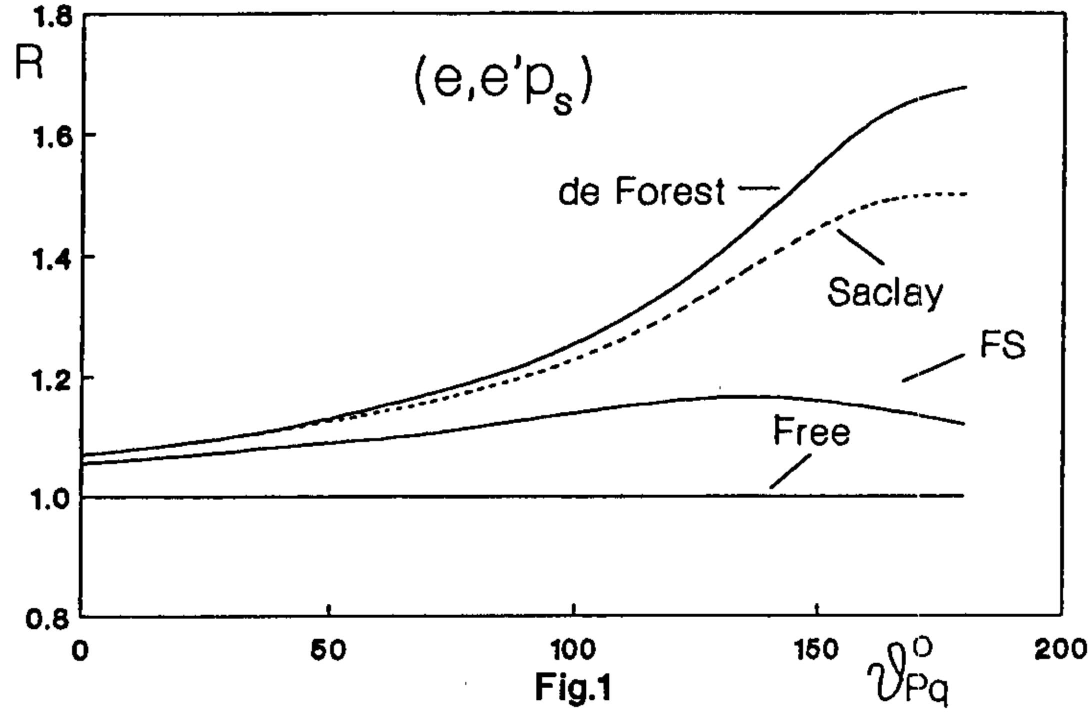
R
(e,e'p_s)
de Forest
Saclay
FS
Free
1.8
1.6
1.4
1.2
1.0
0.8
0
50
100
150
200
ϑ°Pq

Fig.1

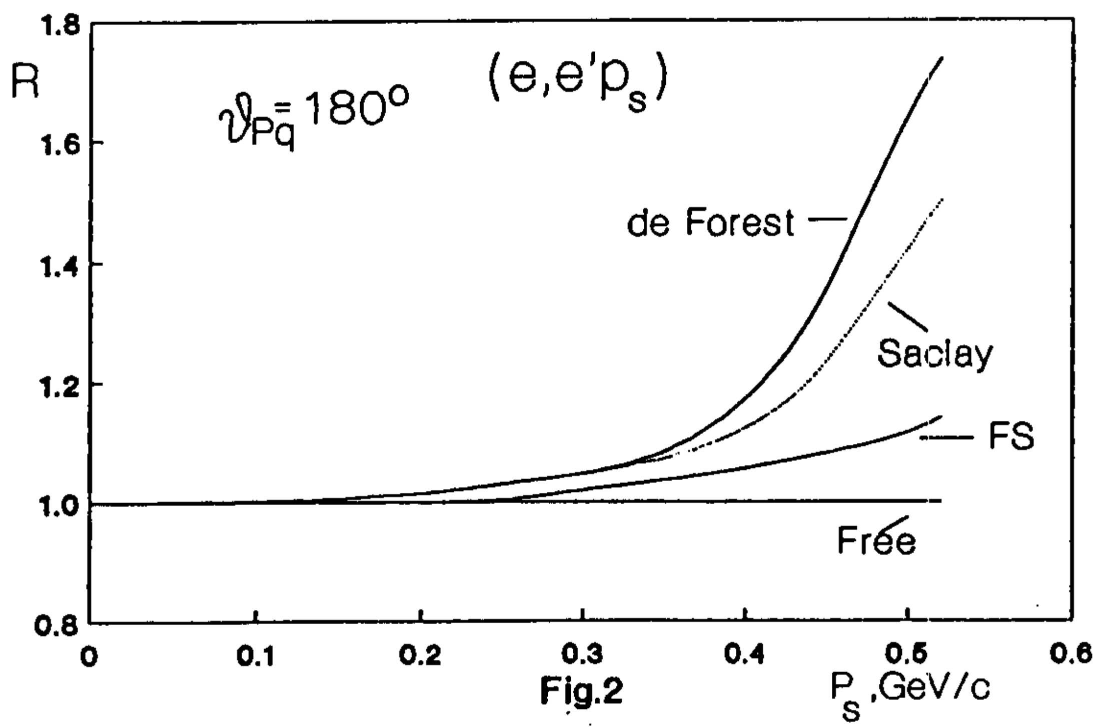
R
ϑPq = 180°
(e,e'p_s)
de Forest
Saclay
FS
Free
1.8
1.6
1.4
1.2
1.0
0.8
0
0.1
0.2
0.3
0.4
0.5
0.6
P_s ,GeV/c

Fig.2

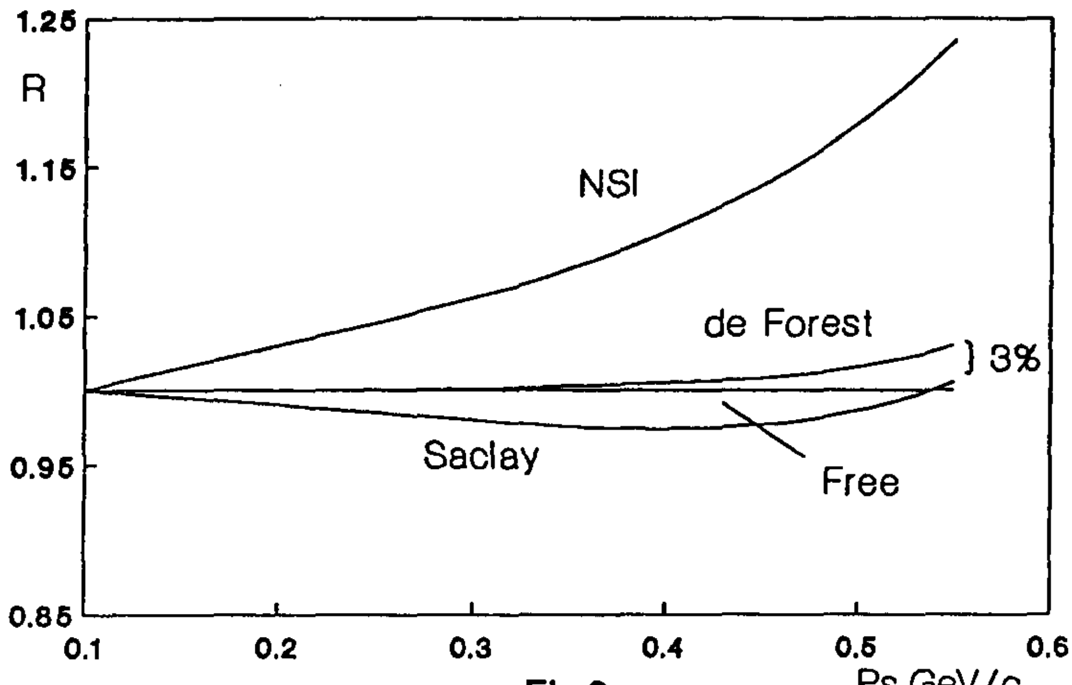
1.25
R
1.15
1.05
0.95
0.85
0.1
0.2
0.3
0.4
0.5
0.6
NSI
de Forest
} 3%
Saclay
Free
Ps,GeV/c

Fig.3

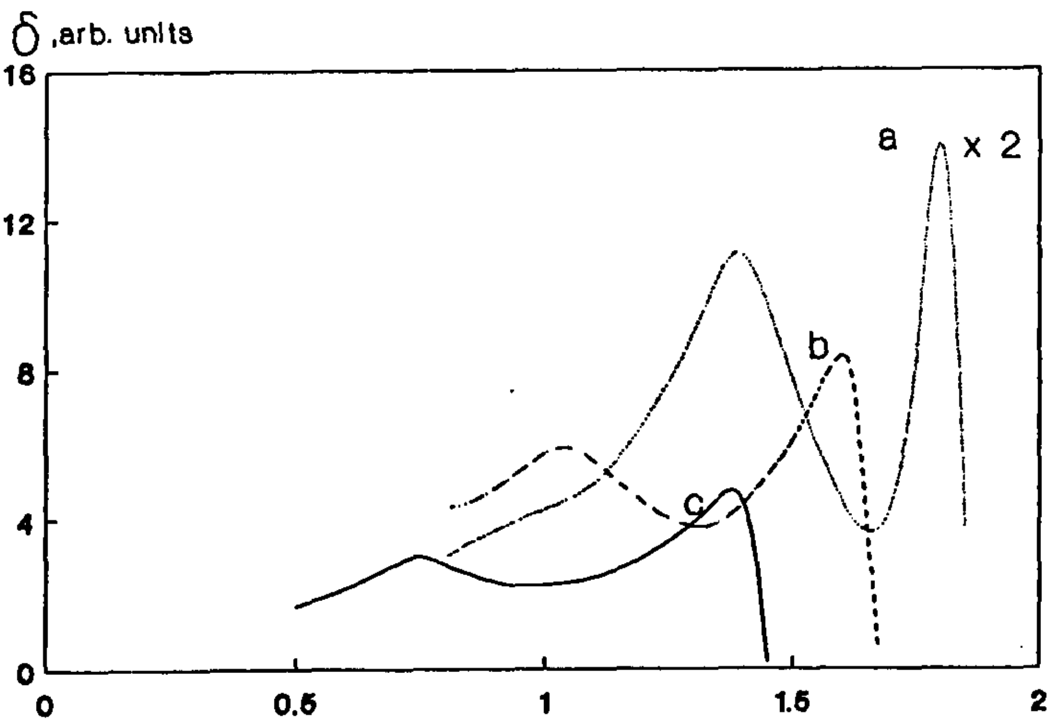
δ ,arb. units
16
12
8
4
0
0
0.5
1
1.5
2
a
x 2
b
c
Ee'[GeV]

Fig.4

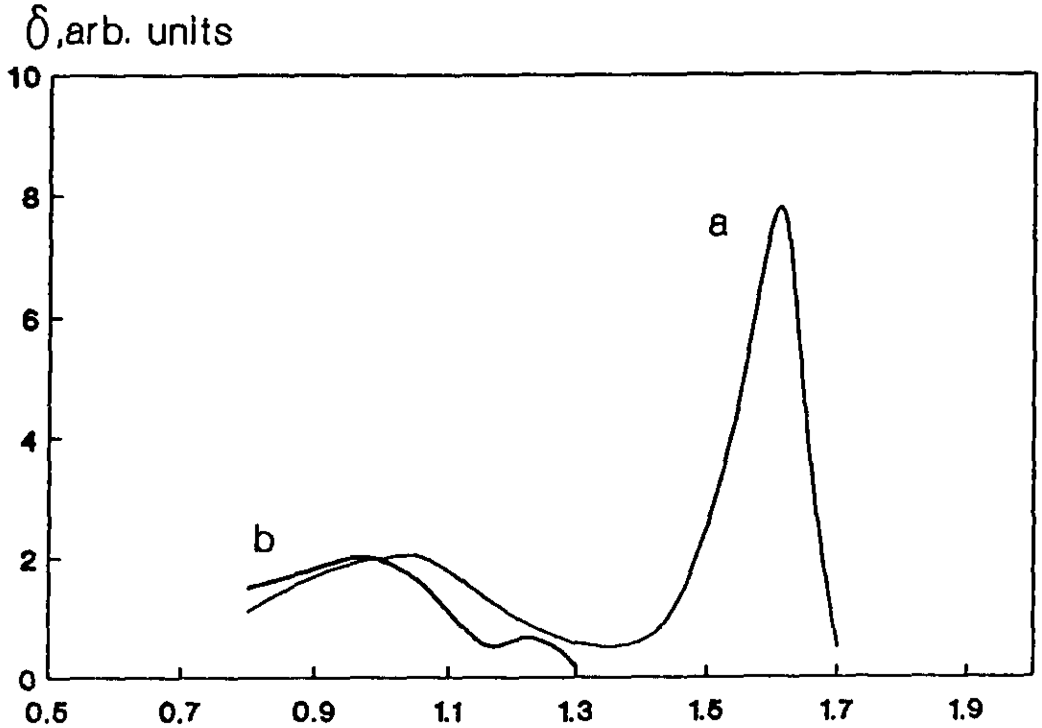
δ,arb. units
10
8
6
4
2
0
0.5
0.7
0.9
1.1
1.3
1.5
1.7
1.9
a
b
Ee'[GeV]

Fig.5

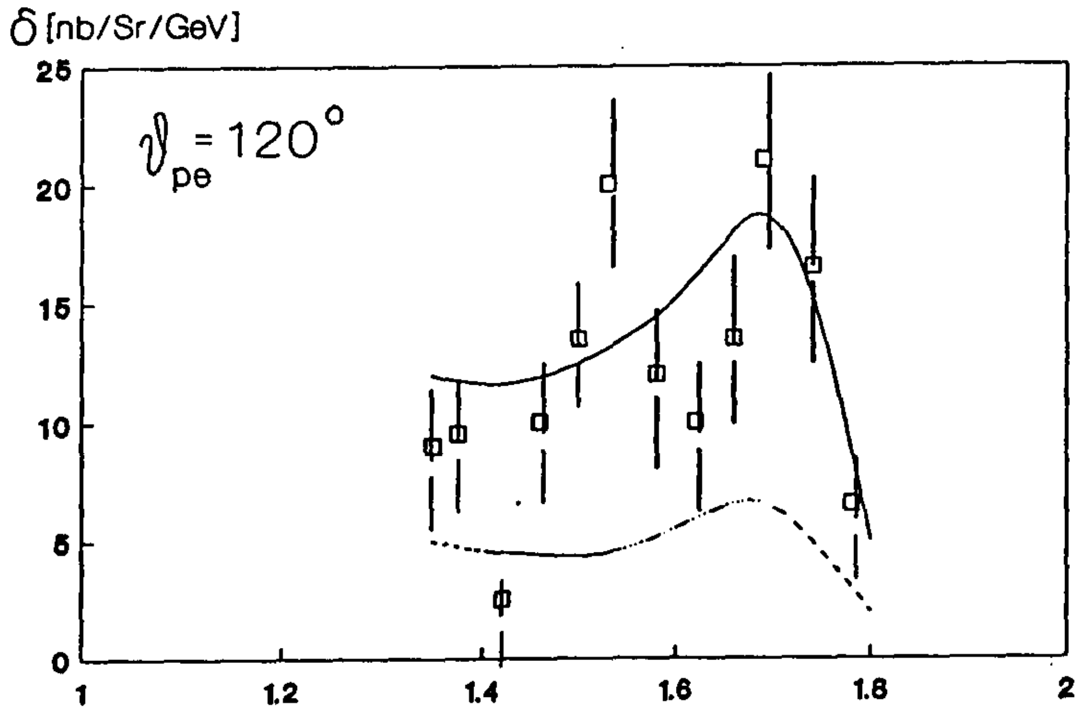
δ [nb/Sr/GeV]
25
20
15
10
5
0
1
1.2
1.4
1.6
1.8
2
$\vartheta_{pe} = 120^{\circ}$
Ee'[GeV]

Fig.6

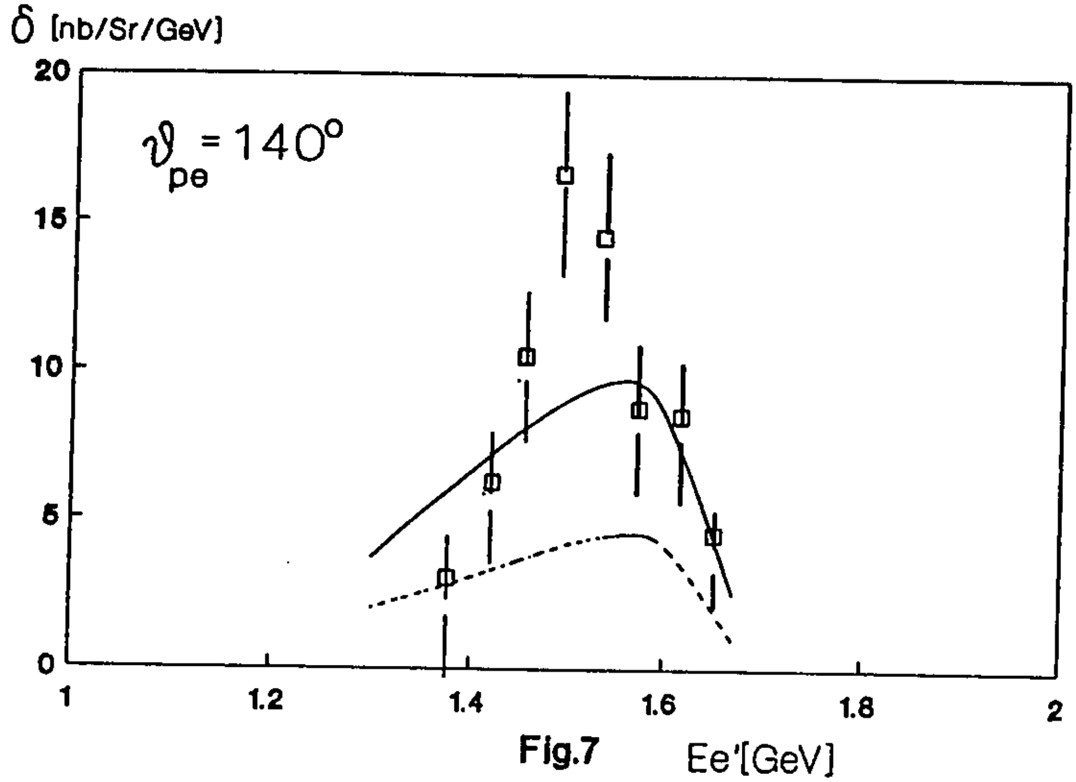

Fig.7