THE STRUCTURE EFFECTS IN POLARIZATION AND CROSS SECTION IN INELASTIC A(p, p')X REACTION WITH THE ⁴⁰Ca AND ¹²C NUCLEI AT 1 GeV

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The polarization of the secondary protons in the inelastic (p, p') reaction on the ⁴⁰Ca and ¹²C nuclei at the initial proton energy 1 GeV was measured in a wide range of the scattered proton momenta at a laboratory angle Θ=21°. The cross sections of the reaction were measured as well. The outgoing protons from the reaction were detected using a magnetic spectrometer equipped with a multiwire-proportional chambers polarimeter. A structure in the polarization and cross section data, related probably to scattering off the nucleon correlations in the nuclei, was observed.

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1 Introduction

—This work is a part of the experimental program in the framework of which the effects of nucleon clusterization in nuclear matter is studied at the PNPI synchrocyclotron with the 1 GeV proton beam [1, 2]. Earlier, in the first inclusive experiment, the scattered proton polarization in the reaction $^{40}$Ca($p, p' \ )X$ at $\Theta=21^\circ$ was measured [1]. At a proper secondary proton momentum, when scattering off the $^4$He-like nucleon cluster (nucleon correlation (NC)) in the $^{40}$Ca nucleus could dominate, the measured polarization was found to be close to that in the free elastic proton-$^4$He scattering. We investigated in details the polarization in the reaction and observed a structure in the experimental data [2]. The latter could be related to scattering off the multi-nucleon correlations in the nucleus [3, 4].

In this paper we present the results of the experiment, in which two inclusive reactions $^{40}$Ca($p, p' \ )X$ and $^{12}$Ca($p, p' \ )X$ at the scattering angle of the secondary protons $\Theta=21^\circ$ were investigated. In this experiment, besides the polarization of the final protons, we also measured the differential cross section of the reactions. These measurements were performed in a wide range of the scattered proton momenta $K$ ($K = 1370 \div 1670 \text{ MeV/c}$). Note that the momentum corresponding to a maximum of the quasielastic $pN$ peak is close to 1480 MeV/c. The data were obtained in narrow momentum intervals ($\simeq 10 \text{ MeV/c}$) and with a small gap between the intervals ($\simeq 10 \text{ MeV/c}$). Of a special interest was to make the measurements at the $K > 1530 \text{ MeV/c}$ up to the momentum corresponding to the excited level of the nucleus under investigation. In this region, since the NC are more massive than nucleons, the quasi-elastic ($p, p' \text{ NC}$) reactions (the elastic scattering off the NC in nuclear medium) are kinematically preferable. At $K > 1580 \text{ MeV/c}$ the scattering off the independent (uncorrelated) nuclear nucleons is strongly suppressed, since they have a minimal momentum larger than the Fermi momentum $K_F$ ($\approx 250 \text{ MeV/c}$) [2].
Figure 1: The experimental setup. TS is the target of the MAP spectrometer; Q1÷Q2 are the magnetic quadrupoles; D is the dipole magnet; C1 is the collimator; S1÷S2 and M1÷M3 are the scintillation counters; PC1÷PC4, PC1’, PC4’ and A are the proportional chambers and the carbon analyzer of the MAP polarimeter, respectively.

Table 1: Target parameters

| Target   | Dimensions, mm | Isotope concentration, % | Density, g/cm³ |
|----------|----------------|--------------------------|---------------|
|          | thickness x width x height |                          |               |
| CH₂      | 4 x 15 x 70    |                          | 1.0           |
| C        | 4 x 15 x 70    | 98.9                     | 1.6           |
| CH₂ foil | 0.1 x 4 x 10   |                          | 1.0           |
| ¹²C      | 4 x 7 x 10     | 98.9                     | 1.6           |
| ⁴⁰Ca     | 4 x 7 x 10     | 97.0                     | 1.55          |

The general layout of the experimental setup is presented in Fig. 1.

2 Experimental method

The proton beam of the PNPI synchrocyclotron was focused onto the target TS of the magnetic spectrometer MAP. The beam intensity was monitored by the scintillation telescope M1, M2, M3. The diameter of the beam spot on the target was ≃ 25 mm. Large CH₂ and C targets, CH₂ foils for the setup calibration, and small ¹²C and ⁴⁰Ca targets for the main measurements were used in the experiment (Table 1).
The spectrometer was used to measure the momenta of the secondary protons from the inclusive \((p, p')\) reaction as well as their polarization. The momentum of the proton was determined using the coordinate information from the proportional chambers PC1-X and PC2-X. The momentum resolution of the spectrometer in this experiment was \(\pm 2.5 \text{ MeV/c}\). This value was estimated by measuring the width of the clearly separated \(2^+\) excited level in the \((p, p')\) reaction with the \(^{12}\text{C}\) nucleus at the scattering angle \(21^\circ\) under investigation (Fig. 2). In Fig. 2 we also observed a peak which can be identified as the \(1^+\) excited level predicted in [5].

The polarization of the final protons was found from an azimuthal asymmetry of the proton scattering off the carbon analyzer A, using the track information from the proportional chambers (PC1÷P4 and PC1', PC4') of the polarimeter [6]. The average analyzing power of the polarimeter was calculated using the parametrization \(A(K, \theta_s)\) from [7].

The main parameters of the MAP spectrometer and the polarimeter are listed in Tables 2 and 3, respectively.

The calibration of the analyzing power of the polarimeter was carried out using the \(pp\) elastic scattering polarization data obtained in this experiment. For the calibration in a wide range of the secondary proton energy we performed the polarization measurements with the polyethylene and carbon targets (the large CH\(_2\) and C targets, Table 1) at different angular \((\Theta = 13.5^\circ \div 23^\circ)\) and proper momentum settings of the spectrometer. The observed values of the \(pp\) polarization were compared with the predictions in the framework of the phase-shift
Table 2: Parameters of the magnetic spectrometer

| Parameter                                         | Value     |
|--------------------------------------------------|-----------|
| Maximum particle momentum, [GeV/c]               | 1.7       |
| Horizontal angle acceptance $\Delta \Theta_H$, [deg] | 0.8       |
| Vertical angle acceptance $\Delta \Theta_V$, [deg] | 1.9       |
| Solid angle acceptance $\Omega$, [sr]            | $4.0 \times 10^{-4}$ |
| Momentum acceptance $\Delta K/K$, [%]            | 8.0       |
| Dispersion in the focal plane $D_f$, [mm/\%]     | 22.0      |
| Momentum resolution (FWHM), [MeV/c]              | $\sim 5.5$ |

Table 3: Polarimeter parameters

| Parameter                                      | Value |
|-----------------------------------------------|------|
| Carbon block thickness, [mm]                  | 155  |
| Polar angular range, [deg]                    | 3÷16 |
| Average analyzing power                       | $\geq 0.2$ |
| Efficiency, [%]                               | $\sim 5$ |

analysis [8] and a correction for the analyzing power of the polarimeter has been done. The uncertainty of the calibration was included in the total error of the polarization measurement.

The relative differential cross section of the reactions $\sigma^{incl} = \frac{d^2\sigma}{d\Omega dK}$ was found from the momentum spectra obtained at different momentum settings of the spectrometer. The monitor number and efficiency of the proportional chamber PC2-X for each momentum setting were taken into account. To subtract a background, the measurements with an empty target and with the 100 $\mu$m tungsten string supports of a target were done. An absolute normalization of the cross section in the reaction with the $^{12}$C nucleus was made with the large CH$_2$ target (Table 1) in a momentum range near the quasi-elastic scattering peak maximum. The cross section in the $pp$ elastic scattering was calculated in the framework of the phase-shift analysis [8]. At the scattering angle $\Theta = 21^\circ$ a value of 2.92 mb/sr (in the centre-of-mass system) was obtained. To make this normalization for the reaction with the $^{40}$Ca nucleus, we made the measurements with the $^{40}$Ca target, with the $^{40}$Ca target + additional target CH$_2$-foil (Table 1), and again with the $^{40}$Ca target. These data allowed us to estimate the admixture of hydrogen in the superficial layer of the $^{40}$Ca target. The relative systematic errors $\delta \sigma^{incl}/\sigma^{incl}$ of the cross section ($\sigma^{incl}$) normalization for the reactions $^{12}$C($p, p'$)X and $^{40}$Ca($p, p'$)X were $\pm 1.5$ % and $\pm 3.5$, respectively. An uncertainty of the cross section calculations in the elastic $pp$ scattering [8] was not included.
3 Experimental results and discussion

In Fig. 3 and Fig. 4 the measured polarizations $P$ (black squares) and cross sections $\frac{d^2\sigma}{d\Omega dK}$ (circles) in the reactions $^{40}$Ca($p,p'$)X and $^{12}$C($p,p'$)X are plotted versus the scattered proton momentum $K$. Small errors of the cross section measurements are presented inside the circles. The experimental data are also given in Tables 4÷7. The empty square corresponds to an estimate of the polarization in the elastic $p-^4$He scattering [9]. The solid curve in Fig. 3 presents the polarization calculated in the framework of a spin-dependent Distorted Wave Impulse Approximation (DWIA) [10]. The dashed curves in Fig. 3 and Fig. 4 are the result of the calculations in the framework of the DWIA taking into account the relativistic distortion of the nucleon spinor in nuclear medium (DWIA*) [10, 11]. In this approach the proton scattering off the independent nuclear nucleons was taken into account only. The calculations were performed using the THREEDEEE code [12].

As seen from Figs. 3, 4 in the region of the $K > 1530$ MeV/c a drop of the cross section slows down at the momenta close to those marked by arrows. The momentum intervals between the adjacent arrows are indicated in the figures as the dotted line segments in an area of the polarization data. Let us denote these
Figure 4: Polarization $P$ of the protons scattered at an angle $\Theta = 21^\circ$ (black squares) in the inclusive reaction $^{12}\text{Ca}(p,p')X$ versus the secondary proton momentum $K$. The circles correspond to the differential cross sections $d^2\sigma/d\Omega dK$ measured in the reaction. Dashed curve is a result of the polarization calculations in the framework of the DWIA*. The empty square corresponds to the polarization in the elastic $p-^4\text{He}$ scattering [9]. The dotted lines cover the $K$ intervals II, III, and IV, defined in the text.

momentum ranges as II, III, and IV in the direction of momentum growth. Note that the onset of each momentum interval (II, III, and IV) for the $^{40}\text{Ca}$ nucleus is shifted with respect to that for the $^{12}\text{C}$ nucleus by $\sim 5 \div 10$ MeV/c towards higher values. The value of the polarization in the momentum ranges is practically constant excluding the interval III for the $^{40}\text{Ca}$ data. The polarization increases from the interval II to interval IV. At momenta $K > 1580$ MeV/c the large values of the polarization and cross section [2] can not be explained only by the proton scattering off the uncorrelated nuclear nucleons. Possible, such behaviour of polarization and cross section in the momentum ranges II, III, and IV can be related to a proton quasielastic scattering off the two-nucleon, three-nucleon, and four-nucleon correlations. The value of the polarization in the proton interaction with a NC can depend on the number and isospin properties of nucleons in the correlation. According to [13], larger values of the secondary proton polarization can be observed in the elastic scattering off a light nucleus in comparison with that in the scattering off independent nuclear nucleons.

The calculated final proton momenta $K_2$, $K_3$ ($K_3^*$), and $K_4$ corresponding to the maxima of the quasi-elastic peaks in the $^{40}\text{Ca}(p,p'\text{NC})X$ and $^{12}\text{C}(p,p'\text{NC})X$ reactions on the stationary NC consisting of two, three, and four nucleons are shown in Figs. 3, 4. In these calculations the masses of real light nuclei with simple structure $^2\text{H}$, $^3\text{He}$ ($^3\text{H}$), and $^4\text{He}$ were used as the NC masses. The resid-
ual nuclei (X) in the reactions were assumed to be in a ground state. As seen in Fig. 3 the momenta $K_2$ (1563 MeV/c), $K_3$ (1599 MeV/c), $K^*_3$ (1593 MeV/c), and $K_4$ (1631 MeV/c), and in Fig. 4 the momenta $K_2$ (1557 MeV/c), $K_3 \approx K^*_3$ (1591 MeV/c), and $K_4$ (1631 MeV/c) are within the momentum intervals II, III, and IV, respectively. This observation stays true if the NC masses were smaller (due to the nuclear medium modification [11]) than the mass of the corresponding free light nucleus. A $\sim 10\%$ decrease of the NC masses reduces the values of the momenta $K_2$, $K_3$ ($K^*_3$), and $K_4$ by $\sim 12$ MeV/c, $\sim 8$ MeV/c, and $\sim 6$ MeV/c, respectively. Note here that a high momentum range, just following the momentum interval IV, possibly corresponds to quasi-elastic scattering off the residual nuclei X of the reactions considered above.

The DWIA* calculations show that the contribution from the quasi-elastic scattering off the uncorrelated nucleons in the momentum interval II is rather large [2]. At $K > 1580$ MeV/c, including the momentum intervals III and IV, this contribution is essentially suppressed since the nuclear nucleons have momenta higher than the Fermi momentum $k_F \approx 250$ MeV/c. The polarizations measured in the momentum interval IV ($P_{IV}$) in the scattering off the $^{40}$Ca and $^{12}$C nuclei (see Figs. 3, 4) are practically the same ($P_{IV}(Ca) = 0.363 \pm 0.009$ and $P_{IV}(C) = 0.348 \pm 0.010$). The polarization $P_{IV}$ is less than that ($P_{4He}$) in the free elastic $p-^{4}$He scattering (empty square) [2]. This can be related to a modification of proton interaction with the four-nucleon cluster in nuclear medium [4]. The relative difference of these polarizations ($P_{4He} - P_{IV})/P_{4He} \sim 0.2$ is close to that of the polarizations ($P_{DWIA^*}$ and $P_{DWIA}$) calculated in the DWIA* and DWIA approximations (Fig. 3) for the quasi-elastic scattering off the uncorrelated nucleons ($P_{DWIA^*} - P_{DWIA}$)/$P_{DWIA}$ $\sim 0.15$ at $K \approx 1580$ MeV/c.

The widths ($\Delta K$) of the momentum intervals II ÷ IV are not determined by the horizontal angular acceptance of the spectrometer alone ($\Delta \Theta_h \sim 1^\circ$). The main contribution to the $\Delta K$ can come from a motion of the NC in the nucleus. For instance, if the scattering occur off the four-nucleon correlations at rest in the nucleus then the $\Delta K$ width of the momentum interval IV would be equal to $\sim 5.5$ MeV/c. This value is about 4.5 times less than that estimated from this experiment $\Delta K \sim 25$ MeV/c. So, due to a motion of the NC, the effective angular acceptance essentially increases ($\Delta \Theta_h \sim 4.5^\circ$). This enables us to observe the polarization angular distribution in scattering from the NC within the momentum interval IV. In Fig. 5 the polarization angular distribution measured in the free elastic $p-^{4}$He scattering is shown [9]. The dotted line segment corresponds to the effective angular acceptance seen in the inclusive reaction in the momentum interval IV. According to the data in the figure, we can expect that the polarization momentum dependence in the proton scattering off the four-nucleon correlations in the nuclei can also be close to uniform. A growth of the polarization in the momentum interval III in the scattering off the $^{40}$Ca nucleus (Fig. 3) is possibly related to that the momentum regions of scattering off the $^3$He- and $^3$H-like correlations overlap only partially. This follows from a noticeable difference of the
momenta $K_3$ and $K_3^*$ mentioned above, being $K_3 > K_3^*$ (for the $^{12}$C data these momenta are almost the same). We suppose that the polarization in the elastic scattering off the $^3$He nucleus is essentially larger than that off the $^3$H nucleus. So, at momenta close to the end of the interval III, the polarization is possibly determined by the scattering off the $^3$He-like correlations. At $K < K_3^*$ the processes of scattering off these three-nucleon correlations are mixed. For reliable verification of the above supposition, the polarization calculations in the framework of the Glauber's multiple nucleon-nucleon scattering theory [14] should be done. We were only based on the fact that at the initial proton energy 1 GeV the polarization in the elastic scattering off neutron is about 25 % less than that in the proton-proton scattering, and the number of neutrons in $^3$He is smaller than in the $^3$H nucleus.

We would like to make some remarks about measured results in the momentum range $1420$ MeV/c $< K < 1530$ MeV/c (denote this range as I) covering the momentum ($K \sim 1480$ MeV/c) corresponding to a maximum of the $pN$ quasi-elastic peak (see Figs. 3, 4). In the range I, where the cross section of the inclusive $(p,p')$ reaction has large values and depends smoothly on the $K$, a contribution from the multi-step processes of knocking out nucleons from a nucleus, can be noticeable [15]. The outgoing proton momentum in these processes decreases as compared with that in the one-step $(p,p')$ reaction under investigation. Due to this effect a shape of the quasi-elastic peak can be distorted. It is important to note here, in the momentum region $K > 1530$ MeV/c, where the cross section dips rapidly with a growth of the $K$, the multi-step processes are essentially unable.
to distort the momentum distribution measured in the reaction. The DWIA* predictions of the outgoing proton polarization for the reaction $^{12}\text{C}(p, p')X$ (Fig. 4) are in a good consent with the experimental data in a narrow region around the momentum $K \approx 1480 \text{ MeV/c}$. The variation of the measured polarization in the range I is apparently a combined effect of the multi-step reactions and a discrete energy-shell structure of the $^{12}\text{C}$ nucleus.

Last we make a comment on the kinematics of the present $(p, p')$ experiment. In the momentum range $1480 \div 1650 \text{ MeV/c}$ the value of the transferred four-momentum $Q$ stays almost constant and is equal to $\approx 600 \text{ MeV/c}$. The latter value is about two times higher than that of the Fermi momentum. So, the Bjorken kinematical variable $x_B = \frac{Q^2}{2m\nu}$ is only determined by the energy transfer $\nu$ (where $m$ is nucleon mass). In Fig. 3, there is an additional horizontal scale for $x_B$ indicated. As seen from the figure, for the reaction with the $^{40}\text{Ca}$ nucleus the momentum intervals II, III, and IV correspond to the $x_B$ intervals $1.5 < x_B < 2$, $2 < x_B < 3$, and $3 < x_B < 4$, respectively. Due to the above mentioned difference in the momentum interval onsets for the $^{12}\text{C}$ and $^{40}\text{Ca}$ nuclei (it is possible related to a large mass difference of the nuclei), the corresponding $x_B$ intervals in the reaction $^{12}\text{C}(p, p')X$ are $1.4 < x_B < 1.8$, $1.8 < x_B < 2.5$, and $2.5 < x_B < 3.7$. It is interesting to note that in the JLAB unpolarized $(e, e')$ experiment at $E_e \sim 4.6 \text{ GeV}$ and $Q^2 > 1.4 \text{ GeV}^2/c^2$, the effects from the two-nucleon and three-nucleon correlations in the cross section were observed in the $x_B$ ranges $1.5 < x_B < 2$ and $2.25 < x_B < 2.8$, respectively [4].

4 Summary

The polarization of the secondary protons in the inelastic $(p, p')$ reaction with the $^{40}\text{Ca}$ and $^{12}\text{C}$ nuclei and the cross section of these reactions were investigated at the 1 GeV initial proton energy and the scattering angle $\Theta = 21^\circ$. The data were obtained in a wide range of the scattered proton momentum $K$ covering the $pN$ quasi-elastic peak and a high momentum region ($K > 1530 \text{ MeV/c}$) up to the momentum corresponding to the exited levels of the nucleus under investigation. The measurements were done in narrow momentum intervals ($\approx 10 \text{ MeV/c}$) and with a small gap between the intervals ($\approx 10 \text{ MeV/c}$).

A polarization growth with the final state proton momentum at $K > 1530 \text{ MeV/c}$ was found. A structure in the polarization and cross section data in this region was observed for the first time. The structure is possibly related to a proton quasielastic scattering off the two-nucleon, three-nucleon, and four-nucleon correlations.

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Table 4: The polarization $P$ of the scattered proton in the reaction \(^{40}\text{Ca}(p, p')X\) at 1 GeV and lab. angle $\Theta=21^\circ$  

| $K$ (MeV/c) | $P$ | $K$ (MeV/c) | $P$ | $K$ (MeV/c) | $P$ |
|-------------|-----|-------------|-----|-------------|-----|
| 1417.3      | 0.217±0.018 | 1502.8      | 0.274±0.011 | 1592.9      | 0.364±0.015 |
| 1427.0      | 0.272±0.018 | 1508.8      | 0.303±0.019 | 1605.1      | 0.387±0.022 |
| 1436.7      | 0.217±0.017 | 1519.1      | 0.281±0.018 | 1618.4      | 0.361±0.014 |
| 1446.6      | 0.233±0.017 | 1529.4      | 0.298±0.019 | 1629.6      | 0.361±0.015 |
| 1455.5      | 0.234±0.011 | 1538.9      | 0.306±0.013 | 1641.6      | 0.368±0.019 |
| 1465.4      | 0.275±0.012 | 1549.3      | 0.302±0.013 | 1652.7      | 0.397±0.022 |
| 1474.8      | 0.296±0.014 | 1559.1      | 0.322±0.017 | 1664.0      | 0.430±0.026 |
| 1484.8      | 0.291±0.014 | 1571.3      | 0.310±0.013 |             |     |
| 1495.0      | 0.304±0.015 | 1582.0      | 0.308±0.013 |             |     |

Table 5: The polarization $P$ of the scattered proton in the reaction \(^{12}\text{C}(p, p')X\) at 1 GeV and lab. angle $\Theta=21^\circ$  

| $K$ (MeV/c) | $P$ | $K$ (MeV/c) | $P$ | $K$ (MeV/c) | $P$ |
|-------------|-----|-------------|-----|-------------|-----|
| 1407.9      | 0.216±0.027 | 1483.8      | 0.297±0.030 | 1571.6      | 0.301±0.015 |
| 1417.4      | 0.295±0.026 | 1496.9      | 0.279±0.018 | 1582.4      | 0.294±0.017 |
| 1427.0      | 0.313±0.025 | 1507.3      | 0.278±0.017 | 1593.3      | 0.296±0.018 |
| 1436.7      | 0.257±0.024 | 1518.8      | 0.268±0.021 | 1605.1      | 0.369±0.025 |
| 1446.5      | 0.224±0.024 | 1529.1      | 0.297±0.022 | 1618.5      | 0.351±0.016 |
| 1455.5      | 0.243±0.018 | 1538.9      | 0.259±0.015 | 1629.7      | 0.337±0.016 |
| 1465.3      | 0.279±0.020 | 1549.3      | 0.282±0.017 | 1641.6      | 0.368±0.022 |
| 1473.8      | 0.285±0.030 | 1559.3      | 0.267±0.022 | 1652.9      | 0.384±0.024 |
Table 6: The cross section of the reaction $^{40}\text{Ca}(p, p')X$ at 1 GeV and lab. angle $\Theta=21^\circ$

| $K$ MeV/c | $\frac{d^2\sigma}{d\Omega dK}$ mb/(sr·MeV/c) | $K$ MeV/c | $\frac{d^2\sigma}{d\Omega dK}$ mb/(sr·MeV/c) | $K$ MeV/c | $\frac{d^2\sigma}{d\Omega dK}$ mb/(sr·MeV/c) |
|-----------|------------------------------------------|-----------|------------------------------------------|-----------|------------------------------------------|
| 1375.0    | .3085±.0032                              | 1475.1    | .4928±.0047                              | 1574.9    | .2814±.0036                              |
| 1385.0    | .3283±.0034                              | 1485.0    | .4922±.0049                              | 1584.9    | .2659±.0070                              |
| 1395.1    | .3547±.0034                              | 1495.0    | .4918±.0047                              | 1594.9    | .2271±.0060                              |
| 1405.1    | .3659±.0038                              | 1505.0    | .4956±.0029                              | 1604.9    | .1950±.0028                              |
| 1415.0    | .3921±.0107                              | 1515.0    | .4760±.0040                              | 1614.9    | .1660±.0028                              |
| 1425.0    | .4083±.0051                              | 1525.0    | .4560±.0043                              | 1625.0    | .1585±.0082                              |
| 1435.1    | .4294±.0053                              | 1535.0    | .4347±.0043                              | 1634.9    | .1331±.0015                              |
| 1445.1    | .4385±.0055                              | 1545.0    | .4023±.0025                              | 1644.9    | .1090±.0015                              |
| 1455.1    | .4750±.0034                              | 1554.9    | .3793±.0076                              | 1654.9    | .0788±.0021                              |
| 1465.1    | .4932±.0043                              | 1565.0    | .3197±.0036                              | 1664.9    | .0622±.0019                              |

Table 7: The cross section of the reaction $^{12}\text{C}(p, p')X$ at 1 GeV and lab. angle $\Theta=21^\circ$

| $K$ MeV/c | $\frac{d^2\sigma}{d\Omega dK}$ mb/(sr·MeV/c) | $K$ MeV/c | $\frac{d^2\sigma}{d\Omega dK}$ mb/(sr·MeV/c) | $K$ MeV/c | $\frac{d^2\sigma}{d\Omega dK}$ mb/(sr·MeV/c) |
|-----------|------------------------------------------|-----------|------------------------------------------|-----------|------------------------------------------|
| 1375.1    | .1774±.0018                              | 1475.0    | .2677±.0024                              | 1574.9    | .1272±.0016                              |
| 1385.1    | .1911±.0020                              | 1485.0    | .2676±.0025                              | 1584.9    | .1186±.0029                              |
| 1395.1    | .2045±.0021                              | 1495.0    | .2676±.0024                              | 1594.9    | .1016±.0013                              |
| 1405.0    | .2197±.0023                              | 1505.0    | .2723±.0023                              | 1604.9    | .0829±.0017                              |
| 1415.0    | .2357±.0056                              | 1515.0    | .2573±.0018                              | 1614.9    | .0722±.0017                              |
| 1425.0    | .2373±.0025                              | 1525.0    | .2410±.0019                              | 1624.9    | .0703±.0041                              |
| 1435.0    | .2494±.0026                              | 1535.0    | .2159±.0017                              | 1635.0    | .0618±.0009                              |
| 1445.0    | .2562±.0028                              | 1544.9    | .2061±.0011                              | 1644.9    | .0476±.0011                              |
| 1455.0    | .2692±.0017                              | 1554.9    | .1810±.0037                              | 1655.0    | .0349±.0012                              |
| 1465.0    | .2677±.0023                              | 1564.9    | .1533±.0015                              |           |                                           |
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