ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

ЛАБОРАТОРИЯ ЯДЕРНЫХ ПРОБЛЕМ

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D - 516

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MEASUREMENT OF THE CORRELATION COEFFICIENT C_{nn} AT 90° AND AN ENERGY OF 315 MEV FOR THE ELASTIC PP-SCATTERING*

* This paper was submitted at the International Conference on High Energy Physics and the results were reported by Prof. Ya.A. Smorodinsky (Kiev, 1959).

In order to obtain detailed information on the interaction of two nucleons experiments on the scattering of polarized nucleons at an unpolarized target should be supplemented by investigations on the scattering of polarized nucleon beams at polarized targets. Difficulties of obtaining polarized targets complicate the carrying out of these experiments V.V. Vladimirsky and Ya.A. Smorodinsky have pointed out the possibility of obtaining data on nucleon interaction in different spin states on the basis of nucleon scattering experiments at usual unpolarized targets. Components of the polarization tensor are determined in these experiments by investigating the polarization correlation of scattered nucleons. Difficulties of running the experiment on determination of spin correlation coefficients are due to a necessity of selecting rare triple nuclear interaction events at the main target and two analyser-targets.

Nowadays correlation experiments are of special importance for pp-scattering at 310 MeV. Earlier at Berkeley a whole set of experiments was carried out at this energy and permitted to perform a phase shift analysis[2,3]. However, due to the errors of measurements this analysis has not provided a digital result. H. Stapp has obtained five sets of phases satisfying experimental data[4]. Determination of the correlation coefficient between the spin components of protons might be used for a more accurate solution of the problem concerning phases describing elastic pp-scattering.

Pioneering spin correlation measurements have been carried out by a group of Liverpool physicists[5] for elastic pp-scattering at 90° (c.m.s.) and an energy of 382 MeV. That experiment has provided the coefficient $C_{nn}=0.416 \pm 0.084$ which determines the correlation between spin components perpendicular to the plane of scattering. However, difficulties of extrapolation of the obtained value to an energy of 310 MeV have not permitted to make comparison with values of the coefficient C_{nn} which correspond to different sets of phases.

We have performed measurements of the coefficient C_{nn} for pp-scattering at 90° (c.m.s.) and an energy of 315 MeV. An additional difficulty we have met with at this energy consists in the fact that the extracted proton beam of the Joint Nuclear Research Institute synchrocyclotron has an energy of 660 MeV and its slowing down to an energy of 315 MeV is concerned with a great loss of intensity. When several variants of the proton beam slowing down had been tested, the most effective method permitting to obtain the proton beam of 315 MeV and the total intensity of 10^{7} proton/sec, was chosen. A carbon absorber was placed just near the vacuum chamber of the accelerator. On passing through the absorber the beam was deflected by 16° by the analysing magnet and was directed into a steel collimator 100 mm in diameter located in a 4 meter concrete wall. Quadrupole lenses with a 120 mm aperture were placed on the collimator output in the experimental hall. Then the beam passed through collimators (40 and 50 mm in diameter) located in the additional shielding and hit a polyethylene target. The target was 20 mm wide, 30 mm long and 30 mm high.

The scheme outlining the arrangement of the registering equipment is given in Fig. 1. Elastic pp-scattering events were selected with two telescopes consisting of scintillation counters 1,2,3 and 4 connected in coincidence. All four scintillators were made of scintillating plastic and had the same dimensions: 90 mm high, 30 mm wide and 7 mm thick. The telescopes were arranged symmetrically relative to the proton beam at an angle of 42.7^{o}. The angular resolution of the first scattering was $\pm 0.93^{o}$.

The operation of the accelerator being normal, the count of coincidences was about 2000/min. The telescopes safely selected the events of elastic proton scattering on hydrogen. In the experiment the polyethylene target was substituted for an equivalent carbon one. This decreased coincidence counts 25 times.

Protons separated by the telescopes traversed then carbon analysers 6.4 gr/cm^2 thick. The carbon analysers were followed by counters 5 and 6 made of scintillating plastic 200 mm high, 100 mm wide and 10 mm thick. Counters 5 and 6 were switched in anticoincidence with the telescope counters. In adjusting the centres of the scintillators of counters 1, 3, 5 and 2, 4, 6 were matched within ± 0.5 mm with strings stretched from the centre of the first target.

Protons moving along the telescope axis did not traverse the anticoincidence counters when they were scattered in the analyser in a horizontal plane at an angle $> 7.75^{o}$.

Consequently, the system of scintillation counters selected rare events when both the protons underwent interaction with carbon in the analysers. If only one anticoincidence counter was switched on, the count was 12% of the number of coincidences $1+2+3+4$. If both the anticoincidence counters were switched on, the count decreased to 1.5% of the number of coincidences.

Switching the coincidence counters without the carbon analysers in the telescopes caused a considerable decrease of the count. Thus, when only one anticoincidence counter was switched on, the count was (2–3)% and when both the counters were switched on, it was (0.05 – 0.1)% of $N_{1+2+3+4}$. A small value of the residual count mostly caused by proton interaction with nuclei of counter scintillators 3 and 4, points out the smallness of the background of the accidental coincidences $1+2+3+4$.

In order to register the direction of proton scattering in the analysers two hodoscopic chambers of gas-discharge counters were used in the regime of controlled pulse supply[6,7]. Each chamber consisted of two parts. In the first part, situated between the analyser and the counter of anti coincidences, here were used only vertically placed counters MC–6 with a tube 22 mm in diameter and a cathode 190 mm long. The second part of the chamber situated behind the counter of anticoincidences consisted of six rows of the same counters placed vertically and 6 rows of counters having a tube 32 mm in diameter, a cathode 290 mm long and placed horizontally. In those cases when the system of scintillation counters registered the event (1+2+3+4−5−6) , the gas-discharge counter received a high voltage pulse with an amplitude abaut 2 KV and duration 10^{-6} sec.

On the panel which was photographed with a camera, neon lamps were arranged in strict correspondence to the Geiger counters. (See Fig. 2). Groups of neon lamps (1, 4) show the projection of scattered proton tracks to the horizontal plane. White squares represent graphite scatterers, light rectangular bands denote counters of anticoincidences. At the bottom of the central part of the still there are rows of neon lamps (2, 3) fixing vertical projections of particle tracks. On the top of the central part of the still there are numbers and neon lamps of the counter of stills.

Photographing of the registering panel containing neon lamps occured each time when the control system of scintillation counters was fixing the event 1+2+3+4−5−6. Only 14% of stills contained the picture of the horizontal projection of the scattered proton track in each hodoscopic chamber. On average only two stills with a horizontal projection of tracks of both the scattered protons fell on a hundred of stills. Only these rare events gave material to clear up the relative probability for protons to undergo right-right, left-left, right-left, left-right scattering. When scanning the stills we took into consideration only those tracks which had 3 or more lighted neon lamps and came from the carbon tar get without traversing the counter of anticoincidences. Besides, the number of unlighted lamps placed in front or between the lighted ones must be smaller than the number lighted lamps. Fig. 2 shows a typical case of scattering of both the protons.

The resolving time of the hodoscopic system was about 2.10^{-6} sec. So the selected stills might contain such events when only in one of the chambers there was observed a track of the scattered proton registered by the control system of scintillation counters and in the second chamber there was observed a track of the accidental particle (which satisfies the conditions of scattering), the time of passing of the latter coinciding with the moment of the selected event 1+2+3+4−5−6 within the time of resolution.

One of the advantages of hodoscope system utilization in the present work consists in the fact that the determination of the probability of arising of background tracks did not require additional time for special measurements and was made according to the number of stills in which more than one track of the scattered proton was observed in the same chamber. (See Fig. 3).

During 100 hours of the accelerator operation 110, 000 stills were obtained. When reading the film, 2608 stills containing tracks of scattered protons in both the chambers (acts of 'triple' scattering) and 443 stills with two tracks of scattered particles in one chamber were found.

The events of triple scattering underwent final treatment which included the test of correspon — dence to the track selection criterion of scattered particles, the registering of the number of lighted neon lamps and the measurement of the scattering angle projection.

These events have been distributed as follows:

$N_{RR} = 687$ $\qquad$ $N_{RL} = 582$

$N_{LL} = 724$ $\qquad$ $N_{LR} = 615$

The average number of the background events per 2608 worked up stills of the triple scattering is $N_{backgr} = 443$. In view of the evenness of the distribution of the background events the correlation coefficient in the distribution of scattered protons have been found to be equal to

$$e' = \frac{N_{RR} + N_{LL} - N_{RL} - N_{LR}}{N_{RR} + N_{LL} + N_{RL} + N_{LR}} = +0.099 \pm 0.023$$

According to the performed calculations false correlation in scattering is due to the geometry of the first scattering,

$$e_f = \pm 0.015 \pm 0.005$$

Hence, the correlation coefficient in the second proton scattering is

$$e = e' - e_f = +0.084 \pm 0.024$$

The coefficient of the spin correlation C_{nn} is connected with the obtained magnitude e by the relation $C_{nn} = \frac{e}{P_1 P_2}$ where P_1 and P_2 are average values of the polarizing abilities of the analysers. According to the conditions of the present experiment $P_1 = P_2$.

Protons of 140 MeV fall upon a graphite analyser. After passing the analyser the average energy of protons is 104 MeV. In order to determine the value of P there were used data from [8] on polarization and the cross section of elastic and inelastic proton scattering on carbon at 135 and 95 MeV. The calculated average value of the polarizing ability of the analyser turned out to be

$P_1 = P_2 = 0.40 \pm 0.05$ and $C_{nn} = 0.52 \pm 0.20$, respectively.*

For more accurate and direct determination of the average polarizing ability a calibration experiment has been undertaken. In this experiment a polyethylene target was installed in the proton beam with an energy of 640MeV and the events of elastic pp-scattering were selected by two telescopes placed at an angle of 26 and 56.5° to the direction of incident protons. Protons registered by the telescope located at 56.5° had the same average energy as in the first experiment. Polarization of those protons is $P_o = 0.32 \pm 0.02$ according to the data of [9]. Observations of asymmetry in the scattering of these pro-

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******In the research presented at the Kiev Conference on High Energy Physics by a Liverpool group of physicists the correlation asymmetry* $e = 0.142 \pm 0.017$ *and the spin correlation coefficient* $C_{nn} = 0.75 \pm 0.11$ *have been obtained by the method of scintillation counters for the same proton energy.*

tons, performed with the help of the hodoscopic chamber, permit to find $P_1 = \frac{e_1}{P_0}$.

According to the first results obtained in the calibration experiment $e_1 = 0.11 \pm 0.02$ and $P_1 = 0.34 \pm 0.06$. This leads to a greater value of the correlation coefficient $C_{nn} = 0.7 \pm 0.3$.

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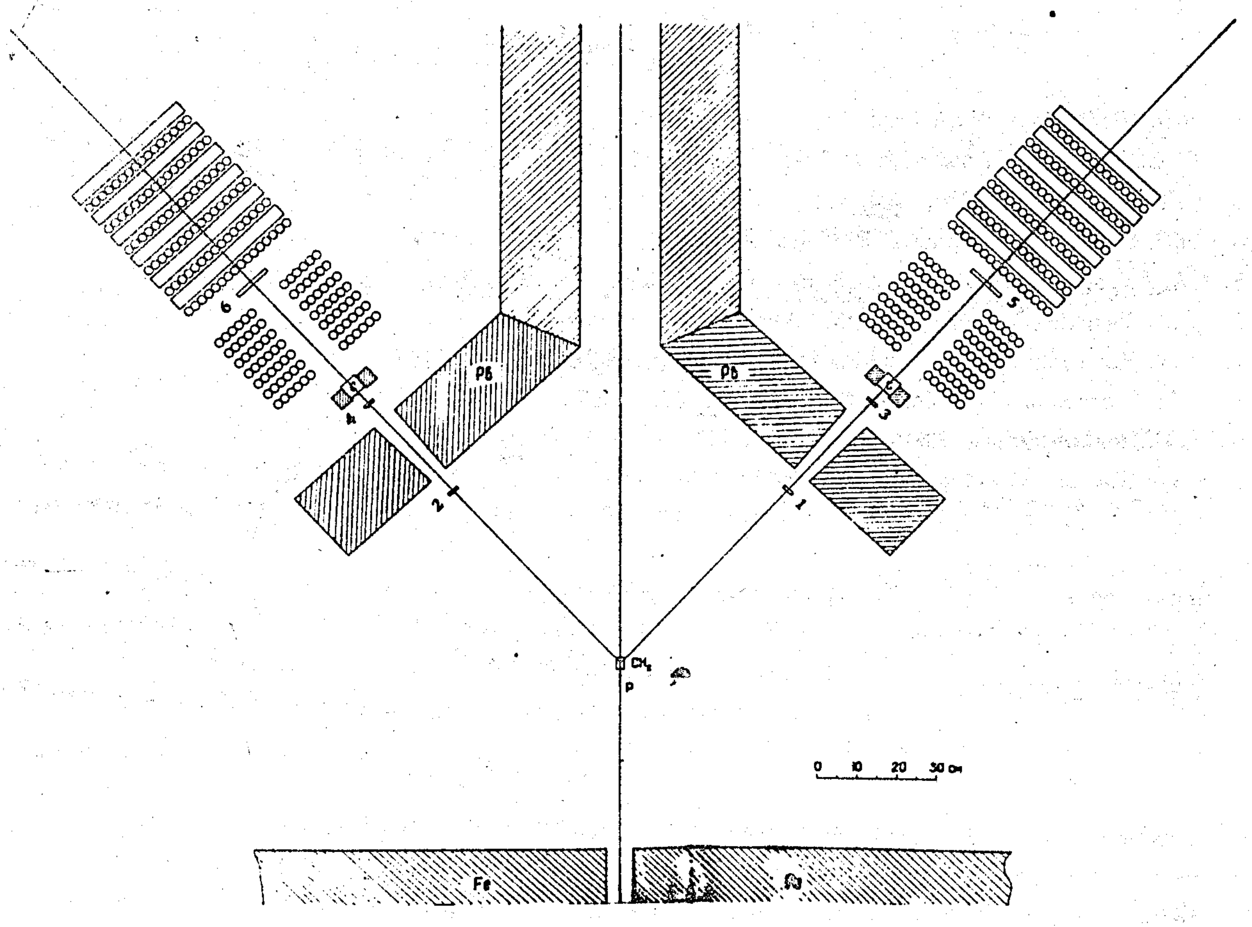
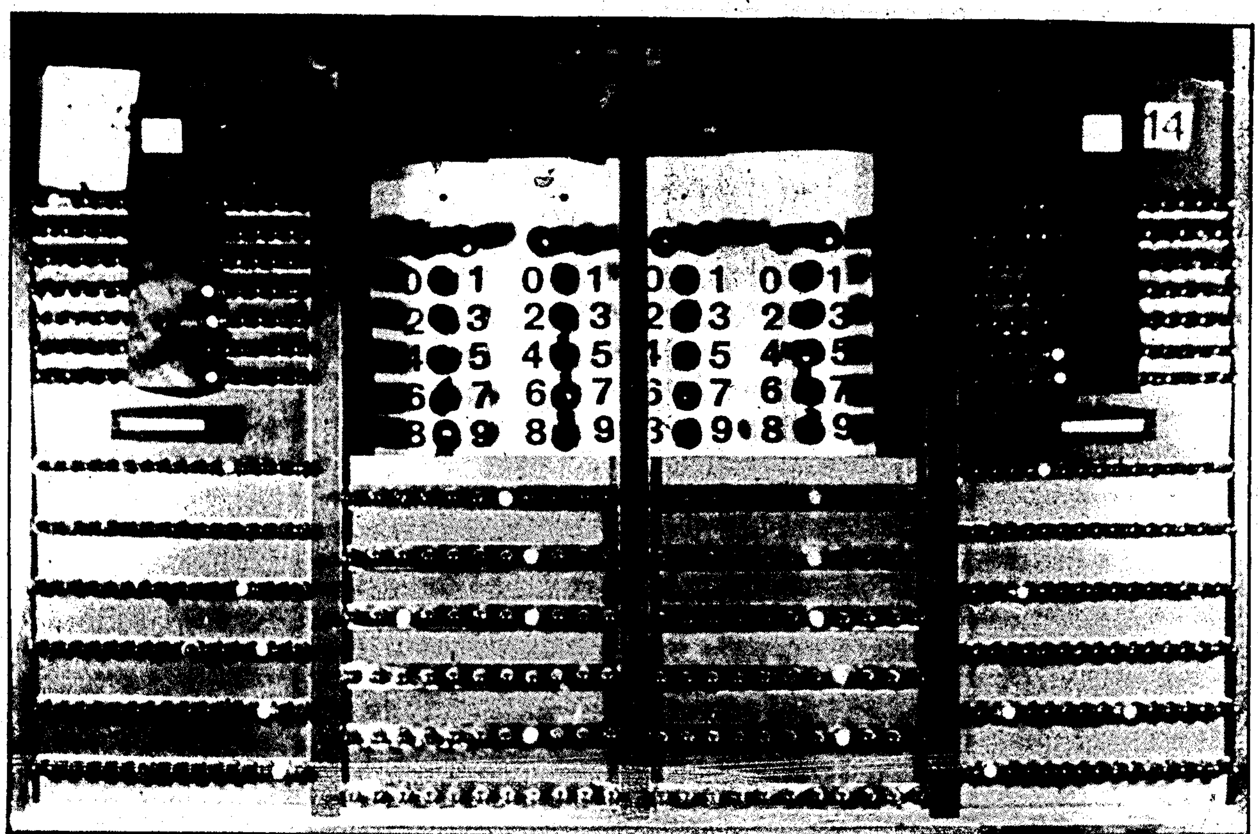


Fig. 1.



1 2 3 4

Fig. 2.

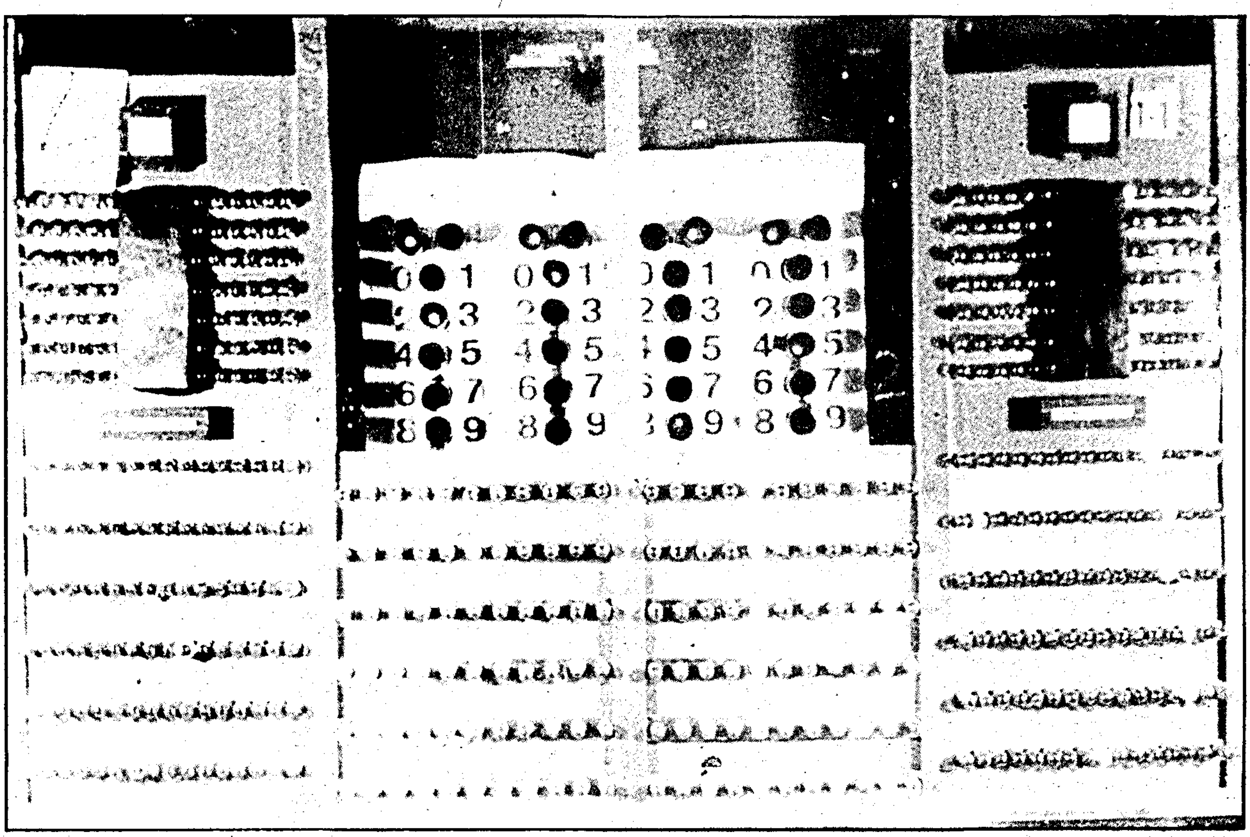


Fig. 3.