УДК 539.171.018 + 539.172.138.12

WHAT SHOULD BE MEASURED IN DEUTERON BREAKUP WITH POLARIZED PROTON TARGET

E.A.Strokovsky

At present, two different approaches are used for interpretation of inclusive data on deuteron breakup with emission of proton-fragments at zero degree by hadrons. According to one of them the observed characteristics of this reaction (cross sections, polarization observables) are determined by the reaction mechanism and the deuteron structure at short distances (in the commonly accepted sense) plays a minor role. According to the other approach it is the deuteron structure at short distances which determines the observed trend of the data. Neither of these approaches can describe the data even qualitatively in the whole investigated region of kinematical variables, having particular success for some narrow region corresponding to long distances. Installation of the polarized proton target at LHE JINR opens an opportunity to perform a rather simple experiment which could discriminate one of these completing approaches. The idea of this experiment is discussed in the present paper. Measurement of the observable suggested here is a particular example of a general problem of a search for spin correlations in inelastic reactions between particles separated well in 4-velocity or rapidity spaces. In our particular case correlations of spin degrees of freedom between particles, one of which is in the target fragmentation region and the other belongs to the projectile fragmentation region, are discussed.

The investigation has been performed at the Laboratory of High Energies, JINR.

Что следует измерить в реакции инклюзивного развала дейтрона поляризованными протонами

Е.А.Строковский

В настоящее время существуют два основных подхода к интерпретации инклюзивных данных о развале дейтрона адронами с вылетом протонов-фрагментов «вперед». Согласно одному из них характеристики этой реакции (сечения и поляризационные наблюдаемые) определяются в первую очередь механизмом реакции, а структура дейтрона на малых расстояниях, понимаемая в общепринятом смысле, играет второстепенную роль. В другом подходе считается, напротив, что именно структура дейтрона на малых расстояниях определяет, в основном, наблюдаемое поведение данных. Ни один из этих подходов не может обеспечить описание данных во всей исследованной области кинематических переменных даже качественно, хотя в обоих достигается неплохое описание данных в некоторой области, отвечающей сравнительно большим расстояниям. Установка поляризованной протонной мишени в ЛВЭ ОИЯИ открывает возможность выполнить сравнительно простой эксперимент, который мог бы дать основу для выбора между этими конкурирующими точками зрения. В данной работе обсуждается идея такого опыта. Измерения наблюдаемой, предложенные в этой работе, представляют собой частный случай общей проблемы поиска корреляций между спинами частиц, хорошо разделенных в пространстве 4-скоростей или быстрот. В частном случае, рассмотренном здесь, обсуждается корреляция между спиновыми степенями свободы частиц, одна из которых принадлежит области фрагментации мишени, а другая — снаряда.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Why an Additional Polarization Observable is Necessary

Reaction $d + (p, A) \to p + X$ of inclusive deuteron breakup when proton is emitted at zero degree with momentum $p > p_d / 2$ is under study about 15 or more years. Here p_d is the momentum of the initial deuteron. Data of high quality are obtained on differential cross sections [1], tensor analysing power T_{20} [2] and spin transfer coefficient κ_0 from the deuteron to the proton-fragment [3]. The main goal of these efforts was to get information about deuteron structure at short distances where its nucleons-constituents can hardly be treated as separate objects and quark-gluon effects should be revealed. Of course, such kind of information can be obtained from experiments with electromagnetic probes as well; a wide-spread belief is that it is the best way. But use of hadron probes has some advantages before electromagnetic ones: apart from higher cross sections disintegration of deuterons by hadrons is sensitive not only to charged (quark) constituents of deuteron but to its gluonic component as well. The expression «deuteron structure» is used here in a commonly accepted sense, i.e., it can be represented in terms of deuteron structure functions or its wave function, which can be found as a solution of some set of equations with boundary conditions corresponding to the problem of the *stable bound system with the deuteron quantum numbers.*

Generally speaking, in the experiments mentioned above the polarization observables were measured in the projectile fragmentation region and correlations of spin degrees of freedom between incident deuteron and its proton-fragment were studied when these particles are more-or-less close to each other in the 4-velocity or rapidity spaces, i.e., the close correlations were studied.

The motivation of experiments on hadro-disintegration of deuteron is based on implicit assumption that the matrix element of this reaction can be factorized on two parts: the one part is determined by deuteron wave function (DWF), the other one describes interaction of the deuteron constituents with target, i.e., represents a particular reaction mechanism. The assumption, or a belief we are talking about, is that the 2nd part of the matrix element, i.e., a particular mechanism of the breakup reaction, has comparatively weak influence on the behaviour of the measurable quantities (the cross sections, polarization observables) which are determined mostly by the DWF. This assumption can be expressed in other words as an assumption of absence of significant spin correlations between target and projectile fragmentation regions when 4-velocity or rapidity spaces are considered. There are evidences in favor of this (see, for examples, Refs. [4,5]). Still, this is not proven neither experimentally nor theoretically so far. Therefore there is no commonly accepted interpretation of the data mentioned above.

According to one point of view, the discrepancies between the data and theoretical model calculations [5] are a signal about necessity to make various modifications of the DWF, according to the others [6], it is the reaction mechanism which is responsible for these discrepancies.

Recently it was shown, that if the DWF has commonly accepted 2-component structure with S and D waves at distances where nucleons can be treated as the separate entities, and if the reaction mechanism does not change the spin state of the detected protons, then the two polarization observables, T_{20} and κ_0 must be related and fill a circle on the $T_{20} - \kappa_0$ plane [7]. The experimental data show that it is not so: at least one of these conditions is not fulfilled [4, 7]. The present state of theory and the experimental data base cannot provide a basis for a definite conclusion which of two possible reasons is responsible for the deviation of the experimental data from theoretical expectations.

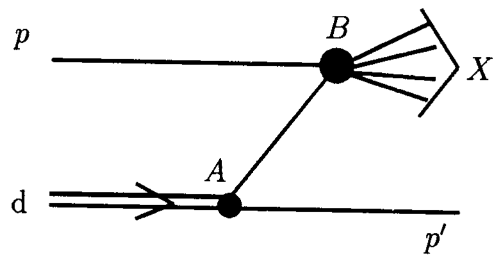

Fig. Inclusive breakup of deuteron in IA-like approximation

In all the experiments on the hadro-disintegration performed so far only unpolarized targets were used. We would like to stress here that the breakup of unpolarized deuterons on *polarized protons* can help much in finding of *definite conclusion* about the relative importance of the reaction mechanism.

Indeed, if one takes the assumption that the reaction mechanism does not change the spin state of the detected proton, i.e., this state is determined by its spin state in the deuteron before it was broken (at distances where it has a sense to talk about spin state of proton in deuteron), then the polarization of protons P_p from breakup of unpolarized deuterons on polarized target must be zero. It is evident from the simplest IA-like graph of the Figure widely used for interpretation of the breakup data. In other words: *there must be no correlation between* P_p *and polarization* P_t *of the target*, i.e., between spin degrees of freedom when one considers particles separated far in the 4-velocity or rapidity spaces. This correlation parameter is denoted here as $K^y_{0,y}$ where lower indices refer to the initial particles (projectile and target) and upper index refers to the detected particle; this notation is constructed in analogy with notations used in Ref. [8] where elastic backward deuteron-proton scattering (BES) was analysed.

On the other hand, if the reaction mechanism does change the spin state of the detected proton, then there *could be sizeable correlation between* P_p *and* P_t . This is evident, for example, if configurations with at least 3 nucleons (2 from deuteron + 1 from target) with relative distances less than ~0.5 Fm in the coordinate space play significant role in the process of the deuteron breakup with emission of a hard proton with momentum $p > p_d/2$.

Therefore the measurement of *the spin transfer from polarized proton target to the proton-fragment*, i.e., $K^y_{0,y}$ in breakup of *unpolarized deuterons* could give an almost definite answer to the key questions: what we are studying in the deuteron breakup: a mechanism of this reaction or the deuteron structure (if they can indeed be disentangled and this question makes sense).

2. Some Details of the Experiment

The experiment can be performed at LHE JINR using Moveable Polarized Proton Target which has been installed in the Laboratory.

In order to reach the main goal formulated above it would be enough to measure $K_{0,y}^{y}$ up to k of 300—400 MeV/c, where large discrepancies are observed between data and almost all theoretical models. Here k is the light-cone variable (see [1, 2, 3, 5] for example). In this kinematical region the breakup cross sections are rather big [1] and problem of particle identification is not so difficult as it was in the previous experiments [2, 3], where data were taken at k close to the kinematical limit.

Because of low content of polarized protons in the target working material used now, it would be better to replace it by irradiated NH_3 which has two main advantages for this experiment:

- all the scattering centers are polarized because the nitrogen nuclei are polarizable as well as protons;
- the upper acceptable level of intensity of the primary beam is much higher with irradiated ammonia.

Another advantage of measuring $K_{0,y}^{y}$ in this experiment (as well as $K_{0,y}^{0,y}$ in BES) in comparison with measurements of κ_0 or spin-spin correlation $C_{y,y}$ in the deuteron breakup or BES [9] is that intensity of unpolarized deuteron beam at the Synchrophasotron or the Nuclotron is much higher than the intensity of polarized deuteron beam. Therefore the data taking rates will be limited by the setup capacity only.

The magnetic spectrometer with momentum resolution of ~0.3—0.5% placed downstream the target must include a proton polarimeter like the POMME polarimeter [10] working at SATURNE or a new polarimeter to be built at LHE.

3. Conclusion

Measurement of the spin transfer coefficient $K_{0,y}^{y}$ from polarized proton target to the hard proton-fragment in reaction of inclusive deuteron breakup at zero degree is suggested to be performed at the extracted beam of unpolarized deuterons of the Synchrophasotron or the Nuclotron. If this coefficient will be small and close to zero up to k ~ 300—400 MeV/c, it will be a strong experimental argument that the breakup of deuteron by hadrons probes the deuteron structure at short distances. If the coefficient $K_{0,y}^{y}$ will deviate significantly from zero at k ~ 300—400 MeV/c, it will be an unambigious argument in favour of alternative approaches like those where reaction mechanism contains strong final state interaction and intermediate isobars and mesons play a decisive role or those where some system of 9 quarks or 3 correlated nucleons appears in the intermediate state.

Of course, other possible spin observables should be examined (first of all theoretically) as well: the coefficient of tensor-to-vector spin transfer from tensorially polarized deuteron to proton and the triple spin correlations (polarized deuteron, polarized target proton and polarized final proton-fragment). Some of them could be unsignificant within IA-like models where graphs like on the Figure are dominant, but could be essentially non-zero in alternative approaches.

In our particular case a particular correlation of spin degrees of freedom between particles belogning to target and projectile fragmentation regions was discussed. In this sense the measurements of observable suggested here give *a particular example of more general problem of a search for spin correlations in inelastic reactions between particles separated well in 4-velocity or rapidity spaces.*

Acknowledgments

The author is grateful to A.P.Kobushkin for his stimulating interest and useful discussions of the topics considered in this paper.

The work was financially supported in part by grant №RFU000 of the International Science Foundation.

References

1. Ableev V.G. et al. — Pis'ma ZhETF, 1983, 37, p.196; Nucl. Phys., 1983, A393, p.491, A411, 541 (E); Pis'ma ZhETF, 1987, 45, p.467; JINR Rapid Comm. 1[52]-92, Dubna, 1992, 10; Few Body Systems, 1990, 8, p.137;
   Perdrisat C.F. et al. — Phys. Rev. Lett., 1987, 59, p.2840;
   Punjabi V. et al. — Phys. Rev., 1989, C39, p.608.
2. Punjabi V. et al. — Phys. Rev., 1989, C39, p.608;
   Ableev V.G. et al. —Pis'ma ZhETF, 1988, 47, p.558; JINR Rapid Comm. 4[43]-90, Dubna, 1990, p.5.
3. Cheung E et al. — Phys. Lett., 1992, B284, p.210;
   Atanasov I et al. — Proc. of the 10-th Internat. Symp. on High Energy Spin Physics, Nov. 9—14, 1992, Nagoya, ed. by Hasegawa T., Horikawa H., Masaike A., Sawada S., Univ. Acad. Press, Inc., Tokyo, p.537;
   Kuehn B. et al. — Phys. Lett., 1994, B334, p.298;
   Nomofilov A.A. et al. — Phys. Lett., 1994, B325, p.327.
4. Azhgirey L.S. et al. — 14th Intern. IUPAP Conf. on Few Body Problems in Phys., May 26—31, 1994, ed. by Franz Gross, Williamsburg, 1994, p.18; ibid p.22; and references therein; see also Refs [5, 7].
5. Kobushkin A.P., Shelest V.P. — Physics of Elementary Particles and Atomic Nuclei, 1983, 14, p.1146;
   Kobushkin A.P. — Proceedings of the International Symposium «Dubna — Deuteron-93», Dubna, Sept. 14—18, 1993, JINR, E2-94-95, Dubna, 1994, p.71;
   Perdrisat C.F., Punjabi V. — Phys. Rev., 1990, C42, p.608;
   Kobushkin A.P. — J. Phys. G: Nucl. Phys., 1986, 12, p.487;

Perdrisat C.F., Punjabi V. — Proceedings of the XI Internat. Seminar on High Energy Physics Problems, Sept. 7—12 1992, Dubna, p.491, ed. by Baldin A.M., Burov V.V., Dubna, 1994.

6. Lykasov G.I., Dolidze M.G. — Z. Phys., 1990, A336, p.339;
   Lykasov G.I. — Physics of Elementary Particles and Atomic Nuclei, 1993, 24, p.140;
   Dorodnykh Yu.L., Lykasov G.I. — Proceedings of the International Symposium «Dubna — Deuteron-93», Dubna, Sept. 14—18, 1993, JINR, E2-94-95, Dubna, 1994, p.83.
7. Kuehn B., Perdrisat C., Strokovsky E.A. — Proceedings of the International Symposium «Dubna — Deuteron-93», Dubna, Sept. 14—18, 1993, JINR, E2-94-95, Dubna, 1994, p.31; JINR Preprint E1-95-7, Dubna, 1995.
8. Kobushkin A.P. et al. — Phys. Rev., 1994, C50, p.2627.
9. Sitnik I.M., Ladygin V.P., Rekalo M.P. — Yad. Fiz., 1994, 57, p.2170.
10. Bonin B. et al. — NIM in Phys. Rev., 1990, A228, p.379.

Received on March 13, 1995.