Zeitschrift: Helvetica Physica Acta

Band: 34 (1961)

Heft: [6]: Supplementum 6. Proceedings of the International Symposium on polarization phenomena of nucleons

Artikel: Nucleon-nucleon polarization experiments

Autor: Phillips, R.J.N

DOI: https://doi.org/10.5169/seals-541276

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Siehe Rechtliche Hinweise.

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. Voir Informations légales.

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. See Legal notice.

Download PDF: 16.03.2025

ETH-Bibliothek Zürich, E-Periodica, https://www.e-periodica.ch

Nucleon-Nucleon Polarization Experiments[1])

By R. J. N. PHILLIPS, A. E. R. E., Harwell

Abstract. Some simple considerations on the set of all possible measurements are given. At any scattering angle there are essentially twenty-five linearly independent measurements (though only nine can be wholly independent), of which only two require a polarized target.

Introduction

Many kinds of polarization experiment have been described and discussed in the literature (e.g. refs [1–6][2]) and references therein). We present here some general considerations on the set of all possible measurements at a given scattering angle.

The scattering amplitude for two given nucleons at a given angle is a matrix M in spin space. Assuming parity conservation, time-reversal invariance and charge-symmetry (for the n–p case), it has the form

$$M = a + i\,c\,(\sigma_N^{(1)} + \sigma_N^{(2)}) + m\,\sigma_N^{(1)}\,\sigma_N^{(2)} + (g+h)\,\sigma_P^{(1)}\,\sigma_P^{(2)} + (g-h)\,\sigma_K^{(1)}\,\sigma_K^{(2)}\,. \quad (1)$$

$\boldsymbol{\sigma}^{(1)}$ and $\boldsymbol{\sigma}^{(2)}$ are the nucleon spin operators. $\boldsymbol{N}, \boldsymbol{P}$ and $\boldsymbol{K}$ are unit vectors in the directions $\boldsymbol{k}_i \times \boldsymbol{k}_f$, $\boldsymbol{k}_i + \boldsymbol{k}_f$ and $\boldsymbol{k}_f - \boldsymbol{k}_i$, where $\boldsymbol{k}_i$ and $\boldsymbol{k}_f$ are initial and final relative momenta. σ_N denotes $\boldsymbol{\sigma} \cdot \boldsymbol{N}$, etc. The complex coefficients a, c, m, g and h are functions of energy and angle. This notation follows STAPP [3].

Polarization experiments essentially measure the quantities

$$\text{trace } M\,X\,M^*\,Y \quad (2)$$

(apart from a possible divisor trace $M\,M^*$), where X and Y are the density matrix for incident polarization and the efficiency matrix for analyzing final polarization, respectively. In general X and Y contain several terms, but for a given experiment it is instructive to consider only the contribution not given by simpler experiments. These characteristic terms are shown schematically below.

---

1) A more detailed account of this work is given in ref. [1].

2) Numbers in brackets refer to References, page 431.

Incident polarization \ Analysis	Cross section	One polarization	Both polarizations
None	tr MM^*	tr $MM^*\sigma$	tr $MM^*\sigma\sigma$
One nucleon	tr $M\sigma M^*$	tr $M\sigma M^*\sigma$	tr $M\sigma M^*\sigma\sigma$
Both nucleons . . .	tr $M\sigma\sigma M^*$	tr $M\sigma\sigma M^*\sigma$	tr $M\sigma\sigma M^*\sigma\sigma$

Linearly Independent Measurements

These characteristic terms are linear combination of the twenty-five quantities $|a|^2$, $Re\ ac^*$, $Im\ ac^*$, etc. However, at most nine[3]) can be wholly independent, for there are only five independent complex coefficients a, c, etc., and their overall phase does not enter. On the other hand, nine measurements will not in general fix M uniquely. To resolve algebraic ambiguities, further *linearly independent* data are needed (which would also be a useful check on the experiments). Hence there is special interest in measurements which, though not fully independent, are at least linearly independent of each other.

We list the number of linearly independent data contributed by each type of experiment. Details of the characteristic terms themselves may be found in references [1] and [6] (there are a few typographical errors in the latter). For identical nucleons, a measurement at scattering angle Θ is equivalent to some measurement at $\pi-\Theta$; also the values of M at these angles are related. Hence both angles must be considered together, when counting measurements.

(i) tr $M M^*$. One measurement.

(ii) tr $M \sigma M^*$ or tr $M M^* \sigma$, (these two are related by time-reversal arguments). One measurement.

(iii) tr $M \sigma M^* \sigma$. Eight linearly independent measurements: four from analyzing the «scattered» nucleon, four from the «recoil» nucleon. With identical nucleons, these are related by $\Theta \to \pi - \Theta$, but we still count eight measurements: see above. (Incidentally, (i)–(iii) contain nine fully independent data).

(iv) tr $M M^* \sigma \sigma$ or tr $M \sigma \sigma M^*$, (related by time-reversal). Four linearly independent measurements.

---

[3]) When inelastic processes can be ignored, and measurements are made at all angles, unitarity imposes further integral constraints [6]. An appeal to charge independence may also be helpful [7]. Our remarks apply to the general case.

(v) tr $M\,\sigma\,M^*\,\sigma\,\sigma$ or tr $M\,\sigma\,\sigma\,M^*\,\sigma$, (related by time-reversal). Ten measurements, but only nine are linearly independent of (i)–(iv).

(vi) tr $M\,\sigma\,\sigma\,M^*\,\sigma\,\sigma$. Fifteen measurements, but only two are linearly independent of (i)–(v).

Conclusion

Although there are at most nine fully independent measurements at a given angle, further *linearly* independent data will generally be needed to resolve ambiguities in M. (They would also check the internal consistency of experiments, against systematic errors).

There are altogether twenty-five linearly independent measurements.

Experiments of types (i)–(iv), (up to triple-scattering and spin correlation experiments), provide fourteen linearly independent data, which should be more than enough (indeed, (i)–(iii) might suffice). Types (v) and (vi) would then be unnecessary.

In particular, a polarized target should not be necessary[4]). Type (vi) are the only measurements that definitely require one.

REFERENCES

[1] R. J. N. Phillips, Harwell report AERE-R3141 (1960).
[2] L. Wolfenstein, Ann. Rev. Nucl. Sci. *6*, 43 (1956).
[3] H. P. Stapp, California thesis, UCRL-3098 (1955).
[4] R. J. N. Phillips, Rep. Progr. Phys. *22*, 562 (1959).
[5] J. L. Gammel and R. M. Thaler, Progress in Elementary Particle and Cosmic Ray Physics *5*, 99 (1960).
[6] L. Puzikov, R. Ryndin, and J. Smorodinsky, Nucl. Phys. *3*, 436 (1957).
[7] B. M. Golovin, V. P. Dzhelepov, V. S. Nadezhdin and V. I. Satarov, Zh. eksper. teor. Fiz. *36*, 433: see Soviet Physics – J.E.T.P., *36*, 302 (1959).

[4]) This does not mean that such a target would not be useful in performing more familiar measurements.