MEMO CP-C/75

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Subject: Polarization

Attached is a proposal for a new LEXFOR entry on polarization.

Following are the dictionary entries which would be needed.

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ATOMIC	(ATOMIC BEAM SOURCE)
LAMB	(LAMB-SHIFT SOURCE)
POLTR	(POLARIZED TARGET)
VECTR	(VECTOR) for polarization
TENSR	(TENSR) for polarization

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POL-BM	BEAM POLARIZATION
POL-TR	TARGET POLARIZATION
COORD-1	COORDINATE 1
COORD-2	COORDINATE 2

Dictionary 32 (Parameter)

FM	(POLARIZATION * CS)
FM2	(POLARIZATION * CS-SQ)

Dictionary 34 (Modifier)

ANA	(ANALYZING POWER)
VEC	(VECTOR)
TEN	(TENSOR)
SPH	(SPHERICAL COORDINATES)

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Polarization

Theory

Under the influence of a spin-orbit force, an unpolarized beam of particles becomes at least partially polarized (i.e., the particles acquire a preferred spin).

The inverse of this situation is the asymmetric scattering of a polarized beam of particles. The degree of polarization of such a beam may be determined by measuring the left-right asymmetry upon scattering from a target nucleus which plays the role of an Analyzer.

The asymmetry (ε) is defined as:

$$\varepsilon(E,\theta) = \frac{L-R}{L-R} = P(1)\cdot P(2)$$

where: P(1) = Polarization of incident particle
P(2) = Analyzing power of scatterer
R,L = Intensity of the particles scattered right and left in the same plane under the same angle.

The principle of Polarization-Asymmetry Equality states that, for time-reversal invariant reactions, the polarization induced in a previously completely unpolarized beam by elastic scattering from spin-zero nuclei is identically equal to the asymmetry ensuing from the scattering of a perfectly polarized beam under the same conditions.

Definitions

1. Basel Convention for spin-1/2 Particles

   In nuclear interactions the positive polarization of particles with spin 1/2 is taken in the direction of the vector product k(i) X k(o), where k(i) and k(o) are circular wave vectors of the incoming and outgoing particles respectively.

   See Reference 1 for more detail.

2. Madison Convention for spin-one particles

1. Polarization effects involving spin-one particles should be described by:

   either Spherical tensor operators τ (kq), with normalization given by:

   $$\mathrm{Tr}\left\{ \tau((kq)\tau^{\dagger}(k'q') \right\} = 3\delta(kk')\delta(qq')$$

   or Cartesian operators S(i),(3/2)(S(i)S(j)+(S(j)S(i))-2δ(ij);i=x,y,z

   S(i) denotes the usual spin-one angular momentum operators.

   See Reference 4 for spherical coordinates; see Reference 5 for Cartesian coordinates.

2. The state of spin orientation of an assembly of particles, referred to as polarization, should be denoted by the symbols t(kq) (spherical) or p(i),p(ij) (Cartesian). These quantities should be referred to a right-handed coordinate system in which the positive z-axis is along the direction of momentum of the particles, and the positive y-axis is along k(i) X k(o) for the nuclear reaction which the polarized particles initiate, or from which they emerge.

3. Terms used to describe the effect of initial polarization of a beam or target on the differential cross section for a nuclear reaction should include the modifiers analyzing or efficiency, denoted by T(kq) (spherical) or A(i),A(ij) (Cartesian). These quantities should be referred to a right-handed coordinate system in which the positive z-axis is along the beam direction of the incident particles and the y-axis is along k(i) X k(o) for the reaction in question.

4. In the expression for a nuclear reaction A(b,c)D, an arrow placed over the symbol denotes a particle which is initially in a polarized state or whose state of polarization is measured.

   Example: $A(b,\vec{c})D$; polarization is measured for a particle c emerging from a reaction between unpolarized particles A and b.

See Reference 2 for more details.

An attempt was made to extend this convention at Zurich in 1975 (see Reference 3) to cover polarization-transfer and Spin-correlation coefficients. However, this proposal, which was not submitted to the I.U.P.A.P., differed, to some extent, with the nomenclature of the "Madison" Convention and was not generally accepted at the Zurich meeting. Therefore, only the "Madison" Convention will be used, recognizing that there is a deficiency in the description of such coefficients.

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3. Figure of Merit

In many polarization or analyzing power experiments, an experimentalist will also deduce a "figure of merit" related to the time required to perform an experiment. These figures of merit are given either in terms of $P(E,\theta)\sigma(E,\theta)$ or in terms of $P(E,\theta)\sigma^2(E,\theta)$. The latter is directly related to the inverse of the time required. These figures of merit is usually expressed in terms of expansions in $\sin^2(\theta)$ or expansions in terms of associated Legendre polynomials of the first kind.

See Fitting Coefficients for additional details.

References

1. "Proceedings of the International Symposium on Polarization Phenomena of Nucleons", P.Huber and K.P.Meyer, eds. Helvetica Phys.Acta, Suppl. VI (1961)

2. "Polarization Phenomena in Nuclear Reactions", page XXV, H.H.Barschall and W.Haeberli, eds. The University of Wisconsin Press, Madison (1971)

3. "Procedings of the Fourth International Symposium on Polarization Phenomena in Nuclear Reactions", W.Gruebler and V.Koenig. Experentia Supplememtum, 25 (1975)

4. W.Larkin, Phys. Rev. 98, 139 (1955)

5. L.J.B.Goldfarb, Nuclear Phys. 7, 622 (1958)

6. A.Simon, Phys. Rev. 92, 1050 (1953)

7. "Physics of Nuclei and Particles", Vol. II, Ch. 13, P.Marmier and E.Sheldon, Academic Press, 1970.

Coding

The sign should follow the "Basel" or "Madison" Convention.

The following quantities are coded in EXFOR:

1. The spin-polarization probability, integrated over all pertinent angles is coded with 'POL' in REACTION SF6.

2. The differential spin-polarization probability with respect to angle of emmission is coded with 'POL/DA' in REACTION SF6.

3. The differential spin-polarization probability with respect to energy of emitted particles is coded with 'POL/DE' in REACTION SF6.

4. The differential spin-polarization probability with respect to angle and energy of the emitted particle is coded with 'POL/DA/DE' in REACTION SF6.

5. The figure of merit is coded with 'FM/DA' or 'FM2/DA' in REACTION SF6.

6. The "assymmetry", or the product of beam polarization and analyzer or source polarization power, is coded with 'POL' in REACTION SF6 and 'ASY' in SF8.

7. The analyzing power, or efficiency of an initial polarization of beam or target, is coded with 'POL' in REACTION SF6 and 'ANA' in SF8.

If spherical coordinates are used the modifier 'SPH' should be coded in SF8. Cartesian coordinates require no modifier.

Polarized incident-projectile source

Entries should be made under the Information-Identifier Keyword N-SOURCE for the following cases:

1. A polarized neutron Source is entered using the code 'POLNS'.

2. A polarized target is entered using the code 'POLTR'.

3. An atomic beam source is entered using the code 'ATOMIC'.

4. A Lamb-shift source is entered using the code 'LAMB'.

The incident-projectile source shpuld be coded in sufficient detail to describe the reaction. The polarization of the beam and target should be given in the data table, if known, using the data headings POL-BM and POL-TR, respectively.

Example: N-SOURCE (POLTR,LAMB) Polarized target and Lamb-shift ion source