

NATIONAL NUCLEAR DATA CENTER
Bldg. 197D
Brookhaven National Laboratory
P. O. Box 5000
Upton, NY 11973-5000 U.S.A.

(Internet) "NNDC@BNL.GOV"
(Hepnet) BNL::NNDC

Telephone: (516)344-2902
FAX: (516)344-2806

Memo CP-C/228

DATE: April 22, 1997
TO: Distribution
FROM: V.McLane *ym*
SUBJECT: Polarization: Dictionary additions, LEXFOR writeup.

Attached is the proposed new LEXFOR entry for polarization.

The following is a list of codes associated with polarization. I have included codes from memo CP-C/222 for the sake of completeness.

Add to Dictionary 24 (Data headings)

KQ Indicis for tensor analyzing power

Add to Dictionary 31 (Branch)

LL Beam and target spins parallel to beam direction in scattering plane (= zz)
LON Longitudinally polarized
LS Target spin perpendicular, to beam direction in scattering plane
NN Beam and target spins normal to scattering plane (= yy)
SL Beam spin perpendicular, target spin parallel, to beam direction in scattering plane
SS Target and beam spins perpendicular to beam
TRS Transversely polarized

Modify in Dictionary 34 (Modifiers)

ANA Vector analyzing power, A(y), for incident beam
AYY Tensor analyzing power, incident projectile spin normal to scattering plane
AZZ Tensor analyzing power, incident projectile spin parallel to beam direction in scattering plane

Distribution:

M. Chiba, Sapporo
F. E. Chukreev, CaJaD
K. Kato, JCPDG
V. N. Manokhin, CJD
O. Schwerer, NDS
NNDC (3)

F. T. Tárkányi, Debrecen
N. Tubbs, NEADB
Y. Tendow, RIKEN
V. Varlamov, CDFE
Zhang Zingshang, CNDC

cc: Arcilla
Lammer
Muir
Oblozinsky
Schwerer
Wienke

Add to Dictionary 34 (Modifiers)

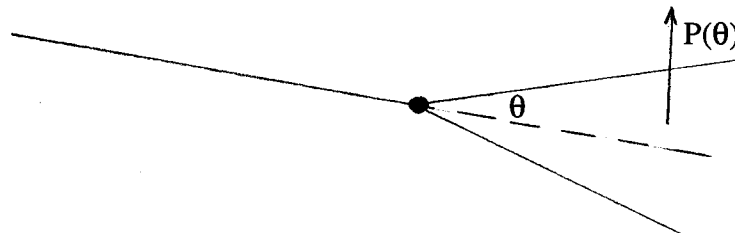
C	Spin-Correlation Parameter
DSP	Difference for spins parallel - antiparallel
K	Spin-Transfer Parameter
SF	Spin Flip
SS	Difference for spins parallel - antiparallel
TAP	Tensor analyzing power, spherical coordinates
VAP	Vector analyzing power, spherical coordinates

Add to Dictionary 36 (Quantities)

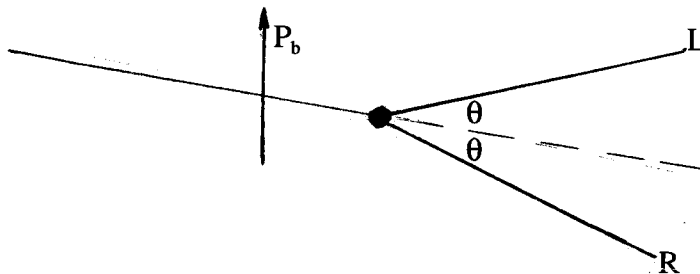
,POL/DA,,ANA	Normal analyzing power, A(y)
,POL/DA,,SF	Spin-flip probability, S(nn)
,POL/DA,,TAP	Tensor analyzing power, T(kq), spherical coordinates
,POL/DA,,VAP	Tensor analyzing power, iT(11), spherical coordinates
,SIG,,SF	Spin-flip cross section
LL,POL/DA,,C	Spin correlation function, C(LL)
LL,POL/DA,,K	Spin-transfer parameter, K(LL)
LL/PAR,POL/DA,,K	Spin-transfer parameter, K(LL), partl reaction
LON,SIG,,DSP	Cross section difference, longitudinal spins, parallel - anti parallel
LS,POL/DA,,C	Spin correl. function, C(LS)
LS,POL/DA,,K	Spin-transfer parameter, K(LS)
LS/PAR,POL/DA,,K	Spin-transfer parameter, K(LS), partl reaction
NN,POL/DA,,C	Spin correl. function, C(NN)
NN,POL/DA,,K	Spin-transfer parameter, K(NN)
NN/PAR,POL/DA,,K	Spin-transfer parameter, K(NN), partl reaction
NN/PAR,POL/DA,RCL,K	Spin-transfer param,recoil nucl, K(NN), partl reaction
PAR,POL/DA,,TAP	Tensor analyzing power, T(kq) for partial reaction, spherical coord.
PAR,POL/DA,,VAP	Tensor analyzing power, iT(11) for partial reaction, spherical coord.
SL,POL/DA,,C	Spin correl. function, C(SL)
SL,POL/DA,,K	Spin-transfer parameter, K(SL)
SL/PAR,POL/DA,,K	Spin-transfer parameter, K(SL), partl reaction
SS,POL/DA,,C	Spin correlation function, C(SS)
SS,POL/DA,,K	Spin-transfer parameter, K(SS)
SS/PAR,POL/DA,,K	Spin-transfer parameter, K(SS), partl reaction
TRS,POL/DA,,ANA	Transverse vector analyzing power, A(x)
TRS,SIG,,DSP	Cross section difference, transverse spins, parallel - anti parallel

Polarization

Under the influence of a spin-orbit force, an unpolarized beam of particles becomes at least partially polarized upon scattering from a target.



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.



Conventions

All terms are given following the Madison Convention [2]. The following conventions are used.

1. In the expression for a nuclear reaction $A(b,c)D$, an arrow placed over the symbol denotes a particle in a polarized state.

Example: $A(\vec{b},\vec{c})D$

2. The following notations are used to describe polarization and analyzing power.

Coordinate system	Polarization	Analyzing Power
Spherical	t_{kq}	T_{kq} $ q \leq k$
Cartesian	P_i, P_{ij}	A_i, A_{ij} $i, j = x, y, z$

3. Polarization is referred to a right-handed coordinate system in which the positive z-axis is along the direction of momentum of the incident particles, and the positive y-axis along $\vec{k}_{in} \times \vec{k}_{out}$ (scattering plane).
4. Analyzing power is referred to a right-handed coordinate system in which the positive z-axis is along the direction of of the incident beam (\vec{k}_{in}), and the positive y-axis along $\vec{k}_{in} \times \vec{k}_{out}$.

POLARIZATION

Quantities given in Cartesian Coordinates

The following subscripts are defined:

b refers to the incident beam polarization

t refers to the target polarization

$N = y$ = normal to the scattering plane

$L = z$ = longitudinal, *i.e.*, parallel to beam direction in scattering plane

$S = x = N \times L$ (sideways), *i.e.*, perpendicular to beam direction in scattering plane

\uparrow = spin up

\downarrow = spin down

Y is the normalized yield

σ_0 = differential cross section for an unpolarized (spin-averaged) beam

The differential cross section for a reaction initiated by a beam of particles with spin-1 may be written as

$$\sigma = \sigma_0 \left[1 + \frac{3}{2} p_y A_y + \frac{1}{2} p_{zz} A_{zz} + \frac{2}{3} (p_{xz} A_{xz} + \frac{1}{6} (p_{xx} - p_{yy}) (A_{xx} - A_{yy})) \right]$$

Polarization: $A(b, \vec{c})D$

$P(\theta)$, the polarization of the outgoing particle beam as a function of angle.

$$\sigma_p = \sigma_0 P(\theta)$$

REACTION Coding: , POL/DA

Asymmetry: $A(\vec{b}, c)D$

$$\epsilon = \frac{L-R}{L+R} = P_b A_y$$

where ϵ = left-right asymmetry

P_b = incident beam polarization

A_y = analyzing power of target

L, R = intensity of particles scattered left and right in the same plane under the same angle.

A_y , the difference in the number of particles scattered to the right and to the left in the reaction plane.

REACTION Coding: , POL/DA, , ASY

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 a spin-zero nucleus is identically equal to the asymmetry ensuing from the scattering of a perfectly polarized beam under the same conditions.

POLARIZATION

For polarized beam:

$$\epsilon_b = \frac{Y_{11}^- - Y_{11}^+ + Y_{11}^- - Y_{11}^+}{Y_{11}^+ + Y_{11}^- + Y_{11}^+ + Y_{11}^-}$$

For polarized target:

$$\epsilon_t = \frac{Y_{11}^- - Y_{11}^- - Y_{11}^+ + Y_{11}^+}{Y_{11}^+ + Y_{11}^- + Y_{11}^+ + Y_{11}^-}$$

Polarized beam and target (spin-correlation asymmetry):

$$\epsilon_{bt} = \frac{Y_{11}^+ + Y_{11}^- - Y_{11}^- - Y_{11}^+}{Y_{11}^+ + Y_{11}^- + Y_{11}^+ + Y_{11}^-}$$

Analyzing Power: relative difference in cross sections for the corresponding spin up vs. spin down.

Vector Analyzing Power:

$$A_y = \frac{\epsilon}{P_b P_t}$$

REACTION Coding Examples:

, POL/DA, , ANA	A_{y0} , incident projectile analyzing power, unpolarized target, incident projectile spin normal to scattering plane
, POL/DA, *, ANA	A_{0y} , target analyzing power, unpolarized target, incident projectile spin normal to scattering plane, where * refers to the nuclide code (e.g., 6-C-12).

Tensor Analyzing Power: A_{ij}

REACTION Coding Examples:

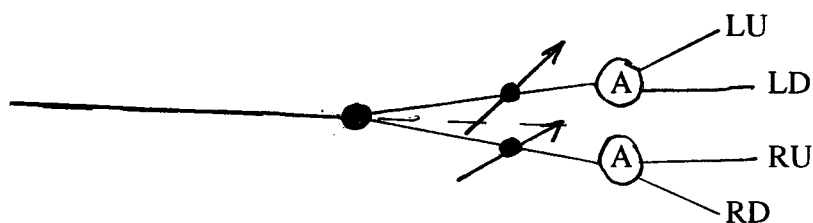
, POL/DA, , AYY	A_{yy} , Tensor analyzing power, incident projectile spin normal to scattering plane
-----------------	--

Spin-Correlation Parameter: $\vec{A}(\vec{b}, \vec{c})\vec{D}$ and $A(\vec{b}, \vec{c})\vec{D}$; cross section is measured.

$$C_{it} = \frac{d\sigma/d\Omega_{11}^+ + d\sigma/d\Omega_{11}^- - d\sigma/d\Omega_{11}^- - d\sigma/d\Omega_{11}^+}{d\sigma/d\Omega_{11}^+ + d\sigma/d\Omega_{11}^- + d\sigma/d\Omega_{11}^- + d\sigma/d\Omega_{11}^+} = \frac{1}{P_t P_b} \frac{Y_{11}^+ + Y_{11}^- - Y_{11}^- - Y_{11}^+}{Y_{11}^+ + Y_{11}^- + Y_{11}^- + Y_{11}^+}$$

where i refers to the i^{th} component of the incident beam.

POLARIZATION



REACTION Coding Example:

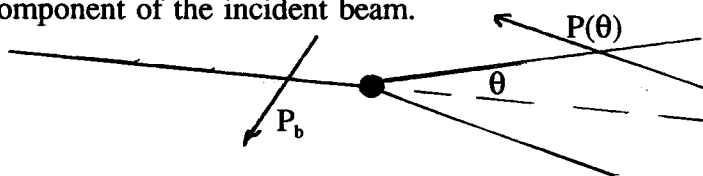
NN, POL/DA, , C

C_{NN} , polarized target and beam; target and beam spins parallel to beam direction in scattering plane; outgoing particles scattered right and left analyzed¹.

Spin-Transfer Parameter: $A(\vec{b}, \vec{c})D$; polarization is measured².

$$K_{it} = \frac{P_t}{B_i}$$

where B_i is the i component of the incident beam.



K_{LS} (D_{LS}) is sometimes referred to as the Spin Rotation Function (SRF or Q).

$$K_{LS} = \sqrt{1-A_y^2} \sin\beta$$

where β is the spin rotation angle

REACTION Coding Example:

NN, POL/DA, , K

K_{NN} , spin transfer parameter, target and beam spins normal to scattering plane

Spin-Flip Probability (S_{nn}) is related to the Spin-Transfer Parameter by:

$$S_{nn} = \frac{1}{2} (1 - K_{nn})$$

REACTION Coding: POL/DA, , SF

¹ Sometimes referred to as A_{YY} .

² Sometimes referred to as the Spin-Rotation Parameter, D_{ij} .

POLARIZATION

Quantities given in Spherical Coordinates

The following subscripts are defined:

k refers to rank

q refers to projection

The differential cross section for a reaction initiated by a beam with tensor components t_{kq} is given by

$$\sigma = \sigma_0 \left(\sum_{k,q} t_{kq} T_{kq}^* \right)$$

where σ_0 is the cross section for unpolarized particles.

The definitions given, following, refer to spin-1 particles.

If parity is conserved, $T_{10} = 0$, T_{11} = pure imaginary, and T_{2q} = pure real, the cross section may be written as

$$\sigma = \sigma_0 [1 + 2i T_{11} \text{Re}(it_{11}) + T_{20} t_{20} + 2T_{21} \text{Re}(t_{21}) + 2T_{22} \text{Re}(t_{22})]$$

Analyzing Power

Vector Analyzing Power, iT_{11} .

REACTION Coding: , , POL/DA , , VAP

Tensor Analyzing Power, T_{20} , T_{21} , T_{22} .

REACTION Coding: TAP in REACTION SF3, T_{kq}

k and q given under data heading KQ with units NO-DIM.

Coding Example:

REACTION (6-C-12(3-LI-6,EL)6-C-12, , POL/DA , , TAP)

```
-----  
DATA  
KQ          ANG          DATA          DATA-ERR  
NO-DIM      ADEG         NO-DIM         NO-DIM  
20.          10.0          0.XXXX         0.XXXX  
20.          20.0          0.XXXX         0.XXXX  
20.          30.0          0.XXXX         0.XXXX  
21.          10.0          0.XXXX         0.XXXX  
21.          20.0          0.XXXX         0.XXXX  
21.          30.0          0.XXXX         0.XXXX  
-----
```

ENDDATA