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EXTREME VALUES OF THE ANALYZING POWER FOR SPIN-1 POLARIZATION

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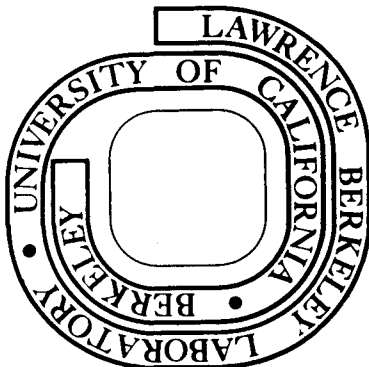
F. Seiler, F. N. Rad, and H. E. Conzett

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## EXTREME VALUES OF THE ANALYZING POWER FOR SPIN-1 POLARIZATION\*

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The large experimental values of the components  $A_y$  and  $A_{yy}$  of the analyzing power for deuterons in several processes suggest the possibility of extreme values  $A_y = \pm 1$  and  $A_{yy} = 1$ . Criteria to judge maximum possible polarization states for an ensemble of polarized spin-1 particles produced in a nuclear reaction have been given by Lakin<sup>1)</sup> and Minnaert<sup>2)</sup>. They are based on the fact that the density matrix is positive semidefinite. Its expansion in terms of tensor operators  $T_{kq}$  imposes conditions on the tensor moments  $t_{kq}$ . Due to time reversal invariance, identical limitations apply for the polarization efficiencies  $T_{kq}$ . They are particularly simple in a transverse coordinate system  $S'$  with the  $z'$ -axis perpendicular to the reaction plane.

$$\delta^2 = \frac{1}{2} [(T'_{10})^2 + (T'_{20})^2 + 2|T'_{22}|^2] \leq 1. \quad (1)$$

$$\epsilon^2 = (T'_{20} + \sqrt{2})^2 - 3(T'_{10})^2 - 6|T'_{22}|^2 \geq 0. \quad (2)$$

The observables  $T'_{kq}$  in terms of those defined by the Madison Convention are

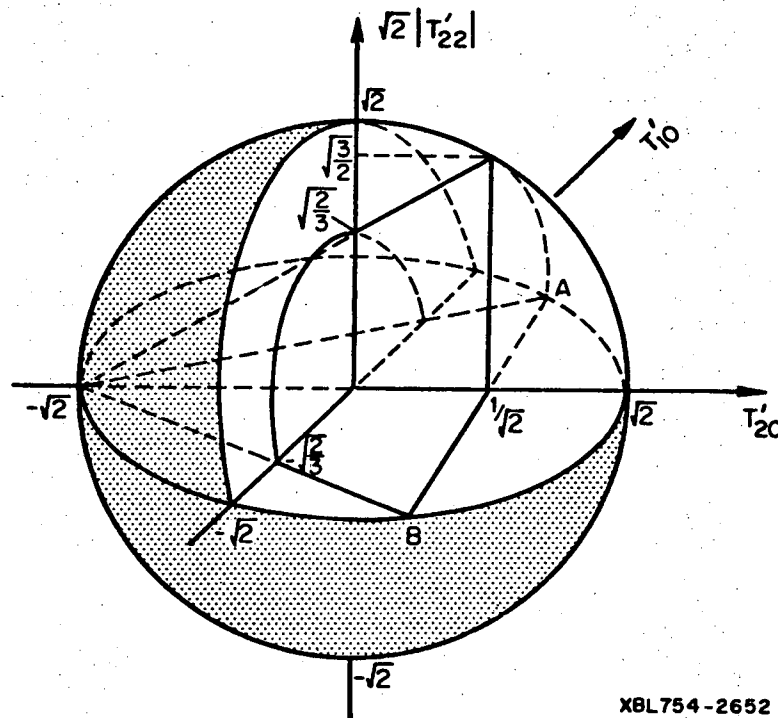
$$\begin{aligned} T'_{10} &= \sqrt{2} iT_{11} = \frac{1}{2} \sqrt{6} A_y, \\ T'_{20} &= -\frac{1}{2} (T_{20} + \sqrt{6} T_{22}) = \frac{1}{2} \sqrt{2} A_{yy}, \\ T'_{22} &= \frac{1}{4} (\sqrt{6} T_{20} - 2T_{22}) - iT_{21} = \frac{1}{6} \sqrt{3} [(A_{zz} - A_{xx}) + i2A_{xz}]. \end{aligned} \quad (3)$$

In the space  $(T'_{10}, \sqrt{2}|T'_{22}|, T'_{20})$ ,  $\delta = 1$  defines a sphere and  $\epsilon = 0$  an inscribed cone (figure). Points with  $A_{yy} = 1$  lie on the base of the Lakin cone ( $T'_{20} = 1/2 \sqrt{2}$ ). Only there, values of  $A_y = \pm 1$  can be attained (points A and B), and then only if  $|T'_{22}| = 0$ . Thus

$$A_{yy} = 1, \quad A_{xx} = A_{zz} = -\frac{1}{2}, \quad A_{xz} = 0. \quad (4)$$

Consequently  $A_{yy} = 1$  is a prerequisite for  $A_y = \pm 1$ , and the other efficiencies are numerically determined. This was shown for  ${}^4\text{He}(d,d){}^4\text{He}$  by Gruebler et al.<sup>3)</sup>, using the properties of that particular M-matrix. From the derivation here, it is obvious that eqs.(4) are always valid. In several reactions, regions with large values of  $A_y$  have been found<sup>4)</sup>, where eqs. (4) are nearly satisfied, but the data density is not good enough to allow any conclusions. Also eqs. (4) are necessary but not sufficient conditions for  $A_y = \pm 1$ , since they are satisfied by any point on the line AB. In order to prove the existence of any extreme value, the fulfillment of the relevant conditions on the M-matrix has to be established. However these conditions, given for several reactions in papers contributed to this conference, are not necessarily independent. For  $A_y = \pm 1$  for instance, eq. (2) for  $\epsilon^2 = 0$  directly imposes the requirement  $A_{yy} = 1$ .

It also should be noted that it is the direction perpendicular to the scattering plane (y-axis) which yields the large values of the analyzing power. The Madison Convention, generally used for the description of both the M-matrix and the experimental data, does not use this preferred direction as the quantization axis. An investigation of the conditions on the M-matrix in a transverse coordinate system is in progress.



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### References

- \* Work performed under the auspices of the U. S. Energy Research and Development Administration.
- + On leave of absence from the University of Basel, Switzerland.
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