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To: Distribution
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Subject: Reference frame of analyzing power ~~and Rutherford ratio~~

Angular distribution and analyzing power are related to count numbers as follows:

$$\sigma(\theta) = C\,\Delta N(\theta) / \Delta\Omega(\theta)$$
$$pA_y(\theta) = (\Delta N_U(\theta) - \Delta N_D(\theta)) / (\Delta N_U(\theta) + \Delta N_D(\theta)),$$

where C is a constant, $\Delta N(\theta)$, $\Delta N_U(\theta)$, $\Delta N_D(\theta)$ are count numbers for unpolarized beam, beam polarized along +y and beam polarized along –y axis at a detector having solid angle $\Delta\Omega(\theta)$. p is beam polarization. The setting angle of the detector is θ_{lab} in the laboratory system and it is θ_{cm} in the center of mass system. Two angles in reaction A(a,b)B are related by the relation:

$$\tan\theta_{lab} = \frac{\sin\theta_{cm}}{\gamma + \cos\theta_{cm}}, \text{ where } \gamma = \sqrt{\frac{m_a m_b}{m_A m_B}\frac{E_{cm}}{E_{cm}+Q}} \text{ and } E_{cm} = \frac{m_A}{m_a + m_A}E_{lab}$$

All count numbers does *not* depend on the reference frame (=frame where measurement is done). $\Delta N_{lab}(\theta) = \Delta N_{cm}(\theta)$ etc., but the solid angle depends on the reference frame: $\Delta\Omega_{lab}(\theta) = J\,\Delta\Omega_{cm}(\theta)$, where J for reaction is

$$J = \frac{\left|1 + \gamma\cos\theta_{cm}\right|}{(1 + \gamma^2 + 2\gamma\cos\theta_{cm})^{3/2}}\ .$$

Therefore angular distribution at the detector depends on the reference frame, i.e. $\sigma_{lab}(\theta) = \sigma_{cm}(\theta) / J$, while analyzing power at the detector does *not* depend on the reference frame, i.e. $A_{y\,lab}(\theta) = A_{y\,cm}(\theta)$. This means `DATA-CM` is useless for analyzing power. It is same for angular distribution of other polarization quantities. ~~We can prove that Rutherford ratio also takes same value in the laboratory and center of mass system by same way.~~

Below I summarize the usage of data heading for angular distribution~~, Rutherford ratio~~ and analyzing power:

Angle (x)	Quantity (y)	Heading (x)	Heading (y)
θ_{lab}	σ_{lab}	ANG	DATA
θ_{lab}	σ_{cm}	ANG	DATA-CM
θ_{cm}	σ_{lab}	ANG-CM	DATA
θ_{cm}	σ_{cm}	ANG-CM	DATA-CM
~~θ_{lab}~~	~~σ / σ_R~~	~~ANG~~	~~DATA~~
~~θ_{cm}~~		~~ANG-CM~~	~~DATA~~
θ_{lab}	A_y	ANG	DATA
θ_{cm}		ANG-CM	**DATA**

The reference frame of quantity is often omitted by authors, and .JCPRG usually assumes the reference frame of the quantity given and reference frame of the angle are same for such data.

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