IMPROVING THE ENERGY RESOLUTION BY " DISPERSION MATCHING " AND " REDUCTION OF KINEMATIC BROADENING "

Narayan Bhattacharya

Variable Energy Cyclotron Centre
Bhabha Atomic Research Centre
1/AF Bidhan Nagar, Calcutta - 700 064, India

ABSTRACT

The energy resolution in a scattering experiment is determined by the line width at the detector, which is a function of the energy dispersion of the beam as well as that of the " Kinematic broadening ". By reducing these two factors, the energy resolution of the overall system can be improved appreciably.

A generalised analytical treatment has been presented using the matrix formalism. The advantage of the present method is that these conditions can be realised in practice for any beam transport system by controlling beam line parameters through a computer very conveniently.

ENERGY RESOLUTION

The energy resolution at the detector is given by

$$\frac{\Delta E}{E} = 2 \frac{Wm}{D} \quad ..(1)$$

where Wm is the image width FWHM and D is the dispersion coefficient. Hence in order to improve the resolution Wm must be made minimum. The spatial position of the detected particle is represented as

$$x = a_{11} x_0 + a_{12} \theta_0 + a_{16} \delta_0 \quad ..(2)$$

where x_0, θ_0 and δ_0 are the intial position, slope and momentum dispersion of the initial particle and a's the corresponding coefficents.

The conditions for minimising the line broadenings are

$a_{12} = 0$ "reducing kinematic broadening

$a_{16} = 0$ " dispersion matching " ..(3)

Let us consider a scattering experiment shown in fig. 1.

The intial and final co-ordinates are shown in the matrix formalism/1/.

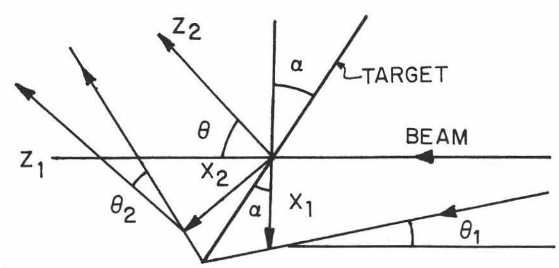

FIGURE 1.

CONVENTION OF CO-ORDINATES IN THE HORIZONTAL PLANE AT THE TARGET.

$$\begin{array}{ccccccc} \text{Detector plane} & & \text{Target} & & \text{beam line} & & \text{cyclotron} \\ \begin{pmatrix} x \\ \theta \\ y \\ \phi \\ l \\ \delta \end{pmatrix} & = S * & \begin{pmatrix} x_2 \\ \theta_2 \\ y_2 \\ \phi_2 \\ l_2 \\ \delta_2 \end{pmatrix} & M * & \begin{pmatrix} x_1 \\ \theta_1 \\ y_1 \\ \phi_1 \\ l_1 \\ \delta_1 \end{pmatrix} & B * & \begin{pmatrix} x_0 \\ \theta_0 \\ y_0 \\ \phi_0 \\ l_0 \\ \delta_0 \end{pmatrix} \end{array} \quad (4)$$

where S, M and B are matrices corresponding to detector assembly, target and beam line. For simplicity we are restricting to first order matrix.

From fig. 1,

$$x_2 = T\, x_1$$

$$\theta_2 = T\, x_1 / L_D \qquad \text{.. (5)}$$

where $T = \dfrac{\cos(\theta - \alpha)}{\cos\alpha}$, L_D is the detector distance. The momentum of the particle after the scattering can be written as

$$p_2 = f(\alpha, p_0); \quad \Delta p_2 = \frac{\partial f}{\partial \alpha}\Delta\alpha + \frac{\partial f}{\partial p_0}\Delta p_0$$

$$\delta_2 = K_2 \Delta\alpha + C\,\delta_0 \qquad \text{.. (6)}$$

where $K = \dfrac{1}{p_2}\dfrac{\partial p_2}{\partial \alpha}$, $C = \dfrac{p_0}{p_2}\dfrac{\partial p_2}{\partial p_0}$

$$\Delta\alpha = \theta_2 - \theta_1$$

It can be show that the final spatial co-ordinate is given by

$$x = x_0\,(S_{11} B_{11} T - S_{16} B_{21} K) + (S_{11} B_{12} T - S_{16} B_{22} K).\theta_0 + (S_{12} + S_{16} K).\theta_2 + (S_{11} B_{16} T - S_{16} B_{26} K + S_{16} C).\,\delta_0 \qquad \text{.. (7)}$$

Comparing eq. (7) with eq. (2) we have, for dispersion matching

$$T = S_{16}/B_{16}\,.\,(B_{26} K - C)\, S_{11} \qquad \text{.. (8)}$$

which is similar to the expression derived by Cohen /2/.

For reducing the kinematic energy broadening one has to satisfy simultaneously,

$$S_{12} + S_{16} K = 0 \text{ and } S_{11} B_{12} T - S_{16} B_{22} K = 0 \qquad \text{.. (9)}$$

which gives

$$B_{12}/B_{22} = -\, S_{12}/S_{11}.T \qquad \text{.. (10)}$$

Hence for improving the energy resolution the matrix elements S_{11}, S_{12}, S_{16}, B_{12}, B_{22}, B_{16} and B_{26} have to be so adjusted that eqs. (8) and (10) are satisfied simultaneously. As a special case, when the detector system does not include a magnetic spectrometer, but consits of simply a detector placed at a distance d from the target, we have for theS matrix

$S_{12} = d$, $S_{11} = 1$, $S_{16} = 1$, and eq. (10)

reduces to

$$B_{12}/B_{22} = -\, d/T \qquad \text{.. (11)}$$

which is similar to the equation derived by Falk /3/ by geometric method.

/1/ J. Reich, S. Martin, D. Protic and G. Reipe
Proc. Intl. Conf. on Cyclotrons and and their applications (Birk hauser, Basel, 1975) p. 235-239

/2/ B.L. Cohen, Rev. Sci. Instr. V.30 No. 6 (1959) p. 415-418

/3/ W.R. Falk, O. ABOU-ZEID and L.PH. ROESCH Nucl. Instr. & Meth 137 (1976) p. 261-266.