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Satellite Peaks in the Beta Spectrometers of the Kofoed-Hansen Type

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In the spectrometers of the Kofoed-Hansen type the magnetic field between the gap profiles (input and output curve) is given by $H = A/r$ and is zero outside (see Fig. 1).

If an input curve ls is given the parametric equations

$$r_{ls} = z_s f_s(\psi_s),$$
$$z_{ls} = z_s[1+f_s(\psi_s)\cot\psi_s],$$

the output curve lf which guarantees focusing (z_f remaining constant regardless of the value of ψ_s) is completely determined[1]:

$$z_{lf} = z_f f_f(\psi_f) = z_s f_s(\psi_s)\exp[-K(\cos\psi_s - \cos\psi_f)],$$
$$\begin{aligned} z_{lf} &= z_f[1+f_f(\psi_f)\cot\psi_f] \\ &= z_s\{1+f_s(\psi_s)\cot\psi_s + Kf_s(\psi_s)\exp(K\cos\psi_s) \\ &\quad \times [V(K,\psi_f)-V(K,\psi_s)+2\pi(n_f-n_s)iJ_1(iK)]\}, \end{aligned}$$

where ψ_f and ψ_s are related by the equation

$$\begin{aligned} &\cot\psi_f\exp(-K\cos\psi_f)-KU(K,\psi_f)-K2\pi n_f iJ_1(iK) \\ &\quad = \cot\psi_s\exp(-K\cos\psi_s)-KU(K,\psi_s) \\ &\qquad -K2\pi n_g iJ_1(iK)-\frac{z_f-z_s}{z_s}\,\frac{\exp(-K\cos\psi_s)}{f_s(\psi_s)}. \end{aligned}$$

If $f_s(\psi_s)$, z_s, z_f, n_s, y, n_f are given, then each value of K determines an output curve. Consequently, a family of output curves is determined. If K is held constant and the previously given values of $f_s(\psi_s)$, z_s, y and z_f are used, then the output curve corresponding to various values of n_s and/or n_f will cut the family described in the preceding sentence at points A, B, C and D (Fig. 2). The physical significance of the foregoing is as follows: an instrument designed with parameters (n_s, n_f, K) in such a way that electrons which start from the point (Z_s, 0, 0) are focused at (z_f, 0, 0), independently of ψ_s, provided $mv = KAe$, will also focus electrons with different (n_f', n_s', K') and this according to the value of ψ_s. In other words, with the same field we can focus electrons having different momenta, mv. Similarly, a monoenergetic source will give, in addition to the main peak, other less intense but broader peaks which are called satellites. For large values of ψ_s, the trajectories in which $n_s \neq 0$ cannot go through the instrument because they intersect the input curve a second time and escape from the gap (Fig. 3).

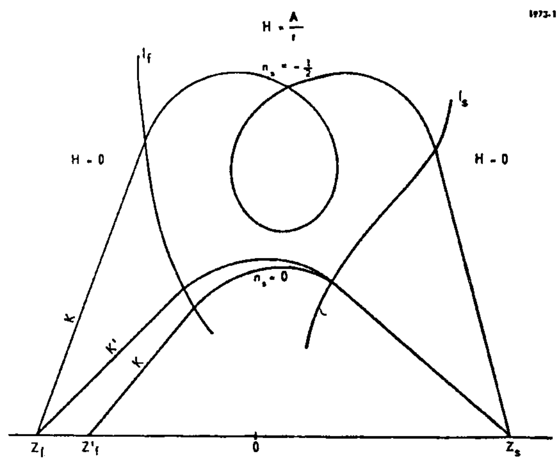

Figure 1

As a concrete example of the foregoing, let us consider the case of symmetrical instruments ($n_s = -n_f$; $b_1 = 0$) limiting ourselves to $n_s = 0, -\frac{1}{2}, -1, -\frac{3}{2}$. The function $f_s(\psi_s)$ is given by[1]

$$(f_s(\psi_s))^{-1} = K\exp(K\cos\psi_s)[U(K,\psi_s)+2\pi n_s iJ_1(iK)] - \cot\psi_s.$$

Intersection of curves indicates equal values of $f_s(\psi_s)$ for the same ψ_s or

$$\begin{aligned} &K\exp(K\cos\psi_s)[U(K,\psi_s)+2\pi n_s iJ(Ki)] \\ &\quad = K'\exp(K'\cos\psi_s)[U(K,\psi_s)+2\pi n_s' iJ_1(Ki')], \end{aligned}$$

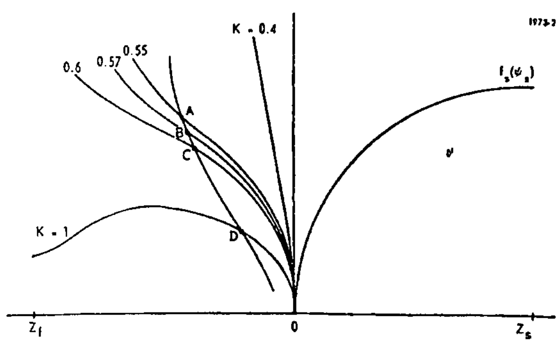

Figure 2

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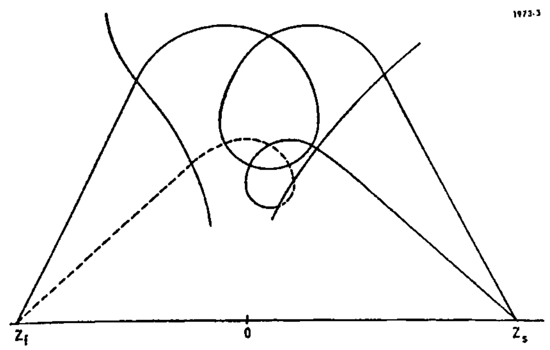

Figure 3

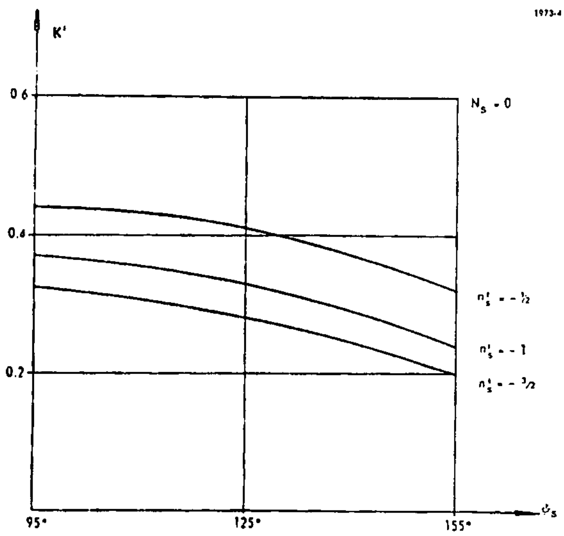

Figure 4

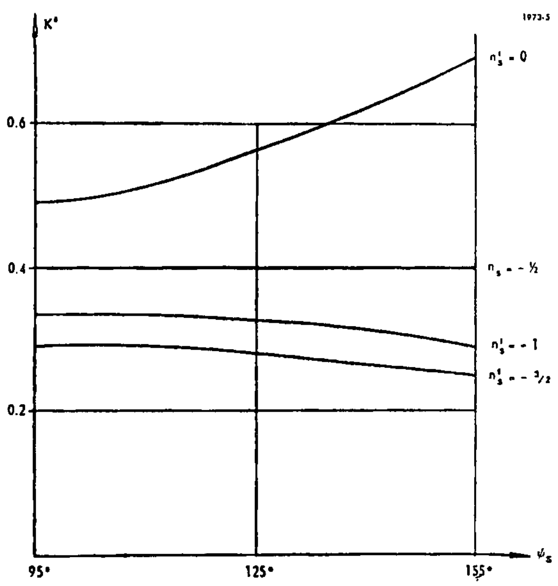

Figure 5

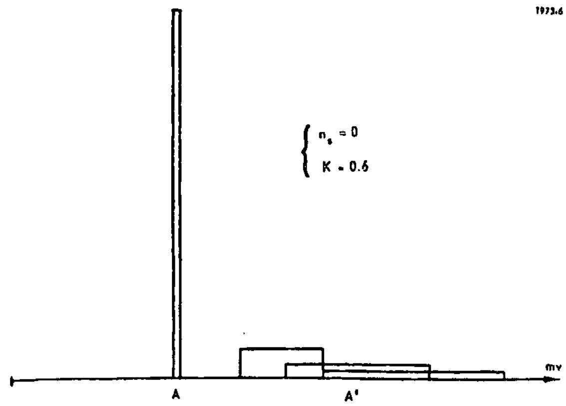

Figure 6

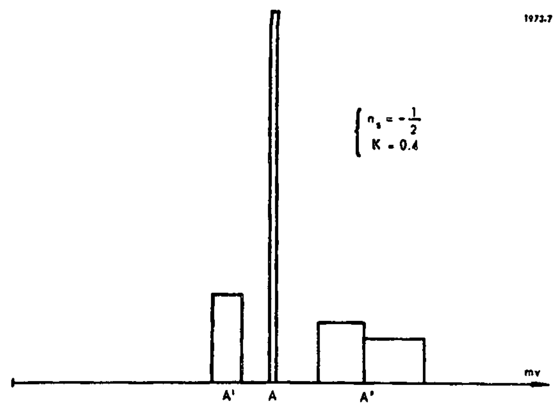

Figure 7

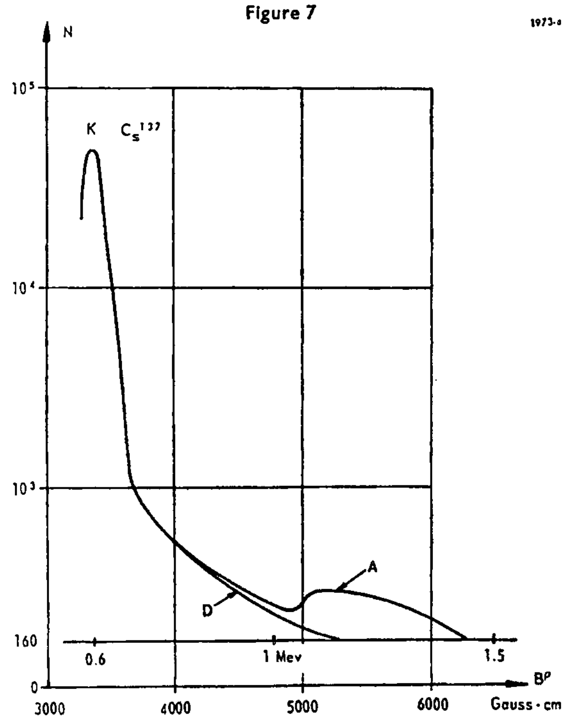

Figure 8

from which it follows that

$$K' = K'(K, n_s, n_s', \psi_s).$$

The numerical results are shown in Figs. 4 and 5, in the former, for an instrument in which $n_s = 0$ and $K = 0.6$ and in the latter for another in which $n_s = -\frac{1}{2}$ and $K = 0.4$. From the expression $K = mv/Ae$ it follows that $A' = AK/K'$, which enables us to predict the spectrum of a monoenergetic source (Figs. 6 and 7).

Experimental verification of this effect was carried out in an instrument having 8 gaps with a 10° aperture between $(\psi_s)_{min} = 95°$ and $(\psi_s)_{max} = 145°$, designed for loopless trajectories ($n_s = 0$). Figure 8 shows the appearance of the K line of Cs^{137} before (A) and after (D) placing in the gap a diaphragm which intersects trajectories having $n_s = 0$ but does not intersect those having $n_s \neq 0$.

The satellite peak is very clear and its relative position confirms quantitatively the theoretical predictions.

REFERENCE

1. C. A. Mallmann, Publ. Comm. Nac. de Energía Atómica, Ser. Física, Vol. 1, No. 1 (1953).