BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

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INTERSECTING STORAGE ACCELERATOR NOTES

DETERMINATION OF LUMINOSITY USING THE INTERSECTION OF A
HIGH β WITH A LOW β SECTION

R. B. Palmer

June 29, 1972

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If the luminosity of any special region is known and the rate for any arbitrary reaction measured in that region, then the luminosity at any other region can be established by a measurement of that same rate.

We therefore propose a special crossing whose luminosity is low but whose characteristics make an exact determination of luminosity relatively easy. We propose the intersection of two beams, one with low β and the other with high β , at a finite crossing angle. Consider, for instance, the intersection of a beam with $\beta_1 = 1$ meter (diameter $d_1 \approx .5$ mm) with a beam with $\beta_2 = 1000$ meters (diameter $d_2 \approx 15$ mm) at a crossing angle θ of .03 radians. The intersection will look as in Fig. 1. The intersection region is ≈ 50 cm long which is reasonable. In the approximation $\beta_1 \ll \beta_2$ the luminosity will be given by

$$L \approx \frac{1}{e^2 c} \cdot I_1 \frac{\partial I_2}{\partial y} \frac{1}{\sin \theta} \quad (1)$$

$$\approx 1.3 \times 10^{27} I_1 I_2 \frac{1}{d_2 \sin \theta}$$

which for $I_1 = I_2 = 15$ amps gives

$$L \approx 6.5 \times 10^{30} \quad (2)$$

This, while not great, is reasonable for determination of total cross sections and elastic scattering at medium angles.

Returning to Equation (1), we note that L is not dependent (to first order) on the size or shape of the low β beam. It is dependent only on the currents (which can be accurately determined) and on the $\partial I_2 / \partial y$ of

the high β beam. Now this $\partial I_2 / \partial y$ can be determined by displacing the low β beam vertically and noting the counting rate $R(y)$ as a function of this displacement (y)

$$\frac{\partial I_2}{\partial y} \text{ (at } y = 0) = \frac{I_2 R(0)}{\int R(y) dy}$$

Thus

$$L = \frac{1}{e^2 c} \frac{I_1 I_2}{\sin \theta} \cdot \frac{R(0)}{\int R(y) dy} \quad (3)$$

This, of course, is the old Van de Meer formula, but although the formula is the same the errors are not.

In the Van de Meer method the two beams have approximately the same diameter. The trouble arises when one beam is displaced vertically to obtain $R(y)$. There is no way of assuring that the vertical distribution of the displaced beam does not change as a function of its displacement. When the two beams are of similar size such variations effect the result. In contrast, when the displaced beam is small compared to the fixed beam, such variations have only a second-order effect. A change in mean diameter of the low β beam by a factor ϵ of 10% will only cause a change in $\int R(y) dy$ of $(d_1/d_2)\epsilon$ or 0.3%. Ten percent seems a conservative estimate for ϵ since larger changes could be observed and measured. Errors in current measurement could be made negligible and thus we conclude that this method could give luminosities to the order of 0.3% accuracy.

Figure 1