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BNL-20109

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

CRISP 75-4

ACCELERATOR DEPARTMENT
Informal Report

MODIFIED USE OF VAN DE MEER METHOD
FOR LUMINOSITY DETERMINATION

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May 7, 1975

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for Luminosity Determination

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A. Van de Meer Method

The luminosity (L) at an ISR is given by

$$L = \frac{I_1 I_2}{e^2 c \tan \frac{\theta}{2}} \cdot \frac{1}{H}$$

where

$$\frac{1}{H} = \int \rho_1(X) \rho_2(X) dX / \int \rho_1(X) dX \cdot \int \rho_2(X) dX, \quad (1)$$

where $\rho_1(X)$ and $\rho_2(X)$ are current densities in the two beams measured as a function of the distance X perpendicular to the plane containing the crossing beams. θ is the crossing angle, I_1 and I_2 the total currents.

Van de Meer's method involves determining $1/H$ by shifting one of the two beams in the direction X by amounts δ ($\langle X_1 \rangle - \langle X_2 \rangle = \delta$) and observing the interaction rate $R(\delta)$. Then

$$\frac{1}{H} = \frac{R(\delta=0)}{\int R(\delta) d\delta} \quad (2)$$

Inaccuracies in the method arise because of the following factors:

(1) The method assumes no change in the current density distributions $\rho(X-\delta)$ as δ is varied.

(2) At CERN at least H and thus L is determined at relatively infrequent intervals. The L at other times must then be estimated using some normalization such as the counting rate of a given set of counters that are subject to background, etc.

(3) Accurate knowledge of the displacement δ is complicated by the need to trace the deflected trajectories through magnets of the lattice.

B. Suggested Modification to Method

We suggest two modifications in procedure that should improve the accuracy of the method.

1. We propose to insert 4 bending magnets between the quadrupoles of a given experimental straight section (Fig. 1). These bending magnets would be connected in series and so shimmed that when powered the beam is displaced but the machine parameters are in no way affected.

2. We propose to drive the magnets described above with a special power supply such that the current in these magnets follows a zigzag pattern with uniform rate of change of current ($\partial B/\partial t$) up and down (Fig. 2). The rate (τ) of such changes should be of order one per second; the magnitude (X) such that at each limit the beam beam interactions go to zero.

3. We propose that experiments that require accurate luminosity determination should be run while the deflection magnets are being driven with the oscillatory current pattern.

C. L Determination with these Modifications

First we note that the mean luminosity $\bar{L}$ during such a procedure is given by

$$\begin{aligned} \bar{L} &= \frac{\int_{-\frac{X}{2}}^{+\frac{X}{2}} L(\delta) d\delta}{X} \\ &= \frac{I_1 I_2}{e^2 c \tan \frac{\theta}{2}} \cdot \frac{\int_{-\frac{X}{2}}^{+\frac{X}{2}} R(\delta) d\delta}{\int_{-\infty}^{+\infty} R(\delta) d\delta} \cdot \frac{1}{X} \end{aligned}$$

since $R(\delta)$ for $|\delta| > \frac{X}{2} = 0$. Then

$$\bar{L} = \frac{I_1 I_2}{e^2 c \tan^2 \frac{\theta}{2}} \cdot \frac{1}{X} \quad (3)$$

We note that $\bar{L}$ is not a function of ρ_1 or ρ_2 but only of the currents, crossing angle, and of the magnitude of the oscillatory deflection X . On reflection this is an obvious result. By oscillating one beam we have in effect spread it out in the vertical direction, in a uniform manner, and over a known distance X . If beam (1) is so spread out over a distance larger than the extent of beam (2), then the Luminosity is given by

$$L = \frac{I_2}{e^2 c \tan^2 \frac{\theta}{2}} \cdot \frac{\partial I_1}{\partial X} \quad (4)$$

which is of course equal to the mean luminosity determined above (Eq. 3).

We note at this point that we require constant $\partial \delta_1 / \partial t$ only over the region where $|\delta_1| \leq$ the extent of beam 2. Beyond that some nonuniformity of $\partial \delta_1 / \partial t$ is allowed (see Fig. 2 again).

That some part of the deflection should be beyond the extent of beam 2 is in fact desirable since, during the time when it is beyond this limit, the observed rate will be pure background. If the vacuum in the intersection region is good enough, we can then assume that the background is independent of the deflection and use the time when beam 1 is beyond beam 2 to determine and allow subtraction of this background (Fig. 3).

This method thus allows a continuous determination of both Luminosity and background both to a high accuracy. The only loss in the method

is in absolute luminosity (by a factor ~ 10) but this is probably of little consequence for the type of experiment requiring good Luminosity determination (e.g. total cross sections).

D. Further Refinements

A further refinement of this method is afforded if magnets are provided on both intersecting beams so that either beam can be deflected independently. The following checks can then be performed.

(1) Check that the same experimental rate is obtained when deflecting beam 1 or beam 2.

(2) Check that the rate is constant when both beams are deflected simultaneously in the same phase.

(3) Leave beam (1) oscillating up and down by the normal amount and then drive beam (2) slowly across. If the vertical position of the slowly moving beam is given by δ_2 , then if we integrate over the rapid changes of rate due to the oscillations δ_1 we can observe a mean rate $\bar{R}$ as a function of δ_2 . This should look as in Fig. 4. Validity of the method assumes that $\bar{R}$ is uniform over the combined widths of the two beams and this we can check. We can also determine the amplitude X_1 of deflections on beam 1. But even more powerful than performing more checks, we can perform a second-order Van de Meer determination:

$$\bar{L}(\delta_2=0) = \frac{I_1 I_2}{e^2 c \tan \frac{\theta}{2}} \frac{\bar{R}(\delta_2=0)}{\int \bar{R}(\delta_2) d\delta_2} \quad (5)$$

Such a determination would then correct for any nonuniformity of $\bar{R}$ (e.g. a sinusoidal deflection could be used) and assumes only that beam 2 is small compared to X_1 , a condition that can easily be met.

Fig 1 Deflection System.

Fig 2 Time Dependence of Deflection

Fig 3 Background Subtraction

Fig 4 Second order Van De Meer.