LUMINOSITY CONSIDERATIONS - HEAD-ON COLLISIONS*

J. W. Humphrey
Brookhaven National Laboratory
Upton, N.Y. 11973

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

I. Where is the interaction region?

An interaction region with head-on collisions may, in fact, not run with truly head-on collisions. True head-on collisions imply the existence of other bunch collisions with a spacing equal to half the spacing between bunches. For the collider, the distance between collisions is 2.8 meters. If an experiment is designed to take advantage of a small interaction length longitudinally, the existence of these other collision regions may be unacceptable.

A possible solution to this problem is to cross the beams in the horizontal plane (for example) at some small angle. Since the angular divergence of the beam is one milliradian, the small angle crossing is restricted to that size. If this solution works (i.e. if the beam lifetime doesn't drastically diminish¹), then the effective beam half width is increased by $l_B \alpha / 4$.² l_B is the total bunch length, α is the crossing angle. The effective area is given by:

$$A = \pi h \sqrt{w^2 + \left(\frac{l_B \alpha}{4}\right)^2} \quad h = w = .3 \text{ mm}$$

MASTER

h is the vertical size. w is the horizontal size. For a bunch length of 60 cm, the finite crossing angle will increase the effective area by approximately 10%.

There are two actions which will move the interaction region longitudinally. A slipping of the RF buckets in one beam with respect to the other will displace the interaction region. A change in the horizontal crossing angle will displace the interaction region both longitudinally and transversely. The transverse

* Work performed under the auspices of the U.S. Energy Research and Development Administration.

displacement is unimportant compared to the longitudinal displacement. For a crossing of one milliradian, a change in angle of 1% will displace the interaction region by 25 centimeters -- enough to cause the bunches to miss.

For these reasons, it will probably be necessary for experiments to include in their design a monitor to look at the length of the interaction region. It is possible to monitor the bunch length in each beam independently by means of pickup electrodes. By comparing the results of what one would predict from these measurements to the longitudinal interaction region measured by the proposed monitor, one should be able to see if the interaction region is moving. The time scale for movements of this kind is expected to be very long, $\gg 15$ minutes.³

II. Measuring Luminosity

This is a low beta insertion which has ~ 1 milliradian of divergence. This divergence is too large to consider using a measurement of coulomb interference to measure luminosity. The region of coulomb interference is $t \sim .001 \text{ (GeV/c)}^2$, which corresponds to an angle of .03 (.2) milliradians at 1000 (150) GeV/c. The coulomb interference region is thus lost in the angular divergence of the beam. (See Larry Jones' note for this summer study on Luminosity Determination. He proposes to calibrate a monitor with respect to a coulomb interference measurement at high beta, and then use the calibrated monitor to measure the luminosity at low beta.)

For true head-on collisions, the measurement of luminosity by the Vander Meer method should be relatively straightforward. Four trim dipoles per beam -- two before and two after the interaction region -- allow one to displace the beam while maintaining its direction in space constant. Thus one can measure the effective height or width. Finite crossing angles complicate the problem.

Assuming horizontal crossing, one measures the effective height by displacing the beams vertically, as before. Now, how does one measure the effective width? One can displace the beam horizontally. Assuming that the bunch length correction is negligible, this works. The assumption mentioned implies that the measurement is only good to about 10%. Larry Jones has suggested that measuring the luminosity as a function of slipping the RF buckets of one beam with respect to the other will give one a measure of the effective width.⁴ I have been unable to prove this assertion.

Conclusions

For true head-on collisions, measuring luminosity appears to be straightforward. Small crossing angles, even if they work, complicate the situation very much -- especially if one wishes to know the luminosity better than 10%. However, except for the possible necessity of some extra trim magnets, it is hard to see how these considerations can affect the design of the ED/S Collider in a significant way.

Note that, if true head-on collisions are implemented, a monitor of luminosity and interaction region location can be placed away from the experiment. For small angle crossings, the experimenters have to include such facilities in their experimental design.

1. Due to beam-beam effects. One should not forget that SPEAR did not succeed in getting such small angle crossings to work.
2. The factor of 4 comes from two sources. A factor of 2 is introduced because the above formula uses total bunch length. The other factor of 2 comes from the fact that the relative velocity of the two colliding bunches is $2c$.
3. Private communication from T. Collins and M. Month.
4. L. Jones, "Luminosity Determination," this summer study.