RHIC-PG-53

Luminosity for Proton Debunched Beam Colliding with Gold Bunched Beam

A. G. Ruggiero

BNL, April 27, 1984

The luminosity for a bunched beam colliding with an unbunched beam is

$$L = N_1 N_2 B f_{rev} F'$$

where

N_1 is the <u>total</u> number of particles in the beam #1, completely unbunched

N_2 is the number of particles per bunch in the beam #2, assumed bunched

B, the number of bunches in beam #2

f_{rev}, revolution frequency common to both beams

$$F' = \frac{1}{2\pi^2 R} \int_{-\ell/2}^{+\ell/2} \frac{e^{-\frac{\alpha^2 y^2}{2(\sigma_{x_1}^2 + \sigma_{x_2}^2)}}}{\sqrt{\sigma_{z_1}^2 + \sigma_{z_2}^2}\sqrt{\sigma_{x_1}^2 + \sigma_{x_2}^2}} dy \qquad (1)$$

R is the average radius of both beam circumference

ℓ is the length of the interaction region where the two beams are visible to each other

α is the total crossing angle

y is the longitudinal coordinate

σ_z and σ_x are the rms beam dimensions in the transverse directions.

The crossing here is assumed to take place in the x-plane, which we assume to be the horizontal one.

In the approximation that the "diamond" region, that is the region of most immediate interaction is short, we can take σ_x and σ_z for both beams constant.

In which case we have

$$F' = \frac{1}{\pi\sqrt{2\pi}\, R\, \alpha \sqrt{\sigma_{z_1}^2 + \sigma_{z_2}^2}} \quad (2)$$

We consider the case of Gold beam colliding with the Proton Beam.

Gold Beam is bunched at 100 GeV/A

$N_2 = 1.1 \times 10^9$
$B = 57$

Proton Beam is unbunched at 250 GeV/A

$N_1 = 57 \times 10^{12}$

Also

$f_{rev} = 78.2$ KHz

$\alpha = 2$ mrad

$R = 610.2$ m

At the crossing point we take

$$\beta_V^* = 6.3 \text{ m}$$
$$\beta_H^* = 0.9 \text{ m} \quad \text{(not required)}$$
$$\eta^* = 0 \text{ m}$$

Normalized emittance (95% of beam)

proton beam = $20\,\pi$ mm·mrad
gold beam = $10\,\pi$ mm·mrad

$$\sigma_{z1} = 0.29 \text{ mm}$$

$$\sigma_{z2} = 0.32 \text{ mm}$$

This gives a luminosity

$$L = 0.67 \times 10^{28} \text{ cm}^{-2}\,\text{s}^{-1}$$