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# Luminosity For Proton Debunched Beam Colliding With Gold Bunched Beam

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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 total 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

$$F' = \frac{1}{2\pi^2 R} \int_{-\ell/2}^{+\ell/2} \frac{e^{-\frac{\alpha^2 y^2}{2(\sigma_{x_1}^2 + \sigma_{x_2}^2)}}}{\sqrt{\sigma_{z_1}^2 + \sigma_{z_2}^2}\sqrt{\sigma_{x1}^2 + \sigma_{x2}^2}} dy \qquad (1)$$

$R$ is the average radius of both beam circumference

$\ell$ is the length of the interaction region where the two beams are visible to each other

$\alpha$ is the total crossing angle

$y$ is the longitudinal coordinate

$\sigma_z$ and $\sigma_x$ 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 $\sigma_x$ and $\sigma_z$ for both beams constant.

In which case we have

$$F' = \frac{1}{\pi\sqrt{2\pi}\, R\, \alpha \sqrt{\sigma_{z1}^2 + \sigma_{z2}^2}} \quad \cdots (2)$$

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

$\beta_V^* = 6.3$ m

$\beta_H^* = 0.9$ m (not required)

$\eta^* = 0.$ m

Normalized emittance (95% of beam)

proton beam = 20 $\pi$ mm·mrad

gold beam = 10 $\pi$ mm·mrad

$\sigma_{z1} = 0.29$ mm

$\sigma_{z2} = 0.32$ mm

This gives a luminosity

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