

Luminosity For Proton Debunched Beam Colliding With Gold Bunched Beam

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(1)

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

$$F' = \frac{1}{2\pi^2 R} \int_{-b/2}^{+b/2} \frac{e^{-\frac{\alpha^2 y^2}{2(\sigma_{x1}^2 + \sigma_{x2}^2)}}}{\sqrt{\sigma_{z1}^2 + \sigma_{z2}^2} \sqrt{\sigma_{x1}^2 + \sigma_{x2}^2}} dy$$

(1)

(2)

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

(3)

$$F' = \frac{1}{\pi \sqrt{2\pi} R \alpha \sqrt{\sigma_{21}^2 + \sigma_{22}^2}} \quad (2)$$

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

$$f_{rev} = 78.2 \text{ kHz}$$

$$\alpha = 2 \text{ mrad}$$

$$R = 610.2 \text{ m}$$

At the crossing point we take

$$\begin{aligned} \beta_v^* &= 5.3 \text{ m} \\ \beta_H^* &= 0.9 \text{ m} \quad (\text{not required}) \\ \eta^* &= 0 \text{ m} \end{aligned}$$

Normalized emittance (95% of beam)

$$\begin{aligned} \text{proton beam} &= 20 \pi \text{ mm-mrad} \\ \text{gold beam} &= 10 \pi \text{ mm-mrad} \end{aligned}$$

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

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

This gives a luminosity



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