Paul Avery
PHZ4390
Oct. 13, 2013

Bonus Question 6

Due Wednesday, Oct. 23

The luminosity for two colliding beams, assuming that the beams are organized in bunches and gaussian distributed in the xy plane with standard deviations σ_x and σ_y, is given by

$$\mathcal{L} = f_B \frac{N_1 N_2}{4\pi\sigma_x\sigma_y}$$

where N_1 and N_2 are number of particles per bunch for beams 1 and 2 and f_B is the frequency of bunch collisions. The integrated luminosity is $\mathcal{L}_{\text{int}} = \int \mathcal{L}\, dt$.

During a "fill" (the period from the start of collisions until the beams are dumped), various physics processes such as beam-beam collisions, beam-gas scattering, magnetic field inhomogeneities, etc. cause the number of particles per bunch to fall as $e^{-t/\tau}$, where τ is known as the "beam lifetime". This in turns causes a steady decline in the luminosity. Typical beam lifetimes in the LHC are about 60 hours. After colliding for a time T_{fill} the beams are dumped and refilled to full luminosity, a process that takes approximately 2 hours (not counting cases where the beams are dumped prematurely because of problems). At the LHC in October 2012, the parameters were such that the luminosity at the start of a fill was $\mathcal{L}_0 = 7.1\times10^{33}\text{cm}^{-2}\text{s}^{-1}$.

1. (2 pts) What is the lifetime of the luminosity?
2. (5 pts) What is the optimum value of T_{fill} (in hours) that achieves the highest possible integrated luminosity over many fills? This is a very practical consideration in running colliding beam facilities because experimenters want the largest possible integrated luminosity over time.
3. (3 pts) Plot the average luminosity over time in units of $\mathcal{L}_0$ for different fill periods T_{fill} (hours). What is the maximum value (corresponding to the answer in part 1)?