

PP collisions at different energies

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Abstract

Attempt to answer how much energy difference between proton beams in two *RHIC* rings while maintaining collision between them. Suppose the circumferences of the two beams differ by $2cm$, the energy difference is approximately $93GeV$.

Each *RHIC* ring contains a beam of equally spaced bunches, the spacing between adjacent bunches is the same in both rings. After each meeting of these two beams of bunches, to ensure all bunches in each beam collide in the interaction region, it is necessary that each beam maintains the same revolution frequency around the ring. The common storage cavities next to one interaction region guarantee this condition.

If it is desired to have one proton beam at one energy to collide with the other proton beam at another energy. How much difference in energy (or momentum) is possible? Let's look at the fundamental equation

$$p = e\rho_0 \left(\frac{R}{R_0} \right)^{\frac{1}{\alpha_p}} B. \quad (1)$$

where e is the charge state of the particles, ρ_0 is the bending radius of the dipoles, R_0 the radius of the reference orbit, R is the radius of the orbit, α_p is the momentum compaction factor and related to the transition energy γ_{tr} by $\alpha_p = 1/\gamma_{tr}^2$, B is the magnetic dipole field; and the relationship between revolution frequency f and circumference C ($C = 2\pi R$) of the orbit.

$$f = \beta c / C \quad (2)$$

where c is the speed of light. From these two equations, one can derive the following differential relationship

$$\frac{dp}{p} = \gamma^2 \frac{df}{f} + \gamma^2 \frac{dR}{R}. \quad (3)$$

One easily finds out that a relation between momentum difference and the orbit difference while holding the revolution frequency constant

$$\frac{dp}{p} = \gamma^2 \frac{dR}{R}. \quad (4)$$

The difference in orbits comes from moving the beam inward or outward to the beam pipe, which is limited by the physical size of the beam pipe. Given the same limit on orbit difference,

Suppose $dC = 2\pi dR = 2.0\text{cm}$, then $\frac{dR}{R} \approx 5.2 \times 10^{-6}$. At a reference top energy ($\gamma = 268$), $\frac{dp}{p} \approx 0.37$. The momentum difference is $dp = 250\text{GeV}/c \times 0.37 = 93\text{GeV}/c$; that is one beam at 250GeV , the other beam at energy 157GeV .

Figure 1 gives the difference variation as a function of the reference momentum.

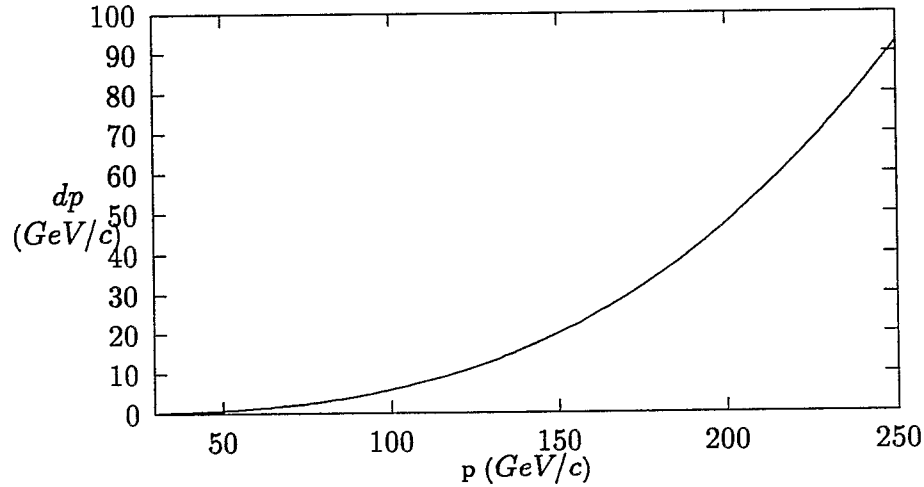


Figure 1: Momentum difference (GeV/c) between two beams when $dC = 2.0\text{cm}$

Another way is to let both beams travel on the designed orbit and their revolution frequencies to be in simple integer harmonic. The simplest ratio is 1:2. The revolution frequency of a beam at 250GeV is approximately 78.2kHz , the other beam could be at revolution frequency of 39.1kHz which is to say the beam is at $\beta = 0.5$ or 1.1GeV .

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I would like to thank M. Harrison for bringing the question to me, and M. Harrison, J. Wei, S. Tepikian, S. Peggs, W. MacKay, D. Trbojevic for fruitful discussions.

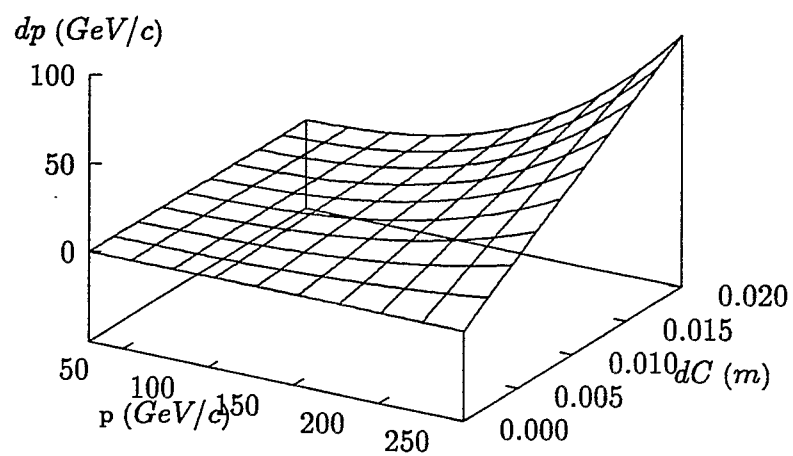


Figure 2: Momentum difference (GeV/c) between two beams.