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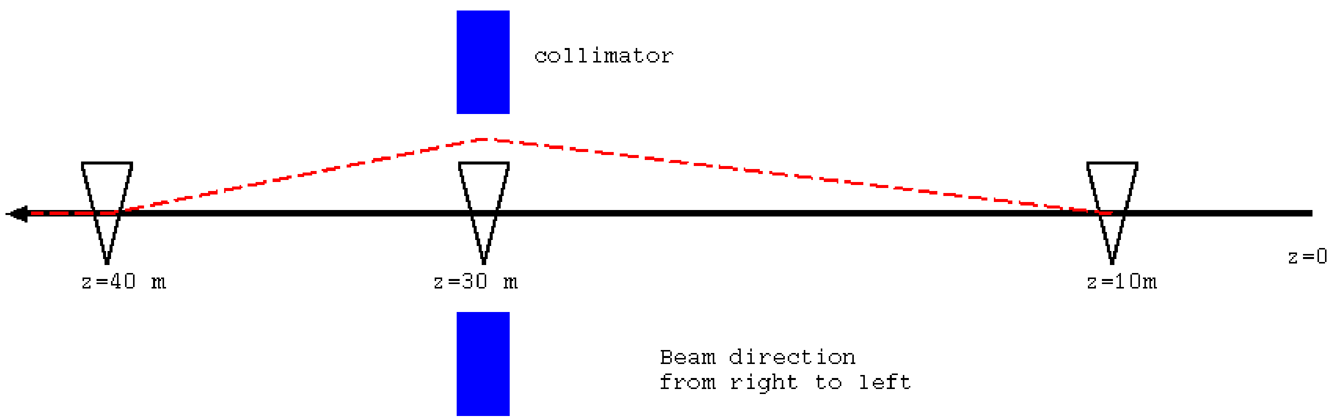
Homework assignment for the Accelerator Physics part of the Detector Course in Stockholm on September 8, 2008.

Theme: Collimation

Note that all calculations are at most a bunch of multiplications of 2x2 matrices. Do not get carried away towards advanced beam optics codes. They are not necessary for these exercises. Moreover we will only consider a one-dimensional horizontal system. Exercise number 6 might benefit from Matlab, Octave, or Mathematica, though because of the numerics.

1. Consider the figure below. There is a beam at postition z=0m with emittance $\varepsilon=10^{-6}$ mrad and beta function $\beta=10$ m, $\alpha=0$. What is the beam size σ, angular divergence σ' and the x-x' correlation of the beam?



2. Thirty meter downstream of the starting there is a collimator. Assume that the collimator is infiitely short in these exercises. What is the beam size at the collimator assuming the initial beam from part 1? There are no magnetic beam optical elements between z=0 and 30 m.

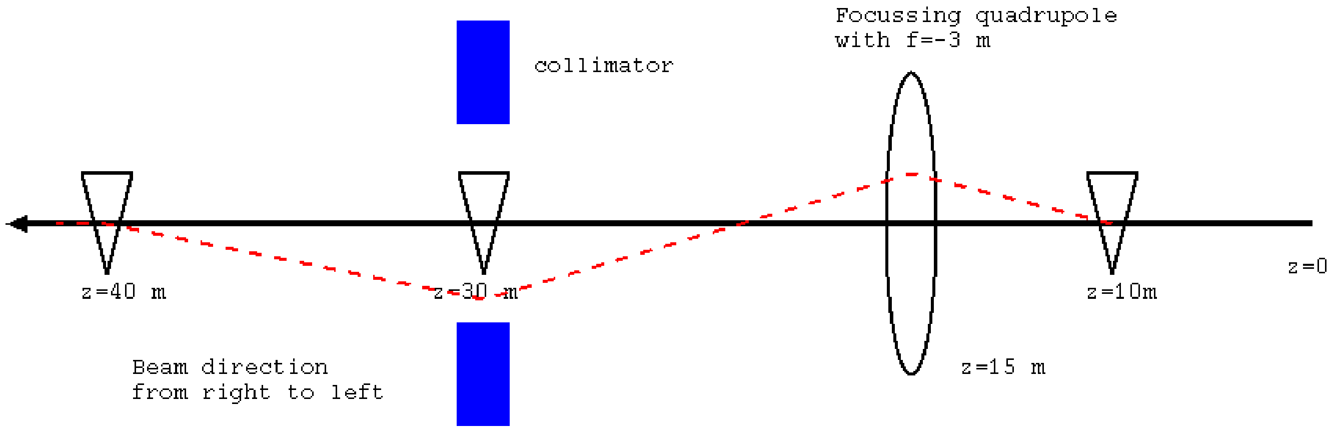
3. If you want to collimate at six sigma, how close do you have to move the collimator jaw to the center of the beam pipe? ("Collimate at six sigma" means to put the collimator jaws at six times the rms beam size from the center of the beam.)

4. Now the collimator is stuck at a position 100 mm from the beam pipe. The best you can do is to move the beam closer to the jaw on one side of the collimator, let's say the upper one in the figure above. By how much do you have to move the beam at the location of the collimator, if you still want to collimate at six sigmas?

5. Assume that there are three steering corrector dipoles (they just apply a kick to the beam, a few milli-radians typically) at location z=10, 30, 40 m. Calculate the excitation (in mrad) of the three magnets such that the excursion of the beam at the collimator is the desired on from point 4. Make sure that the 'bump is closed', which means that the orbit offset at the collimator is cancelled after the last steering magnet. This is shown as the dashed line in the above figure.

6. Now assume that there is a focussing quadrupole at z=15 m with a focal length of f=-3 m. See the figure below for a visualization

- What is the beam size at the collimator in that case? (Same question as Q2, but with quad)
- How close to the beam do you have to have to move the collimator jaws? (~Q3)
- How far do you have to move the beam if it is stuck at 150 mm? If it were stuck at 100 mm, at how many sigmas would you collimate (~Q4)? Discuss why this could be a problem to operate the accelerator.
- Calculate the steering magnet excitations (in milli-radian) for the configuration (~Q5) where the orbit is displaced in such a way that the collimator at 150 mm cuts at six sigma.



7. Consider the beam line in the Figure just below with a spectrometer dipole magnet and a quadrupole. Assume that the beam has a waist (or focus or 'betafunction has a minimum') at the location indicated by the dashed line. The dipole is used to disperse the incoming beam according to the momentum of the particles. The quadrupole is located half-way between the location with the waist and the screen. You want to use this setup to collimate the low-energy tail of the beam as accurately as possible. How do you choose the strength (focal length) of the quadrupole to minimize the effect of the beam size and emittance of the incoming beam such that you predominantly collimate the particles according to their momentum? Assume that the distance between the waist and Collimator is *L*.