AGS IPM and eIPM Beta Function Measurements

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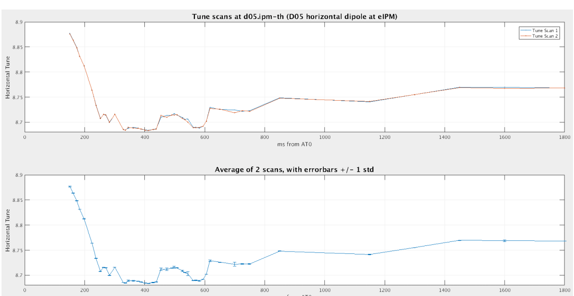
Introduction

Knowing the transverse emittance of the beam throughout the Alternating Gradient Synchrotron acceleration cycle is imperative for productive running conditions. In order to gain an understanding of what the emittance is, we start by measuring the width of the beam. This is translated into an emittance by knowing the beta function at the measuring instrument. Essentially we need:

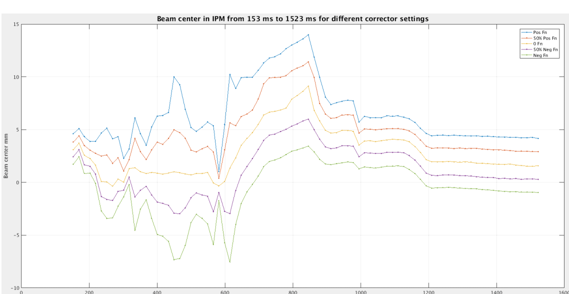
$$\varepsilon = \sigma^2\beta$$

Therefore the knowledge of the emittance is dependent on the understanding of the beta function. The understanding of the beta function measurement is particularly important for the polarized proton program. In the AGS, helical dipoles otherwise known as partial snakes are introduced to preserve the proton polarization. These partial snakes run at constant fields and generate significant optics distortion at low energies. This helical field is hard to precisely model so the measurement is necessary to obtain the real beta function.

Data Acquisition and Analysis



Above denotes a typical tune measurement. At least two two scans are taken and the average is used. Below shows an example of the beam centroid with the varied corrector current. A Python script will take the centroid data if the machine is stable and a dipole corrector function is input.



Measurement Process

We can learn the beta by distorting the equilibrium orbit and measuring the orbit motion. This is done by installing vertical or horizontal dipoles at the respective IPMs at the max beta. This dipole in turn puts a cusp in the closed orbit at the IPM. From there, the IPM measures the change in the profile center as the current in the corrector is varied in order to quantify the local beta function. Beam position shift *dY* due to a known dipole kick (with kick strength k) is given by:

$$dY = 1/2\ k\beta[\ \cos(\pi Q)\ \sin(\pi Q)\ ]$$

where Q is the betatron tune. β is the beta function at the point where the beta function is measured. The kick strength can be given as:

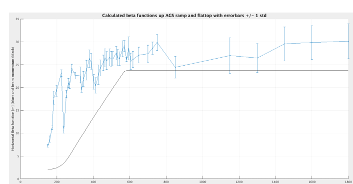
$$k = Bdl/B\rho$$

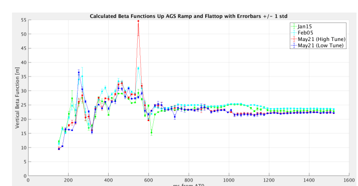
where $Bdl = I_{mag} \cdot T_{mag}$. The terms I_{mag} and T_{mag} denote the dipole current and the transfer function respectively. With this we can further simplify the equation above to get the beta function:

$$\beta = (2/T_{mag})(dY/I_{mag}) \cdot B\rho \cdot \tan(\pi Q)$$

Therefore, in order to attain this we need to measure the beam rigidity (Bρ), the tune (Q), and the change of the position at the IPM (dY) as we change the dipole current (I_{mag}).

Results





Above show some examples of resulting beta function measurement data taken during Run17 while RHIC was running polarized protons. The left shows a horizontal measurement using the D05 eIPM and the right shows results throughout Run17 using the vertical IPM at E15. The results are generated using Matlab. This measurement is also diverse in that it can run at various flattop energies (below, left) and has been used to compare the beta function when the partial snakes are not