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The Possible Method to Measure Twiss Parameters and Emittance of the AGS Ejected Beam

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AD/RHIC/RD-15

RHIC PROJECT
Brookhaven National Laboratory

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THE POSSIBLE METHOD TO MEASURE TWISS PARAMETERS AND EMITTANCE OF THE AGS EJECTED BEAM

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The Twiss parameters and emittance of the AGS ejected beam are important parameters for the tuning of the transport line from AGS to RHIC and the AGS fast ejection beam line. In 1985 Dr. J. Ryan and R. Thern have measured these parameters carefully except the dispersion functions. They have measured the beam profiles at various quadrupole strengths. From the transfer matrix for each setting of the quadrupole strength and the corresponding beam width the Twiss parameters and emittance were calculated. For each setting, ten profiles have been measured to improve the accuracy. The necessary monitor and some programs required for data treatment were developed. The error of that measurement is about 2.2% to 3% in the y-direction and larger than 10% in the horizontal direction. Probably this is because the calculated dispersion was used in the treatment of the datas in the x-direction. The measure accuracy may be improved further if the following means will be adopted.

1. Extend the measure range of the SEM

In the above mentioned measurement the maximum measure range is 300 mils. If the range can be extended to 30 mm or even 40 mm the relative measure accuracy may be improved by a factor of 3 or 4. By tuning the quadrupole strengths, we can easily enlarge the beam profile to this range. This improvement may be much easier than to improve the resolution power (It is about 1 mm now)by a factor of 3 and keep the measure range unvaried. For each setting of the quadrupole strengths ten or more profiles should be measured to improve the accuracy.

2. The proposed monitor arrangement

In order to measure both betatron parameters and dispersion,I propose to use two SEMs in the U-line. The arrangement is shown in figure 1. Ma will be installed about 1 meter downstream of UQ3 and Mb about 4 meters upstream of UQ4. The y-profiles will be measured mainly by Mb, because we can easily get large y-profile there. Of cause, Ma can also be used to take the y-profile datas. The procedure of the y-direction measurement can be the same as described in reference 1. For the dispersion measurement both Ma and Mb will be used simultaneously.

3. Measure the dispersion functions separately

For the x-direction measurement we can either measure the betatron parameters and the dispersion separately or both by the profile measurement. In order to measure the dispersion separately, we can measure the beam position changes corresponding to the changes of AGS ejection beam energy but keep the AGS bump, kicker, septum, main magnet and the U-line magnet strengths unvaried. The beam position change will be:

$$\Delta X = D_x \frac{\Delta P}{P} \qquad (1).$$

From the following equations we can get D_{ax} and D'_{ax}.

$$D_{ax} = \Delta X_a \Big/ \frac{\Delta P}{P} \qquad (2),$$

and

$$D'_{ax} = \frac{\Delta X_b - \Delta X_a}{L(\Delta P/P)} \qquad (3).$$

Where ΔX_a and ΔX_b are the beam position changes at Ma and Mb corresponding to the same AGS energy and L is the distance between the two monitors.

We can tune UQ1, UQ2 and UQ3 so that at Ma and Mb D_x are 3 m and 7 m respectively. For $\Delta P/P$ equals 3×10^{-3}, ΔX_a and ΔX_b will be 9 mm and 21 mm (the beam betatron radius is 6 mm and 15 mm at Ma and Mb). The measure accuracy depends upon not only the SEM measurements but also the accuracy of the determination of the beam energy and the field stability. If the measuring sensitivity of the closed orbit position in AGS is 0.1 mm, it corresponds to a relative energy determination accuracy to an order of 5×10^{-5} (D_x in AGS is about 2 meters). For $\Delta P/P$ equals 3×10^{-3}, it corresponds to an error 1.6×10^{-2}. The field instability will directly introduce errors to the measure results also. For some stationary magnets the field stability may be better than 5×10^{-4} but for some pulsed magnet such as kicker will be worse. If the repeatability of the kicker field is 10^{-2}, the caused error in beam position and direction at septum at H10 will be 0.19 mm and 0.006 mrad, which will introduce an error in D_x and D'_x (when $\Delta P/P$ is 3×10^{-3}) 2.8% and 1.3% respectively. The field instability and the energy instability are mainly random. At each $\Delta P/P$ measuring 10 or more times ΔX_a and ΔX_b will improve the accuracy of the results and investigate the stability of the AGS ejection beam performance. Measuring ΔX_a and ΔX_b simultaneously will decrease the influence of these instabilities and get better accuracy in the D'_{ax} measurements.

The nonlinear field distribution along the ejected beam trajectory will also influence the result because when beam energy changes but the field strength keeps constant the beam trajectory changes. We should measure D_{ax} and D'_{ax} at different $\Delta P/P$ and extrapolate the results to get the D_{ax} and D'_{ax} at the central orbit ($\Delta P/P = 0$) and at the same time we can get some information about the field nonlinearity along the ejection beam trajectory and its influence on the ejected beam performance.

Another possibility is to increase the AGS beam energy spread by changing its synchronous phase. We measure the beam widths corresponding to different energy spreads and get D_{ax} and D_{bx} by the following equations:

$$D_{ax} = (X_{a2} - X_{a1}) \Big/ \left[\left(\frac{\Delta P}{P}\right)_2 - \left(\frac{\Delta P}{P}\right)_1 \right] \qquad (5),$$

$$D_{bx} = (X_{b2} - X_{b1}) \Big/ \left[\left(\frac{\Delta P}{P}\right)_2 - \left(\frac{\Delta P}{P}\right)_1 \right] \qquad (6).$$

Where X_{a2}, X_{a1}, X_{b2} and X_{b1} are the beam widths corresponding to energy spread equals $(\Delta P/P)_2$, $(\Delta P/P)_1$ at Ma or Mb. And D'_{ax} equals:

$$D'_{ax} = (D_{bx} - D_{ax})/L^{*} \quad (7)$$

In this method ,the orbit does not change so the influence of the nonlinear field distribution will be smaller but the accuracy of the energy spread determination will effect the measure results directly.

The dispersion at H13-the starting point of the beam transport line D_{ox} and D'_{ox} can be calculated from the following equations:

$$D_{ox} = m_{22a}(D_{ax} - D_{oa}) - m_{12a}(D'_{ax} - D'_{oa}) \quad (8),$$

$$D'_{ox} = m_{11a}(D'_{ax} - D'_{oa}) - m_{21a}(D_{ax} - D_{oa}) \quad (9).$$

Where m_{11a} to m_{22a} and D_{oa}, D'_{oa} are the transfer matrix elements from H13 to Ma in horizontal direction for the setting of the U-line magnet strength when D_{ax} and D'_{ax} are determined.

Once D_{ox} and D'_{ox} are determined we can measure the beam widths at different settings of U-line quadrupole strengths at an achromatic point (probably downstream of UQ4) and then determine other required parameters in x-direction just as the y-direction measurements. If at some setting,at the measuring point there are small D_x and D'_x (not achromatic) we can get the required parameters by subtracting the contributions of dispersion from the measured beam widths.

4. Measure both dispersion and betatron parameters by measuring beam widths

The realization of the measurement described in the proceeding paragraph depends on the fine adjustment of the AGS operation and the precise measurement of its beam parameter. We can also get all the required parameters including dispersion by profile measurements.

The relation between beam width and the beam parameters can be expressed as following:

$$X_a^2 - (m_{11a} D_{ox} + m_{12a} D'_{ox} + D_{oa})^2 \delta^2 = m_{11a}^2 \beta_{ox} \epsilon_x - 2m_{12a} m_{11a} \alpha_{ox} \epsilon_x + m_{12a}^2 \gamma_{ox} \epsilon_x \quad (11).$$

For each setting of the U-line quadrupole strengths we can get similar equation and for X_b at Mb also.

There are five unknowns β_{ox}, α_{ox}, ϵ_x, D_{ox} and D'_{ox} which are the beam parameters at H13. So,taking the values of X_a, m_{11a} , m_{12a}, D_{oa} for different settings including the values at Mb at the same setting as taking datas at Ma, we can get five equations in which there are five unknowns. Solving these five algebric equations the required five parameters can be determined.

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*Generally D'_{ax} should be expressed as following:

$$D'_{ax} = (D_{bx} - D_{abx} - m_{11ab} D_{ax})/m_{12ab} .$$

Where m_{11ab}, m_{12ab} and D_{abx} are the transfer matrix elements from Ma to Mb.

For all the above mentioned measure method, the accuracy of the calibaration of the relations between the focusing parameters and the exciting currents of U-line quadrupoles will influence the measuring accuracy also. This factor will introduce an constant error.

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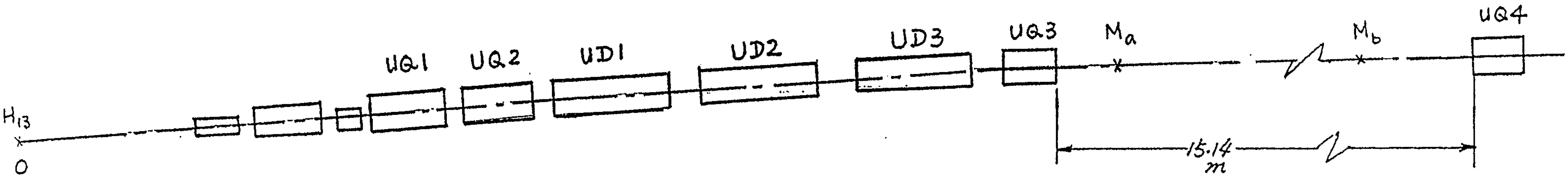

Figure 1.