Longitudinal displacements of the QS0’s and their compensation.

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1 Introduction.

During the 94/95 shutdown the QS0’s have been put at their nominal longitudinal positions (information from M. Hublin), but these positions have not been updated in the LEP database before the startup. As the optics is matched with the structure in the latter, this resulted in a mismatch of the optics in the actual machine.

In this note we evaluate with MAD the effect of this mismatch and its compensation with trims on the QS0 gradients. A comparison with the experimental QS0 gradient trims is made.

2 Effect of the longitudinal misalignment of the QS0.

The longitudinal positions of QS0’s in the database at the beginning of 1995 were not the nominal ones, the differences in millimeters are given in table 1.

<table>
<thead>
<tr>
<th>L2</th>
<th>R2</th>
<th>L4</th>
<th>R4</th>
<th>L6</th>
<th>R6</th>
<th>L8</th>
<th>R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>-6.0</td>
<td>+6.4</td>
<td>-3.3</td>
<td>+4.5</td>
<td>-9.3</td>
<td>+7.6</td>
<td>-5.7</td>
<td>+5.5</td>
</tr>
</tbody>
</table>

Table 1: Longitudinal displacements, in millimeters, of the QS0’s with respect to their nominal positions in the database at the beginning of 1995. The origin is in IP1.

In order to estimate the mismatch resulting from the use of the L05P46v6 optics, the QS0’s are placed at their nominal longitudinal positions, i.e. 3.7 m from the IP’s except in IP6 where this distance is 3.88 m and the TWISS parameters are computed after having set the tunes to the nominal values of $Q_\pi = 90.29$
and $Q_y = 76.19$ using the QF and QD's. The perturbations of the main optics parameters are summarized on line 1 of table 2.

<table>
<thead>
<tr>
<th></th>
<th>$\Delta Q_x$</th>
<th>$\Delta Q'_x$</th>
<th>$\frac{\Delta \beta}{\beta_x}$/%</th>
<th>$\Delta Q_y$</th>
<th>$\Delta Q'_y$</th>
<th>$\frac{\Delta \beta}{\beta_x}$/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSO’s to nom. pos.</td>
<td>+0.0108</td>
<td>+0.21</td>
<td>3.2</td>
<td>-0.0817</td>
<td>-2.24</td>
<td>24.7</td>
</tr>
<tr>
<td>trim KQS0 (sec. 3)</td>
<td>+0.0083</td>
<td>+0.11</td>
<td>2.6</td>
<td>+0.0012</td>
<td>-0.03</td>
<td>0.7</td>
</tr>
<tr>
<td>trim QSO pos. (sec. 4)</td>
<td>+0.0250</td>
<td>+0.34</td>
<td>9.3</td>
<td>+0.0027</td>
<td>-0.13</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Table 2: Tune-shifts observed when the QSO’s are set to their nominal positions with the optics L05P46v6 and after the QSO’s have been trimmed to recover $\beta_y^* = 5$ cm. The chromaticity shifts and beta-beating (observed in the arc) are those after the tunes have been set to nominal: $Q_x = 90.29$, $Q_y = 76.19$.

3 Compensation of the longitudinal misalignment of the QSO with gradient changes.

With the same machine conditions as in the preceding section, we compute here the QSO relative gradient changes in per-mil ($\Delta K/Q$) to be applied to recover the values of $\beta_y^*$. For each IP, both left and right QSO gradients are incremented by the same quantity. This quantity is used as a variable in a matching done with the cell command in MAD. In this process, it is fundamental to keep the tunes at the nominal values with the QF and QD gradients (as is done experimentally), in order to constrain the QSO gradient changes to act only on the beta functions and not on the tunes. Otherwise the trims found do not give the right $\beta_y^*$ when the tunes are set back to the nominal values. The relative gradient changes obtained to recover the $\beta_y^*$ values using the L05P46v6 optics and the nominal position of the QSO’s are given in table 3, line 1 and 2.

The experimental values of $\beta_y^*$ are deduced from the measurement of the tune-shifts associated with QSO gradient changes. In order to recover the design $\beta_y^*$ values, the QSO gradients are then appropriately trimmed. These experimental trims are given on line 3 of table 3. They are usually applied directly to the QSO calibration tables. The relative difference between the present calibration tables and the original tables provided by the magnet group is in fact equal to the opposite of the relative gradient changes given in table 3.

The relative gradient changes found experimentally are quite different from those expected from the MAD calculation (lines 1 and 2 of table 3).

Note also that the trims to the calibration tables applied this year lead to a measured $\beta_y^* = 4.8$ cm instead of the design 5 cm value. This difference produces a vertical beta-beating of the order of 5%. The matching of QSO gradients for the nominal positions has been done for both $\beta_y^* = 5$ cm and $\beta_y^* = 4.8$ cm and the differences are small.
Table 3: Relative gradient changes in per-mil computed with MAD to set the $\beta^*$'s to 5 cm, resp. 4.8 cm, with the L05P46v6 optics after the QS0's are brought back to nominal positions. The gradient changes found experimentally in 1995 in order to set $\beta^*_y = 4.8$ cm are also shown.

For all cases, the beta-beating measured or computed is not larger than what we can expect from the random gradient errors in the machine.

4 Estimate of the QS0 displacements to explain the measured trims.

The QS0 gradients are first modified using the experimental trims and the QS0 positions then used as matching variables to recover the $\beta^*_y$ values of 5 cm, resp. 4.8 cm. At each IP both QS0's are moved symmetrically from the IP. The tunes are kept constant with the $Q_F$ and $Q_D$ gradients as for the case of the gradient matching. The results are given in table 4.

Table 4: Symmetric displacements of the QS0's in millimeters at each IP to recover $\beta^*_y = 5$ cm, resp. 4.8 cm, with the L05P46v6 optics and the experimental trims. Negative values mean that both QS0's of a given IP are moved towards the IP.

We observe a huge difference between these values and the QS0 displacements in table 1. This was expected given the large difference between the experimental trims and those computed in section 3 and shown in table 3. In fact the actual difference is a little smaller. It has been shown indeed that the decrease of the QS0 gradients at their ends makes them less focusing because of the steep variation of $\beta_y$ at this place. This lack of focusing has to be compensated by a positive relative gradient change of $7 \times 10^{-4}$ [1]. Therefore the numbers in table 4 are probably slightly overestimated.

The perturbations of the optics parameters obtained after this computation are given on line 3 of table 2. They are smaller than those due to random
gradient errors in the machine. As the displacements found here are much larger than the estimated ones (table 1), the experimental trims must compensate for other effects such as errors in calibration tables or in survey measurements.

5 Conclusion

Trimming the Q50’s is an efficient way of correcting the errors in their longitudinal positions. The mismatch of the beta-functions resulting from this action is below what can be measured for errors of the longitudinal positions of up to four centimeters.

Consequently it is not critical to rematch an optics, once the Q50 trims have been done experimentally, if a wrong longitudinal positioning of the Q50’s is found in the course of the operation period. It is nevertheless important that the optics be matched with the correct positions at the beginning of each year in order not to accumulate systematic optical errors which would eventually lead to the impossibility of correcting both the $\beta^*$s and the beta-beating.

References