

Measure Twiss and Coupling at IP

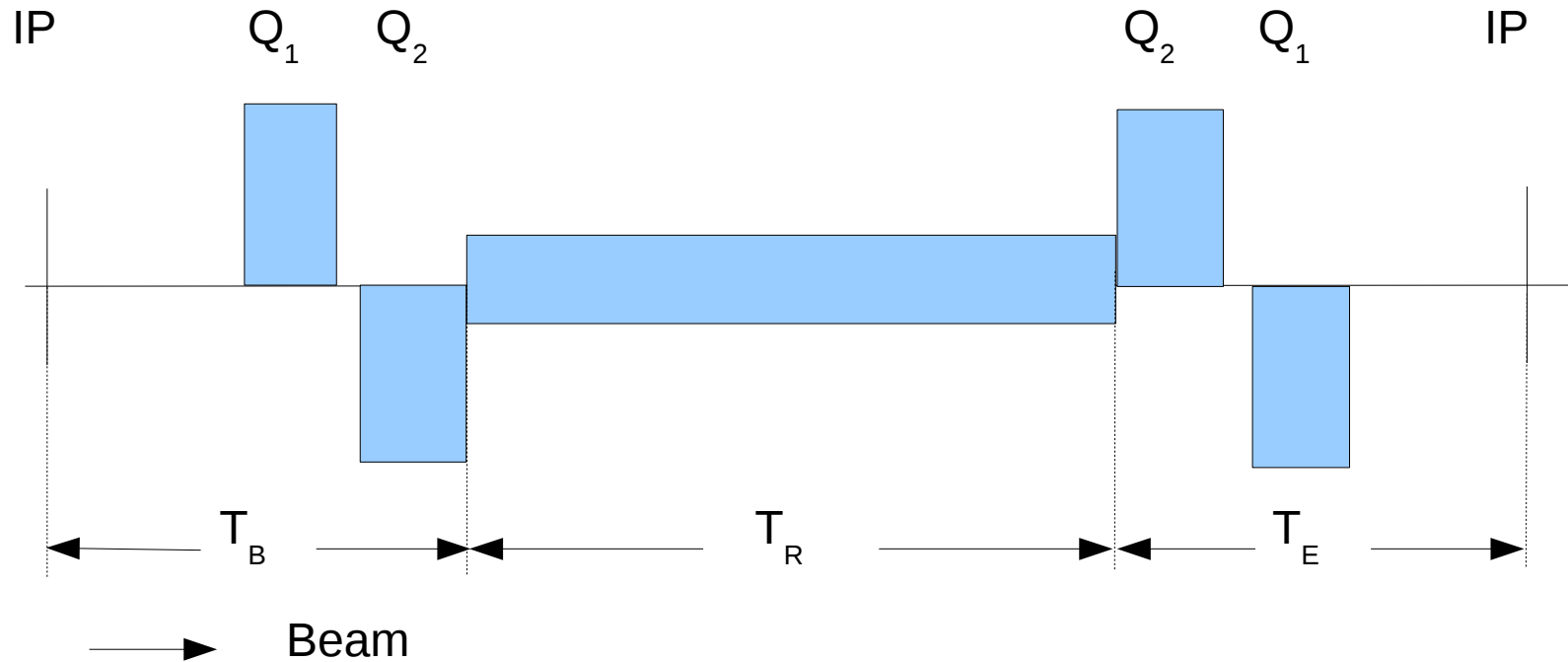


Figure 1: Schematic of the synchrotron from an IP through two of the triplet quadrupoles and back to the IP. Thus the beam transfer matrix is: $T = T_E T_R T_B$.

$$T = T_E T_R T_B$$

$$T_B = T_{Q_2} T_{Drift} T_{Q_1} T_{Drift} \quad T_E = T_{Drift} T_{Q_1} T_{Drift} T_{Q_2}$$

10 parameters:

$$[\mu_x, \alpha_x, \beta_x, \mu_y, \alpha_y, \beta_y, a, b, c, d]$$

The eigen-tunes from the transfer matrix:

$$Q_{\pm} = \text{Tune}_{\pm}(\mathbf{T}) = \frac{1}{2\pi} \arccos\left(\frac{1}{2}(\text{Tr}(\mathbf{A}) + \text{Tr}(\mathbf{D}))\right) \pm \sqrt{\frac{1}{4}(\text{Tr}(\mathbf{A}) - \text{Tr}(\mathbf{D}))^2 + \det(\bar{\mathbf{B}} + \mathbf{C})}$$

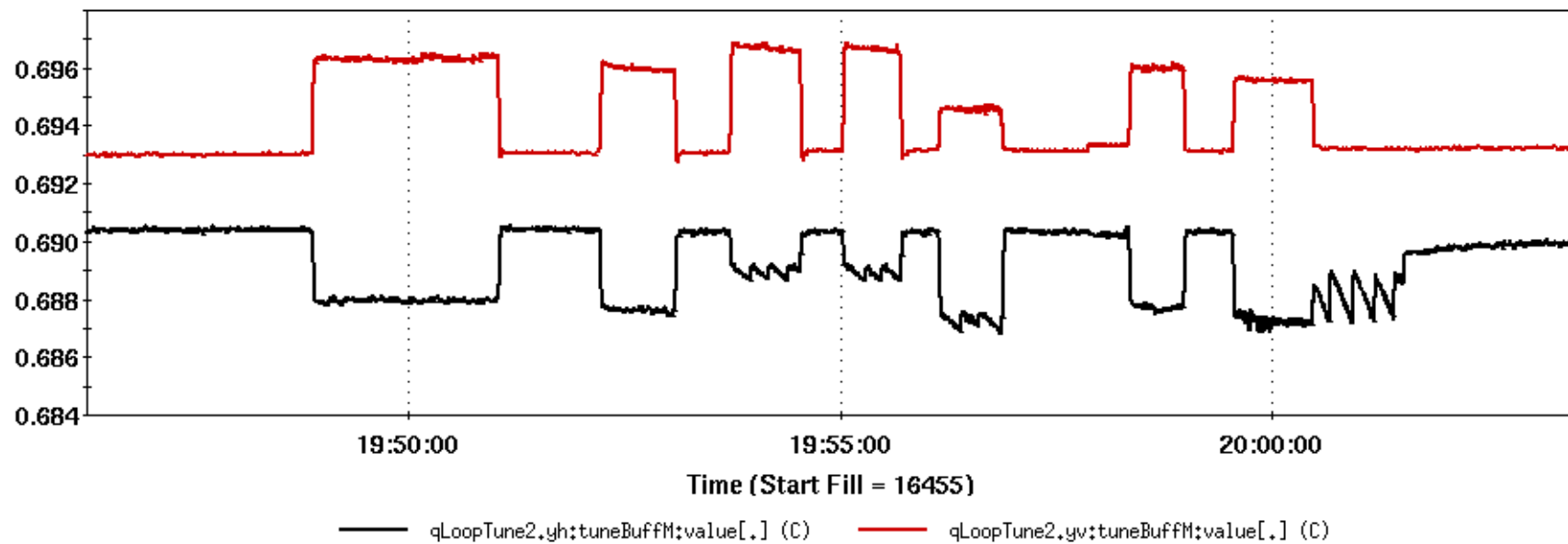
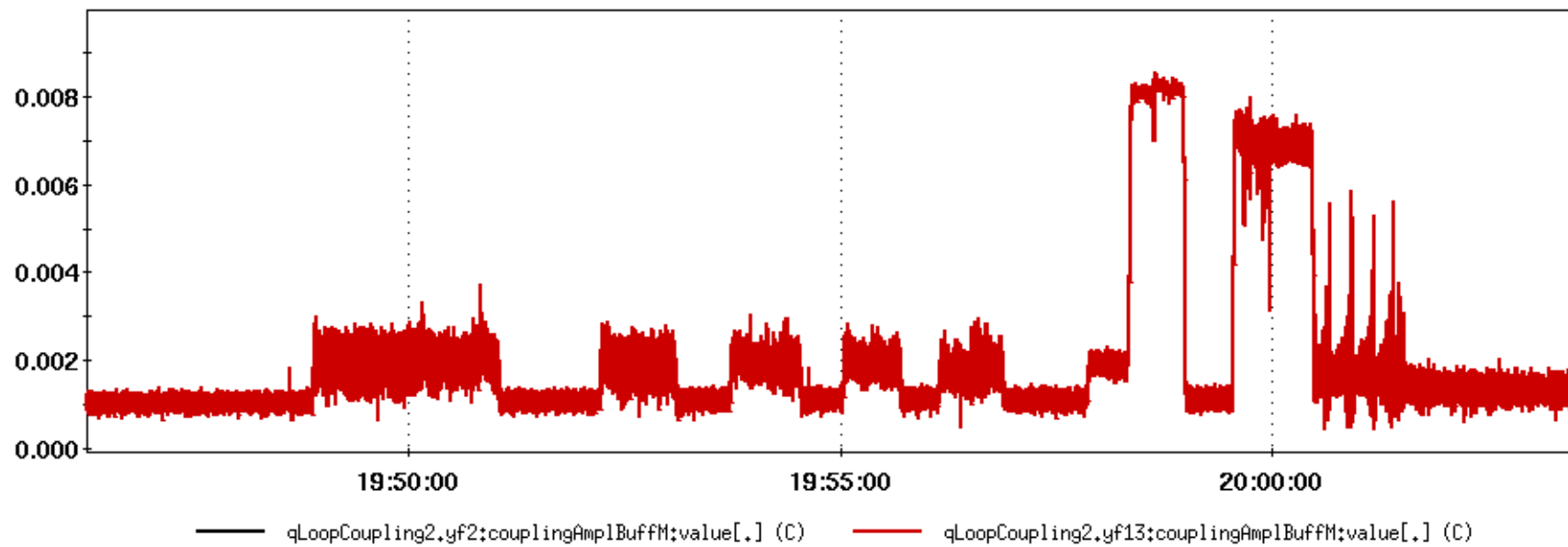
The ΔQ_{min} from the transfer matrix:

$$\Delta Q_{min} = \text{DtuneMin}(\mathbf{T}) = \frac{\sqrt{\det(\bar{\mathbf{B}} + \mathbf{C})}}{\pi[\sin(2\pi Q_+) + \sin(2\pi Q_-)]}$$

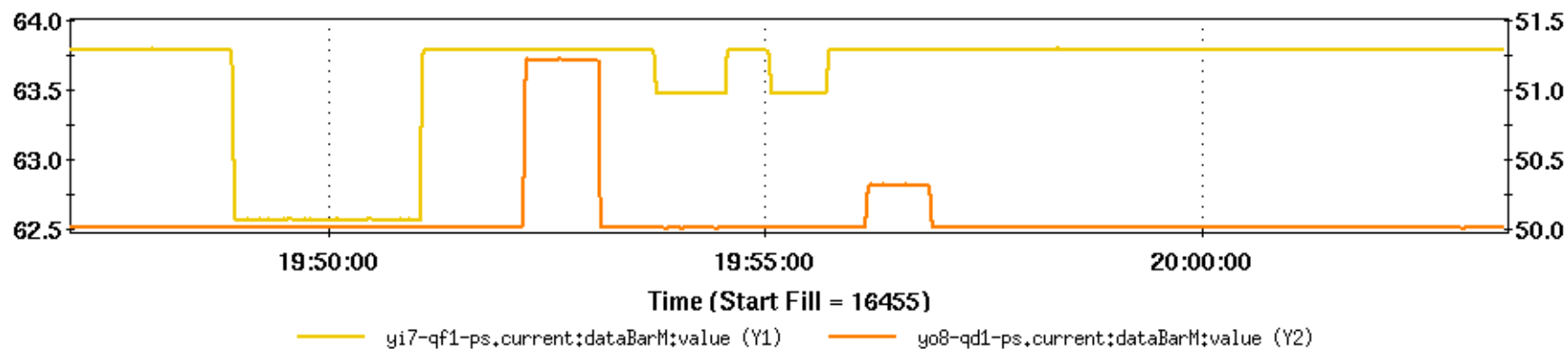
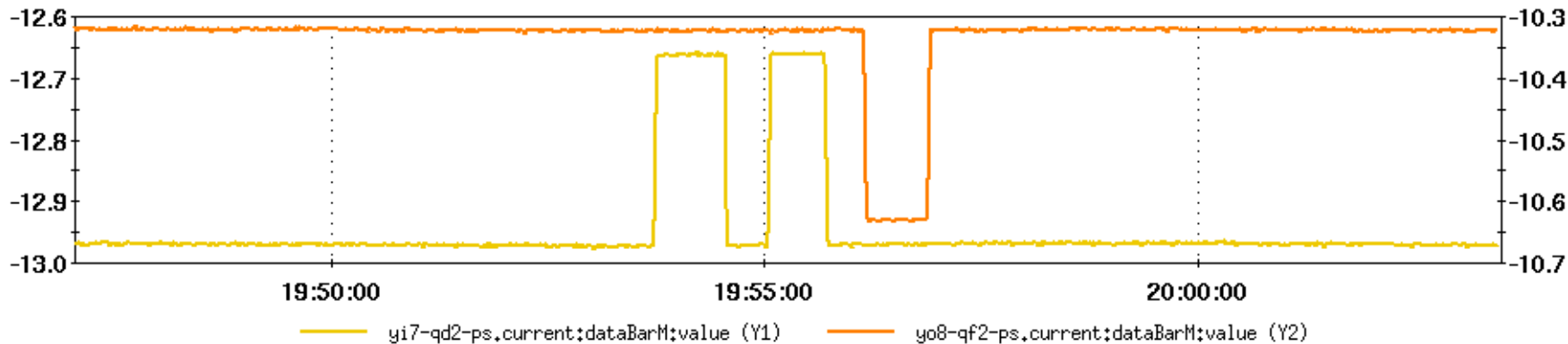
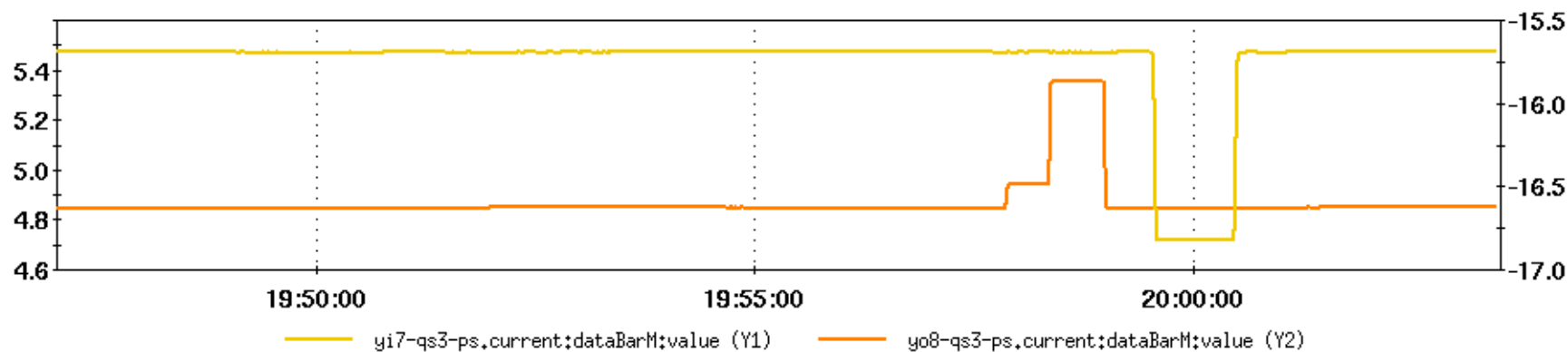
BBQ measures the eigen-tunes and the ΔQ_{min} . Using the above equations, we solve for the 10 parameters that describe the transfer matrix T .



File Window Markers Analysis



File Window Markers Analysis



Time (Start Fill = 16455)

Yellow IP8

First fit using all six quadrupoles. β^* is quite large as well as α^* is far from zero.

OptiCalc:

$$\beta_x = 0.842m$$

$$\alpha_x = -0.0147$$

$$\beta_y = 0.918m$$

$$\alpha_y = 0.0055$$

Yellow-IP8-16455.ctm -- Coupled Transfer Matrix

Beam lines Measurements/Solver

Measured Base Tunes

| Qx | Qy | ΔQ_{min} |
|--------|----------|------------------|
| 0.6904 | 0.693005 | 0.00104392 |

Measured Tweak Tunes

| Quadrupole | ΔK_L | Qx | Qy | ΔQ_{min} |
|------------|--------------|----------|----------|------------------|
| q1b | -0.00005 | 0.687961 | 0.696317 | 0.00199415 |
| q2b | -0.00003 | 0.688946 | 0.696676 | 0.001967 |
| q3b | 0.00005 | 0.687247 | 0.695583 | 0.00689778 |
| q3e | -0.00005 | 0.687713 | 0.695996 | 0.00814993 |
| q2e | -0.00003 | 0.687252 | 0.694572 | 0.00178459 |
| q1e | -0.00005 | 0.687632 | 0.695981 | 0.00196421 |

Solve Evaluate Method: Q1 - Q2 - Q3

Base Tunes

| Qx | Qy | ΔQ_{min} |
|--------|----------|------------------|
| 0.6904 | 0.693005 | 0.00104412430967 |

Twiss Parameters and Coupling

| α_x | β_x | Couple ₁₁ | Couple ₁₂ |
|-----------------|---------------|----------------------|----------------------|
| -1.52799608818 | 2.97042604824 | -0.374527987916 | 0.284389656218 |
| α_y | β_y | Couple ₂₁ | Couple ₂₂ |
| -0.677877479836 | 1.67482408809 | -0.225328918318 | 0.0542777060989 |

Beam Transfer Matrix

| | | | |
|-----------------|----------------|------------------|----------------|
| -1.7779612133 | 2.69757597863 | -0.332714340179 | 0.508951063766 |
| -1.08438061563 | 1.04766917182 | -0.0935713049937 | 0.330936032675 |
| -0.341903053581 | 0.517278631814 | -1.08337856024 | 1.66507638631 |
| -0.10016944195 | 0.334303713355 | -0.886053086395 | 0.381087588208 |

Model and Measurement Differences

| Device | ΔQ_x | ΔQ_y | 100* $\Delta(\Delta Q_{min})$ |
|-------------------------------------|-------------------|-------------------|-------------------------------|
| Base | 0.0 | 0.0 | 2.04309670761e-05 |
| q1b | 0.00612351813889 | 0.00651739637231 | 0.00019550053253 |
| q2b | 0.00364898854638 | 0.00714155724876 | 0.000361562155763 |
| q3b | 0.00123686258259 | 0.000206289368912 | 5.34528242401e-05 |
| q3e | 0.000553206474962 | 0.000343278894594 | 8.05366950796e-05 |
| q2e | 0.00675895293461 | 0.00325094393534 | 0.000652359550853 |
| q1e | 0.00613439305323 | 0.00570740006195 | 0.000580931092945 |
| Penalty (sum of the squares) | | | 0.000273686186574 |

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Yellow IP8

The scalloping of the tunes occurred during the tweaking of the Q2 quadrupoles. I removed Q2s from the fitting.

OptiCalc:

$$\beta_x = 0.842m$$

$$\alpha_x = -0.0147$$

$$\beta_y = 0.918m$$

$$\alpha_y = 0.0055$$

yellow-IP8-16455.ctm -- Coupled Transfer Matrix

Beam lines Measurements/Solver

Measured Base Tunes

| Qx | Qy | ΔQ_{min} |
|--------|----------|------------------|
| 0.6904 | 0.693005 | 0.00104392 |

Measured Tweak Tunes

| Quadrupole | ΔK_L | Qx | Qy | ΔQ_{min} |
|------------|--------------|----------|----------|------------------|
| q1b | -0.00005 | 0.687961 | 0.696317 | 0.00199415 |
| q2b | -0.00003 | 0.688946 | 0.696676 | 0.001967 |
| q3b | 0.00005 | 0.687247 | 0.695583 | 0.00689778 |
| q3e | -0.00005 | 0.687713 | 0.695996 | 0.00814993 |
| q2e | -0.00003 | 0.687252 | 0.694572 | 0.00178459 |
| q1e | -0.00005 | 0.687632 | 0.695981 | 0.00196421 |

Solve Evaluate Method: Q1 - Q3

Base Tunes

| Qx | Qy | ΔQ_{min} |
|--------|----------|------------------|
| 0.6904 | 0.693005 | 0.00104357358708 |

Twiss Parameters and Coupling

| α_x | β_x | Couple ₁₁ | Couple ₁₂ |
|-----------------|----------------|----------------------|----------------------|
| -0.111642729388 | 0.990603222464 | 0.053762966347 | 0.15428616951 |
| α_y | β_y | Couple ₂₁ | Couple ₂₂ |
| 0.675749320191 | 1.52638617302 | -0.29441483649 | -0.0320258328539 |

Beam Transfer Matrix

| | | | |
|-----------------|------------------|-----------------|------------------|
| -0.473272125874 | 0.89914569698 | -0.151026615203 | -0.0154199788824 |
| -1.01341119255 | -0.257021328519 | 0.078299672321 | 0.225474978983 |
| -0.223900602582 | -0.0109019152256 | 0.278414575456 | 1.39559495886 |
| 0.0696781284911 | 0.150088781618 | -0.93572111348 | -0.980704134585 |

Model and Measurement Differences

| Device | ΔQ_x | ΔQ_y | 100* $\Delta(\Delta Q_{min})$ |
|-------------------------------------|-------------------|-------------------|-------------------------------|
| Base | 0.0 | 0.0 | 3.46412919354e-05 |
| q1b | 0.00568477465356 | 0.0063934629779 | 4.39486079572e-05 |
| q2b | 0.00341923899681 | 0.00699636817743 | 0.0152597998839 |
| q3b | 0.000545165571568 | 0.000481831754932 | 3.20056951813e-05 |
| q3e | 7.16949493593e-05 | 0.000284232326712 | 4.33108389991e-05 |
| q2e | 0.00681007458993 | 0.00345038636741 | 0.00869562247182 |
| q1e | 0.00617396171472 | 0.00609475300319 | 1.98052455679e-05 |
| Penalty (sum of the squares) | | | 0.000576476556265 |

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An example using the model of the Blue ring from MADX at IP6.

blue-model.ctm -- Coupled Transfer Matrix

Beam lines Measurements/Solver

Measured Base Tunes

| Qx | Qy | ΔQ_{min} |
|------------|------------|------------------|
| 0.30771057 | 0.09007106 | 0.259040957 |

Measured Tweak Tunes

| Quadrupole | ΔKL | Qx | Qy | ΔQ_{min} |
|------------|-------------|------------|------------|------------------|
| q1b | -0.0005 | 0.06811015 | 0.31271773 | 0.290227414 |
| q2b | 0.0003 | 0.32604323 | 0.10527101 | 0.245917277 |
| q3b | 0.0001 | 0.31768672 | 0.06586341 | 0.321721359 |
| q3e | -0.0001 | 0.2983241 | 0.11036535 | 0.213091014 |
| q2e | -0.0003 | 0.10258543 | 0.32280093 | 0.254030754 |
| q1e | 0.0005 | 0.31641966 | 0.07390171 | 0.274338218 |

Solve Evaluate Method: Q1 - Q2 - Q3

Base Tunes

| Qx | Qy | ΔQ_{min} |
|------------|------------|------------------|
| 0.30771057 | 0.09007106 | 0.259040957 |

Twiss Parameters and Coupling

| α_x | β_x | Couple ₁₁ | Couple ₁₂ |
|-----------------|----------------|----------------------|----------------------|
| -0.188338093604 | 0.765511172027 | -0.982826129926 | -0.0501451285919 |
| α_y | β_y | Couple ₂₁ | Couple ₂₂ |
| 0.864665329782 | 0.621858588478 | -0.148802672556 | -0.926521153041 |

Beam Transfer Matrix

| | | | |
|----------------|-----------------|-----------------|-----------------|
| 0.408493215614 | 0.551111391094 | -0.990729416557 | 0.231298647818 |
| -1.5045088565 | 0.0198753892813 | 0.278721668089 | -0.229322972196 |
| -1.00884984109 | 0.168125383442 | 0.347987145494 | 0.549269813262 |
| 0.091258781122 | -0.176509902481 | -1.3961068303 | 0.202397109888 |

Model and Measurement Differences

| Device | ΔQ_x | ΔQ_y | 100* $\Delta(\Delta Q_{min})$ |
|-------------------------------------|-------------------|-------------------|-------------------------------|
| Base | 0.0 | 0.0 | 4.20496970577e-11 |
| q1b | 6.56810829336e-09 | 5.94139315524e-09 | 3.49498208152e-11 |
| q2b | 4.08071559876e-09 | 3.75021720622e-09 | 5.53446177776e-12 |
| q3b | 7.55905943395e-09 | 2.36770805739e-09 | 6.32049967919e-11 |
| q3e | 1.57279789192e-09 | 3.51268882037e-09 | 7.22755189031e-11 |
| q2e | 4.55255620702e-09 | 6.94561491654e-09 | 7.27085058827e-11 |
| q1e | 7.26935717177e-09 | 5.16481968305e-10 | 7.59392548844e-12 |
| Penalty (sum of the squares) | | | 3.08809890014e-16 |

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