Effect of skew quad corrections at post-IP wire-scanner

Benoît BOLZON (LAPP)
Philip BAMBADE (LAL)

Introduction

- ✓ Study of coupling and dispersion corrections with skew quadrupoles thanks to MAD optics code:
  - At the post-IP wire-scanner (waist)
  - With the current lattice
  - With energy spread=0 at the entrance to DR extraction kicker (to take into account only x-y betatron coupling effects)
  - Matricial calculation (not tracking)

- ✓ For dispersion corrections: use of skew quadrupoles QS1X and QS2X

- ✓ For coupling corrections: use of skew quadrupoles QK1X to QK4X

- ✓ Complementary to simulations of Glen White who uses IP sextupoles for dispersion corrections

Dispersion correction with sum knob QS1X+QS2X

✓ QS1X/QS2X used for dispersion correction

➔ Designed not to introduce coupling with sum knob (QS1X+QS2X)

	QS1	QS2	QS1+QS2
Dy [m]	-0.005	-0.005	**-0.010**
σy_{ind}=Dy*dp/p [m] (dp/p=8e-4)	-4.0e-6	-4.0e-6	**-8.0e-6 (17.2*σy)**
Dy' [rad]	0.082	0.081	**0.163**
$\sigma y'_{ind}$=Dy'*dp/p [rad] (dp/p=8e-4)	6.6e-5	6.5e-5	**1.3e-4 (5.1*σy')**

- **Spatial dispersion (Dy):**
  ➔ increase of vertical nominal beam size of a factor 17
- **Angular dispersion (Dy):**
  ➔ increase of angular vertical beam size of a factor 5

➡ **Mostly spatial dispersion**

✓ However, big coupling introduced and emittance increase of 50%

	QS1	QS2	QS1+QS2	QS1=QS2=0
<xy>	-0.79	0.92	**0.73**	**0.00**
<xy'>	0.50	-0.63	**-0.21**	**0.00**
<x'y>	-0.43	0.24	**-0.16**	**0.00**
<x'y'>	0.29	-0.18	**0.11**	**0.00**
εy [m]	2.88e-11	3.93e-11	**1.80e-11**	**1.18e-11**

Dispersion correction with sum knob QS1X+QS2X

- ✓ Currently, emittance measurements give 5pm
- ✓ For this value, QS1+QS2 increases the emittance by a factor 2 (9.7pm):

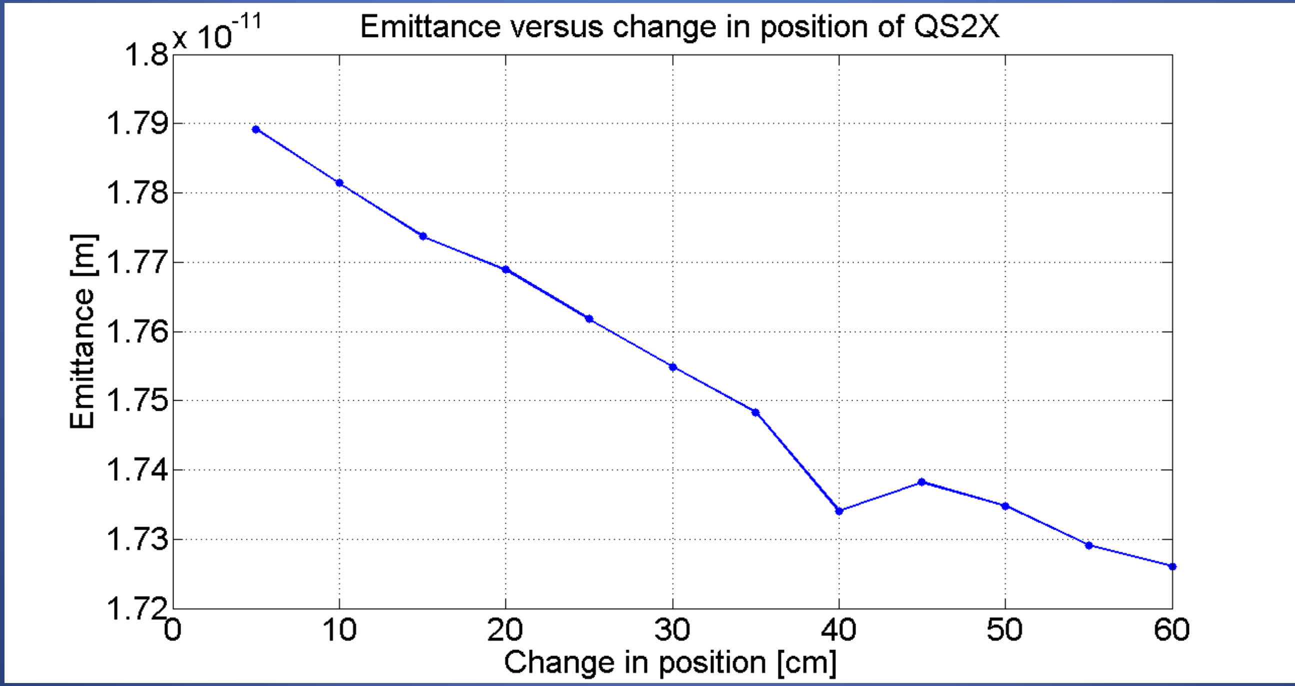
	QS1	QS2	QS1+QS2	QS1=QS2=0
<xy>	-0.81	0.91	**0.85**	**0.00**
<xy'>	0.56	-0.56	**0.04**	**0.00**
<x'y>	-0.46	0.31	**-0.05**	**0.00**
<x'y'>	0.33	-0.20	**0.18**	**0.00**
εy [m]	17.8e-12	24.6e-012	**9.7e-12**	**5.0e-12**

- ✓ N.B: For the nominal lattice, QS1+QS2 gives almost the same emittance than for the current one (17.3pm):

	QS1	QS2	QS1+QS2	QS1=QS2=0
<xy>	-0.268595	0.114885	**-0.170277**	**0.00**
<xy'>	0.214471	-0.099922	**0.147981**	**0.00**
<x'y>	0.855622	-0.940809	**-0.703025**	**0.00**
<x'y'>	-0.647924	0.705066	**0.115216**	**0.00**
εy [m]	28.9e-12	38.9e-12	**17.3e-12**	**11.7e-12**

Dispersion correction with sum knob QS1X+QS2X

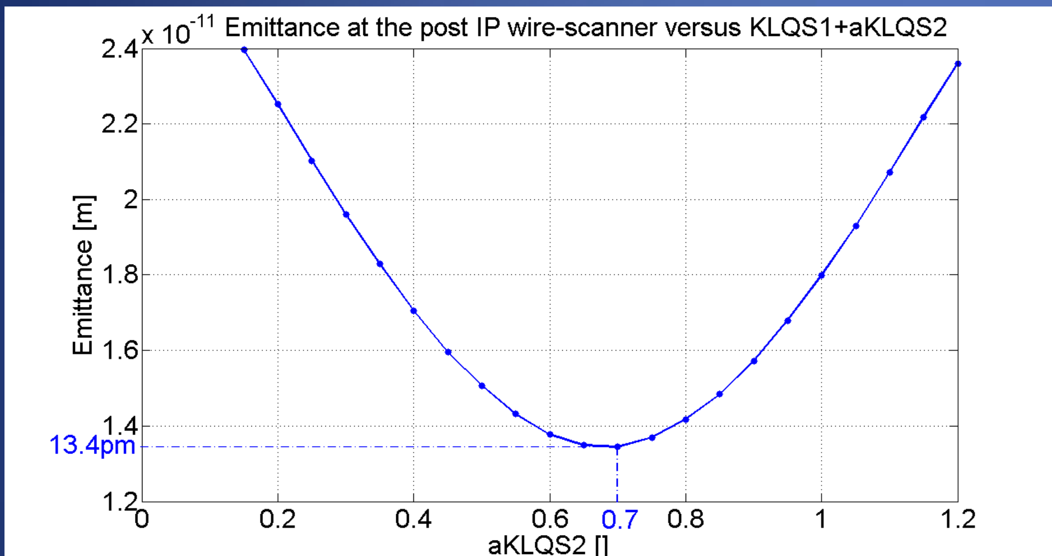
- ✓ Coupling introduced by sum knob QS1+QS2 whereas they should not
  ➔ QS1 and QS2 at the good location compared to the design?
- ✓ QS2 could in principle be moved up to ~1m towards the IP
  ➔ Effect of its position change on the emittance at post-IP WS



- ➢ Almost no decrease of emittance with the change in position of QS2
  ➔ What is the position of QS1 and QS2 given by the design?

Dispersion correction with quasi sum knob QS1/2X

✓ Idea: Vary the strength of QS2 around the one of QS1 (fixed) to find the minimal emittance since sum knob increases the emittance



➤ Minimal emittance of 13.4pm with quasi sum knob QS1+70%QS2

➤ Much better than with sum knob (18.0pm) and close to the nominal value (11.8pm)

✓ Dispersions induced by the sum knob and the quasi sum-knob

	Dy [m]	σy_{ind}=Dy*dp/p [m] (dp/p=8e-4)	Dy' [rad]	$\sigma y'_{ind}$=Dy'*dp/p [rad] (dp/p=8e-4)
QS1+QS2	-0.010	-8.0e-6 **(17.2*σy)**	0.163	1.3e-4 **(5.1*σy')**
QS1+70%QS2	-0.008	6.4e-6 **(13.7*σy)**	0.138	1.1e-4 **(4.3*σy')**

➤ Only slightly lower with knob QS1+70%QS2 than with knob QS1+QS2

Coupling correction with QK1-4X

✓ Correction of the coupling induced by sum knob QS1X+QS2X with QK1X, QK2X, QK3X and QK4X

➢ Calculation of the QK1-4X knobs to get <xy>=-0.73, <xy’> =0.21, <x’y>=0.16, <x’y’>=-0.11:

$$\begin{pmatrix} \langle xy \rangle \\ \langle xy' \rangle \\ \langle x'y \rangle \\ \langle x'y' \rangle \end{pmatrix} = M \begin{pmatrix} KLQK1X \\ KLQK2X \\ KLQK3X \\ KLQK4X \end{pmatrix}$$

⇓

$$\begin{pmatrix} KLQK1X \\ KLQK2X \\ KLQK3X \\ KLQK4X \end{pmatrix} = M^{-1} \begin{pmatrix} \langle xy \rangle \\ \langle xy' \rangle \\ \langle x'y \rangle \\ \langle x'y' \rangle \end{pmatrix}$$

Matrice M	QK1X	QK2X	QK3X	QK4X
<xy>	0.683017	-0.324563	-0.366813	-0.587186
<xy’>	-0.587207	-0.366819	0.324574	-0.683027
<x’y>	0.366830	0.587194	0.683026	-0.324577
<x’y’>	-0.324589	0.683036	-0.587215	-0.366836

✓ Knob obtained by matricial calculation

	QK1X	QK2X	QK3X	QK4X
Normalized	-1	0.3262	0.9749	0.5305

✓ Correlations obtained (no sum knob): very good

	<xy>	<xy’>	<x’y>	<x’y’>
	-0.73	**0.22**	**0.16**	**-0.14**

Coupling correction with QK1-4X

✓ Results obtained with sum knob QS1X+QS2X and coupling corrections with QK1-4X

	No correction	correction
r13	0.73	**-0.010**
r14	-0.21	**0.009**
r23	-0.16	**0.014**
r24	0.11	**-0.035**
εy	1.80e-011	**1.18e-011**
Dy	-0.010	-0.010
Dy’	0.163	0.163

- Correlations completely corrected (almost 0)
- Vertical emittance: from 18.0pm with no corrections to the nominal value with corrections (11.8pm)

→ Corrections of coupling and emittance induced by sum knob QS1X+QS2X with QK1-4X completely succeed!!

Coupling correction with QK1-4X

✓ Efficiency of the matricial method: calculation of knobs to independently correct <xy>, <xy'>, <x'y> and <x'y'> (value of 1)

Knob (Normalized)	QK1X	QK2X	QK3X	QK4X
<xy> (1st knob)	1	-0.4667	-0.5500	-0.8722
<xy'> (2nd knob)	-0.8722	-0.5500	0.4667	-1
<x'y> (3rd knob)	0.5500	0.8722	1	-0.4667
<x'y'> (4th knob)	-0.4667	1	-0.8722	-0.5500

✓ Correlations obtained with the calculated knobs:

Correlations	1st knob	2nd knob	3rd knob	4th knob
<xy>	**0.83**	-0.12	0.00	0.00
<xy'>	0.12	**0.83**	-0.00	0.00
<x'y>	0.00	-0.00	**0.83**	-0.12
<x'y'>	0.00	-0.01	0.12	**0.83**

➢ Knobs well orthogonal

Conclusion

✓ Sum knob QS1X+QS2X: good spatial dispersions (lower angular dispersion) but coupling and emittance increase while they should not

- ➢ Was the design respected? (In simulations, move QS2 up to 60cm but almost no decrease of emittance)

✓ To correct coupling and emittance increase, 2 methods were tried:

- ➢ Quasi sum knob KLQS1+aKLQS2: minimal emittance of 13.4pm found for a=70% (nominal: 11.8pm)
  - ➔ Dispersion just slightly lower than with sum knob
- ➢ QK1-4X correctors: down to nominal emittance/coupling almost 0

➡

✓ With QK1-4X correctors: emittance completely corrected contrary to quasi sum knob method

✓ But with quasi sum knob: no use of QK1-4X

- ➢ can then be used for other coupling corrections
- ➢ avoid the combinaison of 6 correctors which is more sensitive to the correctness of the optics

Prospects and further studies

✓ Check the corrector behavior (for quasi-sum knob, correctors of orthogonal coupling…) in the presence of:

- ➢ Errors on β-functions at the injection
- ➢ Residual coupling not corrected in the damping ring

✓ Understand why sum knob QS1+QS2 introduces coupling and emittance increase while they were designed not to do that

- ➢ Has the location of QS1 and QS2 been changed due to a problem of place? This can be checked by:
  - ➔ Doing the same simulations with the lattice of 2007 for ex.
  - ➔ Looking where the β-functions are exactly symmetric and of same amplitude (it will give the exact locations to cancel coupling)