Local Second-Order Chromatic Compensation of the LHC High Luminosity IRs

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With collision optics of $\beta^* = 0.25$ the interaction regions (IRs) contribute most of the machine chromaticity due to the very large β functions across the final focus triplets. The presently envisioned method of compensating machine chromaticity is via a global scheme using 4 x 8 = 32 sextupole families per beam[1]. In this note a scheme is proposed, based on the approach of ref.[2], which corrects the IR contribution to Q' and Q" with a more localized set of 4 sextupole families per beam. Localized correction has the advantage that the IRs can be operated independently and the global chromaticity and tunes fixed by other constraints.

The local scheme requires using the full complement of arc sextupoles in the 22 cells in each sector bracketing the IRs. With the phase advance in the arc cells close to 90° in both planes the fractional tunes across the entire IR plus 44 cell section are tuned to (.75, .75), which helps to reduce the first order chromatic β-waves[2]. The distribution of sextupoles is illustrated in Figure 1. The SF1 and SD1 families are situated $^{(2n+1)}/_{2}\pi$ in phase from the IP. The SF2 and SD2 are interleaved with members of the first families and spaced $m\pi$ in phase from the IP.

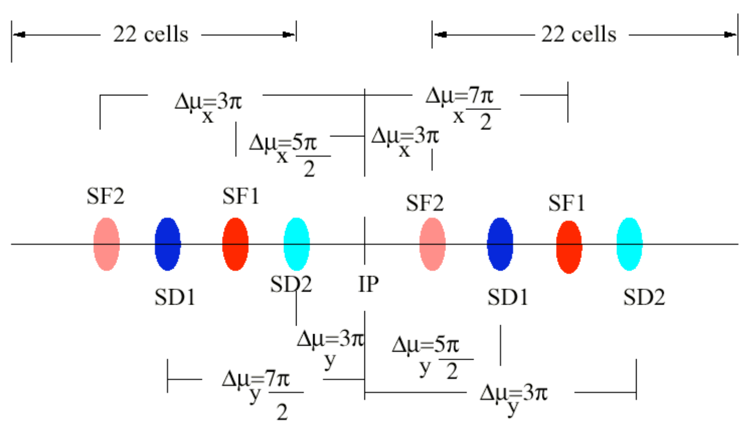

Fig.1. Distribution of local chromatic correction sextupoles.

To correct just the linear chromaticity only 2 families of sextupoles are required, in which case the fields of SF2 = SF1 and SD2 = SD1. Table 1 lists the contributions from the IR and arcs to Q' and the sextupole strengths needed to cancel them. (The maximum available sextupole strength is 4500 T/m^2). Note that 80% of the total Q' comes from the insertion.

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[1] Second Order Chromaticity Correction of LHC V6.0 at Collision, Stephane Fartoukh, LHC-project-report-308, October, 1999.
[2] Chromaticity Correction for the SSC Collider Rings, T. Sen, *et al*, IEEE proceedings, 143-145, 1993.

Q'_x(IR)	-61.3	Q'_y(IR)	-61.3
Q'_x(arcs)	-15.1	Q'_y(arcs)	-15.1
SF1/SF2	2045 T/m^2	SD1/SD2	-4188 T/m^2

Table 1. Sextupole strengths to cancel first order chromaticity in either IR1 or IR5 for beam 1.

Correction of the second order chromaticity Q" requires all 4 sextupole families. By adding and subtracting equal strengths to the SF1 and SF2 sextupoles, respectively, Q' is guaranteed not to change to first order, but provides the flexibility to cancel Q" as well. (Similarly for SD1 and SD2). The final sextupole fields are given in Table 2. The SD1 family has a margin of 2.3% from the maximum field strength available.

SF1	2136 T/m^2	SD1	-4392 T/m^2
SF2	1955 T/m^2	SD2	-3984 T/m^2

Table 2. Sextupole strengths to cancel both Q' and Q" in either IR1 or IR5 for beam 1.

Figure 2 shows the tune variation with momentum across the 2 sectors plus IR for Q' = 0, and both Q' and Q" = 0. ($\Delta p/p = \pm 3.33e\text{-}4$ is the full bucket size). Correction of the second order terms significantly flattens the tune variation. The residual curvature is due to third order terms.

Corresponding results for $\Delta\beta^*/\beta^*$ variation with momentum are shown in Figure 3. After canceling Q' and Q", $\Delta\beta^*/\beta^*$ changes are on the level of ~1% across the range $\Delta p/p = \pm 3.33e\text{-}4$.

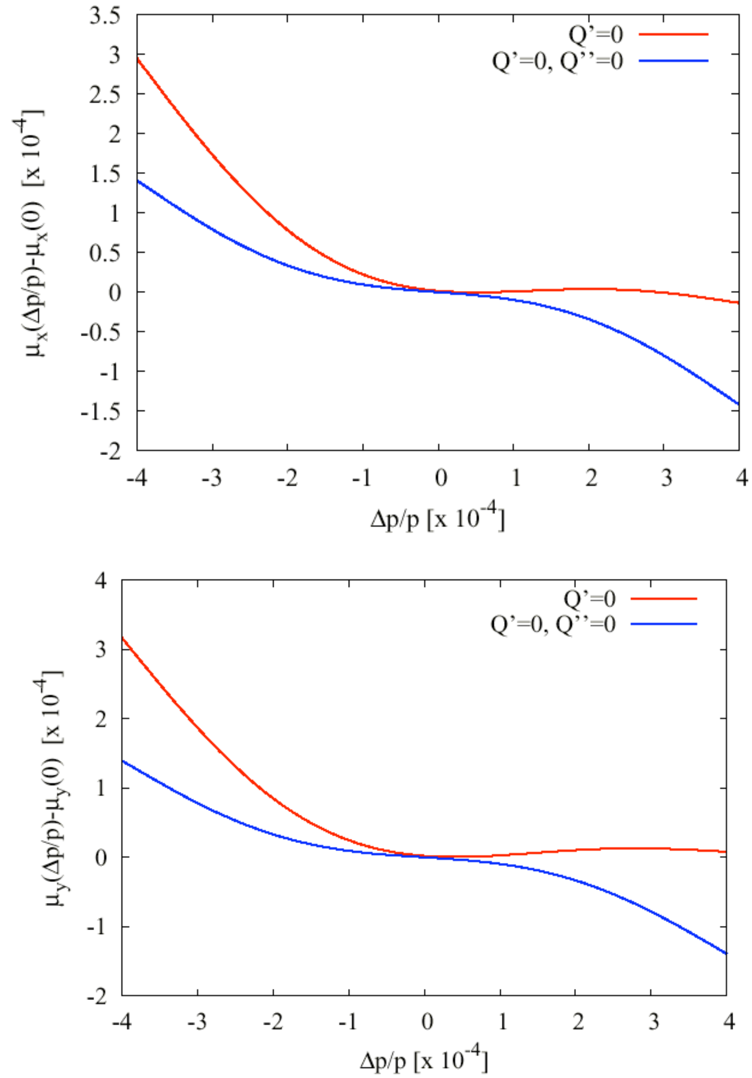

Fig.2 Tune variation with momentum after correcting for Q', and both Q' and Q''. Top is horizontal, vertical is shown in the bottom graph.

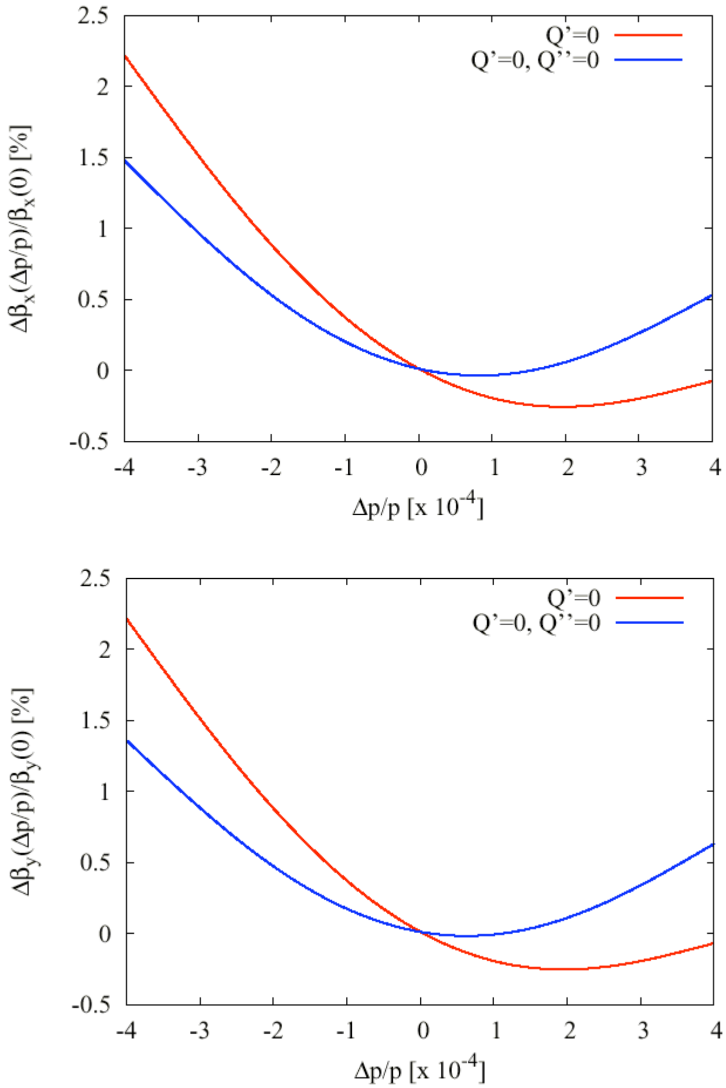

Fig.3 Relative variation of $\Delta\beta^*/\beta^*$ (in %)with momentum after correcting for Q', and both Q' and Q''. Top is horizontal, vertical is shown in the bottom graph.