Analysis of Multipole Measurements of "4Q17" Quad for use as QF1FF at ATF2

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Magnet Measurement Summary

The existing quadrupole in use as QF1FF ("QC3" type) (final double quadrupole at ATF2) has many multipole components measured to be larger than the desired tolerances (see figures 3 and 4)[1]. A possible replacement has been sourced, a "4Q17" type quad extracted from the old PEPII LER (see fig.1).
Figures 3 and 4 show themultipole components up to dodecupole (normal and skew) for this magnet as measured by a rotating coil assembly (setup shown in fig.1). Also shown are the required tolerances. Compared with the existing QC3 magnet, this magnet has considerably improved harmonic field components (especially with respect to the skew 12-pole component).
Tolerances were computed with 2 different lattices, the design "1 x 1" lattice and the relaxed IP horizontal beta lattice currently preferred "10 x 1".
With this new magnet all tolerances are met with the exception of a small excess over the required skew-sextupole tolerance. The skew-sextupole tolerance is more flexible than the higher-order multipoles in that it can be tuned-out with the newly installed skew-sextupole magnets. Figure 10 shows a MADX optimisation of the 1 x 1 (original design) ATF2 FFS optics using a simulation with these measured QF1FF multipoles. It is possible to get 38nm vertical beam size at the IP (tuneable down to ~35 with skew-sextupoles). Previously this was only possible by increasing the horizontal beta function at the IP to at least 2.5 times the original design.

BPM Kovar Feed-through Measurements Summary

The sma-connector feed-through material used on the s-band cavity BPMs in the final doublet area contain kovar steel which becomes magnetised in the presence of fringe fields from the final-doublet magnets. To assess the likely magnitude of the effect of these feed-through's on the multiple components of the quadrupole magnets, one such piece was placed close to the core of the 4Q17 under measurement here. It was mounted using an aluminium holding strut as seen in figure 1 at distances 1cm-10cm away from the face of the coil (a distance of about 5cm corresponds to the approximate location with respect to the FD magnets at ATF2). To approximate the transverse positions in the BPM at ATF2, it was placed in one of 2 positions shown in figure 2 (position A is the vertically oriented location, position B the horizontal one).

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[1]Tolerances defined as magnitude of specified normal or skew multipole component that causes a 1nm increase in the vertical beam spot size at the IP.

The results of the kovar feed-through measurements are presented in figures 5 through 8. The only significant effect is on the skew-sextupole component. This effect is non-negligible however and different for the 2 tested positions. A summary of the skew-sextupole component for the different feed-through locations is shown in figure 9. 4Q17 has twice the bore diameter than the QC3 magnets (QD0FF and QF1FF). This will lessen the impact of the material, as the fields will extend less far longitudinally from the QC3 magnet. To attempt to mimic the expected effect on QD0FF we placed the kovar at 10cm instead of 5cm. Here the skew-sextupole is almost reduced to the tolerance value but not completely.
Only a single kovar piece was available for this test, it should be noted that different effects could be produced with multiple (there are s-band BPMs with 2 or 4 feed-through's in use) feed-through's in place. Also one can expect different results with different harmonic components as are present in QD0FF.
An attempt was made to use mu-metal wrapping around the kovar in the measurement setup to try and reduce the effect on the multipoles. This had no effect on the measured data however.

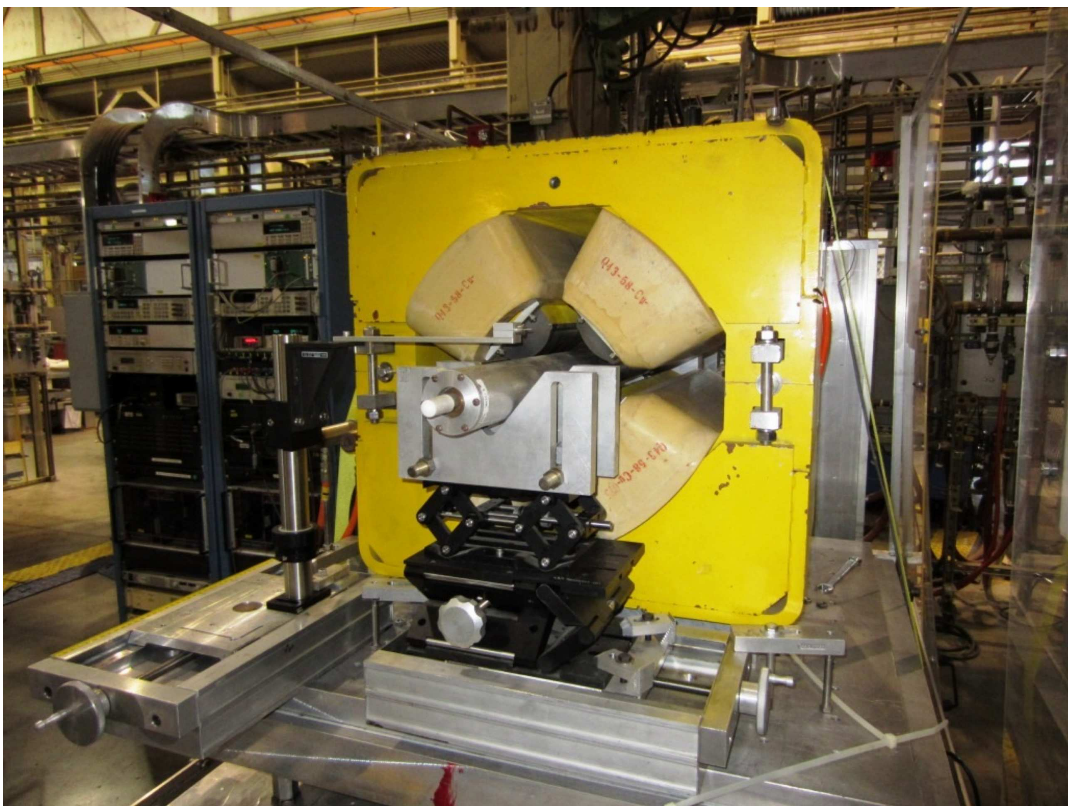

Figure 1: 4Q17 magnet with rotating coil and feedthrough holder setup

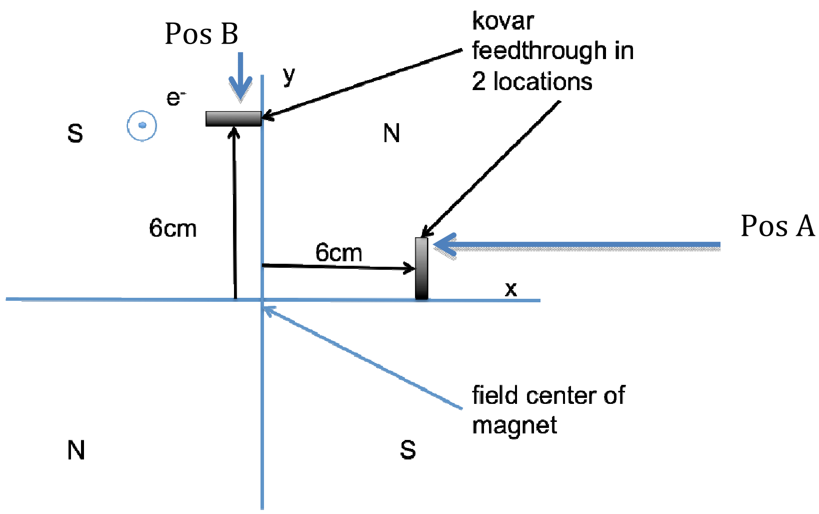

Figure 2: location of 2 feedthough positions transversely from magnet axis. Position A= verticaly aligned feedthrough. Position B= horizontally aligned feedthrough.

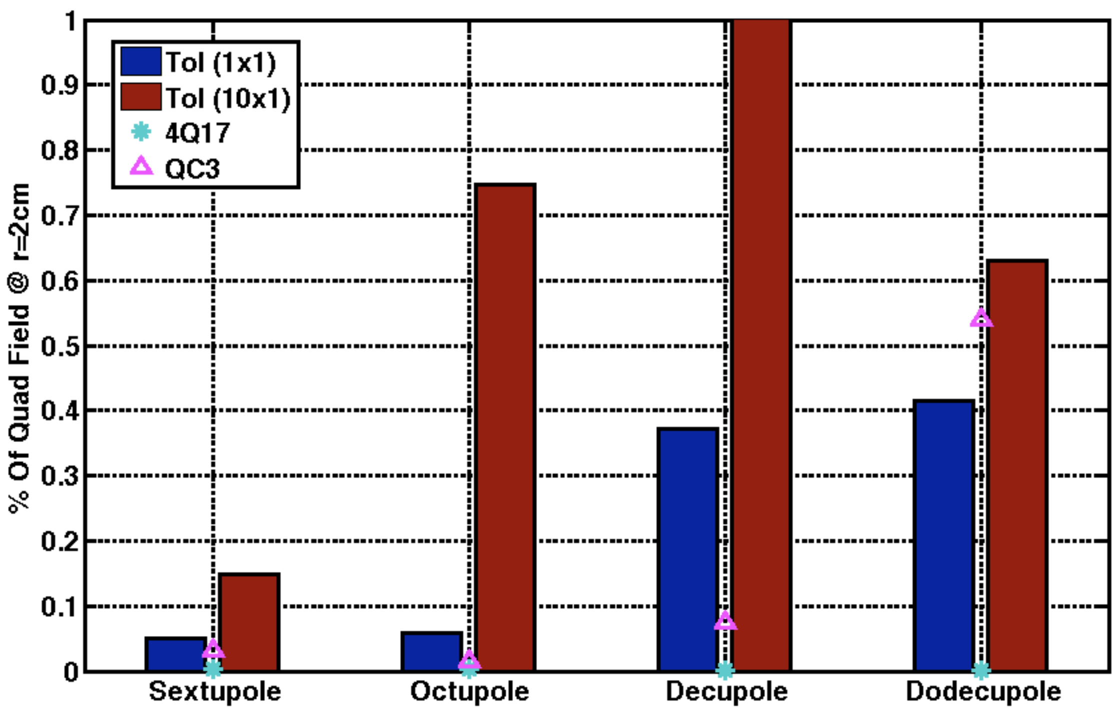

Figure 3: Normal multipole components measured as % of quad field at a radius of 2cm.

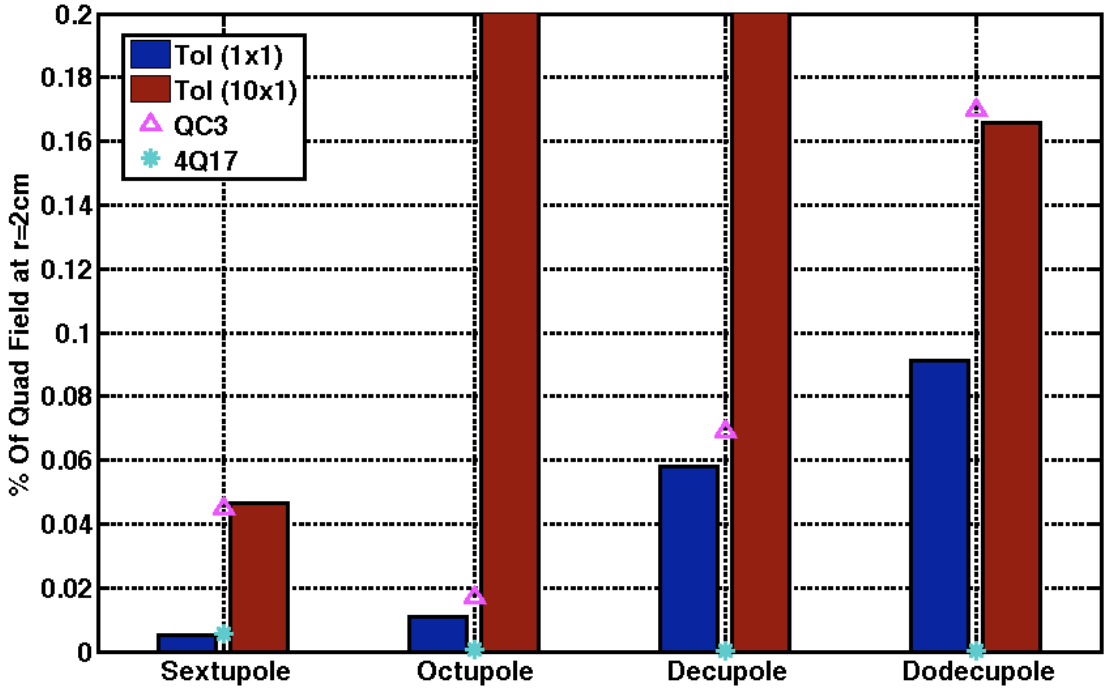

Figure 4: Measured skew multipole components.

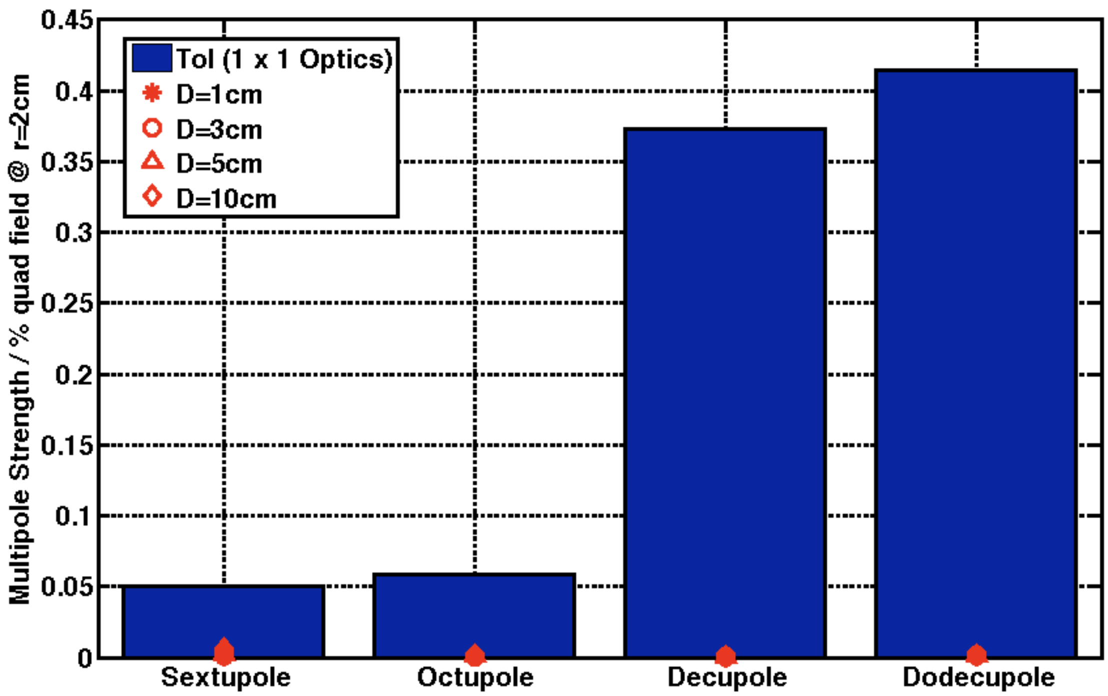

Figure 5: Normal multipole components measured with kovarfeedthrough in position A at varying distances from magnet coil face.

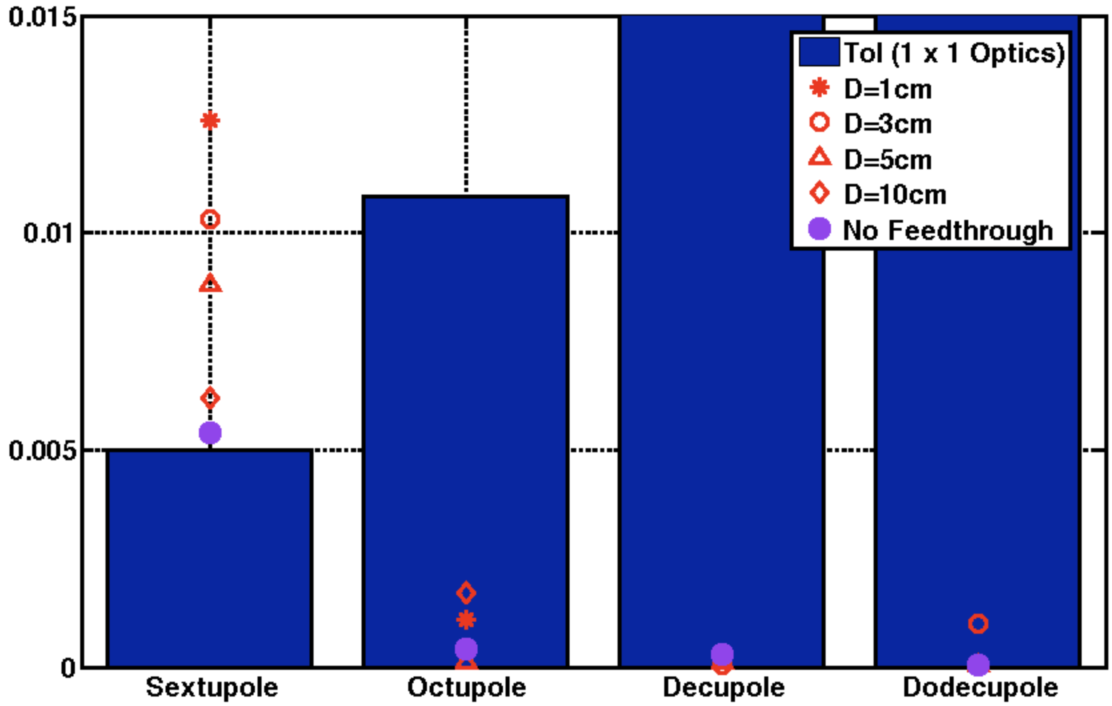

Figure 6: Skew multipole components measured with kovarfeedthrough in position A at varying distances from magnet coil face.

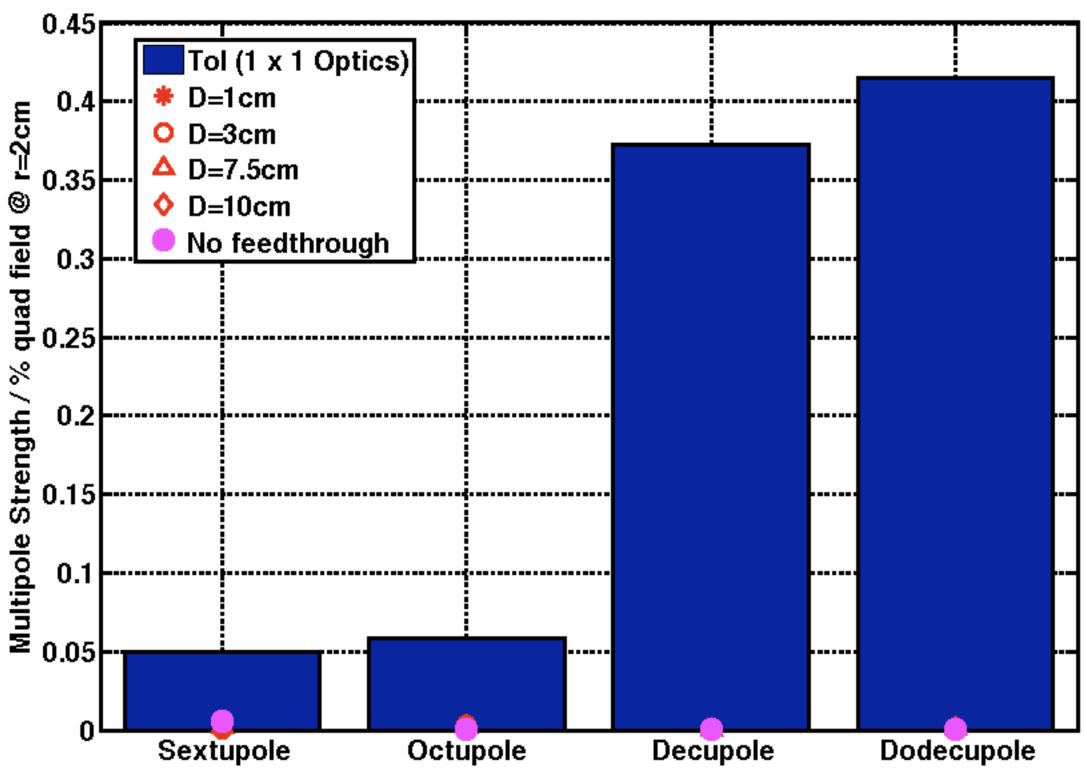

Figure 7: Normal multipole components measured with kovarfeedthrough in position B at varying distances from magnet coil face

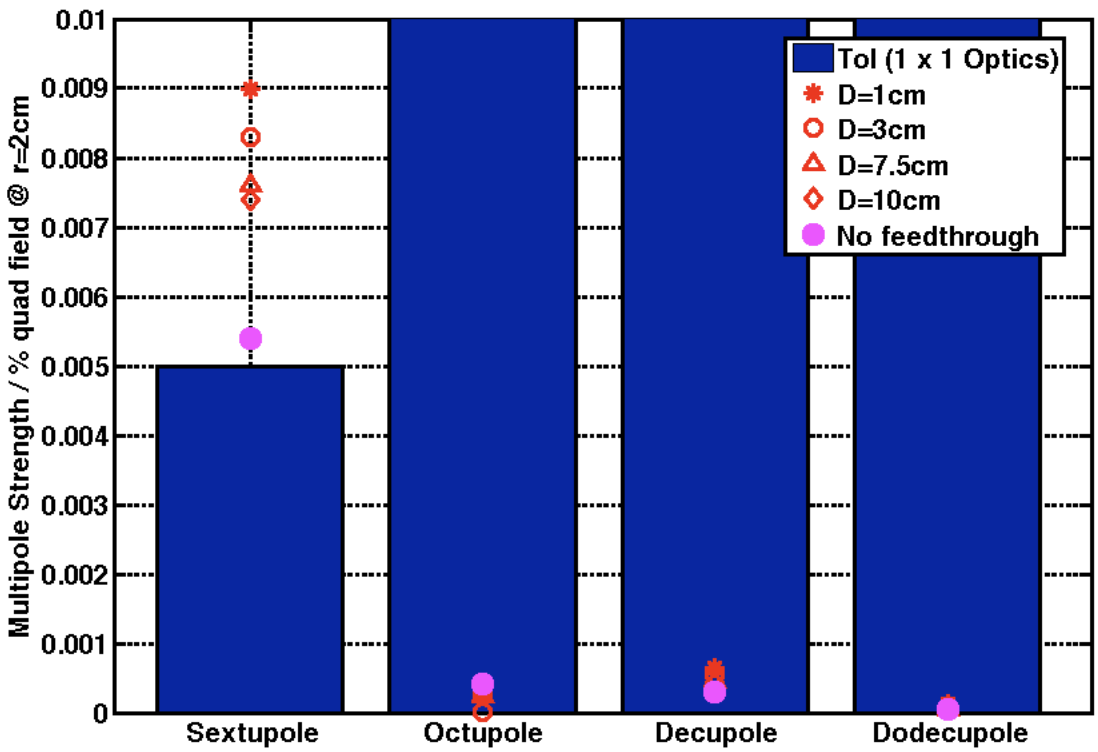

Figure 8: Skew multipole components measured with kovarfeedthrough in position B at varying distances from magnet coil face

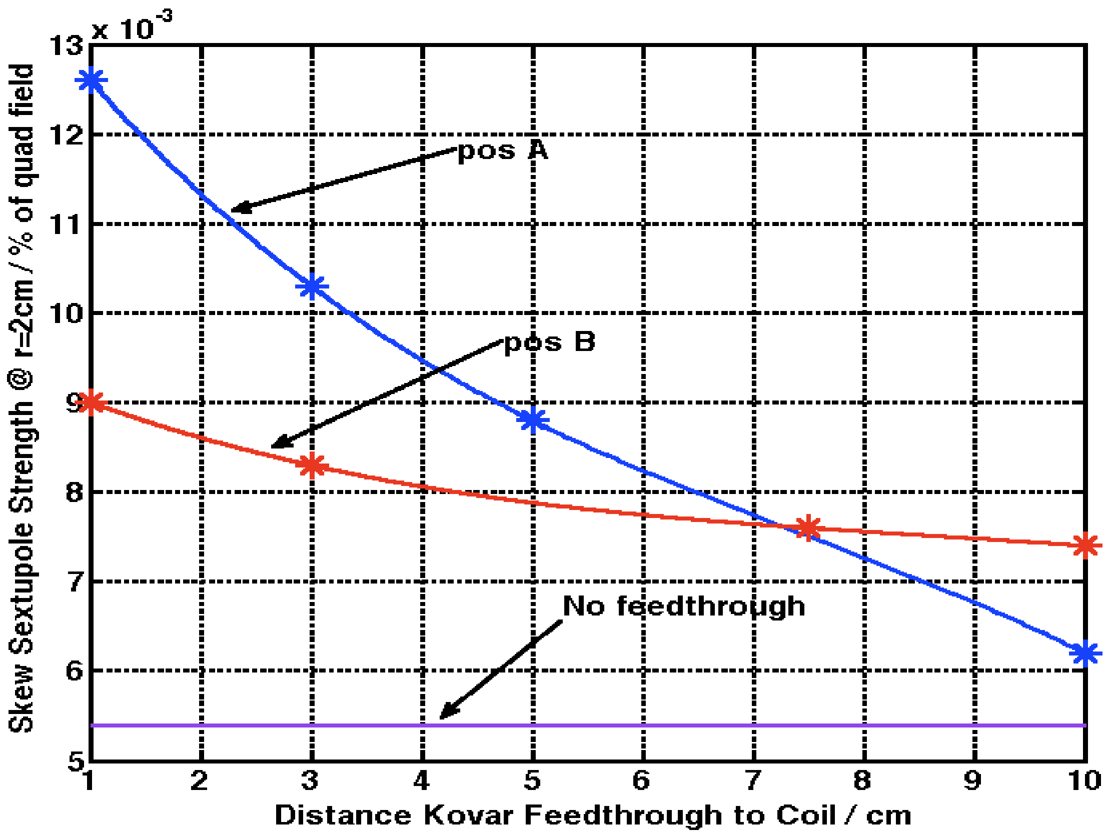

Figure 9: Effect of kovarfeedthrough on skew sextupole component

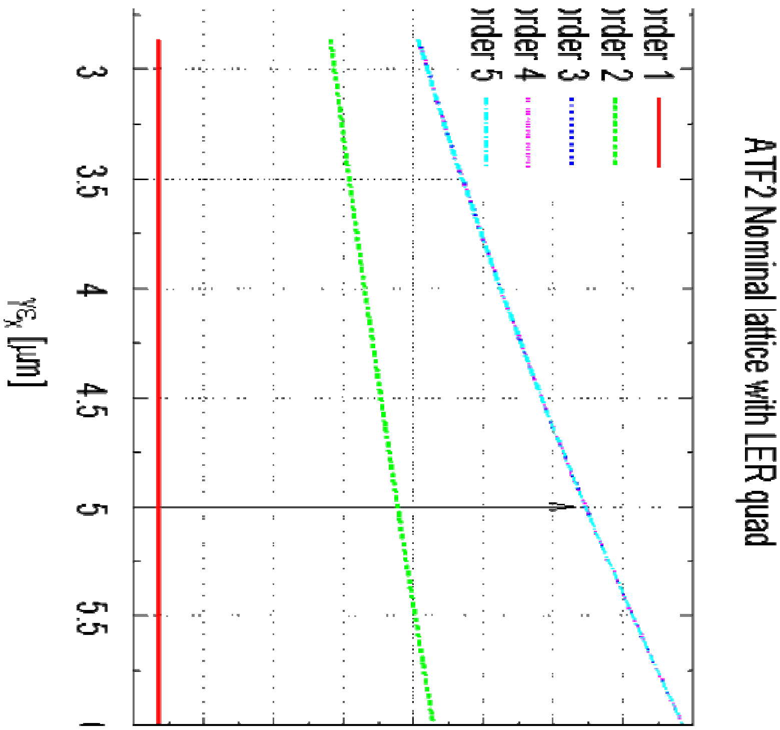

Figure 10: Tracked RMS beam size for nominal (1 x 1) optics with new QF1FF magnet. Fitted gaussian size is ~38nm and can be reduced to design 35nm with further tuning from skew-sextupoles.

Tables of measured and computed tolerances for multipoles for QF1FF magnet. Values are shown as % of main quad field at a radius of 2cm

Table 1 Measuredmultipoles for 4Q17 magnet

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.0034	0.0024	6.1E-5	0.0014
Skew	0.0054	4.2E-4	2.9E-4	4.2E-5

Table 2Multipoles measured withKovarfeedthrough in position A at D=1cm from coil face

	Sextupole	Octupole	Decupole	Dodecupole
Normal	2.2E-4	4.6E-4	7.1E-4	0.0012
Skew	0.0126	0.0011	8.3E-5	2.0E-4

Table 3Multipoles measured with Kovarfeedthrough in position A at D=3cm from coil face

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.0012	9E-4	3.9E-4	0.0013
Skew	0.0103	4.6E-4	5.1E-5	9.9E-4

Table 4Multipoles measured with Kovarfeedthrough in position A at D=5cm from coil face

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.002	0.0013	2.3E-4	0.0013
Skew	0.0088	1.1E-4	1.0E-4	4.2E-5

Table 5Multipoles measured with Kovarfeedthrough in position A at D=10cm from coil face

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.0059	0.0013	3.2E-4	0.0014
Skew	0.0062	0.0017	2E-4	4E-5

Table 6 Multipole tolerances for 1 x 1 optics

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.05	0.0583	0.3729	0.4145
Skew	0.0050	0.0108	0.0579	0.0912

Table 7 Multipole tolerances for 10 x 1 optics

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.1492	0.7467	10.3750	0.6300
Skew	0.0465	0.2900	3.7292	0.1658

Table 8 Measured multipoles for QC3 magnet

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.031	0.015	0.075	0.54
Skew	0.045	0.017	0.069	0.17

Table 9: Kovarfeedthrough position B at D=1cm

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.0015	0.0036	5.2E-4	0.0013
Skew	0.009	2.5E-4	6.4E-4	1.3E-4

Table 10: Kovarfeedthrough position B at D=3cm

	Sextupole	Octupole	Decupole	Dodecupole
Normal	2.2E-4	0.0028	3.4E-4	0.0014
Skew	0.0083	2E-6	5.5E-4	9.2E-4

Table 11: Kovarfeedthrough position B at D=7.5cm

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.0023	0.0021	1.3E-4	0.0014
Skew	0.0076	2.4E-4	4.6E-4	6.5E-5

Table 12: Kovarfeedthrough position B at D=10cm

	Sextupole	Octupole	Decupole	Dodecupole
Normal	0.0027	0.002	9.0E-5	0.0014
Skew	0.0074	2.8E-4	4.4E-4	6.5E-5