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Magnet Note

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Title: Effect of the Vacuum Chamber on the Field Quality in the SNS Dipole Prototype

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Effect of the Vacuum Chamber on the Field Quality in the SNS Dipole Prototype

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1. Introduction:

During production, the field quality in the 17D120 dipoles for SNS will be measured before the installation of the vacuum chamber. It is possible that the presence of the vacuum chamber may influence the field quality. In order to get an estimate of such an effect, the field quality in a prototype dipole magnet was measured both with and without a vacuum chamber. This note describes the results of these measurements.

2. Experimental Set up:

A 40.8 mm radius, 4.75 m long rotating coil was used to measure the integral field quality. The magnet was first assembled with the vacuum chamber, and the coil was nominally centered in it. Since there is no practical way to determine the transverse location of the measuring coil from the magnetic data in the dipole, it was important to maintain the same coil location for the measurements with and without the vacuum chamber. In order to achieve this, plumb lines were placed on both ends of the measuring coil and the locations were marked on the floor during the first set of measurements. These marks were later used to place the coil during the second set of measurements (after removing the vacuum chamber).

The integral field quality was measured at four different currents – 1000 A, 3000 A, 4380 A and 5400 A. At each current, two readings were taken, except for 1000 A, where five readings were taken in order to obtain a better estimate of the random errors in the measurements. After reaching a particular current, the data were taken after a wait of 10 minutes to allow temperature and field steady state conditions to be established.

The field harmonics were expressed at a reference radius of 60 mm, although the coil radius of only 40.8 mm does not allow accurate measurements of higher order harmonics at this radius. Nevertheless, the measured noise in the lower order terms (such as the octupole) was typically below 0.02 unit.

3. Results:

The up ramp and the down ramp data with and without the vacuum chamber are shown in the attached plots on pages 3-5. The data with the vacuum chamber installed are shown using symbols connected by solid lines, whereas the data taken with the vacuum chamber removed are shown using symbols connected by dashed lines.

The integral transfer function at a given current has a noise of approximately 0.05%. This is about a factor of 5 more than 0.01% typically seen in such measurements. This appears to be due to a possible problem with electrical noise linked to the operation of the booster accelerator at BNL. Although the integral transfer function without the vacuum chamber appears to be systematically lower by ~0.1%, it is not possible to draw a definite conclusion due to the rather large noise in the transfer function. It should be noted that a systematic difference of 0.1% can not be due to coil positioning errors, since a rather large error of ~8 mm is required to get a 0.1% change in the transfer function, based on a measured quadrupole term of ~0.77% (77 units) at 60 mm radius.

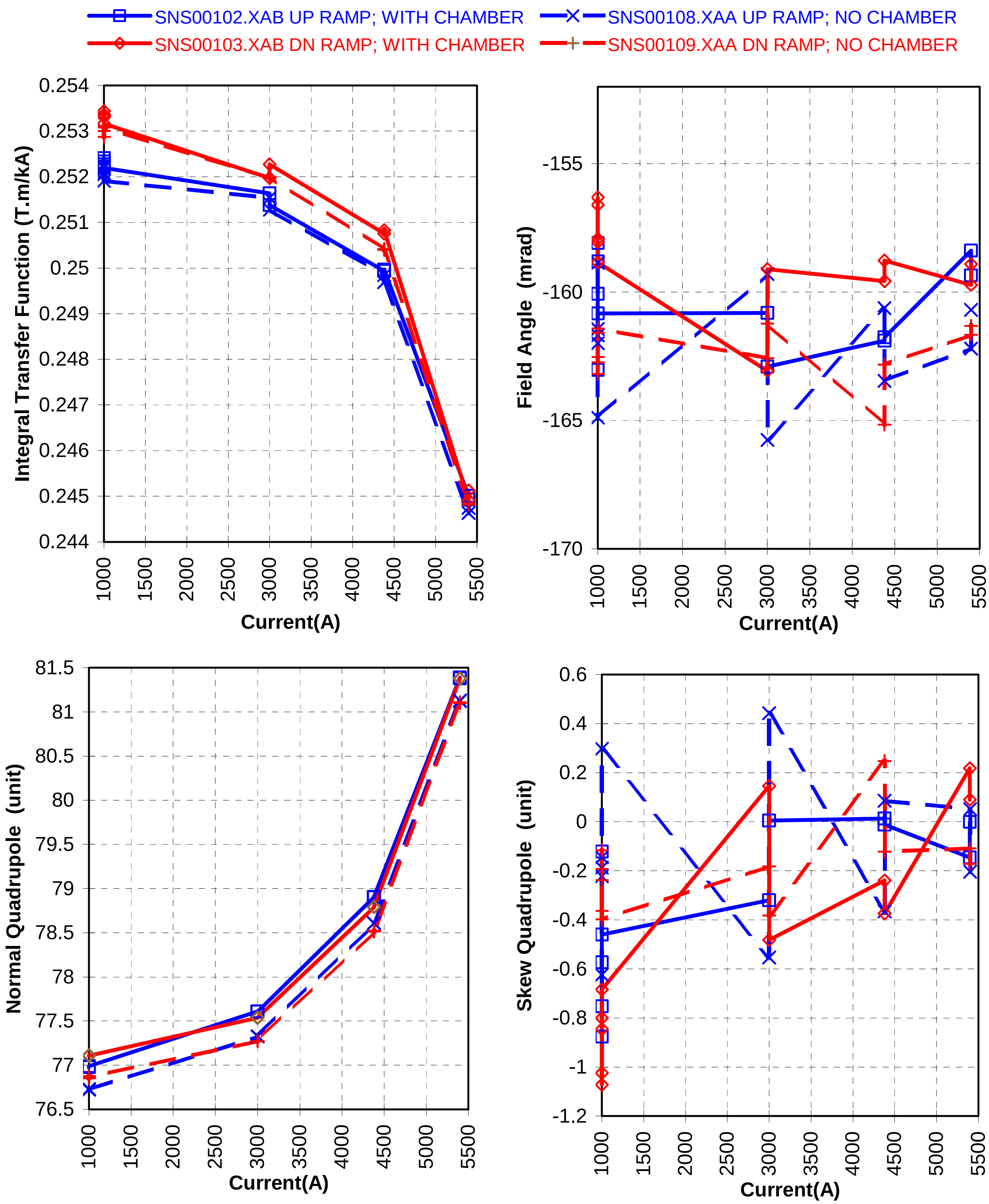
The normal quadrupole, sextupole, and the octupole terms show systematic differences of approximately 0.3 unit at 60 mm radius after removing the vacuum chamber. These differences are at least 10 to 20 times typical noise in the measurements of these terms. Similarly, the decapole term shows a systematic change of ~0.13 unit. This is also about a factor of 6 more than the measurement noise. Both the up ramp and the down ramp data show a similar systematic shift. No such systematic shift is observed in the skew terms. The changes in the higher order terms are essentially zero. The data, averaged over the up ramp and the down ramp, are also summarized in Table I.

The skew quadrupole term has a much larger noise than other similar terms. This appears to arise from a combination of the large normal quadrupole term and a rather large noise in the field angle. The reason for the large noise in the field angle is not very clear, but it may be due to problems with smooth rotation of the measuring coil when operated horizontally.

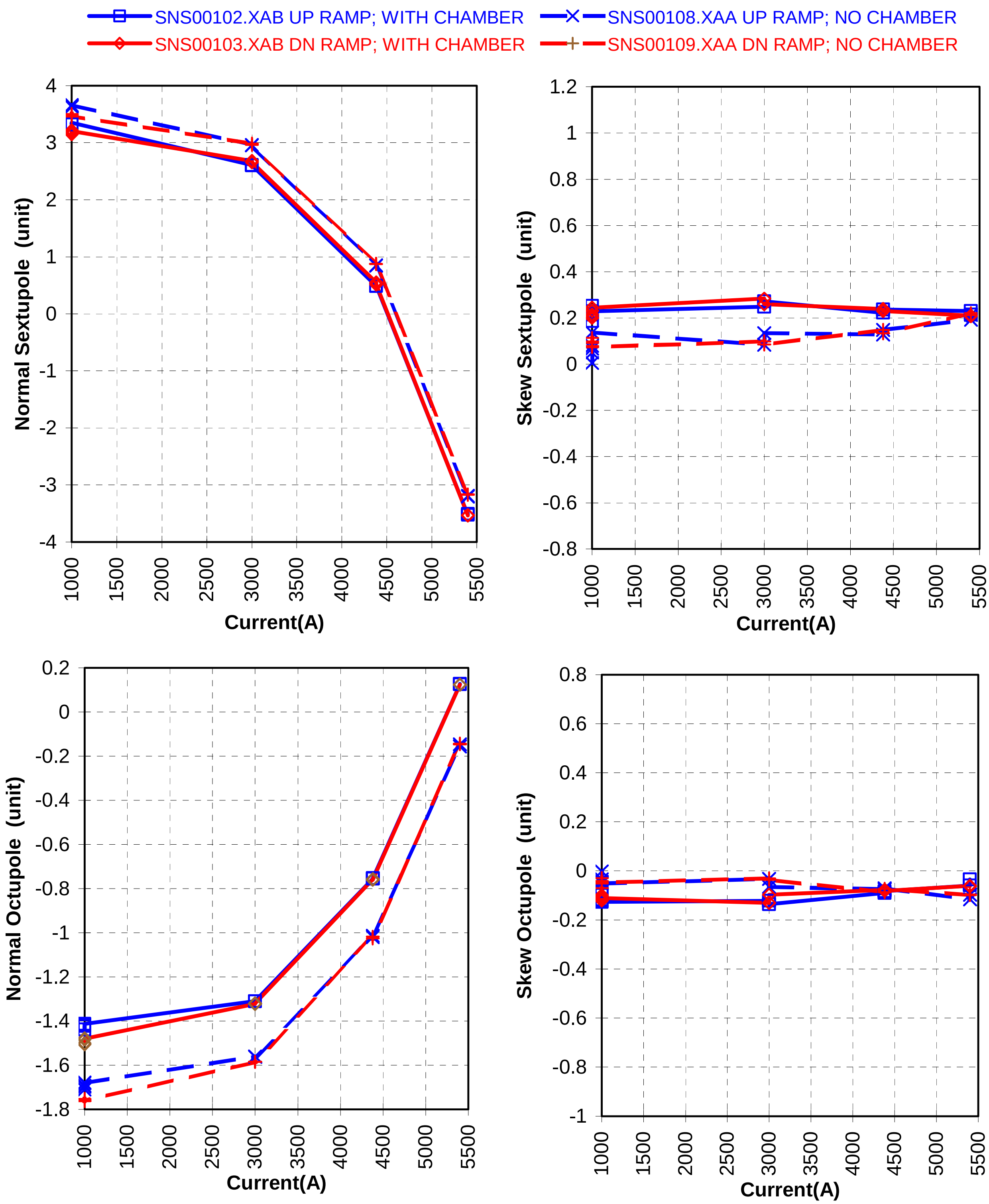
The skew sextupole term shows a small current dependent shift. This is most likely caused by a difficulty in reproducing the vertical position of the measuring coil during the two sets of measurements, and feed down from the octupole term. Since the magnitude of the octupole term is practically zero at 5400 A, there is negligible feed down and the skew sextupole shows no change at this current.

4. Conclusions:

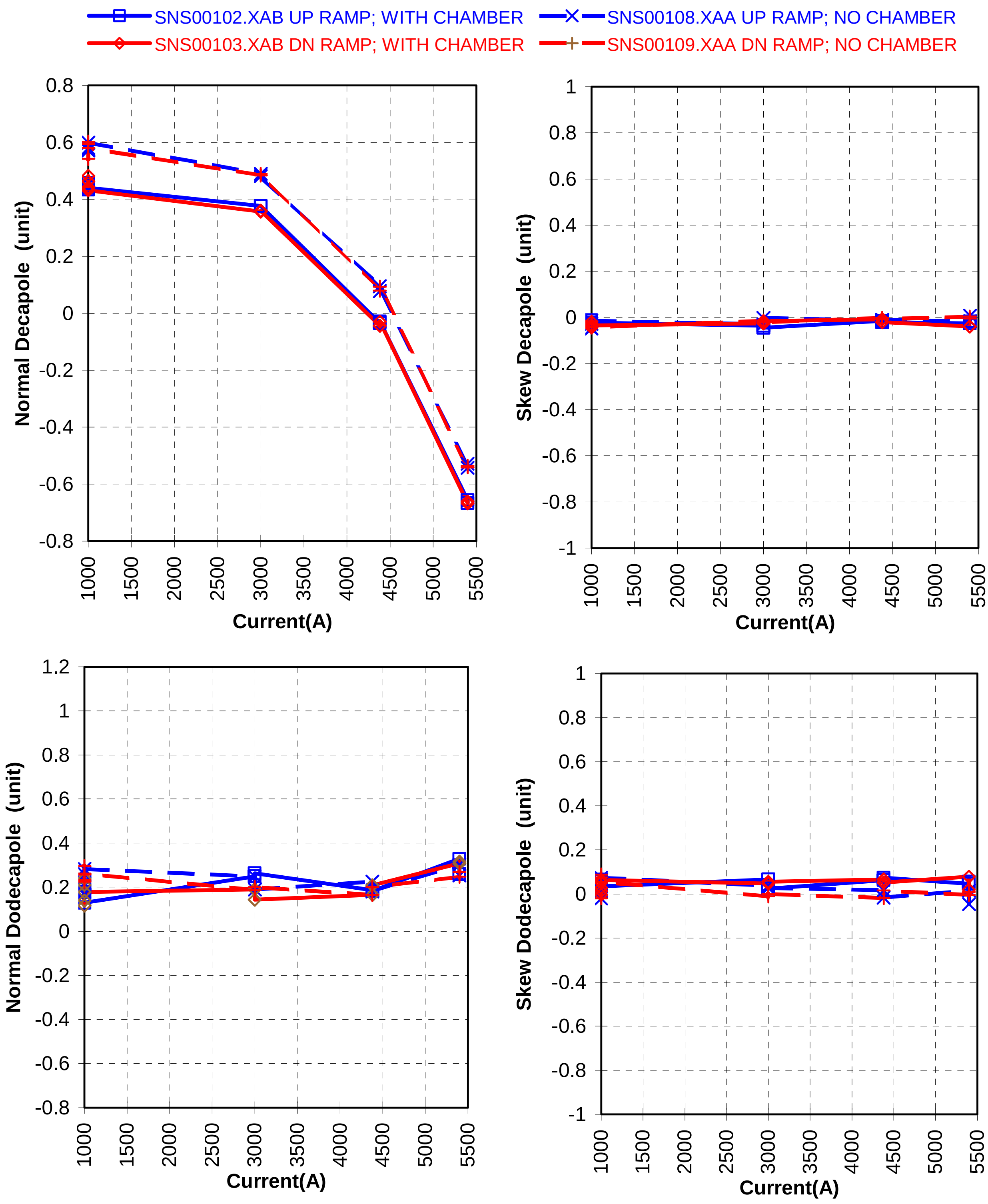
It is seen from the present data that the influence of the vacuum chamber on the field harmonics is small, about 0.3 unit or less at 60 mm. The changes in harmonics appear to be entirely geometric, with no current dependence in the range of 1000 A to 5400 A. Since the magnet had to be disassembled in order to remove the vacuum chamber, it is conceivable that some of the observed changes in the harmonics may have been caused by the mechanical tolerances, rather than the magnetic properties of the vacuum chamber. It is desirable to carry out a series of measurements, after repeatedly disassembling and reassembling the magnet, to obtain an estimate of the amount of change in harmonics that may have been caused due to geometric errors.



Field quality measured with and without the vacuum chamber in the SNS dipole prototype.



Field quality measured with and without the vacuum chamber in the SNS dipole prototype.



Field quality measured with and without the vacuum chamber in the SNS dipole prototype.

Table I

Comparison of Field Quality in SNS001 Prototype Dipole With and Without Vacuum Chamber

Harmonics at 60 mm, measured with a 40.8 mm radius coil; Up/Dn Avg. (Runs 2,3 and 8,9; July 3-11, 2001)

Quantity	1000 A		3000 A		4380 A		5400 A		Differences (With/Without)				Quantity
	With Chamber	Without Chamber	With Chamber	Without Chamber	With chamber	Without Chamber	With chamber	Without Chamber	1000 A	3000 A	4380 A	5400 A	
ITF (T.m/kA)	0.2528	0.2526	0.2518	0.2517	0.2504	0.2501	0.2450	0.2448	**0.10%**	**0.05%**	**0.11%**	**0.10%**	**ITF (T.m/kA)**
Fld. Ang.(mr)	-158.9	-161.4	-160.7	-161.5	-160.5	-162.3	-159.1	-160.7	2.57	0.74	1.76	1.63	**Fld. Ang.(mr)**
b1	77.05	76.79	77.57	77.30	78.85	78.56	81.38	81.12	**0.25**	**0.27**	**0.29**	**0.26**	**b1**
b2	3.26	3.56	2.64	2.96	0.51	0.86	-3.52	-3.18	**-0.30**	**-0.33**	**-0.35**	**-0.34**	**b2**
b3	-1.46	-1.73	-1.32	-1.57	-0.76	-1.02	0.12	-0.15	**0.27**	**0.26**	**0.26**	**0.27**	**b3**
b4	0.45	0.58	0.37	0.49	-0.03	0.09	-0.66	-0.54	**-0.13**	**-0.12**	**-0.12**	**-0.13**	**b4**
b5	0.18	0.24	0.21	0.21	0.19	0.19	0.30	0.27	-0.07	0.00	-0.01	0.04	**b5**
b6	-0.10	-0.12	-0.13	-0.16	-0.18	-0.18	-0.19	-0.22	0.02	0.02	0.01	0.02	**b6**
b7	0.17	0.20	0.08	0.13	0.09	0.09	0.04	0.08	-0.03	-0.05	-0.01	-0.04	**b7**
b8	-0.03	-0.10	0.00	-0.05	0.01	-0.07	0.01	-0.06	0.07	0.04	0.08	0.06	**b8**
a1	-0.26	-0.22	-0.16	-0.17	-0.15	-0.04	0.04	-0.11	-0.05	0.01	-0.11	0.15	**a1**
a2	0.09	0.08	0.27	0.10	0.23	0.14	0.22	0.21	0.01	0.17	0.09	0.01	**a2**
a3	-0.05	-0.04	-0.12	-0.04	-0.08	-0.08	-0.05	-0.10	-0.01	-0.08	-0.01	0.05	**a3**
a4	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01	-0.03	0.00	0.00	-0.01	-0.01	-0.03	**a4**
a5	0.05	0.04	0.05	0.01	0.06	0.00	0.05	-0.01	0.01	0.03	0.06	0.06	**a5**
a6	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.00	0.00	-0.01	0.00	**a6**
a7	0.13	0.13	0.07	0.07	0.05	0.06	0.05	0.06	-0.01	0.00	-0.01	0.00	**a7**
a8	0.04	0.04	0.07	0.04	0.07	0.02	0.05	0.04	0.00	0.03	0.05	0.01	**a8**