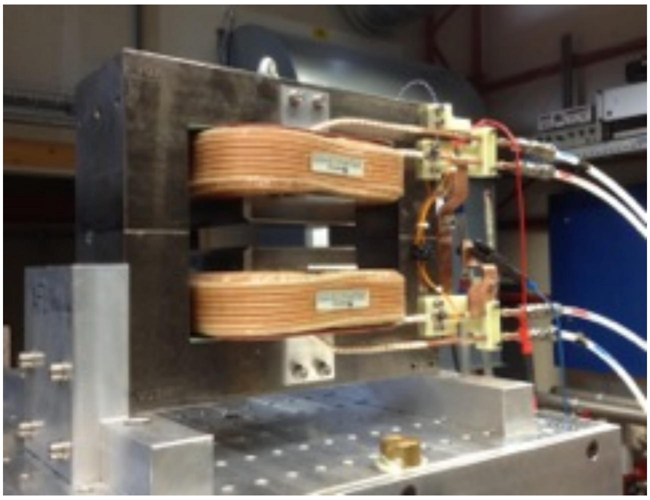
AFL Dipole (SwissFEL, Injector Section)



AFL dipole (#7 of 7)

gap = 20 mm

L120 x W320 x H270 mm

conductor 4 x 4, D 2.5 mm

65 turns/coil

I_{MAX} = 50 A

MEASUREMENT DATE:
13.May–10.July.2014

MEASUREMENT ARM:
brass cylinder interface Ø 40 mm
aluminum pipe Ø 28 mm, 1 m
carbon pipes Ø 10/8/6 mm, 1.5 m

MEASURING SPEED:
4.5 mm/sec (X-axis)
49 mm/sec (Z-axis)

INTEGRATION TIME:
20 msec

DVM-1 (1 V RANGE):
Hall probe sbv175 (150 mA)
powered in series with other 2

DVM-2 (1, 10 V RANGE):
50 V / 200 A (MSG-2.1), 5 A/s

AIR CONDITIONING:
ON (T_{SET} = 24.5°)

OPERATORS:
Roland Deckardt
Vjeran Vranković (#2 and #7)

DATA DIRECTORY:
afs: group/magnet/meas/
SwissFEL/Injector/afl

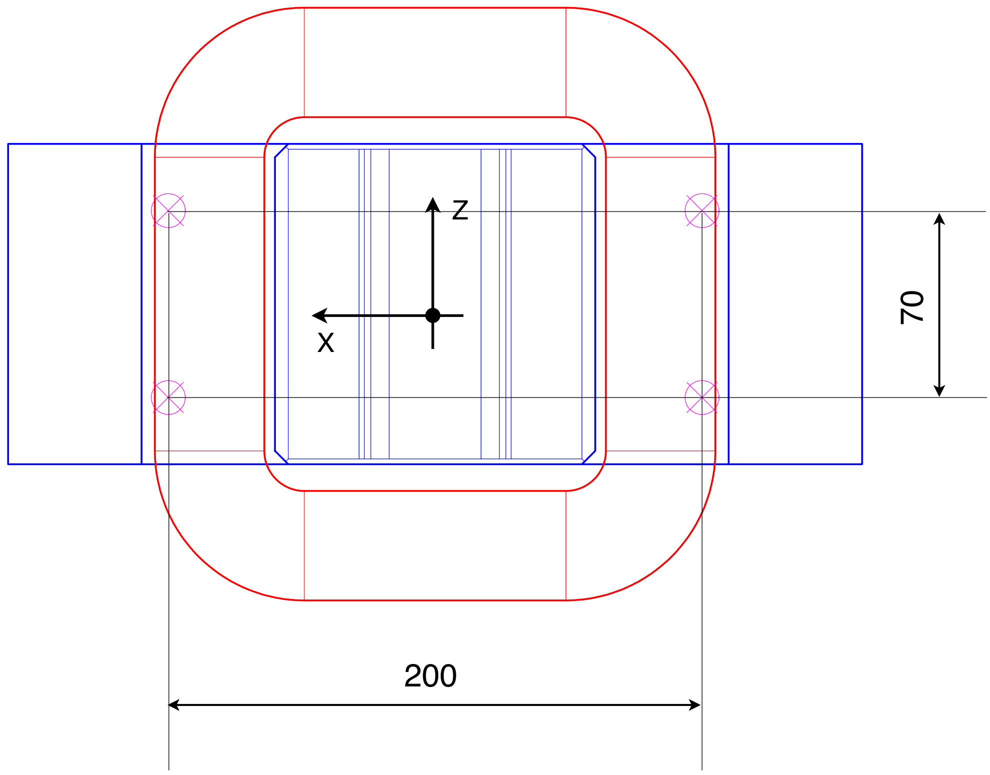
Alignment and positioning

The AFL magnets were placed on adjustable base plate. The base plate was levelled by adjusting its feet heights. To reduce time for aligning 7 AFL magnets to the measurement bench, a support has been made with position limiters defined from alignment of the first measured magnet. This significantly eased the positioning of successive magnets.

In the measurements coordinate system the magnet axis is the Z-axis, vertical axis is the Y-axis (see the sketch).

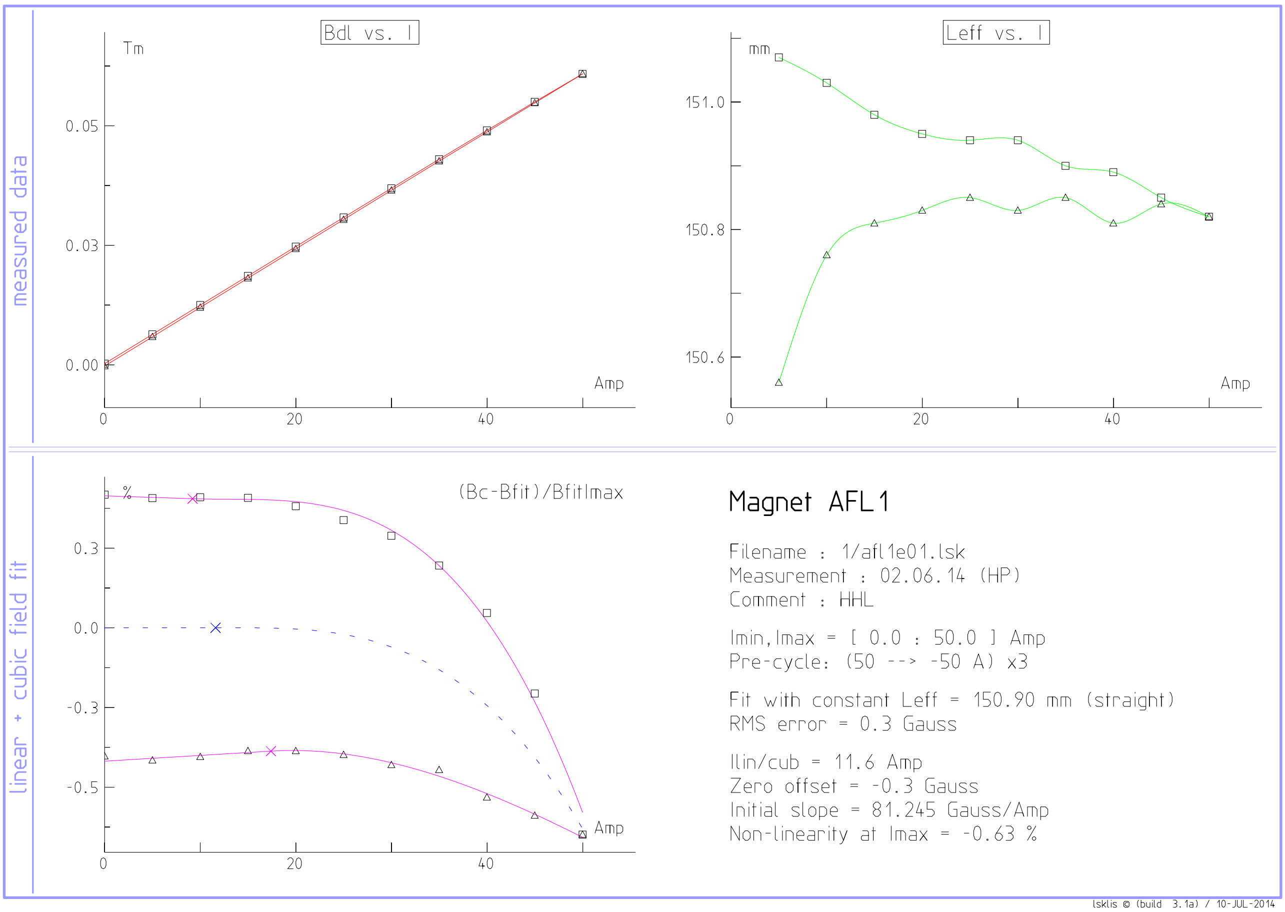
The probe was levelled with a spirit level built into the measuring arm.

The aligning of the first magnet and positioning of all magnets was done magnetically by measuring horizontal field maps of the double reference pin that was inserted in provided four reference holes on the magnet top plate (see the sketch below).



Excitation curve – main coil

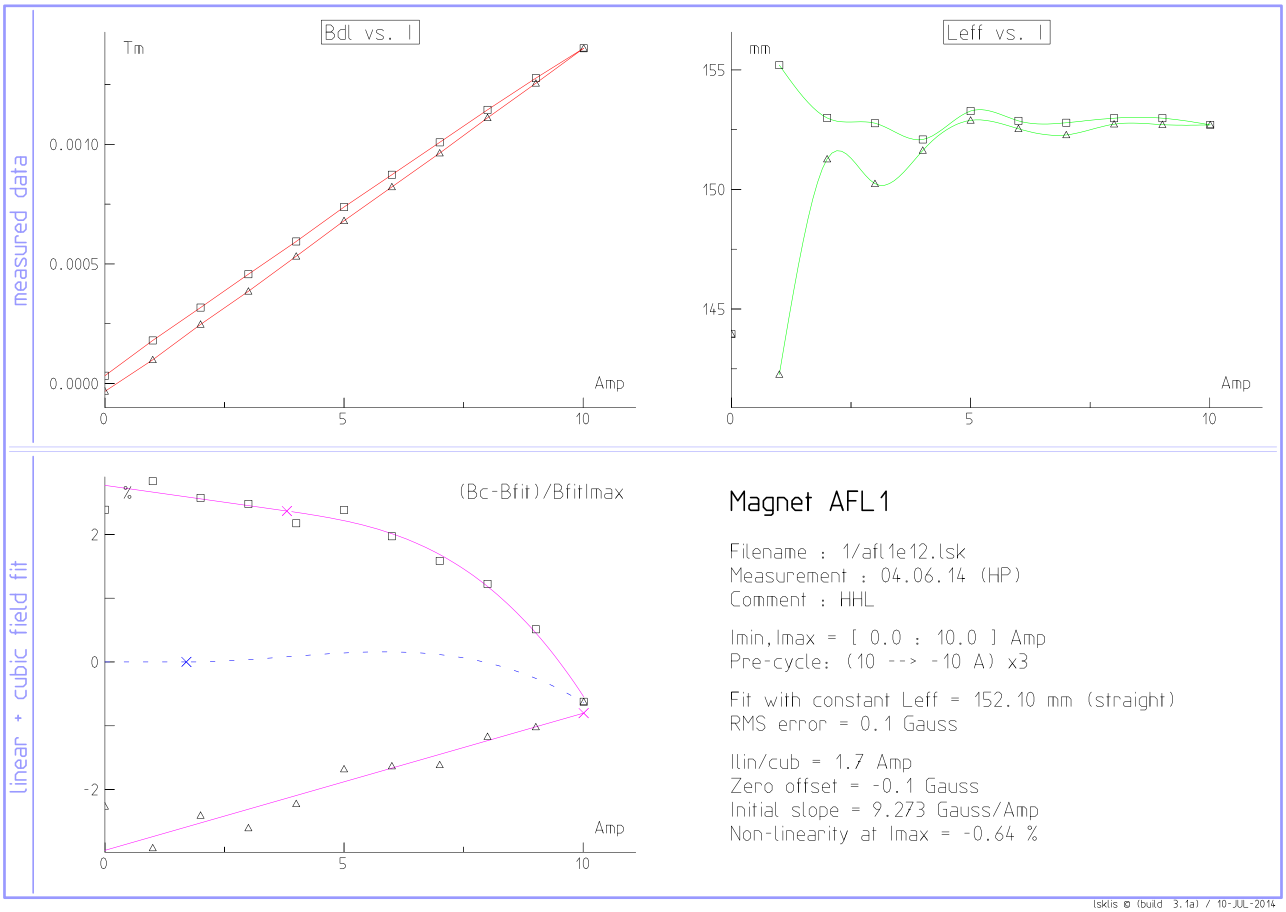
Before measurements the magnet was cycled 3 times from –50 A to 50 A.
The fields are measured at 21 currents on the line X = Y = 0, Z = ±700 mm.



AFL	B·dz(50A) [mT·m]		L_{SEFF} [mm]	I_{LIN} [A]	B_{OFFSET} [Gauss]	B_{SLOPE} [Gauss/A]	NL(I [%]
1	60.873	0.08%	150.9	11.6	-0.3	81.245	-0.63
2	60.747	-0.13%	150.6	5.0	-0.1	81.295	-0.68
3	60.800	-0.04%	150.6	15.1	0.9	81.216	-0.56
4	60.905	0.13%	150.9	7.1	0.3	81.135	-0.47
5	60.924	0.17%	150.9	11.4	-0.1	81.284	-0.60
6	60.815	-0.01%	150.5	15.7	-0.3	81.317	-0.56
7	60.700	-0.20%	150.5	12.1	-0.2	81.264	-0.68
mean	**60.823**						

Excitation curve – correction coil

Before measurements the magnet was cycled 3 times from –10 A to 10 A.
The fields are measured at 21 currents on the line at X = Y = 0, Z = ±700 mm.



AFL	B·dz(10A) [mT·m]		LSEFF [mm]	ILIN [A]	BOFFSET [Gauss]	BSLOPE [Gauss/A]	NL(I [%]
1	1.402	-0.43%	152.1	1.7	-0.1	9.273	-0.64
2	1.398	-0.71%	152.0	6.6	0.0	9.212	-0.51
3	1.420	0.85%	152.5	4.8	0.0	9.388	-0.82
4	1.410	0.14%	152.9	7.7	0.1	9.272	-0.82
5	1.411	0.21%	152.8	7.0	0.0	9.312	-0.90
6	1.405	-0.21%	152.3	3.0	-0.1	9.331	-0.72
7	1.410	0.14%	154.3	4.6	0.1	9.198	-0.93
mean	**1.408**						

Field maps

The field maps were measured at different Y position in order to be able to create full 3D field volume by integrating the measured main field component into potential and then differentiating and interpolating between these potentials.

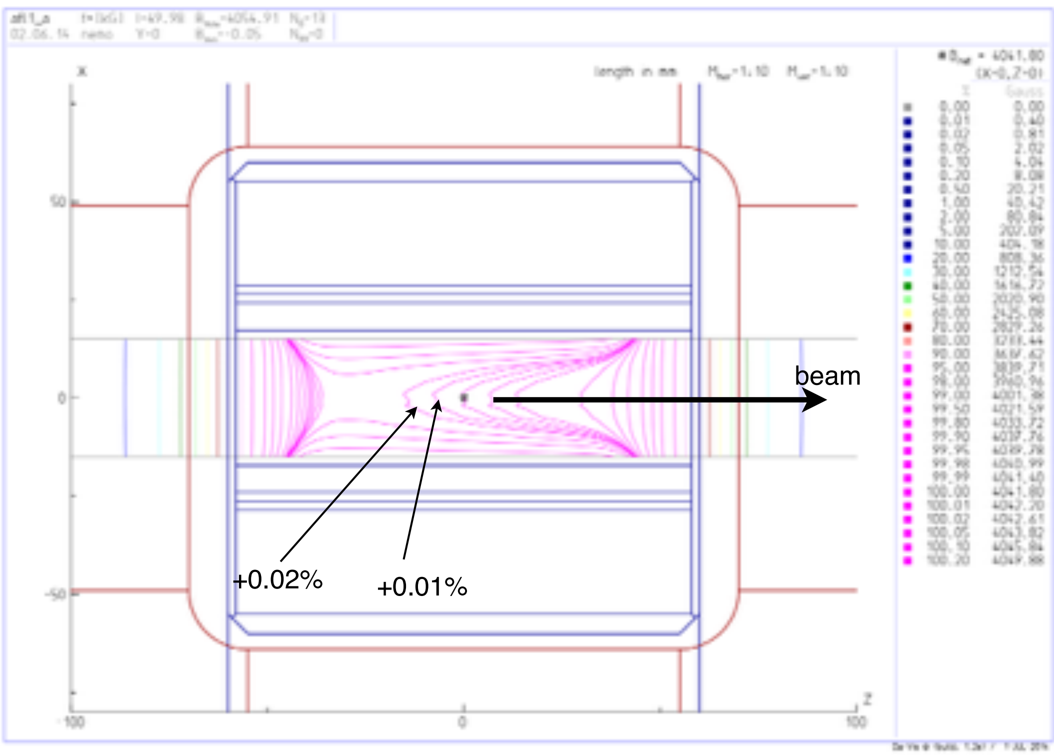
To cancel out errors coming from the probe roll angle the field maps off the magnet mid-plane were measured at two positions ±Y and then the fields were averaged:

$$\frac{measurement(+Y\ position) + measurement(-Y\ position)}{2}$$

The earth and the background fields are removed from the measured fields by:

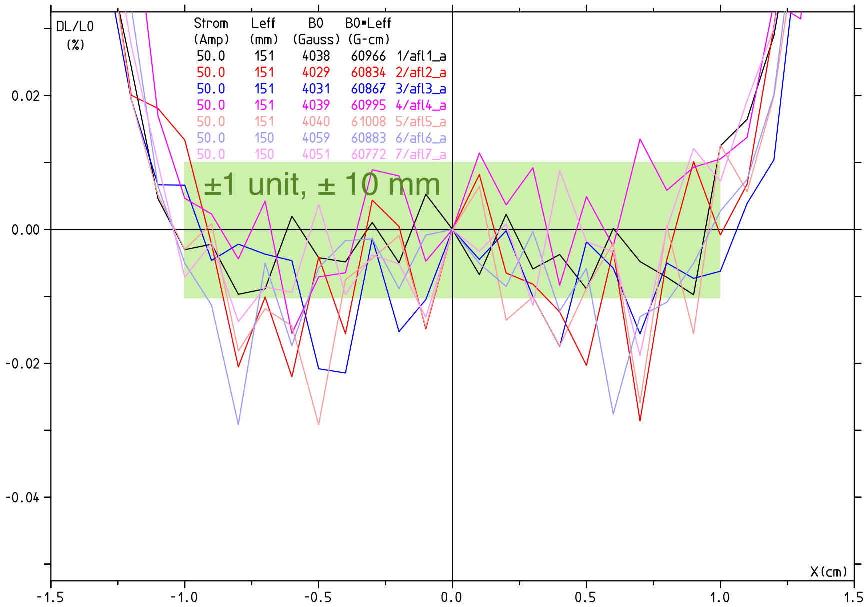
$$\frac{measurement(+current) - measurement(-current)}{2}$$

AFL	I [A]	Y = 0	Y = -3.5 mm	Y = 3.5 mm	Y = -5.0 mm	Y = 5.0 mm
1–7	-50	f09	f08	f10	f07	f11
	50	f04	f03	f05	f02	f06
n	50	_a	_b1	_b2	_c1	_c2
			_b		_c	

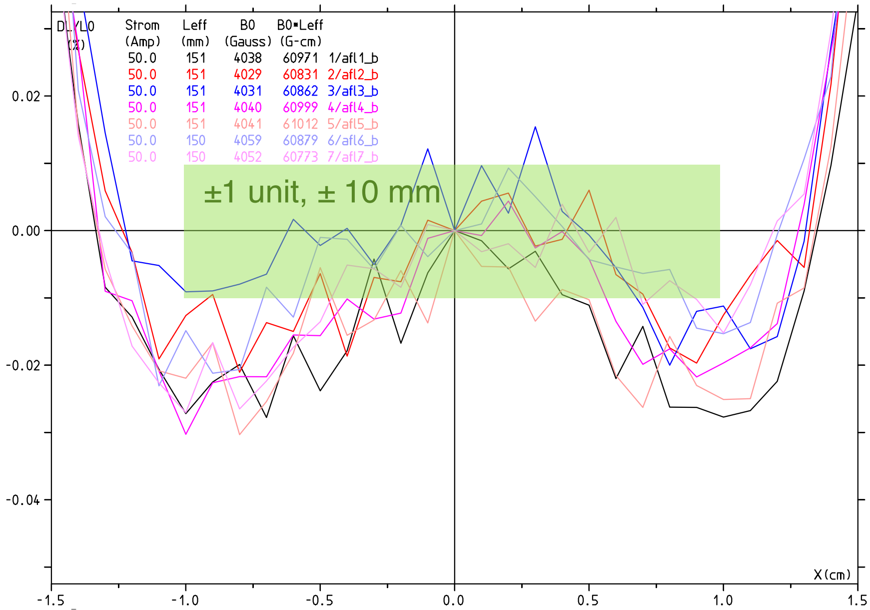


The table summarises central field, straight effective magnetic length and field integrals of all 7 AFL magnets. Differences in L_{SEFF} between the beam entrance and exit side are given.
The field integrals B·dz at different Y-position are almost constant and vary from each other by max. 50 ppm.

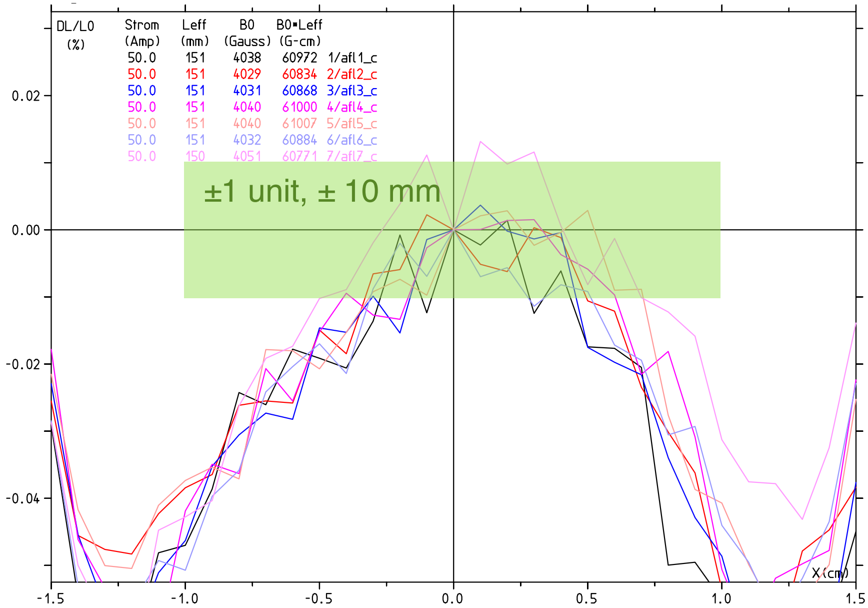
AFL	filename	Y [mm]	B_0	L_{SEFF_IN+OUT}	B·dz [mT·m]
1	**_a**	**0**	**4041.8**	**75.50 + 75.34 = 150.84**	**60.966**
	_b	3.5	4041.7	75.51 + 75.35 = 150.85	60.970
	_c	5.0	4041.5	75.52 + 75.34 = 150.86	60.972
2	**_a**	**0**	**4041.4**	**75.22 + 75.31 = 150.53**	**60.834**
	_b	3.5	4041.1	75.22 + 75.31 = 150.53	60.831
	_c	5.0	4041.0	75.32 + 75.31 = 150.54	60.834
3	**_a**	**0**	**4044.2**	**75.35 + 75.15 = 150.51**	**60.867**
	_b	3.5	4043.9	75.33 + 75.18 = 150.50	60.862
	_c	5.0	4043.9	75.35 + 75.17 = 150.52	60.868
4	**_a**	**0**	**4043.6**	**75.56 + 75.28 = 150.84**	**60.995**
	_b	3.5	4043.5	75.57 + 75.29 = 150.86	60.999
	_c	5.0	4043.3	75.57 + 75.29 = 150.87	61.000
5	**_a**	**0**	**4043.2**	**75.51 + 75.38 = 150.89**	**61.008**
	_b	3.5	4043.0	75.50 + 75.41 = 150.91	61.012
	_c	5.0	4042.8	75.50 + 75.40 = 150.90	61.007
6	**_a**	**0**	**4045.6**	**75.36 + 75.14 = 150.49**	**60.883**
	_b	3.5	4045.3	75.35 + 75.15 = 150.49	60.879
	_c	5.0	4045.1	75.36 + 75.15 = 150.51	60.884
7	**_a**	**0**	**4038.5**	**75.32 + 75.16 = 150.48**	**60.772**
	_b	3.5	4038.4	75.33 + 75.16 = 150.49	60.773
	_c	5.0	4038.1	75.33 + 75.16 = 150.49	60.771
				mean	**60.904**



relative field integrals
at Y = 0 mm



relative field integrals
at Y = 3.5 mm



relative field integrals
at Y = 5.0 mm

The cubic fit for every integral is evaluated in the X range of ±10 mm. The field errors $B_{Nerr} = (B_N - B_0) / B_0$ are shown in units (%%) and are calculated at X = 10 mm.
The average of the field homogeneity on the Y=0 plane is 0.6 units, at Y=3.5 mm it is 2.4 units and at Y=5 mm it is 4.4 units.

AFL	filename	fit_{RMS}	B_{1err}	B_{2err}	B_{3err}	B_{err}
1	_a	**0.5**	**-0.5**	**0.0**	**0.9**	**0.5**
	_b	0.5	0.9	-2.3	-1.2	-2.6
	_c	0.6	0.6	-4.8	-1.4	-5.6
2	_a	**1.1**	**0.0**	**0.6**	**-0.1**	**0.6**
	_b	0.5	1.5	-1.7	-1.9	-2.1
	_c	0.3	1.8	-4.1	-1.7	-4.0
3	_a	**0.6**	**0.7**	**0.7**	**-1.4**	**0.0**
	_b	0.5	0.2	-2.0	-0.6	-2.3
	_c	0.4	1.2	-4.6	-1.6	-5.1
4	_a	**0.7**	**0.9**	**0.4**	**-0.5**	**0.8**
	_b	0.4	1.0	-2.5	-0.8	-2.3
	_c	0.4	1.8	-4.2	-2.1	-4.5
5	_a	**1.0**	**0.1**	**0.5**	**0.2**	**0.8**
	_b	0.6	0.3	-1.8	-0.4	-2.0
	_c	0.4	2.1	-4.0	-2.5	-4.4
6	_a	**0.8**	**-0.7**	**-0.4**	**1.3**	**0.2**
	_b	0.4	0.8	-2.0	-0.6	-1.9
	_c	0.3	0.5	-4.1	-0.1	-3.7
7	_a	**0.7**	**0.1**	**0.4**	**0.7**	**1.2**
	_b	0.4	1.3	-1.9	-0.8	-1.4
	_c	0.4	1.2	-4.4	-0.4	-3.6