AFD1 Dipole (SwissFEL, Aramis Beam Dump)

AFD1 (Aramis beam dump dipole)
on picture is the beam exit end

gap = 20 mm

L2000 x W536 x H480 mm
8° bend downwards

conductor 8 x 8, D 6 mm
108 turns/coil, I_{MAX} = 150 A

MEASUREMENT DATE:
15 Dec. 2014 – 14 Apr. 2015

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)
30 & 49 mm/sec (Z-axis)

INTEGRATION TIME:
20 msec

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

DVM-2 (10 V RANGE):
100 V / 150 A (MSG-2.2), 1 A/s

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

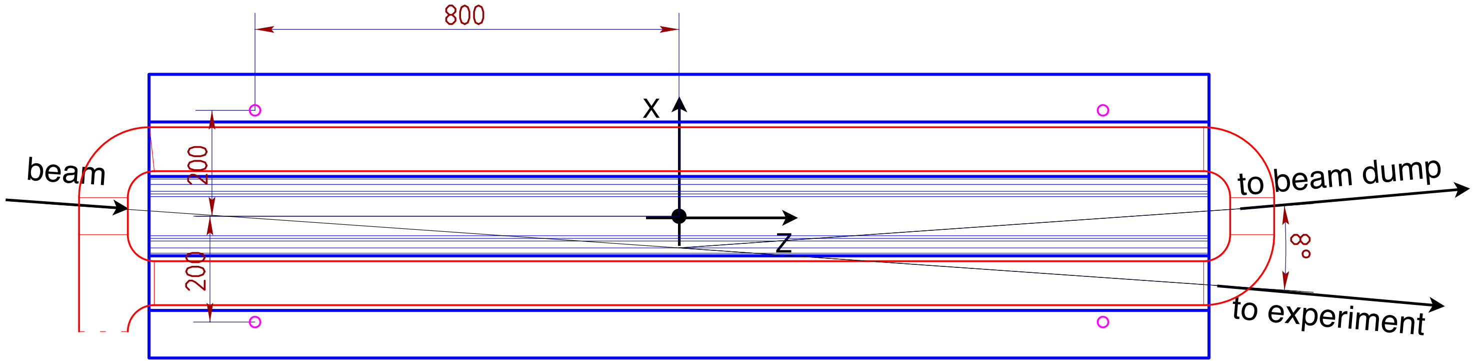
OPERATORS:
Roland Deckardt
Vjeran Vranković

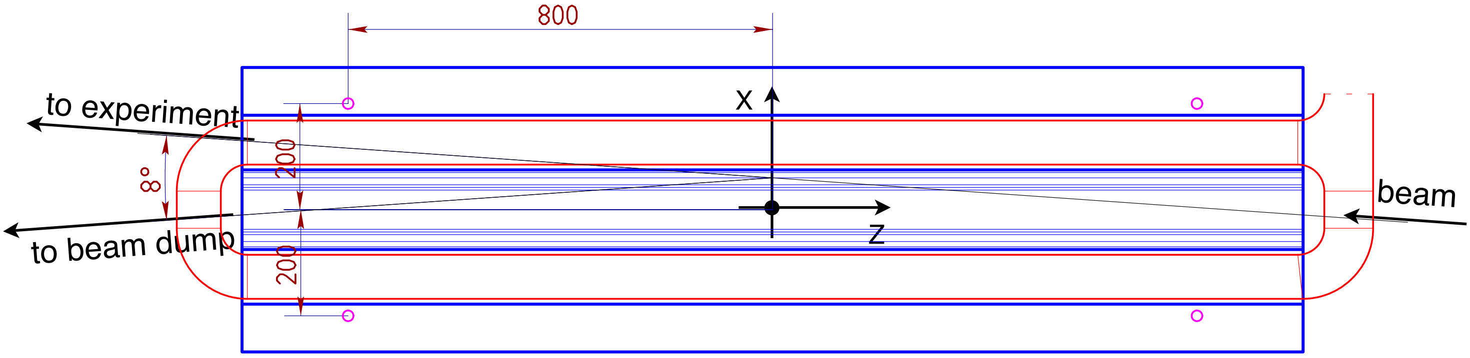
DATA DIRECTORY:
afs: group/magnet/meas/
SwissFEL/afd1

Magnet alignment and positioning

The positioning was done by double reference pin inserted into 4 holes in the return yoke. Another 2 reference points were temporarily created (glued) in the middle between the four reference holes. Since the magnet had to be measured from each end due to its length, the temporary reference holes served as a connection between two separate measurement coordinate systems (see table).

In operation the magnet bending plane is a vertical plane, but for the measurements the magnet was placed so that the bending plane was horizontal. The magnet end with the beam entrance was measured first and then the magnet end with the beam exit.





	file	date	Y	Z	X	Bfit	dist	angle
beam entrance	SEr	15 Dec 2014	-0.020	-0.084	-0.007	-570.32	399.990	89.997
	SEl	15 Dec 2014	-0.190	-0.065	399.983	-569.79		
	SEr01	22 Dec 2014	284.160	-800.013	-200.017	-570.08	400.005	89.998
	SEl01	22 Dec 2014	284.040	-799.999	199.988	-570.03		
	deviation from (-800, 0) and 90˚		0.100	0.006	0.042			0.002
	M101	22 Dec 2014	283.820	7.621	129.820	-649.35	300.124	-91.070
	M201	22 Dec 2014	283.990	2.015	-170.252	-650.00		
	mid-pt: trans & rot			4.825	-20.173			
beam exit	SAr	12 Feb 2015	-1.370	100.084	-399.987	-570.03	399.957	90.049
	SAl	12 Feb 2015	-1.490	99.741	-0.030	-569.92		
	M1	12 Feb 2015	-1.800	892.221	-329.063	-649.51	300.145	88.988
	M2	12 Feb 2015	-1.780	897.524	-28.965	-649.62		
	SAr02	17 Feb 2015	284.050	-799.765	-200.049	-571.19	400.036	90.062
	SAl02	17 Feb 2015	283.930	-800.201	199.987	-570.98		
	SAr03	17 Feb 2015	284.050	-799.886	-200.049	-571.31	400.002	90.056
	SAl03	17 Feb 2015	283.950	-800.275	199.953	-571.36		
	deviation from (800, 0) and 90˚		0.000	-0.080	0.730			179.944
	M1_02	17 Feb 2015	283.620	-7.648	-129.051	-650.23	300.135	88.989
	M2_02	17 Feb 2015	283.620	-2.353	171.037	-650.70		
	mid-pt: trans & rot			4.900	-20.268			
beam entrance	global CS		trans:	0.044	-0.005		rot:	0.002
	SEr01	check		-799.962	-200.050		400.005	90.000
	SEl01			-799.962	199.955			
	M101			7.660	129.816		300.124	-91.068
	M201			2.065	-170.257			
beam exit	global CS		trans:	-0.118	0.777		rot:	179.944
	SAr03	check		799.962	200.048		400.002	-90.000
	SAl03			799.962	-199.954			
	M1_02			7.656	129.821		300.135	-91.067
	M2_02			2.069	-170.262			

beam in	date	I A	X mm	Y mm	Z mm	comment	Bdz(0) T mm
l 03	15 Dec 2014	149.51	0	0	-1900, +50	reproducibility test	-1771.74
l 04		149.50					-1772.11
l 05		149.50					-1772.15
l 06	16 Dec 2014	149.49				fan attached at the other magnet end - off	-1771.36
l 07		149.49				venti ein	-1772.01
f 08		-149.50	-50, +100	0	-1900, +50	2x ±150 A precycle	1772.75
f 09		149.55				2x ±150 A precycle	-1772.37
e 10	17 Dec 2014	31x	0	0	-1900, +50	30 mm/s, 3x ±150 A precycle - parts repeated	
e 11		31x	0	0	-1900, +50	30 mm/s, 3x ±150 A precycle	
l 12	18 Dec 2014	129.56	0	0	-1900, +50	30 mm/s, reproducibility test	-1648.44
l 13		129.55					-1648.33
l 14		129.55					-1648.34
l 15		129.55				49 mm/s, reproducibility test	-1648.37
l 16		129.55					-1648.36
l 17		129.55					-1648.28
f 18		-129.57	-50, +100	0	-1900, +50	30 mm/s, unintentional, 2x ±150 A precycle	1648.83
f 19		129.58				—> 150 A —> 130 A	-1648.42
f 20		-79.75	-50, +100	0	-1900, +50	—> —150 A —> -80 A	1069.52
f 21		79.73				—> 150 A —> 80 A	-1068.89
f 22	19 Dec 2014	-39.87	-50, +100	0	-1900, +50	2x ±150 A precycle, -150 A —> -40 A	541.94
f 23		39.86				—> 150 A —> 40 A	-541.50
f 24		-129.56	-50, +100	-4	-1900, +50	—> —150 A —> -130 A	1648.77
f 25		-129.59		-3			1648.86
f 26		-129.60		0			1648.90
f 27		-129.60		3			1648.91
f 28		-129.60		4			1648.87
f 29		129.59		-4		—> 150 A —> 130 A	-1648.48
f 30		129.59		-3			-1648.47
f 31		129.59		0			-1648.44
f 32	20 Dec 2014	129.59		3			-1648.46
f 33		129.59		4			-1648.42
f 34	22 Dec 2014	0	-50, +100	0	-1900, +50	2x ±150 A precycle —> 0 A	-5.93
l 35		0	0	0	-1900, +50	150 A —> -20 A —> 0 A	1.16
l 36						150 A —> -15 A —> 0 A	0.27
l 37						150 A —> -10 A —> 0 A	-1.02
l 38						150 A —> -14 A —> 0 A	0.05
l 39						-150 A —> 14 A —> 0 A	0.08

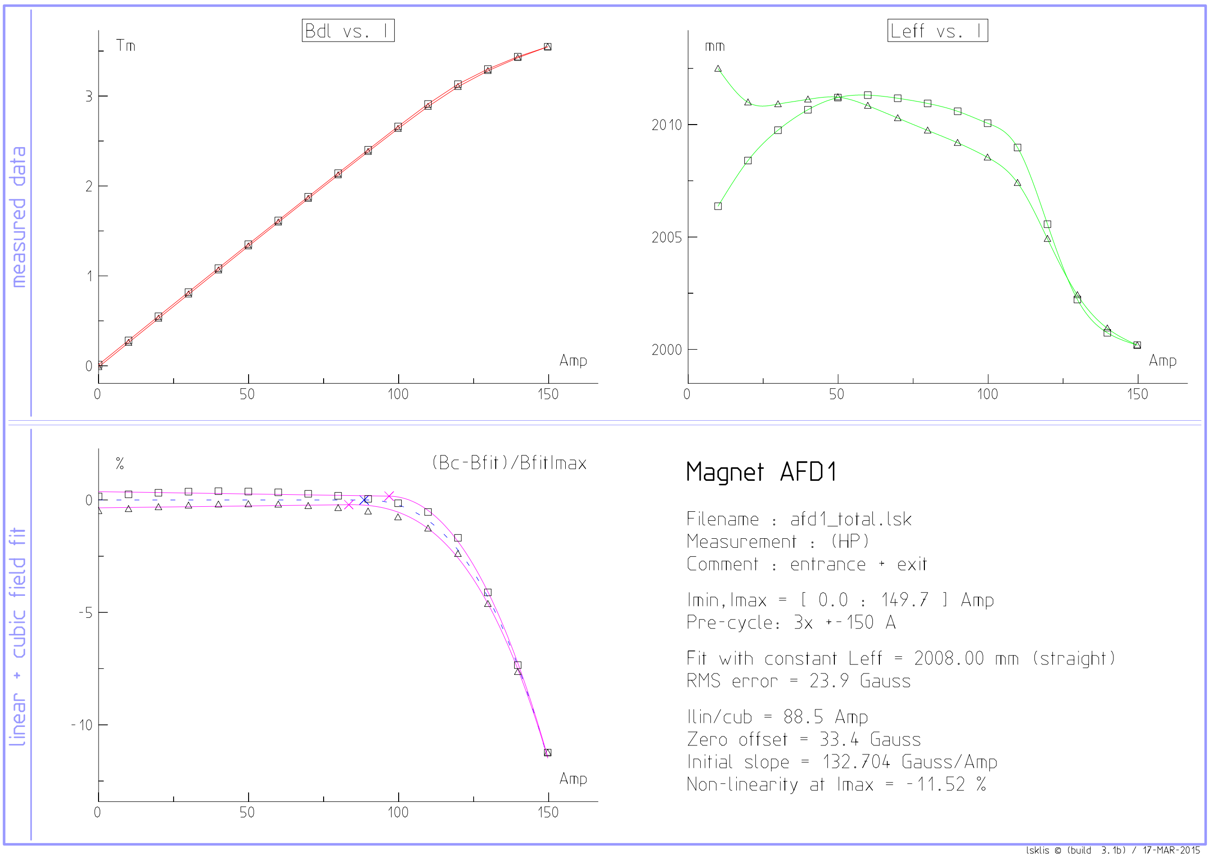
beam out	date	I A	X mm	Y mm	Z mm	comment	Bdz(0) T mm
e 40	13 Feb 2015	21x	0	0	-1900, +50	3x ±150 A precycle	
f 41		-129.93	-100, +50	-4	-1900, +50	—> —150 A —> -130 A	1651.51
f 42		-129.93		-3			1651.46
f 43		-129.93		0			1651.41
f 44		-129.93		3			1651.38
f 45		-129.93		4			1651.38
f 46		129.95		-4		—> 150 A —> 130 A	-1651.05
f 47		129.95		-3			-1650.99
f 48		129.95		0			-1650.98
f 49	14 Feb 2015	129.95		3			-1650.94
f 50		129.95		4			-1650.95
f 51	15 Feb 2015	79.97	-100, +50	0	-1900, +50	—> 150 A —> 80 A	-1071.90
f 52		39.99				—> 80 A —> 40 A	-543.29
f 53		-149.92				—> 40 A —> -150 A	1775.00
f 54		-79.95				—> -150 A —> -80 A	1072.00
f 55		-39.97				—> -80 A —> -40 A	543.38
f 56		149.94				—> -40 A —> 150 A	-1774.42
f 57	16 Feb 2015	0				—> 150 A —> 0 A	-5.98
l 58		0	0	0	-1900, +50	—> 150 A —> -40 A —> 0 A	3.54
l 59						—> 150 A —> -30 A —> 0 A	2.59
l 60						—> 150 A —> -14 A —> 0 A	0.05
e 61		31x	0	0	-1900, +50	3x ±150 A precycle	
l 62		0	0	0	-1900, +50	—> -150 A —> 14 A —> 0 A	0.18

2D field maps are measured at 0 A, 40 A, 80 A and 150 A.
3D field map (one component only) is measured at 130 A.

During measurements the air in the magnet gap was forcefully circulated with fans mounted on the non-measured magnet end. This was done in order to equalise as much as possible the higher air temperature inside the magnet gap to the ambient condition. The temperature affects Hall probe measurement and therefore influences the accuracy. For finding out the absolute field values we recorded accurate NMR readings in the homogeneous region X=0, Z=±800 mm for two magnet currents, 100 A and 150 A.

Excitation curve(s)

Before measurements the magnet was pre-cycled 3 times from 150 A to -150 A. The fields were measured at 31 currents on the line X = Y = 0, Z = -1900:0 mm. The measurements were performed for each magnet half separately. These “half” measurements were afterwards joined together. An error due to the angle between the magnet and the Hall probe measurement direction (0.002°and 0.056°) could not be taken out of the combined measurement data.



clsk.py 31 “r” “<u1,951”						
	B·dz(150A) [T·m]	L_{SEFF} [mm]	I_{LIN} [A]	B_{OFFSET}(0A) [Gauss]	B_{SLOPE} [Gauss/A]	NL(I_{MAX}) [%]
e11 (in) 17 Dec 2014	1.77235	1004.1	88.2	34.3	132.714	-11.5
e61 (out) 16 Feb 2015	1.77471	1003.9	88.9	32.7	132.690	-11.6
total	3.54705	2008	88.5	33.4	132.704	-11.5

/afs/psi.ch/user/v/vrankovic/mymeas/SwissFEL/Aramis/afd1/afd1_total.lsklis
Saved: 19/3/2015 14:56:42

Printed For: Vjeran Vranković

Magnet AFD1

File : afd1_total.lsk
Date :
Meas-type : HP
Comment : entrance + exit

Pre-cycle : 3x +-150 A

#Curr: 31 (nPaths=2)
Z-dir: from -1900.00 to 1900.00 mm, steps of 2.00 mm
X-dir: at -0.000 mm

linear_<1:Ilin> and cubic_<Ilin:Imax> approximation of Bc:
Blin = b0 + b1 * Irel ; Irel = I / Imax
Bcub = Blin + b2 * Irel^2 + b3 * Irel^3 ; Irel = (I - Ilin) / (Imax - Ilin)

	Ilin_A	Imax_A	b0_G	b1_G	b2_G	b3_G	RMS_G
/	83.4	149.7	-36.7	19917.4	-801.4	-1463.0	24.4
\	96.8	149.7	106.3	19806.8	-1919.3	-369.4	22.9
ˉ	88.5	149.7	33.4	19867.7	-1078.7	-1214.1	23.9

/ = increasing current branch
\ = decreasing current branch
ˉ = average

I [A]	p(lsklis) factor = 1	p(TRACK)	factor	0.9996
40	2333.99	2331.05	0.99874	-0.09%
80	4602.26	4599.87	0.99948	-0.01%
130	7091.09	7089.00	0.99971	0.01%
150	7622.09	7620.30	0.99977	0.02%

constLeff (straight) = 2008.00 mm
constLeff = 2009.6 mm
constBendingRadius = 14392.9 mm
fullBendingAngle = 8.0 deg
Leff / Lz = 1.00081
particle E0 = 0.511 MeV

I_Amp	Bdz_Gmm	p_MeV/c	E_MeV	Bc_G	err_G
0.00*	-129068.5	-27.724	27.218	-64.3	-27.6
9.98/	2567592.3	551.516	551.006	1278.7	-13.0
19.97/	5260999.0	1130.058	1129.547	2620.0	0.7
29.95/	7948308.0	1707.289	1706.778	3958.3	10.6
39.92/	10626620.0	2282.588	2282.077	5292.1	17.4
49.91/	13292427.0	2855.201	2854.690	6619.7	16.6
59.88/	15942960.0	3424.533	3424.022	7939.7	9.6
69.87/	18579372.0	3990.832	3990.321	9252.7	-5.8
79.85/	21200194.0	4553.782	4553.271	10557.9	-27.7
89.83/	23798452.0	5111.886	5111.375	11851.8	-53.2
99.81/	26354562.0	5660.937	5660.425	13124.8	-45.0
109.79/	28817342.0	6189.938	6189.427	14351.3	0.4
119.77/	31024984.0	6664.139	6663.627	15450.7	36.0
129.76/	32795878.0	7044.525	7044.014	16332.6	-1.6
139.73/	34244584.0	7355.706	7355.195	17054.1	-23.5
149.71*	35470524.0	7619.037	7618.525	17664.6	44.2 (average of 2 fits)
139.74\	34366916.0	7381.982	7381.471	17115.0	-17.0
129.76\	32999446.0	7088.251	7087.740	16434.0	-5.0
119.78\	31308320.0	6724.999	6724.487	15591.8	31.5
109.80\	29109780.0	6252.754	6252.243	14496.9	-14.4
99.81\	26603768.0	5714.465	5713.954	13248.9	-55.7
89.83\	24024932.0	5160.534	5160.023	11964.6	-26.6
79.85\	21417304.0	4600.417	4599.906	10666.0	-4.2
69.87\	18793930.0	4036.919	4036.408	9359.5	9.7
59.89\	16160182.0	3471.193	3470.682	8047.9	18.3
49.91\	13516183.0	2903.264	2902.753	6731.2	21.9
39.93\	10861552.0	2333.052	2332.541	5409.1	20.2
29.95\	8194202.5	1760.107	1759.596	4080.8	12.2
19.97\	5514163.0	1184.437	1183.926	2746.1	-1.5
9.98\	2824711.0	606.745	606.235	1406.7	-19.9
0.00*	129068.5	27.724	27.218	64.3	-42.0

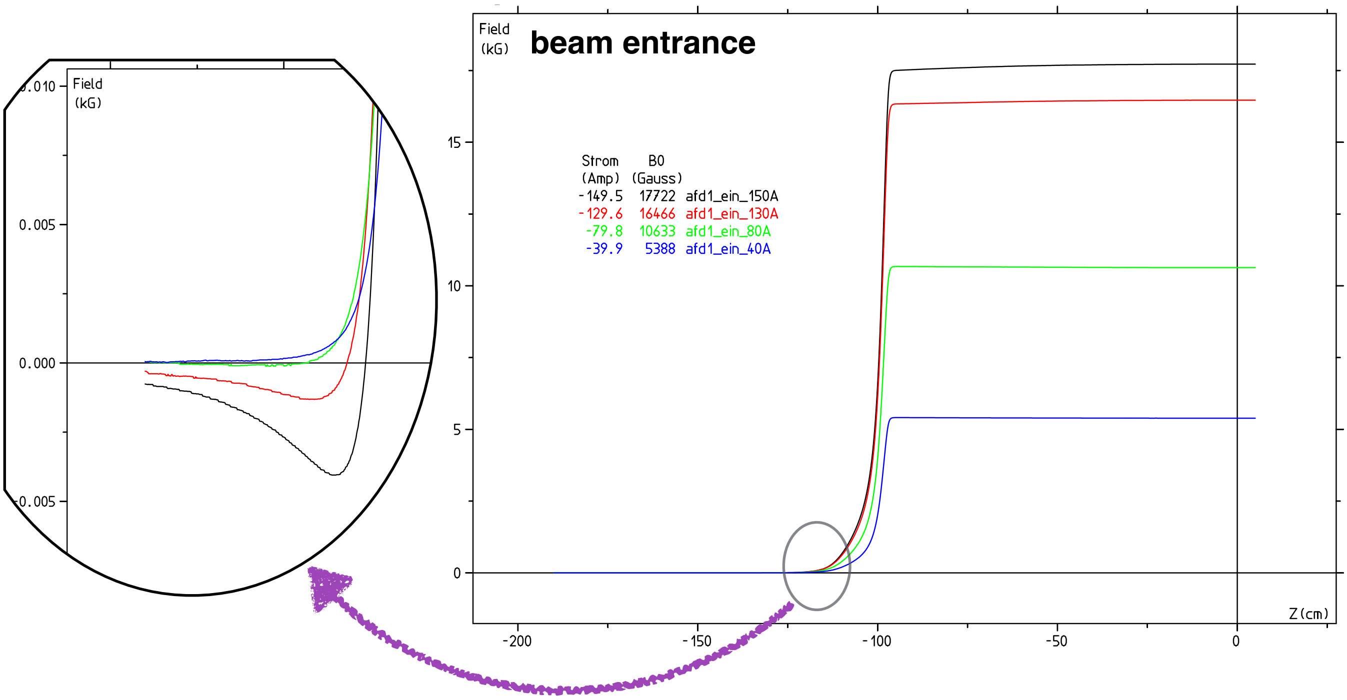
p = Bdz / fullBendingAngle * Leff / Lz * c * e-13 * factor
factor = p(TRACK) / p(LSKLIS) = 0.9996
E = sqrt(E0^2 + p^2) - E0
Bc = Bdz / constLeff
err = Bc - Bfit

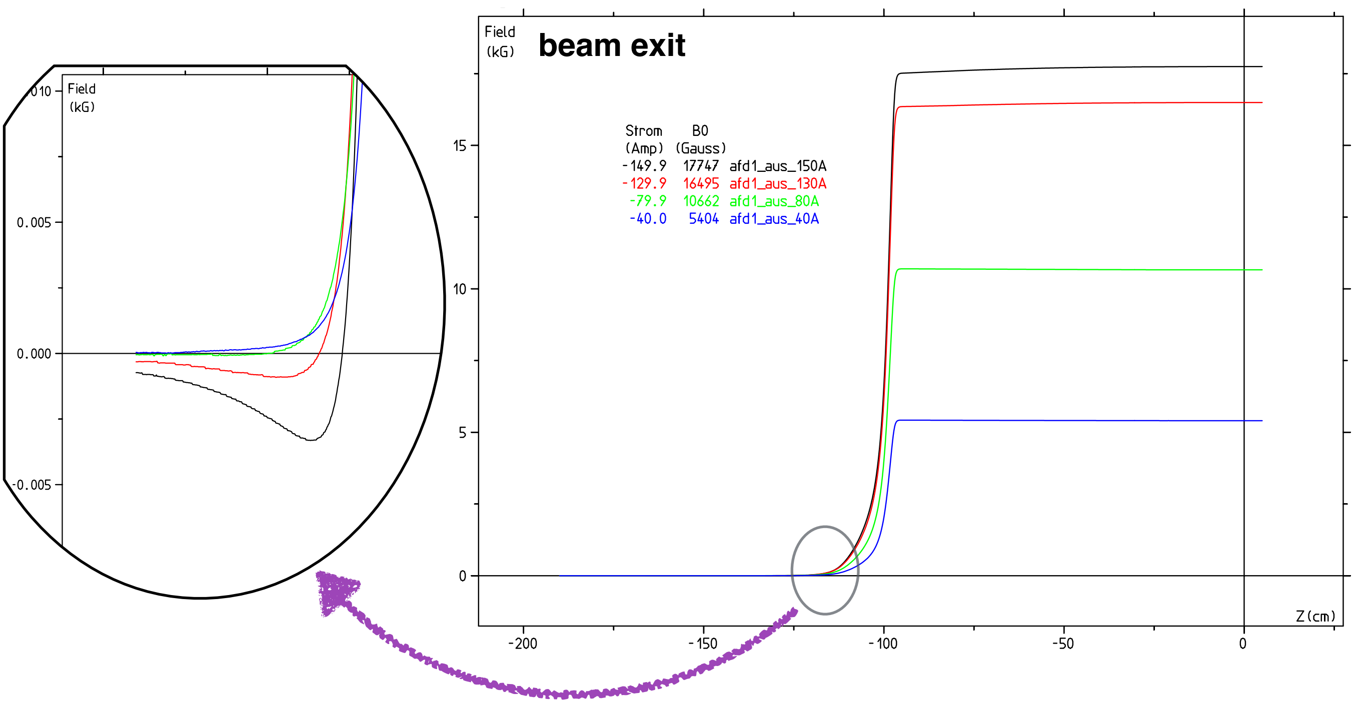
Coil - water cooling

I = 130 A (4 bar, 9 l/min)							
time	Δt	T_{IN}	T_{OUT}	ΔT_{water}		U_{tot}	ΔT_{av_coil}
14:00		26.7	25.1	-1.6			
14:05	5m	27.4	27.0	-0.4	-3%	64.47	
14:10	10m	27.6	34.4	6.8	52%	65.86	5.0
14:15	15m	27.7	37.8	10.1	77%	66.41	6.9
14:20	20m	27.8	39.7	11.9	90%	66.68	7.9
14:33	33m	28.2	40.8	12.6	95%	66.76	8.2
14:48	48m	28.9	41.5	12.6	95%	67.05	9.2
15:00	1h	29.3	42.1	12.8	97%	67.17	9.7
15:40	1h 40m	29.9	43.0	13.1	99%	67.38	10.4
16:10	2h 10m	29.5	42.8	13.3	101%	67.32	10.2
17:05	3h 5m	28.8	42	13.2	100%	67.13	9.5

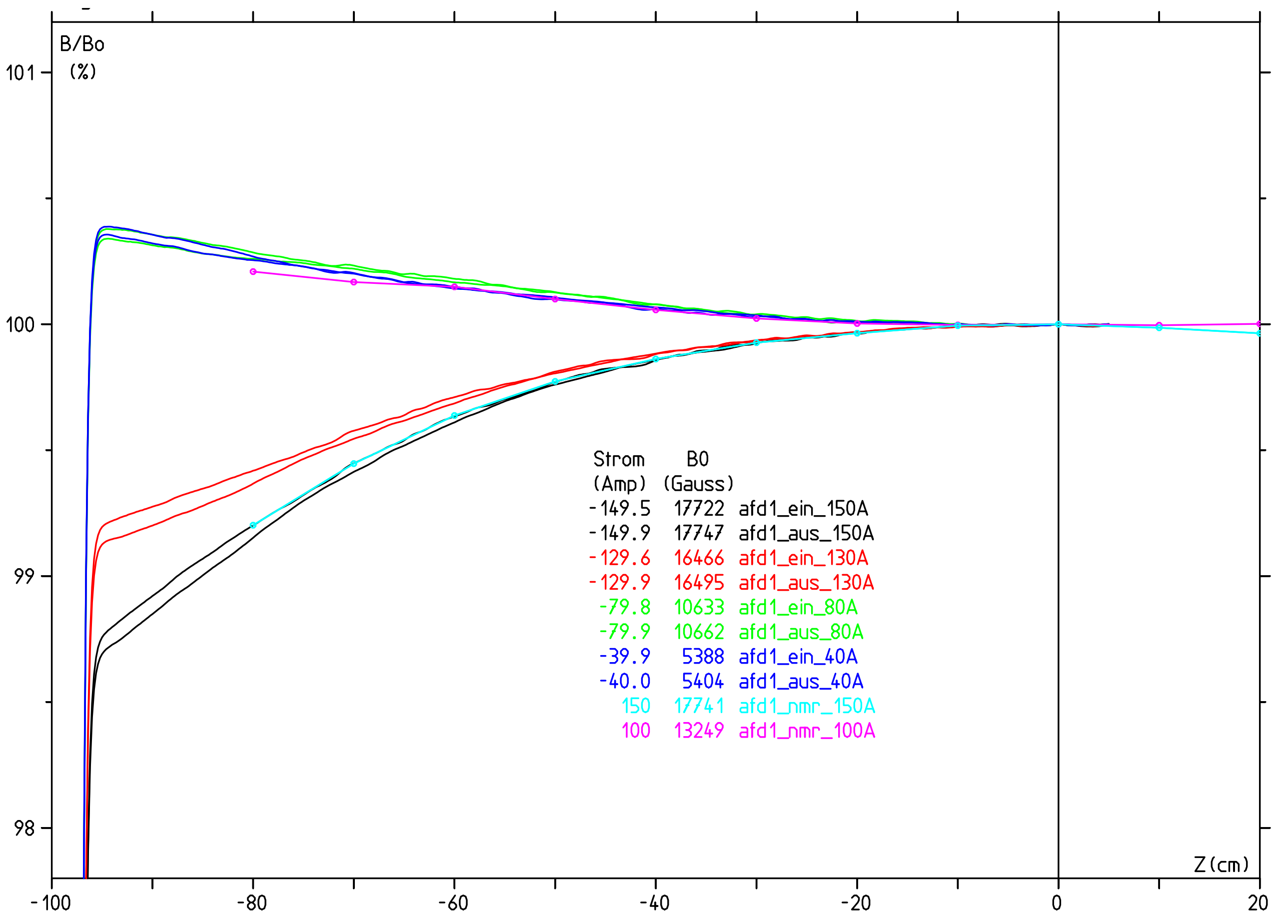
I = 150 A (4 bar, 9 l/min)							
time	Δt	T_{IN}	T_{OUT}	ΔT_{water}		U_{tot}	ΔT_{av_coil}
11:15		25.8	26.1	0.3			
11:20	5m	25.8	26.6	0.8	4%	74.15	
11:25	15m	25.8	34.9	9.1	51%	76.16	6.3
11:30	20m	25.8	39.6	13.8	78%	77.01	8.9
11:35	30m	25.7	41.6	15.9	89%	77.33	9.9
11:45	40m	25.8	42.8	17.0	96%	77.53	10.5
11:55	2h 15m	26.1	43.2	17.1	96%	77.61	10.8
13:30	2h 45m	27.7	45.2	17.5	98%	78.15	12.5
14:00	3h 15m	27.9	45.4	17.5	98%	78.22	12.7
14:30	4h 45m	28.0	45.6	17.6	99%	78.28	12.9
16:00	5h 45m	28.1	45.8	17.7	99%	78.34	13.1
17:00	5h 45m	28.1	45.9	17.8	100%	78.36	13.1

Field maps (40, 80, 130 and 150 A)





Field profile (relative) and NMR readings



Z=-800:0	Bdz (100 A) T mm	Bdz (150 A) T mm
afd1_nmr	1060.724	1416.137
afd1e11 (in)	1058.151	1414.350
afd1e61 (out)	1061.014	1416.469
average (in+out)	1059.583	1415.410
NMR / HP	0.11%	0.05%

Field integrals (straight)

The cubic fit for every straight field integral is evaluated in the X range of ±20 mm (5 mm over 8° bend with sagitta 34.9 mm). The field errors $B_{Nerr} = (B_N - B_0) / B_0$ are shown in ppm and are calculated at X=+20 mm.

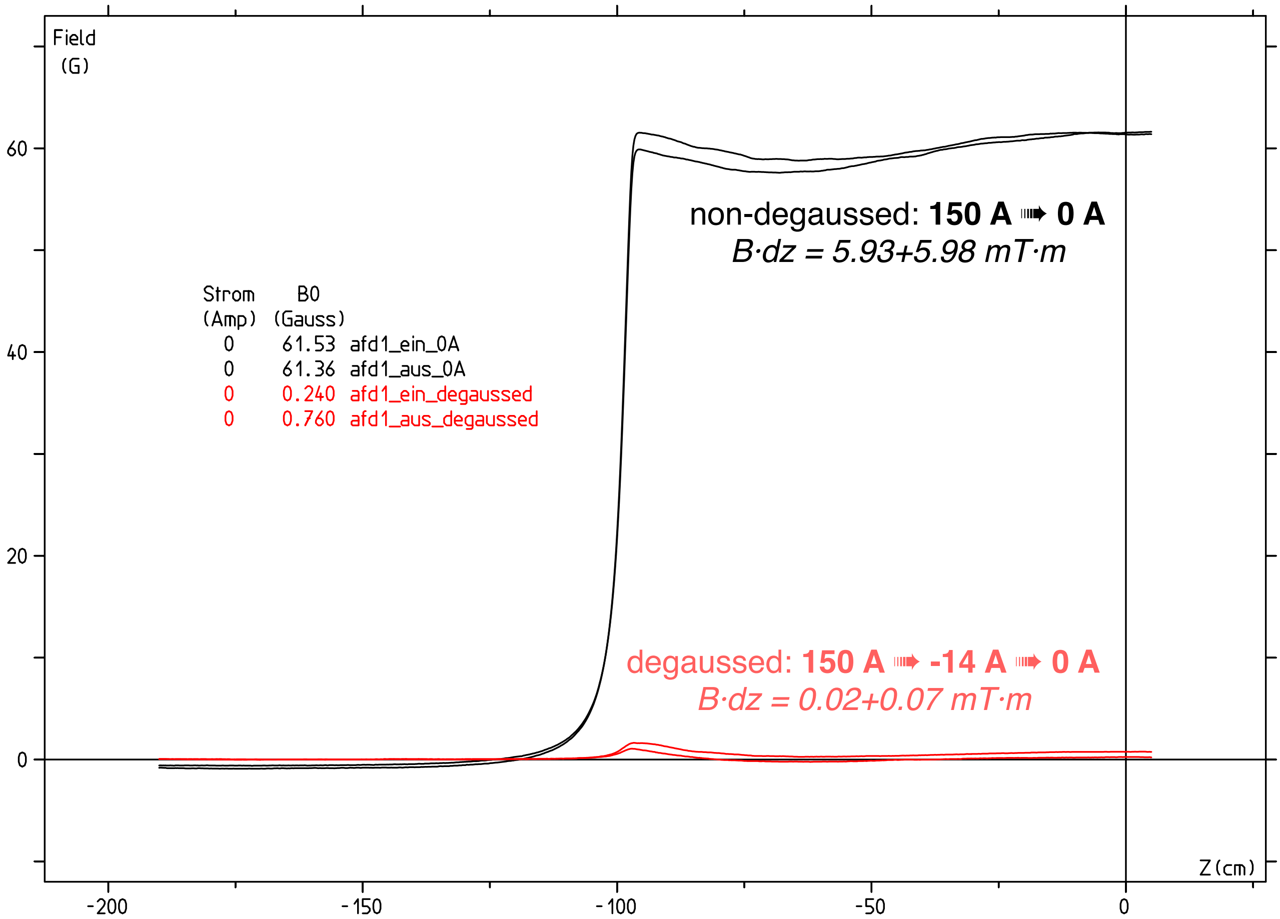
printf “afd1_ein_150A\n<v7,15\\n<u1,951n\n\n\n” | combi

beam in	Y [mm]	fit_{RMS} [ppm]	B_{1err} [ppm]	B_{2err} [ppm]	B_{3err} [ppm]
40 A	0	12	284	39	-185
80 A	0	9	242	-22	-148
	-4	23	408	-10	-328
	-3	16	355	-32	-263
130 A	0	7	278	-60	-158
	3	8	259	-83	-113
	4	10	273	-71	-128
150 A	0	8	301	-126	-163

printf “afd1_aus_150A\n<v17,25\\n<u1,951n\n\n\n” | combi

beam out	Y [mm]	fit_{RMS} [ppm]	B_{1err} [ppm]	B_{2err} [ppm]	B_{3err} [ppm]
40 A	0	12	-188	-25	110
80 A	0	7	-208	-41	125
	-4	11	-259	-101	179
	-3	8	-244	-99	162
130 A	0	8	-233	-100	134
	3	8	-247	-79	159
	4	9	-285	-75	190
150 A	0	6	-246	-146	145

Degaussing



Field
(G)
60
40
20
0
-200
-150
-100
-50
0
Z (cm)
non-degaussed: 150 A ➟ 0 A
B·dz = 5.93+5.98 mT·m
Strom (Amp) B0 (Gauss)
0 61.53 afd1_ein_0A
0 61.36 afd1_aus_0A
0 0.240 afd1_ein_degaussed
0 0.760 afd1_aus_degaussed
degaussed: 150 A ➟ -14 A ➟ 0 A
B·dz = 0.02+0.07 mT·m

Field integral homogeneity analysis with raytracing

Fit *Bdl(x)* with the function:

$$Bdl_{fit}(x) = Bdl_0 \cdot (1 + a_1 \cdot x + a_2 \cdot x^2 + ...)$$

where *x* is transversal to the beam direction.

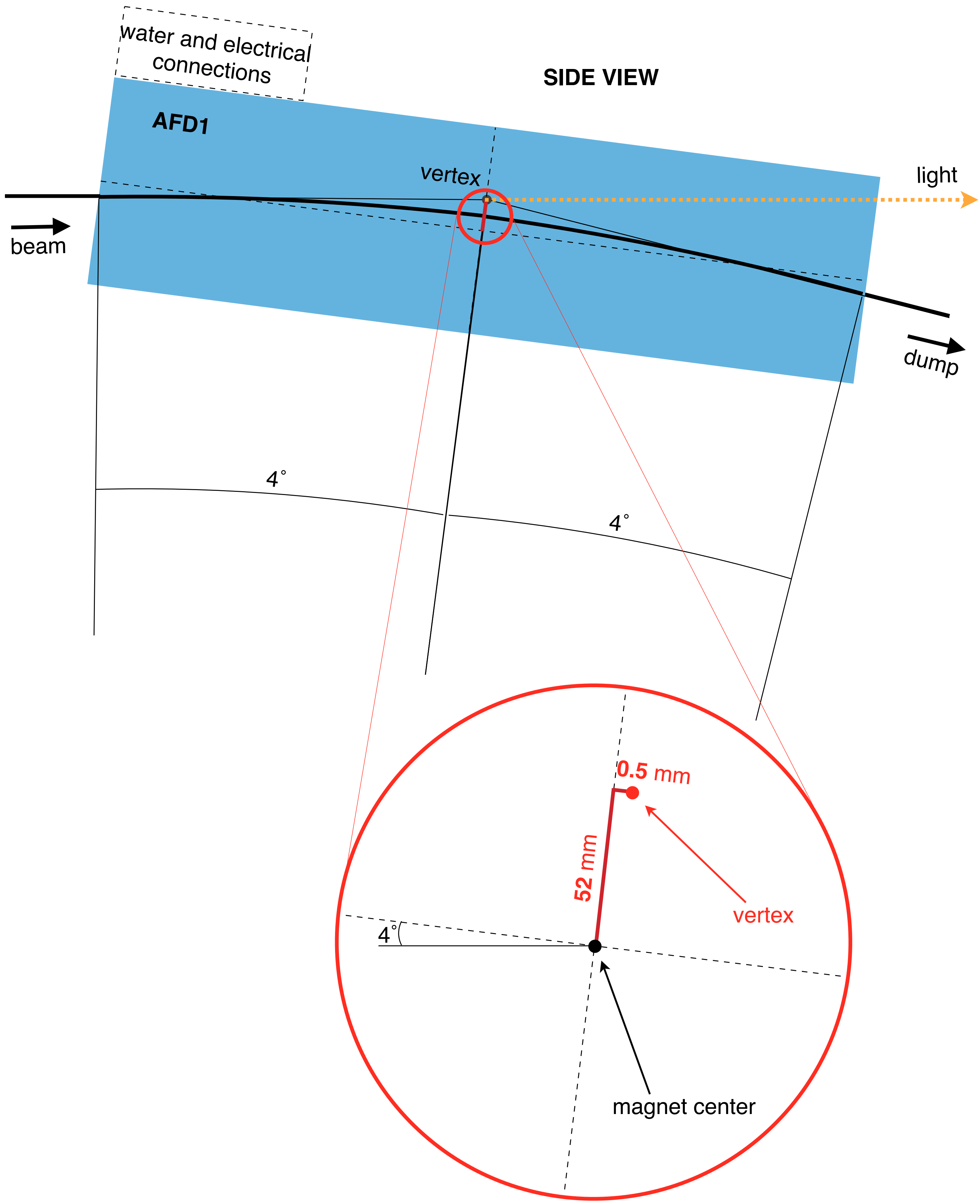
The maximal field inhomogeneity coming from a_1 (quadrupole) at ±5 mm from the beam centre ranges from 62–84 ppm over the whole magnet excitation range (0-150 A). The field integral on the inner side of the beam bend is weaker, the outer side is stronger. The maximal field inhomogeneity from the sextupole component a_2 ranges

afd1.set in TRACK
copy & paste look.set in TRACK
quadFit.py `cat track.out`

		I = 40 A			I = 80 A			I = 130 A			I = 150 A		
$X_{Z=-2000}$ mm	v_x mm	Bdl_0 kG cm	a_1 ppm/cm	a_2 ppm/cm^2	Bdl_0 kG cm	a_1 ppm/cm	a_2 ppm/cm^2	Bdl_0 kG cm	a_1 ppm/cm	a_2 ppm/cm^2	Bdl_0 kG cm	a_1 ppm/cm	a_2 ppm/cm^2
89.854	-50	1085.64	165	8	2142.29	159	17	3301.55	148	-9	3549.03	134	-28
88.854	-51	1085.66	167	8	2142.32	161	15	3301.60	145	-13	3549.07	128	-29
87.854	**-52**	**1085.67**	**167**	**7**	**2142.36**	**162**	**10**	**3301.65**	**140**	**-19**	**3549.12**	**121**	**-36**
86.854	-53	1085.69	168	4	2142.39	163	4	3301.69	135	-29	3549.16	113	-44
85.854	-54	1085.71	170	4	2142.43	163	-5	3301.74	129	-36	3549.20	102	-50
84.854	-55	1085.73	171	7	2142.46	161	-11	3301.78	122	-43	3549.24	91	-62
83.854	-56	1085.75	172	9	2142.50	159	-16	3301.82	114	-45	3549.27	79	-68
82.854	-57	1085.77	173	11	2142.53	156	-16	3301.85	105	-45	3549.29	66	-72
81.854	-58	1085.78	175	11	2142.56	155	-11	3301.89	97	-42	3549.31	52	-71
80.854	-59	1085.80	178	12	2142.60	153	-3	3301.91	88	-38	3549.33	38	-72
79.854	-60	1085.82	179	15	2142.63	153	5	3301.94	80	-35	3549.34	23	-70
78.854	-61	1085.84	182	13	2142.66	154	11	3301.97	72	-37	3549.34	8	-76
77.854	-62	1085.86	183	9	2142.69	155	12	3301.99	62	-48	3549.34	-11	-89

	I = 40 A			I = 80 A			I = 130 A			I = 150 A		
$X_{Z=-2000}$ mm	$X_{Z=+2000}$ mm	v_x mm	v_z mm	$X_{Z=+2000}$ mm	v_x mm	v_z mm	$X_{Z=+2000}$ mm	v_x mm	v_z mm	$X_{Z=+2000}$ mm	v_x mm	v_z mm
87.854	87.756	**-52.0**	**0.7**	87.772	**-52.0**	**0.6**	87.812	**-52.0**	**0.3**	87.822	**-52.0**	**0.2**
CONCLUSION: set the vertex point to (X = -52.0 mm ; Z = +0.5 mm) where the magnet centre is at (0,0)												

Beam vertex point



Coils re-mounted at PSI

The coils were not properly horizontally fixed by the company (Buckley) which might have lead to problems when turning the magnet in its operational vertical position. Therefore we have opened the magnet and fixed the coils. Due to that the magnetic field measurements were repeated.

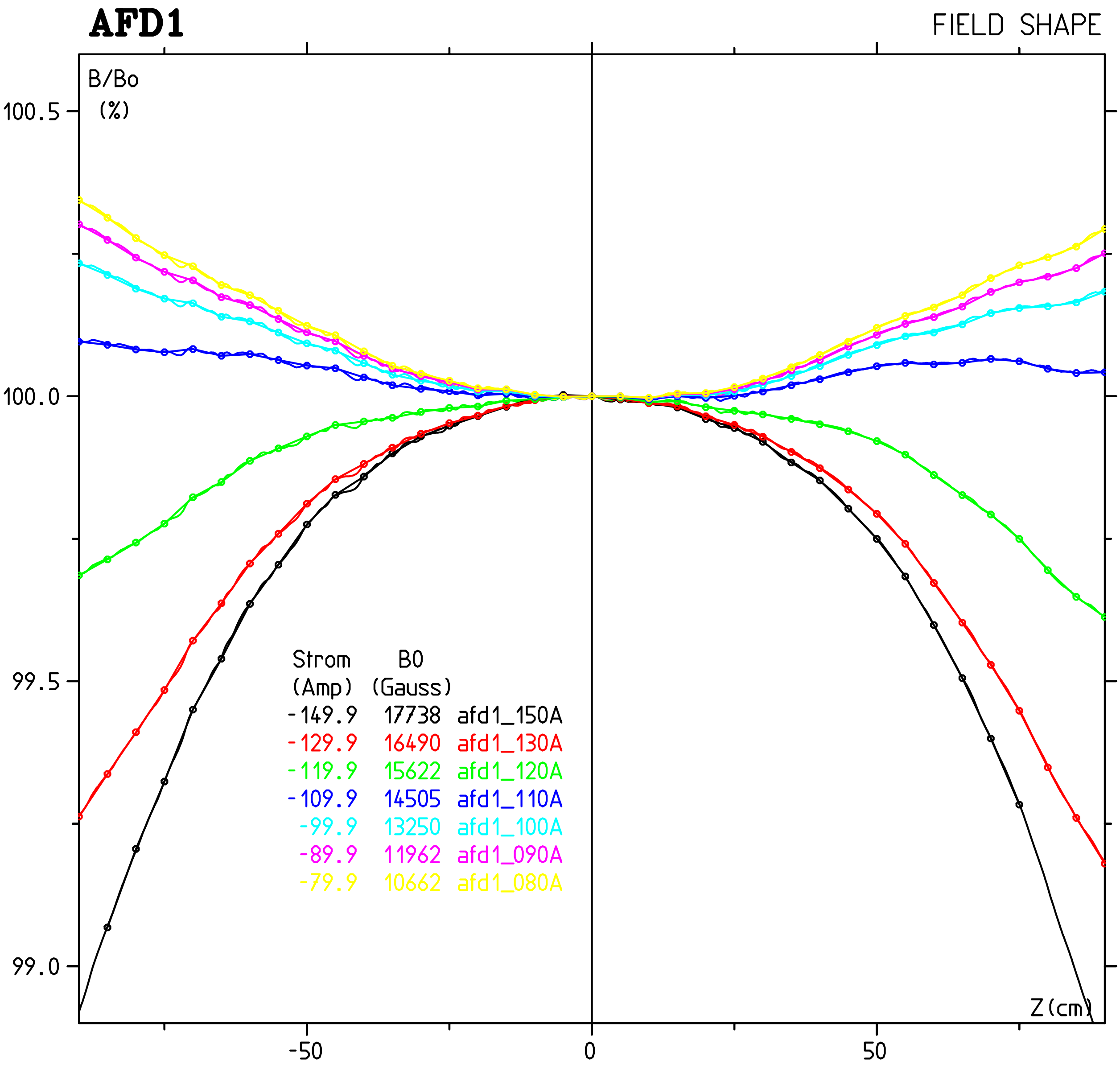
The cubic fit for every straight field integral is evaluated in the X range of ±20 mm (5 mm over 8° bend with sagitta 34.9 mm). The field errors $B_{Nerr} = (B_N - B_0) / B_0$ are shown in ppm and are calculated at X=+20 mm.

printf “ein150A\n<v7,15\\n<u1,951n\n\n\n” I combi						
beam in	B_{fit} [Gauss]	L_{SEFF} [mm]	fit_{RMS} [ppm]	B_{1err} [ppm]	B_{2err} [ppm]	B_{3err} [ppm]
40 A	5404.1	1005.5	11	235	3	-166
80 A	10665.0	1005.6	9	230	-8	-154
90 A	11966.1	1005.5	6	241	-12	-163
100 A	13254.2	1005.2	10	238	-9	-160
110 A	14509.4	1004.6	8	237	-11	-152
120 A	15626.4	1002.4	9	254	-41	-162
130 A	16494.4	1001.3	8	267	-67	-171
150 A	17743.2	1000.4	4	287	-119	-185

printf “aus150A\n<v17,25\\n<u1,951n\n\n\n” I combi						
beam in	B_{fit} [Gauss]	L_{SEFF} [mm]	fit_{RMS} [ppm]	B_{1err} [ppm]	B_{2err} [ppm]	B_{3err} [ppm]
40 A	5403.4	1005.3	11	-206	-11	131
80 A	10663.9	1005.4	11	-218	-42	141
90 A	11964.6	1005.2	7	-203	-39	129
100 A	13252.6	1004.9	9	-214	-34	136
110 A	14507.8	1004.4	8	-222	-47	136
120 A	15625.0	1002.6	7	-227	-66	141
130 A	16492.5	1000.9	9	-250	-98	163
150 A	17740.7	999.9	7	-239	-154	147

Field profile (relative) and NMR readings

	B_{NMR} [Gauss]	B_{ein} [Gauss]	$factor_{ein}$	B_{aus} [Gauss]	$factor_{aus}$
80 A	**10662.0**	10665.0	0.99972	10663.9	0.99982
90 A	**11962.3**	11966.1	0.99969	11964.6	0.99981
100 A	**13250.0**	13254.2	0.99968	13252.6	0.99981
110 A	**14504.8**	14509.4	0.99968	14507.8	0.99980
120 A	**15622.1**	15626.4	0.99972	15625.0	0.99981
130 A	**16490.0**	16494.4	0.99973	16492.5	0.99985
150 A	**17738.4**	17743.2	0.99973	17740.7	0.99987



Field integral homogeneity, beam vertex and energy

Fit *Bdl(x)* with the function:

$$Bdl_{fit}(x) = Bdl_0 \cdot (1 + a_1 \cdot x + a_2 \cdot x^2 + \ldots)$$

where *x* is transversal to the beam direction.

The maximal field inhomogeneity coming from a_1 (quadrupole) at ±5 mm from the beam centre ranges from 64–92 ppm over the whole magnet excitation range (40-150 A). The field integral on the inner side of the beam bend is weaker, the outer side is stronger. The maximal field inhomogeneity from the sextupole component a_2 ranges from -5 to +8 ppm.

The beam vertex position is insensitive to the magnet excitation.

The beam energies shown in the table correspond to magnet currents set on the decreasing current path, i.e. the current is set after the maximum current of 150 A.

TRACK	**E** GeV	**$X_{Z=+2000}$** mm	**V_X** mm	**V_Z** mm	**Bdl_0** kG cm	**a_1** ppm/cm	**a_2** ppm/cm^2
40 A	2.334	87.865	-52.0	-0.1	1087.05	183	30
80 A	4.606	87.870	-52.0	-0.1	2145.51	172	31
90 A	5.167	87.871	-52.0	-0.1	2406.75	172	25
100 A	5.722	87.869	-52.0	-0.1	2665.11	170	26
110 A	6.260	87.869	-52.0	-0.1	2915.87	172	19
120 A	6.731	87.872	-52.0	-0.1	3135.04	161	14
130 A	7.093	87.875	-52.0	-0.1	3303.70	154	-4
150 A	7.622	87.877	-52.0	-0.2	3550.31	138	-20