CESRc Wiggler Magnets

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Specification choice

1. Peak field

In wigglers dominated machine: $\frac{?_E}{E} \,\square\, \sqrt{B_w}; \quad \frac{1}{?} \,\square\, B_w^2 L_w$

To keep energy spread < 8e-4, Bw should be < 2.1T. To provide damping time ~ 55ms, Lw (total wiggler length) should be ~ 18.2m

2. Wiggler period and field roll of requirement :

$$\square y' ? ? \frac{B_w^2 L}{2(B?)^2} ? y ? \frac{2}{3} ? \frac{2?}{?} ?^2 y^3 ? \ldots ?$$

$$\square x' ? ? \frac{L x_p}{2(B?)} \frac{? B_y(x)}{? x}; \quad x_p ? \frac{B_w}{B?} ? \frac{?}{2?} ?^2$$

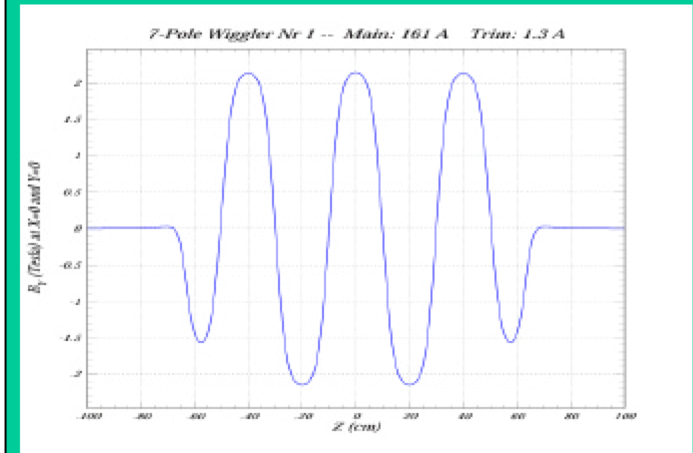
Longer period results in weaker cubic non-linearity, but increases orbit excursion which increase sensitivity to field non-uniformity across wiggler poles. Reasonable compromise:

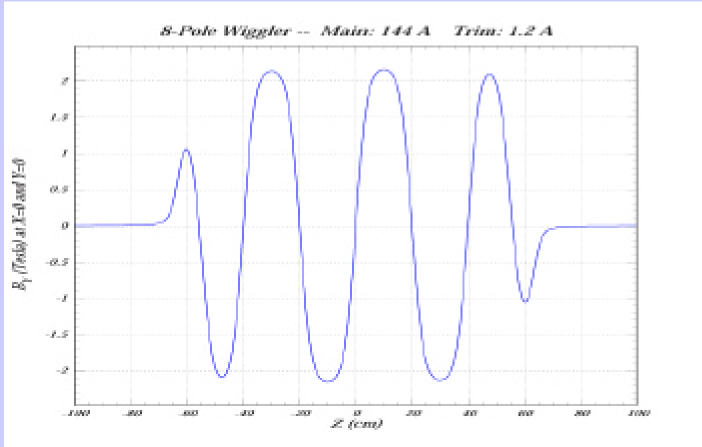
? ?? ??cm; dB/B at 4cm ~ 2.5e-3

Magnetic design: two types

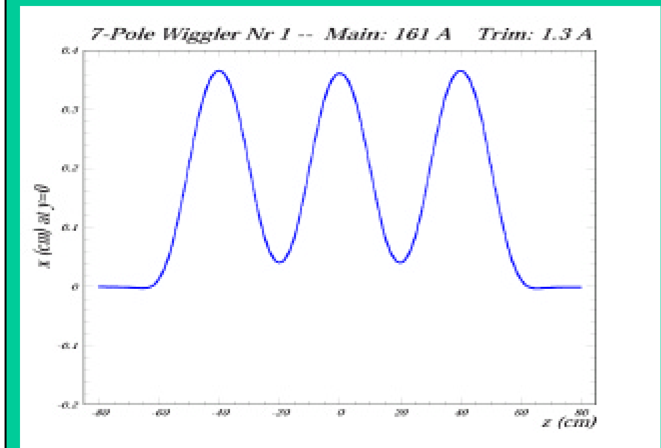
	7 poles (symmetric)	8 poles (asymmetric)
Poles length [cm]	15+20+20+20+20+20+15 = 130	10+15+20+20+20+20+15+10 = 130
Bmax/pole [T]	-1.6/2.1/-2.1/2.1/-2.1/2.1/-1.6	-1.1/2.1/-2.1/2.1/-2.1/2.1/-2.1/1.1

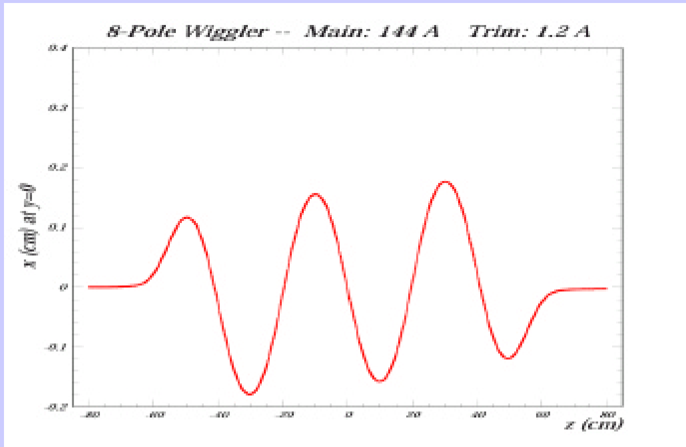
Field along magnet





Beam trajectory

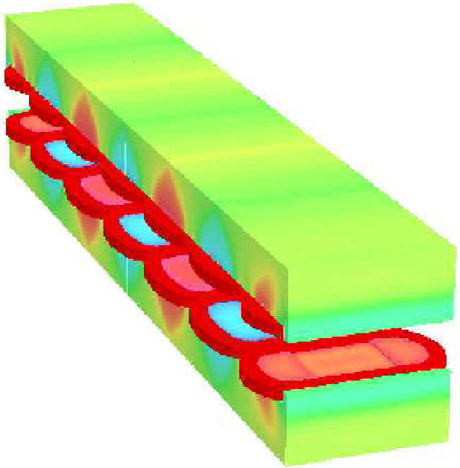




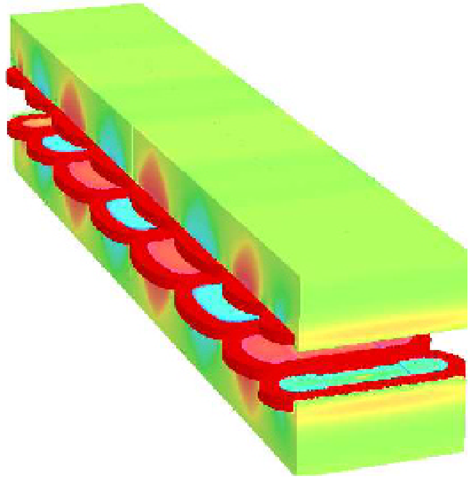
Model Calculation

3-D model magnetic field calculation with “Vector Field” software

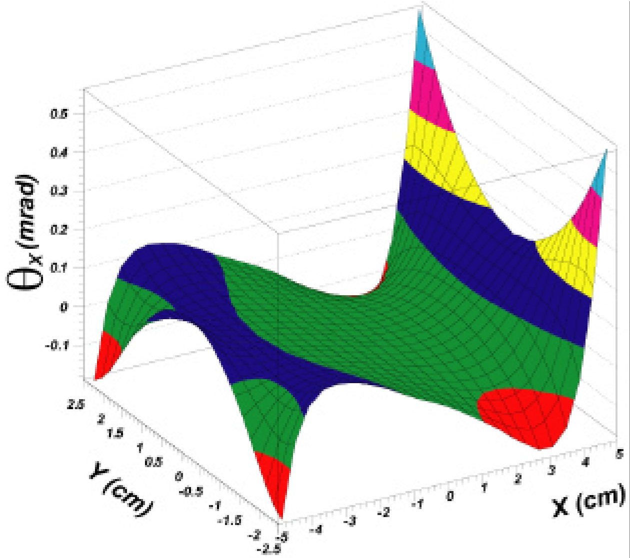
7 pole model

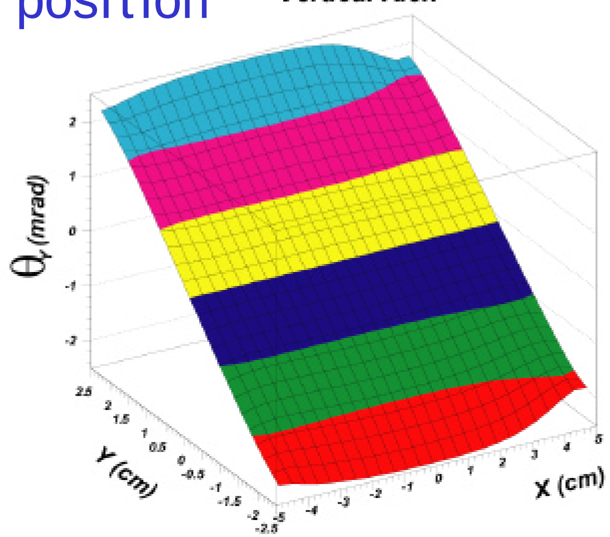


8 pole model



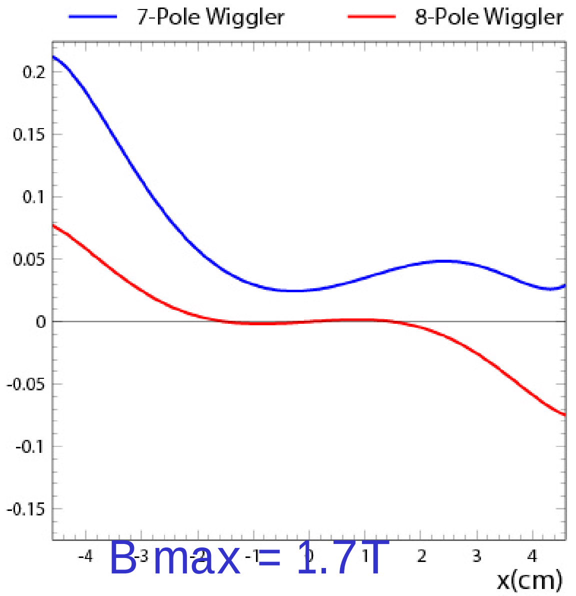
Wiggler (7 pole model) transfer function: horizontal and vertical kicks as function of horizontal and vertical beam position



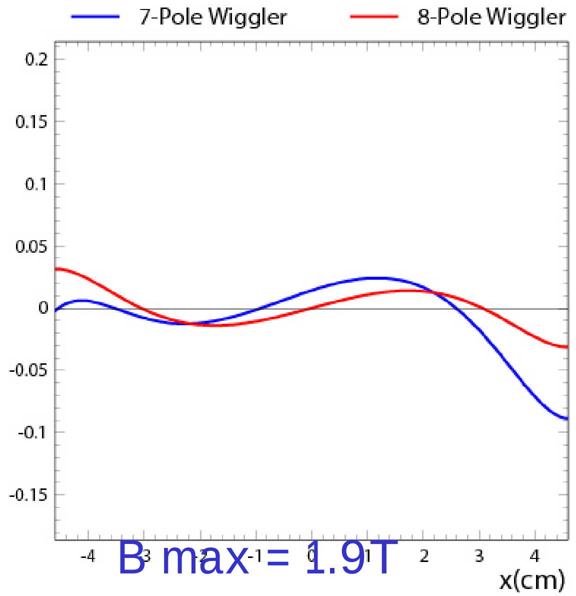


Model Calculation

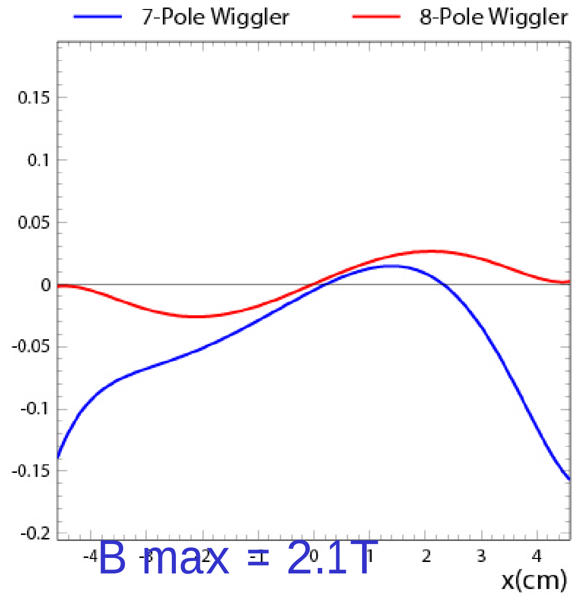
7-pole and 8-pole wigglers horizontal transfer function, x ' (x, y=0)



B max = 1.7T

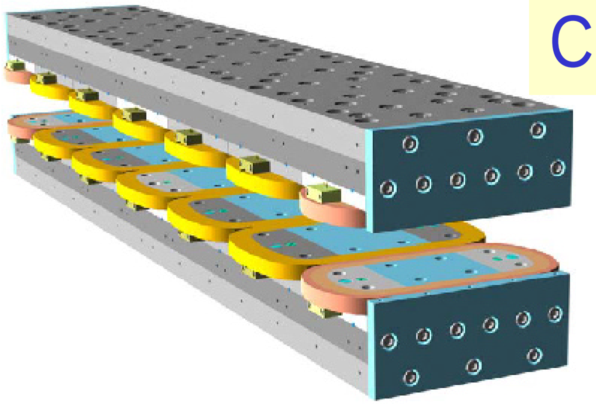


B max = 1.9T

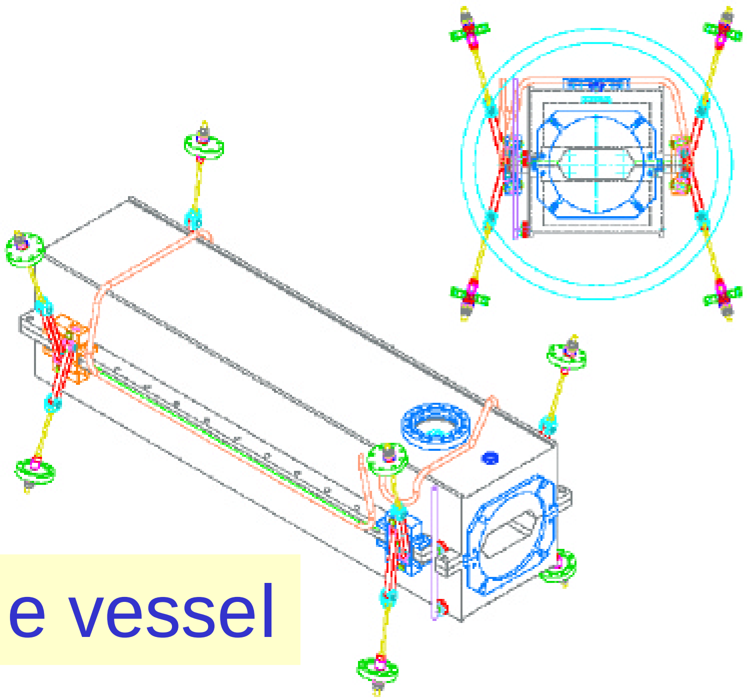


B max = 2.1T

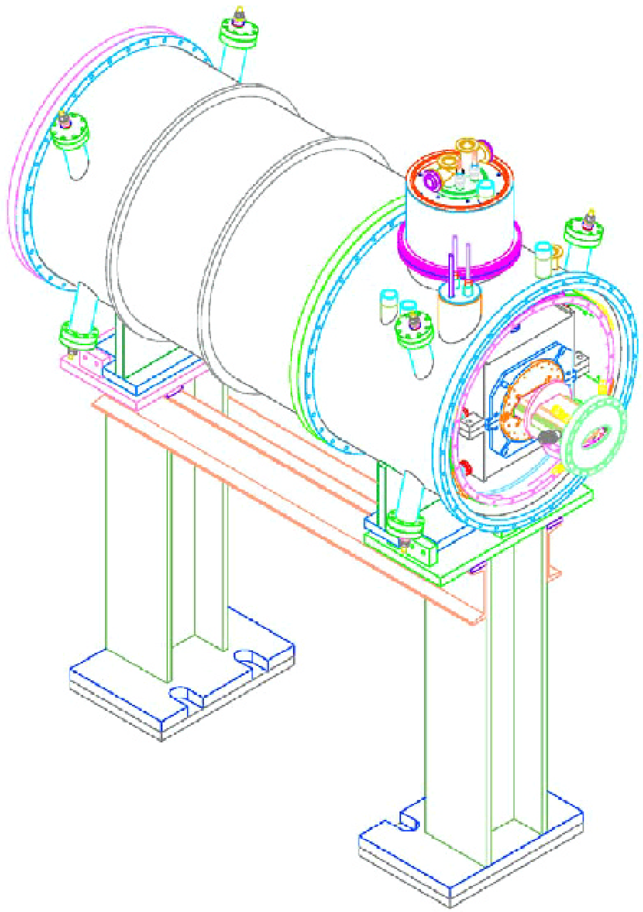
Cold mass and cryostat design



Cold mass



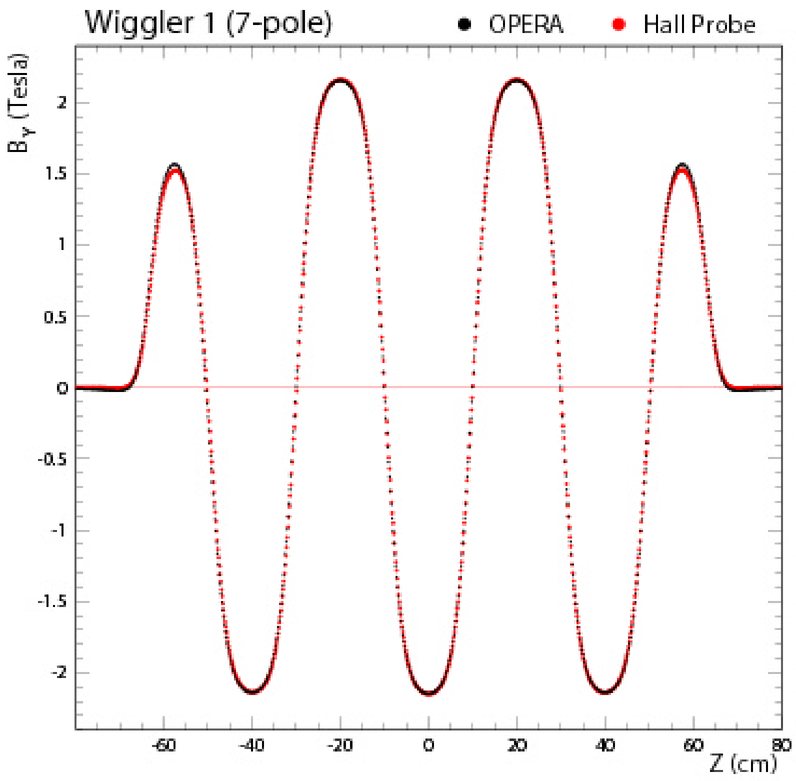
LHe vessel

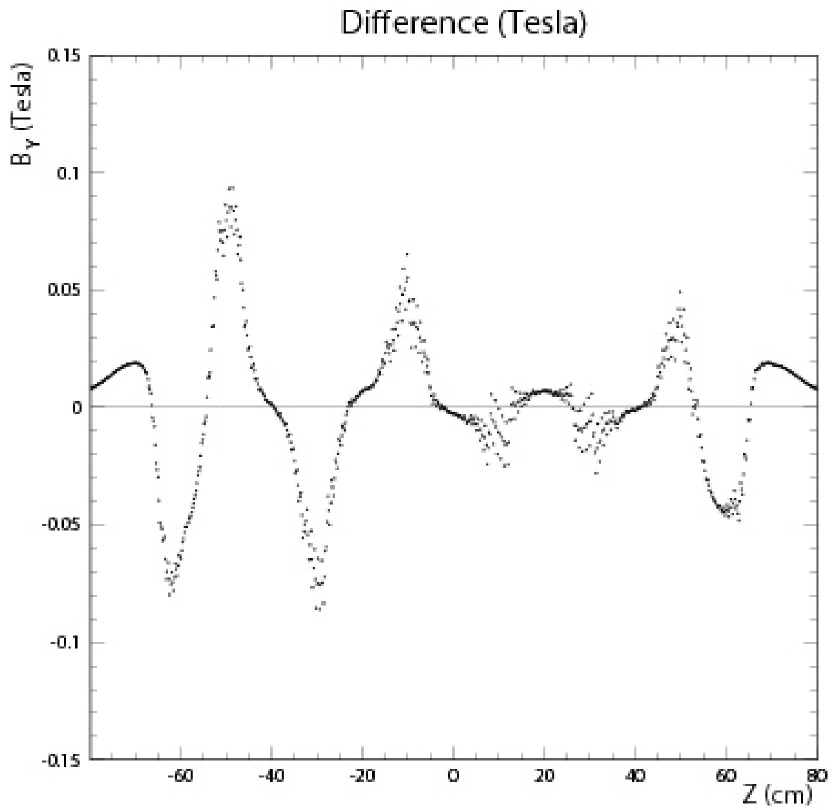


Assembly in cryostat

Magnetic field performance: Hall probe field mapping

Wiggler #1, 7poles

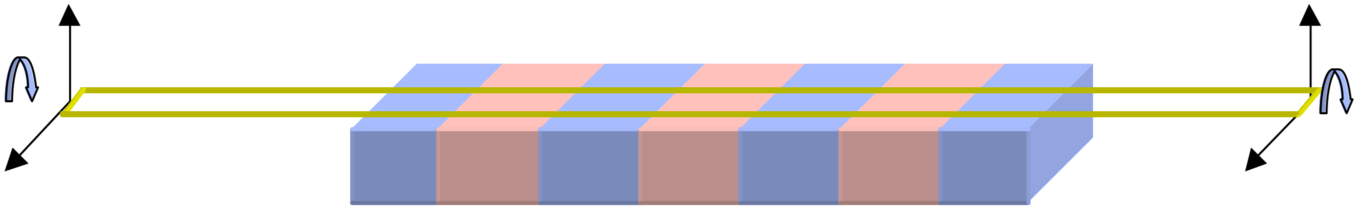




By(z), Hall probe measurement and model calculation

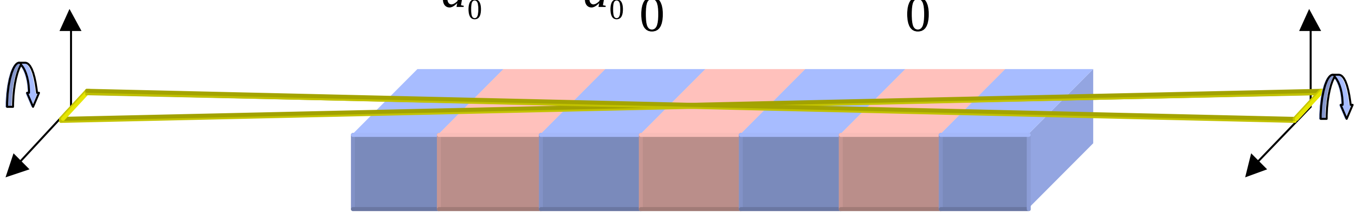
Difference between measurement and calculation

Magnetic field performance: stretched coil measurement.



First integral with strait coil:

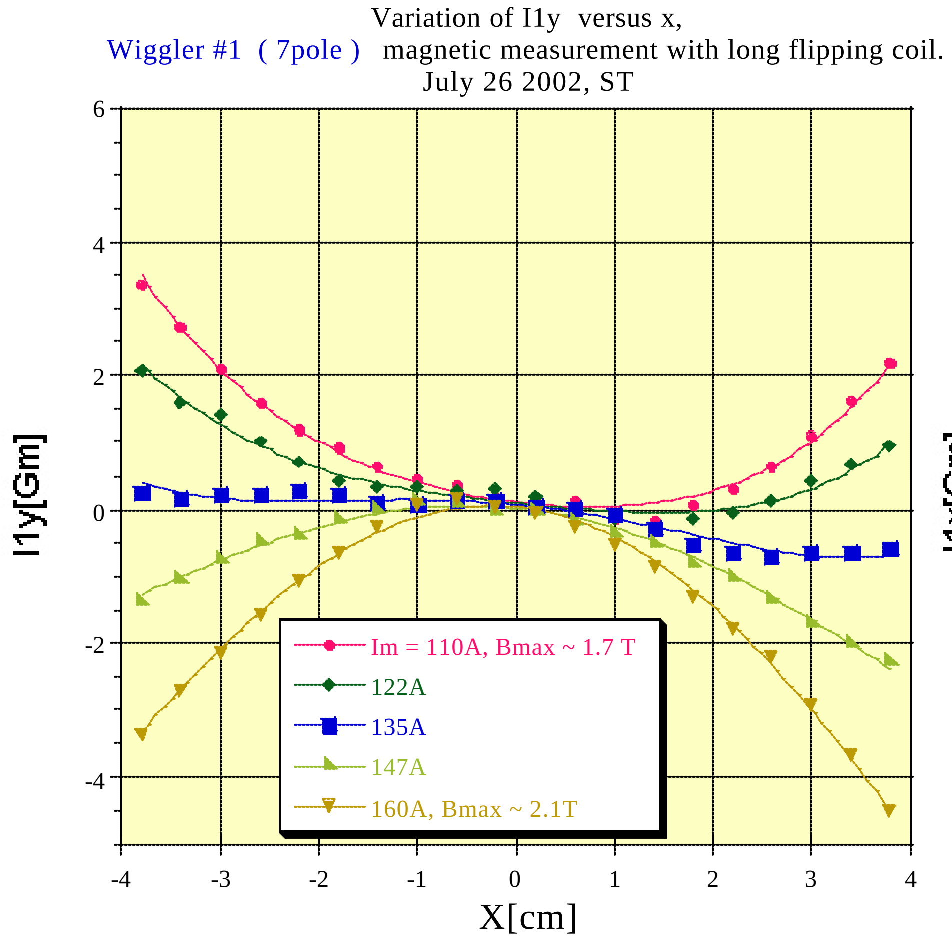
$$\tilde{I}_1 \;?\; \frac{Flux_{st}}{a_0} \;?\; \frac{1}{a_0} \, ?_0^l a_0 B(z)dz \;?\; ?_0^l B(z)dz \;? I_1$$

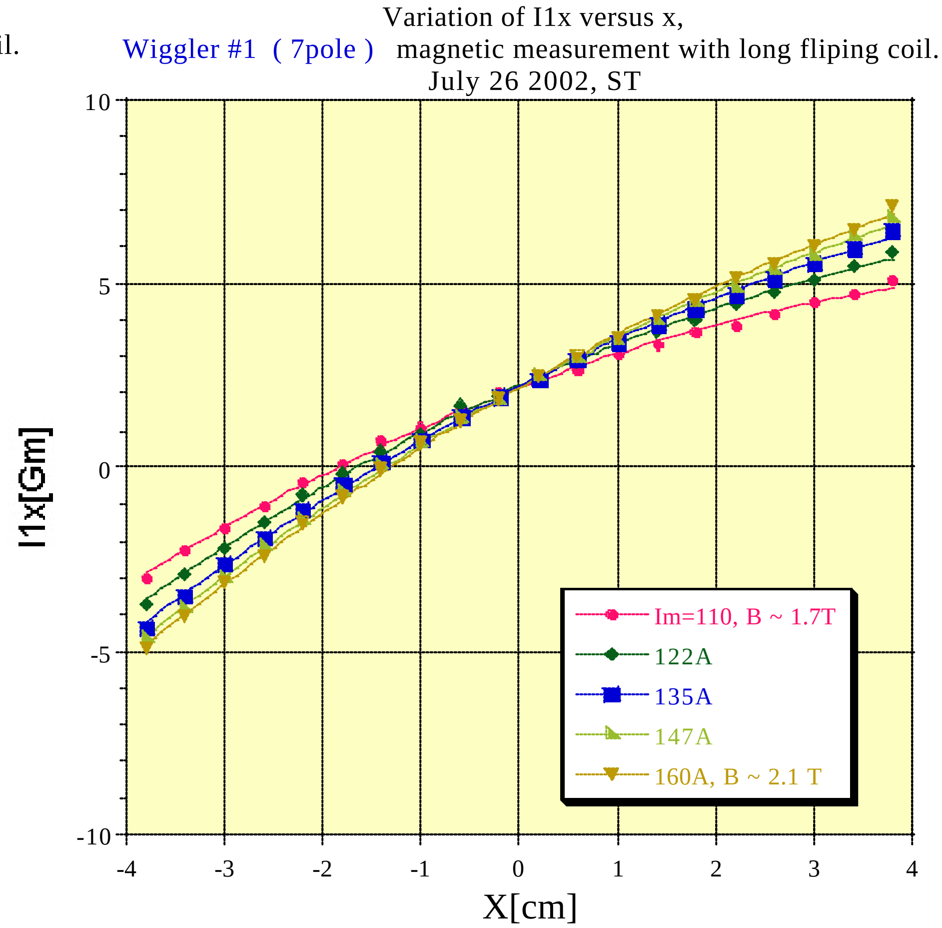


Second integral with twisted coil:

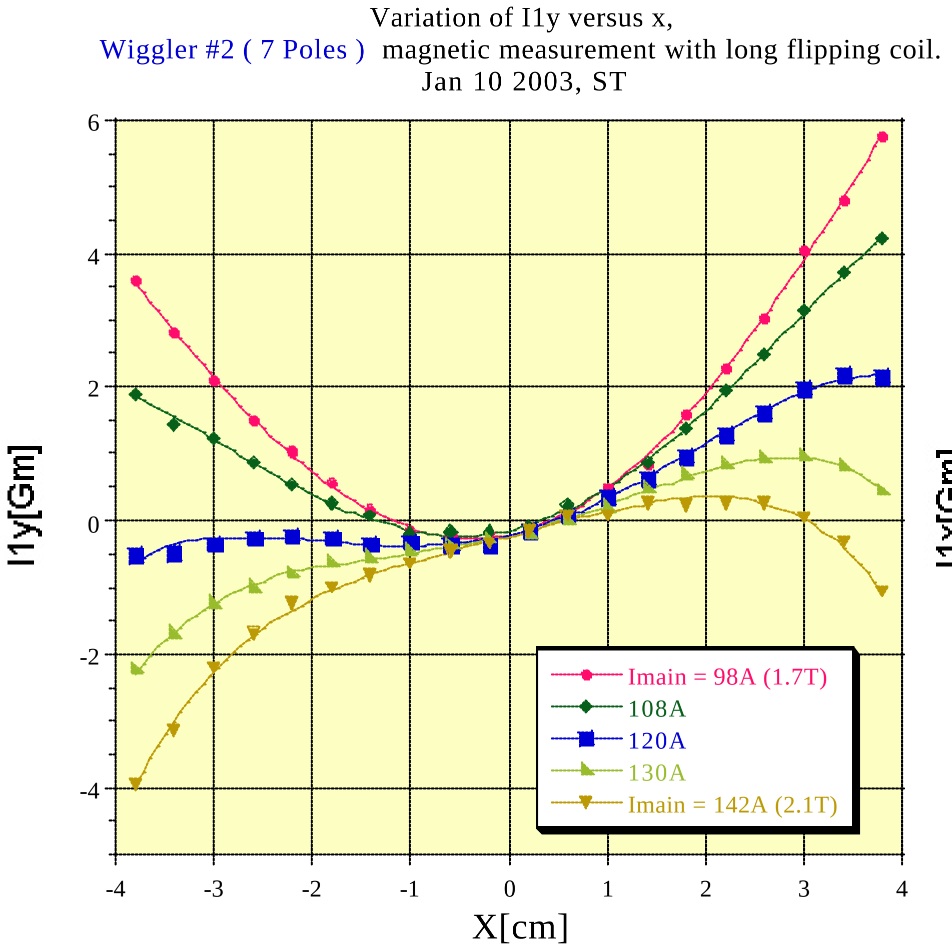
$$\tilde{I}_2 \;?\; \frac{Flux_{tw}}{a_0} \;?\; \frac{1}{a_0} \, ?_0^l B(z)a(z)dz \;?\; \frac{1}{a_0} \, ?_0^l B(z)a_0(1 \;?\; \frac{2z}{l})dz \;?\; ?_0^l B(z)dz \;?\; \frac{2}{l} \, ?_0^l B(z)zdz \;?\; I_1 \;?\; \frac{2}{l} I_2$$

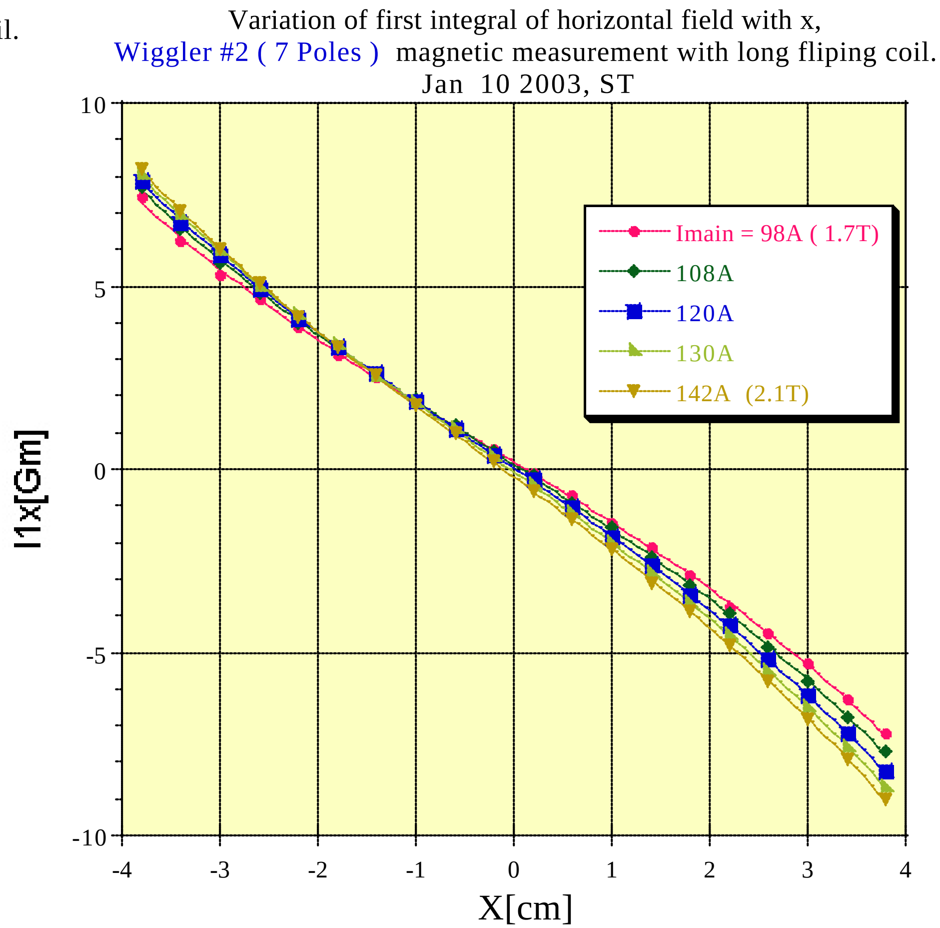
Magnetic field performance: wiggler #1 (7p)



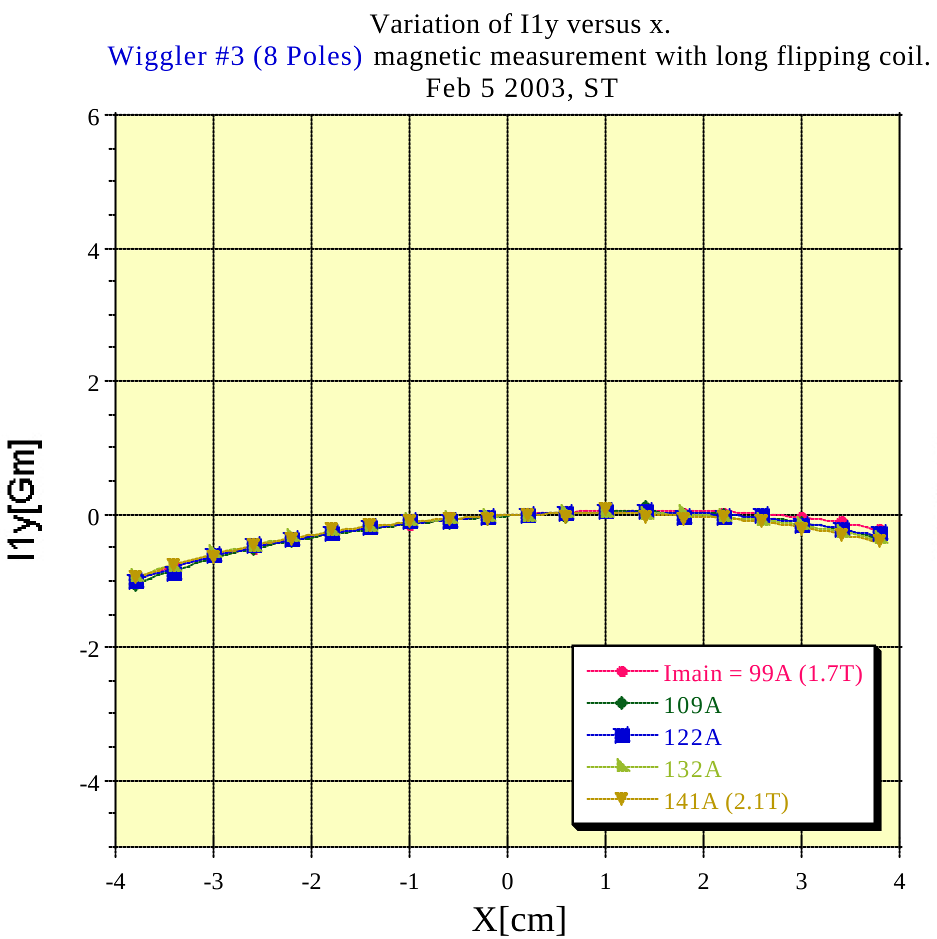


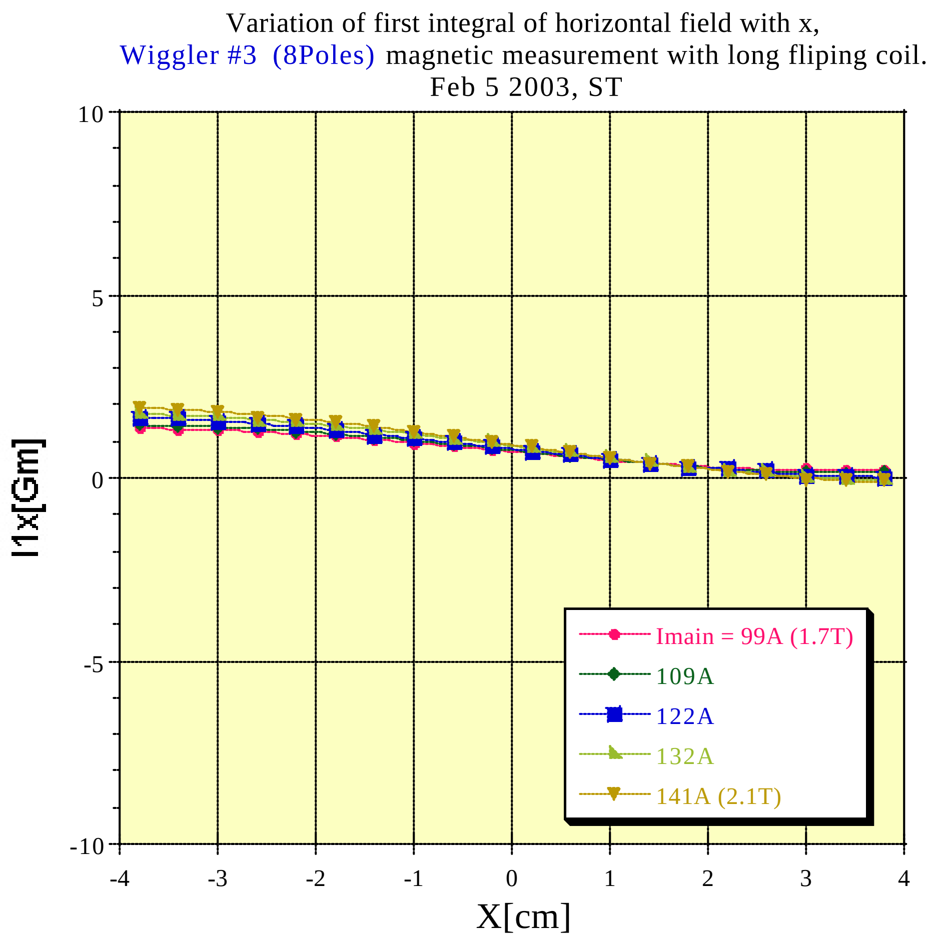
Magnetic field performance: wiggler #2 (7p)



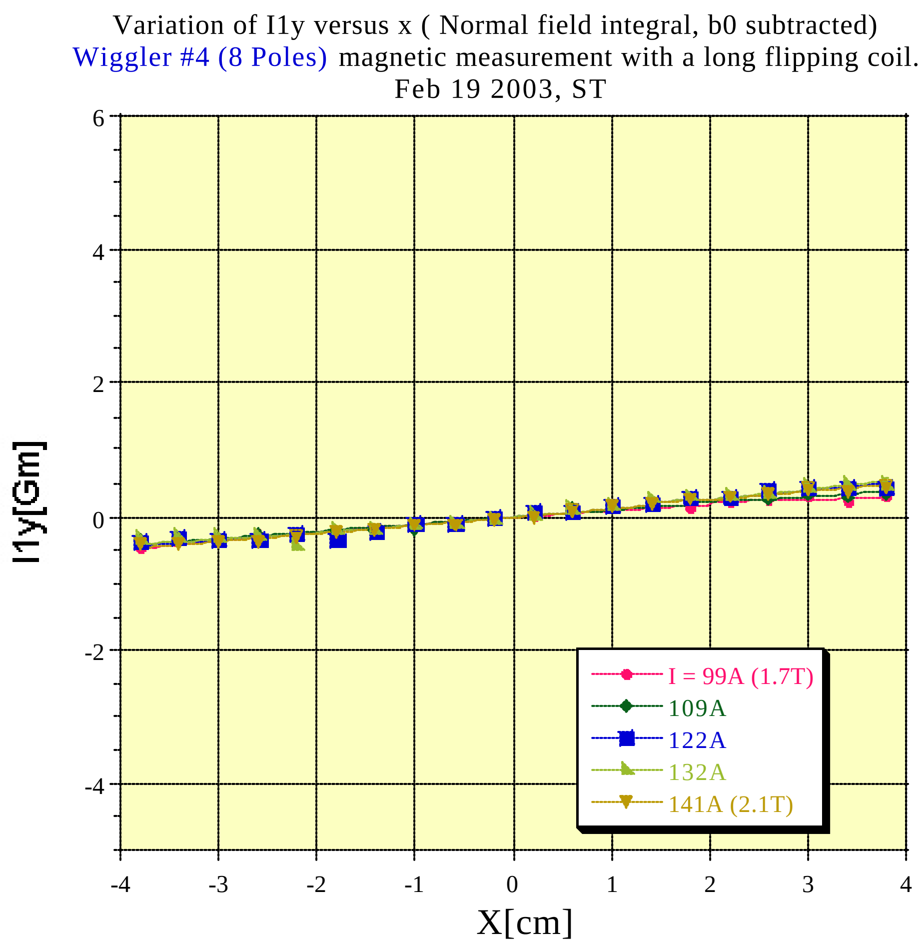


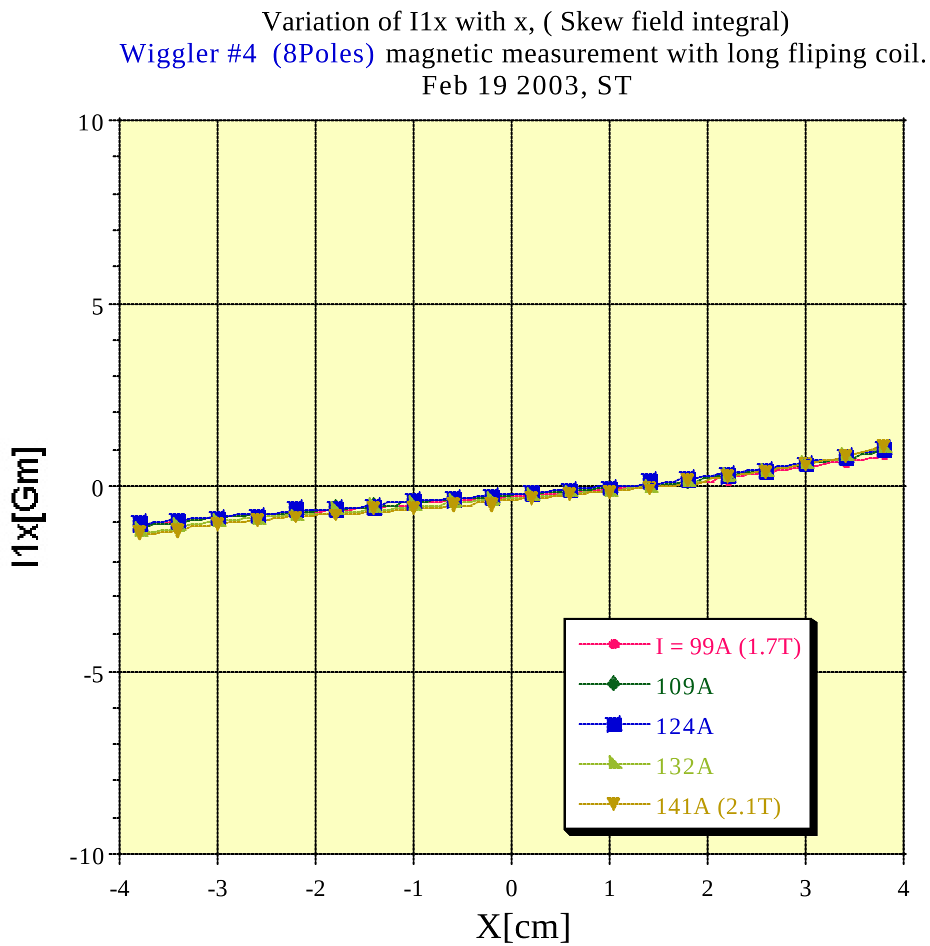
Magnetic field performance: wiggler #3 (8p)



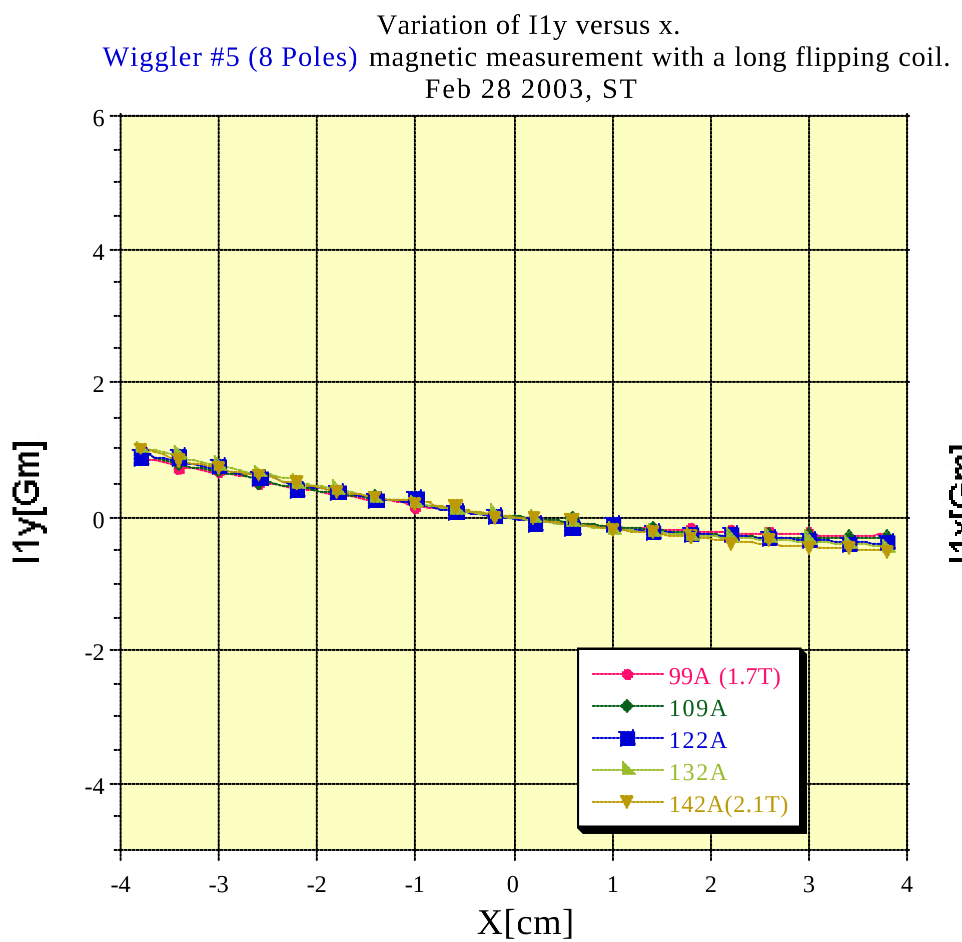


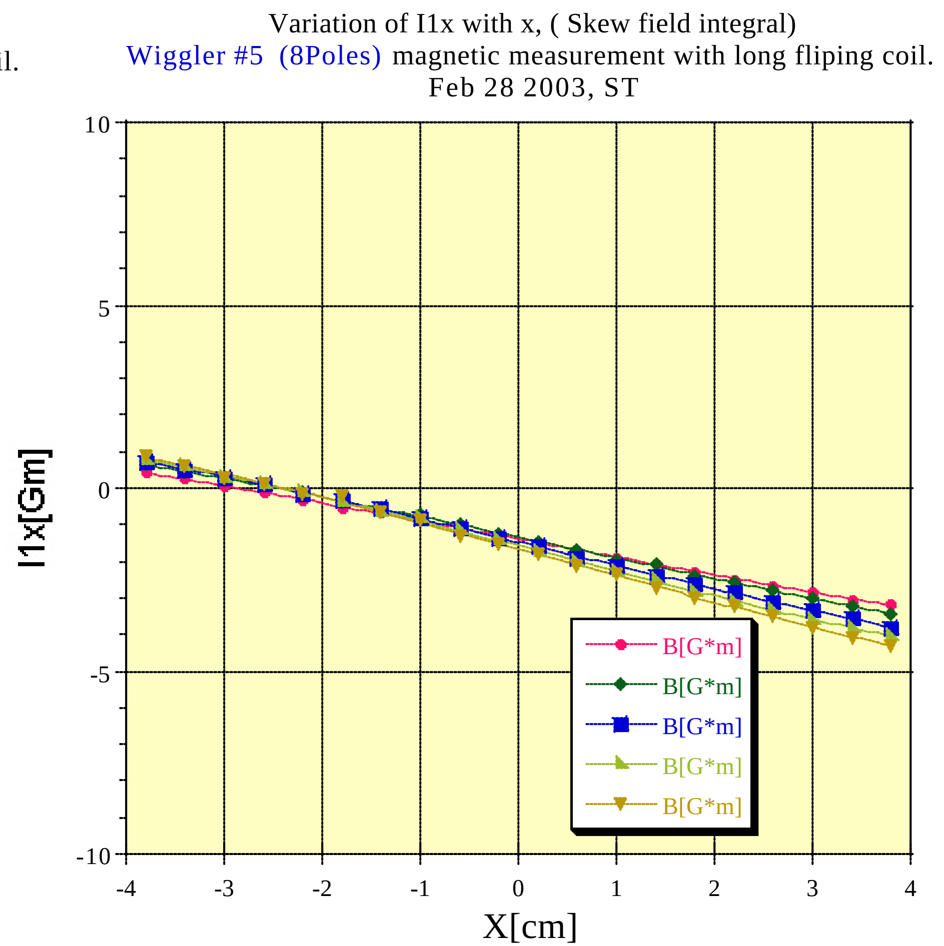
Magnetic field performance: wiggler #4 (8p)



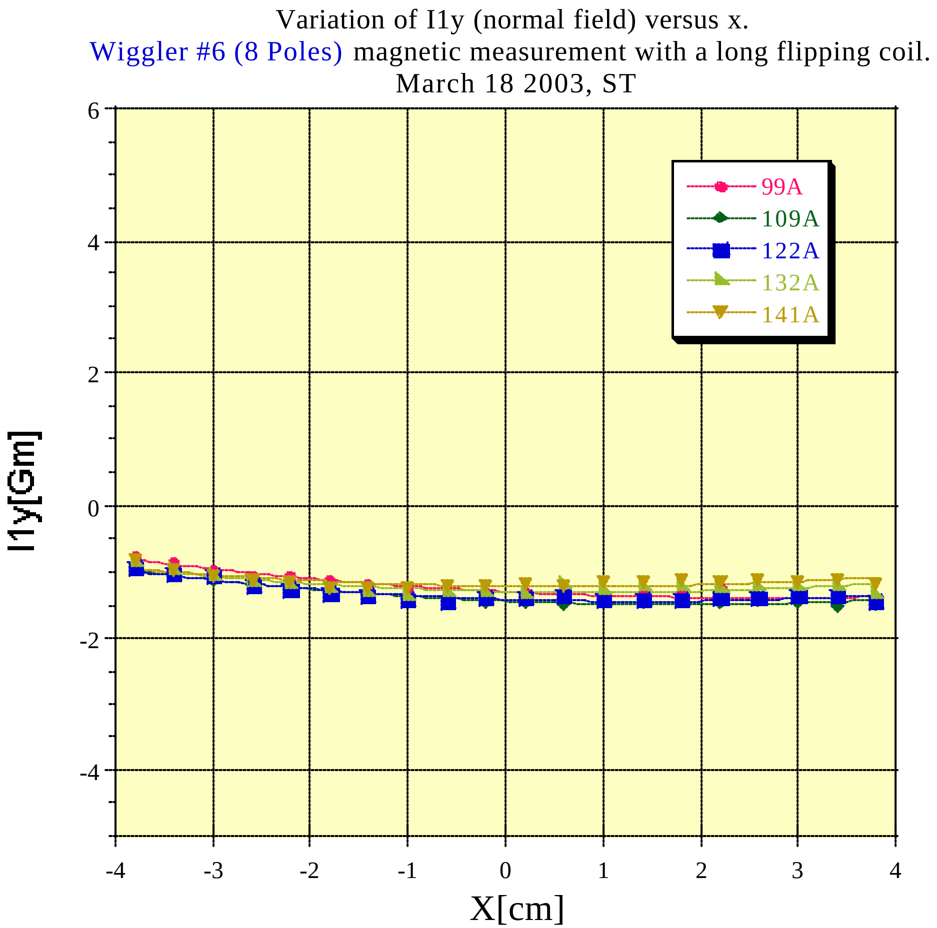


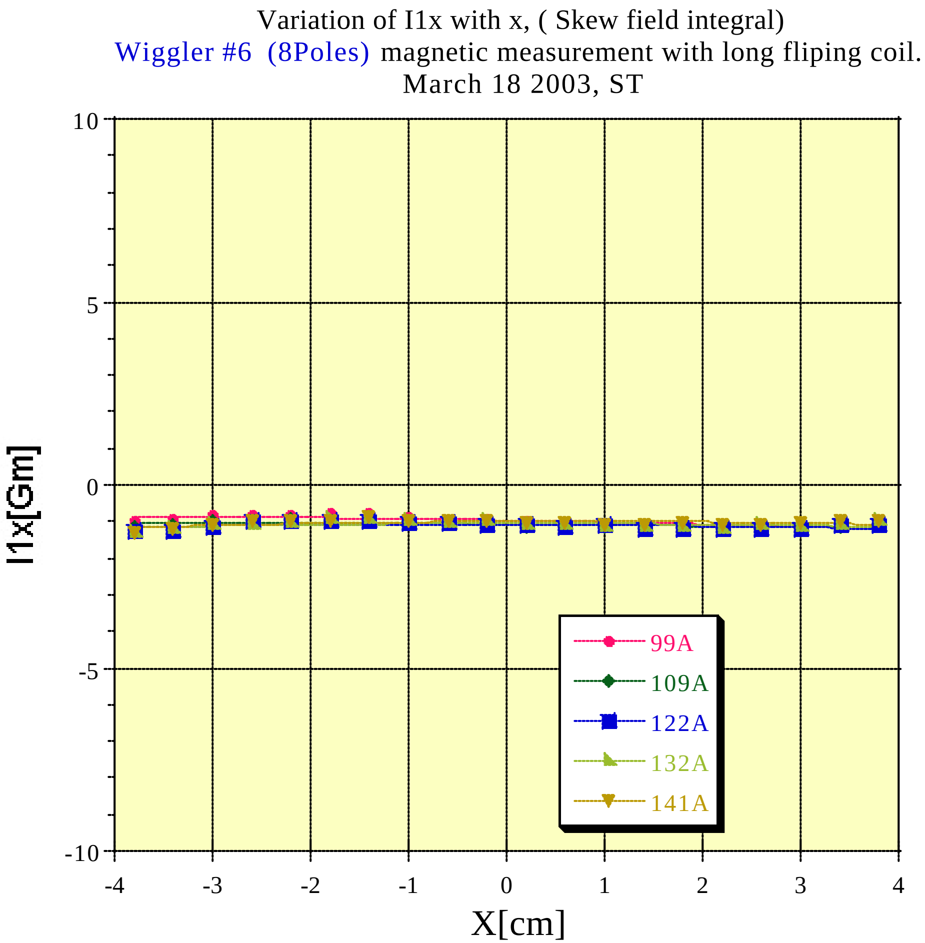
Magnetic field performance: wiggler #5 (8p)





Magnetic field performance: wiggler #6 (8p)



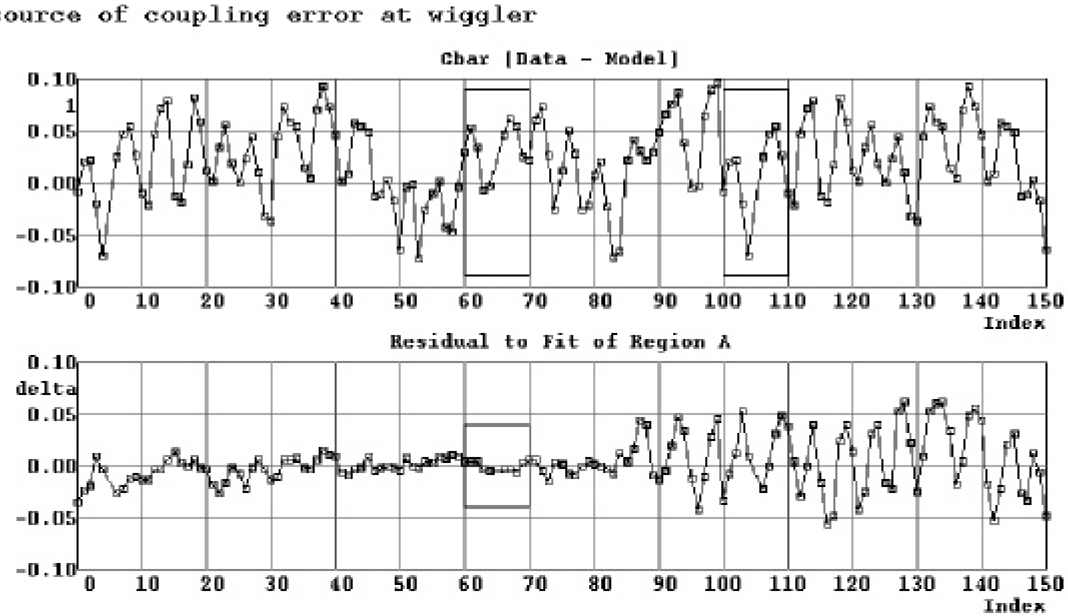


Beam based characterization: Nov 2002, one wiggler optics, wiggler #1 (7p)

1) Wiggler generated coupling:

Local coupling around the ring

Wave analysis indicated the source of the coupling at the wiggler location (BPM#85).

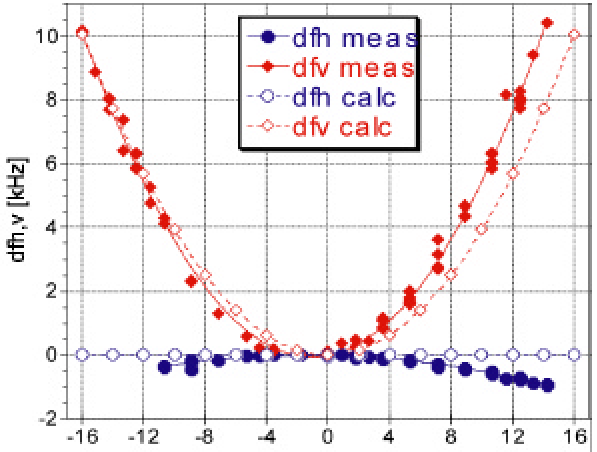


Skew quadrupole moment measured with beam ~ 2Gm/cm
From magnetic measurement ~ 1.5Gm/cm
In model skew quadrupole moment is “zero”.

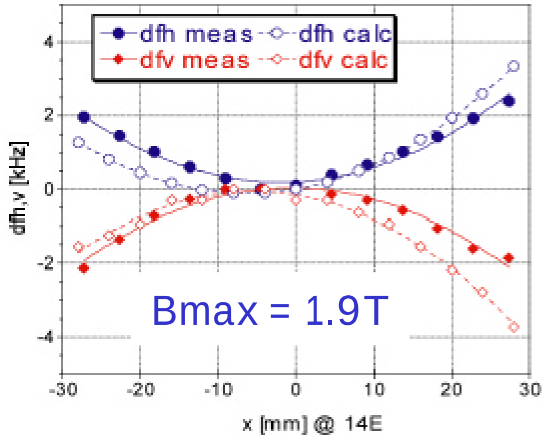
Beam based characterization: Nov 2002, one wiggler optics, wiggler #1 (7p)

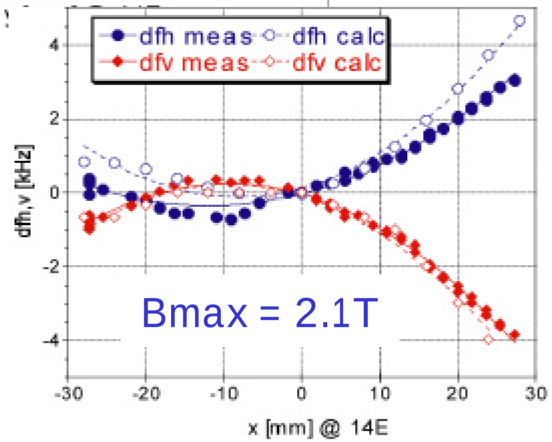
2) Wiggler generated tune dependence on beam position

Measured and calculated* dependence of vertical/horizontal tune versus vertical beam position in wiggler. Bmax = 2.1T



Measured and calculated* dependence of vertical/horizontal tune versus horizontal beam position in wiggler.

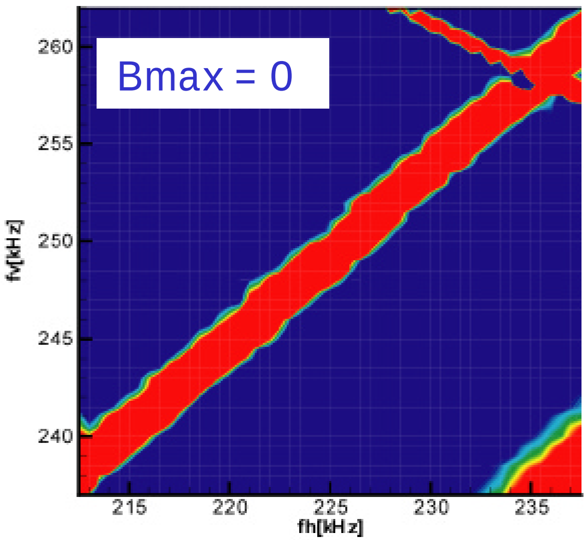


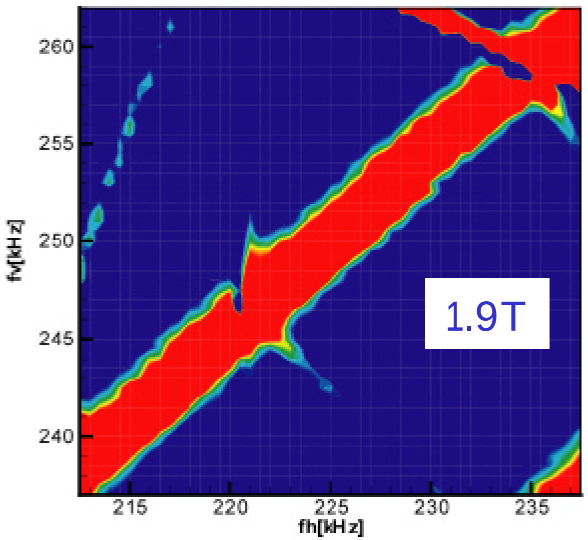


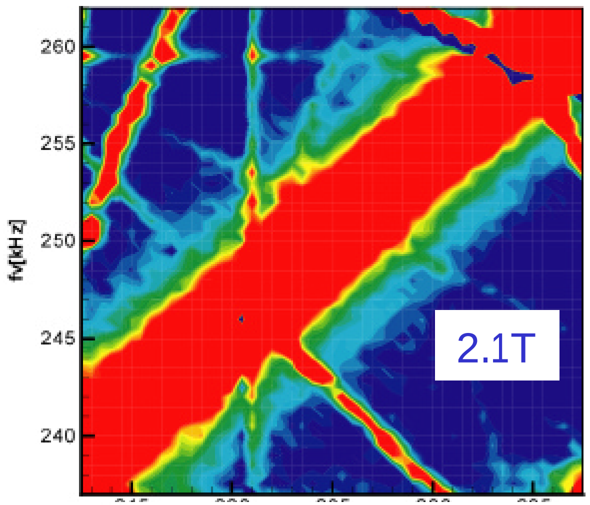
* from the wiggler transfer function

Beam based characterization: Nov 2002, one wiggler optics, wiggler #1 (7p)

3) 2D tune scan: vertical beam versus tune, evaluation with wiggler field

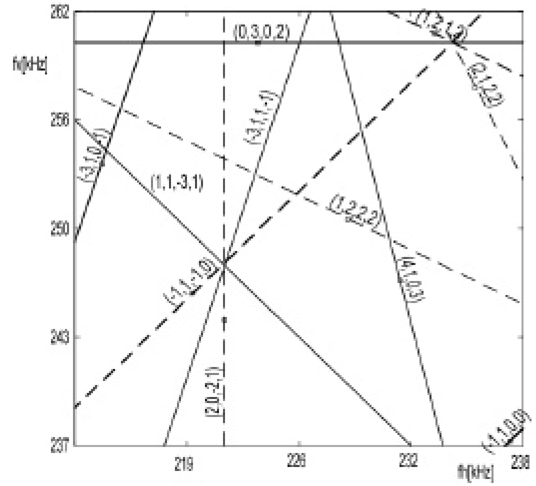






Oct. 14 2002, Optics: 1843MeV_1WIG_R3_OT, fs = 25kHz

Observed resonances

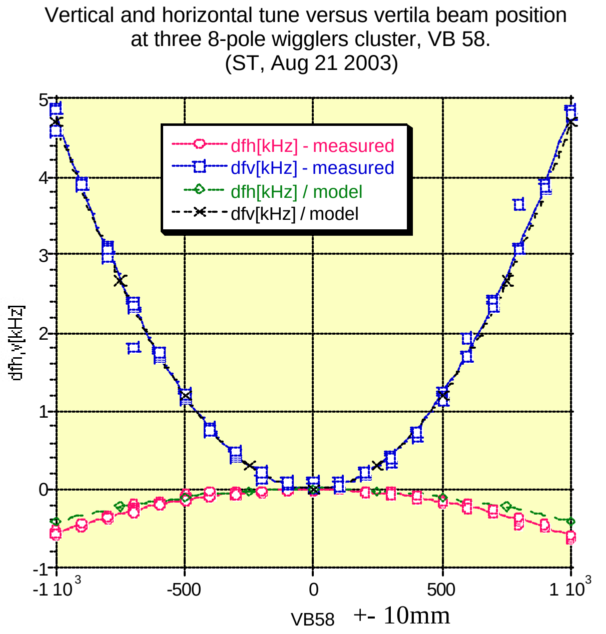


Wiggler OFF: -fh+fv = 0, -fh+fh-fs=0, fh+2fv + fs = 2f0, Pmax = 3

Wiggler ON: -3fh+fv= -f0, fh+fv-3fs=f0, 3fv=2f0, fh+2fv+2fs=2f0, 4fh+fv=3f0, 2fh+fv+2fs=2f0, 2fh-2fs=f0 and -3fh+fv+fs=-f0, Pmax = 5

Beam based characterization: Aug 2003, 6 wigglers optics (4x8p + 2x7p)

- Three 8-pole wigglers group test using local orbit distortion

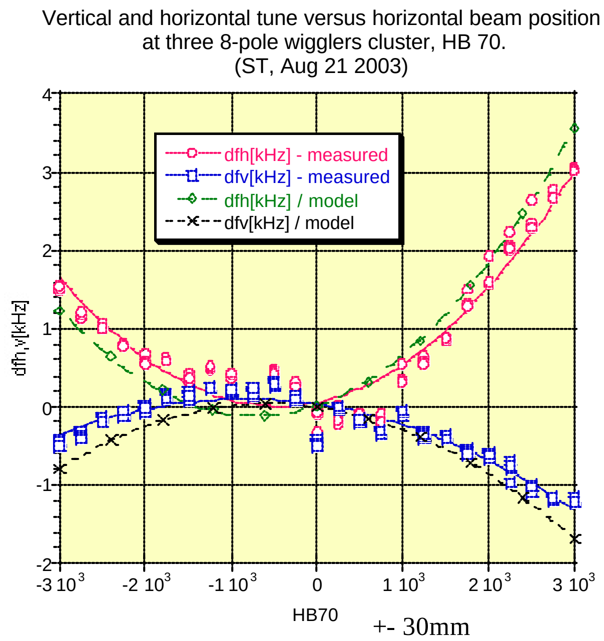


Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	-0.0022588
M1	-1.9531e-05
M2	-5.7511e-07
R	0.99344

Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	0.00051815
M1	1.983e-05
M2	4.8043e-06
R	0.99829

Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	0.0035498
M1	0
M2	-4.1385e-07
R	0.99994

Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	0.015455
M1	-2.6666e-06
M2	4.6909e-06
R	0.99997



Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	0.059295
M1	0.00022736
M2	2.5315e-07
R	0.95831

Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	0.033497
M1	-0.00016229
M2	-9.7726e-08
R	0.9352

Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	0.014522
M1	0.00038242
M2	2.6541e-07
R	0.99985

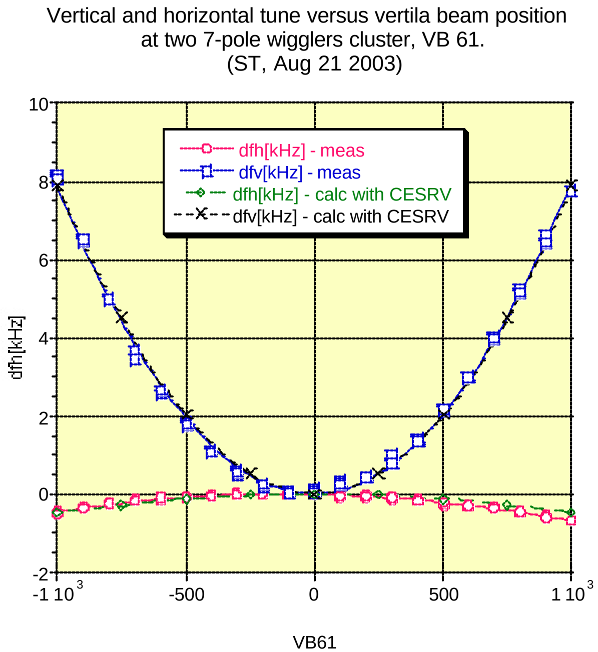
Y = M0 + M1*x + ... M8*x 8 + M9*x 9	
M0	-0.0040093
M1	-0.00015152
M2	-1.3727e-07
R	0.99997

Measured and calculated tune versus vertical beam position in 18E wiggler cluster.

Measured and calculated tune versus horizontal beam position in 18E wiggler cluster.

Beam based characterization: Aug 2003, 6 wigglers optics (4x8p + 2x7p)

- Two 7-pole wigglers group test using local orbit distortion.



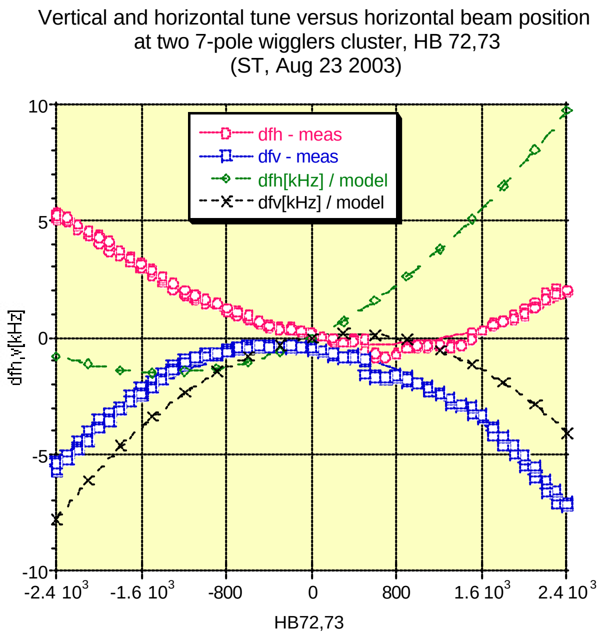
Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	-0.0045218
M1	-0.00012701
M2	-5.6615e-07
R	0.99225

Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.0032263
M1	7.5994e-05
M2	7.9232e-06
R	0.99856

Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.0027273
M1	2.6667e-06
M2	-4.9455e-07
R	0.9998

Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.036017
M1	0
M2	7.8816e-06
R	0.99995

Measured and calculated tune versus vertical beam position in 14E wiggler cluster.



Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	-0.03094
M1	-0.00079741
M2	6.5755e-07
R	0.98883

Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	-0.43478
M1	-0.00037765
M2	-1.0147e-06
R	0.99443

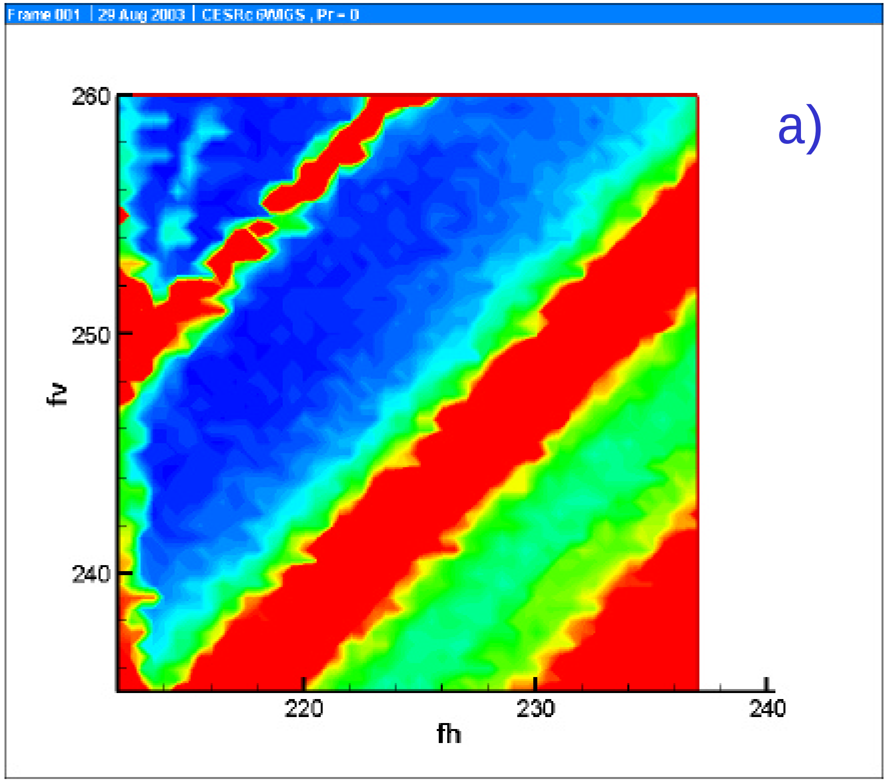
Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.0063468
M1	0.0021941
M2	7.8328e-07
R	0.99999

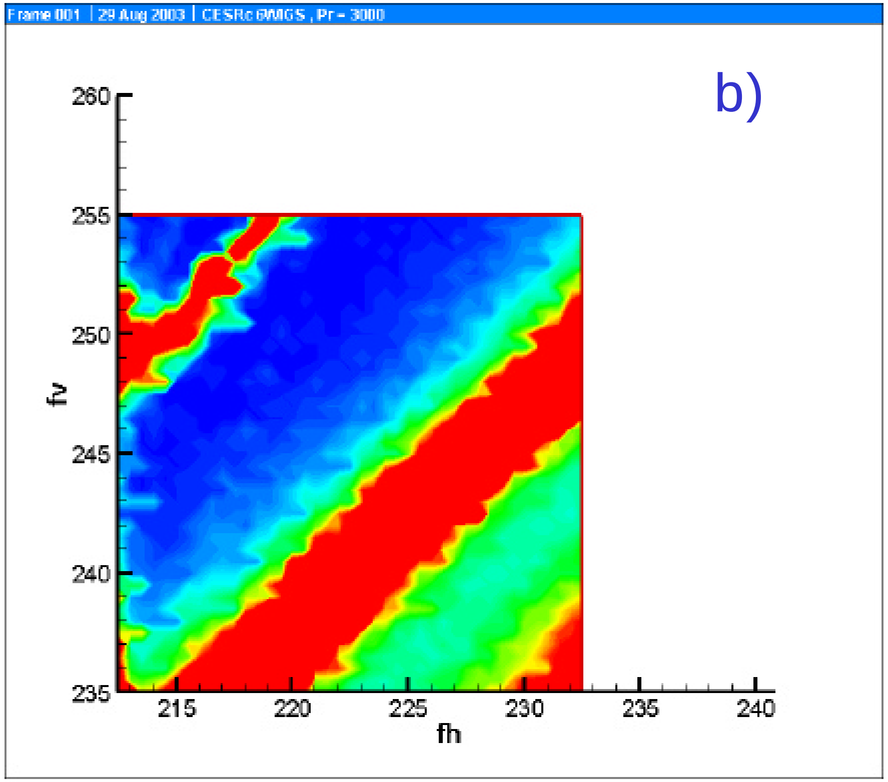
Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.036718
M1	0.00076332
M2	-1.0314e-06
R	0.9999

Measured and calculated tune versus horizontal beam position in 14E wiggler cluster.

Beam based characterization: Aug 2003, 6 wigglers optics (4x8p + 2x7p)

Optics: 6wigs_lum_ ... , fs = 18kHz





Vertical beam size versus tune. a) flatten orbit, b) pretzeled orbit (horizontal orbit distortion ~ +-10mm)

Conclusion

1. Two versions of the CESRc wiggler magnets with symmetric (7 poles) and asymmetric (8 poles) structure have been developed, built and tested.

2. Magnetic field measurement reveled that magnets with asymmetric structure have significantly less variation of integrated magnetic field properties with excitation than with symmetric.

3. Beam based characterization of the wiggler magnets confirmed model calculation and results of magnetic field measurement.

Material from the following references has been used in presentation:

1. J. Crittenden, A. Mikhailichenko, A. Temnykh, Design Considerations for CESR-c Wiggler Magnets, to be published in PAC2003 proceedings.

2. D. Rice, S. Chapman, R. Gallagher et al. Production and Testing Considerations for CESR-c Wiggler Magnets, to be published in PAC2003 proceedings.

3. A. Temnykh, Vibrating Wire and Long Integrating Coil Based Magnetic Measurements of a 7-pole Super-Conducting Wiggler for CESR, to be published in PAC2003 proceedings.

4. J. Safranek et al., Nonlinear Dynamics in SPEAR Wigglers, EPAC' 2000, p.295

b2 (normal sextupole) and a1(skew quad) components vs current for wigglers #1,2,3,4,5,6