Updates on Mechanically Adjustable PM Final Doublet

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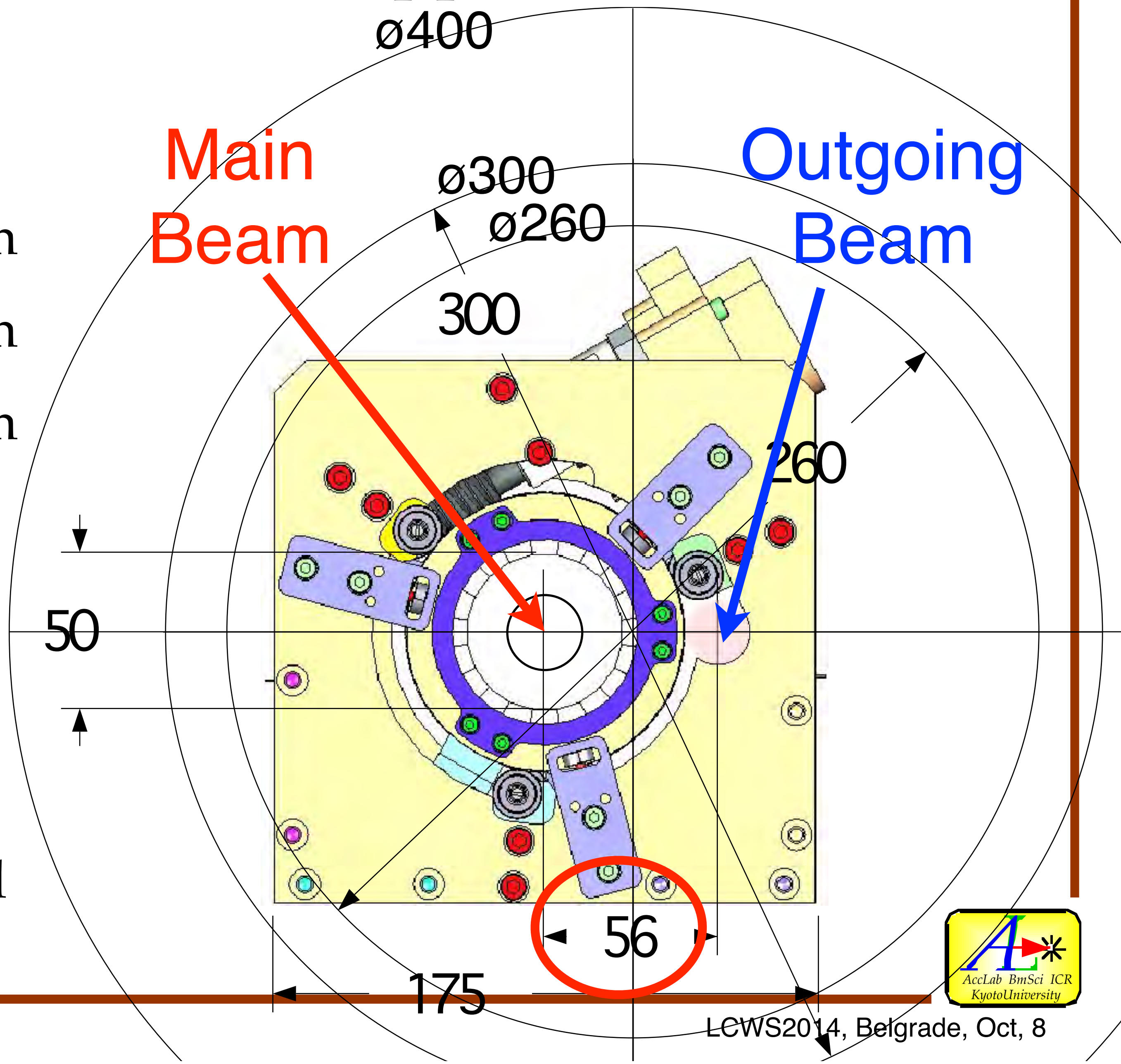
Contents

- Layout in support tube
  – Vibration Free
- Mechanism of gradient adjustment
- Fine tune for good field quality
- Demagnetization
- Adjustable multipoles (PMSx, PMO ...)
- Semi-passive Antisolenoid

Cross Section

— ATF2 version in a support tube —

- Separation:
  - 14mr x 4.0 = 56mm
  - 14mr x 4.5 = 64mm
  - 14mr x 5.0 = 70mm
- Corners may be cut.
- No magnetic mat'l.
- Supersonic Motor.
- Mover to be installed

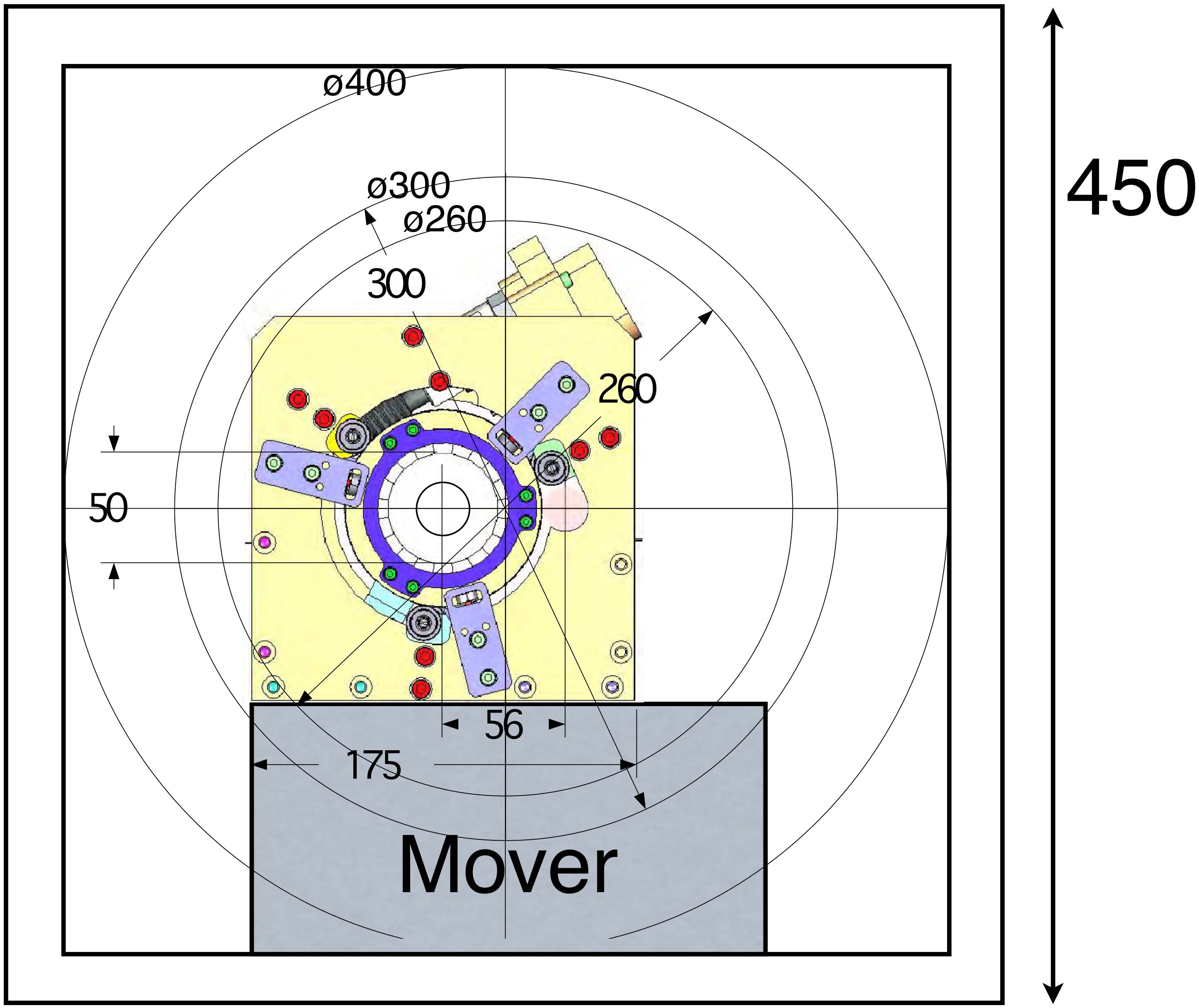


QD0 support

- **Outer dimensions of 600x600mm**
- **25mm thick**

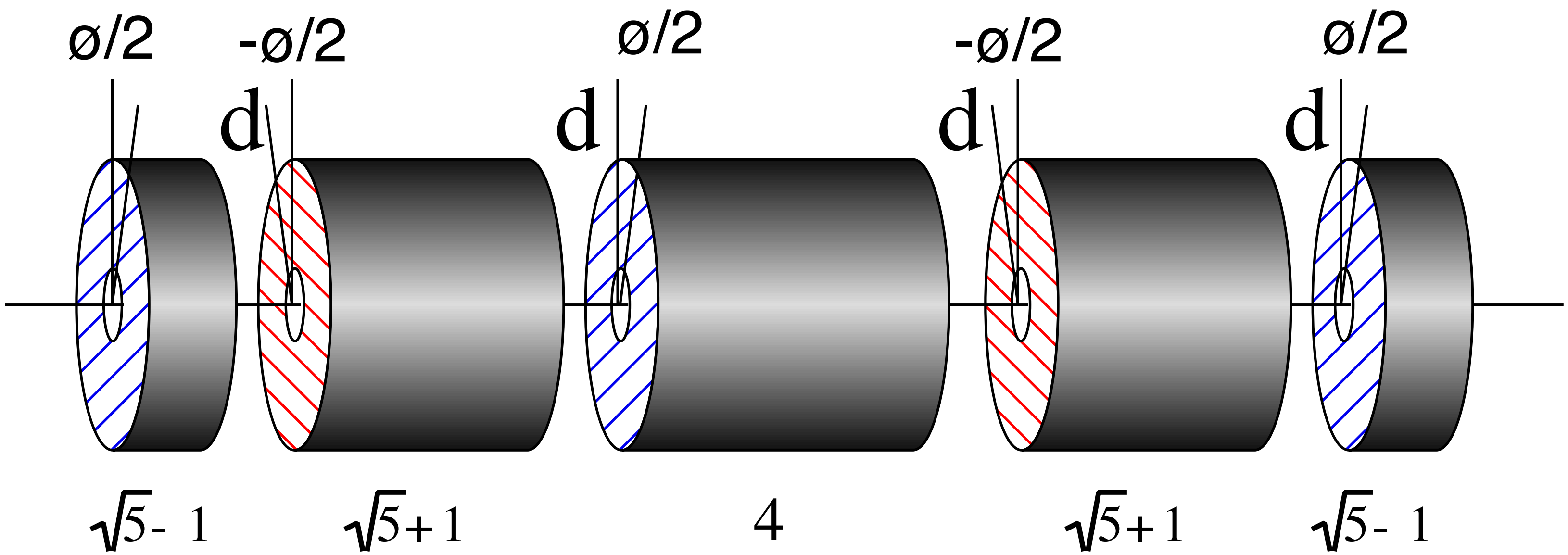
Cross Section

— Square support tube —



Gluckstern's adjustable PMQ

Gluckstern's skewless variable PMQ



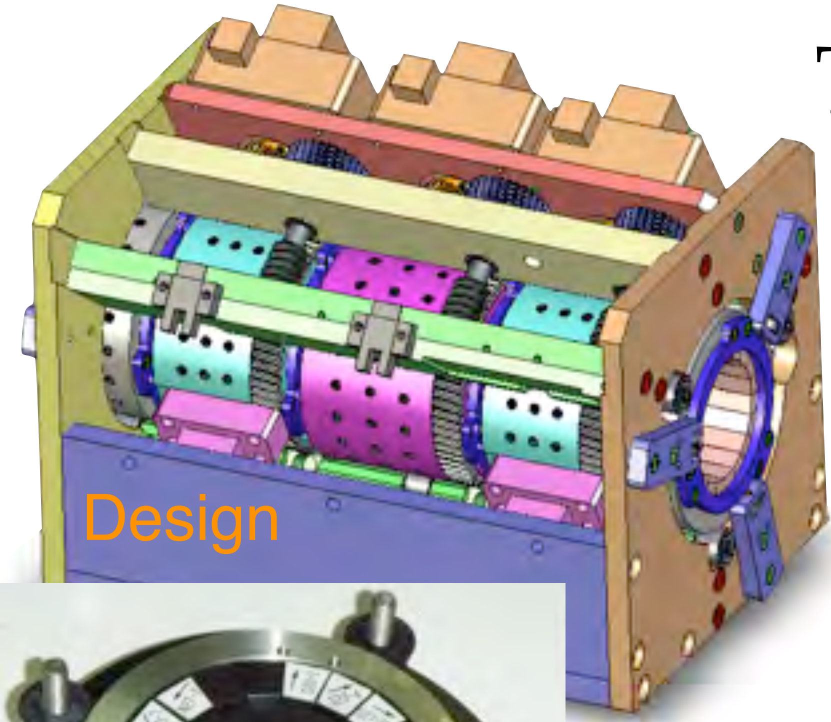
$$M = R \bullet M2 \bullet R^{-2} \bullet M1 \bullet R^{2} \bullet M0 \bullet R^{-2} \bullet M1 \bullet R^{2} \bullet M2 \bullet R^{-1}$$

$$\text{4x4 matrix: } M = \begin{pmatrix} Mxx & O^5 \\ O^5 & Myy \end{pmatrix} \text{ when } d=0.$$

R.L. Gluckstern and R.F. Holsinger: Adjustable Strength REC Quadrupoles, IEEE Trans. Nucl. Sci., Vol. NS-30, NO. 4, August 1983, http://epaper.kek.jp/p83/PDF/PAC1983_3326.PDF

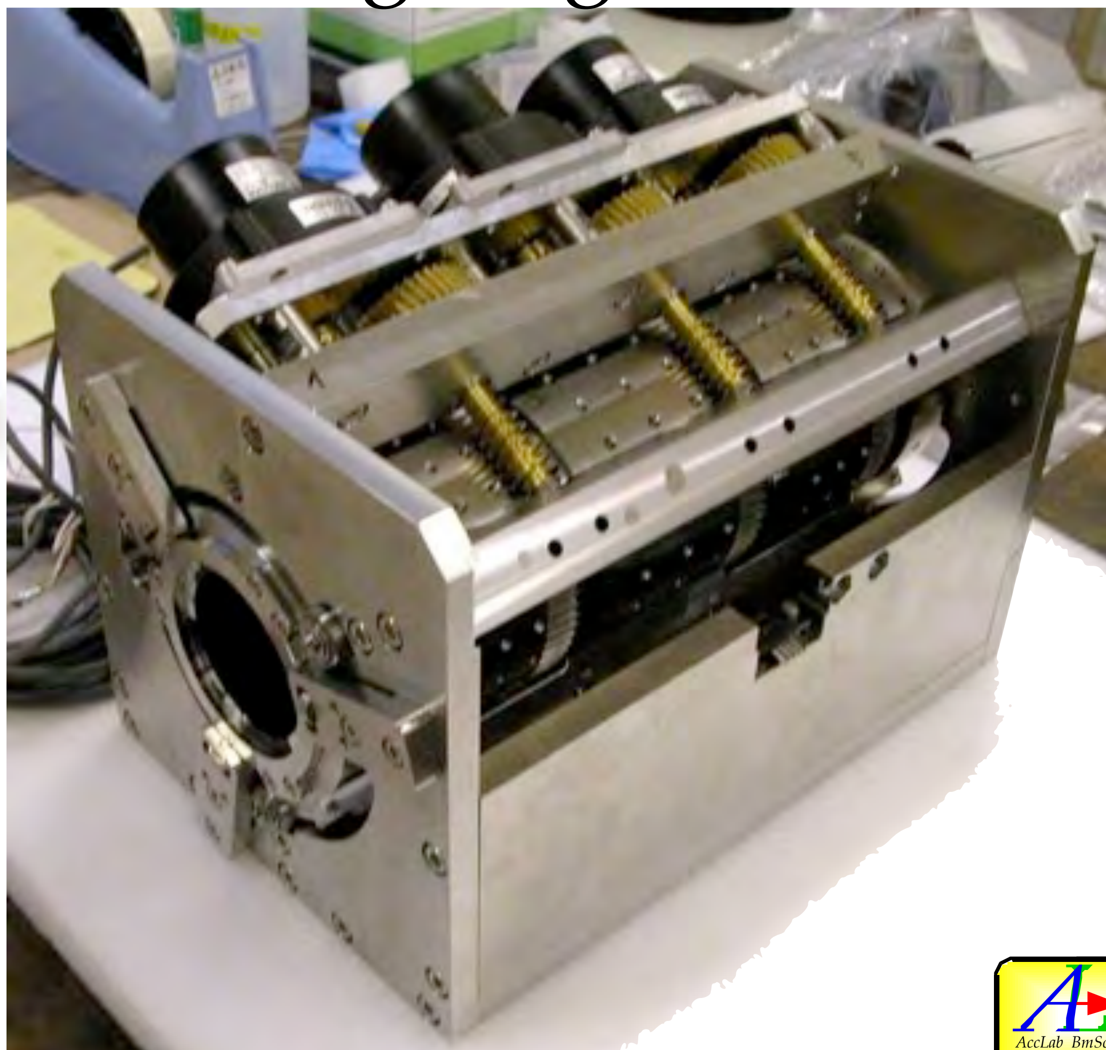
Gluckstern's 5-ring PMQ Singlet(2):

"Continuously Adjustable" PMQ fabricated



Disc(20mm)

The 5-ring singlet PM-FFQ



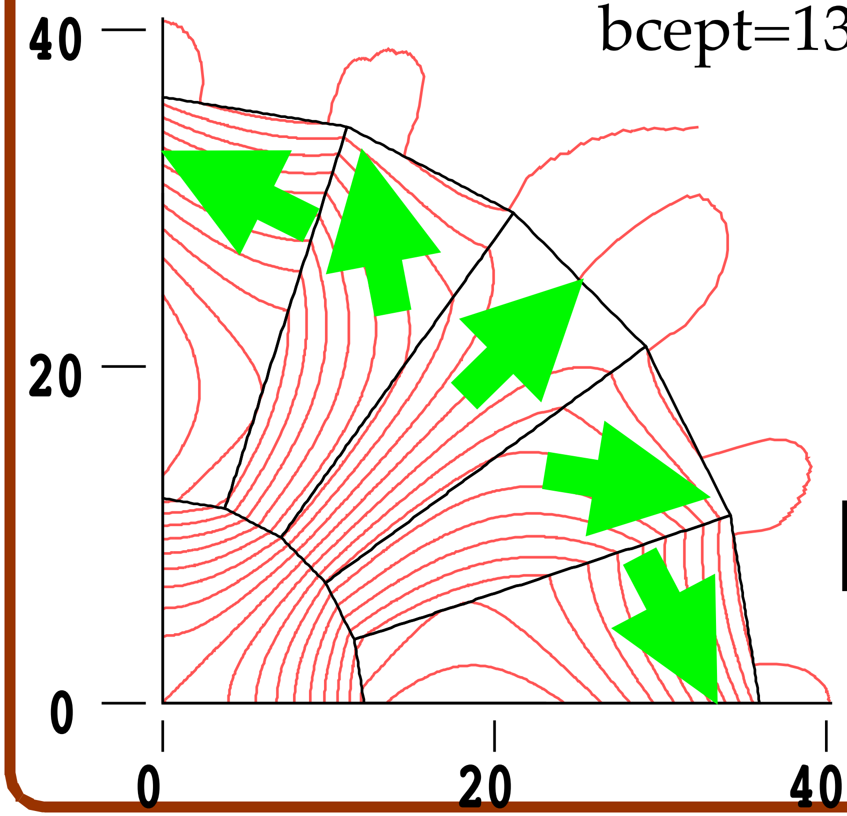
Test at ATF2 – replace QD0

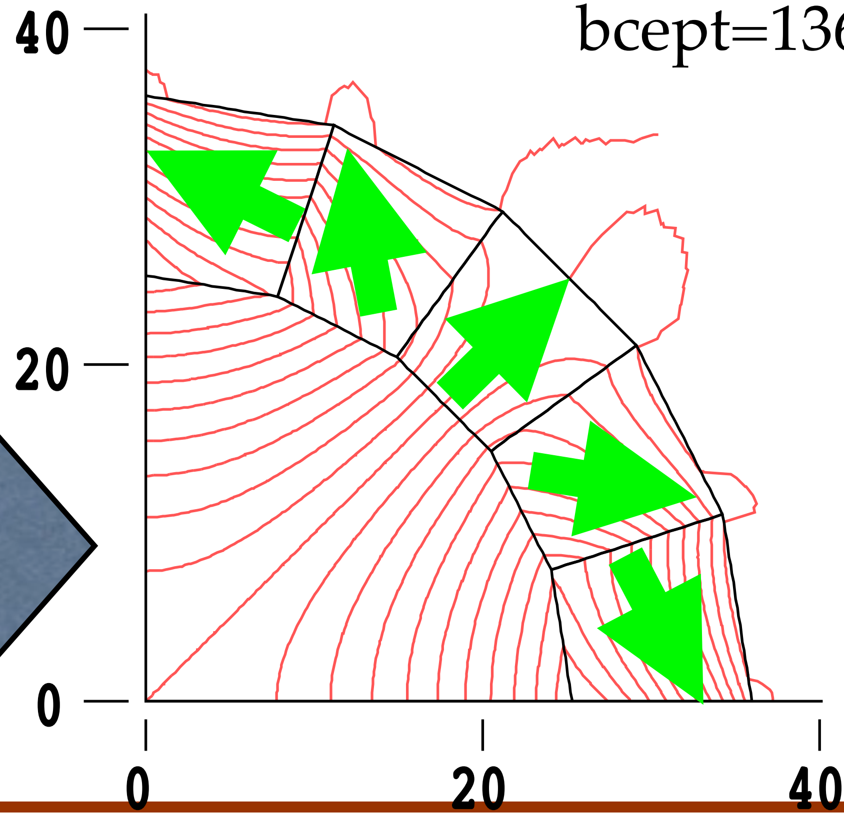
Req'd spec for QD0: L=45cm, ø50mm, G=13T/m

OD: ø72 (=2x(56-20))   GL=5.85 T

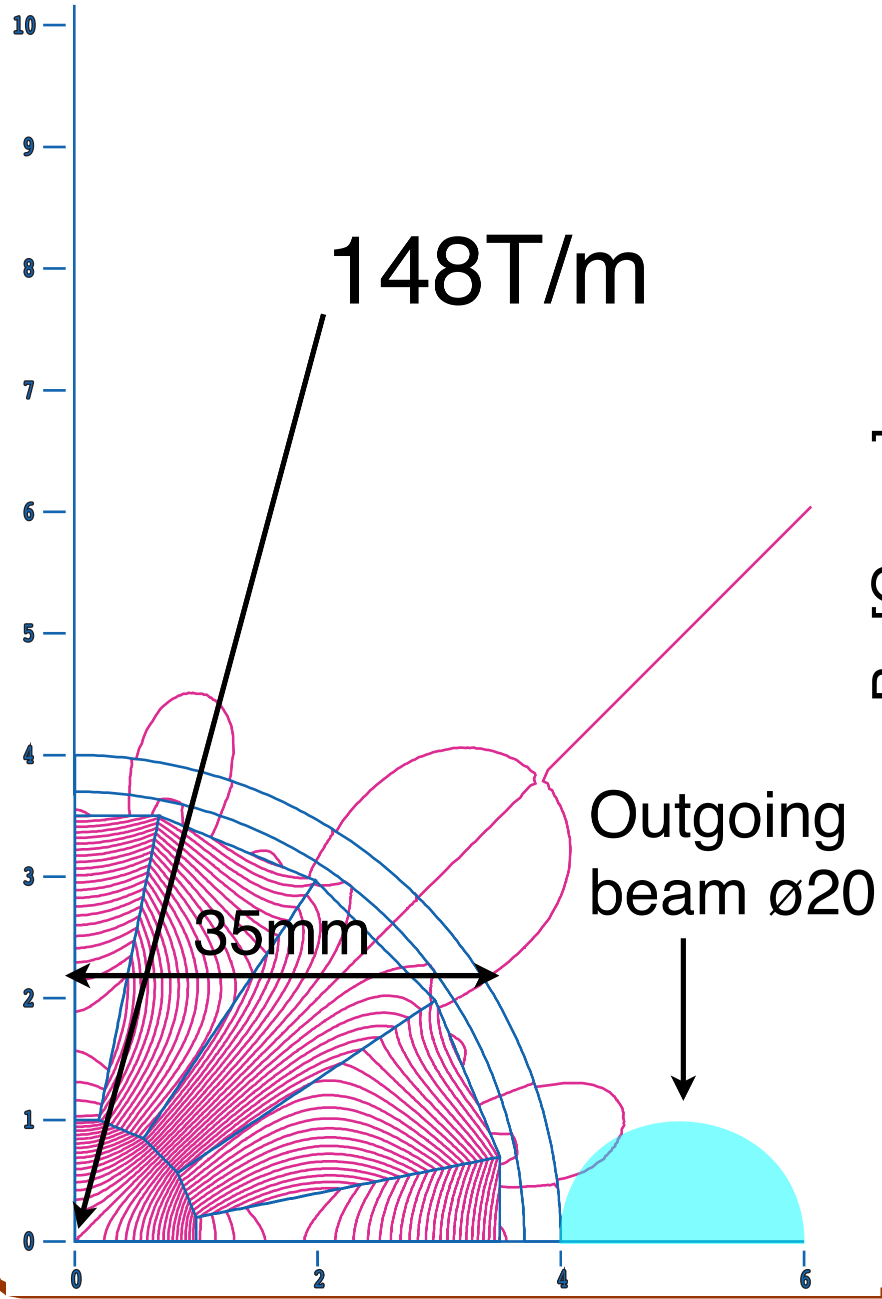
140T/m @ ø24   48H hcept=-12890, bcept=13600.

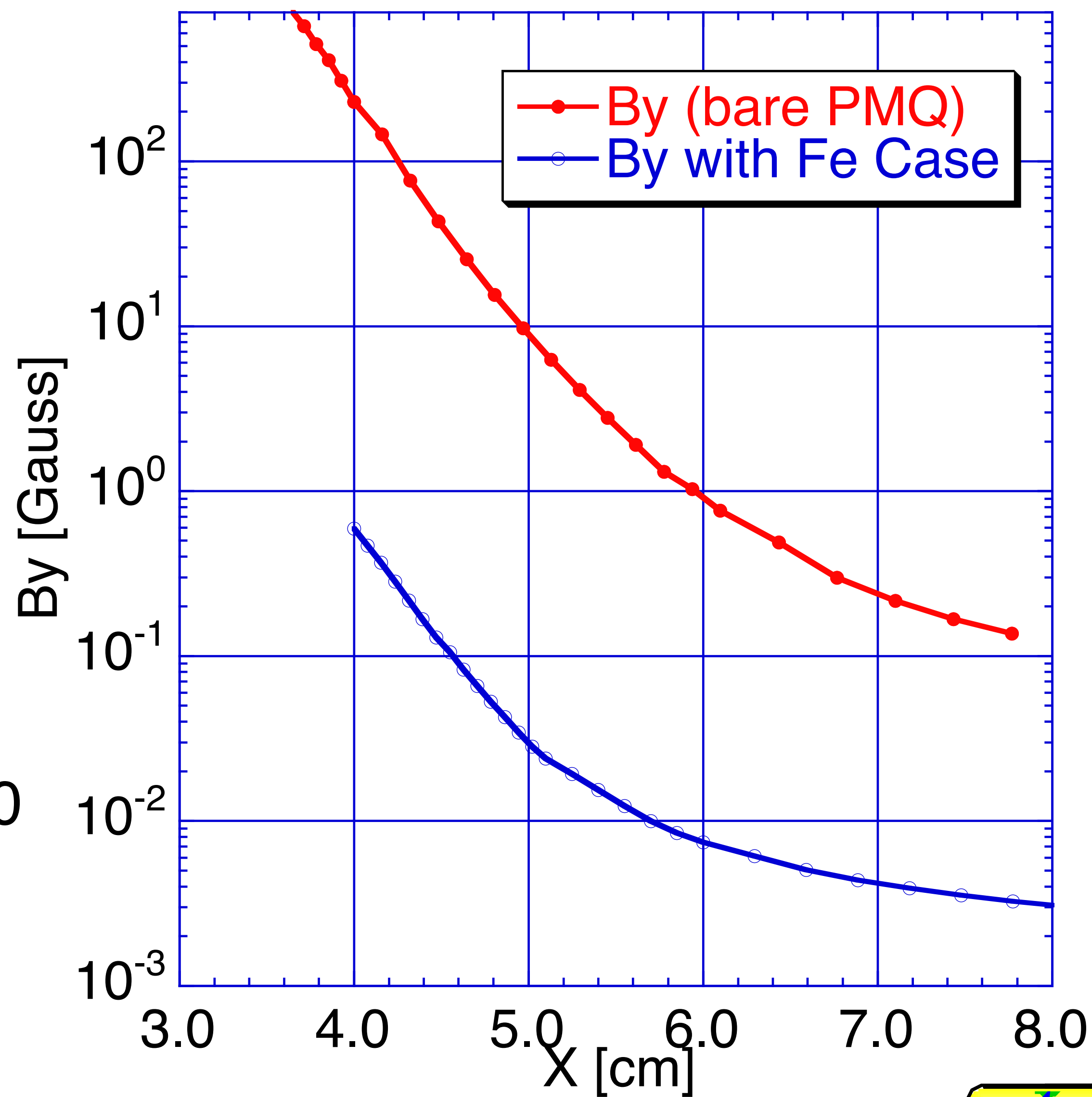
30T/m @ ø50   48H hcept=-12890, bcept=13600.





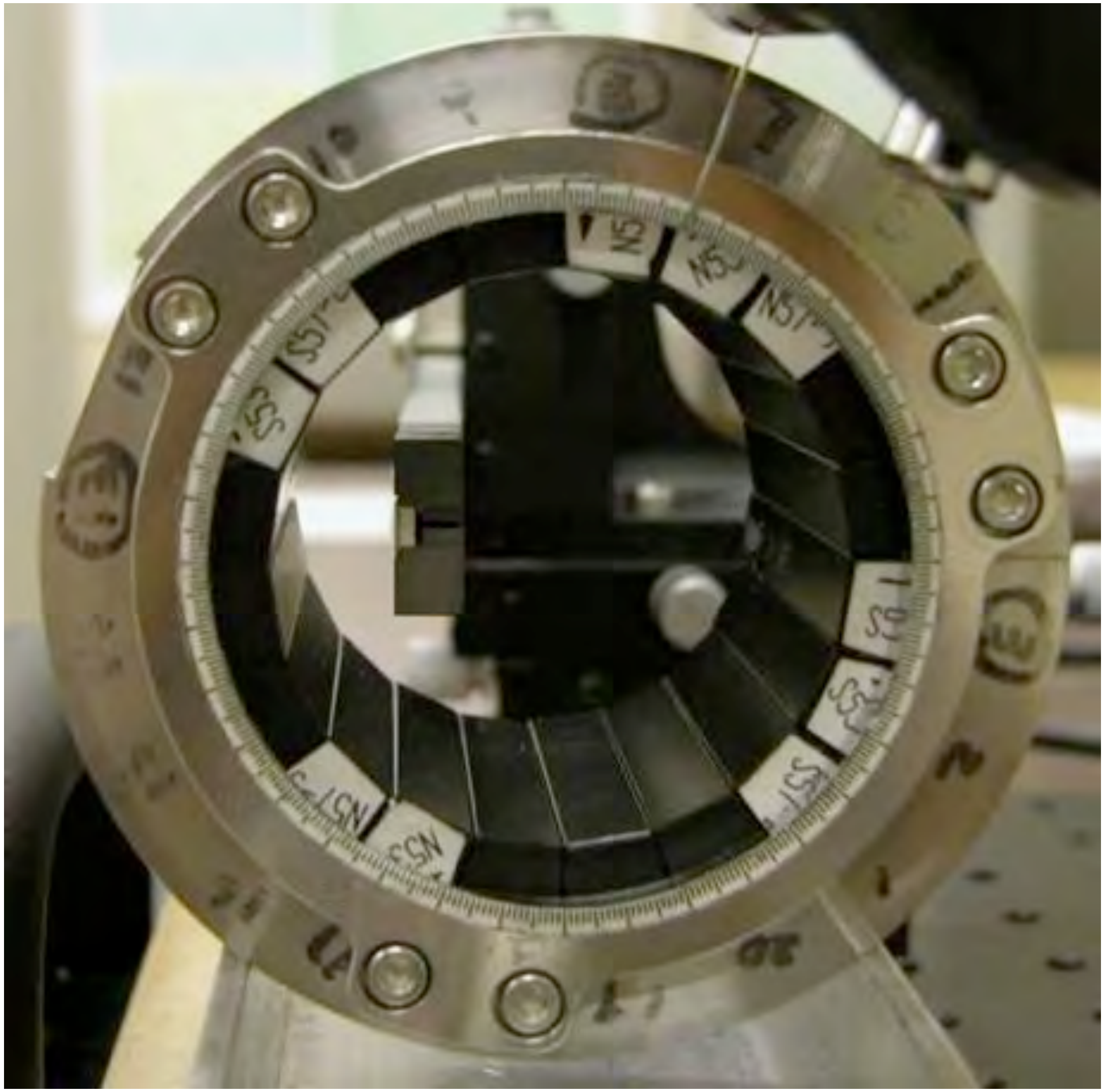
External Stray Field



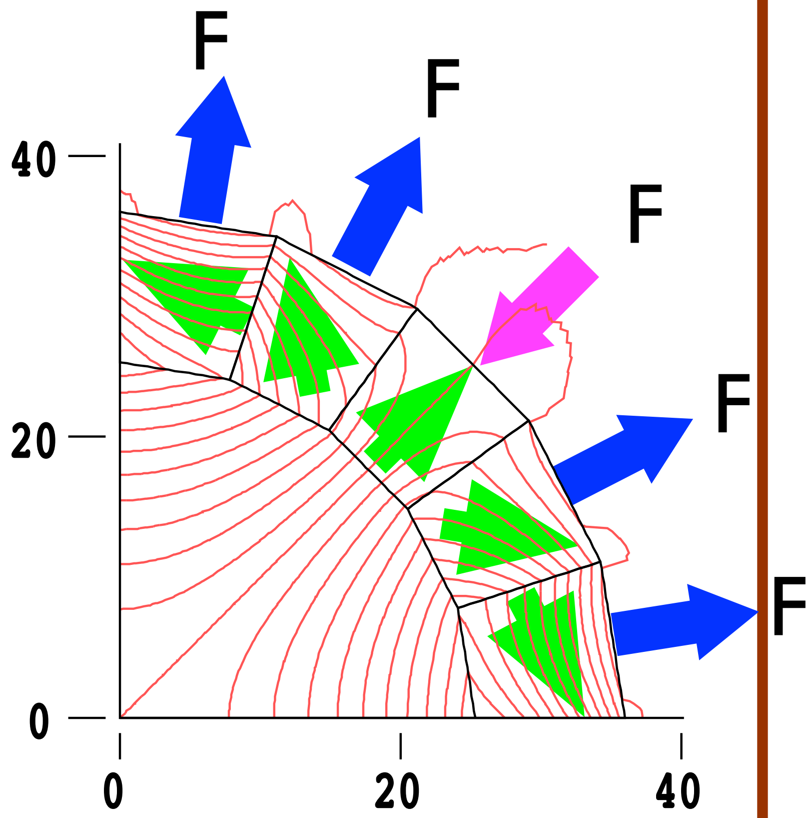


Fine Tune of Rings

Magnet Bore



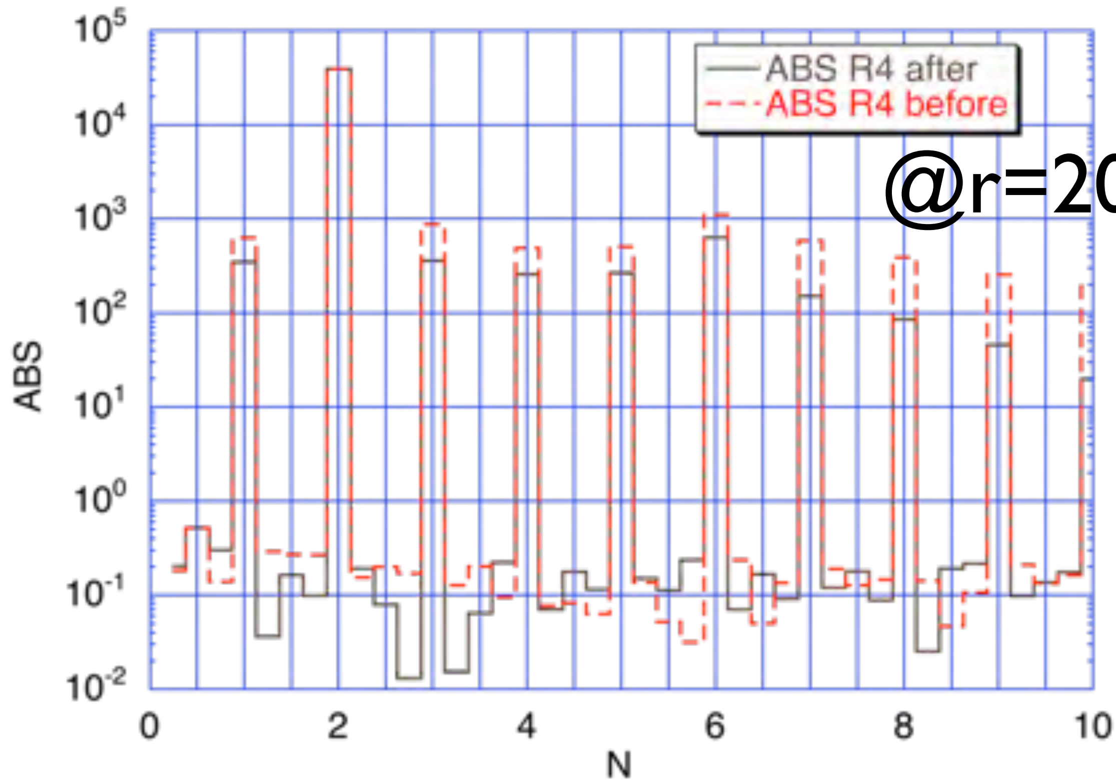
Pole magnets are attracted.



Others are repulsive.

Measurement on each PMQ

Just before and after a wrong magnet piece replacement



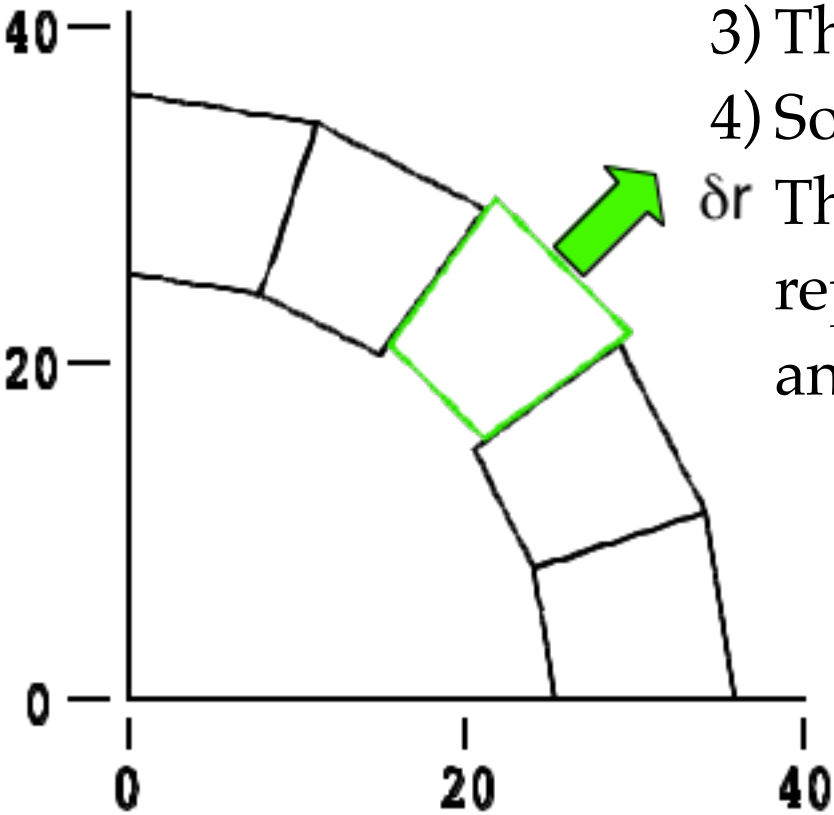
@r=20mm

- Reduced errors (still large - to be adjusted).
- noise level < 10^{-5}

Adjustment Algorithm

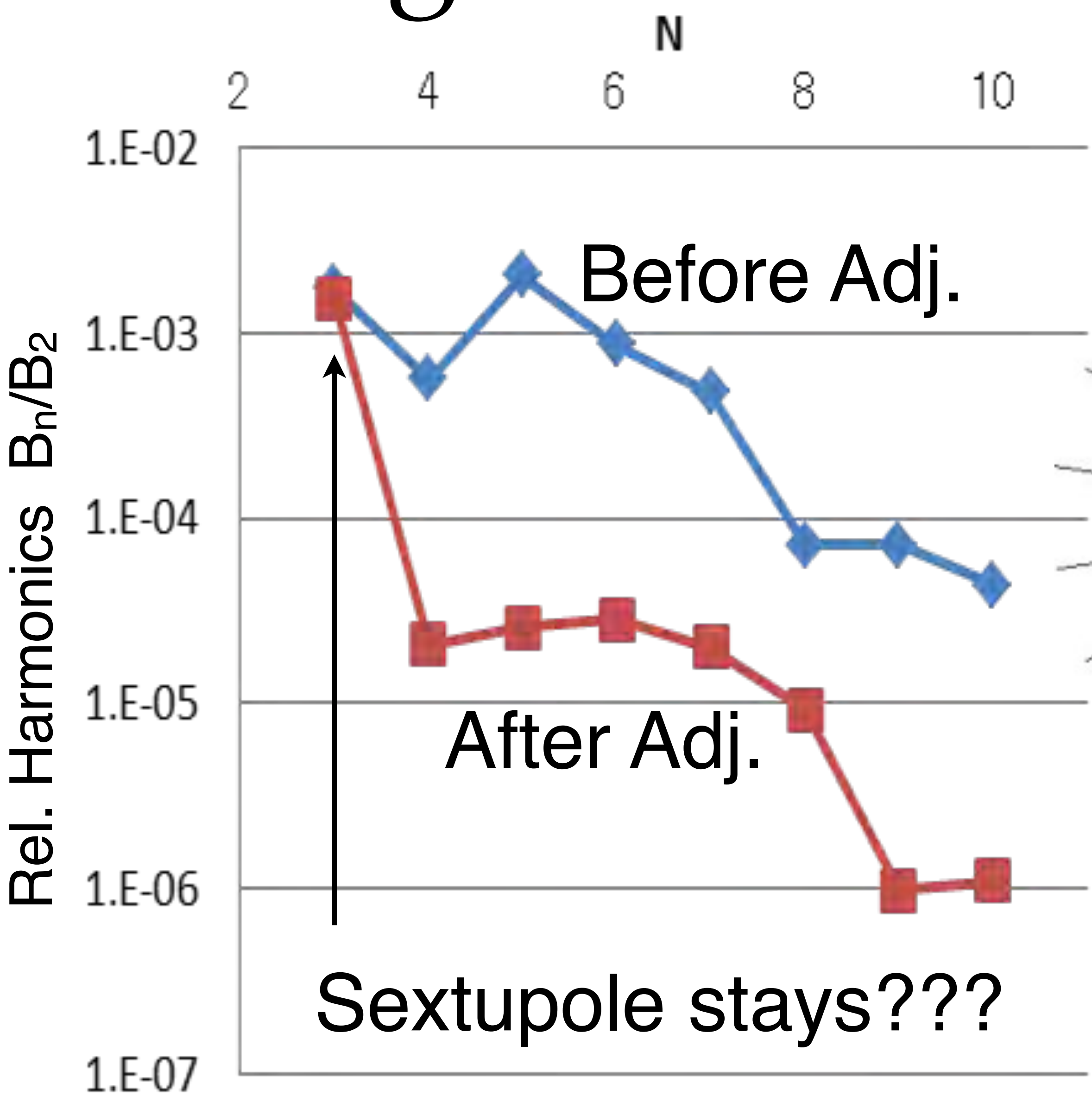
1) Multipole components (up to 11) generated by single piece and those with 1mm offset are calculated by PANDIRA.
2) The differences (11 Re and Im values) are obtained for all 20 pieces.
3) They consists of total 22x20 values.
4) Solve equ.

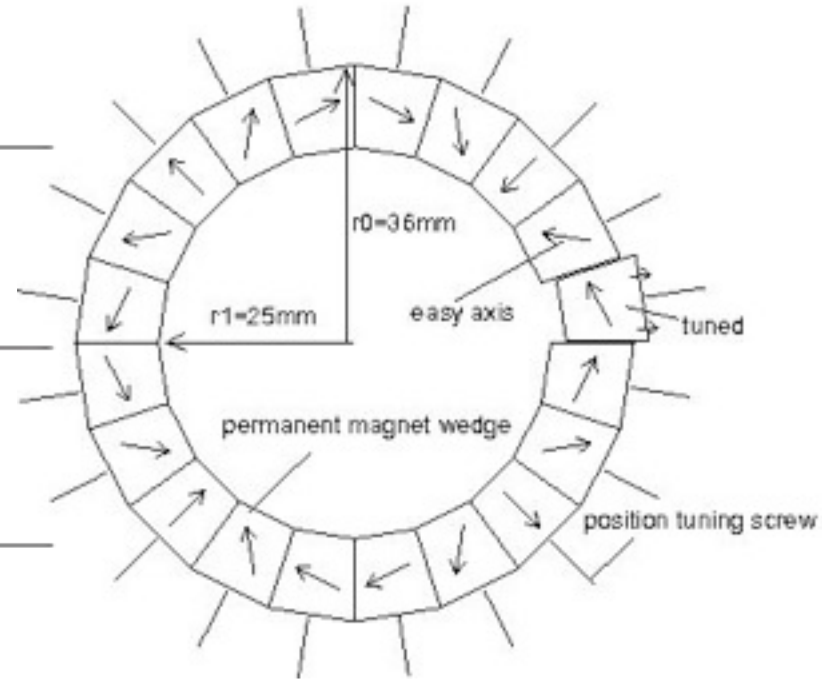
The equ's correspond to Q should be replaced by all 1's (to keep circumference) and the one of 11th.



$$\begin{pmatrix} \frac{dC_1}{dr_1} & \frac{dC_1}{dr_2} & \cdots & \frac{dC_1}{dr_{20}} \\ \frac{dC_2}{dr_1} & \frac{dC_2}{dr_2} & \cdots & \frac{dC_2}{dr_{20}} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{dC_{20}}{dr_1} & \frac{dC_{20}}{dr_2} & \cdots & \frac{dC_{20}}{dr_{20}} \end{pmatrix} \begin{pmatrix} \Delta r_1 \\ \Delta r_2 \\ \cdots \\ \Delta r_{20} \end{pmatrix} = \begin{pmatrix} C_1 \\ C_2 \\ \cdots \\ C_{20} \end{pmatrix}$$

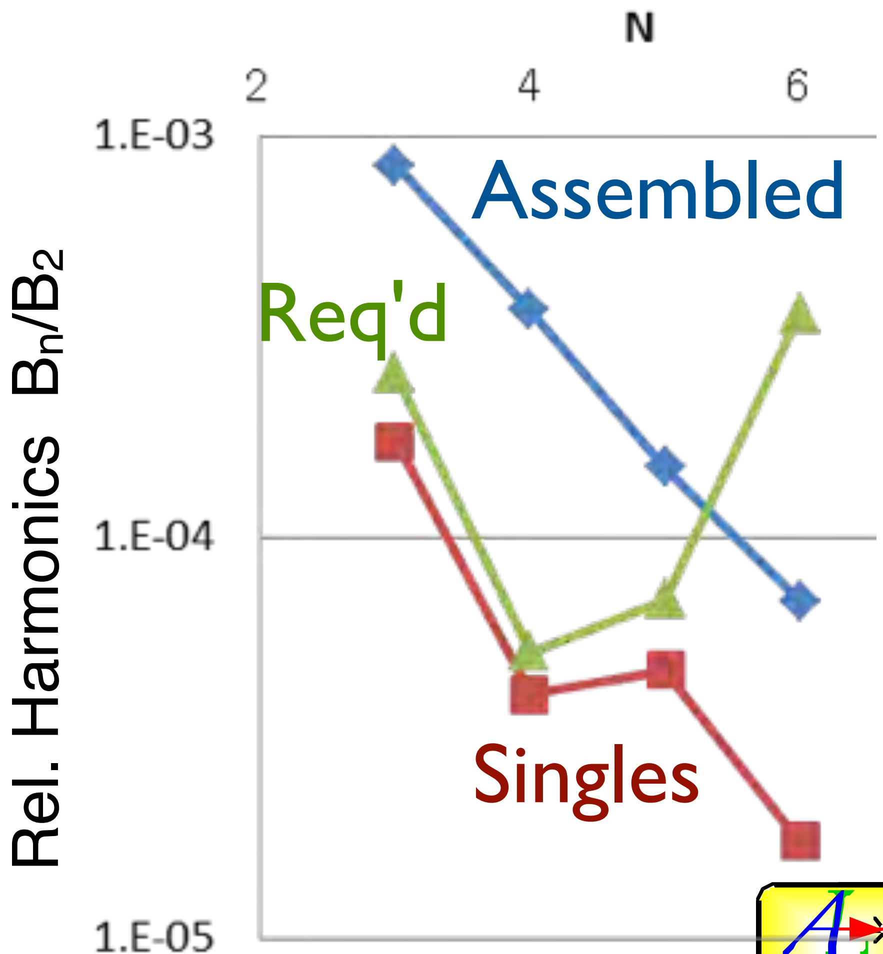
Magnet Piece Alignment





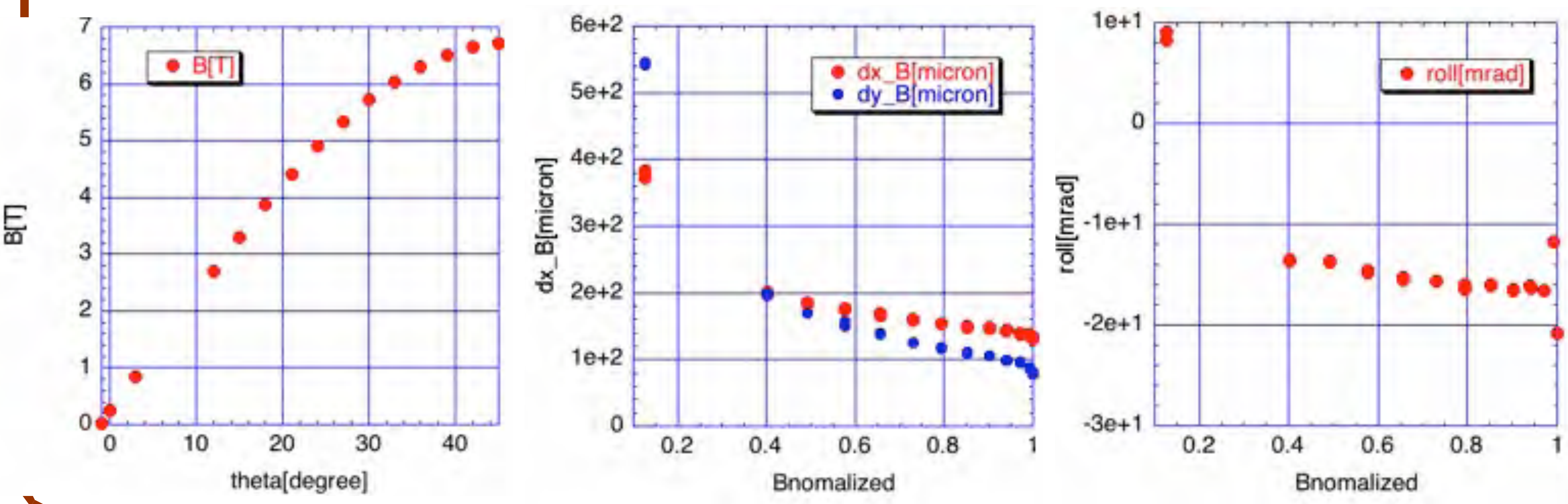
Assembled Lens

- Measured assembled lens.
- Multipoles increased factor 3-10.
- Reproducibility has to be checked.



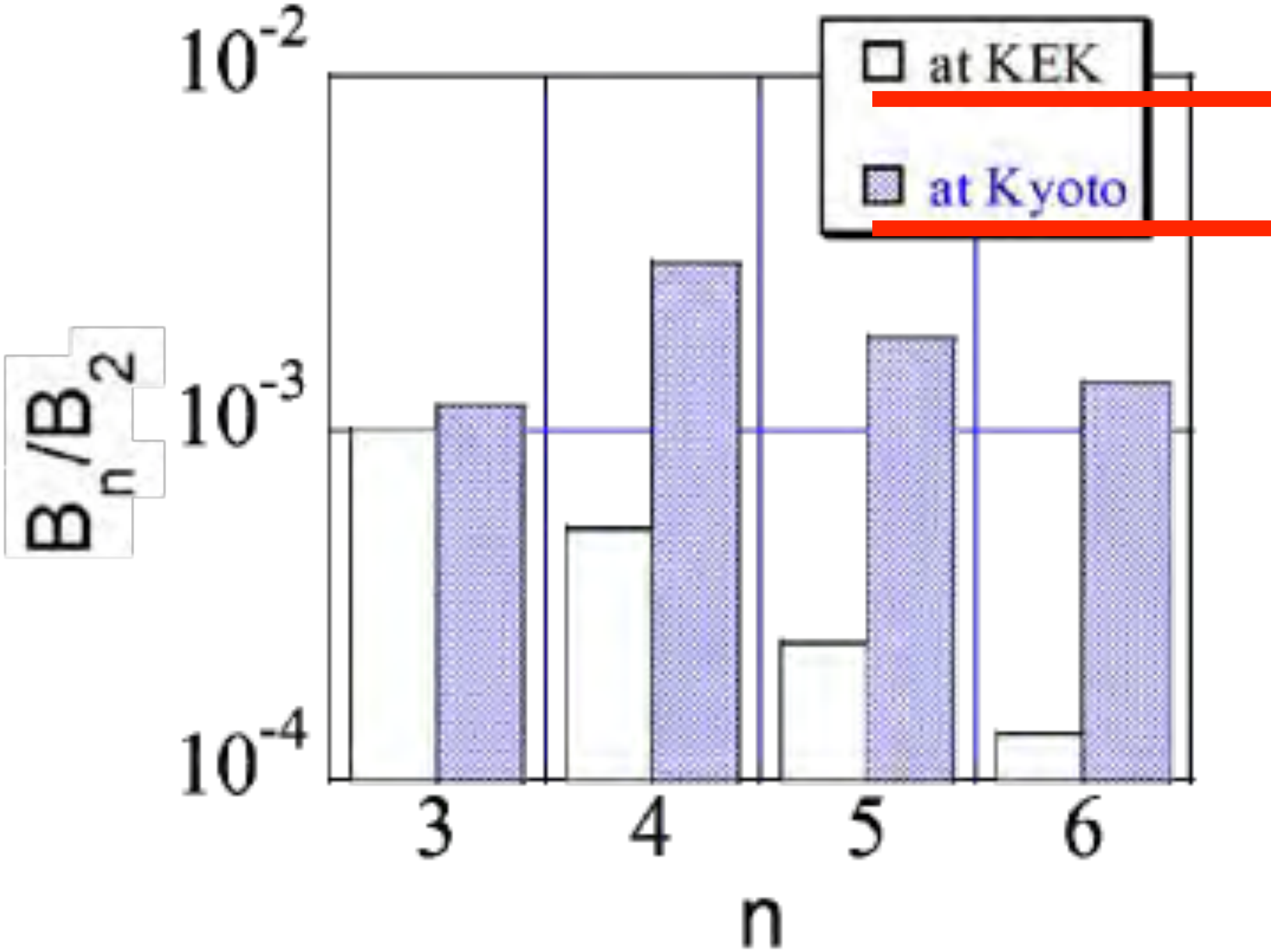
Quadrupole Value

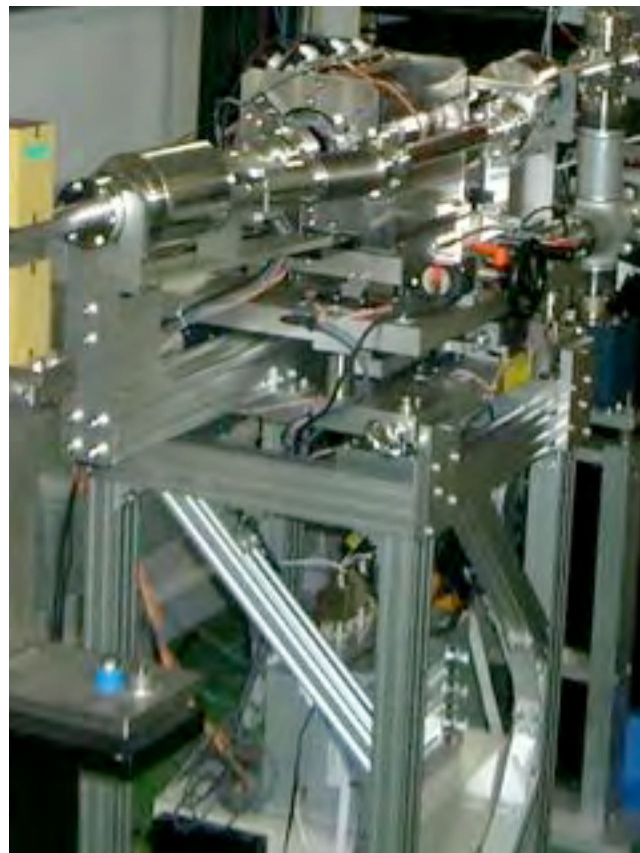
- Maximum GL =6.8T@270mm ~25.7 T/m ave.
- Minimum GL < 0.3%
- Center axis shift δx ~ 50μm, δy ~ 100μm for GL range of 40-100%
- Less than 5 mrad rotation



Multipoles before and after

(East Japan Earthquake at 2011.3.11?)





The magnet was returned back from KEK after the disaster.

Demagnetization by Radiation

Energy deposit

	GLD	SiD	SiD (by Takahashi)	neutron
BeamCAL	17mW	13mW	29mW	
QD0	94mW	97mW	147mW	10^5 [n/cm^{2}s]
SD0	11mW	11mW	11mW	
QF1	16mW	18mW	15mW	
SF1	0.4mW	0.3mW	1mW	

very preliminary results by T.Abe (university of Tokyo), in private communication

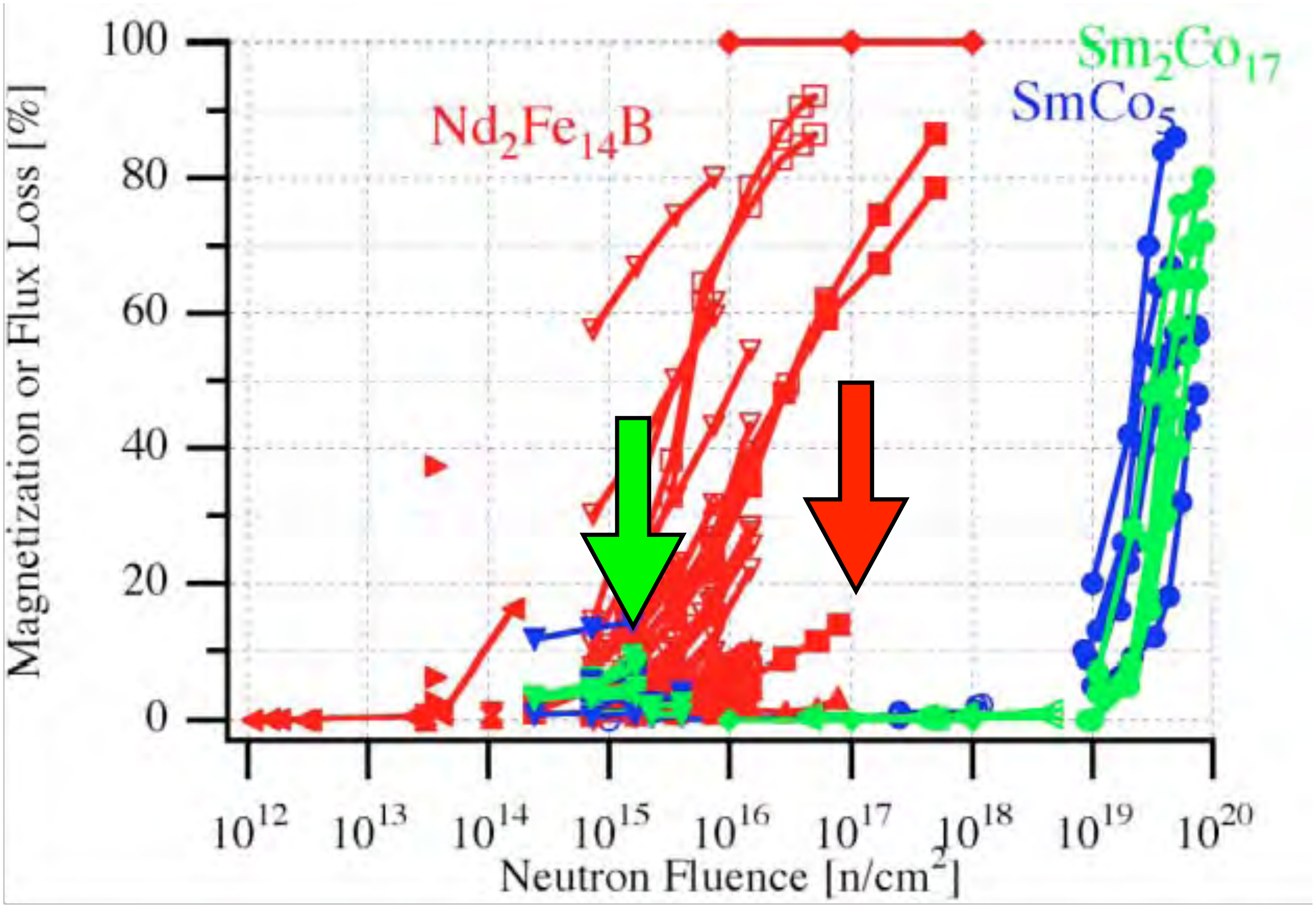
Demagnetization by 14MeV neutron

Magnet	Demag. ratio [/1x10^{13}n/cm^2]	iHc [Oe]
47H	10.2%	
44H	1.8%	16
39SH	0.7%	21
32EH	0.3%	30

T. Kawakubo, et al., The 14th Symposium on Accelerator Science and Technology, Tsukuba, Japan, November 2003, pp. 208-210, in Japanese, http://conference.kek.jp/sast03it/WebPDF/1P027.pdf

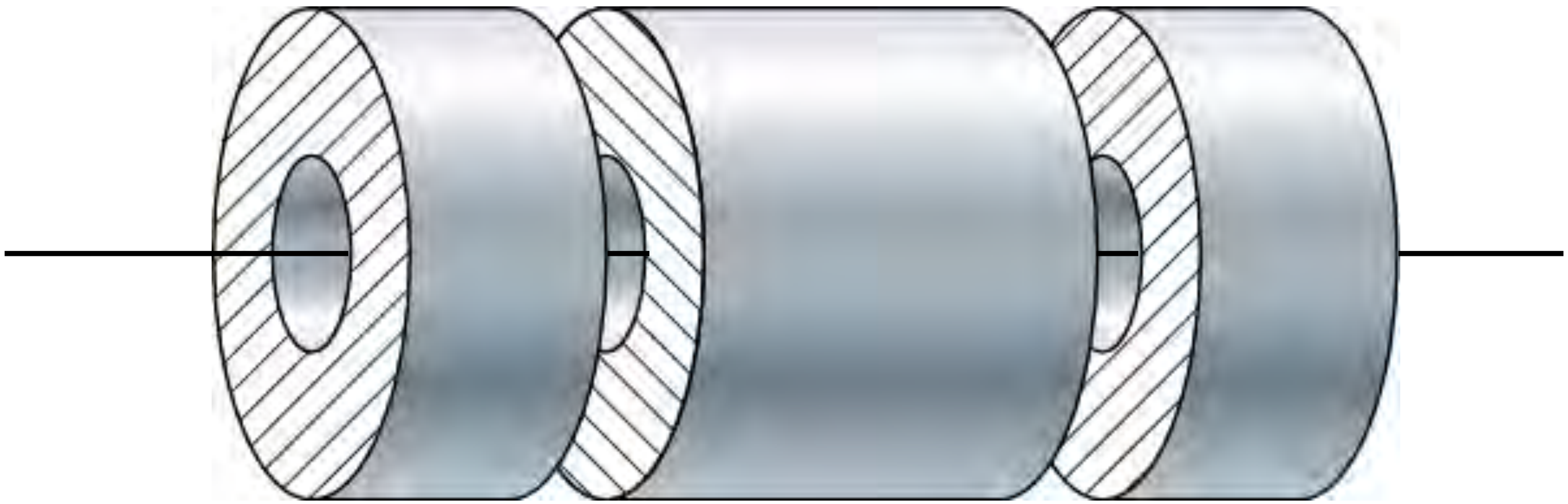
Continuous 1mo.(2.6x10^{6}s) operation may cause about 0.01[%] of (reversible?) demagnetization on NEOMAX 32EH. (1% for 10 years) ... needs more info.

Flux or remanence loss as a function of the neutron fluence



X.-M. Maréchal, et al., EPAC 2006,THPCH135

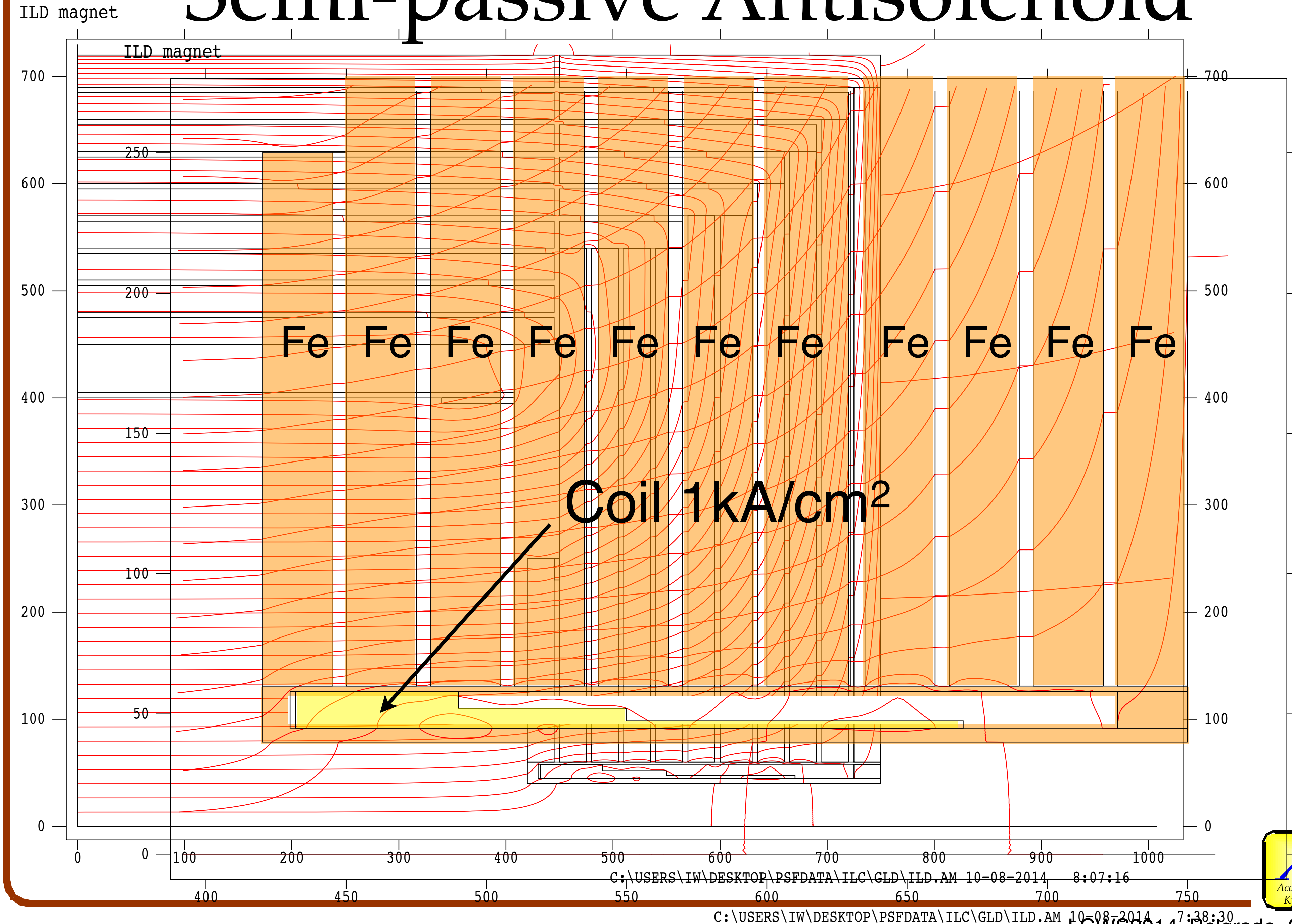
PMSx, PMO



PMSx triplet (1:2:1):
Rotate opposite direction.
Similar technique to PMQ but less rings.

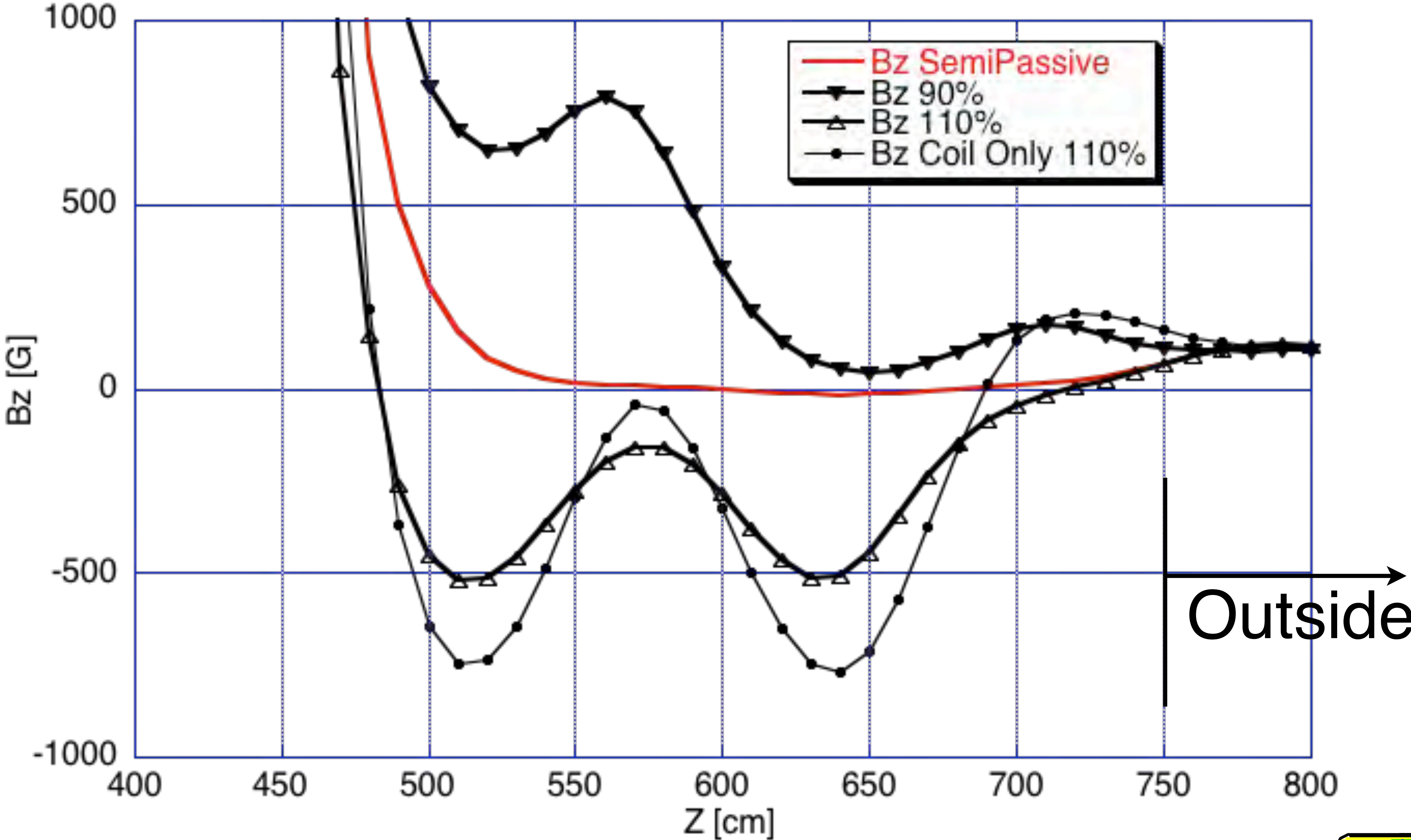
Semi-passive Antisolenoid

Semi-passive Antisolenoid



AccLab BmSci ICR
KyotoUniversity

Sensitivity on Coil Current



Summary

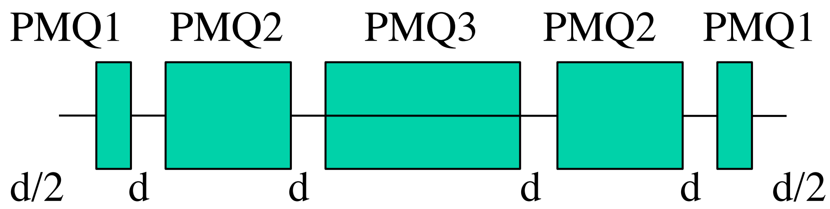
- Current 5-ring Singlet can fit in the support tube – Vibration Free
- External stray field can be reduced by Fe case.
- Fine tuned setup degraded after years... – possible mechanical shock (3.11).
- Demagnetization may not be serious – depends on neutron dose.
- Adjustable multipoles (PMSx, PMO ...)
- Semi-passive Antisolenoid is less sensitive.

Appendix

Final Focus Optics with Permanent Q

Permanent Mgnet

Unit of magnet



Dimensions

L[PMQ1]=a, L[PMQ2]=b, L[PMQ3]=c

a:b:c:=1.81046: 5: 6.37909 (Iwashita)

2a+2b+c=20cm

1cm Drift space between Q (d=1cm)

Qs are rotated by θ(PMQ1,3) and - θ(PMQ2) to adjust K1.

Permanent QD0

As QD0, 12 units of magnet are used.
Total length is 301cm including half drift spaces at both sides.

Installation of Permanent QD0

Starting with ‘ilc2006b.ilcbds1’(14mrad version)
Since the original QD0 is of 2.2m length, adjustment of drift space is required to keep the total length unchanged.

D1B(QF1-SD0) L : 1.35 → 0.945m

D0 (L*) L : 3.51 → 3.105m

Procedure of Fine Tuning for Optics with Permanent Q

Starting with 'ilc2006b.ilcbds1'(14mrad version), permanent QD0 is installed.

1. Linear Optics Matching
   Since the permanent QD0 changed not only α^* and β^* but also η^*, we need to adjust some Q in dispersion region(FF section). QF1 is chosen as that knob because there is no change of transfer matrices between SXs upstream.
   Variables for the matching:
      K1 of QM(matching Q) and QF1
      θ of PMQ(Fixed field gradient of 140T/m is assumed)
   Matching requirement:
      $\alpha x = \alpha y = 0$, $\beta x = 0.021$m, $\beta y = 400$um, $\eta x = 0$ at IP
   Final θ of PMQ is 6.58 degree.

2. Off-Momentum Matching
   Since the FF optics downstream of QF1 has been changed, we need to re-optimize K2 of SXs.
3. Fine Tuning of K2 of SXs looking at the beam size at IP.
   Final beam size obtained: $\sigma x/\sigma y$=656 / 5.44nm for $\gamma\varepsilon x/\gamma\varepsilon y$=9.2e-6/3.4e-8m and $\sigma\delta$=6e-4.
   (636 / 5.25nm for original design)

QNAME	K1[1/m]	
	before	after
QM16	-0.00876	-0.00829
QM15	-0.00200	0.00128
QM14	0.00898	0.0156
QM13A	-0.0110	0.0117
QM13B	0.0423	0.0429
QM12	-0.0190	-0.0321
QM11	0.0179	0.0201
QF1	0.0963	0.0994

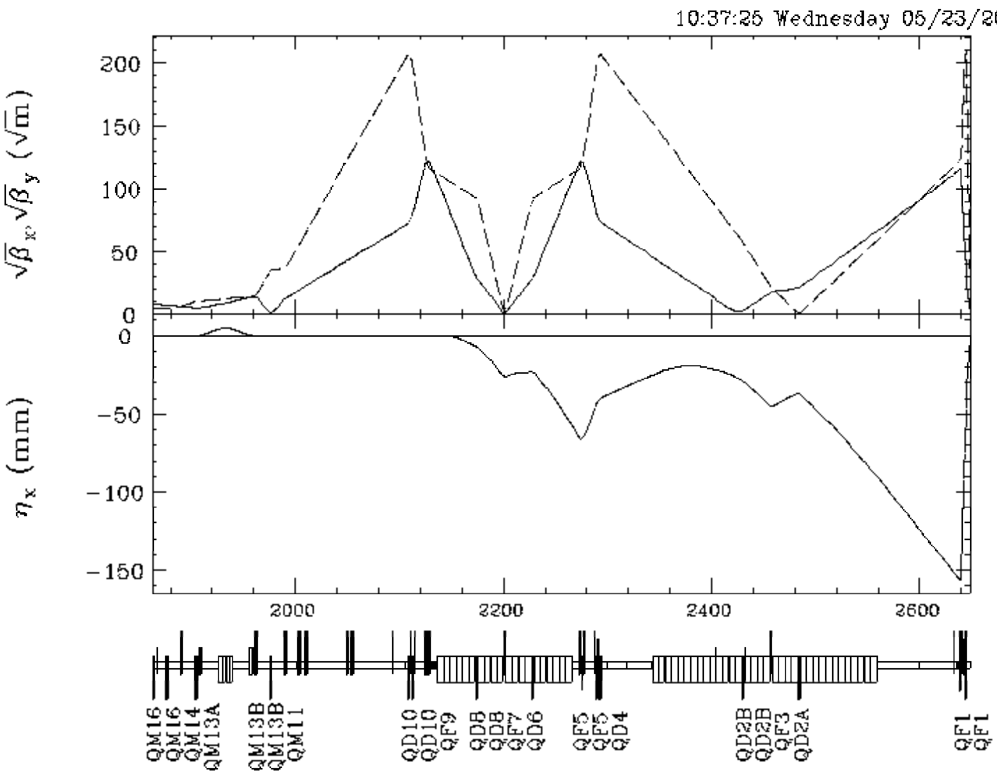
SXNAME	K2[1/m^2]	
	before	after
SF6	0.843	0.888
SF5	-0.217	-0.188
SD4	1.65	1.68
SF1	-1.09	-1.26
SD0	2.32	2.51

	DP				
	-6e-4	-3e-4	0	3e-4	6e-4
αx	-0.0372	-0.0184	-3.22e-7	0.0180	0.0357
βx	0.0210	.0210	0.0210	0.0210	00210
αy	0.252	0.124	7.82e-6	-0.120	-0.236
βy	4.19e-4	4.03e-4	4.00e-4	4.09e-4	4.30e-4
ηx	7.48e-6	3.62e-6	6.16e-11	-3.37e-6	-6.50e-6

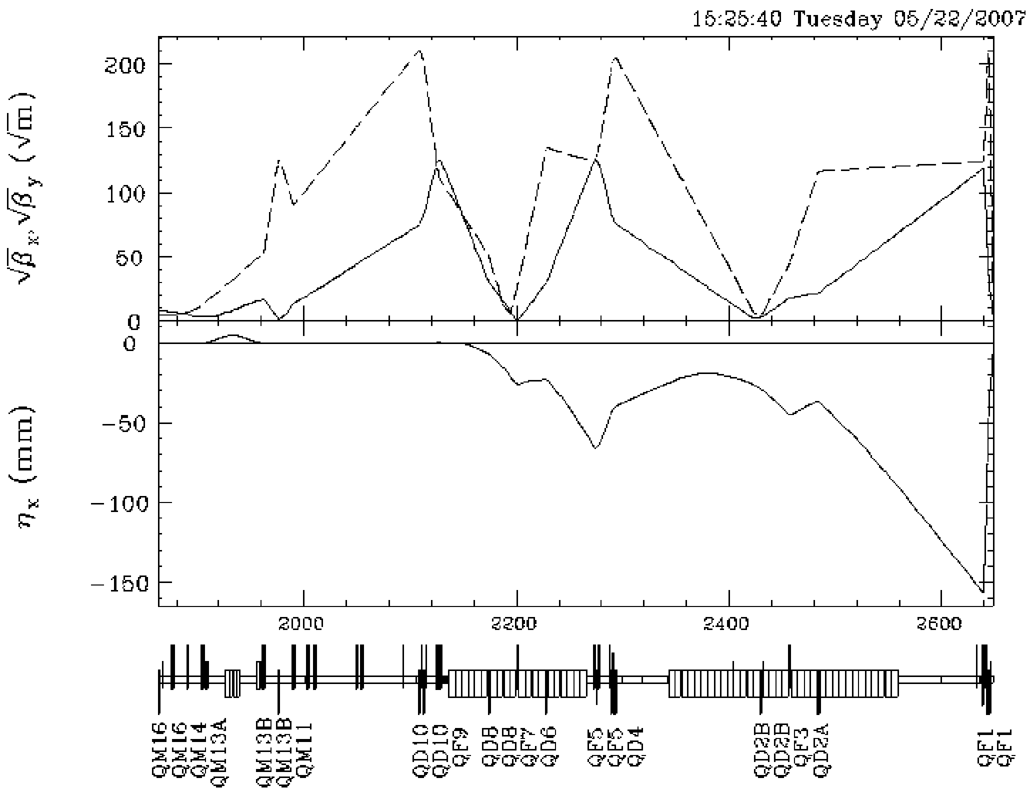
Strength of SF1&SD0 must be checked.

Optics with Permanent Q

Original optics



Optics with permanent QD0



Optics with permanent QD0 is somewhat ugly.
Need to restore symmetry around the B section of s ≈ 2200m?
Optimization is not perfect(e.g. Octupole magnets were not touched...).

Need someone to complete the design.
deck file is available at SAD computer:
'/users/kuroda/sad/jlc/ilc2006b.ebds1ForPMQ'